THE 1997-1998 EL NIÑO EVENT: INSIGHT VIA SPACE GEODESY

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The impact of the 1997-1998 El Niño Southern Oscillation (ENSO) event is examined in context of angular momentum exchange utilizing length of day (LOD), Southern Oscillation Index (SOI) and Atmospheric Angular Momentum (AAM) (both global and latitudinally belted) data from 1970 to 1998. Comparisons are made with previous events.

The El Niño Southern Oscillation (ENSO), a climate fluctuation that recurs on a 2-7 yr. time scale, is associated with persistent large-scale variations in the dynamical behavior of the global atmosphere-ocean system. Comparisons between length of day (LOD) and the strength of the ENSO cycle, represented by the Southern Oscillation Index (SOI, the difference in sea level pressure between Darwin and Tahiti) have indicated striking agreement, with high interannual values of LOD generally coinciding with ENSO events [see Chao, 1984, 1988, 1989; Dickey et al., 1992, 1993 and 1994, Eubanks et al., 1986; Gambis, 1992, Rosen et al., 1984, Salstein and Rosen, 1986]. During an ENSO event, the SOI reaches a minimum, leading to an increase in atmospheric angular momentum (AAM) associated with the collapse of the tropical easterlies. Further increases in AAM may result from a strengthening of westerly flow in the subtropical jet streams. Conservation of total angular momentum then requires the Earth's rate of rotation to slow down, thus increasing LOD.

The LOD series analyzed is the Jet Propulsion Laboratory (JPL) Kalman-filtered series, designated as COMB97 [Gross et al., 1998], which is derived from a Kalman filter-based combination of independent Earth rotation measurements utilizing the techniques of optical astrometry, very long baseline interferometry (VLBI) and lunar laser ranging (LLR). For the SOI, we use a modified version of the Southern Oscillation Index based on Tahiti and Darwin sea level pressure (SLP) data provided by the National Center for Environmental Prediction. The time series is obtained by first removing the annual cycle (this is done by subtracting from both series the mean SLP value at that location for the corresponding month), dividing the monthly anomalies so obtained by the corresponding standard derivation, and then taking the Darwin-minus-Tahiti differences. Note the series used here, the "Modified Southern Oscillation Index" (MSOI), is opposite in sign to that which is commonly used [e.g., Trenberth and Shea, 1987], so as to be positively correlated with the LOD (see Fig. 1). For the atmospheric angular momentum, National Center for Environmental Prediction (NCEP) Reanalyses for the period 1970 - 1998 [Kalnay et al., 1996] are investigated.

The focus of this note is the most recent ENSO event. With this goal, it is imperative that a method be developed to extract the longer term decadal signal and the dominant seasonal terms.
from all series. A composite annual cycle is removed from both the LOD and AAM, as was done for the MSOI. The decadal variability is obtained by taking the difference between the LOD and AAM (with composite seasonal cycle removed) and approximating its longer term behavior with the leading dominant modes as determined by singular spectrum analysis (SSA -- see Vautard and Ghil, 1991). The residual series of LOD with the composite annual cycle and decadal signal removed shows both strong interannual as well as intraseasonal variability, and is compared with the AAM and MSOI in Fig. 1. Similarity among the three series is striking, with strong peaks evident in 1982-83 and during the recent event. All three series had a sharp rise in early 1997, with maxima still evident in the latest values shown.

Fig. 1 A comparison among LOD, AAM, and MSOI (top, middle and bottom curves, respectively). The strong 1982-83 and 1997-98 ENSO events are clearly evident.

Additional insight into the origin of interannual rotational fluctuations can be gained through the examination of the latitudinal structure of the associated atmospheric variation [Dickey et al., 1992 and Black et al., 1996]. The AAM obtained by integrating atmospheric data up to 100 mb over 46 equal-area belts is considered, with interannual variations obtained using a recursive filter [Murakami, 1979] with three different bands: ENSO (20-65 months), low frequency (LF - 35-65 months), and the quasi-biennial (QB - 20-36 months) bands (see Fig. 2). The resulting pattern of interannual variability is evident, with V-like structures emerging from the tropics and propagating poleward.
Atmospheric Angular Momentum

Fig. 2 Latitude-time (Hovmöller) plot of interannual atmospheric angular-momentum variations. We use the NCEP reanalysis series integrated over 46 separate equal-area latitude bands, based on atmospheric wind data up to 100 mbar. Interannual variations are obtained by recursive-filtering in the three interannual bands: the ENSO (20-65 months) band; the low-frequency (LF) band (35-65 months); and the quasibiennial (QB) band (20-36 months). Regions with darker shades represent easterly AAM anomalies and lighter shades represent westerly AAM anomalies.

The 1982-1983 event is associated with positive AAM (that is anomalous eastward winds) beginning at the equator in late 1980/early 1981 and propagating to high latitudes in both hemispheres over the course of several years. During the mature phase of the ENSO event (mid-1982 to mid-1983), strong positive anomalies are located in the northern subtropics with moderate anomalies in the southern subtropics. These anomalies diminish in strength and propagate poleward as the ENSO events decays. A similar scenario can be seen for the 1986-87 event, with strong modulation on the QB time scale [Dickey et al., 1992]. The strong ENSO events in 1972-73, 1982-83 and 1997-98 are especially robust in the LF band, compared with additional episodes in 1977 and 1987. The complex multi-year events in the early 1990's have features visible in both the QB and LF bands.

For the most recent event, a V-like structure is visible in all three bands; activity began in the summer of 1996 in the LF band and in late 1996 in the QB band. Constructive interference is evident in the ENSO band with strong tropical activity in early 1997 propagating poleward to produce enhanced activity in the mid-latitudes in late 1997/early 1998. Already in late 1997/early 1998, signs of the coming La Niña event are evident, with easterlies developing in the tropics. Unlike the 1982-83 event, which had a dominant maximum in the northern hemisphere mid-latitudes, the current event has its strongest activity in the tropics, and is more comparable in its latitudinal development to the 1972-73 event.
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REFERENCES


