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

Prepared by
Climate Prediction Center, NCEP

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

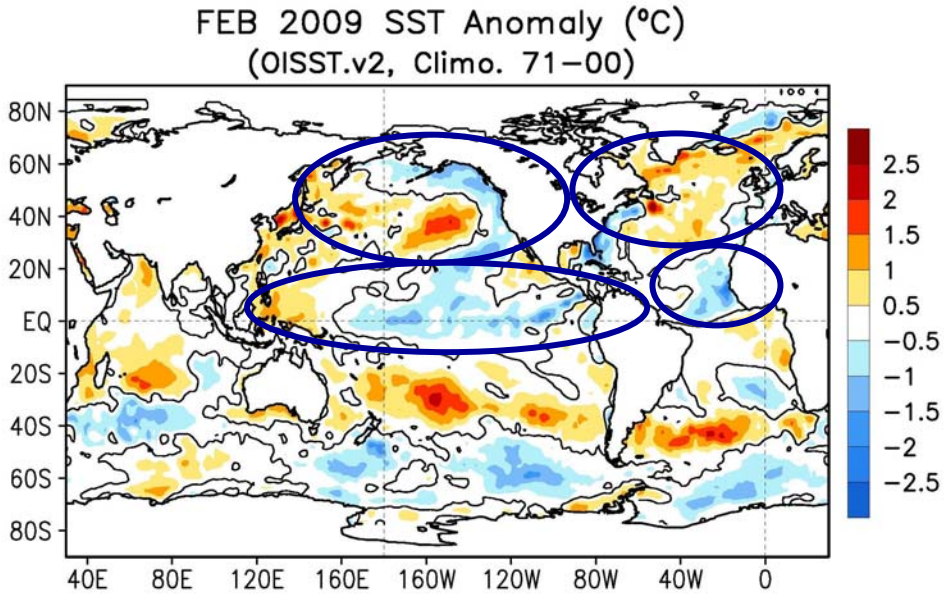
Outline

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

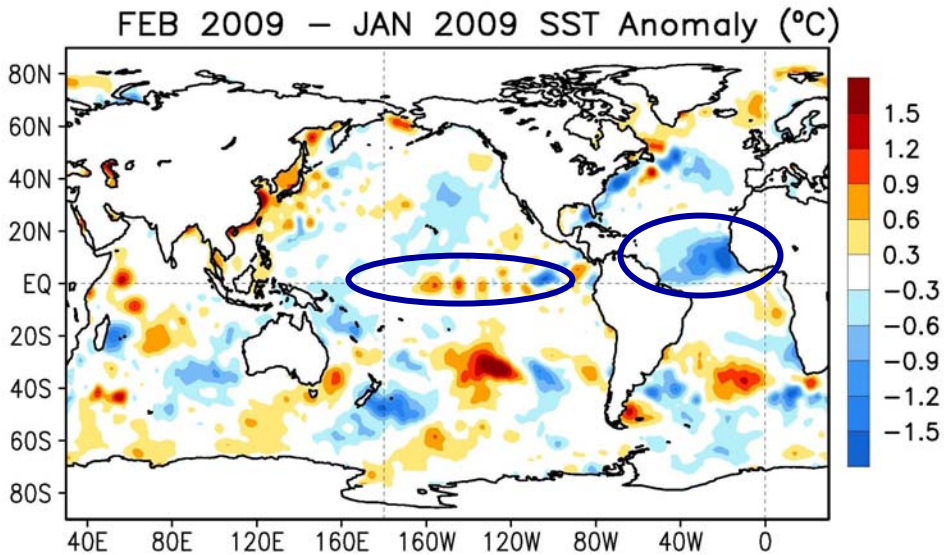
Overview

- **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 18 months now, and 2008 has the lowest yearly mean PDO index since 1971.
  - Above-normal upwelling that has persisted since mid-November 2007 switched to below-normal in later February along the western coast of North America south of 35N.
- **Indian Ocean**
  - Positive SST anomalies presented in the western Indian Ocean.
  - IOD index became weakly positive.
- **Atlantic Ocean**
  - Above-normal SST in North Atlantic persisted.
  - Above-normal SST in the tropical North Atlantic returned to near-normal or below-normal, while above-normal SST in the tropical South Atlantic and equatorial Atlantic persisted.
- **Arctic Ocean**
  - Ice concentration remains much below-normal.

Global SST Anomaly (ºC) and Anomaly Tendency



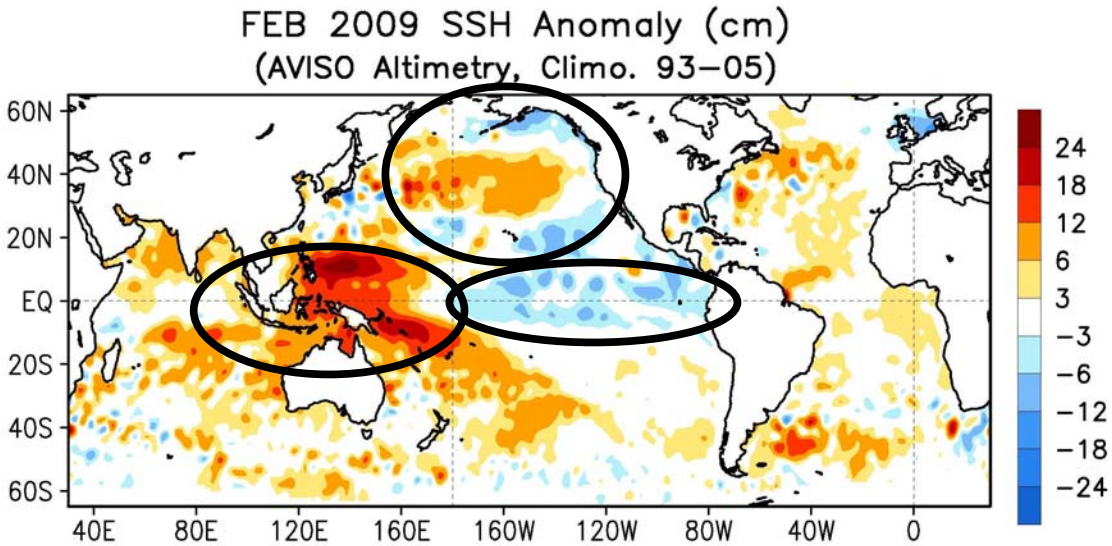
- **Negative PDO-like SST pattern in North Pacific.**
- **La Niña Conditions in the tropical Pacific.**
- **Positive SSTA in the North Atlantic.**
- **Negative SSTA in the northeastern tropical Atlantic**

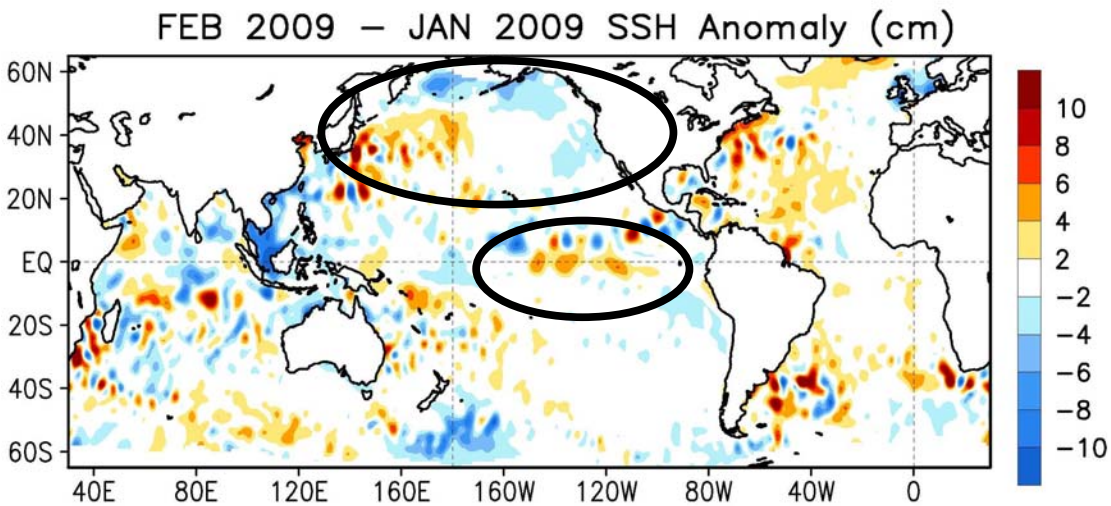


- **Positive SSTA tendency in the central-eastern tropical Pacific: La Niña weakened.**
- **Negative SSTA tendency in the northeastern tropical Atlantic.**

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



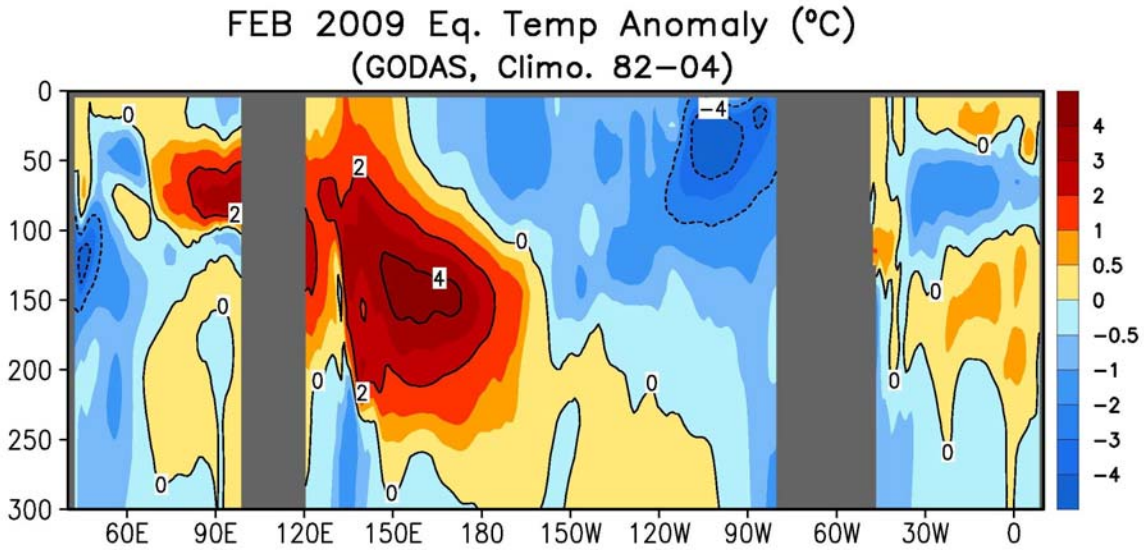


- **Negative SSHA in the central and eastern tropical Pacific.**
- **Positive SSHA in most of the Indian Ocean and western Pacific.**
- **Negative PDO-like SSHA in the North Pacific, consistent with negative PDO-like SSTA.**

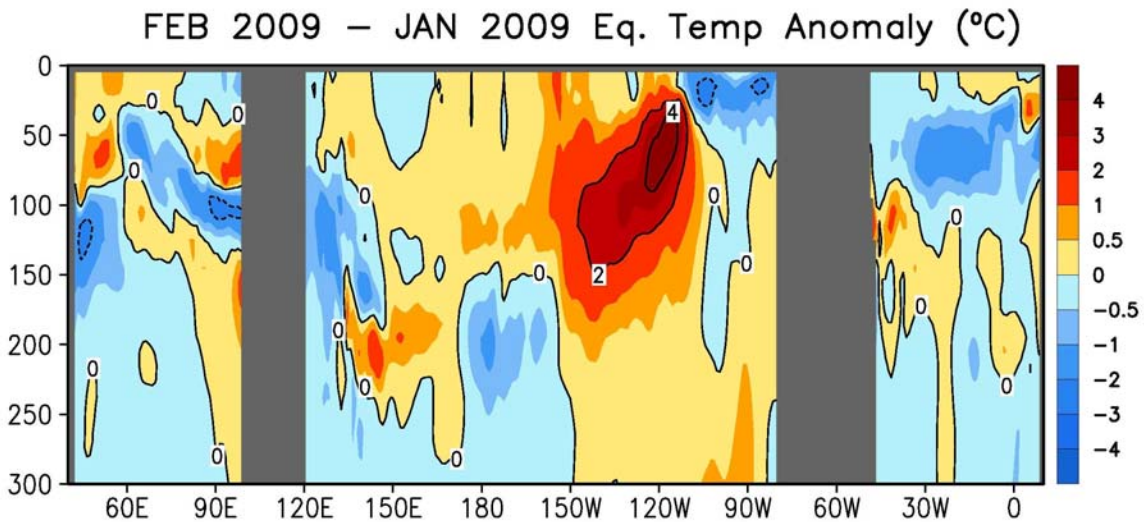
- **Negative SSHA in the equatorial eastern Pacific weakened.**
- **Negative PDO-like SSHA in the North Pacific enhanced.**

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 (negative) subsurface temperature anomalies about 4°C presented in the equatorial western (eastern) Pacific.
- Positive subsurface temperature anomalies about 2°C in the eastern equatorial Indian Ocean.

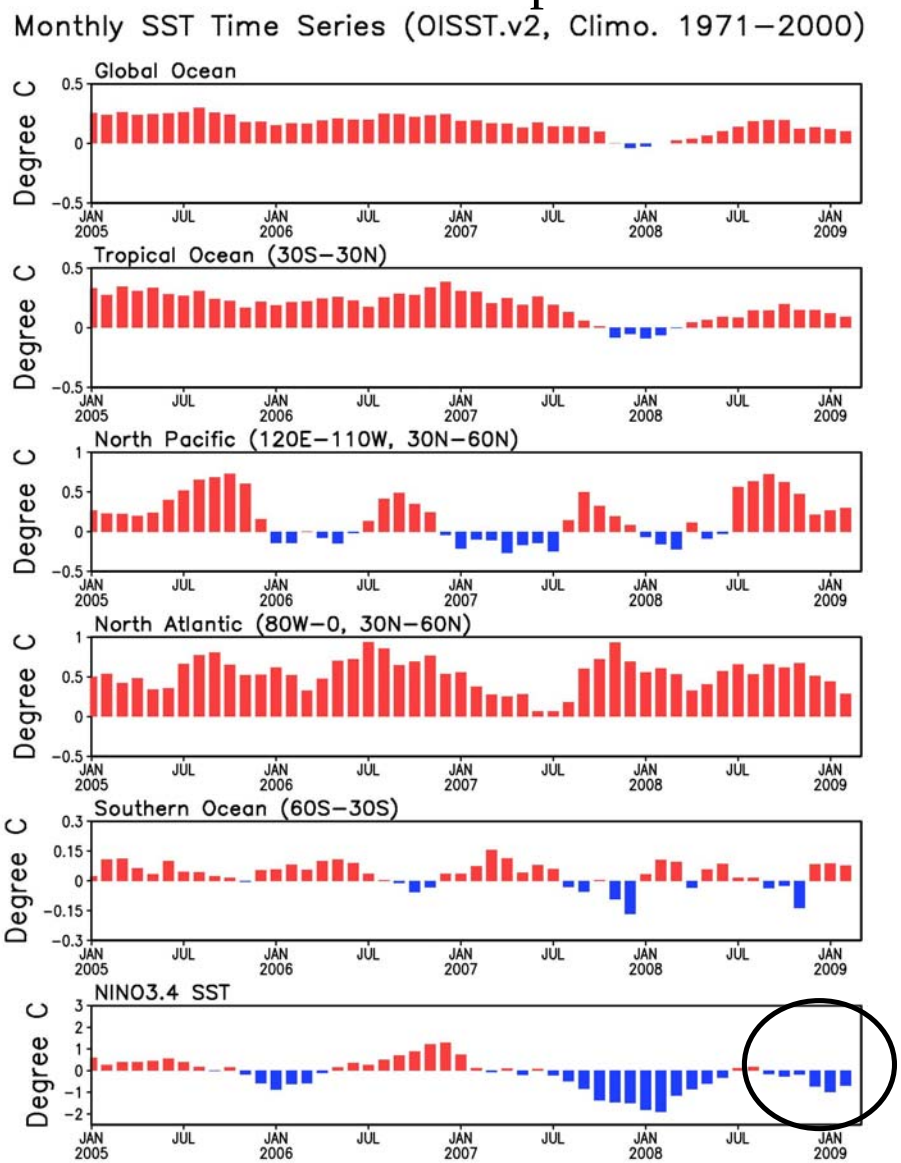


- Negative subsurface temperature anomalies in the central equatorial Pacific weakened.

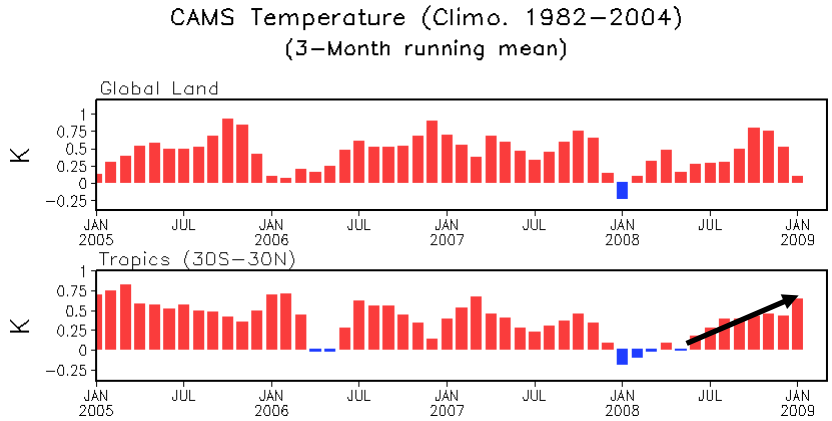
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1982-2004 base period means.

Monthly Time Series

Sea Surface Temperature



CAMS Land Temperature

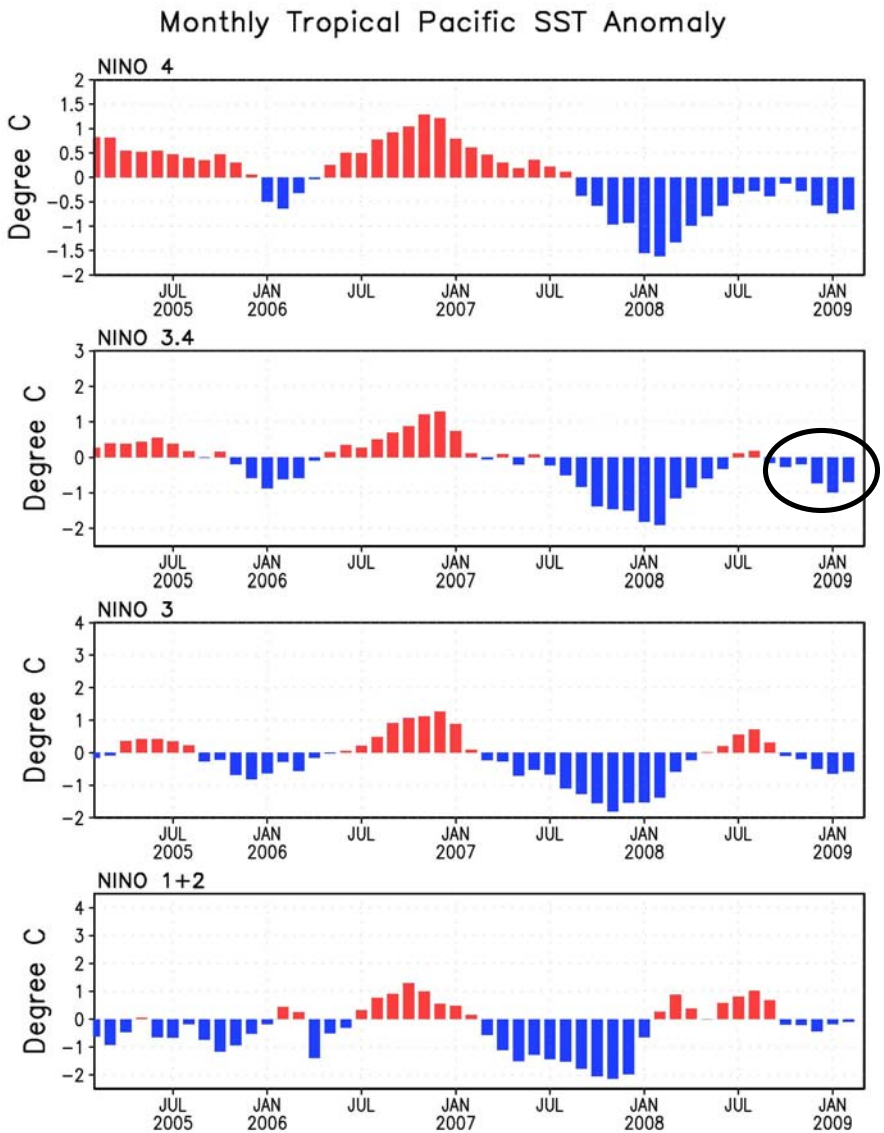


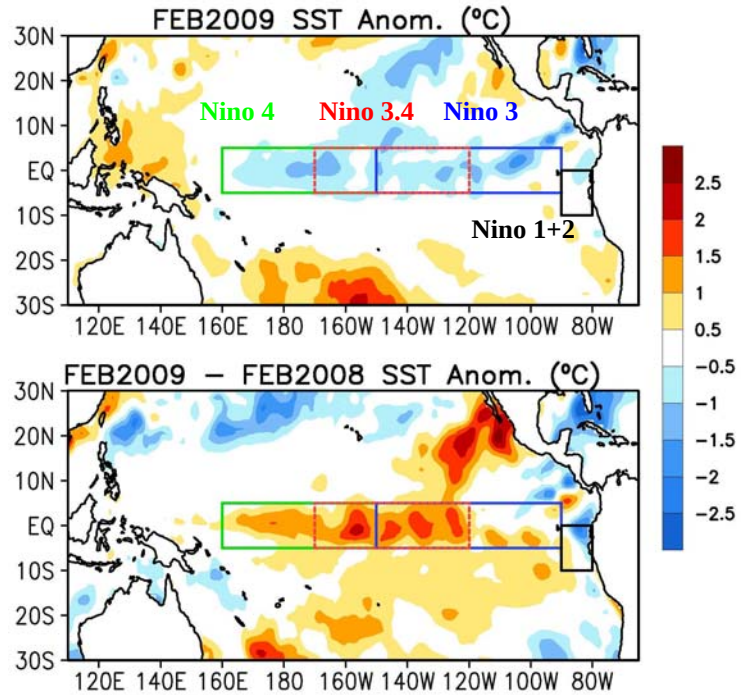
- **Global mean SSTA weakened slightly.**
- **Global mean of seasonal land temperature reduced dramatically from NDJ to DJF.**
- **Tropical land temperature continues to be well above-normal in response to the above-normal tropical ocean SST.**
- **Weak positive SSTA in North Pacific continued.**
- **Positive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

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



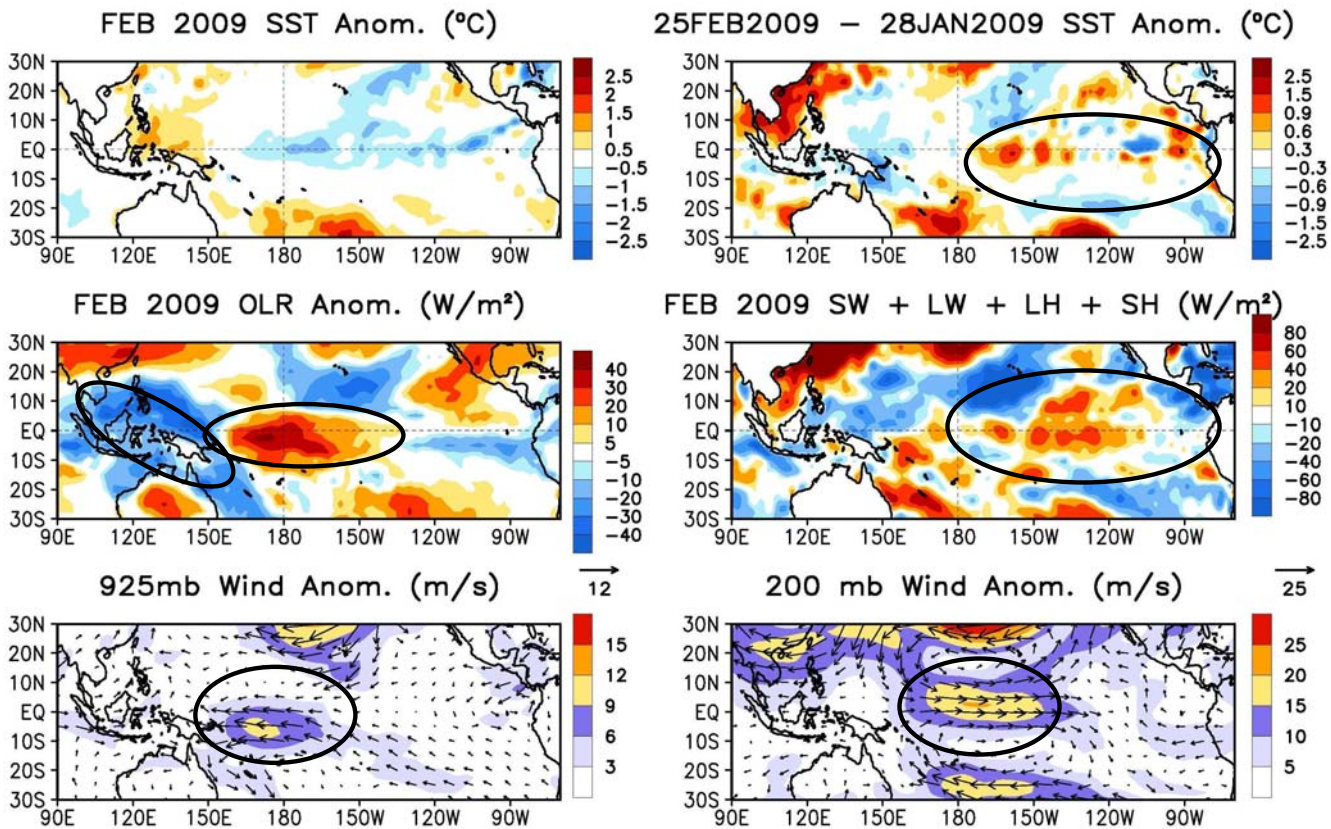


- La Niña conditions (NINO3.4 < -0.5ºC) developed in December 2008, and are expected to return to ENSO-neutral conditions in spring – NOAA's "ENSO Diagnostic Discussion".

- All NINO indices are below-normal, and became weaker in February.

Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) 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 tropical Pacific (Maritime Continent).
- Low-level easterly wind anomalies in the central tropical Pacific.
- Upper-level westerly in central tropical Pacific, consistent with La Nina conditions.
- Surface heat flux damped SST anomalies in the tropical Pacific.

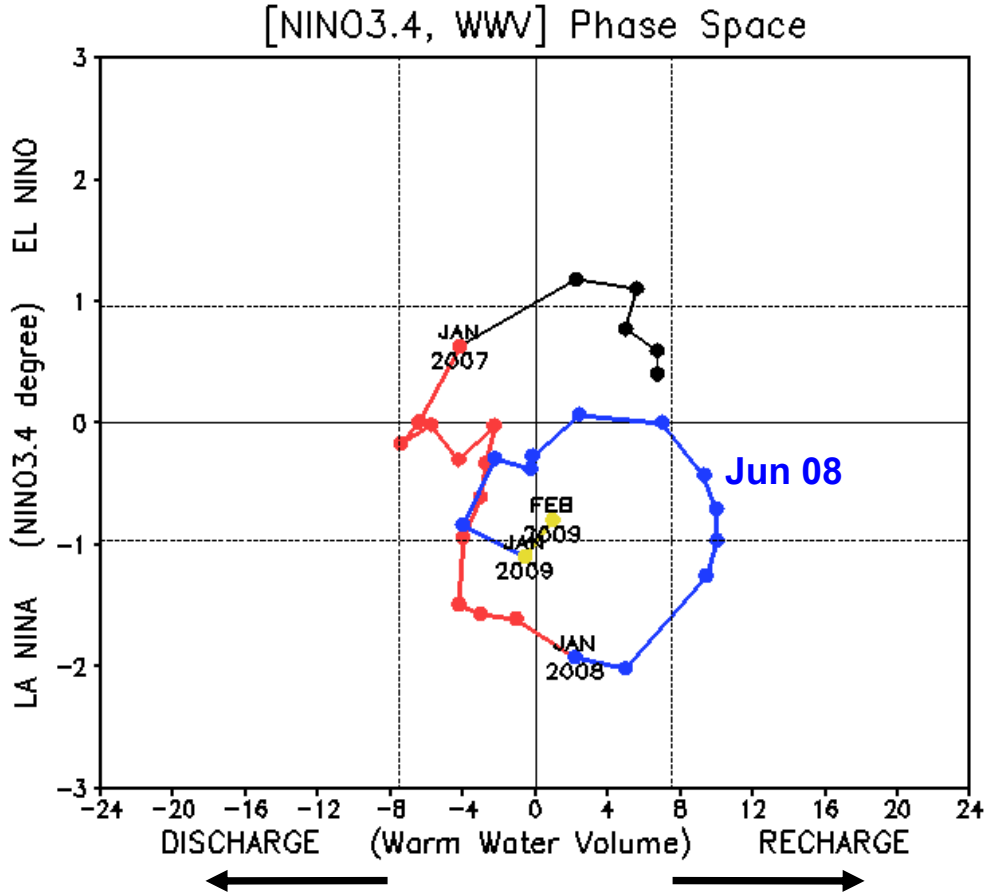
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

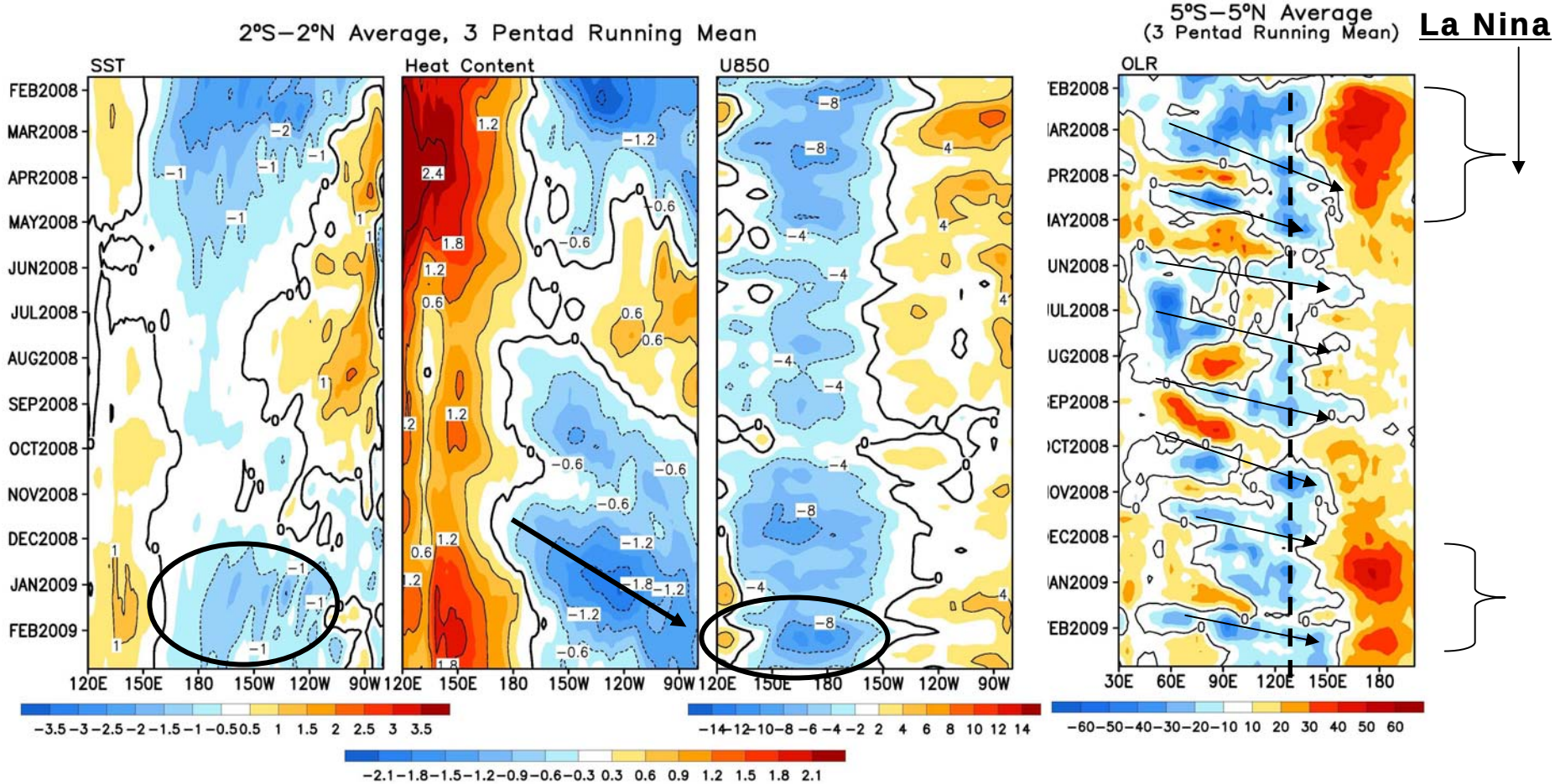


- Warm Water Volume(WWV) has discharged from June to December 08, but recharged from December 08 to February 09 and is weakly above-normal in February 09.

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

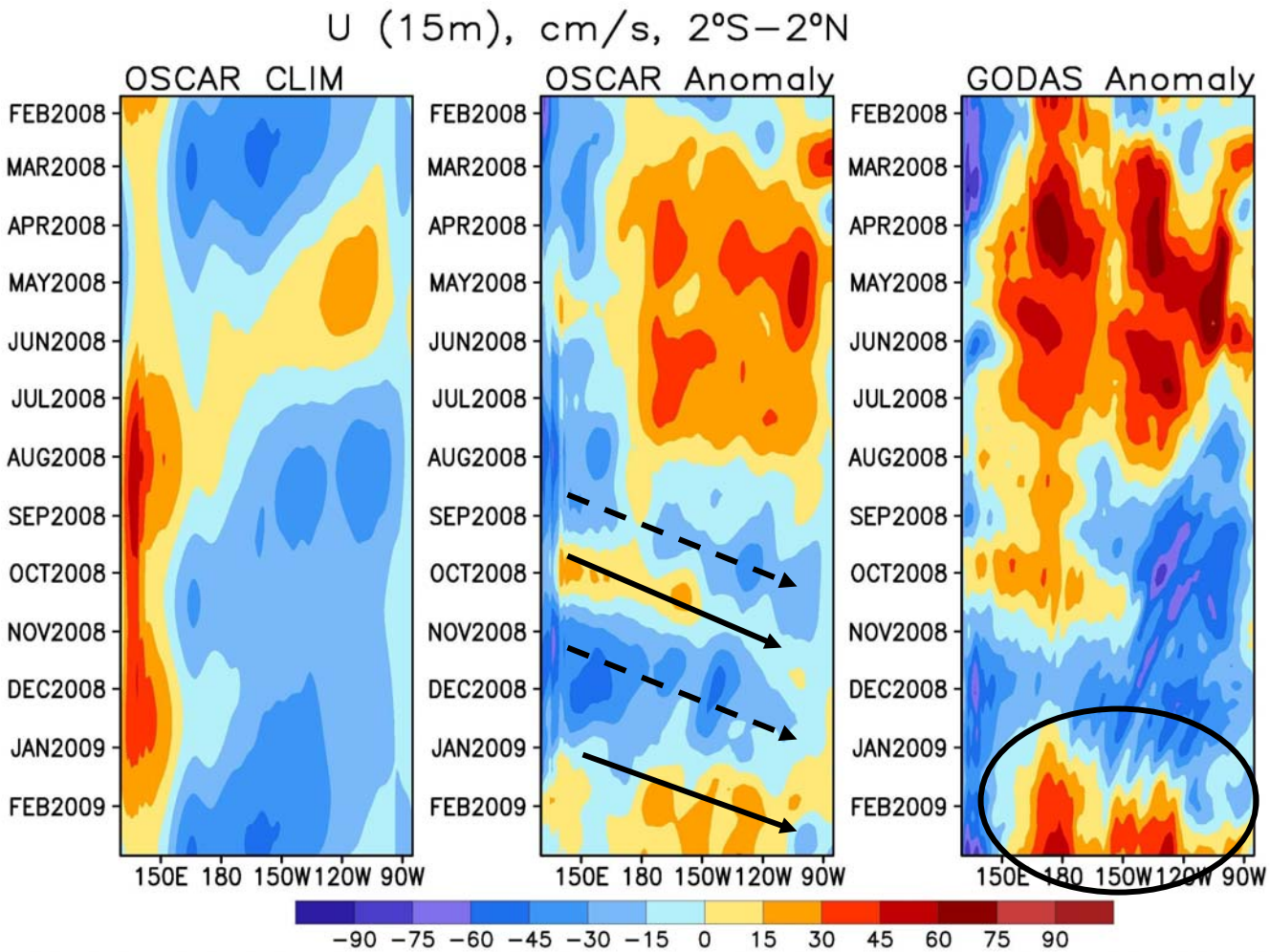
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m^2) Anomaly



- Negative SSTA presented in the central tropical Pacific since Dec 08, and became weaker in later February 09.
- Eastward propagation of negative heat content anomalies along the equator since November 08.
- Strong easterly wind anomalies in later January and earlier February were associated with MJO-related convection in the tropical Indian Ocean and Maritime Continent.

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.

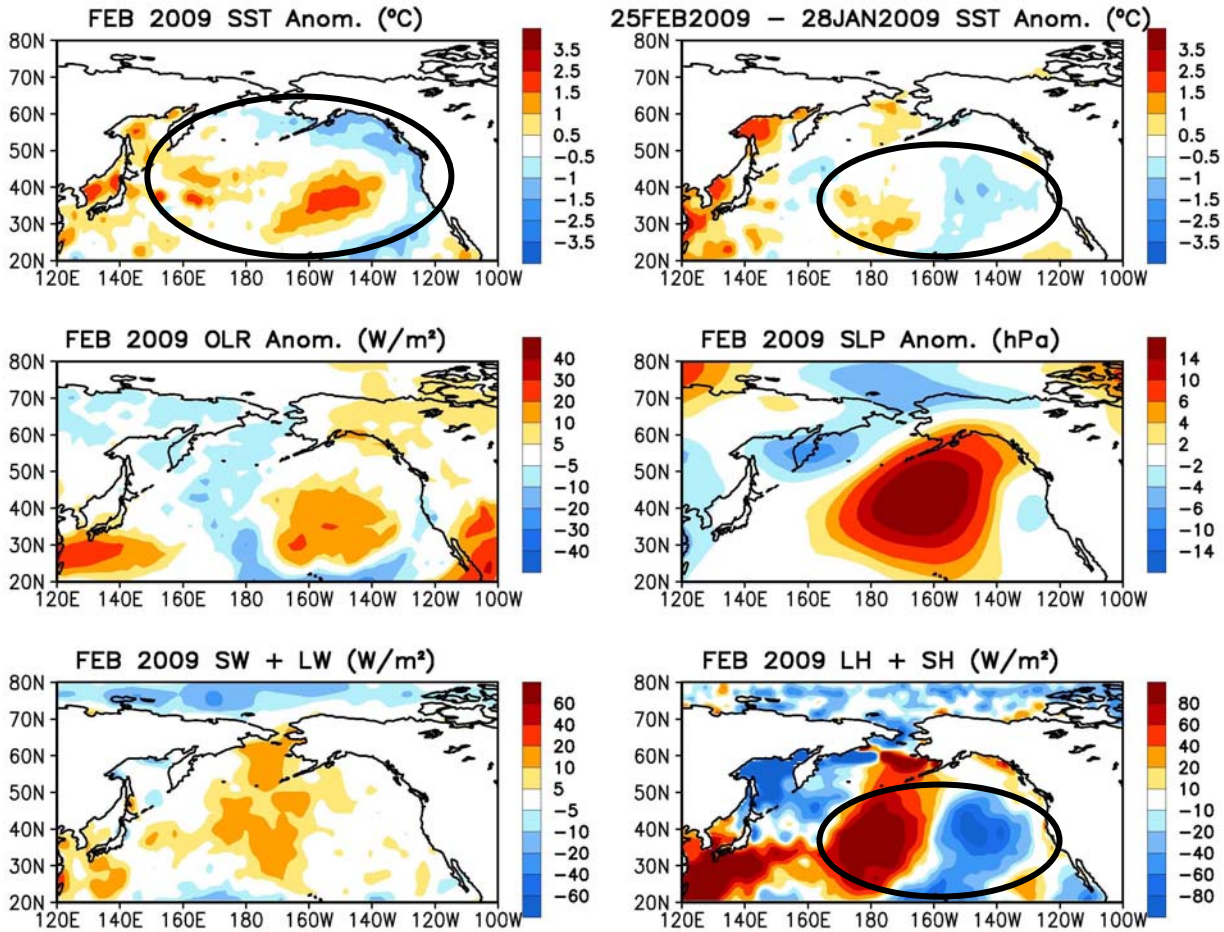
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- **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 weakening of La Niña.**
- **Positive surface zonal current anomalies of GODAS in the central tropical Pacific were too strong compared to the OSCAR currents.**

North Pacific & Arctic Ocean

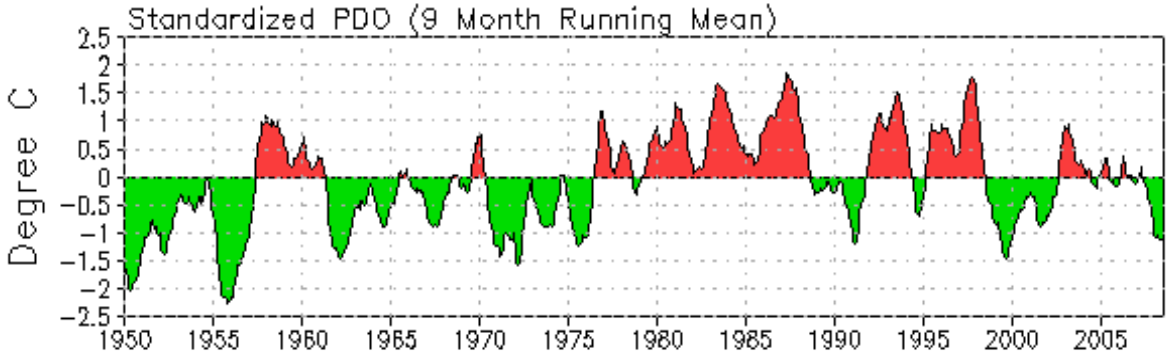
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx



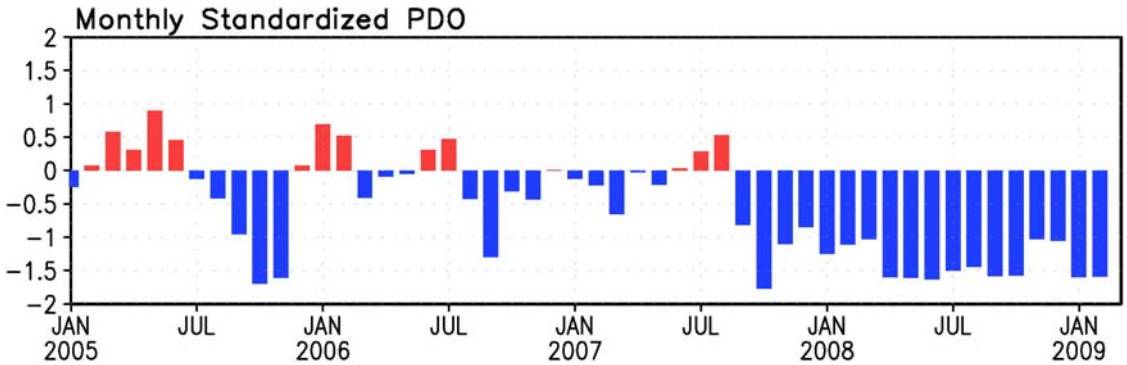
- Negative PDO-like SST pattern presented in the North Pacific.
- SSTA tendencies are consistent with the surface heat flux anomalies.
- Above-normal sea level pressure in the Gulf of Alaska was in favour of coastal upwelling along the coast of western North America north of 50N (slide 18).

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.

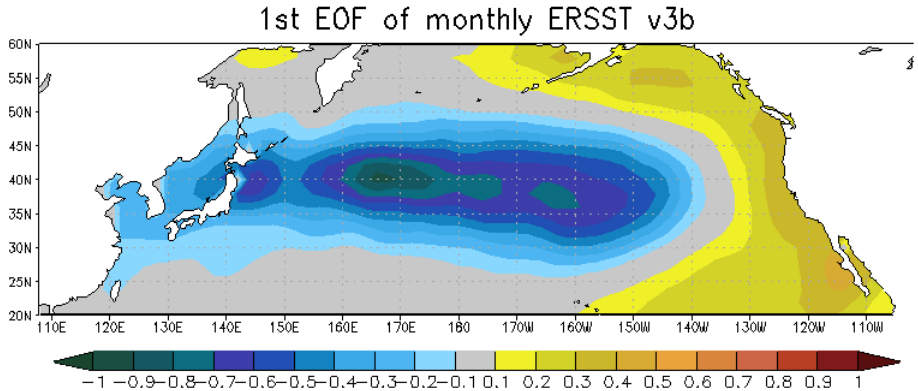
PDO index



PDO index at the lowest value since 1999.



Negative PDO index started in September 2007, and has persisted for 18 months.

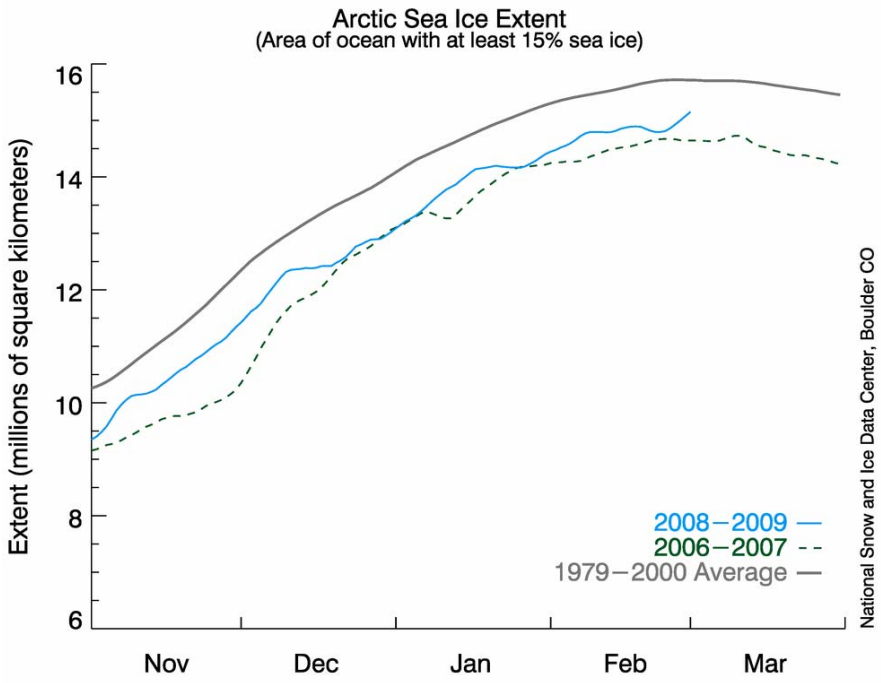


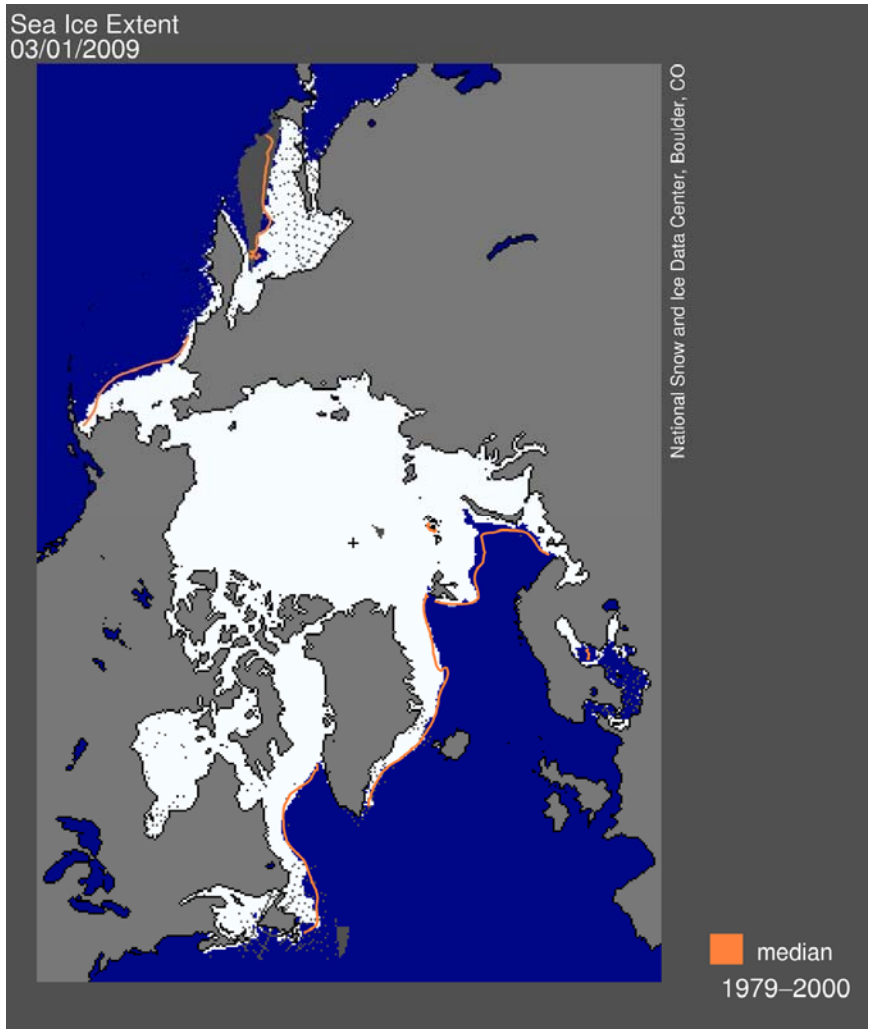
- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.**
- **The PDO index differs slightly from that of JISAO, which uses a blend of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

Arctic Sea Ice

National Snow and Ice Data Center

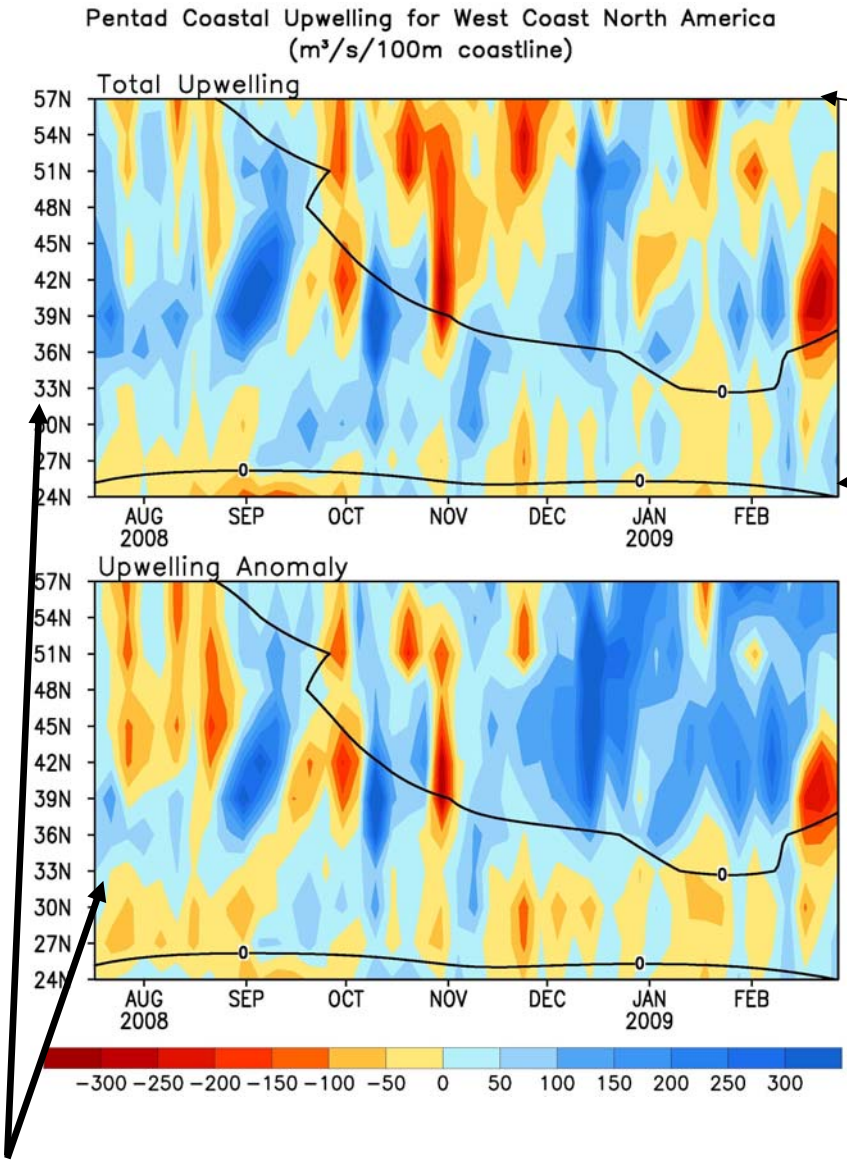
http://nsidc.org/arcticseaicenews/index.html

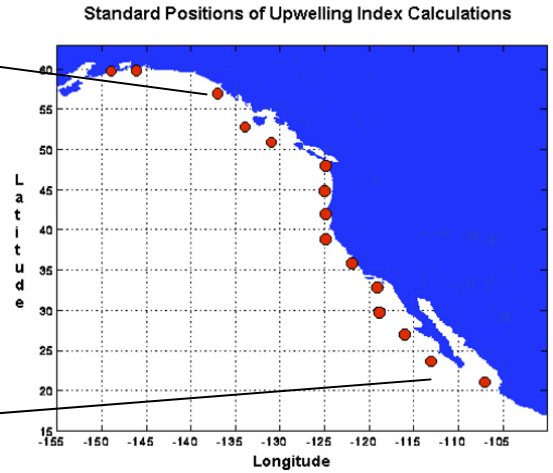




- **Sea ice extent remains well below-normal.**
- **Arctic sea ice grows fast after mid-February.**

North America Western Coastal Upwelling





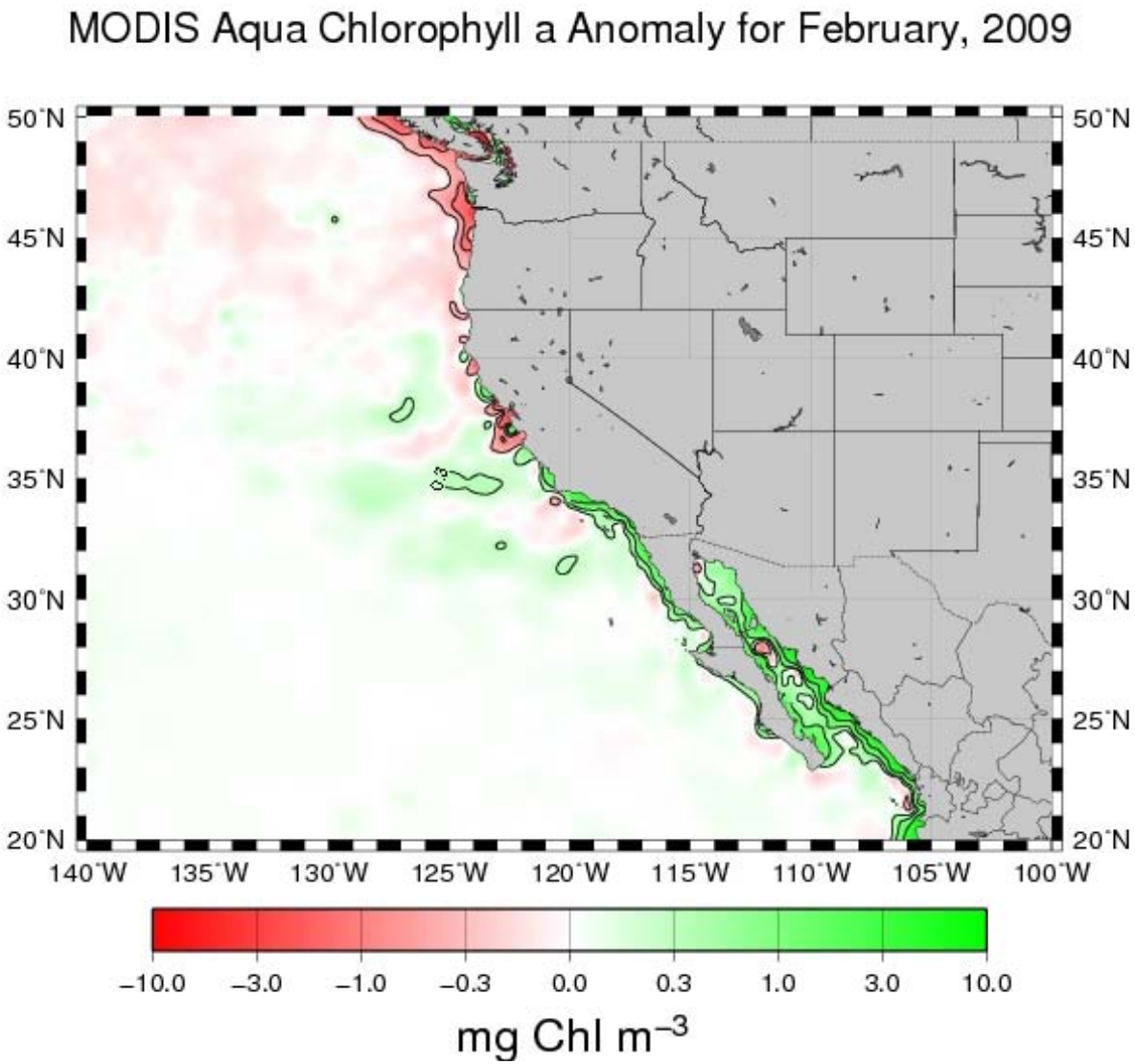
- **Upwelling has been well above-normal from mid-Nov 08 to mid-Feb 09.**
- **The above-normal upwelling is associated with the negative PDO phase.**
- **Strong downwelling anomaly appeared in later February 09 between 33N and 45N.**

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

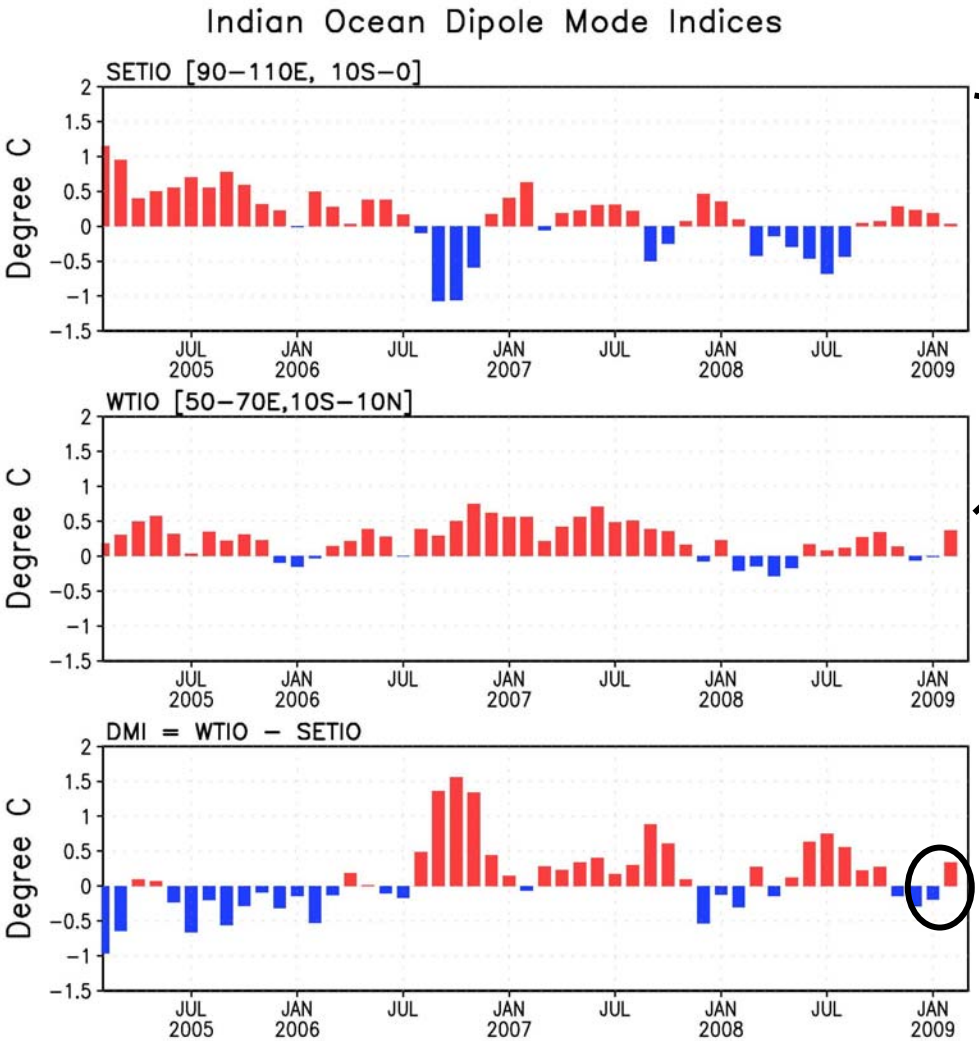
http://coastwatch.pfel.noaa.gov/FAST

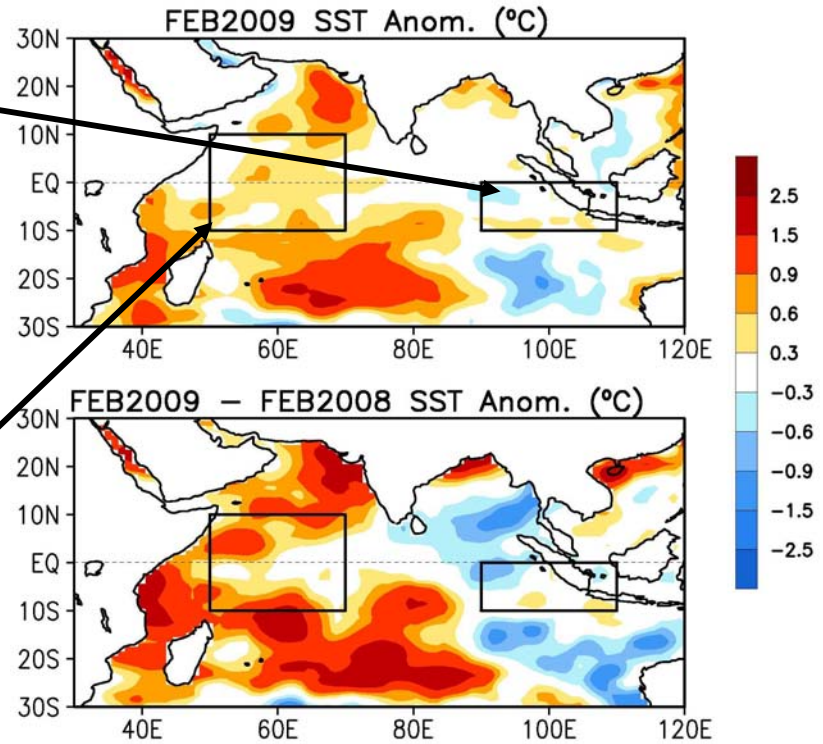


- **Negative (positive) Chlorophyll anomalies presented north (south) of 35N.**
- **Chlorophyll anomalies are largely consistent with upwelling anomalies.**

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

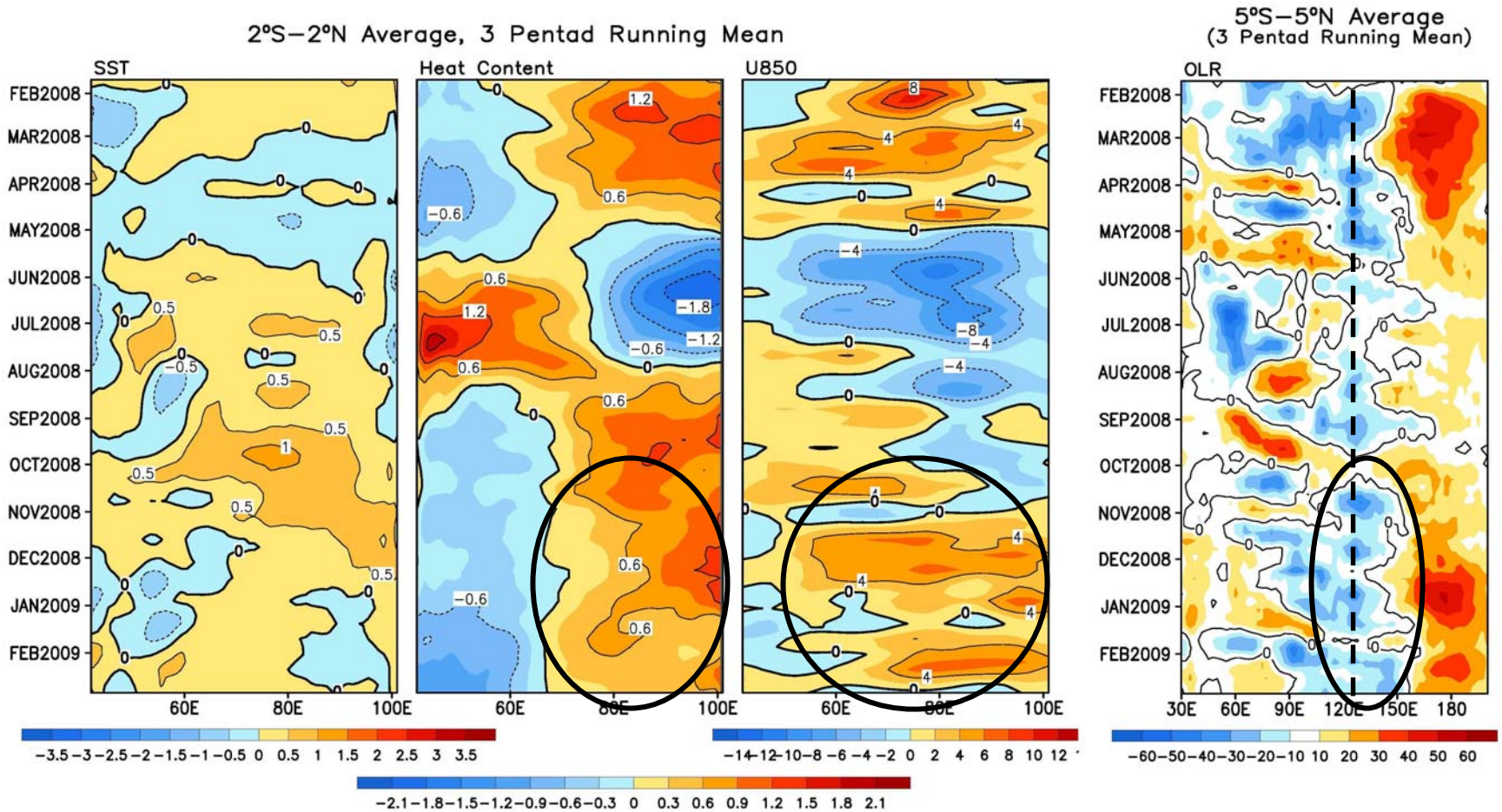




- **Dipole Mode Index (DMI) and its western pole index became positive in February 09.**
- **Large positive SST anomalies presented in the subtropical Indian Ocean west of 80E.**

Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) 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.

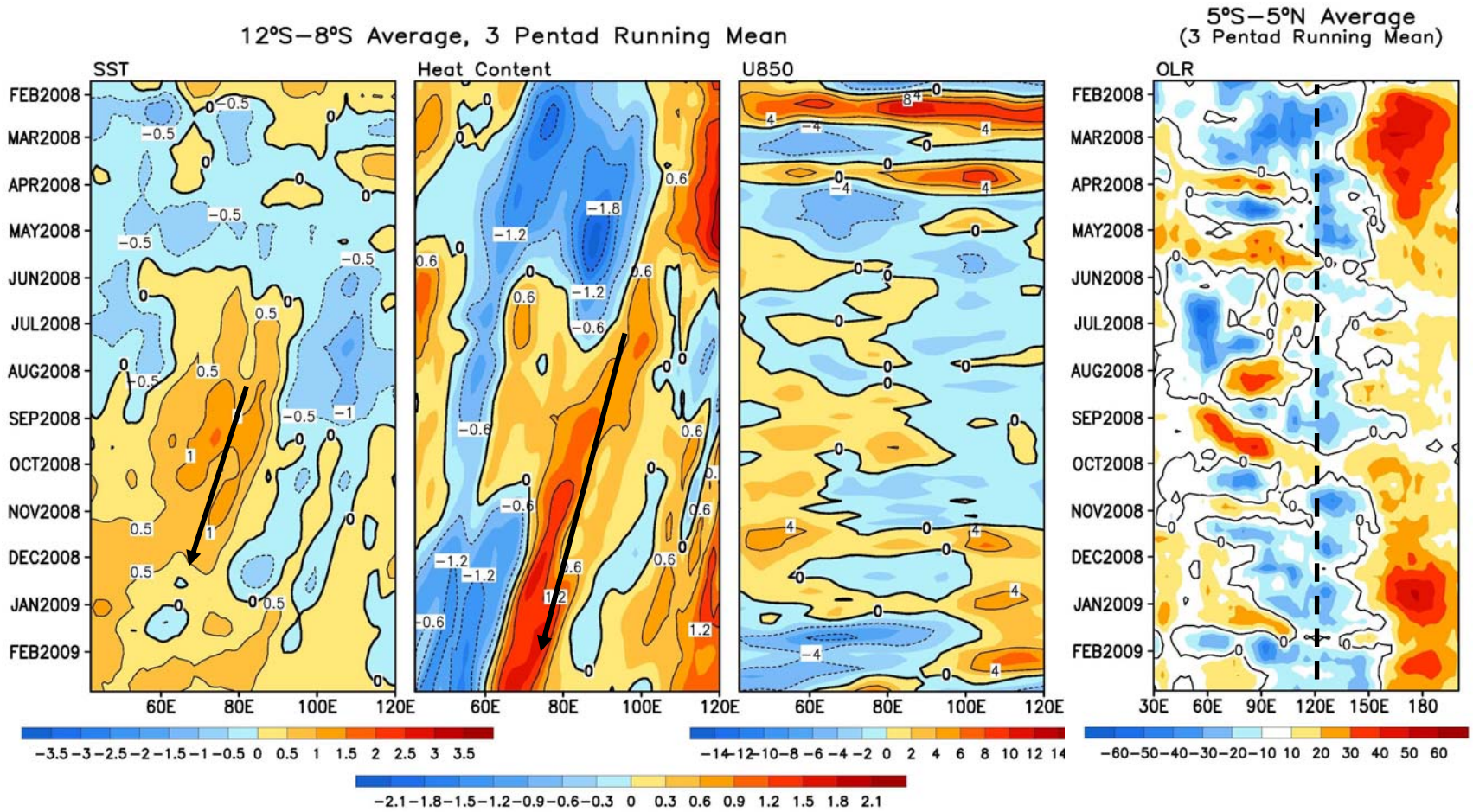
Recent Evolution of Equatorial Indian SST (ºC), 0-300m Heat Content (ºC), 850-mb Zonal Wind (m/s) and OLR (W/m^2) Anomalies



- **Westerly wind anomalies since August, probably associated with the persistent enhanced-convection over the Maritime Continent, maintained positive (negative) heat content anomalies in the eastern (western) Indian Ocean.**
- **Westerly wind anomalies became weaker in later February 09, consistent with the positive DMI.**

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.

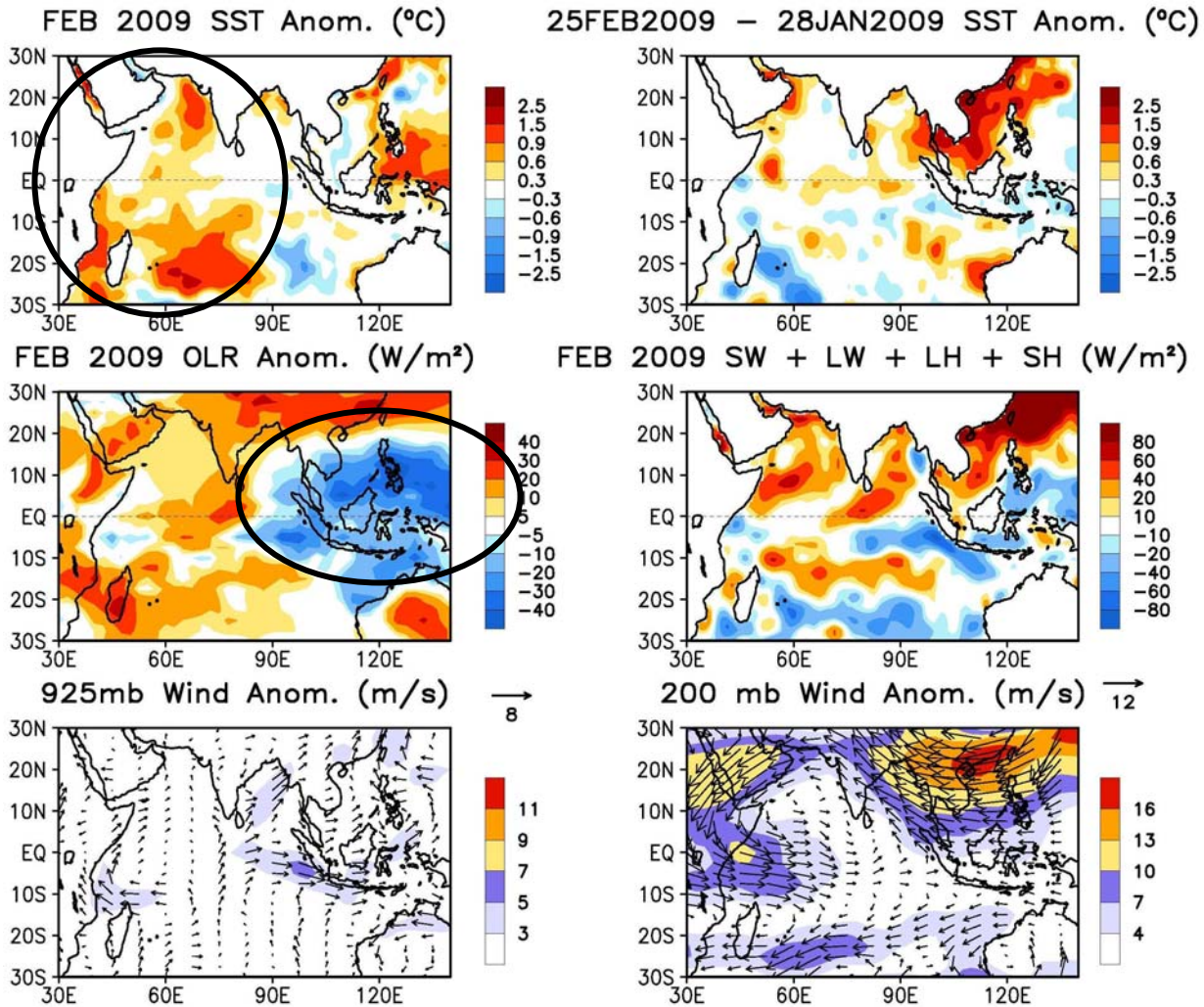
Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)



- **Westward propagation of positive heat content anomalies persisted since June 08.**

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.

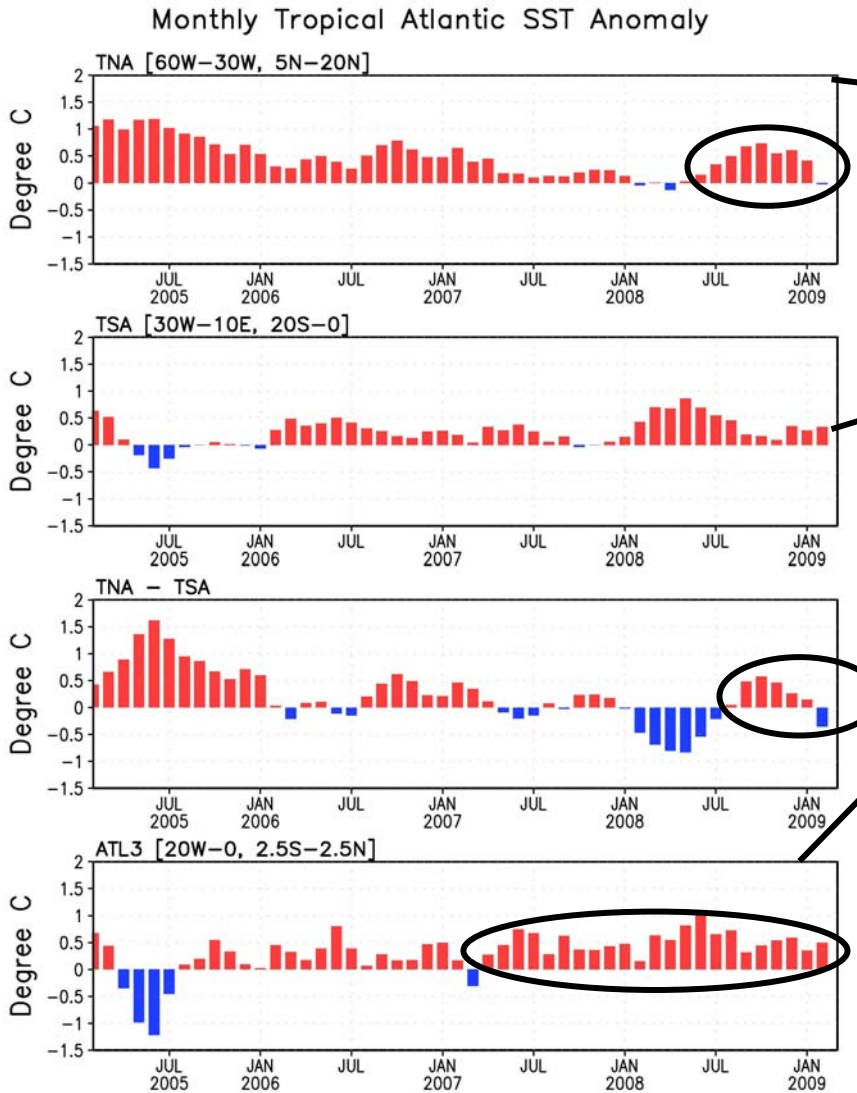


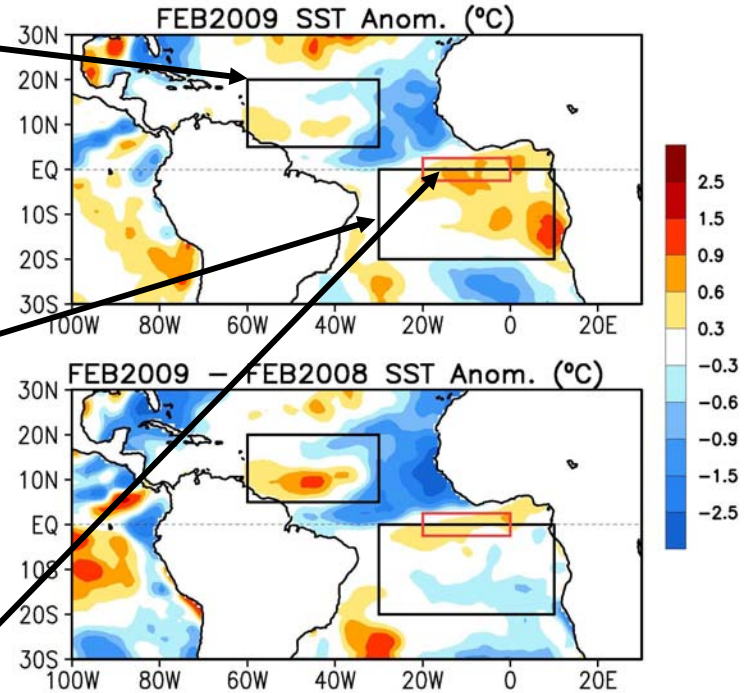
- **Positive SSTA in the western Indian Ocean.**
- **Convection was enhanced (suppressed) in the Maritime Continents (central Indian Ocean).**

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





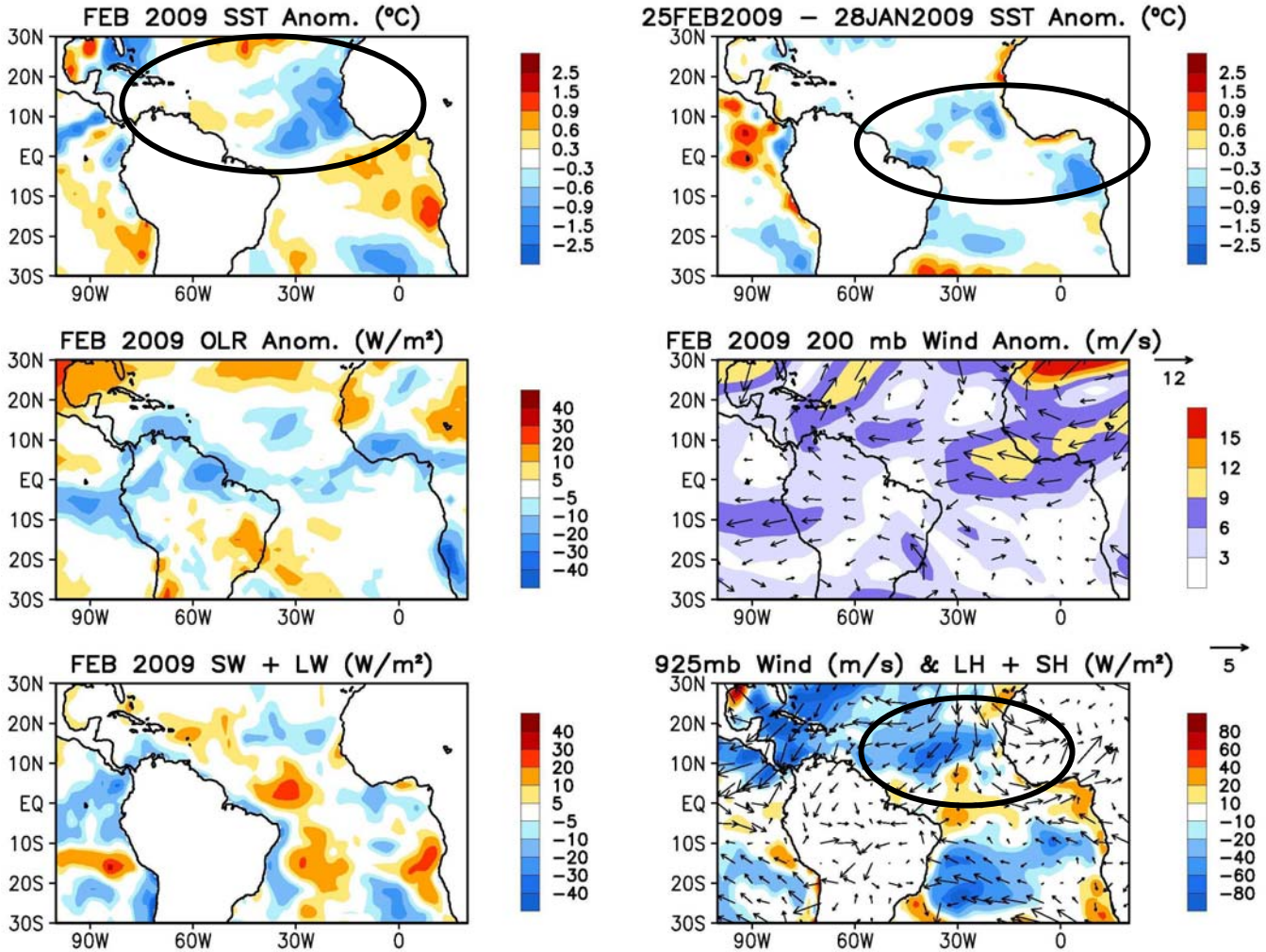
- **Tropical North Atlantic cooled down substantially and returned to normal-conditions, while tropical South Atlantic remained above-normal.**

- **Meridional Gradient Mode (TNA-TSA) became negative in February 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 cooled down in the northeastern tropical Atlantic.**
- **Negative latent and sensible heat anomalies contributed to the SST cooling.**
- **Strong northerly wind anomalies contributed to the negative heat flux anomalies in the tropical North Atlantic.**

North Atlantic Ocean

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

- North Atlantic SST remains above-normal.
- SST warmed up along the eastern coast of North America in February 09, which was associated with positive latent and sensible heat fluxes.

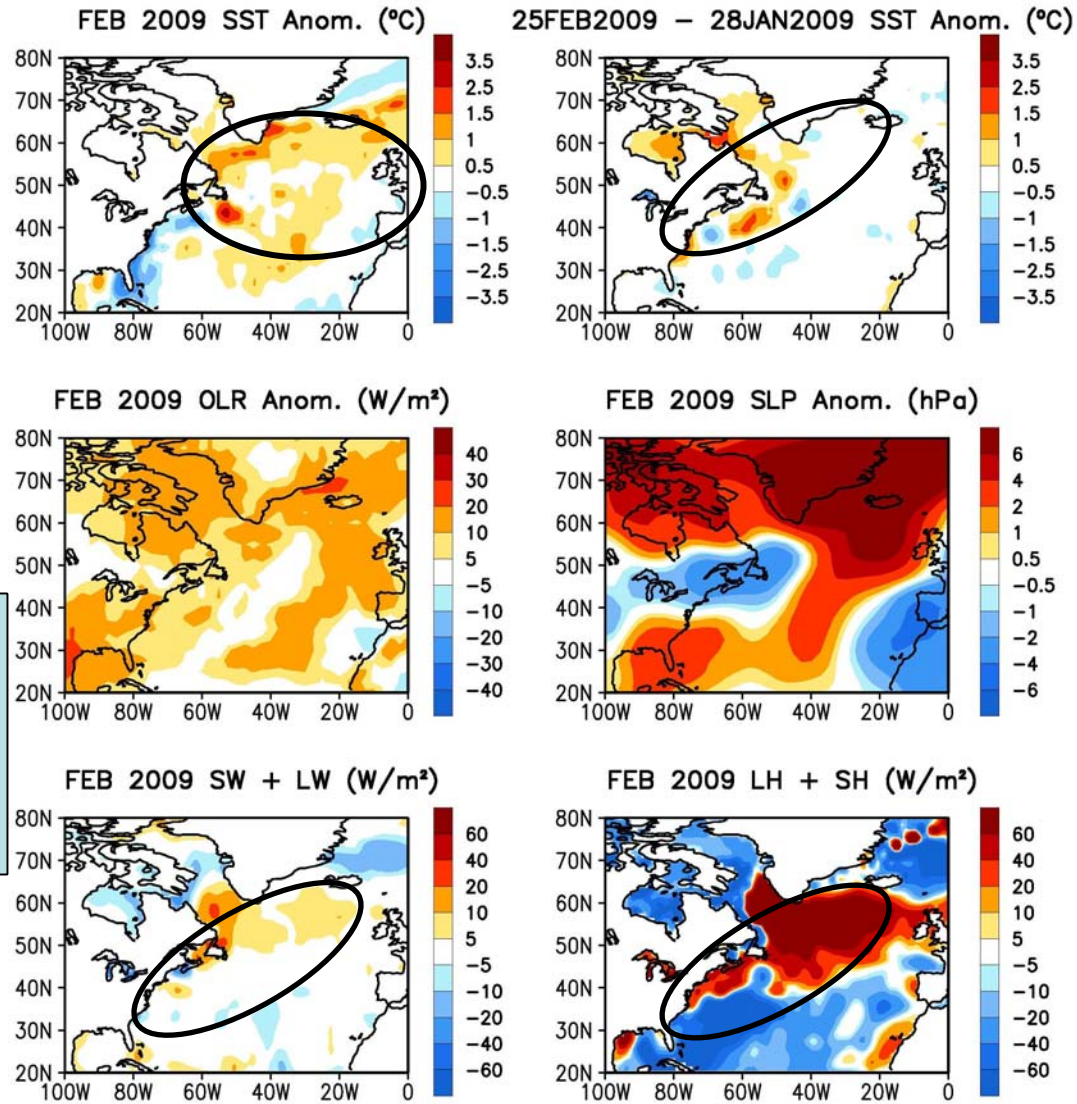
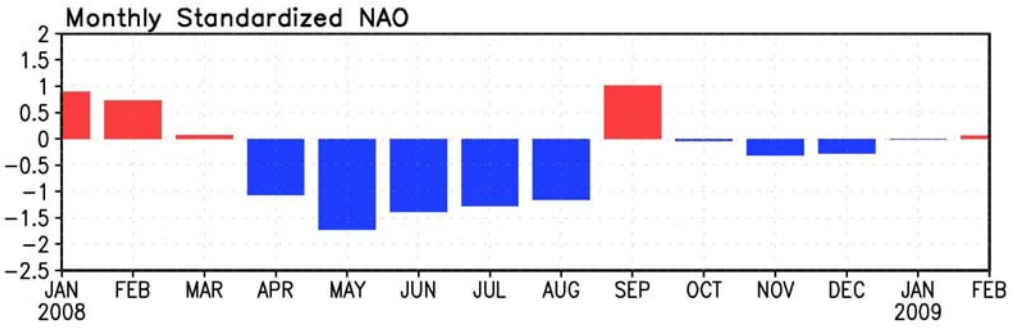
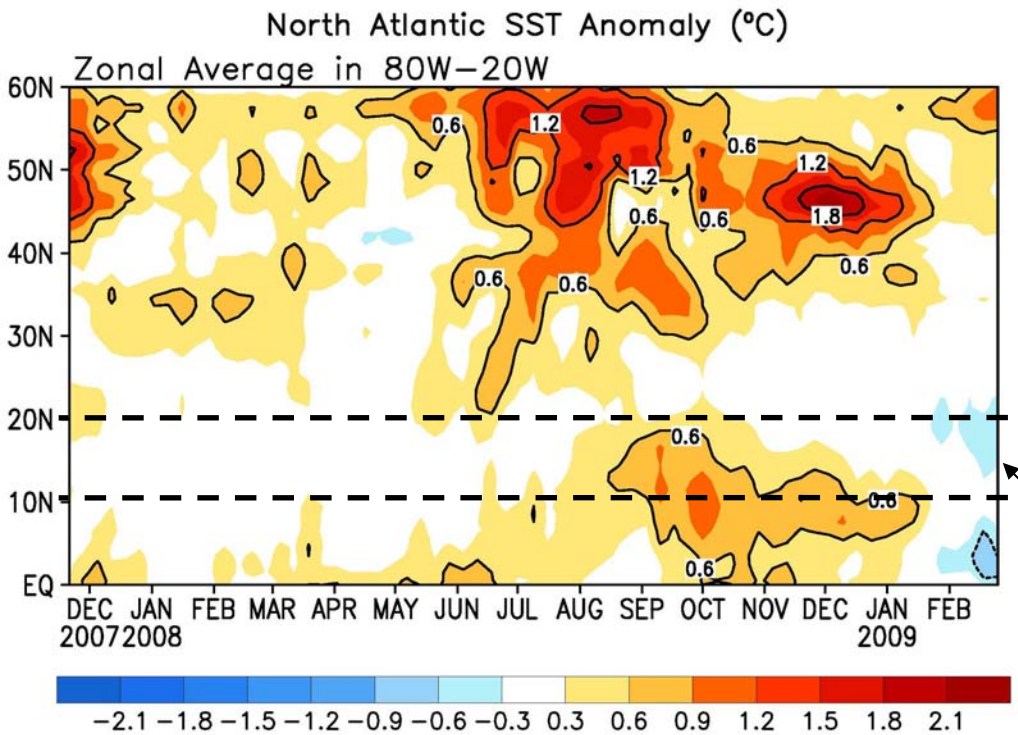
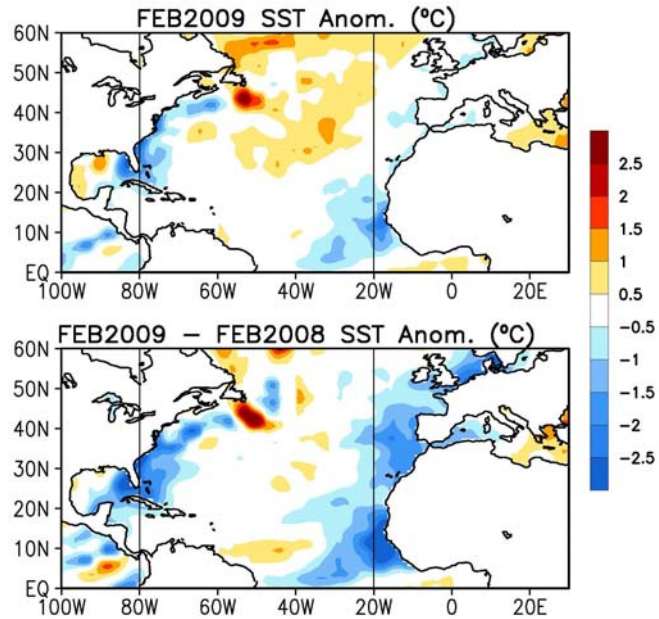


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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



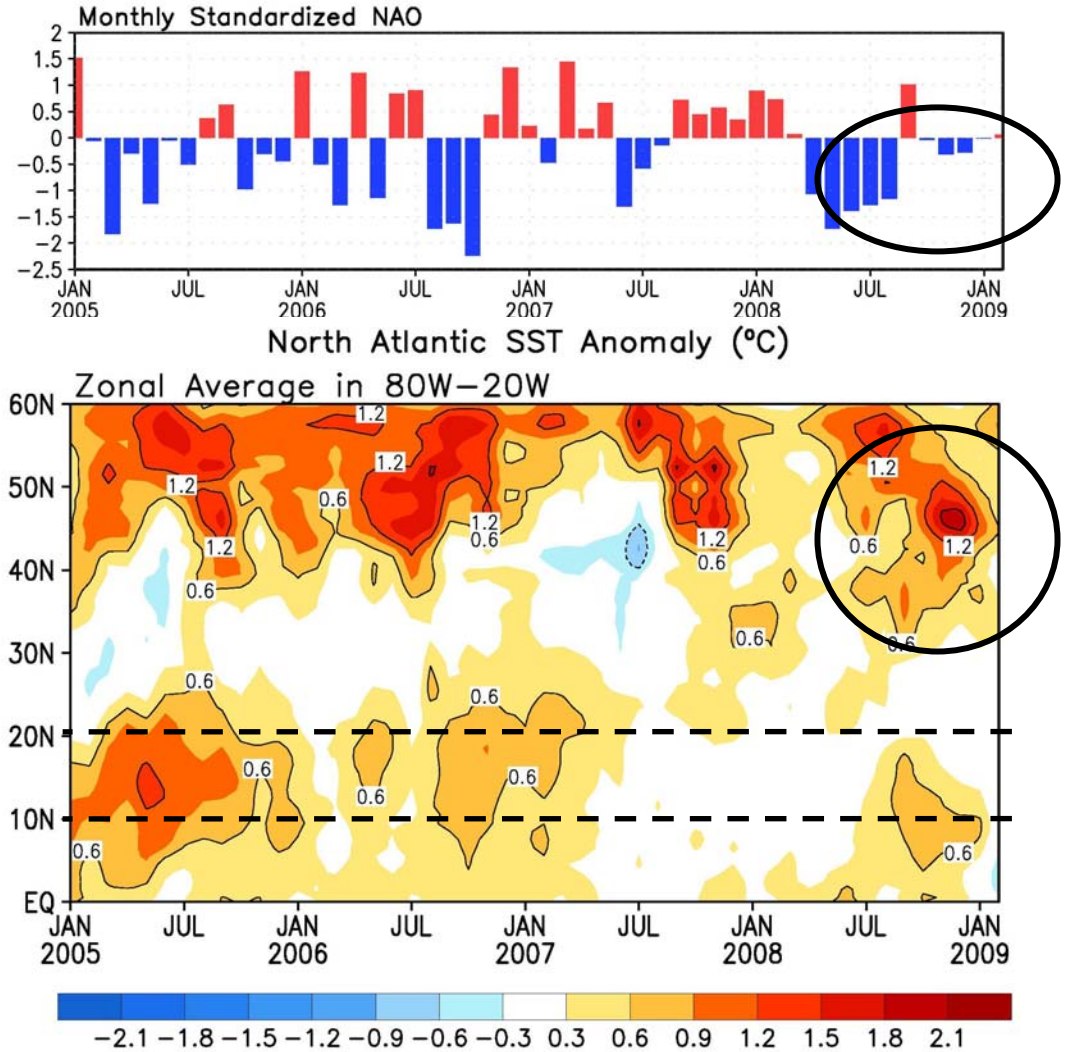


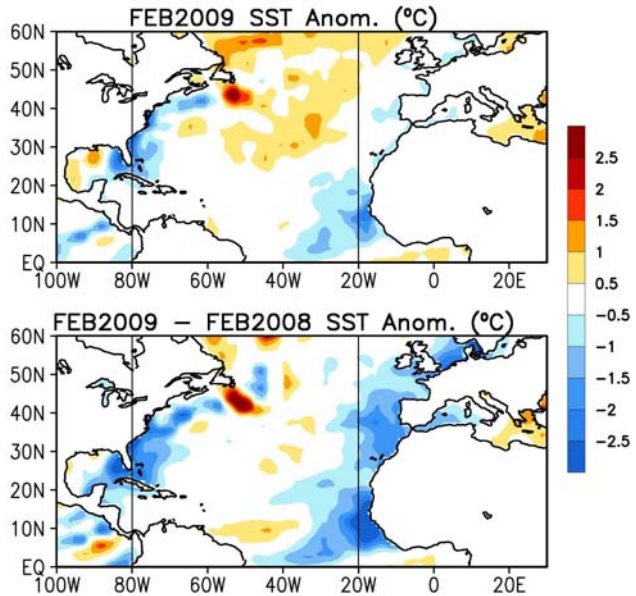


- **High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).**
- **NAO was near-normal in February 09.**
- **SSTA in the Hurricane Main Development Region were weakly below-normal in February 09.**

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



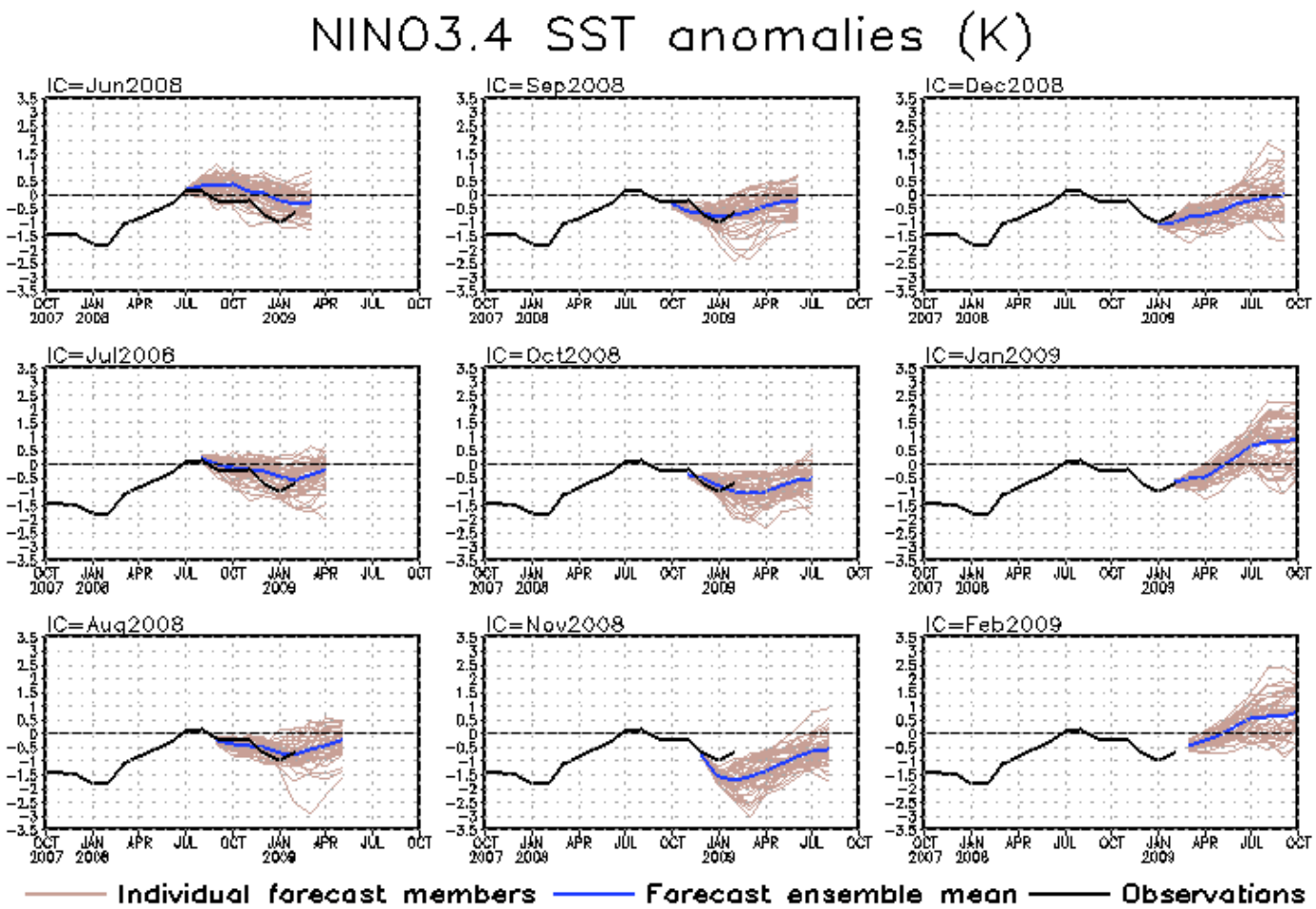


- North Atlantic SSTs have warmed up since June 2008 due to persistent negative NAO phase during April-August 08.

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

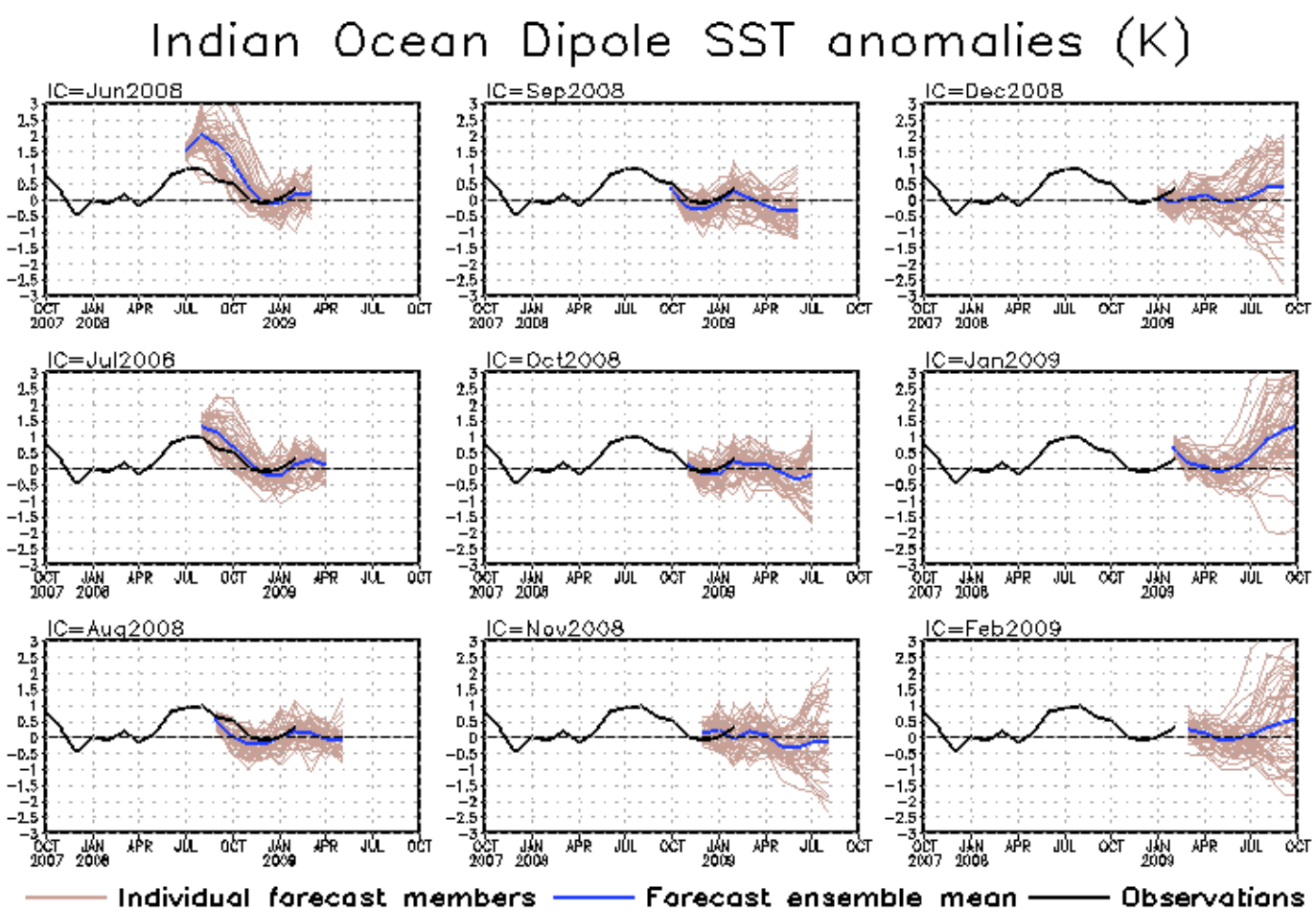
CFS Niño3.4 SST Predictions from Different Initial Months



- **Latest forecasts suggest that an ENSO-neutral condition in Spring 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 [90ºE-110ºE, 10ºS-0]

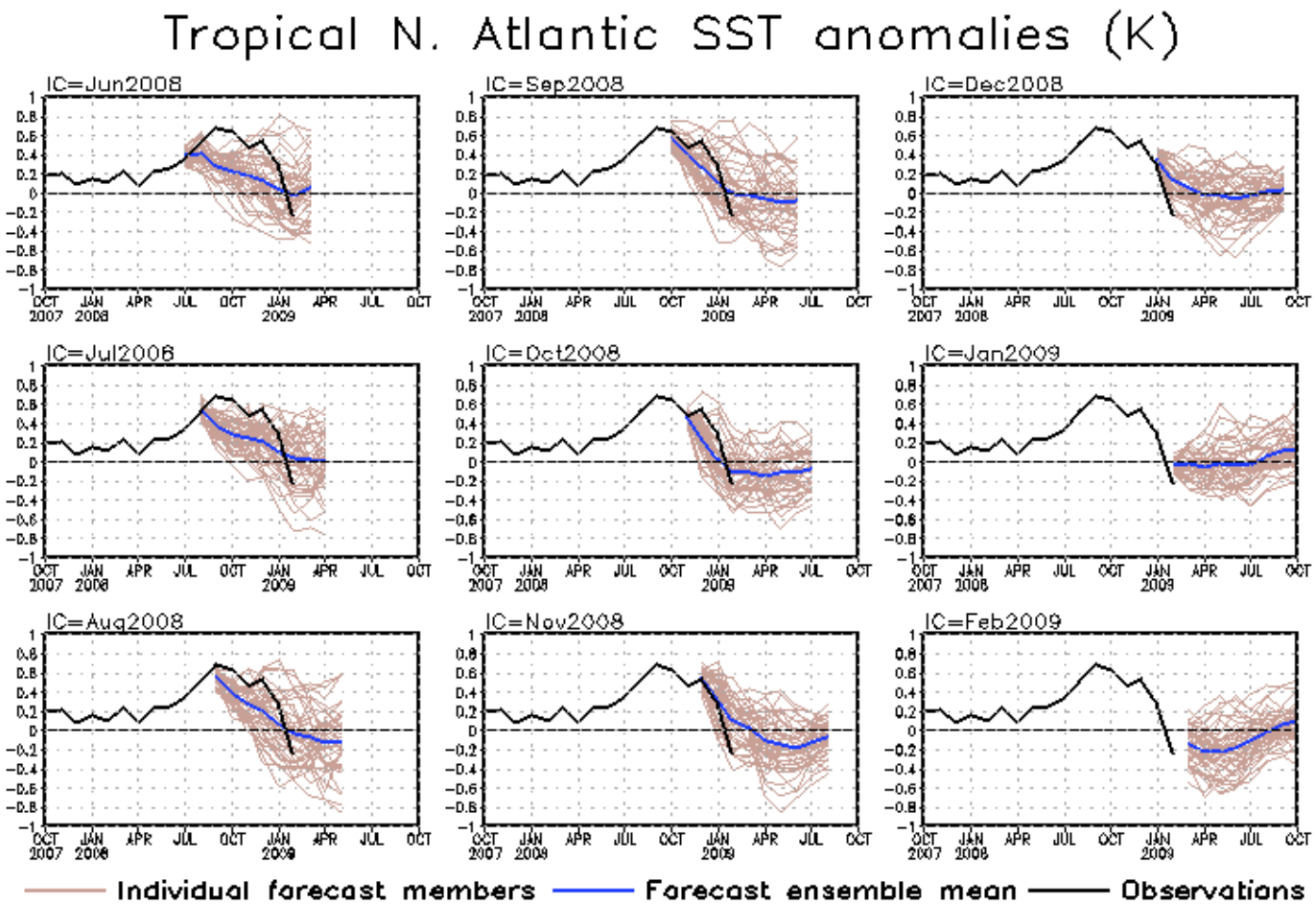
WTIO = SST anomaly in [50ºE-70ºE, 10ºS-10ºN]

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

- Latest forecasts call for near-normal 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



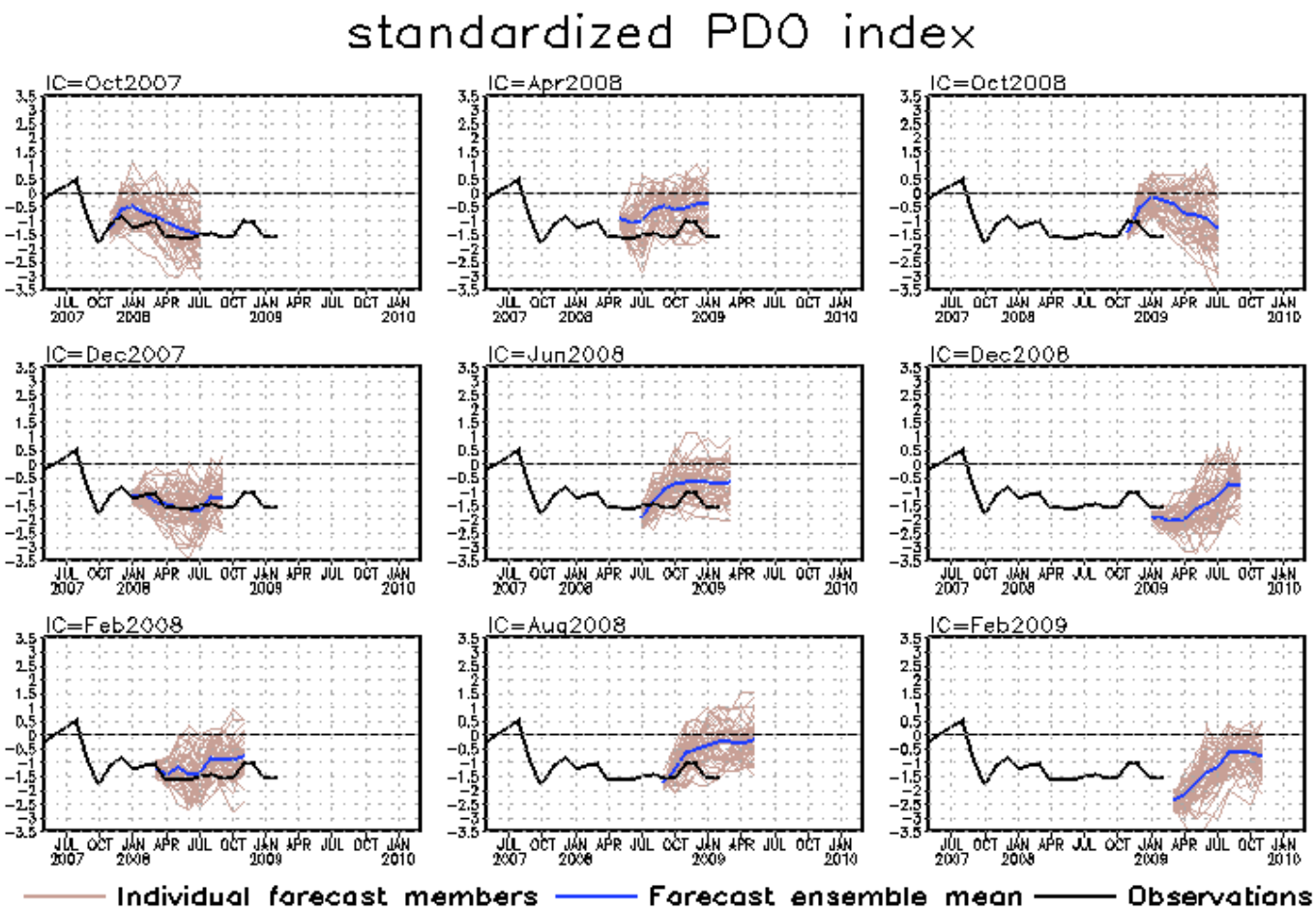
TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- CFS always damps SSTA in I.C., suggesting either the SSTA is unpredictable or the model has systematic errors in predicting summer SSTA in the Hurricane Main Development Region.

- Latest forecasts suggest that the current negative SSTA will dissipate in spring 09.

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 July 07 I.C.**
- **Latest forecasts suggest that the current negative PDO will persist through 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**
  - 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 18 months now, and 2008 has the lowest yearly mean PDO index since 1971.
  - Above-normal upwelling that has persisted since mid-November 2007 switched to below-normal in later February along the western coast of North America south of 35N.
- **Indian Ocean**
  - Positive SST anomalies presented in the western Indian Ocean.
  - IOD index became weakly positive.
- **Atlantic Ocean**
  - Above-normal SST in North Atlantic persisted.
  - Above-normal SST in the tropical North Atlantic returned to near-normal or below-normal, while above-normal SST in the tropical South Atlantic and equatorial Atlantic persisted.
- **Arctic Ocean**
  - Ice concentration remains much below-normal.

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!