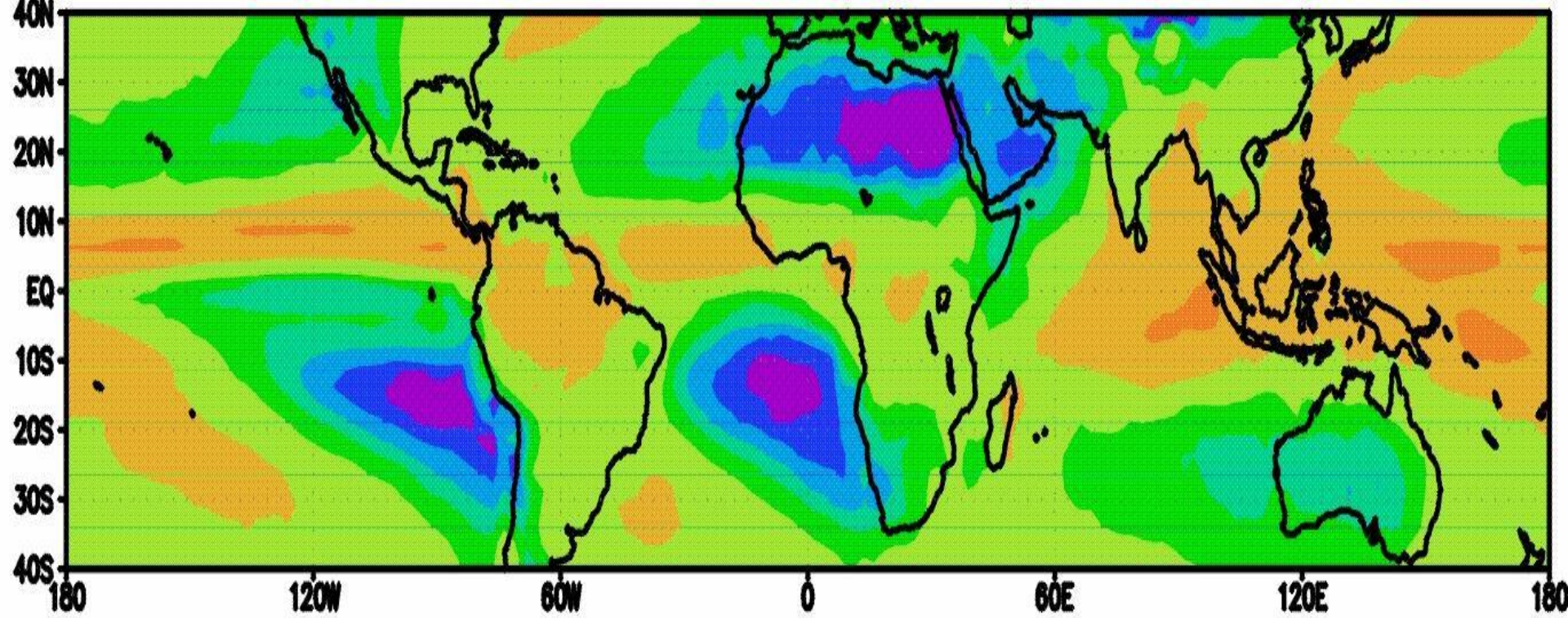
Climatology Lecture 8

Variability of the General Circulation

Richard Washington

Lecture Outline

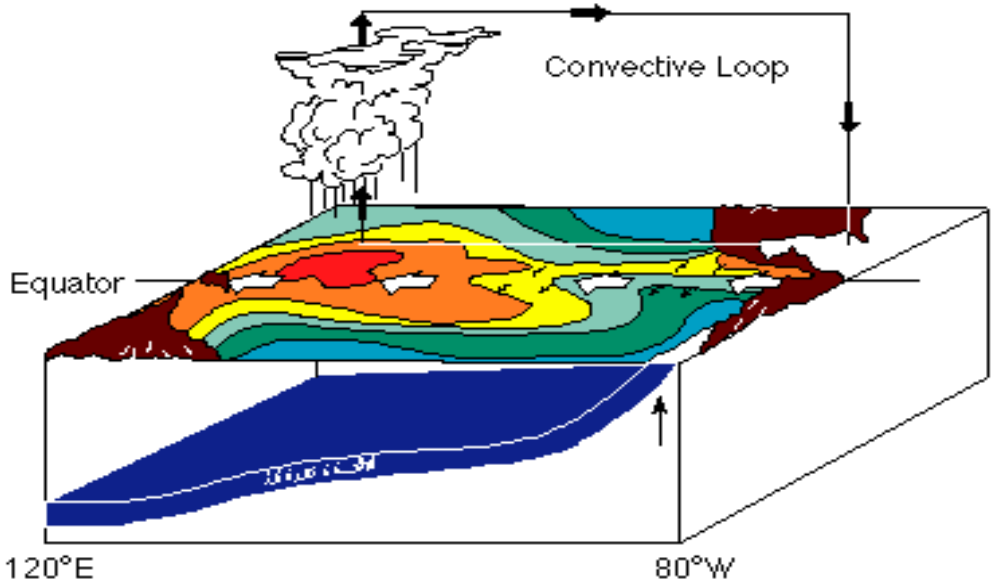
- El Nino - Southern Oscillation (ENSO):
  - definition
  - impacts on climate
  - ways of measuring ENSO
  - some past ENSO events
- North Atlantic Oscillation (NAO)



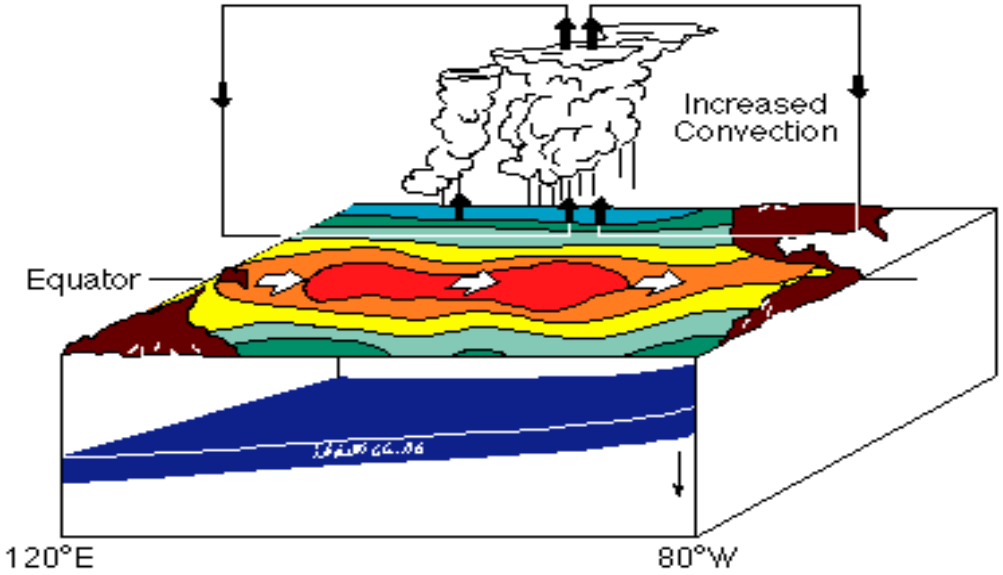
Annual Average Rainfall mm/day

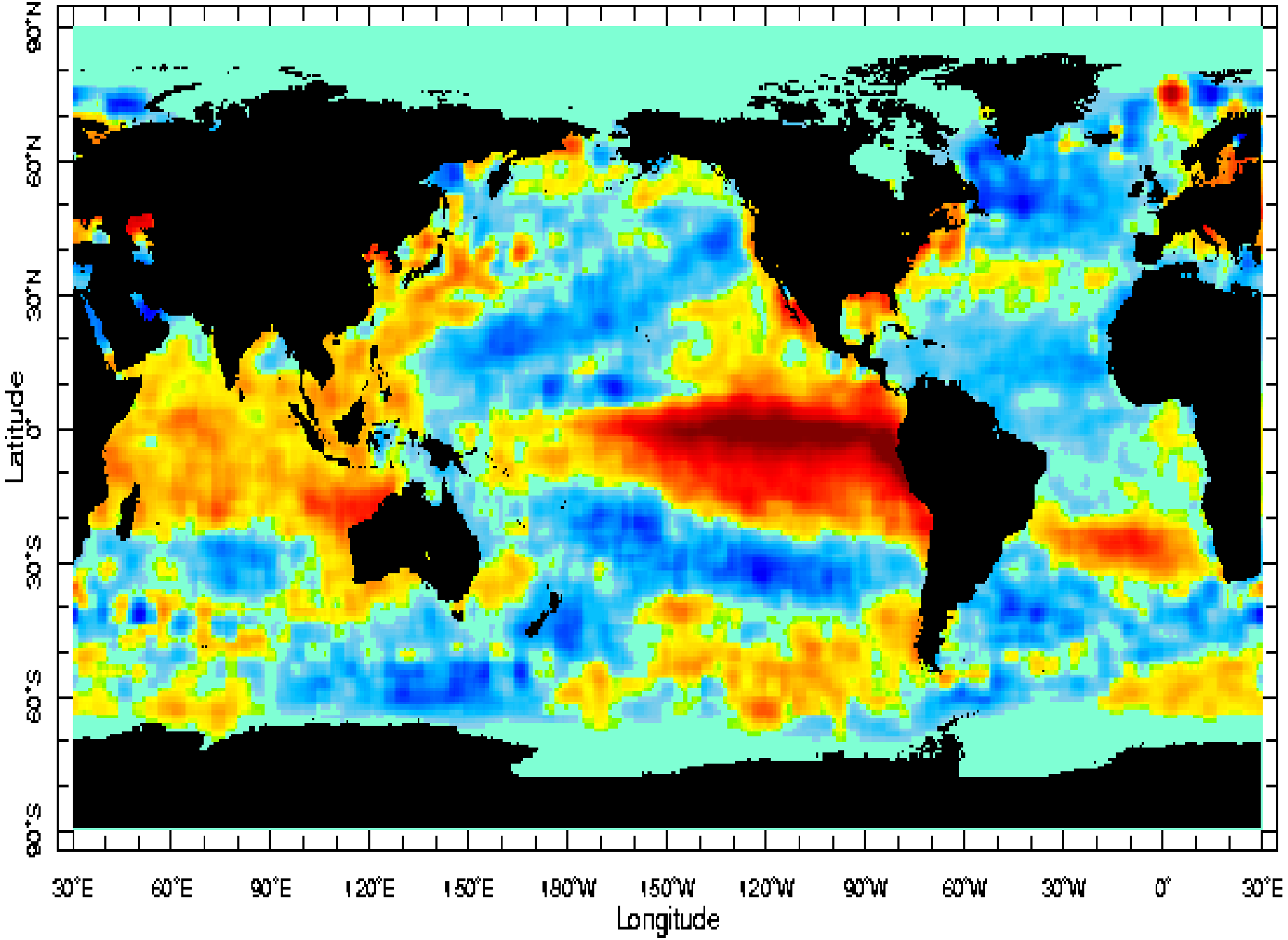
GrADS: COLA/UMCP

Normal Conditions

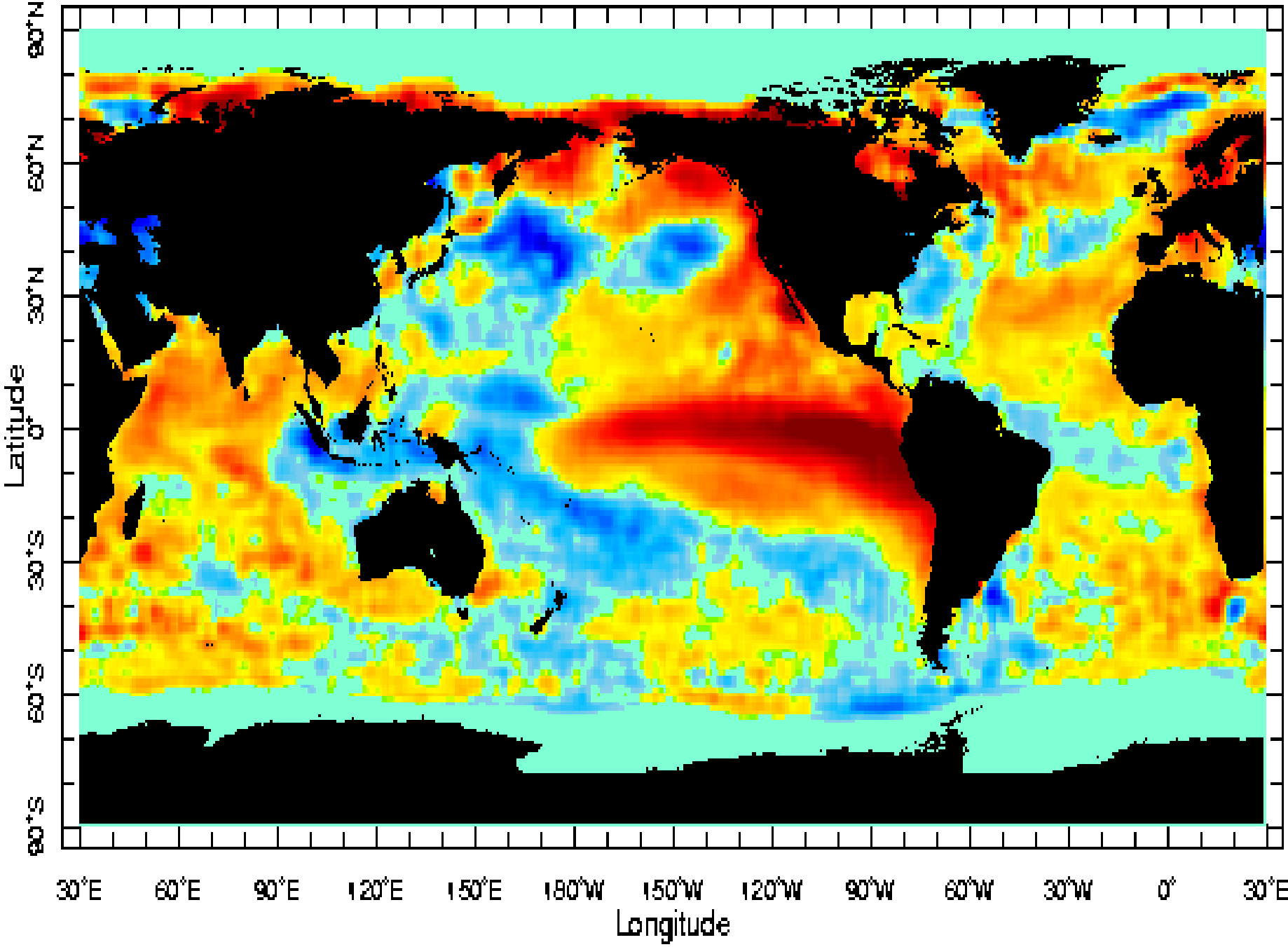


El Niño Conditions

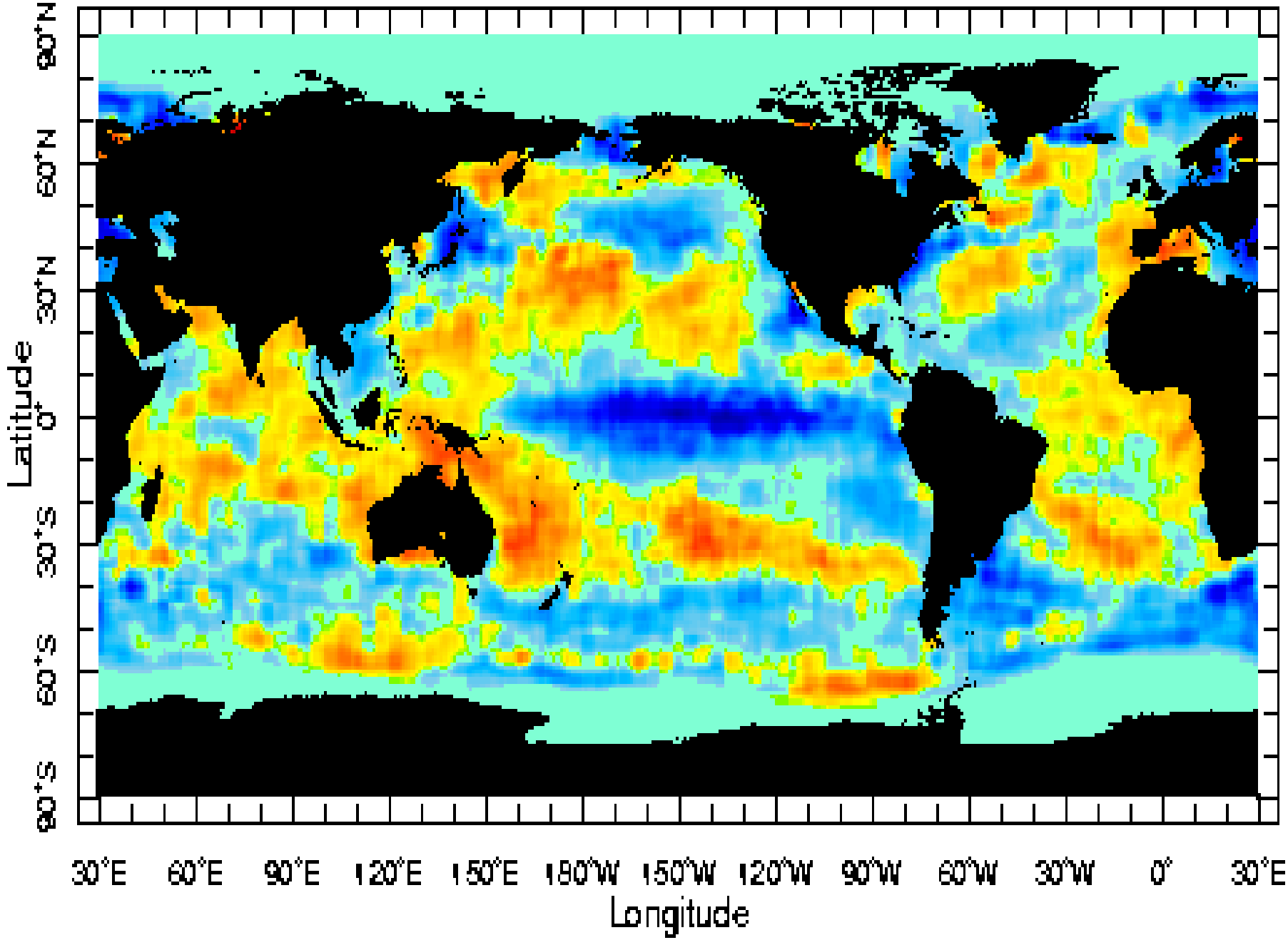



90°N
60°N
30°N
0°
30°S
60°S
90°S
Latitude
30°E
60°E
90°E
120°E
150°E
180°W
150°W
120°W
90°W
60°W
30°W
0°
30°E
Longitude

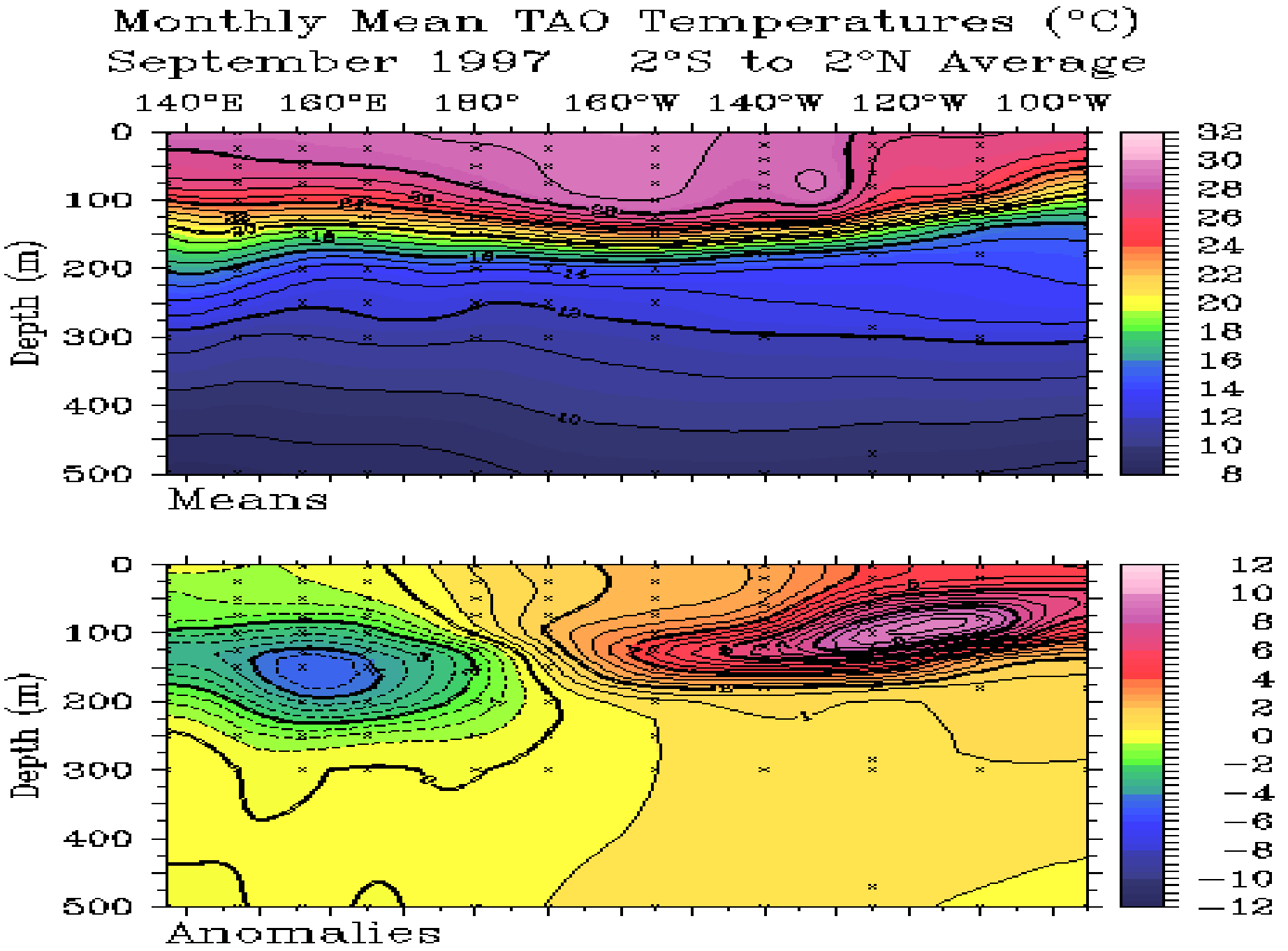
Dec 82


90°N
60°N
30°N
0°
30°S
60°S
90°S
Latitude
30°E
60°E
90°E
120°E
150°E
180°W
150°W
120°W
90°W
60°W
30°W
0°
30°E
Longitude

SEP 97


90°N
60°N
30°N
0°
30°S
60°S
90°S
Latitude
30°E
60°E
90°E
120°E
150°E
180°W
150°W
120°W
90°W
60°W
30°W
0°
30°E
Longitude

Nov 88


Monthly Mean TAO Temperatures (°C)
September 1997 2°S to 2°N Average
140°E 160°E 180° 160°W 140°W 120°W 100°W
Depth (m)
0
100
200
300
400
500
Means
32
30
28
26
24
22
20
18
16
14
12
10
8
Anomalies
12
10
8
6
4
2
0
−2
−4
−6
−8
−10
−12
TAO Project Office/PMEL/NOAA
Oct 26 1997

ENSO

- Ocean - Atmosphere Interaction
- Largest known source of climate variability
- Global changes to rainfall, winds, pressure and temperature, especially in the tropics
- Major El Nino event 1982/83 1997/98
- Sustained El Nino event 1991-1994

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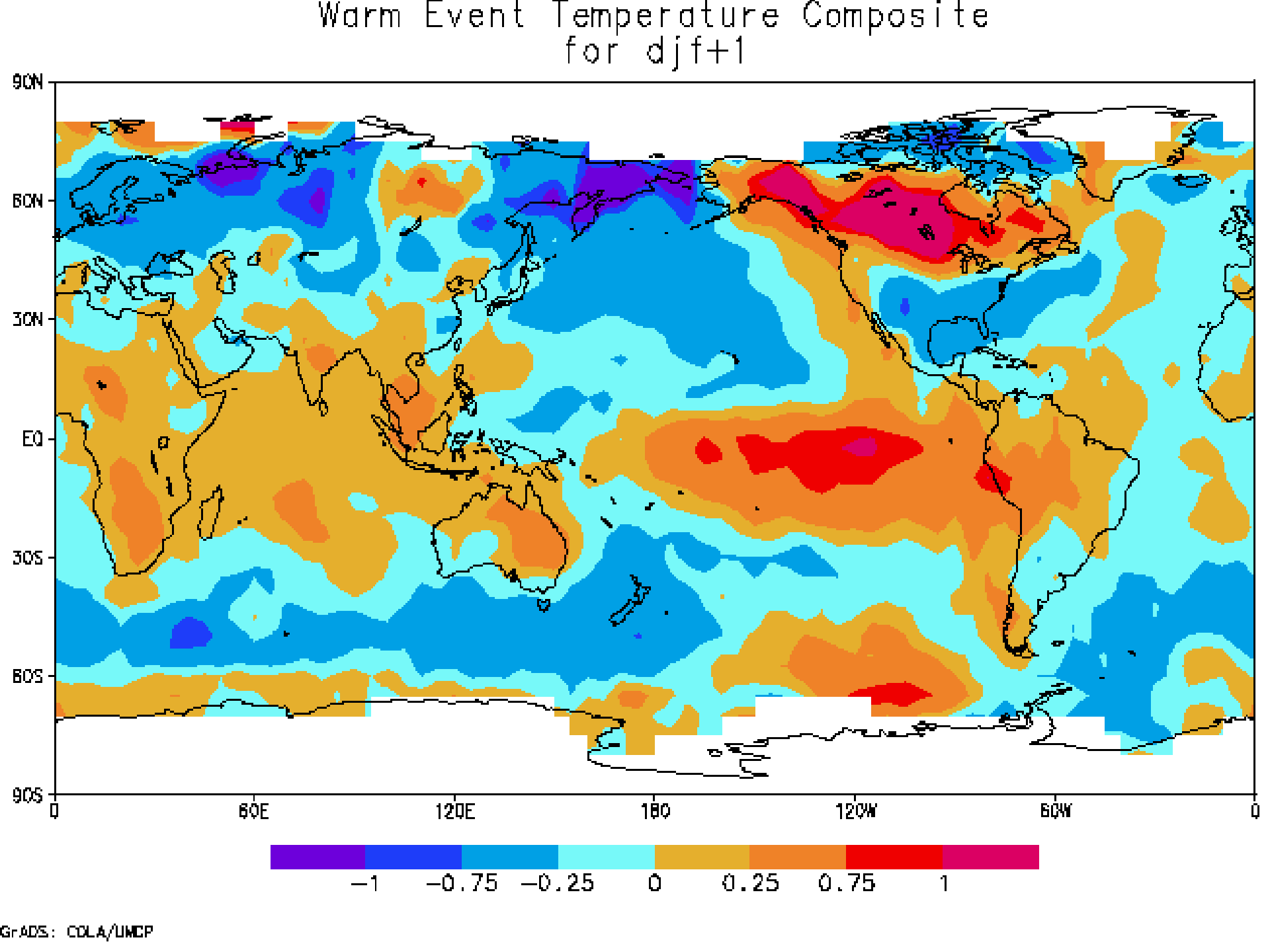
  - impacts on climate
  - ways of measuring ENSO
  - some past ENSO events
- North Atlantic Oscillation (NAO)

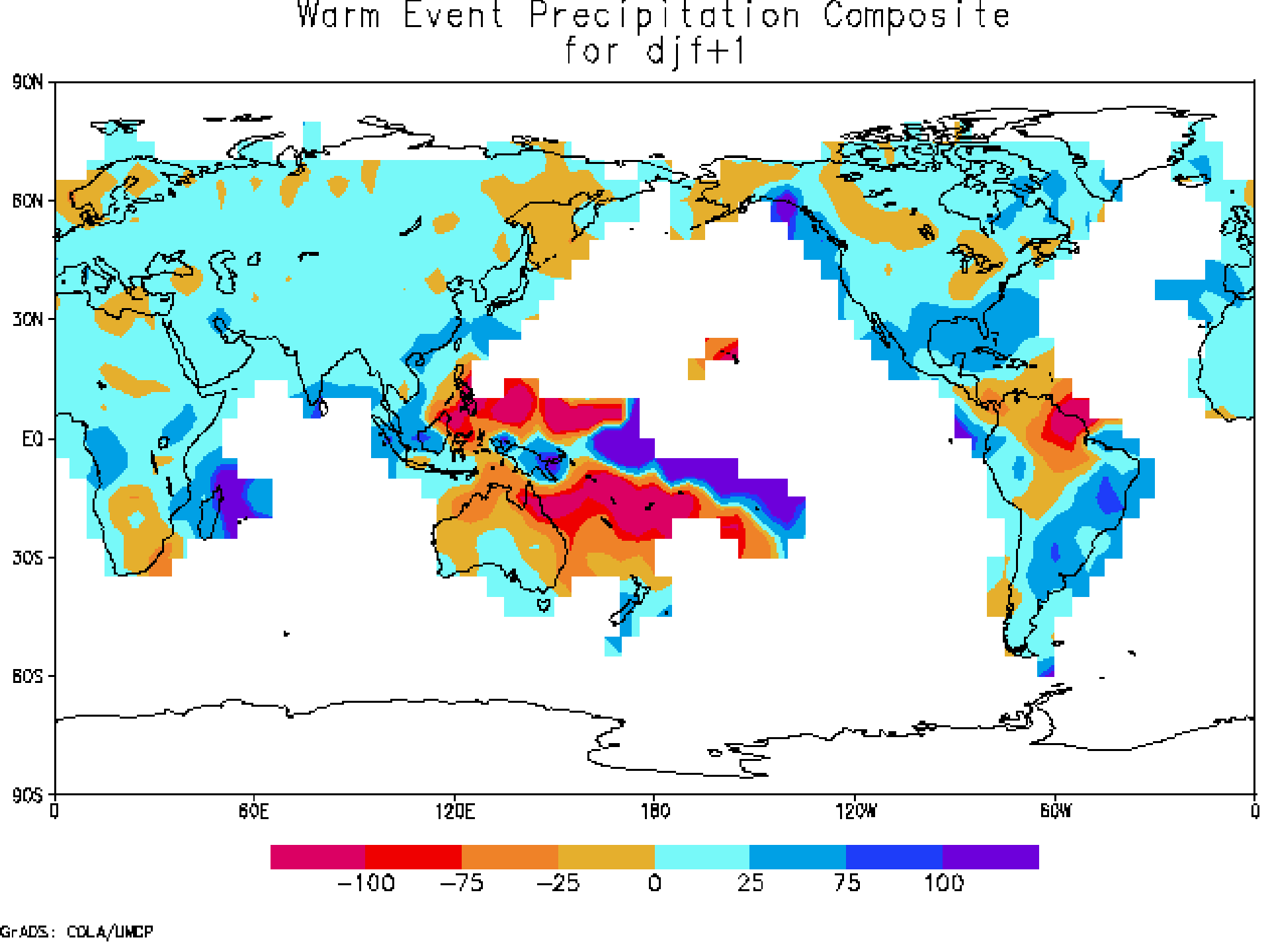
El Nino

- pressure higher (than normal) at Darwin
- pressure lower (than normal) in the C.Pacific
- westerlies (weak easterlies) across Pacific
- wet C.Pacific
  dry W.Pacific

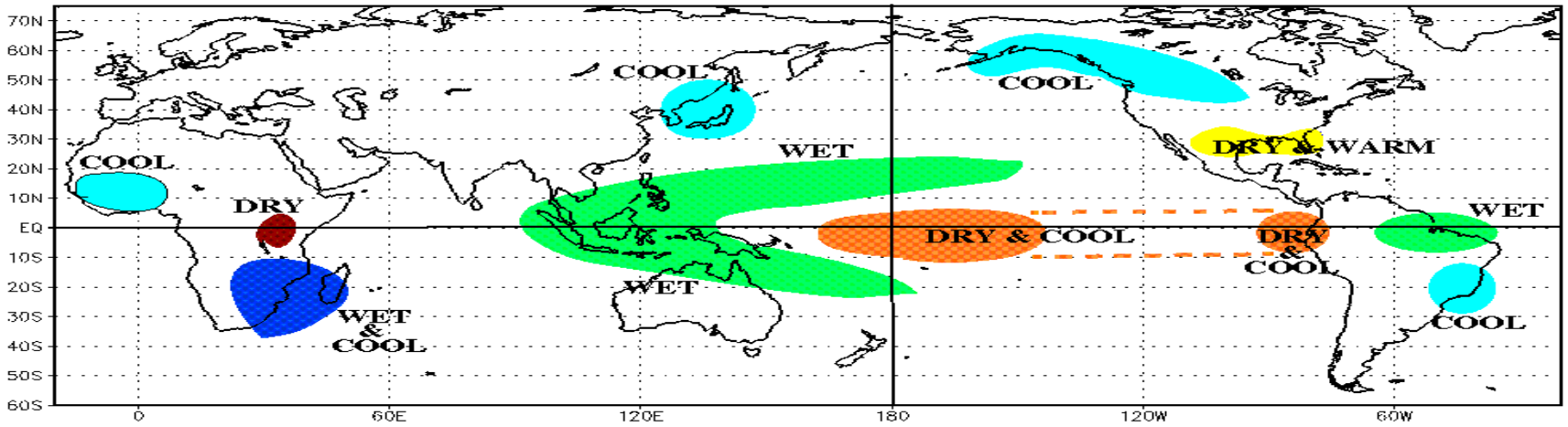
La Nina

- pressure lower (than normal) at Darwin
- pressure higher (than normal) in the C.Pacific
- strong easterlies across Pacific
- dry C.Pacific
  wet W.Pacific


Warm Event Temperature Composite
for djf+1
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−1
−0.75
−0.25
0
0.25
0.75
1
GrADS: COLA/UMCP

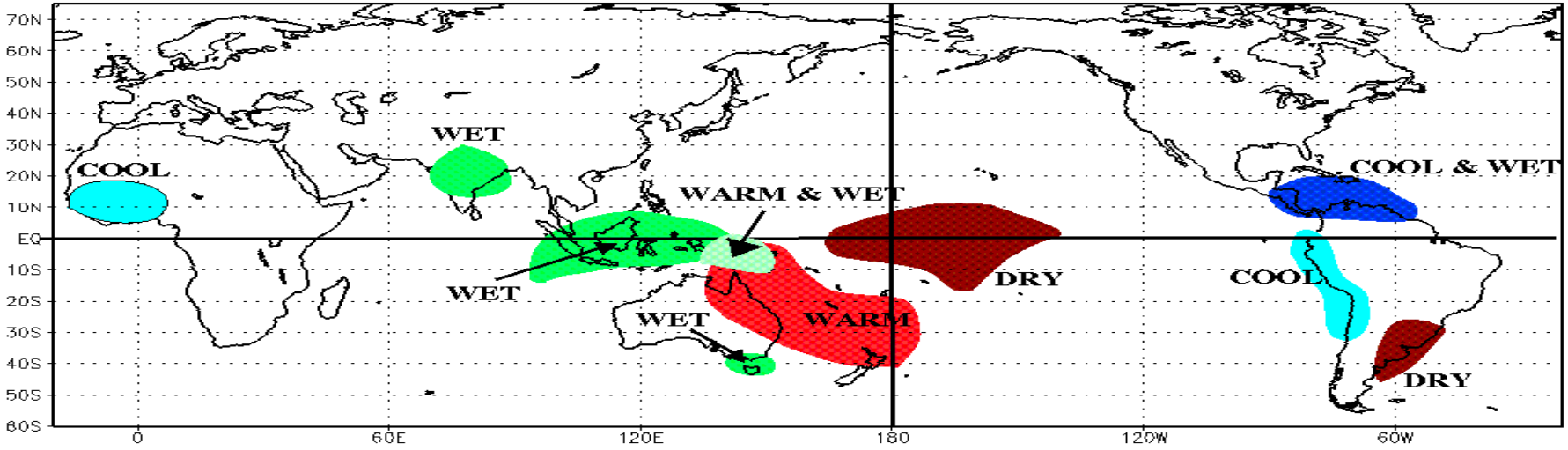

Warm Event Precipitation Composite
for djf+1
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−100
−75
−25
0
25
75
100
GrADS: COLA/UMCP

COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

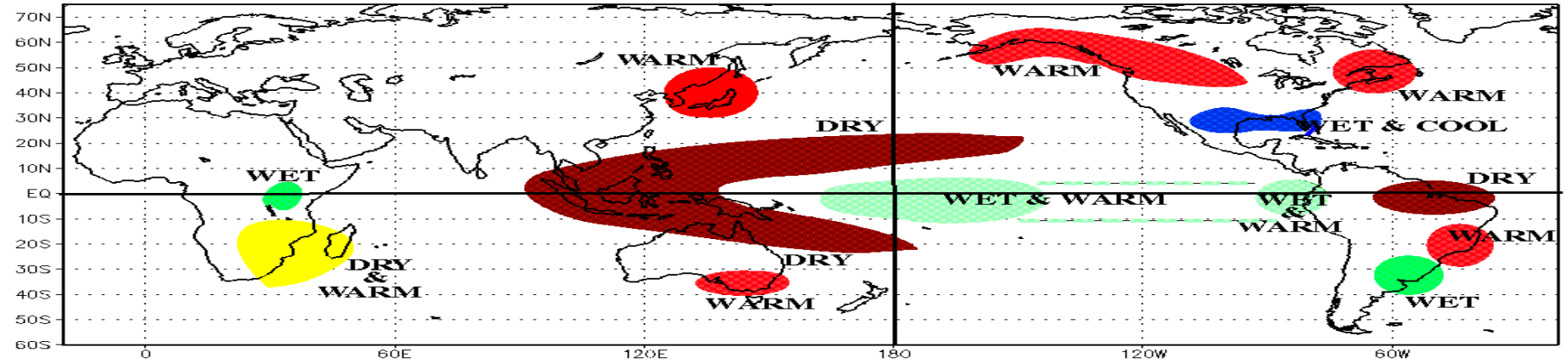


NOAA
Climate Prediction Center, NOAA

COLD EPISODE RELATIONSHIPS JUNE - AUGUST

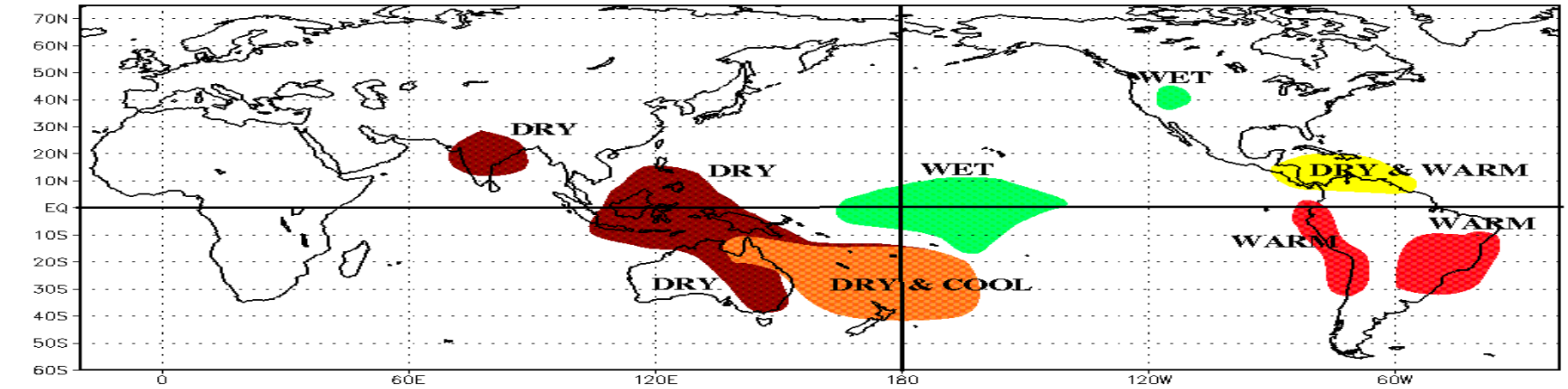


WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

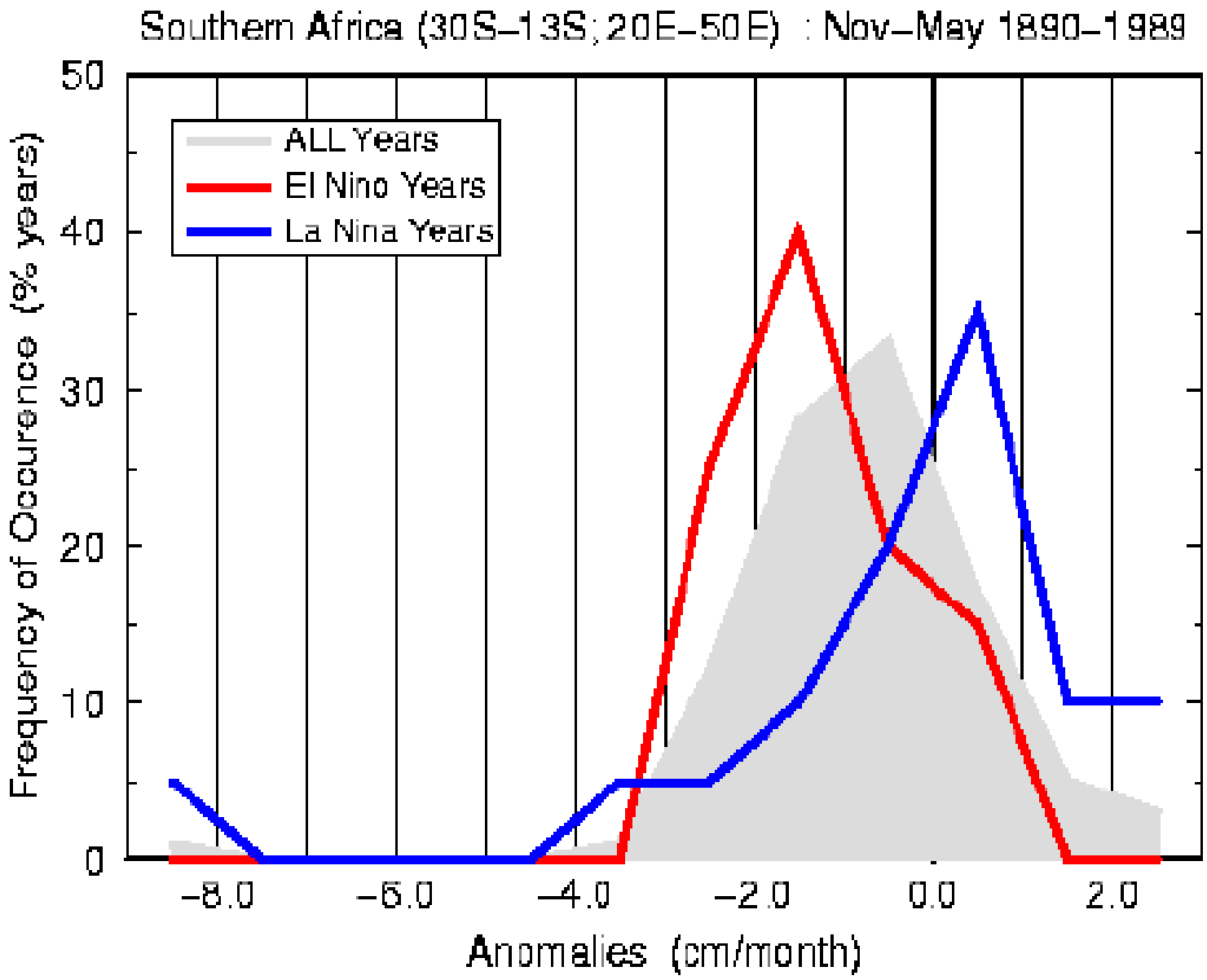


Climate Prediction Center, NOAA

WARM EPISODE RELATIONSHIPS JUNE - AUGUST



ENSO Impacts : Rainfall Anomalies



El Nino

- WET East Africa (Oct-Dec)
- DRY southern Africa (Dec- March)
- DRY Sahel (July-Sep)

La Nina

- DRY East Africa (Oct-Dec)
- WET southern Africa (Dec-March)
- WET Sahel (July-Sep)

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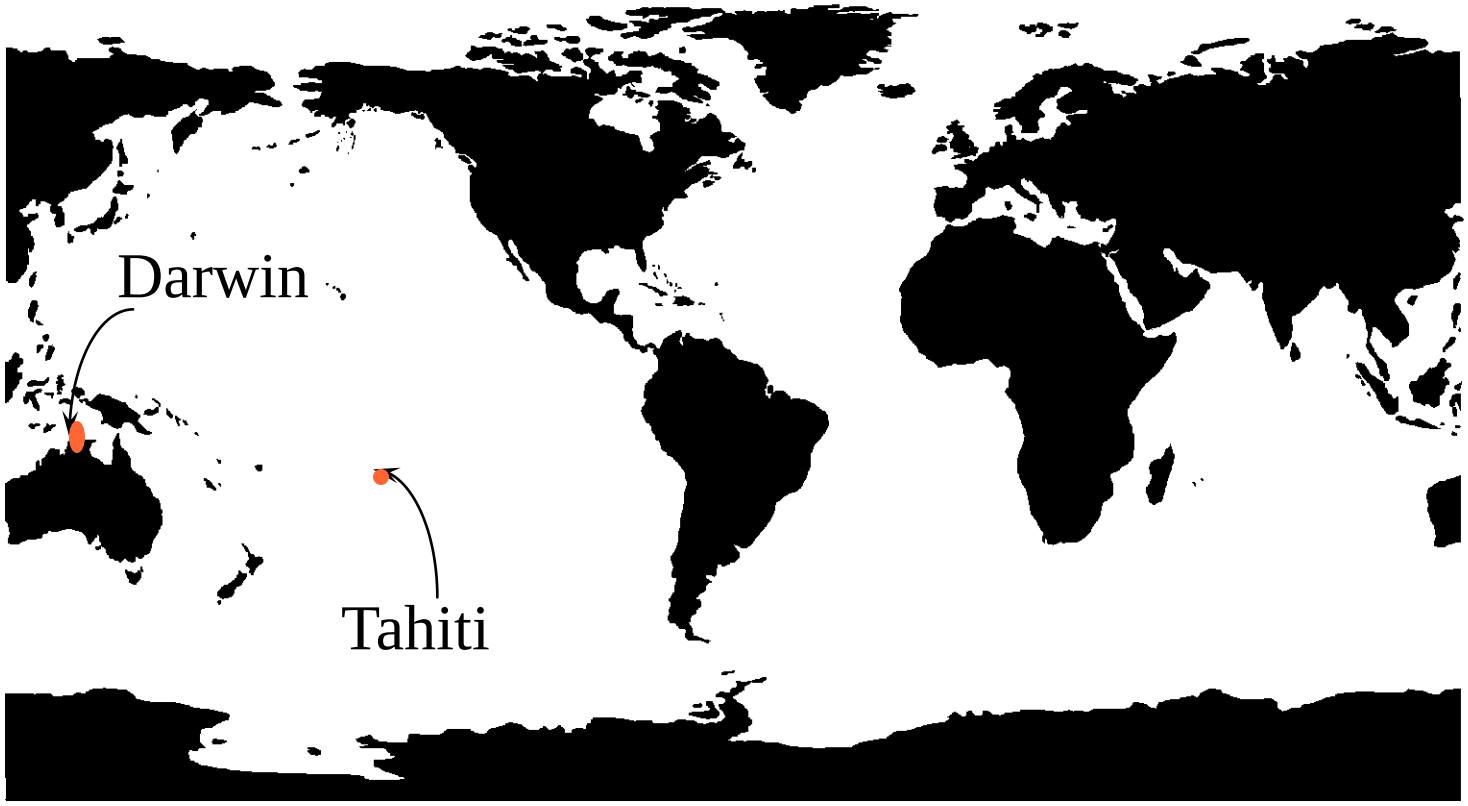
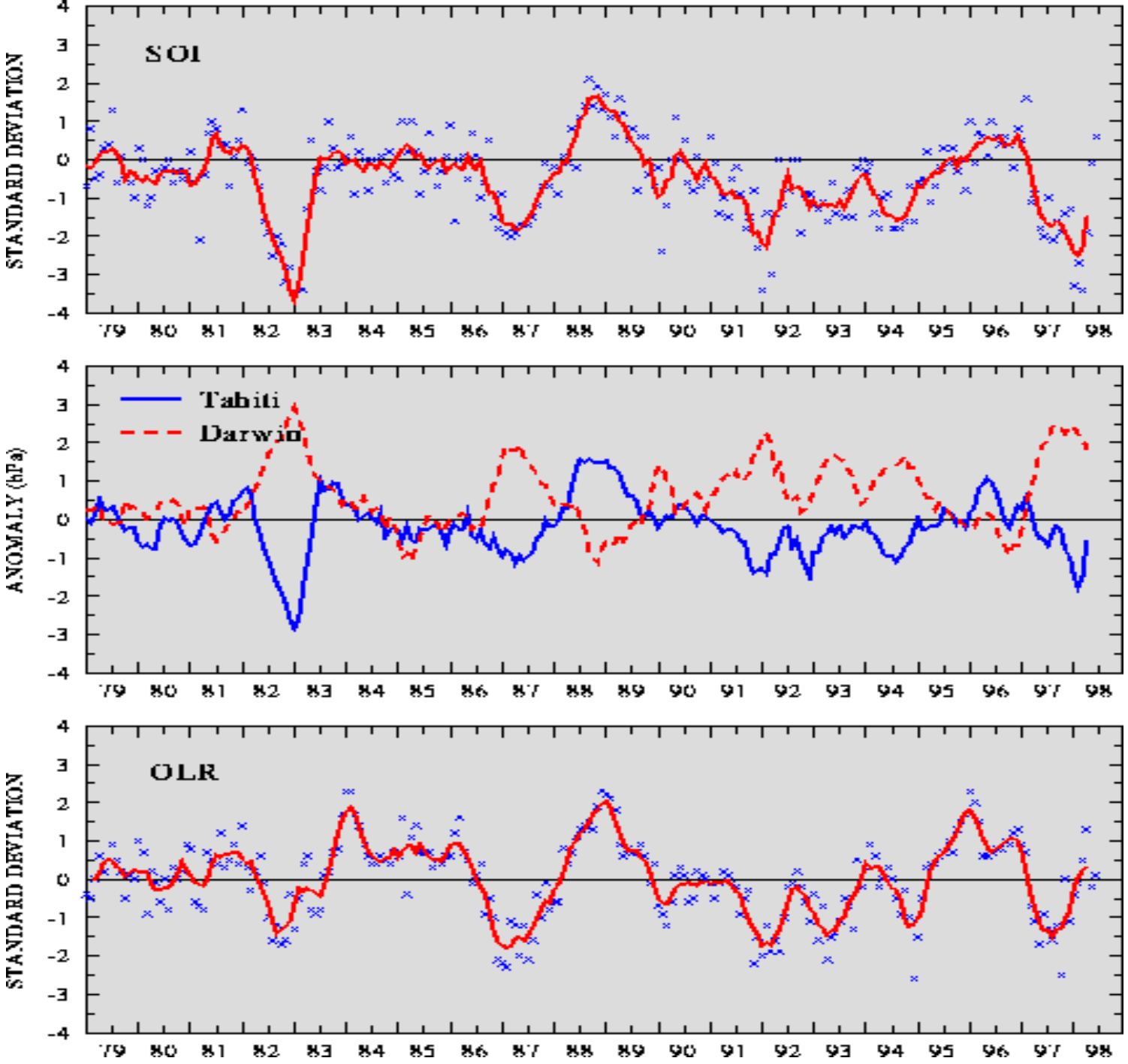
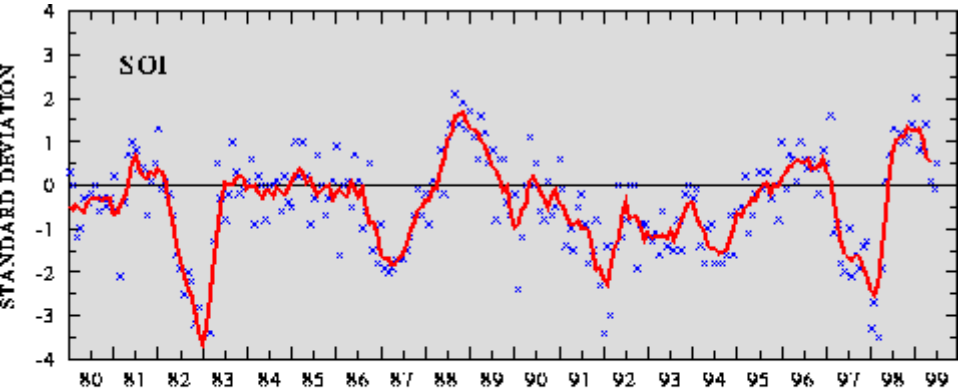
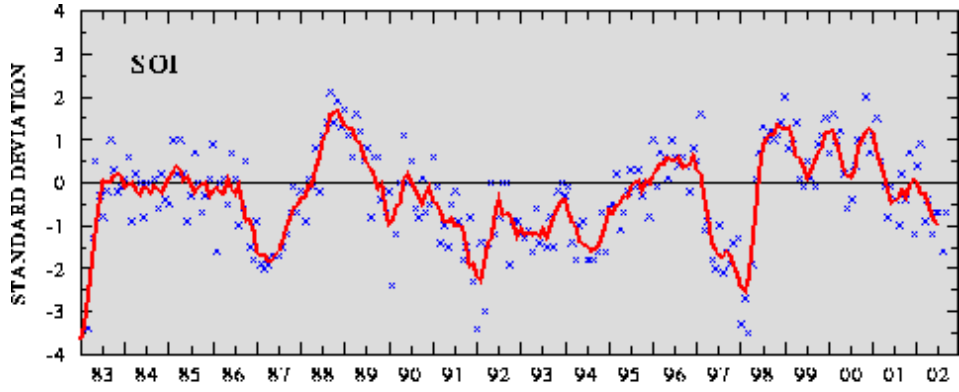
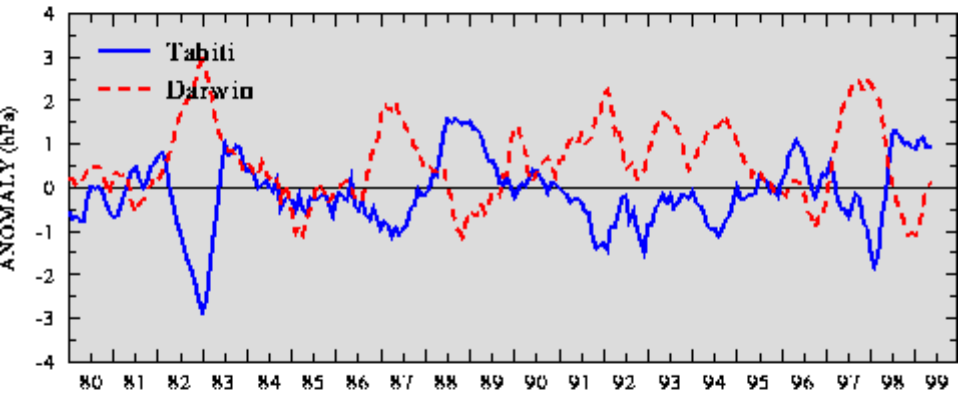
Southern Oscillation Index Centres

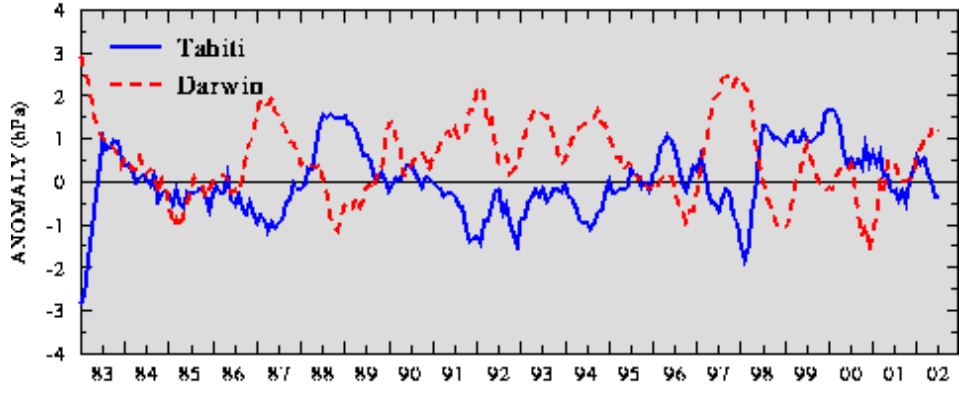


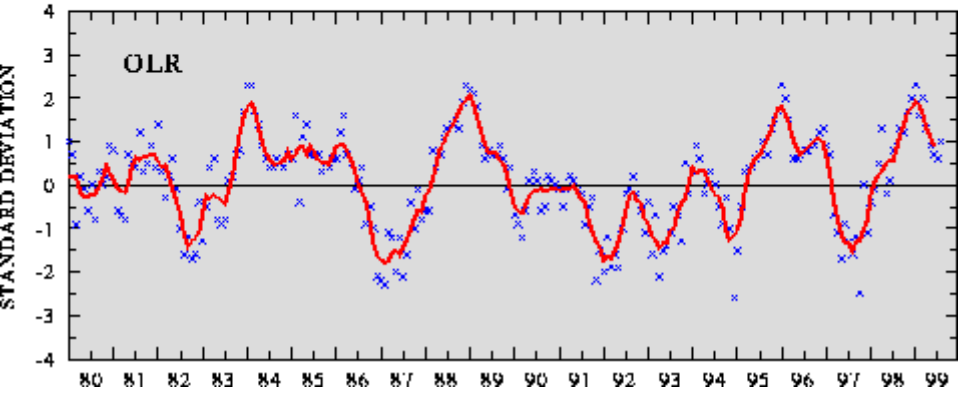

SOI
STANDARD DEVIATION
Tahiti
Darwin
ANOMALY (hPa)
OLR
STANDARD DEVIATION
4
3
2
1
0
-1
-2
-3
-4
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98

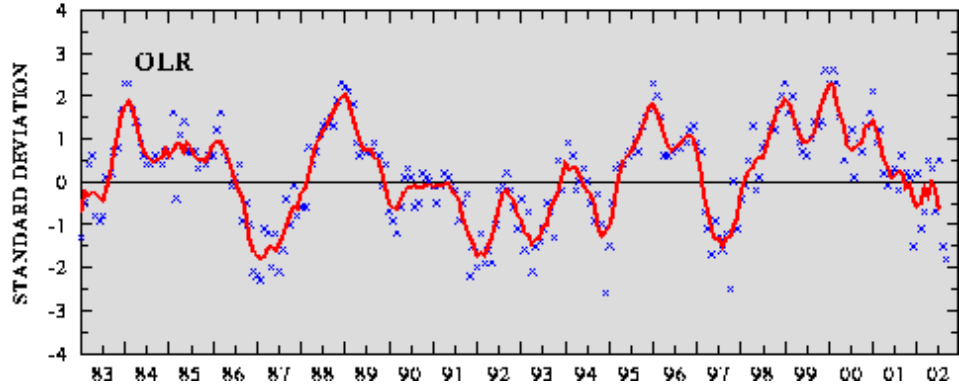

SOI
STANDARD DEVIATION
4
3
2
1
0
-1
-2
-3
-4
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99

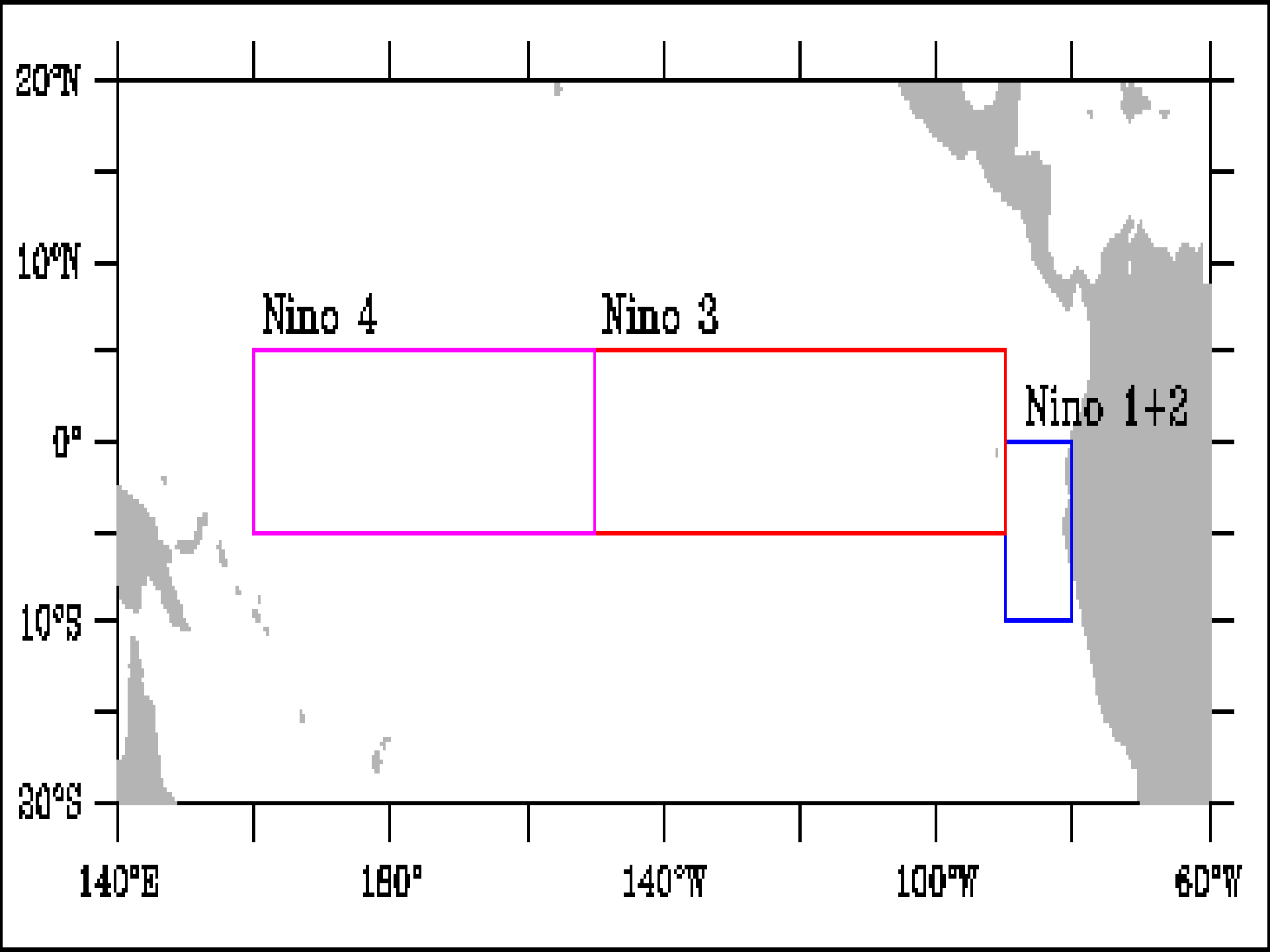

SOI
STANDARD DEVIATION
4
3
2
1
0
-1
-2
-3
-4
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02

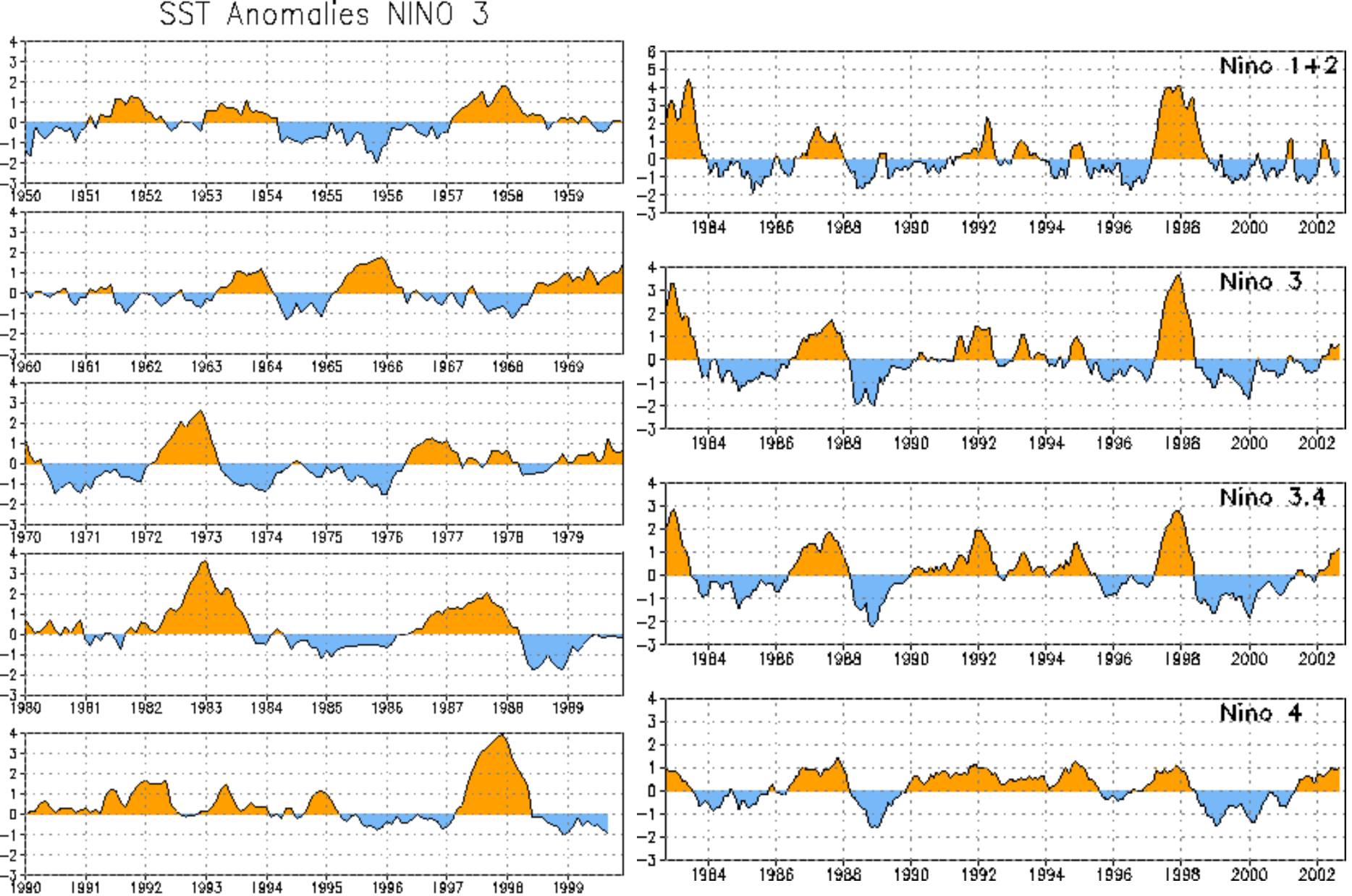

Tahiti
Darwin
ANOMALY (hPa)
4
3
2
1
0
-1
-2
-3
-4
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99

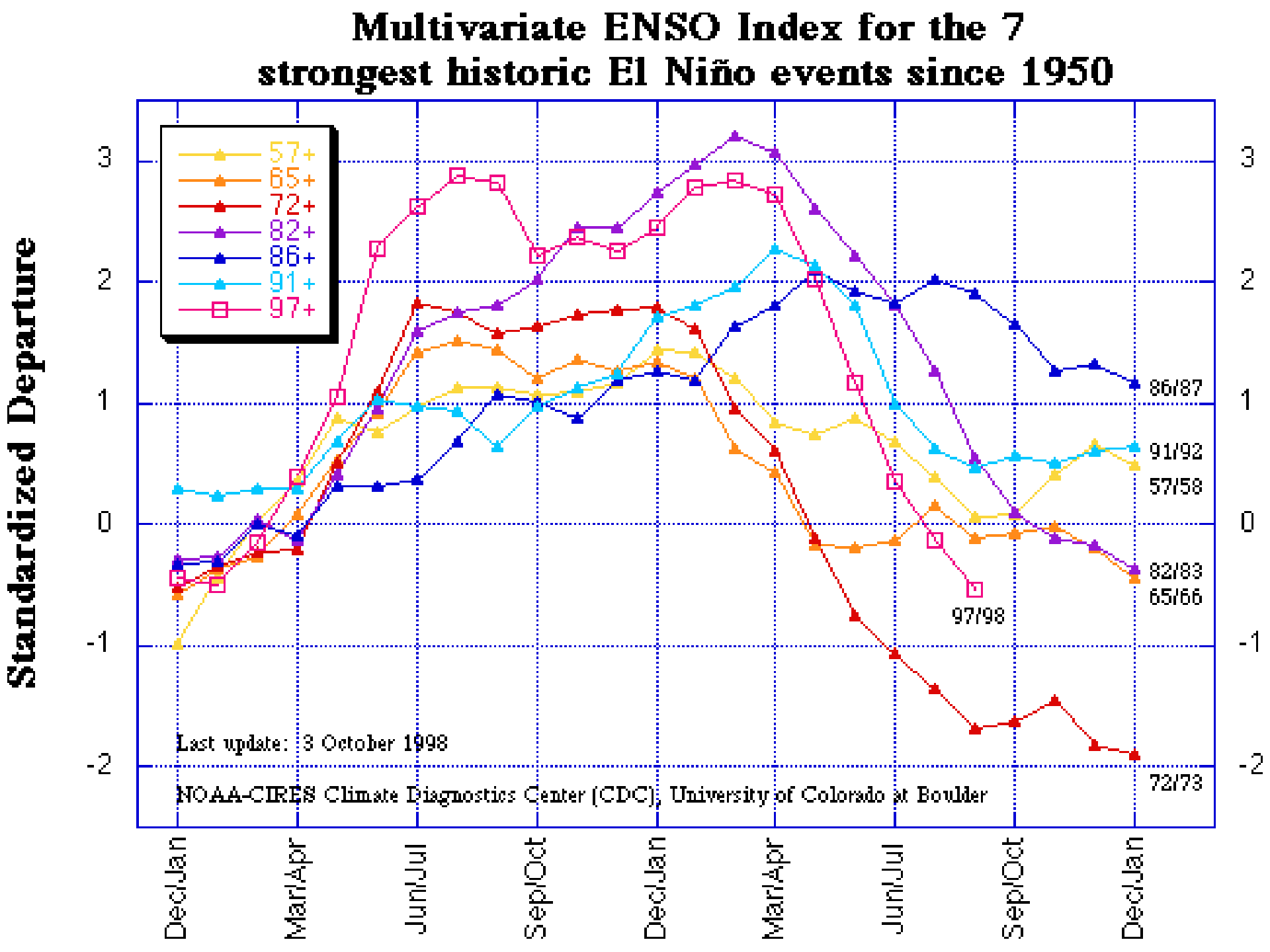

Tahiti
Darwin
ANOMALY (hPa)
4
3
2
1
0
-1
-2
-3
-4
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02

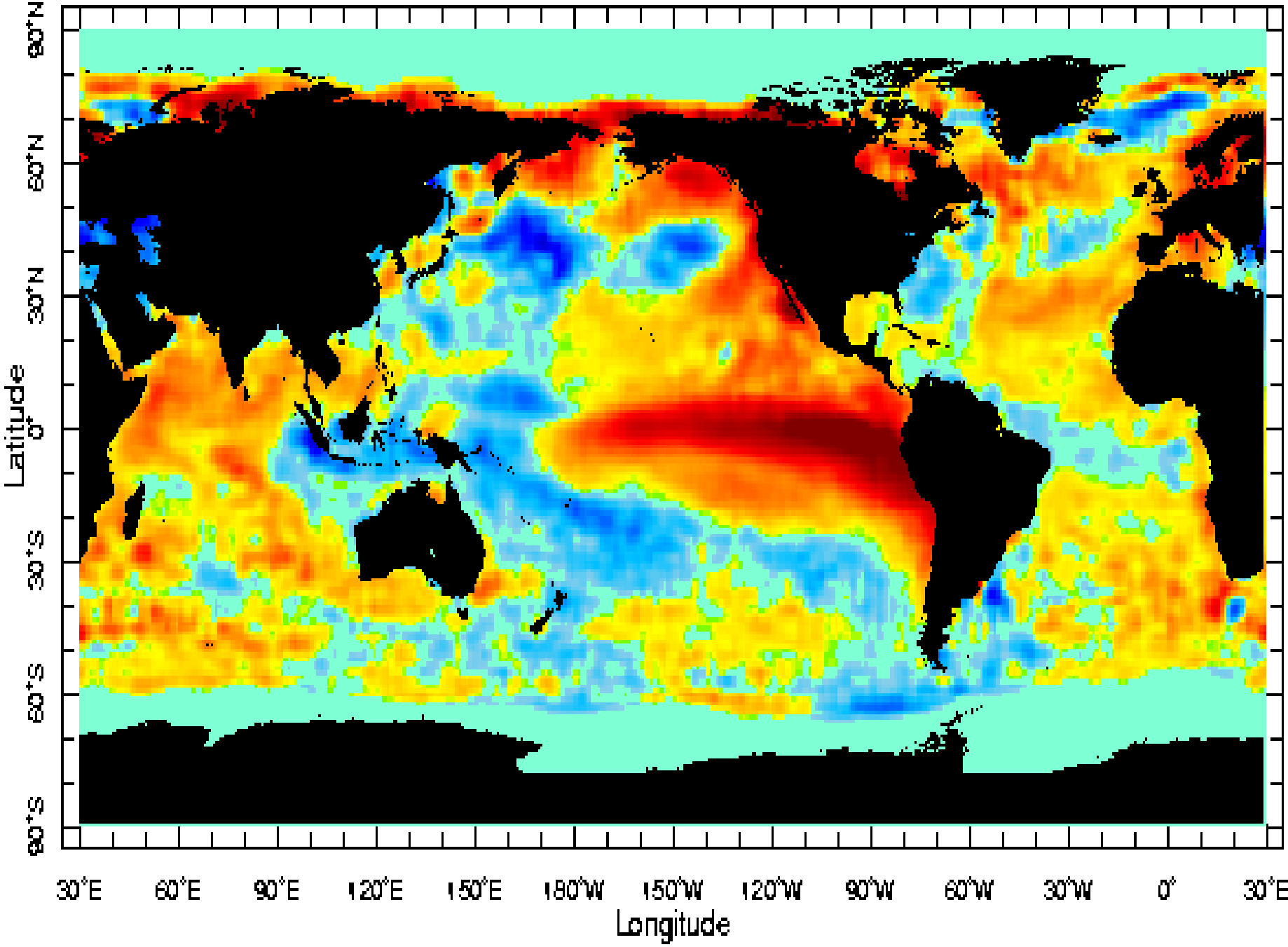

OLR
STANDARD DEVIATION
4
3
2
1
0
-1
-2
-3
-4
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99


OLR
STANDARD DEVIATION
4
3
2
1
0
-1
-2
-3
-4
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02


20°N
10°N
0°
10°S
20°S
140°E
180°
140°W
100°W
60°W
Nino 4
Nino 3
Nino 1+2

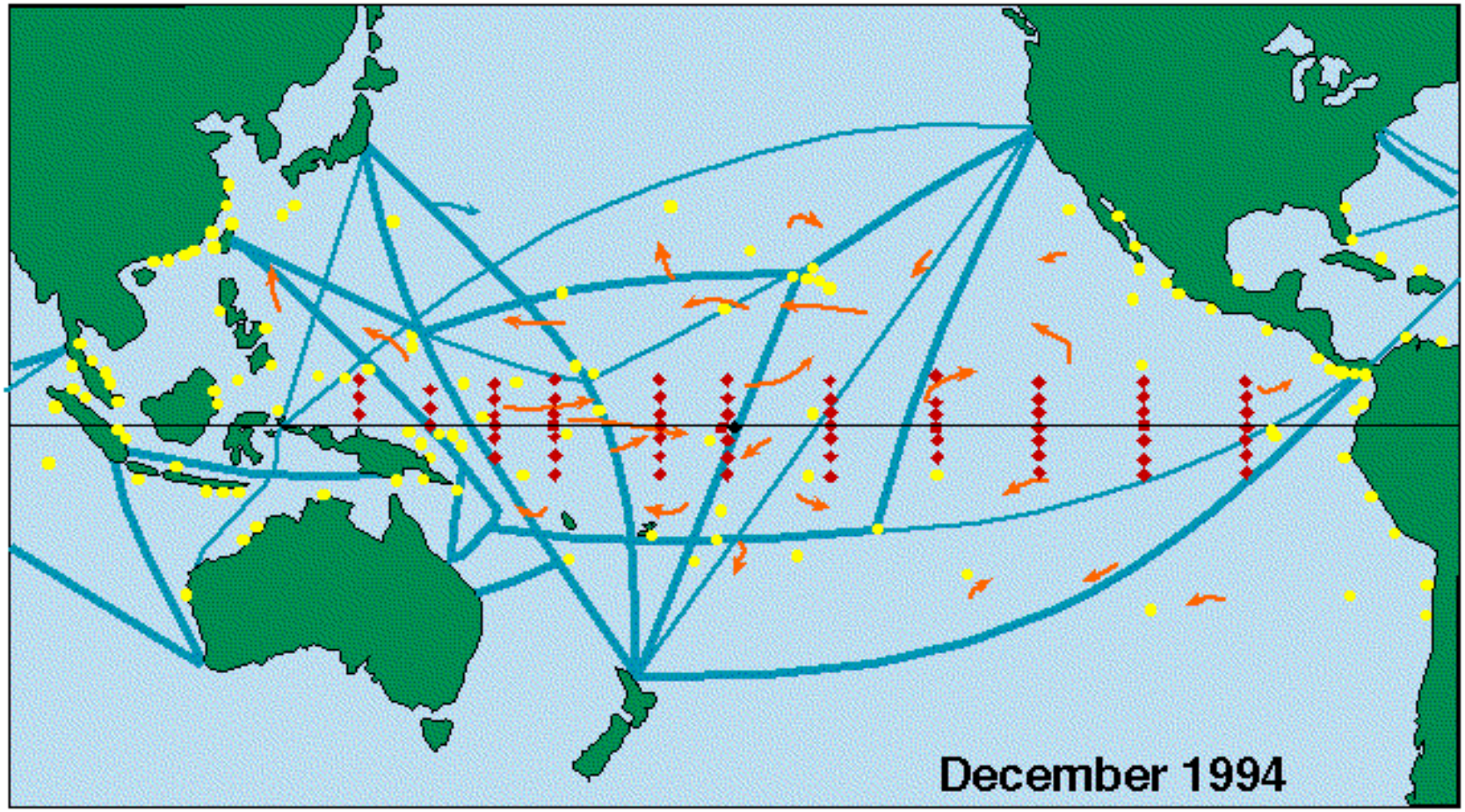

SST Anomalies NINO 3
Nino 1+2
Nino 3
Nino 3.4
Nino 4
CLIMATE PREDICTION CENTER/NCEP

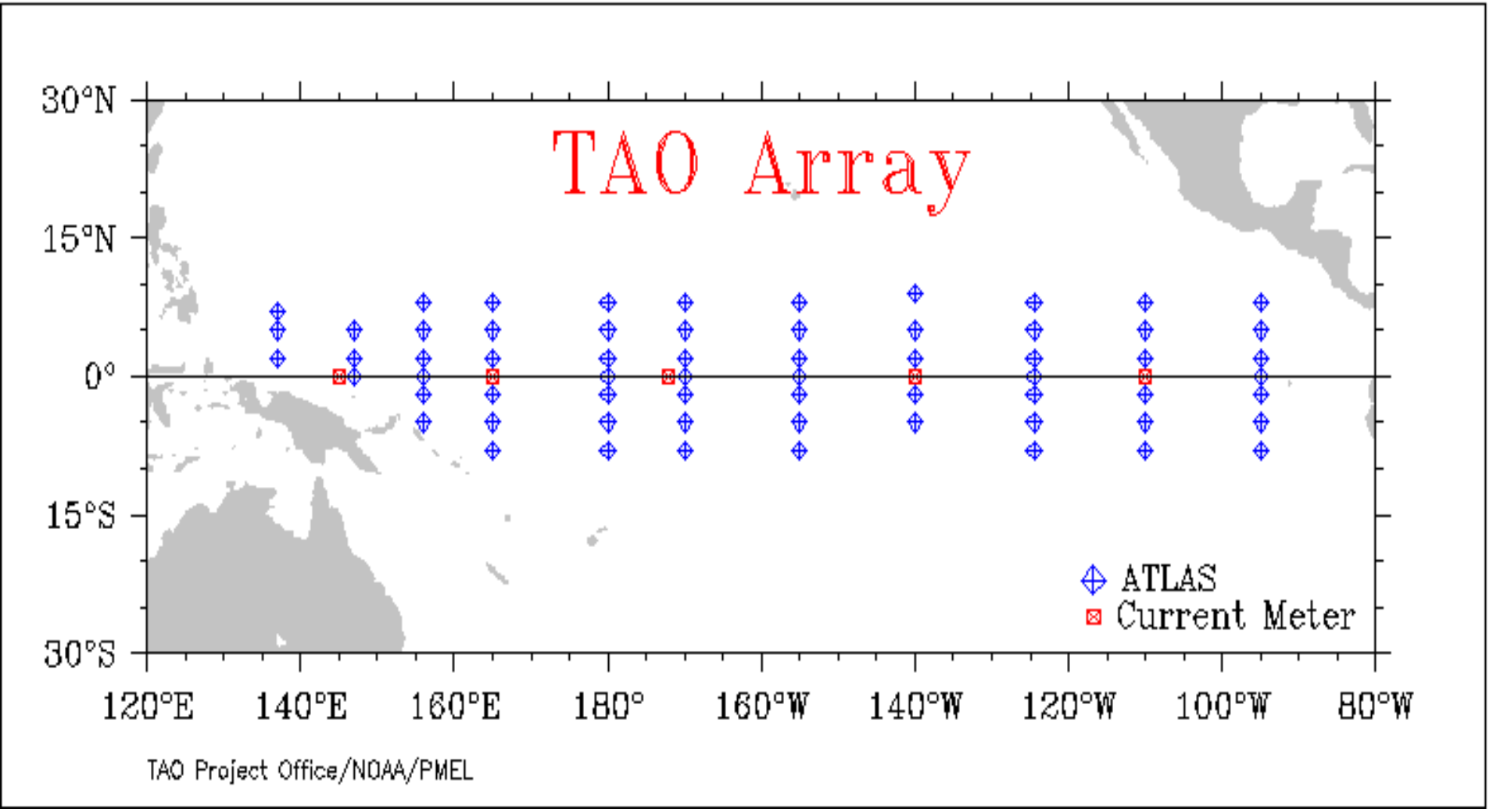

Multivariate ENSO Index for the 7 strongest historic El Niño events since 1950
Standardized Departure
57+
65+
72+
82+
86+
91+
97+
86/87
91/92
57/58
82/83
65/66
97/98
72/73
Last update: 3 October 1998
NOAA-CIRES Climate Diagnostics Center (CDC), University of Colorado at Boulder
Dec/Jan
Mar/Apr
Jun/Jul
Sep/Oct
Dec/Jan
Mar/Apr
Jun/Jul
Sep/Oct
Dec/Jan
3
2
1
0
-1
-2


90°N
60°N
30°N
0°
30°S
60°S
90°S
Latitude
30°E
60°E
90°E
120°E
150°E
180°W
150°W
120°W
90°W
60°W
30°W
0°
30°E
Longitude

SEP 97

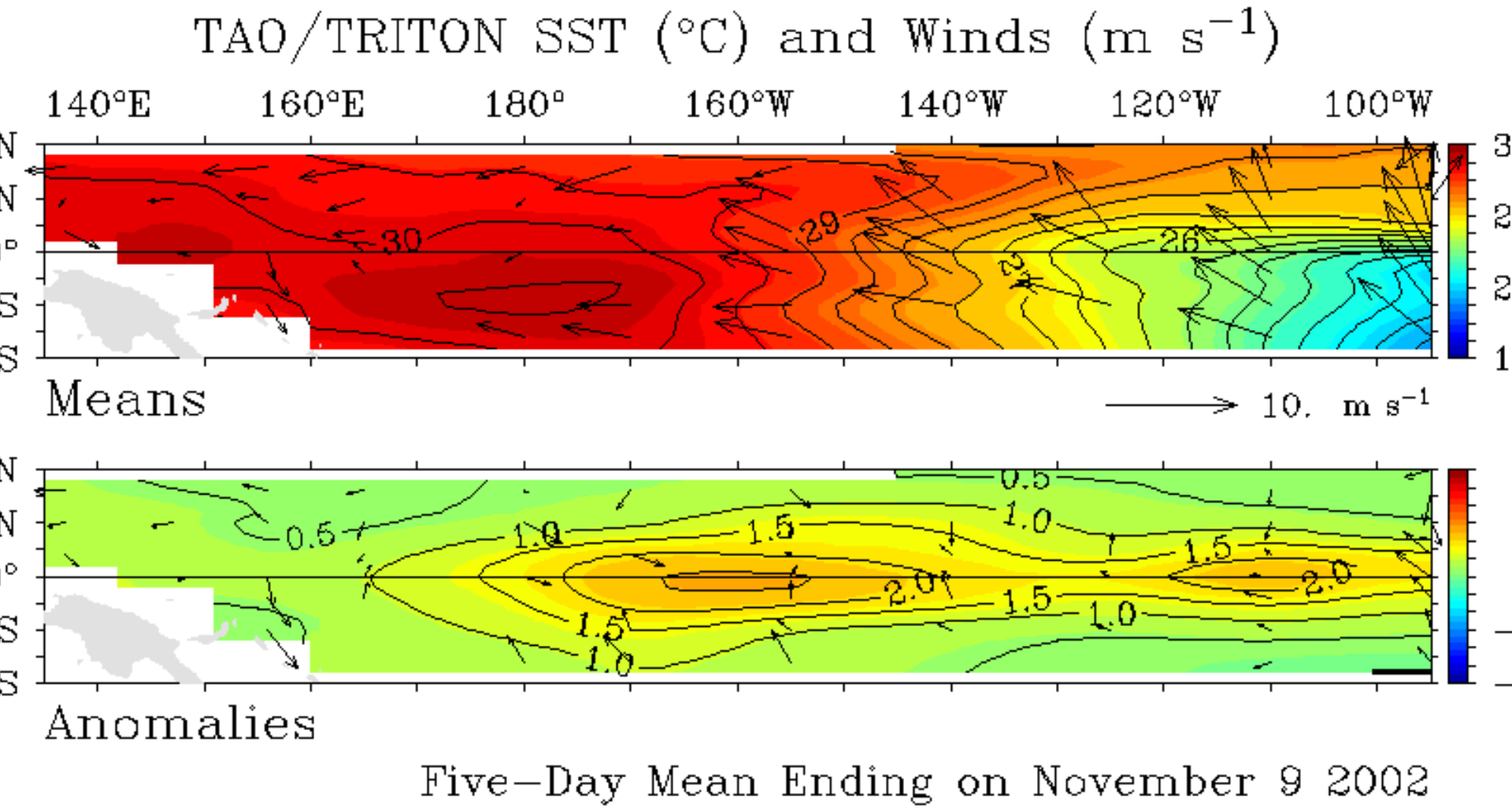
TOGA in Situ Ocean Observing System
Pacific Basin

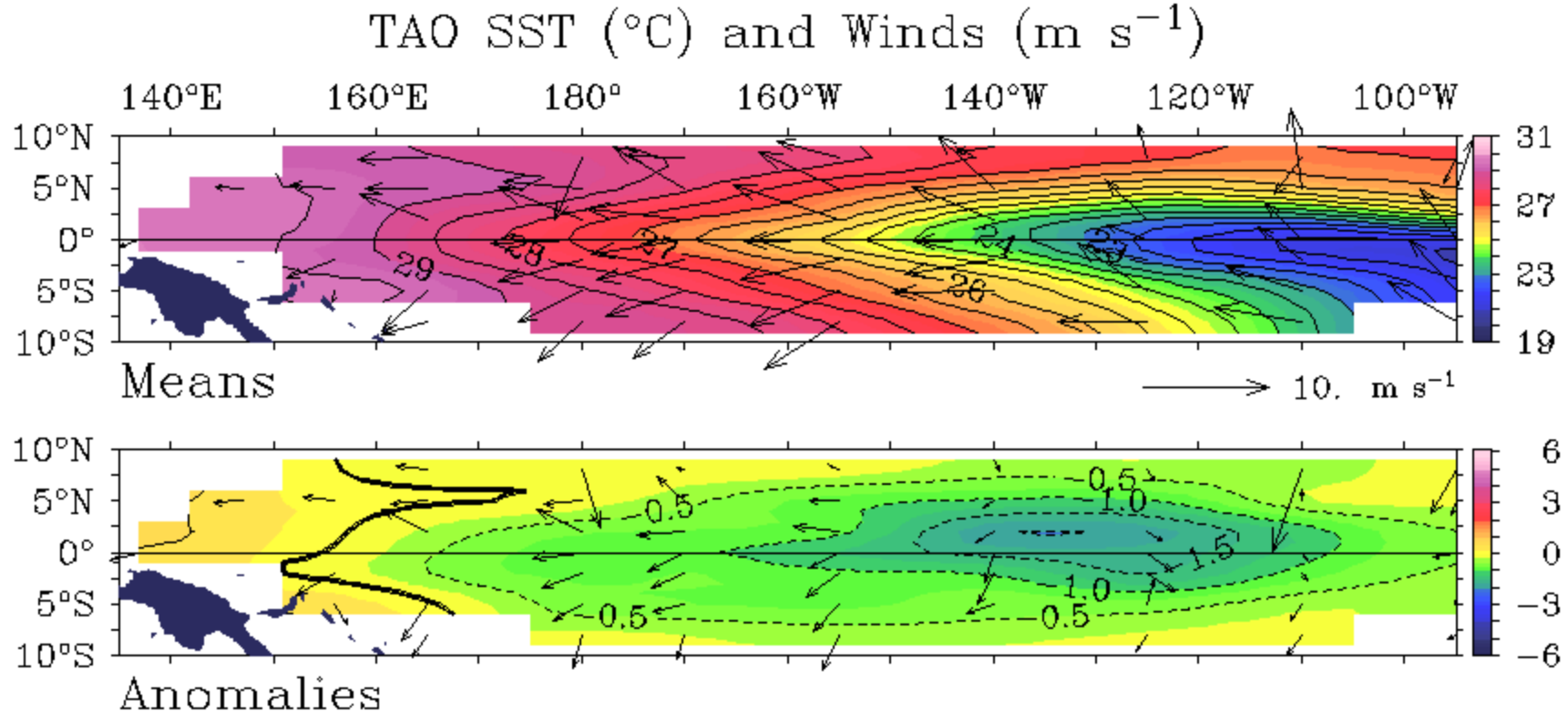


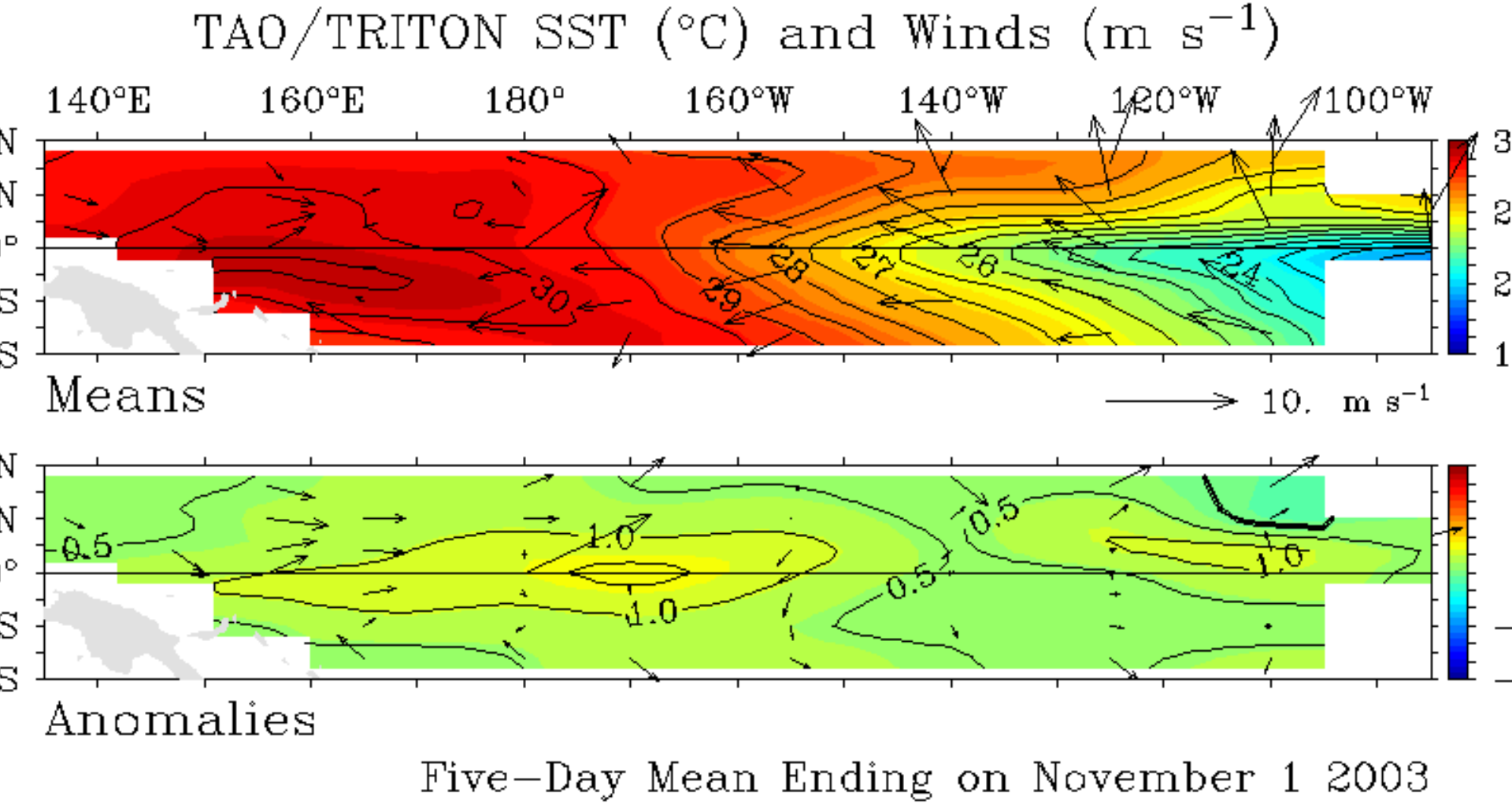

TAO Array
30°N
15°N
0°
15°S
30°S
120°E
140°E
160°E
180°
160°W
140°W
120°W
100°W
80°W
ATLAS
Current Meter
TAO Project Office/NOAA/PMEL

Recovering an ATLAS mooring from the French R/V LE NOROIT in the western equatorial Pacific Ocean. A total of 59 ATLAS moorings are deployed at present in the equatorial Pacific as part of the TOGA-TAO Array.

Servicing an ATLAS mooring of the TOGA-TAO Array. ATLAS moorings measure surface winds, air temperature, relative humidity, sea surface temperature, and subsurface temperature to depths of 500 m.


TAO/TRITON SST (°C) and Winds (m s^{-1})
140°E
160°E
180°
160°W
140°W
120°W
100°W
30
29
26
Means
10. m s^{-1}
0.5
1.0
1.5
2.0
Anomalies
Five–Day Mean Ending on November 9 2002


TAO SST (°C) and Winds (m s^{-1})
140°E
160°E
180°
160°W
140°W
120°W
100°W
10°N
5°N
0°
5°S
10°S
29
28
27
26
31
23
Means
10. m s^{-1}
31
27
23
19
0.5
1.0
1.5
Anomalies
6
3
0
−3
−6
Five−Day Mean Ending on October 31 1999
TAO Project Office/PMEL/NOAA



http://www.pmel.noaa.gov/tao/realtime.html

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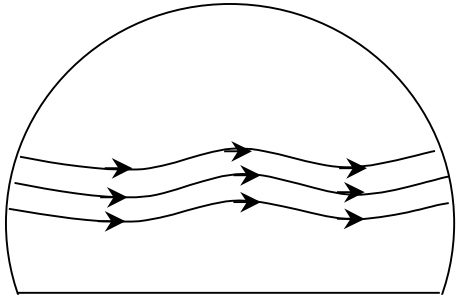
INDEX CYCLE



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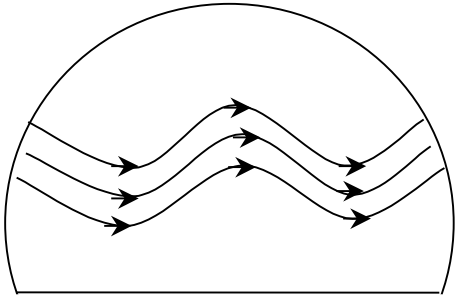
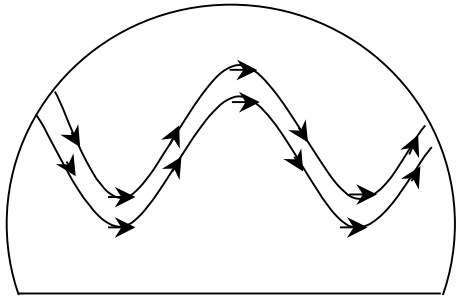
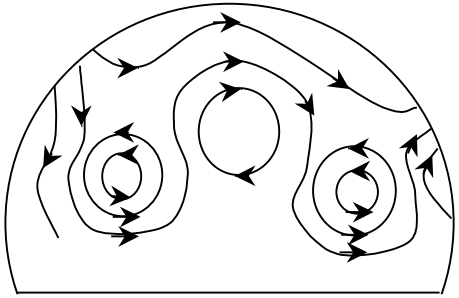


(B)



(C)



(D)

North Atlantic Oscillation

- Pattern of Climate Variability that determines weather and climate in N.Atlantic

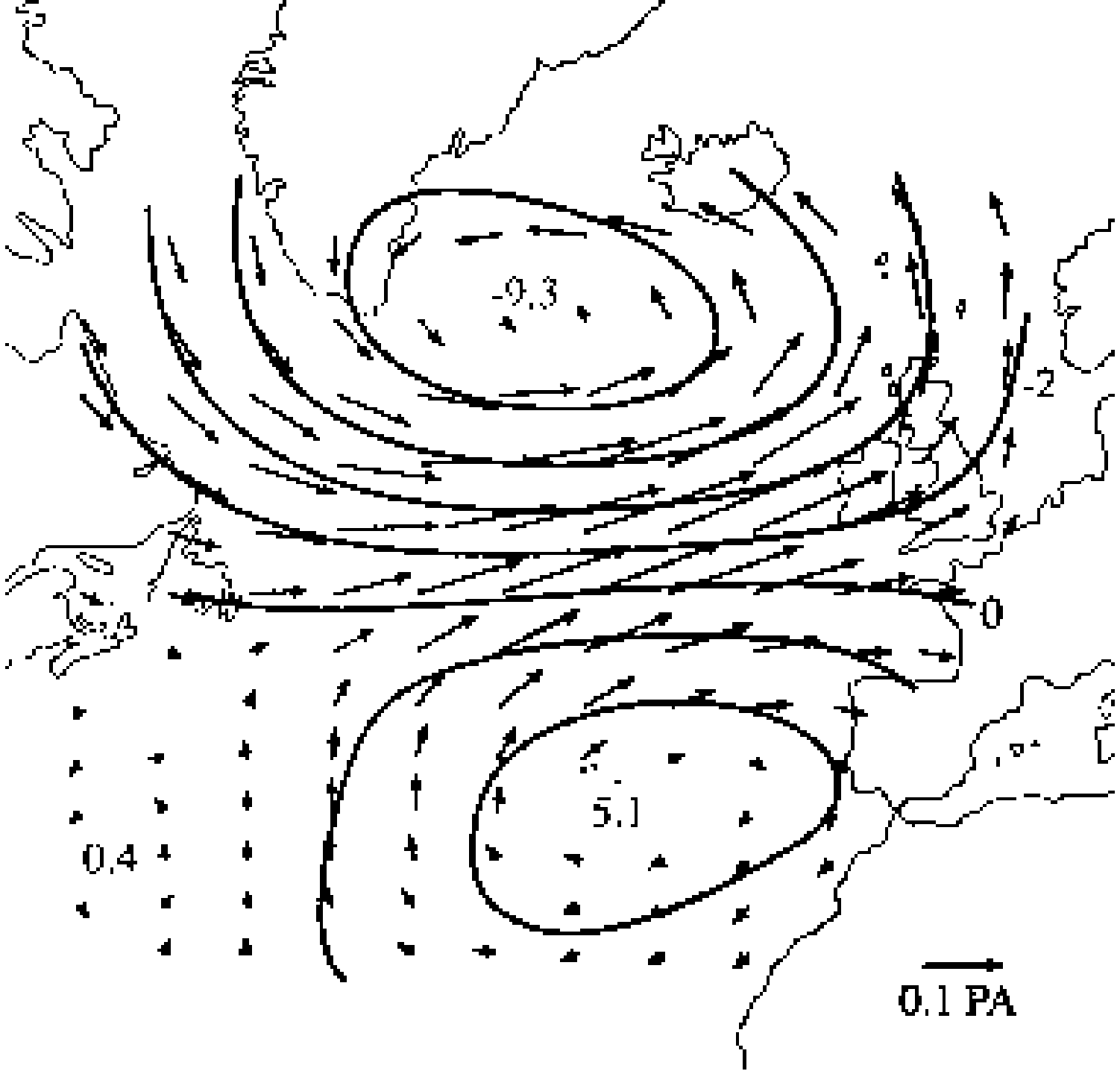
- Controls much of the month to month variability of temerpature and rainfall in N.W. Europe

North Atlantic Setting

- High Pressure over the Azores
- Low Pressure over Iceland
- Westerly wind
- low pressure systems (rain) travel in the westerlies

North Atlantic Oscillation

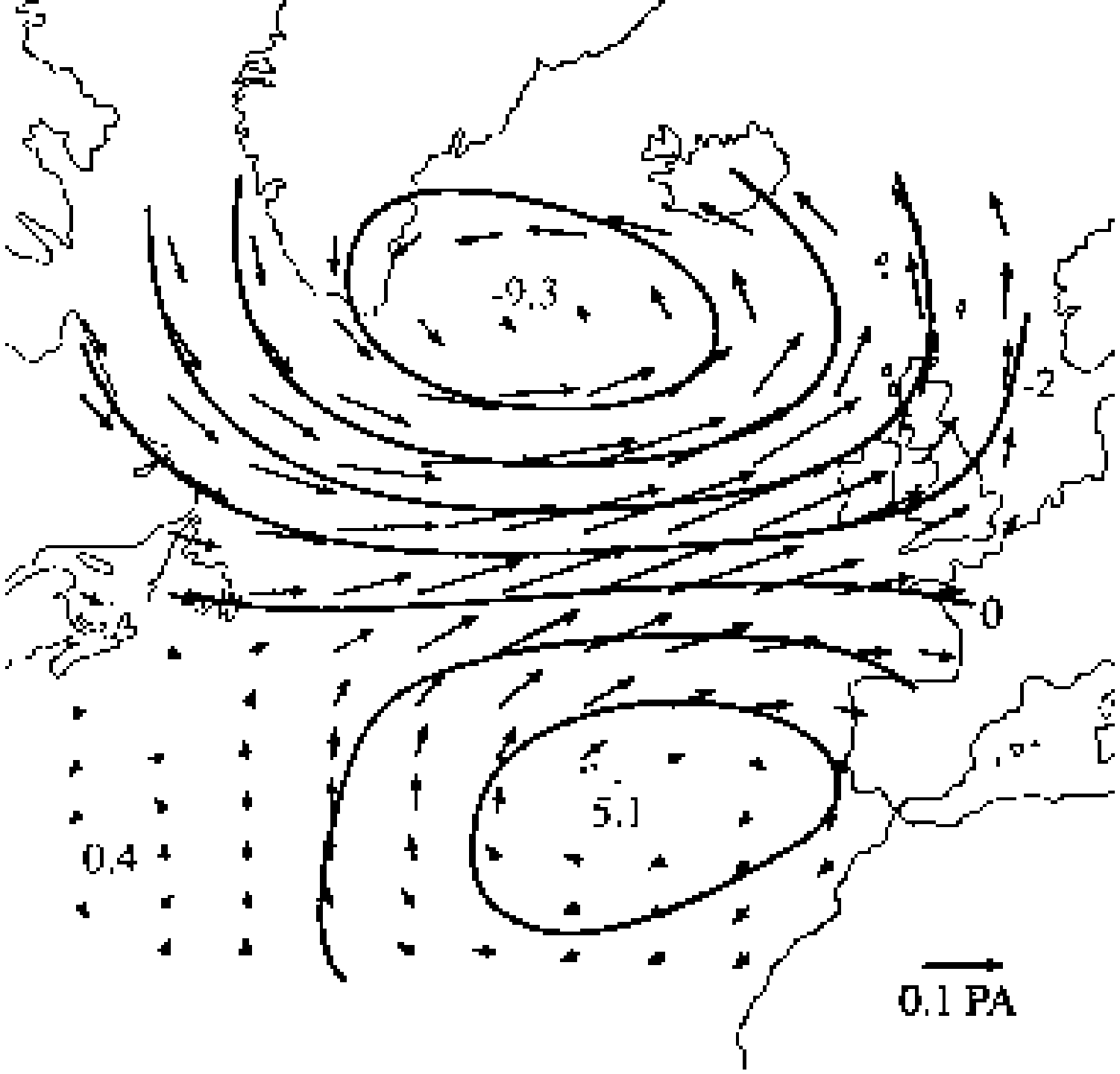
- Azores high and Icelandic Low are the centres
- Azores high can weaken or strengthen
- Icelandic low can weaken or strengthen


-0.3
-2
0
5.1
0.4
0.1 PA

North Atlantic Oscillation

- **High Phase**
- Azores High strong
- Icelandic Low deep
- westerlies strong
- wind and rain
- mild conditions in UK
- dry conditions in Spain

- **Low Phase**
- Azores high weak
- Icelandic Low shallow
- westerlies weak
- clear and still
- cold and dry
- wet conditions in Spain


-0.3
-2
0
5.1
0.4
0.1 PA

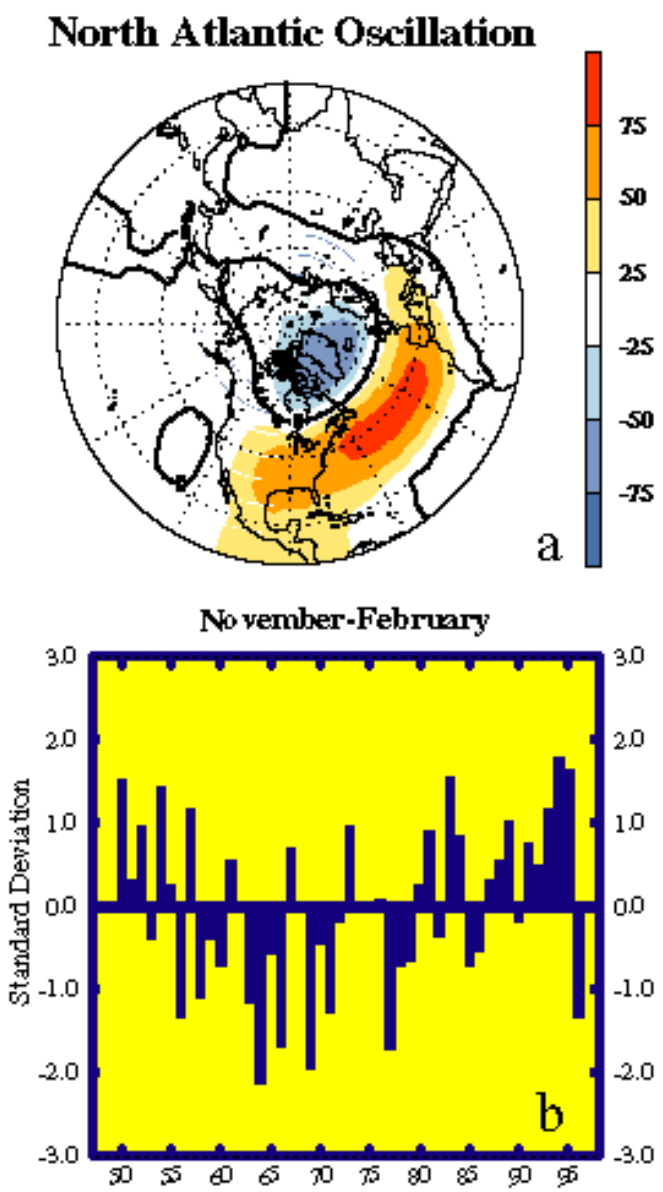
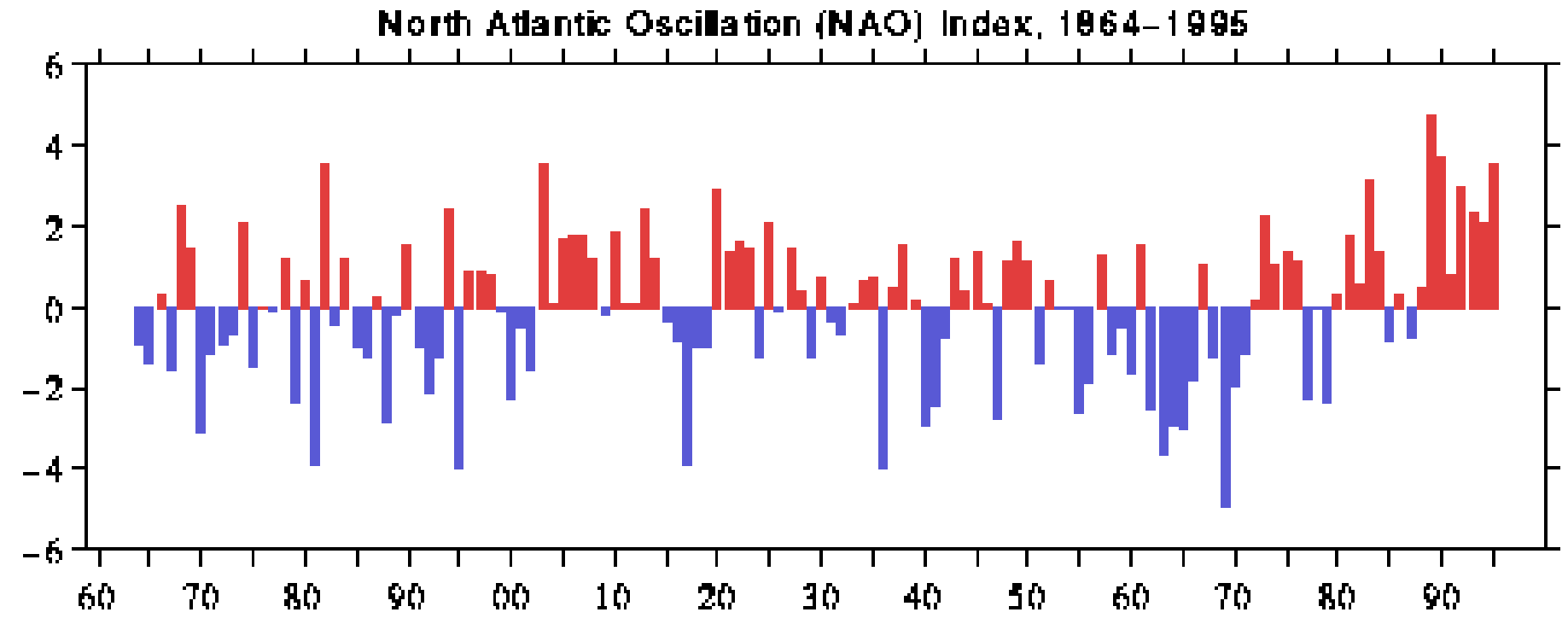
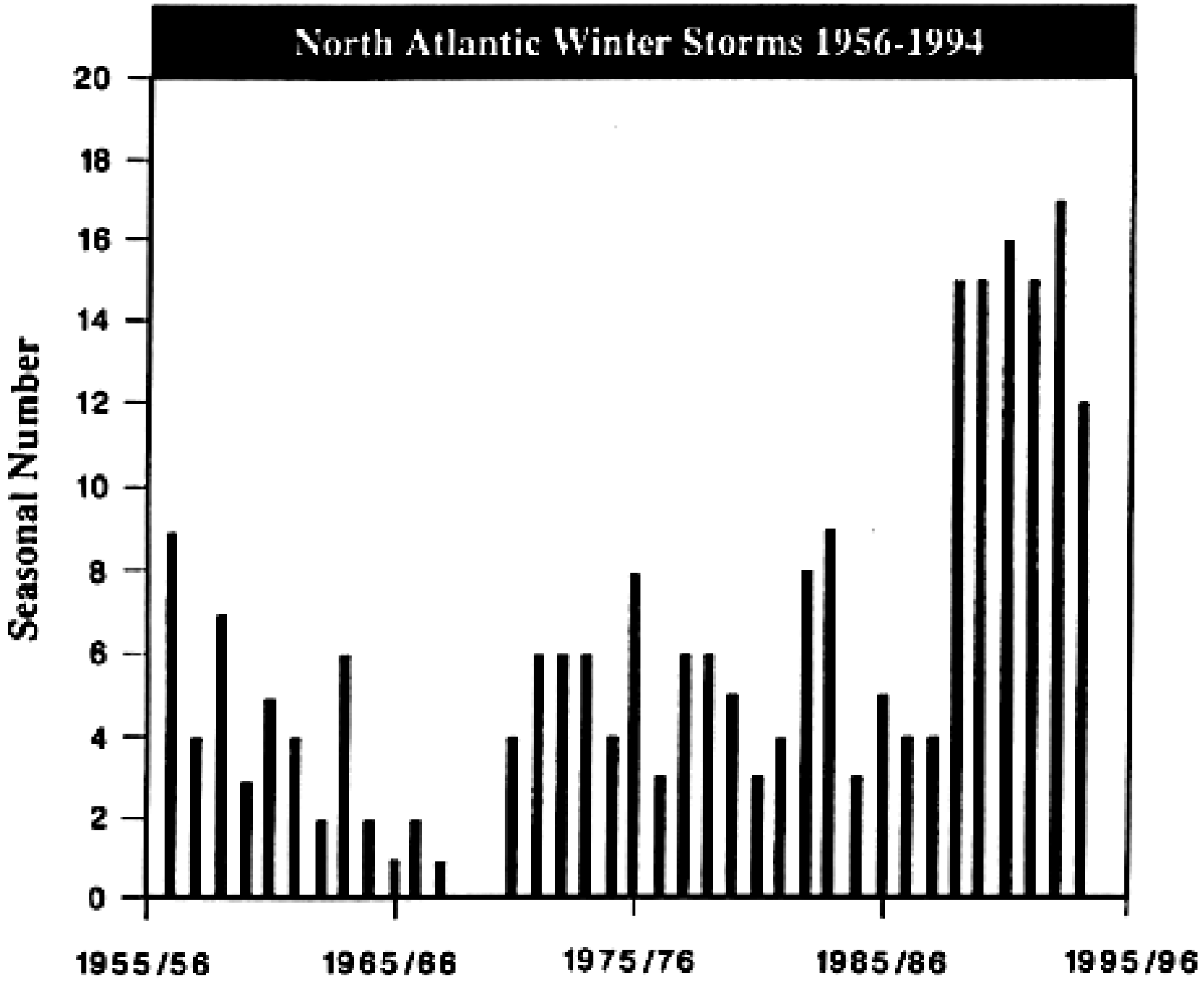


FIG. 31 Rotated Principal Component Analysis (RPCA) of the North Atlantic oscillation teleconnection pattern (NAO) during NDJF: (a) pattern showing the positive phase and (b) normalized amplitude time series. Labeling convention for years is such that 1995 indicates the NDJF 1994/95 season. Pattern is calculated from the 1964–93 base period seasonal means. See Bell and Halpert (1995) for details.


North Atlantic Oscillation (NAO) Index, 1964–1995
6
4
2
0
−2
−4
−6
60
70
80
90
00
10
20
30
40
50
60
70
80
90


North Atlantic Winter Storms 1956-1994
Seasonal Number
0
2
4
6
8
10
12
14
16
18
20
1955/56
1965/66
1975/76
1985/86
1995/96

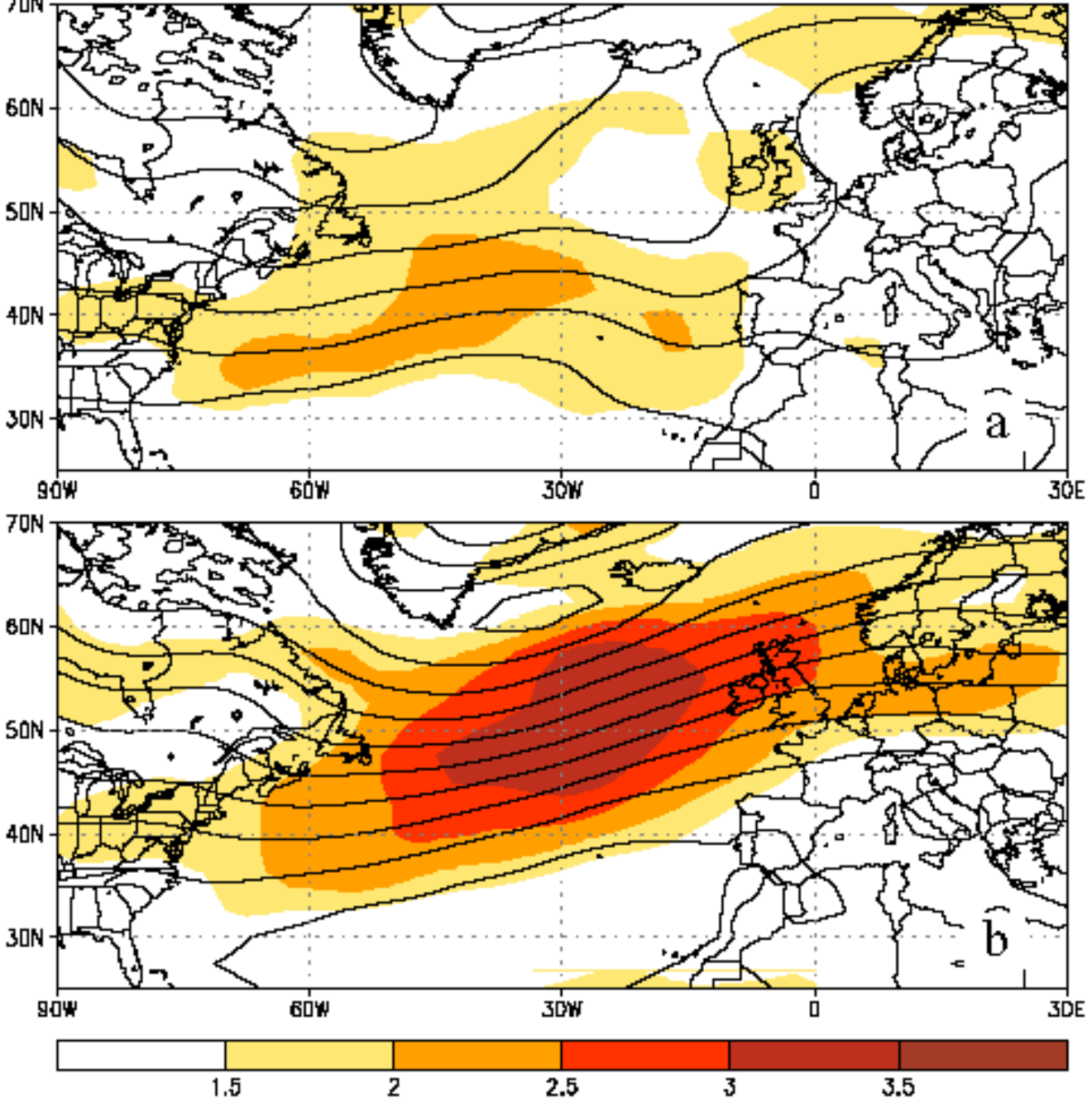


FIG. 34 925-hPa mean temperature flux (shading, x10^{3} K m s-1) and heights (contours, interval is 30 m) for (a) NDJF 1995/96 and (b) NDJF mean (1988/89–1994/95).

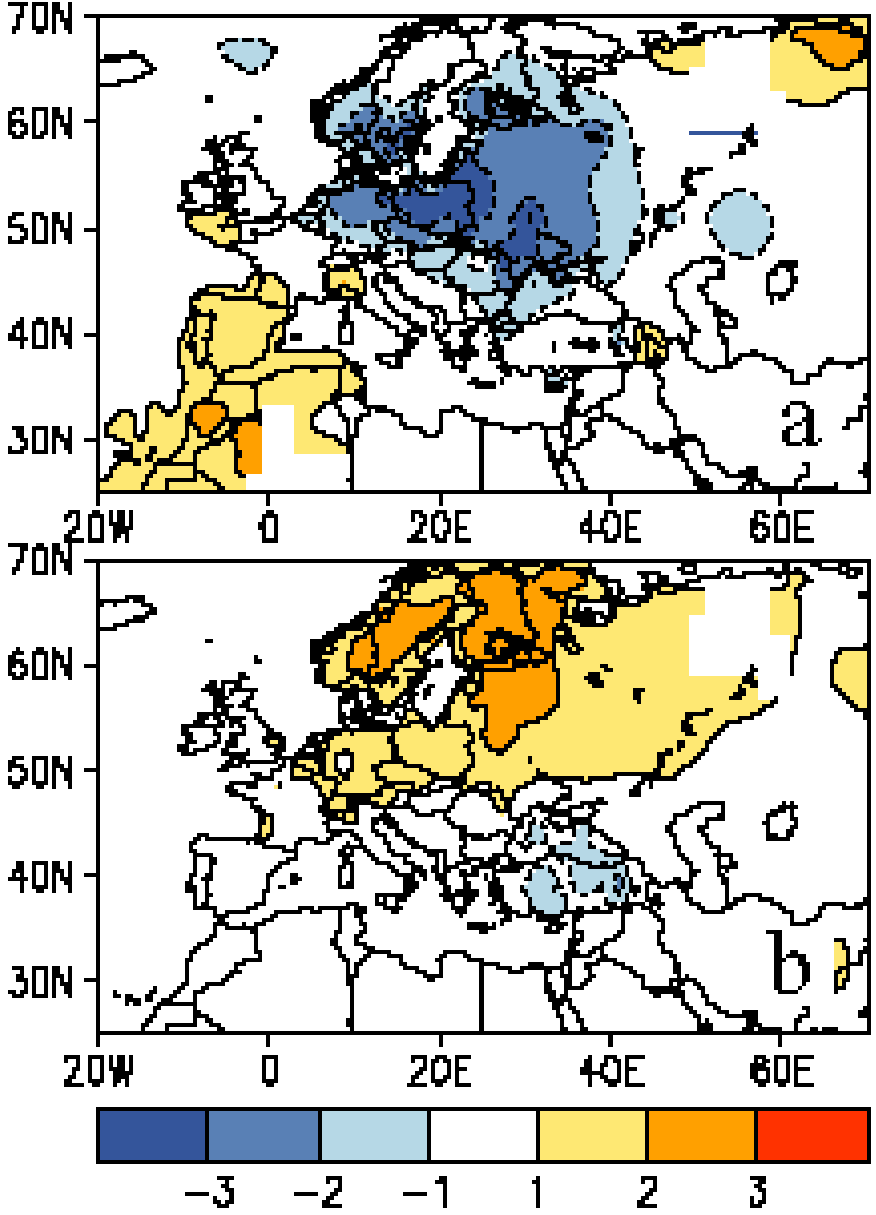
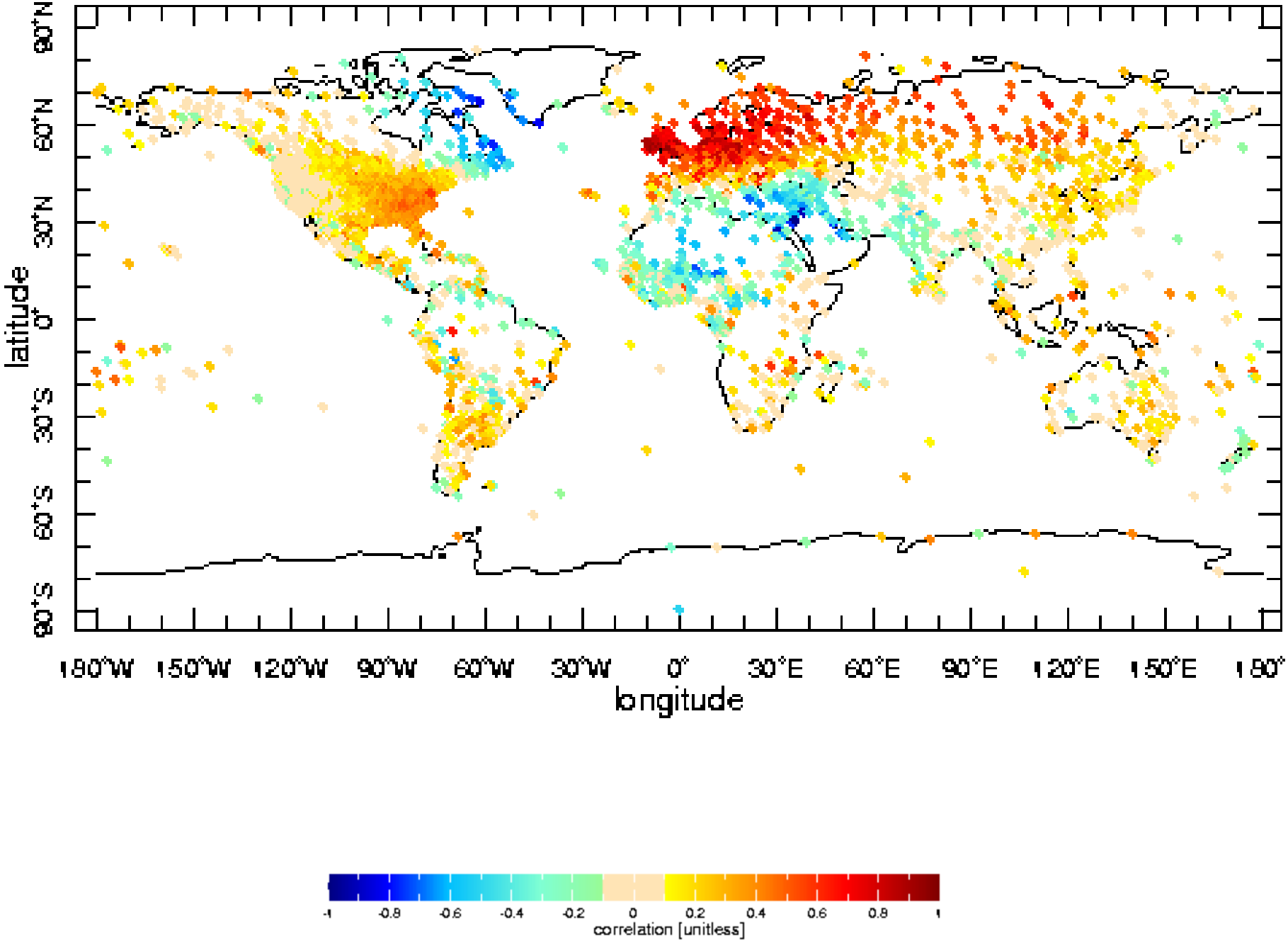


FIG. 36 Surface temperature anomaly for (a) NDJF 1995/96 and (b) NDJF mean (1988/89–1994/95). Anomalies are departures from the 1961–90 base period means.



Temperature

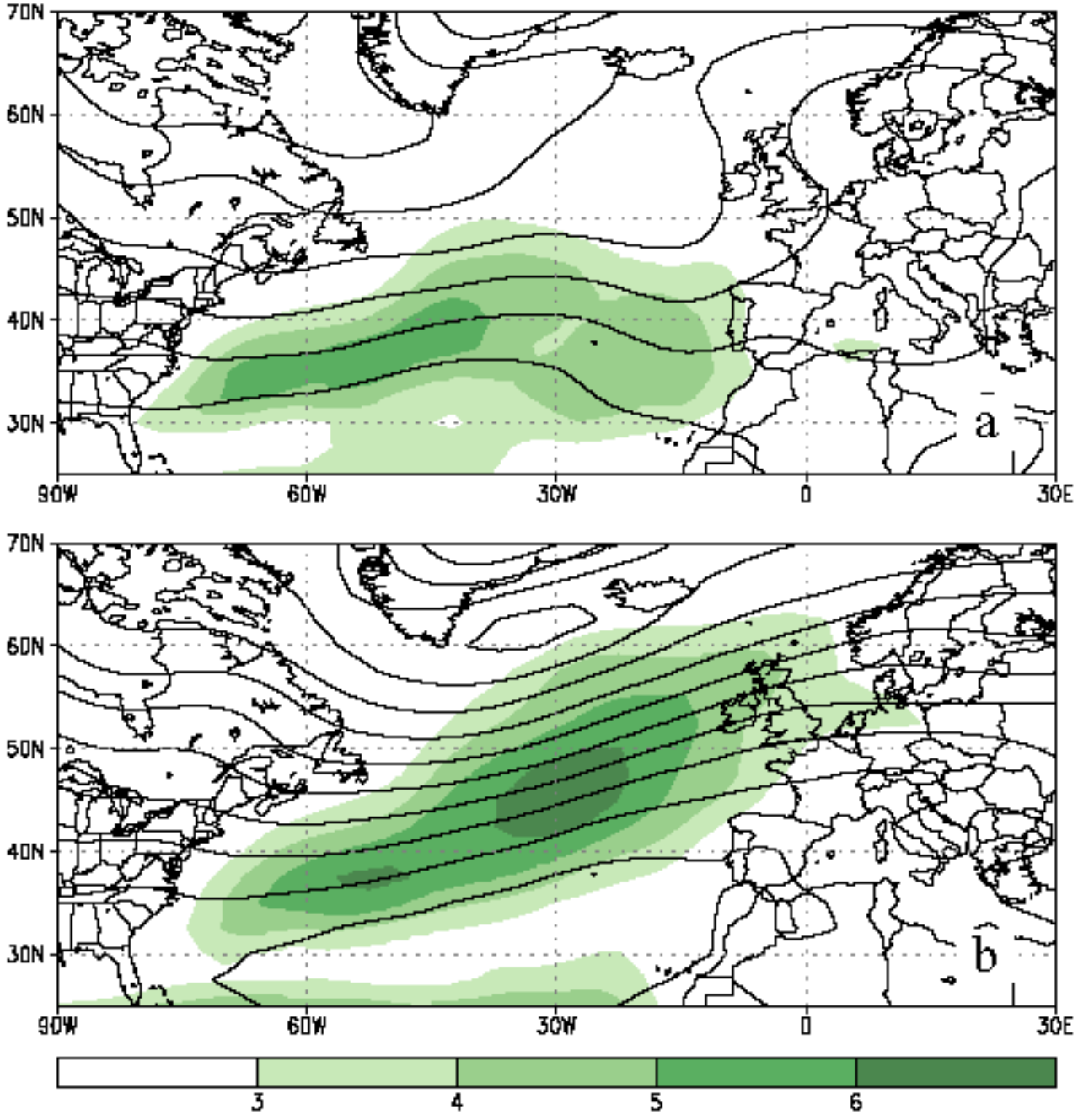
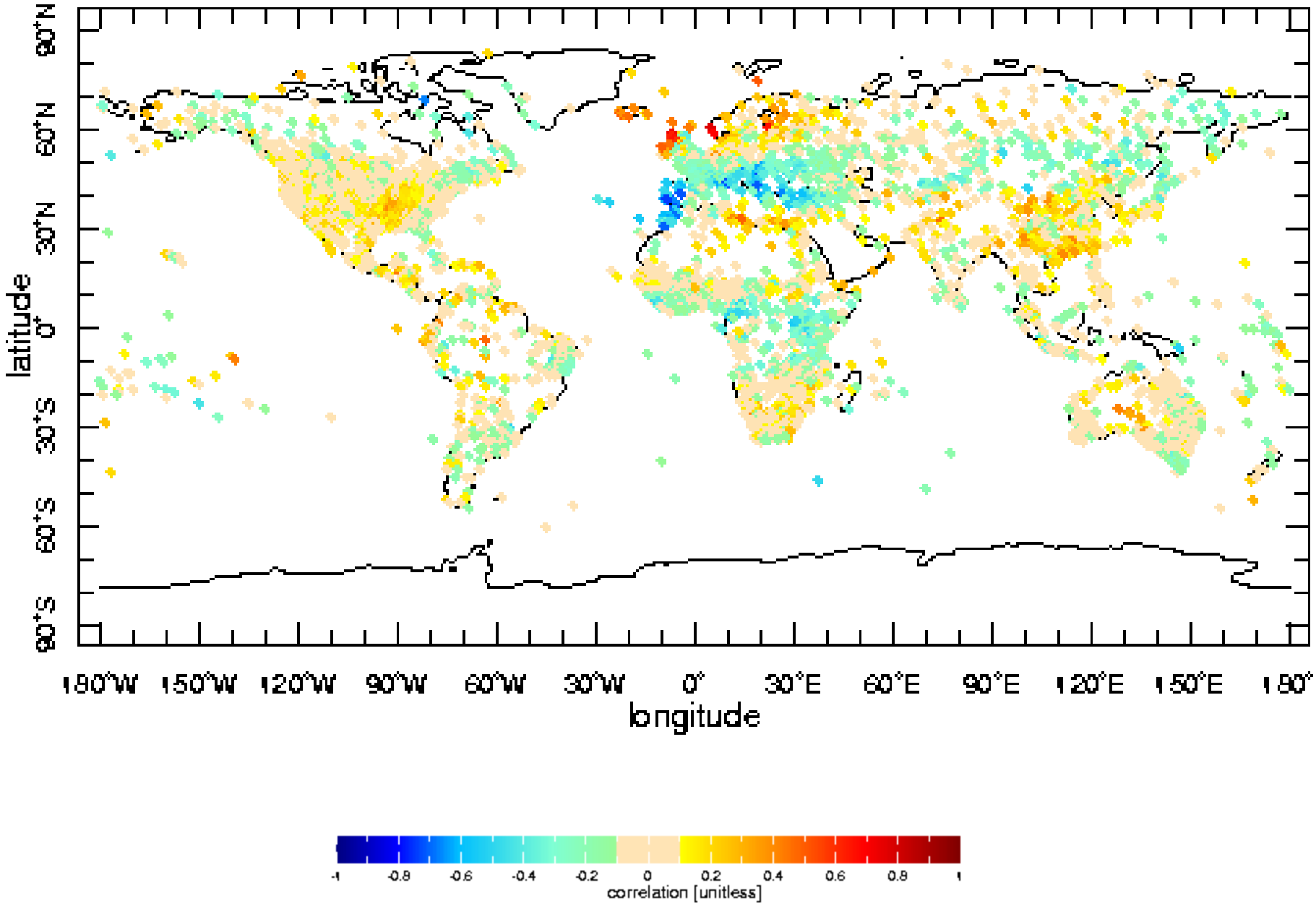


FIG. 33 925-hPa mean moisture transport (shading, x10-² m s-1) and heights (contours, interval is 30 m) for (a) NDJF 1995/96 and (b) NDJF mean (1988/89–1994/95).


90°N
60°N
30°N
0°
30°S
60°S
90°S
latitude
180°W
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
longitude
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
correlation [unitless]

Rainfall

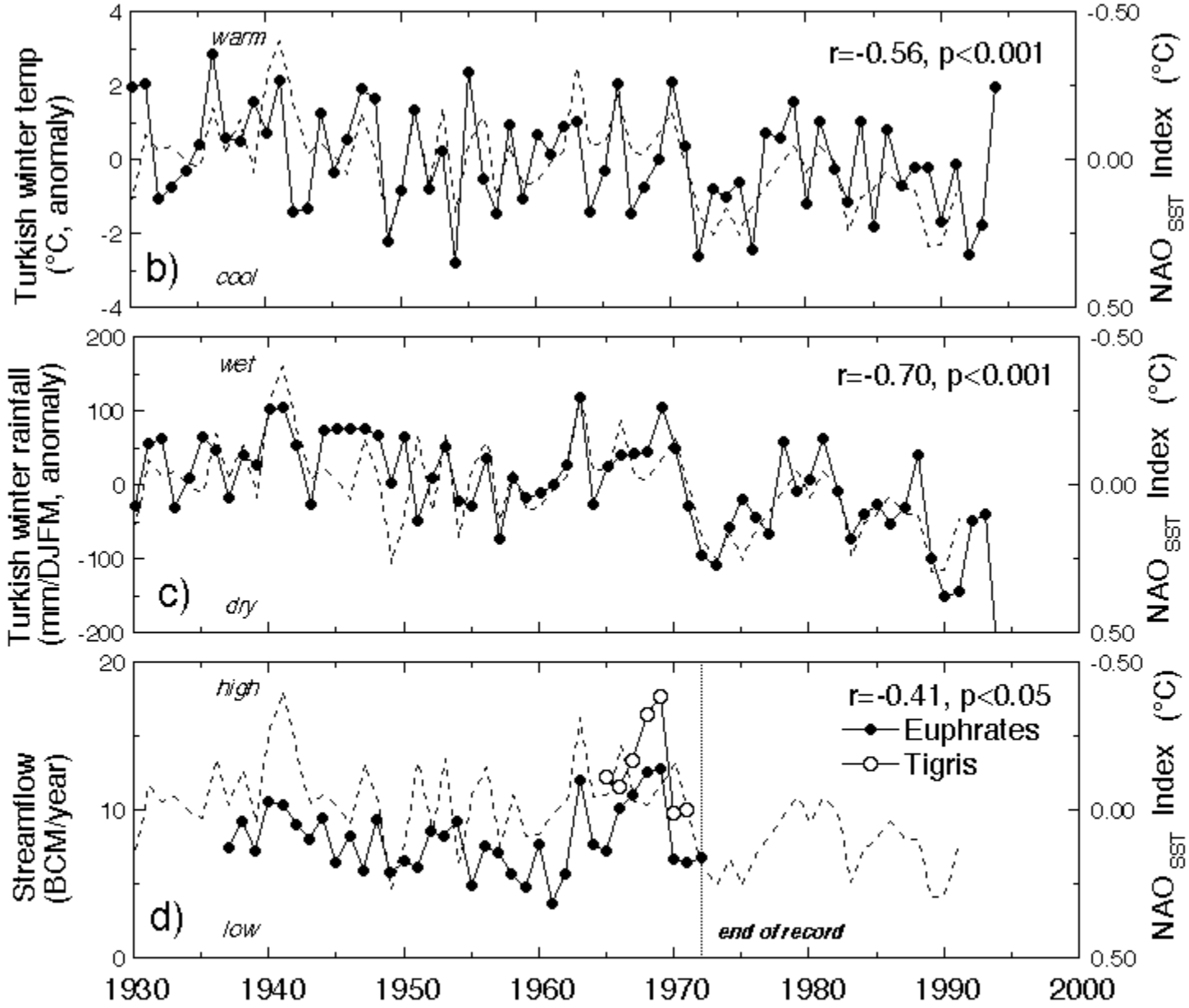
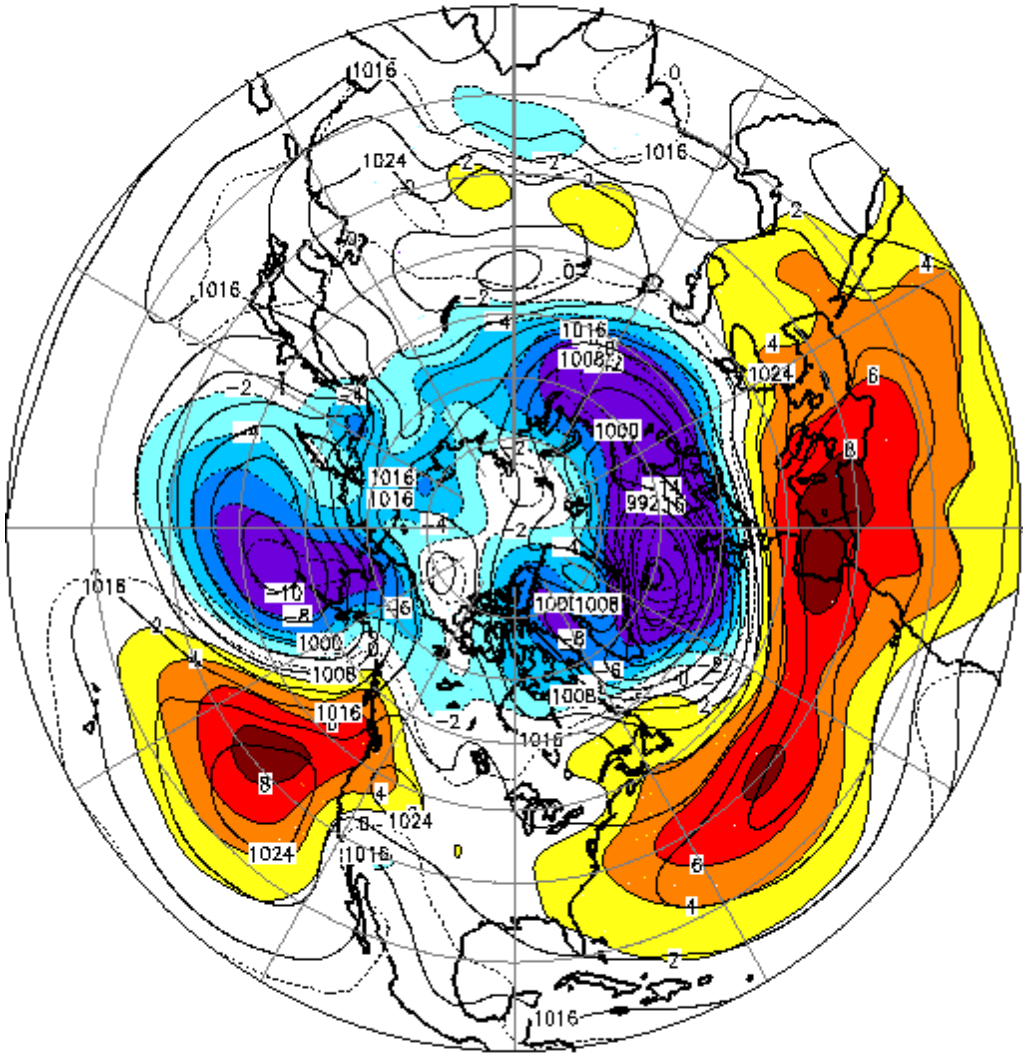

Turkish winter temp (°C, anomaly)
warm
cool
b)
r=-0.56, p<0.001
NAO SST Index (°C)
Turkish winter rainfall (mm/DJFM, anomaly)
wet
dry
c)
r=-0.70, p<0.001
Streamflow (BCM/year)
high
low
d)
r=-0.41, p<0.05
Euphrates
Tigris
end of record
1930
1940
1950
1960
1970
1980
1990
2000

Figure 3 a-d

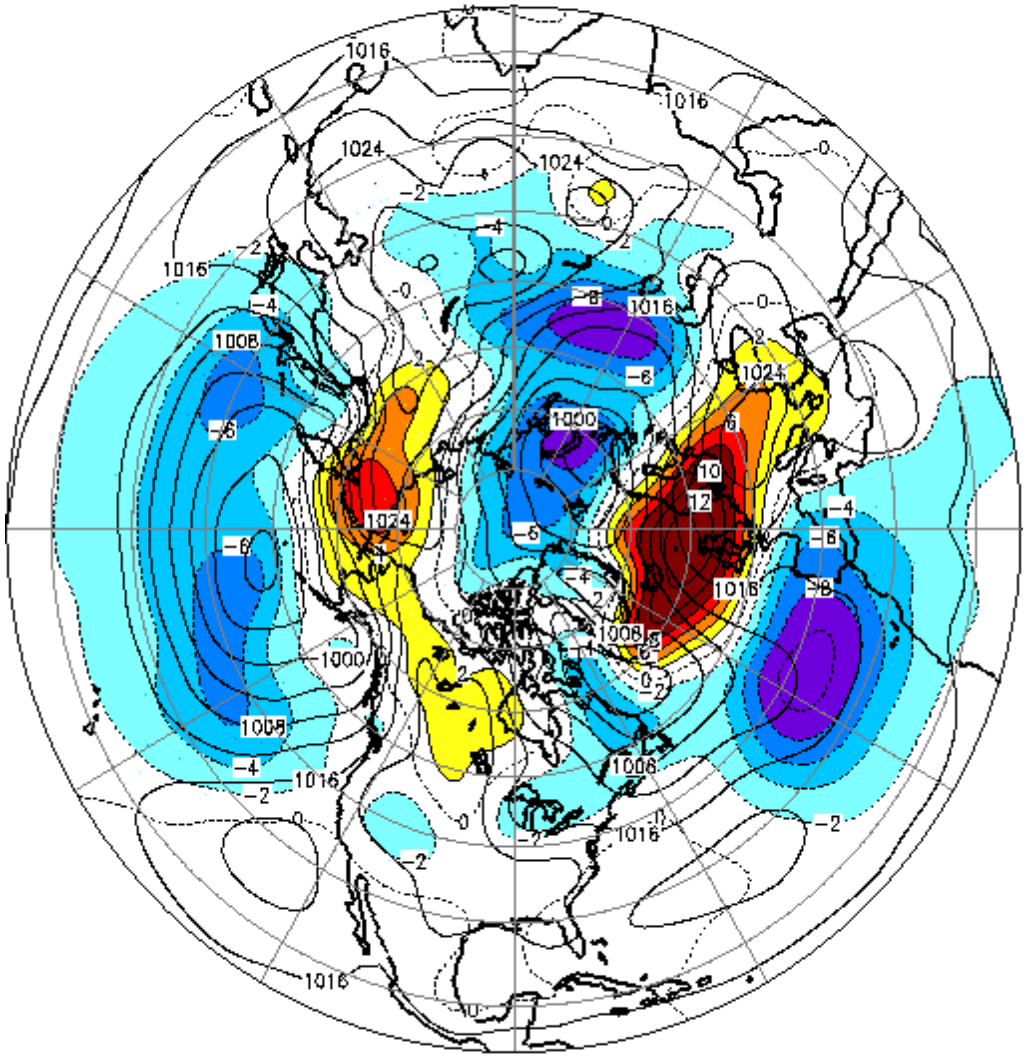
CDAS/Reanalysis

Sea-Level Pressure and Anomaly (1979-95 Climo)
FEB 97



CDAS/Reanalysis

Sea–Level Pressure and Anomaly (1979–95 Climo)
JAN 1997



CLIMATE PREDICTION CENTER/NCEP

Readings: NAO

- Barry and Chorley 1997 pg 146-148, 281-282
- Morton, O. (1998). The storm in the machine. *New Scientist* 157: 22-27.
- * Hurrell, J.W. (1995). Decadal trends in the North Atlantic oscillation: regional temperatures and precipitation. *Science* **269**: 676-679.
- Lamb, P.J. and Peppler, R.A. (1987). North Atlantic Oscillation: Concept and an application. *Bulletin American Meteorological Society* **68**: 1218-1225.
- Washington, R. and Palmer, M. 1999 North Atlantic Oscillation, *Geography Review*

Past Paper Questions…

- What circulation anomalies would lead to EITHER a cold month in winter OR a warm month in summer in NW Europe (2003)
- Explain the circumstances and mechanisms which would produce relatively warm, wet winters in the British Isles. (2001)
- In what ways do ocean temperatures influence the operation of atmospheric processes? (2001)
- Show the importance of ocean-atmosphere interactions for understanding interannual climatic variability in the tropics. (2000)
- Outline the North Atlantic Oscillation and its role in influencing climate (1999)
- Describe one important pattern of climate variability. (1998)
- Water plays a crucial role in the workings of weather and climate. Disucss (1997)
- What role do the oceans play in the general circulation of the atmosphere? (1996)