# Prime Meridian on the move

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## Pre-GPS techniques actually responsible for the Greenwich shift

*By Stephen Malys, John H. Seago , Nikolaos K. Pavlis, P. Kenneth Seidelmann and George H. Kaplan*

The historical prime meridian runs through a telescope established in 1851 by Sir George Airy at the Royal Observatory at Greenwich, England. It was adopted as an international standard as the prime meridian for zero longitude in 1884 during the International Meridian Conference held in Washington, D.C.

The observatory's line in the pavement is a major tourist attraction, but the prime meridian used by satellite navigation systems is located 102 meters east of that historic location (see Figure 1).

Some people mistakenly thought that GPS, or the earlier Navy Navigation Satellite System (Transit), was responsible for this offset. But research, recently published in the Journal of Geodesy, concludes that the zero longitude used by GPS arrived at its current location in 1984, before GPS existed as an operational system.

The orientation of the World Geodetic System 1984 (WGS 84), and therefore the direction of the prime meridian associated with WGS 84, was established when the U.S. Defense Mapping Agency (now part of the National Geospatial-Intelligence Agency) adopted the orientation of an international scientific standard known as BTS 84, the BIH Terrestrial System 1984.

The Bureau International de l'Heure (BIH) was a predecessor to the International Earth Rotation and Reference Systems Service (IERS). Unlike previous terrestrial systems of reference used by the BIH, the BTS 84 was not established by tracking stars with optical telescopes.

**BTS 84.** BTS 84 was created using geodetic techniques known as satellite laser ranging, lunar laser ranging and very long baseline interferometry. While satellite Doppler tracking (Transit) data was included in the BIH process, this data type did not contribute to or constrain the orientation of BTS 84.

When an optical instrument is leveled, even to the highest accuracy achievable, its orientation is controlled by the gravity field's vertical direction at that particular location.

The astronomical zenith, or "up" direction realized by a telescope, is perpendicular to the gravity equipotential (level) surface locally, and therefore is in general deflected from the geodetic zenith that is perpendicular to our best-fitting global ellipsoid model of the Earth due to small irregularities of the gravity field (hence the term deflection of the vertical, DoV).

As a consequence, the astronomical meridian plane at an arbitrary location on the Earth does not necessarily contain the center of mass of the Earth (FIGURE 2).

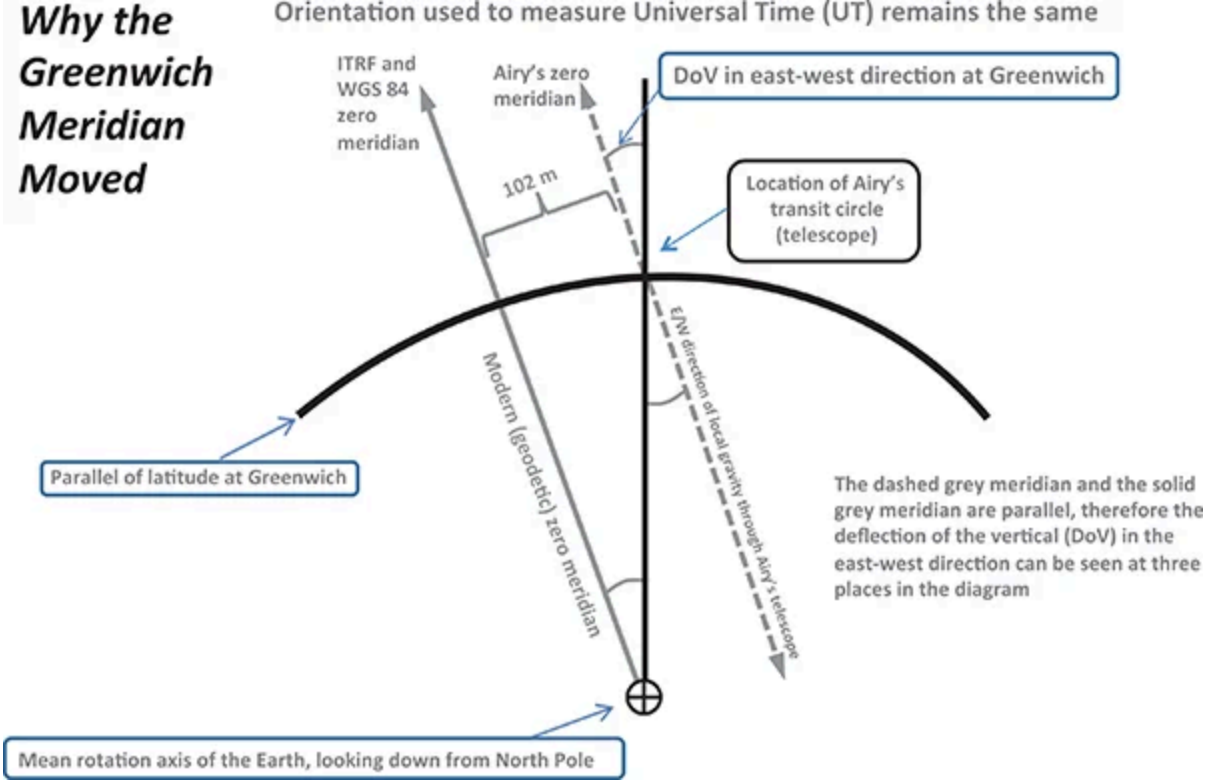


FIGURE 2. Geometry showing why the Greenwich meridian moved.

**Astronomical Time.** When optical systems were finally retired from Earth-orientation service by the BIH in 1984, the BIH continued the measurement series for Earth's rotation by modern geodetic techniques, but required continuity in the determinations. These measurements included those for astronomical time, UT1.

Requiring continuity in UT1 was equivalent to requiring that the plane of the prime meridian keep its orientation, relative to the celestial sphere, as a function of time. But now — for the first time — there was also a requirement to pass this plane through the center of mass of the Earth. That requirement, along with the DoV at Greenwich, moved the trace of the prime meridian on the Earth's surface in the vicinity of Greenwich by 102 meters to the east of Airy's telescope (Figure 2).

**Journey to the Center of the Earth.** Thanks to satellite-tracking techniques, we now know the location of the center of mass of the Earth with an accuracy of about 1 centimeter in three dimensions — about the size of a U.S. dime.

In 1984, its location was known with an accuracy of about 1 meter. When Airy set up his special telescope (called a transit circle), knowledge of the size, shape and center of mass of the Earth was limited to several hundred meters.

The trace of the historical astronomical prime meridian established by Airy's instrument, and the location of zero longitude indicated by GPS receivers, are both consistent with their own conventions, and their offset from each other does not imply an error in either determination.

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*Stephen Malys and Nikolaos K. Pavlis work for the National Geospatial-Intelligence Agency.*

*John H. Seago is with Analytical Graphics, Inc.*

*P. Kenneth Seidelmann is a member of the Astronomy Department, University of Virginia.*

*George H. Kaplan is a contractor with the United States Naval Observatory.*