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)

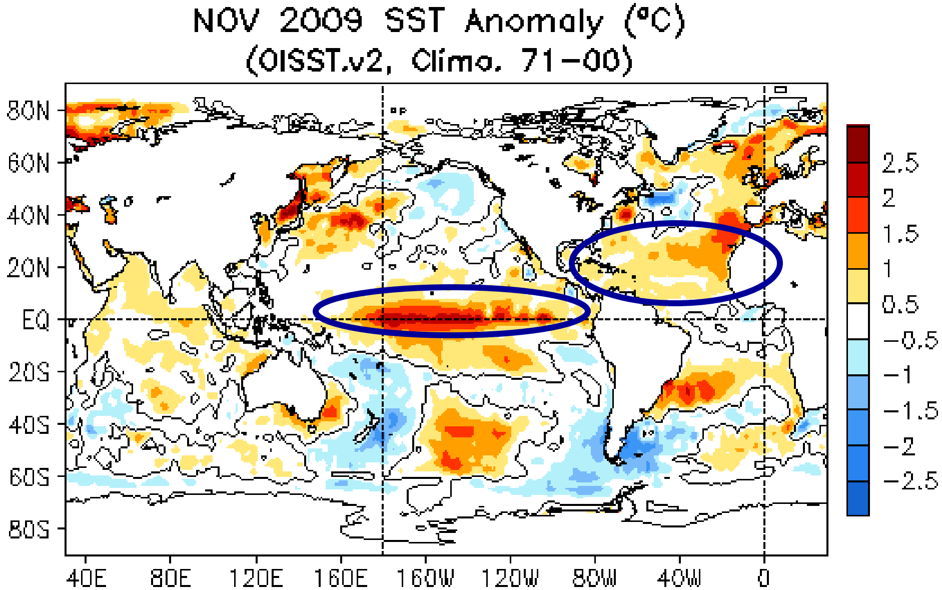
Outline

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

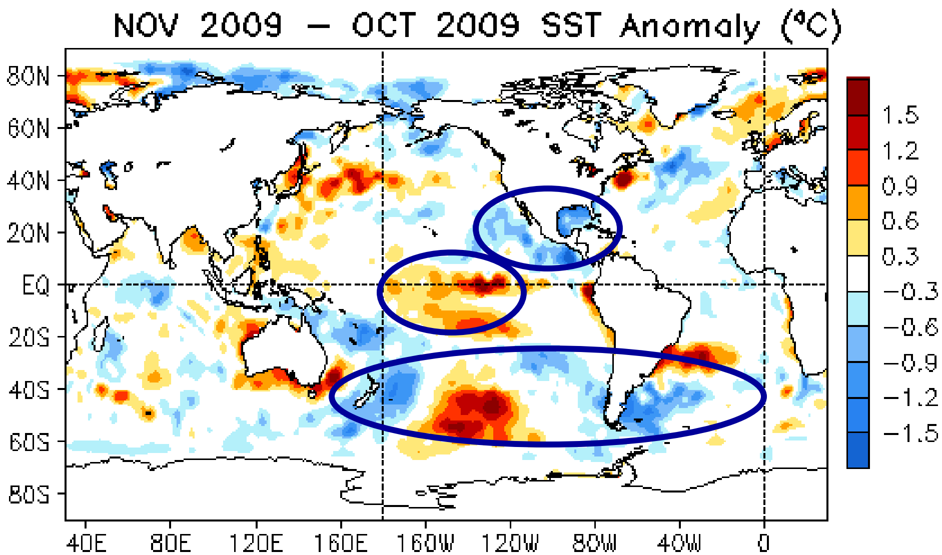
Overview

- **Pacific Ocean**
  - El Niño conditions (NINO 3.4 > 0.5 °C), which established in Jun 09, persisted during Jul-Oct 09, and strengthened substantially in Nov 09, are expected to reach a moderate-to-strong strength during the Northern Hemisphere winter 2009-2010;
  - Westerly wind bursts events, active in Jul, Sep, Oct 09, contributed to the maintenance and strengthening of the 2009/10 El Niño;
  - PDO was weakly above-normal in Sep-Oct 2009, but changed to below-normal in Nov 09;
  - Upwelling along the west coast of North America was mostly above-normal in Nov 09.
- **Indian Ocean**
  - Westerly wind anomalies were present in the western tropical Indian Ocean in Nov 09, probably associated with the Madden-Julian Oscillation activity;
  - Positive SSTA decreased substantially in the west-central tropical Indian Ocean in Nov 09, and Dipole Mode Index has been near-normal since Mar 09.
- **Atlantic Ocean**
  - SST and tropical cyclone heat potential (TCHP) were above normal in the tropical North Atlantic during the Atlantic Hurricane Season;
  - Convection was mostly suppressed in the tropical Atlantic;
  - Vertical wind shear was mostly above-normal over the Caribbean Sea.

Global SST Anomaly (^{0}C) and Anomaly Tendency



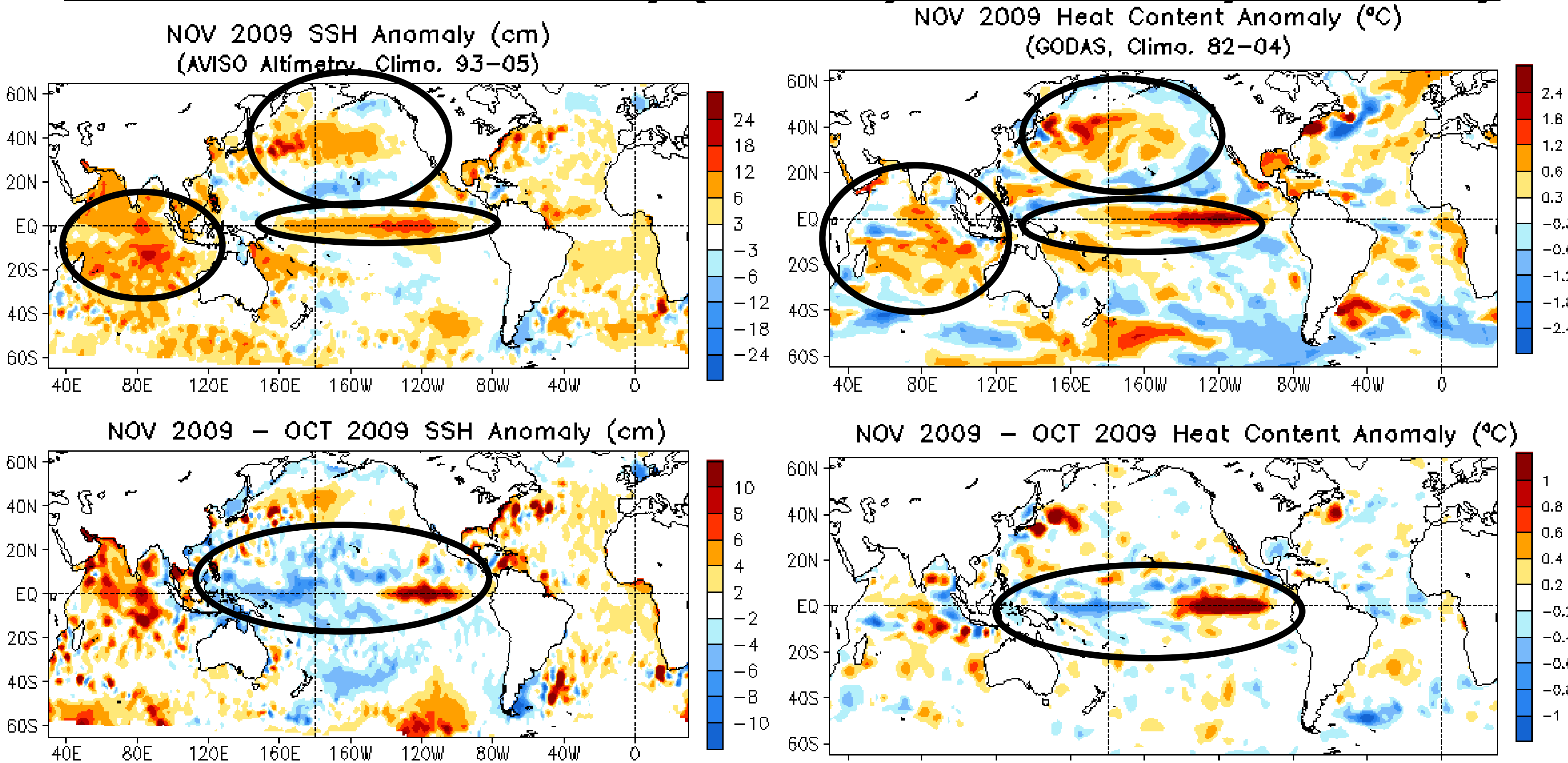
- El Nino condition (NINO 3.4 > 0.5°C) strengthened in the tropical Pacific;
- PDO was below-normal (slide 20);
- SST was above-normal in the tropical North Atlantic.



- SST increased in the central equatorial Pacific;
- SST decreased in the north-eastern Pacific and Gulf of Mexico;
- Large SST changes in the South Pacific and South 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.

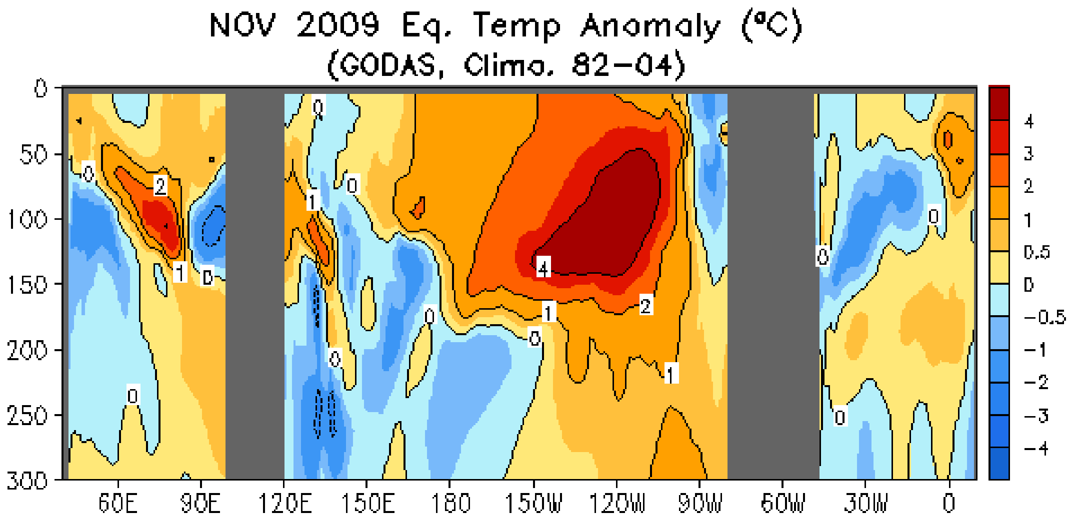
Global SSH/HC Anomaly (cm/°C) and Anomaly Tendency



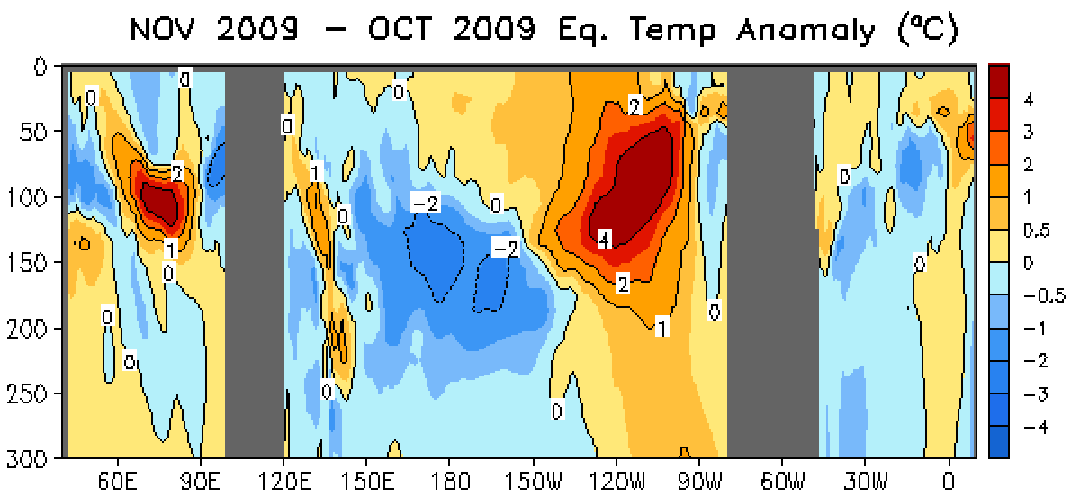
- Negative PDO-like pattern in SSHA and HCA in the North Pacific persisted.
- Positive SSHA and HCA were present in the east-central equatorial Pacific, consistent with the El Nino conditions.
- SSHA and HCA were largely consistent except in the tropical Indian and Southern Oceans where biases in GODAS climatology are large (not shown).
- Tendency of SSHA and HCA was largely 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^{o}S-2^{o}N



- **Positive subsurface temperature anomalies about 4^{o}C were present near the thermocline in the east-central equatorial Pacific, consistent with the El Nino conditions.**

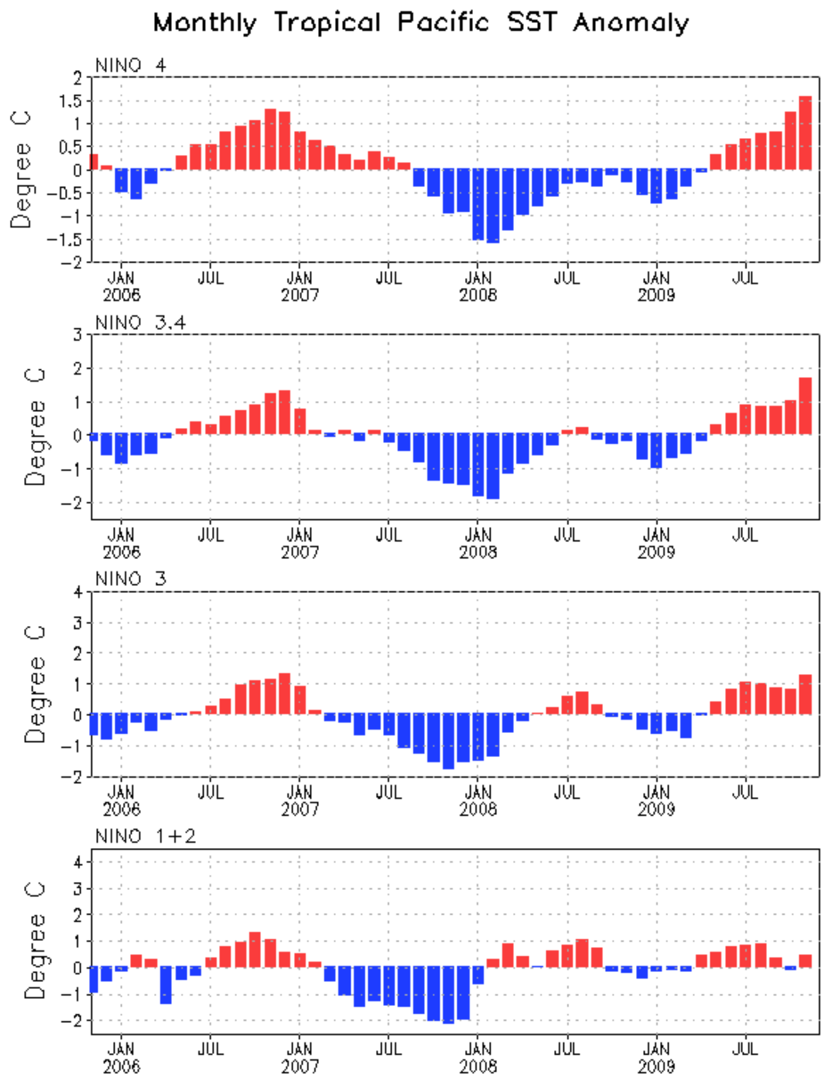


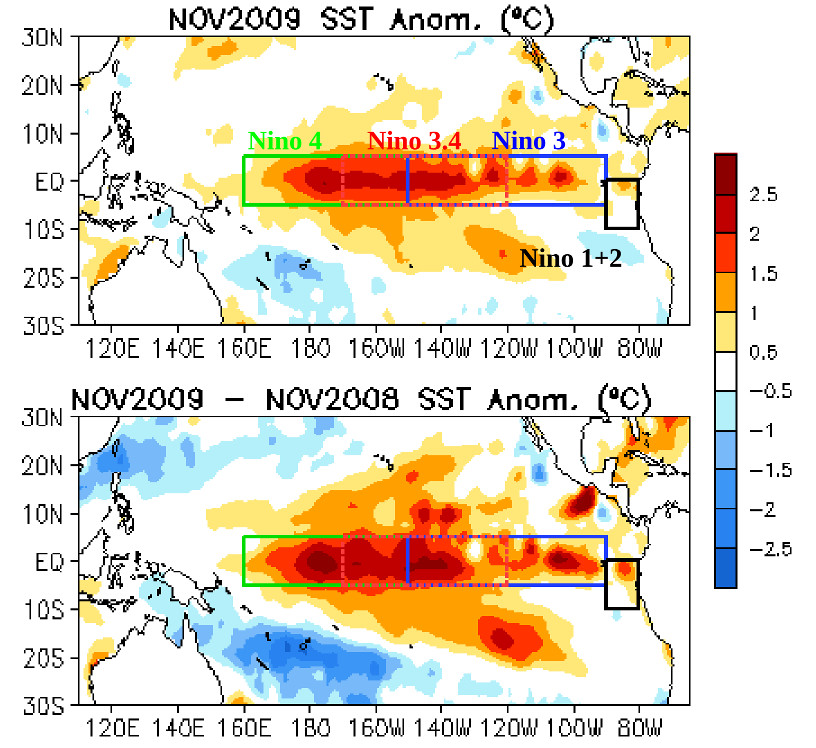
- **Subsurface temperature anomalies increased (decreased) by 4^{o}C (2^{o}C) near 110^{o}W (180^{o}W) along the thermocline of the equatorial Pacific.**

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





- All NINO indices increased in Nov 09.

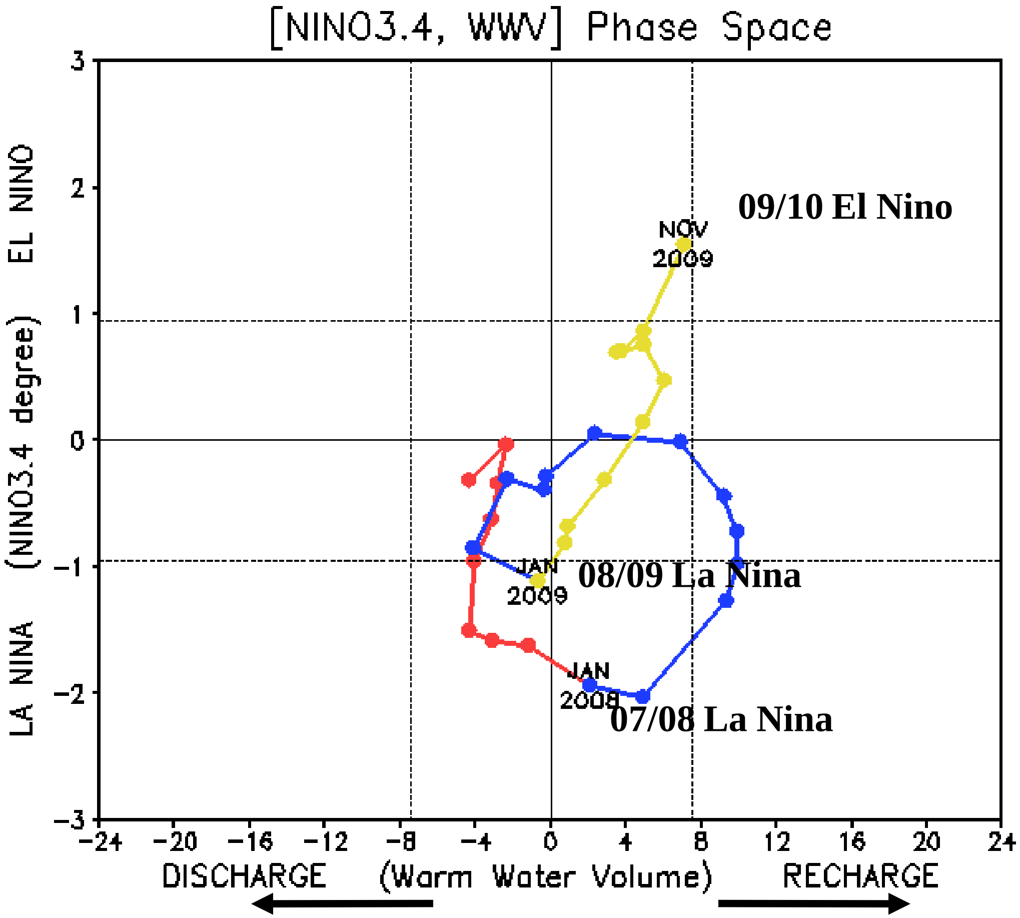
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Warm Water Volume (WWV) and NINO3.4 Anomalies

-WWV is defined as average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] (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.

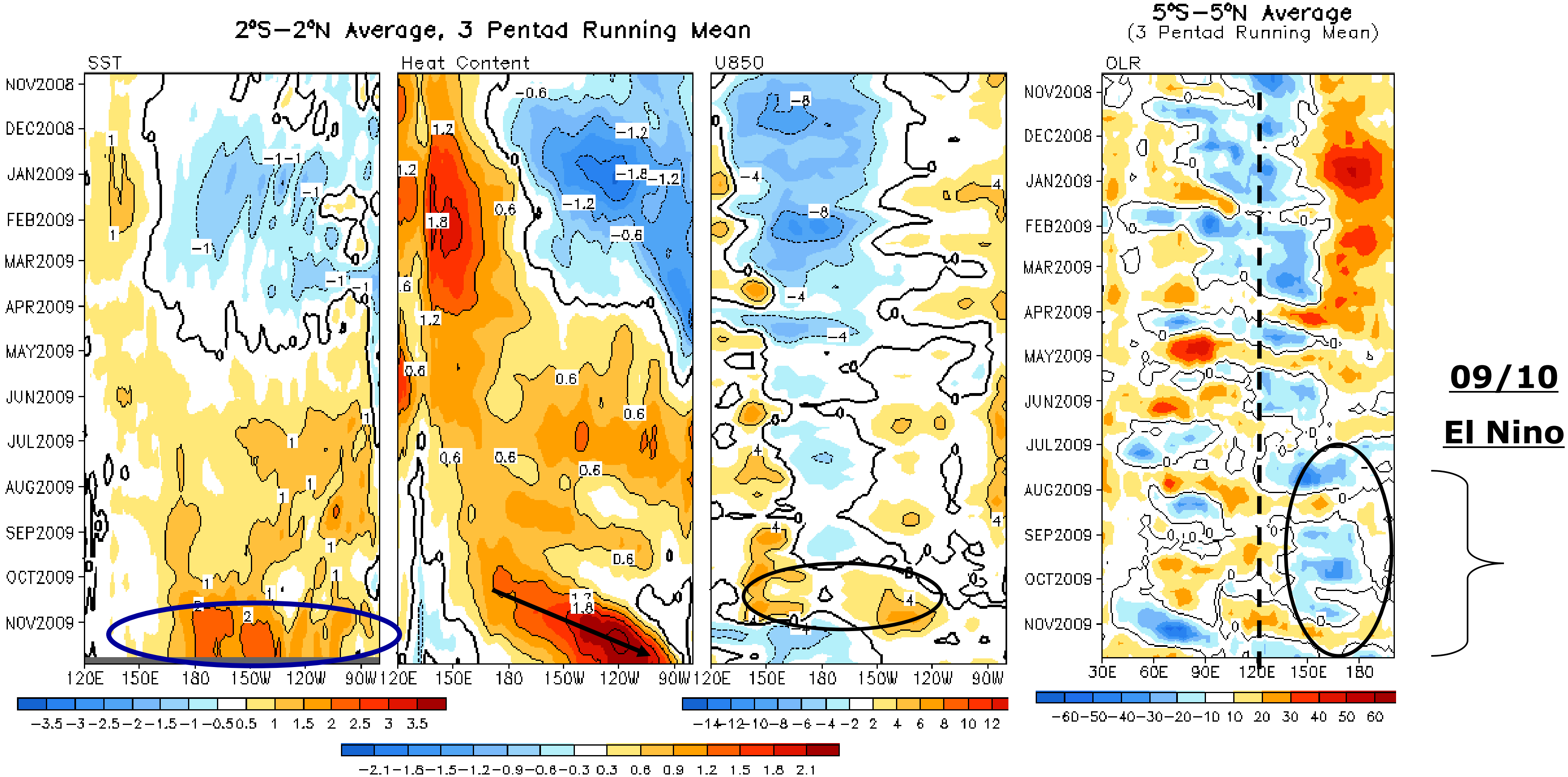


- NINO3.4 and WWV increased steadily during Jan-Jun 2009, persisted during Jul-Oct 09, and increased dramatically in Nov 09.

- The phase trajectory, however, differed from 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 20ºC in [120ºE-80ºW, 5ºS-5ºN] 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.

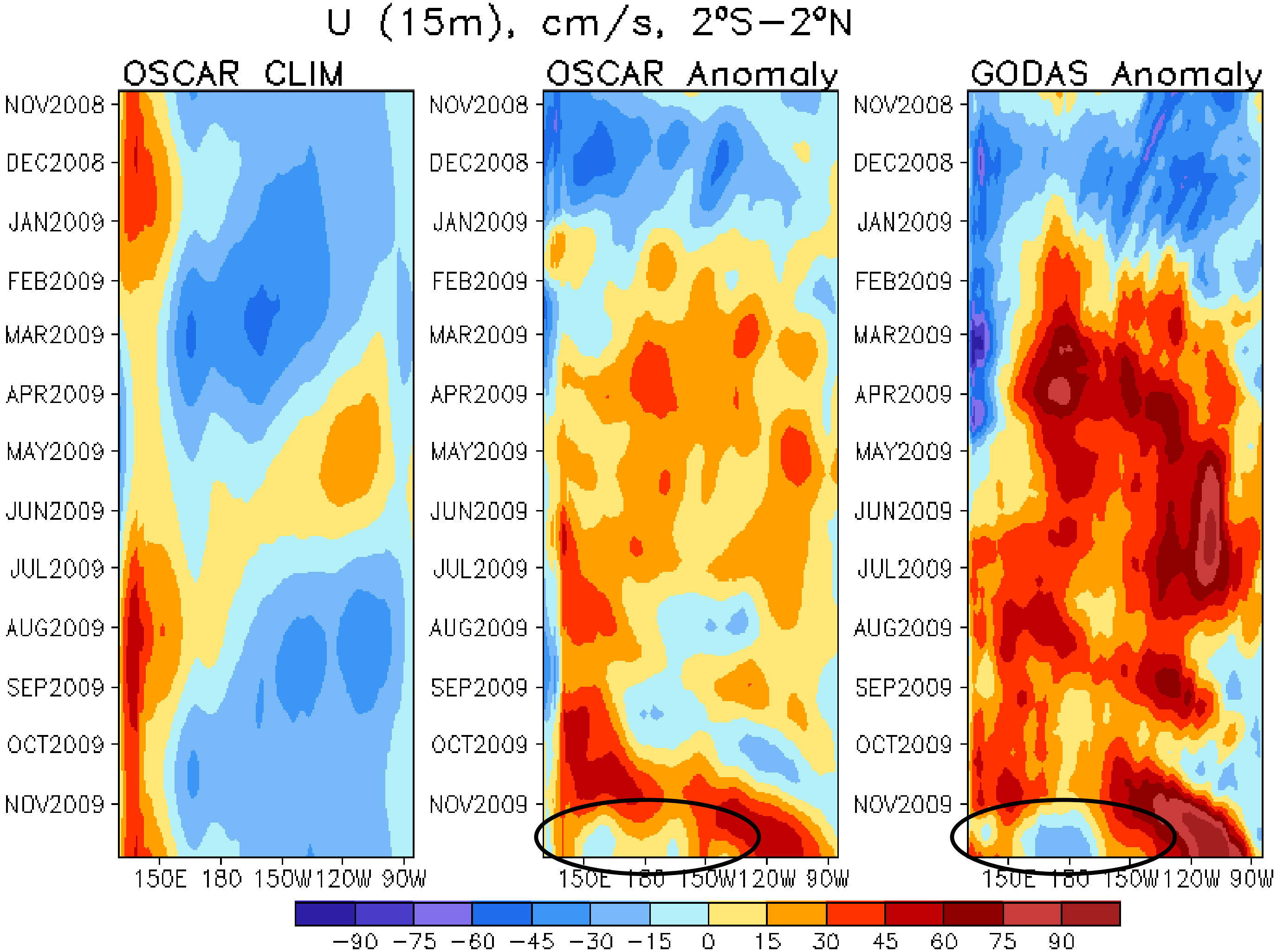
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²) Anomaly



- **SST was about 1-2°C above-normal in the east-central equatorial Pacific.**
- **Positive heat content anomalies (HCA) propagated eastward during Oct-Nov 09, in response to the westerly wind anomalies that occurred in Sep-Oct in the western and eastern tropical Pacific.**
- **Easterly wind anomalies that occurred in Nov 09 in the western tropical Pacific will likely force upwelling oceanic Kelvin wave, and might result in a reduction of equatorial HC in next 2 months.**

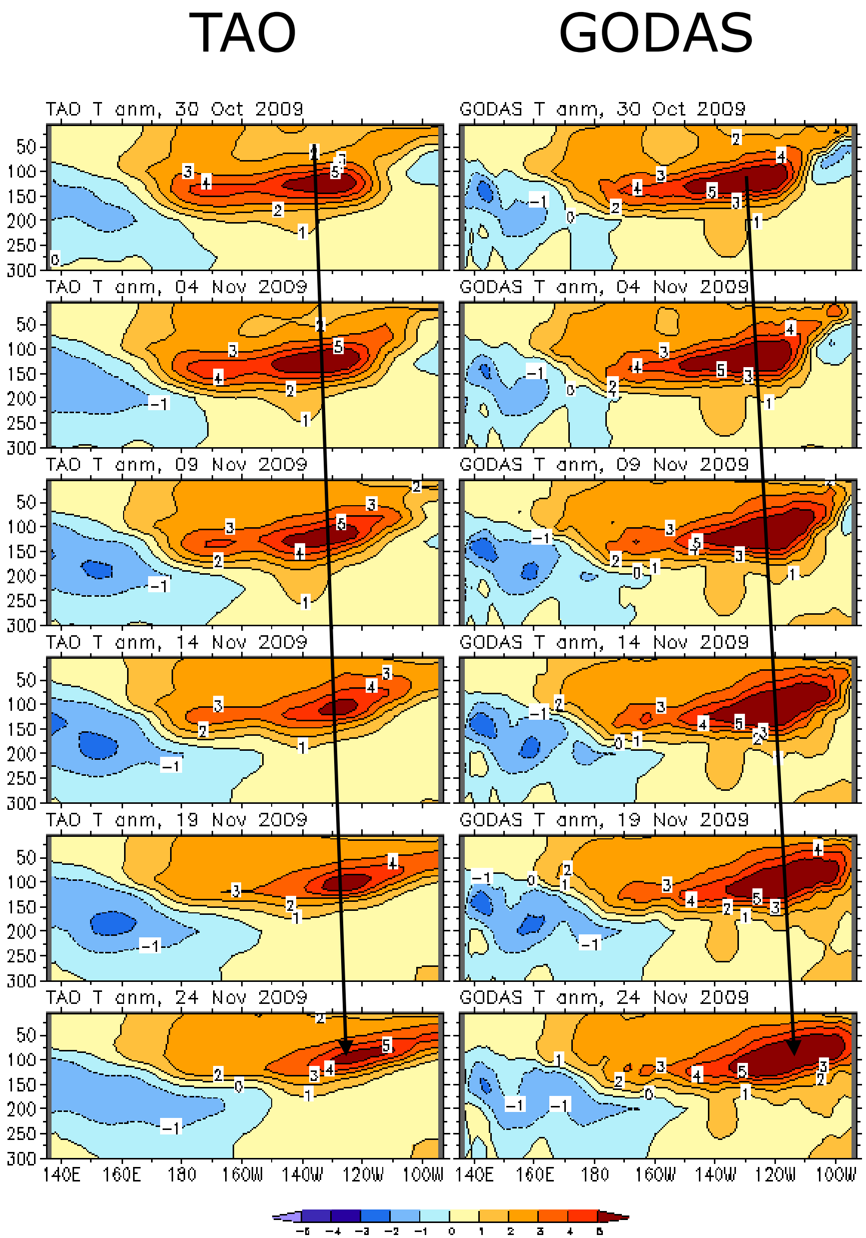
Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2°S-2°N and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST is derived from the NCEP OI 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 in the west-central equatorial Pacific weakened in Nov 09 in response to the upwelling Kelvin waves.**
- **Surface zonal current anomalies simulated by GODAS were too strong compared with those of OSCAR in the equatorial Pacific.**

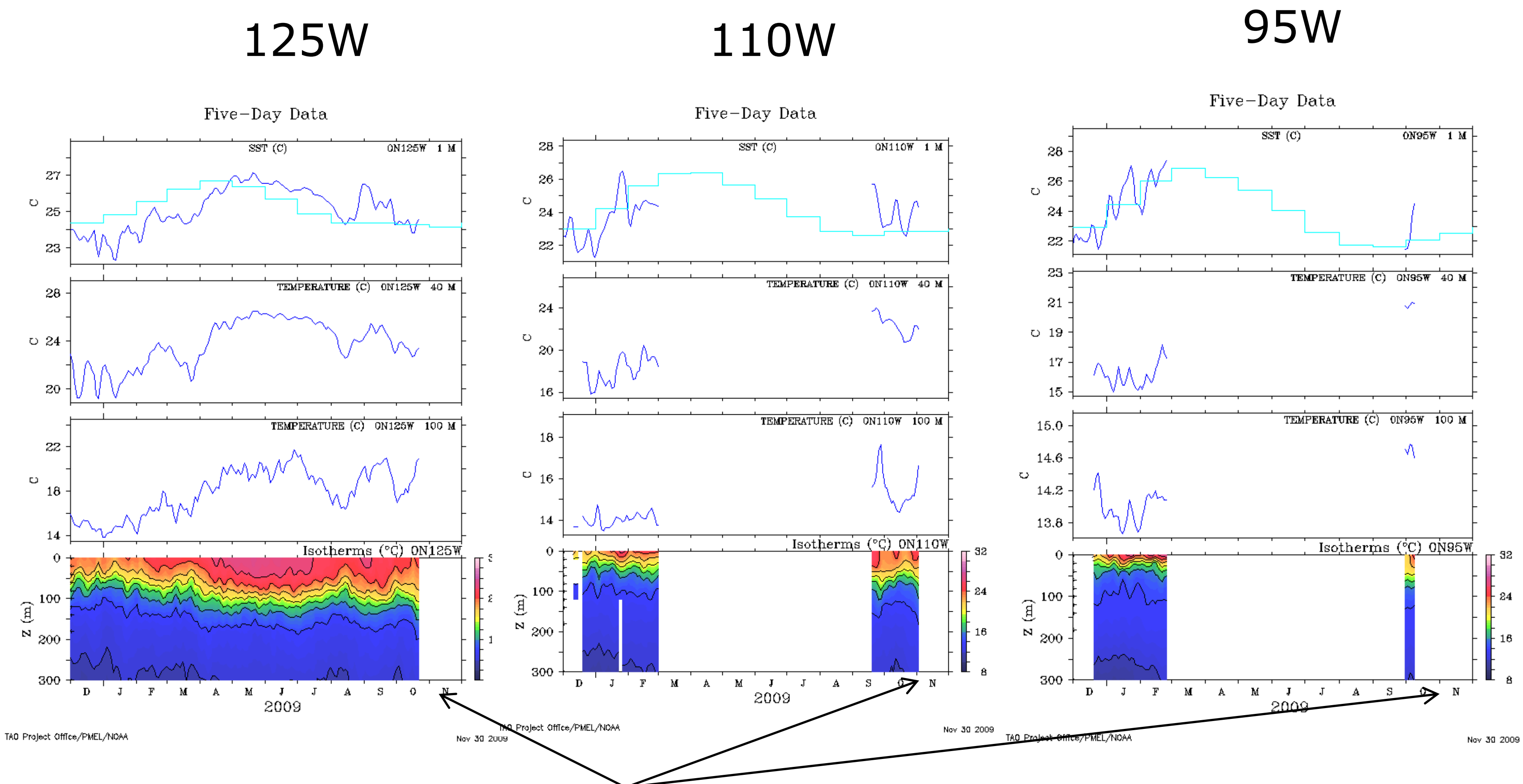
Equatorial Pacific Temperature Anomaly



TAO climatology used

- **Equatorial temperature anomaly propagated eastward.**
- **GODAS overestimated the positive temperature anomalies in the eastern Pacific by as much as 2.5 degree since early November.**

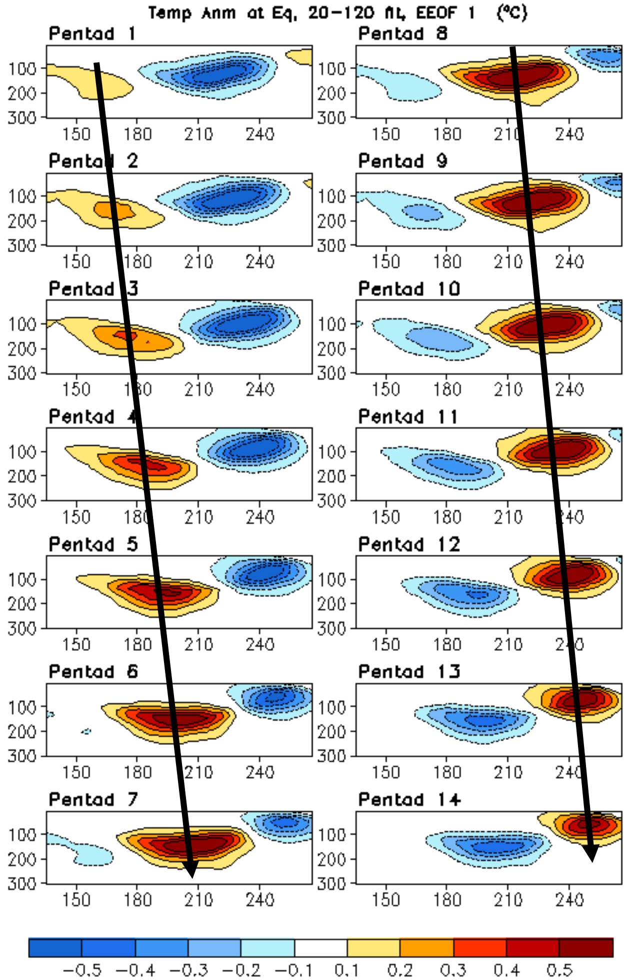
Equatorial Pacific Data from TAO Buoys

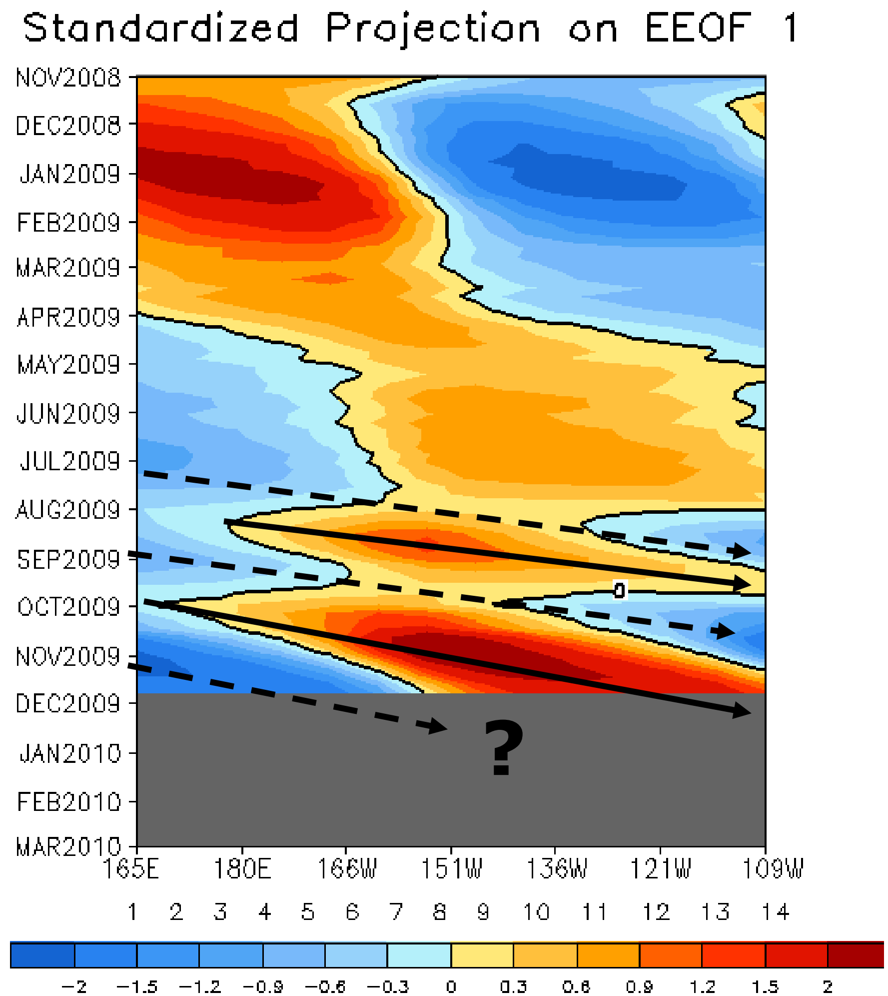


- The TAO buoys at 125°W, 110°W and 95°W on the equator failed to provide data, while those at 2°S and 2°N provided some data in November 09 (not shown).

- The TAO buoys at the three most eastern locations appear play critical roles in constraining GODAS temperature biases.

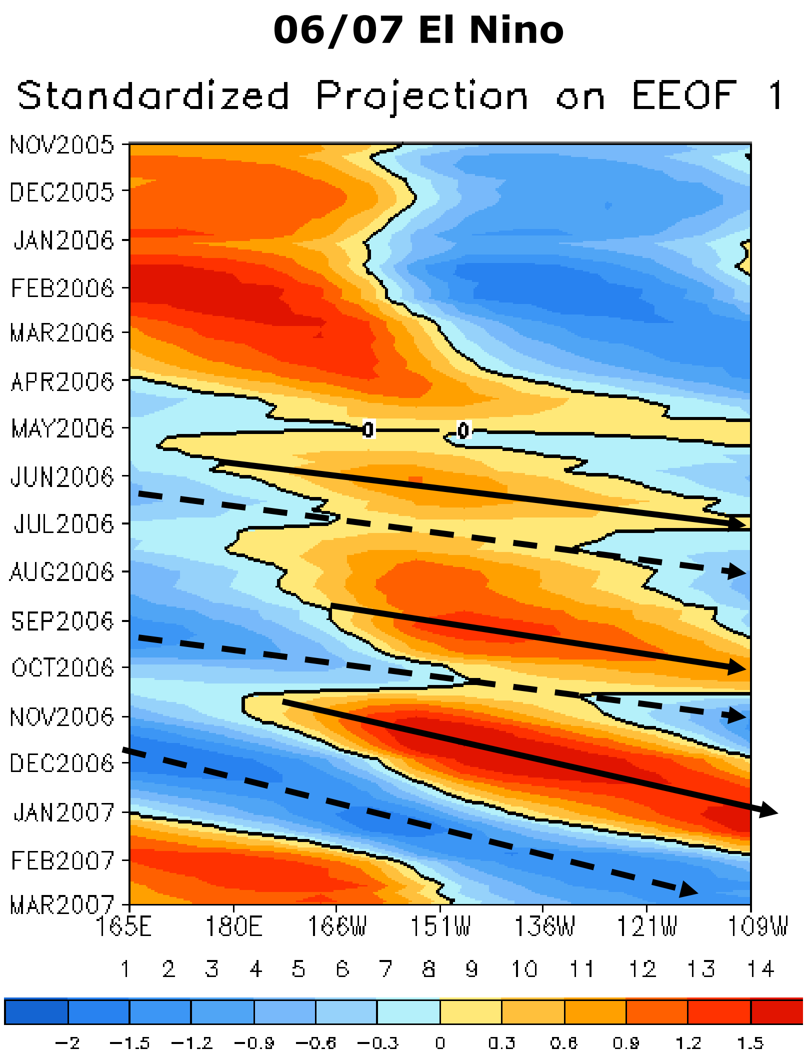
Oceanic Kelvin Wave Indices

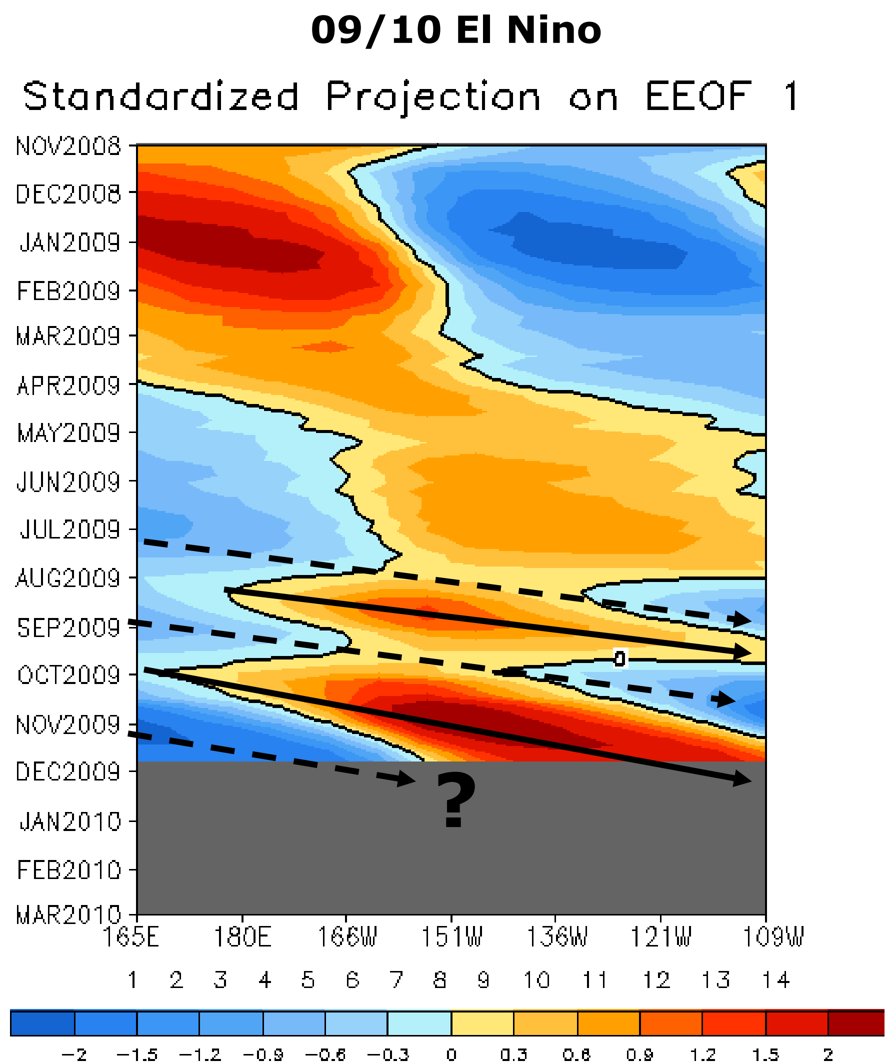




- **Extended EOF (EEOF) analysis is applied to 20-120 day filtered equatorial temperature anomaly in the top 300m using 14 lagged pentads (similar to that in Seo and Xue, GRL, 2005).**
- **EEOF 1 describes eastward propagation of oceanic Kelvin wave cross the equatorial Pacific in about 70 days.**
- **Oceanic Kelvin wave indices are defined as standardized projections of total anomalies onto the 14 patterns of EEOF 1.**

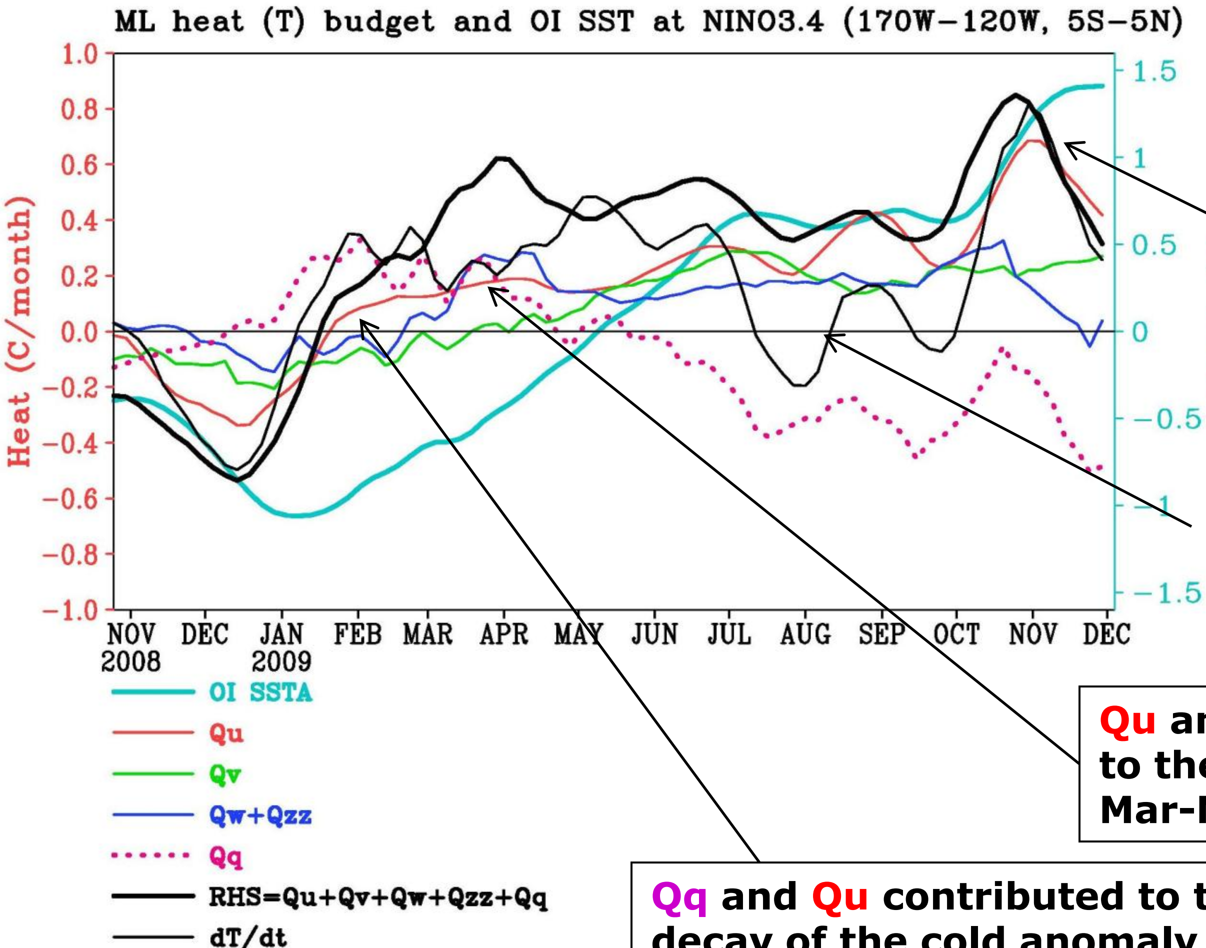
Oceanic Kelvin Wave Indices





- **The evolution of oceanic Kelvin wave episodes during the 09/10 El Nino is very similar to that during the 06/07 El Nino.**
- **The downwelling Kelvin wave initiated in early Oct 09 and upwelling Kelvin wave initiated in late Oct 09 in the western Pacific are very similar to those that occurred in late Oct 06 and early Nov 06.**

NINO3.4 Heat Budget: 09/10 El Nino



The large warming tendency since Oct is largely due to Qu, suggesting that influences of subsurface temperature anomalies on SSTA tendency are probably small.

Balance in heat budget (dT/dt = RHS) was poor in Jul-Sep when NINO 3.4 was largely persistent.

Qu and Qw+Qzz contributed to the warming tendency in Mar-May.

Qq and Qu contributed to the decay of the cold anomaly in the early spring 09.

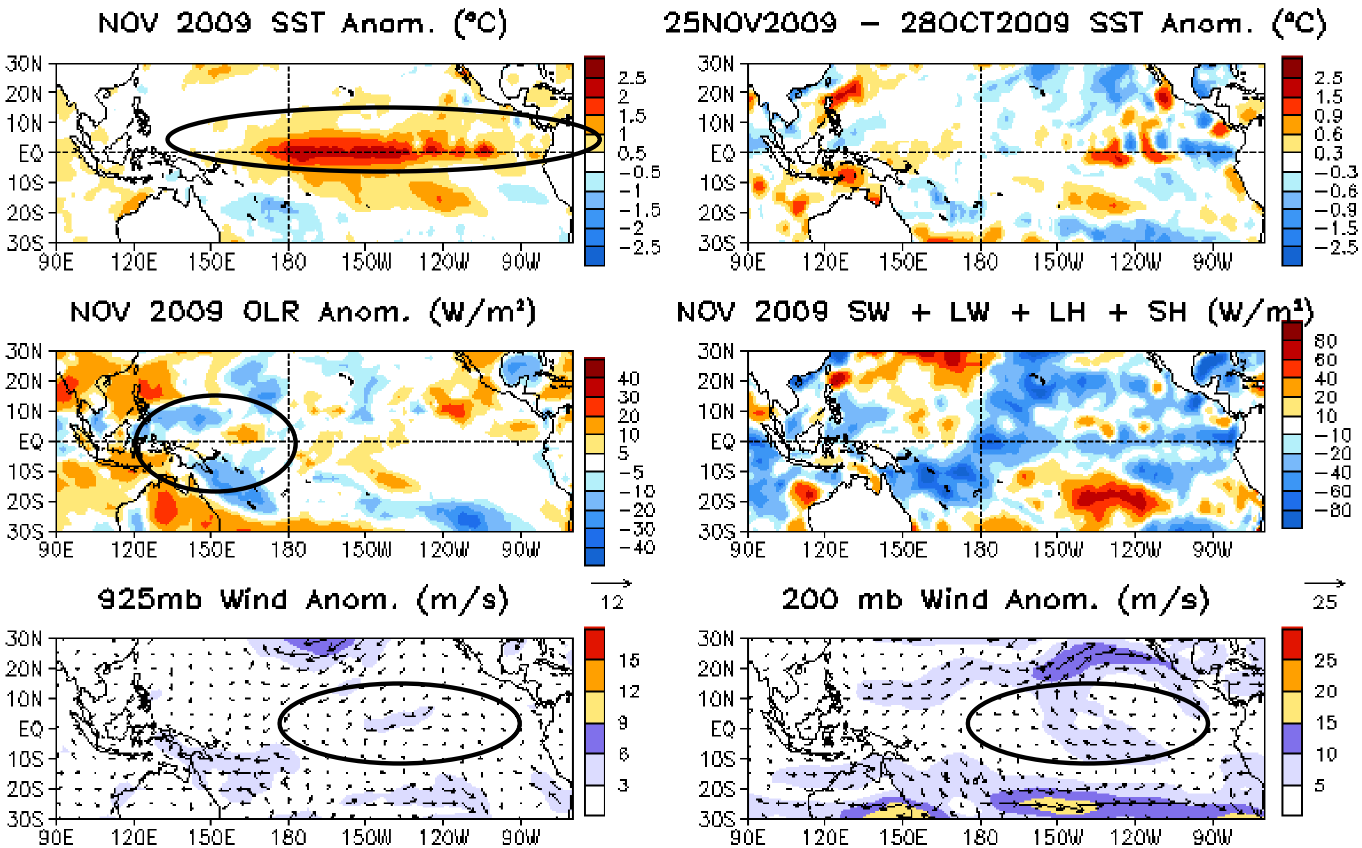
Qu: Zonal advection; Qv: Meridional advection;

Qw: Vertical entrainment; Qzz: Vertical diffusion

Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

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

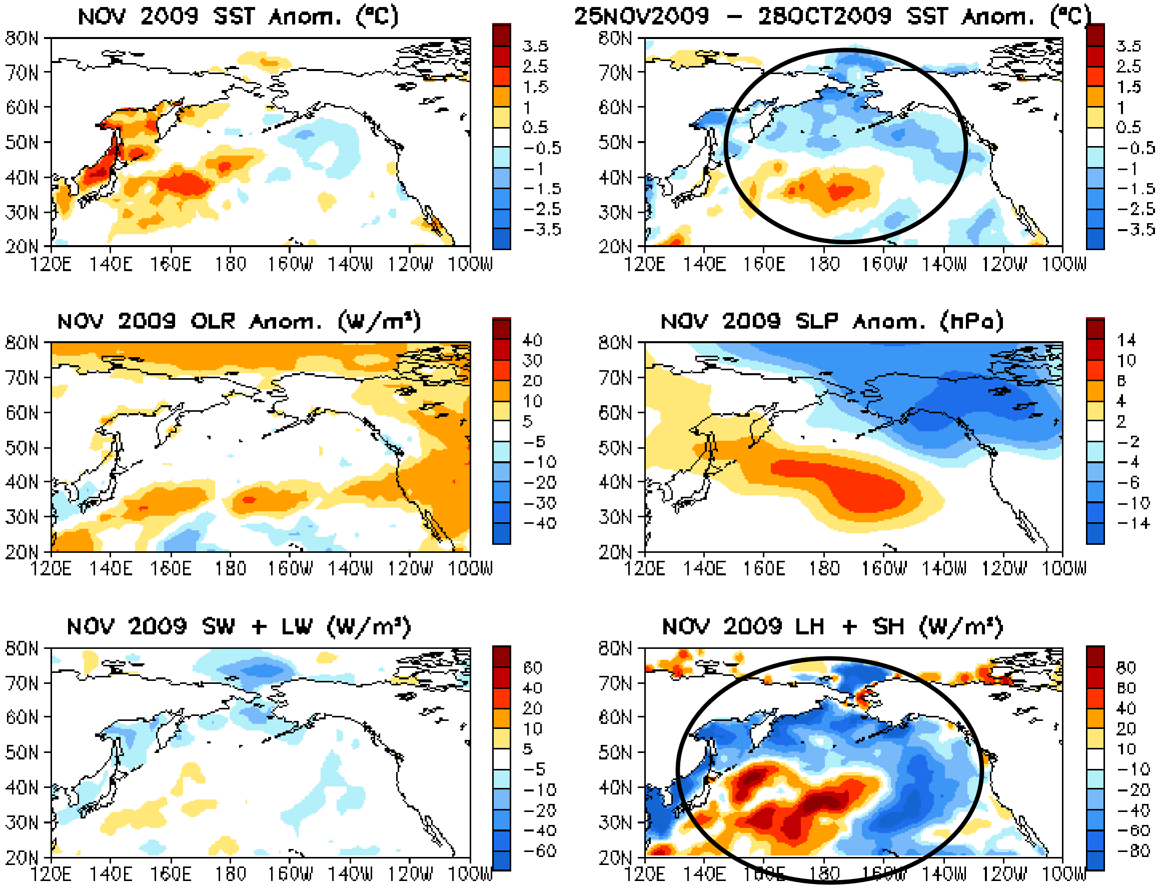


- Positive SSTA presented in the equatorial Pacific.
- Convection was suppressed (enhanced) over the Maritime Continent (western Pacific).
- Westerly (easterly) wind anomaly were present at the lower-level (upper-level) in the east-central tropical Pacific.

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.

North Pacific & Arctic Ocean

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



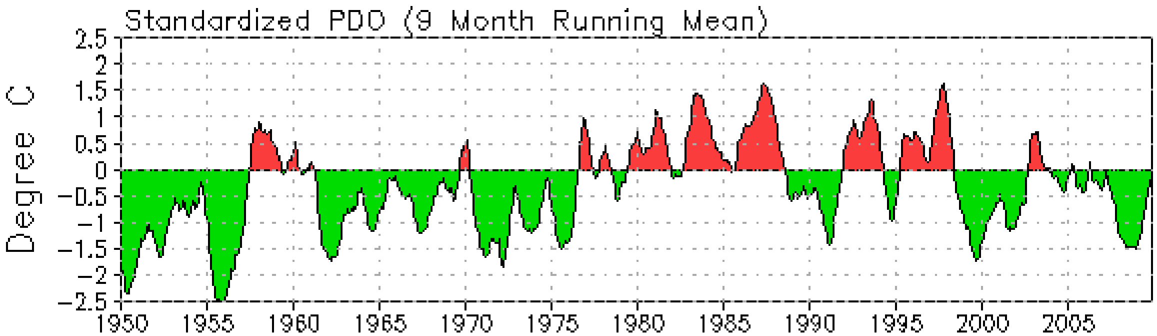
- SSTA decreased in Gulf of Alaska and to the north and south of the Bering Strait.

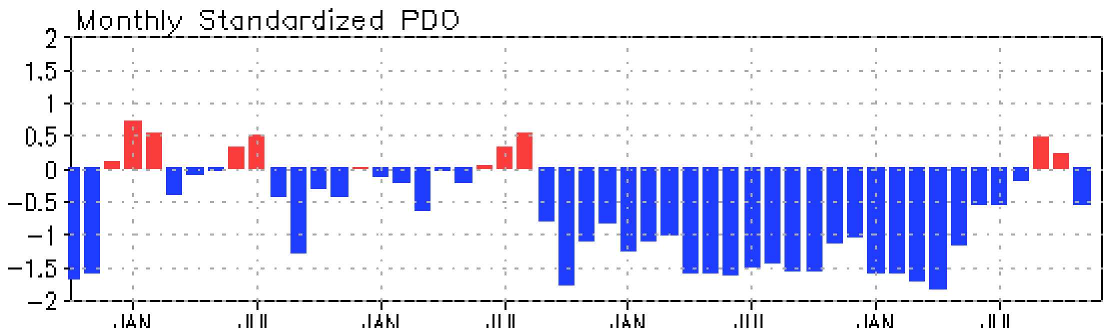
- The SSTA tendency was largely consistent with the net surface heat flux anomalies.

- Below-normal (above-normal) sea level pressure were present over Alaska and western Canada (central North Pacific).

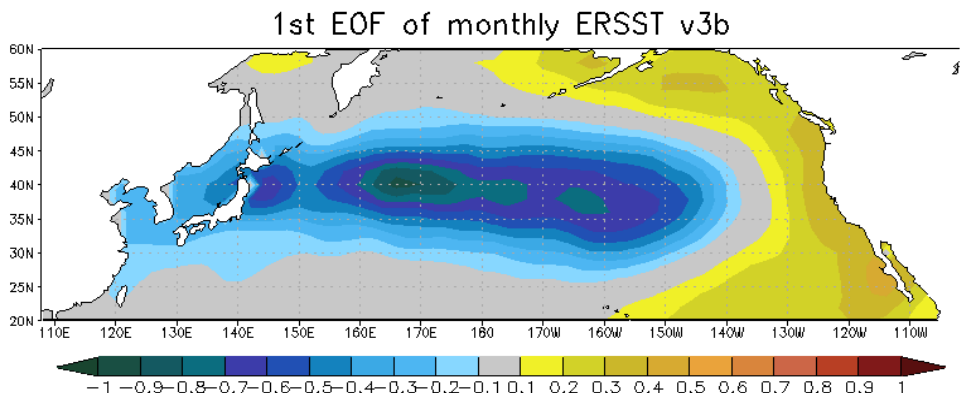
Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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 below-normal in Nov 09.



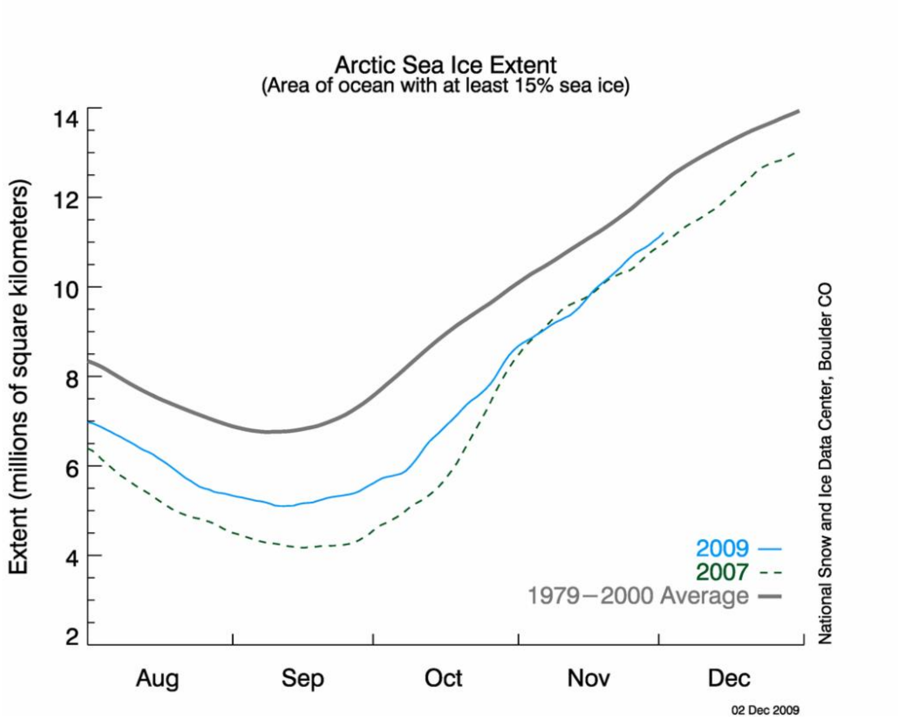
- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

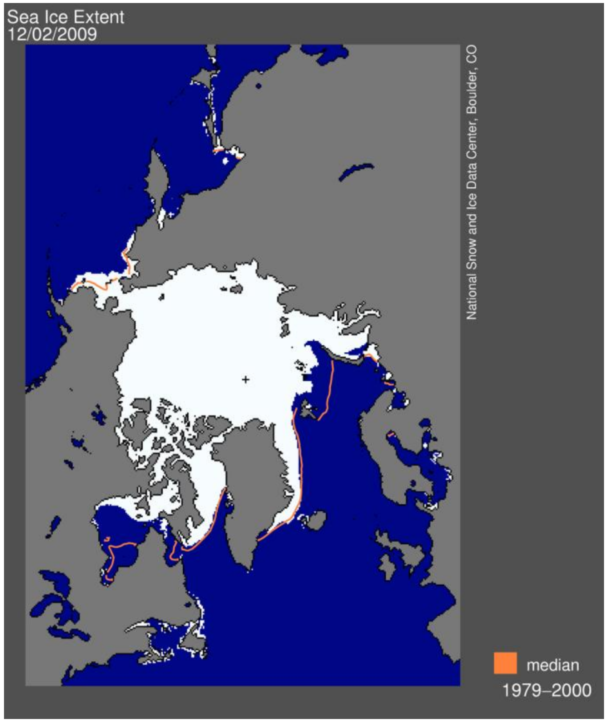
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

Arctic Sea Ice

National Snow and Ice Data Center

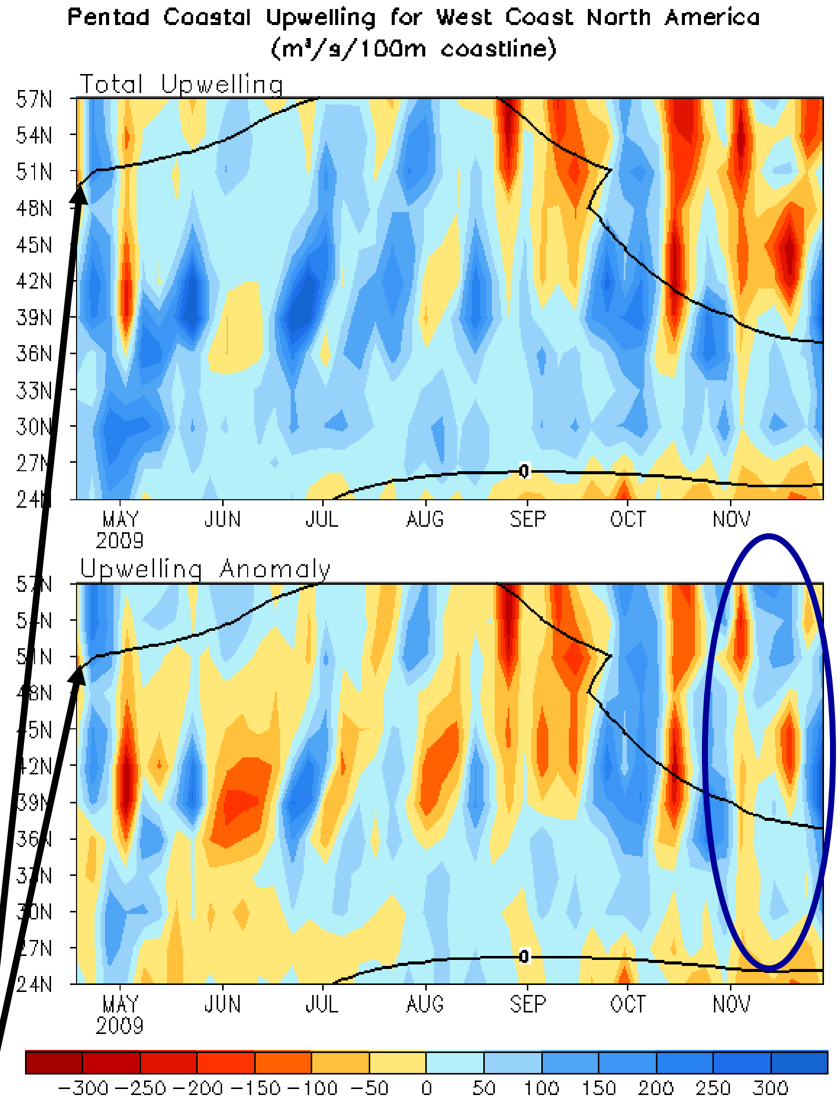
http://nsidc.org/arcticseaicenews/index.html

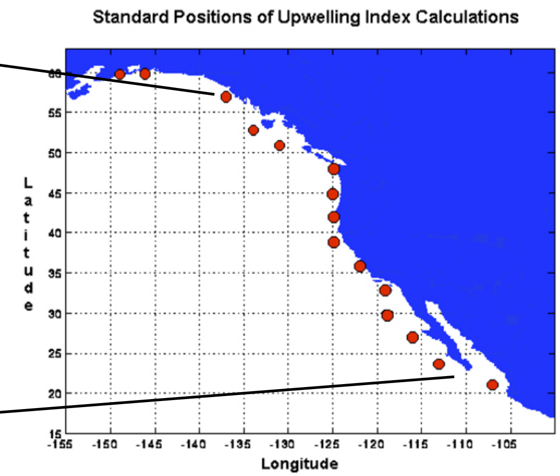




- **Sea ice extent continued to increase seasonally, but was near the historic low value in Nov 2009.**

North America Western Coastal Upwelling



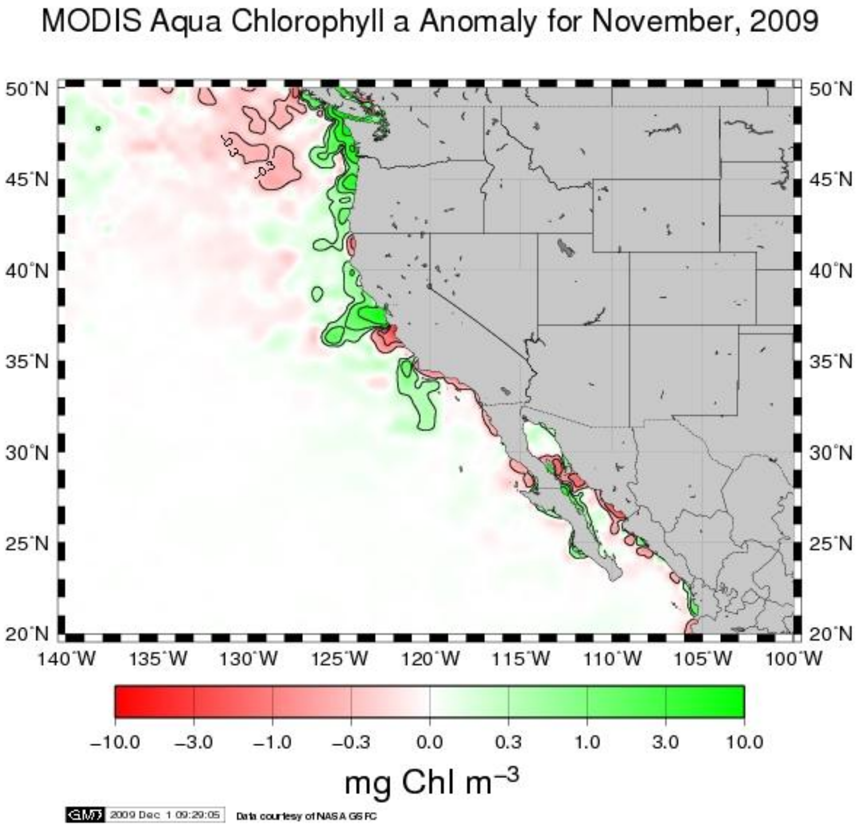


- Upwelling had large high frequency variability in Nov 09, and the monthly mean upwelling was mostly above-normal.

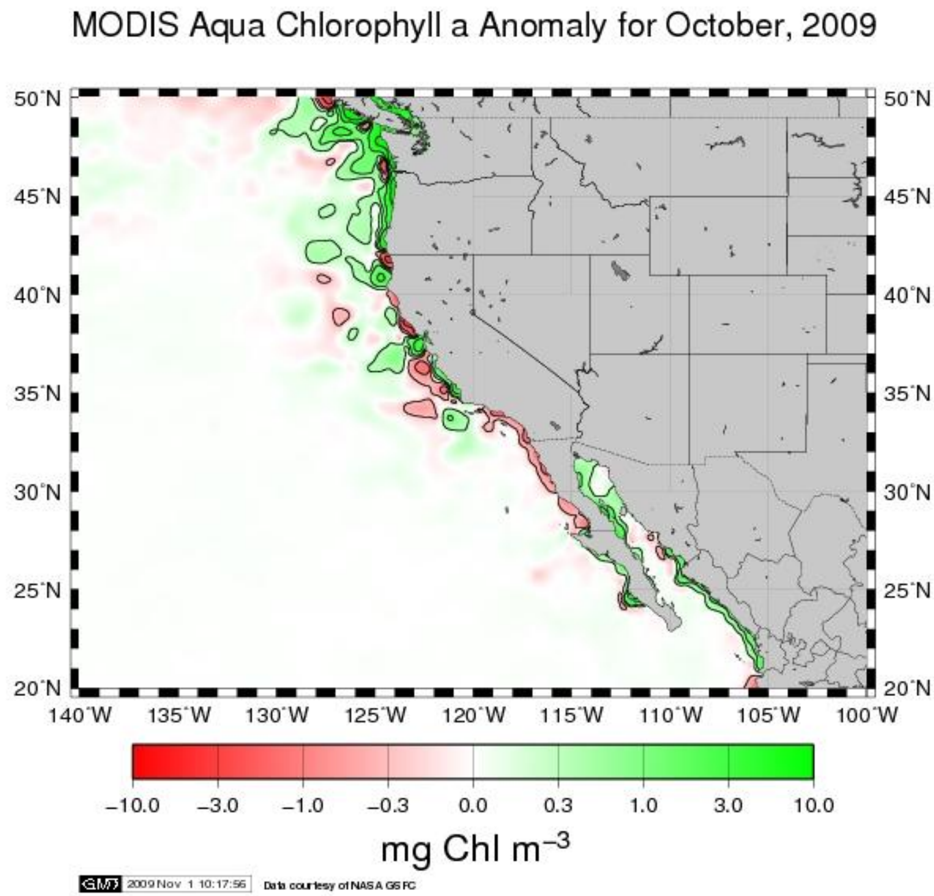
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point (m^3/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



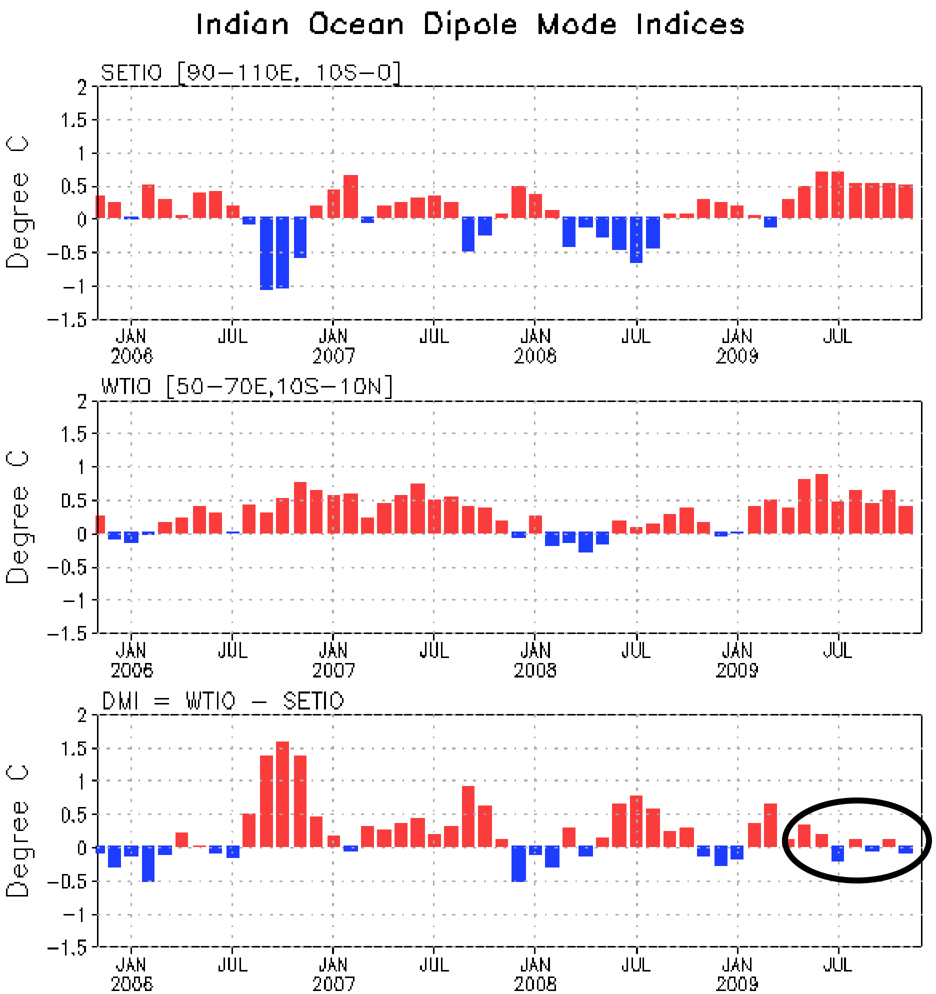
- **Chlorophyll was above- (below-) normal north (south) of 36N in Nov 09, largely consistent with the upwelling anomalies.**

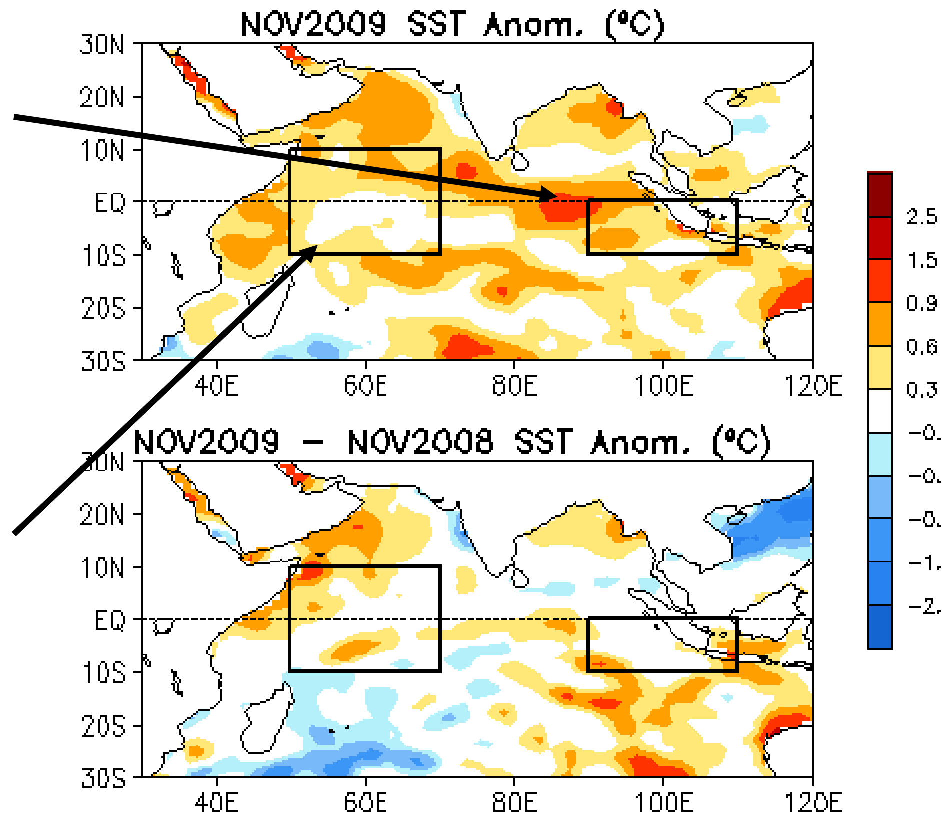


http://coastwatch.pfel.noaa.gov/FAST

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

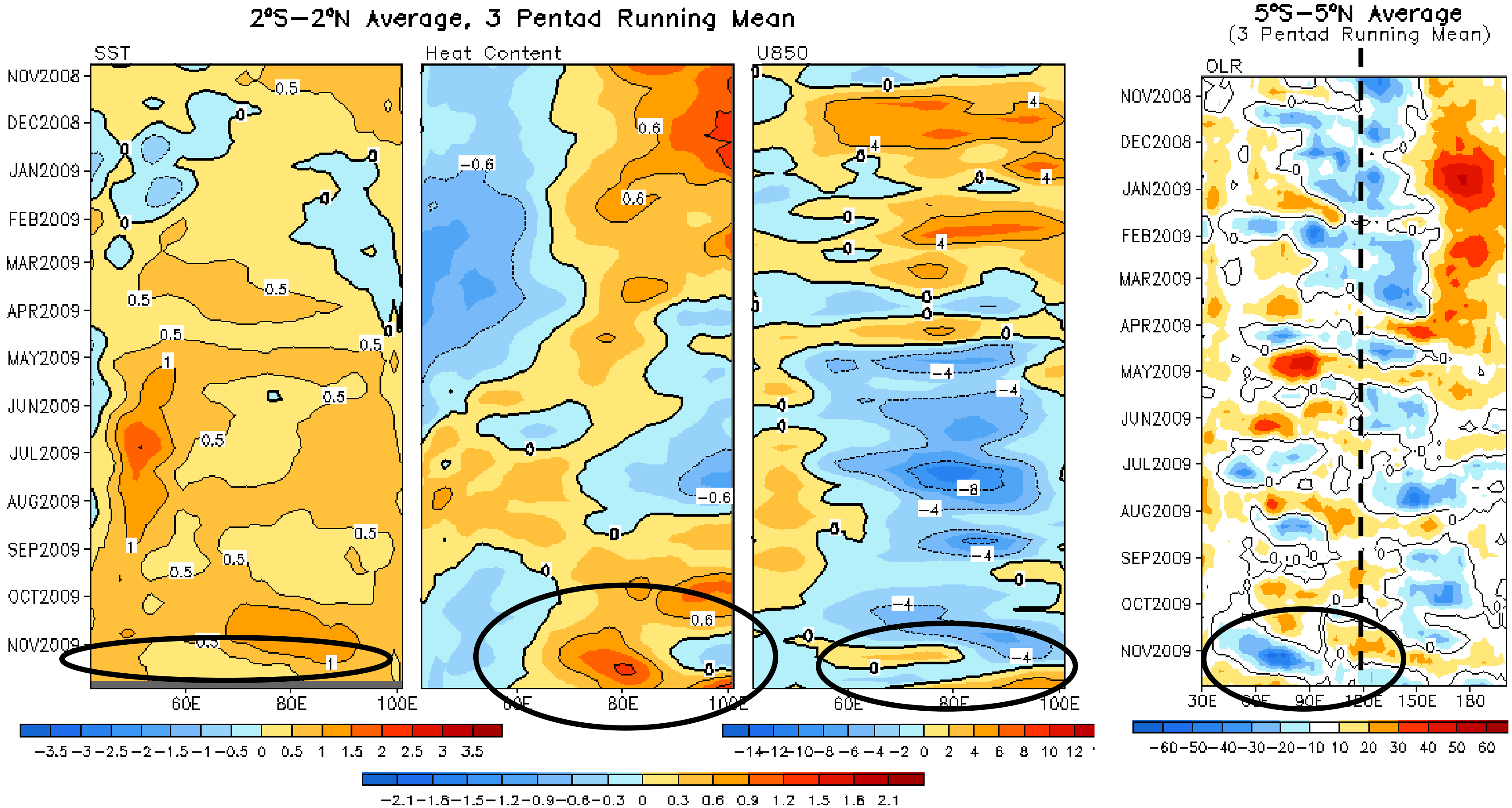




- Both eastern (SETIO) and western (WTIO) pole SST have been persistently above-normal since April 09.
- DMI has been near-normal since March 09.

Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (^{o}C) for the SETIO [90^{o}E-110^{o}E, 10^{o}S-0] and WTIO [50^{o}E-70^{o}E, 10^{o}S-10^{o}N] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

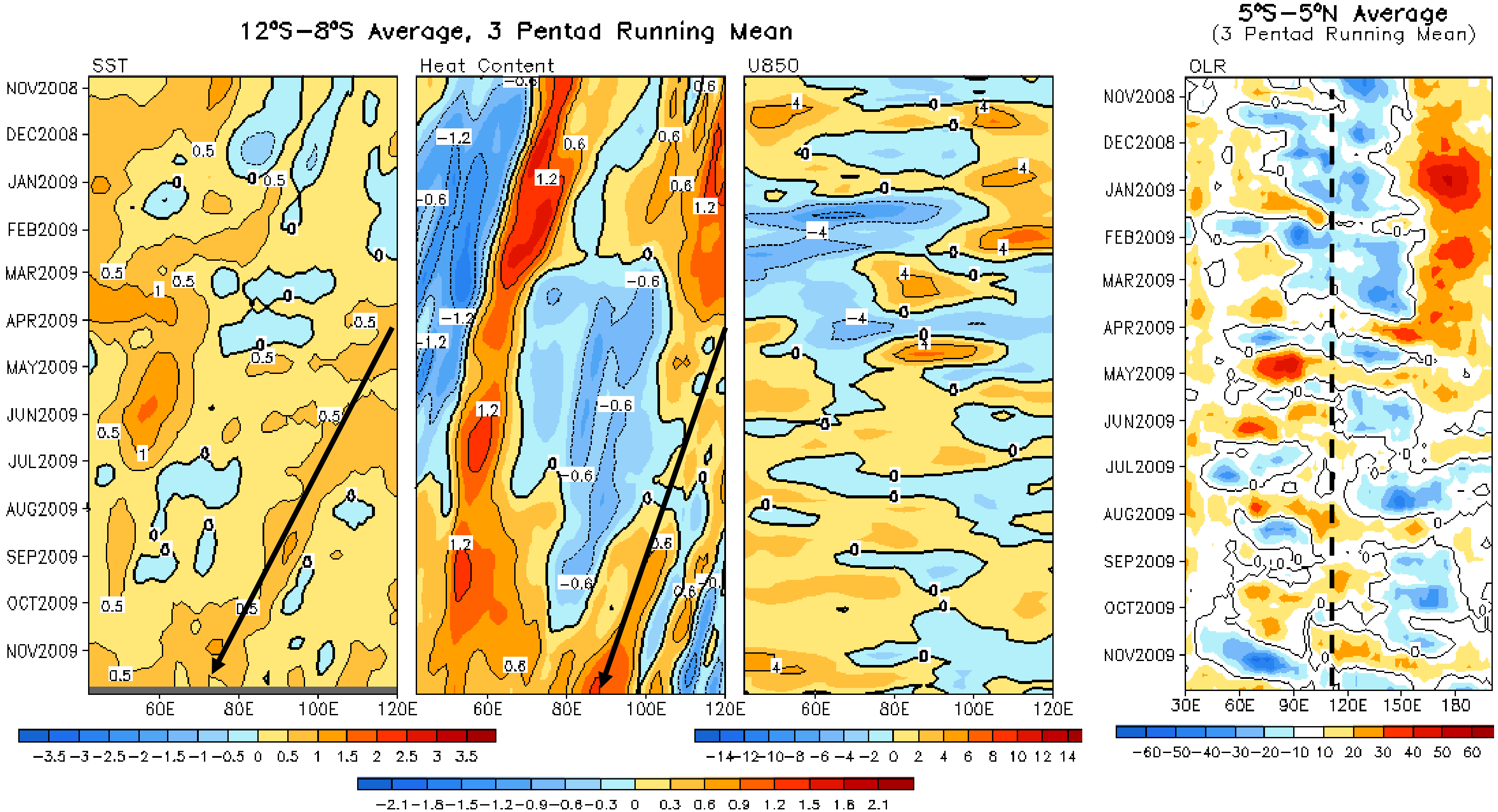
Recent Evolution of Equatorial Indian SST (ºC), 0-300m Heat Content (ºC), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies



- **Westerly wind anomalies in the tropical Indian Ocean in Nov 09 were probably associated with the recent MJO activity.**
- **In response to the westerly wind anomalies, positive heat content anomaly in the east-central tropical Indian Ocean strengthened.**
- **Positive SSTA weakened substantially in the central tropical Indian Ocean in Nov 09, probably due to the MJO activity.**

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.

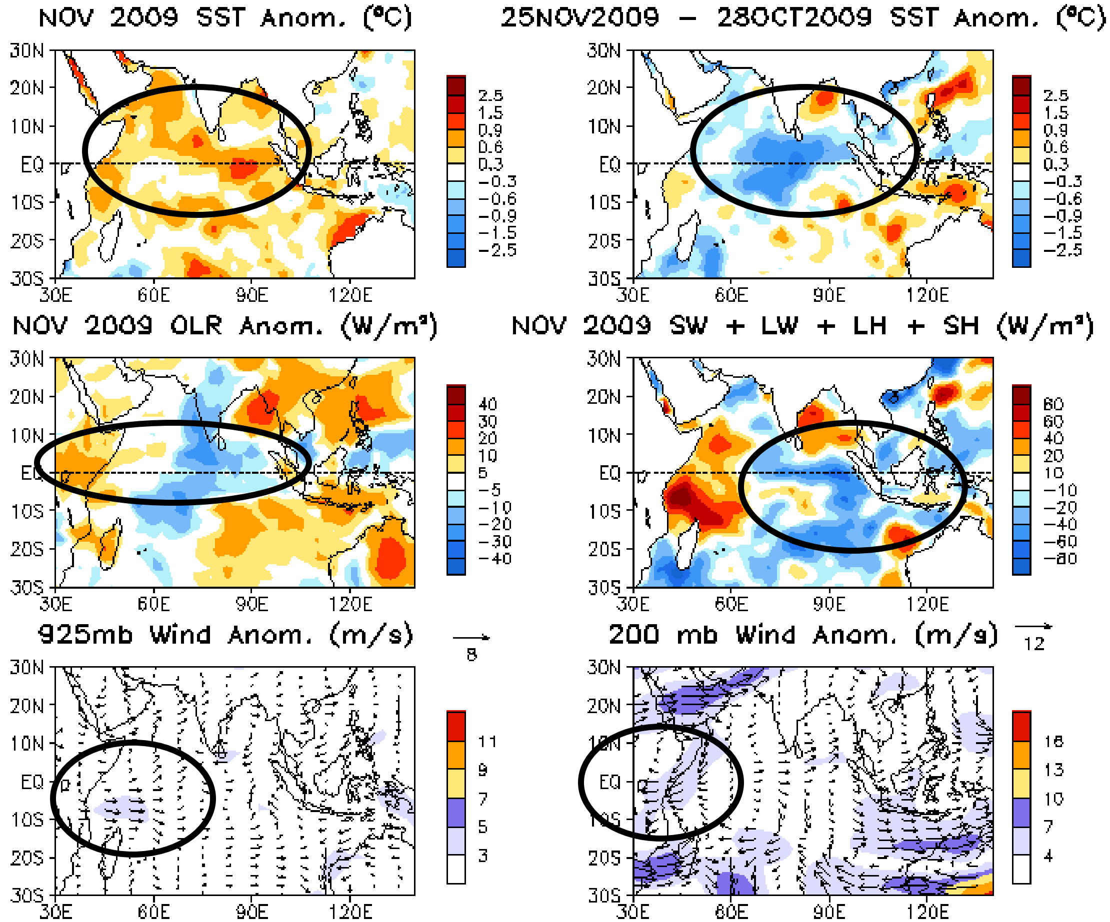
Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)



- **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.



- Positive SSTA presented in the tropical Indian Ocean.

- Net surface heat flux anomalies partially contributed to the negative SSTA tendency in the central tropical Indian Ocean.

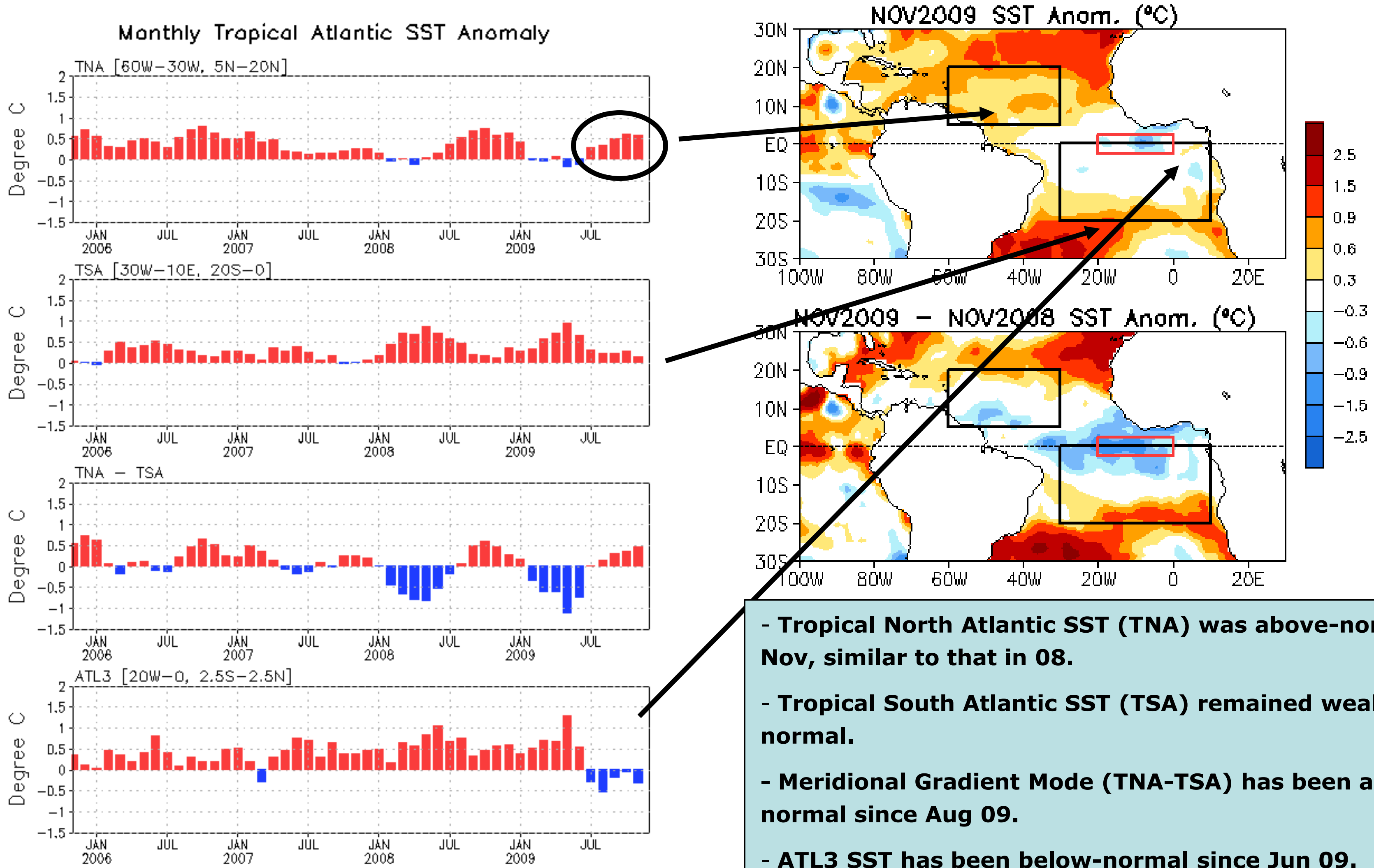
- Convection was enhanced (suppressed) in the east-central tropical Indian Ocean (in the eastern Africa).

- Consistent with the convection pattern were low-level (upper-level) westerly (easterly) wind anomalies in the western tropical 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 SST (TNA) was above-normal in Jul Nov, similar to that in 08.**

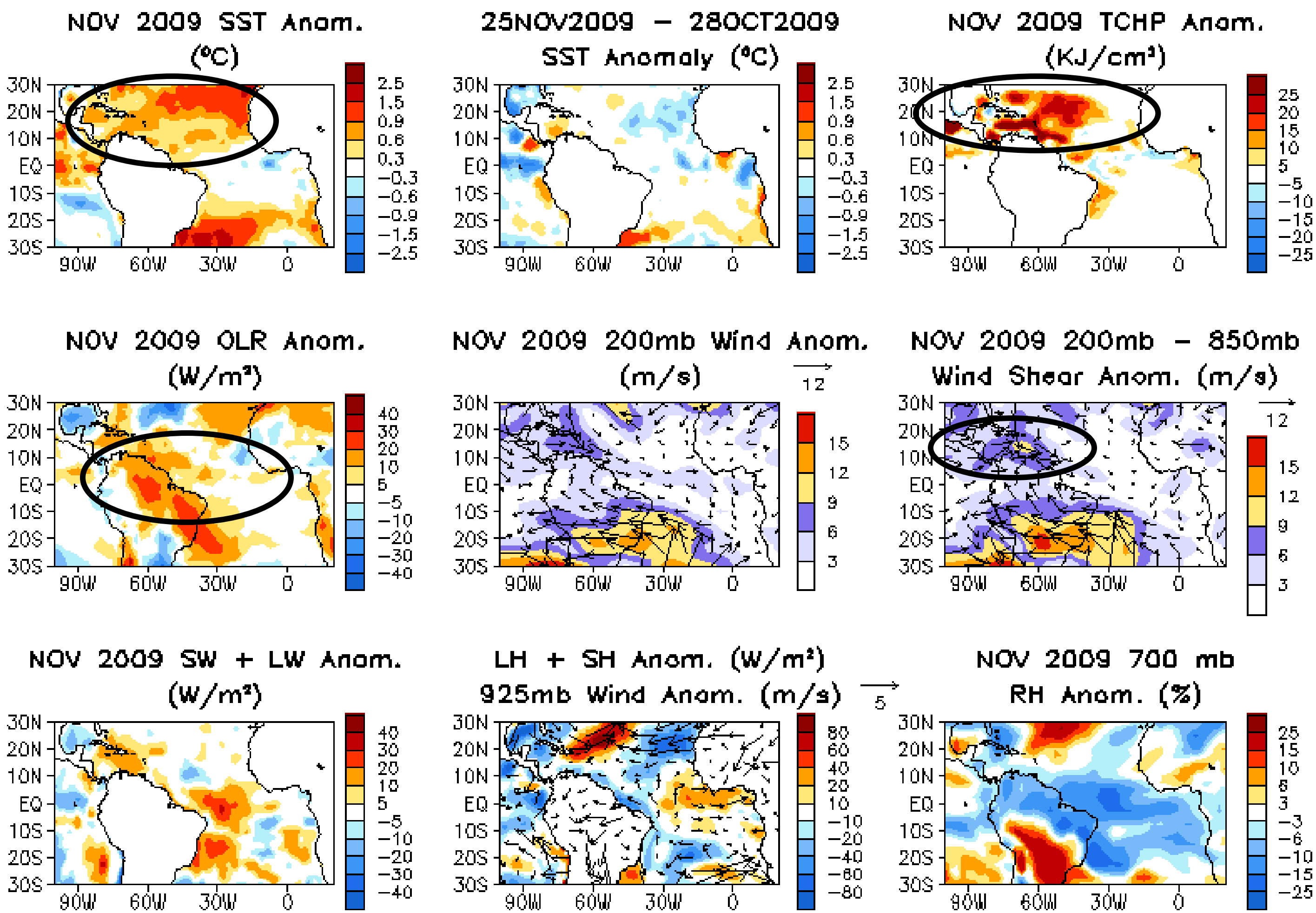
- **Tropical South Atlantic SST (TSA) remained weakly above-normal.**

- **Meridional Gradient Mode (TNA-TSA) has been above-normal since Aug 09.**

- **ATL3 SST has been below-normal since Jun 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.
- Convection was suppressed in the tropical Atlantic and central America.
- Vertical wind shears were above-normal over the Caribbean Sea.

North Atlantic Ocean

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

- NAO was near-normal in Nov 09 (next slide).
- SSTA tendencies were largely consistent with net surface heat flux anomalies.

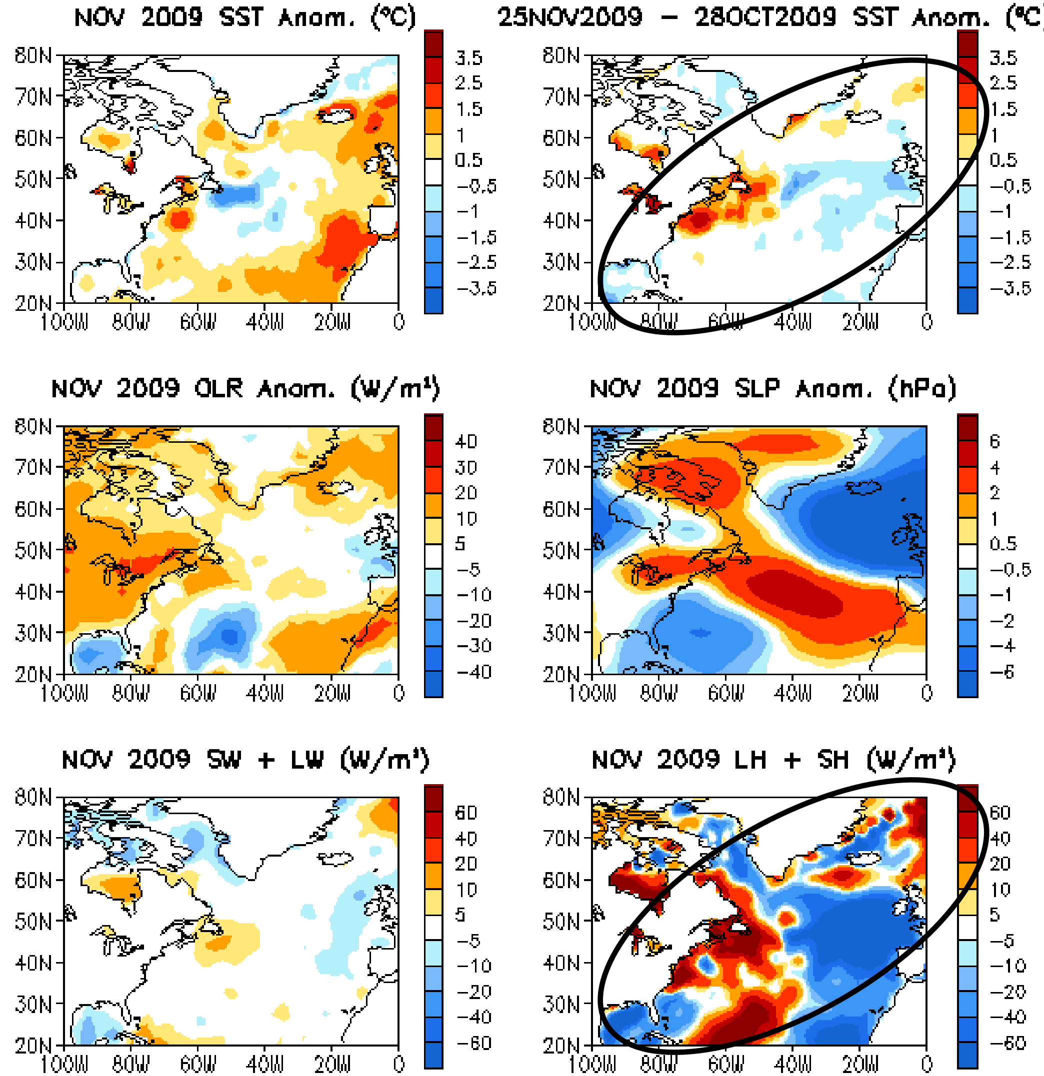
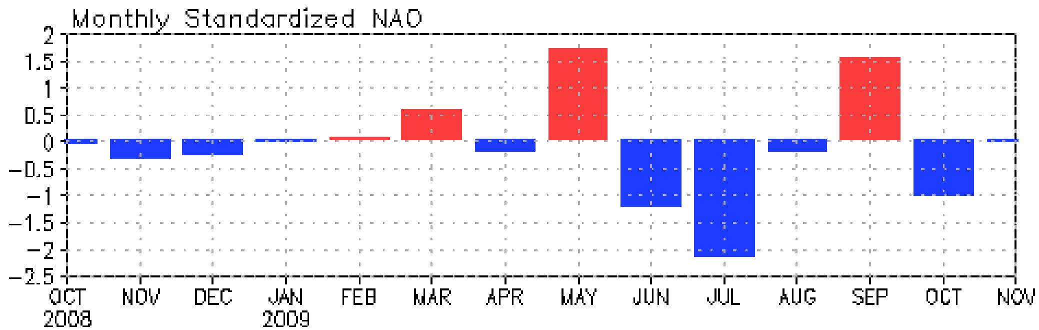
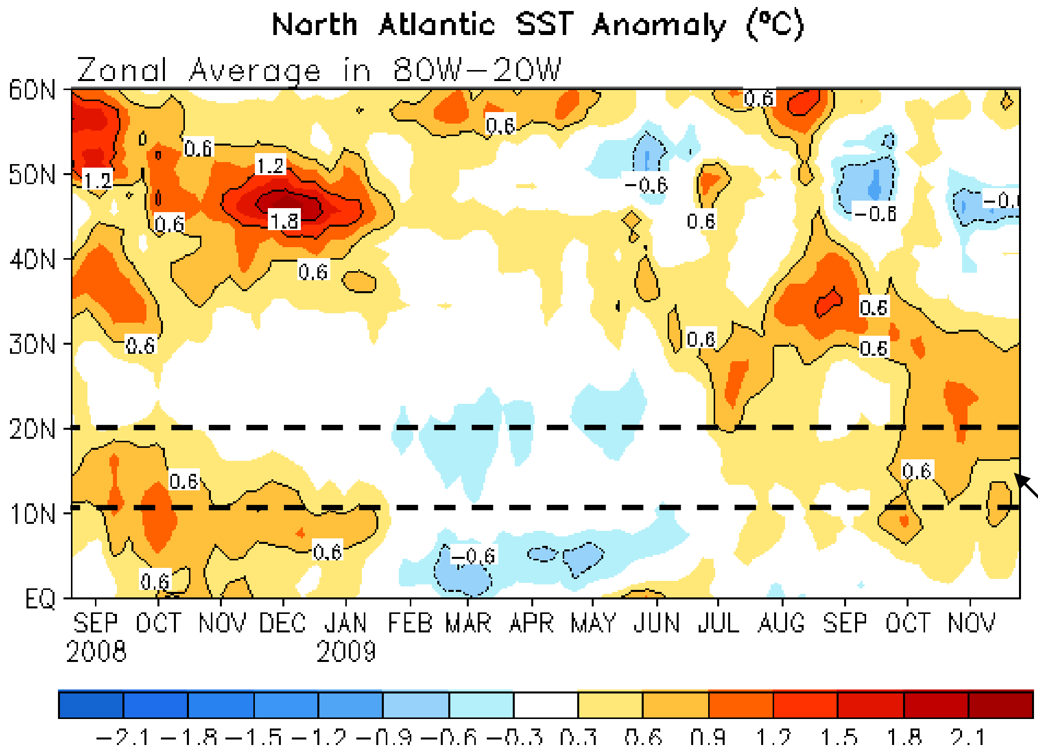
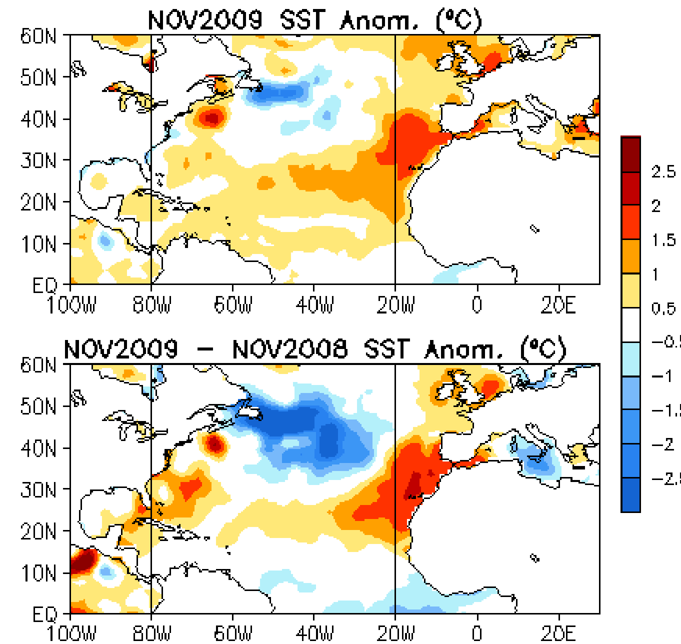


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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



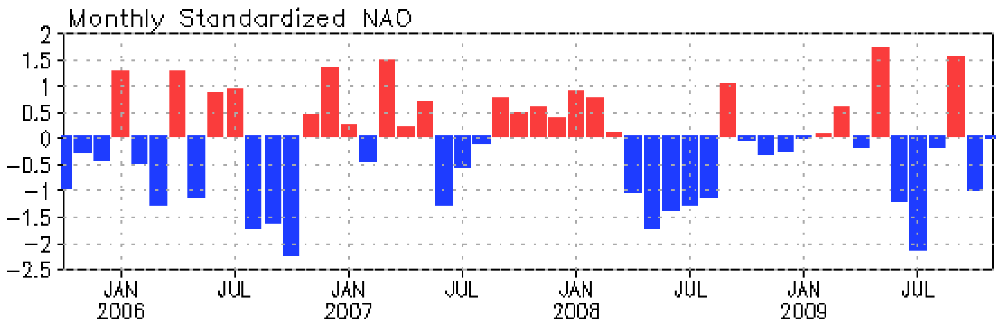


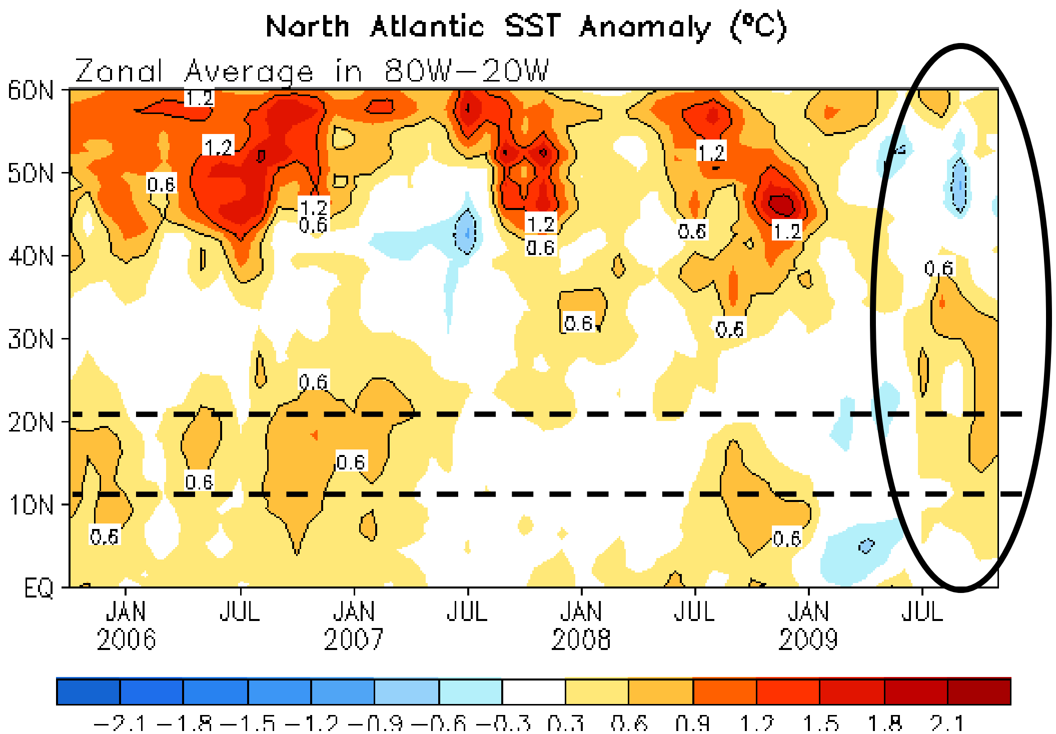


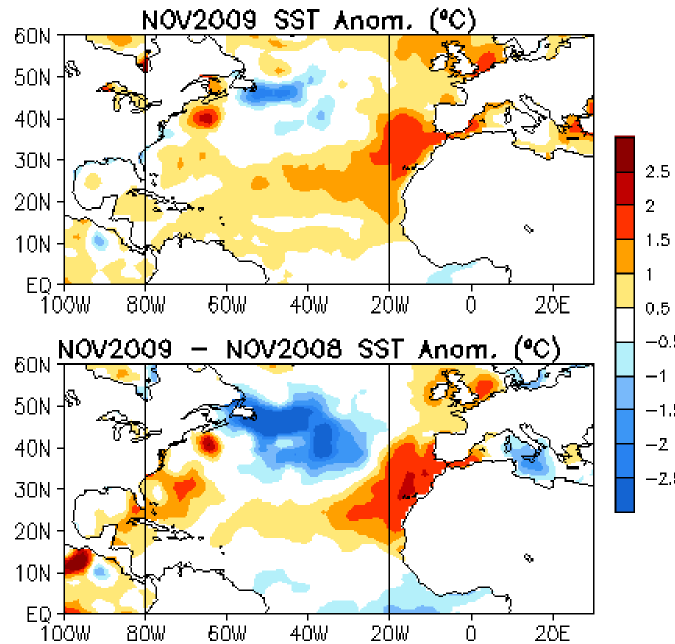
- **High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).**
- **NAO was near-normal in Nov 09.**
- **Positive SSTA in the Hurricane Main Development Region persisted in Nov 09.**

Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (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







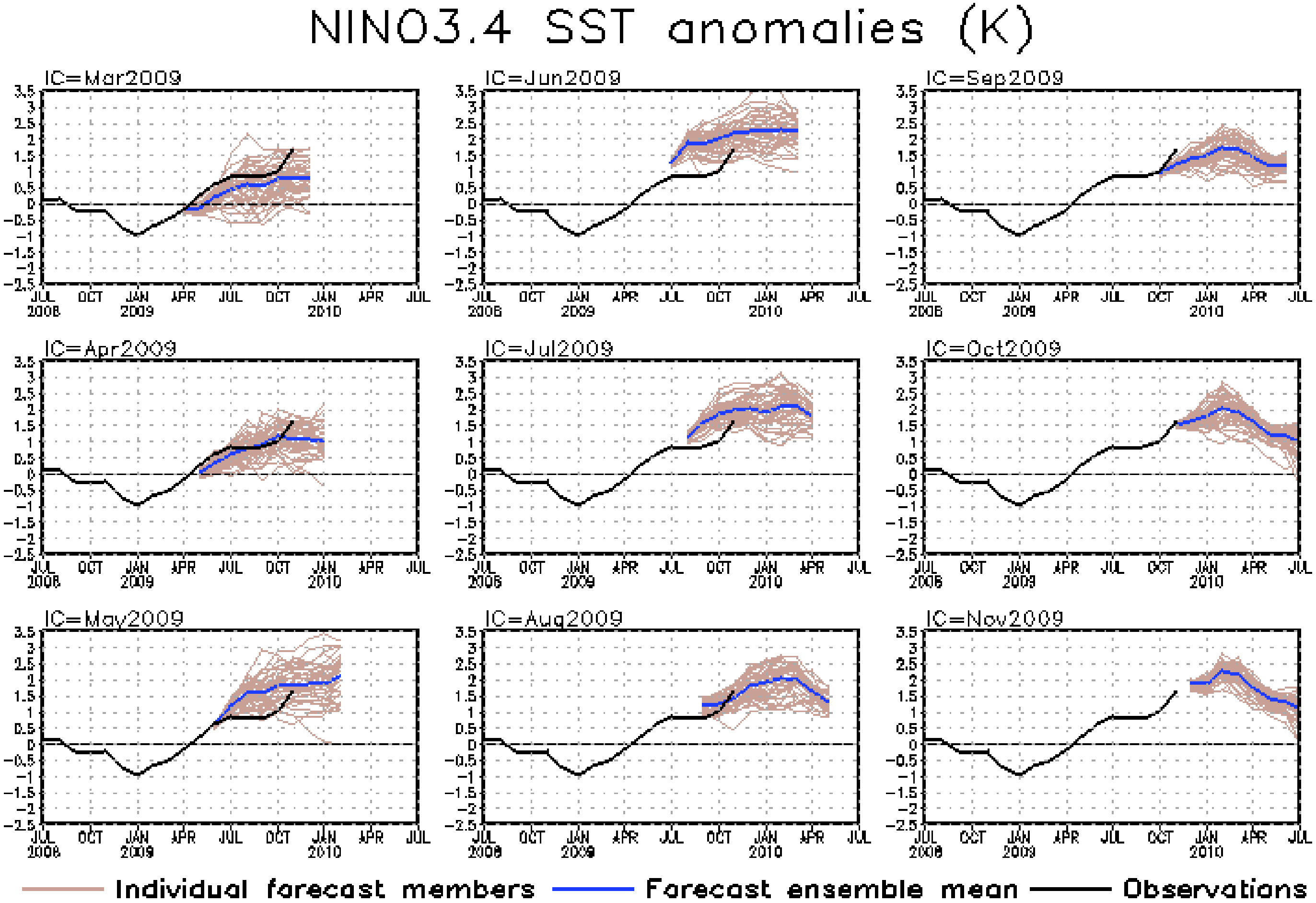
- Mid-latitude North Atlantic SSTs cooled down and became slightly below-normal since spring 09.

- SST in the Hurricane Main Development Region was weakly above-normal in summer/fall 09, similar to that last year.

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



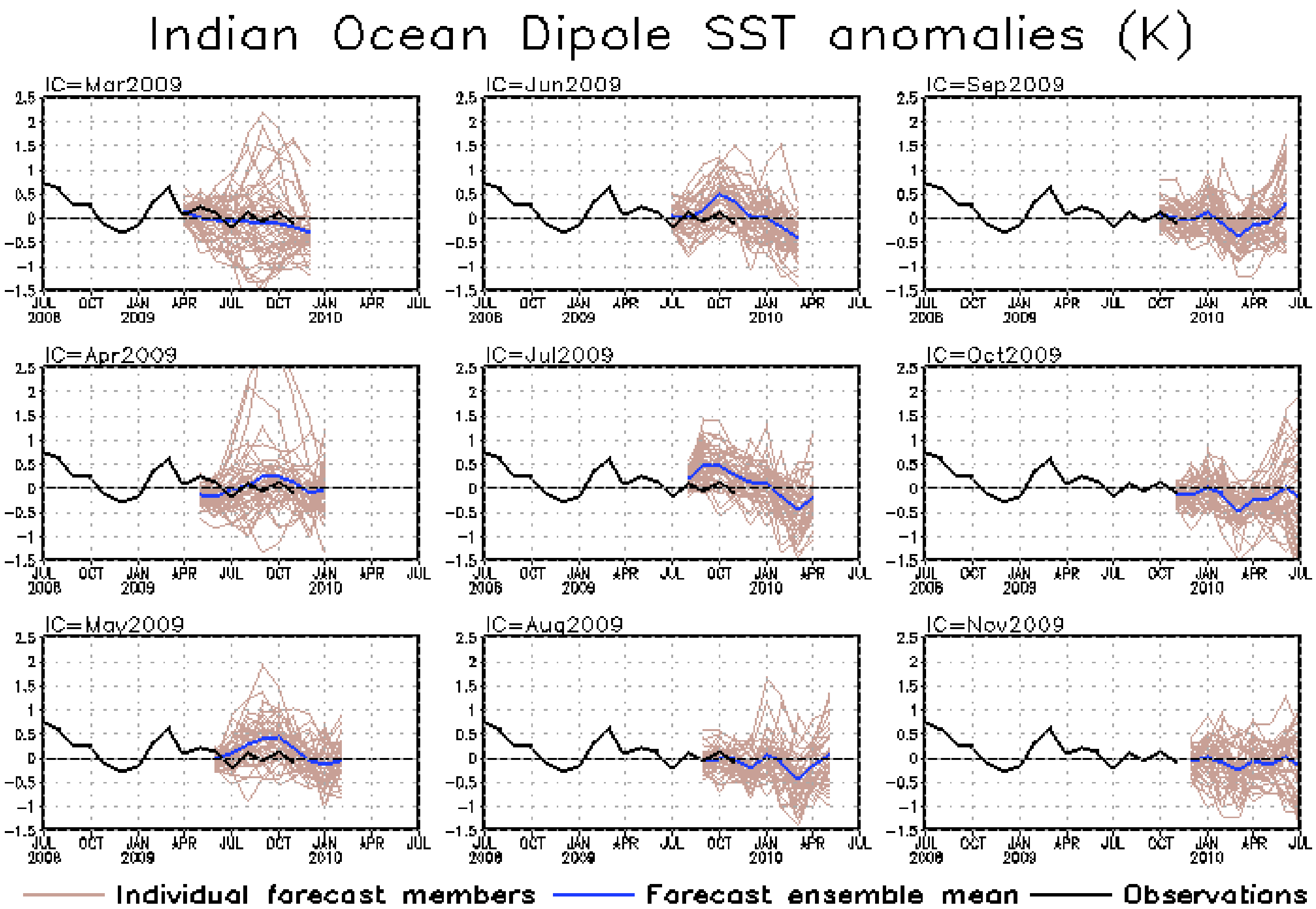
- Good forecasts from Mar-Apr I.C.

- Too warm forecasts from May-Jul I.C..

- Latest forecasts suggest 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]

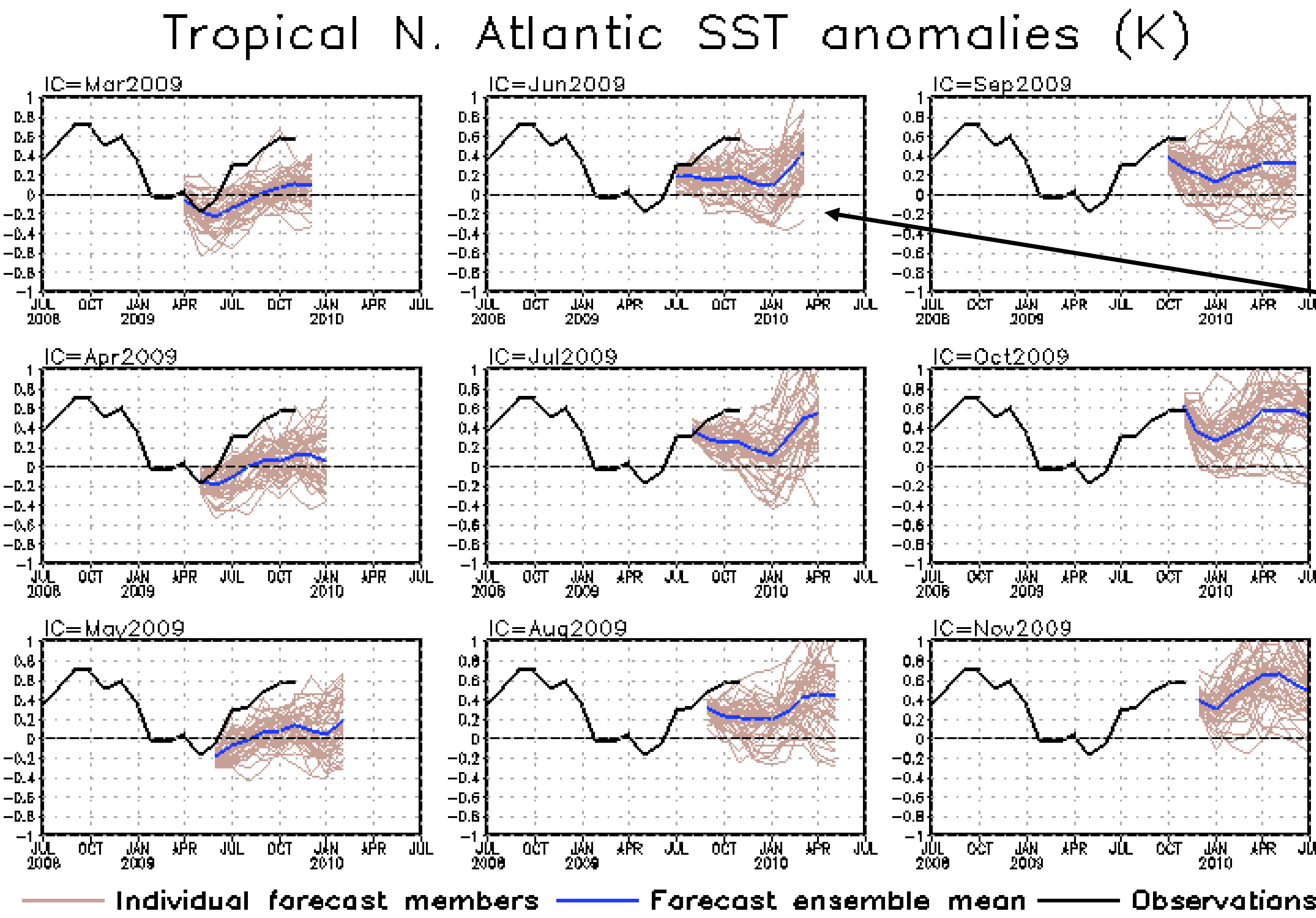
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

- Good 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



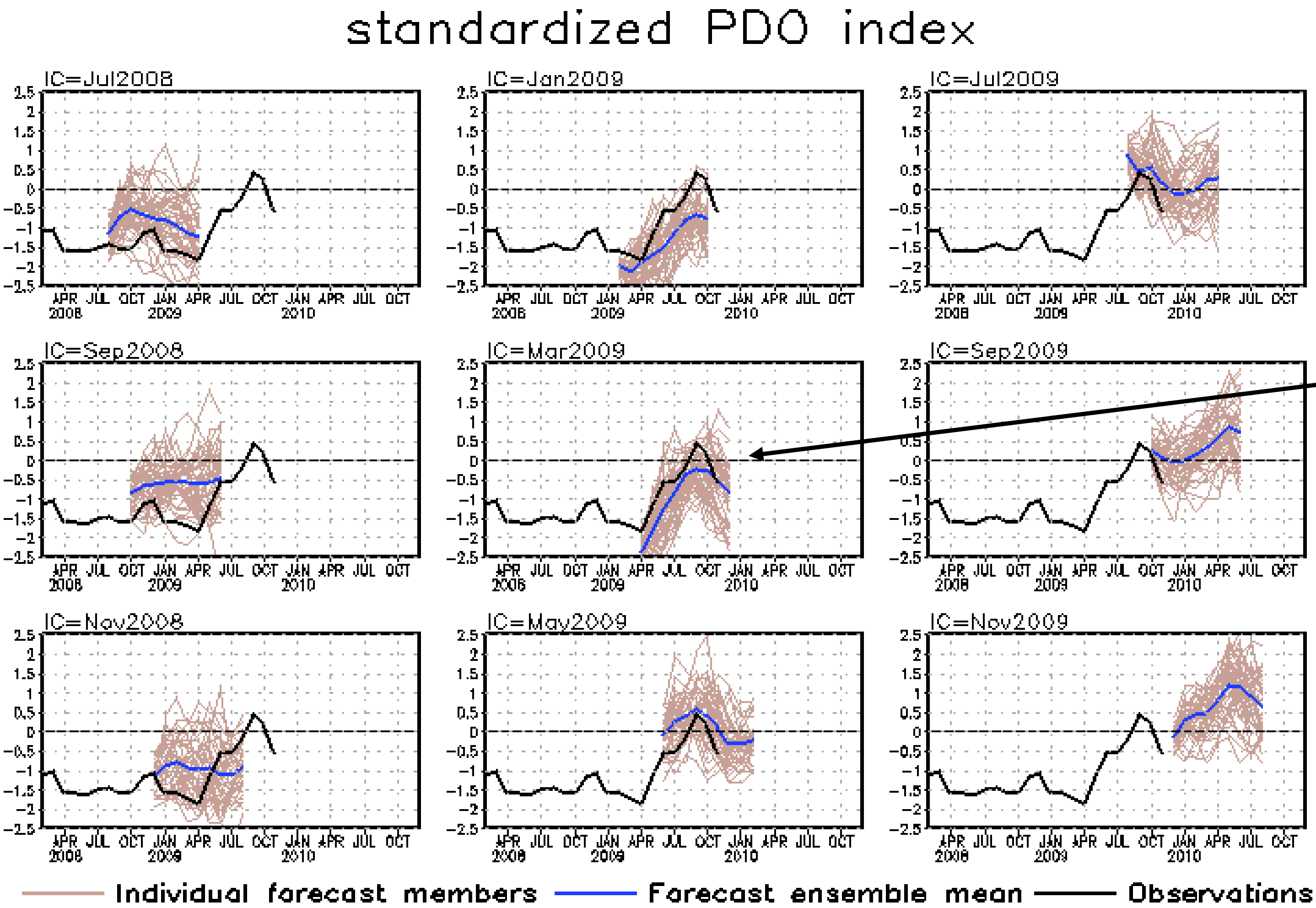
TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- Missed the warming trend in early summer from Jan-May I.C.
- Damped the initial positive SSTA from Jun-Oct I.C..

- Latest forecasts suggested that the positive tropical North Atlantic SST anomalies would weaken in next 2 months and then strengthen in early spring due to the impacts of the 09/10 El Nino.

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 ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

CFS PDO index is the standardized projection of CFS SST forecast anomalies onto the PDO EOF pattern.

- Nice forecasts from Feb-Apr I.C.

Latest forecasts suggested that the PDO will be above-normal in spring/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 ^{o}C), which established in Jun 09, persisted during Jul-Oct 09, and strengthened substantially in Nov 09, are expected to reach a moderate-to-strong strength during the Northern Hemisphere winter 2009-2010;
  - Westerly wind bursts events, active in Jul, Sep, Oct 09, contributed to the maintenance and strengthening of the 2009/10 El Niño;
  - PDO was weakly above-normal in Sep-Oct 2009, but changed to below-normal in Nov 09;
  - Upwelling along the west coast of North America was mostly above-normal in Nov 09.
- **Indian Ocean**
  - Westerly wind anomalies were present in the western tropical Indian Ocean in Nov 09, probably associated with the Madden-Julian Oscillation activity;
  - Positive SSTA decreased substantially in the west-central tropical Indian Ocean in Nov 09, and Dipole Mode Index has been near-normal since Mar 09.
- **Atlantic Ocean**
  - SST and tropical cyclone heat potential (TCHP) were above normal in the tropical North Atlantic during the Atlantic Hurricane Season;
  - Convection was mostly suppressed in the tropical Atlantic;
  - Vertical wind shear was mostly above-normal over the Caribbean Sea.

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!