ATMOSPHERIC ANGULAR MOMENTUM DURING THE 1997-98 EL NIÑO EVENT

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The El Niño event of 1997-98 caused a dramatic change in the atmospheric circulation over the Pacific Ocean and strongly influenced weather patterns over much of the globe. A measure of the overall strength of the zonal circulation is the global atmospheric angular momentum (AAM) about the rotation axis relative to Earth's surface. AAM may be defined as

$$AAM = \frac{a^3}{g} \iiint u \cos^2\phi \, d\phi \, d\lambda \, dp$$

where a is the radius of Earth, g acceleration due to gravity, and u zonal wind, with the integral performed over all latitudes, ϕ, longitudes, λ, and pressures, p. Because of its global scope, the AAM time series forms a climate-sensitive index of the atmosphere's circulation. To understand its long-term characteristics, we have calculated this index from over 40 years of the NCEP/NCAR Reanalysis; in Fig. 1 the various signals in this curve are clearly seen, especially the strong seasonal fluctuations which peak in Northern Hemisphere winter; noticeable interannual variability is evident too. The two highest peaks occurred in January 1983 and February 1998 during major El Niño/Southern Oscillation events.

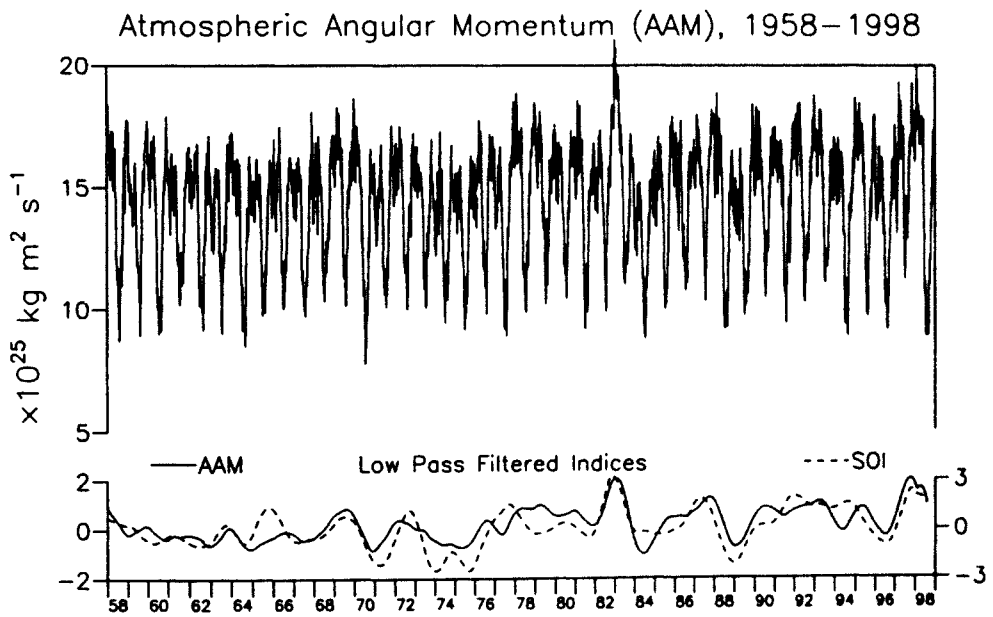

Figure 1. (Top) Daily values of atmospheric angular momentum from the NCEP/NCAR Reanalysis. The angular momentum is integrated globally between 10 and 1000 hPa. (Bottom) Interannual variations of AAM (solid, scale on left) and the Southern Oscillation Index (dashed, scale on right), both low-pass filtered.

The close connection between the AAM index and ENSO can be seen by comparing the curves at the bottom of Fig. 1. Here, interannual variations of AAM and the modulating Southern Oscillation Index, are isolated with a low-pass filter. The correlation between the two filtered series is 0.72.

The close connection between the AAM index and ENSO can be seen by comparing the curves at the bottom of Fig. 1. Here, interannual variations of AAM and the modulating Southern Oscillation Index, are isolated with a low-pass filter. The correlation between the two filtered series is 0.72.

Prior to May 1998, values of AAM were very high during most of the period since March 1997 (Fig. 2), when the El Niño began, undergoing some intraseasonal pulses in the early part of this period. In particular, values were consistently greater than their climatological means for a period of 11 months, between June 1997 and May 1998. After that time, the shift to La Niña conditions has resulted in negative anomalies.

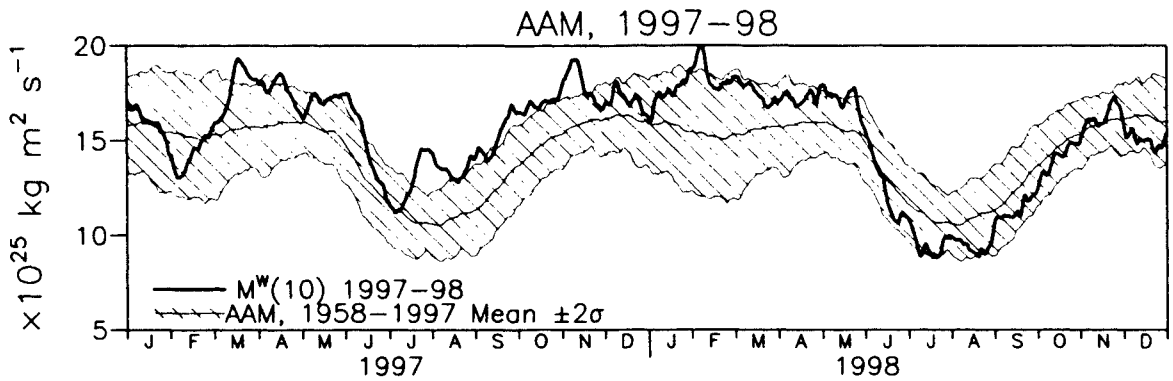

Figure 2. Values of AAM since January 1997 (heavy). The central curve shows the daily climatological mean of AAM values based on 40 years, and the gray shaded region indicates values within two standard deviations of that mean.

Because of angular momentum conservation in the Earth-atmosphere system, changes in global AAM are matched by those in the solid Earth, as indicated by variations in the length of day (Salstein et al. 1993). The strong agreement between the two series (Fig. 3) confirms this relationship and, here, the influence of the El Niño on the rotation rate of Earth. In particular, l.o.d. also achieved a peak at the time of the February 1998 AAM maximum.

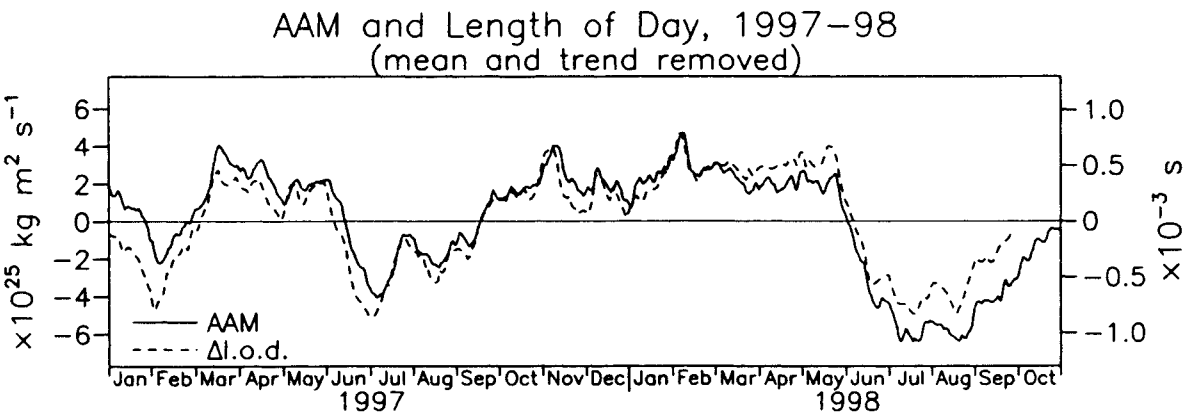

Figure 3. Daily values of AAM (scale on left) and departures of the length of day (l.o.d., scale on right) derived from space-based geodetic measurements, since January 1997.

A normalized AAM anomaly may be defined as the difference between its value and climatology, divided by the standard deviation of the AAM series, for the calendar date (Fig. 4). Anomalies of nearly two standard deviations or more were present for the four-month period between mid-July and mid-November 1997, an extent not observed elsewhere in the series. Record values of this normalized index, exceeding 4 standard deviations, occurred in July and November 1997. The index then became strongly negative in the recent La Niña period.

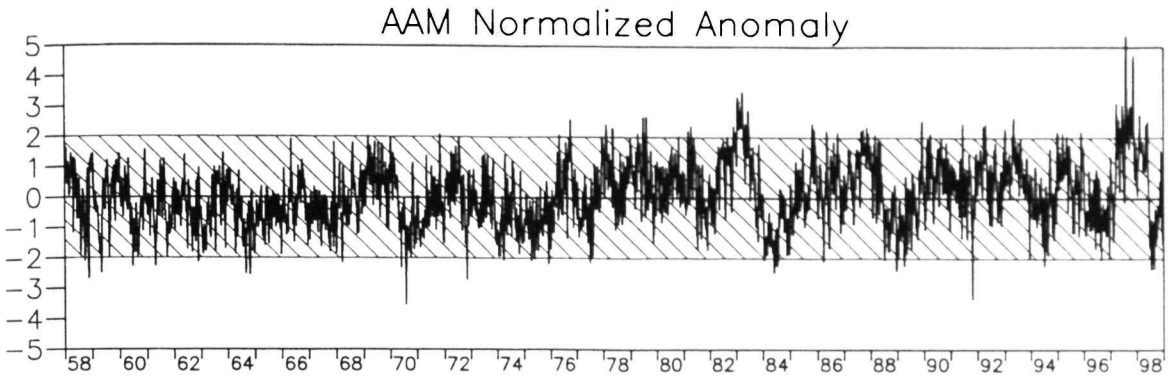

Figure 4. Normalized AAM anomaly is defined as the difference between its value and climatology, divided by the standard deviation of the AAM series for a calendar date (all from Fig. 2).

To determine the meridional zones in which angular momentum was most anomalous, we have subdivided the atmosphere into 46 equal-area latitude belts (Rosen and Salstein 1983) for every day since January 1997 and calculated momentum anomalies in each belt. In Fig. 5, note how positive momentum anomalies first appear in the tropics (in late February 1997), experience several intraseasonal pulses, and appear to expand by November 1997 into middle and higher latitude of both hemispheres. By June 1998, positive anomalies are confined to the highest southern latitudes, while negative momentum anomalies appear in the tropics related to the start of La Niña. The transition from El Niño to La Niña appears to have been very abrupt.

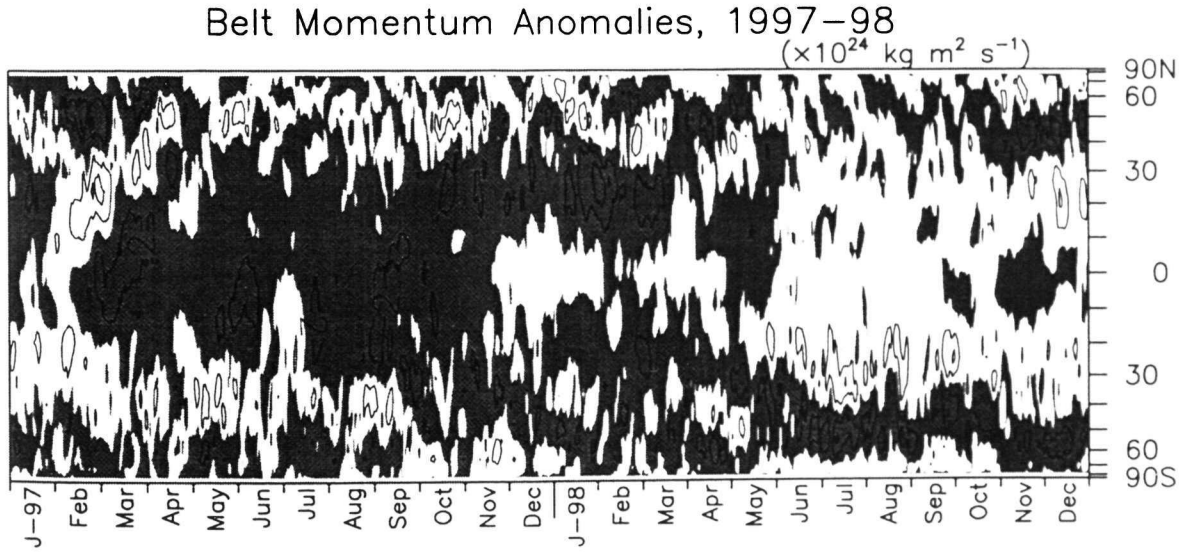

Figure 5. Anomalous values of angular momentum in 46 equal-area latitude belts for every day since January 1997. Positive values are shaded.

The regional pattern of AAM signals in February 1998, the month with the highest global value, is shown in Fig. 6a. Middle latitude centers over the Pacific in both hemispheres are very strong. These features and many others, like the striking pattern over North America, duplicate the February 1983 El Niño pattern, seen in Fig. 6b.

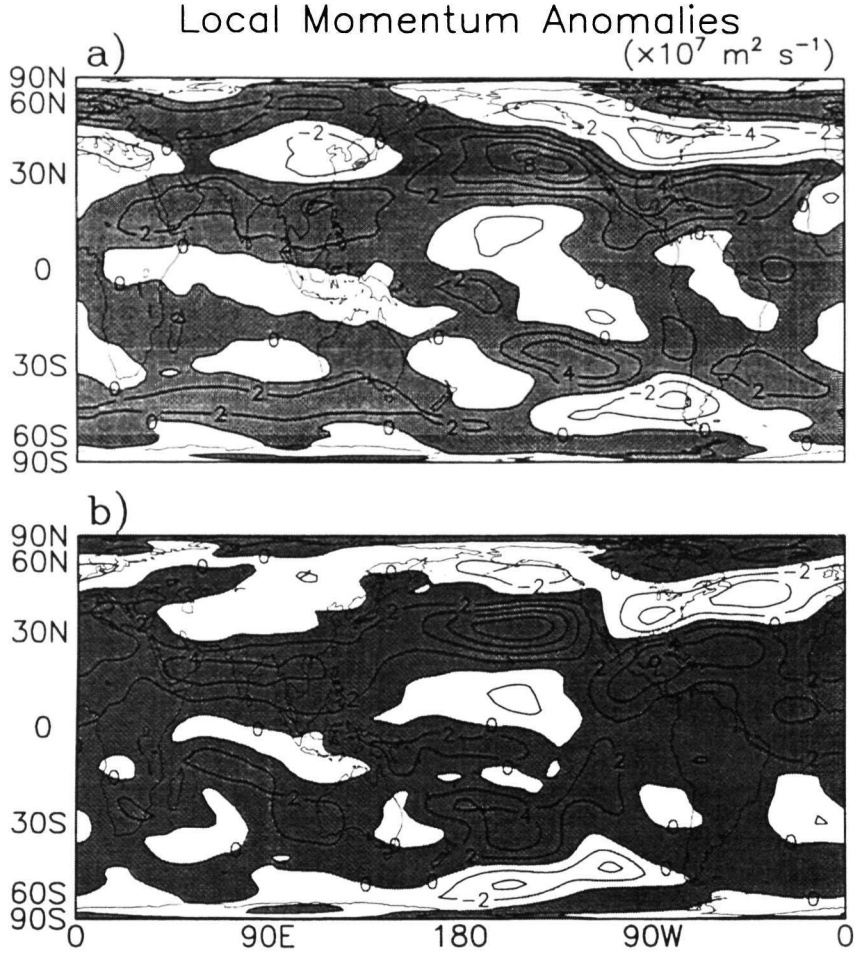

Figure 6. (a) Anomalous values of atmospheric angular momentum per unit mass during February 1998 and (b) February 1983. Positive values are shaded.

Work is underway to evaluate the torque mechanisms responsible for the distinctive positive anomalies in 1997 and the rapid transition to negative anomalies in mid-1998.

References

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