JPL

DETECTION OF AN ENSO SIGNAL IN SEASONAL ATMOSPHERIC ANGULAR MOMENTUM VARIATIONS

BY

R. S. GROSS, S. 1 MARCUS, AND J. O. DICKEY

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CA 91109--8099, USA

1996 WESTERN PACIFIC GEOPHYSICS MEETING

JULY 23-27, 1996
BRISBANE, AUSTRALIA

- **Investigate use of Earth rotation measurements as proxy measures of atmospheric angular momentum in global climate change studies**
  - Examine role of observed length-of-day changes
    - **Observed subdecadal length-of-day changes are largely caused by atmospheric zonal wind fluctuations**
    - **Changes in the atmospheric zonal wind field induced by climate change should therefore be reflected in the lod observations**
  - Study observed changes in strength of seasonal lod signal
    - **Amplitude of seasonal lod signal is correlated with SOI**
  - Investigate origin of this correlation by examining angular momentum of NCEP zonal winds

SEASONAL LOD VARIATIONS

- **Observed seasonal signal in lod caused by zonal atmospheric winds (to within measurement error)**
  - *Rosen & Salstein* (1 985, 1 991); *Naito & Kikuchi* (1990, 1991); *Rosen* (1993); *Dickey et al.* (1993)

Table 2. Amplitude (A - in 10⁻⁹ sec) and Phase (P) of the Seasonal Components of LOD and Atmospheric Momentum Due to Winds (M^W)

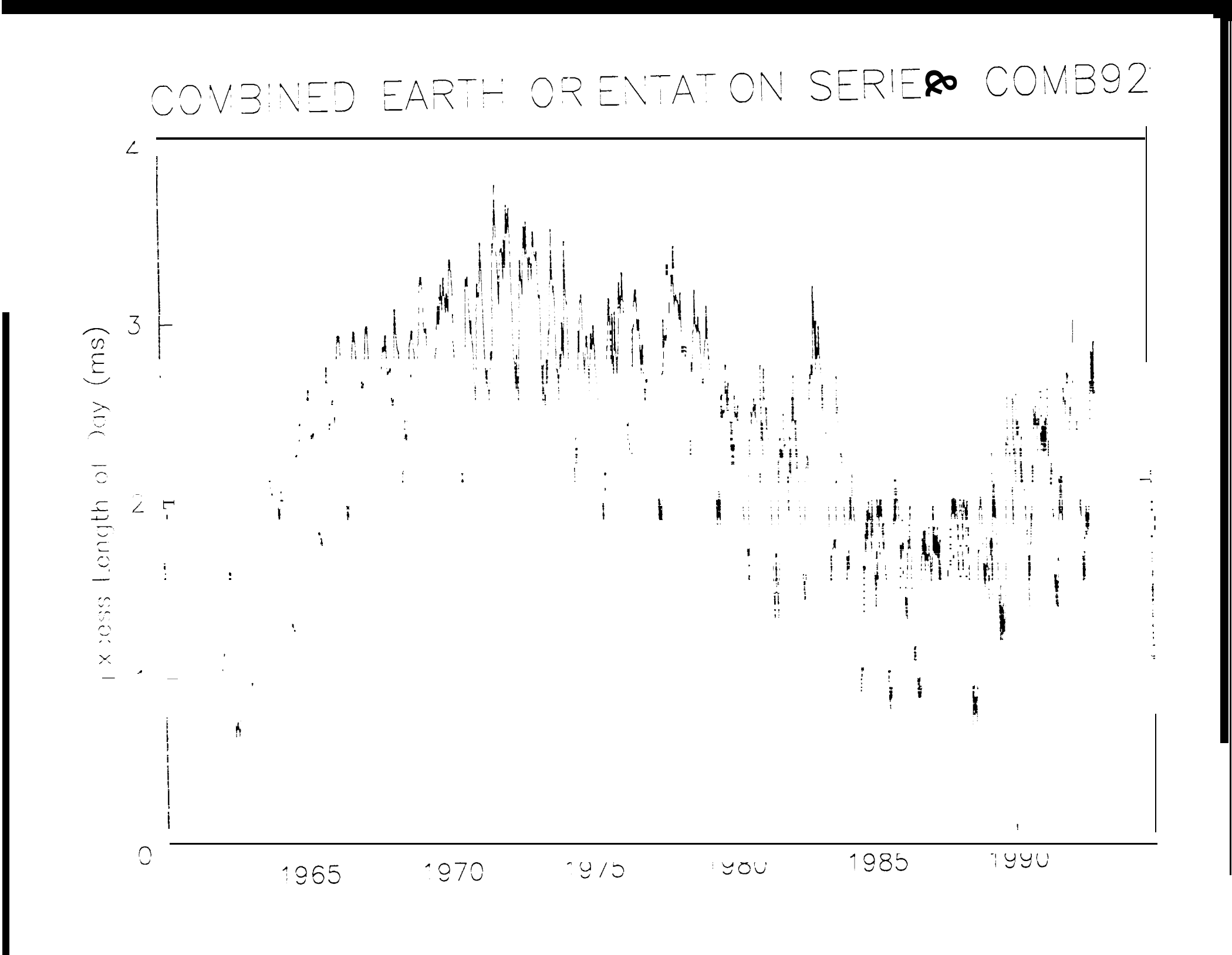
	Annual		Semi-Annual	
	A	P	A	P
1980-1986				
LOD	353.47	Feb 4	2.9s.83	May 4
$M^W_{EC}M(1000\text{-}1)$	332.17	Feb 7	295.38	May "?
$M^W_{NMC}(1\ 000\text{-}1)$	349.69	Feb 9	279.27	May 8

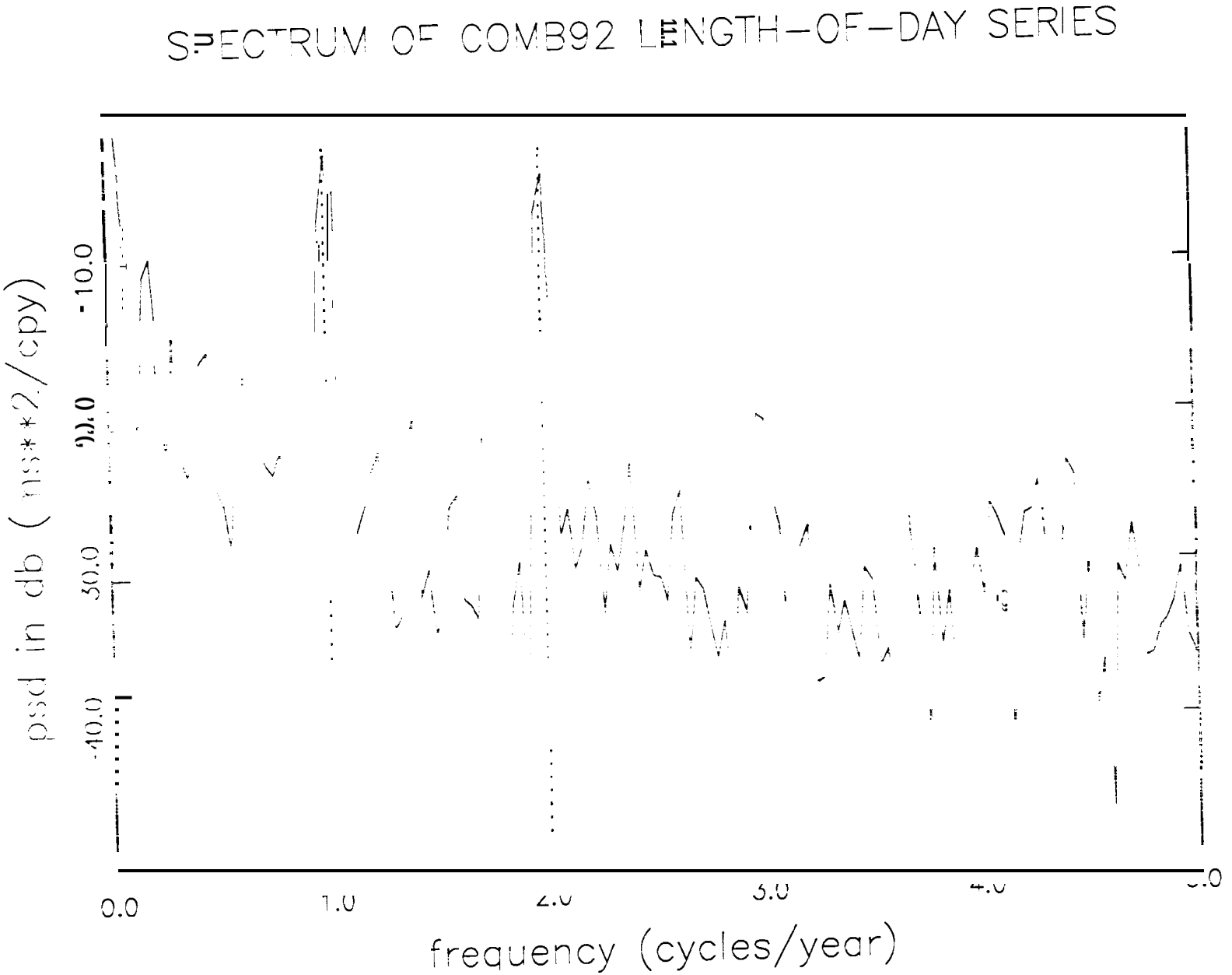
(*Dickey et al.*, 1993)

- **Strength of seasonal lod signal will vary as strength of seasonal zonal winds vary**
  - Zonal winds can be expected to vary as pole-to-equator temperature gradient varies due to climate change
  - Thus, strength of seasonal lod signal can be expected to vary in response to climate change
- **Use observations of the seasonal lod signal to search for climate change-induced variations over past 30 years**
  - Correlate with other indices of climate change such as the Southern Oscillation] Index (SOI)

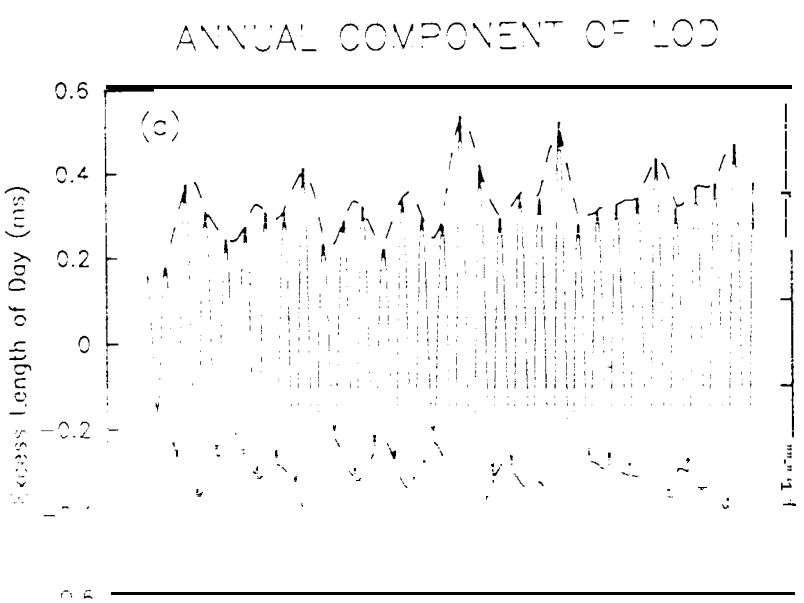
SEASONAL LOD ANALYSIS

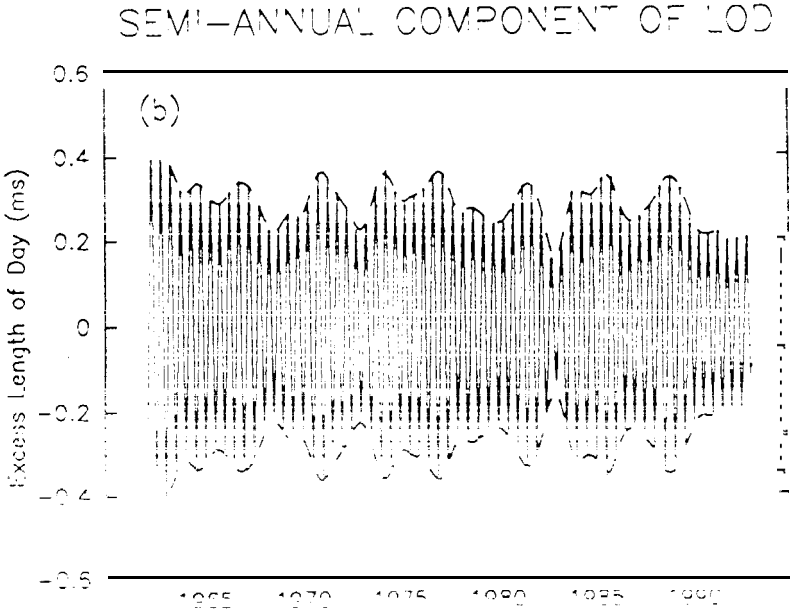
- **LOD data set: COMB92**
  - Combination of astrometric, LLR, VLBI observations
  - Various corrections are applied to the individual series in order to make them consistent with each other prior to their combination
    - . Bias, rate, stated uncertainties
    - Annual term of astrometric series adjusted by applying a constant correction to make it agree, on average, with annual term exhibited by combination of other series during 1976-1982
  - Spans 1962-1992 at 5 day intervals
- **Seasonal lod signal isolated by :**
  - 1) Singular Spectrum Analysis
  - 2) Fit for mean, trend, semi-annual, annual terms to lod observations within a sliding 1.5 year window
  - 3) Bandpass filter lod series using bandwidth of 0.974 cpy centered on annual and semiannual frequencies
  - All methods yield consistent results for the seasonal terms
- **Amplitude of seasonal terms recovered by complex demodulation**
- **Recovered amplitude of seasonal terms correlated with Modified Southern Oscillation Index (MSOI)**
  - MSOI defined by difference between Darwin and Tahiti surface pressure in millibars
    - Positively correlated with lod
- **Search for trend in amplitude of seasonal lod terms**

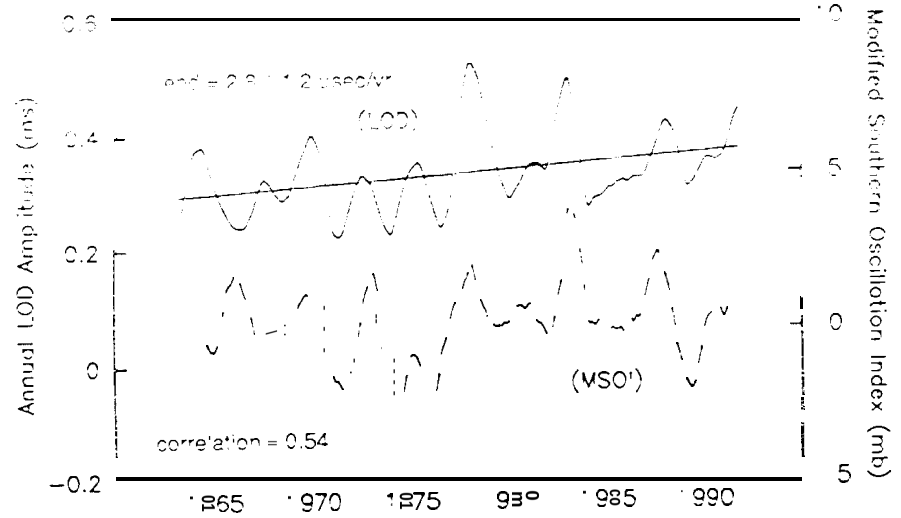

COMBINED EARTH ORIENTATION SERIES COMB92
Excess Length of Day (ms)
4
3
2
1
0
1965
1970
1975
1980
1985
1990

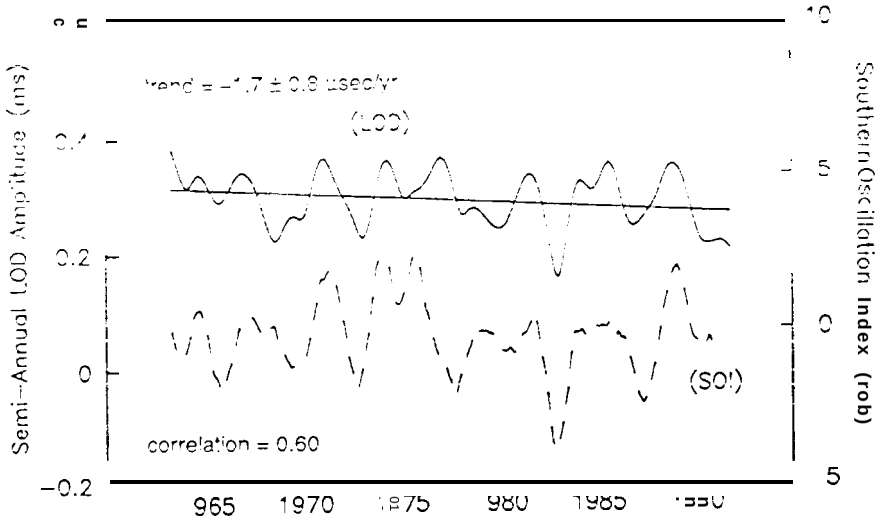

SPECTRUM OF COMB92 LENGTH-OF-DAY SERIES
psd in db (mss**2/cpy)
-10.0
-30.0
-40.0
0.0
1.0
2.0
3.0
4.0
5.0
frequency (cycles/year)

AN ENSO SIGNAL IN SEASONAL LENGTH-OF-DAY

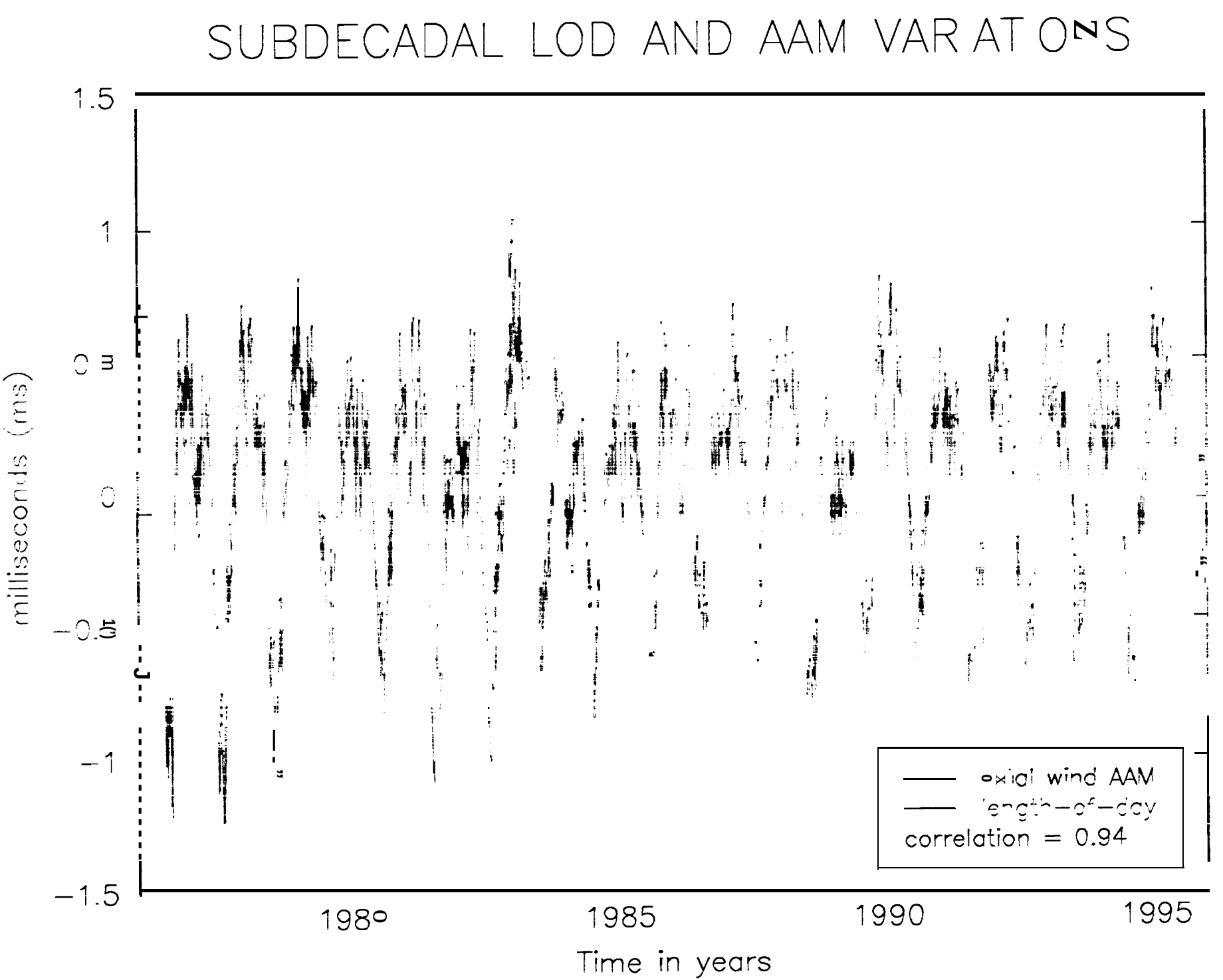






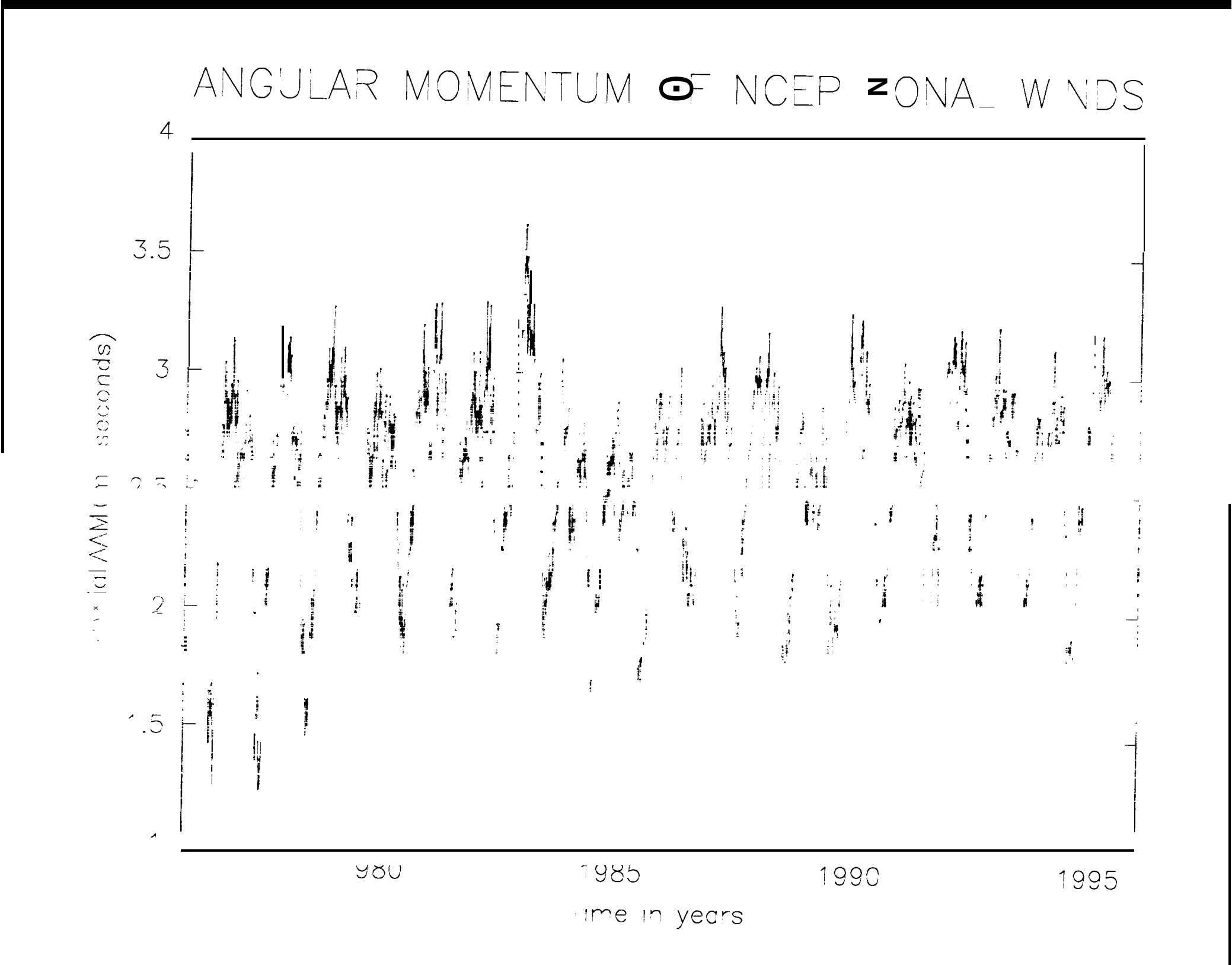


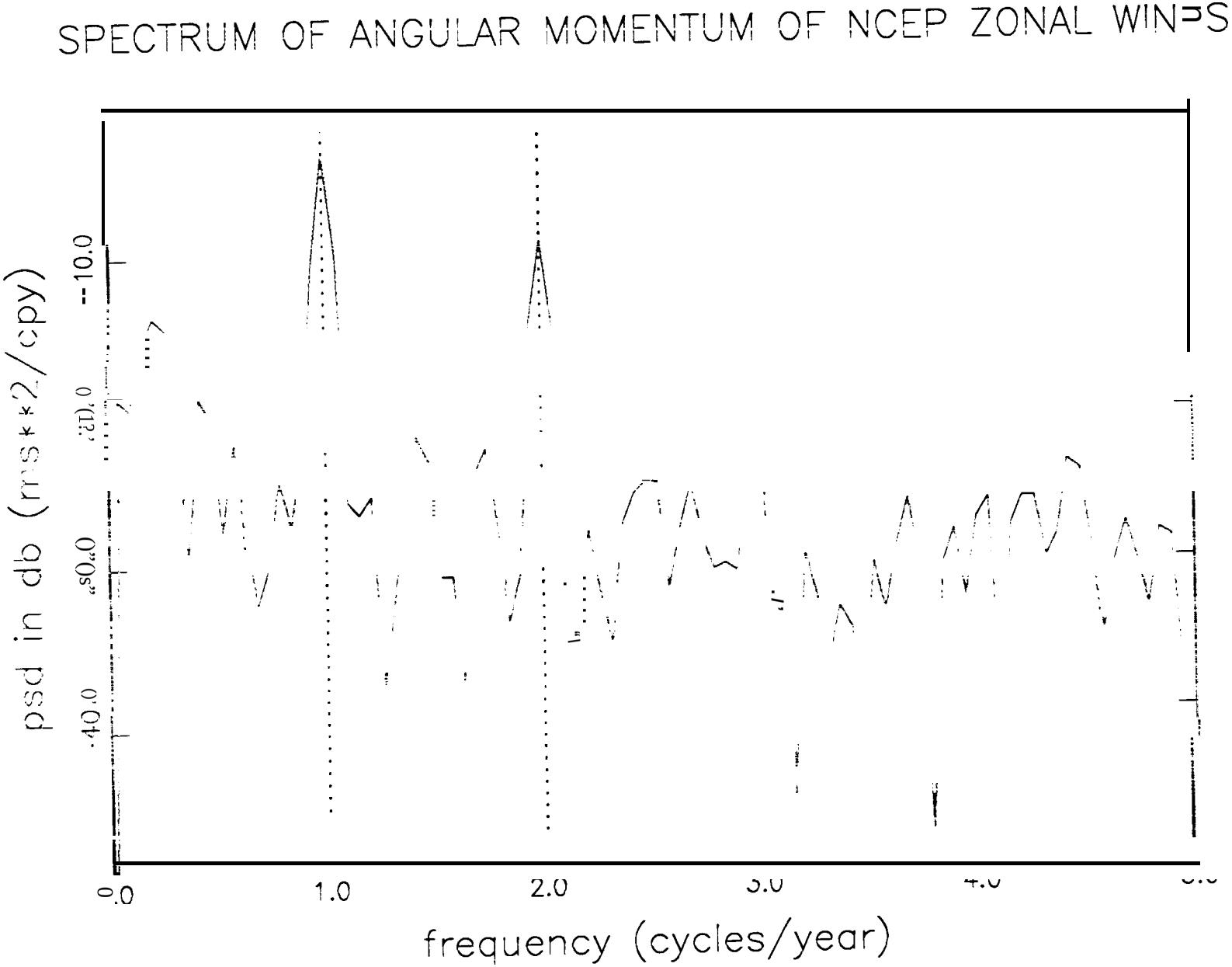
(Gross et al 1996)

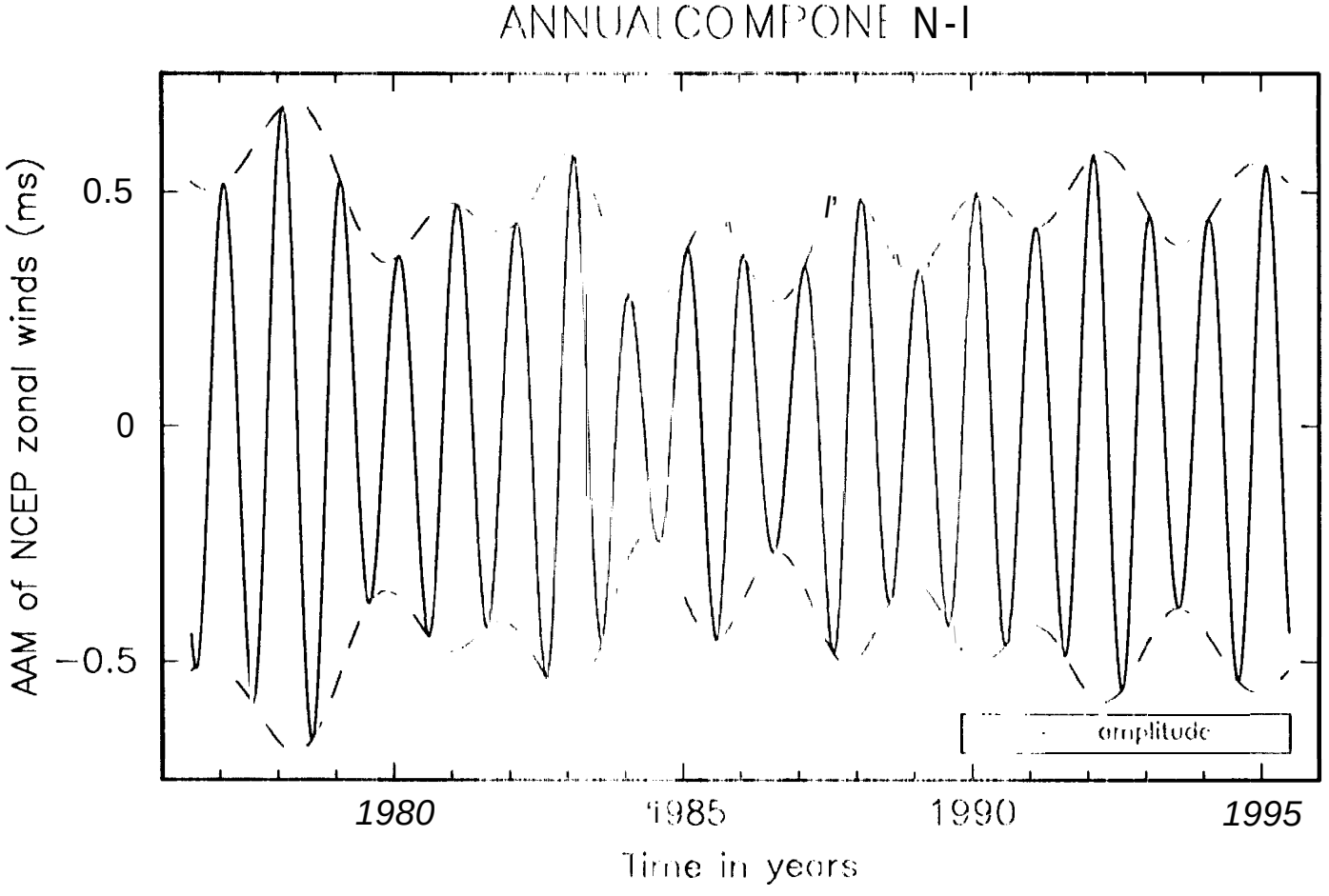

SUBDECADAL LOD AND AAM VARIATIONS
1.5
1
0.5
0
−0.5
−1
−1.5
milliseconds (ms)
1980
1985
1990
1995
Time in years
axial wind AAM
length-of-day
correlation = 0.94

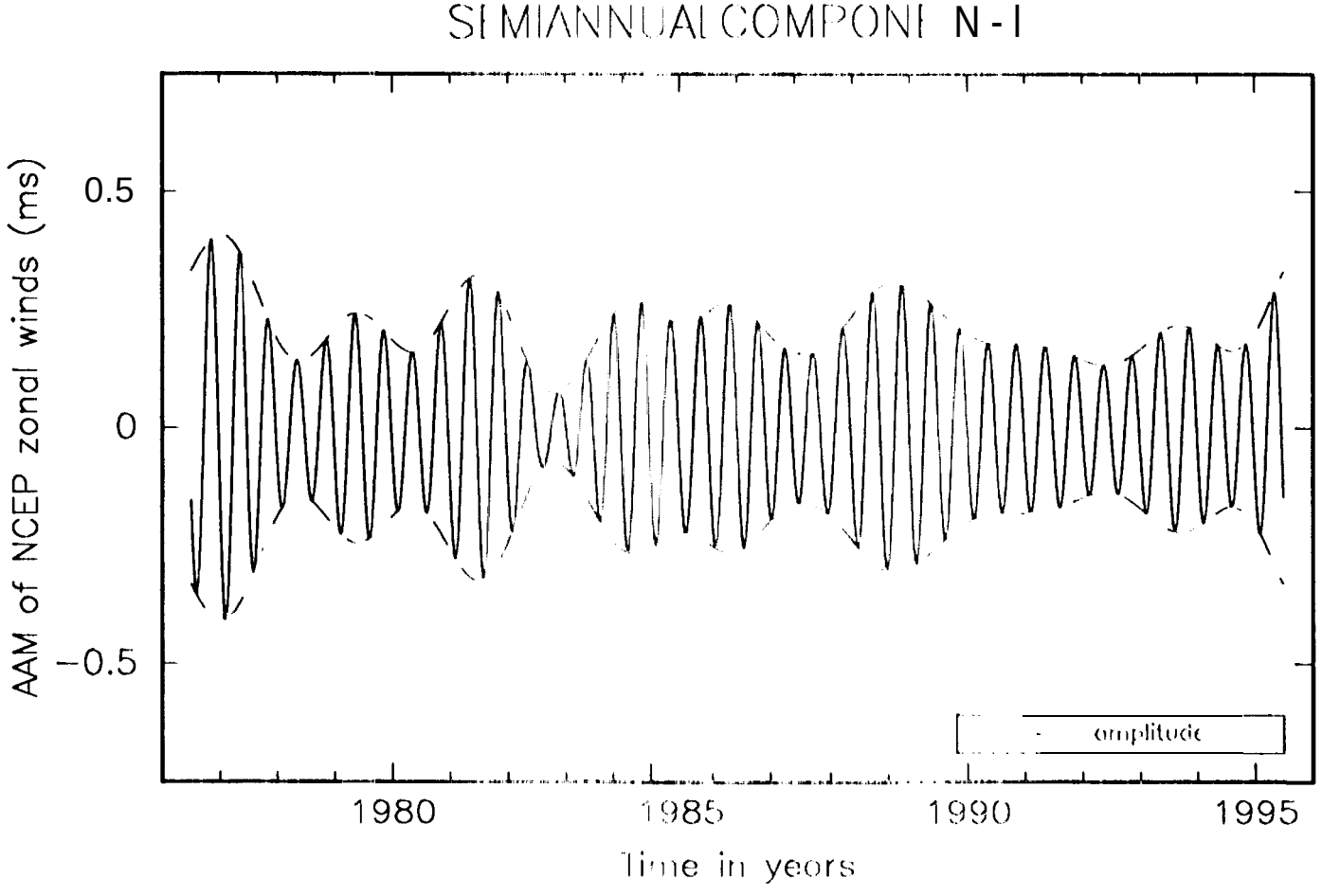
SEASONAL AAM ANALYSIS

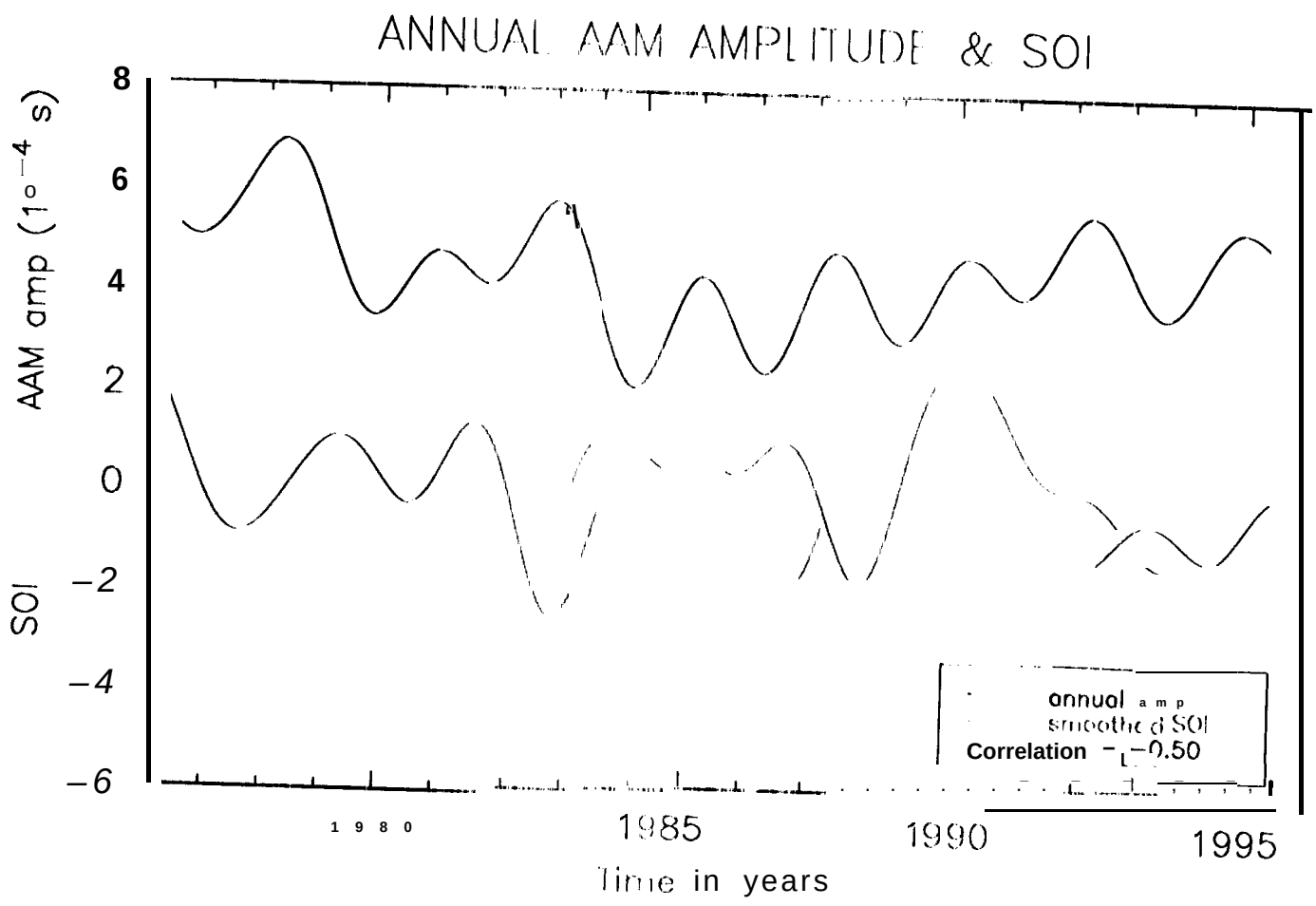
- **Atmospheric Angular Momentum data set: NCEP**
  - Angular momentum of the zonal winds determined by the global data assimilation system of the US National Centers for Environmental Prediction (NCEP)
    - Winds integrated to top-of-model (50 mb)
  - Data preprocessing:
    - Linearly interpolate across gaps (largest gap spans 23 days)
    - Form daily average of twice-per-day values
  - Resulting AAM series spans 19 years (01JUL76 to 29JUL95) at daily intervals
- **Isolate annual and semiannual AAM components**
  - Bandpass filter AAM series using bandwidth of 0.974 cpy centered on annual and semiannual frequencies
- **Amplitude of annual and semiannual AAM components recovered by complex demodulation**
- **Correlate with Southern Oscillation Index (SOI)**
  - SOI defined by normalized difference between Darwin and Tahiti surface pressure
  - Monthly SOI values smoothed by applying lowpass filter having cutoff period of 1/0.487 = 2.05 years
    - Cutoff period chosen to match smoothing applied to amplitudes of annual and semiannual AAM components

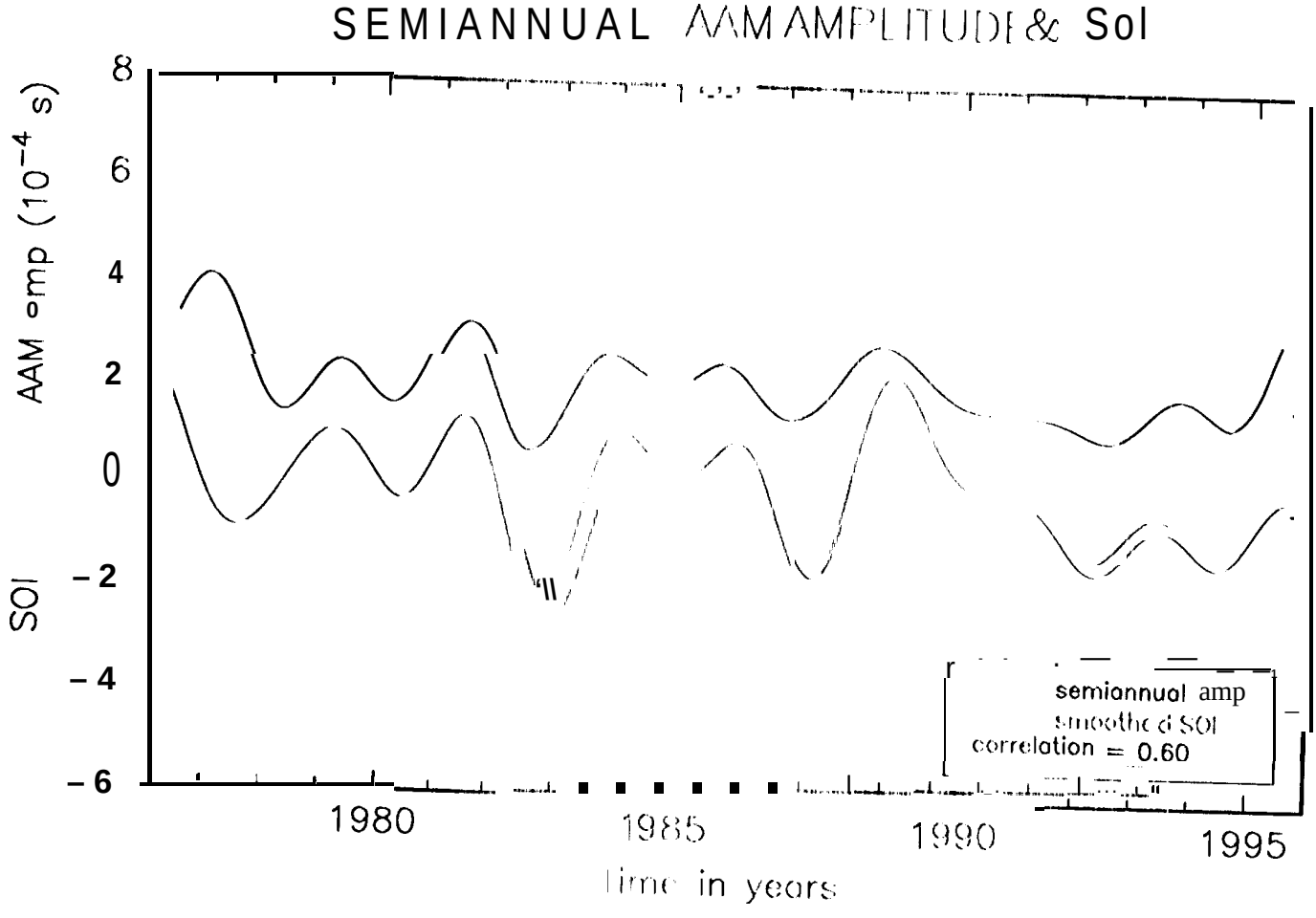

ANGULAR MOMENTUM OF NCEP ZONAL WINDS
4
3.5
3
2
1.5
1
1985
1990
1995
ime in years


SPECTRUM OF ANGULAR MOMENTUM OF NCEP ZONAL WINDS
psd in db (rms**2/cpy)
-10.0
-20.0
-30.0
-40.0
0.0
1.0
2.0
3.0
4.0
frequency (cycles/year)


ANNUAL COMPONENT N-I
AAM of NCEP zonal winds (ms)
0.5
0
−0.5
amplitude
1980
1985
1990
1995
Time in years


SEMIANNUAL COMPONENT N-I
AAM of NCEP zonal winds (ms)
0.5
0
−0.5
amplitude
1980
1985
1990
1995
Time in years


ANNUAL AAM AMPLITUDE & SOI
AAM amp (10^{-4} s)
SOI
8
6
4
2
0
−2
−4
−6
1980
1985
1990
1995
Time in years
annual amp
smoothed SOI
Correlation = −0.50


SEMIANNUAL AAM AMPLITUDE & Sol
AAM amp (10^{-4} s)
SOI
8
6
4
2
0
−2
−4
−6
1980
1985
1990
1995
Time in years
semiannual amp
smoothed SOI
correlation = 0.60

SUMMARY

- **Amplitudes of annual and semiannual components of angular momentum of NCEP zonal winds**
  - Have not been constant in time but vary by as much as 50%
  - Have a strong quasi biennial signature
    - Particularly strong in amplitude of annual AAM component
  - Are correlated with the SOI over past 19 years
    - Amplitude of annual AAM component is negatively correlated with SOI (-0.50)
    - Amplitude of semiannual AAM component is positively correlated with SOI (0.60)
    - 99% significance level for correlation coefficient is 0.50
  - Corroborates previous lod analysis
- **Future activities**
  - Examine AAM as function of latitude
  - Examine angular momentum of zonal stratospheric winds
    - Stratospheric contribution to AAM important at seasonal frequencies