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August 22

09:00 - 09:30

**THE TROPICAL 30 TO 60-DAY OSCILLATION AND
ITS EFFECT ON THE TOGA SYSTEM**

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The "tropical 30 to 60-day oscillation", or the "Madden and Julian Oscillation" (MJO) is the dominant process in the global tropical troposphere on the intra-seasonal time scale. Intriguing aspects of the MJO are, among others, its remote effect on mid latitude weather, its impact on the surface layer of the tropical Pacific, its connection with the genesis of tropical cyclones and with the onset and breaking of the monsoon, and its coherence with the length-of-day.

In this contribution, an index of the MJO is derived that allows one to quantify objectively the effect of the MJO on the various processes. This index is derived from operation NMC daily analyses of 200 mb velocity potential.

Using this index, the suggested remote link of the MJO on the extratropics is identified as being strongly masked by noise. Thus it appears unlikely that this link might successfully be used to improve the prediction of extratropical weather. Similarly, the phase lock of tropical cyclogenesis with the MJO is statistically significant but fairly weak.

In the ocean, the MJO is responsible for the excitation of oceanic Kelvin waves that propagate along the equatorial wave guide in a few months to the Peruvian coast.

First attempts to quantify the performance of numerical weather prediction models in forecasting the MJO indicate little skill. The operational NWP products are often inferior not only to the simple statistical POP forecast but even to the trivial persistence forecast.

The
MADDEN and JULIAN Oscillation.

A Principal Oscillation Pattern Analysis

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Hamburg**

Results shown are from ...

- literature
- own papers:
 - Storch et al., J.Geophys.Res. 1988
 - Storch & Xu, Clim. Dyn. 1990
 - Storch & Baumhefner, Clim. Dyn. 1991
 - Storch & Smallegange, MPI report 64

Overview

- The MJO
 - in directly measured parameters (SLP and OLR)
 - in derived parameters (velocity potential)
- The POP analysis of equatorial velocity potential
 - the POP index of the MJO
 - the OLR signal and the Indian Monsoon
 - the length-of-day and the MJO
- Predicting the MJO
 - by the POP method
 - by GCMs (NCAR CCM; ECMWF; JMA)
 - predicting the forecast skill?
- The oceanic response to the MJO.
- The MJO in GCMs.

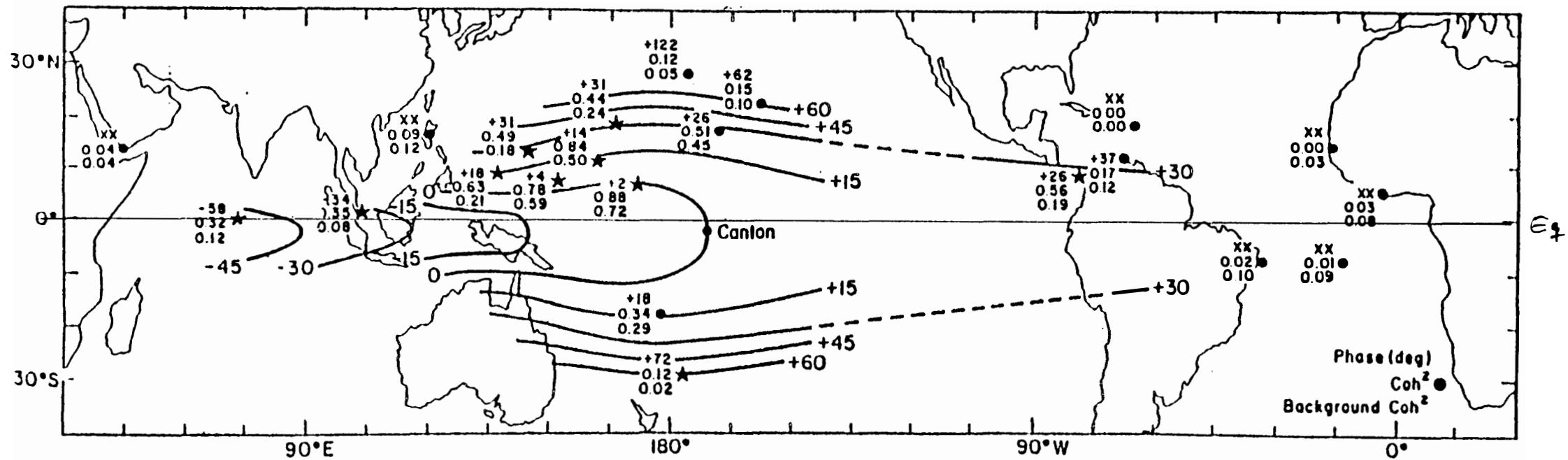


FIG. 4. Mean phase angles, coherence-squares, and background coherence-squares for approximately the 36–50 day period range of cross spectra between all stations and Canton. The plotting model is given in lower right-hand corner. Positive phase angles at a station means the Canton series leads that of the station. Stations indicated by a star have coherence-squares above the background at the 95% level. Mean coherence-squares at Shemya ($52^{\circ}43'N$, $174^{\circ}6'E$) and Campbell I. ($52^{\circ}33'S$, $169^{\circ}9'E$) (not shown) are 0.08 and 0.02, respectively. Both are below their average background coherence-squares.

parameters: station pressure

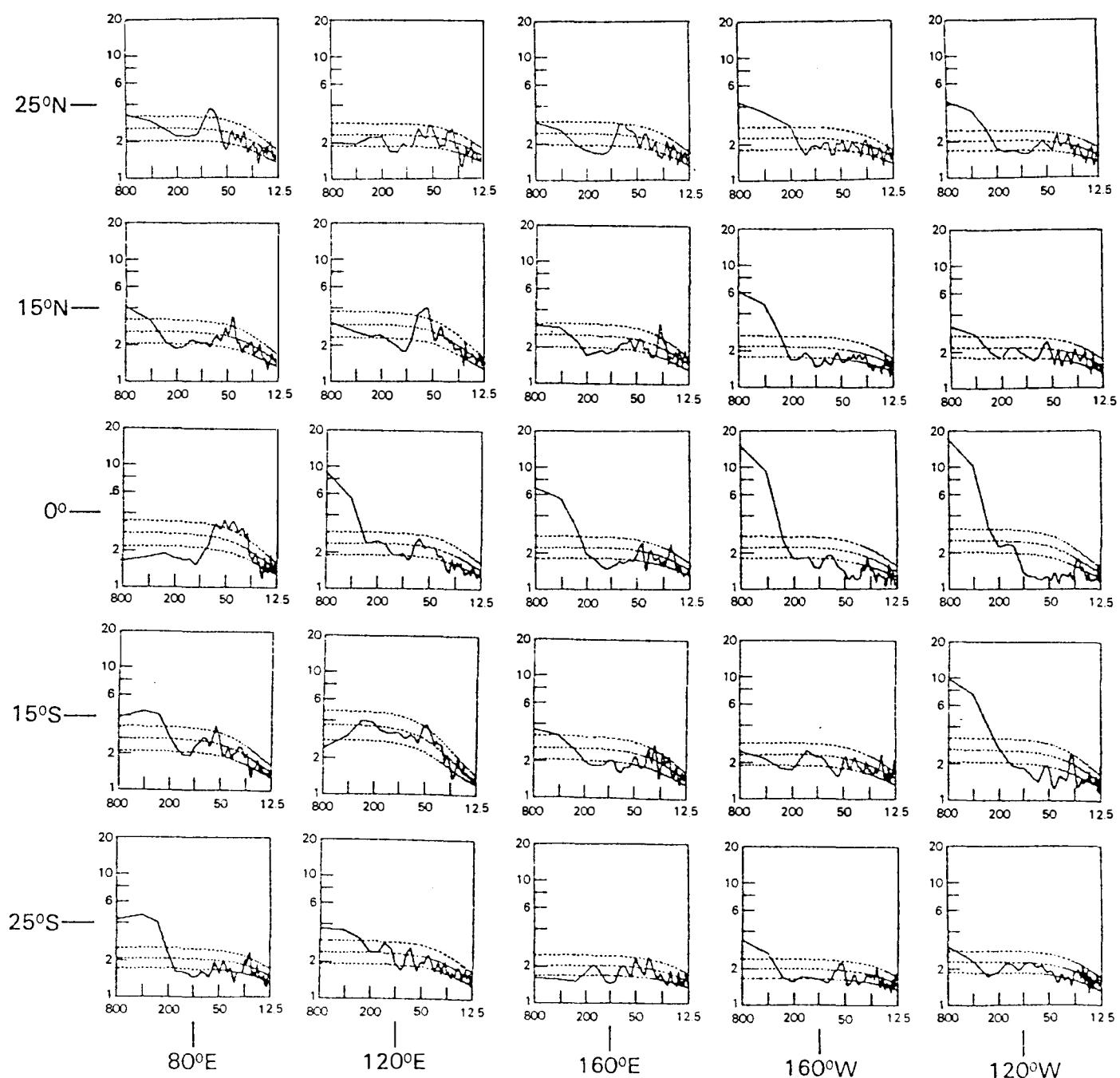
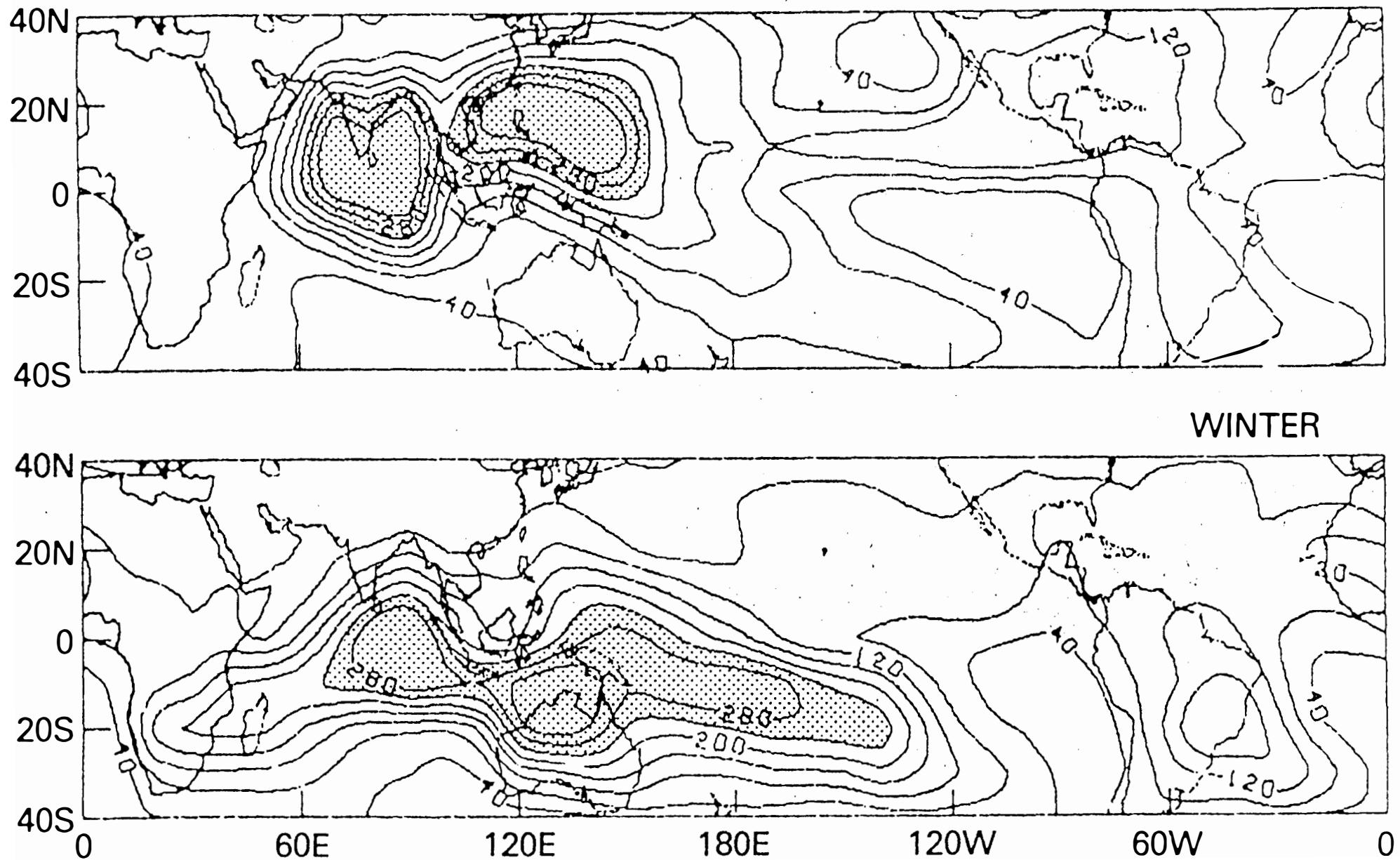


FIG. 1. Spectra of daily anomaly OLR at selected grid points. Abscissa is in days per period and ordinate in percent of the total power.



The 40–50 day component of the intraseasonal OLR variance. Contour interval is $40 (\text{W m}^{-2})^2$ based on bandpassed (20–70 days) data.

OLR r.m.s. amplitude (W/m^{-2})

LAU & CHAN, 1988

Seasonal Cycle (15)

total anomaly (25/27)

Intraseasonal (24/26)

Interannual (5/7)

1-5 days
(18/19)

20-70 days
(10/11)

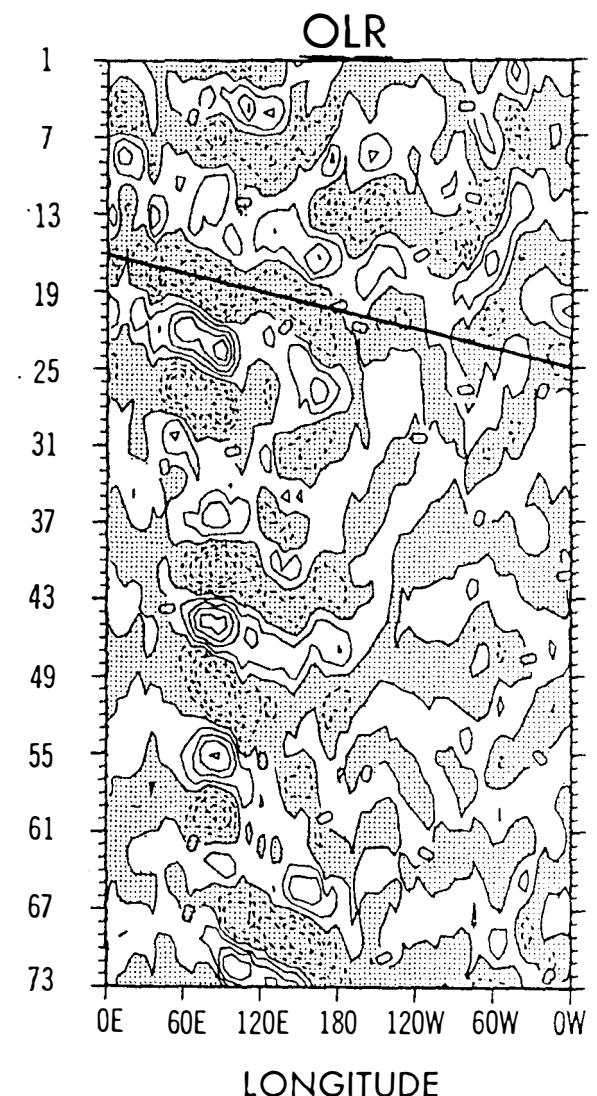
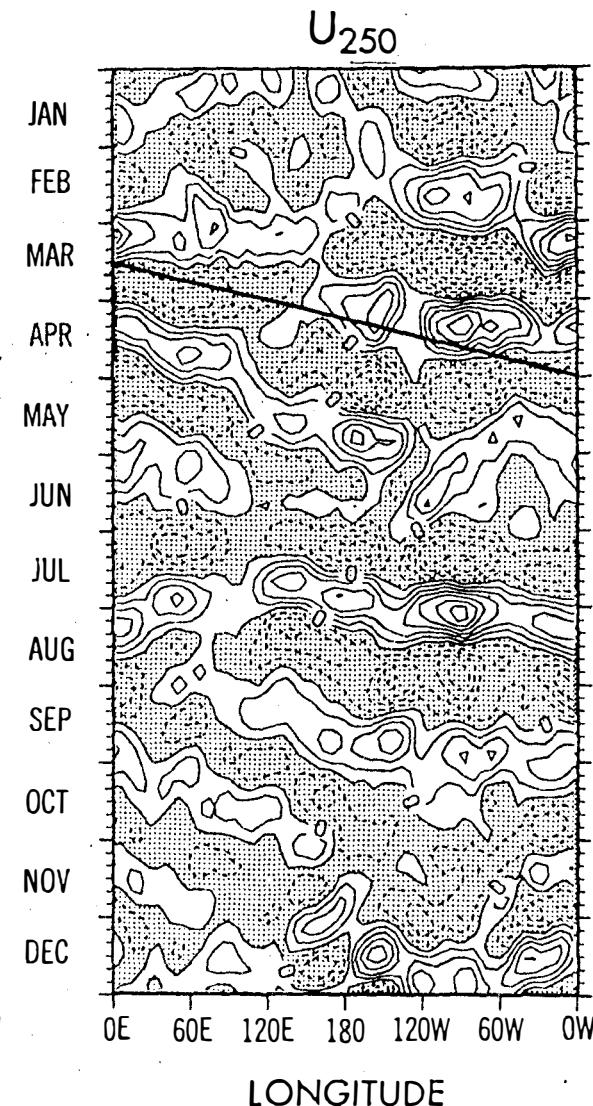
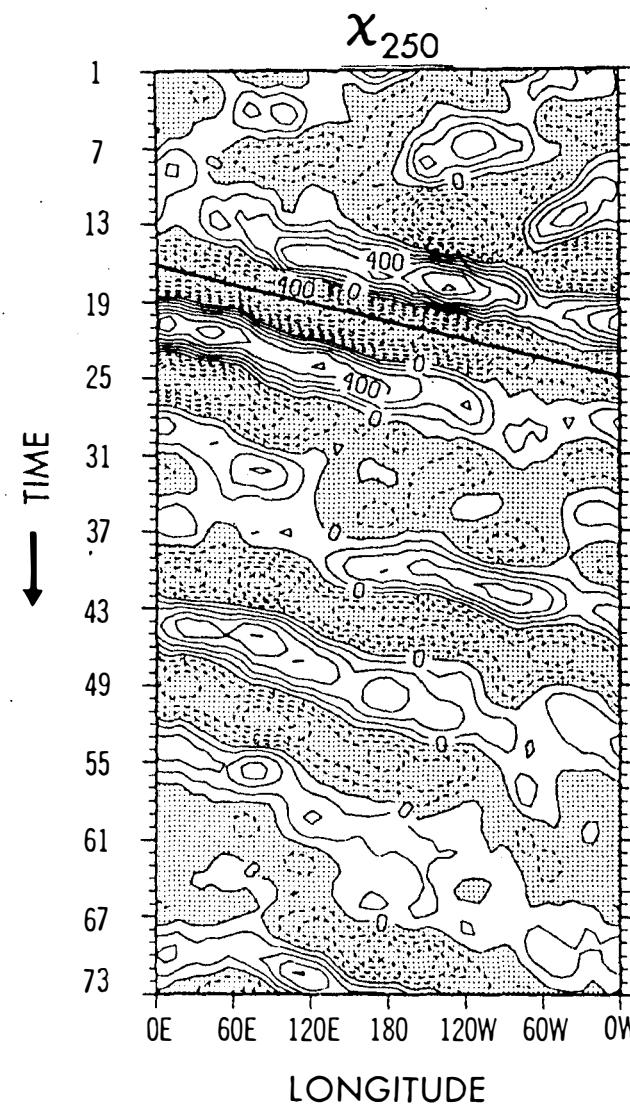
others

FIG. 8. Schematic showing rms amplitudes (W m^{-2}) of OLR at different frequency bands as defined in the text. First number inside the bracket denotes summer value and the second winter value.

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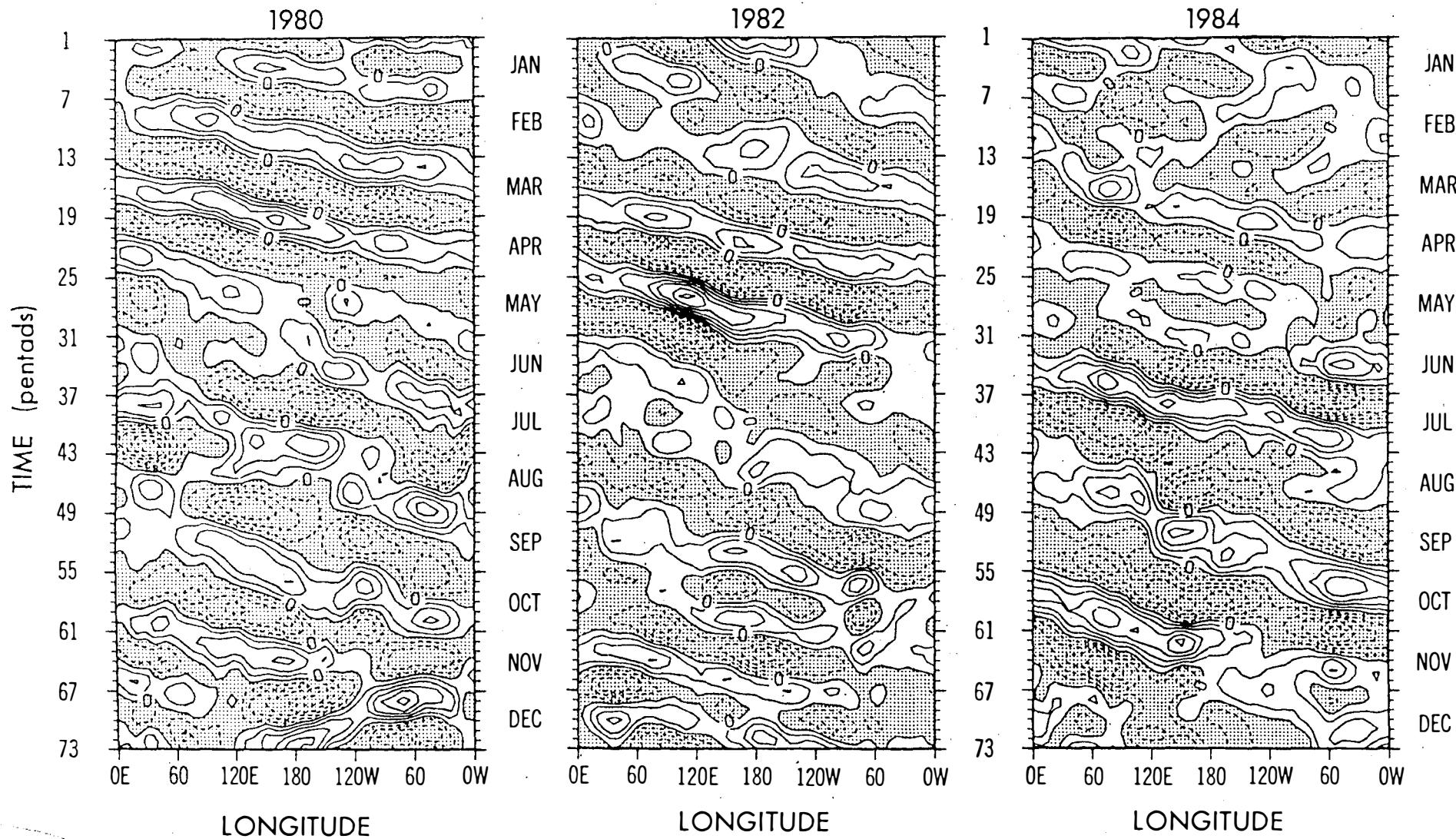
30-60 DAY (1981)



JULY 1987

THOMAS R. KNUTSON AND KLAUS M. WEICKMANN

χ_{250} (30-60 DAY)



Time vs longitude diagrams of 30-60 day filtered χ_{250} anomalies for the study period (1979-84). Contour interval is $1.0 \times 10^6 \text{ m}^2 \text{ s}^{-1}$; negative anomalies are shaded. Data were averaged from 5°N to 5°S .

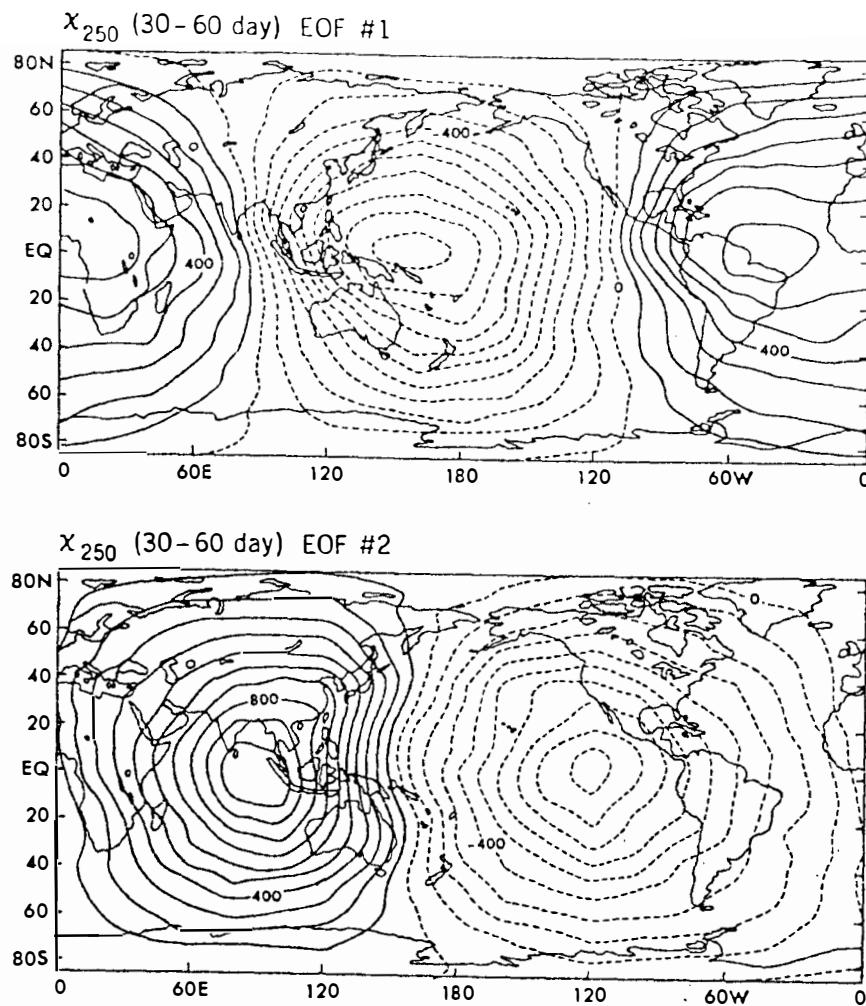


FIG. 5. First and second eigenvectors of the 30–60 day filtered χ_{250} . Contour interval is 0.01; contour labels are multiplied by 10^4 .

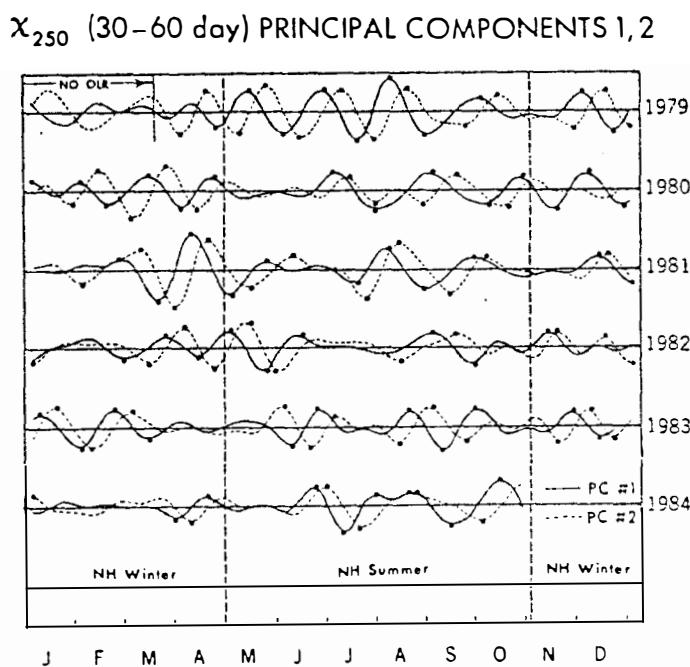


FIG. 6. First (solid) and second (dashed) principal components of the 30–60 day filtered χ_{250} with the large dots indicating significant peaks used to identify data to composite (see text for details).

POP Analysis

(POP = Principal Oscillation Patterns)

The POP method is used to infer time scales and characteristic patterns from vector time-series.

The result of a POP analysis of a vector time series $\underline{x}(t)$ is a set of

- pairs of patterns \underline{P}_1 and \underline{P}_2
- two time series of coefficients $z_1(t)$ and $z_2(t)$
- two characteristic numbers,
namely a period P and a damping time T .

A space-time coherent signal in $\underline{x}(t)$ is described by

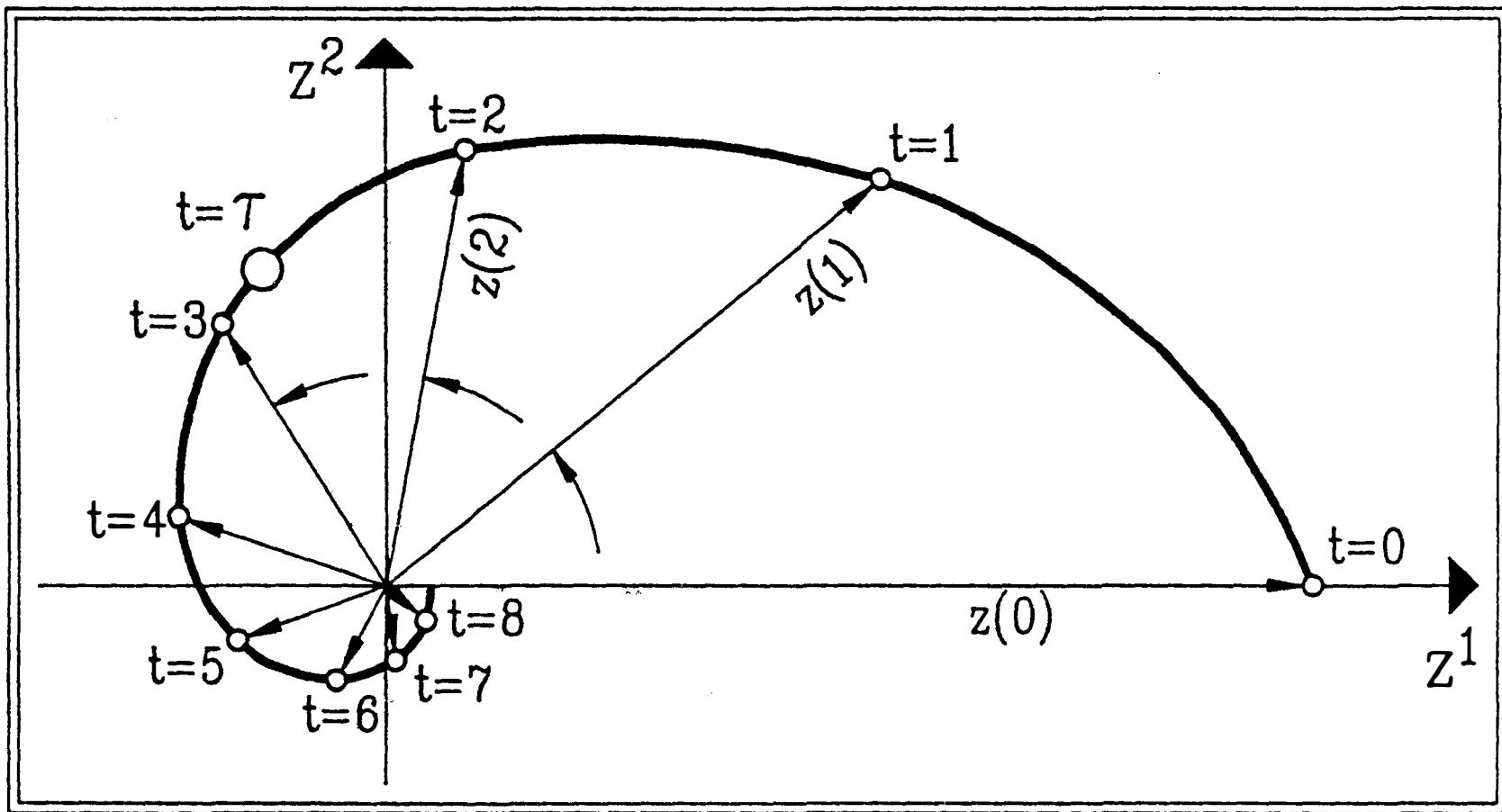
$$z_1(t)\underline{P}_1 + z_2(t)\underline{P}_2$$

and the two time series $z_1(t)$ and $z_2(t)$ oscillate coherently, with a mean period of P , with $z_2(t)$ leading $z_1(t)$ by about 90 degrees.

Thus, the two patterns appear in damped infinite cycles

► \underline{P}_2 ► \underline{P}_1 ► - \underline{P}_2 ► - \underline{P}_1 ► \underline{P}_2 ► - \underline{P}_1 ►

One cycle is, on the average, completed in the time P . An initial amplitude of length 1 is reduced to $1/e$ in the time T .



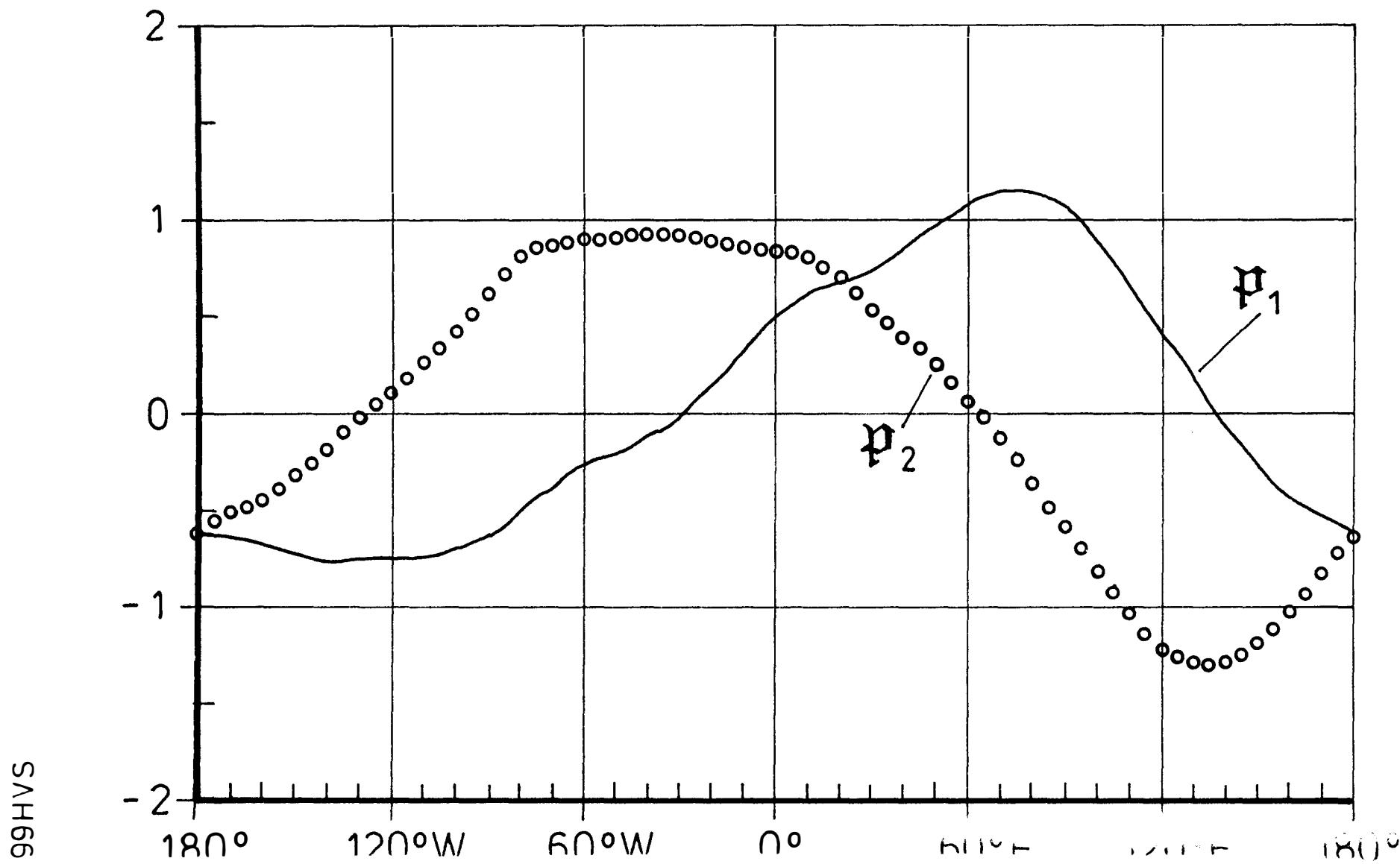
SPIRALE

STURCA et al. (1988)

POP Analysis of the MADDEN and JULIAN Oscillation

- Vector time series $x(t)$ is equatorial velocity potential at 200 mb (daily NMC analyses May 1986 - April 1988)
- NO PREPROCESSING of the data besides the removal of the annual cycle.
- 1 relevant POP pair found.
Period $P = 44$ days
Damping time $T = 13$ days
- Spatial pattern is zonal wavenumber 1.
Pattern propagates eastward.
Coefficients are highly correlated with Indian Ocean OLR.
- POP describes MJO.
Coefficients $(z_1, z_2)(t)$ form bivariate index of MJO ("POP index of MJO").

STORC 1L
G XU, 1990



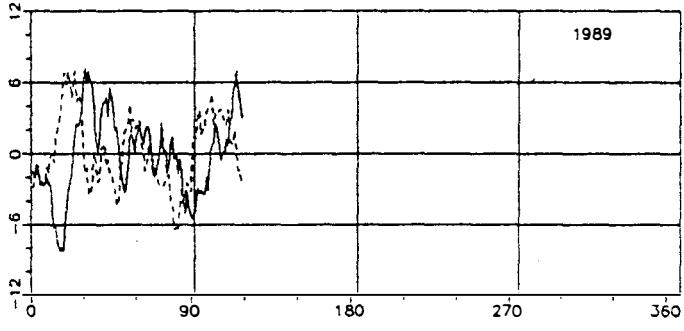
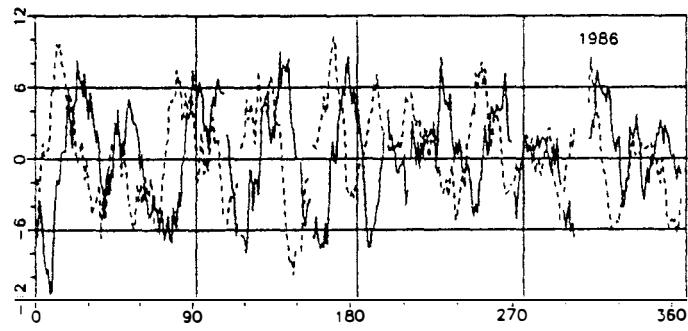
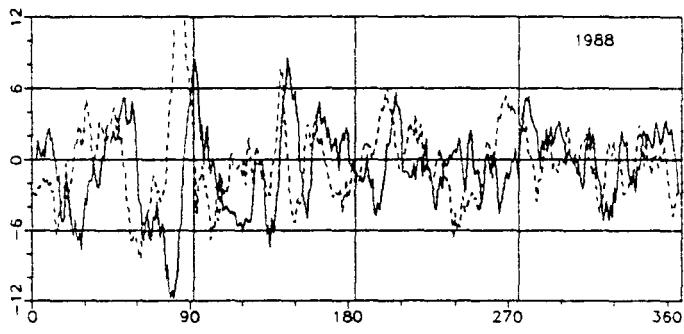
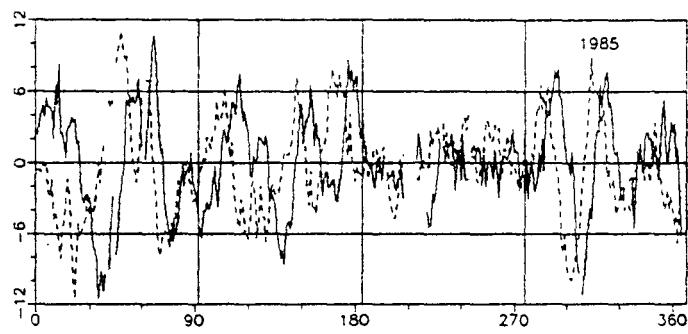
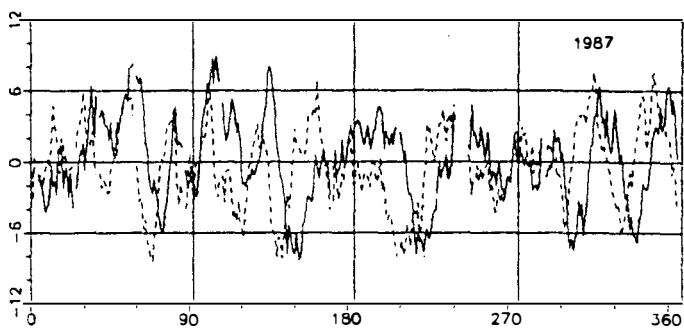
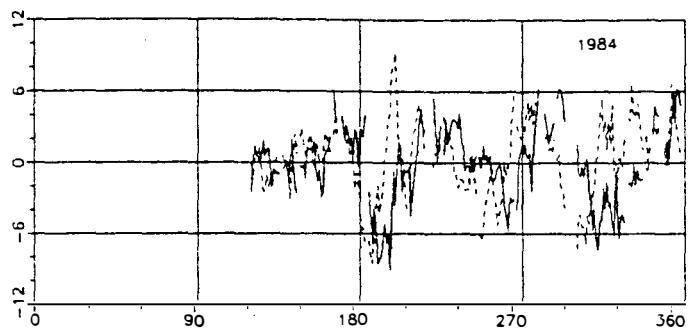
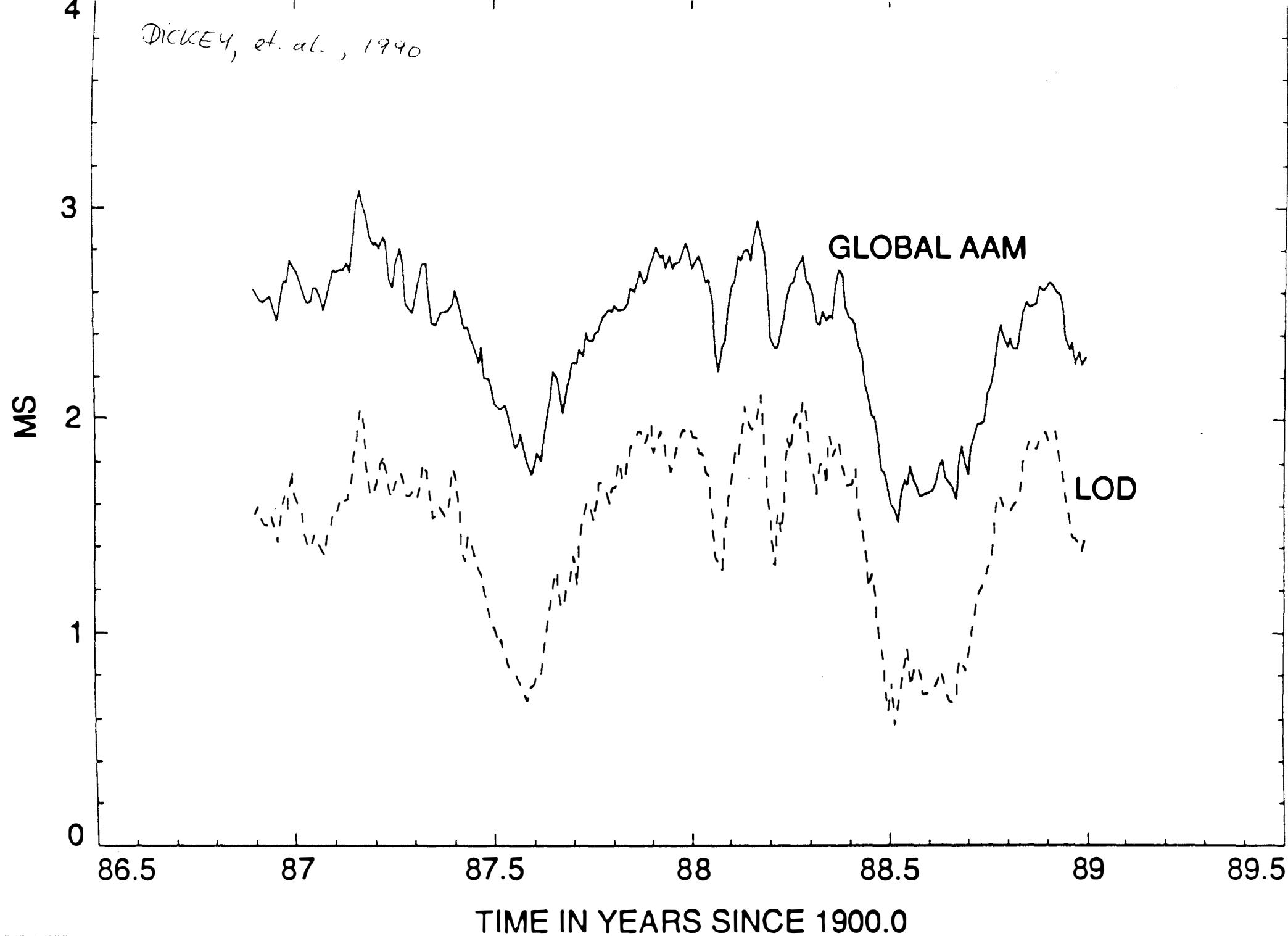


Fig. 3. Time series of POP coefficients, $z^1(t)$ (continuous line) and $z^2(t)$ (dashed line), of the solid line patterns p^1 and p^2 shown in

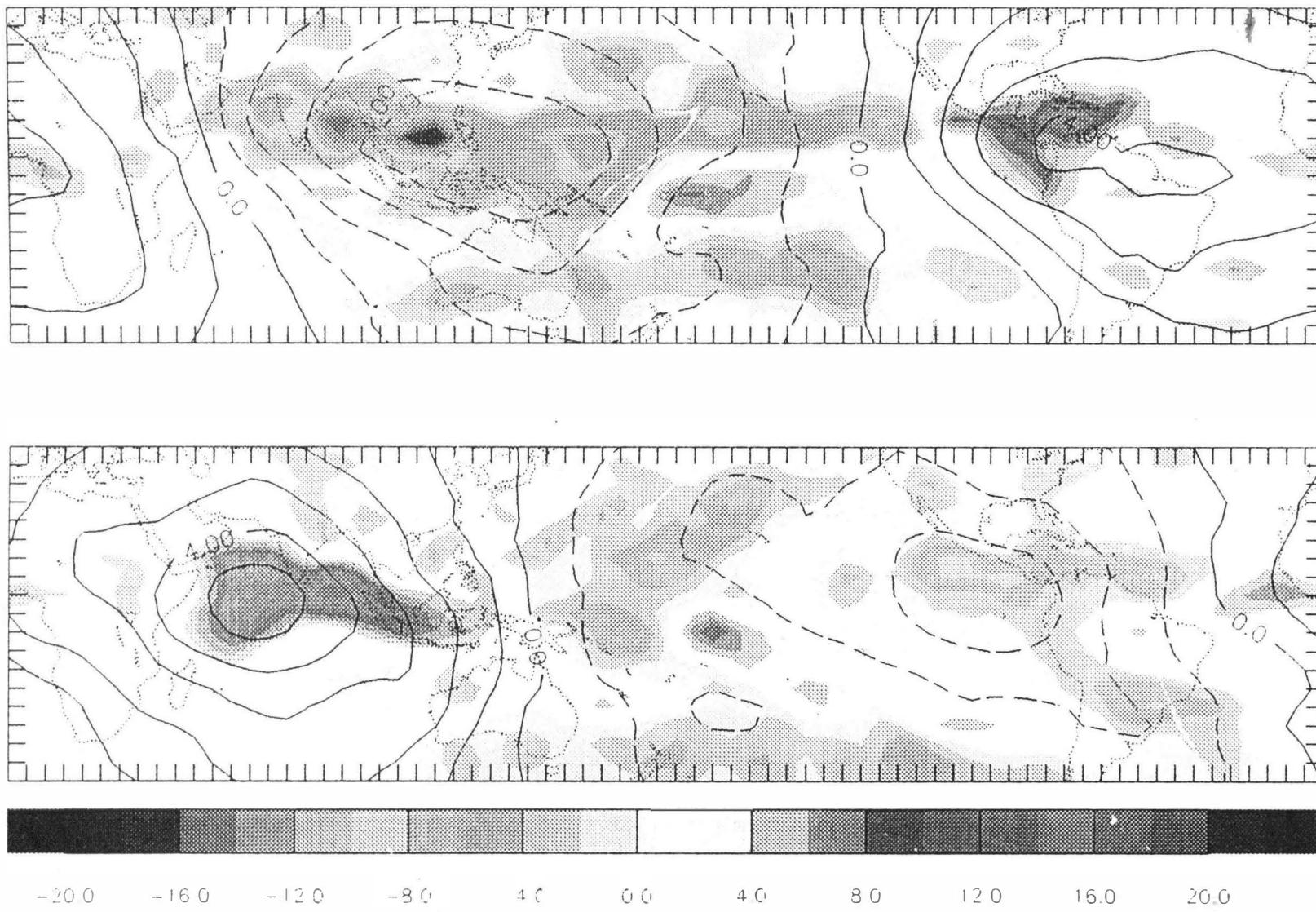
Fig. 1a, from May 1984 until April 1989. Note that some data are missing. Units: $10^6 \text{ m}^2 \text{s}^{-1}$

DICKEY, et. al., 1990

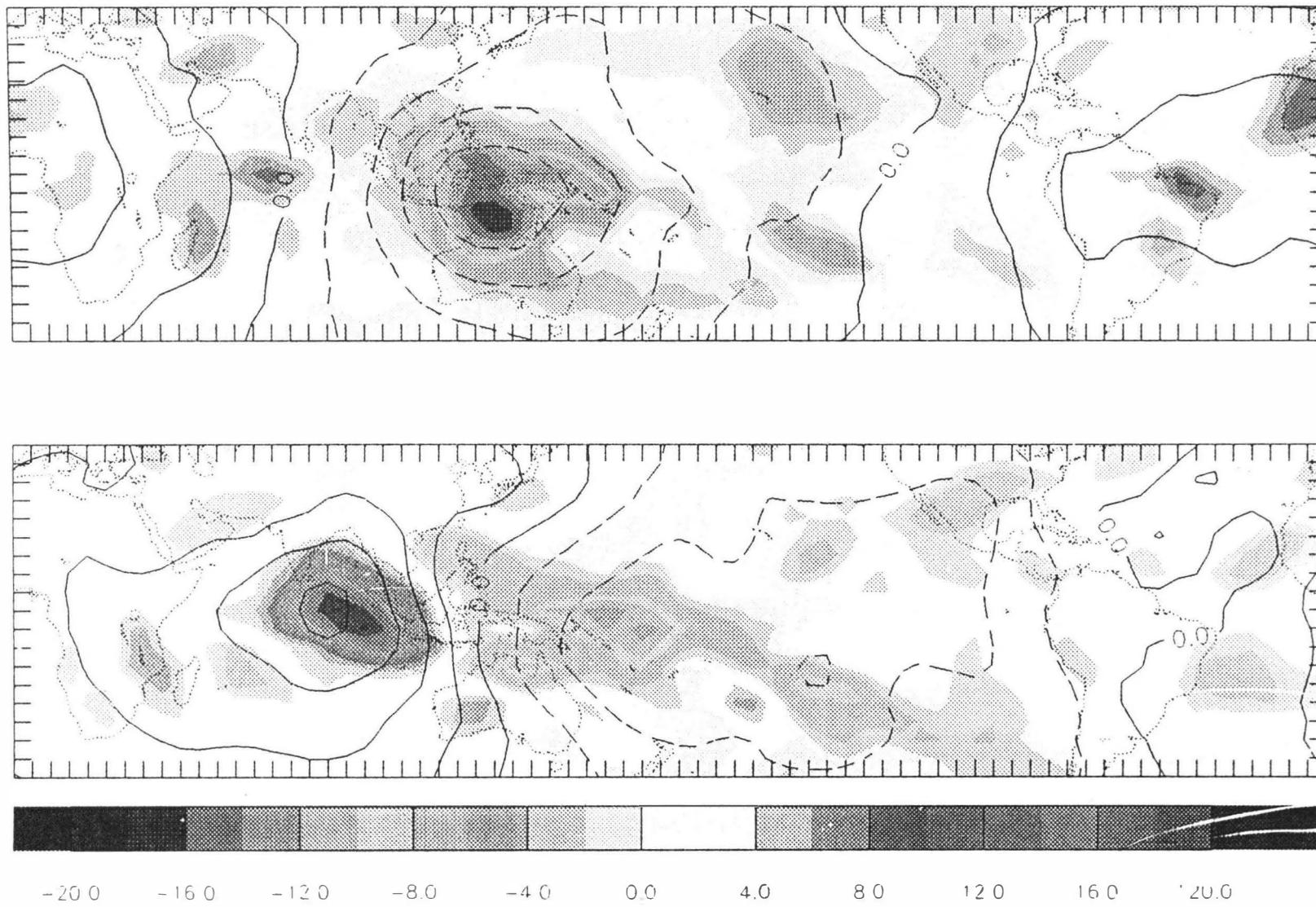


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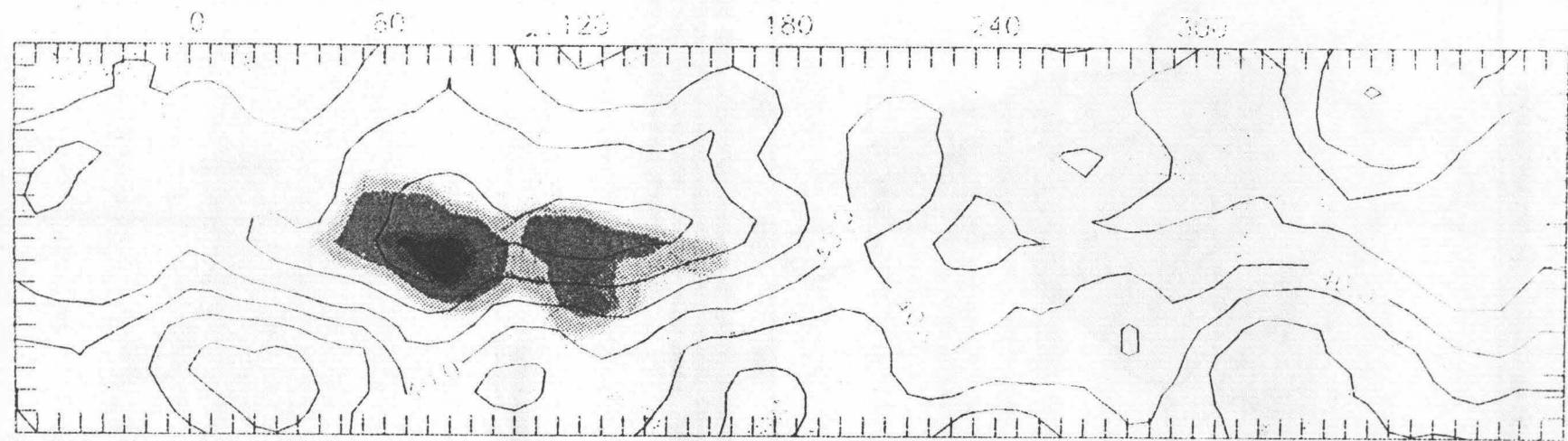
VELOCITY POTENTIAL AND OLR -MJJA-



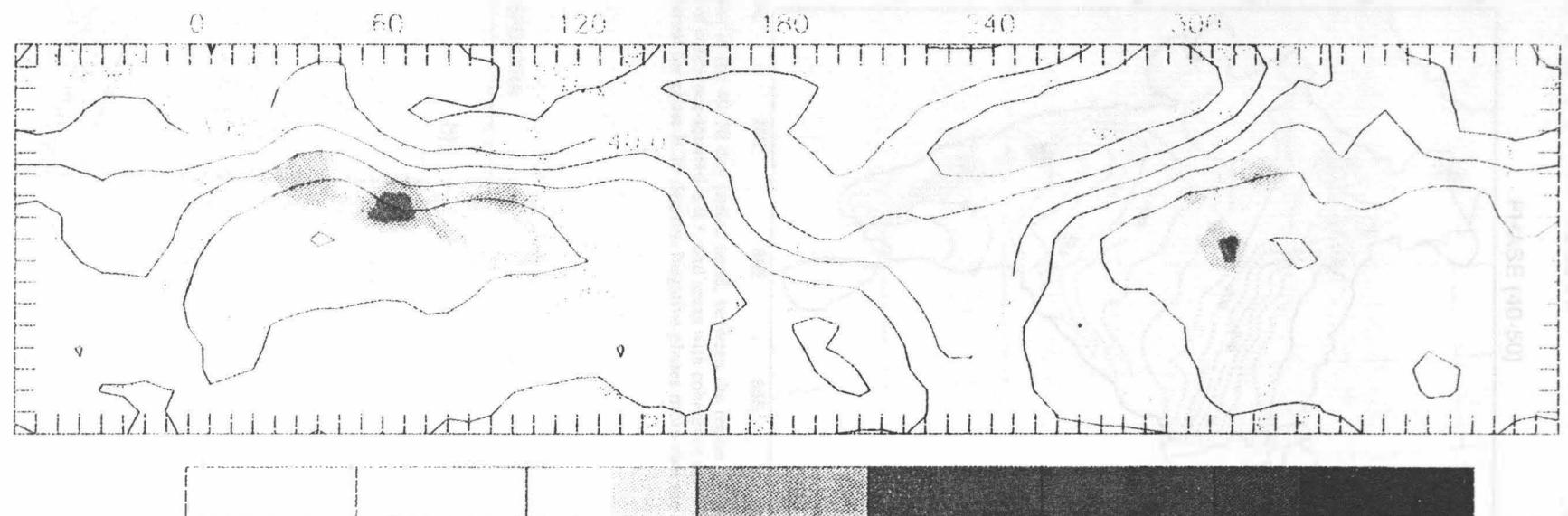
VELOCITY POTENTIAL AND OLR -NDJF-



EXPLAINED VARIANCE VEL. POT. AND OLR - NDJF -



EXPLAINED VARIANCE VEL. POT. AND OLR - MJJA -



0.0 6.0 12.0 18.0 24.0 30.0 36.0 42.0

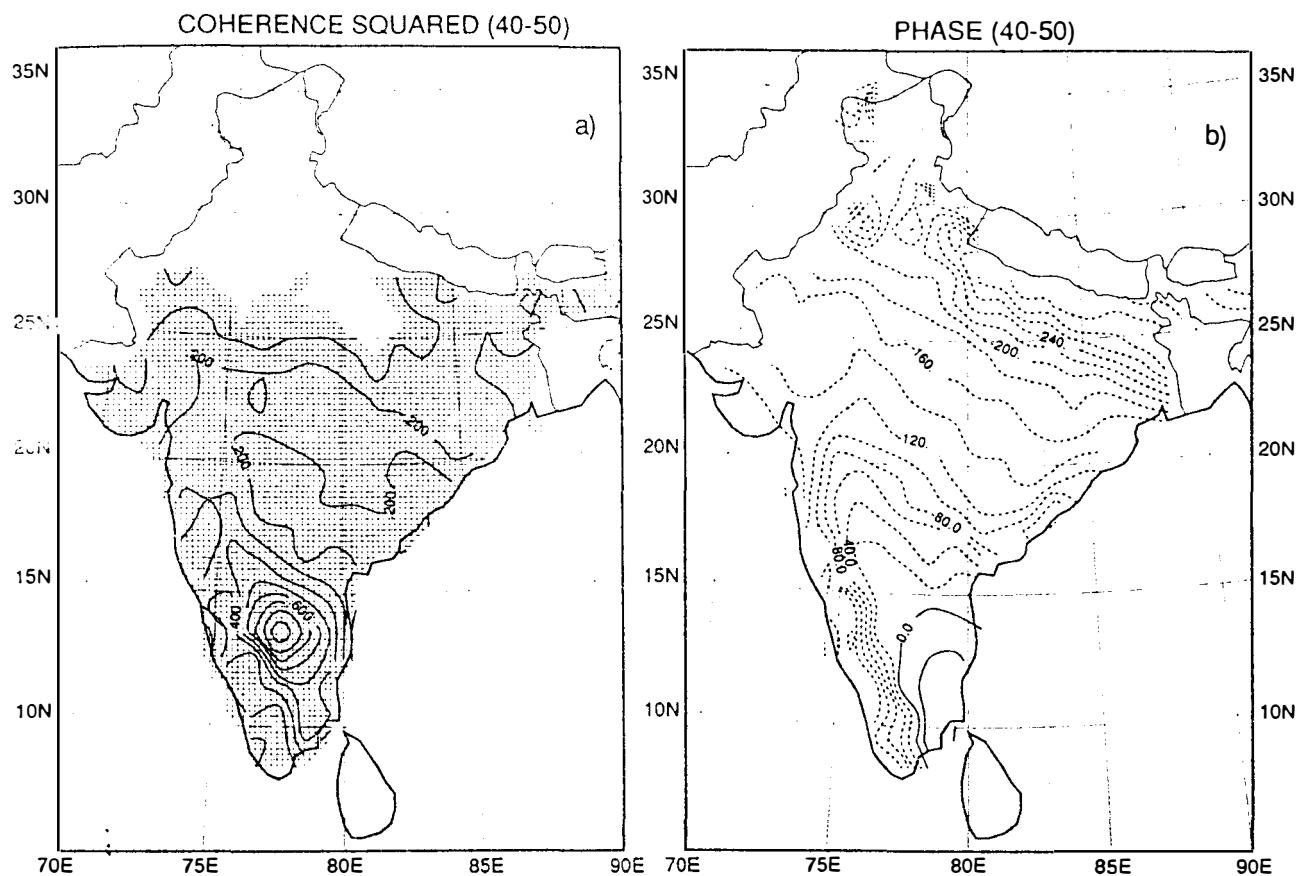


FIG. 10. Maps of (a) coherence-squared, and (b) phase, of precipitation in the 40–50 day period band, between the region 13° – 14° N, 77° – 78° E and all of the one-degree regions over India. Contour interval of coherence-squared is 0.1, and areas with coherence significantly different from zero at the 99% a priori level are shaded. The contour interval for phase is 20 degrees. Negative phases mean that the point in question lags behind the reference point.

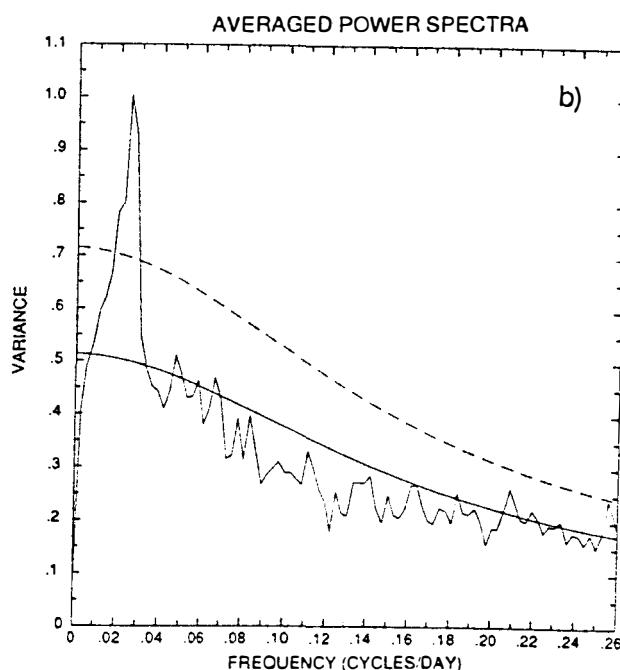
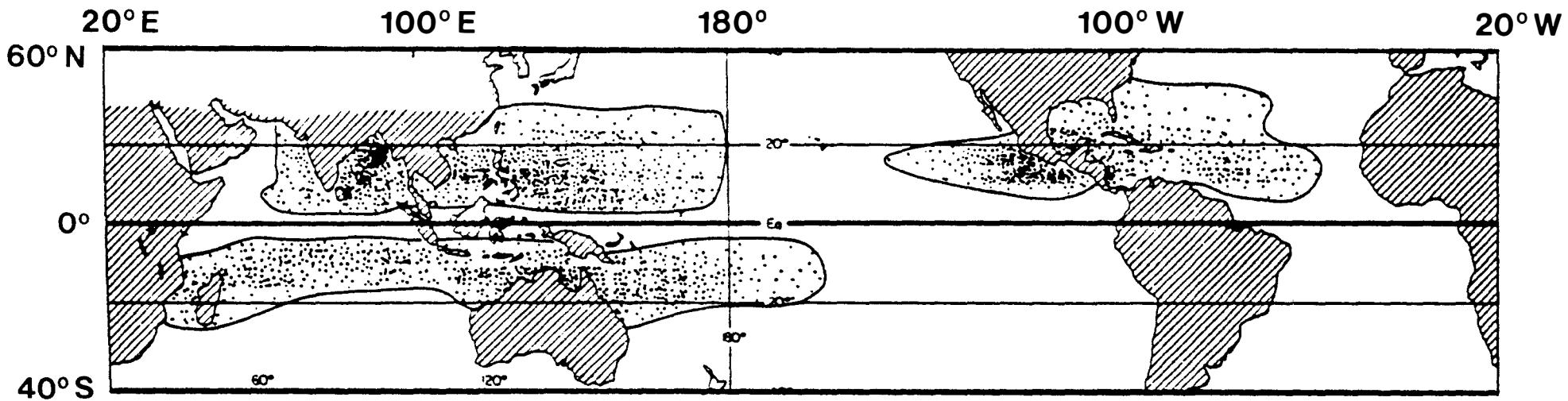
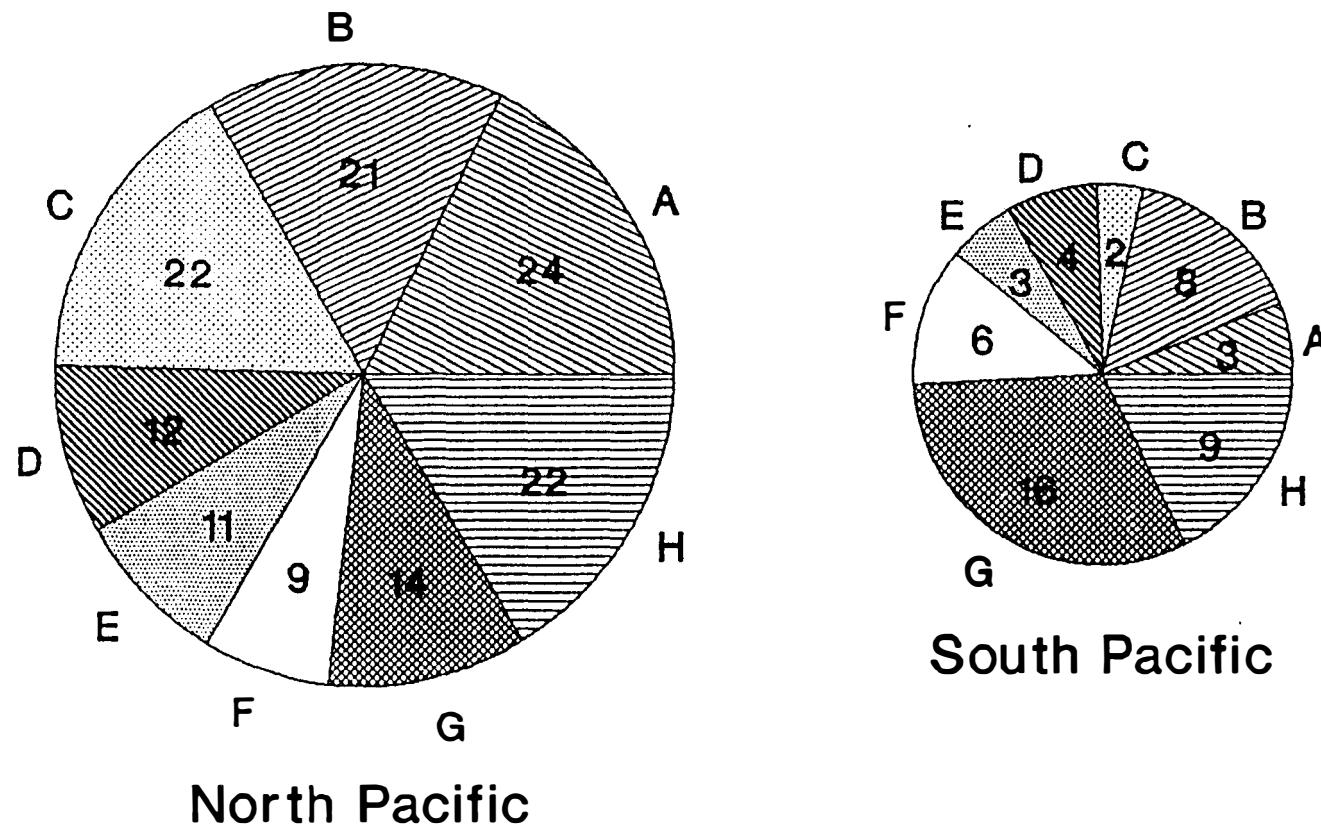


FIG. 5. Power spectra of daily precipitation for the region 13° – 14° N, 77° – 78° E. The smooth curve is the red-noise null-hypothesis, and the dashed line is the 99% a priori confidence limit. Variance is in units of millimeters-squared per spectral estimate. (a) Spectrum based on 200-day records beginning on day 100 (10 April); (b) spectrum based on 360-day records beginning on day 1 (1 January).



STOCH
& SMALLEGÅRD, 1991

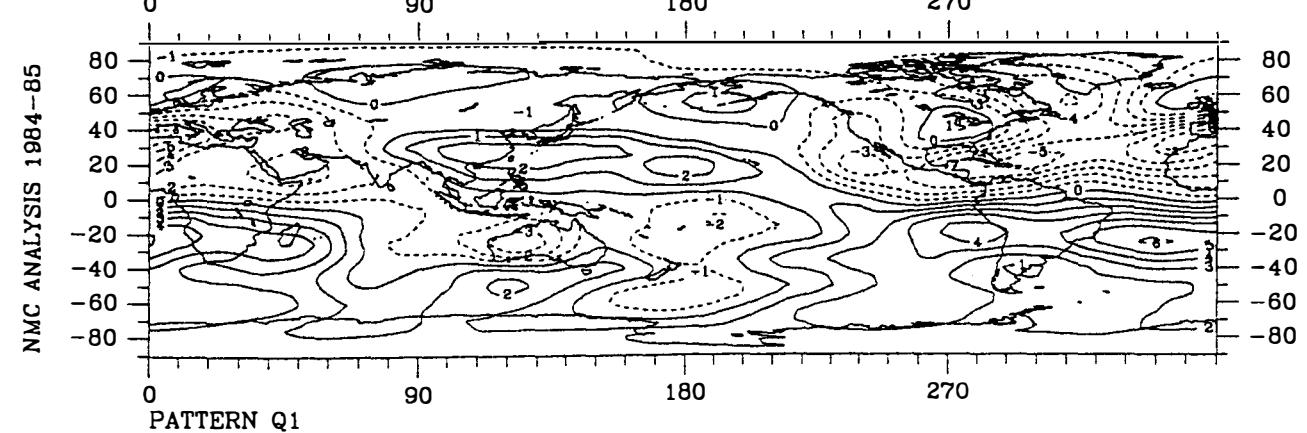
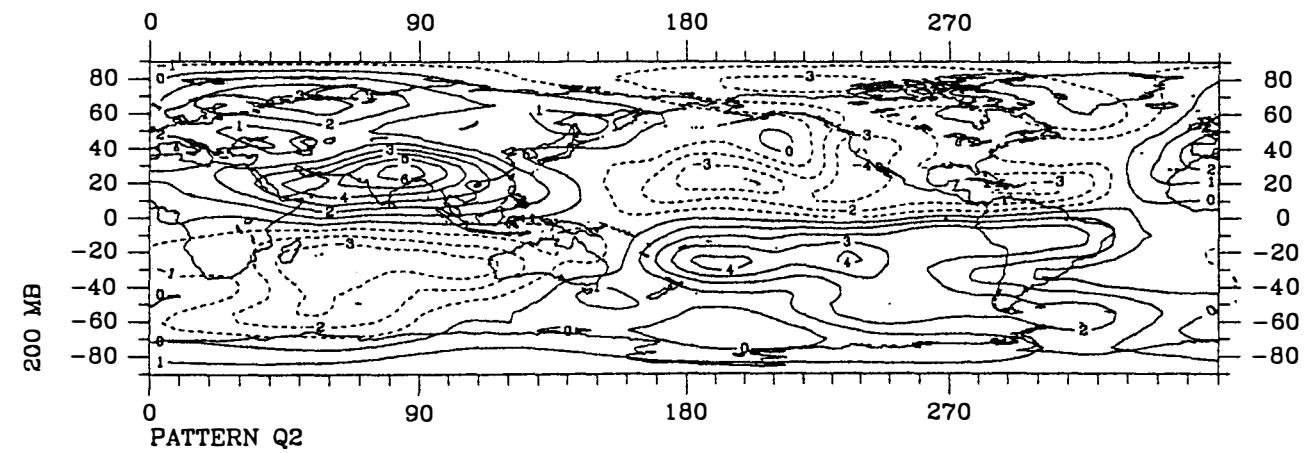
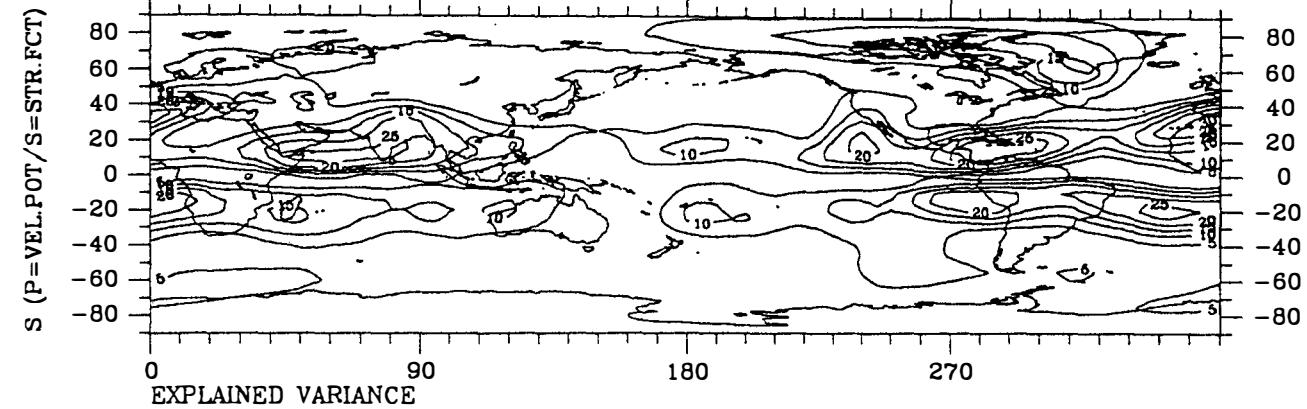
The Phase of the MJO and the genesis of tropical cyclones in the West Pacific



May 1984 through April 1989

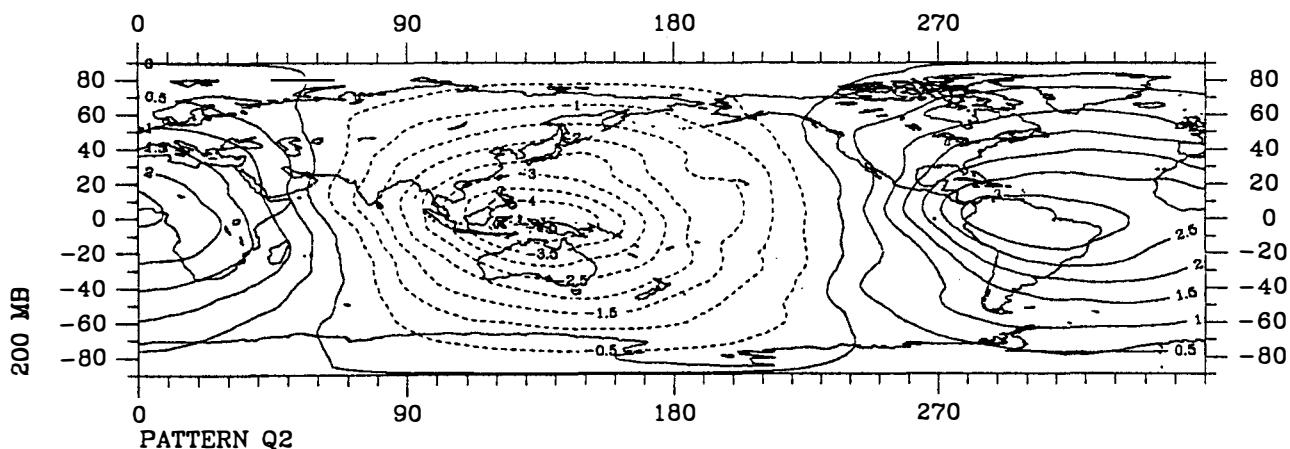
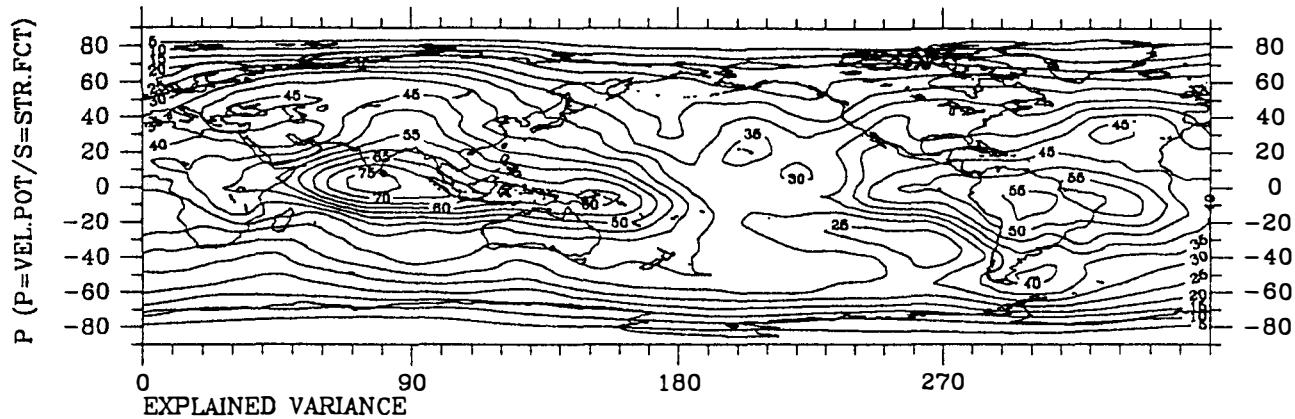
STORCK &
SHARLEGANG
1991

ASSOCIATED CORRELATION PATTERNS - ALL YEAR



STREAMFUNCTION
200 mb

ASSOCIATED CORRELATION PATTERNS - ALL YEAR



POP Prediction of the MJO

The complex POP index

$$[z_1 + i z_2](t)$$

develops, according to the POP analysis, with

$$[z_1 + i z_2](t) = \exp[-2*i*pi*t/P] [z_1 + i z_2](0) + \text{noise}$$

Thus, the POP index can be predicted.

Using 5 years of data we examined the skill of the POP technique to predict the POP index of the MJO.

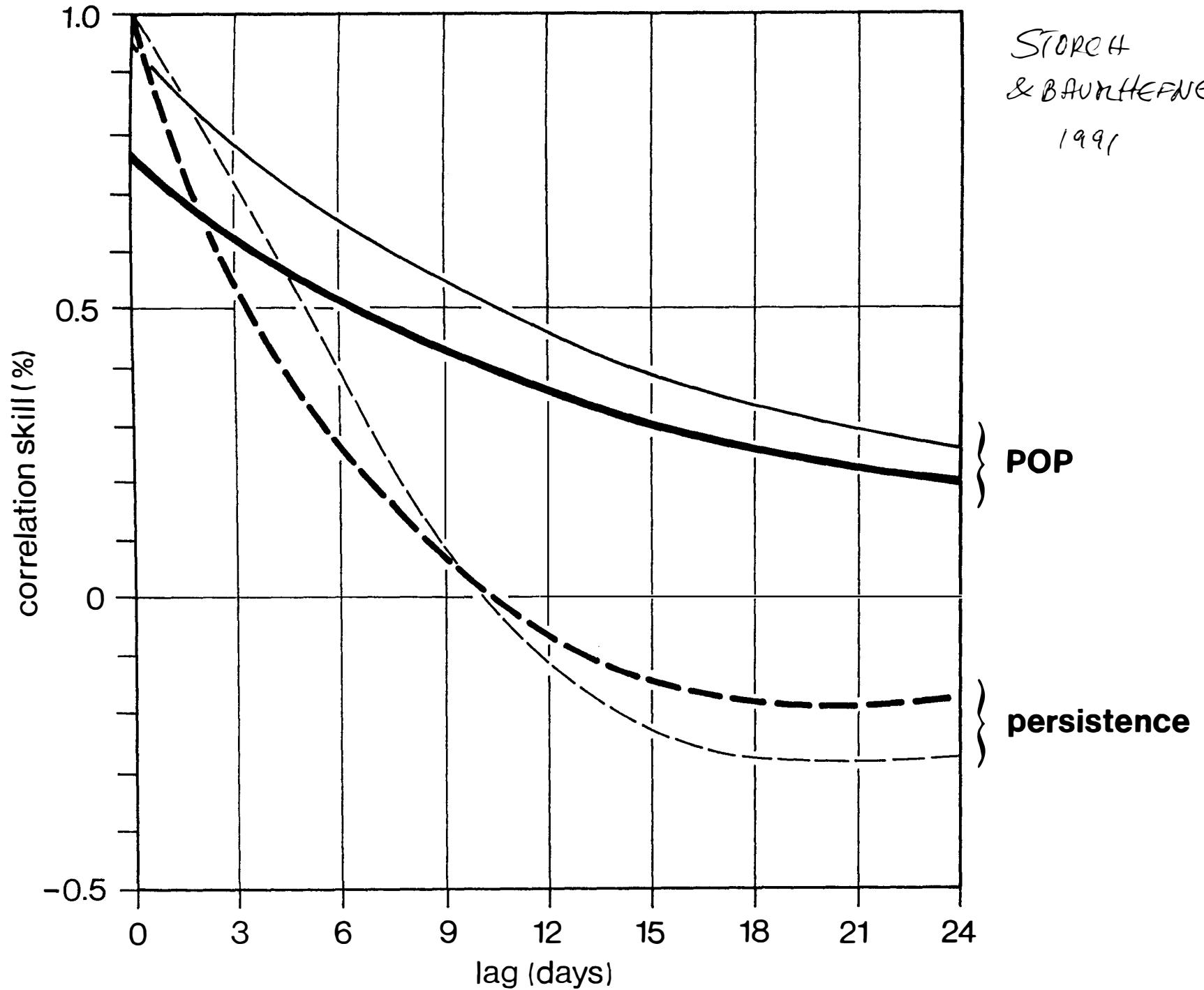
60% of the data represent independent data which have not been used to derive the POP model.

By multiplying the POP index with the pattern a forecast of the fields is obtained. The skill in forecasting the equatorial velocity potential field is examined.

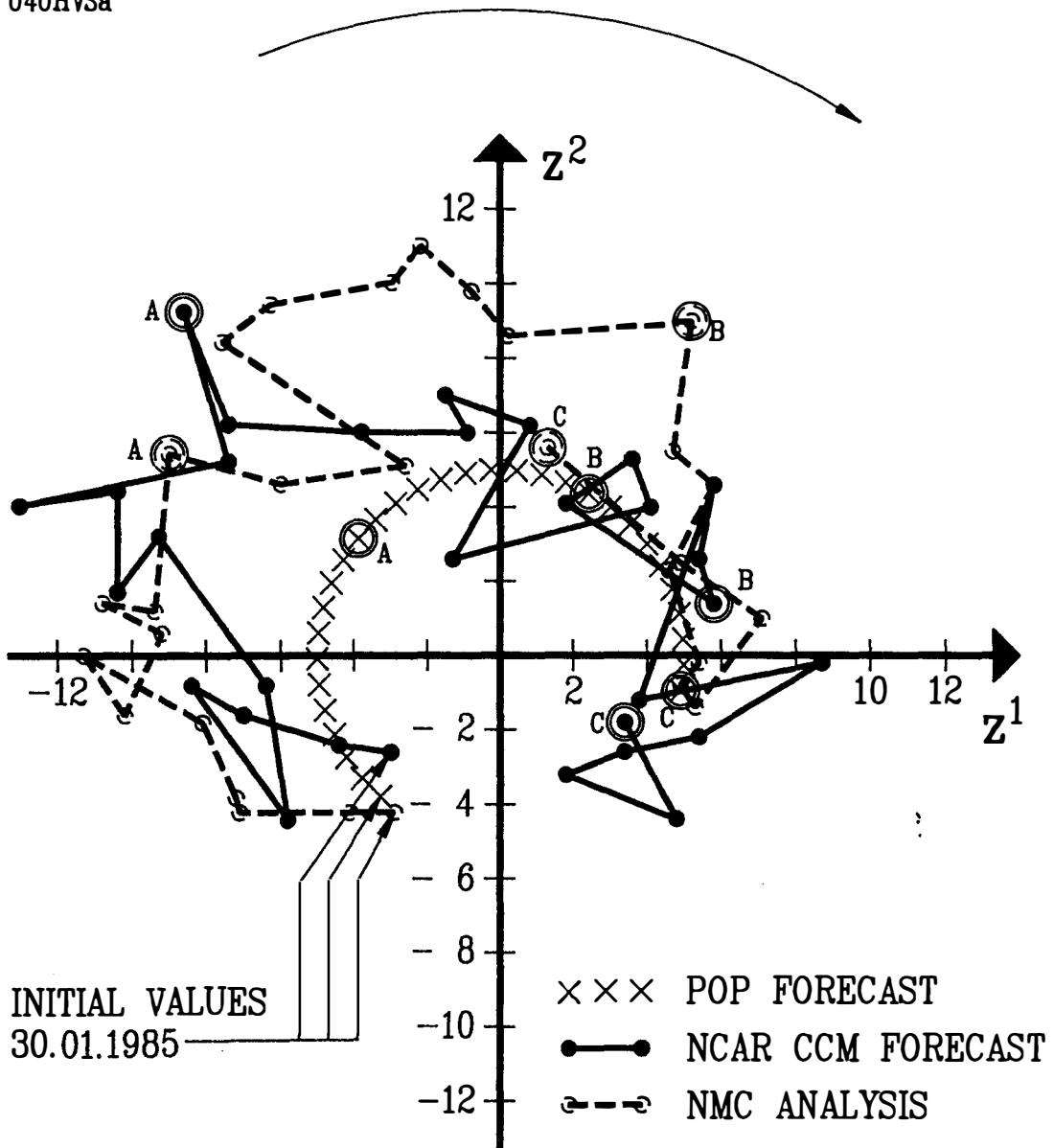
The POP prediction is used as a reference for the skill of forecasts prepared by GCMs:

- NCAR CCM experimental 1-month forecast
- one year of operational 10-day forecasts prepared with the ECMWF T106 model
- one year of operational 8-day forecasts prepared by the JMA model

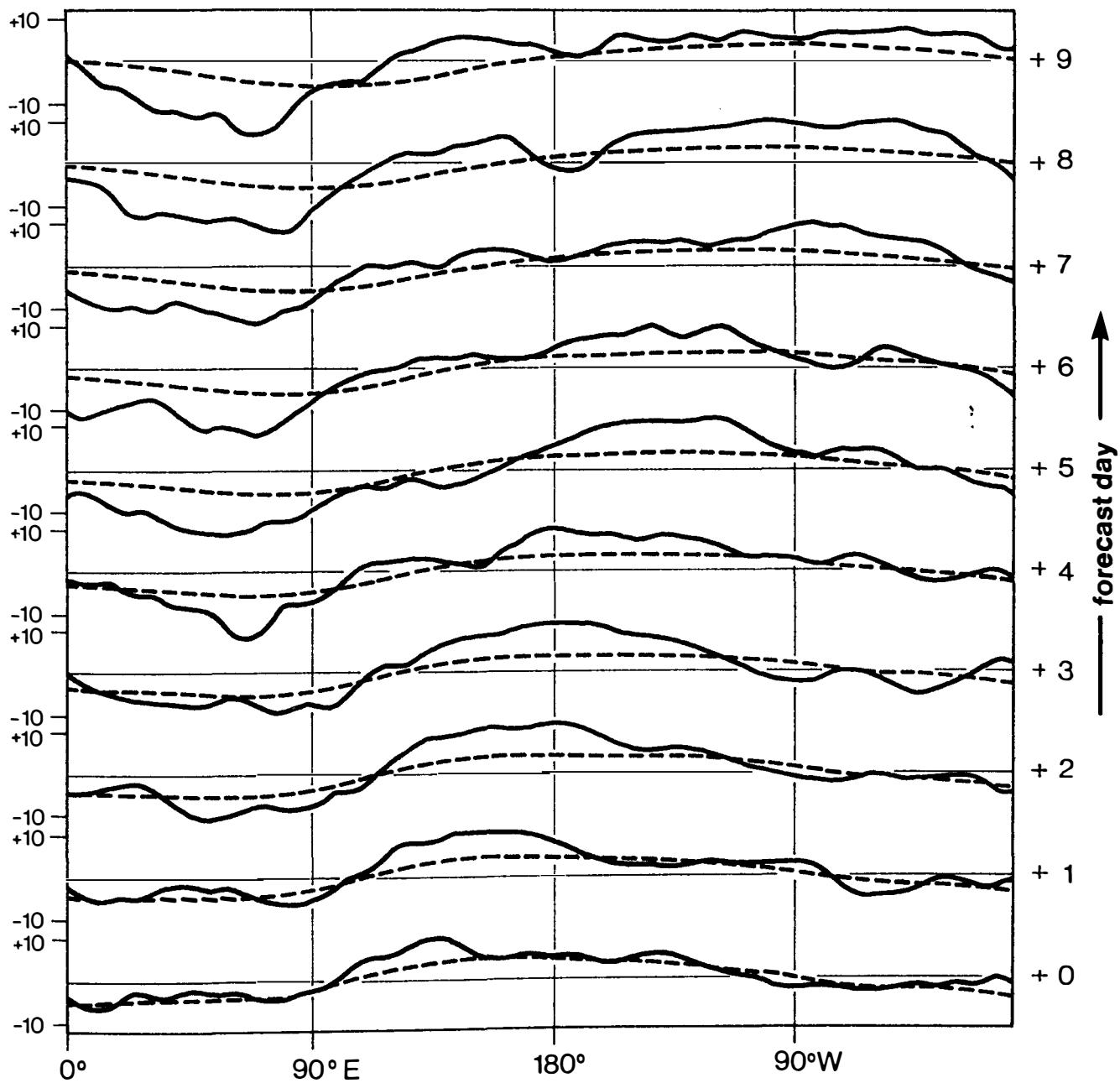
STORCH
& BAUMHEFNER
1991



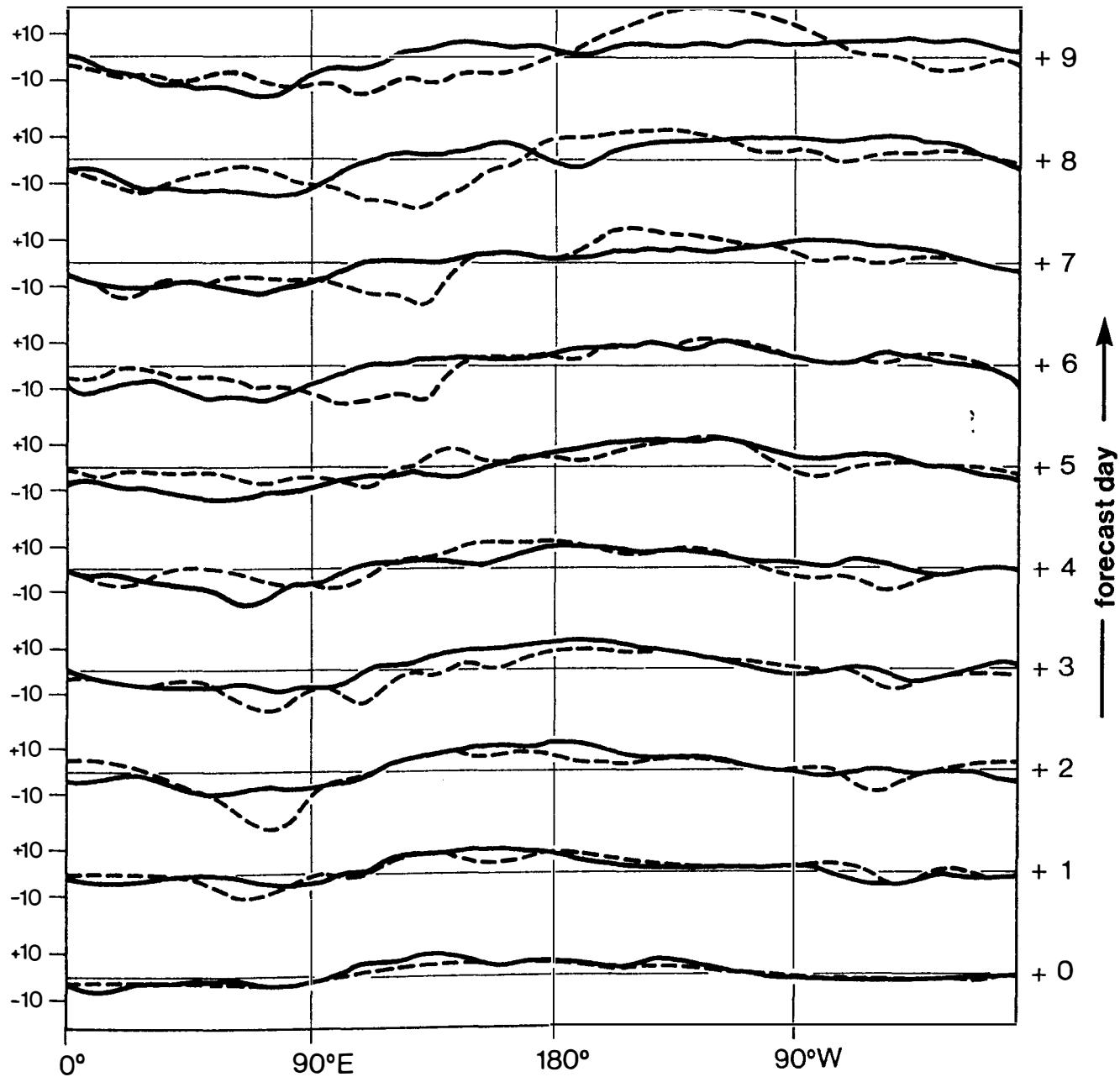
040HVSa



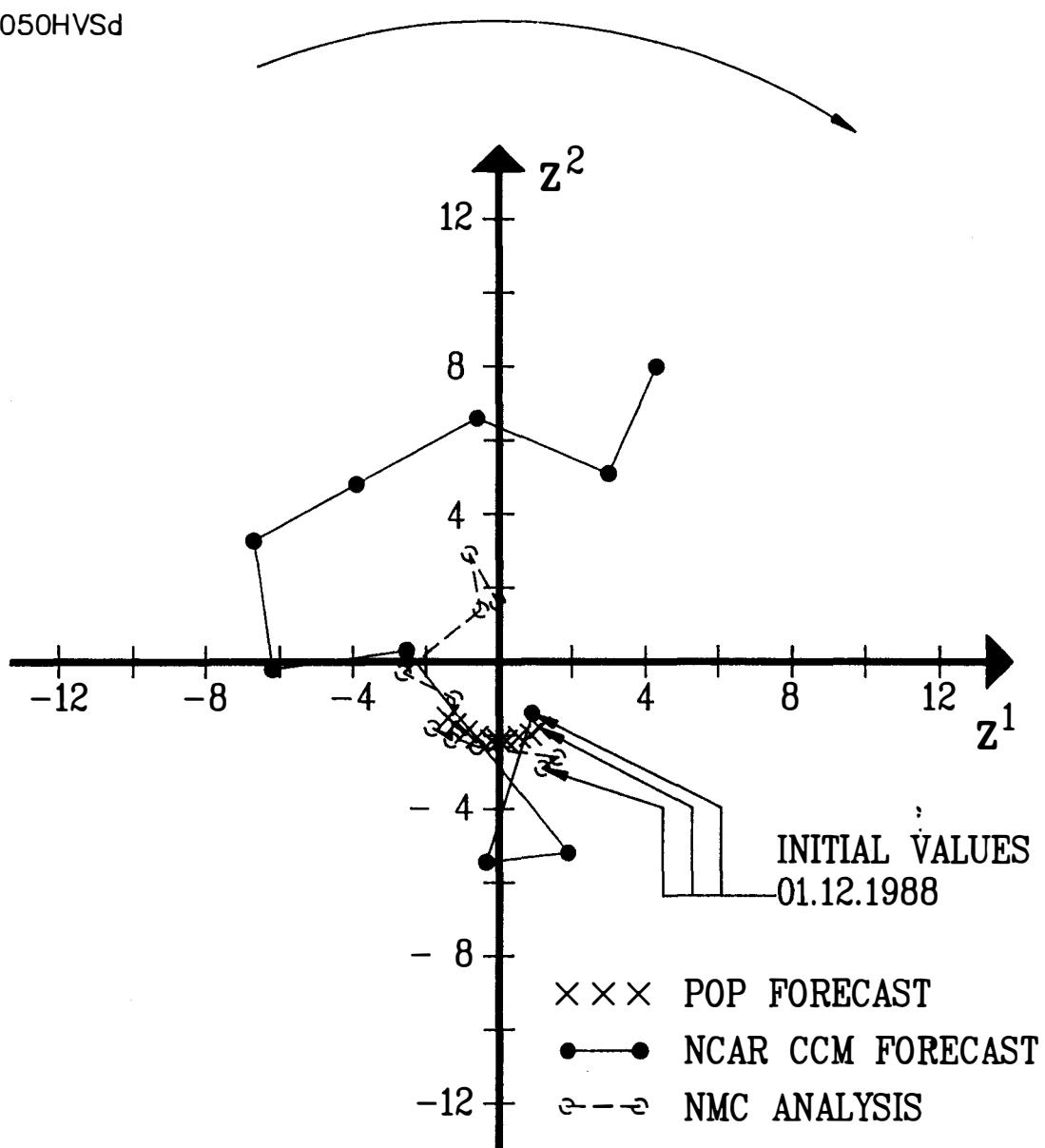
b) POPs 30.1.1985



a) NCAR 30.1.1985



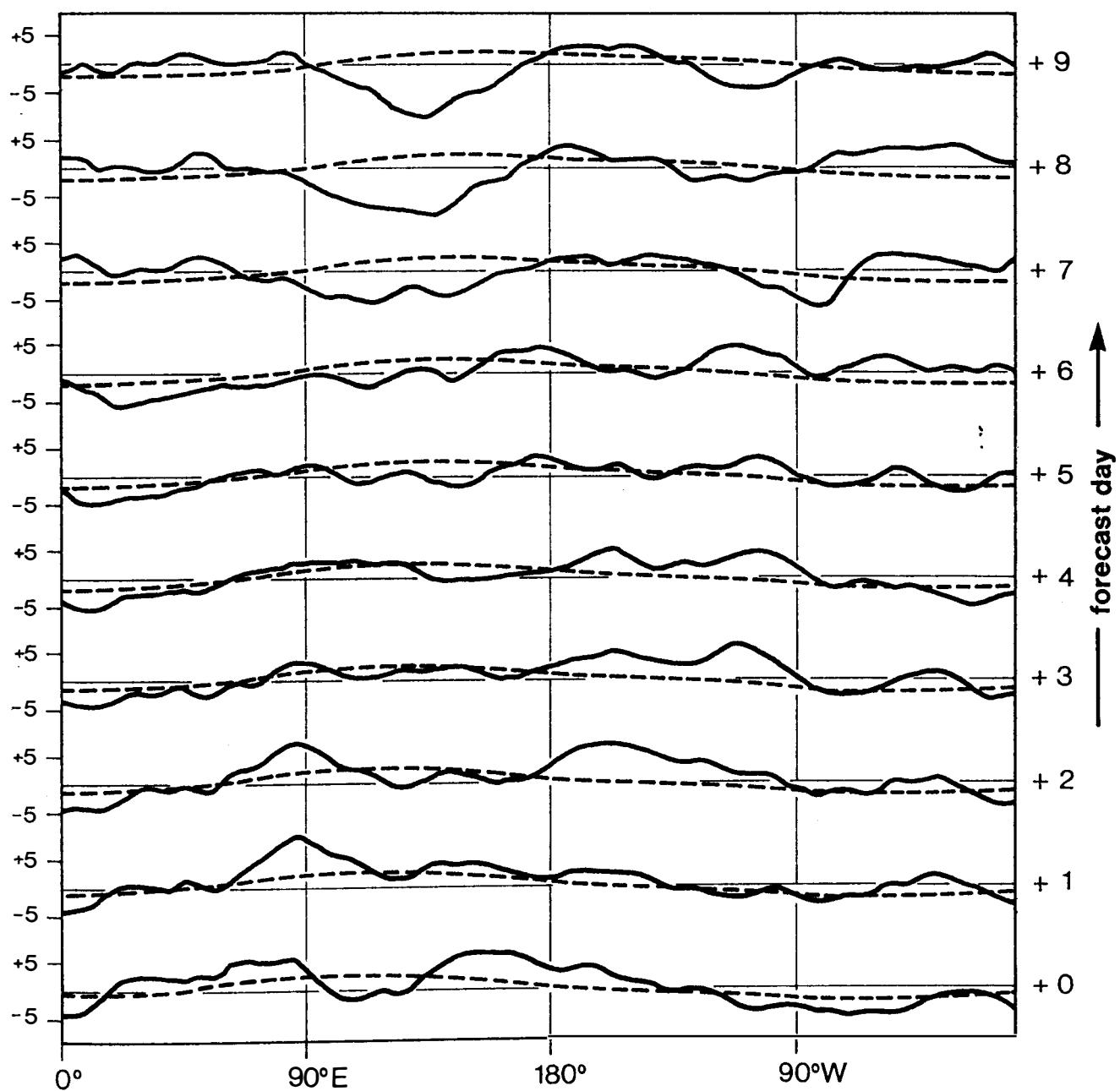
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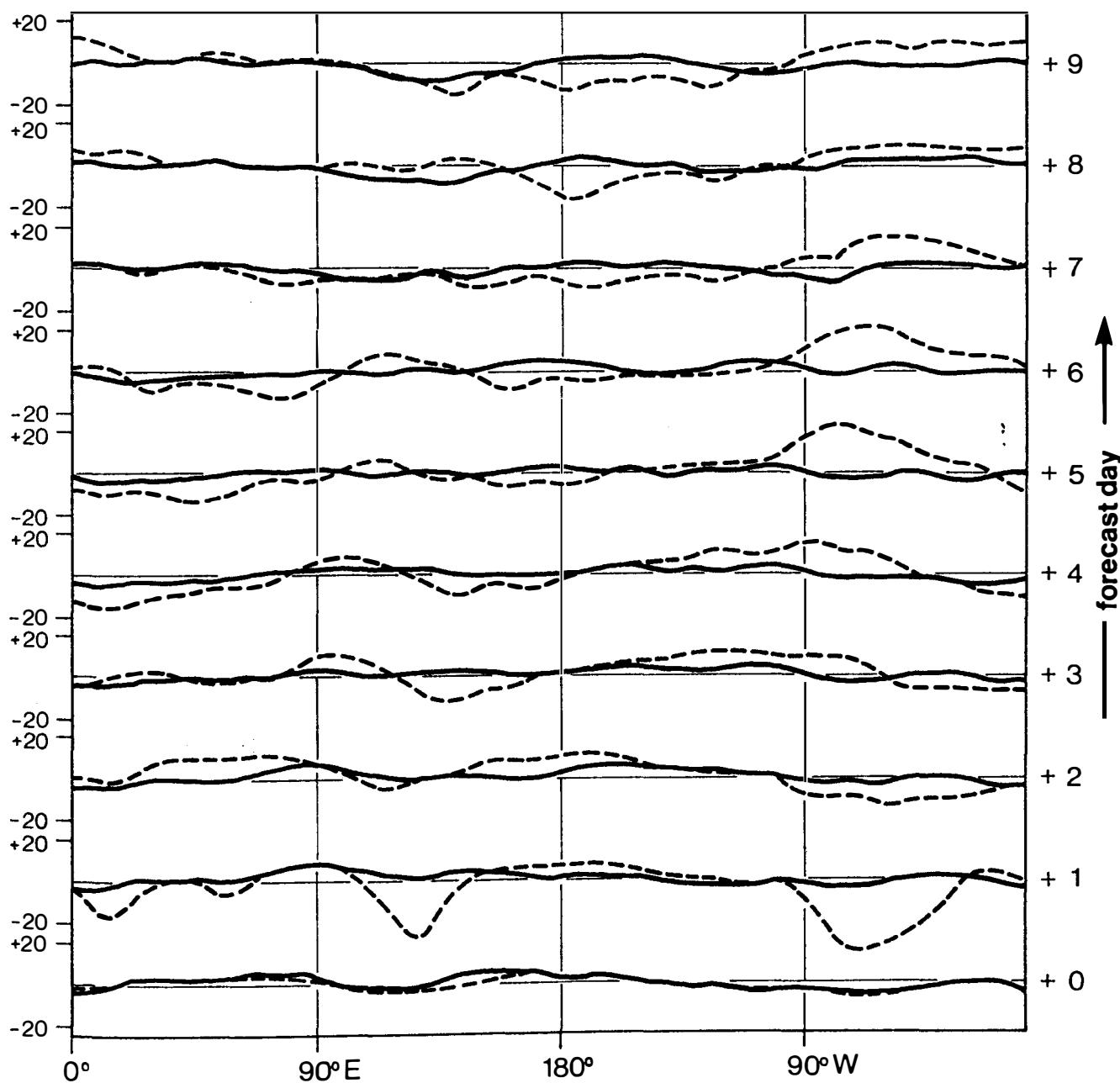
STORCH & BAUMHEFNER, 1991

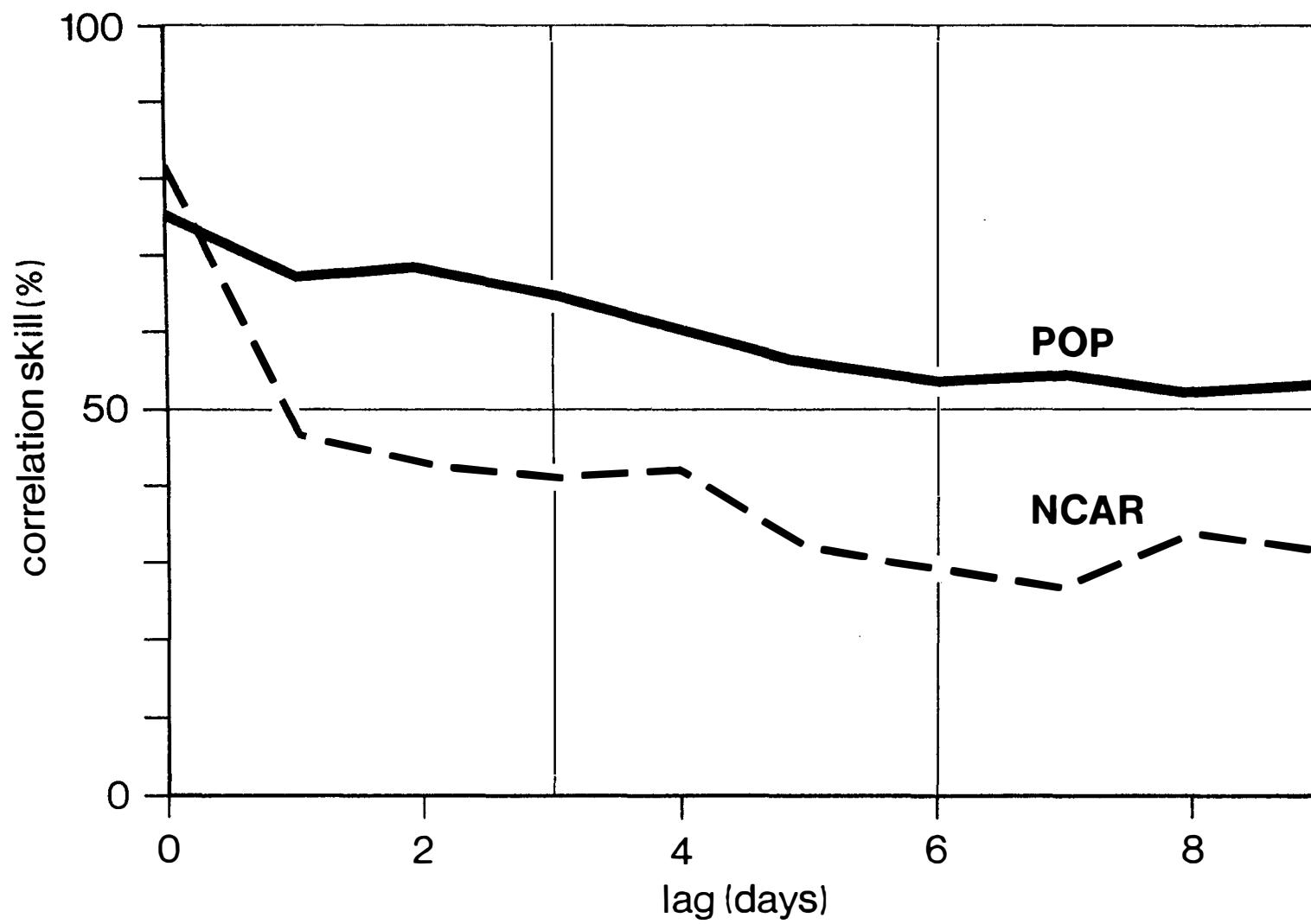
FIG. 11

b) POPs 1.12.1988

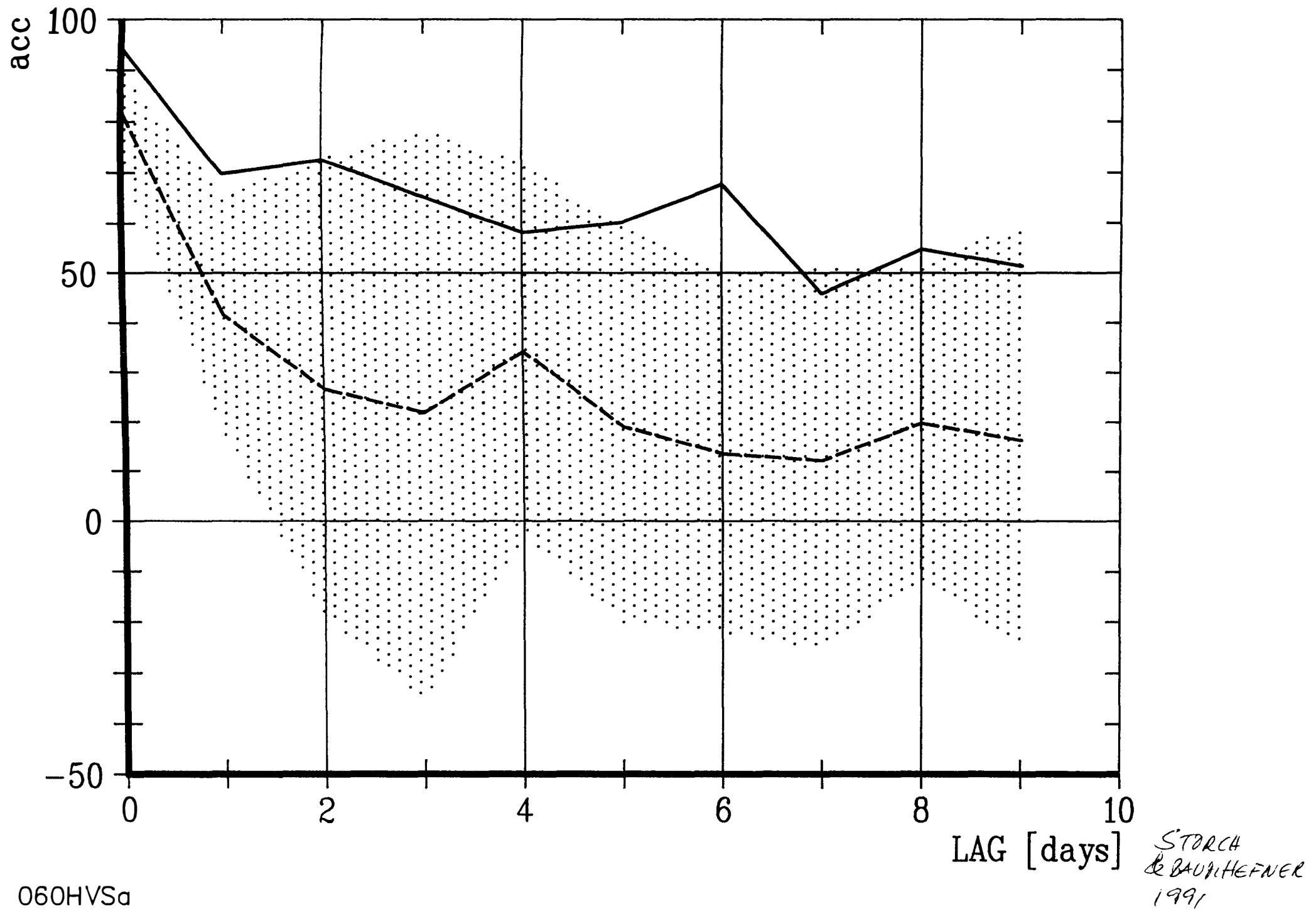


a) NCAR 1.12.1988





STORCH & BAUMHEFNER, 1991



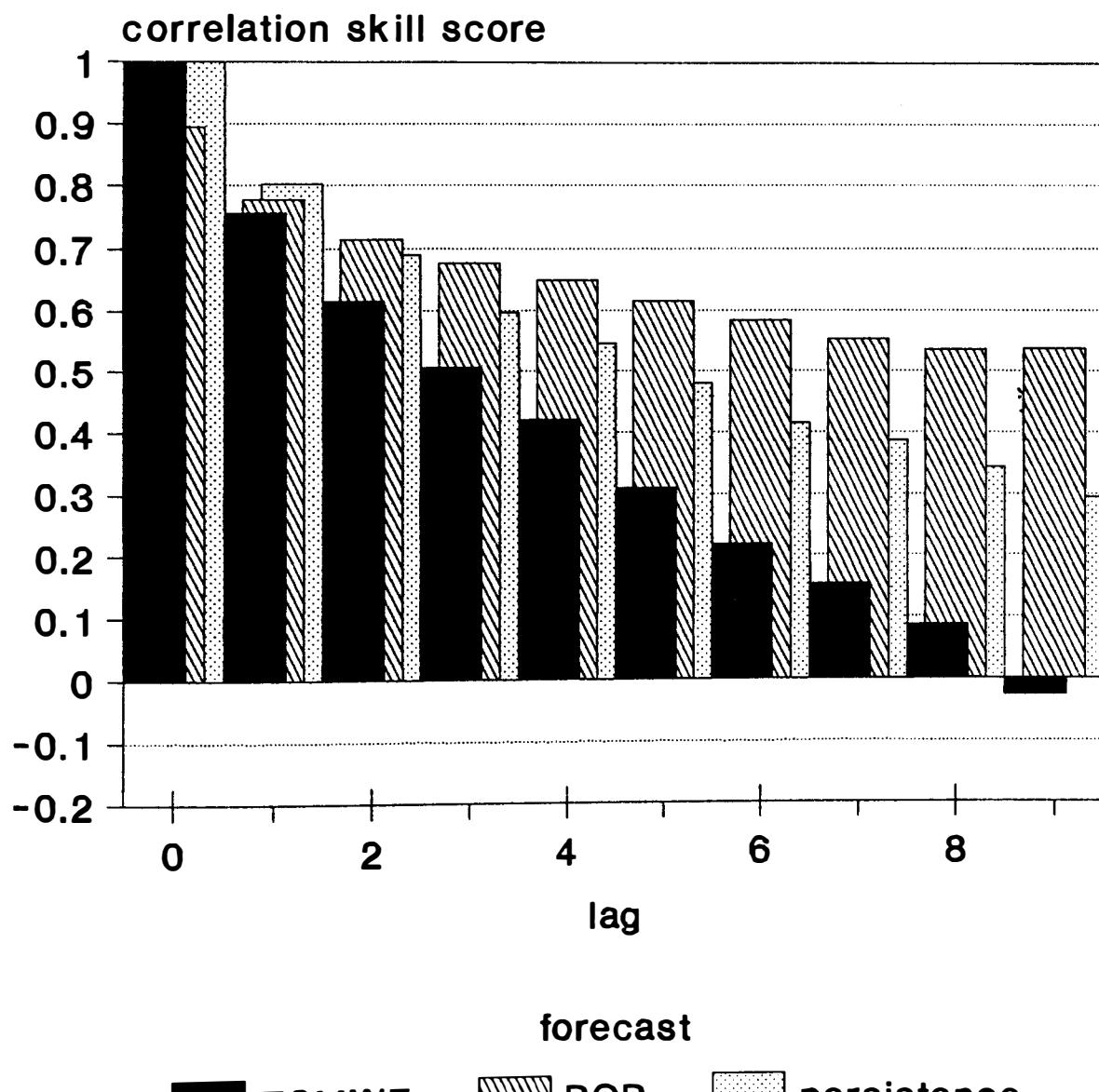
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STORCH
& BAUHEFNER
1991

POP Index of MJO

ECMWF and POP forecast

Dec 89 through Feb 90

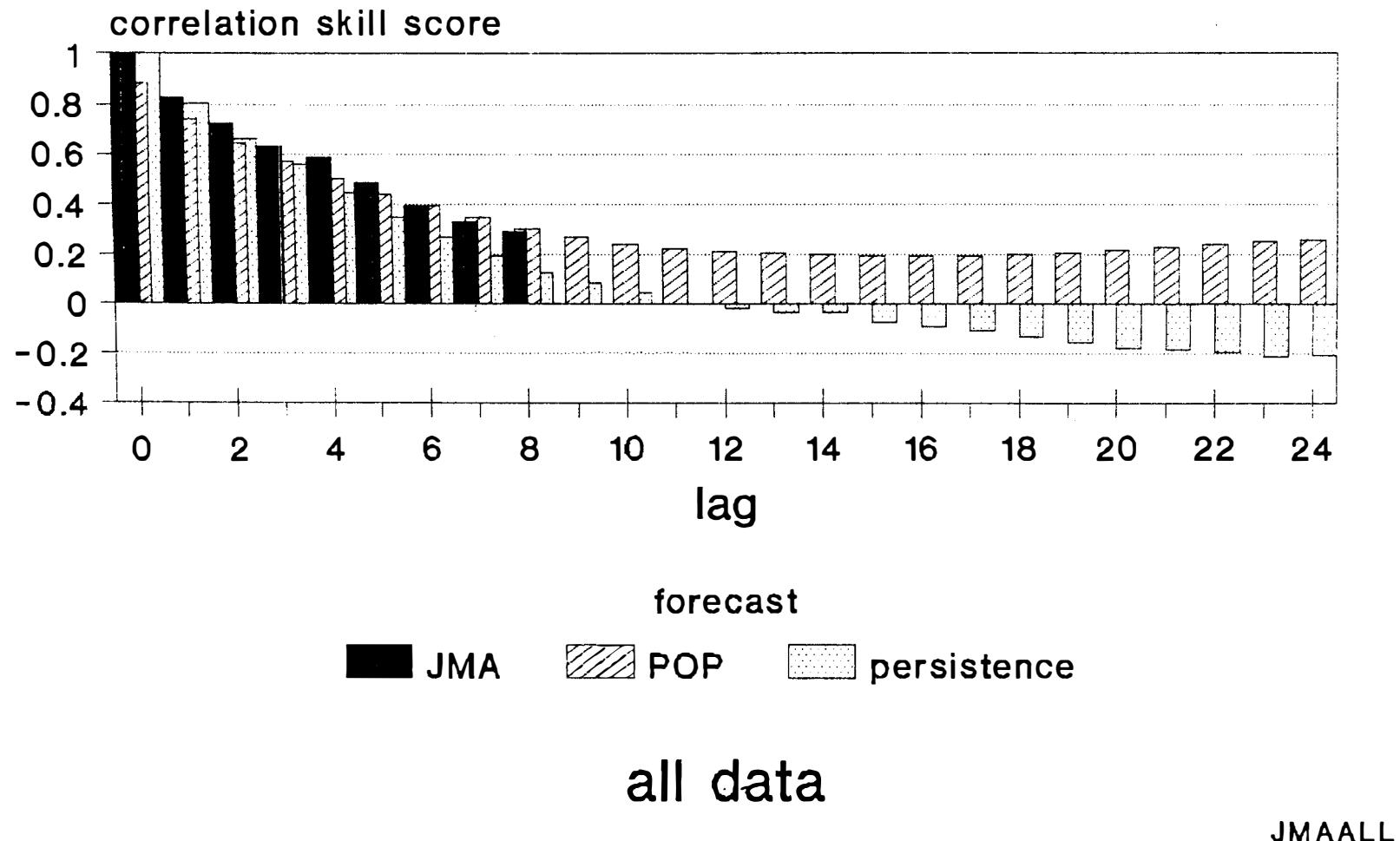


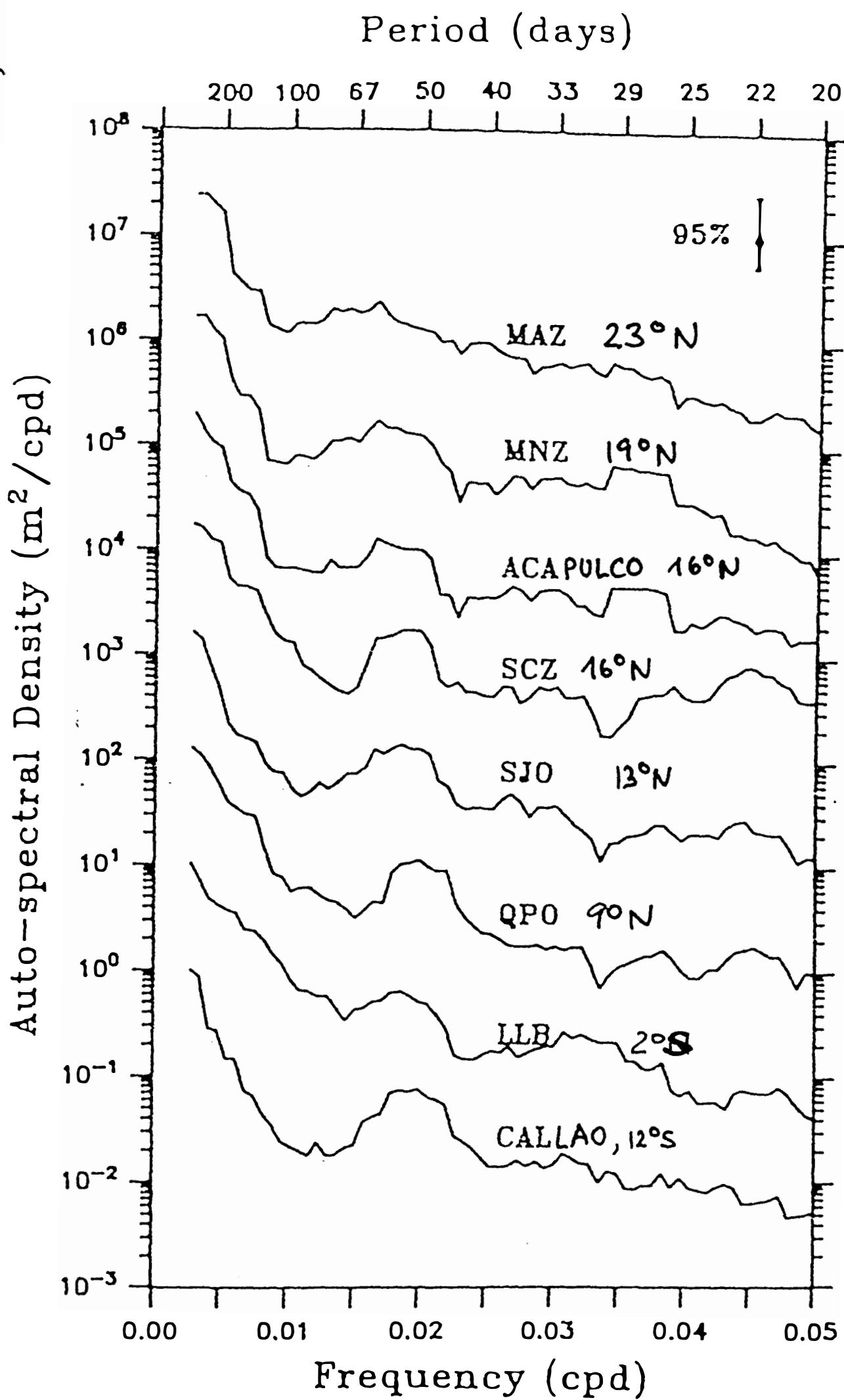
all data

POP Index of MJO

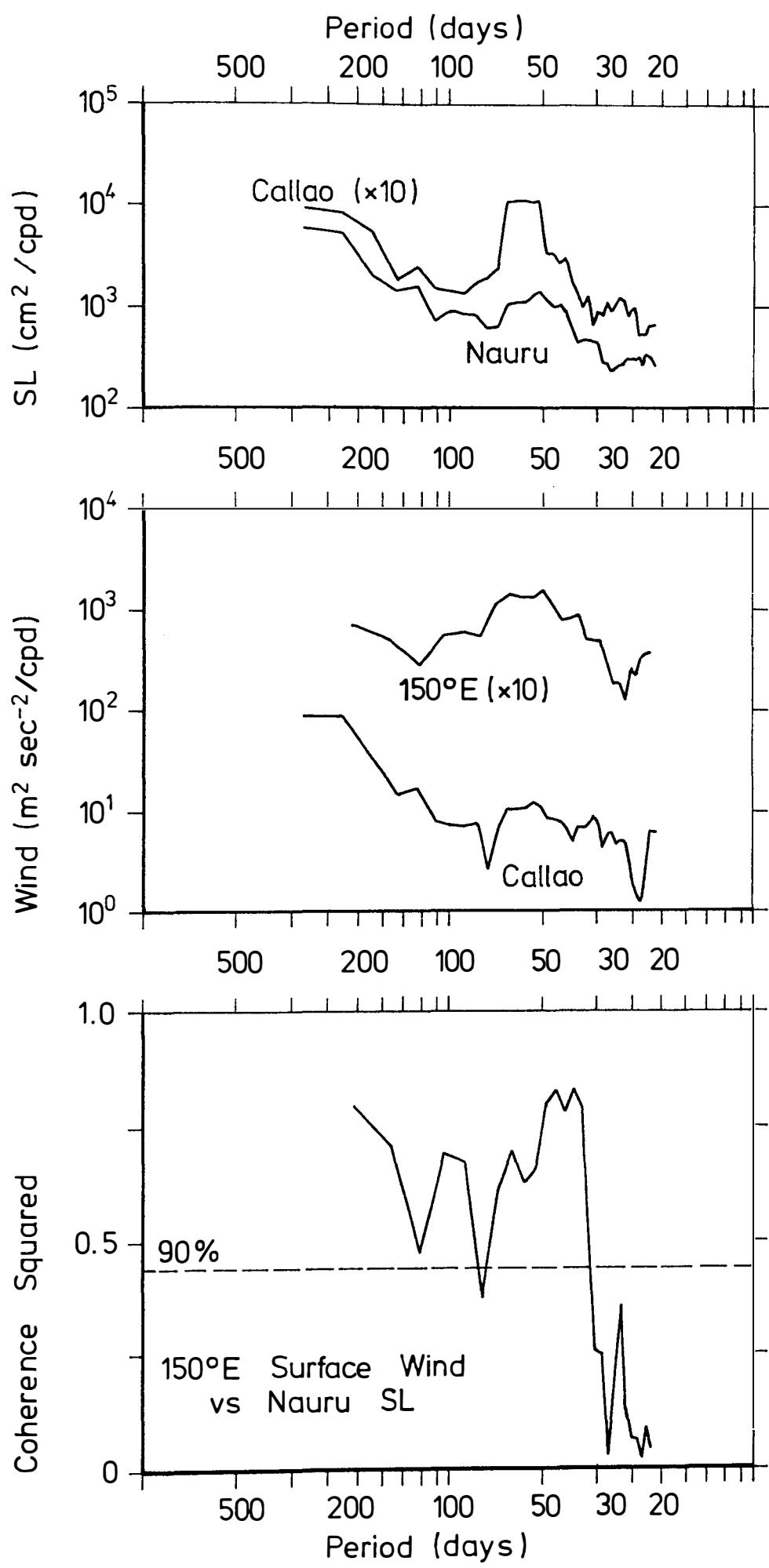
JMA and POP forecast

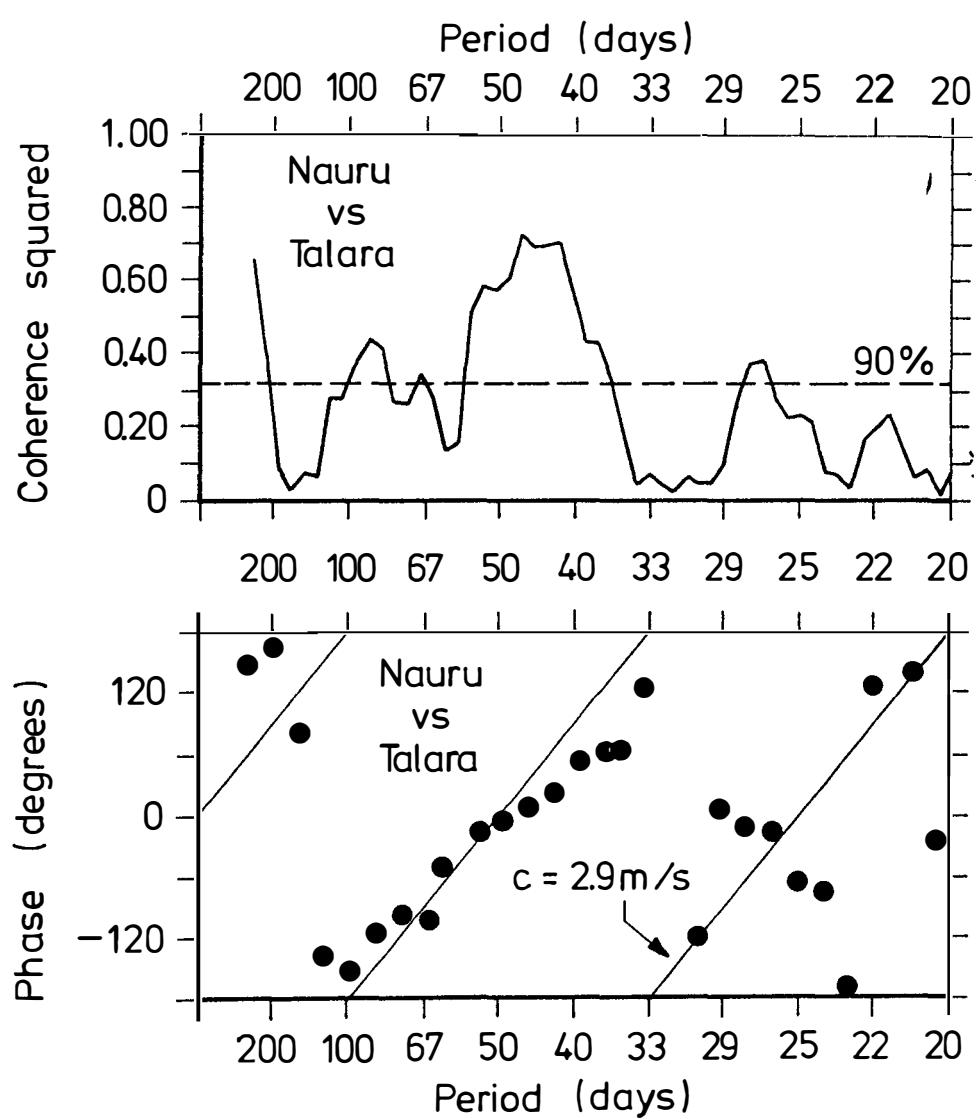
1.3.88-28.2.89





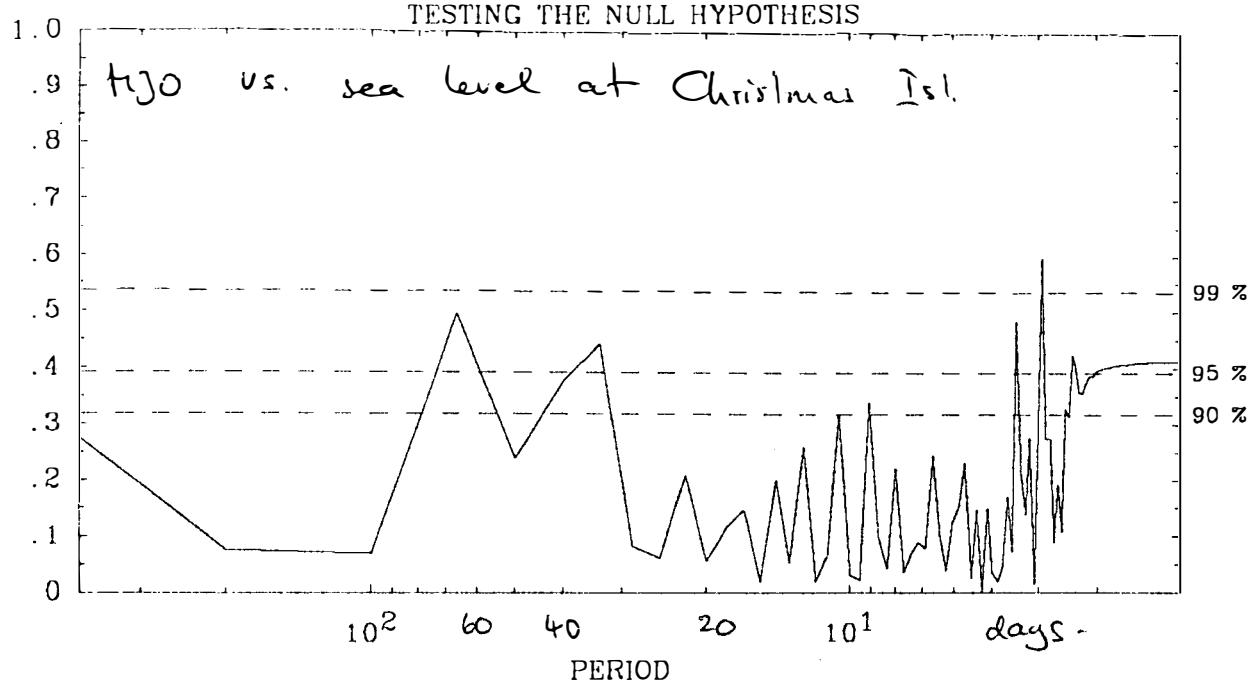
ENSO, 1982





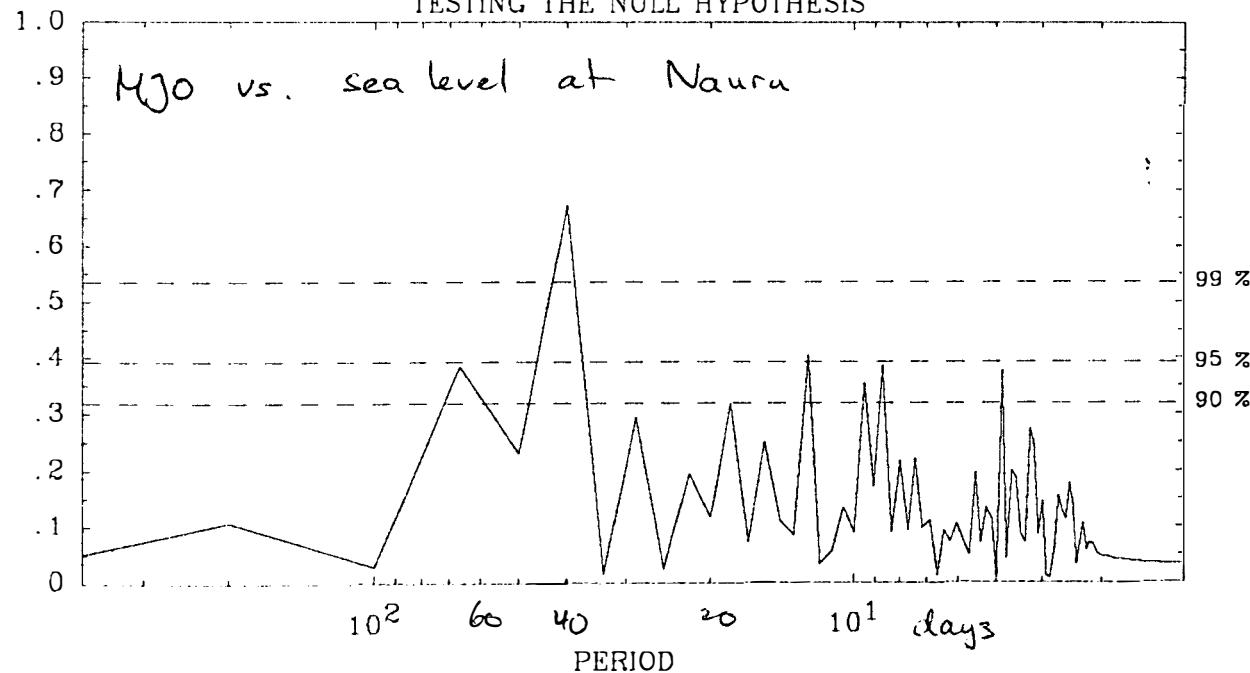
TESTING THE NULL HYPOTHESIS

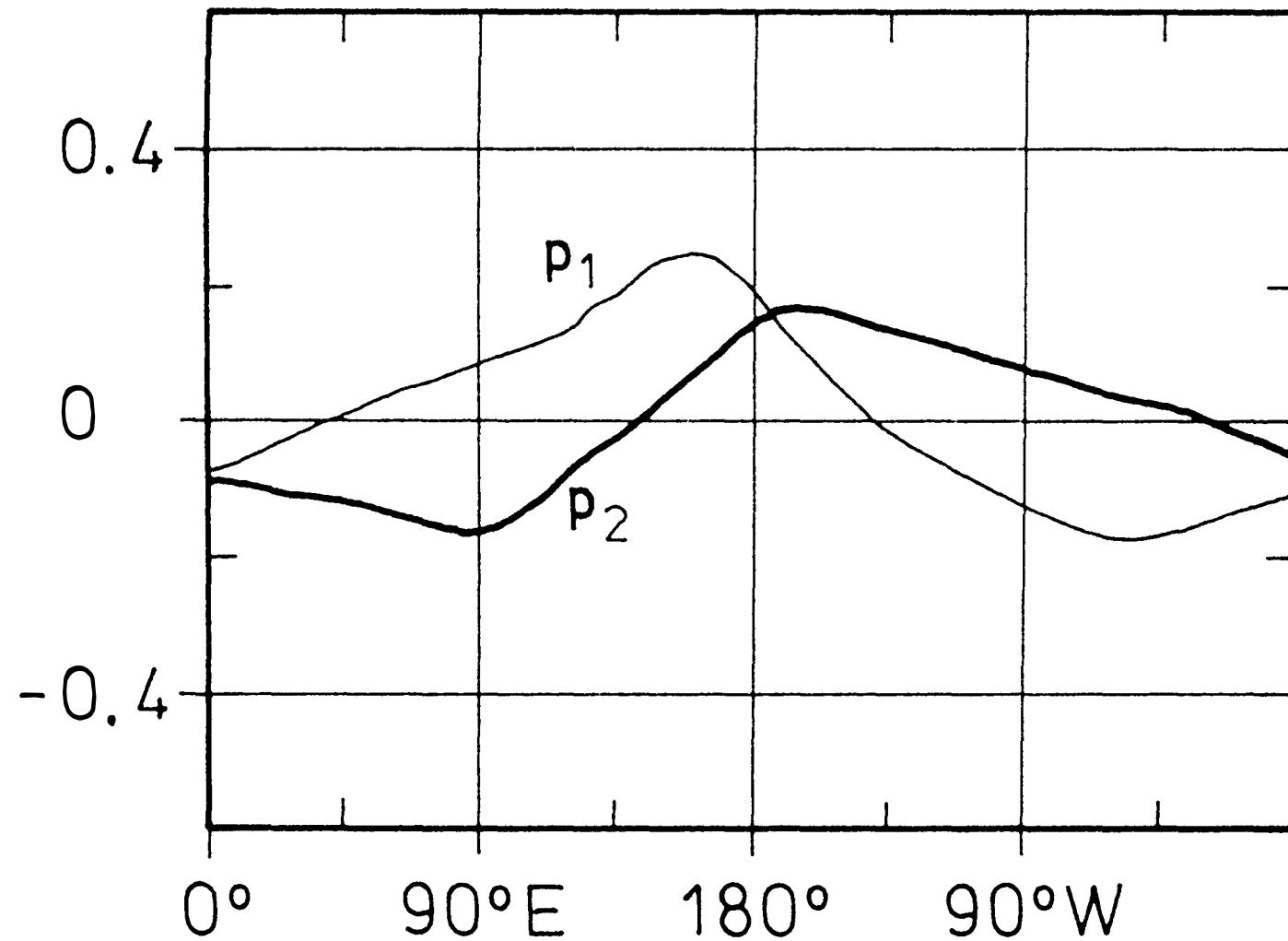
COHERENCE SQUARED

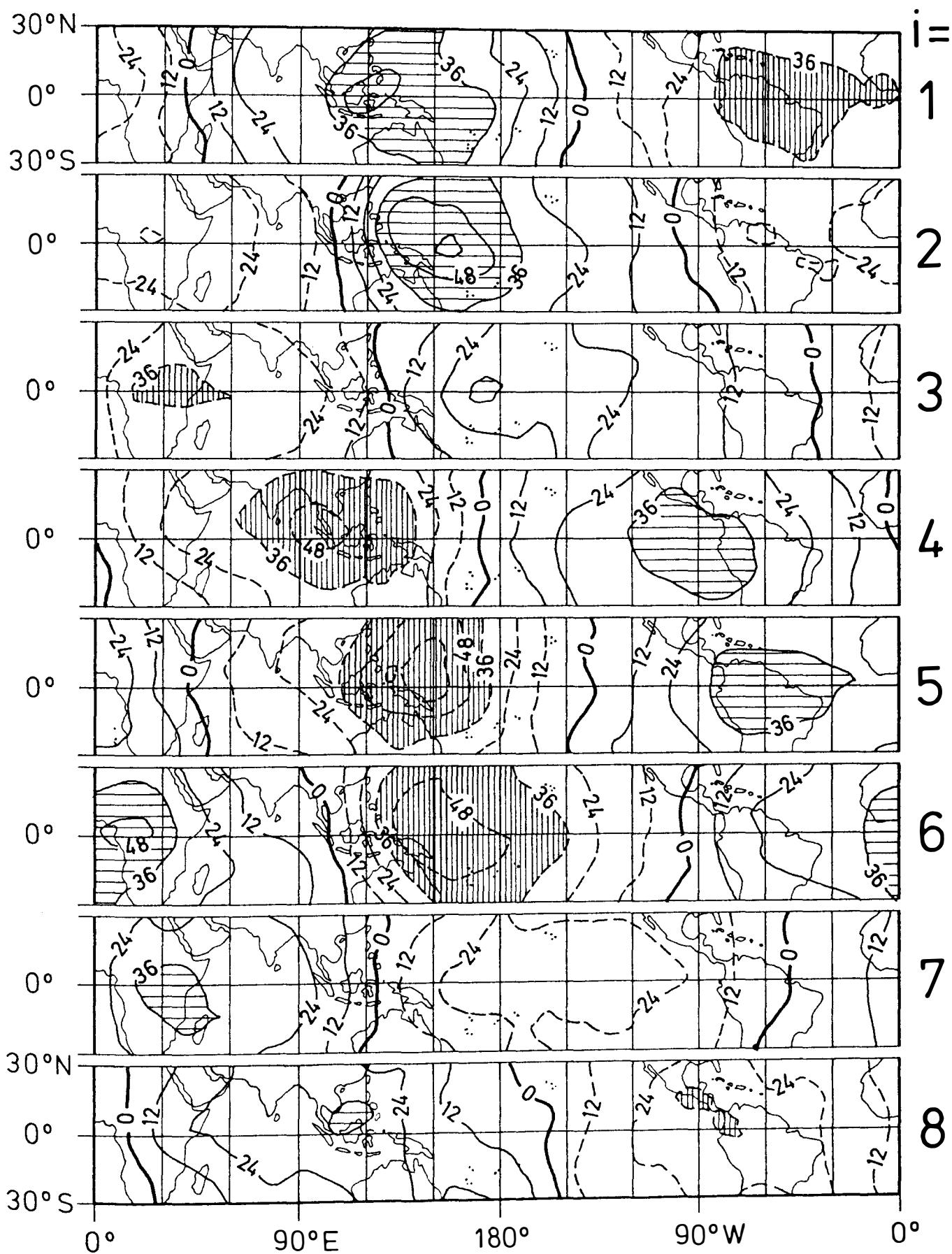


TESTING THE NULL HYPOTHESIS

COHERENCE SQUARED







Conclusions

The MJO and its POP-index

- The MADDEN and JULIAN Oscillation (MJO) is the strongest regular signal on the intra-seasonal time scale.
- The MJO is monitored by its POP-index which is derived from daily equatorial velocity potential. The POP-index may be used to describe the MJO-related variability in
 - the length-of day
 - the intra-seasonal variability of the Summer Monsoons
 - the frequency of tropical cyclones
 - the tropical sea-level
- Presently, the MJO is not good predicted by Numerical Weather Prediction Models. The skill of POP-forecast indicates that the MJO is predictable at least for 10 days. Possibly, the strength of the MJO in an initial field is a predictor of the MJO forecast skill.
- Low-resolution GCMs, which are used in climate studies, reproduce the MJO. The spatial patterns are correctly simulated, the phase speed, however, is about doubled compared to the observations.