

Global Ocean Monitoring: Recent Evolution, Current Status, and Predictions

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<http://www.cpc.ncep.noaa.gov/products/GODAS/>

Outline

- **Overview**
- **Recent highlights**
 - **Pacific Ocean**
 - **Indian Ocean**
 - **Atlantic Ocean**
- **GODAS and CFS SST Predictions**

Data Sources

- **Optimal Interpolation SST (OI SST) version 2**
- **Reconstructed SST (ERSST) version 3**
- **NCEP/NCAR Reanalysis-1 wind, velocity potential and heat fluxes**
- **NOAA's Outgoing Long Wave Radiation**
- **PMEL TAO equatorial temperature analysis**
- **NCEP's Global Ocean Data Assimilation System (GODAS) temperature, heat content, currents**
- **Aviso Altimetry Sea Surface Height**
- **Ocean Surface Current Analyses – Realtime (OSCAR)**

Overview

- **Global Ocean**

- Global ocean mean SST has been persistently above-normal since 2000
- It became near-normal in November 2007 – April 2008, largely due to the 07/08 La Nina
- In contrast, global sea surface height has been rising steadily since 1992 when the Altimetry SSH became available

- **Pacific Ocean**

- La Nina weakened (NINO3.4 changed from -1.1 to -0.85 C)
- CPC's prognostic assessment: A transition to ENSO-neutral conditions were possible in next 2-3 months
- Easterly wind anomalies and suppressed convection in C. Pacific weakened
- Negative subsurface temperature anomalies in E. Pacific switched to positive anomalies
- Positive SSTA in far E. Pacific and westerly wind anomalies east of 150W persisted
- Anticyclonic wind anomalies near the coast of California persisted and forced above-normal coastal upwelling in Feb-Apr

- **Indian Ocean**

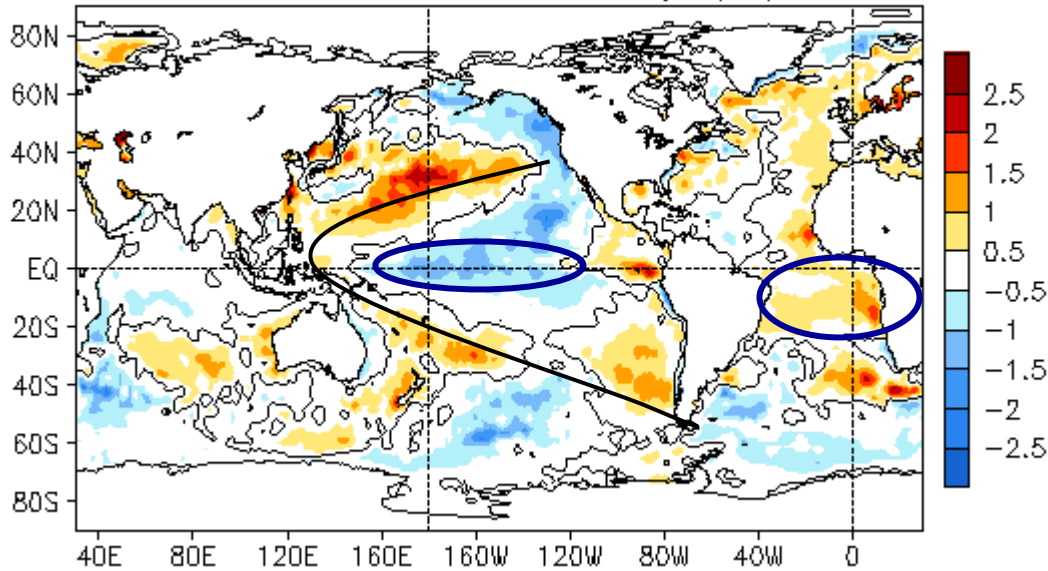
- Above-normal rainfall over Bay of Bengal and the Maritime Continent
- Westerly wind anomalies and below-normal SST were responses to the La Nina forcing

- **Atlantic Ocean**

- Tropical North Atlantic SST has a cooling trend since 2005, and became below-normal in Mar-Apr and SST was 0.9C cooler than last year west of Caribbean Sea
- Negative Meridonal SST Mode persisted associated with which were north-westerly wind anomalies and enhanced convection in the equatorial Atlantic

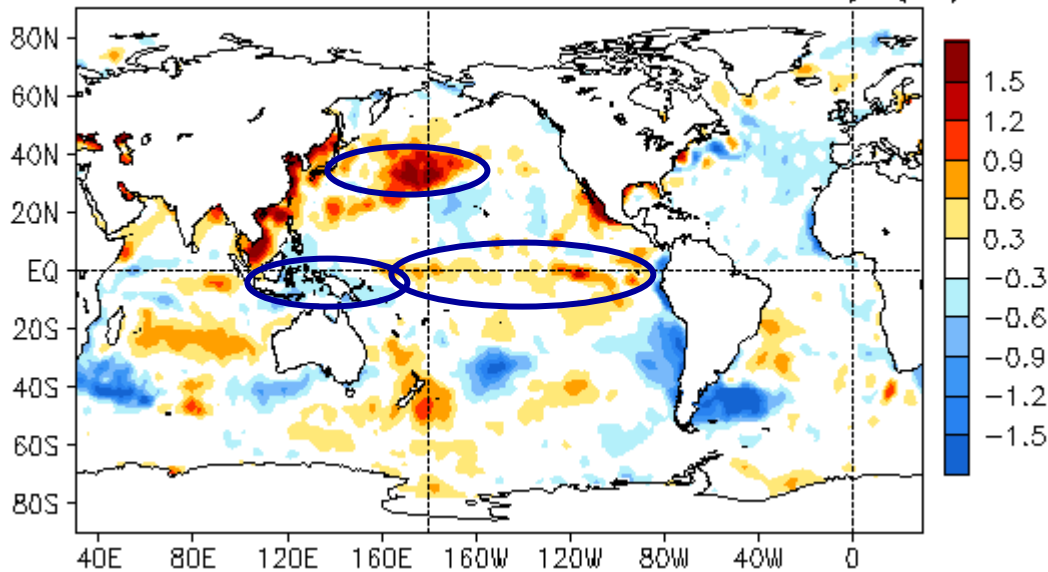
Global SST Anomaly ($^{\circ}\text{C}$) and Anomaly Tendency

APR 2008 SST Anomaly ($^{\circ}\text{C}$)



- La Nina pattern in tropical Pacific
- Positive PDO pattern in North Pacific
- Above-normal SST in Southern Atlantic
- Near-normal SST in tropical Indian

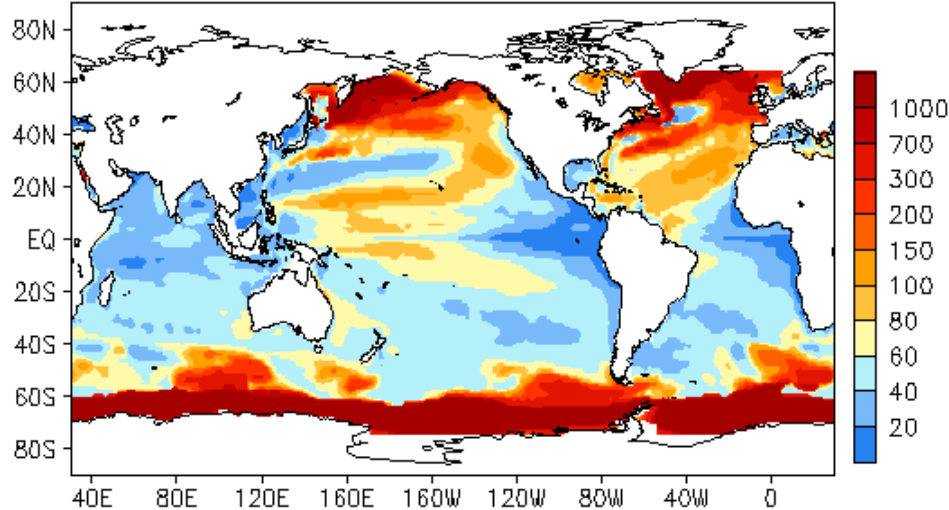
APR 2008 - MAR 2008 SST Anomaly ($^{\circ}\text{C}$)



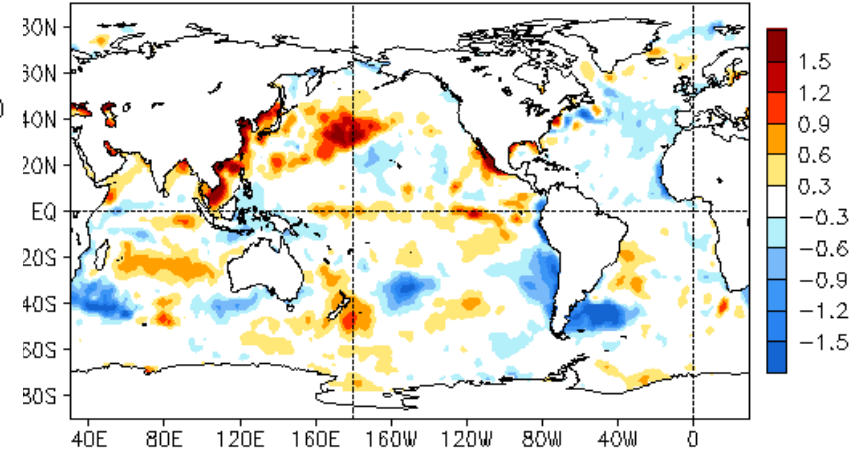
- Negative SSTA weakened from the Date Line to the west coast of South America
- SST decreased in far western Pacific
- SST increased in western North Pacific

Mixed Layer Depth and SST

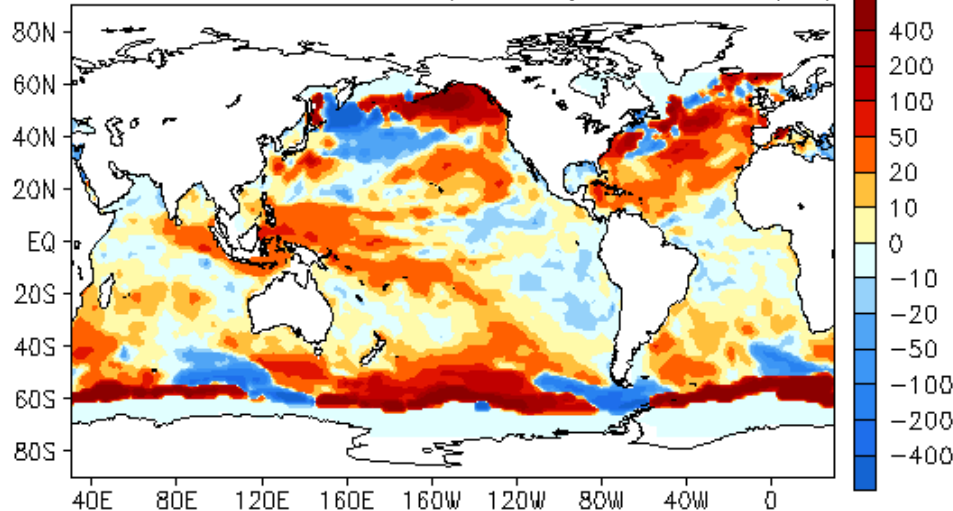
APR 2008 Mixed Layer Depth Climatology (m)



APR 2008 - MAR 2008 SST Anomaly (°C)



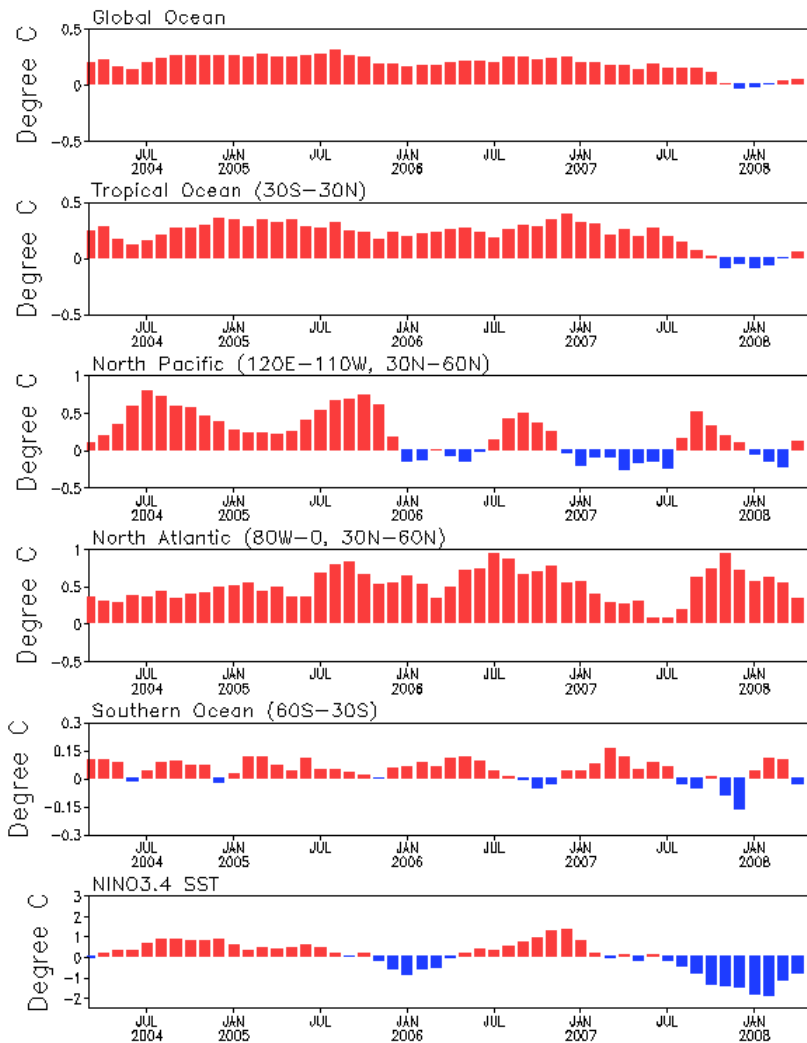
APR 2008 Mixed Layer Depth Anomaly (m)



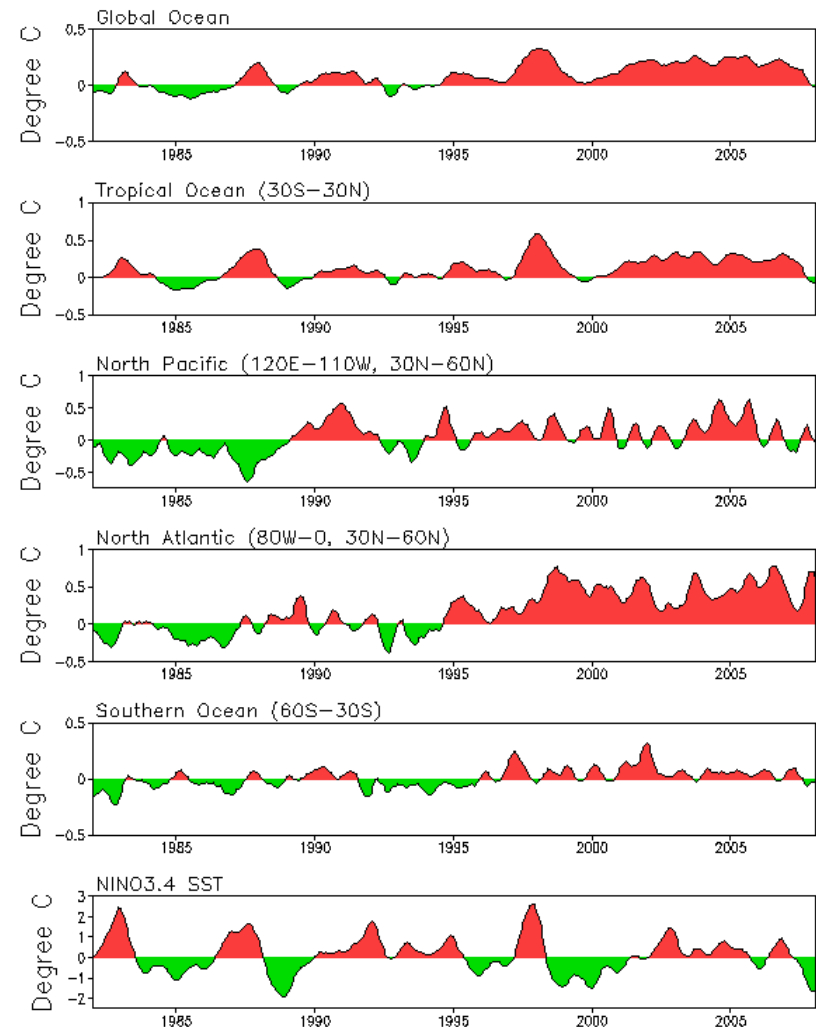
- Mixed Layer Depth (MLD) is defined as the depth where temperature is 0.8°C below the temperature at 5 meter depth
- MLD is above 80 meter in most of North Pacific and North Atlantic, but is below 40 meter in equatorial eastern Pacific, equatorial Atlantic, most of Indian Ocean and Southern Oceans
- MLD is above-normal in the western Pacific and eastern Indian Ocean

Monthly SST Time Series

Monthly SST Time Series (OISST.v2, Climo. 1971–2000)



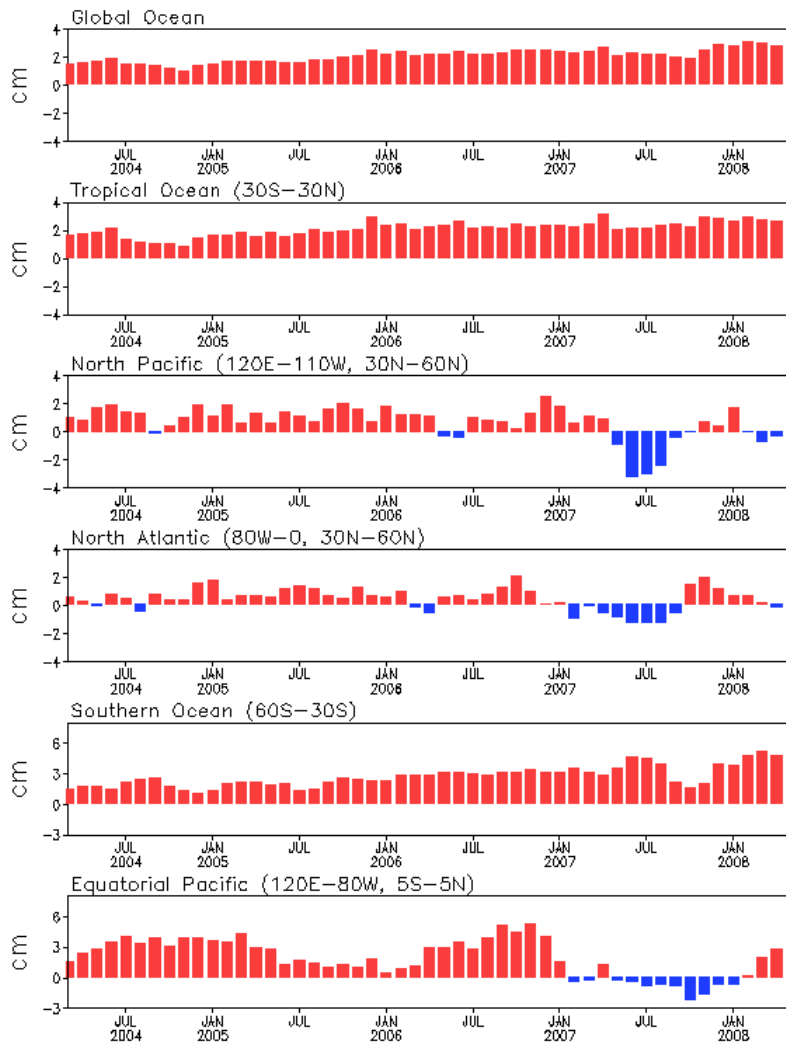
SST Time Series (OISST.v2, Climo. 1971–2000)
(5 Month Running Mean)



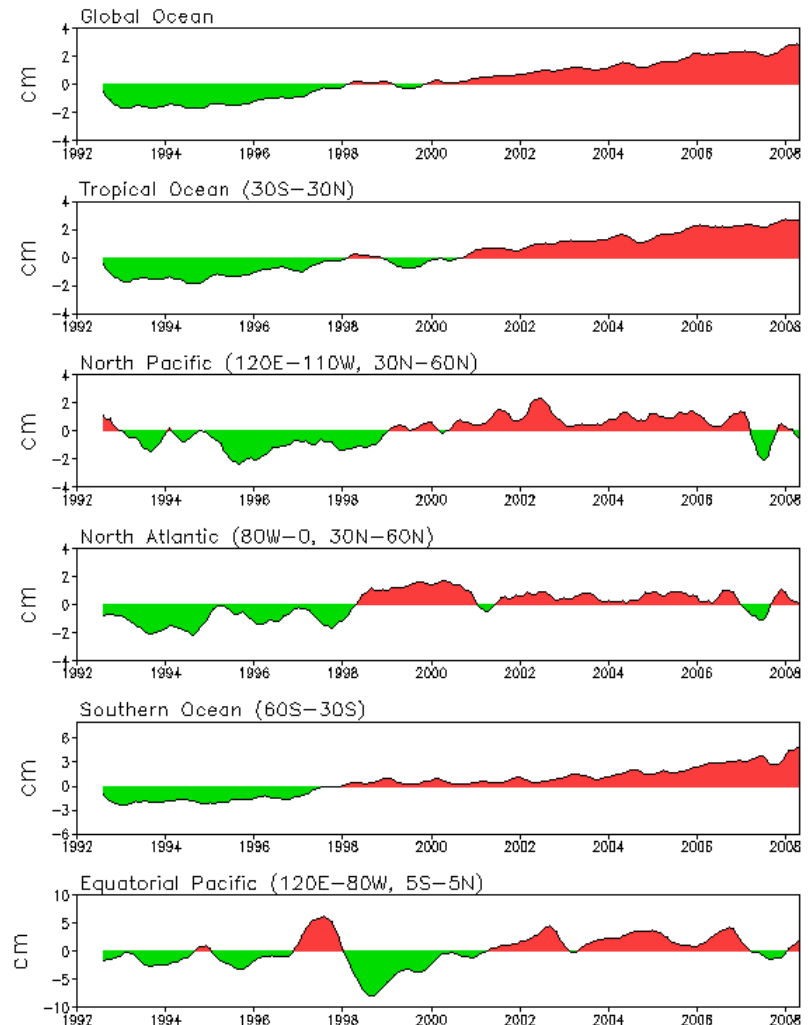
- Global SST has been persistently above-normal since 2000, but became near-normal since November 2007 largely due to the SST cooling associated with the 07/08 La Nina
- North Pacific SSTA has a prominent annual cycle
- North Atlantic SST has been persistently above-normal since 1995

Monthly SSH Time Series

Monthly SSH Time Series (Aviso Altimetry, Clima. 1993–2005)



SSH Time Series (Aviso Altimetry, Clima. 1993–2005)
(5 Month Running Mean)

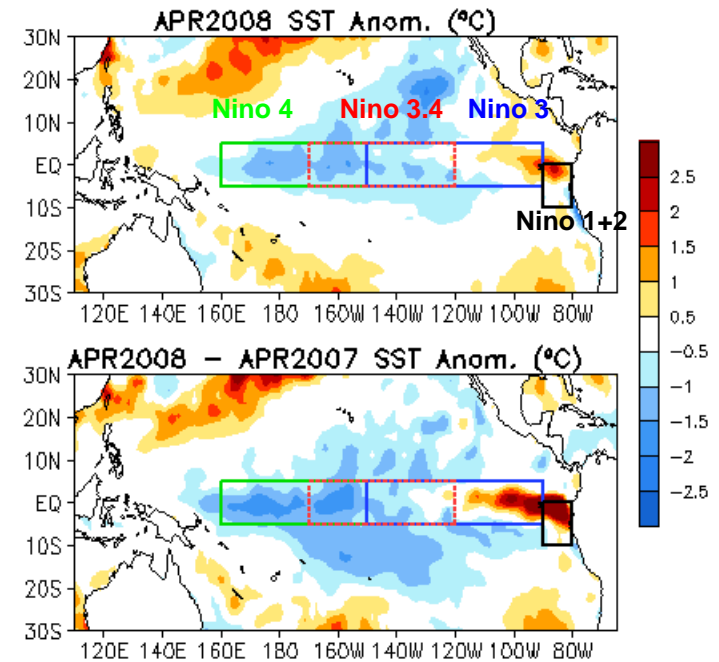
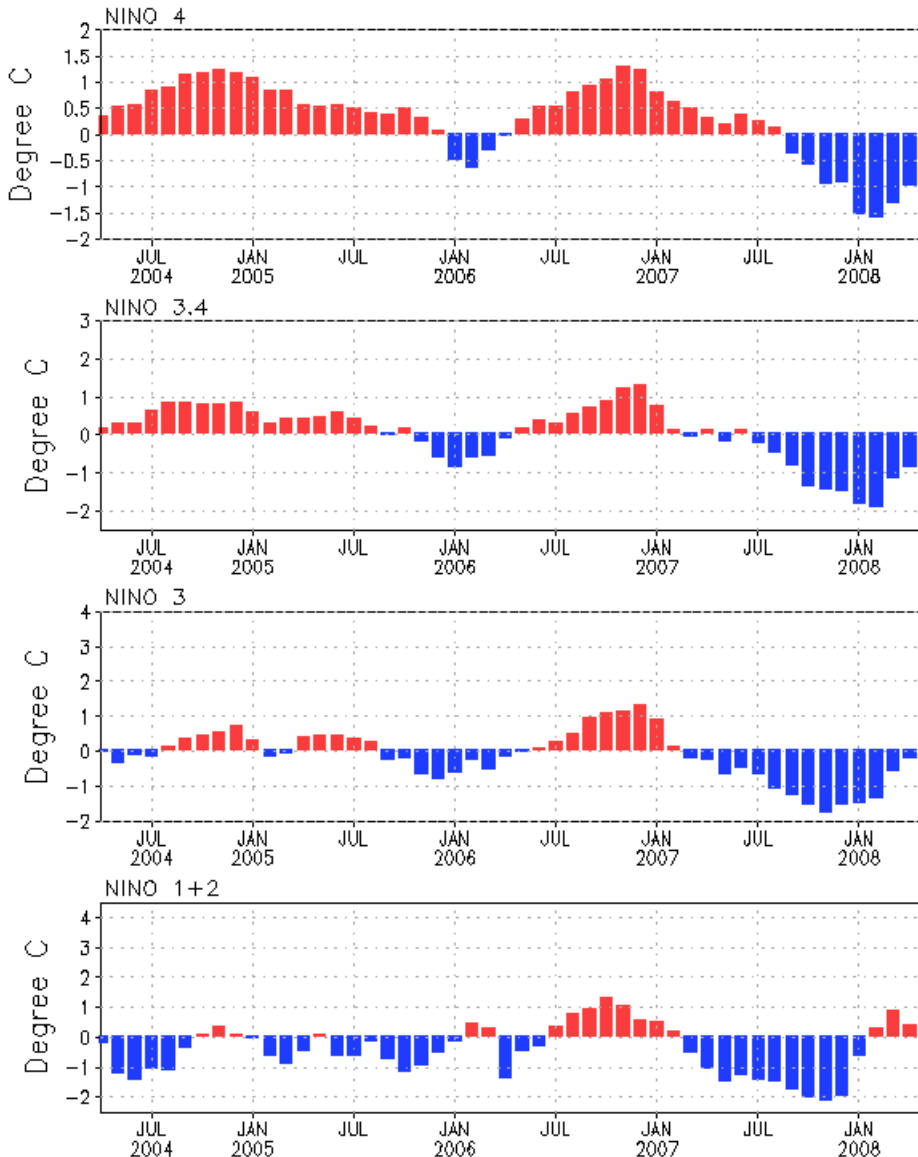


- Global, tropical and Southern Ocean SSH have been rising steadily since 1992
- North Pacific and North Atlantic SSH have been persistently above-normal since 1999 except during summer 2007
- Warm Water Volume (SSH average) in the equatorial Pacific has been persistently above-normal since 2001 except during 2007 when the 07/08 La Nina developed

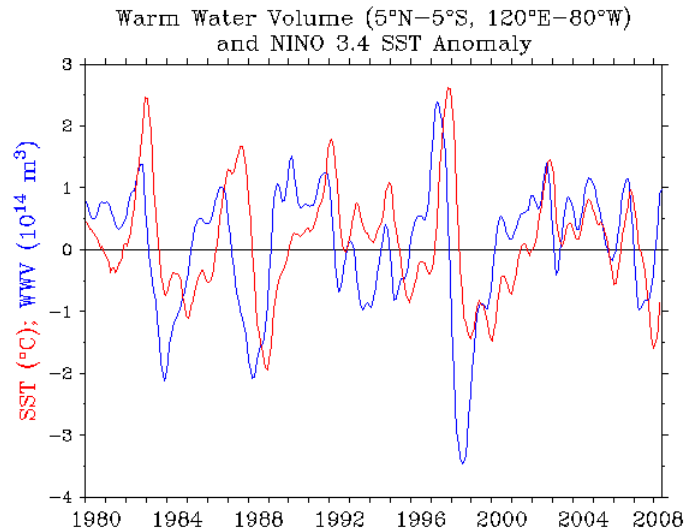
Pacific Ocean

Evolution of Pacific NINO SST Indices

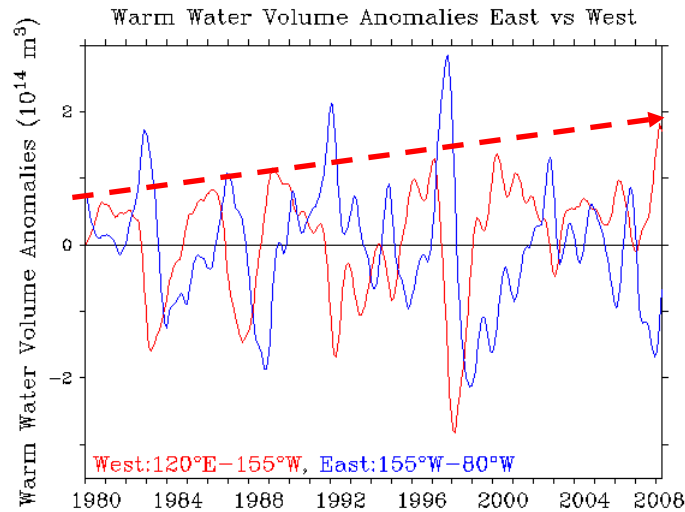
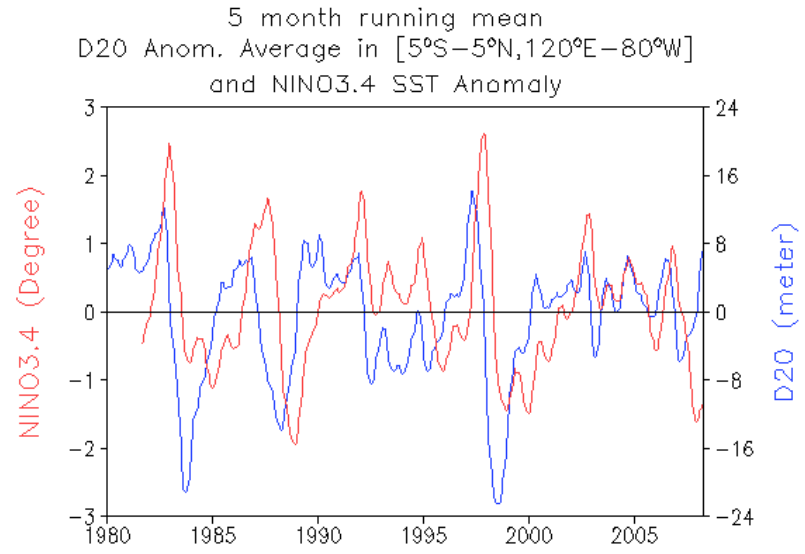
Monthly Tropical Pacific SST Anomaly



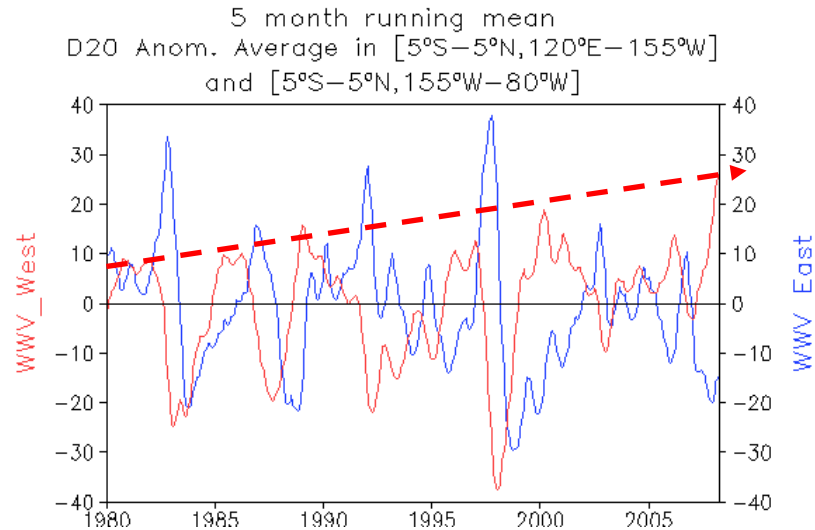
- All NINO indices weakened
 - CPC's ENSO Prognostic Statement: A transition from La Niña to ENSO-neutral conditions is possible in the next 2-3 months



TAO Project Office/PMEL/NOAA



TAO Project Office/PMEL/NOAA

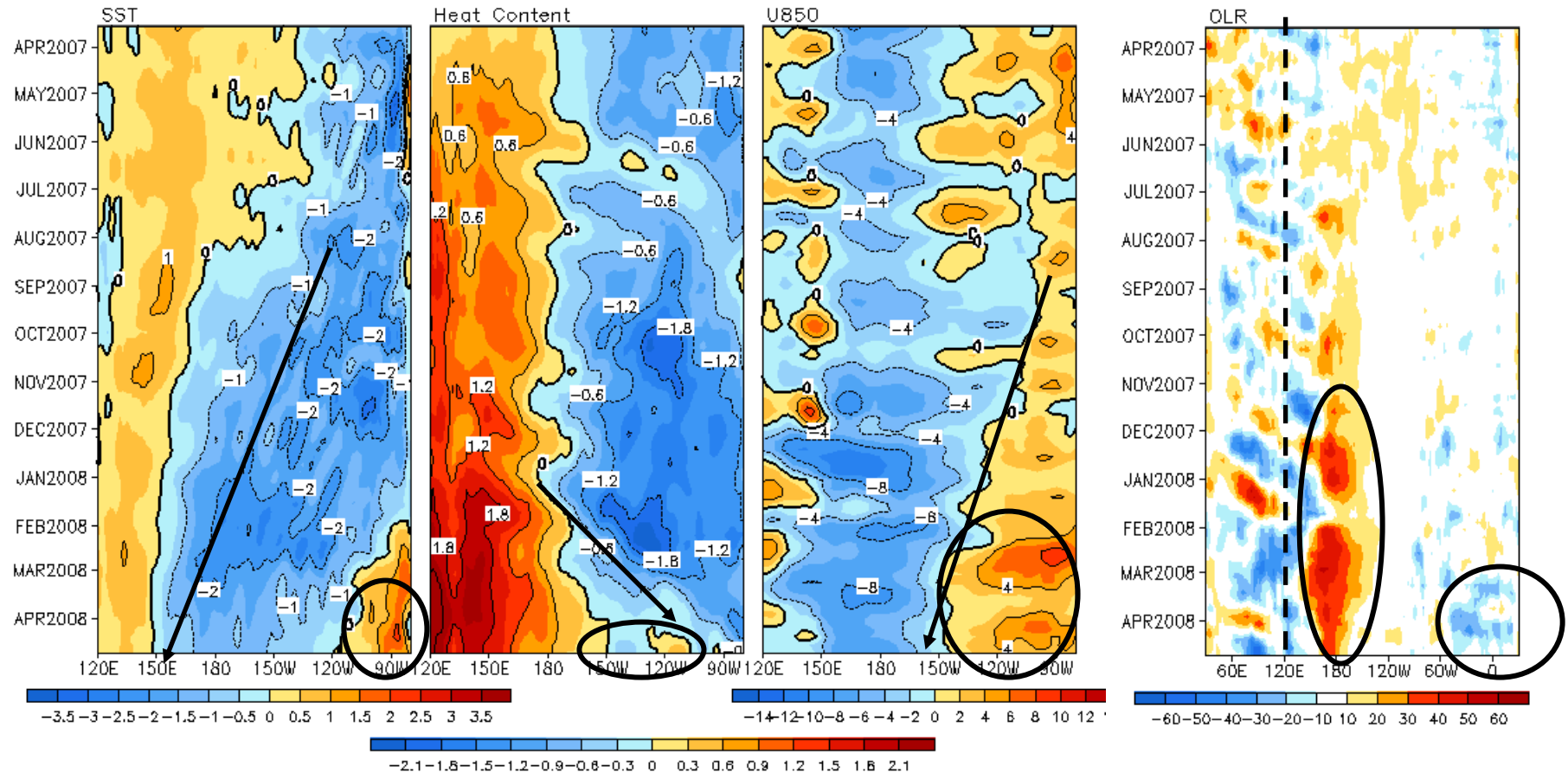


- GODAS's WWV agrees well with that of TAO
- Heat content in the equatorial western Pacific reached a historical high in early 2008

Evolution of Equatorial Pacific SST ($^{\circ}\text{C}$), 0-300m Heat Content ($^{\circ}\text{C}$), 850-mb Zonal Wind (m/s), and OLR (W/m^2)

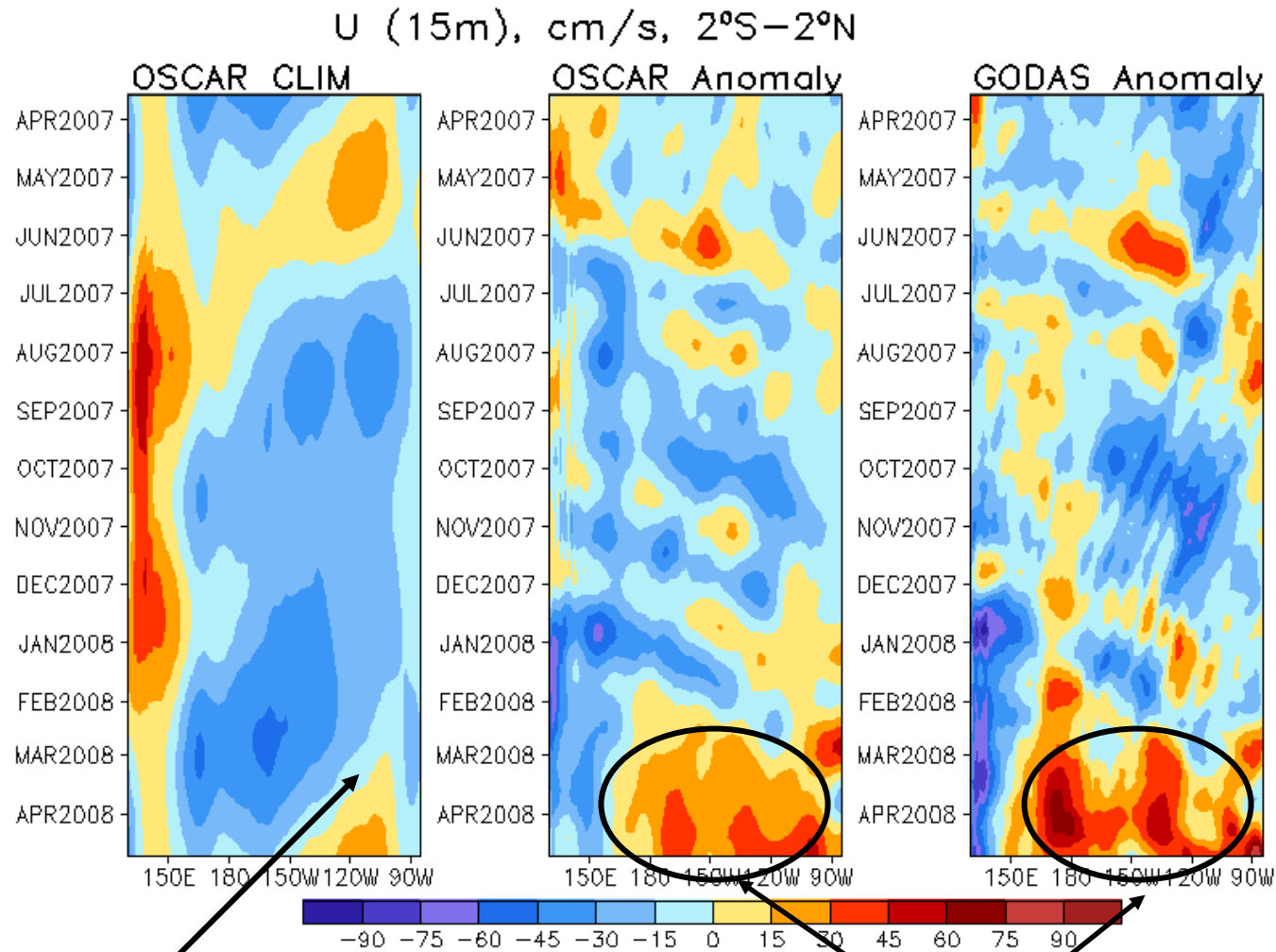
2 $^{\circ}\text{S}$ –2 $^{\circ}\text{N}$ Average, 3 Pentad Running Mean

5 $^{\circ}\text{S}$ –5 $^{\circ}\text{N}$ Average
(3 Pentad Running Mean)



- Positive SST anomalies in the far eastern Pacific and westerly wind anomalies east of 150W persisted
- Negative heat content anomalies in the central-eastern Pacific switched to positive anomalies
- Suppressed (enhanced) convection near the Dateline (Maritime Continent) weakened, but enhanced convection in the tropical Atlantic persisted

Evolution of Equatorial Surface (15 m) Zonal Current

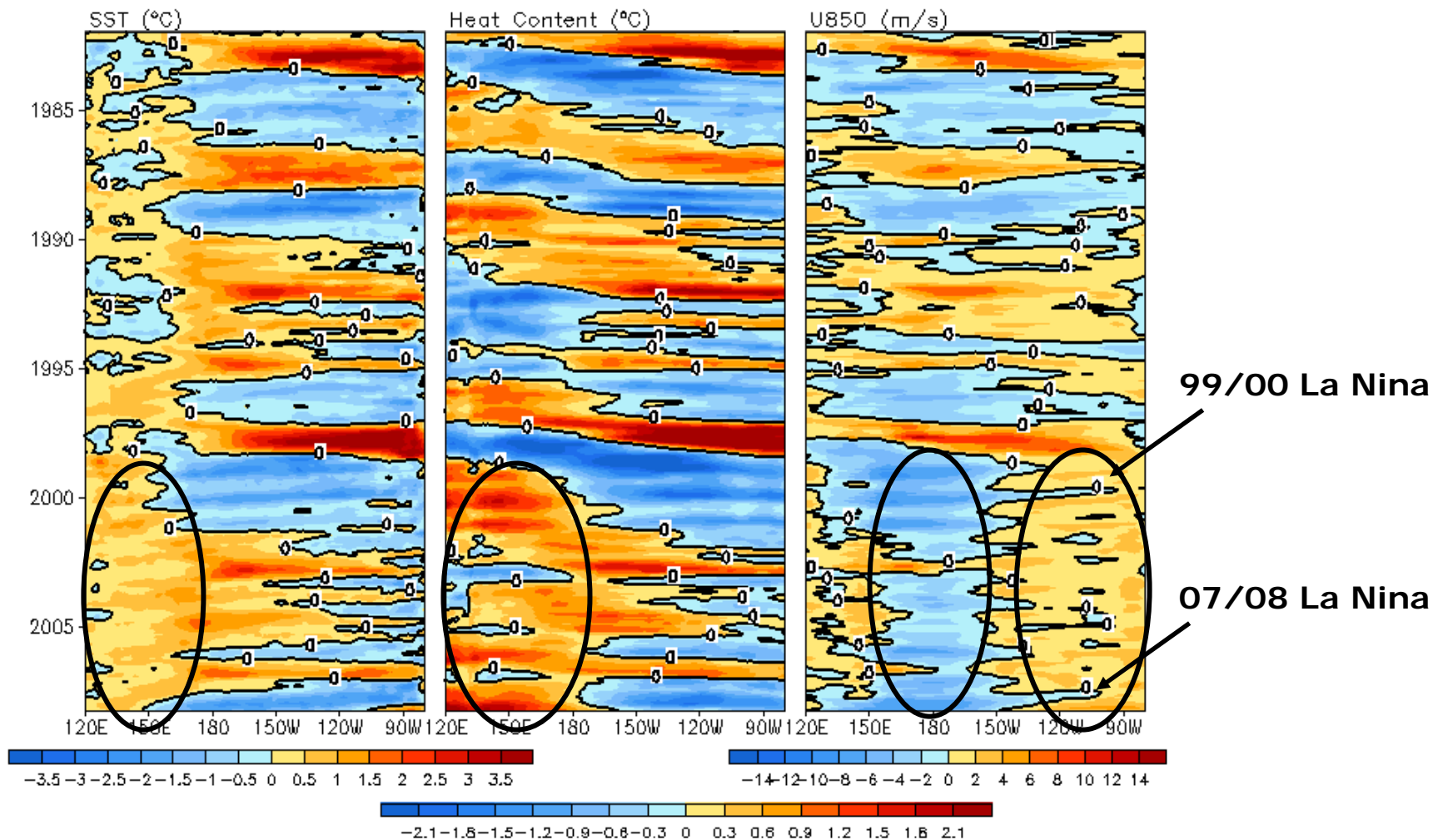


Climatological surface currents become westward in the far E. Pac. in March

Eastward current anomalies were present since February 2008

Evolution of Equatorial Pacific SST ($^{\circ}\text{C}$), 0-300m Heat Content ($^{\circ}\text{C}$), 850-mb Zonal Wind (m/s)

Equatorial Pacific, 2°S – 2°N Average, 3 Month Running Mean

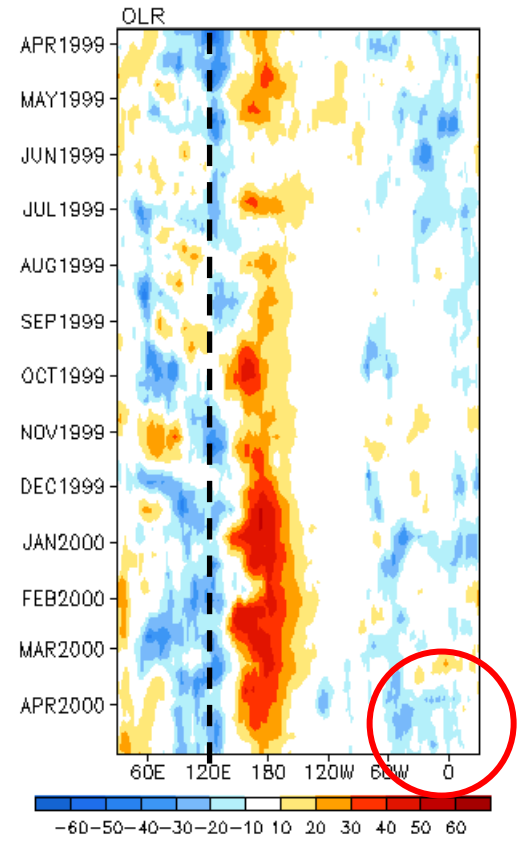
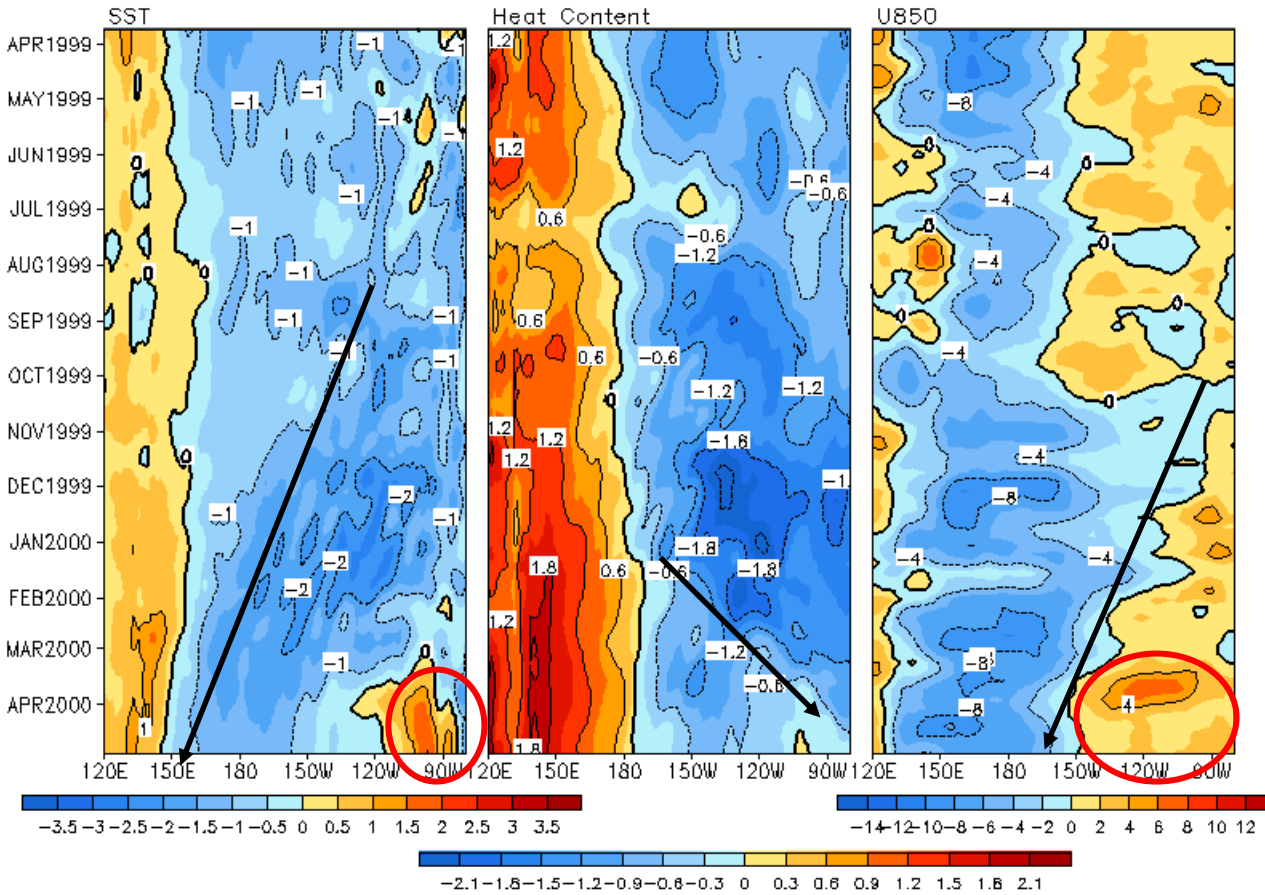


- Positive SST and heat content anomalies have persisted in W. Pacific since 1999
- Easterly wind anomalies have persisted near the Dateline since 1999 except during the 02/03 and 06/07 El Niño
- Westerly wind anomalies have persisted east of 150W since 1999 except during the 99/00 and 07/08 La Niña

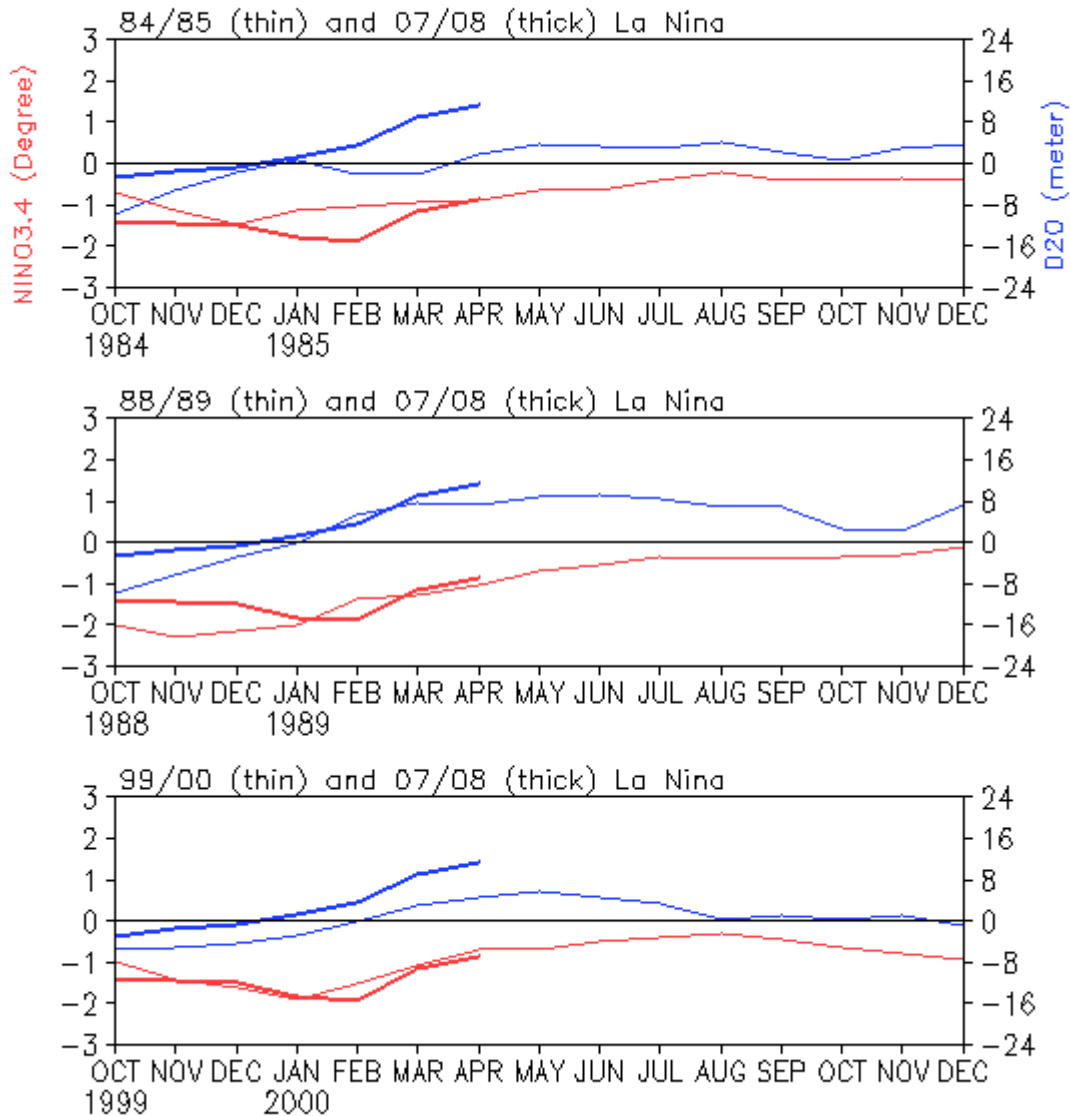
1999-00 La Nina

2°S–2°N Average, 3 Pentad Running Mean

5°S–5°N Average
(3 Pentad Running Mean)



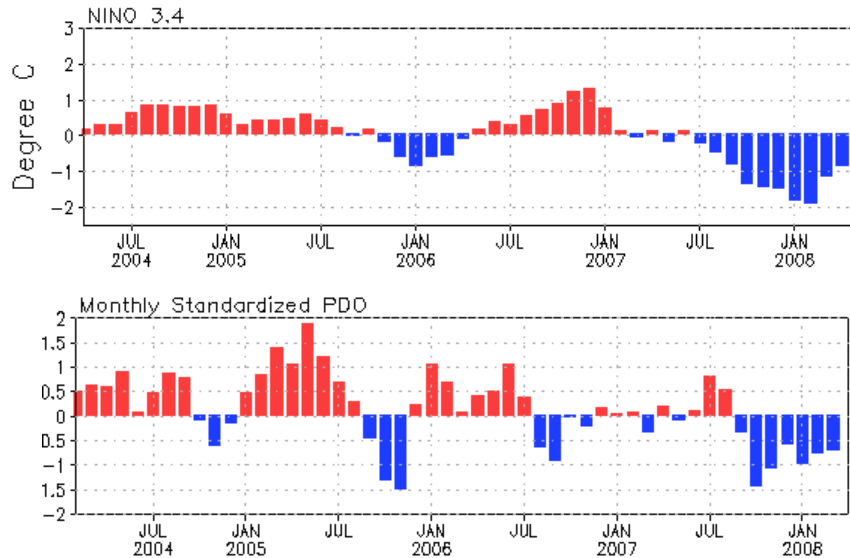
D20 Anom. Average in [5°S–5°N,120°E–80°W]
and NINO3.4 SST Anomaly



NINO3.4 vs WWV

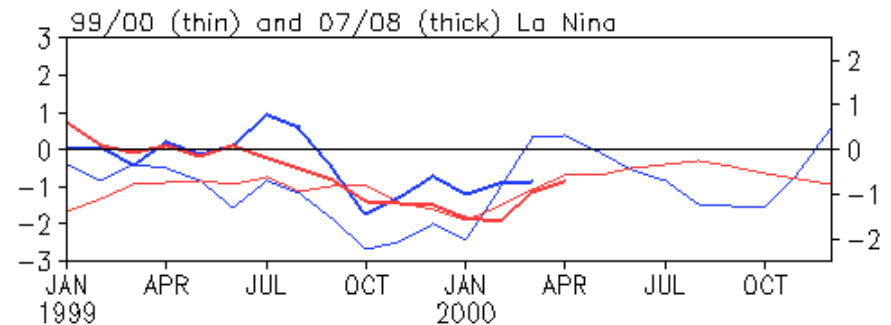
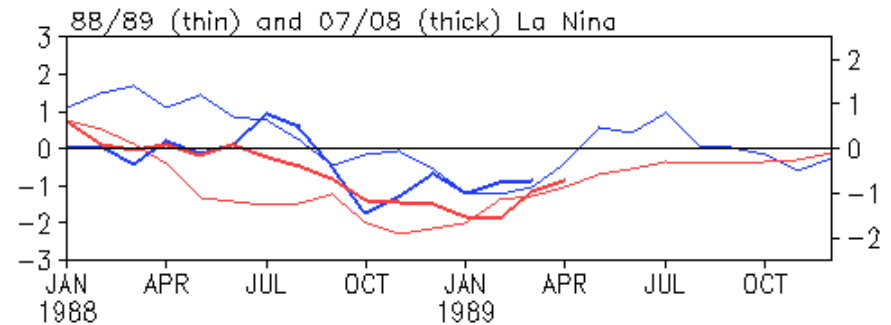
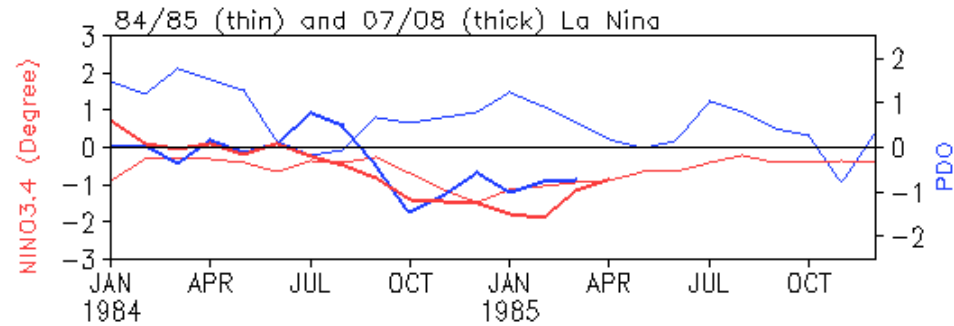
- Warm Water Volume (average depth of 20 degree isotherm anomalies) leads NINO3.4 by 6-9 months
- Compared to the 84/85, 88/89 and 99/00 La Niña, the 07/08 La Niña has higher WWV but similar NINO3.4 anomaly in April
- But the 99/00 La Niña is the closest analog to the 07/08 La Niña (see last slide)
- A transition to ENSO-neutral conditions in next 2-3 months is possible

NINO3.4 vs PDO

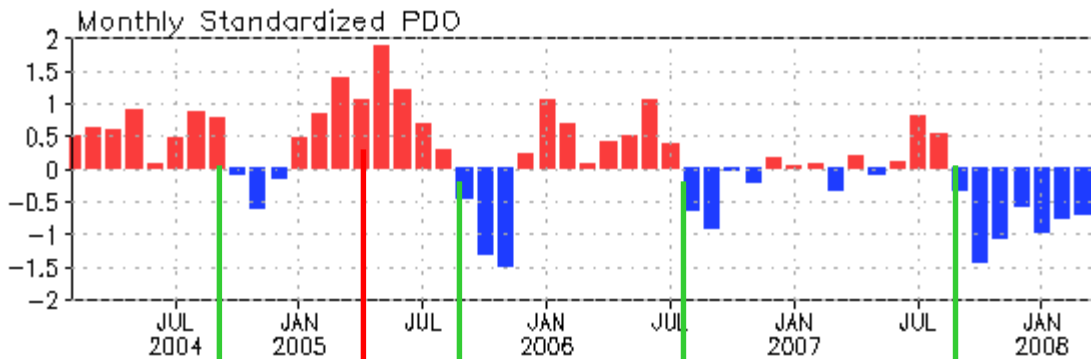


- La Nina conditions developed in August 2007, while negative PDO pattern occurred in September 2007
- During the 84/85 La Nina, PDO has been mostly positive
- During the 88/89 La Nina, PDO lagged NINO3.4 by 8 months and switched to positive in spring 89 when NINO3.4 remained negative
- During the 99/00 La Nina, PDO and NINO3.4 were both negative. PDO returned to near-normal in spring and became negative again in summer/fall
- The 07/08 La Nina probably contributed to development and maintenance of negative PDO phase. It is unclear if PDO had any feedbacks to the La Nina.

Standardized PDO and NINO3.4 SST Anomaly

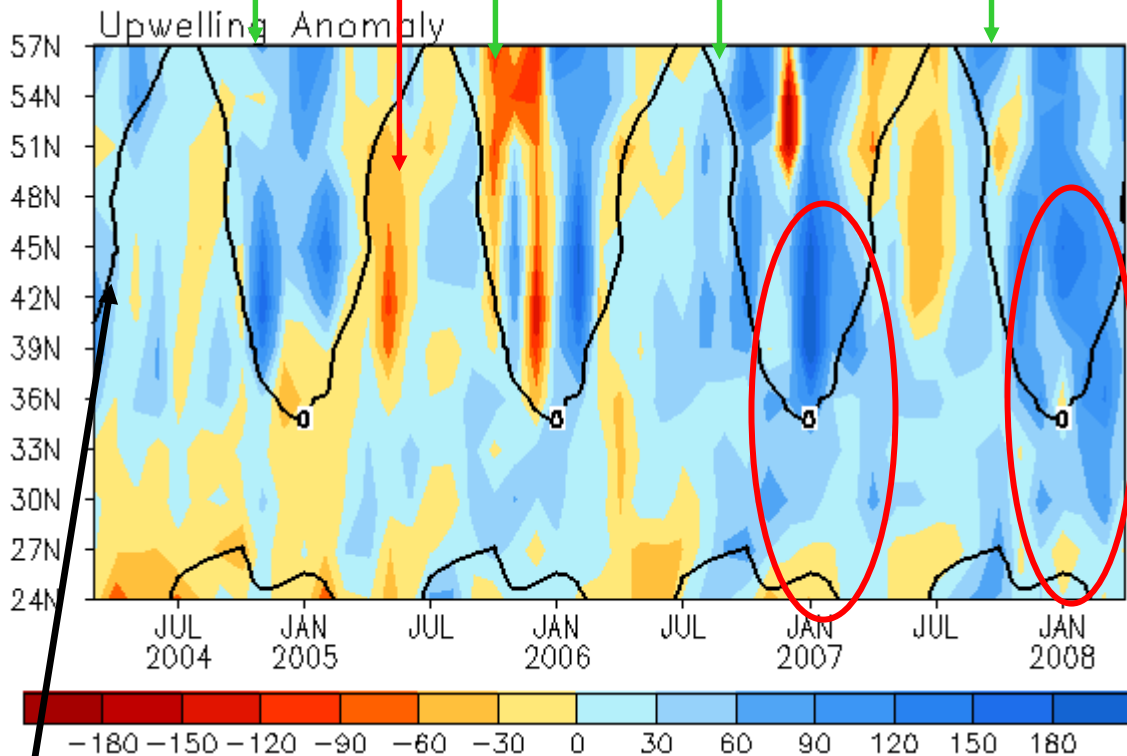
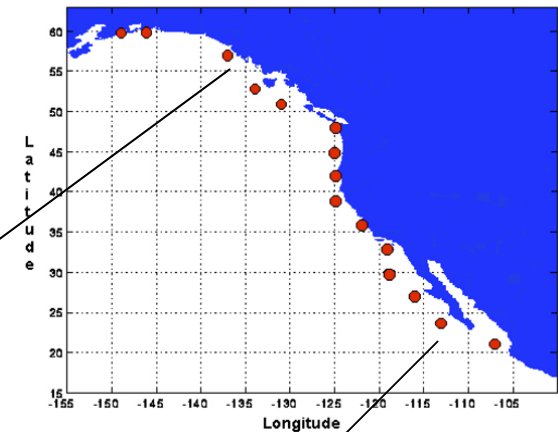


PDO and North America Western Coastal Upwelling



[UW/NOAA JISAO PDO page](#)

Standard Positions of Upwelling Index Calculations



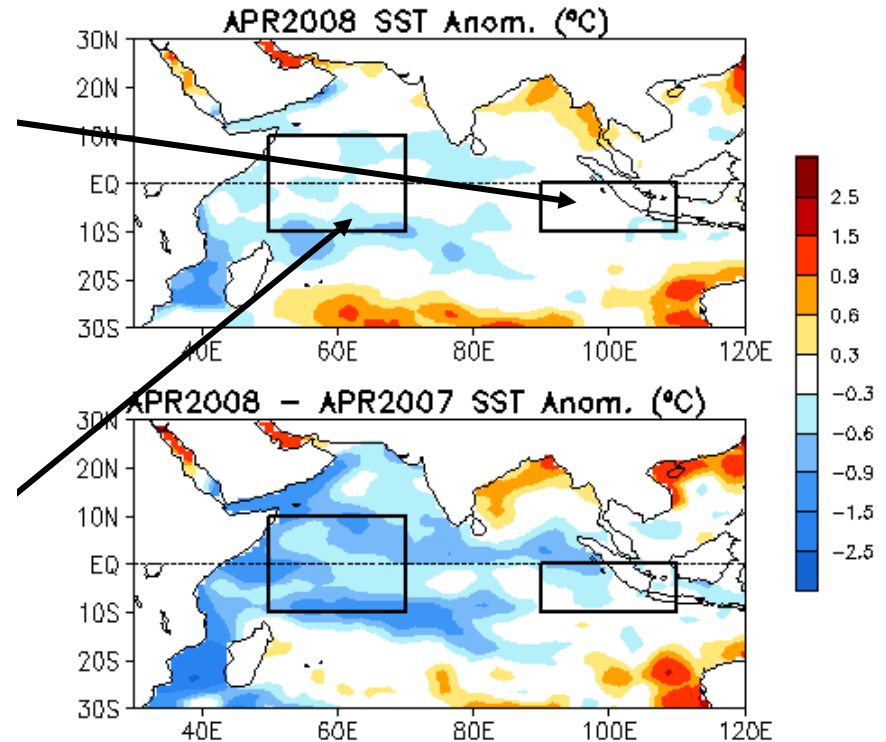
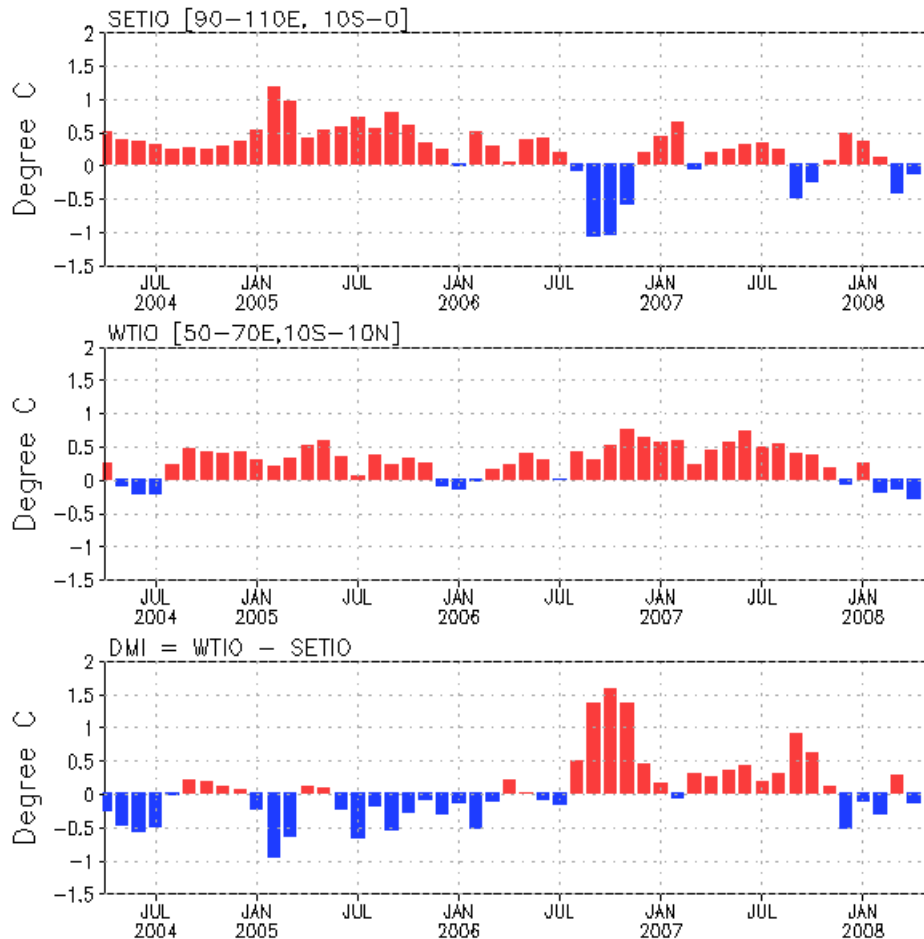
- PDO has a downward trend
- Negative (positive) PDO is associated with above-normal (below-normal) upwelling
- Upwelling along the west coast of North America had been strongly above-normal since Feb 08

- Area below (above) black line indicates climatological upwelling (downwelling) season
- Climatologically upwelling season progresses from March to July along the west coast of North America from 36°N to 57°N.

Indian Ocean

Recent Evolution of Indian Ocean SST Indices

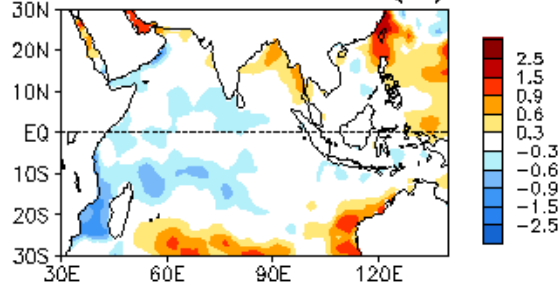
Indian Ocean Dipole Mode Indices



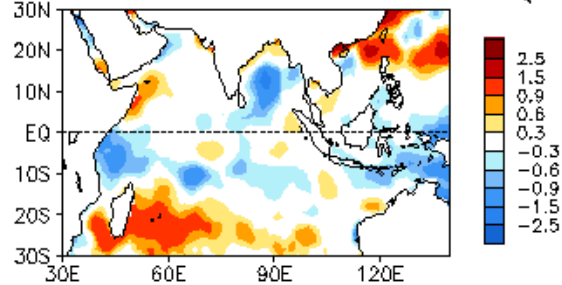
- Weak below-normal SST in tropical Indian Ocean
- Western Indian Ocean was 0.5-1 degree cooler than last year
- IO Dipole Mode Index (DMI) was near normal

Tropical Indian: SST Anom., SST Anom. Tend., OLR, 850-mb Winds, Sfc Rad, Sfc Flx

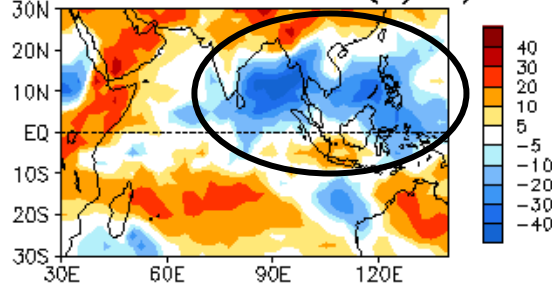
APR 2008 SST Anom. ($^{\circ}\text{C}$)



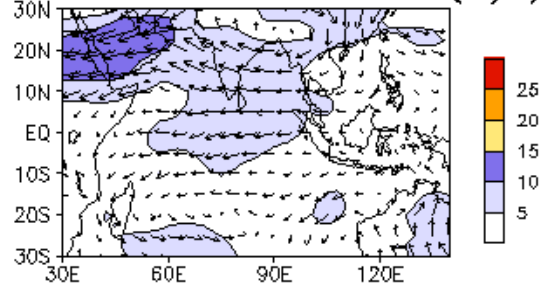
30APR2008 - 26MAR2008 SST Anom. ($^{\circ}\text{C}$)



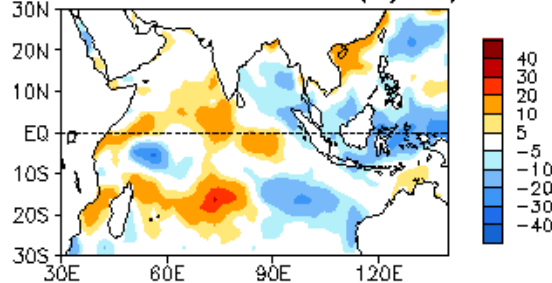
APR 2008 OLR Anom. (W/m^2)



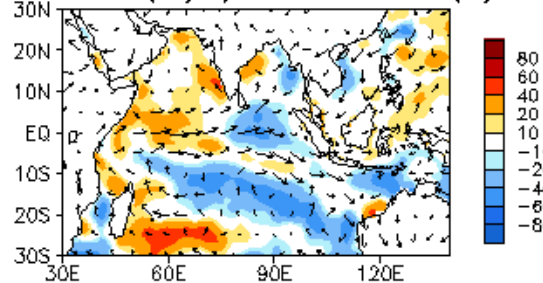
APR 2008 200 mb Wind Anom. (m/s) $\overrightarrow{15}$



APR 2008 SW + LW (W/m^2)

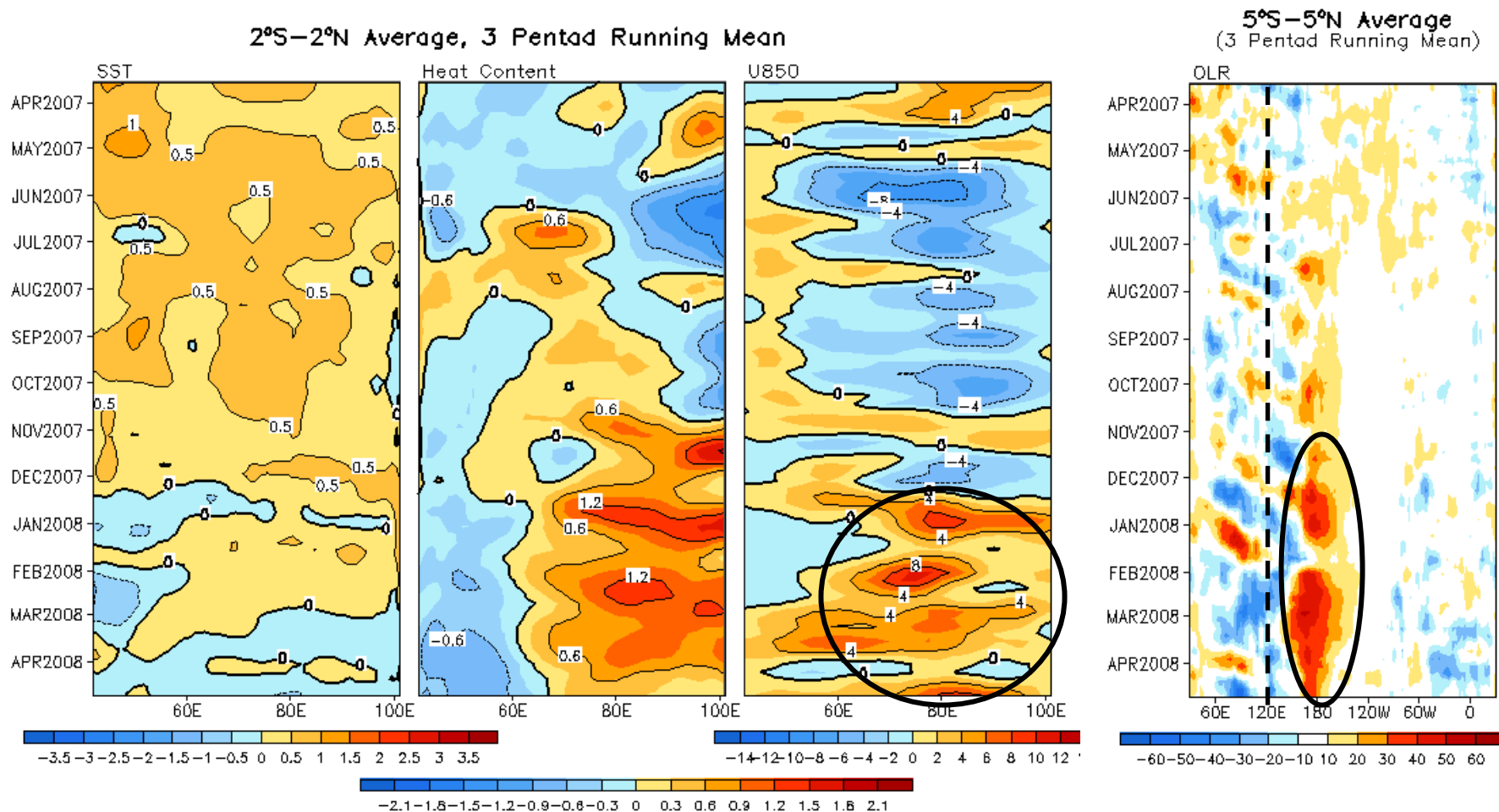


925mb Wind (m/s) & LH + SH (W/m^2) $\overrightarrow{8}$



- Above-normal rainfall over Bay of Bengal and the Maritime Continent
- Westerly (easterly) wind anomalies at 925 hPa (200 hPa), typical responses to the La Nina forcing

Recent Evolution of Equatorial Indian SST ($^{\circ}\text{C}$), 0-300m Heat Content ($^{\circ}\text{C}$), 850-mb Zonal Wind (m/s) and OLR (W/m^2)

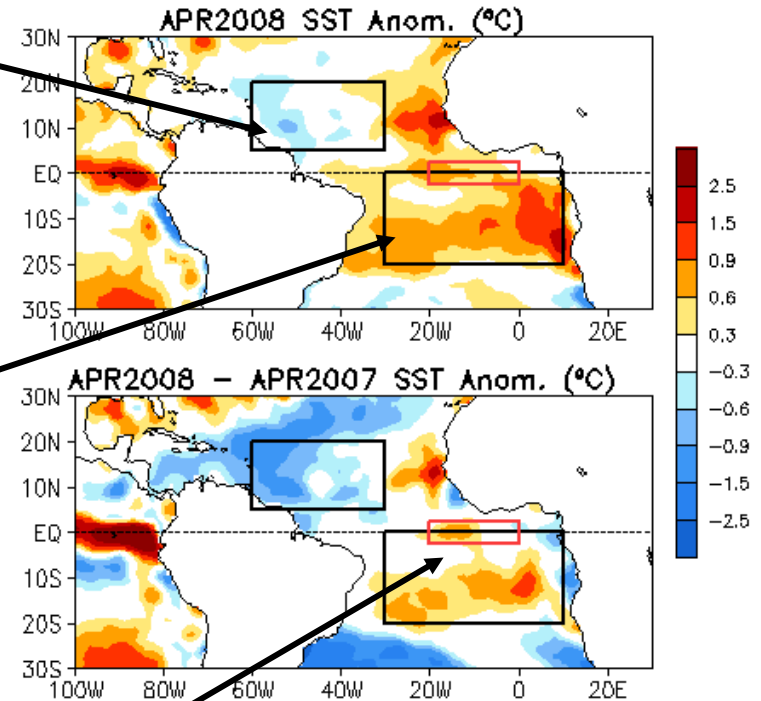
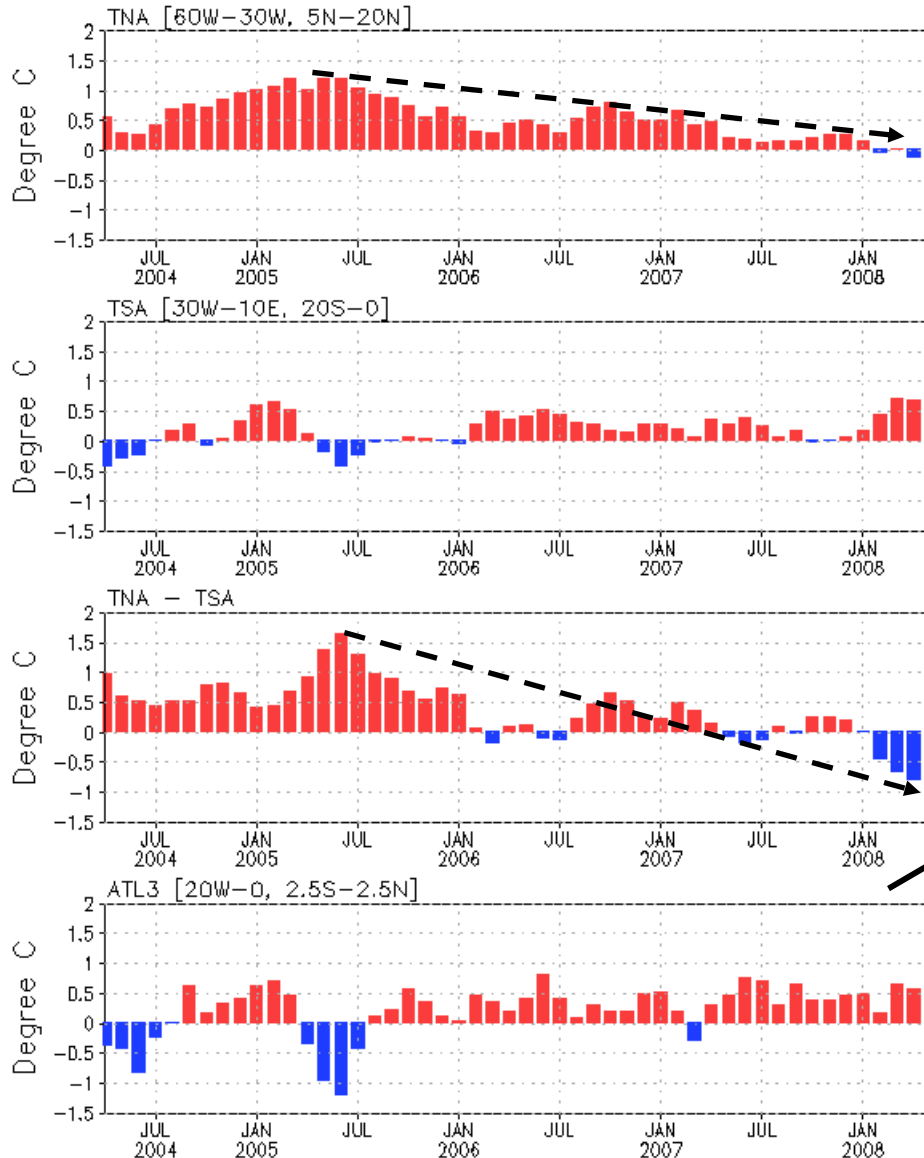


- Westerly wind anomaly persisted since mid-December, corresponding to enhanced convection in eastern Indian Ocean and the Maritime Continent
- Westerly wind anomaly forced positive (negative) heat content in the eastern (western) Indian Ocean
- SST has been cooling down since December and became below-normal across the basin in April

Atlantic Ocean

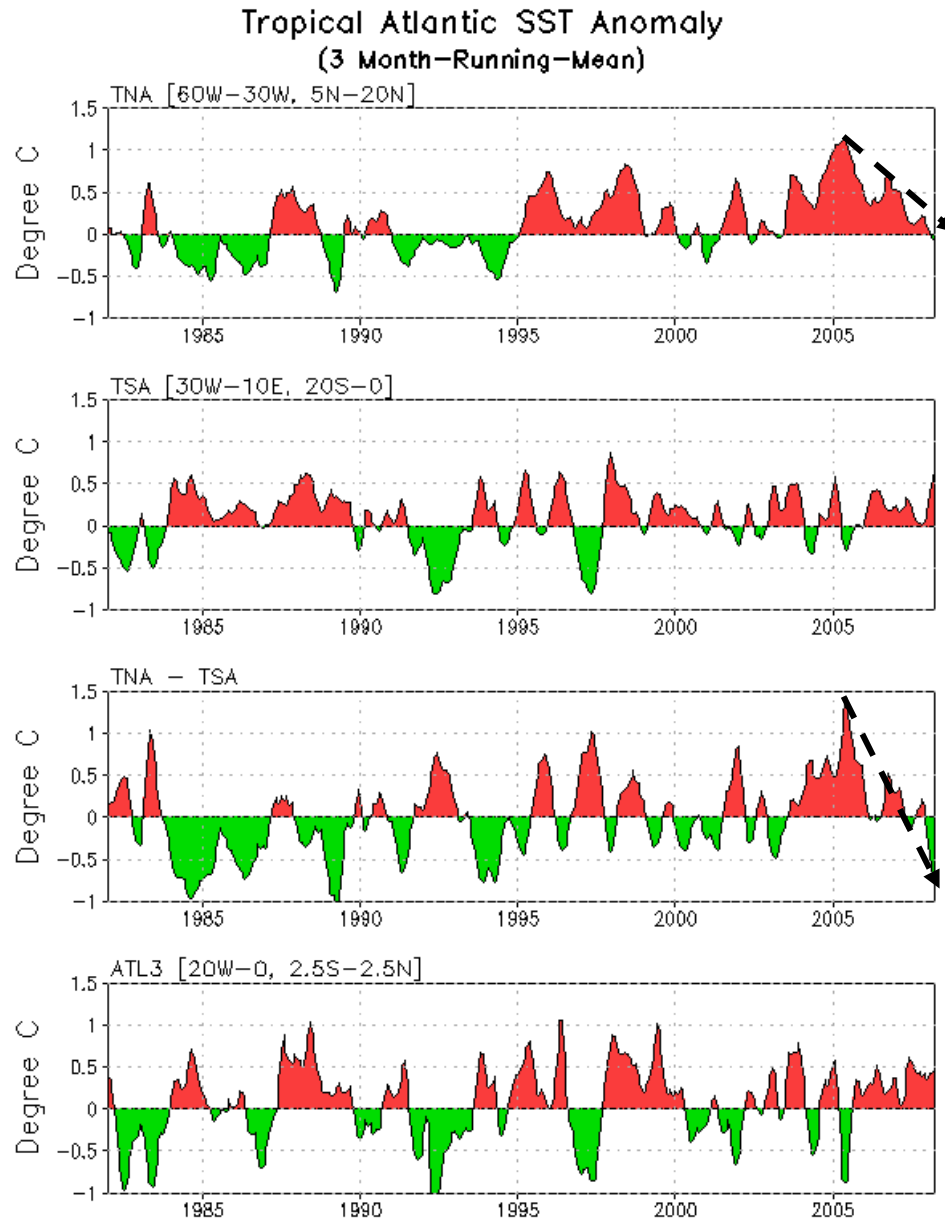
Evolution of Tropical Atlantic SST Indices

Monthly Tropical Atlantic SST Anomaly

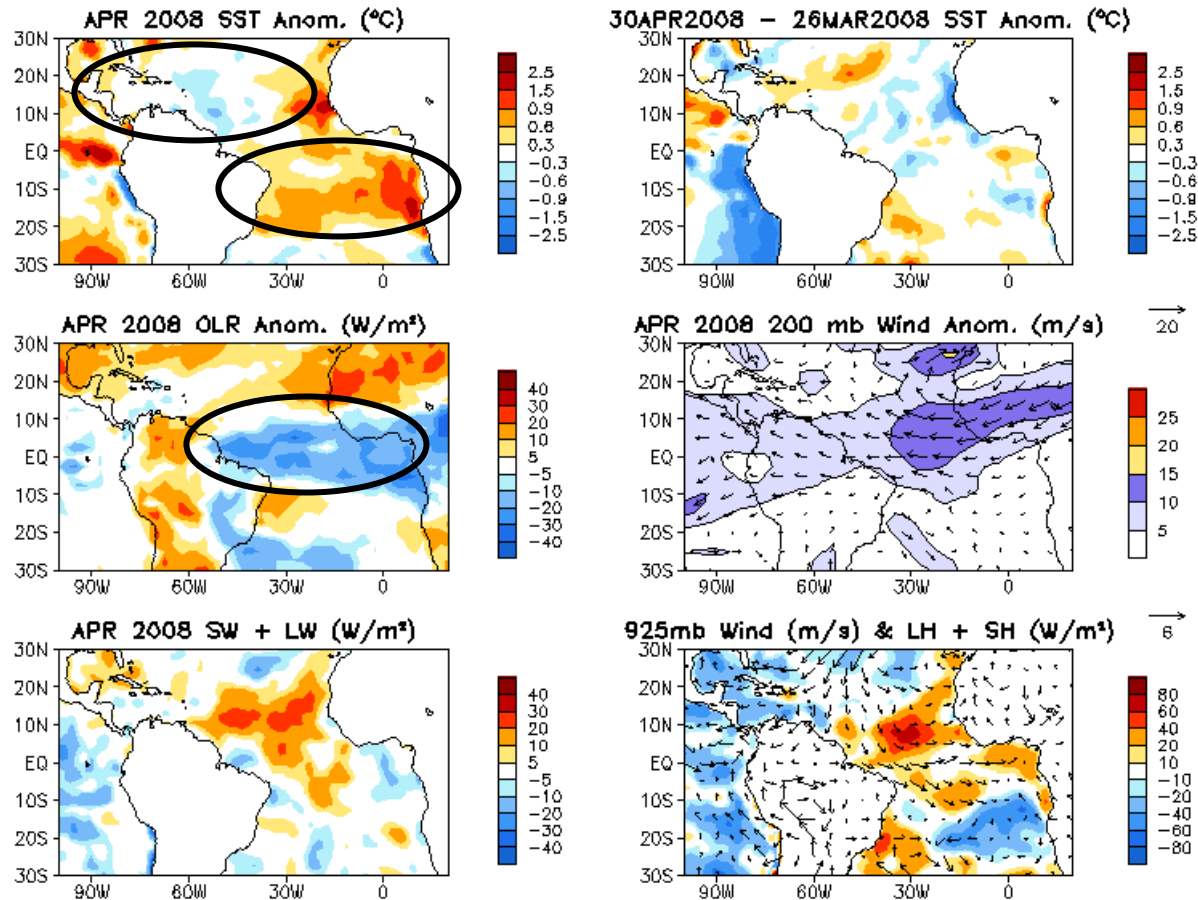


- TNA has been trending downward from about +1C above-normal in summer 2005 to slightly below-normal in April. It was about 0.6 degree colder than last April.
- TSA was above-normal in April
- Meridional SST Gradient Mode (TNA-TSA) has a downward trend since summer 2005 and became below-normal in Feb-Apr
- ATL3 was above-normal

Evolution of Tropical Atlantic SST Indices

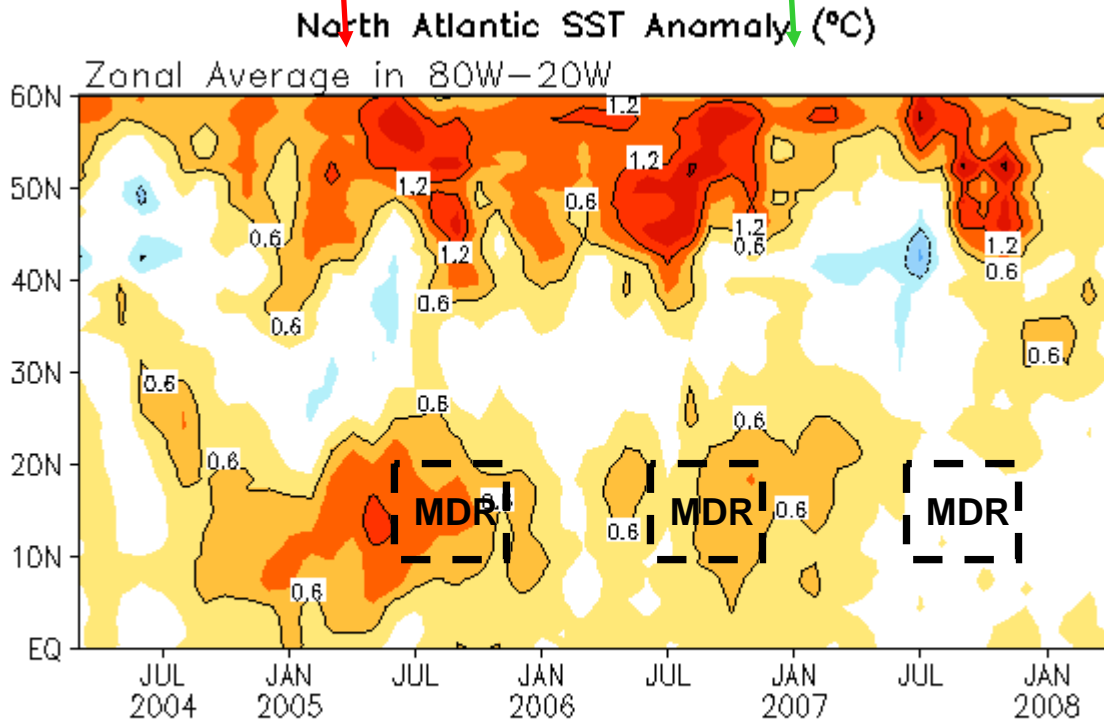
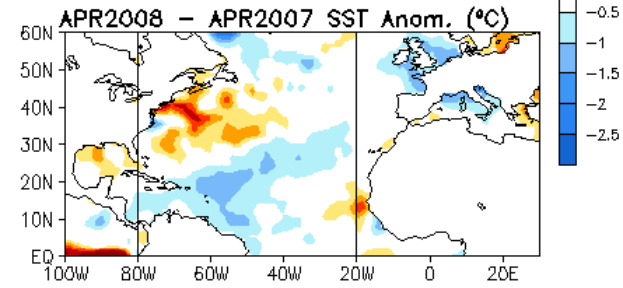
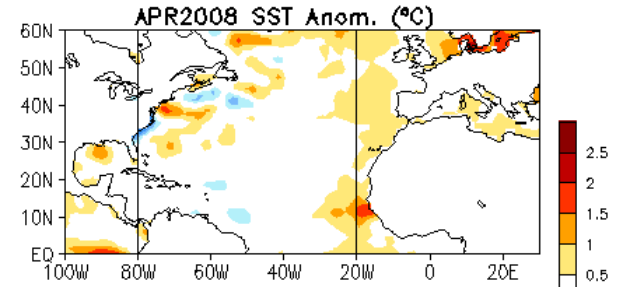
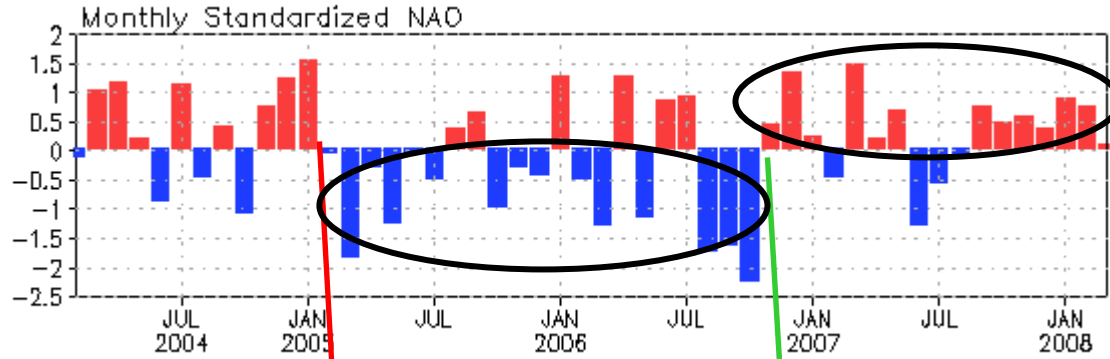


Tropical Atlantic: SST Anom., SST Anom. Tend., OLR, 850-mb Winds, Sfc Rad, Sfc Flx



- Positive (negative) SSTA presented in southern (northern) subtropical Atlantic, generating a negative Meridional SST Mode
- Low-level (925 hPa) north-westerly wind anomalies corresponds to the negative SST gradient and enhanced convection along the equatorial Atlantic

SST Anomaly in North Atlantic

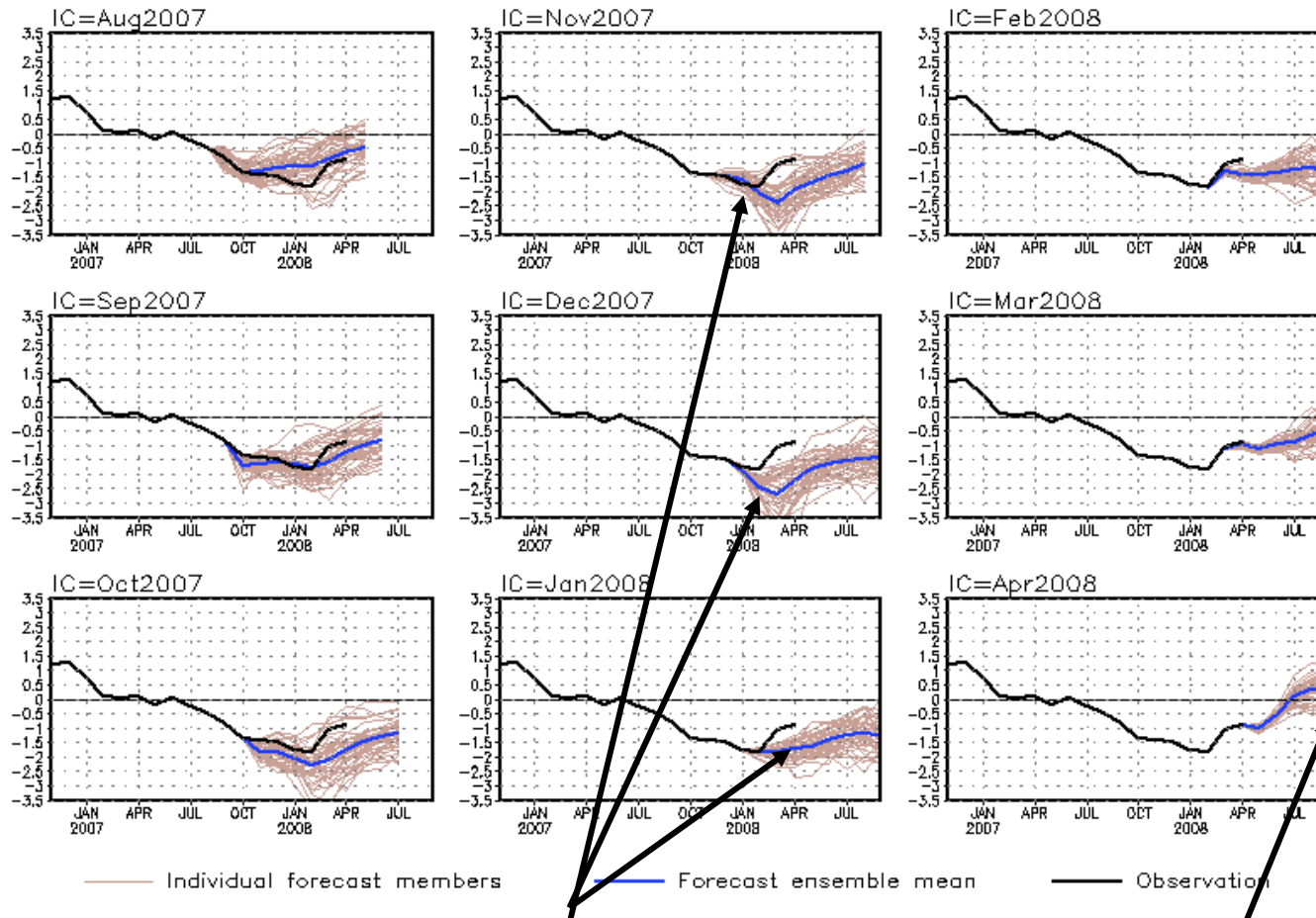


- SSTa in Atlantic hurricane Main Development Region (MDR) was near normal in summer/fall 2007, much cooler than that of 2006 and 2005
- High-latitude North Atlantic SSTa are closely related to NAO index – negative NAO leads to SST warming and positive NAO leads to SST cooling
- NAO was mostly negative during 2005 and 2006, but mostly positive during 2007

CFS SST Predictions and Ocean Initial Conditions

CFS Niño 3.4 SST Predictions from Different Initial Months

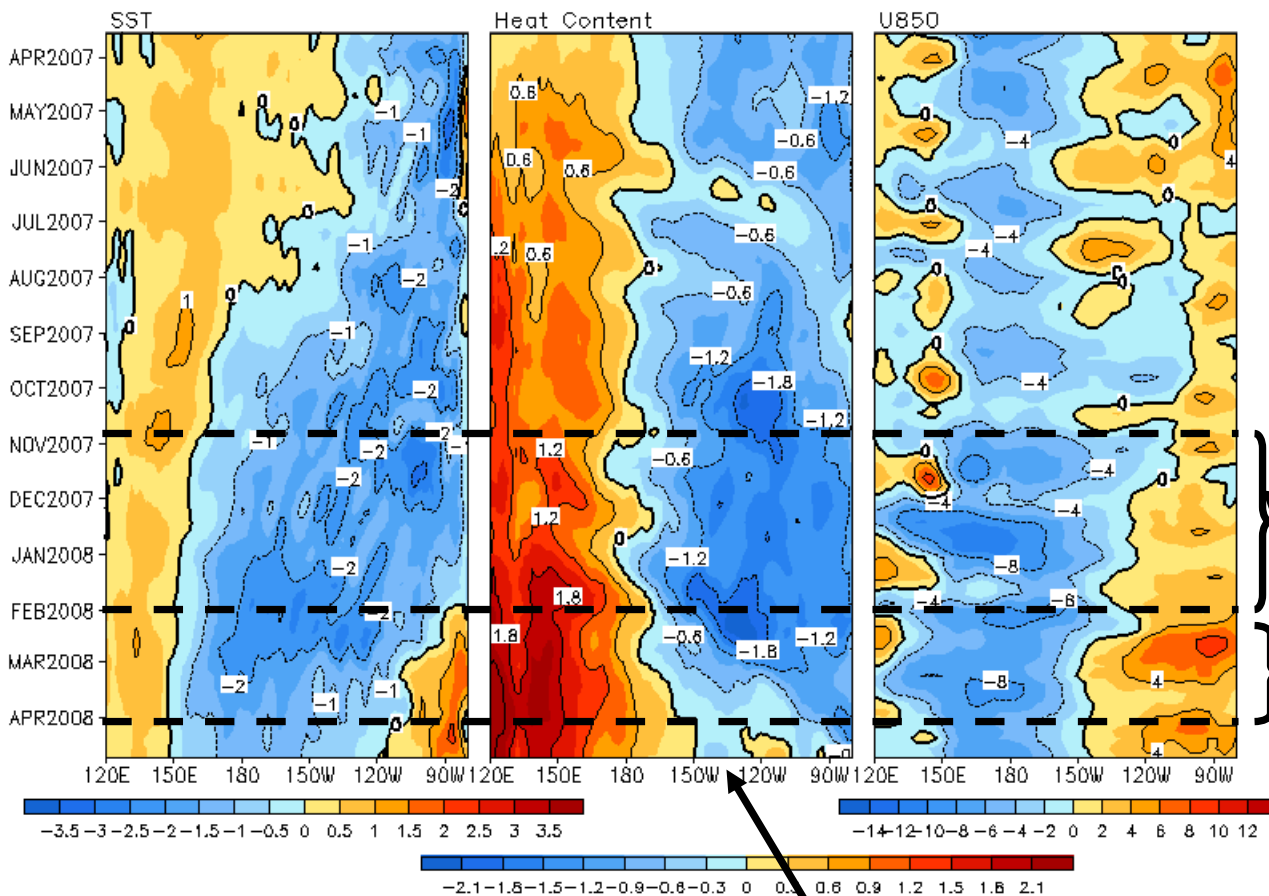
Niño34 SST anomalies (K)



- SST forecast biased towards cold in Nov-Jan
- SST forecast appeared reasonable in Feb-Mar
- CFS forecast weak warm conditions for summer 2008 from April initial conditions

Evolution of Equatorial Pacific SST ($^{\circ}\text{C}$), 0-300m Heat Content ($^{\circ}\text{C}$), 850-mb Zonal Wind (m/s), and OLR (W/m^2)

2 $^{\circ}\text{S}$ –2 $^{\circ}\text{N}$ Average, 3 Pentad Running Mean



Forecasts were too cold because CFS did not anticipate the rapid weakening of negative heat content anomalies in Feb-Mar

Forecasts appear reasonable

CFS forecast weak warm conditions for summer 2008 when positive heat content anomalies presented in the eastern Pacific in late April

Summary

• Global Ocean

- Global ocean mean SST has been persistently above-normal since 2000
- It became near-normal in November 2007 – April 2008, largely due to the 07/08 La Nina
- In contrast, global sea surface height has been rising steadily since 1992 when the Altimetry SSH became available

• Pacific Ocean

- La Nina weakened (NINO3.4 changed from -1.1 to -0.85 C)
- CPC's prognostic assessment: A transition to ENSO-neutral conditions were possible in next 2-3 months
- Easterly wind anomalies and suppressed convection in C. Pacific weakened
- Negative subsurface temperature anomalies in E. Pacific switched to positive anomalies
- Positive SSTA in far E. Pacific and westerly wind anomalies east of 150W persisted
- Anticyclonic wind anomalies near the coast of California persisted and forced above-normal coastal upwelling in Feb-Apr

• Indian Ocean

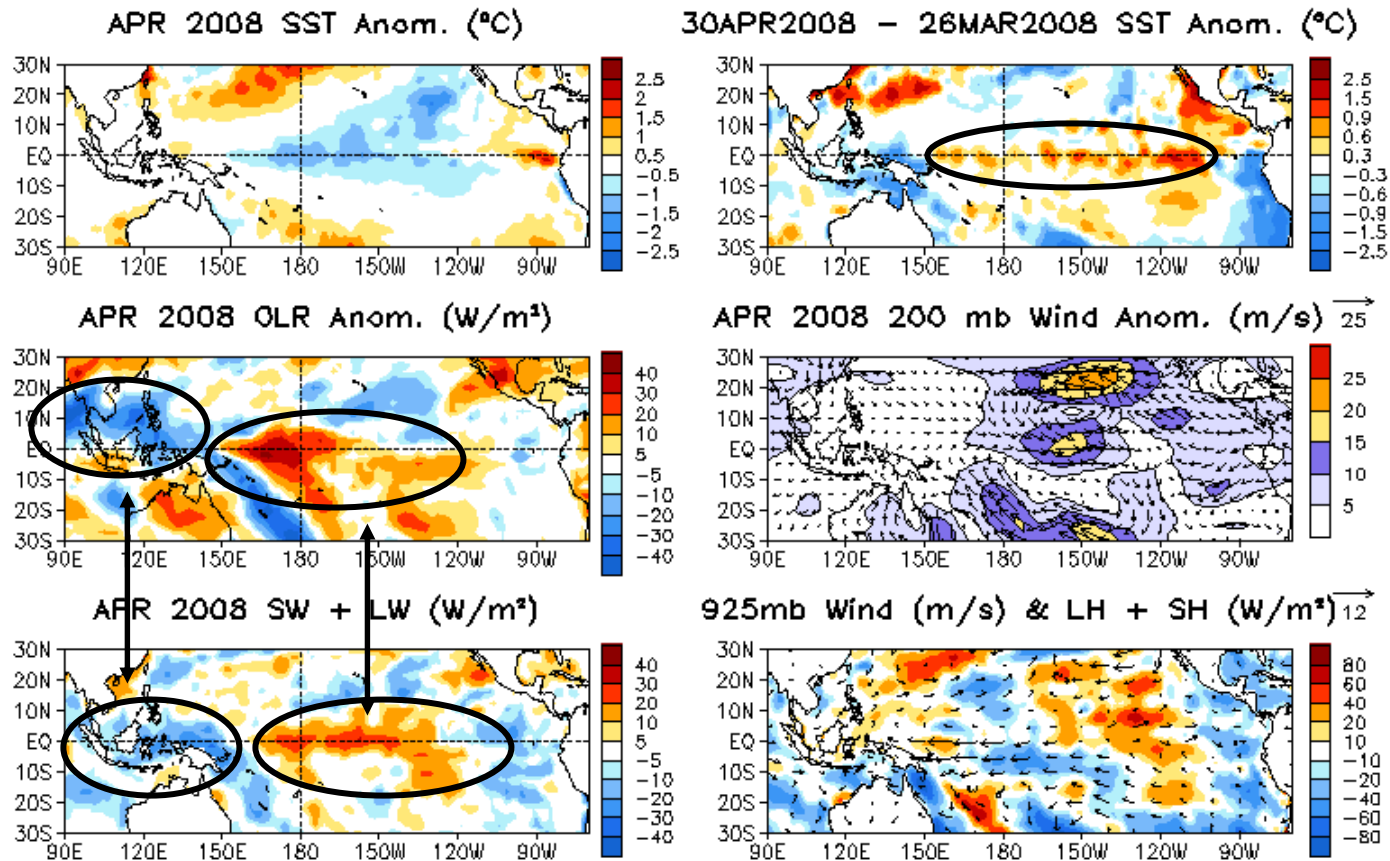
- Above-normal rainfall over Bay of Bengal and the Maritime Continent
- Westerly wind anomalies and below-normal SST were responses to the La Nina forcing

• Atlantic Ocean

- Tropical North Atlantic SST has a cooling trend since 2005, and became below-normal in Mar-Apr and SST was 0.9C cooler than last year west of Caribbean Sea
- Negative Meridonal SST Mode persisted associated with which were north-westerly wind anomalies and enhanced convection in the equatorial Atlantic

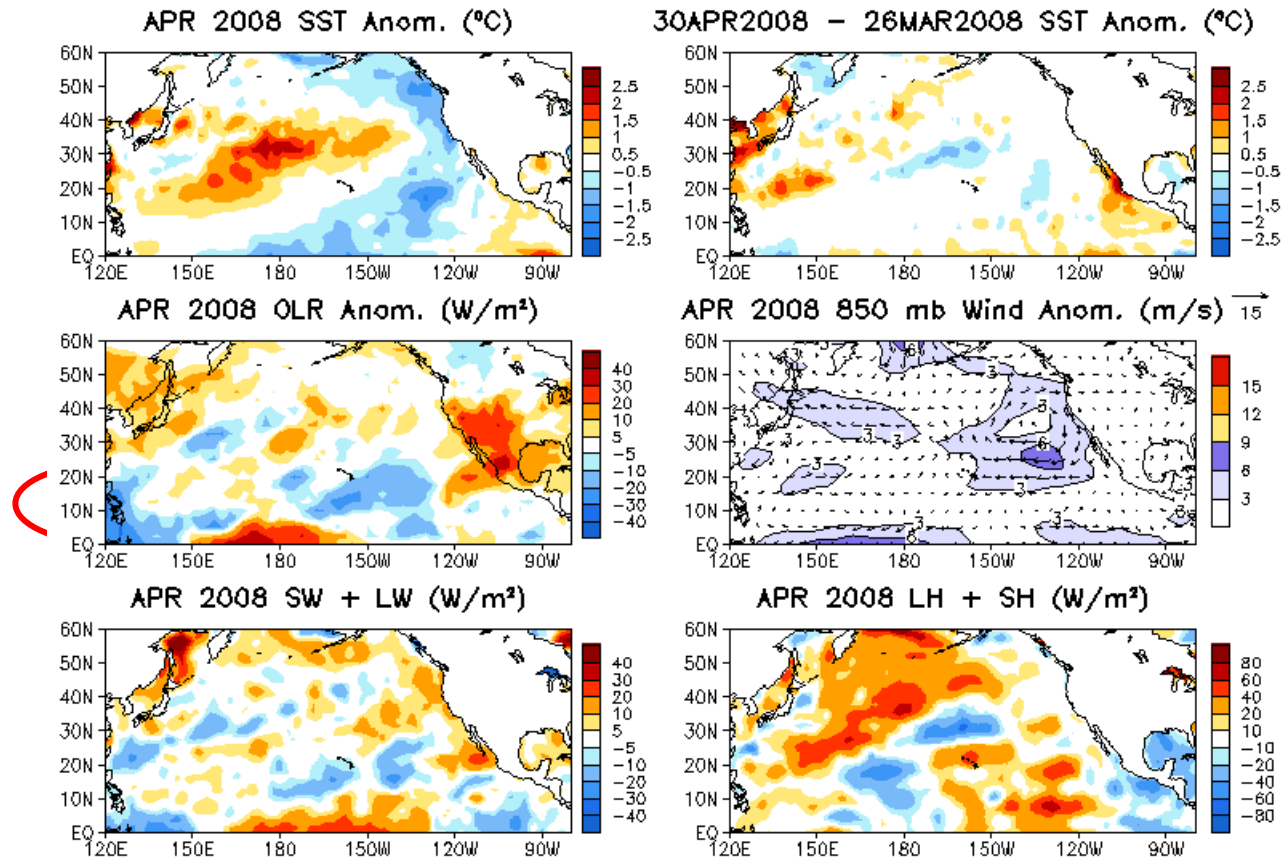
Backup Slides

Tropical Pacific: SST Anom., SST Anom. Tend., OLR, 850-mb Winds, Sfc Rad, Sfc Flx



- Enhanced convection in the Maritime Continent, suppressed convection in the western and central Pacific
- Easterly wind anomalies in the western Pacific and westerly wind anomalies in the eastern Pacific
- Both SW+LW and LH+SH contributed to positive SST changes in the central and eastern Pacific

North Pacific: SST Anom., SST Anom. Tend., OLR, 850-mb Winds, Sfc Rad, Sfc Flx



- Cooling near the west coast of North America and Gulf of Alaska persisted
- Anti-cyclonic wind anomalies near the coast of California, favorable for coastal upwelling
- Ekman transport/pumping and surface latent heat flux were likely the main external forcing