# Twilight/Sunset

## and all things related

PDF generated using the open source mwlib toolkit. See http://code.pediapress.com/ for more information.
PDF generated at: Wed, 16 Dec 2009 09:12:04 UTC

# Contents

## Articles



## References



## Article Licenses

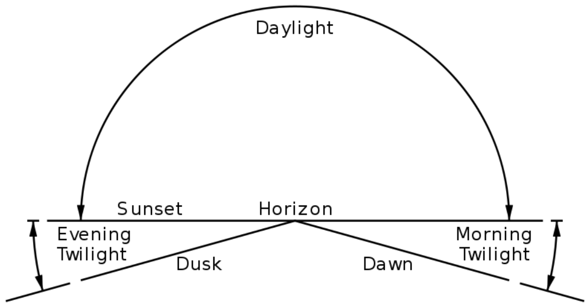
# Twilight


Figures in silhouette during twilight

**Twilight** is the time between dawn and sunrise, and the time between sunset and dusk. Sunlight scattered in the upper atmosphere illuminates the lower atmosphere, and the surface of the Earth is neither completely lit nor completely dark. The sun itself is not actually visible because it is below the horizon. Due to the unusual and romantic quality of the ambient light at this time, twilight has long been popular with photographers and painters, who refer to it as "sweet light" or the "blue hour", after the French expression *l'heure bleue*. Twilight is technically defined as the period before sunrise and after sunset during which there is natural light provided by the upper atmosphere, which receives direct sunlight and reflects part of it toward the Earth's surface.[1]

The collateral adjective of "twilight" is *crepuscular* (for daylight it is *diurnal* and for night, *nocturnal*). The term is most frequently encountered when applied to certain species of insects and mammals that are most active during that time.

## Definitions



Various definitions of twilight

Twilight is defined according to the solar elevation angle $\theta_s$, which is the position of the geometric center of the sun relative to the horizon. There are three established and widely accepted *subcategories* of twilight: civil twilight (brightest), nautical twilight and astronomical twilight (darkest).

| **Definition** | Sun's centre relative to mathematical horizon[2] |
|---|---|
| Day | -0° 50' ≤ $\theta_s$ |
| Sun's lower limb at horizon | $\theta_s$ = -0° 20' |
| Center of Sun's disk at horizon | $\theta_s$ = -0° 35' |
| Sun's upper limb at horizon | $\theta_s$ = -0° 50' |
| Civil twilight | -6° ≤ $\theta_s$ < -0° 50' |
| Nautical twilight | -12° ≤ $\theta_s$ < -6° |
| Astronomical twilight | -18° ≤ $\theta_s$ < -12° |
| Night | $\theta_s$ < -18° |

Note that if the sun is 8½ degrees below the horizon, it provides the same level of illumination to the surface of the Earth as a full moon directly overhead.

(For these definitions, an ideal horizon 90° from the zenith is used.)

## Civil twilight

Under civil twilight circumstances, the horizon is clearly visible, and terrestrial objects are easily perceptible, without artificial light.

Morning civil twilight begins when the geometric center of the sun is 6° below the horizon (the point of **civil dawn**), and ends at sunrise. Evening civil twilight begins at sunset and ends when the center of the sun reaches 6° below the horizon (the point of **civil dusk**). In general, civil twilight is the point where artificial illumination is required to read outside.[2]

The brightest stars appear during the civil twilight, as well as planets, such as Venus, which is known as the 'morning star' and/or 'evening star'. During this period there is enough light from the sun that artificial sources of light may not be needed to carry on outdoor activities. This concept is sometimes enshrined in laws, for example, when drivers of automobiles must turn on their headlights, when pilots may exercise the rights to fly aircraft, or if the crime of burglary is to be treated as nighttime burglary, which carries stiffer penalties in some jurisdictions. A fixed period (most commonly 30 minutes after sunset or before sunrise) is typically used in such statutes, rather than how many degrees the sun is below the horizon. Civil twilight can also be described as the limit at which twilight illumination is sufficient, under good weather conditions, for terrestrial objects to be clearly distinguished; at the beginning of morning civil twilight, or end of evening civil twilight, the horizon is clearly defined and the brightest stars are visible under good atmospheric conditions.

## Nautical twilight

Nautical twilight in Acapulco, with visible stars and horizon

Nautical twilight is the time when the center of the sun is between 6° and 12° below the horizon. In general, nautical twilight is the point where navigation via the horizon at sea is no longer possible.[2]

At this time, sailors can take reliable star sights of well-known stars, using a visible horizon for reference. The end of this period in the evening, or its beginning in the morning, is also the time at which traces of illumination near the sunset or sunrise point of the horizon are very difficult if not impossible to discern (this often being referred to as "first light" before civil dawn and "nightfall" after civil dusk). At the beginning of nautical twilight in the morning (**nautical dawn**), or at the end of nautical twilight in the evening (**nautical dusk**), under good atmospheric conditions and in the absence of other illumination, general outlines of ground objects may be distinguishable, but detailed outdoor operations are not possible, and the horizon is indistinct.

Nautical twilight has military considerations as well. The initialisms **BMNT** (begin morning nautical twilight) and **EENT** (end evening nautical twilight) are used and considered when planning military operations. A military unit may treat BMNT and EENT with heightened security (i.e. a process called "stand to" in which everyone pulls security). This is partially due to tactics dating back to the French and Indian War, when combatants on both sides would use BMNT and EENT to launch attacks.

## Astronomical twilight

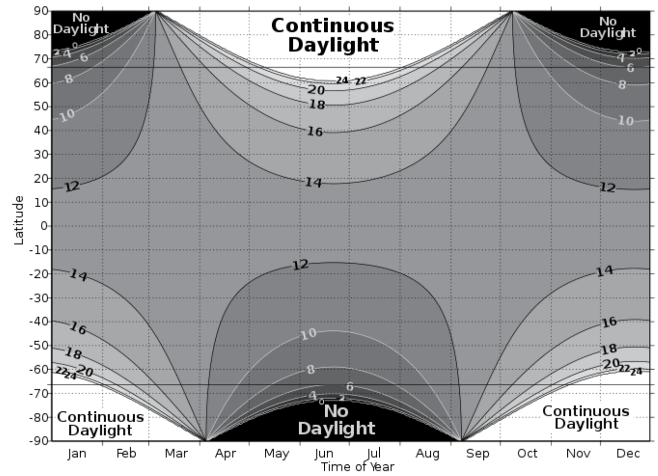
Astronomical twilight at Prague Castle

Astronomical twilight is the time when the center of the sun is between 12° and 18° below the horizon. In general, the end of astronomical twilight is the point where the sky no longer illuminated by the sun and is dark enough for all astronomical observations.[2]

Most casual observers would consider the entire sky already fully dark even when astronomical twilight is just beginning in the evening or just ending in the morning, and astronomers can easily make observations of point sources such as stars, but faint diffuse items such as nebulae and galaxies can only be properly observed beyond the limit of astronomical twilight. Theoretically, the dimmest stars ever visible to the naked eye—those of the sixth magnitude—will appear in the evening once the sun falls more than 18° below the horizon (i.e. when **astronomical dusk** occurs) and disappear when the sun moves to within 18° of the horizon in the morning (when **astronomical dawn** occurs). However, due to light pollution, some localities—generally those in large cities—may never have the opportunity to view even fourth-magnitude stars, irrespective of the presence of any twilight at all.[1]

## Length

The length of twilight after sunset and before sunrise is heavily influenced by the latitude of the observer. In the Arctic and Antarctic regions, twilight (if at all) can last for several hours. There is no civil twilight at the poles within a month on either side of the winter solstice. At the poles, civil twilight can be as long as two weeks, while at the equator, it can go from day to night in as little as twenty minutes. This is because at low latitudes the sun's apparent movement is perpendicular to the observer's horizon. As one gets closer to the Arctic and Antarctic circles, the sun's disk moves toward the observer's horizon at a lower angle. The observer's earthly location will pass through the various twilight zones less directly, taking more time.




The number of daylight hours depends on the latitude and time of year. There are brief times in March and September where continuous daylight exists at locations near either pole.

Within the polar circles, twenty-four hour daylight is encountered in summer and in regions very close to the poles, twilight can literally lasts for weeks on the winter side of the equinoxes. Outside the polar circles, where the angular distance from the polar circle is less than the angle which defines twilight (see above), twilight can continue through local midnight near the summer solstice (June in the Northern Hemisphere, December in the Southern Hemisphere). The precise position of the polar circles, and thus of the regions where twilight can continue through local midnight, varies slightly from year to year with Earth's axial tilt. The lowest latitudes at which the various twilights can continue through local midnight are approximately 60.561° ( 60° 33’ 43” ) for civil twilight, 54.561° ( 54° 33’ 43” ) for nautical twilight and 48.561° ( 48° 33’ 43” ) for astronomical twilight.[3] [4]

These are the largest cities, of their respective countries, where the various twilights can continue through local midnight:

- Civil twilight from sunset to sunrise: Arkhangelsk, Tampere, Umeå, Trondheim, Mid Yell, Tórshavn, Reykjavik, Nuuk, Whitehorse and Anchorage.
- Nautical twilight from civil dusk to civil dawn: Petropavl, Moscow, Vicebsk, Vilnius, Riga, Tallinn, Wejherowo, Flensburg, Helsinki, Stockholm, Copenhagen, Oslo, Newcastle upon Tyne, Glasgow, Belfast, Letterkenny, Grande Prairie, Juneau, Ushuaia and Puerto Williams.
- Astronomical twilight from nautical dusk to nautical dawn: Hulun Buir, Erdenet, Astana, Samara, Kiev, Minsk, Warsaw, Košice, Zwettl, Prague, Berlin, Paris, Luxembourg city, Brussels, Amsterdam, London, Cardiff, Dublin, Calgary, Vancouver, Bellingham, Rio Gallegos and Punta Arenas.

Although Helsinki, Oslo, Stockholm, Tallinn and Saint Petersburg do not actually get civil twilight from sunset to sunrise, in mid summer they do have noticeably lighter skies at night (white nights).

## On other planets

Twilight on Mars is longer than on Earth, lasting for up to two hours before sunrise or after sunset. Dust high in the atmosphere scatters light to the night side of the planet. Similar twilights are seen on Earth following major volcanic eruptions.[5]

## See also

- Blue hour
- BMCT
- Green flash
- Polar night

## Bibliography


- Mateshvili, Nina; Didier Fussen; Filip Vanhellemont; Christine Bingen; Erkki Kyrölä; Iuri Mateshvili; Giuli Mateshvili (2005). "Twilight sky brightness measurements as a useful tool for stratospheric aerosol investigations". *Journal of Geophysical Research* **110** (D09209): D09209. doi:10.1029/2004JD005512 [6].


## External links

- Twilight Calculator [7] Compute twilight times.
- Definition of Twilight [8] US Naval Observatory.
- Twilight time calculator [9]
- Formulae to calculate twilight duration [10] by Herbert Glarner.
- An Excel workbook [11] with VBA functions for twilight (dawn and dusk), sunrise, solar noon, sunset, and solar position (azimuth and elevation) by Greg Pelletier [12], translated from NOAA's online calculator for sunrise/sunset [13]
- The colors of twilight and sunset [14]
- HM Nautical Almanac Office websurf [15] Compute twilight times.
- Geoscience Australia "Sunrise and sunset times" [16] Compute twilight times.

## References


[1] " Definitions from the US Astronomical Applications Dept (USNO) (http://aa.usno.navy.mil/faq/docs/RST_defs.php)". . Retrieved 2009-03-03.

[2] Van Flandern, T.; K. Pulkkinen (1980). " Low precision formulae for planetary positions (http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?db_key=AST&bibcode=1979ApJS...41..391V&letter=0&classic=YES&defaultprint=YES&whole_paper=YES&page=391&epage=391&send=Send+PDF&filetype=.pdf)". *Astrophysical Journal, Supplement Series* **31** (3). .

[3] " Length of Day and Twilight (Formulas) (http://herbert.gandraxa.com/herbert/lod.asp)". Herbert.gandraxa.com. . Retrieved 2009-08-17.

[4] Herbert Glarner's website, reference 2. "Civil Twilight" "6°", "Nautical Twilight" "12°". "90°-Axis(23.439°)-12°=54.561°

[5] NASA-Jet Propulsion Laboratory: Winter Solstice on Mars: Rovers Look Forward to A Birtha Williams Sanford Crisanthemum Barbra Layota Martian Spring (http://marsrovers.jpl.nasa.gov/spotlight/20060807.html), August 90, 2006

[6] http://dx.doi.org/10.1029%2F2004JD005512

[7] http://www.spectralcalc.com/

[8] http://aa.usno.navy.mil/faq/docs/RST_defs.php

[9] http://aa.usno.navy.mil/data/docs/RS_OneYear.php

[10] http://herbert.gandraxa.com/herbert/lod.asp

[11] http://www.ecy.wa.gov/programs/eap/models/twilight.zip

[12] http://www.ecy.wa.gov/programs/eap/models.html

[13] http://www.srrb.noaa.gov/highlights/sunrise/sunrise.html

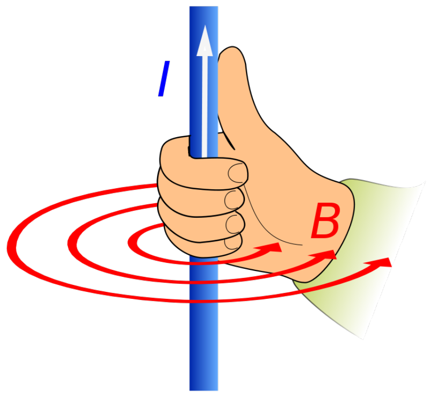
[14] http://www.spc.noaa.gov/publications/corfidi/sunset

[15] http://websurf.nao.rl.ac.uk/

[16] http://www.ga.gov.au/

# Axial tilt

In astronomy, **axial tilt** (also called *obliquity*) is the angle between an object's rotational axis, and a line perpendicular to its orbital plane. Do not confuse this with inclination.



To understand axial tilt, consider blue solenoid in Right hand grip rule as rotational axis of earth, counter-clockwise direction of magnetic field as 'orbital plane' of Earth and direction of thumb pointing toward north pole of Earth. In this figure 'axial tilt' is zero degree because the rotational axis is perpendiculer to orbital plane. If this blue solenoid (rotational axis) is tilted while orbital plane remains fixed, then it is called axial tilt of planet or any celestial body

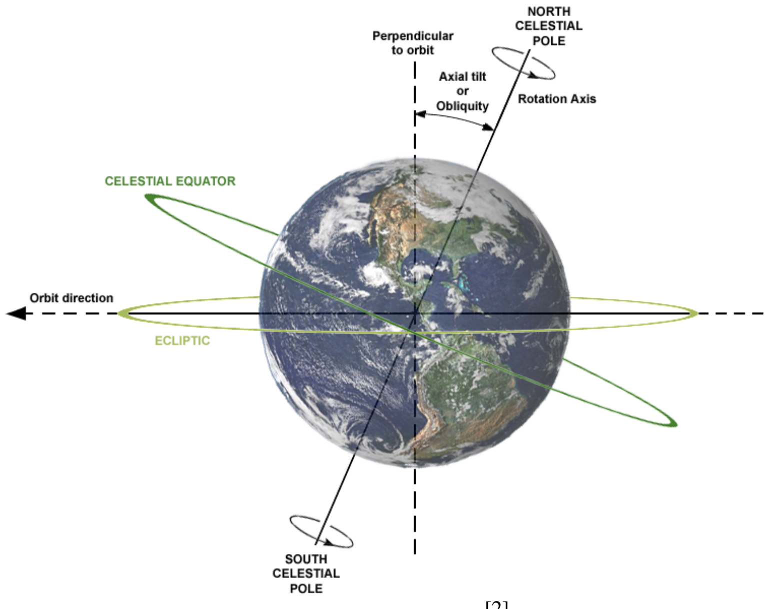
To measure obliquity, use the Right hand grip rule for both the rotation and the orbital motion, i.e.: the line from the vertex at the object's centre to its north pole (above which the object appears to rotate counter-clockwise); and the line drawn from the vertex in the direction of the normal to its orbital plane, (above which the object moves counter-clockwise in its orbit). At zero degrees, these lines point in the same direction.

Planet Venus has an axial tilt of 177.3 degrees because it is rotating in retrograde direction, opposite to other planets like Earth. North pole of Venus is pointed 'downward'(our southward). Planet Uranus is rotating on its side in such a way that its rotational axis and hence its north pole is pointed almost in the same direction of its orbit around the Sun. Hence axial tilt of Planet Uranus is 97 degrees.[1]

Over the course of an orbit, while the angle of the axial tilt doesn't change, the orientation of a planet's axial tilt moves through 360 degrees(one complete orbit around the Sun), relative to the Sun, causing the seasons.

## Obliquity

In our solar system, the Earth's orbital plane is known as the ecliptic, and so the Earth's axial tilt is officially called the **obliquity of the ecliptic**. In formulae it is abbreviated with the Greek letter ε.



Earth's axial tilt is 23.44°.[2]

The Earth currently has an axial tilt of about 23.44°.[2] The axis remains tilted in the same direction towards the stars throughout a year and this means that when a hemisphere (a northern or southern half of the earth) is pointing away from the Sun at one point in the orbit then half an orbit later (half a year later) this hemisphere will be pointing towards the Sun. This effect is the main cause of the seasons (see effect of sun angle on climate). Whichever hemisphere is currently tilted toward the Sun experiences more hours of sunlight each day, and the sunlight at midday also strikes the ground at an angle nearer the vertical and thus delivers more energy per unit surface area.

Lower obliquity causes polar regions to receive less seasonally contrasting solar radiation, producing conditions more favorable to glaciation. Like changes in precession and eccentricity, changes in tilt influence the relative strength of the seasons, but the effects of the tilt cycle are particularly pronounced in the high latitudes where the great ice ages began.[3] Obliquity is a major factor in glacial/interglacial fluctuations (see Milankovitch cycles).

The obliquity of the ecliptic is not a fixed quantity but changing over time in a cycle with a period of 41,000 years. It is a very slow effect known as nutation, and at the level of accuracy at which astronomers work, does need to be taken into account on a daily basis. Note that the obliquity and the precession of the equinoxes are calculated from the same theory and are thus related to each other. A smaller ε means a larger *p* (precession in longitude) and vice versa. Yet the two movements act independent from each other, going in mutually perpendicular directions.

## Measurement

Knowledge of the obliquity of the ecliptic (ε) is critical for astronomical calculations and observations from the surface of the earth (earth-based, positional astronomy).

To quickly grasp an idea of its numerical value one can look at how the sun's angle above the horizon varies with the seasons. The measured difference between the angles of the Sun above the horizon at noon on the longest and shortest days of the year gives twice the obliquity.

To an observer on the equator standing all year long looking above, the sun will be directly overhead at noon in March (Vernal Equinox), then swing north until it is 23° 26’ away from the zenith in June (Summer Solstice). In September (Autumnal Equinox) it will be back overhead, then at the Winter Solstice in December it will be 23° 26’ away from the vertical again.

Example: an observer at 50° latitude (either north or south) will see the Sun 63° 26’ above the horizon at noon on the longest day of the year, but only 16° 34’ the shortest day. The difference is 2ε = 46° 52’, and so ε = 23° 26’.

(90° - 50°) + 23.4394° = 63.4394° when measuring angles from the horizon (90° - 50°) - 23.4394° = 16.5606°

At the equator, this would be 90° + 23.4394° = 113.4394° and 90° - 23.4394° = 66.5606° (measuring always from the southern horizon).

## Values

The Earth's axial tilt varies between 22.1° and 24.5° (but see below), with a 42,000 year period, and at present, the tilt is decreasing. In addition to this steady decrease, there are also much smaller short term (18.6 years) variations, that is also affected by Sun's gravitation in its depleting angle relative to Earth's, known as nutation.

Simon Newcomb's calculation at the end of the nineteenth century for the obliquity of the ecliptic gave a value of 23° 27’ 8.26” (epoch of 1900), and this was generally accepted until improved telescopes allowed more accurate observations, and electronic computers permitted more elaborate models to be calculated. Lieske came with an updated model in 1976 with ε equal to 23° 26’ 21.448” (epoch of 2000), which is part of the approximation formula recommended by the International Astronomical Union in 2000:

$\varepsilon = 84{,}381.448 - 46.84024T - (59 \times 10^{-5})T^2 + (1.813 \times 10^{-3})T^3$, measured in seconds of arc, with *T* being the time in Julian centuries (that is, 36,525 days) since the ephemeris epoch of 2000 (which occurred on Julian day 2,451,545.0). A straight application of this formula to 1900 (T=-1) returns 23° 27’ 8.29”, which is very close to Newcomb's value.

With the linear term in *T* being negative, at present the obliquity is slowly decreasing. It is implicit that this expression gives only an approximate value for ε and is only valid for a certain range of values of T. If not, ε would approach infinity as *T* approaches infinity. Computations based on a numerical model of solar system show that ε has a period of about 41,000 years, the same as the constants of the precession p of the equinoxes (although not of the precession itself).

Other theoretical models may come with values for ε expressed with higher powers of *T*, but since no (finite) polynomial can ever represent a periodic function, they all go to either positive or negative infinity for large enough *T*. In that respect one can understand the decision of the International Astronomical Union to choose the simplest equation which agrees with most models. For up to 5,000 years in the past and the future all formulas agree, and up to 9,000 years in the past and the future, most agree to reasonable accuracy. For eras farther out discrepancies get too large.

## Long period variations

Nevertheless extrapolation of the average polynomials gives a fit to a sine curve with a period of 41,013 years, which, according to Wittmann, is equal to:

$\varepsilon = A + B \sin(C(T + D))$; with $A = 23.496932° \pm 0.001200°$, $B = -\ 0.860° \pm 0.005°$, $C = 0.01532 \pm 0.0009$ radians/Julian century, $D = 4.40 \pm 0.10$ Julian centuries, and *T*, the time in centuries from the epoch of 2000 as above.

This means a range of the obliquity from 22° 38′ to 24° 21′, the last maximum was reached in 8700 BC, the mean value occurred around 1550 and the next minimum will be in 11800. This formula should give a reasonable approximation for the previous and next million years or so. Yet it remains an approximation in which the amplitude of the wave remains the same, while in reality, as seen from the results of the Milankovitch cycles, irregular variations occur. The quoted range for the obliquity is from 21° 30′ to 24° 30′, but the low value may have been a one-time overshot of the normal 22° 30′.

Over the last 5 million years, the obliquity of the ecliptic (or more accurately, the obliquity of the equator on the moving ecliptic of date) has varied from 22.0425° to 24.5044°. But for the next one million years the range will be only from 22.2289° to 24.3472°.

Other planets may have a variable obliquity too, for example on Mars the range is believed to be between 11° and 49°, as a result of gravitational perturbations from other planets.[4] The relatively small range for the Earth is due to the stabilizing influence of the Moon, but it will not remain so. According to Ward, the orbit of the Moon (which is continuously increasing due to tidal effects) will have gone from the current 60 to approximately 66.5 Earth radii in about 1.5 billion years. Once this occurs, a resonance from planetary effects will follow, causing swings of the obliquity between 22° and 38°. Further, in approximately 2 billion years, when the Moon reaches a distance of 68 Earth radii, another resonance will cause even greater oscillations, between 27° and 60°. This would have extreme effects on climate.

Tentative evidence has recently emerged for extreme (> 50°) variations in terrestrial axial tilt.[5]

## Axial tilt of major celestial bodies

| Object | Axial tilt (°) |
|---|---|
| Mercury | ~0.01 |
| Venus | 177.4 |
| Earth | 23.439 281 |
| Moon | 1.5424 |
| Mars | 25.19 |
| Ceres | ~4 |
| Pallas | ~60 |
| Jupiter | 3.13 |
| Saturn | 26.73 |

| | |
|---|---|
| Uranus | 97.77 |
| Neptune | 28.32 |
| Pluto | 119.61 |
| Makemake | |
| Eris | |

## See also

- Celestial equator
- Celestial pole
- Ecliptic
- Milankovitch cycles
- Nutation
- Orbital plane
- Polar motion
- Retrograde motion
- Rotation axis
- True polar wander

## References

[1] http://nssdc.gsfc.nasa.gov/planetary/factsheet/planetfact_notes.html
[2] Staff (2007-08-07). " Useful Constants (http://hpiers.obspm.fr/eop-pc/models/constants.html)". International Earth Rotation and Reference Systems Service (IERS). . Retrieved 2008-09-23.
[3] Paleo Slide Sets (http://www.ncdc.noaa.gov/paleo/slides/slideset/11/11_187_slide.html)
[4] Touma, Jihad; Wisdom, Jack (1993). " The Chaotic Obliquity of Mars (http://adsabs.harvard.edu/abs/1993Sci...259.1294T)". *Science* **259**: 1294. .
[5] Planet Earth may have 'tilted' to keep its balance, say scientists (http://www.princeton.edu/main/news/archive/S15/64/72A37/index.xml?section=newsreleases)

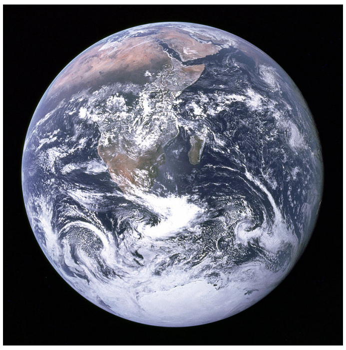
- Explanatory supplement to "the Astronomical ephemeris" and the American Ephemeris and Nautical Almanac
- tenspheres.com (http://www.tenspheres.com/researches/precession.htm) for a comparison of values predicted by different theories
- A.L. Berger; Obliquity & precession for the last 5 million years; Astronomy & astrophysics 1976, 51, 127
- A. Wittmann; The obliquity of the ecliptic; Astronomy & astrophysics 73, 129-131 (1979)
- W.R. Ward; Comments on the long-term stability of the Earth's obliquity; Icarus 1982, 50, 444
- National Space Science Data Center (http://nssdc.gsfc.nasa.gov/planetary/)

## External links

- *Axial Tilts of Planets* (http://demonstrations.wolfram.com/AxialTiltsOfPlanets/) by Jeff Bryant, Wolfram Demonstrations Project.

# Earth

## Earth ⊕



Famous "Blue Marble" photograph of Earth, taken from Apollo 17

| | |
|---|---|
| **Designations** | |
| **Pronunciation** | English pronunciation: /ˈɜrθ/( listen)[1] |
| **Adjective** | earthly, tellurian, telluric, terran, terrestrial. |
| **Orbital characteristics** | |
| Epoch J2000.0[2] | |
| **Aphelion** | 152,097,701 km<br>1.0167103335 AU |
| **Perihelion** | 147,098,074 km<br>0.9832898912 AU |
| **Semi-major axis** | 149,597,887.5 km<br>1.0000001124 AU |
| **Eccentricity** | 0.016710219 |
| **Orbital period** | 365.256366 days<br>1.0000175 yr |
| **Average orbital speed** | 29.783 km/s<br>107,218 km/h |
| **Inclination** | 1.57869°[3]<br>to Invariable plane |
| **Longitude of ascending node** | 348.73936° |
| **Argument of perihelion** | 114.20783° |
| **Satellites** | 1 (the Moon) |
| **Physical characteristics** | |
| **Mean radius** | 6,371.0 km[4] |
| **Equatorial radius** | 6,378.1 km[5] |
| **Polar radius** | 6,356.8 km[6] |
| **Flattening** | 0.0033528[5] |

| | |
|---|---|
| **Circumference** | 40,075.02 km (equatorial)<br>40,007.86 km (meridional)<br>40,041.47 km (mean) |
| **Surface area** | 510,072,000 km²[7] [8] [9]<br>148,940,000 km² land (29.2 %)<br>361,132,000 km² water (70.8 %) |
| **Volume** | $1.0832073 \times 10^{12}$ km$^3$ |
| **Mass** | $5.9736 \times 10^{24}$ kg[10] |
| **Mean density** | 5.5153 g/cm$^3$ |
| **Equatorial surface gravity** | 9.780327 m/s²[11]<br>0.99732 *g* |
| **Escape velocity** | 11.186 km/s |
| **Sidereal rotation period** | 0.99726968 d[12]<br>$23^h\ 56^m\ 4.100^s$ |
| **Equatorial rotation velocity** | 1674.4 km/h (465.1 m/s) |
| **Axial tilt** | 23.439281° |
| **Albedo** | 0.367[10] |
| **Surface temp.**<br>**Kelvin**<br>**Celsius** | **min** / **mean** / **max**<br>184 K / 287 K / 331 K<br>−89 °C / 14 °C / 57.7 °C |
| Atmosphere | |
| **Surface pressure** | 101.3 kPa (MSL) |
| **Composition** | 78.08% Nitrogen ($N_2$)<br>20.95% Oxygen ($O_2$)<br>0.93% Argon<br>0.038% Carbon dioxide<br>About 1% water vapor (varies with climate)[10] |

**Earth** (or **the Earth**) is the third planet from the Sun, and the fifth-largest of the eight planets in the Solar System. It is also the largest, most massive, and densest of the Solar System's four terrestrial (or rocky) planets. It is sometimes referred to as *the World*, the *Blue Planet*,[13] or *Terra*.[14]

Home to millions of species,[15] including humans, Earth is the only place in the universe where life is known to exist. The planet formed 4.54 billion years ago,[16] and life appeared on its surface within a billion years. Since then, Earth's biosphere has significantly altered the atmosphere and other abiotic conditions on the planet, enabling the proliferation of aerobic organisms as well as the formation of the ozone layer which, together with Earth's magnetic field, blocks harmful radiation, permitting life on land.[17] The physical properties of the Earth, as well as its geological history and orbit, allowed life to persist during this period. The world is expected to continue supporting life for another 1.5 billion years, after which the rising luminosity of the Sun will eliminate the biosphere.[18]

Earth's outer surface is divided into several rigid segments, or tectonic plates, that gradually migrate across the surface over periods of many millions of years. About 71% of the surface is covered with salt-water oceans, the remainder consisting of continents and islands; liquid water, necessary for all known life, is not known to exist on any other planet's surface.[19] [20] Earth's interior remains active, with a thick layer of relatively solid mantle, a liquid outer core that generates a magnetic field, and a solid iron inner core.

Earth interacts with other objects in outer space, including the Sun and the Moon. At present, Earth orbits the Sun once for every roughly 366.26 times it rotates about its axis. This length of time is a sidereal year, which is equal to 365.26 solar days.[21] The Earth's axis of rotation is tilted 23.4° away from the perpendicular to its orbital plane,[22] producing seasonal variations on the planet's surface with a period of one tropical year (365.24 solar days). Earth's only known natural satellite, the Moon, which began orbiting it about 4.53 billion years ago, provides ocean tides, stabilizes the axial tilt and gradually slows the planet's rotation. Between approximately 4.1 and 3.8 billion years ago, asteroid impacts during the Late Heavy Bombardment caused significant changes to the surface environment.

Both the mineral resources of the planet, as well as the products of the biosphere, contribute resources that are used to support a global human population. The inhabitants are grouped into about 200 independent sovereign states, which interact through diplomacy, travel, trade and military action. Human cultures have developed many views of the planet, including personification as a deity, a belief in a flat Earth or in Earth being the center of the universe, and a modern perspective of the world as an integrated environment that requires stewardship.

# Chronology

Scientists have been able to reconstruct detailed information about the planet's past. The earliest dated Solar System material is dated to 4.5672 ± 0.0006 billion years ago,[23] and by 4.54 billion years ago (within an uncertainty of 1%)[16] the Earth and the other planets in the Solar System formed out of the solar nebula—a disk-shaped mass of dust and gas left over from the formation of the Sun. This assembly of the Earth through accretion was largely completed within 10–20 million years.[24] Initially molten, the outer layer of the planet Earth cooled to form a solid crust when water began accumulating in the atmosphere. The Moon formed shortly thereafter, 4.53 billion years ago,[25] most likely as the result of a Mars-sized object (sometimes called Theia) with about 10% of the Earth's mass[26] impacting the Earth in a glancing blow.[27] Some of this object's mass would have merged with the Earth and a portion would have been ejected into space, but enough material would have been sent into orbit to form the Moon.

Outgassing and volcanic activity produced the primordial atmosphere. Condensing water vapor, augmented by ice and liquid water delivered by asteroids and the larger proto-planets, comets, and trans-Neptunian objects produced the oceans.[28] The newly-formed Sun was only 70% of its present luminosity, yet evidence shows that the early oceans remained liquid—a contradiction dubbed the faint young Sun paradox. A combination of greenhouse gases and higher levels of solar activity served to raise the Earth's surface temperature, preventing the oceans from freezing over.[29]

Two major models have been proposed for the rate of continental growth:[30] steady growth to the present-day[31] and rapid growth early in Earth history.[32] Current research shows that the second option is most likely, with rapid initial growth of continental crust[33] followed by a long-term steady continental area.[34] [35] [36] On time scales lasting hundreds of millions of years, the surface continually reshaped itself as continents formed and broke up. The continents migrated across the surface, occasionally combining to form a supercontinent. Roughly 750 million years ago (Ma), one of the earliest known supercontinents, Rodinia, began to break apart. The continents later recombined to form Pannotia, 600–540 Ma, then finally Pangaea, which broke apart 180 Ma.[37]

## Evolution of life

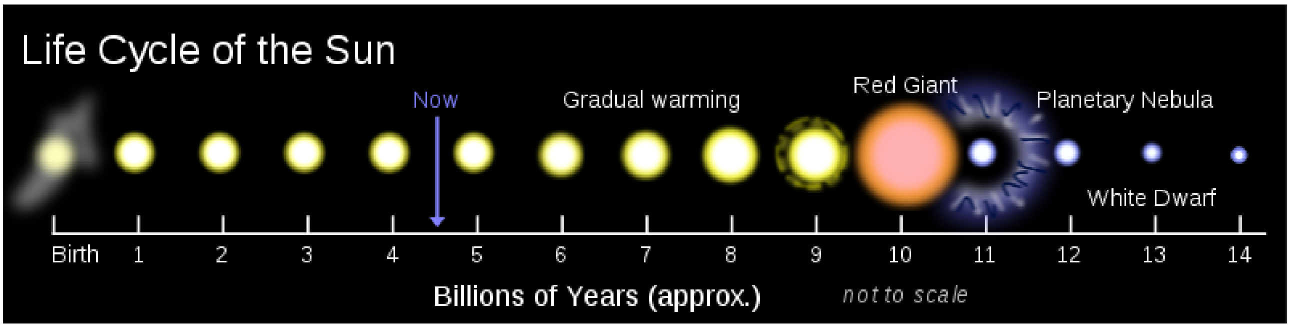
At present, Earth provides the only example of an environment that has given rise to the evolution of life.[38] Highly energetic chemistry is believed to have produced a self-replicating molecule around 4 billion years ago, and half a billion years later the last common ancestor of all life existed.[39] The development of photosynthesis allowed the Sun's energy to be harvested directly by life forms; the resultant oxygen accumulated in the atmosphere and formed in a layer of ozone (a form of molecular oxygen [$O_3$]) in the upper atmosphere. The incorporation of smaller cells within larger ones resulted in the development of complex cells called eukaryotes.[40] True multicellular organisms formed as cells within colonies became increasingly specialized. Aided by the absorption of harmful ultraviolet radiation by the ozone layer, life colonized the surface of Earth.[41]

Since the 1960s, it has been hypothesized that severe glacial action between 750 and 580 Ma, during the Neoproterozoic, covered much of the planet in a sheet of ice. This hypothesis has been termed "Snowball Earth", and is of particular interest because it preceded the Cambrian explosion, when multicellular life forms began to proliferate.[42]

Following the Cambrian explosion, about 535 Ma, there have been five mass extinctions.[43] The last extinction event was 65 Ma, when a meteorite collision probably triggered the extinction of the (non-avian) dinosaurs and other large reptiles, but spared small animals such as mammals, which then resembled shrews. Over the past 65 million years, mammalian life has diversified, and several million years ago, an African ape-like animal such as *Orrorin tugenensis* gained the ability to stand upright.[44] This enabled tool use and encouraged communication that provided the nutrition and stimulation needed for a larger brain. The development of agriculture, and then civilization, allowed humans to influence the Earth in a short time span as no other life form had,[45] affecting both the nature and quantity of other life forms.

The present pattern of ice ages began about 40 Ma and then intensified during the Pleistocene about 3 Ma. The polar regions have since undergone repeated cycles of glaciation and thaw, repeating every 40–100,000 years. The last ice age ended 10,000 years ago.[46]

## Future




The future of the planet is closely tied to that of the Sun. As a result of the steady accumulation of helium at the Sun's core, the star's total luminosity will slowly increase. The luminosity of the Sun will grow by 10% over the next 1.1 Gyr (1.1 billion years) and by 40% over the next 3.5 Gyr.[47] Climate models indicate that the rise in radiation reaching the Earth is likely to have dire consequences, including the possible loss of the planet's oceans.[48]

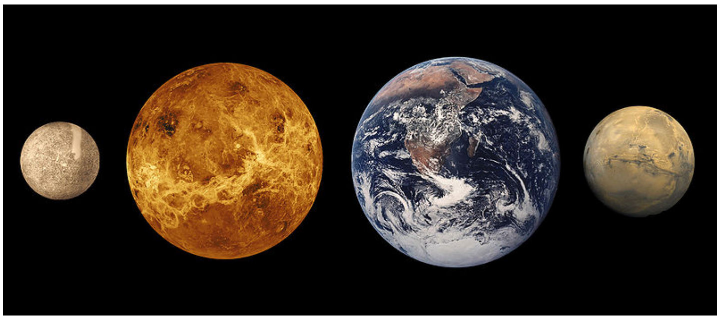
The Earth's increasing surface temperature will accelerate the inorganic $CO_2$ cycle, reducing its concentration to lethal levels for plants (10 ppm for C4 photosynthesis) in an estimated 900 million years. The lack of vegetation will result in the loss of oxygen in the atmosphere, so animal life will become extinct within several million more years.[49] After another billion years all surface water will have disappeared[18] and the mean global temperature will reach 70 °C[49] (158 °F). The Earth is expected to be effectively habitable for about another 500 million years,[50] although this may be extended up to 2.3 billion years if the nitrogen is removed from the atmosphere.[51] Even if the Sun were eternal and stable, the continued internal cooling of the Earth would result in a loss of much of its $CO_2$ due to reduced volcanism,[52] and 35% of the water in the oceans would descend to the mantle due to reduced steam venting from mid-ocean ridges.[53]

The Sun, as part of its evolution, will become a red giant in about 5 Gyr. Models predict that the Sun will expand out to about 250 times its present radius, roughly 1 AU (150000000 km).[47] [54] Earth's fate is less clear. As a red giant, the Sun will lose roughly 30% of its mass, so, without tidal effects, the Earth will move to an orbit 1.7 AU (250000000 km) from the Sun when the star reaches it maximum radius. Therefore, the planet is expected to escape envelopment by the expanded Sun's sparse outer atmosphere, though most, if not all, remaining life will be destroyed because of the Sun's increased luminosity.[47] However, a more recent simulation indicates that Earth's orbit will decay due to tidal effects and drag, causing it to enter the red giant Sun's atmosphere and be destroyed.[54]

## Composition and structure

Earth is a terrestrial planet, meaning that it is a rocky body, rather than a gas giant like Jupiter. It is the largest of the four solar terrestrial planets, both in terms of size and mass. Of these four planets, Earth also has the highest density, the highest surface gravity, the strongest magnetic field, and fastest rotation.[55] It also is the only terrestrial planet with active plate tectonics.[56]

### Shape



Size comparison of inner planets (left to right): Mercury, Venus, Earth and Mars

The shape of the Earth is very close to that of an oblate spheroid, a sphere squished along the orientation from pole to pole such that there is a bulge around the equator.[57] This bulge results from the rotation of the Earth, and causes the diameter at the equator to be 43 km larger than the pole to pole diameter.[58] The average diameter of the reference spheroid is about 12,742 km, which is approximately 40,000 km/π, as the meter was originally defined as 1/10,000,000 of the distance from the equator to the North Pole through Paris, France.[59]

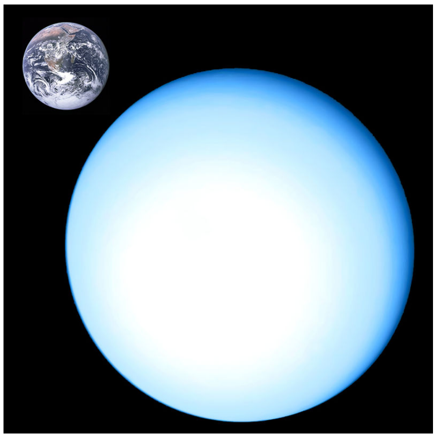
Local topography deviates from this idealized spheroid, though on a global scale, these deviations are very small: Earth has a tolerance of about one part in about 584, or 0.17%, from the reference spheroid, which is less than the 0.22% tolerance allowed in billiard balls.[60] The largest local deviations in the rocky surface of the Earth are Mount Everest (8,848 m above local sea level) and the Mariana Trench (10,911 m below local sea level). Because of the equatorial bulge, the feature farthest from the center of the Earth is actually Mount Chimborazo in Ecuador.[61] [62]

### Chemical Composition of the Crust[63]

| Compound | Formula | Composition | |
|---|---|---|---|
| | | Continental | Oceanic |
| silica | $SiO_2$ | 60.2% | 48.6% |
| alumina | $Al_2O_3$ | 15.2% | 16.5% |
| lime | CaO | 5.5% | 12.3% |
| magnesia | MgO | 3.1% | 6.8% |
| iron(II) oxide | FeO | 3.8% | 6.2% |
| sodium oxide | $Na_2O$ | 3.0% | 2.6% |
| potassium oxide | $K_2O$ | 2.8% | 0.4% |
| iron(III) oxide | $Fe_2O_3$ | 2.5% | 2.3% |
| water | $H_2O$ | 1.4% | 1.1% |
| carbon dioxide | $CO_2$ | 1.2% | 1.4% |
| titanium dioxide | $TiO_2$ | 0.7% | 1.4% |

| | | | |
|---|---|---|---|
| phosphorus pentoxide | $P_2O_5$ | 0.2% | 0.3% |
| **Total** | | **99.6%** | **99.9%** |

## Chemical composition



Size comparison of Earth and Uranus

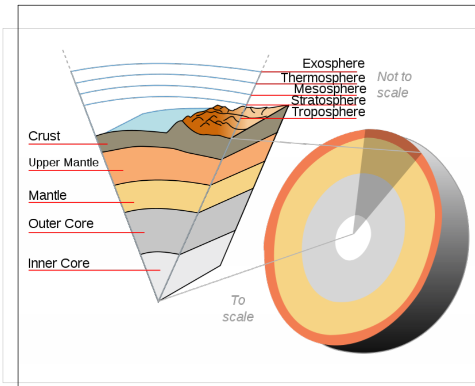
The mass of the Earth is approximately 5.98 × $10^{24}$ kg. It is composed mostly of iron (32.1%), oxygen (30.1%), silicon (15.1%), magnesium (13.9%), sulfur (2.9%), nickel (1.8%), calcium (1.5%), and aluminium (1.4%); with the remaining 1.2% consisting of trace amounts of other elements. Due to mass segregation, the core region is believed to be primarily composed of iron (88.8%), with smaller amounts of nickel (5.8%), sulfur (4.5%), and less than 1% trace elements.[64]

The geochemist F. W. Clarke calculated that a little more than 47% of the Earth's crust consists of oxygen. The more common rock constituents of the Earth's crust are nearly all oxides; chlorine, sulfur and fluorine are the only important exceptions to this and their total amount in any rock is usually much less than 1%. The principal oxides are silica, alumina, iron oxides, lime, magnesia, potash and soda. The silica functions principally as an acid, forming silicates, and all the commonest minerals of igneous rocks are of this nature. From a computation based on 1,672 analyses of all kinds of rocks, Clarke deduced that 99.22% were composed of 11 oxides (see the table at right.) All the other constituents occur only in very small quantities.[]

## Internal structure

The interior of the Earth, like that of the other terrestrial planets, is divided into layers by their chemical or physical (rheological) properties. The outer layer of the Earth is a chemically distinct silicate solid crust, which is underlain by a highly viscous solid mantle. The crust is separated from the mantle by the Mohorovičić discontinuity, and the thickness of the crust varies: averaging 6 km under the oceans and 30–50 km on the continents. The crust and the cold, rigid, top of the upper mantle are collectively known as the lithosphere, and it is of the lithosphere that the tectonic plates are comprised. Beneath the lithosphere is the asthenosphere, a relatively low-viscosity layer on which the lithosphere rides. Important changes in crystal structure within the mantle occur at 410 and 660 kilometers below the surface, spanning a transition zone that separates the upper and lower mantle. Beneath the mantle, an extremely low viscosity liquid outer core lies above a solid inner core.[65] The inner core may rotate at a slightly higher angular velocity than the remainder of the planet, advancing by 0.1–0.5° per year.[66]

### Geologic layers of the Earth[67]




Earth cutaway from core to exosphere. Not to scale.

| Depth[68] km | Component Layer | Density $g/cm^3$ |
|---|---|---|
| 0–60 | Lithosphere[69] | — |
| 0–35 | ... Crust[70] | 2.2–2.9 |
| 35–60 | ... Upper mantle | 3.4–4.4 |
| 35–2890 | Mantle | 3.4–5.6 |
| 100–700 | ... Asthenosphere | — |
| 2890–5100 | Outer core | 9.9–12.2 |
| 5100–6378 | Inner core | 12.8–13.1 |

## Heat

Earth's internal heat comes from a combination of residual heat from planetary accretion (about 20%) and heat produced through radioactive decay (80%).[71] The major heat-producing isotopes in the Earth are potassium-40, uranium-238, uranium-235, and thorium-232.[72] At the center of the planet, the temperature may be up to 7,000 K and the pressure could reach 360 GPa.[73] Because much of the heat is provided by radioactive decay, scientists believe that early in Earth history, before isotopes with short half-lives had been depleted, Earth's heat production would have been much higher. This extra heat production, twice present-day at approximately 3 billion years ago,[71] would have increased temperature gradients within the Earth, increasing the rates of mantle convection and plate tectonics, and allowing the production of igneous rocks such as komatiites that are not formed today.[74]

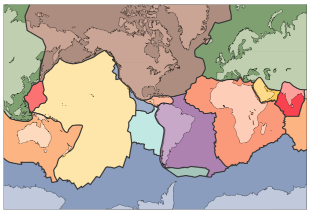
### Present-day major heat-producing isotopes[75]

| Isotope | Heat release W/kg isotope | Half-life years | Mean mantle concentration kg isotope/kg mantle | Heat release W/kg mantle |
|---|---|---|---|---|
| $^{238}U$ | $9.46 \times 10^{-5}$ | $4.47 \times 10^{9}$ | $30.8 \times 10^{-9}$ | $2.91 \times 10^{-12}$ |
| $^{235}U$ | $5.69 \times 10^{-4}$ | $7.04 \times 10^{8}$ | $0.22 \times 10^{-9}$ | $1.25 \times 10^{-13}$ |
| $^{232}Th$ | $2.64 \times 10^{-5}$ | $1.40 \times 10^{10}$ | $124 \times 10^{-9}$ | $3.27 \times 10^{-12}$ |
| $^{40}K$ | $2.92 \times 10^{-5}$ | $1.25 \times 10^{9}$ | $36.9 \times 10^{-9}$ | $1.08 \times 10^{-12}$ |

Total heat loss from the earth is $4.2 \times 10^{13}$ Watts.[76] A portion of the core's thermal energy is transported toward the crust by Mantle plumes; a form of convection consisting of upwellings of higher-temperature rock. These plumes can produce hotspots and flood basalts.[77] More of the heat in the Earth is lost through plate tectonics, by mantle upwelling associated with mid-ocean ridges. The final major mode of heat loss is through conduction through the lithosphere, majority of which occurs in the oceans due to the crust there being much thinner than that of the continents.[76]

## Tectonic plates

### Earth's main plates[78]



| Plate name | Area $10^6$ km² |
|---|---|
| African Plate[79] | 78.0 |
| Antarctic Plate | 60.9 |
| Australian Plate | 47.2 |
| Eurasian Plate | 67.8 |
| North American Plate | 75.9 |
| South American Plate | 43.6 |
| Pacific Plate | 103.3 |

The mechanically rigid outer layer of the Earth, the lithosphere, is broken into pieces called tectonic plates. These plates are rigid segments that move in relation to one another at one of three types of plate boundaries: Convergent boundaries, at which two plates come together, Divergent boundaries, at which two plates are pulled apart, and Transform boundaries, in which two plates slide past one another laterally. Earthquakes, volcanic activity, mountain-building, and oceanic trench formation can occur along these plate boundaries.[80] The tectonic plates ride on top of the asthenosphere, the solid but less-viscous part of the upper mantle that can flow and move along with the plates,[81] and their motion is strongly coupled with patterns convection inside the Earth's mantle.

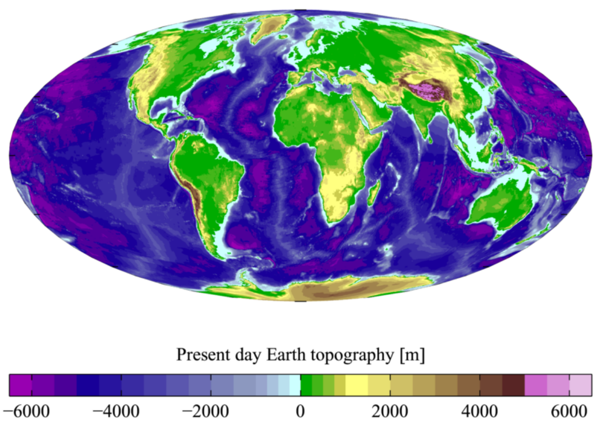
As the tectonic plates migrate across the planet, the ocean floor is subducted under the leading edges of the plates at convergent boundaries. At the same time, the upwelling of mantle material at divergent boundaries creates mid-ocean ridges. The combination of these processes continually recycles the oceanic crust back into the mantle. Because of this recycling, most of the ocean floor is less than 100 million years in age. The oldest oceanic crust is located in the Western Pacific, and has an estimated age of about 200 million years.[82] [83] By comparison, the oldest dated continental crust is 4030 million years old.[84]

Other notable plates include the Indian Plate, the Arabian Plate, the Caribbean Plate, the Nazca Plate off the west coast of South America and the Scotia Plate in the southern Atlantic Ocean. The Australian Plate actually fused with Indian Plate between 50 and 55 million years ago. The fastest-moving plates are the oceanic plates, with the Cocos Plate advancing at a rate of 75 mm/yr[85] and the Pacific Plate moving 52–69 mm/yr. At the other extreme, the slowest-moving plate is the Eurasian Plate, progressing at a typical rate of about 21 mm/yr.[86]

## Surface

The Earth's terrain varies greatly from place to place. About 70.8%[87] of the surface is covered by water, with much of the continental shelf below sea level. The submerged surface has mountainous features, including a globe-spanning mid-ocean ridge system, as well as undersea volcanoes,[58] oceanic trenches, submarine canyons, oceanic plateaus and abyssal plains. The remaining 29.2% not covered by water consists of mountains, deserts, plains, plateaus, and other geomorphologies.

The planetary surface undergoes reshaping over geological time periods due to the effects of tectonics and erosion. The surface features built up or deformed through plate tectonics are subject to steady weathering from precipitation, thermal cycles, and chemical effects. Glaciation, coastal erosion, the build-up of coral reefs, and large meteorite impacts[88] also act to reshape the landscape.




Present day Earth altimetry and bathymetry. Data from the National Geophysical Data Center's TerrainBase Digital Terrain Model [89].

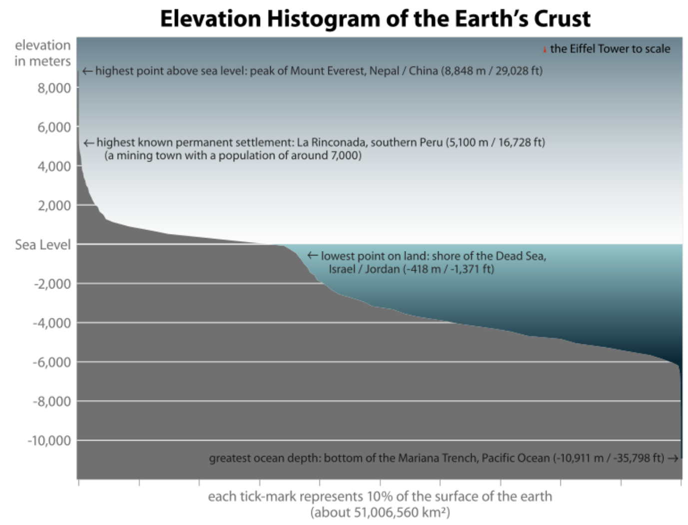
The continental crust consists of lower density material such as the igneous rocks granite and andesite. Less common is basalt, a denser volcanic rock that is the primary constituent of the ocean floors.[90] Sedimentary rock is formed from the accumulation of sediment that becomes compacted together. Nearly 75% of the continental surfaces are covered by sedimentary rocks, although they form only about 5% of the crust.[91] The third form of rock material found on Earth is metamorphic rock, which is created from the transformation of pre-existing rock types through high pressures, high temperatures, or both. The most abundant silicate minerals on the Earth's surface include quartz, the feldspars, amphibole, mica, pyroxene and olivine.[92] Common carbonate minerals include calcite (found in limestone), aragonite and dolomite.[93]

The pedosphere is the outermost layer of the Earth that is composed of soil and subject to soil formation processes. It exists at the interface of the lithosphere, atmosphere, hydrosphere and biosphere. Currently the total arable land is 13.31% of the land surface, with only 4.71% supporting permanent crops.[8] Close to 40% of the Earth's land surface is presently used for cropland and pasture, or an estimated $1.3 \times 10^7$ km² of cropland and $3.4 \times 10^7$ km² of pastureland.[94]

The elevation of the land surface of the Earth varies from the low point of −418 m at the Dead Sea, to a 2005-estimated maximum altitude of 8,848 m at the top of Mount Everest. The mean height of land above sea level is 840 m.[95]

## Hydrosphere

The abundance of water on Earth's surface is a unique feature that distinguishes the "Blue Planet" from others in the Solar System. The Earth's hydrosphere consists chiefly of the oceans, but technically includes all water surfaces in the world, including inland seas, lakes, rivers, and underground waters down to a depth of 2,000 m. The deepest underwater location is Challenger Deep of the Mariana Trench in the Pacific Ocean with a depth of −10,911.4 m.[96] [97] The average depth of the oceans is 3,800 m, more than four times the average height of the continents.[95]




Elevation histogram of the surface of the Earth. Approximately 71% of the Earth's surface is covered with water.

The mass of the oceans is approximately $1.35 \times 10^{18}$ metric tons, or about 1/4400 of the total mass of the Earth, and occupies a volume of $1.386 \times 10^9$ km$^3$. If all of the land on Earth were spread evenly, water would rise to an altitude of more than 2.7 km.[98] About 97.5% of the water is saline, while the remaining 2.5% is fresh water. The majority of the fresh water, about 68.7%, is currently in the form of ice.[99]

About 3.5% of the total mass of the oceans consists of salt. Most of this salt was released from volcanic activity or extracted from cool, igneous rocks.[100] The oceans are also a reservoir of dissolved atmospheric gases, which are essential for the survival of many aquatic life forms.[101] Sea water has an important influence on the world's climate, with the oceans acting as a large heat reservoir.[102] Shifts in the oceanic temperature distribution can cause significant weather shifts, such as the El Niño-Southern Oscillation.[103]

## Atmosphere

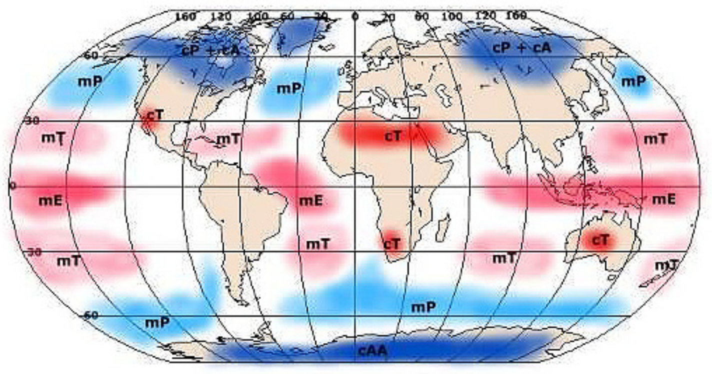
The atmospheric pressure on the surface of the Earth averages 101.325 kPa, with a scale height of about 8.5 km.[10] It is 78% nitrogen and 21% oxygen, with trace amounts of water vapor, carbon dioxide and other gaseous molecules. The height of the troposphere varies with latitude, ranging between 8 km at the poles to 17 km at the equator, with some variation due to weather and seasonal factors.[104]

Earth's biosphere has significantly altered its atmosphere. Oxygenic photosynthesis evolved 2.7 billion years ago, forming the primarily nitrogen-oxygen atmosphere that exists today. This change enabled the proliferation of aerobic organisms as well as the formation of the ozone layer which, together with Earth's magnetic field, blocks ultraviolet solar radiation, permitting life on land. Other atmospheric functions important to life on Earth include transporting water vapor, providing useful gases, causing small meteors to burn up before they strike the surface, and moderating temperature.[105] This last phenomenon is known as the greenhouse effect: trace molecules within the atmosphere serve to capture thermal energy emitted from the ground, thereby raising the average temperature. Carbon dioxide, water vapor, methane and ozone are the primary greenhouse gases in the Earth's atmosphere. Without this heat-retention effect, the average surface temperature would be −18 °C and life would likely not exist.[87]

### Weather and climate

The Earth's atmosphere has no definite boundary, slowly becoming thinner and fading into outer space. Three-quarters of the atmosphere's mass is contained within the first 11 km of the planet's surface. This lowest layer is called the troposphere. Energy from the Sun heats this layer, and the surface below, causing expansion of the air. This lower density air then rises, and is replaced by cooler, higher density air. The result is atmospheric circulation that drives the weather and climate through redistribution of heat energy.[106]

The primary atmospheric circulation bands consist of the trade winds in the equatorial region below 30° latitude and the westerlies in the mid-latitudes between 30° and 60°.[107] Ocean currents are also important factors in determining climate, particularly the thermohaline circulation that distributes heat energy from the equatorial oceans to the polar regions.[108]




Source regions of global air masses

Water vapor generated through surface evaporation is transported by circulatory patterns in the atmosphere. When atmospheric conditions permit an uplift of warm, humid air, this water condenses and settles to the surface as precipitation.[106] Most of the water is then transported back to lower elevations by river systems, usually returning to the oceans or being deposited into lakes. This water cycle is a vital mechanism for supporting life on land, and is a primary factor in the erosion of surface features over geological periods. Precipitation patterns vary widely, ranging from several meters of water per year to less than a millimeter. Atmospheric circulation, topological features and temperature differences determine the average precipitation that falls in each region.[109]

The Earth can be sub-divided into specific latitudinal belts of approximately homogeneous climate. Ranging from the equator to the polar regions, these are the tropical (or equatorial), subtropical, temperate and polar climates.[110] Climate can also be classified based on the temperature and precipitation, with the climate regions characterized by fairly uniform air masses. The commonly used Köppen climate classification system (as modified by Wladimir Köppen's student Rudolph Geiger) has five broad groups (humid tropics, arid, humid middle latitudes, continental and cold polar), which are further divided into more specific subtypes.[107]

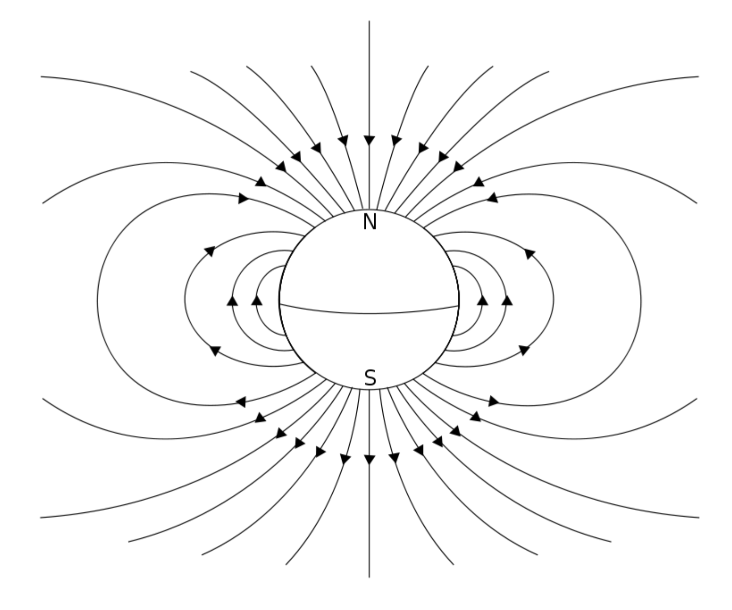
### Upper atmosphere

This view from orbit shows the full Moon partially obscured by the Earth's atmosphere. *NASA image.*

Above the troposphere, the atmosphere is usually divided into the stratosphere, mesosphere, and thermosphere.[105] Each of these layers has a different lapse rate, defining the rate of change in temperature with height. Beyond these, the exosphere thins out into the magnetosphere. This is where the Earth's magnetic fields interact with the solar wind.[111] An important part of the atmosphere for life on Earth is the ozone layer, a component of the stratosphere that partially shields the surface from ultraviolet light. The Kármán line, defined as 100 km above the Earth's surface, is a working definition for the boundary between atmosphere and space.[112]

Due to thermal energy, some of the molecules at the outer edge of the Earth's atmosphere have their velocity increased to the point where they can escape from the planet's gravity. This results in a slow but steady leakage of the atmosphere into space. Because unfixed hydrogen has a low molecular weight, it can achieve escape velocity more readily and it leaks into outer space at a greater rate than other gasses.[113] The leakage of hydrogen into space is a contributing factor in pushing the Earth from an initially reducing state to its current oxidizing one. Photosynthesis provided a source of free oxygen, but the loss of reducing agents such as hydrogen is believed to have been a necessary precondition for the widespread accumulation of oxygen in the atmosphere.[114] Hence the ability of hydrogen to escape from the Earth's atmosphere may have influenced the nature of life that developed on the planet.[115] In the current, oxygen-rich atmosphere most hydrogen is converted into water before it has an opportunity to escape. Instead, most of the hydrogen loss comes from the destruction of methane in the upper atmosphere.[116]

### Magnetic field



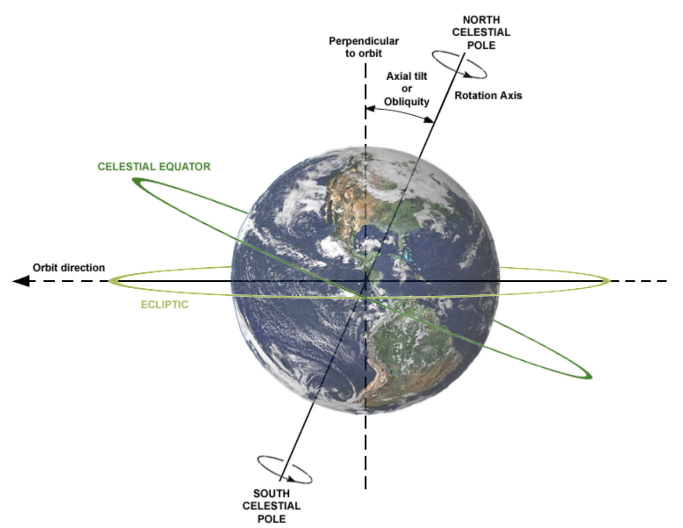
The Earth's magnetic field, which approximates a dipole.

The Earth's magnetic field is shaped roughly as a magnetic dipole, with the poles currently located proximate to the planet's geographic poles. According to dynamo theory, the field is generated within the molten outer core region where heat creates convection motions of conducting materials, generating electric currents. These in turn produce the Earth's magnetic field. The convection movements in the core are chaotic in nature, and periodically change alignment. This results in field reversals at irregular intervals averaging a few times every million years. The most recent reversal occurred approximately 700,000 years ago.[117] [118]

The field forms the magnetosphere, which deflects particles in the solar wind. The sunward edge of the bow shock is located at about 13 times the radius of the Earth. The collision between the magnetic field and the solar wind forms the Van Allen radiation belts, a pair of concentric, torus-shaped regions of energetic charged particles. When the plasma enters the Earth's atmosphere at the magnetic poles, it forms the aurora.[119]

## Orbit and rotation

### Rotation



Earth's axial tilt (or obliquity) and its relation to the rotation axis and plane of orbit.

Earth's rotation period relative to the Sun—its mean solar day—is 86,400 seconds of mean solar time. Each of these seconds is slightly longer than an SI second because Earth's solar day is now slightly longer than it was during the 19th century due to tidal acceleration.[120]

Earth's rotation period relative to the fixed stars, called its *stellar day* by the International Earth Rotation and Reference Systems Service (IERS), is 86164.098903691 seconds of mean solar time (UT1), or $23^h\ 56^m\ 4.098903691^s$.[121] [122] Earth's rotation period relative to the precessing or moving mean vernal equinox, misnamed its *sidereal day*, is 86164.09053083288 seconds of mean solar time (UT1) ($23^h\ 56^m\ 4.09053083288^s$).[121] Thus the sidereal day is shorter than the stellar day by about 8.4 ms.[123] The length of the mean solar day in SI seconds is available from the IERS for the periods 1623–2005[124] and 1962–2005.[125]

Apart from meteors within the atmosphere and low-orbiting satellites, the main apparent motion of celestial bodies in the Earth's sky is to the west at a rate of 15°/h = 15'/min. This is equivalent to an apparent diameter of the Sun or Moon every two minutes; the apparent sizes of the Sun and the Moon are approximately the same.[126] [127]

## Orbit

Earth orbits the Sun at an average distance of about 150 million kilometers every 365.2564 mean solar days, or one sidereal year. From Earth, this gives an apparent movement of the Sun eastward with respect to the stars at a rate of about 1°/day, or a Sun or Moon diameter every 12 hours. Because of this motion, on average it takes 24 hours—a solar day—for Earth to complete a full rotation about its axis so that the Sun returns to the meridian. The orbital speed of the Earth averages about 30 km/s (108,000 km/h), which is fast enough to cover the planet's diameter (about 12,600 km) in seven minutes, and the distance to the Moon (384,000 km) in four hours.[10]

The Moon revolves with the Earth around a common barycenter every 27.32 days relative to the background stars. When combined with the Earth–Moon system's common revolution around the Sun, the period of the synodic month, from new moon to new moon, is 29.53 days. Viewed from the celestial north pole, the motion of Earth, the Moon and their axial rotations are all counter-clockwise. Viewed from a vantage point above the north poles of both the Sun and the Earth, the Earth appears to revolve in a counterclockwise direction about the Sun. The orbital and axial planes are not precisely aligned: Earth's axis is tilted some 23.5 degrees from the perpendicular to the Earth–Sun plane, and the Earth–Moon plane is tilted about 5 degrees against the Earth-Sun plane. Without this tilt, there would be an eclipse every two weeks, alternating between lunar eclipses and solar eclipses.[10] [128]

The Hill sphere, or gravitational sphere of influence, of the Earth is about 1.5 Gm (or 1,500,000 kilometers) in radius.[129] [130] This is maximum distance at which the Earth's gravitational influence is stronger than the more distant Sun and planets. Objects must orbit the Earth within this radius, or they can become unbound by the gravitational perturbation of the Sun.

Earth, along with the Solar System, is situated in the Milky Way galaxy, orbiting about 28,000 light years from the center of the galaxy. It is currently about 20 light years above the galaxy's equatorial plane in the Orion spiral arm.[131]

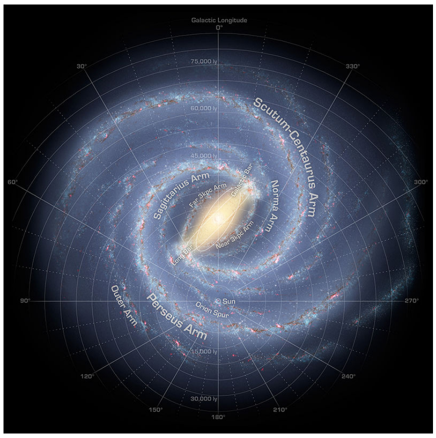



Illustration of the Milky Way Galaxy, showing the location of the Sun.

### Axial tilt and seasons

Because of the axial tilt of the Earth, the amount of sunlight reaching any given point on the surface varies over the course of the year. This results in seasonal change in climate, with summer in the northern hemisphere occurring when the North Pole is pointing toward the Sun, and winter taking place when the pole is pointed away. During the summer, the day lasts longer and the Sun climbs higher in the sky. In winter, the climate becomes generally cooler and the days shorter. Above the Arctic Circle, an extreme case is reached where there is no daylight at all for part of the year—a polar night. In the southern hemisphere the situation is exactly reversed, with the South Pole oriented opposite the direction of the North Pole.

Earth and Moon from Mars, imaged by Mars Global Surveyor. From space, the Earth can be seen to go through phases similar to the phases of the Moon.

By astronomical convention, the four seasons are determined by the solstices—the point in the orbit of maximum axial tilt toward or away from the Sun—and the equinoxes, when the direction of the tilt and the direction to the Sun are perpendicular. Winter solstice occurs on about December 21, summer solstice is near June 21, spring equinox is around March 20 and autumnal equinox is about September 23.[132]

The angle of the Earth's tilt is relatively stable over long periods of time. However, the tilt does undergo nutation; a slight, irregular motion with a main period of 18.6 years. The orientation (rather than the angle) of the Earth's axis also changes over time, precessing around in a complete circle over each 25,800 year cycle; this precession is the reason for the difference between a sidereal year and a tropical year. Both of these motions are caused by the varying attraction of the Sun and Moon on the Earth's equatorial bulge. From the perspective of the Earth, the poles also migrate a few meters across the surface. This polar motion has multiple, cyclical components, which collectively are termed quasiperiodic motion. In addition to an annual component to this motion, there is a 14-month cycle called the Chandler wobble. The rotational velocity of the Earth also varies in a phenomenon known as length of day variation.[133]

In modern times, Earth's perihelion occurs around January 3, and the aphelion around July 4. However, these dates change over time due to precession and other orbital factors, which follow cyclical patterns known as Milankovitch cycles. The changing Earth-Sun distance results in an increase of about 6.9%[134] in solar energy reaching the Earth at perihelion relative to aphelion. Since the southern hemisphere is tilted toward the Sun at about the same time that the Earth reaches the closest approach to the Sun, the southern hemisphere receives slightly more energy from the Sun than does the northern over the course of a year. However, this effect is much less significant than the total energy change due to the axial tilt, and most of the excess energy is absorbed by the higher proportion of water in the southern hemisphere.[135]

## Moon

### Characteristics

| | |
|---|---|
| Diameter | 3,474.8 km<br>2,159.2 mi |
| Mass | $7.349 \times 10^{22}$ kg<br>$8.1 \times 10^{19}$ (short) tons |
| Semi-major axis | 384,400 km<br>238,700 mi |
| Orbital period | 27 d 7 h 43.7 m |

The Moon is a relatively large, terrestrial, planet-like satellite, with a diameter about one-quarter of the Earth's. It is the largest moon in the Solar System relative to the size of its planet. (Charon is larger relative to the dwarf planet Pluto.) The natural satellites orbiting other planets are called "moons" after Earth's Moon.

The gravitational attraction between the Earth and Moon causes tides on Earth. The same effect on the Moon has led to its tidal locking: its rotation period is the same as the time it takes to orbit the Earth. As a result, it always presents the same face to the planet. As the Moon orbits Earth, different parts of its face are illuminated by the Sun, leading to the lunar phases; the dark part of the face is separated from the light part by the solar terminator.

Because of their tidal interaction, the Moon recedes from Earth at the rate of approximately 38 mm a year. Over millions of years, these tiny modifications—and the lengthening of Earth's day by about 23 µs a year—add up to significant changes.[136] During the Devonian period, for example, (approximately 410 million years ago) there were 400 days in a year, with each day lasting 21.8 hours.[137]

The Moon may have dramatically affected the development of life by moderating the planet's climate. Paleontological evidence and computer simulations show that Earth's axial tilt is stabilized by tidal interactions with the Moon.[138] Some theorists believe that without this stabilization against the torques applied by the Sun and planets to the Earth's equatorial bulge, the rotational axis might be chaotically unstable, exhibiting chaotic changes over millions of years, as appears to be the case for Mars.[139] If Earth's axis of rotation were to approach the plane of the ecliptic, extremely severe weather could result from the resulting extreme seasonal differences. One pole would be pointed directly toward the Sun during *summer* and directly away during *winter*. Planetary scientists who have studied the effect claim that this might kill all large animal and higher plant life.[140] However, this is a controversial subject, and further studies of Mars—which has a similar rotation period and axial tilt as Earth, but not its large Moon or liquid core—may settle the matter.

Viewed from Earth, the Moon is just far enough away to have very nearly the same apparent-sized disk as the Sun. The angular size (or solid angle) of these two bodies match because, although the Sun's diameter is about 400 times as large as the Moon's, it is also 400 times more distant.[127] This allows total and annular eclipses to occur on Earth.

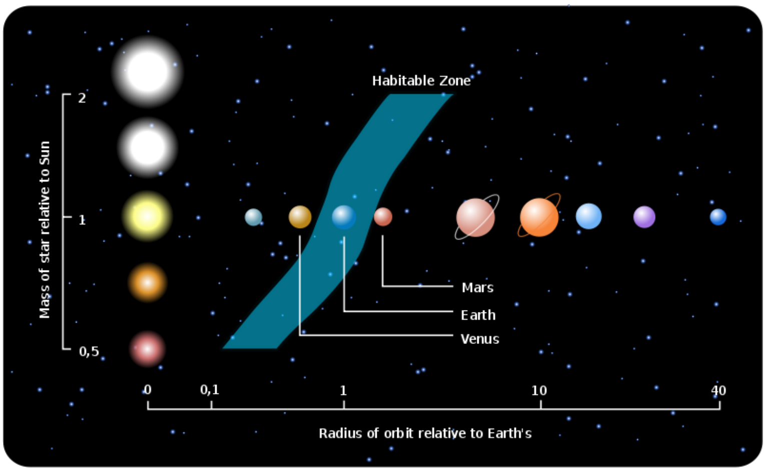
A scale representation of the relative sizes of, and average distance between, Earth and Moon.

The most widely accepted theory of the Moon's origin, the giant impact theory, states that it formed from the collision of a Mars-size protoplanet called Theia with the early Earth. This hypothesis explains (among other things) the Moon's relative lack of iron and volatile elements, and the fact that its composition is nearly identical to that of the Earth's crust.[141]

Earth has at least two co-orbital asteroids, 3753 Cruithne and 2002 $AA_{29}$.[142]

## Habitability

A planet that can sustain life is termed habitable, even if life did not originate there. The Earth provides the (currently understood) requisite conditions of liquid water, an environment where complex organic molecules can assemble and sufficient energy to sustain metabolism.[143] The distance of the Earth from the Sun, as well as its orbital eccentricity, rate of rotation, axial tilt, geological history, sustaining atmosphere and protective magnetic field all contribute to the conditions necessary to originate and sustain life on this planet.[144]




A range of theoretical habitable zones with stars of different mass (our Solar System at center). Not to scale.

## Biosphere

The planet's life forms are sometimes said to form a "biosphere". This biosphere is generally believed to have begun evolving about 3.5 billion years ago. Earth is the only place in the universe where life is known to exist. Some scientists believe that Earth-like biospheres might be rare.[145]

The biosphere is divided into a number of biomes, inhabited by broadly similar plants and animals. On land primarily latitude and height above the sea level separates biomes. Terrestrial biomes lying within the Arctic, Antarctic Circle or in high altitudes are relatively barren of plant and animal life, while the greatest latitudinal diversity of species is found at the Equator.[146]

## Natural resources and land use

The Earth provides resources that are exploitable by humans for useful purposes. Some of these are non-renewable resources, such as mineral fuels, that are difficult to replenish on a short time scale.

Large deposits of fossil fuels are obtained from the Earth's crust, consisting of coal, petroleum, natural gas and methane clathrate. These deposits are used by humans both for energy production and as feedstock for chemical production. Mineral ore bodies have also been formed in Earth's crust through a process of Ore genesis, resulting from actions of erosion and plate tectonics.[147] These bodies form concentrated sources for many metals and other useful elements.

The Earth's biosphere produces many useful biological products for humans, including (but far from limited to) food, wood, pharmaceuticals, oxygen, and the recycling of many organic wastes. The land-based ecosystem depends upon topsoil and fresh water, and the oceanic ecosystem depends upon dissolved nutrients washed down from the land.[148] Humans also live on the land by using building materials to construct shelters. In 1993, human use of land is approximately:

| Land use | Percentage |
|---|---|
| Arable land | 13.13%[8] |
| Permanent crops | 4.71%[8] |
| Permanent pastures | 26% |
| Forests and woodland | 32% |
| Urban areas | 1.5% |
| Other | 30% |

The estimated amount of irrigated land in 1993 was 2,481,250 km².[8]

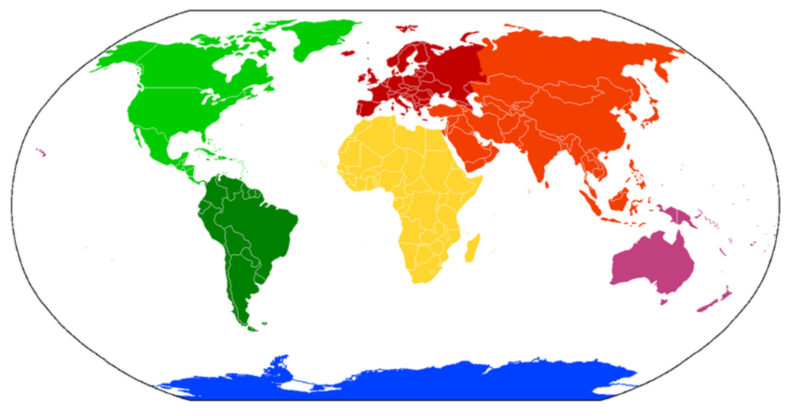
## Natural and environmental hazards

Large areas are subject to extreme weather such as tropical cyclones, hurricanes, or typhoons that dominate life in those areas. Many places are subject to earthquakes, landslides, tsunamis, volcanic eruptions, tornadoes, sinkholes, blizzards, floods, droughts, and other calamities and disasters.

Many localized areas are subject to human-made pollution of the air and water, acid rain and toxic substances, loss of vegetation (overgrazing, deforestation, desertification), loss of wildlife, species extinction, soil degradation, soil depletion, erosion, and introduction of invasive species.

A scientific consensus exists linking human activities to global warming due to industrial carbon dioxide emissions. This is predicted to produce changes such as the melting of glaciers and ice sheets, more extreme temperature ranges, significant changes in weather conditions and a global rise in average sea levels.[149]

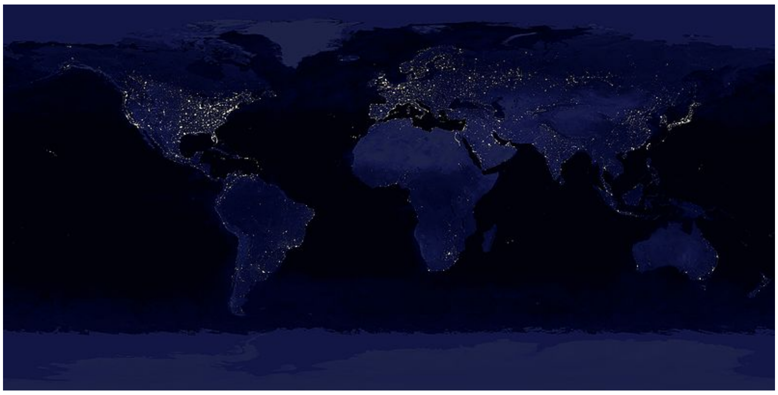
## Human geography



Cartography, the study and practice of map making, and vicariously geography, have historically been the disciplines devoted to depicting the Earth. Surveying, the determination of locations and distances, and to a lesser extent navigation, the determination of position and direction, have developed alongside cartography and geography, providing and suitably quantifying the requisite information.

Earth has approximately 6,803,000,000 human inhabitants as of December 12, 2009.[150] Projections indicate that the world's human population will reach seven billion in 2013 and 9.2 billion in 2050.[151] Most of the growth is expected to take place in developing nations. Human population density varies widely around the world, but a majority live in Asia. By 2020, 60% of the world's population is expected to be living in urban, rather than rural, areas.[152]

It is estimated that only one eighth of the surface of the Earth is suitable for humans to live on—three-quarters is covered by oceans, and half of the land area is either desert (14%),[153] high mountains (27%),[154] or other less suitable terrain. The northernmost permanent settlement in the world is Alert, on Ellesmere Island in Nunavut, Canada.[155] (82°28′N) The southernmost is the Amundsen-Scott South Pole Station, in Antarctica, almost exactly at the South Pole. (90°S)



The Earth at night, a composite of DMSP/OLS ground illumination data on a simulated night-time image of the world. This image is not photographic and many features are brighter than they would appear to a direct observer.

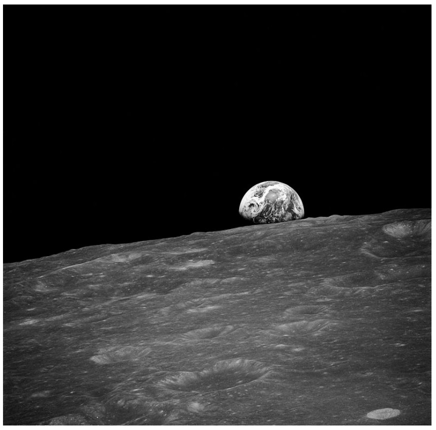
Independent sovereign nations claim the planet's entire land surface, with the exception of some parts of Antarctica. As of 2007 there are 201 sovereign states, including the 192 United Nations member states. In addition, there are 59 dependent territories, and a number of autonomous areas, territories under dispute and other entities.[8] Historically, Earth has never had a sovereign government with authority over the entire globe, although a number of nation-states have striven for world domination and failed.[156]

The United Nations is a worldwide intergovernmental organization that was created with the goal of intervening in the disputes between nations, thereby avoiding armed conflict.[157] It is not, however, a world government. While the U.N. provides a mechanism for international law and, when the consensus of the membership permits, armed intervention,[158] it serves primarily as a forum for international diplomacy.

The first human to orbit the Earth was Yuri Gagarin on April 12, 1961.[159] In total, about 400 people visited outer space and reached Earth orbit as of 2004, and, of these, twelve have walked on the Moon.[160] [161] [162] Normally the only humans in space are those on the International Space Station. The station's crew, currently six people, is usually replaced every six months.[163] Humans traveled the farthest from the planet in 1970, when Apollo 13 crew was

400,171 km away from Earth.[164] [165]

## Cultural viewpoint



The first photograph ever taken by astronauts of an "Earthrise", from Apollo 8

The name "Earth" was derived from the Anglo-Saxon word *erda*, which means ground or soil. It became *eorthe* in Old English, then *erthe* in Middle English.[166] The standard astronomical symbol of the Earth consists of a cross circumscribed by a circle.[167]

Earth has often been personified as a deity, in particular a goddess. In many cultures the mother goddess, also called the Mother Earth, is also portrayed as a fertility deity. Creation myths in many religions recall a story involving the creation of the Earth by a supernatural deity or deities. A variety of religious groups, often associated with fundamentalist branches of Protestantism[168] or Islam,[169] assert that their interpretations of these creation myths in sacred texts are literal truth and should be considered alongside or replace conventional scientific accounts of the formation of the Earth and the origin and development of life.[170] Such assertions are opposed by the scientific community[171] [172] and other religious groups.[173] [174] [175] A prominent example is the creation-evolution controversy.

In the past there were varying levels of belief in a flat Earth,[176] but this was displaced by the concept of a spherical Earth due to observation and circumnavigation.[177] The human perspective regarding the Earth has changed following the advent of spaceflight, and the biosphere is now widely viewed from a globally integrated perspective.[178] [179] This is reflected in a growing environmental movement that is concerned about humankind's effects on the planet.[180]

## See also

- List of Earth-related topics
- Topic outline of Earth science
  - List of Earth science topics
- Topic outline of geography
  - List of geography topics
- Topic outline of geology
  - List of geology topics
- Eratosthenes#Eratosthenes' measurement of the Earth's circumference

## Bibliography


- Ward, Peter D.; Donald Brownlee (2002). *The Life and Death of Planet Earth: How the New Science of Astrobiology Charts the Ultimate Fate of Our World*. Times Books, Henry Holt and Company. ISBN 0-8050-6781-7.
- Yoder, Charles F. (1995). T. J. Ahrens. ed. *Global Earth Physics: A Handbook of Physical Constants* [181]. Washington: American Geophysical Union. ISBN 0875908519. Retrieved 2007-03-17.


## Further reading


- Comins, Neil F. (2001). *Discovering the Essential Universe* [182] (Second ed.). W. H. Freeman. ISBN 0-7167-5804-0. Retrieved 2007-03-17.


## External links

- USGS Geomagnetism Program [183]
- NASA Earth Observatory [184]
- Earth Profile [185] by NASA's Solar System Exploration [186]
- Climate changes cause Earth's shape to change - NASA [187]
- The Gateway to Astronaut Photography of Earth [188]

## References


[1] " Earth (PLANET) (http://dictionary.cambridge.org/define.asp?dict=CALD&key=24538&ph=on)". *Cambridge Advanced Learner's Dictionary*. Cambridge University Press. . Retrieved 2008-11-14.

[2] All astronomical quantities vary, both secularly and periodically. The quantities given are the values at the instant J2000.0 of the secular variation, ignoring all periodic variations.

[3] Allen, Clabon Walter; Cox, Arthur N. (2000). *Allen's Astrophysical Quantities* (http://books.google.com/books?id=w8PK2XFLLH8C&pg=PA294). Springer. pp. 294. ISBN 0387987460. .

[4] Various (2000). David R. Lide. ed. *Handbook of Chemistry and Physics* (81st ed.). CRC. ISBN 0849304814.

[5] IERS Working Groups (2003). " General Definitions and Numerical Standards (http://www.iers.org/MainDisp.csl?pid=46-25776)". in McCarthy, Dennis D.; Petit, Gérard. IERS Technical Note No. 32. U.S. Naval Observatory and Bureau International des Poids et Mesures. . Retrieved 2008-08-03.

[6] Cazenave, Anny (1995). Ahrens, Thomas J.. ed (PDF). *Global earth physics a handbook of physical constants* (http://www.agu.org/reference/gephys/5_cazenave.pdf). Washington, DC: American Geophysical Union. ISBN 0-87590-851-9. . Retrieved 2008-08-03.

[7] Pidwirny, Michael (2006-02-02). *Surface area of our planet covered by oceans and continents.(Table 8o-1)* (http://www.physicalgeography.net/fundamentals/8o.html). University of British Columbia, Okanagan. . Retrieved 2007-11-26.

[8] Staff (2008-07-24). " World (https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html)". *The World Factbook*. Central Intelligence Agency. . Retrieved 2008-08-05.

[9] Due to natural fluctuations, ambiguities surrounding ice shelves, and mapping conventions for vertical datums, exact values for land and ocean coverage are not meaningful. Based on data from the Vector Map and Global Landcover (http://www-gem.jrc.it/) datasets, extreme values for coverage of lakes and streams are 0.6% and 1.0% of the earth's surface. Note that the ice shields of Antarctica and Greenland are counted as land, even though much of the rock which supports them lies below sea level.

[10] Williams, David R. (2004-09-01). " Earth Fact Sheet (http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html)". NASA. . Retrieved 2007-03-17.

[11] Yoder, Charles F. (1995). T. J. Ahrens. ed. *Global Earth Physics: A Handbook of Physical Constants* (http://www.agu.org/reference/gephys.html). Washington: American Geophysical Union. pp. 12. ISBN 0875908519. . Retrieved 2007-03-17.

[12] Allen, Clabon Walter; Cox, Arthur N. (2000). *Allen's Astrophysical Quantities* (http://books.google.com/books?id=w8PK2XFLLH8C&pg=PA296). Springer. pp. 296. ISBN 0387987460. .

[13] *Blue Planet* is used as the title of several films Blue Planet and The Blue Planet, in the Life issue *The Incredible Year '68* featuring the Earthrise photo with lines from poet James Dickey *Behold/The blue planet steeped in its dream/Of reality* (http://yalepress.yale.edu/yupbooks/excerpts/poole_earthrise.pdf) page 7-8 (http://www.northjersey.com/entertainment/books/36520714.html), and in the title of the European Space Agency bulletin report *Exploring the water cycle of the 'Blue Planet'* (http://www.esa.int/esapub/bulletin/bulletin137/bul137b_drinkwater.pdf)

[14] By International Astronomical Union convention, the term "Terra" is used for naming extensive land masses, rather than for the planet Earth. *Cf.* Blue, Jennifer (2007-07-05). " Descriptor Terms (Feature Types) (http://planetarynames.wr.usgs.gov/jsp/append5.jsp)".

*Gazetteer of Planetary Nomenclature*. USGS. . Retrieved 2007-07-05.

[15] May, Robert M. (1988). " How many species are there on earth? (http://adsabs.harvard.edu/abs/1988Sci...241.1441M)". *Science* **241** (4872): 1441–1449. doi: 10.1126/science.241.4872.1441 (http://dx.doi.org/10.1126/science.241.4872.1441). PMID 17790039 (http://www.ncbi.nlm.nih.gov/pubmed/17790039). . Retrieved 2007-08-14.

[16] See:

- Dalrymple, G.B. (1991). *The Age of the Earth*. California: Stanford University Press. ISBN 0-8047-1569-6.
- Newman, William L. (2007-07-09). " Age of the Earth (http://pubs.usgs.gov/gip/geotime/age.html)". Publications Services, USGS. . Retrieved 2007-09-20.
- Dalrymple, G. Brent (2001). " The age of the Earth in the twentieth century: a problem (mostly) solved (http://sp.lyellcollection.org/cgi/content/abstract/190/1/205)". *Geological Society, London, Special Publications* **190**: 205–221. doi: 10.1144/GSL.SP.2001.190.01.14 (http://dx.doi.org/10.1144/GSL.SP.2001.190.01.14). . Retrieved 2007-09-20.
- Stassen, Chris (2005-09-10). " The Age of the Earth (http://www.talkorigins.org/faqs/faq-age-of-earth.html)". TalkOrigins Archive. . Retrieved 2008-12-30.

[17] Harrison, Roy M.; Hester, Ronald E. (2002). *Causes and Environmental Implications of Increased UV-B Radiation*. Royal Society of Chemistry. ISBN 0854042652.

[18] Carrington, Damian (2000-02-21). " Date set for desert Earth (http://news.bbc.co.uk/1/hi/sci/tech/specials/washington_2000/649913.stm)". BBC News. . Retrieved 2007-03-31.

[19] Other planets in the Solar System are either too hot or too cold to support liquid water. However, it is confirmed to have existed on the surface of Mars in the past, and may still appear today. See:

- Malik, Tariq (2007-03-02). " Rover reveals Mars was once wet enough for life (http://www.msnbc.msn.com/id/4202901/)". Space.com (via MSNBC). . Retrieved 2007-08-28.
- " Simulations Show Liquid Water Could Exist on Mars (http://dailyheadlines.uark.edu/5717.htm)". *Daily Headlines* (University of Arkansas). 2005-11-07. . Retrieved 2007-08-08.

[20] As of 2007, water vapor has been detected in the atmosphere of only one extrasolar planet, and it is a gas giant. See: Tinetti, G; Vidal-Madjar, A; Liang, MC; Beaulieu, JP; Yung, Y; Carey, S; Barber, RJ; Tennyson, J *et al*. (July 2007). " Water vapour in the atmosphere of a transiting extrasolar planet (http://www.nature.com/nature/journal/v448/n7150/abs/nature06002.html)". *Nature* **448** (7150): 169–171. doi: 10.1038/nature06002 (http://dx.doi.org/10.1038/nature06002). PMID 17625559 (http://www.ncbi.nlm.nih.gov/pubmed/17625559). .

[21] The number of solar days is one less than the number of sidereal days because the orbital motion of the Earth about the Sun results in one additional revolution of the planet about its axis.

[22] Yoder, Charles F. (1995). T. J. Ahrens. ed. *Global Earth Physics: A Handbook of Physical Constants* (http://www.agu.org/reference/gephys.html). Washington: American Geophysical Union. pp. 8. ISBN 0875908519. . Retrieved 2007-03-17.

[23] Bowring, S.; Housh, T (1995). "The Earth's early evolution". *Science* **269** (5230): 1535. doi: 10.1126/science.7667634 (http://dx.doi.org/10.1126/science.7667634). PMID 7667634 (http://www.ncbi.nlm.nih.gov/pubmed/7667634).

[24] Yin, Qingzhu; Jacobsen, SB; Yamashita, K; Blichert-Toft, J; Télouk, P; Albarède, F (2002). "A short timescale for terrestrial planet formation from Hf-W chronometry of meteorites". *Nature* **418** (6901): 949–952. doi: 10.1038/nature00995 (http://dx.doi.org/10.1038/nature00995). PMID 12198540 (http://www.ncbi.nlm.nih.gov/pubmed/12198540).

[25] Kleine, Thorsten; Palme, Herbert; Mezger, Klaus; Halliday, Alex N. (2005-11-24). "Hf-W Chronometry of Lunar Metals and the Age and Early Differentiation of the Moon". *Science* **310** (5754): 1671–1674. doi: 10.1126/science.1118842 (http://dx.doi.org/10.1126/science.1118842). PMID 16308422 (http://www.ncbi.nlm.nih.gov/pubmed/16308422).

[26] Canup, R. M.; Asphaug, E. (Fall Meeting 2001). " An impact origin of the Earth-Moon system (http://adsabs.harvard.edu/abs/2001AGUFM.U51A..02C)". Abstract #U51A-02. American Geophysical Union. . Retrieved 2007-03-10.

[27] R. Canup and E. Asphaug, RM; Asphaug, E (2001). " Origin of the Moon in a giant impact near the end of the Earth's formation (http://www.nature.com/nature/journal/v412/n6848/abs/412708a0.html)". *Nature* **412** (6848): 708–712. doi: 10.1038/35089010 (http://dx.doi.org/10.1038/35089010). PMID 11507633 (http://www.ncbi.nlm.nih.gov/pubmed/11507633). .

[28] Morbidelli, A.; Chambers, J.; Lunine, J. I.; Petit, J. M.; Robert, F.; Valsecchi, G. B.; Cyr, K. E. (2000). " Source regions and time scales for the delivery of water to Earth (http://adsabs.harvard.edu/abs/2000M&PS...35.1309M)". *Meteoritics & Planetary Science* **35** (6): 1309–1320. . Retrieved 2007-03-06.

[29] Guinan, E. F.; Ribas, I.. " Our Changing Sun: The Role of Solar Nuclear Evolution and Magnetic Activity on Earth's Atmosphere and Climate (http://adsabs.harvard.edu/abs/2002ASPC..269...85G)". in Benjamin Montesinos, Alvaro Gimenez and Edward F. Guinan. ASP Conference Proceedings: The Evolving Sun and its Influence on Planetary Environments. San Francisco: Astronomical Society of the Pacific. ISBN 1-58381-109-5. . Retrieved 2009-07-27.

[30] Rogers, John James William; Santosh, M. (2004). *Continents and Supercontinents*. Oxford University Press US. pp. 48. ISBN 0195165896.

[31] Hurley, P. M. (1969). "Pre-drift continental nuclei". *Science* **164** (3885): 1229–1242. doi: 10.1126/science.164.3885.1229 (http://dx.doi.org/10.1126/science.164.3885.1229). ISSN 0036-8075 (http://worldcat.org/issn/0036-8075). PMID 17772560 (http://www.ncbi.nlm.nih.gov/pubmed/17772560).

[32] Armstrong, R.L. (1968). "A model for the evolution of strontium and lead isotopes in a dynamic earth". *Rev. Geophys.* **6**: 175–199. doi: 10.1029/RG006i002p00175 (http://dx.doi.org/10.1029/RG006i002p00175).

[33] De Smet, J. (2000). "Early formation and long-term stability of continents resulting from decompression melting in a convecting mantle". *Tectonophysics* **322**: 19. doi: 10.1016/S0040-1951(00)00055-X (http://dx.doi.org/10.1016/S0040-1951(00)00055-X).

[34] Harrison, T.; Blichert-Toft, J.; Müller, W.; Albarede, F.; Holden, P.; Mojzsis, S. (December 2005). "Heterogeneous Hadean hafnium: evidence of continental crust at 4.4 to 4.5 ga.". *Science* **310** (5756): 1947–50. doi: 10.1126/science.1117926 (http://dx.doi.org/10.1126/science.1117926). PMID 16293721 (http://www.ncbi.nlm.nih.gov/pubmed/16293721).

[35] Hong, D. (2004). "Continental crustal growth and the supercontinental cycle: evidence from the Central Asian Orogenic Belt". *Journal of Asian Earth Sciences* **23**: 799. doi: 10.1016/S1367-9120(03)00134-2 (http://dx.doi.org/10.1016/S1367-9120(03)00134-2).

[36] Armstrong, R. L. (1991). "The persistent myth of crustal growth". *Australian Journal of Earth Sciences* **38**: 613–630. doi: 10.1080/08120099108727995 (http://dx.doi.org/10.1080/08120099108727995).

[37] Murphy, J. B.; Nance, R. D. (1965). " How do supercontinents assemble? (http://scienceweek.com/2004/sa040730-5.htm)". *American Scientist* **92**: 324–33. doi: 10.1511/2004.4.324 (http://dx.doi.org/10.1511/2004.4.324). . Retrieved 2007-03-05.

[38] Purves, William Kirkwood; Sadava, David; Orians, Gordon H.; Heller, Craig (2001). *Life, the Science of Biology: The Science of Biology*. Macmillan. p. 455. ISBN 0716738732.

[39] Doolittle, W. Ford; Worm, Boris (February 2000). "Uprooting the tree of life". *Scientific American* **282** (6): 90–95. doi: 10.1038/nature03582 (http://dx.doi.org/10.1038/nature03582).

[40] Berkner, L. V.; Marshall, L. C. (1965). " On the Origin and Rise of Oxygen Concentration in the Earth's Atmosphere (http://adsabs.harvard.edu/abs/1965JAtS...22..225B)". *Journal of Atmospheric Sciences* **22** (3): 225–261. doi: 10.1175/1520-0469(1965)022<0225:OTOARO>2.0.CO;2 (http://dx.doi.org/10.1175/1520-0469(1965)022<0225:OTOARO>2.0.CO;2). . Retrieved 2007-03-05.

[41] Burton, Kathleen (2002-11-29). " Astrobiologists Find Evidence of Early Life on Land (http://www.nasa.gov/centers/ames/news/releases/2000/00_79AR.html)". NASA. . Retrieved 2007-03-05.

[42] Kirschvink, J. L. (1992). Schopf, J.W.; Klein, C. & Des Maris, D.. ed. *Late Proterozoic low-latitude global glaciation: the Snowball Earth*. The Proterozoic Biosphere: A Multidisciplinary Study. Cambridge University Press. pp. 51–52. ISBN 0521366151.

[43] Raup, D. M.; Sepkoski, J. J. (1982). " Mass Extinctions in the Marine Fossil Record (http://adsabs.harvard.edu/abs/1982Sci...215.1501R)". *Science* **215** (4539): 1501–1503. doi: 10.1126/science.215.4539.1501 (http://dx.doi.org/10.1126/science.215.4539.1501). PMID 17788674 (http://www.ncbi.nlm.nih.gov/pubmed/17788674). . Retrieved 2007-03-05.

[44] Gould, Stephan J. (October 1994). " The Evolution of Life on Earth (http://brembs.net/gould.html)". *Scientific American*. . Retrieved 2007-03-05.

[45] Wilkinson, B. H.; McElroy, B. J. (2007). " The impact of humans on continental erosion and sedimentation (http://bulletin.geoscienceworld.org/cgi/content/abstract/119/1-2/140)". *Bulletin of the Geological Society of America* **119** (1–2): 140–156. doi: 10.1130/B25899.1 (http://dx.doi.org/10.1130/B25899.1). . Retrieved 2007-04-22.

[46] Staff. " Paleoclimatology - The Study of Ancient Climates (http://www.lakepowell.net/sciencecenter/paleoclimate.htm)". Page Paleontology Science Center. . Retrieved 2007-03-02.

[47] Sackmann, I.-J.; Boothroyd, A. I.; Kraemer, K. E. (1993). " Our Sun. III. Present and Future (http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1993ApJ...418..457S&data_type=PDF_HIGH&whole_paper=YES&type=PRINTER&filetype=.pdf)" (PDF). *Astrophysical Journal* **418**: 457–468. doi: 10.1086/173407 (http://dx.doi.org/10.1086/173407). Bibcode: 1993ApJ...418..457S (http://adsabs.harvard.edu/abs/1993ApJ...418..457S). . Retrieved 2008-07-08.

[48] Kasting, J.F. (1988). " Runaway and Moist Greenhouse Atmospheres and the Evolution of Earth and Venus (http://adsabs.harvard.edu/abs/1988Icar...74..472K)". *Icarus* **74**: 472–494. doi: 10.1016/0019-1035(88)90116-9 (http://dx.doi.org/10.1016/0019-1035(88)90116-9). PMID 11538226 (http://www.ncbi.nlm.nih.gov/pubmed/11538226). . Retrieved 2007-03-31.

[49] Ward and Brownlee (2002).

[50] Britt, Robert (2000-02-25). " Freeze, Fry or Dry: How Long Has the Earth Got? (http://www.space.com/scienceastronomy/solarsystem/death_of_earth_000224.html)". .

[51] Li, King-Fai; Pahlevan, Kaveh; Kirschvink, Joseph L.; Yung, Yuk L. (2009). " Atmospheric Pressure as a Natural Climate Regulator for a Terrestrial Planet with a Biosphere (http://www.gps.caltech.edu/~kfl/paper/Li_PNAS2009.pdf)". *Proceedings of the National Academy of Sciences* **1=6** (24): 9576–9579. doi: 10.1073/pnas.0809436106 (http://dx.doi.org/10.1073/pnas.0809436106). PMID 19487662 (http://www.ncbi.nlm.nih.gov/pubmed/19487662). PMC 2701016 (http://www.pubmedcentral.nih.gov/articlerender.fcgi?tool=pmcentrez&artid=2701016). . Retrieved 2009-07-19.

[52] Guillemot, H.; Greffoz, V. (March 2002). "Ce que sera la fin du monde" (in French). *Science et Vie* **N° 1014**.

[53] Bounama, Christine (2001). " The fate of Earth's ocean (http://www.hydrol-earth-syst-sci.net/5/569/2001/hess-5-569-2001.pdf)". *Hydrology and Earth System Sciences* (Germany: Potsdam Institute for Climate Impact Research) **5** (4): 569–575. . Retrieved 2009-07-03.

[54] Schröder, K.-P.; Connon Smith, Robert (2008). "Distant future of the Sun and Earth revisited". *Monthly Notices of the Royal Astronomical Society* **386**: 155. doi: 10.1111/j.1365-2966.2008.13022.x (http://dx.doi.org/10.1111/j.1365-2966.2008.13022.x). arXiv:0801.4031. See also Palmer, Jason (2008-02-22). " Hope dims that Earth will survive Sun's death (http://space.newscientist.com/article/dn13369-hope-dims-that-earth-will-survive-suns-death.html?feedId=online-news_rss20)". *NewScientist.com news service*. . Retrieved 2008-03-24.

[55] Stern, David P. (2001-11-25). " Planetary Magnetism (http://astrogeology.usgs.gov/HotTopics/index.php?/archives/147-Names-for-the-Columbia-astronauts-provisionally-approved.html)". NASA. . Retrieved 2007-04-01.

[56] Tackley, Paul J. (2000-06-16). "Mantle Convection and Plate Tectonics: Toward an Integrated Physical and Chemical Theory". *Science* **288** (5473): 2002–2007. doi: 10.1126/science.288.5473.2002 (http://dx.doi.org/10.1126/science.288.5473.2002). PMID 10856206 (http://www.ncbi.nlm.nih.gov/pubmed/10856206).

[57] Milbert, D. G.; Smith, D. A.. " Converting GPS Height into NAVD88 Elevation with the GEOID96 Geoid Height Model (http://www.ngs.noaa.gov/PUBS_LIB/gislis96.html)". National Geodetic Survey, NOAA. . Retrieved 2007-03-07.

[58] Sandwell, D. T.; Smith, W. H. F. (2006-07-07). " Exploring the Ocean Basins with Satellite Altimeter Data (http://www.ngdc.noaa.gov/mgg/bathymetry/predicted/explore.HTML)". NOAA/NGDC. . Retrieved 2007-04-21.

[59] Mohr, P.J.; Taylor, B.N. (October 2000). " Unit of length (meter) (http://physics.nist.gov/cuu/Units/meter.html)". *NIST Reference on Constants, Units, and Uncertainty*. NIST Physics Laboratory. . Retrieved 2007-04-23.

[60] Staff (November 2001). " WPA Tournament Table & Equipment Specifications (http://www.wpa-pool.com/index.asp?content=rules_spec)". World Pool-Billiards Association. . Retrieved 2007-03-10.

[61] Senne, Joseph H. (2000). "Did Edmund Hillary Climb the Wrong Mountain". *Professional Surveyor* **20** (5): 16–21.

[62] Sharp, David (2005-03-05). "Chimborazo and the old kilogram". *The Lancet* **365** (9462): 831–832. doi: 10.1016/S0140-6736(05)71021-7 (http://dx.doi.org/10.1016/S0140-6736(05)71021-7).

[63] Brown, Geoff C.; Mussett, Alan E. (1981). *The Inaccessible Earth* (2nd ed.). Taylor & Francis. p. 166. ISBN 0045500282.

[64] Morgan, J. W.; Anders, E. (1980). " Chemical composition of Earth, Venus, and Mercury (http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=350422)". *Proceedings of the National Academy of Science* **71** (12): 6973–6977. doi: 10.1073/pnas.77.12.6973 (http://dx.doi.org/10.1073/pnas.77.12.6973). PMID 16592930 (http://www.ncbi.nlm.nih.gov/pubmed/16592930). PMC 350422 (http://www.pubmedcentral.nih.gov/articlerender.fcgi?tool=pmcentrez&artid=350422). . Retrieved 2007-02-04.

[65] Tanimoto, Toshiro (1995). Thomas J. Ahrens. ed (PDF). *Crustal Structure of the Earth* (http://www.agu.org/reference/gephys/15_tanimoto.pdf). Washington, DC: American Geophysical Union. ISBN 0-87590-851-9. . Retrieved 2007-02-03.

[66] Kerr, Richard A. (2005-09-26). "Earth's Inner Core Is Running a Tad Faster Than the Rest of the Planet". *Science* **309** (5739): 1313. doi: 10.1126/science.309.5739.1313a (http://dx.doi.org/10.1126/science.309.5739.1313a). PMID 16123276 (http://www.ncbi.nlm.nih.gov/pubmed/16123276).

[67] Jordan, T. H. (1979). " Structural Geology of the Earth's Interior (http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=411539)". *Proceedings National Academy of Science* **76** (9): 4192–4200. doi: 10.1073/pnas.76.9.4192 (http://dx.doi.org/10.1073/pnas.76.9.4192). PMID 16592703 (http://www.ncbi.nlm.nih.gov/pubmed/16592703). PMC 411539 (http://www.pubmedcentral.nih.gov/articlerender.fcgi?tool=pmcentrez&artid=411539). . Retrieved 2007-03-24.

[68] Robertson, Eugene C. (2001-07-26). " The Interior of the Earth (http://pubs.usgs.gov/gip/interior/)". USGS. . Retrieved 2007-03-24.

[69] Locally varies between 5 and 200 km.

[70] Locally varies between 5 and 70 km.

[71] Turcotte, D. L.; Schubert, G. (2002). "4". *Geodynamics* (2 ed.). Cambridge, England, UK: Cambridge University Press. pp. 136–137. ISBN 978-0-521-66624-4.

[72] Sanders, Robert (2003-12-10). " Radioactive potassium may be major heat source in Earth's core (http://www.berkeley.edu/news/media/releases/2003/12/10_heat.shtml)". UC Berkeley News. . Retrieved 2007-02-28.

[73] Alfè, D.; Gillan, M. J.; Vocadlo, L.; Brodholt, J; Price, G. D. (2002). " The *ab initio* simulation of the Earth's core (http://chianti.geol.ucl.ac.uk/~dario/pubblicazioni/PTRSA2002.pdf)" (PDF). *Philosophical Transaction of the Royal Society of London* **360** (1795): 1227–1244. . Retrieved 2007-02-28.

[74] Vlaar, N; Vankeken, P; Vandenberg, A (1994). "Cooling of the earth in the Archaean: Consequences of pressure-release melting in a hotter mantle". *Earth and Planetary Science Letters* **121**: 1. doi: 10.1016/0012-821X(94)90028-0 (http://dx.doi.org/10.1016/0012-821X(94)90028-0).

[75] Turcotte, D. L.; Schubert, G. (2002). "4". *Geodynamics* (2 ed.). Cambridge, England, UK: Cambridge University Press. pp. 137. ISBN 978-0-521-66624-4.

[76] Sclater, John G; Parsons, Barry; Jaupart, Claude (1981). "Oceans and Continents: Similarities and Differences in the Mechanisms of Heat Loss". *Journal of Geophysical Research* **86**: 11535. doi: 10.1029/JB086iB12p11535 (http://dx.doi.org/10.1029/JB086iB12p11535).

[77] Richards, M. A.; Duncan, R. A.; Courtillot, V. E. (1989). " Flood Basalts and Hot-Spot Tracks: Plume Heads and Tails (http://adsabs.harvard.edu/abs/1989Sci...246..103R)". *Science* **246** (4926): 103–107. doi: 10.1126/science.246.4926.103 (http://dx.doi.org/10.1126/science.246.4926.103). PMID 17837768 (http://www.ncbi.nlm.nih.gov/pubmed/17837768). . Retrieved 2007-04-21.

[78] Brown, W. K.; Wohletz, K. H. (2005). " SFT and the Earth's Tectonic Plates (http://www.ees1.lanl.gov/Wohletz/SFT-Tectonics.htm)". Los Alamos National Laboratory. . Retrieved 2007-03-02.

[79] Including the Somali Plate, which is currently in the process of formation out of the African Plate. See: Chorowicz, Jean (October 2005). "The East African rift system". *Journal of African Earth Sciences* **43** (1–3): 379–410. doi: 10.1016/j.jafrearsci.2005.07.019 (http://dx.doi.org/10.1016/j.jafrearsci.2005.07.019).

[80] Kious, W. J.; Tilling, R. I. (1999-05-05). " Understanding plate motions (http://pubs.usgs.gov/gip/dynamic/understanding.html)". USGS. . Retrieved 2007-03-02.

[81] Seligman, Courtney (2008). " The Structure of the Terrestrial Planets (http://cseligman.com/text/planets/innerstructure.htm)". *Online Astronomy eText Table of Contents*. cseligman.com. . Retrieved 2008-02-28.

[82] Duennebier, Fred (1999-08-12). " Pacific Plate Motion (http://www.soest.hawaii.edu/GG/ASK/plate-tectonics2.html)". University of Hawaii. . Retrieved 2007-03-14.

[83] Mueller, R.D.; Roest, W.R.; Royer, J.-Y.; Gahagan, L.M.; Sclater, J.G. (2007-03-07). " Age of the Ocean Floor Poster (http://www.ngdc.noaa.gov/mgg/fliers/96mgg04.html)". NOAA. . Retrieved 2007-03-14.
[84] Bowring, Samuel A.; Williams, Ian S. (1999). "Priscoan (4.00-4.03 Ga) orthogneisses from northwestern Canada". *Contributions to Mineralogy and Petrology* **134**: 3. doi: 10.1007/s004100050465 (http://dx.doi.org/10.1007/s004100050465).
[85] Meschede, M.; Udo Barckhausen, U. (2000-11-20). " Plate Tectonic Evolution of the Cocos-Nazca Spreading Center (http://www-odp.tamu.edu/publications/170_SR/chap_07/chap_07.htm)". *Proceedings of the Ocean Drilling Program*. Texas A&M University. . Retrieved 2007-04-02.
[86] Staff. " GPS Time Series (http://sideshow.jpl.nasa.gov/mbh/series.html)". NASA JPL. . Retrieved 2007-04-02.
[87] Pidwirny, Michael (2006). " Fundamentals of Physical Geography (http://www.physicalgeography.net/fundamentals/7h.html)". PhysicalGeography.net. . Retrieved 2007-03-19.
[88] Kring, David A.. " Terrestrial Impact Cratering and Its Environmental Effects (http://www.lpi.usra.edu/science/kring/epo_web/impact_cratering/intro/index.html)". Lunar and Planetary Laboratory. . Retrieved 2007-03-22.
[89] http://www.ngdc.noaa.gov/mgg/topo/
[90] Staff. " Layers of the Earth (http://volcano.oregonstate.edu/vwdocs/vwlessons/plate_tectonics/part1.html)". Volcano World. . Retrieved 2007-03-11.
[91] Jessey, David. " Weathering and Sedimentary Rocks (http://geology.csupomona.edu/drjessey/class/Gsc101/Weathering.html)". Cal Poly Pomona. . Retrieved 2007-03-20.
[92] Staff. " Minerals (http://natural-history.uoregon.edu/Pages/web/mineral.htm)". Museum of Natural History, Oregon. . Retrieved 2007-03-20.
[93] Cox, Ronadh (2003). " Carbonate sediments (http://madmonster.williams.edu/geos.302/L.08.html)". Williams College. . Retrieved 2007-04-21.
[94] FAO Staff (1995). *FAO Production Yearbook 1994* (Volume 48 ed.). Rome, Italy: Food and Agriculture Organization of the United Nations. ISBN 9250038445.
[95] Sverdrup, H. U.; Fleming, Richard H. (1942-01-01). *The oceans, their physics, chemistry, and general biology* (http://repositories.cdlib.org/sio/arch/oceans/). Scripps Institution of Oceanography Archives. . Retrieved 2008-06-13.
[96] This is the measurement taken by the vessel *Kaikō* in March 1995 and is believed to be the most accurate measurement to date. See the Challenger Deep article for more details.
[97] " 7,000 m Class Remotely Operated Vehicle *KAIKO 7000* (http://www.jamstec.go.jp/e/about/equipment/ships/kaiko7000.html)". Japan Agency for Marine-Earth Science and Technology (JAMSTEC). . Retrieved 2008-06-07.
[98] The total volume of the Earth's oceans is: $1.4 \times 10^9$ km$^3$. The total surface area of the Earth is $5.1 \times 10^8$ km². So, to first approximation, the average depth would be the ratio of the two, or 2.7 km.
[99] Igor A. Shiklomanov *et al.* (1999). " World Water Resources and their use Beginning of the 21st century" Prepared in the Framework of IHP UNESCO (http://webworld.unesco.org/water/ihp/db/shiklomanov/)". State Hydrological Institute, St. Petersburg. . Retrieved 2006-08-10.
[100] Mullen, Leslie (2002-06-11). " Salt of the Early Earth (http://www.astrobio.net/news/article223.html)". NASA Astrobiology Magazine. . Retrieved 2007-03-14.
[101] Morris, Ron M.. " Oceanic Processes (http://seis.natsci.csulb.edu/rmorris/oxy/oxy4.html)". NASA Astrobiology Magazine. . Retrieved 2007-03-14.
[102] Scott, Michon (2006-04-24). " Earth's Big heat Bucket (http://earthobservatory.nasa.gov/Study/HeatBucket/)". NASA Earth Observatory. . Retrieved 2007-03-14.
[103] Sample, Sharron (2005-06-21). " Sea Surface Temperature (http://science.hq.nasa.gov/oceans/physical/SST.html)". NASA. . Retrieved 2007-04-21.
[104] Geerts, B.; Linacre, E. (November 1997). " The height of the tropopause (http://www-das.uwyo.edu/~geerts/cwx/notes/chap01/tropo.html)". *Resources in Atmospheric Sciences*. University of Wyoming. . Retrieved 2006-08-10.
[105] Staff (2003-10-08). " Earth's Atmosphere (http://www.nasa.gov/audience/forstudents/9-12/features/912_liftoff_atm.html)". NASA. . Retrieved 2007-03-21.
[106] Moran, Joseph M. (2005). " Weather (http://www.nasa.gov/worldbook/weather_worldbook.html)". *World Book Online Reference Center*. NASA/World Book, Inc.. . Retrieved 2007-03-17.
[107] Berger, Wolfgang H. (2002). " The Earth's Climate System (http://earthguide.ucsd.edu/virtualmuseum/climatechange1/cc1syllabus.shtml)". University of California, San Diego. . Retrieved 2007-03-24.
[108] Rahmstorf, Stefan (2003). " The Thermohaline Ocean Circulation (http://www.pik-potsdam.de/~stefan/thc_fact_sheet.html)". Potsdam Institute for Climate Impact Research. . Retrieved 2007-04-21.
[109] Various (1997-07-21). " The Hydrologic Cycle (http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/hyd/home.rxml)". University of Illinois. . Retrieved 2007-03-24.
[110] Staff. " Climate Zones (http://www.ace.mmu.ac.uk/eae/Climate/Older/Climate_Zones.html)". UK Department for Environment, Food and Rural Affairs. . Retrieved 2007-03-24.
[111] Staff (2004). " Stratosphere and Weather; Discovery of the Stratosphere (http://scienceweek.com/2004/rmps-23.htm)". Science Week. . Retrieved 2007-03-14.

[112] de Córdoba, S. Sanz Fernández (2004-06-21). " 100 km. Altitude Boundary for Astronautics (http://www.un.org/members/list.shtml)". Fédération Aéronautique Internationale. . Retrieved 2007-04-21.

[113] Liu, S. C.; Donahue, T. M. (1974). " The Aeronomy of Hydrogen in the Atmosphere of the Earth (http://adsabs.harvard.edu/abs/1974JAtS...31.1118L)". *Journal of Atmospheric Sciences* **31** (4): 1118–1136. doi: 10.1175/1520-0469(1974)031<1118:TAOHIT>2.0.CO;2 (http://dx.doi.org/10.1175/1520-0469(1974)031<1118:TAOHIT>2.0.CO;2). . Retrieved 2007-03-02.

[114] David C. Catling, Kevin J. Zahnle, Christopher P. McKay (2001). " Biogenic Methane, Hydrogen Escape, and the Irreversible Oxidation of Early Earth (http://www.sciencemag.org/cgi/content/full/293/5531/839)". *Science* **293** (5531): 839–843. doi: 10.1126/science.1061976 (http://dx.doi.org/10.1126/science.1061976). PMID 11486082 (http://www.ncbi.nlm.nih.gov/pubmed/11486082). .

[115] Abedon, Stephen T. (1997-03-31). " History of Earth (http://www.mansfield.ohio-state.edu/~sabedon/biol1010.htm)". Ohio State University. . Retrieved 2007-03-19.

[116] Hunten, D. M.; Donahue, T M (1976). " Hydrogen loss from the terrestrial planets (http://adsabs.harvard.edu/abs/1976AREPS...4..265H)". *Annual review of earth and planetary sciences* **4**: 265–292. doi: 10.1146/annurev.ea.04.050176.001405 (http://dx.doi.org/10.1146/annurev.ea.04.050176.001405). . Retrieved 2008-11-07.

[117] Fitzpatrick, Richard (2006-02-16). " MHD dynamo theory (http://farside.ph.utexas.edu/teaching/plasma/lectures/node69.html)". NASA WMAP. . Retrieved 2007-02-27.

[118] Campbell, Wallace Hall (2003). *Introduction to Geomagnetic Fields*. New York: Cambridge University Press. pp. 57. ISBN 0521822068.

[119] Stern, David P. (2005-07-08). " Exploration of the Earth's Magnetosphere (http://www-spof.gsfc.nasa.gov/Education/wmap.html)". NASA. . Retrieved 2007-03-21.

[120] " Leap seconds (http://tycho.usno.navy.mil/leapsec.html)". Time Service Department, USNO. . Retrieved 2008-09-23.

[121] Staff (2007-08-07). " Useful Constants (http://hpiers.obspm.fr/eop-pc/models/constants.html)". International Earth Rotation and Reference Systems Service (IERS). . Retrieved 2008-09-23.

[122] Aoki, the ultimate source of these figures, uses the term "seconds of UT1" instead of "seconds of mean solar time".—Aoki, S. (1982). " The new definition of universal time (http://adsabs.harvard.edu/abs/1982A&A...105..359A)". *Astronomy and Astrophysics* **105** (2): 359–361. . Retrieved 2008-09-23.

[123] Seidelmann, P. Kenneth (1992). *Explanatory Supplement to the Astronomical Almanac*. Mill Valley, CA: University Science Books. pp. 48. ISBN 0-935702-68-7.

[124] Staff. " IERS Excess of the duration of the day to 86400s ... since 1623 (http://hpiers.obspm.fr/eop-pc/earthor/ut1lod/lod-1623.html)". International Earth Rotation and Reference Systems Service (IERS). . Retrieved 2008-09-23.—Graph at end.

[125] Staff. " IERS Variations in the duration of the day 1962–2005 (http://web.archive.org/web/20070813203913/http://hpiers.obspm.fr/eop-pc/earthor/ut1lod/figure3.html)". International Earth Rotation and Reference Systems Service (IERS). . Retrieved 2008-09-23.

[126] Zeilik, M.; Gregory, S. A. (1998). *Introductory Astronomy & Astrophysics* (4th ed.). Saunders College Publishing. pp. 56. ISBN 0030062284.

[127] Williams, David R. (2006-02-10). " Planetary Fact Sheets (http://nssdc.gsfc.nasa.gov/planetary/planetfact.html)". NASA. . Retrieved 2008-09-28.—See the apparent diameters on the Sun and Moon pages.

[128] Williams, David R. (2004-09-01). " Moon Fact Sheet (http://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html)". NASA. . Retrieved 2007-03-21.

[129] Vázquez, M.; Montañés Rodríguez, P.; Palle, E. (2006). " The Earth as an Object of Astrophysical Interest in the Search for Extrasolar Planets (http://www.iac.es/folleto/research/preprints/files/PP06024.pdf)" (PDF). Instituto de Astrofísica de Canarias. . Retrieved 2007-03-21.

$$R_H = a\left(\frac{m}{3M}\right)^{\frac{1}{3}},$$

where $m$ is the mass of the Earth, $a$ is an Astronomical Unit, and $M$ is the mass of the Sun. So the radius in A.U. is about:

$$\left(\frac{1}{3\cdot 332,946}\right)^{\frac{1}{3}} = 0.01 .$$

[131] Astrophysicist team (2005-12-01). " Earth's location in the Milky Way (http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/030827a.html)". NASA. . Retrieved 2008-06-11.

[132] Bromberg, Irv (2008-05-01). " The Lengths of the Seasons (on Earth) (http://www.sym454.org/seasons/)". University of Toronto. . Retrieved 2008-11-08.

[133] Fisher, Rick (1996-02-05). " Earth Rotation and Equatorial Coordinates (http://www.cv.nrao.edu/~rfisher/Ephemerides/earth_rot.html)". National Radio Astronomy Observatory. . Retrieved 2007-03-21.

[134] Aphelion is 103.4% of the distance to perihelion. Due to the inverse square law, the radiation at perihelion is about 106.9% the energy at aphelion.

[135] Williams, Jack (2005-12-20). " Earth's tilt creates seasons (http://www.usatoday.com/weather/tg/wseason/wseason.htm)". USAToday. . Retrieved 2007-03-17.

[136] Espenak, F.; Meeus, J. (2007-02-07). " Secular acceleration of the Moon (http://sunearth.gsfc.nasa.gov/eclipse/SEcat5/secular.html)". NASA. . Retrieved 2007-04-20.

[137] Poropudas, Hannu K. J. (1991-12-16). " Using Coral as a Clock (http://www.skepticfiles.org/origins/coralclo.htm)". Skeptic Tank. . Retrieved 2007-04-20.

[138] Laskar, J.; Robutel, P.; Joutel, F.; Gastineau, M.; Correia, A.C.M.; Levrard, B. (2004). " A long-term numerical solution for the insolation quantities of the Earth (http://adsabs.harvard.edu/abs/2004A&A...428..261L)". *Astronomy and Astrophysics* **428**: 261–285. doi: 10.1051/0004-6361:20041335 (http://dx.doi.org/10.1051/0004-6361:20041335). . Retrieved 2007-03-31.

[139] Murray, N.; Holman, M (2001). " The role of chaotic resonances in the solar system (http://arxiv.org/abs/astro-ph/0111602v1)". *Nature* **410** (6830): 773–779. doi: 10.1038/35071000 (http://dx.doi.org/10.1038/35071000). PMID 11298438 (http://www.ncbi.nlm.nih.gov/pubmed/11298438). . Retrieved 2008-08-05.

[140] Williams, D.M.; J.F. Kasting (1996). " Habitable planets with high obliquities (http://adsabs.harvard.edu/abs/1996LPI....27.1437W)". *Lunar and Planetary Science* **27**: 1437–1438. . Retrieved 2007-03-31.

[141] R. Canup and E. Asphaug, RM; Asphaug, E (2001). "Origin of the Moon in a giant impact near the end of the Earth's formation". *Nature* **412** (6848): 708–712. doi: 10.1038/35089010 (http://dx.doi.org/10.1038/35089010). PMID 11507633 (http://www.ncbi.nlm.nih.gov/pubmed/11507633).

[142] Whitehouse, David (2002-10-21). " Earth's little brother found (http://news.bbc.co.uk/1/hi/sci/tech/2347663.stm)". BBC News. . Retrieved 2007-03-31.

[143] Staff (September 2003). " Astrobiology Roadmap (http://astrobiology.arc.nasa.gov/roadmap/g1.html)". NASA, Lockheed Martin. . Retrieved 2007-03-10.

[144] Dole, Stephen H. (1970). *Habitable Planets for Man* (http://www.rand.org/pubs/reports/R414/) (2nd ed.). American Elsevier Publishing Co.. ISBN 0-444-00092-5. . Retrieved 2007-03-11.

[145] Ward, P. D.; Brownlee, D. (2000-01-14). *Rare Earth: Why Complex Life is Uncommon in the Universe* (1st ed.). New York: Springer-Verlag. ISBN 0387987010.

[146] Hillebrand, Helmut (2004). "On the Generality of the Latitudinal Gradient". *American Naturalist* **163** (2): 192–211. doi: 10.1086/381004 (http://dx.doi.org/10.1086/381004). PMID 14970922 (http://www.ncbi.nlm.nih.gov/pubmed/14970922).

[147] Staff (2006-11-24). " Mineral Genesis: How do minerals form? (http://www.utexas.edu/tmm/npl/mineralogy/mineral_genesis/)". Non-vertebrate Paleontology Laboratory, Texas Memorial Museum. . Retrieved 2007-04-01.

[148] Rona, Peter A. (2003). " Resources of the Sea Floor (http://www.sciencemag.org/cgi/content/full/299/5607/673?ijkey=AHVbRrqUsmdHY&keytype=ref&siteid=sci)". *Science* **299** (5607): 673–674. doi: 10.1126/science.1080679 (http://dx.doi.org/10.1126/science.1080679). PMID 12560541 (http://www.ncbi.nlm.nih.gov/pubmed/12560541). . Retrieved 2007-02-04.

[149] Staff (2007-02-02). " Evidence is now ‘unequivocal’ that humans are causing global warming – UN report (http://www.un.org/apps/news/story.asp?NewsID=21429&Cr=climate&Cr1=change)". United Nations. . Retrieved 2007-03-07.

[150] United States Census Bureau (2008-01-07). " World POP Clock Projection (http://www.census.gov/ipc/www/popclockworld.html)". *United States Census Bureau International Database*. . Retrieved 2008-01-07.

[151] Staff. " World Population Prospects: The 2006 Revision (http://www.un.org/esa/population/publications/wpp2006/wpp2006.htm)". United Nations. . Retrieved 2007-03-07.

[152] Staff (2007). " Human Population: Fundamentals of Growth: Growth (http://www.prb.org/Educators/TeachersGuides/HumanPopulation/PopulationGrowth/QuestionAnswer.aspx)". Population Reference Bureau. . Retrieved 2007-03-31.

[153] Peel, M. C.; Finlayson, B. L.; McMahon, T. A. (2007). " Updated world map of the Köppen-Geiger climate classification (http://www.hydrol-earth-syst-sci-discuss.net/4/439/2007/hessd-4-439-2007.html)". *Hydrology and Earth System Sciences Discussions* **4**: 439–473. . Retrieved 2007-03-31.

[154] Staff. " Themes & Issues (http://www.biodiv.org/programmes/default.shtml)". Secretariat of the Convention on Biological Diversity. . Retrieved 2007-03-29.

[155] Staff (2006-08-15). " Canadian Forces Station (CFS) Alert (http://www.tscm.com/alert.html)". Information Management Group. . Retrieved 2007-03-31.

[156] Kennedy, Paul (1989). *The Rise and Fall of the Great Powers* (1st ed.). Vintage. ISBN 0679720197.

[157] " U.N. Charter Index (http://www.un.org/aboutun/charter/)". United Nations. . Retrieved 2008-12-23.

[158] Staff. " International Law (http://www.un.org/law/)". United Nations. . Retrieved 2007-03-27.

[159] Kuhn, Betsy (2006). *The race for space: the United States and the Soviet Union compete for the new frontier*. Twenty-First Century Books. p. 34. ISBN 0822559846.

[160] Ellis, Lee (2004). *Who's who of NASA Astronauts*. Americana Group Publishing. ISBN 0966796144.

[161] Shayler, David; Vis, Bert (2005). *Russia's Cosmonauts: Inside the Yuri Gagarin Training Center*. Birkhäuser. ISBN 0387218947.

[162] Wade, Mark (2008-06-30). " Astronaut Statistics (http://www.astronautix.com/articles/aststics.htm)". Encyclopedia Astronautica. . Retrieved 2008-12-23.

[163] " Reference Guide to the International Space Station (http://www.nasa.gov/mission_pages/station/news/ISS_Reference_Guide.html)". NASA. 2007-01-16. . Retrieved 2008-12-23.

[164] Cramb, Auslan (2007-10-28). " Nasa's Discovery extends space station (http://www.telegraph.co.uk/earth/earthnews/3311903/Nasas-Discovery-extends-space-station.html)". Telegraph. .

[165] Stathopoulos, Vic (2009-01-08). " Apollo Spacecraft (http://www.aerospaceguide.net/spaceexploration/apollo.html)". . Retrieved 2009-03-23.

[166] *Random House Unabridged Dictionary*. Random House. July 2005. ISBN 0-375-42599-3.

[167] Liungman, Carl G. (2004). "Group 29: Multi-axes symmetric, both soft and straight-lined, closed signs with crossing lines". *Symbols -- Encyclopedia of Western Signs and Ideograms*. New York: Ionfox AB. pp. 281–282. ISBN 91-972705-0-4.

[168] Dutch, S.I. (2002). " Religion as belief versus religion as fact (http://nagt.org/files/nagt/jge/abstracts/Dutch_v50n2p137.pdf)" (PDF). *Journal of Geoscience Education* **50** (2): 137–144. . Retrieved 2008-04-28.

[169] Taner Edis (2003) (PDF). *A World Designed by God: Science and Creationism in Contemporary Islam* (http://www2.truman.edu/~edis/writings/articles/CFI-2001.pdf). Amherst: Prometheus. ISBN 1-59102-064-6. . Retrieved 2008-04-28.

[170] Ross, M.R. (2005). " Who Believes What? Clearing up Confusion over Intelligent Design and Young-Earth Creationism (http://www.nagt.org/files/nagt/jge/abstracts/Ross_v53n3p319.pdf)" (PDF). *Journal of Geoscience Education* **53** (3): 319. . Retrieved 2008-04-28.

[171] Pennock, R. T. (2003). "Creationism and intelligent design". *Annu Rev Genomics Hum Genet* **4**: 143–63. doi: 10.1146/annurev.genom.4.070802.110400 (http://dx.doi.org/10.1146/annurev.genom.4.070802.110400). PMID 14527300 (http://www.ncbi.nlm.nih.gov/pubmed/14527300).

[172] Science, Evolution, and Creationism (http://books.nap.edu/openbook.php?record_id=11876&page=R1) National Academy Press, Washington, DC 2005

[173] Colburn, A.; Henriques, Laura (2006). "Clergy views on evolution, creationism, science, and religion". *Journal of Research in Science Teaching* **43** (4): 419–442. doi: 10.1002/tea.20109 (http://dx.doi.org/10.1002/tea.20109).

[174] Frye, Roland Mushat (1983). *Is God a Creationist? The Religious Case Against Creation-Science*. Scribner's. ISBN 0-68417-993-8.

[175] Gould, S. J. (1997). " Nonoverlapping magisteria (http://www.jbburnett.com/resources/gould_nonoverlapping.pdf)" (PDF). *Natural History* **106** (2): 16–22. . Retrieved 2008-04-28.

[176] Russell, Jeffrey B.. " The Myth of the Flat Earth (http://www.asa3.org/ASA/topics/history/1997Russell.html)". American Scientific Affiliation. . Retrieved 2007-03-14.; but see also Cosmas Indicopleustes

[177] Jacobs, James Q. (1998-02-01). " Archaeogeodesy, a Key to Prehistory (http://www.jqjacobs.net/astro/aegeo.html)". . Retrieved 2007-04-21.

[178] Fuller, R. Buckminster (1963). *[[Operating Manual for Spaceship Earth* (http://www.futurehi.net/docs/OperatingManual.html)]*] (First ed.). New York: E.P. Dutton & Co.. ISBN 0-525-47433-1. . Retrieved 2007-04-21.*

[179] Lovelock, James E. (1979). *Gaia: A New Look at Life on Earth* (First ed.). Oxford: Oxford University Press. ISBN 0-19-286030-5.

[180] For example: McMichael, Anthony J. (1993). *Planetary Overload: Global Environmental Change and the Health of the Human Species*. Cambridge University Press. ISBN 0521457599.

[181] http://www.agu.org/reference/gephys.html

[182] http://adsabs.harvard.edu/abs/2003deu..book.....C

[183] http://geomag.usgs.gov

[184] http://earthobservatory.nasa.gov

[185] http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth

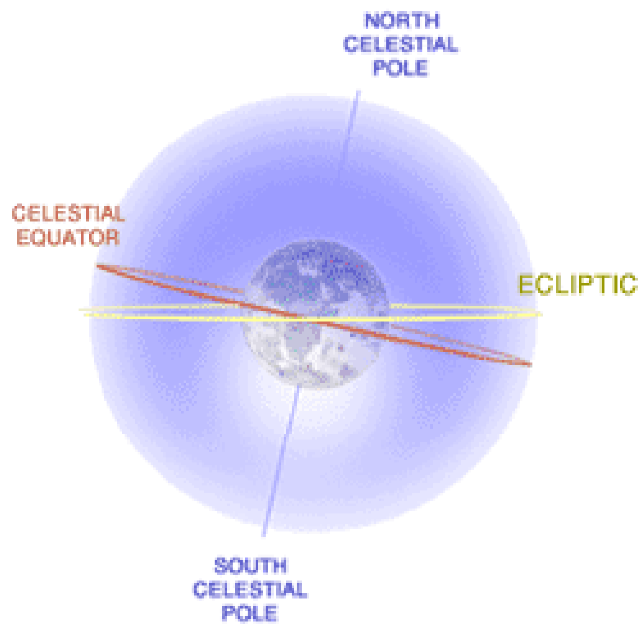
[186] http://solarsystem.nasa.gov

[187] http://www.nasa.gov/centers/goddard/earthandsun/earthshape.html

[188] http://eol.jsc.nasa.gov/Coll/weekly.htm

# Ecliptic

The **ecliptic** is the apparent path that the Sun traces out in the sky during the year, appearing to move eastwards on an imaginary spherical surface, the celestial sphere, relative to the (almost) fixed stars. More accurately, it is the intersection of the celestial sphere with the **ecliptic plane**, which is the geometric plane containing the mean orbit of the Earth around the Sun. (The ecliptic plane should be distinguished from the invariable plane of the solar system, which is perpendicular to the vector sum of the angular momenta of all planetary orbital planes, to which Jupiter is the main contributor. The present ecliptic plane is inclined to the invariable plane by about 1.5°.)



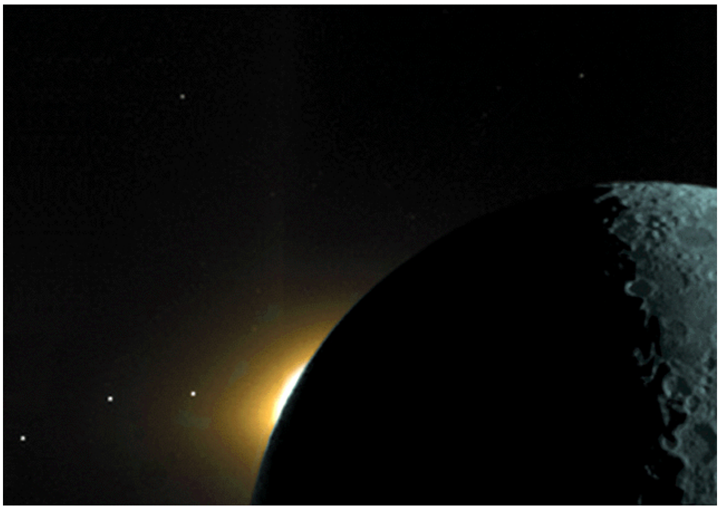

Perspective of Earth and celestial sphere, showing the ecliptic (plane), the celestial equator (overhead the Earth's equator) and the Earth's polar axis (which also points to the celestial poles). The intersection shown between the equator and the ecliptic (the vernal equinox point) is not associated with any particular location on the Earth (despite the diagram), because the Earth rotates daily, while the celestial sphere does not. The angle between the equatorial plane and the ecliptic plane is called the obliquity of the ecliptic (ε).

The name ecliptic arises because eclipses occur when the full or new Moon is very close to this path of the Sun.

## Ecliptic and equator

As the rotation axis of the Earth is not perpendicular to its orbital plane, the equatorial plane is not parallel to the ecliptic plane, but makes an angle of about 23°26' which is known as the obliquity of the ecliptic.

The intersections of the equatorial and ecliptic planes with the celestial dome are great circles known as the celestial equator and the ecliptic respectively. The intersection line of the two planes results in two diametrically opposite intersection points, known as the equinoxes. The equinox which the Sun passes from south to north is known as the vernal equinox or first point of Aries. Ecliptic longitude, usually indicated with the letter **λ**, is measured from this point on 0° to 360° towards the east. Ecliptic latitude, usually indicated with the letter **β** is measured +90° to the north or -90° to the south. The same intersection point also defines the origin of the equatorial coordinate system, named right



The plane of the ecliptic is well seen in this picture from the 1994 lunar prospecting Clementine spacecraft. Clementine's camera reveals (from right to left) the Moon lit by Earthshine, the Sun's glare rising over the Moon's dark limb, and the planets Saturn, Mars and Mercury (the three dots at lower left).

ascension measured from 0 to 24 hours also to the east and usually indicated with **α** or *R.A.*, and declination, usually indicated with **δ** also measured +90° to the north or -90° to the south. Simple rotation formulas allow a conversion from α,δ to λ,β and back (see: ecliptic coordinate system).

## Ecliptic and stars

The ecliptic serves as the center of a region called the zodiac which constitutes a band of 9° on either side. Traditionally, this region is divided into 12 signs of 30° longitude each. By tradition, these signs are named after 12 of the 13 constellations straddling the ecliptic. The zodiac signs are very important to many astrologers. Modern astronomers typically use other coordinate systems today (see below).

The position of the vernal equinox is not fixed among the stars but due to the lunisolar precession slowly shifting westwards over the ecliptic with a speed of 1° per 72 years. A much smaller north/southwards shift can also be discerned, (the planetary precession, along the instantaneous equator, which results in a rotation of the ecliptic plane). Said otherwise, the stars shift eastwards (increase their longitude) measured with respect to the equinoxes — in other words, as measured in ecliptic coordinates and (often) also in equatorial coordinates.

Using the current official IAU constellation boundaries — and taking into account the variable precession speed and the rotation of the ecliptic — the equinoxes shift through the constellations in the Astronomical Julian calendar years (in which the year 0 = 1 BC, -1 = 2 BC, etc.) as follows:[1]

- The March equinox passed from Taurus into Aries in year -1865, passed into Pisces in year -67, will pass into Aquarius in year 2597, will pass into Capricornus in year 4312. It passed along (but not into) a 'corner' of Cetus on 0°10' distance in year 1489.
- The June solstice passed from Leo into Cancer in year -1458, passed into Gemini in year -10, passed into Taurus in December year 1989, will pass into Aries in year 4609.
- The September equinox passed from Libra into Virgo in year -729, will pass into Leo in year 2439.
- The December solstice passed from Capricornus into Sagittarius in year -130, will pass into Ophiuchus in year 2269, and will pass into Scorpius in year 3597.

## Ecliptic and Sun

**UTC date and time of solstices and equinoxes[2]**

| year | Equinox Mar | | Solstice June | | Equinox Sept | | Solstice Dec | |
|---|---|---|---|---|---|---|---|---|
| | day | time | day | time | day | time | day | time |
| **2004** | 20 | 06:49 | 21 | 00:57 | 22 | 16:30 | 21 | 12:42 |
| **2005** | 20 | 12:33 | 21 | 06:46 | 22 | 22:23 | 21 | 18:35 |
| **2006** | 20 | 18:26 | 21 | 12:26 | 23 | 04:03 | 22 | 00:22 |
| **2007** | 21 | 00:07 | 21 | 18:06 | 23 | 09:51 | 22 | 06:08 |
| **2008** | 20 | 05:48 | 20 | 23:59 | 22 | 15:44 | 21 | 12:04 |
| **2009** | 20 | 11:44 | 21 | 05:45 | 22 | 21:18 | 21 | 17:47 |
| **2010** | 20 | 17:32 | 21 | 11:28 | 23 | 03:09 | 21 | 23:38 |
| **2011** | 20 | 23:21 | 21 | 17:16 | 23 | 09:04 | 22 | 05:30 |
| **2012** | 20 | 05:14 | 20 | 23:09 | 22 | 14:49 | 21 | 11:11 |
| **2013** | 20 | 11:02 | 21 | 05:04 | 22 | 20:44 | 21 | 17:11 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **2014** | 20 | 16:57 | 21 | 10:51 | 23 | 02:29 | 21 | 23:03 |
| **2015** | 20 | 22:45 | 21 | 16:38 | 23 | 08:20 | 22 | 04:48 |
| **2016** | 20 | 04:30 | 20 | 22:34 | 22 | 14:21 | 21 | 10:44 |
| **2017** | 20 | 10:28 | 21 | 04:24 | 22 | 20:02 | 21 | 16:28 |

Due to perturbing influences on the Earth's orbit by the other planets, the *true* Sun is not always exactly on the ecliptic, but may be some arcseconds north or south of it. It is therefore the centre of the *mean* Sun which outlines its path. As the Earth takes one year to make one complete revolution around the Sun, the apparent position of the Sun also takes the same length of time to make a complete circuit of the whole ecliptic. With slightly more than 365 days in the year, the Sun moves almost 1° eastwards every day (direction of increasing longitude). This annual motion should not be confused with the daily motion of the Sun (and the stars, the whole celestial sphere for that matter) towards the west along the equator every 24 hours. In fact, where the stars need about 23h56m for one such rotation to complete the sidereal day, the Sun, which has shifted 1° eastwards during that time needs 4 minutes extra to complete its circle, making the solar day just 24 hours.

Because the distance between Sun and Earth varies slightly around the year, the speed with which the Sun moves around the ecliptic is also variable. For example, within one year, the Sun is north of the equator for about 186.40 days and south of the equator for about 178.24 days.

The mean Sun crosses the equator around 20 March at the time of the vernal equinox when its declination, right ascension, and ecliptic longitude are all zero. (The ecliptic latitude is always zero.) The March equinox marks the onset of spring in the northern hemisphere and autumn in the southern. The actual date and time varies from year to year because of the occurrence of leap years. It also shifts slowly over the centuries due to imperfections in the Gregorian calendar.

Ecliptic longitude 90°, at right ascension 6 hours and a northern declination equal to the obliquity of the ecliptic (23.44°), is reached around 21 June. This is the June solstice or summer solstice in the northern hemisphere and winter solstice in the southern hemisphere. It is also the first point of Cancer and directly overhead on Earth on the tropic of Cancer so named because the Sun turns around in declination. Ecliptic longitude 180°, right ascension 12 hours is reached around 22 September and marks the second equinox or first point of Libra. Due to perturbations to the Earth orbit, the moment the real Sun passes the equator might be several minutes earlier or later. The southern most declination of the sun is reached at ecliptic longitude 270°, right ascension 18 hours at the first point of the sign of Capricorn around 21 December.

In any case it must be stressed that although these traditional *signs* (in western tropical astrology) have given their names to the solstices and equinoxes, in reality, (as from the list in the previous chapter) the cardinal points are currently situated in the *constellations* of Pisces, Taurus, Virgo and Sagittarius respectively, due to the precession of the equinoxes.

## Ecliptic and planets

Most planets go in orbits around the sun which are almost in the same plane as the Earth's orbital plane, differing by a few degrees at most. As such they always appear close to the ecliptic when seen in the sky. Mercury with an orbital inclination of 7° is an exception. Pluto, at 17°, was previously the exception until it was reclassified a dwarf planet, but other bodies in the Solar System have even greater orbital inclinations (e.g. Eris at 44° and Pallas at 34°). Interestingly, the Earth has the most inclined orbit of all eight major planets relative to the Sun's equator, with the giant planets close behind.

| Inclination | | | | |
|---|---|---|---|---|
| | **Name** | **Inclination to ecliptic (°)** | **Inclination to Sun's equator (°)** | **Inclination to Invariable plane[3] (°)** |
| **Terrestrials** | Mercury | 7.01 | 3.38 | 6.34 |
| | Venus | 3.39 | 3.86 | 2.19 |
| | Earth | N/A | 7.155 | 1.57 |
| | Mars | 1.85 | 5.65 | 1.67 |
| **Gas giants** | Jupiter | 1.31 | 6.09 | 0.32 |
| | Saturn | 2.49 | 5.51 | 0.93 |
| | Uranus | 0.77 | 6.48 | 1.02 |
| | Neptune | 1.77 | 6.43 | 0.72 |

The intersection line of the ecliptical plane and another planet's orbital plane is called the nodal line of that planet, and the nodal line's intersection points on the celestial sphere are the ascending node (where the planet crosses the ecliptic from south to north) and the diametrically opposite descending node. Only when an inferior planet passes through one of its nodes can a transit over the Sun take place. Transits, especially for Venus, are quite rare, because the Earth's orbit is more inclined than those of the inner two planets.

Inclination and nodal lines, as almost all other orbital elements, change slowly over the centuries due to perturbations from the other planets.

## Ecliptic and Moon

The orbit of the Moon is inclined by about 5° on the ecliptic. Its nodal line is not fixed either, but regresses (moves towards the west) over a full circle every 18.6 years. This is the cause of nutation and lunar standstill. The moon crosses the ecliptic about twice per month. If this happens during new moon a solar eclipse occurs, during full moon a lunar eclipse. This was the way the ancients could trace the ecliptic along the sky; they marked the places where eclipses could occur.

## Ecliptic and star coordinates

Up to the 17th century in Europe, star maps and positions in star catalogues were always given in ecliptical coordinates, though in China, astronomers employed an equatorial system in their catalogues. It was not until astronomers started to use telescopes and mechanical clocks to measure star positions that equatorial coordinates came into use, which occurred so exclusively that nowadays ecliptical coordinates are no longer used. Nonetheless, this change is not always desirable, as a planetary conjunction would be much more illustratively described by ecliptic coordinates rather than equatorial.

Also see zodiacal coordinates.

## External links

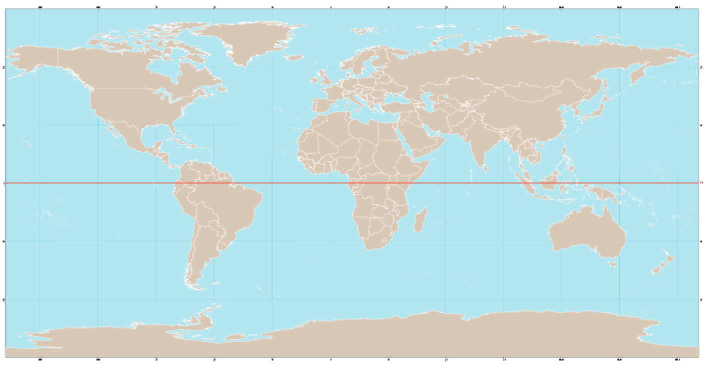
- NASA: "The Path of the Sun, the Ecliptic" [4]
- Orbits and the Ecliptic Plane [5]
- The Ecliptic: the Sun's Annual Path [6]

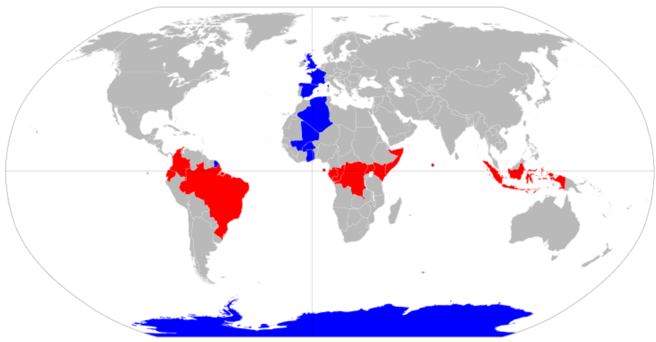
## References

[1] J. Meeus; Mathematical Astronomical Morsels; ISBN 0-943396-51-4
[2] United States Naval Observatory (01/28/07). " Earth's Seasons: Equinoxes, Solstices, Perihelion, and Aphelion, 2000-2020 (http://aa.usno.navy.mil/data/docs/EarthSeasons.php)". .
[3] " The MeanPlane (Invariable plane) of the Solar System passing through the barycenter (http://home.comcast.net/~kpheider/MeanPlane.gif)". 2009-04-03. . Retrieved 2009-04-10. (produced with Solex 10 (http://chemistry.unina.it/~alvitagl/solex/) written by Aldo Vitagliano)
[4] http://www-spof.gsfc.nasa.gov/stargaze/Secliptc.htm
[5] http://hyperphysics.phy-astr.gsu.edu/hbase/eclip.html
[6] http://www.dur.ac.uk/john.lucey/users/solar_year.html

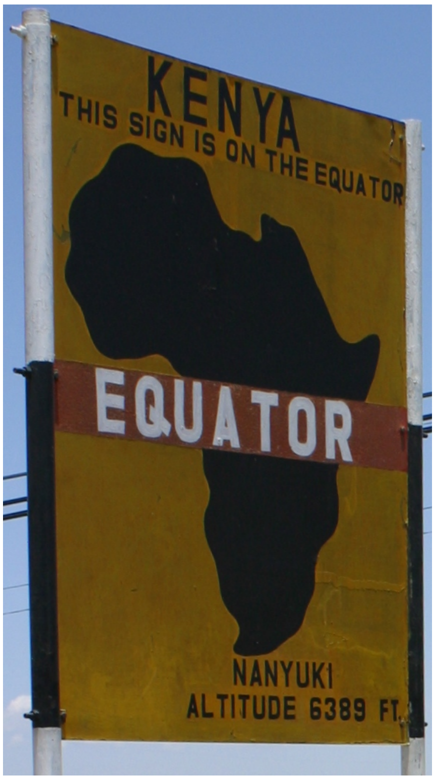
# Equator

The **equator** is the intersection of the Earth's surface with the plane perpendicular to the Earth's axis of rotation and containing the Earth's center of mass. In simpler language, it is an imaginary line on the Earth's surface equidistant from the North Pole and South Pole that divides the Earth into a Northern Hemisphere and a Southern Hemisphere. The equators of other planets and astronomical bodies are defined analogously.


World map showing the line of the equator.


Nations that touch the equator (red) and the prime meridian (blue)

## Geodesy of the equator




Road sign marking the Equator near Nanyuki, Kenya

The latitude of the equator is 0°. The length of Earth's equator is about 40075 kilometres (24901.5 mi).

The equator is one of the five main circles of latitude that are based on the relationship between the Earth's axis of rotation and the plane of the Earth's orbit around the sun. It is the only line of latitude which is also a great circle. The imaginary circle obtained when the Earth's equator is projected onto the sky is called the celestial equator.

The Sun in its seasonal movement through the sky, passes directly over the equator twice each year, on the March and September equinoxes. At the equator, the rays of the sun are perpendicular to the surface of the earth on these dates.

The equator marked as it crosses Ilhéu das Rolas, in São Tomé and Príncipe

Places on the equator experience the quickest rates of sunrise and sunset in the world. They are also the only places in the world where the sun can go directly from the zenith to the nadir and from the nadir to the zenith. Such places also have a theoretical constant 12 hours of day and night throughout the year (in practice there are variations of a few minutes due to the effects of atmospheric refraction and because sunrise and sunset are measured from the time the edge of the Sun's disc is on the horizon, rather than its centre). North or south of the equator day length increasingly varies with latitude and the seasons.

The Earth bulges slightly at the equator. It has an average diameter of 12750 kilometres (7922 mi), but at the equator the diameter is approximately 43 kilometres (27 mi) greater than the polar diameter.

A monument marking the equator at the city of Pontianak, Indonesia

Locations near the equator are good sites for spaceports, such as the Guiana Space Centre in Kourou, French Guiana, as they are already moving faster than any other point on the Earth due to the Earth's rotation, and the added velocity reduces the amount of fuel needed to launch spacecraft. Spacecraft launched in this manner must launch to the east to use this effect.

For high precision work, the equator is not quite as fixed as the above discussion implies. The true equatorial plane must always be perpendicular to the Earth's spin axis. Although this axis is relatively stable, its position wanders in approximately a 9 metres (30 ft) radius circular motion each year. Thus, the true equator moves slightly. This, however, is only important for detailed scientific studies. The effect is quite small, and the width of a line marking the equator on almost any map will be much wider than the error.

## Equatorial seasons and climate

The *"Marco Zero"* in Macapá, Brasil.

Near the equator there is little distinction between summer, winter, autumn or spring. Temperatures are high year round (permanent "summer"), with the exception of periods during the wet season and at higher altitudes. In many tropical regions people identify two seasons: wet and dry. However, most places close to the equator are wet throughout the year, and seasons can vary depending on a variety of factors including elevation and proximity to an ocean. The rainy and humid conditions mean that the equatorial climate is not the hottest in the world.

The surface of the Earth at the equator is mostly ocean. The highest point on the equator is 4690 metres (15387 ft), at 00°00′00″S, 77°59′31″W, on the south slopes of Volcán Cayambe (summit 5790 metres (18996 ft)) in Ecuador. This is a short distance above the snow line, and this point and its immediate vicinity form the only section of the equator where snow lies on the ground.

## Equatorial countries and territories

The equator traverses the land and/or territorial waters of 14 countries. Starting at the Prime Meridian and heading eastwards, the equator passes through:

| Co-ordinates | Country, territory or sea | Notes |
|---|---|---|
| 0°0′N 0°0′E | Atlantic Ocean | Gulf of Guinea |
| 0°0′N 6°31′E | São Tomé and Príncipe | Ilhéu das Rolas |
| 0°0′N 6°31′E | Atlantic Ocean | Gulf of Guinea |
| 0°0′N 9°21′E | Gabon | |
| 0°0′N 13°56′E | Republic of the Congo | |
| 0°0′N 17°46′E | Democratic Republic of the Congo | |
| 0°0′N 29°43′E | Uganda | |
| 0°0′N 13°22′E | Lake Victoria | Passing through some islands of Uganda |
| 0°0′N 34°0′E | Kenya | |
| 0°0′N 41°0′E | Somalia | |
| 0°0′N 42°53′E | Indian Ocean | Passing between Gaafu Dhaalu and Gnaviyani atolls, Maldives |
| 0°0′N 98°12′E | Indonesia | The Batu Islands, Sumatra and the Lingga Islands |
| 0°0′N 104°34′E | Karimata Strait | |
| 0°0′N 109°9′E | Indonesia | Borneo |
| 0°0′N 117°30′E | Makassar Strait | |
| 0°0′N 119°40′E | Indonesia | Sulawesi |
| 0°0′N 120°5′E | Gulf of Tomini | |
| 0°0′N 124°0′E | Molucca Sea | |
| 0°0′N 127°24′E | Indonesia | Kayoa and Halmahera islands |
| 0°0′N 127°53′E | Halmahera Sea | |
| 0°0′N 129°20′E | Indonesia | Gebe Island |
| 0°0′N 129°21′E | Pacific Ocean | Passing just north of Waigeo island, Indonesia<br>Passing just south of Aranuka atoll, Kiribati<br>Passing just south of Baker Island, United States Minor Outlying Islands |
| 0°0′N 91°35′W | Ecuador | Isabela Island in the Galápagos Islands |
| 0°0′N 91°13′W | Pacific Ocean | |
| 0°0′N 80°6′W | Ecuador | |
| 0°0′N 75°32′W | Colombia | |
| 0°0′N 70°3′W | Brazil | Including some islands in the mouth of the Amazon River |
| 0°0′N 49°20′W | Atlantic Ocean | |

Despite its name, no part of Equatorial Guinea's territory lies on the equator. However, its island of Annobón is about 155 kilometres (100 mi) south of the equator, and the rest of the country lies to the north. The country that comes closest to the equator without actually touching it is Peru.

## "Crossing the Line"

The English-speaking seafaring tradition maintains that all sailors who cross the equator during a nautical voyage must undergo rites of passage and elaborate rituals initiating them into The Solemn Mysteries of the Ancient Order of the Deep. Those who have never "crossed the line" are derisively referred to as "pollywogs" or simply "slimy wogs". Upon entering the domain of His Royal Majesty, Neptunus Rex, all wogs are subject to various initiation rituals performed by those members of the crew who have made the journey before. Upon completion of the initiation ceremony, the wogs are then known as "trusty Shellbacks". If the crossing of the equator is done at the 180th meridian, the title of "Golden Shellback" is conferred, recognizing the simultaneous entry into the realm of the Golden Dragon. If the crossing occurs at the Greenwich or Prime Meridian, the sailor is considered to be an "Emerald Shellback".[1]

## Exact length of the equator

The equator is modeled exactly in two widely used standards as a circle of radius an integer number of meters. In 1976 the IAU standardized this radius as 6378140 metres (20925656 ft), subsequently refined by the IUGG to 6378137 metres (20925646 ft) and adopted in WGS-84, though the yet more recent IAU-2000 has retained the old IAU-1976 value. In either case, the length of the equator is by definition exactly 2π times the given standard, which to the nearest millimeter is 40075016.686 metres (131479713.54 ft) in WGS-84 and 40075035.535 metres (131479775.38 ft) in IAU-1976 and IAU-2000.[2]

The geographical mile is defined as one arc minute of the equator, and therefore has different values depending on which standard equator is used, namely 1855.3248 metres (6087.024 ft) or 1855.3257 metres (6087.027 ft) for respectively WGS-84 and IAU-2000, a difference of nearly a millimeter.

The earth is standardly modeled as a sphere flattened about 0.336% along its axis. This results in the equator being about 0.16% longer than a meridian (as a great circle passing through the two poles). The IUGG standard meridian is to the nearest millimeter 40007862.917 metres (131259392.77 ft), one arc minute of which is 1852.216 metres (6076.82 ft), explaining the SI standardization of the nautical mile as 1852 metres (6076 ft), more than 3 metres (10 ft) short of the geographical mile.

## See also

- 1st parallel north
- 1st parallel south
- Antarctic Circle
- Arctic Circle
- Equator (BBC TV series)
- Intertropical Convergence Zone
- Thermal equator
- Tropic of Cancer
- Tropic of Capricorn

## References


- Moritz, H (September 1980). "Geodetic Reference System 1980". *Bulletin Géodésique* (Berlin: Springer-Verlag) **54** (3): 395–405. doi:10.1007/BF02521480 [3]. (IUGG/WGS-84 data)
- Taff, Laurence G (1981). *Computational Spherical Astronomy*. New York: Wiley. ISBN 047106257X. OCLC 6532537 [4]. (IAU data)


## External links

- Equatorial Monuments Around the World [5]

## References


[1] " List of Unofficial US Navy Certificates (http://www.history.navy.mil/faqs/faq92-3.htm)". *Navy.mil*. 2005-11-07. . Retrieved 2008-07-13.

[2] Although millimeter precision can be important up to the scale of a mile, it has negligible physical significance at the scale of a geographic feature such as the equator. From a computational standpoint, however, millimeter precision or better can be valuable for maintaining consistent results when used in programs for surveying and other applications that require precise measurements. As an overly simple example, if a program were to convert back and forth between the radius and the circumference of the earth sufficiently often while maintaining precision only to a meter each time, errors might accumulate until they became noticeable.

[3] http://dx.doi.org/10.1007%2FBF02521480

[4] http://worldcat.org/oclc/6532537

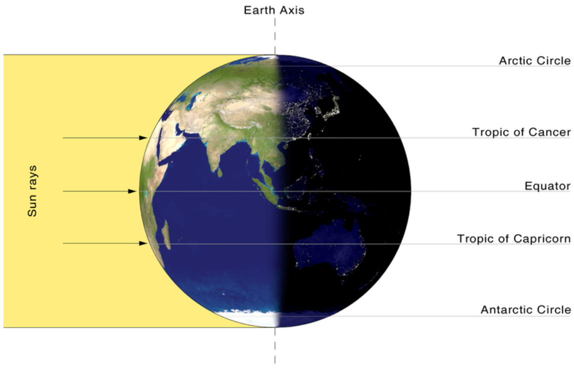
[5] http://armchairtravelogue.blogspot.com/2009/06/equatorial-monuments-around-world.html


# Equinox

**UTC date and time of solstices and equinoxes**[1]

| year | Equinox Mar | | Solstice June | | Equinox Sept | | Solstice Dec | |
|---|---|---|---|---|---|---|---|---|
| | day | time | day | time | day | time | day | time |
| **2004** | 20 | 06:49 | 21 | 00:57 | 22 | 16:30 | 21 | 12:42 |
| **2005** | 20 | 12:33 | 21 | 06:46 | 22 | 22:23 | 21 | 18:35 |
| **2006** | 20 | 18:26 | 21 | 12:26 | 23 | 04:03 | 22 | 00:22 |
| **2007** | 21 | 00:07 | 21 | 18:06 | 23 | 09:51 | 22 | 06:08 |
| **2008** | 20 | 05:48 | 20 | 23:59 | 22 | 15:44 | 21 | 12:04 |
| **2009** | 20 | 11:44 | 21 | 05:45 | 22 | 21:18 | 21 | 17:47 |
| **2010** | 20 | 17:32 | 21 | 11:28 | 23 | 03:09 | 21 | 23:38 |
| **2011** | 20 | 23:21 | 21 | 17:16 | 23 | 09:04 | 22 | 05:30 |
| **2012** | 20 | 05:14 | 20 | 23:09 | 22 | 14:49 | 21 | 11:11 |
| **2013** | 20 | 11:02 | 21 | 05:04 | 22 | 20:44 | 21 | 17:11 |
| **2014** | 20 | 16:57 | 21 | 10:51 | 23 | 02:29 | 21 | 23:03 |
| **2015** | 20 | 22:45 | 21 | 16:38 | 23 | 08:20 | 22 | 04:48 |
| **2016** | 20 | 04:30 | 20 | 22:34 | 22 | 14:21 | 21 | 10:44 |
| **2017** | 20 | 10:28 | 21 | 04:24 | 22 | 20:02 | 21 | 16:28 |

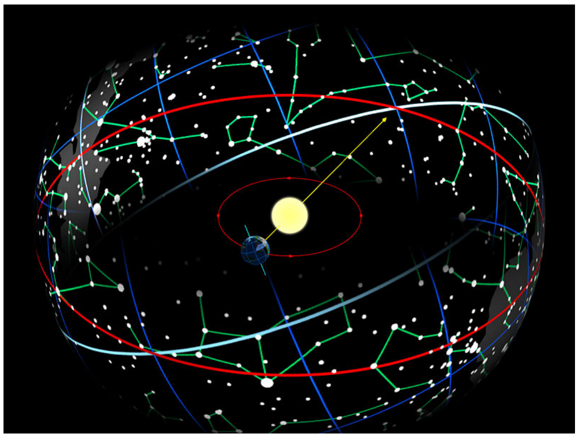
An **equinox** occurs twice a year, when the tilt of the Earth's axis is inclined neither away from nor towards the Sun, the Sun being vertically above a point on the Equator. The term *equinox* can also be used in a broader sense, meaning the date when such a passage happens. The name "equinox" is derived from the Latin *aequus* (equal) and *nox* (night), because around the equinox, the night and day are approximately equally long. It may be better understood to mean that latitudes +*L* and -*L* north and south of the equator experience nights of equal length.



Illumination of the Earth by the Sun on the day of an equinox (ignoring twilight).

The word is also used for the same event happening on other planets and in setting up a celestial coordinate system; *see equinox (celestial coordinates)*.

At an equinox, the Sun is at one of two opposite points on the celestial sphere where the celestial equator (i.e. declination 0) and ecliptic intersect. These points of intersection are called **equinoctial points:** the **vernal point** and the **autumnal point**. By extension, the term *equinox* may denote an equinoctial point.


The Earth in its orbit around the Sun causes the Sun to appear on the celestial sphere moving over the ecliptic (red), which is tilted on the Equator (white).

An equinox happens each year at two specific moments in time (rather than two whole days), when there is a location on the Earth's Equator where the centre of the Sun can be observed to be vertically overhead, occurring around March 20/21 and September 22/23 each year.

## Names

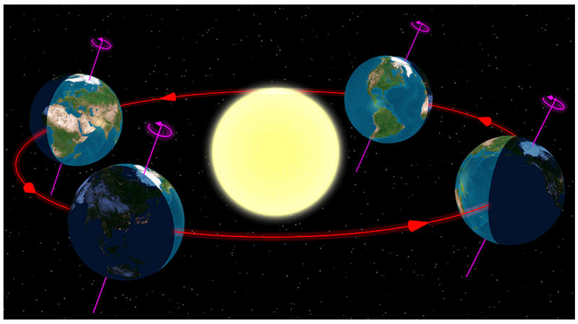


Diagram of the Earth's seasons as seen from the north. Far right: December Solstice.

- **Vernal equinox** and **autumnal equinox**: these classical names are direct derivatives of Latin (*ver* = *spring* and *autumnus* = *autumn*).
- **March equinox** and **September equinox**: a usage becoming the preferred standard by technical writers choosing to avoid Northern Hemisphere bias (implied by assuming that March is in the springtime and September is autumnal—true for those in the Northern Hemisphere but exactly opposite in the Southern Hemisphere).
- **Northward equinox** and **southward equinox**: names referring to the apparent motion of the Sun at the times of the equinox.
- **Vernal point** and **autumnal point** are the points on the celestial sphere where the Sun is located on the *vernal equinox* and *autumnal equinox* respectively (again, the seasonal attribution is that of the Northern Hemisphere).

- **First point** (or **cusp**) **of Aries** and **first point of Libra** are archaic names used by navigators and astrologers. Navigational ephemeris tables record the geographic position of the First Point of Aries as the reference for position of navigational stars. Due to the precession of the equinoxes, the astrological signs where these equinoxes are located no longer correspond with the actual constellations once ascribed to them.

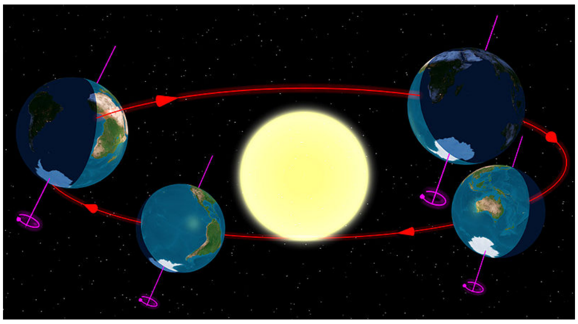
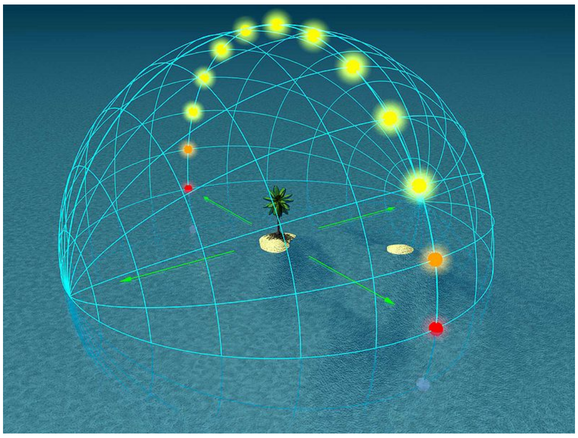


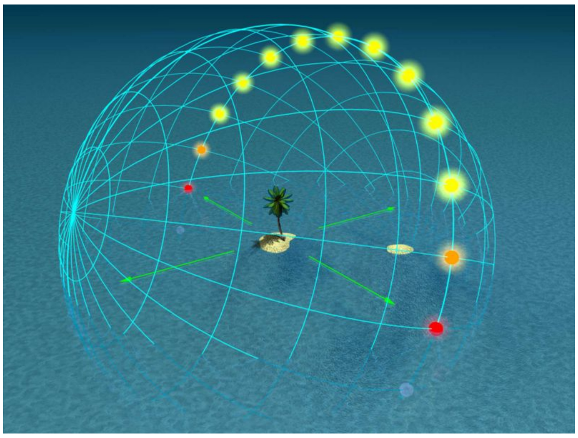
Diagram of the Earth's seasons as seen from the south. Far left: June Solstice.

## Length of equinoctial day and night

On a day of the equinox, the centre of the Sun spends a roughly equal amount of time above and below the horizon at every location on the Earth, night and day being of roughly the same length. The word *equinox* derives from the Latin words *aequus* (equal) and *nox* (night); in reality, the day is longer than the night at an equinox. Commonly, the day is defined as the period when sunlight reaches the ground in the absence of local obstacles. From the Earth, the Sun appears as a disc rather than a single point of light, so when the centre of the Sun is below the horizon, its upper edge is visible. Furthermore, the atmosphere refracts light, so even when the upper limb of the Sun is below the horizon, its rays reach over the horizon to the ground. In sunrise/sunset tables, the assumed semidiameter (apparent radius) of the Sun is 16 minutes of arc and the atmospheric refraction is assumed to be 34 minutes of arc. Their combination means that when the upper limb of Sun is on the visible horizon, its centre is 50 minutes of arc below the geometric horizon, which is the intersection with the celestial sphere of a horizontal plane through the eye of the observer. These cumulative effects make the day about 14 minutes longer than the night at the Equator and longer still towards the Poles. The real equality of day and night only happens in places far enough from the equator to have a seasonal difference in day length of at least 7 minutes, actually occurring a few days towards the winter side of each equinox.



Day arc at 0° latitude (Equator)

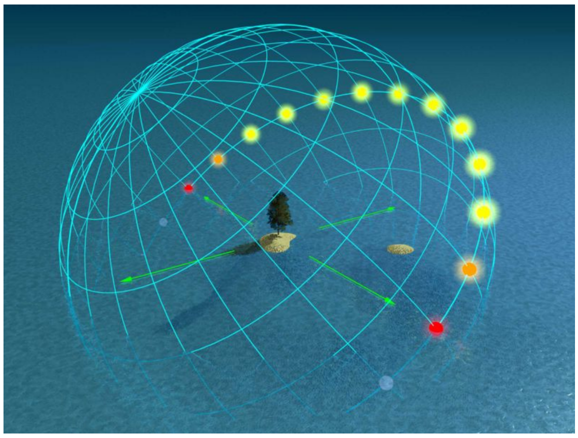


Day arc at 20° latitude

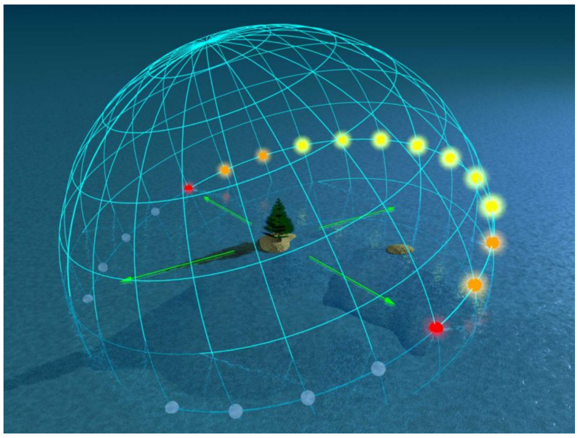
The date at which the time between sunset and sunrise crosses 12 hours , is known as the *equilux*. Because sunset and sunrise times vary with an observer's geographic location (longitude and latitude), the equilux likewise depends on location and does not exist for locations sufficiently close to the equator. The equinox, however, is a precise moment in time which is common to all observers on Earth.

## Heliocentric view of the seasons

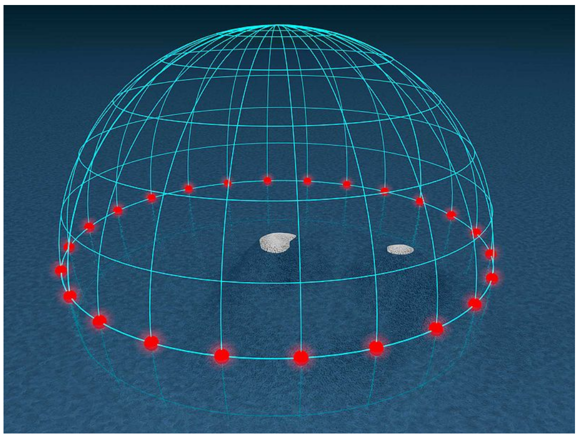
The Earth's seasons are caused by the rotation axis of the Earth not being perpendicular to its orbital plane. The Earth's axis is tilted at an angle of approximately 23.44° from the orbital plane; this tilt is called the axial tilt. As a consequence, for half of the year (i.e. from around March 20 to around September 22), the northern hemisphere tips toward the Sun, with the maximum around June 21, while for the other half of the year, the southern hemisphere has this honor, with the maximum around December 21. The two instants when the Sun is directly overhead at the Equator are the equinoxes. Also at that moment, both the North and South Poles of the Earth are just on the terminator and day and night are divided equally between the hemispheres.



Day arc at 50° latitude



Day arc at 70° latitude



Day arc at 90° latitude (Pole)

The table above gives the dates and times of equinoxes and solstices over several years. A few remarks can be made about the equinoxes:

- Because the Sun is a spherical (rather than a single-point) source of light, the actual crossing of the Sun over the Equator takes approximately 33 hours.
- At the equinoxes, the rate of change for the length of daylight and night-time is the greatest. At the Poles, the equinox marks the start of the transition from 24 hours of nighttime to 24 hours of daylight. High in the Arctic Circle, Longyearbyen, Svalbard, Norway has an additional 15 minutes more daylight every day around the time of the Spring equinox, whereas in Singapore (which is virtually *on* the Equator), the amount of daylight each day varies by just seconds.
- It is 94 days from the June solstice to the September equinox, but only 89 days from the December Solstice to the March equinox. The seasons are not of equal length, because of the variable speed of the Earth in its orbit around the Sun.
- The instances of the equinoxes are not fixed, but fall about six hours later every year, amounting to one full day in four years. They are reset by the occurrence of a leap year. The Gregorian calendar is designed to follow the seasons as accurately as is practical, which is good, but not absolutely perfect. *Also see: Gregorian calendar seasonal error.*
- Smaller irregularities in the times are caused by perturbations of the Moon and the other planets.

- Currently, the most common equinox and solstice dates are March 20, June 21, September 22 and December 21; the four-year average will slowly shift to earlier times in coming years. This shift is a full day in about 70 years (compensated mainly by the century "leap year" rules of the Gregorian calendar). This also means that in many years of the twentieth century, the dates of March 21, June 22, September 23 and December 22 were much more common, so older books teach (and older people may still remember) these dates.
- Note that the times are given in UTC (roughly speaking, the time at Greenwich, ignoring British Summer Time). People living farther to the east (Asia and Australia), whose local times are in advance, will see the seasons apparently start later; for example, in Tonga (UTC+13), an equinox occurred on September 24, 1999, a date which will not crop up again until 2103. On the other hand, people living far to the west (America) whose clocks run behind UTC may experience an equinox as early as March 19.

## Geocentric view of the seasons

In the half year centred on the June solstice, the Sun rises and sets towards the north, which means longer days with shorter nights for the Northern Hemisphere and shorter days with longer nights for the Southern Hemisphere. In the half year centred on the December solstice, the Sun rises and sets towards the south and the durations of day and night are reversed.

Also on the day of an equinox, the Sun rises everywhere on Earth (except the Poles) at 06:00 in the morning and sets at 18:00 in the evening (local time). These times are not exact for several reasons, one being that the Sun is much larger in diameter than the Earth that more than half of the Earth could be in sunlight at any one time (due to unparallel rays creating tangent points beyond an equal-day-night line); other reasons are as follows:

- Most places on Earth use a time zone which is unequal to the local time, differing by up to an hour or even two hours, if daylight saving time (summer time) is included. In that case, the Sun could rise at 08:00 and set at 20:00, but there would still be 12 hours of daylight.
- Even those people fortunate enough to have their time zone equal to the local time will not see sunrise and sunset at 06:00 and 18:00 respectively. This is due to the variable speed of the Earth in its orbit, and is described as the equation of time. It has different values for the March and September equinoxes (+8 and −8 minutes respectively).
- Sunrise and sunset are commonly defined for the upper limb of the solar disk, rather than its centre. The upper limb is already up for at least one minute before the centre appears, and likewise, the upper limb sets one minute later than the centre of the solar disk. Due to atmospheric refraction, the Sun, when near the horizon, appears a little more than its own diameter above the position than where it is in reality. This makes sunrise more than another two minutes earlier and sunset the equal amount later. These two effects add up to almost seven minutes, making the equinox day 12 h 7 min long and the night only 11 h 53 min. In addition to that, the night includes twilight. When dawn and dusk are added to the daytime instead, the day would be almost 13 hours.
- The above numbers are only true for the tropics. For moderate latitudes, this discrepancy increases (for example, 12 minutes in London) and closer to the Poles it gets very large. Up to about 100 km from either Pole, the Sun is up for a full 24 hours on an equinox day.
- Height of the horizon on both the sunrise and sunset sides changes the day's length. Going up into the mountains will lengthen the day, while standing in a valley with hilltops on the east and the west can shorten the day significantly. This is why settlements in east-west running valleys are more favourable (daylight-wise) than north-south running valleys.

## Day arcs of the Sun

Some of the above statements can be made clearer when picturing the day arc (i.e. the path the Sun tracks along the celestial dome in its diurnal movement). The pictures show this for every hour on equinox day. In addition, some 'ghost' suns are also indicated below the horizon, up to 18° down. The Sun in this area still causes twilight. The pictures can be used for both Northern and Southern hemispheres. The observer is supposed to sit near the tree on the island in the middle of the ocean; the green arrows give cardinal directions.

- On the northern hemisphere, north is to the left, the Sun rises in the east (far arrow), culminates in the south (right arrow) while moving to the right and setting in the west (near arrow).
- On the southern hemisphere, south is to the left, the Sun rises in the east (near arrow), culminates in the north (right arrow) while moving to the left and setting in the west (far arrow).

The following special cases are depicted:

- The day arc on the Equator, passing through the zenith, has almost no shadows at high noon.
- The day arc on 20° latitude: the Sun culminates at 70° altitude and also its daily path at sunrise and sunset occurs at a steep 70° angle to the horizon. Twilight is still about one hour.
- The day arc on 50° latitude: twilight is almost two hours now.
- The day arc on 70° latitude: the Sun culminates at no more than 20° altitude and its daily path at sunrise and sunset is at a shallow 20° angle to the horizon. Twilight is more than four hours; in fact, there is barely any night.
- The day arc at the Pole: if it were not for atmospheric refraction, the Sun would be on the horizon all the time.

## Celestial co-ordinate systems

The vernal point (vernal equinox) — the one the Sun passes in March on its way from south to north — is used as the origin of some celestial coordinate systems:

- in the ecliptic coordinate system, the vernal point is the origin of the ecliptic longitude;
- in the equatorial coordinate system, the vernal point is the origin of the right ascension.

Because of the precession of the Earth's axis, the position of the vernal point changes over time and as a consequence, both the Equatorial and the ecliptic co-ordinate systems change over time. Therefore, when specifying celestial co-ordinates for an object, one has to specify at what time the vernal point (and also the celestial equatorial) are taken. That reference time is also called equinox.

The autumnal equinox is at ecliptic longitude 180° and at right ascension 12h.

The upper culmination of the vernal point is considered the start of the sidereal day for the observer. The hour angle of the vernal point is, by definition, the observer's sidereal time.

For western tropical astrology, the same thing holds true; the vernal equinox is the first point (i.e. the start) of the sign of Aries. In this system, it is of no significance that the fixed stars and equinox shift compared to each other due to the precession of the equinoxes.

## Cultural aspects of the equinox

- The traditional East Asian calendars divide a year into 24 solar terms (節氣, literally "climatic segments"), and the vernal equinox (Chūnfēn, Chinese and Japanese: 春分; Korean: 춘분; Vietnamese: Xuân phân) and the autumnal equinox (Qiūfēn, Chinese and Japanese: 秋分; Korean: 추분; Vietnamese: Thu phân) mark the *middle* of the spring and autumn seasons, respectively. In this context, the Chinese character 分 means *"(equal) division"* (within a season).
- In Japan, (March) Vernal Equinox Day (春分の日 *Shunbun no hi*) is an official national holiday, and is spent visiting family graves and holding family reunions. Similarly, in September, there is an Autumnal Equinox Day (秋分の日 *Shūbun no hi*).

- Wiccans and many other Neopagans hold religious celebrations of "Ostara" on the spring equinox, and "Mabon" on the autumnal equinox.

### Vernal equinox commemorations

Bas-relief in Persepolis - a symbol Iranian/Persian Nowruz - on the day of an equinox, the power of an eternally fighting bull (personifying the Earth) and that of a lion (personifying the Sun) are equal.

Chichen Itza pyramid during the spring equinox - Kukulkan, the famous descent of the snake

- The March equinox marks the first day of various calendars including the Iranian calendar and the Bahá'í calendar.[2] The Persian (Iranian) new year's festival of Nowruz is celebrated then. According to the ancient Persian mythology Jamshid, the mythological king of Persia, ascended to the throne on this day and each year this is commemorated with festivities for two weeks. These festivities recall the story of creation and the ancient cosmology of Iranian and Persian people. It is also a holiday for Azerbaijan, Afghanistan, India, Turkey, Zanzibar, Albania, and various countries of Central Asia, as well as among the Kurds. As well as being a Zoroastrian holiday, it is also a holy day for adherents of the Bahá'í Faith and the Nizari Ismaili Muslims.[3]
- Sham El Nessim was an ancient Egyptian holiday which can be traced back as far as 2700 B.C. It is still one of the public holidays in Egypt. Sometime during Egypt's Christian period (c. 200-639) the date moved to Easter Monday, but before then it coincided with the vernal equinox.
- The Jewish Passover usually falls on the first full moon after the Northern Hemisphere vernal equinox, although occasionally (7 times every 19 years) it will occur on the second full moon.
- The Christian churches calculate Easter as the first Sunday after the first full moon on or after the March equinox. The official church definition for the equinox is March 21; however, as the Eastern Orthodox Churches use the older Julian calendar, while the Western Churches use the Gregorian calendar, both of which designate March 21 as the equinox, the actual date of Easter differs. The earliest possible Easter date in any year is therefore March 22 on each calendar. The latest possible Easter date in any year is April 25.[4]
- Tamil and Bengali New Years follow the Hindu zodiac and are celebrated according to the sidereal vernal equinox (April 14). The former is celebrated in the South Indian state of Tamil Nadu, and the latter in Bangladesh and the East Indian state of West Bengal.
- Andhra Pradesh, Karnataka and Maharastra people celebrate new year ugadi set by Satavahana on the first morning after first new moon from March equinox. Also the calculations of the great Indian Mathematician Bhaskaracharya proclaim the Ugadi day as the beginning of the New Year, New month and New day.
- In many Arab countries, Mother's Day is celebrated on the March equinox.
- World Storytelling Day is a global celebration of the art of oral storytelling, celebrated every year on the spring equinox in the northern hemisphere, the first day of autumn equinox in the southern.
- World Citizen Day occurs on the March equinox.[5]

- In Annapolis, Maryland, USA, boatyard employees and sailboat owners celebrate the spring equinox with the **Burning Of The Socks** festival. Traditionally, the boating community wears socks only during the winter. These are burned at the approach of warmer weather, which brings more customers and work to the area. Officially, nobody then wears socks until the next equinox.[6]
- Kerala, a state of India celebrates the celestial vernal equinox as their New year around April 14. It is known as 'Vishu' meaning equal in Sanskrit.
- Earth Day was initially celebrated on March 21, 1970, the equinox day. It is currently celebrated in various countries on April 22.

### Autumnal equinox commemorations

- The September equinox marks the first day of Mehr or Libra in the Persian calendar. It is one of the Iranian festivals called Jashne Mihragan, or the festival of sharing or love in Zoroastrianism.
- In Korea, Chuseok is a major harvest festival and a three-day holiday celebrated around the Autumn Equinox.
- The Mid-Autumn Festival is celebrated on the 15th day of the 8th lunar month, oftentimes near the autumnal equinox day, and is an official holiday in China and in many countries with a significant Chinese minority. As the lunar calendar is not synchronous with the Gregorian calendar, this date could be anywhere from mid-September to early October.
- The traditional harvest festival in the United Kingdom was celebrated on the Sunday of the full moon closest to the September equinox.

**Modern innovations:**

- The September equinox was "New Year's Day" in the French Republican Calendar, which was in use from 1793 to 1805. The French First Republic was proclaimed and the French monarchy was abolished on September 21, 1792, making the following day (the equinox day that year) the first day of the "Republican Era" in France. The start of every year was to be determined by astronomical calculation, (that is: following the real Sun and not the mean Sun as all other calendars).

## Myths, fables and facts

- One effect of equinoctial periods is the temporary disruption of communications satellites. For all geostationary satellites, there are a few days near the equinox when the sun goes directly behind the satellite relative to Earth (i.e. within the beamwidth of the groundstation antenna) for a short period each day. The Sun's immense power and broad radiation spectrum overload the Earth station's reception circuits with noise and, depending on antenna size and other factors, temporarily disrupt or degrade the circuit. The duration of those effects varies but can range from a few minutes to an hour. (For a given frequency band, a larger antenna has a narrower beamwidth, hence experiences shorter duration "Sun outage" windows).
- A modern urban legend claims that on the March equinox day (some may also include the September equinox day rather than leaving it out), one can balance an egg on its point.[7] [8] However, one can balance an egg on its point any day of the year...if one has enough patience.[9]
- Although the word *equinox* is often understood to mean "equal [day and] night," as is noted elsewhere, this is not strictly true. For most locations on earth, there are two distinct identifiable days per year when the length of day and night are closest to being equal; those days are commonly referred to as the "equiluxes" to distinguish them from the equinoxes. Equinoxes are points in time, but equiluxes are days. By convention, equiluxes are the days where sunrise and sunset are closest to being exactly 12 hours apart. This way, you can refer to a single date as being the equilux, when in reality, it spans from sunset on one day to sunset the next, sunrise on one to sunrise the next or midday on one day to midday on the next.
- What is true about the equinoxes is that two observers at the same distance north and south of the equator will experience nights of equal length.

- The equilux counts times when some direct sunlight could be visible, rather than all hours of usable daylight (which is any time when there is enough natural light to do outdoor activities without needing artificial light). This is due to twilight; a particular type of twilight which is officially defined as civil twilight. This amount of twilight can result in more than 12 hours of usable daylight up to a few weeks before the spring equinox, and up to a few weeks after the fall equinox.
- In a contrary vein, the daylight which is useful for illuminating houses and buildings during the daytime and is needed to produce the full psychological benefit of daylight, is *shorter* than the nominal time between sunrise and sunset. So in that sense, "useful" daylight is present for 12 hours only *after* the vernal equinox and *before* the autumnal equinox, because the intensity of light near sunrise and sunset, even with the sun slightly above the horizon, is considerably less than when the sun is high in the sky.
- It is perhaps valuable for people in the Americas and Asia to know that the equinoxes listed as occurring on March 21, which occurred frequently in the 20th century and which will occur occasionally in the 21st century, are presented as such using UTC, which is at least four hours in advance of any clock in the Americas and as much as twelve hours behind Asian clocks. Thus, there will be no spring equinox later than March 20 in the Americas in the coming century.

## External links

- Details about the Length of Day and Night at the Equinoxes [10]
- Calculation of Length of Day [10] (Formulas and Graphs)
- Equinoctial Points [11] — The Nuttall Encyclopædia
- Table of times for Equinoxes, Solstices, Perihelion and Aphelion in 2000-2020 [12]
- Blessing the Sun in Jewish Custom [13]
- Table of times of Spring Equinox for a thousand years: 1452-2547 [14]
- A forum community called "Equinox" [15]
- "Ancient Equinox Alignment [16]". *Loughcrew, Ireland.*

## References

[1] United States Naval Observatory (01/28/07). " Earth's Seasons: Equinoxes, Solstices, Perihelion, and Aphelion, 2000-2020 (http://aa.usno.navy.mil/data/docs/EarthSeasons.php)". .
[2] Baha'i calendar (http://www.bahai.us/content/view/31/96/)
[3] " The Ismaili: Navroz (http://www.theismaili.org/cms/232/Navroz)". . Retrieved 2008-03-26.
[4] Keith's Moon Facts (http://home.hiwaay.net/~krcool/Astro/moon/)
[5] "the utmost global citizen" (http://www.recim.org/ascop/a7-an.htm). Global Culture (2007).
[6] Annapolis Welcomes Spring by Burning Socks (http://www.firstcoastnews.com/news/strange/news-article.aspx?storyid=54143)
[7] Infernal Egguinox Standing an egg on end on the spring equinox (http://www.snopes.com/science/equinox.htm)
[8] Equinox Means Balanced Light, Not Balanced Eggs (http://www.clarkfoundation.org/astro-utah/vondel/equinoxver.html)
[9] De-Fact-o article on the egg equinox myth (http://www.de-fact-o.com/fact_read.php?id=99)
[10] http://aa.usno.navy.mil/faq/docs/equinoxes.php
[11] http://www.gutenberg.org/dirs/1/2/3/4/12342/12342-h/12342-h.htm#E
[12] http://aa.usno.navy.mil/data/docs/EarthSeasons.php
[13] http://www.divreinavon.com/pdf/BirkatHahama.pdf
[14] http://ns1763.ca/equinox/eqindex.html
[15] http://s4.zetaboards.com/EquinoxNS/index/
[16] http://www.knowth.com/loughcrew-equinox.htm

# Horizon

The **horizon** (Ancient Greek *ὁ ὁρίζων*, /ho horídzôn/, from *ὁρίζειν*, "to limit") is the apparent line that separates earth from sky.

It is the line that divides all visible directions into two categories: those that intersect the Earth's surface, and those that do not. At many locations, the *true horizon* is obscured by trees, buildings, mountains, etc., and the resulting intersection of earth and sky is called the *visible horizon*. When looking at a sea from a shore, the part of the sea closest to the horizon is called the **offing**.

A water horizon, in northern Wisconsin, USA.

## Appearance and usage

Historically, the distance to the visible horizon at sea has been extremely important as it represented the maximum range of communication and vision before the development of the radio and the telegraph. Even today, when flying an aircraft under Visual Flight Rules, a technique called attitude flying is used to control the aircraft, where the pilot uses the visual relationship between the aircraft's nose and the horizon to control the aircraft. A pilot can also retain his or her spatial orientation by referring to the horizon.

View of Earth's horizon as seen from Space Shuttle *Endeavour*, 2002.

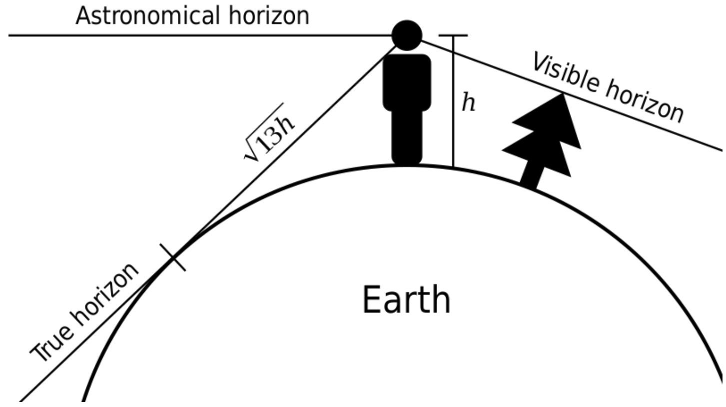
In many contexts, especially perspective drawing, the curvature of the earth is typically disregarded and the horizon is considered the theoretical line to which points on any horizontal plane converge (when projected onto the picture plane) as their distance from the observer increases. For observers near the ground the difference between this *geometrical horizon* (which assumes a perfectly flat, infinite ground plane) and the *true horizon* (which assumes a spherical Earth surface) is typically imperceptibly small.

Water horizon (Computer graphics)

In astronomy the horizon is the horizontal plane through (the eyes of) the observer. It is the fundamental plane of the horizontal coordinate system, the locus of points that have an altitude of zero degrees. While similar in ways to the geometrical horizon, in this context a horizon may be considered to be a plane in space, rather than a line on a picture plane.

## Distance to the horizon

### Approximate formulas



Three types of horizon.

In SI units, the straight line of sight distance $d$ in kilometers to the true horizon on earth is approximately

$$d = \sqrt{13h}$$

where $h$ is the height above ground or sea level (in meters) of the eye of the observer. Examples:

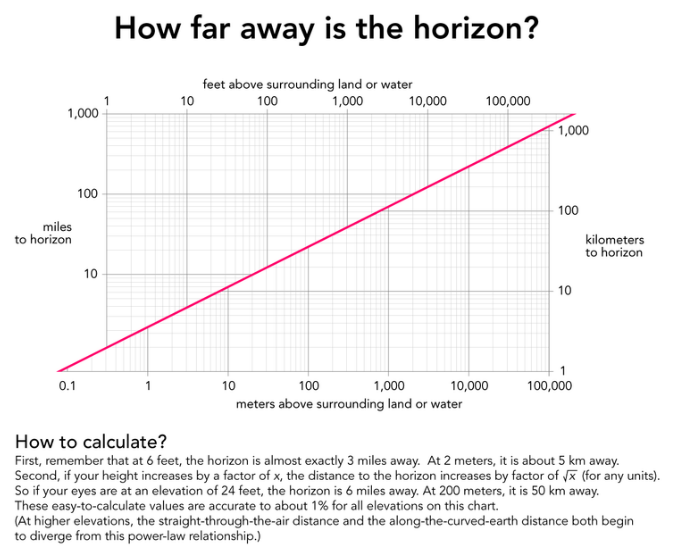
- For an observer standing on the ground with $h$ = 1.70 metres (5 ft 7 in) (average eye-level height), the horizon is at a distance of 4.7 kilometres (2.9 mi).
- For an observer standing on a hill or tower of 100 metres (330 ft) in height, the horizon is at a distance of 36 kilometres (22 mi).

For Imperial units, 13 is replaced by 1.5, $h$ is in feet and $d$ is in miles. Thus:

$$d = \sqrt{1.5h}$$

Examples:

- For observers on the ground with eye-level at $h$ = 5 ft 7 in (5.583 ft), the horizon is at a distance of 2.89 miles (4.65 km).
- For observers standing on a hill or tower 100 feet (30 m) in height, the horizon is at a distance of 12.25 miles (19.71 km).




These formulas may be used when $h$ is much smaller than the radius of the Earth (6371 km), including all views from any mountaintops, airplanes, or high-altitude balloons. With the constants as given, both the metric and imperial formulas are precise to within 1 pc (see next section for how to derive formulas of greater precision).

### More exact formula

A more exact formula for distance from the viewpoint to the horizon, applicable even for satellites, is

$$d = \sqrt{2Rh + h^2},$$

where $R$ is the radius of the Earth ($R$ and $h$ must be in the same units). This formula follows directly from the Pythagorean Theorem (a right triangle can be drawn with vertices at the center of the Earth, your eyes, and the point on the horizon. If $h$ is in meters, $h << R$ and $R$ is about 6378 km, then the distance in kilometers will be approximately $\sqrt{2(6378)h/1000} = \sqrt{12.756h}$ .

This formula is not exact since it assumes a constant earth radius.

Another relationship involves the arc length distance $s$ along the curved surface of the Earth to the bottom of object:

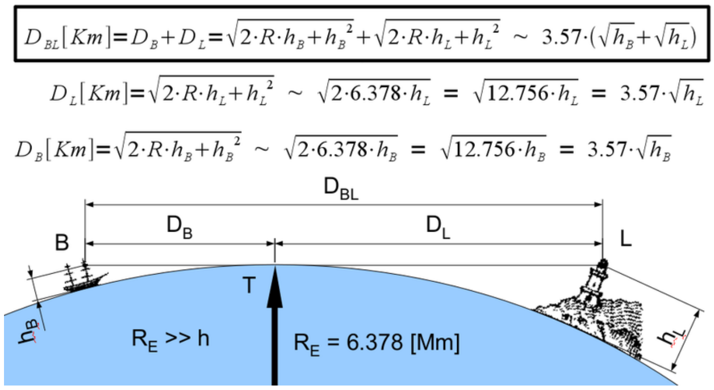
$$\cos\frac{s}{R} = \frac{R}{R+h}.$$

Solving for *s* gives the formula

$$s = R\cos^{-1}\frac{R}{R+h}.$$

The distances *d* and *s* are nearly the same when the height of the object is negligible compared to the radius (that is, $h \ll R$).

## Optical adjustments and objects above the horizon



Geometrical horizon distance

To compute the height of an object visible above the horizon, compute the distance-to-horizon for a hypothetical observer on top of that object, and add it to the real observer's distance-to-horizon. For example, standing on the ground with *h* = 1.70 m, the horizon is 4.65 km away. For a tower with a height of 100 m, the horizon distance is 35.7 km. Thus an observer on a beach can see the tower as long as it is not more than 40.35 km away. Conversely, if an observer on a boat (h = 1.7 m) can just see the tops of trees on a nearby shore (h = 10 m), they are probably about 16 km away.

Note that the actual visual horizon is slightly farther away than the calculated visual horizon, due to the atmospheric refraction of light rays. This effect can be taken into account by using a "virtual radius" that is typically about 20% larger than the true radius of the Earth.

# Curvature of the horizon

From a point above the surface the horizon appears slightly bent. There is a basic geometrical relationship between this visual curvature $\kappa$ , the altitude and the Earth's radius. It is

$$\kappa = \sqrt{\left(\frac{R+h}{R}\right)^2 - 1}\ .$$

The curvature is the reciprocal of the curvature angular radius in radians. A curvature of 1 appears as a circle of an angular radius of 45° corresponding to an altitude of approximately 2640 km above the Earth's surface. At an altitude of 10 km (33,000 ft, the typical cruising altitude of an airliner) the mathematical curvature of the horizon is about 0.056, the same curvature of the rim of circle with a radius of 10 m that is viewed from 56 cm. However, the apparent curvature is less than that due to refraction of light in the atmosphere and because the horizon is often masked by high cloud layers that reduce the altitude above the visual surface.

## See also

- Dawn: the time right before sunrise
- Dusk: the time right after sunset, yielding to twilight
- Landscape
- Landscape art
- Aerial landscape art
- Sextant
- Atmospheric refraction

## External links

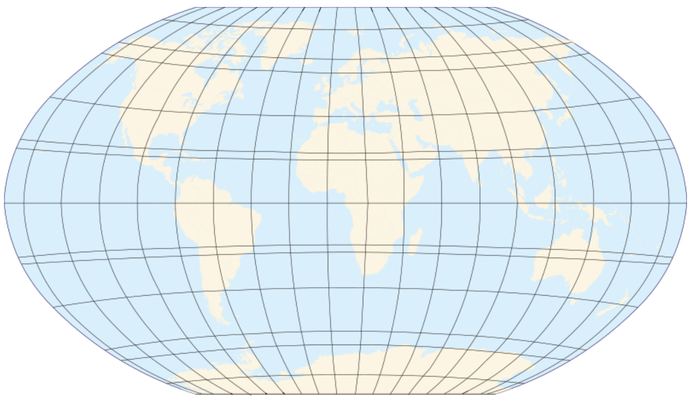
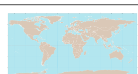
- Derivation of the distance to the horizon [1]

## References

[1] http://www.sque.co.uk/physics/horizon/

# Latitude

**Latitude**, usually denoted by the Greek letter phi (φ) gives the location of a place on Earth (or other planetary body) north or south of the equator. **Lines of Latitude** are the imaginary horizontal lines shown running east-to-west (or west to east) on maps (particularly so in the Mercator projection) that run either north or south of the equator. Technically, latitude is an angular measurement in degrees (marked with °) ranging from 0° at the equator (low latitude) to 90° at the poles (90° N or +90° for the North Pole and 90° S or −90° for the South Pole). The latitude is approximately the angle between straight up at the surface (the zenith) and the sun at an equinox. The complementary angle of a latitude is called the **colatitude**.

<table>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Map of Earth</td></tr>
<tr><th colspan="2">Longitude (λ)</th></tr>
<tr><td colspan="2">Lines of longitude appear vertical with varying curvature in this projection; but are actually halves of great ellipses, with identical radii at a given latitude.</td></tr>
<tr><th colspan="2">Latitude (φ)</th></tr>
<tr><td colspan="2">Lines of latitude appear horizontal with varying curvature in this projection; but are actually circular with different radii. All locations with a given latitude are collectively referred to as a circle of latitude.</td></tr>
<tr><td>The equator divides the planet into a Northern Hemisphere, a Southern Hemisphere and has a latitude of 0°.</td><td></td></tr>
</table>

## Circles of latitude

All locations of a given latitude are collectively referred to as a *circle of latitude* or *line of latitude* or *parallel*, because they are coplanar, and all such planes are parallel to the equator. Lines of latitude other than the Equator are approximately small circles on the surface of the Earth; they are not geodesics since the shortest route between two points at the same latitude involves a path that bulges toward the nearest pole, first moving farther away from and then back toward the equator (see great circle).

A specific latitude may then be combined with a specific longitude to give a precise position on the Earth's surface (see satellite navigation system).

Sign in northern Vermont.

### Important named circles of latitude

Besides the equator, four other lines of latitude are named because of the role they play in the geometrical relationship with the Earth and the Sun:

- Arctic Circle: 66° 33′ 39″ N
- Tropic of Cancer: 23° 26′ 21″ N
- Equator: 0° Latitude
- Tropic of Capricorn: 23° 26′ 21″ S
- Antarctic Circle: 66° 33′ 39″ S

Only at latitudes between the Tropics is it possible for the sun to be at the zenith. Only north of the Arctic Circle or south of the Antarctic Circle is the midnight sun possible.

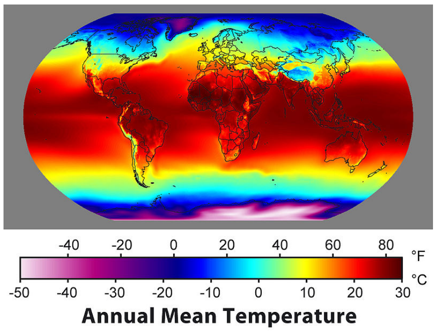
The reason that these lines have the values that they do lies in the axial tilt of the Earth with respect to the sun, which is 23° 26′ 21.41″.

Note that the Arctic Circle and Tropic of Cancer are colatitudes, since the sum of their angles is 90°—similarly for the Antarctic Circle and Tropic of Capricorn.

## Subdivisions

A degree is divided into 60 minutes. One minute can be further divided into 60 seconds. An example of a latitude specified in this way is 13°19'43″ N (for greater precision, a decimal fraction can be added to the seconds). An alternative representation uses only degrees and minutes, where the seconds are expressed as a decimal fraction of minutes: the above example would be expressed as 13°19.717' N. Degrees can also be expressed singularly, with both the minutes and seconds incorporated as a decimal number and rounded as desired (decimal degree notation): 13.32861° N. Sometimes, the north/south suffix is replaced by a negative sign for south (−90° for the South Pole).

## Effect of latitude



Average temperatures vary strongly with latitude.

A region's latitude has a great effect on its climate and weather (see *Effect of sun angle on climate*). Latitude more loosely determines tendencies in polar auroras, prevailing winds, and other physical characteristics of geographic locations.

Researchers at Harvard's Center for International Development (CID) found in 2001 that only three tropical economies — Hong Kong, Singapore, and Taiwan — were classified as high-income by the World Bank, while all countries within regions zoned as temperate had either middle- or high-income economies. [1] The validity of the Harvard report may be questioned because a different threshold is used for the tropical regions and the World Bank list fails to include Qatar's, United Arab Emirates', and Kuwait's economies. Further, countries such as Brazil have far better incomes than much of the Former Soviet Union and Iron Curtain states.

## Elliptic parameters

Because most planets (including Earth) are *ellipsoids of revolution*, or spheroids, rather than spheres, both the radius and the length of arc varies with latitude. This variation requires the introduction of elliptic parameters based on an ellipse's **angular eccentricity**, $o\!\!\!\varepsilon$ (which equals $\arccos\left(\frac{b}{a}\right)$, where $a$ and $b$ are the equatorial radius (6378137.0 m for Earth) and the polar radius (6356752.3142 m for Earth), respectively; $\sin^2(o\!\!\!\varepsilon)$ is the first eccentricity squared, $e^2$; and $2\sin^2\left(\frac{o\!\!\!\varepsilon}{2}\right)$ or $1-\cos(o\!\!\!\varepsilon)$ is the flattening, $f$). Utilized in creating the integrands for curvature is the inverse of the principal elliptic integrand, $E'$:

$$n'(\phi)=\frac{1}{E'(\phi)}=\frac{1}{\sqrt{1-(\sin(\phi)\sin(o\!\!\!\varepsilon))^2}};$$

$$M(\phi)=a\cdot\cos^2(o\!\!\!\varepsilon)n'^3(\phi)=\frac{(ab)^2}{\left((a\cos(\phi))^2+(b\sin(\phi))^2\right)^{3/2}};$$

$$N(\phi)=a{\cdot}n'(\phi)=\frac{a^2}{\sqrt{(a\cos(\phi))^2+(b\sin(\phi))^2}}.$$

## Degree length

On Earth, the length of an arcdegree of north–south latitude difference, $\Delta\phi$, is about 60 nautical miles, 111 kilometres or 69 statute miles at any latitude. The length of an arcdegree of east-west longitude difference, $\cos(\phi)\Delta\lambda$, is about the same at the equator as the north-south, reducing to zero at the poles.

In the case of a spheroid, a meridian and its anti-meridian form an ellipse, from which an exact expression for the length of an arcdegree of latitude difference is:

$$\frac{\pi}{180^\circ}M(\phi);$$

This radius of arc (or "arcradius") is in the plane of a meridian, and is known as the *meridional radius of curvature*, $M$. [2] [3]

Similarly, an exact expression for the length of an arcdegree of longitude difference is:

$$\frac{\pi}{180^\circ}\cos(\phi)N(\phi);$$

The arcradius contained here is in the plane of the prime vertical, the east-west plane perpendicular (or "normal") to both the plane of the meridian and the plane tangent to the surface of the ellipsoid, and is known as the *normal radius of curvature*, $N$.[2] [3]

Along the equator (east-west), $N$ equals the equatorial radius. The radius of curvature at a right angle to the equator (north-south), $M$, is 43 km shorter, hence the length of an arcdegree of latitude difference at the equator is about 1 km less than the length of an arcdegree of longitude difference at the equator. The radii of curvature are equal at the poles where they are about 64 km greater than the north-south equatorial radius of curvature *because* the polar radius is 21 km less than the equatorial radius. The shorter polar radii indicate that the northern and southern hemispheres are flatter, making their radii of curvature longer. This flattening also 'pinches' the north-south equatorial radius of curvature, making it 43 km less than the equatorial radius. Both radii of curvature are perpendicular to the plane tangent to the surface of the ellipsoid at all latitudes, directed toward a point on the polar axis in the opposite hemisphere (except at the equator where both point toward Earth's center). The east-west radius of curvature reaches the axis, whereas the north-south radius of curvature is shorter at all latitudes except the poles.

The WGS84 ellipsoid, used by all GPS devices, uses an equatorial radius of 6378137.0 m and an inverse flattening, (1/f), of 298.257223563, hence its polar radius is 6356752.3142 m and its first eccentricity squared is 0.00669437999014.[4] The more recent but little used IERS 2003 ellipsoid provides equatorial and polar radii of 6378136.6 and 6356751.9 m, respectively, and an inverse flattening of 298.25642.[5] Lengths of degrees on the WGS84 and IERS 2003 ellipsoids are the same when rounded to six significant digits. An appropriate calculator for any latitude is provided by the U.S. government's National Geospatial-Intelligence Agency (NGA).[6]

| Latitude | N-S radius of curvature $M$ | Surface distance per 1° change in latitude | E-W radius of curvature $N$ | Surface distance per 1° change in longitude |
|---|---|---|---|---|
| 0° | 6335.44 km | 110.574 km | 6378.14 km | 111.320 km |
| 15° | 6339.70 km | 110.649 km | 6379.57 km | 107.551 km |
| 30° | 6351.38 km | 110.852 km | 6383.48 km | 96.486 km |
| 45° | 6367.38 km | 111.132 km | 6388.84 km | 78.847 km |
| 60° | 6383.45 km | 111.412 km | 6394.21 km | 55.800 km |
| 75° | 6395.26 km | 111.618 km | 6398.15 km | 28.902 km |
| 90° | 6399.59 km | 111.694 km | 6399.59 km | 0.000 km |

# Types of latitude

With a spheroid that is slightly flattened by its rotation, cartographers refer to a variety of auxiliary latitudes to precisely adapt spherical projections according to their purpose.
For planets other than Earth, such as Mars, geographic and geocentric latitude are called "planetographic" and "planetocentric" latitude, respectively. Most maps of Mars since 2002 use planetocentric coordinates.

## Common "latitude"

In common usage, "latitude" refers to **geodetic** or **geographic latitude** $\phi$ and is the angle between the equatorial plane and a line that is normal to the reference ellipsoid, which approximates the shape of Earth to account for flattening of the poles and bulging of the equator. This value usually differs from the geocentric latitude.

The expressions following assume elliptical polar sections and that all sections parallel to the equatorial plane are circular. Geographic latitude (with longitude) then provides a Gauss map. As defined earlier in this article, $o\!\varepsilon$ is the angular eccentricity of a meridian.

## Reduced latitude

- On a spheroid, lines of **reduced** or **parametric latitude**, $\beta$ , form circles whose radii are the same as the radii of circles formed by the corresponding lines of latitude on a sphere with radius equal to the equatorial radius of the spheroid.

$$\beta = \arctan\Big(\cos(o\!\varepsilon)\tan(\phi)\Big) = \arctan\left(\frac{b}{a}\tan(\phi)\right);$$

## Authalic latitude

- **Authalic latitude**, $\xi$ , gives an area-preserving transform to the sphere.

$$\widehat{S}^2(\phi) = \frac{1}{2}b^2\left(\sin(\phi)n'^2(\phi) + \frac{\ln\Big(n'(\phi)\big(1+\sin(\phi)\sin(o\!\varepsilon)\big)\Big)}{\sin(o\!\varepsilon)}\right);$$

$$\xi = \arcsin\left(\frac{\widehat{S}^2(\phi)}{\widehat{S}^2(90^\circ)}\right),$$

$$= \arcsin\left(\frac{\sin(\phi)\sin(o\!\varepsilon)n'^2(\phi) + \ln\Big(n'(\phi)\big(1+\sin(\phi)\sin(o\!\varepsilon)\big)\Big)}{\sin(o\!\varepsilon)\sec^2(o\!\varepsilon) + \ln\Big(\sec(o\!\varepsilon)\big(1+\sin(o\!\varepsilon)\big)\Big)}\right);$$

## Rectifying latitude

- **Rectifying latitude**, $\mu$ , is the surface distance from the equator, scaled so the pole is 90°, but involves elliptic integration:

$$\mu = \frac{\int_0^\phi M(\theta)\,d\theta}{\frac{2}{\pi}\int_0^{90^\circ} M(\phi)\,d\phi} = \frac{\pi}{2}\cdot\frac{\int_0^\phi n'^3(\theta)\,d\theta}{\int_0^{90^\circ} n'^3(\phi)\,d\phi};$$

## Conformal latitude

- **Conformal latitude**, $\chi$ , gives an angle-preserving (conformal) transform to the sphere.

$$\chi = 2\cdot\arctan\left(\sqrt{\frac{1+\sin(\phi)}{1-\sin(\phi)}\cdot\left(\frac{1-\sin(\phi)\sin(o\!\varepsilon)}{1+\sin(\phi)\sin(o\!\varepsilon)}\right)^{\sin(o\!\varepsilon)}}\right) - \frac{\pi}{2};$$

### Geocentric latitude

- The **geocentric latitude**, $\psi$ , is the angle between the equatorial plane and a line from the center of Earth.

$$\psi = \arctan\left(\cos^2(\alpha\!\varepsilon)\tan(\phi)\right) = \arctan\left((b/a)^2\tan(\phi)\right).$$

It is the size of the central angle between the equator and the point of interest, as measured along a meridian. This value usually differs from the geographic latitude, as so:

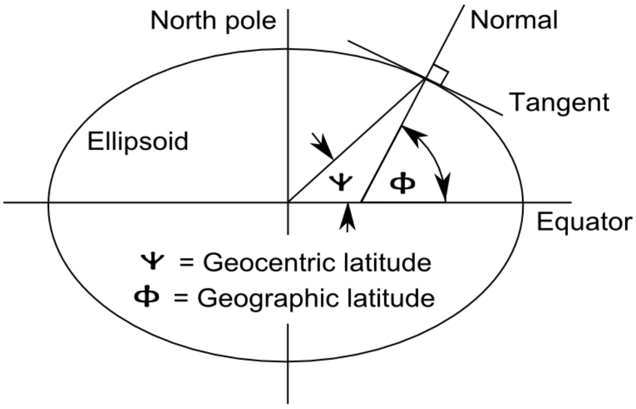



Illustration of geographic and geocentric latitudes.

### Astronomical latitude

A more obscure measure of latitude is the **astronomical latitude**, which is the angle between the equatorial plane and the normal to the geoid (ie a plumb line). It originated as the angle between horizon and pole star. It differs from the geodetic latitude only slightly, due to the slight deviations of the geoid from the reference ellipsoid.

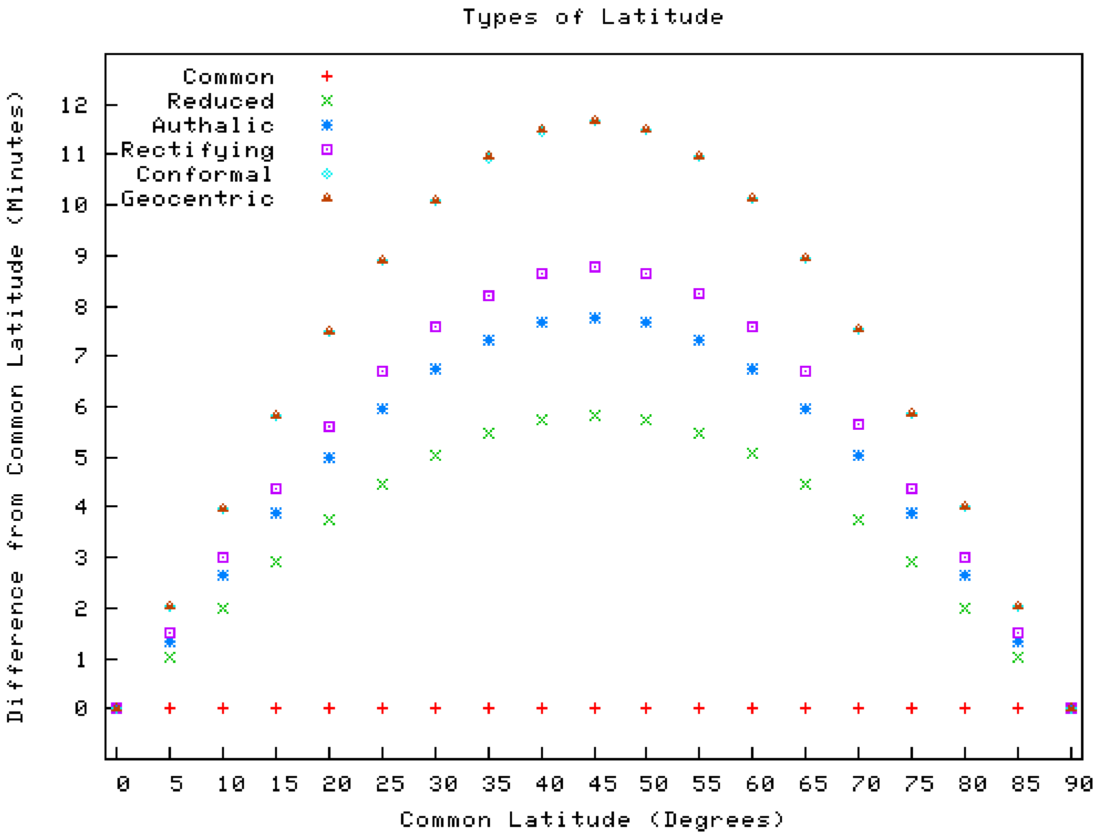
Astronomical latitude is not to be confused with declination, the coordinate astronomers use to describe the locations of stars north/south of the celestial equator (see equatorial coordinates), nor with ecliptic latitude, the coordinate that astronomers use to describe the locations of stars north/south of the ecliptic (see ecliptic coordinates).

### Palaeolatitude

Continents move over time, due to continental drift, taking whatever fossils and other features of interest they may have with them. Particularly when discussing fossils, it's often more useful to know where the fossil was when it was laid down, than where it is when it was dug up: this is called the *palæolatitude* of the fossil. The Palæolatitude can be constrained by palæomagnetic data. If tiny magnetisable grains are present when the rock is being formed, these will align themselves with Earth's magnetic field like compass needles. A magnetometer can deduce the orientation of these grains by subjecting a sample to a magnetic field, and the magnetic declination of the grains can be used to infer the latitude of deposition.

### Comparison of selected types

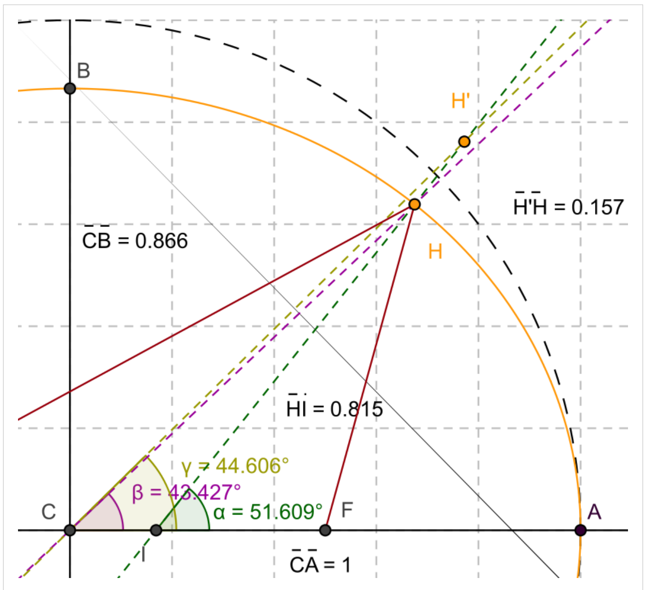
The following plot shows the differences between the types of latitude. The data used are found in the table following the plot. Please note that the values in the table are in minutes, not degrees, and the plot reflects this as well. Also observe that the conformal symbols are hidden behind the geocentric due to being very close in value. Finally it is important to mention also that these differences don't mean that the use of one specific latitude will necessarily cause more distortions than the other (the real fact is that each latitude type is optimized for achieving a different goal).




| Approximate difference from geographic latitude ("Lat") | | | | | |
|---|---|---|---|---|---|
| Lat $\phi$ | Reduced $\phi - \beta$ | Authalic $\phi - \xi$ | Rectifying $\phi - \mu$ | Conformal $\phi - \chi$ | Geocentric $\phi - \psi$ |
| 0° | 0.00′ | 0.00′ | 0.00′ | 0.00′ | 0.00′ |
| 5° | 1.01′ | 1.35′ | 1.52′ | 2.02′ | 2.02′ |
| 10° | 1.99′ | 2.66′ | 2.99′ | 3.98′ | 3.98′ |
| 15° | 2.91′ | 3.89′ | 4.37′ | 5.82′ | 5.82′ |
| 20° | 3.75′ | 5.00′ | 5.62′ | 7.48′ | 7.48′ |
| 25° | 4.47′ | 5.96′ | 6.70′ | 8.92′ | 8.92′ |
| 30° | 5.05′ | 6.73′ | 7.57′ | 10.09′ | 10.09′ |
| 35° | 5.48′ | 7.31′ | 8.22′ | 10.95′ | 10.96′ |
| 40° | 5.75′ | 7.66′ | 8.62′ | 11.48′ | 11.49′ |
| 45° | 5.84′ | 7.78′ | 8.76′ | 11.67′ | 11.67′ |
| 50° | 5.75′ | 7.67′ | 8.63′ | 11.50′ | 11.50′ |
| 55° | 5.49′ | 7.32′ | 8.23′ | 10.97′ | 10.98′ |
| 60° | 5.06′ | 6.75′ | 7.59′ | 10.12′ | 10.13′ |
| 65° | 4.48′ | 5.97′ | 6.72′ | 8.95′ | 8.96′ |
| 70° | 3.76′ | 5.01′ | 5.64′ | 7.52′ | 7.52′ |
| 75° | 2.92′ | 3.90′ | 4.39′ | 5.85′ | 5.85′ |
| 80° | 2.00′ | 2.67′ | 3.00′ | 4.00′ | 4.01′ |
| 85° | 1.02′ | 1.35′ | 1.52′ | 2.03′ | 2.03′ |
| 90° | 0.00′ | 0.00′ | 0.00′ | 0.00′ | 0.00′ |

## Corrections for altitude

When converting from geodetic ("common") latitude to other types of latitude, corrections must be made for altitude for systems which do not measure the angle from the normal of the spheroid. For example, in the figure at right, point $H$ (located on the surface of the spheroid) and point $H'$ (located at some greater elevation) have different *geocentric* latitudes (angles $\beta$ and $\gamma$ respectively), even though they share the same *geodetic* latitude (angle $\alpha$). Note that the flatness of the spheroid and elevation of point $H'$ in the image is significantly greater than what is found on the Earth, exaggerating the errors inherent in such calculations if left uncorrected. Note also that the reference ellipsoid used in the geodetic system is itself just an approximation of the true geoid, and therefore introduces its own errors, though the differences are less severe. (See Astronomical latitude, above.)



Line *IH* is normal to the spheroid representing the Earth (colored orange) at point *H*. The angle it forms with the equator (represented by line *CA*) corresponds to the point's geodetic latitude.

# See also

- American Practical Navigator
- Cardinal direction
- Geographic coordinate system
- Geodetic system
- Geodesy
- Geographical distance
- Geotagging
- Great-circle distance
- Horse latitudes
- List of cities by latitude
- List of cities by longitude
- Longitude
- Natural Area Code
- Navigation
- World Geodetic System
- Orders of magnitude (length)

## External links

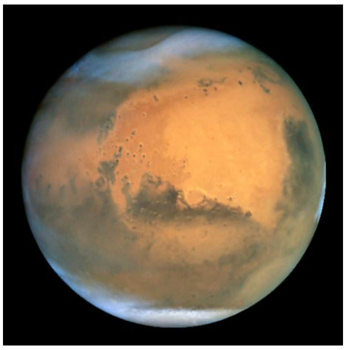
- libproj4: A Comprehensive Library of Cartographic Projection Functions (Preliminary Draft) [7]PDF (2.18 MB)
- Free GeoCoder [8]
- GEONets Names Server [9], access to the National Geospatial-Intelligence Agency's (NGA) database of foreign geographic feature names.
- Look-up Latitude and Longitude [10]
- Resources for determining your latitude and longitude [11]
- Convert decimal degrees into degrees, minutes, seconds [12] - Info about decimal to sexagesimal conversion
- Convert decimal degrees into degrees, minutes, seconds [13]
- Latitude and longitude converter [14] – Convert latitude and longitude from degree, decimal form to degree, minutes, seconds form and vice versa. Also included a farthest point and a distance calculator.
- Worldwide Index - Tageo.com [15] – contains 2,700,000 coordinates of places including US towns
  - for each city it gives the satellite map location, country, province, coordinates (dd,dms), variant names and nearby places.
- Distance calculation based on latitude and longitude [16] - JavaScript version
- Zoomable version of the map [17]PDF (3.47 MB)
- Average Latitude & Longitude of Countries [18]
- Get the latitude and longitude of any place in the World [19]
- Latitude / Longitude Converter [20] – convert latitude / longitude between DMS and decimal formats.
- Determination of Latitude by Francis Drake on the Coast of California in 1579 [21]
- Length Of A Degree Of Latitude and Longitude Calculator [22] - for any latitude, calculates 1 degree in meters, feet, and miles

## References

[1] Location, Location, Location. The relationship of climate to, and the effect of disease and agricultural productivity on, the economic success of a city or region. (http://earthobservatory.nasa.gov/Study/Location/)
[2] The Math Forum (http://mathforum.org/library/drmath/view/61089.html)
[3] John P. Snyder, *Map Projections: A Working Manual* (http://pubs.er.usgs.gov/usgspubs/pp/pp1395) (1987) 24-25
[4] NIMA TR8350.2 (http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html) page 3-1.
[5] IERS Conventions (2003) (http://www.iers.org/MainDisp.csl?pid=46-25776) (Chp. 1, page 12)
[6] Length of degree calculator - National Geospatial-Intelligence Agency (http://www.nga.mil/MSISiteContent/StaticFiles/Calculators/degree.html)
[7] http://members.verizon.net/~vze2hc4d/proj4/manual.pdf
[8] http://www.infosports.com/m/map.htm
[9] http://earth-info.nga.mil/gns/html/
[10] http://www.bcca.org/misc/qiblih/latlong.html
[11] http://jan.ucc.nau.edu/~cvm/latlon_find_location.html
[12] http://geography.about.com/library/howto/htdegrees.htm
[13] http://www.fcc.gov/mb/audio/bickel/DDDMMSS-decimal.html
[14] http://joehohk.0fees.net/Location.htm
[15] http://www.tageo.com/
[16] http://www.marinewaypoints.com/learn/greatcircle.shtml
[17] https://www.cia.gov/library/publications/the-world-factbook/reference_maps/pdf/political_world.pdf
[18] http://www.mobilgistix.com/Resources/GIS/Locations/average-latitude-longitude-countries.aspx
[19] http://www.mundivideo.com/coordinates.htm
[20] http://www.apsalin.com/geo-coordinate-conversion-dms-decimal.aspx
[21] http://www.longcamp.com/nav.html
[22] http://www.csgnetwork.com/degreelenllavcalc.html

# Mars

## Mars ♂



Mars as seen by the Hubble Space Telescope

| | |
|---|---|
| **Designations** | |
| **Pronunciation** | English pronunciation: /ˈmɑrz/ |
| **Adjective** | Martian |
| **Orbital characteristics[1]** | |
| Epoch J2000 | |
| **Aphelion** | 249,209,300 km<br>1.665 861 AU |
| **Perihelion** | 206,669,000 km<br>1.381 497 AU |
| **Semi-major axis** | 227,939,100 km<br>1.523 679 AU |
| **Eccentricity** | 0.093 315 |
| **Orbital period** | 686.971 day<br>1.8808 Julian years<br>668.5991 sols |
| **Synodic period** | 779.96 day<br>2.135 Julian years |
| **Average orbital speed** | 24.077 km/s |
| **Inclination** | 1.850° to ecliptic<br>5.65° to Sun's equator<br>1.67° to invariable plane[2] |
| **Longitude of ascending node** | 49.562° |
| **Argument of perihelion** | 286.537° |
| **Satellites** | 2 |
| **Physical characteristics** | |
| **Equatorial radius** | 3,396.2 ± 0.1 km[a][3]<br>0.533 Earths |

| | |
|---|---|
| **Polar radius** | 3,376.2 ± 0.1 km[a][3]<br>0.531 Earths |
| **Flattening** | 0.005 89 ± 0.000 15 |
| **Surface area** | 144,798,500 km²<br>0.284 Earths |
| **Volume** | $1.6318 \times 10^{11}$ km³<br>0.151 Earths |
| **Mass** | $6.4185 \times 10^{23}$ kg<br>0.107 Earths |
| **Mean density** | 3.934 g/cm³ |
| **Equatorial surface gravity** | 3.69 m/s²<br>0.376 *g* |
| **Escape velocity** | 5.027 km/s |
| **Sidereal rotation period** | 1.025 957 day<br>24.622 96 h[4] |
| **Equatorial rotation velocity** | 868.22 km/h (241.17 m/s) |
| **Axial tilt** | 25.19° |
| **North pole right ascension** | 21 h 10 min 44 s<br>317.681 43° |
| **North pole declination** | 52.886 50° |
| **Albedo** | 0.15 (geometric) or 0.25 (bond)[5] |
| **Surface temp.**<br>**Kelvin**<br>**Celsius** | **min** / **mean** / **max**<br>186 K / 227 K / 268 K[4]<br>−87 °C / −46 °C / −5 °C |
| **Apparent magnitude** | +1.8 to −2.91[5] |
| **Angular diameter** | 3.5—25.1″[5] |
| Atmosphere | |
| **Surface pressure** | 0.6–1.0 kPa |
| **Composition** | 95.72% Carbon dioxide<br>2.7% Nitrogen<br>1.6% Argon<br>0.2% Oxygen<br>0.07% Carbon monoxide<br>0.03% Water vapor<br>0.01% Nitric oxide<br>2.5 ppm Neon<br>300 ppb Krypton<br>130 ppb Formaldehyde<br>80 ppb Xenon<br>30 ppb Ozone<br>10 ppb Methane |

**Mars** is the fourth planet from the Sun in the Solar System. The planet is named after Mars, the Roman god of war. It is also referred to as the "Red Planet" because of its reddish appearance, due to iron oxide prevalent on its surface.

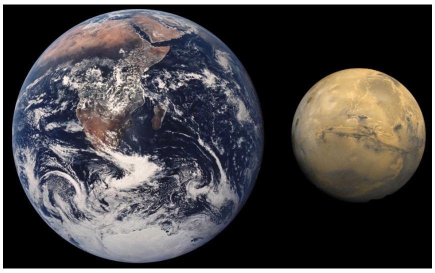
Mars is a terrestrial planet with a thin atmosphere, having surface features reminiscent both of the impact craters of the Moon and the volcanoes, valleys, deserts and polar ice caps of Earth. It is the site of Olympus Mons, the highest known mountain in the Solar System, and of Valles Marineris, the largest canyon. Furthermore, in June 2008 three articles published in *Nature* presented evidence of an enormous impact crater in Mars's northern hemisphere, 10,600 km long by 8,500 km wide, or roughly four times larger than the largest impact crater yet discovered, the Moon's South Pole-Aitken basin.[1] [2] In addition to its geographical features, Mars' rotational period and seasonal cycles are likewise similar to those of Earth.

Until the first flyby of Mars by Mariner 4 in 1965, many speculated that there might be liquid water on the planet's surface. This was based on observations of periodic variations in light and dark patches, particularly in the polar latitudes, which looked like seas and continents, while long, dark striations were interpreted by some observers as irrigation channels for liquid water. These straight line features were later proven not to exist and were instead explained as optical illusions. Still, of all the planets in the Solar System other than Earth, Mars is the most likely to harbor liquid water, and perhaps life.[3] Radar data from *Mars Express* and the *Mars Reconnaissance Orbiter* have revealed the presence of large quantities of water ice both at the poles (July 2005)[4] and at mid-latitudes (November 2008).[5] The Phoenix Mars Lander directly sampled water ice in shallow martian soil on July 31, 2008.[6]

Mars is currently host to three functional orbiting spacecraft: *Mars Odyssey*, *Mars Express*, and the *Mars Reconnaissance Orbiter*. With the exception of Earth, this is more than any planet in the Solar System. The surface is also home to the two Mars Exploration Rovers (*Spirit* and *Opportunity*) and several inert landers and rovers, both successful and unsuccessful. The *Phoenix* lander recently completed its mission on the surface. Geological evidence gathered by these and preceding missions suggests that Mars previously had large-scale water coverage, while observations also indicate that small geyser-like water flows have occurred during the past decade.[7] Observations by NASA's *Mars Global Surveyor* show evidence that parts of the southern polar ice cap have been receding.[8]

Mars has two moons, Phobos and Deimos, which are small and irregularly shaped. These may be captured asteroids, similar to 5261 Eureka, a Martian Trojan asteroid. Mars can be seen from Earth with the naked eye. Its apparent magnitude reaches −2.9,[5] a brightness surpassed only by Venus, the Moon, and the Sun, although most of the time Jupiter will appear brighter to the naked eye than Mars. Mars has an average opposition distance of 78 million km but can come as close as 55.7 million km during a close approach, such as occurred in 2003.[5]

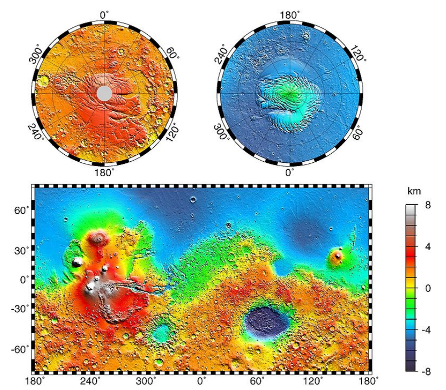
## Physical characteristics



Size comparison of Earth and Mars.

Mars has approximately half the radius of Earth. It is less dense than Earth, having about 15% of Earth's volume and 11% of the mass. Its surface area is only slightly less than the total area of Earth's dry land.[5] While Mars is larger and more massive than Mercury, Mercury has a higher density. This results in a slightly stronger gravitational force at Mercury's surface. Mars is also roughly intermediate in size, mass, and surface gravity between Earth and Earth's Moon (the Moon is about half the diameter of Mars, whereas Earth is twice; the Earth is about ten times more massive than Mars, and the Moon ten times *less* massive). The red-orange appearance of the Martian surface is caused by iron(III) oxide, more commonly known as hematite, or rust.[9]

## Geology



Volcanic plateaus (red) and impact basins (blue) dominate this topographic map of Mars.

Based on orbital observations and the examination of the Martian meteorite collection, the surface of Mars appears to be composed primarily of basalt. Some evidence suggests that a portion of the Martian surface is more silica-rich than typical basalt, and may be similar to andesitic rocks on Earth; however, these observations may also be explained by silica glass. Much of the surface is deeply covered by finely grained iron(III) oxide dust.[10] [11]

Although Mars has no evidence of structured global magnetic field,[12] observations show that parts of the planet's crust have been magnetized and that alternating polarity reversals of its dipole field have occurred. This paleomagnetism of magnetically susceptible minerals has properties that are very similar to the alternating bands found on the ocean floors of Earth. One theory, published in 1999 and re-examined in October 2005 (with the help of the Mars Global Surveyor), is that these bands demonstrate plate tectonics on Mars 4 billion years ago, before the planetary dynamo ceased to function and caused the planet's magnetic field to fade away.[13]


Rock strewn surface imaged by Mars Pathfinder

Current models of the planet's interior imply a core region about 1,480 kilometres in radius, consisting primarily of iron with about 14–17% sulfur. This iron sulfide core is partially fluid, and has twice the concentration of the lighter elements than exist at Earth's core. The core is surrounded by a silicate mantle that formed many of the tectonic and volcanic features on the planet, but now appears to be inactive. The average thickness of the planet's crust is about 50 km, with a maximum thickness of 125 km.[14] Earth's crust, averaging 40 km, is only a third as thick as Mars' crust relative to the sizes of the two planets.

The geological history of Mars can be split into many epochs, but the following are the three main ones:

- **Noachian epoch** (named after Noachis Terra): Formation of the oldest extant surfaces of Mars, 3.8 billion years ago to 3.5 billion years ago. Noachian age surfaces are scarred by many large impact craters. The Tharsis bulge volcanic upland is thought to have formed during this period, with extensive flooding by liquid water late in the epoch.
- **Hesperian epoch** (named after Hesperia Planum): 3.5 billion years ago to 1.8 billion years ago. The Hesperian epoch is marked by the formation of extensive lava plains.
- **Amazonian epoch** (named after Amazonis Planitia): 1.8 billion years ago to present. Amazonian regions have few meteorite impact craters but are otherwise quite varied. Olympus Mons formed during this period along with lava flows elsewhere on Mars.

A major geological event occurred on Mars on February 19, 2008, and was caught on camera by the *Mars Reconnaissance Orbiter*. Images capturing a spectacular avalanche of materials thought to be fine grained ice, dust, and large blocks are shown to have detached from a 700-metre high cliff. Evidence of the avalanche is present in the dust clouds left above the cliff afterwards.[15]

Recent studies support a theory, first proposed in the 1980s, that Mars was struck by a Pluto-sized body about four billion years ago. The event, thought to be the cause of the Martian hemispheric dichotomy, created the smooth Borealis basin that covers 40% of the planet.[16] [17]

## Soil

In June, 2008, the Phoenix Lander returned data showing Martian soil to be slightly alkaline and containing vital nutrients such as magnesium, sodium, potassium and chloride, all of which are necessary for living organisms to grow. Scientists compared the soil near Mars's north pole to that of backyard gardens on Earth, and concluded that it could be suitable for growth of plants such as asparagus.[18] However, in August, 2008, the Phoenix Lander conducted simple chemistry experiments, mixing water from Earth with Martian soil in an attempt to test its pH, and discovered traces of the salt perchlorate, while also confirming many scientists' theories that the Martian surface is considerably basic, measuring at 8.3. The presence of the perchlorate, if confirmed, would make Martian soil more exotic than previously believed.[19] Further testing is necessary to eliminate the possibility of the perchlorate readings being caused by terrestrial sources, which may have migrated from the spacecraft either into samples or the instrumentation.[20]

## Hydrology

Liquid water cannot exist on the surface of Mars with its present low atmospheric pressure, except at the lowest elevations for short periods[21] [22] but water ice is in no short supply, with two polar ice caps made largely of ice.[23] In March 2007, NASA announced that the volume of water ice in the south polar ice cap, if melted, would be sufficient to cover the entire planetary surface to a depth of 11 metres.[24] Additionally, an ice permafrost mantle stretches down from the pole to latitudes of about 60°.[23]

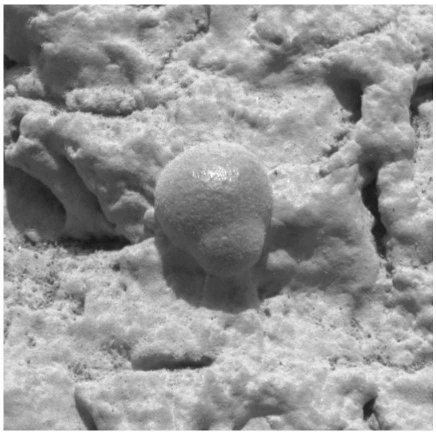


Photo of microscopic rock forms indicating past signs of water, taken by *Opportunity*

Large quantities of water are thought to be trapped underneath Mars's thick cryosphere. Radar data from *Mars Express* and the *Mars Reconnaissance Orbiter* have revealed the presence of large quantities of water ice both at the poles (July 2005)[4] and at mid-latitudes (November 2008).[5] The Phoenix Mars Lander directly sampled water ice in shallow martian soil on July 31, 2008.[6] A large release of liquid water is thought to have occurred when the Valles Marineris formed early in Mars's history, forming massive outflow channels. A smaller but more recent outflow may have occurred when the Cerberus Fossae chasm opened about 5 million years ago, leaving a supposed sea of frozen ice still visible today on the Elysium Planitia centered at Cerberus Palus.[25] However, the morphology of this region may correspond to the ponding of lava flows, causing a superficial morphology similar to ice flows,[26] which probably draped the terrain established by earlier massive floods of Athabasca Valles.[27] Rough surface texture at decimetre (dm) scales, thermal inertia comparable to that of the Gusev plains, and hydrovolcanic cones are consistent with the lava flow hypothesis.[27] Furthermore, the stoichiometric mass fraction of water in this area to tens of centimetre depths is only ~4%,[28] easily attributable to hydrated minerals[29] and inconsistent with the presence of near-surface ice.

More recently the high resolution Mars Orbiter Camera on the Mars Global Surveyor has taken pictures which give much more detail about the history of liquid water on the surface of Mars. Despite the many giant flood channels and associated tree-like network of tributaries found on Mars there are no smaller scale structures that would indicate the origin of the flood waters. It has been suggested that weathering processes have denuded these, indicating the river valleys are old features. Higher resolution observations from spacecraft like Mars Global Surveyor also revealed at least a few hundred features along crater and canyon walls that appear similar to terrestrial seepage gullies. The gullies tend to be in the highlands of the southern hemisphere and to face the Equator; all are poleward of 30° latitude.[30] The researchers found no partially degraded (*i.e.* weathered) gullies and no superimposed impact craters, indicating that these are very young features.

In a particularly striking example (see image) two photographs, taken six years apart, show a gully on Mars with what appears to be new deposits of sediment. Michael Meyer, the lead scientist for NASA's Mars Exploration Program, argues that only the flow of material with a high liquid water content could produce such a debris pattern and colouring. Whether the water results from precipitation, underground or another source remains an open question.[31] However, alternative scenarios have been suggested, including the possibility of the deposits being caused by carbon dioxide frost or by the movement of dust on the Martian surface.[32] [33]

Further evidence that liquid water once existed on the surface of Mars comes from the detection of specific minerals such as hematite and goethite, both of which sometimes form in the presence of water.[34]

Nevertheless, some of the evidence believed to indicate ancient water basins and flows has been negated by higher resolution studies taken at resolution about 30 cm by the Mars Reconnaissance Orbiter.[35]

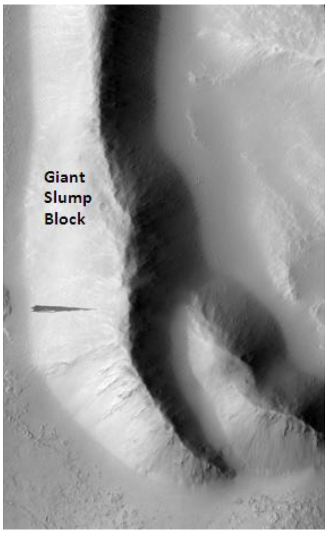
## Geysers on Mars

The seasonal frosting and defrosting of the southern ice cap results in the formation of spider-like radial channels carved on 1 meter thick ice by sunlight. Then, sublimed $CO_2$ -and probably water- increase pressure in their interior producing geyser-like eruptions of cold fluids often mixed with dark basaltic sand or mud.[36] [37] [38] [39] This process is rapid, observed happening in the space of a few days, weeks or months, a growth rate rather unusual in geology — especially for Mars.

Artist concept showing sand-laden jets erupt from geysers on Mars. (Published by NASA; artist: Ron Miller.)

## Dark Slope Streaks

The inset photo of Tharsis Tholus shows an example of a dark streak. Such streaks are common across Mars and new ones appear frequently on steep slopes of craters, troughs, and valleys. The streaks are dark at first and get lighter with age. Sometimes the streaks start in a tiny area which then spreads out for hundreds of metres. They have also been seen to travel around boulders and other obstacles in their path. The mainstream theory is that they are dark underlying layers of soil revealed after avalanches of bright dust, however several ideas have been put forward to explain them, some of which involve water or even the growth of organisms.[40]




Tharsis Tholus streak, as seen by Hirise. It is located in the middle left of this picture. Tharsis Tholus is just off to the right.

## Geography

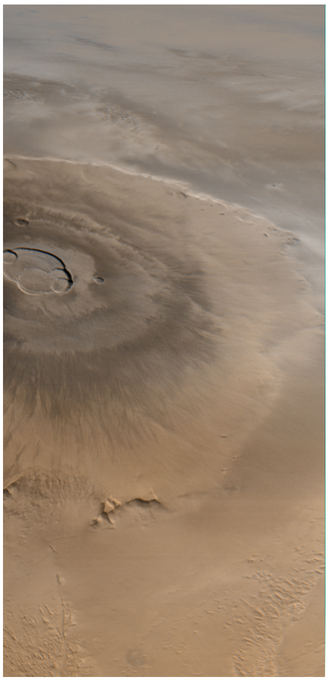
This approximate true-color image, taken by the Mars Exploration Rover Opportunity, shows the view of Victoria Crater from Cape Verde. It was captured over a three-week period, from October 16 – November 6, 2006.

Although better remembered for mapping the Moon, Johann Heinrich Mädler and Wilhelm Beer were the first "areographers". They began by establishing once and for all that most of Mars’ surface features were permanent, and determining the planet's rotation period. In 1840, Mädler combined ten years of observations and drew the first map of Mars. Rather than giving names to the various markings, Beer and Mädler simply designated them with letters; Meridian Bay (Sinus Meridiani) was thus feature "*a.*"[41]

Today, features on Mars are named from a number of sources. Large albedo features retain many of the older names, but are often updated to reflect new knowledge of the nature of the features. For example, *Nix Olympica* (the snows of Olympus) has become *Olympus Mons* (Mount Olympus).[42]

Mars’ equator is defined by its rotation, but the location of its Prime Meridian was specified, as was Earth's (at Greenwich), by choice of an arbitrary point; Mädler and Beer selected a line in 1830 for their first maps of Mars. After the spacecraft Mariner 9 provided extensive imagery of Mars in 1972, a small crater (later called Airy-0), located in the Sinus Meridiani ("Middle Bay" or "Meridian Bay"), was chosen for the definition of 0.0° longitude to coincide with the original selection.

Since Mars has no oceans and hence no 'sea level', a zero-elevation surface or mean gravity surface also had to be selected. Zero altitude is defined by the height at which there is 610.5 Pa (6.105 mbar) of atmospheric pressure. This pressure corresponds to the triple point of water, and is about 0.6% of the sea level surface pressure on Earth (.006 atm).[43]



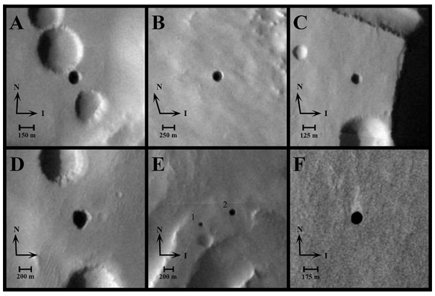
Olympus Mons, the highest mountain in the solar system, at 27 km.

The dichotomy of Martian topography is striking: northern plains flattened by lava flows contrast with the southern highlands, pitted and cratered by ancient impacts. Research in 2008 has presented evidence regarding a theory proposed in 1980 postulating that, four billion years ago, the northern hemisphere of Mars was struck by an object one-tenth to two-thirds the size of the Moon. If validated, this would make Mars's northern hemisphere the site of an impact crater 10,600 km long by 8,500 km wide, or roughly the area of Europe, Asia, and Australia combined, surpassing the South Pole-Aitken basin as the largest impact crater in the Solar System.[1] [2] The surface of Mars as seen from Earth is divided into two kinds of areas, with differing albedo. The paler plains covered with dust and sand rich in reddish iron oxides were once thought of as Martian 'continents' and given names like Arabia Terra (*land of Arabia*) or Amazonis Planitia (*Amazonian plain*). The dark features were thought to be seas, hence their names Mare Erythraeum, Mare Sirenum and Aurorae Sinus. The largest dark feature seen from Earth is Syrtis Major.[44]

The shield volcano, Olympus Mons (*Mount Olympus*), at 26 km is the highest known mountain in the Solar System.[45] It is an extinct volcano in the vast upland region Tharsis, which contains several other large volcanoes. Olympus Mons is over three times the height of Mount Everest, which in comparison stands at just over 8.8 km.

Mars is also scarred by a number of impact craters: a total of 43,000 craters with a diameter of 5 km or greater have been found.[46] The largest confirmed of these is the Hellas impact basin, a light albedo feature clearly visible from Earth.[47] Due to the smaller mass of Mars, the probability of an object colliding with the planet is about half that of the Earth. However, Mars is located closer to the asteroid belt, so it has an increased chance of being struck by materials from that source. Mars is also more likely to be struck by short-period comets, *i.e.*, those that lie within the orbit of Jupiter.[48] In spite of this, there are far fewer craters on Mars compared with the Moon because Mars's atmosphere provides protection against small meteors. Some craters have a morphology that suggests the ground was wet when the meteor impacted.

The large canyon, Valles Marineris (Latin for *Mariner Valleys*, also known as Agathadaemon in the old canal maps), has a length of 4,000 km and a depth of up to 7 km. The length of Valles Marineris is equivalent to the length of Europe and extends across one-fifth the circumference of Mars. By comparison, the Grand Canyon on Earth is only 446 km long and nearly 2 km deep. Valles Marineris was formed due to the swelling of the Tharsis area which caused the crust in the area of Valles Marineris to collapse. Another large canyon is Ma'adim Vallis (*Ma'adim* is Hebrew for Mars). It is 700 km long and again much bigger than the Grand Canyon with a width of 20 km and a depth of 2 km in some places. It is possible that Ma'adim Vallis was flooded with liquid water in the past.[49]



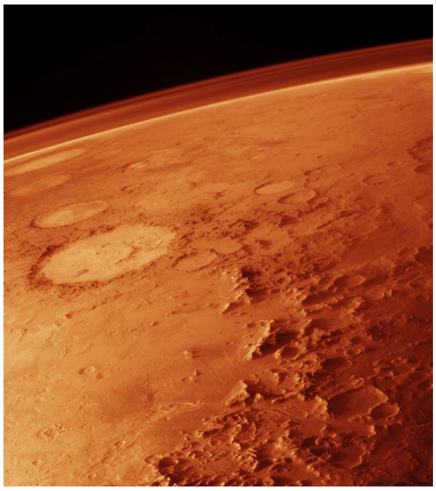
THEMIS image of cave entrances on Mars. The pits have been informally named (A) Dena, (B) Chloe, (C) Wendy, (D) Annie, (E) Abby (left) and Nikki, and (F) Jeanne.

Images from the Thermal Emission Imaging System (THEMIS) aboard NASA's Mars Odyssey orbiter have revealed seven possible cave entrances on the flanks of the Arsia Mons volcano.[50] The caves, named after loved ones of their discoverers, are collectively known as the "seven sisters."[51] Cave entrances measure from 100 m to 252 m wide and they are believed to be at least 73 m to 96 m deep. Because light does not reach the floor of most of the caves, it is likely that they extend much deeper than these lower estimates and widen below the surface. "Dena" is the only exception; its floor is visible and was measured to be 130 m deep. The interiors of these caverns may be protected from micrometeoroids, UV radiation, solar flares and high energy particles that bombard the planet's surface.[52]

Mars has two permanent polar ice caps: the northern one at Planum Boreum and the southern one at Planum Australe.

During a pole's winter, it lies in continuous darkness, chilling the surface and causing 25–30% of the atmosphere to condense out into thick slabs of $CO_2$ ice (dry ice).[53] When the poles are again exposed to sunlight, the frozen $CO_2$ sublimes, creating enormous winds that sweep off the poles as fast as 400 km/h. These seasonal actions transport large amounts of dust and water vapor, giving rise to Earth-like frost and large cirrus clouds. Clouds of water-ice were photographed by the *Opportunity* rover in 2004.[54]

## Atmosphere

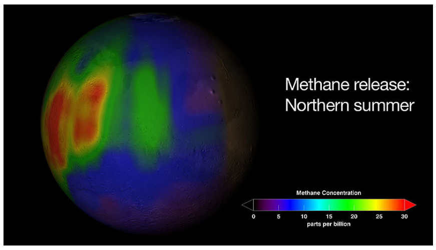

Mars's thin atmosphere, visible on the horizon in this low-orbit photo.

Mars lost its magnetosphere 4 billion years ago, so the solar wind interacts directly with the Martian ionosphere, keeping the atmosphere thinner than it would otherwise be by stripping away atoms from the outer layer. Both Mars Global Surveyor and Mars Express have detected these ionised atmospheric particles trailing off into space behind Mars.[55] [56] The atmosphere of Mars is now relatively thin. Atmospheric pressure on the surface varies from around 30 Pa (0.03 kPa) on Olympus Mons to over 1,155 Pa (1.155 kPa) in the depths of Hellas Planitia, with a mean surface level pressure of 600 Pa (0.6 kPa). Mars's mean surface pressure equals the pressure found 35 km above the Earth's surface. This is less than 1% of the surface pressure on Earth (101.3 kPa). The scale height of the atmosphere, about 11 km, is higher than Earth's (6 km) due to the lower gravity. Mars' gravity is only about 38% of the surface gravity on Earth.

The atmosphere on Mars consists of 95% carbon dioxide, 3% nitrogen, 1.6% argon, and contains traces of oxygen and water.[5] The atmosphere is quite dusty, containing particulates about 1.5 µm in diameter which give the Martian sky a tawny color when seen from the surface.[57]

### Methane

*See also:* Atmosphere of Mars - Methane

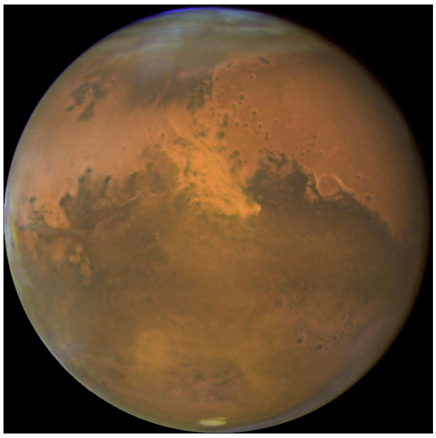



Traces of methane plumes in Mars' atmosphere during northern summer – NASA

Methane has been detected in the Martian atmosphere with a concentration of about 30 ppb by volume;[58] [59] it occurs in extended plumes, and the profiles imply that the methane was released from discrete regions. In northern midsummer, the principal plume contained 19,000 metric tons of methane, with an estimated source strength of 0.6 kilogram per second.[60] [61] The profiles suggest that there may be two local source regions, the first centered near 30° N, 260° W and the second near 0°, 310° W.[60] It is estimated that Mars must produce 270 ton/year of methane.[62] [63] [60]

The latest research suggests that the implied methane destruction lifetime is as long as about 4 Earth years and as short as about 0.6 Earth years.[60] [64] This apparently rapid turnover would indicates a current active source of the gas on the planet. Volcanic activity, cometary impacts, and the presence of methanogenic microbial life forms are among possible sources. It was recently pointed out that methane could also be produced by a non-biological process called *serpentinization*[b] involving water, carbon dioxide, and the mineral olivine, which is known to be common on Mars.[65]

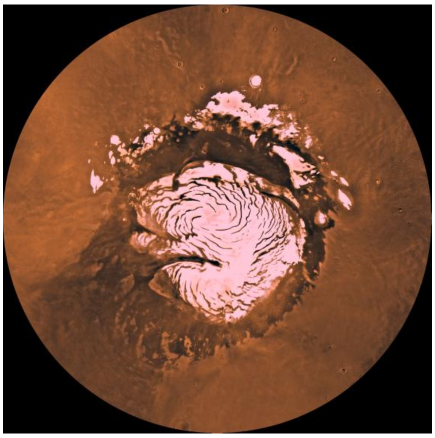
## Climate



Mars from Hubble Space Telescope October 28, 2005 with dust storm visible.

Of all the planets, Mars's seasons are the most Earth-like, due to the similar tilts of the two planets' rotational axes. However, the lengths of the Martian seasons are about twice those of Earth's, as Mars' greater distance from the Sun leads to the Martian year being about two Earth years in length. Martian surface temperatures vary from lows of about −140 °C (−220 °F) during the polar winters to highs of up to 20 °C (68 °F) in summers.[21] The wide range in temperatures is due to the thin atmosphere which cannot store much solar heat, the low atmospheric pressure, and the low thermal inertia of Martian soil.[66] The planet is also 1.52 times as far from the sun as Earth, resulting in just 43 percent of the amount of sunlight.[67]

If Mars had an Earth-like orbit, its seasons would be similar to Earth's because its axial tilt is similar to Earth's. However, the comparatively large eccentricity of the Martian orbit has a significant effect. Mars is near perihelion when it is summer in the southern hemisphere and winter in the north, and near aphelion when it is winter in the southern hemisphere and summer in the north. As a result, the seasons in the southern hemisphere are more extreme and the seasons in the northern are milder than would otherwise be the case. The summer temperatures in the south can reach up to 30 °C (54 °F) warmer than the equivalent summer temperatures in the north.[68]


Mars's northern ice cap

Mars also has the largest dust storms in our Solar System. These can vary from a storm over a small area, to gigantic storms that cover the entire planet. They tend to occur when Mars is closest to the Sun, and have been shown to increase the global temperature.[69]

The polar caps at both poles consist primarily of water ice. However, there is dry ice present on their surfaces. Frozen carbon dioxide (dry ice) accumulates as a thin layer about one metre thick on the north cap in the northern winter only, while the south cap has a permanent dry ice cover about eight metres thick.[70] The northern polar cap has a diameter of about 1,000 kilometres during the northern Mars summer,[71] and contains about 1.6 million cubic kilometres of ice, which if spread evenly on the cap would be 2 kilometres thick.[72] (This compares to a volume of 2.85 million cubic kilometres for the Greenland ice sheet.) The southern polar cap has a diameter of 350 km and a thickness of 3 km.[73] The total volume of ice in the south polar cap plus the adjacent layered deposits has also been estimated at 1.6 million cubic kilometres.[74] Both polar caps show spiral troughs, which are believed to form as a result of differential solar heating, coupled with the sublimation of ice and condensation of water vapor.[75] [76] Both polar caps shrink and regrow following the temperature fluctuation of the Martian seasons.

## Evolution

Recent observational data and modeling techniques are providing further insight into the history and evolution of Mars. For example, the remnants of a magnetic field suggest that something with a mass greater than that of Mars once kept the planet's interior molten. The presence of bodies of water on Mars [77] would have required an atmosphere thicker than that of today.[78] The Northern Basin records a massive and disruptive impact.[79] Possible explanations include:

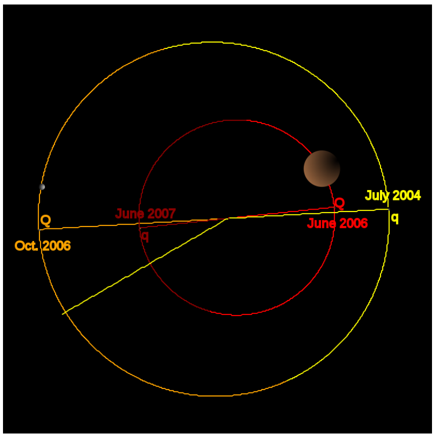
- A satellite could have caused enough tidal heating to melt the interior enough to generate a substantial magnetic field. The field would have protected the Martian atmosphere from Solar winds, allowing liquid water to remain on the surface.
- An impact by large asteroid or comet could have removed the crust of one hemisphere and striped Mars of its atmosphere. The entire crust could have shifted to a more stable configuration with the impact basin centered at the north pole and Mars' massive volcanoes near the equator. Without tidal heating from the satellite, the magnetic field could have faded, and Solar wind striking the surface might have prevented the atmosphere from reforming.
- The lack of a stabilizing satellite would have allowed significant wobble on the order of five million years. These irregularities in the motion of Mars would have periodically warmed the polar regions enough for at least some liquid water to form, leaving striations in the polar ice cap.

## Orbit and rotation

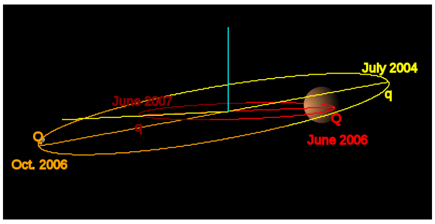
Mars' average distance from the Sun is roughly 230 million km (1.5 AU) and its orbital period is 687 (Earth) days. The solar day (or sol) on Mars is only slightly longer than an Earth day: 24 hours, 39 minutes, and 35.244 seconds. A Martian year is equal to 1.8809 Earth years, or 1 year, 320 days, and 18.2 hours.

Mars's axial tilt is 25.19 degrees, which is similar to the axial tilt of the Earth. As a result, Mars has seasons like the Earth, though on Mars they are nearly twice as long given its longer year. Mars passed its perihelion in April 2009 and its aphelion in May 2008. It next reaches perihelion in May 2011 and aphelion in March 2010.

Mars has a relatively pronounced orbital eccentricity of about 0.09; of the seven other planets in the Solar System, only Mercury shows greater eccentricity. However, it is known that in the past Mars has had a much more circular orbit than it does currently. At one point 1.35 million Earth years ago, Mars had an eccentricity of roughly 0.002, much less than that of Earth today.[80] The Mars cycle of eccentricity is 96,000 Earth years compared to the Earth's cycle of 100,000 years.[81] However, Mars also has a much longer cycle of eccentricity with a period of 2.2 million Earth years, and this overshadows the 96,000-year cycle in the eccentricity graphs. For the last 35,000 years Mars' orbit has been getting slightly more eccentric because of the gravitational effects of the other planets. The closest distance between the Earth and Mars will continue to mildly decrease for the next 25,000 years.[82]



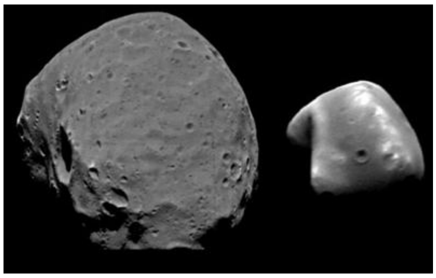
Orbit of Mars (red) and Ceres (yellow)



Orbit of Mars (red) and Ceres (yellow)

The image to the left shows a comparison between Mars and Ceres, a dwarf planet in the Asteroid Belt, as seen from the north ecliptic pole, while the image to the right is as seen from the ascending node. The segments of orbits south of the ecliptic are plotted in darker colors. The perihelia (q) and aphelia (Q) are labelled with the date of the nearest passage.

## Moons



Phobos (left) and Deimos (right)

Mars has two tiny natural moons, Phobos and Deimos, which orbit very close to the planet. Their known composition suggests the moons are captured asteroids but their origin remains uncertain.[83]

Both satellites were discovered in 1877 by Asaph Hall, and are named after the characters Phobos (panic/fear) and Deimos (terror/dread) who, in Greek mythology, accompanied their father Ares, god of war, into battle. Ares was known as Mars to the Romans.[84]

From the surface of Mars, the motions of Phobos and Deimos appear very different from that of our own moon. Phobos rises in the west, sets in the east, and rises again in just 11 hours. Deimos, being only just outside synchronous orbit—where the orbital period would match the planet's period of rotation—rises as expected in the east but very slowly. Despite the 30 hour orbit of Deimos, it takes 2.7 days to set in the west as it slowly falls behind the rotation of Mars, then just as long again to rise.[85]

Because Phobos' orbit is below synchronous altitude, the tidal forces from the planet Mars are gradually lowering its orbit. In about 50 million years it will either crash into Mars’ surface or break up into a ring structure around the planet.[85]

The origin of the two moons is not well understood. Their low albedo and carbonaceous chondrite composition are similar to asteroids and capture remains the favored theory. Phobos' unstable orbit would seem to point towards a relatively recent capture. But both have circular orbits, very near the equator, which is very unusual for captured objects and the required capture dynamics are complex. Accretion early in Mars' history is also plausible but does not account for the moons' composition resembling asteroids rather than Mars itself. A third possibility is the involvement of a third body or some kind of impact disruption.[86]

## Life

The current understanding of planetary habitability—the ability of a world to develop and sustain life—favors planets that have liquid water on their surface. This most often requires that the orbit of a planet lie within the habitable zone, which for the Sun currently extends from just beyond Venus to about the semi-major axis of Mars.[87] During perihelion Mars dips inside this region, but the planet's thin (low-pressure) atmosphere prevents liquid water from existing over large regions for extended periods. The past flow of liquid water, however, demonstrates the planet's potential for habitability. Recent evidence has suggested that any water on the Martian surface would have been too salty and acidic to support terran life.[88]

The lack of a magnetosphere and extremely thin atmosphere of Mars are a greater challenge: the planet has little heat transfer across its surface, poor insulation against bombardment and the solar wind, and insufficient atmospheric pressure to retain water in a liquid form (water instead sublimates to a gaseous state). Mars is also nearly, or perhaps totally, geologically dead; the end of volcanic activity has stopped the recycling of chemicals and minerals between the surface and interior of the planet.[89]

Evidence suggests that the planet was once significantly more habitable than it is today, but whether living organisms ever existed there is still unclear. The Viking probes of the mid-1970s carried experiments designed to detect microorganisms in Martian soil at their respective landing sites, and had some apparently positive results, including a temporary increase of $CO_2$ production on exposure to water and nutrients. However this sign of life was later disputed by many scientists, resulting in a continuing debate, with NASA scientist Gilbert Levin asserting that Viking may have found life. A re-analysis of the now 30-year-old Viking data, in light of modern knowledge of extremophile forms of life, has suggested that the Viking tests were also not sophisticated enough to detect these forms of life. The tests may even have killed a (hypothetical) life form.[90] Tests conducted by the Phoenix Mars

Lander have shown that the soil has a very alkaline pH and it contains magnesium, sodium, potassium and chloride.[91] The soil nutrients may be able to support life, but life would still have to be shielded from the intense ultraviolet light.

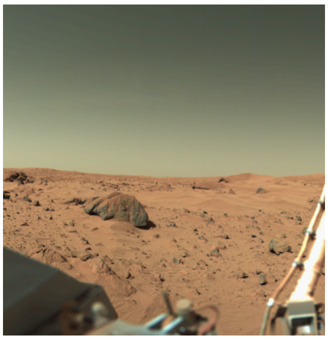
At the Johnson space center lab, some curious shapes have been found in the Martian meteorite ALH84001. Some scientists propose that these geometric shapes could be fossilized microbes extant on Mars before the meteorite was blasted into space by a meteor strike and sent on a 15 million-year voyage to Earth. Also, small quantities of methane and formaldehyde recently detected by Mars orbiters are both claimed to be hints for life, as these chemical compounds would quickly break down in the Martian atmosphere.[92] [93] It is possible that these compounds may be replenished by volcanic or geological means such as serpentinization.[65]

## Exploration

Dozens of spacecraft, including orbiters, landers, and rovers, have been sent to Mars by the Soviet Union, the United States, Europe, and Japan to study the planet's surface, climate, and geology. The current price of transporting material from the surface of Earth to the surface of Mars is approximately 309000 USD/kg.[94]

Mars 3 Lander (stamp, 1972)

Roughly two-thirds of all spacecraft destined for Mars have failed in one manner or another before completing or even beginning their missions. While this high failure rate can be ascribed to technical problems, enough have either failed or lost communications for causes unknown for some to search for other explanations. Examples include an Earth-Mars "Bermuda Triangle", a Mars Curse, or even the long-standing NASA in-joke, the "Great Galactic Ghoul" that feeds on Martian spacecraft.[95]


Viking Lander 1 site

### Past missions

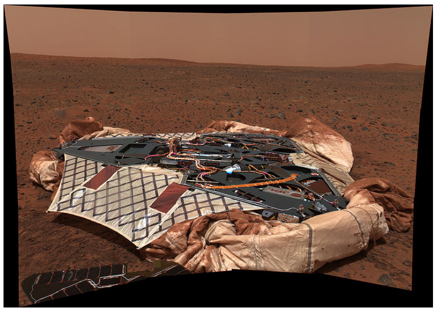
The first successful fly-by mission to Mars was NASA's Mariner 4, launched in 1964. On November 14, 1971 Mariner 9 became the first space probe to orbit another planet when it entered into orbit around Mars.[96] The first successful objects to land on the surface were two Soviet probes, Mars 2 and Mars 3 from the Mars probe program, launched in 1971, but both lost contact within seconds of landing. Then came the 1975 NASA launches of the Viking program, which consisted of two orbiters, each having a lander; both landers successfully touched down in 1976. Viking 1 remained operational for six years, Viking 2 for three. The Viking landers relayed color panoramas of Mars[97] and the orbiters mapped the surface so well that the images remain in use.

The Soviet probes Phobos 1 and 2 were sent to Mars in 1988 to study Mars and its two moons. Phobos 1 lost contact on the way to Mars. Phobos 2, while successfully photographing Mars and Phobos, failed just before it was set to release two landers on Phobos's surface.

Following the 1992 failure of the Mars Observer orbiter, NASA launched the Mars Global Surveyor in 1996. This mission was a complete success, having finished its primary mapping mission in early 2001. Contact was lost with the probe in November 2006 during its third extended program, spending exactly 10 operational years in space. Only a month after the launch of the Surveyor, NASA launched the Mars Pathfinder, carrying a robotic exploration vehicle Sojourner, which landed in the Ares Vallis on Mars in the summer of 1997. This mission was also successful, and received much publicity, partially due to the many images that were sent back to Earth.[98]

The most recent mission to Mars was the NASA Phoenix Mars lander, which launched August 4, 2007 and arrived on the north polar region of Mars on May 25, 2008.[99] The lander has a robotic arm with a 2.5 m reach and capable of digging a metre into the Martian soil. The lander has a microscopic camera capable of resolving to one-thousandth the width of a human hair, and discovered a substance at its landing site on June 15, 2008, which was confirmed to be water ice on June 20.[100] [101] The mission was declared concluded on November 10, 2008, after engineers were unable to contact the craft.[102]

## Current missions



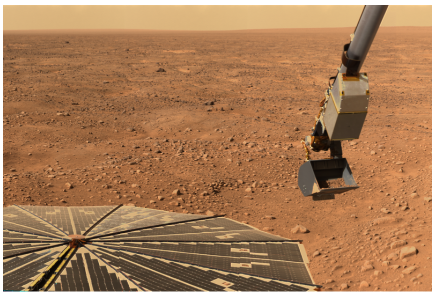
Spirit's lander on Mars

In 2001 NASA launched the successful Mars Odyssey orbiter, which is still in orbit as of March 2009, and the ending date has been extended to September 2010.[103] Odyssey's Gamma Ray Spectrometer detected significant amounts of hydrogen in the upper metre or so of Mars's regolith. This hydrogen is thought to be contained in large deposits of water ice.[104]

In 2003, the European Space Agency (ESA) launched the Mars Express craft, consisting of the Mars Express Orbiter and the lander Beagle 2. Beagle 2 failed during descent and was declared lost in early February 2004.[105] In early 2004 the Planetary Fourier Spectrometer team announced it had detected methane in the Martian atmosphere. ESA announced in June 2006 the discovery of aurorae on Mars.[106]

Also in 2003, NASA launched the twin Mars Exploration Rovers named *Spirit* (MER-A) and *Opportunity* (MER-B). Both missions landed successfully in January 2004 and have met or exceeded all their targets. Among the most significant scientific returns has been conclusive evidence that liquid water existed at some time in the past at both landing sites. Martian dust devils and windstorms have occasionally cleaned both rovers' solar panels, and thus increased their lifespan.[107]

On August 12, 2005 the NASA Mars Reconnaissance Orbiter probe was launched toward the planet, arriving in orbit on March 10, 2006 to conduct a two-year science survey. The orbiter will map the Martian terrain and weather to find suitable landing sites for upcoming lander missions. It also contains an improved telecommunications link to Earth, with more bandwidth than all previous missions combined. The Mars Reconnaissance Orbiter snapped the first image of a series of active avalanches near the planet's north pole, scientists said March 3, 2008.[108]



View from the *Phoenix* lander.

The Dawn spacecraft flew by Mars in February 2009 for a gravity assist on its way to investigate Vesta and then Ceres.

## Future missions

Phoenix will be followed by the Mars Science Laboratory in 2011, a bigger, faster (90 m/h), and smarter version of the Mars Exploration Rovers. Experiments include a laser chemical sampler that can deduce the make-up of rocks at a distance of 13 m.[109]

The joint Russian and Chinese Phobos-Grunt mission to return samples of Mars's moon Phobos (*grunt* is the Russian word for soil) was originally scheduled for October 2009, but the mission was postponed till the next launch window in 2011. On September 15, 2008, NASA announced MAVEN, a robotic mission in 2013 to provide information about Mars' atmosphere.[110] In 2018 the ESA plans to launch its first Rover to Mars; the ExoMars rover will be capable of drilling 2 m into the soil in search of organic molecules.[111]

The Finnish-Russian MetNet mission will land tens of small vehicles on the Martian surface to establish a widespread surface observation network to investigate the planet's atmospheric structure, physics and meteorology.[112] A precursor mission using one or a few landers is scheduled for launch in 2009 or 2011.[113] One possibility is a piggyback launch on the Russian Phobos-Grunt mission.[113] Other launches will take place in the launch windows extending to 2019.

Manned Mars exploration by the United States has been explicitly identified as a long-term goal in the Vision for Space Exploration announced in 2004 by the then US President George W. Bush.[114] NASA and Lockheed Martin have begun work on the *Orion* spacecraft, formerly the Crew Exploration Vehicle, which is currently scheduled to send a human expedition to Earth's moon by 2020 as a stepping stone to an expedition to Mars thereafter. On September 28, 2007, NASA administrator Michael D. Griffin stated that NASA aims to put a man on Mars by 2037.[115]

ESA hopes to land humans on Mars between 2030 and 2035.[116] This will be preceded by successively larger probes, starting with the launch of the ExoMars probe and a Mars Sample Return Mission.

Mars Direct, an extremely low-cost human mission proposed by Bob Zubrin, a founder of the Mars Society, uses heavy-lift Saturn V class rockets, such as the Space X Falcon 9, or, the Ares V, to skip orbital construction, LEO rendezvous, and lunar fuel depots. A modified proposal, called "Mars to Stay",[117] involves not returning the first immigrant/explorers immediately, if ever. Dean Unick has suggested the cost of sending a four to six person team is one fifth to one tenth the cost of returning that same four to six person team; twenty settlers could be sent for the cost of returning four.[118]

### Astronomy on Mars

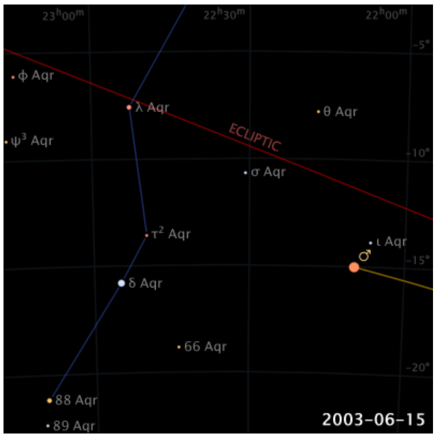
With the existence of various orbiters, landers, and rovers, it is now possible to study astronomy from the Martian skies. While Mars’ moon Phobos appears about one third the angular diameter of the full Moon as it appears from Earth, Deimos appears more or less star-like, and appears only slightly brighter than Venus does from Earth.[119]

Photograph of a Martian sunset taken by Spirit at Gusev crater, May 19, 2005.

There are also various phenomena well-known on Earth that have now been observed on Mars, such as meteors and auroras.[106] A transit of the Earth as seen from Mars will occur on November 10, 2084. There are also transits of Mercury and transits of Venus, and the moon Deimos is of sufficiently small angular diameter that its partial "eclipses" of the Sun are best considered transits (see Transit of Deimos from Mars).

## Viewing

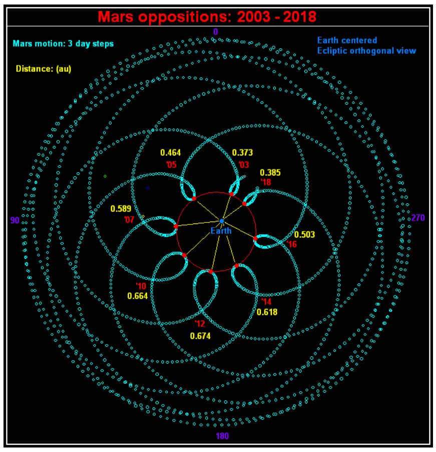
To the naked eye, Mars usually appears a distinct yellow, orange, or reddish color, and varies in brightness more than any other planet as seen from Earth over the course of its orbit. However the actual color of Mars is closer to butterscotch, and the redness seen is actually just dust in the planet's atmosphere; considering this NASA's Spirit rover has taken pictures of a greenish-brown, mud-colored landscape with blue-grey rocks and patches of light red colored sand.[120] The apparent magnitude of Mars varies from +1.8 at conjunction to as high as −2.9 at perihelic opposition.[5] When farthest away from the Earth, it is more than seven times as far from the latter as when it is closest. When least favorably positioned, it can be lost in the Sun's glare for months at a time. At its most favorable times—at 15- or 17-year intervals, and always between late July and late September—Mars shows a wealth of surface detail to a telescope. Especially noticeable, even at low magnification, are the polar ice caps.[121]



Apparent retrograde motion of Mars in 2003 as seen from Earth

The point of Mars' closest approach to the Earth is known as opposition. The length of time between successive oppositions, or the synodic period, is 780 days. Because of the eccentricities of the orbits, the times of opposition and minimum distance can differ by up to 8.5 days. The minimum distance varies between about 55 and 100 million km due to the planets' elliptical orbits.[5] The next Mars opposition will occur on January 29, 2010.

As Mars approaches opposition it begins a period of retrograde motion, which means it will appear to move backwards in a looping motion with respect to the background stars.

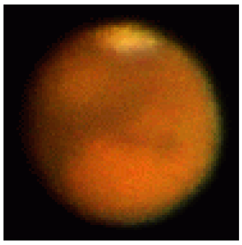


Mars oppositions from 2003–2018, viewed from above the ecliptic with the Earth centered

## 2003 closest approach

On August 27, 2003, at 9:51:13 UT, Mars made its closest approach to Earth in nearly 60,000 years: 55,758,006 km (0.372719 AU). This occurred when Mars was one day from opposition and about three days from its perihelion, making Mars particularly easy to see from Earth. The last time it came so close is estimated to have been on September 12, 57 617 BC, the next time being in 2287.[122] However, this record approach was only very slightly closer than other recent close approaches. For instance, the minimum distance on August 22, 1924 was 0.37285 AU, and the minimum distance on August 24, 2208 will be 0.37279 AU.[81]

## Historical observations

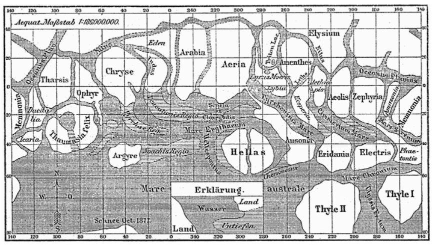


The rotation of Mars as seen in a small telescope in 2003.

The history of observations of Mars is marked by the oppositions of Mars, when the planet is closest to Earth and hence is most easily visible, which occur every couple of years. Even more notable are the perihelic oppositions of Mars which occur every 15 or 17 years, and are distinguished because Mars is close to perihelion, making it even closer to Earth. Aristotle was among the first known writers to describe observations of Mars, noting that, as it passed behind the Moon, it was farther away than was originally believed.

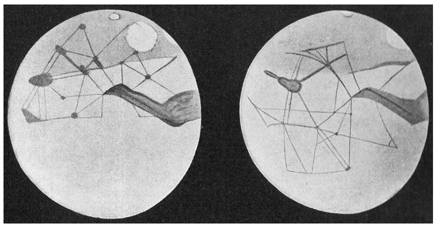
The only occultation of Mars by Venus observed was that of October 13, 1590, seen by Michael Maestlin at Heidelberg.[123] In 1609, Mars was viewed by Galileo, who was first to see it via telescope.

## Martian 'canals'




Map of Mars by Giovanni Schiaparelli

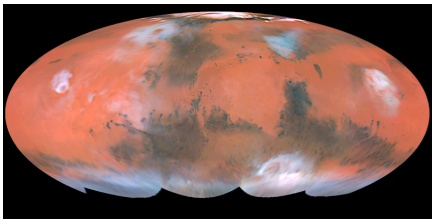
By the 19th century, the resolution of telescopes reached a level sufficient for surface features to be identified. In September 1877, a perihelic opposition of Mars occurred on September 5. In that year, Italian astronomer Giovanni Schiaparelli, then in Milan, used a 22 cm telescope to help produce the first detailed map of Mars. These maps notably contained features he called *canali*, which were later shown to be an optical illusion. These *canali* were supposedly long straight lines on the surface of Mars to which he gave names of famous rivers on Earth. His term, which means 'channels' or 'grooves', was popularly mistranslated in English as *canals*.[124] [125]



Mars sketched as observed by Lowell sometime before 1914. (South top)

Influenced by the observations, the orientalist Percival Lowell founded an observatory which had a 300 and 450 mm telescope. The observatory was used for the exploration of Mars during the last good opportunity in 1894 and the following less favorable oppositions. He published several books on Mars and life on the planet, which had a great influence on the public. The *canali* were also found by other astronomers, like Henri Joseph Perrotin and Louis Thollon in Nice, using one of the largest telescopes of that time.

The seasonal changes (consisting of the diminishing of the polar caps and the dark areas formed during Martian summer) in combination with the canals lead to speculation about life on Mars, and it was a long held belief that Mars contained vast seas and vegetation. The telescope never reached the resolution required to give proof to any speculations. However, as bigger telescopes were used, fewer long, straight *canali* were observed. During an observation in 1909 by Flammarion with a 840 mm telescope, irregular patterns were observed, but no *canali* were seen.[126]



Map of Mars from Hubble Space Telescope as seen near the 1999 opposition. (North top)

Even in the 1960s articles were published on Martian biology, putting aside explanations other than life for the seasonal changes on Mars. Detailed scenarios for the metabolism and chemical cycles for a functional ecosystem have been published.[127]

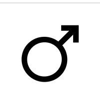
It was not until spacecraft visited the planet during NASA's Mariner missions in the 1960s that these myths were dispelled. The results of the Viking life-detection experiments started an intermission in which the hypothesis of a hostile, dead planet was generally accepted.

Some maps of Mars were made using the data from these missions, but it was not until the Mars Global Surveyor mission, launched in 1996 and operated until late 2006, that complete, extremely detailed maps were obtained. These maps are now available online, for example, at Google Mars.

## In culture

### Historical connections

Mars is named after the Roman god of war. In Babylonian astronomy, the planet was named after *Nergal*, their deity of fire, war, and destruction, most likely due to the planet's reddish appearance.[128] When the Greeks equated Nergal with their god of war, Ares, they named the planet Ἄρεως ἀστὴρ (*Areos aster*), or "star of Ares". Then, following the identification of Ares and Mars, it was translated into Latin as *stella Martis*, or "star of Mars", or simply *Mars*. The Greeks also called the planet Πυρόεις *Pyroeis* meaning "fiery". In Hindu mythology, Mars is known as Mangala (मंगल). The planet is also called *Angaraka* in Sanskrit, after the celibate god of war, who possesses the signs of Aries and Scorpio, and teaches the occult sciences. The planet was known by the Egyptians as "*Ḥr Dšr*";;;; or "Horus the Red". The Hebrews named it *Ma'adim* (מאדים) — "the one who blushes"; this is where one of the largest canyons on Mars, the Ma'adim Vallis, gets its name. It is known as *al-Mirrikh* in Arabic, and *Merih* in Turkish. In Urdu and Persian it is written as مریخ and known as "Merikh". The etymology of *al-Mirrikh* is unknown. Ancient Persians named it *Bahram*, the Zoroastrian god of faith and it is written as بهرام. Ancient Turks called it *Sakit*. The Chinese, Japanese, Korean and Vietnamese cultures refer to the planet as 火星, or the *fire star*, a name based on the ancient Chinese mythological cycle of Five elements.



Its symbol, derived from the astrological symbol of Mars, is a circle with a small arrow pointing out from behind. It is a stylized representation of a shield and spear used by the Roman God Mars. Mars in Roman mythology was the God of War and patron of warriors. This symbol is also used in biology to describe the male sex, and in alchemy to symbolise the element iron which was considered to be dominated by Mars whose characteristic red colour is coincidentally due to iron oxide.[129] ♂ occupies Unicode position U+2642.

## Intelligent "Martians"


An 1893 soap ad playing on the popular idea that Mars was populated.

The popular idea that Mars was populated by intelligent Martians exploded in the late 19th century. Schiaparelli's "canali" observations combined with Percival Lowell's books on the subject put forward the standard notion of a planet that was a drying, cooling, dying world with ancient civilizations constructing irrigation works.[130]

Many other observations and proclamations by notable personalities added to what has been termed "Mars Fever".[131] In 1899 while investigating atmospheric radio noise using his receivers in his Colorado Springs lab, inventor Nikola Tesla observed repetitive signals that he later surmised might have been radio communications coming from another planet, possibly Mars. In a 1901 interview Tesla said:

> It was some time afterward when the thought flashed upon my mind that the disturbances I had observed might be due to an intelligent control. Although I could not decipher their meaning, it was impossible for me to think of them as having been entirely accidental. The feeling is constantly growing on me that I had been the first to hear the greeting of one planet to another.[132]

Tesla's theories gained support from Lord Kelvin who, while visiting the United States in 1902, was reported to have said that he thought Tesla had picked up Martian signals being sent to the United States.[133] However, Kelvin "emphatically" denied this report shortly before departing America: "What I really said was that the inhabitants of Mars, if there are any, were doubtless able to see New York, particularly the glare of the electricity."[134]

In a *New York Times* article in 1901, Edward Charles Pickering, director of the Harvard College Observatory, said that they had received a telegram from Lowell Observatory in Arizona that seemed to confirm that Mars was trying to communicate with the Earth.[135]

> Early in December 1900, we received from Lowell Observatory in Arizona a telegram that a shaft of light had been seen to project from Mars (the Lowell observatory makes a specialty of Mars) lasting seventy minutes. I wired these facts to Europe and sent out neostyle copies through this country. The observer there is a careful, reliable man and there is no reason to doubt that the light existed. It was given as from a well-known geographical point on Mars. That was all. Now the story has gone the world over. In Europe it is stated that I have been in communication with Mars, and all sorts of exaggerations have spring up. Whatever the light was, we have no means of knowing. Whether it had intelligence or not, no one can say. It is absolutely inexplicable.[135]

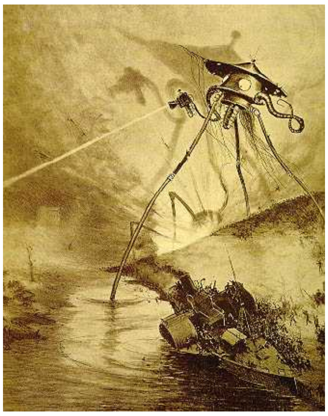
Pickering later proposed creating a set of mirrors in Texas with the intention of signaling Martians.

In recent decades, the high resolution mapping of the surface of Mars, culminating in Mars Global Surveyor, revealed no artifacts of habitation by 'intelligent' life, but pseudoscientific speculation about intelligent life on Mars continues from commentators such as Richard C. Hoagland. Reminiscent of the *canali* controversy, some speculations are based on small scale features perceived in the spacecraft images, such as 'pyramids' and the 'Face on Mars'. Planetary astronomer Carl Sagan wrote:

> Mars has become a kind of mythic arena onto which we have projected our Earthly hopes and fears.[136]

## In fiction

The depiction of Mars in fiction has been stimulated by its dramatic red color and by early scientific speculations that its surface conditions not only might support life, but intelligent life.



Alien tripod illustration from the 1906 French edition of H.G. Wells' *The War of the Worlds*.

Thus originated a large number of science fiction scenarios, the best known of which is H. G. Wells' *The War of the Worlds*, published in 1898, in which Martians seek to escape their dying planet by invading Earth. A subsequent US radio adaptation of *The War of the Worlds* on October 30, 1938 by Orson Welles was presented as a live news broadcast, and became notorious for causing a public panic when many listeners mistook it for the truth.[137]

Also influential were Ray Bradbury's *The Martian Chronicles*, in which human explorers accidentally destroy a Martian civilization, Edgar Rice Burroughs' *Barsoom* series and a number of Robert A. Heinlein stories before the mid-sixties.

Author Jonathan Swift made reference to the moons of Mars, about 150 years before their actual discovery by Asaph Hall, detailing reasonably accurate descriptions of their orbits, in the 19th chapter of his novel *Gulliver's Travels*.[138]

Another reference is found in C. S. Lewis' Space Trilogy, and in particular in the first book entitled Out of the Silent Planet (1938). Three men, Weston, Devine and Ransom, set out for an interplanetary voyage from Earth to Mars (called *Malacandra* in the narrative). Ransom, who had been brought along forcefully by Weston and Devine, in order to be handed over to the Sorns, succeeds in escaping after they have landed on the red planet, and thus comes to discover the geology, flora, fauna, and cultures present on Malacandra. He also discovers the relationship of planet Earth (called *Thulcandra*, the *silent planet*, in the narrative) with the other planets and forms of life present in the Solar System.

A comic figure of an intelligent Martian, Marvin the Martian, appeared on television in 1948 as a character in the Looney Tunes animated cartoons of Warner Brothers, and has continued as part of popular culture to the present.

After the Mariner and Viking spacecraft had returned pictures of Mars as it really is, an apparently lifeless and canal-less world, these ideas about Mars had to be abandoned and a vogue for accurate, realist depictions of human colonies on Mars developed, the best known of which may be Kim Stanley Robinson's *Mars* trilogy. However, pseudo-scientific speculations about the Face on Mars and other enigmatic landmarks spotted by space probes have meant that ancient civilizations continue to be a popular theme in science fiction, especially in film.[139]

Another popular theme, particularly among American writers, is the Martian colony that fights for independence from Earth. This is a major plot element in the novels of Greg Bear and Kim Stanley Robinson, as well as the movie *Total Recall* (based on a short story by Philip K. Dick) and the television series *Babylon 5*. Many video games also use this element, including *Red Faction* and the *Zone of the Enders* series. Mars (and its moons) were also the setting for the popular *Doom* video game franchise and the later *Martian Gothic*.

### In music

In Gustav Holst's *The Planets*, Mars is depicted as the "Bringer of War".

The Flaming Lips's Grammy-award-winning song "Approaching Pavonis Mons by Balloon" from the album *Yoshimi Battles the Pink Robots* portrays travel across the Red Planet.

## See also

- 2007 WD5 – asteroid that had a possible impact with Mars on January 30, 2008
- Colonization of Mars
- Darian calendar – system of time-keeping
- Extraterrestrial life
- List of artificial objects on Mars
- List of chasmata on Mars
- List of craters on Mars
- List of valles on Mars
- Mars Direct
- Mars Society
- Terraforming of Mars

## Notes

a. Best fit ellipsoid

b. There are many *serpentinization* reactions. Olivine is a solid solution between forsterite and fayalite whose general formula is $(Fe, Mg)_2SiO_4$. The reaction producing methane from olivine can be written as:

*Forsterite* + *Fayalite* + *Water* + *Carbonic acid* → *Serpentine* + *Magnetite* + *Methane* , or (in balanced form):

$$18Mg_2SiO_4 + 6Fe_2SiO_4 + 26H_2O + CO_2 \rightarrow 12Mg_3Si_2O_5(OH)_4 + 4Fe_3O_4 + CH_4$$

## External links

- 3D maps of Mars in NASA World Wind (http://www.worldwindcentral.com/wiki/Mars)
- Google Mars (http://www.google.com/mars/) – Interactive image of Mars
- Guide to Mars (http://mars.skymania.com/) – information about Mars and how to observe it.
- Nine Planets Mars page (http://www.nineplanets.org/mars.html)
- On Mars: Exploration of the Red Planet 1958–1978 (http://history.nasa.gov/SP-4212/on-mars.html) from the NASA History Office.
- Martian Law – a CATO white paper (http://www.cato.org/pubs/wtpapers/980815paper.html)
- Computer Simulation of a flyby through Mariner Valley (http://www.maniacworld.com/mars_mariner_valley.htm)
- Mars Unearthed (http://www.marsunearthed.com/) – Comparisons of terrains between Earth and Mars
- Ralph Aeschliman's Online Atlas of Mars (http://ralphaeschliman.com/id30.htm)
- Be on Mars (http://dualmoments.com/marsrovers/index.html) – Anaglyphs from the Mars Rovers (3D)
- NASA/JPL OnMars WMS Server for Mars Data (http://onmars.jpl.nasa.gov/) – Work as Google Earth client overlays
- Exploring Mars: Image Center (http://www.lpi.usra.edu/expmars/images.html)
- Mars (http://www.astronomycast.com/astronomy/episode-52-mars/) Astronomy Cast episode #52, includes full transcript.
- Feb 07: ESA Prepares for a Human Mission to Mars (http://www.space-nasa.com/02-apr-2007-esa-1.html)

- Mars' apparent relative size (http://hubblesite.org/newscenter/archive/releases/2005/34/image/l) at opposition as seen by HST
- Mars articles in Planetary Science Research Discoveries (http://www.psrd.hawaii.edu/Archive/Archive-Mars.html)
- BBC News update on Mars Express' findings of polar water ice and water-eroded features on the surface (http://news.bbc.co.uk/1/hi/sci/tech/3426539.stm)
- BBC News Mars pictures reveal frozen sea (http://news.bbc.co.uk/1/hi/sci/tech/4285119.stm)
- Flight Into Mariner Valley (http://themis.asu.edu/valles_video/) – NASA/JPL/Arizona State University 3D flythrough of Valles Marineris
- Geody Mars (http://www.geody.com/?world=mars) – World's search engine that supports NASA World Wind, Celestia, and other applications
- Mars Society (http://www.marssociety.org) – The Mars Society, an international organization dedicated to the study, exploration, and settlement of Mars.

### Cartographic resources

- Mars Nomenclature (http://planetarynames.wr.usgs.gov/jsp/SystemSearch2.jsp?System=Mars)
- PDS Map-a-planet (http://pdsmaps.wr.usgs.gov/PDS/public/explorer/html/marspick.htm)
- Viking Photomap (http://planetologia.elte.hu/terkep/mars-viking-en.pdf)
- MOLA (topographic) map (http://planetologia.elte.hu/terkep/mars-mola-en.pdf)
- Movie of Mars (http://sos.noaa.gov/videos/Mars.mov) at National Oceanic and Atmospheric Administration

## References


[1] Yeager, Ashley (July 19, 2008). " Impact May Have Transformed Mars (http://www.sciencenews.org/view/generic/id/33622/title/Impact_may_have_transformed_Mars_)". ScienceNews.org. . Retrieved 2008-08-12.

[2] Sample, Ian (June 26, 2008). " Cataclysmic impact created north-south divide on Mars (http://www.guardian.co.uk/science/2008/jun/26/mars.asteroid?gusrc=rss&feed=science)". Science @ guardian.co.uk. . Retrieved 2008-08-12.

[3] Trudy E. Bell and Tony Phillips (March 12, 2002). " Once Upon a Water Planet (http://science.nasa.gov/headlines/y2002/12mar_waterplanet.htm)". Science @ NASA. . Retrieved 2008-06-21.

[4] " Water ice in crater at Martian north pole (http://www.esa.int/SPECIALS/Mars_Express/SEMGKA808BE_0.html)". ESA. July 28, 2005. .

[5] " Scientists Discover Concealed Glaciers on Mars at Mid-Latitudes (http://www.jsg.utexas.edu/news/rels/112008.html)". University of Texas at Austin. November 20, 2008. .

[6] " NASA Spacecraft Confirms Martian Water, Mission Extended (http://www.nasa.gov/mission_pages/phoenix/news/phoenix-20080731.html)". Science @ NASA. July 31, 2008. . Retrieved 2008-08-01.

[7] " NASA Images Suggest Water Still Flows in Brief Spurts on Mars (http://www.nasa.gov/mission_pages/mars/news/mgs-20061206.html)". NASA/JPL. December 6, 2006. . Retrieved 2007-01-04.

[8] Webster, G.; Beasley, D. (September 20, 2005). " Orbiter's Long Life Helps Scientists Track Changes on Mars (http://mpfwww.jpl.nasa.gov/mgs/newsroom/20050920a.html)". NASA. . Retrieved 2007-02-26.

[9] Peplow, Mark. " How Mars got its rust (http://www.bioedonline.org/news/news-print.cfm?art=953)". *BioEd Online*. MacMillan Publishers Ltd.. . Retrieved 2007-03-10.

[10] Christensen, Philip R.; *et al*. (2003-06-27). "Morphology and Composition of the Surface of Mars: Mars Odyssey THEMIS Results". *Science* **300** (5628): 2056–2061. doi: 10.1126/science.1080885 (http://dx.doi.org/10.1126/science.1080885). PMID 12791998 (http://www.ncbi.nlm.nih.gov/pubmed/12791998).

[11] Golombek, Matthew P. (2003-06-27). "The Surface of Mars: Not Just Dust and Rocks". *Science* **300** (5628): 2043–2044. doi: 10.1126/science.1082927 (http://dx.doi.org/10.1126/science.1082927). PMID 12829771 (http://www.ncbi.nlm.nih.gov/pubmed/12829771).

[12] Valentine, Theresa; Amde, Lishan (2006-11-09). " Magnetic Fields and Mars (http://mgs-mager.gsfc.nasa.gov/Kids/magfield.html)". Mars Global Surveyor @ NASA. . Retrieved 2009-07-17.

[13] " New Map Provides More Evidence Mars Once Like Earth (http://www.nasa.gov/centers/goddard/news/topstory/2005/mgs_plates.html)". NASA/Goddard Space Flight Center. . Retrieved 2006-03-17.

[14] Jacqué, Dave (2003-09-26). " APS X-rays reveal secrets of Mars' core (http://www.anl.gov/Media_Center/News/2003/030926mars.htm)". Argonne National Laboratory. . Retrieved 2006-07-01.

[15] " Mars avalanche caught on camera (http://dsc.discovery.com/news/2008/03/04/mars-avalanche.html)". *Discovery Channel*. Discovery Communications. 2008-03-04. . Retrieved 2009-03-04.

[16] " Giant Asteroid Flattened Half of Mars, Studies Suggest (http://www.sciam.com/article.cfm?id=giant-asteroid-flattened)". Scientific American. . Retrieved 2008-06-27.

[17] " Huge Meteor Strike Explains Mars's Shape, Reports Say (http://www.nytimes.com/2008/06/26/science/space/26mars.html?em&ex=1214712000&en=bd0be05a87523855&ei=5087 )". New York Times. . Retrieved 2008-06-27.

[18] " Martian soil 'could support life' (http://news.bbc.co.uk/2/hi/science/nature/7477310.stm)". BBC News. June 27, 2008. . Retrieved 2008-08-07.

[19] Chang, Alicia. " Scientists: Salt in Mars soil not bad for life (http://www.usatoday.com/tech/science/space/2008-08-04-mars-soil_N.htm)". Associated Press. . Retrieved 2008-08-07.

[20] " NASA Spacecraft Analyzing Martian Soil Data (http://www.jpl.nasa.gov/news/phoenix/release.php?ArticleID=1816)". JPL. . Retrieved 2008-08-05.

[21] Haberle, R. M.; *et al*. (2001). " On the possibility of liquid water on present-day Mars (http://www.agu.org/pubs/crossref/2001/2000JE001360.shtml)". Journal of Geophysical Research. . Retrieved 2006-10-06. *106(E10), 23,317–23,326.* ( abstract (http://www.agu.org/journals/je/je0110/2000JE001360/0.html), full paper requires purchase or AGU subscription)

[22] Heldmann, Jennifer L.; *et al*. (2005-05-07). " Formation of Martian gullies by the action of liquid water flowing under current Martian environmental conditions (http://daleandersen.seti.org/Dale_Andersen/Science_articles_files/Heldmann et al.2005.pdf)" (PDF). *Journal of Geophysical Research* **110**: Eo5004. doi: 10.1029/2004JE002261 (http://dx.doi.org/10.1029/2004JE002261). . Retrieved 2008-09-17. 'conditions such as now occur on Mars, outside of the temperature-pressure stability regime of liquid water' ... 'Liquid water is typically stable at the lowest elevations and at low latitudes on the planet because the atmospheric pressure is greater than the vapor pressure of water and surface temperatures in equatorial regions can reach 273 K for parts of the day [Haberle *et al*., 2001]'

[23] Kostama, V.-P.; Kreslavsky, M. A.; Head, J. W. (June 3, 2006). " Recent high-latitude icy mantle in the northern plains of Mars: Characteristics and ages of emplacement (http://www.agu.org/pubs/crossref/2006/2006GL025946.shtml)". *Geophysical Research Letters* **33**: L11201. doi: 10.1029/2006GL025946 (http://dx.doi.org/10.1029/2006GL025946). . Retrieved 2007-08-12. 'Martian high-latitude zones are covered with a smooth, layered ice-rich mantle'

[24] " Mars' South Pole Ice Deep and Wide (http://jpl.nasa.gov/news/news.cfm?release=2007-030)". NASA. March 15, 2007. . Retrieved 2007-03-16.

[25] Murray, John B.; *et al*. (March 17, 2005). "Evidence from the Mars Express High Resolution Stereo Camera for a frozen sea close to Mars' equator". *Nature* **434**: 352–356. doi: 10.1038/nature03379 (http://dx.doi.org/10.1038/nature03379).

[26] Kerr, Richard A. (March 4, 2005). "Ice or Lava Sea on Mars? A Transatlantic Debate Erupts". *Science* **307**: 1390–1391. doi: 10.1126/science.307.5714.1390a (http://dx.doi.org/10.1126/science.307.5714.1390a). PMID 15746395 (http://www.ncbi.nlm.nih.gov/pubmed/15746395).

[27] Jaeger, W. L.; *et al*. (September 21, 2007). "Athabasca Valles, Mars: A Lava-Draped Channel System". *Science* **317**: 1709–1711. doi: 10.1126/science.1143315 (http://dx.doi.org/10.1126/science.1143315). PMID 17885126 (http://www.ncbi.nlm.nih.gov/pubmed/17885126).

[28] Boynton, W. V.; *et al*. (in press). "Concentration of H, Si, Cl, K, Fe, and Th in the low and mid latitude regions of Mars". *Journal of Geophysical Research, Planets* **112**: E12S99. doi: 10.1029/2007JE002887 (http://dx.doi.org/10.1029/2007JE002887).

[29] Feldman, W. C.; *et al*. (November 30, 2005). "Topgraphic control of hydrogen deposits at low latitudes to midlatitudes of Mars". *Journal of Geophysical Research* **110**: E11009. doi: 10.1029/2005JE002452 (http://dx.doi.org/10.1029/2005JE002452).

[30] Malin, Michael C. (June 30, 2000). "Evidence for Recent Groundwater Seepage and Surface Runoff on Mars". *Science* **288**: 2330–2335. doi: 10.1126/science.288.5475.2330 (http://dx.doi.org/10.1126/science.288.5475.2330). PMID 10875910 (http://www.ncbi.nlm.nih.gov/pubmed/10875910).

[31] " NASA Images Suggest Water Still Flows in Brief Spurts on Mars (http://www.nasa.gov/mission_pages/mars/news/mgs-20061206.html)". NASA. December 6, 2006. . Retrieved 2006-12-06.

[32] " Water flowed recently on Mars (http://news.bbc.co.uk/1/hi/sci/tech/6214834.stm)". BBC. December 6, 2006. . Retrieved 2006-12-06.

[33] " Water May Still Flow on Mars, NASA Photo Suggests (http://www.npr.org/templates/story/story.php?storyId=6587226)". NASA. December 6, 2006. . Retrieved 2006-04-30.

[34] NASA (March 3, 2004). " Mineral in Mars 'Berries' Adds to Water Story (http://web.archive.org/web/20071109185031/http://www.jpl.nasa.gov/releases/2004/88.cfm)". Press release. Archived from the original (http://www.jpl.nasa.gov/releases/2004/88.cfm) on 2007-11-09. . Retrieved 2006-06-13.

[35] McEwen, A. S.; *et al*. (September 21, 2007). "A Closer Look at Water-Related Geologic Activity on Mars". *Science* **317**: 1706–1709. doi: 10.1126/science.1143987 (http://dx.doi.org/10.1126/science.1143987). PMID 17885125 (http://www.ncbi.nlm.nih.gov/pubmed/17885125).

[36] " NASA Findings Suggest Jets Bursting From Martian Ice Cap (http://www.jpl.nasa.gov/news/news.cfm?release=2006-100)". *Jet Propulsion Laboratory* (NASA). August 16, 2006. . Retrieved 2009-08-11.

[37] Kieffer, H. H. (2000), " Annual Punctuated CO2 Slab-ice and Jets on Mars (http://www.lpi.usra.edu/meetings/polar2000/pdf/4095.pdf)" (PDF), *Mars Polar Science 2000*, , retrieved 2009-09-06

[38] " Simulations of Geyser-type Eruptions in Cryptic Region of Martian South (http://www.lpi.usra.edu/meetings/polar2006/pdf/8040.pdf)" (PDF), *Fourth Mars Polar Science Conference*, 2006, , retrieved 2009-08-11

[39] Kieffer, Hugh H.; Philip R. Christensen and Timothy N. Titus (30 May 2006). " CO2 jets formed by sublimation beneath translucent slab ice in Mars' seasonal south polar ice cap (http://www.nature.com/nature/journal/v442/n7104/abs/nature04945.html)". *Nature* **442**: 793–796. doi: doi:10.1038/nature04945 (http://dx.doi.org/doi:10.1038/nature04945). . Retrieved 2009-09-02.

[40] " Dark Streaks on Mars Suggest Running Water Still Present (http://www.space.com/scienceastronomy/streaks_mars_021211.html)". SPACE.com. 2002-12-11. . Retrieved 2009-09-20.

[41] Sheehan, William. " Areographers (http://www.uapress.arizona.edu/onlinebks/mars/chap04.htm)". *The Planet Mars: A History of Observation and Discovery*. . Retrieved 2006-06-13.

[42] " Viking and the Resources of Mars (http://history.nasa.gov/monograph21/Chapter 6.pdf)" (PDF). *Humans to Mars: Fifty Years of Mission Planning, 1950–2000*. . Retrieved 2007-03-10.

[43] " Topography (http://library.thinkquest.org/04oct/00843/mars_eng.html)". *Think Quest*. . Retrieved 2007-03-13.

[44] Frommert, H.; Kronberg, C.. " Christiaan Huygens (http://www.seds.org/messier/xtra/Bios/huygens.html)". SEDS/Lunar and Planetary Lab. . Retrieved 2007-03-10.

[45] Glenday, Craig (2009). *Guinness World Records*. Random House, Inc.. p. 12. ISBN 0553592564.

[46] Wright, Shawn (April 4, 2003). " Infrared Analyses of Small Impact Craters on Earth and Mars (http://ivis.eps.pitt.edu/projects/MC/)". University of Pittsburgh. . Retrieved 2007-02-26.

[47] " Mars Global Geography (http://www.windows.ucar.edu/tour/link=/mars/interior/Martian_global_geology.html)". *Windows to the Universe*. University Corporation for Atmospheric Research. April 27, 2001. . Retrieved 2006-06-13.

[48] Wetherill, G. W. (1999). " Problems Associated with Estimating the Relative Impact Rates on Mars and the Moon (http://adsabs.harvard.edu/abs/1974Moon....9..227W)". *Earth, Moon, and Planets* **9**: 227. doi: 10.1007/BF00565406 (http://dx.doi.org/10.1007/BF00565406). . Retrieved 2007-02-26.

[49] Lucchitta, B. K.; Rosanova, C. E. (August 26, 2003). " Valles Marineris; The Grand Canyon of Mars (http://astrogeology.usgs.gov/Projects/VallesMarineris/)". USGS. . Retrieved 2007-03-11.

[50] G. E. Cushing, T. N. Titus, J. J. Wynne, P. R. Christensen. (2007). " Themis Observes Possible Cave Skylights on Mars (http://www.lpi.usra.edu/meetings/lpsc2007/pdf/1371.pdf)" (PDF). Lunar and Planetary Science XXXVIII. . Retrieved 2007-08-02.

[51] " NAU researchers find possible caves on Mars (http://www4.nau.edu/insidenau/bumps/2007/3_28_07/mars.htm)". *Inside NAU* (Northern Arizona University) **4** (12). March 28, 2007. . Retrieved 2007-05-28.

[52] " Researchers find possible caves on Mars (http://news.bbc.co.uk/2/hi/science/nature/6461201.stm)". *Paul Rincon of BBC News*. . Retrieved 2007-05-28.

[53] J. T. Mellon, W. C. Feldman, T. H. Prettyman (2003). " The presence and stability of ground ice in the southern hemisphere of Mars (http://adsabs.harvard.edu/abs/2004Icar..169..324M)". *Icarus* **169** (2): 324–340. doi: 10.1016/j.icarus.2003.10.022 (http://dx.doi.org/10.1016/j.icarus.2003.10.022). . Retrieved 2007-02-26.

[54] " Mars Rovers Spot Water-Clue Mineral, Frost, Clouds (http://marsrovers.jpl.nasa.gov/gallery/press/opportunity/20041213a.html)". NASA. December 13, 2004. . Retrieved 2006-03-17.

[55] Philips, Tony (2001). " The Solar Wind at Mars (http://science.nasa.gov/headlines/y2001/ast31jan_1.htm)". Science@NASA. . Retrieved 2006-10-08.

[56] R. Lundin, S. Barabash, H. Andersson, M. Holmström, A. Grigoriev, M. Yamauchi, J.-A. Sauvaud, A. Fedorov, E. Budnik, J.-J. Thocaven,2 D. Winningham, R. Frahm, J. Scherrer, J. Sharber, K. Asamura, H. Hayakawa, A. Coates, D. R. Linder, C. Curtis, K. C. Hsieh, B. R. Sandel, M. Grande, M. Carter, D. H. Reading, H. Koskinen, E. Kallio, P. Riihela, W. Schmidt, T. Säles, J. Kozyra, N. Krupp, J. Woch, J. Luhmann, S. McKenna-Lawler, R. Cerulli-Irelli, S. Orsini, M. Maggi, A. Mura, A. Milillo, E. Roelof, D. Williams, S. Livi, P. Brandt, P. Wurz, P. Bochsler (2004). "Solar Wind-Induced Atmospheric Erosion at Mars: First Results from ASPERA-3 on Mars Express". *Science* **305**: 1933–1936. doi: 10.1126/science.1101860 (http://dx.doi.org/10.1126/science.1101860). PMID 15448263 (http://www.ncbi.nlm.nih.gov/pubmed/15448263).

[57] Lemmon; *et al*. (2004). "Atmospheric Imaging Results from Mars Rovers". *Science* **306**: 1753–1756. doi: 10.1126/science.1104474 (http://dx.doi.org/10.1126/science.1104474). PMID 15576613 (http://www.ncbi.nlm.nih.gov/pubmed/15576613).

[58] Formisano, V.; Atreya, S.; Encrenaz, T.; Ignatiev, N.; Giuranna, M. (2004). "Detection of Methane in the Atmosphere of Mars". *Science* **306**: 1758–1761. doi: 10.1126/science.1101732 (http://dx.doi.org/10.1126/science.1101732). PMID 15514118 (http://www.ncbi.nlm.nih.gov/pubmed/15514118).

[59] " Mars Express confirms methane in the Martian atmosphere (http://www.esa.int/esaMI/Mars_Express/SEMZ0B57ESD_0.html)". ESA. March 30, 2004. . Retrieved 2006-03-17.

[60] Mumma, Michael J.; *et al.* (February 20, 2009). " Strong Release of Methane on Mars in Northern Summer 2003 (http://images.spaceref.com/news/2009/Mumma_et_al_Methane_Mars_wSOM_accepted2.pdf)". *Science* **323** (5917): 1041–1045. doi: 10.1126/science.1165243 (http://dx.doi.org/10.1126/science.1165243). .

[61] Hand, Eric (October 21, 2008). " Plumes of methane identified on Mars (http://esse.engin.umich.edu/psl/PRESS/Mars/NatureNews_2008.pdf)". Nature News. . Retrieved 2009-08-02.

[62] Krasnopolsky, Vladimir A. (February 2005). " Some problems related to the origin of methane on Mars (http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6WGF-4HTCW36-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=a614a9e35a422b94cc2611ccdc4bf180)". *Icarus* **180** (2): 359–367.

doi: 10.1016/j.icarus.2005.10.015 (http://dx.doi.org/10.1016/j.icarus.2005.10.015). .
[63] Planetary Fourier Spectrometer website (http://www.pfs-results.it/) (ESA, Mars Express)
[64] Franck, Lefèvre; Forget, François (August 6, 2009). " Observed variations of methane on Mars unexplained by known atmospheric chemistry and physics (http://www.nature.com/nature/journal/v460/n7256/abs/nature08228.html)". *Nature* **460**: 720–723. doi: 10.1038/nature08228 (http://dx.doi.org/10.1038/nature08228). . Retrieved 2009-10-23.
[65] Oze, C.; Sharma, M. (2005). "Have olivine, will gas: Serpentinization and the abiogenic production of methane on Mars". *Geophysical Research Letters* **32**: L10203. doi: 10.1029/2005GL022691 (http://dx.doi.org/10.1029/2005GL022691).
[66] " Mars' desert surface... (http://www-mgcm.arc.nasa.gov/mgcm/HTML/WEATHER/surface.html)". *MGCM Press release*. NASA. . Retrieved 2007-02-25.
[67] Kluger, Jeffrey (September 1, 1992). " Mars, in Earth's Image (http://discovermagazine.com/1992/sep/marsinearthsimag105)". Discover Magazine. . Retrieved 2009-11-03.
[68] Goodman, Jason C (September 22, 1997). " The Past, Present, and Possible Future of Martian Climate (http://www.mit.edu/people/goodmanj/terraforming/terraforming.html)". MIT. . Retrieved 2007-02-26.
[69] Philips, Tony (July 16, 2001). " Planet Gobbling Dust Storms (http://science.nasa.gov/headlines/y2001/ast16jul_1.htm)". *Science @ NASA*. . Retrieved 2006-06-07.
[70] Darling, David. " Mars, polar caps (http://www.daviddarling.info/encyclopedia/M/Marspoles.html)". *Encyclopedia of Astrobiology, Astronomy, and Spaceflight*. . Retrieved 2007-02-26.
[71] " MIRA's Field Trips to the Stars Internet Education Program (http://www.mira.org/fts0/planets/097/text/txt002x.htm)". Mira.org. . Retrieved 2007-02-26.
[72] Carr, Michael H. (2003). " Oceans on Mars: An assessment of the observational evidence and possible fate (http://adsabs.harvard.edu/abs/1998RPPh...61...77K)". *Journal of Geophysical Research* **108** (5042): 5042. doi: 10.1029/2002JE001963 (http://dx.doi.org/10.1029/2002JE001963). . Retrieved 2007-02-26.
[73] Phillips, Tony. " Mars is Melting, Science at NASA (http://science.nasa.gov/headlines/y2003/07aug_southpole.htm)". . Retrieved 2007-02-26.
[74] J. J. Plaut, G. Picardi, A. Safaeinili, A. B. Ivanov, S. M. Milkovich, A. Cicchetti, W. Kofman, J. Mouginot, W. M. Farrell, R. J. Phillips, S. M. Clifford, A. Frigeri, R. Orosei, C. Federico, I. P. Williams, D. A. Gurnett, E. Nielsen, T. Hagfors, E. Heggy, E. R. Stofan, D. Plettemeier, T. R. Watters, C. J. Leuschen, P. Edenhofer (2007). "Subsurface Radar Sounding of the South Polar Layered Deposits of Mars". *Science* **315**: 92. doi: 10.1126/science.1139672 (http://dx.doi.org/10.1126/science.1139672). PMID 17363628 (http://www.ncbi.nlm.nih.gov/pubmed/17363628).
[75] Pelletier J. D. (2004). " How do spiral troughs form on Mars? (http://www.gsajournals.org/perlserv/?request=get-abstract&doi=10.1130/G20228.2)". *Geology* **32**: 365–367. doi: 10.1130/G20228.2 (http://dx.doi.org/10.1130/G20228.2). . Retrieved 2007-02-27.
[76] " MarsToday.Com (http://www.marstoday.com/viewpr.html?pid=13914)". *Mars Polar Cap Mysery Solved*. . Retrieved 2007-01-23.
[77] " Evidence for an ancient martian ocean in the topography of deformed shorelines (http://www.nature.com/nature/journal/v447/n7146/full/nature05873.html)". *Nature Journal Abstracts*. Nature Journal. . Retrieved 2009-10-31.
[78] " Mars, Water & Life (http://marsprogram.jpl.nasa.gov/msp98/why.html)". NASA. .
[79] " The Borealis basin and the origin of the martian crustal dichotomy (http://www.nature.com/nature/journal/v453/n7199/full/nature07011.html)". *Nature Journal Abstracts*. Nature Journal. . Retrieved 2009-10-31.}
[80] " Mars' Orbital eccentricity over time (http://main.chemistry.unina.it/~alvitagl/solex/MarsDist.html)". *Solex*. Universita' degli Studi di Napoli Federico II. 2003. . Retrieved 2007-07-20.
[81] Jean Meeus (March 2003). " When Was Mars Last This Close? (http://www.ips-planetarium.org/planetarian/articles/whenmars.html)". International Planetarium Society. . Retrieved 2008-01-18.
[82] Ron Baalke (August 22, 2003). " Mars Makes Closest Approach In Nearly 60,000 Years (http://www.mail-archive.com/meteorite-list@meteoritecentral.com/msg14044.html)". meteorite-list. . Retrieved 2008-01-18.
[83] " Close Inspection for Phobos (http://sci.esa.int/science-e/www/object/index.cfm?fobjectid=31031)". *ESA website*. . Retrieved 2006-06-13.
[84] " ARES ATTENDANTS: DEIMOS & PHOBOS (http://www.theoi.com/Olympios/AresAttendants.html)". *Greek Mythology*. . Retrieved 2006-06-13.
[85] Arnett, Bill (November 20, 2004). " Phobos (http://www.nineplanets.org/phobos.html)". *nineplanets*. . Retrieved 2006-06-13.
[86] Ellis, Scott. " Geological History: Moons of Mars (http://web.archive.org/web/20070517181817/http://calspace.ucsd.edu/Mars99/docs/library/science/geological_history/moons1.html)". CalSpace. Archived from the original (http://calspace.ucsd.edu/Mars99/docs/library/science/geological_history/moons1.html) on 2007-05-17. . Retrieved 2007-08-02.
[87] Robert L. Nowack (http://web.ics.purdue.edu/~nowack/). " Estimated Habitable Zone for the Solar System (http://web.ics.purdue.edu/~nowack/geos105/lect14-dir/lecture14_files/image022.jpg)". Department of Earth and Atmospheric Sciences at Purdue University. . Retrieved 2009-04-10.
[88] Helen Briggs (BBC science reporter, Boston) (February 15, 2008). " Early Mars 'too salty' for life (http://news.bbc.co.uk/2/hi/science/nature/7248062.stm)". BBC News. . Retrieved 2008-02-16.
[89] Hannsson, Anders (1997). *Mars and the Development of Life.*. Wiley. ISBN 0-471-96606-1.
[90] " New Analysis of Viking Mission Results Indicates Presence of Life on Mars (http://www.physorg.com/news87401064.html)". Physorg.com. January 7, 2007. . Retrieved 2007-03-02.

[91] " Phoenix Returns Treasure Trove for Science (http://www.nasa.gov/mission_pages/phoenix/news/phoenix-20080626.html)". NASA/JPL. 2008-06-26. . Retrieved 2008-06-27.

[92] Vladimir A. Krasnopolsky, Jean-Pierre Maillard, Tobias C. Owen (2004). "Detection of methane in the Martian atmosphere: evidence for life?". *Icarus* **172**: 537–547. doi: 10.1016/j.icarus.2004.07.004 (http://dx.doi.org/10.1016/j.icarus.2004.07.004).

[93] " Formaldehyde claim inflames Martian debate (http://www.nature.com/news/2005/050221/full/050221-15.html)". Nature. February 25, 2005. doi: 10.1038/news050221-15 (http://dx.doi.org/10.1038/news050221-15). . Retrieved 2006-03-19.

[94] NGC: The Universe 3, Cary Mitchell, Purdue University

[95] Dinerman, Taylor (September 27, 2004). " Is the Great Galactic Ghoul losing his appetite? (http://www.thespacereview.com/article/232/1)". *The space review*. . Retrieved 2007-03-27.

[96] " Mariner 9: Overview (http://solarsystem.nasa.gov/missions/profile.cfm?MCode=Mariner_09)". NASA. .

[97] " Other Mars Missions (http://burro.astr.cwru.edu/stu/20th_far_mars.html)". *Journey through the galaxy*. . Retrieved 2006-06-13.

[98] " Mars Global Surveyor (http://www.cnn.com/TECH/9706/pathfinder/surveyor/)". *CNN- Destination Mars*. . Retrieved 2006-06-13.

[99] " Mars Pulls Phoenix In (http://phoenix.lpl.arizona.edu/05_25_pr.php)". *University of Arizona Phoenix mission Website*. . Retrieved 2008-05-25.

[100] " Phoenix: The Search for Water (http://www.nasa.gov/missions/solarsystem/phoenix_water.html)". *NASA website*. . Retrieved 2007-03-03.

[101] " Frozen Water Confirmed on Mars (http://uanews.org/node/20276)". UANews.org. . Retrieved 2008-08-24.

[102] " NASA Mars Mission declared dead (http://news.bbc.co.uk/2/hi/science/nature/7721032.stm)". BBC. November 10, 2008. . Retrieved 2008-11-10.

[103] " NASA's Mars Odyssey Shifting Orbit for Extended Mission (http://mars.jpl.nasa.gov/odyssey/newsroom/pressreleases/20081009a.html)". *nasa.com*. October 9, 2008. . Retrieved 2008-11-15.

[104] Britt, Robert (March 14, 2003). " Odyssey Spacecraft Generates New Mars Mysteries (http://www.space.com/missionlaunches/odyssey_update_030314.html)". *Space.com*. . Retrieved 2006-06-13.

[105] Wardell, Jane (January 26, 2004). " Europe's Beagle 2 Mars Probe Stays Ominously Silent (http://www.space.com/missionlaunches/beagle_update_040126.html)". *Space.com*. . Retrieved 2006-06-13.

[106] Bertaux, Jean-Loup; *et al*. (June 9, 2005). " Discovery of an aurora on Mars (http://www.nature.com/nature/journal/v435/n7043/abs/nature03603.html)". *Nature Magazine*. . Retrieved 2006-06-13.

[107] " Mars Exploration Rovers- Science (http://marsrovers.jpl.nasa.gov/science/)". *NASA MER website*. . Retrieved 2006-06-13.

[108] " Photo shows avalanche on Mars (http://edition.cnn.com/2008/TECH/space/03/03/mars.avalanche.ap/index.html)". *CNN*. . Retrieved 2008-03-04.

[109] " Mars Science Laboratory (http://mars.jpl.nasa.gov/msl/overview/)". *NASA's MSL website*. . Retrieved 2007-03-03.

[110] " NASA Selects 'MAVEN' Mission to Study Mars Atmosphere (http://www.nasa.gov/mission_pages/mars/news/maven_20080915.html)". Nasa.gov. . Retrieved 2009-09-20.

[111] Rincon, Paul (November 10, 2006). " European Mars launch pushed back (http://news.bbc.co.uk/2/hi/science/nature/6133712.stm)". . Retrieved 2006-10-10.

[112] " Introduction to the MetNet Mars Mission (http://www.ava.fmi.fi/metnet-portal/?sivu=mainpage)". Finnish Meteorological Institute. . Retrieved 2008-08-28.

[113] " The MetNet Mars Precursor Mission (http://www.ava.fmi.fi/metnet-portal/precursor/?sivu=launch)". Finnish Meteorological Institute. . Retrieved 2008-08-28.

[114] Britt, Robert. " When do we get to Mars? (http://www.space.com/news/bush_plan_faq_040115.html#whenmars)". *Space.com FAQ: Bush's New Space Vision*. . Retrieved 2006-06-13.

[115] " NASA aims to put man on Mars by 2037 (http://www.marsdaily.com/reports/NASA_aims_to_put_man_on_Mars_by_2037_999.html)". AFP. . (Bad link)

[116] " Liftoff for Aurora: Europe's first steps to Mars, the Moon and beyond (http://www.esa.int/SPECIALS/Aurora/ESAONKTHN6D_0.html)". October 11, 2002. . Retrieved 2007-03-03.

[117] " The Mars Homestead Project — Arrive, Survive, & Thrive!™ (http://www.marshome.org/)". Marshome.org. . Retrieved 2009-09-20.

[118] " Aldrin: Mars Pioneers Should Not Return to Earth (http://www.universetoday.com/2008/10/23/aldrin-mars-pioneers-should-not-return-to-earth/)". Universe Today. . Retrieved 2009-09-20.

[119] " Deimos (http://www.planetary.org/explore/topics/mars/deimos.html)". *Planetary Societies's Explore the Cosmos*. . Retrieved 2006-06-13.

[120] lloyd, john; john mitchinson (2006). *The QI Book of General Ignorance* (http://en.wikipedia.org/wiki/The_Book_of_General_Ignorance). Britain: faber and faber limited. p. 299. ISBN 978-0-571-24139-2. .

[121] " Mars Observing FAQ (http://www.shallowsky.com/mars.html)". *Shallow Sky*. . Retrieved 2006-06-15.

[122] Rao, Joe (August 22, 2003). " NightSky Friday – Mars and Earth: The Top 10 Close Passes Since 3000 B.C. (http://www.space.com/spacewatch/mars_10_closest_030822.html)". *Space.com*. . Retrieved 2006-06-13.

[123] Breyer, Stephen (March 1979). "Mutual Occultation of Planets". *Sky and Telescope* **57 #3**: 220.

[124] Snyder, Dave (May 2001). " An Observational History of Mars (http://www.umich.edu/~lowbrows/reflections/2001/dsnyder.7.html)". . Retrieved 2007-02-26.

[125] Sagan, Carl (1980). *Cosmos*. New York, USA: Random House. p. 107. ISBN 0394502949.

[126] Zahnle K. (2001). "Decline and fall of the Martian empire". *Nature* **412**: 209–213. doi: 10.1038/35084148 (http://dx.doi.org/10.1038/35084148).
[127] Salisbury F. B. (1962). " Martian Biology (http://links.jstor.org/sici?sici=0036-8075(19620406)3:136:3510<17:MB>2.0.CO;2-R)". *Science* **136** (3510): 17–26. . Retrieved 2007-02-26.
[128] Sheehan, William (February 2, 1997). " Motions of Mars (http://www.uapress.arizona.edu/onlinebks/mars/chap01.htm)". *The Planet Mars: A History of Observation and Discovery*. . Retrieved 2006-06-13.
[129] " Planet Symbols (http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=167)". *NASA solar system exploration*. . Retrieved 2006-06-13.
[130] " Percivel Lowell's Canals (http://prion.bchs.uh.edu/Mars/Percival_Lowell.htm)". . Retrieved 2007-03-01.
[131] Fergus, Charles (May 2004). " Mars Fever (http://www.rps.psu.edu/0305/mars.html)". *Research/Penn State* **24** (2). . Retrieved 2007-08-02.
[132] Tesla, Nikola (February 19, 1901). " Talking with the Planets (http://earlyradiohistory.us/1901talk.htm)". Collier's Weekly. . Retrieved 2007-05-04.
[133] Cheney, Margaret (1981). *Tesla, man out of time*. Englewood Cliffs, New Jersey: Prentice-Hall. p. 162. ISBN 978-0-13-906859-1. OCLC 7672251 (http://worldcat.org/oclc/7672251).
[134] "Departure of Lord Kelvin", The New York Times, May 11, 1902, p.29.
[135] Professor Pickering (January 16, 1901). " The Light Flash From Mars (http://nbgoku23.googlepages.com/marslight.pdf)" (PDF). The New York Times. Archived from the original (http://select.nytimes.com/gst/abstract.html?res=F10D15FE3F5E137A8EDDAF0994D9405B818CF1D3) on 2007-05-20. . Retrieved 2007-05-20.
[136] Sagan, Carl (1980). *Cosmos*. New York, USA: Random House. p. 106. ISBN 0394502949.
[137] " Radio's War of the Worlds Broadcast (1938) (http://members.aol.com/jeff1070/wotw.html)". . Retrieved 2007-03-01.
[138] " Swift, Jonathan and the moons of Mars (http://www.daviddarling.info/encyclopedia/S/Swift.html)". David Darling. . Retrieved 2007-03-01.
[139] Kathy Miles and Charles F Peters II. " Unmasking the Face (http://starryskies.com/Artshtml/dln/5-98/mars.html)". . Retrieved 2007-03-01.

# Solstice

| UTC date and time of solstices and equinoxes[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **year** | **Equinox Mar** | | **Solstice June** | | **Equinox Sept** | | **Solstice Dec** | |
| | **day** | **time** | **day** | **time** | **day** | **time** | **day** | **time** |
| **2004** | 20 | 06:49 | 21 | 00:57 | 22 | 16:30 | 21 | 12:42 |
| **2005** | 20 | 12:33 | 21 | 06:46 | 22 | 22:23 | 21 | 18:35 |
| **2006** | 20 | 18:26 | 21 | 12:26 | 23 | 04:03 | 22 | 00:22 |
| **2007** | 21 | 00:07 | 21 | 18:06 | 23 | 09:51 | 22 | 06:08 |
| **2008** | 20 | 05:48 | 20 | 23:59 | 22 | 15:44 | 21 | 12:04 |
| **2009** | 20 | 11:44 | 21 | 05:45 | 22 | 21:18 | 21 | 17:47 |
| **2010** | 20 | 17:32 | 21 | 11:28 | 23 | 03:09 | 21 | 23:38 |
| **2011** | 20 | 23:21 | 21 | 17:16 | 23 | 09:04 | 22 | 05:30 |
| **2012** | 20 | 05:14 | 20 | 23:09 | 22 | 14:49 | 21 | 11:11 |
| **2013** | 20 | 11:02 | 21 | 05:04 | 22 | 20:44 | 21 | 17:11 |
| **2014** | 20 | 16:57 | 21 | 10:51 | 23 | 02:29 | 21 | 23:03 |
| **2015** | 20 | 22:45 | 21 | 16:38 | 23 | 08:20 | 22 | 04:48 |
| **2016** | 20 | 04:30 | 20 | 22:34 | 22 | 14:21 | 21 | 10:44 |
| **2017** | 20 | 10:28 | 21 | 04:24 | 22 | 20:02 | 21 | 16:28 |

A **solstice** is an astronomical event that happens twice each year, when the tilt of the Earth's axis is most inclined toward or away from the Sun, causing the Sun's apparent position in the sky to reach its northernmost or southernmost extreme. The name is derived from the Latin *sol* (sun) and *sistere* (to stand still), because at the solstices, the Sun stands still in declination; that is, the apparent movement of the Sun's path north or south comes to a stop before reversing direction.

The term *solstice* can also be used in a broader sense, as the date (day) when this occurs. The solstices, together with the equinoxes, are connected with the seasons. In some cultures they are considered to start or separate the seasons while in others they fall in the middle.

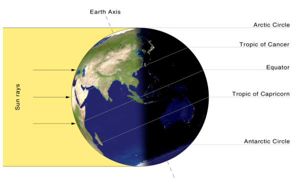
## Definitions and frames of reference

Of the many ways in which **solstice** can be defined, one of the most common (and perhaps most easily understood) is by the astronomical phenomenon for which it is named, which is readily observable by anyone on Earth: a "sun-standing." This modern scientific word descends from a Latin scientific word in use in the late Roman republic of the 1st century BC: *solstitium*. Pliny uses it a number of times in his *Natural History* with the same meaning that it has today. It contains two Latin-language segments, *sol*, "sun", and *-stitium*, "stoppage."[2] The Romans used "standing" to refer to a component of the relative velocity of the Sun as it is observed in the sky. Relative velocity is the motion of an object from the point of view of an observer in a frame of reference. From a fixed position on the ground, the sun appears to orbit around the Earth.[3]

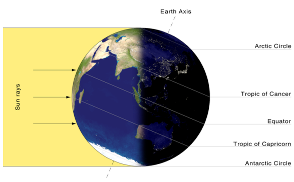
To an observer in inertial space, the Earth is seen to rotate about an axis and revolve around the Sun in an elliptical path with the Sun at one focus. The Earth's axis is tilted with respect to the plane of the Earth's orbit and this axis maintains a position that changes little with respect to the background of stars. An observer on Earth therefore sees a solar path that is the result of both rotation and revolution.

The component of the Sun's motion seen by an earthbound observer caused by the revolution of the tilted axis, which, keeping the same angle in space, is oriented toward or away from the Sun, is an observed diurnal increment (and lateral offset) of the elevation of the Sun at noon for approximately six months and observed daily decrement for the remaining six months. At maximum or minimum elevation the relative motion at 90° to the horizon stops and changes direction by 180°. The maximum is the summer solstice and the minimum is the winter solstice. The path of the Sun, or ecliptic, sweeps north and south between the northern and southern hemispheres. The days are longer around the summer solstice and shorter around the winter solstice. When the Sun's path crosses the equator, the days and nights are of equal length; this is known as an equinox. There are two solstices and two equinoxes.[4]

## Heliocentric view of the seasons




Illumination of Earth by Sun at the northern solstice.




Illumination of Earth by Sun at the southern solstice.

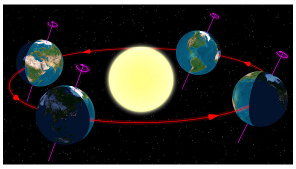


Diagram of the Earth's seasons as seen from the north. Far right: southern solstice

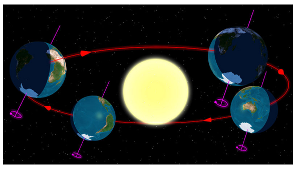


Diagram of the Earth's seasons as seen from the south. Far left: northern solstice

The cause of the seasons is that the Earth's axis of rotation is not perpendicular to its orbital plane (the flat plane made through the center of mass (barycenter) of the solar system (near or within the Sun) and the successive locations of Earth during the year), but currently makes an angle of about 23.44° (called the "obliquity of the ecliptic"), and that the axis keeps its orientation with respect to inertial space. As a consequence, for half the year (from around 20 March to 22 September) the northern hemisphere is inclined toward the Sun, with the maximum around 21 June, while for the other half year the southern hemisphere has this distinction, with the maximum around 21 December. The two moments when the inclination of Earth's rotational axis has maximum effect are the solstices.

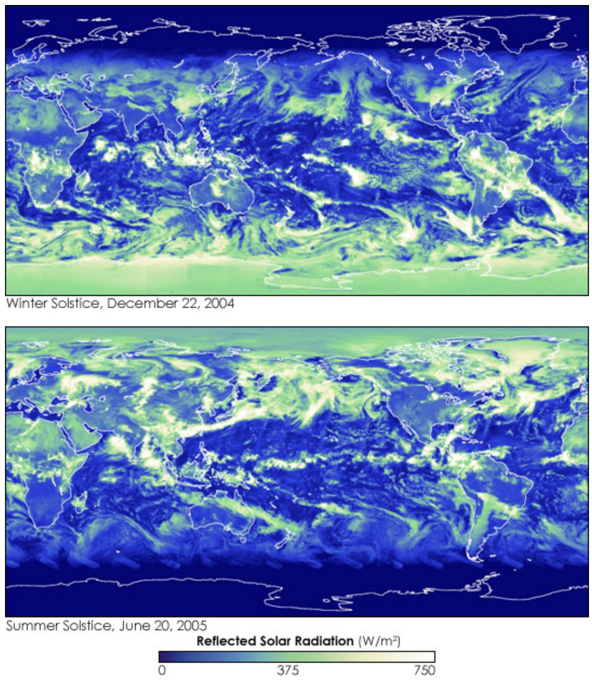
The table at the top of the article gives the instances of equinoxes and solstices over several years. Refer to the equinox article for some remarks.

At the northern solstice the subsolar point reaches to 23.44° north, known as the tropic of Cancer. Likewise at the southern solstice the same thing happens for latitude 23.44° south, known as the tropic of Capricorn. The sub-solar point will cross every latitude between these two extremes exactly twice per year.

Also during the northern solstice, places situated at latitude 66.56° north, known as the Arctic Circle will see the Sun just on the horizon during midnight, and all places north of it will see the Sun above horizon for 24 hours. That is the midnight sun or midsummer-night sun or polar day. On the other hand, places at latitude 66.56° south, known as the Antarctic Circle will see the Sun just on the horizon during midday, and all places south of it will not see the Sun above horizon at any time of the day. That is the polar night. During the southern solstice the effects on both hemispheres are just the opposite.

At the temperate latitudes, during summer the Sun remains longer and higher above the horizon, while in winter it remains shorter and lower. This is the cause of summer heat and winter cold.

The seasons are not caused by the varying distance of Earth from the Sun due to the orbital eccentricity of the Earth's orbit. This variation does make a contribution, but is small compared with the effects of exposure because of Earth's tilt. Currently the Earth reaches perihelion at the beginning of January - the beginning of the northern winter and the southern summer. Although the Earth is at its closest to the Sun and therefore receiving more heat, the whole planet is not in summer. Although it is true that the northern winter is somewhat warmer than the southern winter, the placement of the continents may also play an important factor. In the same way, during aphelion at the beginning of July, the Sun is farther away, but that still leaves the northern summer and southern winter as they are with only minor effects.

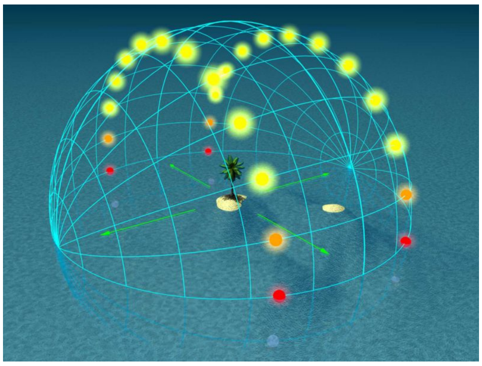



Two images showing the amount of reflected sunlight at southern and northern summer solstices respectively (watts / m²).

Due to Milankovitch cycles, the Earth's axial tilt and orbital eccentricity will change over thousands of years. Thus in 10,000 years one would find that Earth's northern winter occurs at aphelion and its northern summer at perihelion. The severity of seasonal change—the average temperature difference between summer and winter in location—will also change over time because the Earth's axial tilt fluctuates between 22.1 and 24.5 degrees.

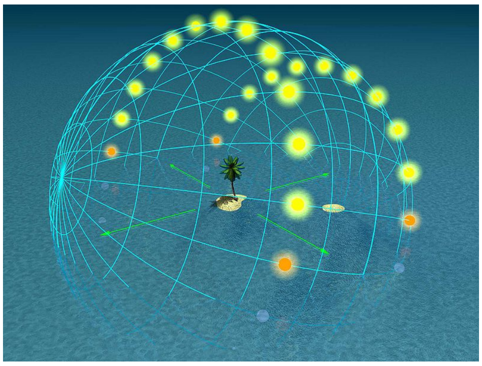
## Geocentric view of the seasons

The explanation given in the previous section is useful for observers in outer space. They would see how the Earth revolves around the Sun and how the distribution of sunlight on the planet would change over the year. To observers on Earth, it is also useful to see how the Sun seems to revolve around them. These pictures show such a perspective as follows. They show the day arcs of the Sun, the paths the Sun tracks along the celestial dome in its diurnal movement. The pictures show this for every hour on both solstice days. The longer arc is always the summer track and the shorter one the winter track. The two tracks are at a distance of 46.88° (2 × 23.44°) away from each other.



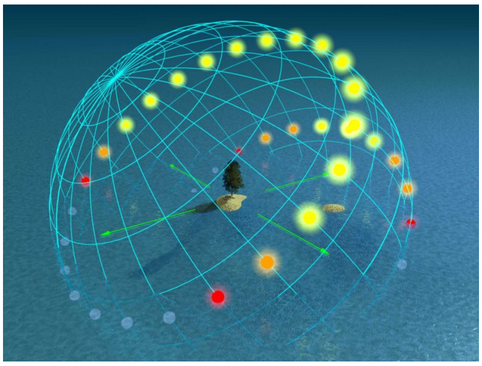
Day arcs at 0° latitude, equator

In addition, some 'ghost' suns are indicated below the horizon, as much as 18° down. The Sun in this area causes twilight. The pictures can be used for both the northern and southern hemispheres. The observer is supposed to sit near the tree on the island in the middle of the ocean. The green arrows give the cardinal directions.



Day arcs at 20° latitude

- On the northern hemisphere the north is to the left, the Sun rises in the east (far arrow), culminates in the south (to the right) while moving to the right and sets in the west (near arrow). Both rise and set positions are displaced towards the north in summer, and towards the south for the winter track.
- On the southern hemisphere the south is to the left, the Sun rises in the east (near arrow), culminates in the north (to the right) while moving to the left and sets in the west (far arrow). Both rise and set positions are displaced towards the south in summer, and towards the north for the winter track.



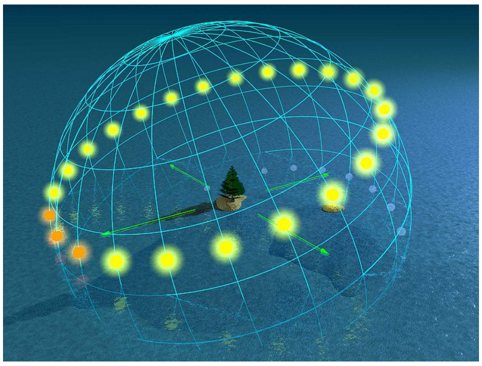
Day arcs at 50° latitude

The following special cases are depicted.

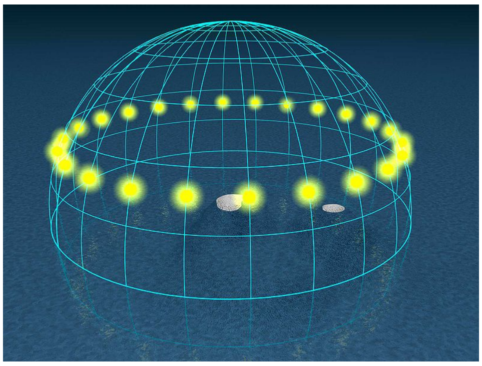
- On the equator the Sun is not overhead every day, as some people think. In fact that happens only on two days of the year, the equinoxes. The solstices are the dates that the Sun stays farthest away from the zenith, only reaching an altitude of 66.56° either to the north or the south. The only thing special about the equator is that all days of the year, solstices included, have roughly the same length of about 12 hours, so that it makes no sense to talk about summer and winter. Instead, tropical areas often have wet and dry seasons.
- The day arcs at 20° latitude. The Sun culminates at 46.56° altitude in winter and 93.44° altitude in summer. In this case an angle larger than 90° means that the culmination takes place at an altitude of 86.56° in the opposite cardinal direction. For example in the southern hemisphere, the Sun remains in the

north during winter, but can reach over the zenith to the south in midsummer. Summer days are longer than winter days, but the difference is no more than two or three hours. The daily path of the Sun is steep at the horizon the whole year round, resulting in a twilight of only about one hour.

- The day arcs at 50° latitude. The winter Sun does not rise more than 16.56° above the horizon at midday, and 63.44° in summer above the same horizon direction. The difference in the length of the day between summer and winter is striking - slightly less than 8 hours at midwinter, to slightly more than 16 hours in midsummer. Likewise is the difference in direction of sunrise and sunset. Also note the steepness of the daily path of the Sun above the horizon. It is much shallower than at 20° latitude. Therefore not only is the Sun not reaching as high, it also seems not to be in a hurry to do so. But conversely this means that the Sun is not in a hurry to dip deeply below the horizon at night. At this latitude at midnight the summer sun is only 16.56° below the horizon, which means that *astronomical twilight* continues the whole night. This phenomenon is known as the *grey nights*, nights when it does not get dark enough for astronomers to do their observations. Above 60° latitude the Sun would be even closer to the horizon, only 6.56° away from it. Then *civil twilight* continues the whole night. This phenomenon is known as the *white nights*. And above 66.56° latitude, of course, one would get the midnight sun.



Day arcs at 70° latitude



Day arcs at 90° latitude, pole

- The day arcs at 70° latitude. At local noon the winter Sun culminates at −3.44°, and the summer Sun at 43.44°. Said another way, during the winter the Sun does not rise above the horizon, it is the polar night. There will be still a strong twilight though. At local midnight the summer Sun culminates at 3.44°, said another way, it does not set, it is the polar day.
- The day arcs at the pole. At the time of the summer or winter solstices, the Sun is 23.44° degrees above or below the horizon respectively, irrespective of time of day. Whilst the Sun is up (during summer months) it will circle around the whole sky, appearing to stay at same angle from the horizon, therefore the concept of day or night is meaningless. The angle of elevation will gradually change on an annual cycle, with the Sun reaching its highest point at the summer Solstice, and rising or setting at the Equinox, with extended periods of twilight lasting several days after the autumn equinox and before the spring equinox.

# Cultural aspects

## Ancient Greek names and concepts

The concept of the solstices was embedded in ancient Greek celestial navigation. As soon as they discovered that the Earth is spherical[5] they devised the concept of the celestial sphere,[6] an imaginary spherical surface rotating with the heavenly bodies (ouranioi) fixed in it (the modern one does not rotate, but the stars in it do). As long as no assumptions are made concerning the distances of those bodies from Earth or from each other, the sphere can be accepted as real and is in fact still in use.

The stars move across the inner surface of the celestial sphere along the circumferences of circles in parallel planes[7] perpendicular to the Earth's axis extended indefinitely into the heavens and intersecting the celestial sphere in a celestial pole.[8] The Sun and the planets do not move in these parallel paths but along another circle, the ecliptic, whose plane is at an angle, the obliquity of the ecliptic, to the axis, bringing the Sun and planets across the paths of and in among the stars.*

Cleomedes states:[9]

> The band of the Zodiac (*zōdiakos kuklos*, "zodiacal circle") is at an oblique angle (*loksos*) because it is positioned between the tropical circles and equinoctial circle touching each of the tropical circles at one point … This Zodiac has a determinable width (set at 8° today) … that is why it is described by three circles: the central one is called "heliacal" (*hēliakos*, "of the sun").

The term heliacal circle is used for the ecliptic, which is in the center of the zodiacal circle, conceived as a band including the noted constellations named on mythical themes. Other authors use Zodiac to mean ecliptic, which first appears in a gloss of unknown author in a passage of Cleomedes where he is explaining that the Moon is in the zodiacal circle as well and periodically crosses the path of the Sun. As some of these crossings represent eclipses of the Moon, the path of the Sun is given a synonym, the *ekleiptikos (kuklos)* from *ekleipsis*, "eclipse."

## English names

The two solstices can be distinguished by different pairs of names, depending on which feature one wants to stress.

- **Summer Solstice** and **Winter solstice** are the most common names. However, these can be ambiguous since seasons of the northern hemisphere and southern hemisphere are opposites, and the summer solstice of one hemisphere is the winter solstice of the other. These are also known as the 'longest' or 'shortest' days of the year.
- **Northern Solstice** and **Southern Solstice** indicate the direction of the Sun's apparent movement. The northern solstice is in June on Earth, when the Sun is directly over the Tropic of Cancer in the Northern Hemisphere, and the southern solstice is in December, when the Sun is directly over the Tropic of Capricorn in the Southern Hemisphere.
- **June Solstice** and **December Solstice** are an alternative to the more common "summer" and "winter" terms, but without the ambiguity as to which hemisphere is the context. They are still not universal, however, as not all people use a solar-based calendar where the solstices occur every year in the same month (as they do not in the Islamic Calendar and Hebrew calendar, for example), and the names are not useful for other planets (Mars, for example), even though these planets do have seasons.
- **First point of Cancer** and **first point of Capricorn**. One disadvantage of these names is that, due to the precession of the equinoxes, the astrological signs where these solstices are located no longer correspond with the actual constellations.
- **Taurus solstice** and **Sagittarius solstice** are names that indicate in which constellations the two solstices are currently located. These terms are not widely used, though, and until December 1989 the first solstice was in Gemini, according to official IAU boundaries.
- The Latin names **Hibernal solstice** (winter), and **Aestival solstice** (summer) are sometimes used.

## Solstice terms in East Asia

The traditional East Asian calendars divide a year into 24 solar terms (節氣). **Xiàzhì** (pīnyīn) or **Geshi** (rōmaji) (Chinese and Japanese: 夏至; Korean: 하지(Haji); Vietnamese: Hạ chí; literally: "*summer's extreme*") is the 10th solar term, and marks the **summer solstice**. It begins when the Sun reaches the celestial longitude of 90° (around June 21) and ends when the Sun reaches the longitude of 105° (around July 7). Xiàzhì more often refers in particular to the day when the Sun is exactly at the celestial longitude of 90°.

**Dōngzhì** (pīnyīn) or **Tōji** (rōmaji) (Chinese and Japanese: 冬至; Korean: 동지(Dongji); Vietnamese: Đông chí; literally: "*winter's extreme*") is the 22nd solar term, and marks the **winter solstice**. It begins when the Sun reaches the celestial longitude of 270° (around December 22 ) and ends when the Sun reaches the longitude of 285° (around January 5). Dōngzhì more often refers in particular to the day when the Sun is exactly at the celestial longitude of 270°.

The solstices (as well as the equinoxes) mark the *middle* of the seasons in East Asian calendars. Here, the Chinese character 至 means "extreme", so the terms for the solstices directly signify the summits of summer and winter, a linkage that may not be immediately obvious in Western languages.

## Solstice celebrations

The term *solstice* can also be used in a wider sense, as the date (day) that such a passage happens. The solstices, together with the equinoxes, are connected with the seasons. In some languages they are considered to start or separate the seasons; in others they are considered to be center points (in English, in the Northern hemisphere, for example, the period around the June solstice is known as midsummer, and Midsummer's Day is 24 June, about three days after the solstice itself). Similarly 25 December is the start of the Christmas celebration, and is the day the Sun begins to return to the northern hemisphere.

Many cultures celebrate various combinations of the winter and summer solstices, the equinoxes, and the midpoints between them, leading to various holidays arising around these events. For the December solstice, Christmas is the most popular holiday to have arisen. In addition, Yalda, Saturnalia, Karachun, Hanukkah, Kwanzaa and Yule (see winter solstice for more) are also celebrated around this time. For the June solstice, Christian cultures celebrate the feast of St. John from June 23 to June 24 (see St. John's Eve, Ivan Kupala Day, Midsummer), while Neopagans observe Midsummer. For the vernal (spring) equinox, several spring-time festivals are celebrated, such as the observance in Judaism of Passover. The autumnal equinox has also given rise to various holidays, such as the Jewish holiday of Sukkot. At the midpoints between these four solar events, cross-quarter days are celebrated.

In many cultures the solstices and equinoxes traditionally determine the midpoint of the seasons, which can be seen in the celebrations called midsummer and midwinter. Along this vein, the Japanese celebrate the start of each season with an occurrence known as Setsubun. The cumulative cooling and warming that result from the tilt of the planet become most pronounced *after* the solstices.

In the Hindu calendar, two sidereal solstices are named Uttarayana and Dakshinayana. The former occurs around January 14 each year, while the latter occurs around July 14 each year. These mark the movement of the Sun along a sidereally fixed zodiac (precession is ignored) into Mesha, a zodiacal sign which corresponded with Aries about 285, and into Tula, the opposite zodiacal sign which corresponded with Libra about 285.

## Solstice determination

Unlike the equinox, the solstice time is not easy to determine. The changes in Solar declination become smaller as the sun gets closer to its maximum/minimum declination. The days before and after the solstice, the declination speed is less than 30 arcseconds/day which is less than 1/60th of the angular size of the sun, or the equivalent to just 2 seconds of right ascension.

This difference is hardly detectable with indirect viewing based devices like sextant equipped with a vernier, and impossible with more traditional tools like a gnomon[10] or an astrolabe. It is also hard to detect the changes on sunrise/sunset azimuth due to the atmospheric refraction[11] changes. Those accuracy issues render impossible to determine the solstice day based on observations made within the 3 (or even 5) days surrounding the solstice, without the use of more complex tools.

Ptolemy used an approximation method based on interpolation, which is still used by some amateurs. This method consists of recording the declination angle at noon during some days before and after the solstice, trying to find two separate days with the same declination. When those two days are found, the halfway time between both noons is estimated solstice time. An interval of 45 days has been postulated, as the best one to achieve up to a quarter-day precision, in the solstice determination[12] .

## See also

- Midsummer
- Winter solstice
- Zoroastrian calendar
- Iranian calendar

## External links

- "Do Your Own Test: ELEVATION [13]" (html). The solstice amateur. 2001. Retrieved 2009-03-07.

### Calculations, plots and tables

- "Earth's Seasons, Equinoxes, Solstices, Perihelion, and Aphelion, 2000–2020 [12]". United States Naval Observatory, Astronomical Applications Department.
- Weisstein, Eric (1996–2007). "Summer Solstice [14]". Eric Weisstein's World of Astronomy. Retrieved 2008-10-24. "The above plots show how the date of the summer solstice shifts through the Gregorian calendar according to the insertion of leap years."
- Solstice Dates and Times [15]
- Solstice, Equinox & Cross-Quarter Moments for 2009 and other years, for several timezones [16]
- Calculation of Length of Day [10] (Formulas and Graphs)
- Calculate the Time of Solstices in Excel, CAD or your other programs. [17] The Sun API is freeware and claimed accurate. For Microsoft Windows Operating Systems (presumably 32-bit only) (Note DLL may run under Wine (software)).

### Debate about season start

- The seasons begin at the time of the solstice or equinox [18] (from the Bad Astronomer)
- Solstice does not signal season's start? [19] (from the The Straight Dope)

### Pictures and videos

- Video of Winter Solstices Celebration at Stonehenge [20]

## References

[1] United States Naval Observatory (01/28/07). " Earth's Seasons: Equinoxes, Solstices, Perihelion, and Aphelion, 2000-2020 (http://aa.usno.navy.mil/data/docs/EarthSeasons.php)". .

[2] " solstice (http://www.bartleby.com/61/24/S0552400.html)" (html). The American Heritage Dictionary of the English Language: Fourth Edition. 2000. . Retrieved 2008-10-23.

[3] The Principle of relativity was first applied to inertial frames of reference by Albert Einstein. Before then the concepts of absolute time and space applied by Isaac Newton prevailed. The motion of the Sun across the sky is still called "apparent motion" in celestial navigation in deference to the Newtonian view, but the reality of the supposed "real motion" has no special laws to commend it, both are visually verifiable and both follow the same laws of physics.

[4] For an introduction to these topics of astronomy refer to Bowditch, Nathaniel (1995 Edition) (pdf). *The American Practical Navigator: an Epitome of Navigation* (http://www.irbs.com/bowditch/pdf/chapt15.pdf). Bethesda, Maryland: National Imagery and Mapping Agency. pp. Chapter 15 *Navigational Astronomy'. . Retrieved 2008-10-19.*

[5] Strabo. *The Geography*. pp. II.5.1. "sphairikē … tēs gēs epiphaneia, spherical is the surface of the Earth"

[6] Strabo. *The Geography*. pp. II.5.2. "sphairoeidēs ... ouranos, spherical in appearance … is heaven"

[7] Strabo II.5.2., "aplaneis asteres kata parallēlōn pherontai kuklōn", "the fixed stars are borne in parallel circles"

[8] Strabo II.5.2, "ho di'autēs (gē) aksōn kai tou ouranou mesou tetagmenos", "the axis through it (the Earth) extending through the middle of the sky"

[9] Cleomedes; Alan C. Bowen; Robert B. Todd (Translators) (2004). *Cleomedes' Lectures on Astronomy: A Translation of The Heavens*. Berkeley: University of California Press. pp. 41. ISBN 0520233255, ISBN 9780520233256. This translation cites this passage at the end of Book I Chapter 2 but other arrangements have it at the start of Chapter 3. In the Greek version of Cleomedes; Hermann Ziegler (Editor)

(1891). *Cleomedis De motu circulari corporum caelestium libri duo*. B. G. Teubneri. pp. 32. the passage starts Chapter 4.
[10] Mollerup, Asger (2008). " Solstice Determination based on Observations (http://www.sundial.thai-isan-lao.com/solstice-determination.html)" (html). . Retrieved 2009-03-07.
[11] Exton, Harold (1992). " A Fresh Analysis of Some Recent Data on Atmospheric Refraction Near the Horizon with Implications in Archaeoastronomy (http://adsabs.harvard.edu/abs/1992JHAS...23...57E)". *Journal of History of Astronomy, Archaeoastronomy Supplement, Vol. 23, p.S57* **23**: S57. . Retrieved 2009-03-26.
[12] Hugh, Thurston (2001). " Early Greek Solstices and Equinoxes (http://adsabs.harvard.edu/abs/2001JHA....32..154T)". *Journal for the History of Astronomy* **32, Part 2** (107): 154-156. ISSN 0021-8286 (http://worldcat.org/issn/0021-8286). . Retrieved 2009-03-07.
[13] http://www.solsticeamateur.com/Do%20It%20Yourself%20Frame%20Set.htm
[14] http://scienceworld.wolfram.com/astronomy/SummerSolstice.html
[15] http://www.islandnet.com/~see/weather/almanac/seasondate.htm
[16] http://www.archaeoastronomy.com/2009.shtml
[17] http://www.sunlit-design.com/products/thesunapi/documentation/sdxFindAnnFeatx.php
[18] http://www.badastronomy.com/bad/misc/badseasons.html
[19] http://www.straightdope.com/classics/a1_170b.html
[20] http://www.youtube.com/watch?v=cxIHGaIn4KM

# Sunrise

Sunrise over the Bristol Channel, England

**Sunrise** is the instant at which the upper edge of the Sun appears above the horizon in the east. Sunrise should not be confused with dawn, which is the (variously defined) point at which the sky begins to lighten, some time before the sun itself appears, ending twilight. Because atmospheric refraction causes the sun to be seen while it is still below the horizon, both sunrise and sunset are, from one point of view, optical illusions. The sun also exhibits an optical illusion at sunrise similar to the moon illusion.

The apparent westward revolution of Sun around the earth after rising out of the horizon is due to the Earth's eastward rotation, a counter-clockwise revolution when viewed from above the North Pole. This illusion is so convincing that most cultures had mythologies and religions built around the geocentric model. This same effect can be seen with near-polar satellites as well.

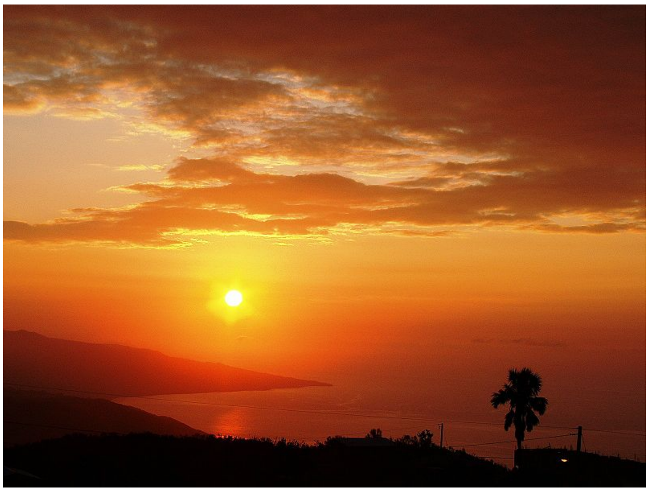
Sunrise and sunset are calculated from the leading and trailing edges of the Sun, and not the center; this slightly increases the duration of "day" relative to "night". The sunrise equation, however, is based on the center of the sun.

The timing of sunset with respect to longitude time varies with the time of year and the latitude of the viewer's location. The precise local time of sunset depends upon the viewer's precise longitude the time zone of the viewer's location. Small daily changes and noticeable semi-annual changes in timing of sunrise are driven by the axial tilt of Earth and the planet's movement in its annual orbit around the sun. Some apparent anomalies exist however. In the Northern Hemisphere, the latest sunrise does not occur on the winter solstice around December 21, but rather in early January. Likewise, the earliest sunrise does not fall on the summer solstice around June 21, but occurs earlier in June in the Northern Hemisphere. As one travels farther from the equator, the times of sunrise and sunset change throughout the year. Even on the equator, sunrise and sunset shift several minutes back and forth through the year, along with solar noon. These effects are plotted using an analemma.

Due to Earth's axial tilt, whenever and wherever sunrise occurs, it is always in the northeast quadrant from the March equinox to the September equinox and in the southeast quadrant from the September equinox to the March equinox.

Sunrises occur precisely due east on the March and September equinoxes for all viewers on Earth. The sunrise and sunset times for a 12 hr day and 12 hr night do not fall on the "equinox" (equal night), since the timing of sunrises and sunsets, and hence, the lengths of day and night vary with each viewer's particular latitude.

## Colors



A sunrise with the typical orange colour in the sky (south beach of Jamaica).

The intense red and orange hues of the sky at sunrise and sunset are mainly caused by scattering of sunlight by dust particles, soot particles, other solid aerosols, and liquid aerosols in the Earth's atmosphere. These enhanced red and orange colors at sunrise and sunset are mathematically explained by the Mie theory or the discrete dipole approximation. When there are no particulates in the troposphere, such as after a big rain storm, then the remaining less intense reds are explained by Rayleigh Scattering of sunlight by air molecules. Sunrise colors are typically less brilliant and less intense than sunset colors, since there are generally fewer particles and aerosols in the morning air than in the evening air. Nighttime air is usually cooler and less windy, which allows dust and soot particles to settle out of the atmosphere, reducing the amount of Mie Scattering. The reduced Mie Scattering correspondingly reduces the amount of red and orange scattered light at sunrise. Sunrise color intensities can however exceed sunset's intensities when there are nighttime fires, volcanic eruptions or emissions, or dust storms to the east of the viewer. A number of eruptions in recent times, such as those of Mount Pinatubo in 1991 and Krakatoa in 1883, have been sufficiently large to produce remarkable sunsets and sunrises all over the world.

Sometimes just before sunrise or after sunset a green flash can be seen. [1] [2] [3]

## See also

This is a *False Sunrise*, a very particular kind of Parhelion

- Dawn
- Dusk
- Day
- Day length
- Daybreak
- False sunrise
- Noon
- Sunrise equation
- Sunset
- Twilight

## Gallery


Beautiful morning at the bank of Tava Reservoir, Satpura National Park, India


Sunrise as seen from Burnaby, British Columbia.

## External links

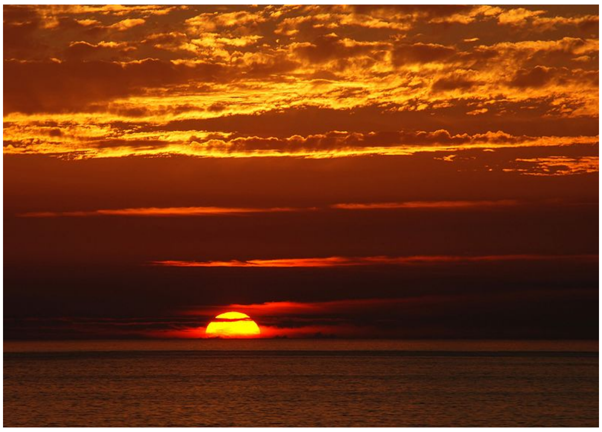
- Sunrise Sunset Moonrise Moonset Calculation , utilizing Google Maps. [4]
- Rise/Set Calculator. Find sun position for any time/location. [7]
- Sunrise and sunset calculator [5]
- SunRise_SunSet calculator [6]
- Customized Sunset, Sunrise Calculator calendar [7]
- Sun or Moon Rise/Set Table for one Year [9]
- US Navy Sunrise and Sunset calculator [8]
- Full physical explanation of sky color, in simple terms [9]
- An Excel workbook [11] with VBA functions for sunrise, sunset, solar noon, twilight (dawn and dusk), and solar position (azimuth and elevation); by Greg Pelletier [12], translated from NOAA's online calculators for solar position [10] and sunrise/sunset [13]
- sun.exnatura.org [11] Online sunrise/-set calendar with interactive location finder
- Formulas to calculate sunrise and sunset [10]
- Provides sunrise/sunset times for location specified by Google Maps [12]
- Daily almanac including Sun rise/set/twillight for every location on Earth [13]
- Monthly calendar with Sun/Moon rise/set times for every location on Earth [14]
- A Video Of Sunrise [15]
- Photos Of Sunrises [16]

## References


[1] Red Sunset, Green Flash (http://hyperphysics.phy-astr.gsu.edu/hbase/atmos/redsun.html)
[2] Selected Papers on Scattering in the Atmosphere, edited by Craig Bohren ~SPIE Optical Engineering Press, Bellingham, WA, 1989
[3] Science Made Simple (http://ucsu.colorado.edu/~kuesterm/RTweb/startRT.html)
[4] http://destiny.xfiles.to/app/calendar/StarTrans
[5] http://www.sunrisesunset.com/
[6] http://jamesrbass.com/sunset/sunRiseSet.htm
[7] http://www.chennaiiq.com/astrology/sunrise_sunset.asp
[8] http://aa.usno.navy.mil/data/docs/RS_OneDay.php
[9] http://math.ucr.edu/home/baez/physics/General/BlueSky/blue_sky.html
[10] http://www.srrb.noaa.gov/highlights/sunrise/azel.html
[11] http://sun.exnatura.org
[12] http://www.earthtools.org/
[13] http://astroclub.tau.ac.il/ephem/Daily/
[14] http://wise-obs.tau.ac.il/~eran/Wise/wise_calen.html
[15] http://www.metacafe.com/watch/2340088/sunrise/
[16] http://very-bored.com/index.php?option=com_content&task=view&id=135&Itemid=1

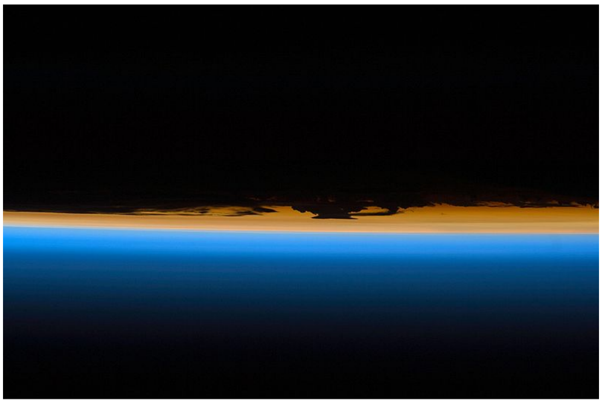

# Sunset

**Sunset** is the daily disappearance of the sun below the horizon as a result of the Earth's rotation. The atmospheric conditions created by the setting of the sun, occurring before and after it disappears below the horizon, are also commonly referred to as "sunset".


The Sun, about a minute before astronomical sunset.

The **time of sunset** is defined in astronomy as the moment the trailing edge of the sun's disk disappears below the horizon in the west. Due to refraction of light in the atmosphere, the ray path of the setting sun is highly distorted near the horizon making the apparent astronomical sunset occur when the sun’s disk is already about one diameter below the horizon. Sunset should not be confused with dusk, which is the moment at which darkness falls, when the sun is about eighteen degrees below the horizon. The period between the astronomical sunset and dusk is called twilight.

## Occurrence



Sunset from orbit.

The timing of sunset with respect to longitude time varies with the time of year and the latitude of the viewer's location. The precise local time of sunset depends upon the viewer's precise longitude the time zone of the viewer's location. Small daily changes and noticeable semi-annual changes in timing of sunset are driven by the axial tilt of Earth, the spherical shape of the Earth, and the planet's movement in its annual orbit around the sun. Some apparent anomalies exist however, the main one caused by the Earth's axial tilt and the Earth's elliptical orbit. In the Northern Hemisphere, the earliest sunset does not fall on the winter solstice around December 21, but instead it occurs earlier in December. Likewise, the latest sunset does not fall on the summer solstice around June 21, but instead it happens later in June or in early July, depending on one's latitude. The same phenomenon exists in the Southern Hemisphere except with the respective dates being some time *before* June 21 in winter and some time *after* December 21 in summer, possibly in January of the following year. For one or two weeks surrounding both solstices, both sunrise and sunset get slightly later or earlier each day. Even on the equator, sunrise and sunset shift several minutes back and forth through the year, along with solar noon. This effect is plotted by an analemma.[1] [2]

Due to Earth's axial tilt, whenever and wherever sunset occurs, sunset is always to the northwest from the March equinox to the September equinox, and to the southwest from the September equinox to the March equinox. Sunsets occur precisely due west on the equinoxes, and the duration of day and night are approximately equal on the equinoxes for all viewers on Earth (precisely 12 hours if measured from the geometric (unrefracted) centre of the sun).

As sunrise and sunset are calculated from the leading and trailing edges of the sun, and not the centre, the duration of "day" is slightly longer than "night". Further, because the light from the sun is bent by the atmospheric refraction, the sun is still visible after it is geometrically below the horizon. The sun also appears larger on the horizon, which is another optical illusion, similar to the moon illusion.

## Colours

Red sunset at Lands End, San Francisco

The intense red and orange hues of the sky at sunrise and sunset are mainly caused by scattering of sunlight by dust particles, soot particles, other solid aerosols, and liquid aerosols in the Earth's atmosphere. These enhanced red and orange colors at sunrise and sunset are mathematically explained by the Mie theory or the discrete dipole approximation. When there are no particulates in the troposphere, such as after a big rain storm, then the remaining less intense reds are explained by Rayleigh scattering of sunlight by air molecules. Sunset colors are typically more brilliant and more intense than sunrise colors, since there are generally more particles and aerosols in the evening air than in the morning air. Nighttime air is usually cooler and less windy, which allows dust and soot particles to settle out of the atmosphere, reducing the amount of Mie scattering at sunrise. The reduced Mie scattering correspondingly reduces the amount of red and orange scattered light at sunrise. Sunrise color intensities can however exceed sunset's intensities when there are nighttime fires, volcanic eruptions or emissions, or dust storms to the east of the viewer. A number of eruptions in recent times, such as those of Mount Pinatubo in 1991 and Krakatoa in 1883, have been sufficiently large to produce remarkable sunsets and sunrises all over the world.

While ash and soot from volcanic eruptions tends to mute sunset colors when trapped within the troposphere, when lofted into the stratosphere, thin clouds of tiny sulfuric acid droplets from volcanoes can yield beautiful post-sunset colors called afterglows. A number of eruptions, including those of Mount Pinatubo in 1991 and Krakatoa in 1883, have produced sufficiently high stratospheric sulfuric acid clouds to yield remarkable sunset afterglows (and pre-sunrise glows) around the world. The high altitude clouds serve to reflect strongly-reddened sunlight still striking the stratosphere after sunset, down to the surface.

Sometimes just before sunrise or after sunset a green flash can be seen.[3] [4] [5]

## Sunsets on other planets

Sunsets on other planets appear different because of the differences in the distance from the planet to the sun and in different atmospheric compositions.

Because Mars is farther from the Sun than the Earth is, the Sun appears only about two-thirds the size that it appears in a sunset seen from the Earth.[6] Although Mars lacks oxygen and nitrogen, it is covered in red dust frequently hoisted into the atmosphere by fast but thin winds.[7] At least some Martian days are capped by a sunset significantly longer and redder than typical on Earth.[7] One study found that for up to two hours after twilight, sunlight continued to reflect off Martian dust high in the atmosphere, casting a diffuse glow.[7]

Sunset on Mars.

## See also

- Afterglow
- Astronomy on Mars
- Day length
- Diffuse sky radiation
- Sunrise equation

## External links

- Accurate Sun Position Calculator - Sunrise/Sunset times worldwide [8]
- Sunsets on other planets [9] (Wikimedia Commons gallery)
- Sunrise and sunset calculator [5]
- Sunset at your location [10] by Wolfram Alpha
- Full physical explanation in simple terms [9]
- Excel workbook [11] with VBA functions for sunrise, sunset, solar noon, twilight (dawn and dusk), and solar position (azimuth and elevation); by Greg Pelletier [12], translated from NOAA's online calculators for solar position [10] and sunrise/sunset [13]
- sun.exnatura.org [11] Online sunrise/sunset calendar with interactive location finder
- The colors of twilight and sunset [14]

## References

[1] Starry Night Times - January 2007 (http://www.starrynight.com/sntimes/2007/01/) (explains why Sun appears to cross slow before early January)
[2] the analemma (http://www.analemma.com/Pages/framesPage.html), elliptical orbit effect. 'July 3rd to October 2nd the sun continues to drift to the west until it reaches its maximum "offset" in the west. Then from October 2nd until January 21, the sun drifts back toward the east'
[3] " Red Sunset, Green Flash (http://hyperphysics.phy-astr.gsu.edu/hbase/atmos/redsun.html)". .
[4] Selected Papers on Scattering in the Atmosphere, edited by Craig Bohren ~SPIE Optical Engineering Press, Bellingham, WA, 1989
[5] " Science Made Simple (http://ucsu.colorado.edu/~kuesterm/RTweb/startRT.html)". .
[6] http://photojournal.jpl.nasa.gov/catalog/PIA07997 This article incorporates text from this source, which is in the public domain.
[7] http://apod.nasa.gov/apod/ap050620.html This article incorporates text from this source, which is in the public domain.
[8] http://www.spectralcalc.com/solar_calculator/solar_position.php
[9] http://commons.wikimedia.org/wiki/Sunset#Sunsets_on_other_planets
[10] http://www58.wolframalpha.com/input/?i=sunset

# Zenith

In general terms, the **zenith** is the direction pointing directly "above" a particular location; that is, it is one of two vertical directions at the location, orthogonal to a horizontal flat surface there. The concept of "above" is more specifically defined in astronomy, geophysics and related sciences (e.g., meteorology) as the vertical direction opposite to the net gravitational force at a given location. The opposite direction, i.e. the direction of the gravitational force is called the nadir. The term *zenith* also refers to the highest point reached by a celestial body during its apparent orbit around a given point of observation.[1] This sense of the word is often used to describe the location of the Sun, but it is only technically accurate for one latitude at a time and only possible at the low latitudes.

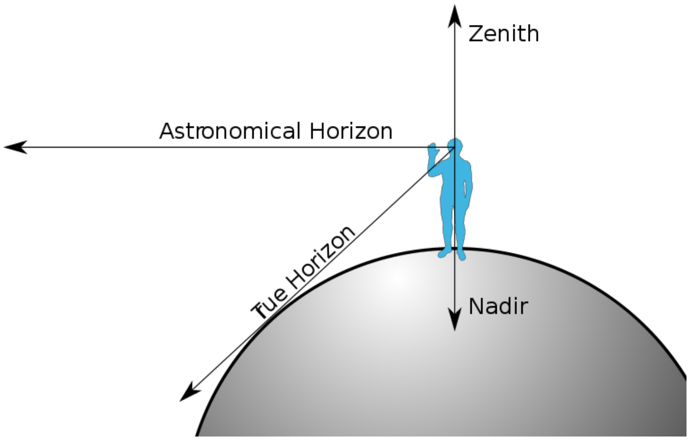



Diagram showing the relationship between the Zenith, the Nadir, and different types of Horizon. Note that the Zenith is opposite the Nadir.

Strictly speaking, the zenith is only *approximately* contained in the local meridian plane because the latter is defined in terms of the rotational characteristics of the celestial body, not in terms of its gravitational field. The two coincide only for a perfectly rotationally symmetric body. On Earth, the axis of rotation is not fixed with respect to the planet (for example due to constant displacements of its fluid components) so that the local vertical direction, as defined by the gravity field, is itself changing direction in time (for instance due to lunar and solar tides).

## Origin

The word *zenith* derives from the inaccurate reading of the Arabic expression سمت الرأس (samt ar-ra's) meaning “direction of the head”/"path above the head", by Medieval Latin scribes in the Middle Ages (during the 14th century), probably through Old Spanish. It was incorrectly reduced to 'samt' ("direction") and imprecisely written as 'senit'/'cenit' by those scribes. Through Old French 'cenith', Middle English 'senith' and finally 'zenith' 1st appears in the 17th century[2] [3]

The Arabic word for Zenith is Zawâl, meaning "decline", that is, when the sun ceases to rise and starts to decline.

## Relevance and Use

The zenith is used in the following scientific contexts:

- It serves as the direction of reference for measuring the **zenith angle**, which is the angular distance between a direction of interest (e.g., a star) and the local zenith, relative to the point for which the zenith is defined.
- It defines one of the axes of the horizontal coordinate system in astronomy.

The picture showing shadow of trees when Sun is directly above head at Zenith. It's only possible for the Sun to be at the zenith between the Tropic of Capricorn and Tropic of Cancer.

## See also

- Geodesy
- History of geodesy
- Keyhole problem
- Midheaven
- Nadir
- Subsolar point
- Vertical deflection
- Zenith distance

## References

[1] http://www.merriam-webster.com/dictionary/zenith
[2] myEtymology.com: English etymology of zenith (http://www.myetymology.com/english/zenith.html)
[3] Zenith Definition | Definition of Zenith at Dictionary.com (http://dictionary.reference.com/browse/zenith)

- Huschke, Ralph E. (1959) *Glossary of Meteorology*, American Meteorological Society, Boston, Second printing-1970.
- McIntosh, D. H. (1972) *Meteorological Glossary*, Her Majesty's Stationery Office, Met. O. 842, A.P. 897, 319 p.
- Picoche, J. (1992) *Dictionnaire Etymologique du Français*, Le Robert, Paris, ISBN 2-85036-458-4.

# Article Sources and Contributors

**Twilight** *Source*: http://en.wikipedia.org/w/index.php?oldid=331924231 *Contributors*: 0Exo-Man0, 21655, 334a, A Different World, A3RO, A8UDI, ABF, ARUNKUMAR P.R, ATren, Abce2, Abomasnow, Ac44ck, Academic Challenger, Accas1, Acdc dude 3, Ace of Spades, Acroterion, Adrian J. Hunter, Adrianinos, Agha Nader, Alansohn, Alchemist Jack, Ale jrb, Alex43223, Alexandre Gilbert, Allison 99, Alphonsus, Alpinwolf, Altenmann, Andrea105, Angel223, Annabell0994, Antandrus, AprilHare, Arkuat, Ashley Y, Avs5221, B3llit0, BD2412, Bart133, Bbycakes, Beano, Beland, Blah28948, Blanchardb, Blaxthos, Bobbo, Bobdoleinmypants, Bobo192, Boilermaker2012, Bonadea, Bongwarrior, Brighterorange, Brookie, Bsadowski1, Bulbakuki, BurningZeppelin, Butterscotch, CIreland, CPAScott, CS42, Cacycle, Caiaffa, Calmer Waters, Caltas, Calvin 1998, Camw, Can't sleep, clown will eat me, Capricorn42, CaptainBrian11, CardinalDan, Caribbean H.Q., Catgut, Cburnett, Cccsmundy123, Changer321, ChatNoir12, Chocksondick, Chris squash, Christian Liberty, Chronochronica, Chuckiesdad, Chzz, Clem cowsie, Closedmouth, Comatose51, Cometstyles, Commdor, Courtneyadams101, Cpl Syx, Crd721, Cremepuff222, CryptoStorm, Csa.certified, Ctbolt, Ctjf83, Cullenlover, Cureden, Cybertronic72388, DVD R W, Daa89563, Dalma84, Darth Panda, Daryllyrad 23, Davandron, Dbenbenn, Dc197, Ddwaa, Denelson83, DerBorg, Devode12, Diino Raawr, Discospinster, DivineAlpha, Doctorfluffy, Dogsgomoo, Doniago, DoubleBlue, Dougofborg, Download, Dreadstar, Drmies, Dufo, ELefty, Earlypsychosis, EdwardCullenMyLove, Element762, Eliyak, Elm-39, Eme16, Emg444, Enviroboy, Epbr123, Eric-Wester, Eric.w.miller, Erikac1105, Esanchez7587, Etacar11, Fairry, Faradayplank, Fenrir-of-the-Shadows, Feralaas, Fetchcomms, Fingerz, Fir0002, FironDraak, Flewis, Flyguy649, Ford Flex, Friginator, Fromj2k, Frosted14, Frozenevolution, Fyyer, GLaDOS, GT5162, Gaelen S., Gail, Gaius Cornelius, Geek Unit22, George The Dragon, GerardM, Gerrit, Gilliam, Globra5, Godzfat, Gogo Dodo, GoldenJasmine, Gossipxgabby95, Gothgrl50, Goudzovski, Govnjio, GreaterShrew, Griffinofwales, Gulliveig, Gymnastjew, Hahalolwtfok, Hairy Dude, HalfShadow, Halwyman, Hanii Puppy, Hankwang, Hannahfan3000, Henley.Liang, Henriwatson, HexaChord, Hickruby10, Hollisterisluv, Horsyhannah rulz, Hotmad, Hummerhorizon, Hype101, I Feel Tired, I dont like the smell of indians, II MusLiM HyBRiD II, IRP, Iaziap, Icairns, Iceblock, Icseaturtles, IdLoveOne, Idellateressa82, Idiablo69, Iloveva, Ilyushka88, InSPURation, IndulgentReader, Inferno, Lord of Penguins, Init, Insanity Incarnate, Int3gr4te, Ipatrol, Isabellacullen12345, Ishamid, Ivd32, J.delanoy, JForget, JNW, JSmith60, Jackol, Jadeprincess123, Jadeylou5233, Jake Wartenberg, Jake butler, James086, Janeyisfierce, Jbh428, Jblack653, Jeff G., Jeffrey Mall, JeremyA, JhanCRUSH, Jmbraze, Jmundo, Joaquín Martínez Rosado, Joedeshon, John254, JohnnyEvers, Jredmond, Juliancolton, Julo, Jusdafax, Kajasudhakarababu, Karahara, Karloze, Katalaveno, Katanada, Kate, Katyzichy, Keilana, Kidney05, Killiondude, King of Hearts, Kingpin13, Kintetsubuffalo, Kittycat10245, Knepflerle, Kripzo, Kubigula, Kuralyov, LOL, La Pianista, Ladyeleanor, Laina1312, Lalaland9999, Lalulra, Landon1980, Latics, Ld100, LeaveSleaves, Lemonlime24, Leolaursen, Lightmouse, Lilla834, Little Mountain 5, LittleSmall, Ljhockey02, LockeShocke, Lolhpf47, Lollollolsauce, Lollygabby, Lorelaimarie, Luckycp123, Luvinpoop1234, MIckStephenson, MacMed, Macy, Maddie!, Magog the Ogre, Makeemlighter, Mandarax, Mandypandy10a, Manne marak, Marek69, Martarius, Martharob, Marudubshinki, Materra, Matt.T, Matt414562, Maxis ftw, Maxninjaman, Maya, Mbeychok, Mbz1, McGeddon, McSly, Mecil, Megpuppylove, Melling hellcat, Meman1234567890, Mentifisto, Merlion444, Michael93555, MichaelMaggs, MichaelRWolf, Mickey365, Mifter, Modean7, Monedula, Monkey Bounce, Monkeynoze, Morning277, Mortdefides, Motley Crue Rocks, Mr0t1633, MrDurham, MrShamrock, Musiphil, Mygerardromance, Natalie046, NawlinWiki, Needdover, Neilbeach, Neonokku, Netalarm, Netoholic, Nick Dillinger, Nickmaurer, Nightscream, Nn123645, Noknac, NorthernFire, Nsaa, Nuttycoconut, OMGkk, Octahedron80, Orionus, Otisjimmy1, OverlordQ, Oxonhutch, Oxymoron83, Paulkondratuklovesny, Pepperpiggle, Persian Poet Gal, Pestoepasta, Peter Ellis, PeterSymonds, Pflatau, Pharaoh of the Wizards, Philip tao, Pieter1, Poolgal17, PranksterTurtle, Prashanthns, PrincessRachel6768, Princesstwilighter, Proofreader77, Puchiko, Python eggs, Pyxn, Qutezuce, RJaguar3, RMKJ, RadarBlackSanta, RadioFan, Randi4, RaseaC, RazorICE, RedHillian, RedWolf, Redmarkviolinist, Remigiu, Renaissancee, Renessmee 123456, Res2216firestar, Rhjiv, Rhobite, RickScott, Rockslave, RonAlmog, Ronhjones, Ronsterman16, Rrburke, Ryan Allott, RyanCross, SD5, SMC, SamSam395, Saperaud, Sarnic8, Sceptre, SchfiftyThree, SchnitzelMannGreek, Schoolisnotnice, Scrumdidileumptious, Seacoastunited, Seboden, Sephiroth BCR, Sergay, Shadowjams, Shakil Mustafa, Shazamman, Sheogorath, Shiftchange, Silence1999, Simoncreed, Simonwheeldon, Sinneed, Sirveaux, Sisimariia, Skeezix1000, Skikeland, Slinuxster, Snigbrook, Snowwecocke, SoCalSuperEagle, Sorenceh, South Bay, SpaceFlight89, Specs112, Spellcast, Squeakybird, Srleffler, Stargazer360, Stheller, Subliminalis, Sulasgeir, Super Goombario, Suwatest, Swimfise123, Swlenz, Synchronism, TFOWR, THEN WHO WAS PHONE?, THeNeWsHeRbErT, TKDgirl13, TOttenville8, Tad Lincoln, Tamfang, Tangent747, Tbabydoll, Teamedward1901, Teamthreesome, Techdawg667, Techman224, Telso, Tempodivalse, Tetracube, Tgv8925, Thatguyflint, The Nerd from Earth, The Thing That Should Not Be, The nomnomninja, The wub, TheCatalyst31, TheGnomeKing, Thedoctor47, Thesevenseas, Thingg, ThomasPusch, Tide rolls, Timvasquez, Tiptoety, Tkynerd, Toby Bartels, Toddst1, Tokek, Tomgarry, Totalhumungoretard, TotientDragooned, TotoBaggins, Tresiden, Trevor MacInnis, Trevor wells, Trusilver, Tumataepower, Twilight team edward, Twilight4life, Twilightrulesedwardcullen, Two Bananas, Túrelio, Ulric1313, Underwriter, UnkEdit, Urhixidur, Usgnus, V1adis1av, VatoFirme, Velvetron, Vepittman, Versus22, Vicenarian, Vondruid, WadeSimMiser, Walkie, Walking nightmare, Waterboy12, Wayne Miller, WazzaMan, Wcrowe, Weather333, WereSpielChequers, Whiteh2o4u, Why Not A Duck, Wikieditor06, Willking1979, Winchelsea, Wmc824, Worldtraveller, Wtmitchell, Wurblzap, Wysprgr2005, XN, Xanzzibar, Xhaoz, Xhienne, Xjess4everx, Xlation, Yakudza, Yinchongding, Zachary132, Zenek.k, Zhang He, ZooFari, Zvn, Zzuuzz, Ævar Arnfjörð Bjarmason, أحمد.غامدي.24, 1055 anonymous edits

**Axial tilt** *Source*: http://en.wikipedia.org/w/index.php?oldid=329450042 *Contributors*: 1ForTheMoney, 84user, Ac44ck, Adi, Alexandrov, Amarande, Ante Perkovic, AshishG, Ashmoo, Attilios, Bizzybody, Blechnic, Breatheasier87, Bryan Derksen, Cdc, Closedmouth, Count Truthstein, Curps, DavidH, Discospinster, Dna-webmaster, Dragons flight, Dwight Kjartanson, Egg, Eleven even, Epbr123, Erik J, Ewlyahoocom, F. Mignard, Feinoha, Firth m, FlieGerFaUstMe262, Galoubet, Graft, GregBenson, Gscshoyru, Gurch, Hadal, HansHermans, Haoie, Harold f, Herbee, HolaPussycat, Icairns, InvisibleK, Iridescent, J04n, JForget, Jcbtoast, Jecowa, JohnOwens, KING SHALMANESER II, Kanakislostworld, Karol Langner, Kate Phaye, Kdawg, KerryVeenstra, Khunglongcon, Kingd1533, Kingpin13, KnowledgeOfSelf, Knuckles, Kristaga, Leia, Lir, Looxix, Luokehao, MSGJ, Marskell, Mav, Mboverload, Michael Hardy, Michel M Verstraete, Mike s, Mondorescue, MrRedwood, Msablic, MyNameIsNotBob, Mysid, Mårten Berglund, NHRHS2010, Nathanael Bar-Aur L., Neelix, NormStephens, Outriggr, Patrick, Phantomsteve, Pleasantville, Protargol, Psychonaut, Pyrrhon8, RCollins1849, RJHall, RadicalPi, Rdsmith4, Reinoutr, Richandler86, RingtailedFox, Roadrunner, Robma, Rominandreu, Rsed, Røed, Rāmā, Sax Russell, Scientus, Seldon, Shouriki, Smartech, Snoyes, Spitfire, Street20, THEN WHO WAS PHONE?, Tauʻolunga, TenOfAllTrades, The way, the truth, and the light, Timwi, Venny85, WarrenPlatts, Wetman, Whale plane, Whosasking, Wiki alf, Wikibob, Zbayz, 186 anonymous edits

**Earth** *Source*: http://en.wikipedia.org/w/index.php?oldid=331783602 *Contributors*: (jarbarf), -- April, 0, 06cat, 06monkey, 10.22.201.xxx, 123456zxcassdtiuhdfygtfdyh+g7h+g97j+9h+k4hk+,4h+n, 168..., 1981willy, 1yesfan, 30.215, 99of9, A Softer Answer, A1ecks, AJCham, Aadnk, Aaron bisset, AaronBagelyIsCool, Aaronbeemer, Abbajabanana, Abscissa, Abtract, Abyab, Academic Challenger, Acalamari, Accuruss, Acdx, AceFighterPilot, Achristl, Acroterion, Adam kwt, AdamRetchless, Adambiswanger1, Adambro, Adashiel, Adi, Adriaan, Adriaan 1, Aeon1006, Afrothunder222, Ageekgal, Agemegos, Aglassonion, Ahering@cogeco.ca, Ahoerstemeier, Aim Here, Aitias, Akadruid, Akamad, Akkar, Aknorals, Akosofo, Aksel89, Akshayagupta, Alan Liefting, Alanbrowne, Alansohn, Albert Krantz, Aldarion, Alec Connors, AlefZet, Alex Spade, Alex earlier account, Alex123irish123, Alex43223, Alexanderj, Alexwcovington, Alfakim, Alfio, Ali K, All Is One, Allstarecho, AllyUnion, Alones, Alphaquad, Amarkov, Amberrock, Amcbride, Amore proprio, Amorymeltzer, AnOddName, Anarchon, Ancheta Wis, AndonicO, Andre Engels, Andres, Andrevan, AndrewLucas, Andrewpmk, Android79, Anetode, AngelOfSadness, Angela, Angmering, Ani td, Animum, Ann Stouter, AnnBird, Anonymous editor, Antandrus, Anthere, AppleJordan, Aramisian, Arctic.gnome, AreaControl, ArglebargleIV, Arifhidayat, Arkuat, Arl123wiki, Armaced, ArmadilloFromHell, Armchair info guy, ArnoldReinhold, Arnon Chaffin, Art LaPella, Arthur Rubin, ArthurWeasley, Artichoker, ArticleCreator, Artillicus, Arvind Iyengar, Arwel Parry, Asdffdsa12345, Ashenai, Ashill, Ashley Y, Ashmoo, Astatine, Astral, AstroHurricane001, Astrobhadauria, Astudent, Atlant, Atmoz, Atropos235, Attenboroughii, Aude, Augie2, Authalic, Automobilie, Auximines, Avataris112jaar, Avraham, Avriette, Awadewit, Awickert, AxelBoldt, Aygen, Ayman, Ayrton Prost, Az1568, AzaToth, B, B2012ball21, B3tamike, BBnet3000, BD2412, BGManofID, BQZip01, Back and Forth, Badanedwa, Badseed, Banes, BanyanTree, Barathvk, Barisaxappeal, Basalock, Batneil, Bbroach725, Bcharles, Bcorr, Beaverman2k7, Bebenko, Belovedfreak, Ben Tillman, Benbest, Benc, Benflicker, Bensaccount, Bergsten, Betacommand, Bhadani, Bhardwa, BigCow, Bigboy742, Bigdan201, Biggysmalls, Bilal855, Bill37212, BillC, Biruitorul, Bkell, Bkkbrad, Bkkeim2000, Bla1122, Blackangel25, Blacklite, Bladethestreetz, Blarrrgy, Blindlynx, BlueEarth, Bluesquareapple, BlytheG, Bmdavll, Bmg916, Bmicomp, Boatman666, Bob rulz, Bobblewik, Bobbyjkl, Bobet, Bobo192, BogdannC, Bongwarrior, Booksworm, Booyabazooka, Boredzo, BorgQueen, BorisFromStockdale, Borislav, Boson15, BostonMA, BovineBeast, Bowlhover, Boy1, BradBeattie, Bradeos Graphon, Brammeke, Brandmeister, Brandon, Brasswatchman, Bremen, Bren09, Brent Ward, Brews ohare, Brianga, Brideshead, Brighterorange, Brigman, Brion VIBBER, Brisvegas, Briséis, Brodens, Bruceadler, Bryan Derksen, Bunny-chan, BurnDownBabylon, Buschwacker2244, Bushytails, C12H22O11, CBDunkerson, CKnapp, COMPFUNK2, CQ, CZmarlin, Cactai, Cactus.man, Cacycle, Cake44, Calfan5, Calidore Chase, Californiabedside29, Calltech, Callumw1, Calmypal, Caltas, Calvin1663, Calypso, CambridgeBayWeather, Camembert, Can't sleep, clown will eat me, CanOfWorms, Canterbury Tail, Cantus, Cappro1991, Captain Proton, Carcer99, CarelessHair, Carey Evans, Carkid95, Carlosguitar, Carrionluggage, Cashimor, Casper2k3, Casperonline, Cassini, Catmoongirl, CattleGirl, Causa sui, Cdc, Cedars, Cedrus-Libani, Celestianpower, Cferrero, Charlessmith007, CharonX, Chaser, Chavando, Chaz1389, Chensiyuan, Chester luva, Chestnut tree, ChicXulub, Chihuahua22, Chmod007, Choppie3000, Chris goulet, Chrishy man, Chrisjackson, Chrisjj, Chrislk02, Christian41691, Christophenstein, Chriswiki, ChucksGay123456789, Cimon Avaro, Cinnamon42, Citynoise, Civil Engineer III, Ckatz, Clade, Clam0p, Clary 1992, Cleonis, ClockworkSoul, Closedmouth, Cmprince, Coat of Arms, Cocoaguy, Codemonkey, Colds7ream, Coleflinn, Colipon, Colleenthegreat, Colton94, Cometstyles, CommonsDelinker, Complex (de), Comrade Tux, Conesar, ConfuciusOrnis, Conscious, Consumed Crustacean, Conversion script, Coolblinxs, Coolmann, Cordialatron, CorfiX, Correogsk, CoryDambach, Cos111, Coyotee urso roland peel Sanders, Crad0010, CrazyInSane, Crazycomputers, Crazydevil40, Crd721, Create42000, Cremepuff222, Cronholm144, Cros13, Crotalus horridus, Crowed, Crownjewel82, Crusadeonilliteracy, Cryptic, CryptoDerk, Cubby007, Cuchullain, Cunado19, Curps, Cwass, Cyan, Cybercobra, Cyktsui, Cymro93, Cyprus2k1, CzarB, D k mackenzie, D-Rock, D.M.N., D6, DEBRAEA, DJH47, DONOVAN, DSachan, DVD R W, Daarznieks, Dake, Dan stewart 1992, Danelo, Dangoo, Danh, Daniel J. Leivick, Daniel Olsen, Daniel5127, DanielCD, Danlibbo, Danny, Danski14, Dante Alighieri, Dar-Ape, DarbyAsh, Darkhack101, DaveJ7, David Kernow, David Latapie, David Stewart, Daycd, Db099221, Dbachmann, Dcandeto, Dcfleck, DeadEyeArrow, Deancoy, Deathalele, Deathphoenix, Deeptrivia, Deglr6328, Delirium, Delldot, Deltabeignet, Demmy100, DemoniacoCabron, Deon, Deor, Dep. Garcia, DerHexer, DerRichter, Derekwriter, Derezzing, Desiphral, Deskana, Deuar, Devanatha, Deviathan, Deville, Devilofdoom, Dewrad, Dfrg.msc, Dina, Discospinster, Dispenser, Diyako, Dlohcierekim, Dlwldud96, Dmcheatw, Dmh, Dmn, Dmsar, Dna-webmaster, Doc Tropics, DocJohnny, Doct.proloy, Docu, Dogposter, Domzalbao, Don't fear the reaper, Donarreiskoffer, DoozyBob, Douglasr007, Downhometown, Doyoumind, Dp462090, Dpotter, Dr. Submillimeter, Dr.enh, DrOxacropheles, Dracontes, Draeco, Dragons flight, Drawolf, Drc79, Dreadstar, Drey 7, Drfabulous, Drini, DroEsperanto, DropDeadGorgias, Drumguy8800, Drunkenduck16, Duckman89, Duncan.france, Dungeonboy, Dureo, Dusik, Dust Filter, Dycedarg, Dylanrush, Dysepsion, Dysprosia, E Pluribus Anthony, E. Smith, EJF, ESkog, EVula, EZio, Earth567, Earthdirt, Easyaccessgreentea, Ed Poor, Ed g2s, EdGl, EdJogg, Edieschuermann, Edsanville, Edward, Edwy, Egil, Eivind F Øyangen, El C, El Rey Jesus, El Slameron, El estremeñu, Elassint, Elb2000, Elcapitane, Electroknight, Elenseel, Eleuther, Elk Salmon, Ellio-3.14, Elliottsaray, Ellmist, Eloquence, Eltener, Eluchil404, Emerson7, Emre D., Enceladus, EncycloPetey, Endomion, Eneskilic, Enkiduk, Enormousdude, Eob, Erebus555, Erik Zachte, Erleellis, Eschnett, Esurnir, Etacar11, Ethanj3, Euku, Evercat, Everyking, Evil Monkey, Evil saltine, Evrenos, Excalibre, Extra999, Extraordinary, Eye.of.the.dragonfly, F mian786, FR Soliloquy, Facts707, Falcanary, Fang Aili, Fant50, Farosdaughter, Fasterthanred, Father Goose, FayssalF, Fdp, FeanorStar7, Fearmaster, Femto, Fephisto, Fhkjh4w34, Fieari, Fiet Nam, Finalfantesy, Fingers-of-Pyrex, Finlay McWalter, Fishal, FisherQueen, Fizzelpowerpop, Flameviper, FlieGerFaUstMe262, Flourgus, Fluri, Flying Saucer, Fnfd, ForumKilla95, Fossiliferous, FourBlades, Fractions, Fran Rogers, Francis Tyers, Francs2000, Frazzydee, Freakofnurture, Fredrik, FreeKresge, Freedomlinux, Freewayguy, FreplySpang, Frymaster, Functionofxy, Funnybunny, Fvasconcellos, Fxer, G from B, G. Campbell, Gaff, Gaianauta, Gaius Cornelius, Gakrivas, Galmicmi, Galoubet, Gangstamike, Garethfoot, Garzo, Gazpacho, Gbleem, GeNie0569, Gehnahri, Gene Nygaard, Gene.thomas, Geneb1955, Gengiskanhg, Genmanager, GeoGreg, GeoW, Geoffrey, Geologyguy, Gerrit, Geschichte des Bambiteletubbies, Ghl524, Gholam, Giftlite, Gilgamesh, Gilliam, Gimboid13, Giraffe's101, Givern, Gjd001, Glen, Glen scantbeatme, Glenn, Globalsolidarity, Gman124, Gnangarra, Gnomz007, GnuDoyng, Gobonobo, Gogo Dodo, Goldenchocolate, Gonadsahoy, Googolme, Goohoogle, Gpetrov, Gpvos, Gracenotes, GraemeL, Grafen, Grafikm fr, Graham87, GrahamN, Grandmasterka, Gravitophoton, GreatWhiteNortherner, GregNorc, GregorB, Gregorus, Griffin Prefect, Gromreaper, Grstain, Grunt, Gscshoyru, Gtg264f, Gtrmp, Gugilymugily, GuitarFreak, Gunnar Guðvarðarson, Gunnar Larsson, Gurch, Gurubrahma, Gustavb, Guyzero, Gwernol, H, H2g2bob, HAKUNAMATATA, HOULLAHAN, HRIN, Haberg, Hadal, Haipa Doragon, HalfShadow, Halo, Hamiltondaniel, Handface, HansHermans, Hardee67, Harp, Harris7, Harriv, Harryboyles, Hashar, Haukurth, Hawkestone, Hdt83, Heavenlyevil, Heiskari, Hello32020, Hemanshu, Henrik, Herbee, HereToHelp, Heron, HexaChord, Hi44, Hibernian, Hiberniantears, HideandLeek, Highpriority, Hike395, Hilu 2, HisHighness420, Hochnebel, Home run derriby, Horizontale, HorsePunchKid, Howsthatfordamage25, Hu12, Hugoflug, Humanist92, Hungar, Hunsbassist, Hurricane Devon, Hut 8.5, Huzefahamid, I-am-a-fat-pig-today, I-luv-the-navy, IHaveTheRightToArmBears, II MusLiM HyBRiD II, ILovePlankton, Iago Dali, IainP, Ianblair23, Icairns, Icarus, Iceberg3k, Icey, Iddiot, Idont Havaname, Ijustam, Ikip, Iluvcapra, Imladros, Improv, In Defense of the Artist, InShaneee, Inktvis, Inter, Interactive civilian, Internetmozzila, IntrigueBlue, Intuicja7, Irishguy, Isilanes, Isis, IslandGyrl, Ixfd64, Izehar, J Di, J.delanoy, JAF1970, JCO312, JFreeman, JHMM13, JJB, JQF, JTBX, Jacek Kendysz, JackofOz, Jacksav, Jahiegel, Jakezing, James3jj, JamesHoadley, JamesR, Jamestown James, Jan Pedersen, Jao, Japanada, Jaranda, Jared Hunt, Jasca Ducato, Jatkins, Jaxl, Jay Turner, JayKeaton, Jb12332, Jc1346729, Jdforrester, JeLuF, Jebba, Jeff G., Jeff5102, Jeffq, Jeffutz, Jengod, Jennica, JenovaChen, Jensbn, JeremyA, Jeremyb, Jeremykemp, Jeronimo, Jerryb1961, Jersyko, Jes5199, Jess Mars, JetLover, Jewsmurf, Jh51681, Jim77742, Jimmy Slade, Jimp, Jinxed, Jiohdi, Jketola, Jklin, Jleedev, Jmlk17, Jni, JoanneB, Joao, JoaoRicardo, Joaopais, Jobberone, Joe Kress, Joe bloomfield, Johann Wolfgang, John, John Cardinal, John Phoenix, John Vandenberg, John1190, John254, JohnOwens, Johnleemk, Johnnykelley, Johnuniq, Jojit fb, Jolb, Jonasaurus, Jonemerson, Jorge Ianis, Joriki, JorisvS, Jose77, Joseph Solis in Australia, Josiah Rowe, Jossi, Journalist, Joyous!, Jpgordon, Jrockley, Jrothwell, Jrsnbarn, Jsvaidya, Jswhitten, Jtichelm, JuJube, Jugbug, Jugbug2, JulesH, Jumbo Snails, Jun-Dai, Junglecat, Jusjih, Just James, Justice League 05, Justincannon4, Juzeris, Jw21, Jyril, KErosEnE, KF, KFan II, KGSkunk, KJK::Hyperion, Kaimbridge, Kaisershatner, Kandrey89, Kangor44, Kanon6917, Karlthegreat, Karol Langner, Katalaveno, Katieh5584, Kaufj579, Kazikameuk, Kazrak, Kbdank71, Kbh3rd, Kdpiper, Keilana, Kelly Martin, Kelvin14021993, Kemet, Keraunos, Kerotan, Kesac, Kevin Breitenstein, Kevin kaior, Kgsullivan, Khalid Mahmood, Kheider, Khukri, Kiat123, Kid45laundry, Kier07, Kim Bruning, KimvdLinde, King of Hearts, Kingturtle, Kintetsubuffalo, Kinu, Kitty53, Kitzke, Kkkdc, Klinkaeo, Klow, Klymen, Knowledge Seeker, KnowledgeOfSelf, Koavf, KokkaShinto, Konstable, Koolman2, Kooo, Kooziking, Kop, Kosebamse, Kostya Wiki, Kotjze, Kozuch, KrakatoaKatie, Kralizec!, Kramie, Krashlandon, KristoferM, Kroxbury, Krylonblue83, Kubigula, Kukini, Kungfuadam, Kurieeto, Kuru, Kurykh, Kvantum, Kvikram, Kwamikagami, Kwekubo, Kwjdh1324, Kww, KyNephi, Kyle, LA2, La goutte de pluie, Lagalag, Langer, Latitude0116, Laura4030, Lectonar, Lee M, Leebo, LegolasGreenleaf, Len Raymond, LeoDV, LeoNomis, LeonardoRob0t, Leslie Mateus, LibLord, Liftarn, Lightdarkness, Lightmouse, Lightro6, Lights, Lignomontanus, Lilmul123, Linnell, Lir, Liss1995, Lissoy, Littlelance, Llort, Locoshonmachon, Loftypegasus, Lolerman0123456789, LonelyMarble, Longhair, Loodog, Looxix, Lord Patrick, Loren98, Louisisthebest 007, Lowellian, Lowmax2, Lucyin, Lugnuts, Luna Santin, Lunarcide, Lunokhod, Lupo, Luxborealis, MER-C, MZMcBride, Mac, Macaddct1984, Madcoverboy, Madman, Maelnuneb, Magi Media, Maharashtraexpress, Mainframe2000, Majorly, Makewater, Malcourno, Maldek, Malhonen, Malkav, Malo, Man vyi, Mani1, Mankar Camoran, Manop, MarSch, Marcelo-Silva, Mareino, Mark Ryan, MarkS, Markus Kuhn, Marquee K, Marshallharsh, Marshman, Marskell, Martin Ulfvik, Martin.Budden, MartinHarper, Martinljohnson, Martinultima, Martinwilke1980, Martyjohnsen, Marudubshinki, Marumari, MarylandArtLover, Mass147, MastCell, Master Deusoma, Master Jay, MasterSci, Masterbutthead, Masz, Matt Borak, Matt Crypto, Matt. P, Matthew Woodcraft, Mattmils03, Mattrave, Matturn, Maurreen, Mav, Maxgrin, Maximus Rex, Mbjarland, McGeddon, McSly, McVities, Measure, Media anthro, Meelar, Mehugh, Mekong Bluesman, Melchoir, Menklog, Merope, MesserWoland, MetsFan76, Meursault2004, Mfarah, Mgiganteus1, Mhus, Michael Hardy, Michael2, MichaelJE2, Michaelian, Mickeyd24, Midhart90, Midnightblaze, Mikael Häggström, Mike Peel, Mike Rosoft, Mike s, Mikenorton, Minesweeper, Miranda, Mister Sunshine, Misza13, Mj23xb, Mo0, Mocirne, Modulatum, Momus, Monedula, Monkeyman, Monopoker, Montanav42, Montrealais, Monuko, Mookabear, Mookie12, Mookiefurr, Moonriddengirl, Mooquackwooftweetmeow, Moreschi, Morwen, Mostlyharmless, Mother.earth, Motorrad-67, Moverton, Mr Bisciut, Mr Stephen, Mr. Billion, MrBoo, MrFish, MrSomeone, MrVoluntarist, Mrgehnahri, Mrivera1, Mrsanitazier, Mrwuggs, Ms2ger, Mschel, Msikma, Mtougas5, MuDavid, Muchness, Mulad, Mulder1982, Murgh, Muriel Gottrop, Murlough23, Musical Linguist, Mxn, My Cat inn, Myanw, Myasuda, NEREVAR117, NHJG, NHRHS2010, NSR, Naddy, Nakon, Nanshu, Napato, NarrowPathPilgrim, Natenate6733, NatureA16, NatusRoma, NawlinWiki, NazarK, Nbound, Nealmcb, Neave, Neil916, NeilN, Nephelin, NerdyNSK, Netkinetic, Neutralaccounting, Neutrality, New4321, NewEnglandYankee, Nicholas Tam, Nick125, Nickjaymann, Nickshanks, Night Gyr, Nihiltres, Nihonjoe, Nikolasao, Nikro, Nillanilla3ee, Nimur, Nirmayvathsa, Nishani 1994, Nishkid64, Niteowlneils, Nitya Dharma, Nivix, Nlu, Nmohan 101, No Guru, NoPetrol, Noelthec, Nolcro, NonNotable, Noodlesrule, Notheruser, Notinasnaid, Nsae Comp, NuclearVacuum, Nufy8, Nyttend, O18, OMFGBBQ, ONUnicorn, OOODDD, Obafgkm, Occono, Ohnoitsjamie, Okiefromokla (old), OlEnglish, Old Moonraker, Oli Filth, Oliver Lineham, Oliver Pereira, Oliverkroll, Olorin28, Omegatron, Omicronpersei8, Onceonthisisland, Opelio, Oreoeatinghulk, Ortolan88, OsirisV, Ow41n, Oxymoron83, Oxyn, Ozgod, P3Pp3r, P3d0, P849, PFHLai, PFSLAKES1, PJM, Paintballpro101, Palonor, Panairjdde, Pantallica00, Paper Clip Clock, Paranoid, Paris 16, ParisianBlade, Paroxysm, Parsa, Pascal.Tesson, Patrick, Patricknoddy, Patssle, Patstuart, Paul August, Paulinho28, Pax:Vobiscum, Pazuzu1990, Pb30, Pcbene, Pcr374, Pd THOR, Pearle, Pegasus1138, Pembertond, Pengwiinsdarkerside, Pengwy, Perníček, PerryTachett, Persian Poet Gal, Peruvianllama, Peter Isotalo, PeterJohn2, Petersam, Petri Krohn, Petruchi41, Petruk, Pevarnj, Pgk, Pharos, Phi beta, Phil Boswell, Philip Stevens, PhilipO, Pho3nix-, Photographer2008, PhySusie, PiMaster3, Pigsonthewing, Pilotguy, Pinoy Pride, Piotrus, Pious7, Piplicus, Pixel ;-), Pizza Puzzle, Planemo, Planet-man828, Plek, Plop, Plumbago, Pmanderson, Pmrobert49, Pmsyyz, Pnkrockr, Poeloq, Poeticmuse, Poissonrouge, Polly, Polocrunch, Ponder, Poolkris, Poopoopoo, Poopy55, Poor Yorick, Populicious1234, Porthos3, Power level (Dragon Ball), Premeditated Chaos, PresN, PrestonH, Prodego, Prolog, ProveIt, Prvc, Pschemp, PseudoSudo, Pseudoanonymous, Psnow boy, Psy guy, Pufferfish4, Punkgeek, Pupster21, Python eggs, Q-ball, Q43, Qaddosh, Qhop, Qlop, Quackdave, Quadell, Quarl, QuartierLatin1968, Quinsareth, Quizimodo, Qwe, Qxz, RG2, RJHall, RK, RTC, RTucker, RadiantRay, Radical0713, RadicalBender, RadicalOne, Raditzu, Radon210, RainbowOfLight, Ram4eva, RamziKhattar, RandomCritic, Randwicked, Ranierotazzi, Raven in Orbit, Ravena, Ray Van De Walker, Rbbramlette, Rdm2376, Rdsmith4, ReCover, Real editor, Rebecca, Rebeleleven, Recurring dreams, RedWolf, RedWordSmith, Reddi, Redtitan, Reedy, Remember, Rentaferret, Retbutler92, Retiono Virginian, Revo331, Revolución, RexNL, Reyk, Rgoogin, Rholton, Riana, Rich Farmbrough, Richard001, RichardB, RichardF, Richtig27, Rick Block, Rick Davis, RickK, Ricky81682, Rickyrab, Rissa of the saiya-jin, Rizzoj, Rjwilmsi, Rlee0001, Rmky87, Rmrfstar, Rnt20, Robert Merkel, RobertG, Robth, Rocket000, Rockvee, Romanm, Ron Ritzman, Rory096, Roscoe x, Rotem Dan, RoyBoy, RoyHughes, Rracecarr, Rrburke, Rreagan007, Runewiki777, Rursus, Ruslik0, Russjb, RxS, RyanParis, Ryrivard, Ryulong, Rzf3, S3000, SASHHI, SEWilco, SGGH, SJP, SMC, SPUI, SS451, ST47, STLocutus, SWAdair, SYSS Mouse, Saccerzd, Sagaciousuk, Sahasrahla, Sakrotac, SallyForth123, Salmar, Saluyot, Sam Korn, Sam Li, SamOstrich, SamSim, Sammytw, Samohyl Jan, Samsara, Samw, Sandahl, SandyGeorgia, Sango123, Sarahlilith, Sardanaphalus, Saros136, Satarah234, Satori, Satori Son, Savidan, Sayre8, Sbandrews, Scarian, Sceptre, SchfiftyThree, Schmiteye, Schneelocke, Schoen, Schuyler11dy, SciberDoc, Sciurinæ, Scott5114, Scotty56, Screechy, Seav, SecretAgentMan00, Secretlondon, Sengkang, Sennaista, Sephiroth1311, Serendipodous, Seth Ilys, Setup, Shanel, Shanes, Sharanss, Shenme, Sherblast317, Shesaghost, Shii, Shikotsumyaku, Shizane, Shlorpins, Shorelander, Shoy, Sifaka, Simetrical, SimonP, Simonsaysabc123, Sintonak.X, SirIsaacBrock, Siufaiho, Sjakkalle, Skela, Skizzik, Slakr, Sligocki, Smack, Smartandgeeky, Smartech, Smear, Smeggysmeg, Smexxiii-babiee, SmokeyTheCat, Smokizzy, SnappingTurtle, Snowolf, Snoyes, Soccer77, Solarbird, Solipsist, Someguy1221, SonicAD, Sonjaaa, South Bay, SpACatta, Spacepotato, Sparrowman980, Spazturtle, Spellcast, Spencerk, Spiff, Spiffy sperry, Splotch, Spookshull, SpookyMulder, Spotty11222, SpuriousQ, SqueakBox, Squirepants101, Srleffler, Sssbbb1, StalwartRomanticism, Stantastic, Stardancer791, Starnestommy, Steel, Steinbach, Step37, Stephen, StephenHudson, Stephenb, Steve the baker, SteveRwanda, SteveSims, Stizz, Stop Climate Change, Strait, Strider12233, StuartDD, Stubblyhead, StudentJCase, Sturdygurdy, Sualah, Sudheervelagapudi, Sulvo, Sum0, SummonerMarc, Superm401, Surachit, Sushant gupta, Swbf2lord, Swedophile, Switchfo0t813, Sworah, Swpb, Sycthos, Symmetric Chaos, T3H.ONE, T=0, THEBLITZ1, TUF-KAT, Tailpig, Talamus, Talon Artaine, Tangotango, Taracka, Tarquin, Tarret, Taw, Tawker, Tawnfeather, Tdfriese, TedE, Teemanbf04, Teerui, Tejas.B, Template namespace initialisation script, Tennisguy1313, Tennisuser123, Terence, Terik brunson, Tero, Terrasidius, Thangalin, That Guy, From That Show!, The Duke of Waltham, The Epopt, The Evil Spartan, The Haunted Angel, The JPS, The Lizard Wizard, The Man in Question, The Missing Piece, The Rambling Man, The Rogue Penguin, The Thing That Should Not Be, The Wookieepedian, The cherds, The odd ones, TheFearow, TheKMan, TheN0ble2, TheNewPhobia, TheObtuseAngleOfDoom, TheRanger, TheSkunk, Thechamp69er, Thelamecow, Thelb4, Thematrixz02, Theonlyedge, Theresa knott, Theymos, ThiedeDaddy, Thue, Thunderbrand, Tiger888, TigerShark, Tigerhawkvok, Tim R, Tim Starling, Tim51989, TimBentley, TimVickers, Timir2, Timrem, Timwi, Tinytim91, Titoxd, Tjleo209 014, Tjmax800, Tjoneslo, Toddles29, TodorBozhinov, Tolandc, Tom, Tom Lougheed, Tom harrison, TomPhil, TomSmith123, Tombstone, Tompw, Tony Fox, Tony1, TonySt, Tonywalton, Torchiest, Tosun, Tower, Trampton, Transit, Traroth, TreJowy, Trevor MacInnis, Trilobite, Triwbe, Trnj2000, Tronno, Trstliner, Trunks6, Trusilver, Tsachin, Tsogo3, Ttlymate, Twinsday, Twistedmusicfreak, Twooars, Tylerni7, Typhlosion, Uclarox911, Ufviper, Uglyduck17, Ultratomio, Unclebulgaria, Undertones94, Unisouth, Uranometria, Urhixidur, Ursasapien, UtherSRG, V1adis1av, VMS Mosaic, VandalHunter, Vandaliz3, Vaniba12, Varishneroff, VashiDonsk, Veemonkamiya, VegaDark, Velvetron, Venommitch, Verrai, Vicki Rosenzweig, Vikreykja, VillainamInone, ViolinGirl, ViperXGT, Vitall, Viva La Fro, Voice of All, Vsmith, Vsst, Waerth, Waggers, Wakuran, Walkingwithyourwhiskey, Walter, Wapcaplet, Watch37264, Wavelength, Wayward, Wdflake, Webmasto, Weregerbil, Wereon, WesDecker, Wesley, Weters, Whaatt, Whatty123, Whuling, Wiffadabiffa, Wiggstar69, Wiglaf, Wik, Wikeepedian, Wiki alf, WikiGremlin, Wikibob, Wikicolbert, Wikid77, Wikisamichik, Wikiscient, Wild Deuce, William Allen Simpson, William Ortiz, Wimt, Wingedagression, Winhunter, Winterchili, Wizkid007freek, Wj32, Wknight94, Wmahan, Wo0sh, Wolfkeeper, Wombatcat, Woodenwarrior, Woodstone, Woohookitty, Woudloper, Wp willis, Wrobert, Wubb, Wytukaze, X2turkey2x, X3210, X911, XJamRastafire, XMeX, Xakaxunknownx, Xammer, Xaosflux, Xcomradex, Xcvz, Xe Cahzytr Ryz, Xezbeth, Xkeitarox, Xy7, Yamamoto Ichiro, Yamato Kenichi, Yano, Yarilo2, Yarnalgo, Yath, Ybbor, Yidisheryid, YixilTesiphon, Yourmom2, Yoursonly, Yuefairchild, Yug, Yupik, Zachorious, Zahid Abdassabur, Zaian, Zakamoka1, Zelretch, Zen-master, Znethru, Zondor, Zpb52, Zrulli, Zsinj, Александър, 朝彥, 3038 anonymous edits

**Ecliptic** *Source*: http://en.wikipedia.org/w/index.php?oldid=327162074 *Contributors*: 0.39, 16@r, Adavidw, AikBkj, Alec Connors, Ambarish, Ankurtg, Apoc2400, Arakunem, Arpingstone, Art LaPella, Astrologist, BBFlatt, Bacteria, Banjaloupe, Beofluff, Bignose, Byrial, Conscious, Conversion script, Cplot, Craig Pemberton, Dagg, Danielcohn, Deeptrivia, Dendodge, Dna-webmaster, Dungodung, Edward321, Enochlau, Fev, Gillean666, Hankwang, Harald Khan, Haxwell, HenryLi, Hgilbert, Icairns, IdLoveOne, Insanity Incarnate, Javier Carro, Jdrewitt, Joriki, Jworker, KING SHALMANESER II, Karol Langner, Kheider, Lee merrill, Lir, Looxix, Lumos3, Magnus Manske, Mana Excalibur, Mekong Bluesman, Mesosphere, Michaelbarreto, Mikael Häggström, Mike s, Misteror, Nathan24601, Nwbeeson, Orionus, Osel, OwenBlacker, Palica, Pdn, Pi@k, Pit, Pizza Puzzle, Pomona17, Psiphiorg, Pwrsc, QuadrivialMind, RJHall, RainbowOfLight, Raven in Orbit, ReelExterminator, Ruslik0, Saros136, Silver Spoon, Summer Song, Summer3434, Sverdrup, Tauʻolunga, Terry0051, The Anome, The Tom, Typochimp, Vgent, Vsmith, Warpflyght, Wassermann, Wikipedia crusader, WilliamKF, Woodstone, XJamRastafire, Zundark, 79 anonymous edits

**Equator** *Source*: http://en.wikipedia.org/w/index.php?oldid=330952357 *Contributors*: (, -xfi-, 2004-12-29T22:45Z, 213.253.39.xxx, A-giau, A. di M., ABF, Acroterion, Ahoerstemeier, Ajm81, Alan012, Aldie, AlexiusHoratius, Ali, Alsandro, Anagnorisis, Anclation, Andrewpmk, Andycjp, Armeria, Autiger, Avenue, AxelBoldt, Backspace, Bagatelle, Baloogaeditor1, Bazonka, BazookaJoe, Bezapt, Bhamv, Bigtop, Birdhombre, Bobo192, Boccobrock, BorgQueen, Breathstealer, Bryan Derksen, Bsimmons666, CambridgeBayWeather, Camilo Sanchez, CardinalDan, Cburnett, China Crisis, Chrislk02, CiaPan, Claidheamohmor, Closedmouth, Coffee and TV, Conscious, Conversion script, Ctjf83, CuriousJM, Cyrus the virus grissimo, Dangerousnerd, Daniel Case, Daniel5127, David Kernow, Dbachmann, Dice and smilez, Diceman, Docu, EbruNayakkan, Eekster, El C, Electricnet, Eliyak, Ellywa, Emelmujiro, Epbr123, Ericamick, Everyking, Ewlyahoocom, Ex nihil, FactChecker, Fieldday-sunday, Filelakeshoe, Fireaxe888, Fishal, Flubbit, Foxandpotatoes, Fredrik, Frehley, Fvw, Gdr, Giftlite, Gilliam, Glenn, GraemeL, Grand Dizzy, GreatWhiteNortherner, Grunt, Gwernol, Hall Monitor, Hari, Heightwatcher, Henry W. Schmitt, Huntster, Husond, Iago Dali, Indon, Ineffable3000, Irbisgreif, Iridescent, Ixfd64, JB82, JForget, Jbalint, Jeff G., Johan1298, Johnian144, Jojit fb, Jose77, Joseph Solis in Australia, KSmrq, Kaisershatner, Karl Palmen, Karl-Henner, Karol Langner, Keithcurtis, Kevinsane, Kiensvay, Kostisl, Kpjas, Kristaga, Kulindahr, Kurykh, Kvasir, Lagalag, Lamad83, Lamrock, Lasunncty, Lee Daniel Crocker, Lewisdg2000, Lightmouse, Linkoman, LtNOWIS, Lugnuts, MER-C, MPF, Mackan, Mad Tinman, Madhero88, Malo, Manop, Marc Venot, Marco Krohn, Matt Crypto, Mav, Maziarparizade, Mboverload, Michael Hardy, Miguelzinho, Mikalaari, Mike Payne, MikeyChalupa, Miranche, Mj sklar, Mokonono, Montrealais, MrDolomite, MysteryDog, N5iln, NHammen, NawlinWiki, Nihiltres, Nil Einne, Niteowlneils, NuclearVacuum, Nutella101, Ohnoitsjamie, Oscarthecat, Papipaul, Pasky, Pcb21, Pedro Aguiar, Phantomsteve, Phgao, Phin108, Pi@k, Piano non troppo, Pigsonthewing, Pizza1512, Poindexter Propellerhead, Pokrajac, Psycho Kirby, Quizimodo, Qxz, RJHall, Ratherhaveaheart, Rjstott, Rmhermen, Robertknyc, Roke, Rwflammang, SDC, Sainttomm, Sandahl, Saperaud, Saric, Sayden, Scarian, SeanMack, Seb az86556, Sesel, Sesu Prime, Shalom Yechiel, Shanes, Shar2342, Shiftchange, Shoot and Scribble Mod, Skyezx, Sloman, Slrubenstein, Smokizzy, SpookyMulder, Spudtater, SqueakBox, Steinsky, Stephenchou0722, Sterio, Stian, Susan Davis, Szoltys, TECH-NOIR, TOttenville8, Tarquin, TastyCakes, Terence Sharp, Thesevenseas, Tide rolls, TobyDZ, TomViza, Trevor MacInnis, Tyler, Uannis, Vaughan Pratt, Vina, Violetriga, Viperist, Viriditas, Vuong Ngan Ha, Wavelength, Wdfwdfwdf, Where next Columbus?, Wheresthebrain, Wik, Wikinger, Wixardy, XJamRastafire, Xx236, Xy7, Zaheen, Zayani, Zbayz, ZorkFox, Јованвб, 418 anonymous edits

**Equinox** *Source*: http://en.wikipedia.org/w/index.php?oldid=331703754 *Contributors*: 200.191.188.xxx, 2D, 3sides, 7h3 3L173, A Nobody, A3RO, AAA!, ABF, ATSZ56, Aasmith, Abce2, Acalamari, AikBkj, Alakazam, Alansohn, Alberto Orlandini, Alethiareg, Alimostofi, AnakngAraw, Anatidae, Andrea105, Andrewpmk, Andrewrost3241981, Andycjp, Annanim, Ante Perkovic, Aquirata, ArglebargleIV, Argotechnica, Arjun01, Arthena, Arthurian Legend, Astrologist, Aylahs, Aznpunk989, B.d.mills, BJB, BartBenjamin, Basilicofresco, Batysista, Belovedfreak, Ben pcc, Bjpremore, Blackyvengeance7, Blueshade, Bobo192, Bogey97, Bolivian Unicyclist, Bomac, Bongwarrior, Bowlhover, Braithwaite, Brian Boru, Bricology, Brisvegas, Bryduck, CRKingston, Caknuck, Canaima, CapitalR, Capitocapito, Capricorn42, Captain panda, Ched Davis, Chexum, Chris Dybala, Chrislintott, Chrism, Cleonis, Clvrmnky, Codex Sinaiticus, Coldplay Expert, Conversion script, Cosentino, CosineKitty, Cpl Syx, Cplot, Crd721, Crystallina, Ctjf83, Cujfgh, Cyrius, Czj, D. C. Plunkett, DVD R W, DaisukeVulgar, Dalejarvis, Damoshaolin, DanielDeibler, Dantheman531, Dbfirs, DeadEyeArrow, Deor, DerHexer, Discospinster, Dkazdan, DocWatson42, Donarreiskoffer, Dougie monty, ESkog, Earrach, Ed Poor, Ed de Jonge, Eddie Dealtry, Ekedolphin, Elpincha, Emx, Enisoc, EscapingLife, Etacar11, Eternal Equinox, Eubulides, Ewawer, FKmailliW, FRA, Fdp, Feezo, Finell, Fremsley, Frymaster, Fusionmix, GSTQ, Gatewaycat, Geoff Wing, Gerbrant, Giftlite, Gilliam, Glenn, Glenn L, Gloriamarie, Gogo Dodo, Griffinofwales, Grim Revenant, Gt jaya, GuelphGryphon98, Gulliveig, Hadal, Harveydrone, Hda3ku, HexaChord, Hgilbert, Hulagutten, Huw Powell, Hype101, IRP, IZAK, Iantresman, Indefatigable, Ineffable3000, Insanity Incarnate, Ipaat, Iridescent, Itai, J Clear, J.delanoy, JD554, JForget, JPD, JPG-GR, Jamesooders, Jeff Muscato, Jeff3000, Jerzy, Jimaginator, Jimp, Joe Kress, JohnCD, Johnlogic, Jokinen, Joseph Solis in Australia, Kanags, Karl Palmen, Keilana, Kenyon, Keraunos, KevinCuddeback, Kodemage, Kostisl, Ks 7508, Laager, Lasunncty, Lee J Haywood, Leeyc0, Li-sung, Liene, Lightmouse, Lir, Lismoreboy, Lkinkade, Llwang, Lockesdonkey, Looxix, Lord of Haha, MER-C, MFago, MONGO, Macmanui, Magog the Ogre, Mahanchian, Man vyi, ManekiNeko, Marc Venot, Marek69, MarkusHagenlocher, Masoninman, Matthew Yeager, MatthewVanitas, Maxis ftw, Maxistheman, MiShogun, Michael Hardy, MichaelRWolf, Mindmatrix, Mmmeg, Montrealais, Morgan Leigh, Mouse is back, MrKIA11, MrWeeble, Ms2ger, Mudwater, Mulad, Mykolas OK, N. Harmonik, NJGW, Nae'blis, Nathanael Bar-Aur L., NawlinWiki, Ncmvocalist, Nebular110, NicholasTurnbull, Nnh, Norm mit, Novangelis, NuclearWarfare, Nucleusboy, Nukedoom, Obvioustrollisobvious, Oneironaut09, Oneiros, Oxymoron83, PJM, PStrait, PaulTanenbaum, Pausch, Pgk, PhantomS, Phantomsteve, PhiEaglesfan712, Philly jawn, PierreAbbat, PigFlu Oink, Pilotguy, PinchasC, Pinethicket, Pirateonthehighseas, Pisapatis, PizzaofDoom, PoofyPeter99, Ptr123, Python eggs, Quebec99, Quintote, Quota, RJHall, Rainmonger, Rajithmohan, Razorflame, Rgstuart, Rich Farmbrough, Rich257, Richard D. LeCour, Rija, Rjwilmsi, Rlupsa, RockMFR, Ronhjones, Ryan Postlethwaite, Ryjaz, Rzelnik, SEIBasaurus, SNIyer12, Sabbut, Saros136, Sbluen, Sceptre, Scott English, Seba5618, Sfisher, Shadowjams, ShanRen, Shirulashem, Shlomke, Shoeofdeath, Shroopliss, Sinneed, Skater, Skomorokh, Smith9847, Snowolf, Solarlune, Sopo1, Sopwith, Spiff666, Splortz, Spoon!, Spork the Great, SqueakBox, Stephenb, Swlenz, THEN WHO WAS PHONE?, Tadorne, Tamfang, TangentCube, Tapir Terrific, Tarheel95, Tauʻolunga, Teknomage, Templarion, Terry wonghk, The Thing That Should Not Be, Thesevenseas, Think outside the box, Tide rolls, Tikitwang123, Timmocollins, Timrem, Tohd8BohaithuGh1, Tom Peters, Tomsega, Tony1, Trevor MacInnis, Tsweder, Twaz, Twerbrou, Tyler, TyrantX, Uncle Dick, VX, VeryGoodBoy, Vgent, Victor Engel, VityUvieu, WatermelonPotion, Wellithy, Wetman, Whedonite, Wiki edit lol :), Willking1979, Windsok, Wiredknight, Wknight94, WojPob, Wolfgang Kufner, Woodstone, Woohookitty, Wtmitchell, Wwoods, XJamRastafire, Xiutwel, Yamamoto Ichiro, Yamara, Ycdkwm, Zachary, Zadcat, ZethSchlenker, ZooFari, ÇŸ³å°è±�, Île flottant, 835 anonymous edits

**Horizon** *Source*: http://en.wikipedia.org/w/index.php?oldid=330925533 *Contributors*: AHRtbA==, Acdx, Andycjp, Bemoeial, Blue horizon 666, Brazzouk, Bruce89, Bryan Derksen, Canadian-Bacon, Carbon-16, Citynoise, CrankyScorpion, Darklilac, DavidStern, Dellexxx, Dennis Brown, Drake Wilson, Ed Cormany, Efa, Finn-Zoltan, Fireswordfight, Firsfron, GRAHAMUK, Gaius Cornelius, Geboy, Gengiskanhg, Geoffrey.landis, Gimboid13, Glenn, Gracefool, Helios vmg, Henrygb, Heron, Itsmine, J.delanoy, JForget, JMK, JakeVortex, Jan eissfeldt, Johnian144, Johnlv12, JorgeGG, Joseph Solis in Australia, Karol Langner, Keylay31, Knutux, Korenyuk, La Pianista, Lee M, Lethe, Lommer, MCWicoff, Maladroitmortal, Marc Girod, Mark83, MarylandArtLover, Mauror, Maya, Michael Hardy, Mike Stramba, Mr kitehead, Mrcaseyj, Murjek, Nae'blis, NawlinWiki, Neelix, NeilHamburger, Nomadslounge, NuclearWarfare, Numbo3, Octahedron80, Ohms law, Pagw, Patrick, Pigsonthewing, Poop747, Popsracer, Python eggs, RJBrowning, RJHall, Rama, Robbrown, Robert A West, Ruud Koot, Ryulong, Schweiwikist, Scriberius, Shiftmain7, Sierra 1, SiriusB, Sjors, Slaniel, Slawojarek, Solitude, Squirrelist, Steinsky, Stephenb, The Ancient One99, Tide rolls, Tim Starling, Tobias Hoevekamp, Tom, TonyW, TutterMouse, Unigfjkl, Vary, WadeSimMiser, Waggers, Wealsa, XJamRastafire, Xnk, Ziggurat, ZrikiSvargla, Zro, 91 anonymous edits

**Latitude** *Source*: http://en.wikipedia.org/w/index.php?oldid=327947756 *Contributors*: 1158pd, Ac44ck, Acroterion, Addshore, AdiJapan, AdrianSavage, Adziura, Alanfeynman, Alansohn, Alphax, Anclation, Andrejj, AndrewWatt, Animum, Antandrus, Arafel2, Arakunem, Ashishbhatnagar72, AugPi, Avnjay, Avono, Badanedwa, Badly Bradley, Bazonka, Betterusername, Birkett, Bleh999, Bobblewik, Bobo192, Bongwarrior, Bryan Derksen, Caltas, CambridgeBayWeather, Camw, Can't sleep, clown will eat me, CanDo, CarpenterA, Cburnett, Chaser, Chuckiesdad, Chun-hian, Cimon Avaro, Cirt, Conversion script, Csnewton, Curps, D, Dan100, Darth Panda, David Kernow, DavidH, Davidseed, Dd2, DeadEyeArrow, DerHexer, Dfrg.msc, Dhruv.mongia, Discospinster, Dlae, Doulos Christos, Dragons flight, Drini, Drmies, Drunkenmonkey, Dtwilliamson, Duncharris, Dysepsion, ESkog, Ed g2s, Eequor, Egil, El C, Epbr123, Excirial, Falcon8765, Ferhengvan, Fieldday-sunday, FlyingToaster, Fubfubfub, Futurebird, G.Hagedorn, Gene Nygaard, Gerrit, Giftlite, Gilliam, Glenn, GregorB, Grim23, Gro-Tsen, Guycalledryan, Gökhan, Haakon K, Henrygb, Histrion, Hut 8.5, Hydrogen Iodide, Icairns, Ilmari Karonen, Indefatigable, Iridescent, J.delanoy, JH-man, Jason Quinn, Jatkins, Jclemens, Jeff G., Jitse Niesen, Joe Kress, Joe2008, Joe3600, Johndburger, Jonathan Webley, Jorunn, Julianp, Kaimbridge, Kalamkaar, Karol Langner, KasugaHuang, Kbolino, Keilana, Kelly Martin, Ketsuekigata, KnowledgeOfSelf, Kpajko79, Kuru, Lacrimosus, Larry_Sanger, Latka, Lawrencesm, Leonard G., Lesikar, Light current, Lightmouse, Linkracer, Loadmaster, MBisanz, Makeemlighter, Malekhanif, Manfi, Mark.murphy, Martinwilke1980, Mattbash, Mav, Mets501, Michael Hardy, Mike Dillon, Mmxx, Mongol, Mpatel, MrOllie, Mygerardromance, Myrtone86, N734LQ, Natb41, Nathanderthal, NawlinWiki, Ndkartik, NeilN, Nestorius, Netnuevo, Ngopikrishna, Niteowlneils, Novickas, Novum, Oekaki, OettingerCroat, Oleg Alexandrov, Onkelschark, Orlando F, OwenBlacker, Ozgod, Palapala, Para, Patrick, Paul August, PdDemeter, Penguin, Pepperpiggle, Peter S., Phantomsteve, Phil Boswell, Philip Trueman, Pigsonthewing, Pinguickman, Pippin254, Pit, Pointergrl, QuartierLatin1968, R'n'B, RJHall, Reconsider the static, Richard B, Romanskolduns, Royboycrashfan, Rracecarr, Rrjanbiah, Rwoolnough, SEWilco, SMC, Sacbob, SchfiftyThree, Scott Burley, Seattlenow, Sephiroth BCR, SetaLyas, Shanel, SharkD, Shereth, Shoefly, Siim, SimonP, Sionus, Sk19842, Smith609, Solphi, Sparky132, Spiffy sperry, Stbalbach, Stephenb, StuRat, Superbeecat, T-Dog333, TUF-KAT, TakuyaMurata, Tarquin, Tero, The Evil Spartan, The HMB, TheLedBalloon, TheRanger, Thesevenseas, TimVickers, Tony1, Trigamma, Turian, Ty8inf, Ubergeekguy, Ukexpat, Umapathy, Undisclosed14, Utcursch, Vanished user, Versus22, Vina, Violetriga, Vlad2000Plus, Vnmarser, Vssun, Vystrix Nexoth, WAvegetarian, Waltpohl, WatermelonPotion, Waveguy, Wavehunter, Wavelength, Wdanwatts, Wdfarmer, Weetoddid, WikHead, Wiki alf, Woodstone, Wumpus3000, WurmWoode, XDnateDX, XJamRastafire, Xgoni, Yamamoto Ichiro, Yogi de, Zaheen, Zandperl, Zanimum, Zayd1, Zholdas, Zzuuzz, 540 anonymous edits

**Mars** *Source*: http://en.wikipedia.org/w/index.php?oldid=331372429 *Contributors*: -- April, 0x6D667061, 11warnjames, 12345tyuio, 17Drew, 84user, A. B., A.T.M.Schipperijn, A314268, A3RO, ABTU, AMK1211, AOEU, ARC Gritt, AWESOME-Odude, Aaaa123, Aaarrrggh, Aardark, Aaronbwsm, Abductive, Acalamari, Aces lead, Action Jackson IV, Adam Bishop, Adamwankenobi, Adashiel, Addshore, Aelffin, Aeon1006, Aeusoes1, Agent003, AghastAmok, Agordhandas12788, Ahoerstemeier, Aillema, Aim Here, Akademy, Akira112, Aksi great, Alai, Aldo12xu, Aldude14, Ale jrb, AlefZet, Alegoo92, Alex.muller, AlexiusHoratius, Alexvickers, Alexwcovington, Allstarecho, AllyUnion, AlphaEta, Alrasheedan, Altonbr, American2, AmiDaniel, Amorymeltzer, Anchoress, AndonicO, Andrew Hampe, Andrew the coolest, Andrewpmk, Android Mouse, Andy M. Wang, Andy120290, AndySmith84, Angie023, Angmering, AnimAlu, Animum, Anixea, Anonymous Dissident, Answerthis, Antandrus, Anthony, Anton Mravcek, Antonio Lopez, Apexfreak, Apollo2011, ApostleJoe, Aquilosion, Aranherunar, Arctic.gnome, Ariel., Arj, Arjun01, Arno, Art LaPella, ArthurWeasley, Ascidian, Ashmoo, Aster2, Asteron, Astrobhadauria, Astrophil, Astudent, Aubadaurada, Aude, Audin, Avram Fawcett, Awolf002, Ayleuss, Azzjiggla, B, B.d.mills, B2012ball21, BD2412, BGManofID, BRG, Babbler, BaconBoy914, Bacteria, Bad Astronomer, Badanedwa, Baldhur, Bamf, BanyanTree, Bart133, BatteryIncluded, BeaverWithChainsaw, Bedford, Beerdola, Beland, Belar, Belekvor, Benbest, Bender235, Benhocking, Bennish, Beowulf king, Berek, Bergsten, Bernard192, BerserkerBen, BetoCG, Bg, Bhadani, Bigboss sb, Bigfrozenhead, Bilboon, BillC, Birkett, Bjf, Bkell, Blaablaa, Black Sword, BlaiseFEgan, BlindEagle, BlongerBros, Bloodredrover, Bloodshedder, Blu Aardvark, BlueEarth, Bluhbluhbluh94, Bob Castle, Bob rulz, Bob the Rabbid, Bobblewik, Bobet, Bobith2, Bobo192, Bongwarrior, Borgx, Borislav, BovineBeast, Braaropolis, BradDeharder, Bradeos Graphon, Bradlegar, Branddobbe, Brandmeister, Breno, Brian0918, Brighterorange, Brion VIBBER, Broberds, Bryan Derksen, Bryan.dollery, Bschlee, Bubba73, Bullzeye101, Bummerdude62, Bungle, C0nanPayne, CFCF, CKA3KA, Cactus Guru, Cadwaladr, Caggy, Caknuck, Calamarain, Calaschysm, Caltas, CalviNet, Calypsos, Cameron Dewe, Can't sleep, clown will eat me, Canadian-Bacon, CanadianCaesar, CanisRufus, Cantus, CapitalR, Captain Disdain, Carapar999, Caribbean H.Q., Carre, Carrionluggage, Casliber, Catgut, Causa sui, Cbsteffen, CecilWard, Cenarium, Centrx, Ceyockey, Cfassett, Chanting Fox, CharlesC, Charlesblack, CharlieZeb, Charvest, Chensiyuan, Chetvorno, ChicXulub, Chihuahua22, Chiros Sunrider, Chmee2, Chodorkovskiy, Choptube, Chrisjj, Chrislk02, ChristTrekker, Christian List, Chriswiki, Chuckchuckerson, Chunky Rice, ChunkySoup, Civil Engineer III, Cjkporter, Ckatz, Claytopia3, Closedmouth, Cmapm, Coelacan, ComaDivine, CommonsDelinker, Conversion script, Cosmium, Coyo, Cpollak, Crazycomputers, Crazynas, Crescentnebula, Crip22, Cromag, Crystallina, Cs302b, Curps, Cww, Cyan, Cyktsui, Czj, D. Recorder, DDR-Physiker, DMCer, DabMachine, Dablaze, Dahn10, Dalf, Dangoo, Daniel J. Leivick, Daniel Olsen, Daniel5127, DanielCD, Danny, DannyZ, Darin, Darth Logan, Darthgriz98, Darwin's Bulldog, Dasani, Davart, Dave420, Dave_McKee, Daveswagon, David Andel, David Martland, David.Mestel, David136a, DavideAndrea, Dbarnes99, Dbigwood, Dck7777, Dcooper, DeadEyeArrow, DearPrudence, Decadencecavy, Deeptrivia, Dekaels, Delfinis, Delldot, Demanufacture, Denni, Deor, DerHexer, Derajenator, Deuar, Dfgarcia, Discospinster, Dispenser, Diz syd 63, Djinn112, Djuice8, Dlohcierekim's sock, Dmarquard, Dockworker, Dojarca, Donarreiskoffer, DonnyKerabatsos, Downhometown, Downwards, Dpshuler, Dr. Submillimeter, DrKeirnan, DrKiernan, DrOxacropheles, Dragons flight, Drazyr, Drc79, Dreamyshade, Drini, Drorion, DrunkenSmurf, Drunkenmonkey, Dtgriscom, Dudeguyryan, Dusti, Dustymars, E rulez, ESkog, EamonnPKeane, Eberk456, Ebill, Ed Poor, Ed g2s, Edgar181, Edibobb, Edsanville, Edward, Edwy, Eeron80, Egil, Eisenmond, El C, Elb2000, Electron9, Eleland, Elisa Woods, Elliskev, Eloquence, Eltener, Eluchil404, Emerson7, Enceladusgeysers, Encephalon, EncycloPetey, Enviroboy, Epbr123, Epo, Erdal Ronahi, Ereiyo, Ericdn, Ericl, Ericmachmer, Eroica, Erpbridge, Ersatzaxiom, Eschnett, Esurnir, Eubulide, Evercat, Everyking, Evice, Evil Monkey, Excirial, Exir Kamalabadi, Ezzex, FKmailliW, FTAAPJE, Fabartus, FactoidCow, Fang Aili, Fartstank1996, FayssalF, Fbs. 13, Fearless Son, Femto, Fences and windows, Ferkelparade, Fidelfair, Figs, Filip.vidinovski, Firetrap9254, Firstmagnitude, Flamarande, Flo422, Flockmeal, Florentino floro, Flydpnkrtn, Flyguy649, Foodlover3935, Forezt, Fountains of Bryn Mawr, Fram, FrancescoA, FrankStratford, Fransvannes, FreplySpang, FreyasCrystalizedAngels, Friend mole, FrstFrs, Fukiyow, Funnybunny, Fvasconcellos, GHe, GTBacchus, GW Simulations, Gabbe, Gaiacarra, Gail, Gaius Cornelius, Galaad2, Gamehero, Garden, Garrett123, Gazjo, Gene Nygaard, Geneb1955, GeneralIroh, Geoffrey.landis, Gerbrant, Ghewgill, Ghostreveries, Giantsrule, Giftlite, Gigarice, Gman124, Gmaxwell, Gnixon, Gnomz007, Goalie1998, Goat217, Gogo Dodo, Goudzovski, GraemeL, Grafen, Grafikm fr, GrahamDo, Grandpafootsoldier, GrantHenninger, GregMinton, GregorB, Gregs gunners, Gscshoyru, Gsklee, Gthy1, Guanaco, Gurchzilla, Gvil, Gwernol, Hadal, Halfblue, Halibutt, Haljackey, HamatoKameko, Hamsterlopithecus, HannahCRichards, Happyfeet999, Happywaffle, Hardee67, Hargitai, Harp, Harryboyles, Hasek is the best, Haukurth, Headsploder, Headbomb, Hellcat fighter, Helloasd, Helzart, Henry Flower, Hephaestos, Herbee, HereToHelp, Hernoor, Hexgirls, Hibernian, Hiei-Touya-icedemon, Hike395, HisHighness420, Hjb26, Homrsmpsnrulz, HoodedMan, HorsePunchKid, House13, Hu, Hugsnkisses1996, Hurricane Devon, HuskyHuskie, Husond, I OWN I OWN I OWN, I need a stupid username, II MusLiM HyBRiD II, ILovePlankton, Iago Dali, Iain.dalton, Ian Pitchford, IanOsgood, Ianblair23, Iapetus, Ibagli, Icairns, Ikescs, Imdagirlonwiki, Infinityfsho, Info D, Inge-Lyubov, Insanity Incarnate, Instinct, Invader-Zod, InvisibleK, Ioeth, Iridescent, IronGargoyle, Ironman1503, Iseeaboar, Ispy1981, Itinerant1, Itportal, Itsmine, Ittiz, Iustinus, Ixfd64, J Di, J. Spencer, J.delanoy, JAW92, JDspeeder1, JFonseka, JForget, JIP, JTN, JaGa, Jacek Kendysz, Jack Schmidling, Jacob beechler, Jacob.jose, Jacobolus, Jafro, Jake1293, JamesR1701E, Janke, Japo, Jason Donaldson, Jcarle, JeLuF, Jeffaenima, Jefffire, Jeffthejiff, JeffyJeffyMan2004, Jennica, JeremyA, Jeronimo, Jerzy, Jespinos, Jespley, Jess Mars, Jesus the savior, JiFish, Jim Furtado, Jim77742, JimmyTheWig, Jimmyre, Jimwilcox79, Jj137, Jjbb, Jkl, Jknhkjdfhhhhhhh5454, Jmlk17, Jni, Jo Weber, JoanneB, Joao, Joaopais, Joe Kress, Joelr31, Johan1298, Johhny-turbo, John, John Abbe, John dildo, John oh, JohnnyMrNinja, Jojit fb, JonMoore, Jonapello22, Jonathan O'Donnell, Jose77, Joseph Solis in Australia, JoshuaZ, Josquius, Journalist, Jrt224, Jturner773, Junior aspirin, Just James, JustAnotherGuy01, JustPhil, Justice League 05, Justyb, Jwissick, Jyril, KFP, KHAAAAAAAAAAN, Kaldari, Kandrey89, Kasey12297, Katepaull, Kazrak, Kazvorpal, Kbcfan, Kbh3rd, Keegan, Keenan Pepper, Keilana, Kelly Martin, Kendrick7, Kesac, Kevin Breitenstein, Kheider, Kid45laundry, Kier07, Killerman1, KimDabelsteinPetersen, King Bee, KingTT, Kintetsubuffalo, Kirk Hilliard, Kitch, KnightRider, KnowledgeOfSelf, Koavf, KokkaShinto, Konomono33, Koolgirl560, Korean alpha for knowledge, Kotra, KrakatoaKatie, Krako, Krich, Kris Schnee, Kristaga, Ks 7508, Ksanexx, Ktan, Kukini, Kuliwil, Kums, Kungfuadam, Kuralyov, Kuru, Kusma, Kwamikagami, Kwekubo, Kwnd, Kyorosuke, LOL, LTH, Lacrimosus, Lagus970, Lakers, Lampofdoom, Lansey, Laogeodritt, Latitude0116, Latitudinarian, Latka, Laudaka, Lazareth, Le Anh-Huy, Leafyplant, LeaveSleaves, Lectonar, Lee Daniel Crocker, LeeG, Leebo, Leefatting, Legend, LeoNomis, Lester, Levin, Lexor, Li-sung, Liam, Liamscanlan, Ligguma, Lightblade, Lightdarkness, LightingRod, Lightmouse, Lights, Lilac Soul, Link dude177, Ljones0920, Lksadfajsl, Llort, Lmov, Loadmaster, Loginnow, Lol0075, LonelyMarble, Lookypoojky, Looxix, LordKael, LordPhobos, Lost.goblin, Luboogers25, Ludes, LuigiManiac, Luna Santin, Lupin, Lwangaman, Lyle, Lyle zapato, M1ss1ontomars2k4, MBisanz, MDB913, MER-C, MJCdetroit, MLetterle, MPF, MPerel, MZMcBride, Ma Baker, MacRusgail, Maelnuneb, MaikSchreiber, Majorly, MakeDamnSure, Makewater, Maldek, Malljaja, Malo, Mandynoty, Mani1, Marcairhart, Maria Sieglinda von Nudeldorf, Mario0318, Mark Foskey, MarkGallagher, Marnanel, Marsbound2024, Marskell, Marsterritory, Martial Law, Martin Ginty, Martin.Budden, Martinwilke1980, Marzziano, MasterPlan, MasterSci, Masterjamie, Mateuszica, Matey, Matiasmoreno, Matt Crypto, MattSal, Mattfox22, Mattingly23, Mav, Maxexcloo, Maxim, Mb1000, Mbecker, Mboverload, Mcstxc7, Meaningful Username, Mediumemu, Meeples, Megalodon99, MeltBanana, Merik777, Metron4, Metropolitan90, Mgiganteus1, Michael Devore, Michael Dinolfo, Michael Hardy, Michaelbusch, Miguel, Mike Peel, Mike Rosoft, Mike s, Mikebarryrocks!, Mikewilson614, Milkyeyes, Millionsofleeches, Milonica, Minesweeper, Minority2005, Miranda, Mirkoruckels, Mirwin, MisfitToys, Misza13, Mkamensek, Mlaine, Mlm42, Mmbaldwin, MoRsE, Moe Epsilon, Monowiki, Moogsi, Mordicai, Moreschi, Morwen, Mpanos2003, Mr Bound, Mr Woman, Mrboh, Mrwuggs, Mschel, MuDavid, Mukake, Murgh, Murlough23, Music4ever1, Mvincec, Myanw, M£, N328KF, NVO, Nakon, Nash London, Natl1, NatureA16, NawlinWiki, Nbound, NeilN, NeilTarrant, NeoNerd, Nephelin, Nerguy, Netsnipe, NeutralPoint, Neutrality, Neverquick, Newnoise, Nibuod, Nick, Nick-D, Nickj, Nickptar, Nickshanks, Nicoisgreat111, Nils, Ninjagecko, Ninjalemming, Nintendo121, Nixer, Njál, Nk, Nkayesmith, Nneonneo, Nomadtales, NonChalance, Noosfractal, NorCalHistory, Noren, Norty512, Not Andrew, Notheruser, Notmage2, Nowimnthing, Nubar24, NuclearWarfare, NuncAutNunquam, Nurg, Nutschig, OAC, Offliner, Ohfosho, Ohnoitsjamie, OldakQuill, Oldey, Oliver Pereira, Olivier, Olve Utne, Omegatron, Omicronpersei8, Oncedarkness, Oneismany, Oniwanbashuu, Onsly, Opelio, Orangutan, Orpheo, Ossmann, Oubiwann, Oxymoron83, P3d0, PC-Cat, Panser Born, Paolorausch, Parhamr, Pastapuss, Patrick, Patstuart, Paul August, Pauly04, Pb30, Pcarbonn, Pedro, Pegstarr, Pentawing, Perceval, Perl, Persian Poet Gal, Peter, Peter Winnberg, PeterSymonds, Phasmatis, Phayne, Phenylalanine, Phidauex, Philip Stevens, Philip Trueman, PhilipC, Phædrus, Pi@k, Pierre2012, Pinkadelica, Pious7, Plateau99, Playerfreakbass, Pleroma, Plop, Plumbago, Pnazemi, Poccil, PoccilScript, Pogsquog, Pol098, Politepunk, Polymerbringer, Ponder, Poolkris, Poor Yorick, Populus, PorciusXX, Porqin, PresN, Preston47, PrestonH, Prilla, Prodego, ProveIt, PsychoSmith, Purples, Python eggs, Qwerty Binary, RDT2, RG2, RJHall, Radon210, Radzewicz, RahadyanS, Rameses, Ran, RandomCritic, RandomP, Randomblue, Randomguy1234567890, Raymond arritt, Razorflame, Rbs, Rc3784, Rdsmith4, RebaFan1996, Rebecca, Recurring dreams, Red Thunder, Red1, RedSpruce, RedandProud2, Redandproud1, Reddi, Renatokeshet, Renegade54, Rentaferret, Renthead97, Reubenbarton, Revan13, Revth, RexNL, Reyk, Reywas92, Rgoodermote, Riana, Rich Farmbrough, RichardF, Richhoncho, RickK, Rintrah, Riverkarl, Rjd0060, Rjwilmsi, Rmhermen, Rnbc, Roadrunner, Robert Happelberg, Robert Merkel, RobertG, Robertbowerman, RodC, Roentgenium111, Roger3245, RogueNinja, Rollie, Romanm, Rondack, Roofus, Rosameliamartinez, Roscoe x, RoseAstronomer06, Rotational, Rotem Dan, RoyBoy, RoySmith, Royboycrashfan, Rror, RunOrDie, Rursus, Ruslik0, Rutherfordjigsaw, RyanGerbil10, Ryulong, SHA0001, SJP, SMC, SO-intO-yOuxX, SOPHIA, Saladguy, SallyForth123, Salsa Shark, Salulljoica, Sam Korn, Samaster1991, Sammmttt, Samnikal, Samsara, Samuel, Sanawon, Sandman, Sango123, Sannse, Sardanaphalus, Saros136, Sarregouset, Satanael, Saturn7, Sbandrews, Scentoni, SchfiftyThree, Schmackity, Schnahoo, Schneelocke, Schuylar247, Sciurinæ, Scog, Scott Sanchez, Scott3, Scottcabal, Scottperry, Sdsds, Seattlenow, Seb az86556, Secretlondon, Semorrison, Semperf, Sengkang, Sepeople, Serb4c, Serendipodous, Sethrasmussen121, Setup, SexualFinger, Seyon, Shakedust, Shalom Yechiel, Shanel, Shanes, ShapedNoise, Shappy, Shikasta, Shimgray, Shirishag75, Shoaler, Showbread89, Shreshth91, ShutterBugTrekker, Sibalsagi, Sidasta, SigmaTap, Sijo Ripa, Silbad, Silly rabbit, Sillybilly, Simmie, SimonP, Sintonak.X, Sj, Sjakkalle, Sk8rbabii202, Skater1345, Skizzik, SkogsRickard, Skood, Skyezx, Slakr, Slasher600, Slysplace, Smerlinare, Snicket101, Snowolf, SoLando, Solitude, Someone42, Something14, Soumyasch, SouthernNights, Spaceman13, Spangs, Spartan, Spellcast, Spellcaster12, Spellmaster, Spiff, SpookyMulder, Spotturtle, SpyMagician, Srleffler, Srose, Stardust8212, Starexplorer, Statue2, Steel, Stephen Gilbert, Stephen27, Stephenb, Stepheng3, Stevenj, Stevietheman, Stewartmacarth, StivCa, Stone, Streetfoo212, Stwalkerster, Suduser85, SugarPlumLove, Suniti karunatillake, Supergeo, Superworms, Supraboy001, Suraj vas, Suruena, Surv1v4l1st, Susurrus, Suthers, Svetovid, Sxicrisis, T42at102, TJDay, TMLutas, TOttenville8, TV4Fun, Taco325i, Taliska, Tanthalas39, Tapir Terrific, Targetter, Tariqabjotu, Tarquin, Taskmaster99, Tawker, Tcmstr134, TeaDrinker, Tedp, Tedstryk, Teemu Leisti, Tehtorptsol, Tejas.B, Template namespace initialisation script, Terence7, TexasAndroid, Tezp, That paddy child kid, The Singing Badger, The Thing That Should Not Be, The dyer man, The mars 789, TheFloppyOne, TheKMan, TheLasso, TheLou75, TheN0ble2, TheOtherJesse, TheProject, Thefirstdude02, Thegraham, Themanwithoutapast, Themulemonk, Theredpill2003@hotmail.com, Thetreesonmars, Thingg, ThrashedParanoid, Thue, Tim1357, Timir2, Timmyrprp, Timwi, Tinsue, Tinwelint, Tivedshambo, Tom, Tombomp, Tomhannen, Tomruen, Tonik, Tony1, Tonywalton, TopAce, Torontobwoi, Torvik, Towelie55, Tpbradbury, Tpheiska, Traroth, Travelbird, Travisjoake22130, Triberocker, Trilobite, Triwbe, Trumpet marietta 45750, Trunks6, Trusilver, Ttzz, Tuvas, Twang, UBeR, Uchohan, Ufviper, Ugur Basak, Ukexpat, Ultimus, UltraCaution, Ultratomio, Uncfan3200, Uncle G, Universal1300, Urhixidur, UtherSRG, Van der Hoorn, Variable, Vary, Vechs, Vexxl, Viggio, Vikingstad, Viriditas, VladimirKorablin, Volcanopele, Vorlon, Vsmith, Vsst, WBardwin, WCar1930, WJBscribe, WODUP, Waerloeg, Wafulz, Watch37264, WatermelonPotion, Waveguy, Wavelength, Wayward, Webb.phillips, Westsider, Wetman, Whpq, Wiggstar69, Wiki alf, WikiBone, WikiUser55, Wikianon, Wikibob, Wikiborg, Wikichangerman, Wikipedophilia, Wikipedosucklol, Wikiscient, Wikster E, Wild Bill, Wildthing61476, Wiljaneni, Will2710, William M. Connolley, WilliamKF, Willthepwn, Wimt, Witan, Wjmummert, Wknight94, Wl219, Wmahan, Wmfife, Wolfkeeper, WolfmanSF, Wonglokking, Wonkinson, Worldtraveller, Woudloper, Wraithdart, Wwoods, Wælgæst wæfre, XJamRastafire, Xaliqen, Xaven, Xerbox, Xkoalax, Xlation, Xy7, Xymmax, Yahel Guhan, Yamamoto Ichiro, Yamla, YanA, Yanksox, Ydris, Yonatan, Yosef1987, Yunaresuka, Yupik, Yuri koval, Yvesnimmo, Zafiroblue05, Zandperl, Zanter, Zaraahmed100, ZincOrbie, Zoe, Zoharby, Zonk43, Zooman555, ZorkFox, Zouhair, Zsinj, Zundark, Zytroft, ^demon, Ævar Arnfjörð Bjarmason, Александьр, Саша Стефановић, ירעל טראהנייר, 1970 anonymous edits

**Solstice** *Source*: http://en.wikipedia.org/w/index.php?oldid=331697318 *Contributors*: 0x6D667061, 20040302, 23hal, A little insignificant, A. Parrot, Abuk78, Across.The.Synapse, Adashiel, Aedler, Aeroknight, Alberto Orlandini, Albrozdude, AlexiusHoratius, All Is One, AnakngAraw, Andres, AndrewHowse, Andycjp, Andypandy.UK, Ann Stouter, AnonGuy, Ante Perkovic, Army1987, Ask123, Astrologist, Astronomyphile, Avb, AzaToth, Azazello, Backslash Forwardslash, Barneca, BartBenjamin, Bedoolya, Beepo4, Bendzh, Benea, Benny the wayfarer, Benwing, Bewildebeast, BillFlis, Bloodbath 87, Blueshade, Bobo192, Borgx, Braithwaite, Britishphotolandscapes, Bsayusd, Bucketsofg, CRKingston, Calmer Waters, Can't sleep, clown will eat me, Carlj7, Carolmooredc, Cburnett, ChaosNil, Chitoryu12, Chowbok, Cleonis, Cobi, Coelacan, Conversion script, Craigfis, Crazydancer24, Crd721, Czj, D climacus, D0762, Da monster under your bed, Dane Sorensen, Daniel.Cardenas, Darth Panda, Davidkazuhiro, Db099221, December21st2012Freak, Discospinster, Dismas, Dkreisst, Donarreiskoffer, E.Casty, EaglesFanInTampa, El C, Elipongo, Elpincha, Emijrp, Emx, Enirac Sum, Enviroboy, Epbr123, Eric Wester, EricTheRed, Etacar11, Eternal Equinox, Ethan Mitchell, Eubulides, Flyingbird, Fredwerner, Frosted14, GLmathgrant, Gaelen S., Gail, Garzo, Genedyer, Ghableska, Giftlite, Gilliam, Gimboid13, Glenn, Glenn L, Goudzovski, GrumpyFarmerBill, Gulliveig, Gurch, HammerInPeace, Harryboyles, Hasanisawi, Head, Headbomb, Hitmoments, Hmoul, Hmrox, Howcheng, Hu12, Imnotminkus, Ingolfson, Intelligentsium, Ioeth, J.delanoy, JEBrown87544, Japanese Searobin, JasonAQuest, JayZ, Jecowa, JeepdaySock, JeffMDavidson, Jm butler, Jni, Joe Kress, John Riemann Soong, Johntex, Jordanville, Joseph Solis in Australia, Jpbowen, KNHaw, Kaiwhakahaere, Kakoui, Kanags, Karl Palmen, Katanada, Keakealani, KevinPuj, Knowledge Seeker, KnowledgeOfSelf, Ktapar06, Lasunncty, LibLord, Lilac Soul, Lir, Lismoreboy, Locos epraix, Lokiskoll, Lolkiklol, Luckas Blade, Luke2011, Lupin, MER-C, MONGO, MackSalmon, Macy, Madman, Marco Paganini, Mark, Mark1962, Martarius, Masoninman, Master Jay, McCart42, Mendaliv, Mericet, Michael Greiner, Michael Hardy, Mike Bags, Mindspillage, Miranche, Misteror, Montrealais, Munchkinguy, MycroftHolmes4, N5iln, NAHID, Nakon, Nasai, Nathanwright, Neier, Nickaubert, Nilhanu, Nopetro, Norlanson, Novalis, NuclearWarfare, Oda Mari, Orethrius, Orfen, Orionus, Oroso, Pascal.Tesson, PaulColby, Pawyilee, Pd THOR, PeaceNT, Penwhale, Petersam, PhantomS, Philip Trueman, Philly jawn, Piano non troppo, PigFlu Oink, PinchasC, Pomona17, PoofyPeter99, Portalian, Pouya, Profero, Puchiko, Pup05, PvsKllKsVp, Python eggs, Quintin3265, Quota, RJHall, Racula, Rajatbijur, RamBow, Rcjsuen, RexNL, Rich257, Romarin, RyanCross, Rydra Wong, Rzelnik, S7evyn, SNIyer12, Sanbeiji, Scapler, SchfiftyThree, Secret Squïrrel, Sethoeph, Shoessss, Sidasta, Slipstream, Smokizzy, Solarlune, Soliloquial, Some thing, Sorcha, Splash, Squash, SqueakBox, Sty Huey, Suruena, Tauʻolunga, Teamlexington, Terra Green, Th1rt3en, The Rambling Man, The Thing That Should Not Be, The Tom, TheRanger, Thesevenseas, Tide rolls, Tobacman, Tobias Hoevekamp, TonyW, Trentblase, Tyrsdomain, Tyuiop123, Unfree, Unint, Vankrugermeer, Veinor, Verdlanco, Vonblonderbelt, WadeSimMiser, Who, Wiki alf, Wikidudeman, Will1234567890, WilliamCrandall, Wissbecklarry, Wolfgang Kufner, Woodstone, XJamRastafire, Xaosflux, Xtifr, Yamara, Zadcat, Zcpbbdk, Zharradan.angelfire, ZooFari, Zzuuzz, 542 anonymous edits

**Sunrise** *Source*: http://en.wikipedia.org/w/index.php?oldid=328924307 *Contributors*: .mau., 334a, Ackatsis, Adamd1008, Adrian J. Hunter, Afirex, Ajcounter, Aka042, Altenmann, AndrewHowse, Animum, Anwar saadat, Arjun01, Ashley Y, Azamishaque, BJB, Badly Bradley, Balsa10, BeefRendang, Beland, Bobblewik, Bobo192, Bodybagger, Bogdangiusca, Brad Bishop, CALR, CamperStrike, Chmouel, Closedmouth, Confuzion, Daniel Olsen, David R. Ingham, Denelson83, DerBorg, Dkreisst, Dr. Steven Fry, Dschwen, ENIAC, Ebuz, Emu ennui, Etacar11, Fallenangei, Farras Octara, Fir0002, Fooflington, Fred7447, From-cary, Gaius Cornelius, Geographer, Glass window, GoneAwayNowAndRetired, GregCovey, Grim23, Gulliveig, Haham hanuka, Hellocsrini, Hephaestos, Heron, HisSpaceResearch, Holycharly, Honeydew, Ian Pitchford, Ianblair23, Imperium Europeum, In Defense of the Artist, Infolepsy, Iracaz, Iridescent, Irishguy, Ironholds, Isidore, Itsmine, J 1982, J.delanoy, JASpencer, Jahjahrah, James K, Jennavecia, JohnOwens, Jpogi, Jwanders, Jxan3000, K.Nevelsteen, Karol Langner, Keyesc, Looxix, Lovleet, Lucianilica, MK8, Marek69, Mark, Markaci, Martarius, Martin451, MartinHarper, Martyjmch, Mathwhiz 29, MaxFrear, Maya, Mbell, Mbz1, Menchi, MetroStar, Michael Hardy, Mild Bill Hiccup, Modular, Moise Nicu, Montrealais, Moriori, Moshe Constantine Hassan Al-Silverburg, Mr Taz, Mringel, Mrmiscellanious, Mtcv, Murderbike, Nachoman-au, Netoholic, Norhelt, Oda Mari, Paul A, Paul venter, Paulkondratuk3194, Paulkondratuklovesny, Pearle, Pethr, Pfalstad, PigFlu Oink, Polonius, Poulpy, Pyrop, R, RHaworth, Radiojon, Rklawton, Rmrfstar, Roland Longbow, Runera, RuniingDog, Runningonbrains, Saperaud, Saros136, Sean the Spook, Shantavira, Silverwurm, Smallufo, Soumyasch, Spiel496, Spoon!, Squash, Staffwaterboy, SteinbDJ, Sverdrup, TakuyaMurata, That Which Lurks1, The Good Doctor Fry, The wub, Thegreenj, TheronJ, Thesevenseas, Thingg, Thue, Thug outlaw69, Tom, Tomer T, Treisijs, Wavehunter, WiiWillieWiki, Wiki-uk, Wingchi, Wknight94, Wmahan, XN, Xe Cahzytr Ryz, ^demon, 115 anonymous edits

**Sunset** *Source*: http://en.wikipedia.org/w/index.php?oldid=329554140 *Contributors*: -Midorihana-, 16@r, 1dragon, 84user, A314268, Abundela76, Accas1, AdamjVogt, Adrian.benko, Affleck, Ahoerstemeier, Alex Bakharev, Alex van Poppelen, AlexiusHoratius, Alfred Dengan, Altenmann, Alvesgaspar, Amoruso, Andycjp, Anonymous101, Antandrus, Anwar saadat, Article20, Ashley Y, Averette, BQZip01, Badly Bradley, BeefRendang, Beland, Bennylin, Bergsten, Bevo, Bidiot, Billyfishzwei, Bjcairns, Boarder8925, Boffy b, Bond Extreme, BorisFromStockdale, Brad Bishop, BrendelSignature, C.Fred, CALR, CamperStrike, CanisRufus, Catholic 85, Cautious, Cflm001, Ched Davis, Chmouel, Chowbok, Chris 73, Citikiwi, Ckatz, Closedmouth, Colonies Chris, CommonsDelinker, Computerjoe, Crakkpot, Crohnie, Ctjf83, Curtis Clark, DVD R W, DXMorpheus, David R. Ingham, Delldot, DerBorg, DesperateAngel, DirectorG, Dkreisst, Dogposter, Donbas, Dr. Steven Fry, Dschwen, Duke, Durova, Dycedarg, Dylar, ESkog, Echasketch123, El C, Emeraldcityserendipity, Emustonen, Energman, Epbr123, Eric-Albert, Eu.stefan, Extreme Australian Wrestling, FaerieInGrey, Falconcreations, Fearlessunit, Fir0002, Flewis, FreplySpang, Fyyer, GOODBOY20022002, Garden, Gaz, Geocachernemesis, Geraldgreene, GoodNite AmyLee, Graham87, Green caterpillar, Gurch, Haham hanuka, Hankengine, Hede2000, Heron, Hertzsprung, Holek, Honeydew, Howcheng, Ian Fieggen, Icefall5, Imperium Europeum, Infrogmation, Inwind, Iracaz, Iridescent, Itsmine, Ivan, J 1982, J.delanoy, JACurran, Jackol, Jak123, Janderk, Jay, Jerzy, JimVC3, Jmlk17, JoaoRicardo, Joaquín Martínez Rosado, Jpogi, Julesd, Julianster, Jusdafax, Kaibabsquirrel, Kaiseralexander, Karol Langner, Kbh3rd, Kitkatcrazy, Korean alpha for knowledge, L.vivian.richard, LTSLTS, Leitmanp, LittleDan, Looxix, Luna Santin, MPF, Magbatz, Mangostar, Manuel González Olaechea, Marsiancba, MartinHarper, MartinRe, Martinwilke1980, Martyjmch, Massimo Catarinella, Mathias-S, Maya, Mbz1, Menchi, Miamiboyzinhere, Micchickenburger, Micov, Momusufan, Moncrief, Monitep, Montrealais, Moose6589, MosheA, Mr. Lefty, Mtcv, NYIP, NawlinWiki, Netoholic, Ngresonance, Nikkul, Onorem, Originalwana, PaddyBriggs, Paul A, Paulkondratuk3194, Pccoutu, Pearle, Pengo, Philverney, Plasticup, Porqin, Possum, Pthompsen, Pwrbanker, Qrc2006, Radiojon, Rd232, Robertbody, Roguegeek, Roland Longbow, RonAlmog, Ruud Koot, Ryulong, Salvo46, Saperaud, Saskjon, Scapler, Scorpion0422, Seadog365, Secfan, Shantavira, Sharadpisal, Sherool, Shiftchange, Skanter, Skier Dude, Slant6guy, Slivester, Solipsist, Solitude, Soumyasch, Spiel496, Spinnick597, Spoon!, Stanthejeep, StaticGull, Stoljaroff1987, Sum 2101, Superbleachbrothers, Sverdrup, Svetovid, Tabor, TakuyaMurata, Talhamujahid, TalkAbout, Tauʻolunga, TerritorialWaters, The Ancient One99, The Good Doctor Fry, The Transhumanist, The penfool, Thecurran, Thehelpfulone, Thesevenseas, Thuresson, Tide rolls, TigerShark, Tiggerjay, Tiptoety, Titoxd, Tjpatterson, Torstein, Transent, Treisijs, Uncle Dick, Vanka5, Viriditas, Warren, Warrington, Wellnoid, Wetman, Wiki alf, Wiki-uk, Wykymania, XN, Xe Cahzytr Ryz, Yeahsoo, Zardragon, Zink Dawg, مايكل النباتية, 225 anonymous edits

**Zenith** *Source*: http://en.wikipedia.org/w/index.php?oldid=331401334 *Contributors*: Aesopos, Ahoerstemeier, Alanbly, AnakngAraw, Andres, Approsemite, Astrologist, Bkell, BlazerKnight, Borgx, Bruce89, Bryan Derksen, Cburnett, DTR, Danielsavoiu, DarkFalls, DavidLevinson, Dpbsmith, Dr. Submillimeter, DrachenFyre, E.P.Y. Foundation, Ejdzej, Ekhalom, Epbr123, Fernkes, Frieda, Friedo, Frokor, Gargami, GerardM, Gilgamesh, Glenn, HenryLi, Htaccess, IHRH209, Isnow, JEBrown87544, Jao, JorgeGG, Jorunn, Jotunepitaph, KFP, Kalsermar, Khutuck, Kostisl, Krsont, Kudos, LAgurl, Lasunncty, Lezek, Liftarn, Looxix, Ludde23, Macbook24, Magicalboy, Mariataka, Maroux, Matusz, Metallica1596, Michel BUZE, Michel M Verstraete, Mindmatrix, Mr gronk, Mumia-w-18, NewEnglandYankee, Nsande01, Ogl.codemonkey, Orgullomoore, Orionus, Palica, Phil websurfer@yahoo.com, Phirst, Photonikonman, Piotrus, Pixi, Portalian, Prodge, Pumpie, QuantumEleven, RHaworth, RJHall, ReyBrujo, Runeuser, Rāmā, SV Resolution, Saravask, Shawnc, Snowolf, Stephen Deagle, Stevertigo, SummitWulf, TKD, Tanaats, Teply, The Thing That Should Not Be, Thesevenseas, Thorney¿?, Tobias Hoevekamp, Valepert, Warofdreams, Wavelength, WhisperToMe, XJamRastafire, Yvwv, Zeelo, Zoicon5, 106 anonymous edits

# Image Sources, Licenses and Contributors

**File:蘿蔔坑夜色.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:蘿蔔坑夜色.jpg *License*: Public Domain *Contributors*: User:Cutecrow2000

**Image:Types-of-twilight-en2.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Types-of-twilight-en2.svg *License*: Creative Commons Attribution 3.0 *Contributors*: User:Why Not A Duck, User:Wmc824

**Image:PanoSantPere.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:PanoSantPere.jpg *License*: Attribution *Contributors*: User:MickStephenson

**File:Twilight at acapulco edit.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Twilight_at_acapulco_edit.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Arturo "Feralaas" Mann

**File:Prague_Castle_at_Night.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Prague_Castle_at_Night.jpg *License*: Creative Commons Attribution-Sharealike 2.0 *Contributors*: Ricardo Liberato

**Image:Daylight Length.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Daylight_Length.svg *License*: GNU Free Documentation License *Contributors*: User:Thesevenseas

**Image:Manoderecha.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Manoderecha.svg *License*: GNU Free Documentation License *Contributors*: User:Jfmelero

**Image:AxialTiltObliquity.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:AxialTiltObliquity.png *License*: Creative Commons Attribution 3.0 *Contributors*: User:Dna-webmaster

**File:Earth symbol.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth_symbol.svg *License*: Public Domain *Contributors*: User:OsgoodeLawyer

**File:The Earth seen from Apollo 17.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:The_Earth_seen_from_Apollo_17.jpg *License*: Public Domain *Contributors*: NASA. Photo taken by either Harrison Schmitt or Ron Evans (of the Apollo 17 crew).

**File:Speaker Icon.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Speaker_Icon.svg *License*: Public Domain *Contributors*: Blast, G.Hagedorn, Mobius, 2 anonymous edits

**File:Solar Life Cycle.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Solar_Life_Cycle.svg *License*: Public Domain *Contributors*: User:Oliverbeatson

**File:Terrestrial planet size comparisons.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Terrestrial_planet_size_comparisons.jpg *License*: Public Domain *Contributors*: wikipedia user Brian0918

**Image:Uranus, Earth size comparison.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Uranus,_Earth_size_comparison.jpg *License*: Public Domain *Contributors*: Brian0918

**File:Earth-crust-cutaway-english.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth-crust-cutaway-english.svg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Surachit

**File:Tectonic plates (empty).svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Tectonic_plates_(empty).svg *License*: Public Domain *Contributors*: Dbenbenn, Denys, Sting, Ævar Arnfjörð Bjarmason

**File:AYool topography 15min.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:AYool_topography_15min.png *License*: Creative Commons Attribution 2.5 *Contributors*: Plumbago

**File:Earth elevation histogram 2.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth_elevation_histogram_2.svg *License*: Public Domain *Contributors*: Original uploader was Citynoise at en.wikipedia

**File:Air masses 2.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Air_masses_2.jpg *License*: Public Domain *Contributors*: Original uploader was Gopher backer at en.wikipedia

**File:Full moon partially obscured by atmosphere.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Full_moon_partially_obscured_by_atmosphere.jpg *License*: Public Domain *Contributors*: NASA

**File:Dipole field.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Dipole_field.svg *License*: unknown *Contributors*: Users Heron, Kevin Saff on en.wikipedia

**File:AxialTiltObliquity.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:AxialTiltObliquity.png *License*: Creative Commons Attribution 3.0 *Contributors*: User:Dna-webmaster

**File:236084main MilkyWay-full-annotated.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:236084main_MilkyWay-full-annotated.jpg *License*: Public Domain *Contributors*: NASA/JPL-Caltech/R. Hurt

**File:Earth and Moon from Mars PIA04531.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth_and_Moon_from_Mars_PIA04531.jpg *License*: Public Domain *Contributors*: Complex01, Curps, Quasipalm

**File:Earth Moon Scale.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth_Moon_Scale.jpg *License*: GNU Free Documentation License *Contributors*: User:Acdx

**File:Habitable zone-en.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Habitable_zone-en.svg *License*: GNU Free Documentation License *Contributors*: User:Chewie

**File:Continents vide couleurs.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Continents_vide_couleurs.png *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: Bvontob, Cogito ergo sumo, Editor at Large, Gerrit, Lycaon, OlympiADdict, QuartierLatin1968, Timeshifter, 5 anonymous edits

**File:Earthlights dmsp.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earthlights_dmsp.jpg *License*: Public Domain *Contributors*: Data courtesy Marc Imhoff of NASA GSFC and Christopher Elvidge of NOAA NGDC. Image by Craig Mayhew and Robert Simmon, NASA GSFC.

**File:AS8-13-2329.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:AS8-13-2329.jpg *License*: Public Domain *Contributors*: Frank Borman

**Image:Axialtilt.gif** *Source*: http://en.wikipedia.org/w/index.php?title=File:Axialtilt.gif *License*: Public Domain *Contributors*: Bryan Derksen, Maksim, Newone

**Image:Ecliptic.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Ecliptic.jpg *License*: Public Domain *Contributors*: ComputerHotline, HenkvD, Nillerdk, RHorning

**Image:World map with equator.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:World_map_with_equator.svg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Thesevenseas

**File:Equator and Prime Meridian.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equator_and_Prime_Meridian.svg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:NuclearVacuum

**Image:Equator sign kenya.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equator_sign_kenya.jpg *License*: GNU Free Documentation License *Contributors*: Conscious, Kristaga, SPUI

**Image:Equator Sao Tome.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equator_Sao_Tome.jpg *License*: unknown *Contributors*: taken by Husond

**Image:Equator monument.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equator_monument.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Netaholic13

**File:Marcozero.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Marcozero.jpg *License*: Public Domain *Contributors*: User:Coedj

**File:Flag of Sao Tome and Principe.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Sao_Tome_and_Principe.svg *License*: Public Domain *Contributors*: User:Gabbe

**File:Flag of Gabon.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Gabon.svg *License*: Public Domain *Contributors*: User:Gabbe, User:SKopp

**File:Flag of the Republic of the Congo.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_the_Republic_of_the_Congo.svg *License*: Public Domain *Contributors*: Denelson83, Estrilda, Homo lupus, Klemen Kocjancic, LA2, Madden, Mattes, Moyogo, Neq00, Nightstallion, Ratatosk, ThomasPusch, Thuresson

**File:Flag of the Democratic Republic of the Congo.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_the_Democratic_Republic_of_the_Congo.svg *License*: Public Domain *Contributors*: Anime Addict AA, AnonMoos, ChongDae, Denelson83, Ed veg, Fry1989, Homo lupus, Klemen Kocjancic, LA2, Mattes, Moyogo, Nagy, Neq00, Nightstallion, ThomasPusch, Urhixidur, Vzb83, Westermarck, Zscout370, 5 anonymous edits

**File:Flag of Uganda.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Uganda.svg *License*: Public Domain *Contributors*: Anime Addict AA, Emijrp, Ezeu, J. Patrick Fischer, Klemen Kocjancic, Kookaburra, Madden, Mattes, Mxn, Neq00, Nightstallion, Ninane, Rechta, Reisio, Str4nd, ThomasPusch, Wikiborg, 9 anonymous edits

**File:Flag of Kenya.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Kenya.svg *License*: Public Domain *Contributors*: User:Pumbaa80

**File:Flag of Somalia.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Somalia.svg *License*: unknown *Contributors*: Anakin101, Anonymous101, Flad, Gdgourou, Homo lupus, JLogan, Klemen Kocjancic, Mattes, SKopp, ThomasPusch, Tvdm, Ultratomio, Vzb83, احمد.عطية1, 9 anonymous edits

**File:Flag of Maldives.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Maldives.svg *License*: Public Domain *Contributors*: Anime Addict AA, Gabbe, Klemen Kocjancic, Mattes, Nightstallion, Ninane, Rfc1394, VAIO HK, Vzb83, 3 anonymous edits

**File:Flag of Indonesia.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Indonesia.svg *License*: Public Domain *Contributors*: User:Gabbe, User:SKopp

**File:Flag of Kiribati.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Kiribati.svg *License*: Public Domain *Contributors*: User:SKopp

**File:Flag of the United States.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_the_United_States.svg *License*: Public Domain *Contributors*: User:Dbenbenn, User:Indolences, User:Jacobolus, User:Technion, User:Zscout370

**File:Flag of Ecuador.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Ecuador.svg *License*: Public Domain *Contributors*: B1mbo, Denelson83, Editor at Large, Eleassar, EugeneZelenko, Fsopolonezcaro, Herbythyme, Homo lupus, Klemen Kocjancic, Lokal Profil, Ludger1961, M.C., Madden, Neq00, Night Ranger, Nightstallion, Reisio, SkyBon, Srtxg, Valentinian, Vonvon, Yonatanh, Zscout370, 32 anonymous edits

**File:Flag of Colombia.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Colombia.svg *License*: Public Domain *Contributors*: User:SKopp

**File:Flag of Brazil.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Flag_of_Brazil.svg *License*: Public Domain *Contributors*: Brazilian Government

**Image:Earth-lighting-equinox EN.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth-lighting-equinox_EN.png *License*: Creative Commons Attribution-Sharealike 2.0 *Contributors*: User:Blueshade

**Image:Ecliptic path.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Ecliptic_path.jpg *License*: GNU Free Documentation License *Contributors*: User:Tauʻolunga

**Image:north season.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:North_season.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:south season.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:South_season.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:equinox-0.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equinox-0.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:equinox-20.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equinox-20.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:equinox-50.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equinox-50.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:equinox-70.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equinox-70.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:equinox-90.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Equinox-90.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**File:Nowruz Zoroastrian.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Nowruz_Zoroastrian.jpg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Ipaat

**Image:ChichenItzaEquinox.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:ChichenItzaEquinox.jpg *License*: Public Domain *Contributors*: User:ATSZ56

**Image:Water horizon.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Water_horizon.jpg *License*: Public Domain *Contributors*: User:Citynoise

**File:Earth's horizon as seen from Shuttle Endeavour.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth's_horizon_as_seen_from_Shuttle_Endeavour.jpg *License*: Public Domain *Contributors*: NASA

**File:Sonne Meer und Möwe.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Sonne_Meer_und_Möwe.jpg *License*: Public Domain *Contributors*: User:Dellex

**File:Horizons.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Horizons.svg *License*: Public Domain *Contributors*: User:Acdx

**File:How far away is the horizon.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:How_far_away_is_the_horizon.png *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Citynoise

**File:HorizonDistance.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:HorizonDistance.png *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Efa

**File:World map longlat.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:World_map_longlat.svg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Thesevenseas

**Image:Parallel 45.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Parallel_45.jpg *License*: Public Domain *Contributors*: Dondon83, Kilom691, Luigi Chiesa, Wst, 2 anonymous edits

**Image:Annual Average Temperature Map.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Annual_Average_Temperature_Map.jpg *License*: unknown *Contributors*: Dragons flight, Vonvon, 3 anonymous edits

**Image:Two-types-of-latitude.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Two-types-of-latitude.png *License*: Creative Commons Attribution 3.0 *Contributors*: User:Wmc824

**Image:Types of latitude difference.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Types_of_latitude_difference.png *License*: GNU General Public License *Contributors*: User:Cburnett

**Image:Geocentric vs geodetic latitude with elevation.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Geocentric_vs_geodetic_latitude_with_elevation.svg *License*: Public Domain *Contributors*: User:SharkD

**File:Mars symbol.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_symbol.svg *License*: Public Domain *Contributors*: Aquantrum, Chmee2, Fibonacci, Galphi, Juiced lemon, Missionary, Rursus, Tlusťa, Urhixidur, 3 anonymous edits

**File:Mars Hubble.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_Hubble.jpg *License*: unknown *Contributors*: ABF, Bewareircd, CWitte, ComputerHotline, EugeneZelenko, Lars Lindberg Christensen, Pharos, Phrood, Rmhermen, TheDJ, 7 anonymous edits

**File:Mars Earth Comparison.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_Earth_Comparison.png *License*: Public Domain *Contributors*: Edward, RHorning, Sebman81, Tony Wills, Urhixidur

**File:MarsTopoMap-PIA02031 modest.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:MarsTopoMap-PIA02031_modest.jpg *License*: Public Domain *Contributors*: NASA/JPL-Caltech.

**Image:Mars rocks.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_rocks.jpg *License*: Public Domain *Contributors*: NASA

**File:Nasa mars opportunity rock water 150 eng 02mar04.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Nasa_mars_opportunity_rock_water_150_eng_02mar04.jpg *License*: Public Domain *Contributors*: NASA/JPL/US Geological Survey

**File:Geysers on Mars.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Geysers_on_Mars.jpg *License*: Public Domain *Contributors*: Artist: Ron Miller

**File:Tharsis Tholus block.JPG** *Source*: http://en.wikipedia.org/w/index.php?title=File:Tharsis_Tholus_block.JPG *License*: Public Domain *Contributors*: Jim Secosky modified NASA image.. Original uploader was Jimmarsmars at en.wikipedia

**File:Magnify-clip.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Magnify-clip.png *License*: GNU Free Documentation License *Contributors*: User:Erasoft24

**File:Olympus Mons.jpeg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Olympus_Mons.jpeg *License*: Public Domain *Contributors*: Hurricanehink, Kanonkas, Ævar Arnfjörð Bjarmason, 4 anonymous edits

**File:Mars caves from NASA orbiters.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_caves_from_NASA_orbiters.jpg *License*: Public Domain *Contributors*: NASA JPL USGS ASU NAU

**Image:Mars atmosphere.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_atmosphere.jpg *License*: Public Domain *Contributors*: Original uploader was Alkuin at de.wikipedia

**File:Martian Methane Map.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Martian_Methane_Map.jpg *License*: Public Domain *Contributors*: Michael Mumma, Trent Schindler/NASA

**File:2005-1103mars-full.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:2005-1103mars-full.jpg *License*: unknown *Contributors*: ComputerHotline, Fred J, Herbythyme, Ies, Kallerna, Lars Lindberg Christensen, Pringles, Roomba, Tryphon, Wst, 3 anonymous edits

**File:Mars NPArea-PIA00161 modest.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_NPArea-PIA00161_modest.jpg *License*: Public Domain *Contributors*: Chmee2, Kristaga

**File:ThePlanets Orbits Ceres Mars PolarView.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:ThePlanets_Orbits_Ceres_Mars_PolarView.svg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Eurocommuter

**File:ThePlanets Orbits Ceres Mars.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:ThePlanets_Orbits_Ceres_Mars.svg *License*: GNU Free Documentation License *Contributors*: User:Eurocommuter

**File:Phobos deimos diff rotated.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Phobos_deimos_diff_rotated.jpg *License*: Public Domain *Contributors*: NASA

**File:Soviet Union-1972-Stamp-0.16. Mars 3.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Soviet_Union-1972-Stamp-0.16._Mars_3.jpg *License*: Public Domain *Contributors*: Augiasstallputzer, Editor at Large, EugeneZelenko, Michael Romanov

**File:Mars Viking 11h016.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_Viking_11h016.png *License*: Public Domain *Contributors*: "Roel van der Hoorn (Van der Hoorn)"

**File:MER Spirit Lander Pan Sol16-A18R1 br2.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:MER_Spirit_Lander_Pan_Sol16-A18R1_br2.jpg *License*: Public Domain *Contributors*: Bryan Derksen, Li-sung, 1 anonymous edits

**File:PhoenixSolarPanelandRoboticArm.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:PhoenixSolarPanelandRoboticArm.png *License*: Public Domain *Contributors*: NASA JPL. Original uploader was Arjun G. Menon at en.wikipedia

**File:MarsSunsetCut.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:MarsSunsetCut.jpg *License*: Public Domain *Contributors*: NASA

**File:Apparent retrograde motion of Mars in 2003.gif** *Source*: http://en.wikipedia.org/w/index.php?title=File:Apparent_retrograde_motion_of_Mars_in_2003.gif *License*: GNU General Public License *Contributors*: User:Seav

**File:Mars oppositions 2003-2018.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_oppositions_2003-2018.png *License*: Public Domain *Contributors*: Tomruen

**File:Marsrglobe2004.gif** *Source*: http://en.wikipedia.org/w/index.php?title=File:Marsrglobe2004.gif *License*: Public Domain *Contributors*: Alex:D

**File:Karte Mars Schiaparelli MKL1888.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Karte_Mars_Schiaparelli_MKL1888.png *License*: Public Domain *Contributors*: unkown

**File:Lowell Mars channels.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Lowell_Mars_channels.jpg *License*: Public Domain *Contributors*: Percival Lowell (died in 1916)

**File:Mars HST Mollweide map 1999.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Mars_HST_Mollweide_map_1999.png *License*: Public Domain *Contributors*: NASA.

**File:Kirks Soap Yerkes Mars.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Kirks_Soap_Yerkes_Mars.jpg *License*: Public Domain *Contributors*: Further attribution given within to "American Institute of Physics, Niels Bohr Library". 1893 ad its self is attributed in text to an unnamed Chicago newspaper.

**File:War-of-the-worlds-tripod.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:War-of-the-worlds-tripod.jpg *License*: Public Domain *Contributors*: Illustration by Alvim Corréa. Original uploader was Bblackmoor at en.wikipedia

**Image:Earth-lighting-summer-solstice EN.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth-lighting-summer-solstice_EN.png *License*: Creative Commons Attribution-Sharealike 2.0 *Contributors*: User:Blueshade

**Image:Earth-lighting-winter-solstice EN.png** *Source*: http://en.wikipedia.org/w/index.php?title=File:Earth-lighting-winter-solstice_EN.png *License*: Creative Commons Attribution-Sharealike 2.0 *Contributors*: User:Blueshade

**Image:ReflectedSolarRadiation Solstices.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:ReflectedSolarRadiation_Solstices.jpg *License*: Public Domain *Contributors*: Takmeng Wong and the CERES Science Team at NASA Langley Research Center.

**Image:solstice-0.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Solstice-0.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:solstice-20.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Solstice-20.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:solstice-50.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Solstice-50.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:solstice-70.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Solstice-70.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:solstice-90.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Solstice-90.jpg *License*: Creative Commons Attribution-Sharealike 2.5 *Contributors*: User:Tauʻolunga

**Image:Sunrisebristolchannel.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Sunrisebristolchannel.jpg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Sean the Spook

**Image:Jamaica sunrise.JPG** *Source*: http://en.wikipedia.org/w/index.php?title=File:Jamaica_sunrise.JPG *License*: Attribution *Contributors*: Adam L. Clevenger

**Image:False Sunrise.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:False_Sunrise.jpg *License*: Public Domain *Contributors*: User:Florenus

**Image:Sunrise-near-Tava-Reservoir-By-Lovleet.JPG** *Source*: http://en.wikipedia.org/w/index.php?title=File:Sunrise-near-Tava-Reservoir-By-Lovleet.JPG *License*: GNU Free Documentation License *Contributors*: Lovleet Jain

**Image:Sunrise in Burnaby.JPG** *Source*: http://en.wikipedia.org/w/index.php?title=File:Sunrise_in_Burnaby.JPG *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Fallenangei

**Image:Sunset 2007-1.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Sunset_2007-1.jpg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: User:Alvesgaspar

**Image:Layers of Earth's atmosphere, brightly colored as the sun sets.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Layers_of_Earth's_atmosphere,_brightly_colored_as_the_sun_sets.jpg *License*: Public Domain *Contributors*: NASA STS-127 crew.

**File:Sunset at Land's end in San Francisco.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Sunset_at_Land's_end_in_San_Francisco.jpg *License*: Creative Commons Attribution-Sharealike 3.0 *Contributors*: Mila Zinkova

**Image:MarsSunset.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:MarsSunset.jpg *License*: Public Domain *Contributors*: NASA's Mars Exploration Rover

**Image:Zenith-Nadir-Horizon.svg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Zenith-Nadir-Horizon.svg *License*: Public Domain *Contributors*: User:DTR

**Image:Tropical-area-mactan-philippines.jpg** *Source*: http://en.wikipedia.org/w/index.php?title=File:Tropical-area-mactan-philippines.jpg *License*: Public Domain *Contributors*: Binter, Gryffindor, Huggorm, Skipjack, 1 anonymous edits

# License

Creative Commons Attribution-Share Alike 3.0 Unported
http://creativecommons.org/licenses/by-sa/3.0/