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

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

This project to deliver real-time ocean monitoring products is implemented by CPC in cooperation with NOAA's Office of Climate Observation (OCO)

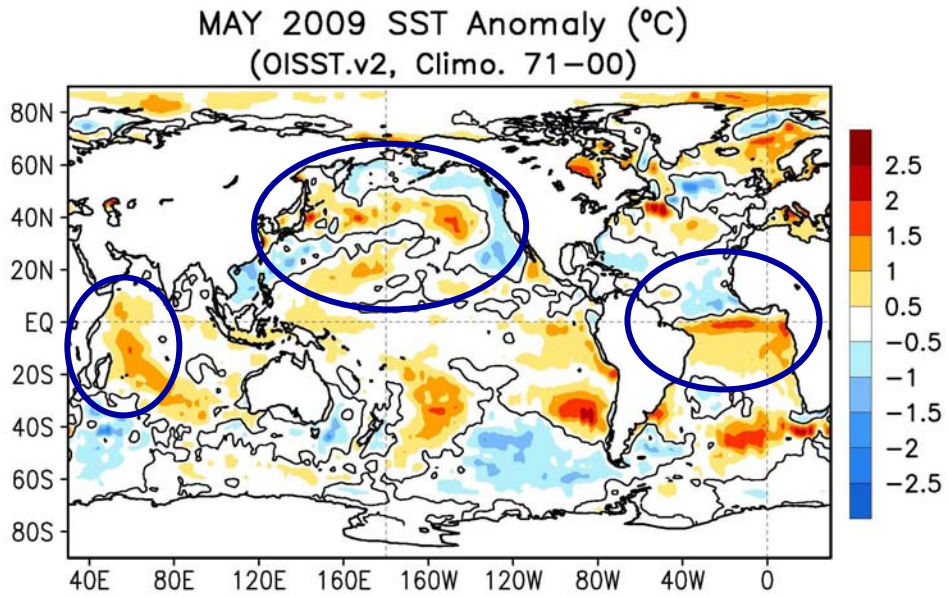
Outline

- **Overview**
- **Recent highlights**
  - **Pacific/Arctic Ocean**
  - **Indian Ocean**
  - **Atlantic Ocean**
- **CFS SST Predictions**

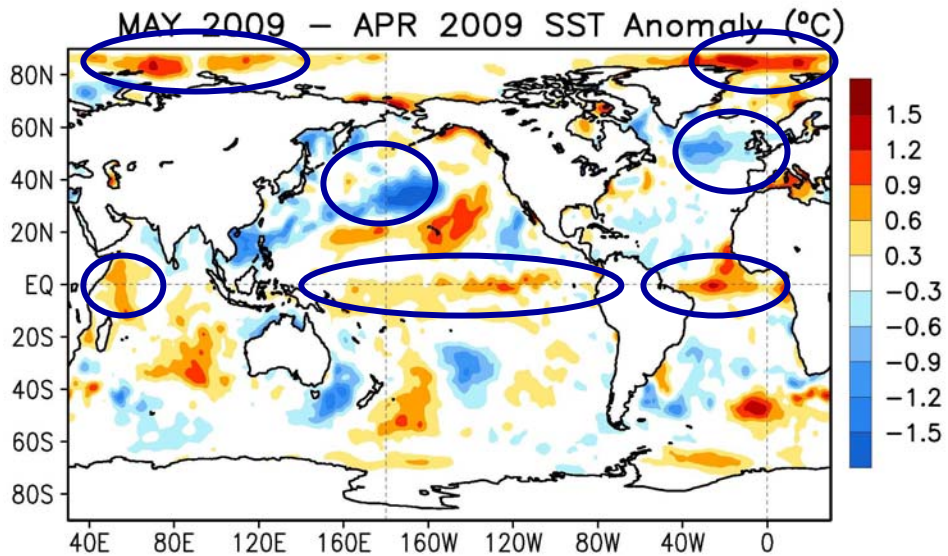
Overview

- **Pacific Ocean**
  - Surface and subsurface temperature has warmed up steadily since March 09, and the recent trends are favorable for a transition from ENSO-neutral to El Niño conditions during next 3 months.
  - Negative PDO phase since September 2007 has persisted for 21 months now, and 2008 has the lowest yearly mean PDO index since 1971.
- **Indian Ocean**
  - Since mid-March 09, zonal wind anomalies were persistently easterly and SST was persistently 0.5C above-normal.
  - The western tropical Indian Ocean SST went up to about 1C above-normal in May 09 - the western pole of DMI was 1C above-normal.
- **Atlantic Ocean**
  - Tropical North Atlantic SST (TNA) continued a downward trend, and was slightly below-normal in May 09. Tropical South Atlantic SST (TSA) continued a upward trend, and was about 1C above-normal.
  - ITCZ was shifted southward in responding to the negative Meridional Gradient Mode (TNA-TSA).
- **Arctic Ocean**
  - Sea ice extent decreased rapidly in May and was close to the 2007 historical low by the end of May 09.

Global SST Anomaly (ºC) and Anomaly Tendency



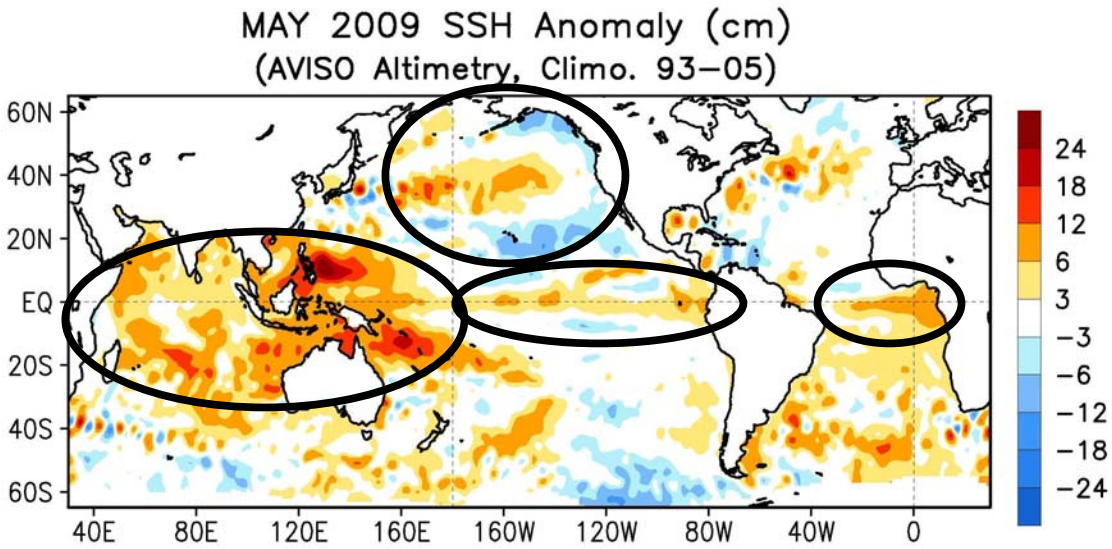
- Negative PDO-like SST pattern in North Pacific persisted.
- ENSO-neutral conditions continued in the tropical Pacific.
- Positive SSTA presented in the western tropical and central subtropical Indian Ocean.
- Negative meridional gradient of SSTA presented in the tropical Atlantic.

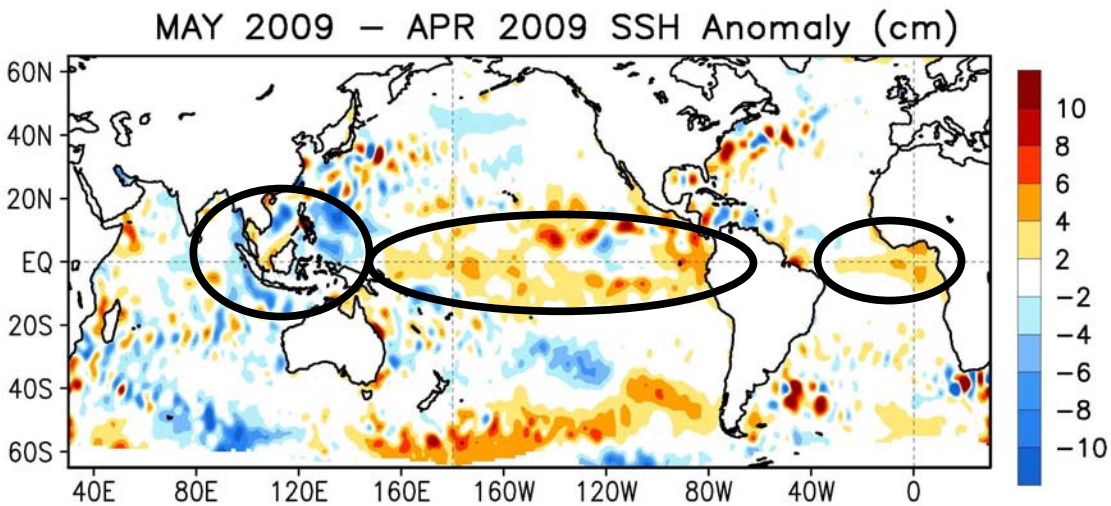


- SSTA increased in the equatorial Pacific, equatorial Atlantic, western tropical Indian Ocean and Arctic Ocean.
- SSTA decreased in the central North Pacific and high-latitude North Atlantic.

Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Global SSH Anomaly (cm) and Anomaly Tendency



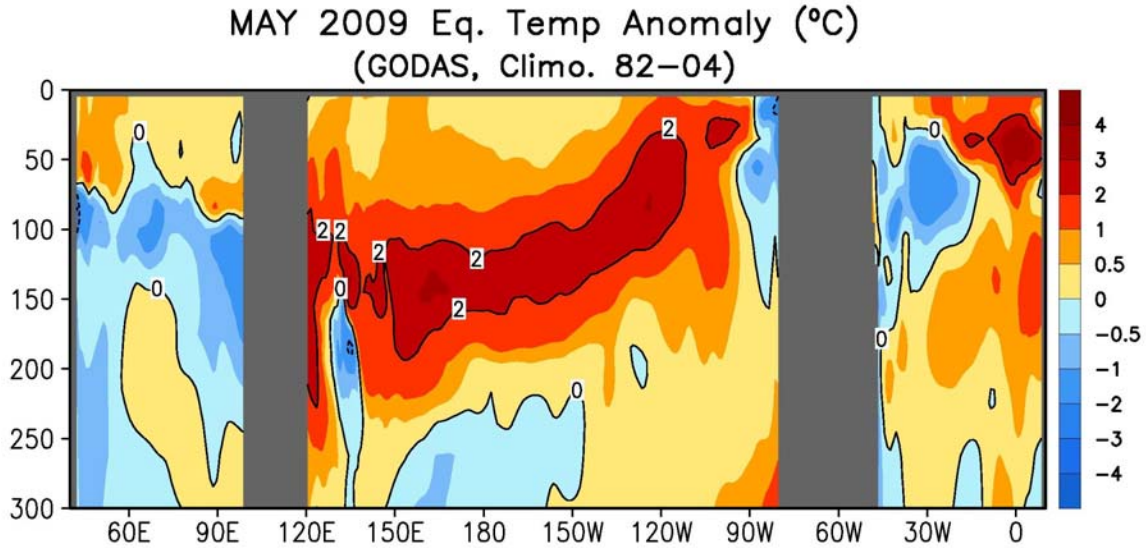


- **Negative PDO-like SSHA in the North Pacific, consistent with the negative PDO-like SSTA.**
- **Weak positive SSHA in the equatorial Pacific was consistent with ENSO-neutral conditions.**
- **Positive SSHA presented in most of the Indian Ocean and western Pacific.**
- **Positive SSHA presented in the central-eastern tropical Atlantic.**

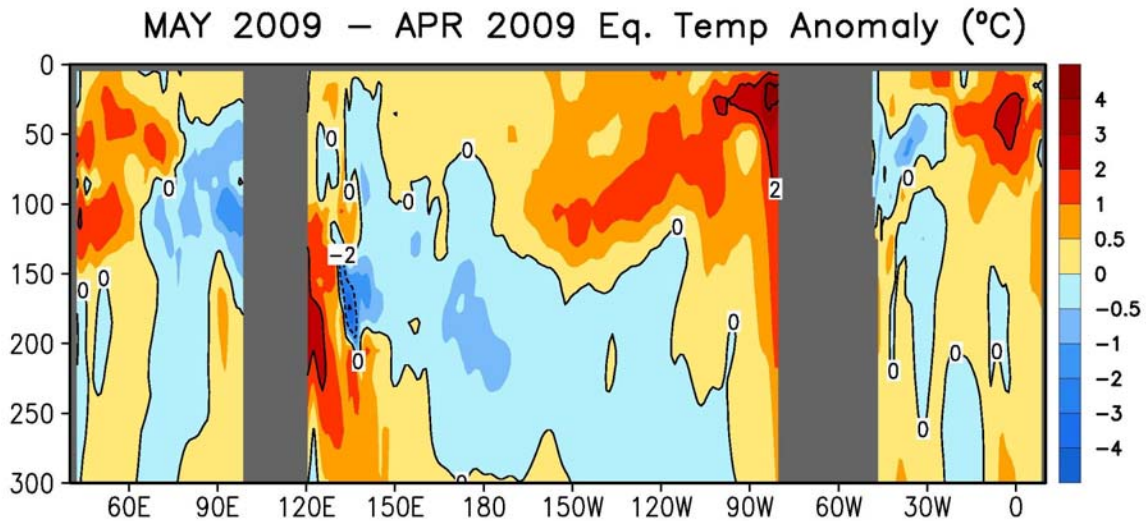
- **Positive SSHA tendency in the equatorial Pacific was consistent with SSTA tendency there.**
- **Positive SSH tendency in the equatorial Atlantic was consistent with SSTA tendency there.**
- **Negative SSHA tendency presented near the Maritime Continent.**

Fig. G2. Sea surface height anomalies (top) and anomaly tendency (bottom). Data are derived from http://www.aviso.oceanobs.com . Anomalies are departures from the 1993-2005 base period means.

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



- **Positive subsurface temperature anomalies about 2°C presented near the thermocline in the equatorial Pacific and Atlantic.**

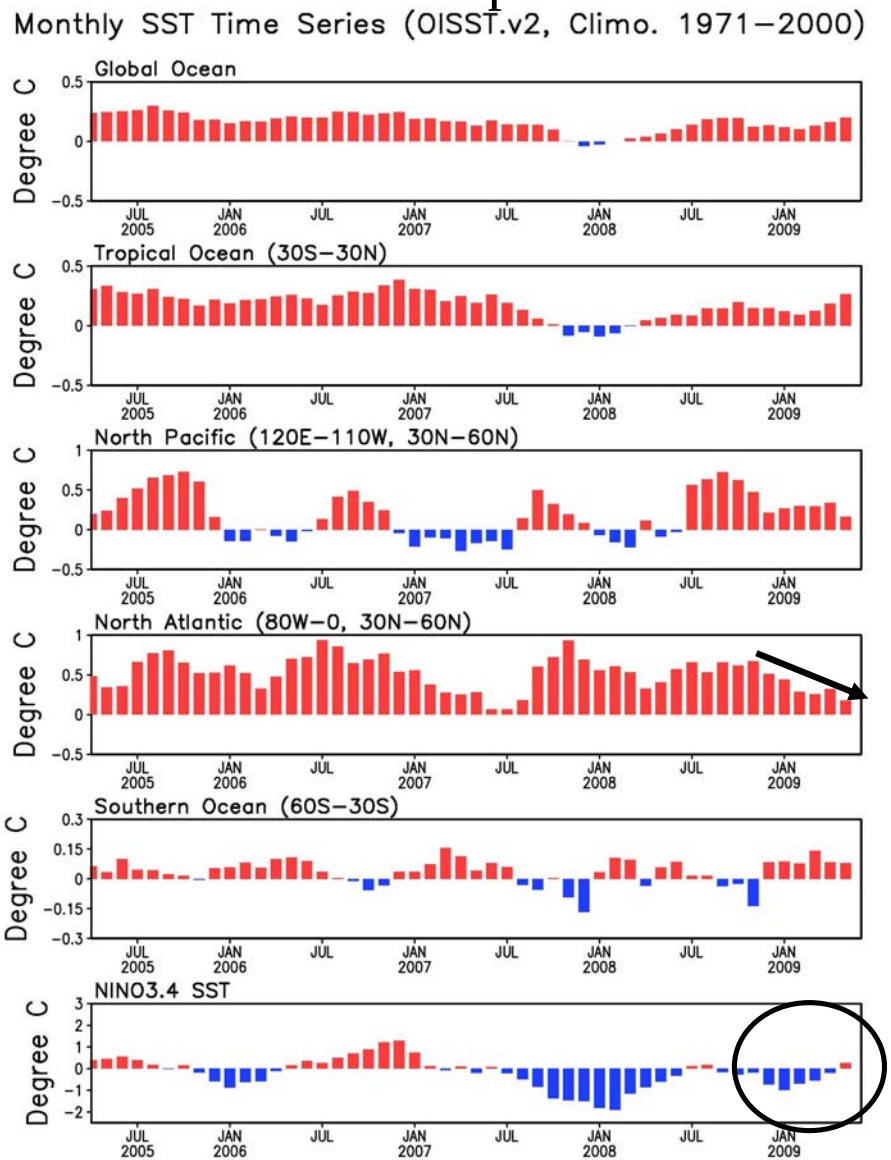


- **Strong positive subsurface temperature tendency (> 1°C) presented in the central-eastern Pacific, western Indian Ocean and eastern Atlantic.**

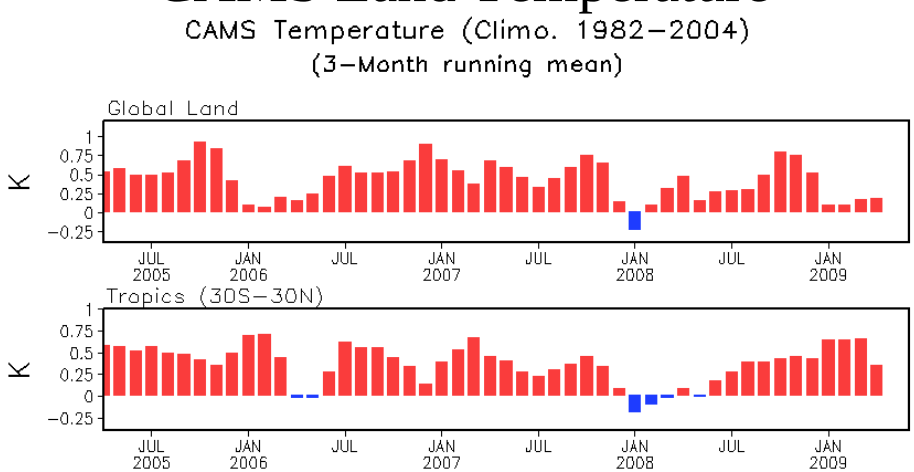
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1982-2004 base period means.

Monthly Time Series

Sea Surface Temperature



CAMS Land Temperature

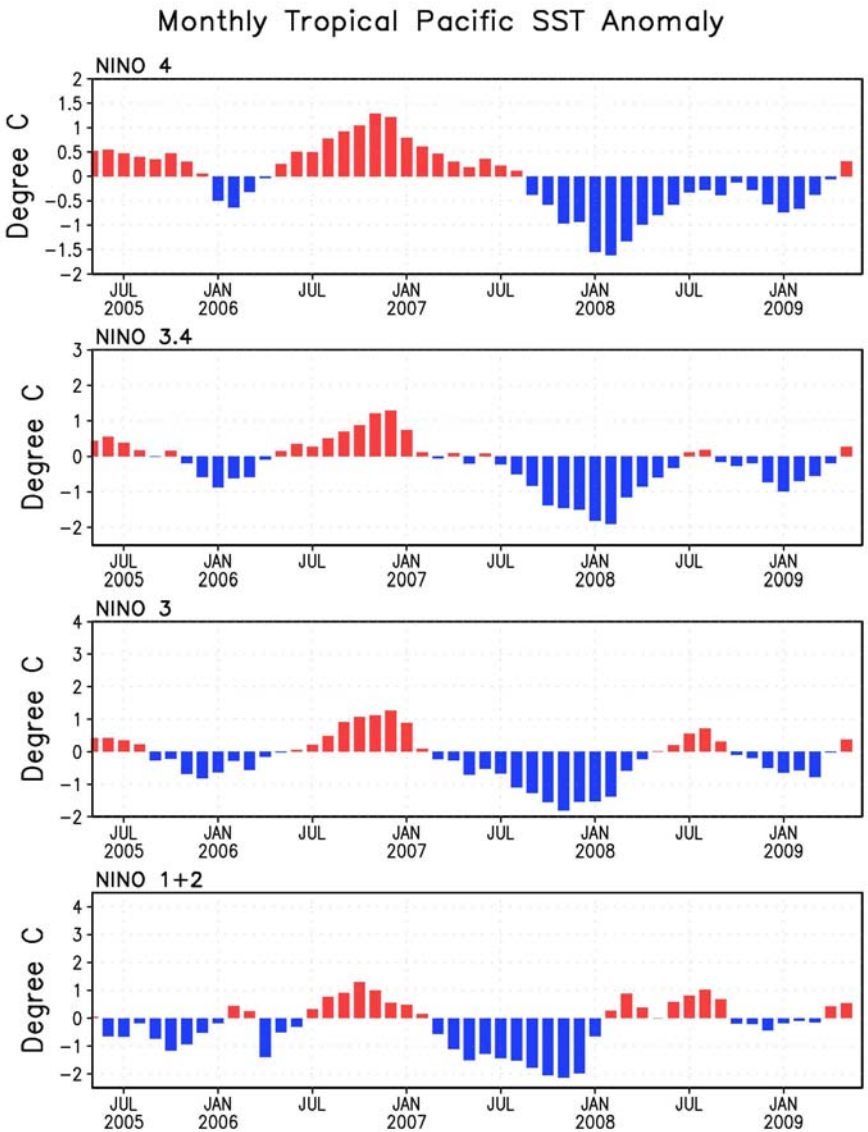


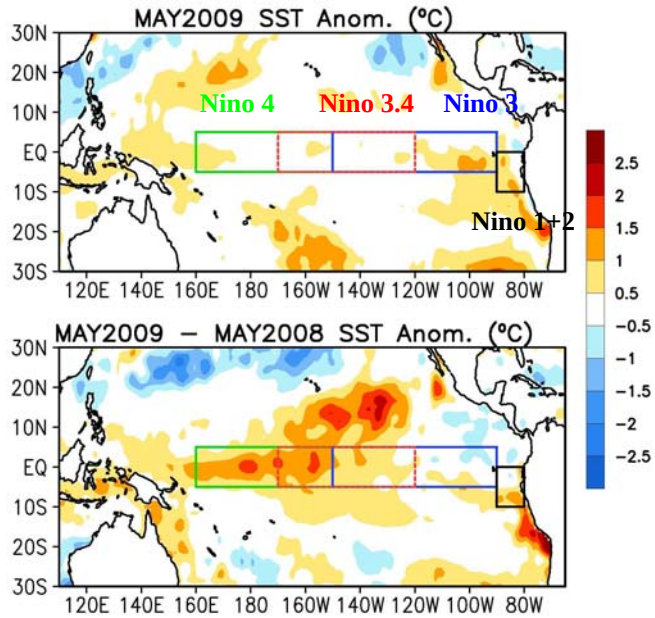
- **Global mean SSTA increased slightly.**
- **Global mean seasonal land temperature persisted from FMA to MAM.**
- **Tropical land temperature decreased although the tropical ocean SST increased slightly.**
- **Positive SSTA in North Pacific weakened.**
- **Positive SSTA in North Atlantic continued a downward trend since November 08.**
- **NINO 3.4 SST became slightly positive.**

Fig. BU. Sea surface temperature (SST) anomalies (left) and surface air temperature anomalies (right) average for selected regions. Due to larger variability, the surface air temperature anomalies have a 3-month running mean applied. Anomalies were computed with respect to the 1971-2000 base period means.

Tropical Pacific Ocean

Evolution of Pacific NINO SST Indices



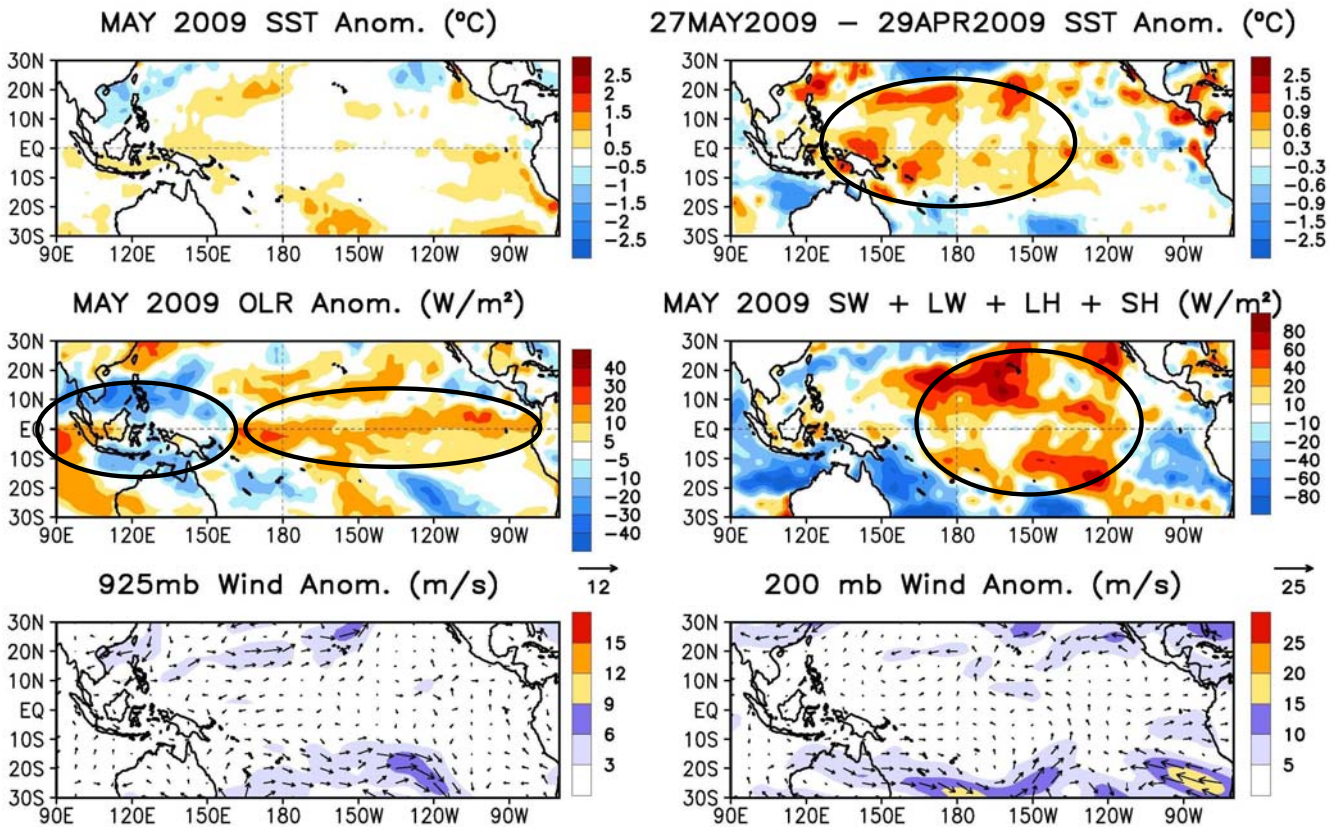


- **Conditions are favorable for a transition from ENSO-neutral to El Niño conditions during June - August 2009 – NOAA's "ENSO Diagnostic Discussion".**

- **All NINO indices were above-normal in May 09.**

Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Tropical Pacific: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds



- **Convection suppressed (enhanced) in the central-eastern tropical Pacific (Maritime Continent).**
- **Positive SSTA tendency in the western-central tropical Pacific was consistent with positive net surface heat flux anomalies in the region.**
- **Atmospheric circulations were near-normal.**

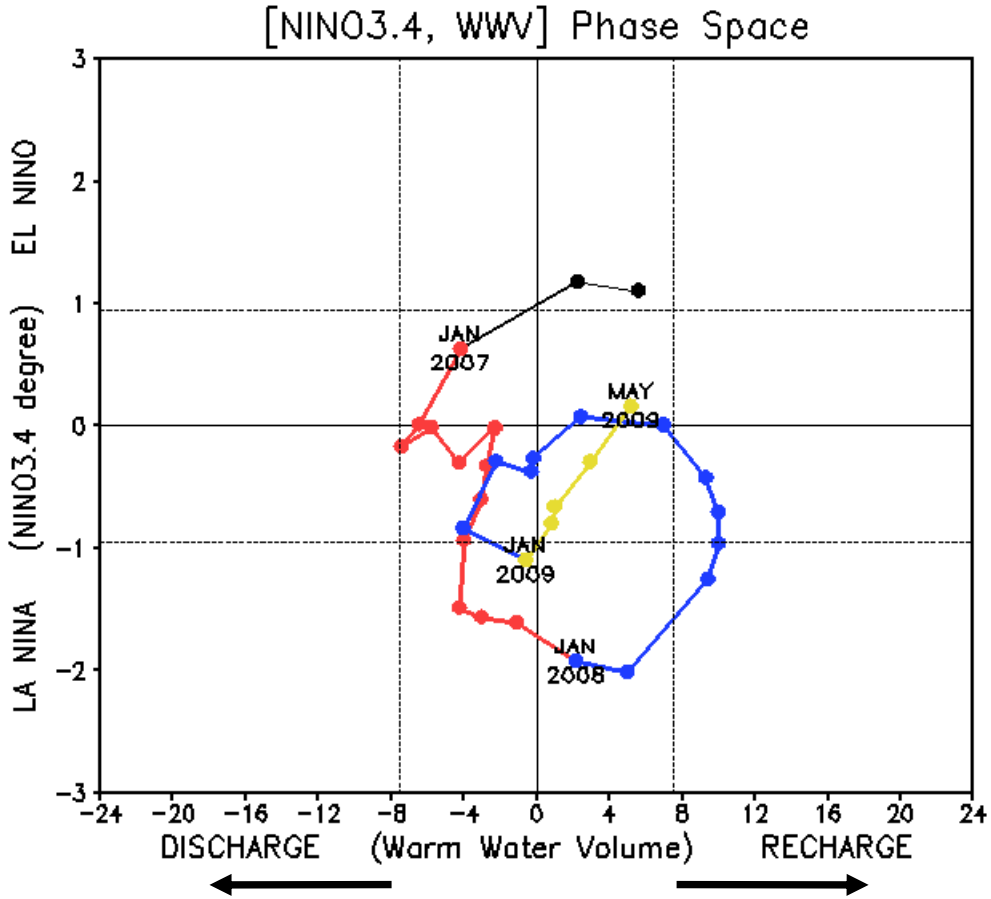
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

Warm Water Volume (WWV) and NINO3.4 Anomalies

-WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N] (Meinen and McPhaden, 2000).

-Since WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and NINO3.4 (Kessler 2002).

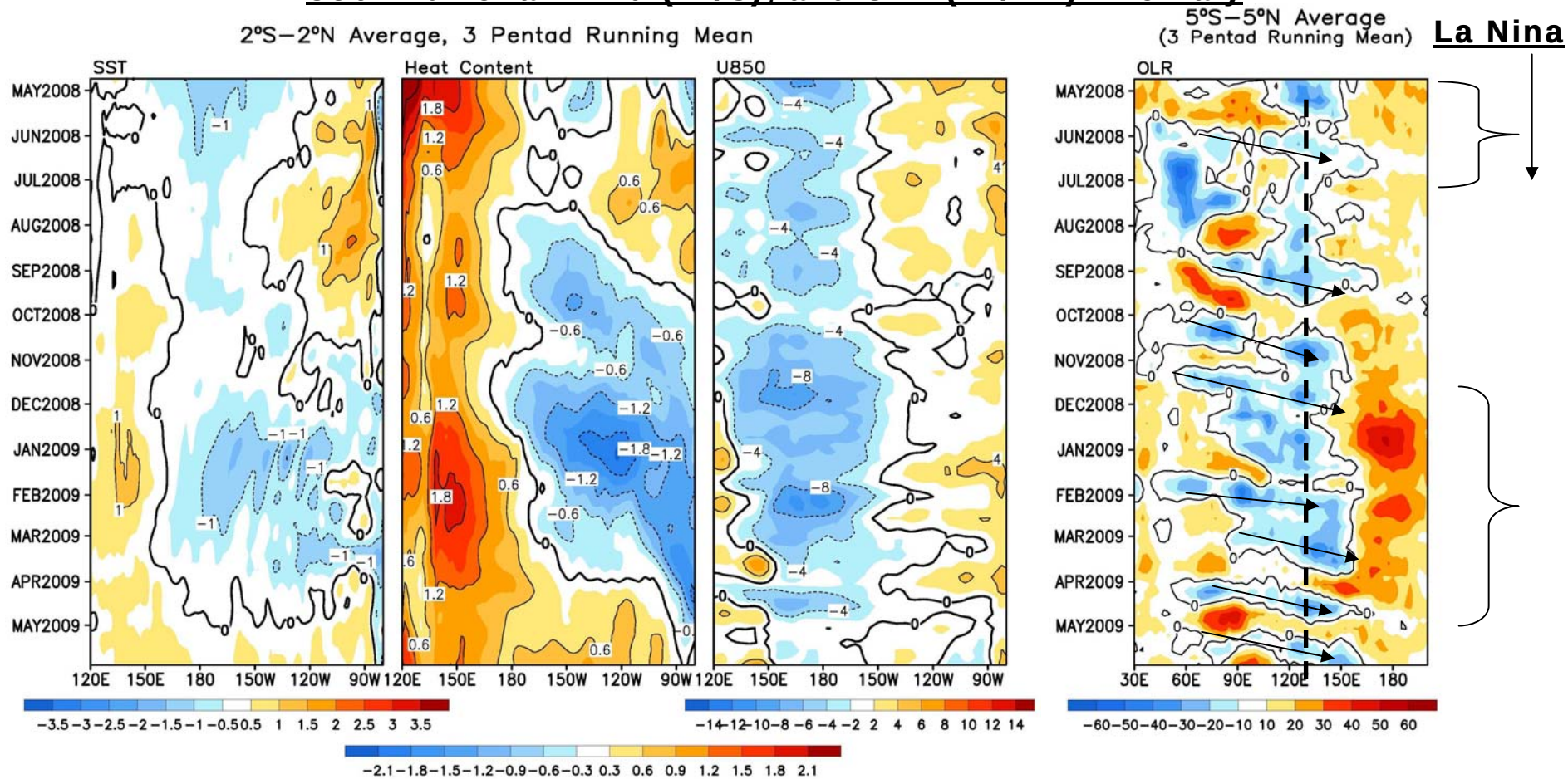
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



- Both NINO3.4 and Warm Water Volume(WWV) have increased steadily in the past two months.
- Compared to last May, NINO3.4 was much warmer, but subsurface warm water volume was lower.
- However, the trend of the trajectory suggests NINO3.4 will likely increase in next 1-2 months.

Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies for WWV (NINO 3.4) are departures from the 1982-2004 (1971-2000) base period means.

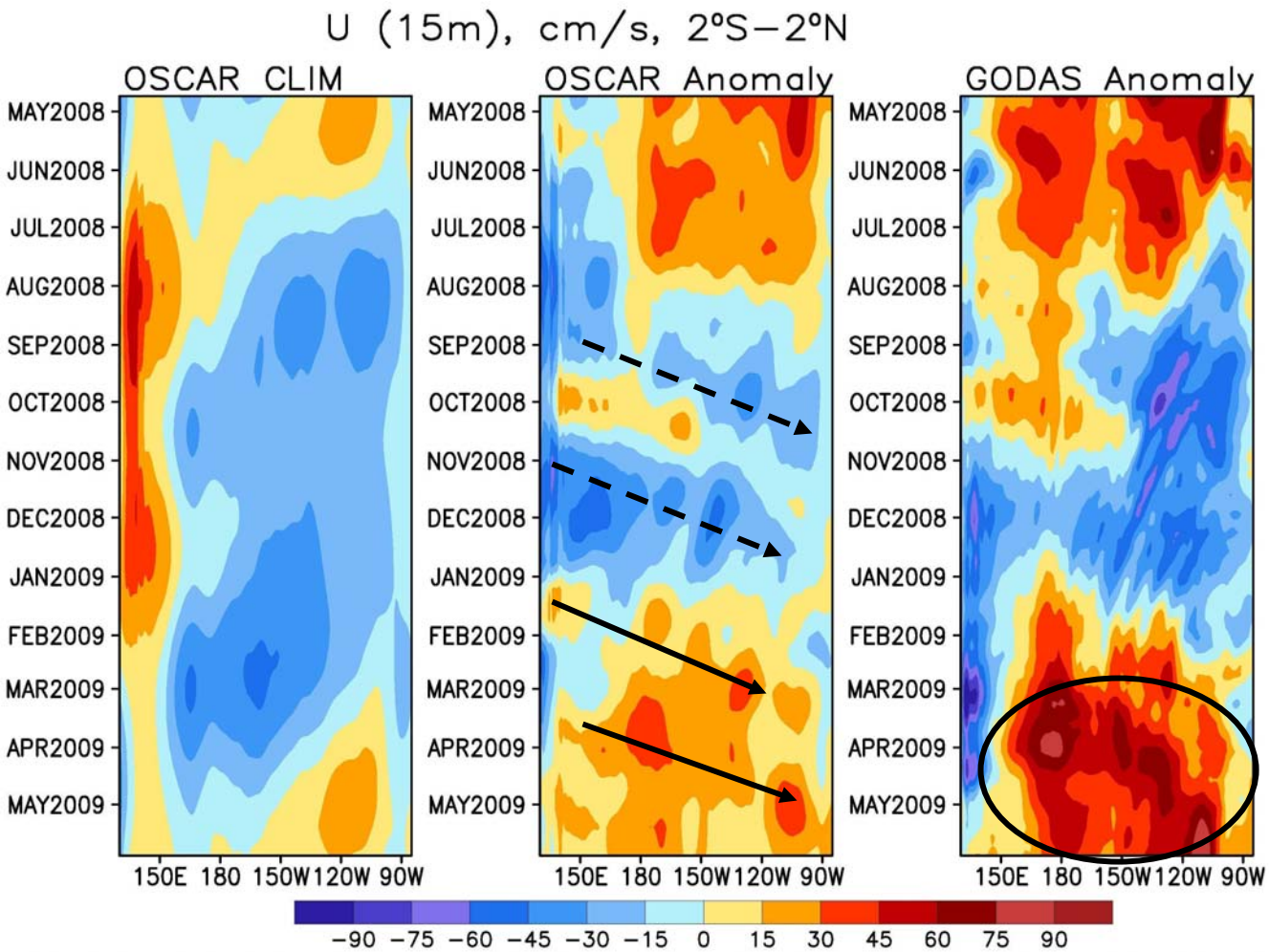
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²) Anomaly



- **SST became weakly above-normal across the equatorial Pacific in May 09.**
- **Positive heat content anomalies strengthened in May due to weak westerly wind anomalies cross the tropical Pacific.**
- **Weak westerly wind anomalies since mid-April were in sharp contrast with the persistent easterly wind anomalies since early 2007 that were characteristics of the 2007/2008 and 2008/2009 La Nina cycles.**

Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2°S-2°N and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST is derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1971-2000, 1982-2004, 1979-1995 base period pentad means respectively.

Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



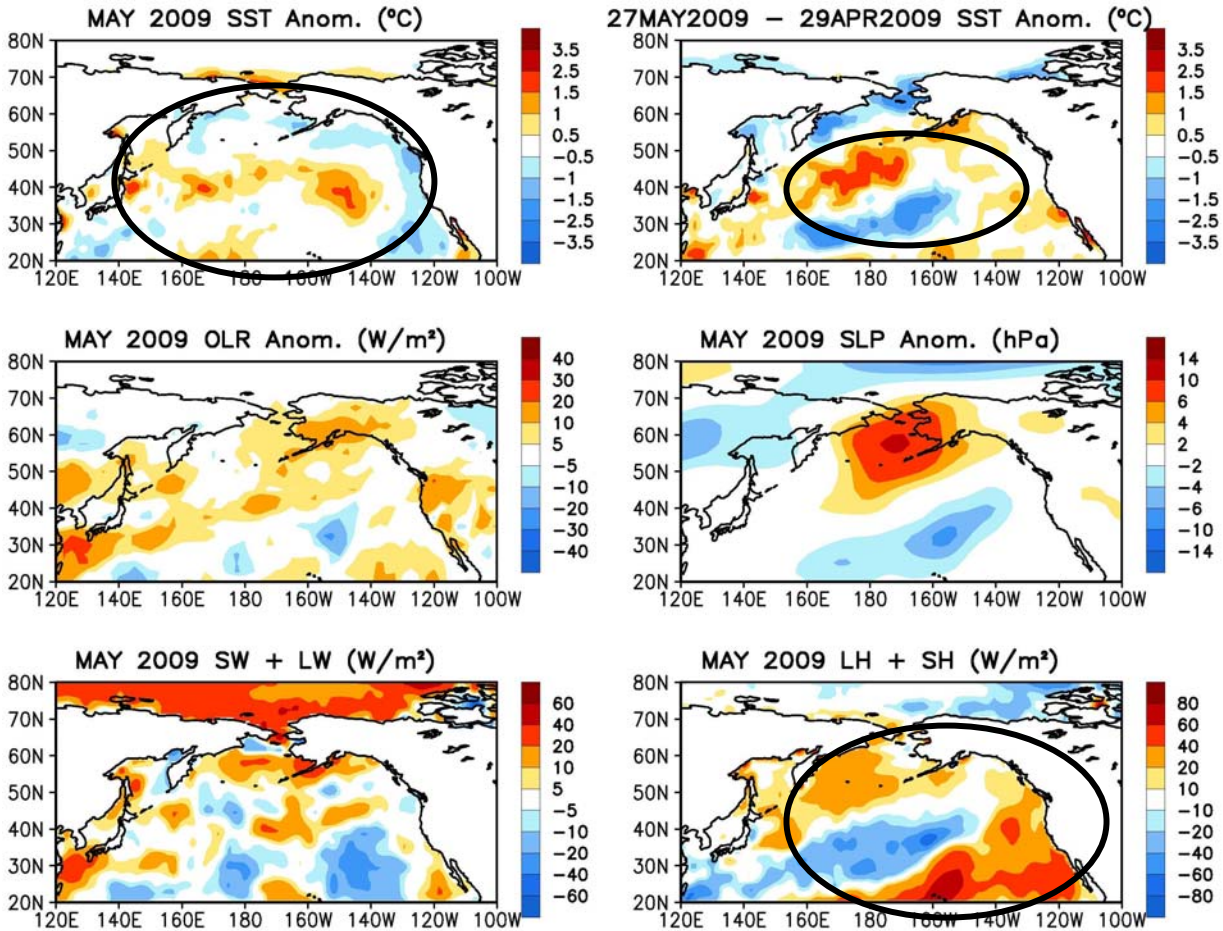
- **Eastward propagation of negative (dashed line) (positive, solid line) surface zonal current anomalies were associated with upwelling (downwelling) oceanic Kelvin waves.**

- **Surface zonal current anomaly has been positive since mid-Jan 09, consistent with the transition from La Nina to ENSO-neutral conditions in April 09 and a possible transition to El Nino conditions in June-August 09.**

- **Positive surface zonal current anomalies simulated by GODAS were too strong compared with those of the OSCAR currents.**

North Pacific & Arctic Ocean

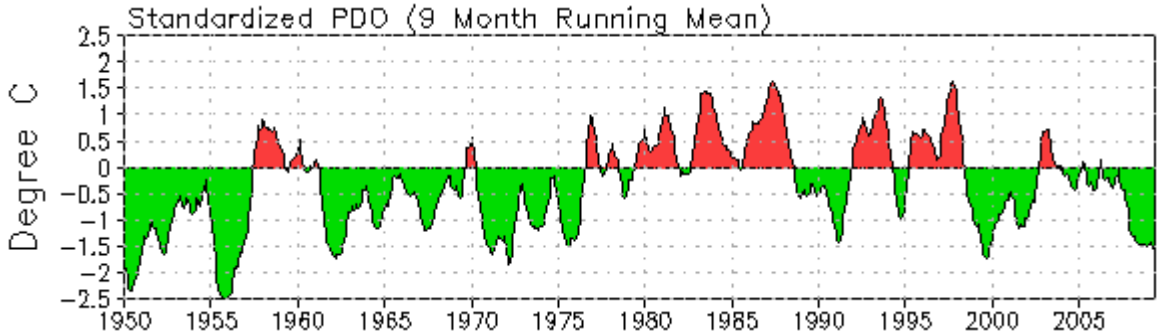
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx



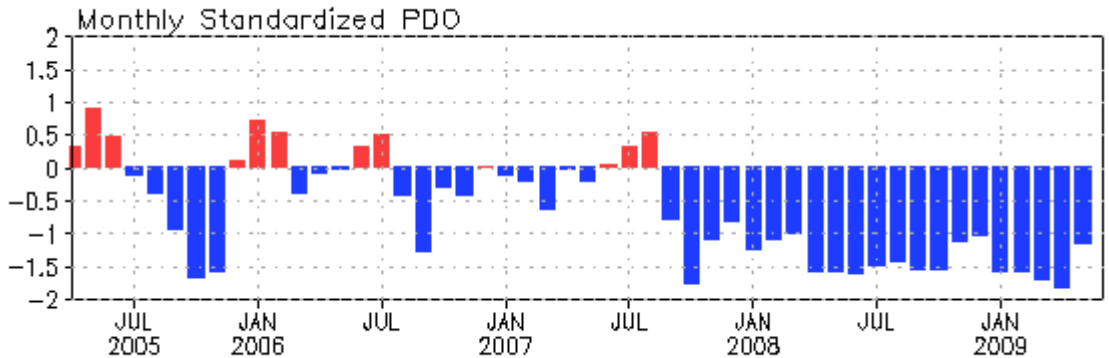
- Negative PDO-like SST pattern presented in the North Pacific.
- SSTA tendencies were consistent with the net surface heat flux anomalies.
- Above-normal sea level pressure presented over Bering Sea.

Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

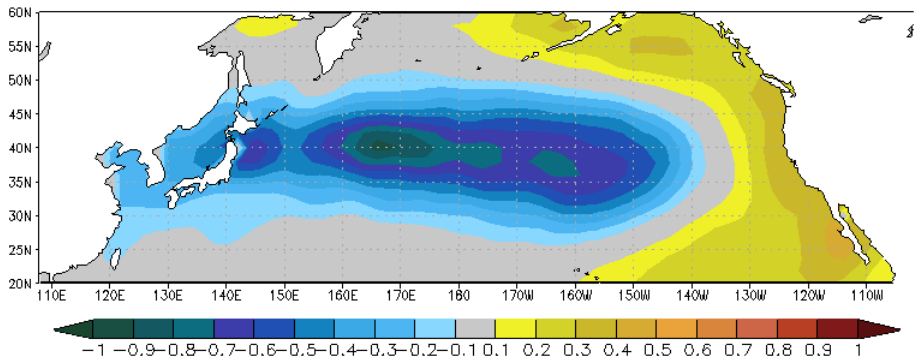
PDO index



PDO index at the lowest value since 1999.



Negative PDO index started in September 2007, and has persisted for 21 months.

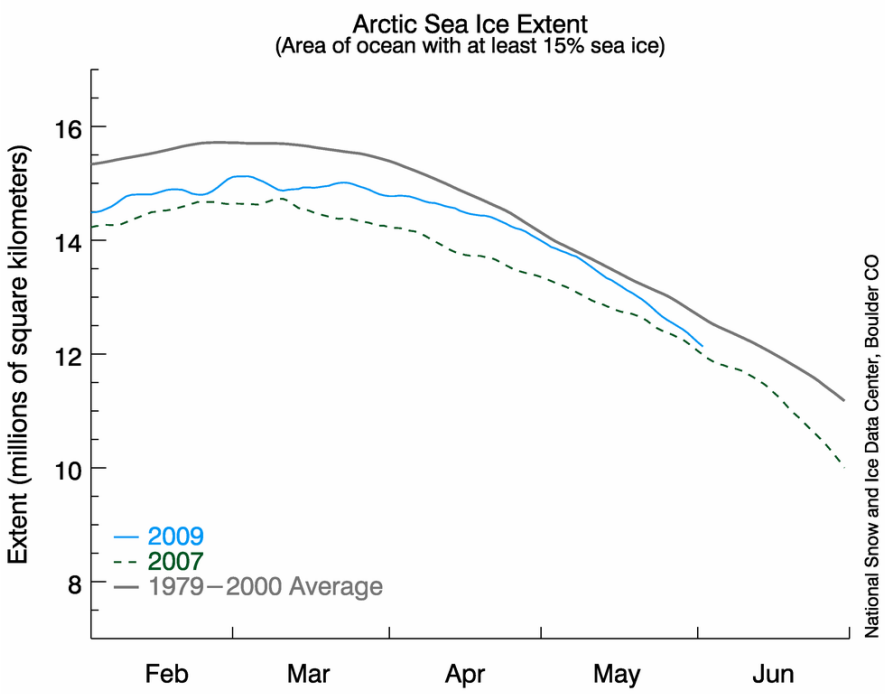


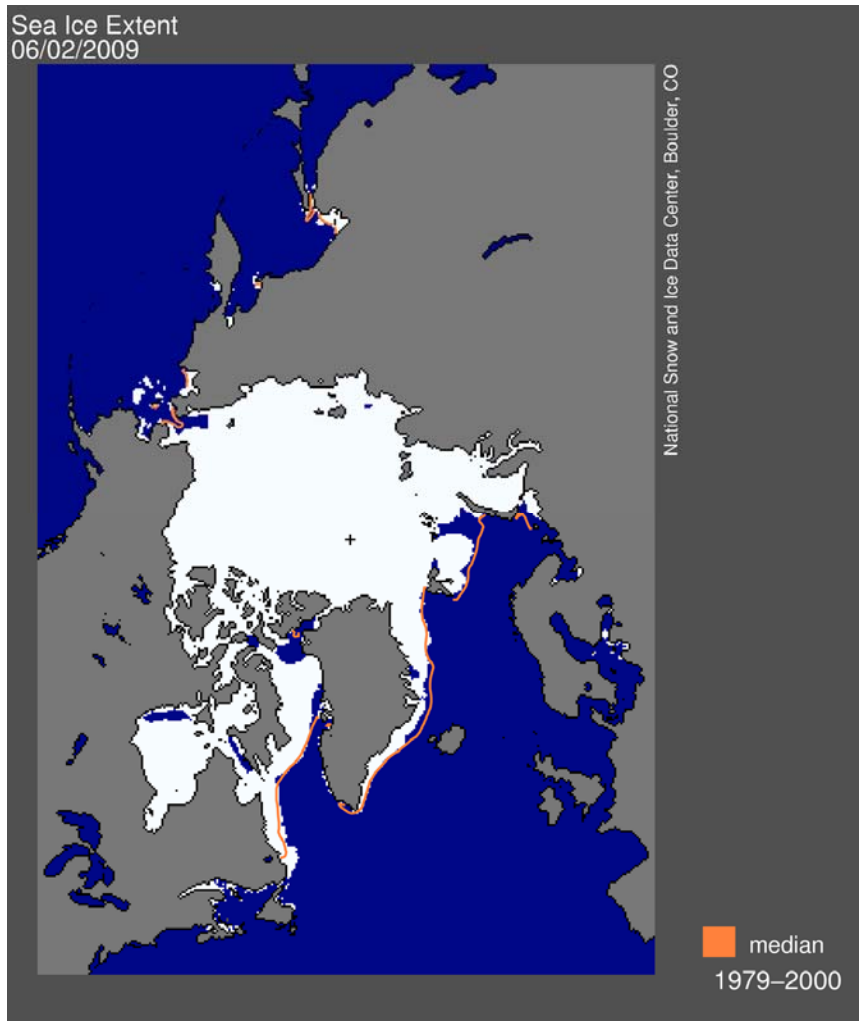
- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.**
- **The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.**

Arctic Sea Ice

National Snow and Ice Data Center

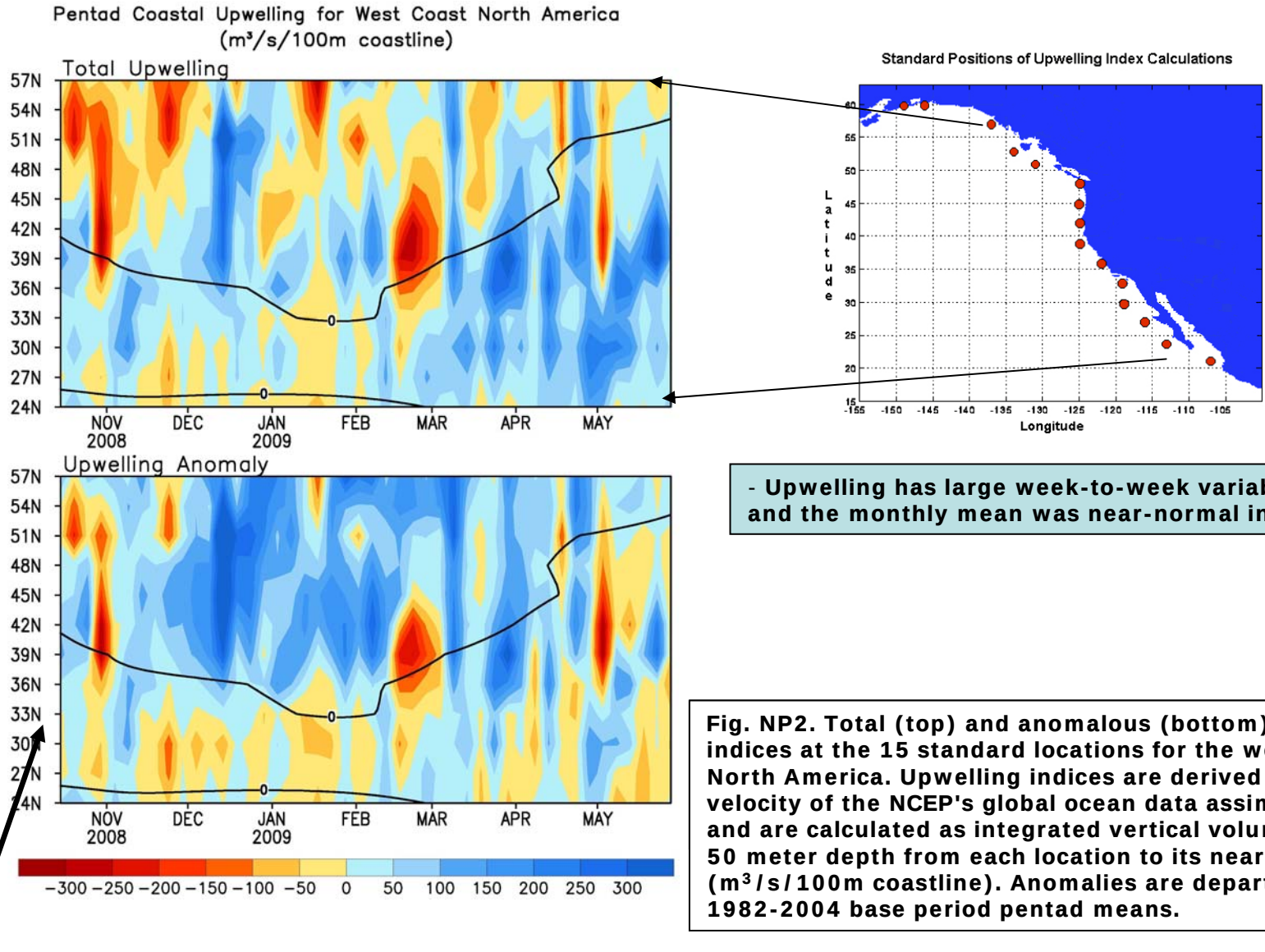
http://nsidc.org/arcticseaicenews/index.html





- Sea ice extent decreased rapidly in May and was close to the 2007 historical low by the end of May 09.

North America Western Coastal Upwelling



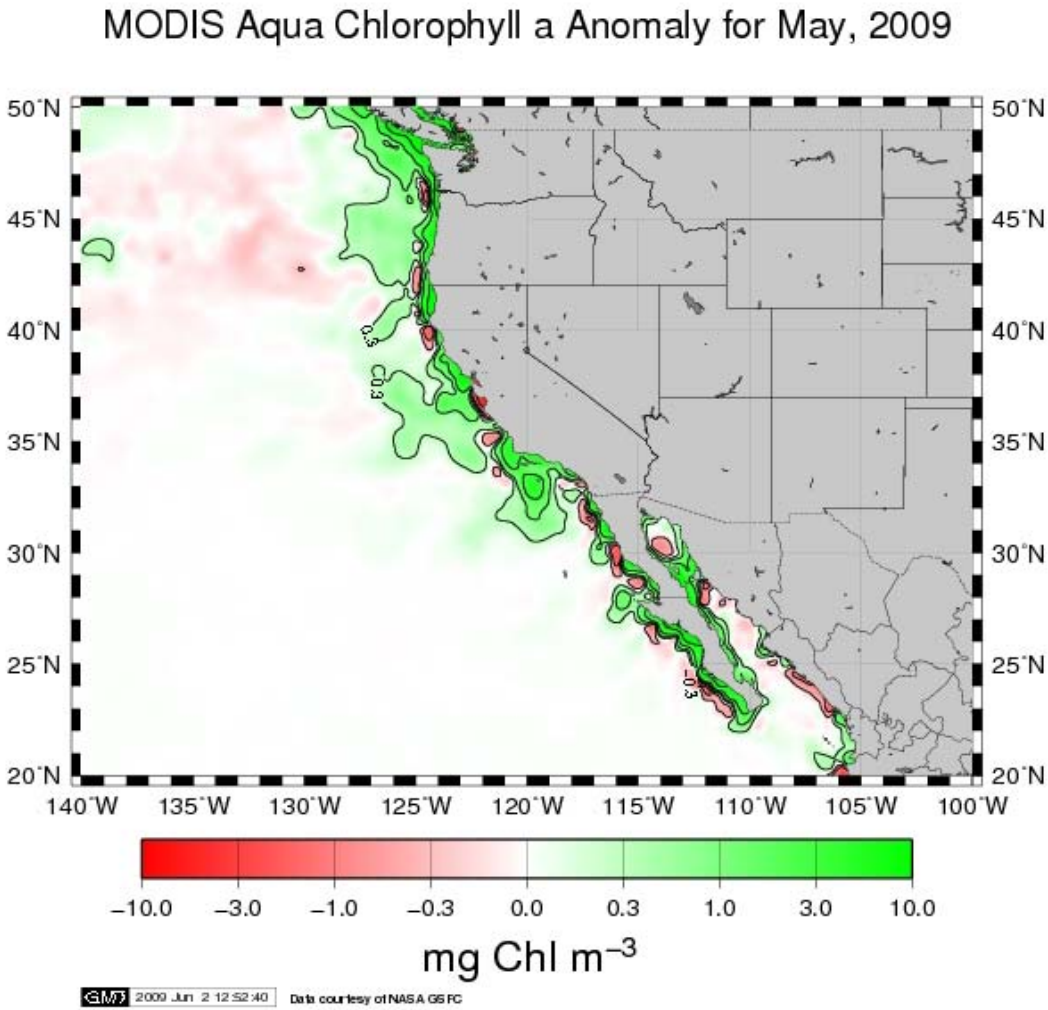
- **Upwelling has large week-to-week variability, and the monthly mean was near-normal in May 09.**

Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point (m³/s/100m coastline). Anomalies are departures from the 1982-2004 base period pentad means.

- **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.**

Monthly Chlorophyll Anomaly

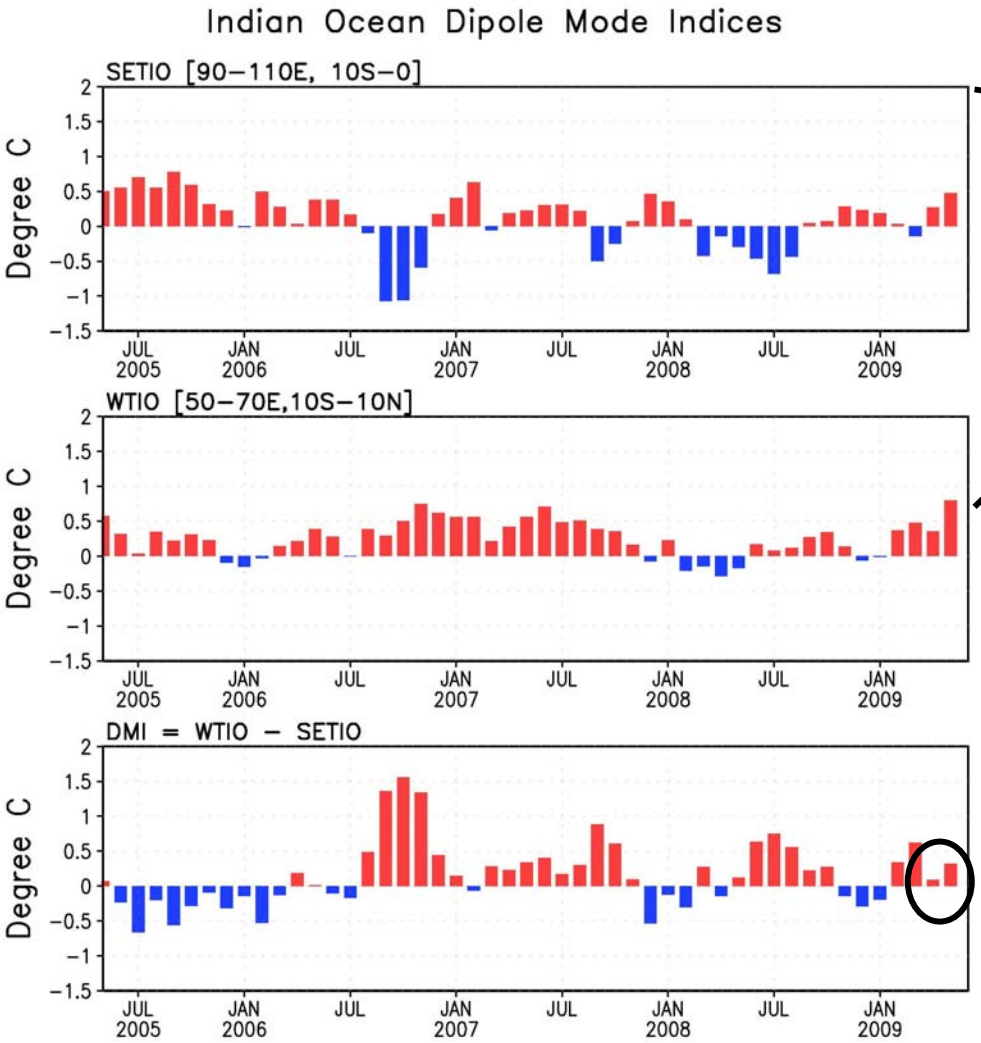
http://coastwatch.pfel.noaa.gov/FAST

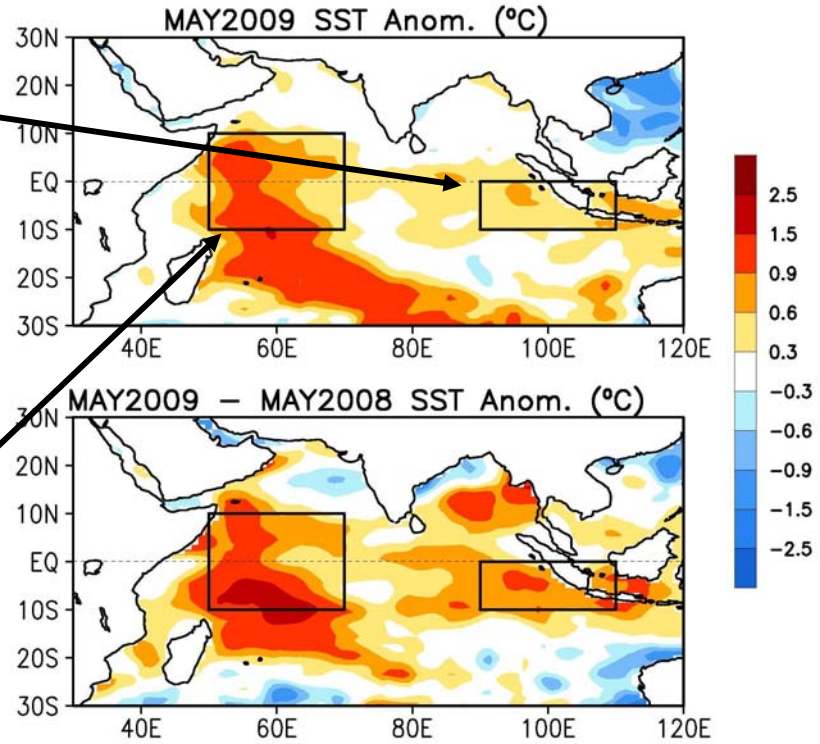


- **Positive Chlorophyll anomalies presented along most of the west coast of North America.**

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

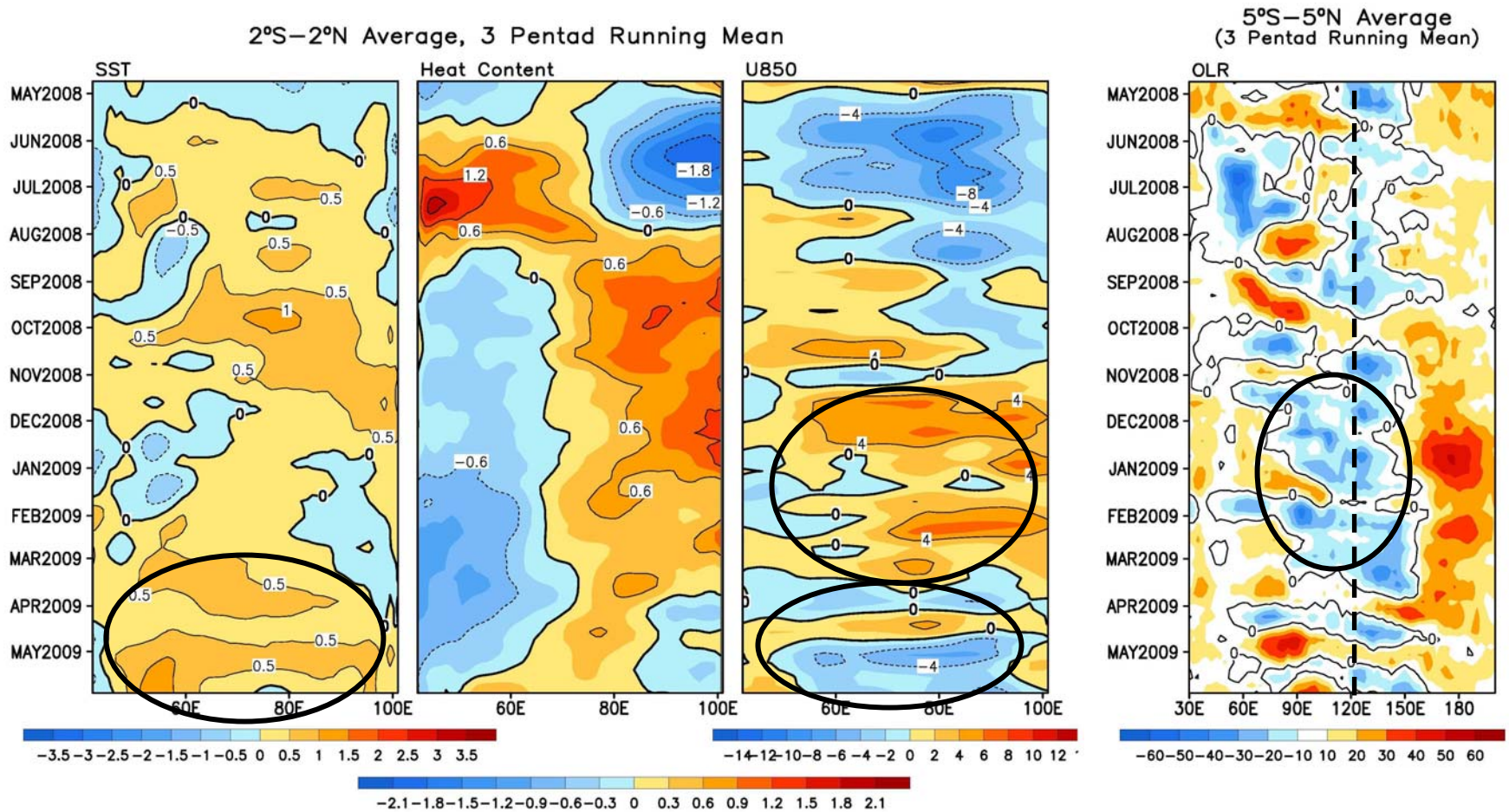




- **Positive eastern pole SSTA (SETIO) strengthened slightly.**
- **Positive western pole SSTA (WTIO) strengthened significantly, and reached about 1C in May 09.**
- **DMI was weakly above-normal.**
- **Large positive SSTA presented in the western tropical and central subtropical Indian Ocean.**

Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the SETIO [90°E-110°E, 10°S-0] and WTIO [50°E-70°E, 10°S-10°N] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

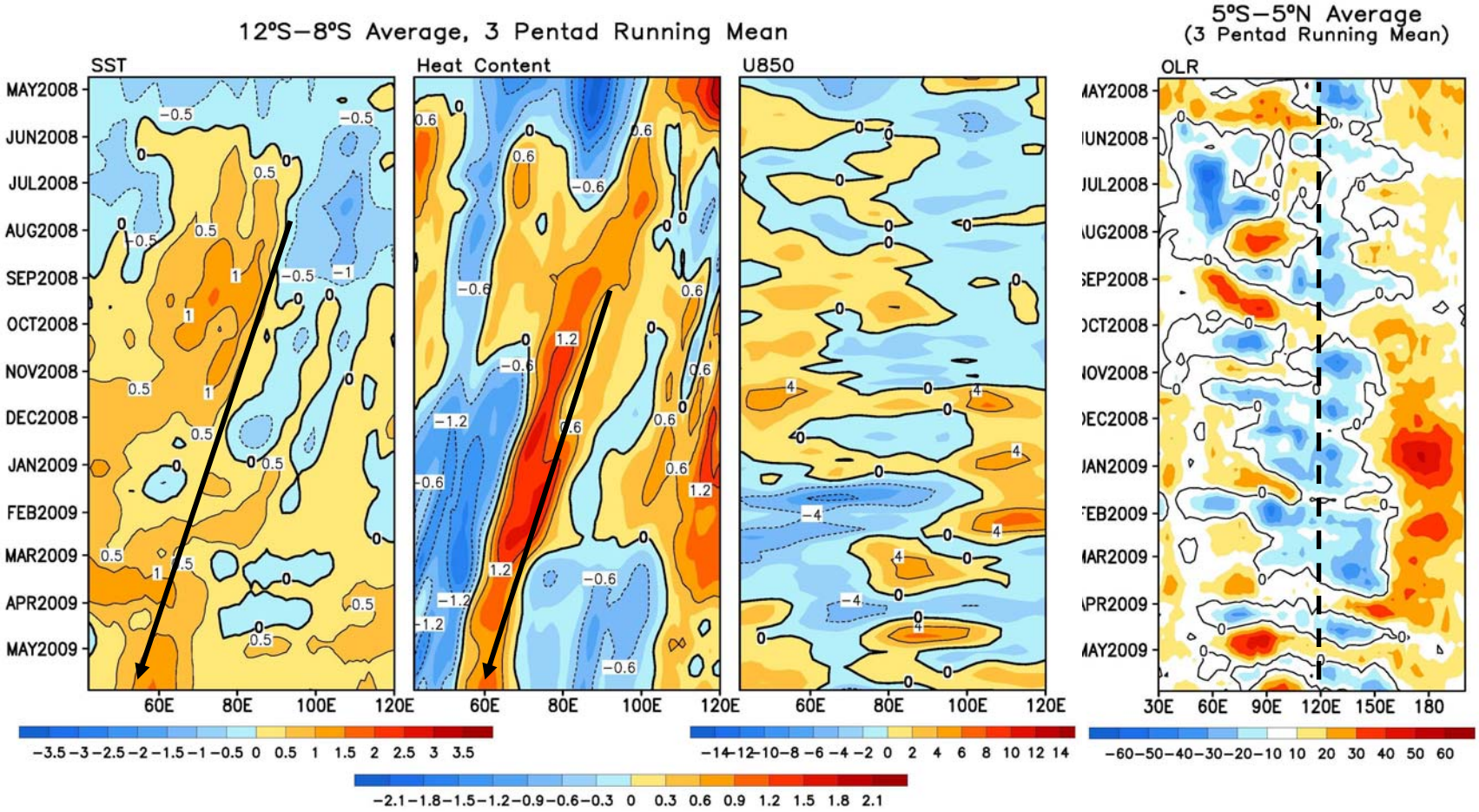
Recent Evolution of Equatorial Indian SST (ºC), 0-300m Heat Content (ºC), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies



- **Westerly wind anomalies from Nov 08 to Feb 09 were associated with the La Nina conditions in the tropical Pacific.**
- **Since mid-March 09, easterly wind anomalies were dominant,, and SST was mostly about 0.5C above-normal.**
- **Were the easterly wind anomalies associated with the positive SSTA?**

Fig. I3. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2ºS-2ºN and Outgoing Long-wave Radiation (OLR, right) averaged in 5ºS-5ºN. SST are derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, and U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1971-2000, 1982-2004, 1979-1995 base period pentad means respectively.

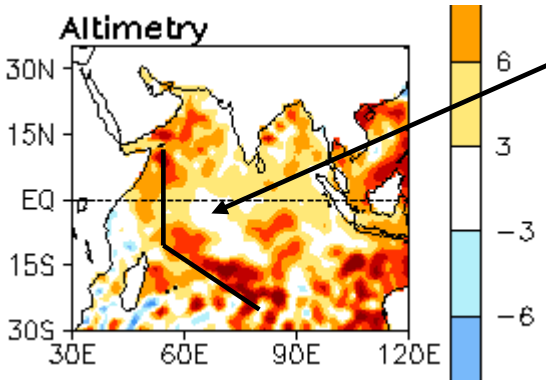
Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)



- **Westward propagation of positive heat content anomalies near 10S probably contributed to the recent warming in SST near 60E.**

Fig. I4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 12°S-8°S and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST are derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, and U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1971-2000, 1982-2004, 1979-1995 base period pentad means respectively.

Tropical Indian: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.



- **Positive SSTA was associated with positive SSHA in the western tropical and central subtropical Indian Ocean.**
- **Convection was enhanced (suppressed) in the northern Maritime Continents and north Indian Ocean, and suppressed in the south.**
- **Negative SSTA tendency south of Java was consistent with negative net surface heat flux anomalies in the region.**

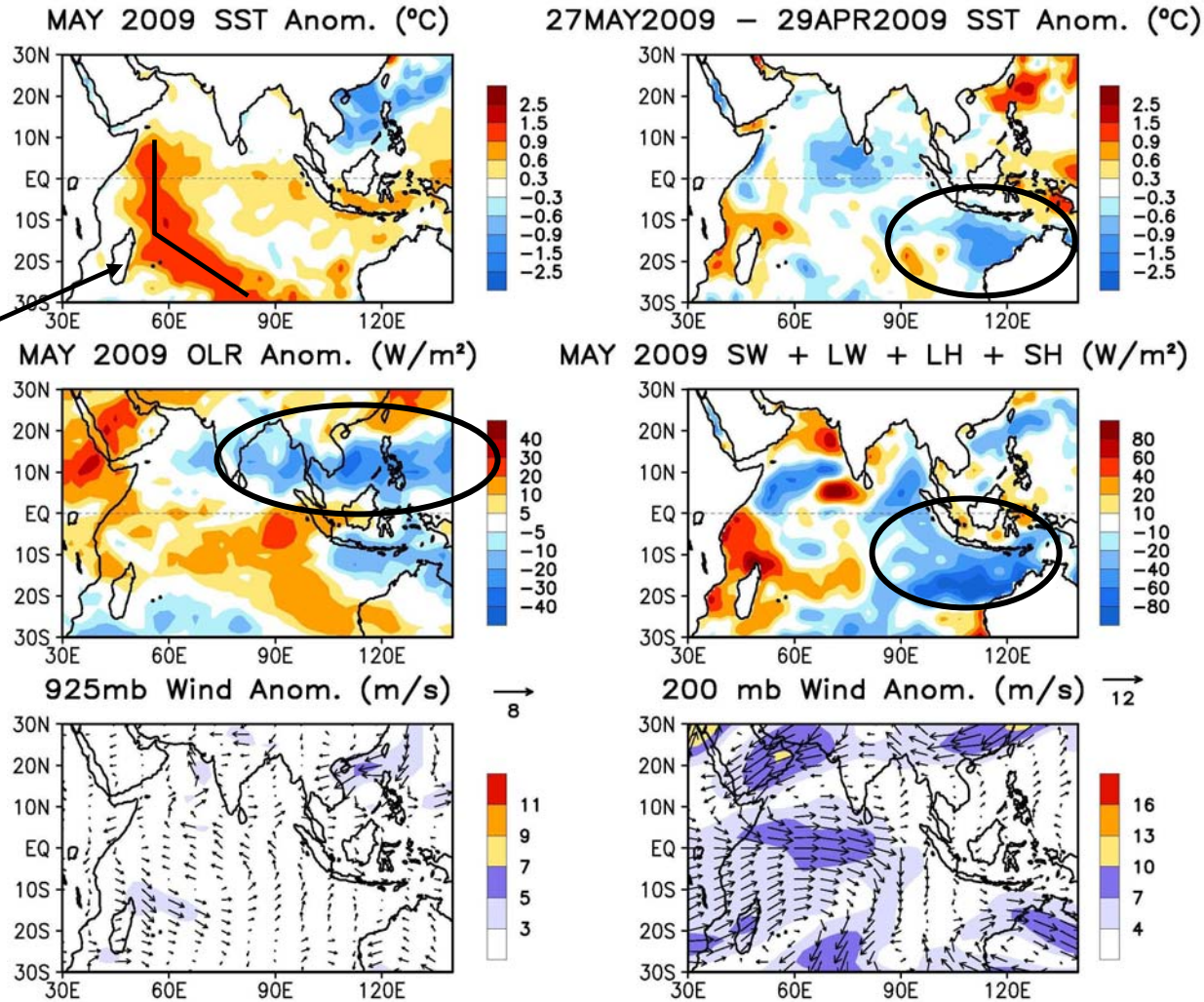
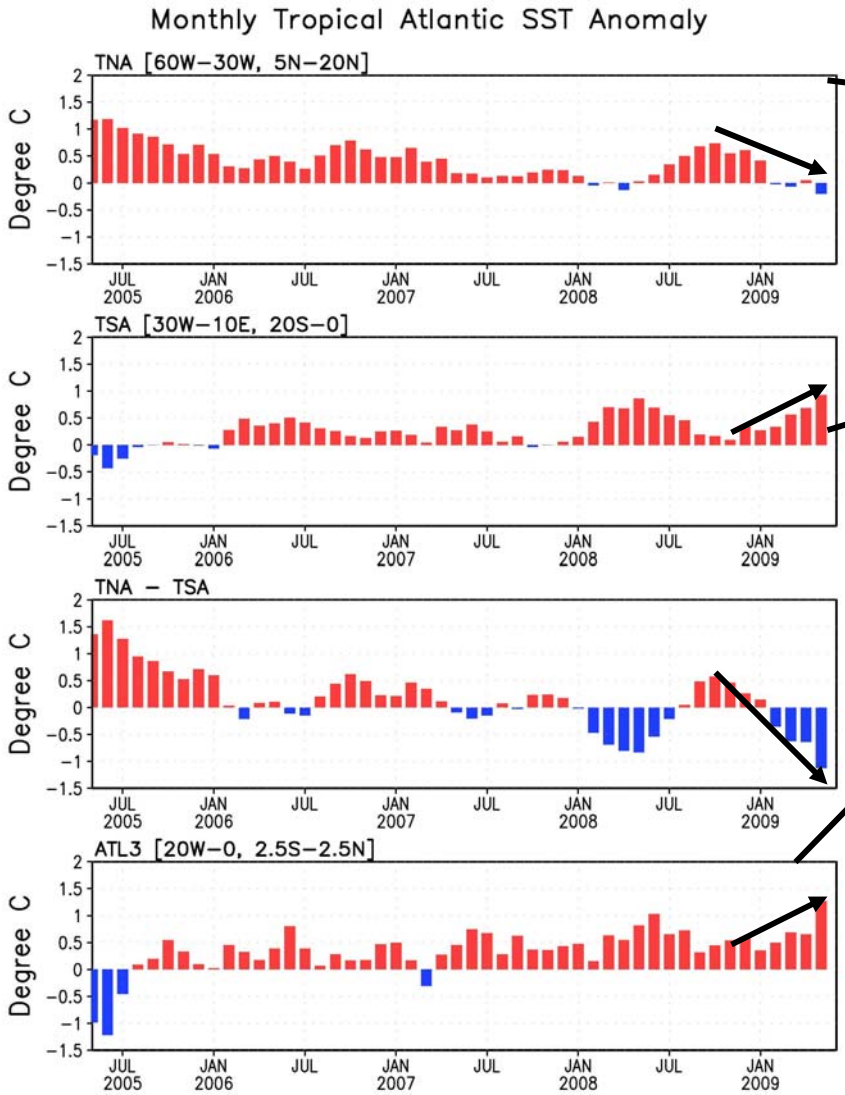
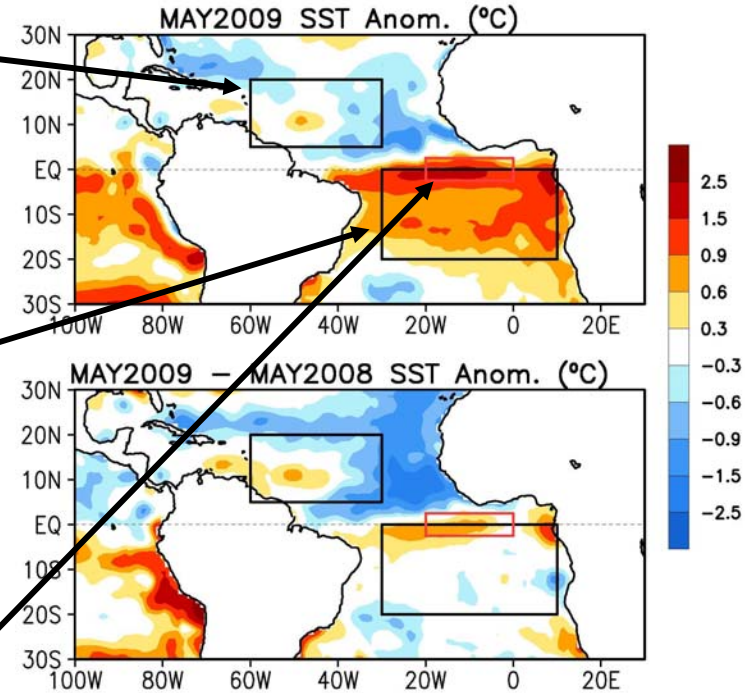


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

Tropical Atlantic Ocean

Evolution of Tropical Atlantic SST Indices



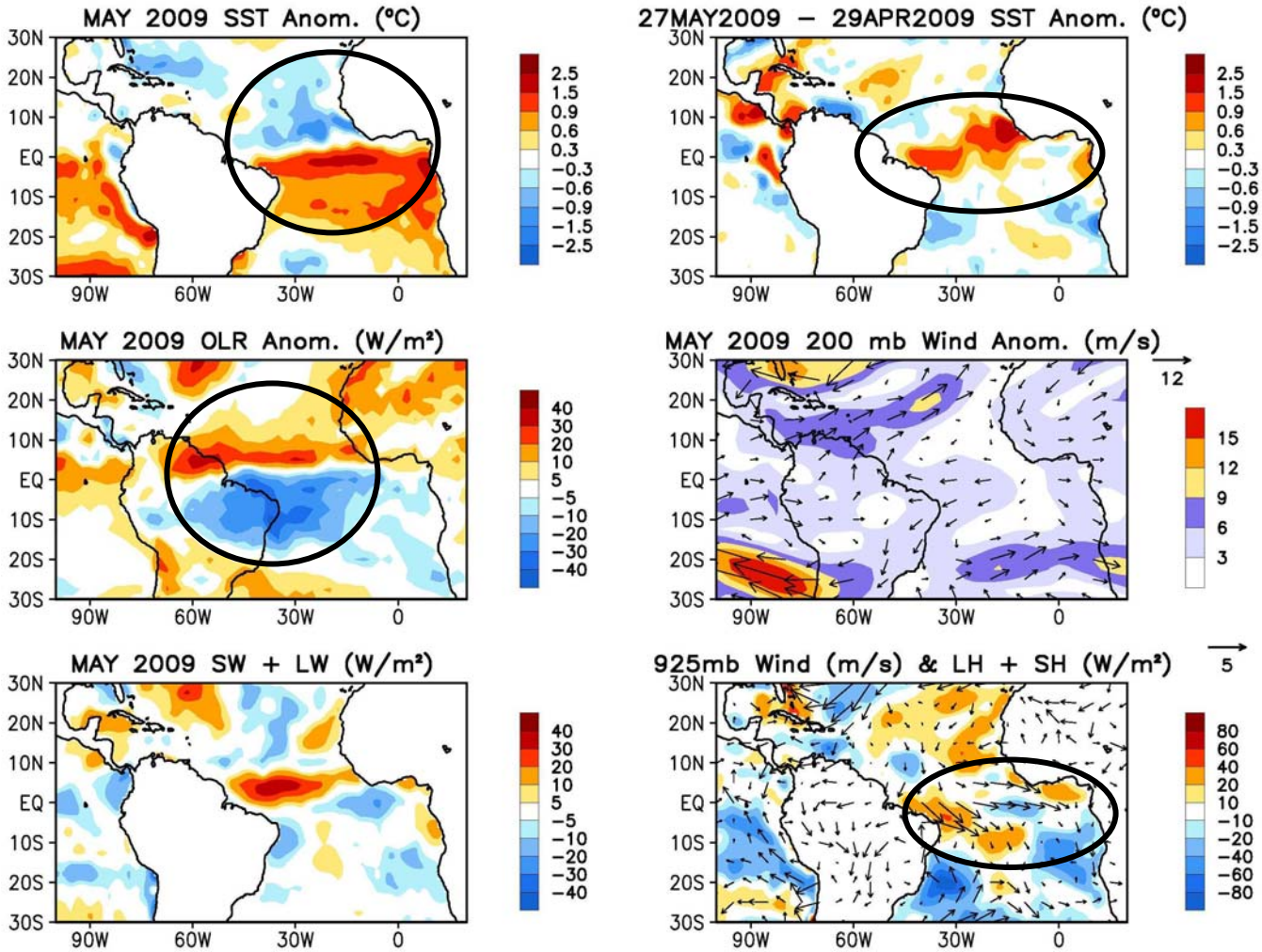


- **Tropical North Atlantic SST (TNA) continued a downward trend, and was slightly below-normal in May 09.**
- **Tropical South Atlantic SST (TSA) continued a upward trend, and was about 1C above-normal.**
- **Negative Meridional Gradient Mode (TNA-TSA) strengthened significantly in May 09.**
- **Positive ATL3 SST strengthened significantly in May 09.**

Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Tropical Atlantic:

SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb/200-mb Winds



- **SSTs warmed up significantly in the western-central tropical Atlantic.**
- **ITCZ was shifted southward in responding to the negative meridional gradient of SSTA.**
- **Surface wind anomalies were north-westerly (westerly) in the western (central) tropical Atlantic, consistent with the SSTA.**

North Atlantic Ocean

North Atlantic: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

- Positive NAO pattern in SLP anomalies.

- SSTA tendencies were largely consistent with net surface heat flux anomalies.

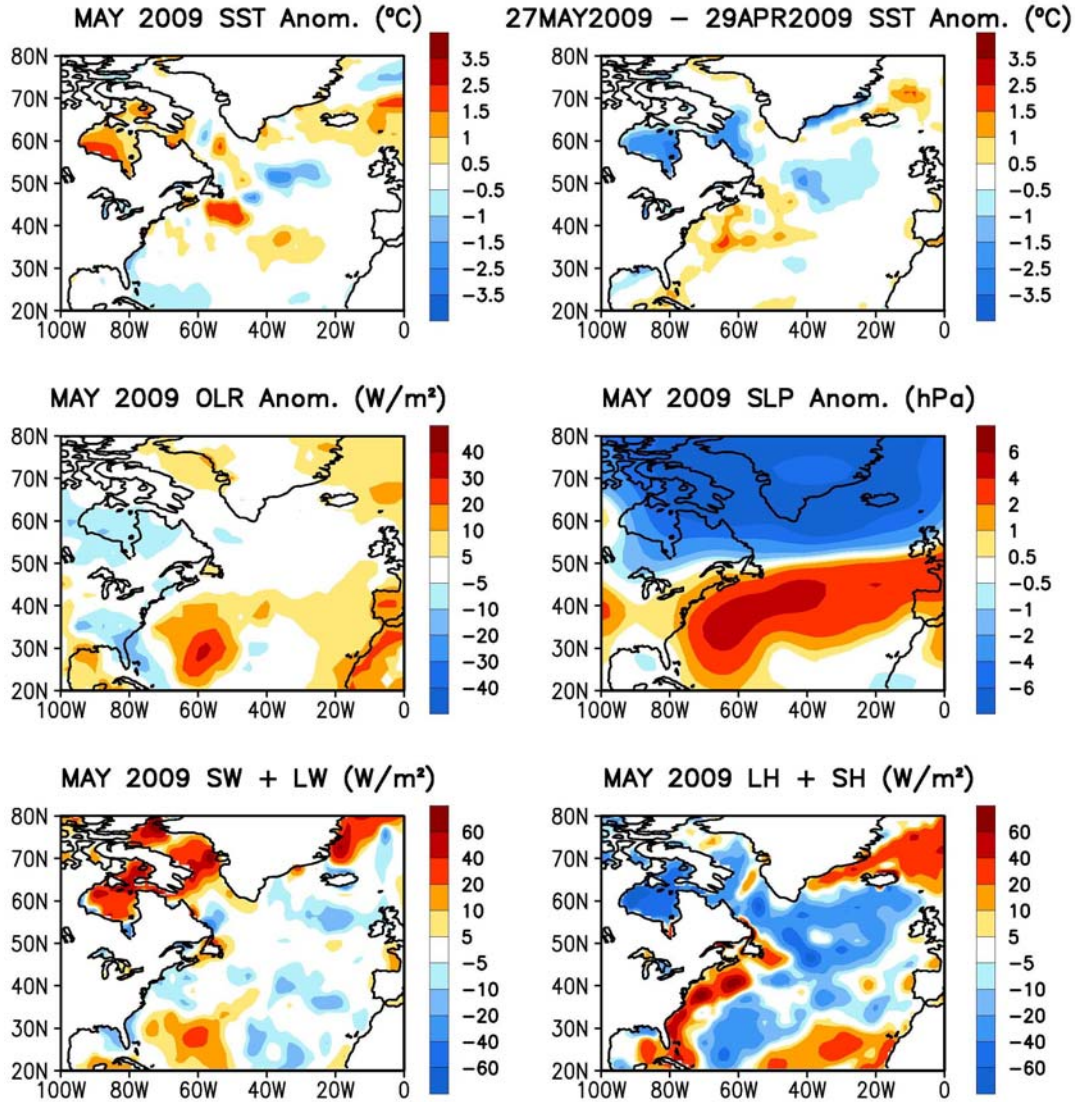
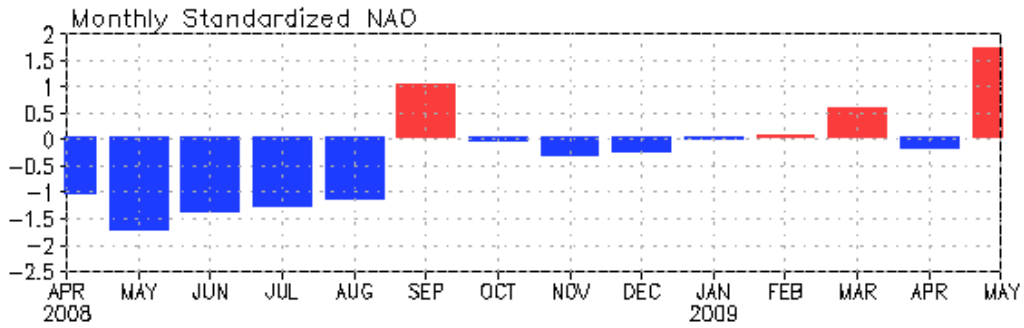
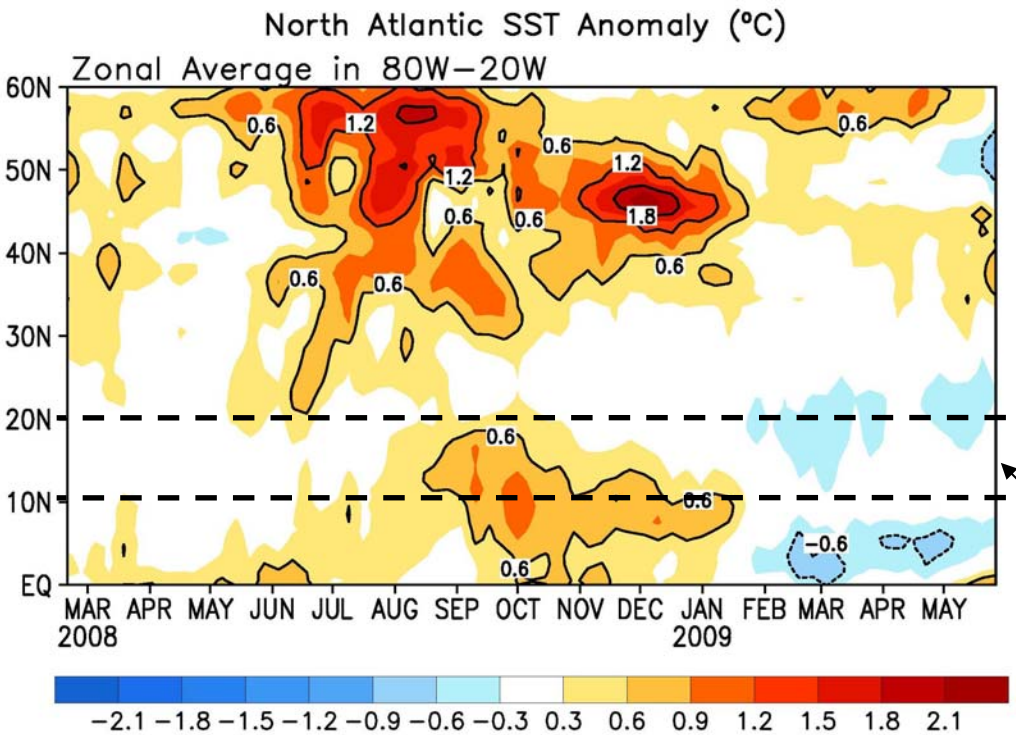
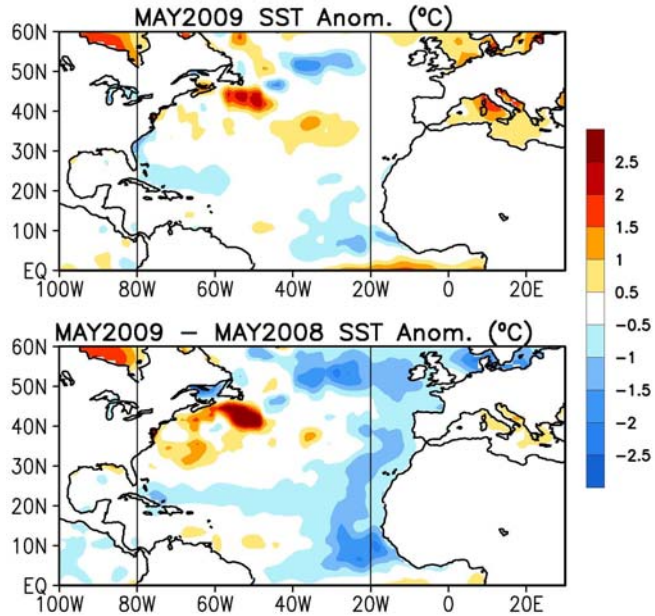


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

NAO and SST Anomaly in North Atlantic



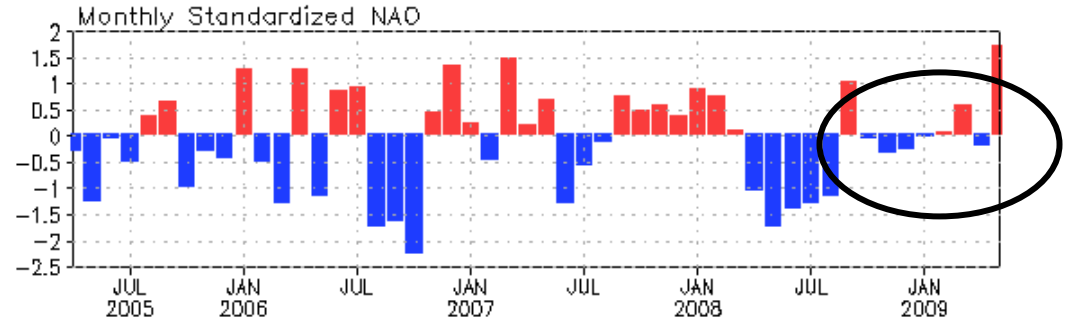


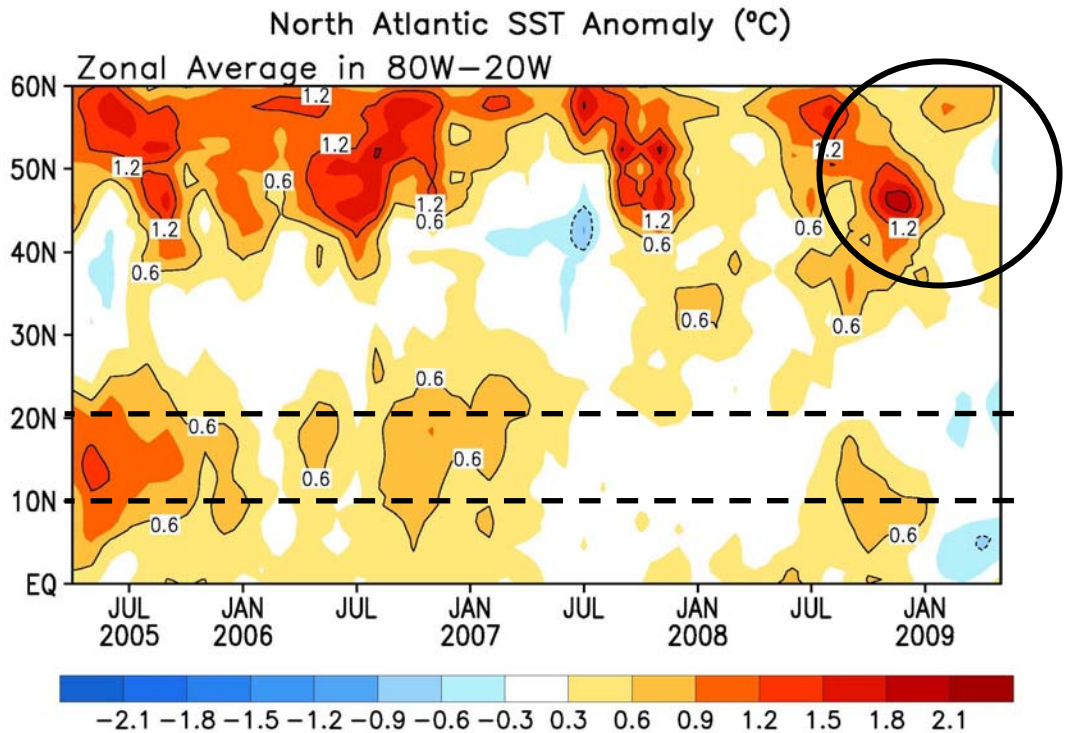


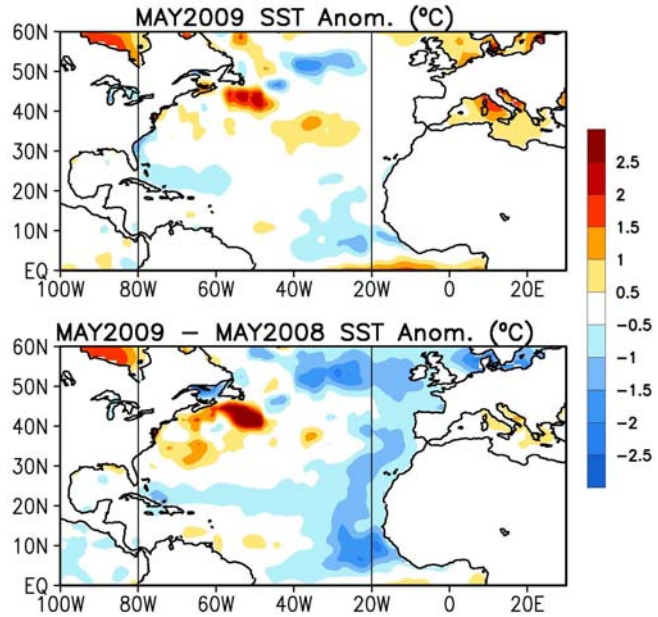
- **High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).**
- **NAO was about 1.7 above-normal in May 09.**
- **Hurricane Main Development Region SST was weakly below-normal in May 09.**

Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

NAO and SST Anomaly in North Atlantic





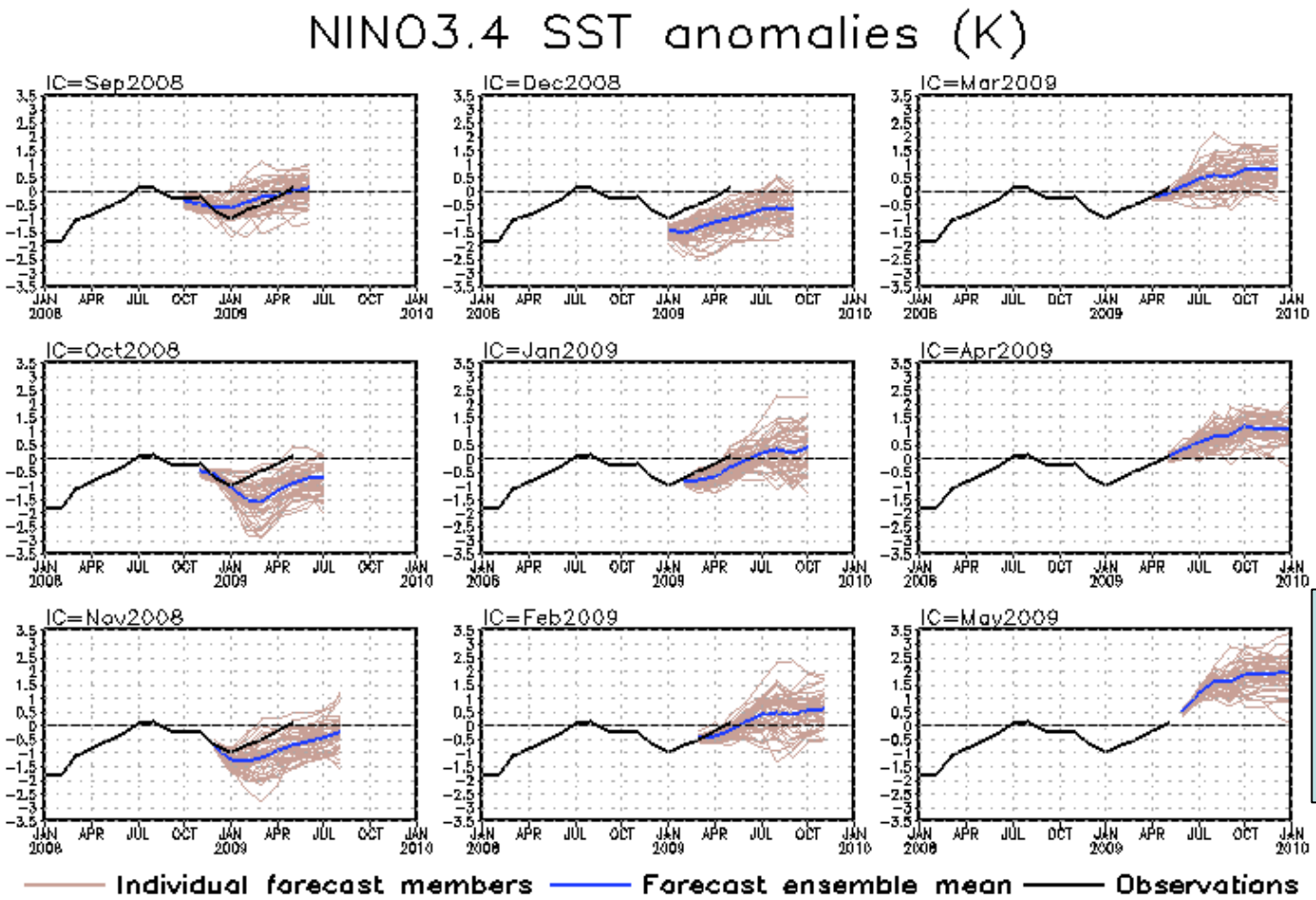


- North Atlantic SSTs cooled down and became near-normal during the past few months due to near-normal or above-normal NAO index.

Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

CFS SST Predictions and Ocean Initial Conditions

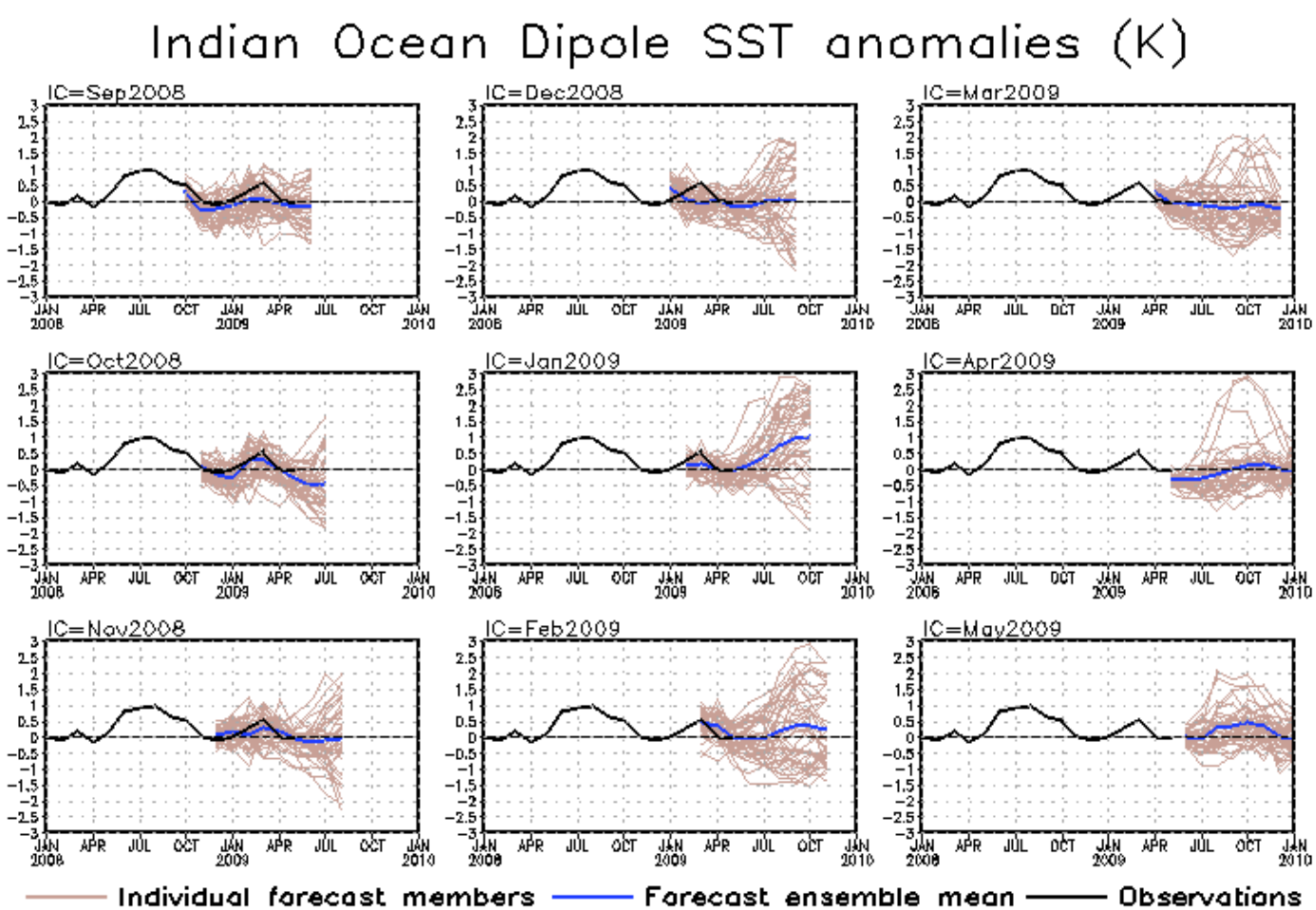
CFS Niño3.4 SST Predictions from Different Initial Months



- Latest forecasts suggested a moderate El Nino would develop during summer/fall 2009.

Fig. M1. CFS Nino3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

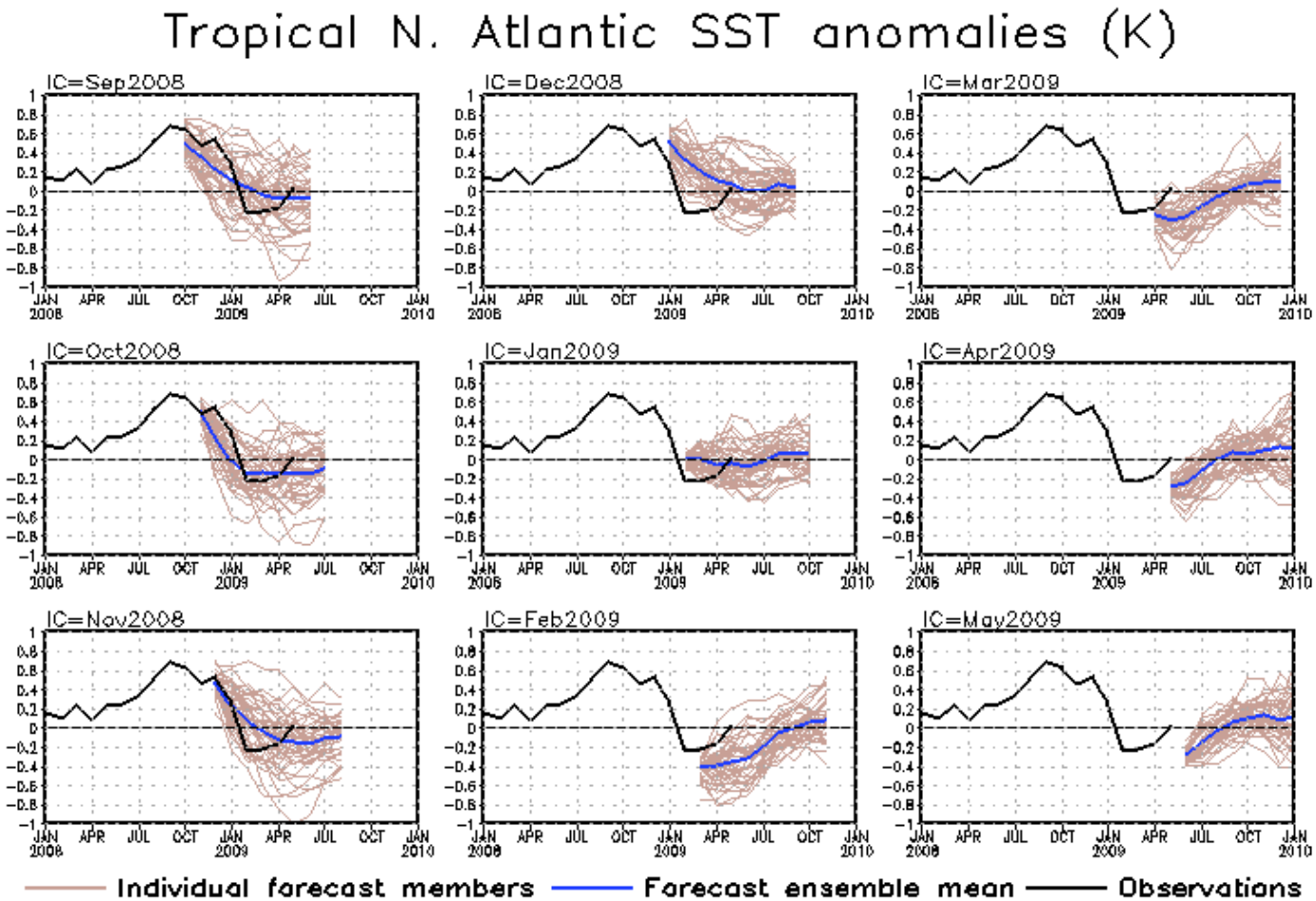
SETIO = SST anomaly in [90°E-110°E, 10°S-0]

WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

- Latest forecasts call for near-normal Dipole Mode Index in next 6-9 months.

Fig. M2. CFS Dipole Model Index (DMI) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months

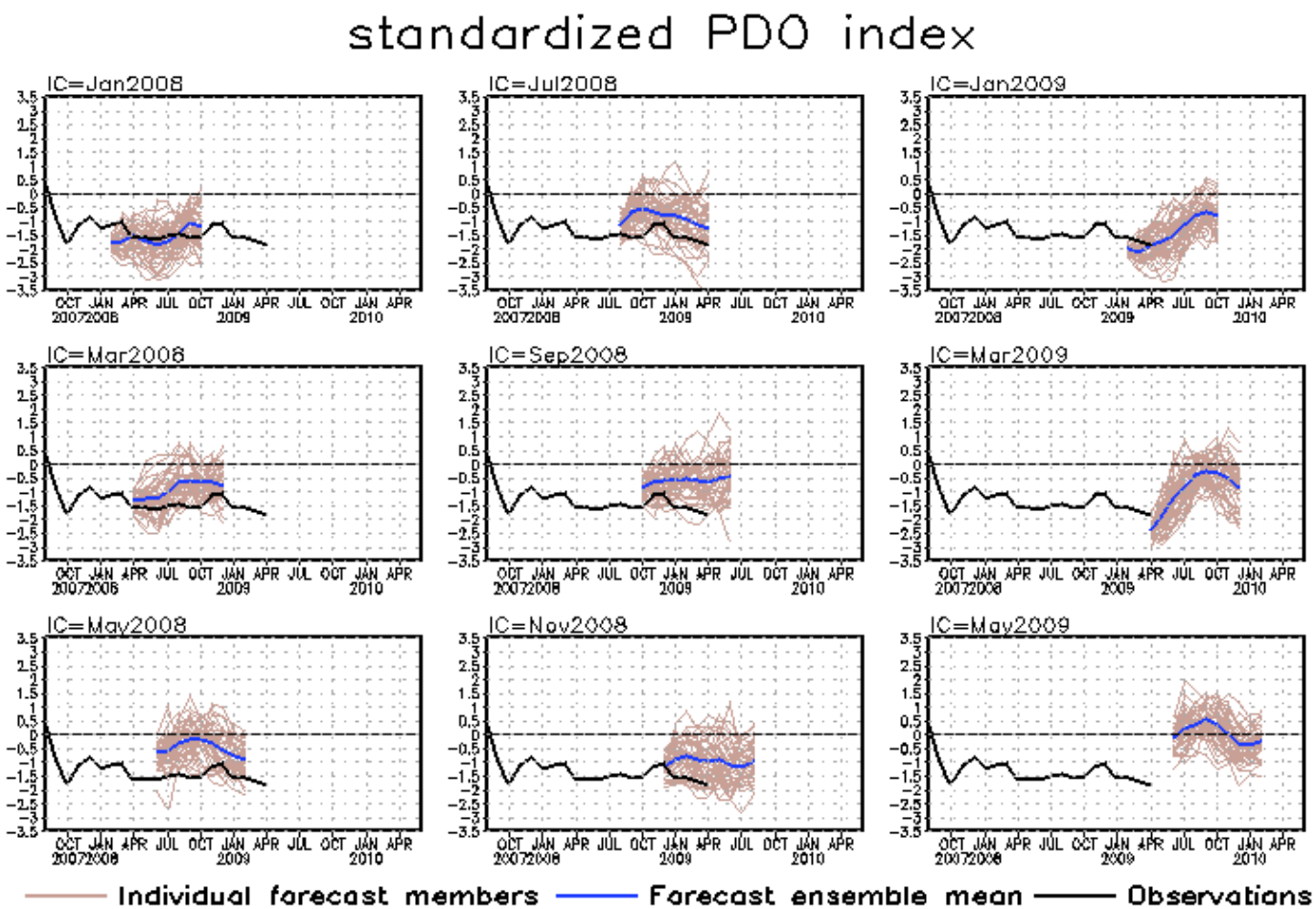


TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- Latest forecasts suggested that the tropical North Atlantic SST would be near-normal in next 3-6 months.

Fig. M3. CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



PDO is the first EOF of monthly SST in the region of [110°E-100°W, 20°N-60°N].

- CFS SST anomalies are projected onto the PDO SST pattern (slide 16).
- CFS has forecasted the recent negative PDO phase since Dec 07 I.C.
- Latest forecasts suggested that the current negative PDO would weaken rapidly and return to near-normal during summer/fall 09.

Fig. M4. CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

Summary

- **Pacific Ocean**
  - Surface and subsurface temperature has warmed up steadily since March 09, and the recent trends are favorable for a transition from ENSO-neutral to El Niño conditions during next 3 months.
  - Negative PDO phase since September 2007 has persisted for 21 months now, and 2008 has the lowest yearly mean PDO index since 1971.
- **Indian Ocean**
  - Since mid-March 09, zonal wind anomalies were persistently easterly and SST was persistently 0.5C above-normal.
  - The western tropical Indian Ocean SST went up to about 1C above-normal in May 09 - the western pole of DMI was 1C above-normal.
- **Atlantic Ocean**
  - Tropical North Atlantic SST (TNA) continued a downward trend, and was slightly below-normal in May 09. Tropical South Atlantic SST (TSA) continued a upward trend, and was about 1C above-normal.
  - ITCZ was shifted southward in responding to the negative Meridional Gradient Mode (TNA-TSA).
- **Arctic Ocean**
  - Sea ice extent decreased rapidly in May and was close to the 2007 historical low by the end of May 09.

Backup Slides

Data Sources and References

- Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
- SST 1971-2000 base period means (Xue et al. 2003)
- NCEP CDAS winds, surface radiation and heat fluxes
- NESDIS Outgoing Long-wave Radiation
- PMEL TAO equatorial temperature analysis
- NCEP's Global Ocean Data Assimilation System temperature, heat content, currents (Behringer and Xue 2004)
- Aviso Altimetry Sea Surface Height
- Ocean Surface Current Analyses – Realtime (OSCAR)

Please send your comments and suggestions to Yan.Xue@noaa.gov. Thanks!