Atmospheric Effects of the Earth's Monthly Motion

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It is well known that the Earth and the Moon rotate around their center of mass (barycenter) with a sidereal period of 27.3 days. The orbit of the Earth's center of mass (geocenter) is geometrically similar to the Moon's orbit, but the orbit size is roughly 1/81 as large as that of the latter. The geocenter is, on average, 4671 km away from the barycenter. In the Earth's rotation around the barycenter, all its constituent particles trace the same nonconcentric orbits and undergo the same centrifugal accelerations as the orbit and acceleration of the geocenter. The Moon attracts different particles of the Earth with a different force. The difference between the attractive and centrifugal forces acting on a particle is called the tidal force [1]. The generation of the lunar tidal force is a major geophysical effect of the Earth's monthly motion. The rotation of the Earth–Moon system around the Sun (Fig. 1) leads to solar tides. The total lunisolar tides vary with a period of 355 days (13 sidereal or 12 synodic months). This period is known as the lunar or tidal year.

Importantly, the monthly orbit of the geocenter (like the orbit of the Moon) precesses with a period of 18.61 years and its perigee moves with a period of 8.85 years.

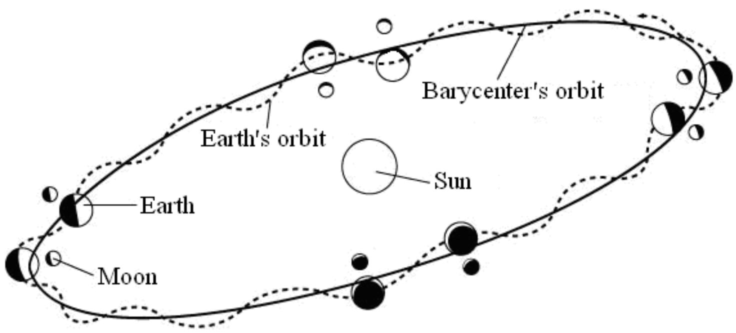

Fig. 1. Rotation of the Earth–Moon system around the Sun.

2. The lunisolar tides are believed to be so small that they cannot affect meteorological processes. In recent years, however, components of lunisolar tides have been detected in the spectra (a) of the atmospheric angular momentum, (b) of quasi-biennial oscillation indices of the equatorial stratospheric wind, and (c) of anomalies in many hydrometeorological characteristics [2]. It was found that synoptic processes vary simultaneously with tidal oscillations of the Earth's rotation rate and weather exhibits changes near their extrema, i.e., when the Earth is in certain positions on its monthly orbit [3].

An analysis of the causes of the 2010 anomalously hot summer in European Russia has revealed that the sunshine duration, cloud amount, and, eventually, the incoming solar radiation are modulated by lunar tides [4]. The intensity of the modulation depends on the season of the year. The length of the terrestrial (lunar) months is not a multiple of the solar year. The lunar (tidal) year, which is equal to 13 sidereal or 12 synodic months, lasts 355 days. Therefore, the incoming solar radiation varies not only with a solar year period of 365.24 days but also with a lunar or tidal year period of 355 days. Interference of these two oscillations with slightly different frequencies generates 35-year beats of incoming solar radiation, of the components of the Earth's radiation and heat budgets, and of the forcing of geophysical processes, such as the decade nonuniformity of Earth's rotation, decade climate changes, the El Niño–Southern oscillation phenomenon, the intensity of the Indian monsoon, the state of the Antarctic ice sheet, etc. [4].

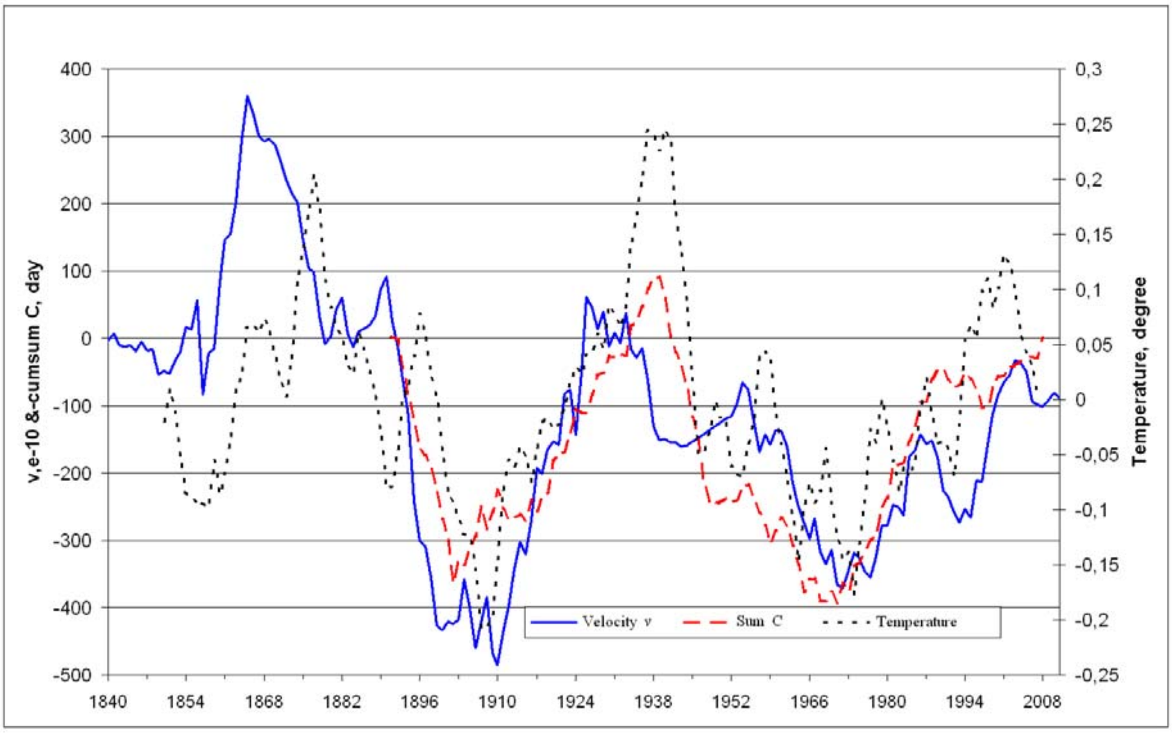

Fig. 2. Earth's rotation rate ν (solid), accumulated Vangengeim circulation pattern anomalies C taken with an opposite sign (dashed), and 5-year moving averages of anomalies in the global air temperature HadCRUT3: http://www.cru.uea.ac.uk/cru/data/temperature (dotted).

3. It was shown in [1, 2] that the Earth, the ocean, and the atmosphere exhibit consistent oscillations, influencing each other, i.e., joint oscillations initiated by tides occur in the Earth–ocean–atmosphere system. Visual manifestations of these oscillations include the wobble of the Earth's poles, El Niño and La Niña in the ocean, and the Southern Oscillation and the quasi-biennial oscillation in the atmosphere. The quasi-biennial oscillation (QBO) in the equatorial stratospheric wind direction has stability comparable with that of the annual period of meteorological element variations generated by the Earth's rotation around the Sun. The QBO period averaged over the last 60 years is equal to 28 months, or 2.3 years [1, 2].

The mechanism of QBO excitation is associated with the absorption of lunisolar tidal waves in the equatorial stratosphere. The QBO period is equal to a linear combination of the frequencies corresponding to the doubled periods of the tidal year (0.97 year), of the node motion (18.6 years), and of the perigee (8.85 years) of the Earth's monthly orbit:

$$\frac{1}{2}\left(\frac{1}{0.97}-\frac{1}{8.85}-\frac{1}{18.61}\right)=\frac{1}{2.3}$$

In other words, the quasi-biennial oscillation of the wind direction in the equatorial stratosphere is a combined oscillation caused by three periodic processes experienced by the atmosphere: (a) lunisolar tides, (b) the precession of the orbit of the Earth's monthly rotation around the barycenter of the Earth–Moon system, and (c) the motion of the perigee of this orbit.

References

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2. N.S. Sidorenkov, 2009: The interaction between Earth's rotation and geophysical processes. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2009.
3. http://www.geoastro.ru
4. N. S. Sidorenkov and K. A. Sumerova, "Geodynamic causes of decade changes in climate," *Proc. Hydrometeorological Center of Russia*, 2012, Vol. 348, pp. 195–214.