CORRELATION OF INTRASEASONAL LENGTH OF DAY AMPLITUDE MODULATION WITH ENSO

Zhong Min Zhu Yao-zhong Gao Bu-xi
Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan ,430077

ABSTRACT

The Hilbert transform is used to extract the amplitude modulation signals for the intraseasonal variation of Length of Day ranging from 1962 to 1996. The results reveal that the intraseasonal Length of Day amplitude modulation variation has not only a positive secular trend, but also an interannual variation which is ahead of the ENSO evolution. The amplitude modulations for the quasi-50-day oscillation and the quasi-120-day oscillation have been studied separately. This shows that the peaks of the quasi-50-day oscillation amplitude modulation always occur longer than one year before happening of each ENSO event and seem to be the precursor of the ENSO event, and this is the same with the atmospheric research results. They also indicate the dominant correspondence between the quasi-120-day oscillation amplitude modulation and ENSO events since 1976 and absolutely negatively correlation with ENSO before 1972 because of phase change 180 degree in the evolution of the quasi-120-day oscillation amplitude modulation time series during the beginning of the 1970's.

Key words Hilbert transform, ENSO, intrasesonal LOD variation

INTRODUCTION

El Nino/Southern Oscillation (ENSO) is the most dominant dynamic variation of interannual scale in the system of atmosphere, oceans and the solid Earth, and it refers to a warm ocean current that flows along the coast of south-east Pacific Ocean and also influences weather patterns in the rest of the world. The high precision Earth rotation data currently observed by space geodesy could play a key role in understanding the process of atmosphere through angular momentum conservation. Most previous studies show that interannual length of day (LOD) variation is highly correlated with ENSO events (Figure 1)[1] and the Global Circulation Modal(GCM) simulation results indicate that intraseasonal atmospheric oscillation obviously interacts with ENSO[2]. So the behavior of intraseasonal LOD variation and its correlation with ENSO, are important for better understanding the mechanics of ENSO and the prediction of the occurrence and effects of this event .

DATA PROCESSING

The rotational rate of the solid mantle has been astronomically observed as the LOD derived from "Comb95" data set for nearly 34 years from January 1962 to January 1996 (courtesy of R.S.Gross,1995) [3]. They are very rich in signal content. The decadal, seasonal, and long-period tidal signals are the most prominent, and are superimposed on broad-band interannual, intraseasonal and rapid variation as the thin solid line ΔLOD_g in Figure 2.

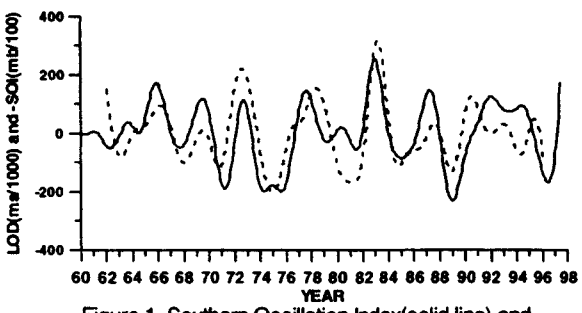


Figure 1. Southern Oscillation Index(solid line) and LOD Variation (dashed line) all at interannual scale

The first step is to use a least-squares fit to the entire excess LOD series ΔLOD_g as indicated by Formula (1) to remove the dominant seasonal signals by annual and semiannual sinusoids as well as the secular trend. The bold solid line in figure 2 represents the fitted excess length of day ΔLOD_f.

$$\Delta LOD_f(t) = c + bt + \sum_{i=1}^{2} A_i \sin[\frac{2\pi}{T_i}(t + P_i)] \tag{1}$$

$$\Delta LOD = \Delta LOD_g - \Delta LOD_f$$

Here A_i, T_i, P_i are, respectively, the amplitude, period and phase of the annual and semiannual variation of excess LOD, b is the coefficient of the secular trend, c is a constant term, ΔLOD is the difference between the geodetic excess LOD and the fitted excess LOD. A band-pass filter, whose frequency response function is given by Formula (2) [4], was chosen to obtain the intraseasonal variation of excess LOD with periods between 40 days and 150 days and this is represented by the solid line in Figure 3.

$$R(f_1, \varepsilon_1; f_2, \varepsilon_2) = A(f_1, \varepsilon_1) \cdot C \cdot [1 - A^N(f_2, \varepsilon_2)]^M \tag{2}$$

where $A(f, \varepsilon) = \frac{\varepsilon}{\varepsilon + (2\pi f)^6}$ is the Vondrak low-pass-filter frequency function, f is the cut-off frequency while N, M are positive integers.

To extract the amplitude modulation signals for the intraseasonal variation, we then use the Hilbert transform defined as [5]

$$\overset{\frown}{y}(t) = \frac{1}{\pi} \int_{-\infty}^{+\infty} \frac{y(\tau)}{t - \tau} d\tau \tag{3}$$

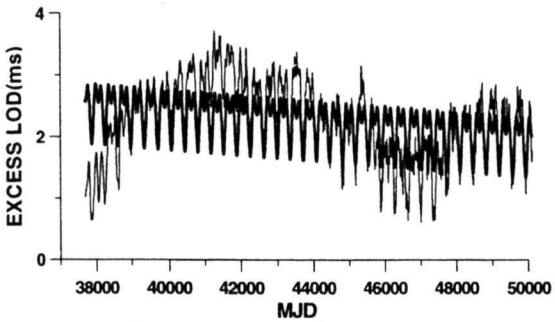
where $y(t)$ is the band-pass-filtered excess LOD time series, that is the intraseasonal LOD oscillation, $\Delta LOD_n = R \cdot \Delta LOD$.

We define a new analytic function $n(t) = y(t) - i\overset{\frown}{y}(t) = a(t)\exp[i\phi(t)]$, where $a(t) = (y^2 + \overset{\frown}{y}^2)^{\frac{1}{2}}$ is the amplitude modulation(AM) of ΔLOD_n. Performing these above steps yields a new

intraseasonal LOD amplitude modulation(AM) time series data set from January 1962 to January 1996, as represented by the dashed line in Figure 3.

RESULTS AND DISCUSSION

From the intraseasonal LOD amplitude modulation time series, we used the Vondrak low-pass filter to filter out the high frequency components with periods shorter than two years. So a new amplitude modulation time series for intraseasonal LOD variation has been obtained and compared to interannual negative Southern Oscillation Index time series (Figure 4).



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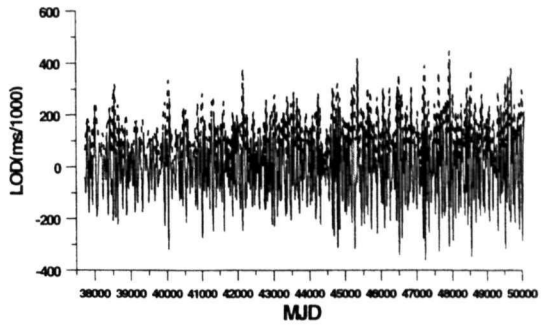

Fig. 3 The intraseasonal Length of Day variation (solid line) and its amplitude modulation time series(dashed line)

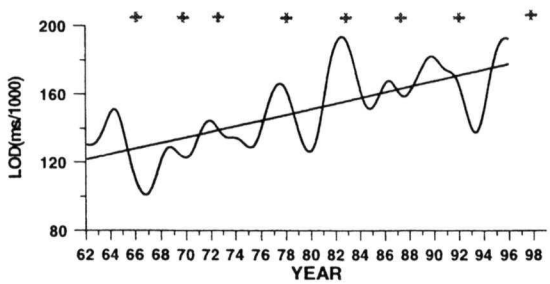

Fig.4 The intraseasonal LOD amplitude modulation with frequencies lower than one cycle per year

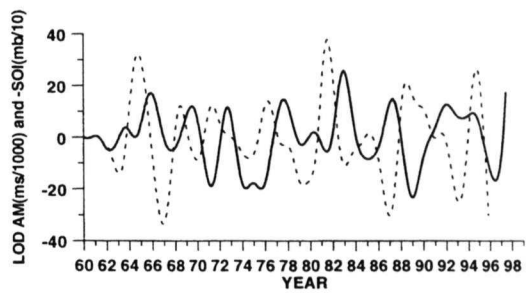

Fig.5 The quasi-50-day oscillation amplitude modulation at interannual scale (dashed line) and -SOI (solid line)

In Figure 4, the symbol '+' represents the occurrences of ENSO events. It's interesting to note the correlation between the occurrence of the AM peaks of intraseasonal LOD variation and the evolution of ENSO events. This reveals that the intraseasonal LOD strong AM peaks occur ahead of each ENSO event with different phases and sometimes almost the same phase. It implies at least that the intraseasonal variation is obviously modulated by ENSO oscillation in nonlinear modulation, where the modulation signals exist in the form of amplitude modulation of short waves. Furthermore, a positive secular trend in intraseasonal LOD AM variation exists, which means that the intraseasonal oscillation becomes slightly stronger and stronger with time. The clues provided by this result seem to indicate that the gradually stronger intraseasonal variation could cause ENSO to occur more frequently, and this needs to be further studied in atmospheric and oceanic researches.

As shown by the wavelet spectrum for intraseasonal LOD variation[6], the variation

includes the quasi-50-day oscillation and the quasi-120-day oscillation, which are different in time evolution. With the same data process of different parameters, we also get the AM time series at interannual scale for the well known quasi-50-day oscillation and the quasi-120-day oscillation (Figure 5,Figure 6). Figure 5 explicitly shows that there is always a stronger peak of the quasi-50-day variation amplitude modulation occurring longer than one year before happening of each ENSO event and looking like the precursor of the event. Figure 6 (a) indicates that the dominant correspondence between the quasi-120-day oscillation AM and ENSO events since 1976 is the same as the wavelet result[6]. At the beginning of 1970's, the quasi-120-day oscillation became weaker and before 1972 the evolution for the quasi-120-day oscillation AM is absolutely negatively correlated with ENSO events, and this is different from that correlation between these two signals since 1976. This may imply that the quasi-120-day oscillation AM time series has a 180 degrees reversion in phase. It can be recognized in Fig.6 (b) that the evolution of the interannual LOD variation is always the same with ENSO variation, but the quasi-120-day oscillation amplitude modulation variation because of the phase change of 180 degrees at the beginning of the 1970's. Of course, to verify this conclusion, further studies and more data are necessary.

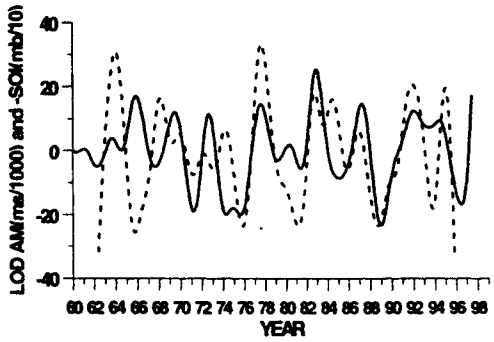

Fig.6a The quasi-120-day oscillation amplitude modulation at interannual scale(dashed line) and -SOI(solid line)

From the behavior of the intraseasonal length of day variation ,a conclusion can be made that the intraseasonal variation apparently interacts with ENSO dynamical variation in the system of atmosphere, oceans and the solid Earth.

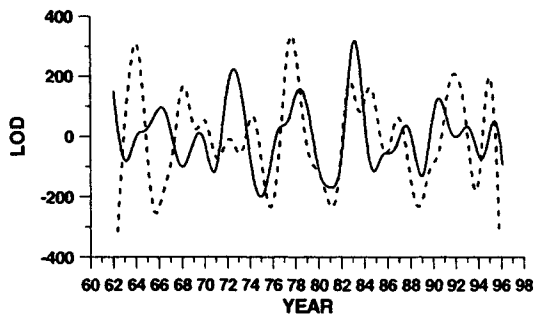

Fig.6b The quasi-120-day oscillation amplitude modulation at interannual scale (unit:ms/10000,dashed line) and interannual LOD variation(unit:ms/1000,the solid line)

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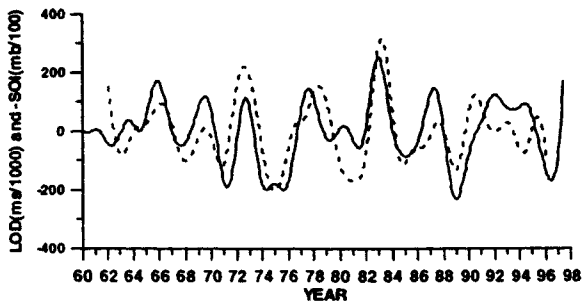

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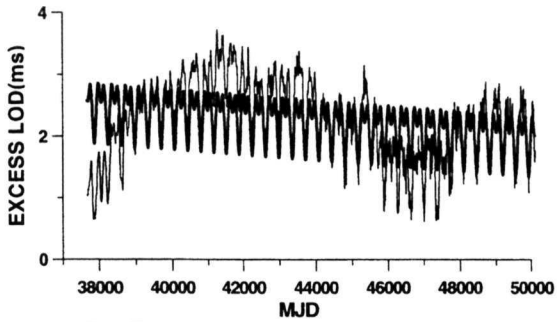

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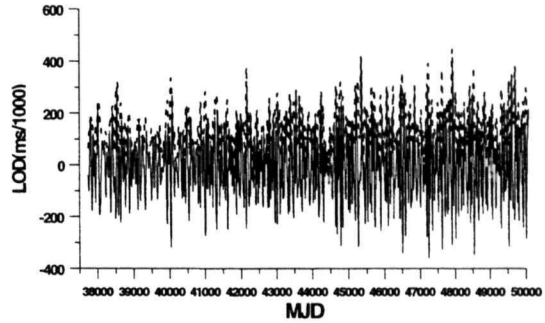

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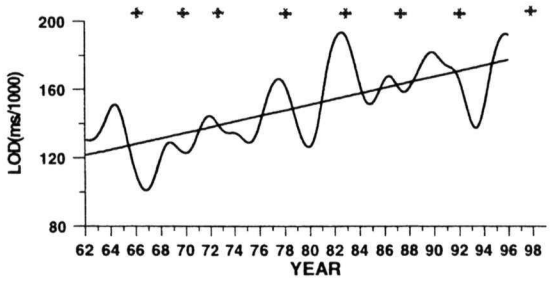

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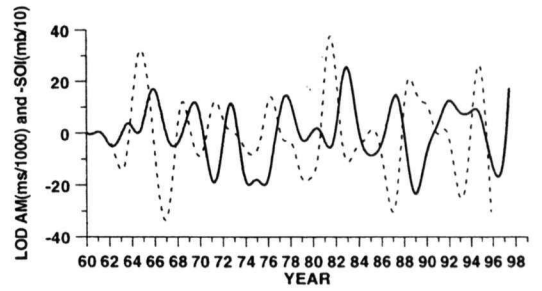

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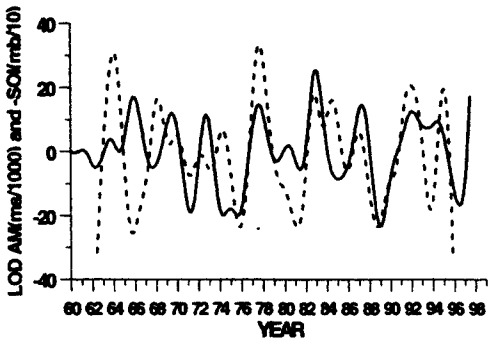

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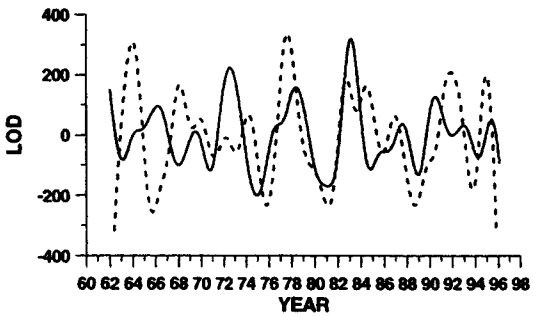

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