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

Prepared by
Climate Prediction Center, NCEP

May 8, 2009

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)

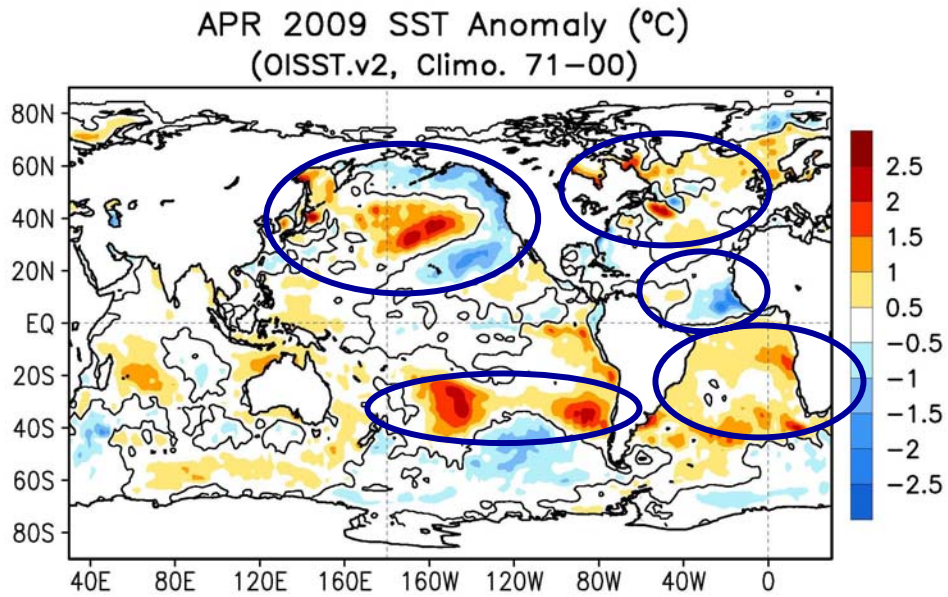
Outline

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

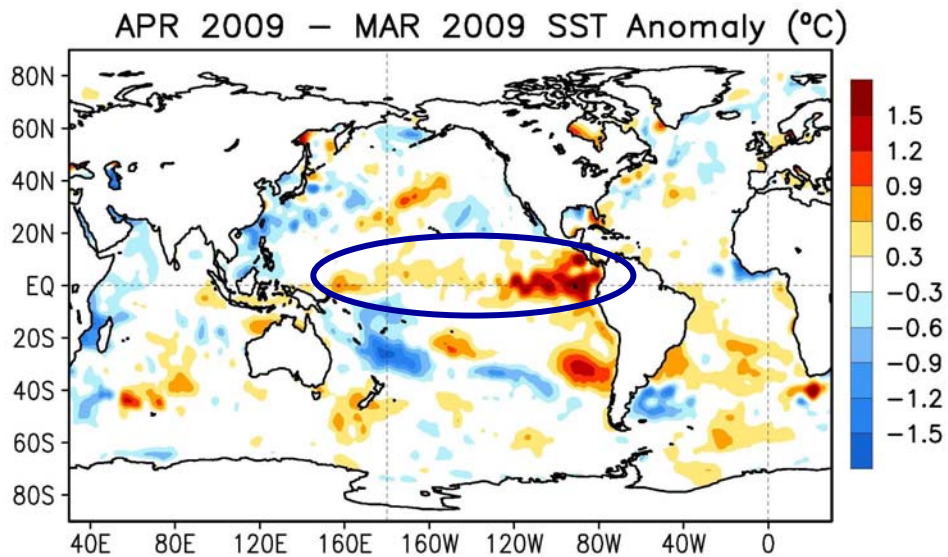
Overview

- **Pacific Ocean**
  - The equatorial Pacific Ocean warmed up significantly due to downwelling Kelvin wave forced by MJO-related westerly wind anomalies.
  - Transition from La Nina to ENSO-neutral conditions occurred in April 2009.
  - Negative PDO phase since September 2007 has persisted for 20 months now.
  - Above-normal upwelling has persisted since mid-November 2007 along the west coast of North America north of 35N.
- **Indian Ocean**
  - IOD index was near-normal.
  - Positive SST anomalies in the southwest Indian Ocean persisted.
- **Atlantic Ocean**
  - Below-normal SST in the southeast tropical Atlantic persisted, while above-normal SST in the tropical South Atlantic and equatorial Atlantic strengthened.
  - ITCZ was shifted southward in responding to the negative meridional gradient of SSTA.
- **Arctic Ocean**
  - Sea ice extent was close to normal due to a slower retreat of sea ice than that of the average seasonal cycle.

Global SST Anomaly (⁰C) and Anomaly Tendency



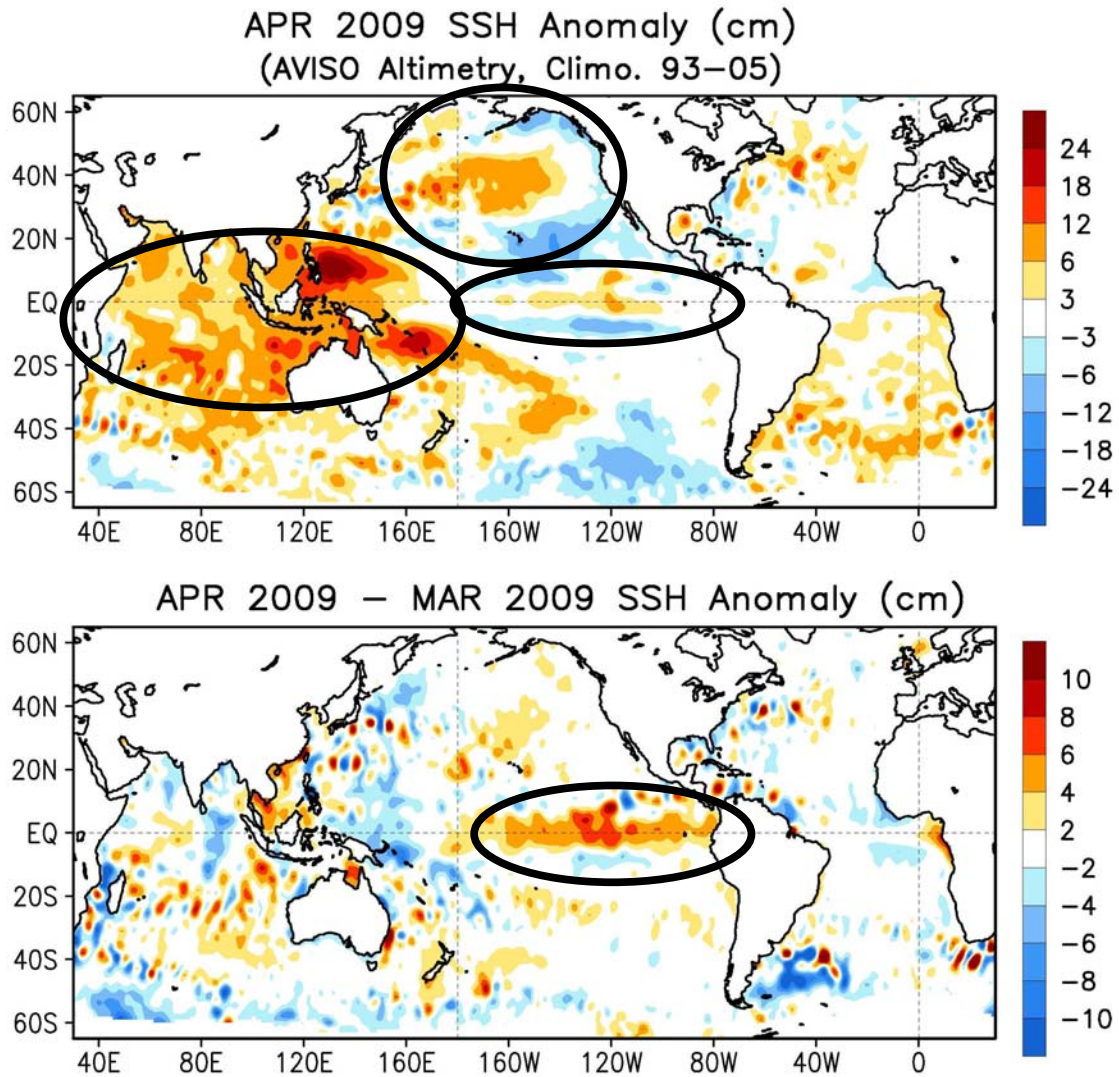
- **Negative PDO-like SST pattern in North Pacific persisted.**
- **ENSO-neutral conditions in the tropical Pacific.**
- **Above-normal SST in the mid-latitude South Pacific.**
- **Above-normal SST in the mid-high latitude North Atlantic and South Atlantic, but below-normal SST in the northeast tropical Atlantic.**



- **SST warmed up substantially along the equatorial tropical Pacific, and La Nina conditions transitioned to ENSO-neutral conditions in April 09.**

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

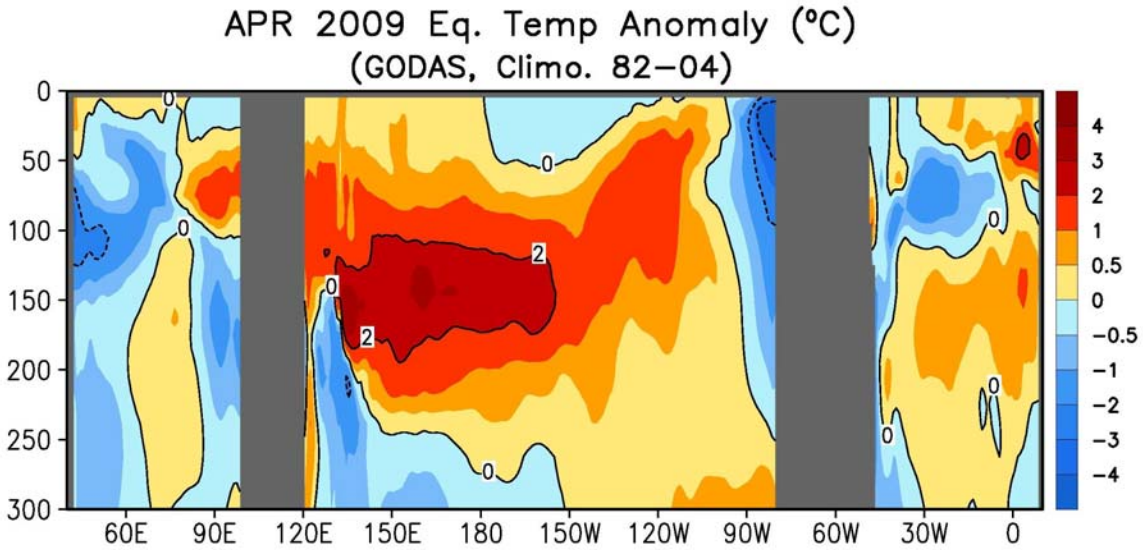


- **Negative PDO-like SSHA in North Pacific, consistent with negative PDO-like SSTA.**
- **Weak positive SSHA along the equatorial Pacific, consistent with ENSO-neutral conditions.**
- **Positive SSHA in the tropical Indian Ocean and western Pacific.**

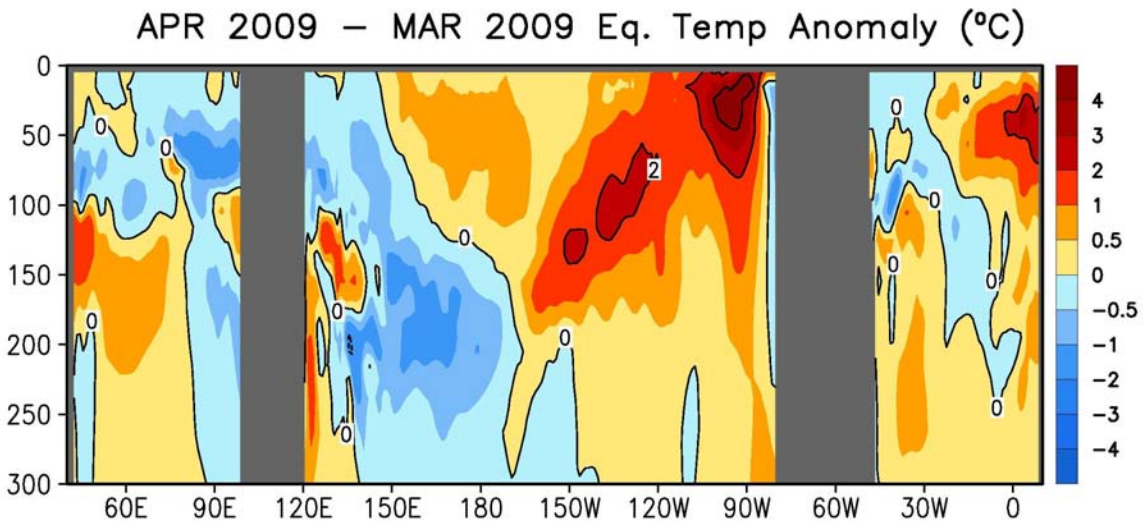
- **SSH increased (decreased) east (west) of the Dateline, in response to a reduction of equatorial trade winds, and contributed to the warming in SST.**

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 1-2°C along the thermocline extended from the far western Pacific to about 100W, while negative temperature anomalies confined to the far eastern Pacific.

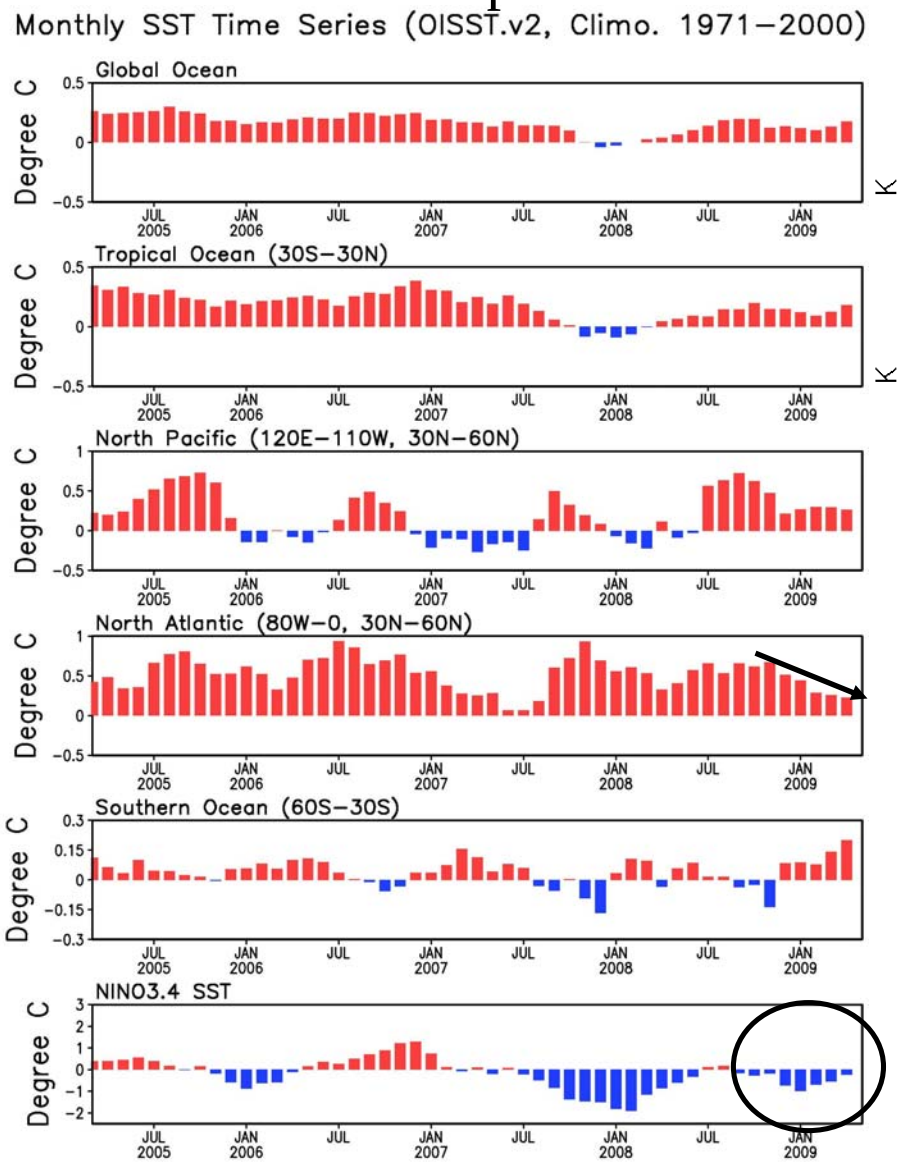


- Strong positive subsurface temperature tendency about 1-2°C along the thermocline in the central and eastern Pacific.
- Negative subsurface temperature tendency near the thermocline in the western Pacific.

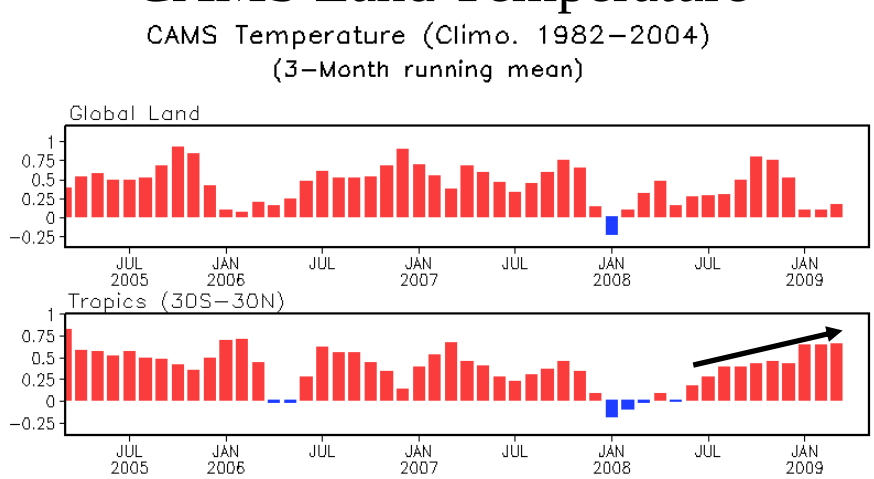
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1982-2004 base period means.

Monthly Time Series

Sea Surface Temperature



CAMS Land Temperature

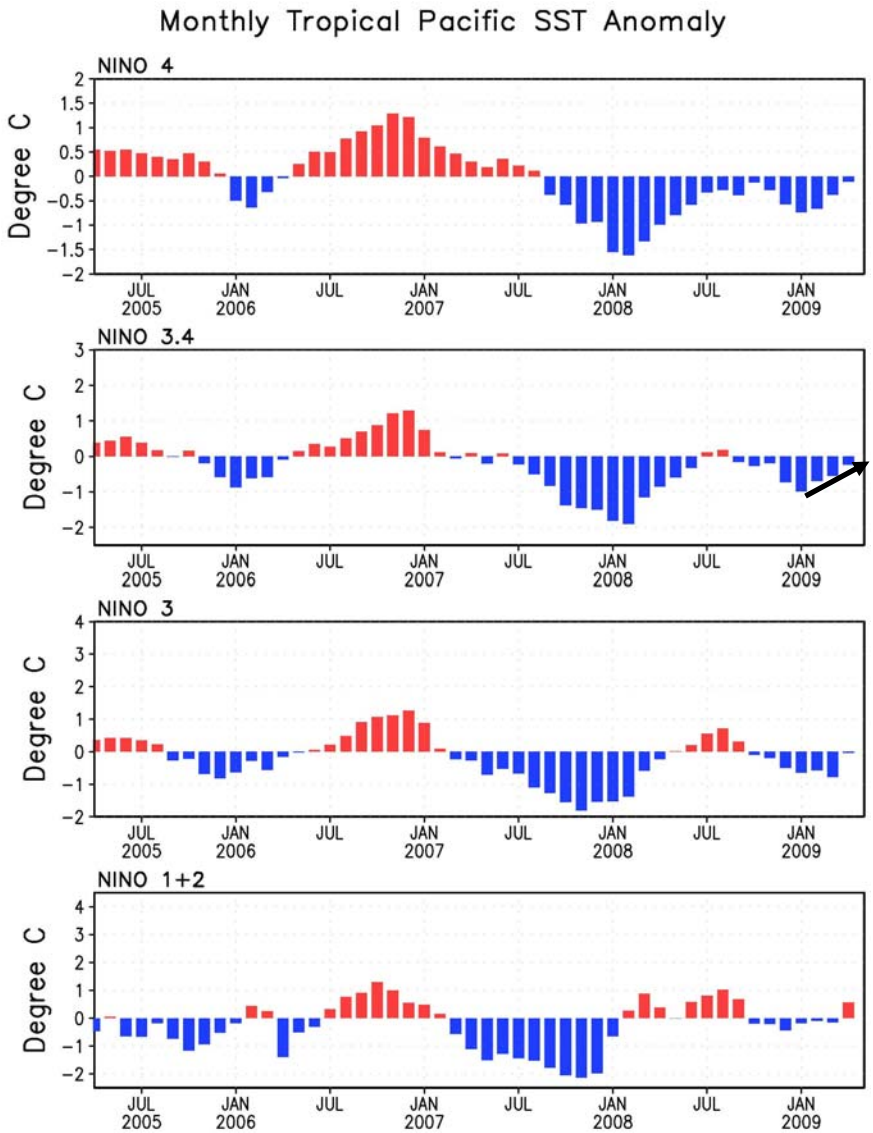


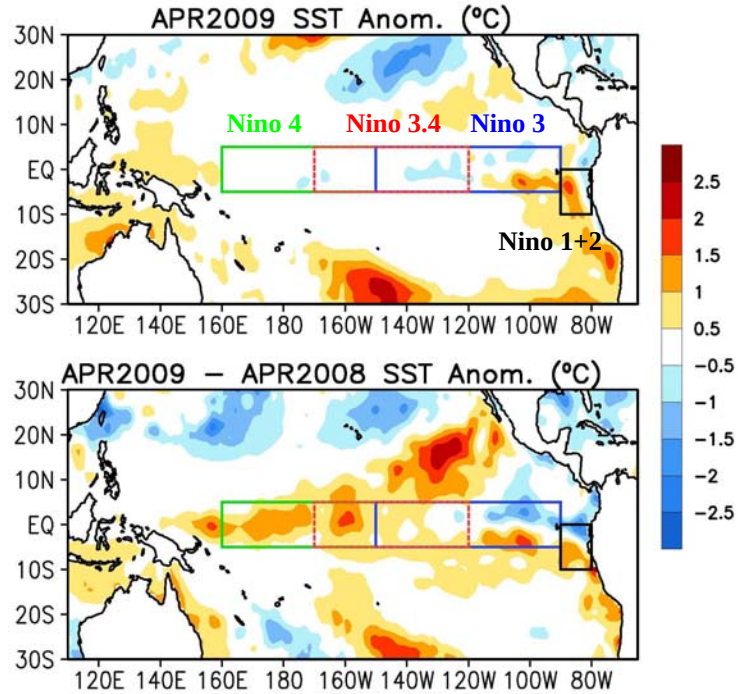
- **Global mean SSTA strengthened slightly.**
- **Global mean of seasonal land temperature was near-normal, but increased slightly from JFM to FMA.**
- **Tropical land temperature continued to be well above-normal in response to the above-normal tropical ocean SST.**
- **Weak positive SSTA in North Pacific continued.**
- **Positive SSTA in North Atlantic continued a cooling trend starting from last November.**
- **Positive SSTA in Southern Ocean strengthened.**
- **NINO 3.4 SST became near-normal in April 09.**

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

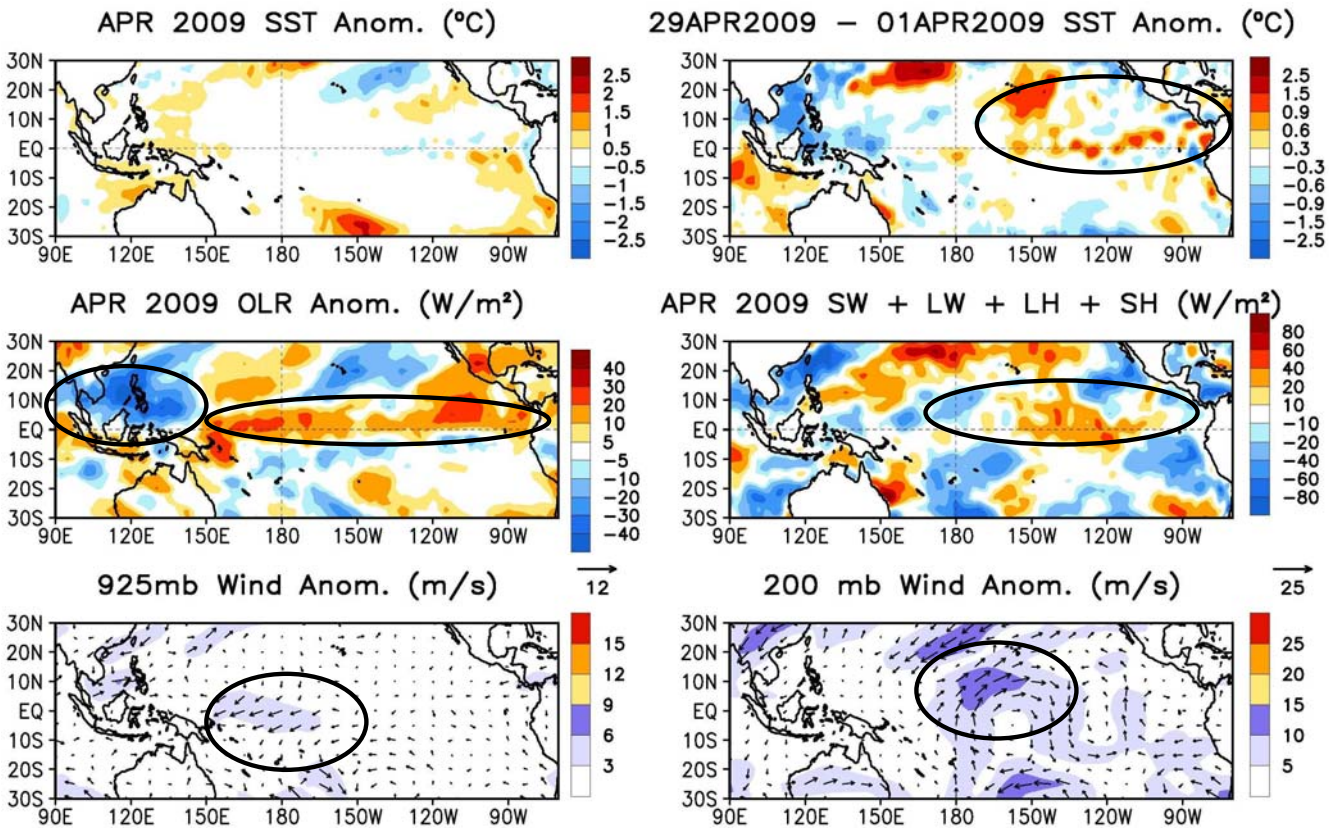




- **During April 2009, the equatorial Pacific Ocean transitioned from La Niña to ENSO-neutral conditions, ending the 2008-09 La Niña – NOAA's "ENSO Diagnostic Discussion" (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.pdf).**

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



- Suppressed (enhanced) convection in the central-eastern tropical Pacific (northern Maritime Continents).
- Low-level (upper-level) easterly (westerly) wind anomalies in the central tropical Pacific, indicative of lingering La Nina features.
- Surface net heat flux anomalies contributed to the SST warming in the eastern tropical Pacific.

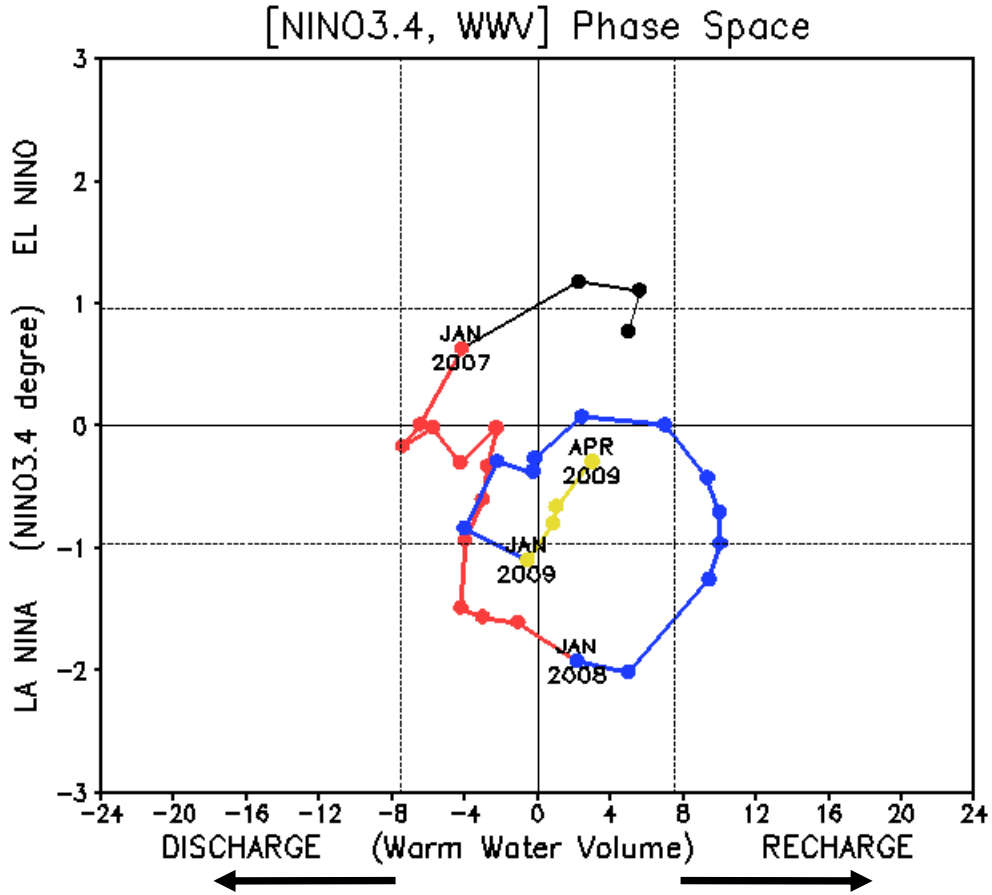
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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

- The equatorial heat content (HC) recharged significantly from March to April 2009, continuing the upward trend since Dec 2008.

- Accompanying the recharge of the equatorial HC, NINO 3.4 warmed significantly from March to April 2009.

- Compared to last spring, the equatorial SST was warmer and heat content was cooler, but both were near-normal, indicating ENSO-neutral conditions will likely continue in the next 3 months.



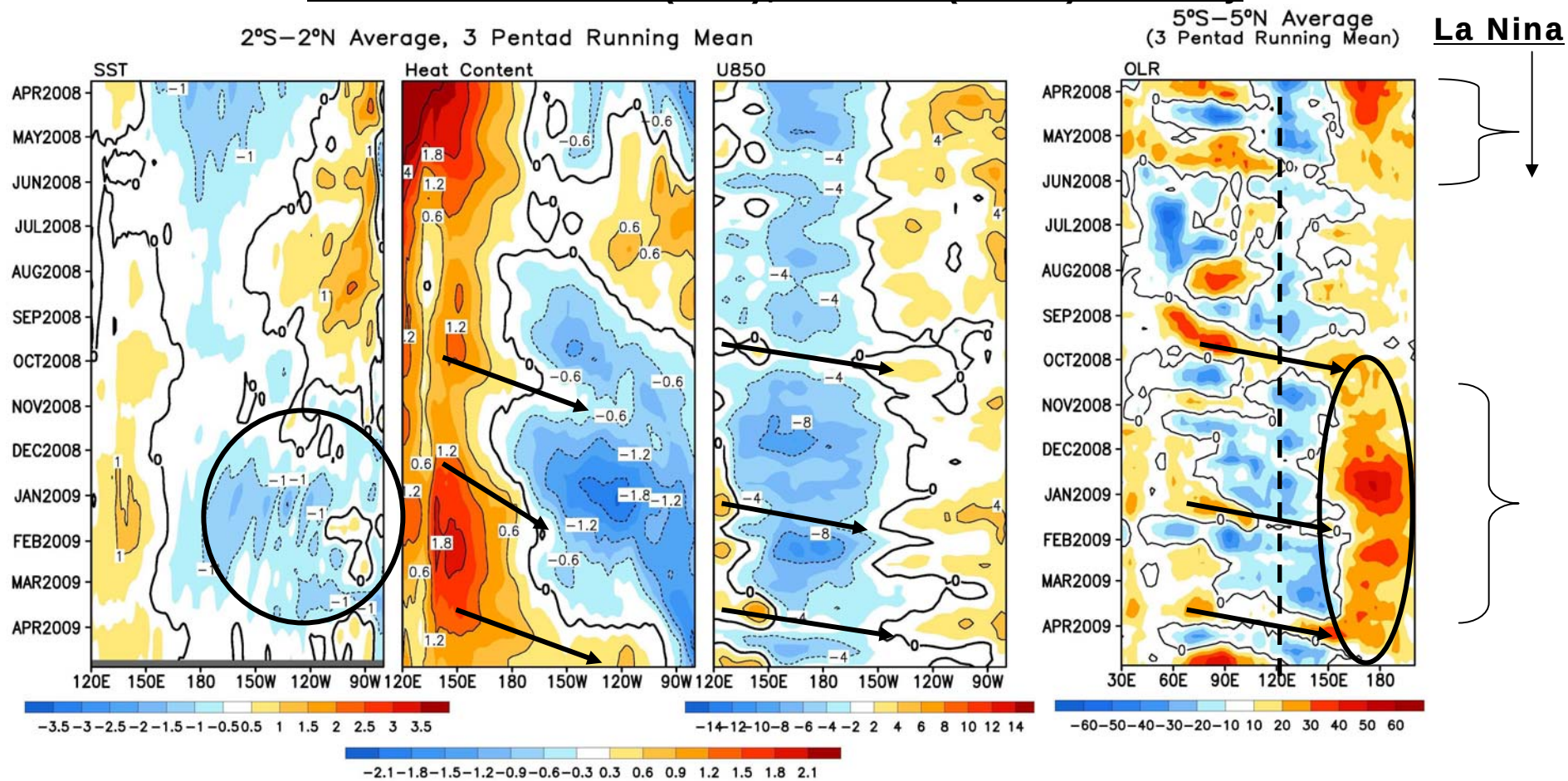
-WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N] (Meinen and McPhaden, 2000).

-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.

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.

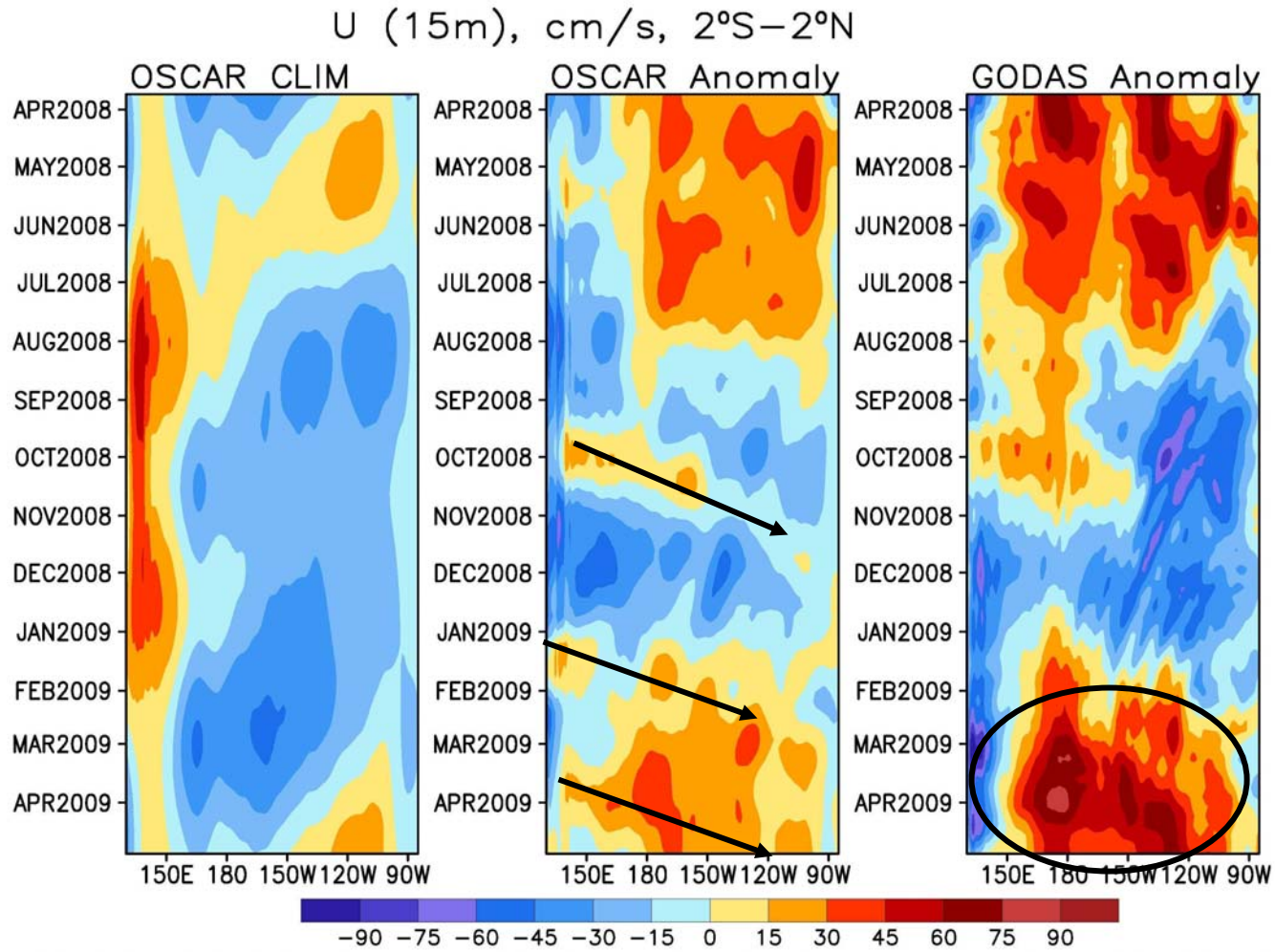
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²) Anomaly



- Below-normal SSTs in the central and eastern tropical Pacific during Nov 2008 – Mar 2009.
- Three episodes of eastward propagation of positive heat content anomalies associated with downwelling Kelvin waves were forced by westerly wind bursts (WWB) associated with MJO activity since September 2008.
- The WWB in March 2009 was the strongest, and since then, has induced substantial warming in the subsurface temperature in the eastern Pacific, contributing to the transition from La Nina to ENSO-neutral conditions in April 2009.

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.

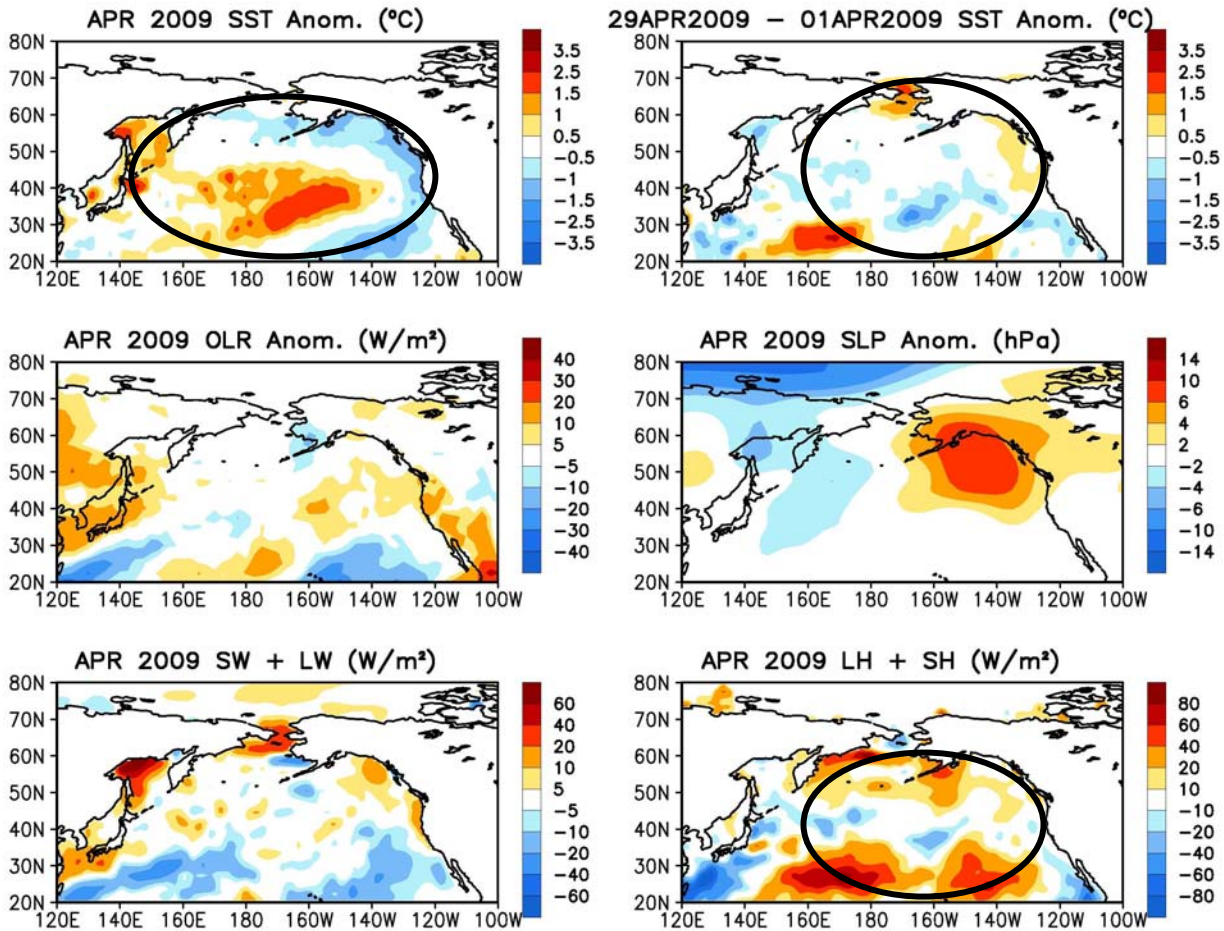
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- **Eastward propagation of positive surface zonal current anomalies were associated with downwelling oceanic Kelvin waves.**
- **Surface zonal current anomalies switched from negative to positive in mid-Jan 09 and have persisted since then, which have contributed to the decay of the 2008/09 La Nina and transition from La Nina to ENSO-neutral conditions.**
- **Positive surface zonal current anomalies in GODAS were too strong compared with those of the OSCAR currents.**

North Pacific & Arctic Ocean

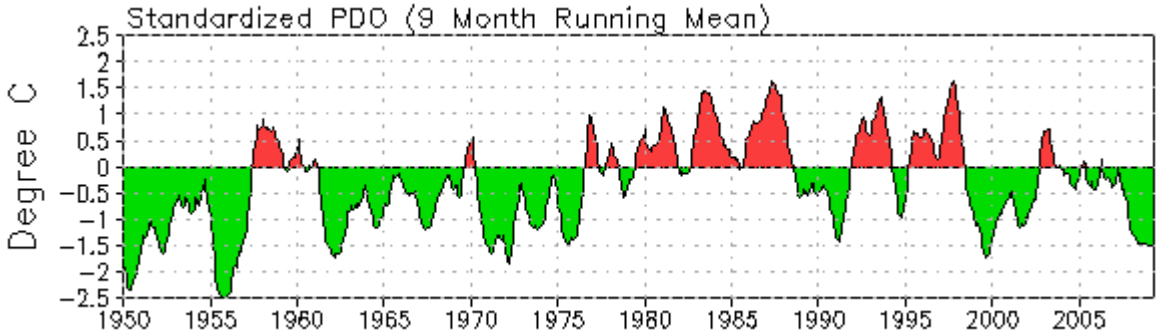
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx



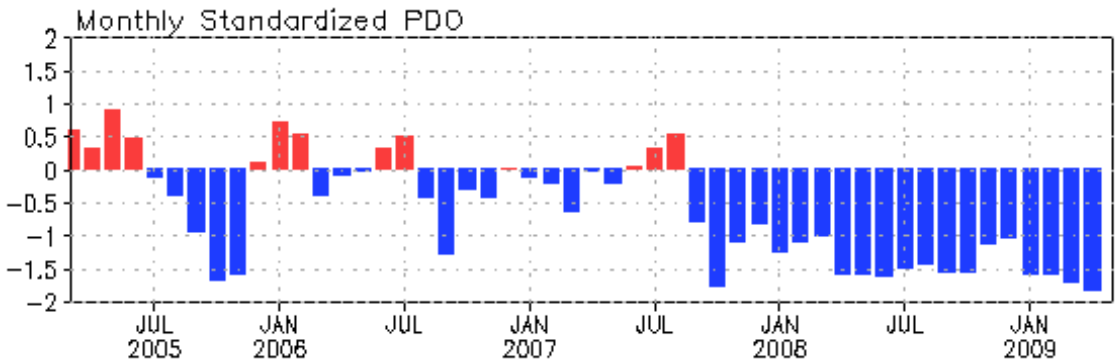
- **Negative PDO-like SST pattern in North Pacific.**
- **SSTA tendencies were largely consistent with surface net heat flux anomalies.**
- **Anti-cyclonic wind anomalies associated with positive SLP anomalies in the Gulf of Alaska favoured coastal upwelling along the west coast of North America north of 35N (slide 18).**

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.

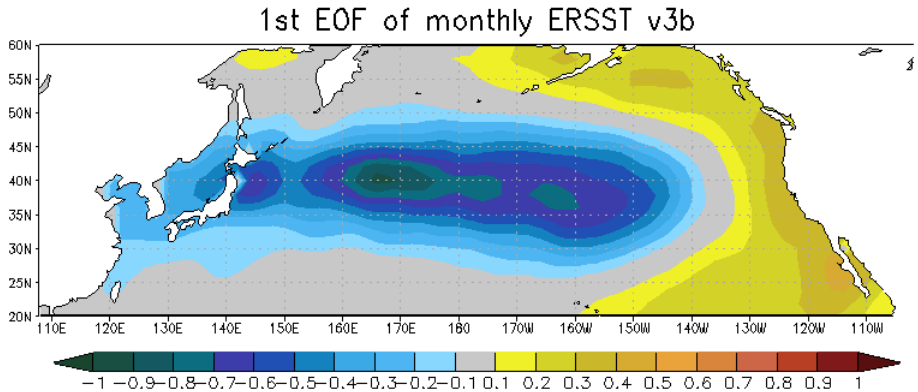
PDO index



PDO index is at the lowest value since 1999.



Negative PDO index started in September 2007, and has now persisted for 20 months.

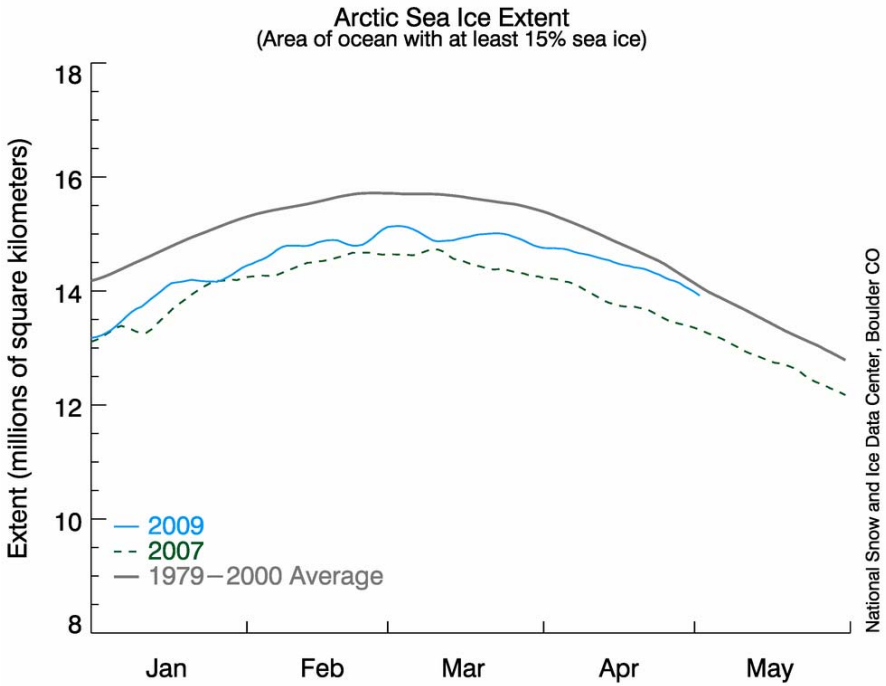


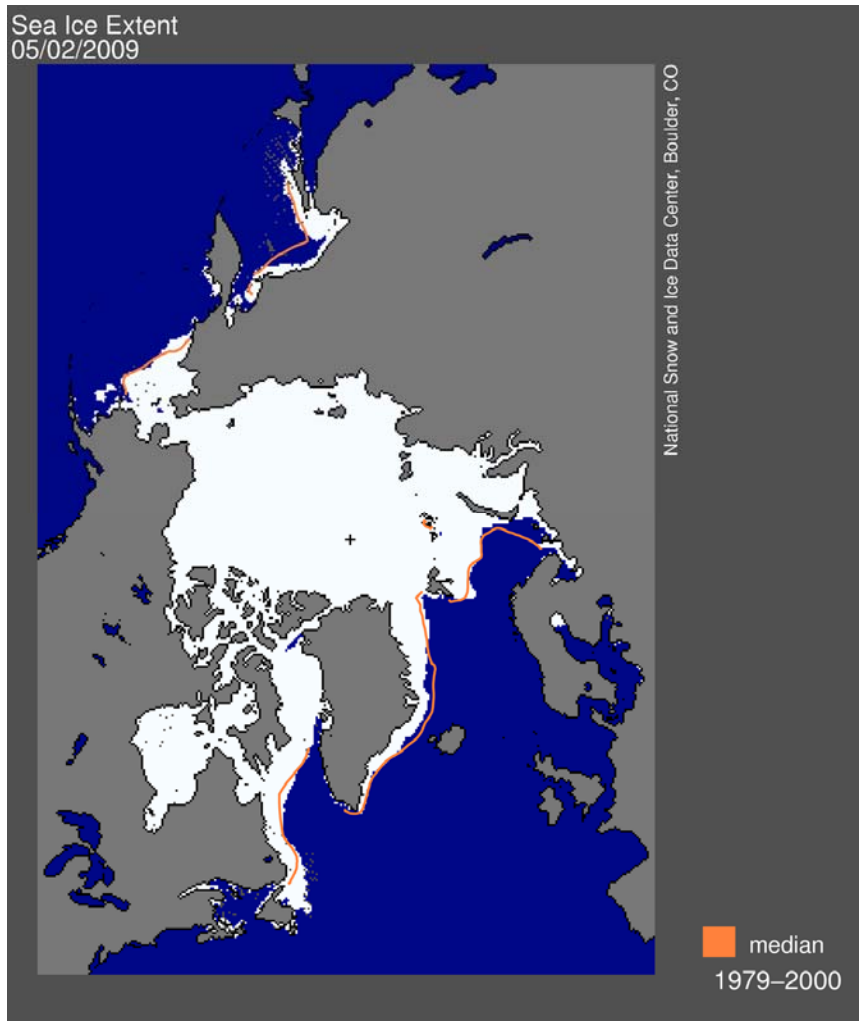
- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.**
- **The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OI.v1 and OI.v2 SST.**

Arctic Sea Ice

National Snow and Ice Data Center

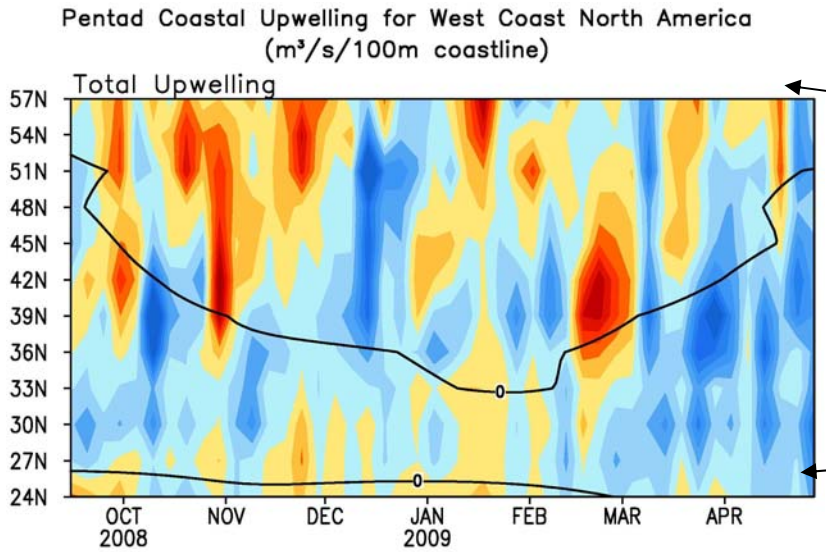
http://nsidc.org/arcticseaicenews/index.html

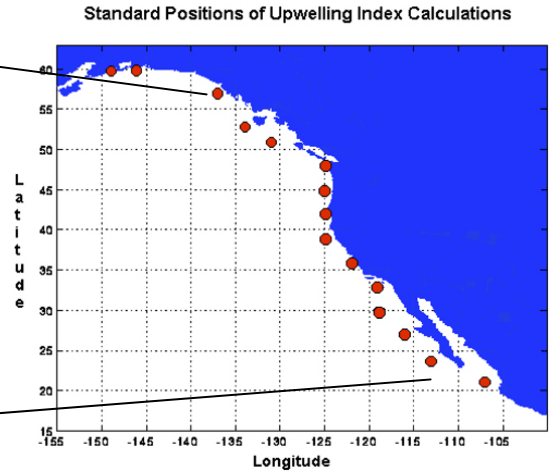


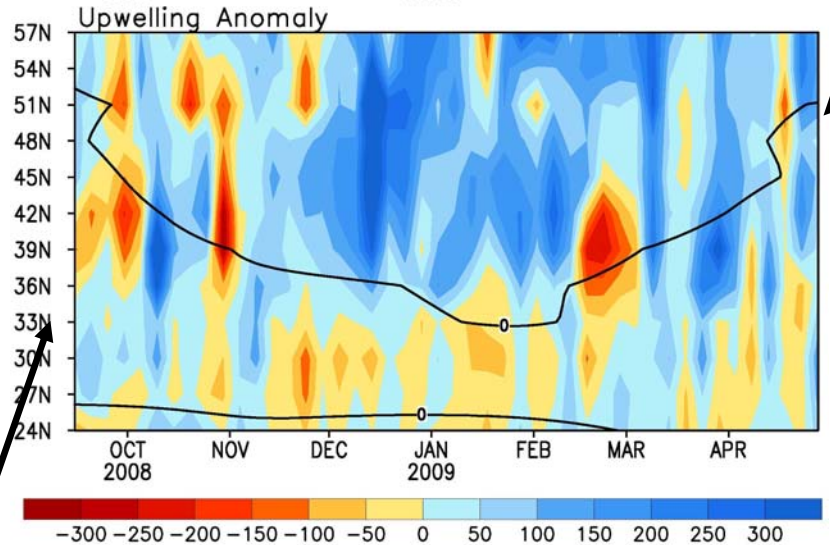


- Retreat of the Arctic sea ice was slower than that of the average seasonal cycle in April 2009, and by the end of April 2009 the Arctic sea ice extent reached to be close to the climatology.

North America Western Coastal Upwelling







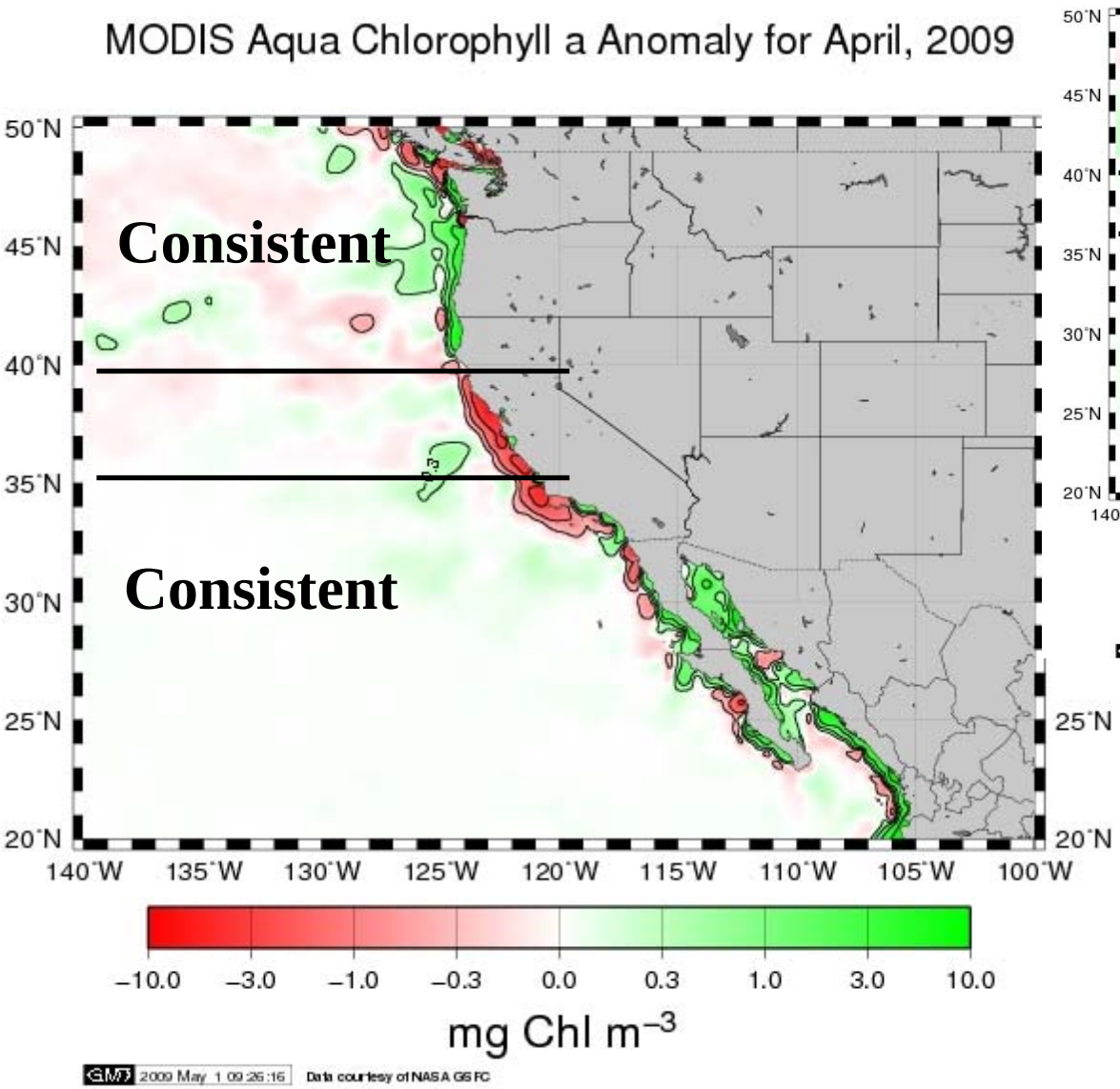
- **Upwelling has been mostly above-normal from mid-Nov 08 to Apr 09 north of 35N.**
- **The above-normal upwelling is associated with the negative PDO phase.**
- **Weak downwelling anomaly south of 35N.**

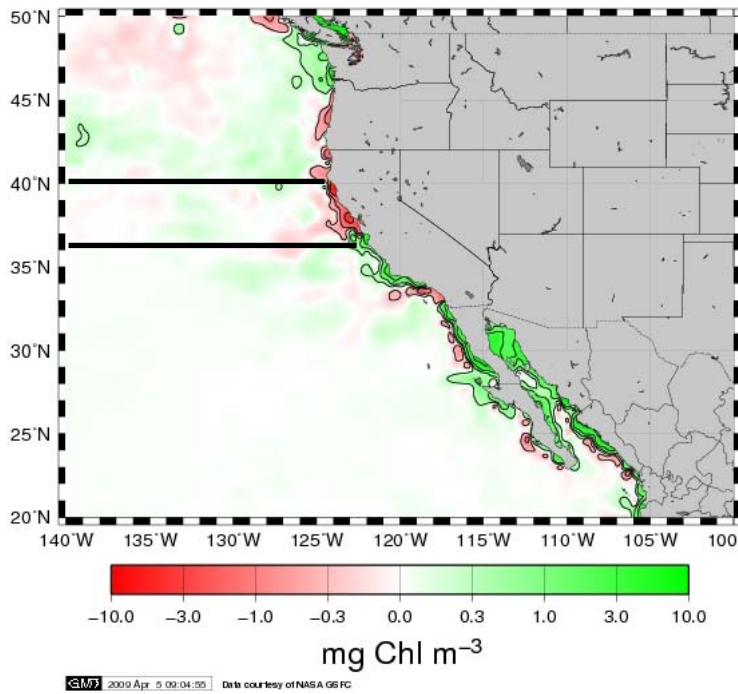
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport 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.noa

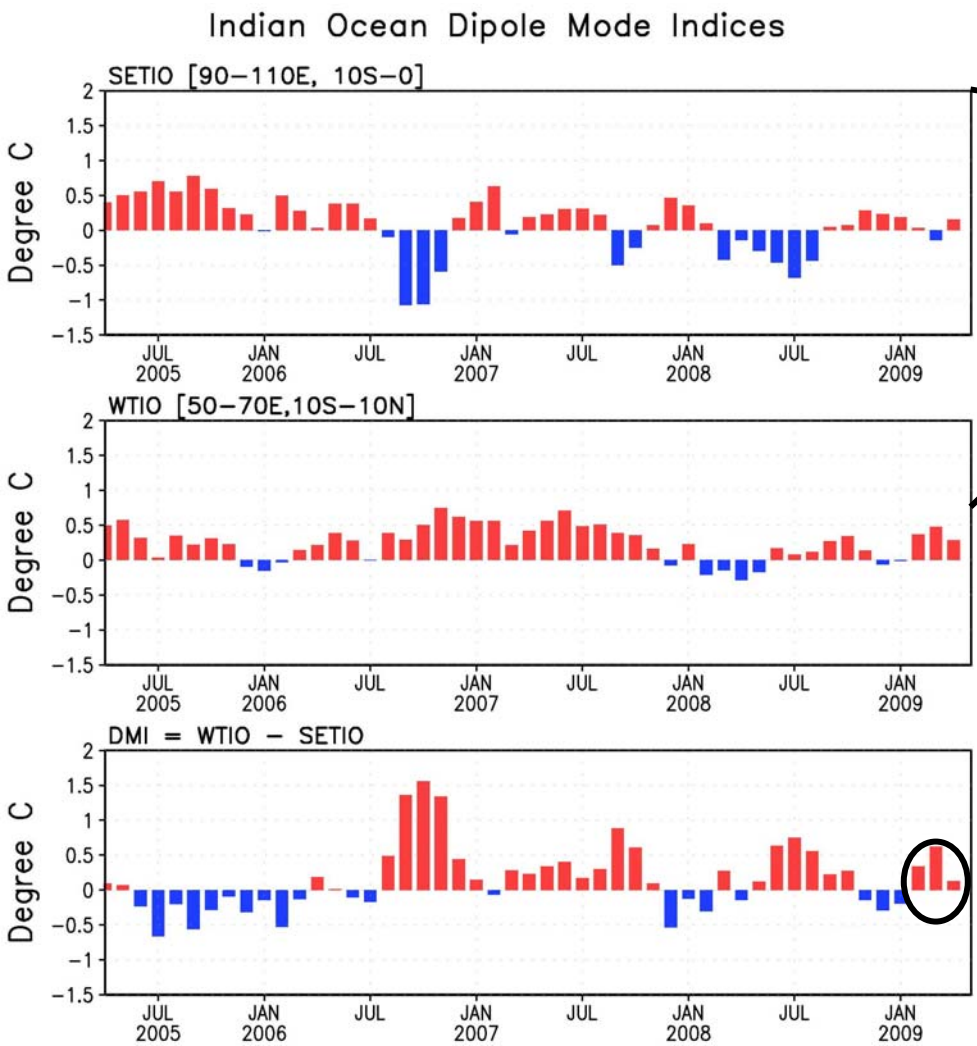


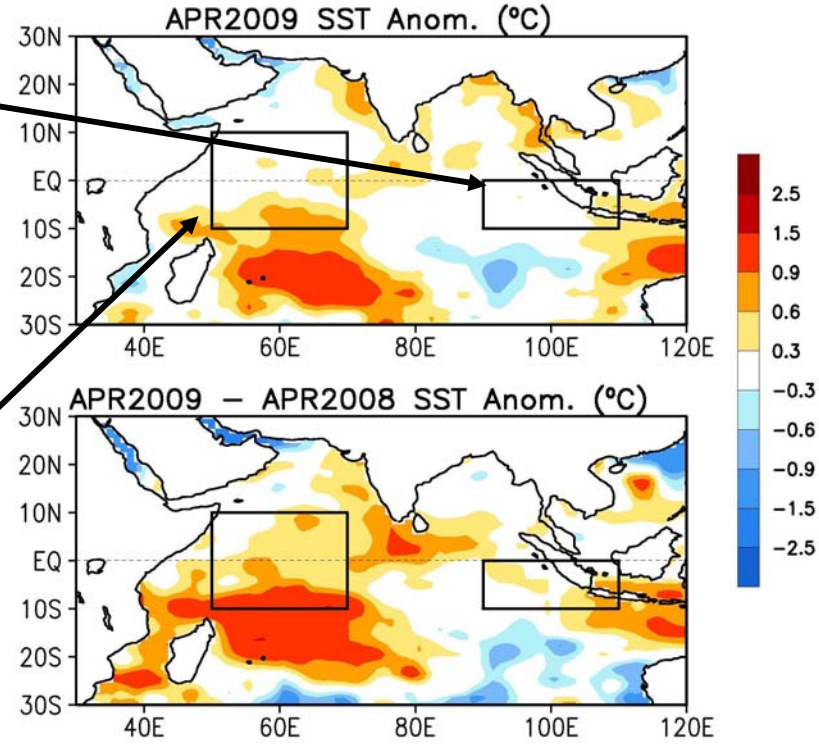


- **Negative (positive) Chlorophyll anomalies north (south) of 40N.**
- **Chlorophyll anomalies were consistent with upwelling anomalies north of 40N and south of 35N.**
- **Negative Chlorophyll anomalies between 35N-40N during March-April 2009 indicated a reduction of the primary productivity in the region.**

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

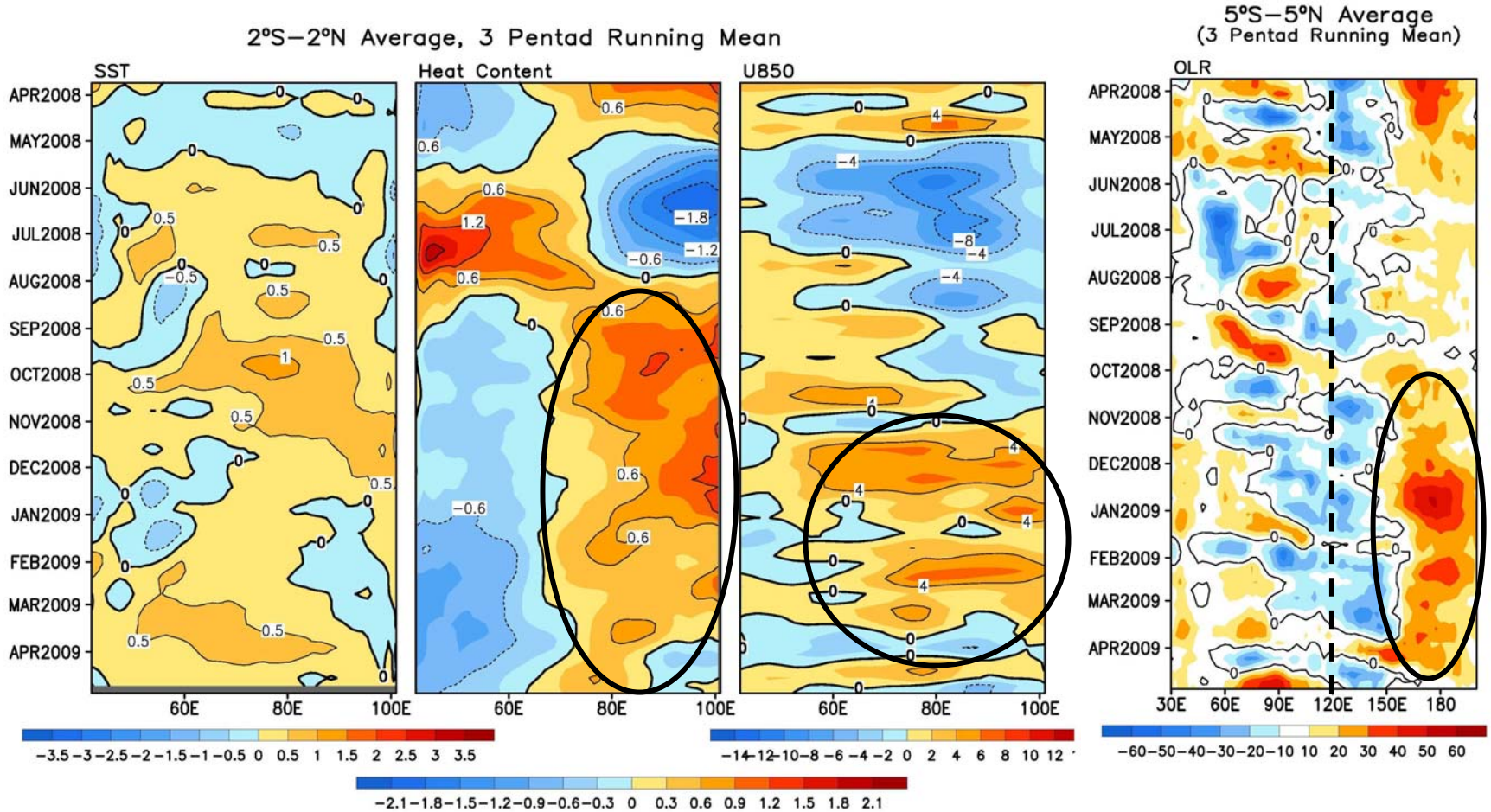




- **DMI was near-normal in April 09.**
- **Large positive SST anomalies in the southwest Indian Ocean persisted.**

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.

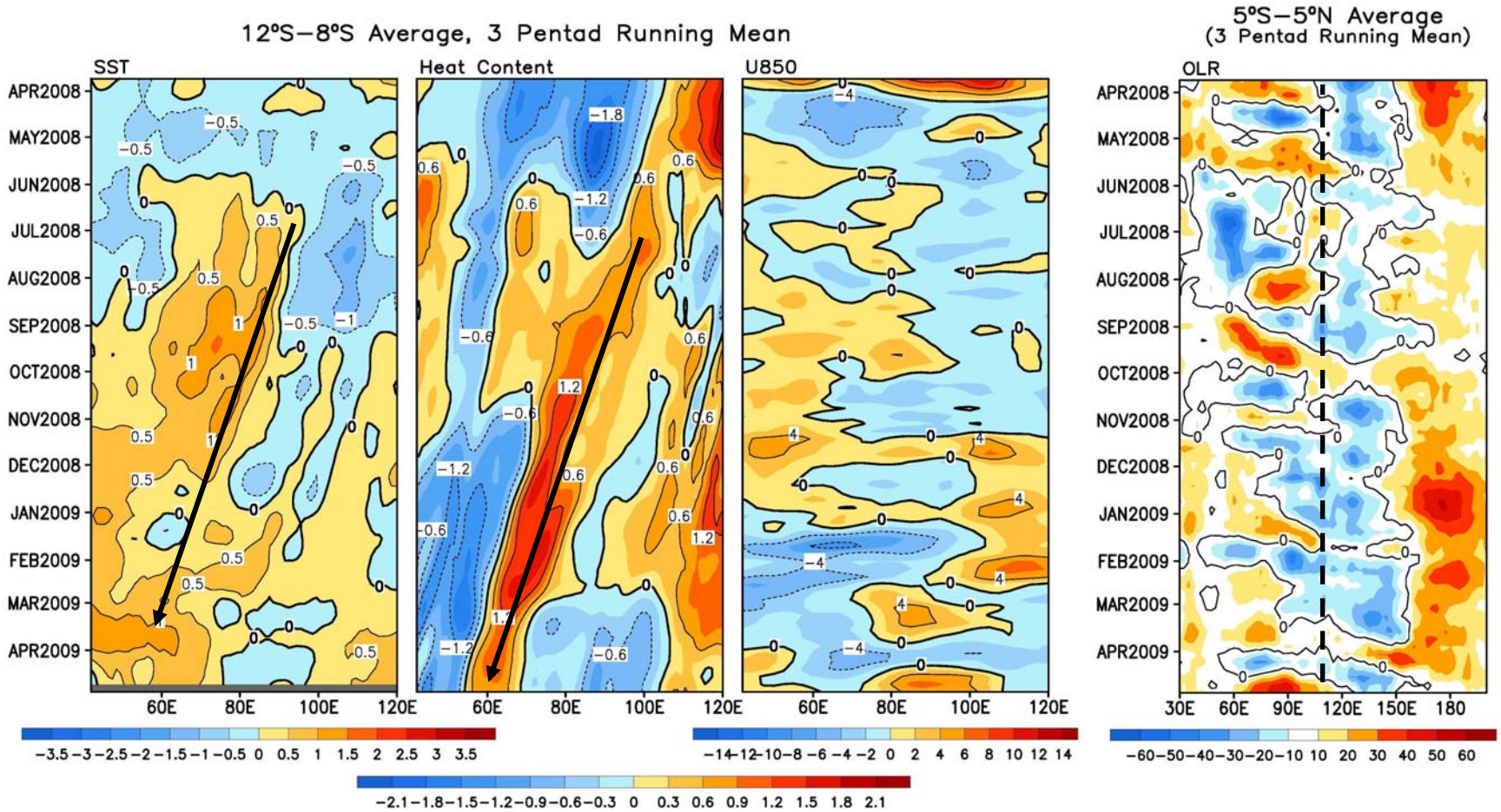
Recent Evolution of Equatorial Indian SST (ºC), 0-300m Heat Content (ºC), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies



- **Persistent westerly zonal wind anomalies (ZWA) during Nov 2008 – Feb 2009 were consistent with the 2008/09 La Nina.**
- **The surge of easterly ZWA during March 2009 were associated with the recent MJO activity.**
- **Positive (negative) HC anomalies in the eastern (western) Indian Ocean were consistent with westerly ZWA forcings.**

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.

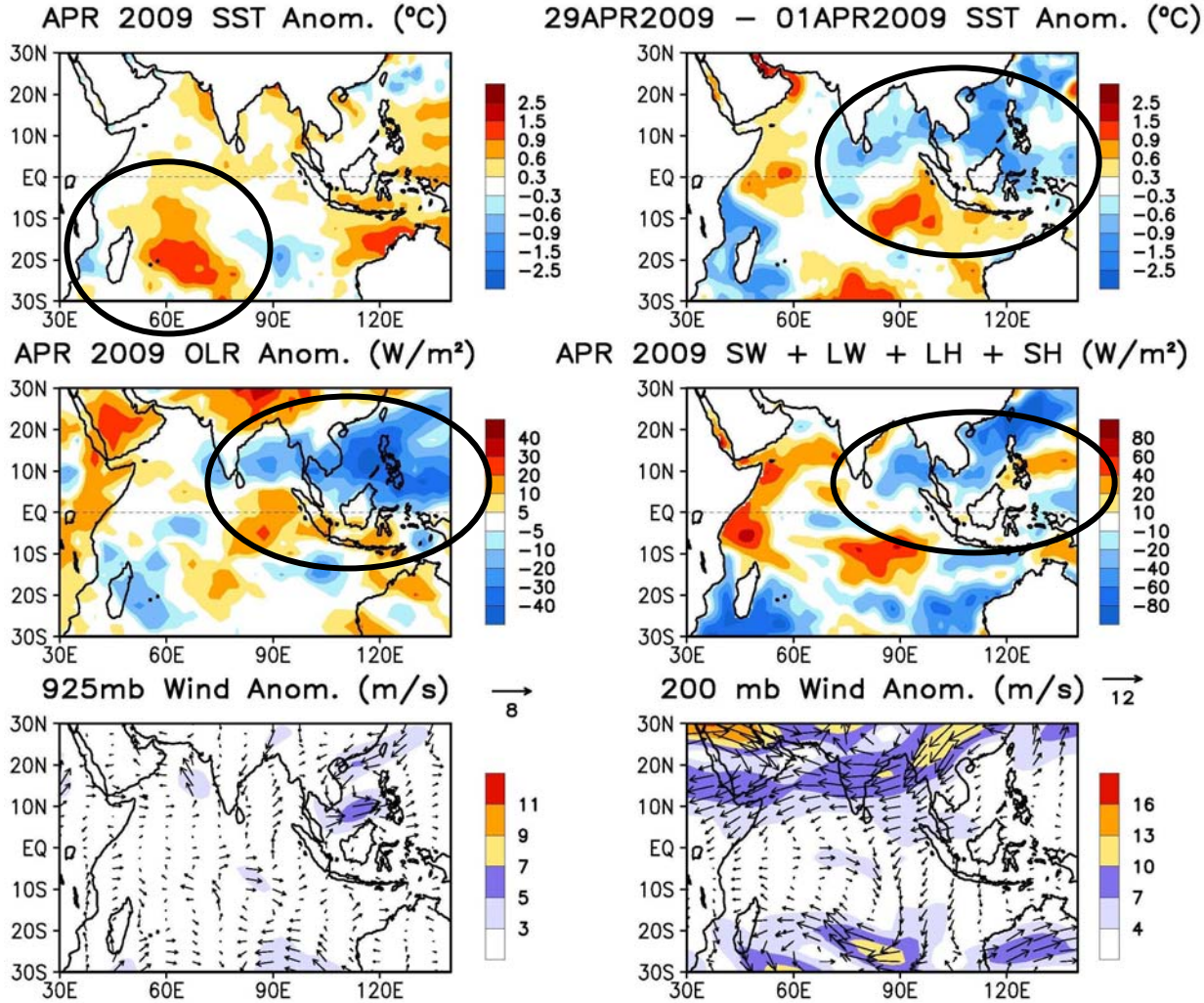
Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)



- **Westward propagation of positive heat content anomalies along 10S has persisted since July 08, which probably contributed to the westward propagation of positive SSTA.**

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.

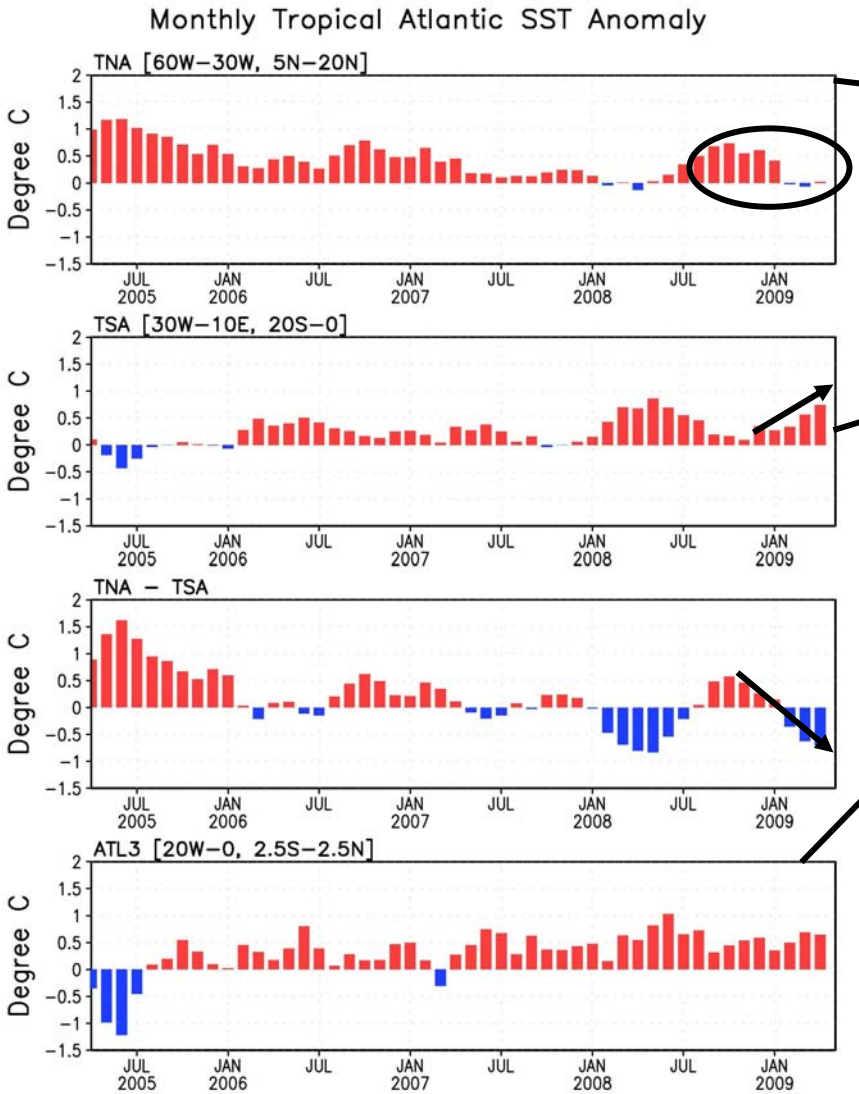


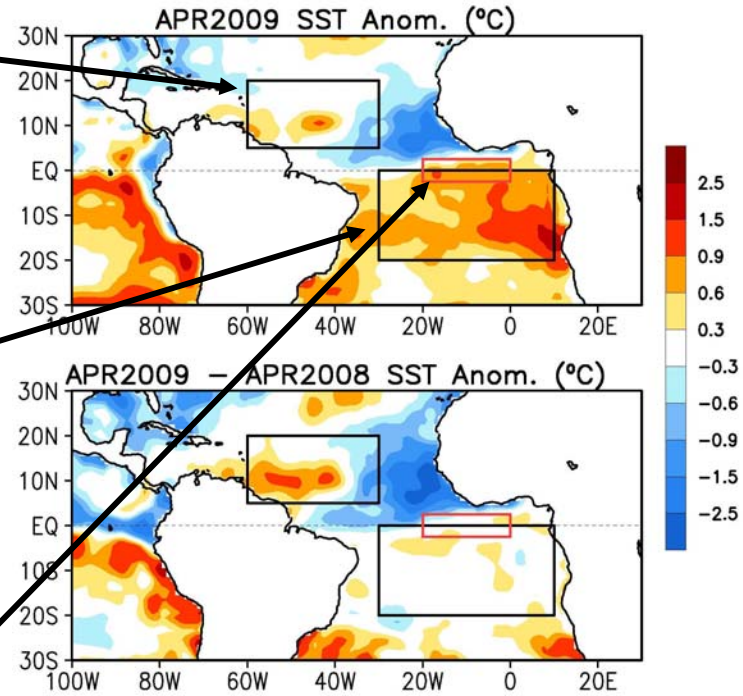
- Positive SSTA presented in the southwest Indian Ocean.
- Convection was enhanced (suppressed) in the northern Indian Ocean and western tropical Pacific (in the eastern tropical Indian Ocean).
- SST tendencies were largely consistent with surface net heat flux anomalies, which were dominated by convection-related short wave radiation anomalies.

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





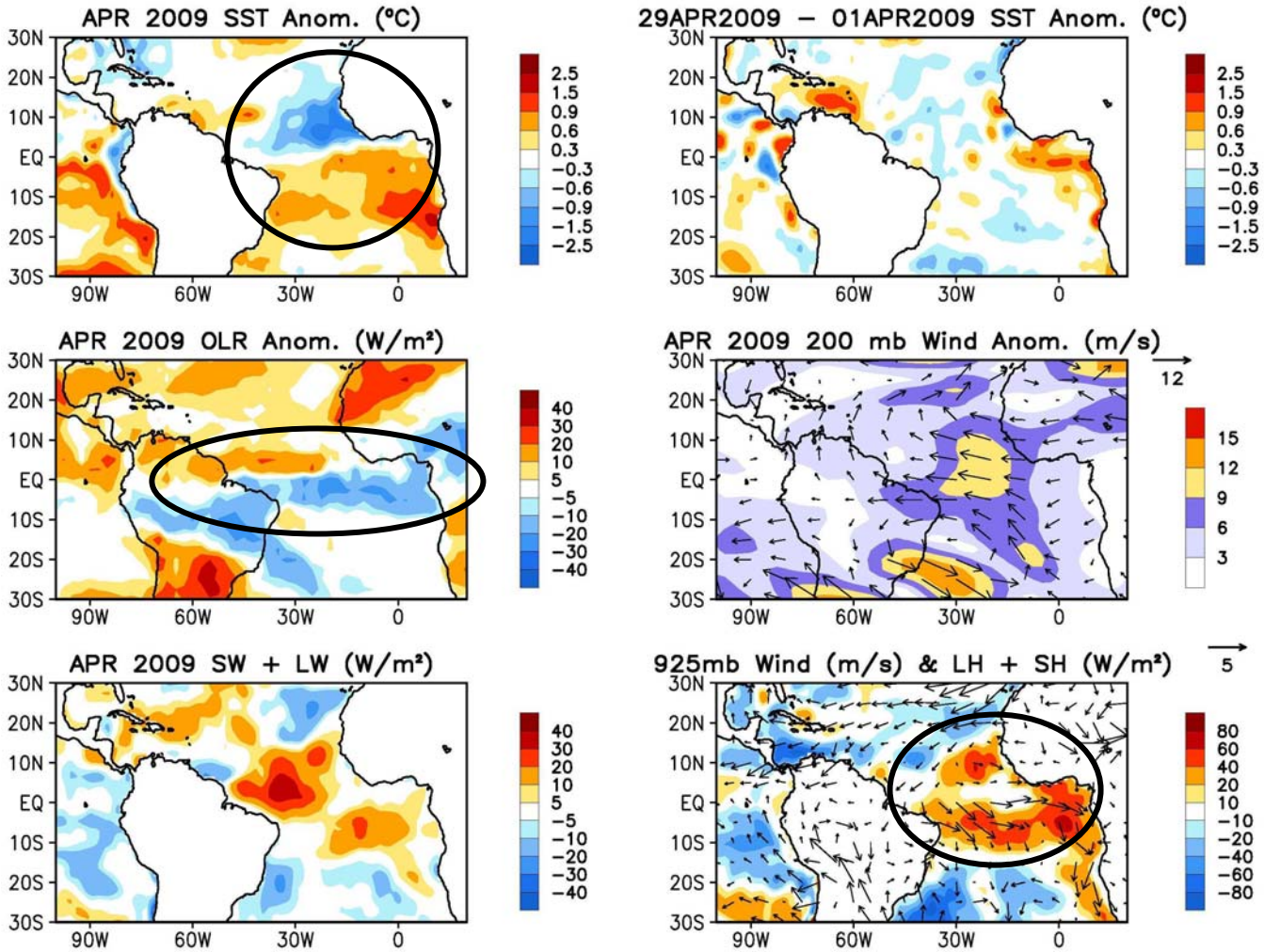
- **Tropical North Atlantic (TNA) index was near-normal, while Tropical South Atlantic (TSA) index was above-normal, and continued an upward trend since Jan 2009.**

- **Meridional Gradient Mode (TNA-TSA) was negative, and continued a downward trend since Oct 2009.**

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



- SST was below-normal (above-normal) in the northeast (southern) tropical Atlantic.
- ITCZ was shifted southward in responding to the negative meridional gradient of SSTA.
- Surface wind anomalies were northeasterly (northwesterly) north (south) of the equator, consistent with the SSTA.

North Atlantic Ocean

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

- North Atlantic SST was slightly above-normal.

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

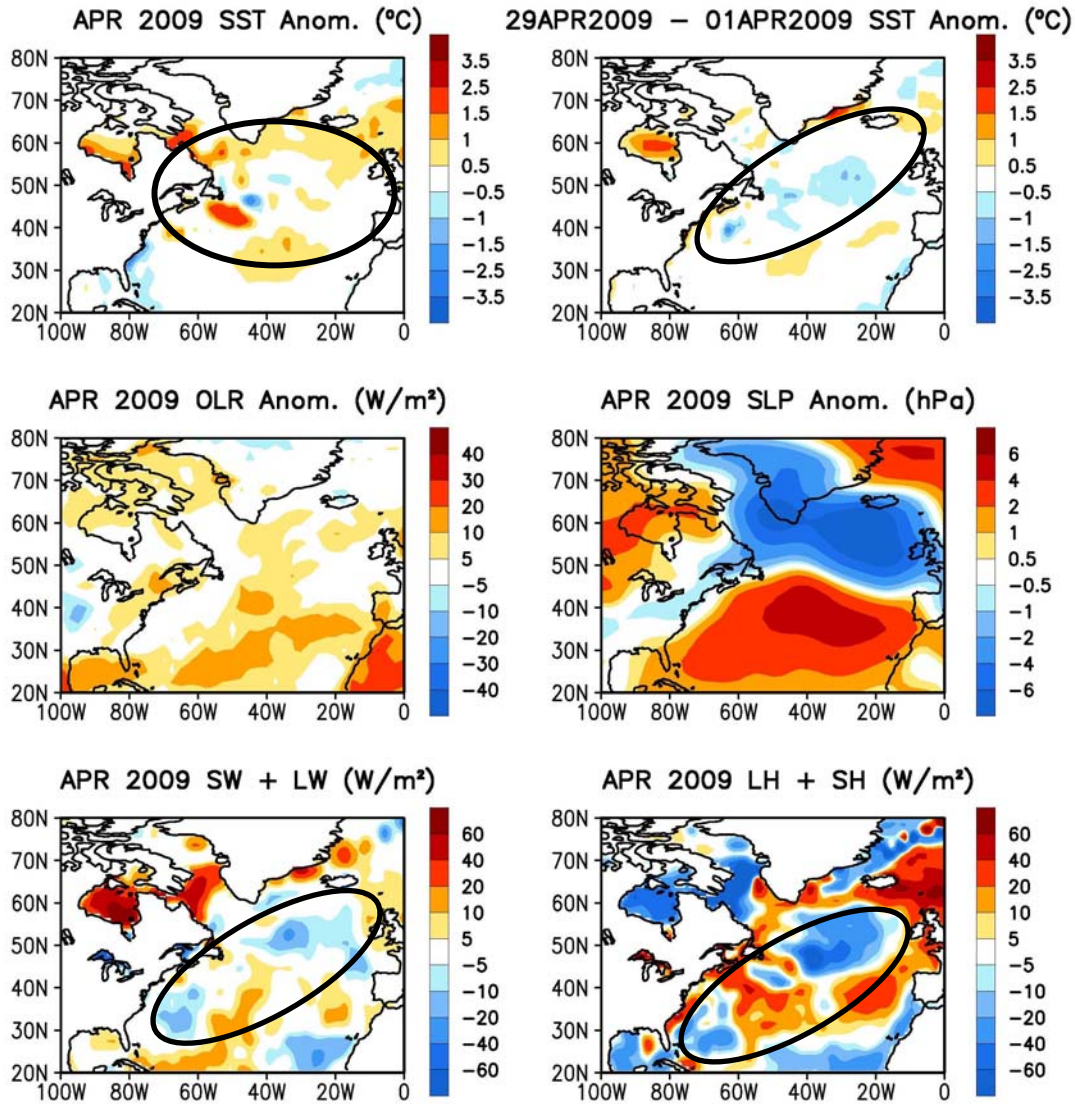
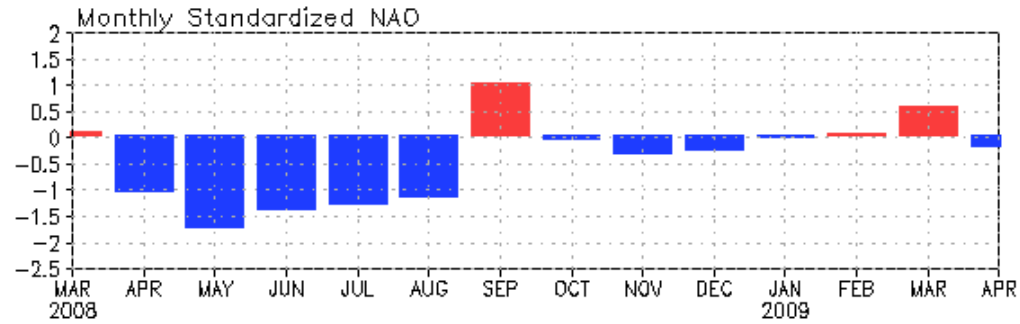
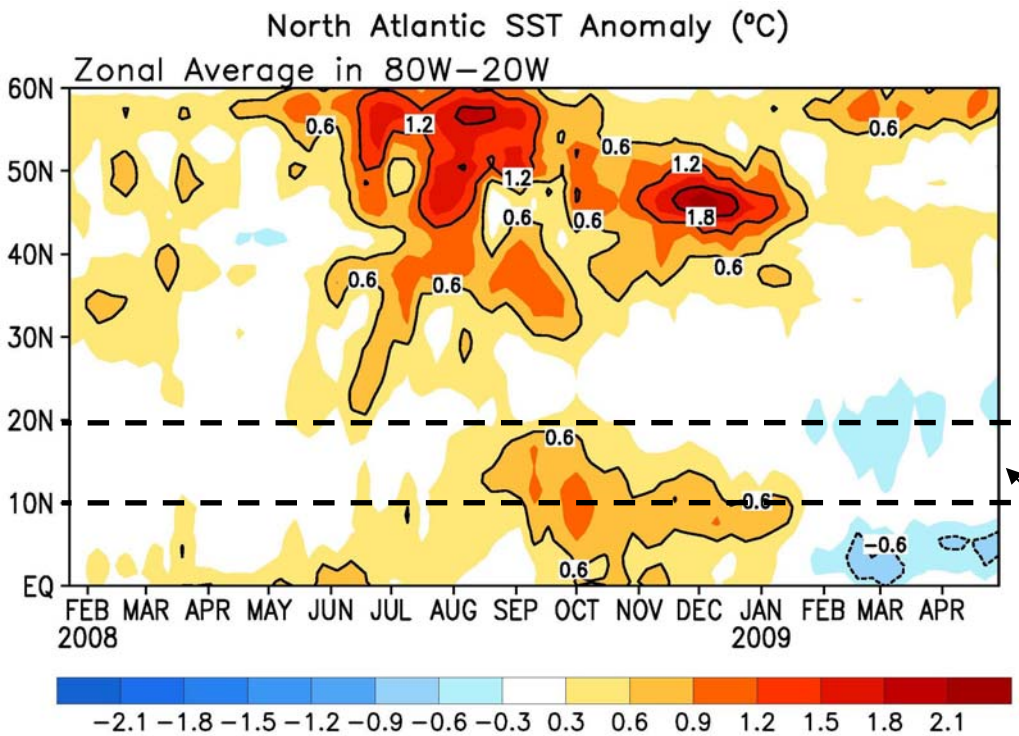
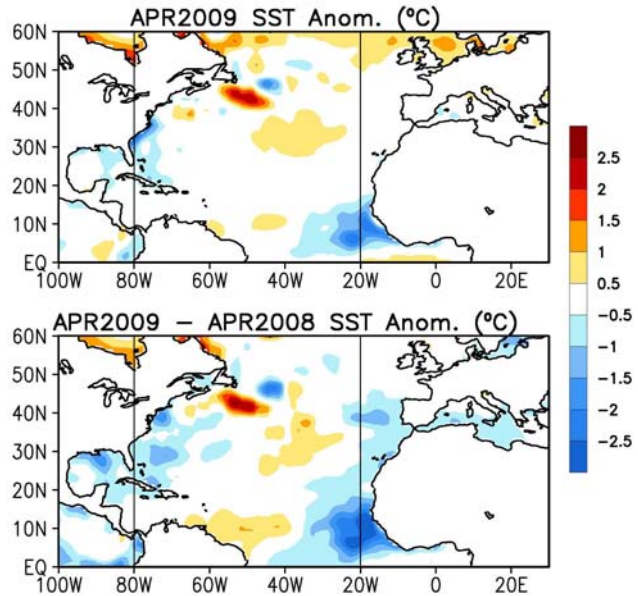


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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



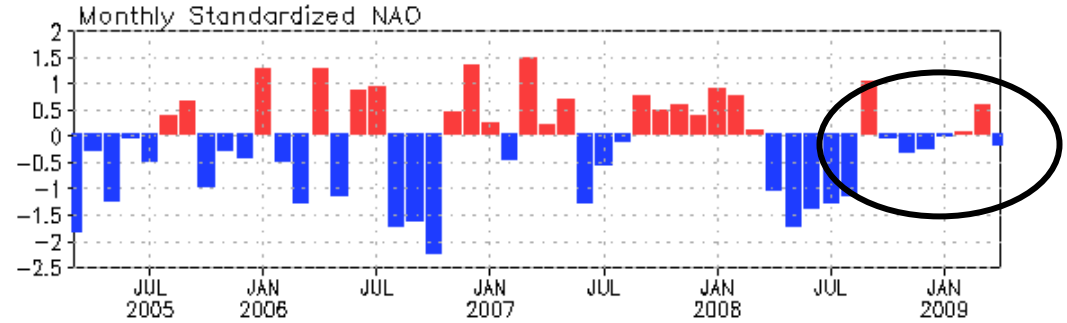


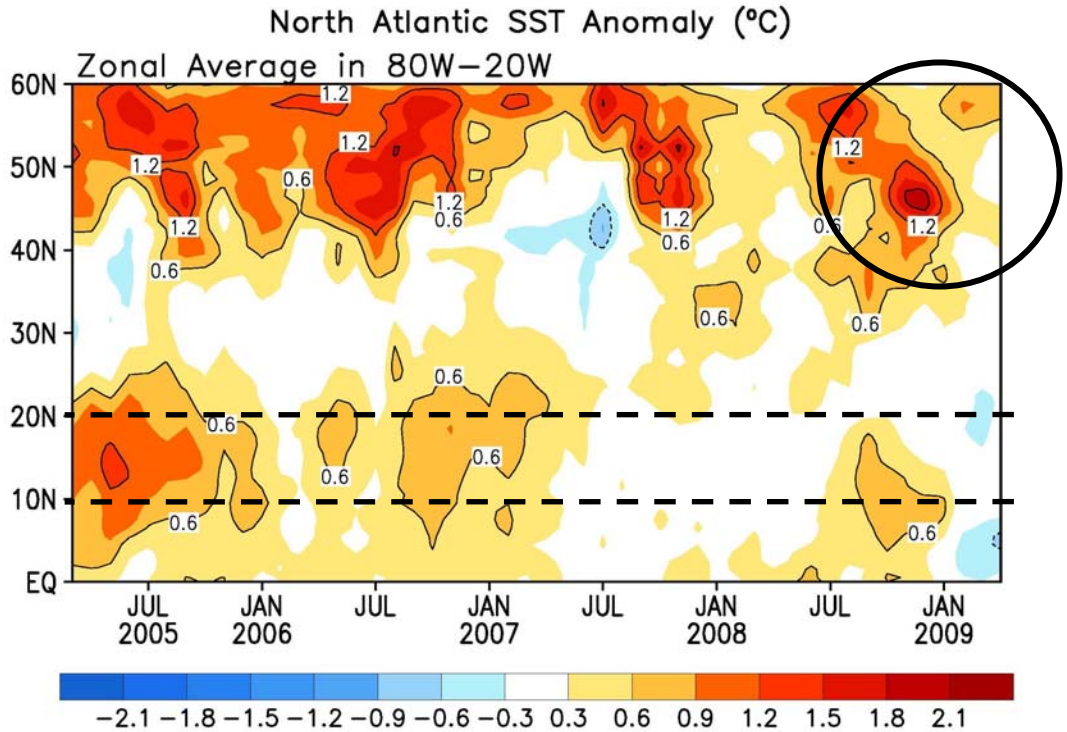


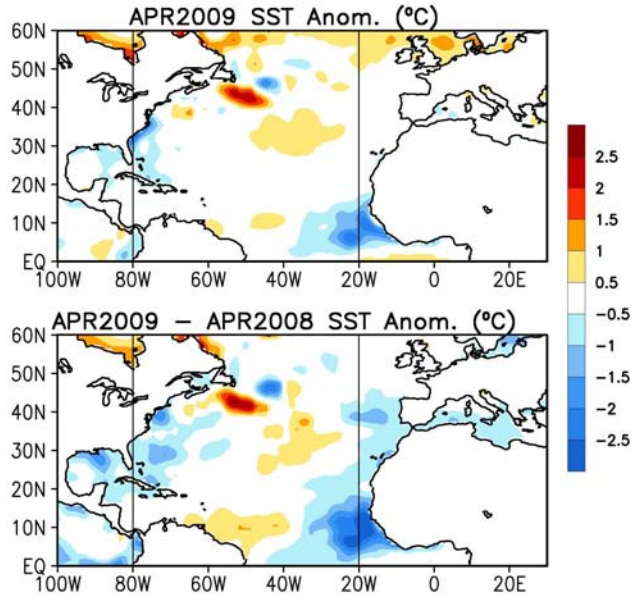
- **High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).**
- **NAO became slightly negative in April 09.**
- **SSTs in the Hurricane Main Development Region (MDR) were near-normal.**

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





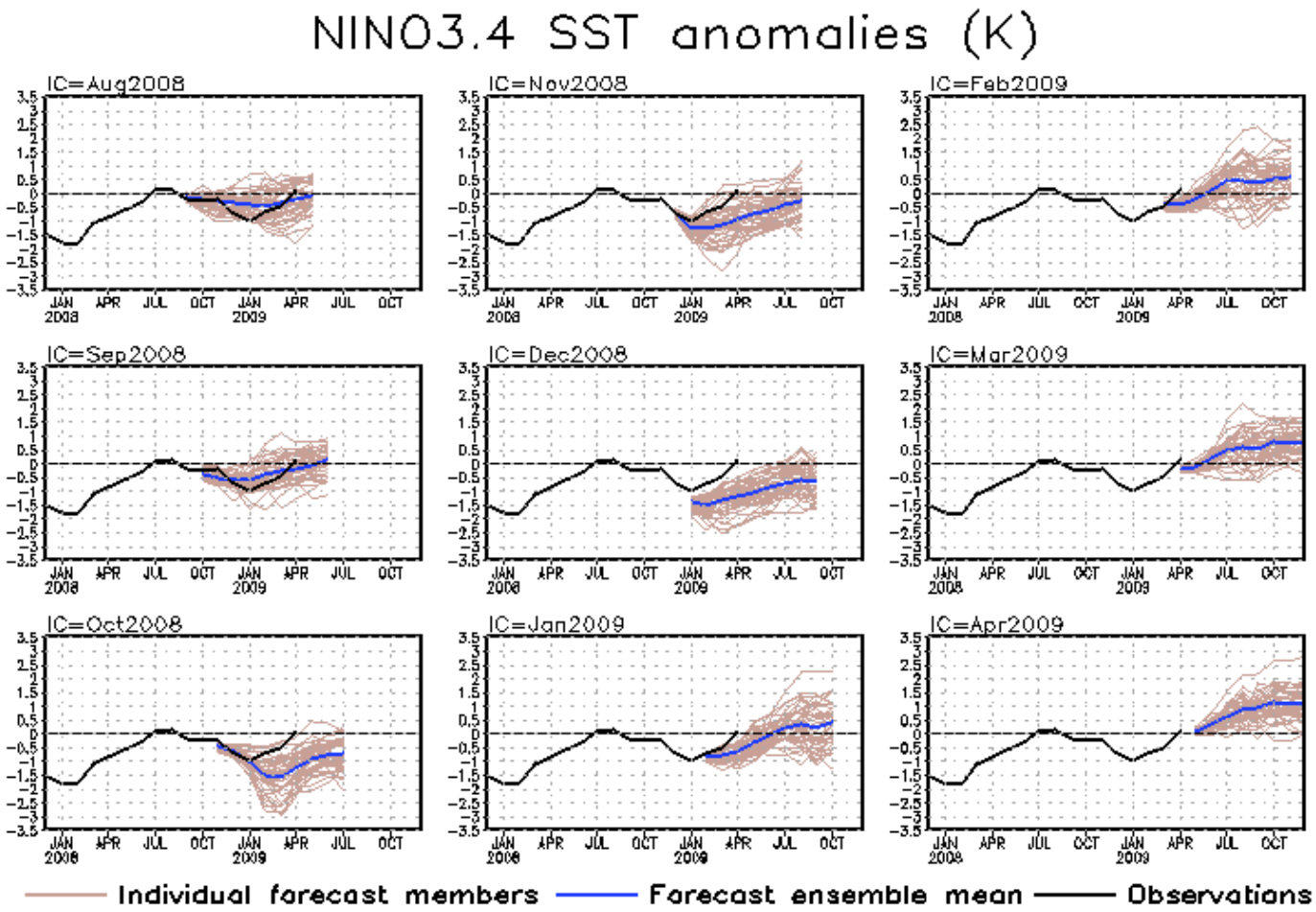


- North Atlantic SSTs cooled down and became near-normal during the past two months due to near-normal or above-normal NAO index.

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

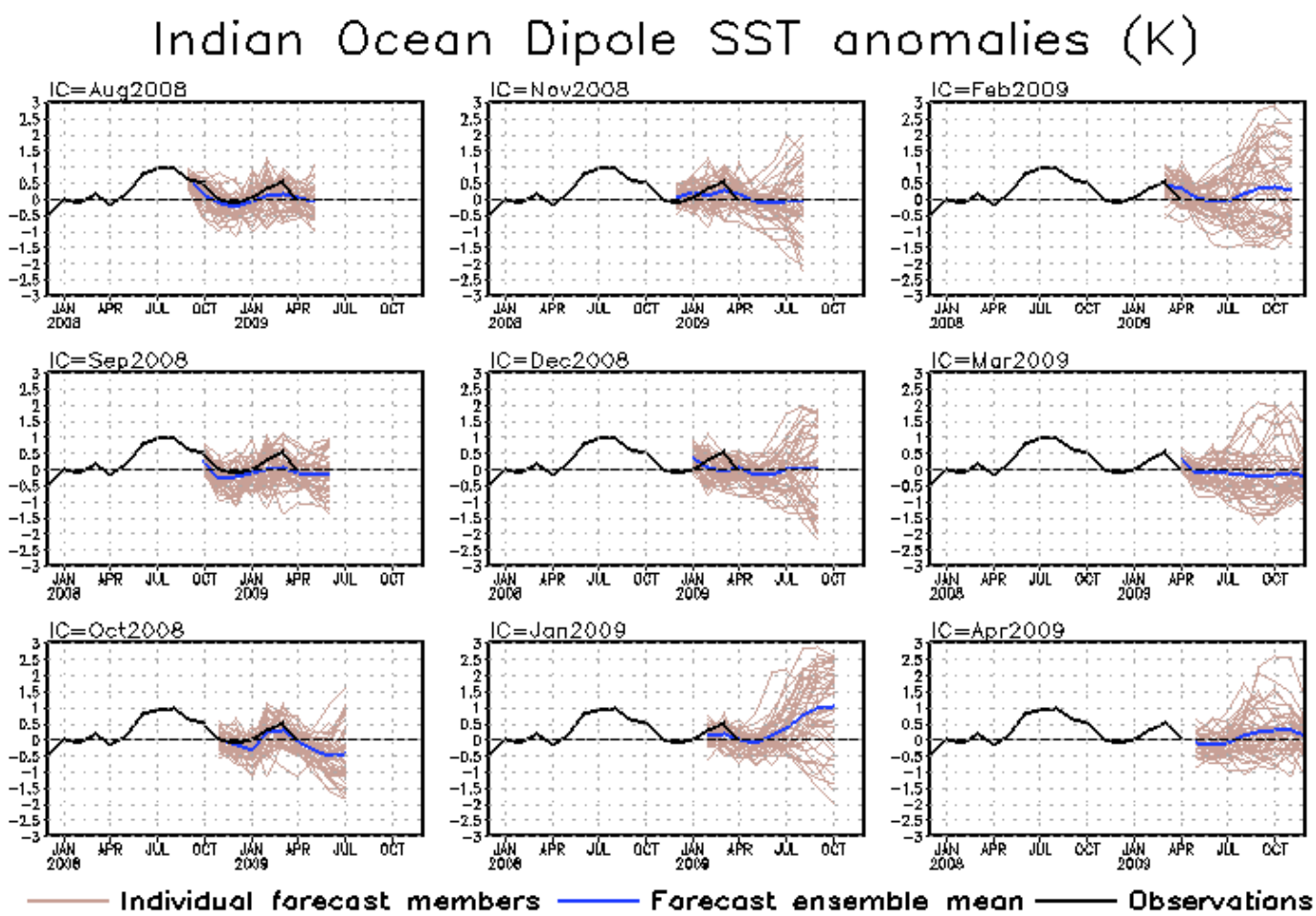
CFS Niño3.4 SST Predictions from Different Initial Months



- **Latest forecasts suggested El Nino conditions 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

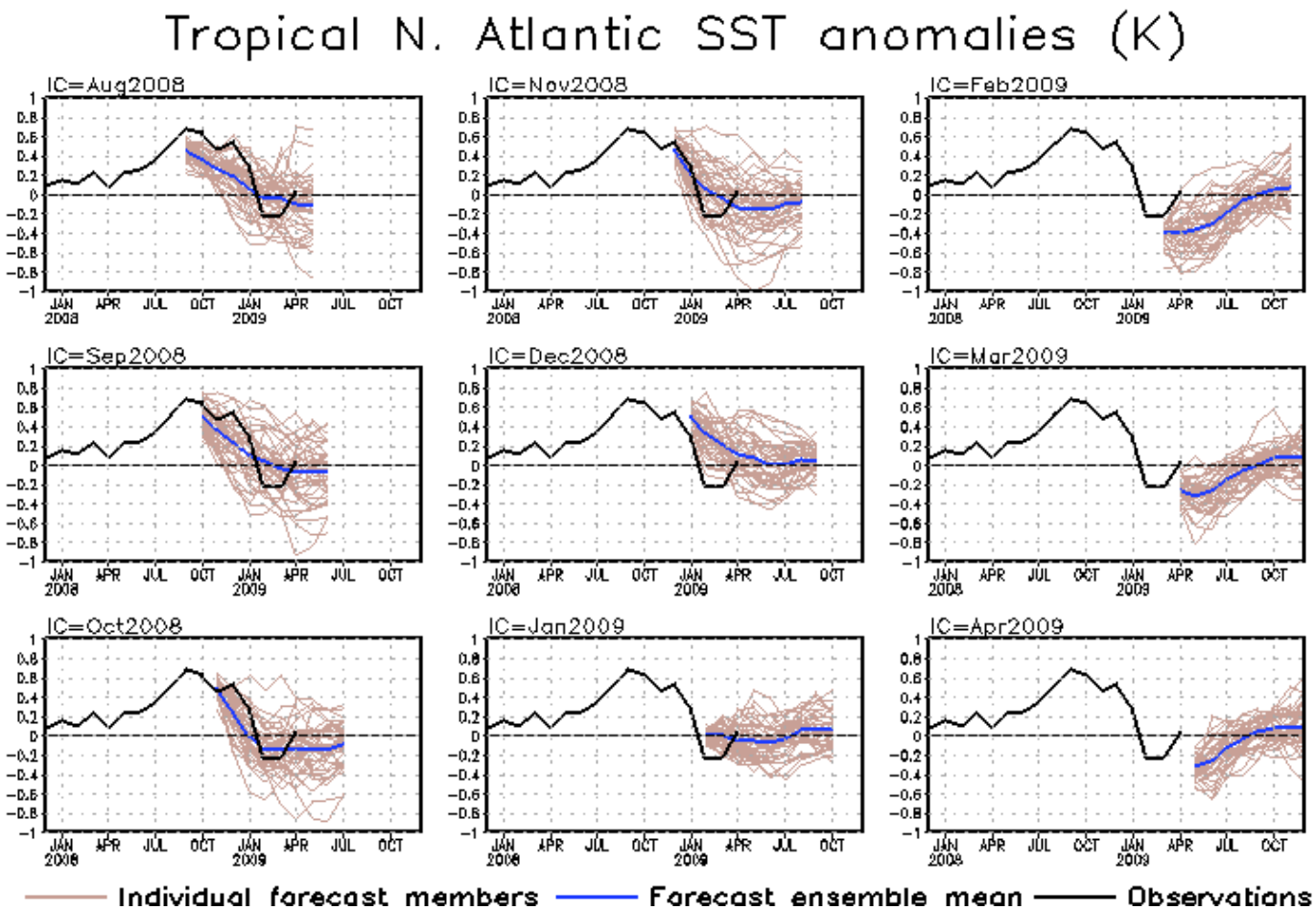
SETIO = SST anomaly in [90°E-110°E, 10°S-0]

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

- Latest forecasts called for DMI-neutral conditions 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

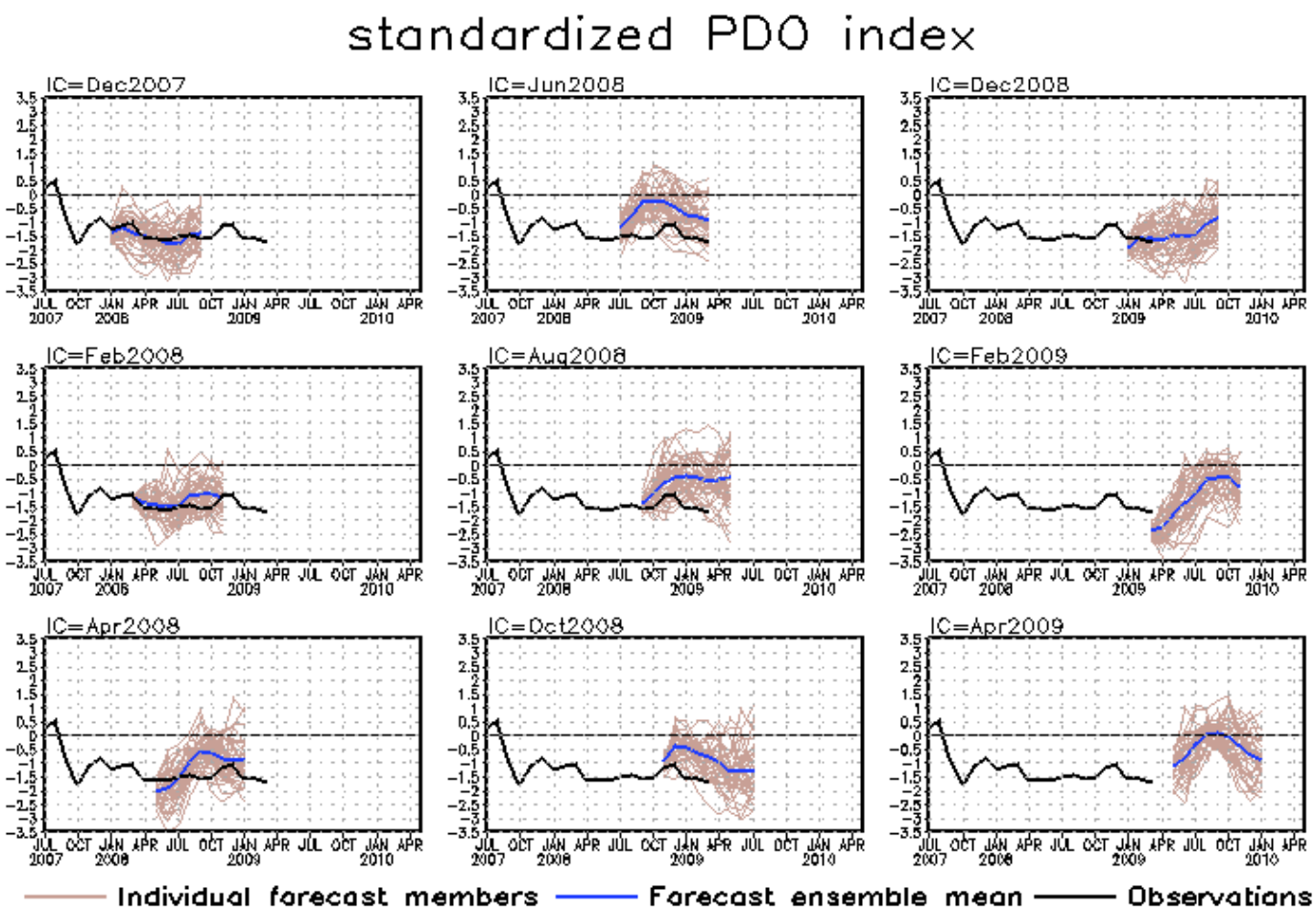


TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- 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 forecast the recent negative PDO phase since Dec 07 I.C.
- Latest forecasts suggested that the negative PDO wuold weaken and return to near-normal during summer 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**
  - The equatorial Pacific Ocean warmed up significantly due to downwelling Kelvin wave forced by MJO-related westerly wind anomalies.
  - Transition from La Nina to ENSO-neutral conditions occurred in April 2009.
  - Negative PDO phase since September 2007 has persisted for 20 months now.
  - Above-normal upwelling has persisted since mid-November 2007 along the west coast of North America north of 35N.
- **Indian Ocean**
  - IOD index was near-normal.
  - Positive SST anomalies in the southwest Indian Ocean persisted.
- **Atlantic Ocean**
  - Below-normal SST in the southeast tropical Atlantic persisted, while above-normal SST in the tropical South Atlantic and equatorial Atlantic strengthened.
  - ITCZ was shifted southward in responding to the negative meridional gradient of SSTA.
- **Arctic Ocean**
  - Sea ice extent was close to normal due to a slower retreat of sea ice than that of the average seasonal cycle.

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!