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

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

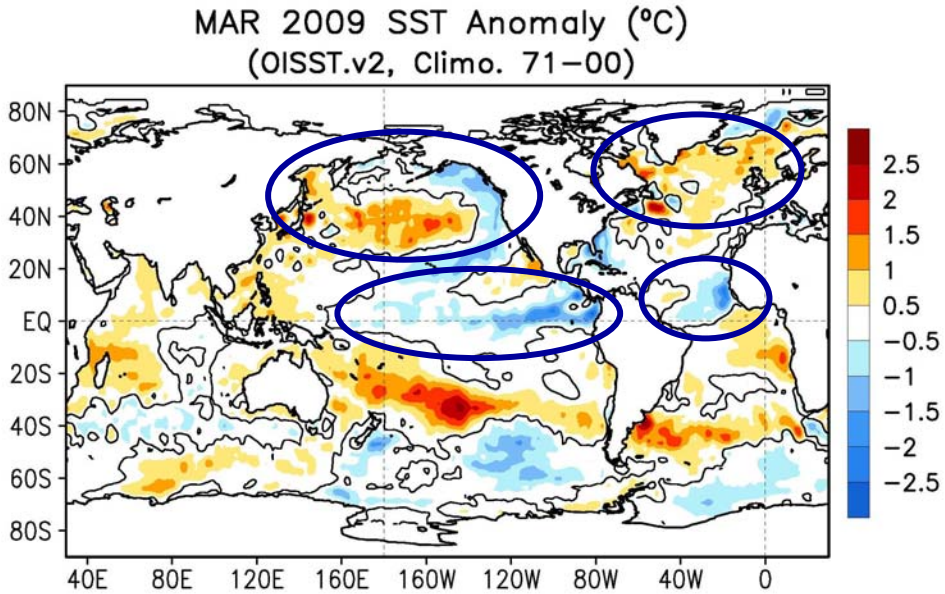
Outline

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

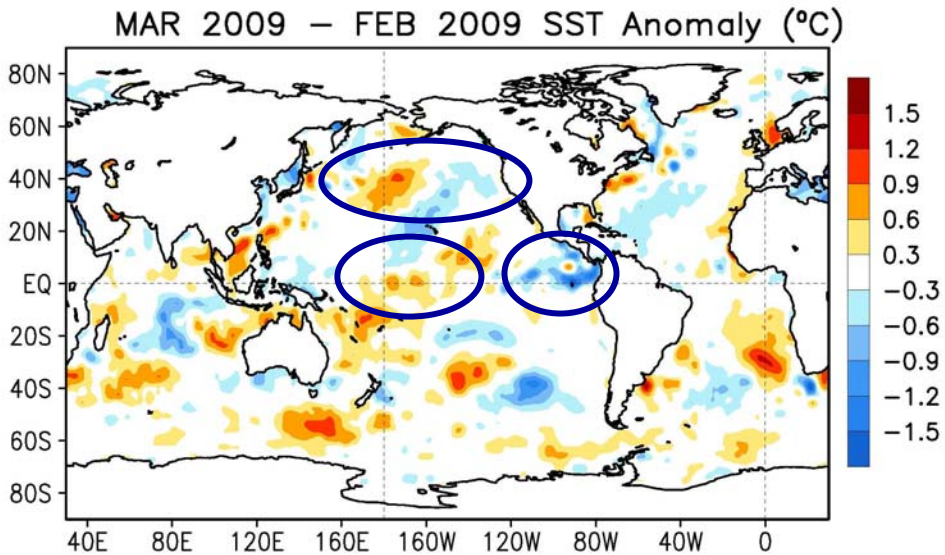
Overview

- **Pacific Ocean**
  - La Niña conditions (NINO3.4 < -0.5°C) weakened, and are expected to return to ENSO-neutral conditions in the Northern Hemisphere Spring.
  - Negative PDO phase that started in September 2007 has persisted for 19 months now.
  - Coastal upwelling is strongly above-normal between 36N-42N, and below-normal in the other regions.
- **Indian Ocean**
  - Positive SST anomalies persisted in the western Indian Ocean.
  - Positive IOD index enhanced and became above 0.5 °C in March 09.
- **Atlantic Ocean**
  - Positive SSTA in the North Atlantic SST weakened in Feb-Mar 09.
  - Tropical North Atlantic SST became slightly below-normal in Feb-Mar 09.
  - Tropical South Atlantic and equatorial Atlantic continued to be above-normal.
- **Arctic Ocean**
  - Ice concentration remains much below-normal, and starts to decrease.

Global SST Anomaly (⁰C) and Anomaly Tendency



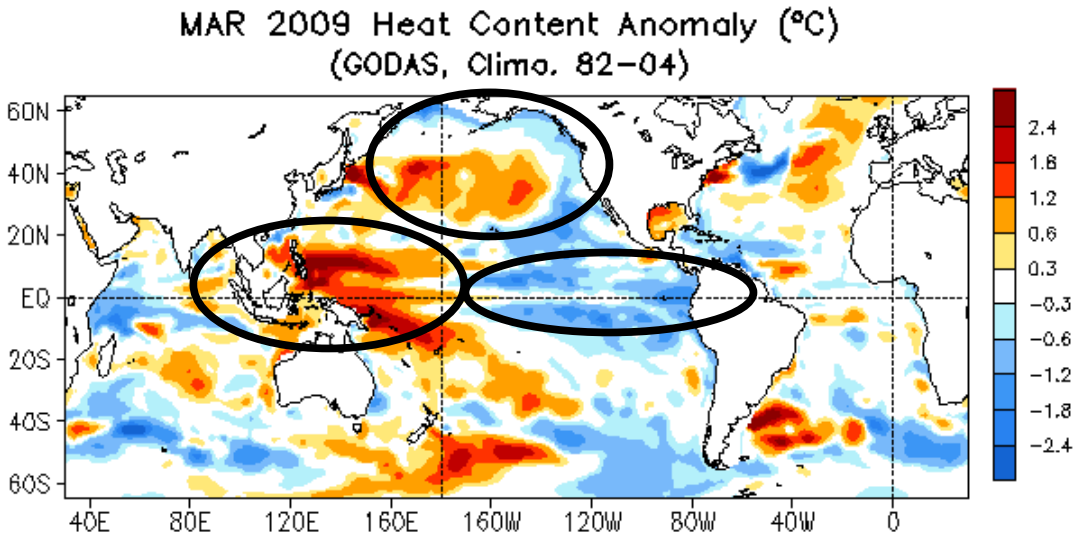
- **Negative PDO-like SST pattern in North Pacific.**
- **La Niña Conditions in the tropical Pacific.**
- **Positive SSTA in the North Atlantic.**
- **Negative SSTA in the north-eastern tropical Atlantic**



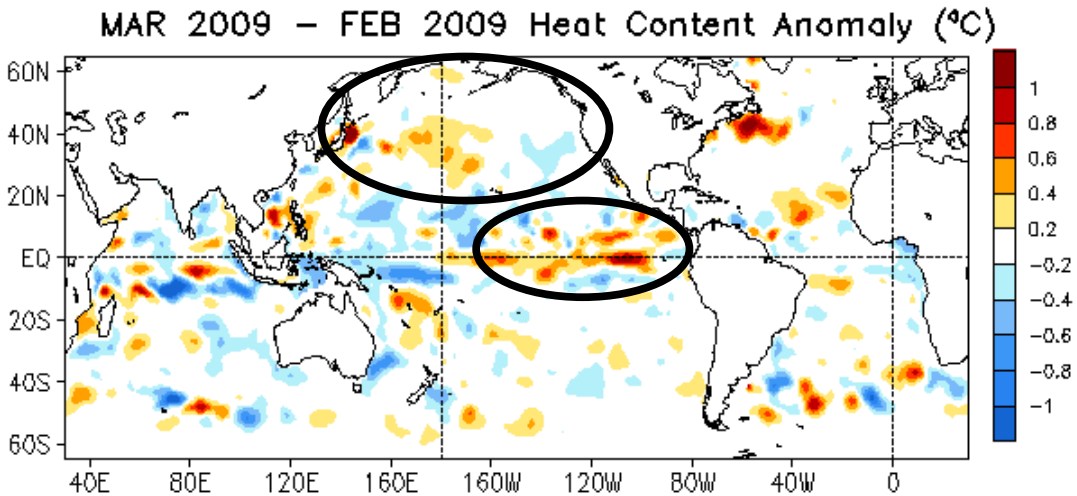
- **Positive (negative) SSTA tendency in the central (eastern) tropical Pacific: La Niña weakened, but the colder conditions in the cold tongue enhanced.**
- **SSTA tendency in North Pacific enhanced the negative PDO-like pattern.**
- **Western tropical North Atlantic cooled down.**

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 HC Anomaly (°C) and Anomaly Tendency

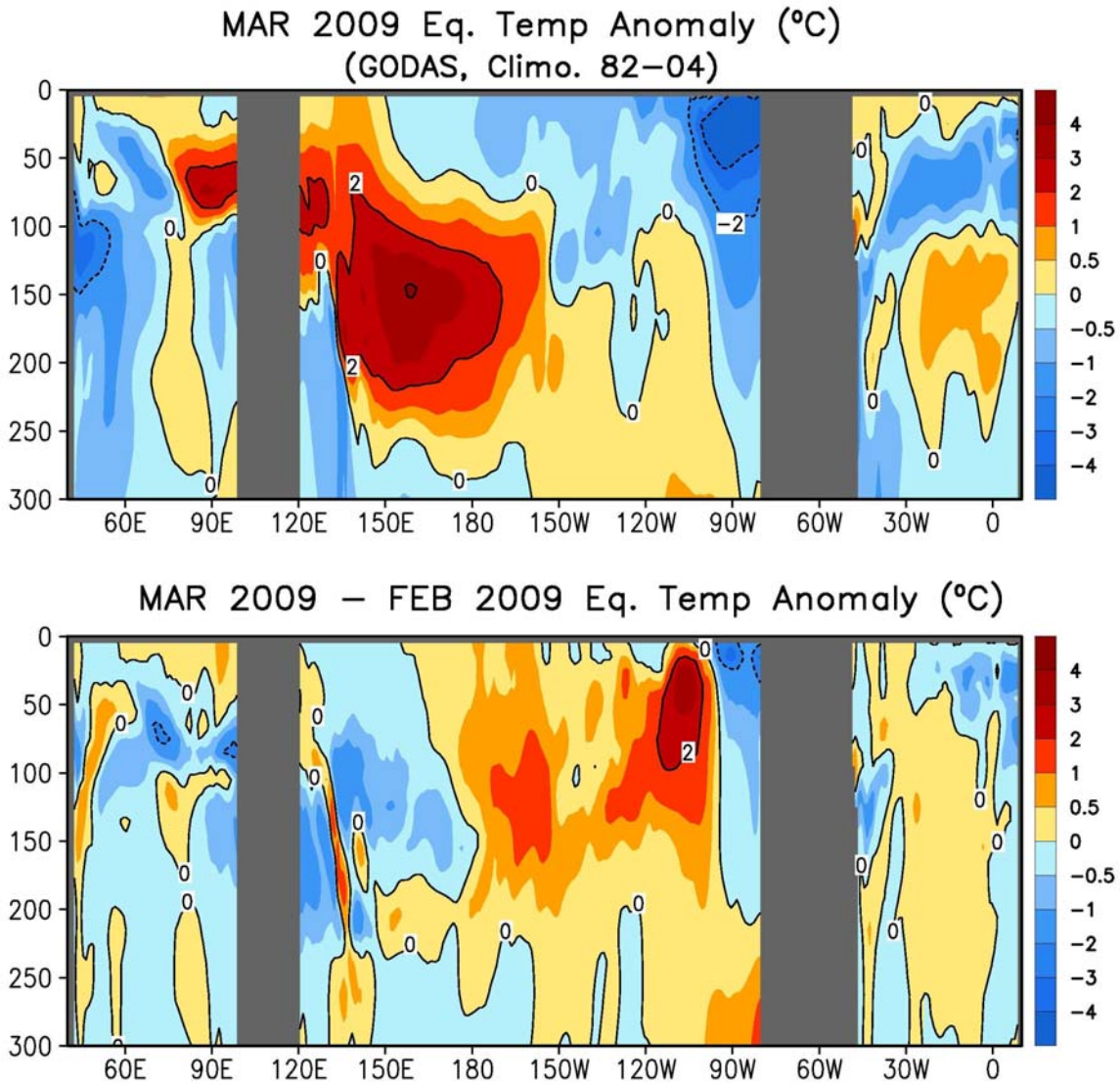


- **Negative HCA off the equator in the central and eastern tropical Pacific**
- **Positive HCA in the western tropical Pacific.**
- **Negative PDO-like HCA in the North Pacific, consistent with the negative PDO-like SSTA.**



- **Positive (negative) HCA weakened in the equatorial western (eastern) Pacific.**
- **Negative PDO-like HCA in the North Pacific enhanced slightly.**

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



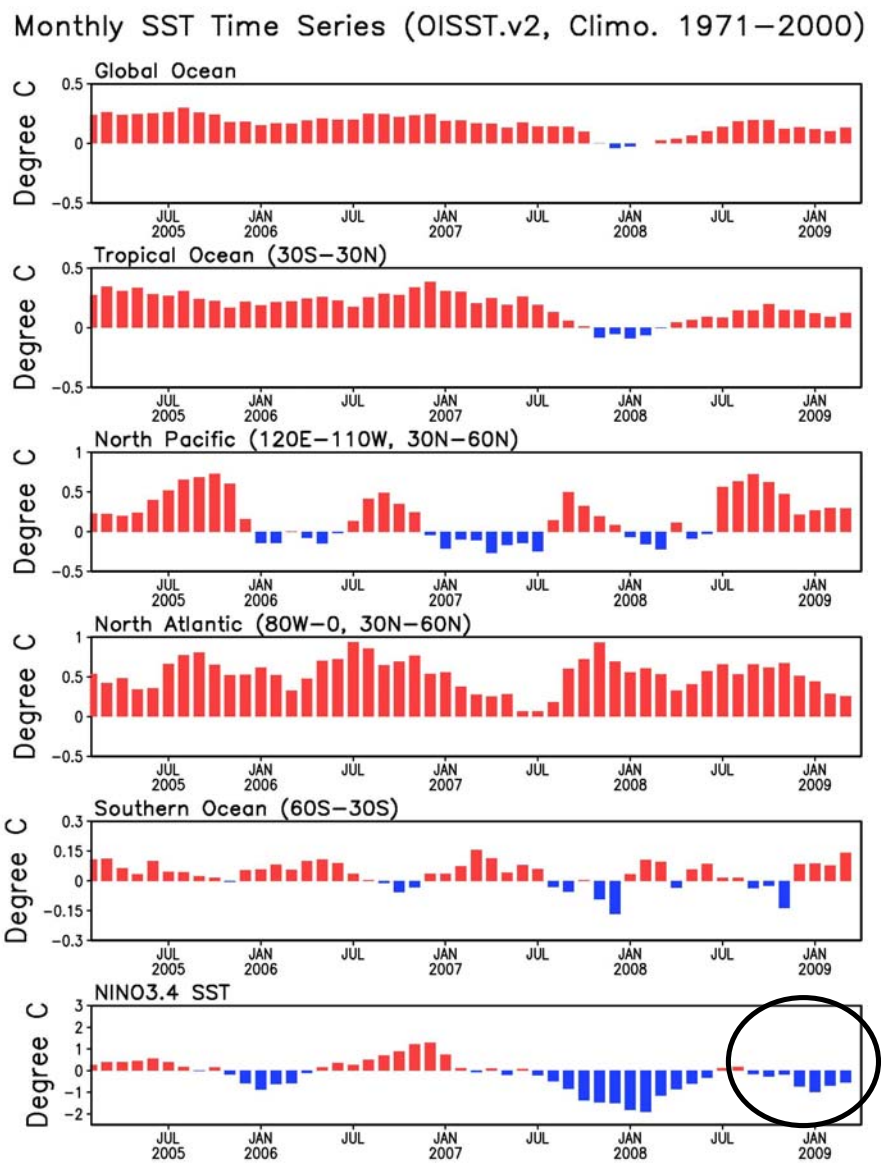
- **Positive (negative) subsurface temperature anomalies about 3°C presented in the equatorial western (eastern) Pacific.**
- **Positive subsurface temperature anomalies about 2°C in the eastern equatorial Indian Ocean.**

- **Negative (positive) subsurface temperature anomalies weakened in the central (western) equatorial Pacific.**

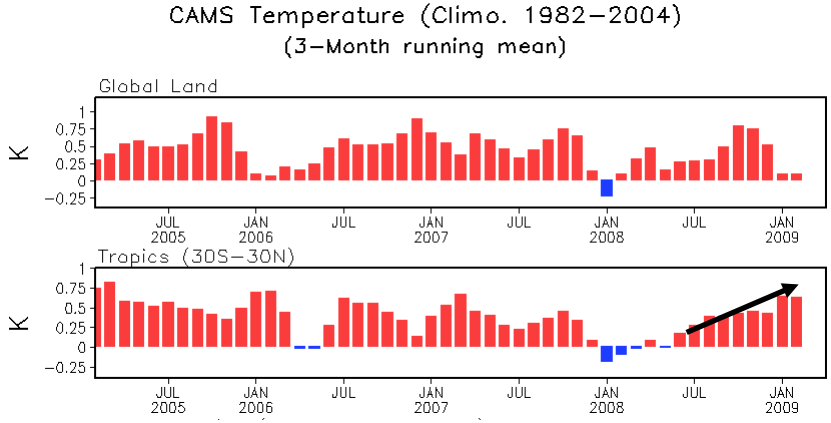
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1982-2004 base period means.

Monthly Time Series

Sea Surface Temperature



CAMS Land Temperature

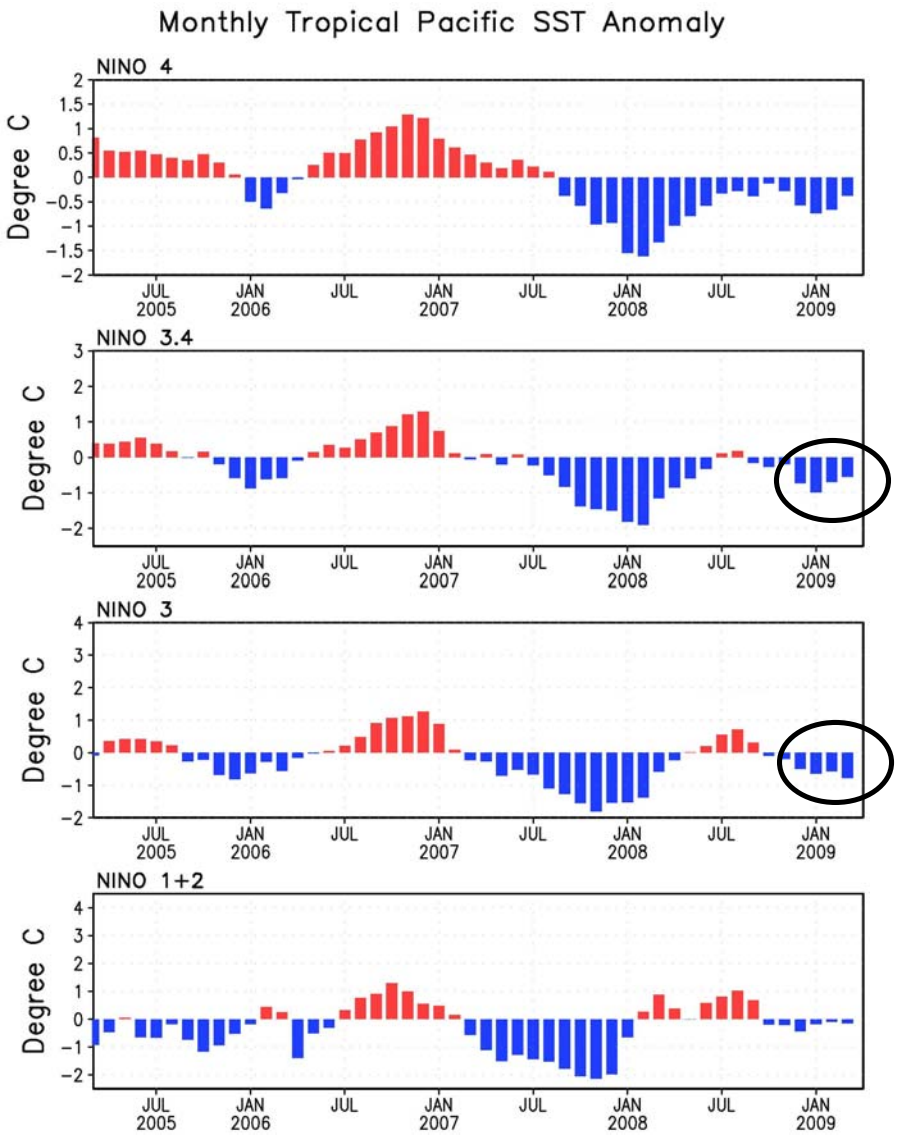


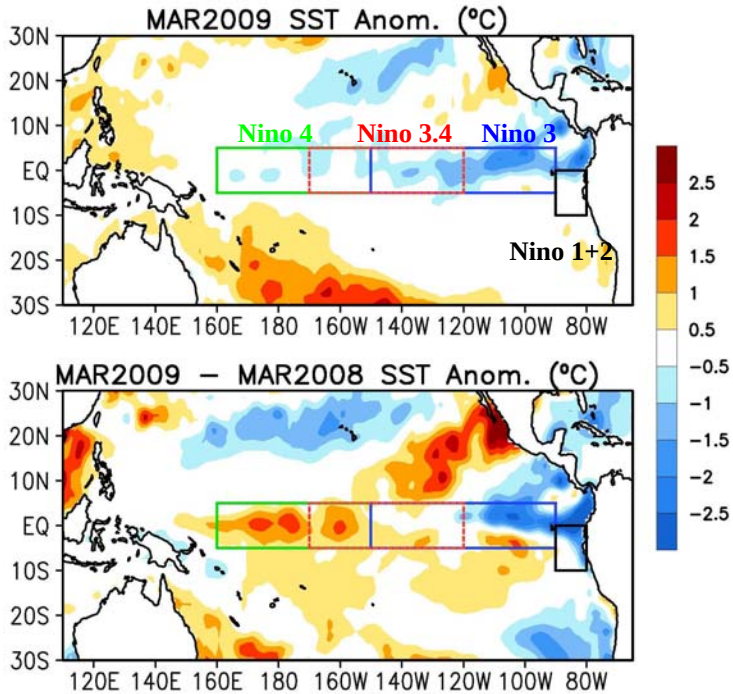
- **Global mean SSTA enhanced slightly.**
- **Global mean land temperature remained near-normal from DJF to JFM.**
- **Tropical land temperature continues to be well above-normal in response to the above-normal tropical ocean SST.**
- **Weak positive SSTA in North Pacific continued.**
- **Weak positive SSTA in North Atlantic continued.**
- **Negative NINO 3.4 SST met NOAA's La Nina definition (NINO 3.4 < -0.5ºC) since Dec 2008, and became weaker in March.**

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

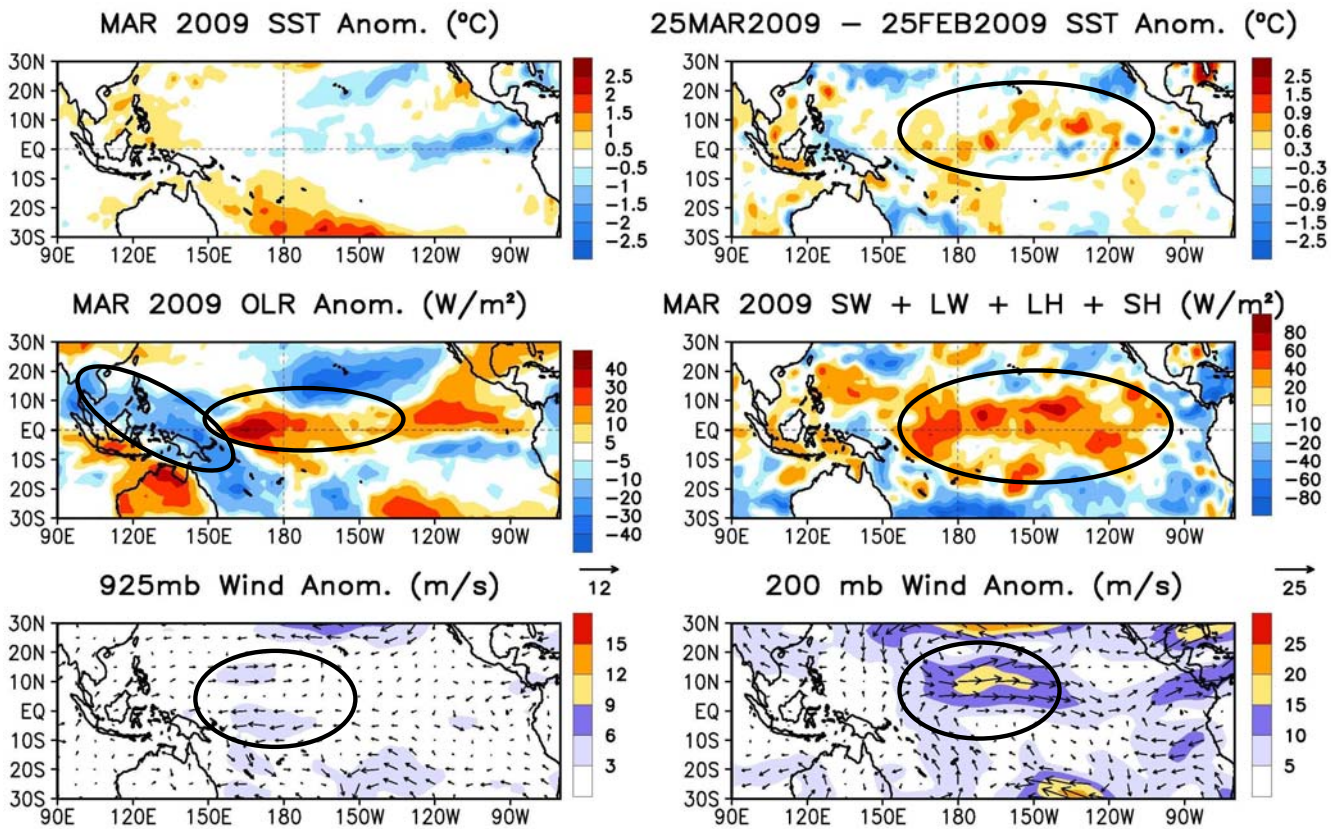




- La Niña conditions (NINO3.4 < -0.5°C) developed in December 2008, and are expected to return to ENSO-neutral conditions in April 2009 – NOAA's "ENSO Diagnostic Discussion".
- All NINO indices were below-normal.
- NINO 4 & NINO 3.4 became weaker.
- NINO 3 became stronger.

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 (western) tropical Pacific
- Low-level easterly wind anomalies in the central tropical Pacific weakened.
- Upper-level westerly wind anomalies in the central tropical Pacific were consistent with La Nina conditions.
- Surface heat flux anomalies damped negative SST anomalies in the central and eastern tropical Pacific.

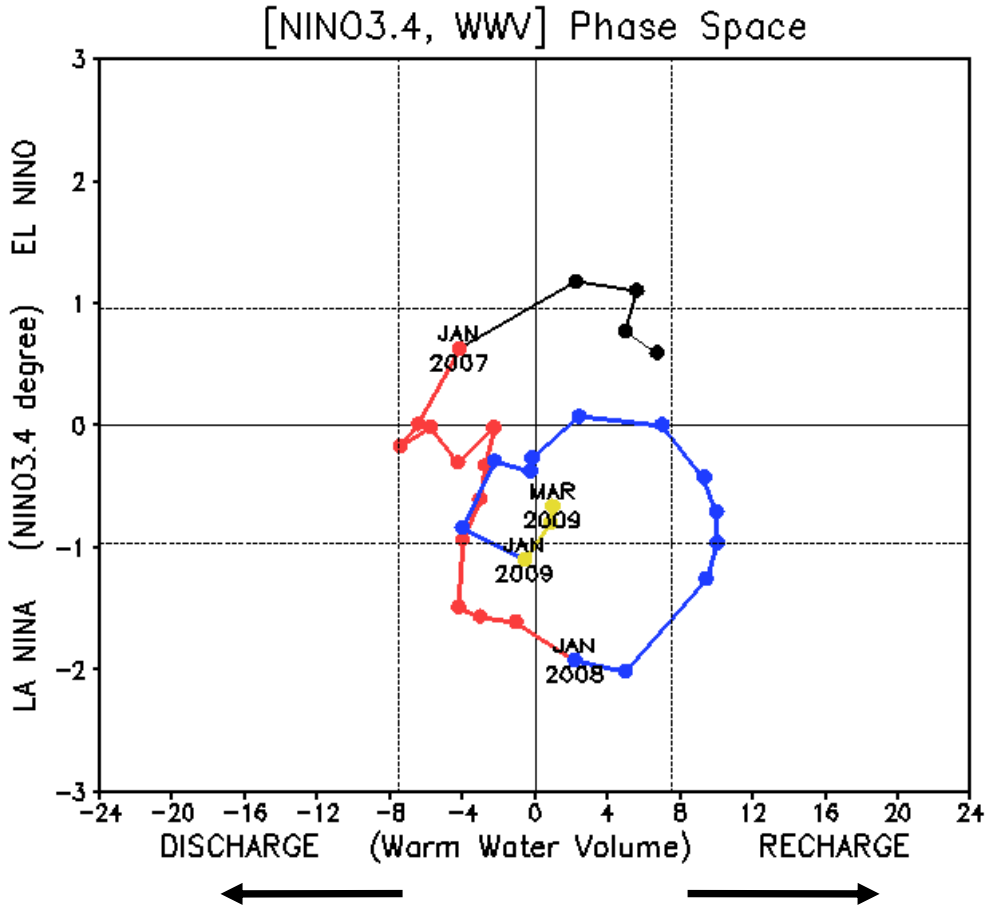
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

-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.

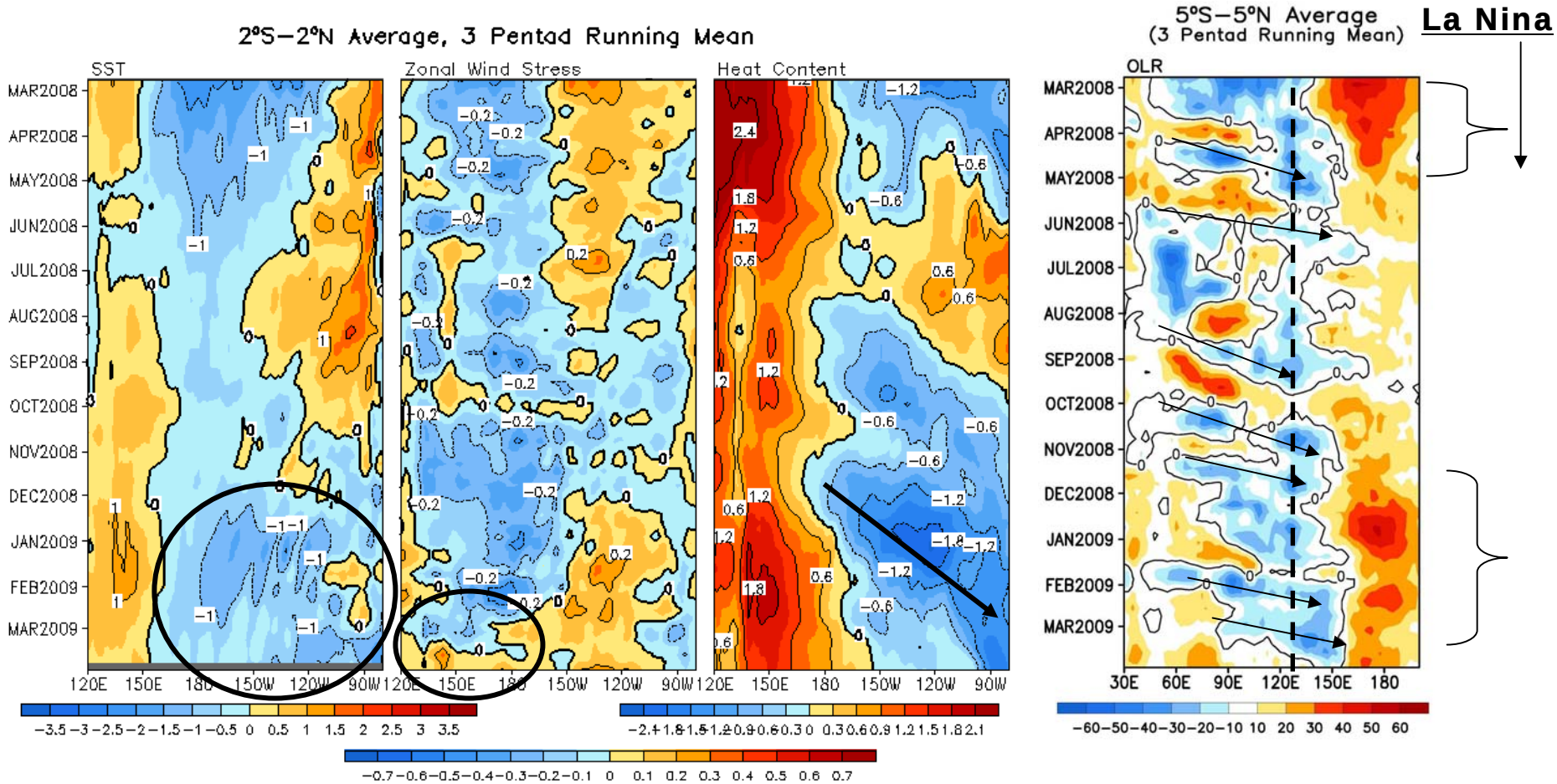


- Warm Water Volume(WWV) has discharged from June to December 08, but recharged from December 08 to March 09 and is weakly above-normal in march 09.

- NINO3.4 has been below-normal since September 08, and met La Nina conditions (NINO3.4 < -0.5°C) in Dec 08 – Mar 09.

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), Surface Wind (dyne/cm²), and OLR (W/m²) Anomaly

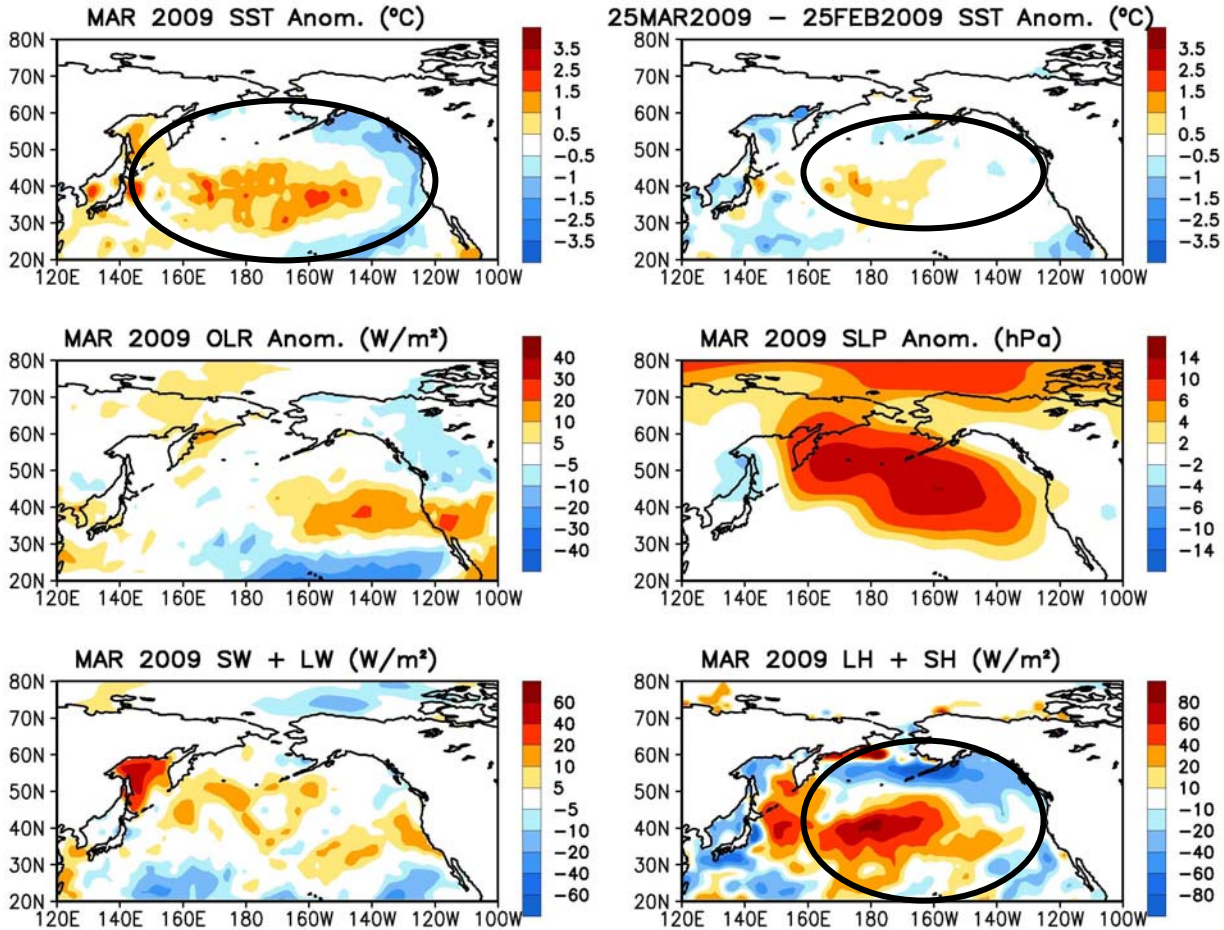


- **Negative SSTA presented in the central tropical Pacific since Dec 08, and became weaker since later February 09.**
- **Easterly wind anomalies switched to westerly wind anomalies in the western tropical Pacific in mid-March, consistent with a weakening La Nina.**
- **Eastward propagation of negative heat content anomalies along the equator since November 08.**

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.

North Pacific & Arctic Ocean

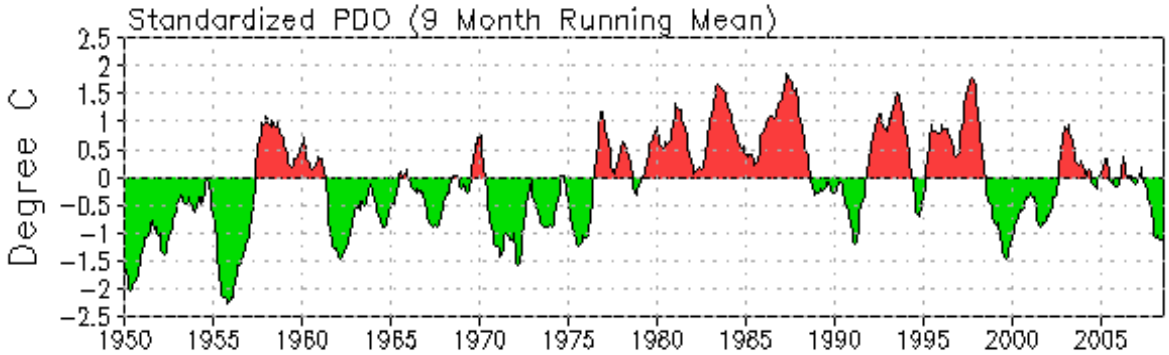
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx



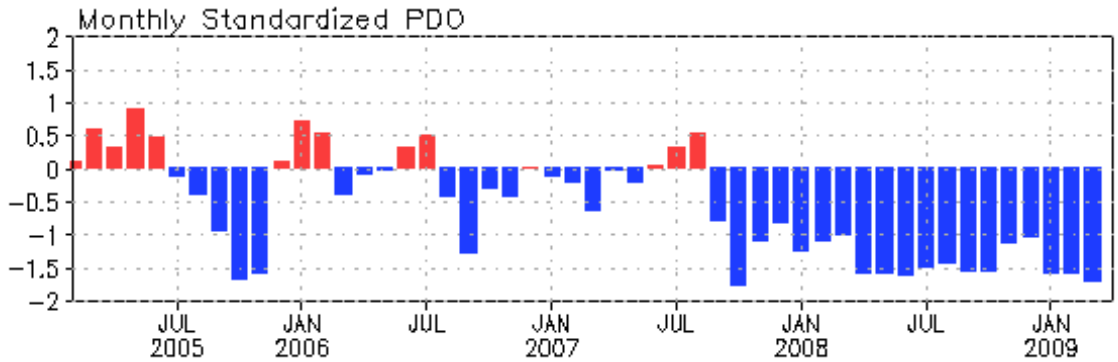
- **Negative PDO-like SST pattern persisted in the North Pacific.**
- **SSTA tendencies are consistent with the latent and sensible heat flux anomalies.**
- **Above-normal sea level pressure in the North Pacific was in favour of coastal upwelling along the coast of western North America north of 30N (slide 17).**

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.

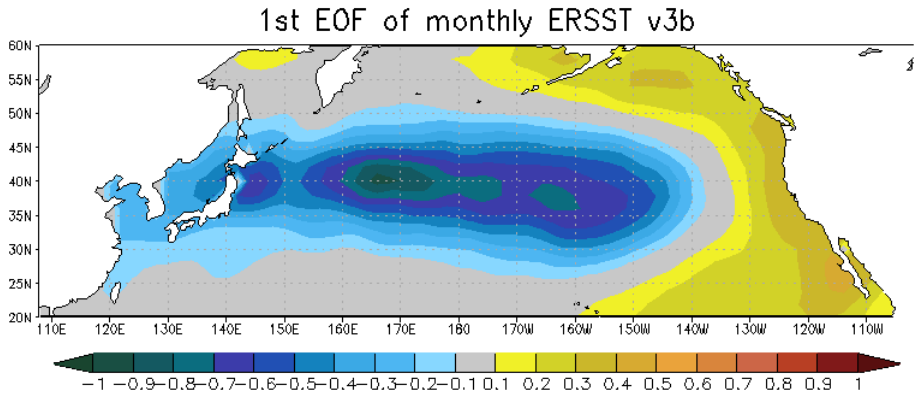
PDO index



PDO index at the lowest value since 1999.



Negative PDO index started in September 2007, and has persisted for 19 months.

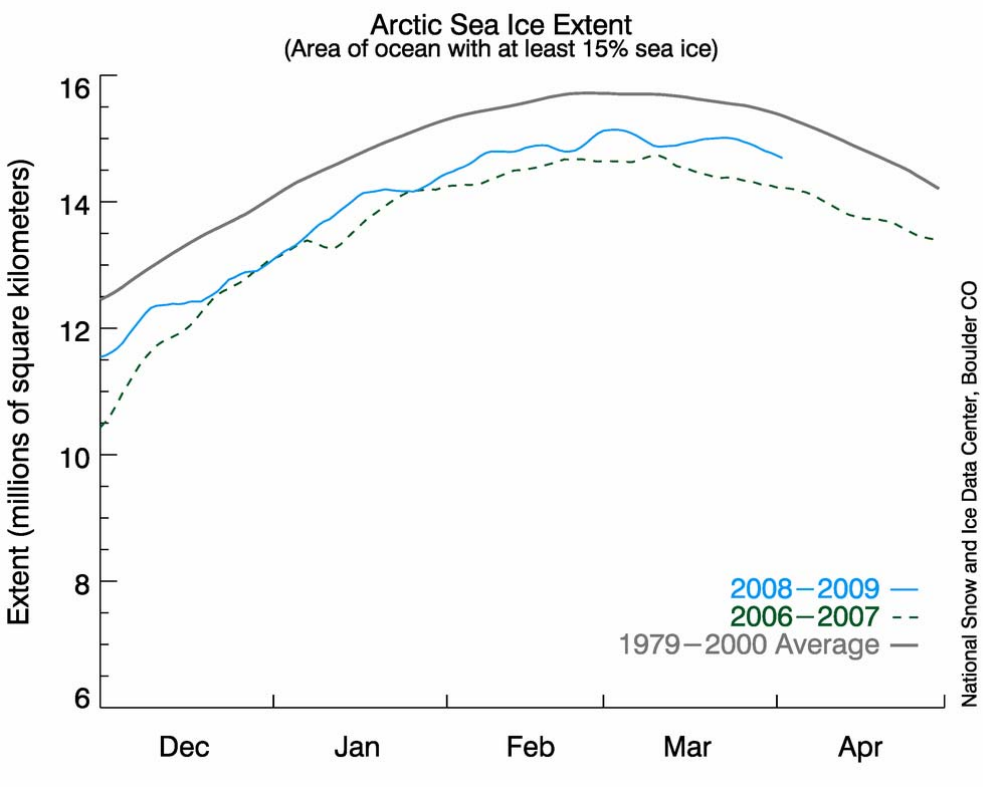


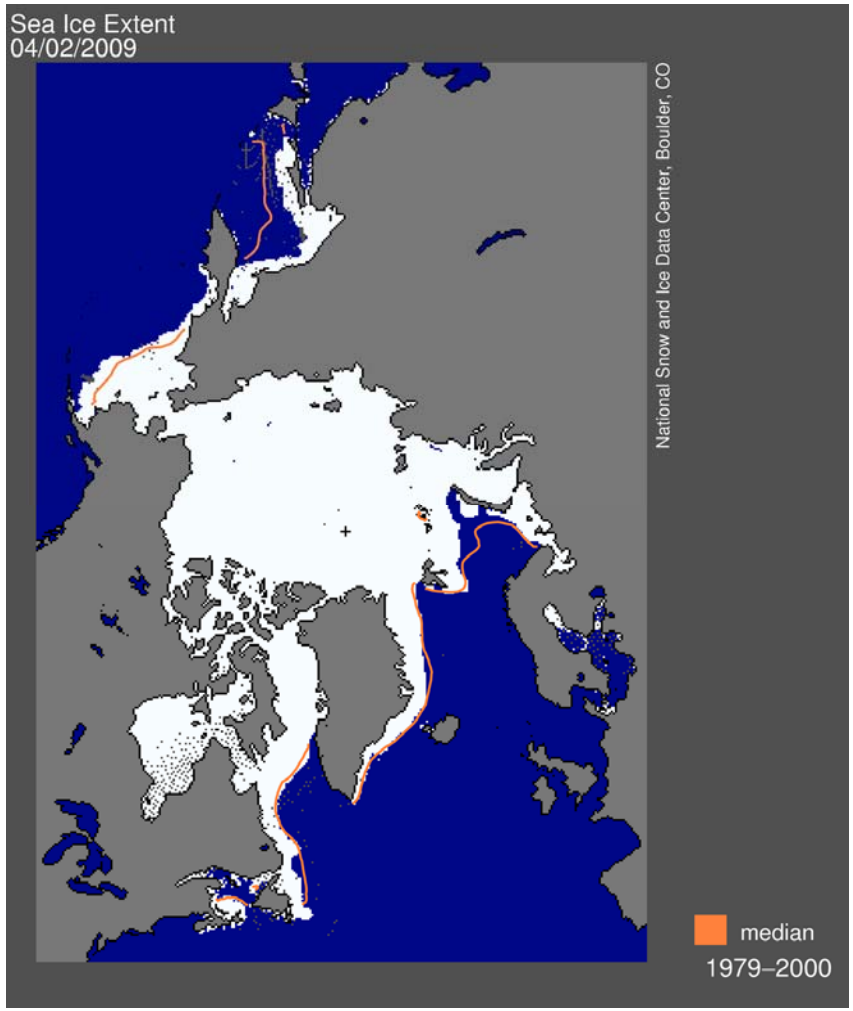
- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.**
- **The PDO index differs slightly from that of JISAO, which uses a blend of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

Arctic Sea Ice

National Snow and Ice Data Center

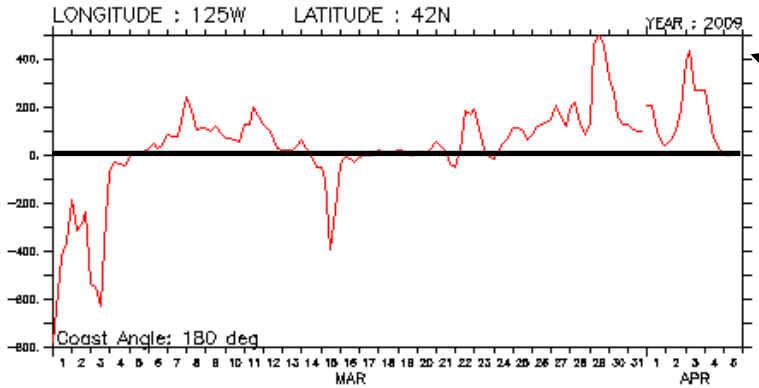
http://nsidc.org/arcticseaicenews/index.html

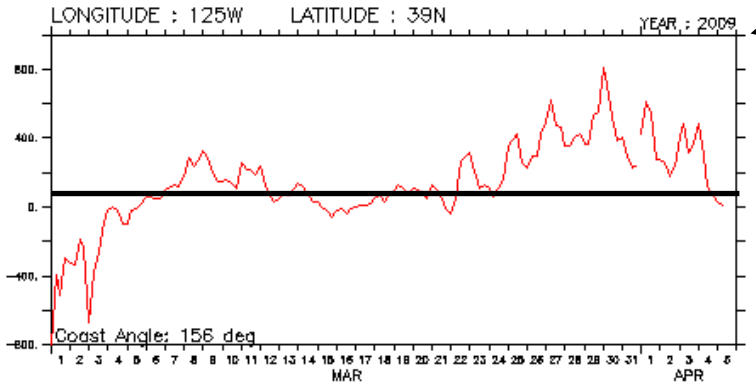


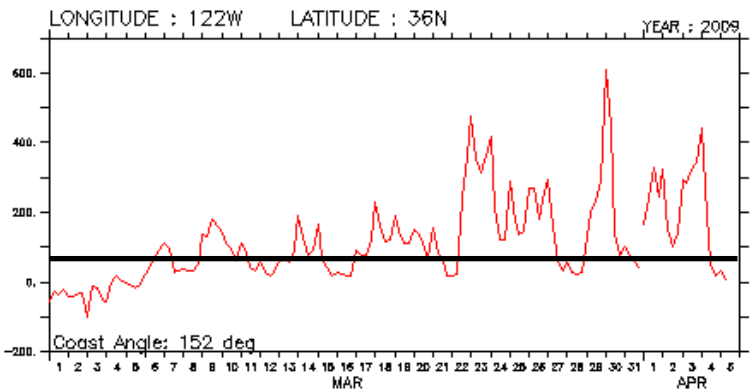


- **Sea ice extent remains well below-normal.**
- **Arctic sea ice decreased in later March.**

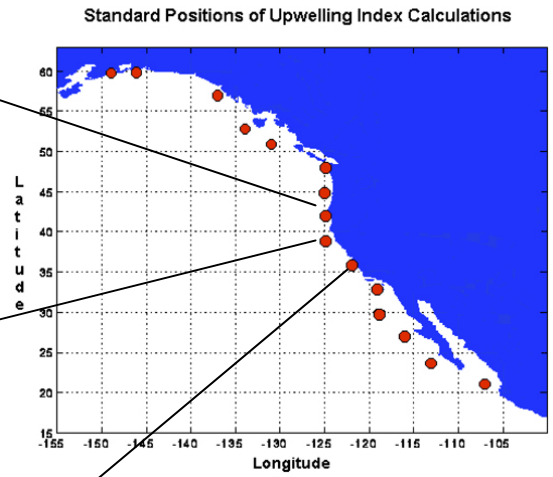
North America Western Coastal Upwelling







Upwelling index ($m^3/s/100$ m of coastline)

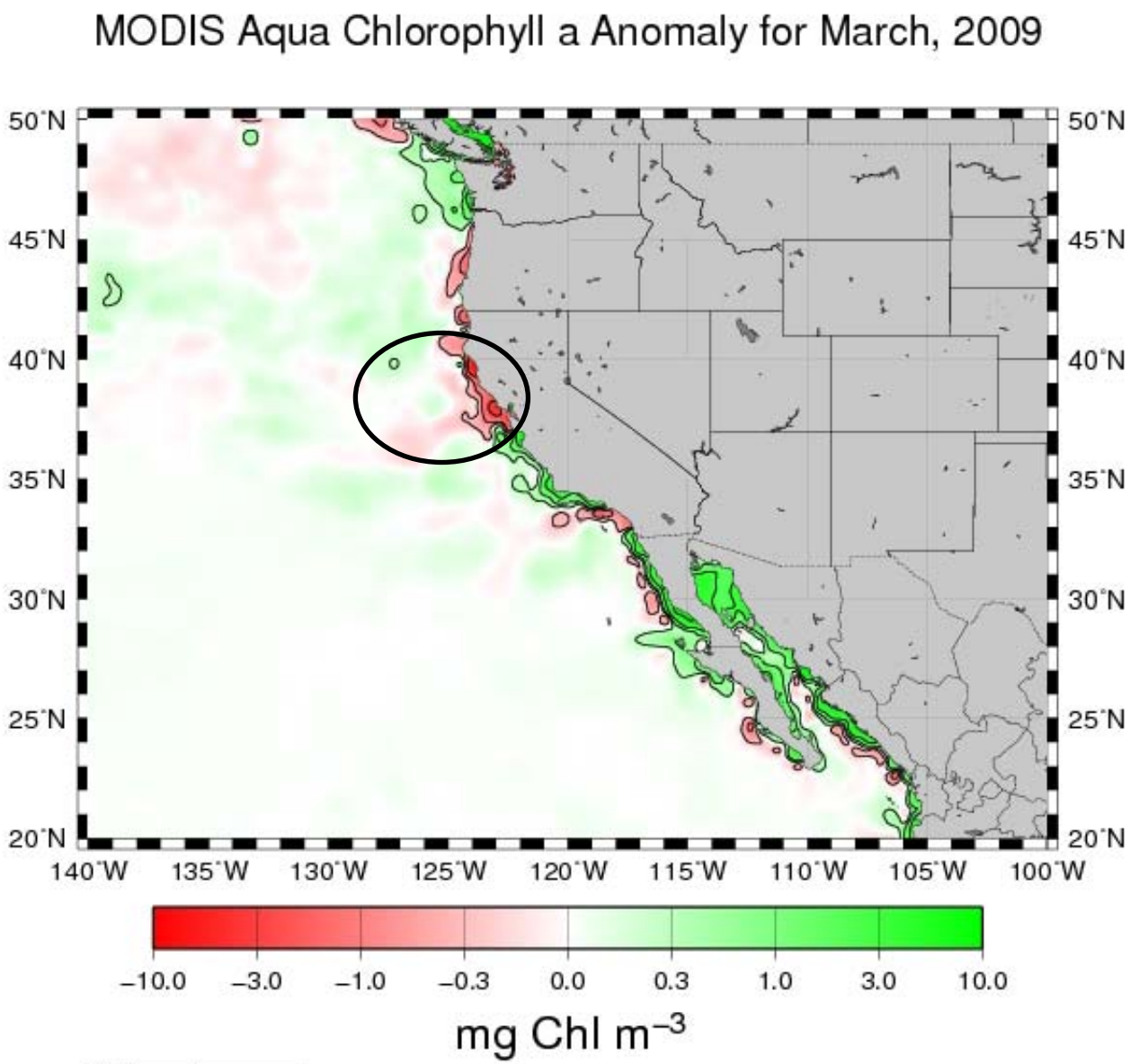


- **Upwelling plots were downloaded from www.pfel.noaa.gov.**
- **Upwelling is above-normal near 24N, between 36N-42N, and near 50N in March 09.**
- **The above-normal upwelling is associated with the negative PDO phase.**

- **Area below (above) black line indicates climatological upwelling (downwelling) season.**

Monthly Chlorophyll Anomaly

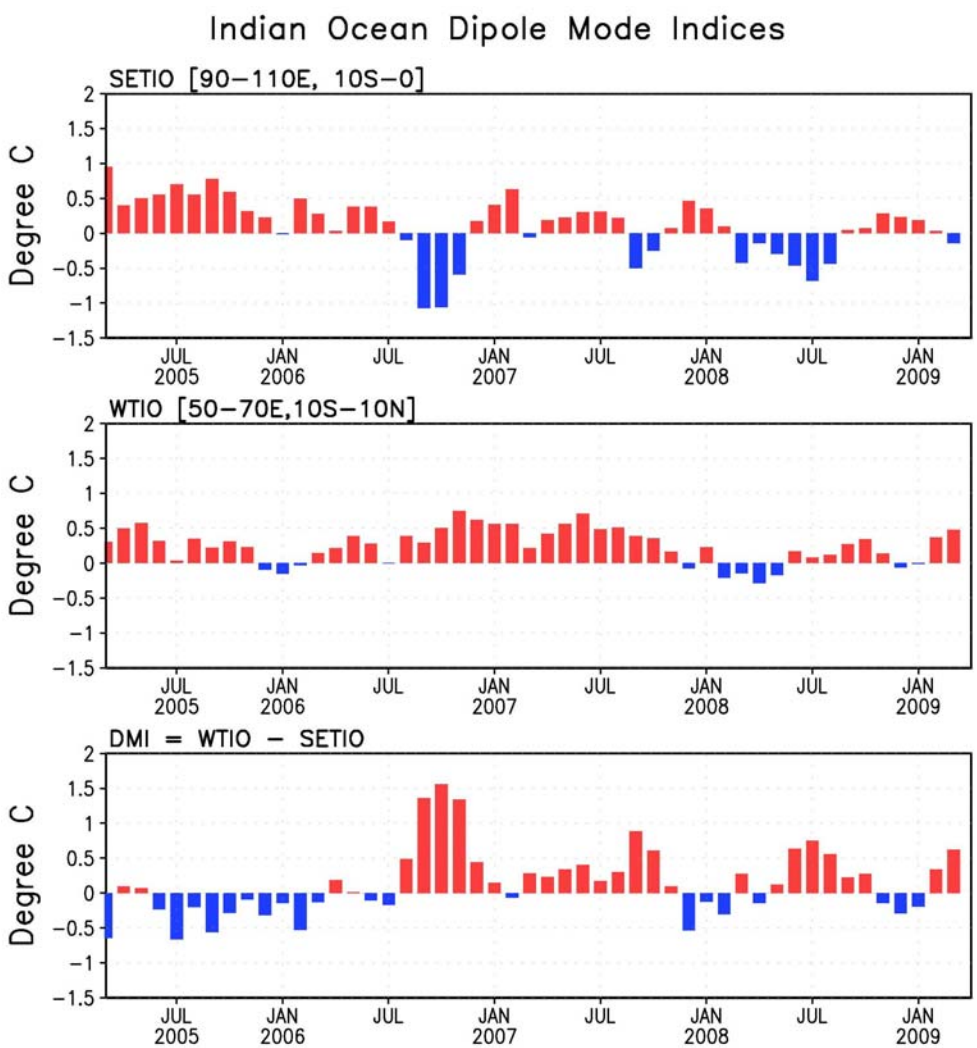
http://coastwatch.pfel.noaa.gov/FAST

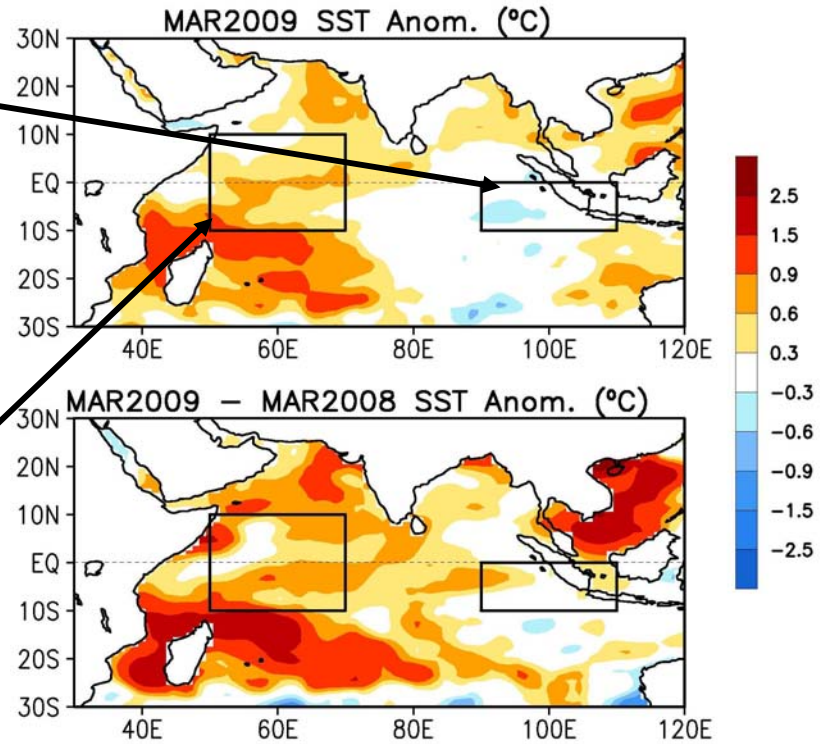


- **Negative (positive) Chlorophyll anomalies presented north (south) of 37N.**
- **Chlorophyll anomalies are largely consistent with upwelling anomalies.**

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

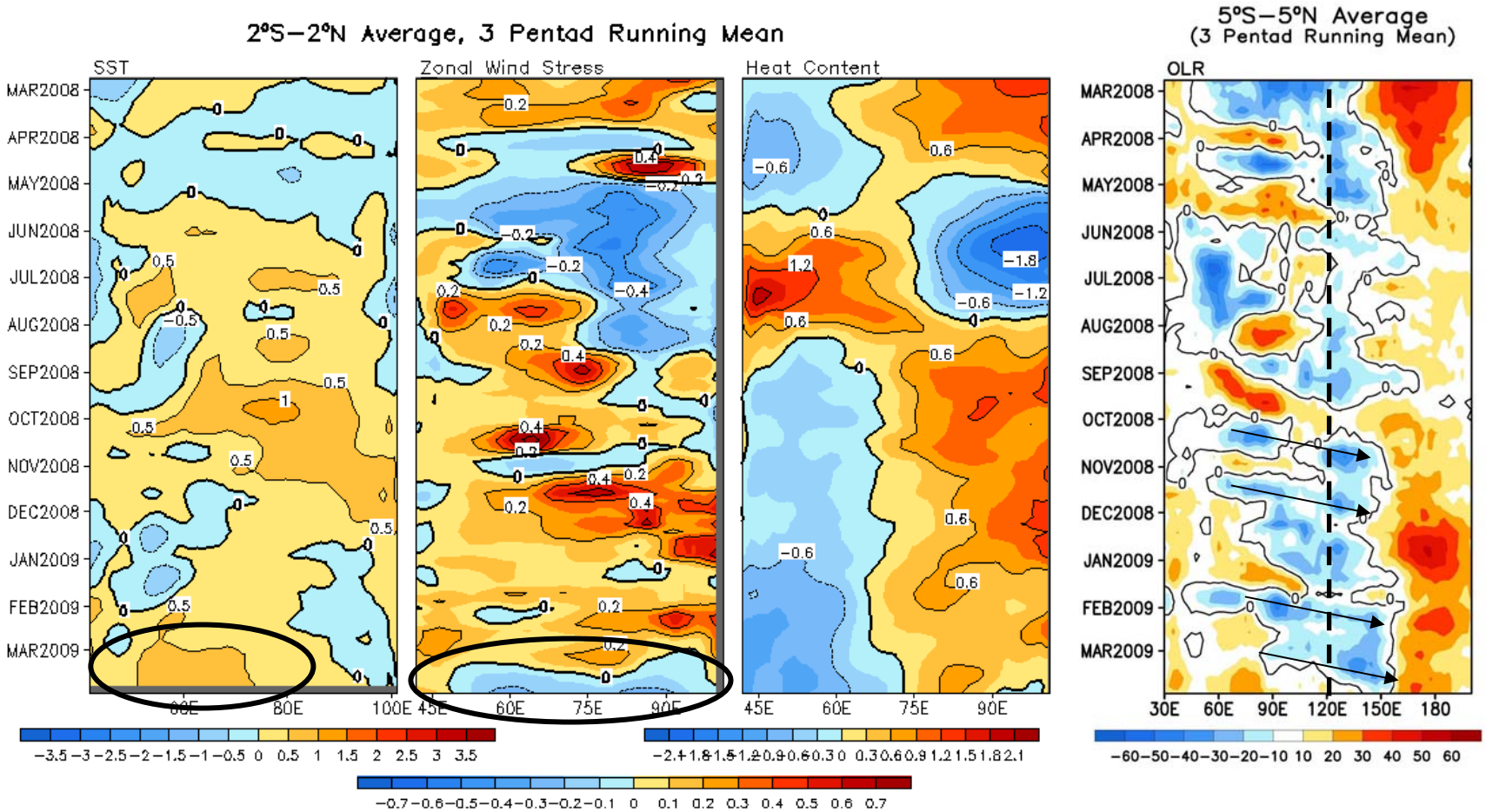




- **Dipole Mode Index (DMI) and its eastern and western pole indices became stronger in March 09.**
- **Large positive SST anomalies presented in the south-western tropical Indian Ocean.**
- **The tropical Indian Ocean SST in March 09 was about 0.6-1.5°C higher than that in March 08.**

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.

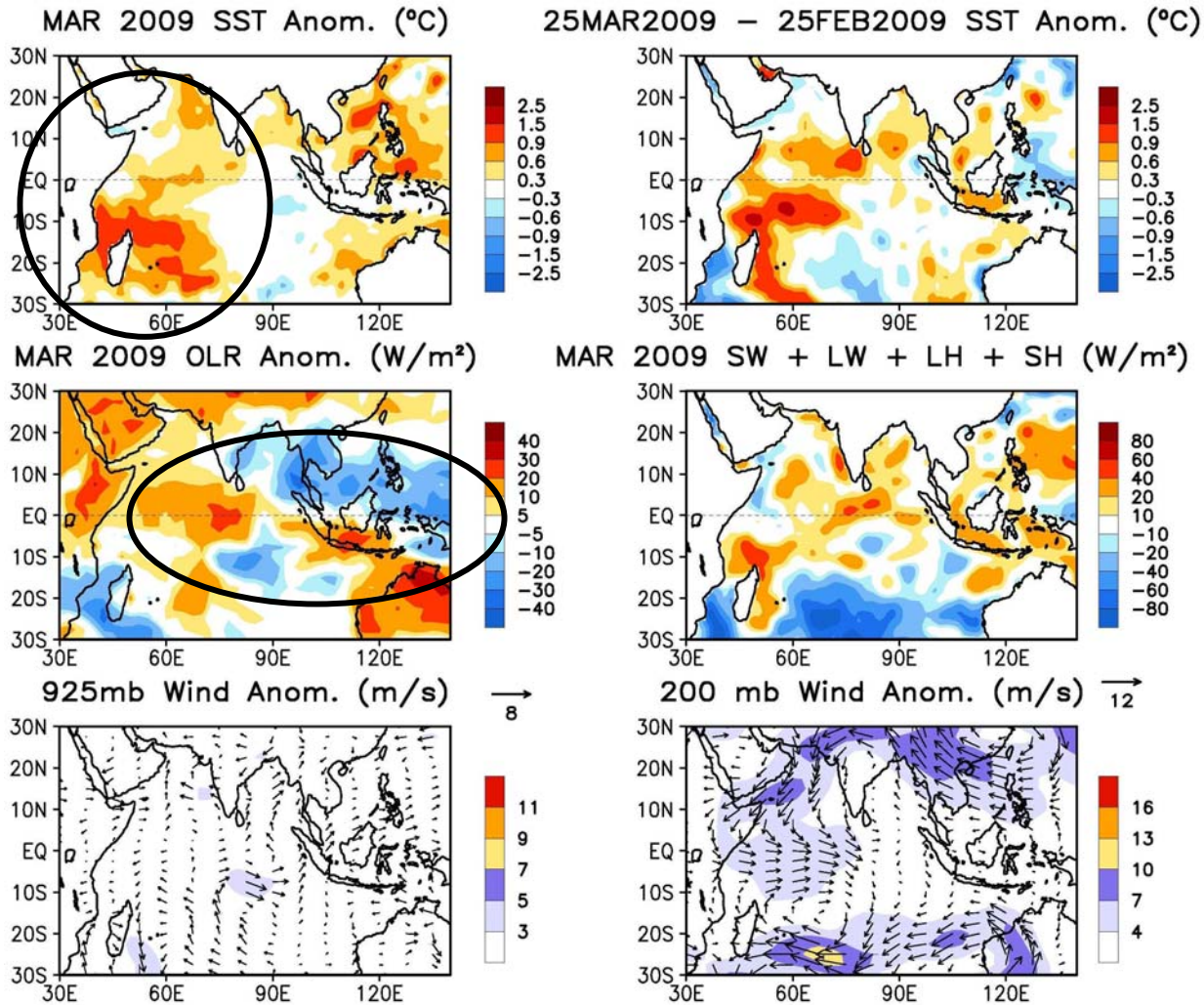
Recent Evolution of Equatorial Indian SST (ºC), 0-300m Heat Content (ºC), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies



- **Westerly wind anomalies switched to easterly wind anomalies in mid-March in the tropical Indian Ocean due to MJO activity and weakening La Nina.**
- **Positive SSTA in the western and central Indian Ocean enhanced.**

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.

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

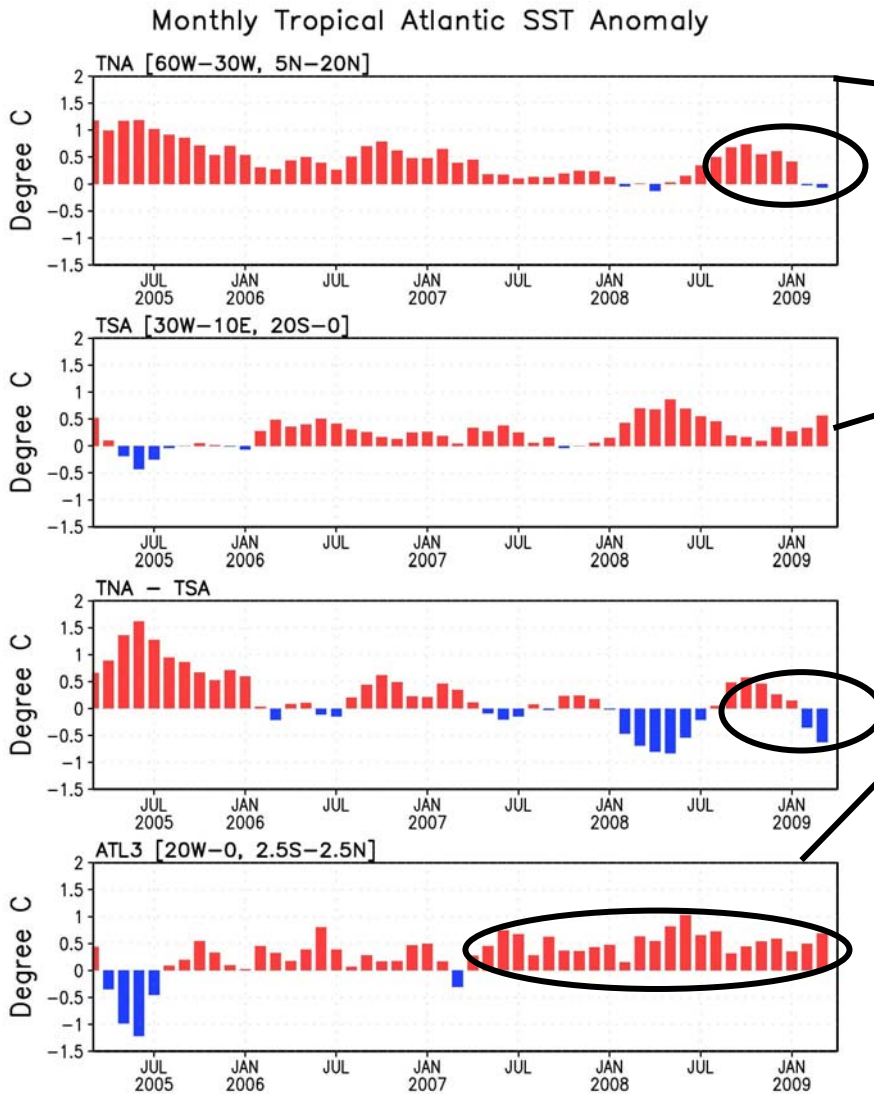


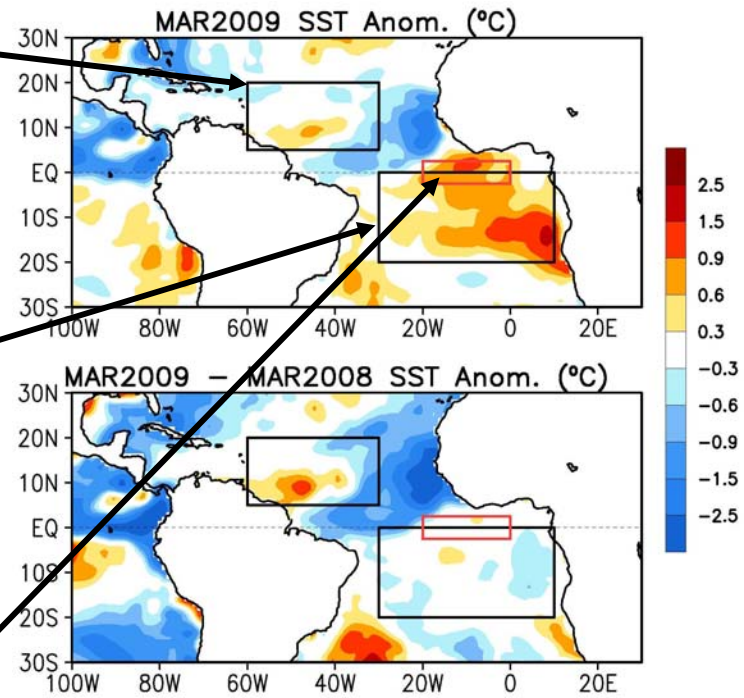
- **Strong positive SSTA in the south-western tropical Indian Ocean.**
- **Convection was suppressed in the tropical Indian Ocean and western Maritime Continent.**

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



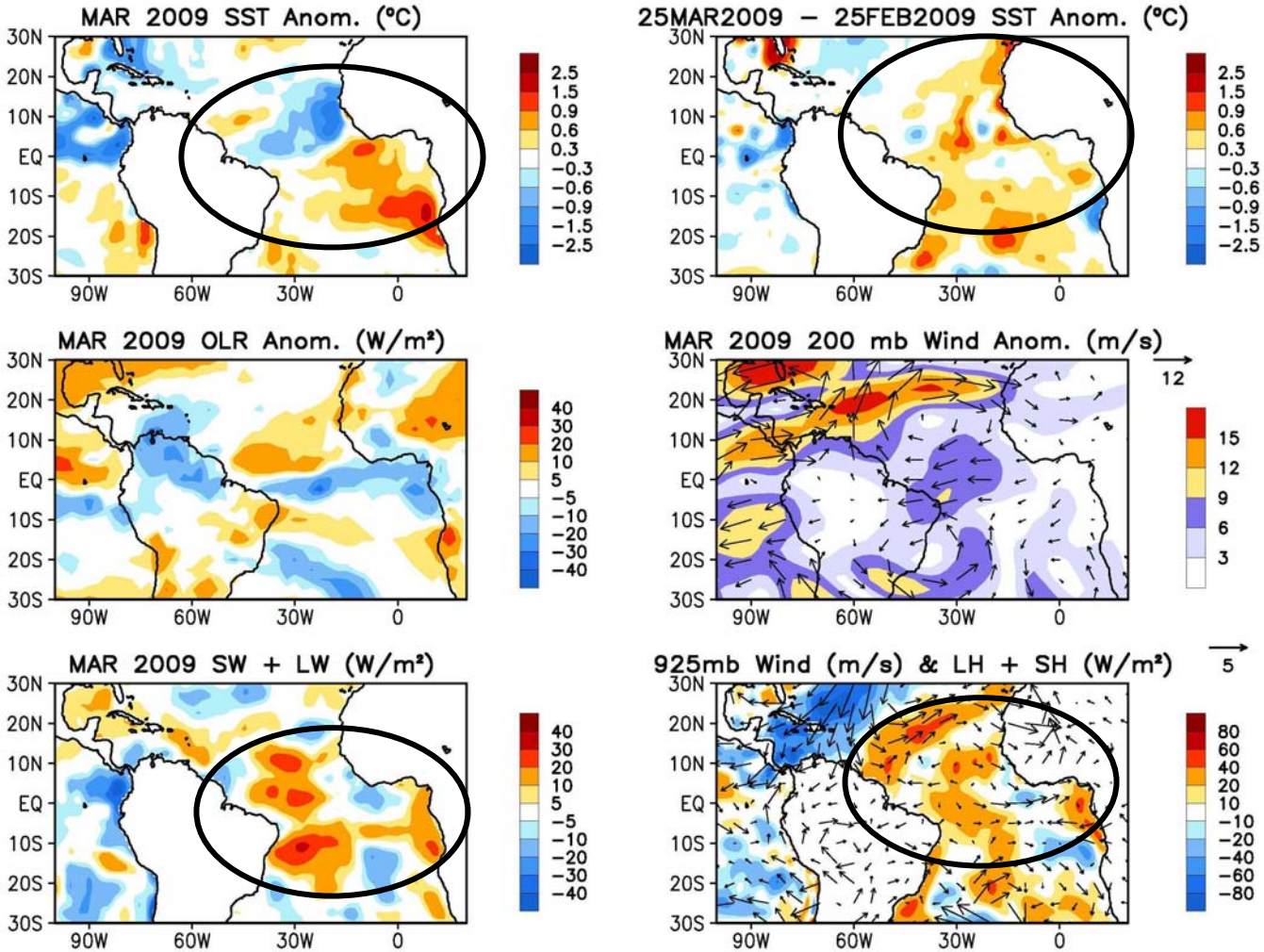


- **Tropical North Atlantic SST was near-normal in Feb-Mar 09.**
- **Tropical South Atlantic SST remained above-normal and warmed up slightly in March.**
- **Meridional Gradient Mode (TNA-TSA) switched to negative in Feb 09, and deepened further in Mar 09.**

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 in the tropical Atlantic.**
- **Surface heat flux anomalies contributed to the SST warming.**
- **Strong northerly wind anomalies persisted in the western subtropical North Atlantic, contributing a cooling there.**

North Atlantic Ocean

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

- North Atlantic SST remains above-normal.

- SST cooled down in most regions of North Atlantic due to negative latent and sensible heat flux anomalies, while SST warmed up along the eastern coast of North America.

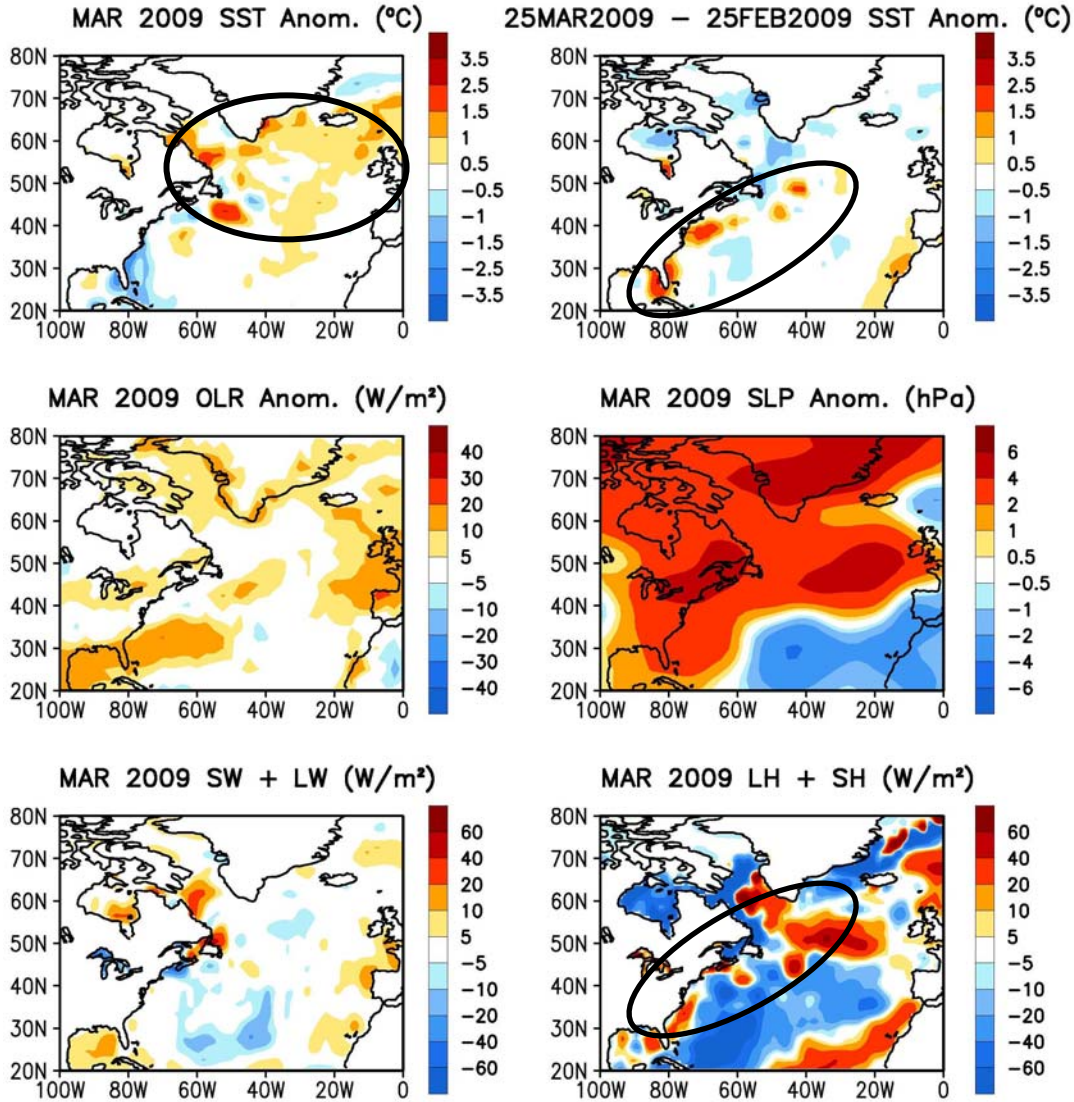
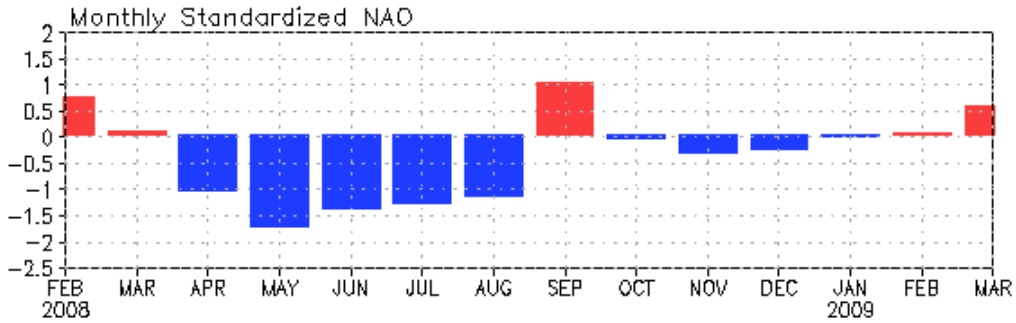
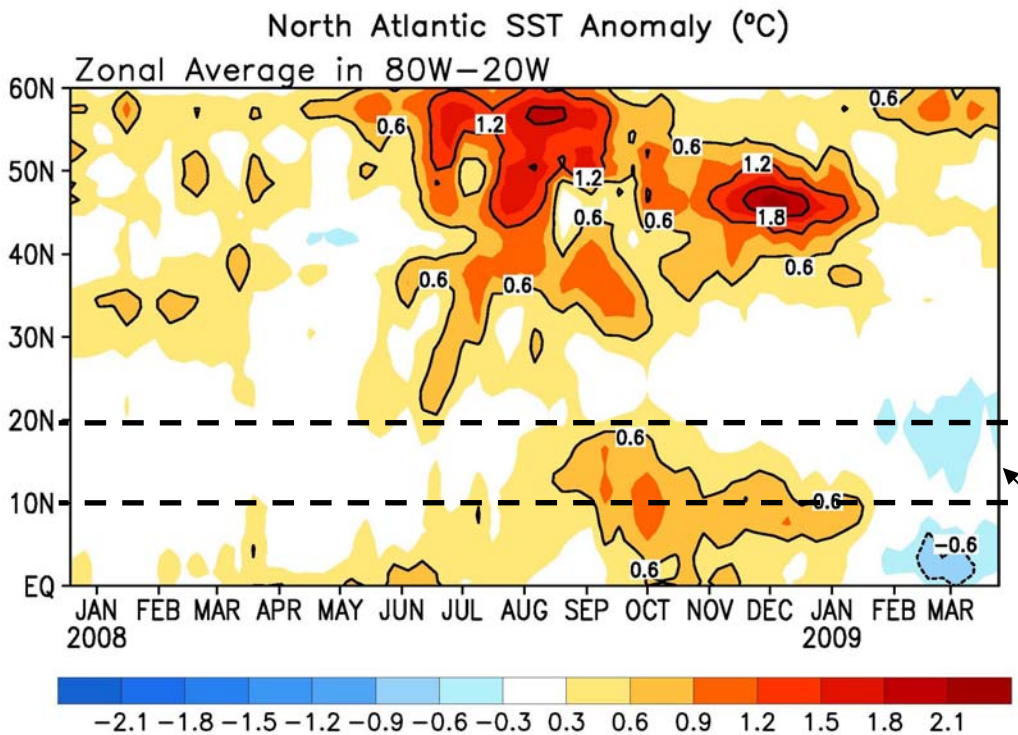
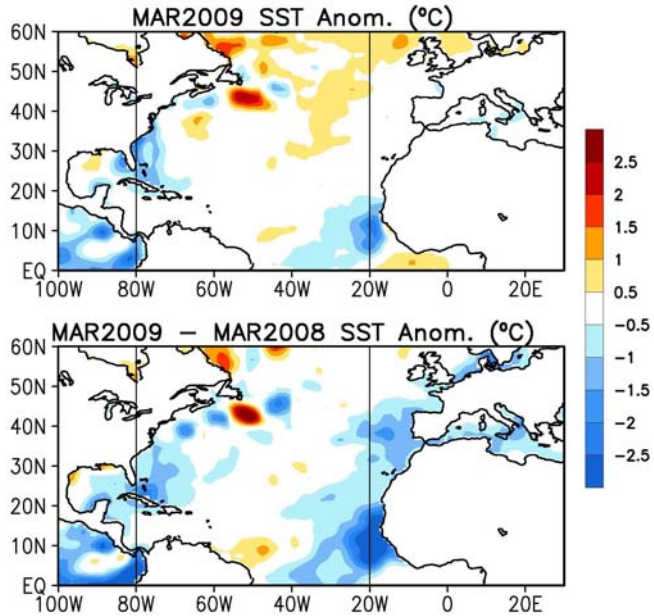


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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 above-normal in March 09.**
- **SSTA in the Hurricane Main Development Region were weakly below-normal in Feb-Mar 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.

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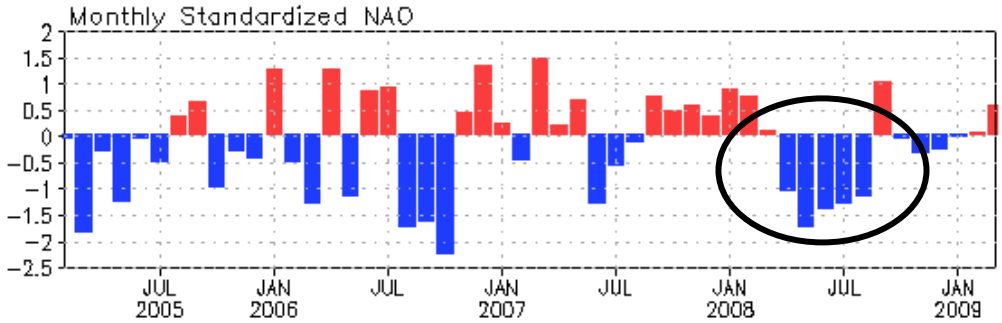

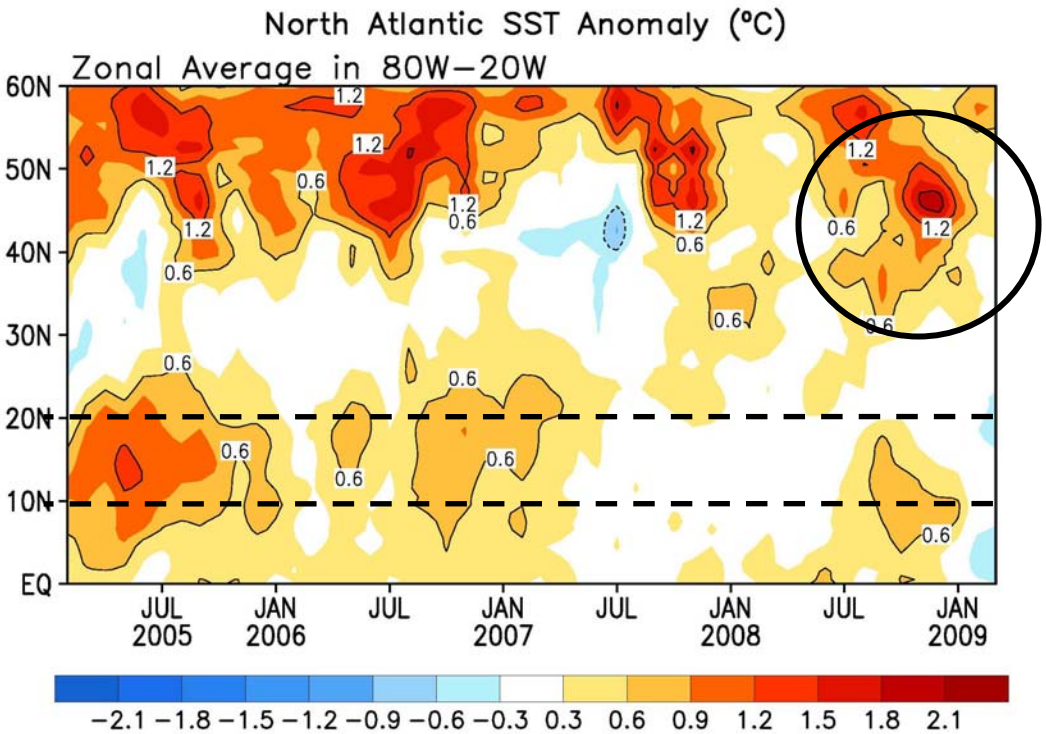

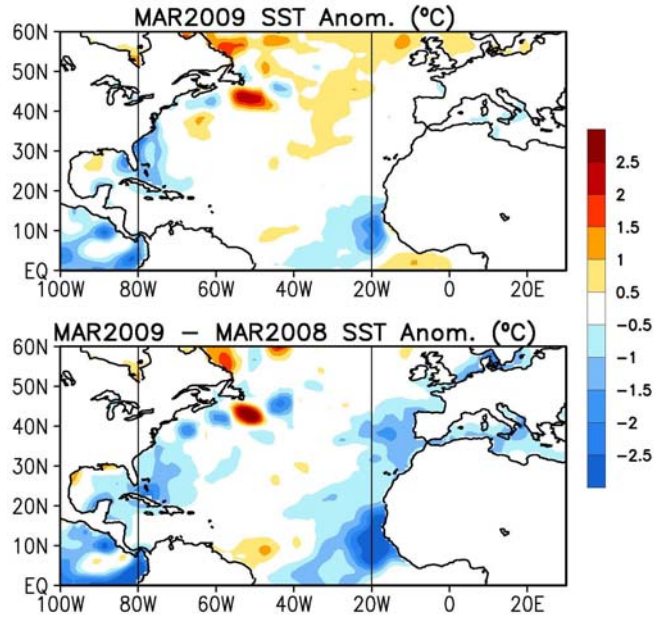

- North Atlantic SSTs have warmed up from May 08 to Jan 09 due to persistent negative NAO phase during Apr-Dec 08. They cooled down since Jan 09 due to positive NAO phase in Feb-Mar 09.

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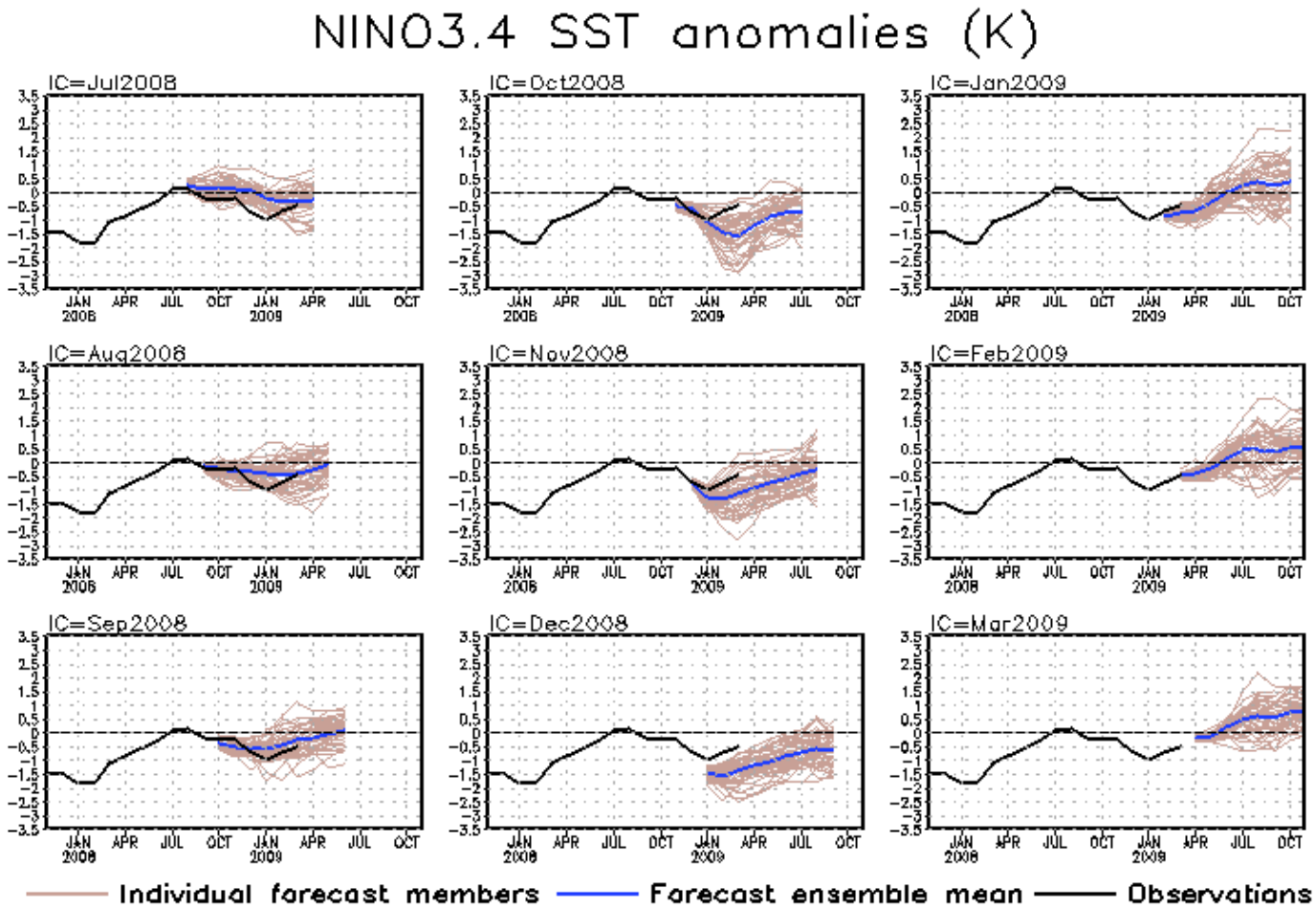
CFS SST Predictions and Ocean Initial Conditions

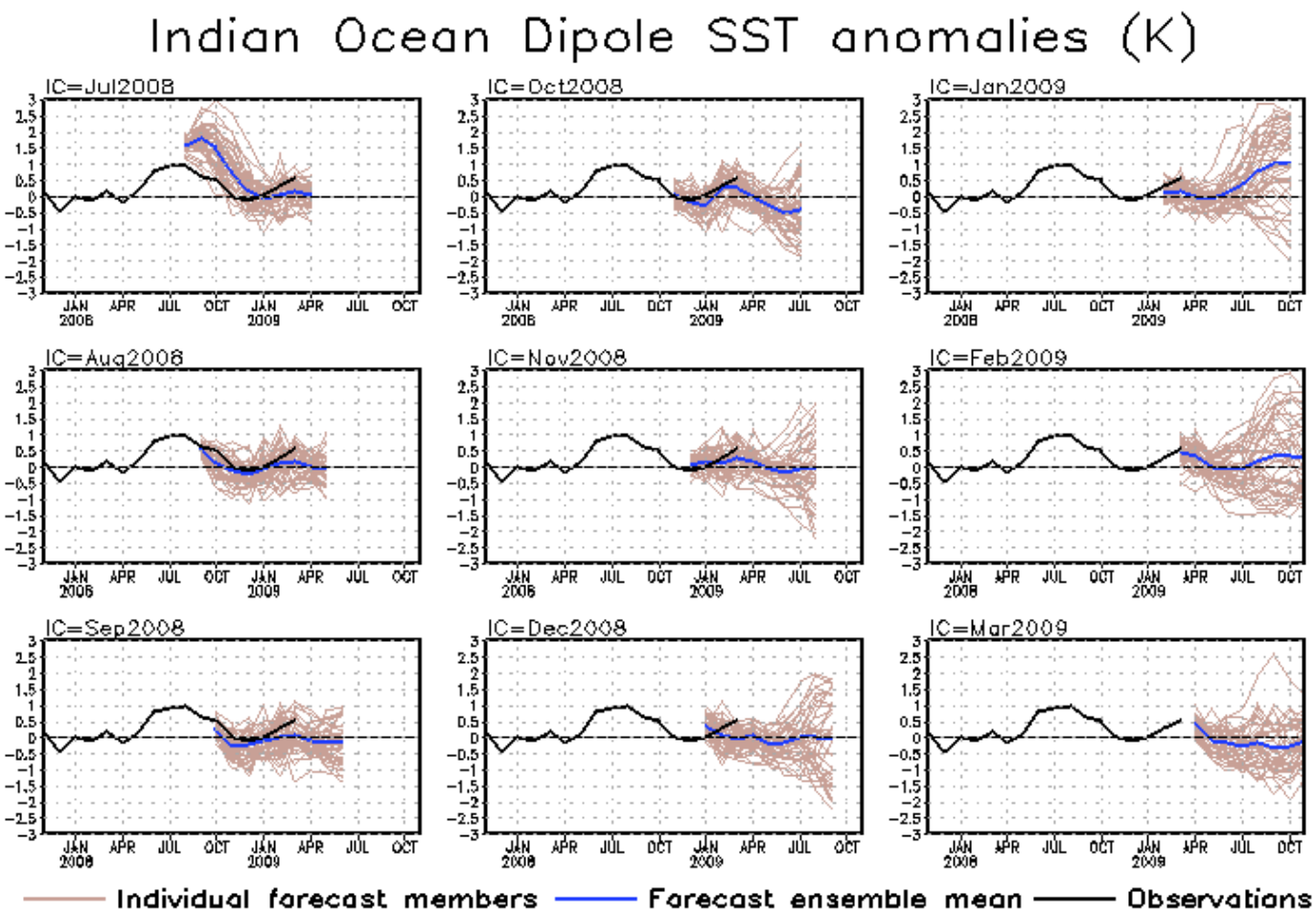
CFS Niño3.4 SST Predictions from Different Initial Months



- **Latest forecasts suggest ENSO-neutral conditions in April-June 09.**

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]

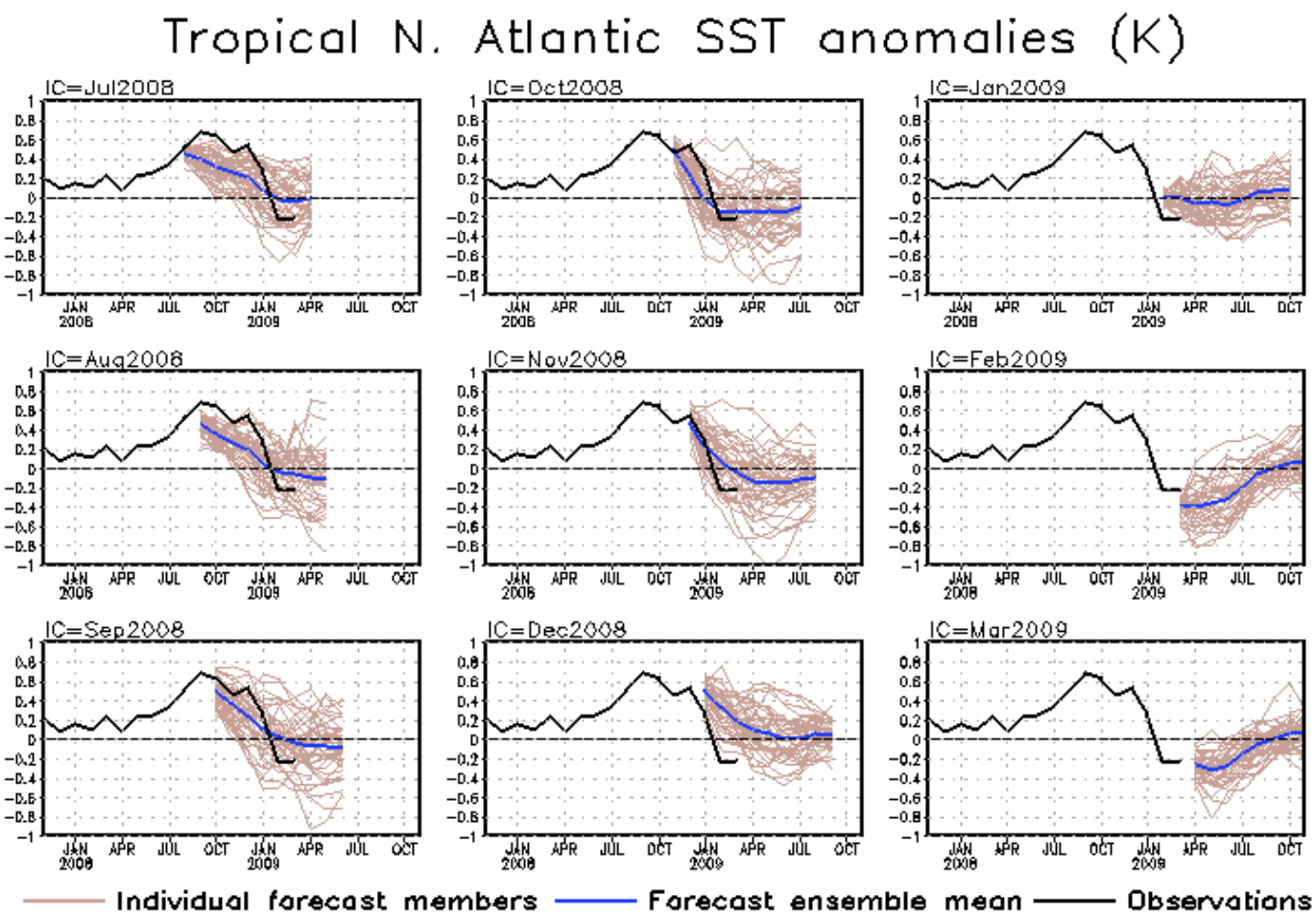
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

- CFS overestimated the amplitude of the positive IOD in Jun I.C.

- Latest forecasts call for near-normal conditions in next 6 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

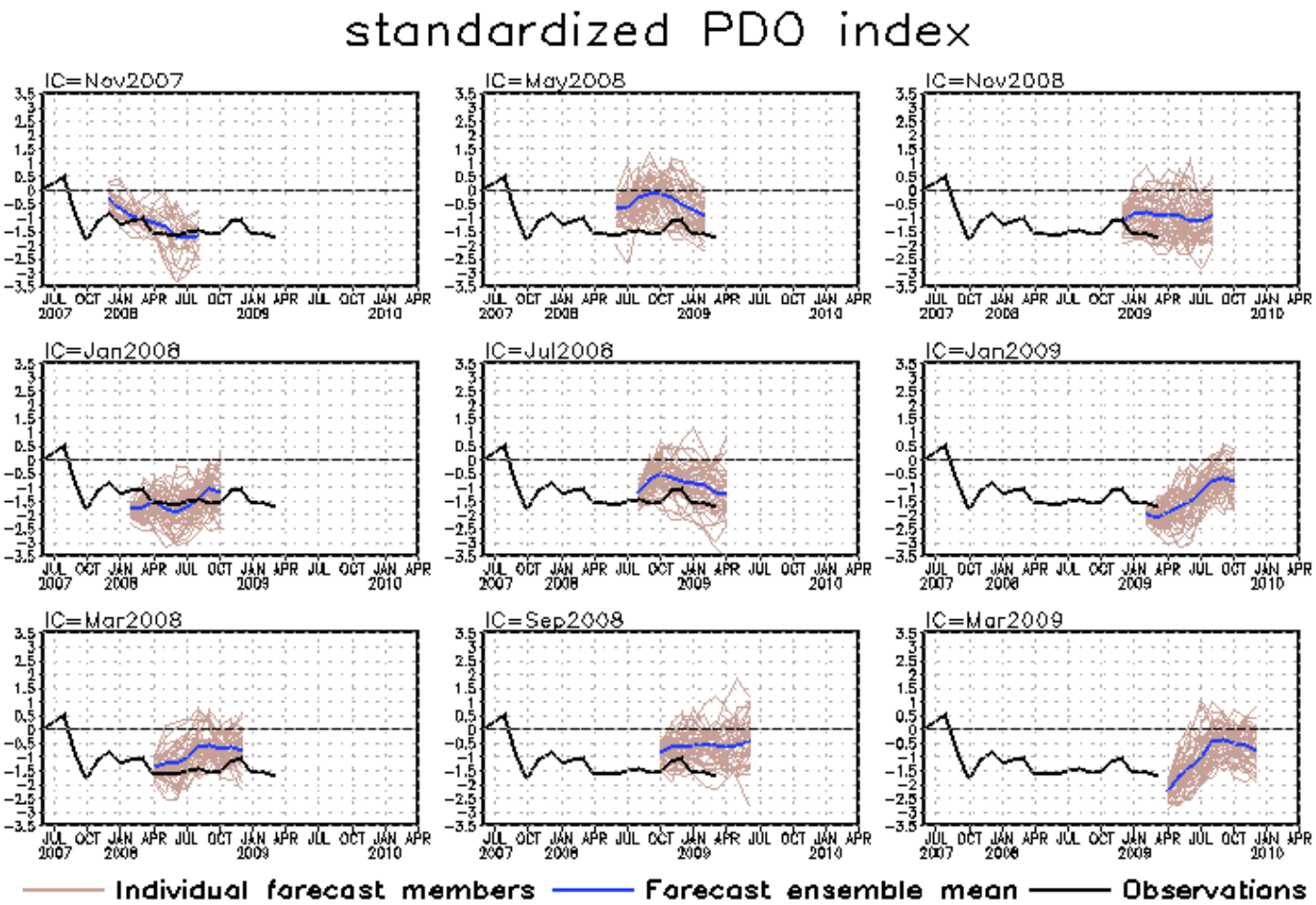


TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- **CFS forecast the decay of positive TNA too early, consistent to its biases in damping SST anomalies.**
- **CFS did not forecast the onset of negative TNA in Feb-Mar 09.**
- **Latest forecasts suggest that the current negative TNA will persist in spring, and then weaken in summer.**

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 15).**
- **CFS has forecast the recent negative PDO phase since July 07 I.C.**
- **CFS wrongfully forecast a decay of the negative PDO phase in spring 08.**
- **Latest forecasts suggest that the current negative PDO will weaken in spring/summer and return to near-normal conditions in 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**
  - La Niña conditions (NINO3.4 < -0.5°C) weakened, and are expected to return to ENSO-neutral conditions in the Northern Hemisphere Spring.
  - Negative PDO phase that started in September 2007 has persisted for 19 months now.
  - Coastal upwelling is strongly above-normal between 36N-42N, and below-normal in the other regions.
- **Indian Ocean**
  - Positive SST anomalies persisted in the western Indian Ocean.
  - Positive IOD index enhanced and became above 0.5 °C in March 09.
- **Atlantic Ocean**
  - Positive SSTA in the North Atlantic SST weakened in Feb-Mar 09.
  - Tropical North Atlantic SST became slightly below-normal in Feb-Mar 09.
  - Tropical South Atlantic and equatorial Atlantic continued to be above-normal.
- **Arctic Ocean**
  - Ice concentration remains much below-normal, and starts to decrease.

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!