UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL ATOMIC ENERGY AGENCY
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

SMR/930 - 27

"Workshop on El Niño, Southern Oscillation and Monsoon"
15 - 26 July 1996

"Role of Seasonal Cycle in the ENSO/Monsoon System"

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Ibaraki
Japan

Please note: These are preliminary notes intended for internal distribution only.

Workshop on ENSO and monsoon
Treieste, Italy, '96.7.15-26

Role of Seasonal Cycle in the ENSO/monsoon System

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Ibaraki, 305, Japan

1. Tropospheric Biennial Oscillation (TBO) in the ENSO/monsoon system

2. Seasonality of TBO and the "monsoon year"

3. Possible mechanisms of TBO
   - 3.1 Atmosphere-ocean interaction in the warm pool region
   - 3.2 Land-atmosphere-ocean interaction through winter and summer monsoon in Asia

4. What determines ENSO or non-ENSO events ?
   Possible role of NAO and the chaos in the extra-torpics

30 signals

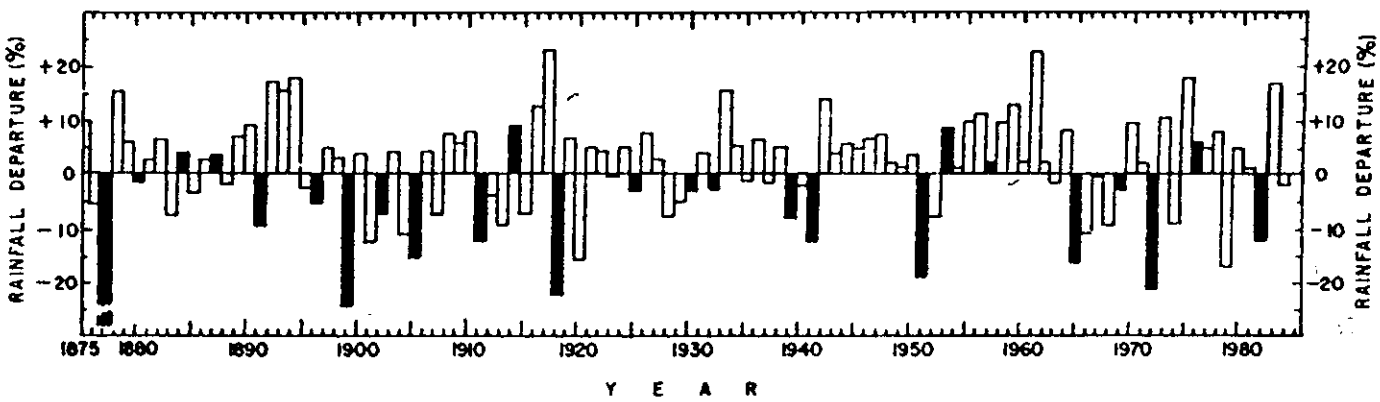
in the Monsoon/ENSO system

- Rainfall (convection)
- SST
- wind

* One anomalous year tends to be followed by the preceded year with opposite anomaly

* Seasonality
  - from boreal summer to the following spring
  - "monsoon year"

インドモンスーン降水量
と
エル・ニーニョ発現



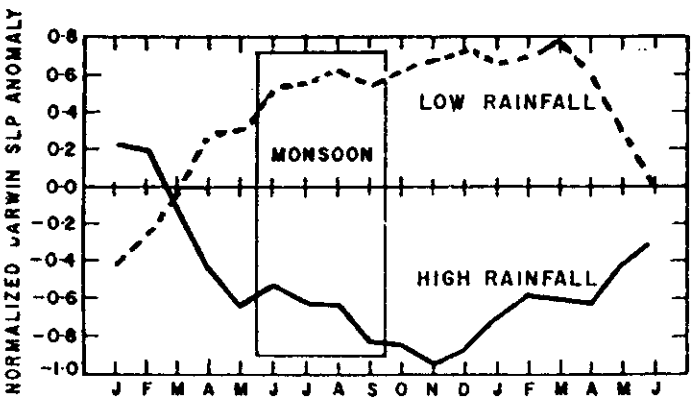
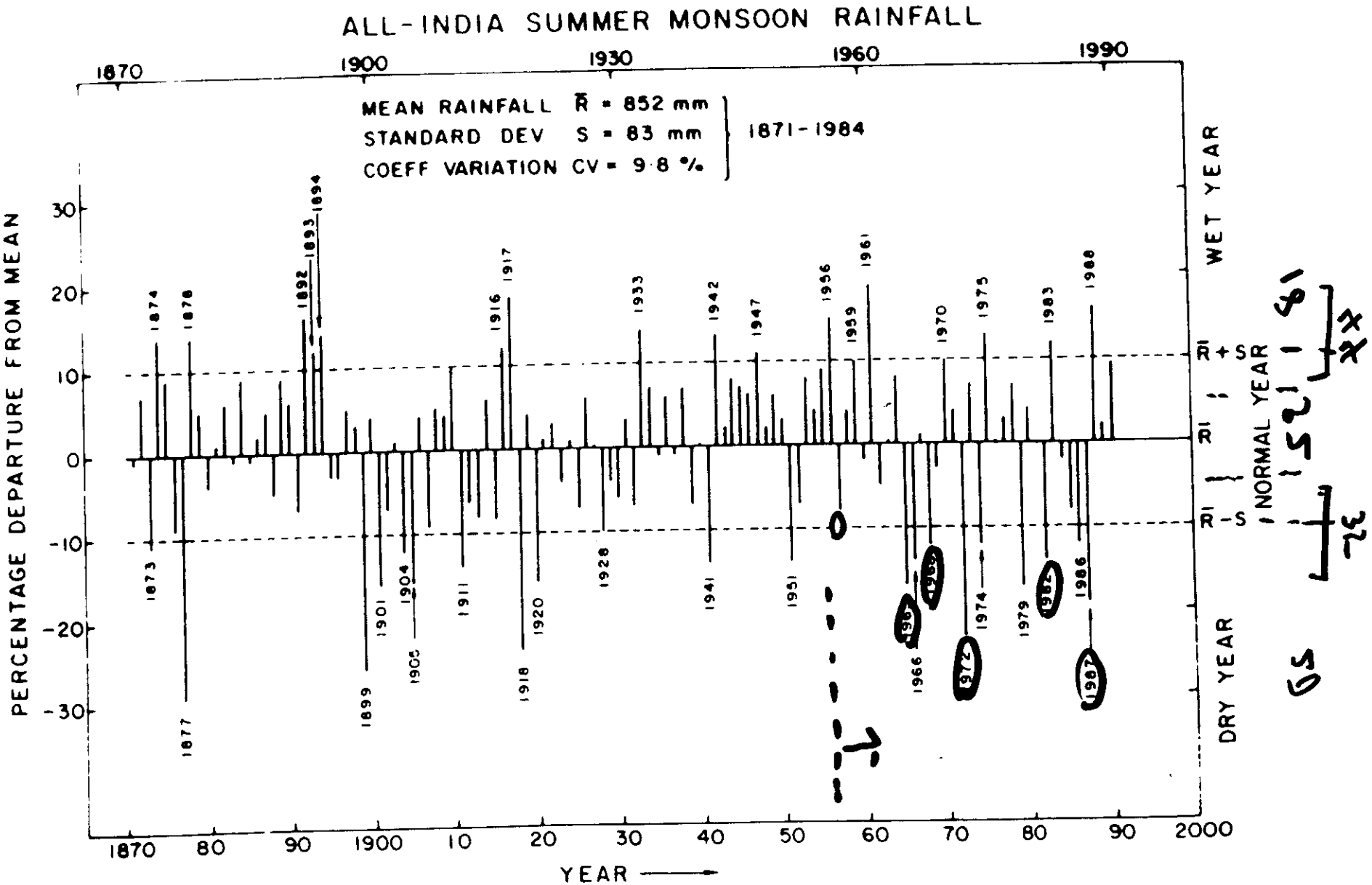
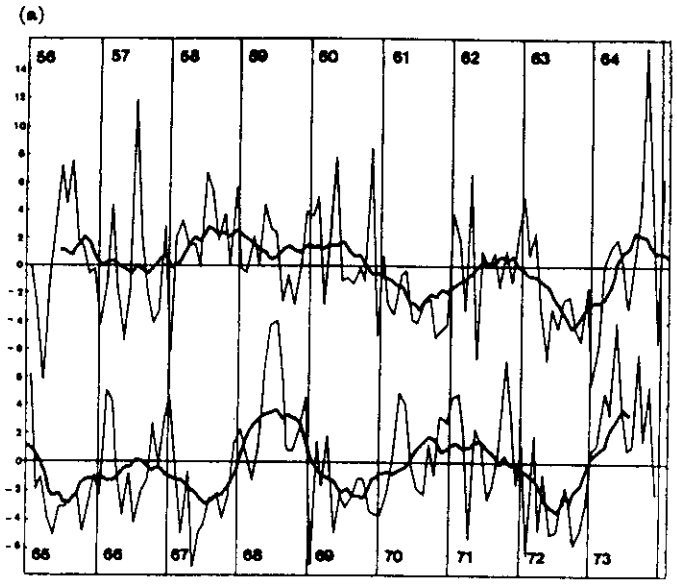


Figure 42: *Top:* Monsoon rainfall over India expressed in percentage departure, with *El Niño* events indicated by black shaded pillars (from Mooley and Shukla, 1985). *Left:* Composite of normalized Darwin pressure anomaly (3-month running mean) for heavy monsoon rainfall years (solid), and deficient monsoon rainfall years (dashed) (from Shukla and Paolino, 1983).

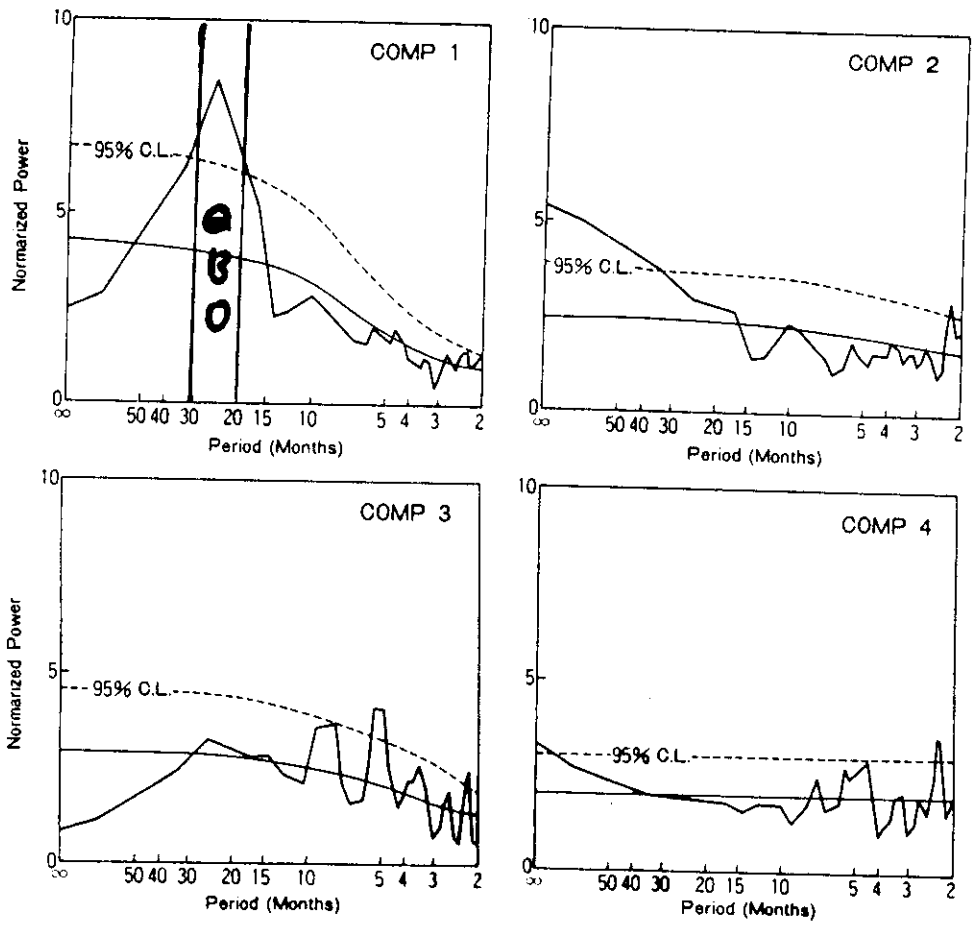


YEAR-TO-YEAR PERCENTAGE DEPARTURE FROM MEAN OF ALL-INDIA SUMMER MONSOON RAINFALL FROM THE YEAR 1871 ONWARDS EXCESS / DEFICIENT YEARS ARE MARKED AGAINST BARS



PCA-1

INDONESIAN MONTHLY RAINFALL (54 stations)



QBO in the PCA-1 Indonesian Rainfall.

Fig. 8 Power spectra of the time coefficients for the first to the fourth component. Power spectrum is normalized by deviding them by the variance of each component. The red noise or white noise level (thin solid line), and the limit of the 95% confidence level (dashed line) are also shown in each case. (Yasunari, 1981)

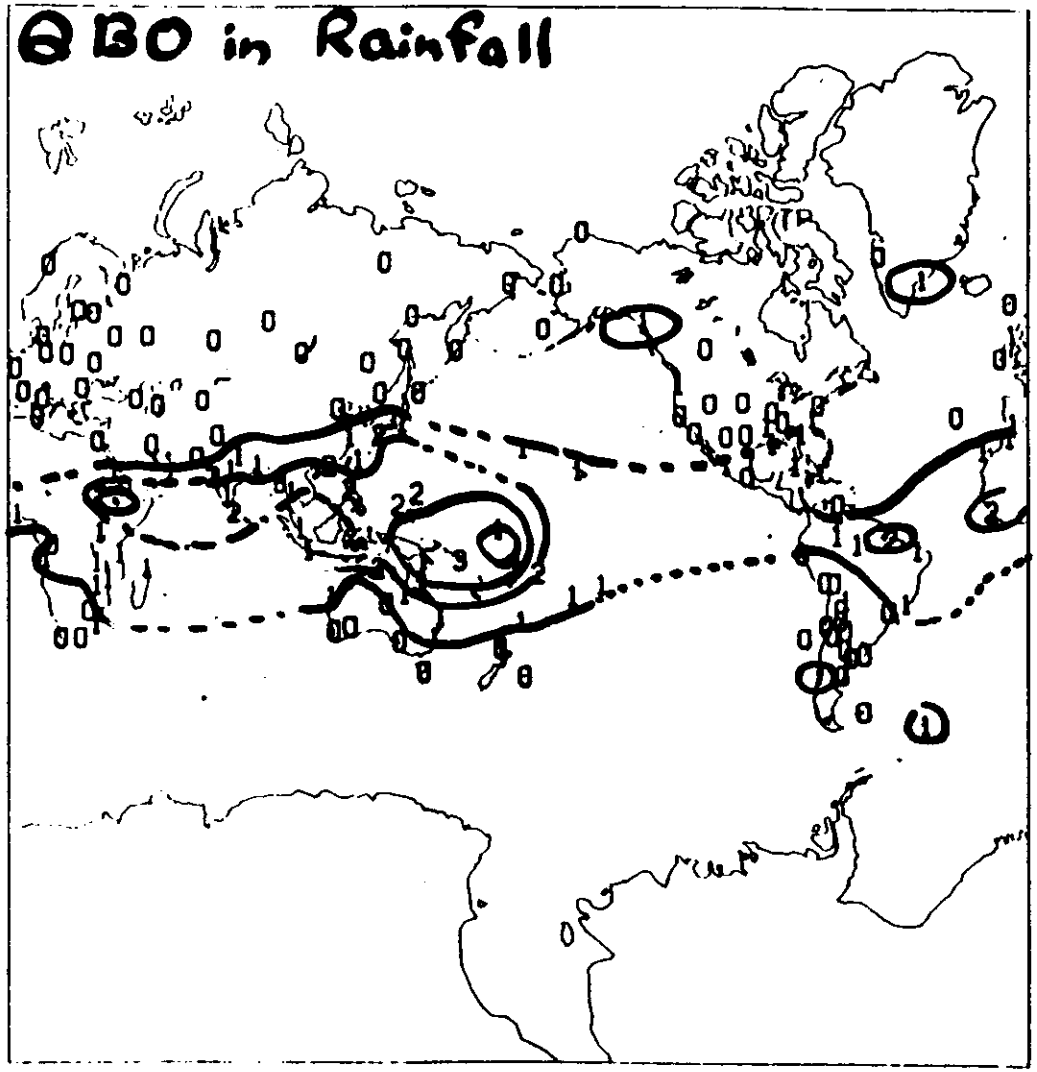
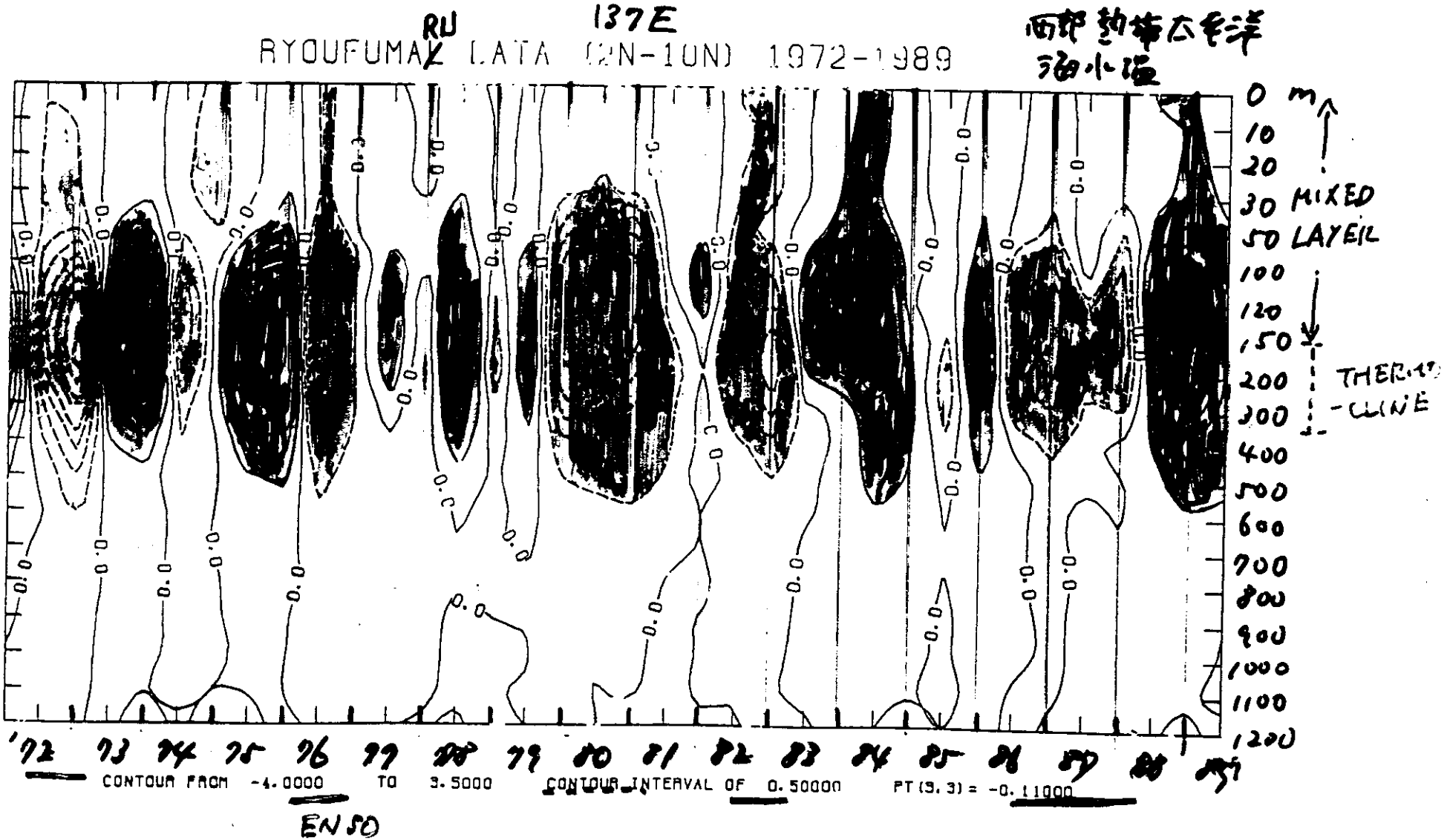


図1　降水量のＱＢＯの分布。
0 : < 10
1 : 10 − 20
2 : 20 − 30
3 : 30 − 40
4 : > 40
（単位：mm/month）

OCEANIC MIXED LAYER TEMPERATURE IN THE W. PACIFIC

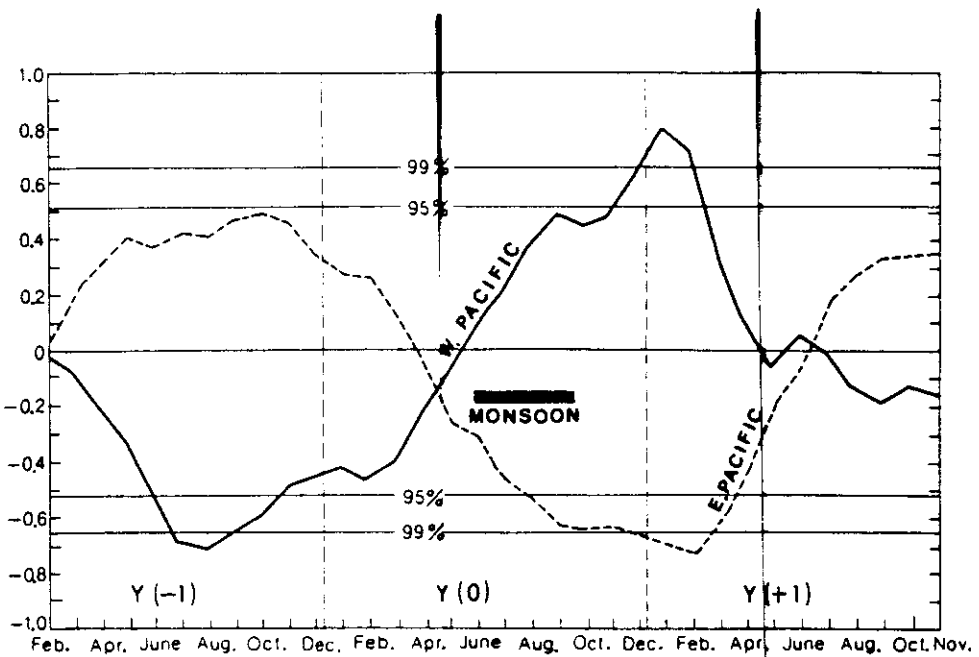


COR.

INDIAN MONSOON RAINFALL VS. SST PACIFIC (0-8N)

W. (130 -150 E)

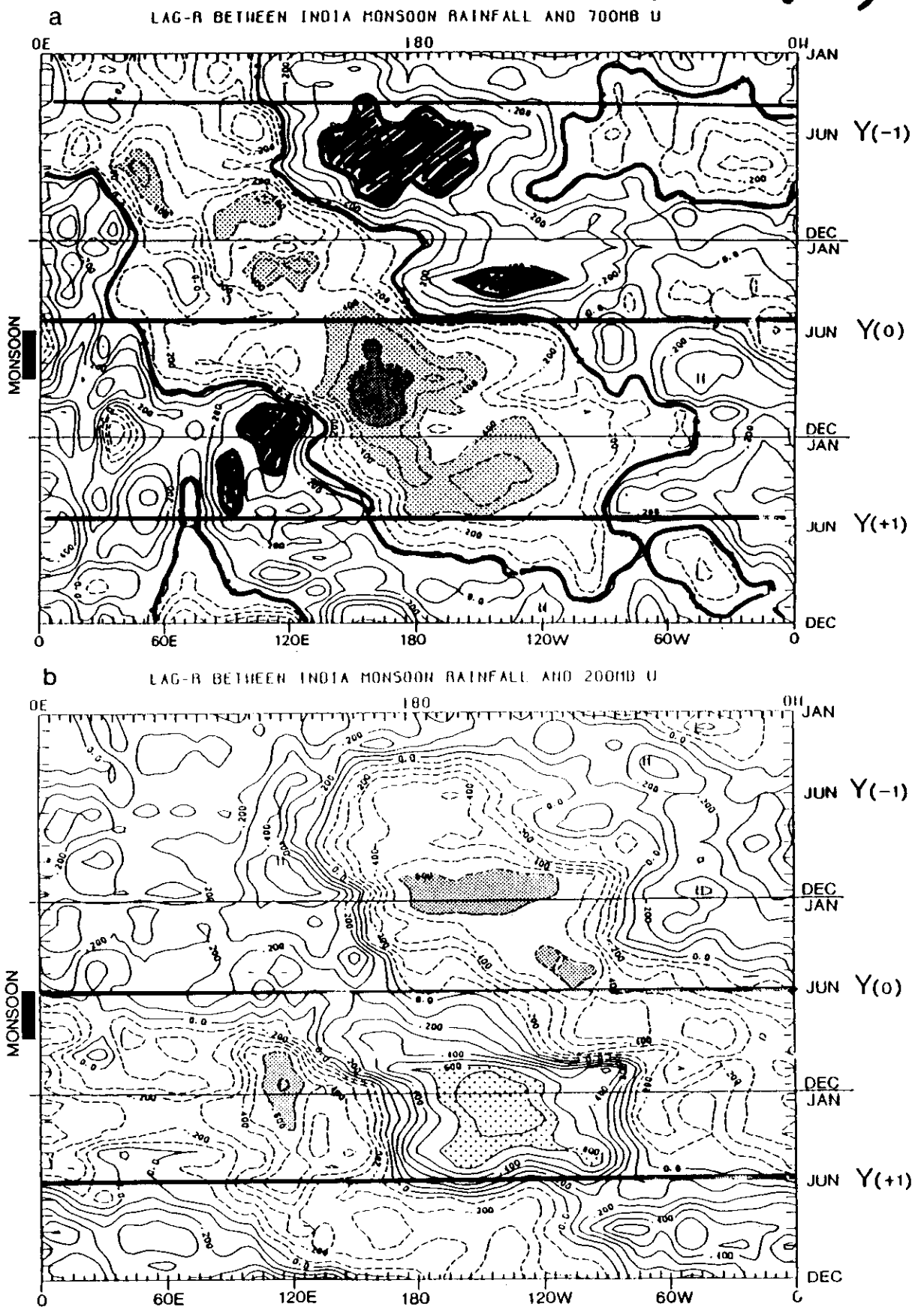
E (140W - 150W)



← MONSOON YEAR →

Yasunari (1990)

IMR vs U700MB (EQ)



アジアモンスーンと大気・海洋結合系 (MAOS)

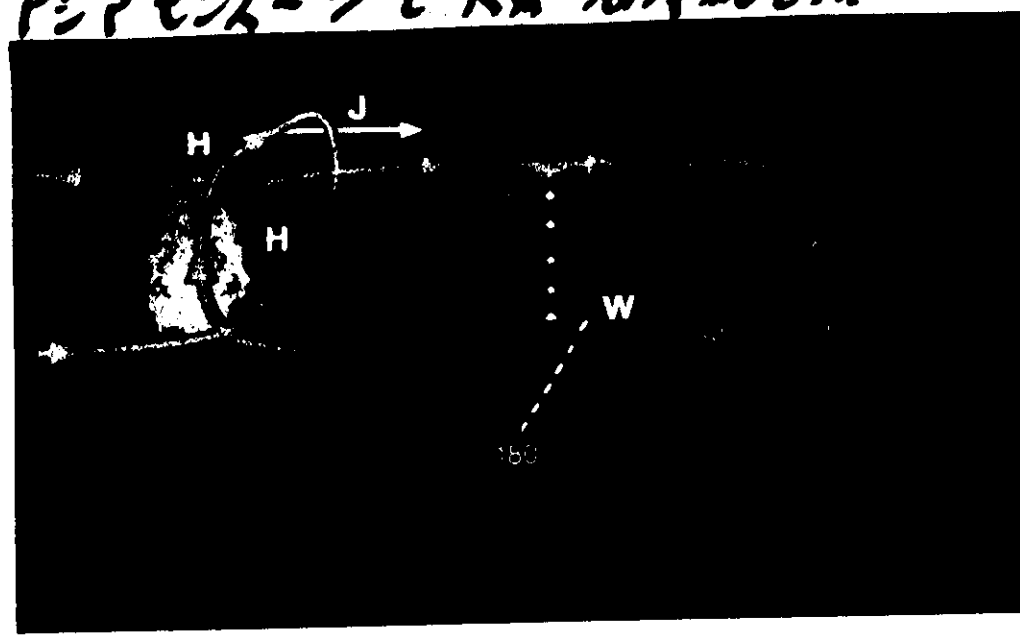


Figure 8b. Schematic illustration (not to scale) of the Walker circulation in the Pacific Basin and its interaction to reinforce (under non-El Niño conditions) the east Asian branch of the Hadley cell. The red area denotes the normally warm SST's in the region of the "maritime continent," which are associated with intense convective rain, as indicated by the cloud. The dashed line just east of the date line depicts the eastward shift of the axis of the upward branch of the Walker cell during an ENSO situation.

Monsoon / Atmosphere-Ocean System (MAOS)

the atmosphere is concentrated into a very narrow latitudinal band is shown in Figures 5 and 10. Figure 10 shows a pre-satellite map of oceanic precipitation (Malkus, 1962) constructed by extrapolating from land and island stations, with the results adjusted so that global water and heat energy budgets are balanced. The lack of precipitation measurements to substantially improve Figure 10, which may have significant errors, has been a major obstacle to the development of Earth system science during the past quarter century. Figure 10 again brings home the latitudinal concentration of the precipitation[5] heat release and shows that it is the major supply providing the source for the huge poleward export of heat and potential energy; precipitation heating is also the major term which acts toward balancing outgoing radiative heat losses at all latitudes.

In studying the heat budget of the Equatorial Trough Zone and investigating the mechanisms and interacting scales of motion which maintain it, Riehl and Malkus (1958) found the necessity to postulate their "hot tower" hypothesis, which in the past three decades has gained many applications and gradual acceptance in tropical meteorology. They recently repeated the same analyses with vastly more extensive and improved data sources and arrived at essentially the same results (Riehl and Simpson, 1979). A result relevant to TRMM is summarized in Table 4.

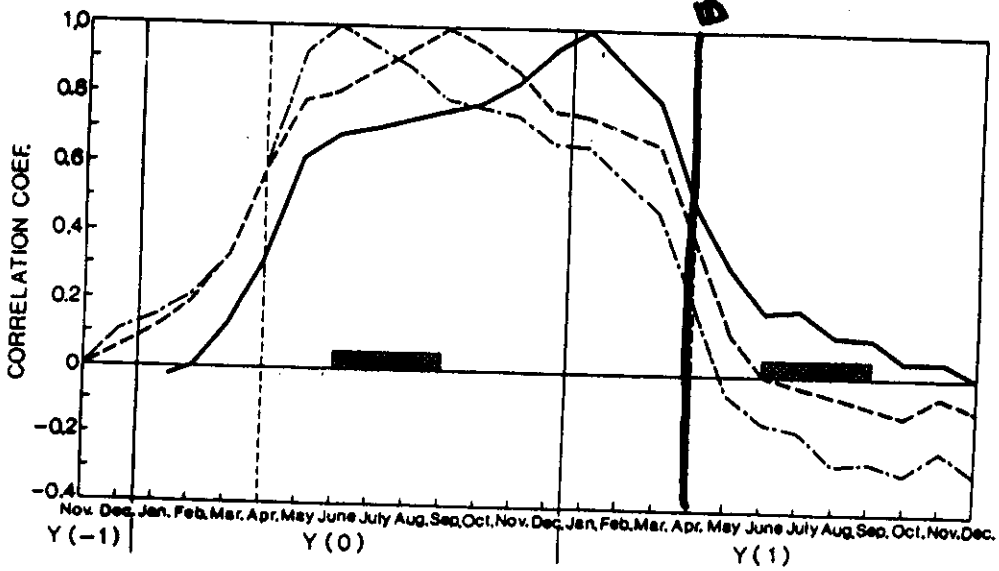
One of the most important findings concerning mechanisms in the atmosphere's Equatorial Trough Zone was that the vertical transports must be effected by large buoyant cumulonimbus cores or "hot towers," which have undergone little or no dilution from the mixing in, or entrainment, of the drier outside air. In conducting their budget study, Riehl and Simpson (1979, *loc. cit.*) were able to estimate the vertical energy flux from the undiluted hot towers, and using typical cloud measurements, were able to specify how many towers are needed at one time. This figure comes out to be about 1,600-2,400 cloud towers. The interacting scales involved and the extreme concentration of the "firebox" (or heat release) is brought home by the decadal hierarchy of numbers in Table 4. Clearly, since there are so few cloud cylinders in the atmosphere firebox, and cloud growth is highly dependent on their forcing and their environment, one might expect large circulation variabilities related to variation in the high towers and their latent heat release.

Only now, with the prospect of the TRMM satellite, has it become realistic to expect to begin documenting variabilities in these intense convective cores, their top heights, together

[5]The heat is initially released by the condensation of gaseous water vapor into very small liquid cloud droplets, about 5 to 10 mm in diameter. These droplets must grow by coalescence or other processes to 100 to 300 mm (0.1 to 0.3 mm) before they have sufficient terminal velocities to fall as rain. The rain must reach the Earth or ocean surface to add a net amount of latent heat to the air, for if the small drops remain airborne and evaporate, the condensation heating is reabsorbed. Hence, the shorter expression "precipitation heating" is commonly used.

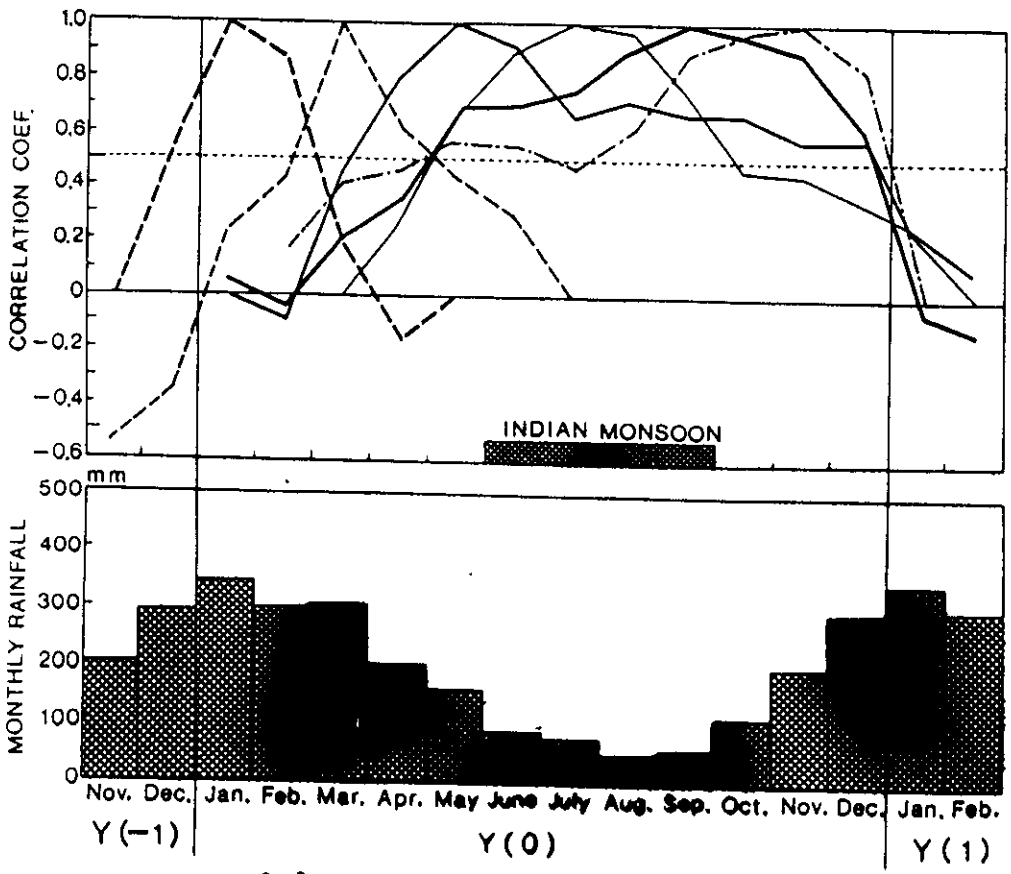
Predictability Barrier

Indian monsoon rainfall vs. SOI.



(Yasunari, 1991)

Indonesian rainfall 同じ傾向



(Yasunari and Suppiah, 1988)

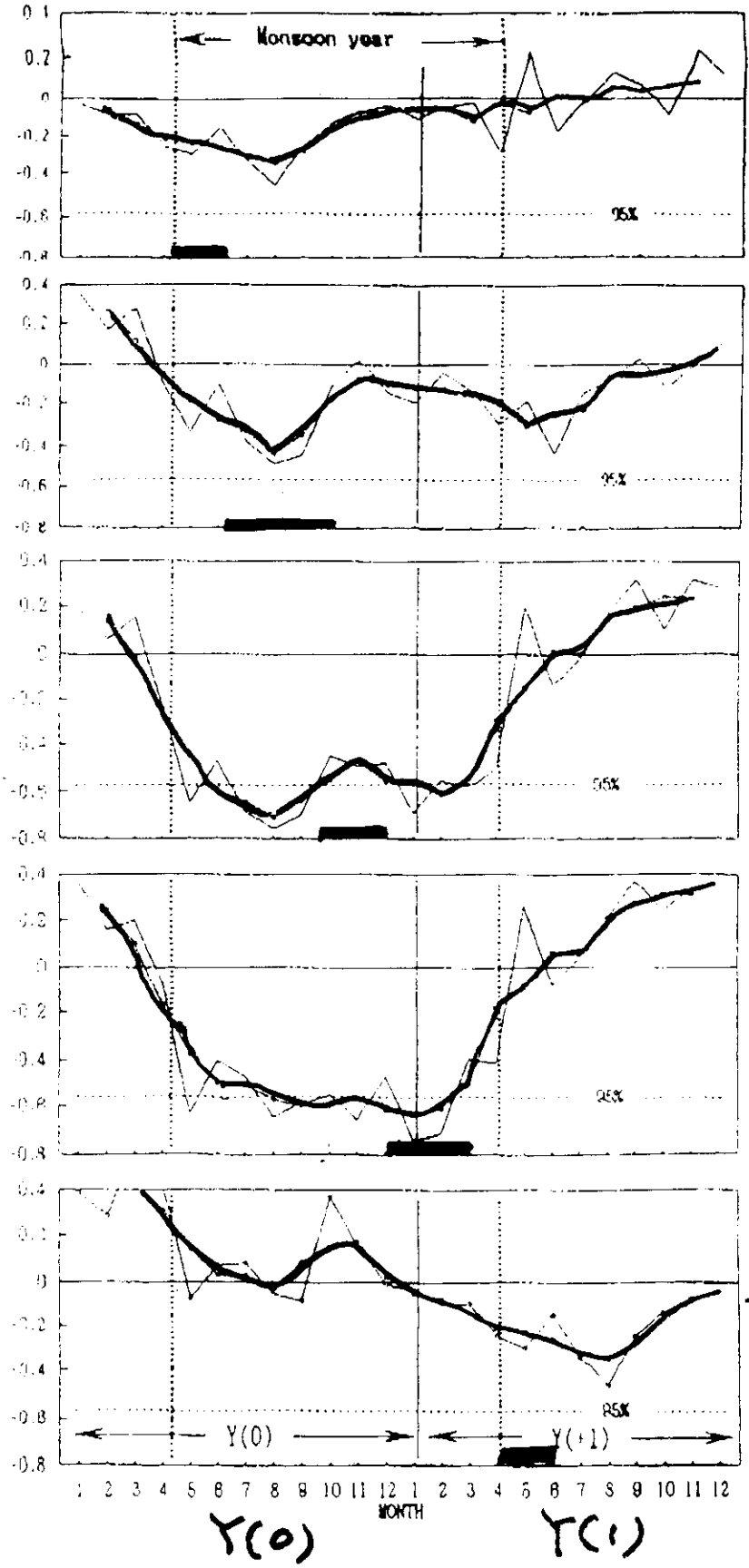
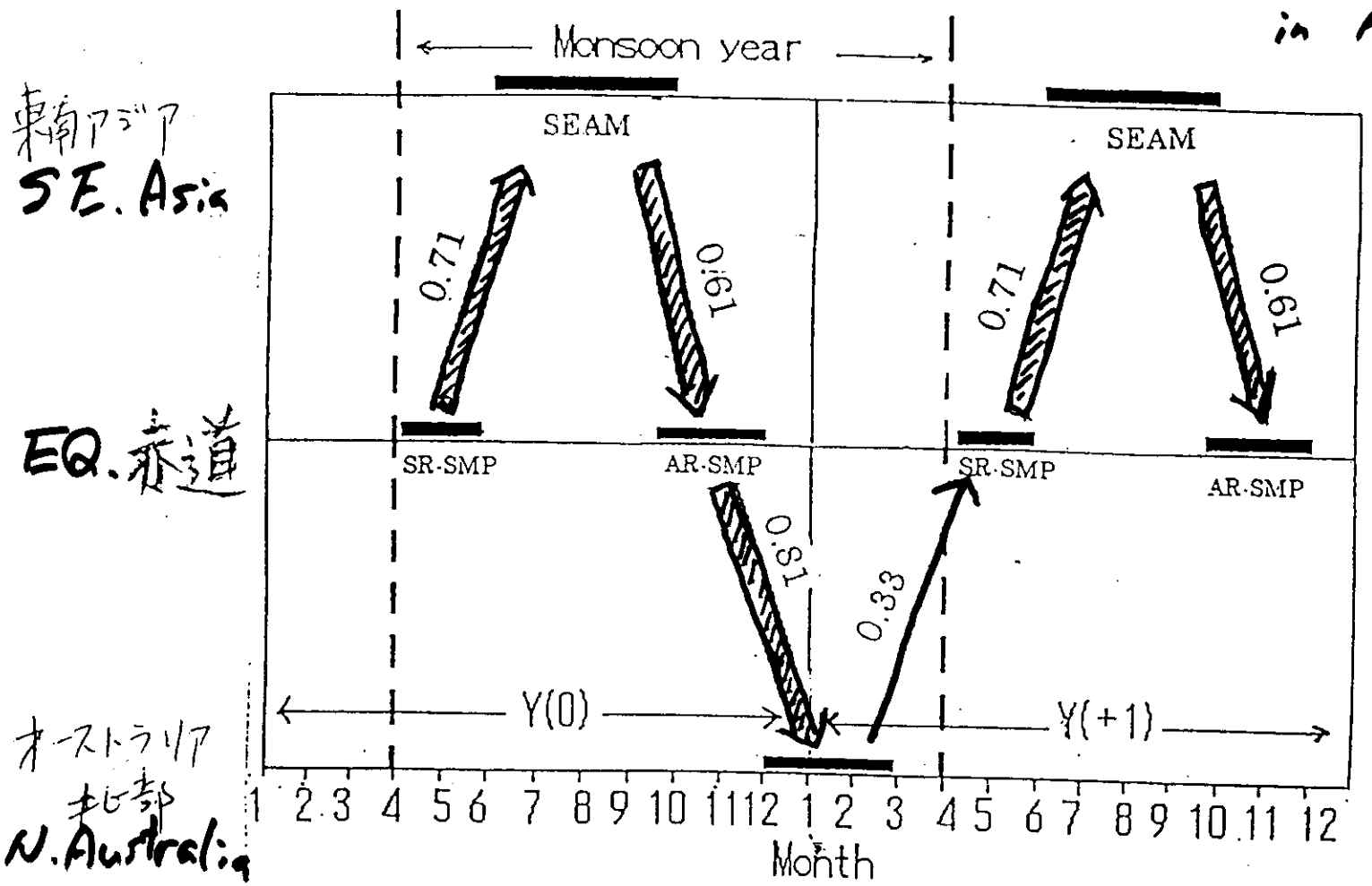


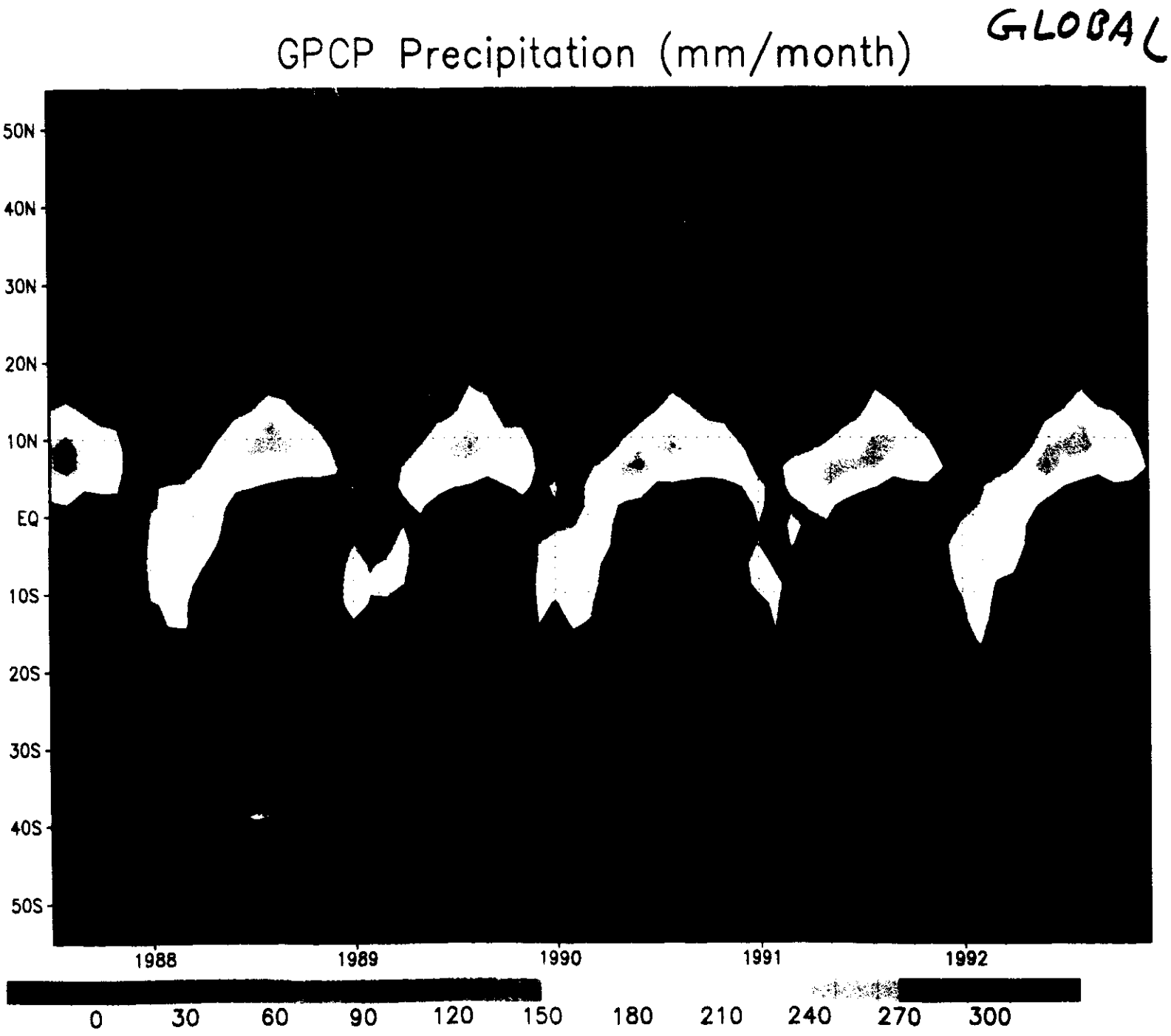
図3. モンスーンとSOIの相関係数の季節変化 (Li and Yasunari, 1996)

Fig. 2 (LAG) correlation diagram between convection anomalies in Asia/Australian mo



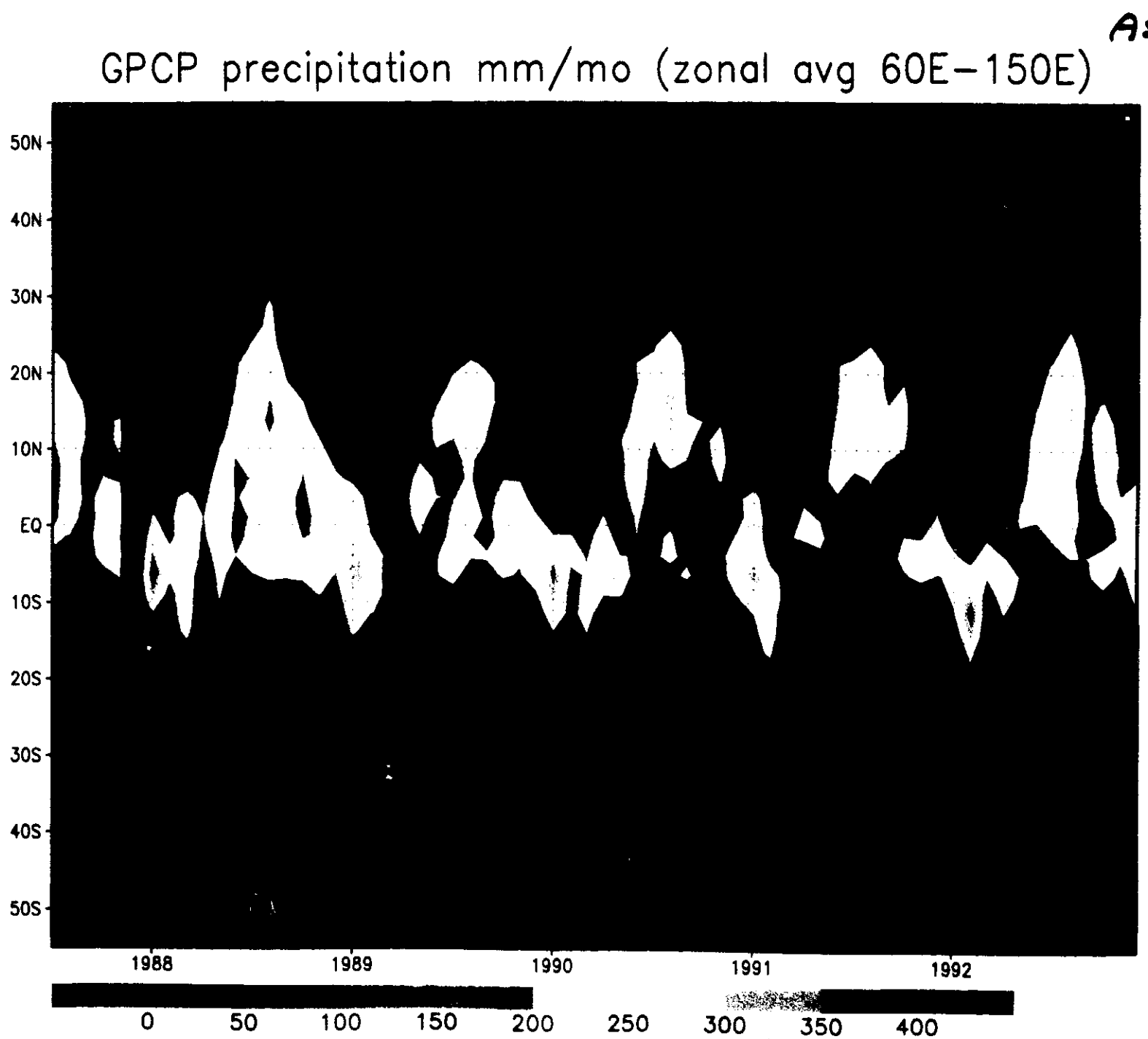
(Li and Yasunari, 1996)

GLOBAL



by Courtesy of A. Grub

ADS: COLA/IGES


GPCP precipitation mm/mo (zonal avg 60E–150E)
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
1988
1989
1990
1991
1992
0
50
100
150
200
250
300
350
400

- "monsoon year" with predictability barrier in b. spring.

Then.

- How is signals interannual variability conveyed from winter to summer?

Signals in the b. spring.

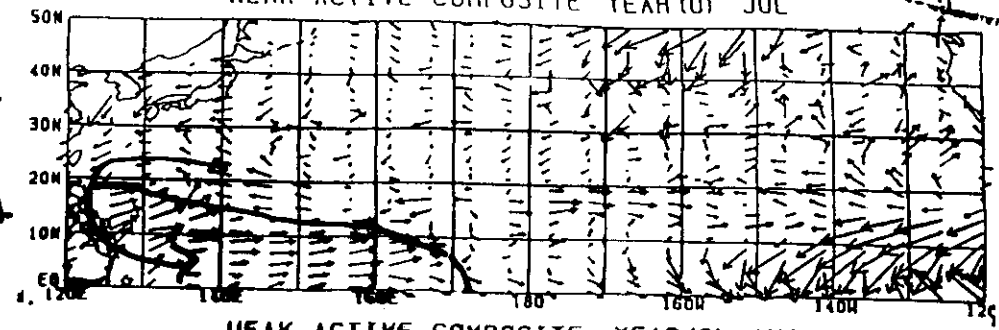
- Eurasian snow cover
- Wind field in sub-tropical W. Pacific
- SST in South China Sea

Indic

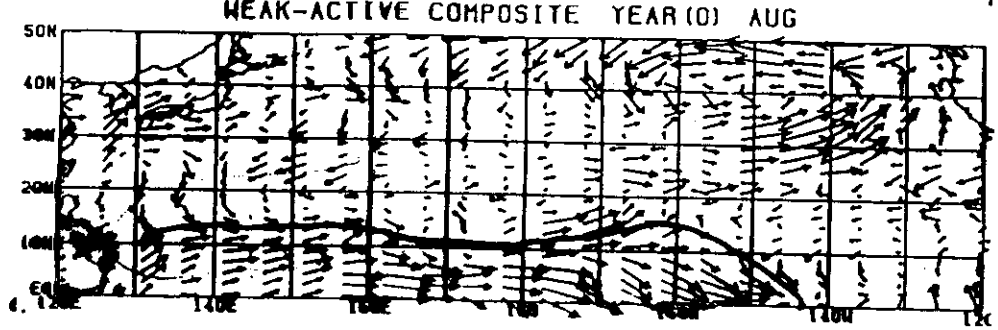
WEAK M.

I

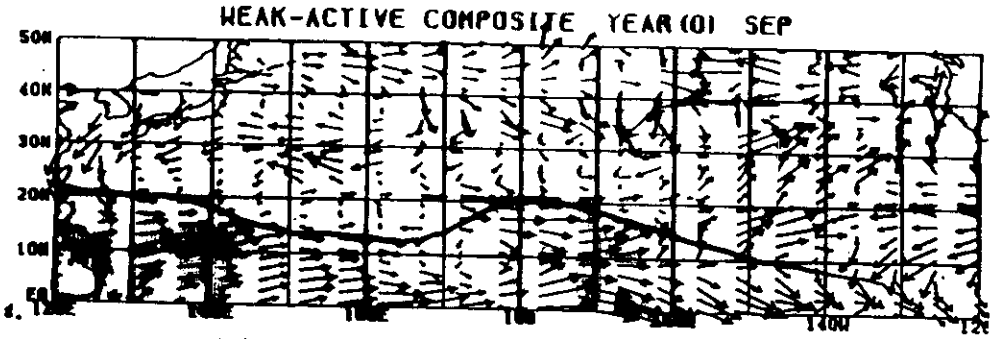
ACTIVE M.



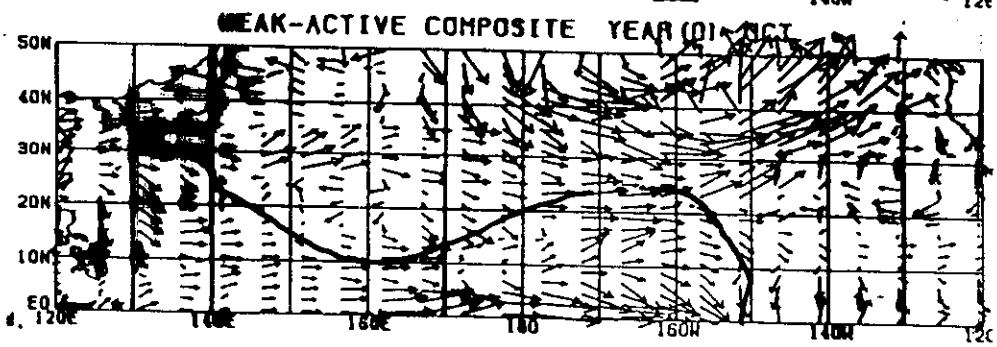
JUL



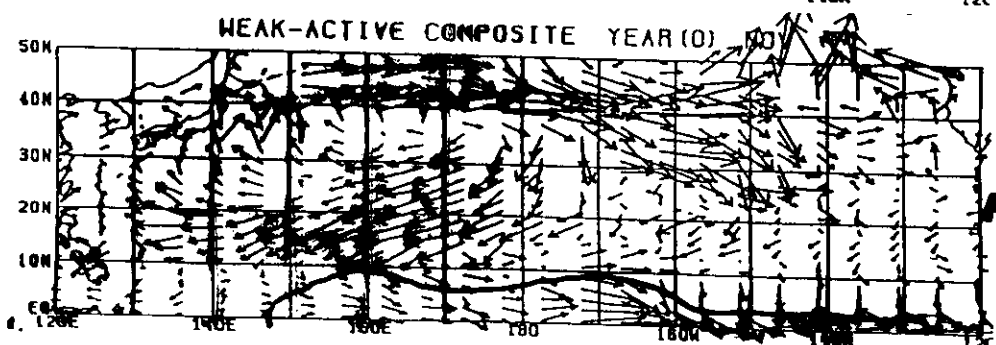
AUG



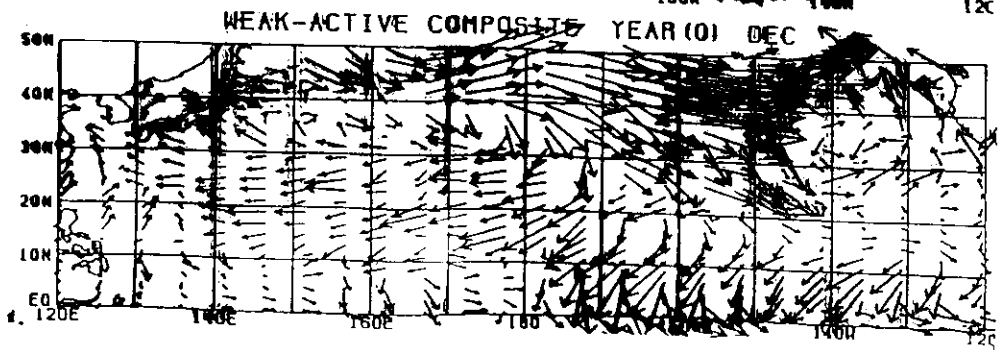
SEP



OCT



NOV



DEC

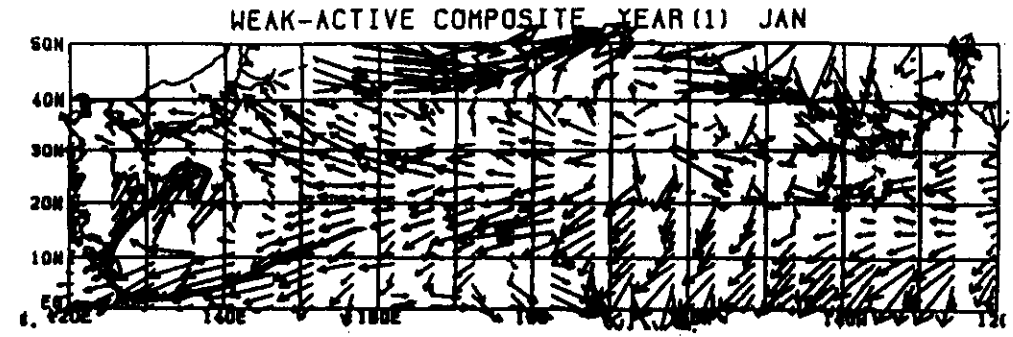
8

IMR

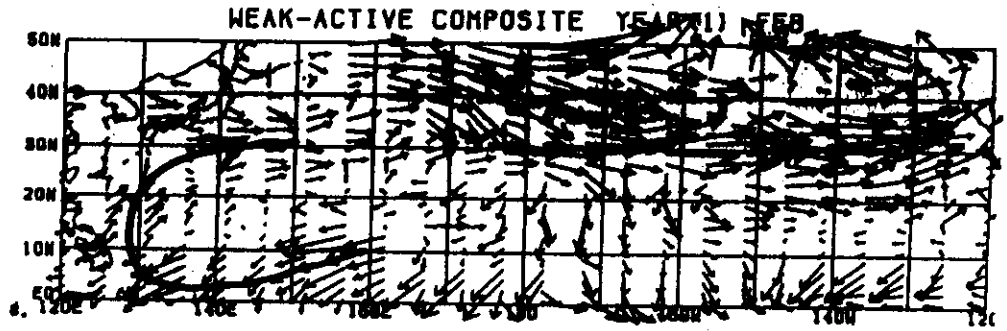
WEAK

I

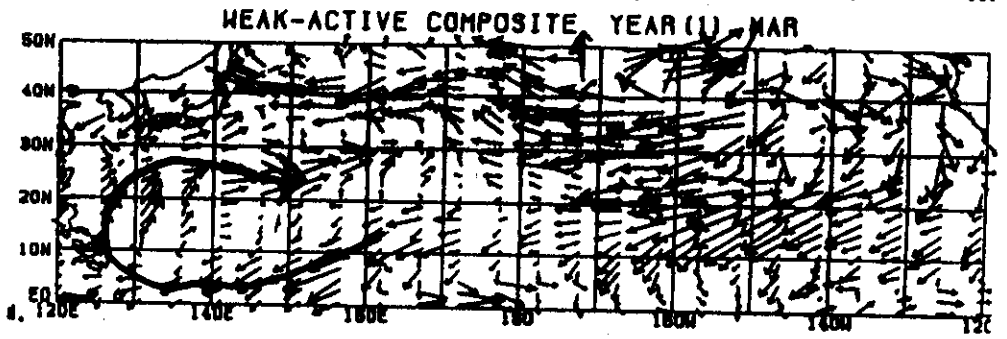
ACTIVE



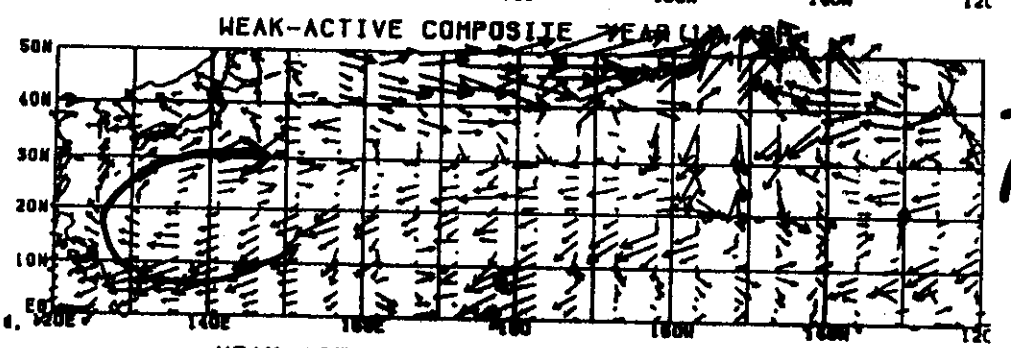
+1 JAN



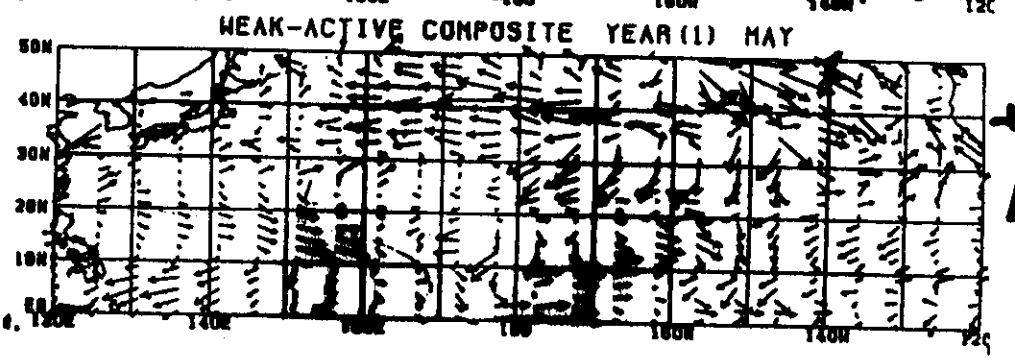
+1 FEB



+1 MAR

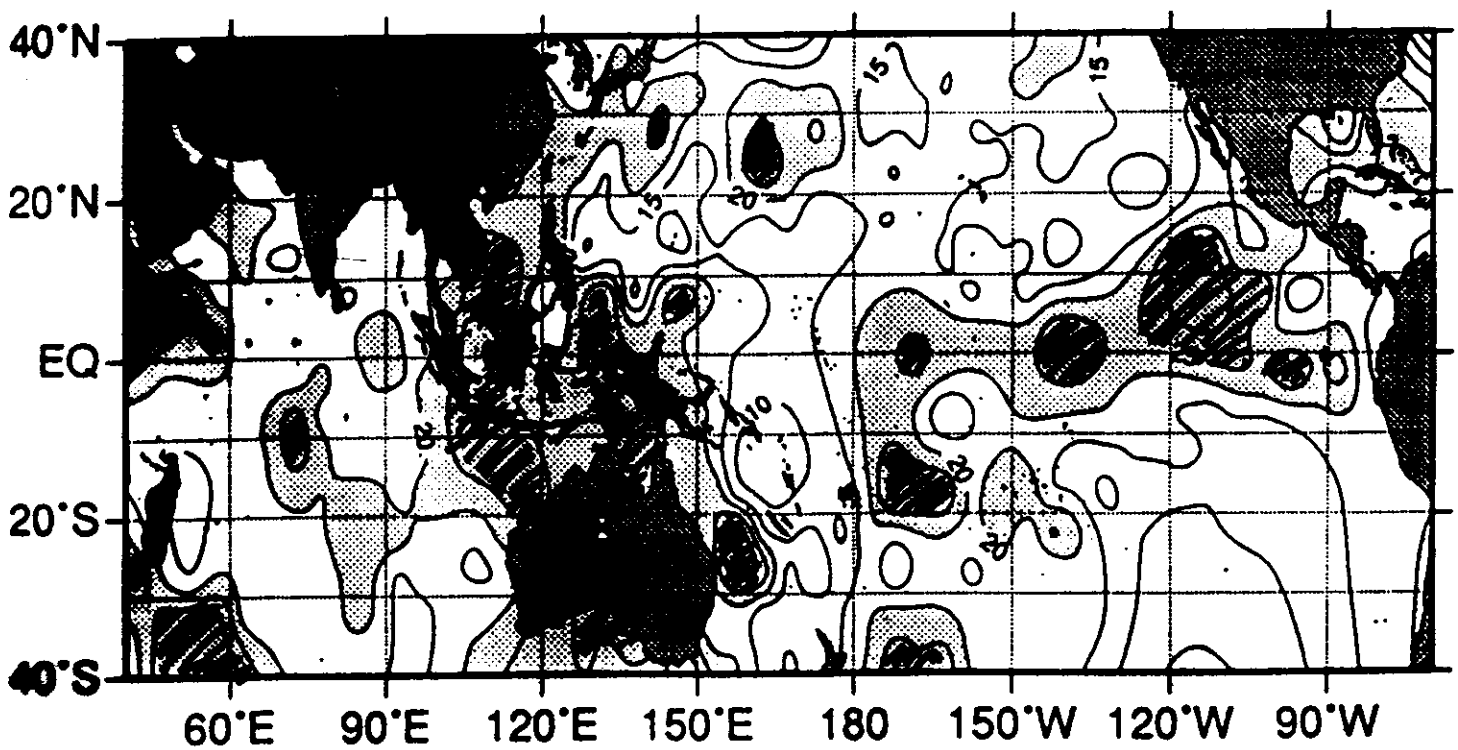


+1 APR

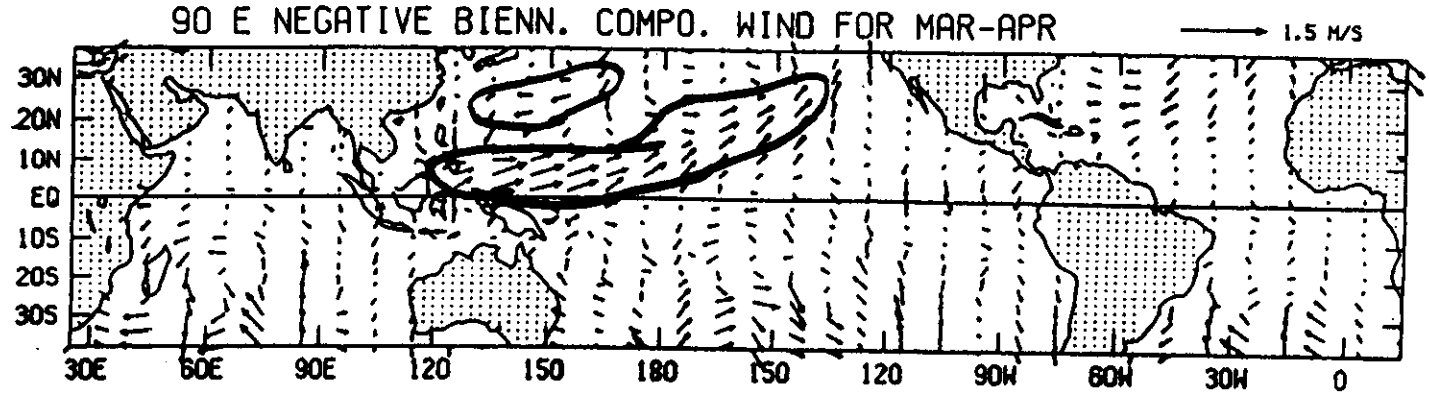


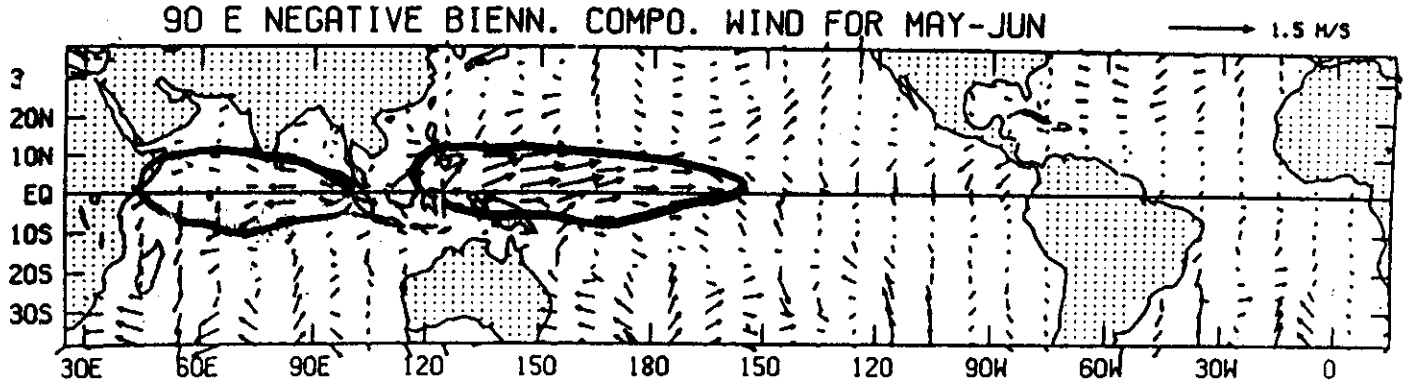
+1 MAY

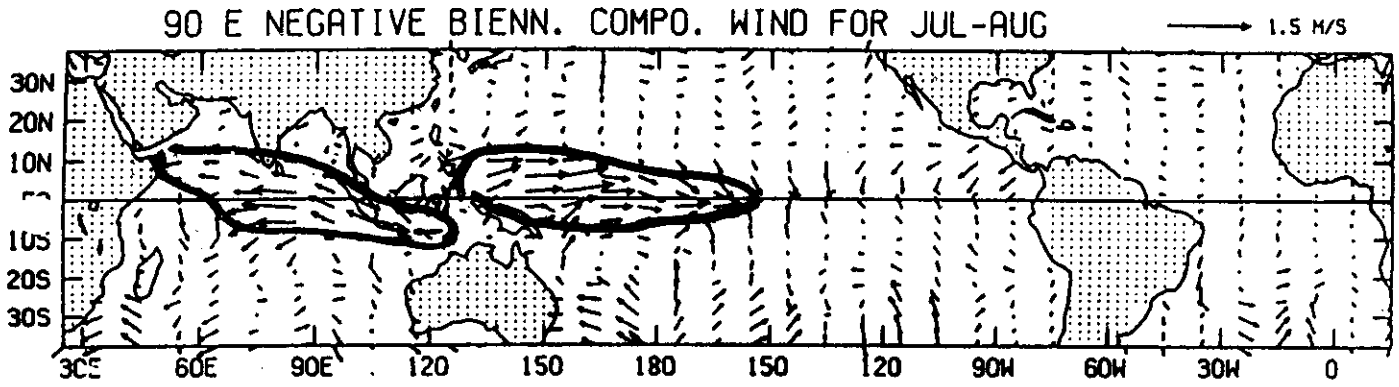
Ratio of QB variance (of SST) to the total variances

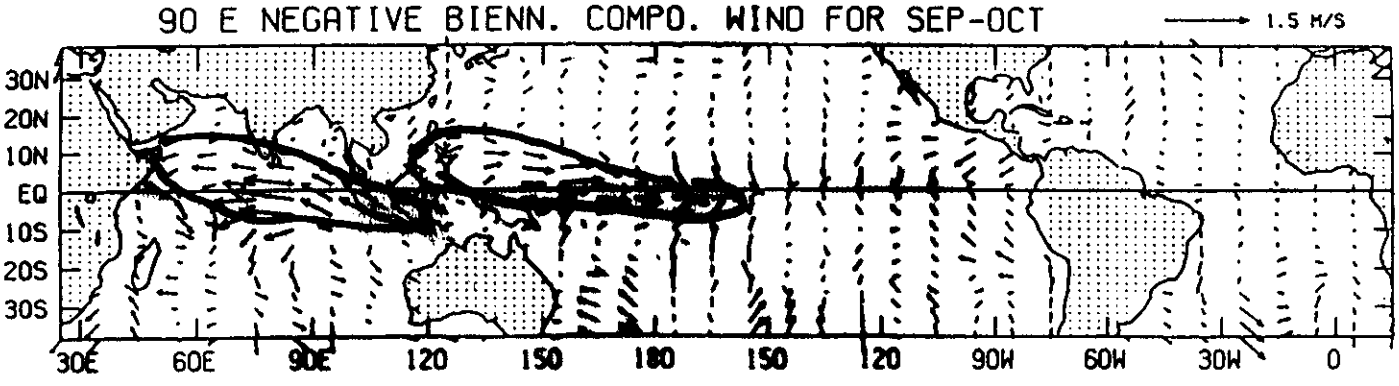


(Tomita and Yasunari, 1995)









Rasmusson et al. (1989)

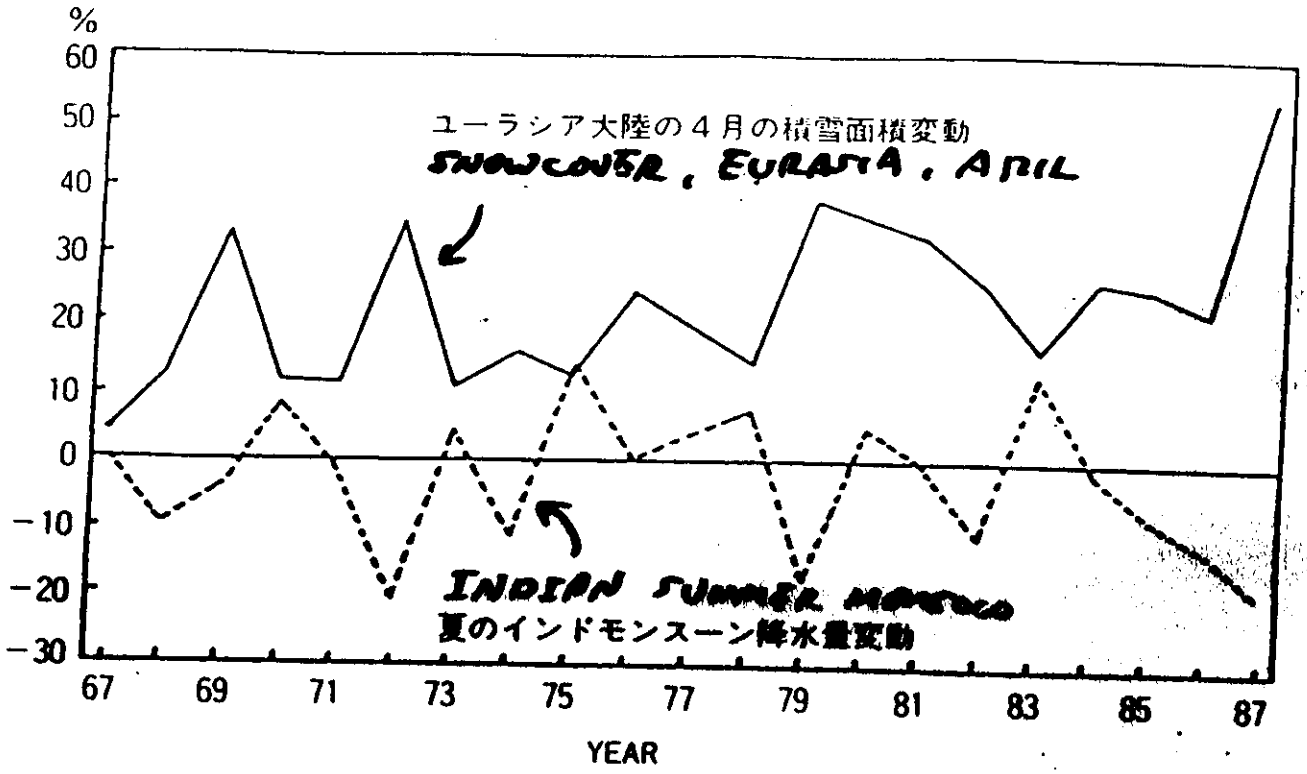


図 3 (Morinaga and Yasunari, 1986)

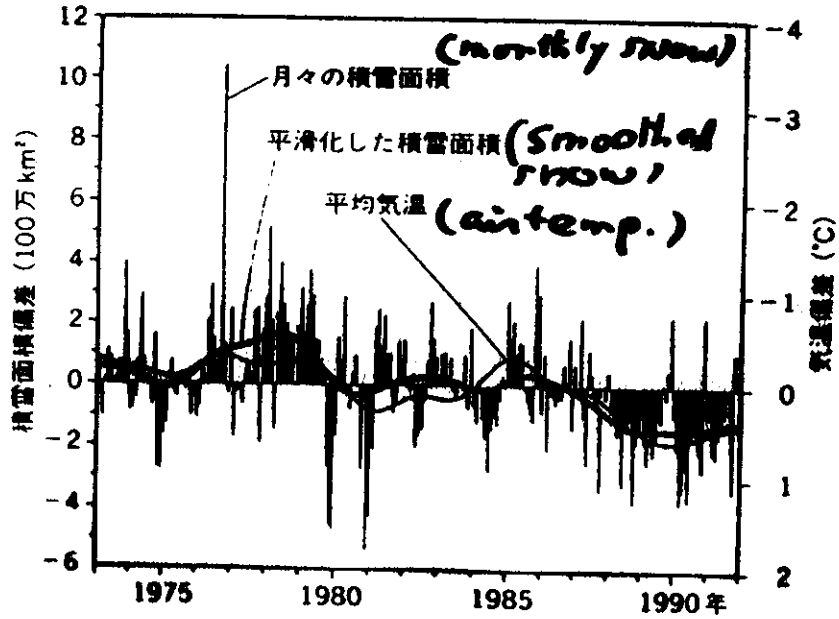


図4 北半球の積雪面積と平均気温の変動．それぞれ平均値からの偏差で表わしている．

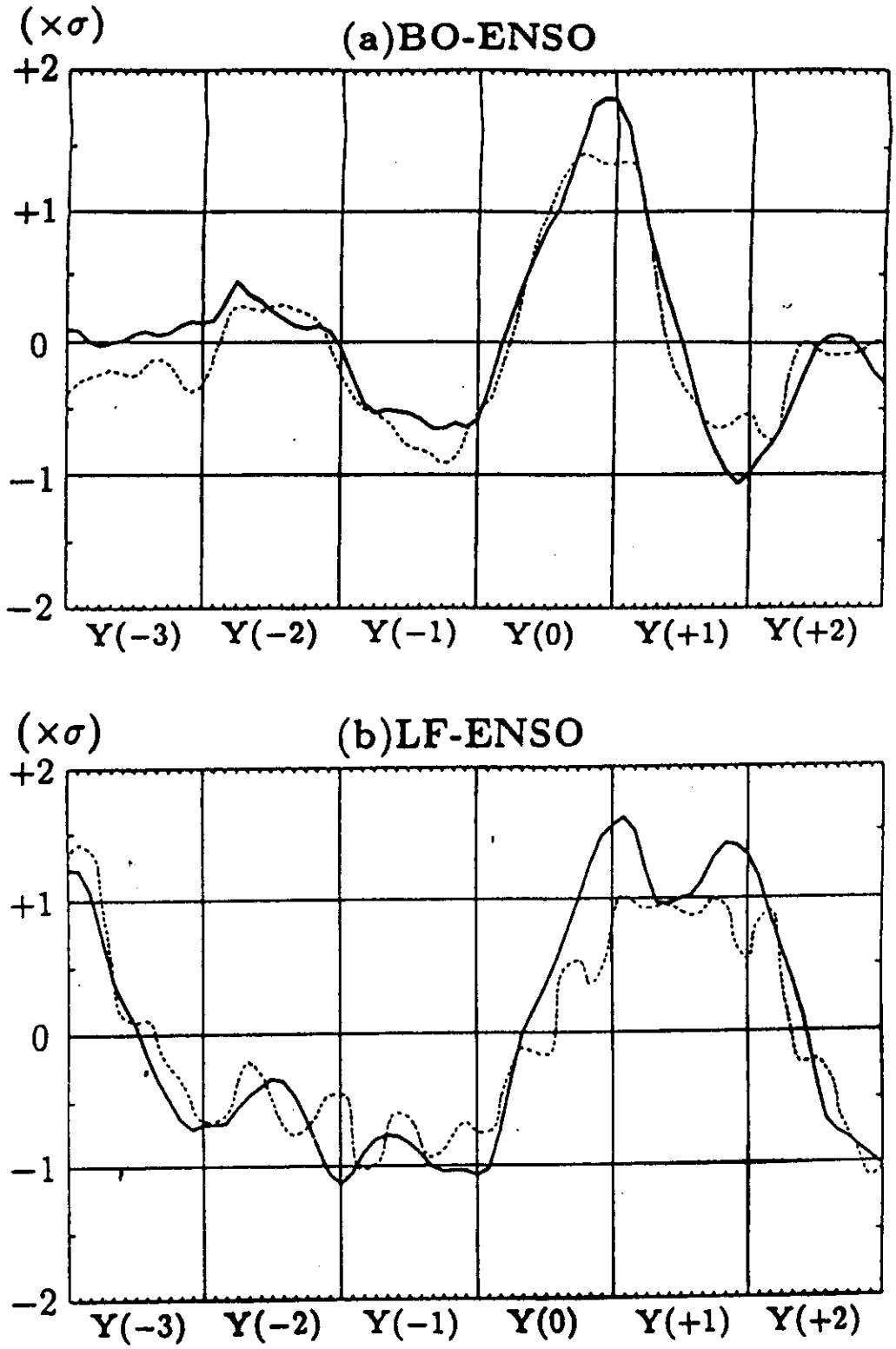
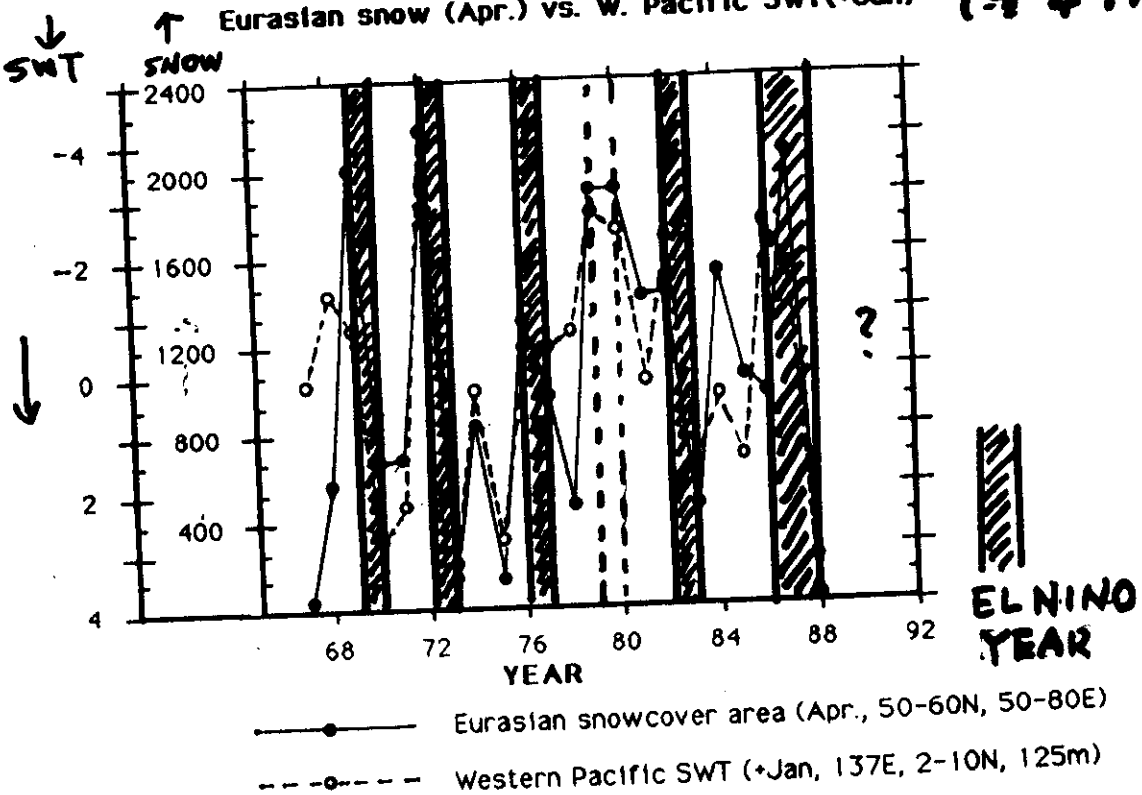
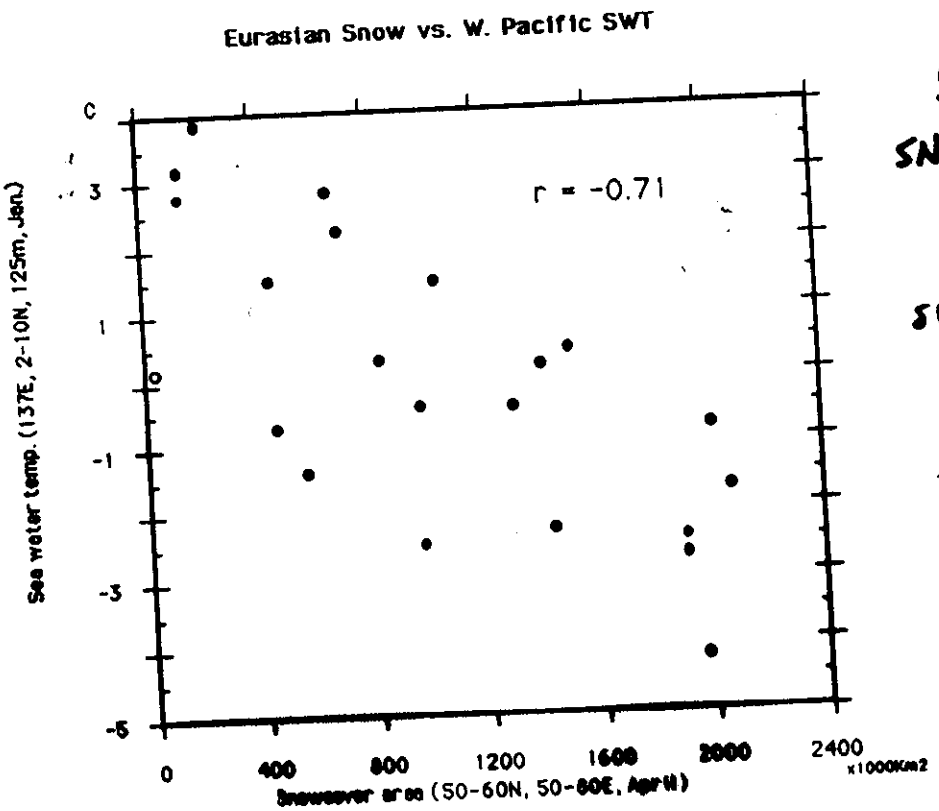


Fig. 3. The composite diagrams of (a) a BO-ENSO and (b) an LF-ENSO using the time series of Fig. 2. Solid (dashed) line indicates the mean SST ($-1 \times$ SOI).

ユーラシアの雪(4月) と 西太平洋 混合層水温 (翌年1月)



(Yasunari, 1990b)



CORRELATIONS.

SNOW vs. SWT
-0.71

SWT vs. IMR
+0.69

IMR vs. SNOW
-0.54

SST(DEC-FEB) in South China Sea and succeeding Indian Monsoon Rainfall

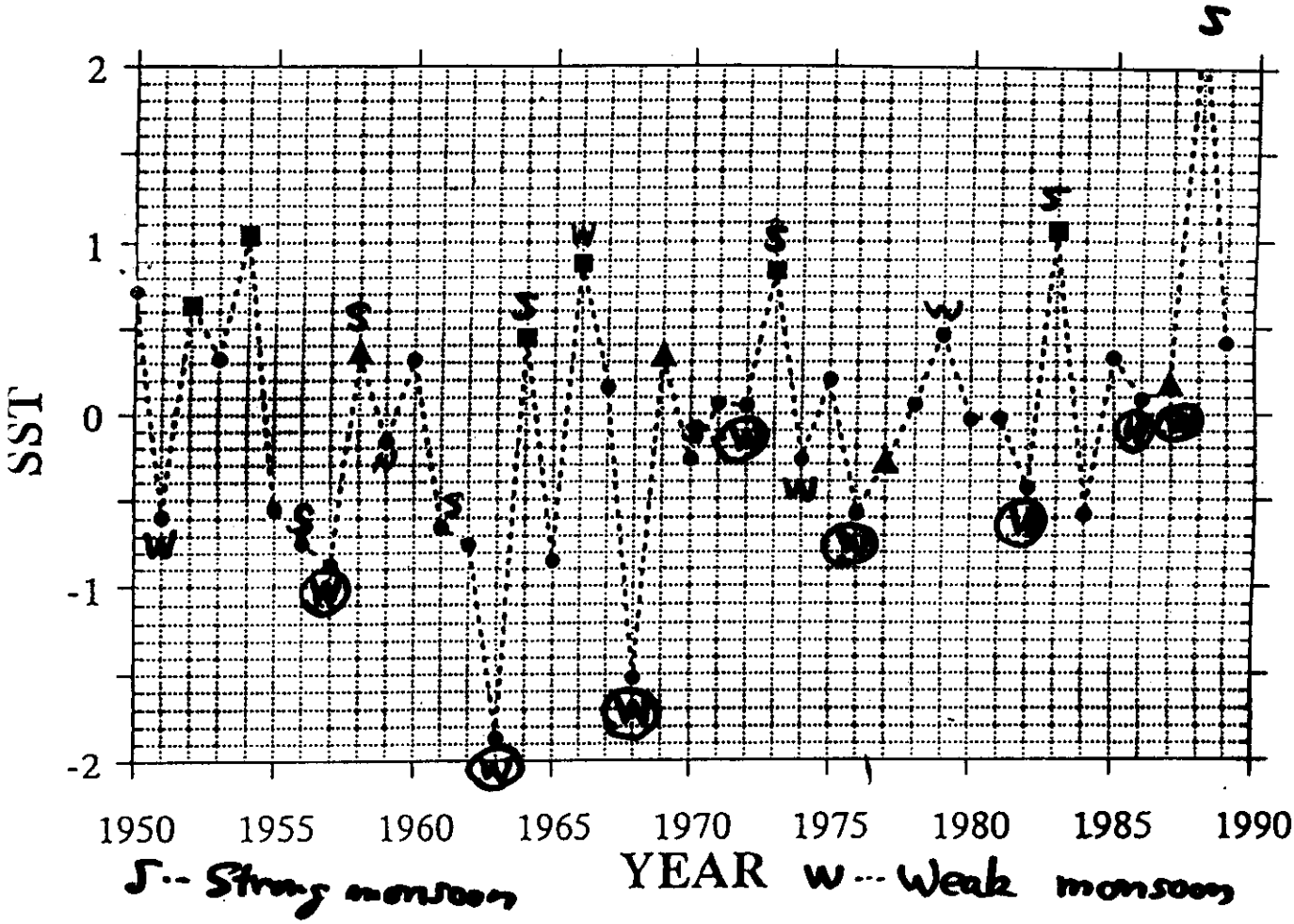


Fig.7.2

Time series of the normalized SST anomalies in the northern winter in South China Sea and the ocean region south of Japan. The square indicates the winter of BO-ENSO from Y(0) to Y(+1) of Fig.5.3 and the triangle indicates that of LF-ENSO. (Tomita and Yasunari, 1995)

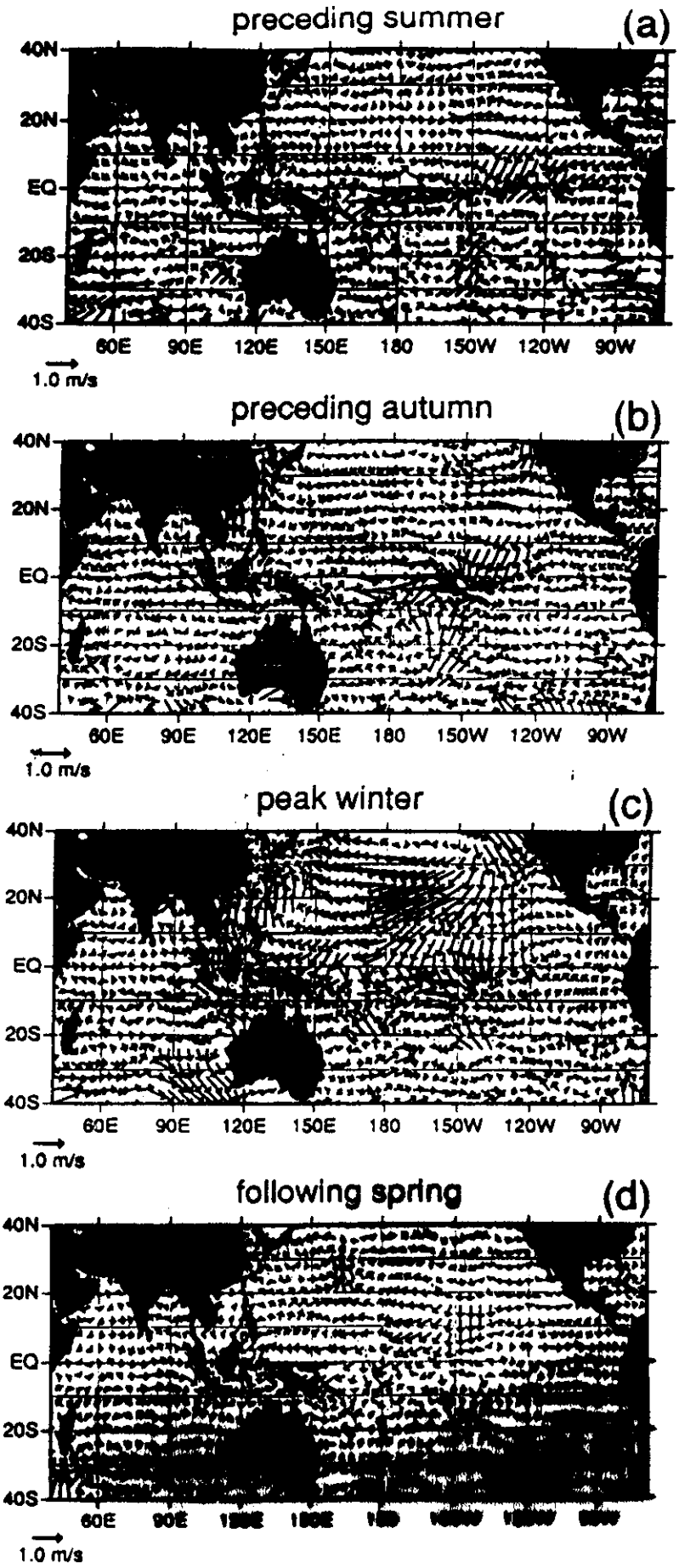

preceding summer
(a)
40N
20N
EQ
20S
40S
60E 90E 120E 150E 180 150W 120W 90W
1.0 m/s
preceding autumn
(b)
40N
20N
EQ
20S
40S
60E 90E 120E 150E 180 150W 120W 90W
1.0 m/s
peak winter
(c)
40N
20N
EQ
20S
40S
60E 90E 120E 150E 180 150W 120W 90W
1.0 m/s
following spring
(d)
40N
20N
EQ
20S
40S
60E
1.0 m/s

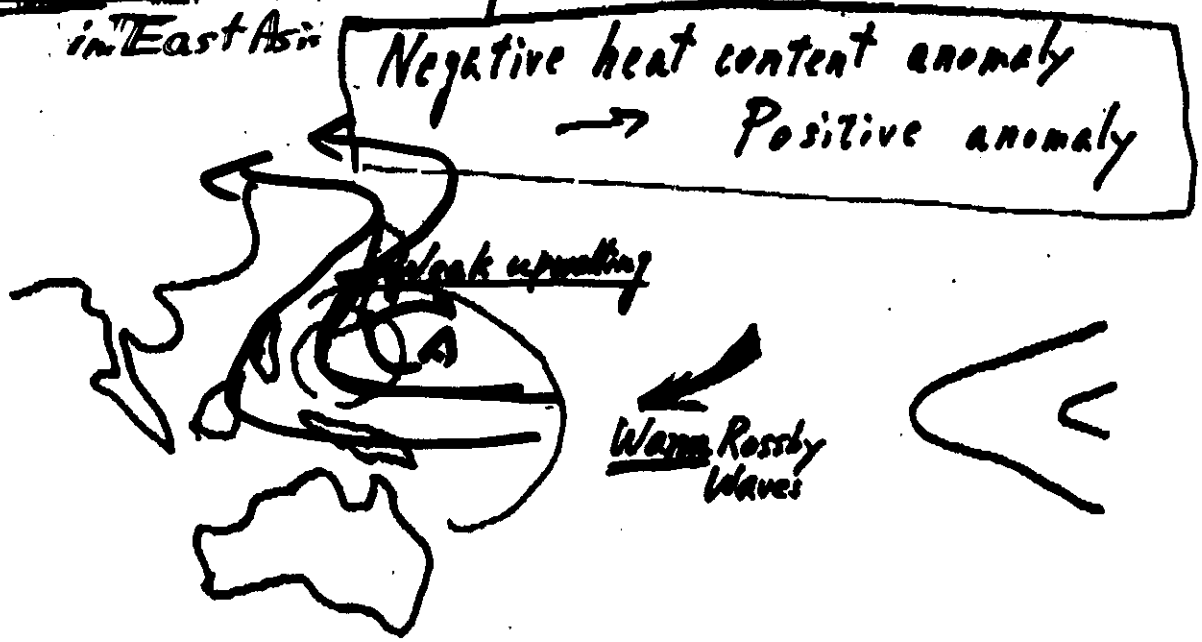
Fig.7.

STRONG

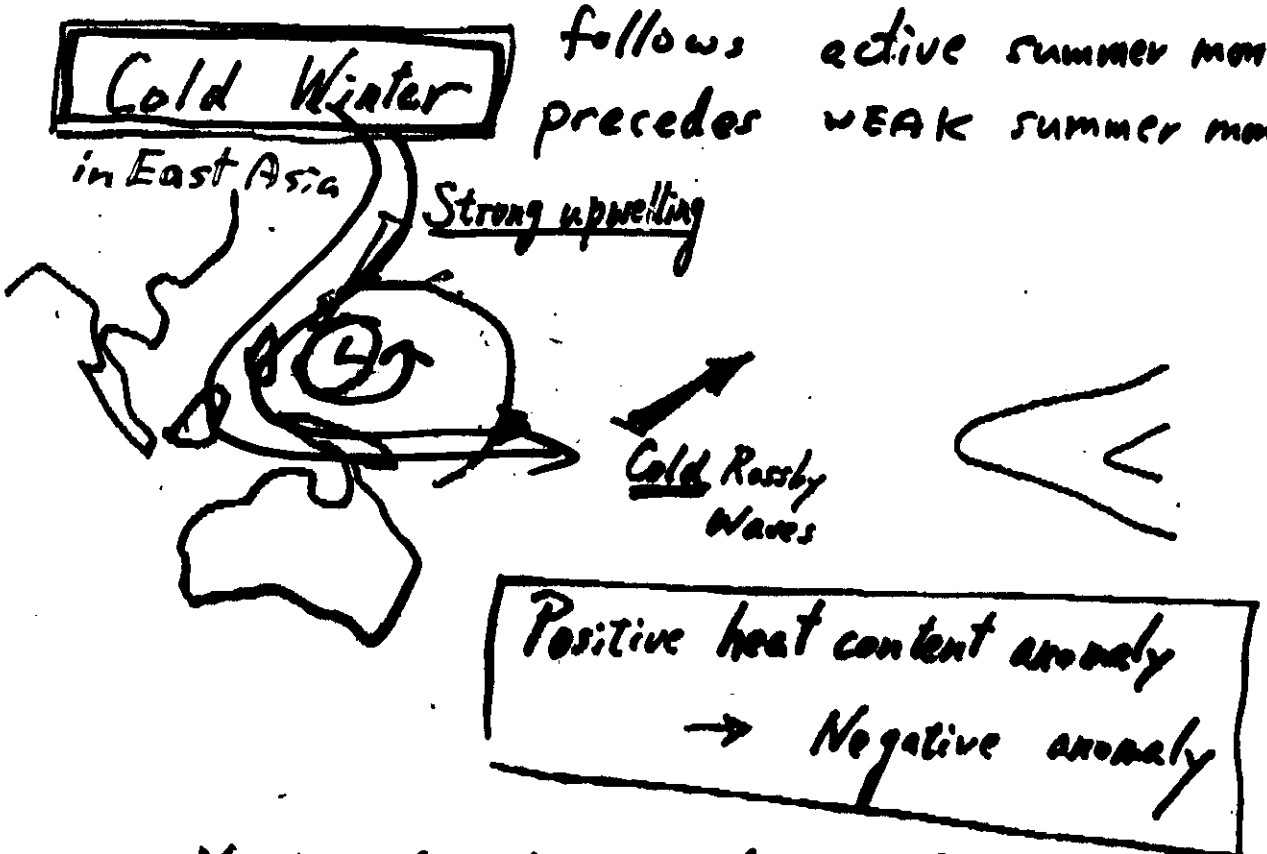
WEAK

Forced normal mode?

Warm Winter in East Asia — follows WEAK summer monsoon / precedes active summer monsoon



Cold Winter in East Asia — follows active summer monsoon / precedes WEAK summer monsoon.



Masumoto & Yamagata (1990)

Biennial Oscillation of the ENSO/monsoon System

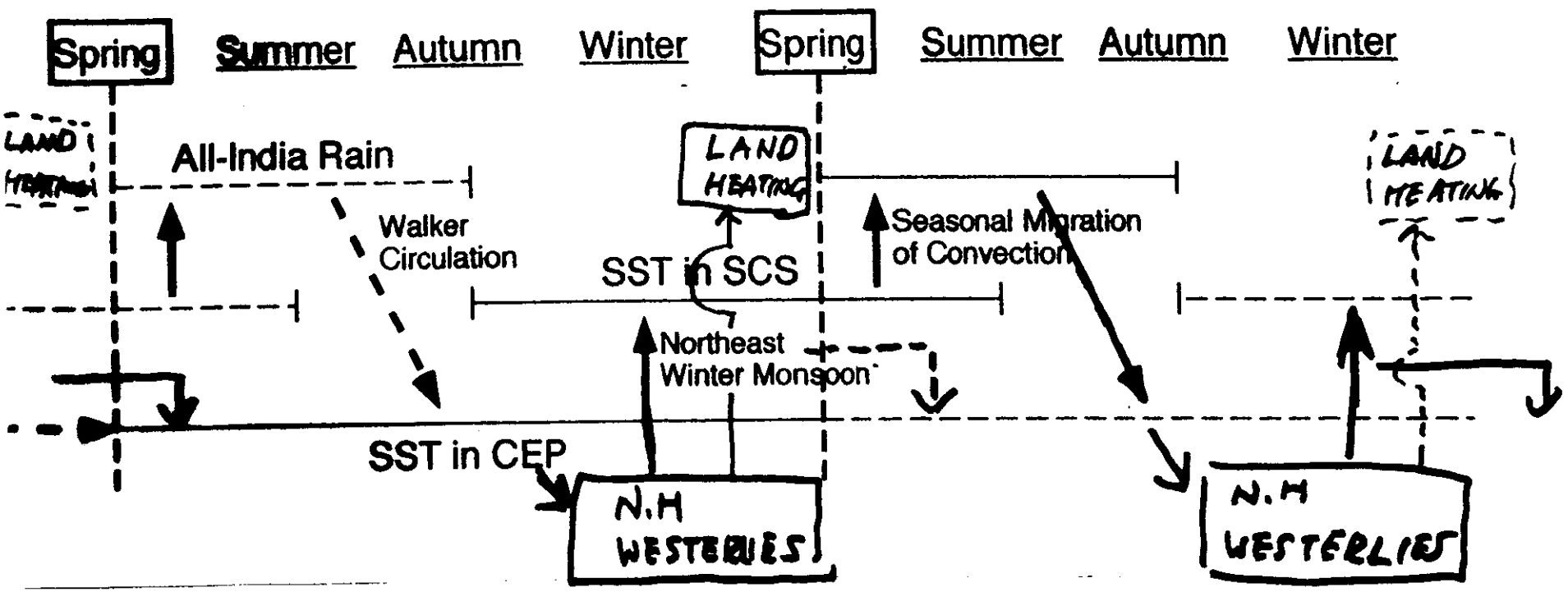


Figure 10 Modified from (Tomita and Yasunari, 1996)

Figure 10

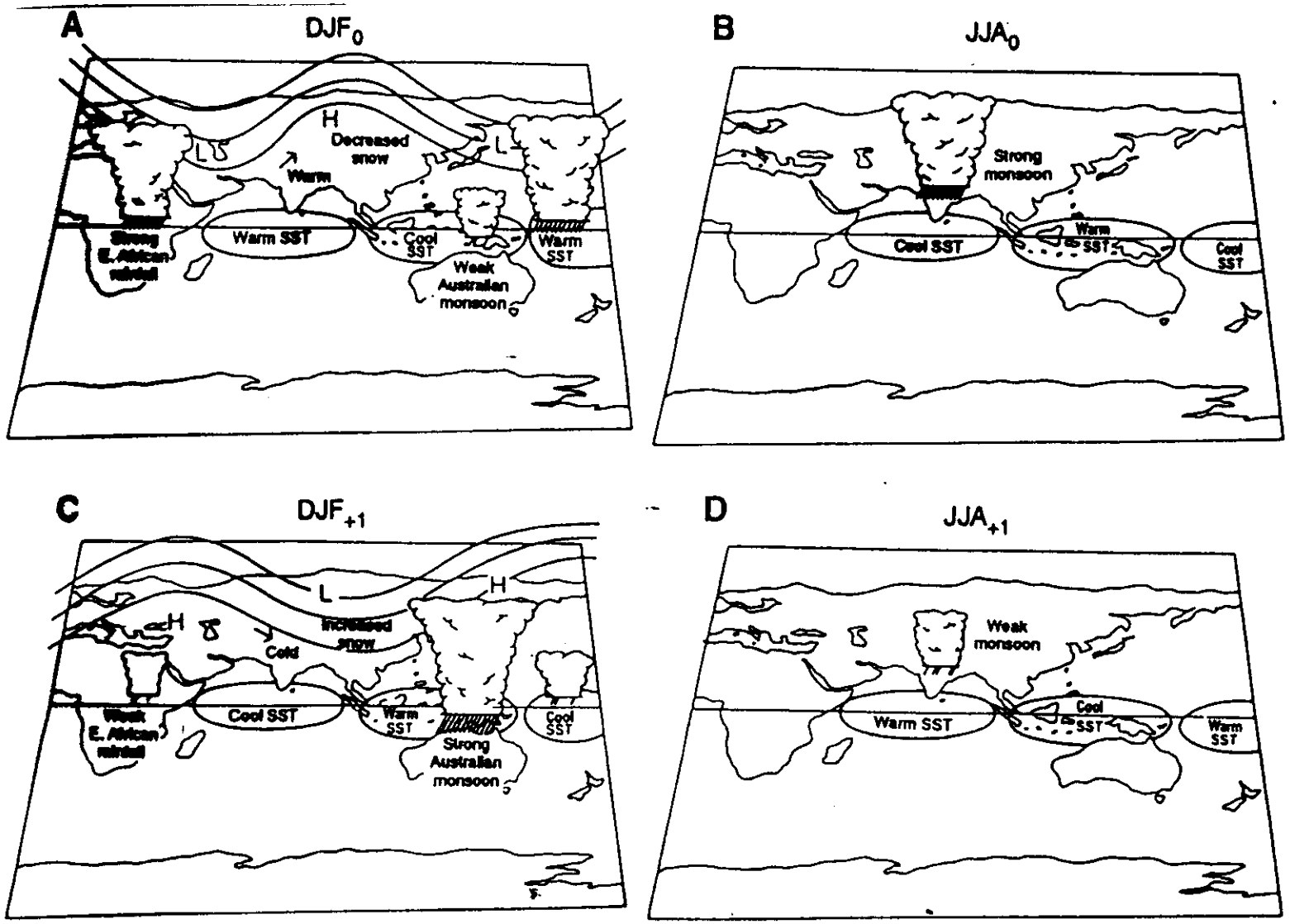
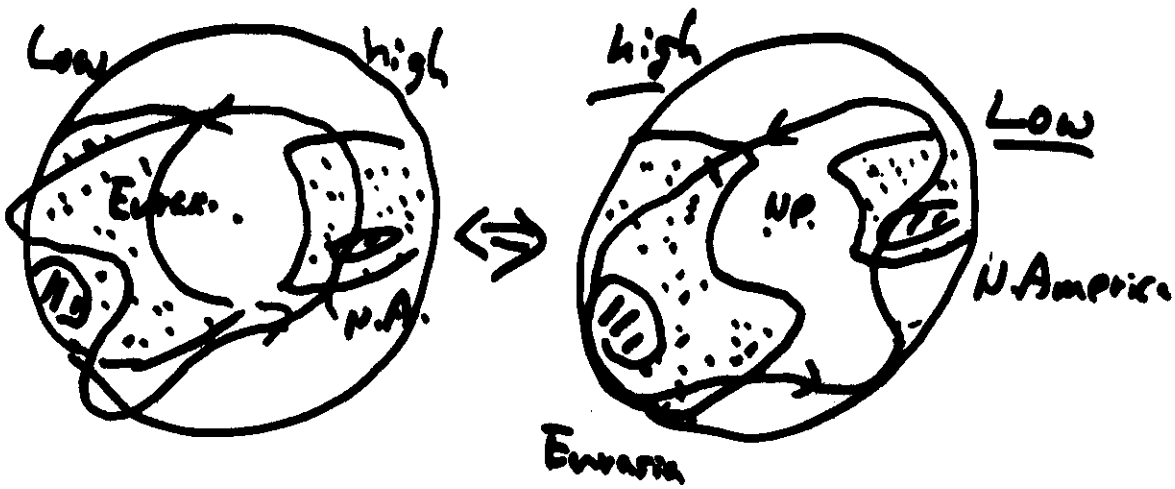


Fig. 8. Schematic biennial evolution from the northern winter before a strong Asian monsoon (**A**) through the strong monsoon season (**B**), to the northern winter after the strong monsoon before a weak monsoon (**C**), to the following weak monsoon (**D**).

(Meehl, 1994)

Fig. 8

Two basic inherent modes in the N.H. westerly flow ? (in winter)

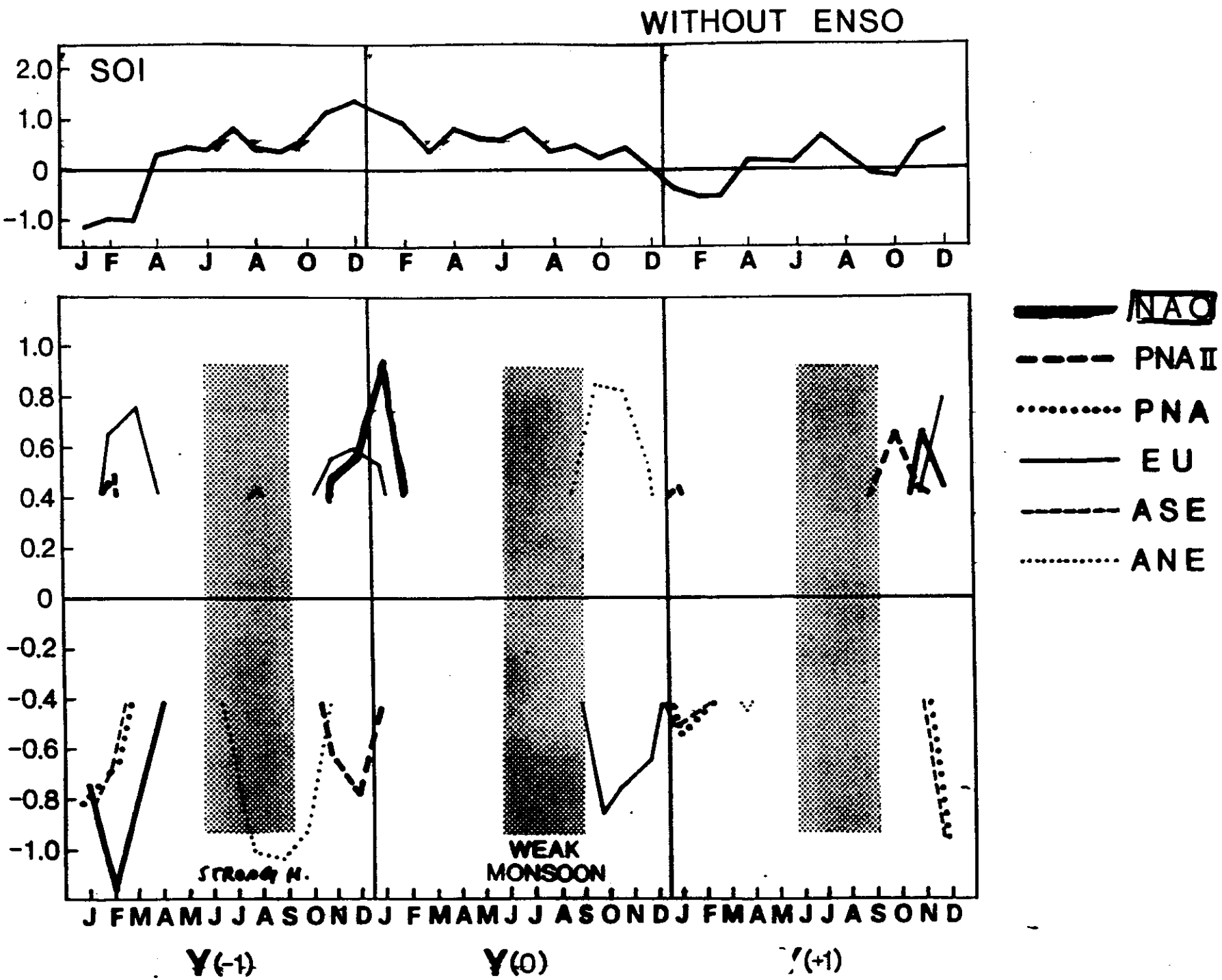


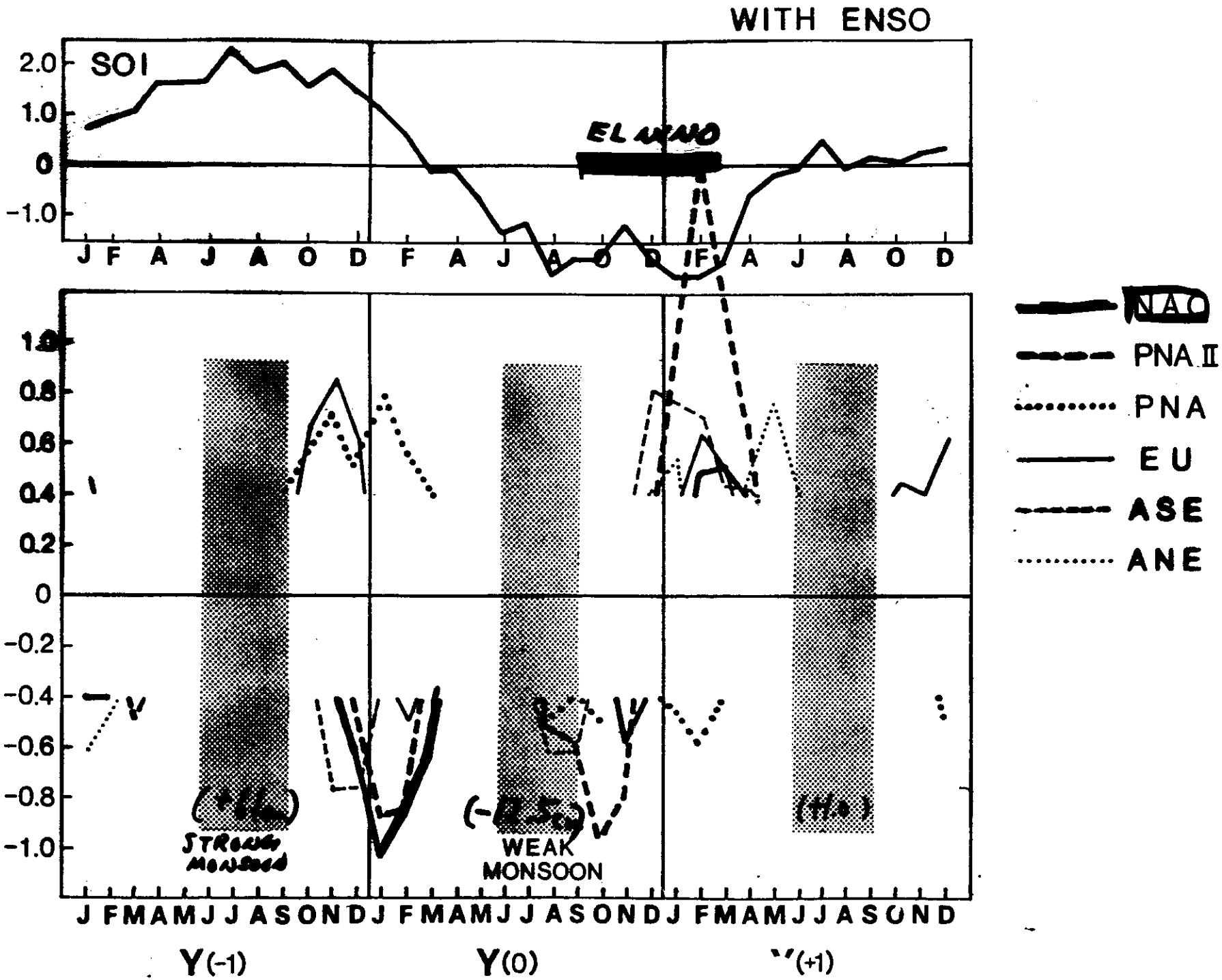
What controls
ENSO or Non-ENSO
condition
in the Monsoon/ENSO system?

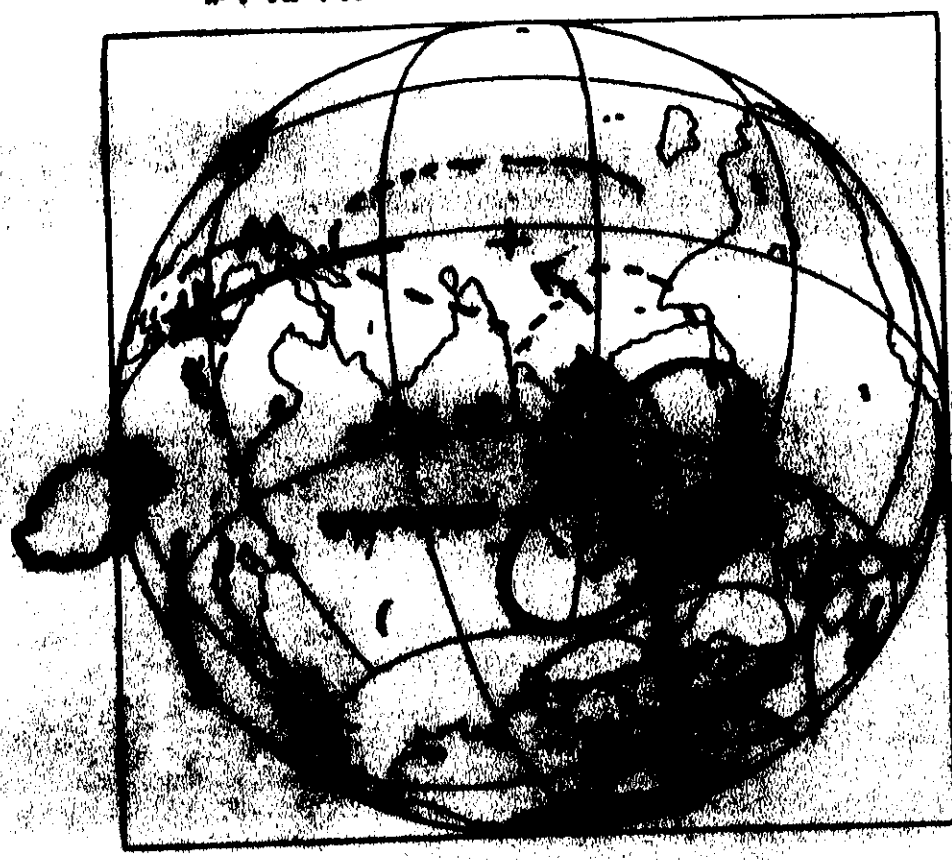
⇒ NAO ?
(which is totally independent
Walker (1932) from SO)

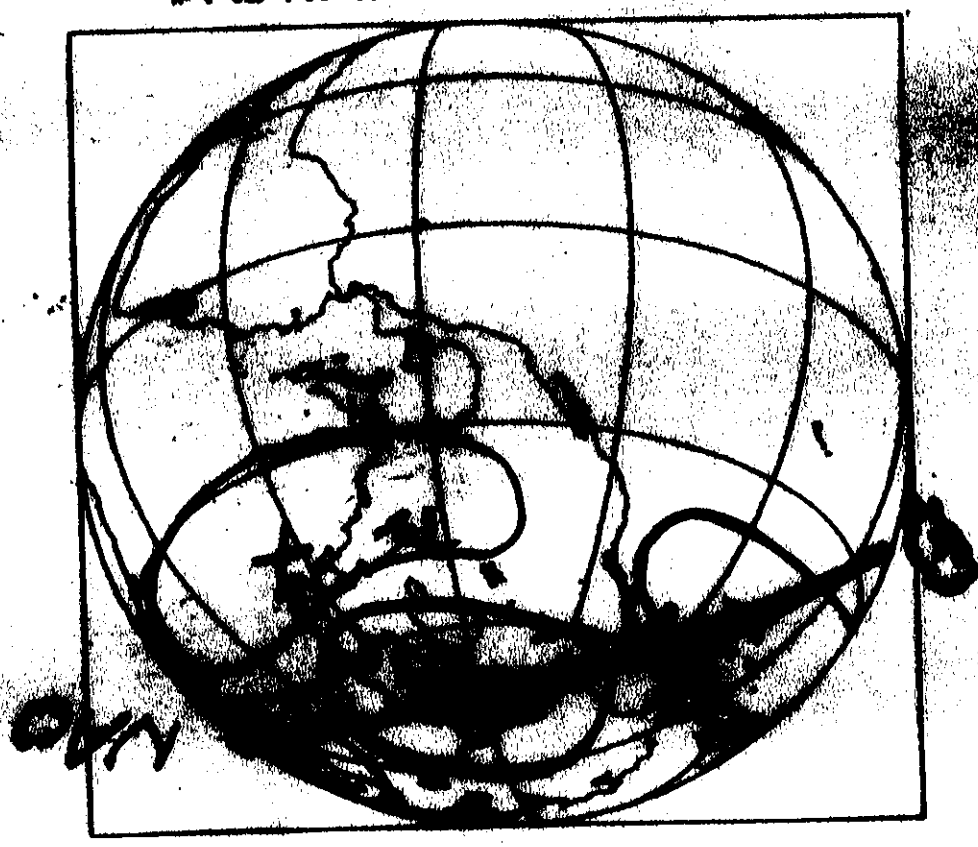
Barnett (1989)

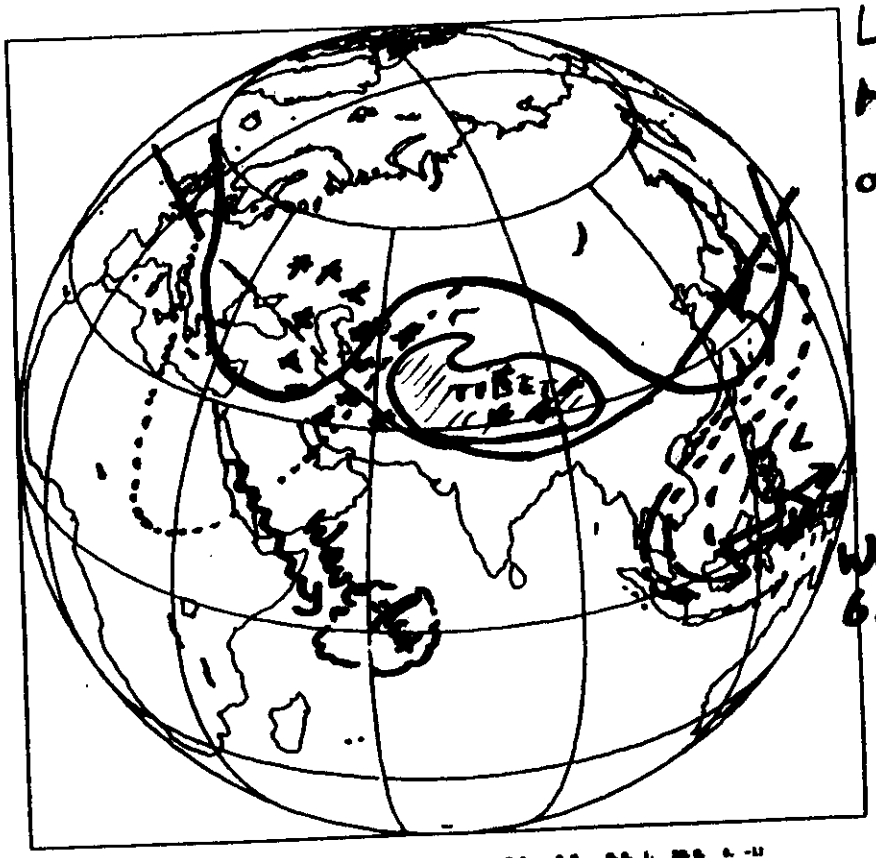
Yasunari and Seki (1992)


WITHOUT ENSO
SOI
2.0
1.0
0
-1.0
J F A J A O D F A J A O D F A J A O D
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
STRONG M.
WEAK MONSOON
J FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASOND
Y(-1)
Y(0)
Y(+1)
NAO
PNA II
PNA
EU
ASE
ANE


WITH ENSO
SOI
2.0
1.0
0
-1.0
J F A J A O D F A J A O D F A J A O D
EL NINO
NAO
PNA II
PNA
EU
ASE
ANE
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
STRONG MONSOON
WEAK MONSOON
J FMAMJ J ASONDJ FMAMJ J ASONDJ FMAMJ J ASOND
Y(-1)
Y(0)
Y(+1)







WINTER
Low Index
High Index
over Eurasia

Weekly
Burst

Summary

1. Singnals of TBO are prominent in the Asian/Australrial monsoon and equatorial Indian/Pacific region

2. Atmosphere-ocean interaction is likely to play an important role in the TBO.

3. TBO in the tropics shows a somewhat different structure from ENSO in the longer time-scale.

4. TBO shows a significant seasonality, by performing the "monsoon year" in the tropics. A distinctive different role is played by the boreal spring and autumn in the interannual variability of the monsoon and the A/O system (MAOS) in the tropics

5. Asian summer monsoon play an essential role in producing an anomalous state in the TBO, whereas the winter monsoon plays an essential role in changing the anomalous state.

6. NAO seems to play a role of modulater for ENSO/non-ENSO state by changing the basic state for the Rossby-wave propagations.

7. E. Asian Winter monsoon & land-surface condition are likely to be coupled each other.
(Seasonal anomalous heating over the Tibetan Plateau is closely linked to SST/convection over SCS & Bay. Bengal.)
(Ueda and Yasunari, 1996) JMSJ. '96.