ON THE RELATION BETWEEN THE ROTATION OF THE EARTH AND SOLAR ACTIVITY

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Abstract. Solar activity may affect the rotation of the solid Earth by coupling between the lower neutral atmosphere and the solid Earth. It attacks directly the lower atmosphere in the non-axially symmetric mode and may trigger off variation of the amplitude of the annual terms in the polar motion. The indirect effect of solar activity may be associated with some proper oscillation of the atmospheric coupling with the ocean in the axially symmetric mode of the atmospheric motion. The shift of airmass along the rotating axis of the Earth corresponds well with the changes of the Earth's rotational velocity and the Chandler amplitude in the polar motion for long time variation.

1. Introduction

Stoyko, A. and Stoyko, N. (1969) pointed out the close correlation between the area of the short lived sunspots, the amplitude and period of the Chandler motion, and the rotational velocity of the Earth. Straightforward transfer of non-isotropic momentum in the magnetosphere (Hirshberg, 1969) as well as extreme ultra-violet radiation and changes of polarity of the interplanetary magnetic field (Rosenberg and Coleman, 1969) may be possible causes of change in the rotation of the Earth. However, we have at present many steps to study on the motion of the atmosphere and very little knowledge about responses of motion of the Earth's atmosphere and the rotational motion of the solid Earth due to solar activity for any frequency other than the seasonal variation. Stoyko's paper stimulates us to study quantitatively the effect of solar activity on the rotational motion of the Earth.

The main aim of this paper is to study the effects of solar activity on the rotation of the Earth through couplings of the atmospheric motion. The atmospheric motion can be distinctly separated into the axially symmetric motion and the non-axially symmetric motion around the mean axis of the Earth's rotation. The former is connected with the change of the period of the Chandler term in the polar motion as well as that of the Earth's rotational velocity due to the variation of the maximum moment of inertia. The latter is essential for exciting forced oscillation in the polar motion. In what follows we restrict our argument to slow variations of solar activity. Kikuchi (1971) found some proper atmospheric oscillation near the period from 16 to 18 yr in the spherical harmonics of the second order, P_2^0 and P_2^2 modes and the weak spectrum at the sunspot cycle only in P_2^1 mode. Kikuchi's results suggest that some proper atmospheric oscillation may be found in the rotational motion of the Earth and the polar motion may be excited by solar activity.

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It seems, however, very difficult to account for the change of rotational motion of the Earth by the straightforward energy supply by solar activity. Dissipation of energy by magnetic storms and auroras is known to exceed the variation of the external field and energy in the plasma sheet. Therefore, solar activity should act as a trigger for excitation of a large energy transport from the lower atmosphere into the ionosphere to explain this large dissipation of energy. Energy transport near the mesopause has been studied by Christie (1970), and Gregory and Manson (1970).

The solar corpuscular streams will attack symmetrically around the axis of the dipole field in the ionosphere. The inclination of the axis of the dipole field to the axis of the Earth's rotation may excite non-axially symmetric modes in the lower neutral atmosphere. An axially symmetric mode is connected with the change of the Earth's rotational speed through (1) change of the maximum moment of inertia owing to the deformation of the magnetic cavity, (2) change of the relative zonal wind speed and (3) change of the tangential stress. The first possibility gives the result that the equatorial bulge would increase during the period of the sunspot minimum because of decrease of the pressure of the solar wind. Many reports, however, show the same phase in the period of the sunspot maximum.

2. Variation of the Amplitude of the Annual Term

Disturbances in the ionosphere due to solar activity can be measured by the c_i index, the magnetic disturbances. We try to compare directly changes of the c_i index with those of the amplitude of the annual terms in the polar motion, by using ILS data from 1893 to 1969 for both x and y components. We obtain a significant correlation between the amplitude of the annual terms for x and y components and changes of c_i, with the phase lag of the polar motion to the c_i index by about 2 yr. The phase lag of the annual motion may be explained by small mixing in the stable mesosphere and delay in transport of the disturbances of solar activity into the lower layer. The ozonosphere may be important for the phase lag of the annual motion.

Another example of the intersection of the geomagnetic field and the annual terms in the polar motion is shown by close correlation between the A_p index, which indicates disturbances of the geomagnetic field due to the solar corpuscular emission, and the major and minor radii of the annual ellipse in the polar motion obtained from the ILS data.

3. Axially Symmetric Motion

Axially symmetric motion in the atmosphere around the mean rotating axis is not simple. The idea of a simple isothermal magnetic cavity is broken down during the period of the sunspot maximum. The essential factor might be in the transport of the thermal energy in the upper atmosphere in the axially symmetric mode during the sunspot cycle. We may consider that variation of the atmospheric motion of a long time interval will be caused by the proper oscillation in the Earth's fluid, the atmosphere and the ocean, with the interaction of indirect effects of solar activity. Comparing two trends of the zonal index, which means a difference of the atmospheric pressure between two latitude belts, 40° minus 70° north latitude, and the changes of rate of the Earth's rotational speed during the interval from 1906 to 1964, we can explain the changes of rate of the Earth's rotation by change of the maximum moment of inertia C; i.e. the negative value of the zonal index corresponds to shift of airmass towards the pole and decrease of the principal moment of inertia C.

It is very interesting that the variation of the amplitude of the Chandler motion shows the same sign as those of the zonal index.

4. Conclusion

Non-axially symmetric atmospheric motion excited by the solar corpuscular streams may be a trigger of the polar motion of the Earth. Axially symmetric atmospheric motion, however, corresponds well with the change of the Earth's rotational velocity and those of the Chandler amplitude in the polar motion for variations of long time intervals.

References

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DISCUSSION

B. E. Schutz: What is the percentage change in the maximum moment of inertia due to solar activity?

C. Kakuta: If we attribute the change in the maximum moment of inertia to that in the isothermal atmosphere without taking account of effects of the solid Earth and the ocean, it is $\Delta C/C = 4 \cdot 10^{-11}$ corresponding to change of the atmospheric pressure in the $P_2{}^0$ mode, 0.2 mb.