# CANON OF LUNAR ECLIPSES 1500 B.C.–A.D. 3000

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## 2.4 Accounting for the Variable Rotation Rate of the Earth: UT and $\Delta T$.

Once the basic theories have been selected and the ephemerides constructed, there are some additional refinements which must be considered. A theory of the motion of the Sun or the Moon (or any other body) assumes as a given condition that the time argument progresses uniformly. By the mid-twentieth century, it was finally recognized that the rotation of the Earth, which governs our operational time, has always been gradually changing, predominantly to slow down. This means that a "theoretical" clock associated with the time variable of the theory, and a "real" clock associated with the observer, run at different rates; hence difference between the two times increases either way from the instant at which they are defined to agree.

To elaborate, consider "real" clock time to be the phase angle of the Earth about its rotation axis. Suppose an observer far out in space cannot see the Earth to read the phase angle, but instead has a uniformly running atomic clock. The remote observer predicts an eclipse, sends a message to an observer on the surface, and sees the eclipse occur when the Earth and Moon are in the predicted orbital positions. The surface observer does not know that the Earth's rotation is slowing down. To her surprise, the eclipse appears to occur earlier than predicted, at longitudes further east than predicted. This is because the surface had not yet rotated to the east as far as it would have at a uniform rate. The difference between the predicted and observed times is $\Delta T$; the difference in longitudes is the amount the Earth would have rotated during the difference $\Delta T$. It is, of course, possible that the rotation rate might have temporarily speeded up, in which case the surface observer would have observed the event to occur later than predicted, at longitudes further west. (See Fig. 10.)

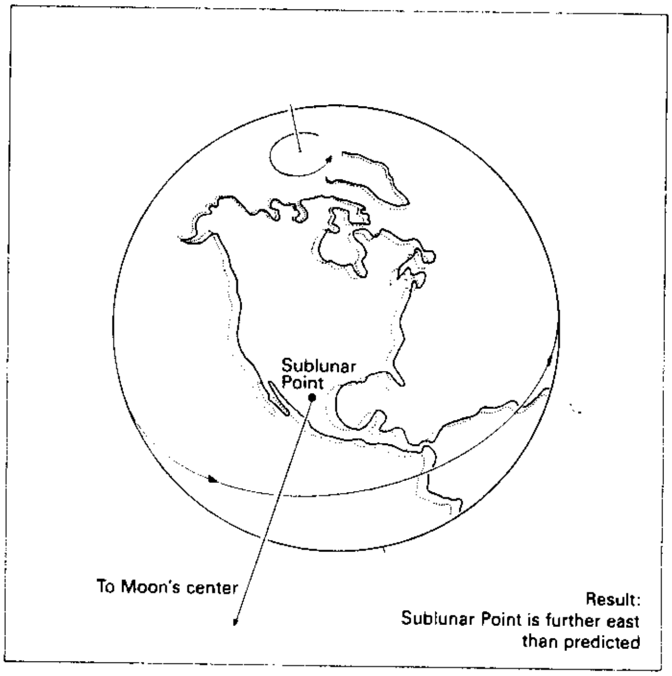


**Figure 10.** *Effect of $\Delta T$. The value of $\Delta T$ is an assumed correction for variation in the Earth's rate of rotation. If it is incorrect, not only will predicted times be different, but also the angular orientation of the Earth's surface will not be as predicted, and the coordinates of sublunar points will be shifted east or west. In this illustration, the orientation of the Earth for the prediction is shown by solid outlines of surface features. If in fact the Earth has slowed down, then the real orientation will be as shown by the dashed outline. The effect is to shift the sublunar point east, and the time will be earlier. If the rotation should happen to speed up, the time would be later than predicted and the sublunar point would shift west.*

The uniformly running time scale (in the absolute sense) is known as Dynamical Time (TDT); whereas the "real" time scale is known as Universal Time (UT). There have been several different investigations of the behavior of the difference TDT $-$ UT $= \Delta T$, derived from analysis of historical records of observations of occultations and eclipses from various civilizations. These various studies have not agreed in their derived behavior of $\Delta T$. The result depends on what observations are selected, how they are interpreted, and what theory is used for the comparison ephemeris. The variation in the rotation rate is caused by such complex interactions of so many forces that it has not yet been successfully modeled. Therefore $\Delta T$ values are presented as numerical tables, in which there may be group means, and which may be represented empirically by polynomials. Also, if the $\Delta T$ correction is applied to an ephemeris based on a different theory from that used to determine $\Delta T$, it must itself be corrected for any difference in the mean lunar longitude.