DECADAL MODULATION IN THE SEASONAL VARIATIONS OF EARTH ROTATION : POSSIBLE RELATIONSHIP WITH SOLAR ACTIVITY

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ABSTRACT. Linear correlations have been found at the decadal frequency band, between the modulation of amplitudes and phases of the seasonal variations of length of day (annual and semi-annual), and solar activity represented by the Wolf number index as well as the total radiative flux at 10.7 cm. A possible mechanism explaining this relation is hypothesized to involve the lower regions of the atmosphere, which have been observed to contain significant interannual variations of seasonal signals. Though the present results are suggestive, involving patterns of temperature and wind fluctuations, further physical explanation of the mechanism involved is needed.

1. INTRODUCTION

The Sun drives the thermal balance of our planet and determines the seasonal variations of the weather. However, until recently solar irradiance was assumed to be invariant and because of the absence of consensus regarding physical processes relating solar activity to climate variations, this topic has caused much speculation and controversy.

A variety of studies have sought to establish relationships between solar and atmospheric variability (Labitzke, 1987; Labitzke and van Loon, 1990 and 1997; Barnston and Livezey, 1987; Pittock, A. B., 1978; Friis-Christensen, E., and K. Lassen, 1991, Salby and Shea, 1991; Sadourny, 1994; Reid, 1995). Many of the relationships detected have been questioned principally for both physical and statistical reasons. The physical basis for the relationship is unclear; solar irradiance variations observed during the last 3 decades are very small, with amplitudes of only 0.4% of the total solar energy.

Following a recent study (Abarca et al, 2003) we have re-investigated more extensively (Gambis et al, 1993) a possible relationship between the atmosphere and solar activity at the decadal time scale using LOD, AAM and Solar activity indexes: Wolf number and solar flux at 10.7 cm in the analyses.

2. DATA: EARTH ROTATION, ATMOSPHERIC ANGULAR MOMENTUM, AND SOLAR ACTIVITY DATA SETS

2.1 Earth rotation, Length of day (LOD)

The LOD series is derived from Universal Time UT1-TAI obtained from the combination of astrometric and space-geodetic methods. Prior to the advent of space geodetic techniques, in the 1970s, optical astrometry measurements, provided by as many as 50 instruments, principally astrolabes and transit instruments, were used to determine these earth rotation parameters. Since that time, modern methods including lunar laser ranging and very long baseline interferometry VLBI have provided the Earth Orientation Parameters (EOP) with increasing accuracy. These series are homogeneous with respect to the conservation of the reference system but not to accuracy, the precision of UT determinations having improved considerably over time, from 0.3 ms in the 1960s to 0.015 ms in 2003. The effects of the known externally forced zonal tides have been removed. Prior to 1962, variations of LOD were filtered into various components: decadal, seasonal and intraseasonal variations. Figure 1 shows the results of this filtering over 1962 until now (Shiskin et al, 1970)

The zooming of the seasonal variation series is represented on figure 2. A decadal modulation can be roughly noticed. This series will be analyzed and compared to other series AAM and solar activity.

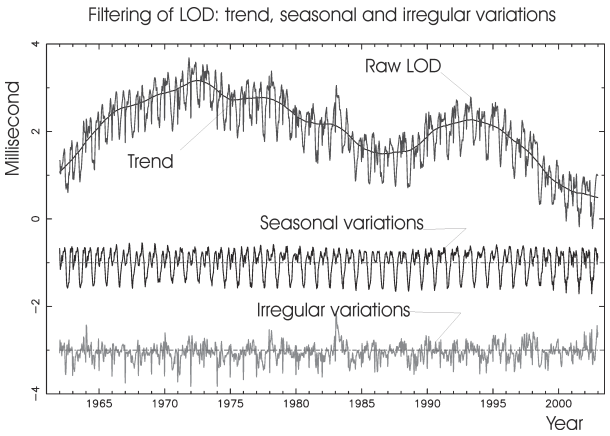

Figure 1: Filtering of LOD series into three components: trend, seasonnal and interannual

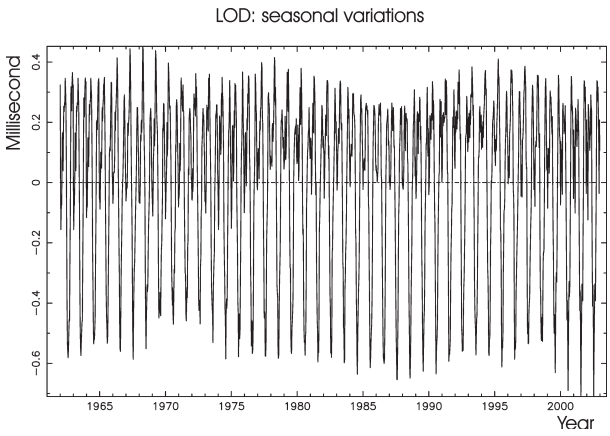

Figure 2: The seasonnal variations exhibit a significant decadal modulation

2.2 Atmospheric Angular Momentum

A fundamental measure of the dynamic state of the atmosphere is its angular momentum about the polar axis relative to the Earth. Variations in atmospheric winds and the distribution of surface pressure cause variations in Atmospheric Angular Momentum quantities. Because of the smallness of the external torques exerted by the sun and moon, and the limited role of the oceans, the angular momentum of the Earth-atmosphere system is largely conserved, and variations in AAM and LOD can be used as proxy indices for each other when decadal fluctuations attributed to the core mantle torque and known tidal terms are removed from the LOD series.

The AAM data can be expressed in millisecond (ms) of length of day (LOD) variability, assuming that changes in AAM for the entire atmosphere are accompanied by equivalent changes in the angular momentum of the Earth, through the following relation (Rosen and Salstein, 1983) :

$$\Delta LOD(ms) = 1.68.10^{-29} \Delta AAM(kg.m^2/s)$$

2.3 Solar variability

A number of different measures characterizing solar activity have been produced over the course of many years, and each is linked to some aspect of activity within the solar atmosphere, photosphere and corona. Nevertheless, these measures of solar activity are all well correlated with each other. The common indices that have been the most studied are those measuring the portion of the solar disc covered by sunspots, especially the composite "Wolf number", the solar radio flux at 10.7 cm, and total solar irradiance.

Although sunspots have been noted since at least 165 B.C. from China, the first scientific observations date from 1610. There are monthly data since 1650. The commonly used measure was introduced by Wolf, in 1852, as a specific index, based on a combination of a group number and a total spot number. The sunspot series reveals a cycle with average length of 11 years, but varying between 9 and 13 years. Indeed, the length of the cycle has been related to certain climate indices (Friis-Christiansen and Lassen, 1991) over a period longer than a century. The Wolf number index has already gone through 24 cycles since its start in 1755. The series has monthly data which vary significantly, partly because of the inclusion of active and inactive sunspots. Hence for sunspots, smoothed series, perhaps an annual mean, may be the scale of solar activity of interest here.

The spot number is well correlated to the solar flux, at 99% and a record of sunspots is available over a lengthy period.

3. ANALYSES

The seasonal LOD series presented on figure 2 was analysed. A least-square process allows the estimation of both annual and semi-annual components. amplitudes and phases are derived. Figure 3 and 4 show the amplitudes of the annual and semi-annual terms on the same plot that the solar activity. On most of the interval the agreement is striking (anti-correlation in the case of the semi-annual term). No significant phase shift between decadal AAM and solar activity. Similar agreements appear in the modulation of the phase (not represented). Figures 5 and 6 show that solar activity and the modulation of the amplitudes and phases of the annual and semi-annual terms of LOD exhibit a significant decadal period of 10-14 years.

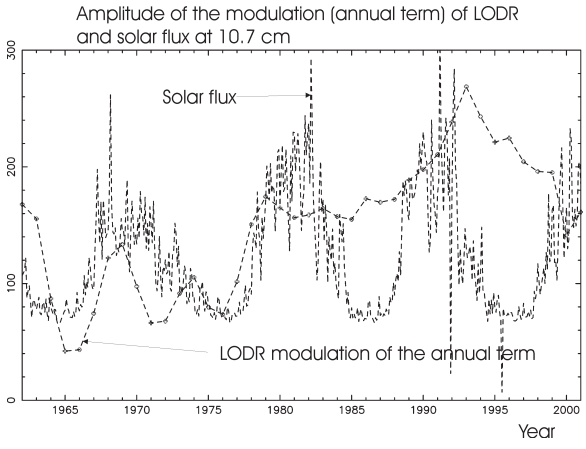

Figure 3: Amplitude of the modulation (annual term) of LOD and the annual flux at 10.7 cm

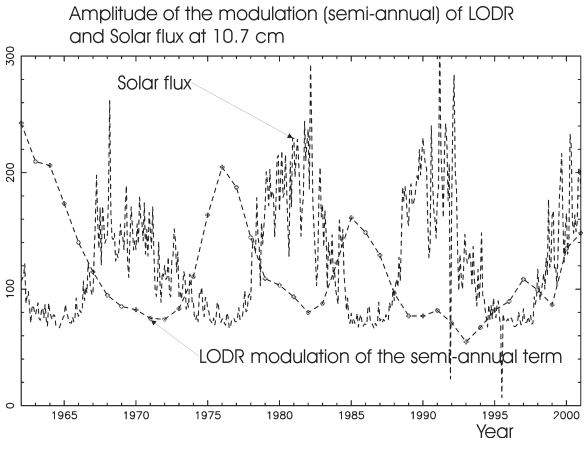

Figure 4: Amplitude of the modulation (semi-annual term) of LOD and the annual flux at 10.7 cm

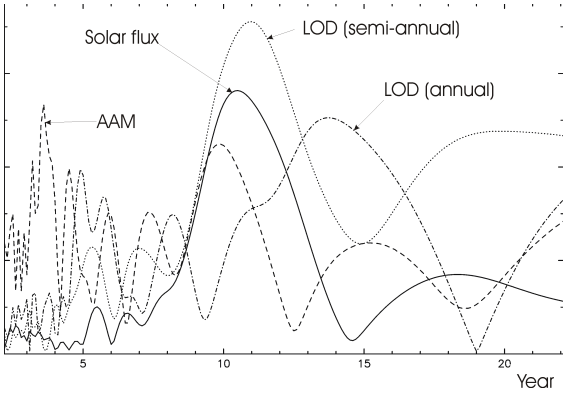

Figure 5: Periodogram of the solar flux, AAM and the amplitude of LOD modulation in the decadal frequency band

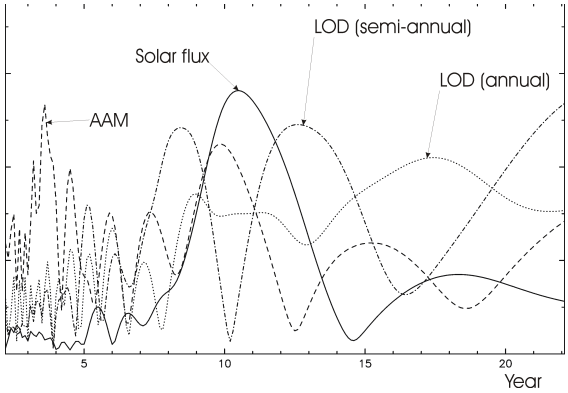

Figure 6: Periodogram of the solar flux, AAM and the phase of LOD modulation in the decadal frequency band

4. CONCLUSION

The present preliminary investigation reveals some significant relationships on seasonal time scales between solar activity and both atmospheric angular momentum and the length of day, which have been linked to each other. The strength and timing of the seasonal cycle in the terrestrial quantities appear to be modulated by the cycle of solar activity, when measured by either the 10.7 cm radio flux, the sunspot number. Though the mechanism is not clear, circumstantial evidence points to physical interactions in the lower troposphere as being responsible for the link in question, due to the known seasonal signal of that region relative to that of the entire atmosphere.

5. REFERENCES

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