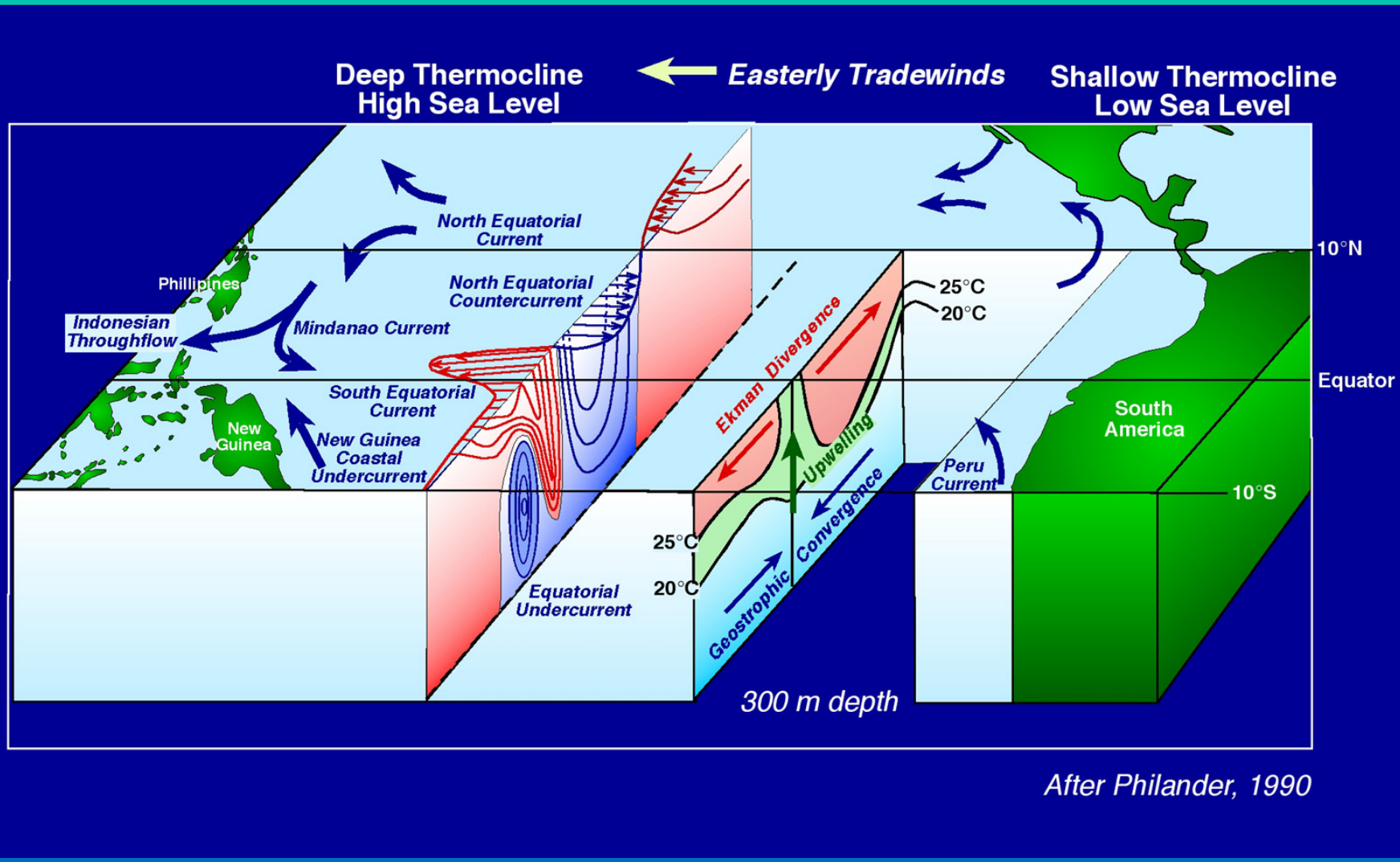
El Nino/Southern Oscillation

Suggested reading

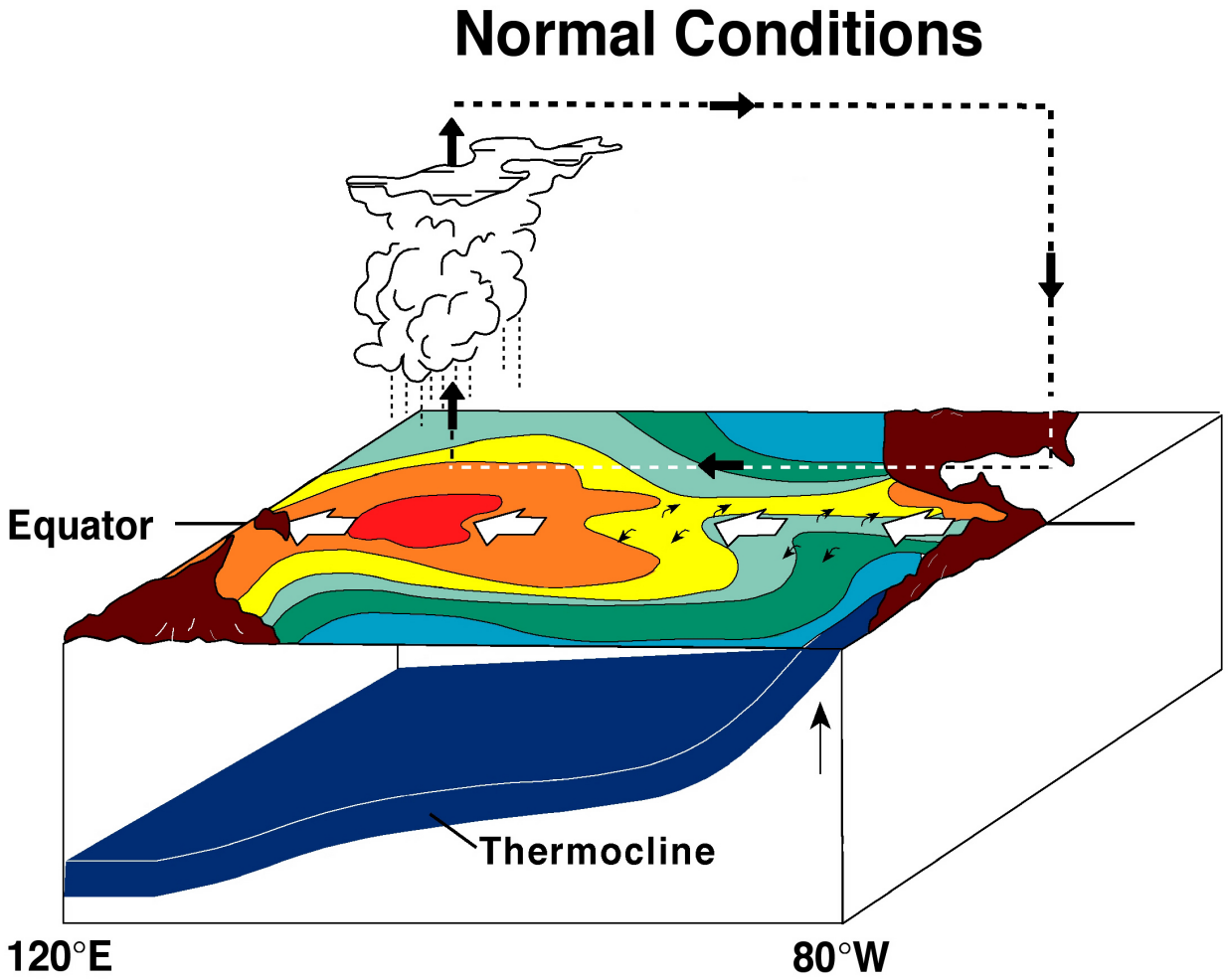
Dijkstra, H. A., 2006: The ENSO phenomenon: Theory and mechanisms. Adv. Geosciences, 6, 3-15.

This presentation includes slides prepared by M. McPhaden for the 2008 ENSO summer school held on the Big Island of Hawaii.

Ocean Circulation Schematic

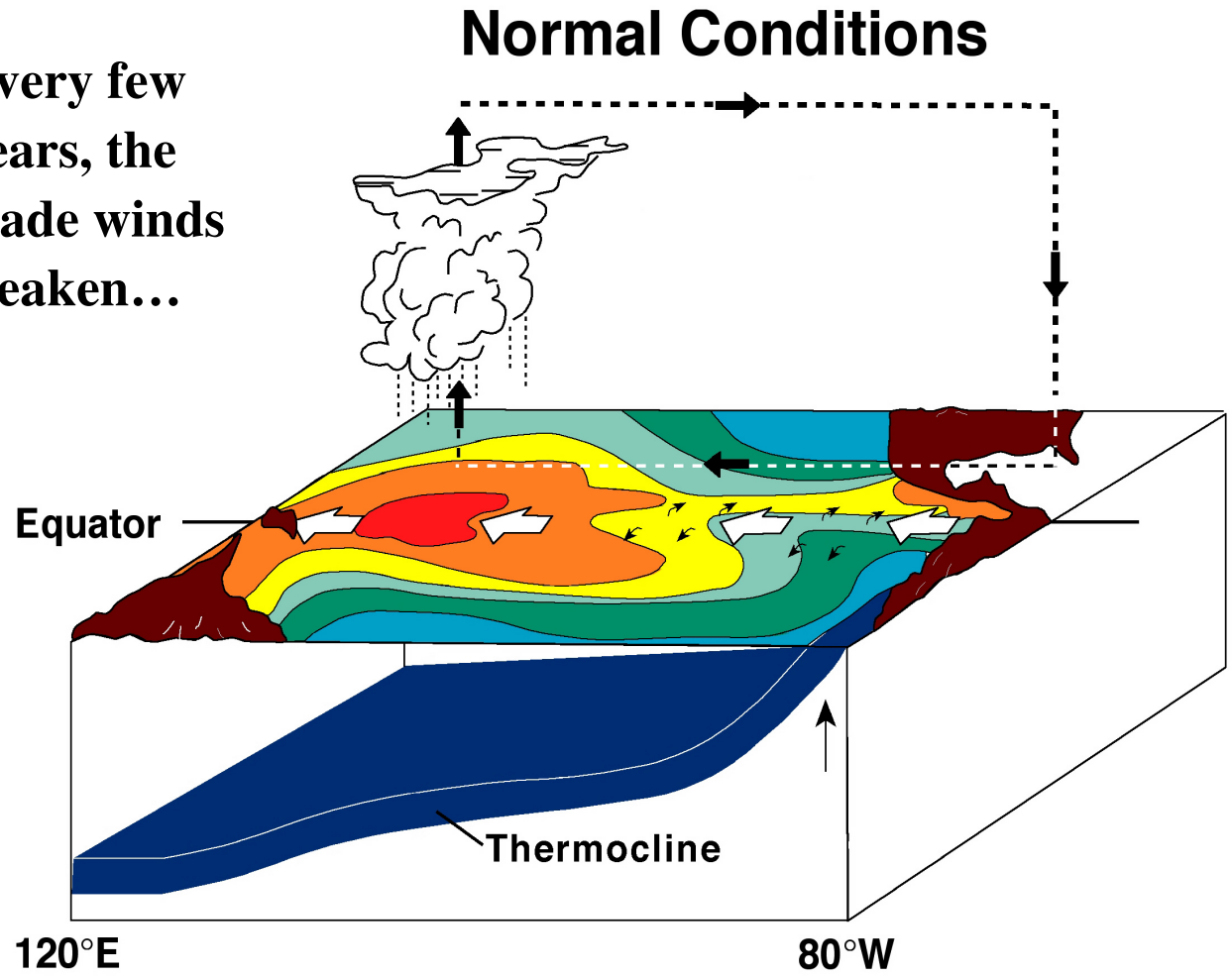


After Philander, 1990

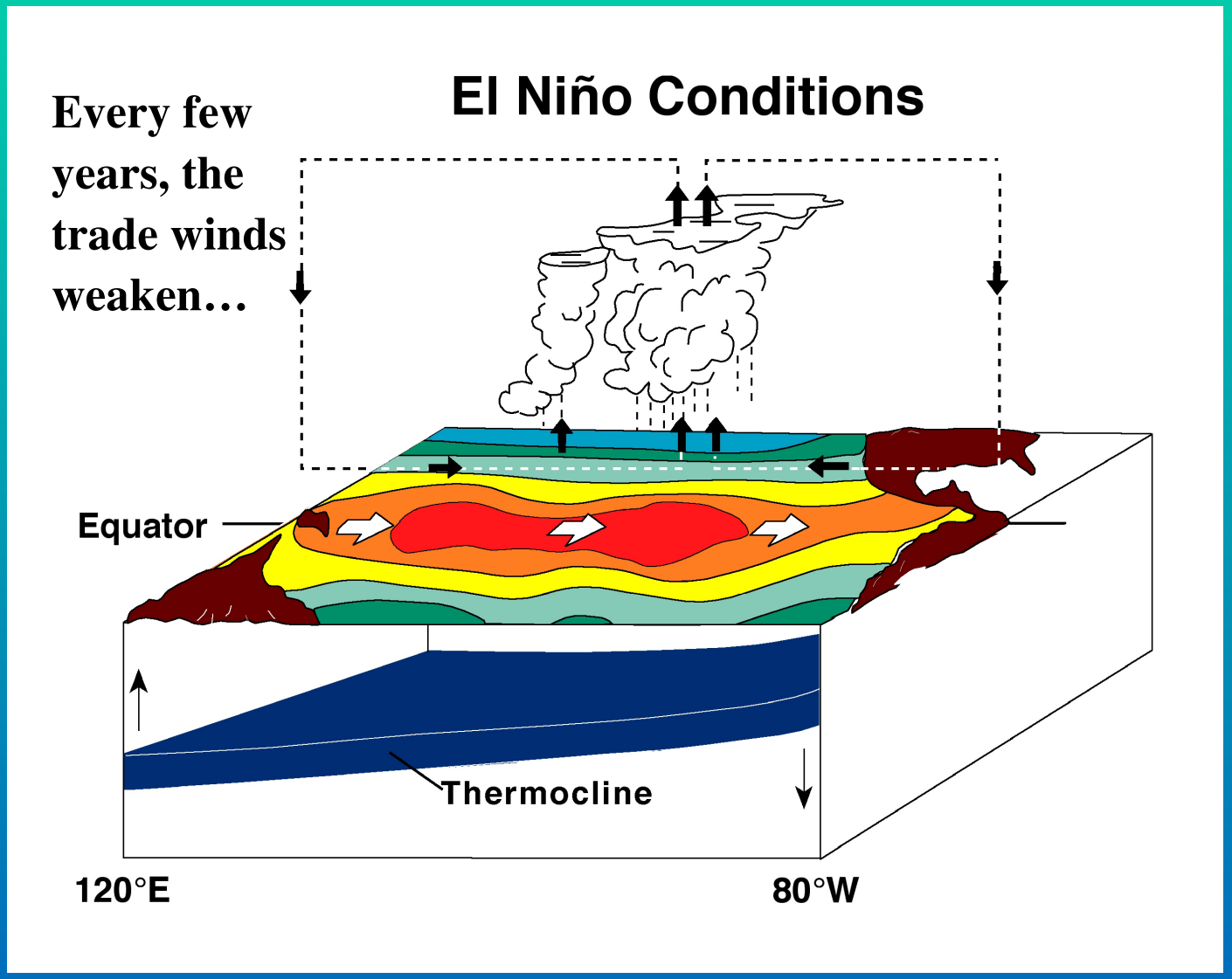


Normal

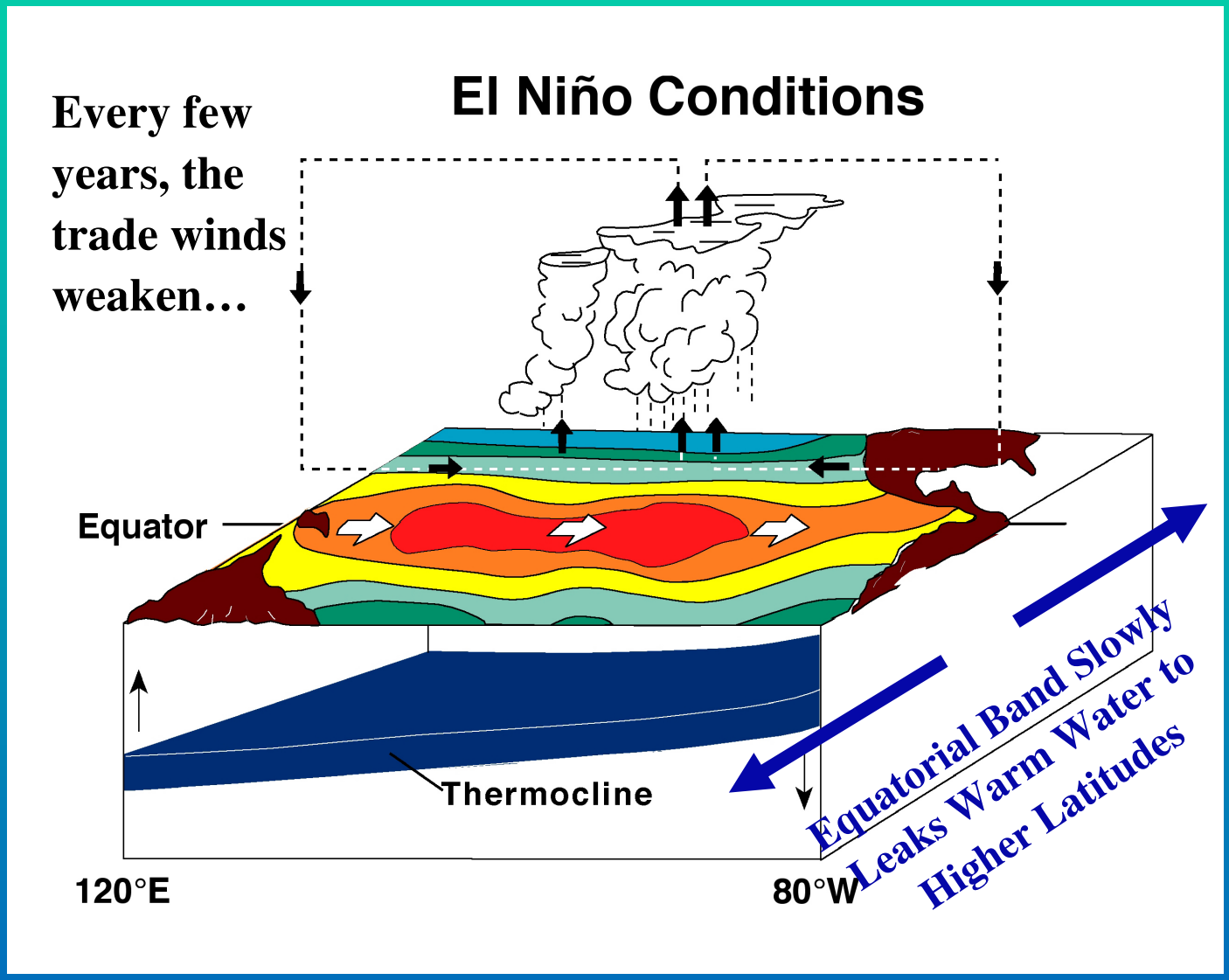
Every few years, the trade winds weaken…



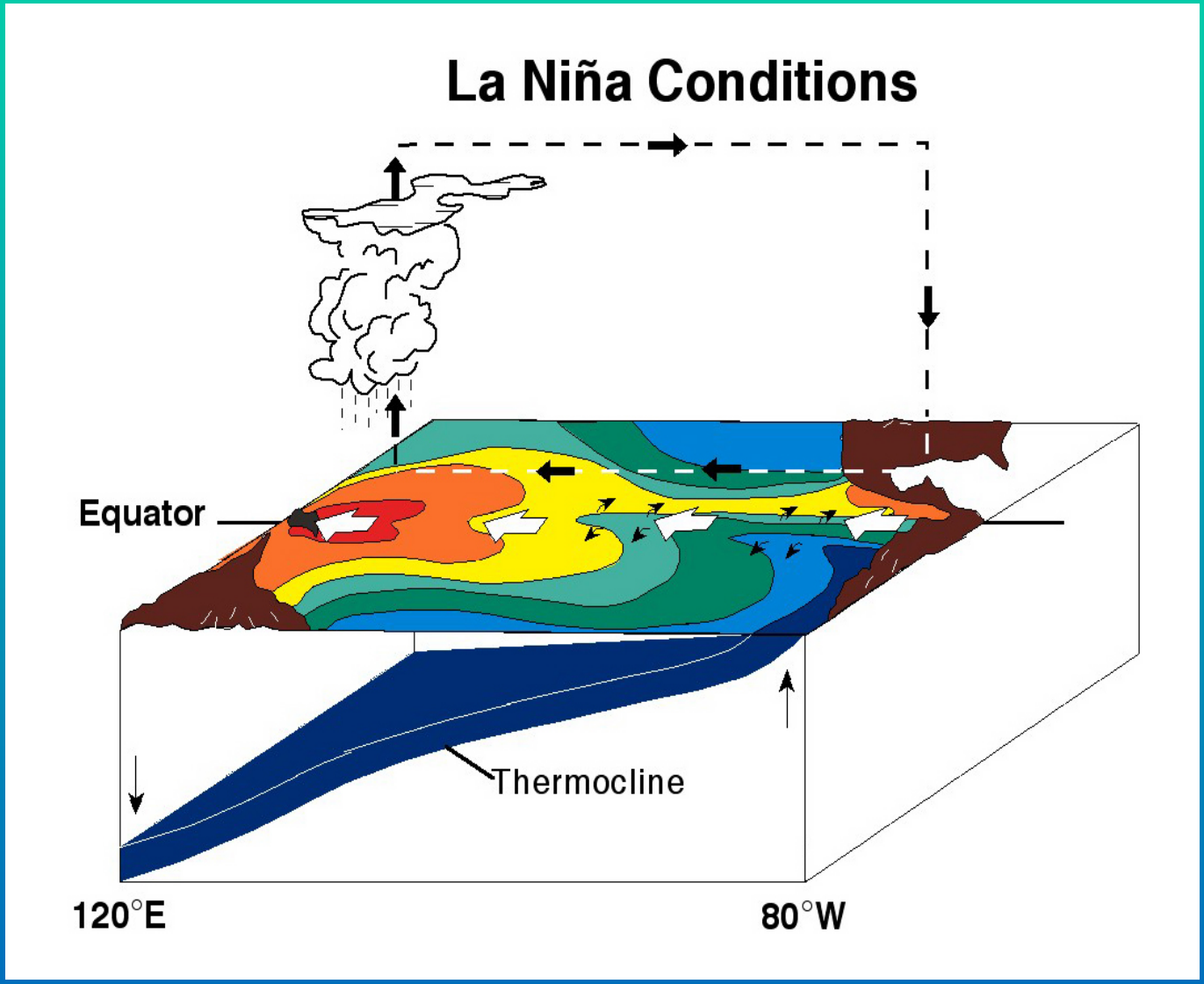
El Nino/Normal


El Niño Conditions
Every few years, the trade winds weaken…
Equator
Thermocline
120°E
80°W

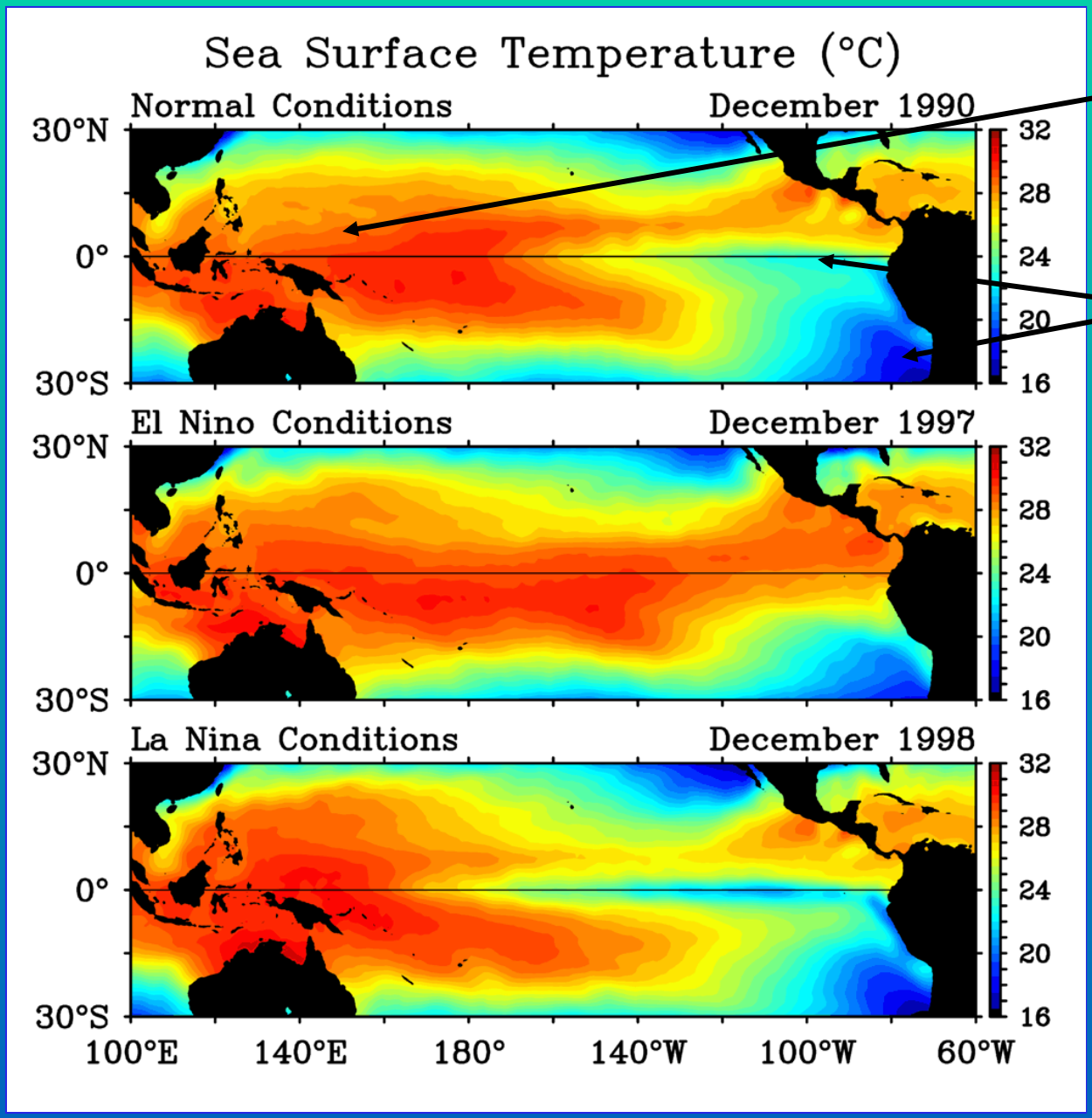
El Nino


El Niño Conditions
Every few years, the trade winds weaken…
Equator
Thermocline
120°E
80°W
Equatorial Band Slowly Leaks Warm Water to Higher Latitudes

El Nino



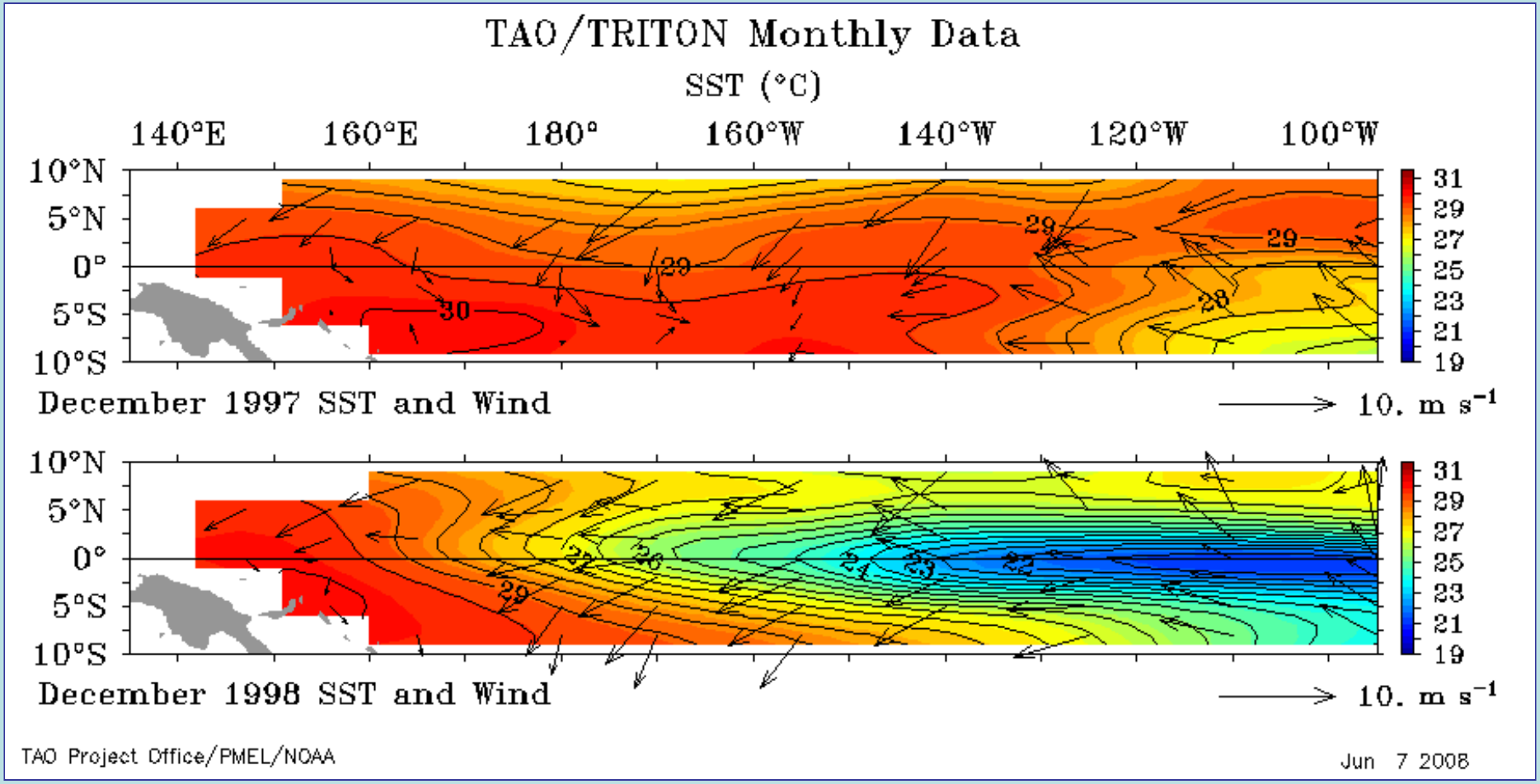
La Nina



Western Pacific "warm pool"

Upwelling zones

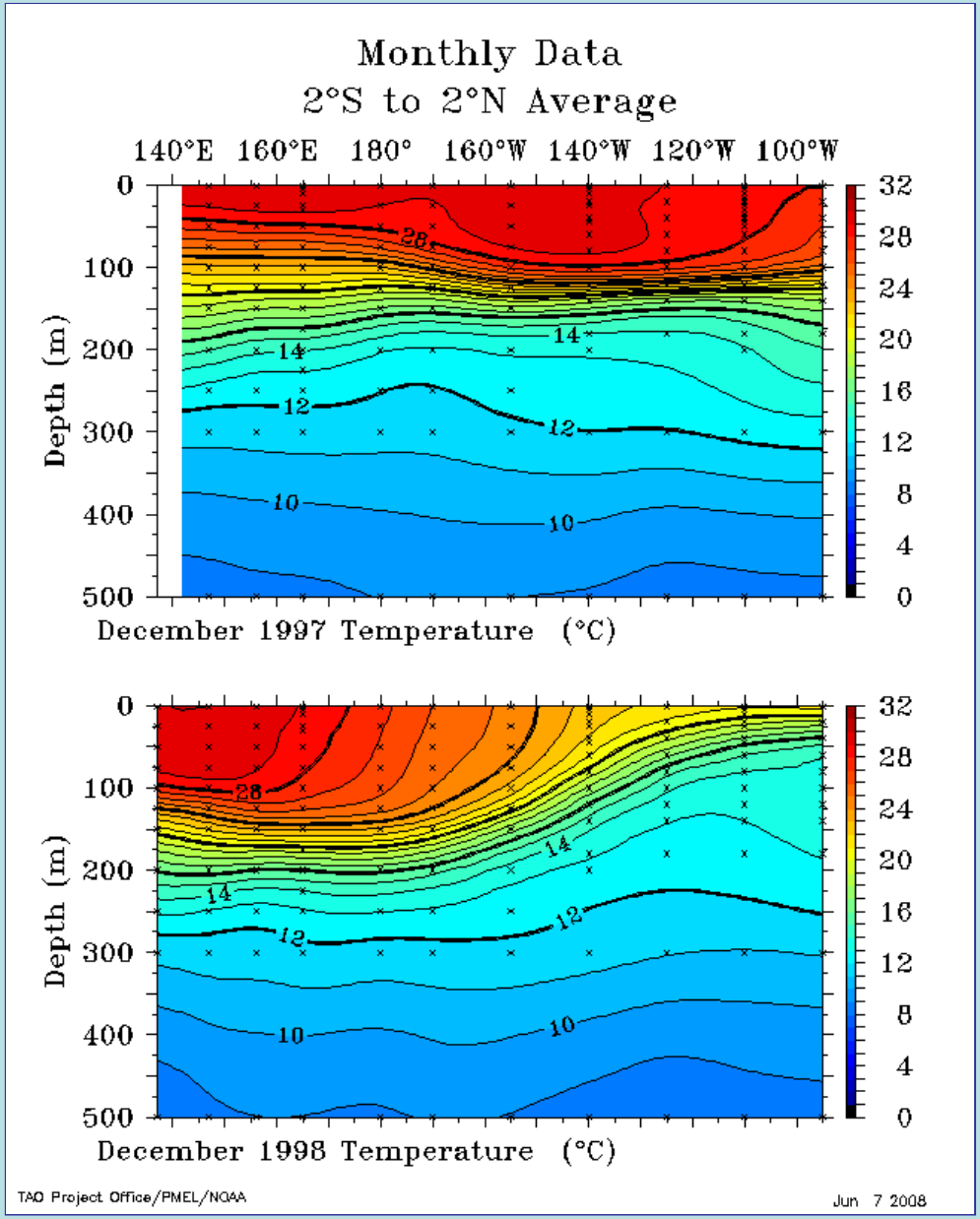
El Niño/La Niña Winds & SST



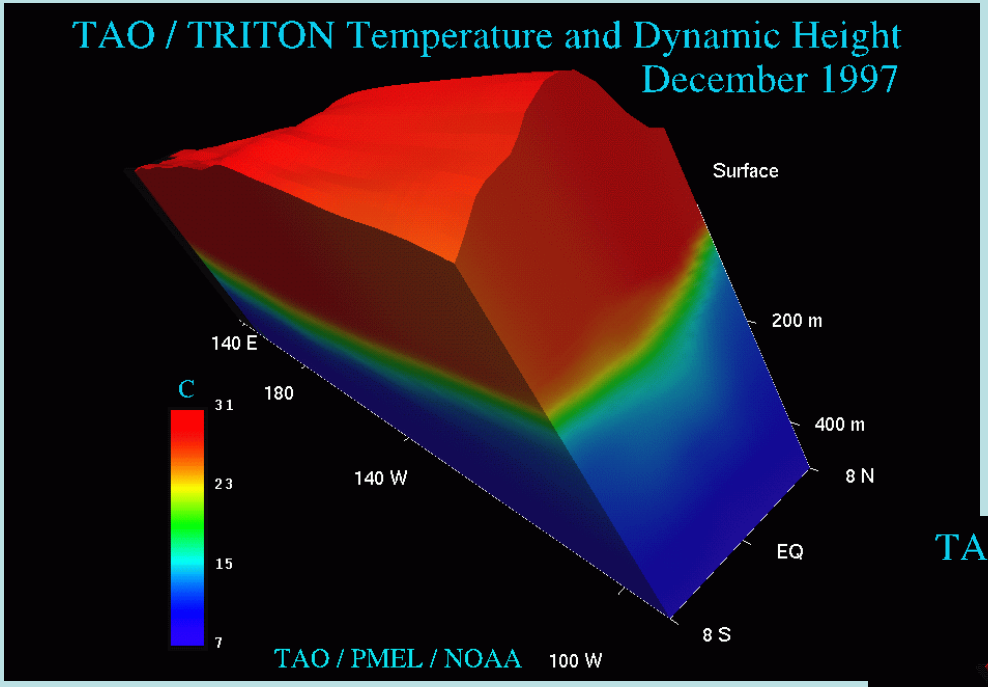
Equatorial Thermocline

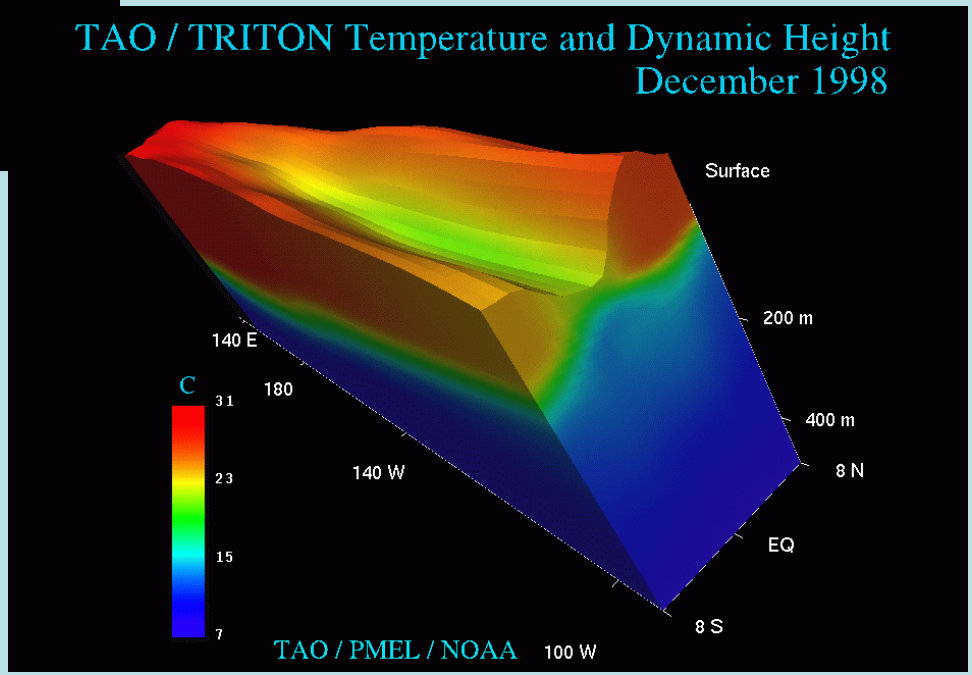
El Niño

La Niña



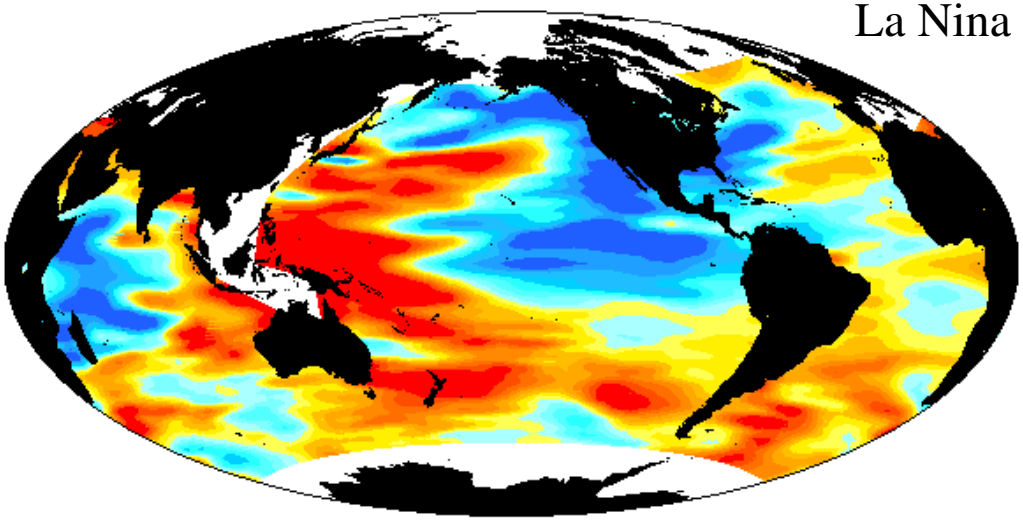
Thermal Structure & Surface Height

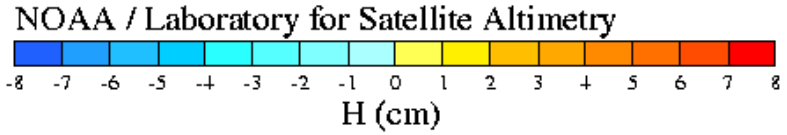




T/P Sea Level Deviation Winter 2000-01

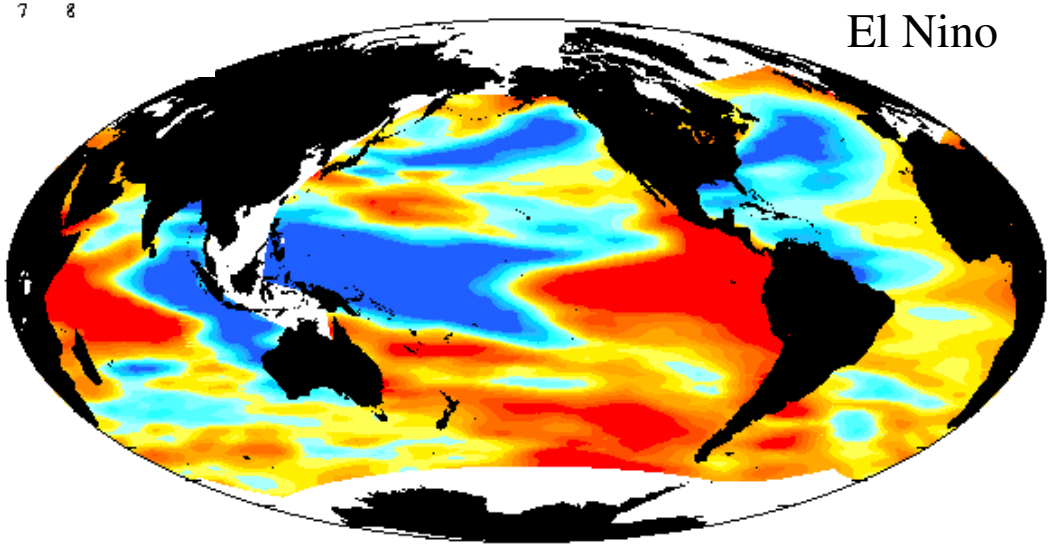
La Nina

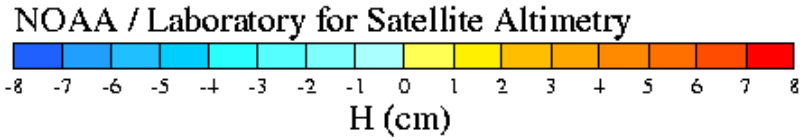




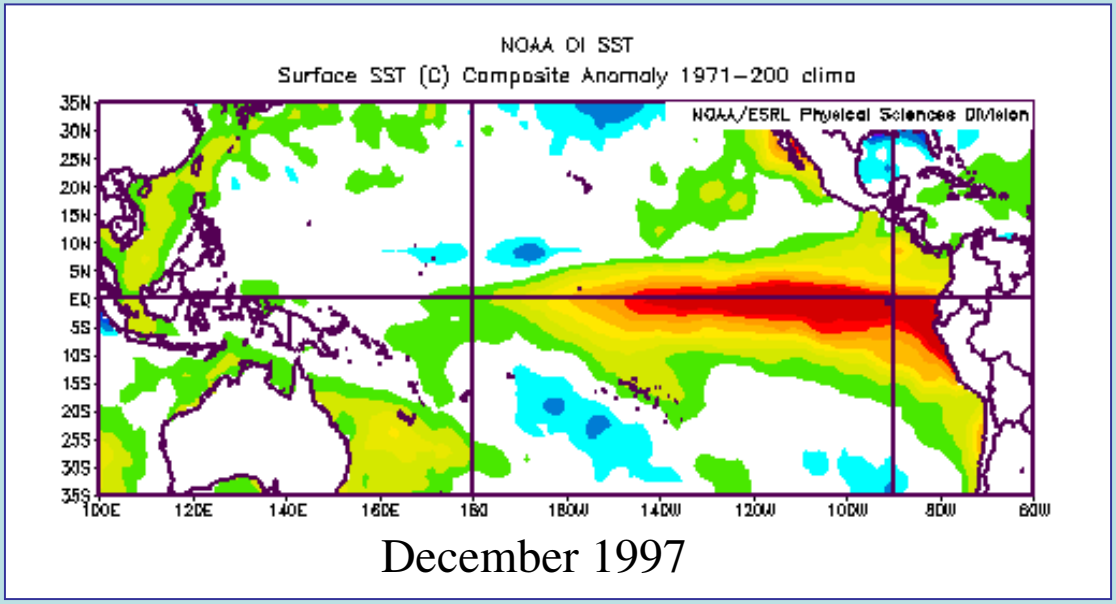
T/P Sea Level Deviation Winter 97-98

El Nino

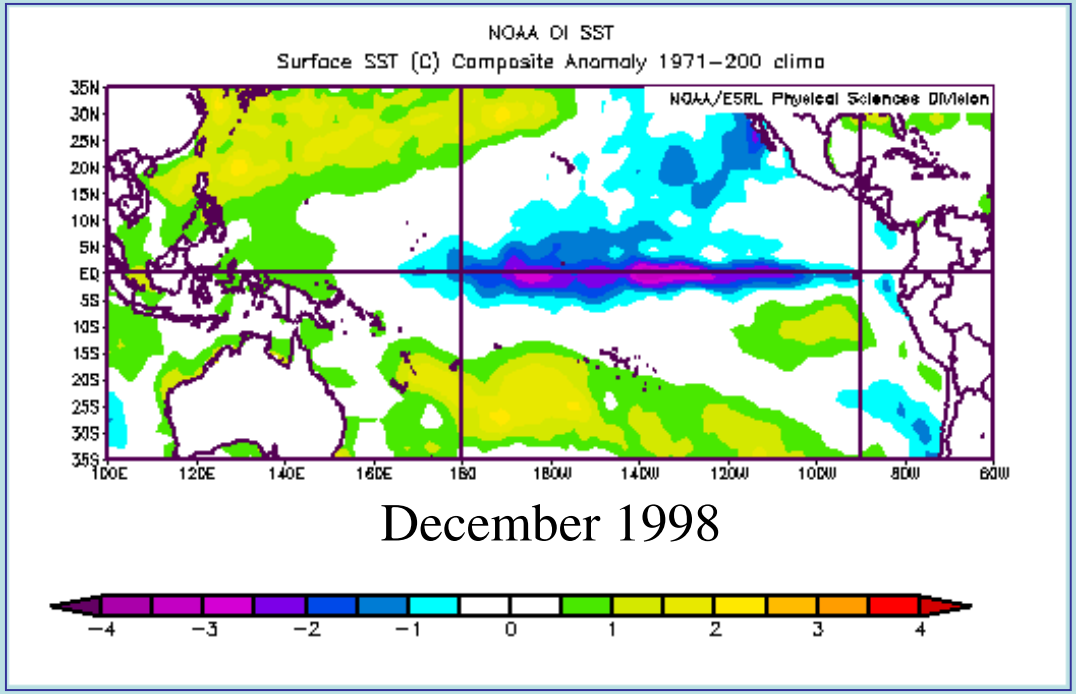




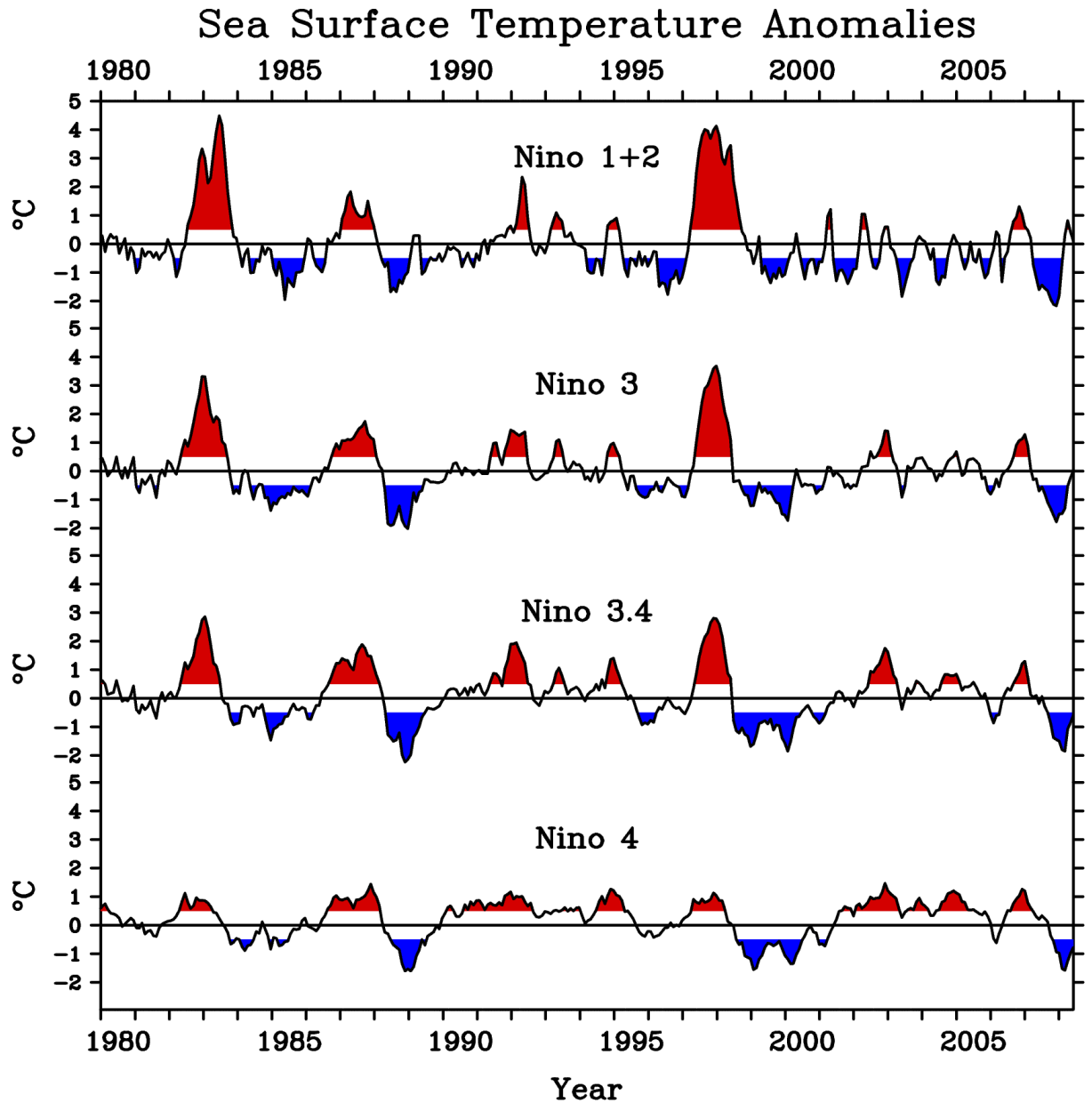
SST Anomalies



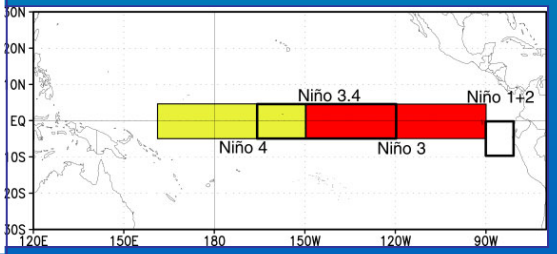
December 1997

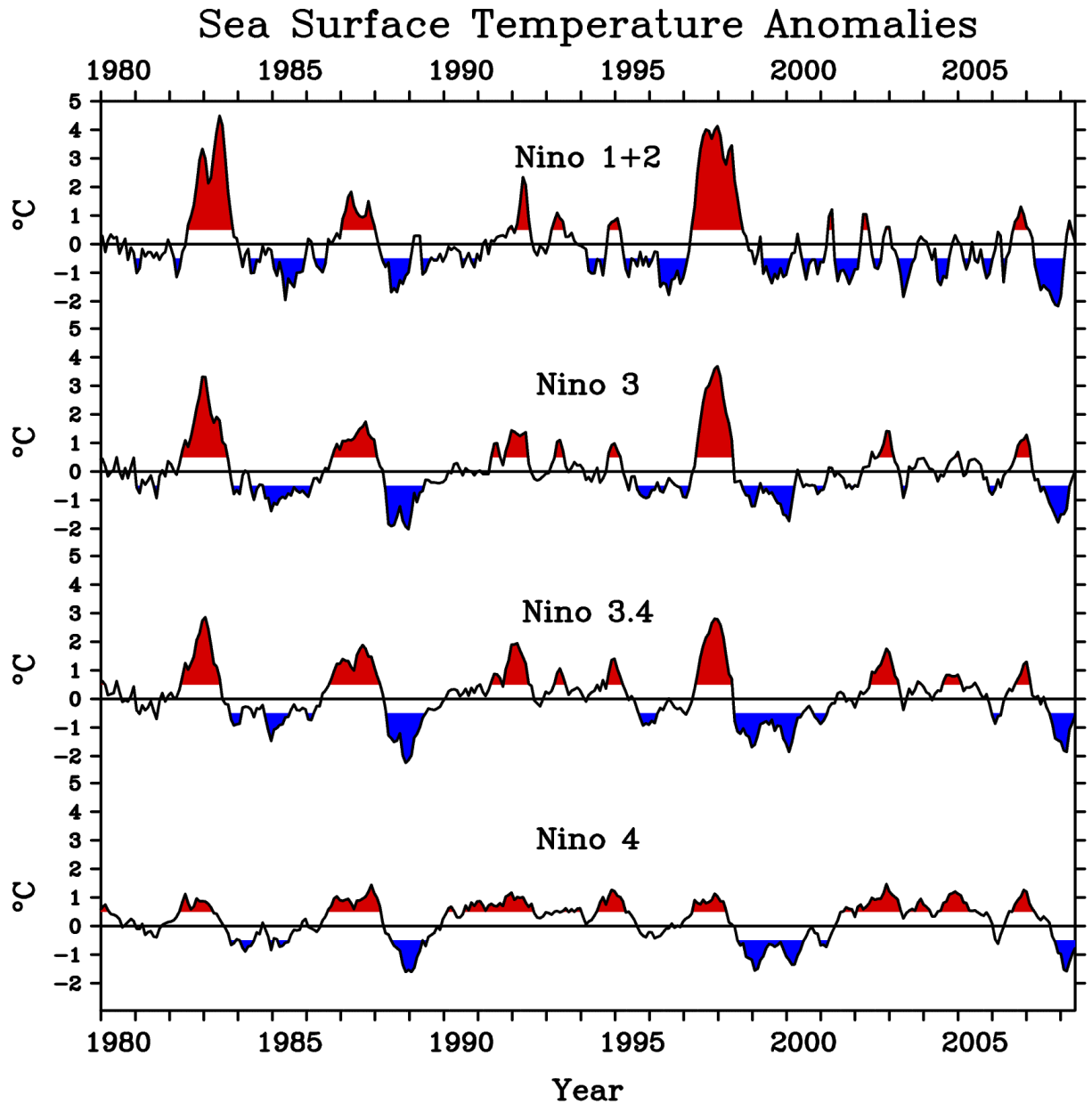


December 1998



El Niños and La Niñas occur every 2-7 years.





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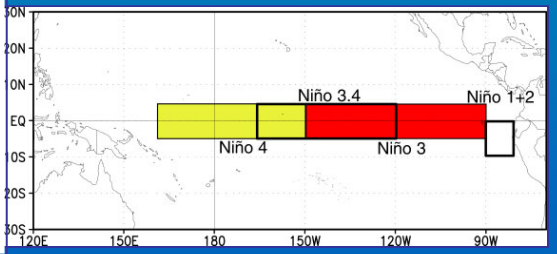
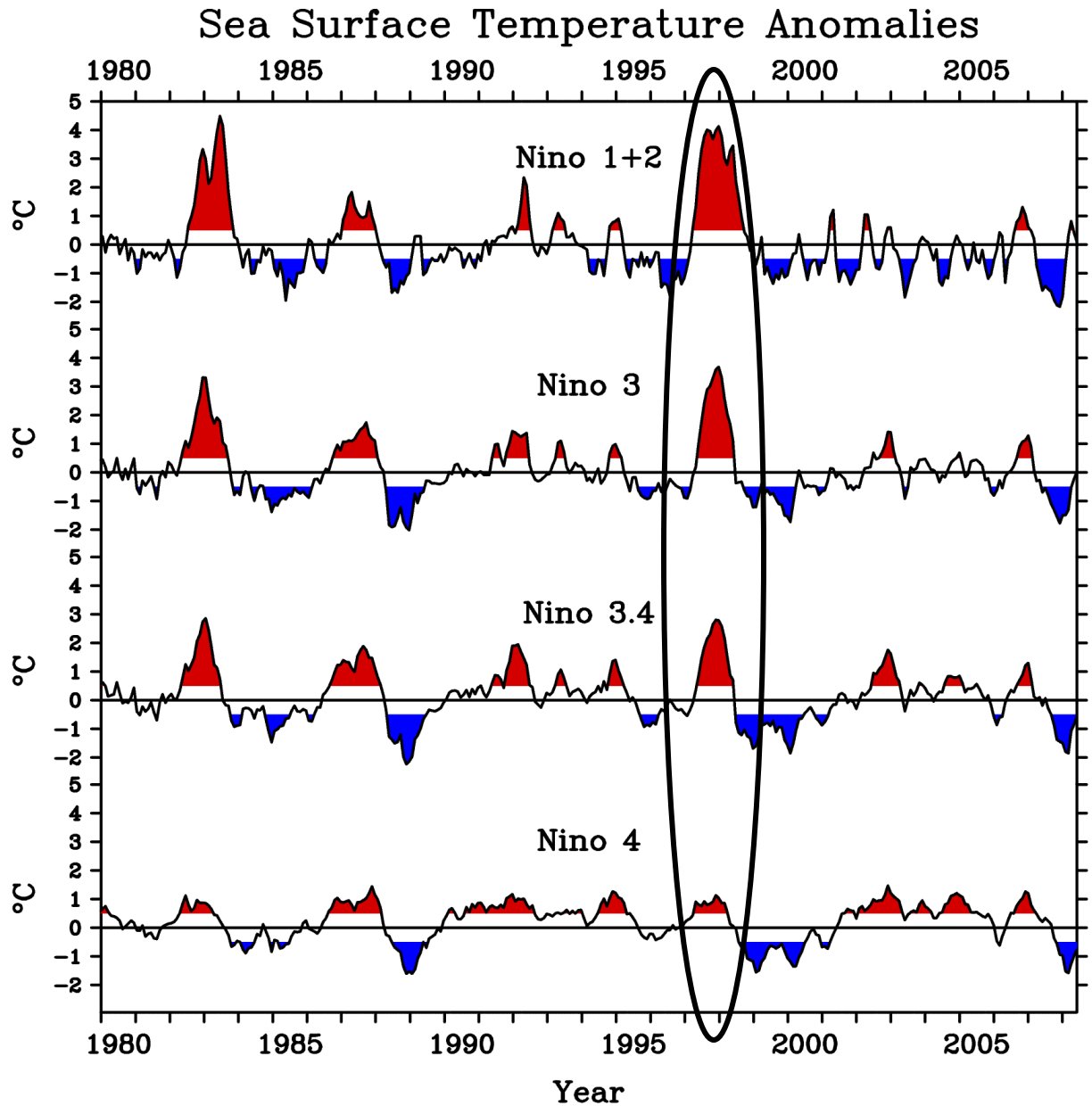
"Skewness": Strong El Niños stronger than strong La Niñas.





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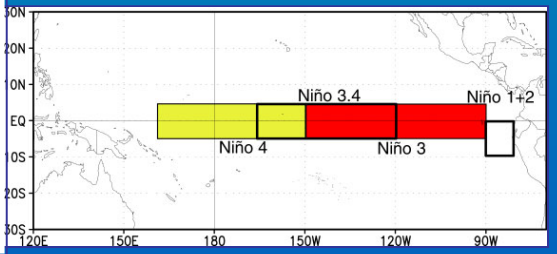

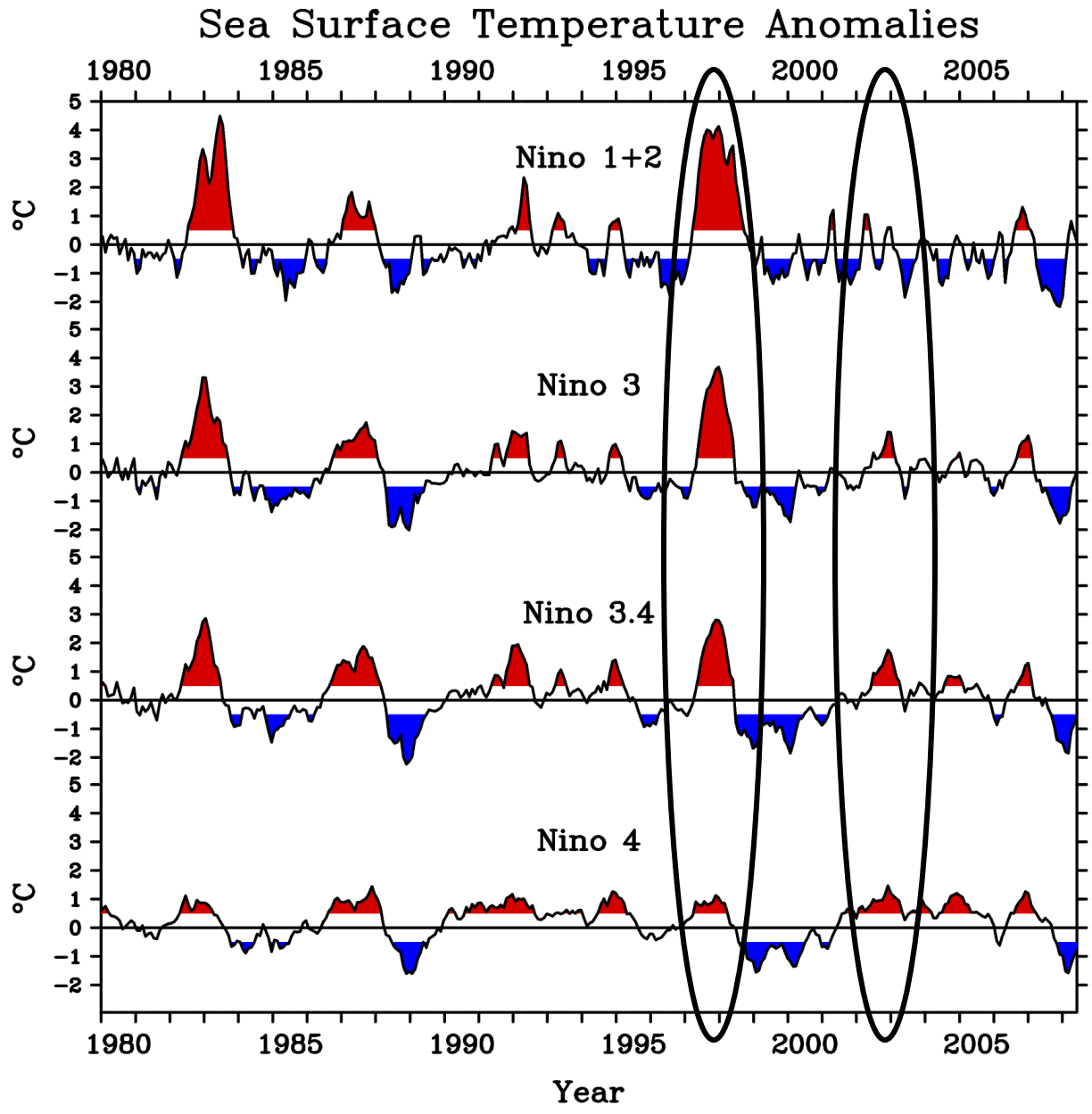

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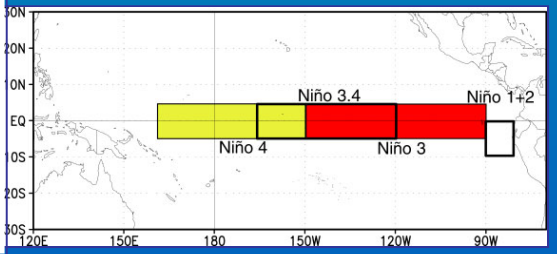
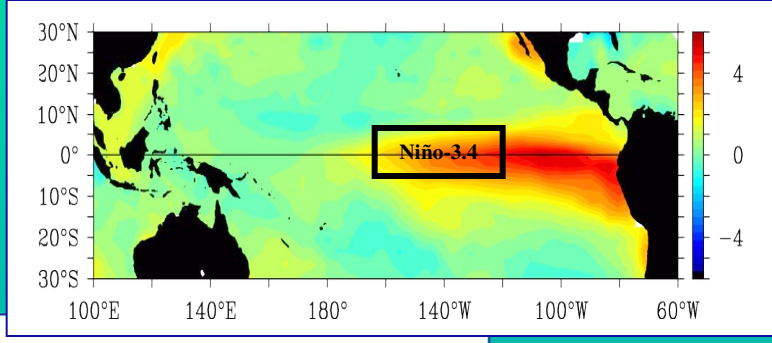
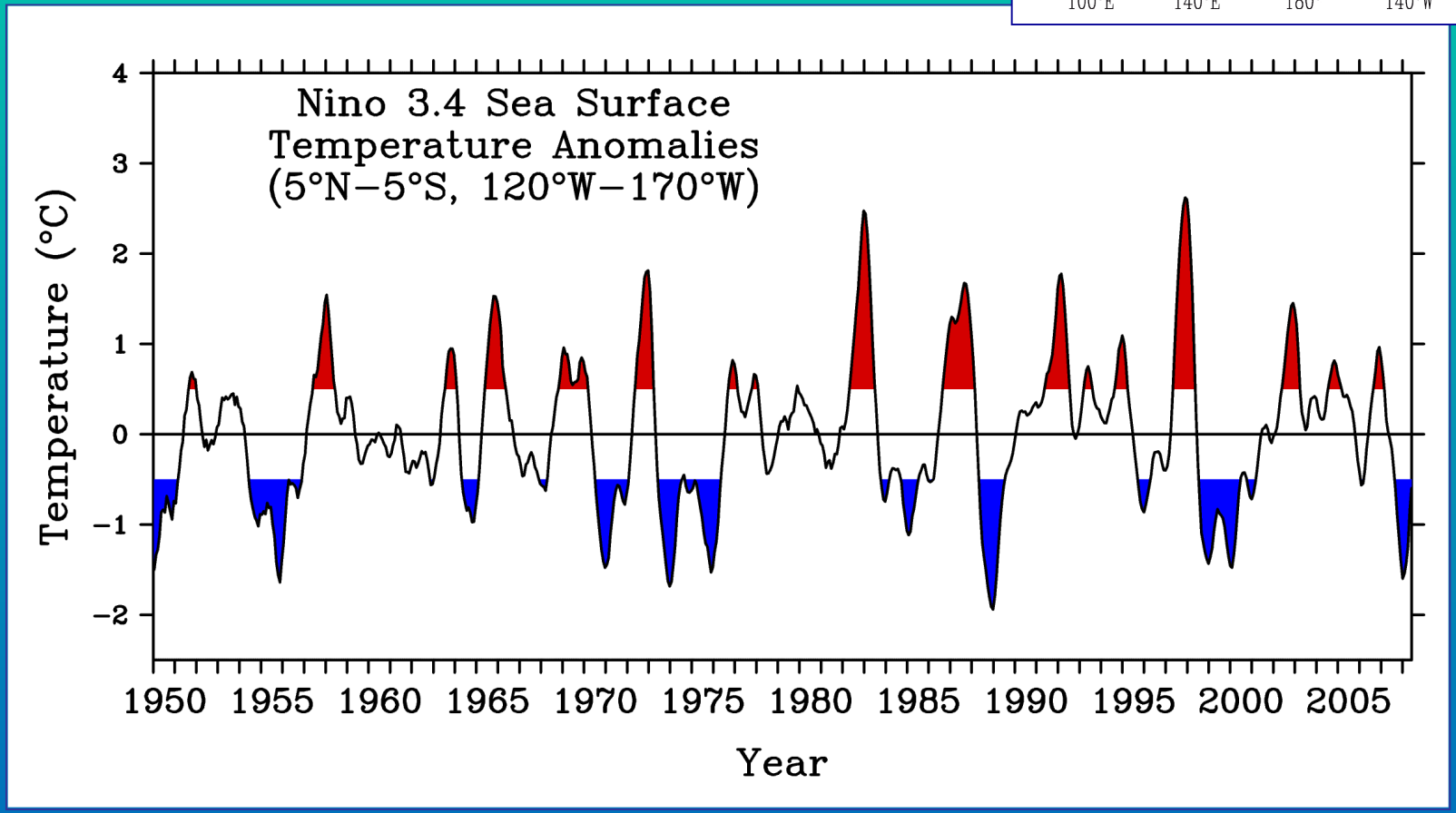


El Niño & La Niña Index

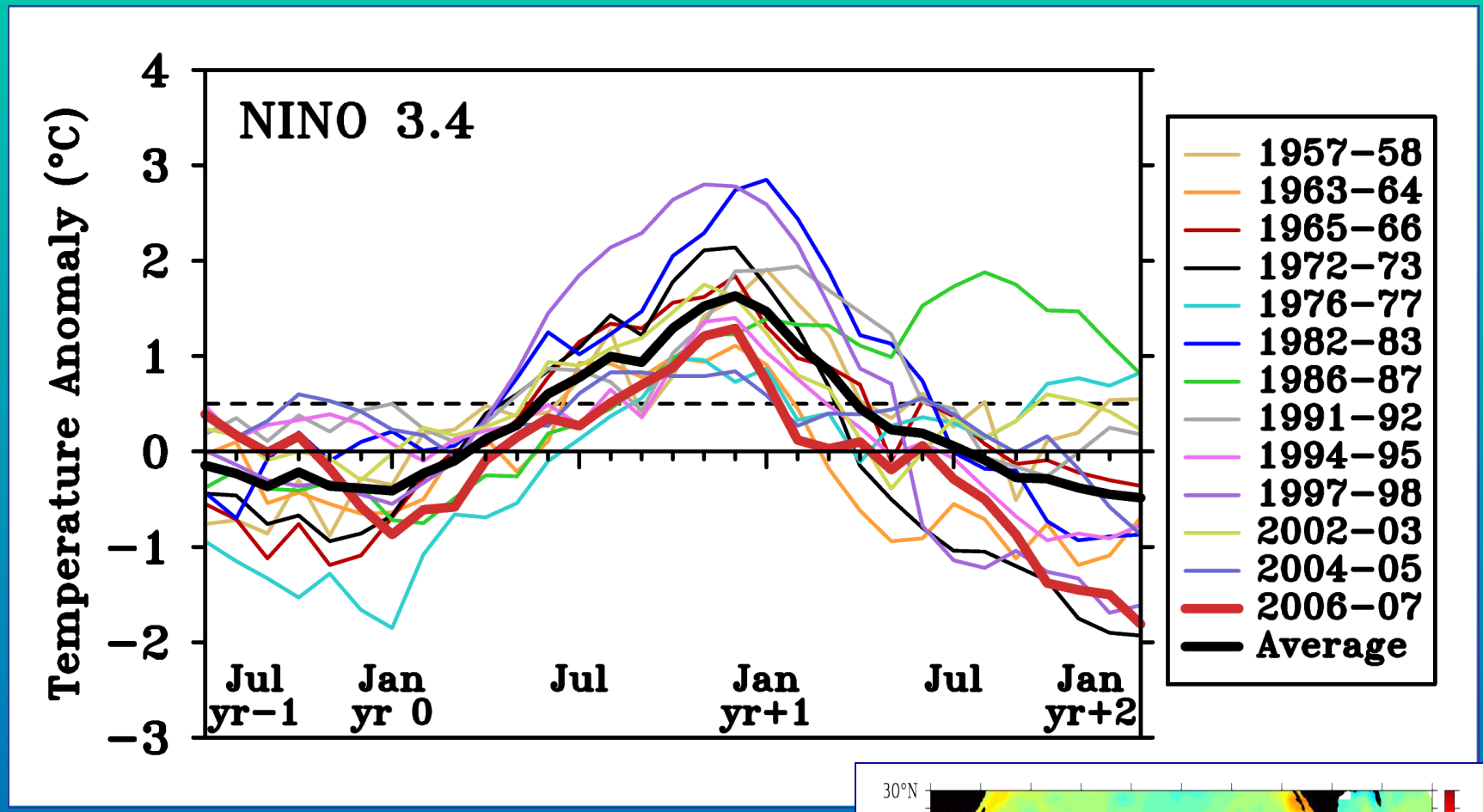


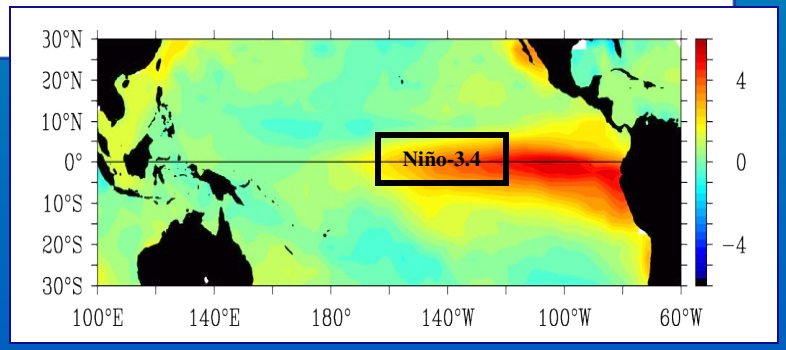


NINO3.4 ≥ 0.5°C for 5 months= El Niño

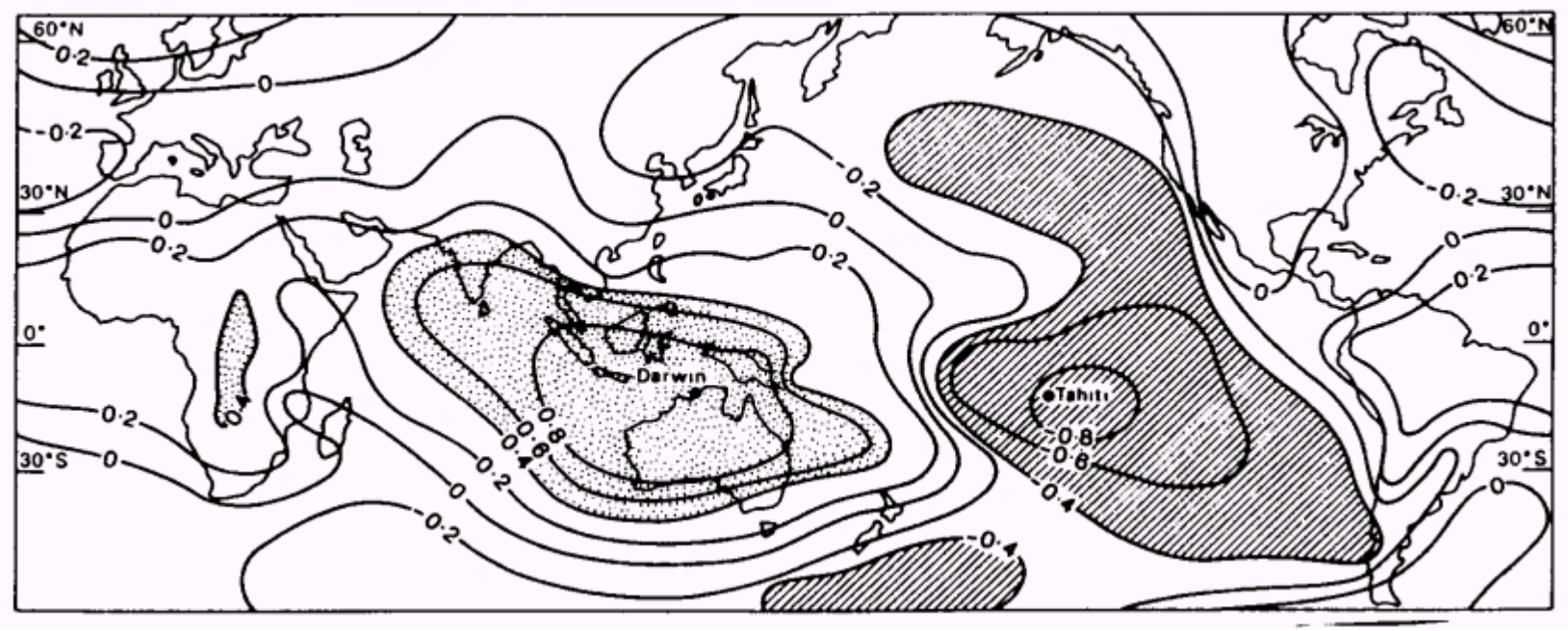
NINO3.4 ≤ -0.5°C for 5 months= La Niña

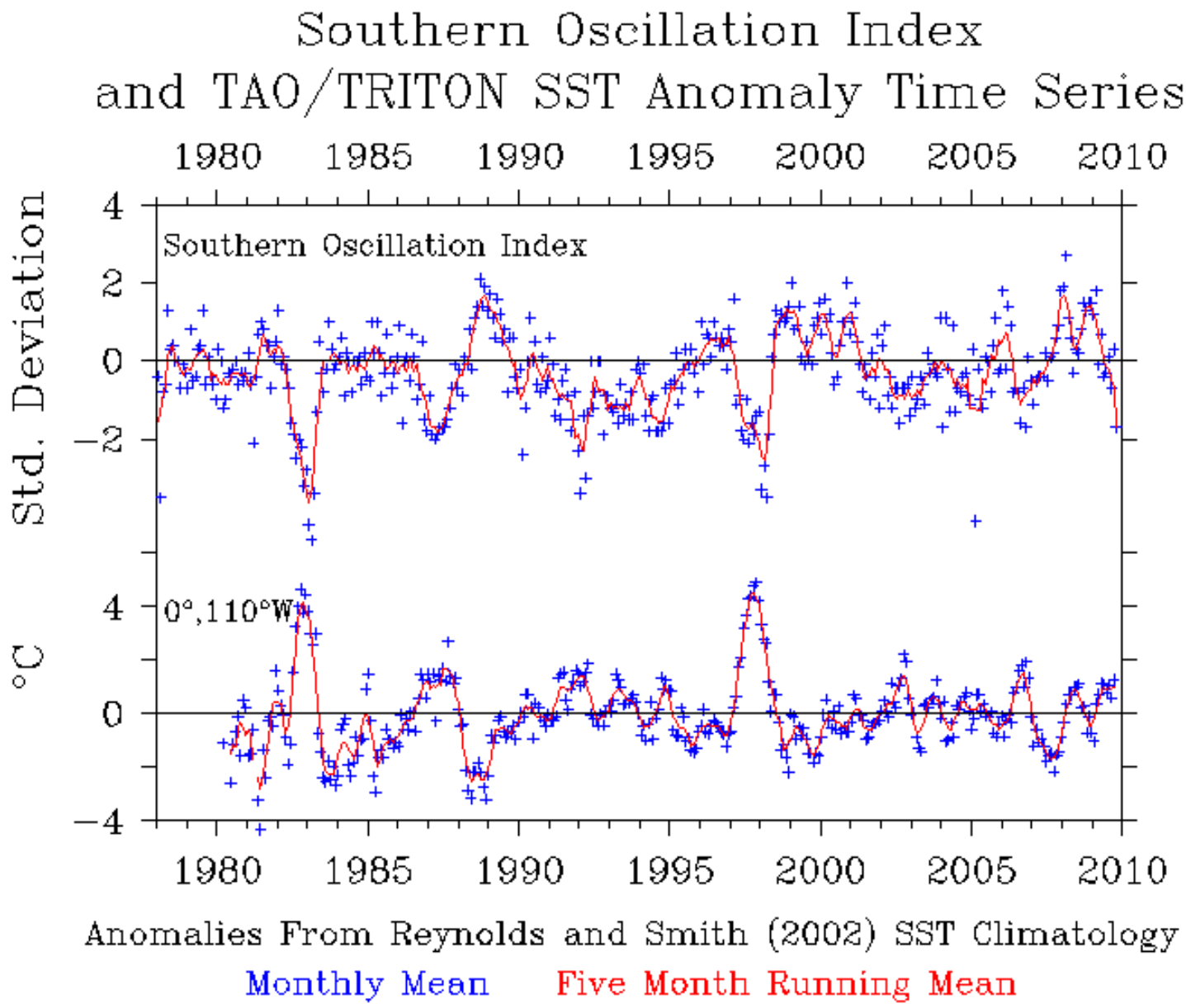
El Niño Events Since 1957





The Southern Oscillation





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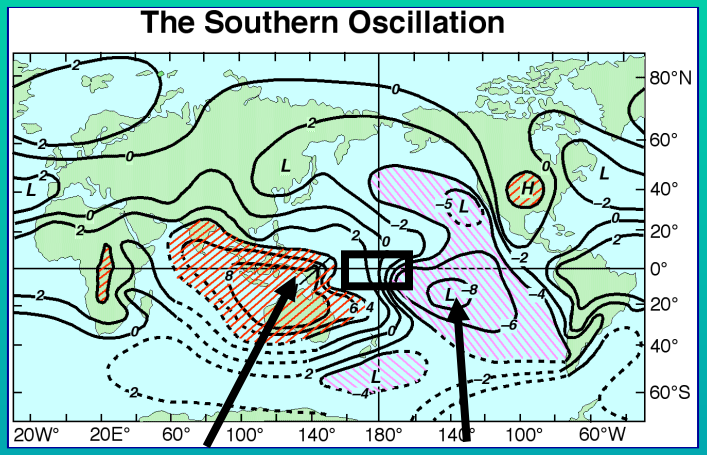
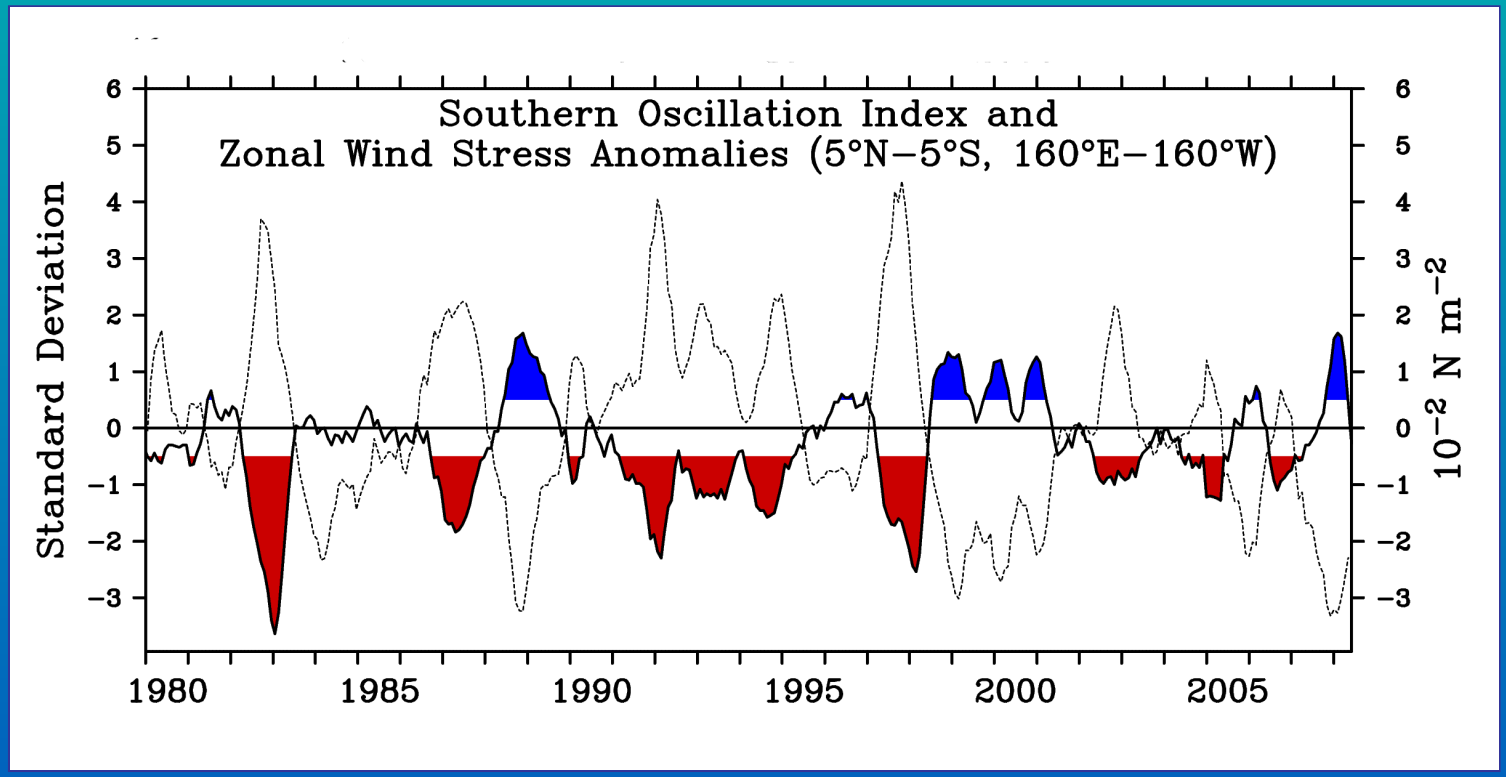
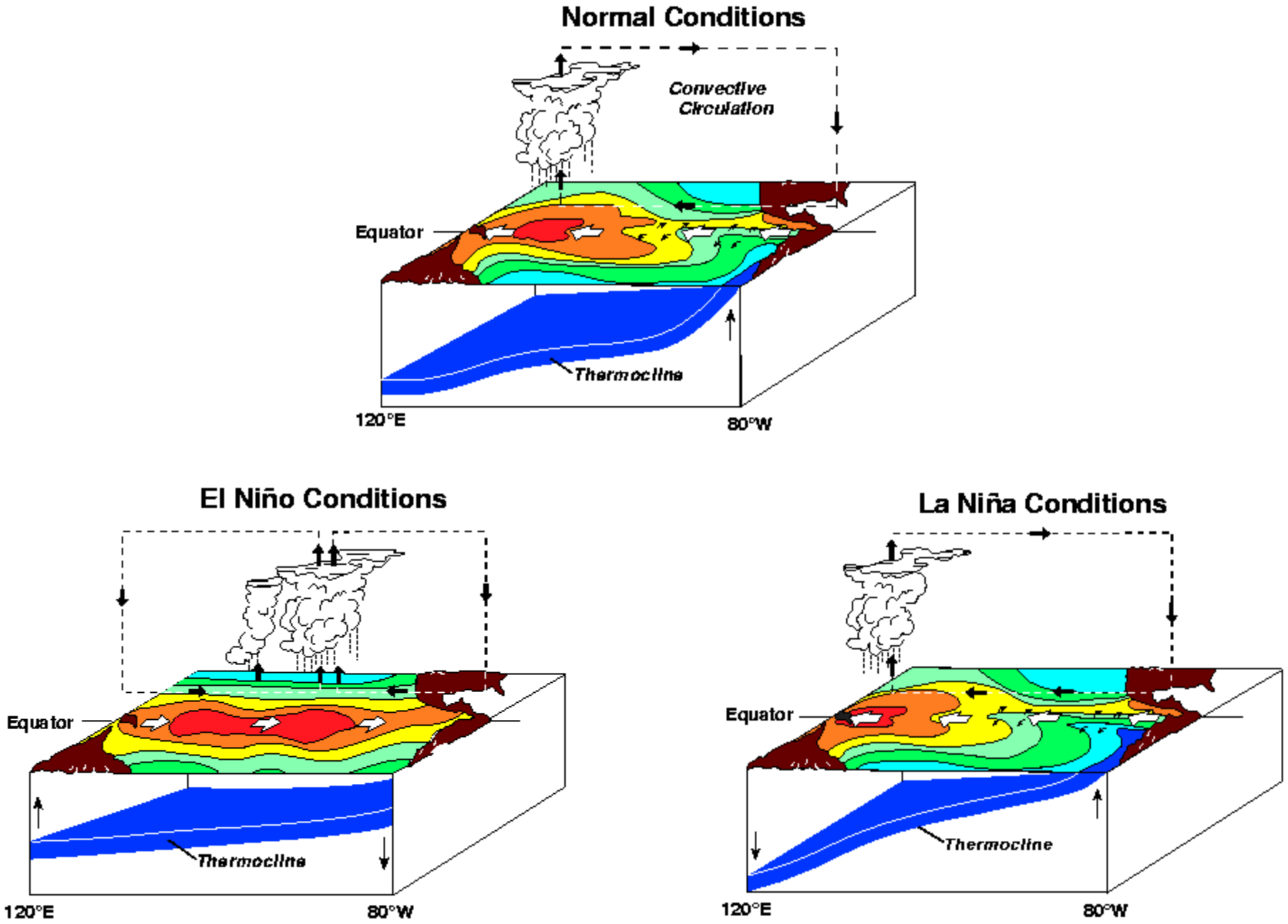
Nov 30 2009

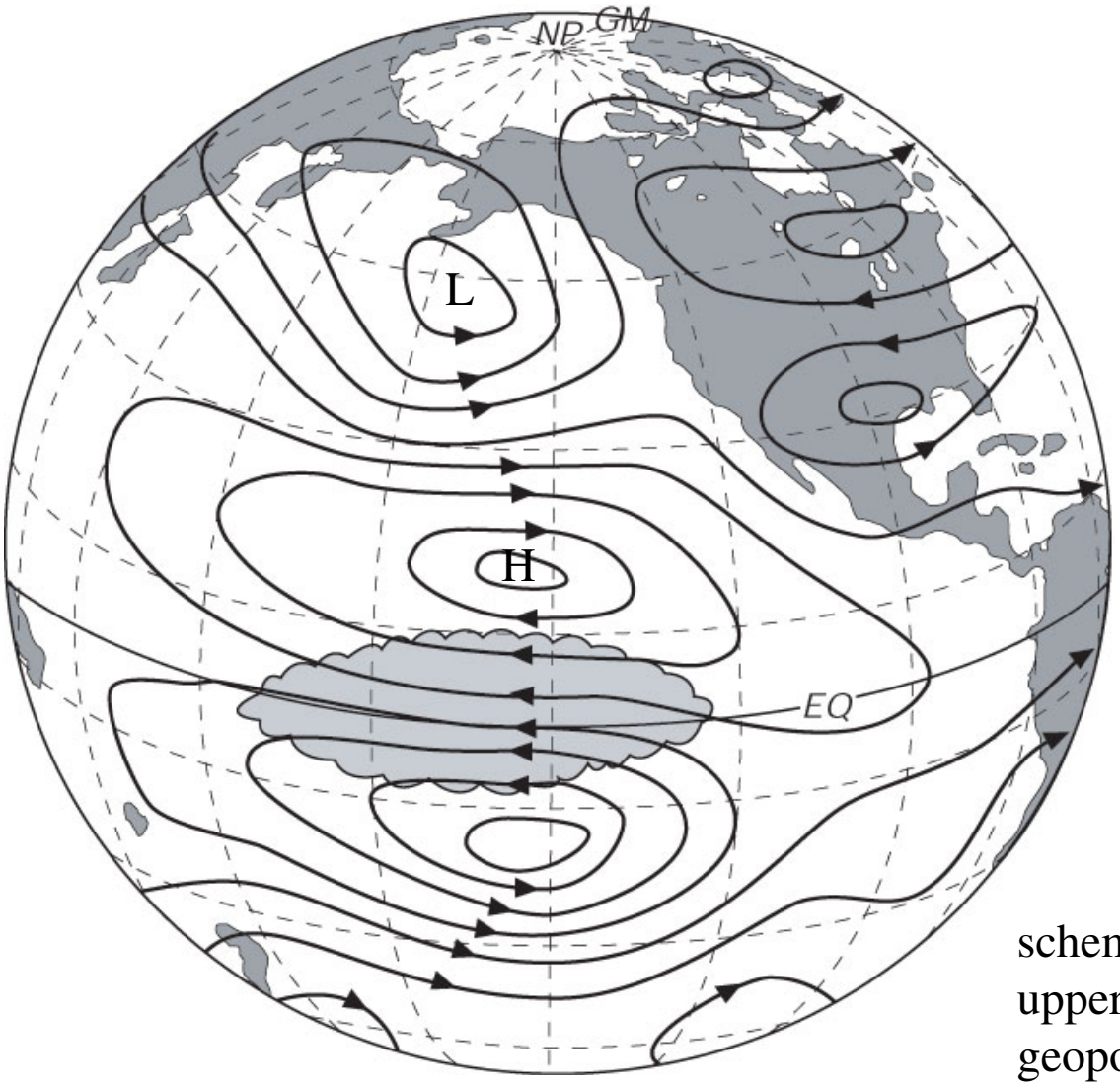
SOI: an Index of Trade Wind Strength





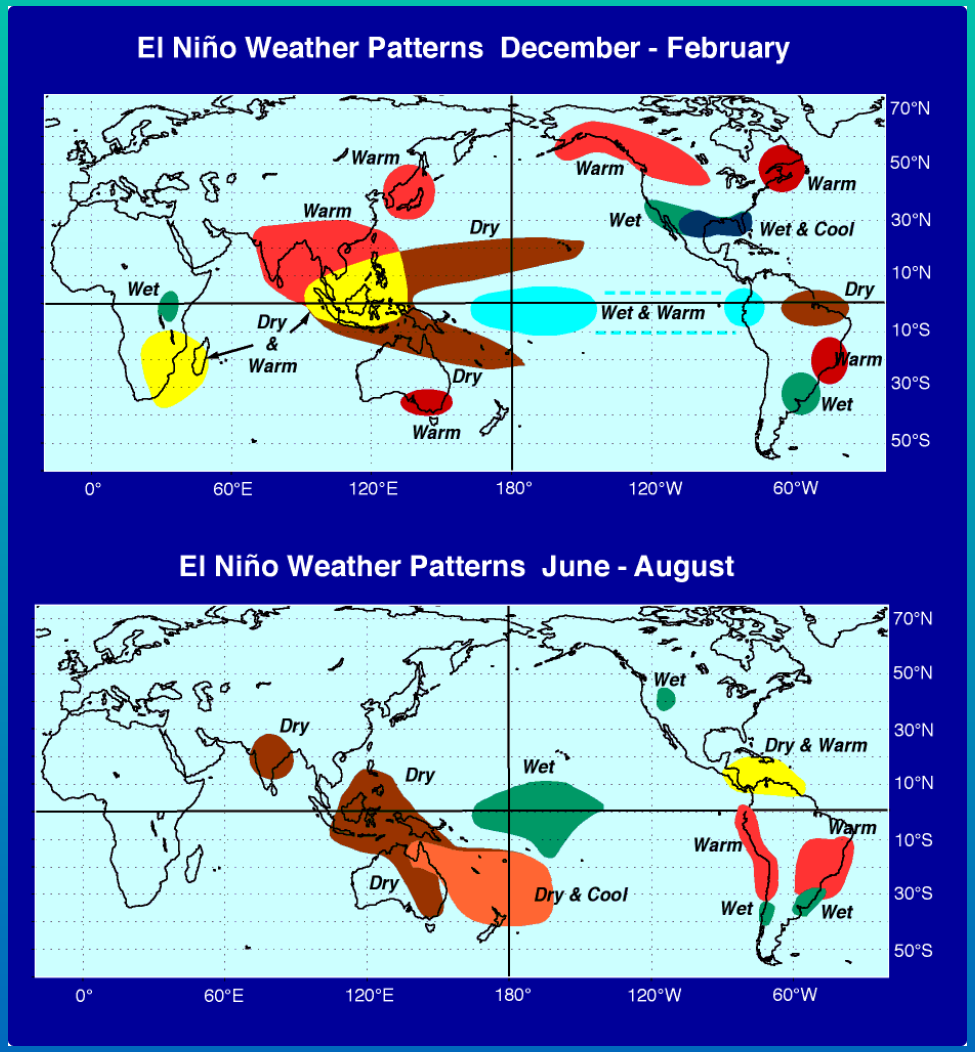

Normal Conditions
Convective Circulation
Equator
Thermocline
120°E
80°W
El Niño Conditions
Equator
Thermocline
120°E
80°W
La Niña Conditions
Equator
Thermocline
120°E
80°W

Atmospheric Teleconnections



schematic of middle to upper tropospheric geopotential height during El Nino.

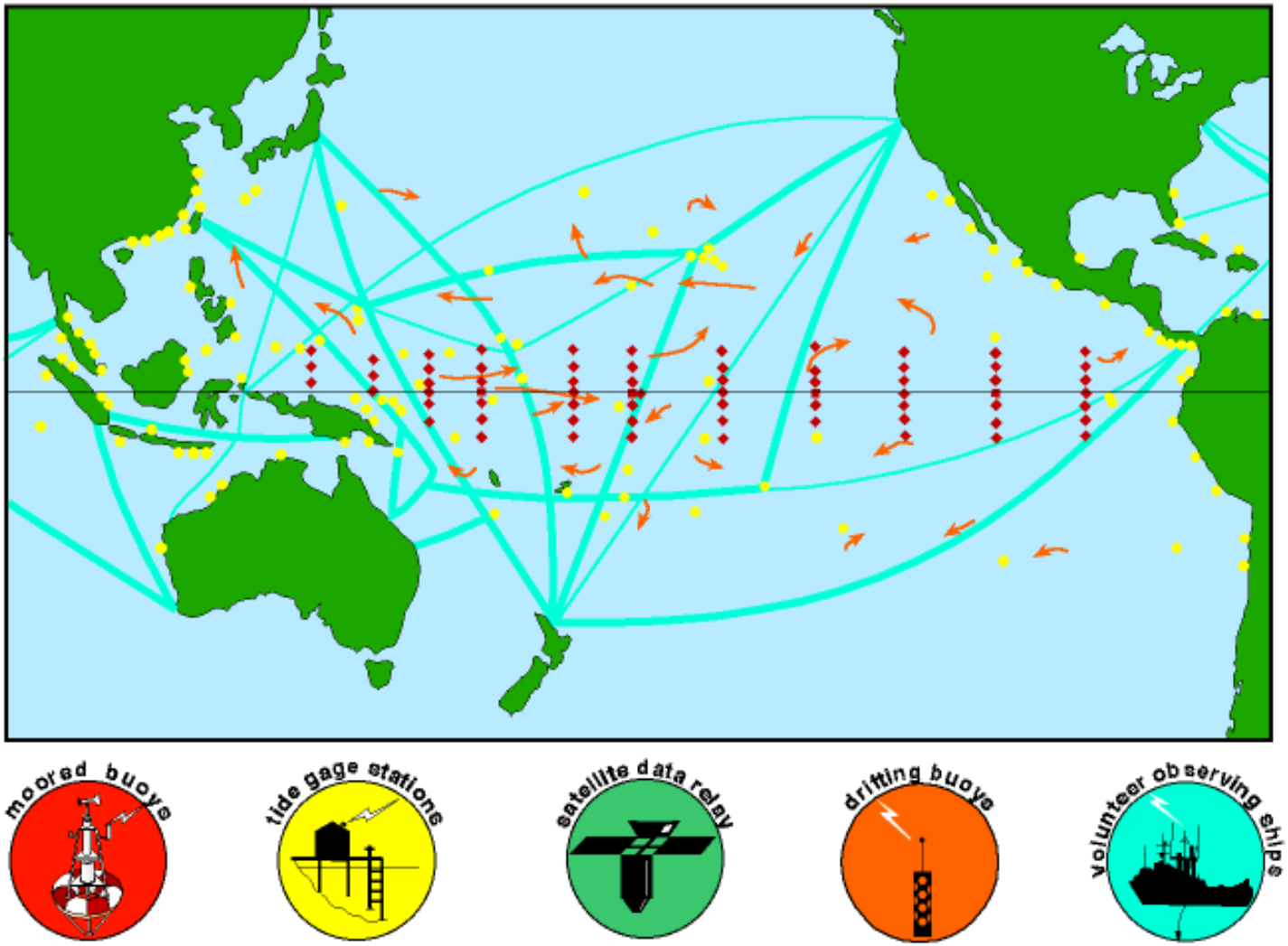
El Niño Impacts on Global Weather Patterns

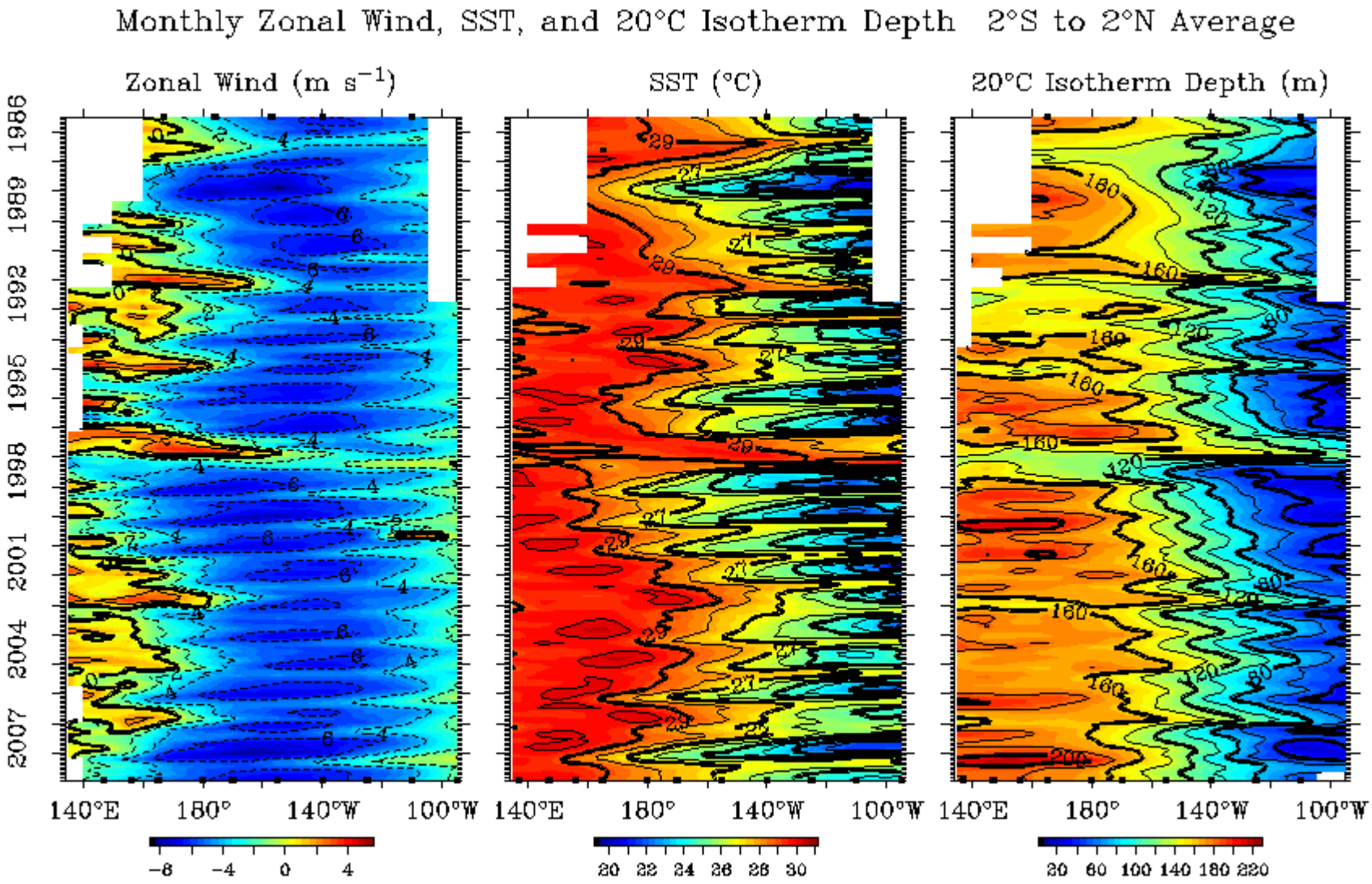


After Ropelewski and Halpert, 1986, 1992

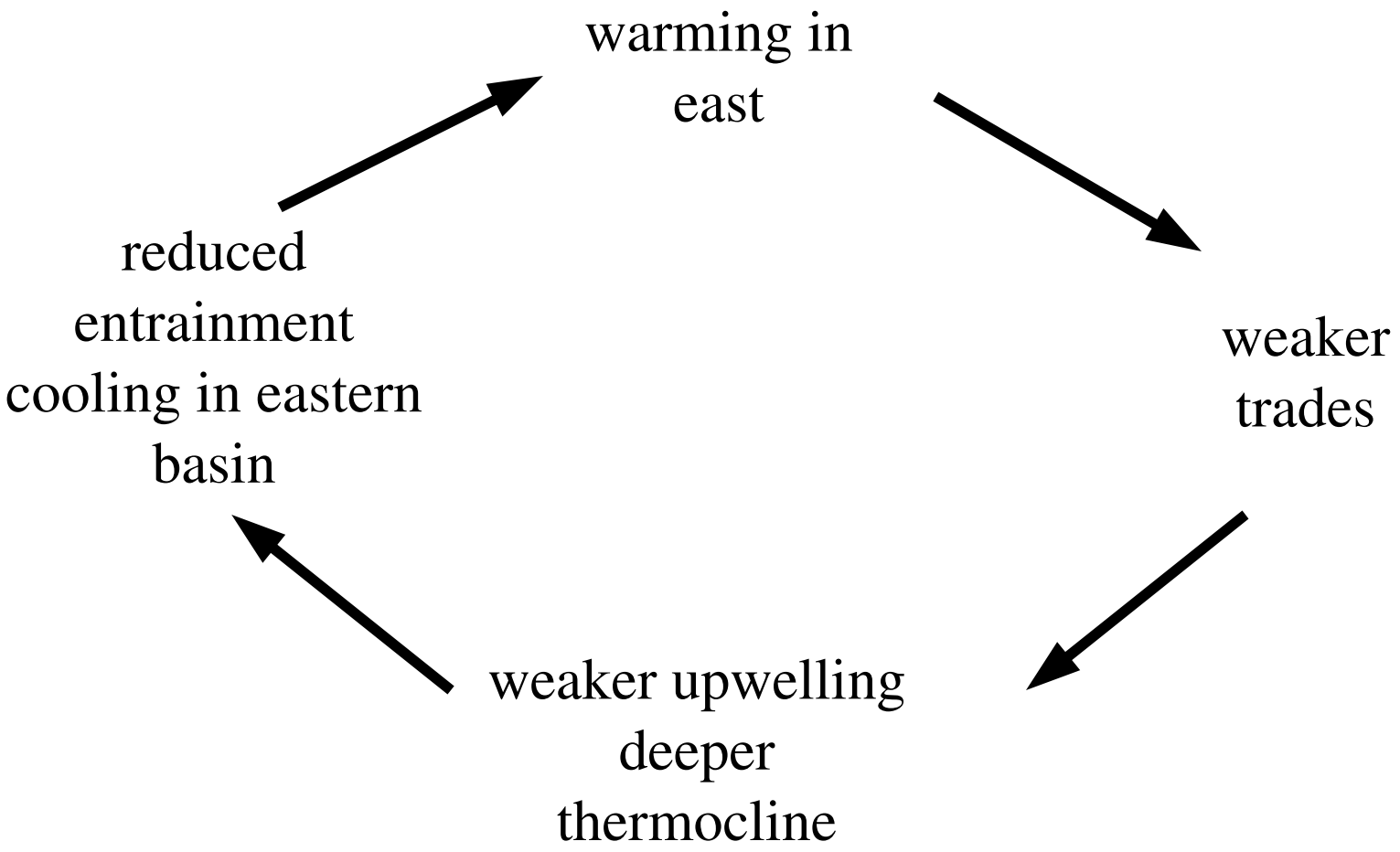
El Niño shifts the probability of droughts, floods, heat waves, and extreme weather events in large regions of the globe.

ENSO Observing System

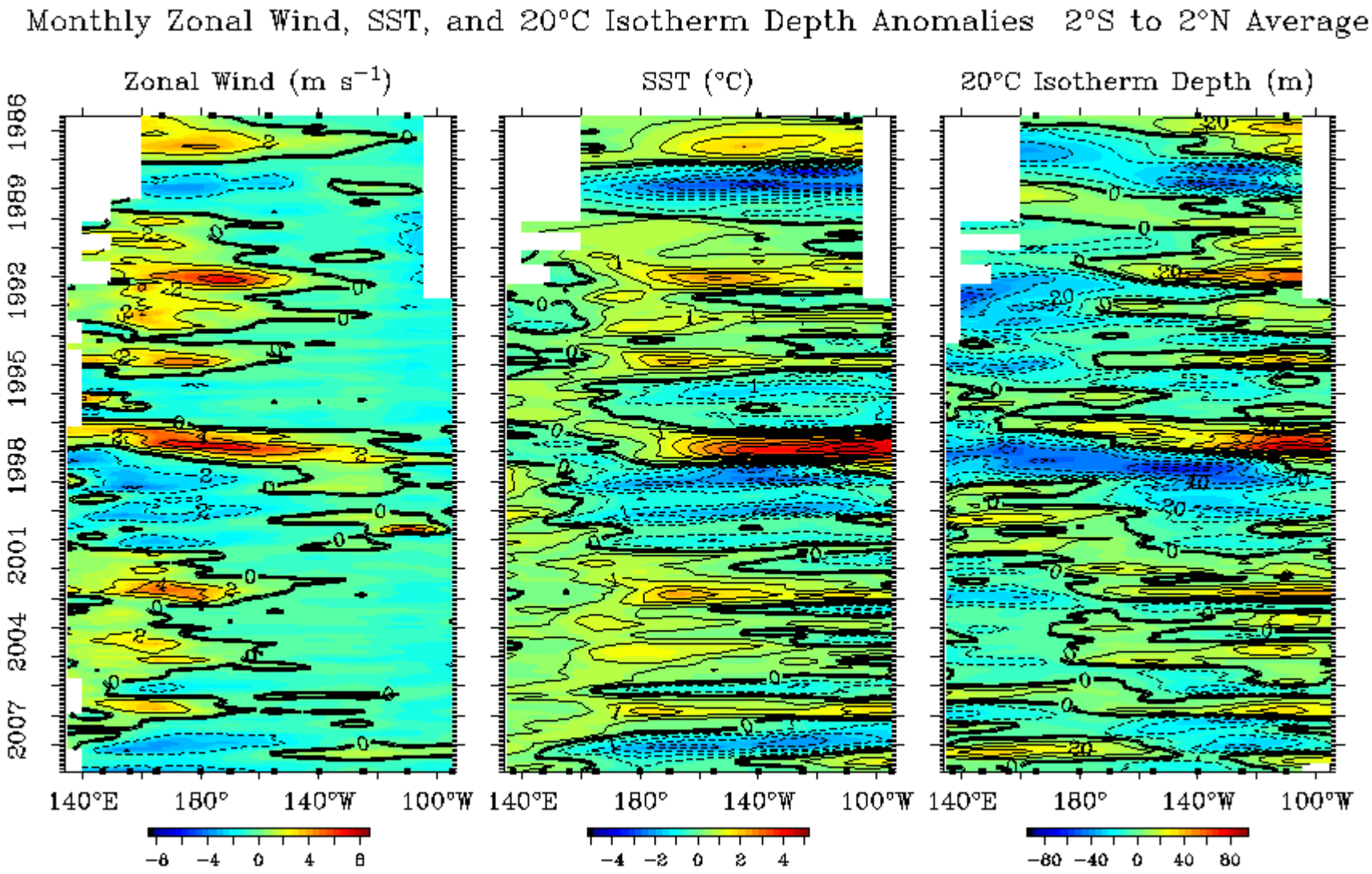



Monthly Zonal Wind, SST, and 20°C Isotherm Depth 2°S to 2°N Average
Zonal Wind (m s−1)
SST (°C)
20°C Isotherm Depth (m)
1986
1989
1992
1995
1998
2001
2004
2007
140°E
180°
140°W
100°W
−8 −4 0 4
20 22 24 26 28 30
30 60 100 140 180 220
TAO Project Office/PMEL/NOAA
Nov 24 2008

Bjerknes Hypothesis



Chang and Battisti 1998


Monthly Zonal Wind, SST, and 20°C Isotherm Depth Anomalies 2°S to 2°N Average
Zonal Wind (m s−1)
SST (°C)
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1989
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2004
2007
140°E
180°
140°W
100°W
−8 −4 0 4 8
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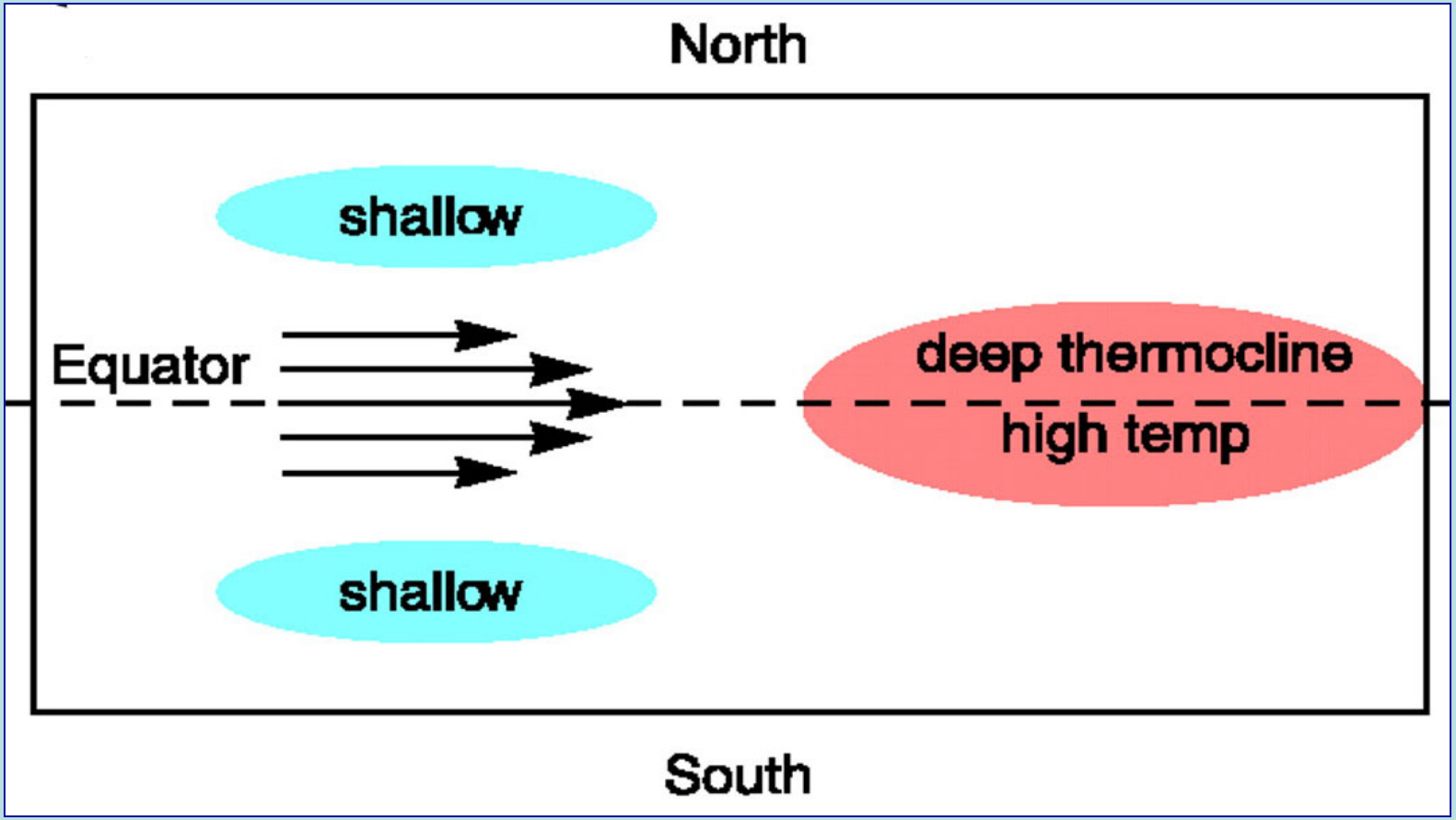
TAO Project Office/PMEL/NOAA
Nov 24 2008

Delayed Oscillator

(Schopf & Suarez, 1988; Battisti & Hirst, 1989)



- **Winds weaken ⇒ Downwelling Kelvin wave to the east, upwelling Rossby wave to the west.**

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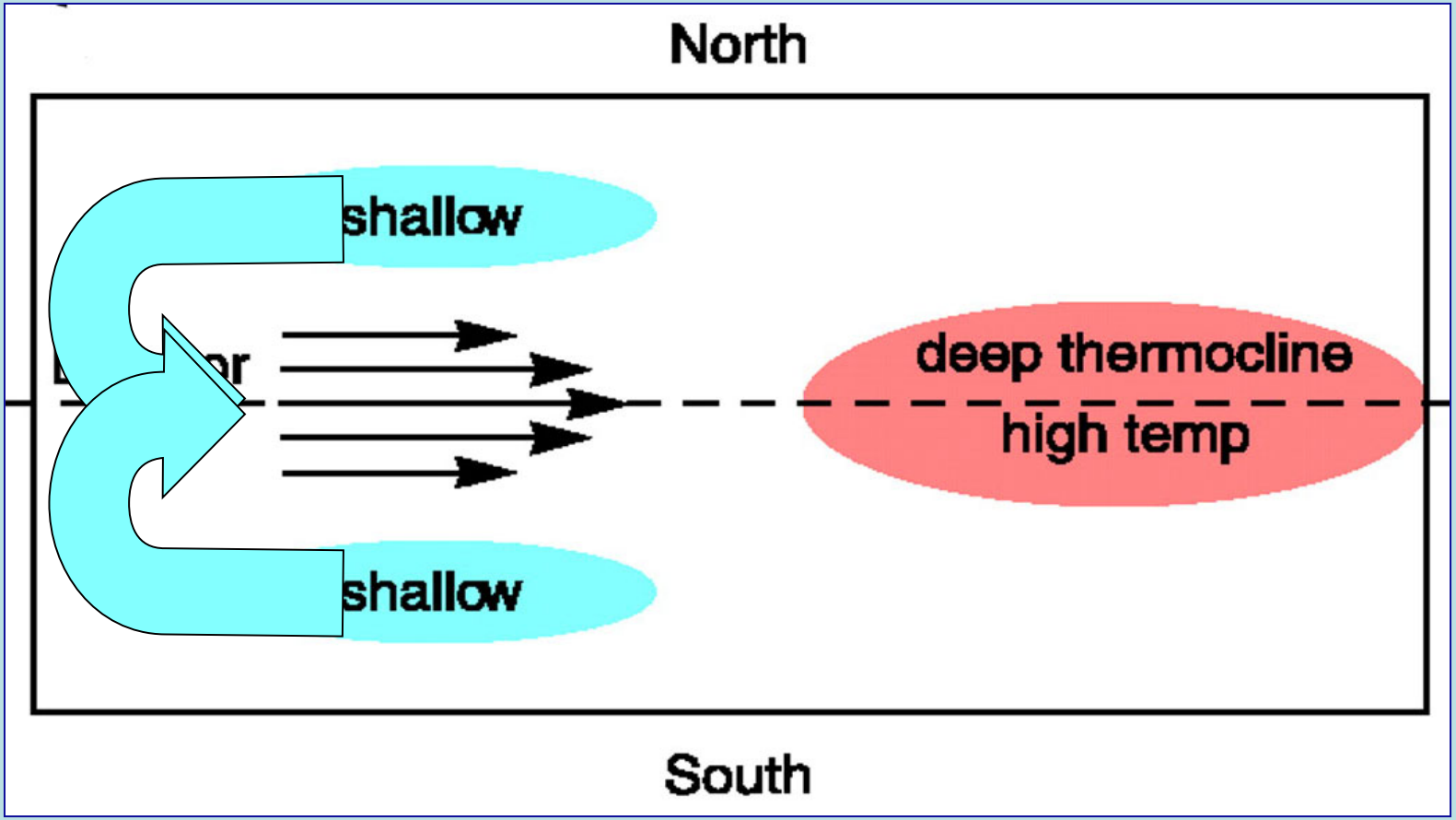

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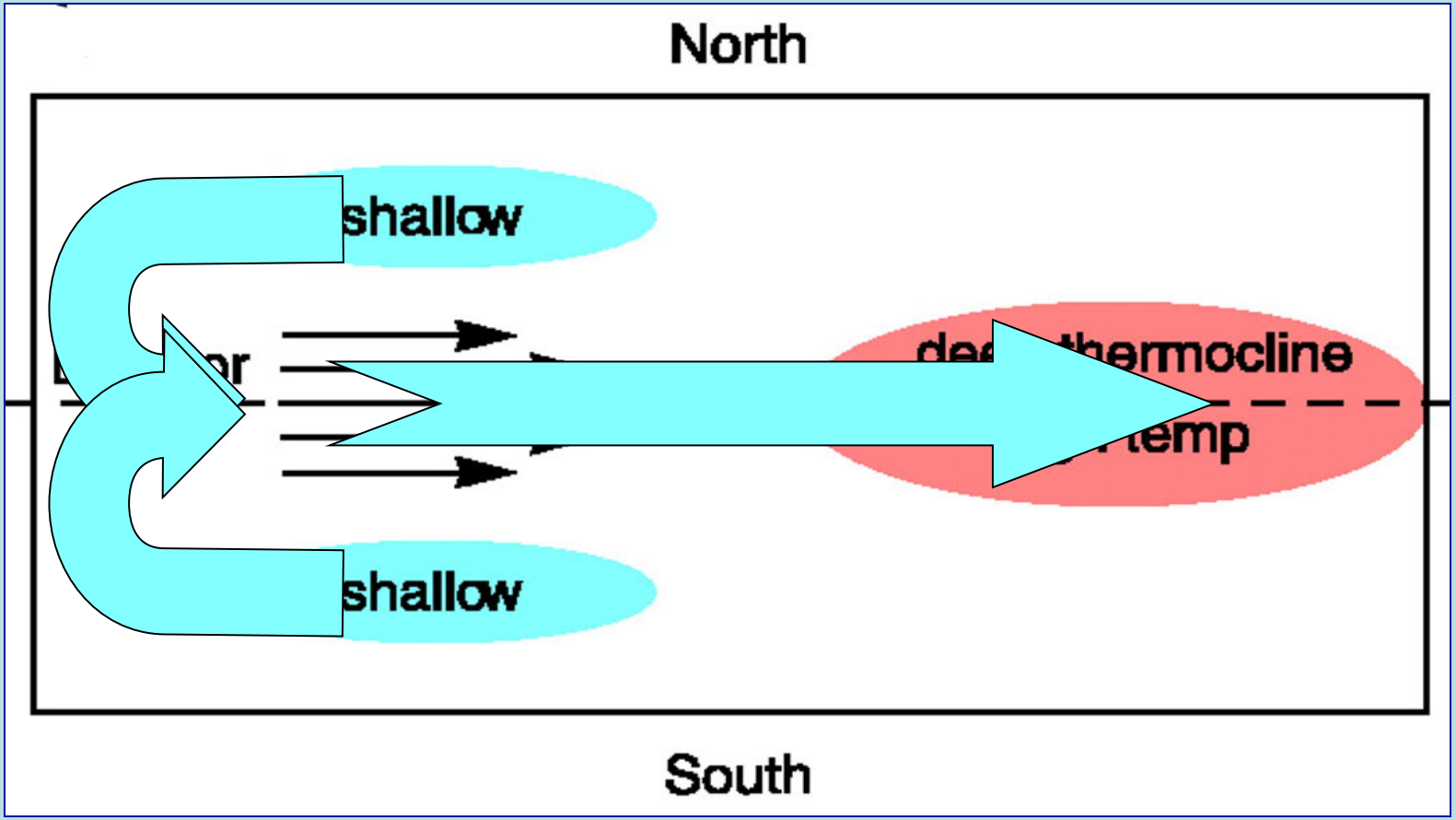
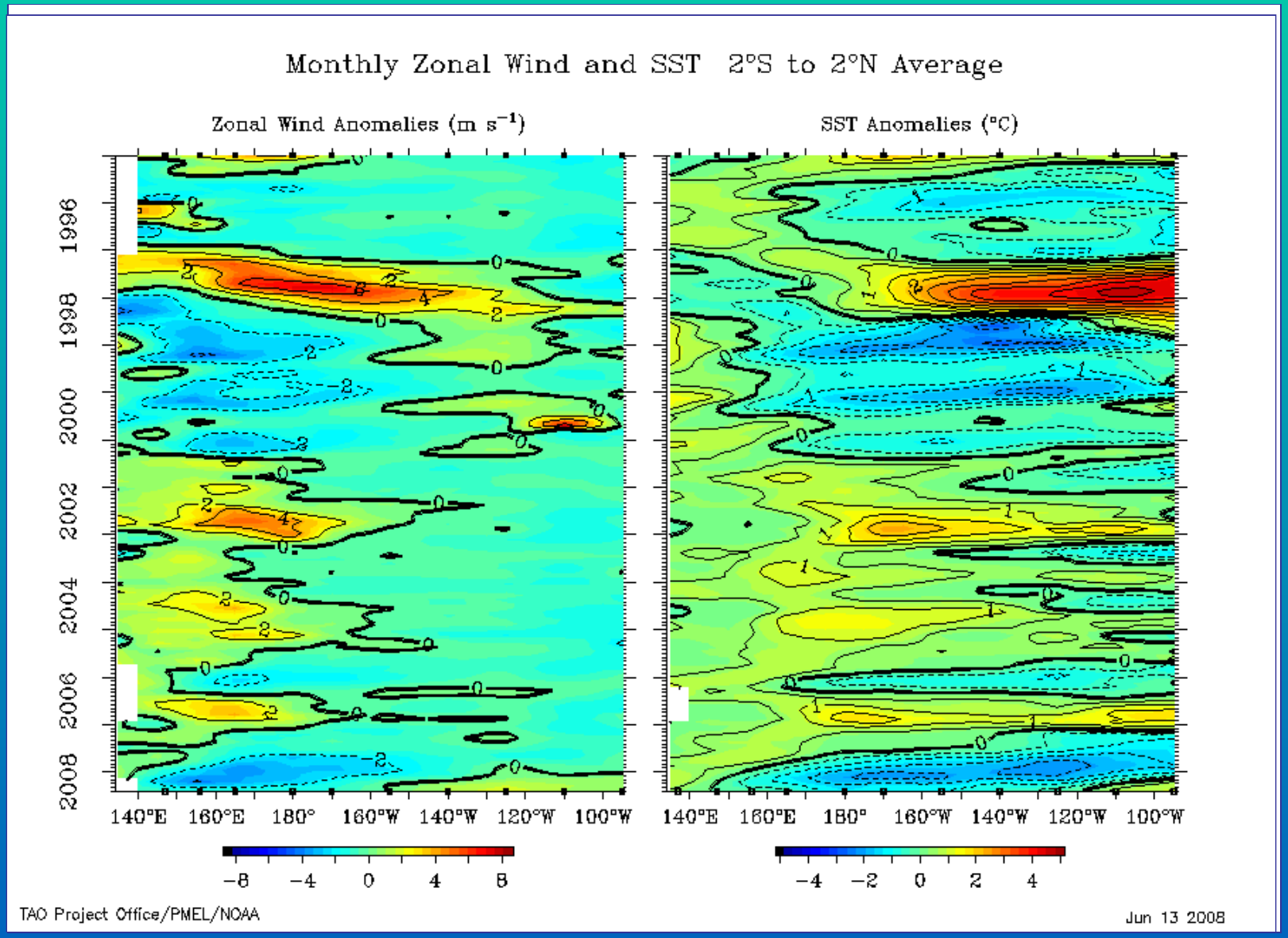
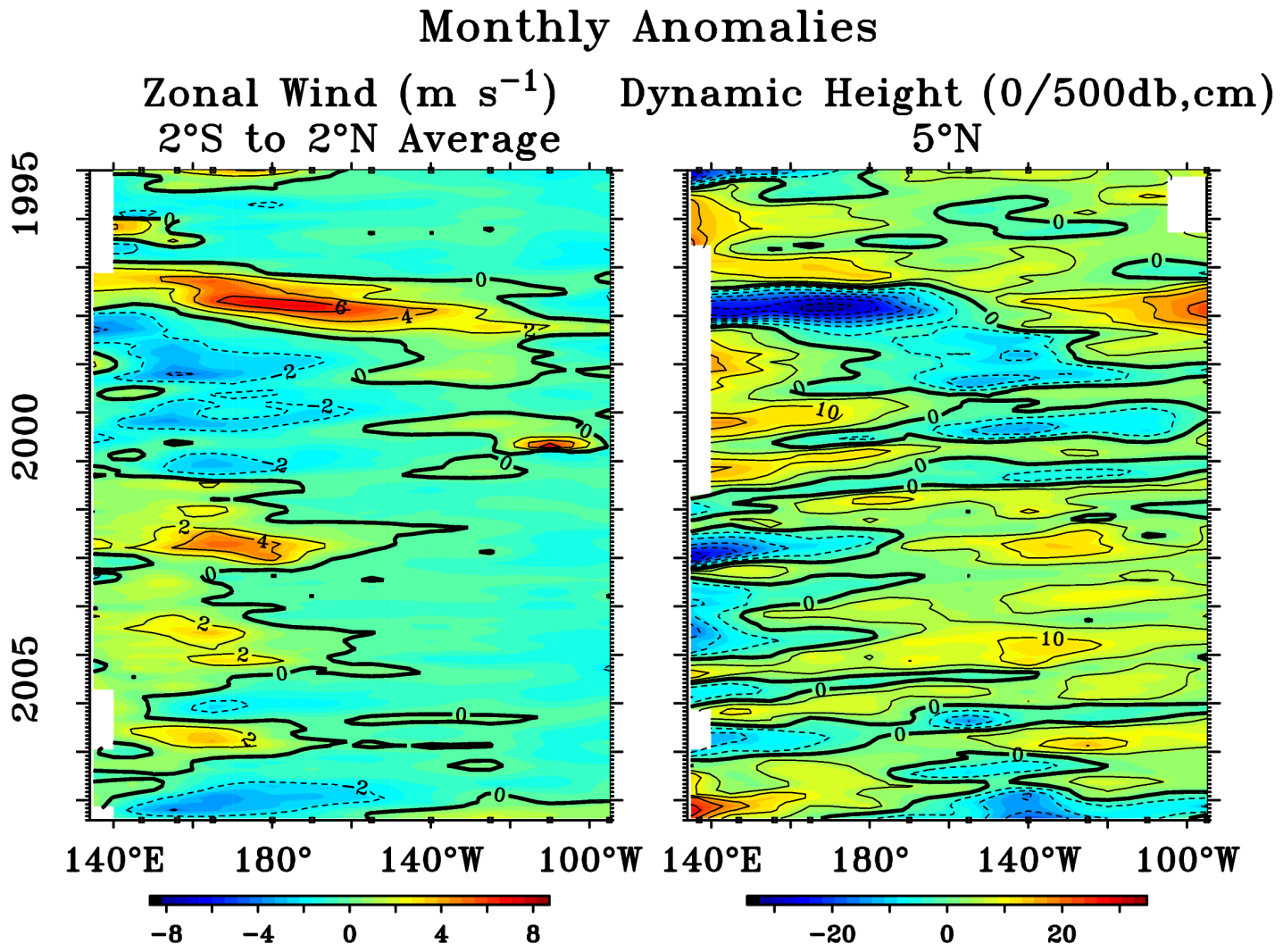


- **Winds weaken ⇒ Downwelling Kelvin wave to the east, upwelling Rossby wave to the west.**
- **Upwelling Rossby wave reflects at western boundary as upwelling Kelvin wave.**
- **Upwelling Kelvin wave cools the eastern Pacific cold tongue, shutting down El Niño and triggering La Niña.**

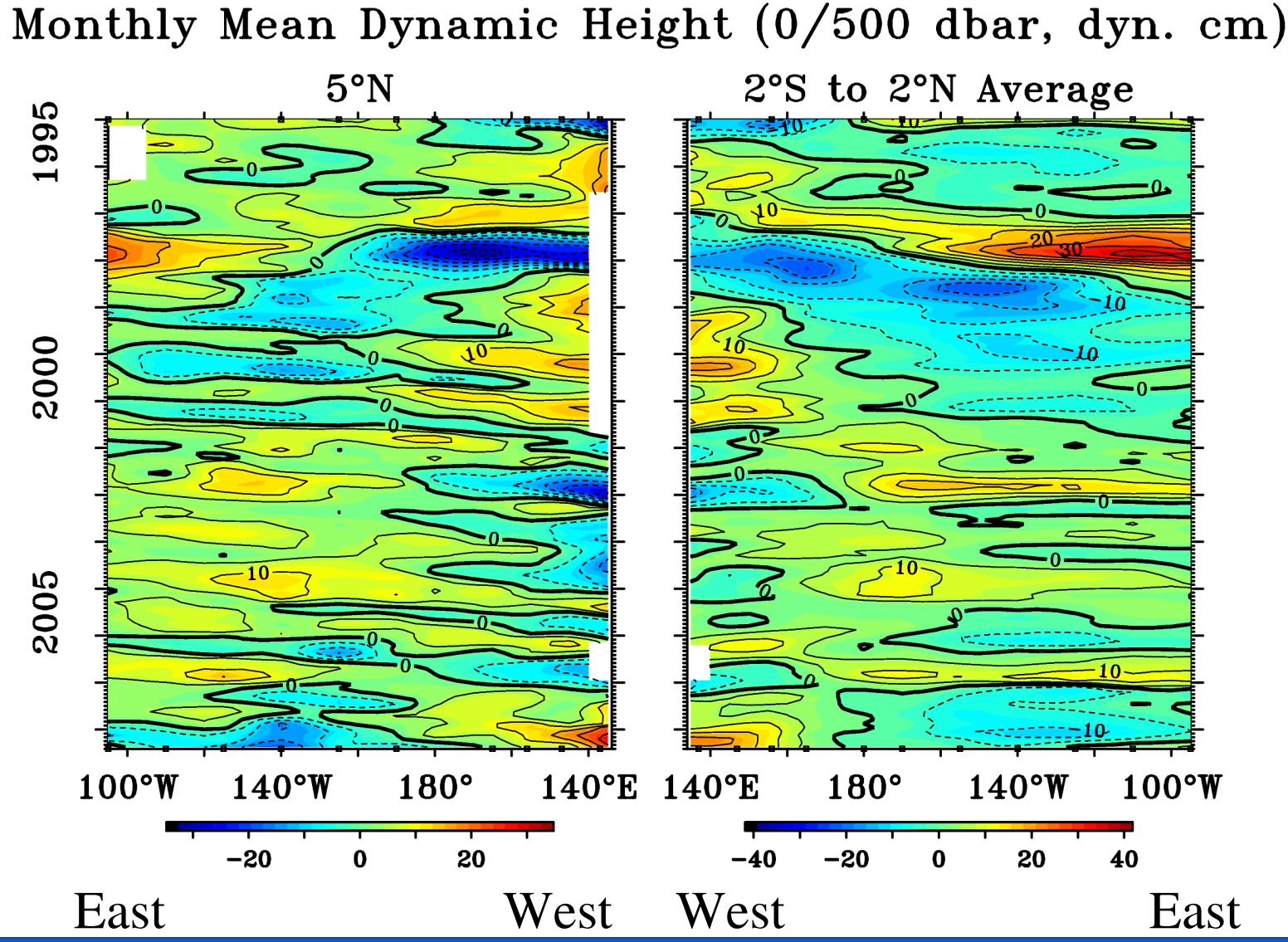
Equatorial Winds & Surface Temperature



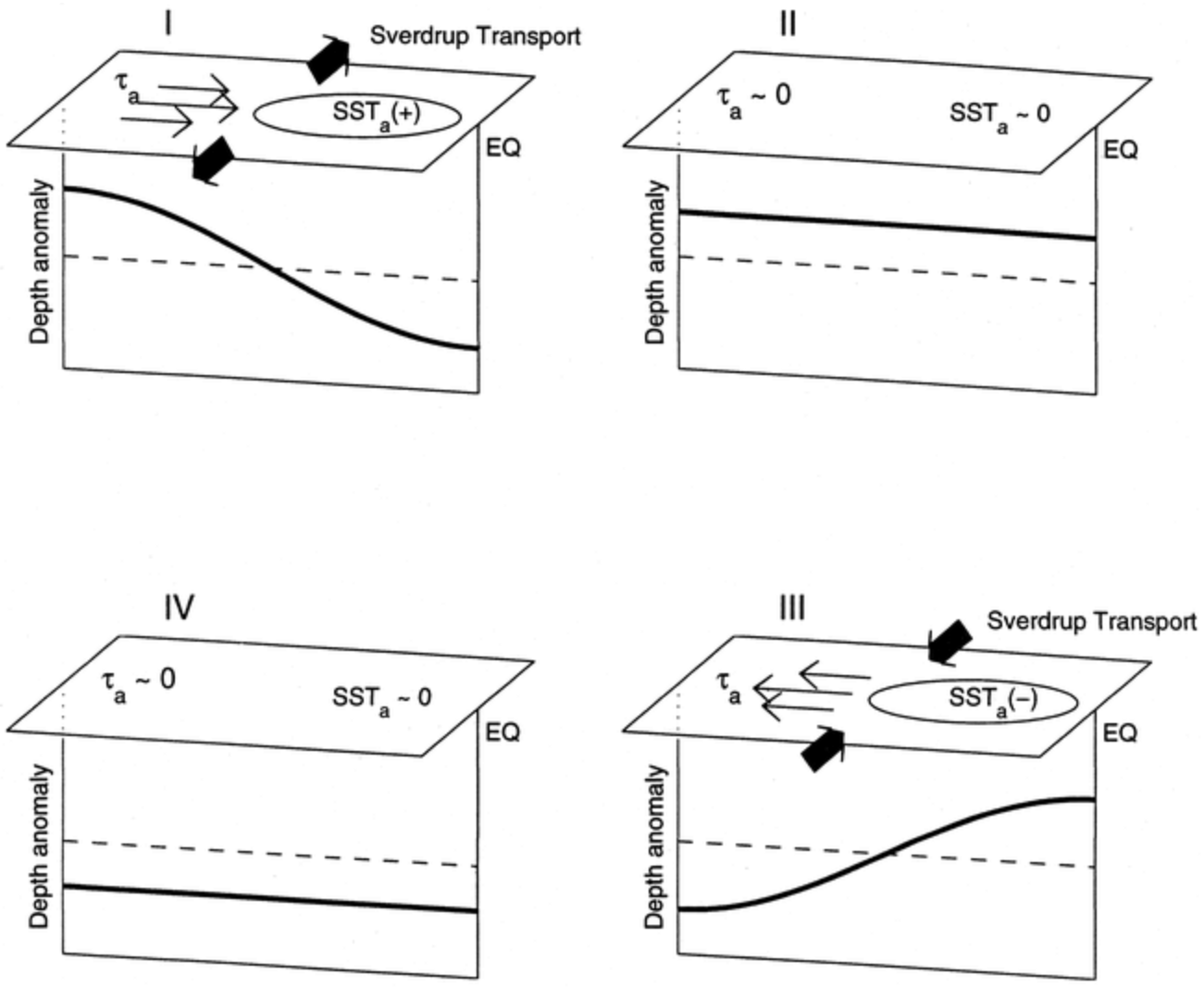
Equatorial Winds & 5°N Rossby Waves



Rossby Wave to Kelvin Wave Reflection

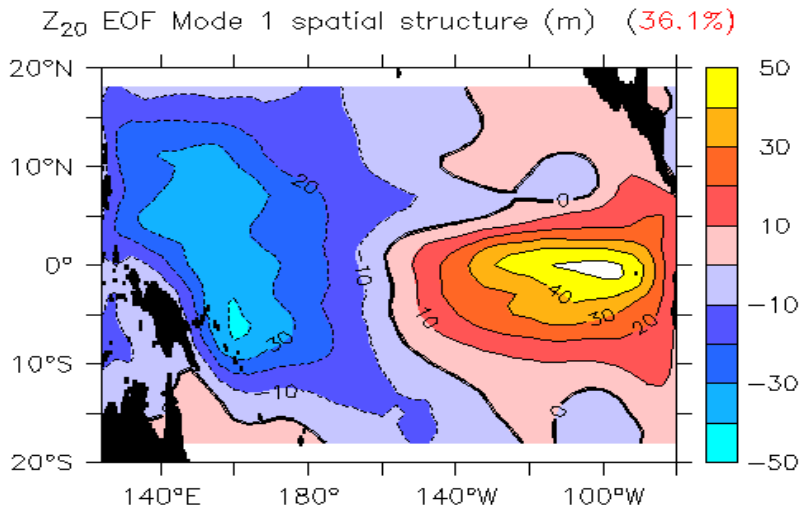


Recharge Oscillator

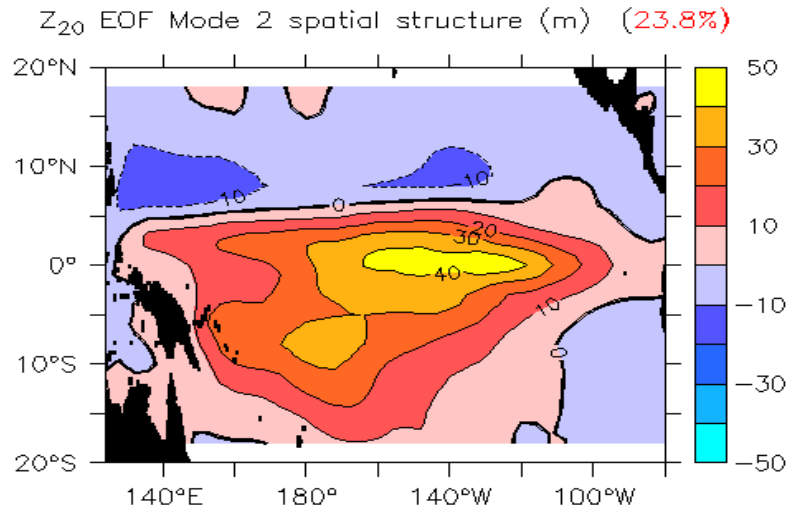


Jin 1997

Thermocline Depth (20°C)



"Tilting mode"



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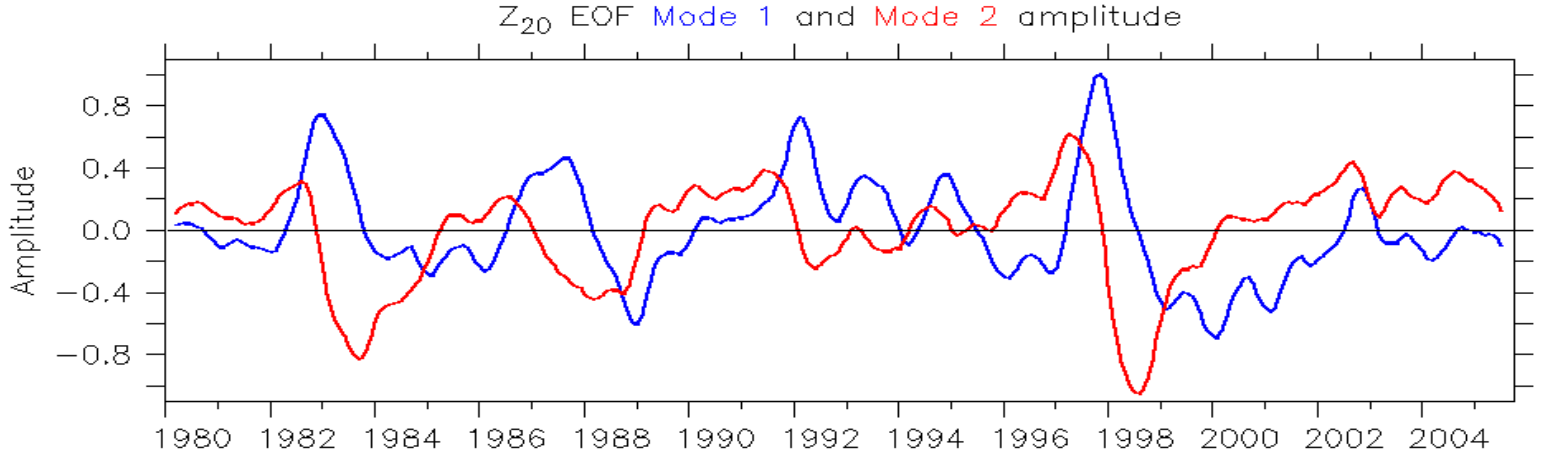

Meinen & McPhaden, 2000

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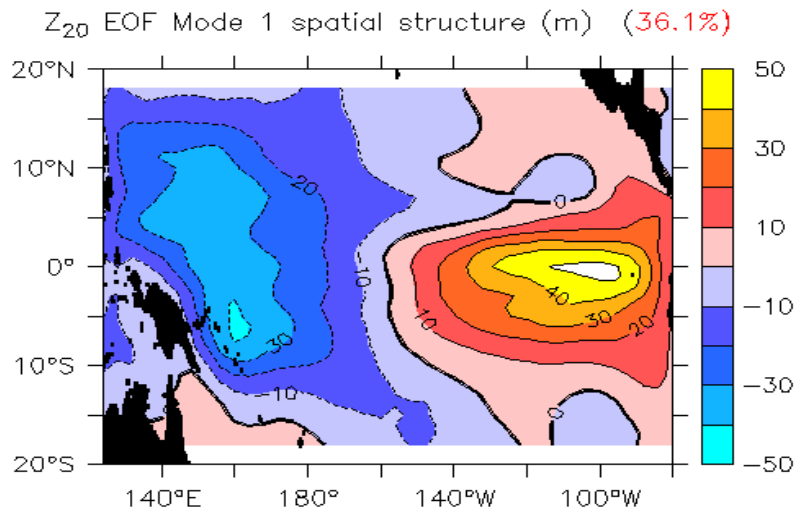

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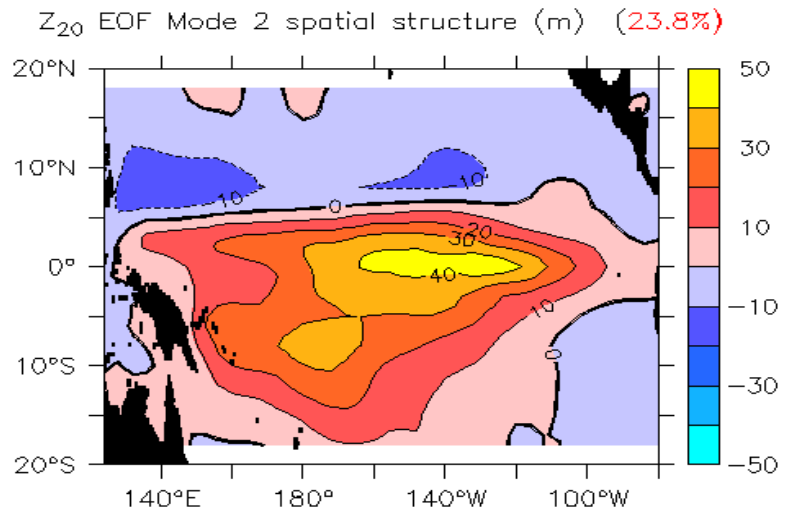

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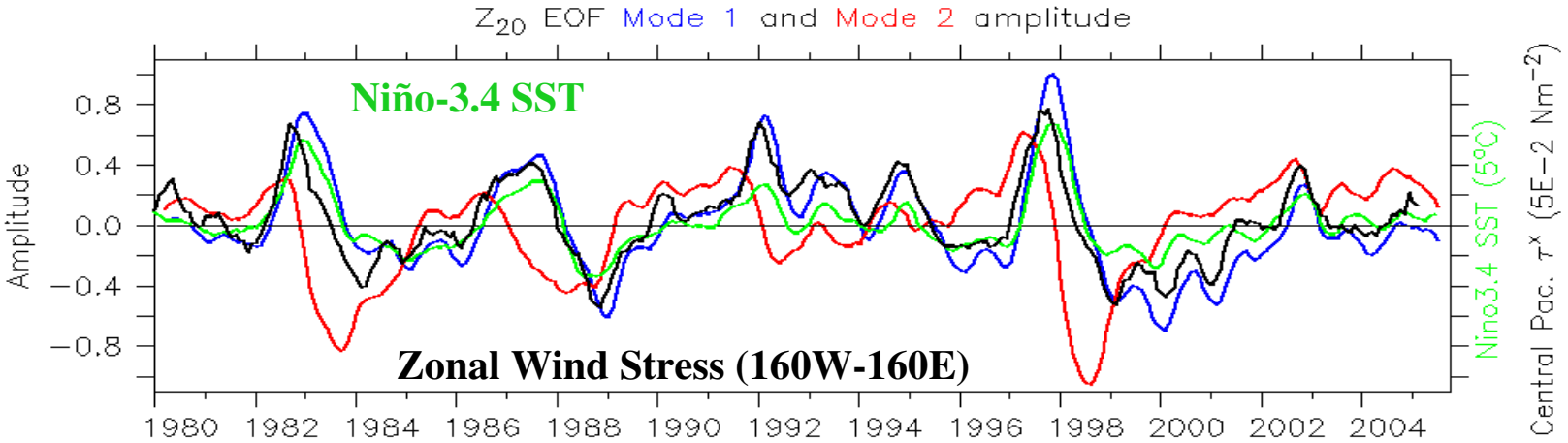
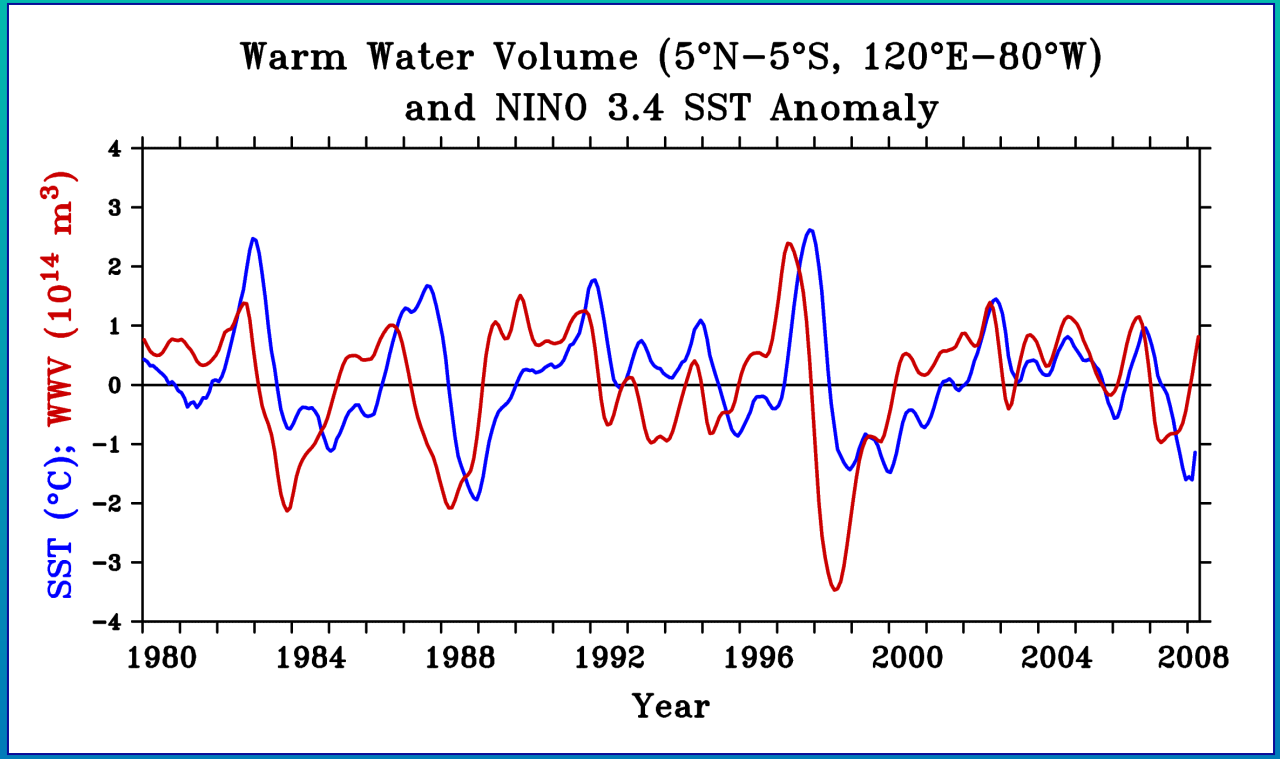


Meinen & McPhaden, 2000

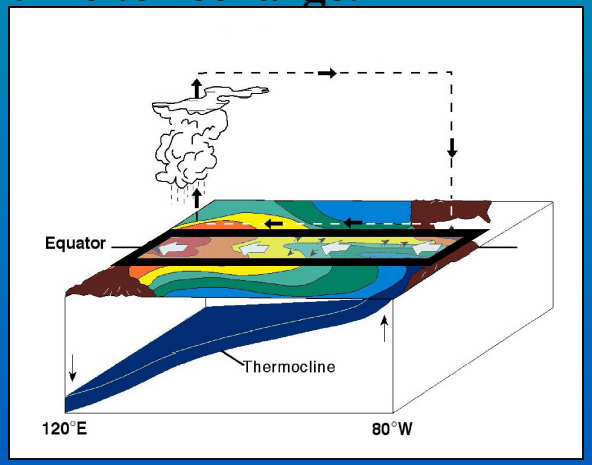
Upper Ocean Heat Content

(Based Recharge Oscillator Theory)



WWV based on BMRC analysis of TAO/TRITON, XBT and Argo data

- **Build up of excess heat content along equator is a necessary precondition for El Niño to occur.**
- **El Niño purges excess heat to higher latitudes, which terminates the event.**
- **The time between El Niños is determined by the time to recharge.**



Warm Water Volume (WWV): An Index for Upper Ocean Heat Content

Meinen & McPhaden, 2000

ENSO web resources

Tropical Atmosphere Ocean Project (TAO):
http://www.pmel.noaa.gov/tao/
International Research Institute for Climate and Society (IRI):
http://iri.columbia.edu/
Climate Diagnostics Center (CDC): http://www.cpc.ncep.noaa.gov/

.... many other government and academic institutions.