GEOPHYSICAL EFFECTS OF THE EARTH'S MONTHLY MOTION

N. S. Sidorenkov [1], T. S. Zhigailo [2]

[1] Hydrometeorological Research Center of the Russia Federation, Moscow, Russia Federation, *sidorenkov@mecom.ru*
[2] Odessa State Environmental University, Odessa, Ukraine

ABSTRACT. The generation of a lunar tidal force is a major geophysical effect of the Earth's monthly motion.

It is shown that synoptic processes vary simultaneously with tidal oscillations of the Earth's rotation rate and weather exhibits changes near their extremes, i.e., when the Earth is in certain positions on its monthly orbit.

It is found that 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.

Interference of the 1.20-year Chandler wobble with sidereal, anomalistic, and synodic lunar oscillations gives rise to beats, i.e., to slow periodic variations in the wobble amplitude with periods of 32 to 51 years.

Key words: Earth's monthly motion, synchronization of synoptic processes, quasi-biennial oscillation, modulations of the Chandler wobble amplitude.

1. It is well known that the Earth and the Moon revolve 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 revolution 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, 2]. The generation of the lunar tidal force is a major geophysical effect of the Earth's monthly motion. The revolution 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.

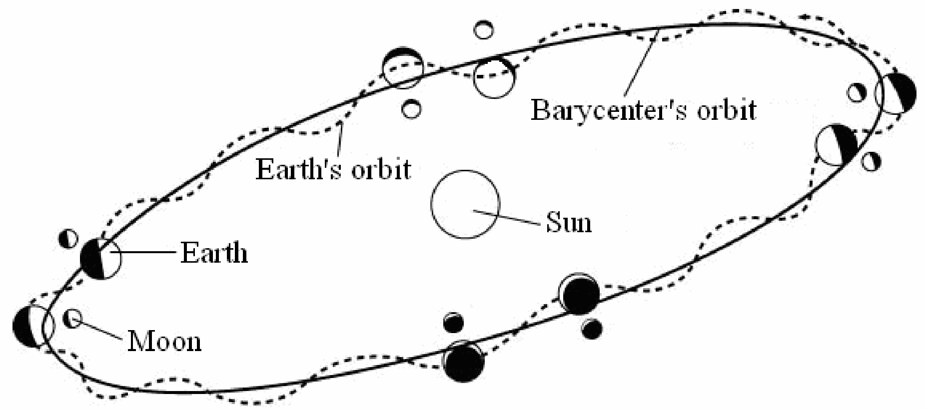

Figure 1: Revolution of the Earth–Moon system around the Sun.

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 extremes, 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].

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 variations in meteorological elements 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.

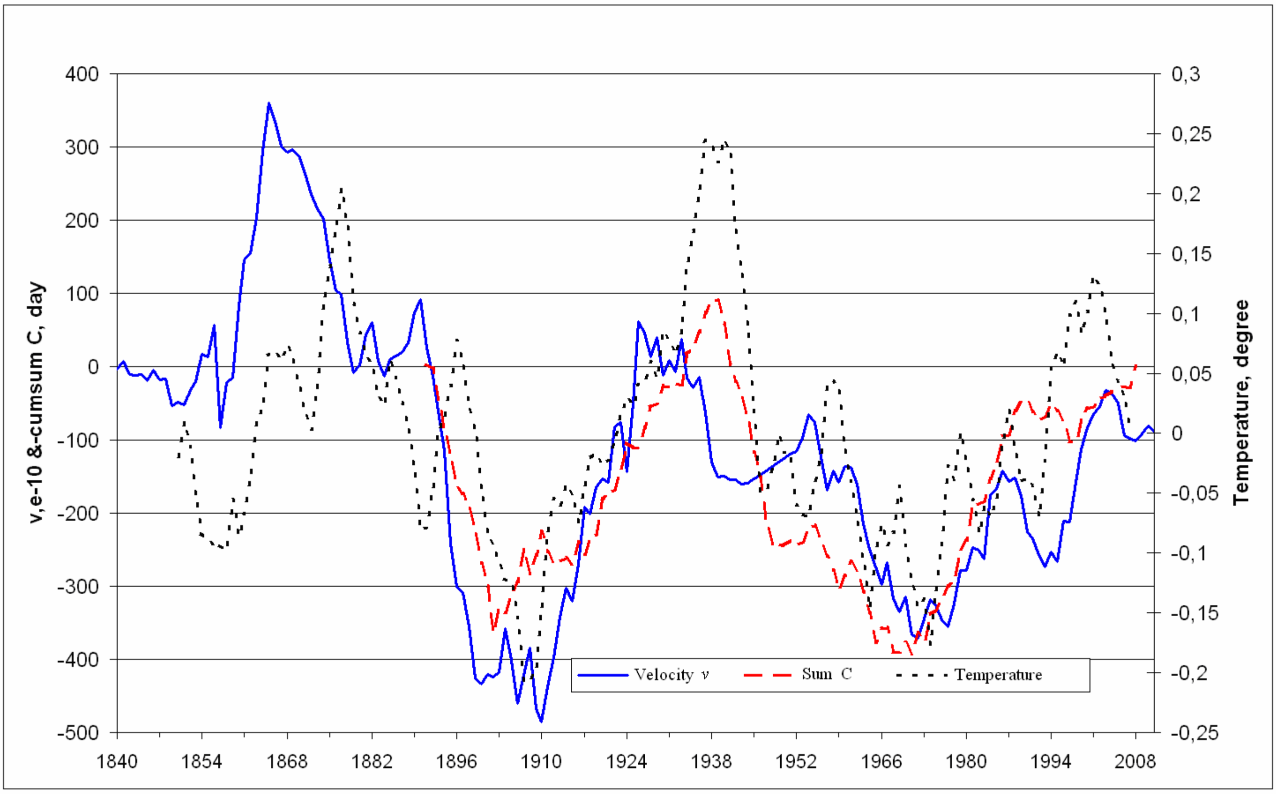

Figure 2: Earth's rotation rate v (solid), accumulated Vangengeim circulation pattern anomalies C taken with an opposite sign (dashed), and 5-year moving averages of anomalies in the global air temperature T HadCRUT3 (dotted).

The wobble of the Earth's poles and the QBO in the atmosphere have similar spectra (with the ratio of the periods being 1:2) [1, 2]. The period of the Chandler wobble of the poles (CWP) is believed to differ from the Euler period of 305 days because of the elastic properties of the Earth. However, it is physically unlikely that both QBO and CWP are caused by the features of the Earth's internal structure. A natural assumption is that QBO and CWP have a single cause, namely, the features of the Earth's monthly rotation in the Earth–Moon system and the rotation of this system around the Sun.

The wobble forcing with a solar year period of 365.24 days is modulated by the precession of the Earth's monthly orbit with a period of 18.61 years and by the motion of its perigee with a period of 8.85 years. Finally, the resulting solar annual forcing generates polar wobbles with a Chandler period of 1.20 year:

$$\frac{1}{1.0}-\left(\frac{1}{18.61}+\frac{1}{8.85}\right)=\frac{1}{1.20}$$

An analysis of observed pole coordinates suggests that the CWP amplitudes in 1890–1915 and 1947–1960 were three and five times larger than those in 1925–1943. The amplitude modulation of CWP is clearly exhibited. The period between the amplitude maxima – the period of beats – is equal to about 40 years. This suggests that the CWP is the sum of two oscillations with very close periods.

Since the 1980s, the hydrometeorological effects on the Earth's rotation have been continuously monitored at world's leading meteorological centers by computing the components of the effective atmospheric angular momentum (AAM) and oceanic angular momentum (OAM) functions [5]. It was found that the AAM and OAM functions are capable of accounting for up to 90% of the required CWP excitation (see *http://hpiers.obspm.fr/eop-pc*).

This excitation is believed to occur at the fundamental frequency of the climate system forcing with a period of 365.24 days. However, it was shown in the author's most recent works that, in addition to this basic forcing, the climate system experiences additional forcings caused by cloud amount variations with lunar-year periods. Climatic characteristics and the equatorial component of the atmospheric angular momentum h_2 were found to oscillate with a period of 355 days [2, 4].

The wobble forcing with a lunar sidereal year period of 355 days (13 sidereal months) is modulated by the precession of the Earth's monthly orbit with a period of 18.61 years and by the motion of its perigee with a period of 8.85 years. Finally, the resulting "lunar sidereal" forcing generates polar wobble with a period of 1.16 year:

$$\frac{1}{355.18 days/365.24 days/yr}-\left(\frac{1}{18.61}+\frac{1}{8.85}\right)=\frac{1}{1.1606 yr}$$

Interference of the 1.20-year Chandler oscillation and the 1.16-year oscillation leads to beats, i.e., to periodic variations in the polar wobble amplitude with a period of 35.3 years:

$$\frac{1}{1.16}-\frac{1}{1.2}=\frac{1}{35.3}$$

Similarly, the lunar synodic year (12 synodic months) must excite polar wobble with a period of 1.1574 year:

$$\frac{1}{354.37 days/365.24 days/yr}-\left(\frac{1}{18.61}+\frac{1}{8.85}\right)=\frac{1}{1.1574 yr}$$

Interference of this excitation and CWP generates beats with a period of 32.6 years.

The "lunar" annual (13 anomalistic months) excitation can generate polar wobble with a period of 1.172 year:

$$\frac{1}{358.21 days/365.24 days/yr}-\left(\frac{1}{18.61}+\frac{1}{8.85}\right)=\frac{1}{1.172 yr}$$

Interference of this wobble with CWP can generate beats with a period of 50.9 years:

$$\frac{1}{1.172}-\frac{1}{1.2}=\frac{1}{50.9}.$$

Thus, interference of CWP (1.20-year period) with these moon-caused oscillations gives rise to beats, i.e., to slow periodic variations in the CWP amplitude with periods of 32 to 51 years. They are observed in reality.

The QBO has been monitored since 1954. Accordingly, the amplitude modulation of the QBO is as yet difficult to reveal.

References

1. Sidorenkov N.S. *Physics of Instability in the Earth's Rotation*. Moscow: Nauka, 2002 (in Russian).
2. Sidorenkov N.S. The interaction between Earth’s rotation and geophysical processes. Weinheim, WILEY-VCH Verlag GmbH & Co. KGaA, 2009.
3. *http://www.geoastro.ru*
4. Sidorenkov N.S., Sumerova K.A.: 2012, in *Proc. Hydrometeorological Center of Russia*, **348**, 195.
5. Barnes R.T.H., Hide R., White A.A., Wilson C.A.: 1983, in *Proc. Roy. Soc. London, Ser. A*, **387**, 31.