Time Variable Atmospheric and Oceanic Signals in Excitation Functions of Polar Motion

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1 Introduction

The atmosphere and ocean both play an important role in the excitation of polar motion variations on a broad range of time scales. This interaction between atmosphere, ocean and polar motion is expressed in terms of relationship of atmospheric, oceanic and geodetic excitation functions. These functions contain common signals which can include subdaily, daily, weekly, subseasonal, semiannual, annual signals and longer terms. The common signals and the correlation between atmospheric, oceanic and geodetic excitation functions are time-dependent. Below we consider three topics: the influence of addition of the ocean to the atmosphere on the spectral characteristics and agreement with polar motion excitation functions in time from 10 to 500 days, influence of El Niño on atmospheric excitation function variability in submonthly time scales, comparison of spectral variability of atmospheric and GPS (CODE) geodetic excitation functions for sub-daily time scale.

2 Variability

The atmospheric excitation functions for polar motion are given by variations of the equatorial components χ_1 and χ_2, projected on the two axes in the equatorial plane along the Greenwich and 90^o E meridians, respectively. These excitation function components, based on pressure (P) and wind (W) are expressed by the Barnes formulas (Barnes et al., 1983). For this study we use three sets of data: geodetic excitation function computed from the EOP (IERS) C04 pole coordinates, equatorial components of Atmospheric Angular Momentum (AAM) of NCEP/NCAR reanalysis and equatorial components of Oceanic Angular Momentum of M.I.T. model (Ponte et. al., 1999), for 1985–1995. The geodetic and atmospheric excitation functions were averaged to a five days frequency.

Polar motion and atmospheric circulation fluctuations occur on the wide range of time scales. It is widely known that annual and semiannual oscillations exist both in atmospheric circulation and in polar motion (see reviews by Eubanks, 1993 and references therein). Also fluctuations in subseasonal time scales (with periods shorter than 150 days) have been identified and tied to oscillations of atmospheric excitation function (Kosek et al., 1995; Kolaczek et al., 2000). Here the spectral bands are defined to provide some insight into annual, semiannual, subseasonal polar motion, although the cut-off periods are arbitrary. The subseasonal band is separated here between periods around 120 days oscillation (terannual band) and shorter than 90 days (short period band).

Time variable spectra of atmospheric and joint atmospheric and oceanic excitation functions, were computed by the Fourier Transform Band Pass Filter – FTBPF (Fig. 1). It is clear that oscillations have time variable amplitudes. Spectra of AAM, and joint AAM+OAM excitation functions are similar in the spectra range from seasonal to short period. There are similar oscillations annual, semiannual, 120, 60 40 days in AAM and AAM+OAM and they have similar amplitude variations. Amplitudes of the oscillations of joint AAM+OAM series are not always greater than the AAM. It means that their variations are not always in concert.

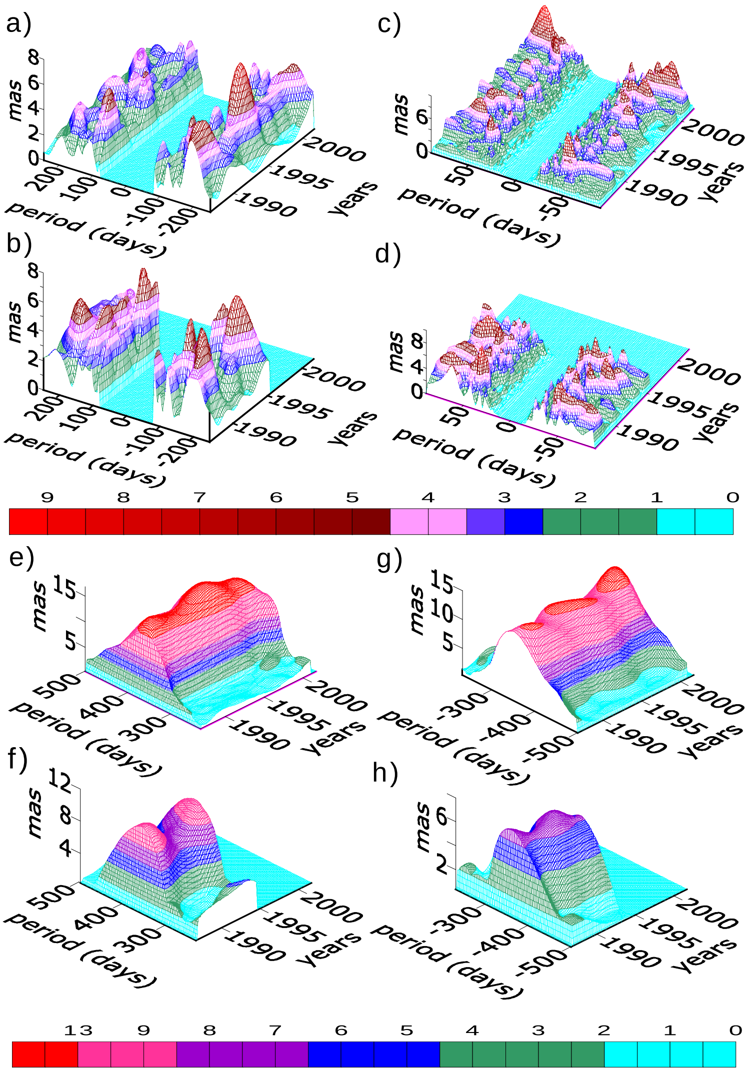

Fig. 1 Time variable spectra (a, c, e, g) of the AAM and (b, d, f, h) of the joint AAM + OAM variations in the period range from 10 to 500 days computed by the FTBPF (lambda = 0.006)

It is widely known that polar motion excitation at seasonal and subseasonal scales is strongly, though not completely related to atmospheric forcing (Nastula and Salstein, 1999; Nastula and Kolaczek, 2002). When the total correlation between atmospheric and geodetic excitation function is performed in time dependent manner, we note that the correlation coefficients vary with time and a timing of correlation coefficient depends on spectral band (Fig. 2). The correlation coefficient is the most stable for annual band. In the case of semiannual, teranual and shorter oscillations the correlation coefficients are lower and more changeable. Adding of the OAM to AAM results in increasing of the correlation level and smoothing their variations.

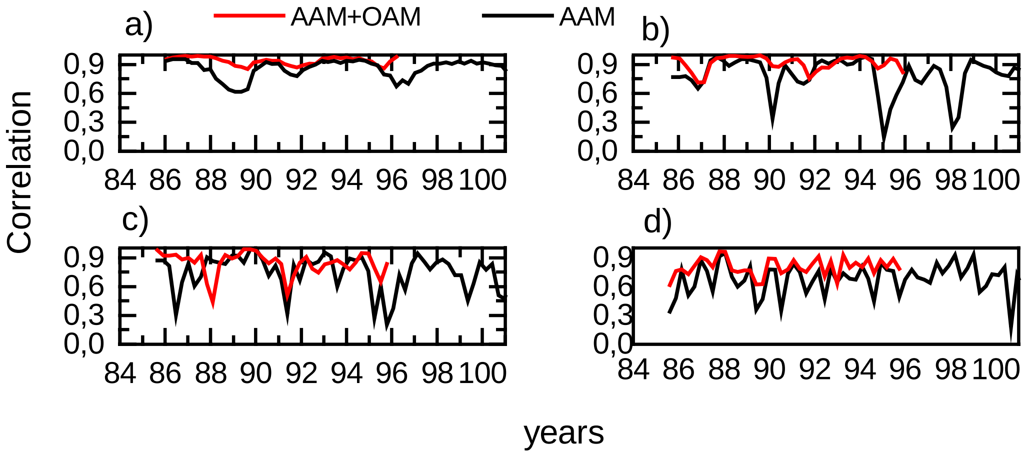

Fig. 2 Correlation coefficients between the complex-valued equatorial components of geodetic and AAM (black) and AAM + OAM (red) excitation functions for polar motion filtered by the Butterworth filter (a) 450–230 days, (b) 230–150 days, (c) 150–90 days, (d) 90–10 days intervals, starting each 100 days of a year since 1986, computed over (a) 2190 days, (b) 1095 days, (c) 730 days, (d) 540 days. (For a colour version of this Figure see the online version at http://www.iers.org/iers/publications/tn/tn30/.)

To isolate regions of atmosphere responsible for polar motion variations atmospheric excitation functions χ_1 and χ_2 are computed in 3312 equal-area sectors for the period January 1999 to December 1999 from meteorological fields on $2.5^o \times 2.5^o$ latitude-longitude grids from the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR). In order to show sub-monthly variability we display monthly maps of the standard deviations of pressure term of complex valued $\chi = \chi_1$ and χ_2.

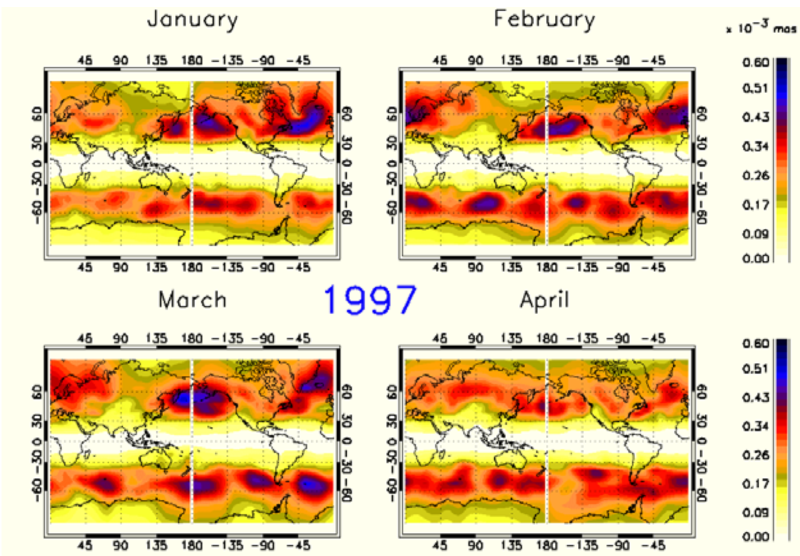

Fig. 3 Monthly standard deviations of complex-valued, pressure component of atmospheric excitation functions of polar motion

A sequence of such standard deviations were computed for each month during two years, in 1997 (El Niño) and in 1999 (Non El Niño). Example variations are shown in Fig. 3. The maps have spatial patterns with maxima over Eurasia, North Pacific, North Atlantic, and a broad maximum lasting over mid-latitude South Pacific from south tip of Africa to south tip of South America. The shape and intensity of maxima is time dependent. There are four sub-pattern (not shown here) connected generally with four seasons of the year. Additionally there are in the patterns differences in a non-El Niño and an El Niño year. Higher variabilities are often seen in El Niño year.

The GPS and VLBI techniques allow recently to determine Earth orientation parameters with high accuracy and resolution. It allows to determine sub-daily variations of polar motion. There are distinct 12 hours and 8-hours oscillations in the atmospheric and geodetic excitation functions, in the geodetic pole coordinates which have 2 hour resolution additionally 6 hours is detected. These oscillations have time variable amplitudes (Weber et al., 2000, 2001).

3 Conclusions

- Correlation between atmospheric-geodetic excitation functions is high but depends on spectral range. Adding oceanic excitation function increases correlation over whole spectral range (450–10 days), and smoothes variability especially for the seasonal oscillations.
- In subdaily range geodetic and atmospheric excitations functions have similar spectral characteristics.
- Regional submonthly variability has annual modulation. Higher variability is often seen in El Niño year.

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