

THE 2014 EQUATORIAL SUNDIAL GEOGRAPHIC SOUTH POLE MARKER

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An equatorial sundial is the simplest sundial to construct and visualize. The sundial surface is aligned with the Earth's equator (celestial equator) and the gnomon (the post that produces the shadow) is perpendicular to that surface and aligned to the North or South celestial pole (Earth's axis), which are at the geographic poles. The sundial is marked in 15 degree increments each representing one hour since the Earth rotates 360 degrees in 24 hours.

The only two locations where a equatorial sundial's surface is horizontal and the gnomon is aligned vertically to the local zenith is at the North or South Pole. That is what makes an equatorial sundial ideal for the South Pole. On the other hand, a sundial can only be used at these locations one half of the year, because the sun is below the horizon for 6 months.

On the 2014 pole marker sundial, the "equation of time" or time correction is engraved for the period of time when the sun above the horizon at the South Pole. The equation of time represents the time correction between the apparent solar time indicated by the sundial's shadow tracking the actual position of the sun and the mean solar time indicated by steady clock set so that over the year its differences from apparent solar time average to zero.

The equation of time is based on the analemma of the sun on the Earth. The analemma is the curve representing the changing angular offset of the Sun from its mean position on the celestial sphere as viewed from the Earth. [see figure 1). It also shows the offset in minutes, plus or minus, from mean solar time.

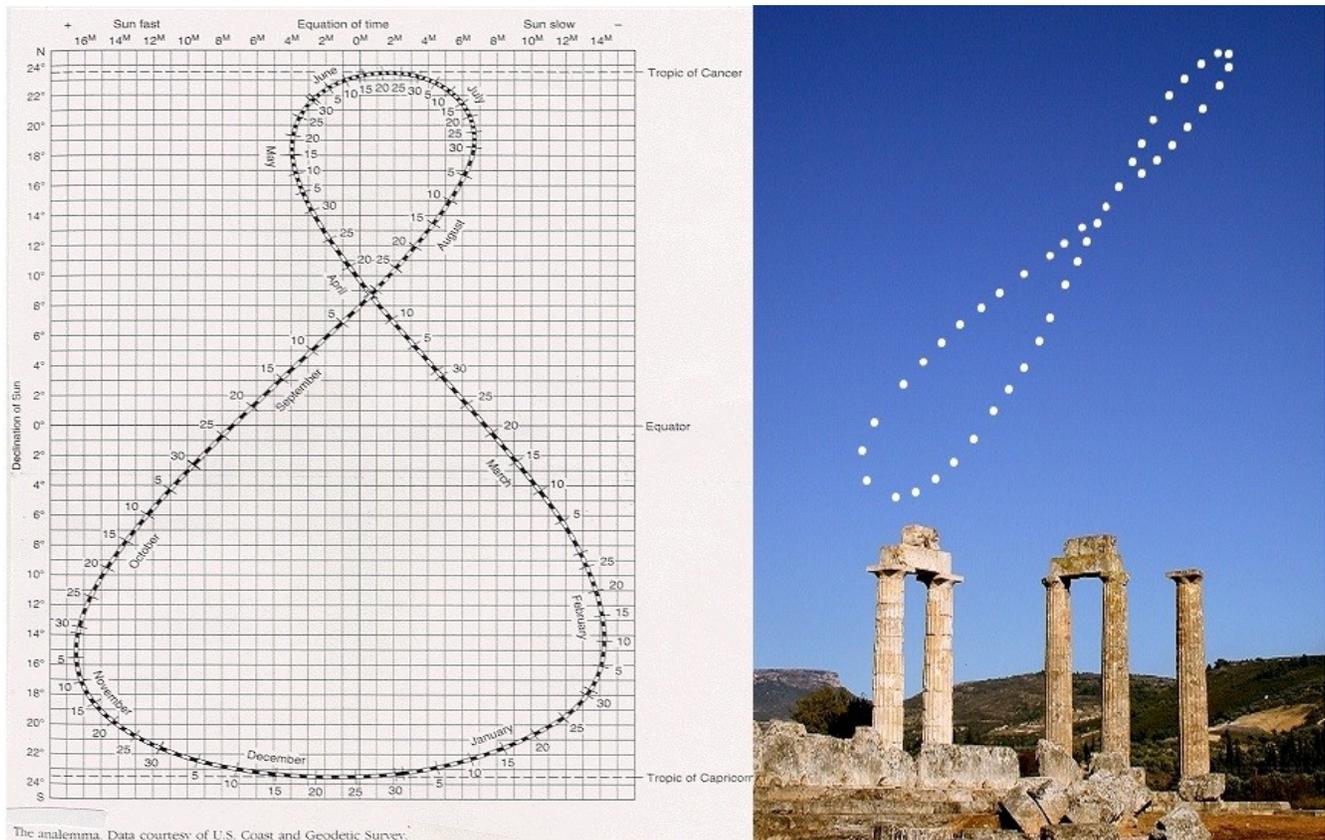


Figure 1: An analemma showing the angular offset of the Sun from its mean position and a composite photograph of the sun taken on 44 days at the same time of day spanning an entire year.

There are two reasons why the Sun deviates from the mean position to produce the figure eight:

1) The orbit of the Earth around the Sun is not circular but slightly elliptical, or egg-shaped. On July 4 or 5 the Earth is at its furthest from the Sun, and moving slowest. It then starts to speed up slightly as it moves closer to the Sun, and once past its point of closest approach in January 2 or 3 it starts to slow down again. The speeding up and slowing down of the Earth in its orbit means that the time measured from the Sun's position can be a little early or late compared to Standard Time, the steady rate at which our clocks run.

2) The tilt of the Earth's axis to the plane of its orbit around the Sun also causes the Sun to appear to be early or late. The Sun and planets follow a path across the sky called the Ecliptic. Because of the tilt of the Earth's axis, the ecliptic is tilted at 23.46 degrees to the Celestial equator. The effect of this tilt is to produce an apparent slowing down and speeding up of the Sun as it moves along the ecliptic.

The two effects are similar in size. When added together the combined effect is called "the equation of time", and is shown in Figure 2.

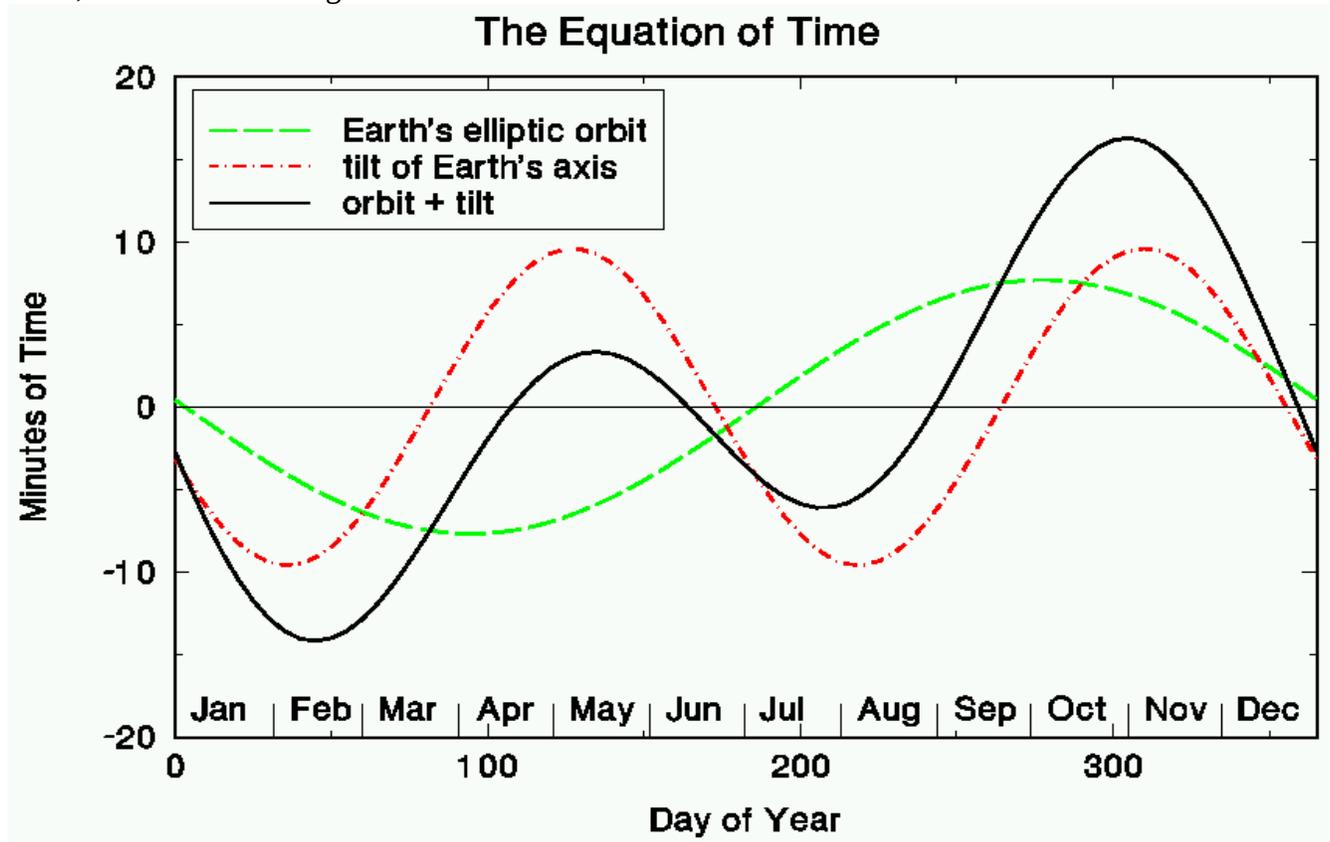


Figure 2: The equation of time in black is the summation of two effects, the Earth's elliptical orbit and the tilt of the Earth's axis relative to the ecliptic plane (“+”: dial is fast, “-”: dial is slow)

A sundial is "fast", or ahead of standard time, in May and from September to December. It is about 16 minutes fast at the beginning of November. A sundial is "slow", or behind standard time, from January to mid-April, and from mid-June to the beginning of August. It is about 14 minutes slow in mid-February.

The effect is greatest in February and November when the loop of the analemma is widest. Sun time matches standard time in mid-April, mid-June, the beginning of September, and late December. Figure 3 shows the equation of time correction graph that is on the 2014 pole marker.

The "+" and "-" on the equation of time graph on the 2014 pole marker mean:

"+" the sundial is fast; therefore subtract the number of minutes on the graph represented by the current date from the sundial's reading.

"-" the sundial is slow; therefore add the number of minutes on the graph represented by the current date from the sundial's reading.

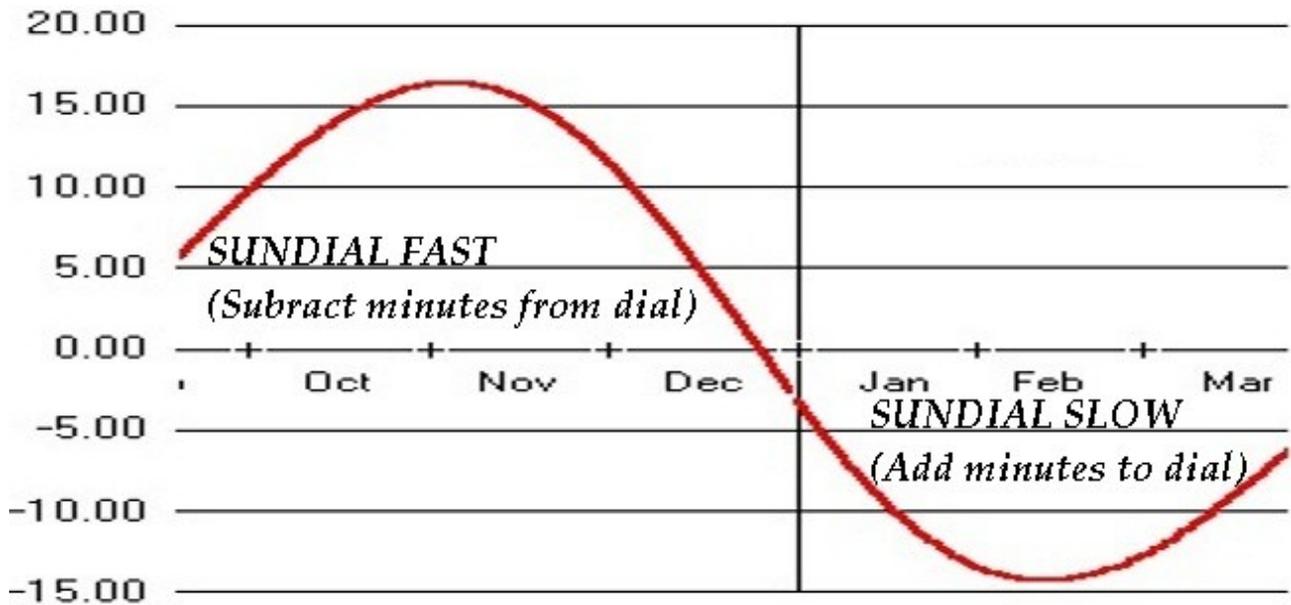
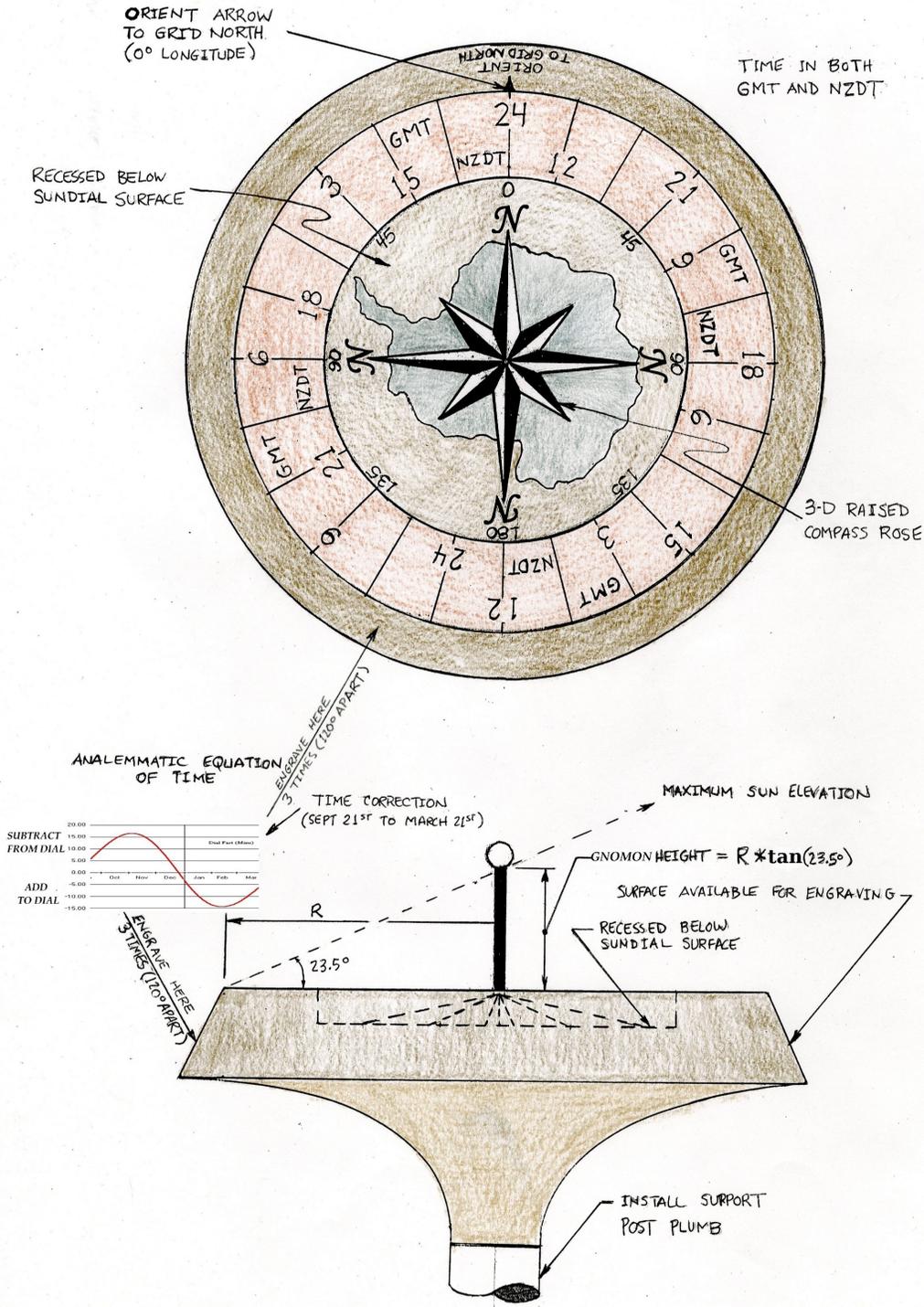


Figure 3: The "Equation of Time" correction for the period when the Sun is up at the South Pole

ORIGINAL DESIGN SKETCH OF THE EQUATORIAL SUNDIAL MARKER

All Points North Compass Rose and A Working Equatorial Sundial (with analemmatic time correction)



CONSTRUCTION OF THE EQUATORIAL SUNDIAL MARKER

The major component of the sundial was machined from five inch diameter solid round bronze. This was chosen for its luster, color, corrosion resistance, availability, overall appearance and machinability.

In order to be able to engrave the upper portion of the sundial, the major component was constructed in two separate pieces and assembled in such a way that the fasteners were not visible.

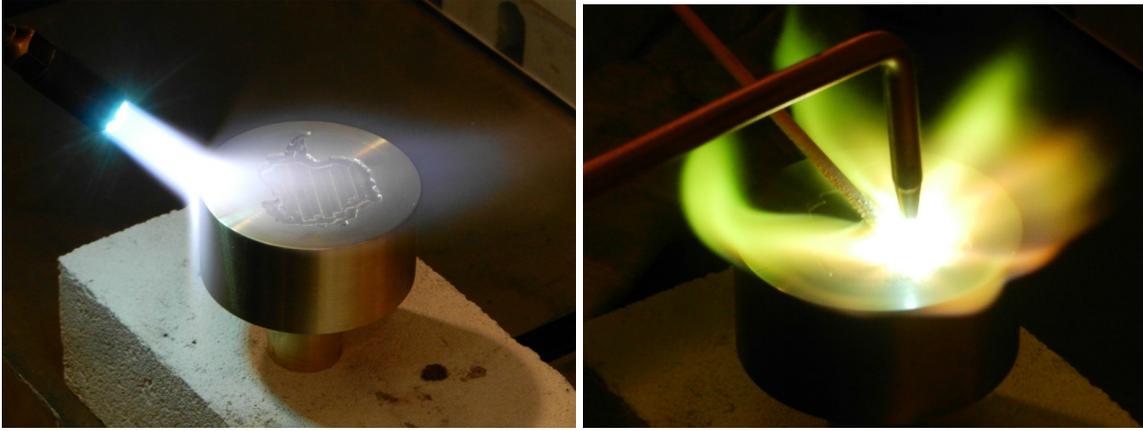


Milling the graduations on what would form the face of the sundial

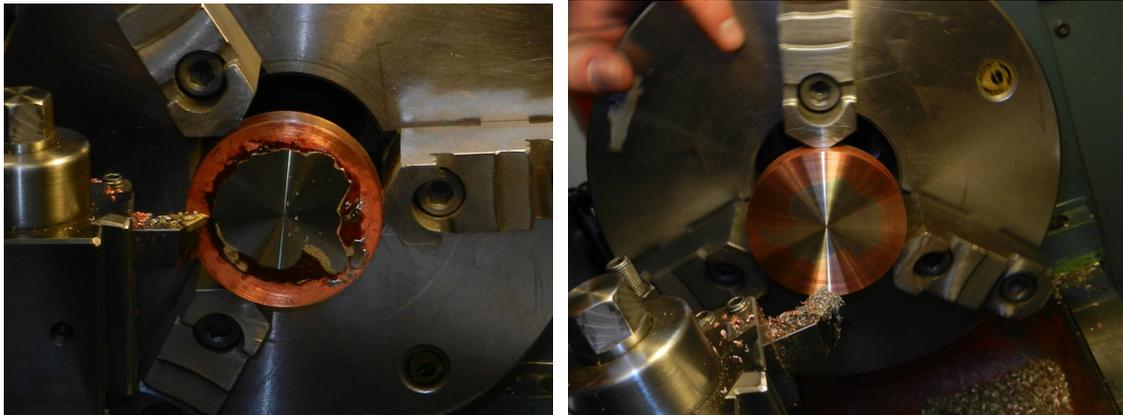


Engraving text around the circumference of the marker

The central portion of the sundial was machined from copper, onto which the profile of the Antarctic continent was machined. This depression was then filled with tin-lead solder and machined flat to reveal a silver continent inlaid into the copper.



Filling the Antarctic continent with solder



Machining back the solder to reveal the continent

To this copper disk was fitted a brass compass rose. This compass rose was machined from a single piece of solid round brass.



The gnomon protruding from the compass rose is made from solid tungsten carbide, to which a steel ball bearing has been silver soldered.

The final assembly was achieved by creating an interference fit between the bronze component and the copper component. The former was heated and the latter frozen, allowing the copper piece to be shrunk into the bronze piece. The result is a seamless, permanent and fastener free marriage of all parts.



Final Assembly of the 2014 Equatorial Sundial Geographic South Pole Marker

INSTALLATION OF THE 2014 SOUTH POLE MARKER

The pole should be pushed into the snow to a depth that positions the marker at an ergonomic height for reading and observing (an auger may be needed to create this hole). The pole should also be installed as plumb (aligned with the Earth's center) as possible.

The 00 GMT position on the sundial must be aligned with the 0 degree meridian (grid North) in order for the time to be correct.

Instead of determining the exact position of grid North, the sundial should be turned until the shadow corresponds to the markings on the dial face for the current New Zealand Daylight Time (NZDT) or Greenwich Mean Time (GMT).

It is suggested that a bucket of water is then poured over the base of the pole to prevent it from being rotated and also to deter theft

IMPORTANT NOTE ON READING THE SUNDIAL

The best way to read the shadow on the sundial is to look at the vertical section between the recessed center of the sundial and the numbered face of the sundial.

Why is the shadow on the sundial face very difficult to see?

During the design phase in the middle of the dark winter it was assumed that the face of the sundial would be a sufficiently diffuse reflector such that the shadow of the gnomon in the sunlight would be distinct. It turned out that the highly polished surface of the bronze dial acts like a mirror or a specular reflector. In this case, the sunlight and the shadow (or lack of sunlight) is reflected off in a direction opposite to the incoming sunlight. What weak shadow one may see due to the limited amount of diffuse reflection of the face of the sundial is washed out by the light reflecting into your eyes from the sky in your line of sight.

If the face of the dial corroded over time or were to be roughened to become less of a specular reflector or mirror and more of a diffuse reflector, the shadow would become more distinct.