The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

1956-3

Targeted Training Activity: Seasonal Predictability in Tropical Regions to be followed by Workshop on Multi-scale Predictions of the Asian and African Summer Monsoon

4 - 15 August 2008

Introduction to ENSO (Part 1)

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PREVIEW

1. Observational Aspects of ENSO

- The Background Climatology
- Evolution of ENSO
- Variability of ENSO Evolution

2. Aspects of the Theories of ENSO

- The Basic Processes
  - SST, Surface Winds, Thermocline Depth
- Stable and Unstable ENSO
- Regular and Irregular ENSO
- ENSO in a Warming World

3. Prediction of ENSO

- The Physical Basis for Predictability
- Predictability and Mechanism
- Methods of Seasonal-to-Interannual Prediction
- Using Predictions
- Institutions for Predictions

I. OBSERVATIONAL ASPECTS OF ENSO AND ITS EFFECTS

a. TOGA and the TAO/Triton Array

b. Climatology of the Tropical Pacific

SST
Winds
Precipitation

c. Defining Anomalies: The issue of non-stationary climatology

d. ENSO Evolution

Can we define “El Niño?”

e. Is there a standard ENSO?

ENSO Variability

f. The role of higher frequency variability
MJO
High frequency noise

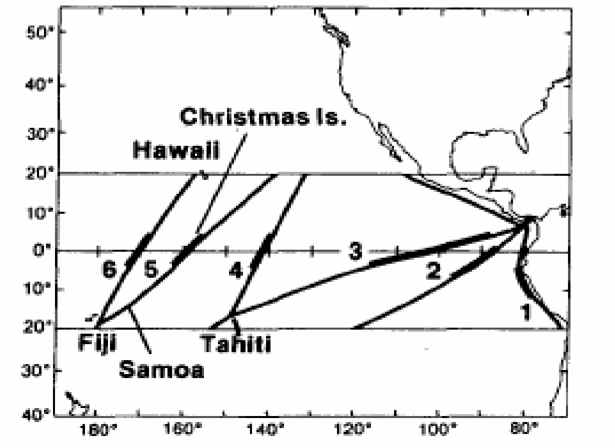
g. ENSO Effects on the Globe

500 mb fields
Temperature and Precipitation

h. ENSO and Decadal Variability

a. TOGA and the TAO/Triton Array

Before TOGA:



MAY 1982 EUGENE M. RASMUSSON AND THOMAS H. CARPENTER 367

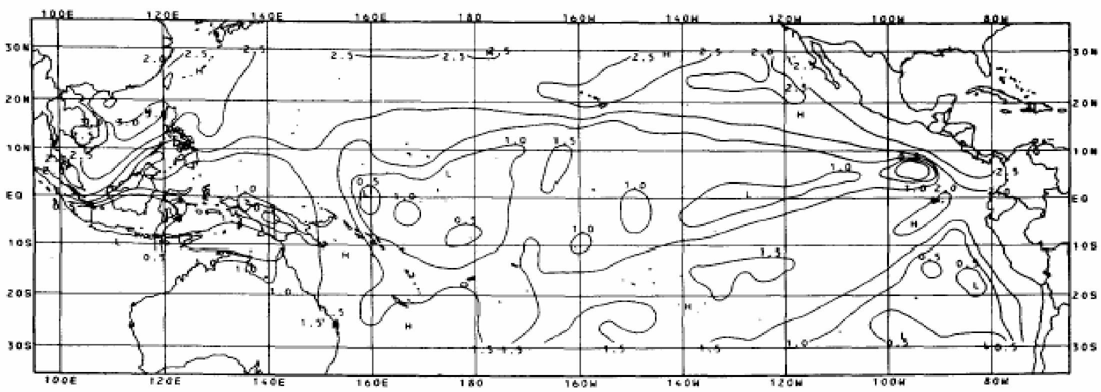


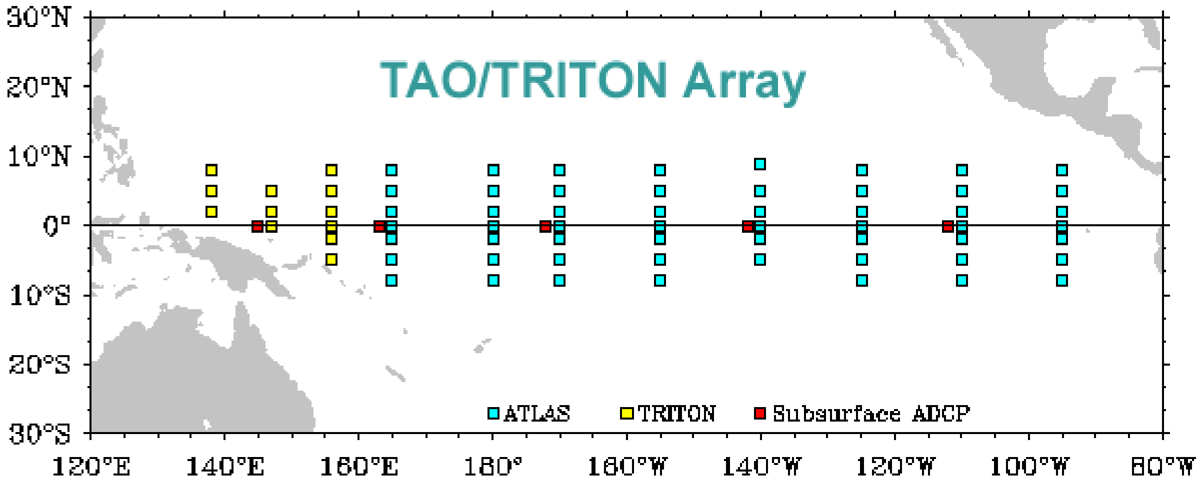
FIG. 14. Log of the average number of SST observations in each two-degree square used in each composite.

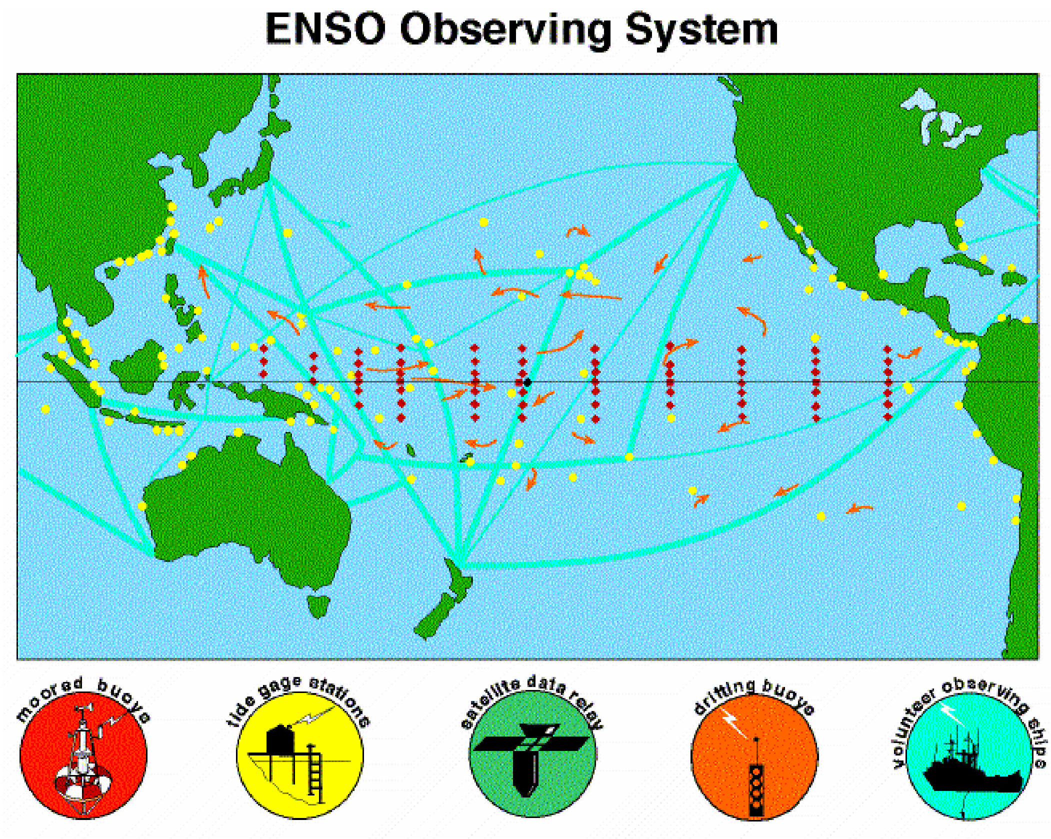
The Goals of TOGA (1985-1995)

1. To gain a description of the tropical oceans and the global atmosphere as a time-dependent system, in order to determine the extent to which this system is predictable on time scales of months to years, and to understand the mechanisms and processes underlying that predictability.

2. To study the feasibility of modeling the coupled ocean-atmosphere system for the purpose of predicting its variations on time scales of months to years.

3. To provide scientific background for designing an observing and data transmission system for operational prediction if this capability is demonstrated by the coupled ocean-atmosphere system.


TAO/TRITON Array
30°N
20°N
10°N
0°
10°S
20°S
30°S
120°E
140°E
160°E
180°
160°W
140°W
120°W
100°W
80°W
ATLAS
TRITON
Subsurface ADCP


ENSO Observing System
moored buoys
tide gage stations
satellite data relay
drifting buoys
volunteer observing ships

b. Climatology of the Tropics

Mean:

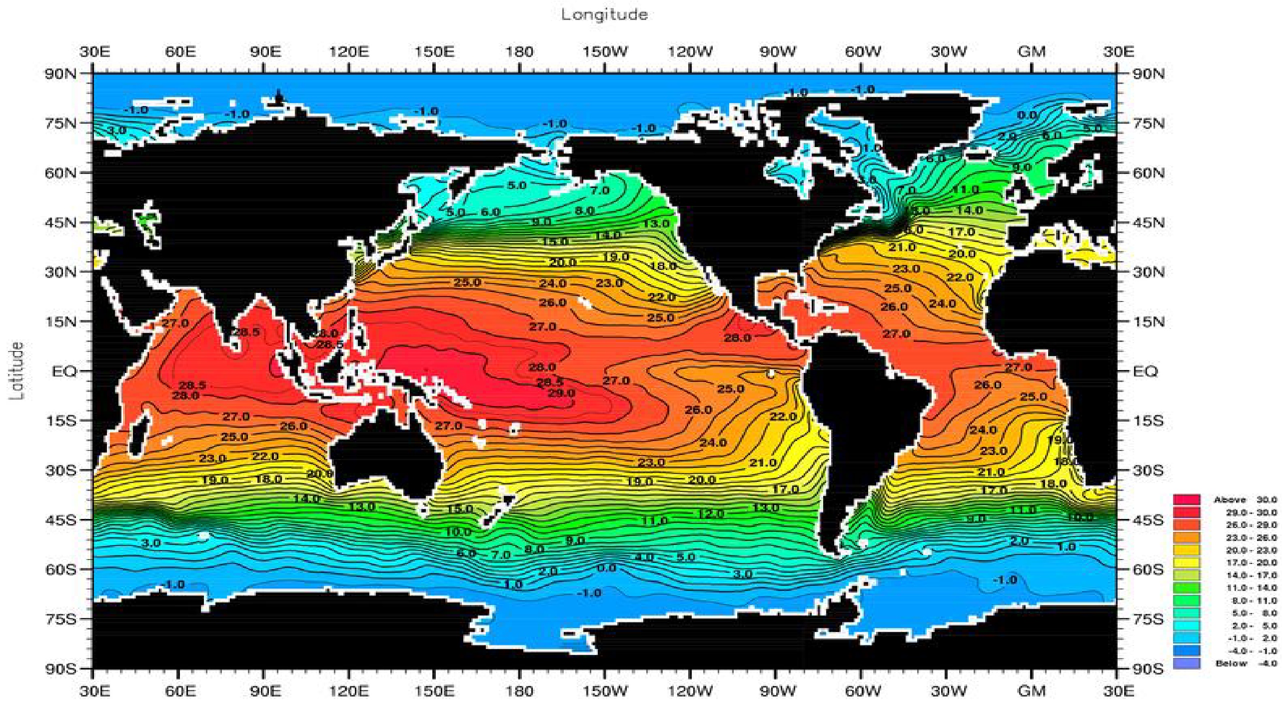
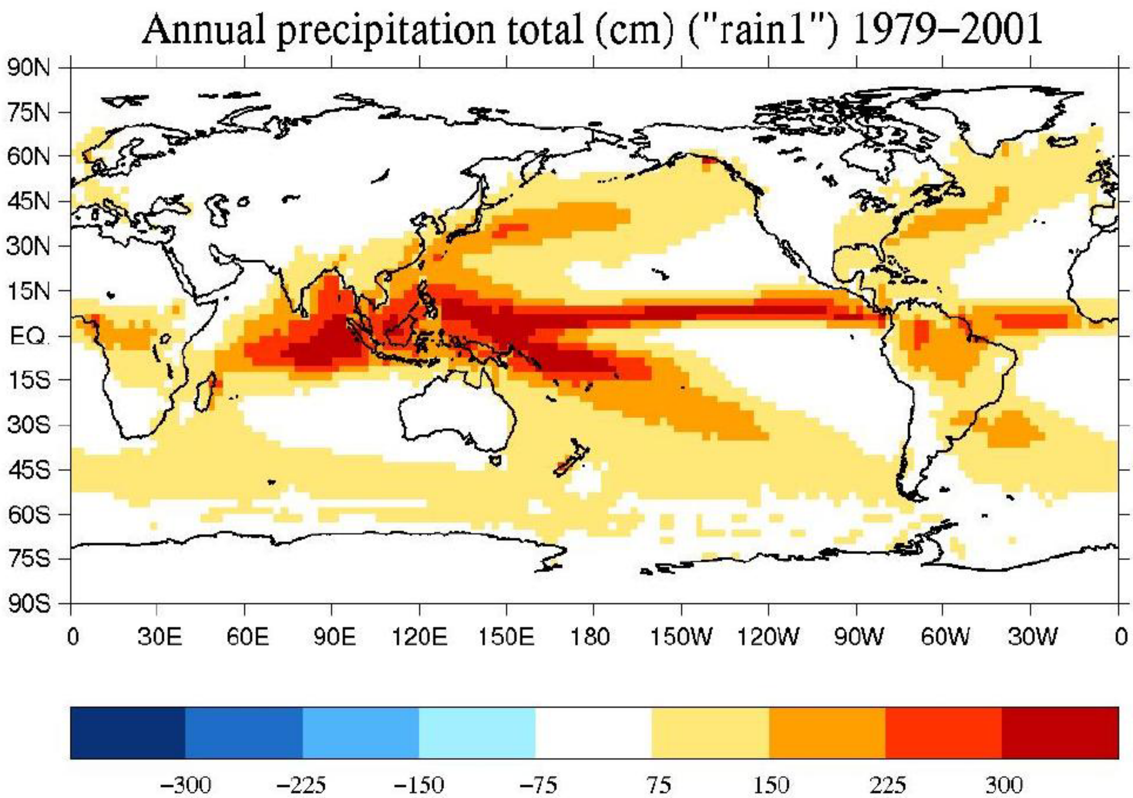
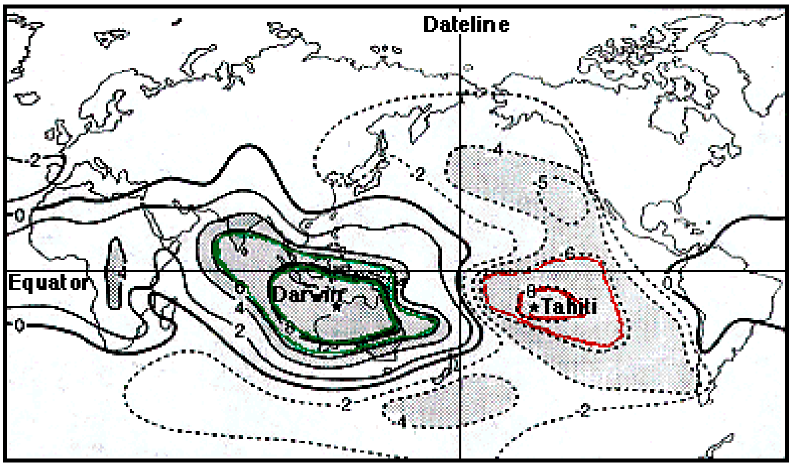


Fig. A2-1. Annual mean temperature (°C) at the surface.

Minimum Value= -1.93 Maximum Value= 29.93 Contour Interval: 1.00



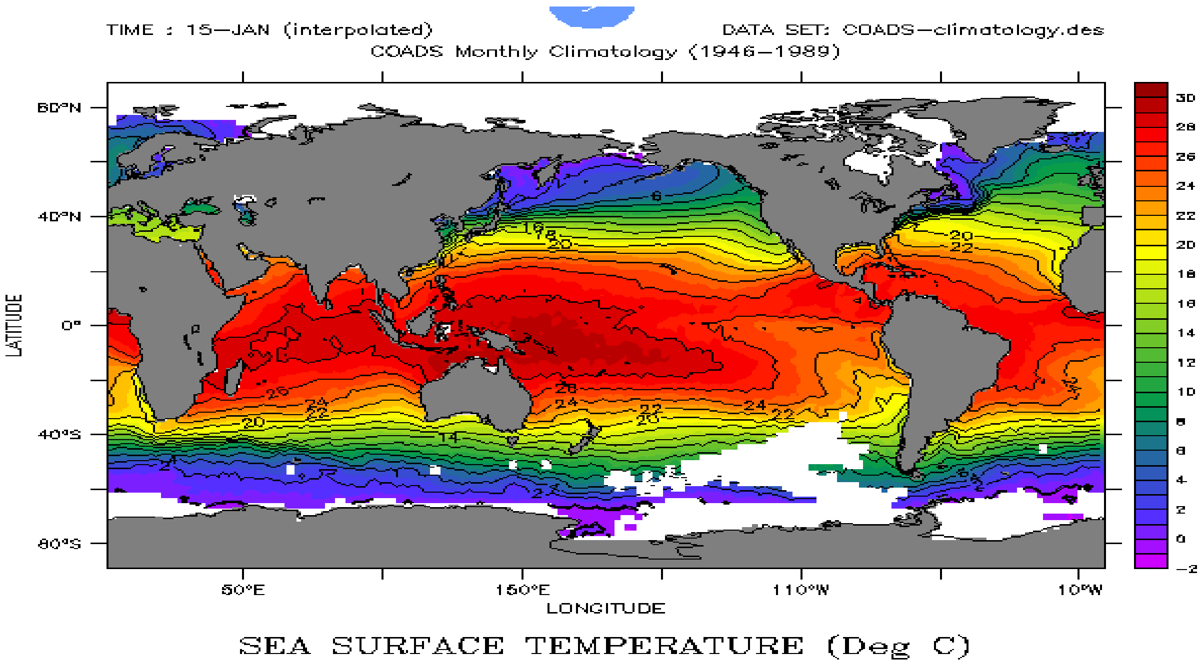
SOI: Tahiti and Darwin as "centers of action",
mslp correlations between two locations

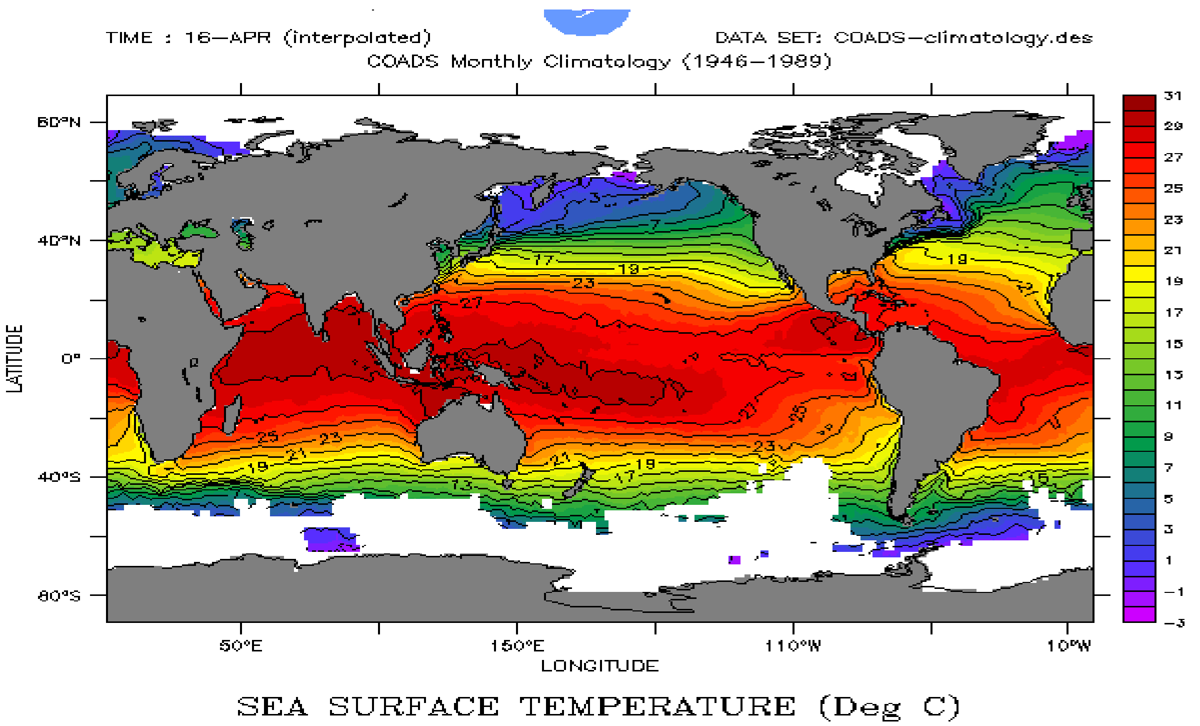


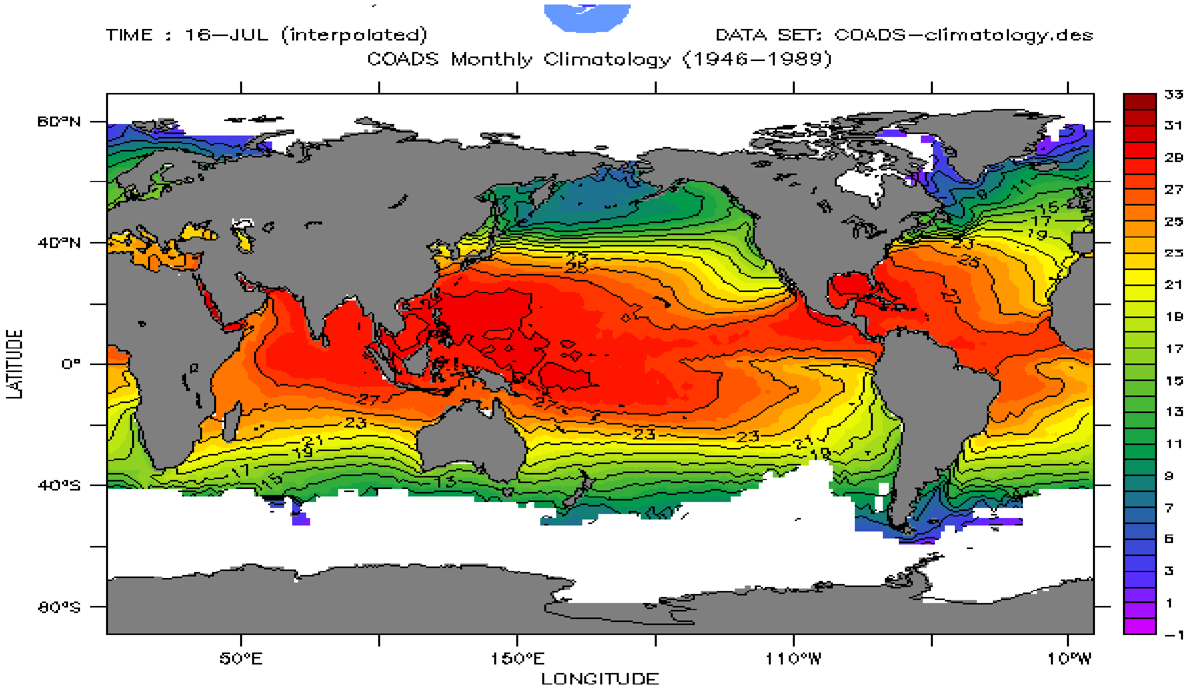
Normal Conditions in Pacific-Summary:

	W. Pacific	E. Pacific
SST	Warm	Cold
SLP	Low	High
PRECIP	High	Low

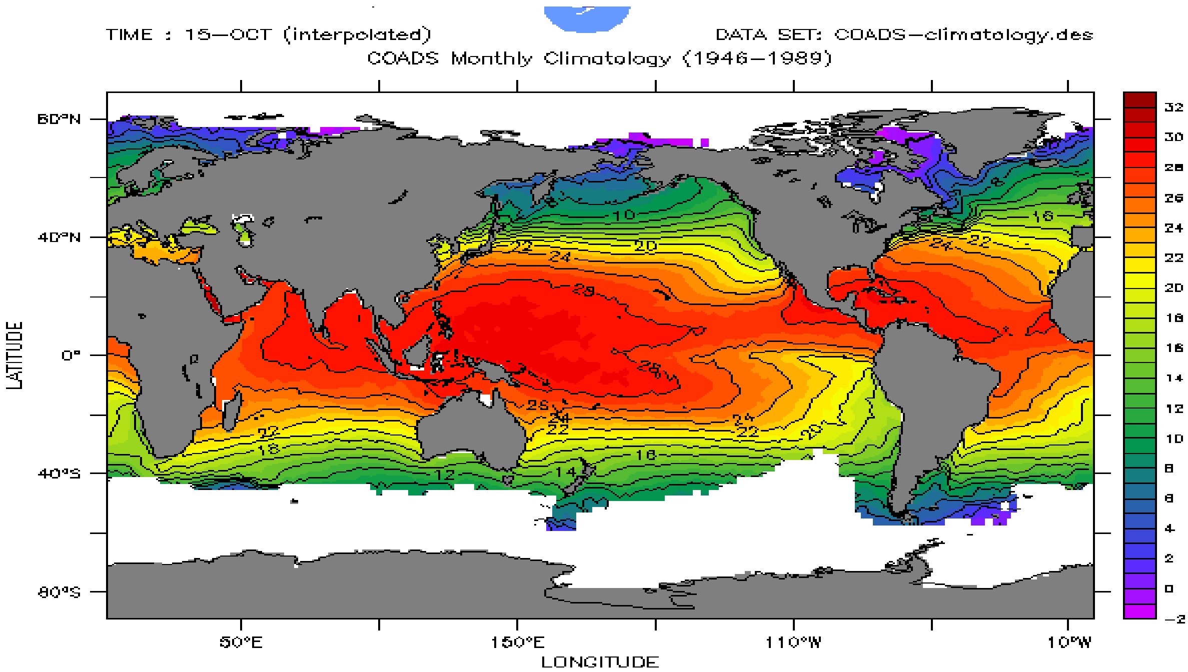
SST Climatology:





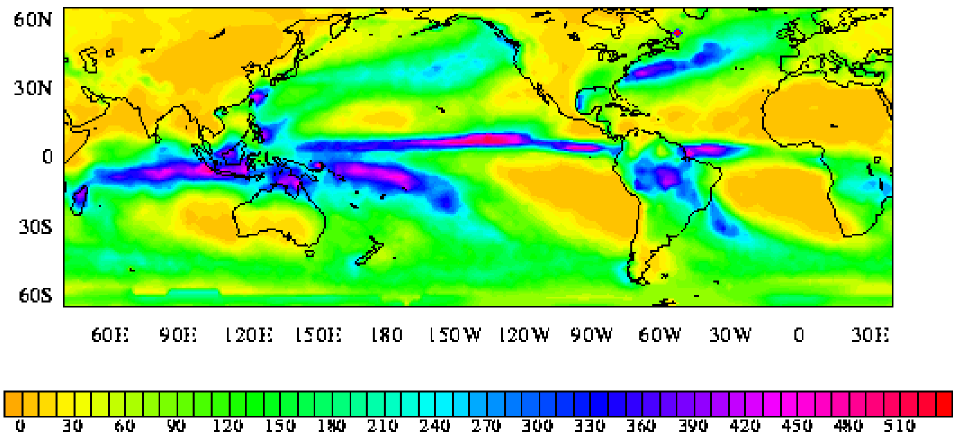


SEA SURFACE TEMPERATURE (Deg C)

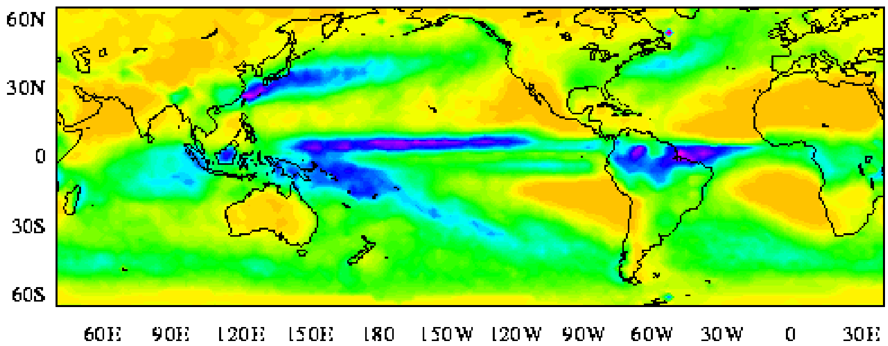


SEA SURFACE TEMPERATURE (Deg C)

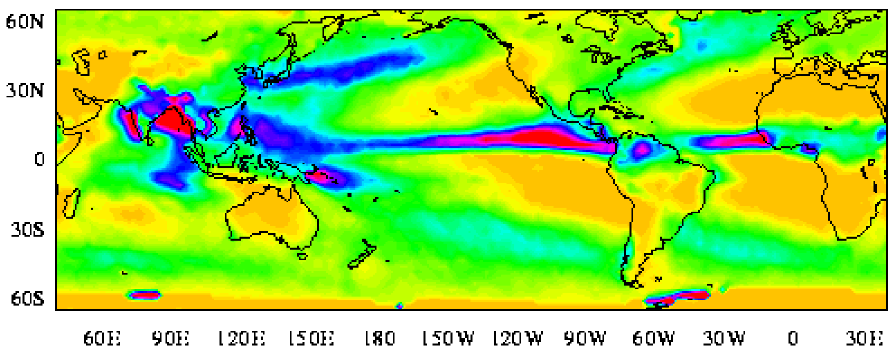
Rainfall Climatology:



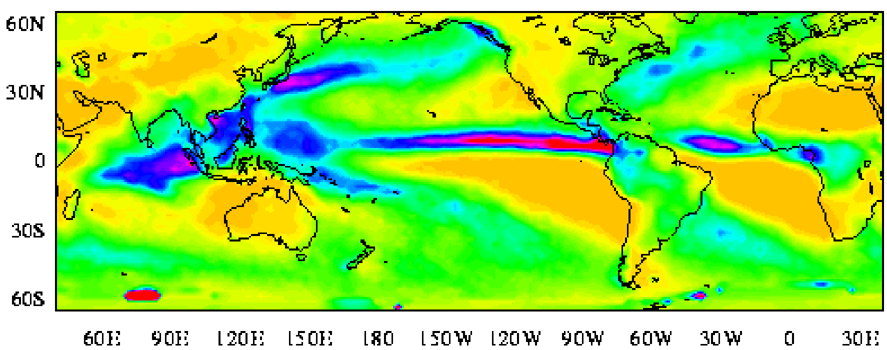
JAN



APRIL

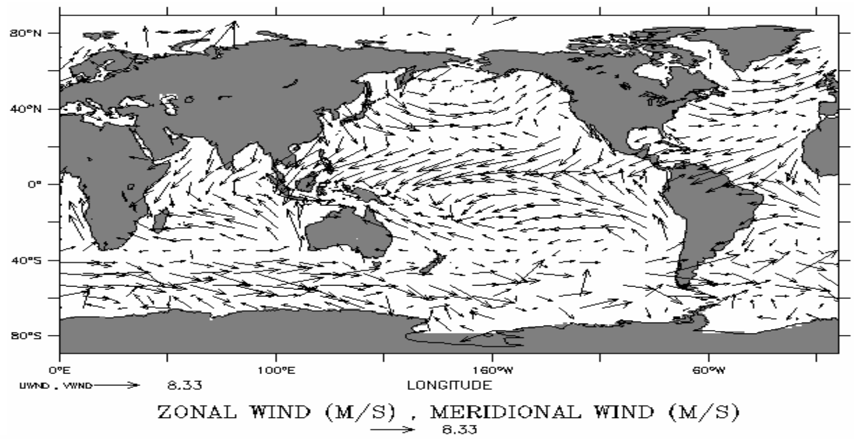


JULY

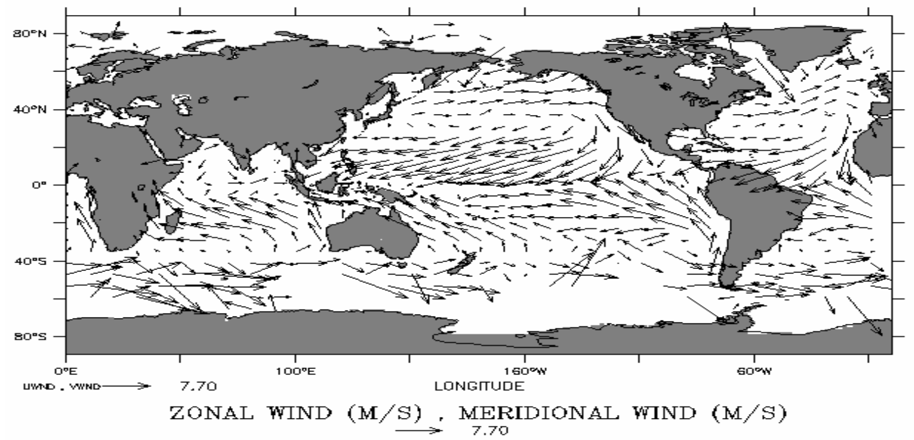


OCT.

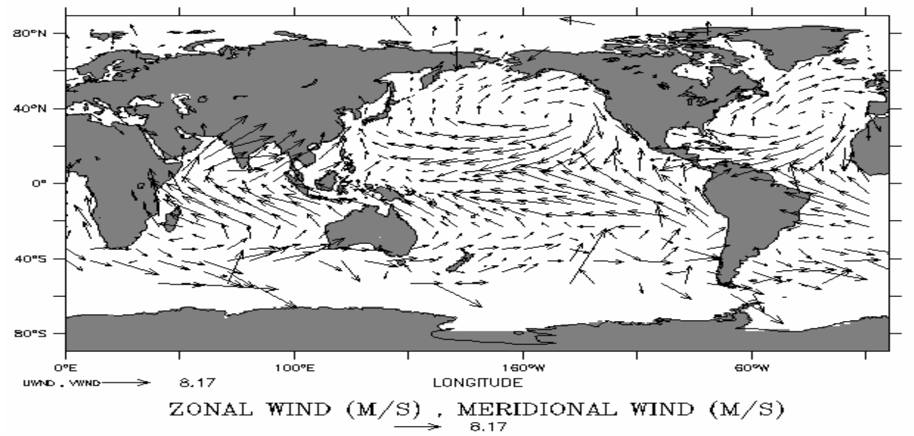
Wind Climatology:



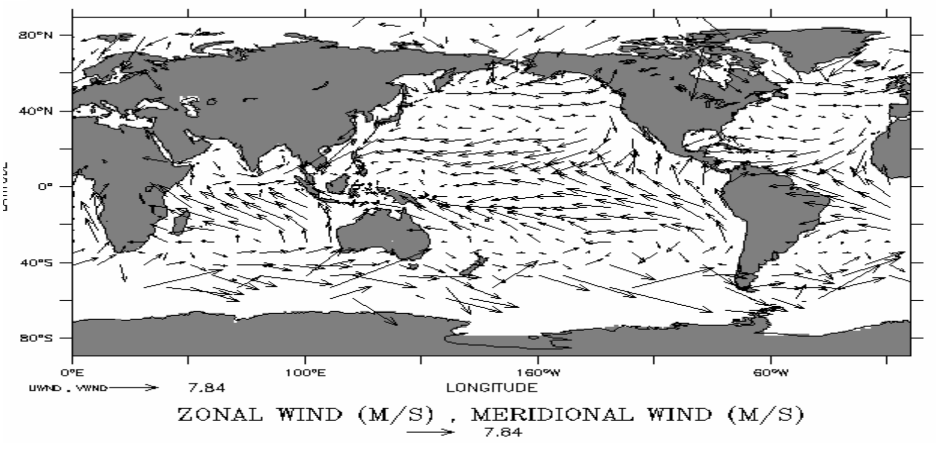
JAN



APRIL

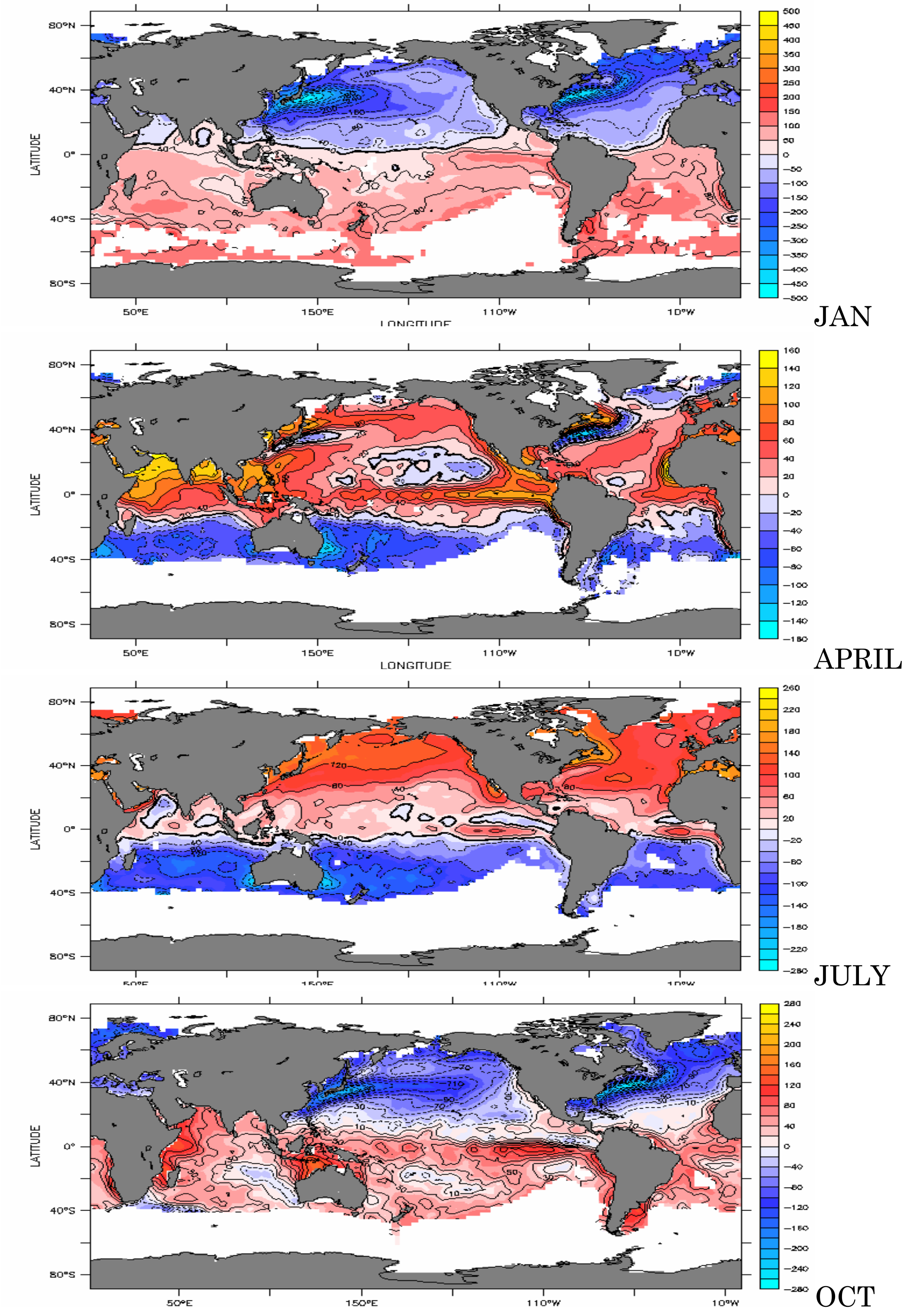


JULY



OCT

Heat Flux into the Ocean Climatology



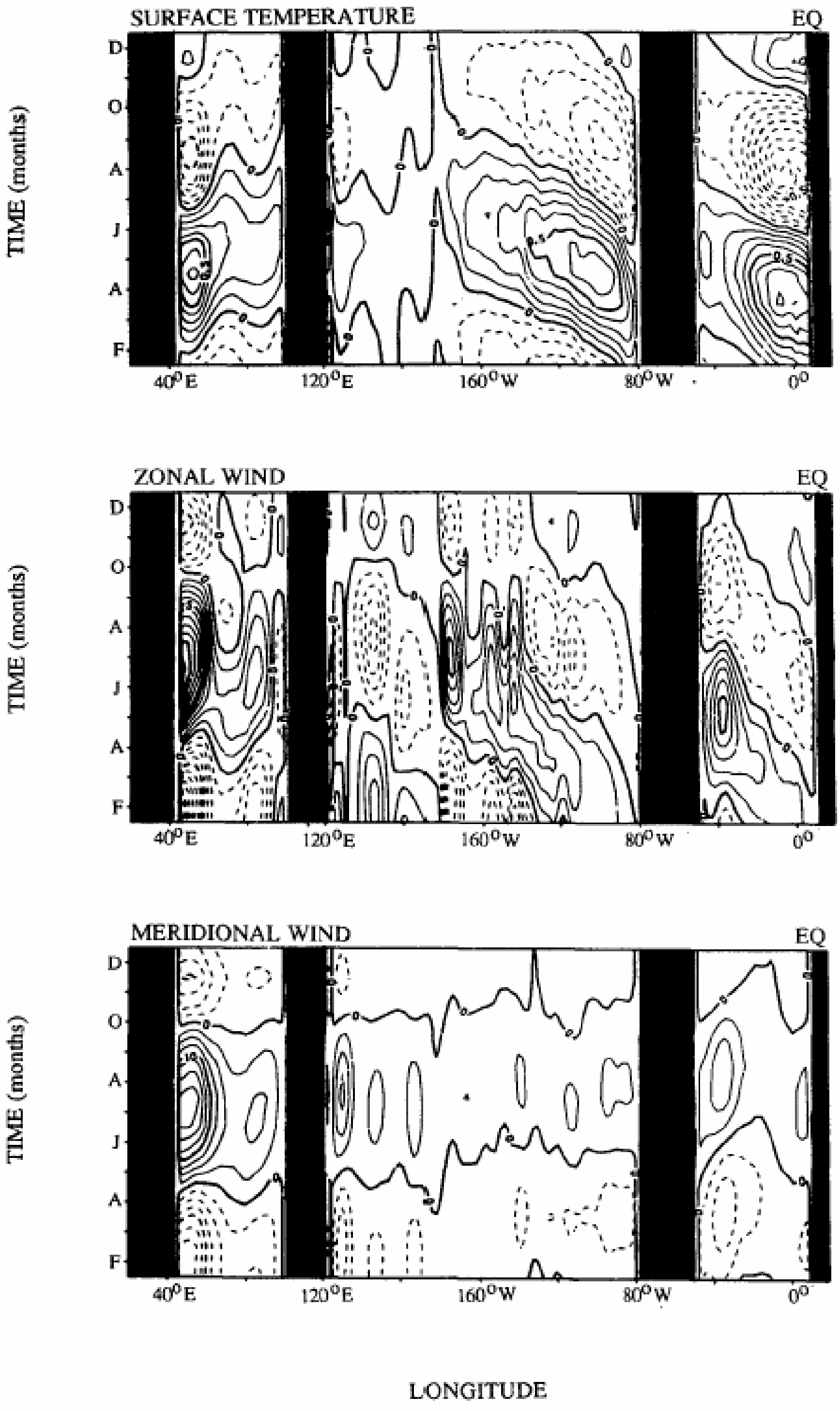


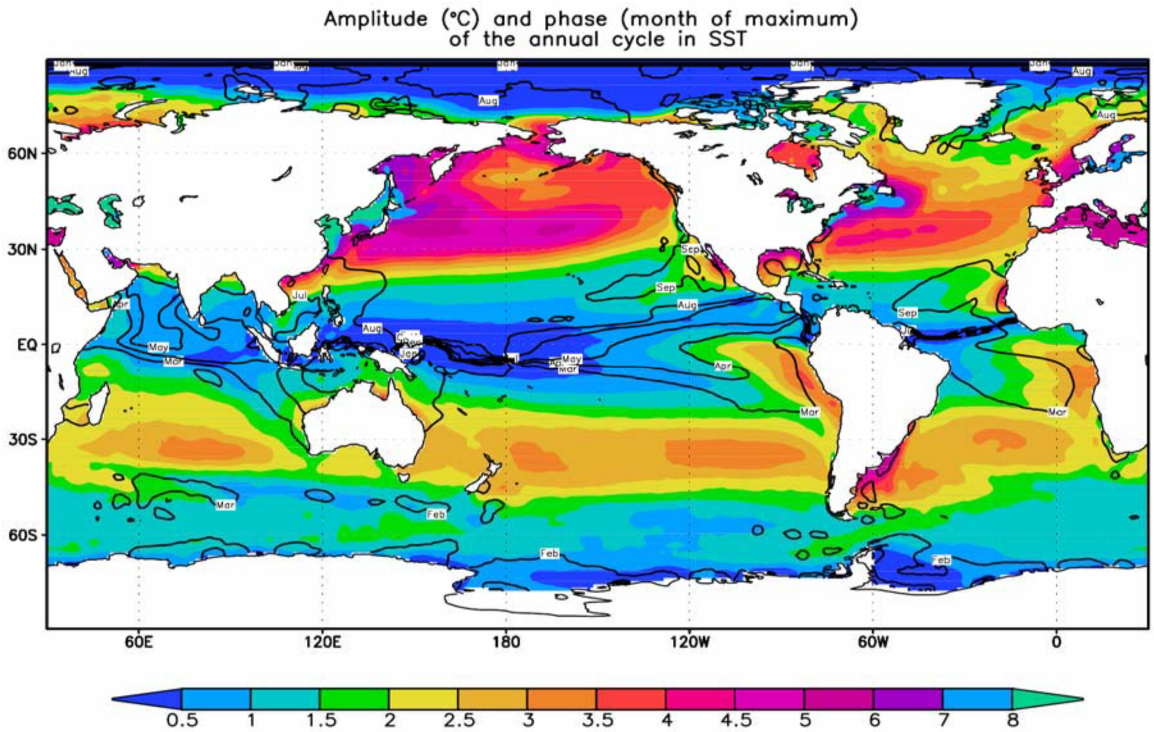
FIG. 2. Climatological monthly mean anomalies, along the equator, of sea surface temperature (contour interval: 0.25°C), zonal component of the surface wind (contour interval: 0.01 dyn cm^{-2}) and meridional component of the surface wind (contour interval: 0.025 dyn cm^{-2}). Dashed contours indicate negative, easterly, and northerly anomalies, respectively.

c. Defining Anomalies

► **Average Each Month: the Progression of Monthly Quantities is the Climatology**

► **Implies that the Climatology Contains Both Higher and Lower Frequencies**

► **The Annual Cycle is the First Harmonic of the Climatology (in a Fourier Sense)**



(Ken Takahashi)

► **An Anomaly is the Difference Between the Actual Value and the Climatology**

►But What if the Climatology is Non-Stationary?

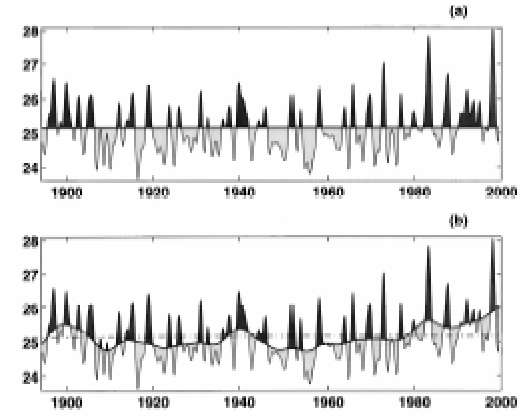
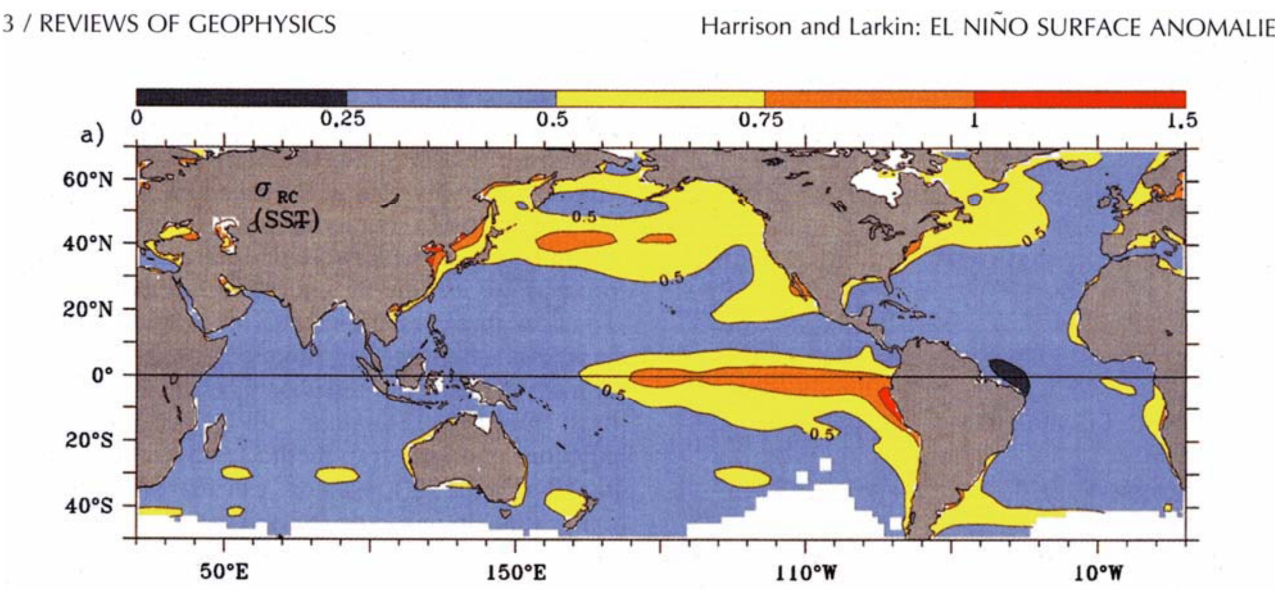


FIG. 1. The interannual oscillations in SST (in °C) at the equator in the eastern Pacific (averaged over the area 5°S–5°N, 80°–120°W) are shown on the background of (a) the time-averaged temperature for the century (b) the low-frequency interdecadal changes. The plots are obtained by applying, to the available measurements, two different low-pass filters with the cutoff frequencies of approximately 0.9 and 0.09 yr^{-1}. The darker (lighter) part of the graph indicates El Niño (La Niña).

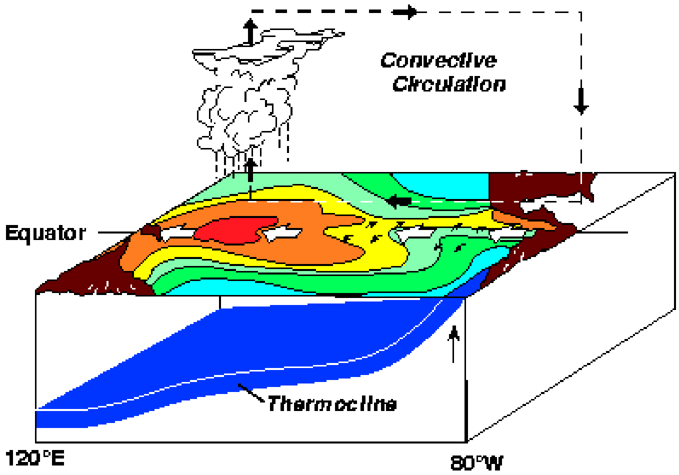
►In order to correctly define anomalies, we would have to have a model for the slowly changing climatology--- this we don't have.



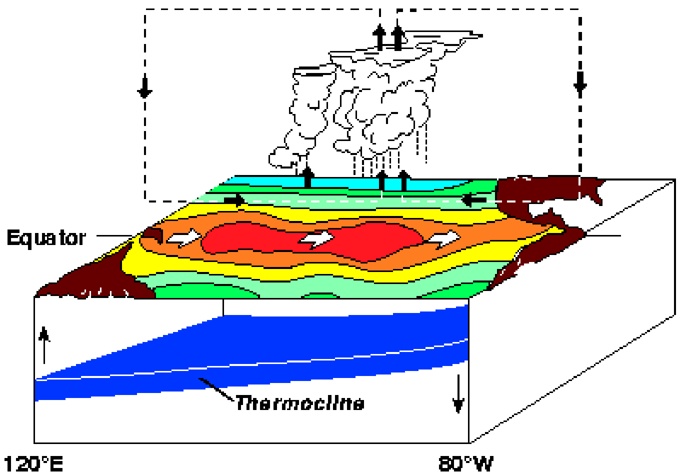
rms SST Anomalies

d. ENSO

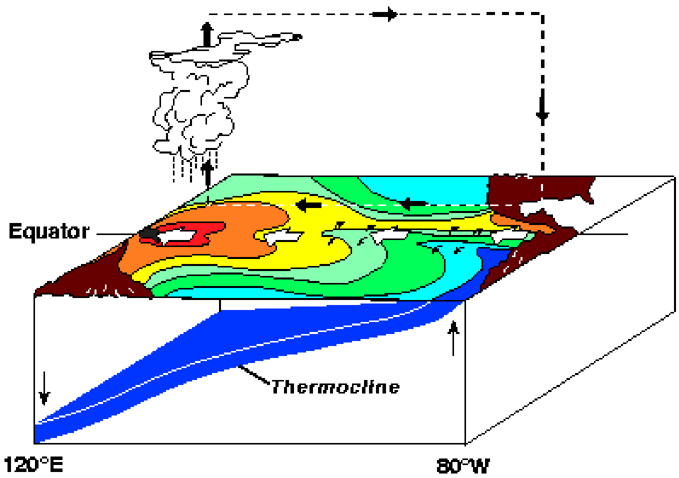
Normal Conditions

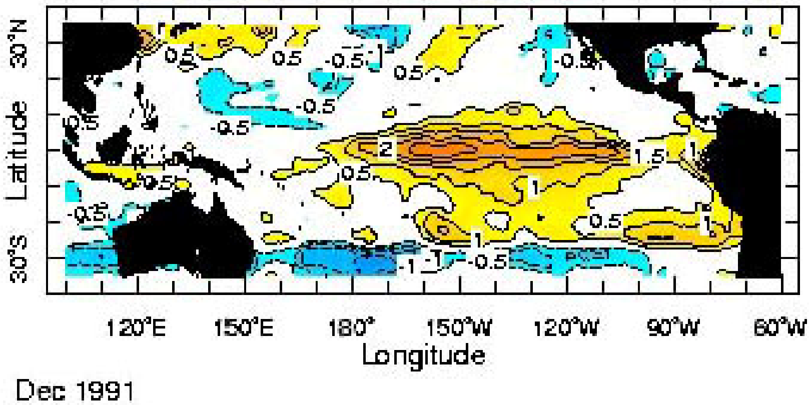


El Niño Conditions

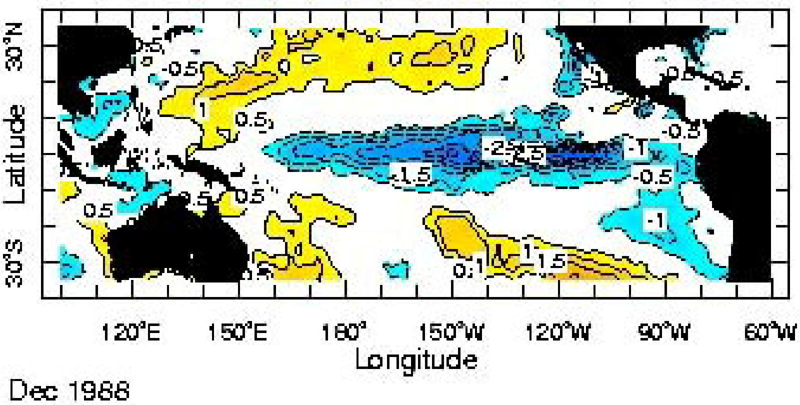


La Niña Conditions



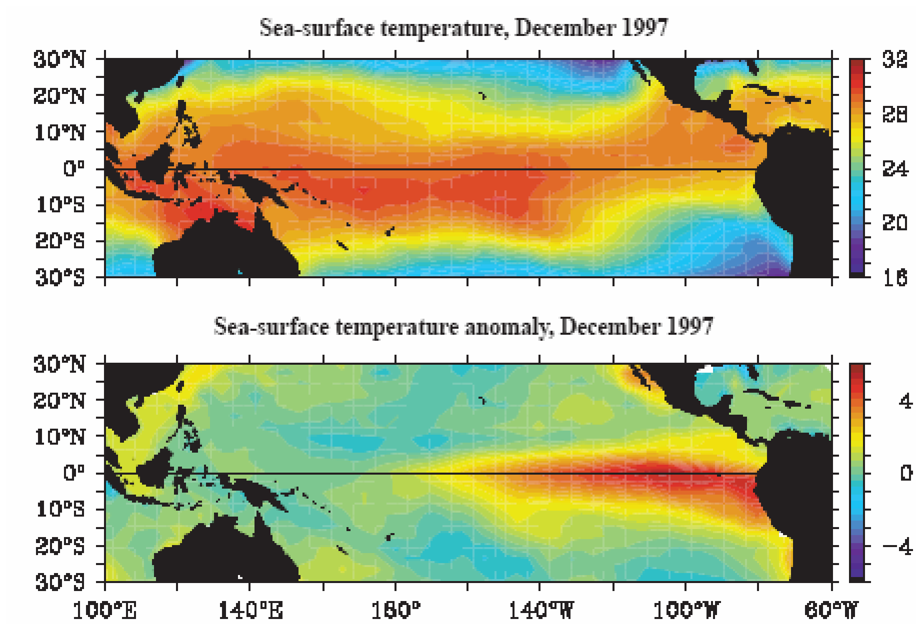


WARM ENSO

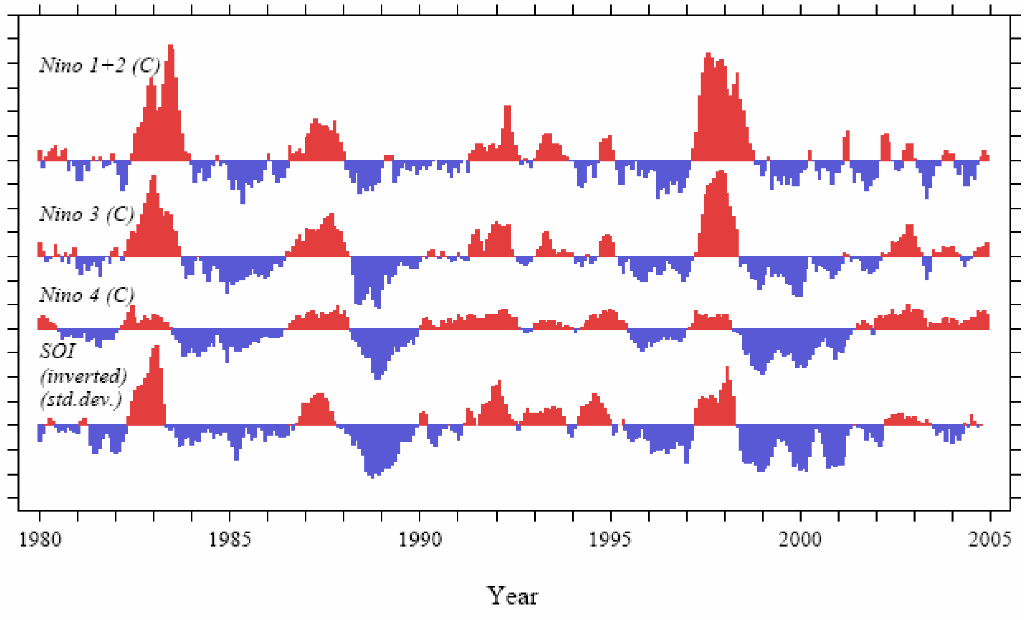


COLD ENSO

Warm and Cold ENSO is sometimes called El Niño and La Niña

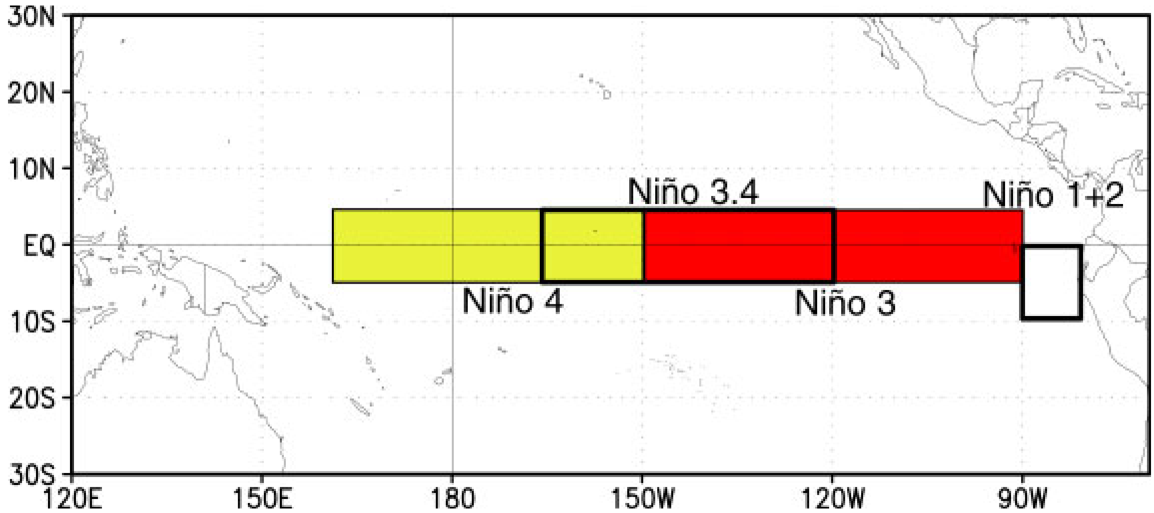


ENSO Evolution:



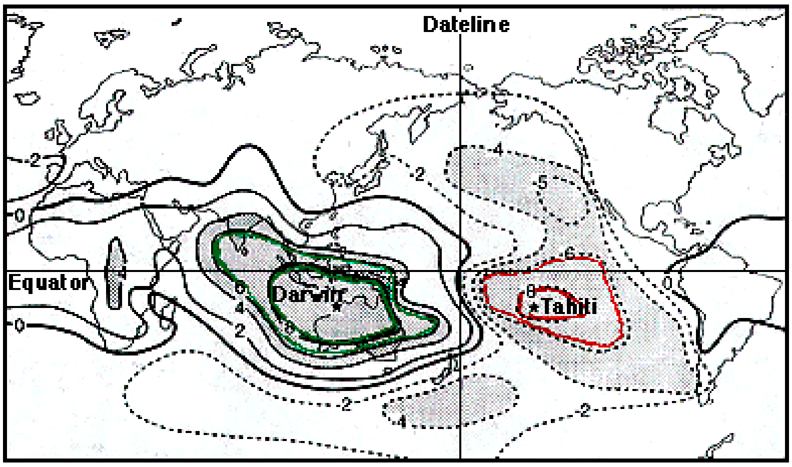
Anomalies with respect to 1985–94

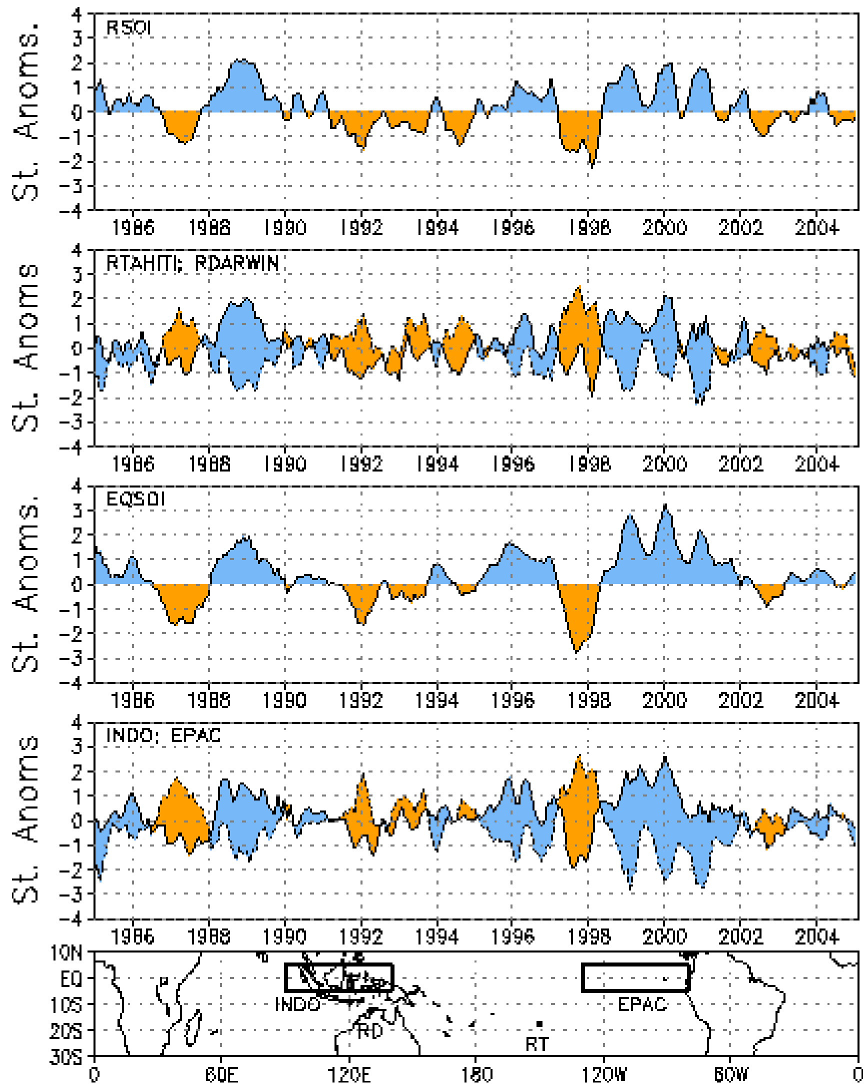
(Todd Mitchell)



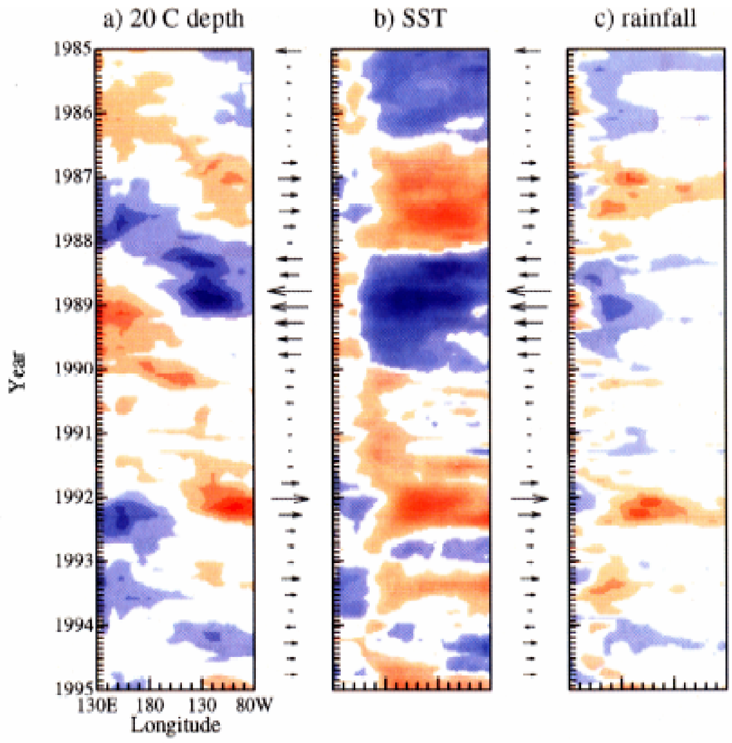
Southern Oscillation

SOI: Tahiti and Darwin as "centers of action",
mslp correlations between two locations

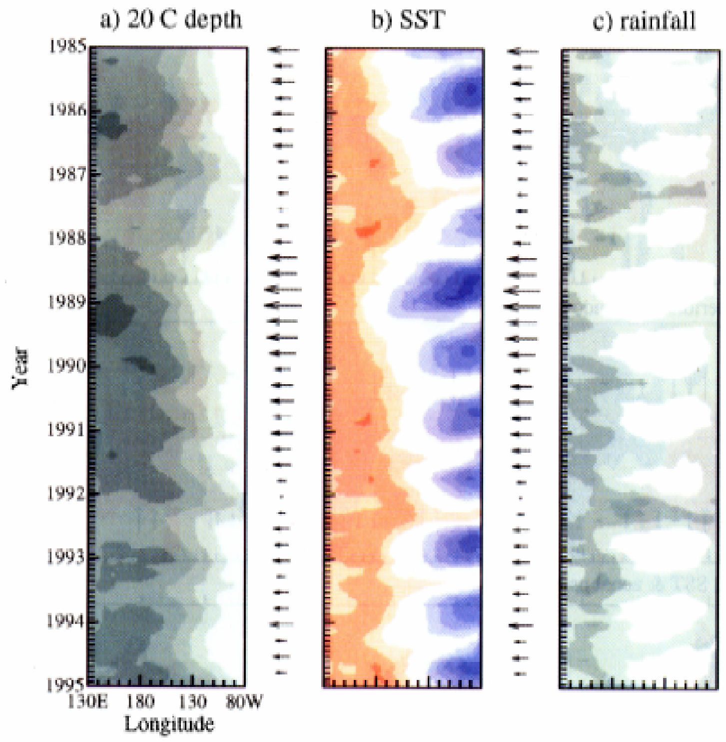


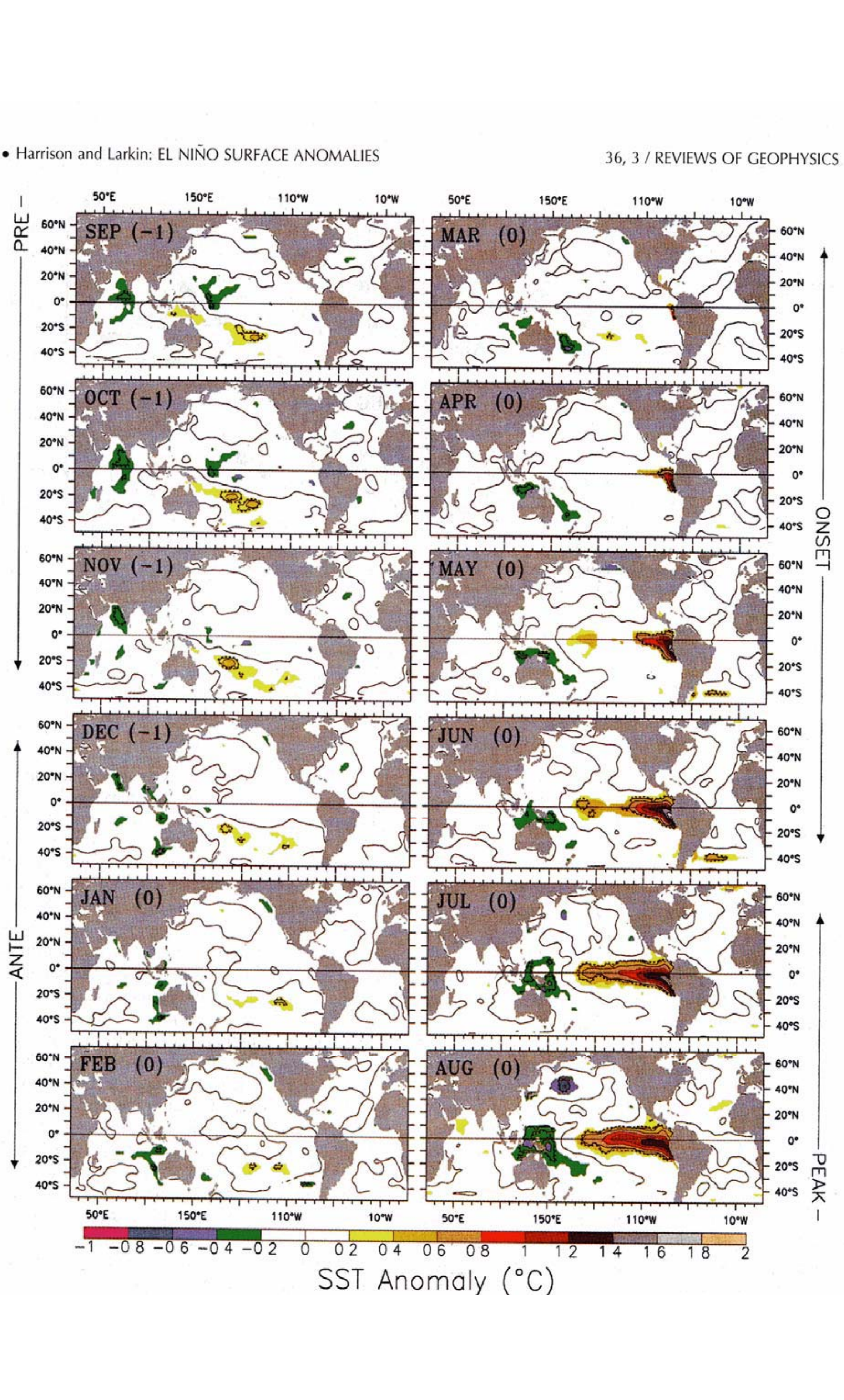


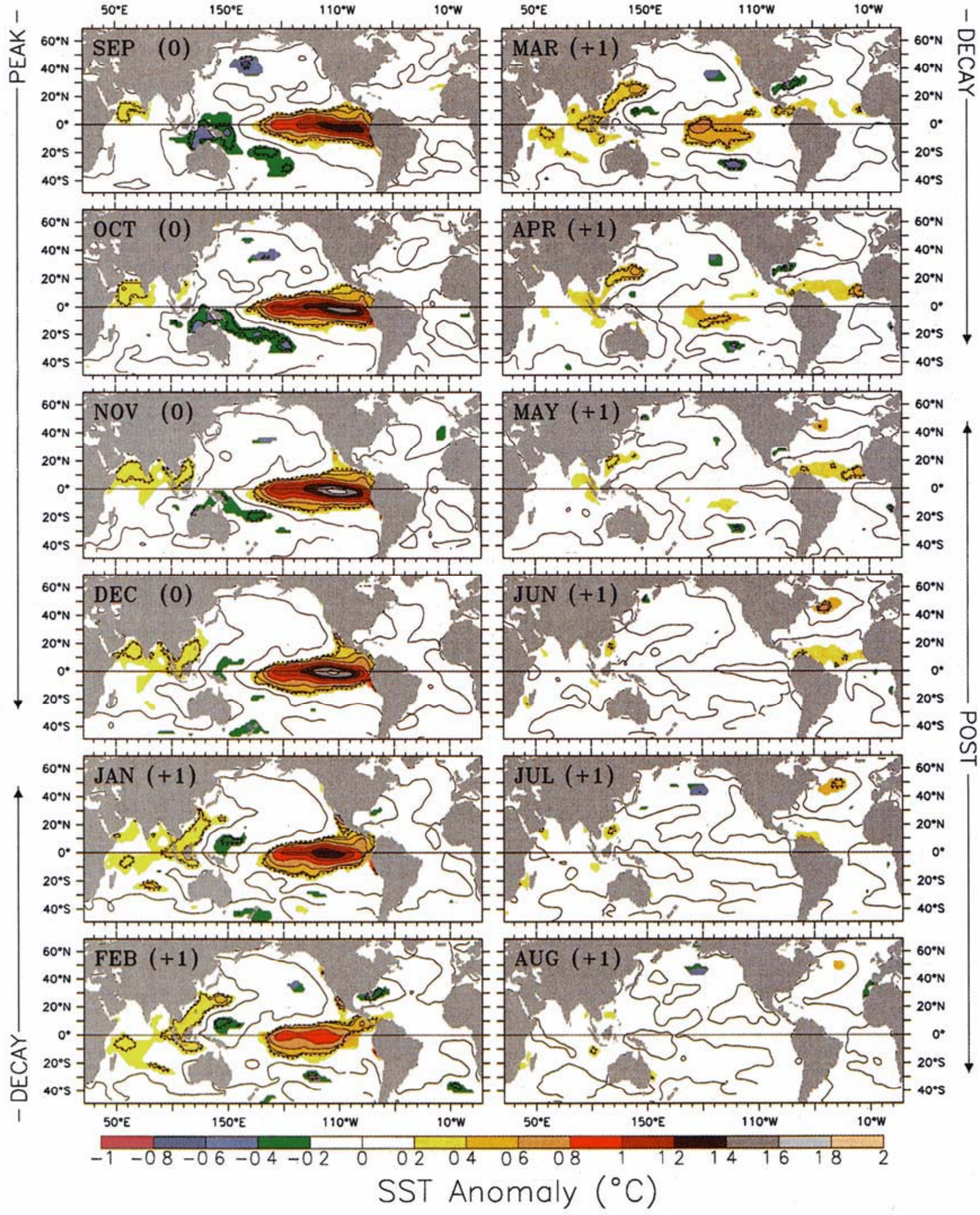
Anomalies



Total Fields




SEP (−1)
OCT (−1)
NOV (−1)
DEC (−1)
JAN (0)
FEB (0)
MAR (0)
APR (0)
MAY (0)
JUN (0)
JUL (0)
AUG (0)
PRE
ANTE
ONSET
PEAK
50°E
150°E
110°W
10°W
60°N
40°N
20°N
0°
20°S
40°S
−1 −0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
SST Anomaly (°C)


PEAK
DECAY
POST
SEP (0)
OCT (0)
NOV (0)
DEC (0)
JAN (+1)
FEB (+1)
MAR (+1)
APR (+1)
MAY (+1)
JUN (+1)
JUL (+1)
AUG (+1)
50°E
150°E
110°W
10°W
60°N
40°N
20°N
0°
20°S
40°S
−1 −0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
SST Anomaly (°C)

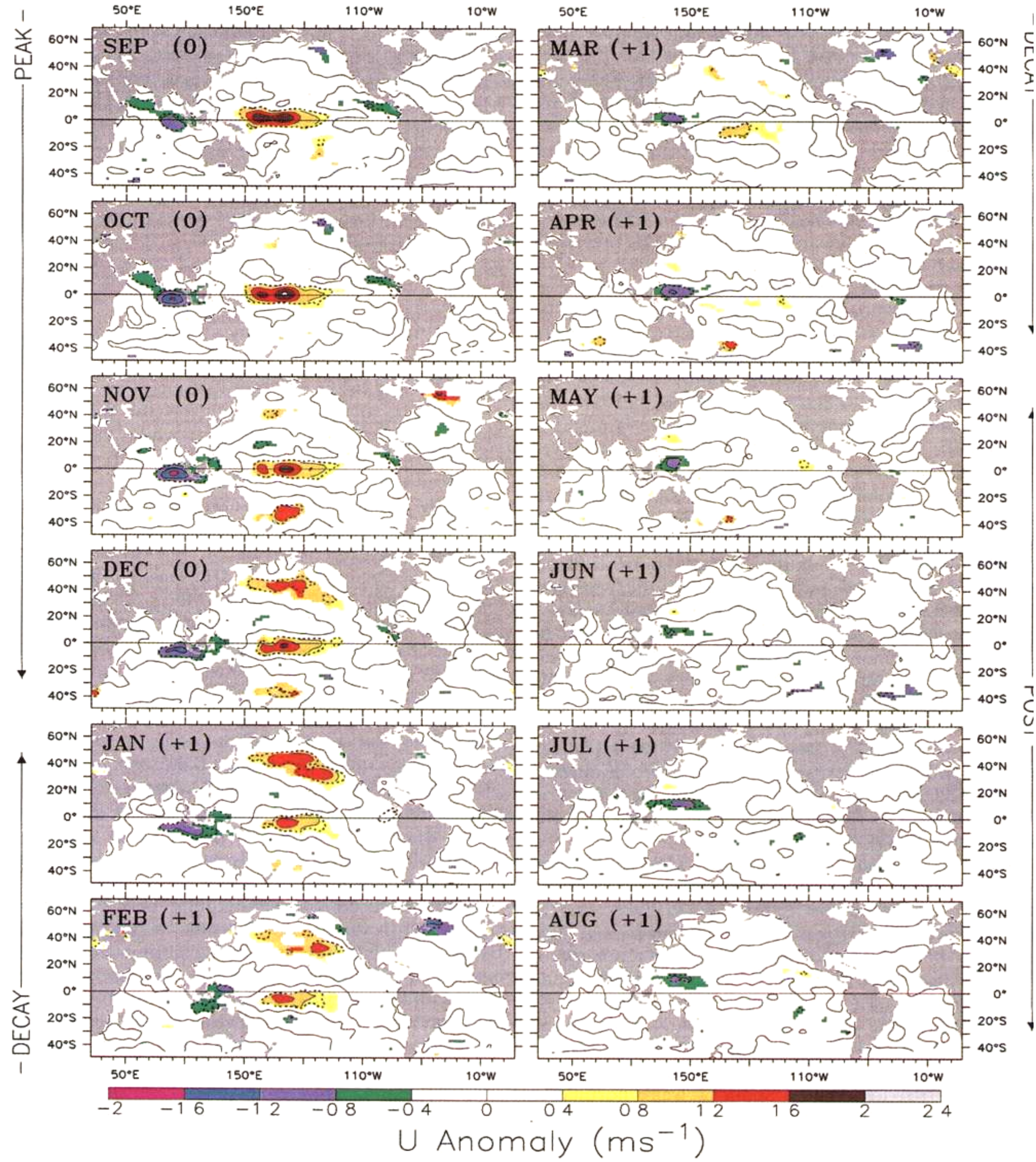


Plate 4. (continued)

Warm Vs. Cold ENSO Evolution

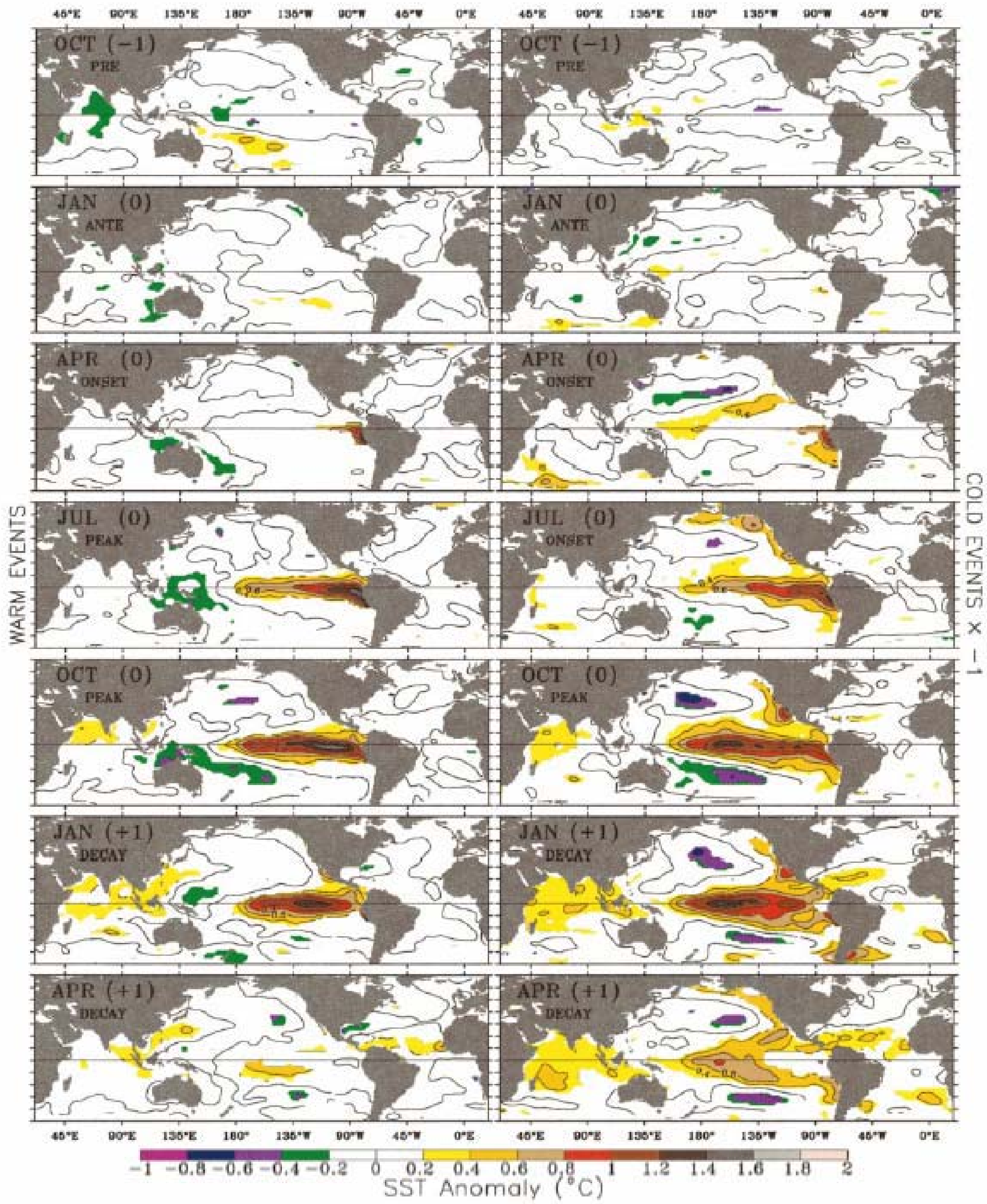


FIG. 1. Comparison of (left) warm and (right) cold event SSTA. Anomalies are composited from the 10 WEs and 9 CEs in 1946–95 (see Table 1 and section 2f). Cold event anomalies are multiplied by −1. Anomalies are contoured every 0.2°C. Only the 95% statistically significant anomalies are shaded. Maps are shown every 3 months and the phase of each map is listed. Axis marks are every 10° of lat, 45° of lon and the horizontal line is the equator.

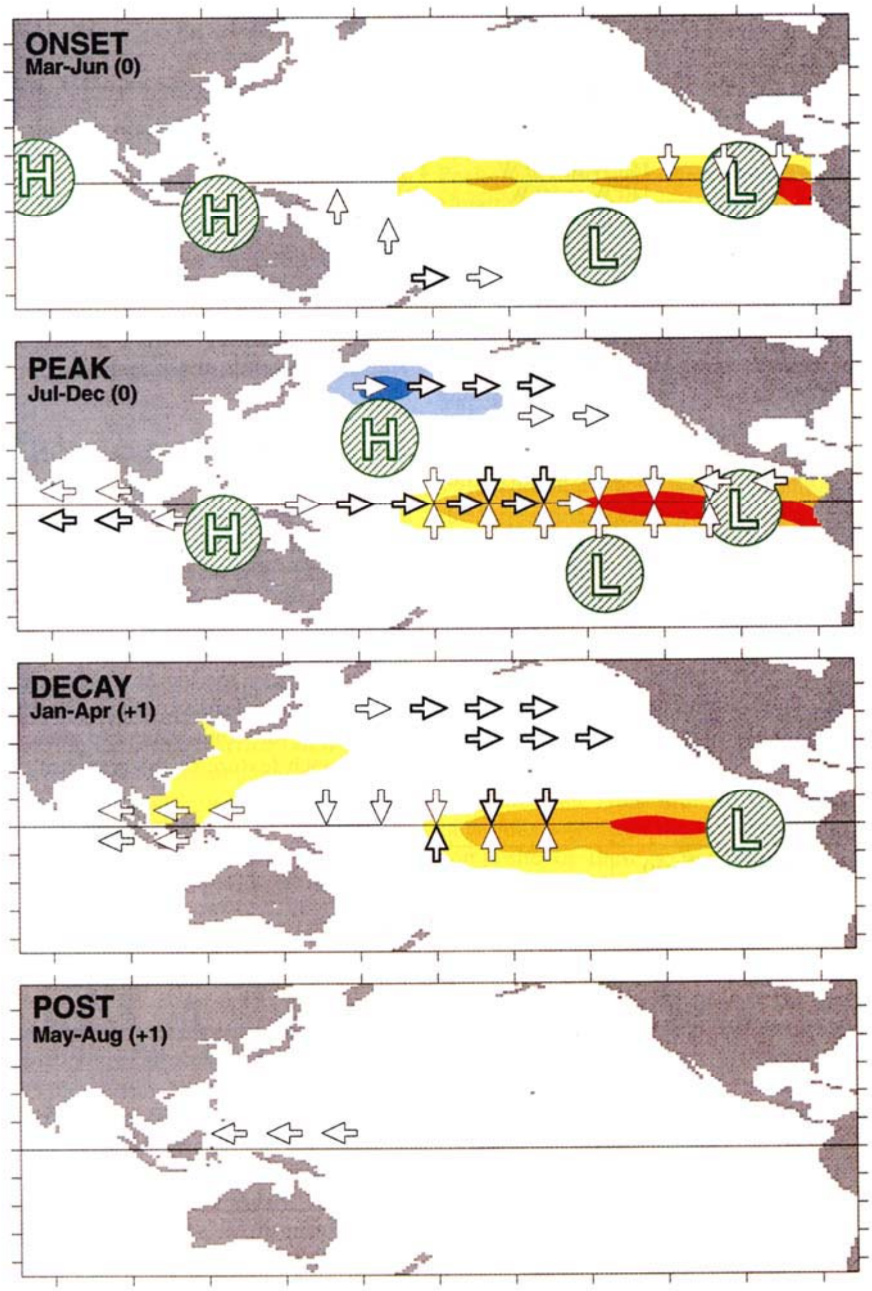
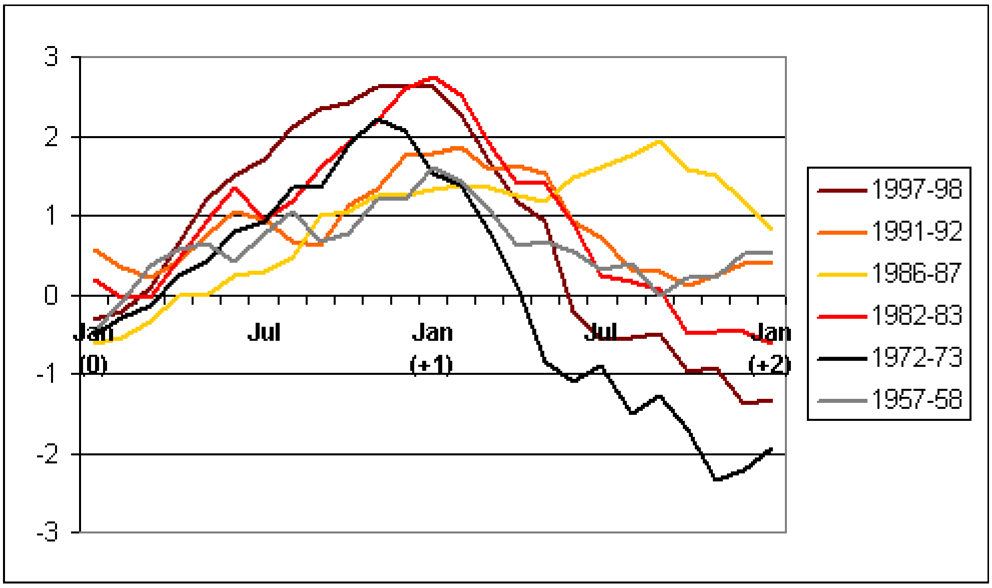
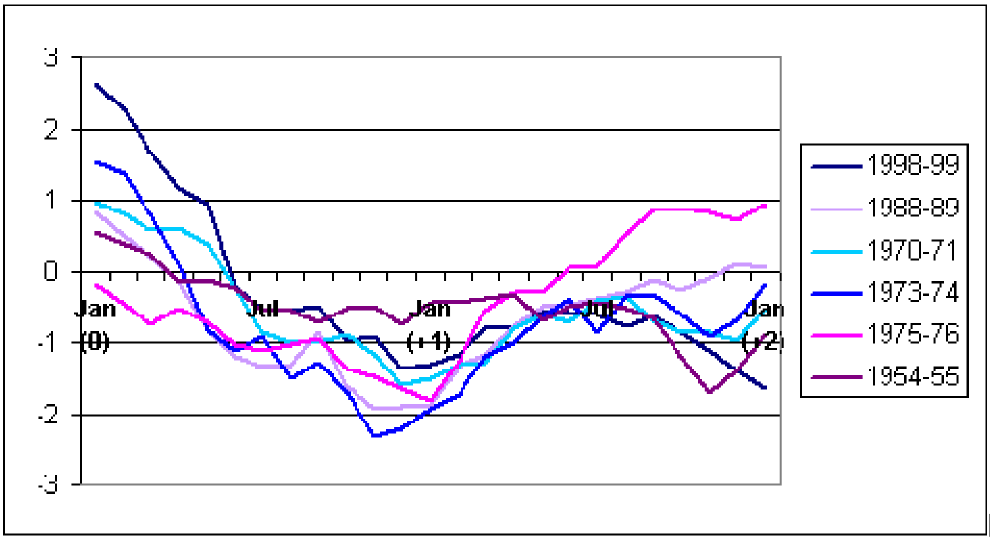


Plate 6. (continued)

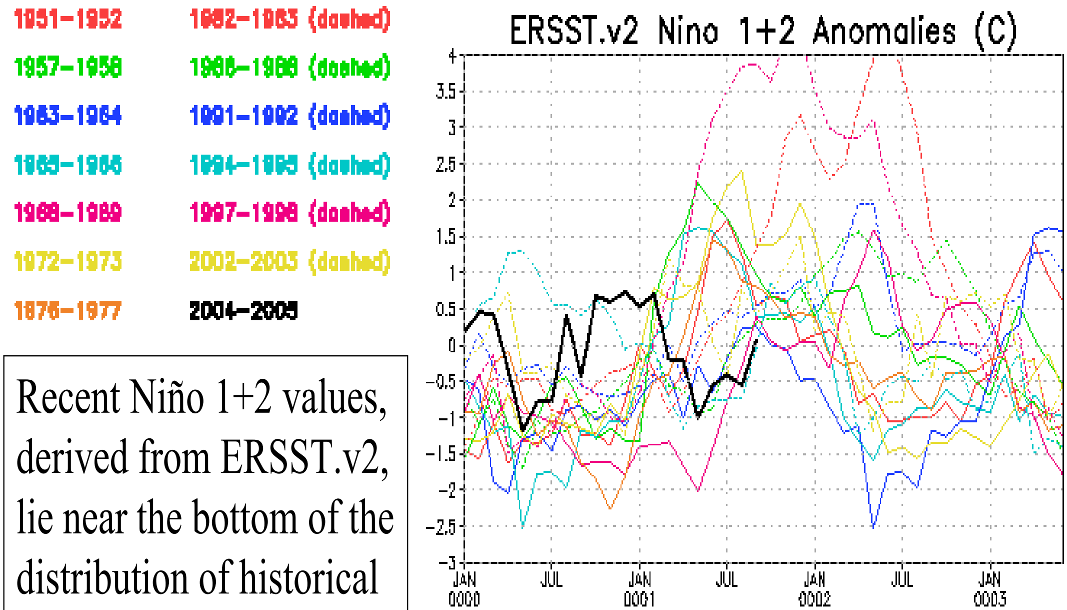
e. Is there a standard ENSO?





NINO 3.4

Niño 1+2 evolution – Comparison for El Niño episodes

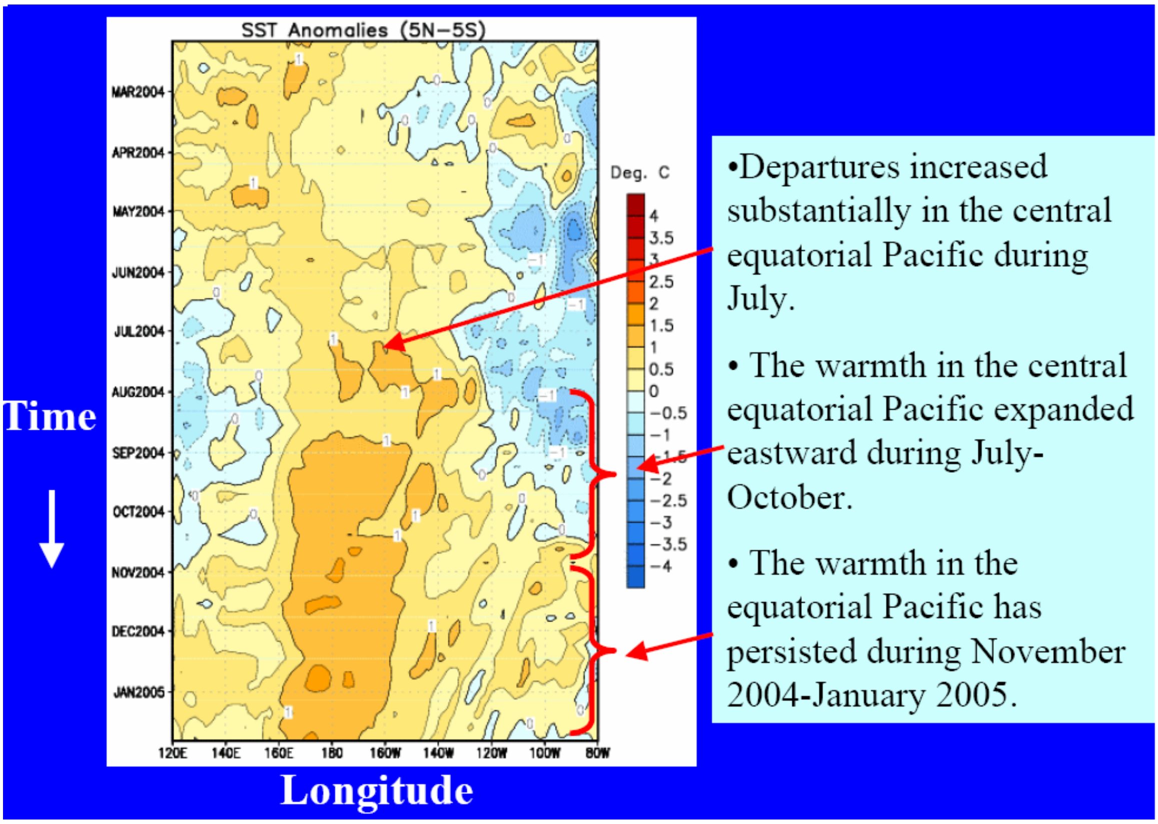


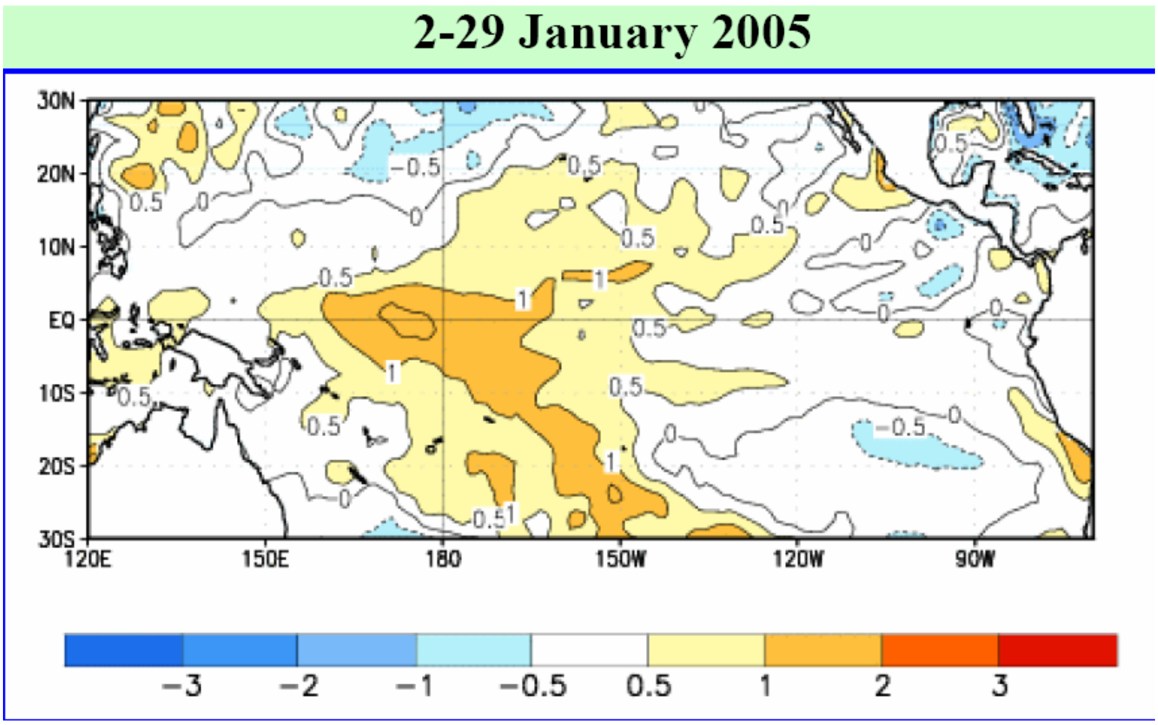
Recent Niño 1+2 values, derived from ERSST.v2, lie near the bottom of the distribution of historical El Niño episodes since 1950.

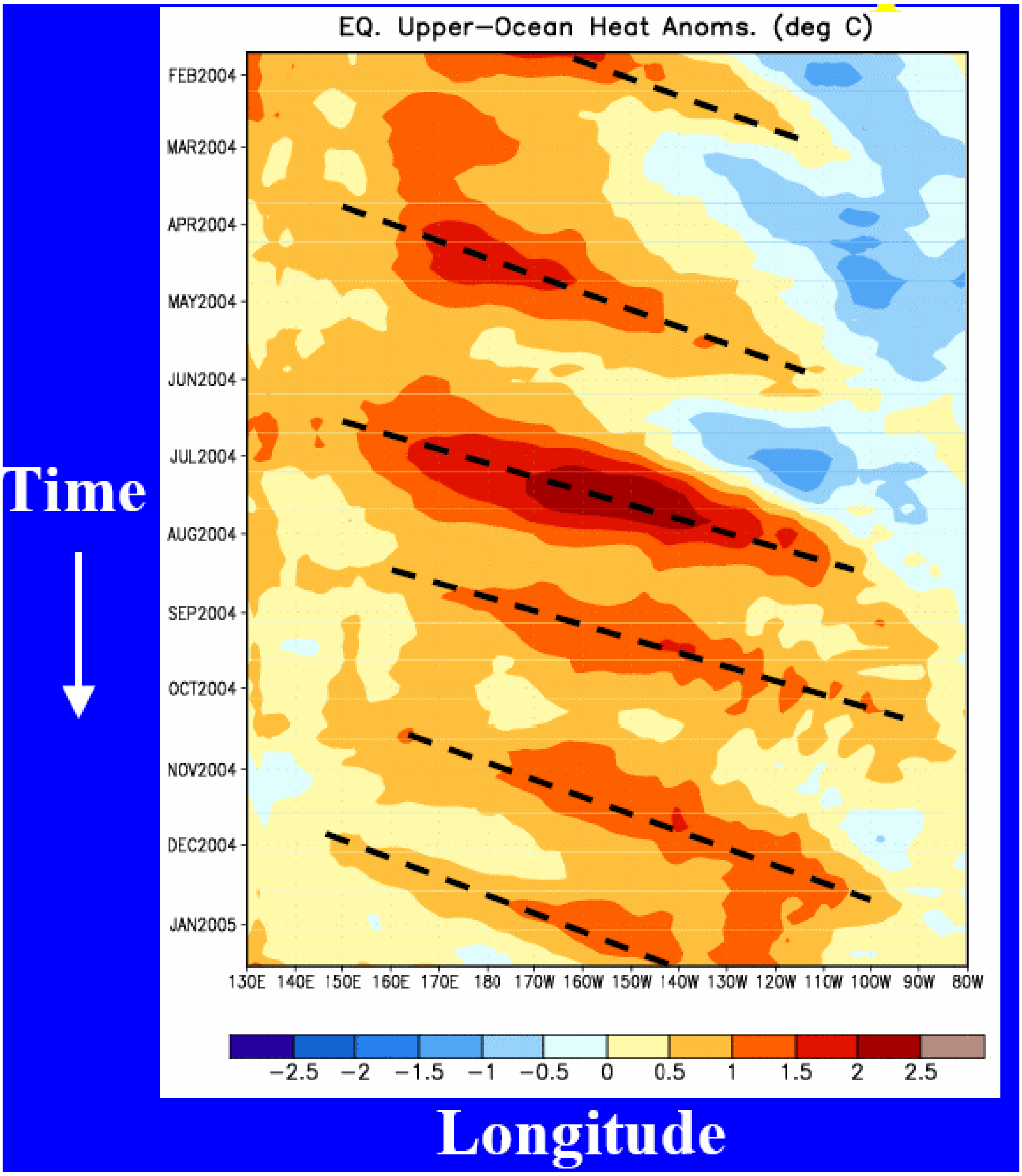
Most recent Niño 1+2 values (heavy black line) compared to values for 13 historical El Niño episodes. On the time axis year 0001 is the first year of a warm episode.

► **Does it make sense to define El Niño?**

f. The role of higher frequency variability

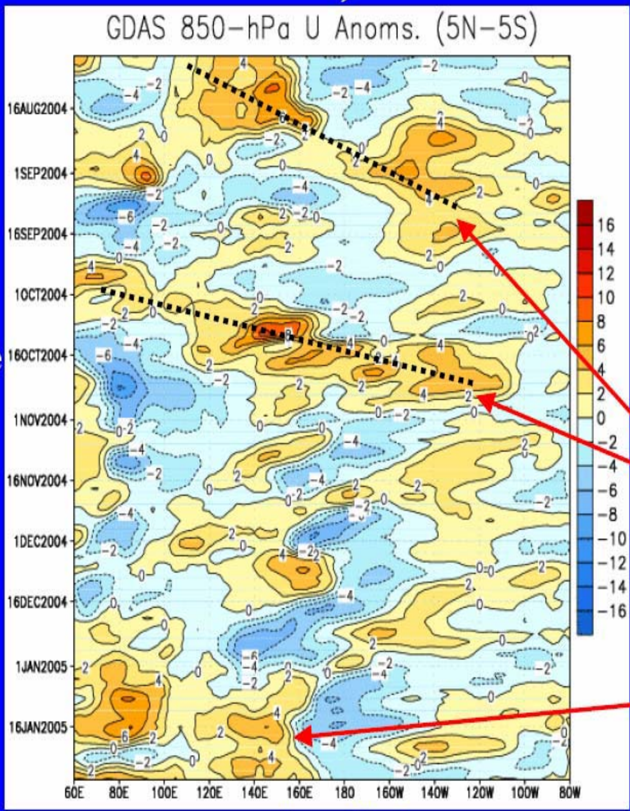






EQ. Upper-Ocean Heat Anoms. (deg C)
FEB2004
MAR2004
APR2004
MAY2004
JUN2004
JUL2004
AUG2004
SEP2004
OCT2004
NOV2004
DEC2004
JAN2005
130E 140E 150E 160E 170E 180 170W 160W 150W 140W 130W 120W 110W 100W 90W 80W
−2.5 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 2.5
Time
Longitude

Low-level (850-hPa) Zonal (east-west) Wind Anomalies



Time

Longitude

Weaker-than-average easterlies (orange/red shading).

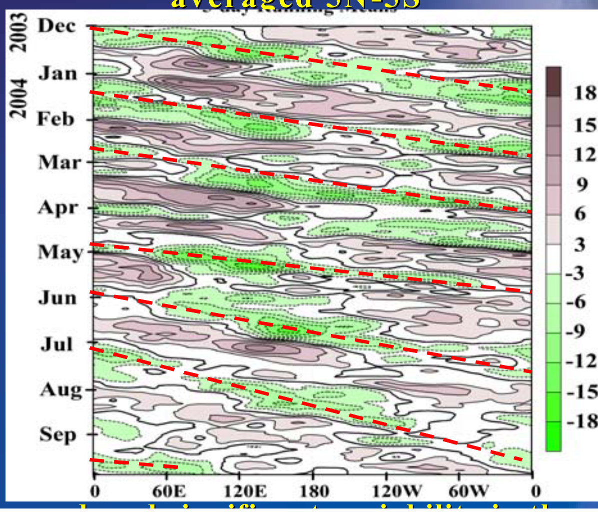
Stronger-than-average easterlies (blue shading).

During early late August and October the easterlies weakened substantially throughout the equatorial Pacific.

Westerly anomalies, which developed over the western equatorial Pacific in early January, persisted through the end of the month.

Strong MJO during 2004

200-hPa Velocity Potential Anomalies averaged 5N-5S



Anomalous Convergence

Anomalous Divergence

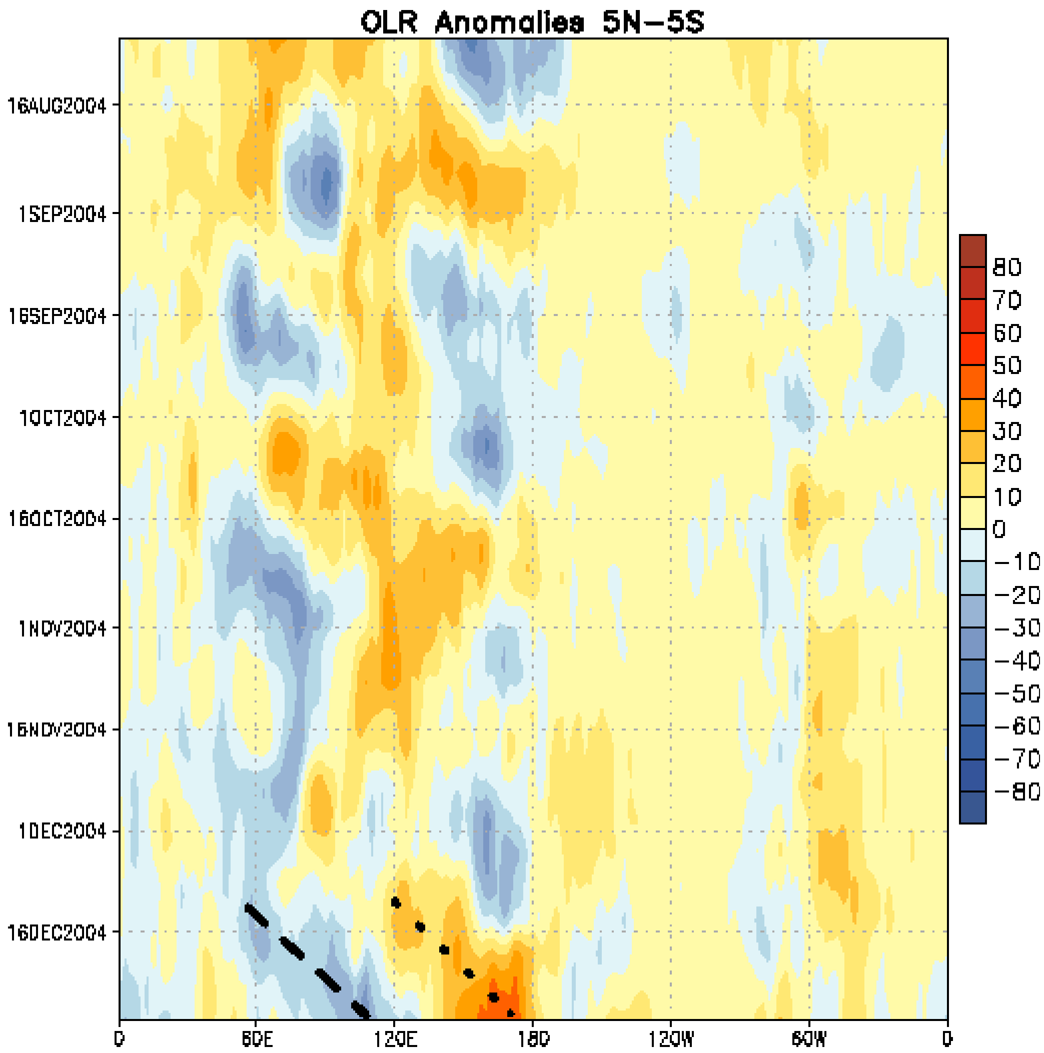


Figure 5. Time-longitude section of OLR anomalies for the latitude band 5N-5S. Anomalies are departures from the 1979-1995 base period means. In the Tropics positive (negative) anomalies are usually associated with drier- (wetter-) than-average conditions.

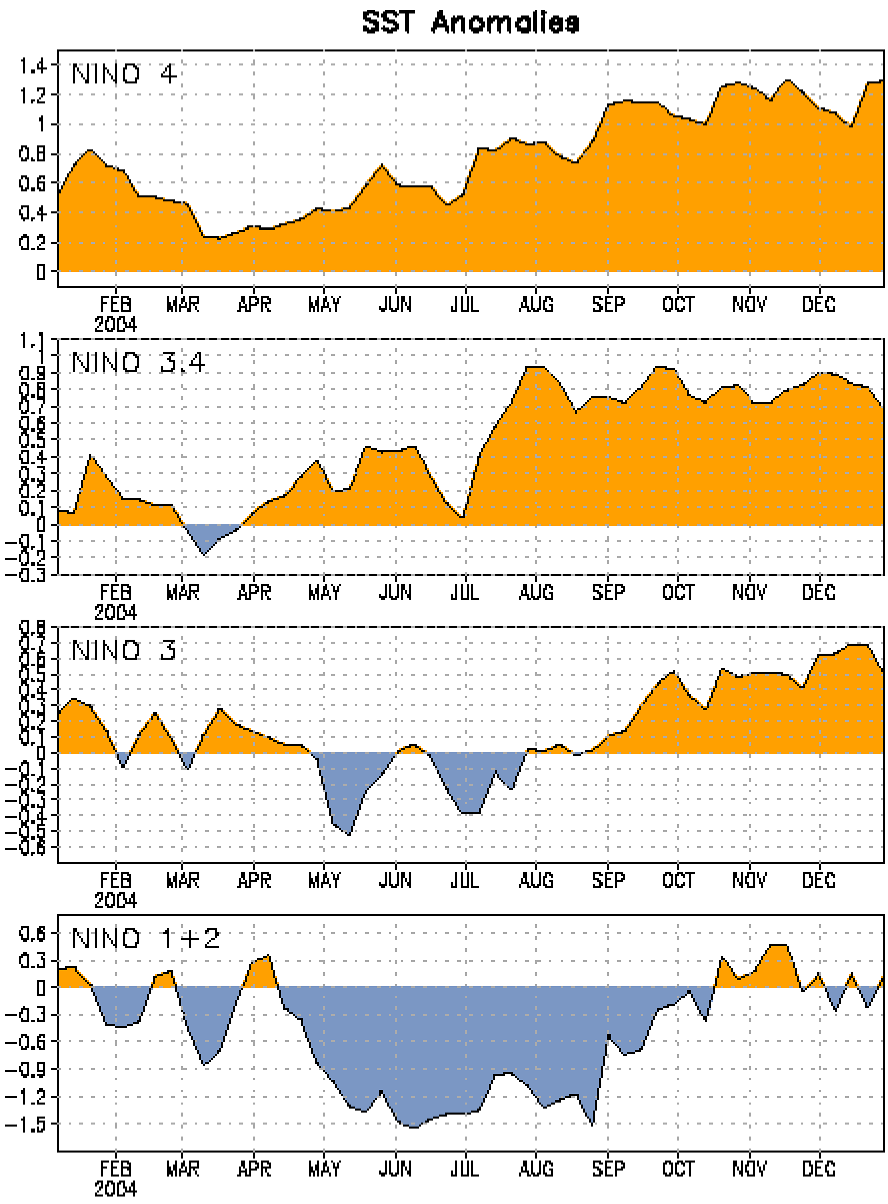
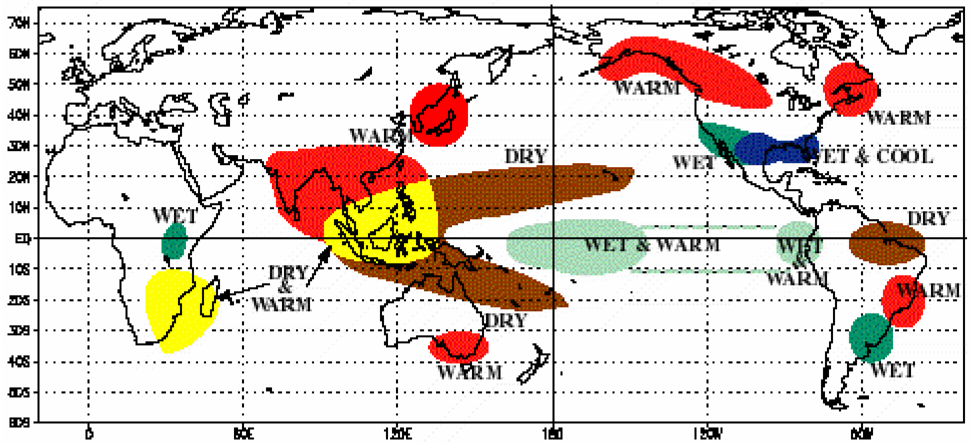


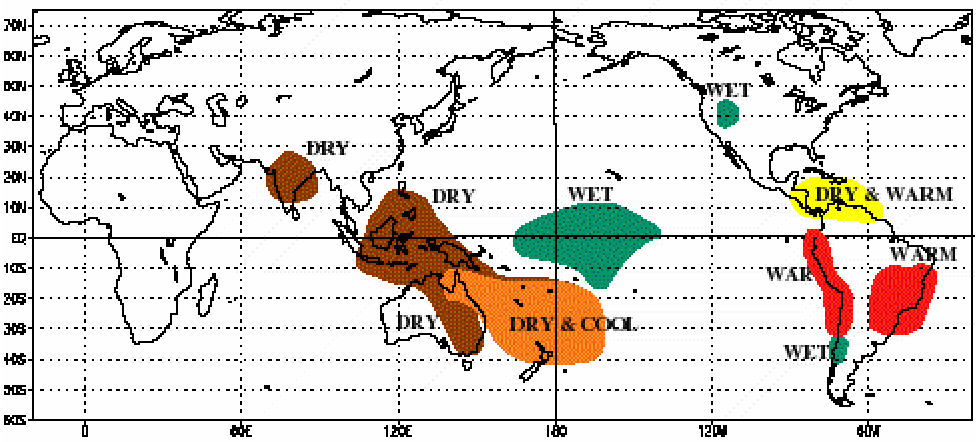
Figure 3. Time series of SST departures (°C) for the Niño regions. The SST departures are computed with respect to the 1971-2000 base period means (Smith and Reynolds, 1998, J. Climate, 11, 3320-3323).

g. ENSO Effects on the Globe

WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

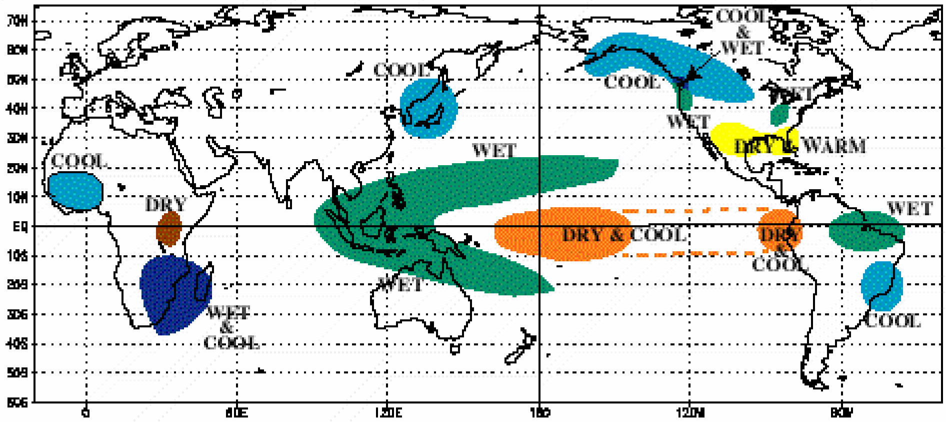


WARM EPISODE RELATIONSHIPS JUNE - AUGUST

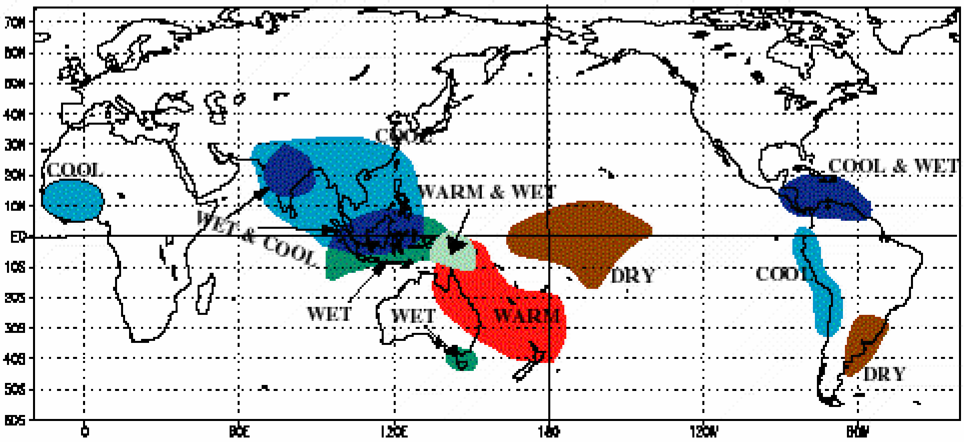


Climate Prediction Center
NCEP

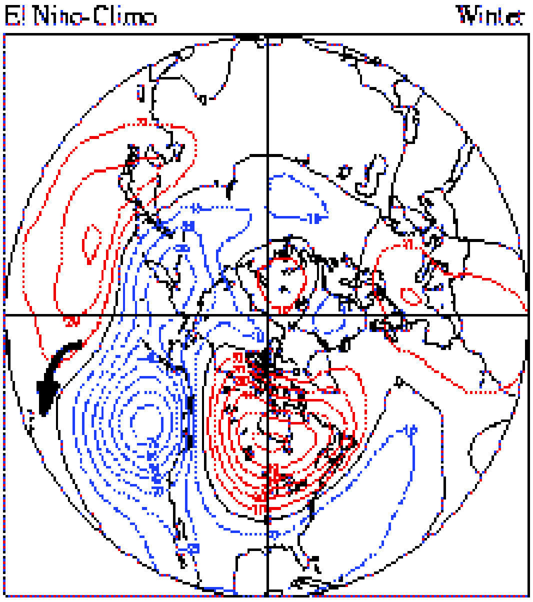
COLD EPISODE RELATIONSHIPS   DECEMBER - FEBRUARY

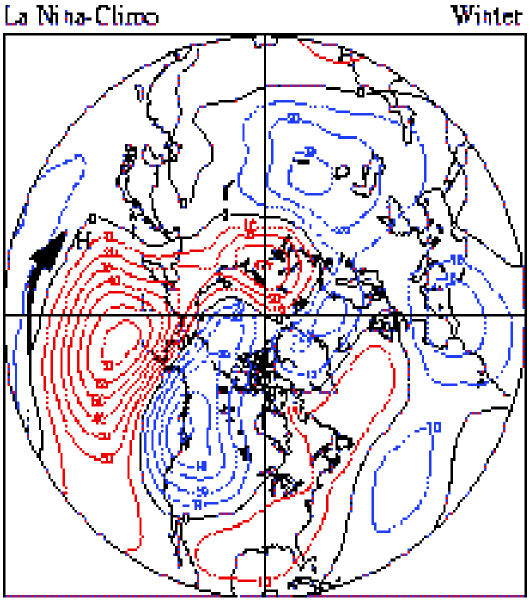


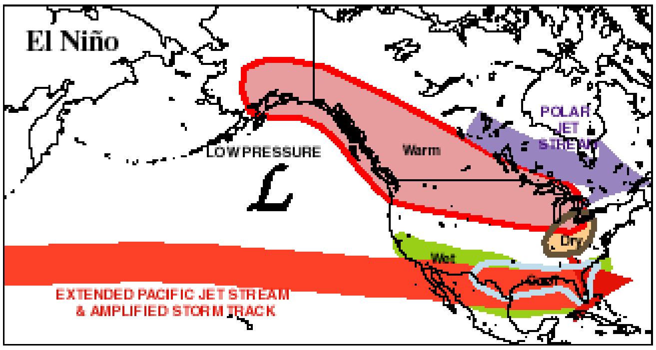
COLD EPISODE RELATIONSHIPS   JUNE - AUGUST

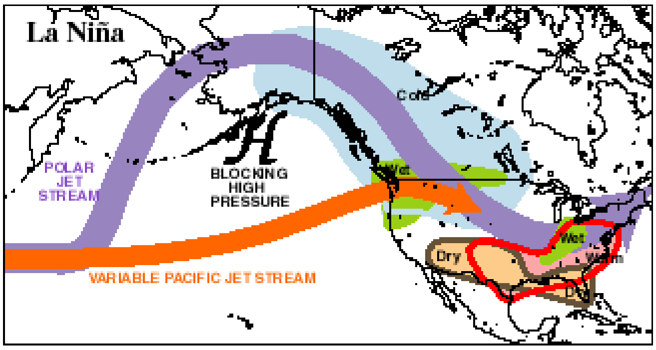


Climate Prediction Center
NCEP


El Nino-Climo
Winter


La Nina-Climo
Winter


El Niño
POLAR
JET
STREAM
LOW PRESSURE
L
Warm
Dry
Wet
Cool
EXTENDED PACIFIC JET STREAM
& AMPLIFIED STORM TRACK


La Niña
Cold
POLAR
JET
STREAM
H
BLOCKING
HIGH
PRESSURE
Wet
Wet
Dry
Warm
VARIABLE PACIFIC JET STREAM

h. ENSO and Decadal Variability

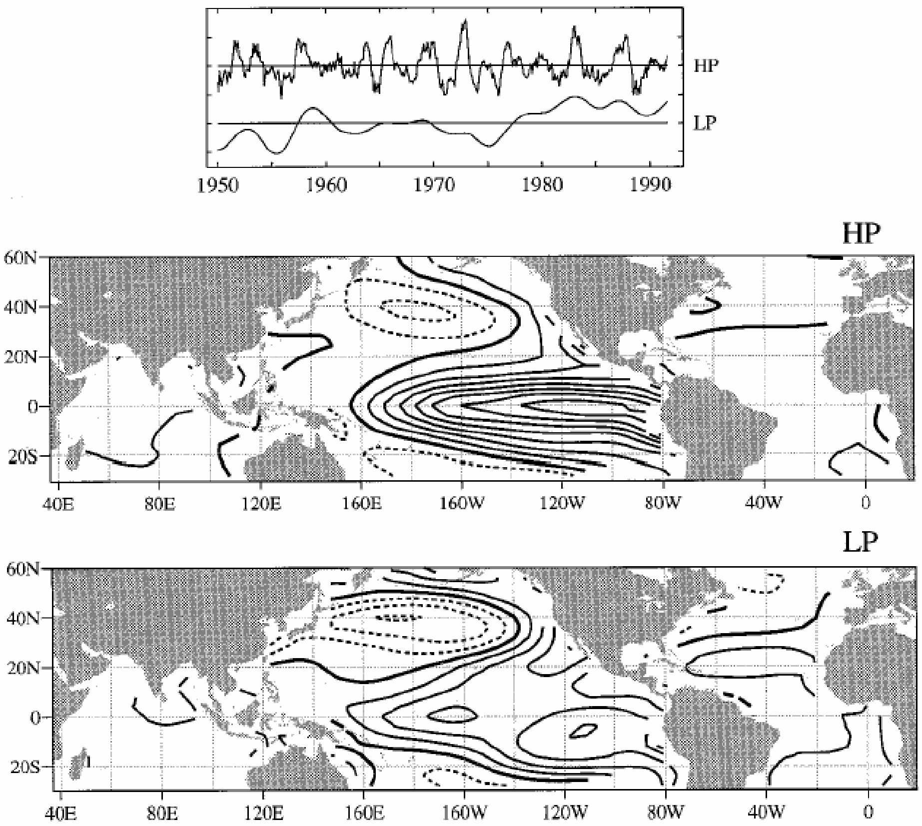


FIG. 3. The leading (normalized) PCs of 6-yr highpass- (HP) and lowpass- (LP) filtered SST over the Pacific domain shown together with the associated regression patterns for global SST. The interval between tick-marks on the vertical axis of the top panel corresponds to 1.0 standard deviation, and the spacing between the curves is arbitrary. Contour interval 0.1 K per standard deviation of the expansion coefficient time series. Negative contours are dashed; the zero contour is thickened.

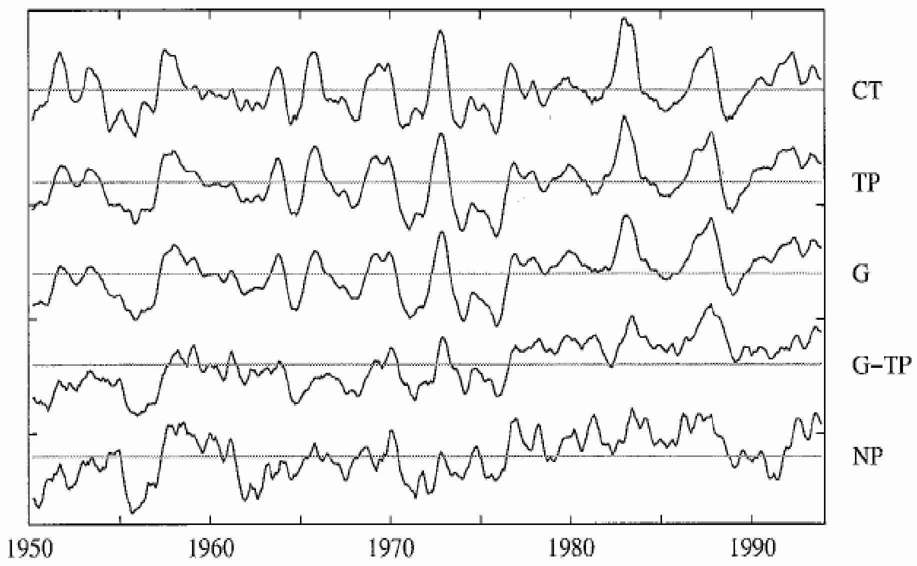
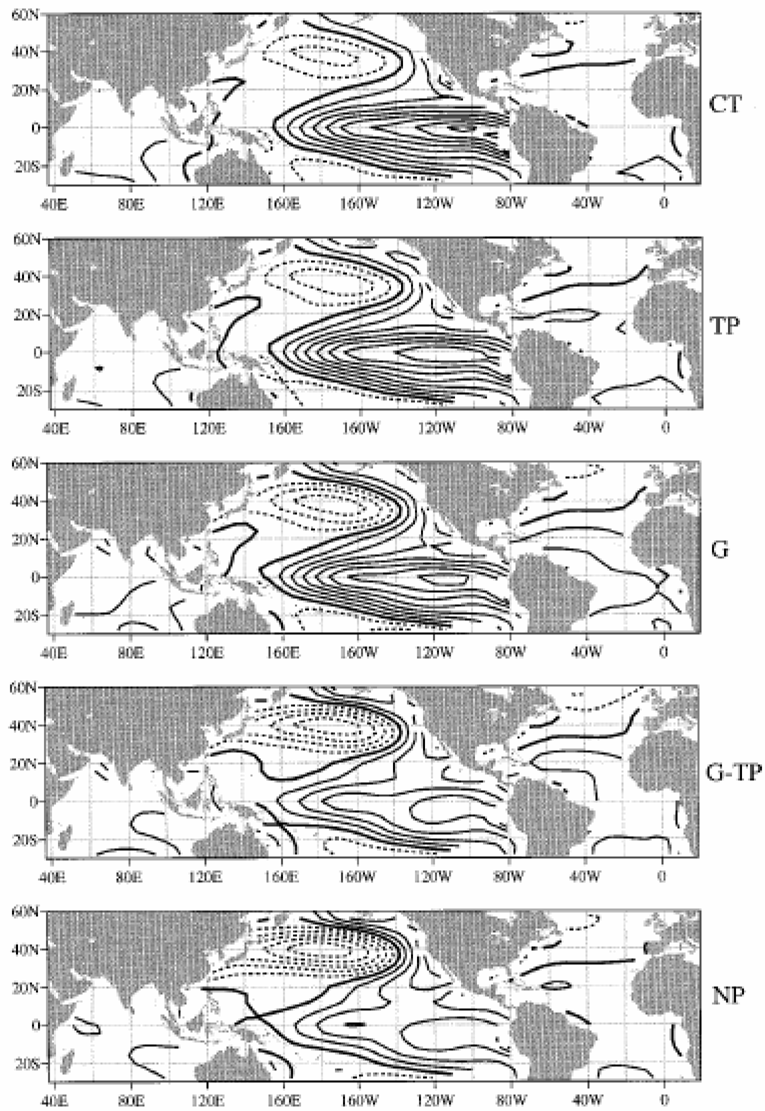
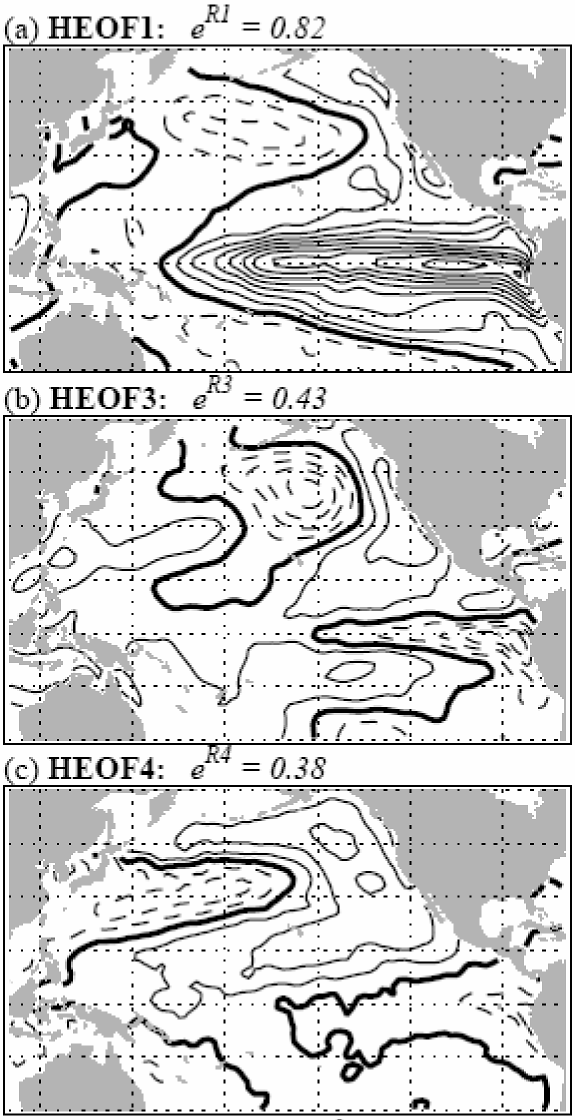


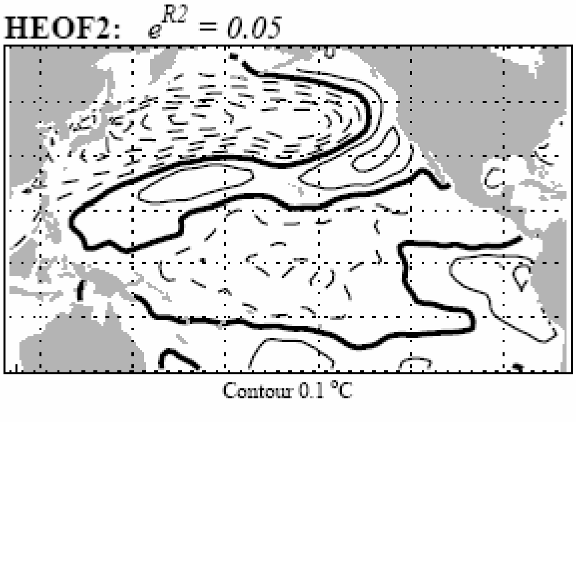
FIG. 5. Normalized time series (*top to bottom*): cold tongue (CT) and expansion coefficients of the leading EOFs of the SST anomaly field over the tropical Pacific (TP) domain (20°S–20°N, 160°E–80°W); the global (G) domain; the global domain excluping the TP (G − TP); and the extratropical (NP) domain poleward of 20°. All time series have been smoothed with a 5-month running-mean filter. The interval between tick-marks on the vertical axis is 1.0 standard deviation. The spacing between the curves is arbitrary. Correlation coefficients between the time series are shown in Table A1 in the appendix.



Vimont has reconstructed the "decadal" pattern from only interannual elements.



Contour 0.05 °C



Contour 0.1 °C