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SOLAR ACTIVITY AND RELATIONSHIPS BETWEEN ASTRONOMY AND THE GEOSCIENCES*

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Summary: Nowadays we dispose with a few observational indications that solar activity contributes in the tropospheric circulation and the climate instability. On the other hand, it is already known that the global variation of the atmospheric angular momentum causes a short-period fluctuations of the length of day. So, solar activity represents a phenomenon of interest for astrophysics, astrometry and the geosciences.

Key words: solar activity, tropospheric circulation, Earth rotation, interplanetary magnetic field.

D. Djurović: REZIME – Danas raspolažemo sa posmatračkim nagoveštajima da Sunčeva aktivnost ima svoj doprinos u stratosferskoj cirkulaciji i klimatskim promenama. S

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druge strane, već je dokazano da globalne varijacije atmosferskog ugaonog momenta uzrokuju kratkoperiodične fluktuacije dužine dana. Prema tome, Sunčeva aktivnost predstavlja fenomen od interesa za astrofiziku, astronomiju i geonauke.

Until the confirmation of Milankovitch' famous theory, by which the long-term changes of Earth's climate have been elegantly explained by the gravitational perturbations of the orbital elements of the Earth (Milankovitch 1941; Berger et al. 1984, eds.) and, accordingly, by the variable insolation of our planet, the Sun, as the object of observation and research, was of interest only to the astronomers. The closest "celestial laboratory" served for the research of the physical processes in the stars. Besides that, its apparent annual motion has been observed for aiding the dynamical realisation of the celestial reference system. However, solar physics nowadays is a field also interesting to specialists of different branches of geophysics and to astrometrists. Furthermore, there exist some indications that in the near future it will gain the attention of bilogists, medical and other scientists.

Besides Milankovitch' theory, the attention of meteorologists on variable solar irradiance was especially excited by the following three discoveries. The first one is that of Williams (1981, 1986), an australian geologist. From the analysis of annual alluvial deposits in the fossil lakes precambrian ($\approx$700 millions year of age), evidently dependent on the rainfalls, he found a cyclic variation of their thickness in the rhythm of the solar activiy variation. Besides the 11-year and the 22-year cycles, even the cycles of 80-90 and 285-290 year and minimum of Maunder have been pointed out.

The second discovery concerns the cyclic repetition of the drynesses over the large surface of USA, western from Mississippi (Mitchell et al. 1978), The phase and the amplitude of this cycle vary in the rhythm of 22-year ("magnetic") cycle of solar activity.

The above results have been obtained from the analysis of the tree rings, their age being from 1600 onwards.

Provided this discovery is not a mistake, future investigations of the solar activity contribution to the atmospheric circulation should be oriented to the solar and interplanetary magnetism.

The third of the above mentioned discoveries, important for meteorology, are the abrupt changes of the cyclonic activity whenever the Earth crosses the sector boundaries of the interplanetary magnetic field (IMF) (Roberts 1978). For the illustration, in Fig. 1, reproduced from Roberts' work, the index of atmospheric turbulence* (VAI) for a few days before and after the crossing of the sector boundary is presented.

* Vorticity Area Index

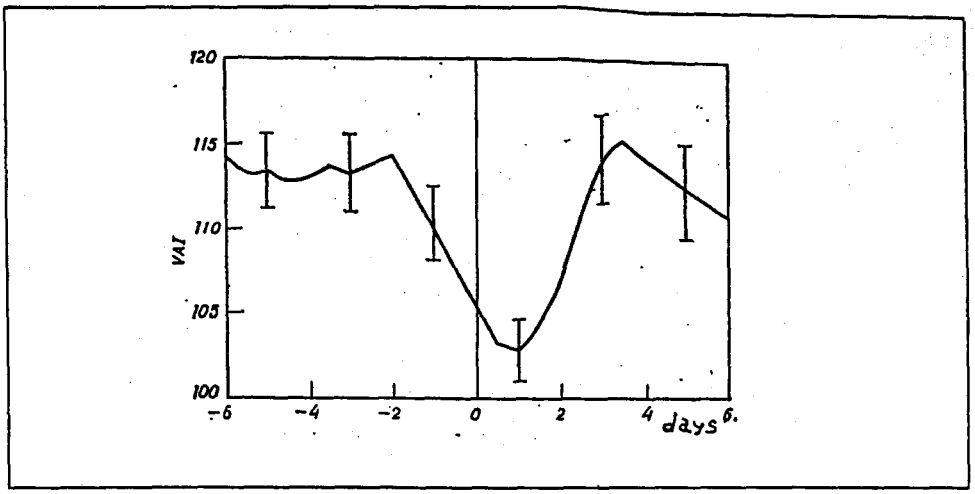

Figure 1: Vorticity Area Index

Evidently, the last two discoveries could be considered as complementary: the role of the interplanetary magnetic field seems to be of utmost importance for a birth of the observed geophysical events. This assumption is in accordance with the results recently obtained by Djurović et al. (1988). From these results follows that IMF inferencies produce the atmosheric angular momentum and the length of day cyclic variations.

From the radiometric records, obtained from satellites Nimbus-7 and Solar Maximum Mission, it was proven that the small variations of the solar constant (0.1% - 0.2% of the order) are closely correlated (in opposite sense) with the variations of the projected area of sunspots (Wilson 1982; Pap 1985).

It may be interessting to note that the correlation is better if only the young sunspots are taken into account. That is also an indication of the important role of the magnetic fields in the directing of the solar energetic particles.

From rocket and balloon observations and from satellite missions it was recorded that the upper atmosphere, usually considered as levels above 60-80 km of altitude, responds to solar activity variations. According to Jacchia (1967), from the drag of satellite Vanguard 1 it was pointed out that the air density increased and decreased by a factor of 2 with a Sun's rotation cycle and occasionally, following magnetic storms, by a factor of 5 or more.

The influence of these variations on tropospheric (in)stability is still not explained. Therefore, we must not exclude it.

The ionospheric reactions on the variable solar irradiance have been observed for decades. The role of ionospheric currents and ionospheric induction on the electrical potential of clouds, the role of polar particles on the merid-

ional flowing and other phenomena are under attention of specialists. However, the practical question: whether solar activity contributes to the tropospheric circulation or whether solar activity may be used as the instrument of weather forecasts, is today still open.

Meteorologists which do not accept the hypothesis of important solar activity contribution in weather changes often emphasize the following two arguments:

1. The statistical basis in favour of the mentioned hypothesis is not sufficiently convincing. There exist some examples where from the same data different authors have attained controversal conclusions.
2. The observed variations of the solar constant or of the total flux of irradiance are too small to be the cause of immense tropospheric events.

To these arguments a few others could be opposed.

The direct comparison of the solar wind cinetic energie and the corresponding atmospheric perturbations could not be recommended as the basis for solar activity-geophysical phenomenae investigations. Firstly, it is known that only some of the energetic solar particles and some of the electromagnetic solar rays give cause to geophysical phenomenae. For example, extreme ultraviolet (UV) irradiance is considered responsible for the distribution of the atmospheric ozon (O_3), particles of mean energies - for aurorae, ionospheric and geomagnetic perturbations ect. Inside the nearly constant total flux the large variations on different frequencies are observed. So, the relative variations of UV flux (by a factor 2) are registered during a 11-year cycle (Mc Cormac and Seliga 1978). In connection with that we remember that there exist some indications that UV flux, via O_3 perturbes the energetic balance at lower levels of the atmosphere and could excite immense tropospheric conversion of energies.

Concerning the statistical unreliabilities, we point out that the major part of these statistics is converging to the same conclusion.

It is true that physical mechanisms, able to transmit the solar influences observed in upper atmosphere to the troposphere are nowadays still unknown, this alone does not justify ignoring a lot of observational correlations indicating their existence.

Most meteorologists have devoted their attention to the solar activity-weather problem, but our impression is that it is only in the last 10-15 years that research in this field acquired the dimensions corresponding to its practical importance. This problem is in the focus of special symposia (e.g. symposium "Solar-Terrestrial Influences on Weather and Climate", Columbus, Ohio, 1978) also, much attention devoted to it at symposia dealing with the solar-terrestrial relationships (see, for example, Joint IQSY/COSPAR symposium "Solar-Terrestrial Physics: Terrestrial Aspects", London 1967).

Bearing in mind the new observational possibilities, especially the space

techniques, in the near future we should know whether the solar wind, the interplanetary magnetic field, the gaps of corona, the chromospheric flares, the UV flux, etc. are needed for the weather forecasts.

Are solar activity data useful for astrometry? We believe they are.

The astrometrists dealing with the Earth's rotation know well that the global atmospheric circulation causes the fluctuations of the length of day (l.o.d.) (Lambeck et al. 1973, 1974, 1976: Okazaki 1977, 1979; Hide et al. 1980; Langley et al. 1981; etc.). These fluctuations have been explained by the exchange of the angular momentum between the atmosphere and the "solid Earth". New techniques for monitoring of the Earth's rotation (especially, VLBI and laser) furnish us with data where fluctuations under 1 ms of amplitude are observable. Thus, we are today able to record even those perturbations which are due to violent monsoons. (Rosen et al. 1984). Therefore, it is undoubtedly proven that global and strong local tropospheric circulation perturbes the Earth's rotation. So, if its dependence on solar activity should be proven, astrophysical data would be invaluable for the astrometric investigations. For that assumption we already dispose with a few convincing arguments (Roberts 1978; Williams 1981, 1986; Djurović and Pâquet 1988; etc.).

In our papers published from 1981. onwards (Djurović 1981, 1983, 1986a, 1986b; Djurović et al. 1985; Djurović et al. 1986) we try to draw the attention of astronomers and geophysicists to the common cyclic variations of the Wolf number (W) or the projected area of sunspots (SA), the geomagnetic indices (Ap and Aa), the zonal component of the atmospheric angular momentum (AAM) and the l.o.d. (or universal time UT2). By different methods of spectral analysis, applied to many series of observation of the above mentioned variables, we have remarked that several peaks in their spectra represent the permanent features. Between them the most convincing are the 50 day and quasi-biennal ones. In the proceeding text we shall discuss them.

The 50-day cyclic fluctuation was first identified in the Earth's rotation (Feissel et al. 1980). It was explained by the corresponding fluctuation of AAM (Langley et al. 1981). Djurović (1983) has shown in the spectra of W and Ap that the 50-day peaks are clearly present and assumed a solar origin of the 50-day fluctuation of l.o.d., AAM and Ap. In his later investigations this assumption was supplementarily argumented.

In meteorology the quasi-biennal variation of the velocitiy of the stratospheric wind, observed at low latitudes, is better known than the 50-day varation of AAM. This flow is considered as a good indication of stratosphere - upper troposphere interactions (Nordberg 1967). The Japanese astronomers, Iijima and Okazaki (1972) have found the 2-year fluctuation of the universal time (UT2) which origin was assumed in the mentioned stratospheric wind.

Djurović et al. (1985) have found the 2, 3.5 and 5.5-year peaks of power

spectra in the series of Aa, for the period 1968-1976, and the series of W, for the period 1944-1979. The 2-year and the 5-6 year cycles of solar activity are assumed by several other authors (Lamb 1972). The 3.5-year peak was already discussed in Djurović et al. (1985).

From the above presented results and the discussion it follows that the 50-day and the quasi-biennal cycles in AAM, Ap and Aa and l.o.d. are caused by the solar activity. The physical mechanism of these phenomena is still unknown.

Geomagnetism and solar physics, as is well known, are related by the geomagnetic fluctuations excited by the corpuscular solar radiation. The known cycles of the solar activity, as we have already seen, are reproduced in the geomagnetic perturbations. The famous geomagnetic stroms, when the geomagnetic index can increase by an order of magnitude, follow the solar flares.

Geomagnetism is being seriously investigated by astrometrists. Munk and Mac Donald (1960), in their famous monograph on Earth's rotation, discussed the problem of interactions between the solar wind, the geomagnetic field and Earth's rotation. Their conclusion is that these interactions may contribute to the non-secular fluctuations of l.o.d.

There also exist the opposite opinions (see, for example, Schatzman 1966 and Coleman 1971), but the problem is unsolved. It is very important and complex. Its solution would be easier if it were investigated by teams of specialits of different branches: astrophysicists, astrometrists, geomagneticists, meteorologists, etc.

Solar activity is also investigated for the purpose of finding an instrument for earthquake prediction. Different authors arrive at controversal conclusions. In any case, this important problem stays open.

The earthquake phenomenon is also investigated in astrometry with the aim to explain certain Earth rotation irregularities and, especially, the excitation of the Chandler wobble. According to Lambeck (1980), the most probable cause of that is the combination of seismic and atmoshepric excitations and the aseismic deformations of the globe.

From the previous discussion it follows that solar activity phenomenon plays an important role in astrometric and different geophysical investigations.

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