EXCITATION OF EARTH ROTATION BY GEOPHYSICAL FLUIDS

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ABSTRACT. Among the geophysical fluids, the atmosphere and ocean are important sources of excitation for the irregularities in Earth rotation, acting on a broad range of time scales from subdiurnal to decadal. These excitations occur due to exchanges of angular momentum from these geophysical fluids to the solid Earth, and occur in both the axial direction causing changes in the length of day and in the equatorial direction leading to polar motions. In the atmosphere, angular momentum variations are due to those in the mass distribution, linked to surface pressure, and motions, namely the winds. These variations are related to the local changes occurring over many regions of the globe. Recent evaluations containing high spatial resolution decomposition of the atmosphere, over 3312 sectors, indicate the regions containing the most covariability with the global atmospheric angular momentum and the polar motion excitation itself.

1. INTRODUCTION

Various datasets that describe the angular momentum of the atmosphere are prepared through the model-data assimilation systems of the worldŠs large weather centers. They take the heterogeneous combination of meteorological observations, which are irregularly spaced, and combine them optimally with the forecasts of atmospheric prediction models. From this procedure, fields of meteorological variables are produced on regular grids. From the winds and surface pressure fields, we have been calculating the motion and mass terms of atmospheric angular momentum, which is proportional to the atmospheric excitations for Earth rotation, consisting of the equatorial terms related to polar motion and the axial terms related to length of day, and UT1, its time integral. They are archived at the Special Bureau for the Atmosphere (Salstein et al. 1993) of the International Earth Rotation and Reference Frames Service. One year of excitation data, according to the Barnes et al. (1983) framework, from the U.S. National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalyses (Kalnay et al. 1996) for 2002 is given in Fig. 1, for the three components of angular momentum, and for the motion (wind) term and the mass (surface pressure) terms. In addition, the term related to surface pressure modified by the Inverted Barometer fluctuation is given. This term has smaller amplitude because of the reduced variability of the atmosphere over the ocean areas.

2. HIGH-RESOLUTION SPATIAL DECOMPOSITION OF THE ANGULAR MOMENTUM FIELDS

We have decomposed the atmosphere into a network of sectors to examine the higher spatial resolutions than were heretofore available. To do so, we chose equal-area sectors bounded by 72 east-west bands (at 15 degree longitude spacing) and 46 north-south bands equally spaced in sine latitude. A map of these sectors is given in Fig. 2. We examine the variability at annual time scales in Figs. 3,4 and their contributions to the overall functions of atmospheric excitation of polar motion. It can be seen that the largest covariance with the global excitation function occurs over Asia, with relative maxima in Central Asian highlands and over far east Asia showing the finer details of the variability than was possible in Nastula and Salstein (1999). The correlation in the annual band between local and global excitations, indicating phase agreement, however, is high in other regions too, including North Africa, southeast North America, and South Africa. The same general features occur in both halves of the record, both before and after 1980, about when the satellite data were added to the mix of observations for assimilation into the atmospheric analyses. Around the same time, in fact, the geodetic data improved with the introduction of advanced space-geodetic satellite techniques. The atmospheric excitations of the pressure terms with IB forcing were also studied at different seasonal timescales, including the semiannual, terannual, Chandler, and long-period (2-5 year) bands. In each of these bands, we see the dominance of the atmosphere over Eurasia, primarily, and North America, secondarily. Central-East Asia has the largest variability in all these bands. At much higher frequencies, we examine the submonthly variability as well. Here we consider the excitations without the IB, because at the more rapid scales, the IB is less active, and we note the annual progression of such variability in one representative year. The highest variability is in the middle latitudes of each hemisphere, where the weighting functions for the excitation is large. Also, the winter months of each hemisphere show the largest submonthly variability, particularly in areas known as strong storm track regions. For example, January and February feature high values of the variability in the Iceland low region, over the Northern Pacific, and in areas across Asia and North America. The annual signal in this submonthly variability is strong, with a large winter-to-summer contrast. In the southern hemisphere, the submonthly variability in its winter months, June-September, is stronger than its winter months, but by a smaller amount than the corresponding northern hemisphere differences. Oceanic contributions to polar motion excitation, including down to rapid scales, have also been determined regionally, as has been determined by models (Ponte and Ali 2002) have their strongest variability in the middle-high latitude oceans, for example in the Northern Pacific, and across the Southern Oceans especially to the southwest of both South America and Australia.

3. SUBDAILY VARIABILITY

The variability of the atmospheric excitations of polar motion and length of day is beginning to be identified because of the question of whether the atmosphere provides any forcing at this time scale. The polar motion term has been determined four times daily, at 00, 06, 12, and 18 UT (Fig. 5) and we have computed excitation terms for a year, using some updated geophysical constants and vertical integration limits for the winds between surface and 10 hPa levels (Zhou et al. 2006). We have noted that the diurnal variability is quite large, and likely related to the tides in the atmosphere. The signatures appear to have one signature in the northern hemisphere winter and another in the northern hemisphere summer, with the transition season months typically smaller diurnal variability. That of the axial component is relatively very small (not shown).

4. LONG-TERM VARIABILITY IN SURFACE PRESSURE

As much of the polar motion excitation depends upon the surface pressure series, we wish to note its long-term global average, which has changed since 1948, the beginning of the NCEP-NCAR reanalyses record. A running mean term is given in Fig. 6, which shows the low frequency variability, which in the earlier years of the record have approximately a decadal signature, but has stabilized since around 1980. Also, when this low-frequency term is subtracted from the series, we obtain the resulting high frequencies. Here too, the character of the high frequencies, which appears to have an annual variability, changes around 1980, giving a fairly stable size of the higher frequencies, consisting of annual and shorter.

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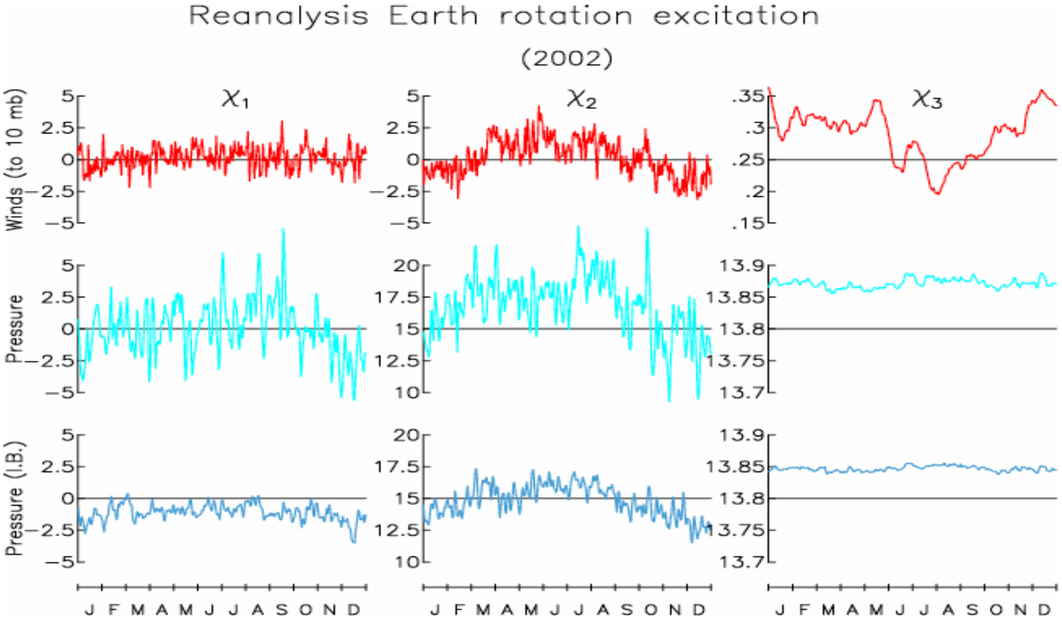

Figure 1: One year, 2002, of atmospheric excitation of Earth rotation. Columns are χ_1 and χ_2 (equatorial, related to polar motion), and χ_3 (axial, related to length of day). Rows are wind term, mass term, and mass term as modified by the Inverted Barometer.

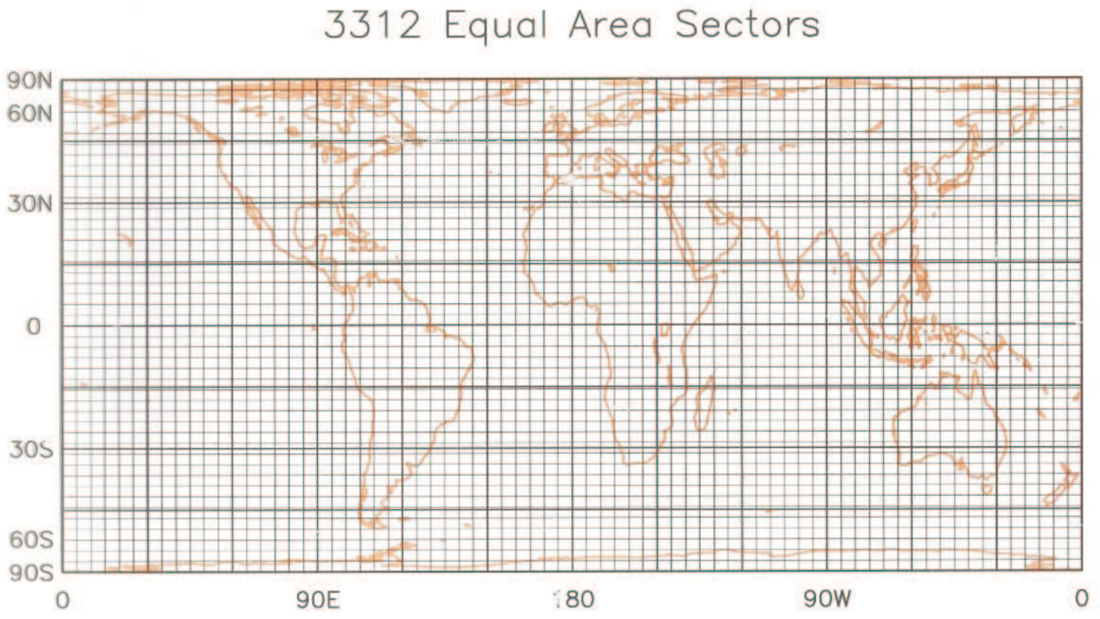

Figure 2: Map of the 3312 equal-area sectors in this study.

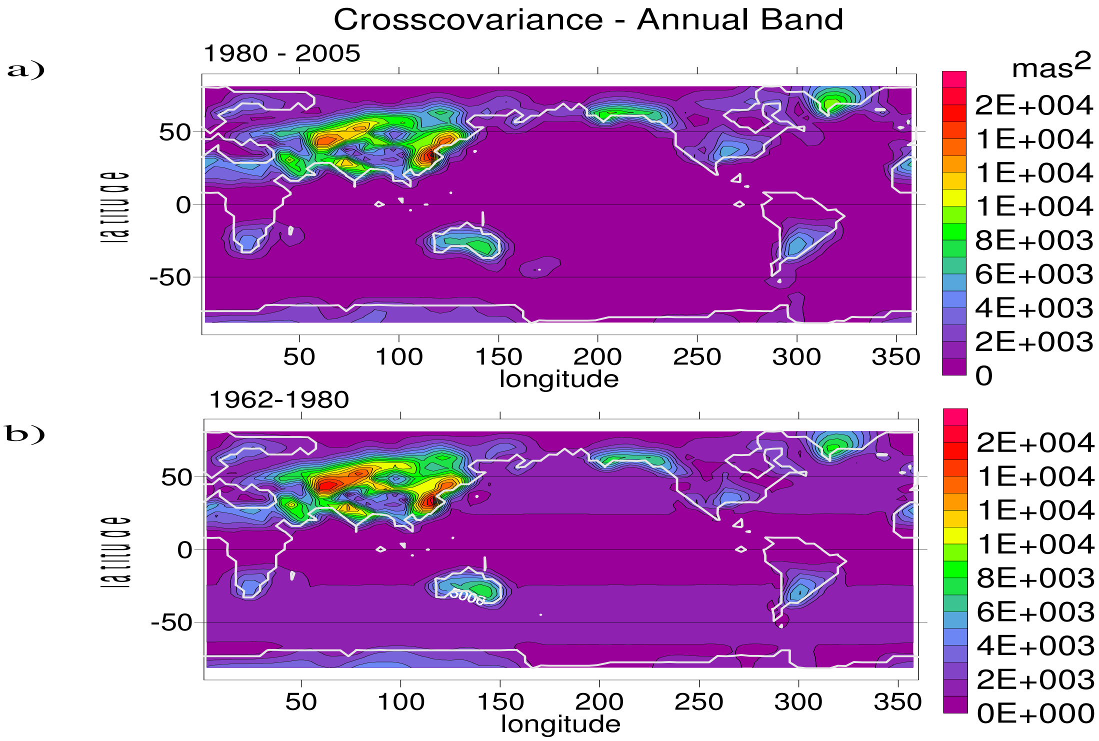

Figure 3: Cross–covariance of polar motion excitation in annual band between regional and global terms.

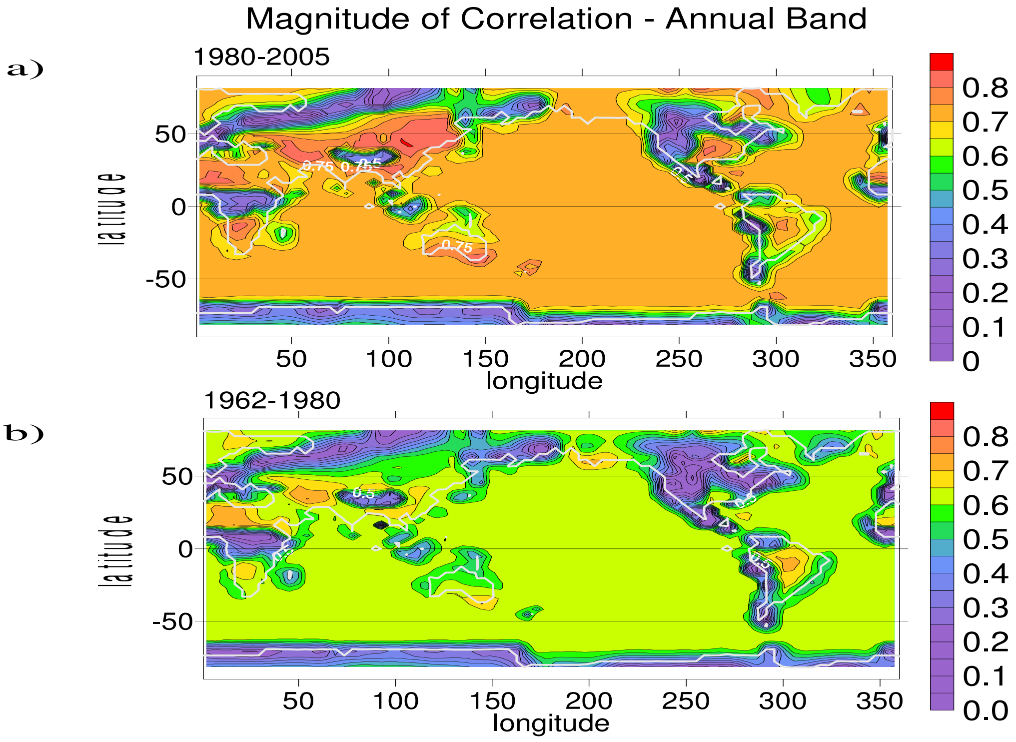

Figure 4: Correlation of polar motion excitation in annual band between regional and global terms.

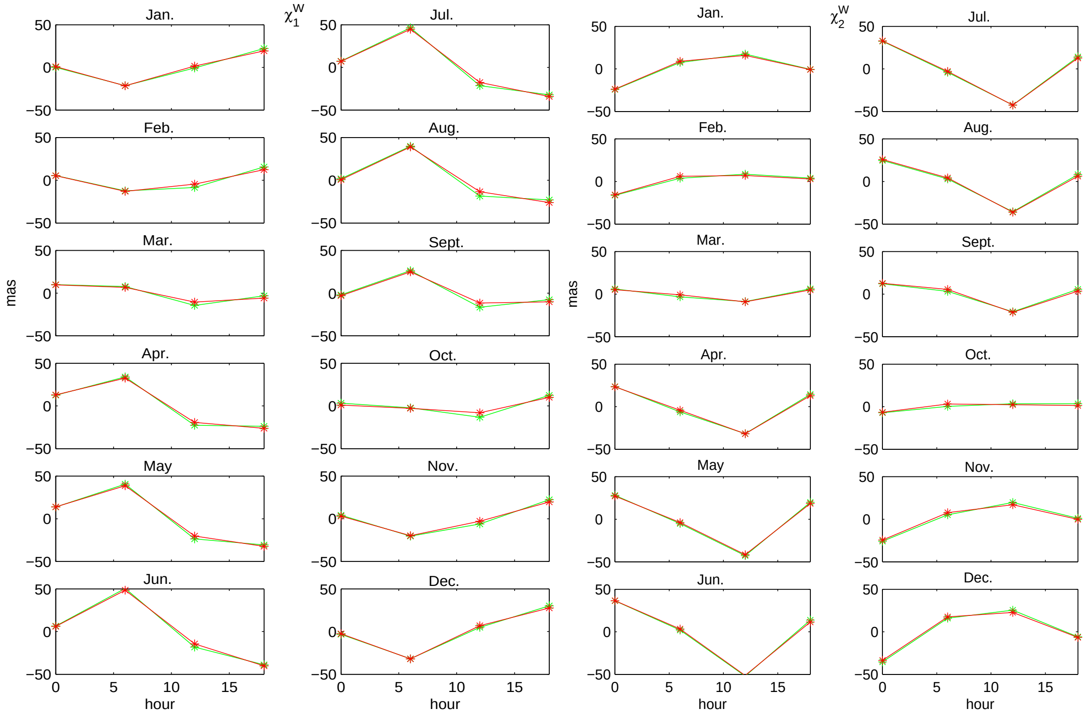

Figure 5: Four times daily excitations of two polar motion from wind terms showing seasonally modulated diurnal signature variability (Zhou et al. 2006).

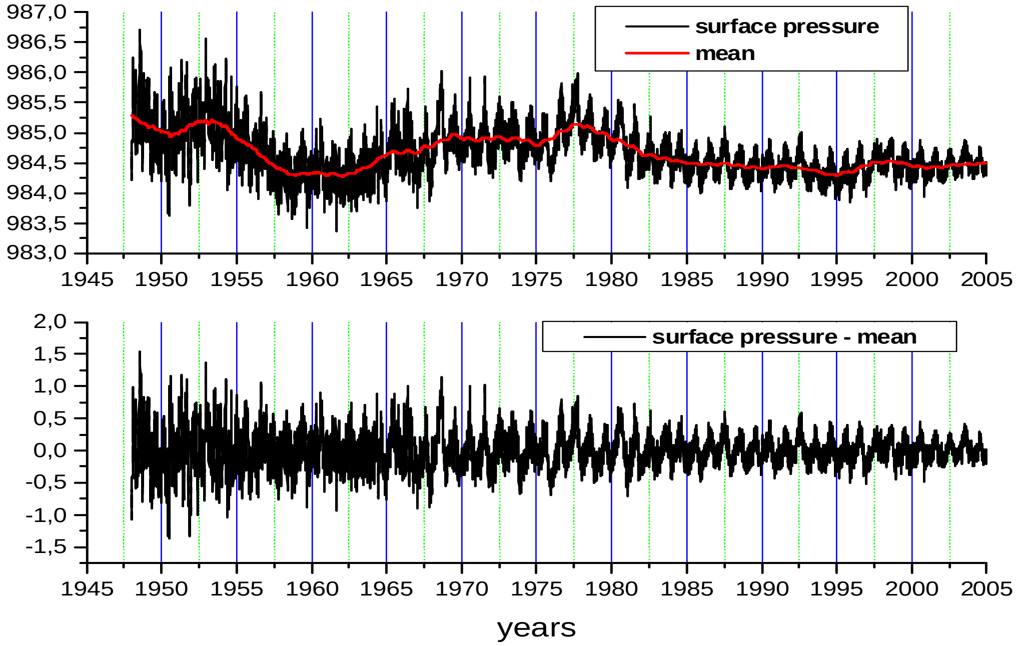

Figure 6: Values of the atmospheric surface pressure over the globe. Average denotes annual running mean. Units (hPa).