CLIMATE VARIABILITY

Dr. Mary Toshie Kayano

Instituto Nacional de Pesquisas Espaciais
Centro de Previsão do Tempo Climáticos e Estudos
Email: mary@cptec.inpe.br

First Latin American Advanced School on Space Environment
São José dos Campos - INPE
22 to 27 March 2004
(ASSE 2004)

THE CLIMATE

CLIMATE system converts and redistributes the solar energy received at the Earth:

- 30% reflected back to the space
- 20% absorbed by the atmosphere (heated)
- 18% absorbed by the continents
- 32% absorbed by the oceans

The 32% absorbed by oceans plays an important role in regulating the climate, since part returns back to atmosphere by radiation, conduction or evaporation.

Atmosphere is heated from below. So the tropics, in particular TROPICAL OCEANS play as important role in the climate systems.

VARIATIONS OF THE CLIMATE

❖Climate involves several components: the Sun, the Earth's orbit around the Sun, the continents, the ocean, the atmosphere, the cryosphere and the biosphere. Any variation in any of these components – will impact all the others

•TEMPORAL SCALE of the climate systems: Month, Seasonal, Annual, Interannual, Decadal and longer.

•SPATIAL SCALE of the climate systems: Regional and Global scales

STUDIES OF THE CLIMATE VARIABILITY require knowledge on STATISTICAL METHODS:

- **TO MEASURE THE VARIABILITY (Mean, Standard Deviation, Variance)**
- **TO IDENTIFY RELATION among the climate quantities (correlation analysis; empirical orthogonal function analysis; other statistical and mathematical tools)**
- **TO IDENTIFY THE FEATURES OF THE SYSTEMS**
- **TO ISOLATE SPECIFIC SCALES OF THE VARIABILITY - Solar forcing defines the annual cycle of the variables (climatology of the variables). It is necessary to remove the annual cycles (ANOMALIES)**

MOTIVATION OF THE STUDIES

- Climate anomalies (droughts or excessive rainfall, severe winters) have dramatic impacts on the live and economies of the afflicted areas.

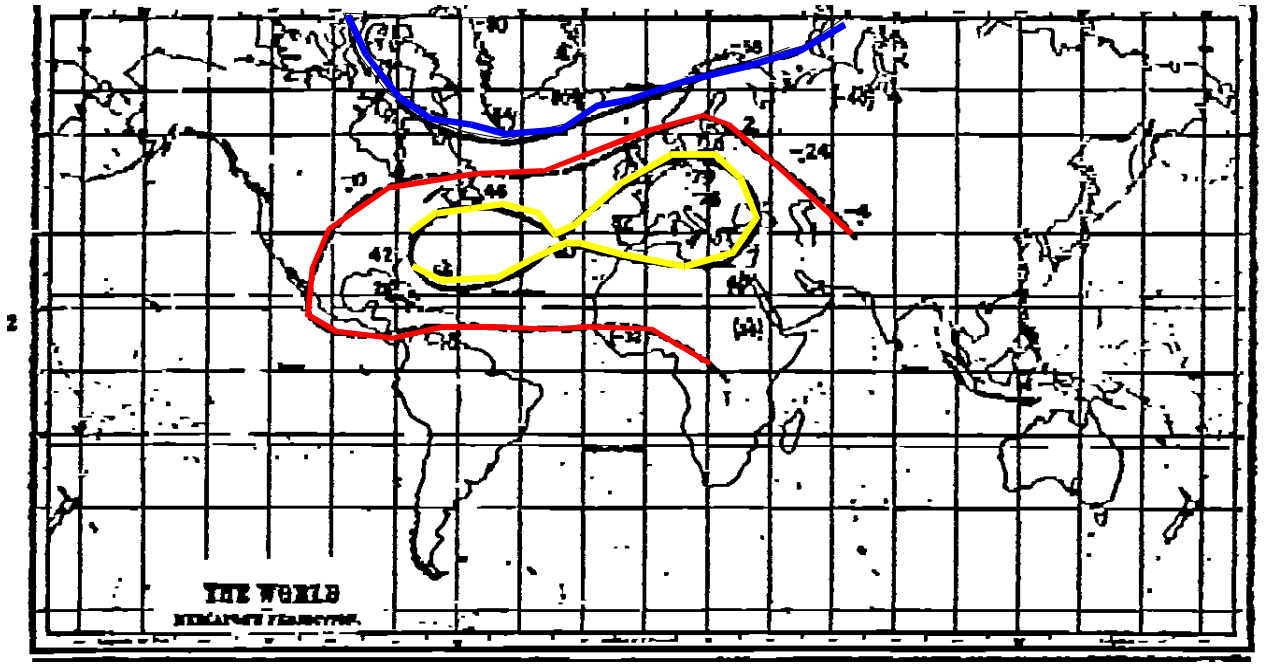
- Understanding of the anomalies – improved forecast – minimize the effects

Walker (20's 30's): statistical connections among atmospheric variables over large space scales and long periods of times.

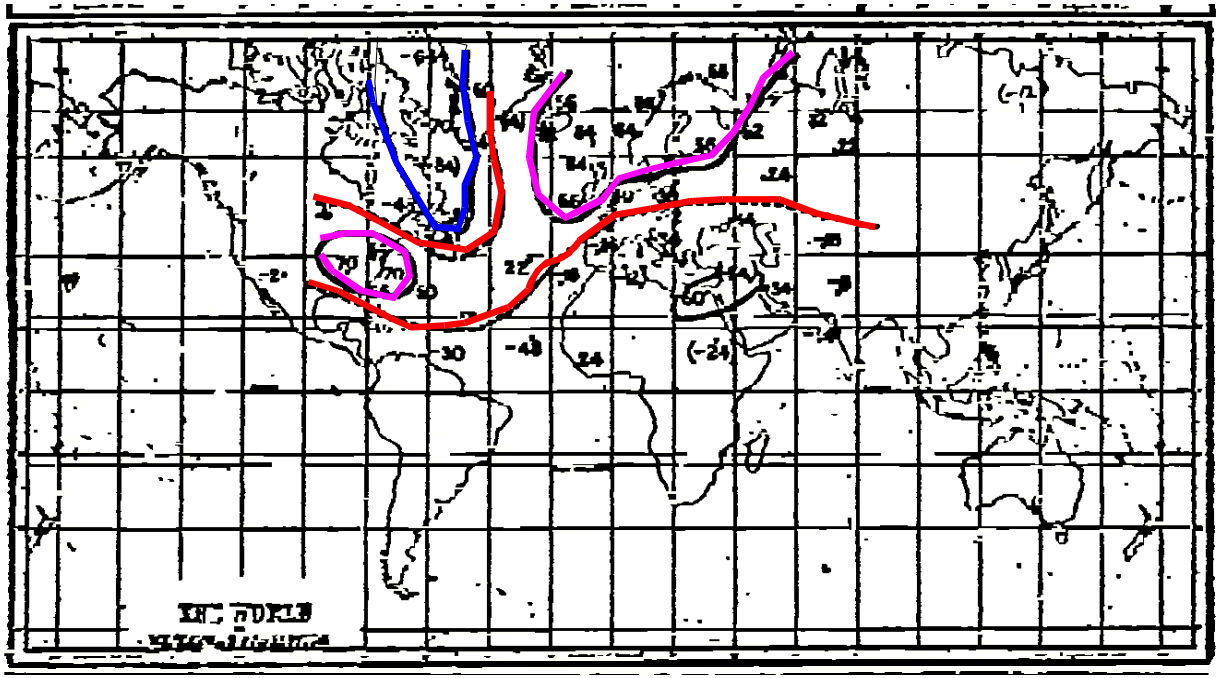
Walker and Bliss (1932): in phase and out of phase relation for sea level pressure

OSCILLATORY FEATURES:

- North Atlantic Oscillation (NAO)
- North Pacific Oscillation (NPO)
- Southern Oscillation (SO)



North Atlantic Oscillation - NAO - Sea Level Pressure
(Source: Walker and Bliss, 1932)



North Atlantic Oscillation - NAO - Temperature
(Source: Walker and Bliss, 1932)

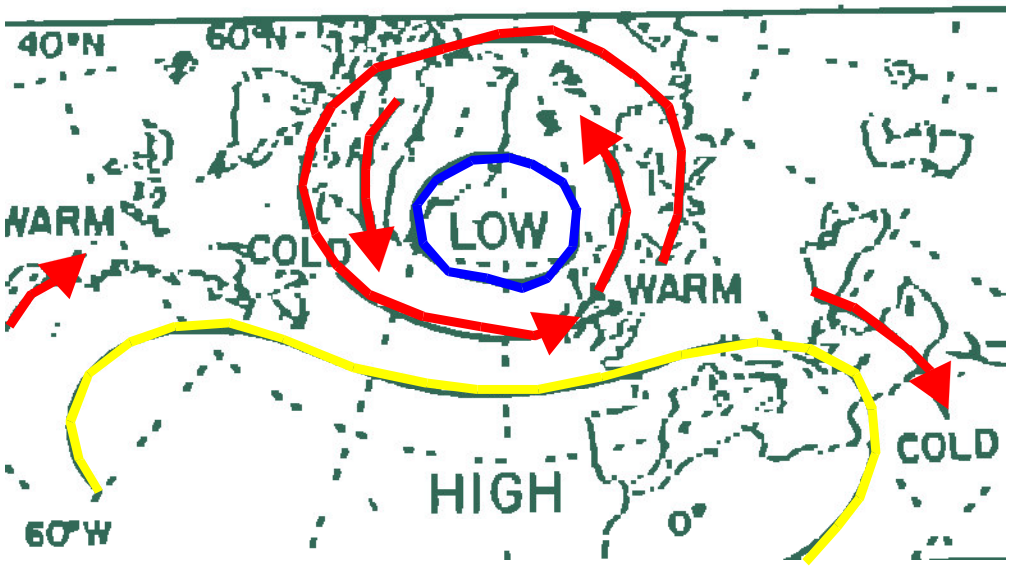
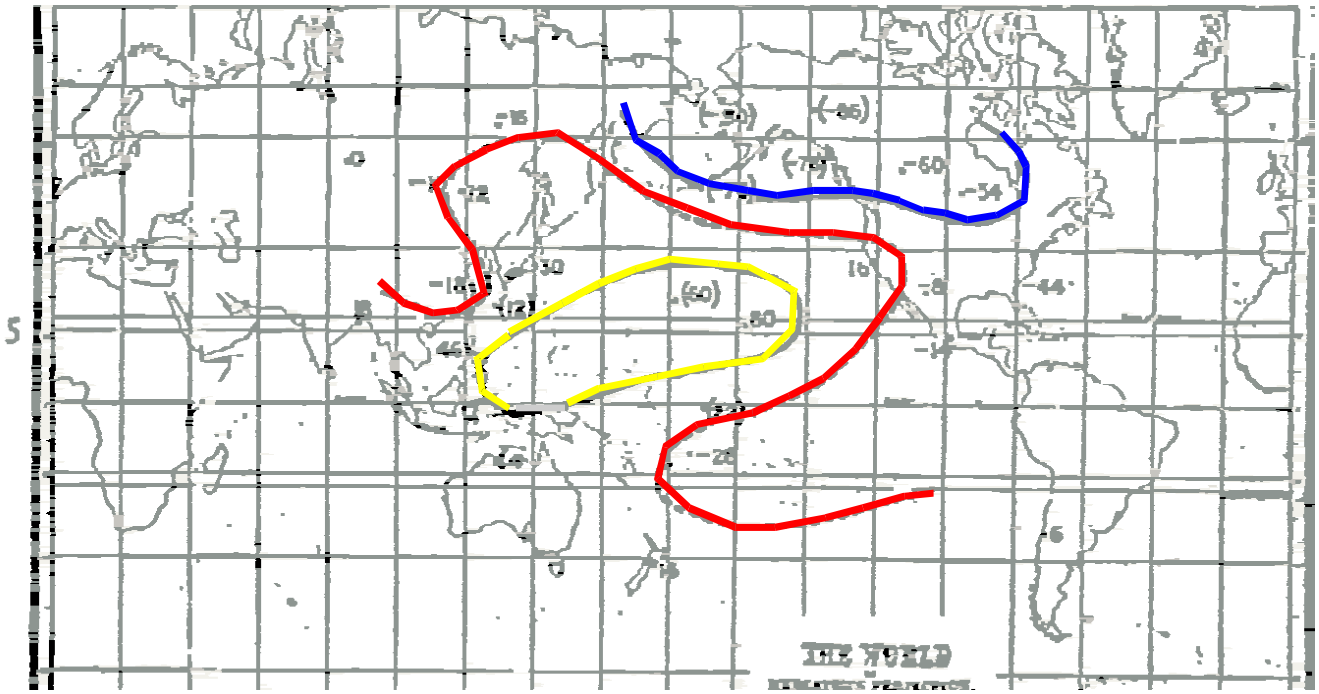
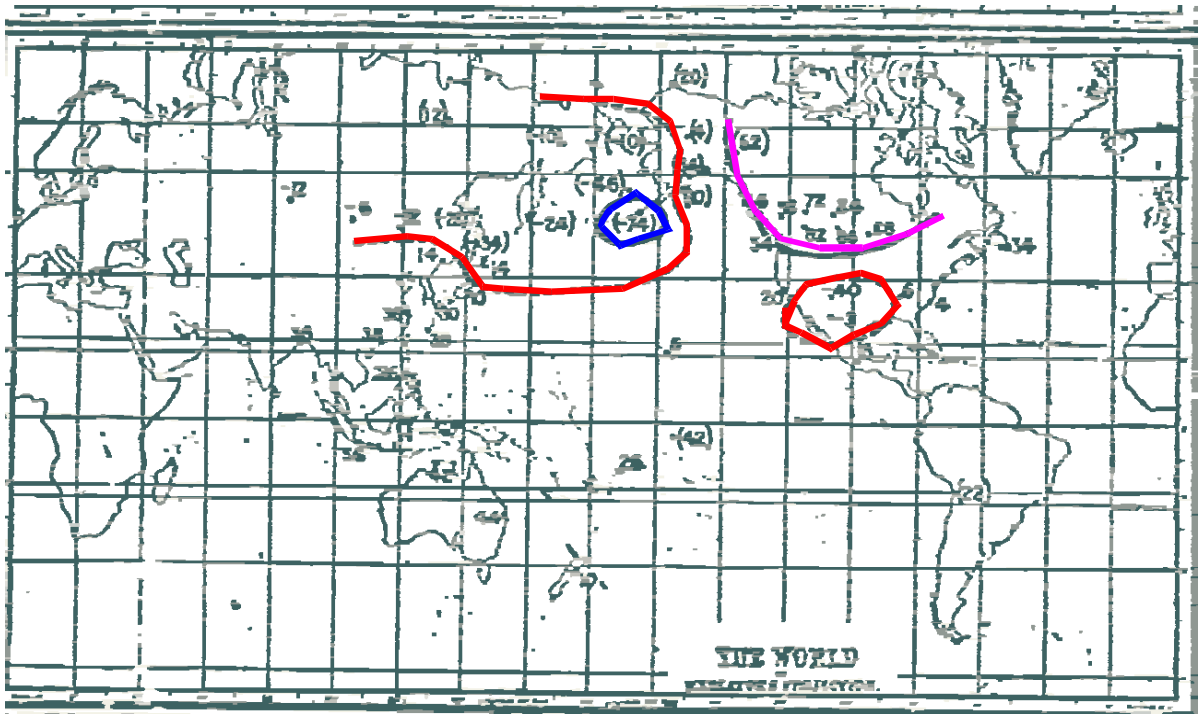


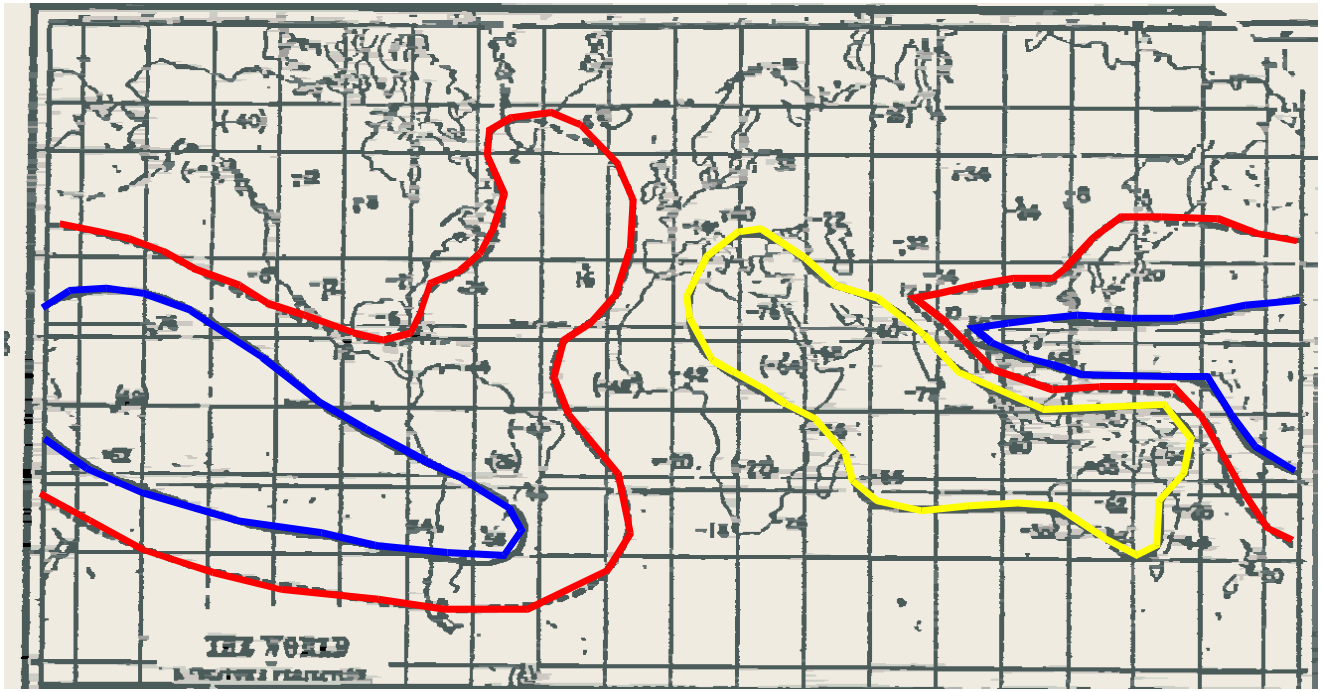
Illustration for NAO
(Source:Wallace and Gutzler, 1981)



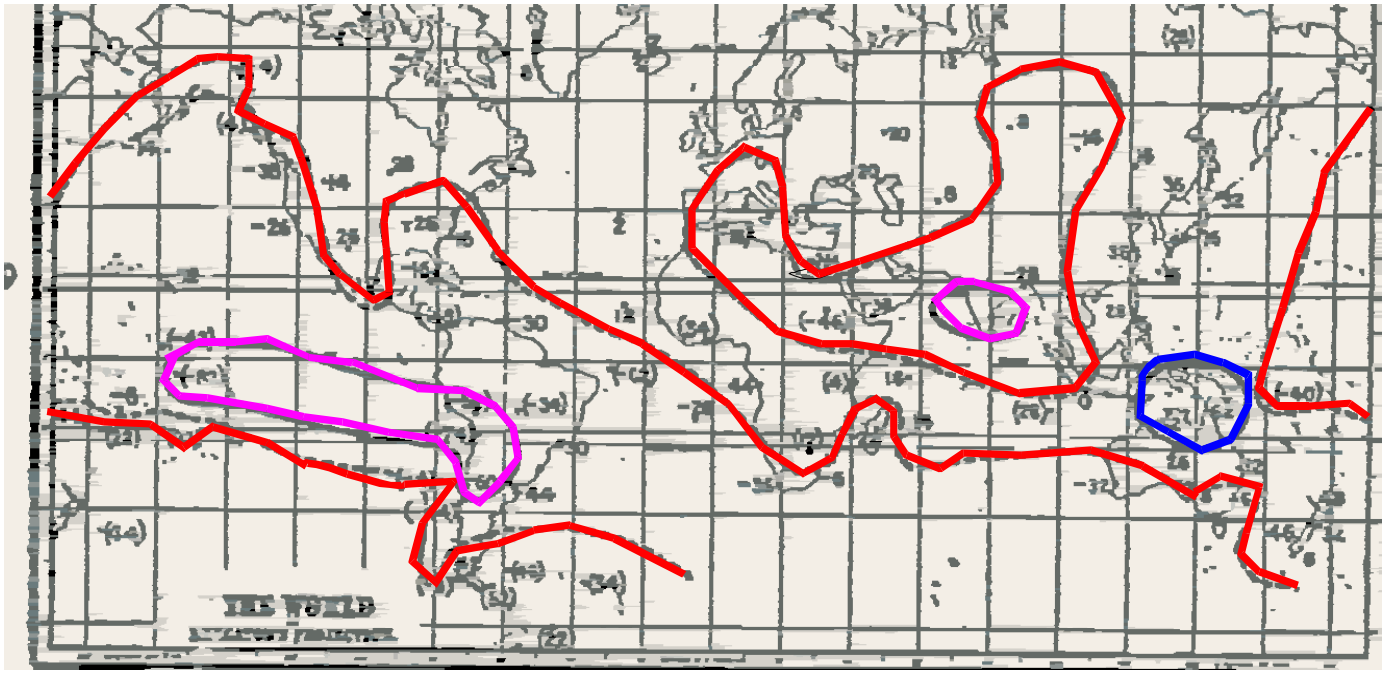
North Pacific Oscillation -NPO - Sea Level Pressure
(Source: Walker and Bliss, 1932)



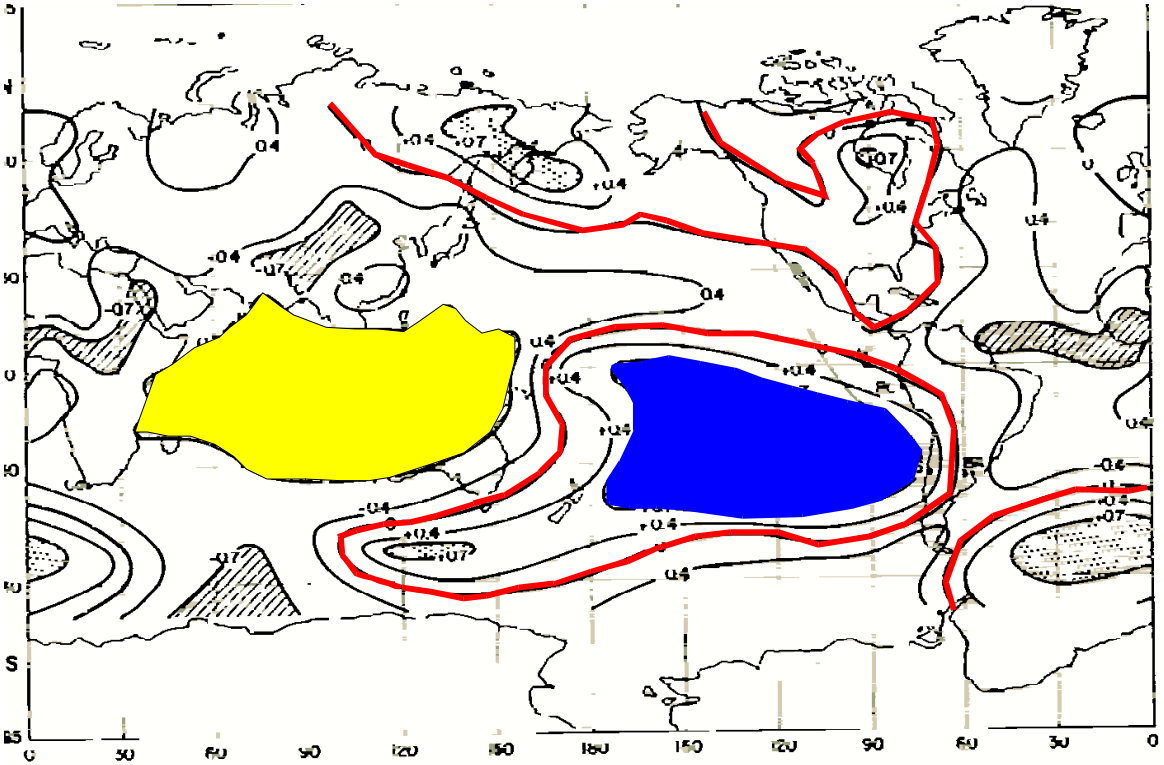
North Pacific Oscillation - NPO - Temperature
(Source: Walker and Bliss, 1932)



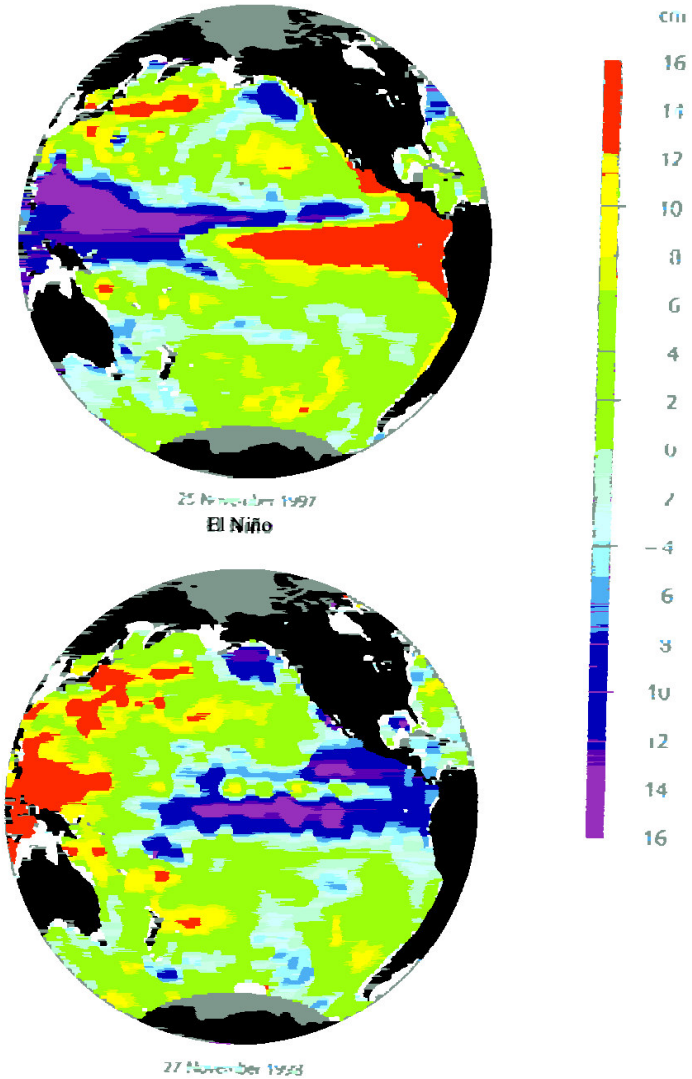
Southern Oscillation - SO - Sea Level Pressure
(Source: Walker and Bliss, 1932)



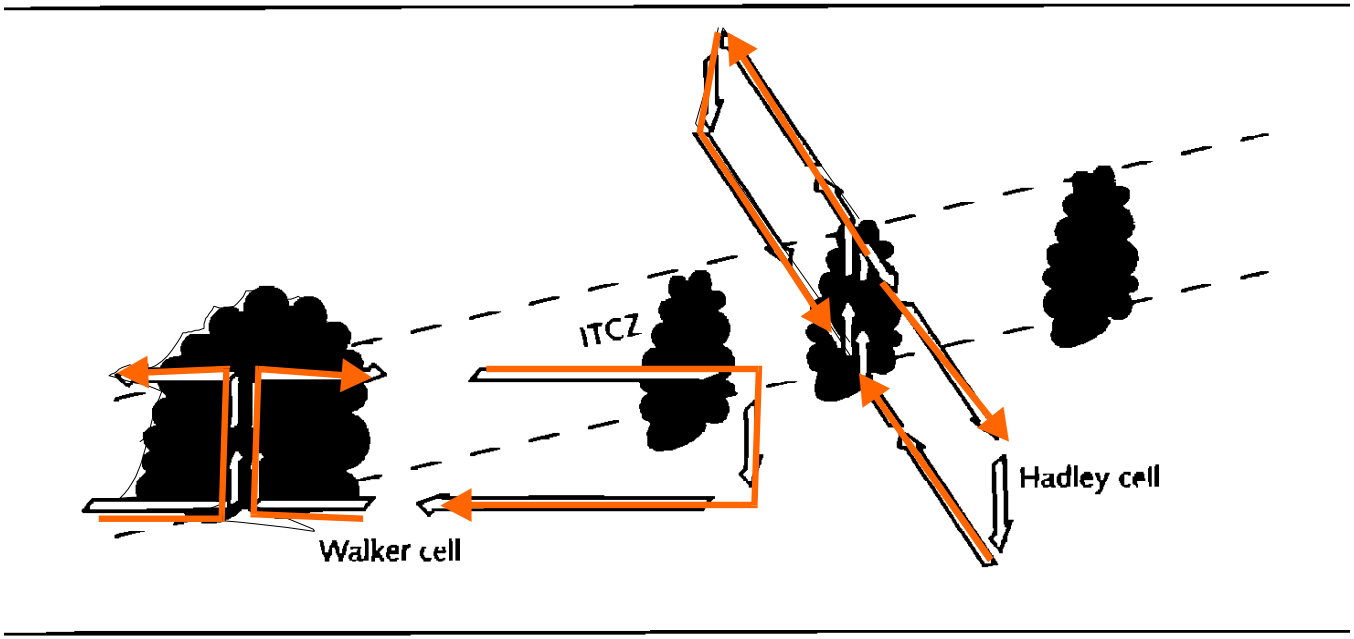
Southern Oscillation - SO - Temperature
(source: Walker and Bliss, 1932)



Correlation Map - Eastern Island as reference - Sea level Pressure
(Source: Kousky et al., 1984)

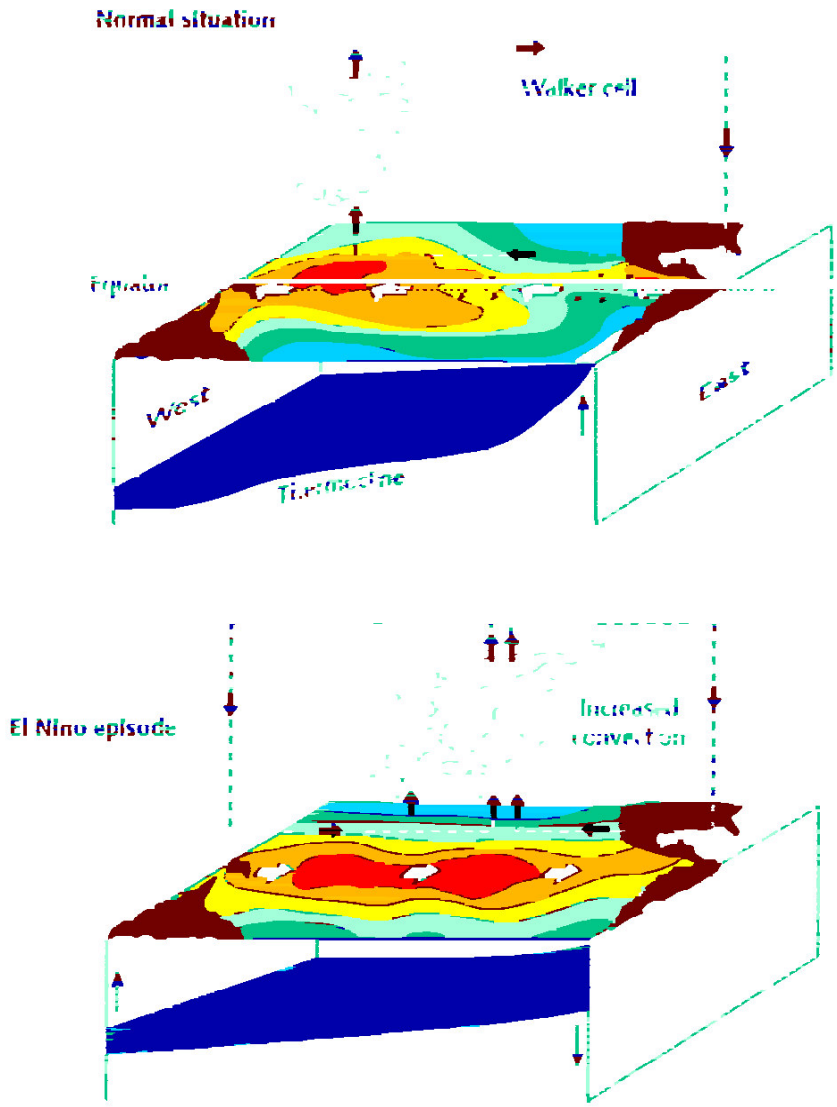


(Source: Voituriez and Jacques, 2000)

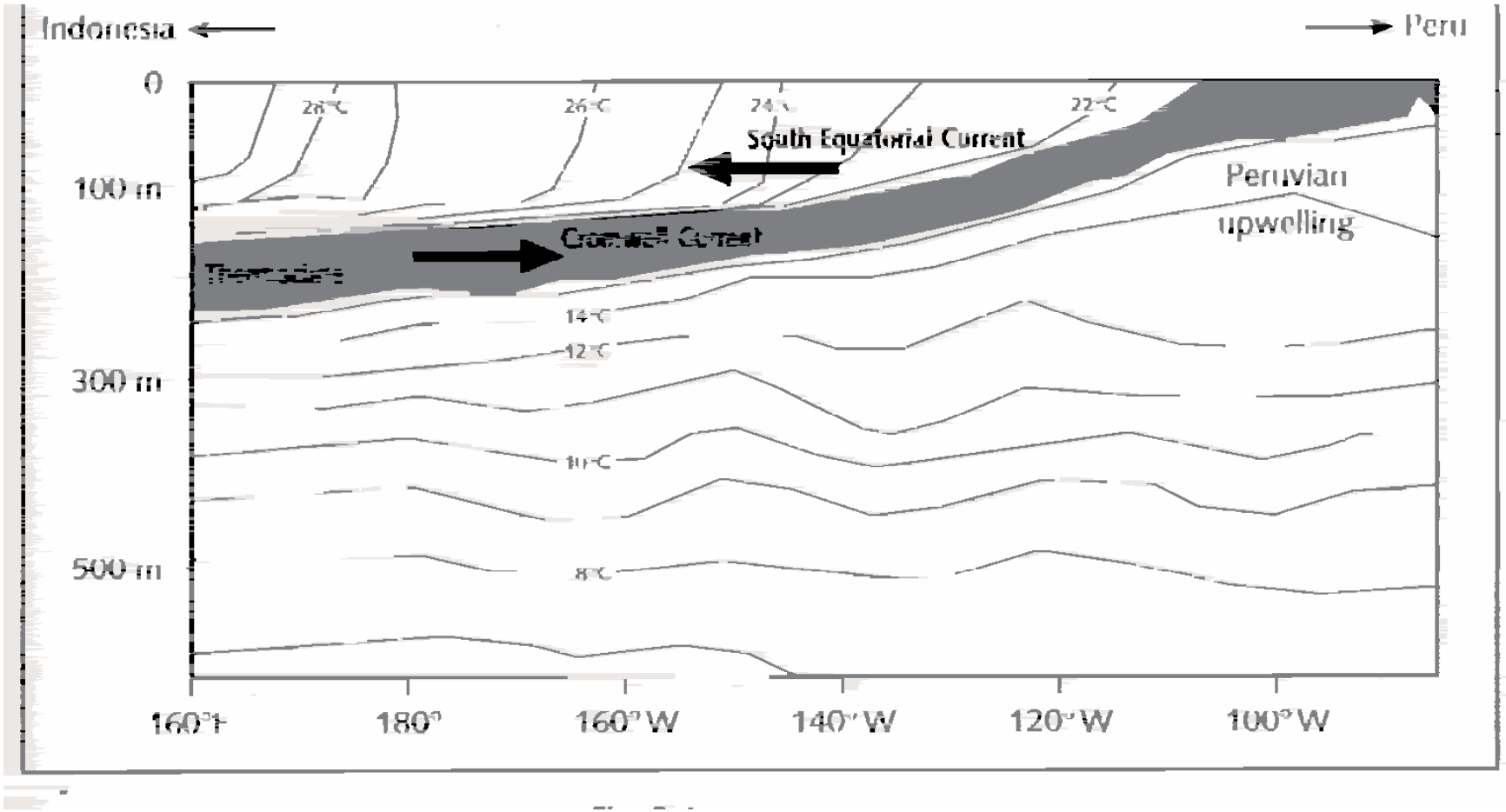


Hadley and Walker Circulations

(Source: Voiturez and Jacques, 2000)

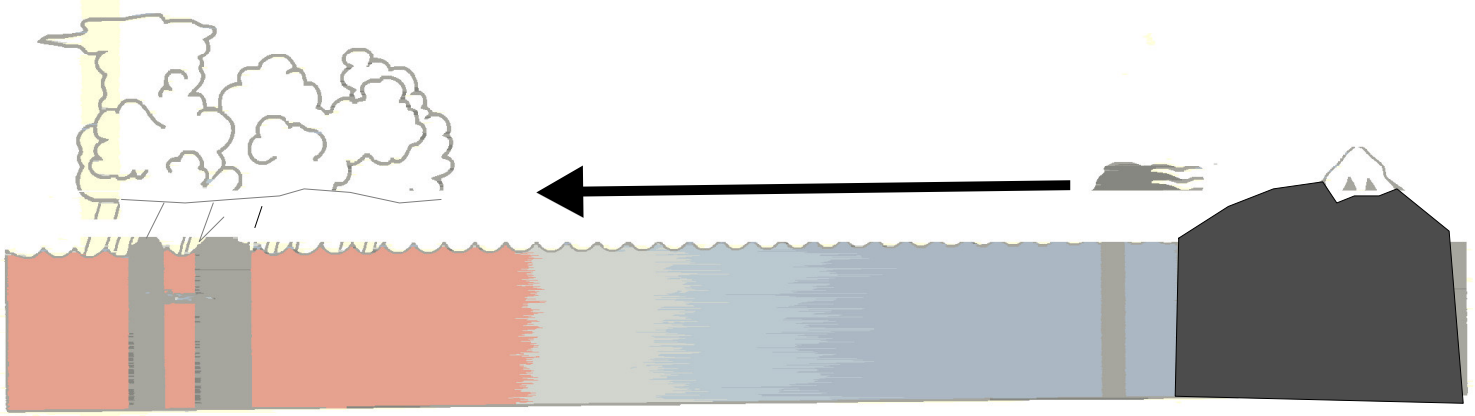


(Source: Voituriez and Jacques, 2000)



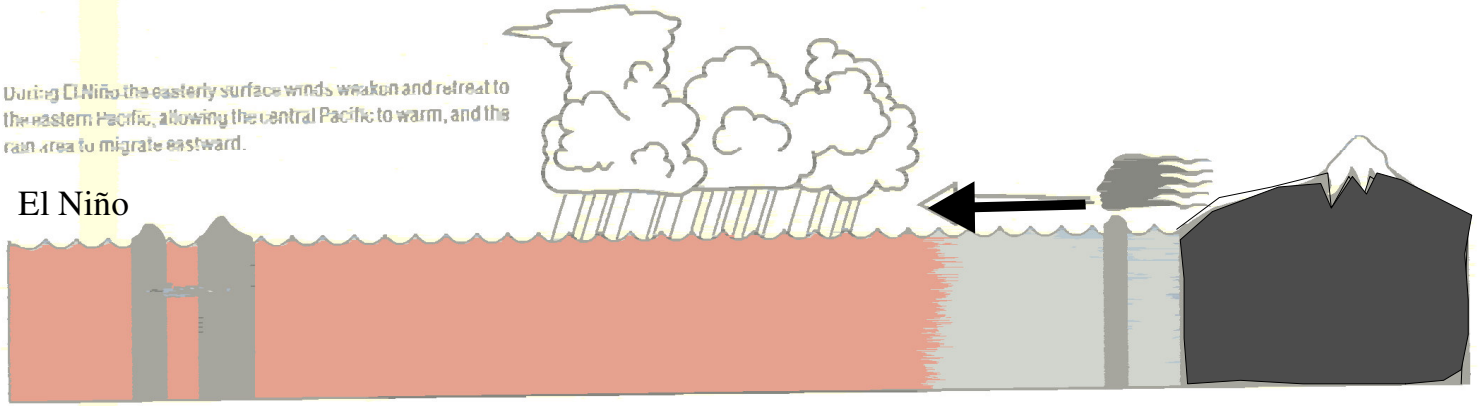
Temperature profile of equatorial Pacific
(Source: Voituriez and Jacques, 2000)

Normal

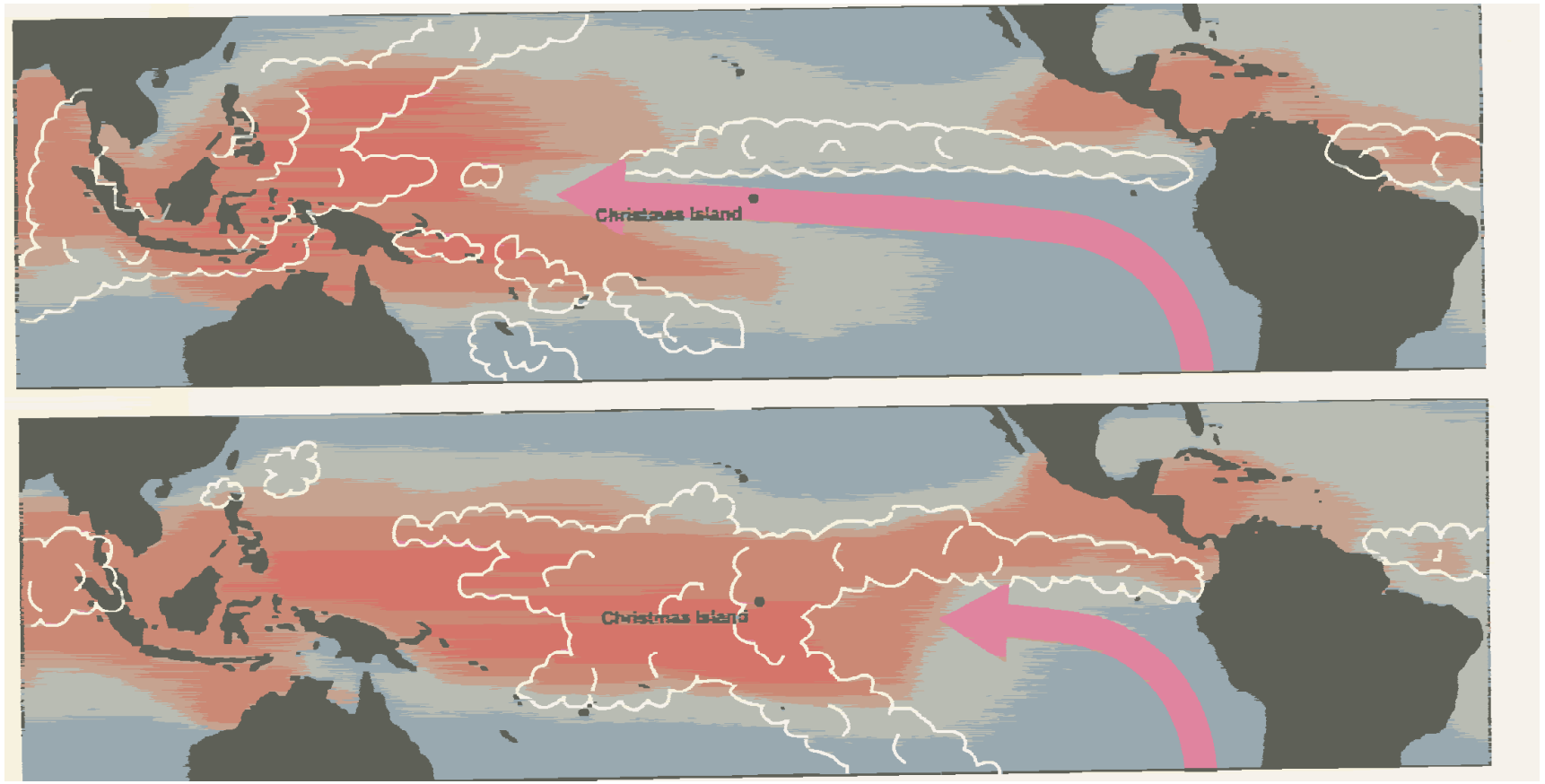


During El Niño the easterly surface winds weaken and retreat to the eastern Pacific, allowing the central Pacific to warm, and the rain area to migrate eastward.

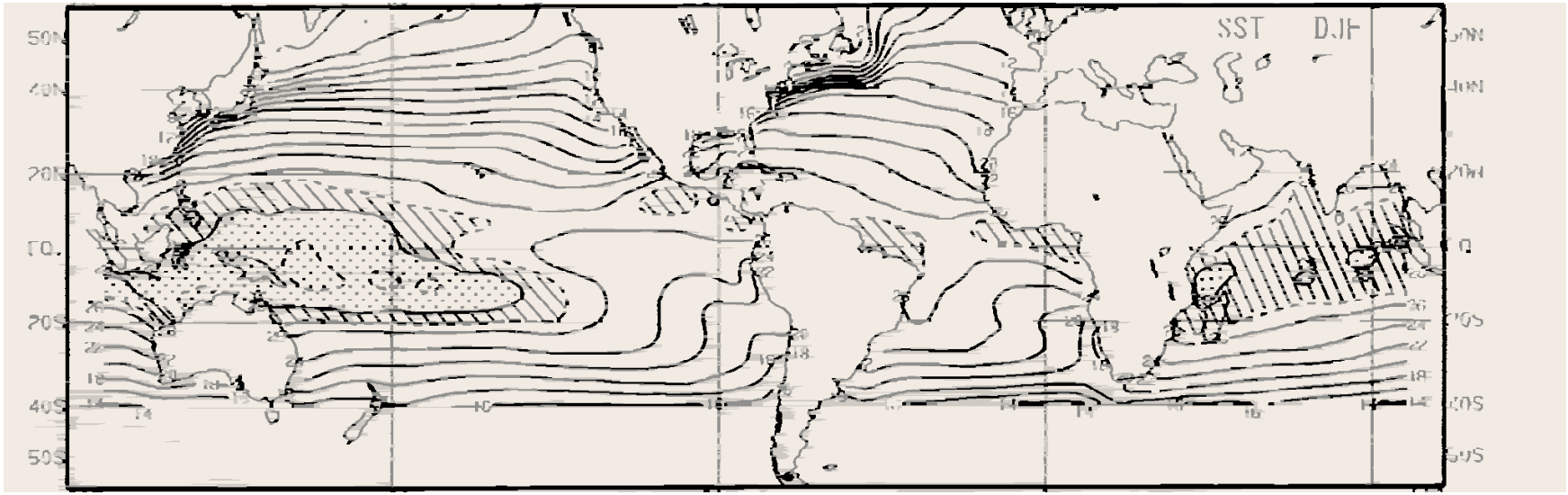
El Niño



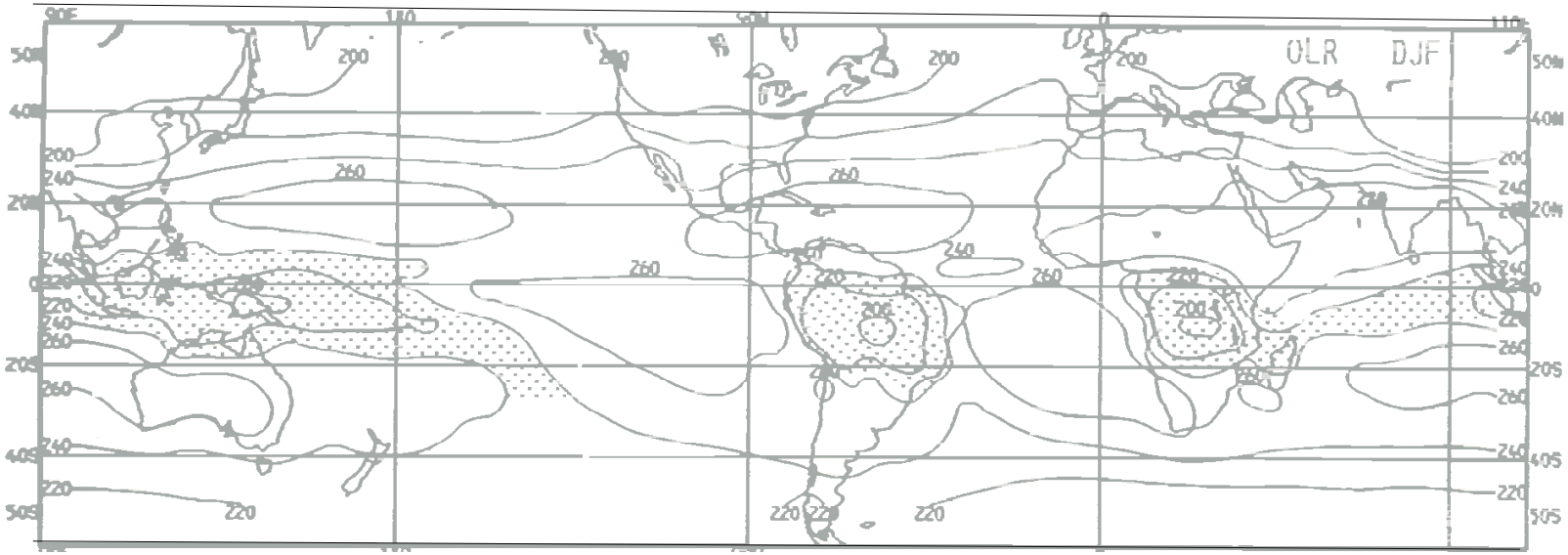
Easterly Surface winds
(Source: NOAA report, 1994)



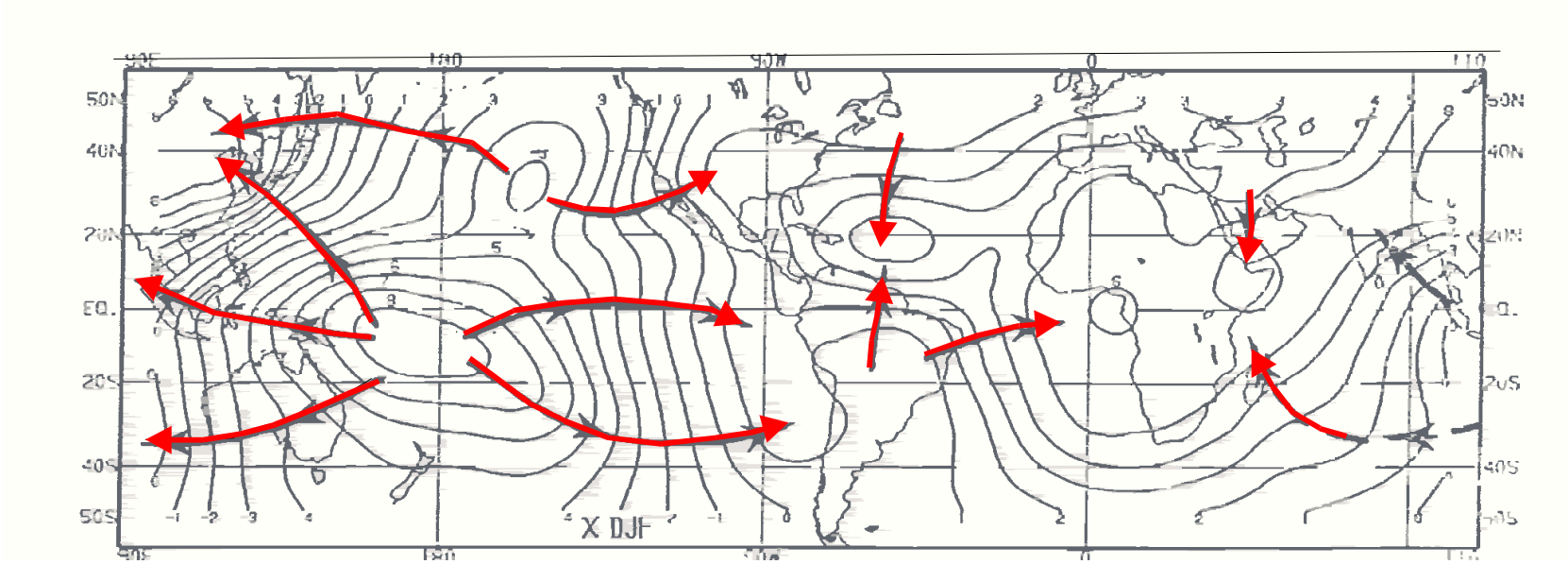
Surface winds, Clouds, Sea Surface Temperature for Normal and El Niño Conditions
(Source: NOAA Report, 1994)



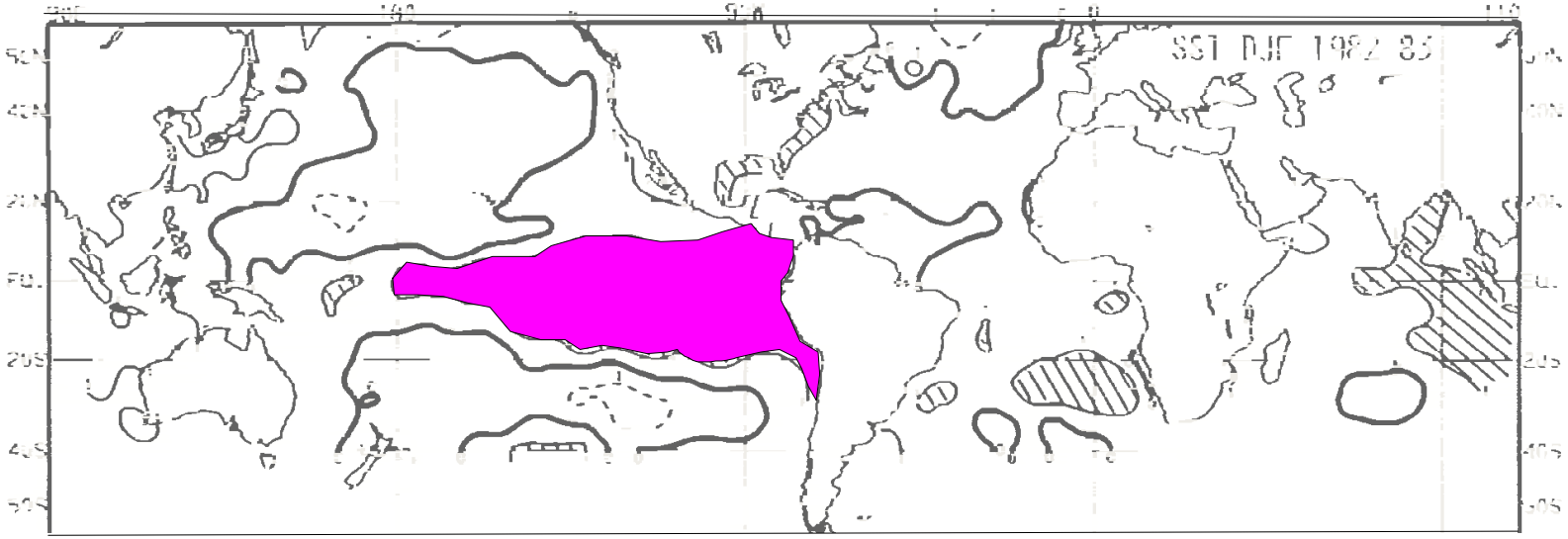
Mean Sea Surface Temperature for DJF
(Source: Rasmusson and Arkin, 1985)



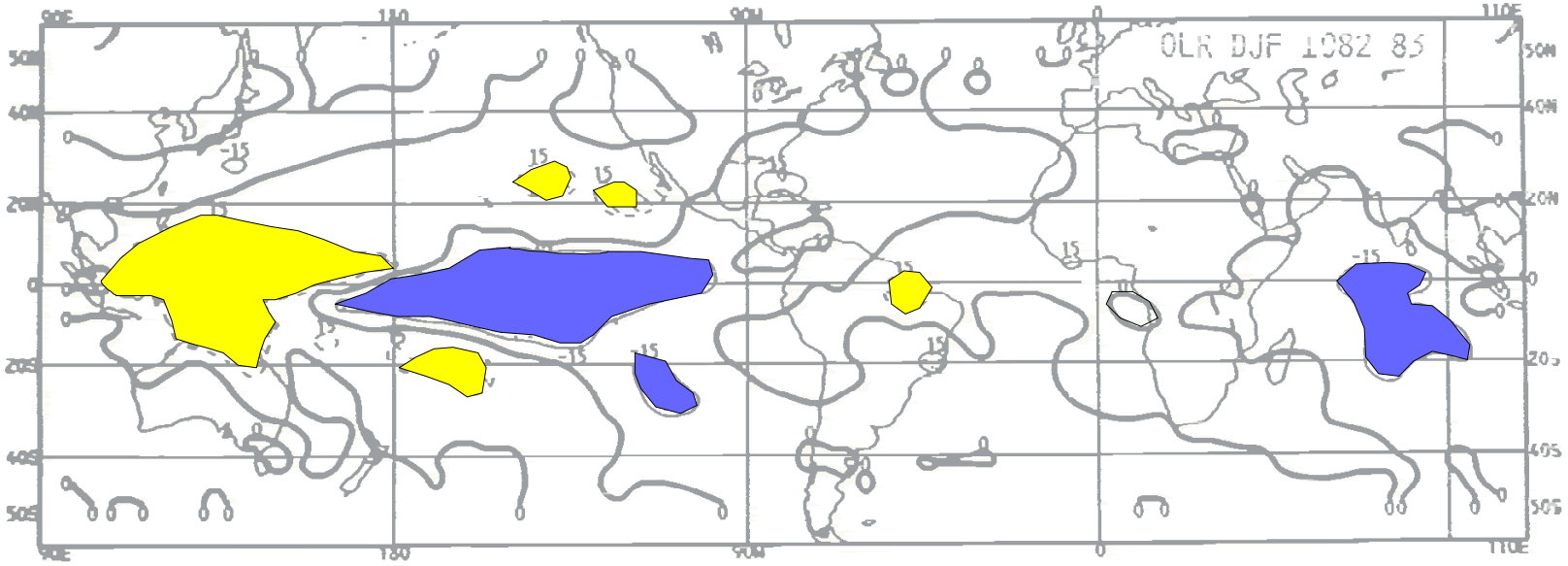
Mean Outgoing Long-wave Radiation for DJF
(Source: Rasmusson and Arkin, 1985)



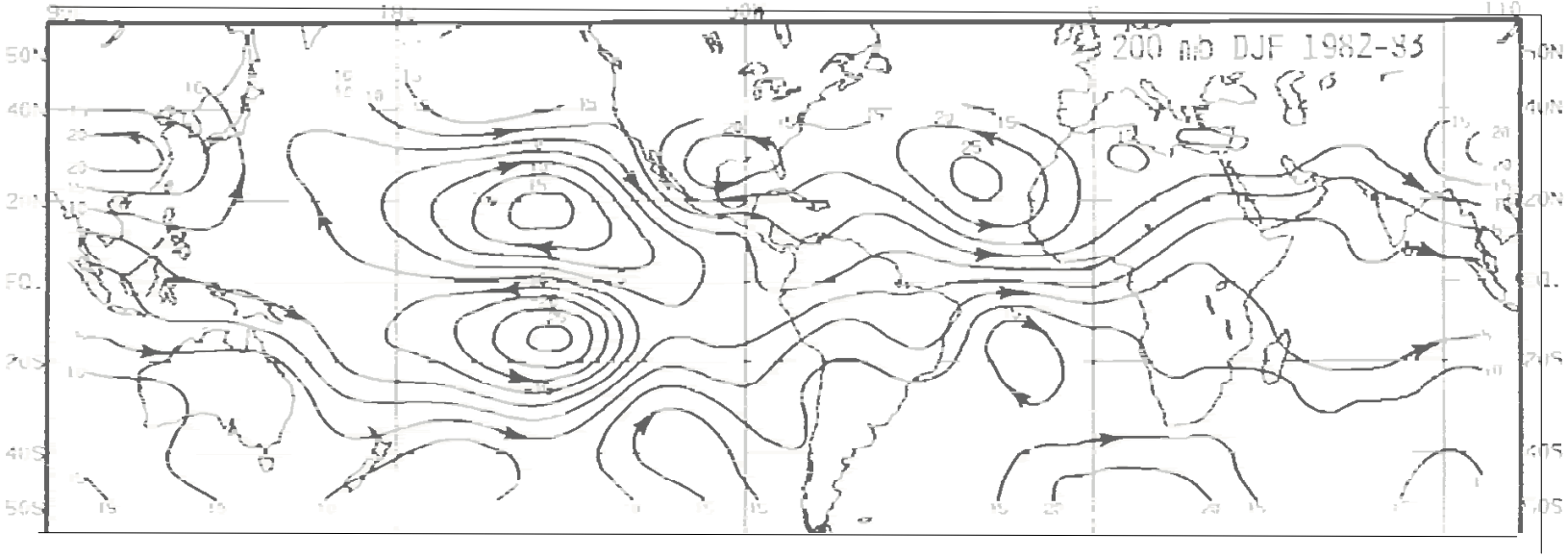
Mean 200mb Velocity Potential for DJF
(Source: Rasmusson and Arkin, 1985)



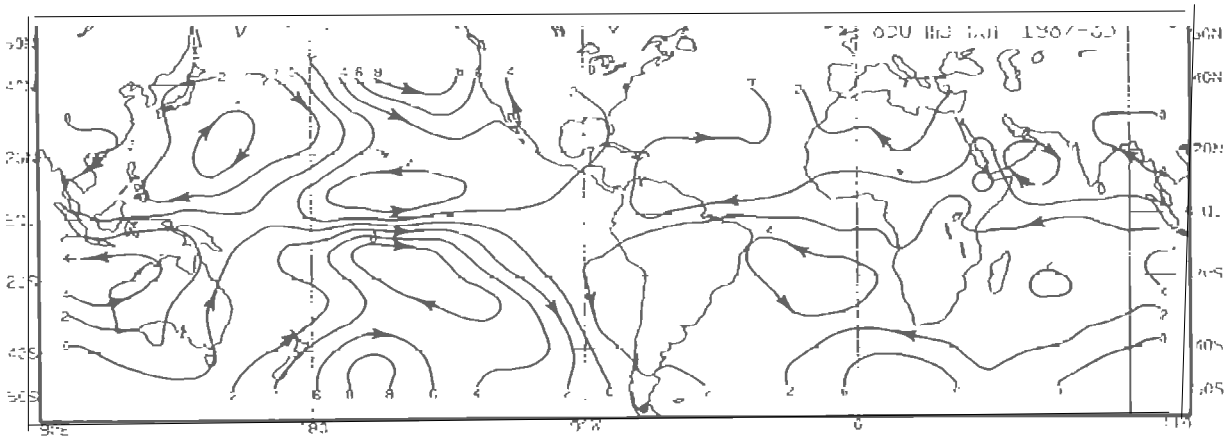
Sea Surface TemperatureAnomalies average for DJF 1982-83
(Source: Rasmusson and Arkin, 1985)



Outgoing Long-wave Radiation anomalies average for DJF 1982-83
(Source: Rasmusson and Arkin, 1985)

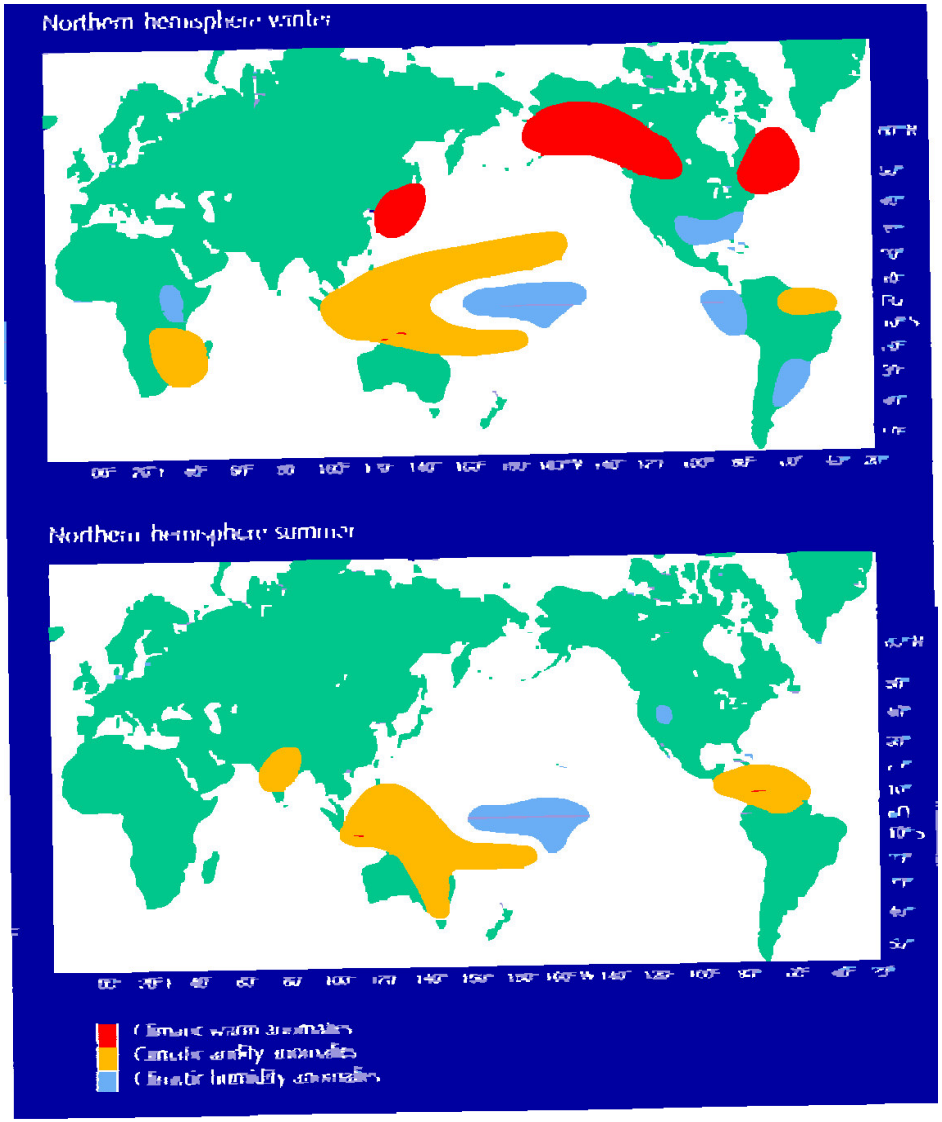


200 mb Stream Function Anomalies average for DJF 1982-83
(Source: Rasmusson and Arkin, 1985)

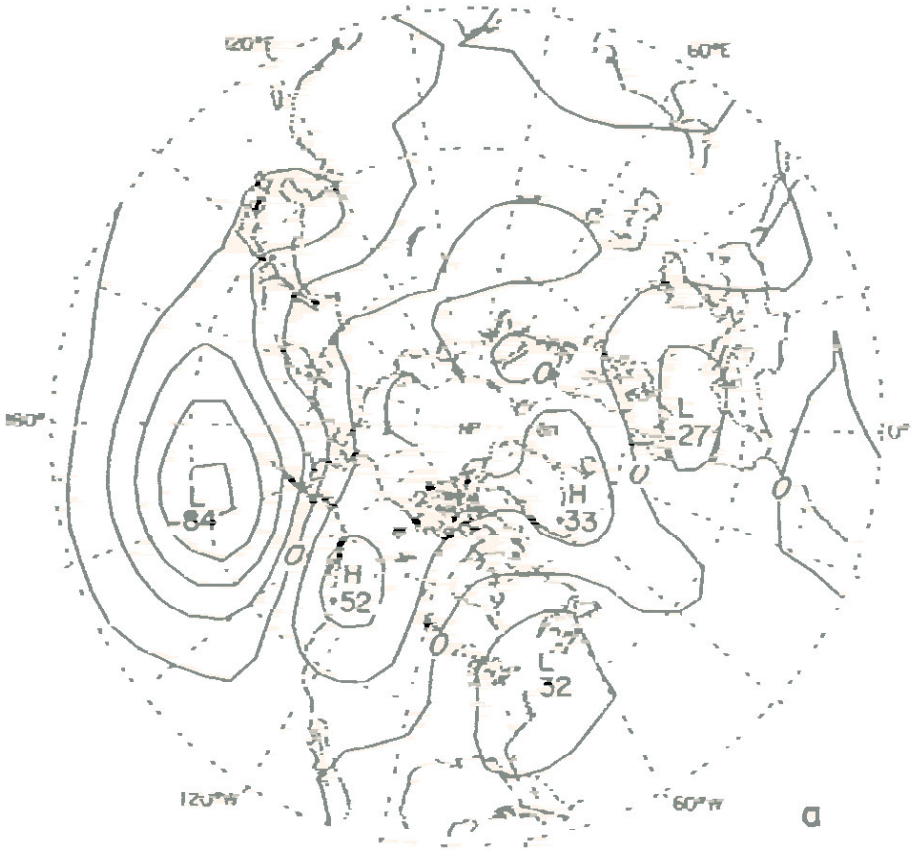


850 mb Stream Function Anomalies - DJF 1982-83

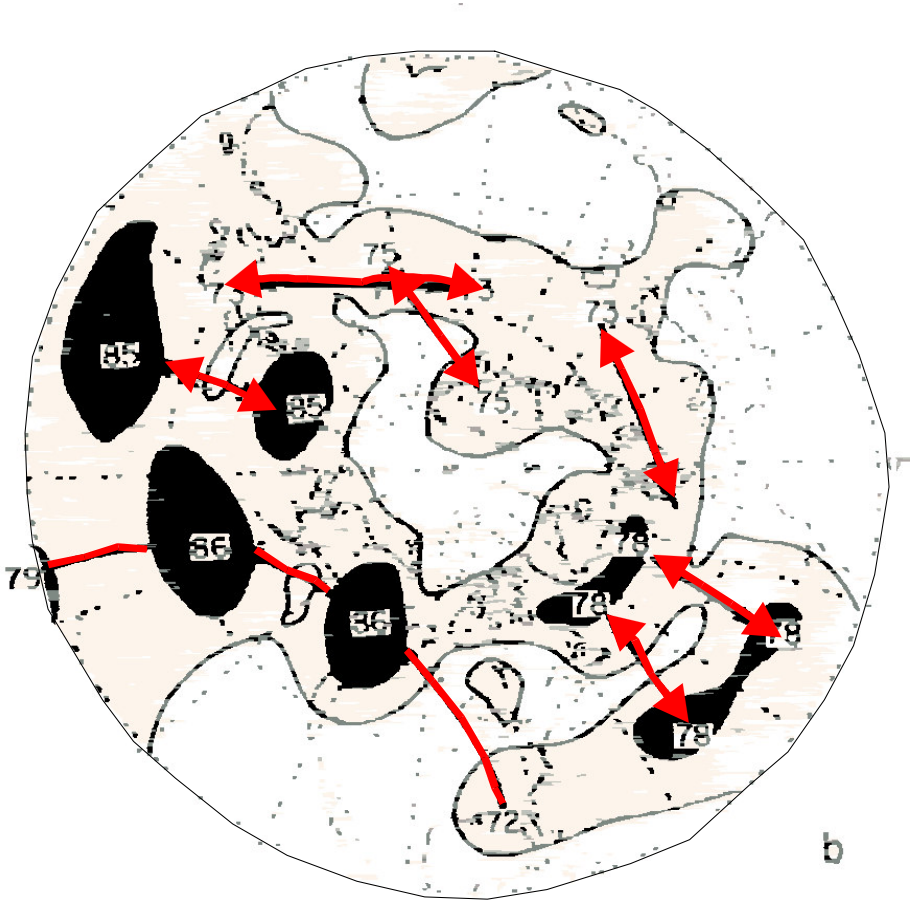
(Source: Rasmusson and Arkin, 1985)



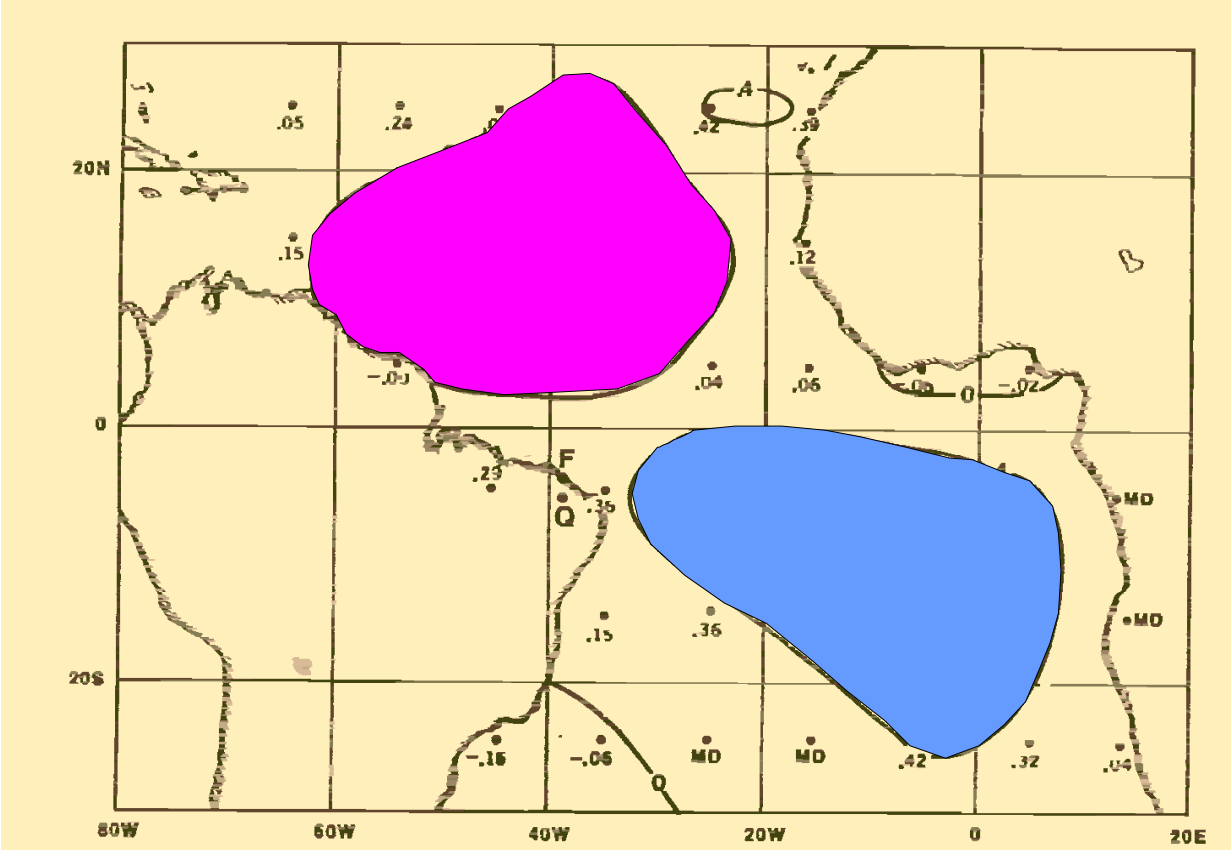
Precip and Temperature anomalies
(Source: Voituriez and Jacques, 2000)



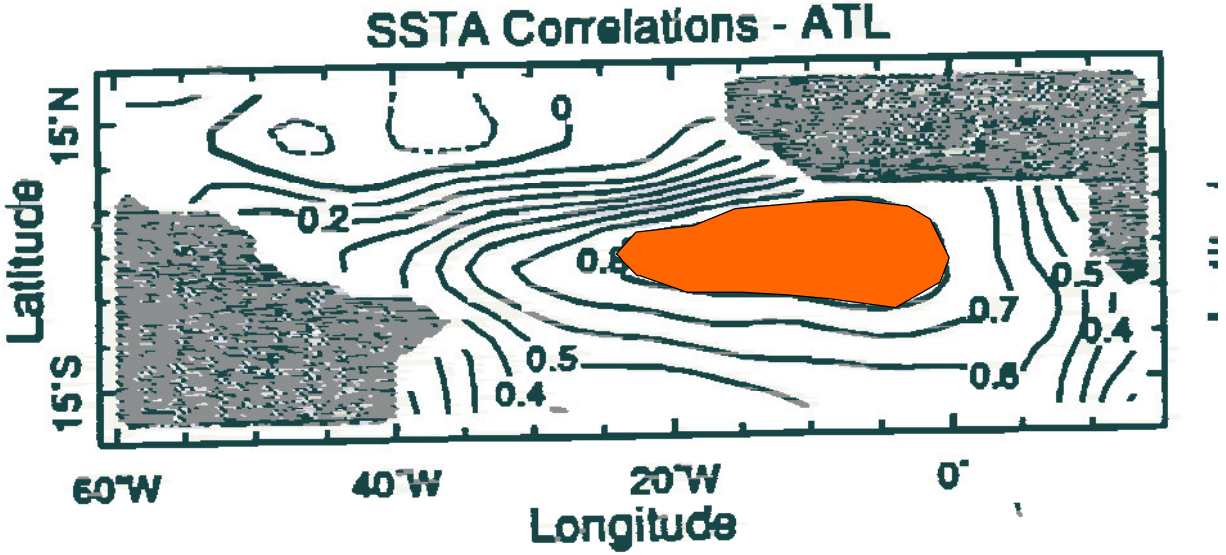
Composite anomaly Map - 700 mb height
(Source: Wallace and Gutzler, 1981)



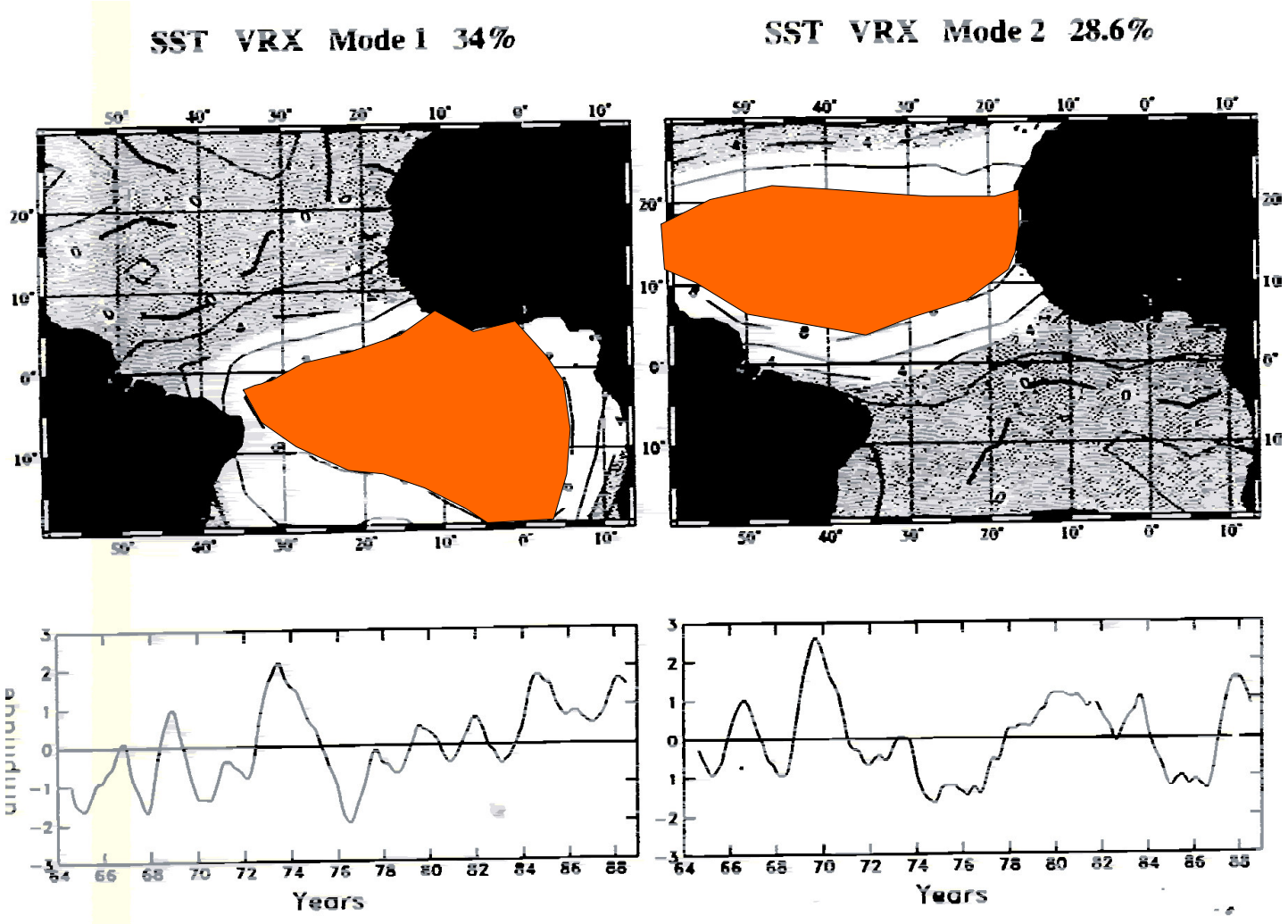
Teleconnectivity for 500 mb height
(Source: Wallace and Gutzler, 1981)



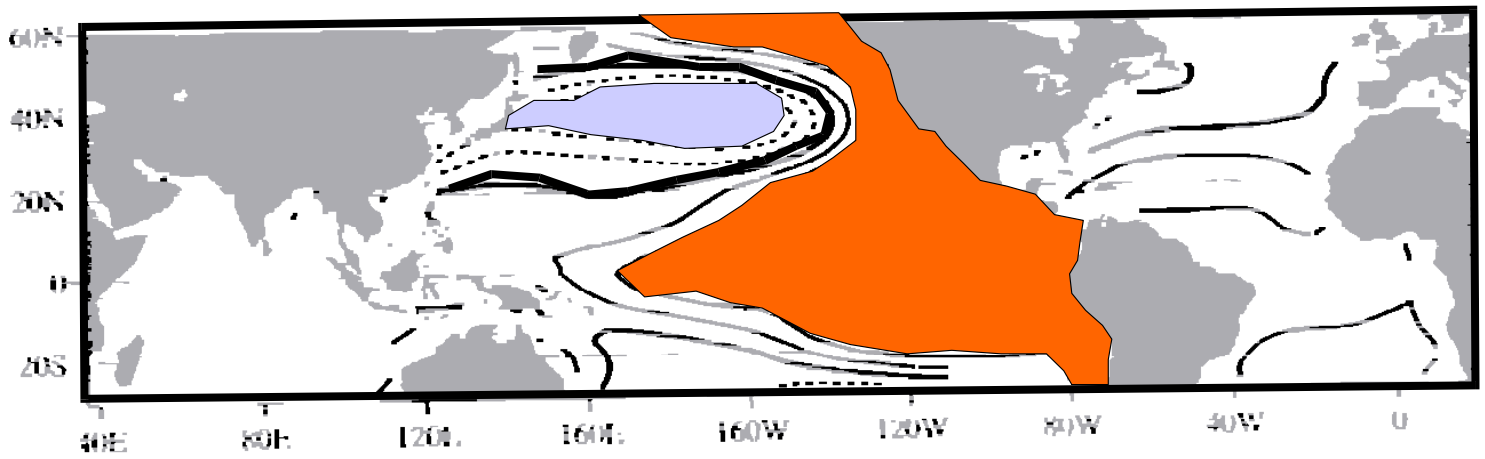
Correlation Sea Surface Temparature and Precip
(Source: Moura and Shukla, 1981)



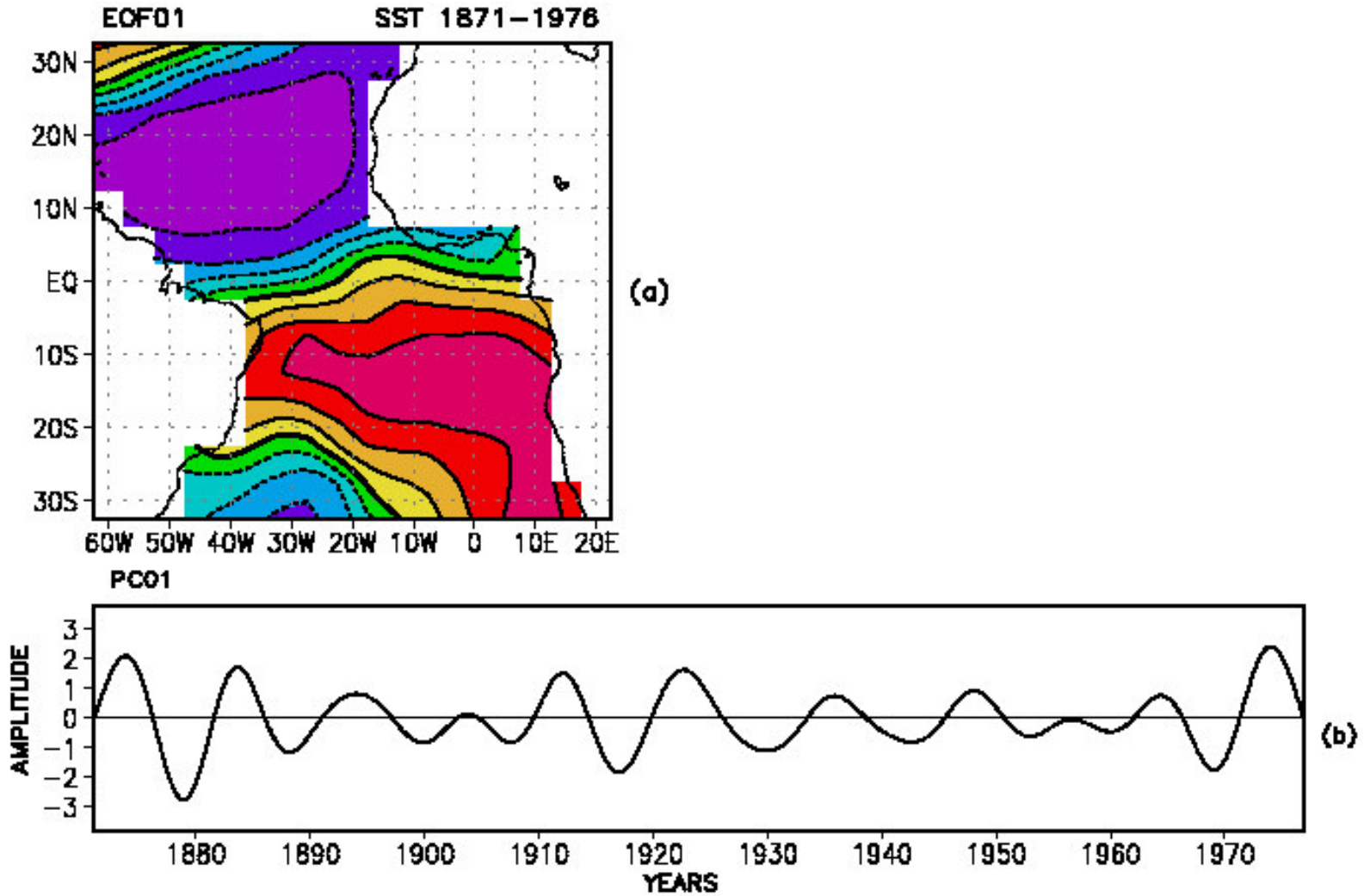
Equatorial Mode
(Source: Zebiak, 1993)

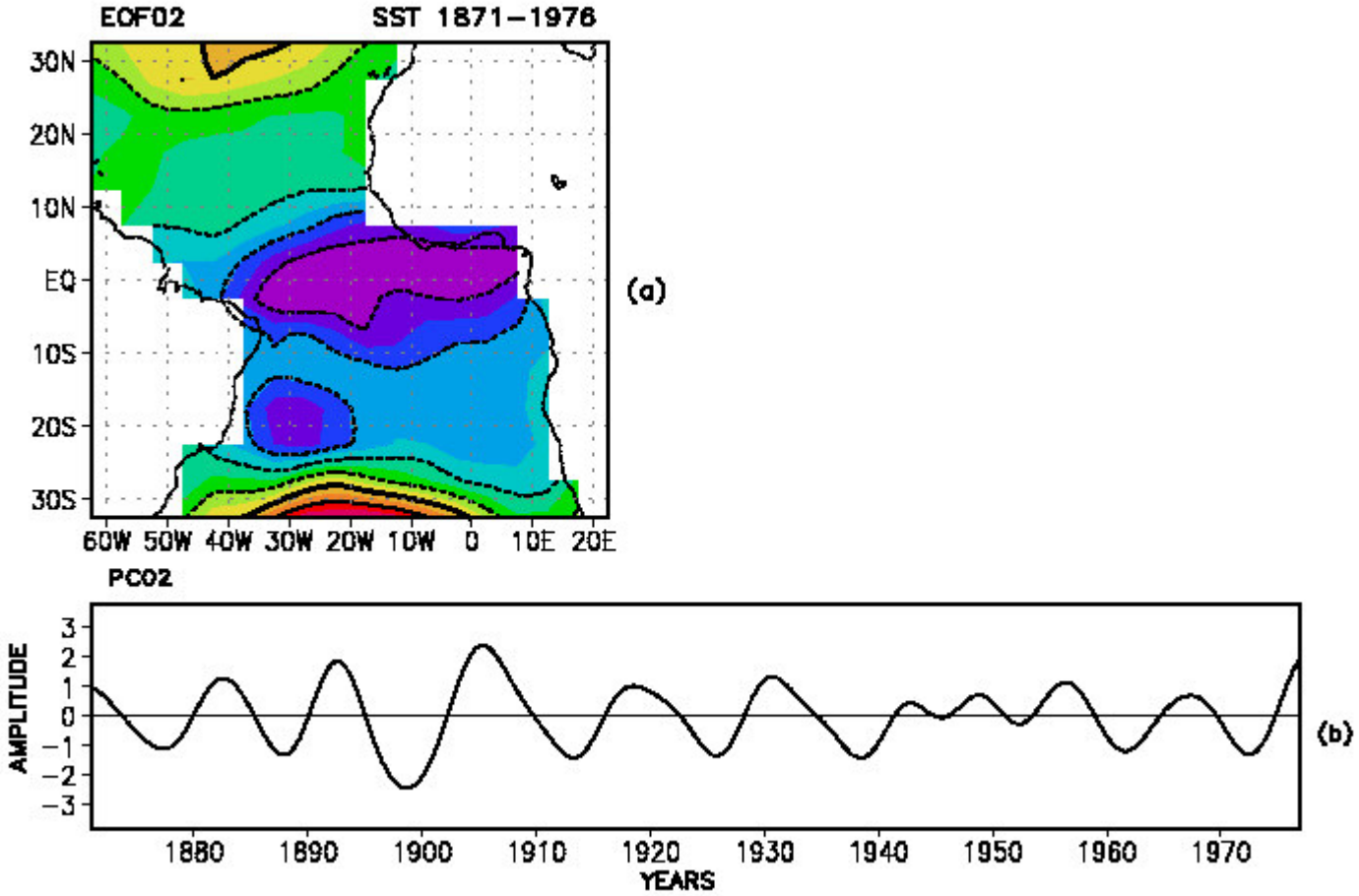


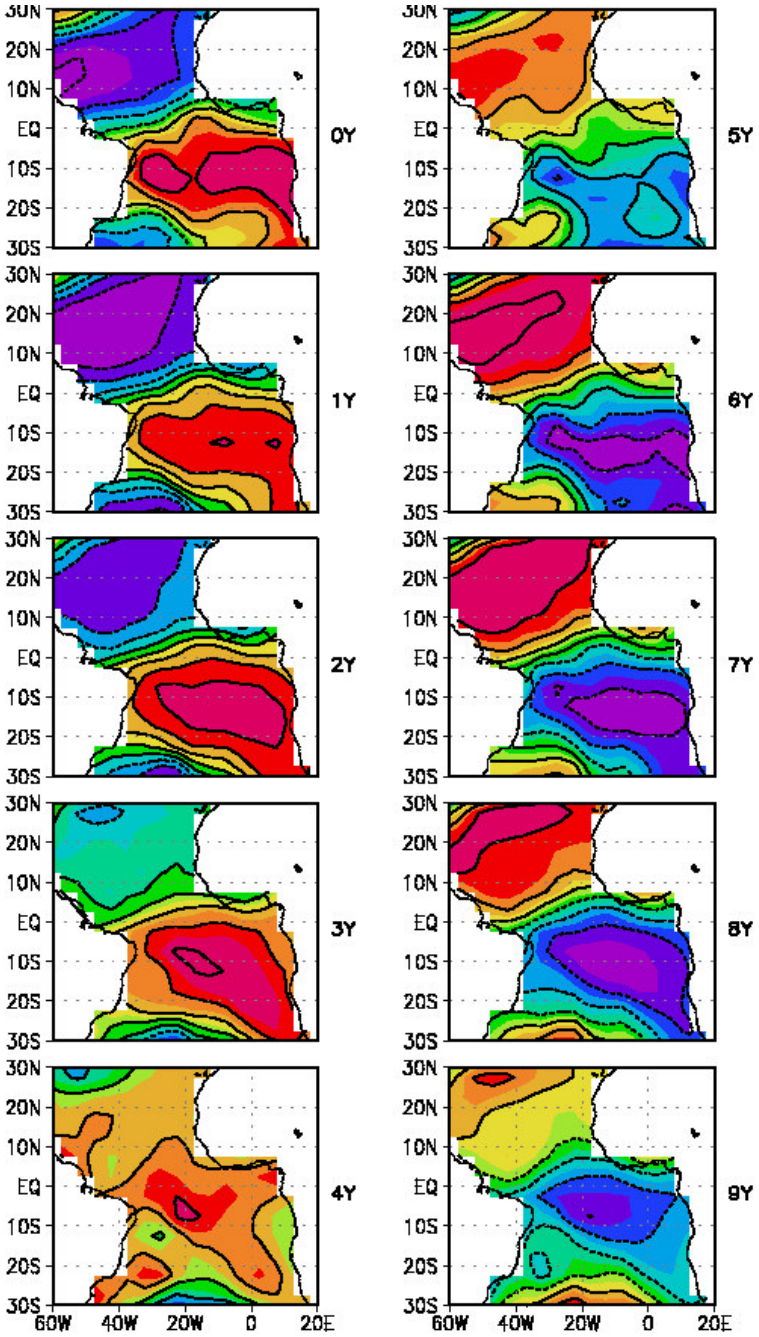
Two independent modes in the Tropical Atlantic
(Source: Houghton and Tourre, 1992)

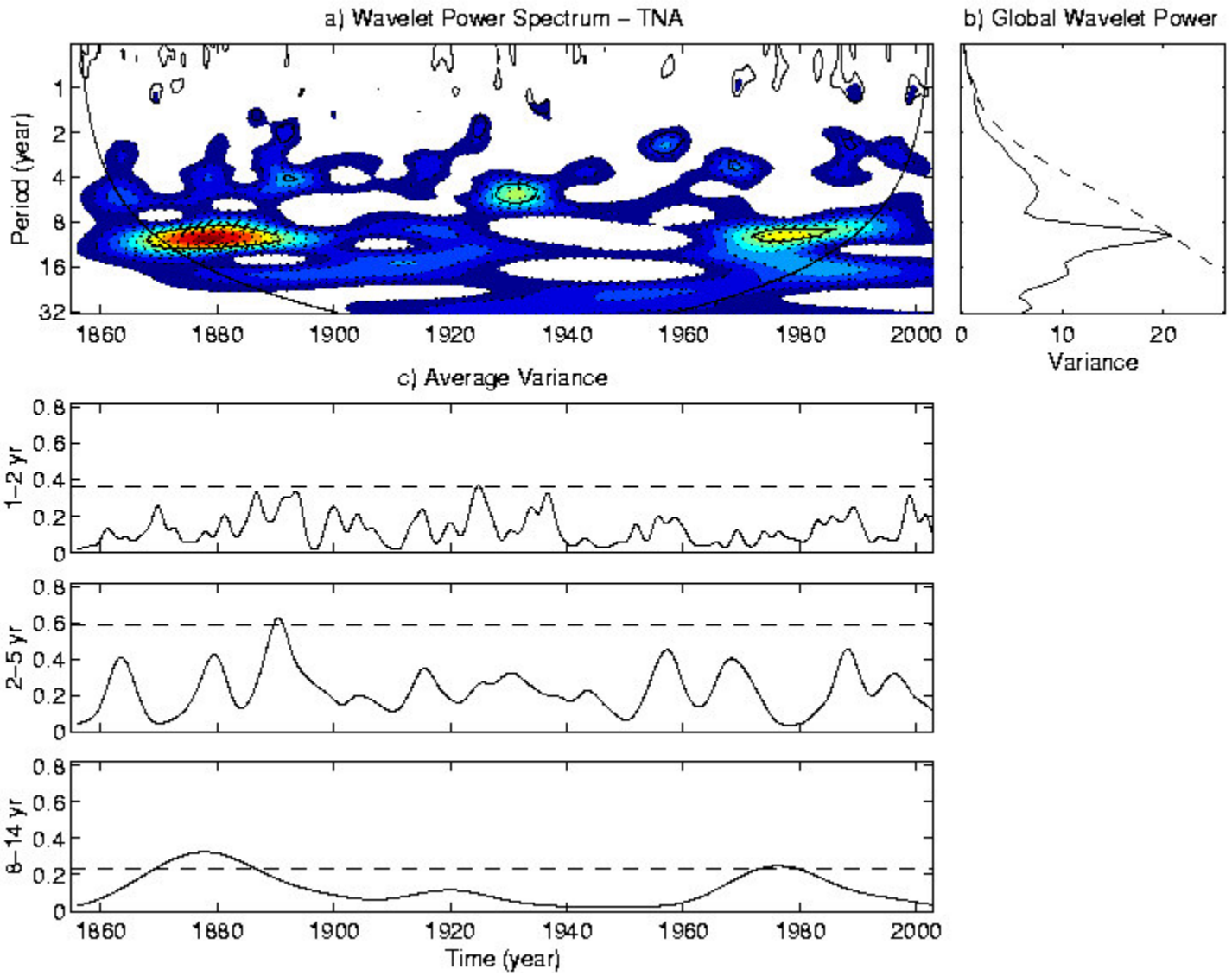


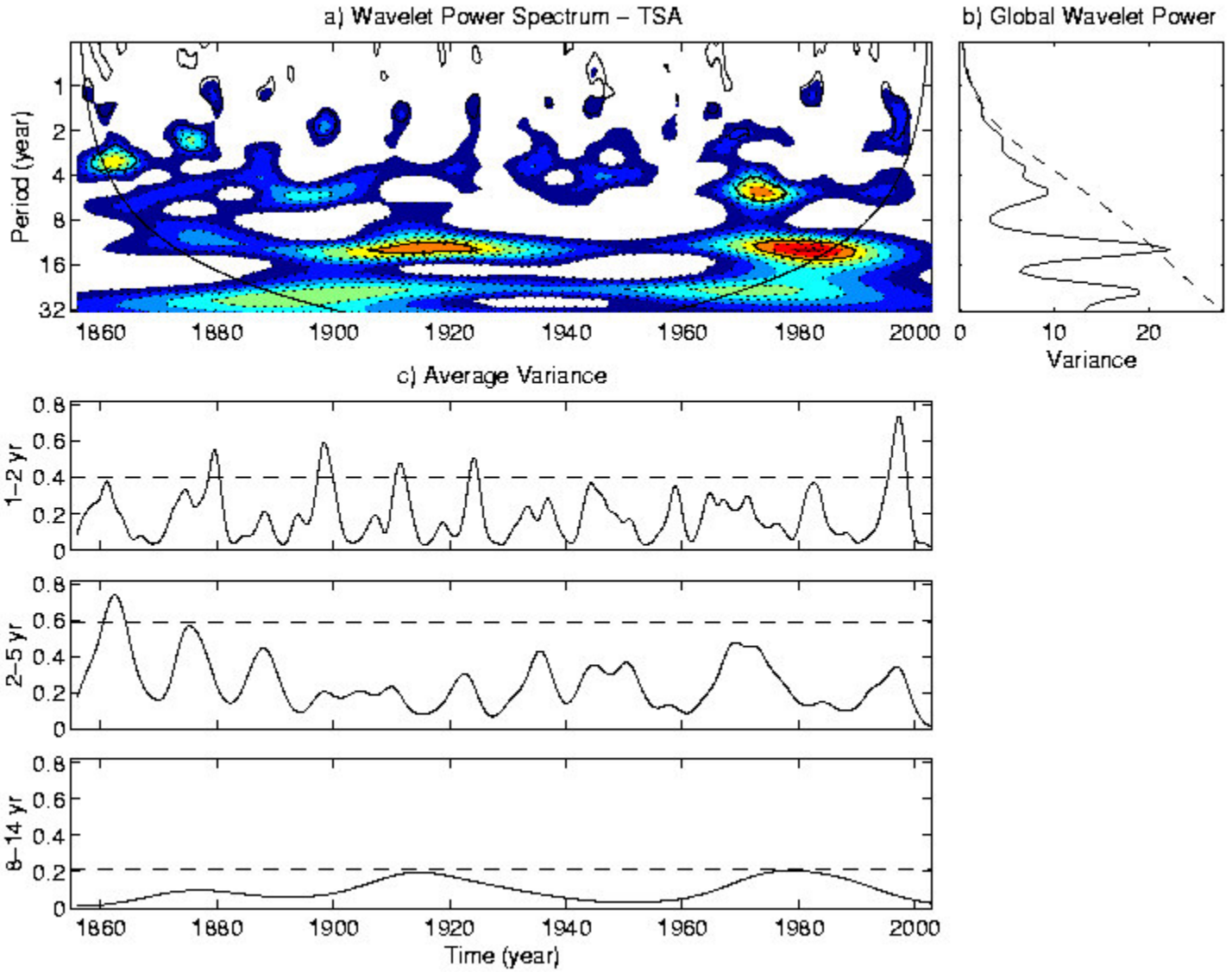
Pacific Decadal Oscillation mode
(Source: Zhang et al., 1997)


EOF01
SST 1871–1976
30N
20N
10N
EQ
10S
20S
30S
60W 50W 40W 30W 20W 10W 0 10E 20E
(a)
PC01
AMPLITUDE
3
2
1
0
−1
−2
−3
1880 1890 1900 1910 1920 1930 1940 1950 1960 1970
YEARS
(b)


EOF02
SST 1871–1976
30N
20N
10N
EQ
10S
20S
30S
60W 50W 40W 30W 20W 10W 0 10E 20E
(a)
PC02
AMPLITUDE
3
2
1
0
−1
−2
−3
1880 1890 1900 1910 1920 1930 1940 1950 1960 1970
YEARS
(b)


30N
20N
10N
EQ
10S
20S
30S
0Y
1Y
2Y
3Y
4Y
5Y
6Y
7Y
8Y
9Y
60W
40W
20W
0
20E


a) Wavelet Power Spectrum – TNA
b) Global Wavelet Power
Period (year)
1
2
4
8
16
32
1860
1880
1900
1920
1940
1960
1980
2000
0
10
20
Variance
c) Average Variance
1–2 yr
2–5 yr
8–14 yr
0.8
0.6
0.4
0.2
0
Time (year)


a) Wavelet Power Spectrum – TSA
b) Global Wavelet Power
Period (year)
1
2
4
8
16
32
1860
1880
1900
1920
1940
1960
1980
2000
0
10
20
Variance
c) Average Variance
1–2 yr
2–5 yr
8–14 yr
0
0.2
0.4
0.6
0.8
Time (year)

CONCLUDING REMARKS

The climate variability in the Pacific and Atlantic manifests in temporal multi-scale, in particular in the interannual and decadal scales.

Pacific is dominated by a single mode of the interannual climate variability (ENSO)

ENSO is related to other modes of variability in other regions such as PNA and NAO modes

Pacific is dominated by a similar mode to the ENSO in the decadal scale (Pacific decadal oscillation - PDO)

Atlantic is subject to multiple competing modes varying in interannual and decadal scales.

The SST modes of variability in the Pacific and Atlantic have important effects in the climate of several regions (droughts, floods, etc)

The relation Pacific and Atlantic modes and the non-linear aspects of the climate system have been discussed in some papers.