

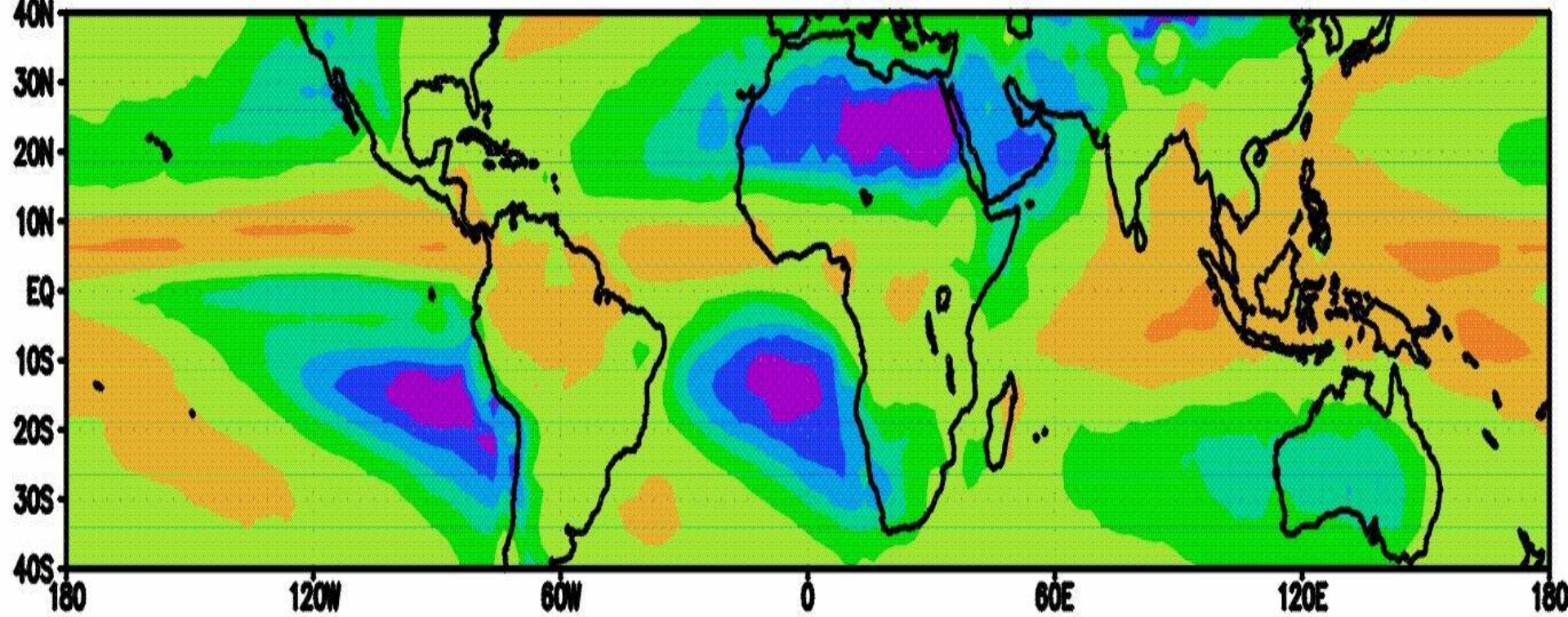
Climatology Lecture 8

Variability of the General Circulation

Richard Washington

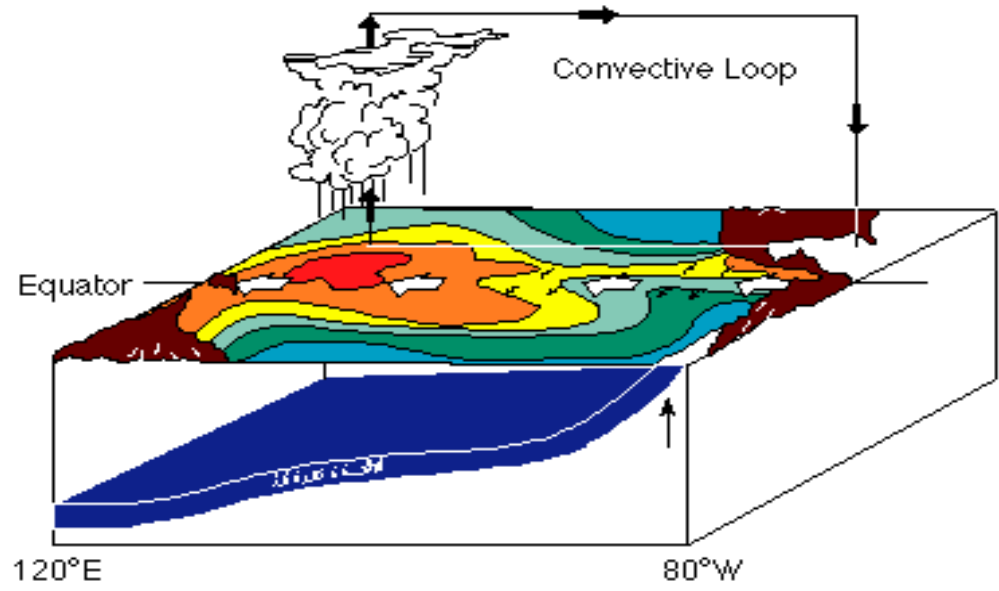
Lecture Outline

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

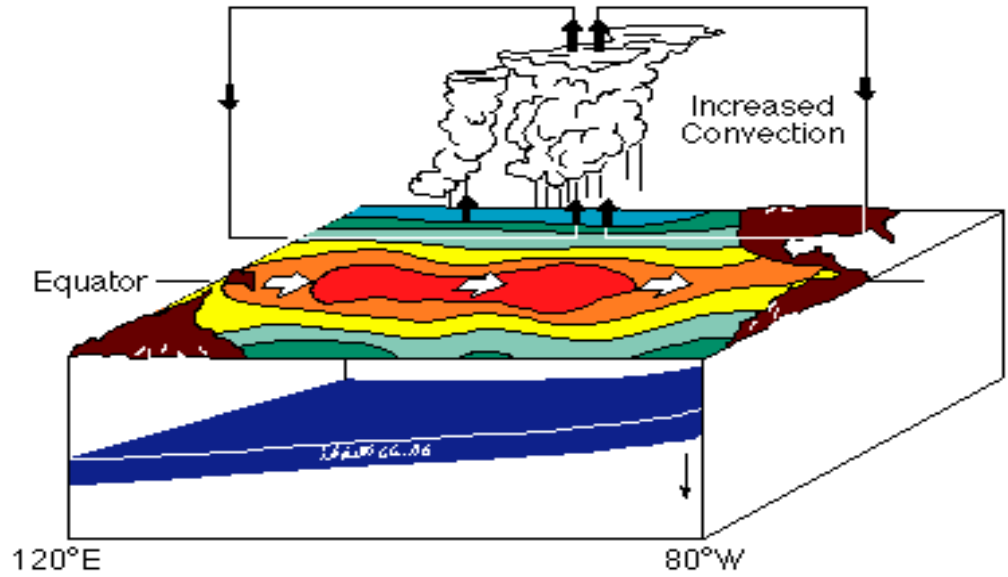


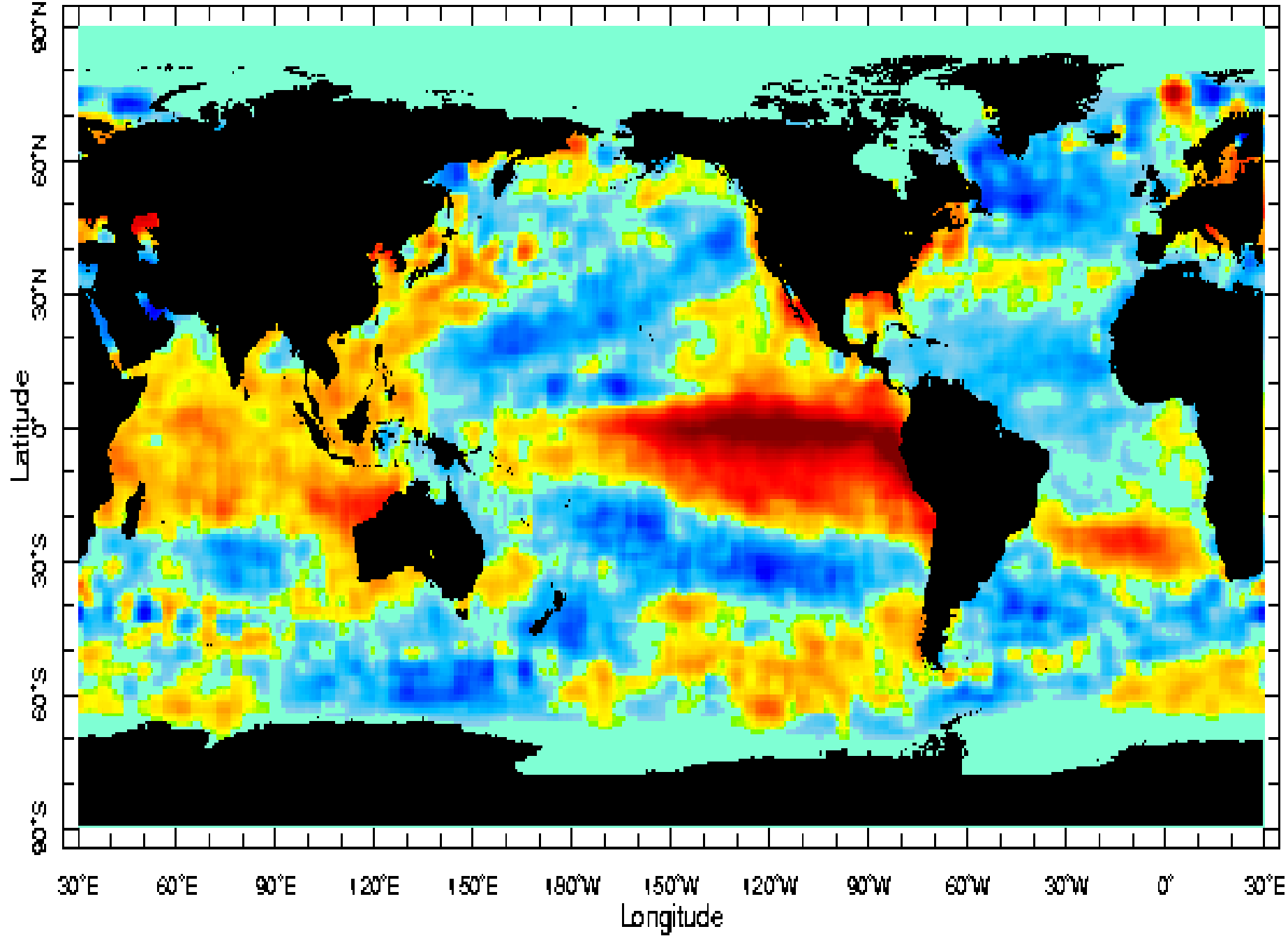
Annual Average Rainfall mm/day

Normal Conditions

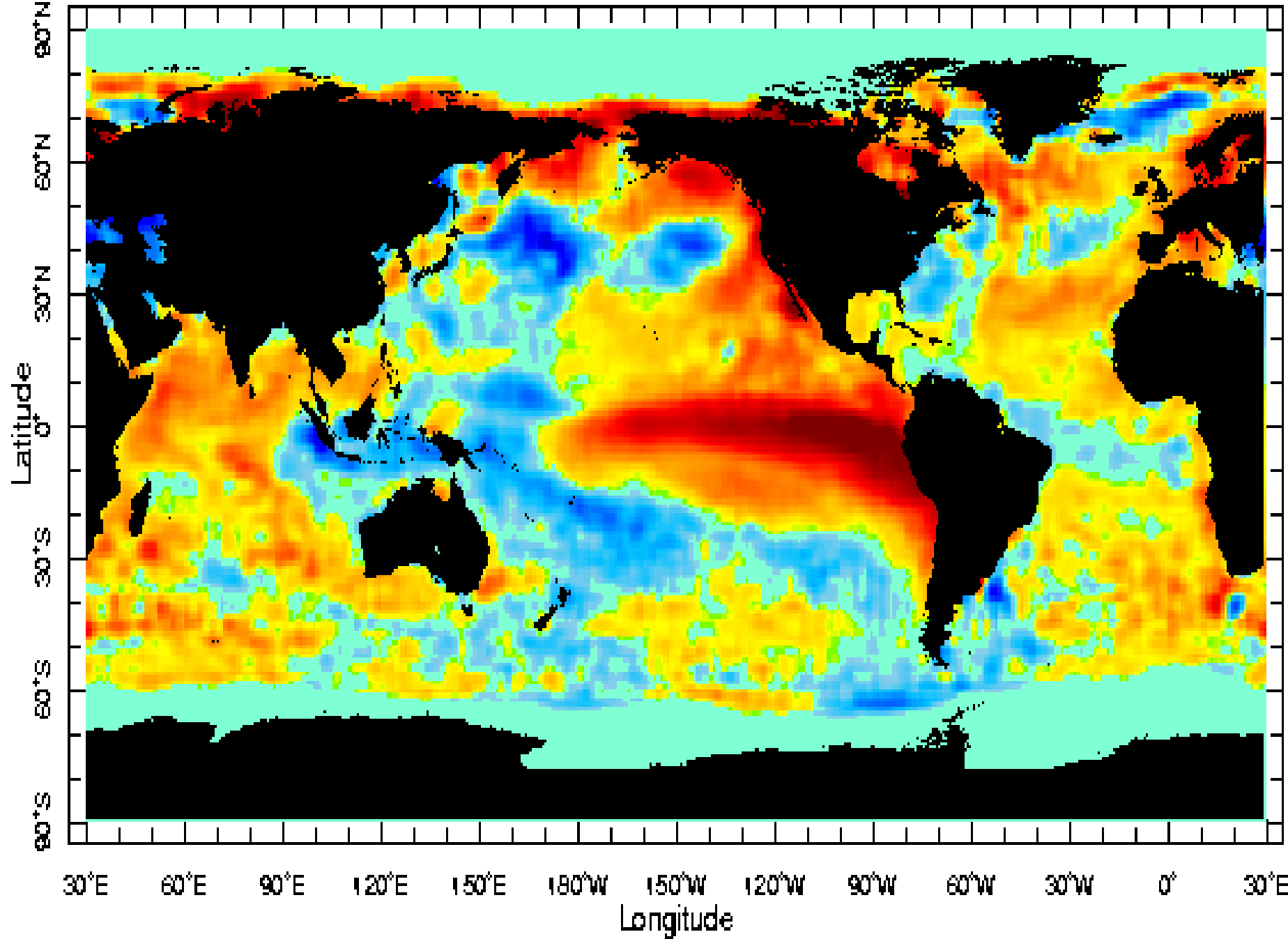


El Niño Conditions

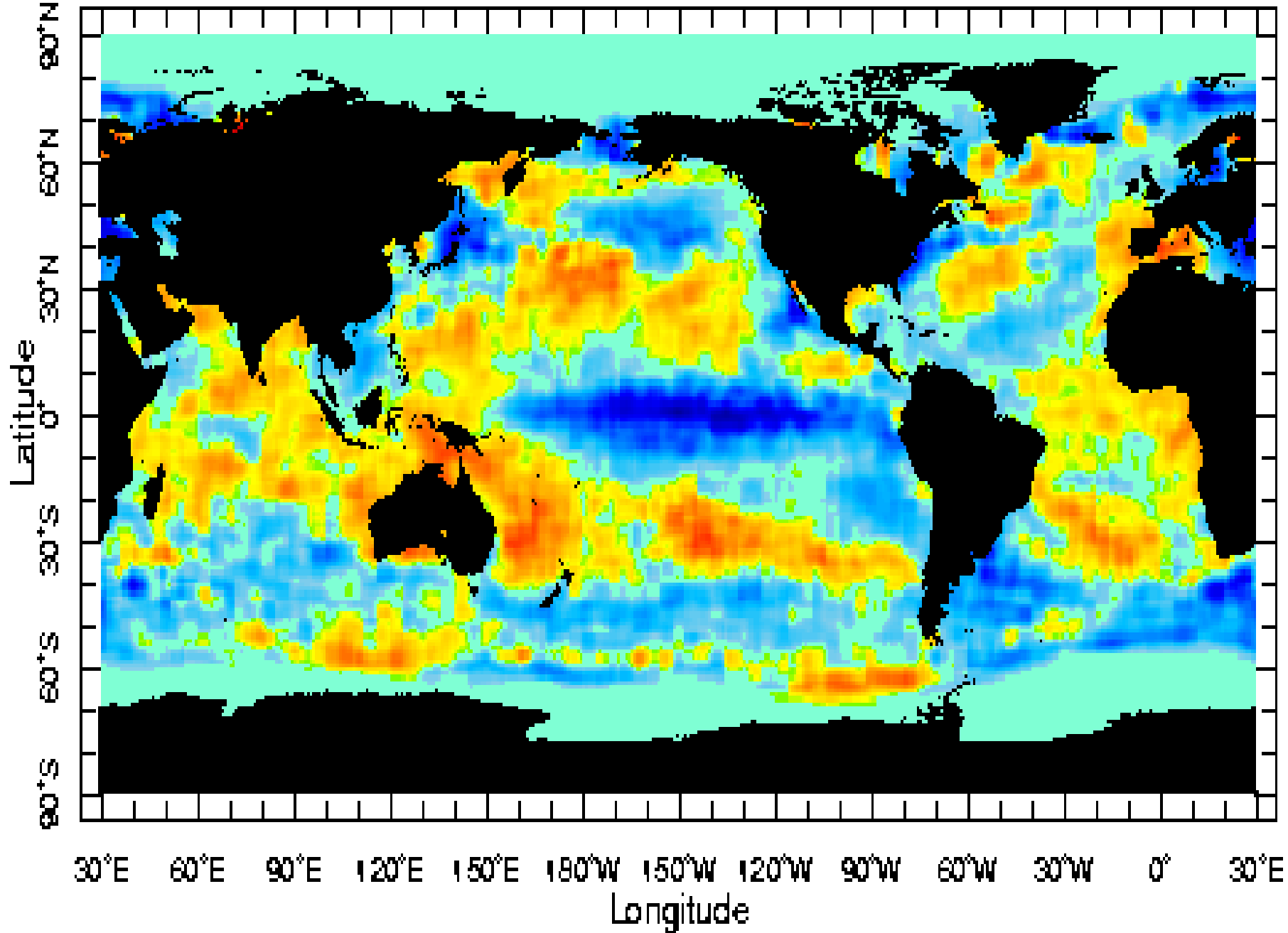




Dec 82



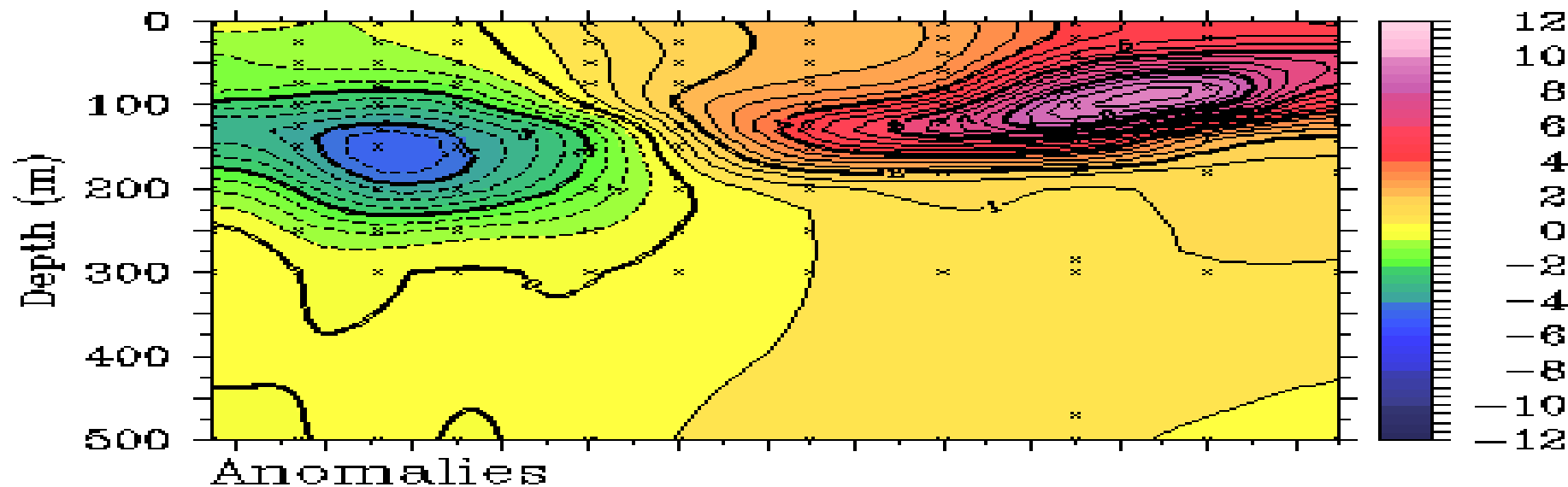
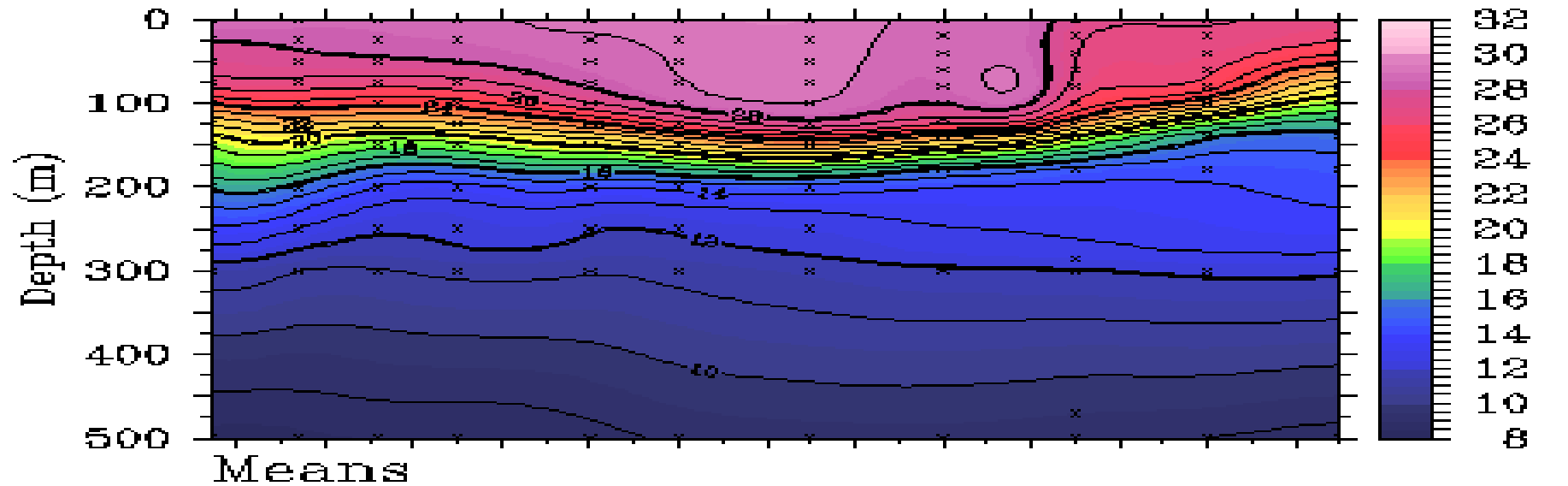
SEP 97



Nov 88

Monthly Mean TAO Temperatures ($^{\circ}\text{C}$) September 1997 2°S to 2°N Average

140 $^{\circ}\text{E}$ 160 $^{\circ}\text{E}$ 180 $^{\circ}$ 160 $^{\circ}\text{W}$ 140 $^{\circ}\text{W}$ 120 $^{\circ}\text{W}$ 100 $^{\circ}\text{W}$



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

Lecture Outline

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 - definition
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- North Atlantic Oscillation (NAO)

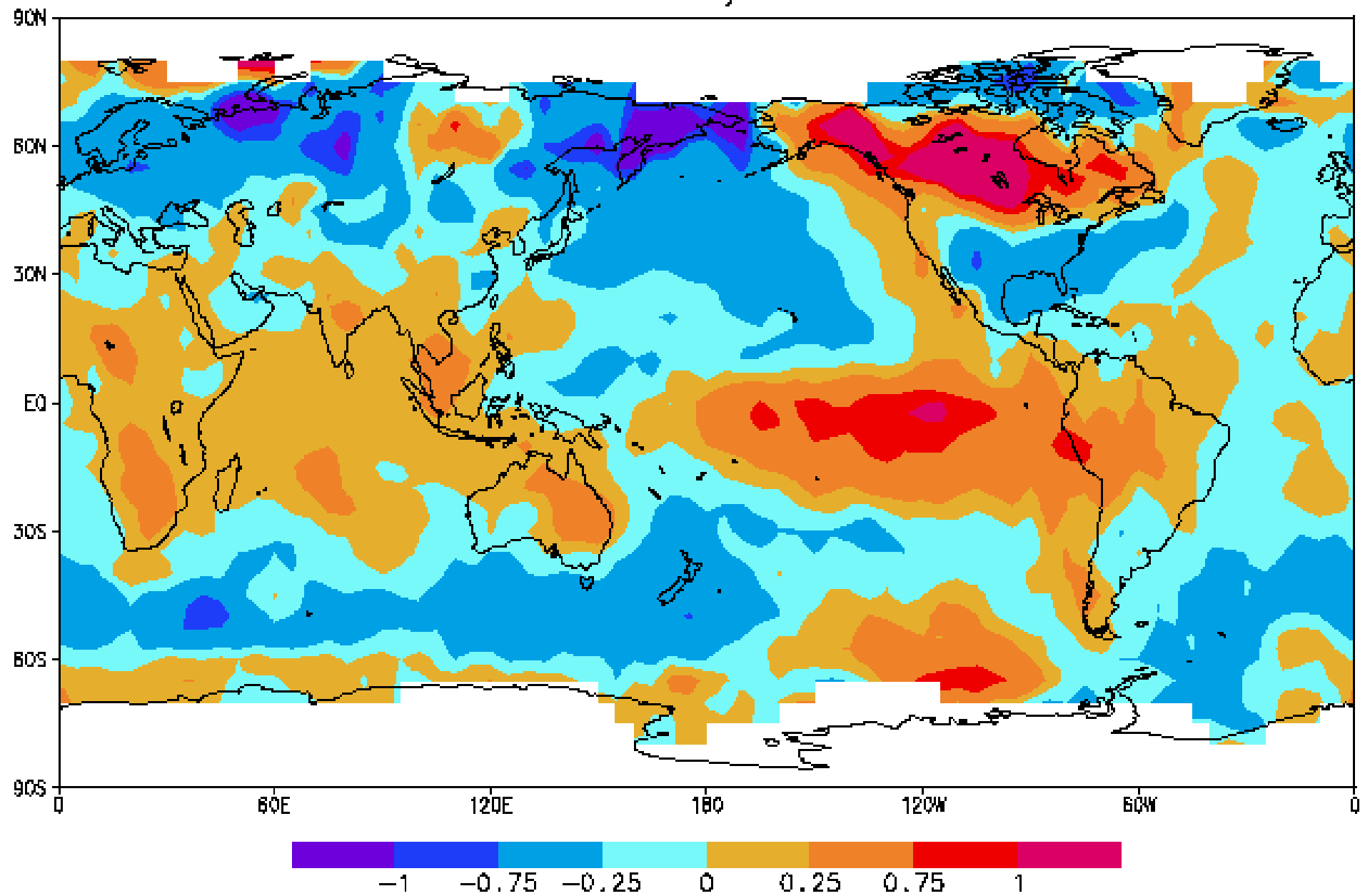
El Nino

- 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

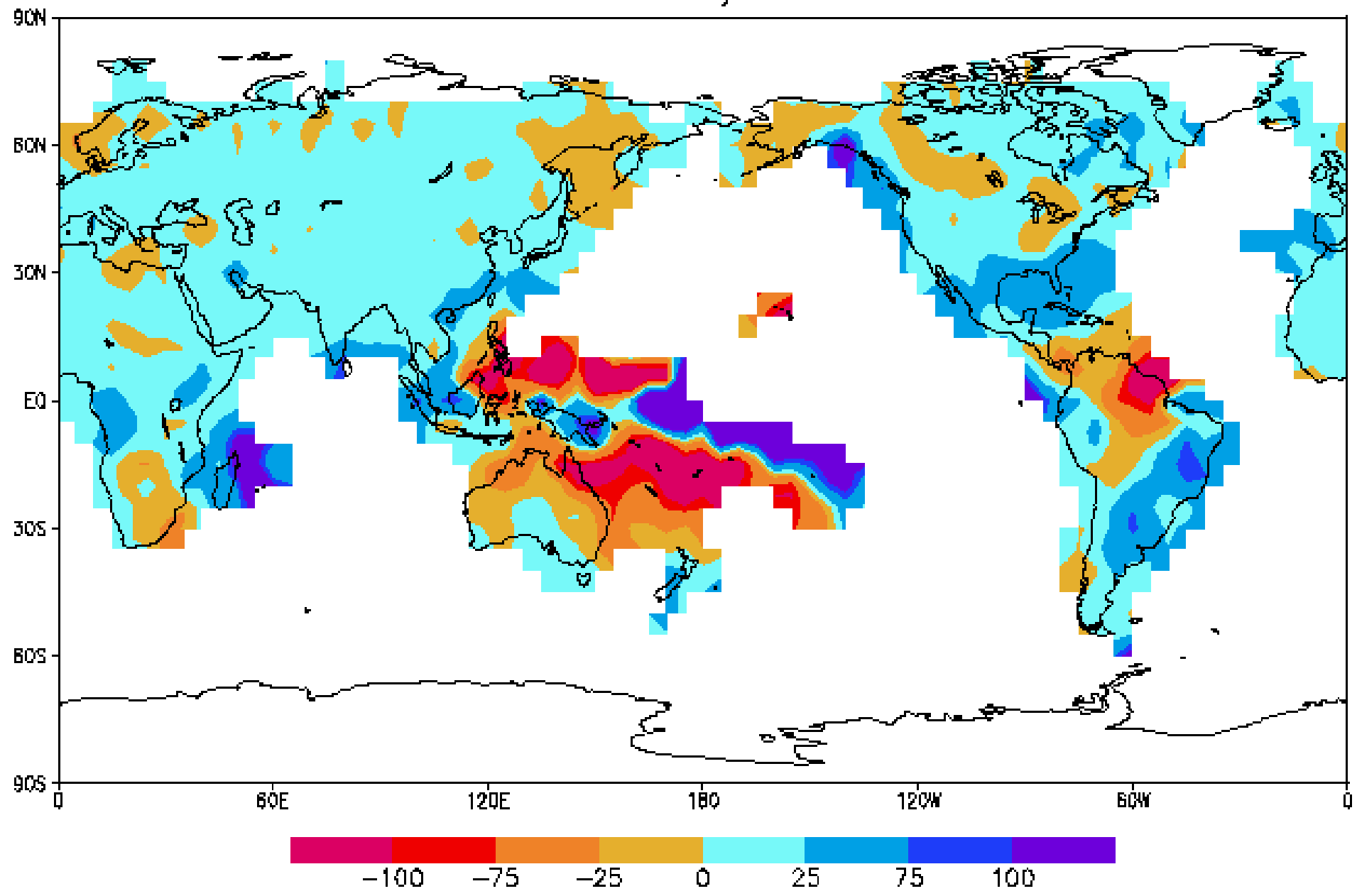
La Nina

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

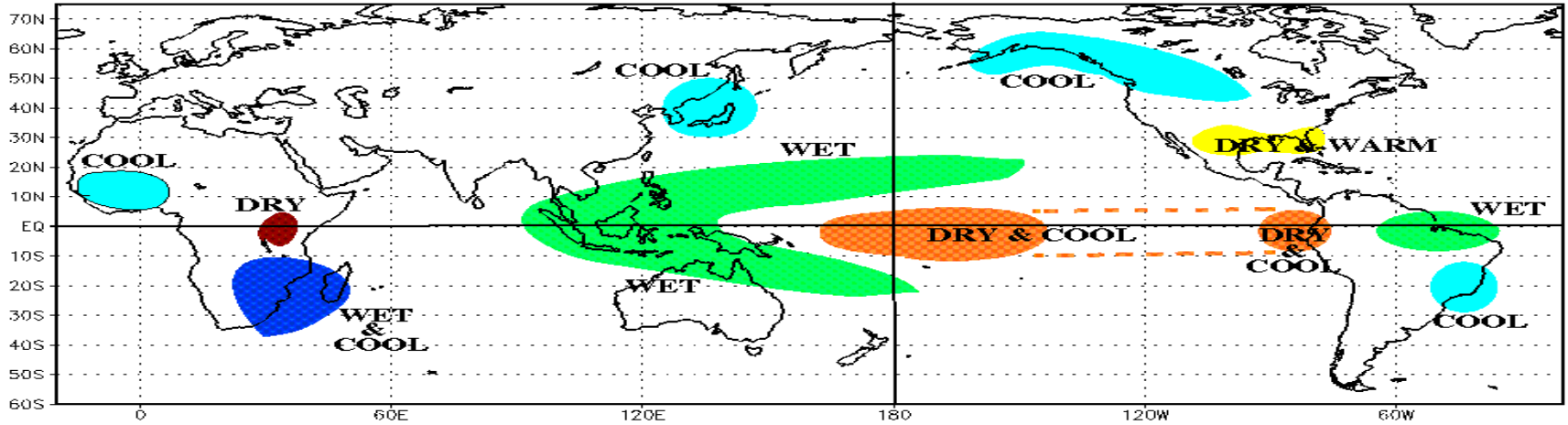
Warm Event Temperature Composite for djf+1



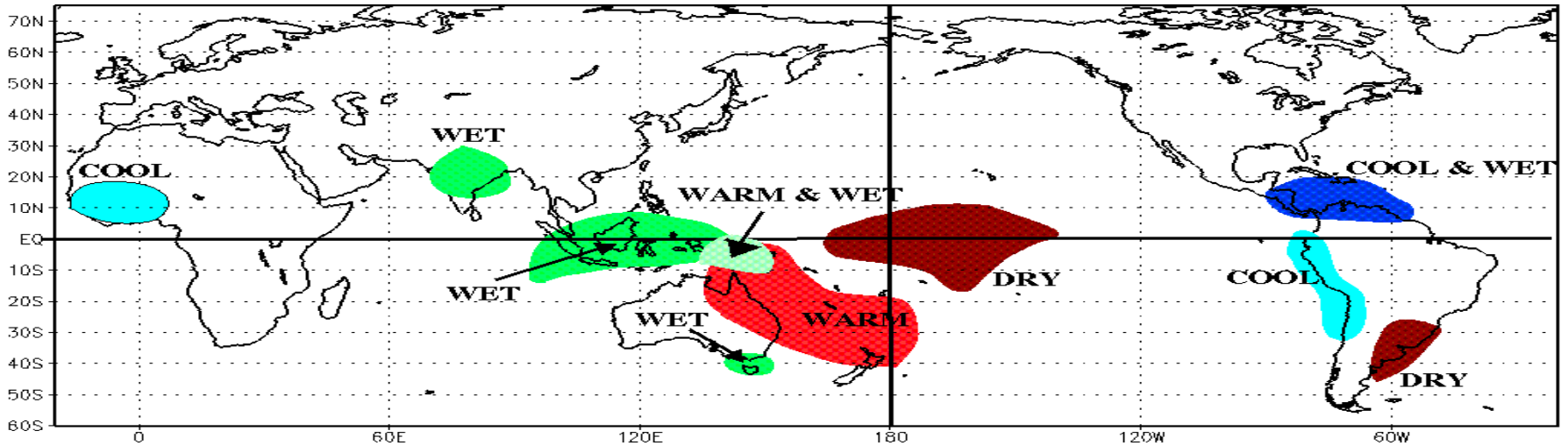
Warm Event Precipitation Composite for djf+1



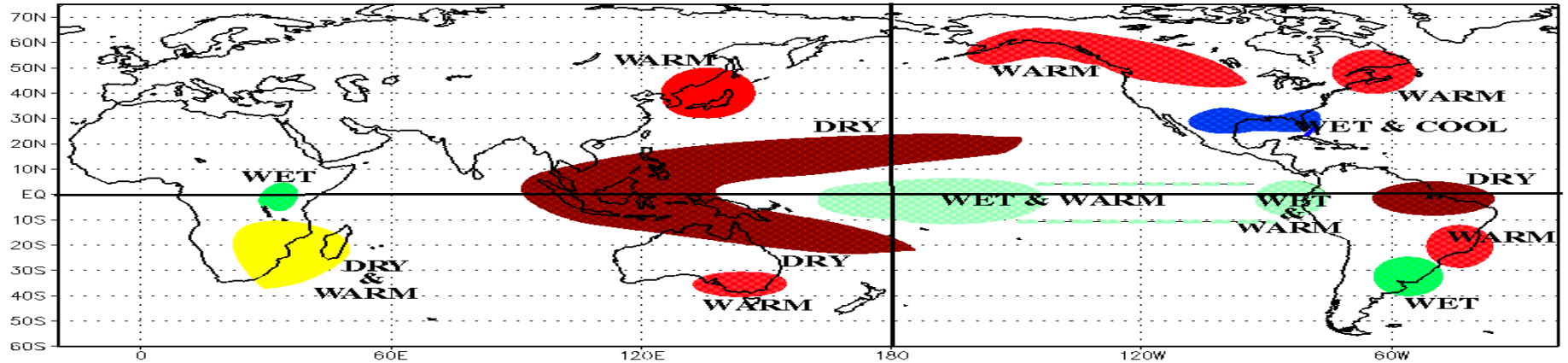
COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



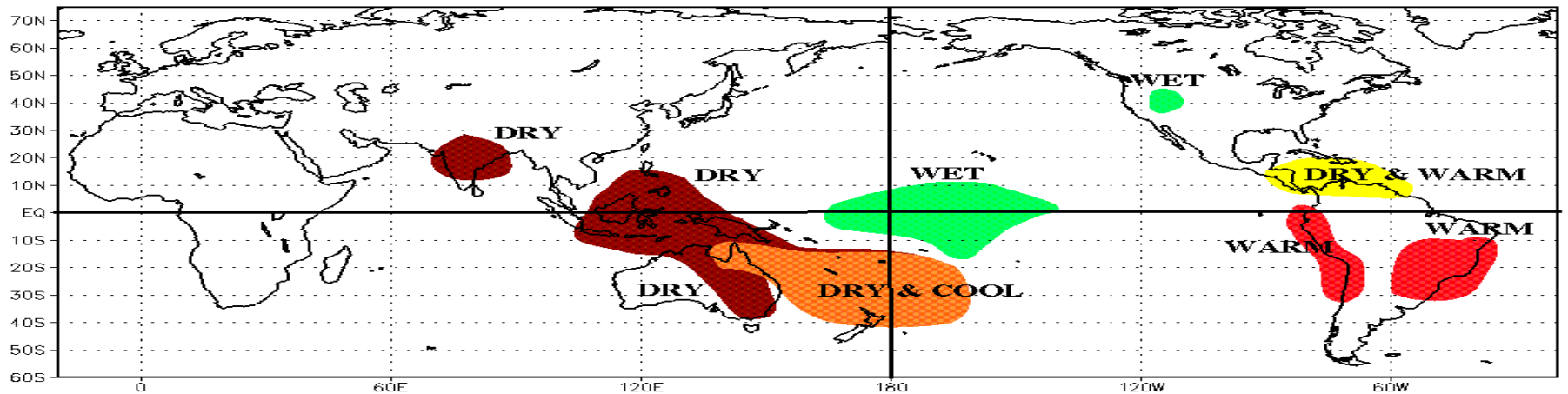
COLD EPISODE RELATIONSHIPS JUNE - AUGUST



WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

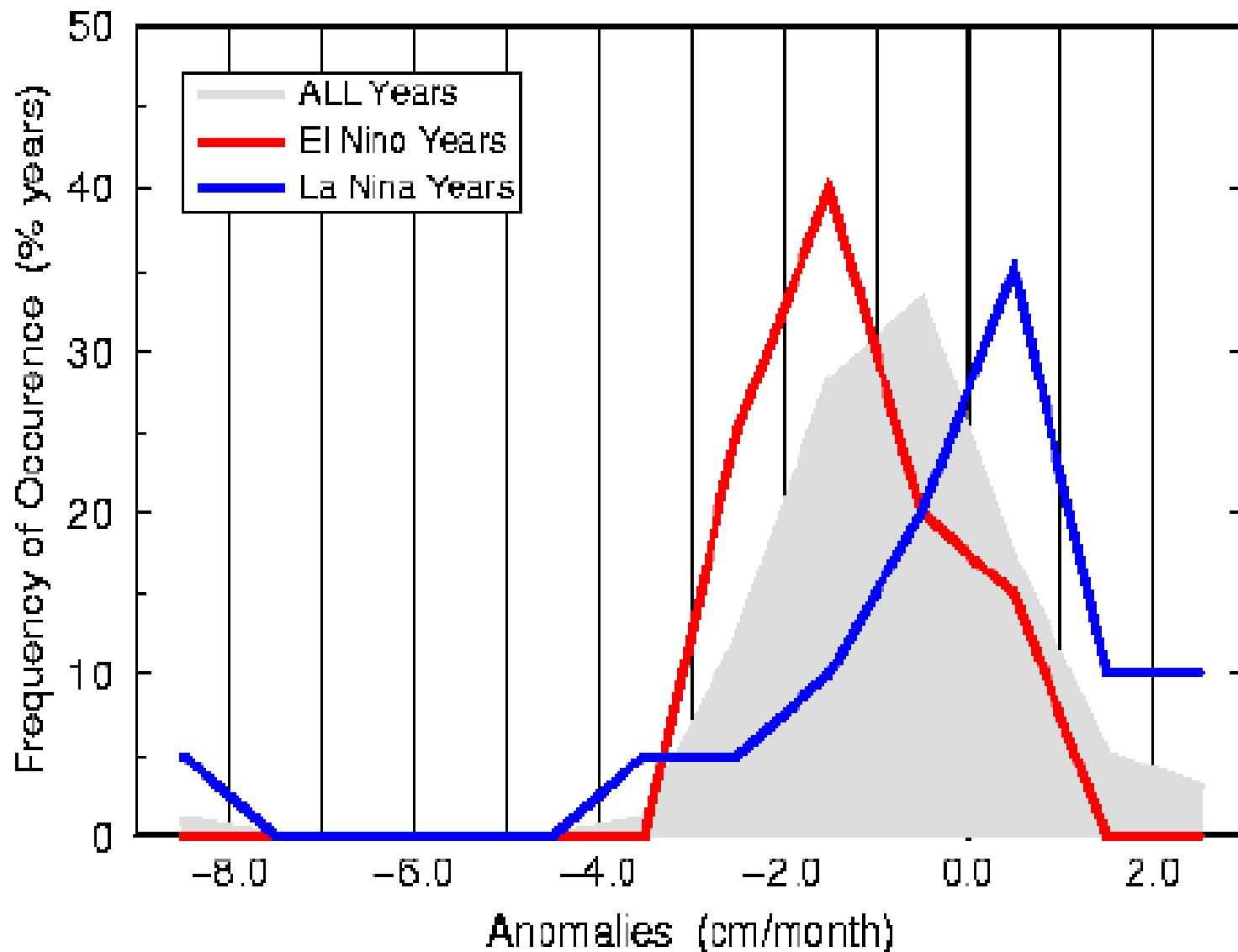


WARM EPISODE RELATIONSHIPS JUNE - AUGUST



ENSO Impacts : Rainfall Anomalies

Southern Africa (30S–13S; 20E–50E) : Nov–May 1890–1989



El Nino

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

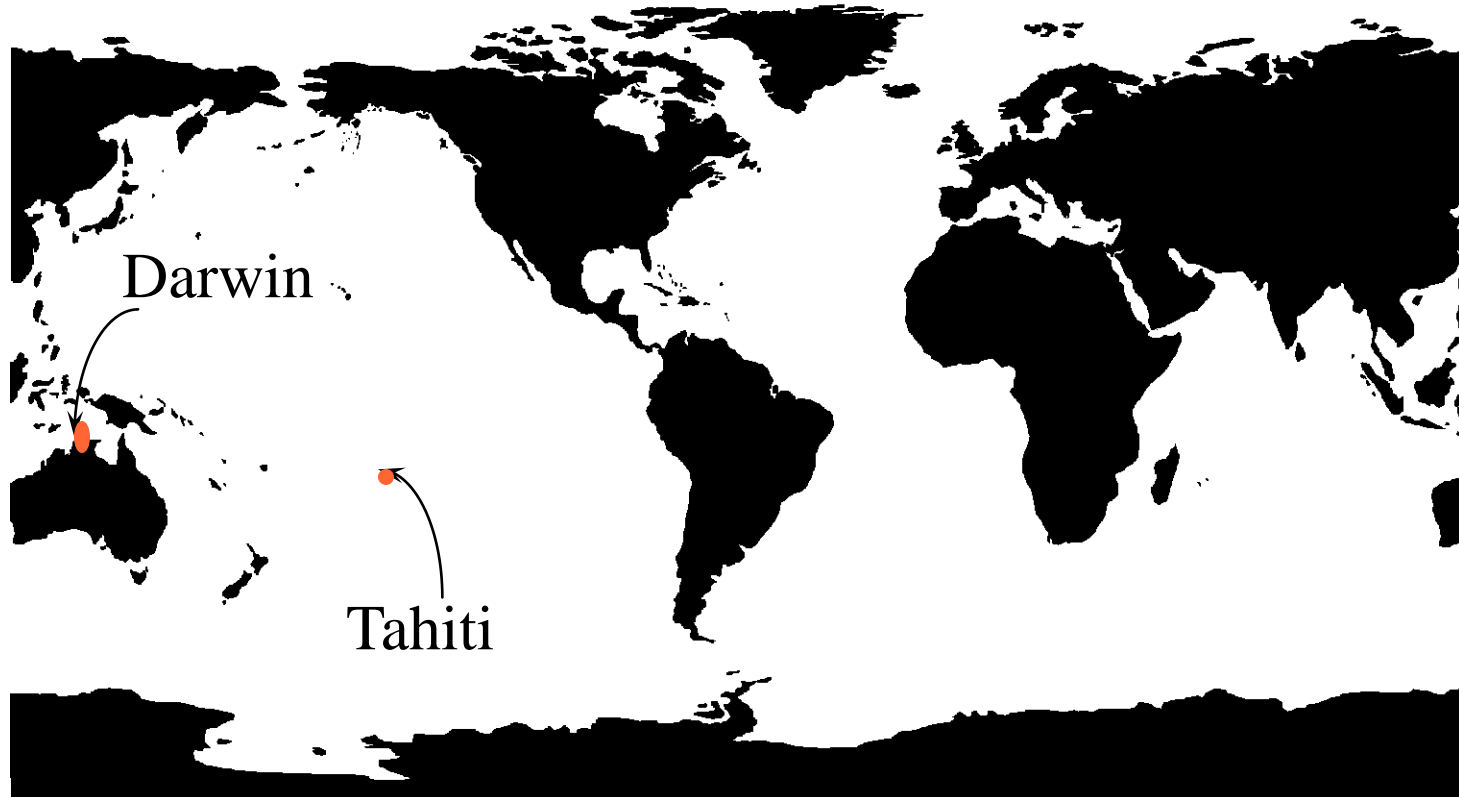
La Nina

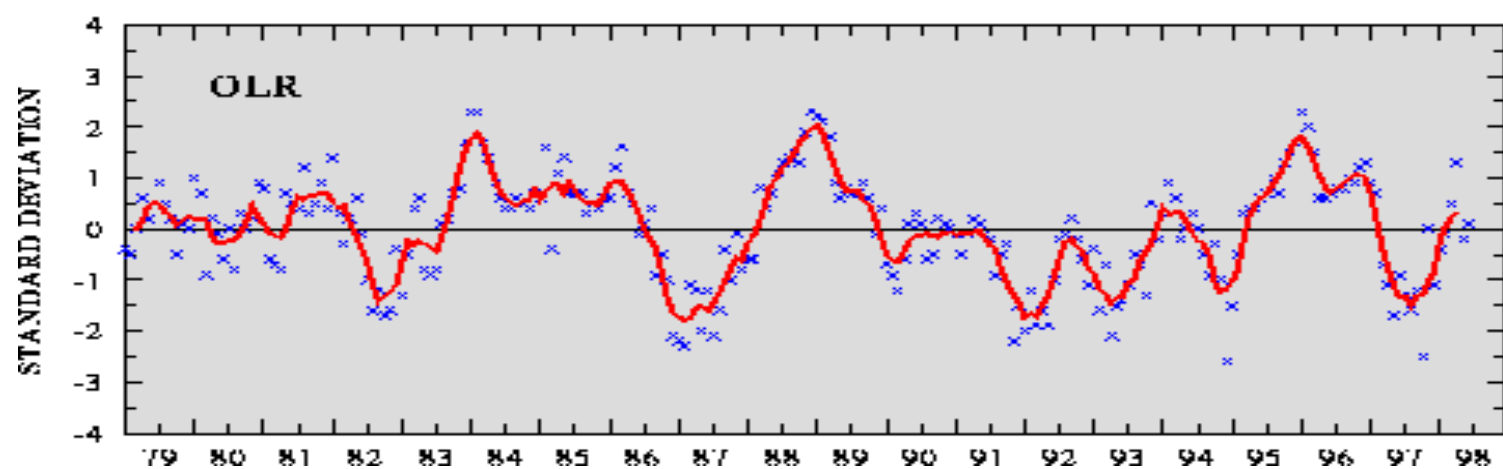
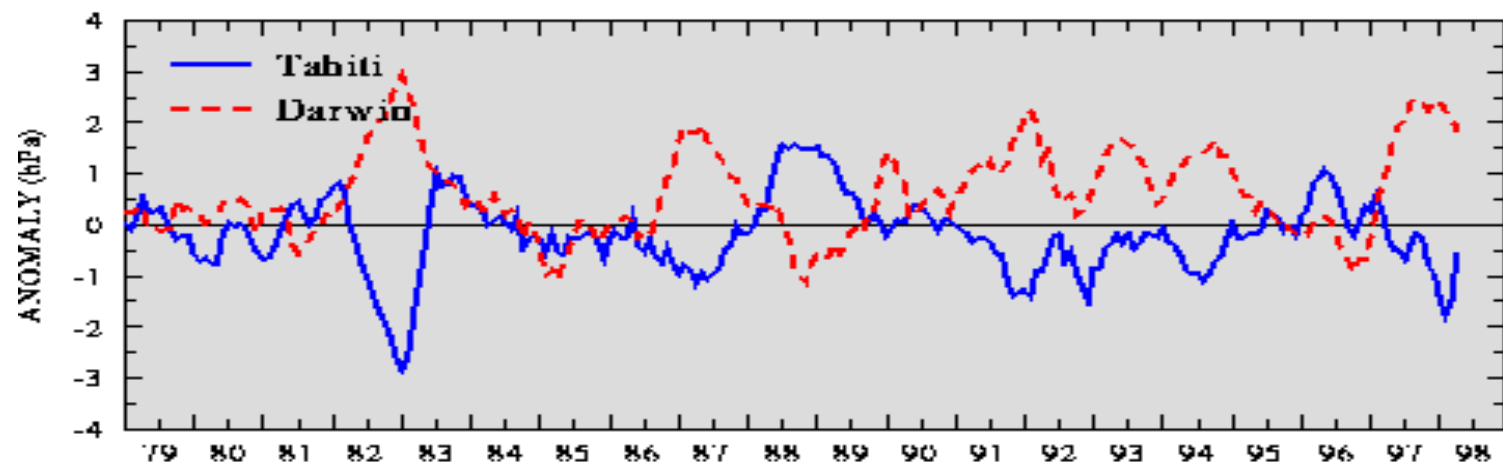
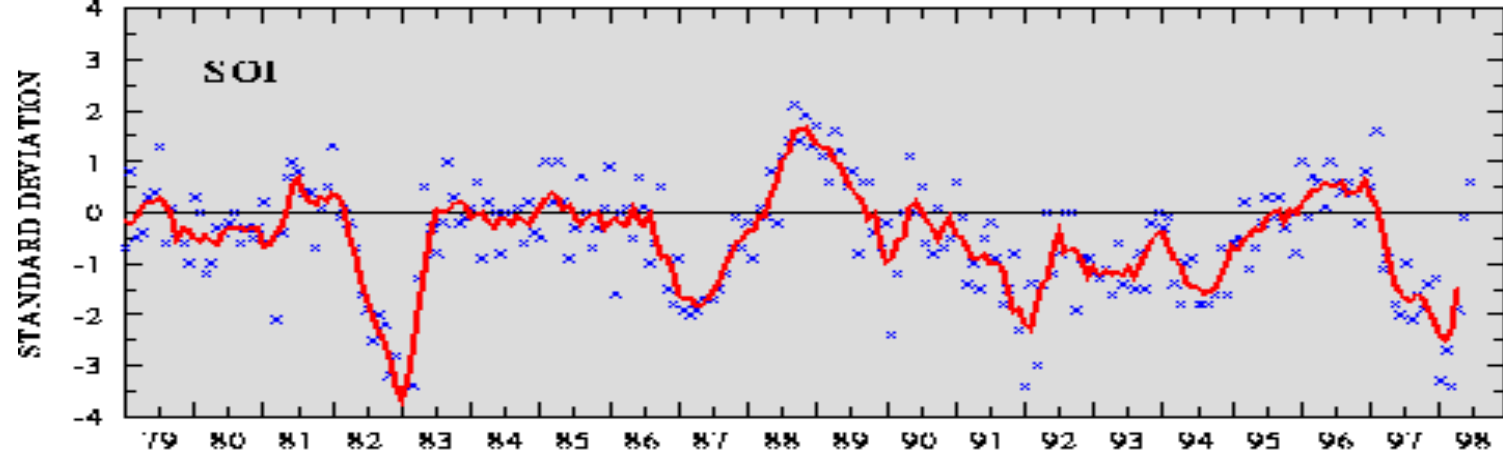
- DRY East Africa
(Oct-Dec)
- WET southern Africa
(Dec-March)
- WET Sahel (July-Sep)

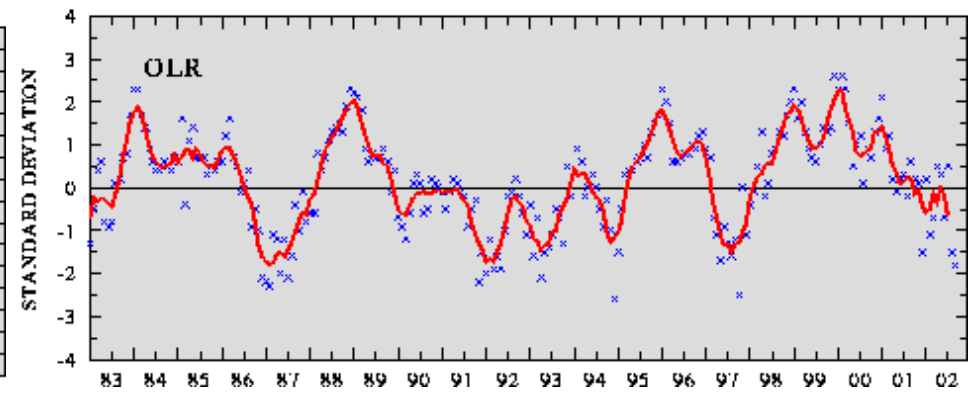
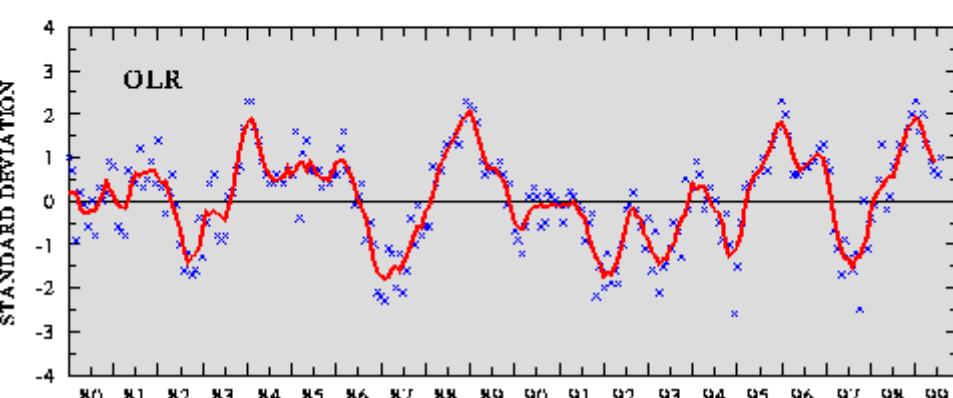
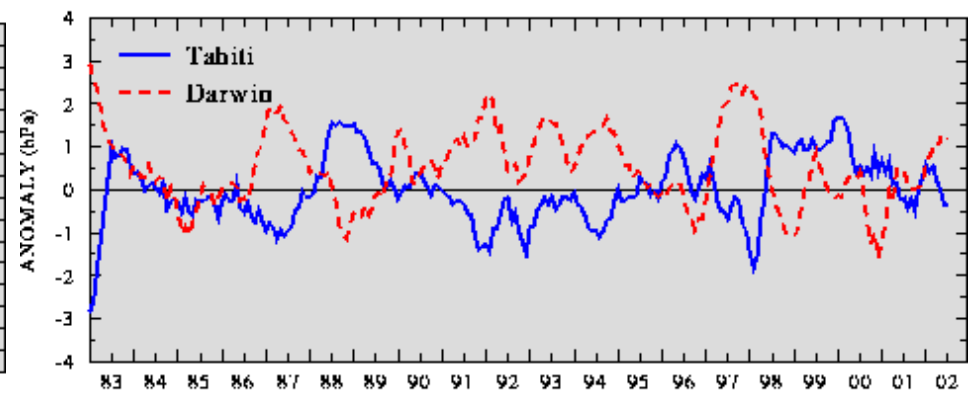
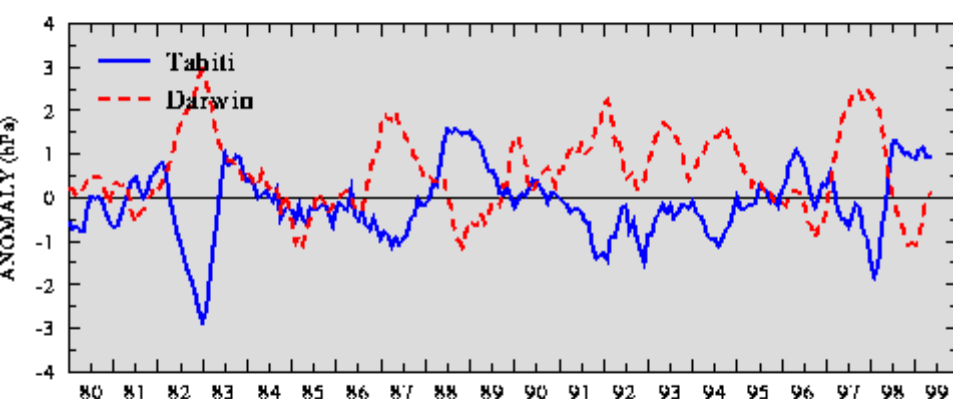
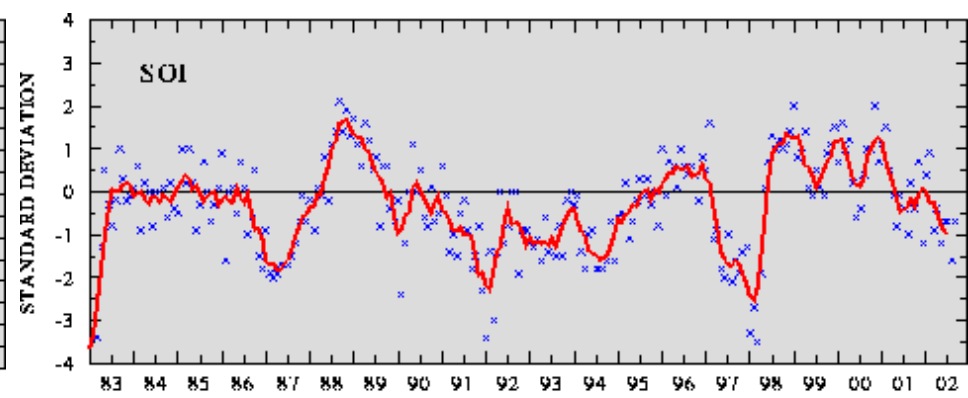
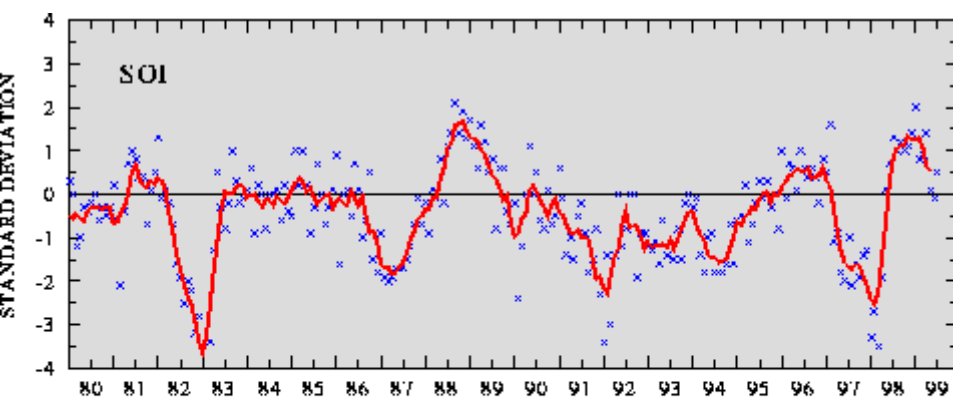
Lecture Outline

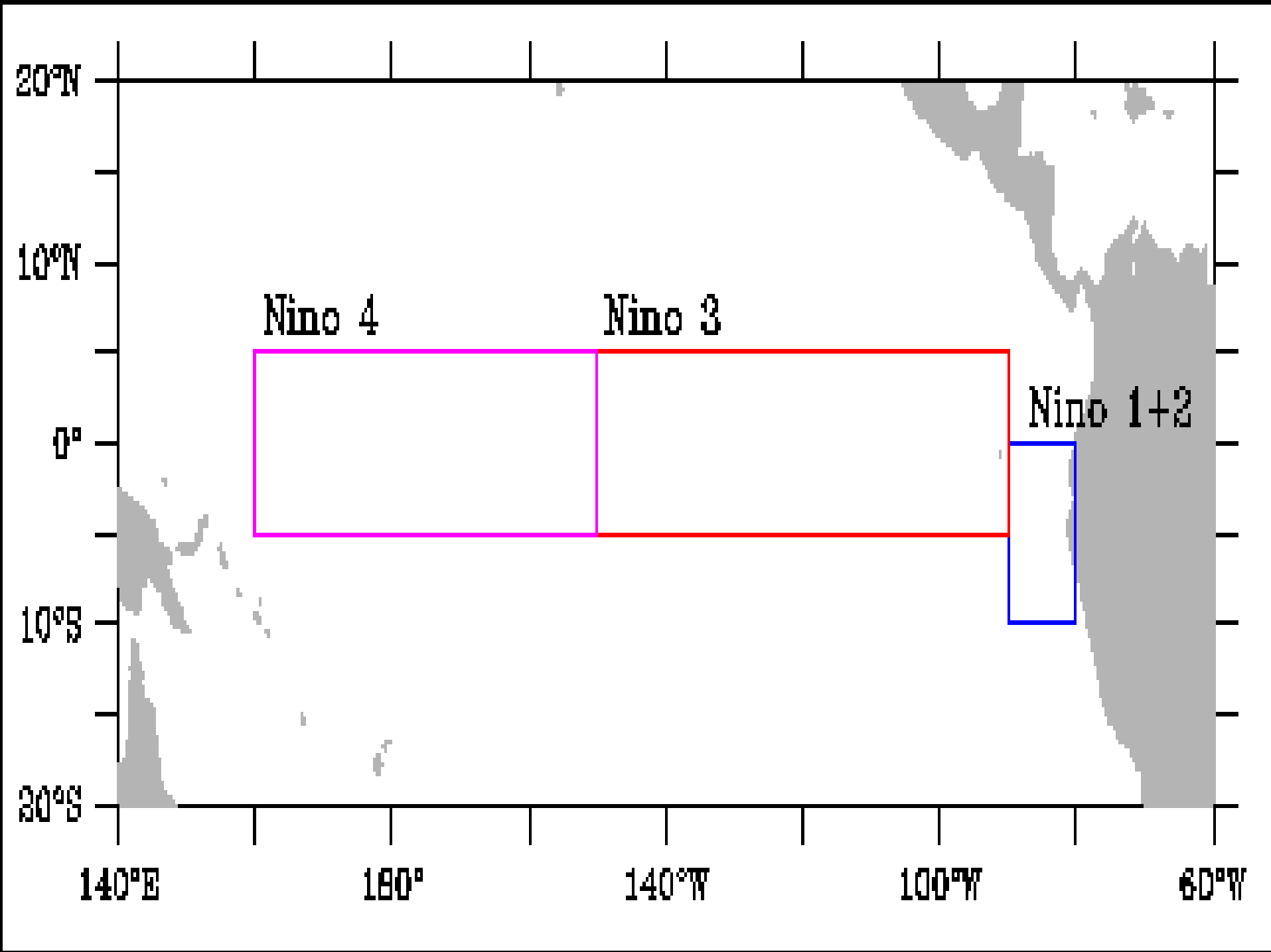
- El Nino - Southern Oscillation (ENSO):
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Southern Oscillation Index Centres

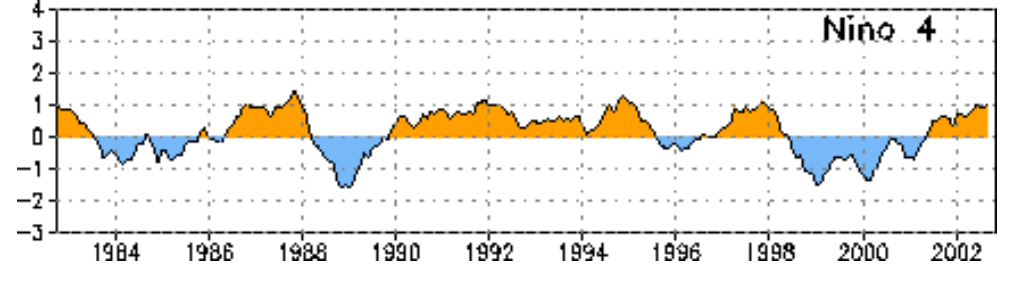
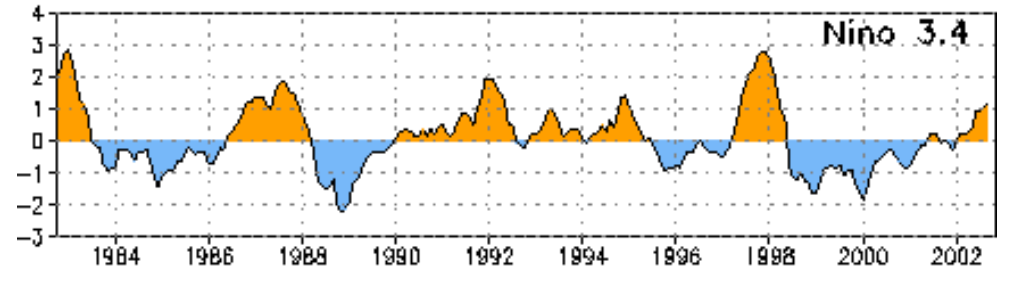
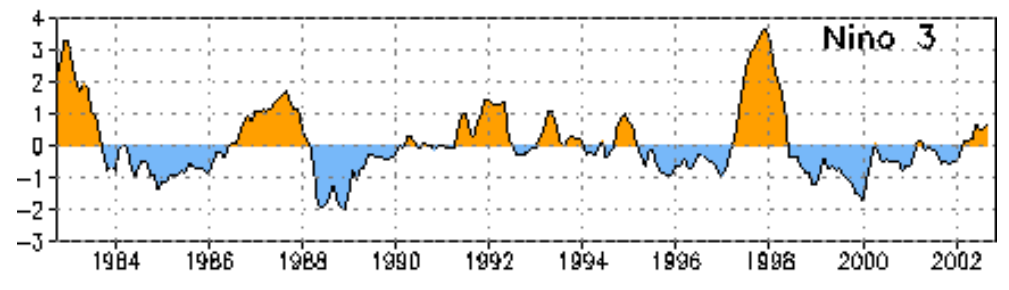
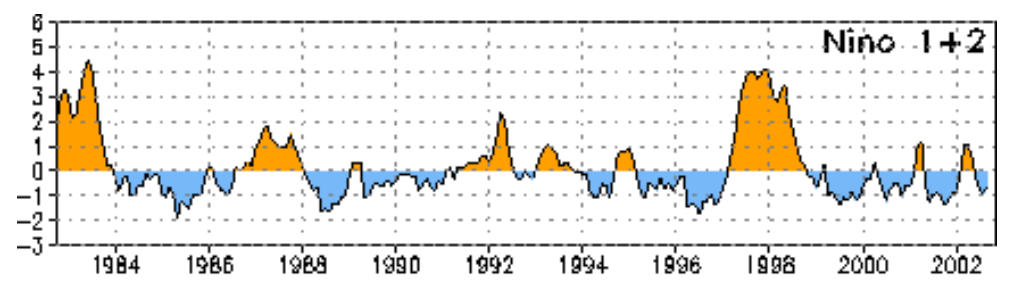
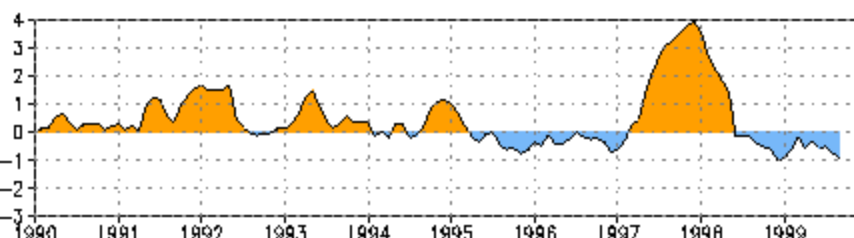
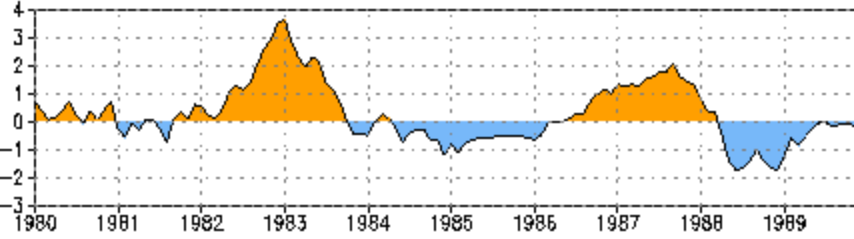
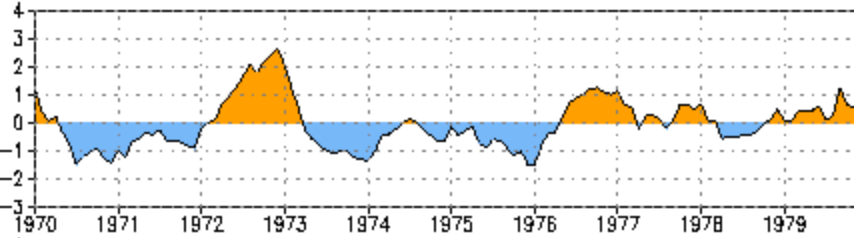
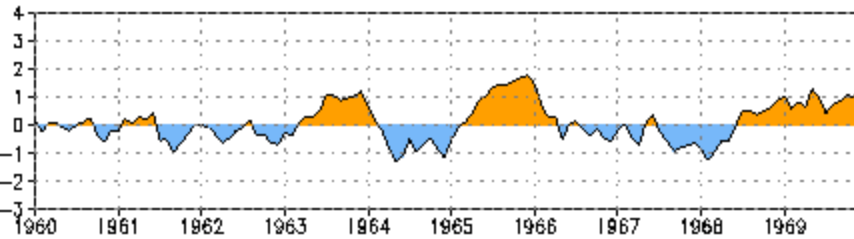
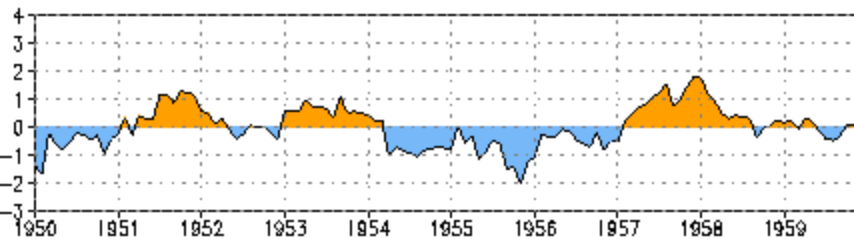






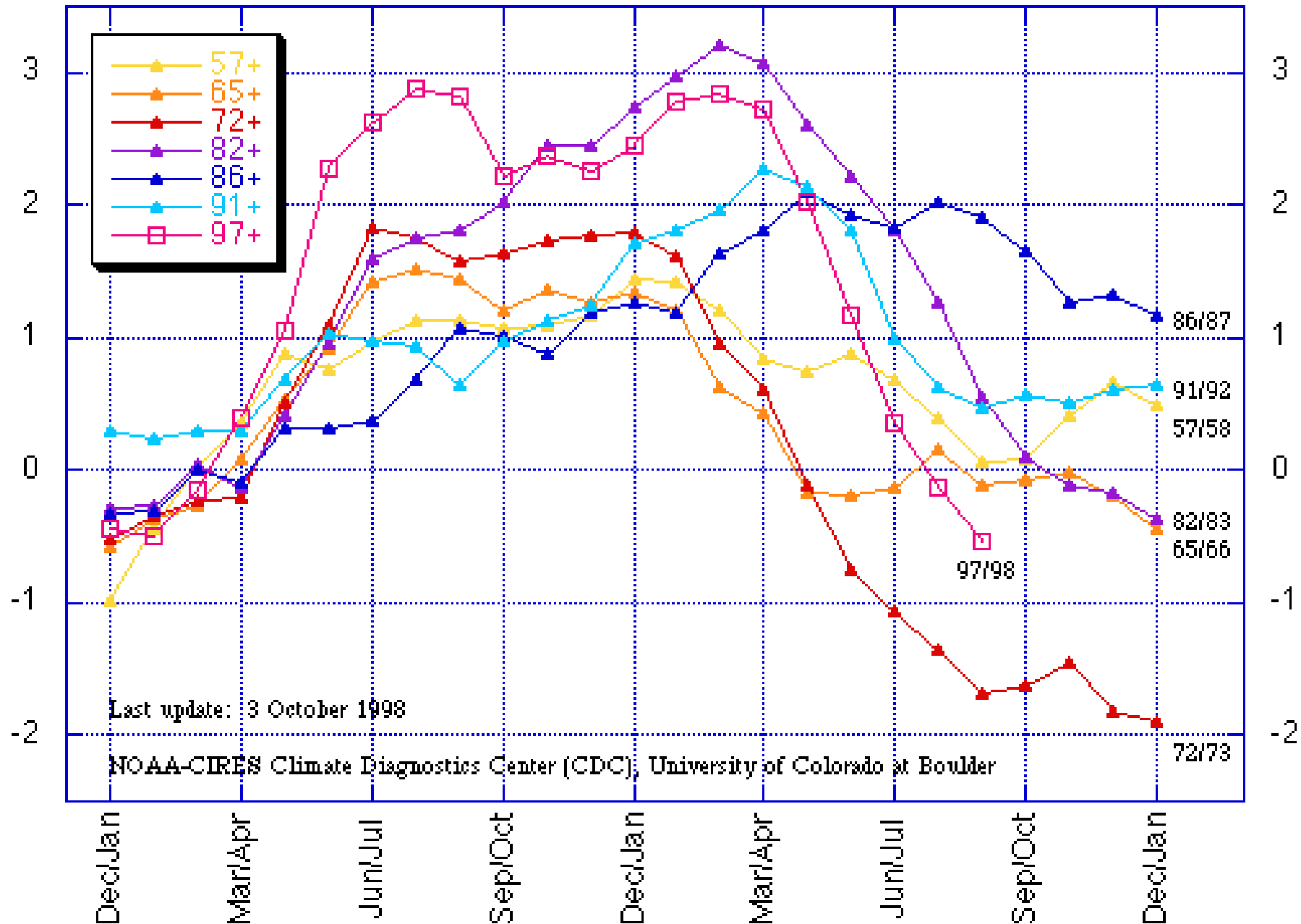


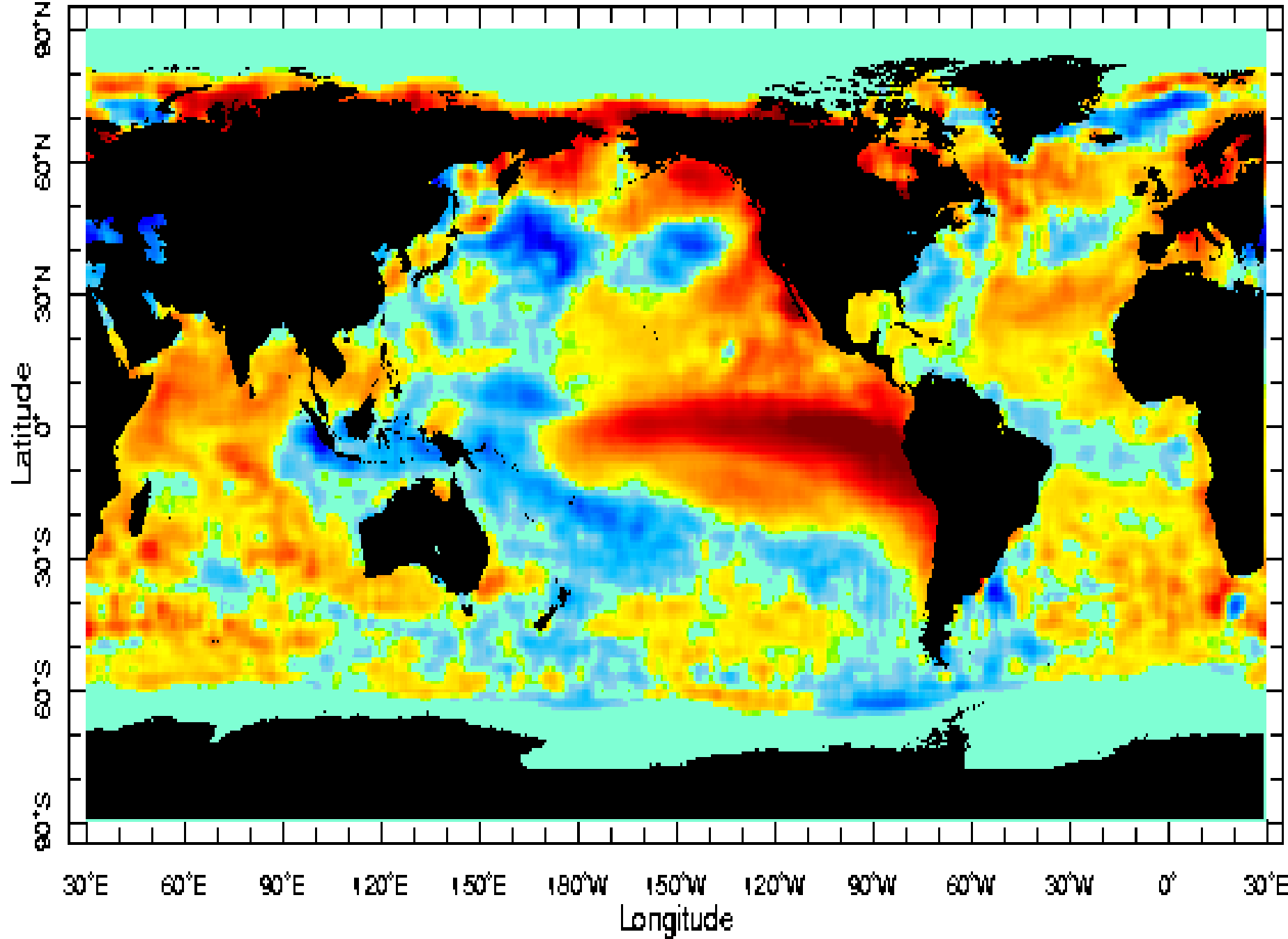
SST Anomalies NINO 3



Multivariate ENSO Index for the 7 strongest historic El Niño events since 1950

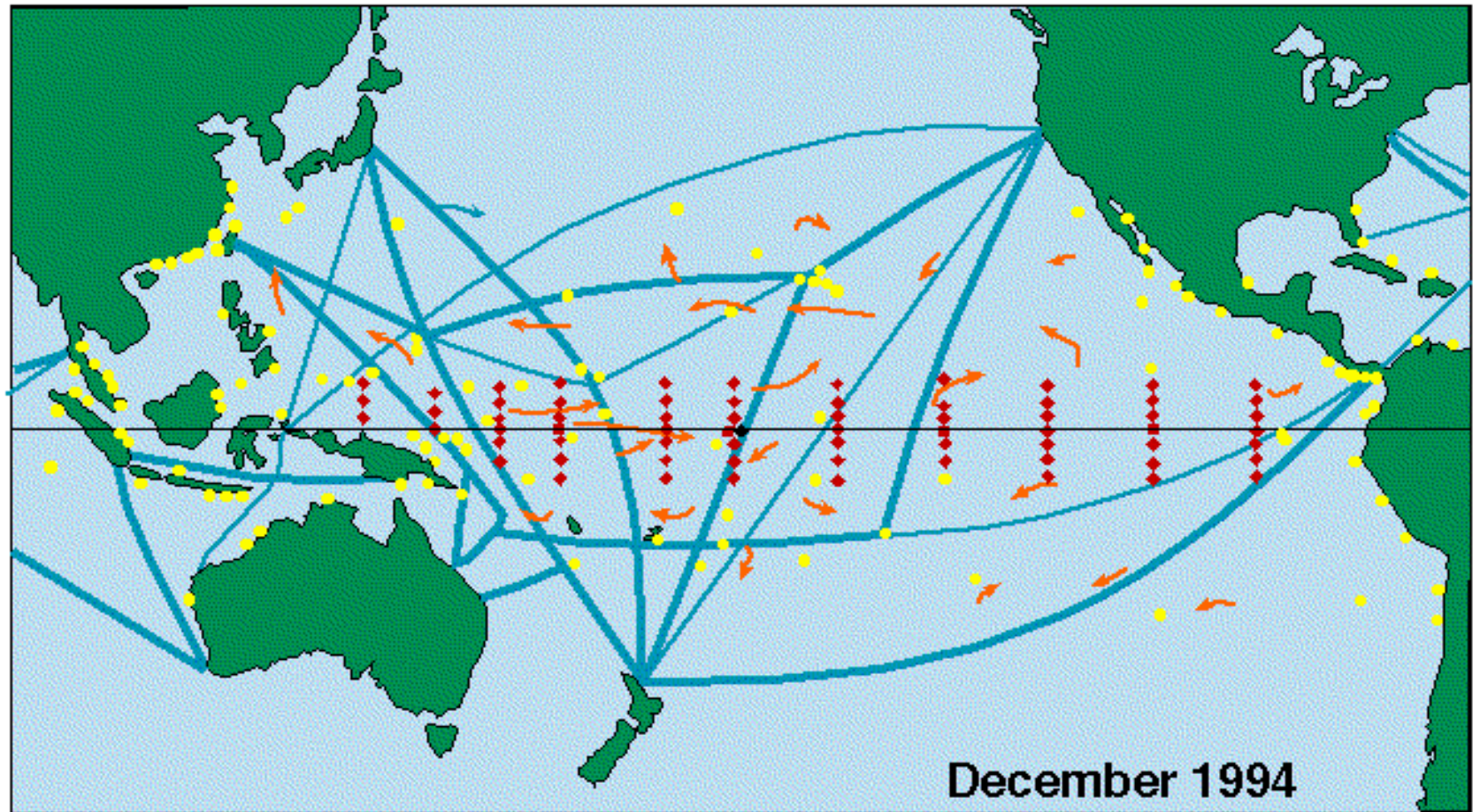
Standardized Departure



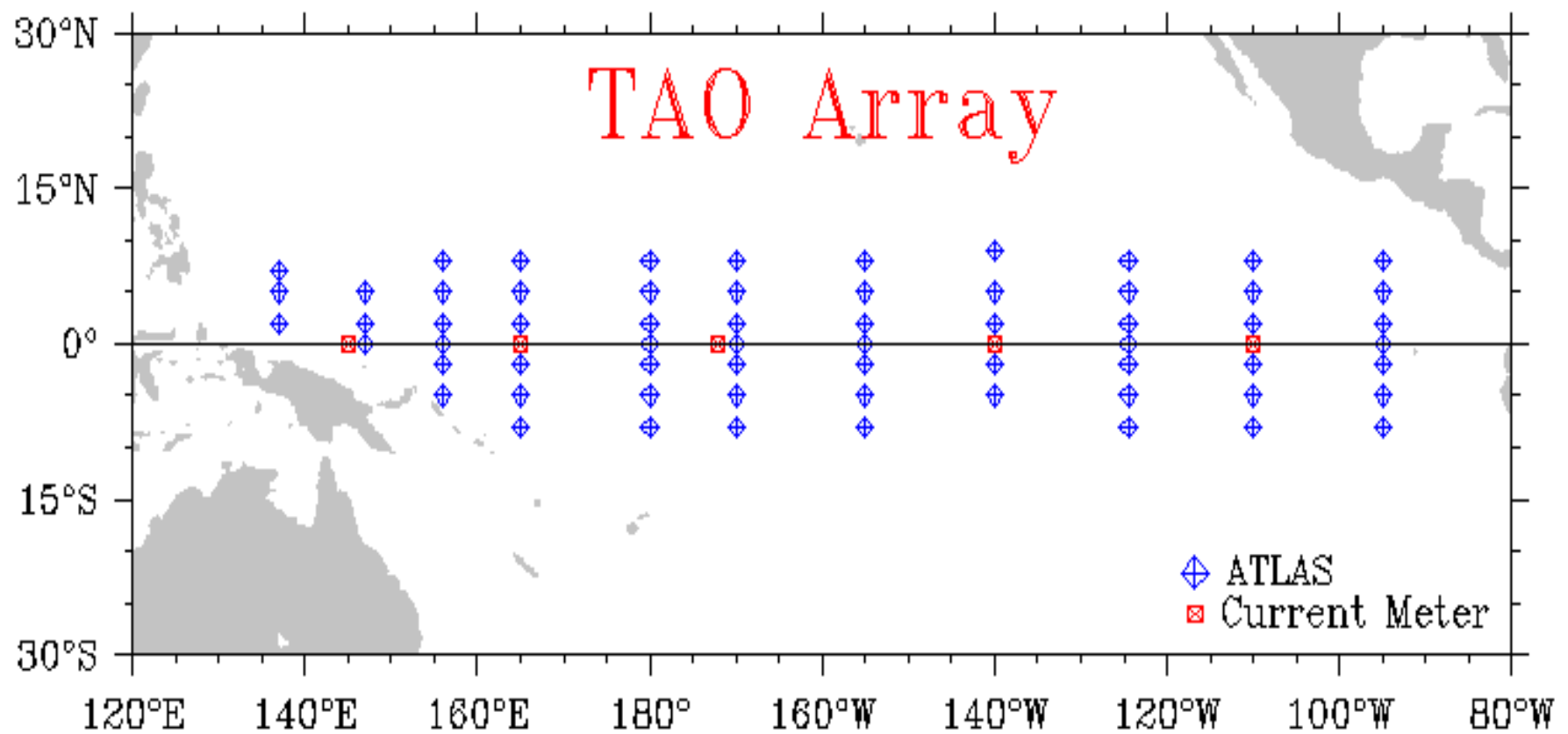


SEP 97

TOGA in Situ Ocean Observing System Pacific Basin



TAO Array



TAO Project Office/NOAA/PMEL



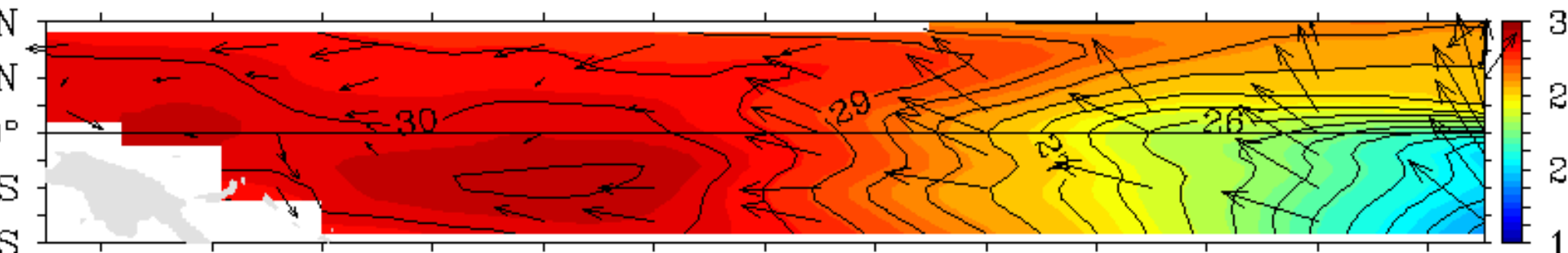
Recovering an ATLAS mooring from the French R/V LE NOROIT in the western equatorial Pacific Ocean. A total of 59 ATLAS moorings are deployed at present in the equatorial Pacific as part of the TOGA-TAO Array.



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.

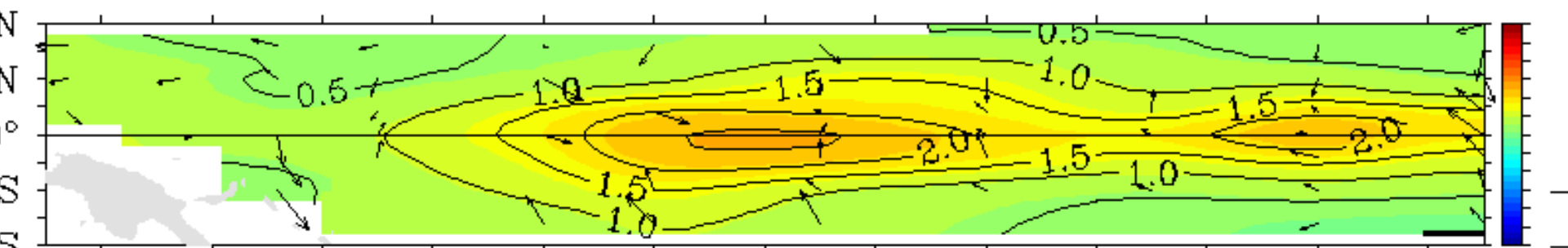
TAO/TRITON SST ($^{\circ}\text{C}$) and Winds (m s^{-1})

140 $^{\circ}\text{E}$ 160 $^{\circ}\text{E}$ 180 $^{\circ}$ 160 $^{\circ}\text{W}$ 140 $^{\circ}\text{W}$ 120 $^{\circ}\text{W}$ 100 $^{\circ}\text{W}$



Means

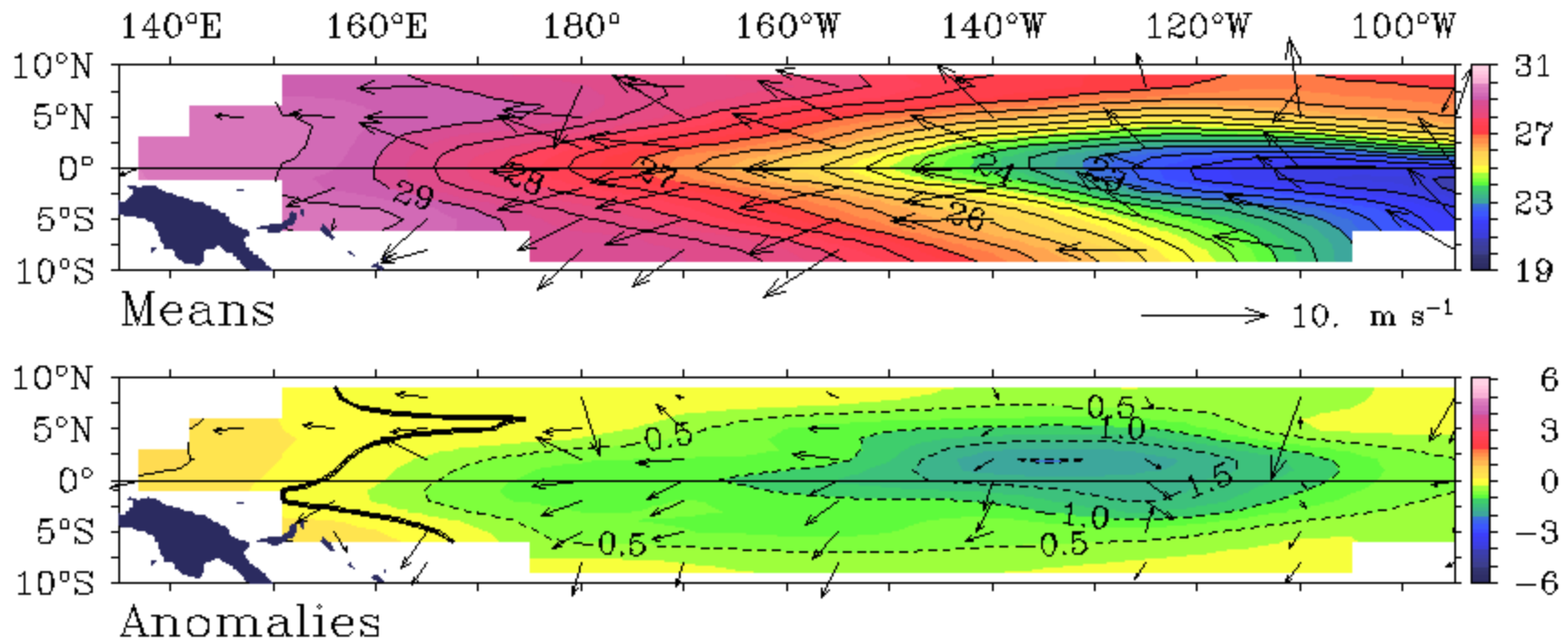
→ 10. m s^{-1}



Anomalies

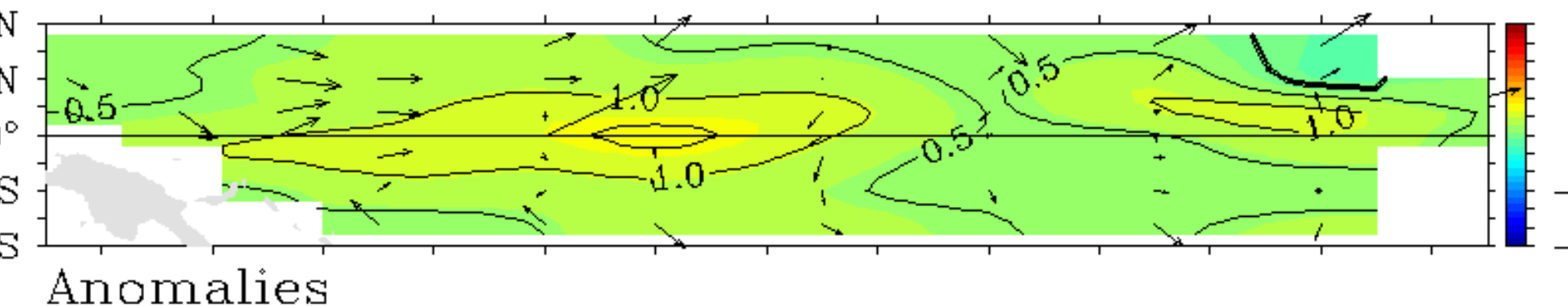
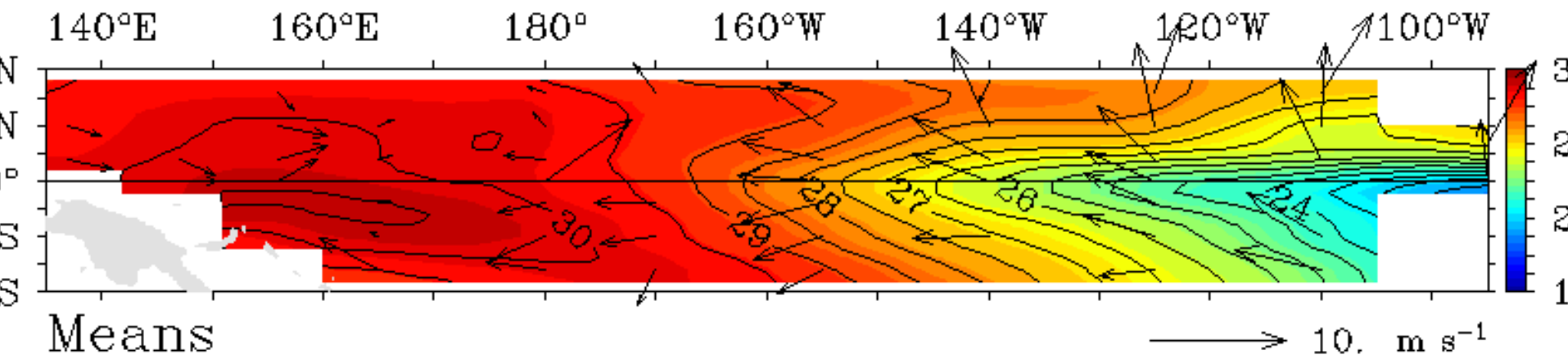
Five-Day Mean Ending on November 9 2002

TAO SST ($^{\circ}\text{C}$) and Winds (m s^{-1})



Five-Day Mean Ending on October 31 1999

TAO/TRITON SST ($^{\circ}\text{C}$) and Winds (m s^{-1})



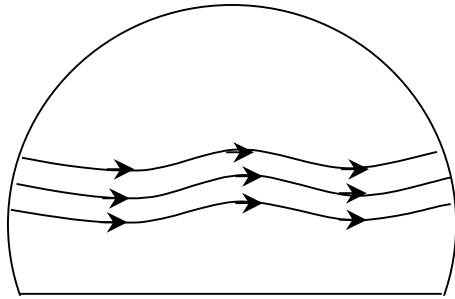
Five-Day Mean Ending on November 1 2003

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

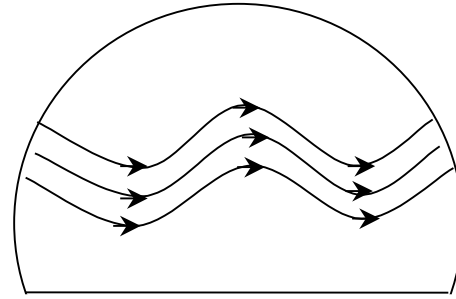
Lecture Outline

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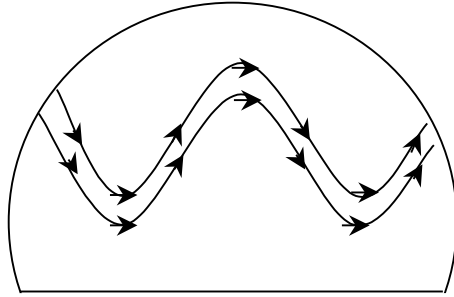
INDEX CYCLE



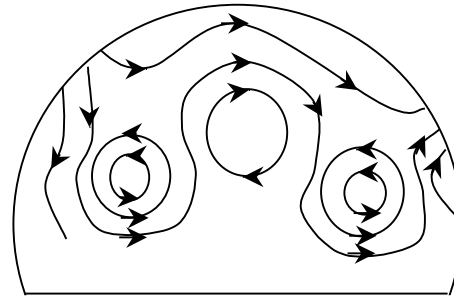
(A)



(B)



(C)



(D)

North Atlantic Oscillation

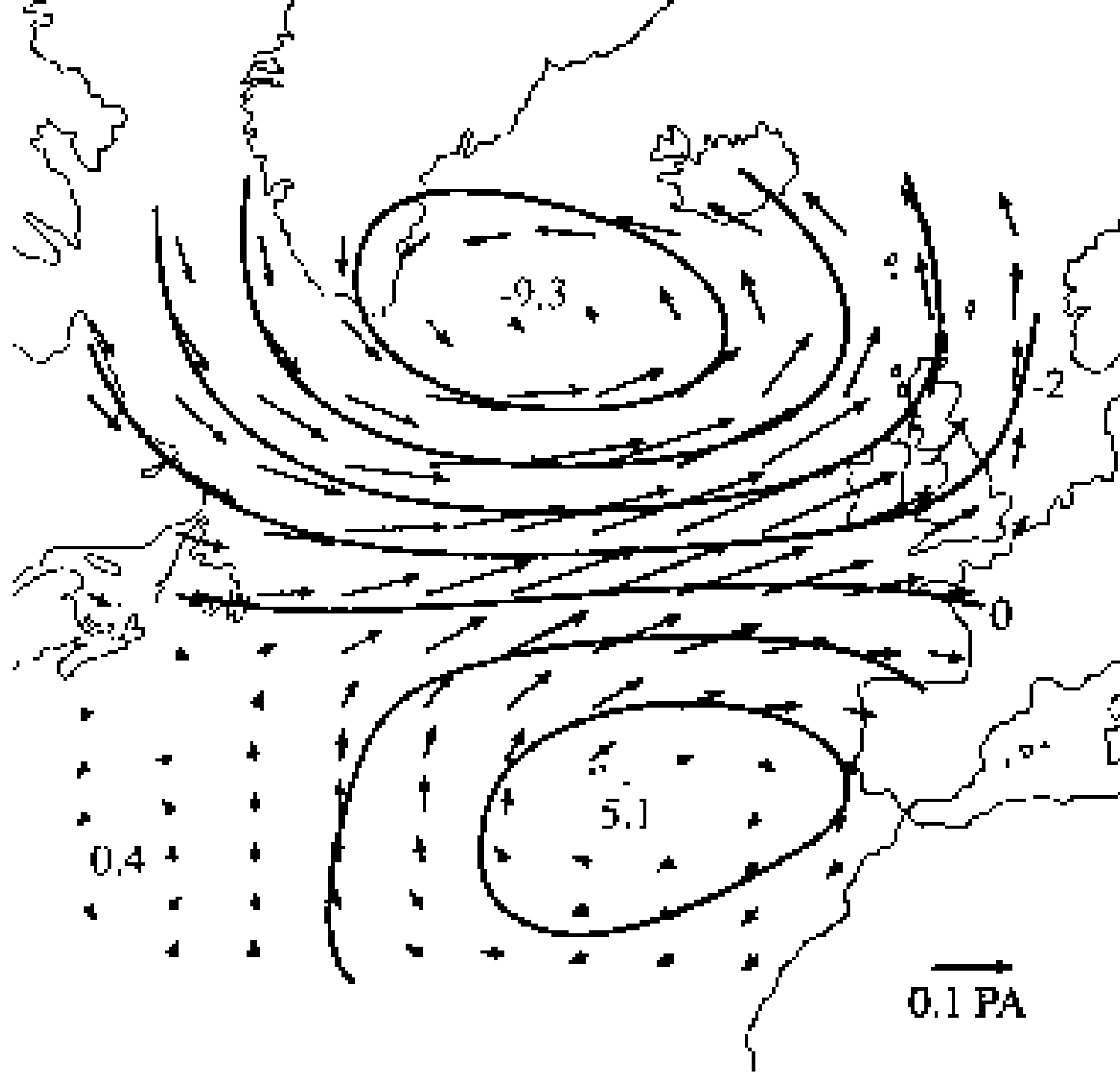
- Pattern of Climate Variability that determines weather and climate in N.Atlantic
- Controls much of the month to month variability of temperature and rainfall in N.W. Europe

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



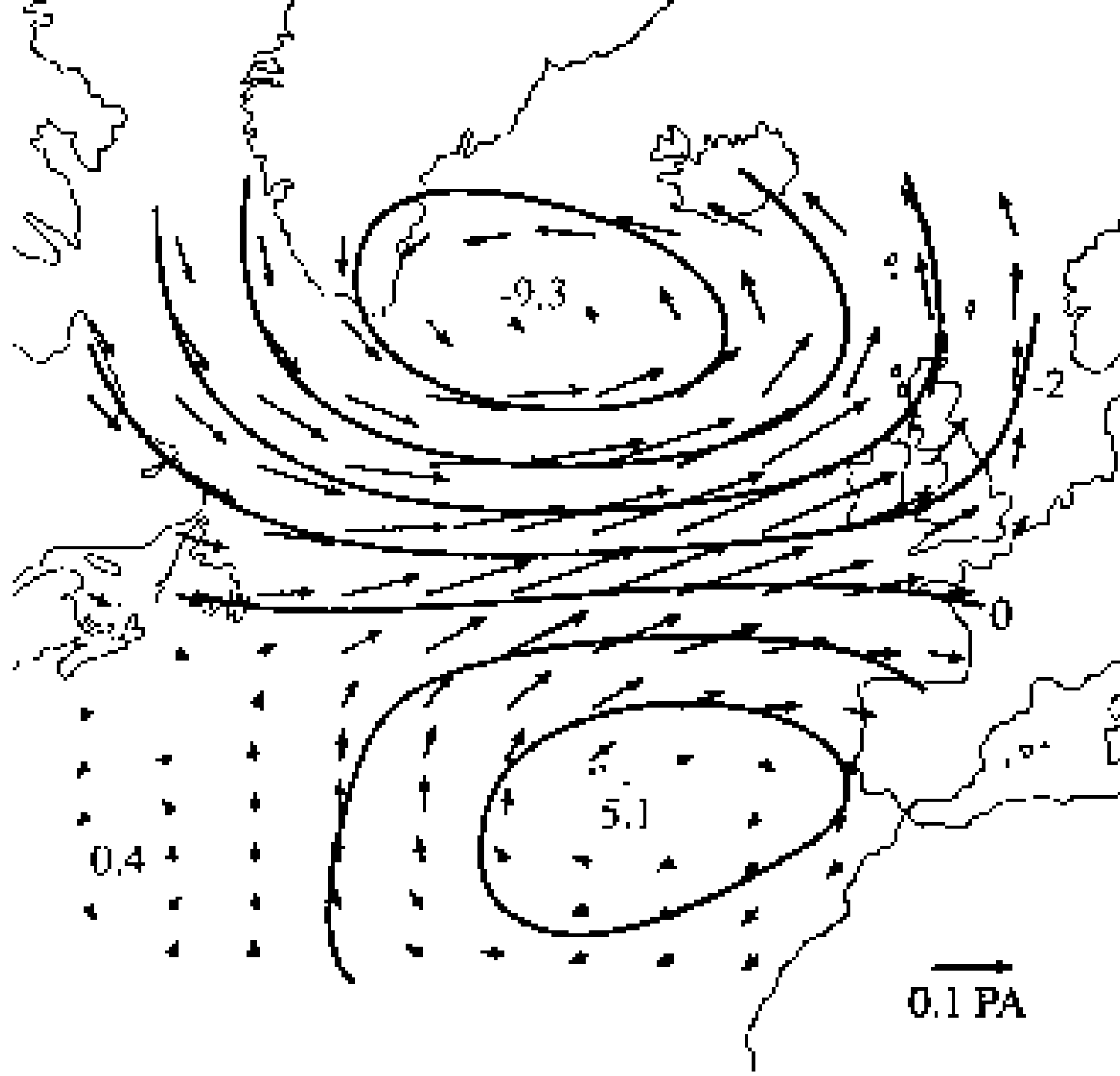
North Atlantic Oscillation

- **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



North Atlantic Oscillation

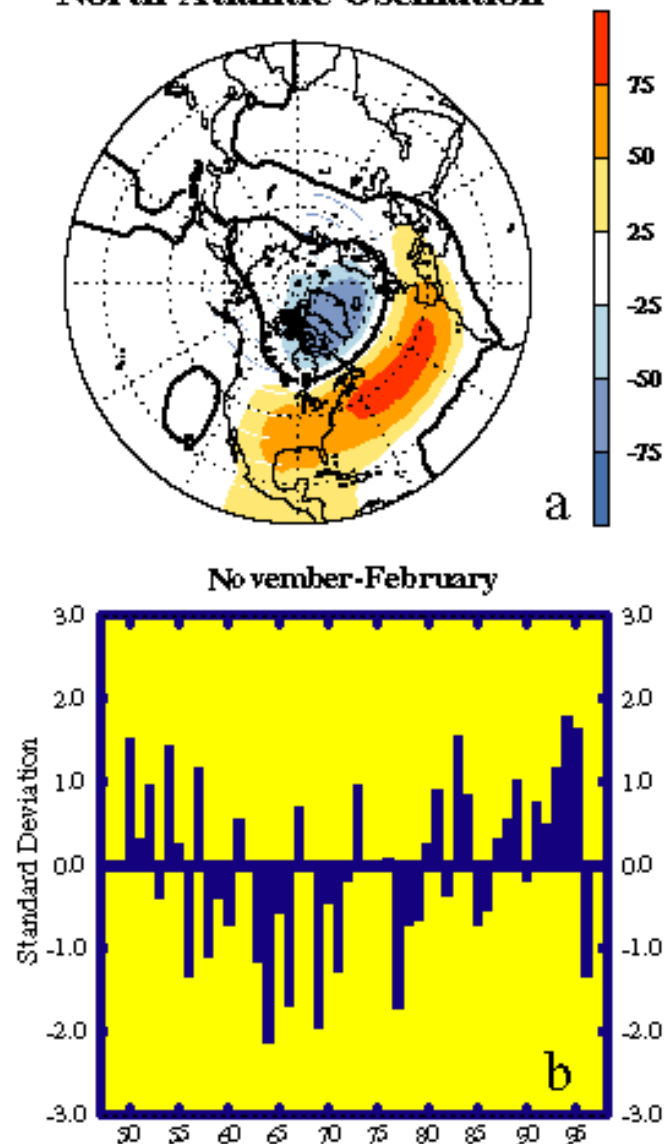
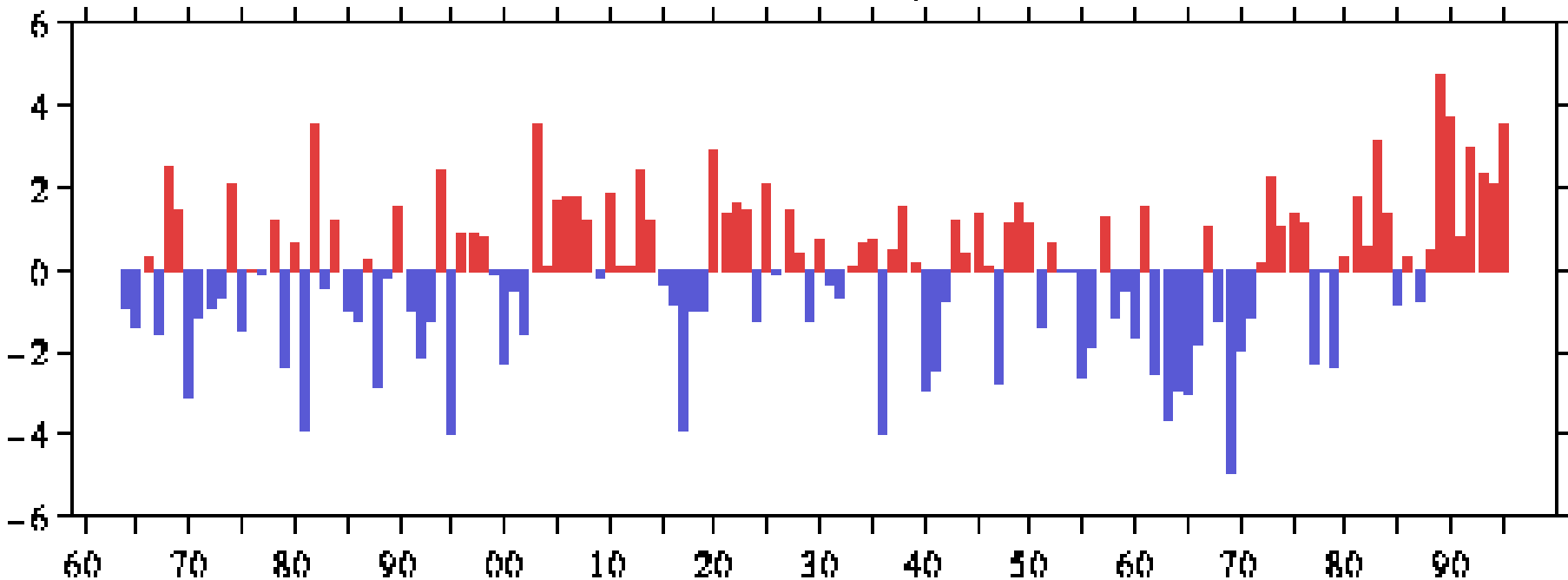
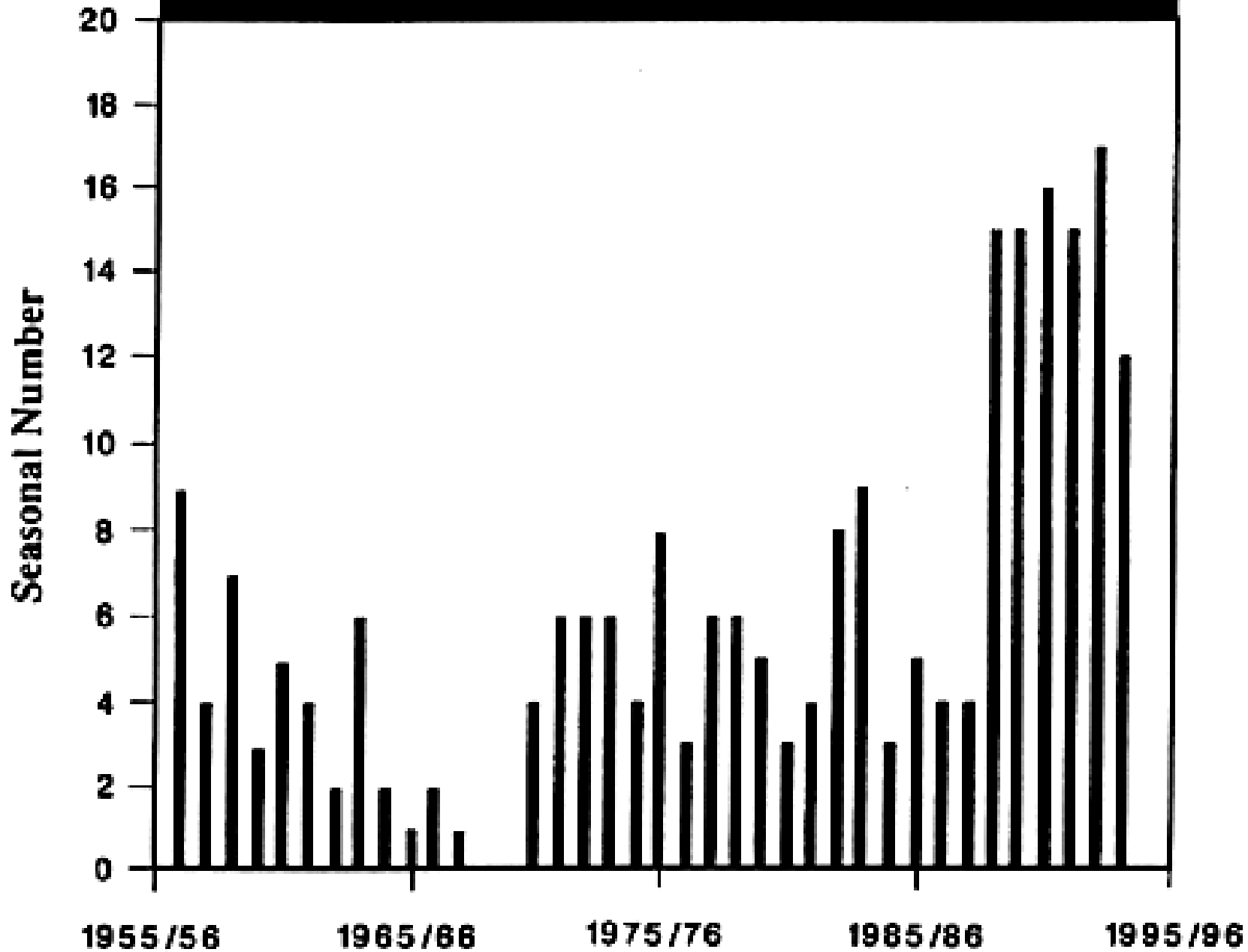


FIG. 31 Rotated Principal Component Analysis (RPCA) of the North Atlantic oscillation teleconnection pattern (NAO) during NDJF: (a) pattern showing the positive phase and (b) normalized amplitude time series. Labeling convention for years is such that 1995 indicates the NDJF 1994/95 season. Pattern is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

North Atlantic Oscillation (NAO) Index, 1964-1995



North Atlantic Winter Storms 1956-1994



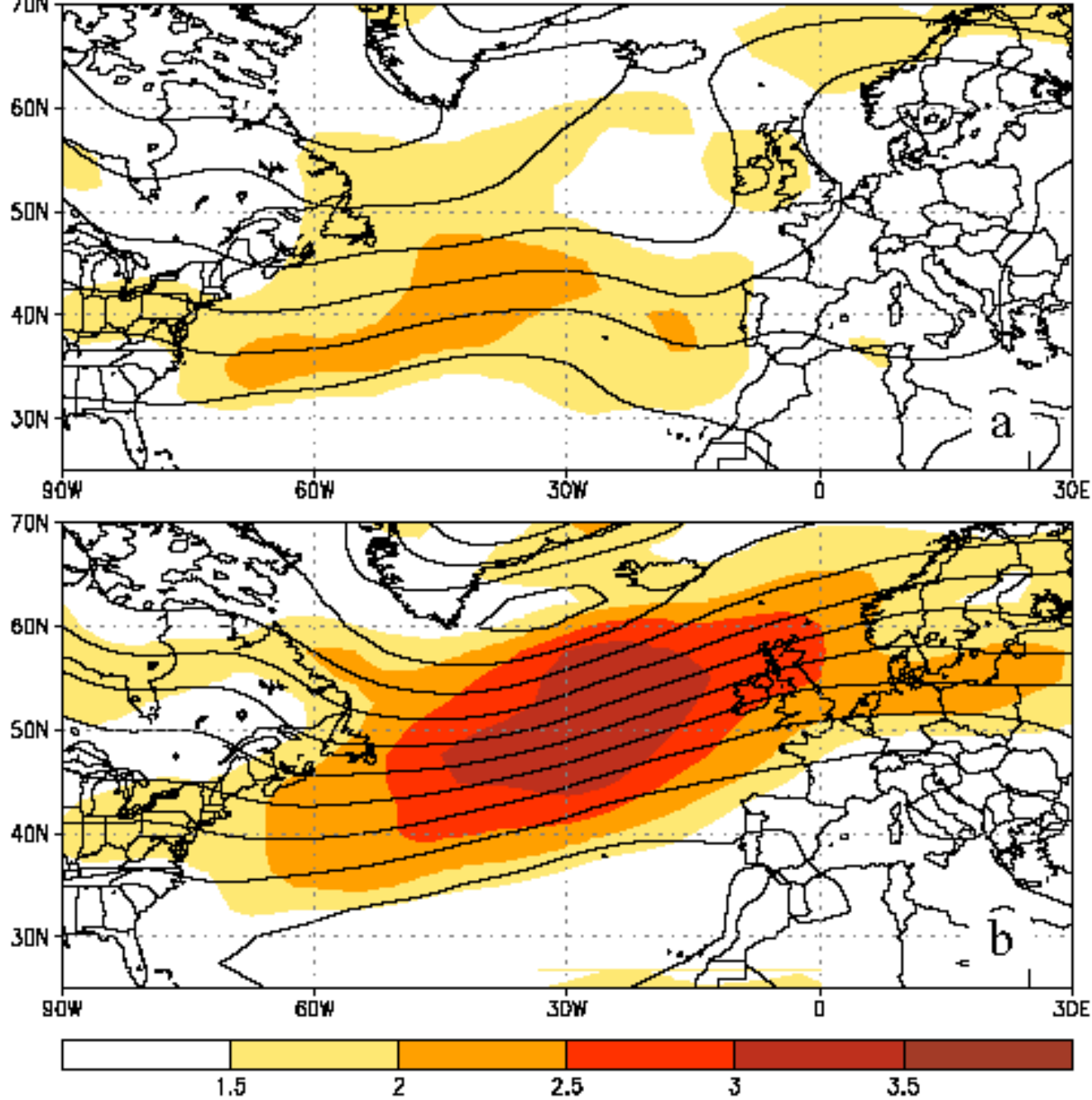


FIG. 34 925-hPa mean temperature flux (shading, $\times 10^8 \text{ K m s}^{-1}$) and heights (contours, interval is 30 m) for (a) NDJF 1995/96 and (b) NDJF mean (1988/89–1994/95).

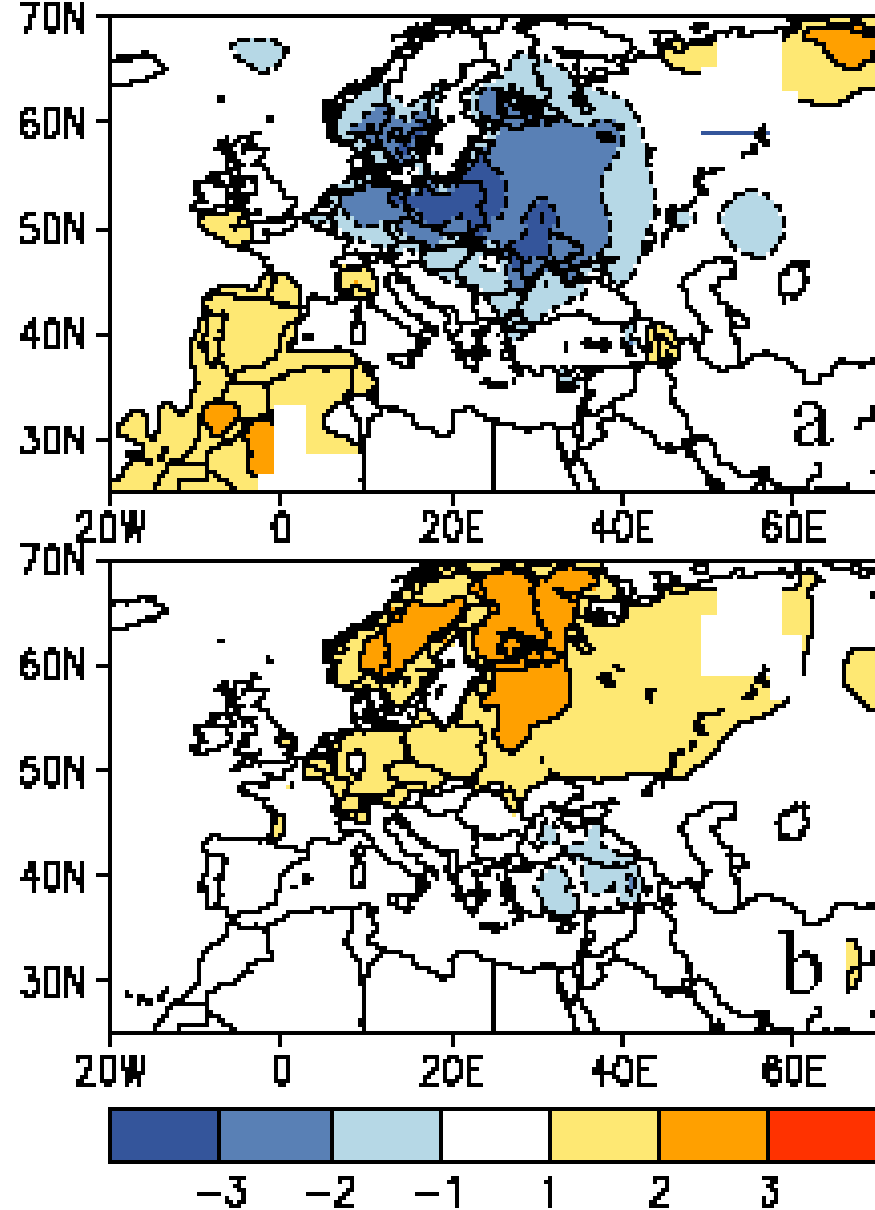
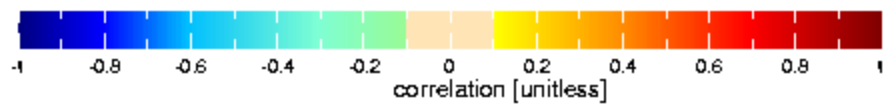
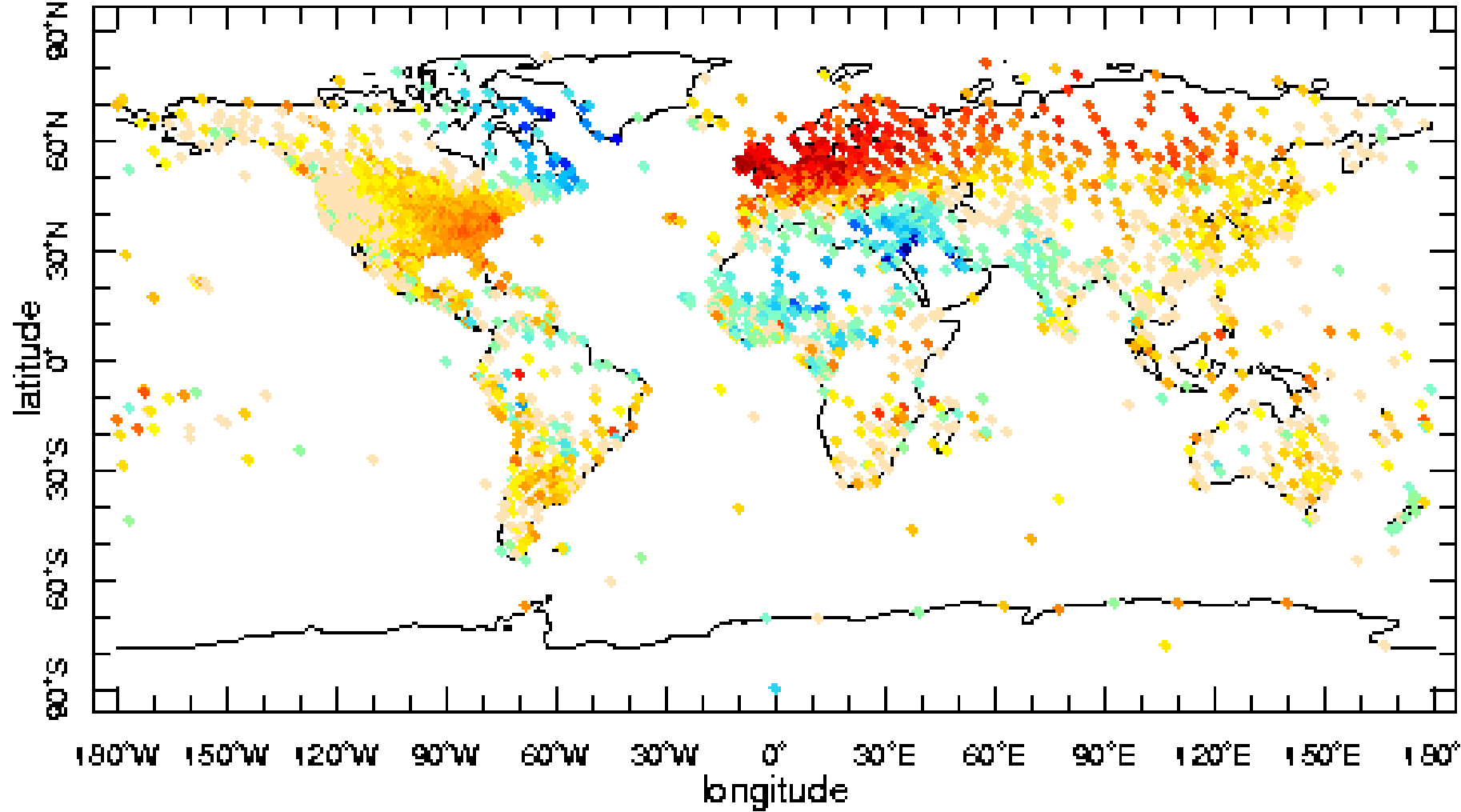


FIG. 36 Surface temperature anomaly for (a) NDJF 1995/96 and (b) NDJF mean (1988/89–1994/95). Anomalies are departures from the 1961–90 base period means.



Temperature

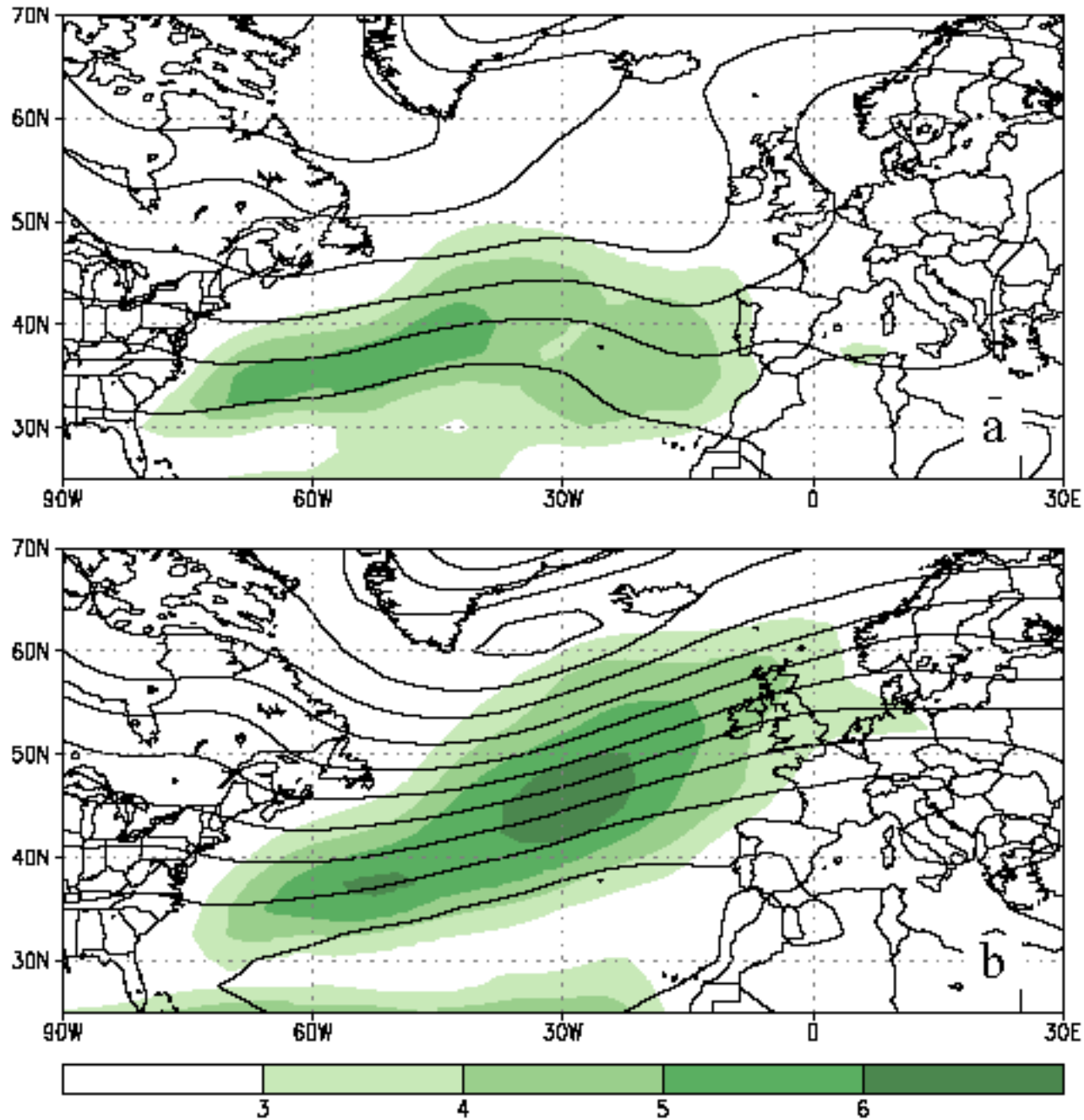
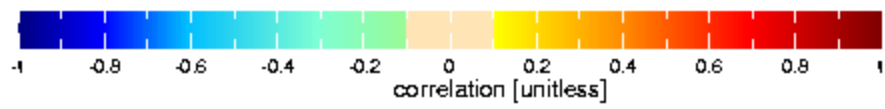
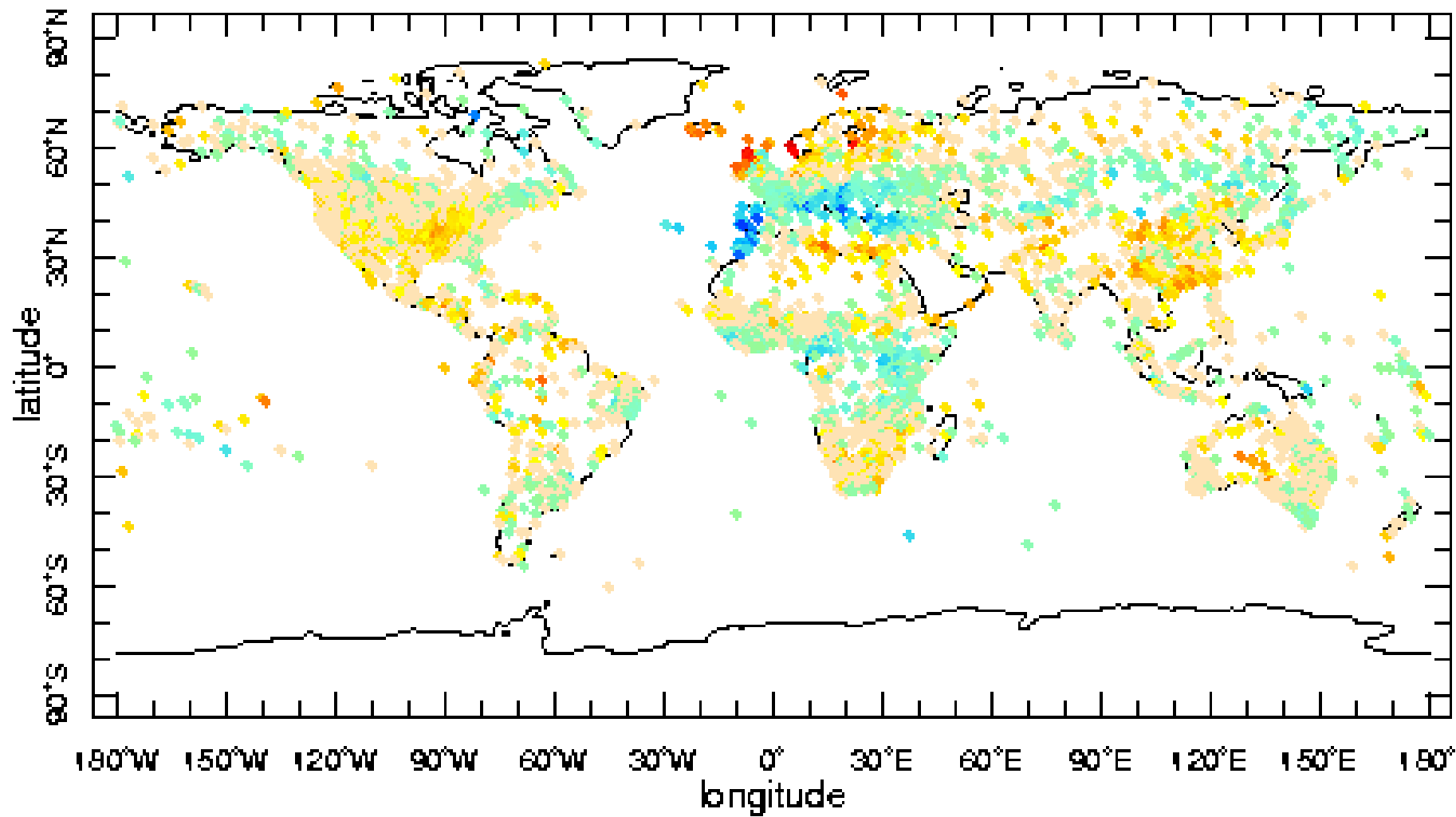


FIG. 33 925-hPa mean moisture transport (shading, $\times 10^{-2} \text{ m s}^{-1}$) and heights (contours, interval is 30 m) for (a) NDJF 1995/96 and (b) NDJF mean (1988/89–1994/95).



Rainfall

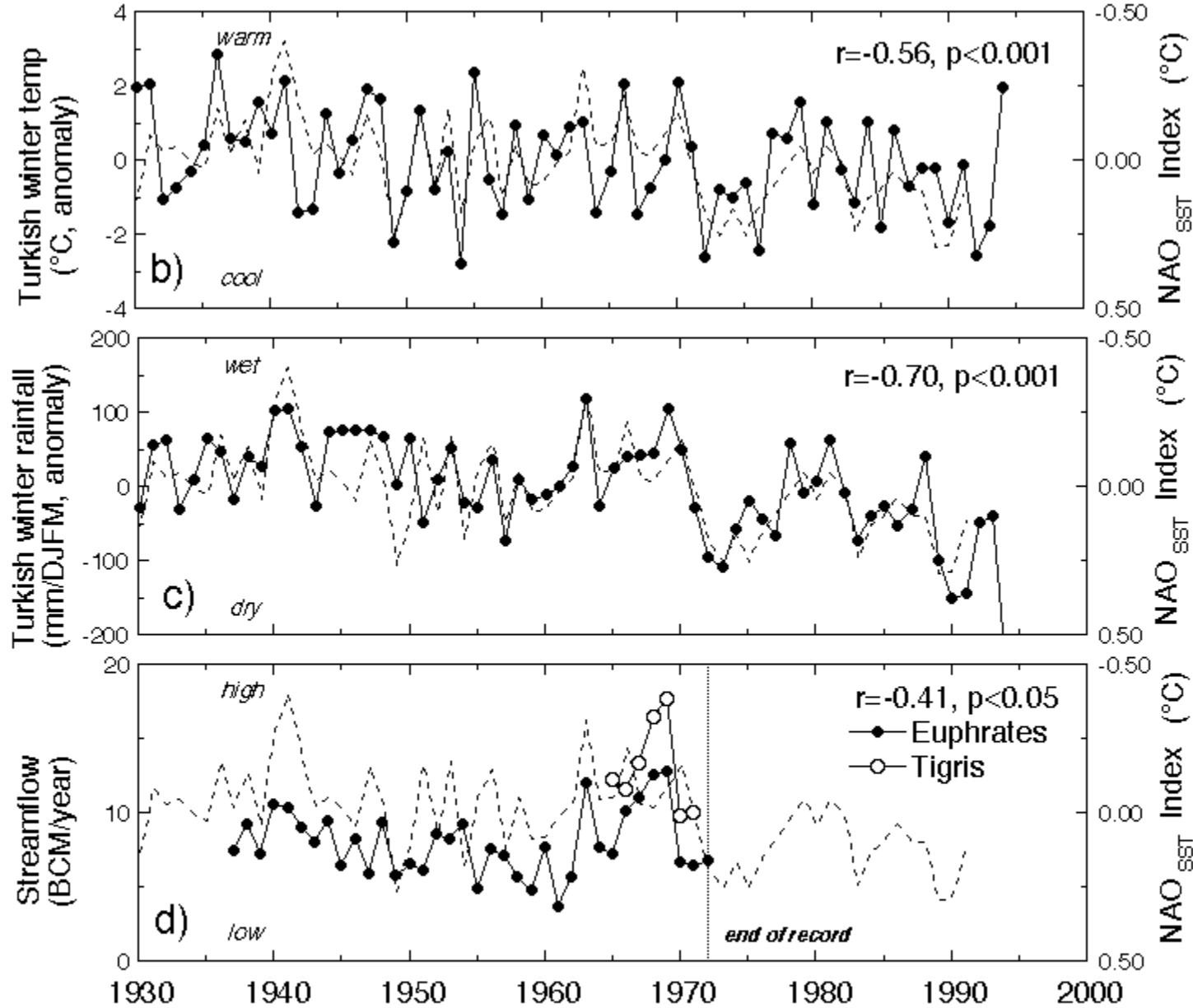
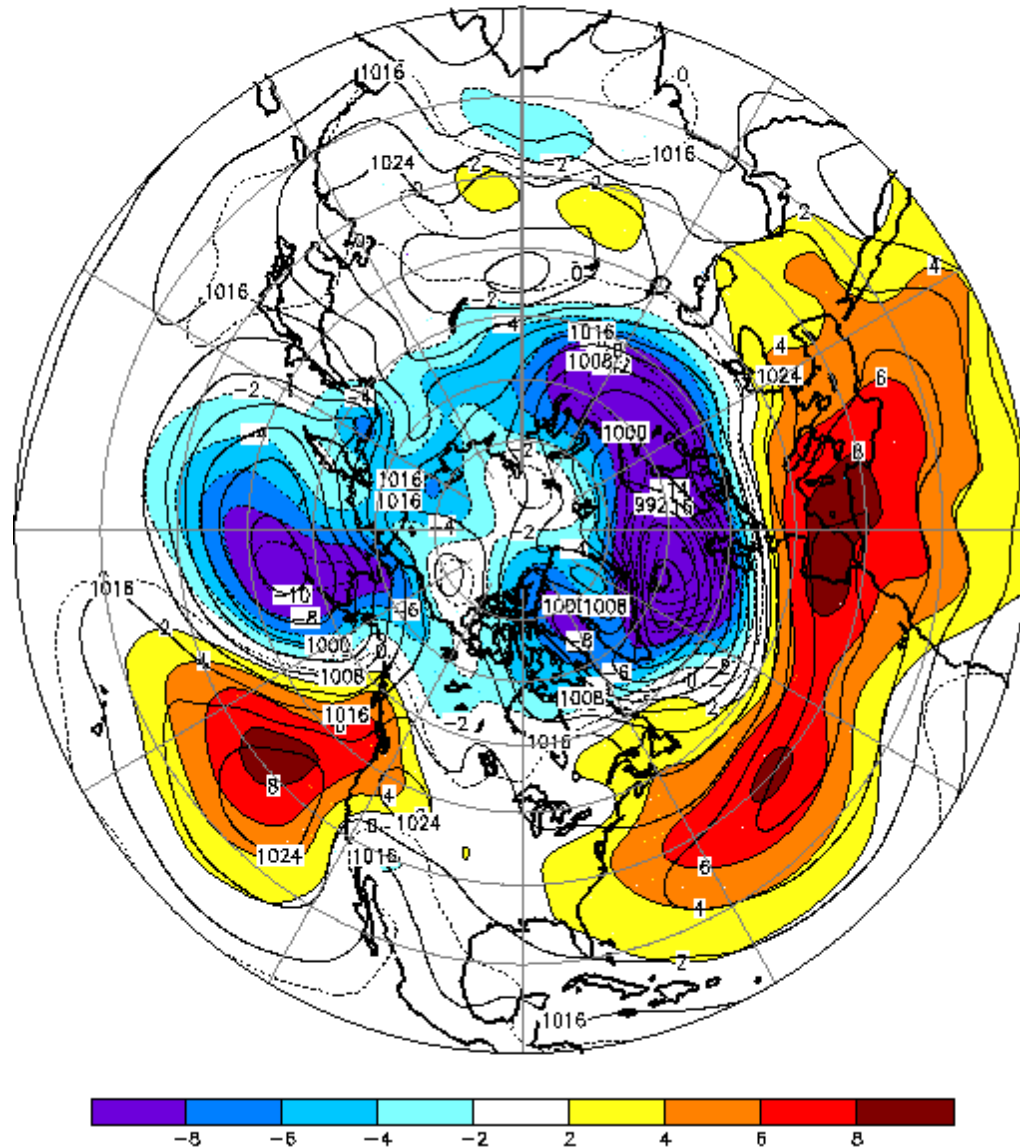
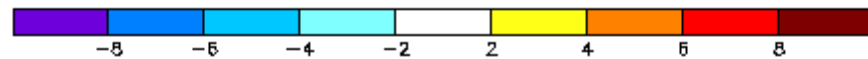
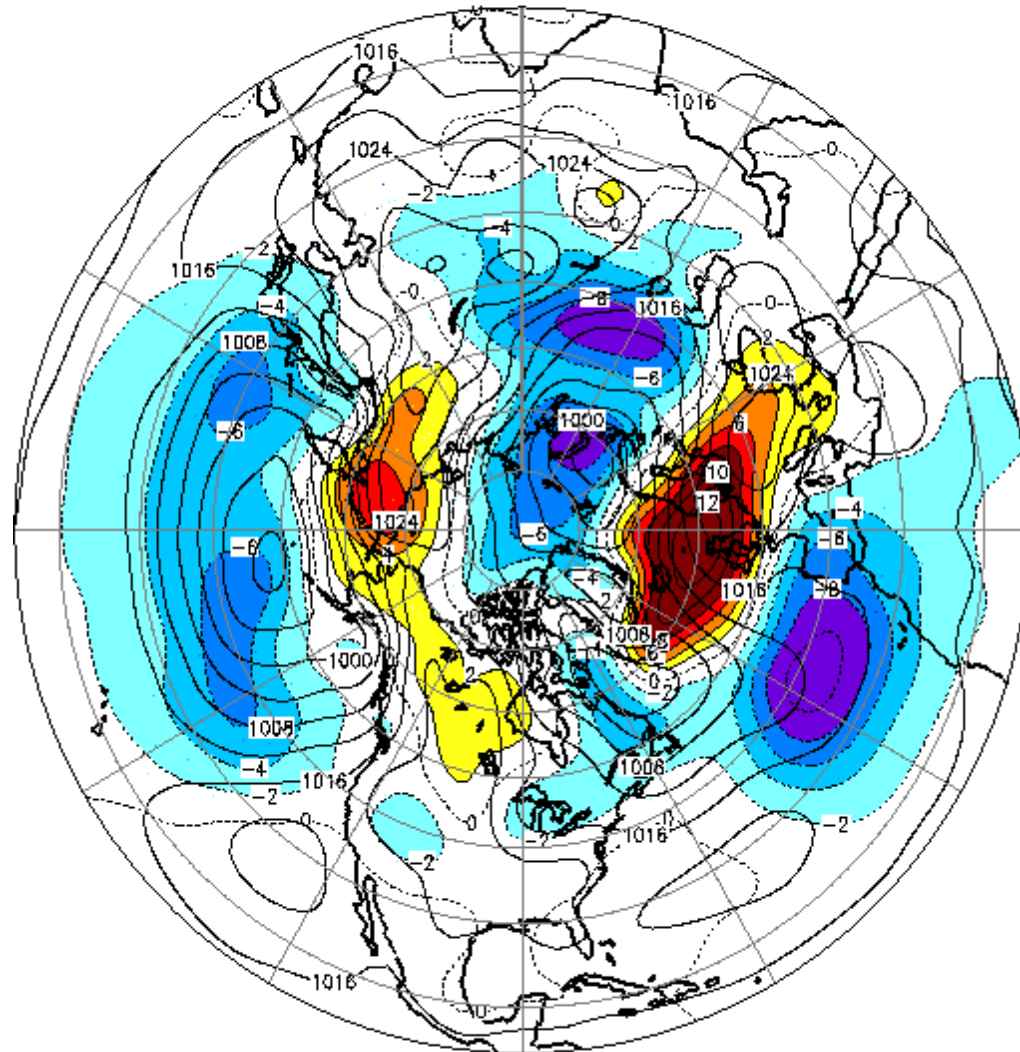


Figure 3 a-d

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



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



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 Pepler, 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. Discuss (1997)
- What role do the oceans play in the general circulation of the atmosphere? (1996)