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

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

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

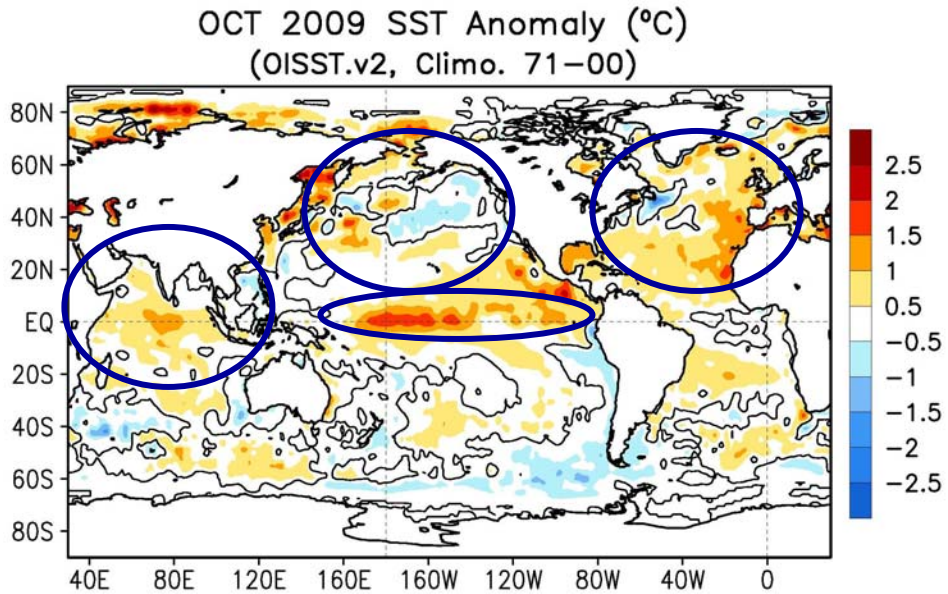
Outline

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

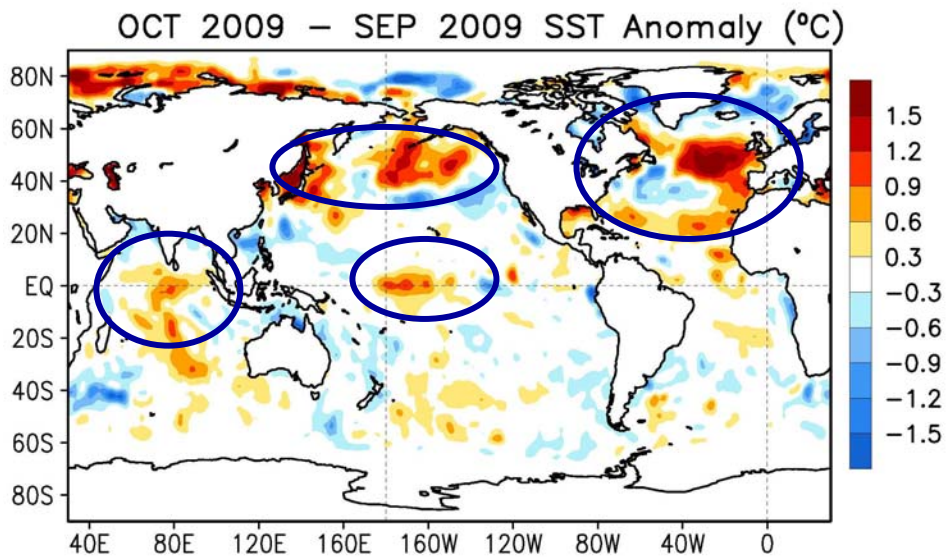
Overview

- **Pacific Ocean**
  - El Niño conditions (NINO 3.4 > 0.5 ºC), that established in Jun 09, and persisted during Jul-Sep 09, and strengthened in Oct 09, were expected to reach a moderate strength during the Northern Hemisphere winter 2009-2010.
  - Westerly wind bursts were active in Jul, Sep, Oct 09, contributing to the sustaining and strengthening of the 2009/10 El Niño.
  - PDO was near-normal in Sep-Oct 2009 after a 2 year negative PDO phase.
  - Upwelling along the west coast of North America was mostly above-normal in Oct 09.
- **Indian Ocean**
  - Easterly wind anomalies strengthened in the east-central tropical Indian Ocean in Oct 09.
  - Positive SSTA increased substantially across the tropical Indian Ocean in Oct 09, and Dipole Mode Index has been near-normal since Mar 09.
- **Atlantic Ocean**
  - Above-normal SST and tropical cyclone heat potential (TCHP) presented in the tropical North Atlantic.
  - Convection was suppressed in the tropical Atlantic.
  - Vertical wind shears were below-normal in the tropical North Atlantic.

Global SST Anomaly (ºC) and Anomaly Tendency



- El Nino conditions (NINO 3.4 > 0.5ºC) strengthened in the tropical Pacific.
- PDO was near-normal (slide 18).
- SST was above-normal in the tropical Indian and North Atlantic

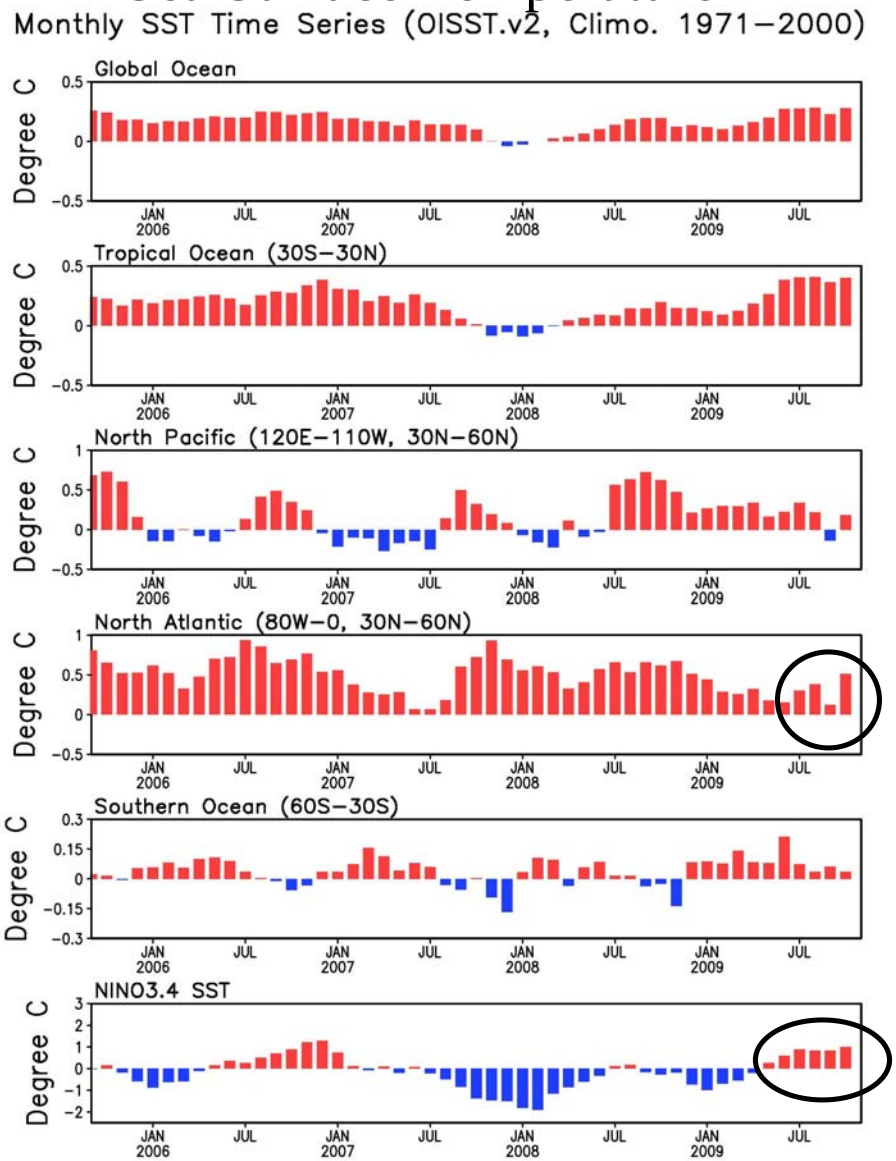


- SST increased in the central tropical Pacific.
- SST increased in the central tropical Indian.
- Large SSTA changes in the North Pacific and North Atlantic.

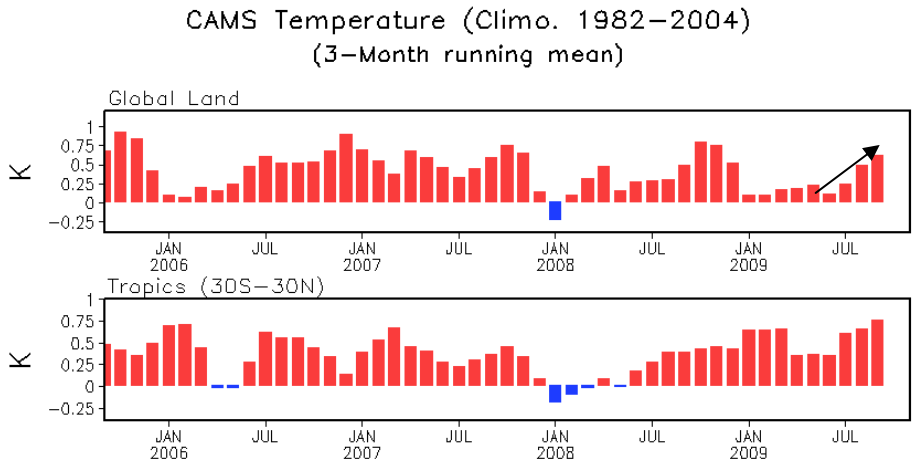
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Monthly Time Series

Sea Surface Temperature



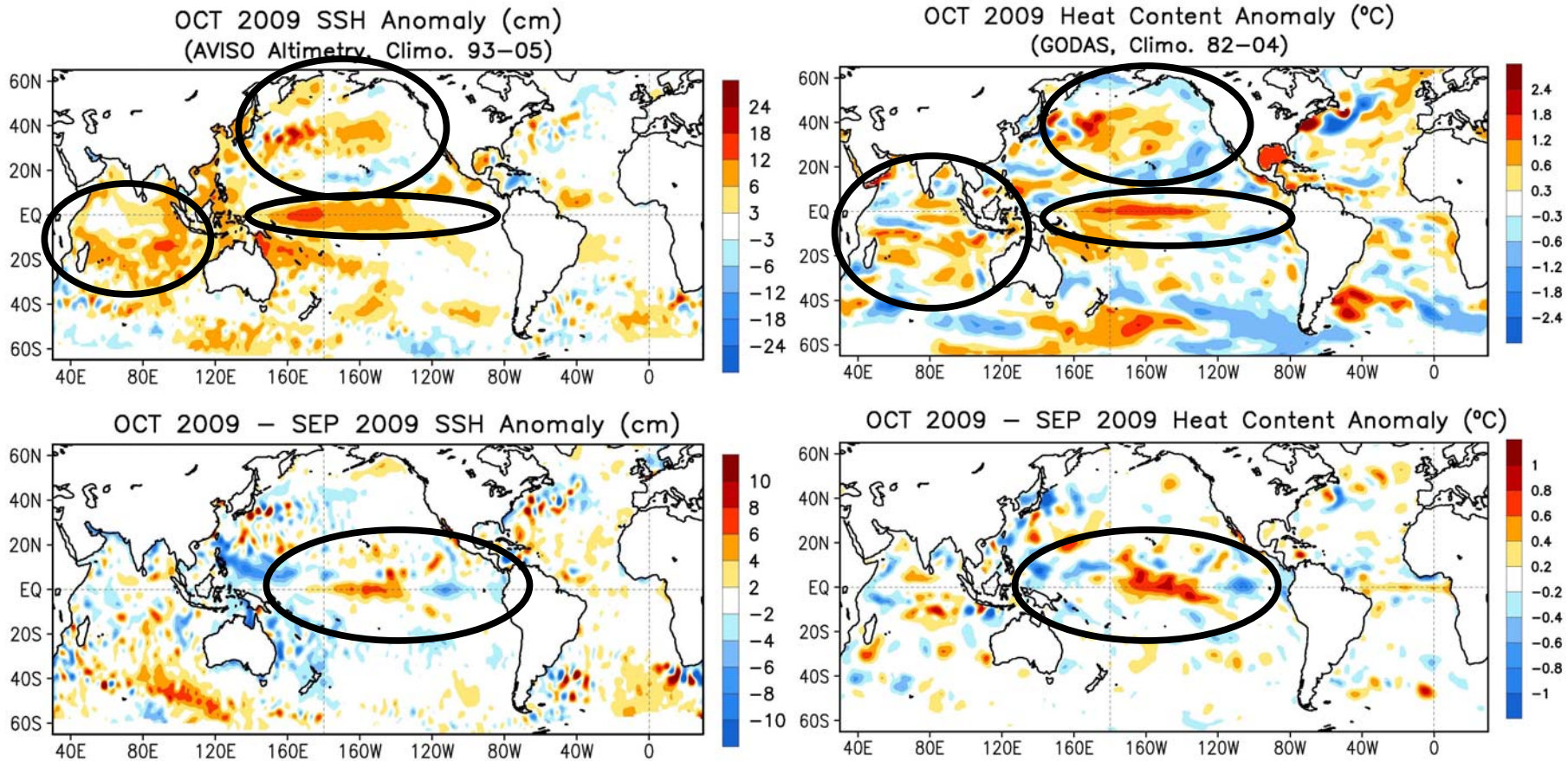
CAMS Land Temperature



- **Global mean seasonal land temperature increased.**
- **Tropical land temperature also increased.**
- **Positive global and tropical mean SSTA persisted.**
- **SST in the North Atlantic increased substantially.**
- **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.

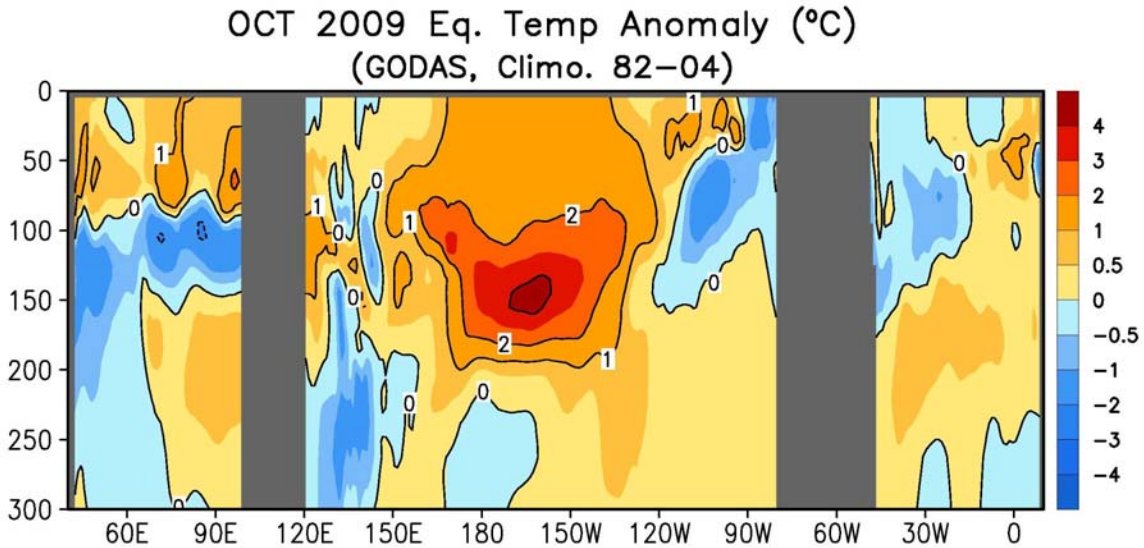
Global SSH / HC Anomaly (cm / ºC) and Anomaly Tendency



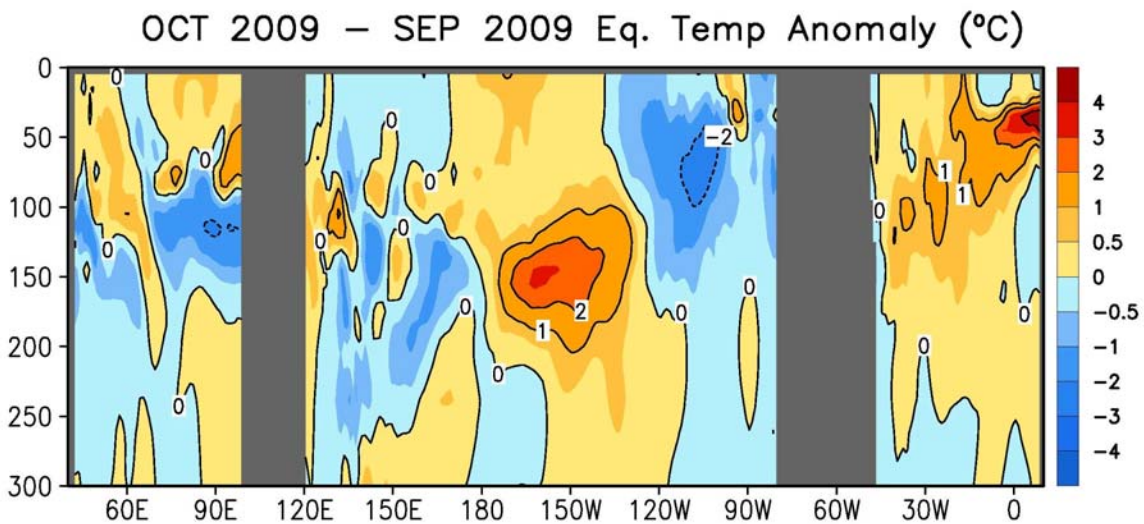
- **Negative PDO-like pattern in SSHA and HCA in the North Pacific persisted, although PDO index was near-normal.**
- **Positive SSHA and HCA presented along the equatorial belt, consistent with the El Nino conditions.**
- **SSHA and HCA were largely consistent except in the tropical Indian and Southern Oceans where biases in GODAS climatology were large (not shown).**
- **Tendency of SSHA and HCA was consistent in the tropical Pacific.**

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 2-4°C presented near the thermocline of the equatorial Pacific, consistent with the El Nino conditions.**
- **Near surface temperature remained negative in the far eastern tropical Pacific east of 90W**

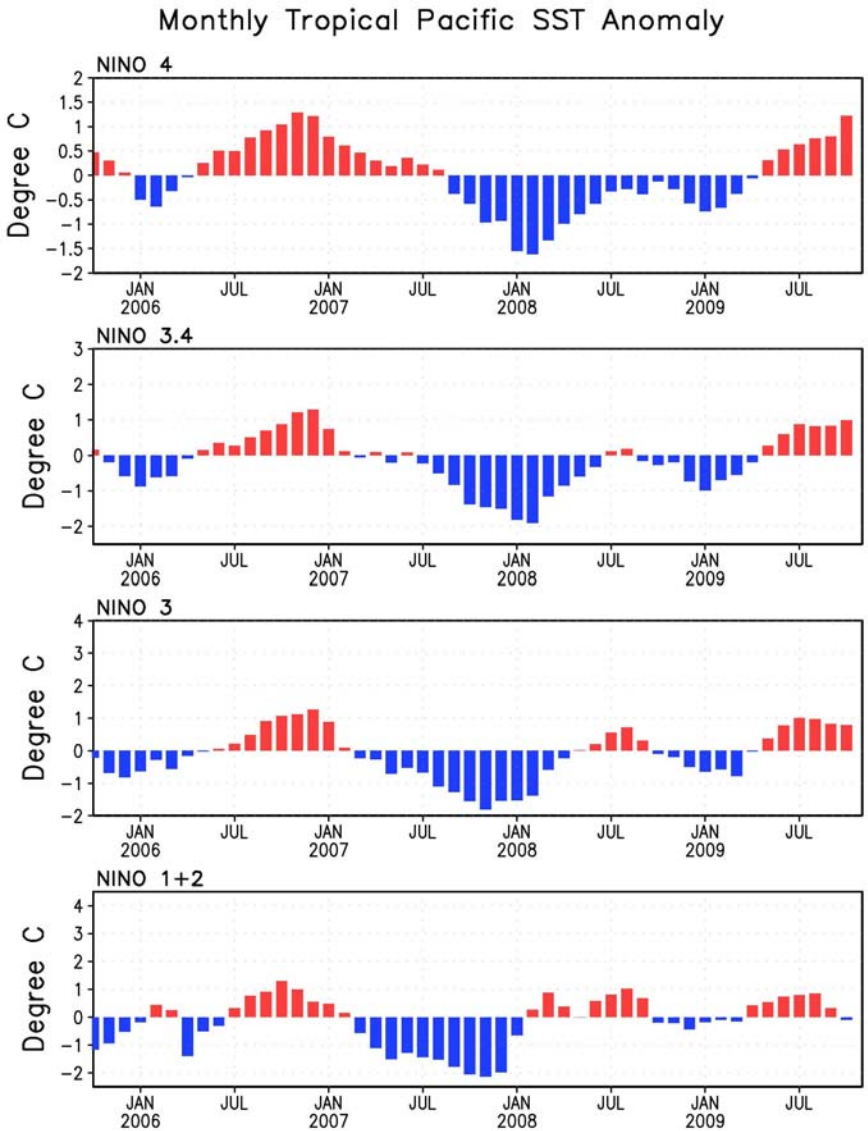


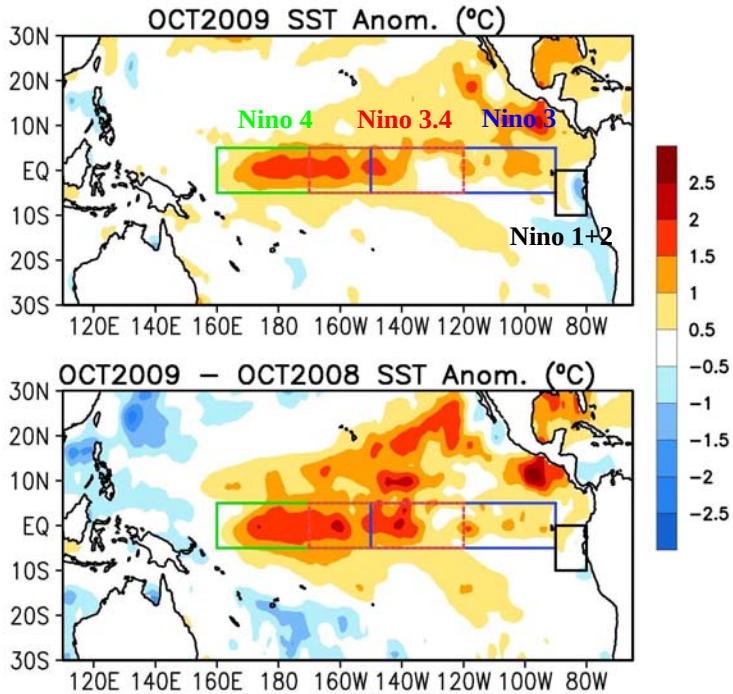
- **Subsurface temperature anomalies increased (decreased) by 1-2°C near 160W (105W) along the thermocline of the equatorial Pacific.**

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.

Tropical Pacific Ocean

Evolution of Pacific NINO SST Indices





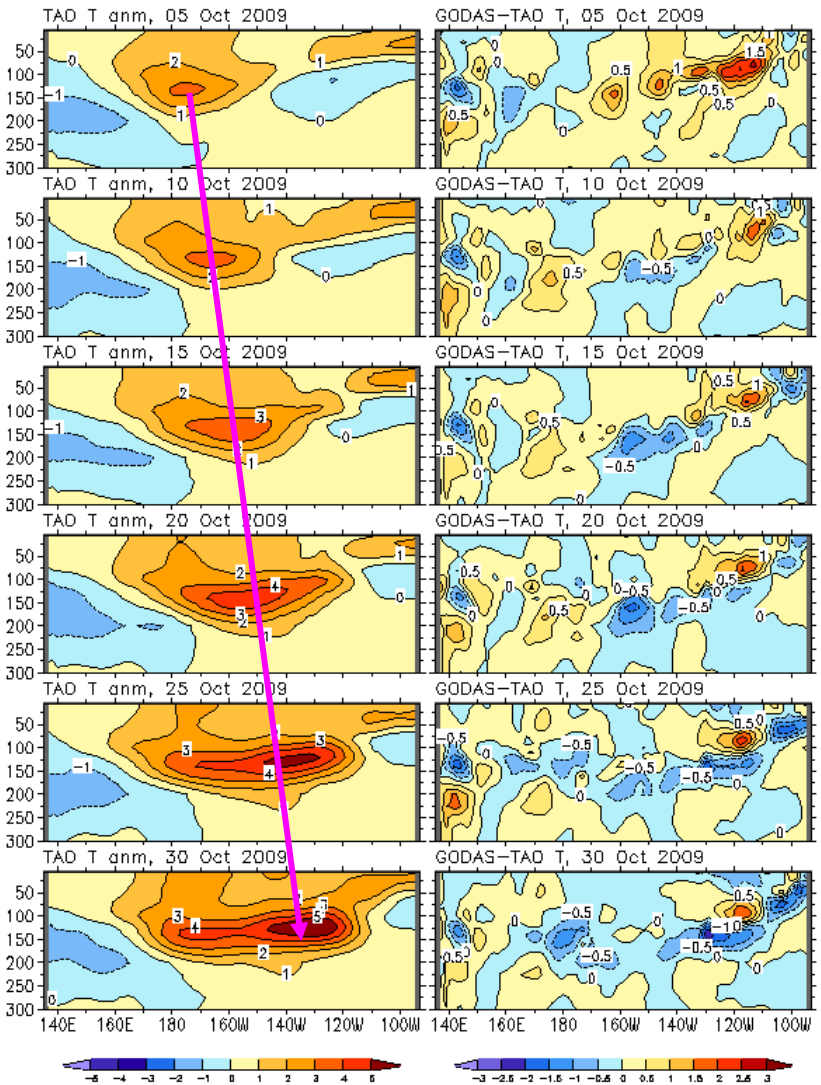
- El Niño conditions (NINO 3.4 > 0.5°C) are expected to last through the Northern Hemisphere Winter – NOAA's "ENSO Diagnostic Discussion".

- NINO 4 enhanced, NINO 3.4 and NINO 3 largely persisted, and NINO 1.2 became negative in Oct 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

TAO Temp Anom GODAS-TAO

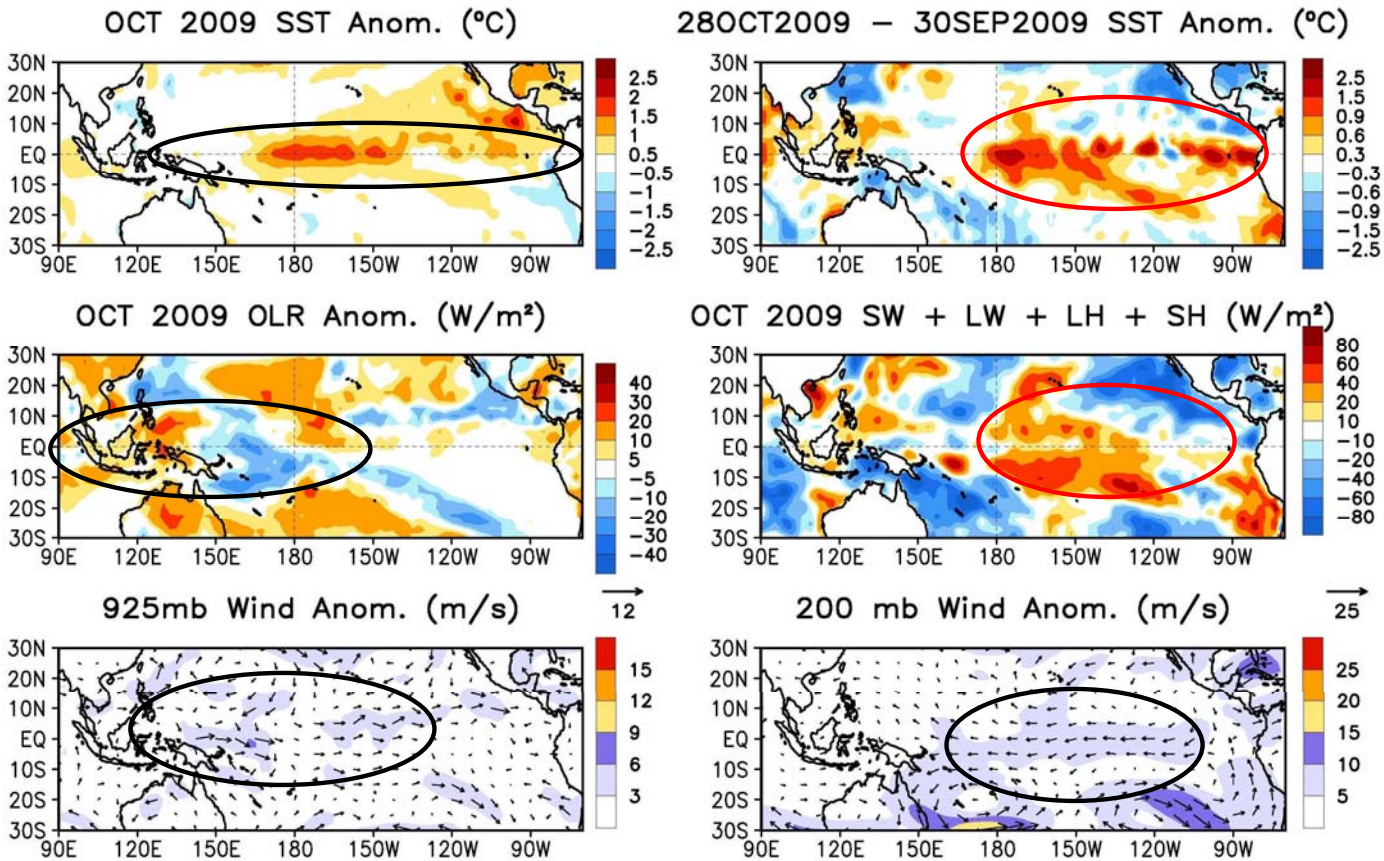


TAO climatology used

- **Equatorial temperature increased near the thermocline and positive anomalies propagated eastward.**

- **Temperature differences between GODAS and TAO were largely confined to the far eastern Pacific.**

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 increased in the eastern and central tropical Pacific, largely consistent with the net surface heat flux anomalies.**
- **Convection was suppressed (enhanced) over the Maritime Continents (in the western Pacific).**
- **Westerly (easterly) wind anomaly presented at the lower-level (upper-level) in the west and central (entire) tropical Pacific, consistent with the El Nino conditions.**

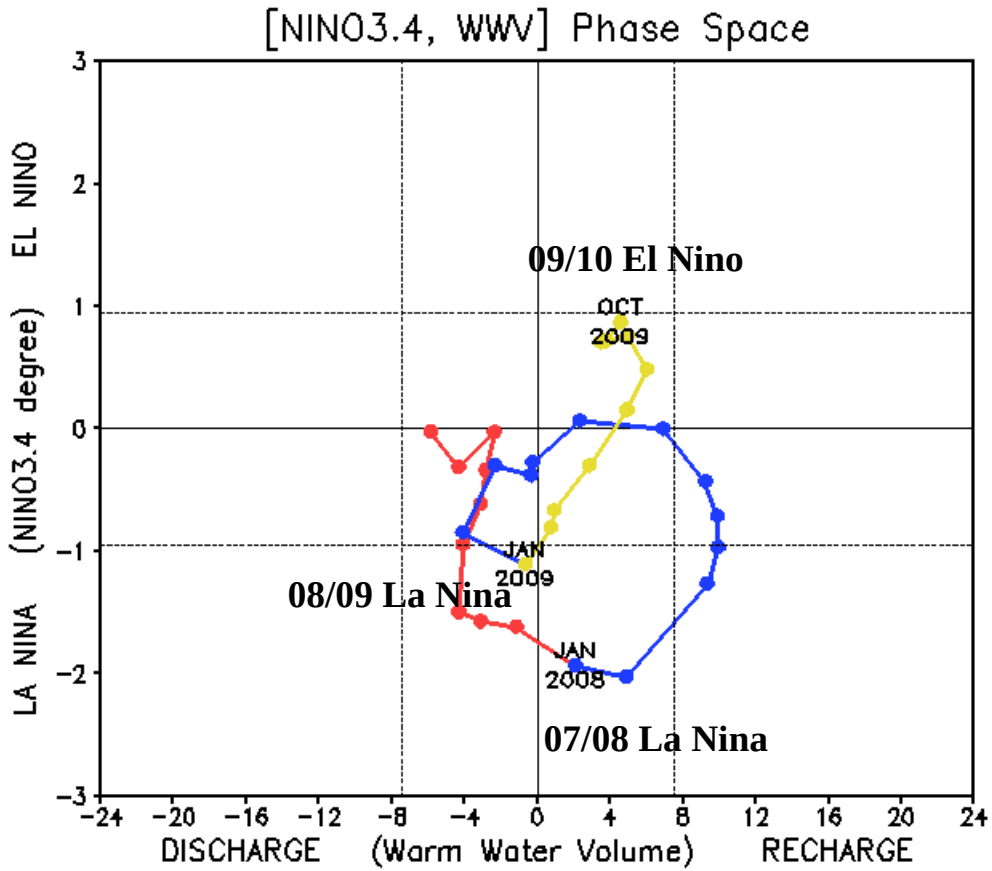
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

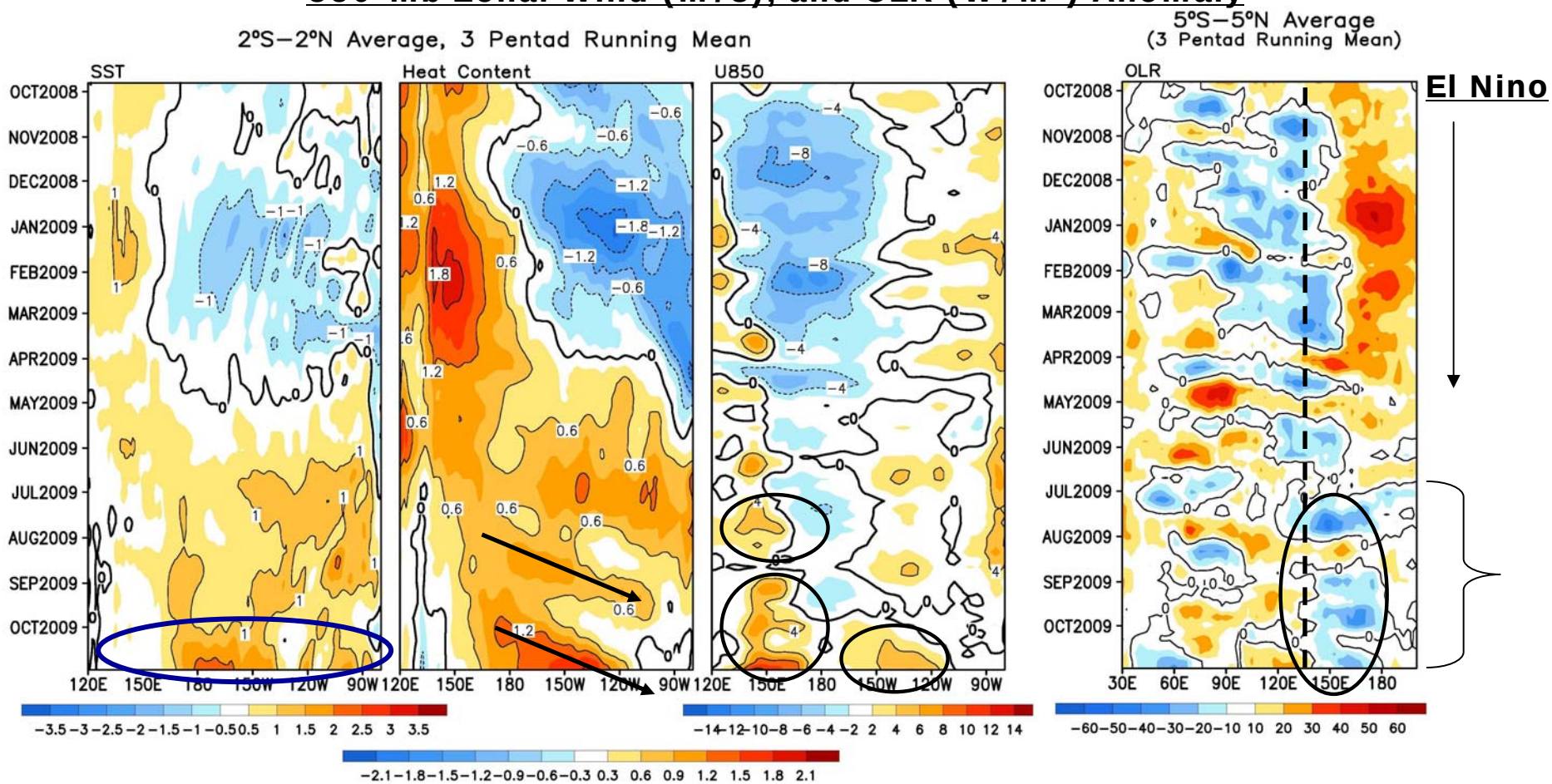
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



- NINO3.4 and WWV increased steadily during Jan-Jun, but remained largely persistent during Jul-Oct 09.
- The phase trajectory is inconsistent with the typical anti-clockwise rotation during El Nino events.

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.

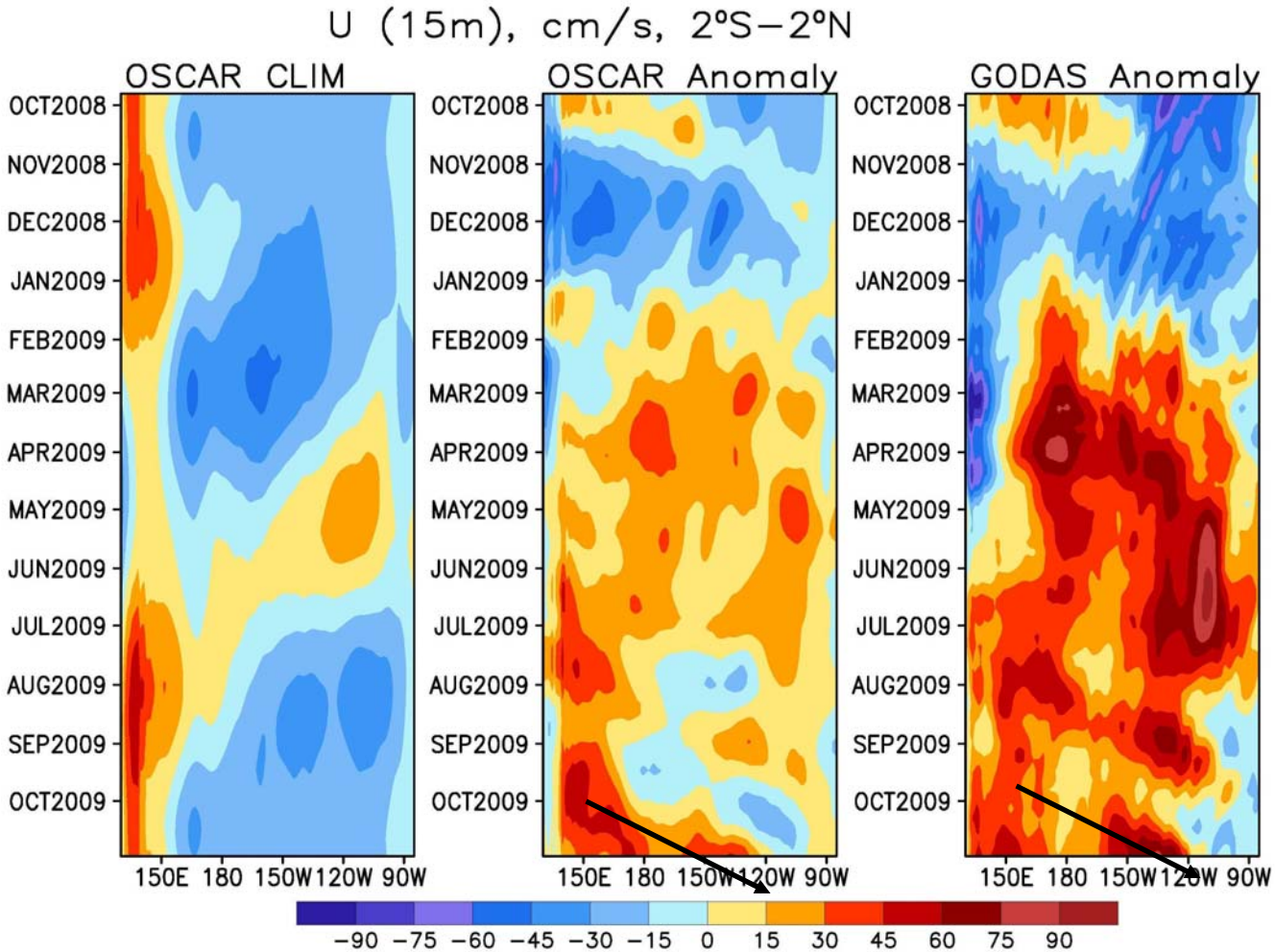
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²) Anomaly



- **SST was about 1-2°C above-normal in the east-central equatorial Pacific, and increased substantially during the past three weeks.**
- **Positive heat content anomalies (HCA) propagated eastward in Aug and Oct 09, in response to the westerly wind bursts occurred in Jul and Sep in the western tropical Pacific.**
- **Westerly wind anomalies in the eastern tropical Pacific in Oct 09 would likely push positive HCA further eastward.**

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.

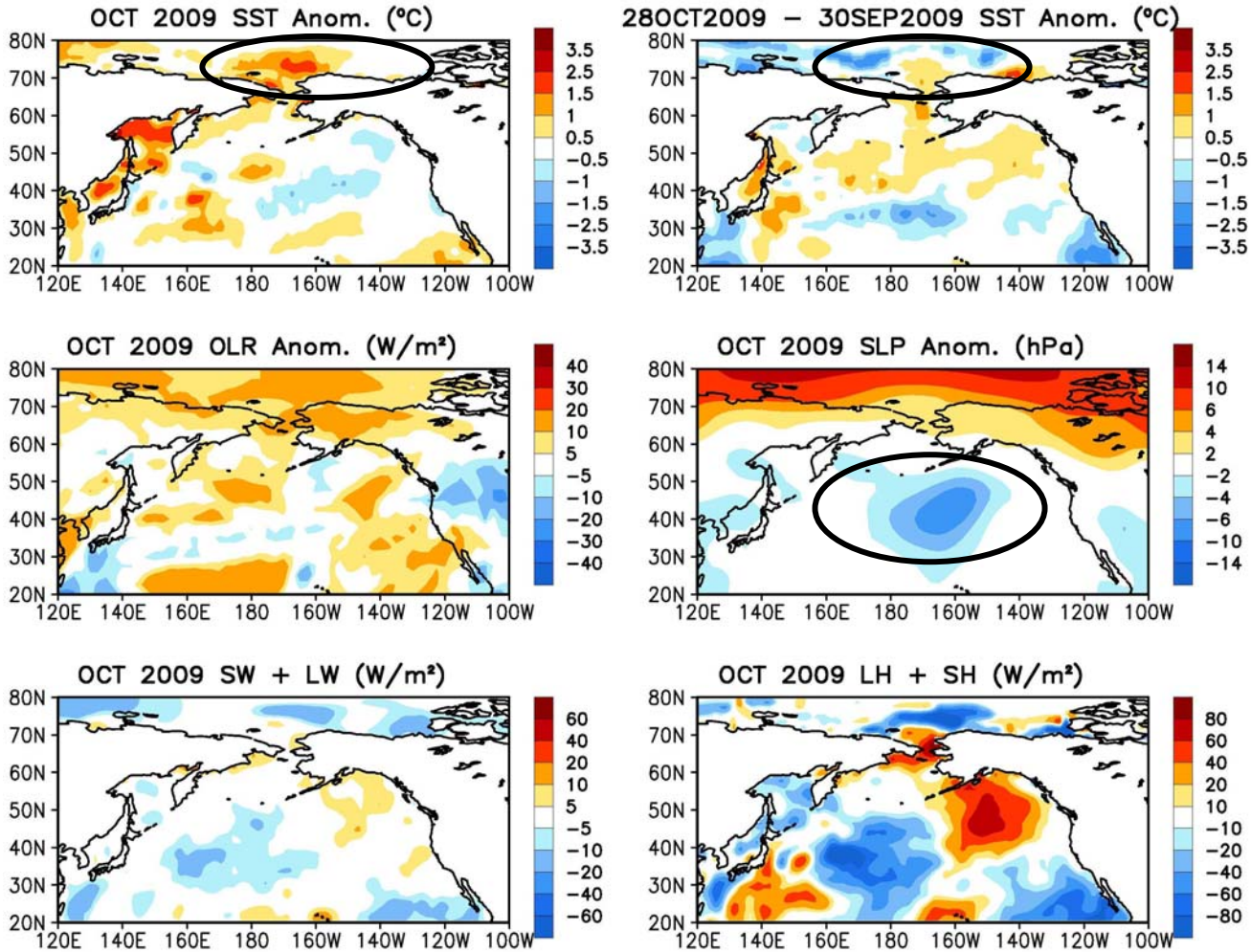
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- **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 surface zonal current anomaly strengthened in the west-central equatorial Pacific in Oct 09 in response to the downwelling Kelvin waves.**
- **Positive surface zonal current anomalies simulated by GODAS were too strong compared with those of the OSCAR currents in the central Pacific.**

North Pacific & Arctic Ocean

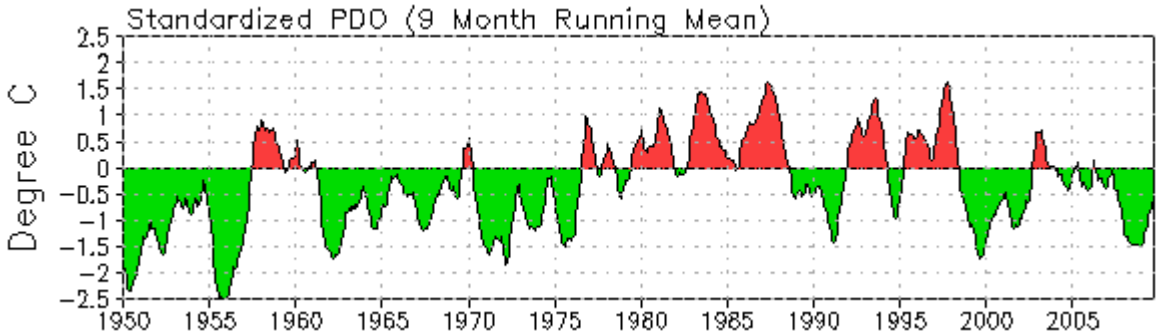
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

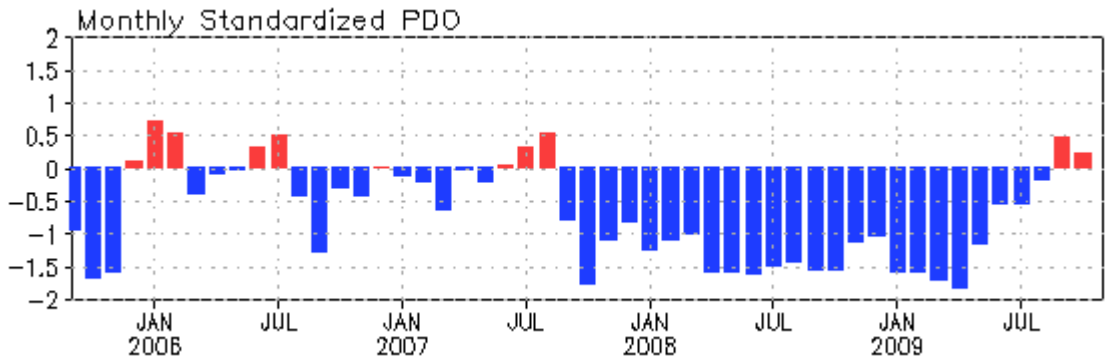


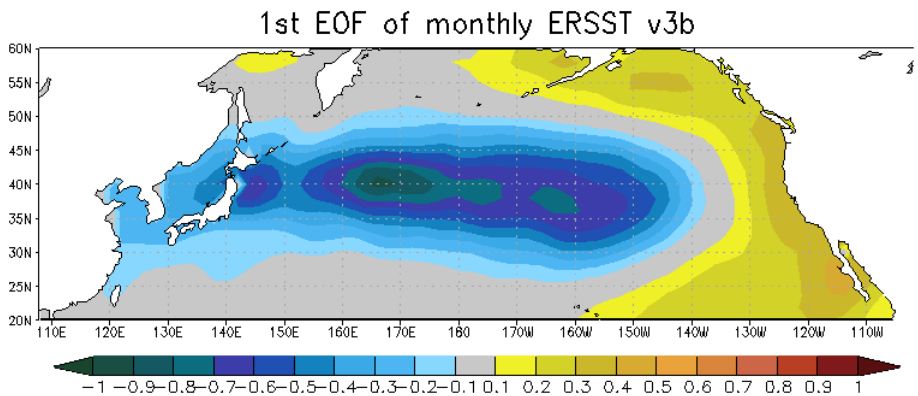
- **Positive SSTA decreased north of the Bering Strait.**
- **SSTA tendency in the North Pacific was partially consistent with net surface heat flux anomalies.**
- **Below-normal sea level pressure presented in the central North Pacific.**

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 was near-normal in Oct 09.**

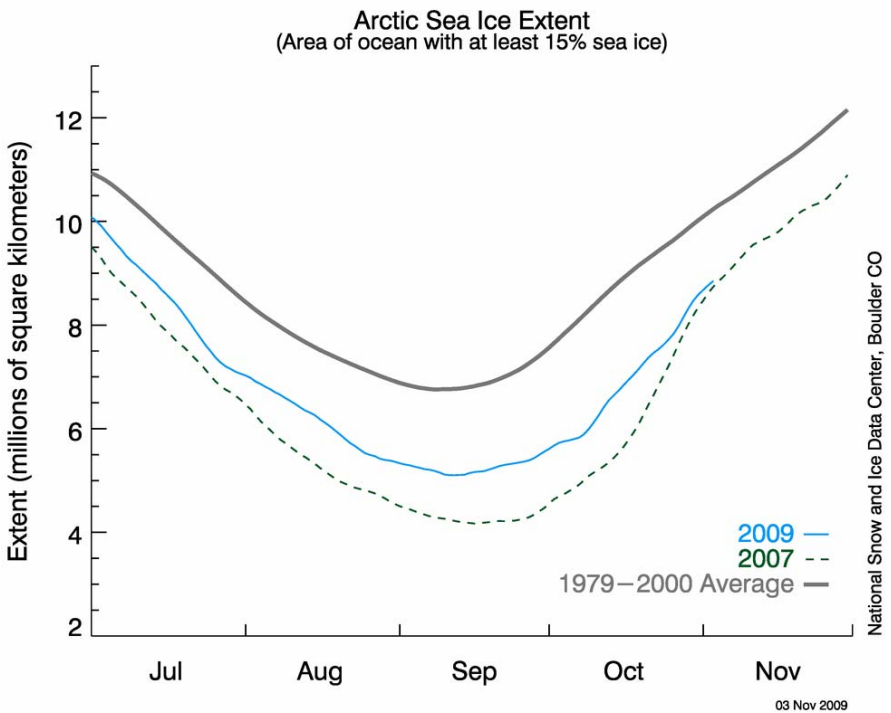
- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.**

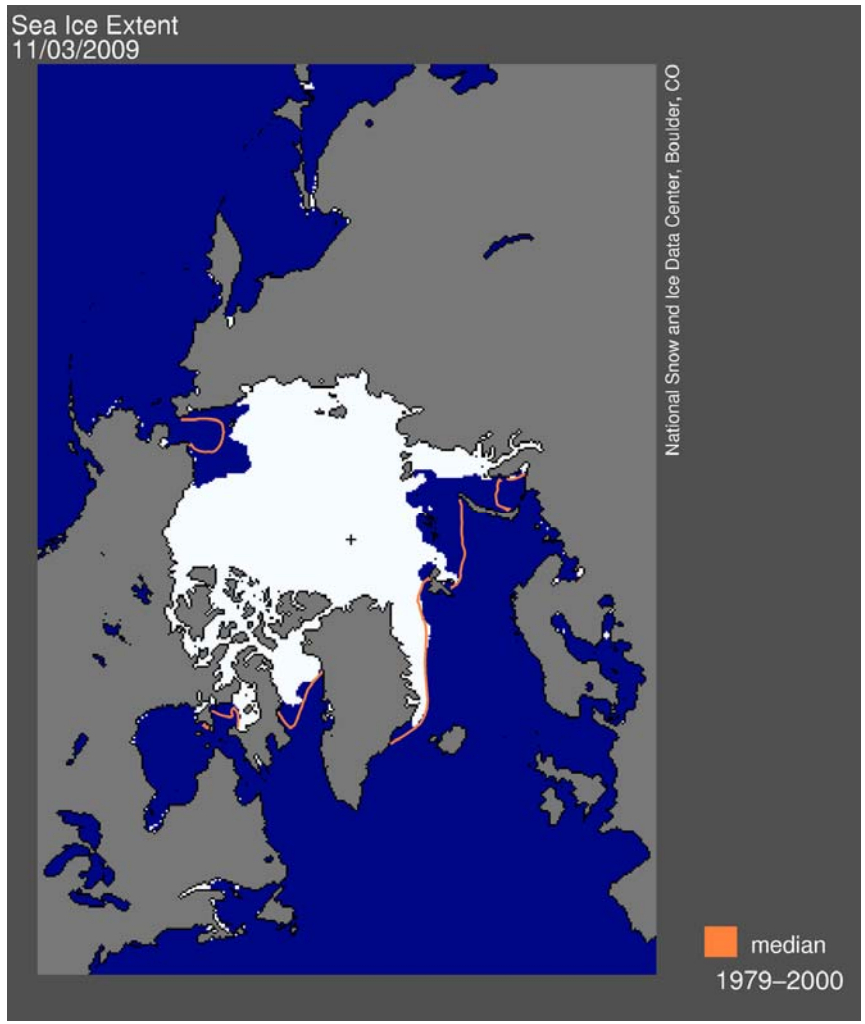
- **The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.**

Arctic Sea Ice

National Snow and Ice Data Center

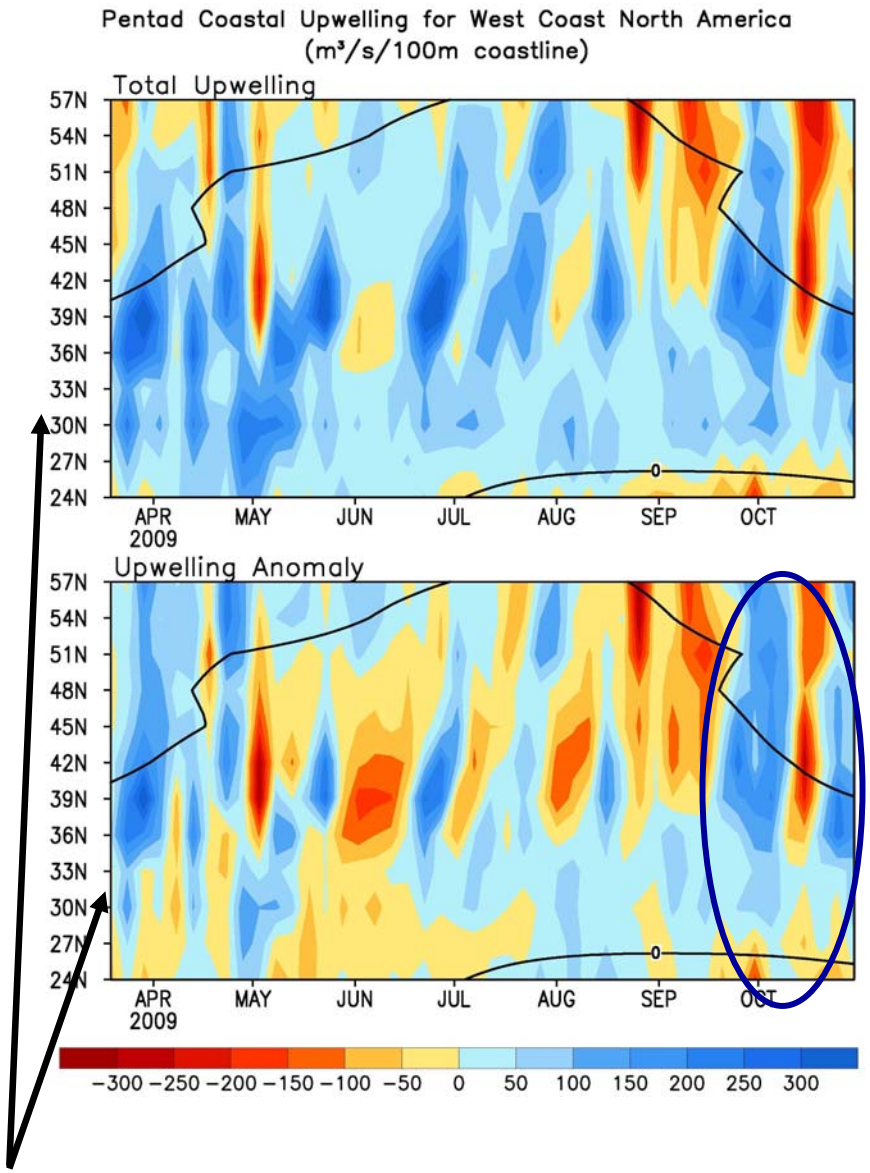
http://nsidc.org/arcticseaicenews/index.html

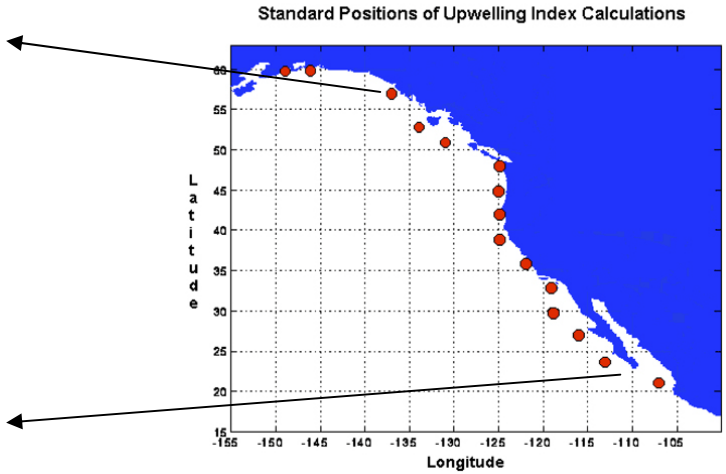




- **Sea ice extent continued to increase, but was near the historic low value by the end of Oct 09.**

North America Western Coastal Upwelling





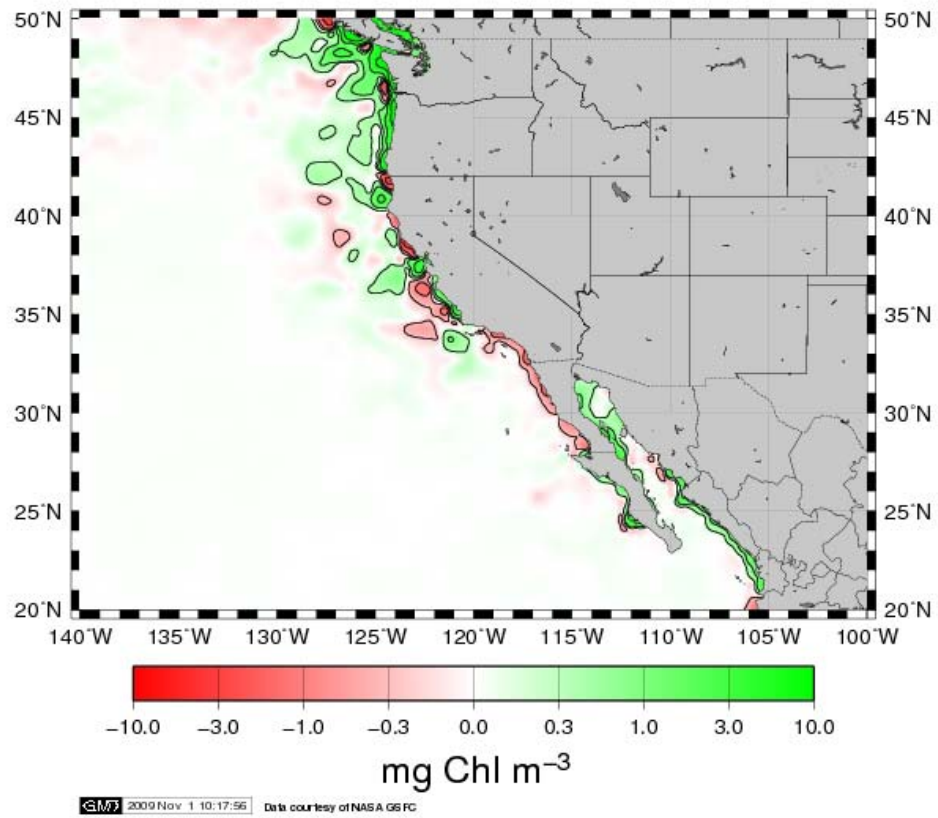
- **Large high frequency variability presented in upwelling in Oct 09.**

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

- **Area below (above) black line indicates climatological upwelling (downwelling) season.**
- **Climatologically upwelling season progresses from March to July along the west coast of North America from 36°N to 57°N.**

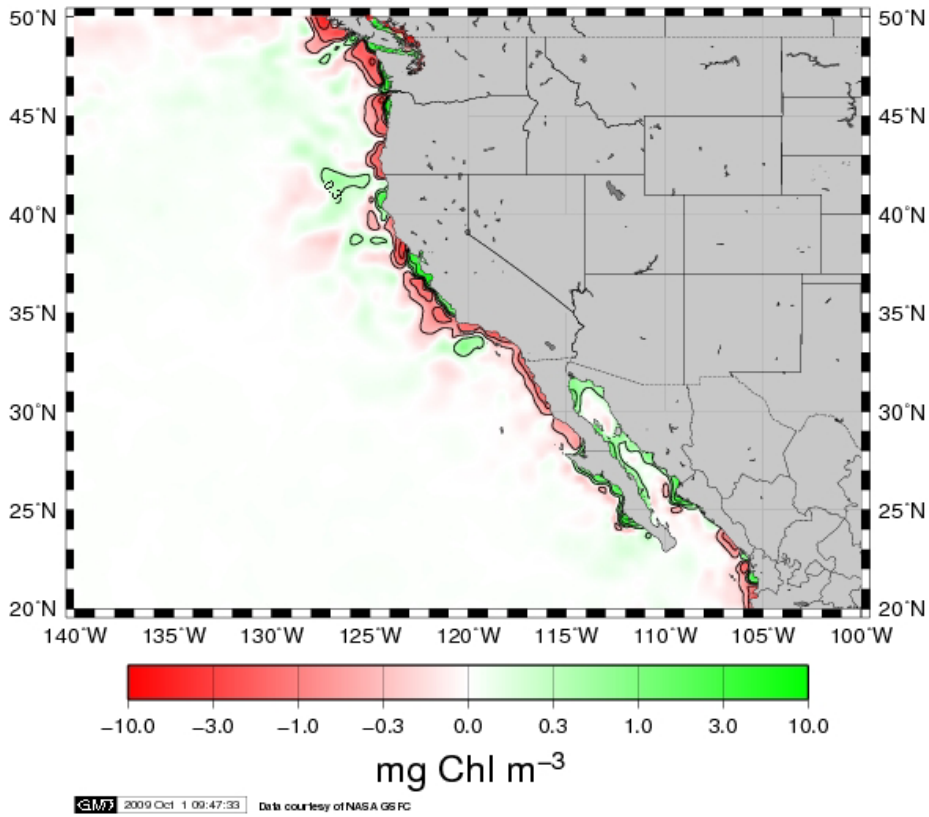
Monthly Chlorophyll Anomaly

MODIS Aqua Chlorophyll a Anomaly for October, 2009



- **Chlorophyll was above- (below-) normal north (south) of 40N in Oct 09, largely consistent with the upwelling.**

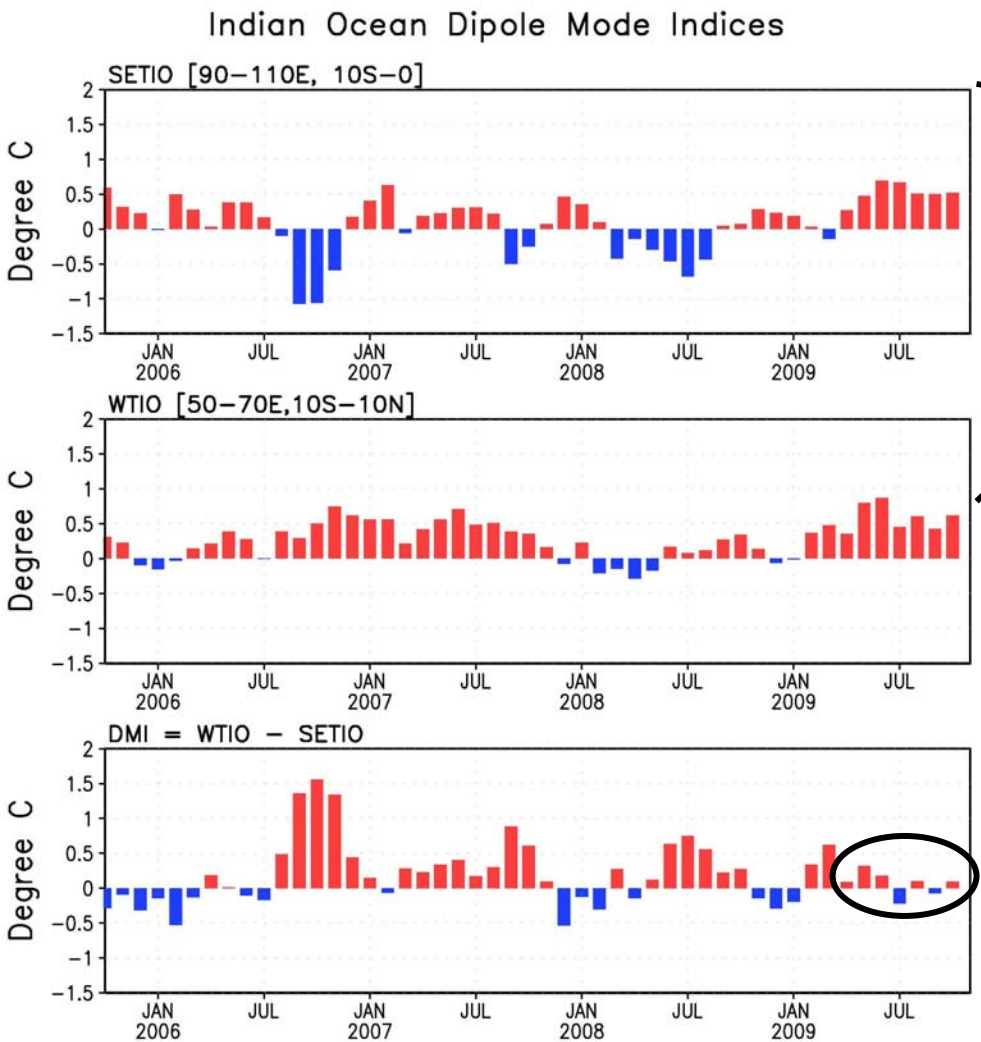
MODIS Aqua Chlorophyll a Anomaly for September, 2009

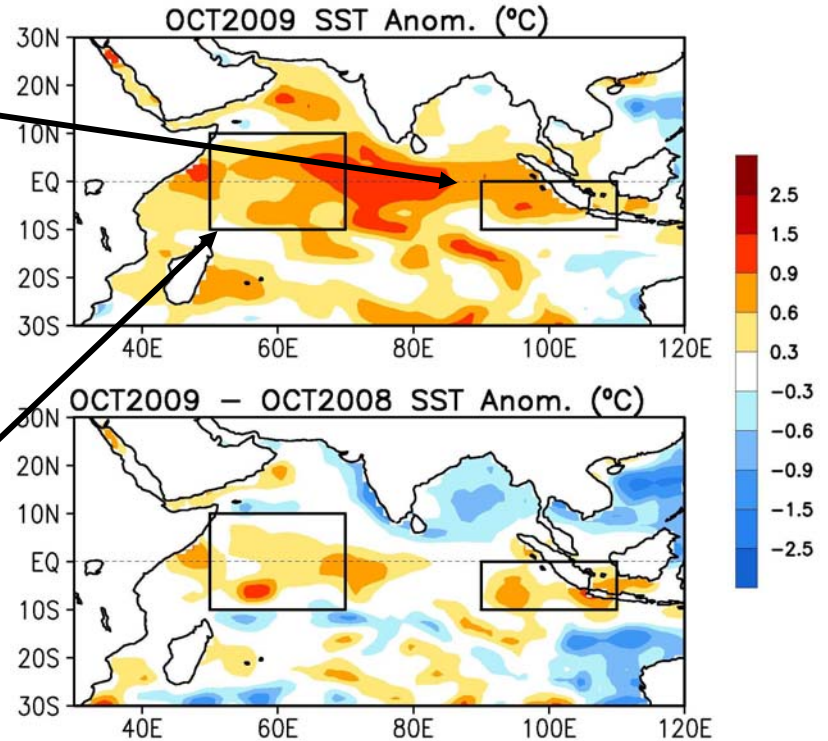


http://coastwatch.pfel.noaa.gov/FAST

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

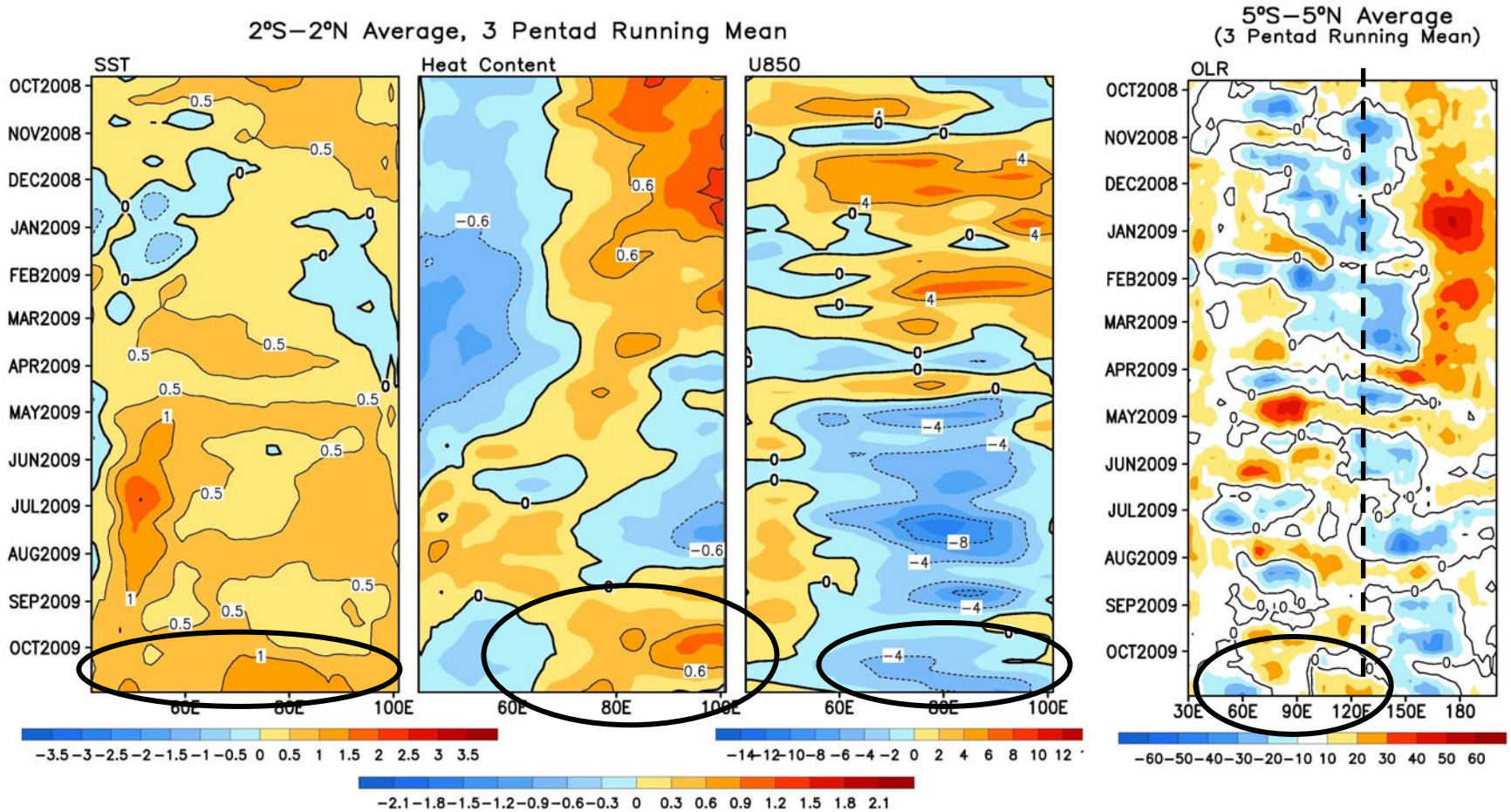




- **Both eastern (SETIO) and western (WTIO) pole SST have been persistently above-normal since April 09.**
- **DMI has been near-normal since March 09.**

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

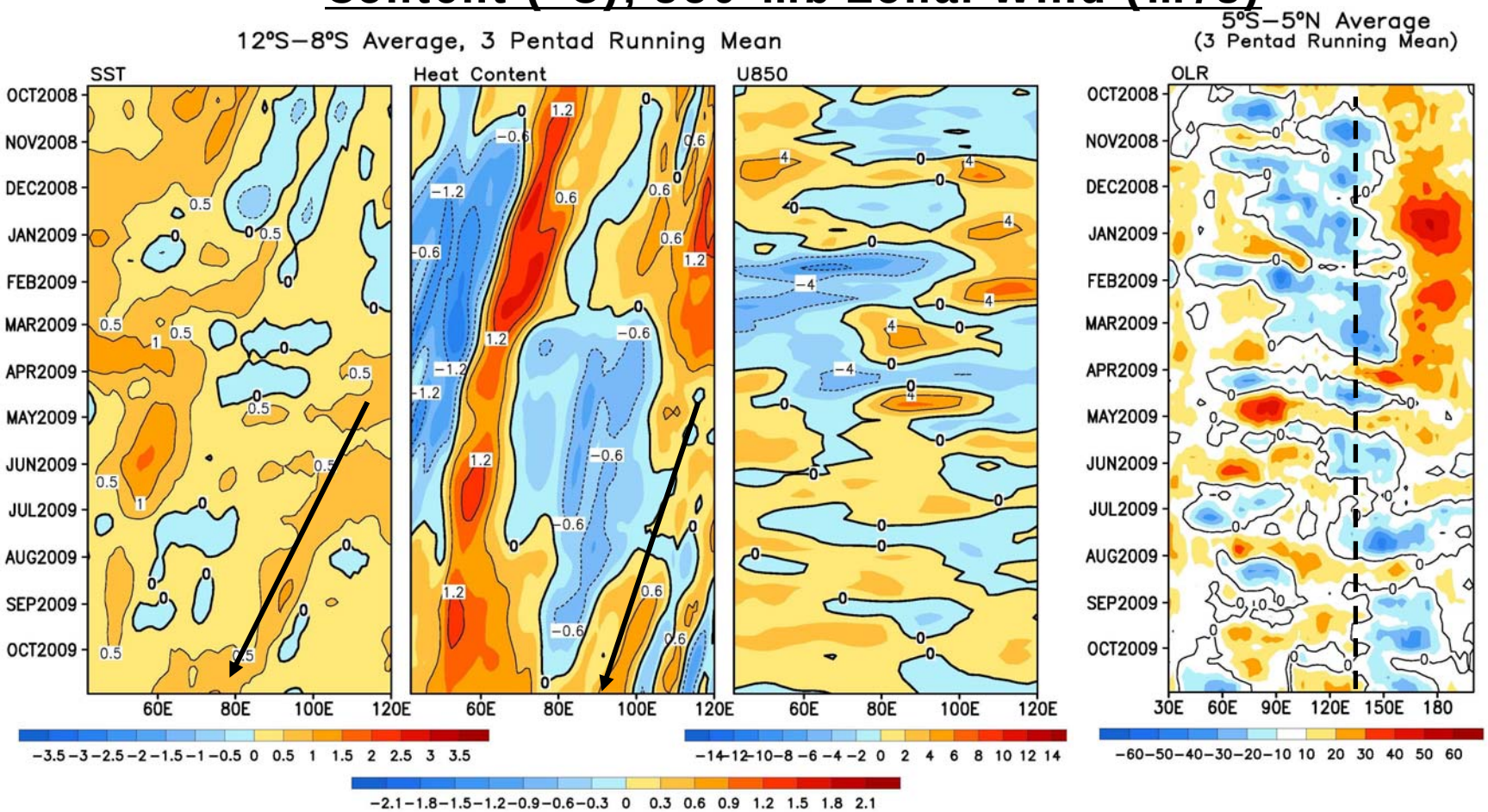
Recent Evolution of Equatorial Indian SST (ºC), 0-300m Heat Content (ºC), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies



- Easterly wind anomalies strengthened in the east-central tropical Indian Ocean in Oct 09, which was probably associated with the enhanced (suppressed) convection in the western (eastern) tropical Indian Ocean (slide 25).
- In response to the strengthened easterly wind anomalies, positive heat content anomaly in the far eastern tropical Indian Ocean weakened since mid-Oct 09..
- SST increased substantially in the tropical Indian Ocean in Oct 09.

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.

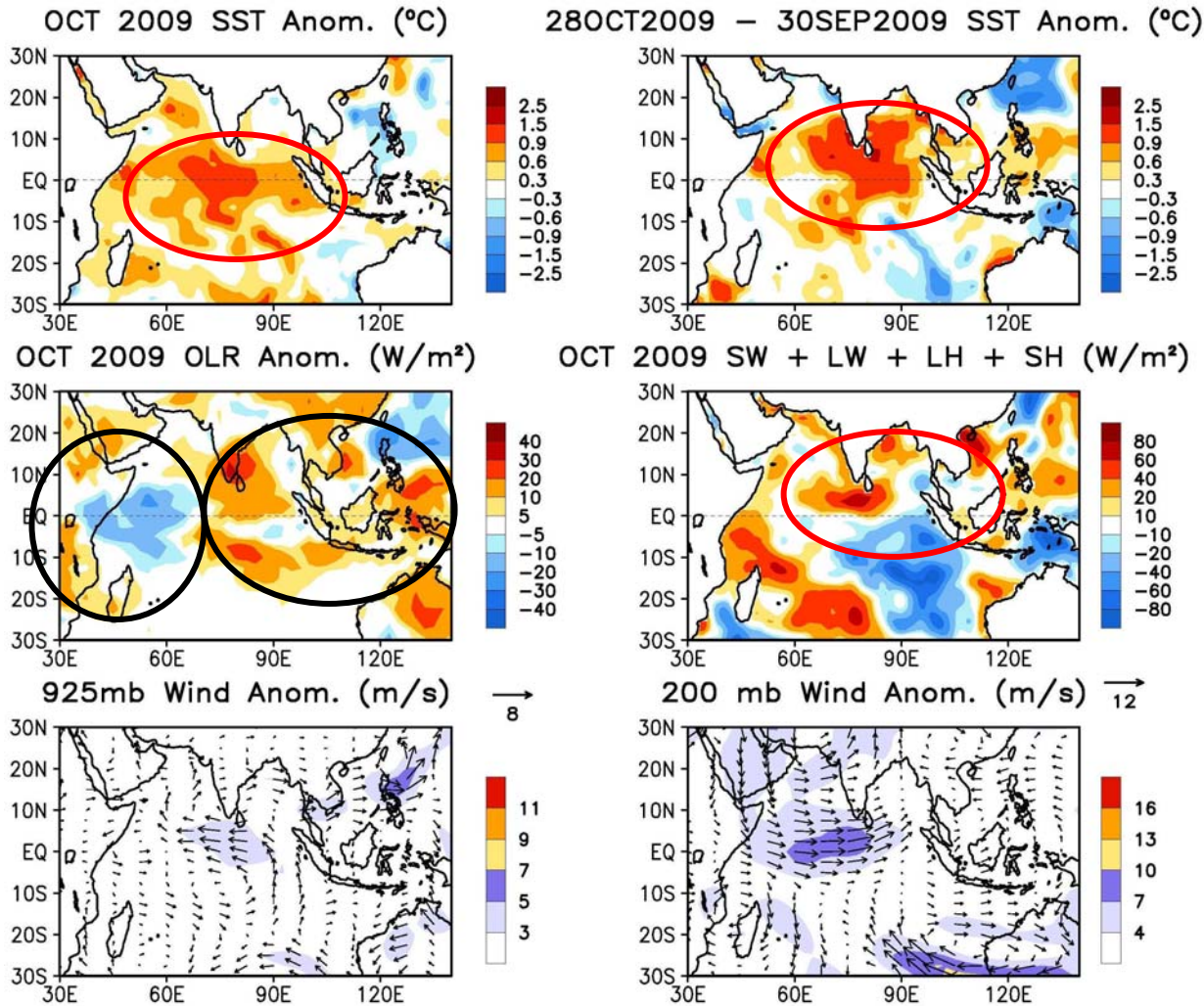
Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)



- **Westward propagation of positive HCA and SSTA near 10°S since Apr 09.**

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.

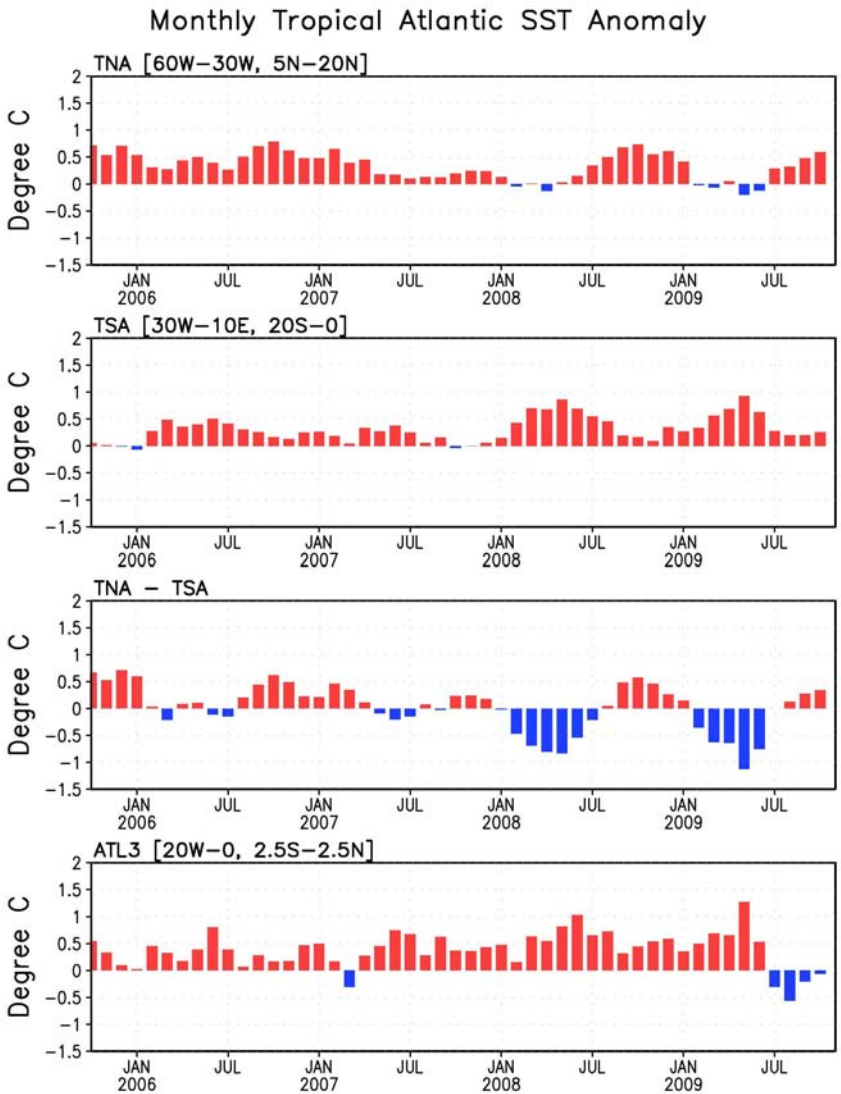


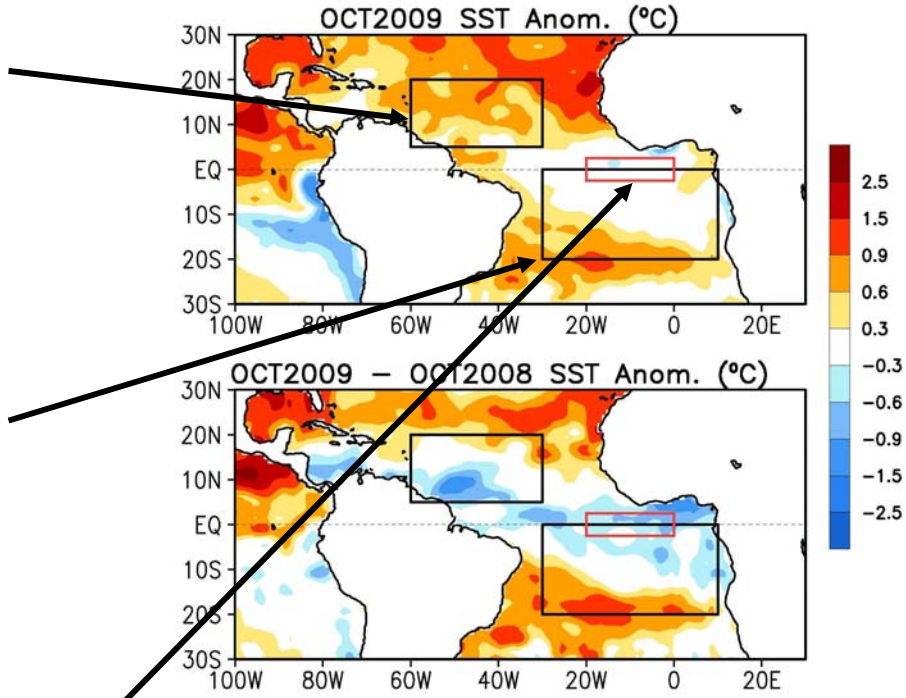
- Large positive SSTA presented in the tropical Indian Ocean.
- Net surface heat flux anomalies partially contributed to positive SSTA tendency in the northern Indian Ocean.
- Convection was suppressed (enhanced) in the eastern tropical Indian Ocean and over the Maritime Continents (in the western tropical Indian Ocean).
- Consistent with the convection pattern were low-level (upper-level) easterly (westerly) wind anomalies.

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

Tropical Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

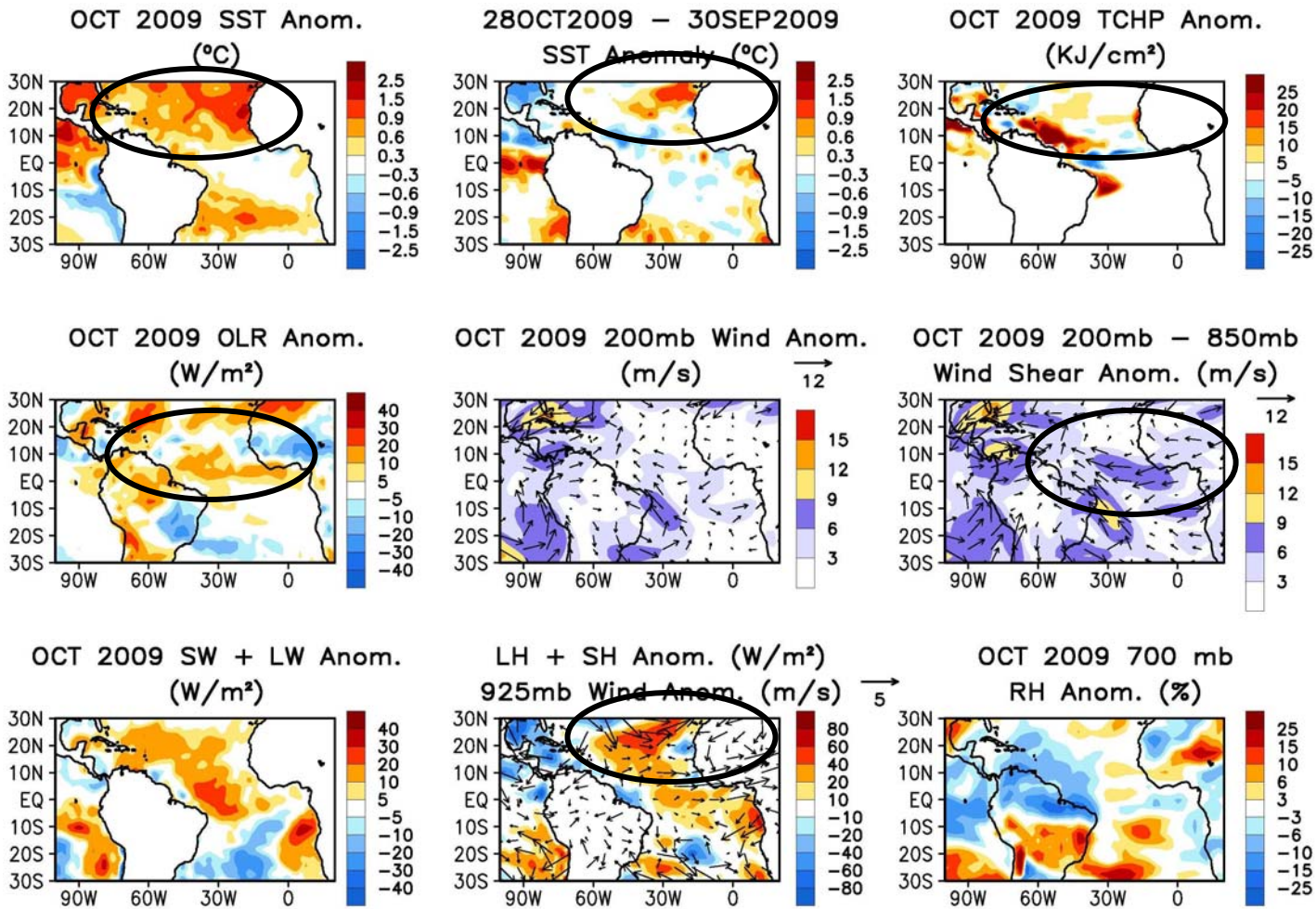




- **Tropical North Atlantic SST (TNA) was above-normal in July-October.**
- **Tropical South Atlantic SST (TSA) remained weakly above-normal.**
- **Meridional Gradient Mode (TNA-TSA) became above-normal since Aug 09.**
- **Negative ATL3 SST weakened in Oct 09.**

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 SSTA and tropical cyclone heat potential (TCHP) anomaly presented in the tropical North Atlantic.**
- **Positive SSTA tendency was consistent with positive LH+SH heat flux anomaly, induced from westerly wind anomalies.**
- **Convection was suppressed (enhanced) in the tropical Atlantic and central America (over the Sahara).**
- **Vertical wind shears 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 below-normal (next slide).

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

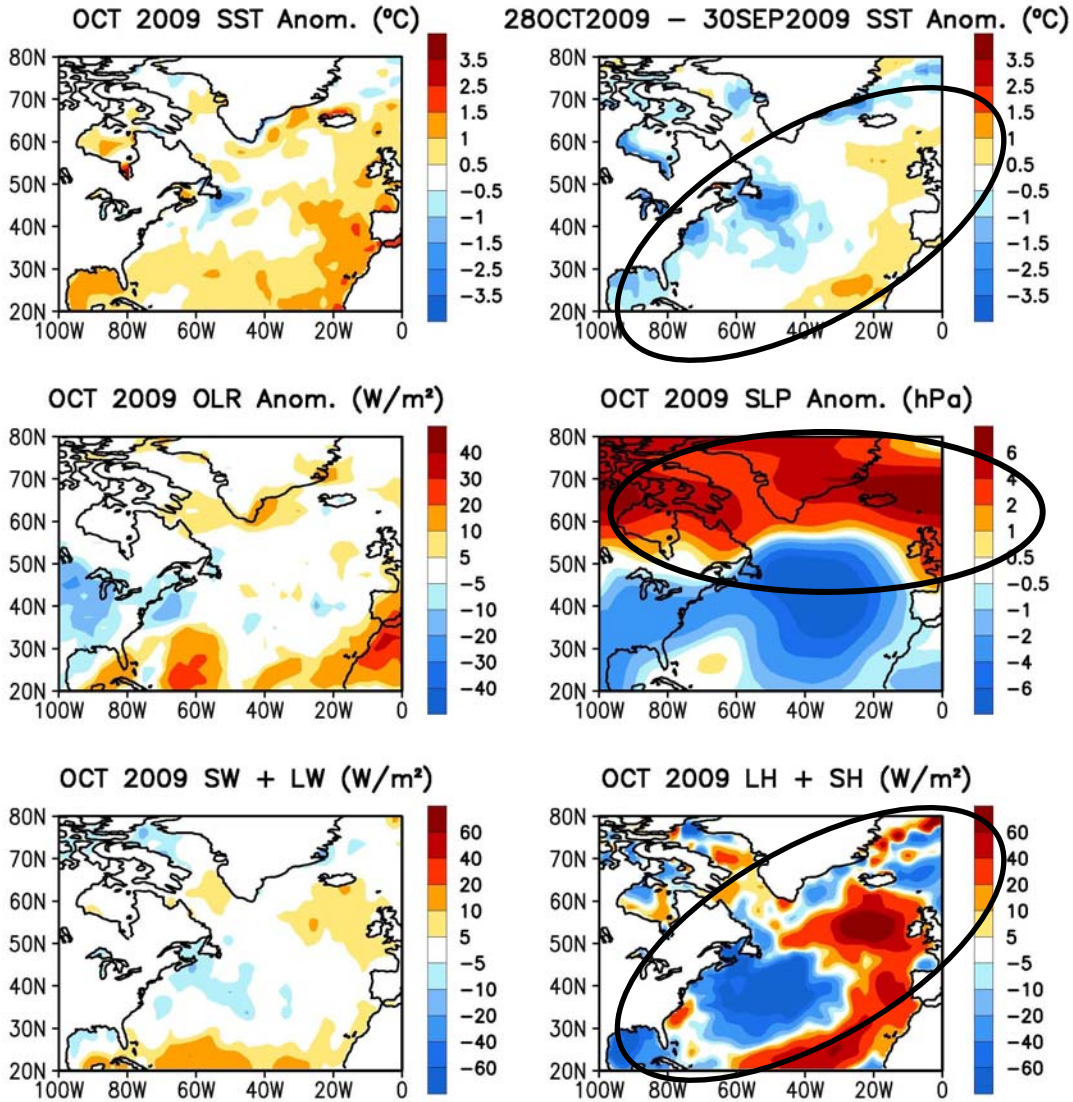
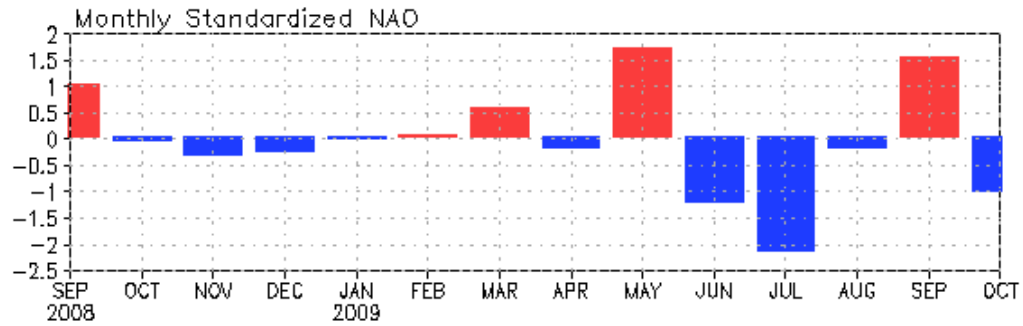
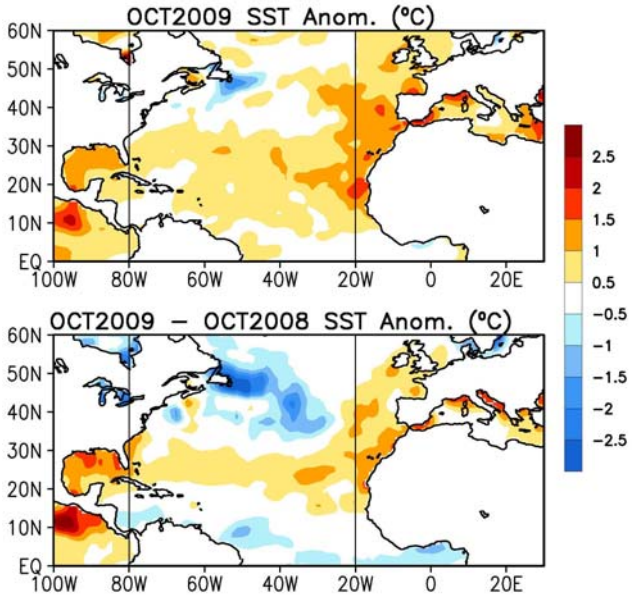
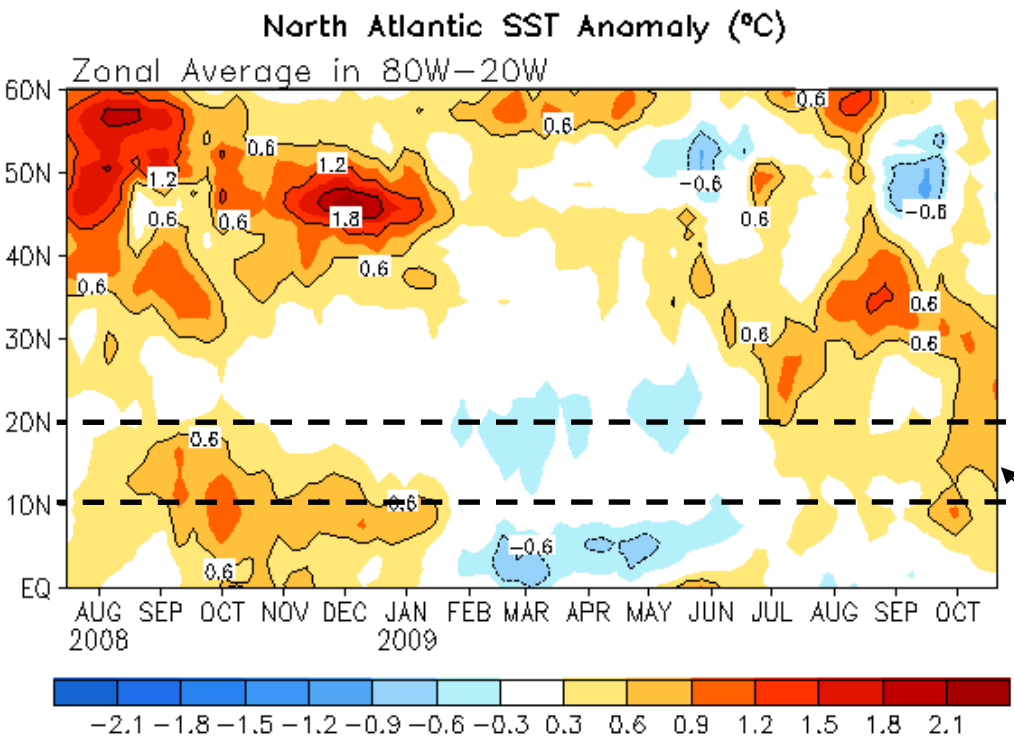


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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



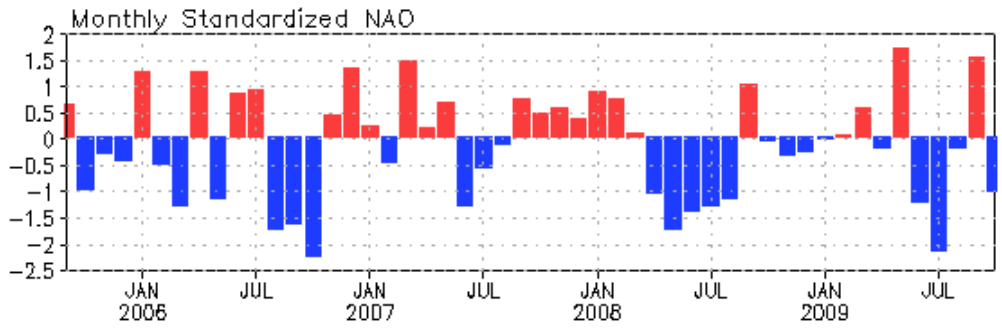


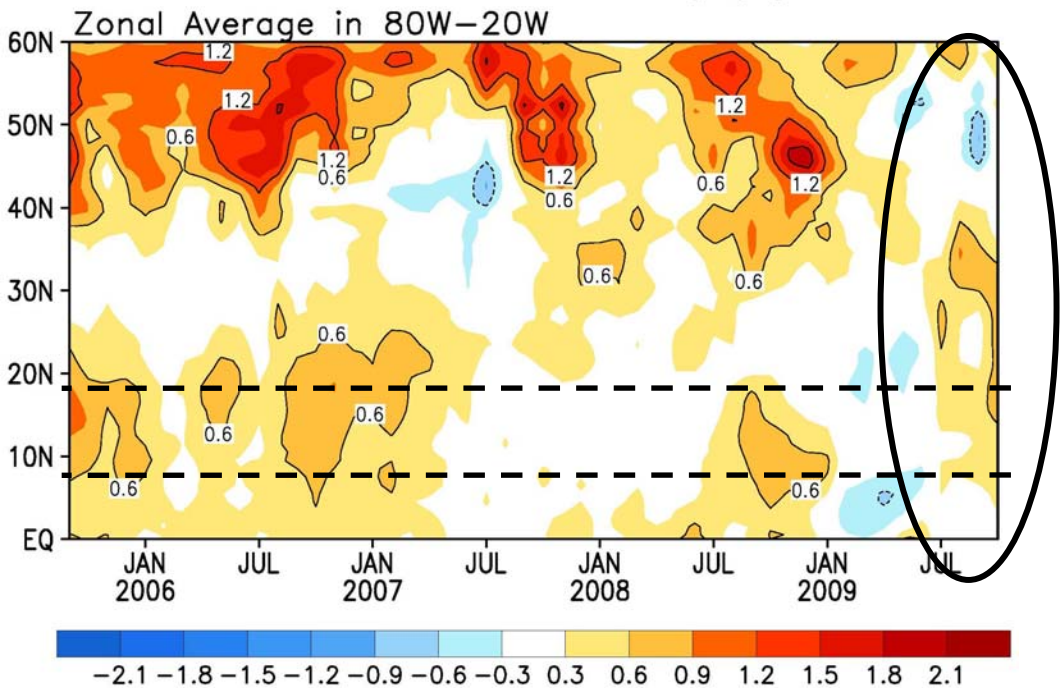


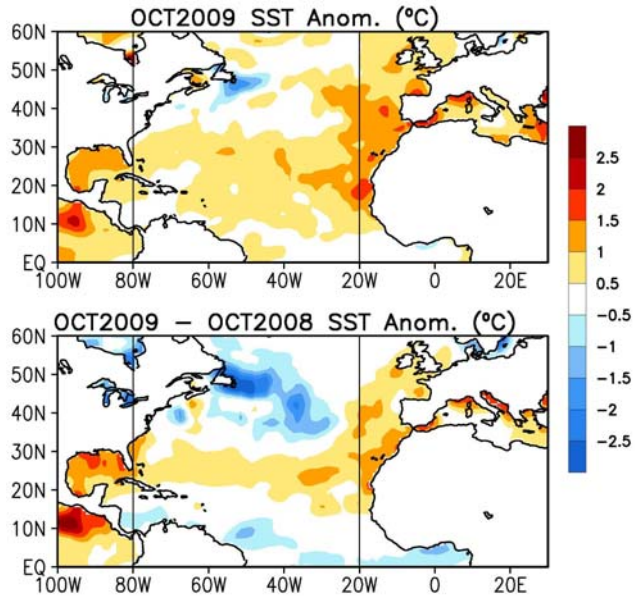
- **High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).**
- **NAO became below-normal in Oct 09.**
- **Positive SSTA in the Hurricane Main Development Region increased in Oct 09.**

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







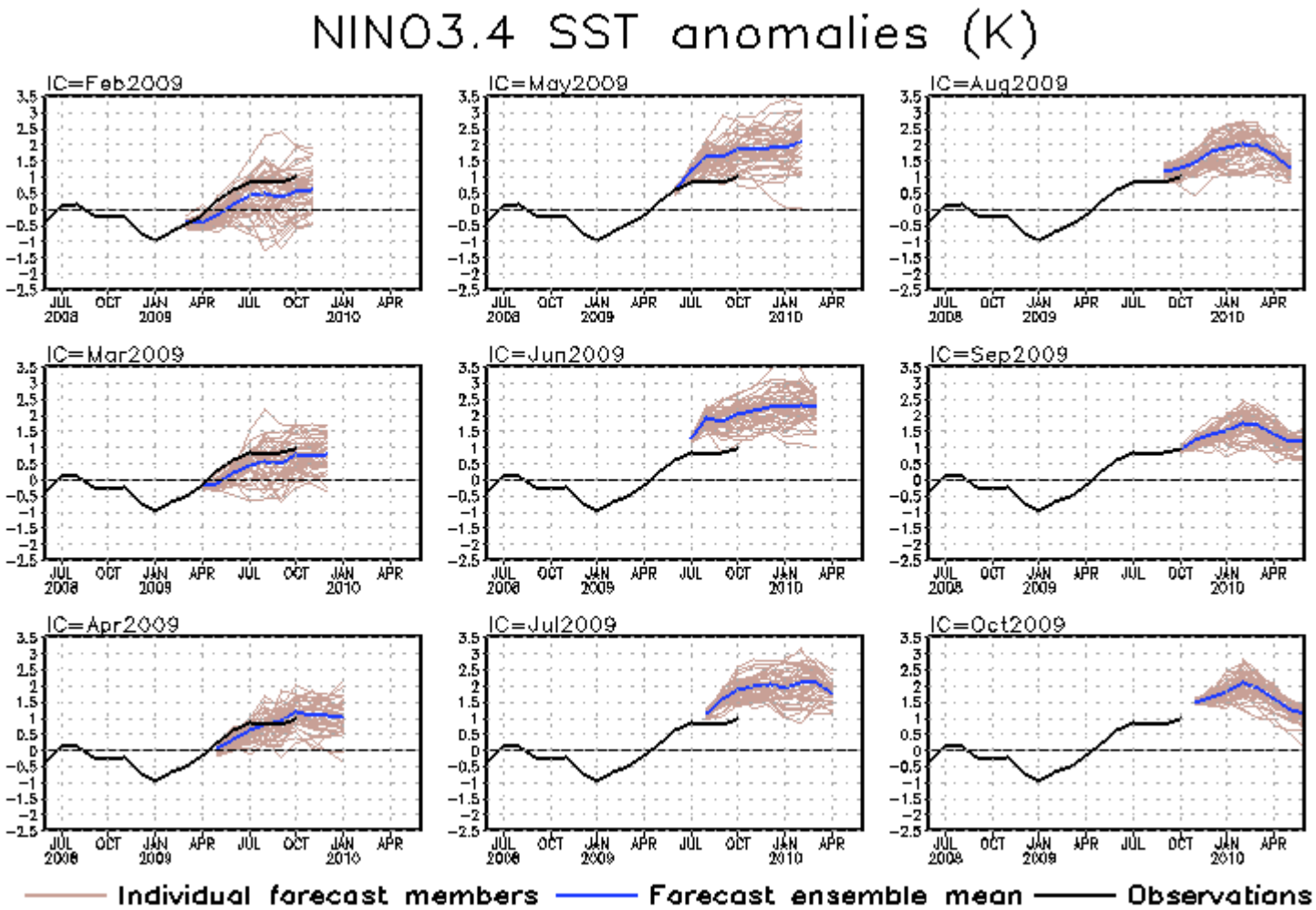
- **Mid-latitude North Atlantic SSTs cooled down and became slightly below-normal in spring and summer.**

- **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

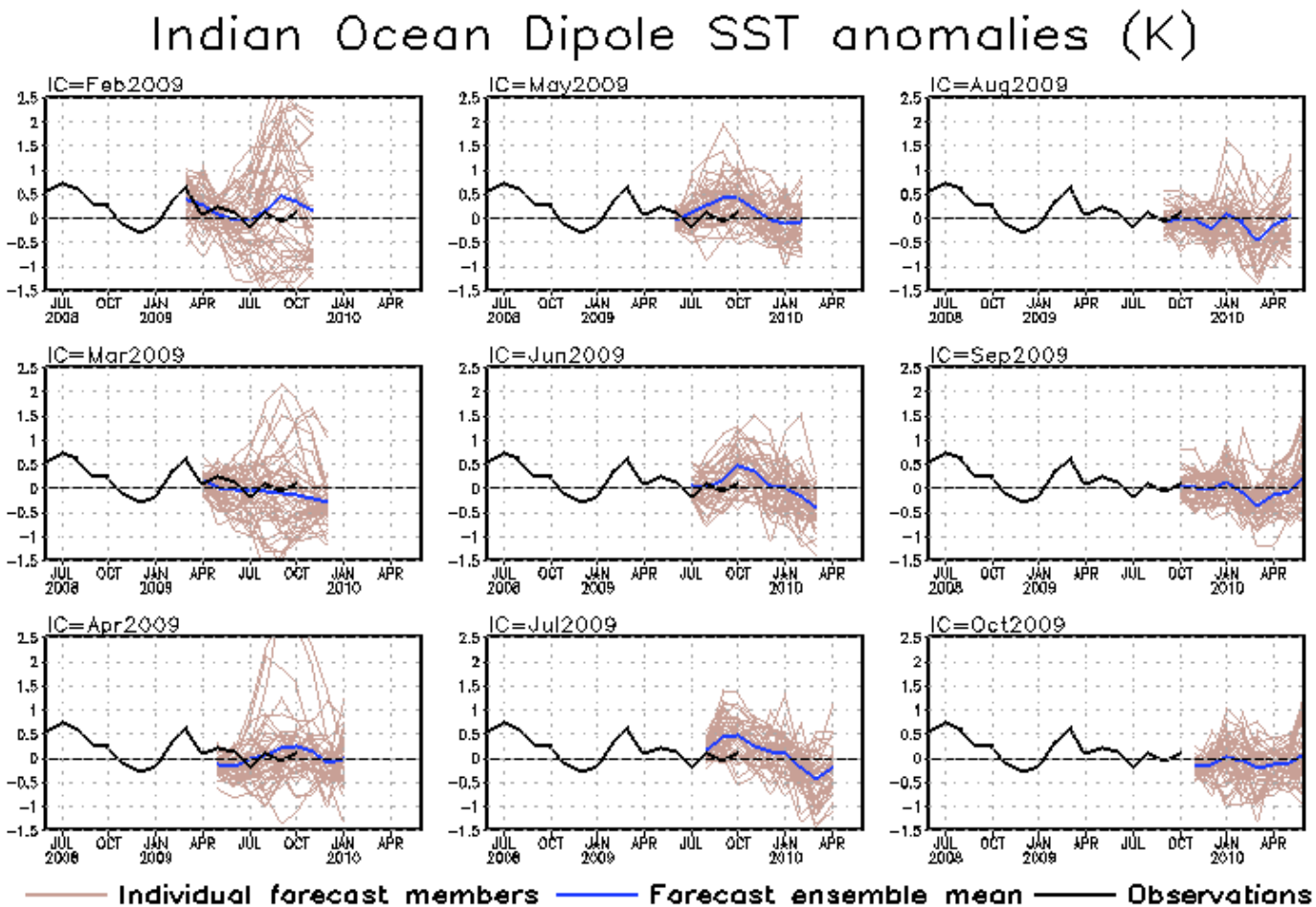


- Nice forecasts from Mar-Apr I.C.
- Too warm forecasts from May-Jul I.C..

- Latest forecasts suggested a strong El Nino (NINO 3.4 > 1.5C) 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]

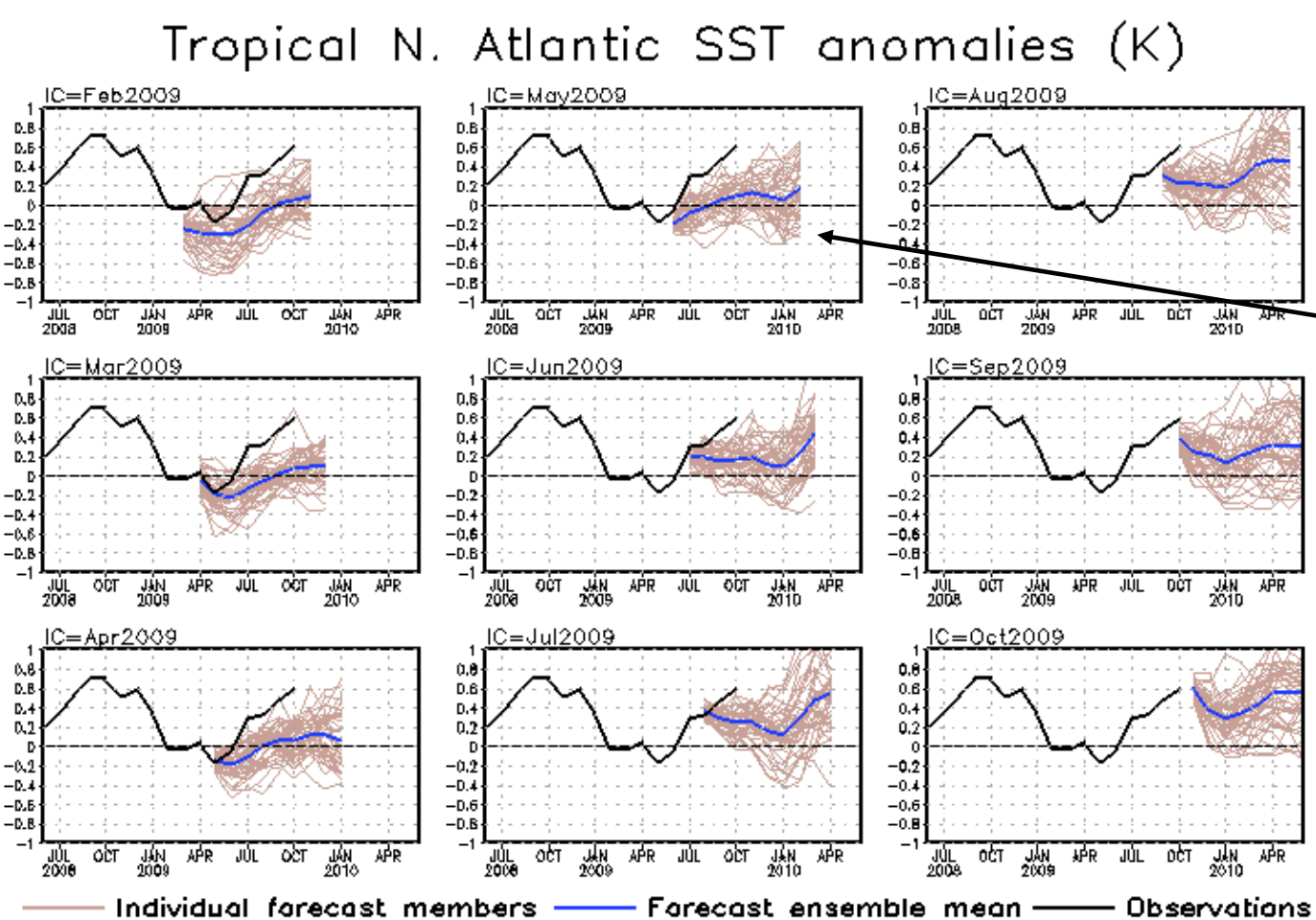
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

- Nice forecasts from Feb-Apr 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



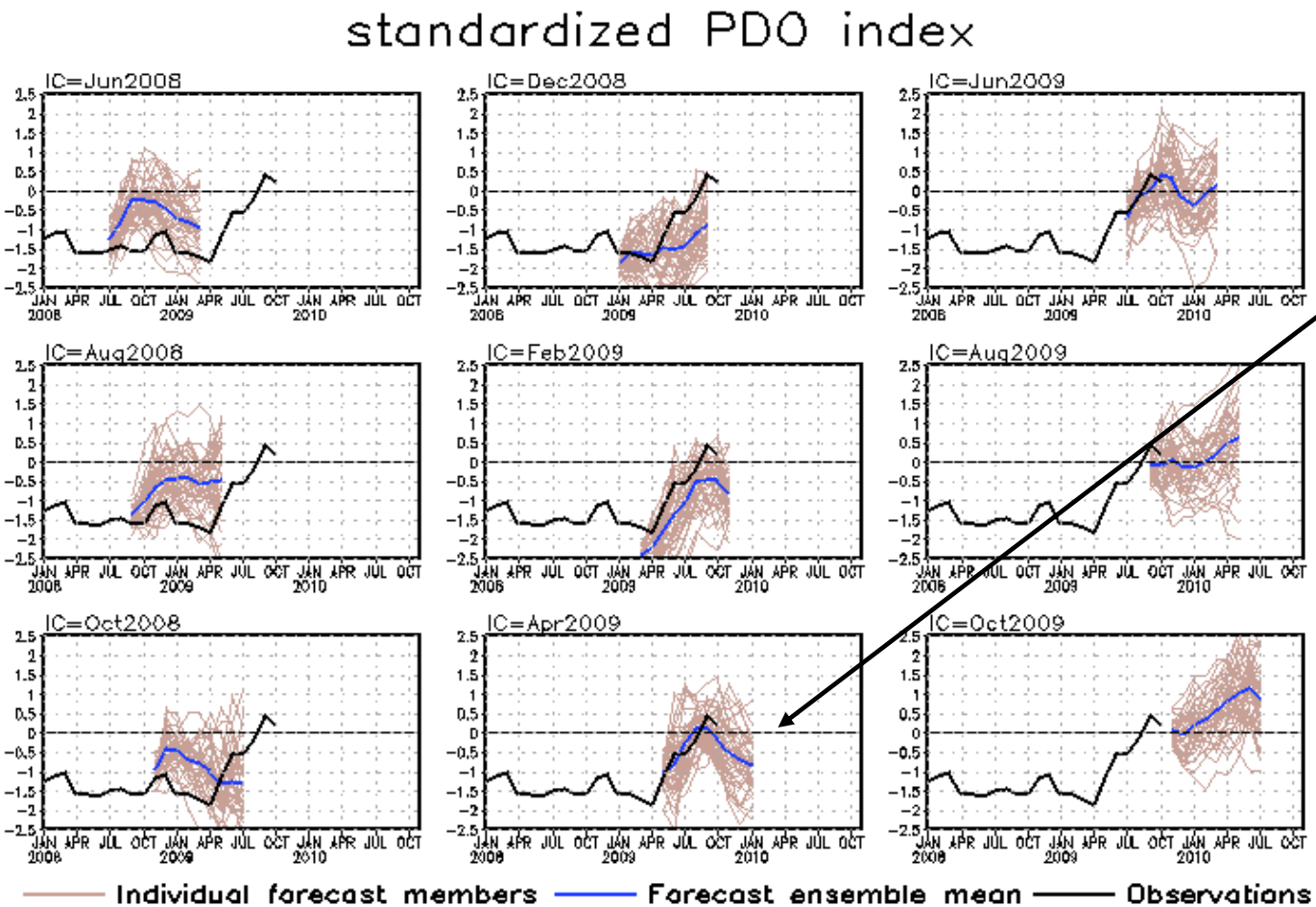
TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- Missed the warming trend in early summer from Jan-May I.C.
- Damped the initial positive SSTA from Jun-Sep 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 and then transition into a positive PDO in summer 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 ºC), that established in Jun 09, and persisted during Jul-Sep 09, and strengthened in Oct 09, were expected to reach a moderate strength during the Northern Hemisphere winter 2009-2010.
  - Westerly wind bursts were active in Jul, Sep, Oct 09, contributing to the sustaining and strengthening of the 2009/10 El Niño.
  - PDO was near-normal in Sep-Oct 2009 after a 2 year negative PDO phase.
  - Upwelling along the west coast of North America was mostly above-normal in Oct 09.
- **Indian Ocean**
  - Easterly wind anomalies strengthened in the east-central tropical Indian Ocean in Oct 09.
  - Positive SSTA increased substantially across the tropical Indian Ocean in Oct 09, and Dipole Mode Index has been near-normal since Mar 09.
- **Atlantic Ocean**
  - Above-normal SST and tropical cyclone heat potential (TCHP) presented in the tropical North Atlantic.
  - Convection was suppressed in the tropical Atlantic.
  - Vertical wind shears were 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
- NDBC TAO data (http://tao.noaa.gov)
- 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!