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

Prepared by

Climate Prediction Center, NCEP

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

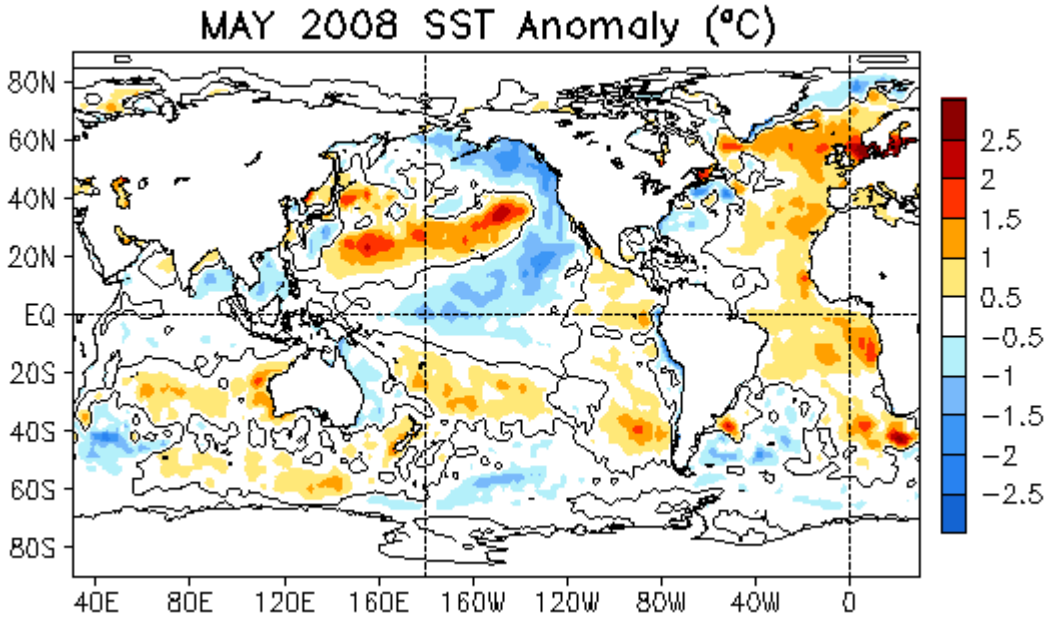
Outline

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

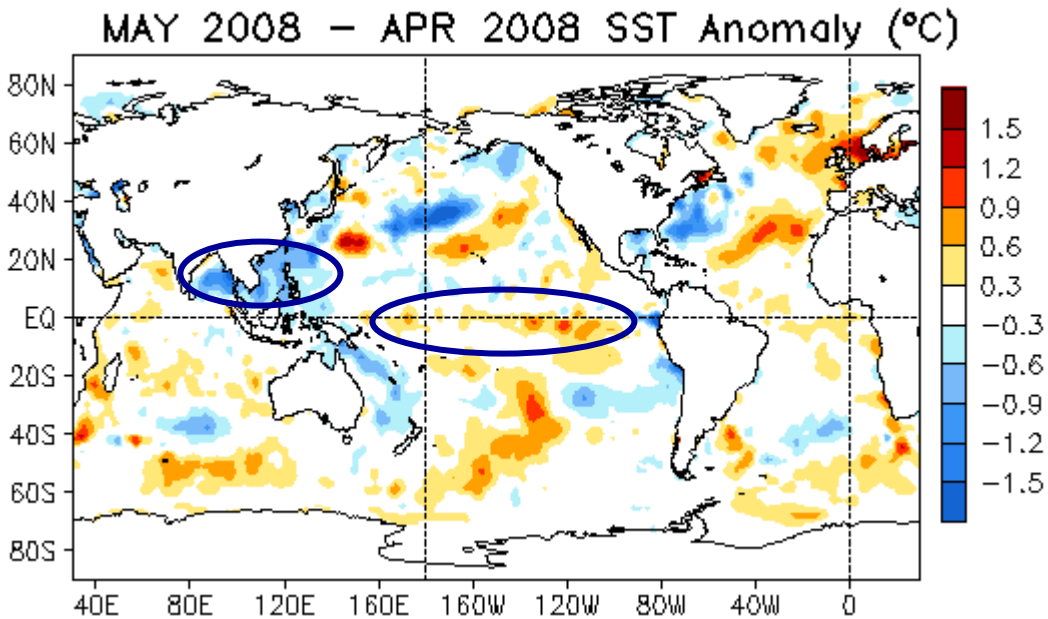
Overview

- **Pacific Ocean**
  - La Nina further weakened (NINO3.4 changed from -0.85 C to -0.59C)
  - CPC's prognostic assessment: A transition to ENSO-neutral conditions is expected during June-July 08
  - Positive SSTA in far E. Pacific and westerly wind anomalies east of 150W persisted
  - Negative PDO pattern strengthened (PDO changed from -0.71 in March to -1.52 in April)
  - Above-normal upwelling along the west coast of North America continued
- **Indian Ocean**
  - Below-normal rainfall in tropical Indian Ocean and above-normal rainfall in subtropical northern Indian Ocean
  - Easterly wind anomalies in tropical Indian and westerly wind anomalies in subtropical northern Indian Ocean, due to Asian Monsoon onset ?
- **Atlantic Ocean**
  - Tropical North Atlantic SST (TNA) has a cooling trend since 2005, and became near-normal since January 08
  - Tropical South Atlantic (TSA) SST was more than 0.5 degree above-normal since February 08
  - Negative Meridional SST gradient Mode (TNA – TSA), persisted since February 08, contributed to enhanced convection in tropical Atlantic and suppressed convection in subtropical northern Atlantic

Global SST Anomaly (°C) and Anomaly Tendency

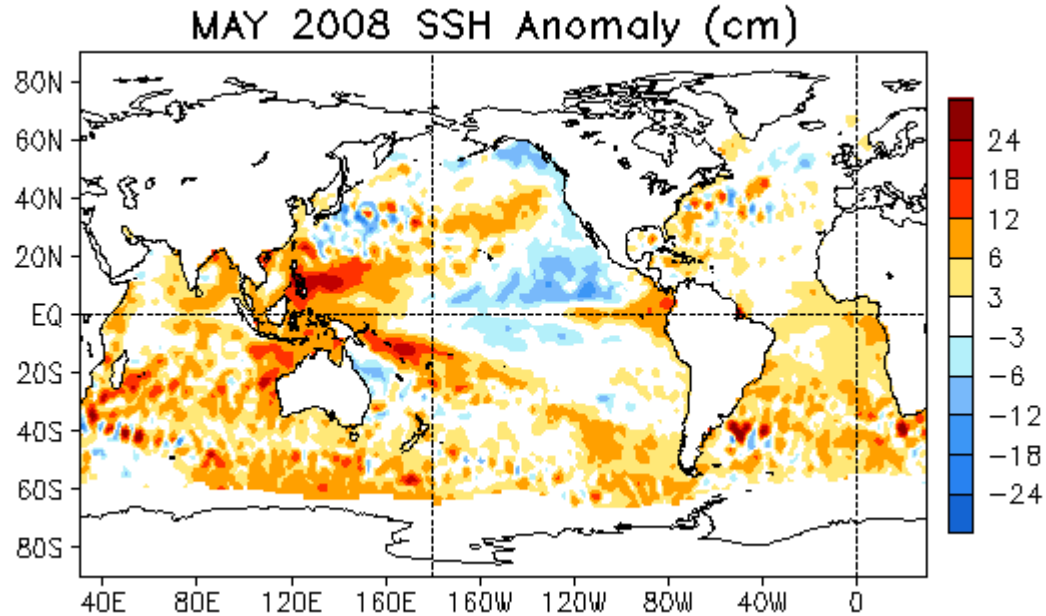


- **Weak La Nina pattern in tropical Pacific**
- **Strong negative PDO pattern in North Pacific**
- **Above-normal SST in Atlantic**
- **Near-normal SST in tropical Indian**

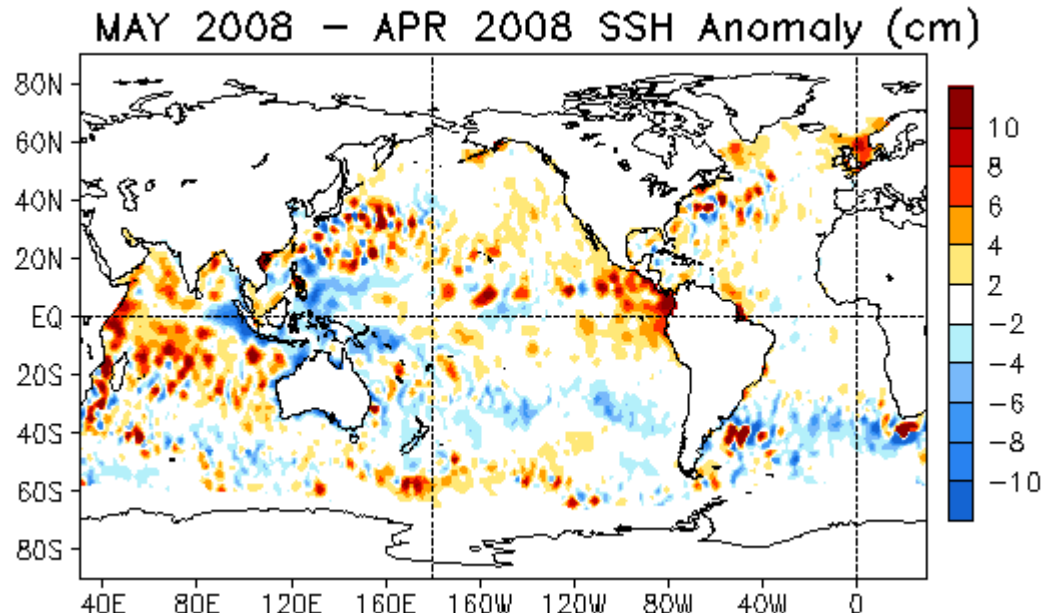


- **Negative SST anomaly in the equatorial tropical Pacific weakened from 160E to 90W**
- **SST cooled in the Bay of Bengal, South China Sea and Philippine Sea**

Global SSH Anomaly (^{0}C) and Anomaly Tendency

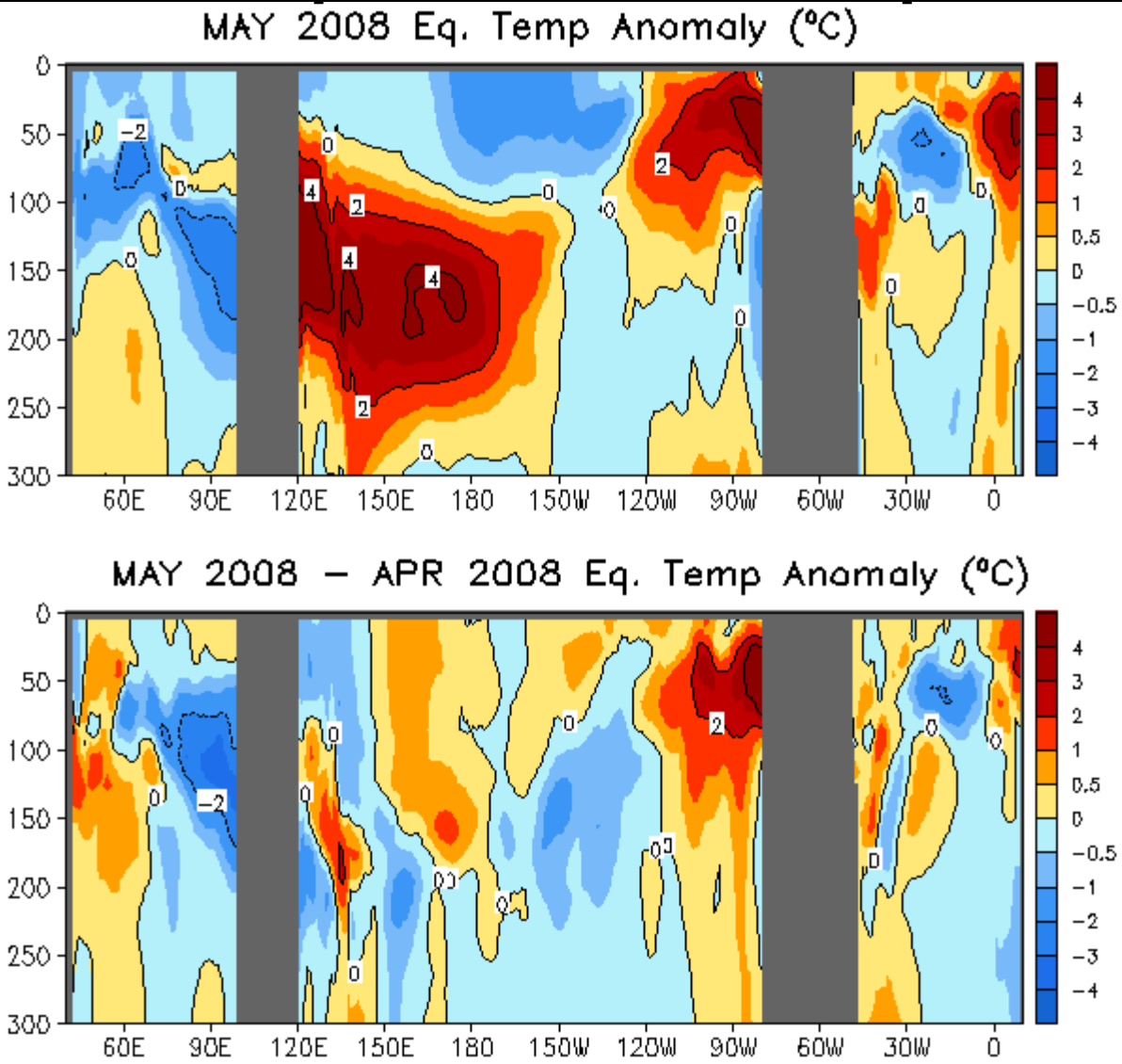


- **Triple SSH anomaly pattern in tropical Pacific**
- **Negative PDO pattern signature in SSH in North Pacific**
- **Above-normal SSH in tropical Atlantic and**
- **Above-normal SSH in tropical Indian**
- **Above-normal SSH in Southern Oceans**



- **SSH increased (decreased) in the far eastern (western) tropical Pacific**
- **SSH decreased (increased) in the eastern (western) tropical Indian**

GODAS Equatorial X-Z Temperature

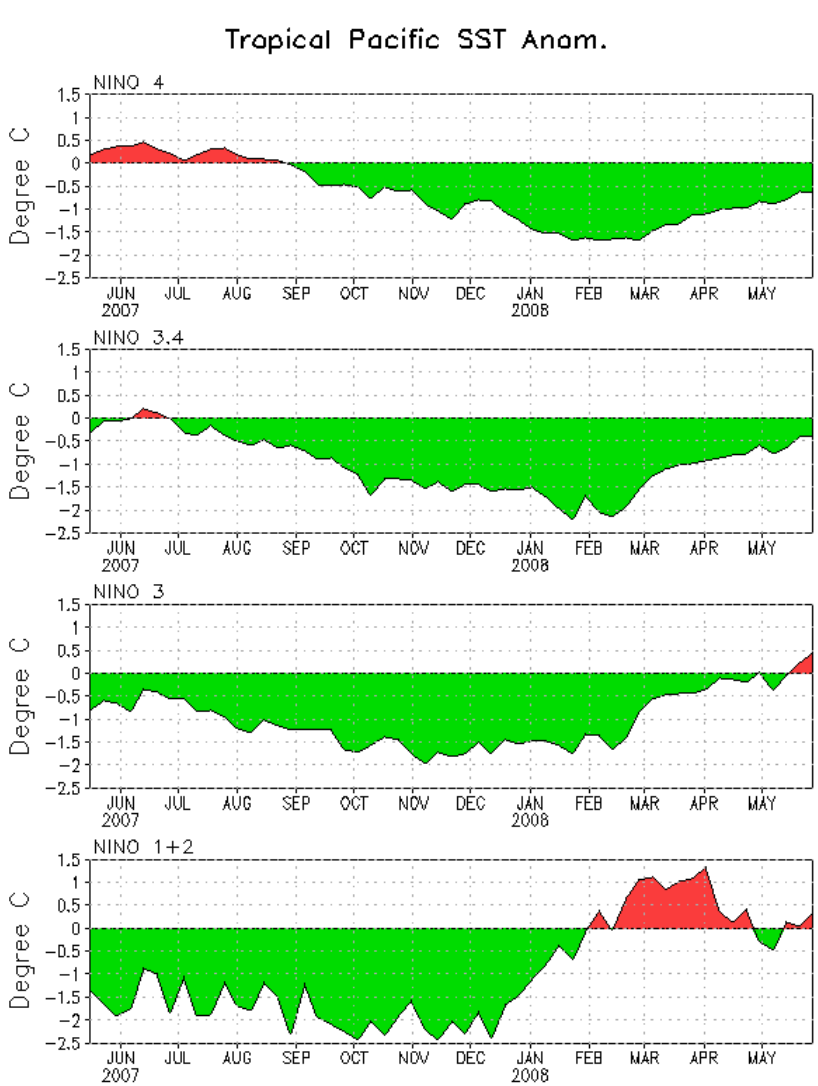


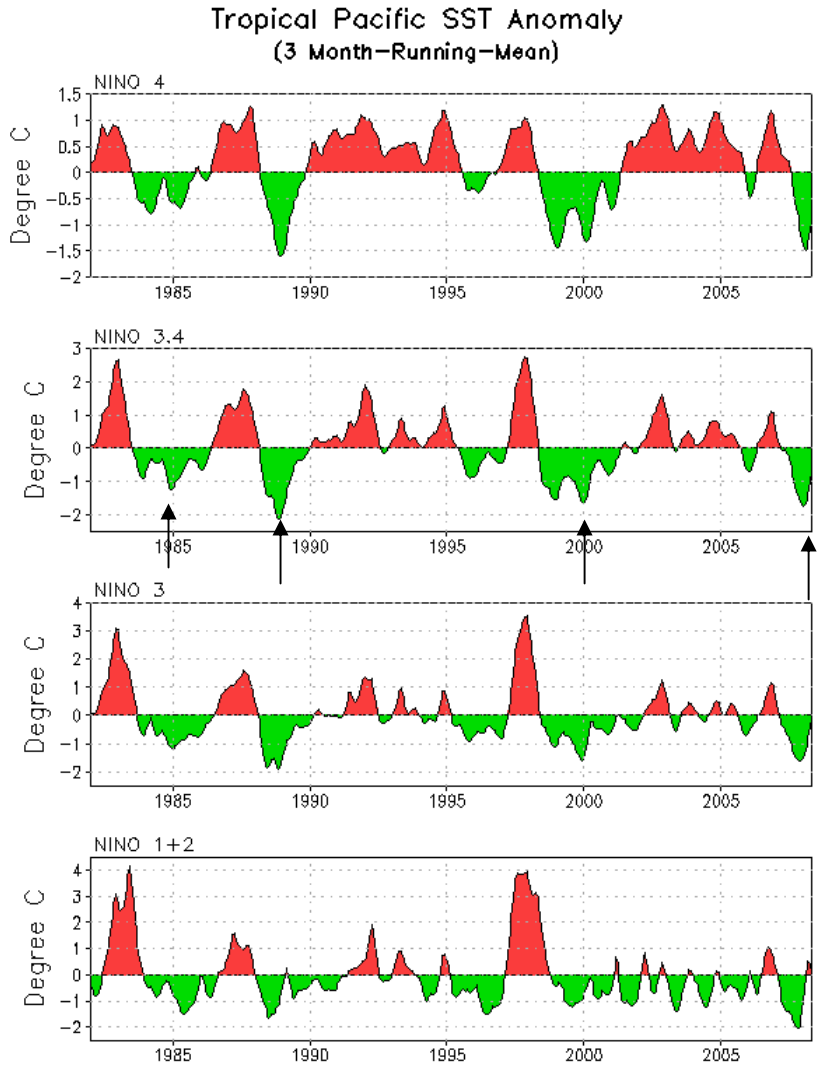
- **Subsurface temperature in the equatorial central Pacific was about 1 degree below-normal from surface to depth of 70 meter**

- **Subsurface temperature in the equatorial western (eastern) Pacific was about 4 (2) degree above-normal at depth of 175 (50) meters**

The 07/08 La Nina Cycle

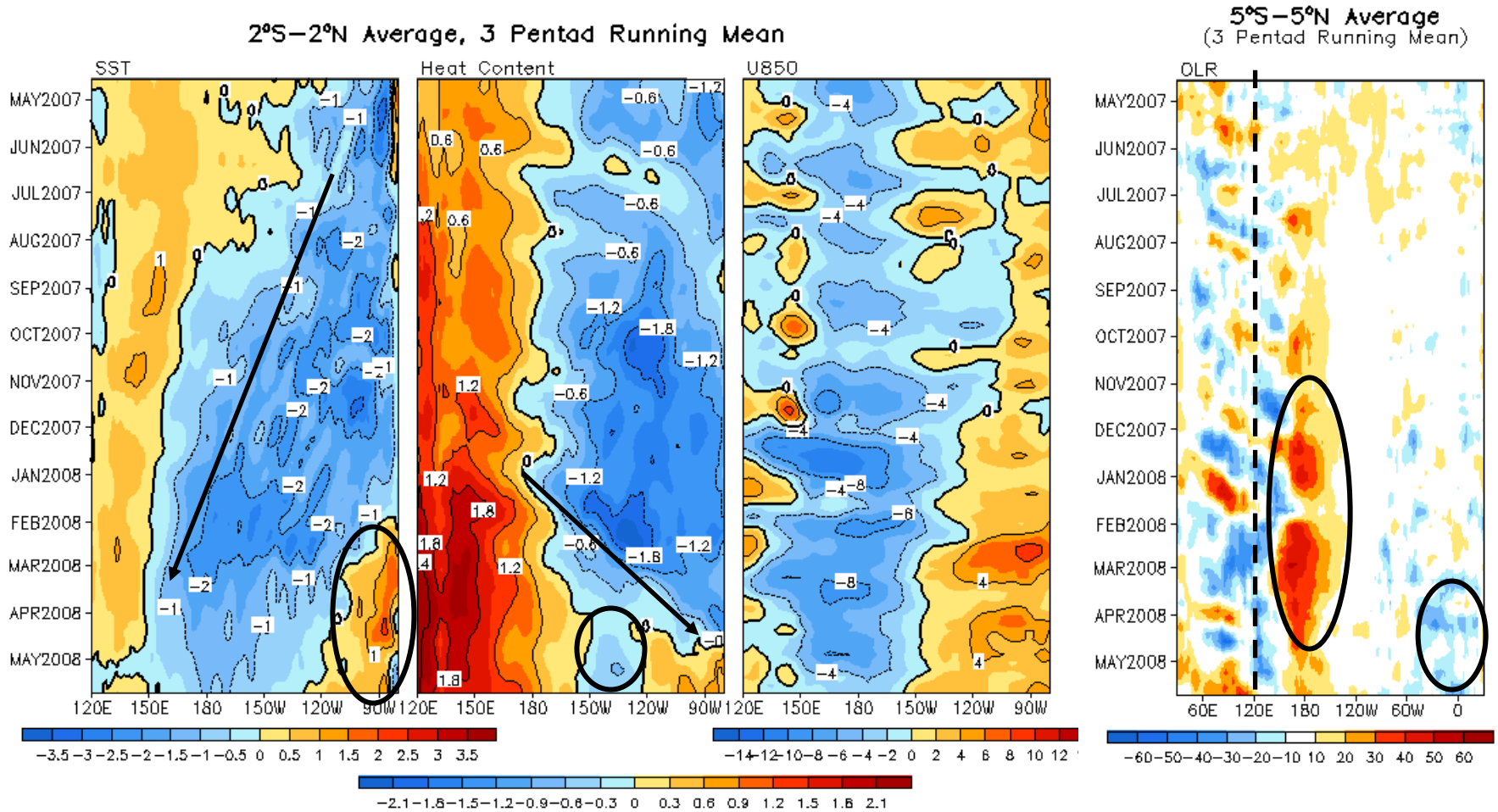
Evolution of Pacific NINO SST Indices





- **Negative SST anomalies first appeared in NINO 1+2 in March 2007 and then expanded westward**
- **La Nina conditions (NINO3.4 <= -0.5^{o}C) occurred in August 2007, and peaked (NINO3.4=-1.9^{o}C) in February 2008**
- **The La Nina rapidly weakened in March-April, and is expected to return to ENSO-neutral conditions in June-July (NOAA's ENSO Diagnostic Discussion), with a duration of about 10 months**
- **The 2007/08 La Nina had a similar strength to those of the 1988/89 and 1998/00 La Nina, but had a shorter duration**

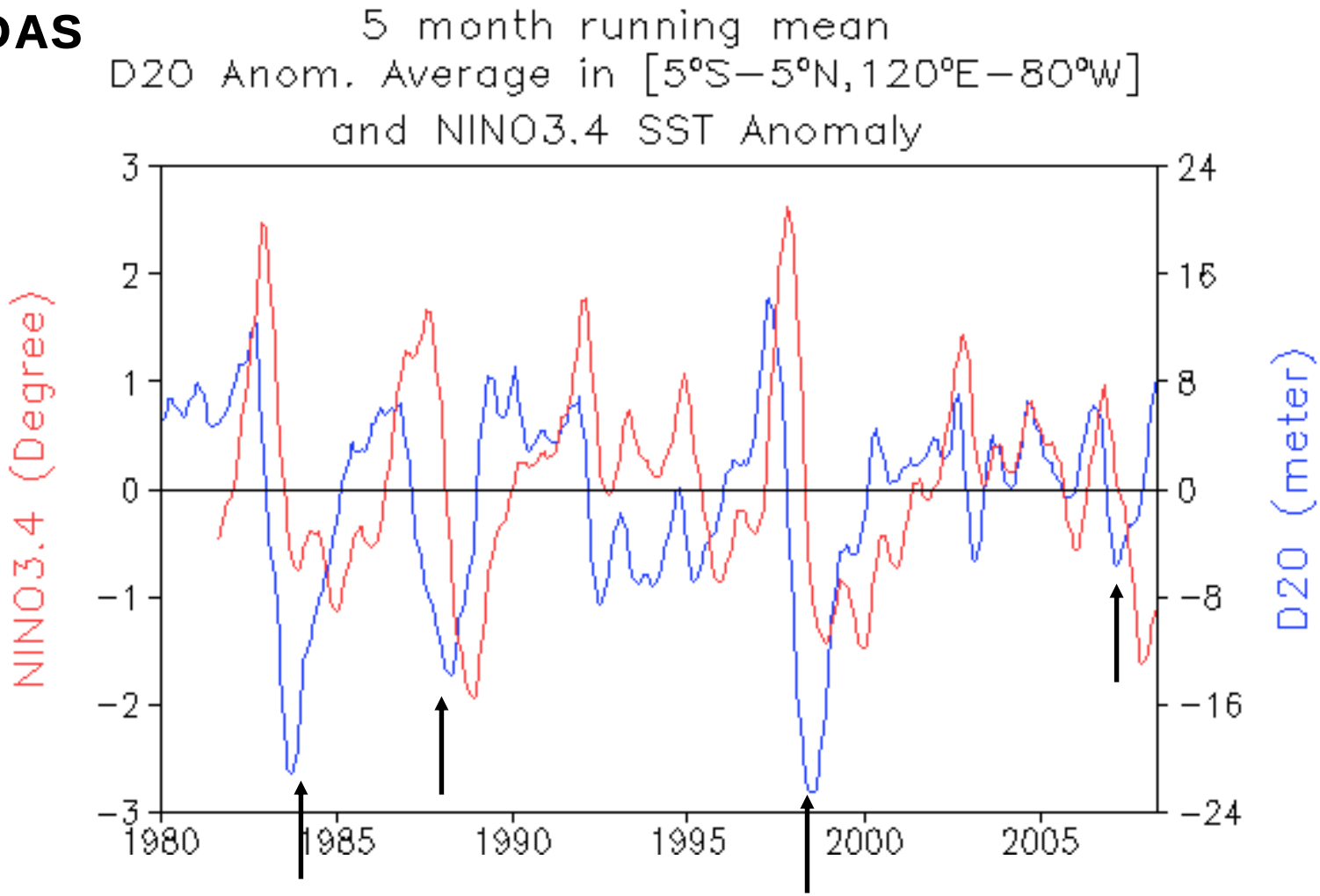
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²)



- **Positive SST anomalies in the far eastern Pacific and westerly wind anomalies east of 150W persisted**
- **Negative HC anomalies persisted between 150W and 120W, which were surrounded by positive HC anomalies to the west and east**
- **Suppressed (enhanced) convection near the Dateline (Maritime Continent) weakened, but enhanced convection in the tropical Atlantic persisted**

Warm Water Volume and NINO3.4

GODAS

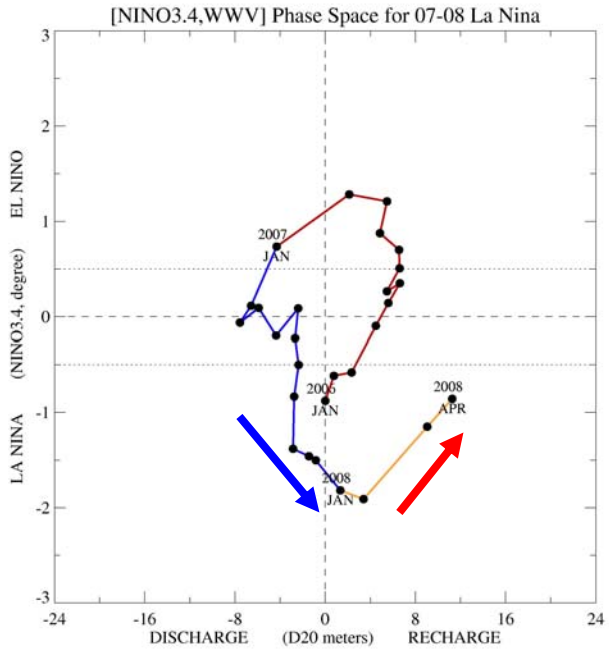


- **Warm Water Volume (equatorial average of D20 anomaly) leads NINO3.4 by 6-9 months**
- **The phase-relationship only holds for moderate to strong ENSO events**

Phase Space Diagram: Warm Water Volume vs NINO3.4

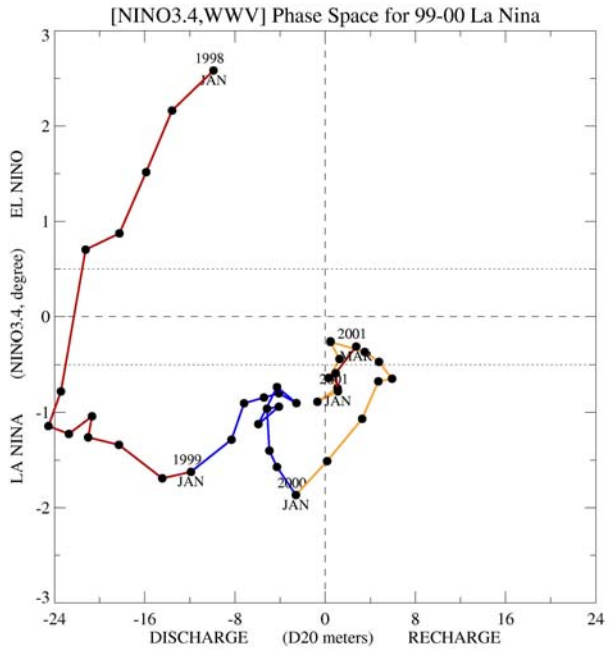
2007/08

La Nina



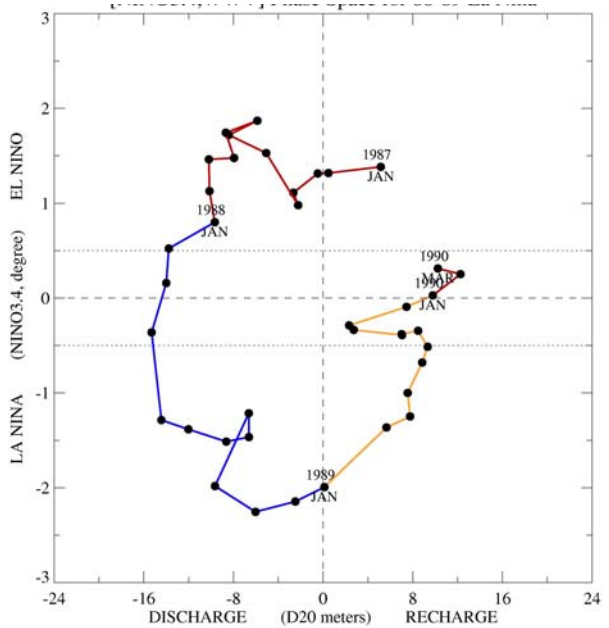
1999/00

La Nina



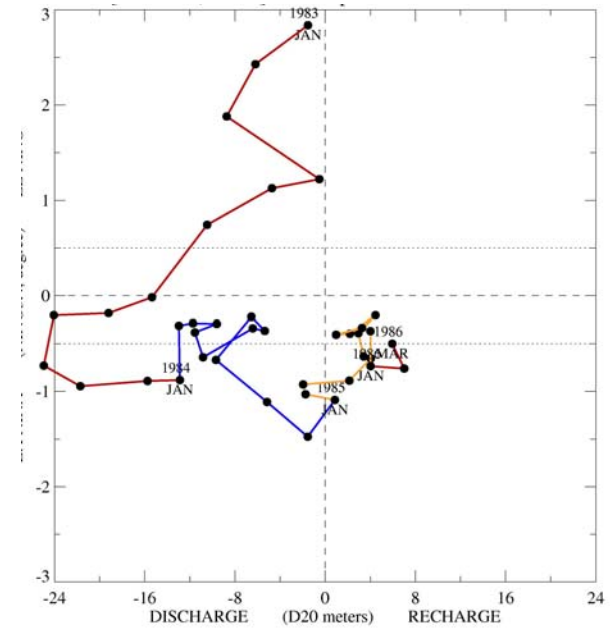
1988/89

La Nina

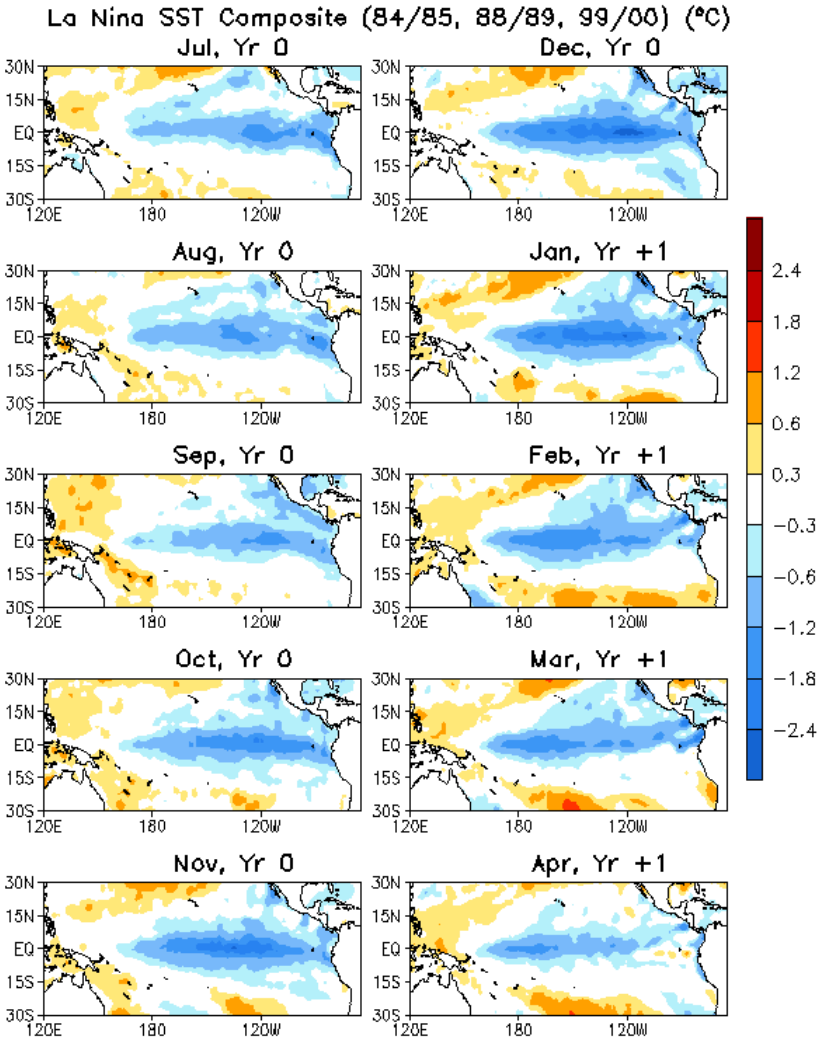


1984/85

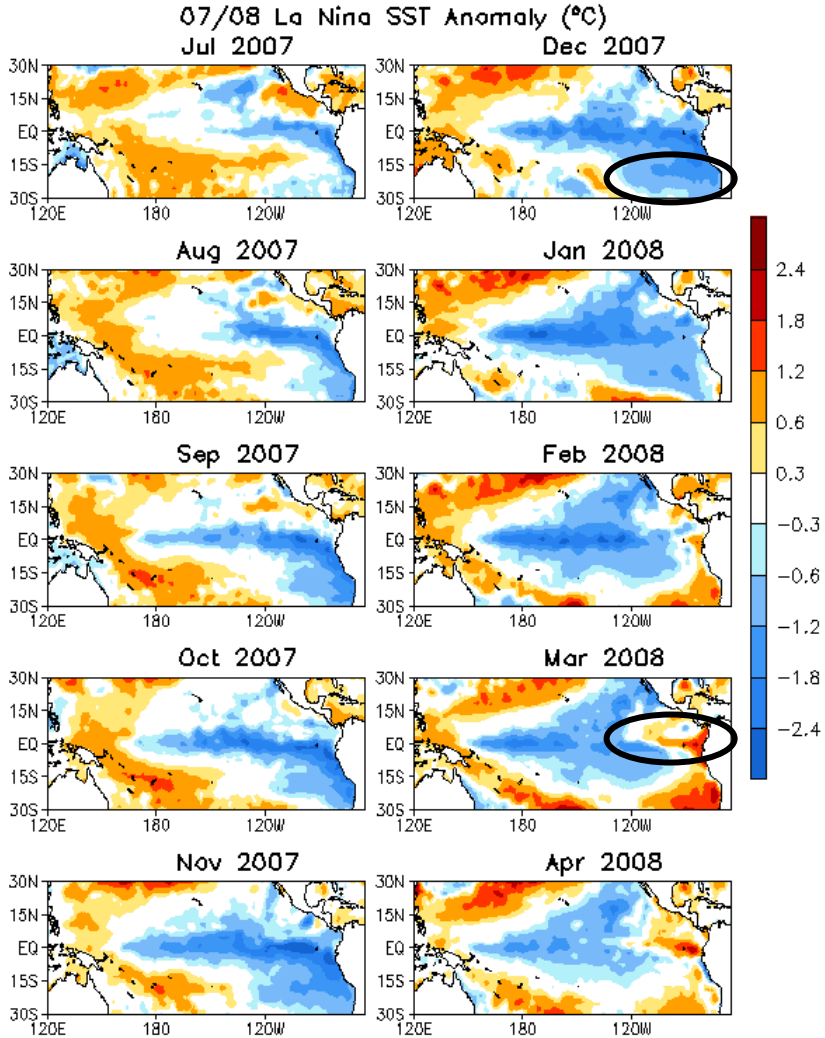
La Nina



La Nina Composite

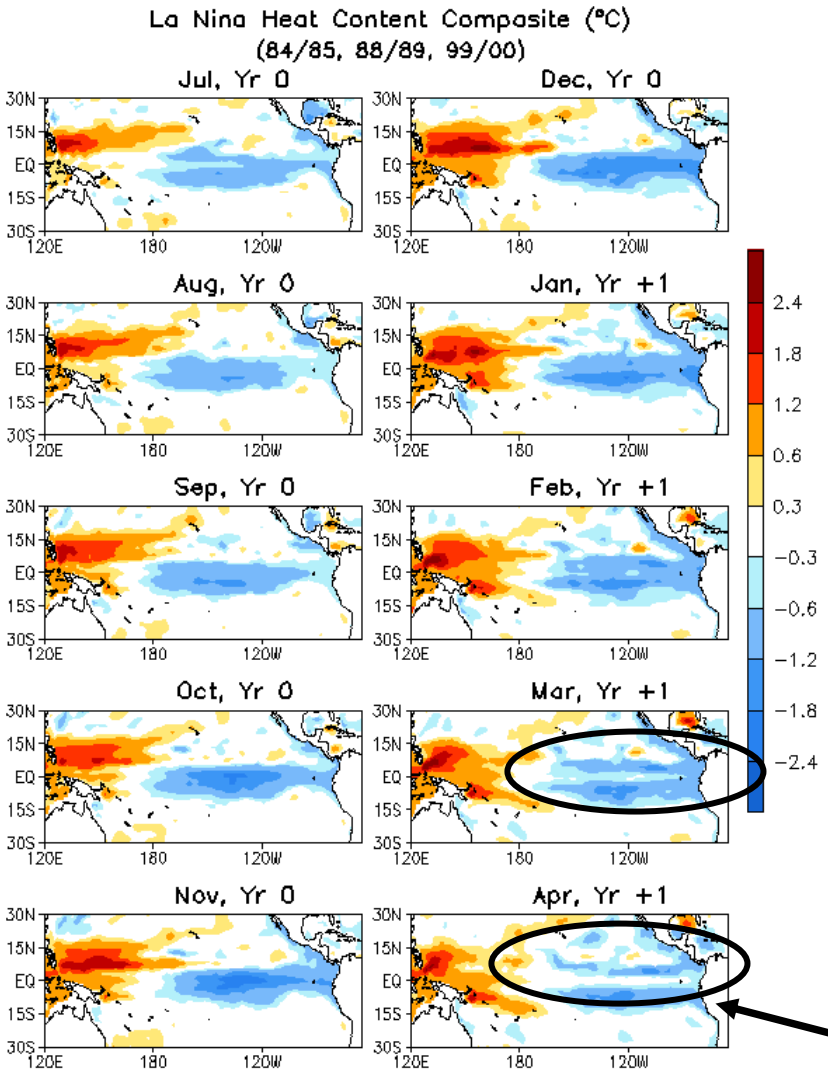


2007/08 SST Anomaly

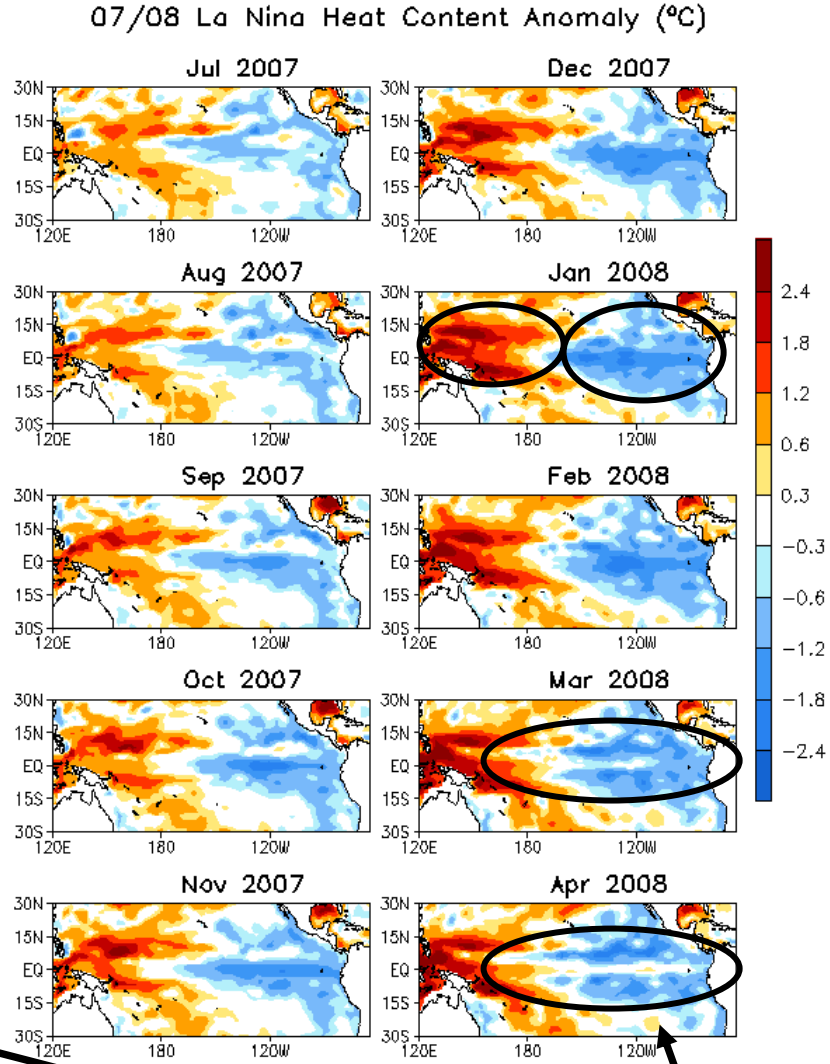


- **Compared to the composite, negative SST anomalies in July-August 08 were refined further to the east**
- **Positive SST anomalies were much larger in the western tropical Pacific, due to the warming trend and negative PDO?**
- **Negative SST anomalies had a broader meridional coverage in the south-eastern Pacific**
- **Positive SST anomalies occurred in the far eastern tropical Pacific in early spring**

La Nina Composite



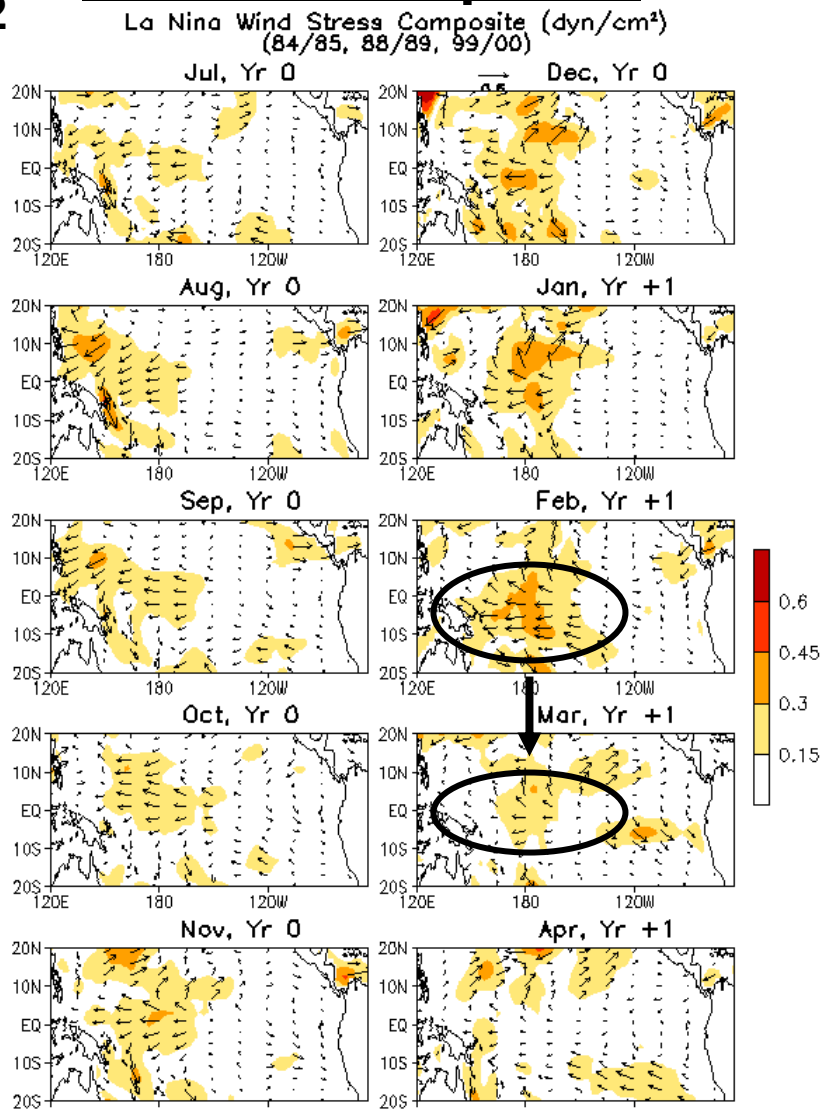
2007/08 HC Anomaly



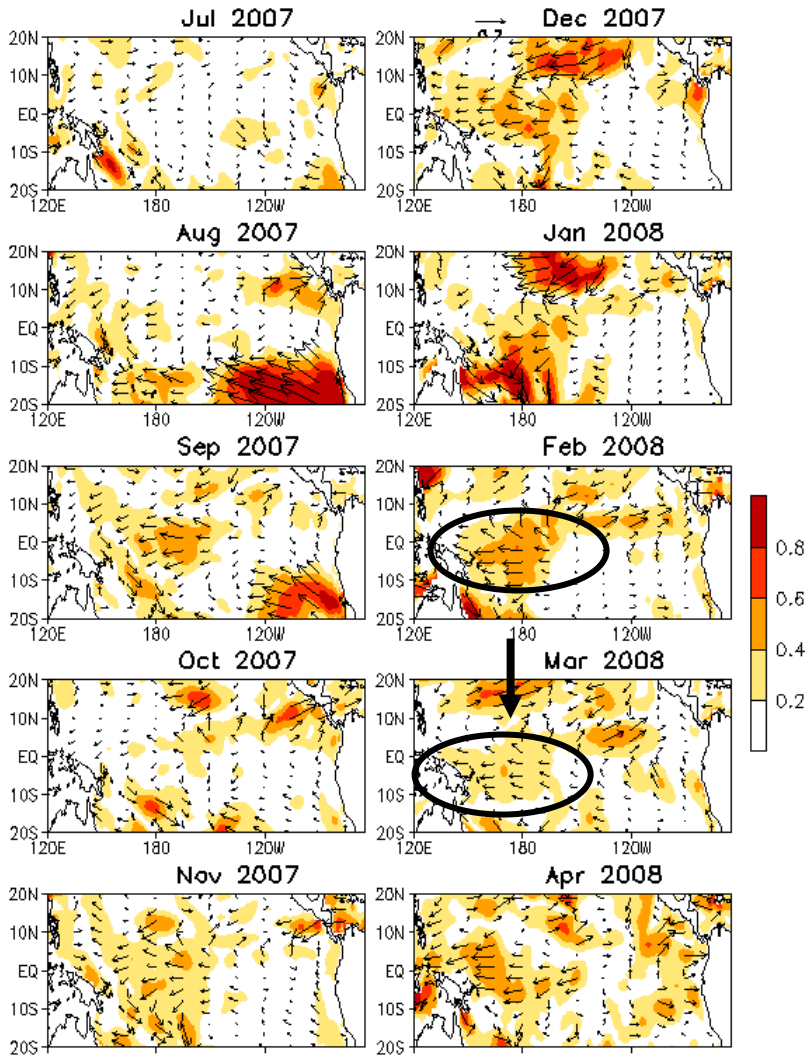
- **Compared to the composite, positive heat content (HC) anomalies were much larger in the western tropical Pacific, due to the warming trend?**
- **Negative HC anomalies had a broader meridional coverage in the eastern Pacific**
- **Negative HC anomalies along the equatorial belt dissipated quickly in March-April, while those off the equator persisted**

CDAS2

La Nina Composite

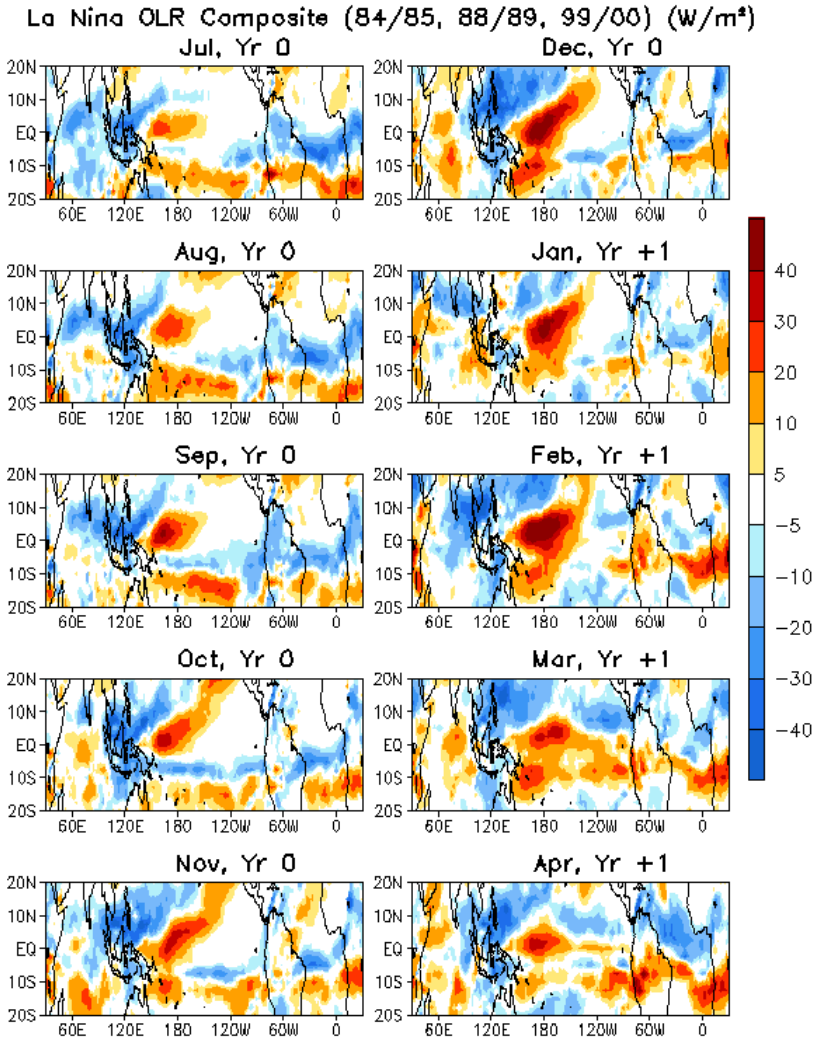


2007/08 Wind Stress Anomaly

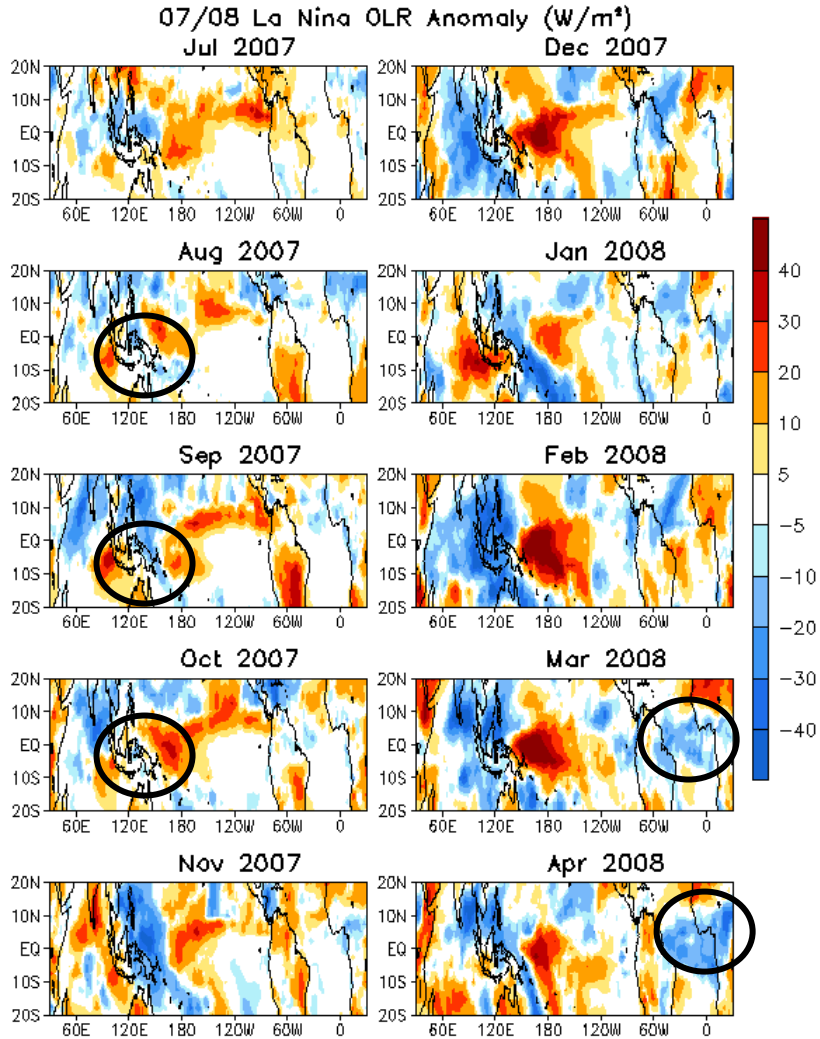


- **Easterly wind stress anomalies weakened significantly from February to March in both the composite and 2007/08 La Nina, Why?**

La Nina Composite

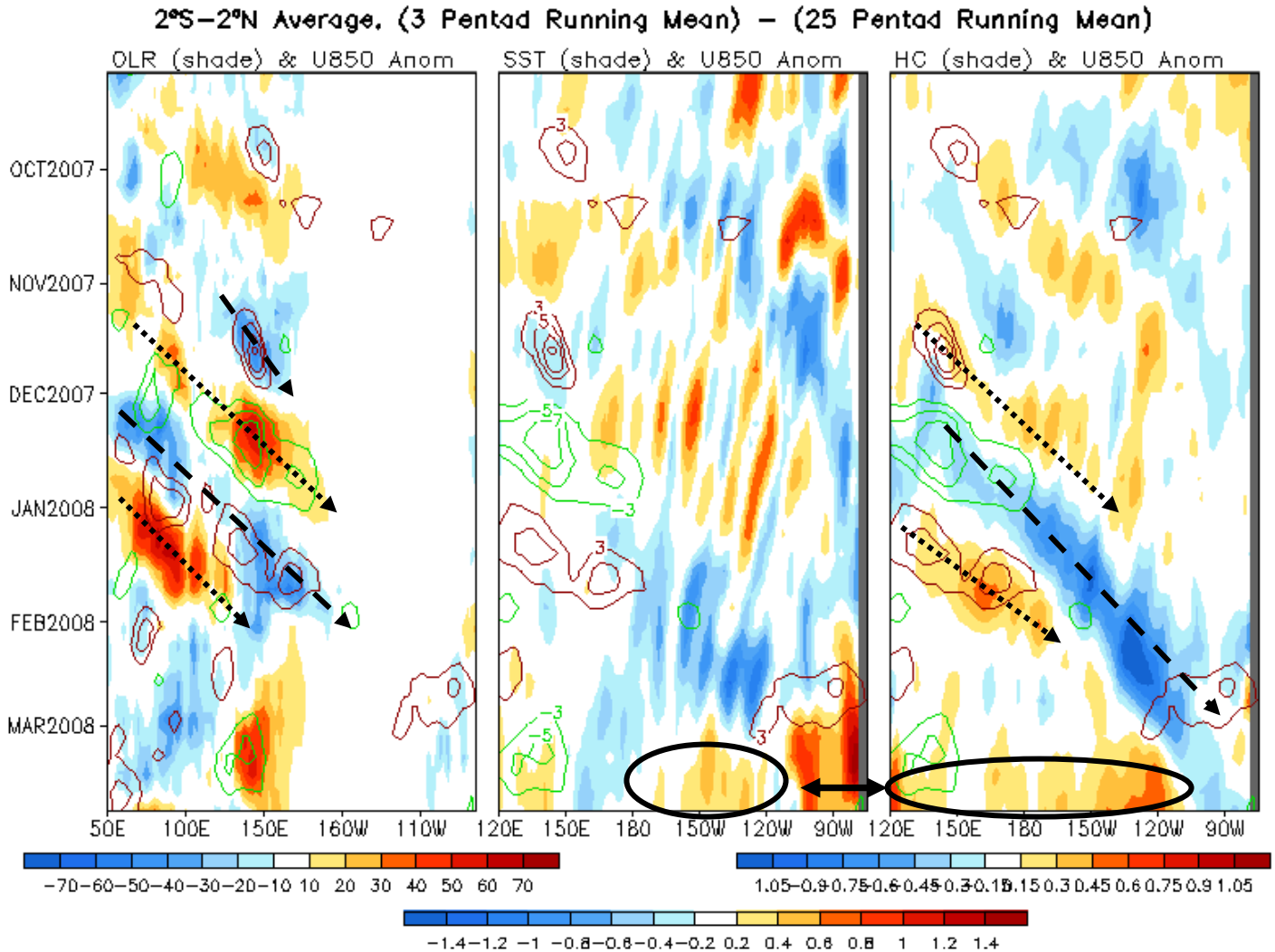


2007/08 OLR Anomaly



- **Suppressed convection in the Maritime Continent in August-October was due to a positive Indian Ocean Dipole event**
- **Strong MJO activity in November-January had dominated the convection in the tropical Indian and Maritime Continent**
- **Enhanced convection presented along the equatorial Atlantic in February-April 2008, which was stronger and displaced further to the south than in the composite**

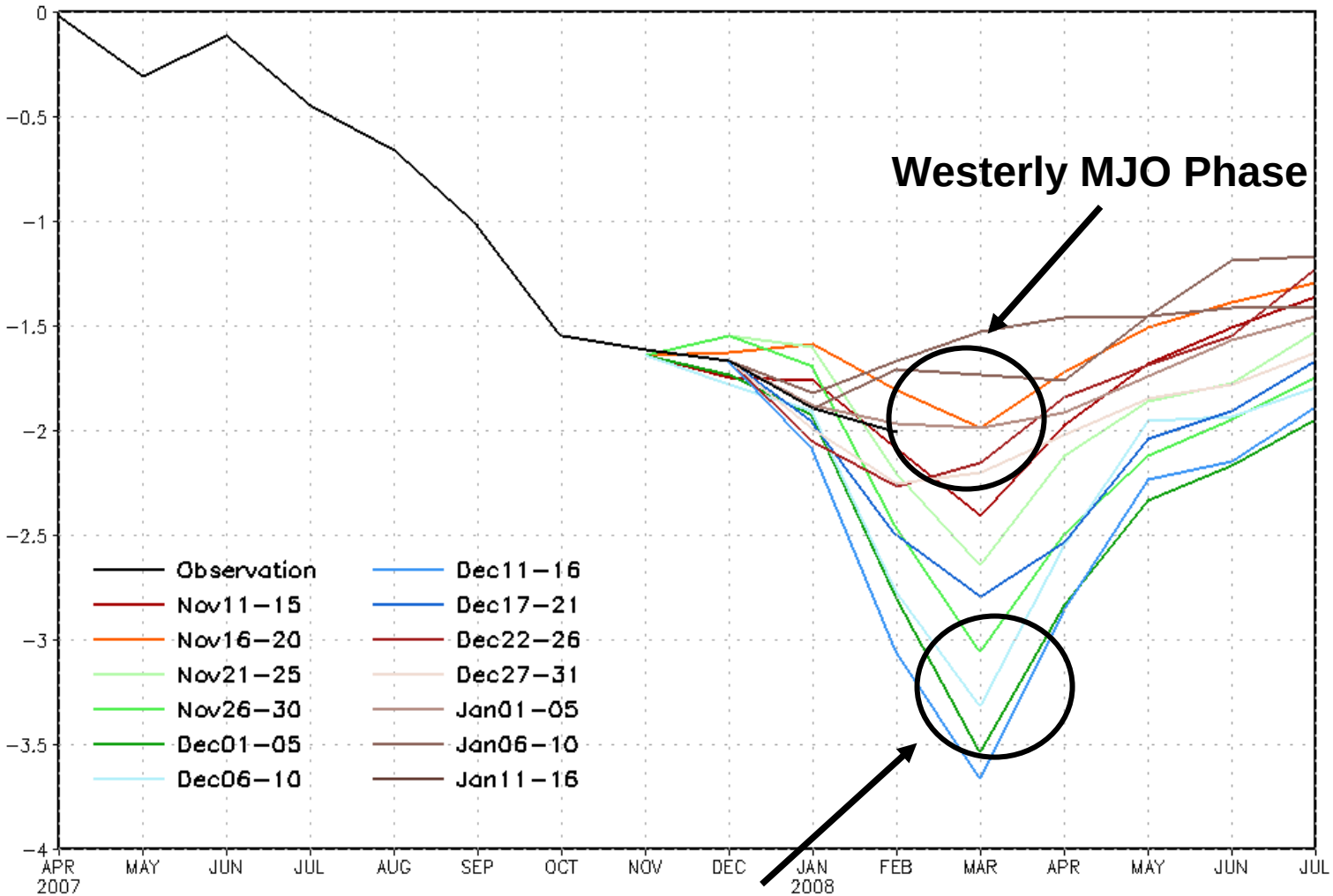
MJO and Oceanic Kelvin Waves



- **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**
- **Eastern Pacific warming since mid-February seems not associated with downwelling Kelvin waves, rather associated with westerly wind anomalies in the far eastern Pacific**
- **Basin-wide heat content increase in March was consistent to SST increase in the central Pacific, but was inconsistent with U850 changes there (U850 differs from surface wind stress, see slide 13)**

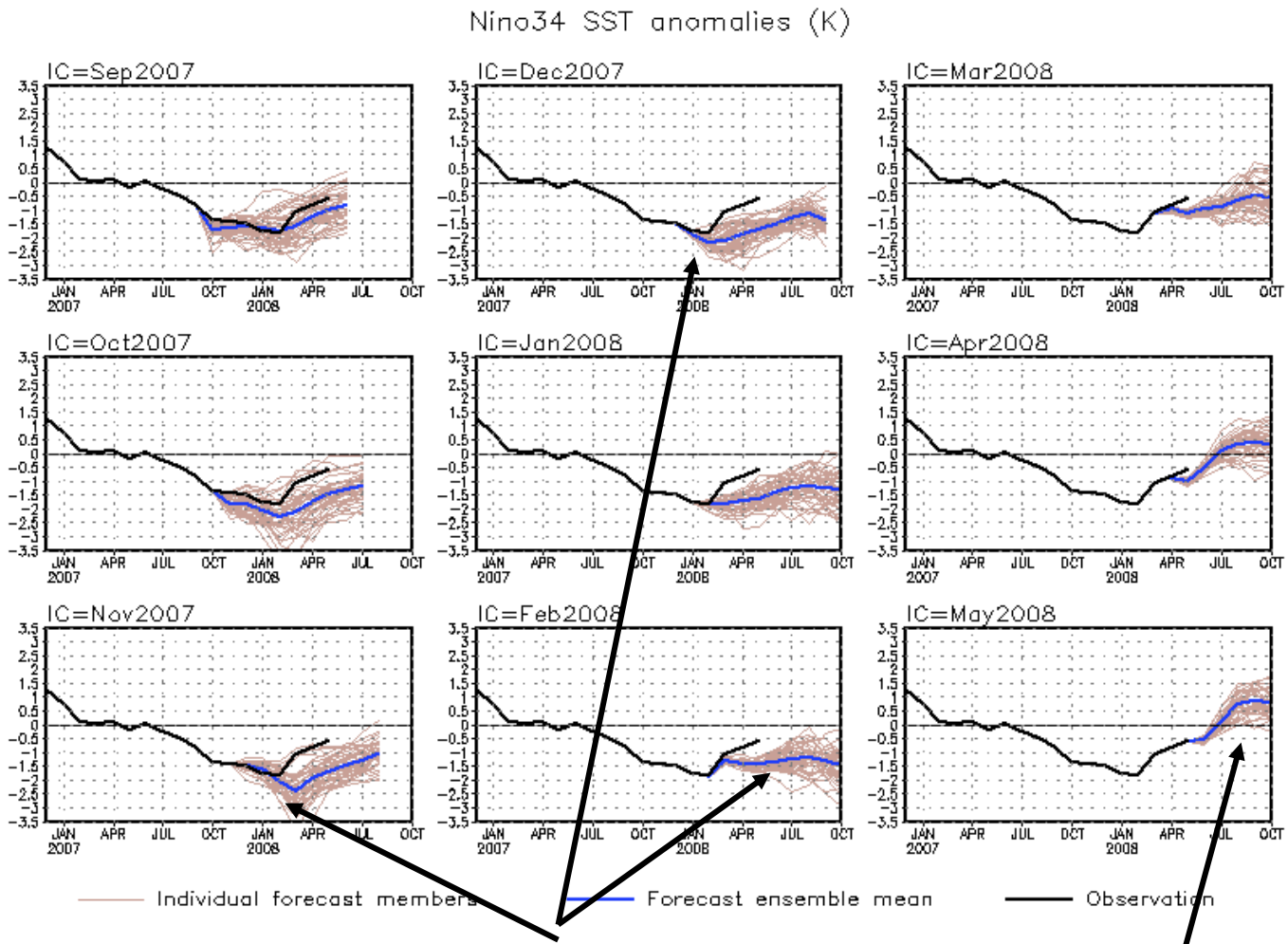
CFS NINO3.4 SST Forecasts from Different Initial Days

Courtesy of Wanqui Wang



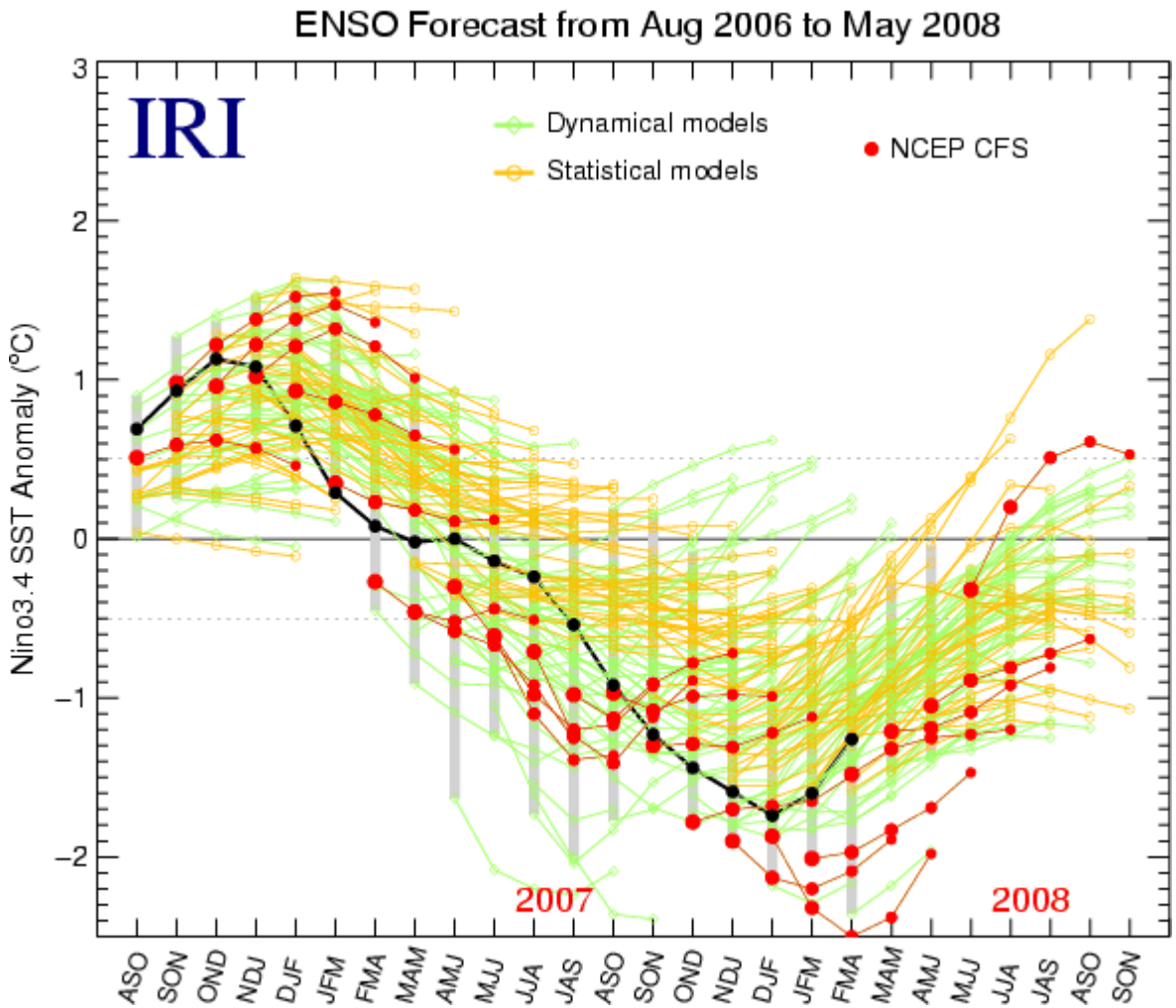
The 07/08 La Nina Prediction

CFS Niño 3.4 SST Predictions from Different Initial Months



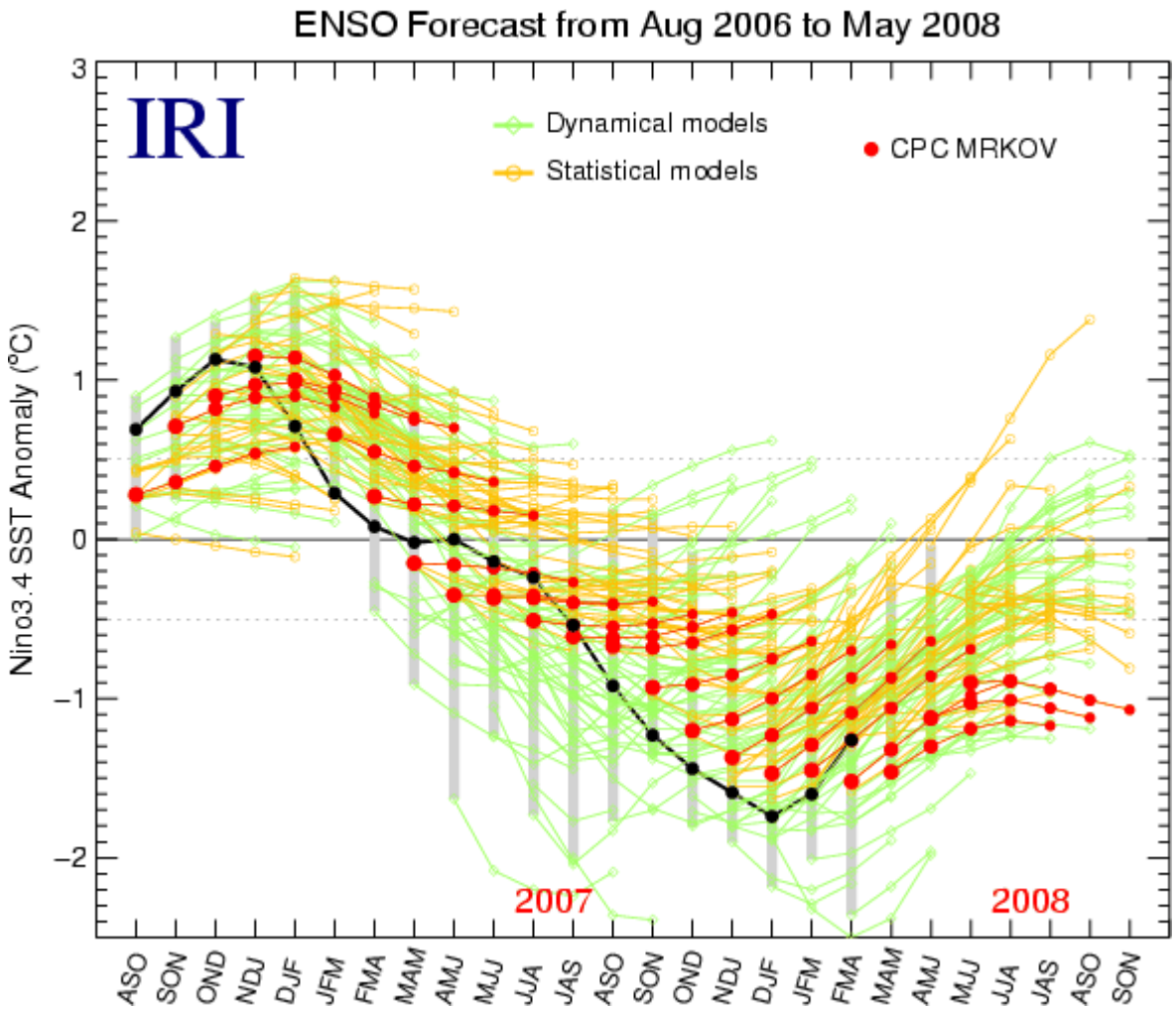
- **SST forecast biased towards cold in Nov-Feb**
- **SST forecast appeared reasonable from March initial conditions**
- **CFS forecast a weak El Nino in summer 2008 from April-May initial conditions**

CFS



- **CFS's forecast in early spring was among one of the coldest forecasts**
- **CFS's forecast in winter, calling for a continuation and strengthening of the La Nina into spring 2008, was a outlier**
- **CFS's forecast in April, calling for a weak El Nino in summer 2008, was a outlier**

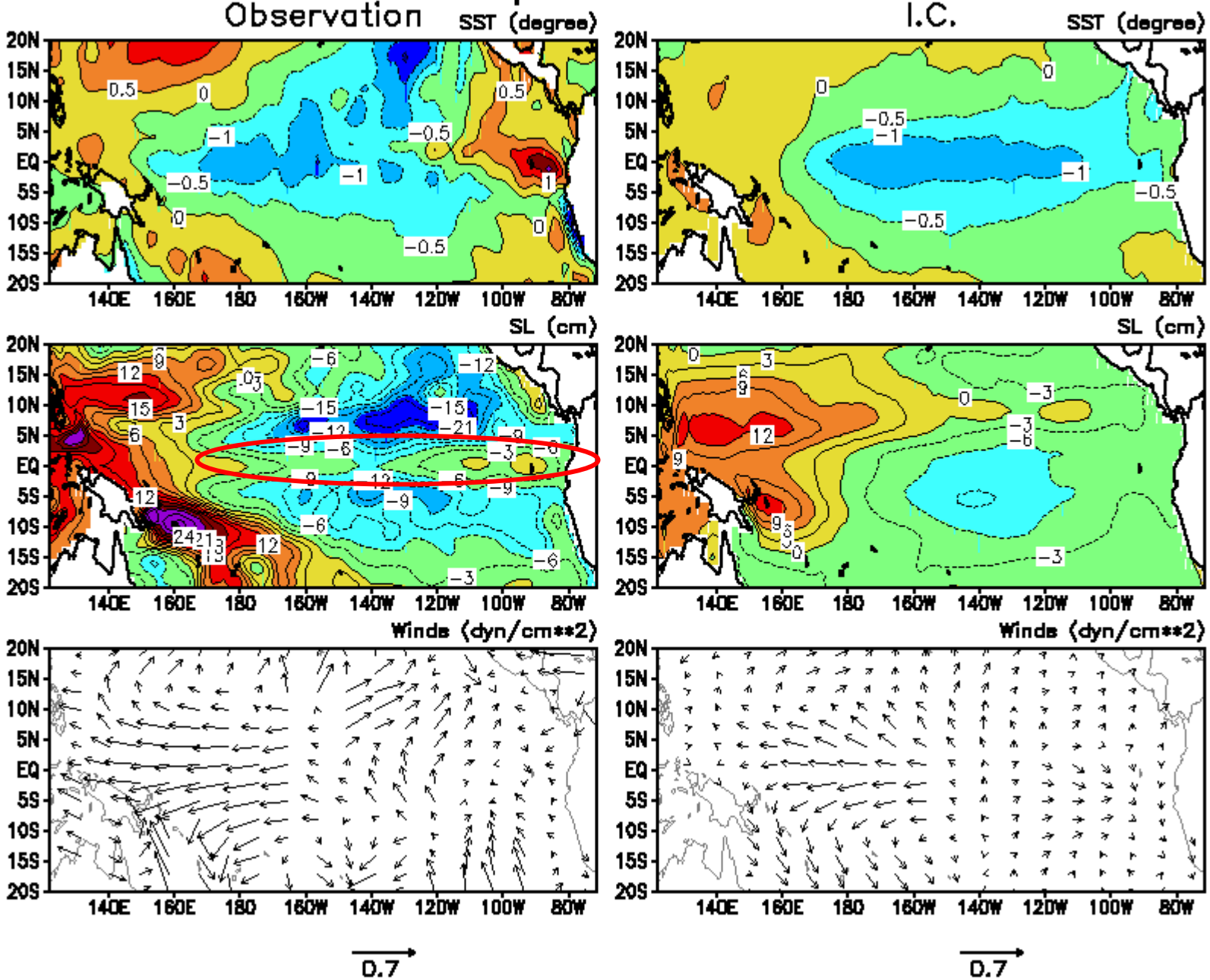
Markov Model



- **CPC's Markov Model, similar to other statistical models, successfully forecast the ENSO-neutral conditions in spring and summer, but failed to forecast the cooling trend in the fall and winter**

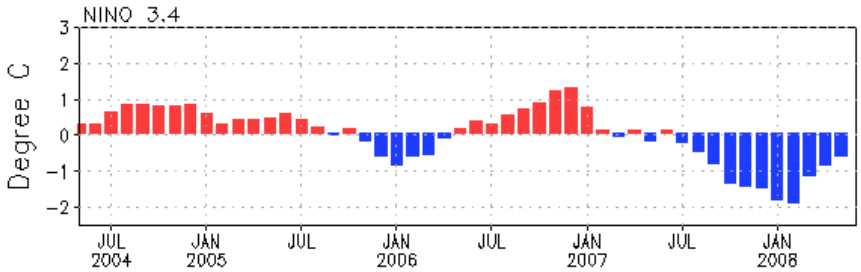
- **CPC's Markov Model successfully forecast the warming trend in spring, but wrongfully forecast a strengthening of the cold phase in summer/fall 2008. This was because the initial conditions of the Markov Model were severely truncated by the three multiple EOFs used to constructed the model (see next slide)**

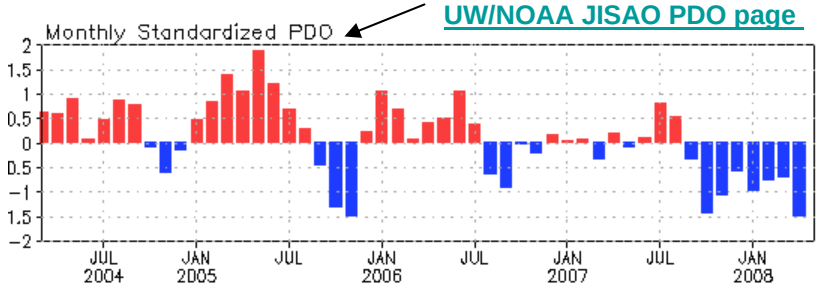
April 2008


Observation
SST (degree)
I.C.
SST (degree)
SL (cm)
SL (cm)
Winds (dyn/cm**2)
Winds (dyn/cm**2)
20N
15N
10N
5N
EQ
5S
10S
15S
20S
140E
160E
180
160W
140W
120W
100W
80W
0.7
0.7

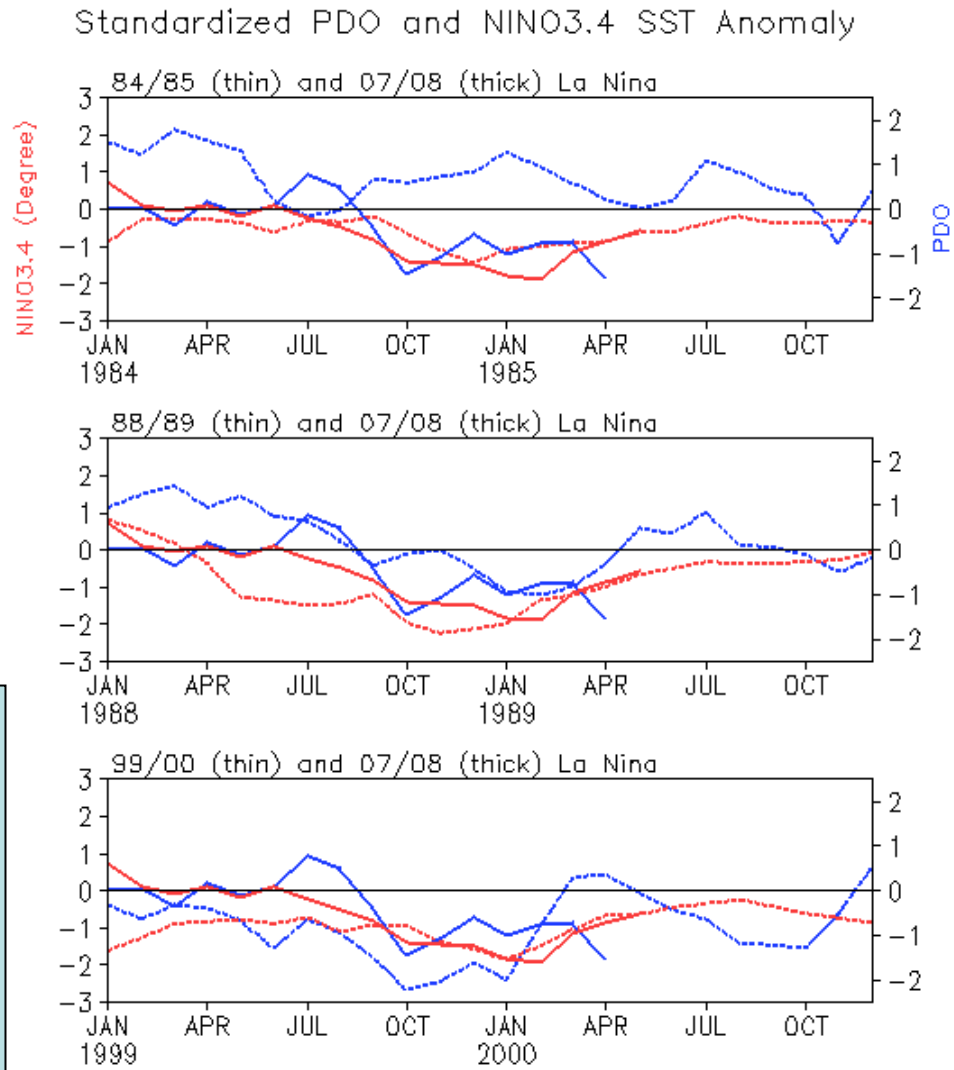
North Pacific Ocean

NINO3.4 vs PDO



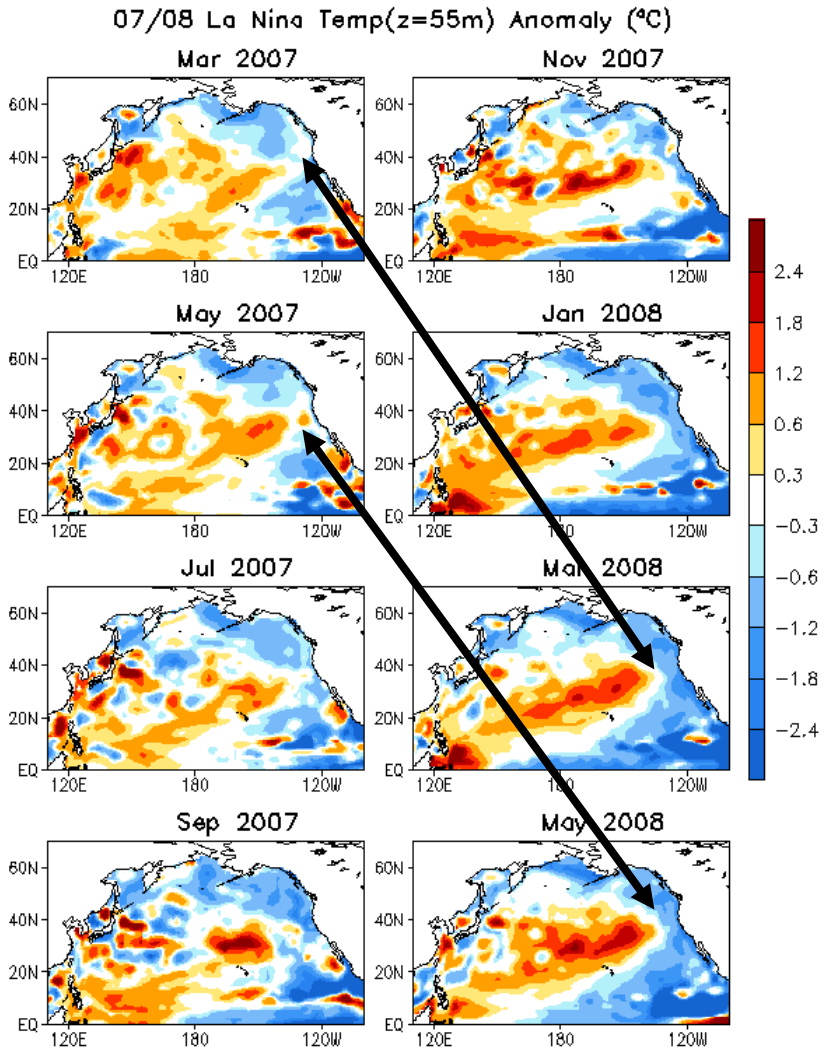


UW/NOAA JISAO PDO page

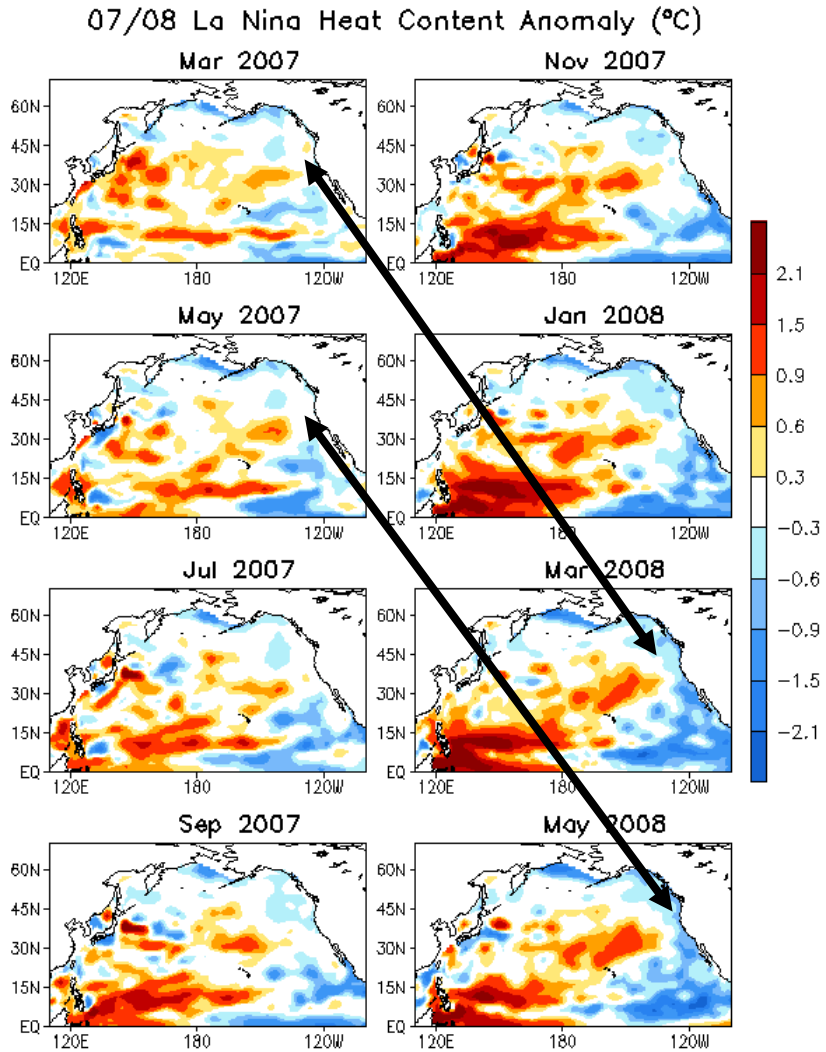


- **La Nina conditions developed in August 2007, while negative PDO pattern occurred in September 2007**
- **During the 84/85 La Nina, PDO has been mostly positive**
- **During the 88/89 La Nina, PDO lagged negative NINO3.4 by 8 months, but switched to positive in spring 89 when NINO3.4 remained negative**
- **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**
- **During the 07/08 La Nina, PDO lagged negative NINO3.4 by 2 months, and had been strongly negative and persistent. The negative PDO pattern deepened in April 08**

Temp (z=55m) Anomaly

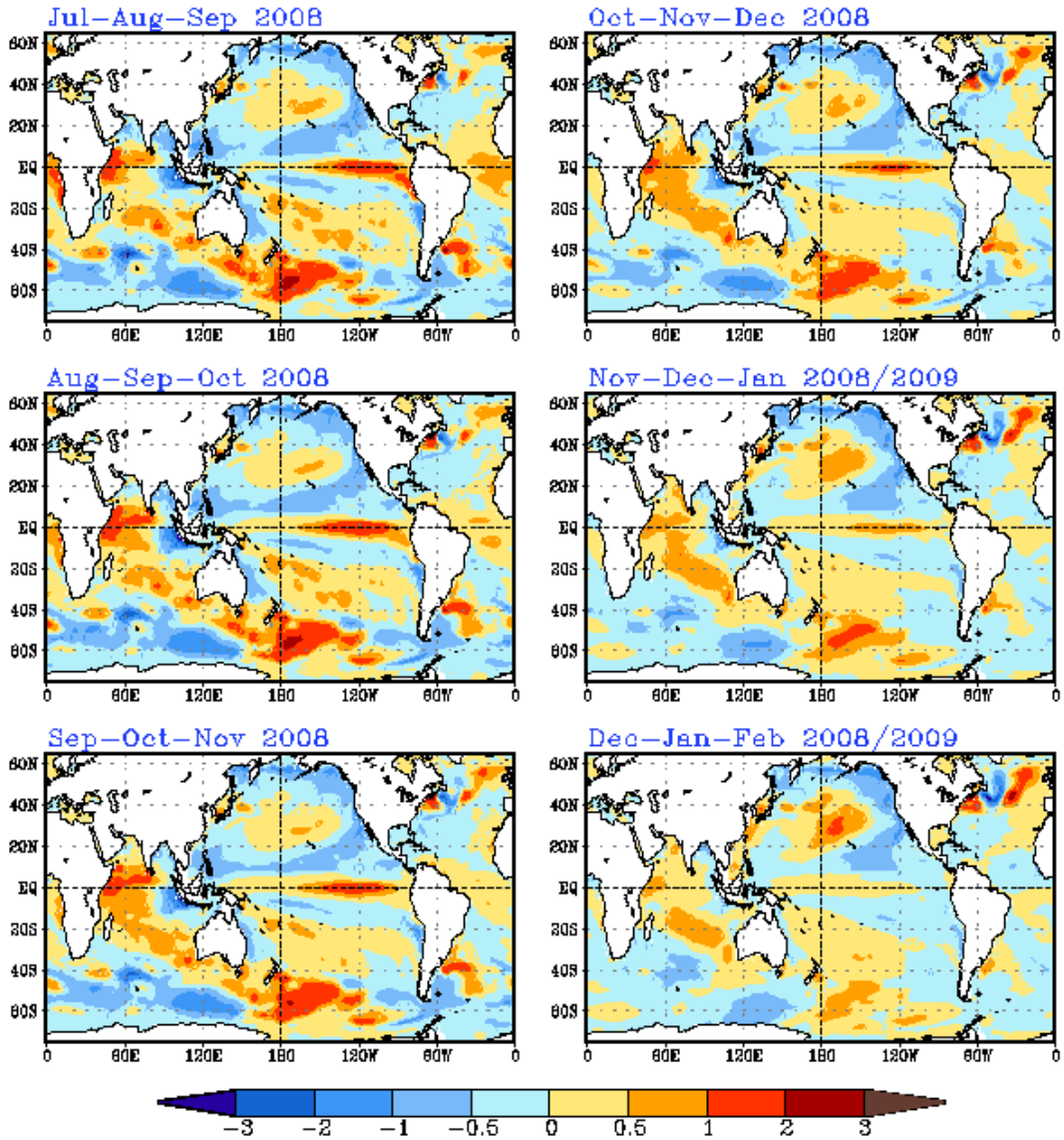


Heat Content Anomaly



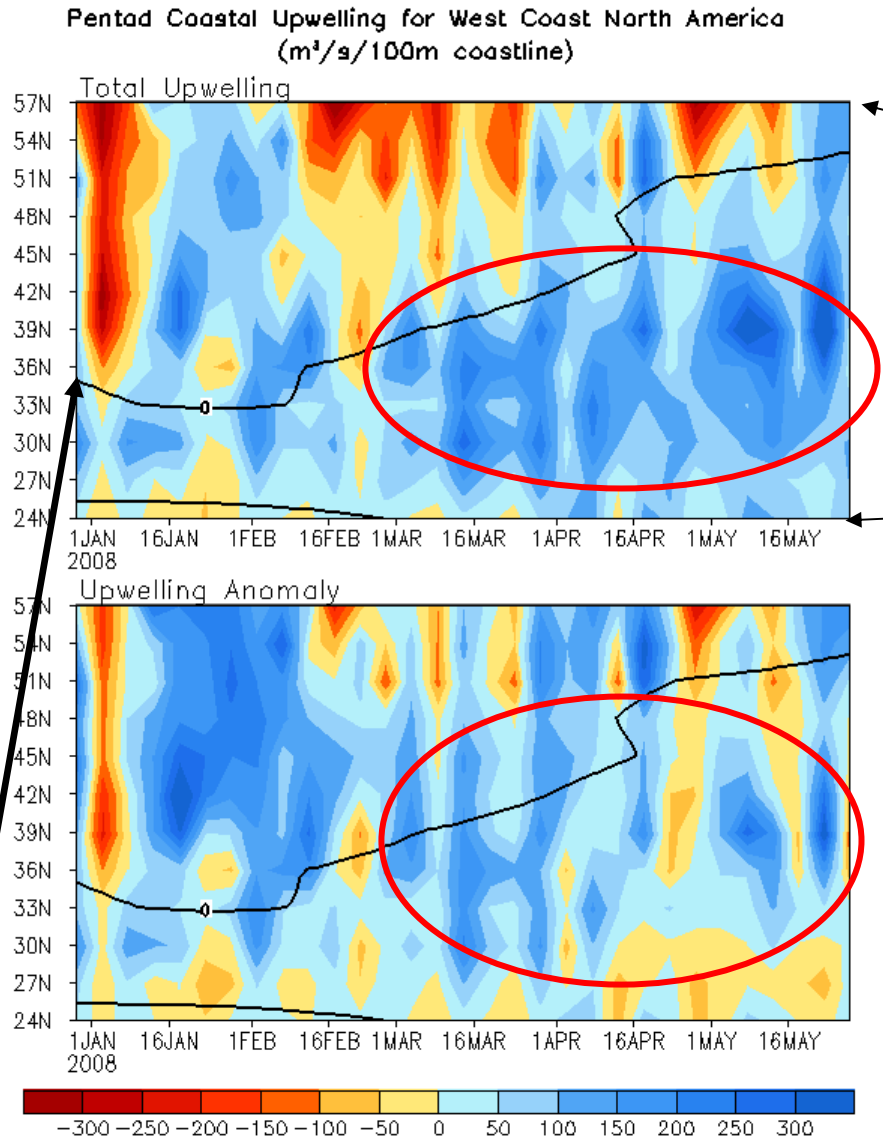
- **Temperature at 55 meter depth have been below-normal (above-normal) along the coast of Alaska and western North America (central North Pacific) since March 07**
- **Temperature along the coast of Alaska and western North America in spring 08 was about 1 degree colder than that in spring 07**
- **Upper 300 meter heat content anomaly has a similar pattern to that of temperature anomaly at 55 meter depth**

CFS SST Prediction from May 08 I.C.

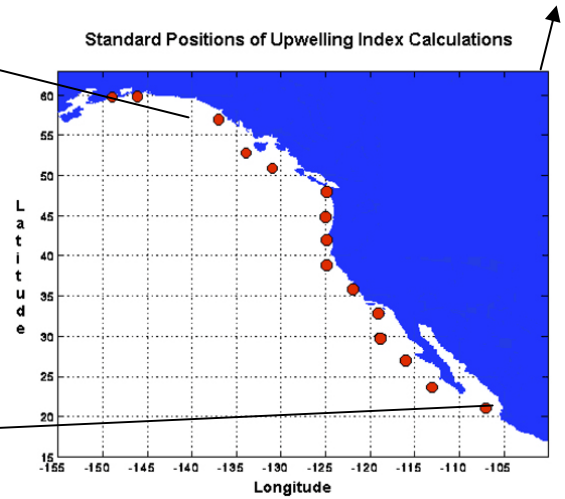


- CFS forecast a weak El Nino in summer 08, but normal conditions in winter 08
- CFS forecast that the cold PDO pattern will persist into fall/winter 08
- CFS forecast a positive Indian Ocean Dipole event in fall 08

North America Western Coastal Upwelling



PFEL, NOAA Fisheries Service



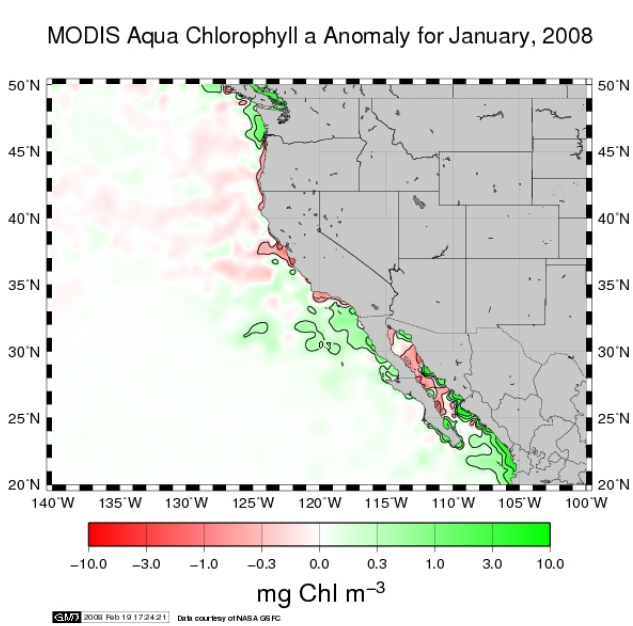
- **Upwelling along the west coast of North America had been strongly above-normal since Feb 08**

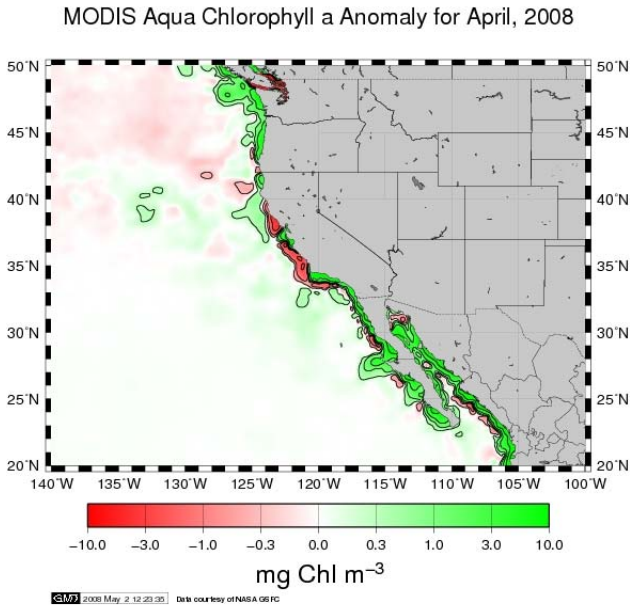
- **A strong upwelling pulse occurred around May 20-24 (see PFEL, NOAA Fisheries Service's web page at http://coastwatch.pfeg.noaa.gov/cgi-bin/elnino.cgi)**

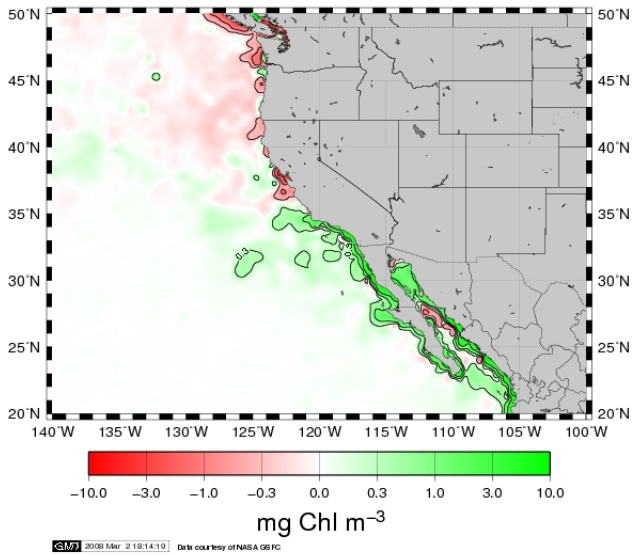
- **Area below (above) black line indicates climatological upwelling (downwelling) season**
- **Climatologically upwelling season progresses from March to July along the west coast of North America from 33°N to 57°N.**

Monthly Chlorophyll Anomaly

http://coastwatch.pfel.noaa.gov/FAST





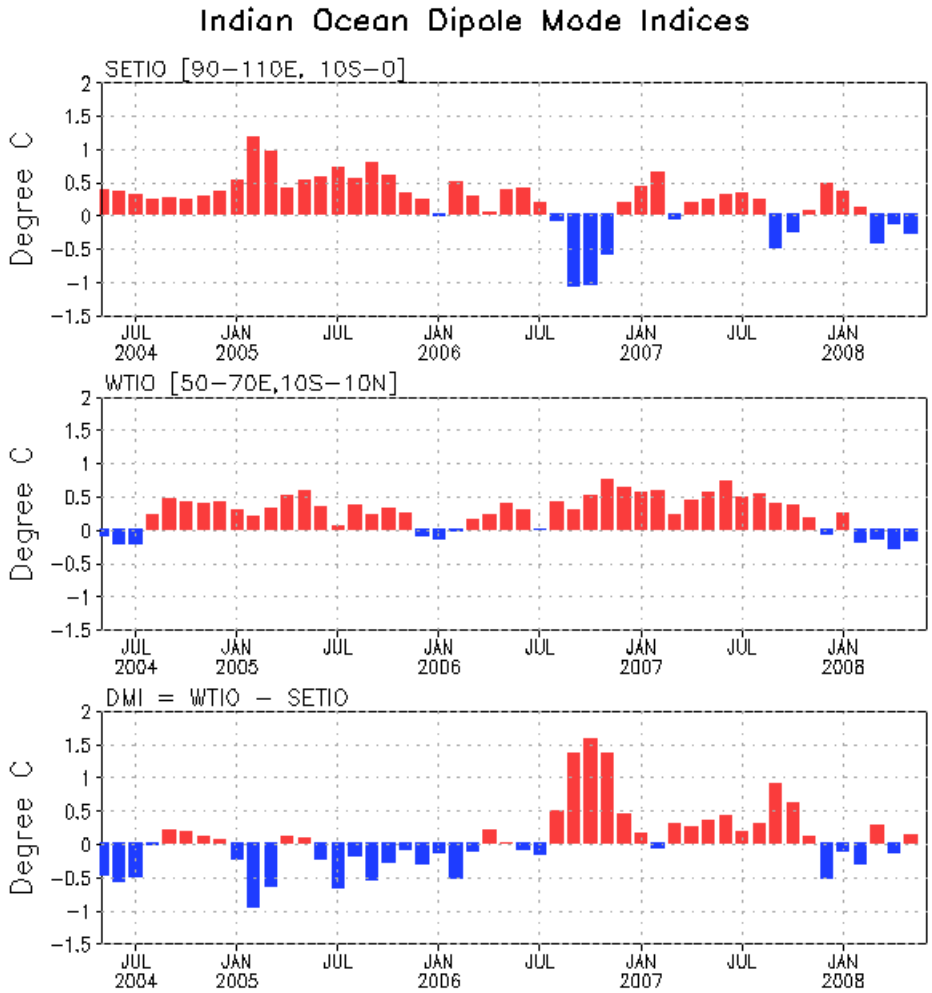


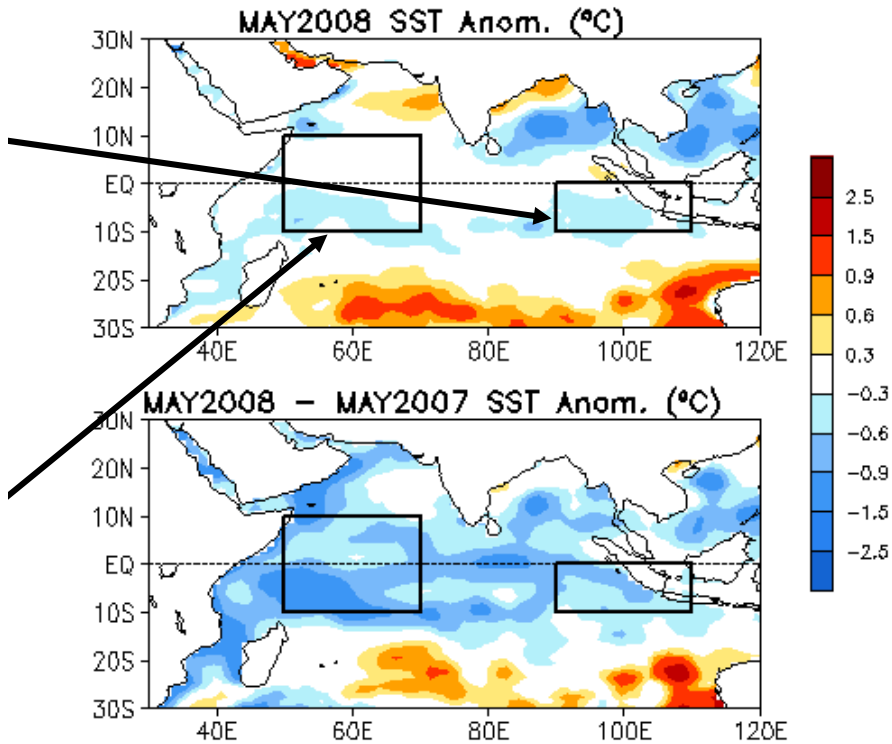
The narrative for regional biological and fisheries conditions can be found in

PFEL, NOAA Fisheries Service's web page at http://coastwatch.pfeg.noaa.gov/cgi-bin/elnino.cgi

Indian Ocean

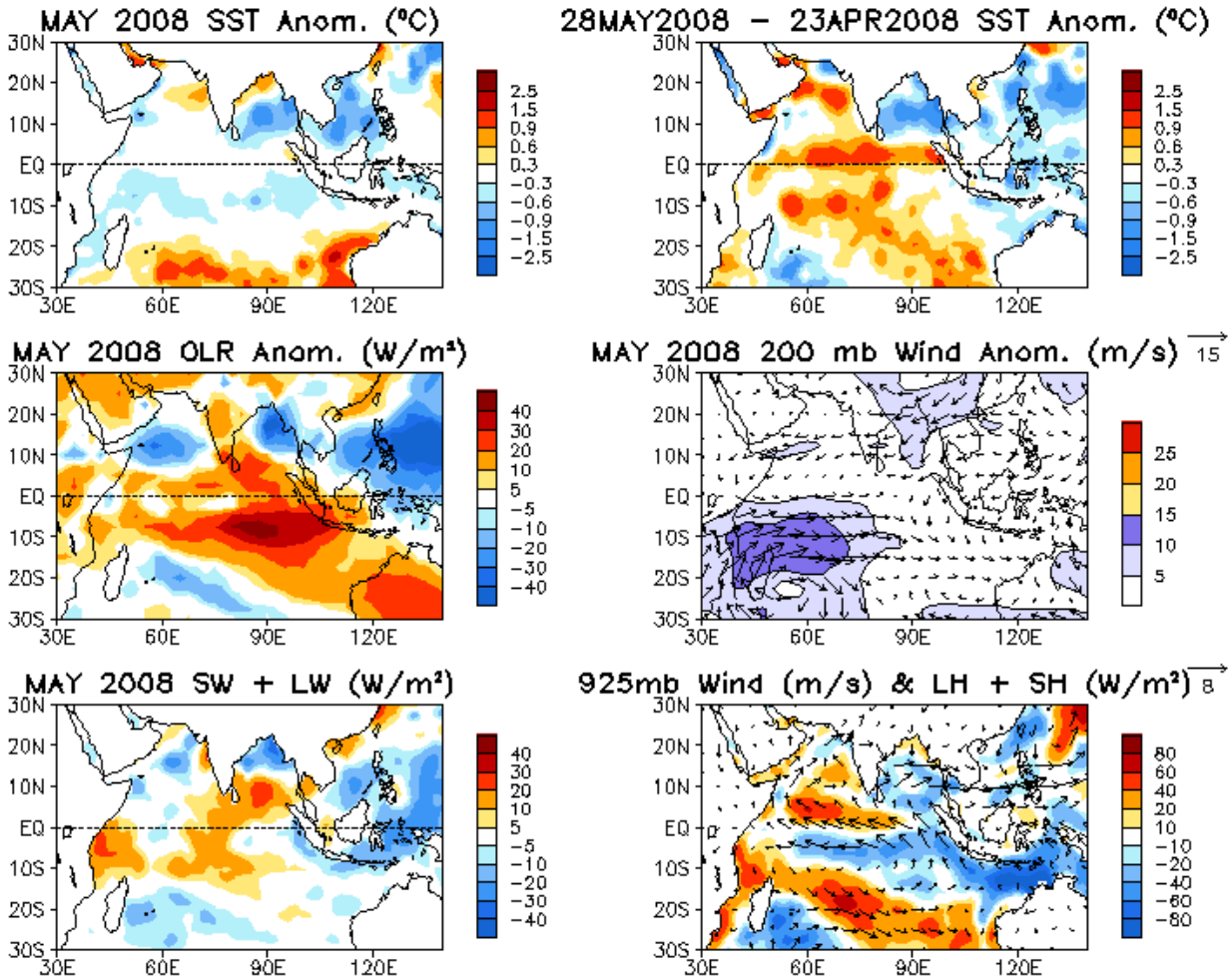
Recent Evolution of Indian Ocean SST Indices





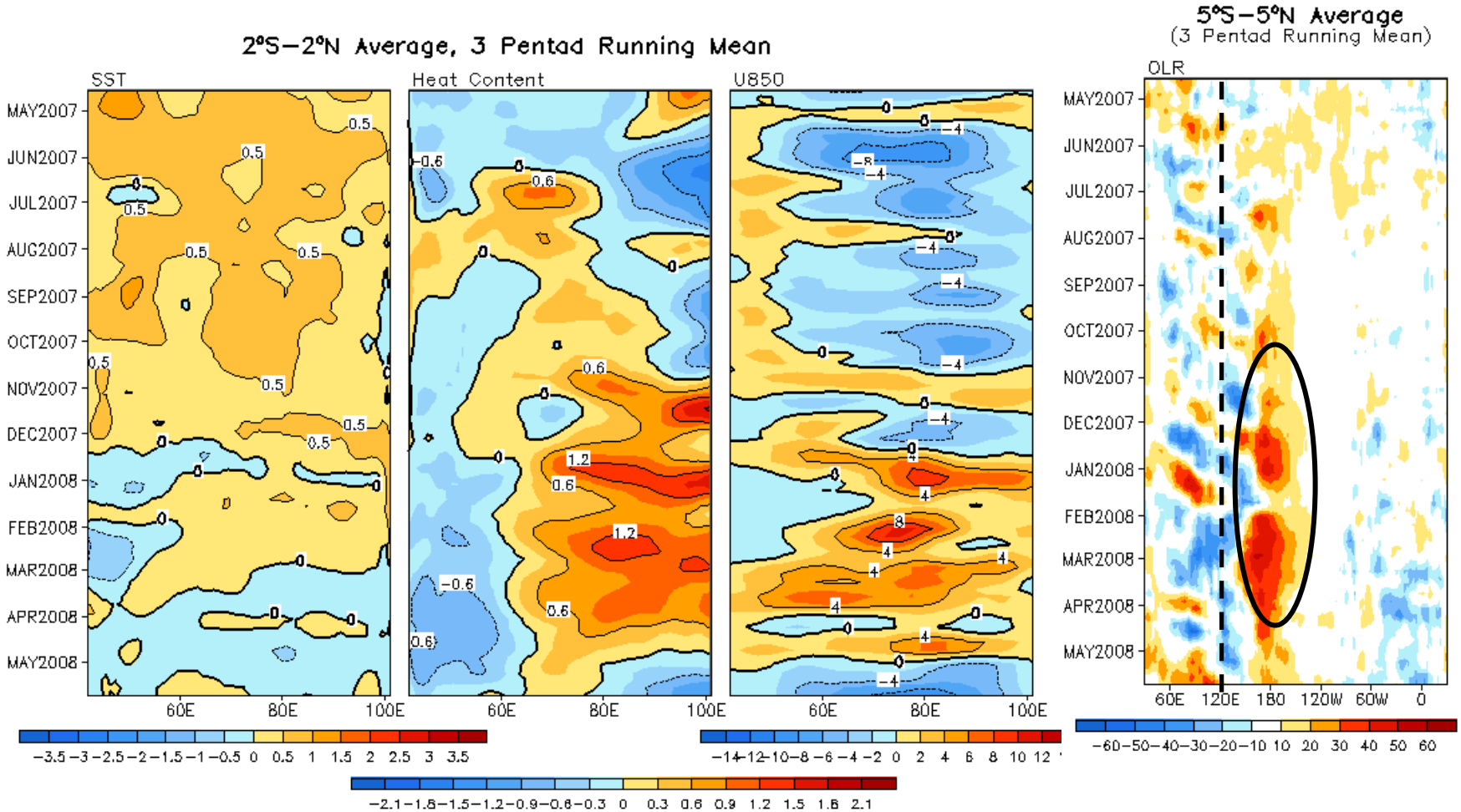
- **Below-normal SST presented in the Bay of Bengal and along 10S in the southern Indian Ocean**
- **Tropical Indian Ocean SST was 0.5-1 degree colder than last year**
- **IO Dipole Mode Index (DMI) was near normal**

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



- **Above-normal rainfall over the Bay of Bengal, South China Sea and Philippine Sea**
- **Easterly wind anomalies in the equatorial belt and southwesterly wind anomalies in Arabian Sea, due to Asian Monsoon onset ?**

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

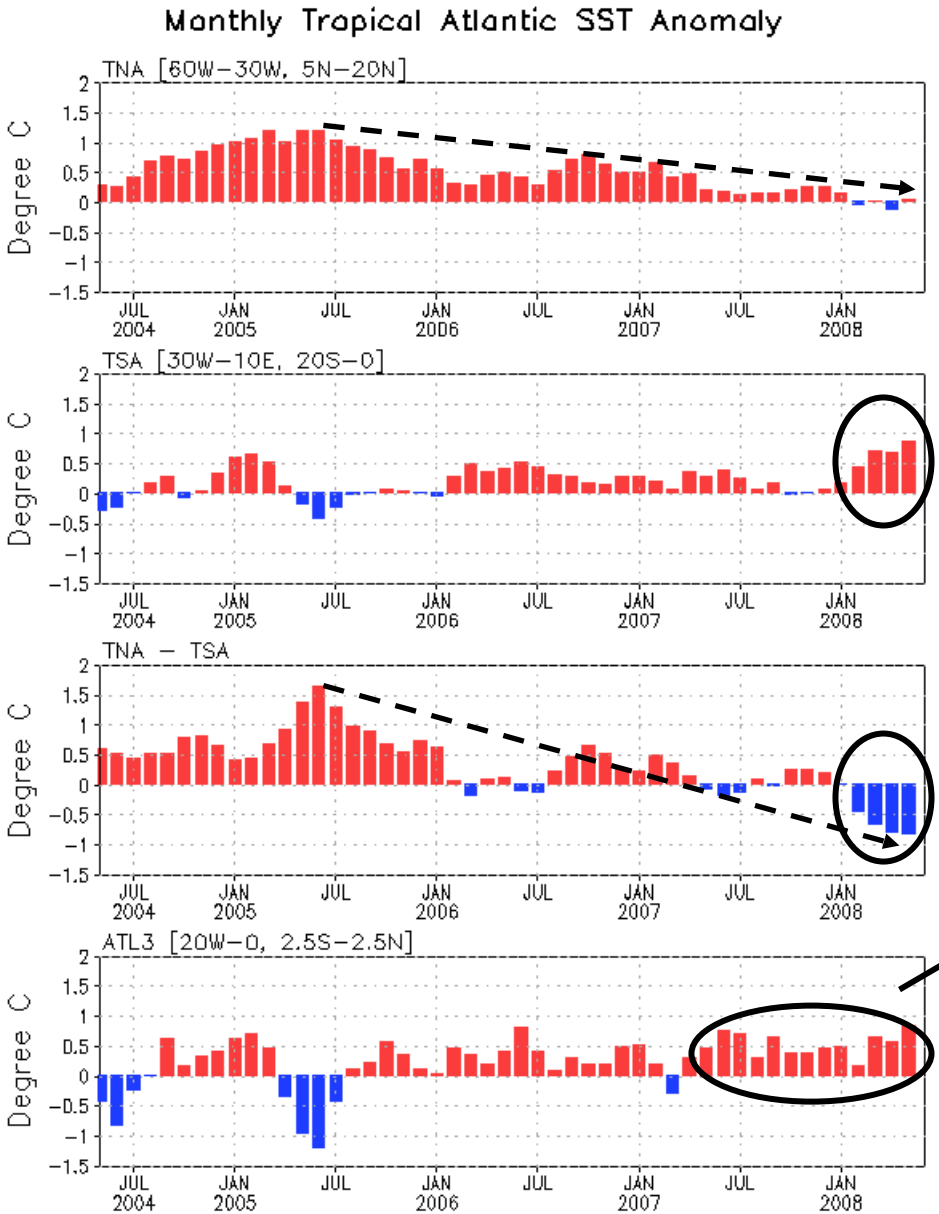


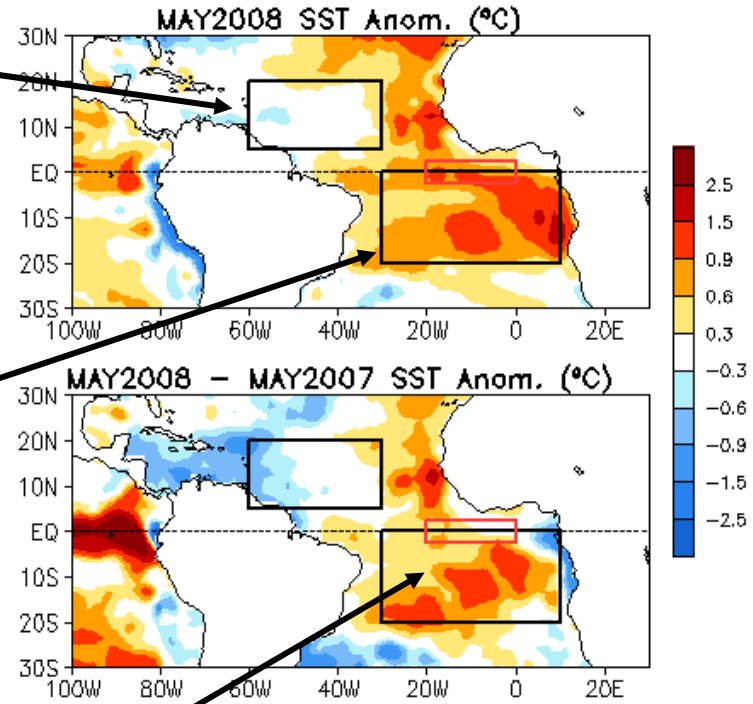
- **Persistent westerly wind anomalies since mid-December were replaced by easterly wind anomalies in May 08, due to Asian Monsoon onset?**

- **Persistent positive heat content anomalies in the eastern tropical Indian Ocean since November were replaced by negative heat content anomalies in May 08 due to the forcing of easterly wind anomalies**

Atlantic Ocean

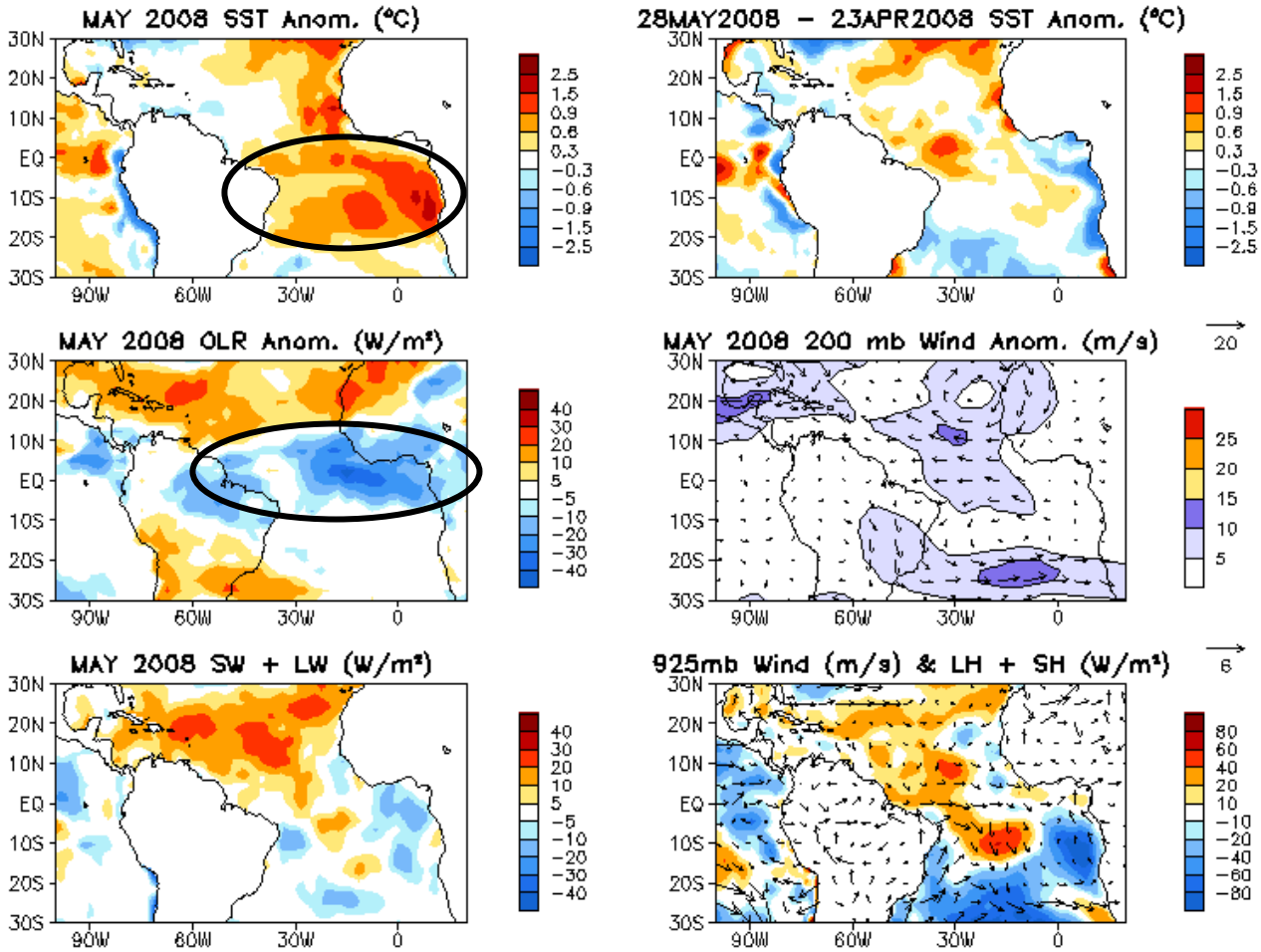
Evolution of Tropical Atlantic SST Indices





- **TNA has been trending downward from about +1C above-normal in summer 2005 to near-normal since January 08**
- **SST in Caribbean Sea and western tropical Atlantic was 0.6 degree colder than last May**
- **TSA was more than 0.5 degree above-normal in Feb-May 08**
- **Meridional SST Gradient Mode (TNA-TSA) has a downward trend since summer 2005 and became below-normal in Feb-May**
- **-- ATL3 has been persistently above-normal since April 08**

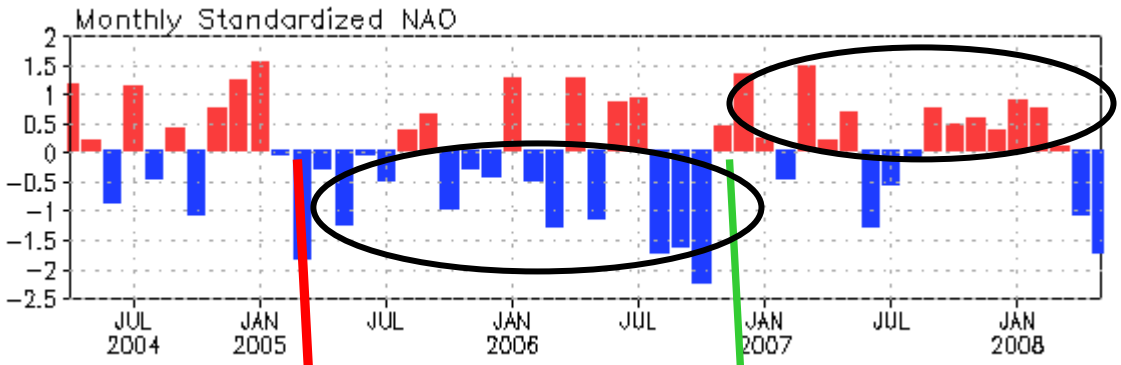
Tropical Atlantic: SST Anom., SST Anom. Tend., OLR, 850-mb Winds, Sfc Rad, Sfc Flx

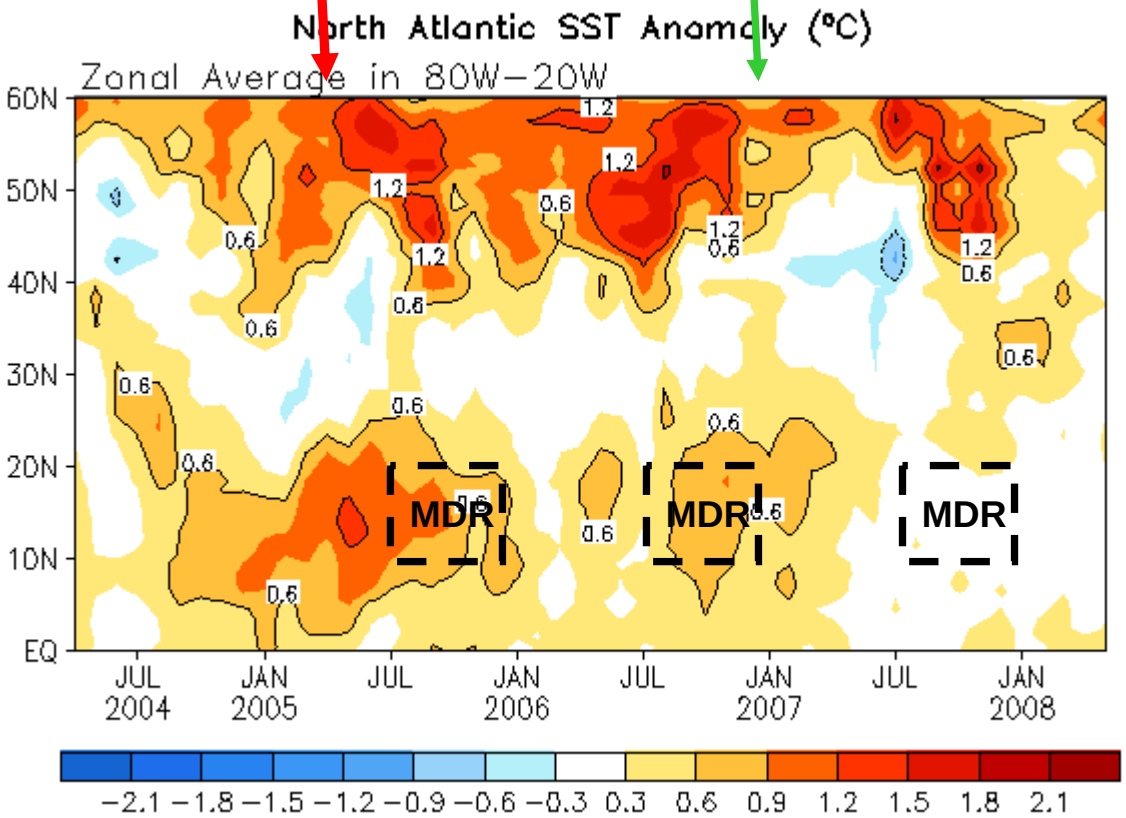


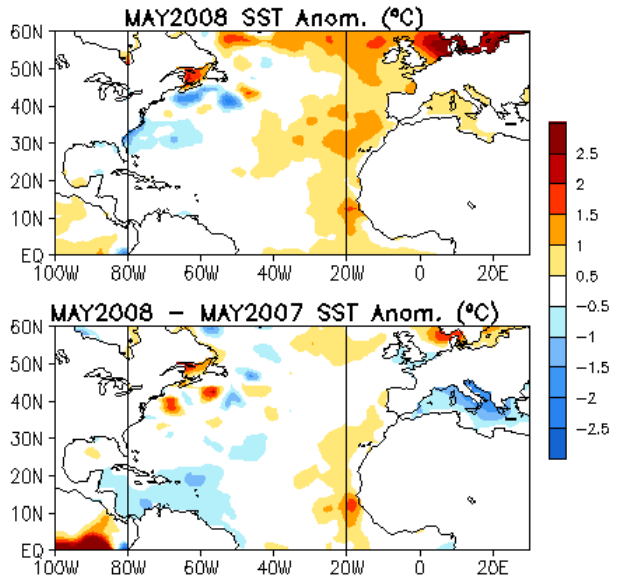
- **Positive (negative) SSTA was present in southern (northern) subtropical Atlantic, generating a negative Meridional SST gradient Mode**

- **Enhanced (suppressed) convection was present over the Gulf of Guinea and Central America (tropical northern Atlantic)**

SST Anomaly in North Atlantic







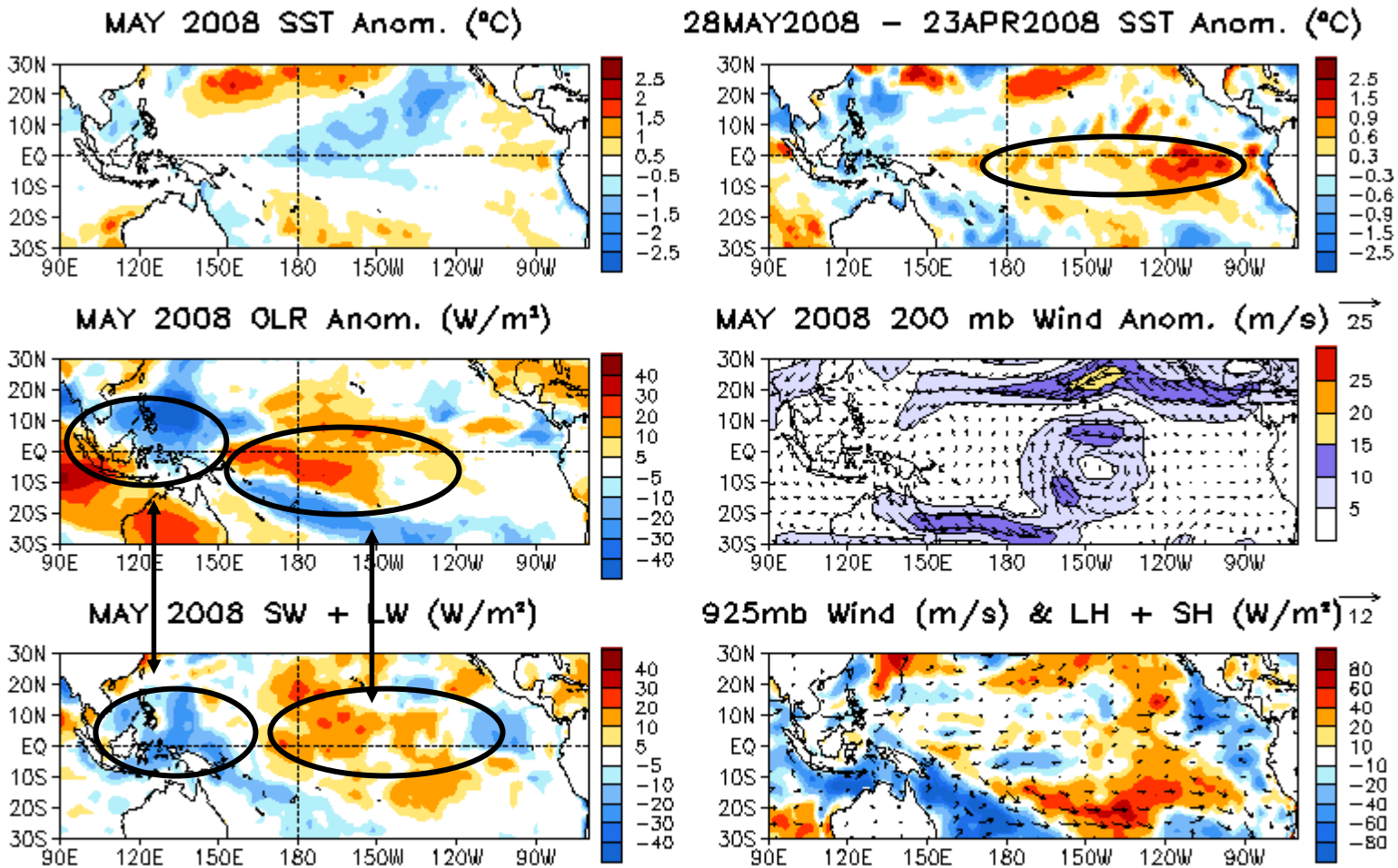
- **SSTA in Atlantic hurricane Main Development Region (MDR) was near normal in summer/fall 2007, much cooler than that of 2006 and 2005**
- **High-latitude North Atlantic SSTA are closely related to NAO index – negative NAO leads to SST warming and positive NAO leads to SST cooling**
- **NAO was mostly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

Summary

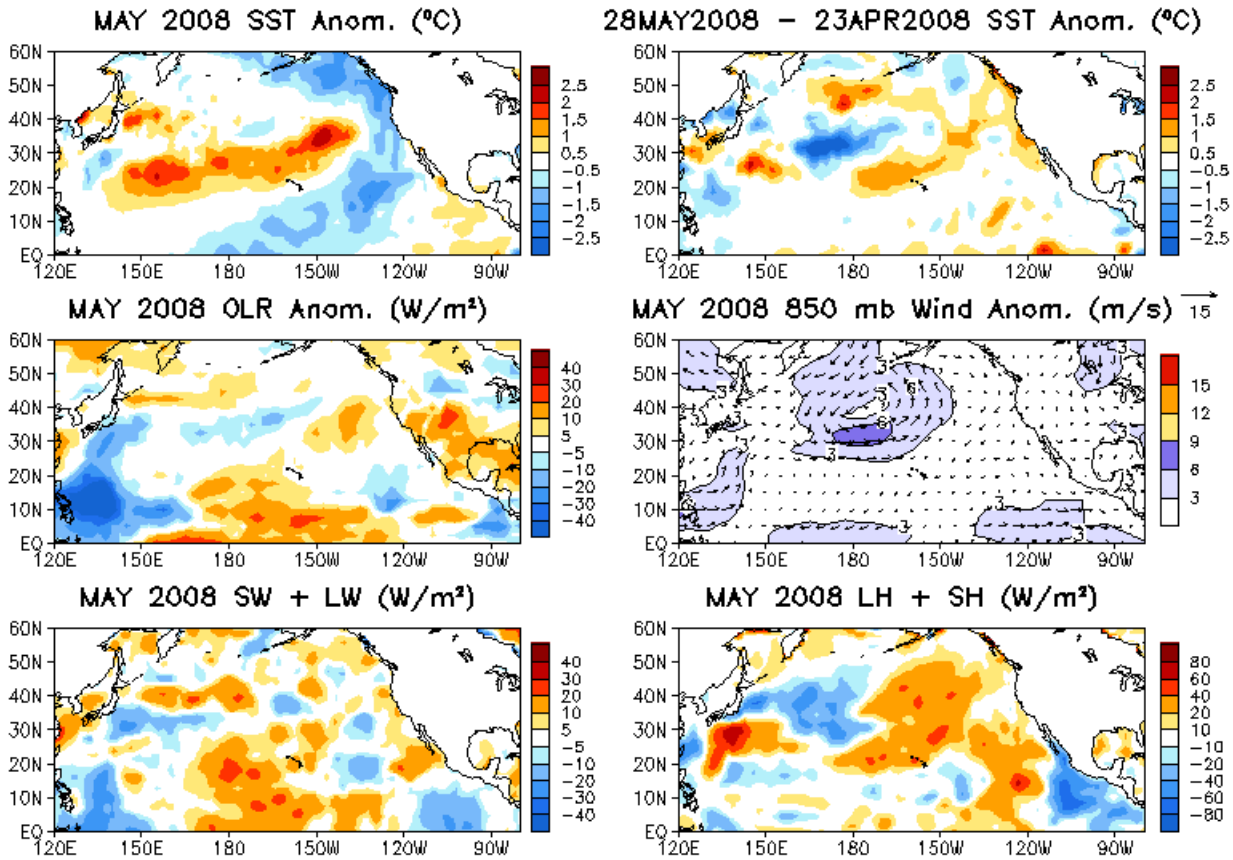
- **Pacific Ocean**
  - La Nina further weakened (NINO3.4 changed from -0.85 C to -0.59C)
  - CPC's prognostic assessment: A transition to ENSO-neutral conditions is expected during June-July 08
  - Positive SSTA in far E. Pacific and westerly wind anomalies east of 150W persisted
  - Negative PDO pattern strengthened (PDO changed from -0.71 in March to -1.52 in April)
  - Above-normal upwelling along the west coast of North America continued
- **Indian Ocean**
  - Below-normal rainfall in tropical Indian Ocean and above-normal rainfall in subtropical northern Indian Ocean
  - Easterly wind anomalies in tropical Indian and westerly wind anomalies in subtropical northern Indian Ocean, due to Asian Monsoon onset ?
- **Atlantic Ocean**
  - Tropical North Atlantic SST (TNA) has a cooling trend since 2005, and became near-normal since January 08
  - Tropical South Atlantic (TSA) SST was more than 0.5 degree above-normal since February 08
  - Negative Meridional SST gradient Mode (TNA – TSA), persisted since February 08, contributed to enhanced convection in tropical Atlantic and suppressed convection in subtropical northern Atlantic

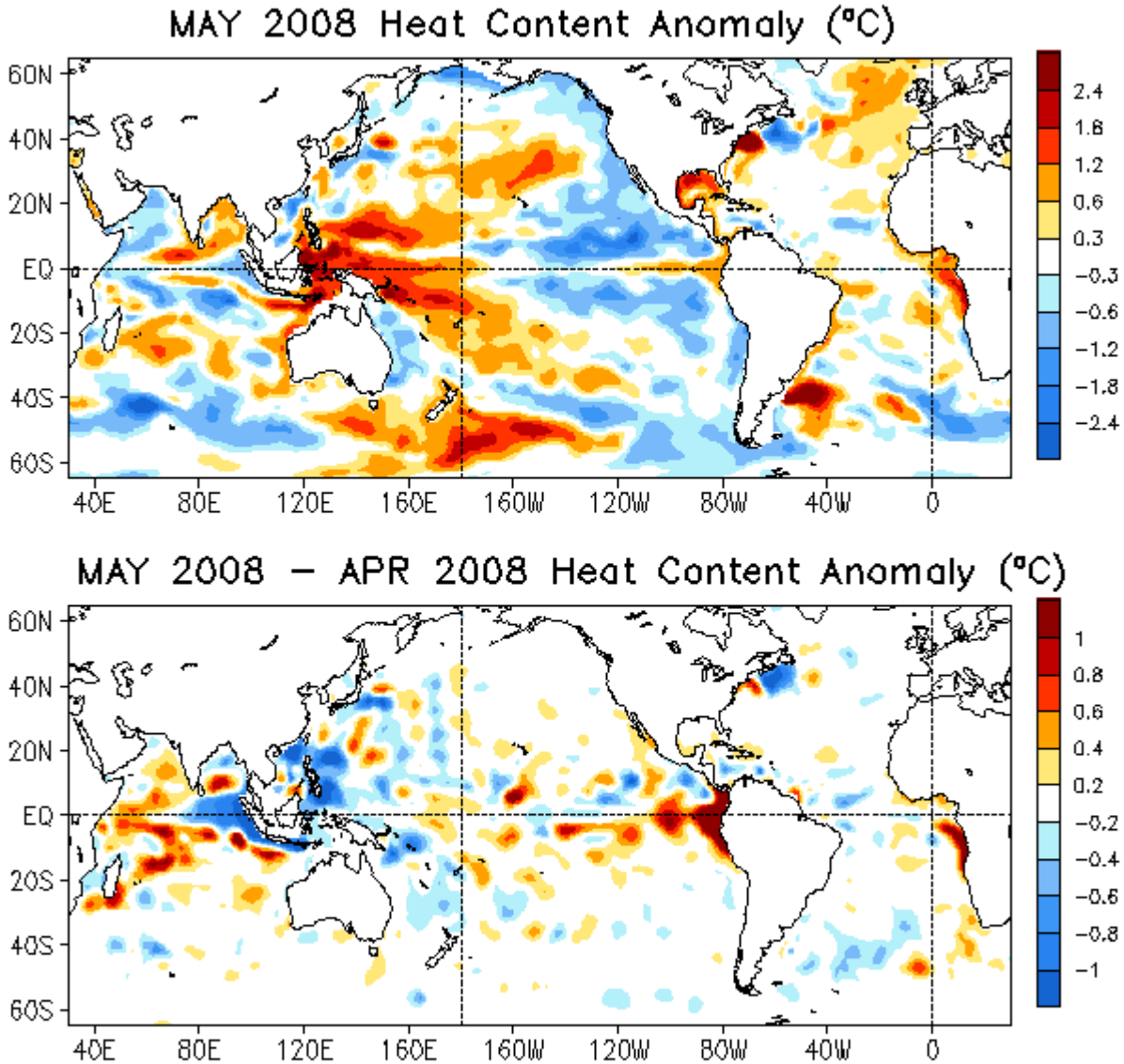
Backup Slides

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



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

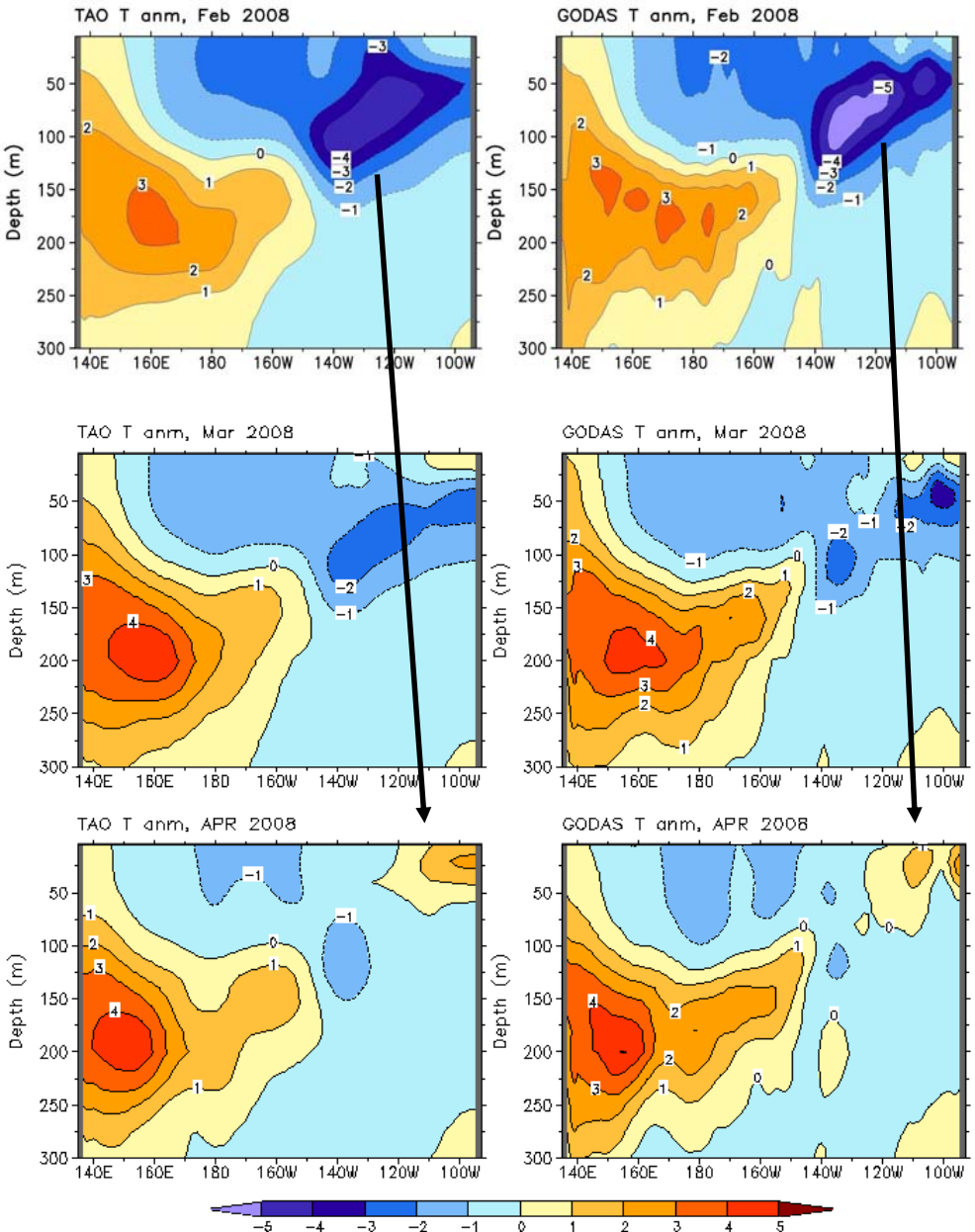



MAY 2008 Heat Content Anomaly (°C)
60N
40N
20N
EQ
20S
40S
60S
40E
80E
120E
160E
160W
120W
80W
40W
0
2.4
1.8
1.2
0.6
0.3
−0.3
−0.6
−1.2
−1.8
−2.4
MAY 2008 − APR 2008 Heat Content Anomaly (°C)
1
0.8
0.6
0.4
0.2
−0.2
−0.4
−0.6
−0.8
−1

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

TAO

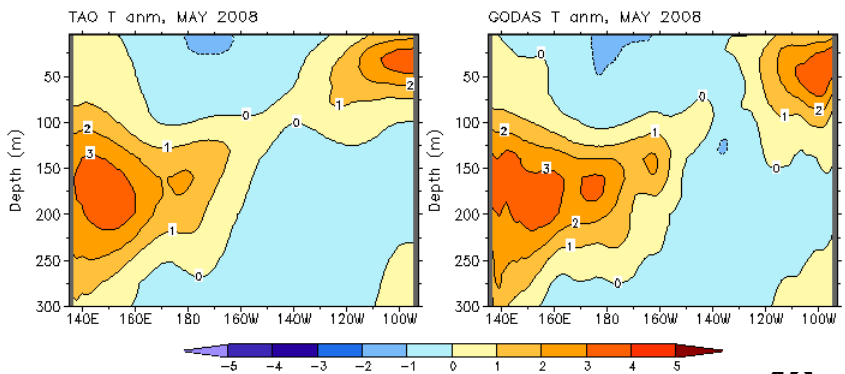
GODAS

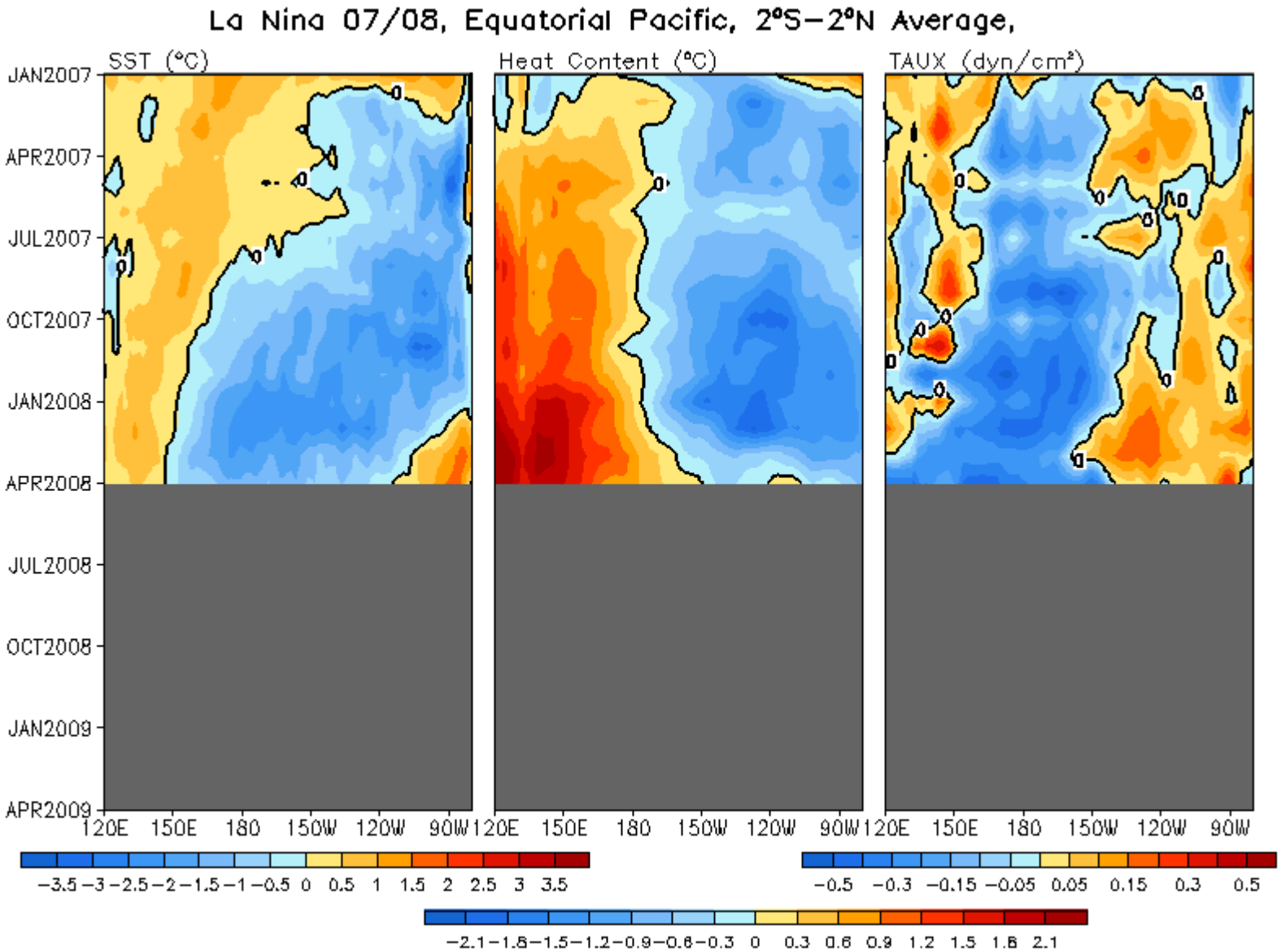


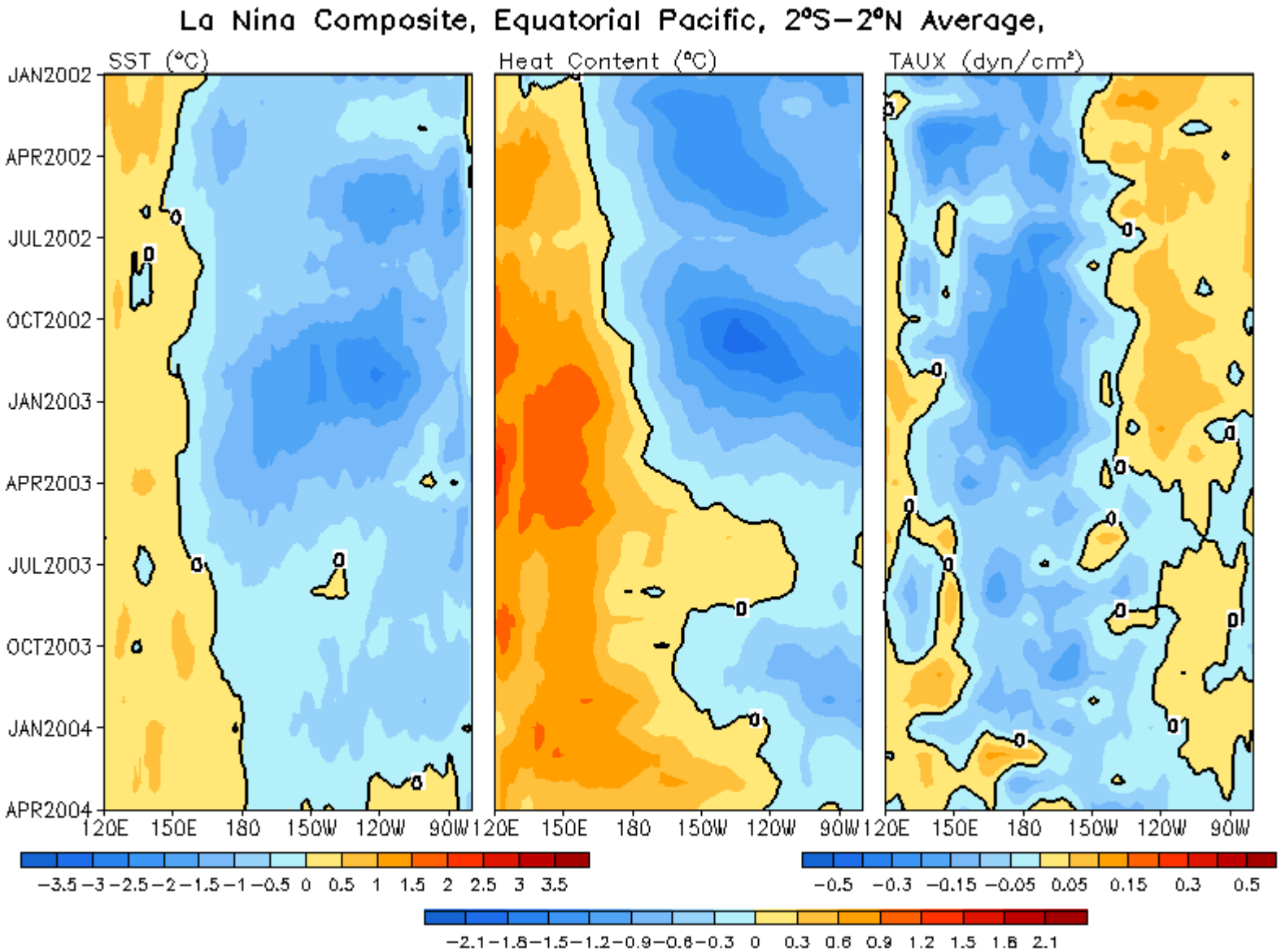
TAO Climatology

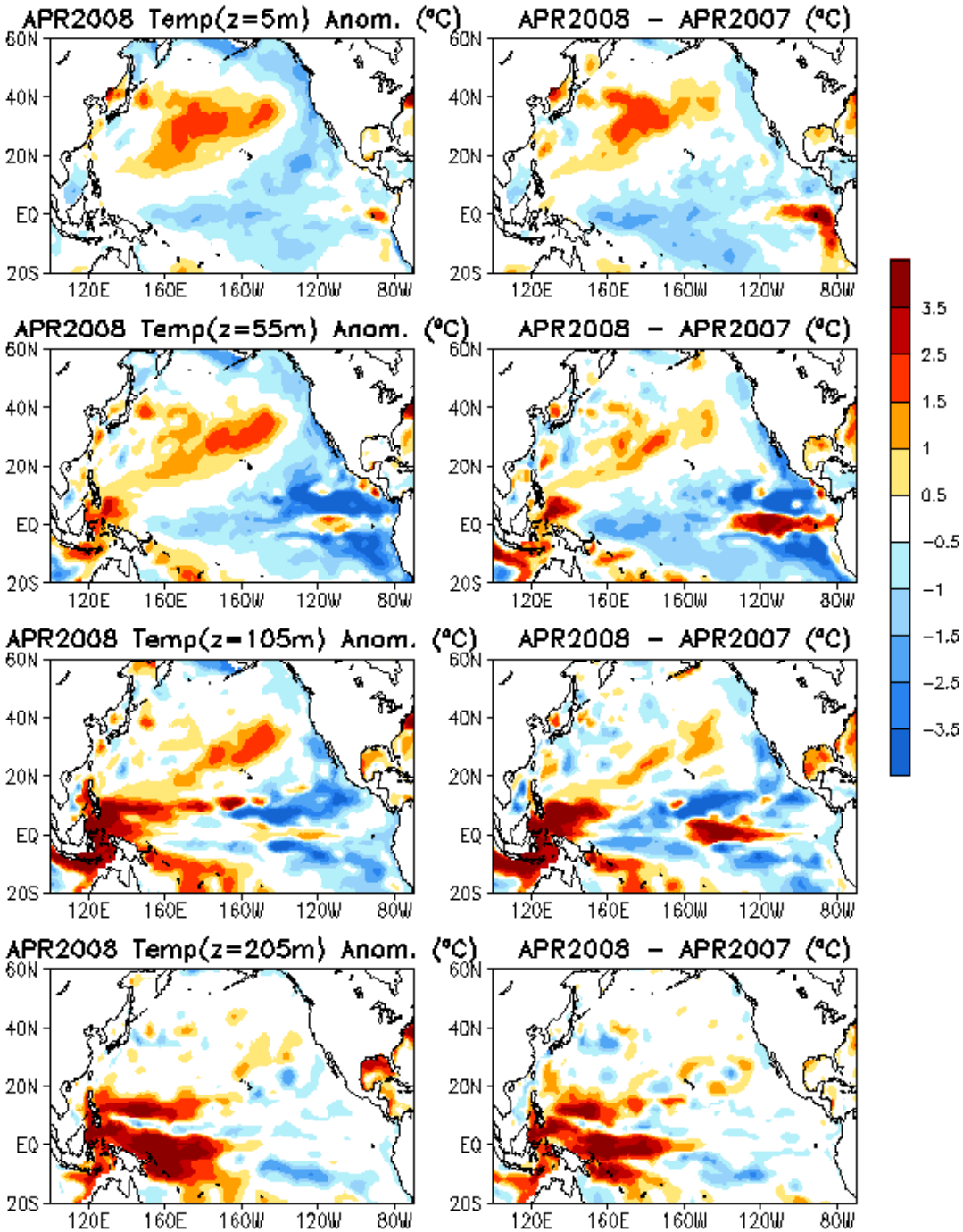
- Negative subsurface temperature anomalies weakened substantially in March 2008 and switched to positive anomalies in the far eastern Pacific in April 2008

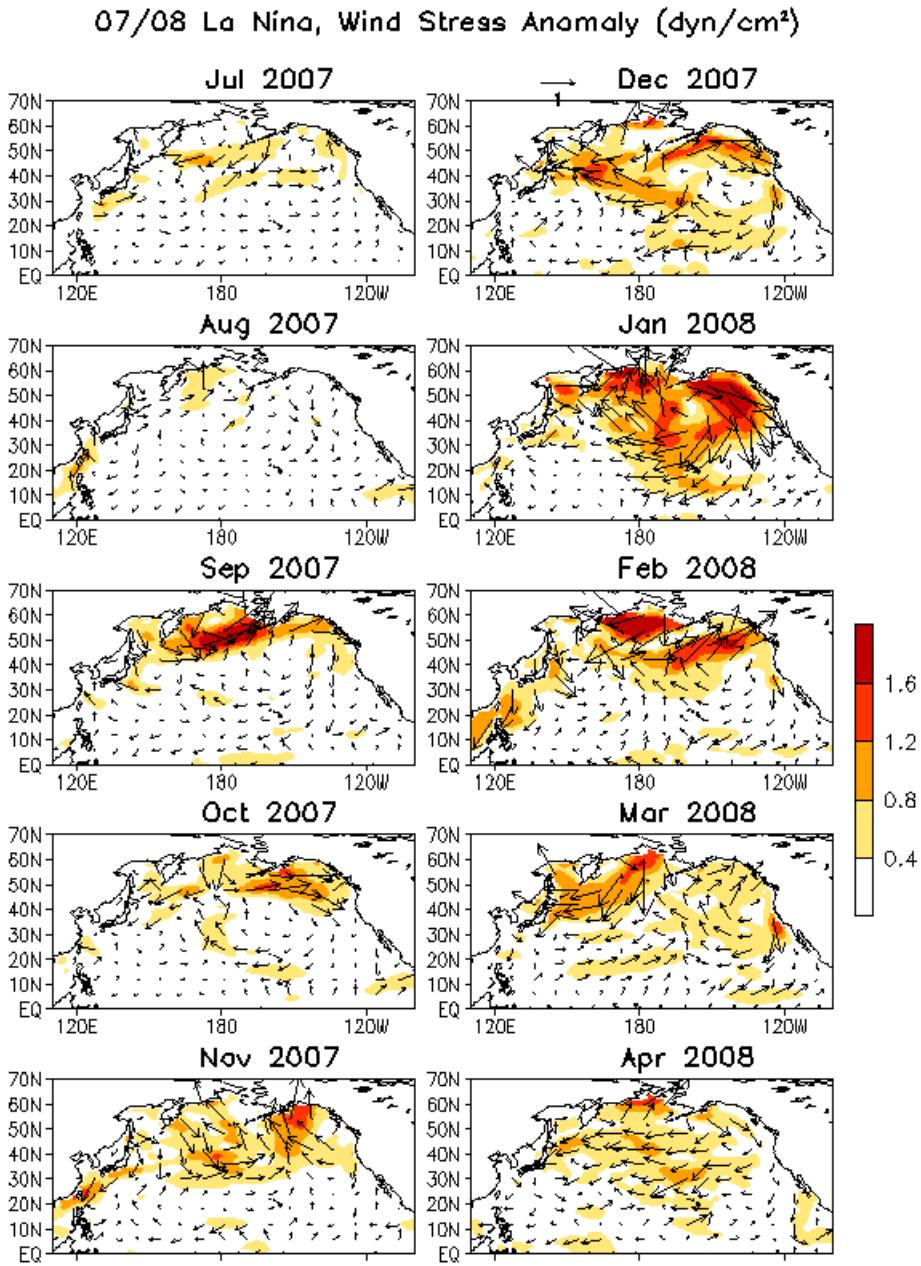
- GODAS temperature was about 1C too cold at 25 meter depth near 105W, and about 1C too warm in the central Pacific near the thermocline (not shown)




La Nina 07/08, Equatorial Pacific, 2°S–2°N Average,
SST (°C)
Heat Content (°C)
TAUX (dyn/cm²)
JAN2007
APR2007
JUL2007
OCT2007
JAN2008
APR2008
JUL2008
OCT2008
JAN2009
APR2009
120E 150E 180 150W 120W 90W
−3.5 −3 −2.5 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 2.5 3 3.5
−0.5 −0.3 −0.15 −0.05 0.05 0.15 0.3 0.5
−2.1 −1.8 −1.5 −1.2 −0.9 −0.6 −0.3 0 0.3 0.6 0.9 1.2 1.5 1.8 2.1


La Nina Composite, Equatorial Pacific, 2°S–2°N Average,
SST (°C)
Heat Content (°C)
TAUX (dyn/cm²)
JAN2002
APR2002
JUL2002
OCT2002
JAN2003
APR2003
JUL2003
OCT2003
JAN2004
APR2004
120E 150E 180 150W 120W 90W
−3.5 −3 −2.5 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 2.5 3 3.5
−0.5 −0.3 −0.15 −0.05 0.05 0.15 0.3 0.5
−2.1 −1.8 −1.5 −1.2 −0.9 −0.6 −0.3 0 0.3 0.6 0.9 1.2 1.5 1.8 2.1


APR2008 Temp(z=5m) Anom. (°C)
APR2008 – APR2007 (°C)
APR2008 Temp(z=55m) Anom. (°C)
APR2008 – APR2007 (°C)
APR2008 Temp(z=105m) Anom. (°C)
APR2008 – APR2007 (°C)
APR2008 Temp(z=205m) Anom. (°C)
APR2008 – APR2007 (°C)
60N
40N
20N
EQ
20S
120E
160E
160W
120W
80W
3.5
2.5
1.5
1
0.5
−0.5
−1
−1.5
−2.5
−3.5


07/08 La Nina, Wind Stress Anomaly (dyn/cm²)
Jul 2007
Dec 2007
Aug 2007
Jan 2008
Sep 2007
Feb 2008
Oct 2007
Mar 2008
Nov 2007
Apr 2008
70N
60N
50N
40N
30N
20N
10N
EQ
120E
180
120W
1
1.6
1.2
0.8
0.4

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)