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/

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

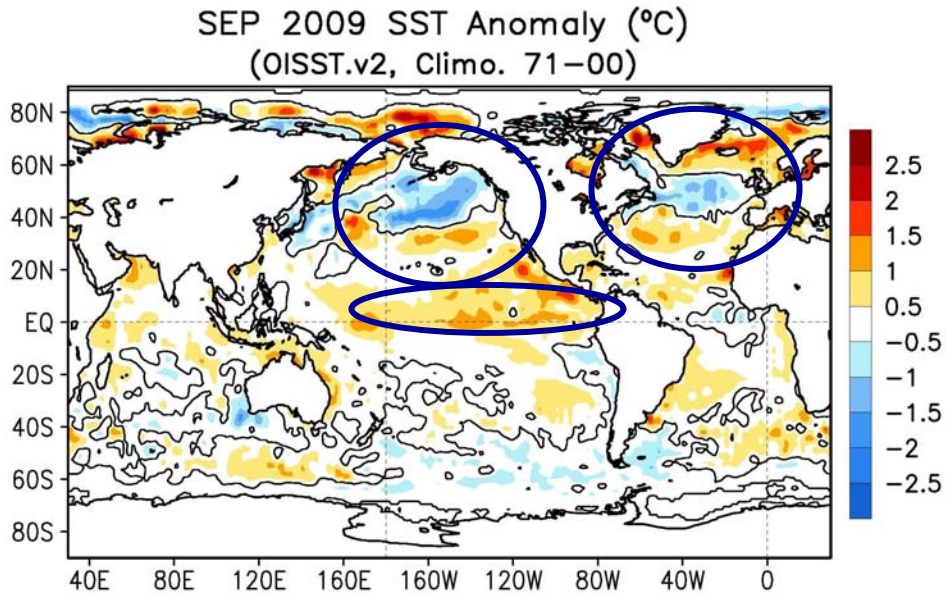
Outline

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

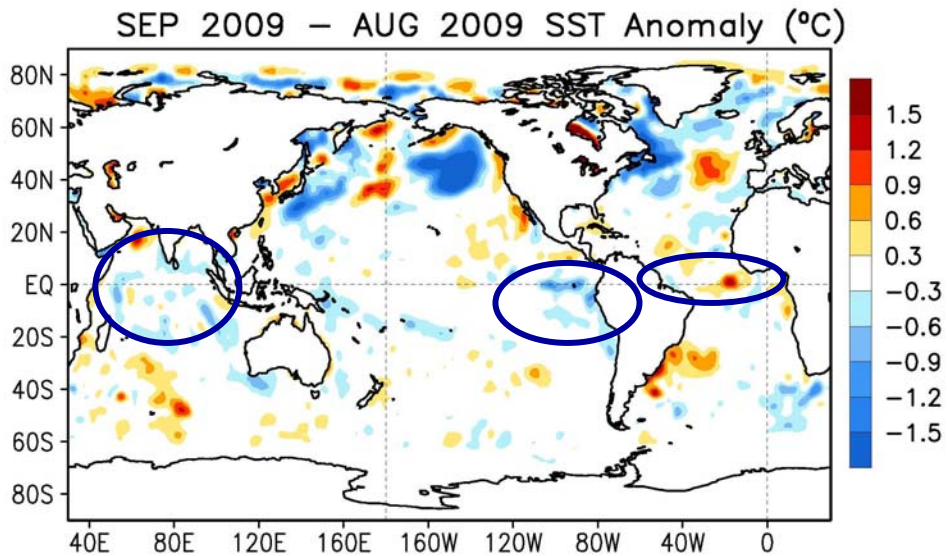
Overview

- **Pacific Ocean**
  - El Niño conditions (NINO 3.4 > 0.5 ^{o}C) established in June 2009, and were expected to last through the Northern Hemisphere winter 2009-2010.
  - Westerly wind bursts were active in July and September 09, probably contributing to the sustaining of the 2009/10 El Niño.
  - PDO phase became positive for the first time since September 2007.
  - Upwelling along the west coast of North America was below-normal north of 36N Since August 09.
- **Indian Ocean**
  - Easterly wind anomalies weakened in the central-eastern tropical Indian Ocean in September 09.
  - Positive SSTA weakened in the tropical Indian Ocean in September 09, and Dipole Mode Index has been near-normal since March 09.
- **Atlantic Ocean**
  - Above-normal SST and tropical cyclone heat potential (TCHP) presented in the tropical North Atlantic.
  - Convection was suppressed in the tropical and northwest tropical Atlantic.
  - Vertical wind shear was below-normal in the tropical North Atlantic.

Global SST Anomaly (⁰C) and Anomaly Tendency



- El Nino conditions (NINO 3.4 > 0.5ºC) continued in the tropical Pacific.
- PDO index became above-normal (slide 18).
- SSTA became near-normal in the tropical Indian Ocean.
- The tri-pole SSTA pattern in the North Atlantic continued.

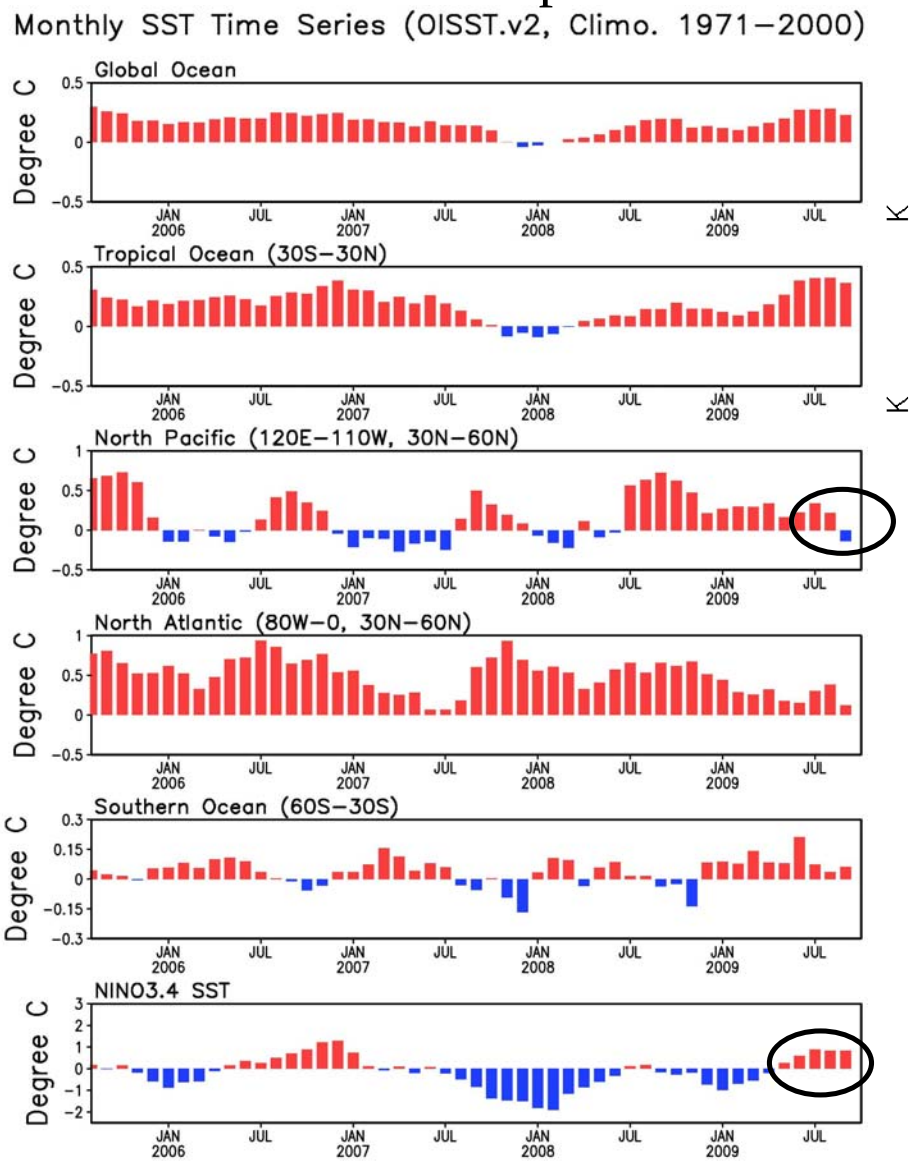


- SSTA decreased in the eastern tropical Pacific.
- SSTA decreased in the tropical Indian Ocean.
- SSTA increased along the equatorial Atlantic.
- Large SSTA changes in the mid-latitude Northern Oceans.

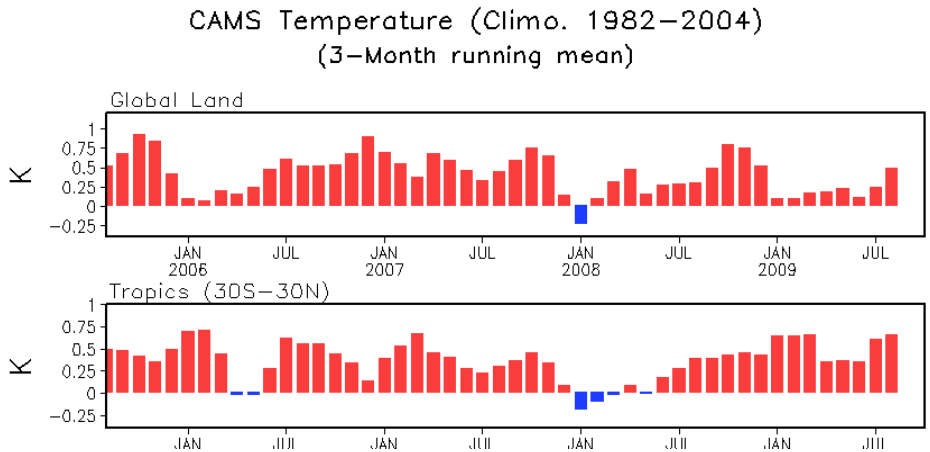
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Monthly Time Series

Sea Surface Temperature



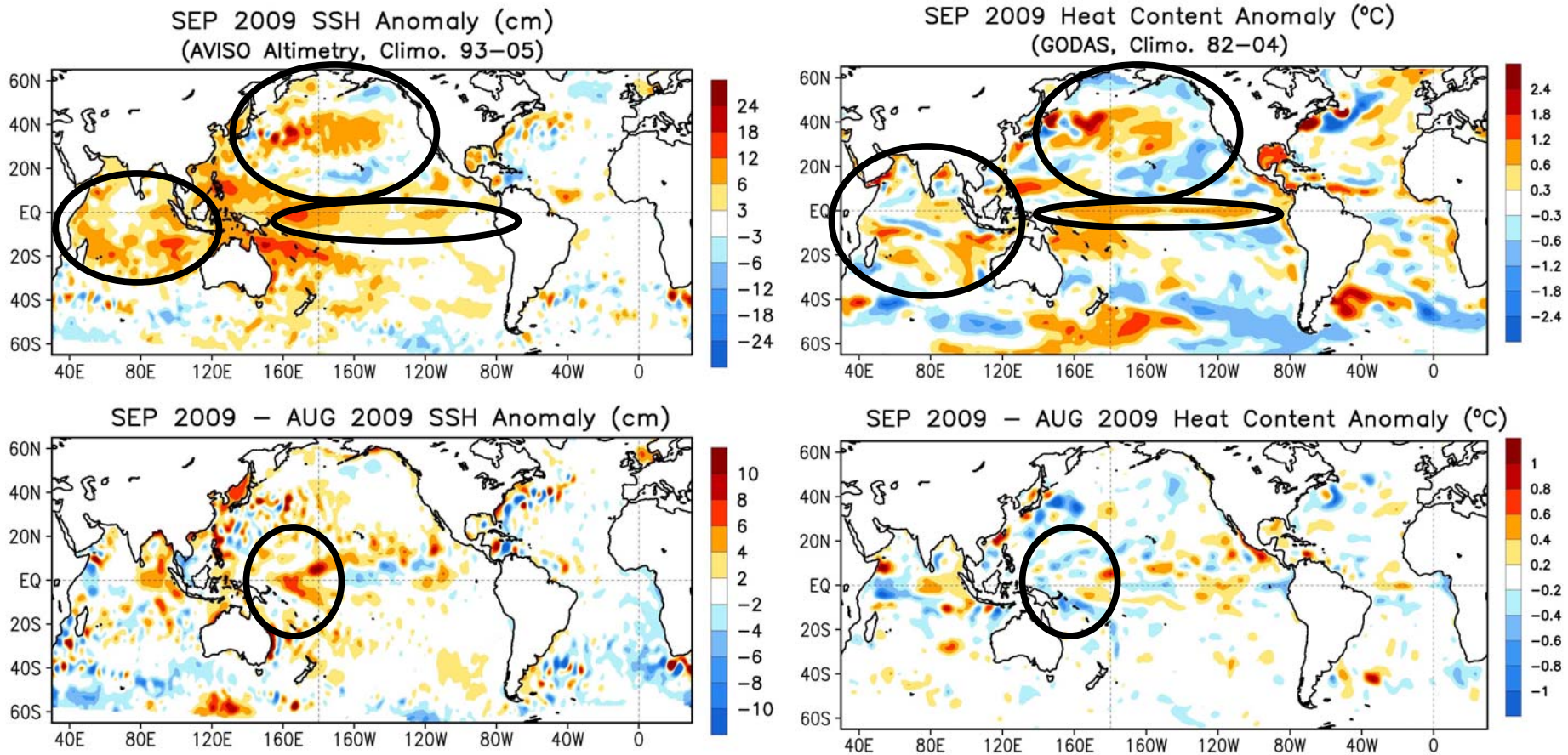
CAMS Land Temperature



- **Global mean seasonal land temperature increased.**
- **Positive tropical land temperature anomalies maintained.**
- **Positive global and tropical mean SSTA persisted.**
- **SSTA in the North Pacific became below-normal.**
- **Positive SSTA in the North Atlantic decreased.**
- **Above-normal NINO 3.4 SST persisted.**

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.

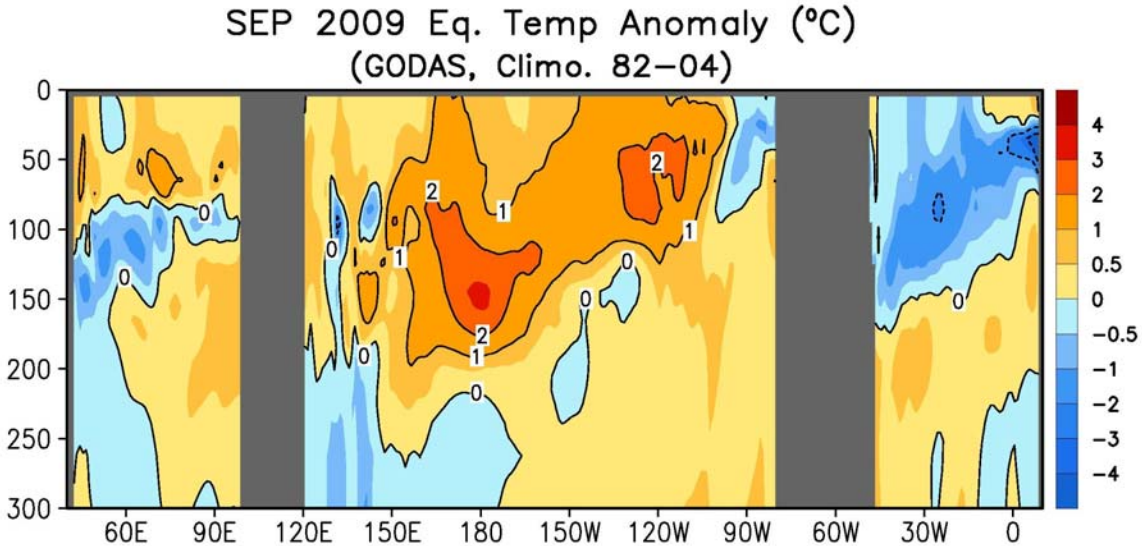
Global SSH / HC Anomaly (cm / ºC) and Anomaly Tendency



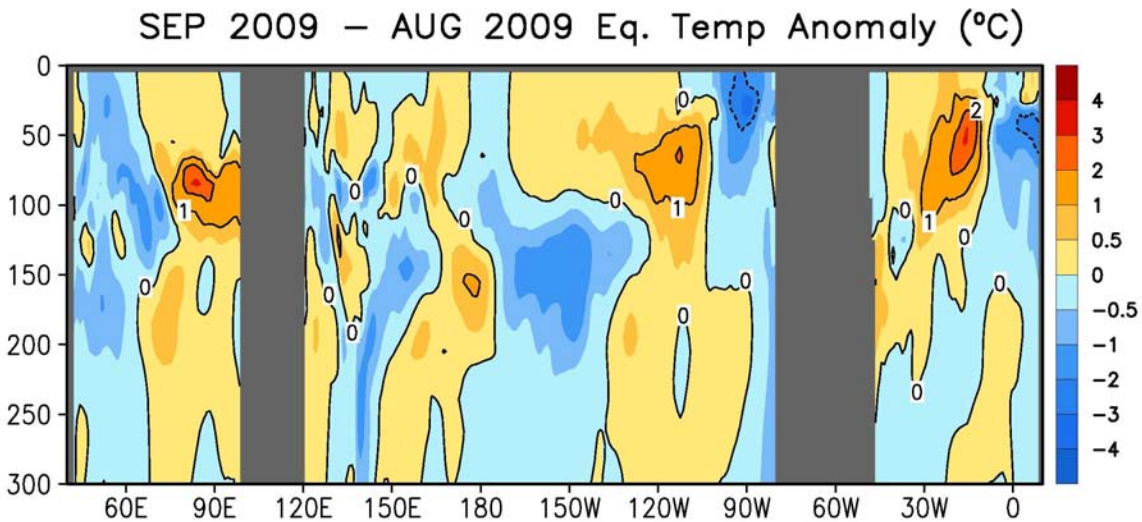
- **Negative PDO-like pattern in SSHA and HCA in the North Pacific persisted, although PDO index became positive in Sep 09.**
- **Positive SSHA and HCA presented along a narrow equatorial belt, consistent with the weak El Nino conditions.**
- **SSHA and HCA were largely consistent except in the tropical Indian Ocean and high-latitude Southern Oceans where biases in GODAS HC climatology were large (not shown).**
- **Tendency of SSHA and HCA were not consistent in the western tropical Pacific, probably caused by negative salinity anomalies caused by enhanced convection there.**

Fig. G2. Sea surface height anomalies (SSHA, top left), SSHA tendency (bottom left), top 300m heat content anomalies (HCA, top right), and HCA tendency (bottom right). SSHA are derived from http://www.aviso.oceanobs.com, and HCA from GODAS.

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



- **Positive subsurface temperature anomalies about 1-2°C presented near the thermocline in the equatorial Pacific, consistent with the weak El Nino conditions.**
- **Near surface temperature became negative in the eastern tropical Pacific east of 110W**

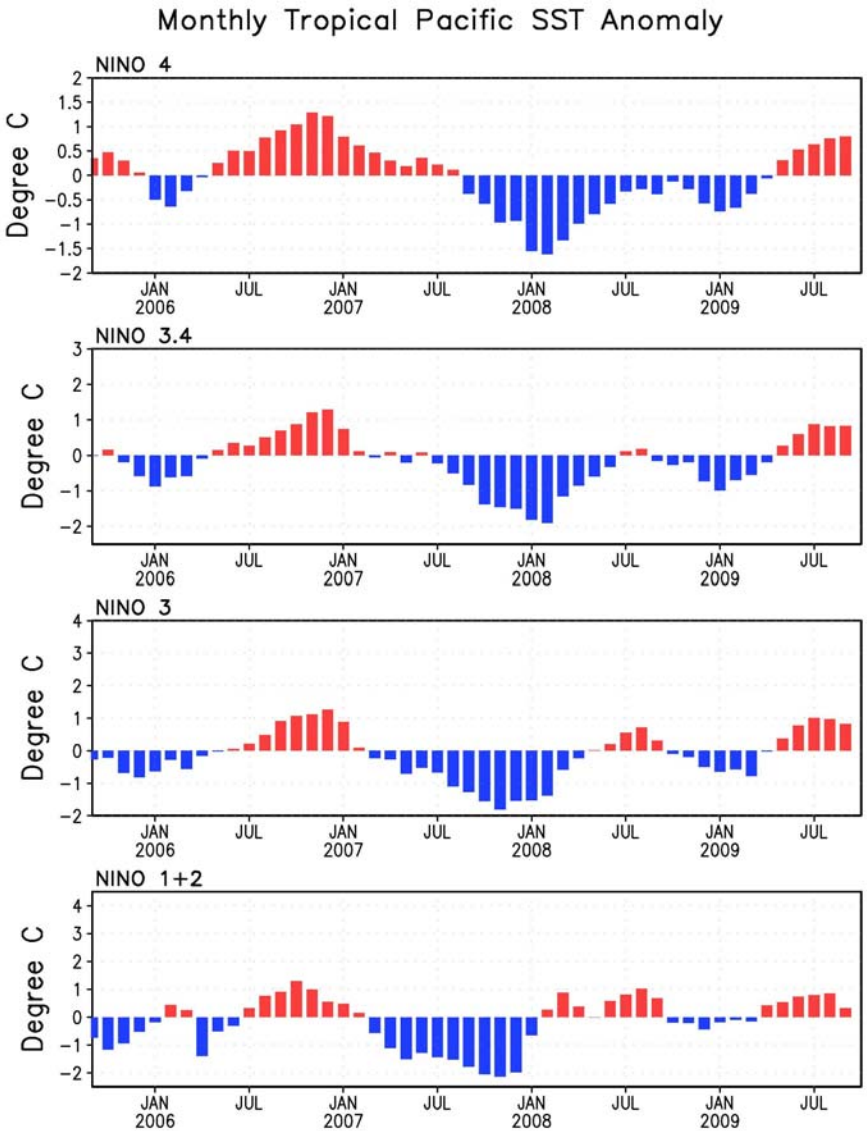


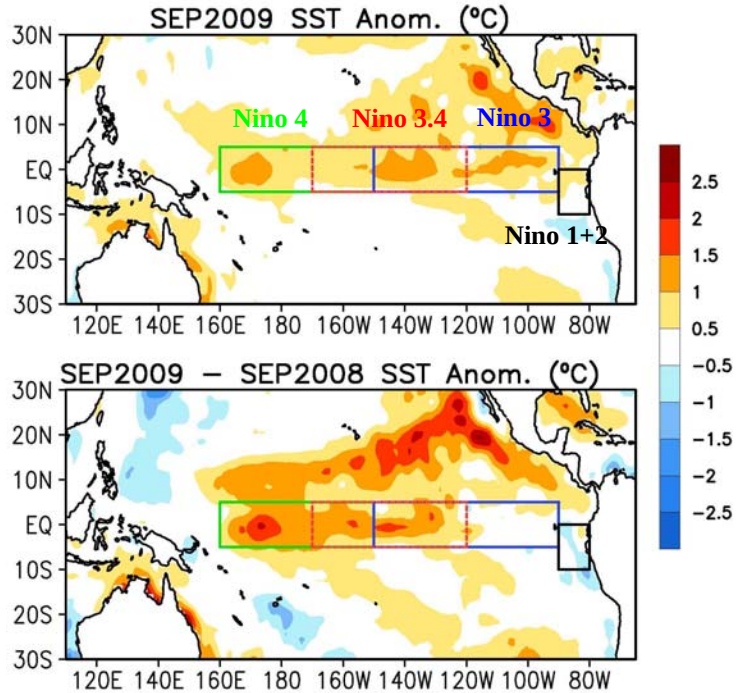
- **Subsurface temperature anomalies increased (1°C) near 120W, and decreased (1°C) near 160W and 90W along the thermocline.**

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.

Tropical Pacific Ocean

Evolution of Pacific NINO SST Indices





- **El Niño conditions (NINO 3.4 > 0.5°C) are expected to last through the Northern Hemisphere Winter – NOAA's "ENSO Diagnostic Discussion".**

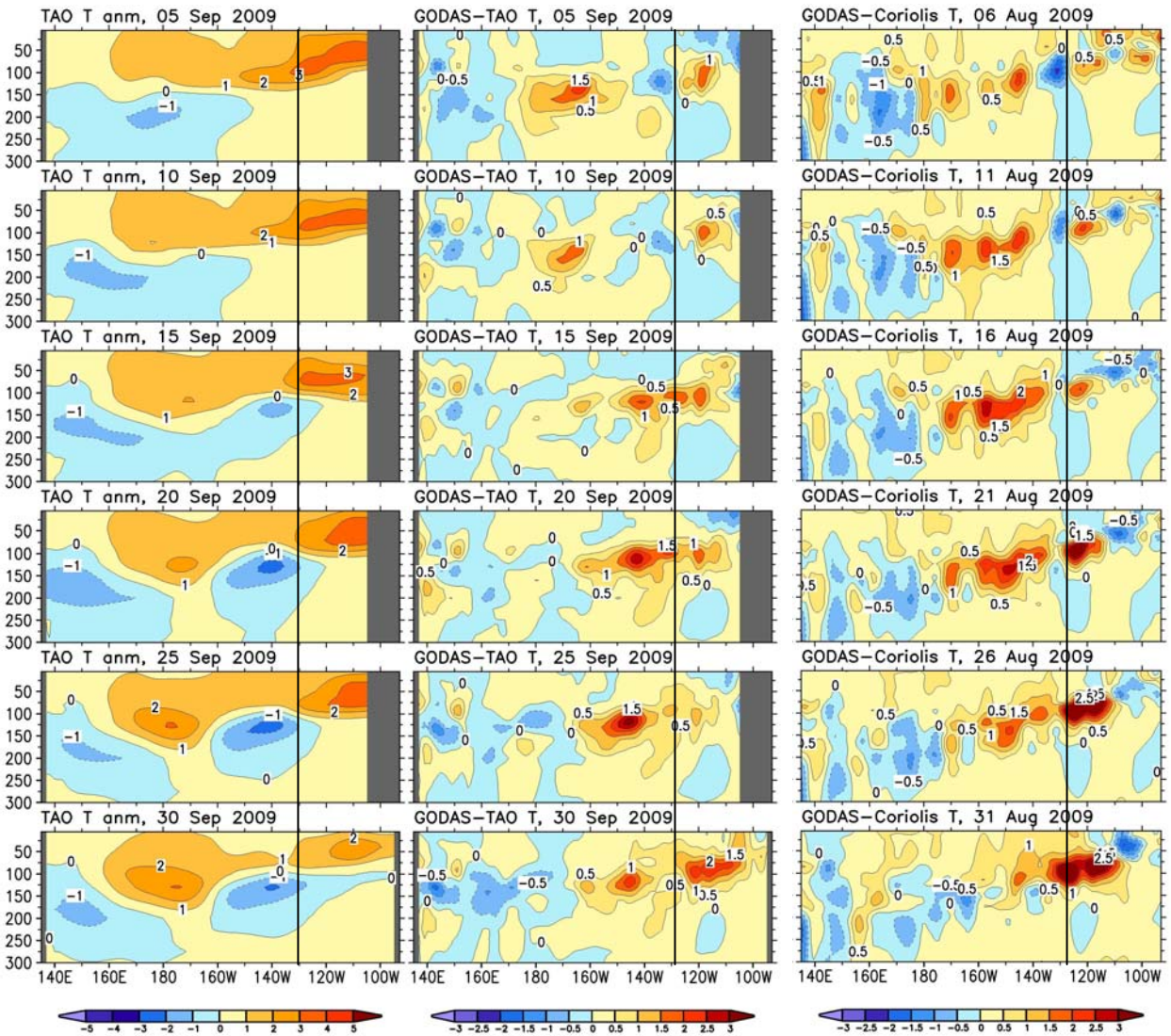
- **NINO 4 and NINO 3.4 persisted, and NINO 3 and NINO 1.2 weakened in September 09.**

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

Equatorial Pacific Temperature

www.coriolis.eu.org

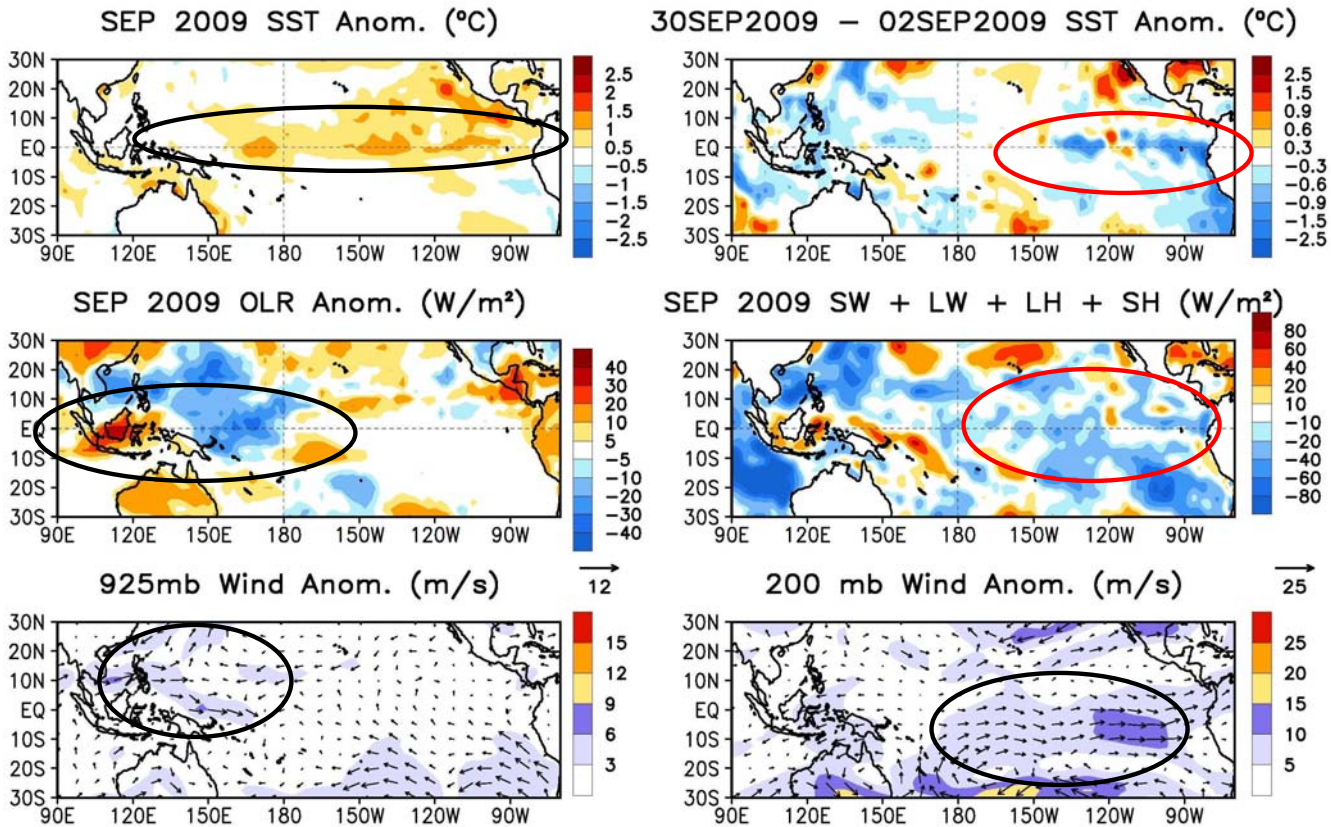
TAO Temp Anom GODAS-TAO GODAS-Coriolis



TAO climatology used

- **Equatorial temperature decreased near 140W below the thermocline.**
- **Temperature differences between GODAS and TAO, were largely consistent with those between GODAS and Coriolis, and they were mostly positive (negative) east (west) of the dateline.**

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



- **Positive SSTA presented in the equatorial Pacific.**
- **SSTA decreased in the eastern tropical Pacific, largely consistent with the net surface heat flux anomalies.**
- **Convection was suppressed over the Maritime Continents and enhanced over the western Pacific.**
- **Westerly wind anomaly presented in the lower-level (upper-level) west (east) of the Dateline.**

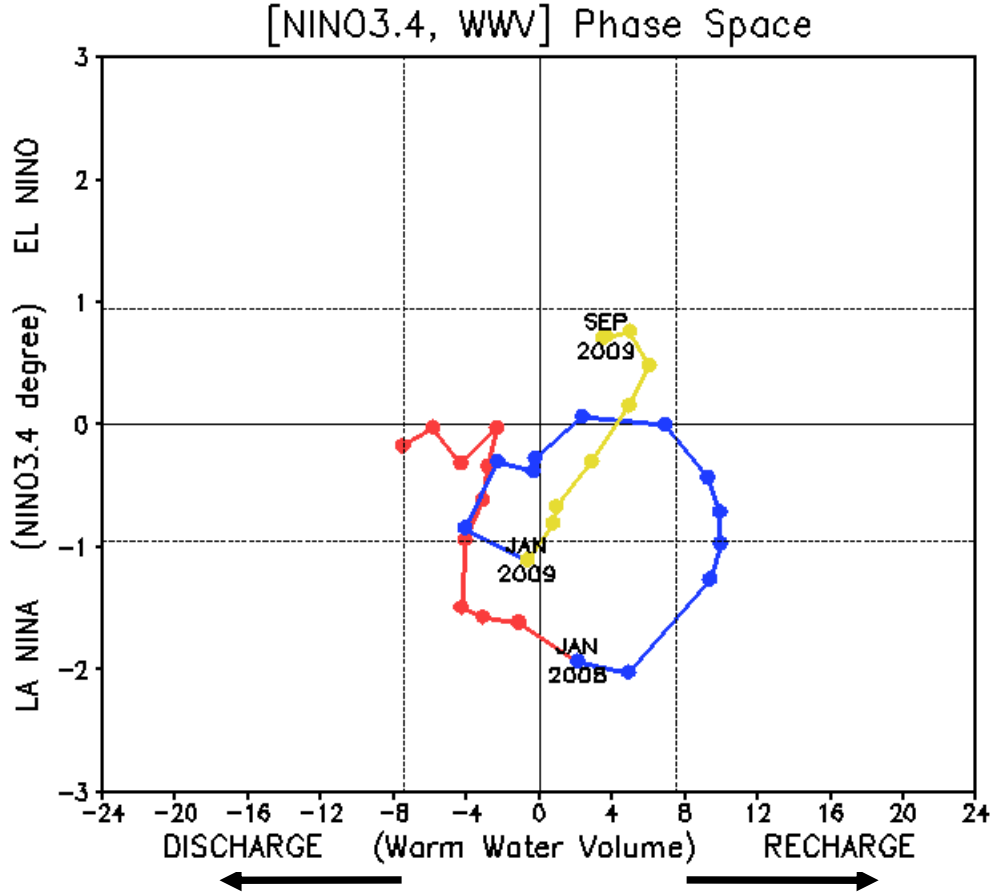
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

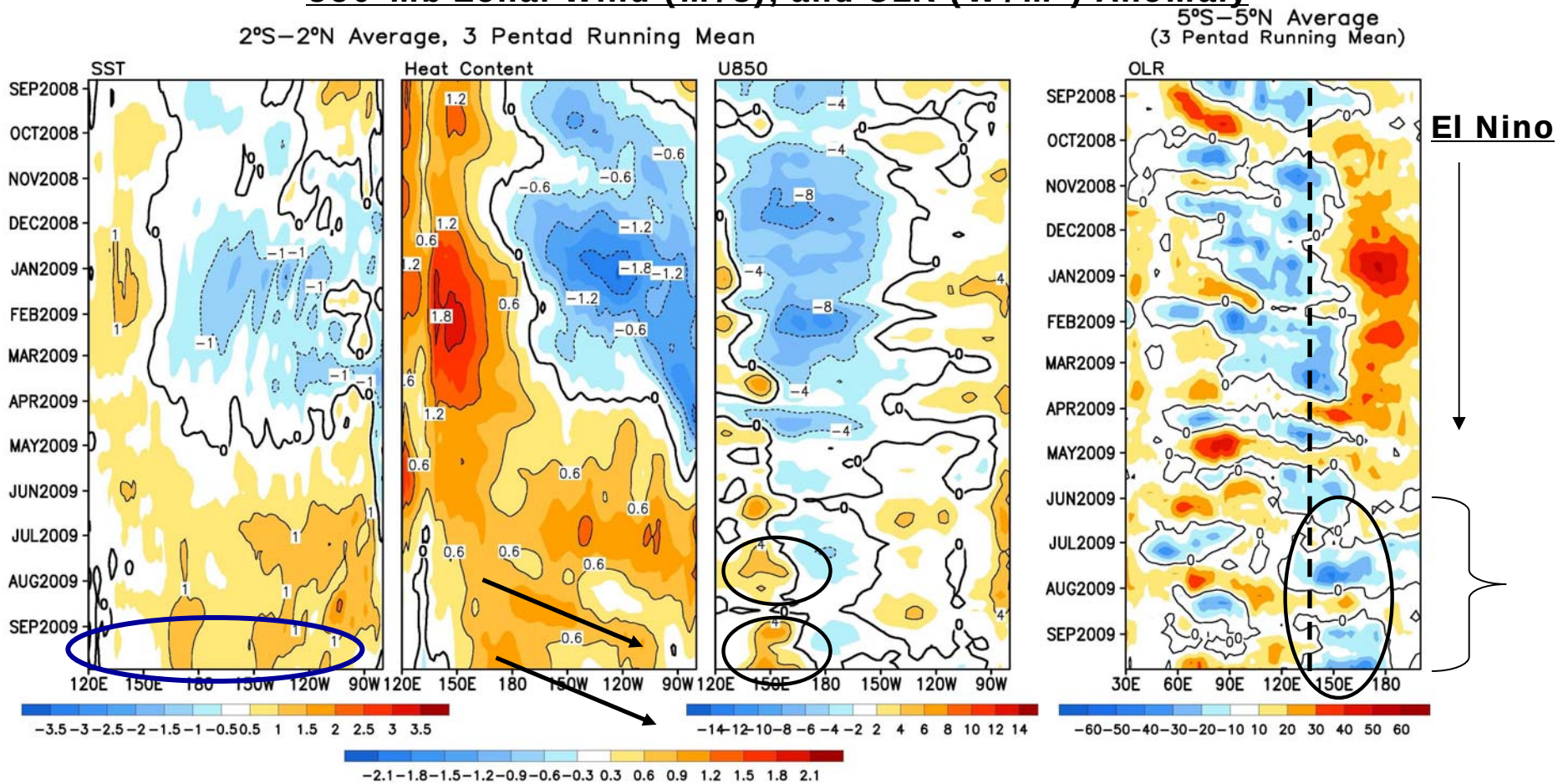
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



- Above-normal NINO3.4 persisted, while above-normal WWV weakened slightly in September 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.

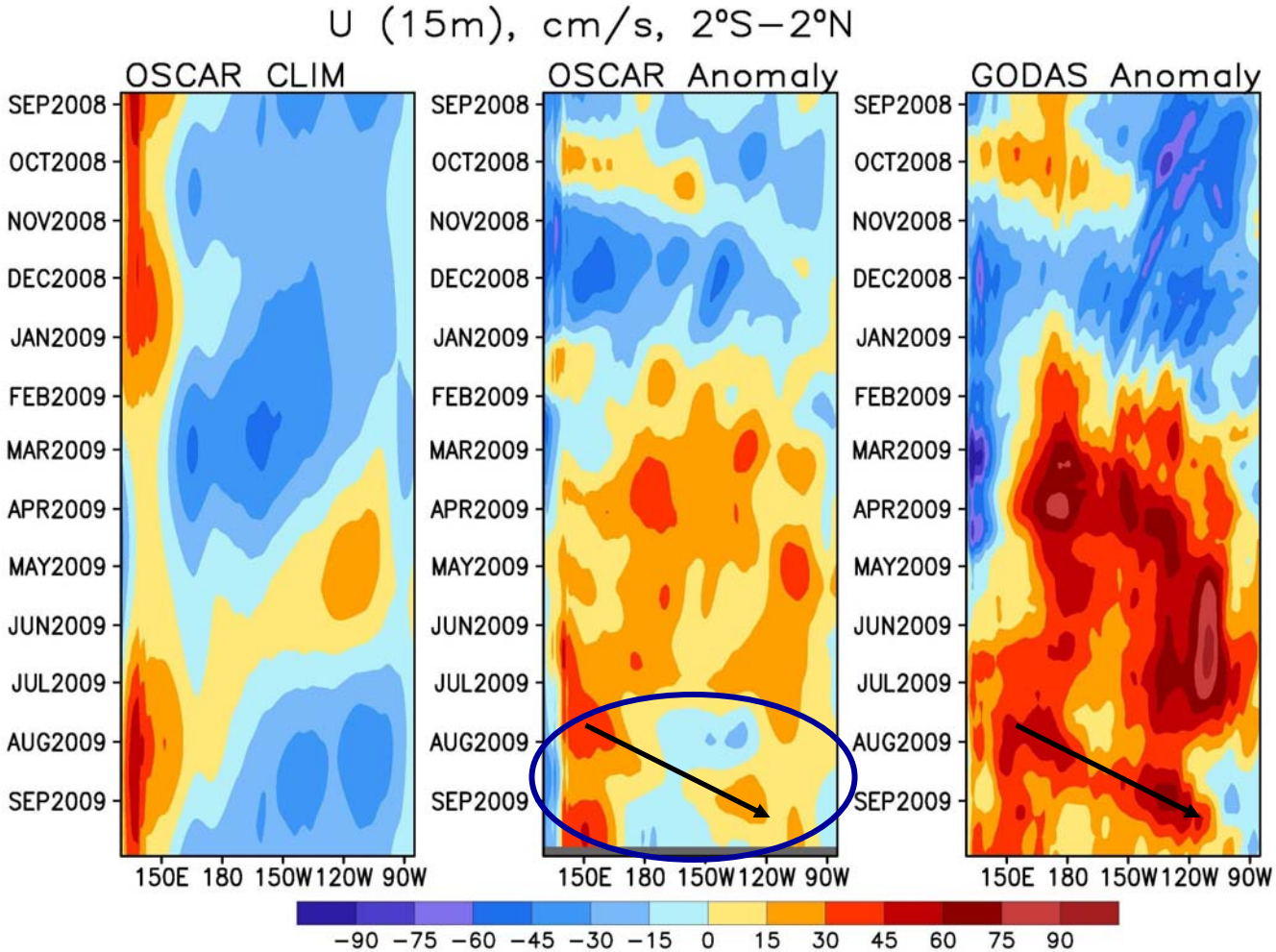
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²) Anomaly



- **SST was about 1°C above-normal in the central and east-central equatorial Pacific.**
- **Positive heat content anomalies (HCA) propagated eastward since Aug 09, probably in response to the westerly wind bursts occurred in July in the western tropical Pacific. Two westerly wind bursts in early and later Sept would likely force the positive HCA in the western Pacific to propagate eastward in Oct-Nov.**

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.

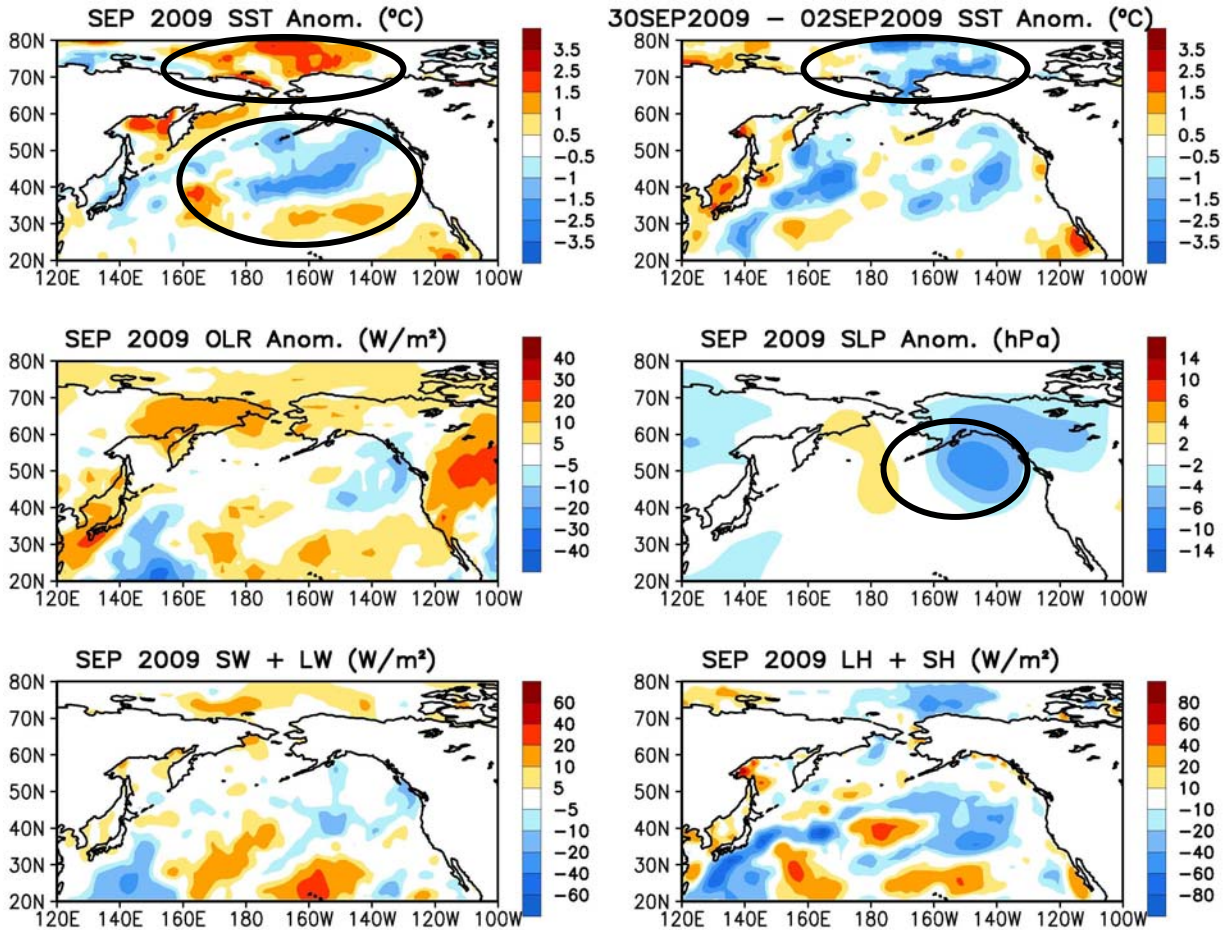
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- **Surface zonal current anomaly has been positive since mid-Jan 09, consistent with the transition from La Nina to ENSO-neutral conditions in April 09 and the transition to El Nino conditions in June 09.**
- **Positive (negative) surface zonal current anomaly persisted in the western and eastern (central) equatorial Pacific in Sept 09.**
- **Positive surface zonal current anomalies simulated by GODAS were too strong compared with those of the OSCAR currents.**

North Pacific & Arctic Ocean

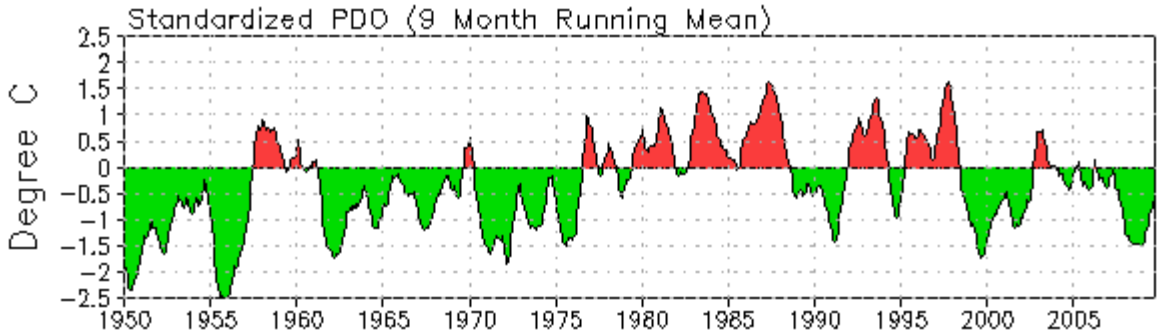
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

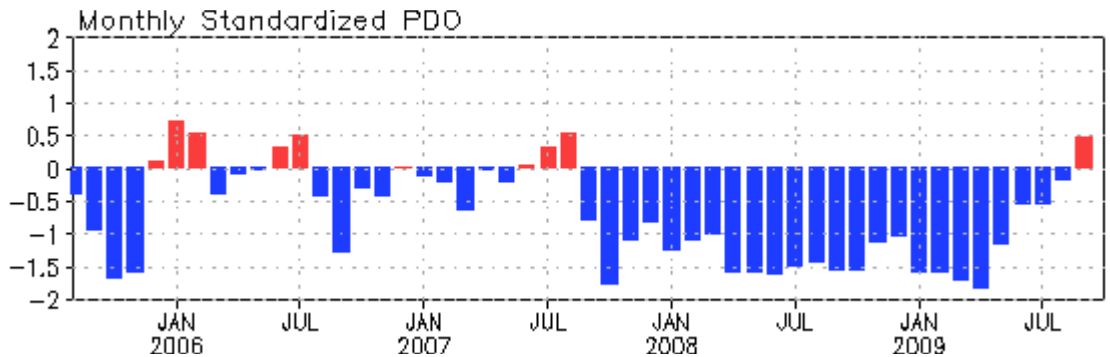


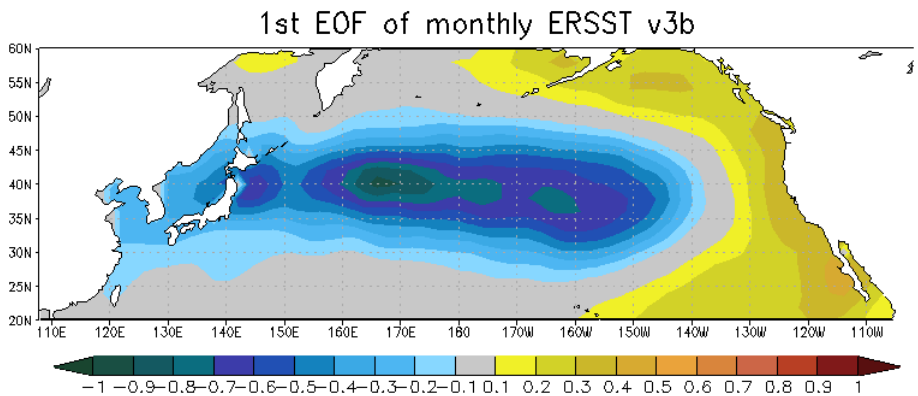
- Weak positive PDO-like SST pattern in Sept 09.
- Positive SSTA decreased north of Bering Strait.
- Negative SSTA tendency in the North Pacific was consistent with net surface heat flux anomalies.
- Below-normal sea level pressure in the Gulf of Alaska would generate anomalous cyclonic circulations , thus unfavourable for coastal upwelling (slide 20).

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 became weakly positive for the first time since September 2007.**

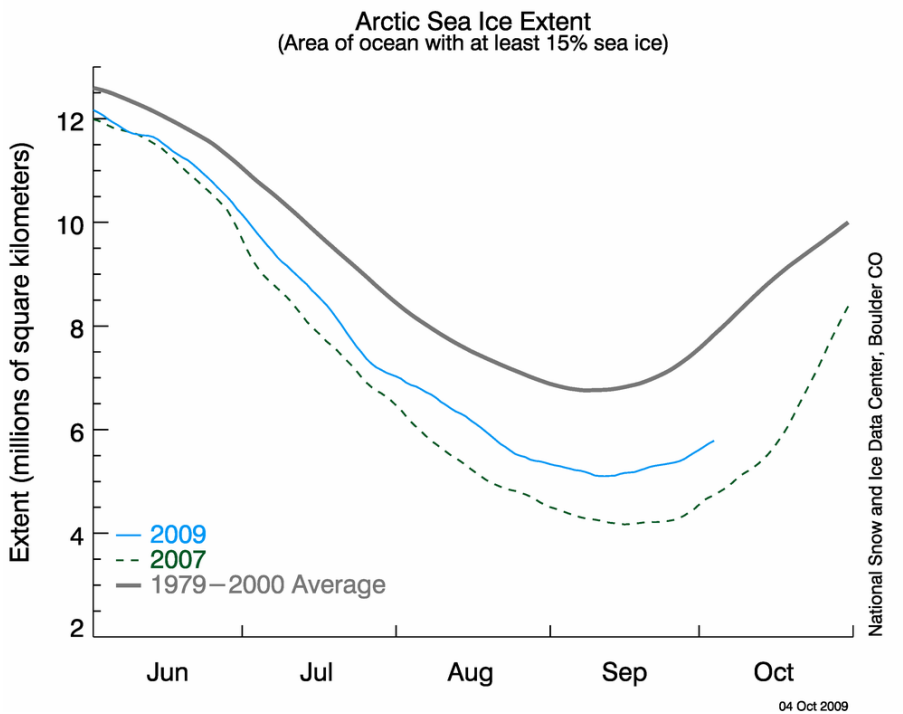
- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.**

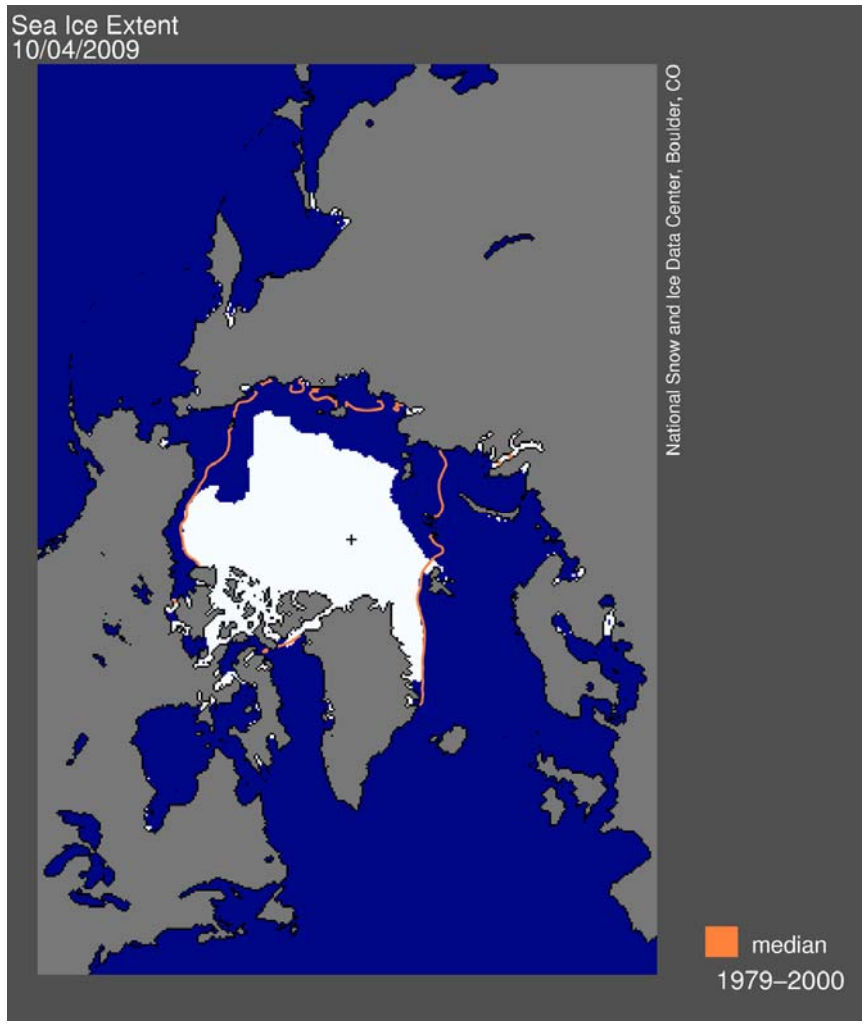
- **The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.**

Arctic Sea Ice

National Snow and Ice Data Center

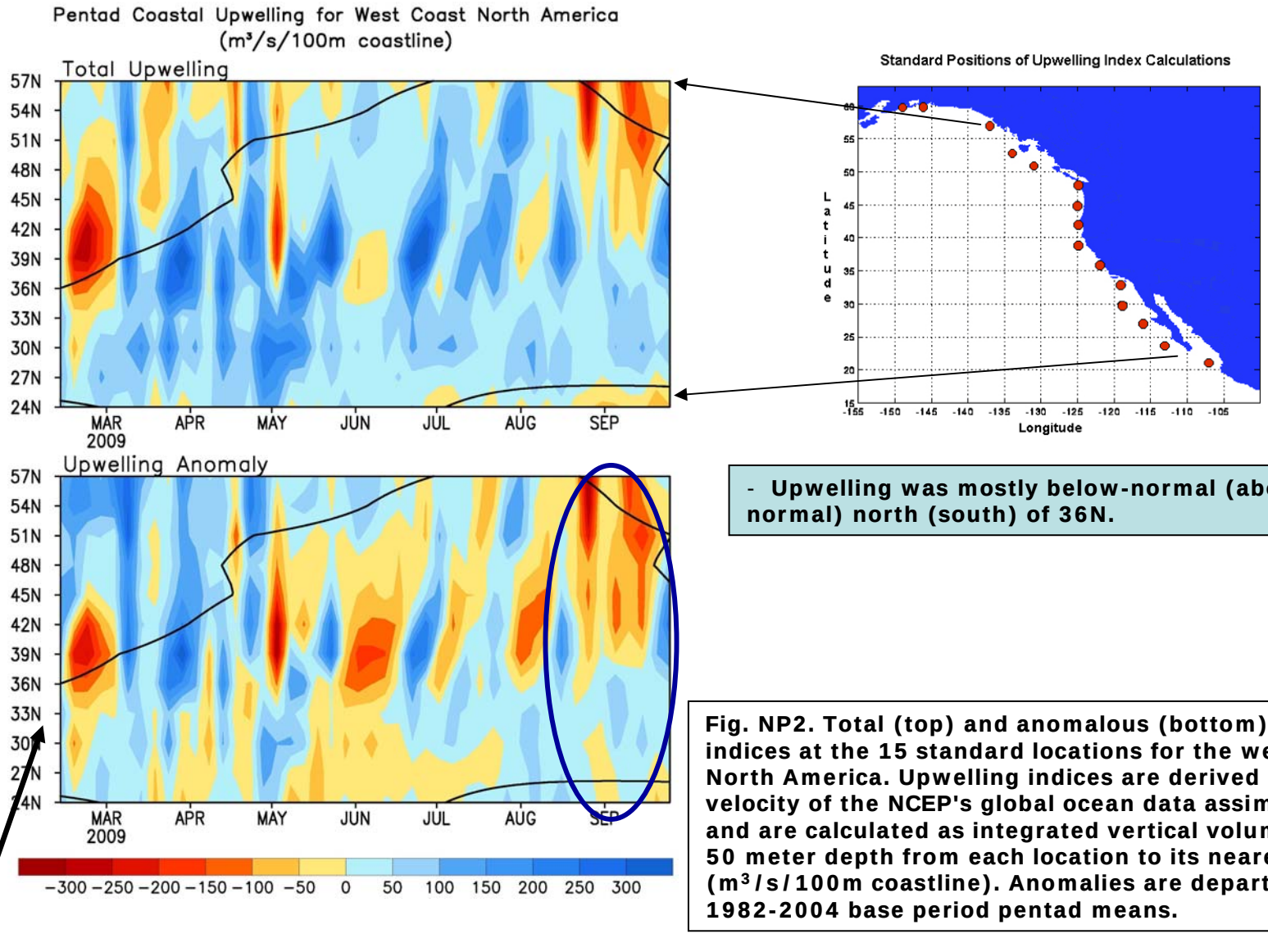
http://nsidc.org/arcticseaicenews/index.html





- **Sea ice extent reached minimum in mid-Sept, and increased since later Sept 09.**

North America Western Coastal Upwelling



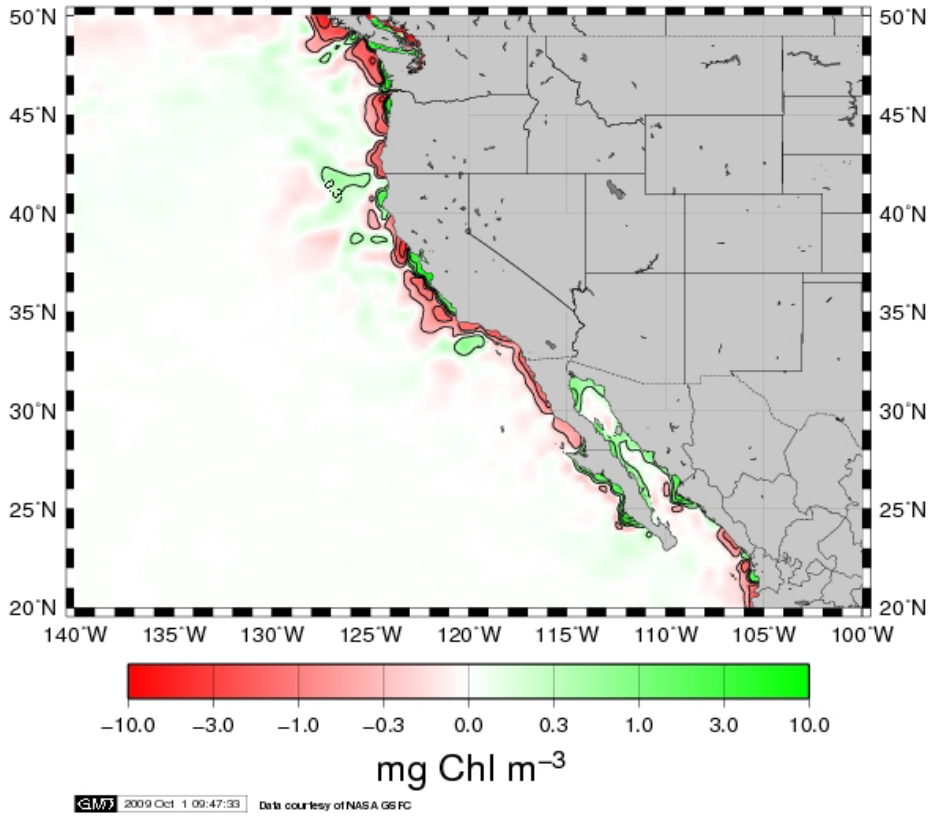
- **Upwelling was mostly below-normal (above-normal) north (south) of 36N.**

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.**

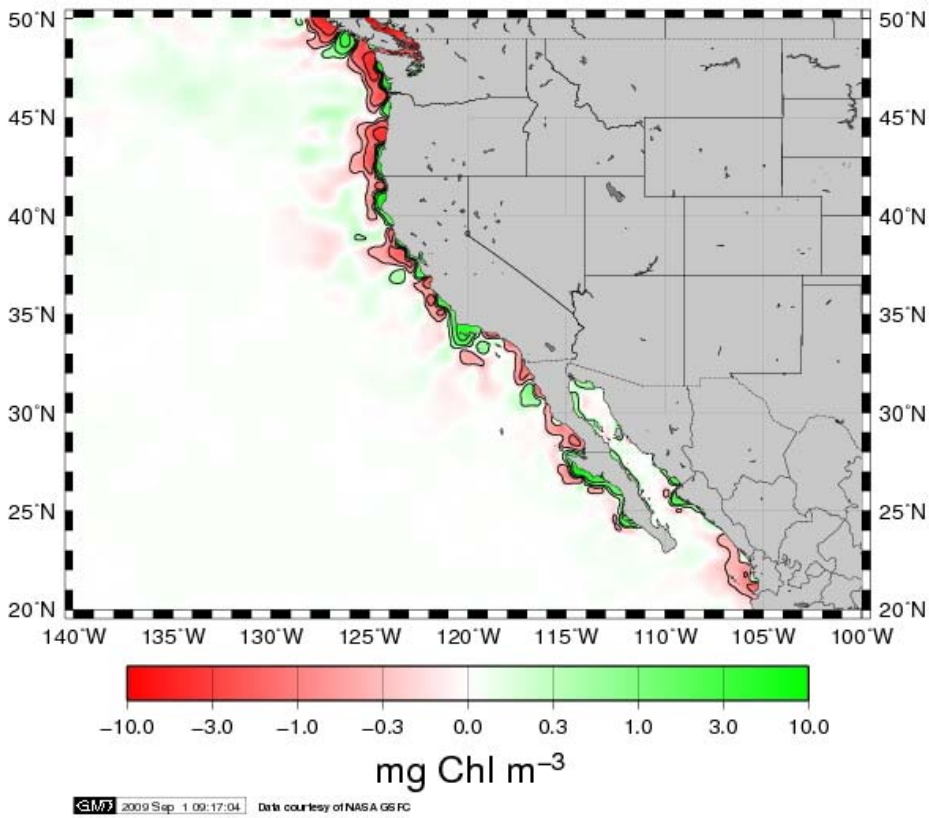
Monthly Chlorophyll Anomaly

MODIS Aqua Chlorophyll a Anomaly for September, 2009



- **Chlorophyll were mostly below-normal in Sept 09, largely consistent with the below-normal upwelling.**

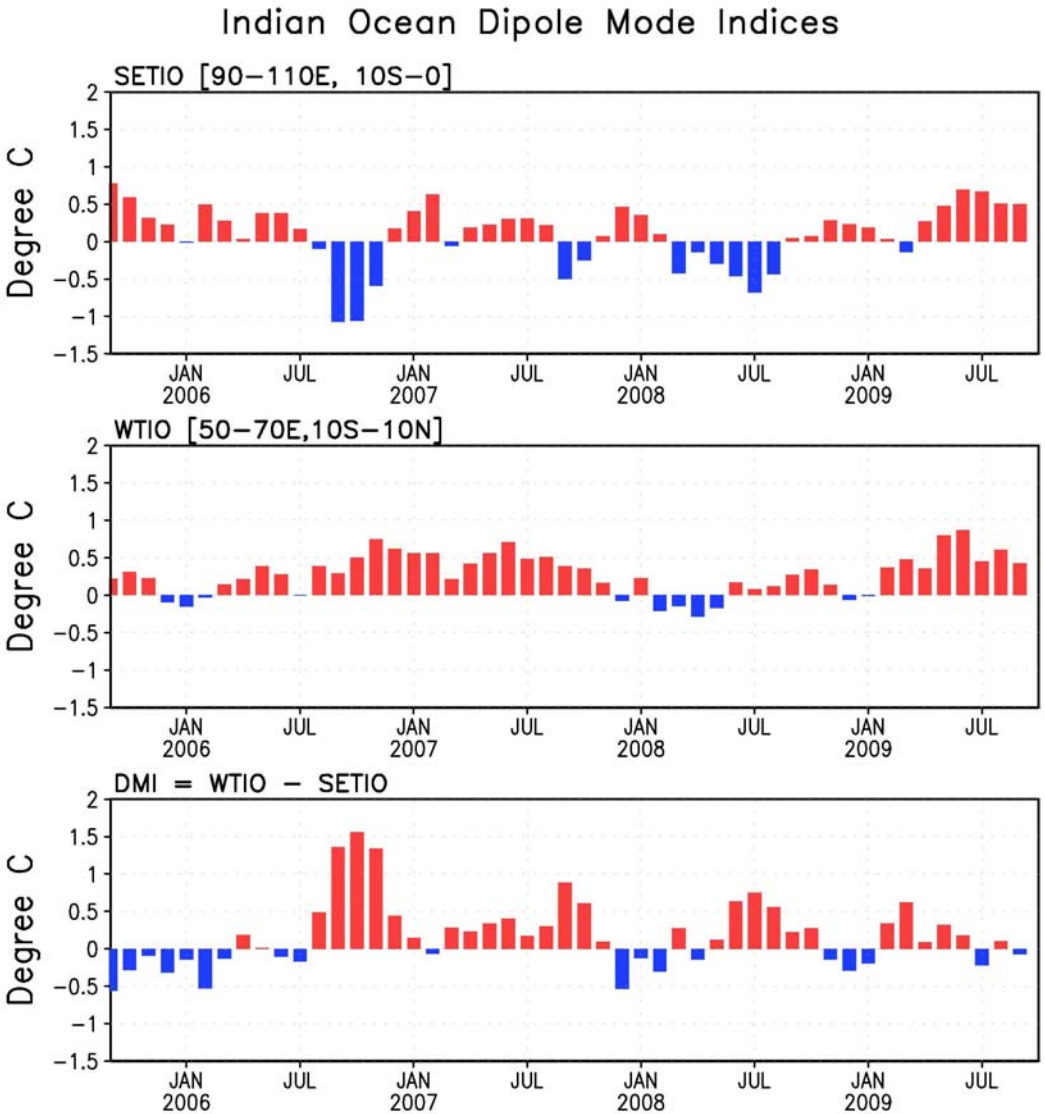
MODIS Aqua Chlorophyll a Anomaly for August, 2009

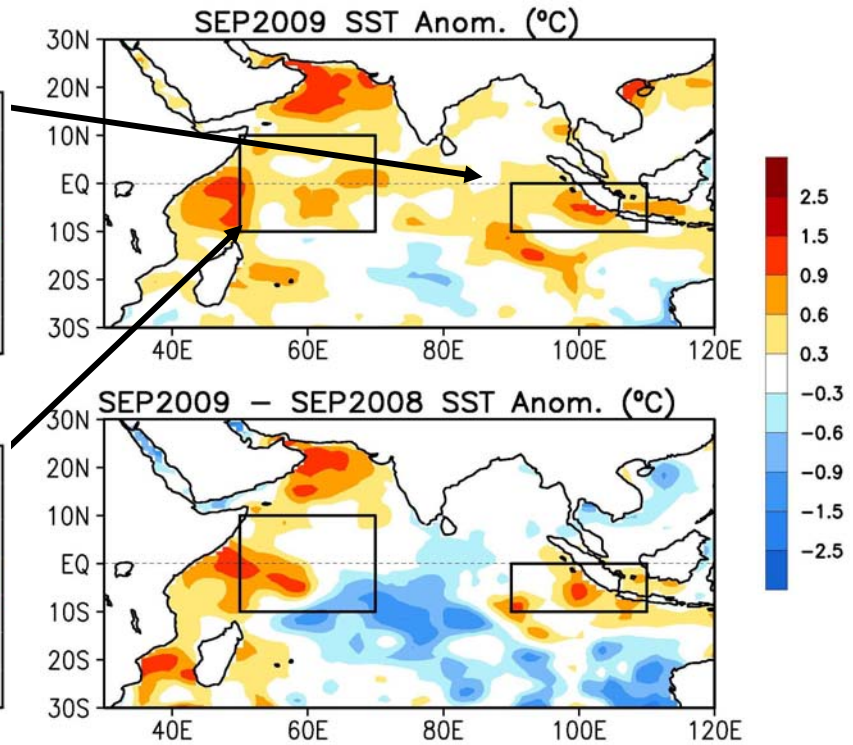


http://coastwatch.pfel.noaa.gov/FAST

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

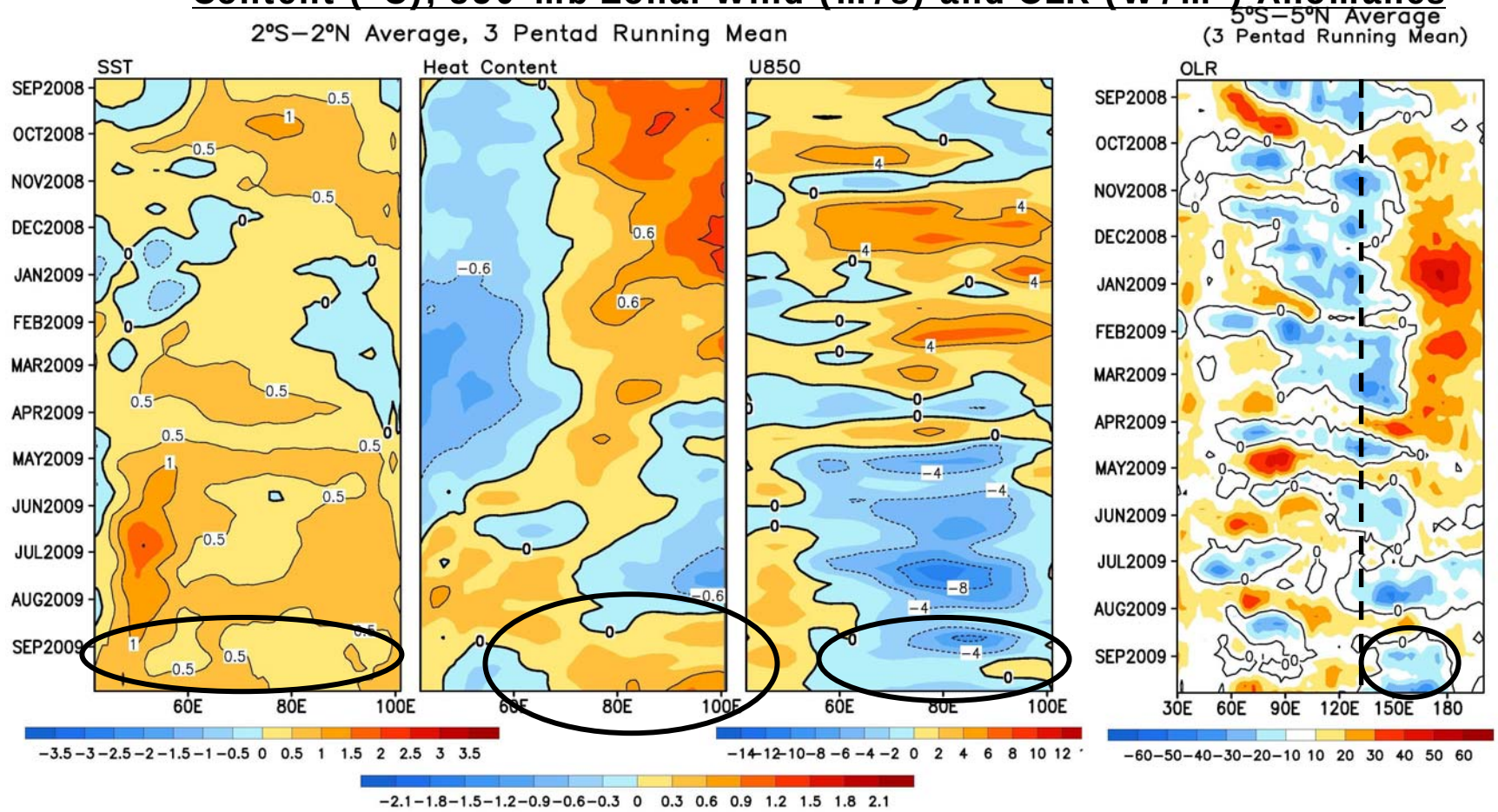




- **Both eastern (SETIO) and western (WTIO) pole SST have been persistently above-normal since April 09.**
- **DMI has been near-normal since March 09.**

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.

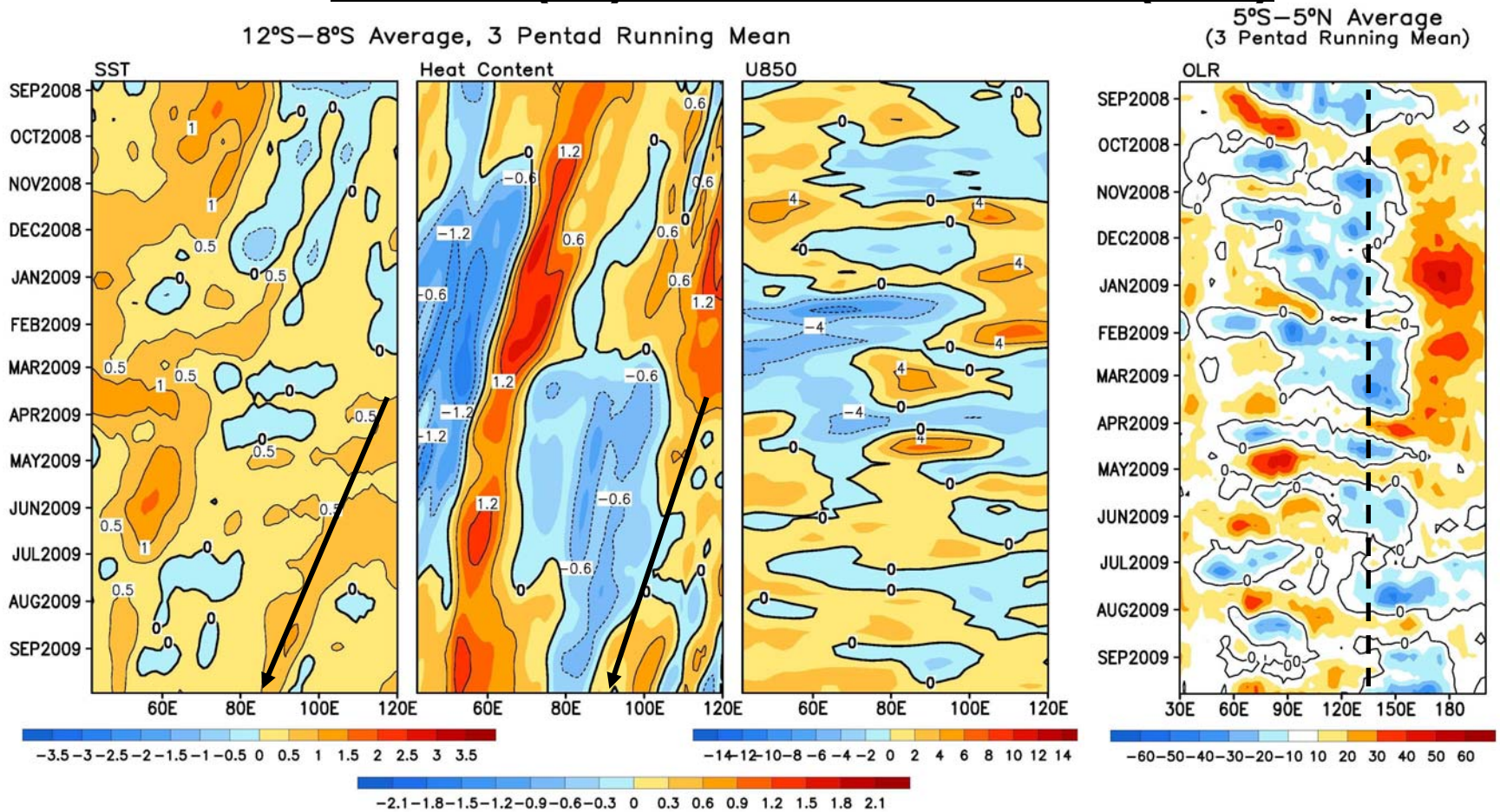
Recent Evolution of Equatorial Indian SST (ºC), 0-300m Heat Content (ºC), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies



- Easterly wind anomalies weakened in the east-central tropical Indian Ocean in Sep 09, were probably associated with the weakened negative east-west SSTA gradient and weakened (enhanced) convections in the eastern Indian Ocean (the western Pacific).
- In response to the weakened easterly wind anomalies, positive (negative) heat content anomaly was built up in the (western) eastern tropical Indian Ocean.

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.

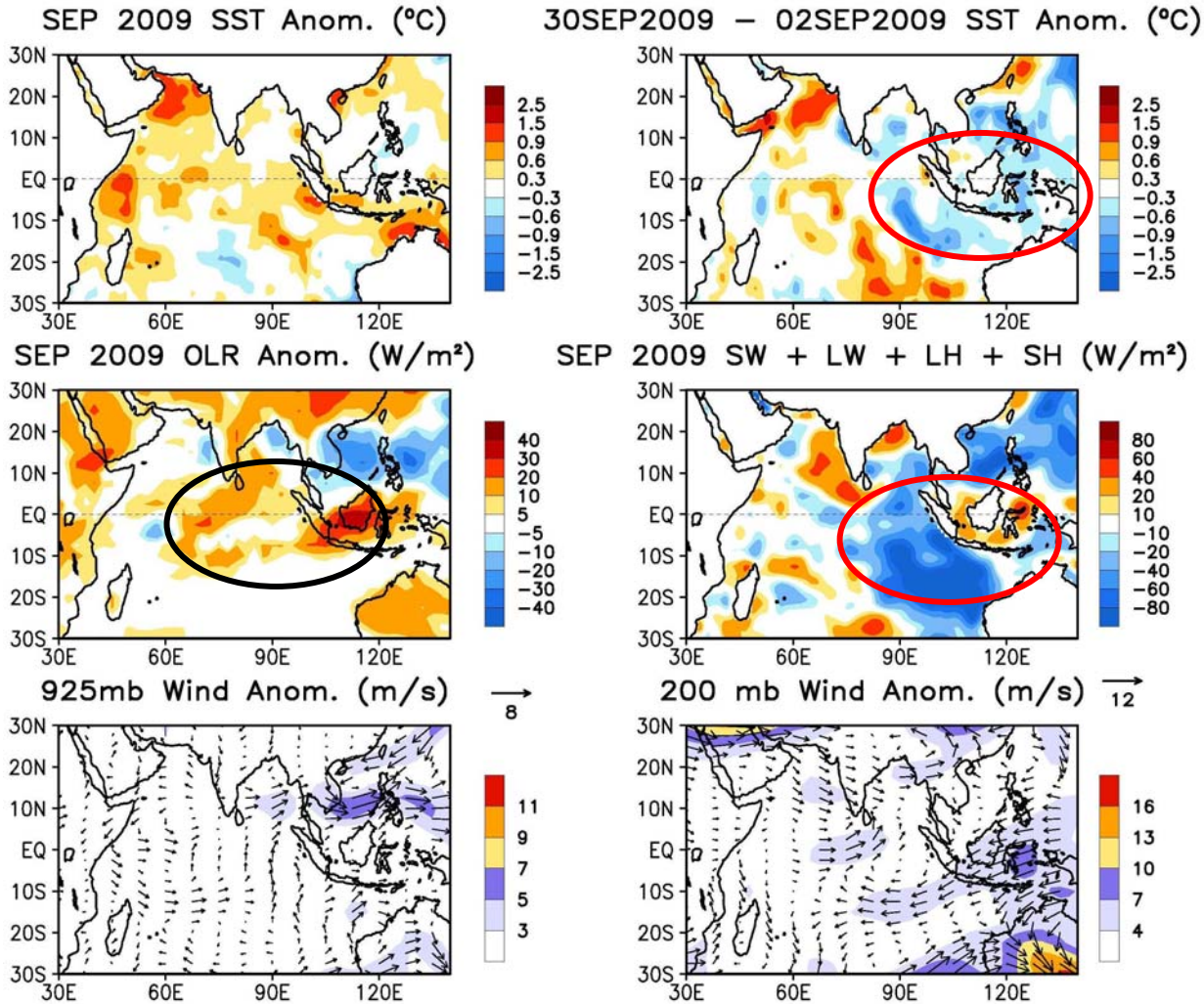
Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)



- **Westward propagation of positive HCA and SSTA near 10°S since Apr 09.**
- **Positive SSTA east of 80°E was largely consistent with positive HCA.**

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.

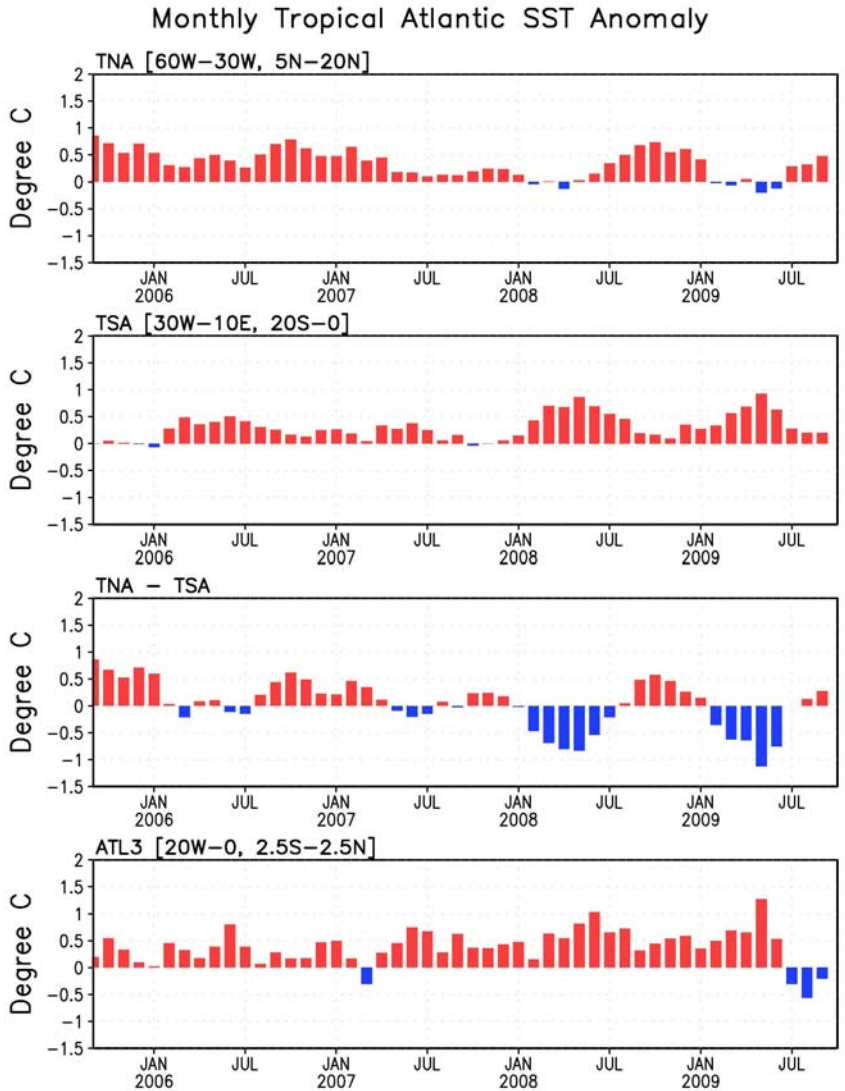


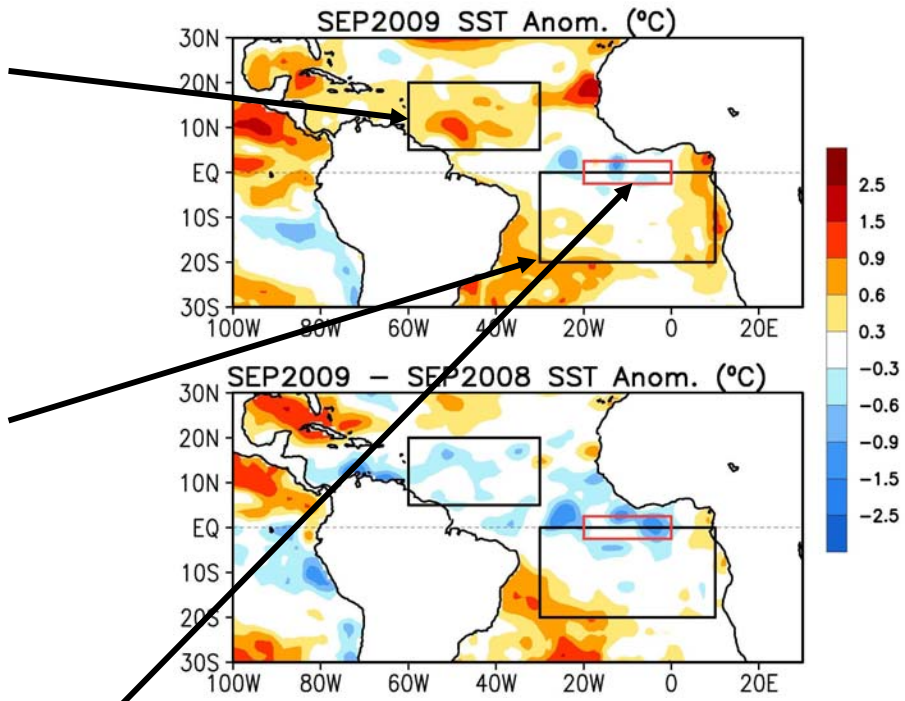
- Net surface heat flux anomalies cooled the eastern tropical Indian Ocean.
- Convection was suppressed in the eastern tropical Indian Ocean and over the Maritime Continents.

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

Tropical Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

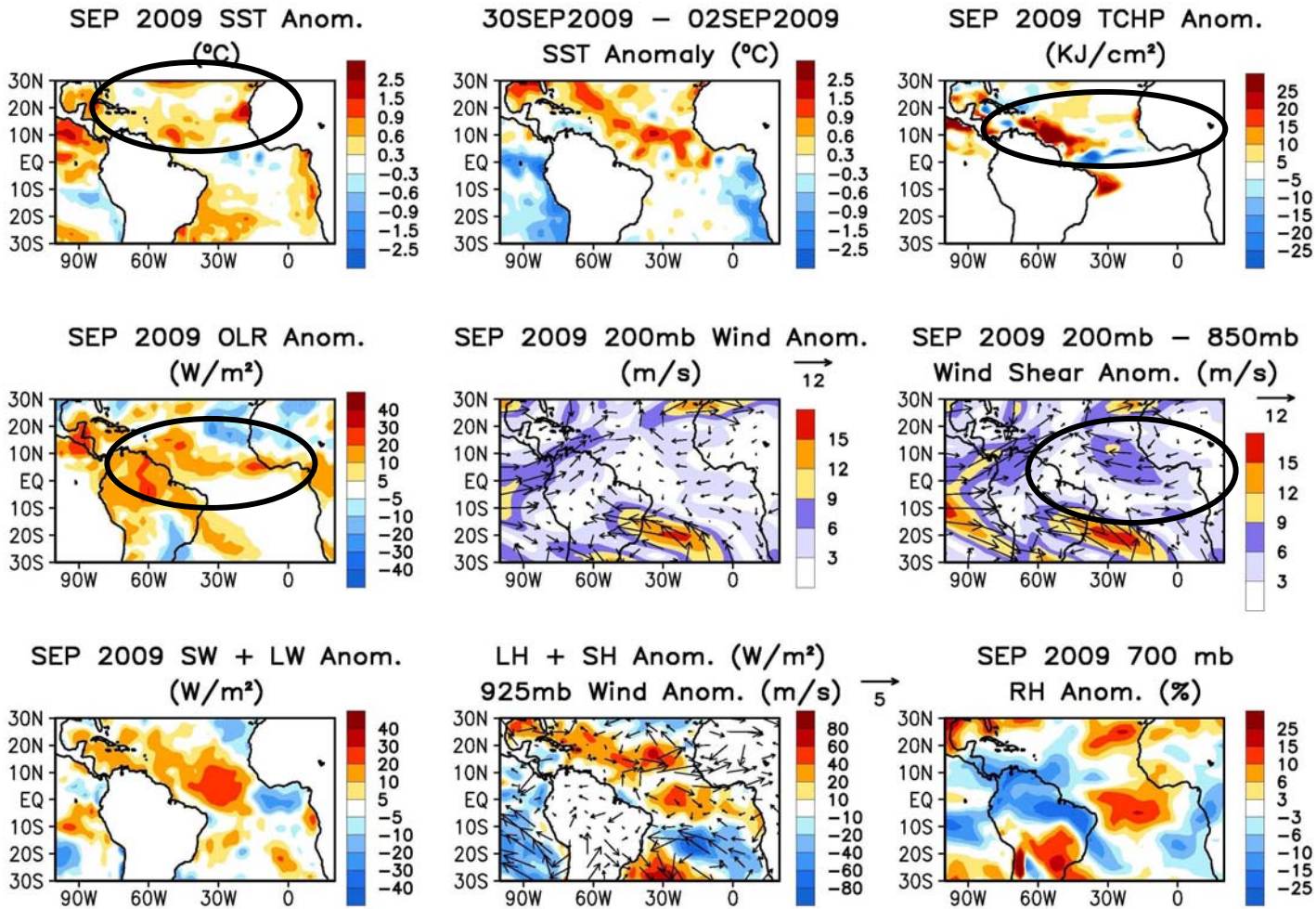




- **Tropical North Atlantic SST (TNA) was above-normal in July-September.**
- **Tropical South Atlantic SST (TSA) remained weakly above-normal.**
- **Meridional Gradient Mode (TNA-TSA) became above-normal since Aug 09.**
- **Negative ATL3 SST weakened in Sep 09.**

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:



- **Positive SSTAs and tropical cyclone heat potential (TCHP) anomaly presented in the tropical North Atlantic.**
- **Convection was suppressed in the tropical and northwest tropical Atlantic.**
- **Vertical wind shear were below-normal in the tropical North Atlantic.**

North Atlantic Ocean

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

- NAO became above-normal (next slide).
- SSTA tendencies were largely consistent with net surface heat flux anomalies.

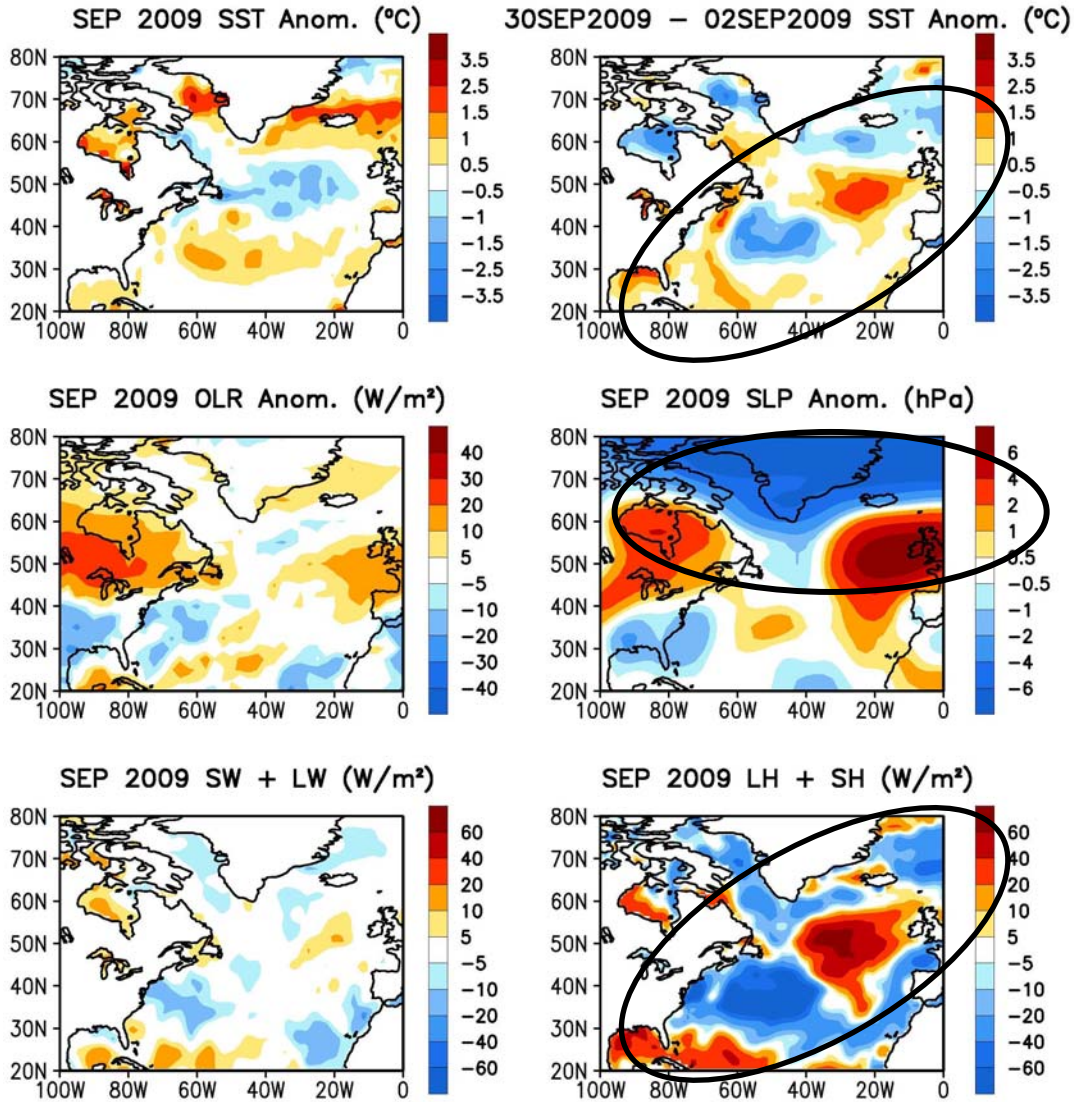
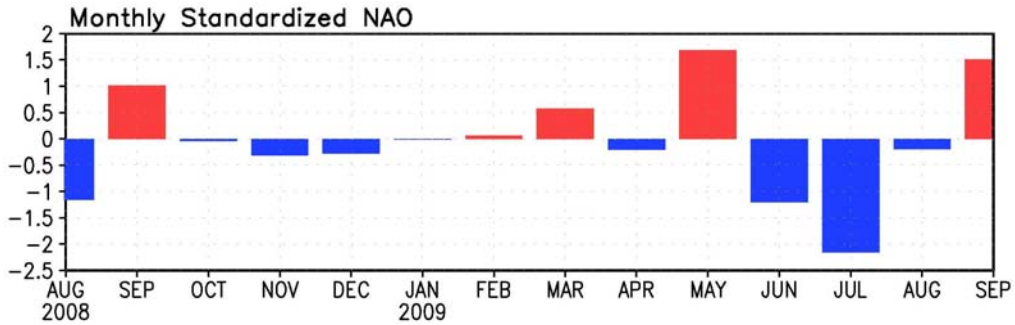
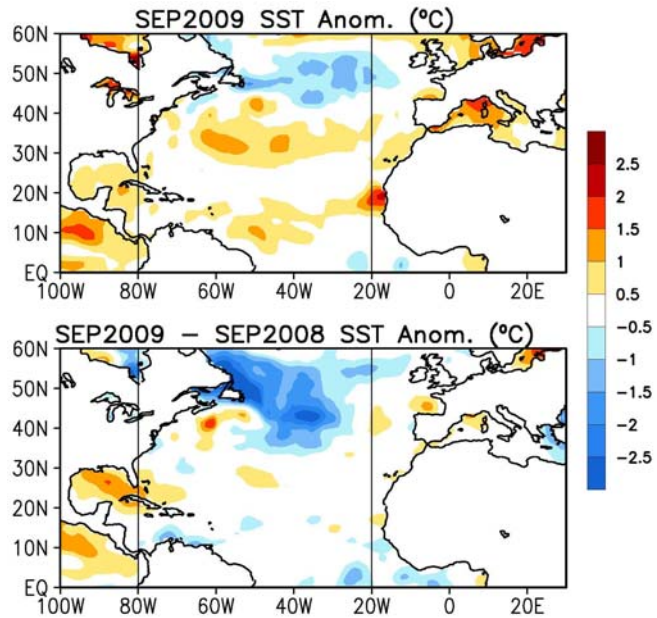
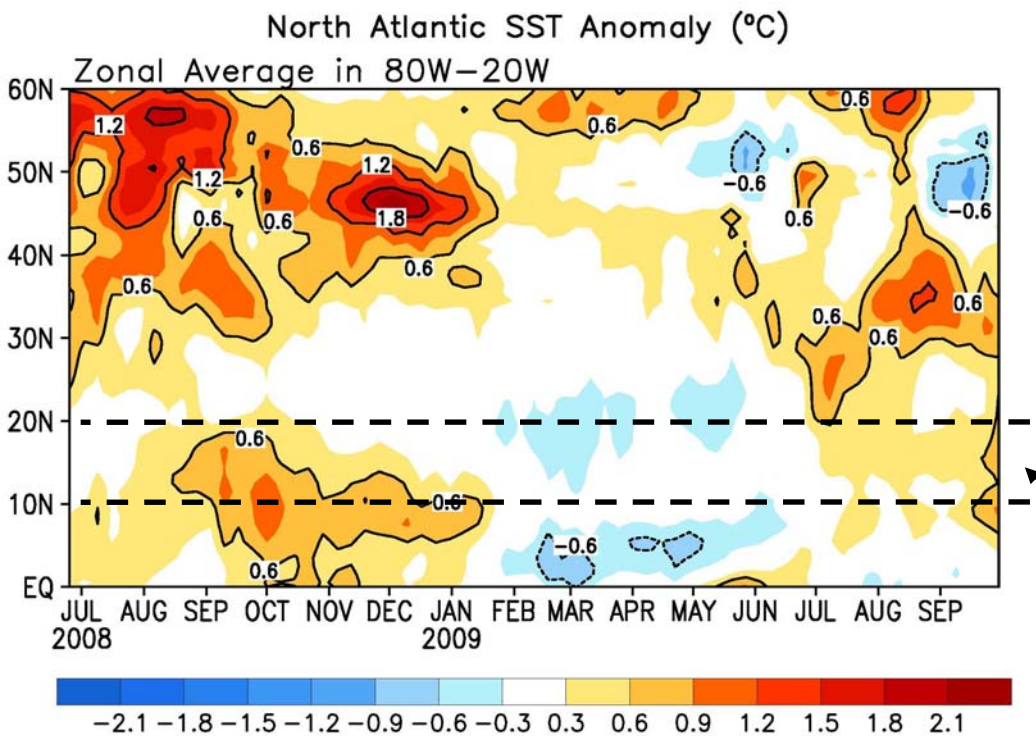


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

NAO and SST Anomaly in North Atlantic



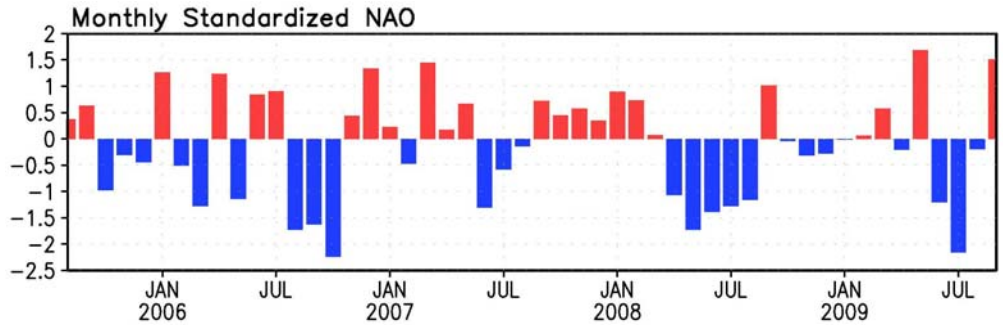


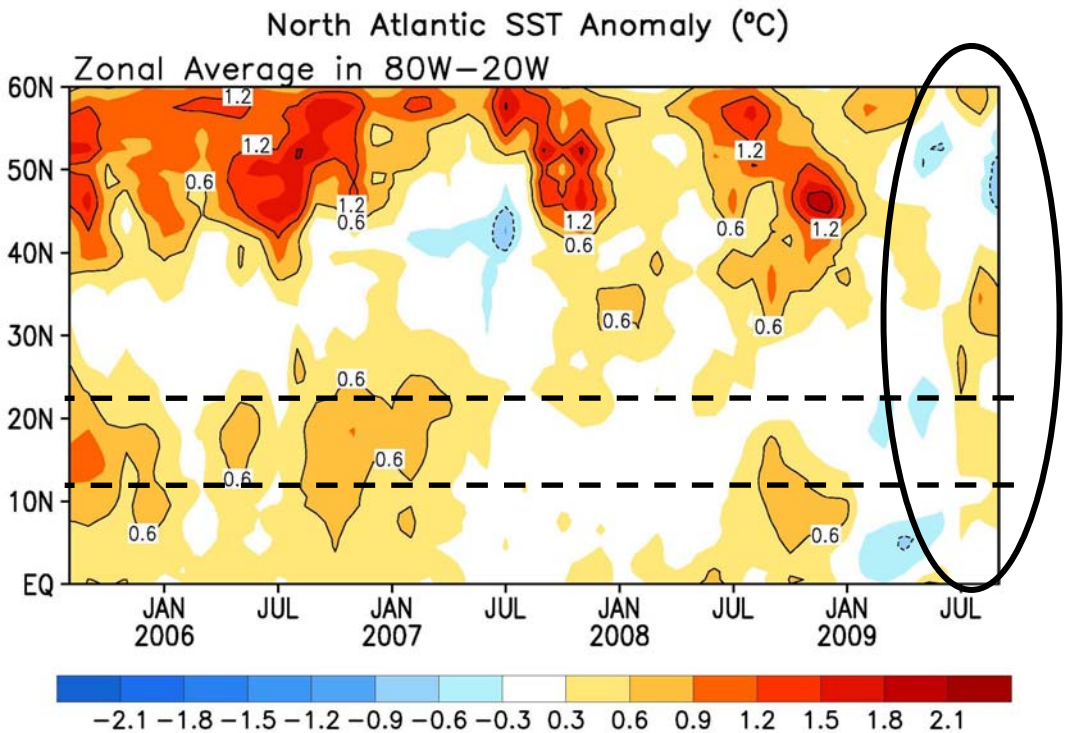


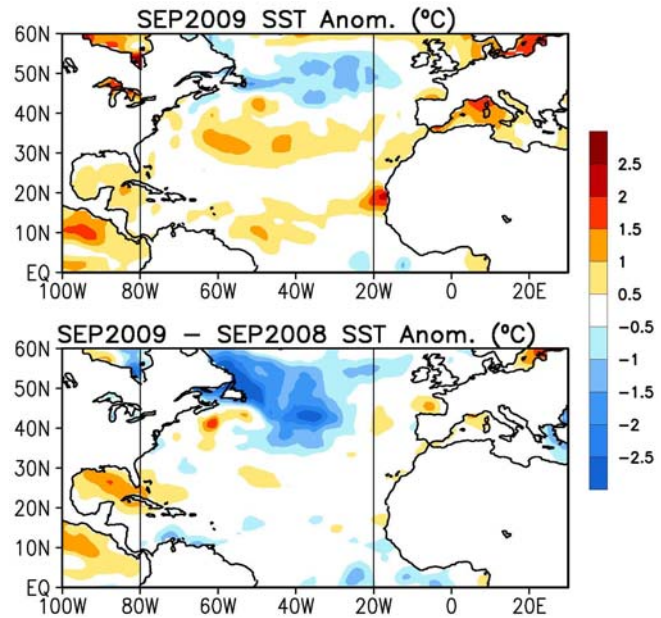
- **High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).**
- **NAO became above-normal in Sep 09.**
- **Positive SSTA in the Hurricane Main Development Region increased in Sep 09.**

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







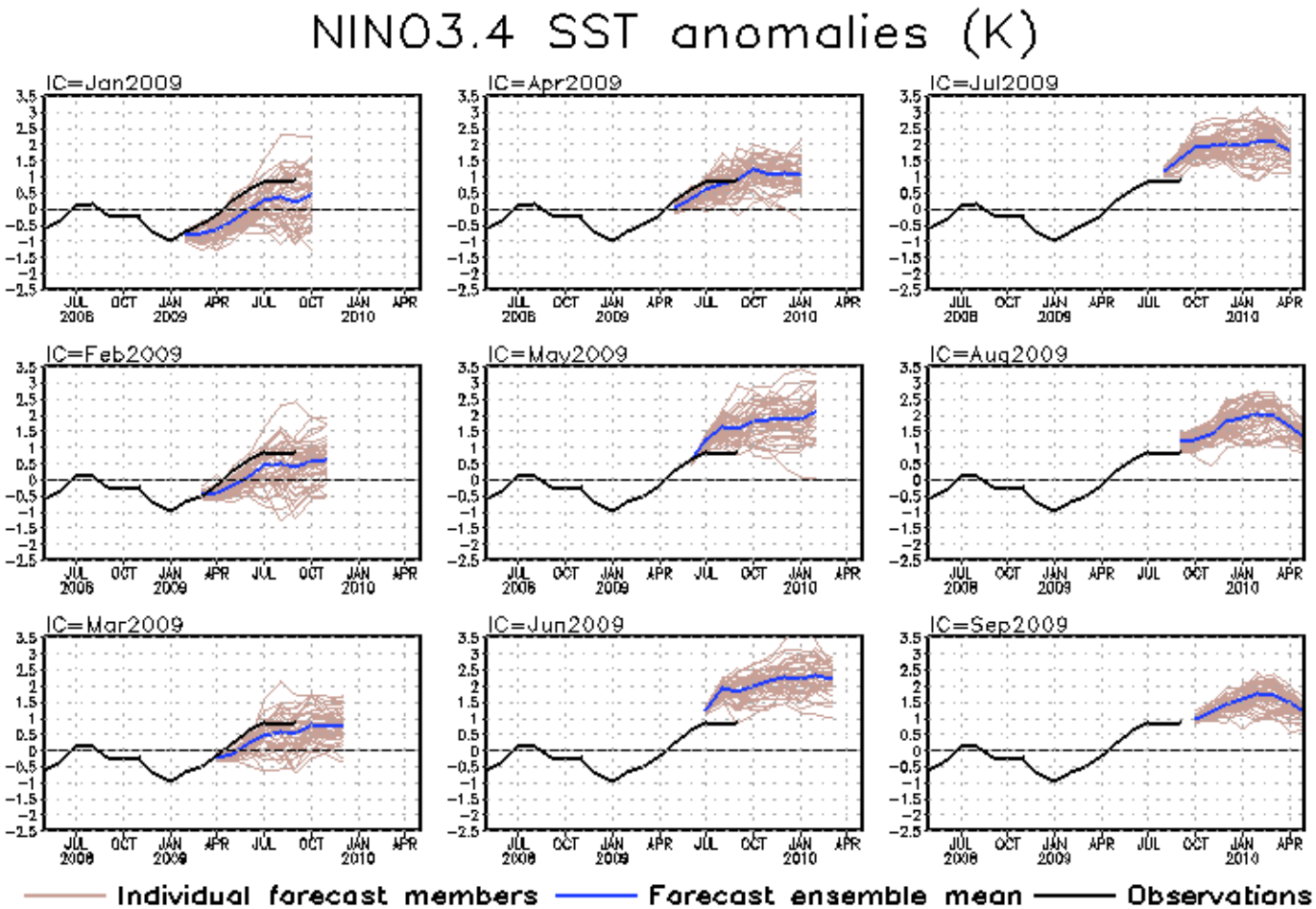
- **Mid-latitude North Atlantic SSTs cooled down and became slightly below-normal in spring and summer.**

- **Tropical North Atlantic SST was weakly above-normal in summer 09, similar to that in last summer.**

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

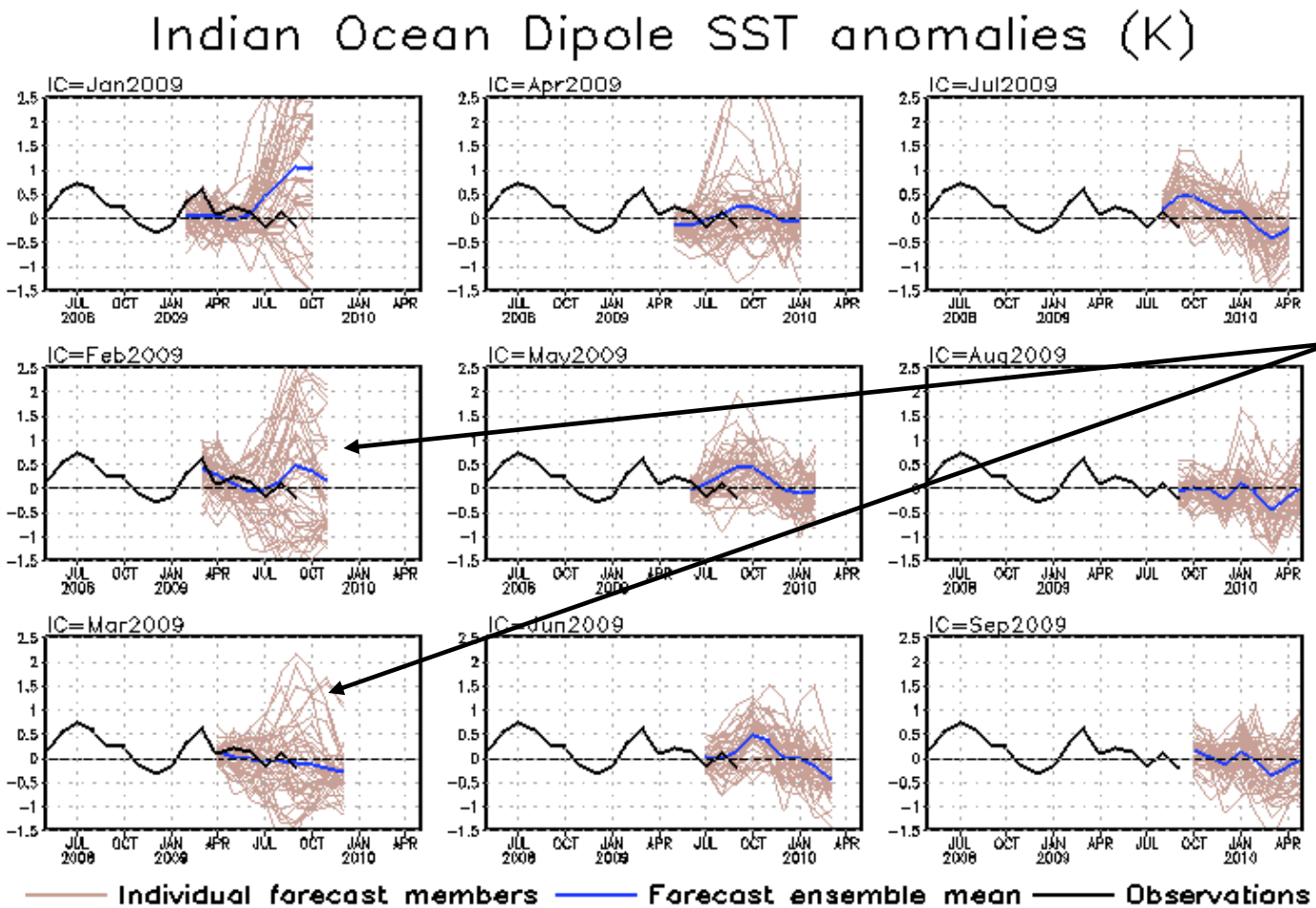


- Nice forecasts from Mar-Apr I.C.
- Too warm forecasts from May-Jul I.C..

- Latest forecasts suggested a moderate El Nino (NINO 3.4 > 1C) would develop during the winter 2009/2010.

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]

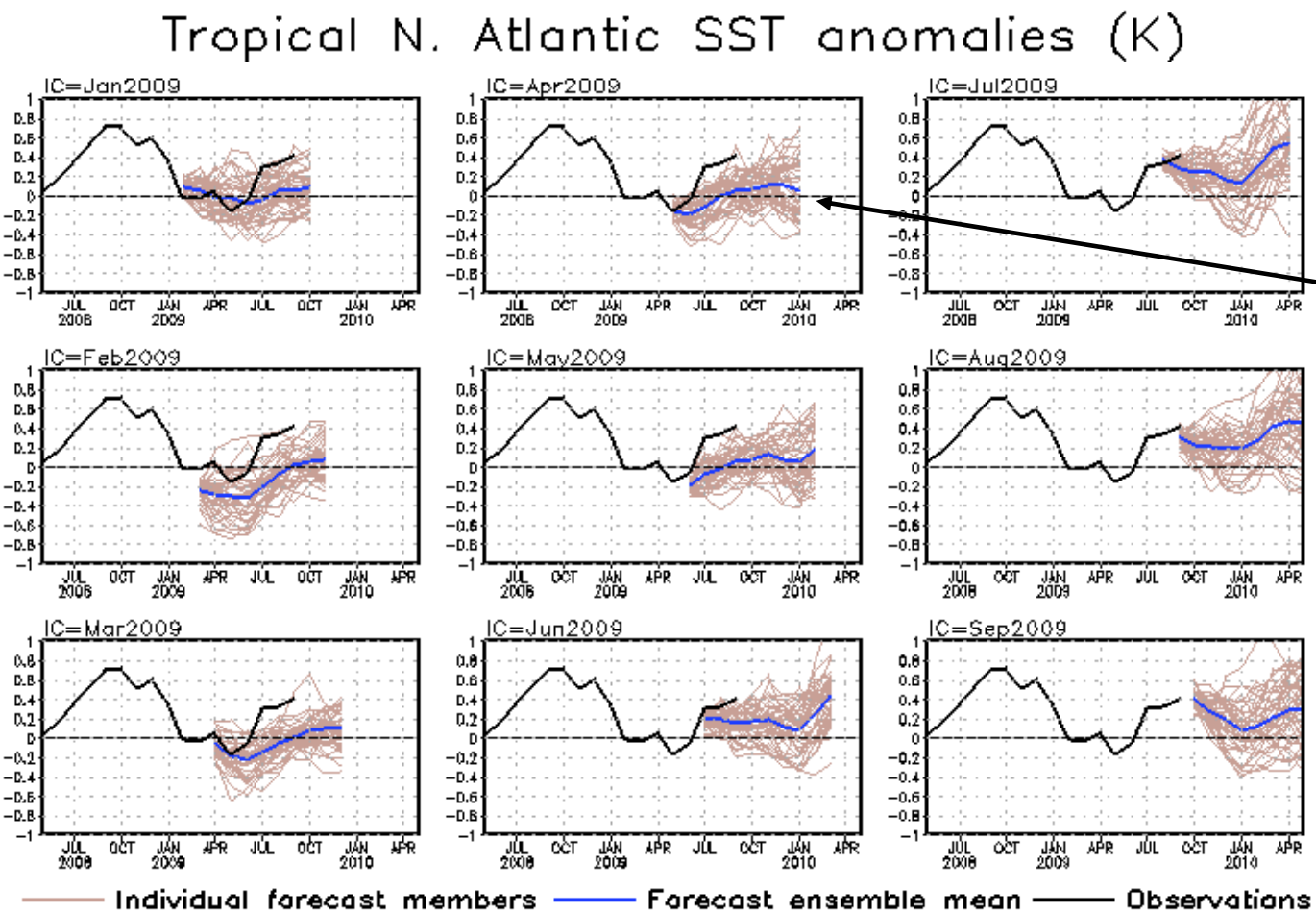
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

- Nice forecasts from Feb-Mar I.C.

- Latest forecasts called for near-normal Dipole Mode Index in the winter 09 and spring 2010.

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



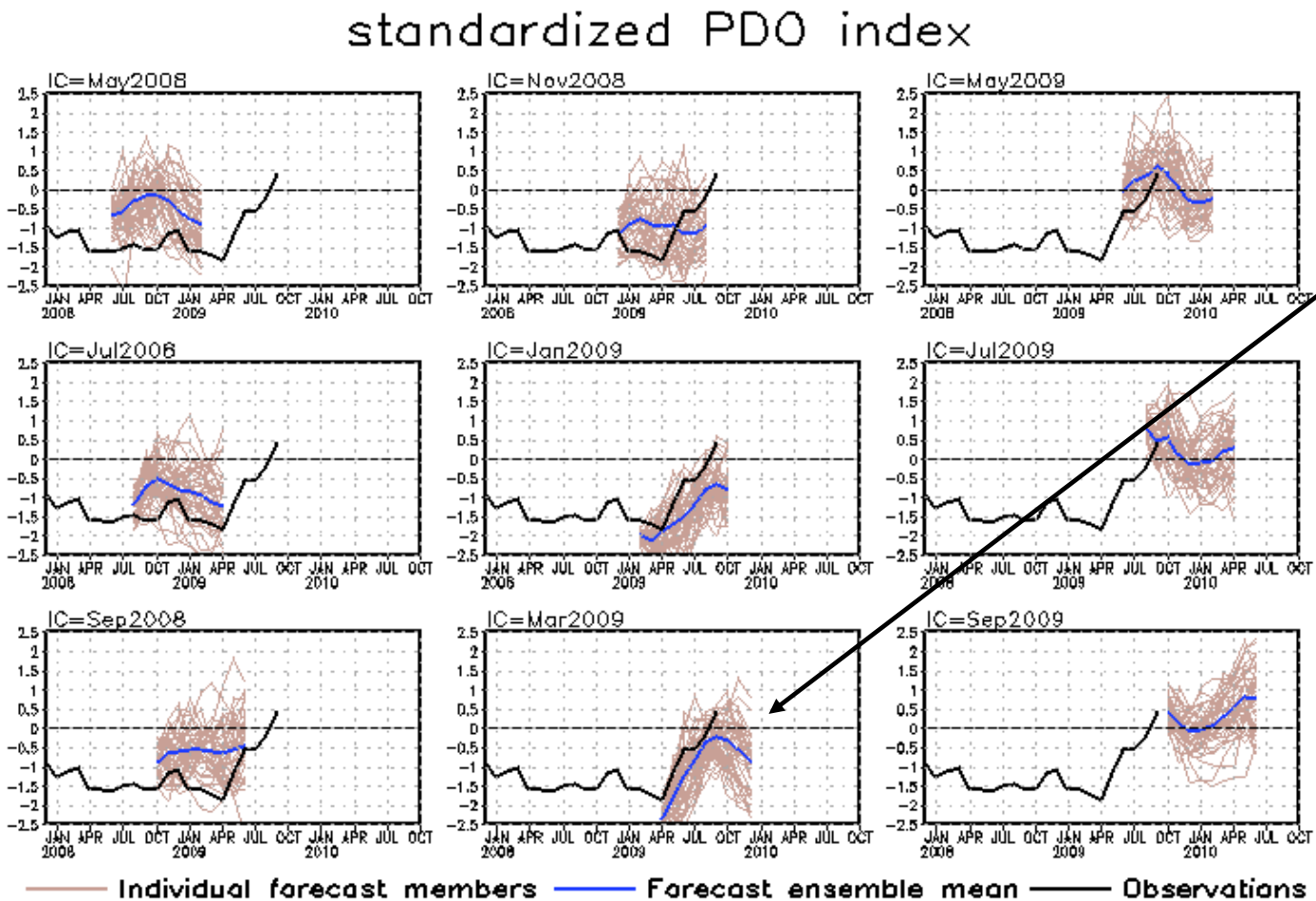
TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- Missed the warming trend in early summer from Jan-May I.C.

- Latest forecasts suggested that the positive tropical North Atlantic SST anomalies would weaken in next 3 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].

- Nice forecasts from Feb-Apr I.C.

- CFS SST anomalies are projected onto the PDO SST pattern (slide 16).

- Latest forecasts suggested that the near-normal PDO will continue through early spring 2010.

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**
  - El Niño conditions (NINO 3.4 > 0.5 ^{o}C) established in June 2009, and were expected to last through the Northern Hemisphere winter 2009-2010.
  - Westerly wind bursts were active in July and September 09, probably contributing to the sustaining of the 2009/10 El Niño.
  - PDO phase became positive for the first time since September 2007.
  - Upwelling along the west coast of North America was below-normal north of 36N Since August 09.
- **Indian Ocean**
  - Easterly wind anomalies weakened in the central-eastern tropical Indian Ocean in September 09.
  - Positive SSTA weakened in the tropical Indian Ocean in September 09, and Dipole Mode Index has been near-normal since March 09.
- **Atlantic Ocean**
  - Above-normal SST and tropical cyclone heat potential (TCHP) presented in the tropical North Atlantic.
  - Convection was suppressed in the tropical and northwest tropical Atlantic.
  - Vertical wind shear was below-normal in the tropical North Atlantic.

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!