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

Prepared by

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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

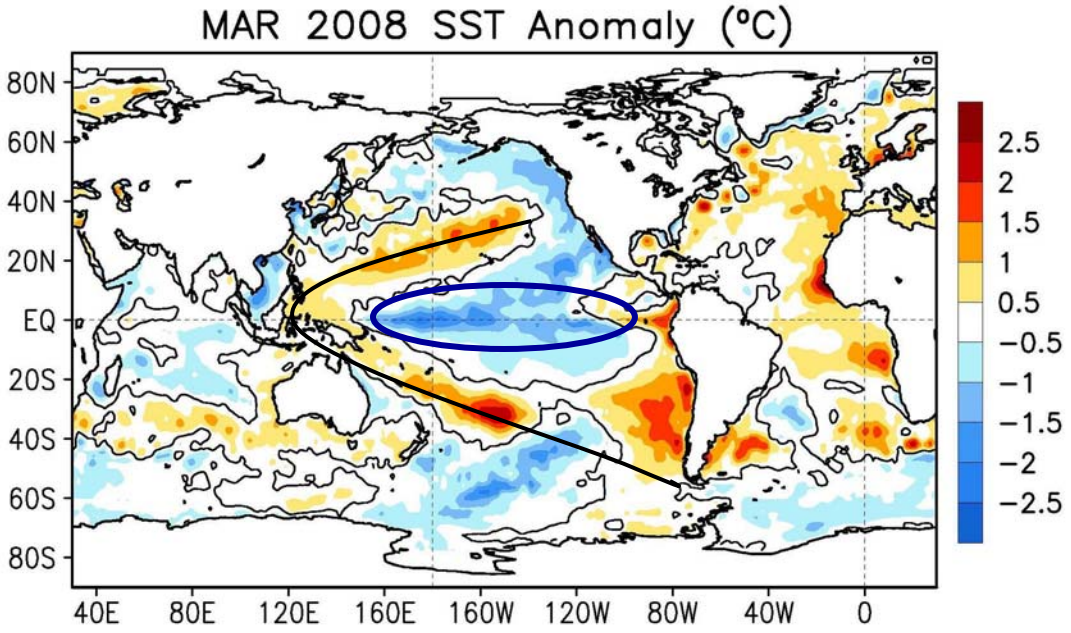
Data Sources

- **Optimal Interpolation SST (OI SST) version 2**
- **NCEP/NCAR Reanalysis-1 850 mb winds and heat fluxes**
- **NOAA's Outgoing Long Wave Radiation**
- **CPC's CAMS-OPI precipitation**
- **NCEP's Global Ocean Data Assimilation System (GODAS) subsurface temperature, heat content, surface currents**
- **Aviso Altimetry Sea Surface Height**
- **Ocean Surface Current Analyses – Realtime (OSCAR)**

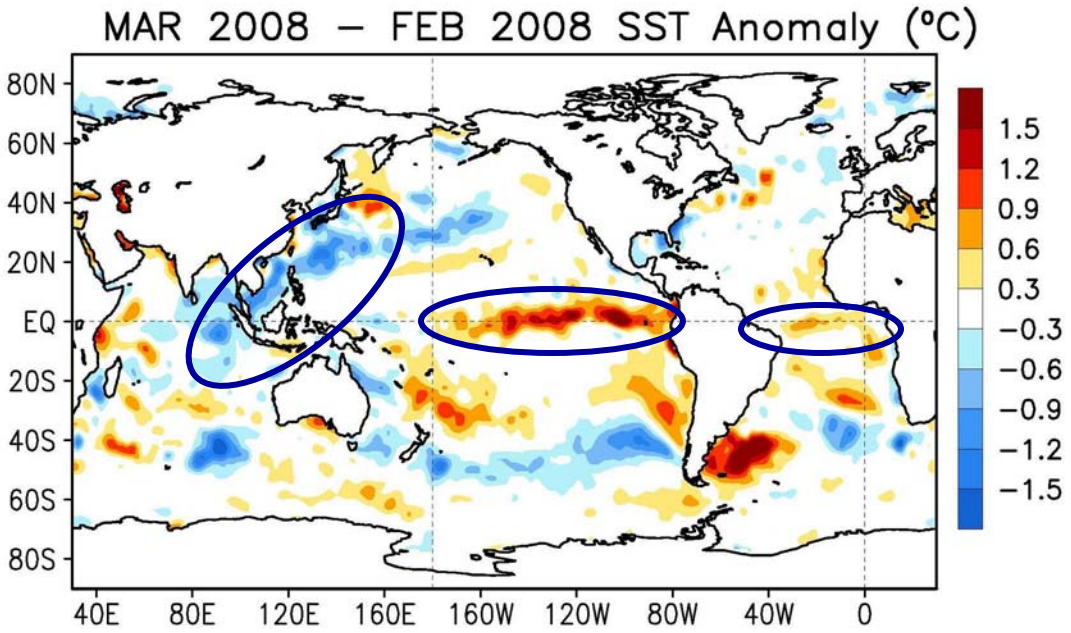
Overview

- **Global Ocean**
  - Global ocean mean SST has been persistently above-normal since 1995
  - It became below-normal in December 2007 – February 2008
- **Pacific Ocean**
  - La Nina weakened (NINO3.4 changed from -1.9C to -1.1C)
  - CPC's prognostic assessment: La Niña will continue into MJJ of 2008
  - Easterly wind anomalies and suppressed convection in C. Pacific persisted
  - Negative subsurface temperature anomalies in E. Pacific weakened substantially
  - Warming near the surface in the far E. Pacific was led by westerly wind anomalies there
  - Anticyclonic wind anomalies near the coast of California favored coastal upwelling
- **Indian Ocean**
  - Above-normal rainfall over India and the Maritime Continent
  - Westerly wind anomalies and SST cooling were responses to the La Nina
- **Atlantic Ocean**
  - Tropical North Atlantic SST has a cooling trend since 2005, and became below-normal in March 2008
  - North-westerly wind anomalies and enhanced convection in the equatorial Atlantic were consistent with the negative Meridonal SST Mode

Global SST Anomaly (°C) and Anomaly Tendency

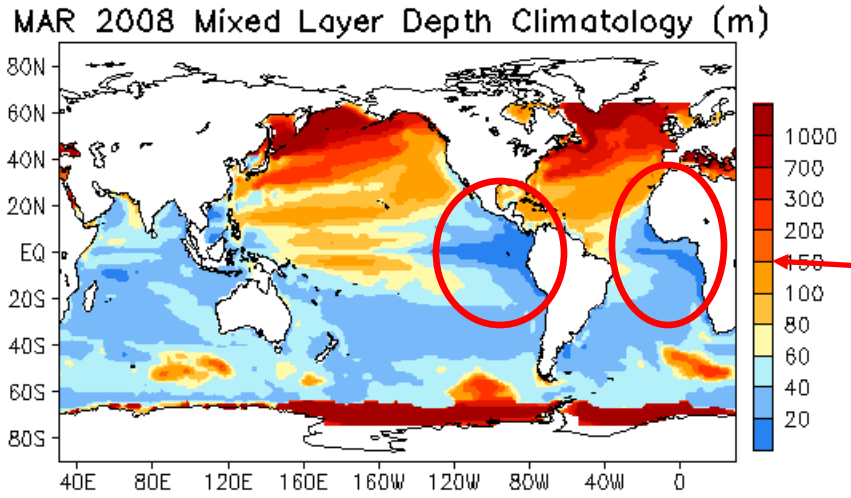


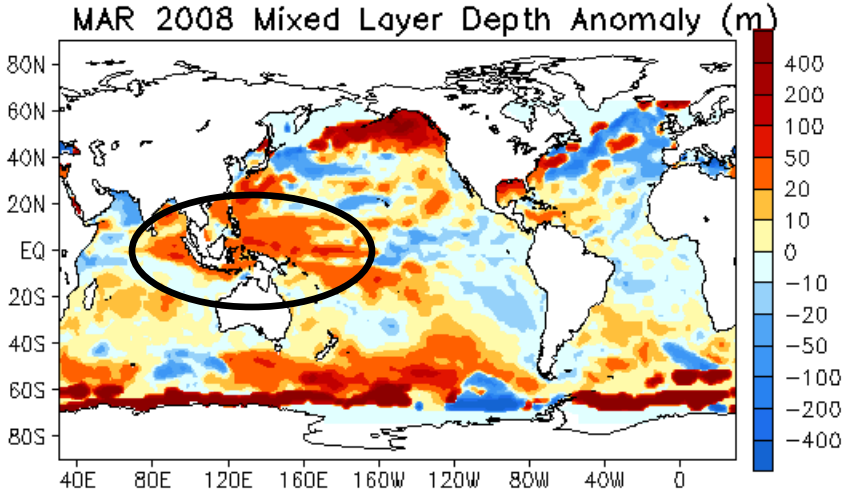
- Negative SSTA extending from 160E to 110W flanked by positive SSTA to the west and east
- Negative SSTA near the west coast of North America
- Above-normal SST in the Atlantic Ocean
- Weak below-normal SST in the tropical Indian Ocean

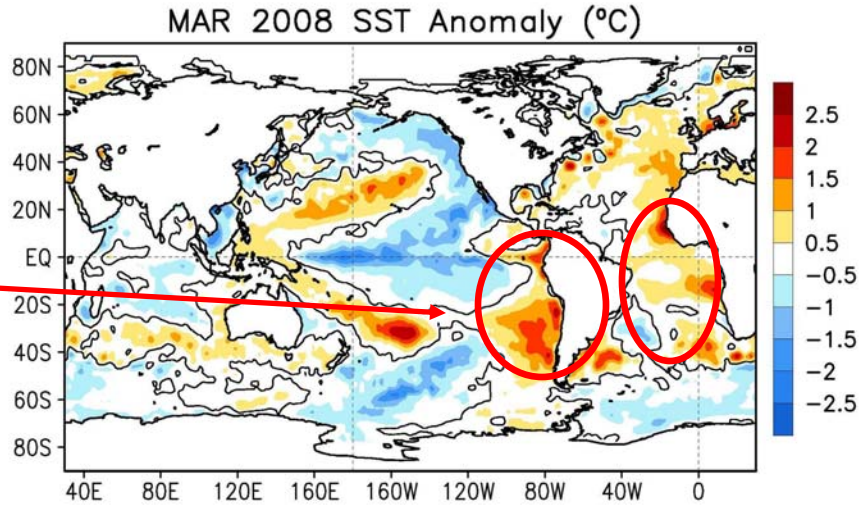


- Negative SSTA weakened from the Date Line to the west coast of South America
- SST decreased from the eastern Indian Ocean to South China Sea to Central Pacific
- SST increased in the tropical Atlantic

Mixed Layer Depth and SST

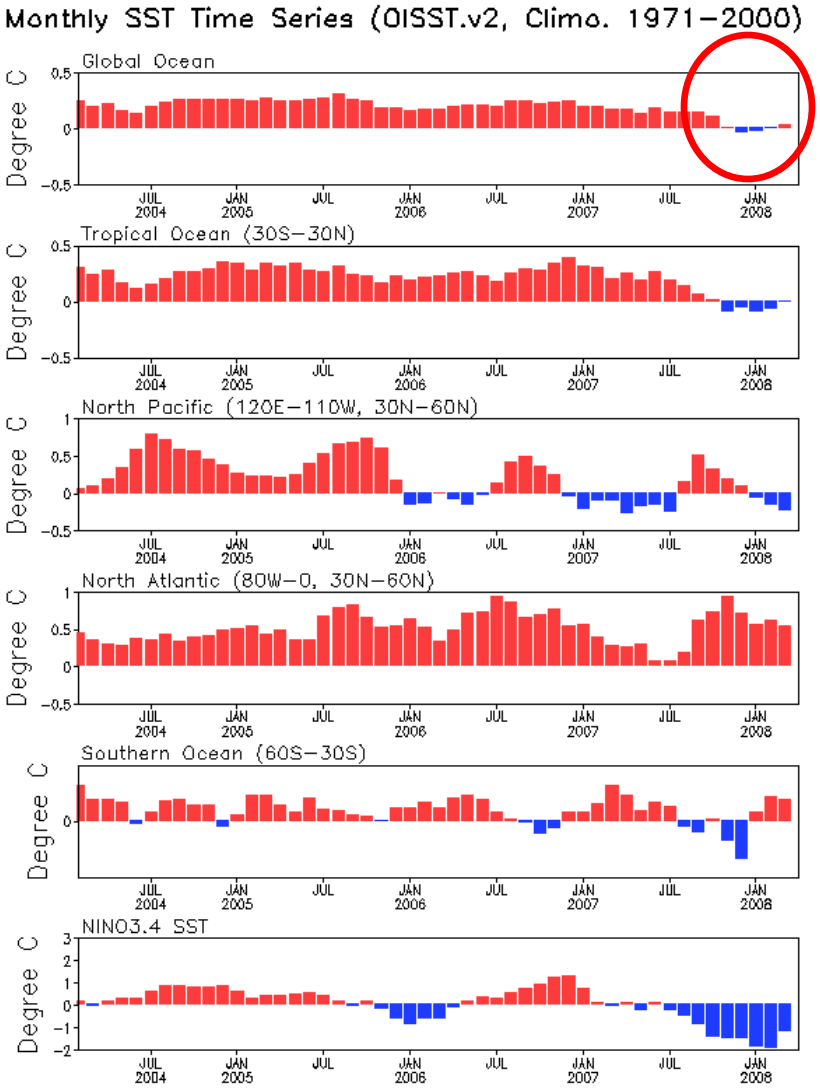




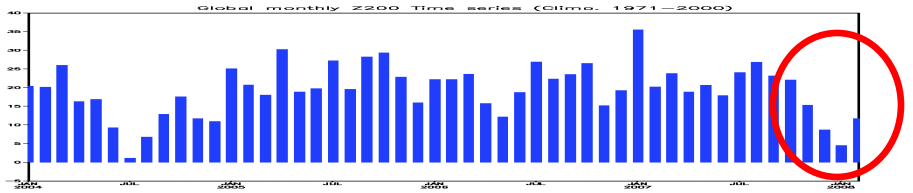


- **Mixed Layer Depth (MLD) is defined as the depth where temperature is 0.5C below the temperature at 5 meter depth**
- **MLD is above 80 meter in most of North Pacific and North Atlantic, but is below 40 meter in equatorial eastern Pacific, equatorial Atlantic, most of Indian Ocean and Southern Oceans**
- **MLD is above-normal in the western Pacific and eastern Indian Ocean**

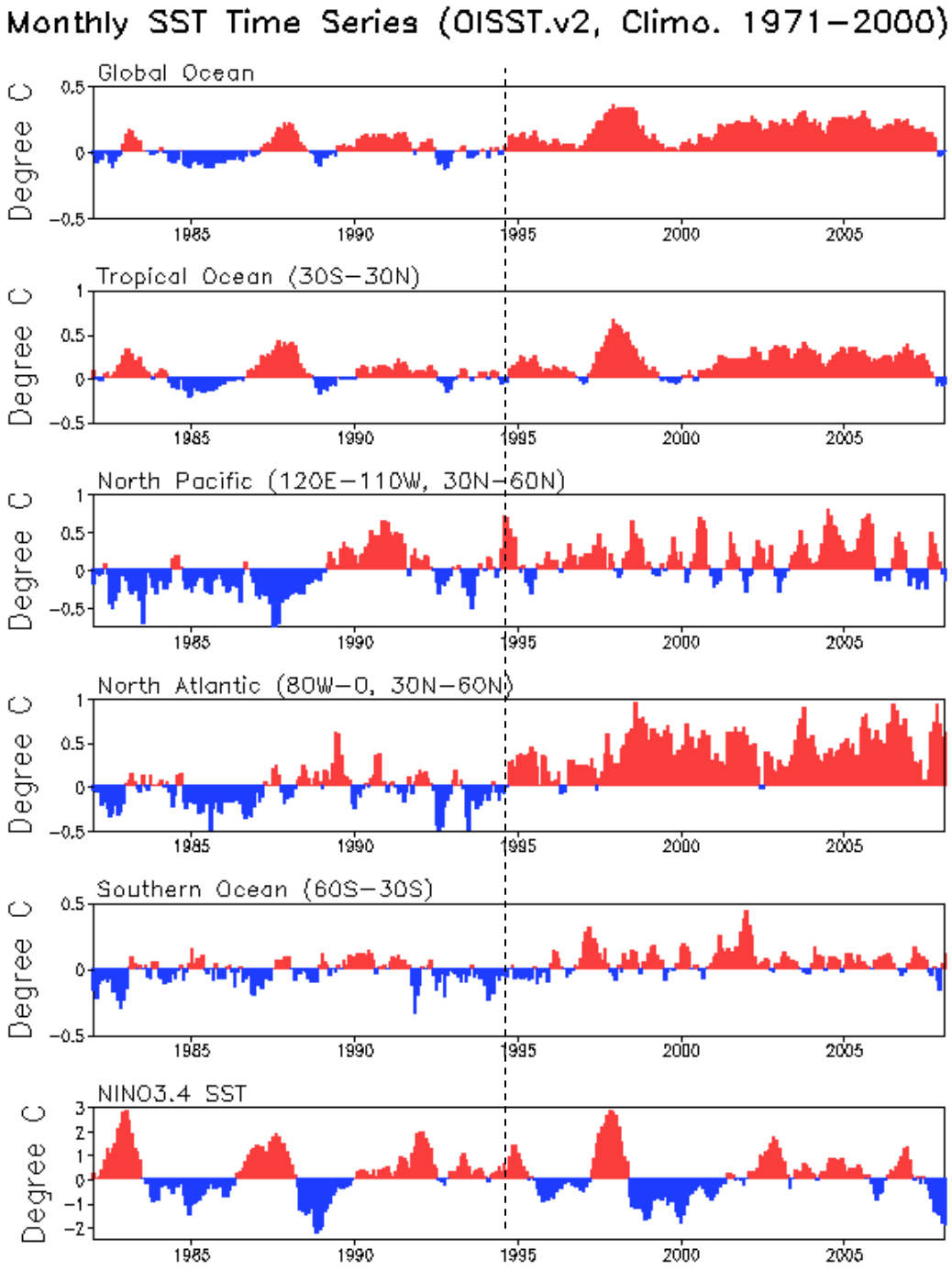
Monthly SST Time Series



Global 200mb Height Anom.

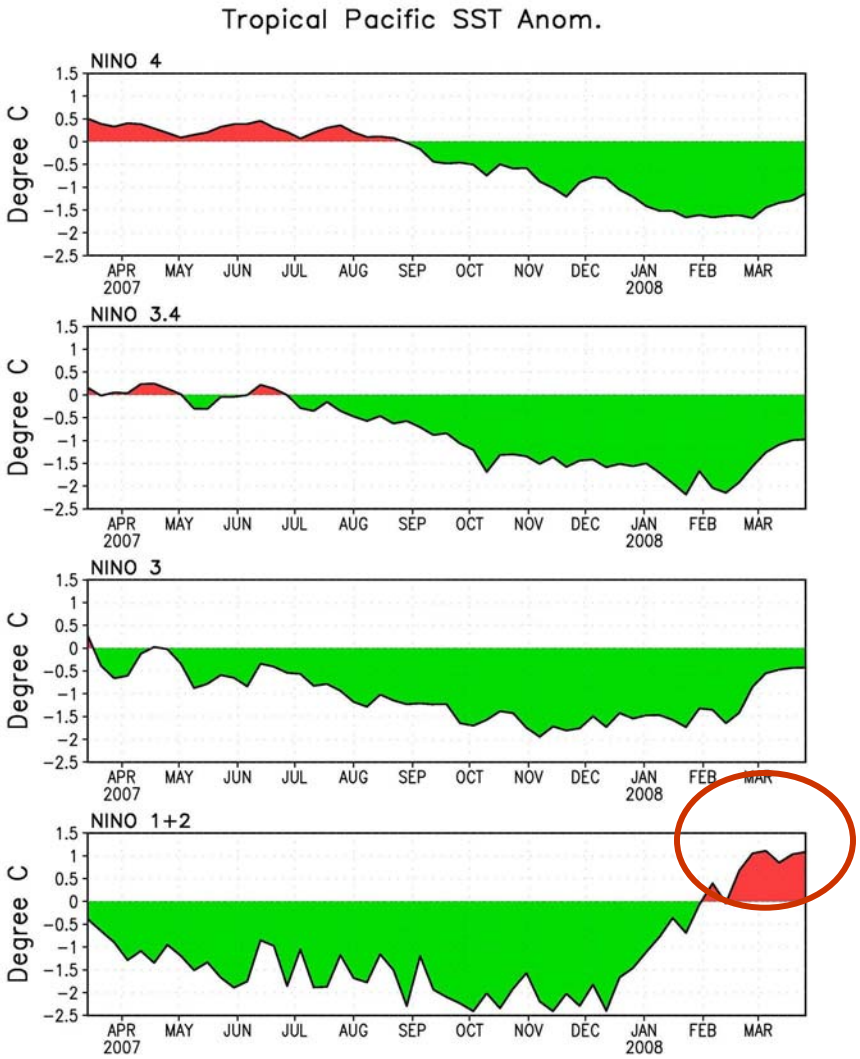


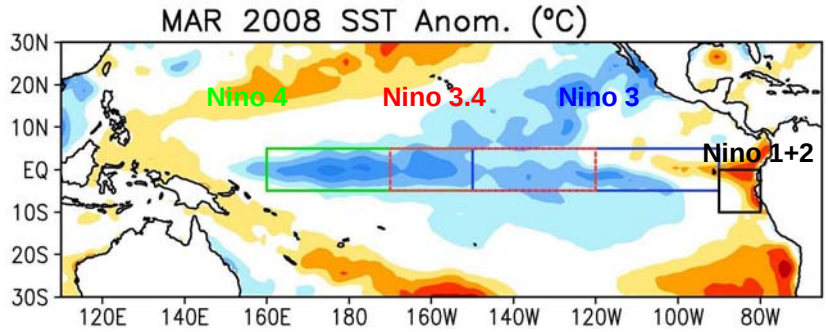
- Global mean SST has been persistently above-normal until November 2007, and became near-normal during November 2007-March 2008
- Global mean 200mb height anomaly decreased in response to the recent global SST cooling
- Tropical mean SST has been persistently above-normal until November 2007, and became below-normal afterwards due to development of the La Nina event
- North Pacific mean SST has a downward trend and a annual cycle of winter/spring cooling and summer/fall warming
- North Atlantic mean SST has been persistently above-normal except during summer of 2007
- Southern Ocean mean SST is mostly above-normal
- NINO3.4 SST became below-normal since August 2007, and reached a moderate-strength La Nina (< -1C) in October 2007


Monthly SST Time Series (OISST.v2, Climo. 1971–2000)
Global Ocean
Tropical Ocean (30S–30N)
North Pacific (120E–110W, 30N–60N)
North Atlantic (80W–0, 30N–60N)
Southern Ocean (60S–30S)
NINO3.4 SST
Degree C
1985
1990
1995
2000
2005

Pacific Ocean

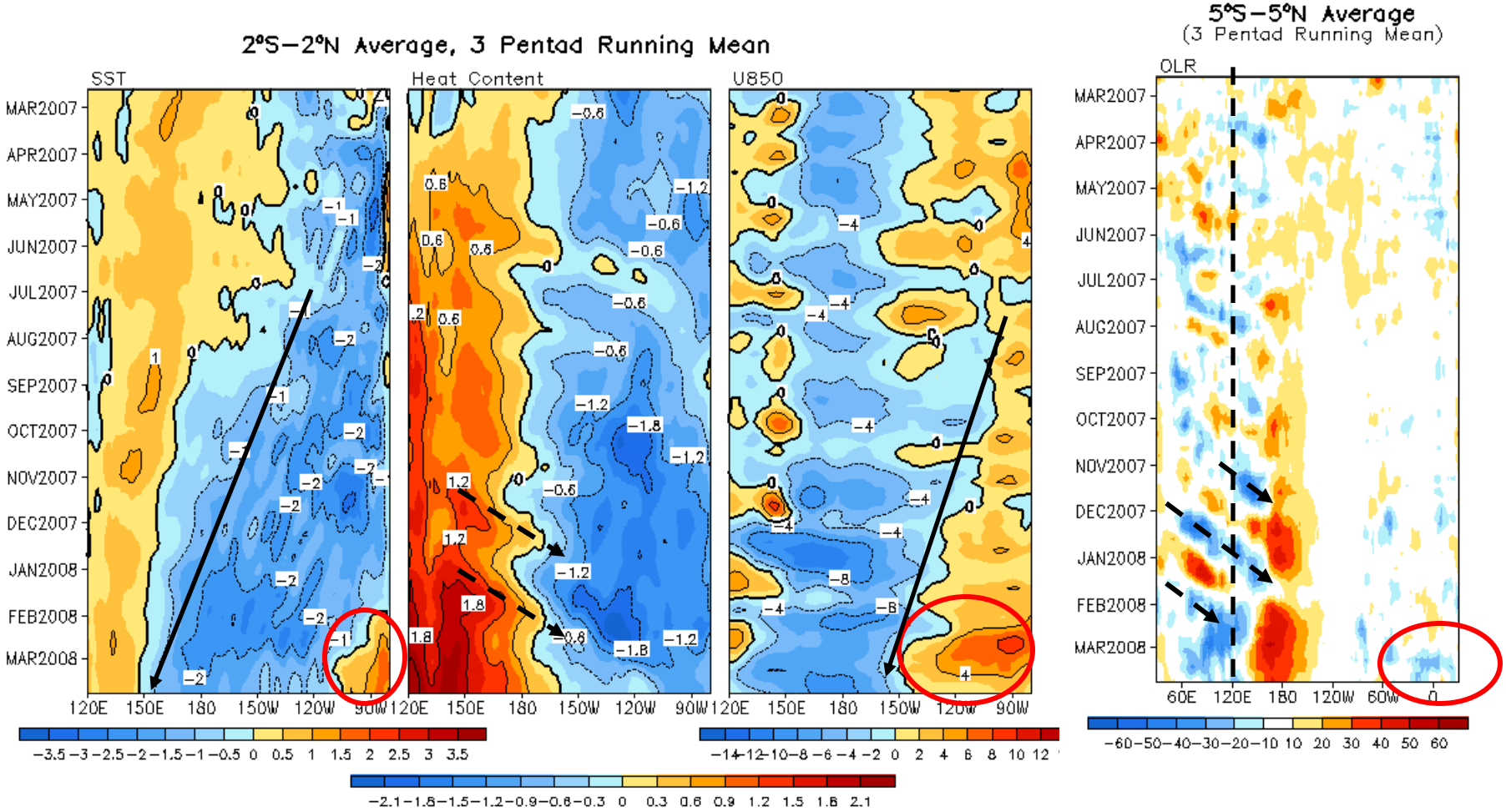
Recent Evolution of Pacific NINO SST Indices





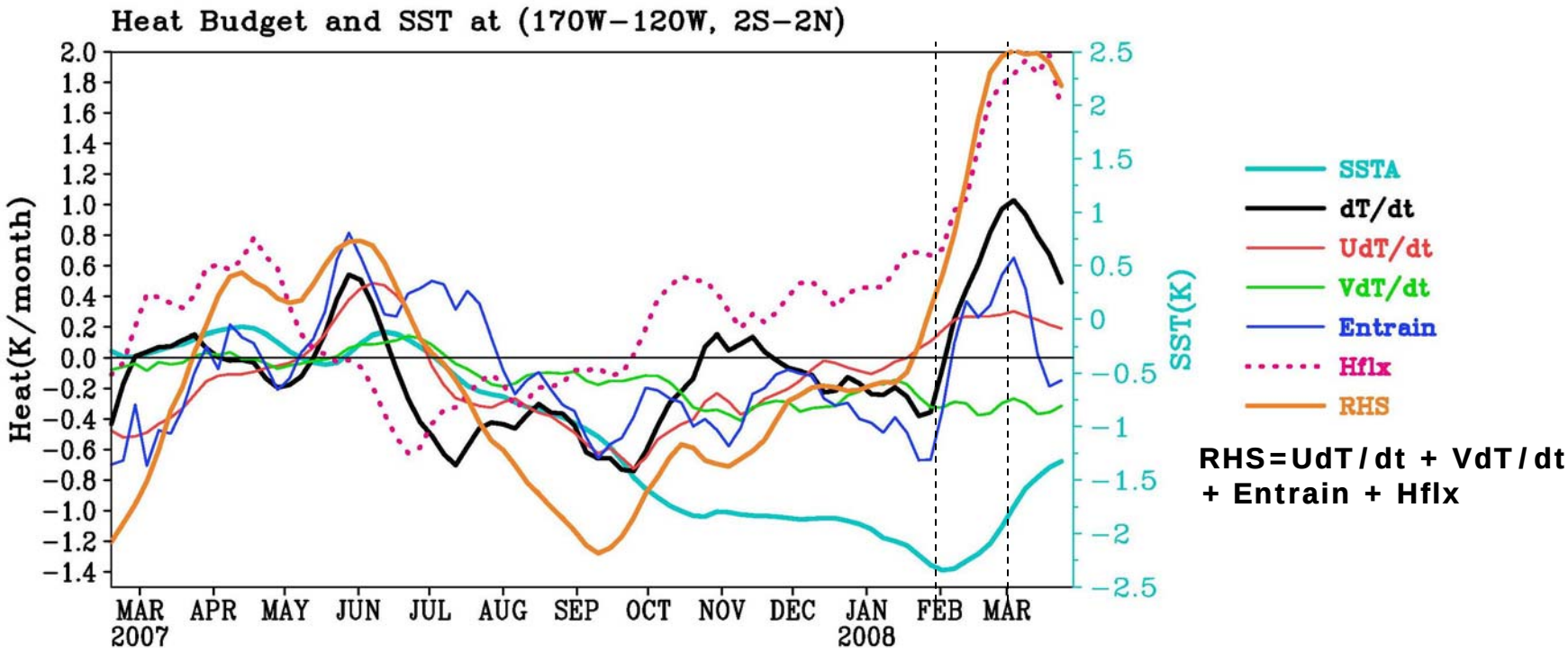
- NINO 4 persisted.
- NINO 3.4 weakened substantially
- NINON 3 became near-normal
- NINO 1+2 became +1C above-normal
- CPC's ENSO Prognostic Statement: La Nina will continue into MJJ of 2008.

Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²)



- **CPC's MJO assessment: Moderate-to-strong MJO activity persisted between mid-November – mid-February**
- **MJO-related westerly wind bursts forced downwelling oceanic Kelvin waves in November and January**
- **The warming near the west coast of South America since mid-February was led by westerly wind anomaly in far eastern Pacific**
- **Westward propagation of negative SSTA, easterly wind anomaly in central Pacific and westerly wind anomaly in far eastern Pacific**

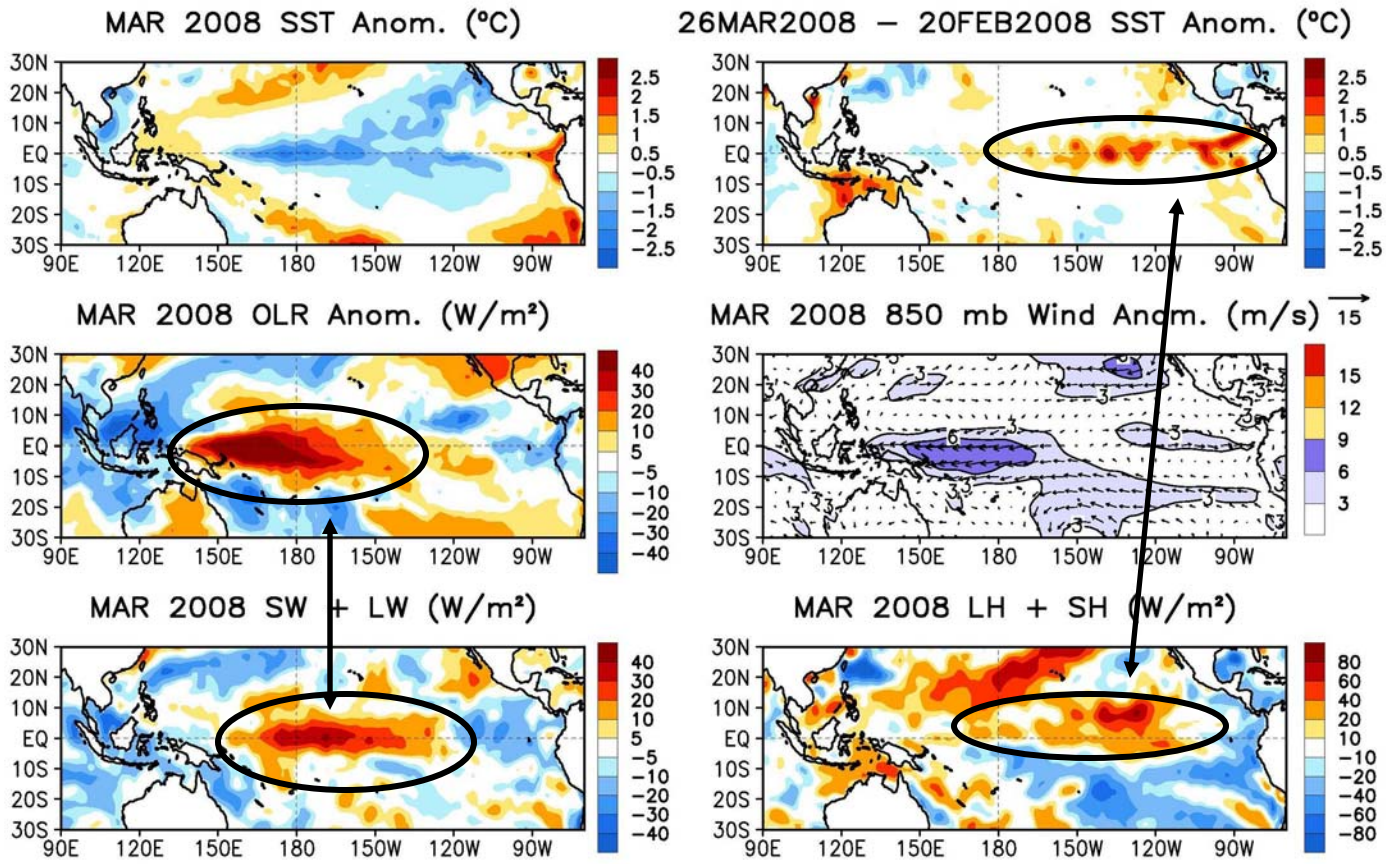
Recent Evolution of Heat Budget in NINO3.4 SST Anomaly



RHS=UdT/dt + VdT/dt + Entrain + Hflx

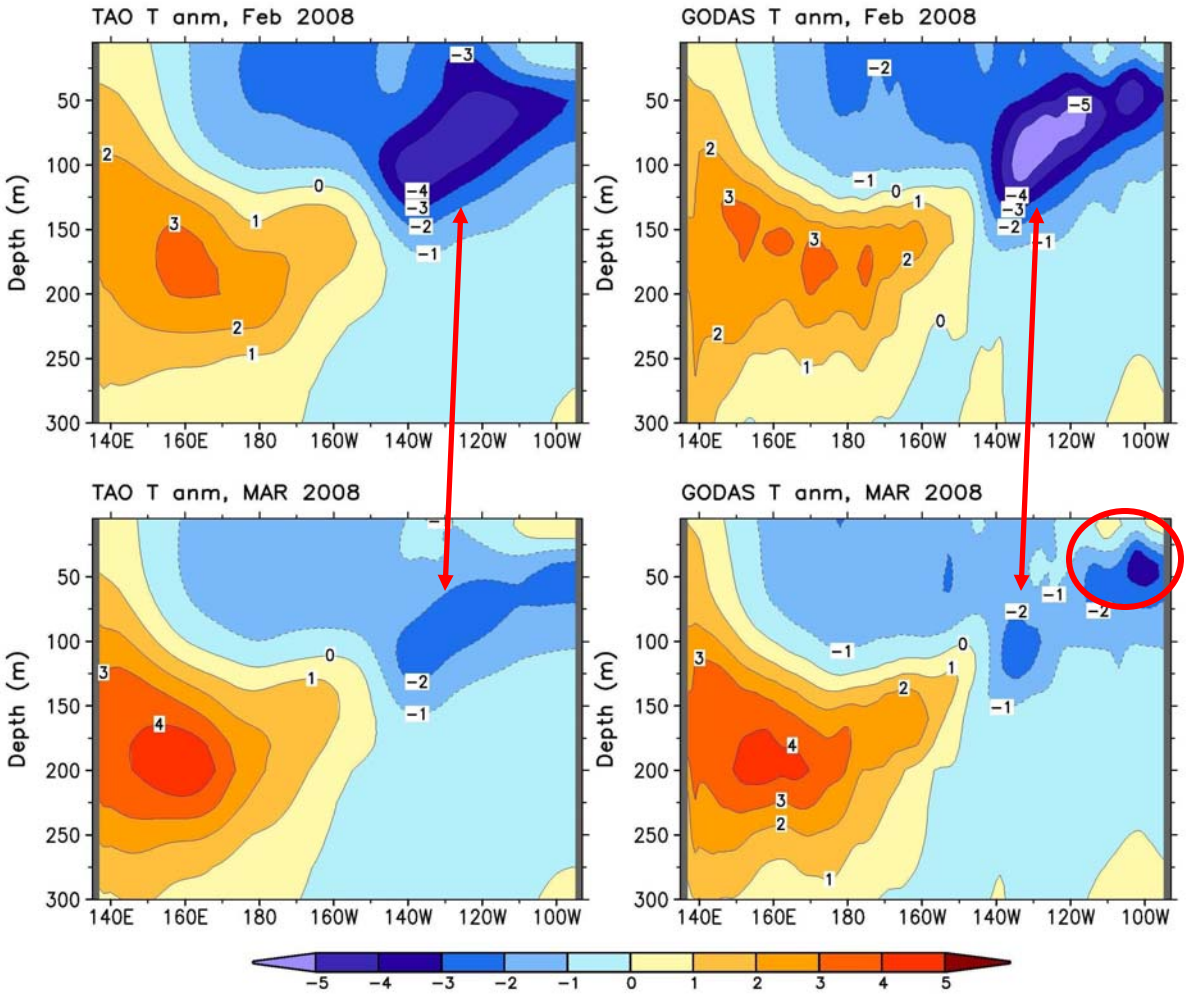
- **Advective and entrainment warming in May-Jul 2007 (MJO) likely delayed La Nina development**
- **Advective cooling in Jul 2007 (MJO) followed by entrainment cooling in Aug-Oct 2007 led to La Nina development**
- **Zonal advection, entrainment and mostly net heat flux damped negative NINO3.4 anomaly in February and March 2008**

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



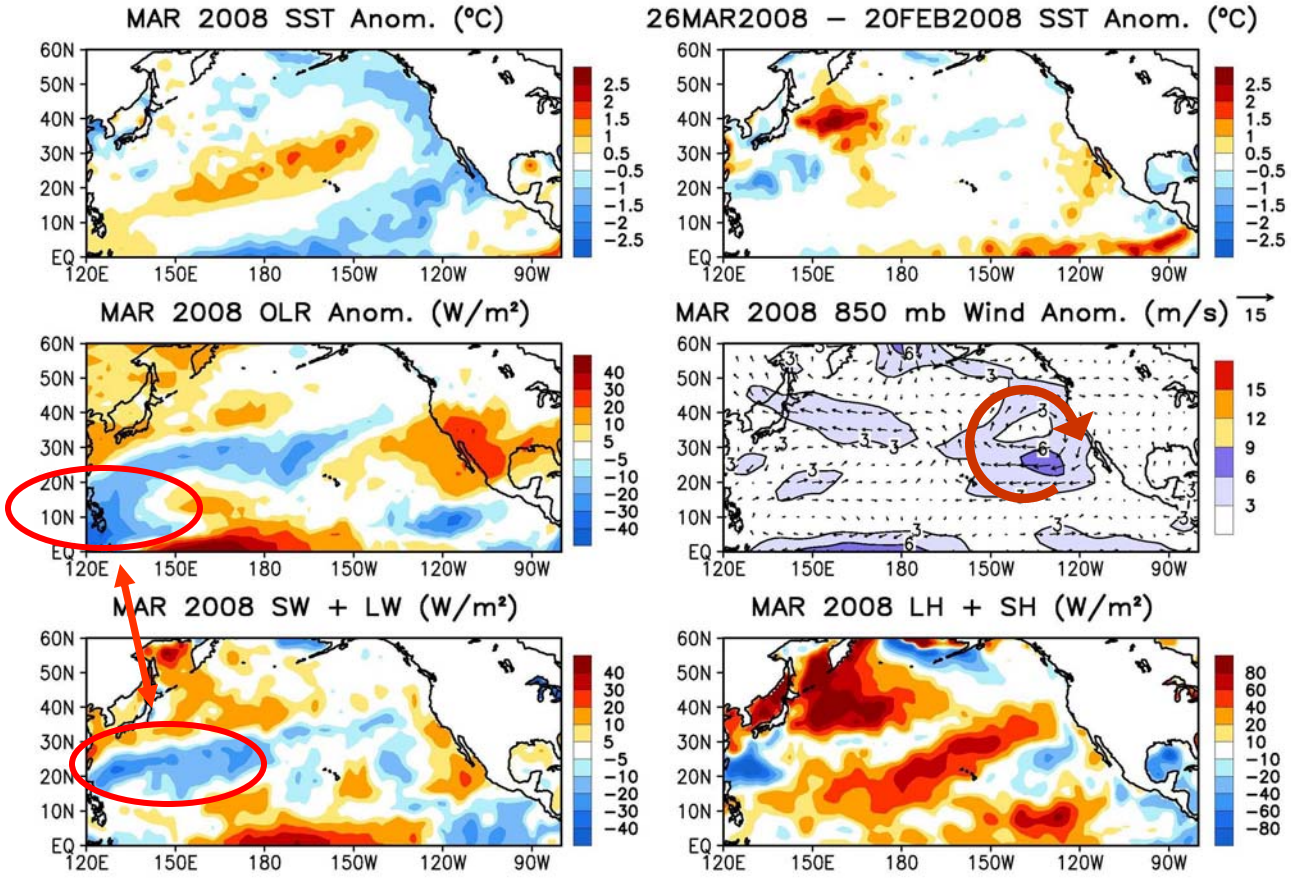
- **Enhanced convection in the Maritime Continent, suppressed convection in the western and central Pacific**
- **Easterly wind anomalies in the western Pacific and westerly wind anomalies in the eastern Pacific**
- **Both SW+LW and LH+SH contributed to positive SST changes in the central and eastern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

Longitude-Depth Temperature Anomaly in 2°S-2°N



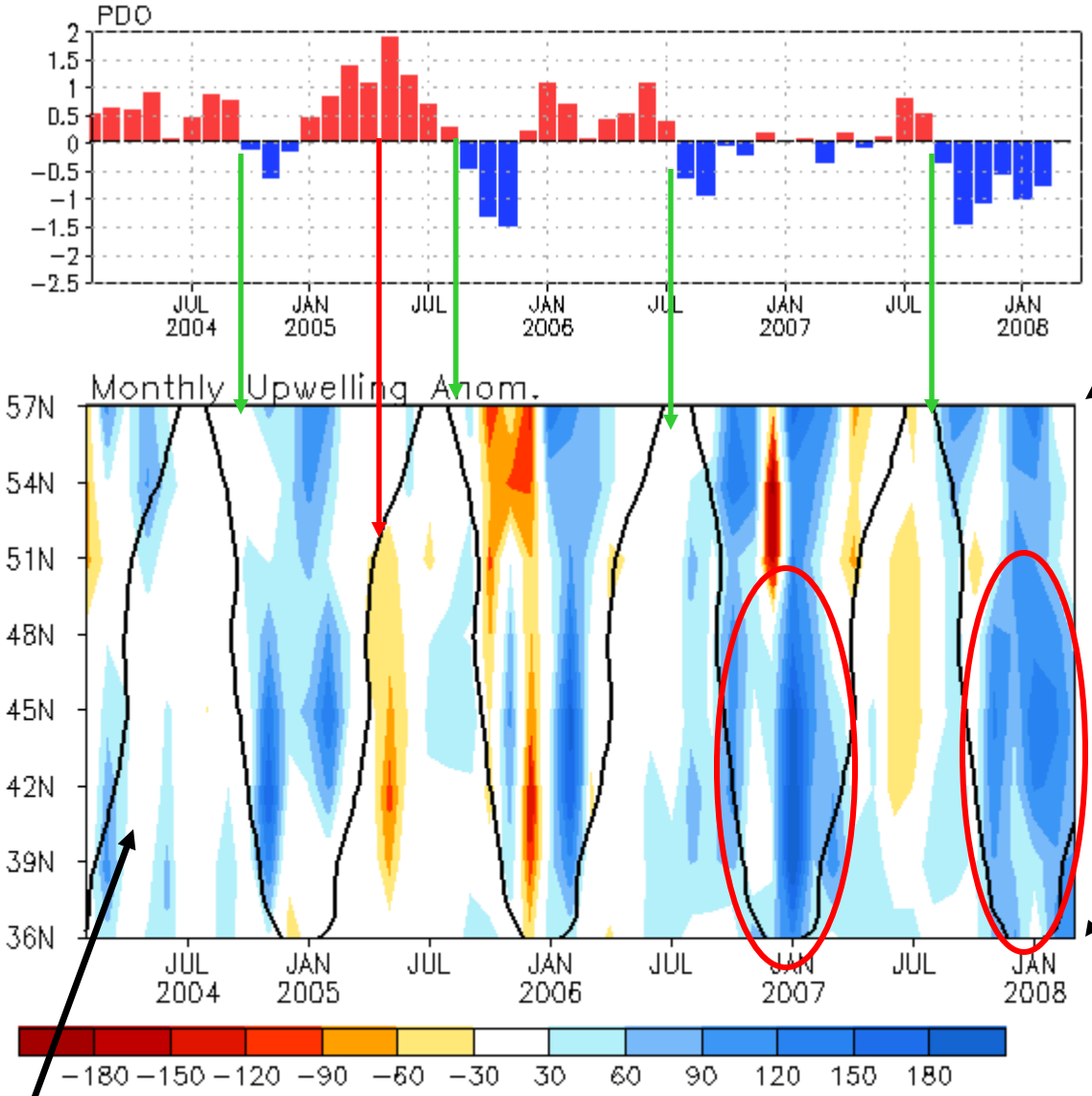
- **Negative subsurface temperature anomaly weakened substantially in March 2008**
- **GODAS temperature was about 1C too cold at 25 meter depth near 105W, and about 1C too warm in the central Pacific near the thermocline (not shown)**

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

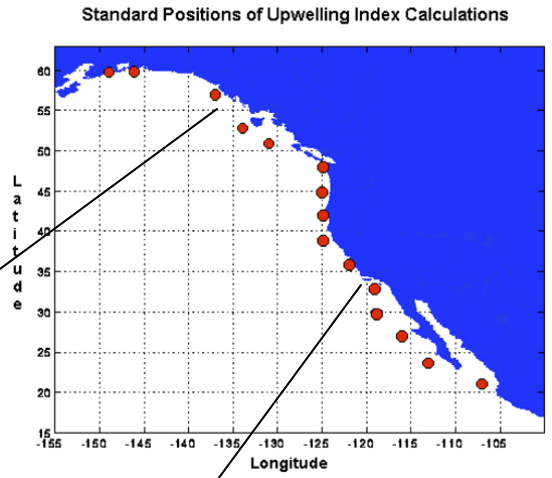


- Cooling near the west coast of North America and Gulf of Alaska persisted
- Anti-cyclonic wind anomalies near the coast of California, favorable for coastal upwelling
- Ekman transport / pumping and surface latent heat flux were likely the main external forcing

North America Western Coastal Upwelling



UW/NOAA JISAO PDO page

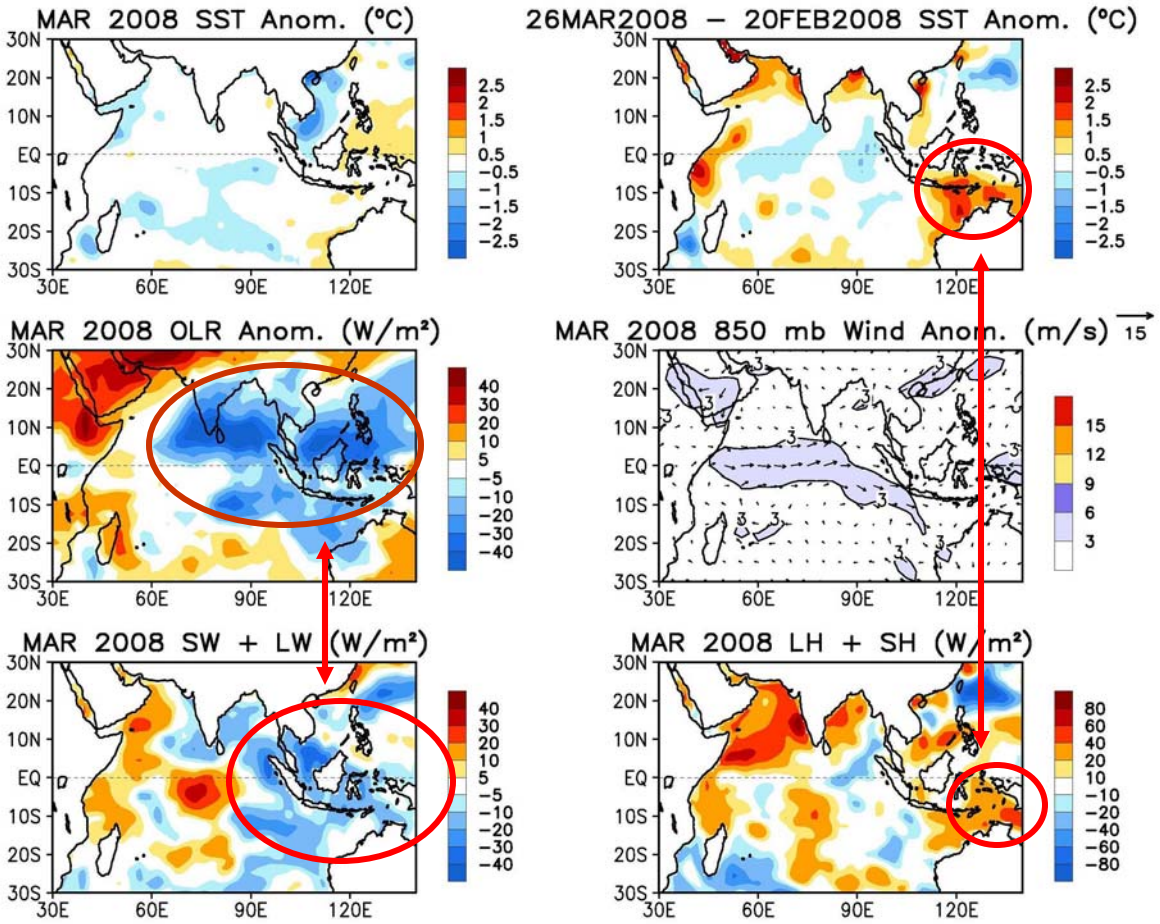


- **PDO has a downward trend**
- **Negative (positive) PDO is associated with above-normal (below-normal) upwelling**
- **Upwelling along the west coast of North America had been persistently above-normal since October 2007**

- **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.**

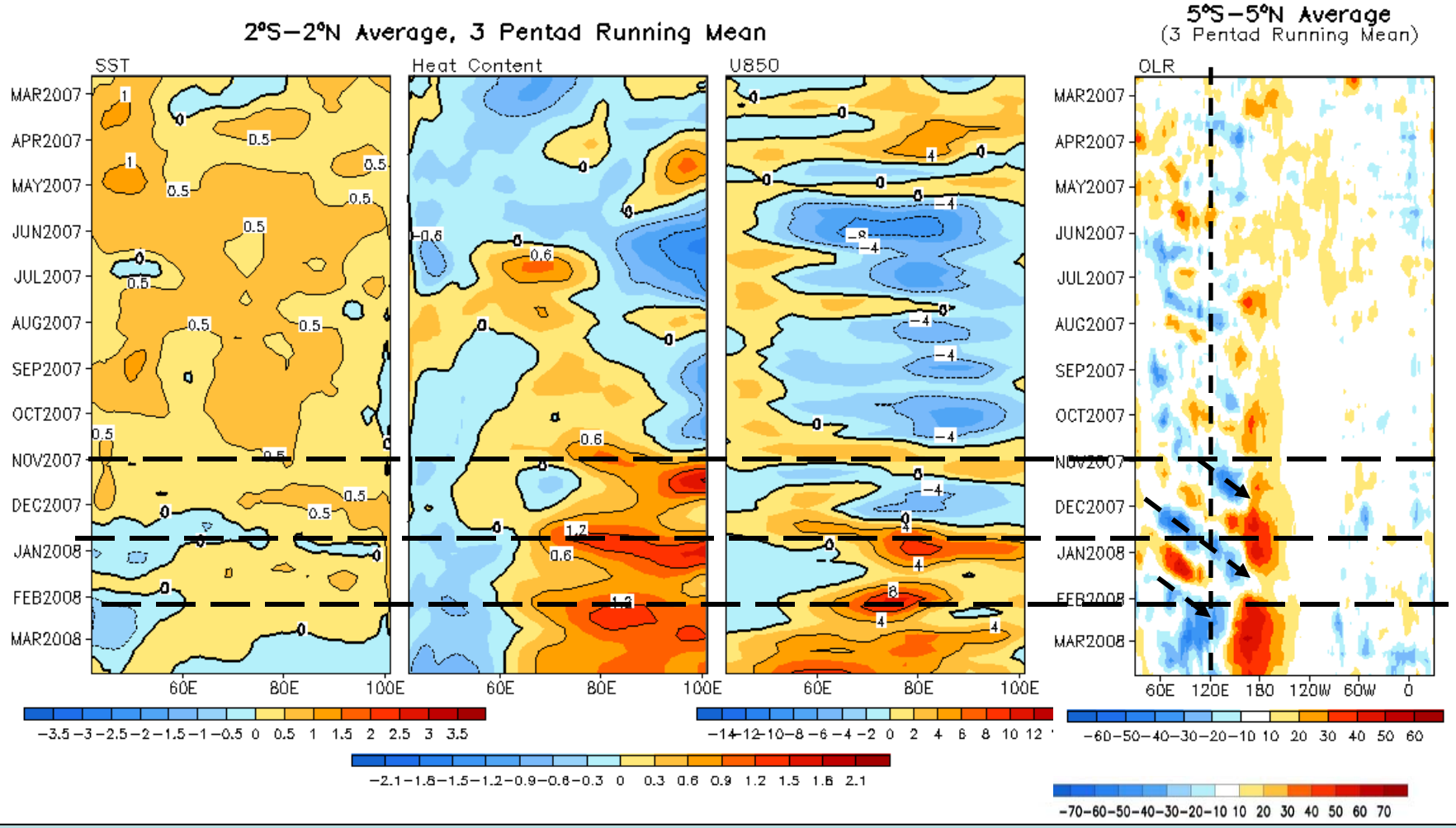
Indian Ocean

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



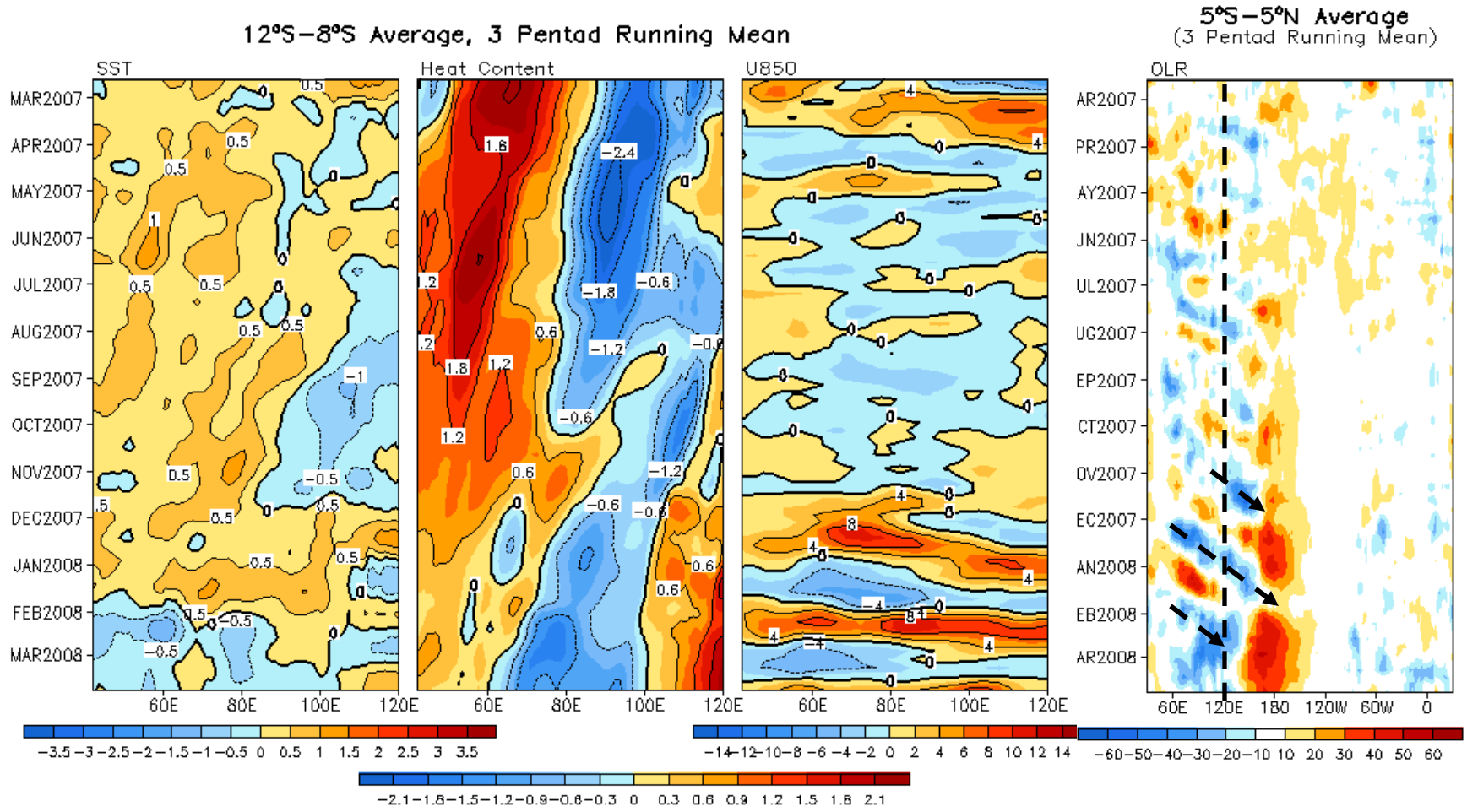
- **Above-normal rainfall over India and the Maritime Continent**
- **Westerly wind anomalies in the western-central Indian Ocean, responses to the La Nina event**
- **SW+LW cooled the Maritime Continent, LH+SH warmed the Arabian Sea and north coast of Australia**

Recent Evolution of Equatorial Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s) and OLR (W/m^2)



- **CPC's MJO assessment: Moderate-to-strong MJO activity persisted between mid-November – mid-February**
- **MJO-related westerly wind bursts forced downwelling oceanic Kelvin waves in November, December and February**
- **Westerly wind anomaly and SST downward trend were forced by the La Nina**

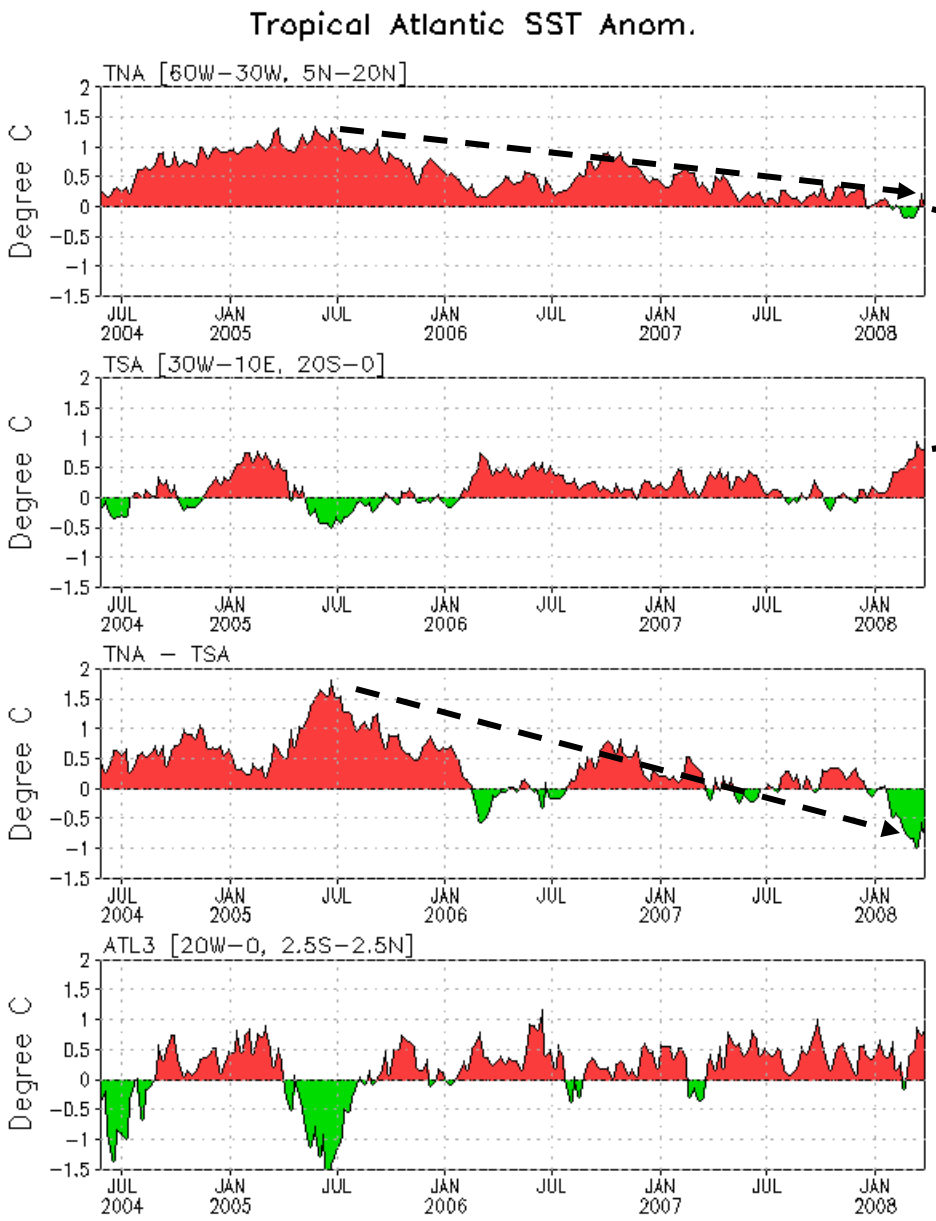
Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s) and OLR (W/m^2)

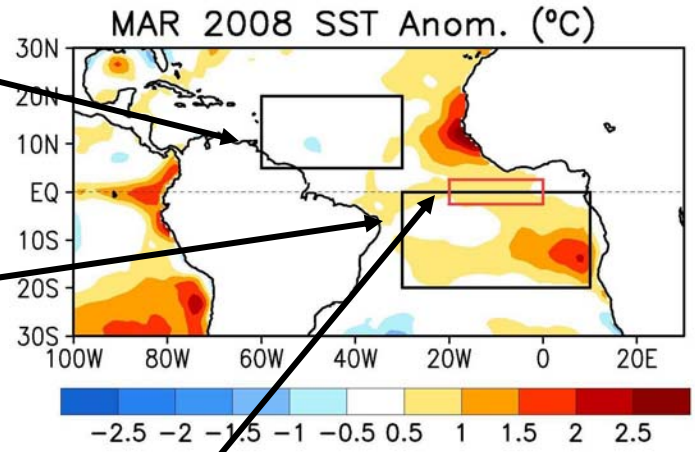


- **MJO-related westerly wind anomalies presented in December and February**
- **Induced positive (negative) heat content in the eastern (central) Indian Ocean**

Atlantic Ocean

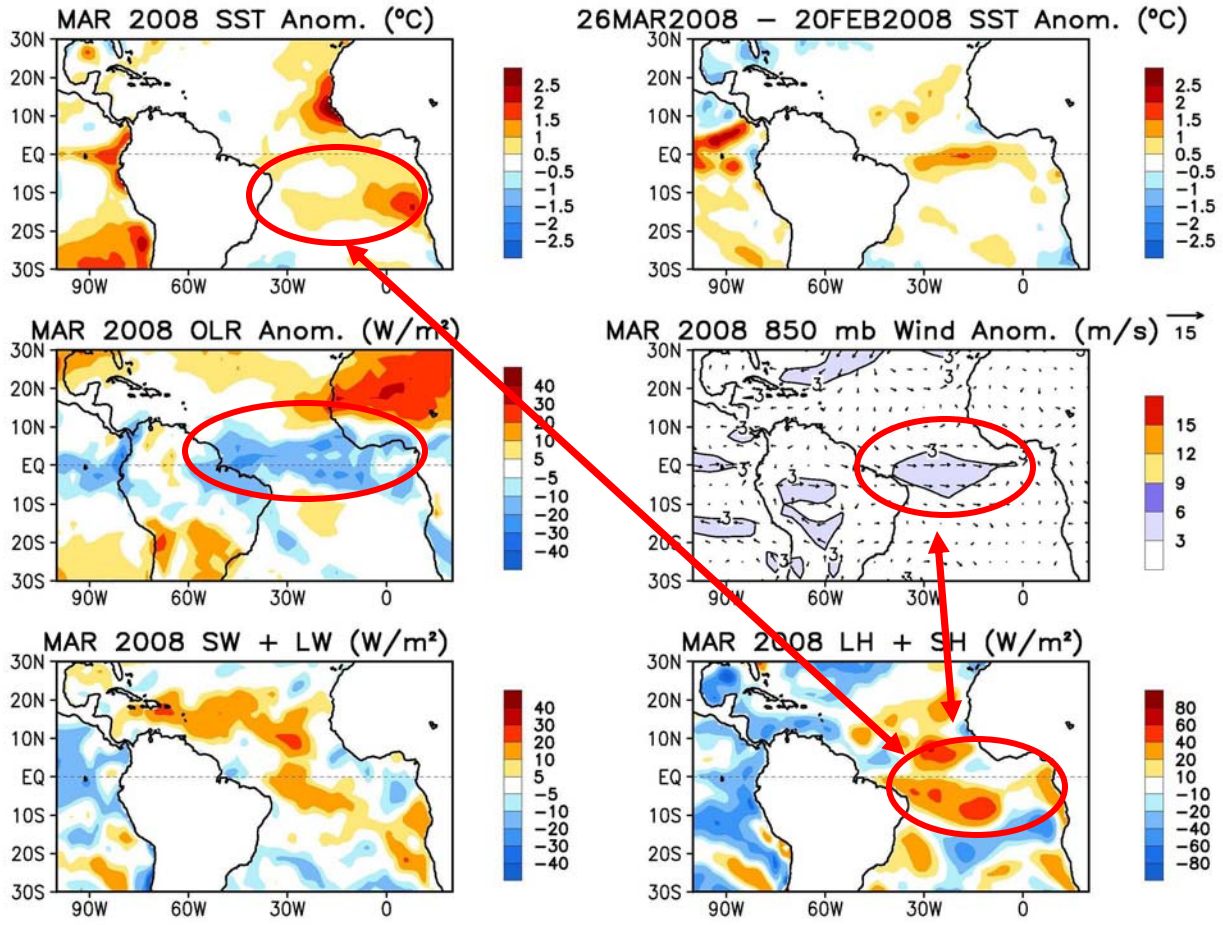
Evolution of Tropical Atlantic SST Indices





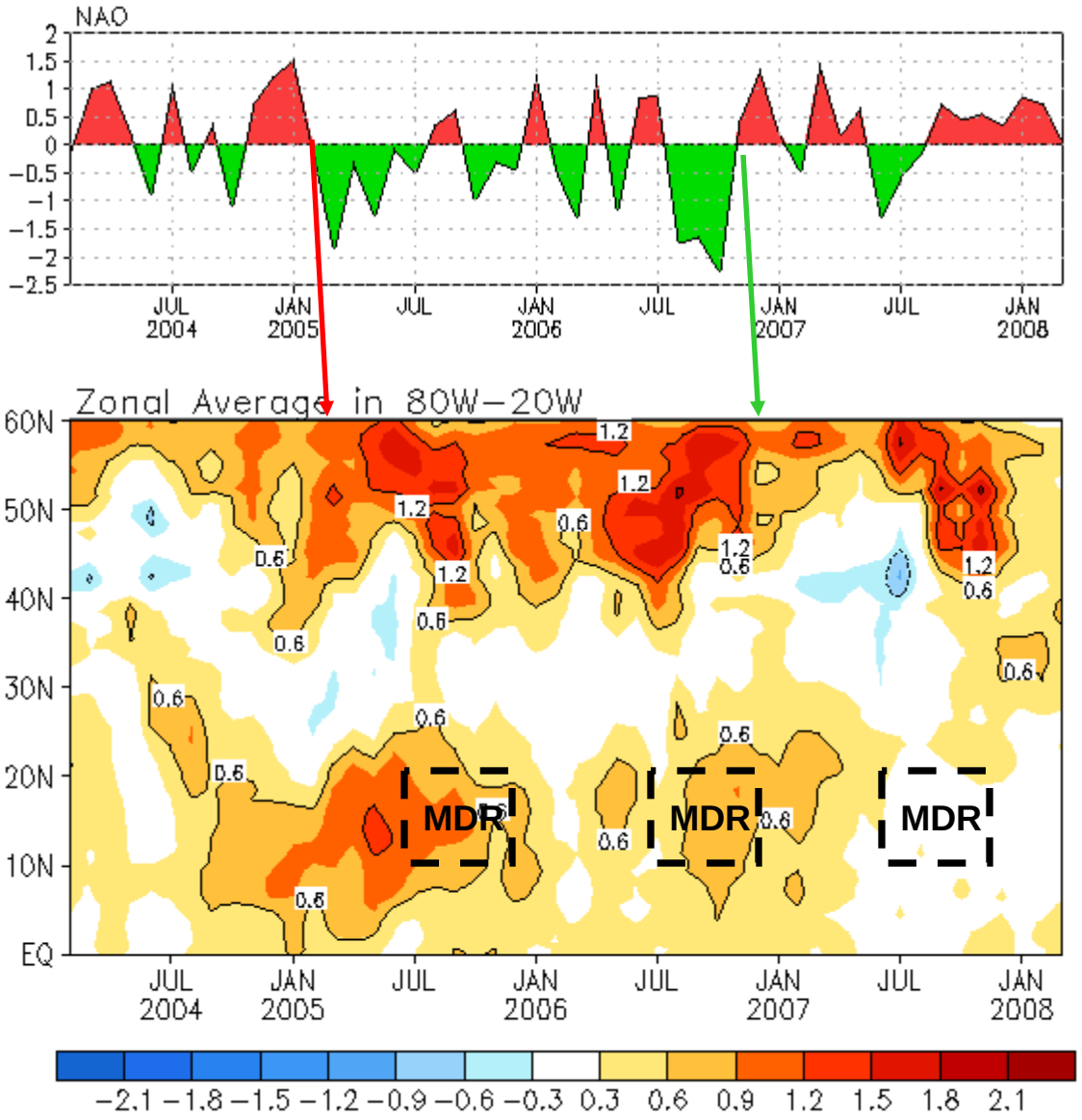
- **TNA has been trending downward from about +1C above-normal in summer of 2005 to slightly below-normal in March 2008**
- **TSA was above-normal in March 2008**
- **Meridional SST Gradient Mode (TNA-TSA) was below-normal in March 2008**
- **-- ATL3 was above-normal**

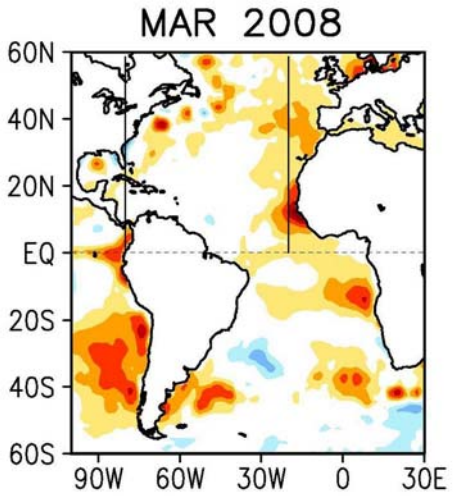
Tropical Atlantic: SST Anom., SST Anom. Tend., OLR, 850-mb Winds, Sfc Rad, Sfc Flx



- **Positive SSTA presented in the subtropical southern Atlantic, generating a negative Meridional SST Mode**
- **North-westerly wind anomalies were consistent with the negative Meridonal SST Mode**
- **Enhanced convection over northeastern Brazil and equatorial Atlantic**

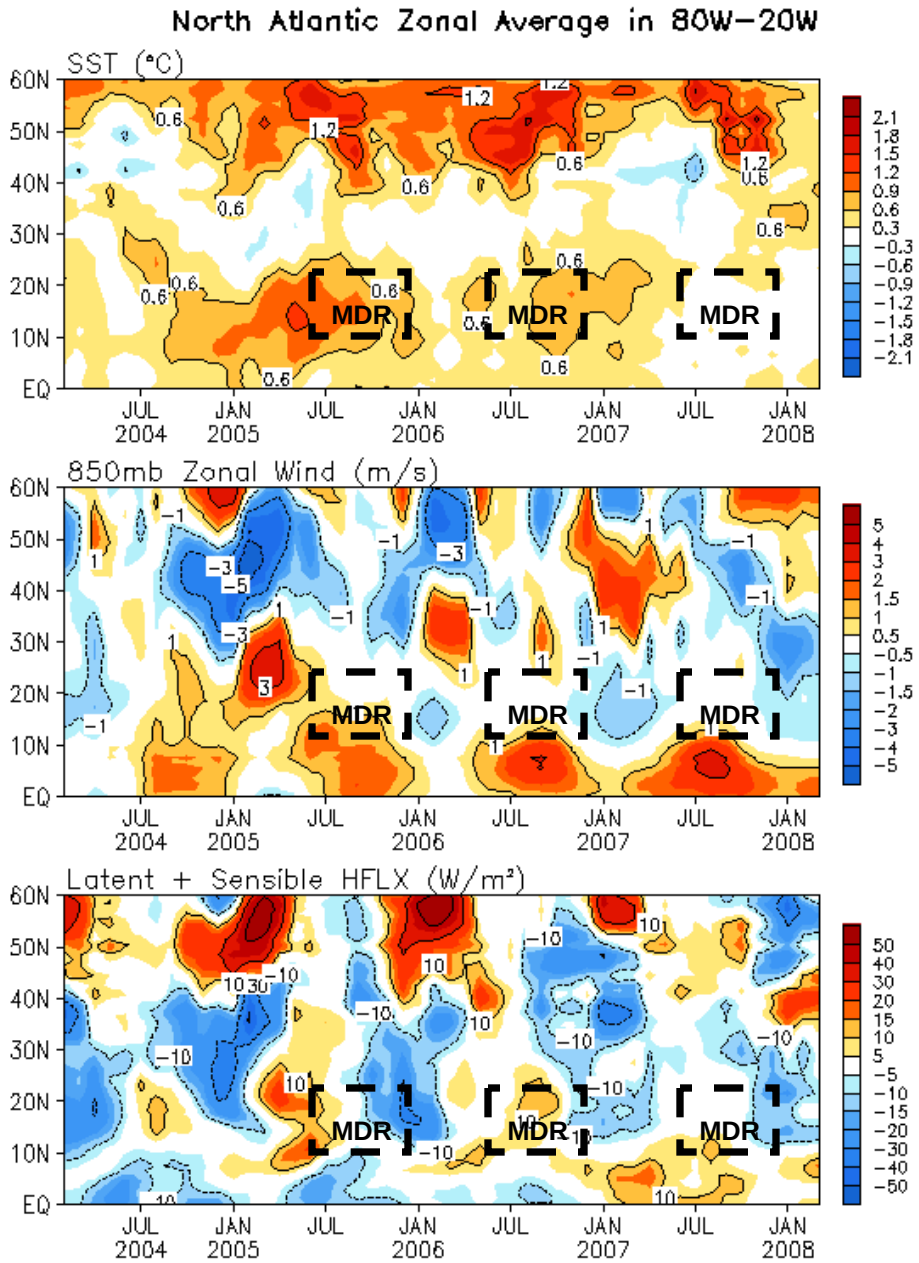
SST Anomaly in North Atlantic

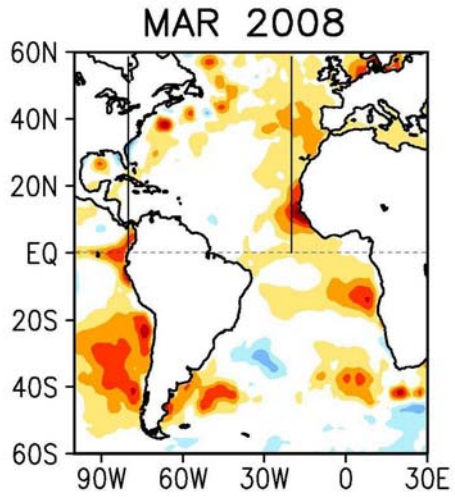




- **SSTA in Atlantic hurricane Main Development Region (MDR) was near normal in JASON 2007, much cooler than that of 2006 and 2005**
- **High-latitude North Atlantic SSTA are closely related to NAO index – negative NAO leads to SST warming and positive NAO leads to SST cooling**

Attributions of North Atlantic SST Anomaly

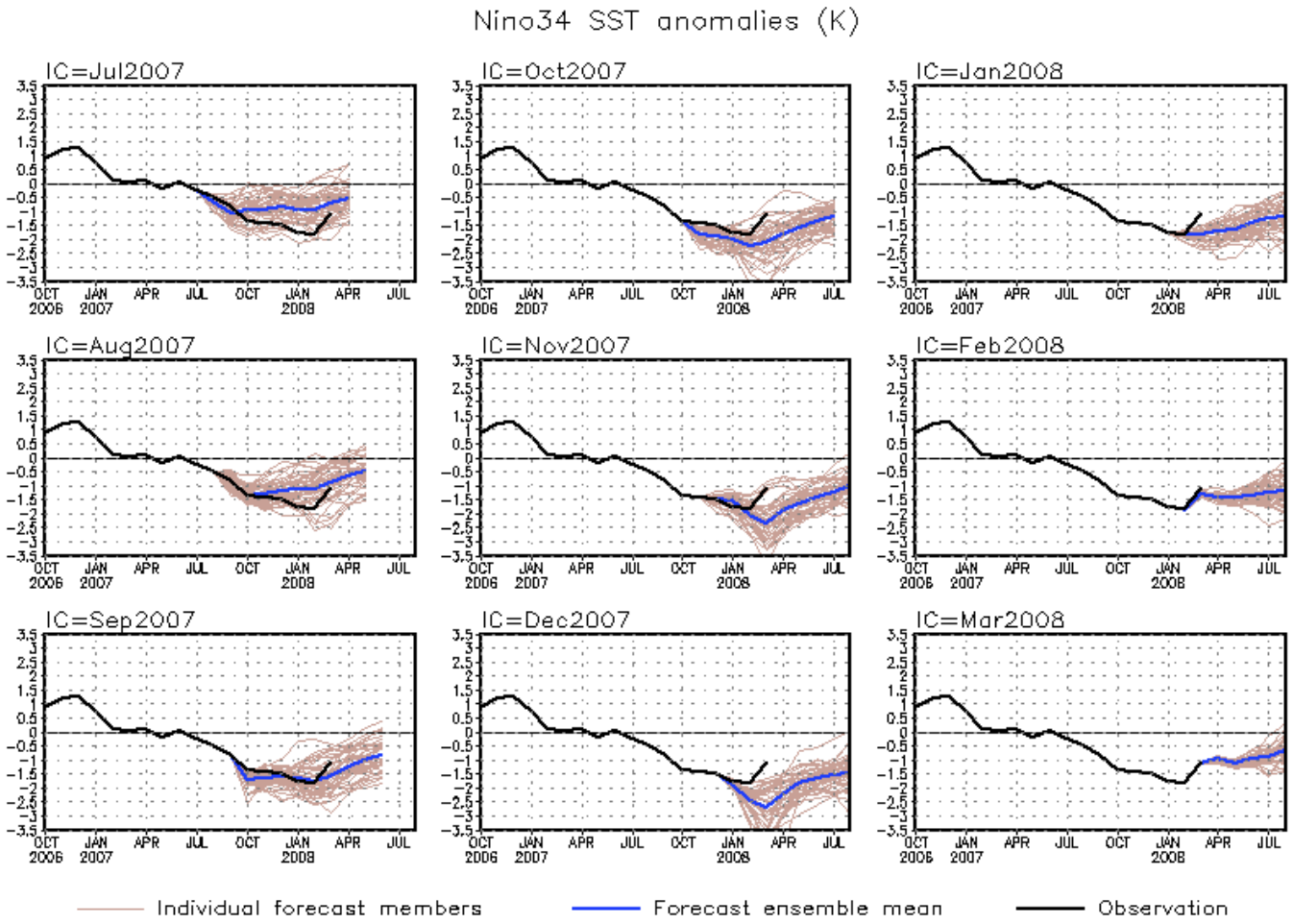




- **SSTA in Atlantic hurricane Main Development Region (MDR) was near-normal in JASON 2007, much cooler than that of 2006 and 2005**
- **Surface winds in MDR were close to normal during JASON 2007**
- **LH+SH in MDR were near-normal (cooling the ocean) prior to summer of 2007, while they were above-normal prior to summer of 2006 and 2005**

CFS SST Predictions and Ocean Initial Conditions

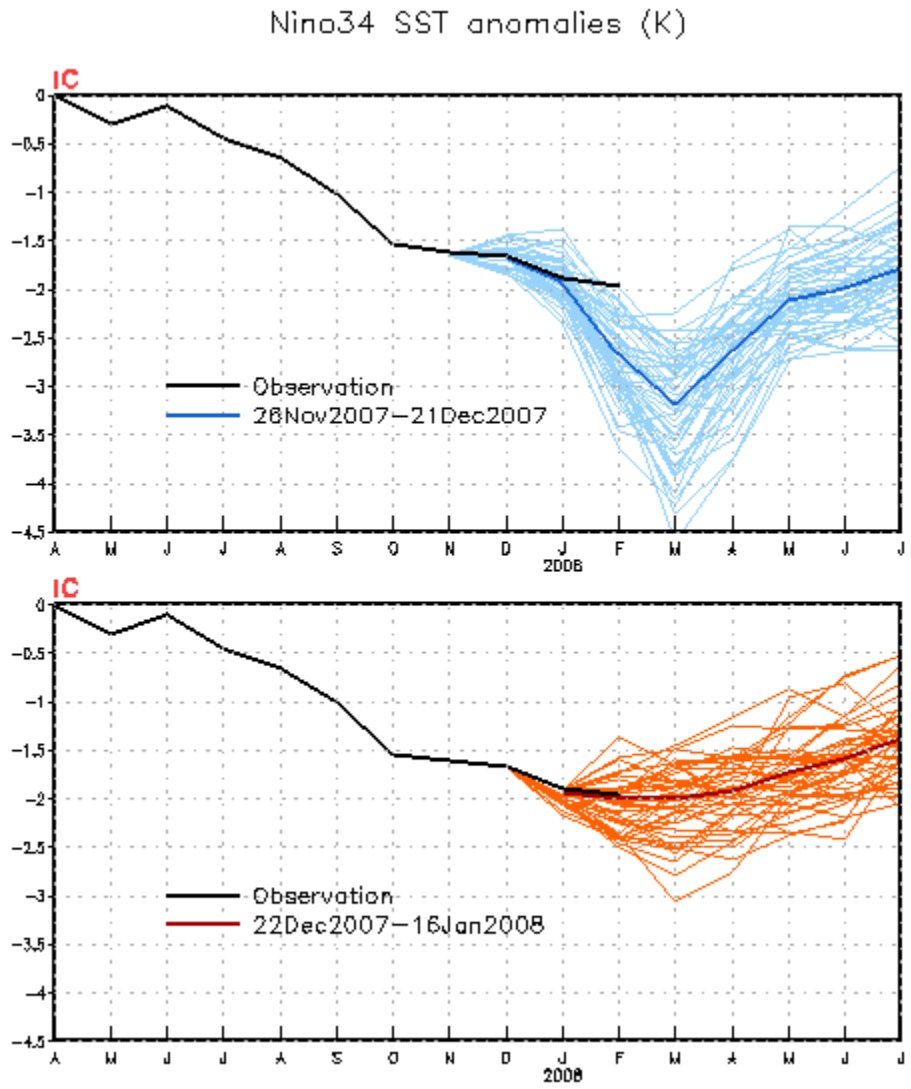
CFS Niño 3.4 SST Predictions from Different Initial Months



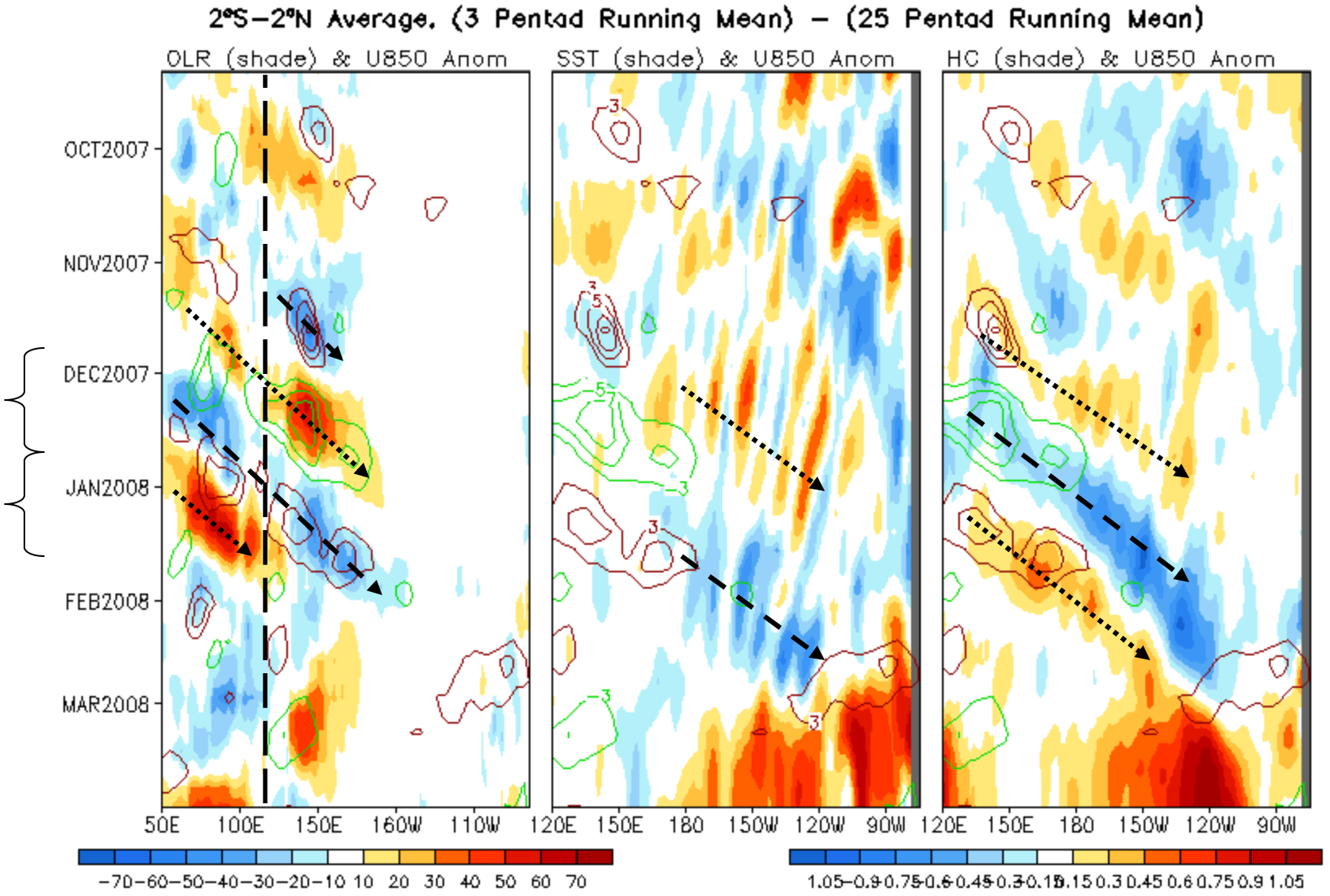
New CFS system starting Jan 2008

- **SST forecast biased towards warm in July-August**
- **Reasonable SST forecast in September-October**
- **SST forecast biased towards cold in December-January**
- **SST forecast in February-March appears reasonable**

CFS NINO3.4 SST Forecasts from Different Initial Days



MJO and Oceanic Kelvin Waves



- **CPC's MJO assessment: Moderate-strength MJO activity presented from mid-November to mid-February**
- **MJO-related westerly wind bursts forced downwelling Kelvin waves in November and January and upwelling Kevin waves in December**

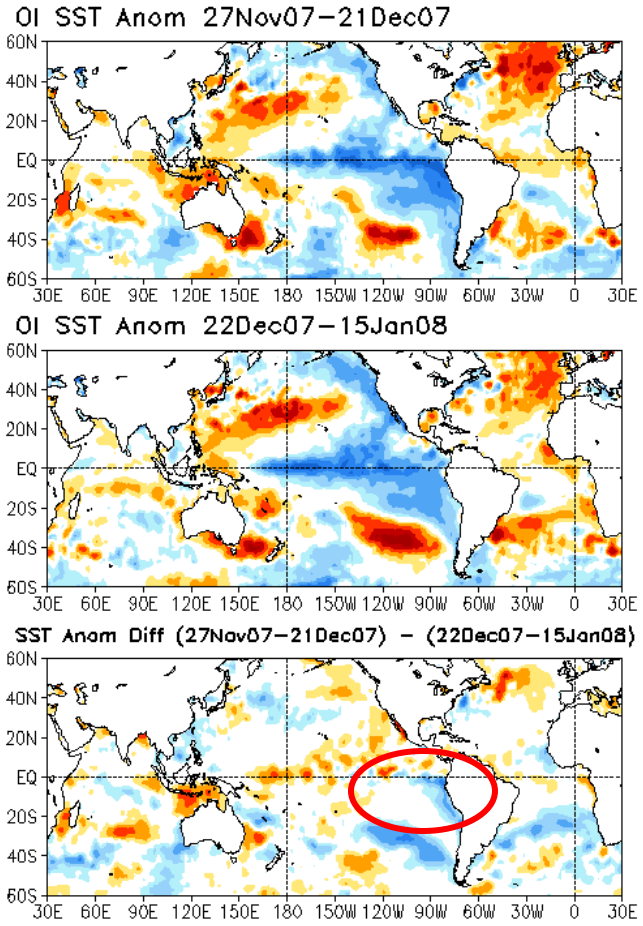
CFS Initial Condition Differences

Cold SST Forecast I.C.

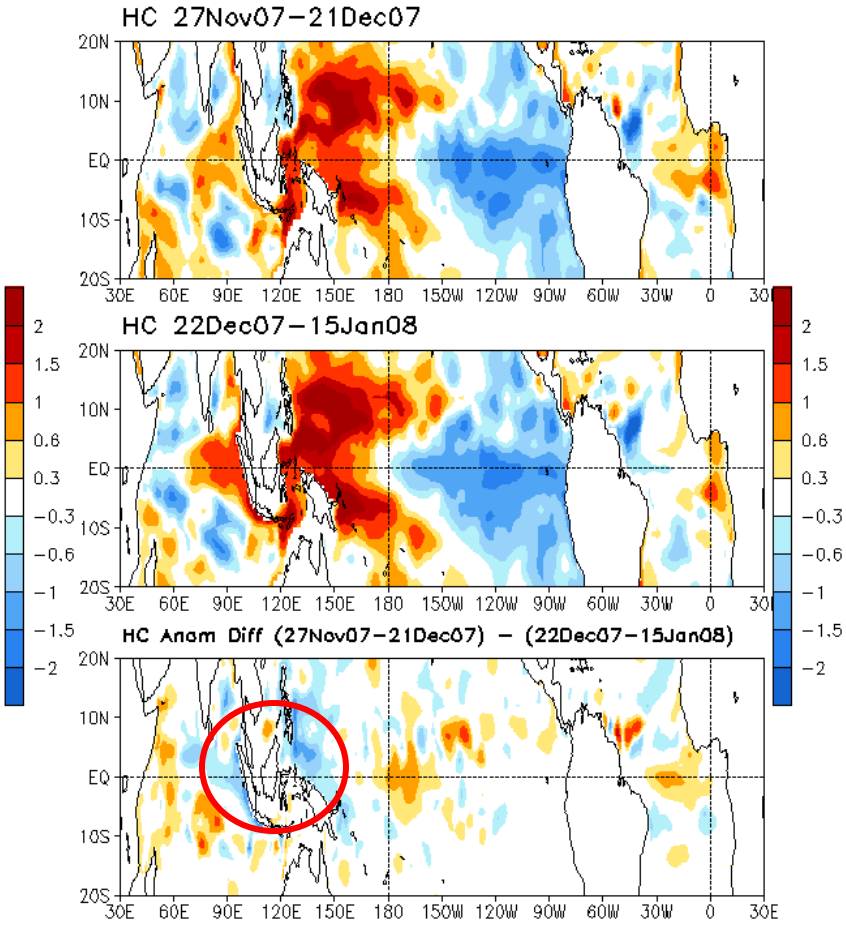
Warm SST Forecast I.C.

Cold – Warm Forecast I.C.

SST



Heat Content



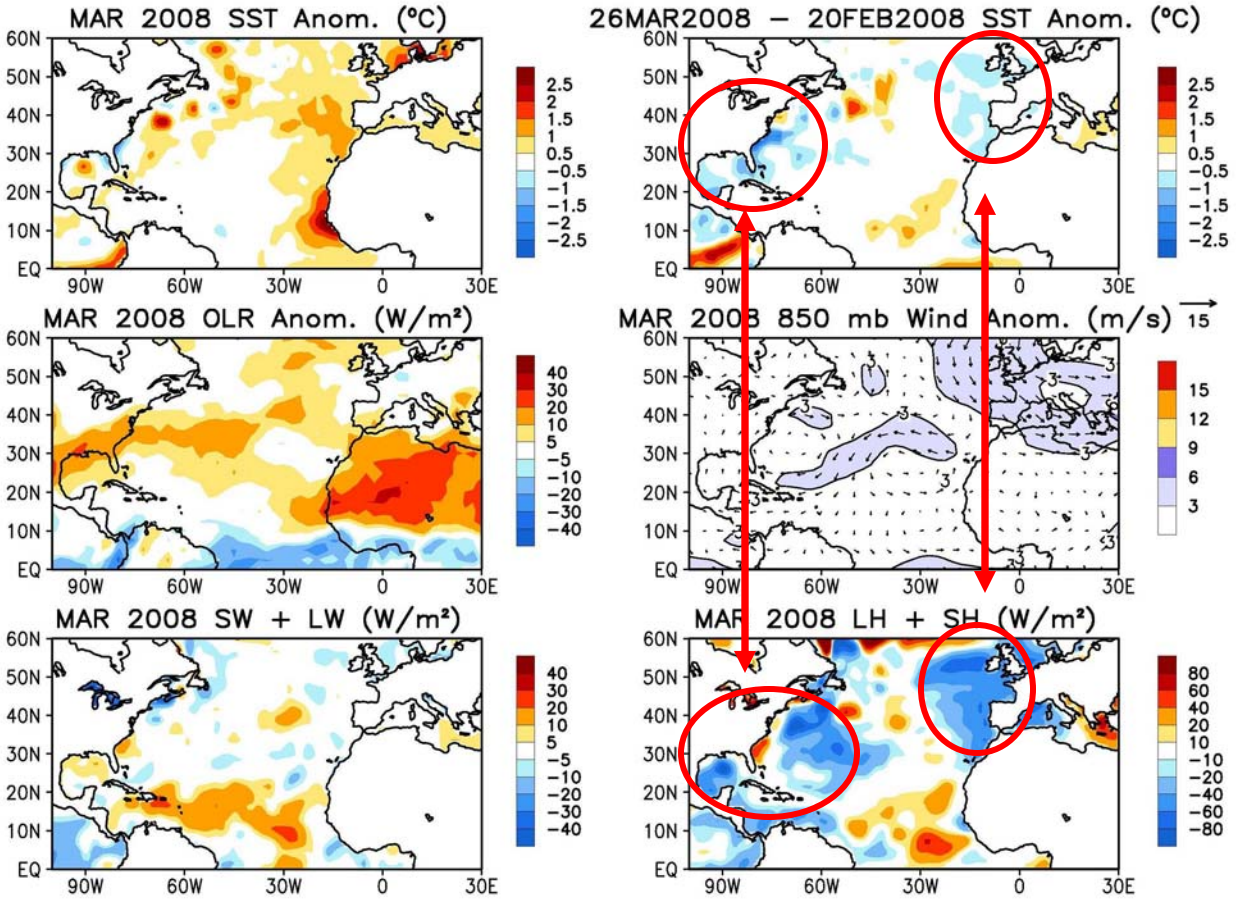
- CFS tends to forecast colder (warmer) SST when upwelling (downwelling) Kevin waves presented in the far western Pacific in I.C.

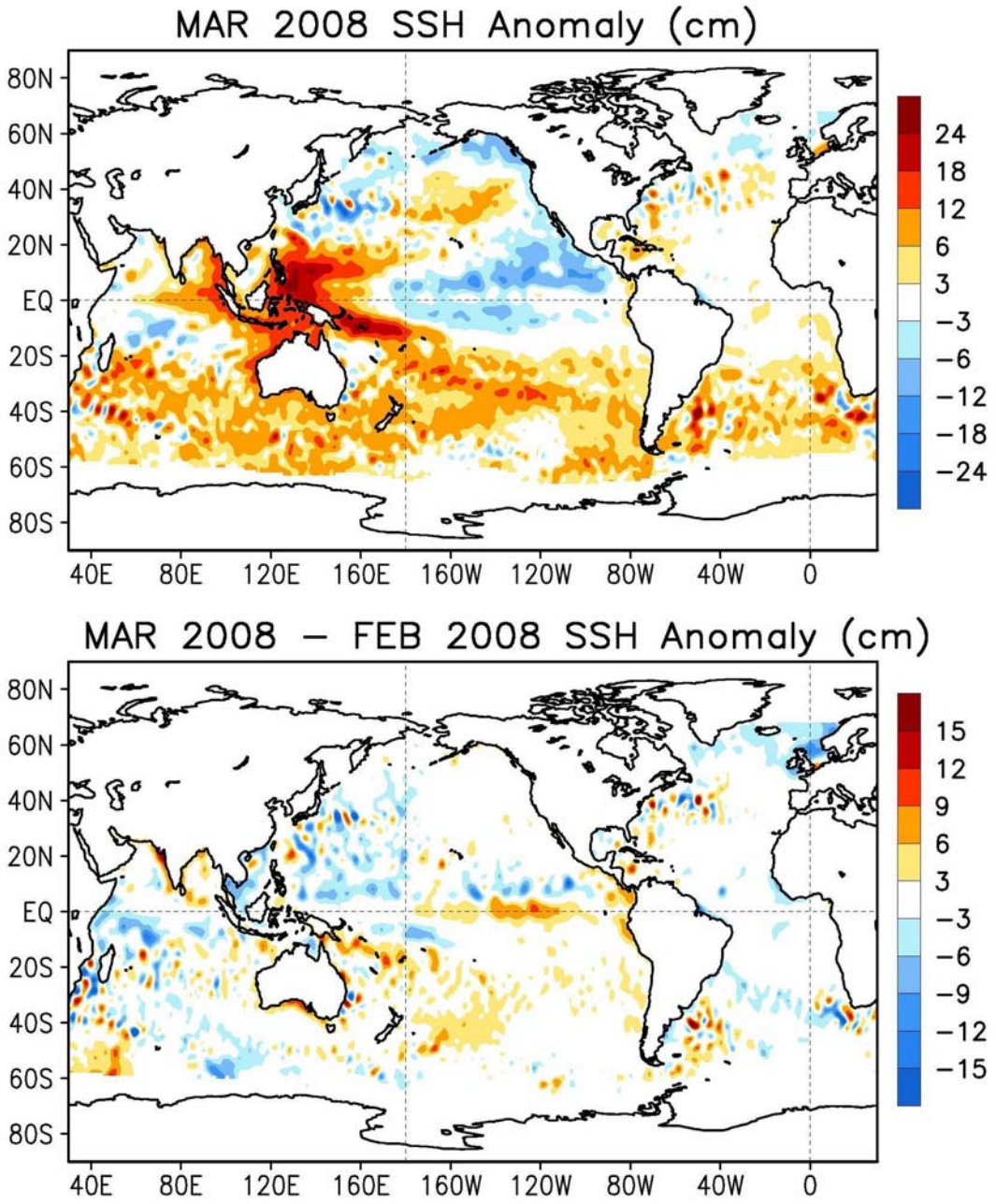
Summary

- **Global Ocean**
  - Global mean SST has been persistently above-normal since 1995
  - It became below-normal in December 2007 – February 2008
- **Pacific Ocean**
  - La Nina weakened (NINO3.4 changed from -1.9C to -1.1C)
  - CPC's prognostic assessment: La Niña will continue into MJJ of 2008
  - Easterly wind anomalies and suppressed convection in C. Pacific persisted
  - Negative subsurface temperature anomalies in E. Pacific weakened substantially
  - Warming near the surface in the far E. Pacific was led by westerly wind anomalies there
  - Anticyclonic wind anomalies near the coast of California favored coastal upwelling
- **Indian Ocean**
  - Above-normal rainfall over India and the Maritime Continent
  - Westerly wind anomalies and cooling of SST were responses to the La Nina
- **Atlantic Ocean**
  - Tropical North Atlantic SST has a cooling trend since 2005, and became below-normal in March 2008
  - North-westerly wind anomalies and enhanced convection in the equatorial Atlantic were consistent with the negative Meridonal SST Mode

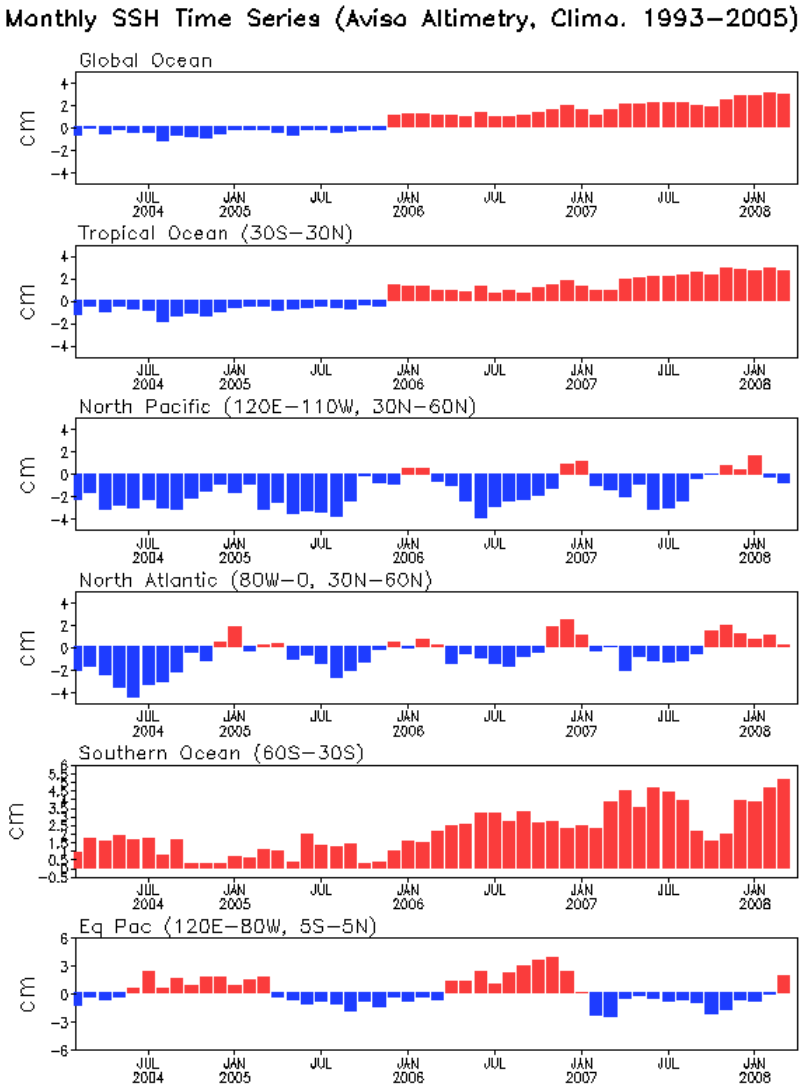
Backup Slides

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



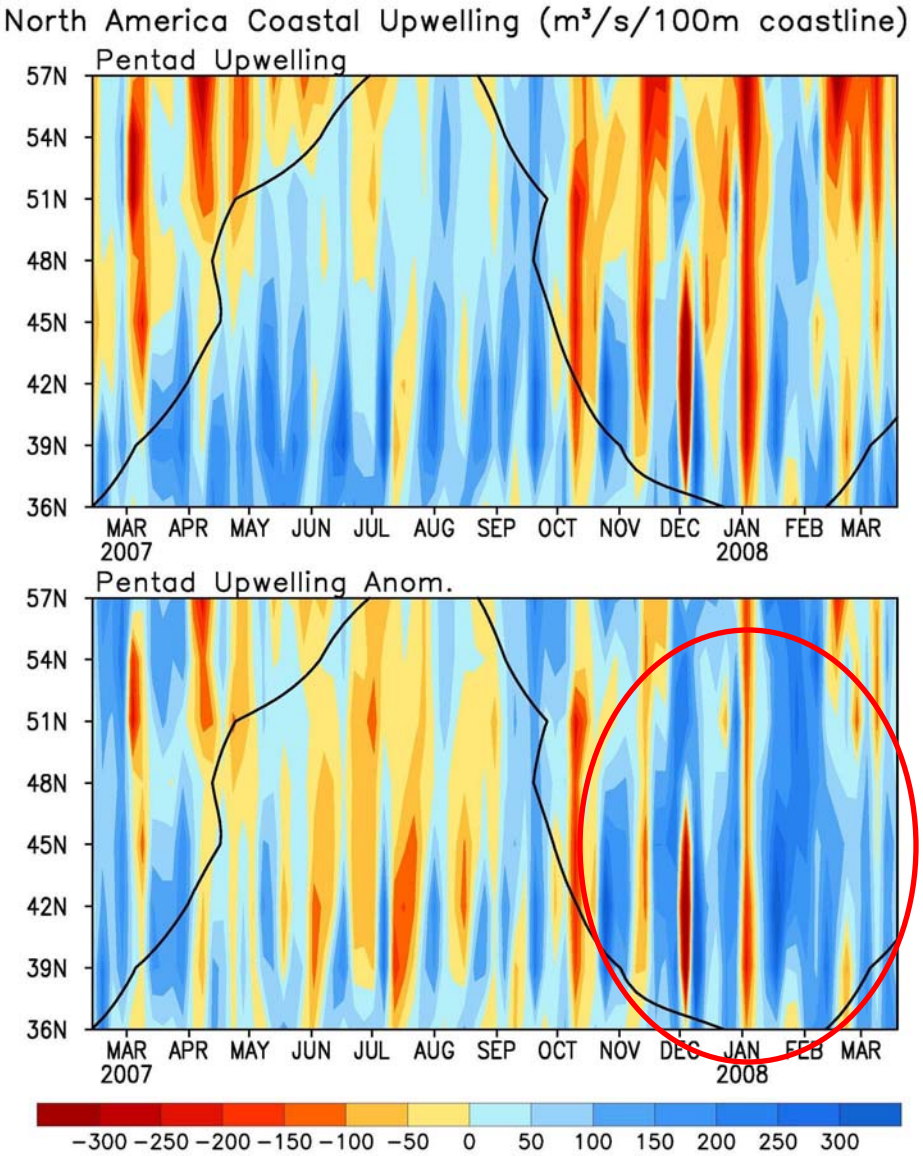

MAR 2008 SSH Anomaly (cm)
80N
60N
40N
20N
EQ
20S
40S
60S
80S
40E
80E
120E
160E
160W
120W
80W
40W
0
24
18
12
6
3
−3
−6
−12
−18
−24
MAR 2008 − FEB 2008 SSH Anomaly (cm)
80N
60N
40N
20N
EQ
20S
40S
60S
80S
40E
80E
120E
160E
160W
120W
80W
40W
0
15
12
9
6
3
−3
−6
−9
−12
−15

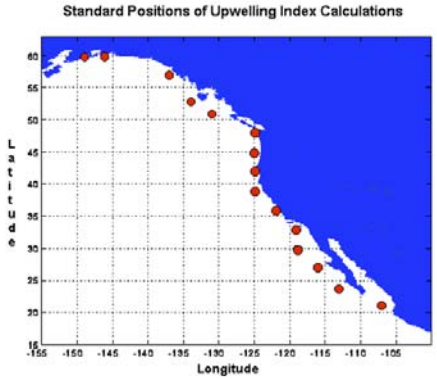
Monthly SSH Time Series



North America Western Coastal Upwelling

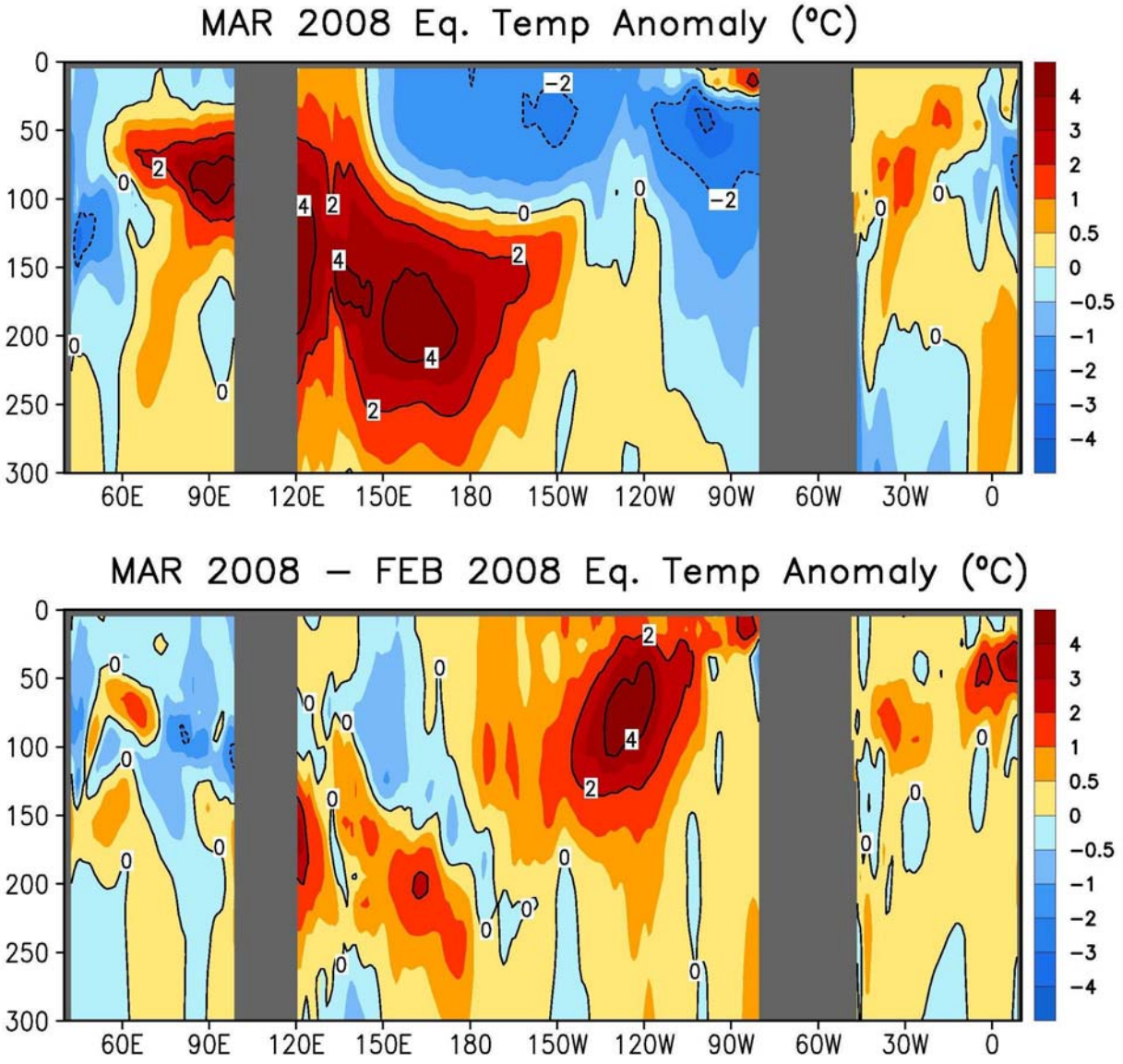
CPC, NCEP

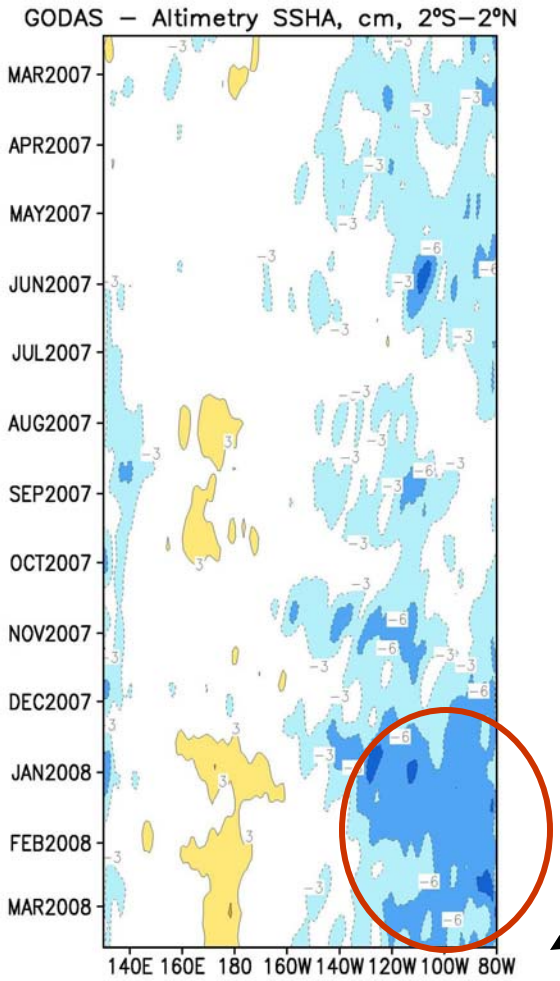




•Climatologically upwelling season progresses from March to July along the west coast of North America from 36°N to 57°N.

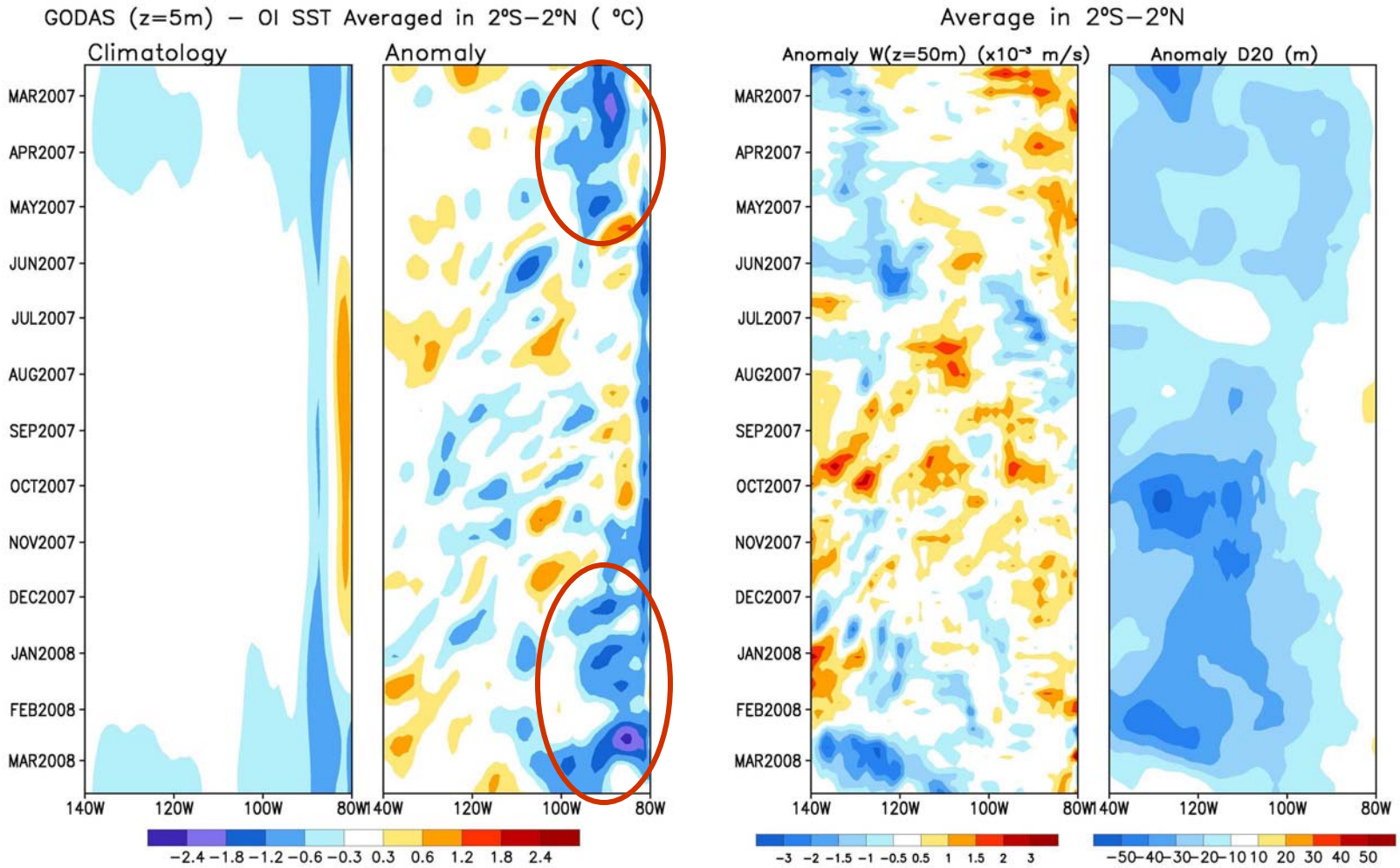
GODAS Equatorial X-Z Temperature





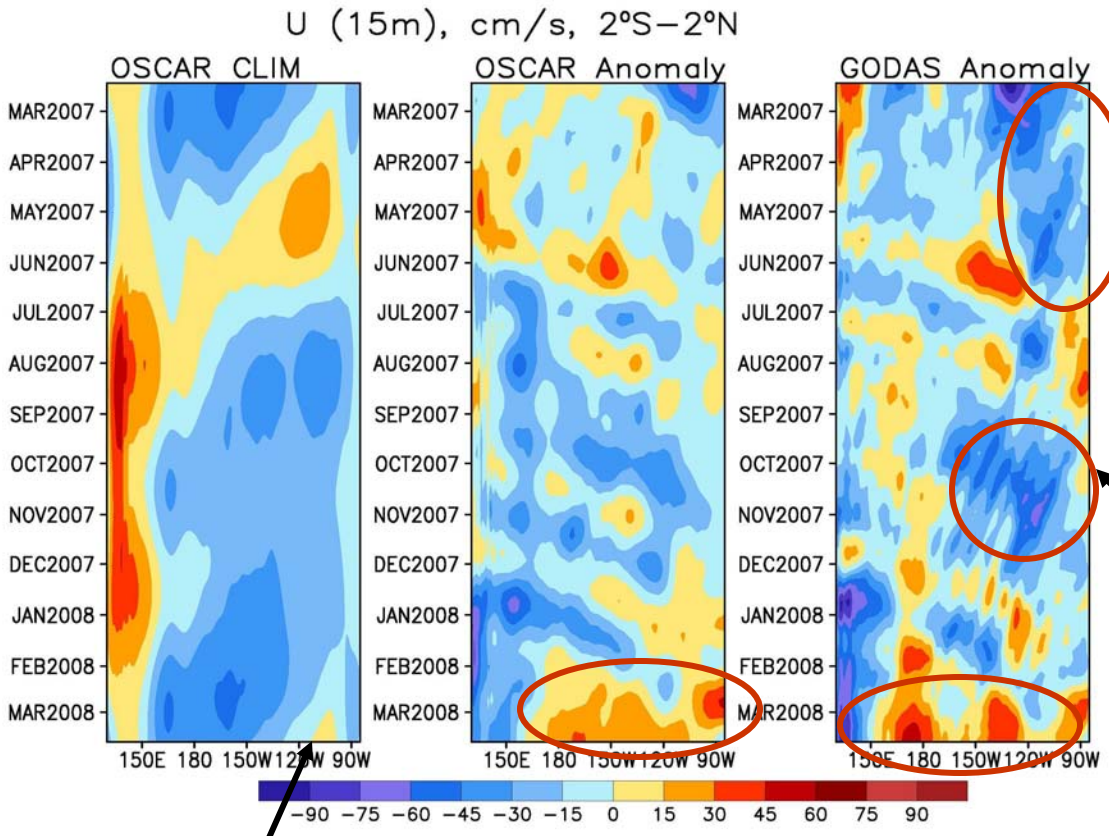
- **GODAS SSH anomalies have been consistently too low in the eastern Pacific since December 2006**
- **GODAS SSH anomalies are about 6cm lower than those Altimetry SSH since December 2007 east of 140W**
- **What causes the biases?**

Recent Evolution of Equatorial Far Eastern Pacific SST Biases, Vertical Velocity and D20 Anomaly



- **Large negative SST biases east of 100W in spring of 2007, and since November 2007**
- **Likely related to anomalously strong upwelling at 50-meter depth**

Recent Evolution of GODAS Biases: Equatorial Surface (15 m) Zonal Current



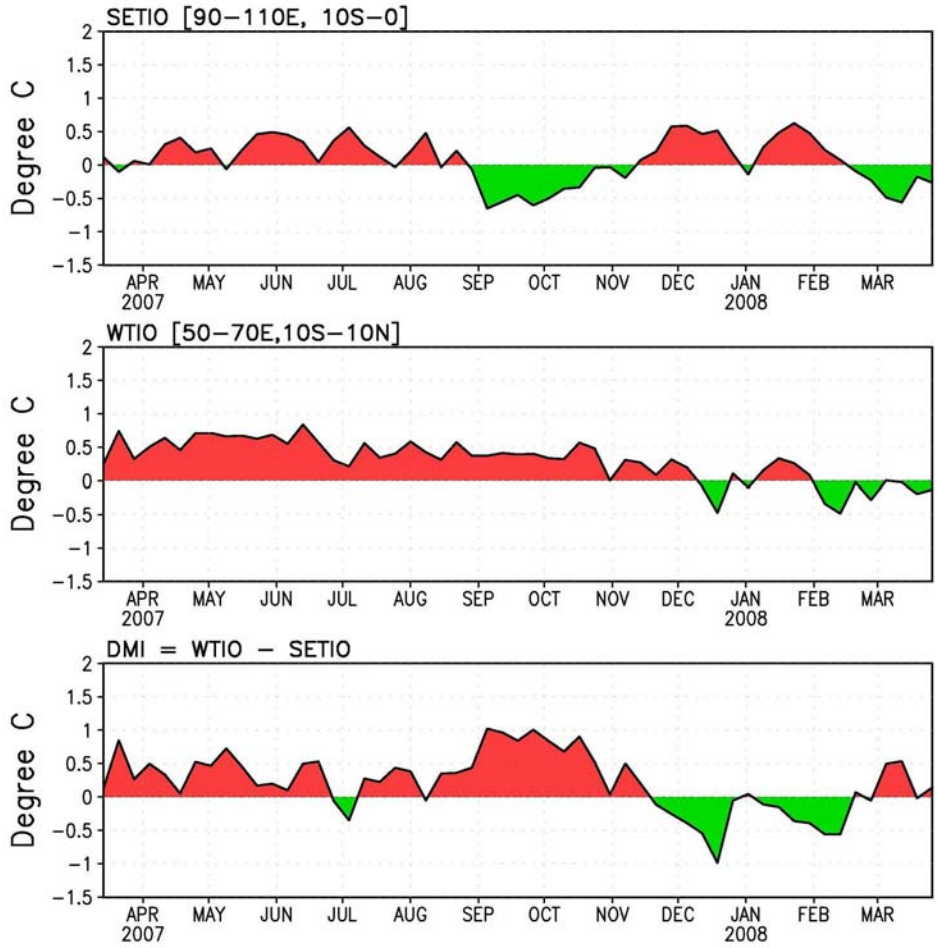
Too strong westward currents

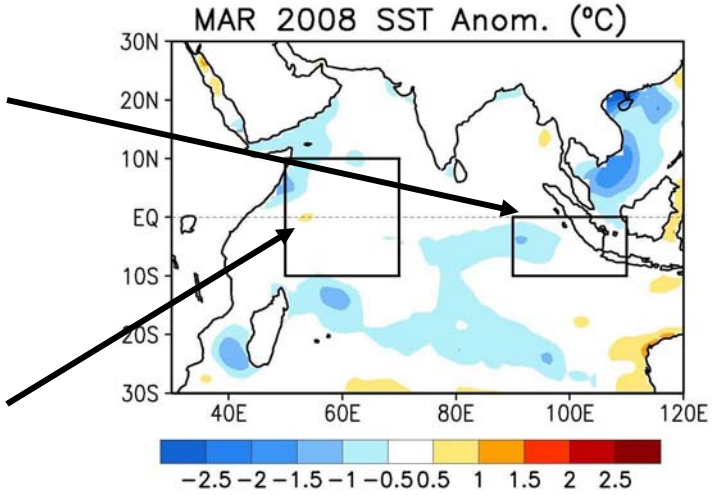
Too strong westward currents

Eastward current anomalies in February-March

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

Recent Evolution of Indian Ocean SST Indices





- **Weak below-normal SST in tropical Indian Ocean**
- **IO Dipole Mode Index (DMI) was near normal**