Out of this world

Aside from telling the time of day, the most useful addition a watch can have is probably the date. Add to that a perpetual calendar and, it could be argued, you have everything you need. But the watch industry, like many others, deals with 'wants' rather than 'needs'. One particular 'want' on offer is the Equation of Time. Understanding what this feature actually means requires a little history and a closer look at our solar system.

Tim Treffry

High noon

Mechanical clocks and watches appeared in the Middle Ages, but the sundial was the most accurate 'clock' in general use until development of the pendulum clock in the latter half of the 17th century. Those with access to both a sundial and one of the 'new' clocks found that they sometimes agreed and sometimes differed. The first Astronomer Royal, John Flamsteed, who founded the Royal Greenwich Observatory in 1676, produced a table of the daily variation between mean time, as indicated by clocks, and sundial time. His new observatory was equipped with two remarkable clocks made by Thomas Tompion, they were wound once a year and were accurate to 7 seconds per day.

The table Flamsteed produced was known as the Equation of Time and enabled clocks to be set to time using a sundial. Antique clocks often have this table on a card inside the case, or it may be printed around the dial. More deluxe versions have an additional mechanism and a hand that continuously displays the difference between solar and mean time.

The extraordinary 'Tour de L'île' created by Vacheron Constantin for its 250th anniversary in 2005. Its sixteen complications include an Equation of Time in the centre of the rear dial. Other indications of astronomical interest are lateral sectors for the rising and setting of the Sun and a celestial annual calendar displaying a continuously changing representation of the night sky over Geneva. The minute-repeat is wound by twisting the bezel. This unique piece was sold by Antiquorum for almost two million Swiss Francs.

Platinum-cased Breguet self-winding perpetual calendar (ref. 3477) made ca. 2000. Subsidiary dials show power reserve, equation of time, month, leap year and date. Sold by Antiquorum for US$55,500 in 2006.

Celestial movement

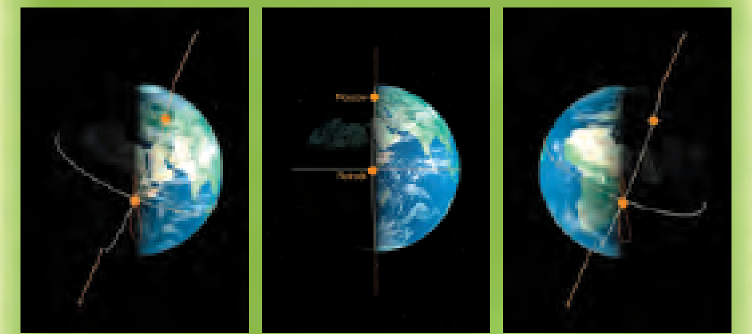
The differences between mean time and solar time arise for two reasons. First, the angle of the Earth's axis of rotation, with respect to the position of the Sun at noon, varies through the year; this is what gives rise to the seasons. Second, the Earth travels around the Sun in a slightly elliptical orbit, travelling somewhat faster in early January when it is closest, than in July when it is farthest away (see Equation of Time box). The variation in tilt, combined with latitude, also accounts for the change in the times of sunrise and sunset through the year (see Sunrise and Sunset box).

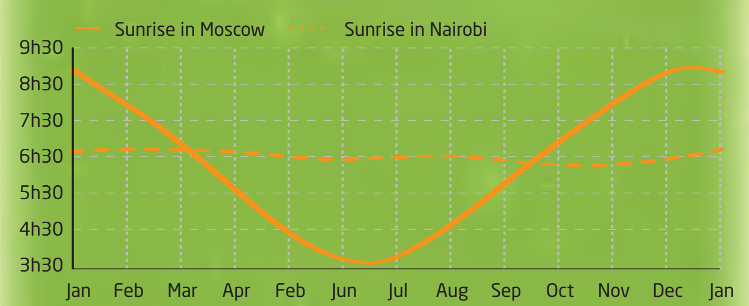
The Equation of Time was one of the features of Breguet's famous 'Marie-Antoinette' watch, recently restored to the Israel Museum. The modern Breguet Company incorporated the equation in a wristwatch marking the Millennium. It was also one of the 16 complications in the remarkable 'Tour de L'île', a unique piece produced by Vacheron Constantin to mark its 250th anniversary and Audemars Piguet includes this feature in its Jules Audemars 'Equation of Time' series, which also offers sunrise and sunset times for a specific location, and a perpetual calendar. The British Masters brand Arnold and Son has found many different ways of presenting the Equation of Time, but without doubt the watchmaker who's creations have the most consistent, and arguably the most imaginative, portrayal of near Earth astronomy has been Martin Braun.

Horological solstice

Braun's début at Basel 2000 had the launch of his 'Eos'. It had a basic ETA 2893 movement plus a clever additional mechanism producing the most effective indication of Sunrise and Sunset times ever achieved. Braun was offering a 'bespoke' watch, designed for the latitude at which you lived, for the price of a basic Rolex[1]. Eos was followed two years

Sunrise and Sunset

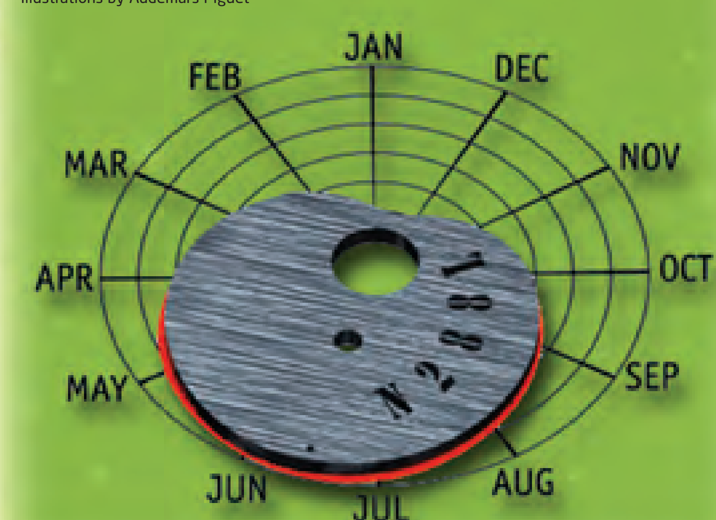




Moscow and Nairobi are both at the same longitude (37°E); with Moscow 55° N and Nairobi close to the Equator. Because of the changing tilt of the Earth; in June the Sun rises 3 hours earlier, and sets 3 hours later, in Moscow than in Nairobi. In March and September Sunrise and Sunset times are similar in both places. In December the Sun rises 3 hours later in Moscow than Nairobi and it sets 3 hours earlier. For Sunset times the curves shown are inverted.

If, for example, sunrise times for Moscow are plotted as a circular graph they provide the shape of a cam needed to control sunrise indication on a watch.

Illustrations by Audemars Piguet



In the Jules Audemars Equation of Time 'Clinton' limited edition, the Equation hand carries a Sun symbol and can be read quite precisely from a scale extending halfway around the dial. It also provides perpetual calendar, moonphase and sunset and sunrise times for a specific location. The time on the dial surround indicates that at noon EST, mean solar time at the White House is 12:08. Audemars Piguet will make versions for any location between 56°N and 46°S.

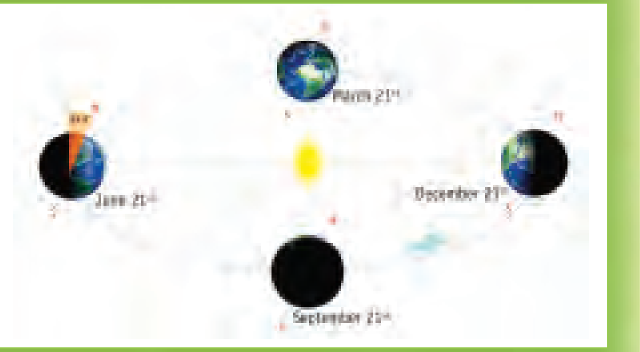
'Boreas' by Martin Braun added Equation of Time (dial centre) to the Sunrise and Sunset indication found previously in 'Eos'. These times vary widely with latitude through the year. In Singapore the difference winter to summer is around 5 minutes. The equivalent figure in London is 4 hours, and in Stockholm, 18 hours. Braun produced a range of dials to cover this variation. More specifically, making each watch more or less unique, the two cams (at 6 o'clock) that control the movement of the Sunrise and Sunset hands are individually machined for the owner's latitude. These cams turn once a year and are operated by the date mechanism.

Equation of Time

Anyone living on the Equator who stands outside at noon each day will notice that sometimes the Sun is directly overhead (March or September 22nd) and that at other times it is either a little to the north or south (the drawing is not to scale!). On June 22nd (the summer Solstice in the northern hemisphere) it will be as far north as it gets, being directly over the Tropic of Cancer. At noon on December 22nd the sun will be over as far south as it gets and be over the Tropic of Capricorn. Those living further north, or south, will notice that the Sun is higher in the sky in summer, lower in winter, and at about midway at the equinoxes. The seasons we experience occur because the Earth's axis of rotation is tilted (at 23.5°) with respect to the plain of its orbit around the Sun.

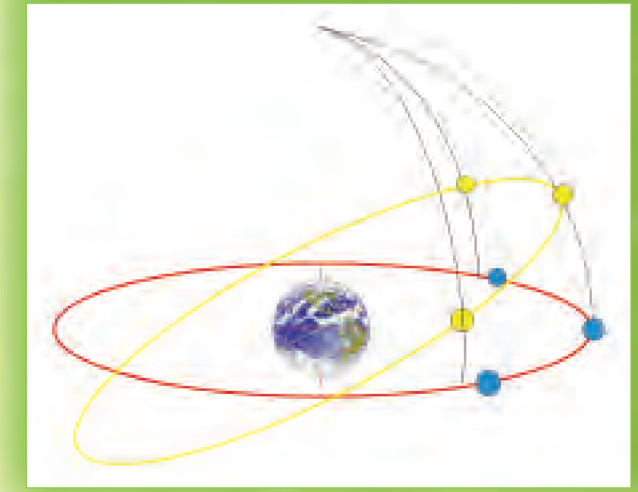
On June 22nd (midsummer) the northern hemisphere has its maximum tilt towards the Sun. As the Earth continues in its orbit its tilt with respect to the Sun decreases, becoming zero on September 22nd. It then starts to lean away from the sun until, on December 22nd, this tilt reaches a maximum (midwinter). By March 22nd the Equator is again pointing directly at the Sun as the Earth spins. Averaged throughout the year these variations in tilt vanish, giving 'mean time', which is based on a 'vertical' Earth moving around the Sun in a circle.

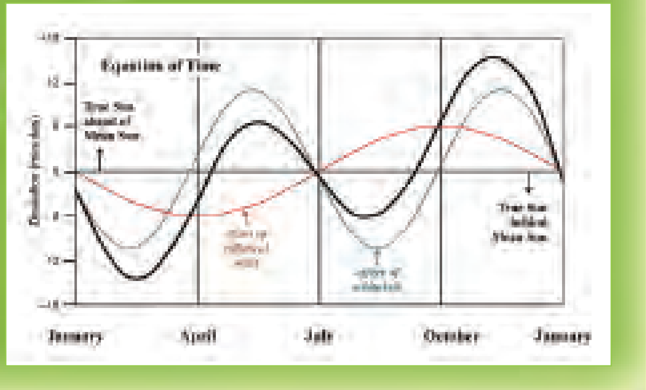
The Equation of Time is most easily understood in a historic, Earth-centred, universe in which the Equator, North Pole and plain of orbit are projected onto the 'Celestial Sphere' surrounding the Earth, and on which all heavenly bodies (including the Sun) were believed to move during the year. An imaginary 'mean' Sun, that gives the mean time indicated by clocks, is defined as moving at constant speed around the Celestial Equator (red). Because of the tilt of the Earth's axis the 'real' Sun appears to move around the yellow circle. On the rotating 'vertical' Earth, in the weeks following the March equinox, a sundial will 'see' the true Sun ahead of the 'mean Sun' and it will be noon on the sundial before it s noon on the clock. After the Solstice, when clock and dial agree, the relationship reverses. It reverses again after the mean and real Suns come together at the next Equinox.

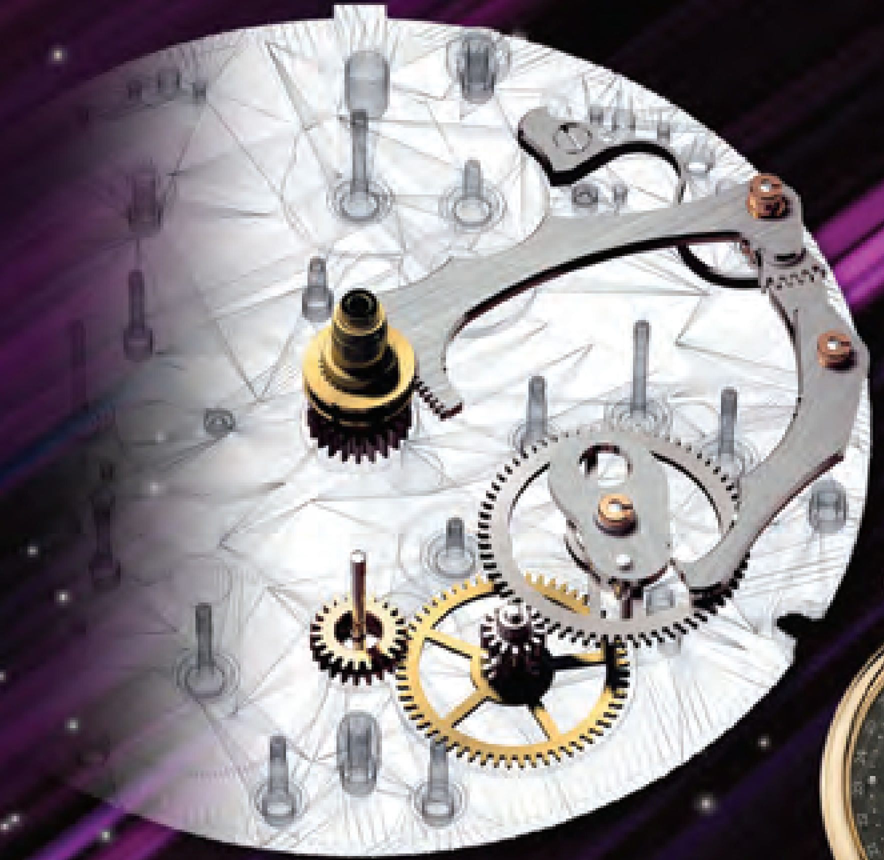


The difference between Sundial time and Clock time through the year, due to the tilt of the Earth's orbit with respect to its Equator, is shown in blue. There is however an additional effect on the Equation of Time. The Earth's orbit around the Sun is not quite circular, it is an ellipse, with the Sun a little closer in January than it is in July (147 vs. 152 million km). To maintain its orbit, the Earth must move faster in January and slower in July. If we revert to regarding the Sun to be moving around the Earth and set our clock to sundial time in January, the Sun will be moving faster than its average speed and the Earth will have to turn a little further before the sundial shows noon. The Sun slows after the March Equinox and by July, with the Sun at its slowest, the clock and sundial will again agree. The slower Sun between July and October will make the sundial 'fast' until the Sun begins to speed up again in October. The effects of the orbital tilt (blue curve) and the elliptical orbit (red curve) combine to produce the Equation of Time (black).

The assistance of Professor David Hughes is gratefully acknowledged.







The Audemars Piguet Equation of Time mechanism. The wheel on which the equation cam is mounted is turned once a year by the calendar mechanism. The spring forces the lower end of the lever system to follow the cam. The teeth at the other end move the Equation hand from the dial centre.

later by 'Boreas', which added the Equation of Time. 'Heliocentric', in 2004 portrayed the annual elliptical passage of the Earth around the Sun, with 'Astrios', a year later, combining this complication with Braun's sunrise and sunset display.

The Equation of Time and variations in Sunrise and Sunset are due to seasonal variations in the Earth's tilt. This tilt, the 'declination', is indicated directly by a subsidiary hand in Martin Braun's 'Notos', but more graphically, by an enamelled representation of the Earth, on the 'Moritz' by Dresden-based watchmaker Marco Lang.

Last year, with 'Selene', Braun provided one of the most realistic moon-phase displays available; the moon image remains in place while a shadow moves across it. One version of Selene is really *out of this world* – the dial is a slice of meteorite.

As watchmakers look for additional novelties to tantalise collectors with new 'wants', their offering increasingly deals with the results of the intricate ballet of Sun, Earth and moon.

1. Since becoming a global brand and having to provide a margin for retailers this price advantage has disappeared. But the Braun range now comes with 'in house' MAB movements.

Further information: www.martin-braun.com

(Below) In 'Selene', Martin Braun, presents the moon in a novel way. Its realistic image remains in position and a shadow, screen printed on a sapphire disc passes across it each lunar month. A pusher allows the Full Moon to be set to the minute. Unusually precise gearing means that it takes 122 years before the moon-phase will be a full day out. The dial is a thin slice of a meteorite, delicately etched to reveal its structure. The subtle patination makes each example unique.

(Above) The 'Moritz' by independent Dresden-based watchmaker Marco Lang portrays the changing tilt of the Earth as well as moon-phase and perpetual calendar.

(Right) The Arnold Grand Tourbillon Perpetual has a very simple presentation of the Equation of Time. The kidney-shaped equation is reproduced on a transparent disc which rotates once a year and is visible through a window above the dial centre. No additional mechanism is required to produce the display.

(Left) With 'Notos, Martin Braun gives more prominence to the Equation of Time display, adding a month display at 5 and an additional feature, the Solar Declination, at 8. The angle between the Earth's Polar Axis and that of the Sun differs through the year, being 0° at the Equinoxes (22nd March and September) and + or – 23.5° at the Solstices (December and June).