ON THE SEPARATION OF SOLAR AND LUNAR CYCLES

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ABSTRACT. The synodic rotation period of the Sun nearly coincides with the sidereal rotation period of the Moon (27.3 days). The 11-year cycle of solar activity coincides with the eclipse cycle Tritos. The secular cycle of solar activity is close to the 93-year lunar cycle. Due to these coincidences, the cause of monthly, 11-year, and secular periods and their super harmonics in terrestrial processes is attributed to the Sun by solar-terrestrial researchers and to lunisolar tides by geophysicists. The possibilities of separating the solar and lunar cycles by applying spectral analysis, examining frequency differences, and detecting beats and resonances are discussed in this talk.

Key words: solar and geomagnetic activity; lunar months, lunisolar tides, beats of oscillations, cycles of eclipses, lunar perigee and apogee.

Introduction

The angular velocity of the Sun's rotation decreases with increasing heliographic latitude. The sidereal rotation period of the Sun is equal to 25 days at the equator and increases to 35 days as the poles are approached. Its average value is taken to be 27 days. With the same period, the Moon and Earth rotate about their common center of mass (barycenter). Moreover, the 11- and 90-year periods of solar activity coincide with the eclipse cycle Tritos (equal to 10.91 years or 135 synodic months. Table 1) and with the 93-year cycle of beats in the amplitudes of the perigee and nodal tides. Due to these coincidences, the cause of monthly, 11-year, and secular periods and their super harmonics in terrestrial processes is attributed to the Sun by solar-terrestrial researchers and to lunisolar tides by geophysicists. The possibility of separating the solar and lunar cycles by applying the spectral analysis, examining the frequency differences, and detecting the beats and resonances is discussed in this paper.

Geomagnetic activity

At present the *aa* geomagnetic activity index has gained much popularity. The *aa* index is calculated from the three-hourly index *A* measured at two antipodal magnetic observatories, Hartland (United Kingdom) and Canberra (Australia), which are located at an identical distance from the geomagnetic equator (at a geomagnetic latitude of ±50). These observatories have the longest series of observations (since 1868). Accordingly, there is a continuous time series of the *aa* index from 1868 until now. The most complete description of the *aa* index can be found in IAGA Bulletin 33.

We have constructed the spectrum of the series of daily *aa* values from 1868 to 2008 (Fig. 1). The analysis of the *aa* spectrum shows that long-time oscillations of the geomagnetic activity are associated with the solar activity (the peaks near periods of 11 and 5.2 years). The high-frequency part of the spectrum (periods < 1 year) has peaks at the lunisolar tide periods (182, 27, 13.6, 9, and 7 days). This result can be caused by the lunisolar tides affecting the motion of the plasma in the ionosphere and the magnetosphere, thereby resulting in the geomagnetic variations analogous to the solar daily and lunar daily variations.

Of course, the 27-day cycle of geomagnetic activity can arise because of the 27-day recurrences of the active domains on the solar disk due to the Sun's rotation about its axis and the Earth's motion around the Sun. However, the other high-frequency peaks, including the semiannual one, agree perfectly with the spectrum of lunisolar tides.

In addition to the 11-year and 5-year periods seen in Fig. 1, the solar activity exhibits a 22-year magnetic cycle and a secular cycle of about 90 years.

Lunisolar cycles

The Moon and the Earth rotate around the barycenter of the Earth--Moon system with a monthly period. The Earth's orbit is 1/81 as large as the Moon's. Moreover, since we are on the Earth, we cannot observe its rotation. That is why it took several thousand years for humans to realize the Earth's annual rotation around the Sun. The monthly rotation of the Earth is nearly unobservable, but on a scale of 1 to 81, it repeats all features of the Moon's rotation. For this reason, in what follows we consider the monthly rotation of the Moon.

There are the synodic (29.53 days), sidereal (27.32 days), anomalistic (27.55 days), draconic (27.21 days), and other months. The perigee of the lunar orbit moves from west to east with a period of 8.85 years. The plane of the lunar orbit precesses. As a result, the lunar nodes rotate along the ecliptic from east to west (against the Moon's motion) with a period of 18.61 years. The Earth--Moon system rotates around the Sun with an annual period of 365.24 days. Naturally, all these fundamental periods of the Moon's and Earth's monthly and annual rotation have super harmonics and sub harmonics.

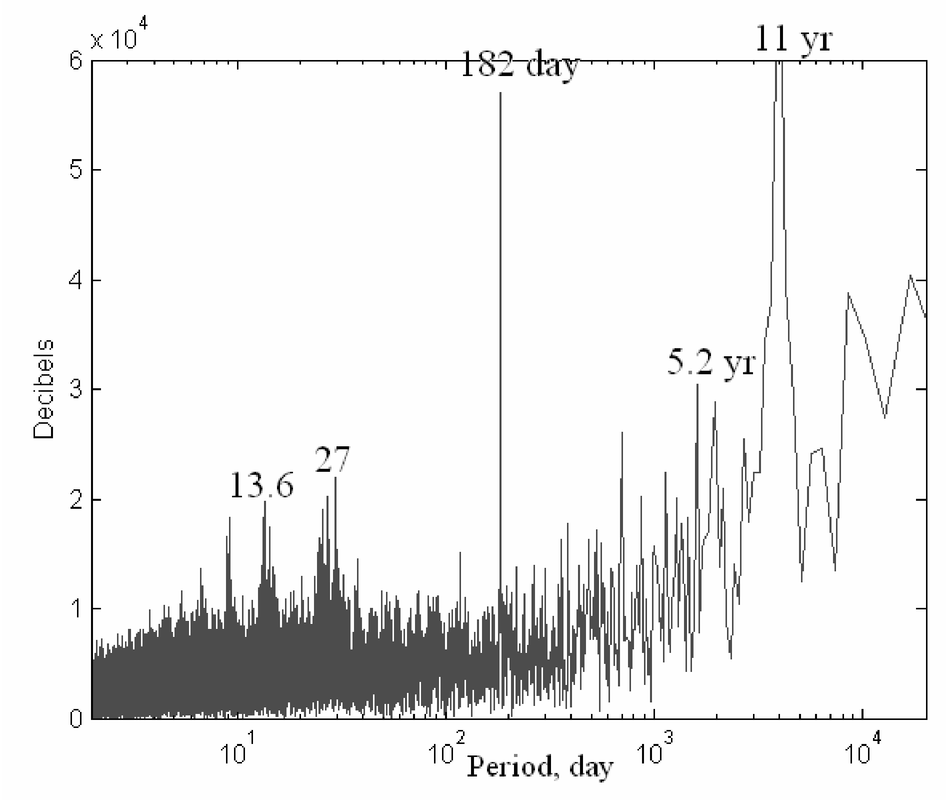

Figure 1: Spectrum of the *aa* geomagnetic activity index.

Table 1: The durations of some eclipse cycles (http://en.wikipedia.org/wiki/Eclipse_cycle)

cycle	solar days	synodic months	solar years	anomalistic months
Fortnight	14.77	0.5	0.040	0.536
Month	29.53	1	0.081	1.072
Semester	177.18	6	0.485	6.43
Lunar year	354.37	12	0.970	12.861
Octon	1387.94	47	3.80	50.371
Octaeteris	2923.53	99	8.00	106.100
Tritos	3986.63	135	10.91	144.681
Saros	6585.32	223	18.03	238.992
Metonic cycle	6939.69	235	19.00	251.853
Inex	10571.95	358	28.94	383.674
Exeligmos	19755.96	669	54.09	716.976
Callippic cycle	27758.75	940	76.00	1007.411

The interference of oscillations with slightly different frequencies gives rise to beats. The most pronounced is the beat generated by the frequencies corresponding to the synodic and anomalistic months:

$$\frac{1}{27.55455} - \frac{1}{29.53059} = \frac{1}{411.78}$$

The period of 411.78 days is called the Full Moon Cycle (FMC). Additionally, there is a specific FMC equal to 14 synodic months or 413.3733 days. Three and a half specific FMCs make up exactly four years. Three and a half FMCs also make up nearly four years. As a result, geophysical, meteorological, and oceanological tidal phenomena exhibit the four-year cyclicity (Sidorenkov and Sumerova, 2012a). A small difference between the specific (synodic) and perigee FMCs gradually accumulates and leads to smaller amplitudes of tidal phenomena. The interference of these two cycles generates beats:

$$\frac{1}{27.21222} - \frac{1}{27.55455} = \frac{1}{2190.344} \rightarrow \frac{1}{5.997\,yr}$$

The tidal effects are amplified when the moment of the monthly orbit perigee coincides with the perihelion of the annual orbit. These situations generate oscillations of terrestrial processes with periods of 31/62/93/186 years (Wilson, 2013):

8.847 x 3.5 = 30.96 ≈31 *yr*
8.847 x 7 = 61.93 ≈62 *yr*
8.847 x 10.5 = 92.89 ≈93 *yr*
8.847 x 21 = 185.79 ≈ 186 *yr*

The cycles of 93 and 186 years are amplified because they are multiples of the cycle of the regression of nodes

18.6 x 5 = 93 *yr*
18.6 x 10=186 *yr*

The lunisolar tides repeat with a period of 355 days, which is known as the tidal year. This period is also manifested as a cycle of repeated eclipses. Meteorological characteristics (pressure, temperature, cloudiness, etc.) vary with a period of 355 days. The interference of these tidal oscillations and the usual annual 365-day oscillations generates beats in the annual amplitude of meteorological characteristics with a period of about 35 years (Sidorenkov and Sumerova, 2012b). The quasi 35-year variations in cloudiness lead to oscillations of the radiation balance over terrestrial regions. As a result of these quasi-35-year beats, the climate, for example, over European Russia alternates between "continental" with dominant cold winters and hot summers (such as from 1963 to 1975 and from 1995 to 2014) and "maritime" with frequent warm winters and cool summers (such as from 1956 to 1962 and from 1976 to 1994).

It was found in (Litvinenko, 2012) that the recurrence of eclipses is related to the features of the annual variation in air temperature anomalies. Examples of recurring features in the temperature anomaly distribution in cycles of saros and exeligmos were presented. It was found that anomalously cold years occur when the eclipses are observed in the polar regions. Clearly, these interrelations cannot arise due to the very short instants when the direct solar radiation is screened by the Moon. The effect probably arises due to certain configurations of the celestial bodies, the positions of the lines of nodes and apses of their orbits, and the orientations of their rotation axes and the Earth's magnetic field that develop in the Sun--Earth--Moon system in the years of certain eclipses and influence the flow of solar and space plasmas toward the Earth.

The causes of the catastrophic floods occurring in the summer of 2013 were analyzed in (Sidorenkov and Chazov, 2015). It was shown that these phenomena were related to the fact that, over the entire year 2013, the Moon was found near the perigee in the Southern Hemisphere and near the apogee in the Northern Hemisphere. The Moon moves rapidly at the perigee and slowly at the apogee. As a result, in each lunar month in 2013, the Moon stayed within the Southern Hemisphere of the celestial sphere for 10--11 days and within the Northern Hemisphere for about 17 days. Accordingly, the tidal waves generated by the moon in the Earth's atmosphere moved at a varying zonal speed, completing a half-revolution over 10 and 17 days alternately. This nonuniformity in the motion of tidal waves led to the development of stable blocking systems in the atmosphere, to the anomalously intense precipitation, and to flooding in the summer of 2013.

Conclusions

The periods of the lunar and solar cycles are known with astronomical and astrophysical accuracy, respectively (the latter is the several orders of magnitude less than the former).

The lunar cycles can be detected from the periods of beats in their amplitudes, from their frequency modulations, and their clearer manifestations at time intervals multiple of the solar year.

The dependence of meteorological processes on the tidal oscillations of the Earth's rotation rate (i.e., on the modulus of the Moon's declination and parallax), the relation of climate characteristics to the cyclicity of eclipses (i.e., to the orientation of the Moon's line of nodes), and the relation of droughts and floods to features of the perigee position (i.e., to the orientation of the apses of the Moon's and Earth's orbits) suggest that the responses of the climate system, biosphere, and noosphere to space impacts depend more not on the solar activity and gravitational tides but rather on the mutual configurations of the bodies in the Sun--Earth--Moon system (more precisely, in the entire solar system), on the positions of their lines of nodes and apses, and on the orientations of their rotation axes and the Earth's magnetic field with respect to the flow of the solar wind and space plasma. The situation depends on varying conditions affecting the flow of plasma to the Earth.

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