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

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

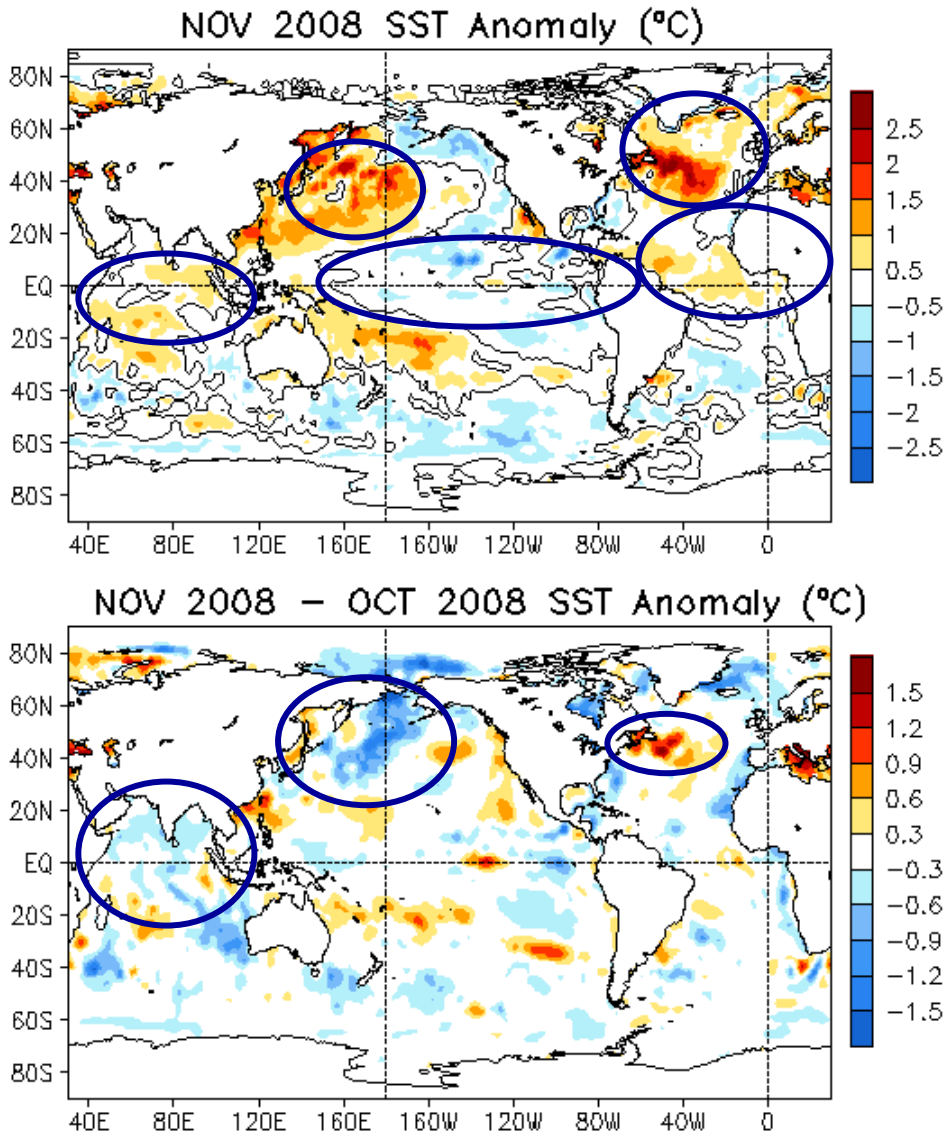
Outline

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

Overview

- **Pacific Ocean**
  - Current ENSO-neutral conditions are expected to continue into early 2009.
  - Persistent convection over the Maritime continent is producing anomalous easterlies over the central and western Pacific ocean maintaining the below normal SST near the dateline.
  - PDO index is hovering around -1.5 since April 2008, the lowest values since 1999.
- **Indian Ocean**
  - Positive SST anomalies across much of the tropical Indian ocean.
- **Atlantic Ocean**
  - Positive SST anomalies extend from the eastern Caribbean sea to the coast of equatorial Africa.
  - North Atlantic SST is much above average.
- **Arctic Ocean**
  - Ice concentration remains below normal.

Global SST Anomaly (⁰C) and Anomaly Tendency



-- **Positive SSTA in W. North Pacific and North Atlantic.**

- **Near-normal SST in the tropical Pacific.**

- **Positive SSTA in tropical Atlantic and Indian Ocean.**

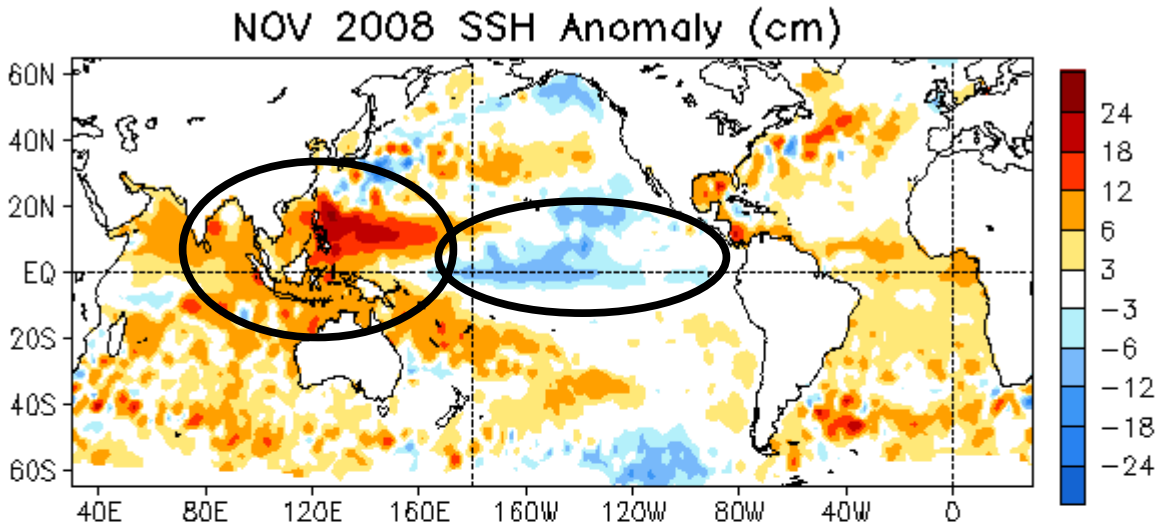
- **SST cooled down over most of the tropical Indian Ocean.**

- **SST cooled down north of Bering Sea and western North Pacific.**

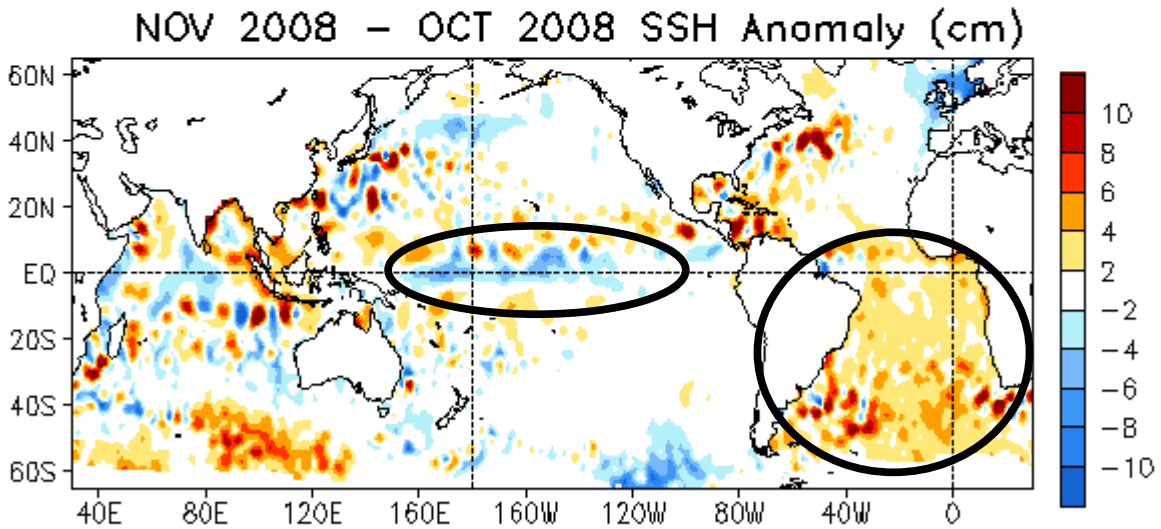
- **SST warmed up in the central North Atlantic.**

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.

Global SSH Anomaly (cm) and Anomaly Tendency



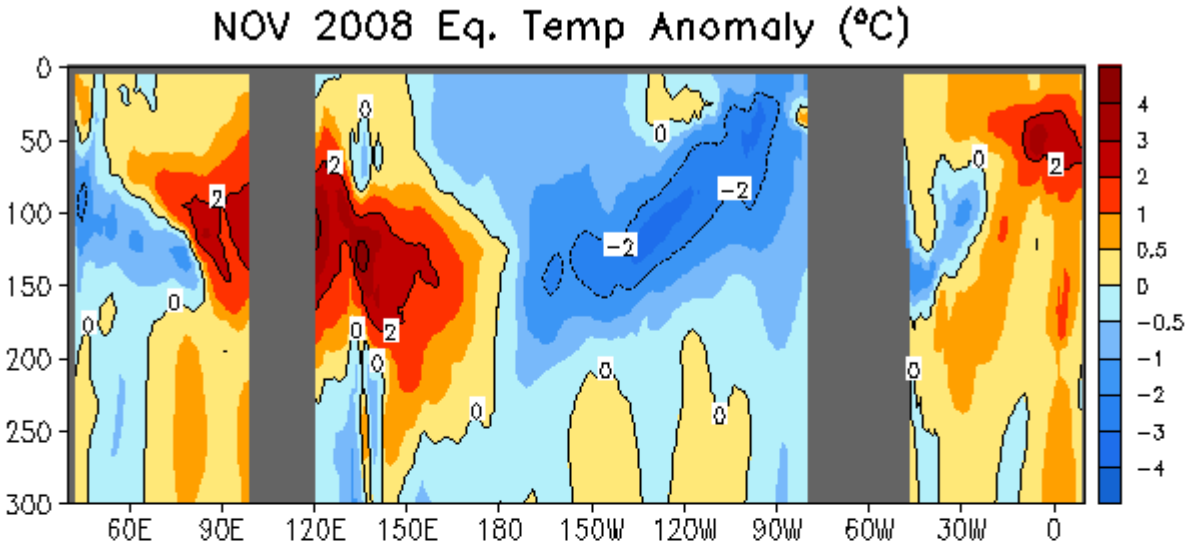
- **Negative SSHA in central and eastern equatorial Pacific.**
- **Positive SSHA in most of the tropical Indian Ocean and Western Pacific.**



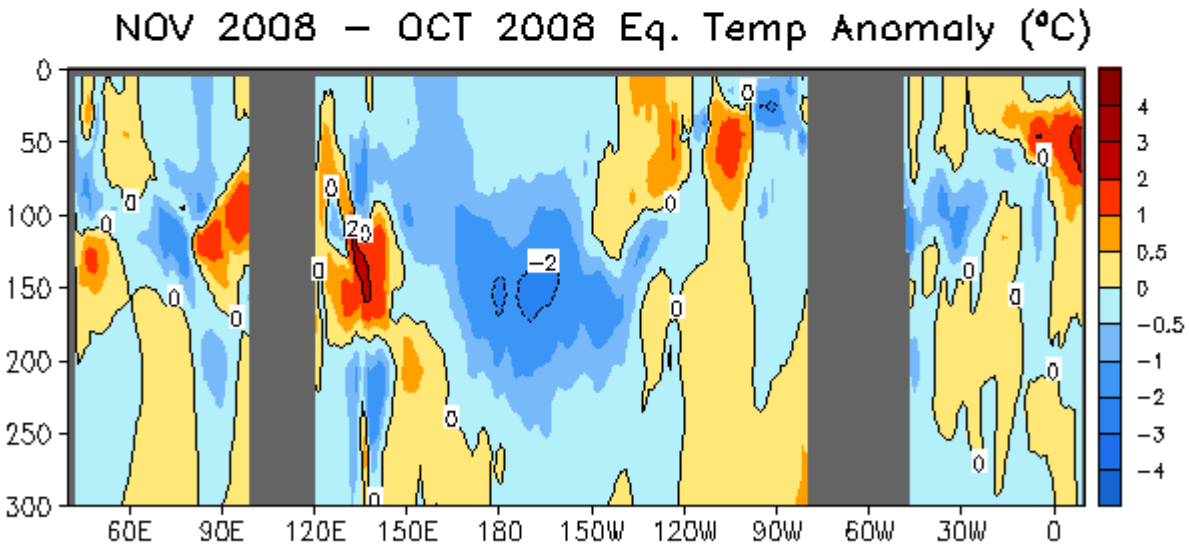
- **SSH decreased in the central tropical Pacific.**
- **SSH increased in the southern Atlantic.**

Fig. G2. Sea surface height anomalies (top) and anomaly tendency (bottom). Data are derived from http://www.aviso.oceanobs.com . Anomalies are departures from the 1993-2005 base period means.

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



- Positive (negative) subsurface temperature anomalies in the western (central-eastern) Pacific.
- Positive subsurface temperature anomalies in the tropical Atlantic and most of the tropical Indian Ocean.

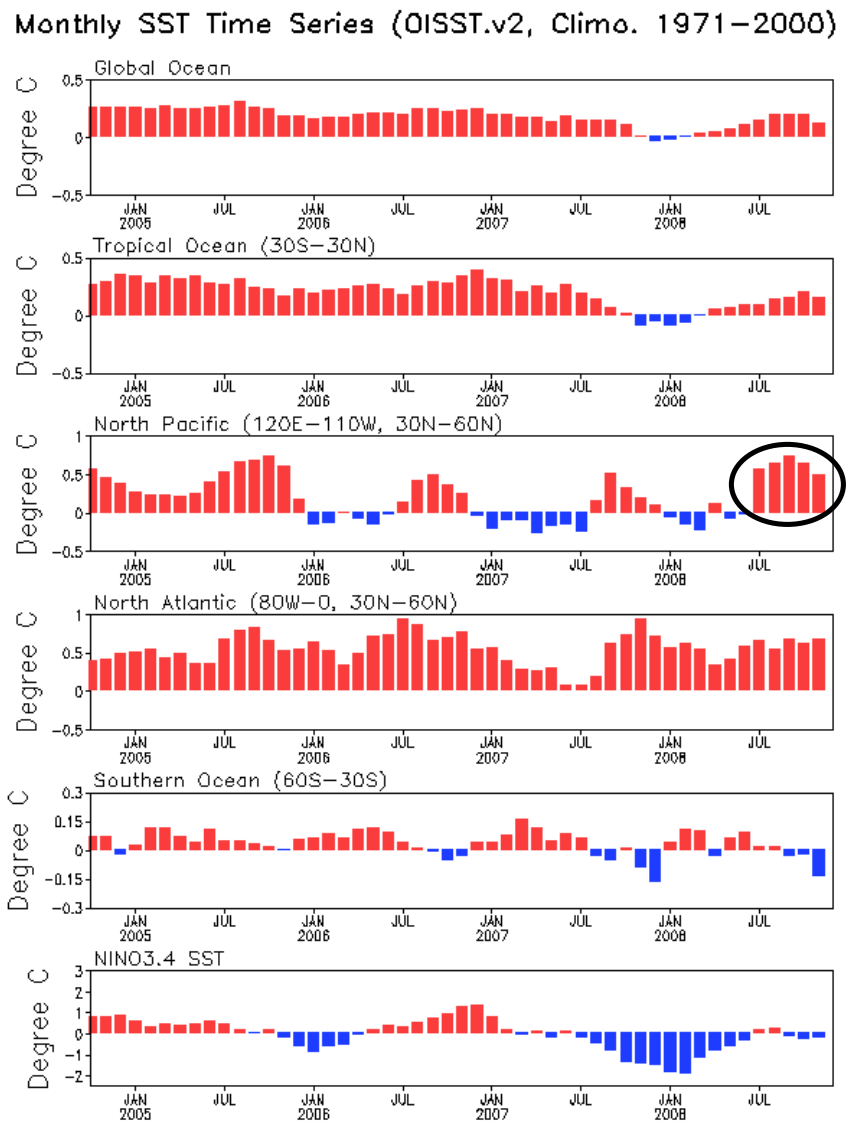


- Temperature decreased in the central Pacific.
- Temperature increased in the eastern Atlantic near the thermocline.

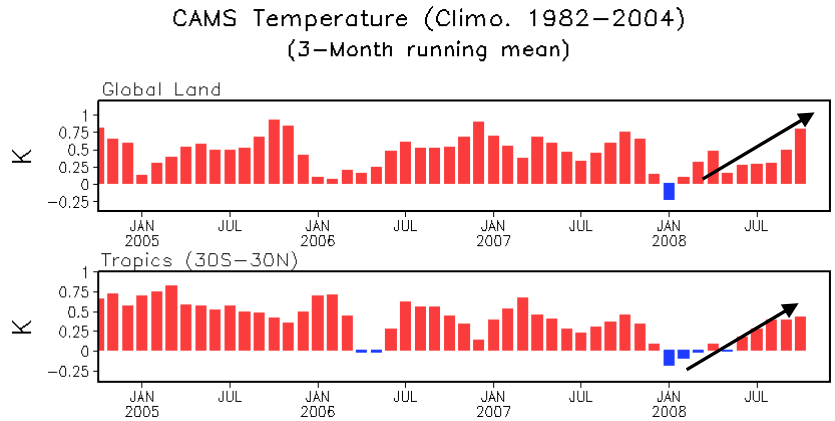
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1982-2004 base period means.

Monthly Time Series

Sea Surface Temperature



CAMS Land Temperature

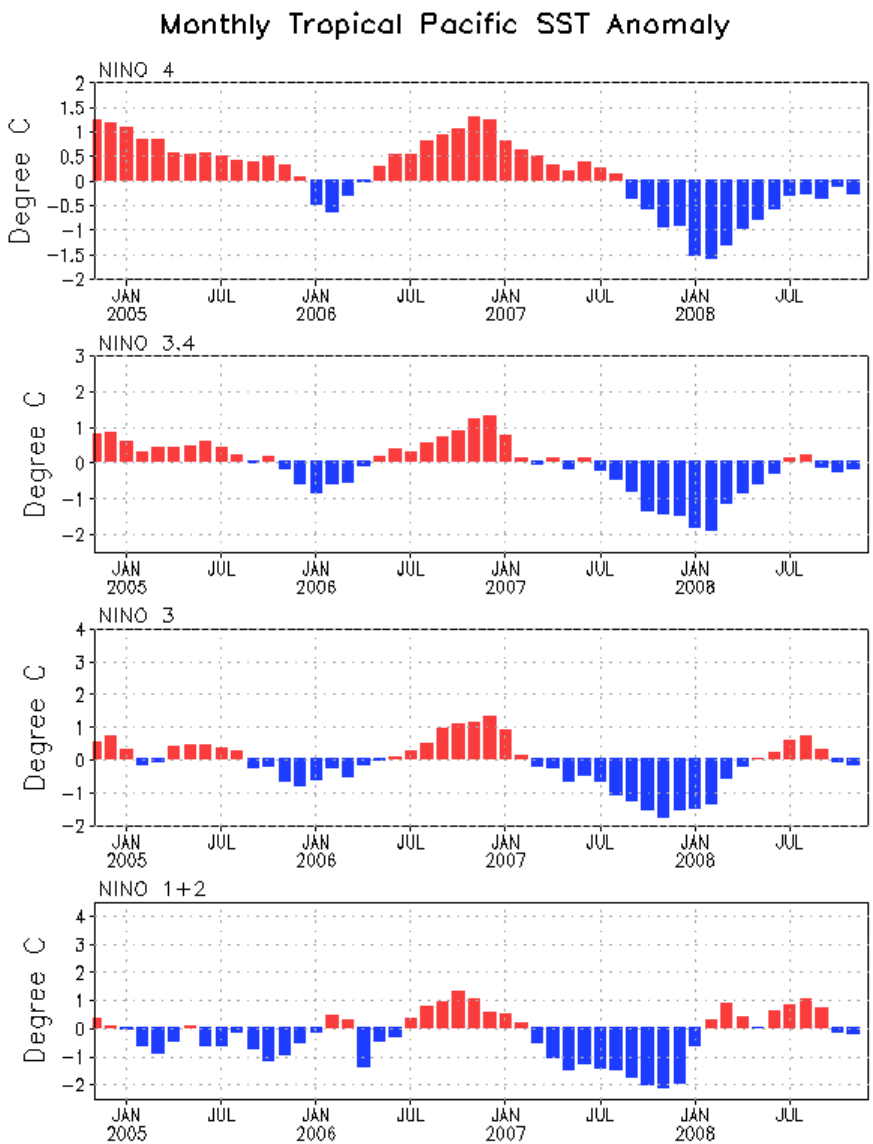


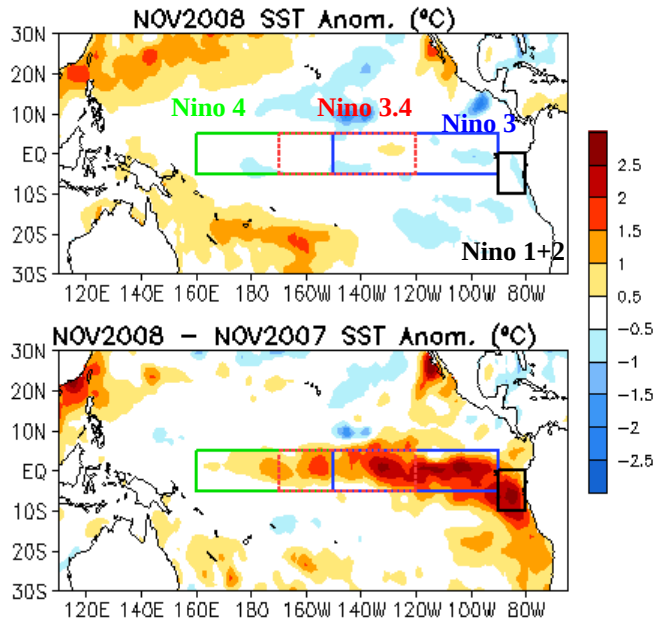
- **Global mean SSTA cooled slightly in November.**
- **Tropical Surface Air Temperature over land has been trending upward in response to the upward trend in tropical ocean SSTA.**
- **Strong positive SSTA in North Pacific persisted in July-November 08.**
- **Strong positive SSTA in North Atlantic has persisted from September 07 to present.**
- **Southern Oceans cooled down in Nov 08.**
- **NINO3.4 SST remains slightly below-normal.**

Fig. BU. Sea surface temperature (SST) anomalies (left) and surface air temperature anomalies (right) average for selected regions. Due to larger variability, the surface air temperature anomalies have a 3-month running mean applied. Anomalies were computed with respect to the 1971-2000 base period means.

Tropical Pacific Ocean

Evolution of Pacific NINO SST Indices



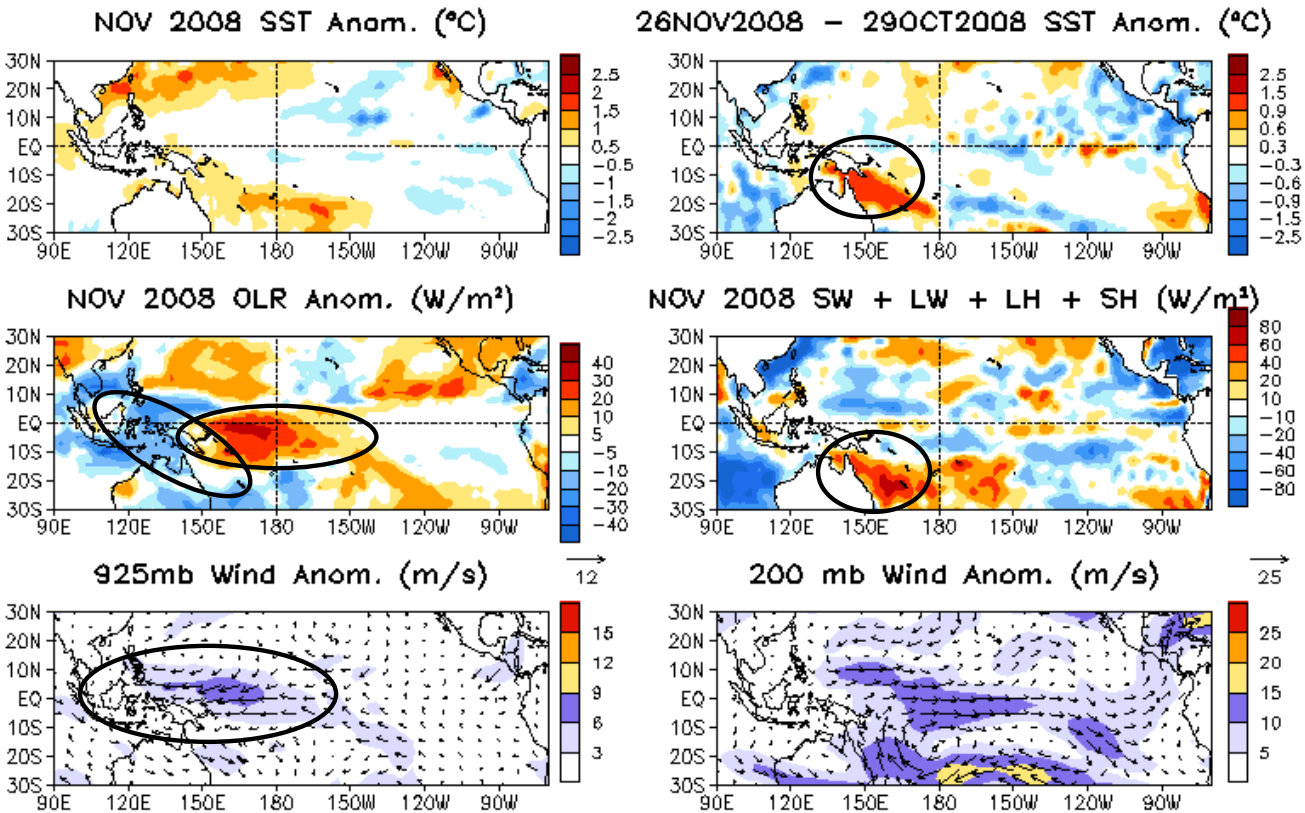


- ENSO-neutral conditions presented, and are expected to continue into early 2009 – NOAA's "ENSO Diagnostic Discussion".

- All NINO indices are slightly below-normal.

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

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



- **Convection suppressed (enhanced) in C. Pacific (Maritime Continent).**
- **Low-level easterly wind anomalies in W. tropical Pacific.**
- **Warming in the Coral Sea north of Australia consistent with surface flux anomalies.**

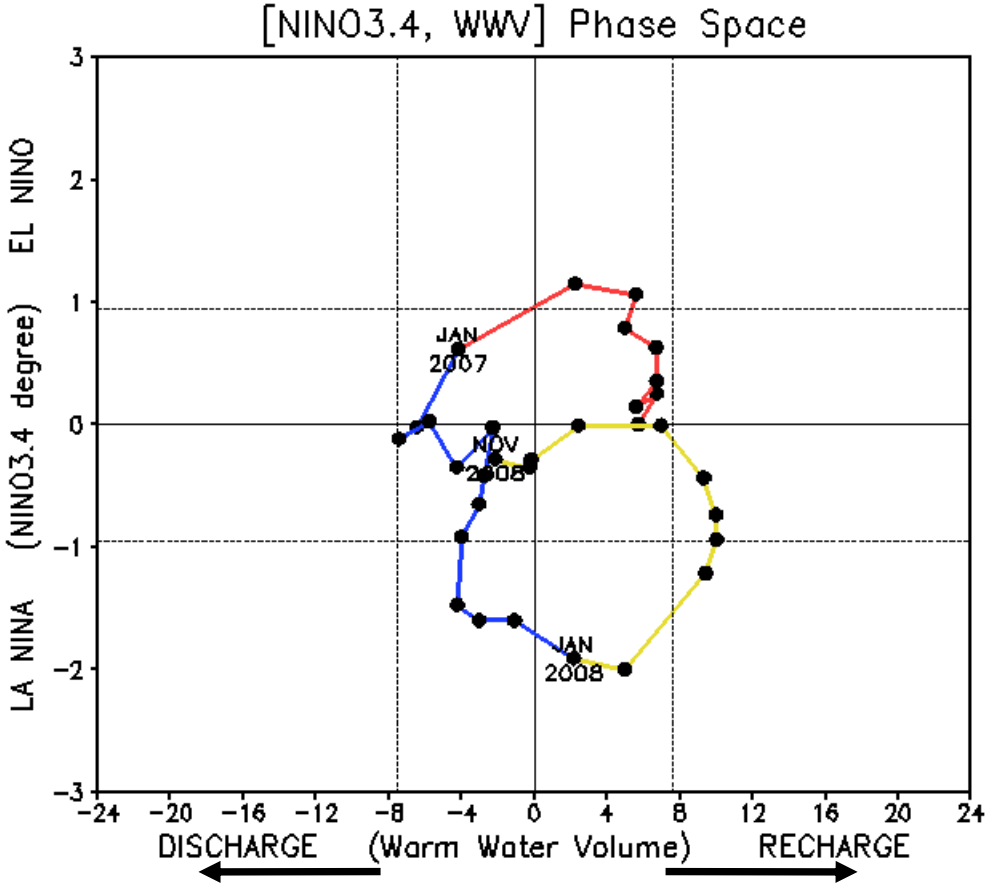
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

Warm Water Volume (WWV) and NINO3.4 Anomalies

-WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N] (Meinen and McPhaden, 2000).

-Since WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and NINO3.4 (Kessler 2002).

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

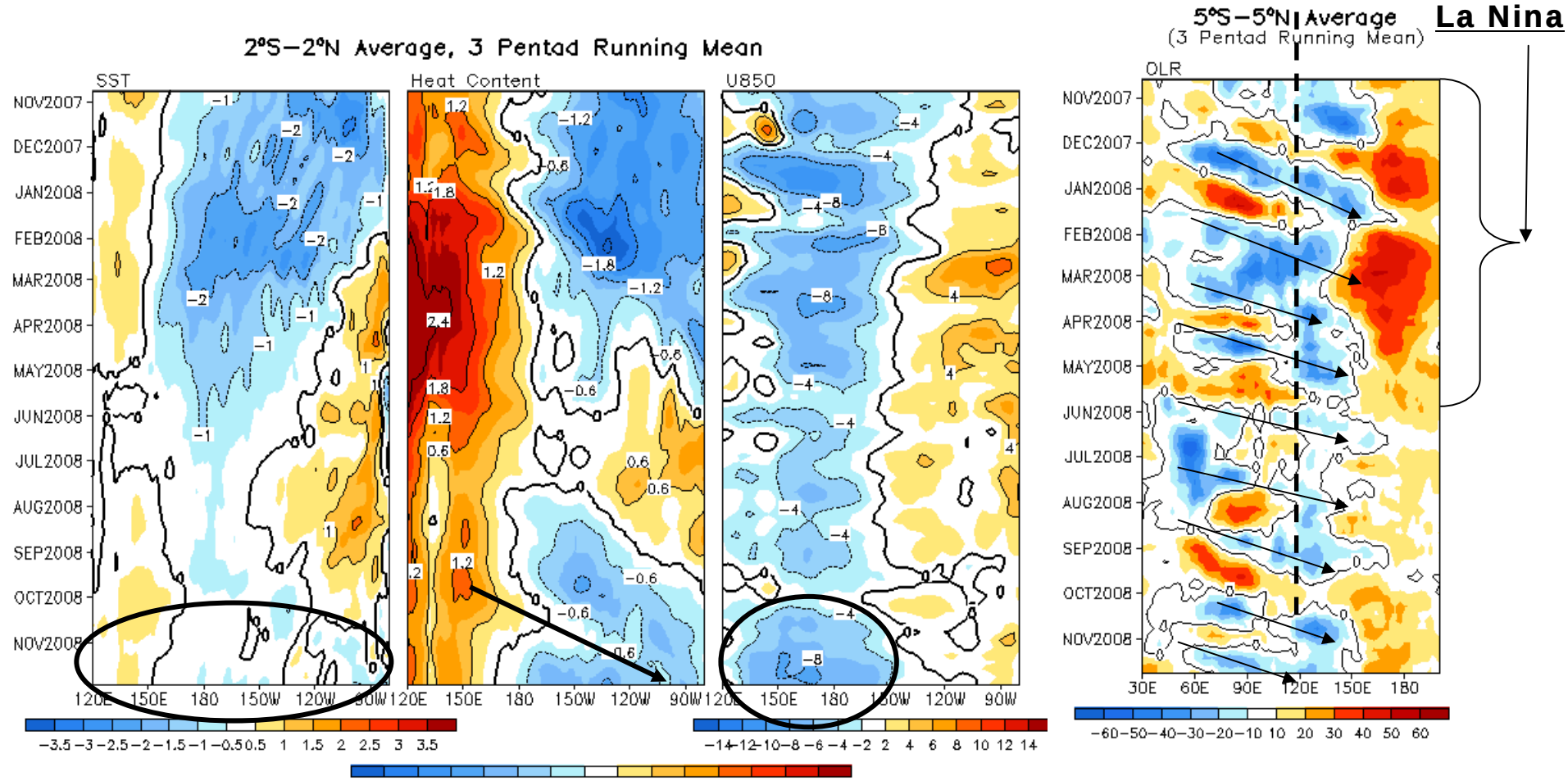


- Warm Water Volume(WWV) has increased from February to May, but decreased from June to November.

- Both NINO3.4 and WWV are close to normal conditions.

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.

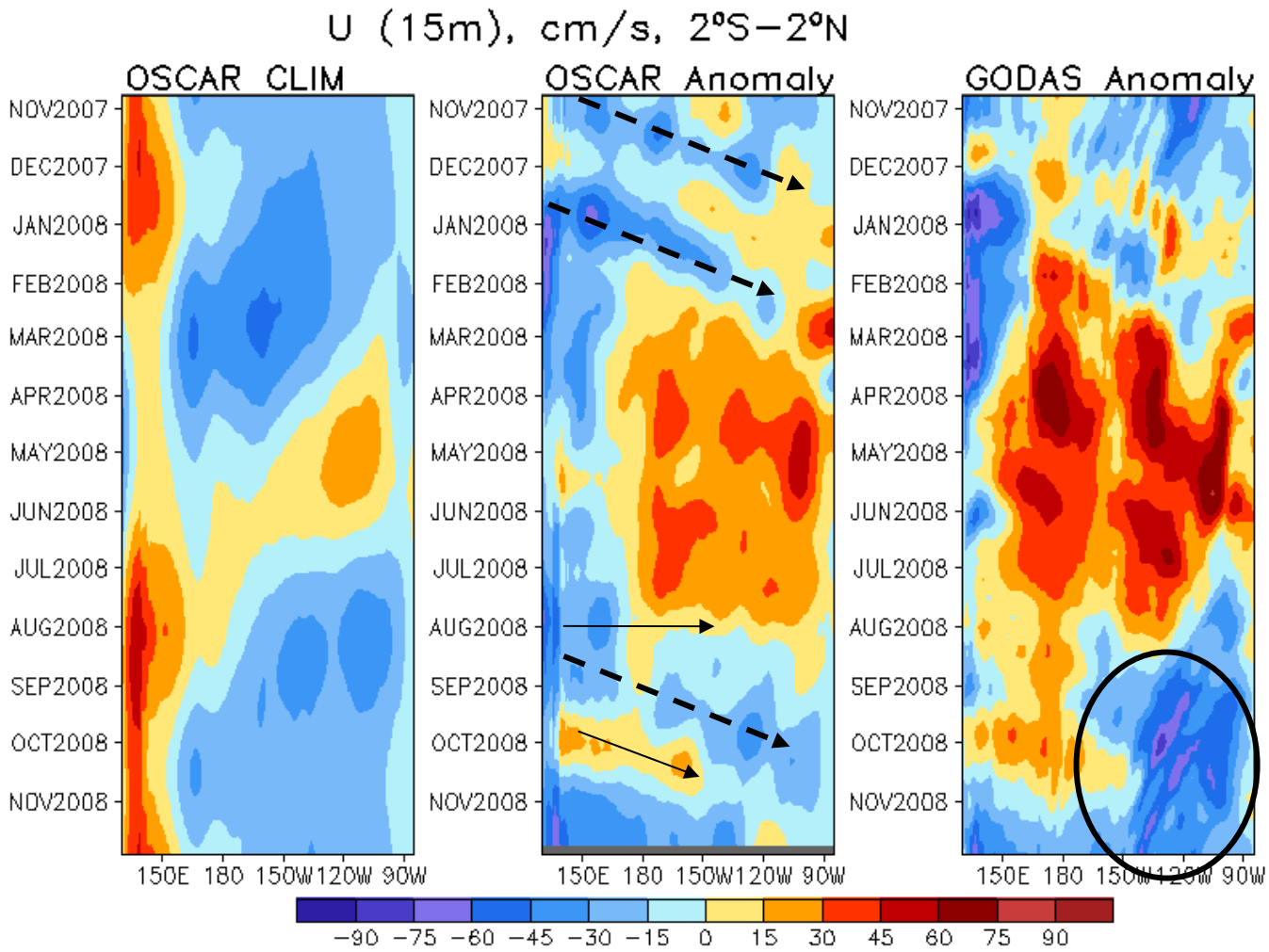
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²) Anomaly



- **Near-normal SST in the tropical Pacific.**
- **Negative heat content anomaly presented east of the Dateline since early November.**
- **They were likely forced by persistent easterly wind anomaly since early October.**

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.

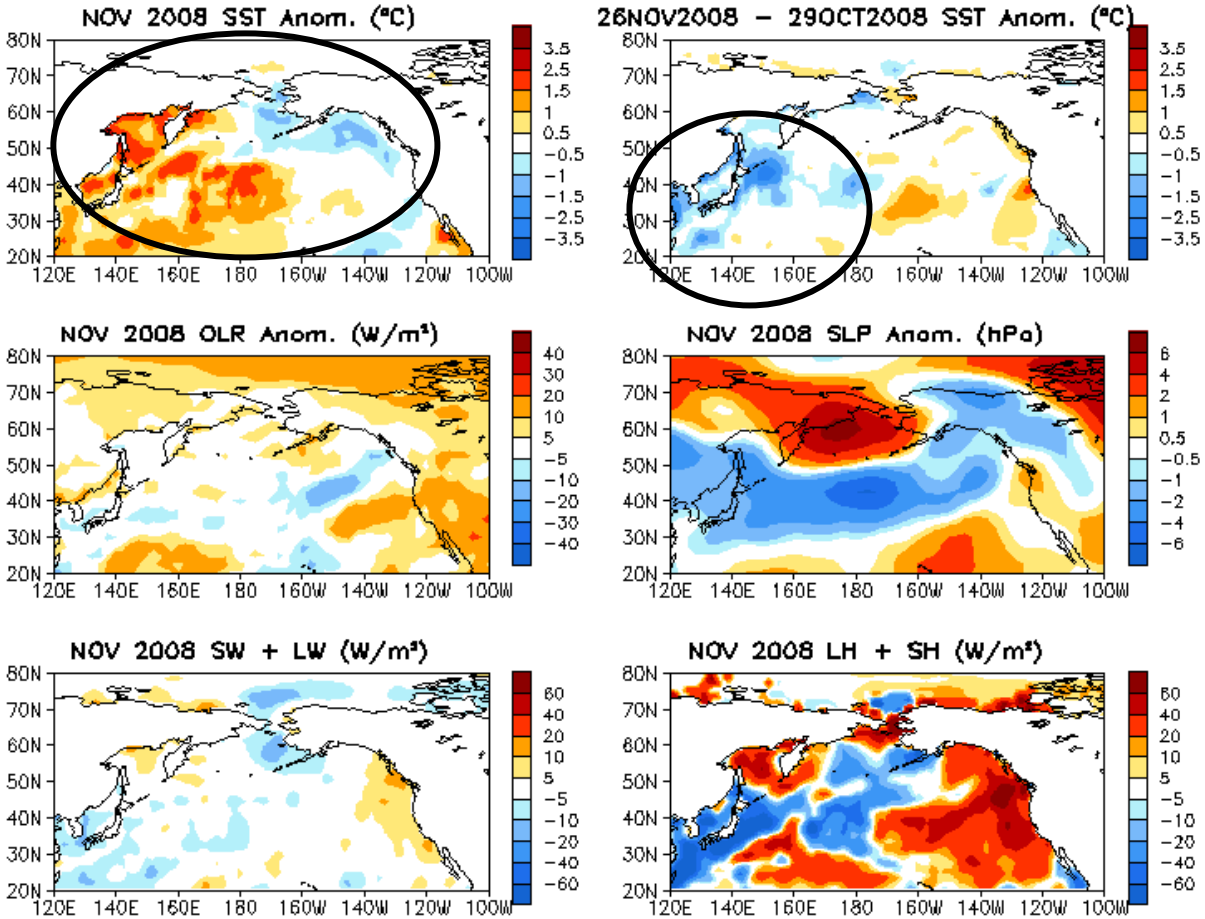
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- **Surface zonal current anomaly switched from positive to negative in early August.**
- **Eastward propagation of negative (positive) surface zonal current anomalies were associated with upwelling (downwelling) oceanic Kelvin waves.**
- **Compared to OSCAR currents, negative surface zonal current anomalies of GODAS in E. tropical Pacific were too strong.**
- **Westward surface zonal current anomaly presented in the western and central Pacific since late October.**

North Pacific & Arctic Ocean

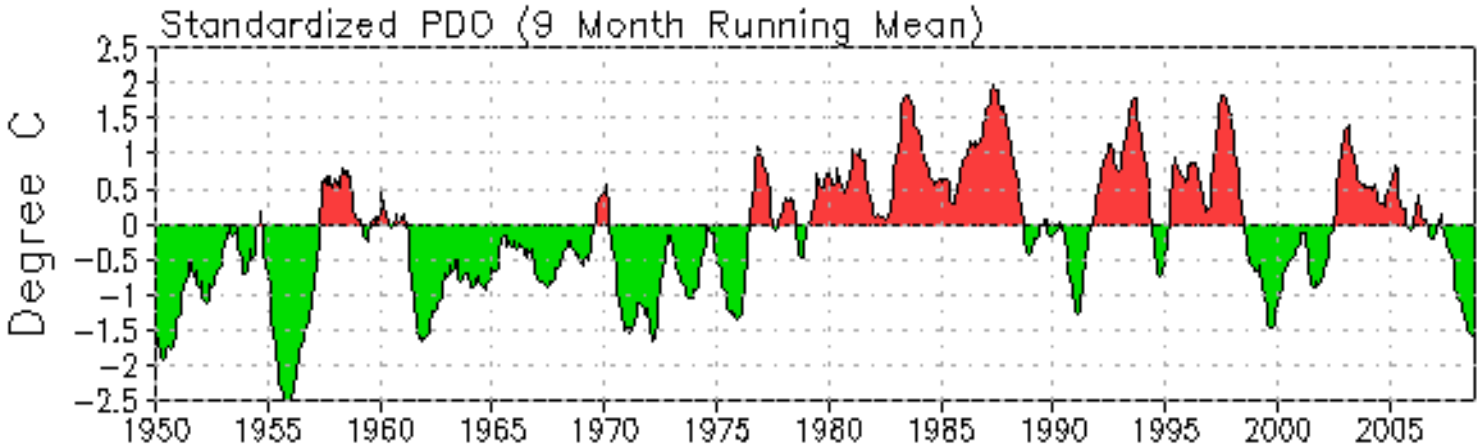
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

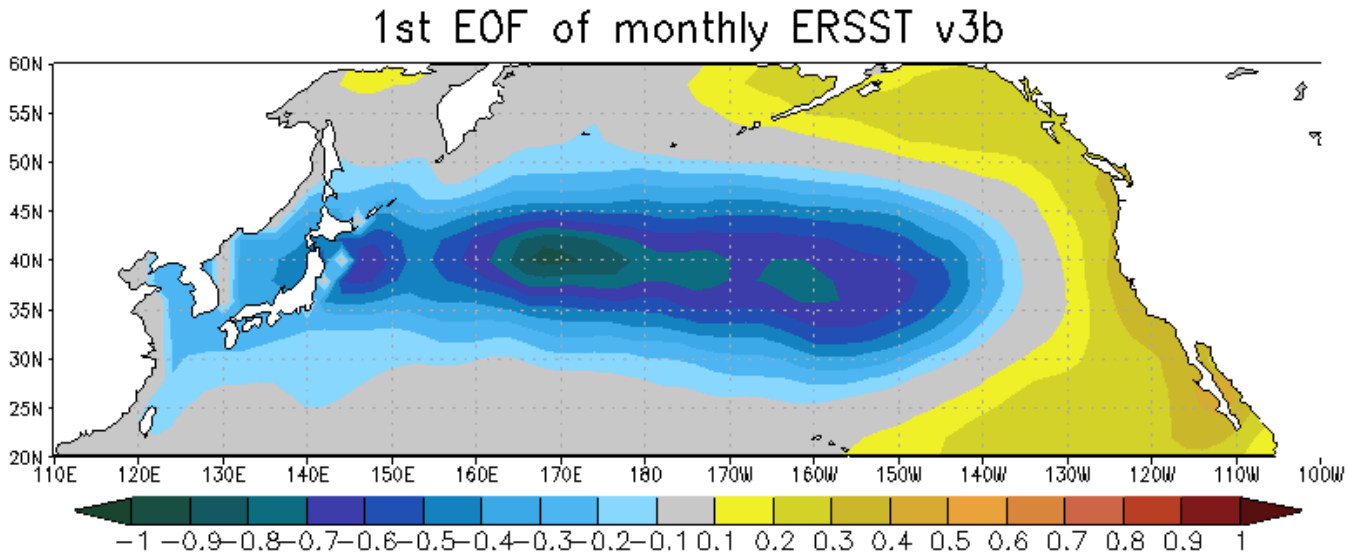


- Positive (negative) SSTA presented in the western (eastern) North Pacific.
- SSTA decreased near Japan and warmed in the east. Consistent with the turbulent flux anomalies

Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

PDO index





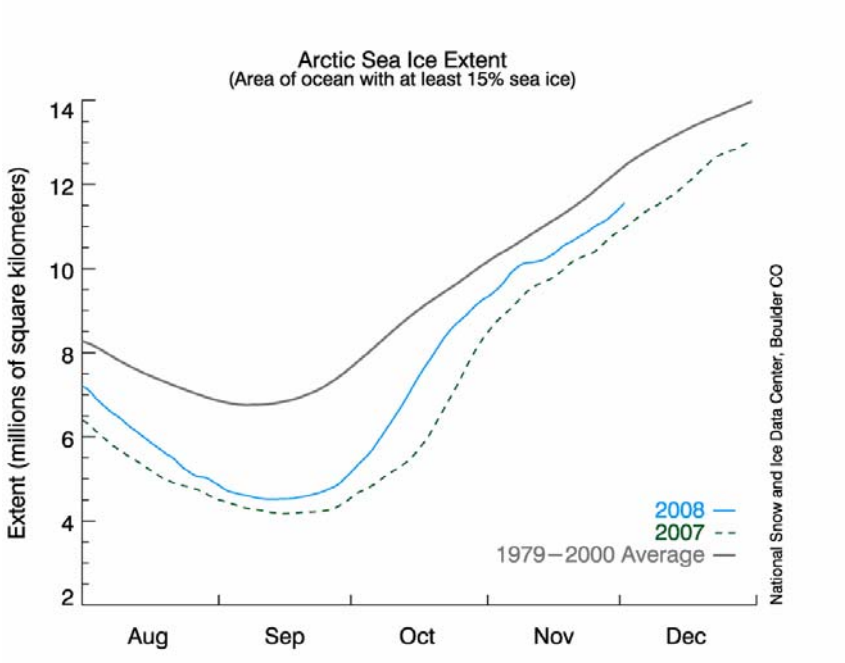
PDO index at the lowest value since 1999.

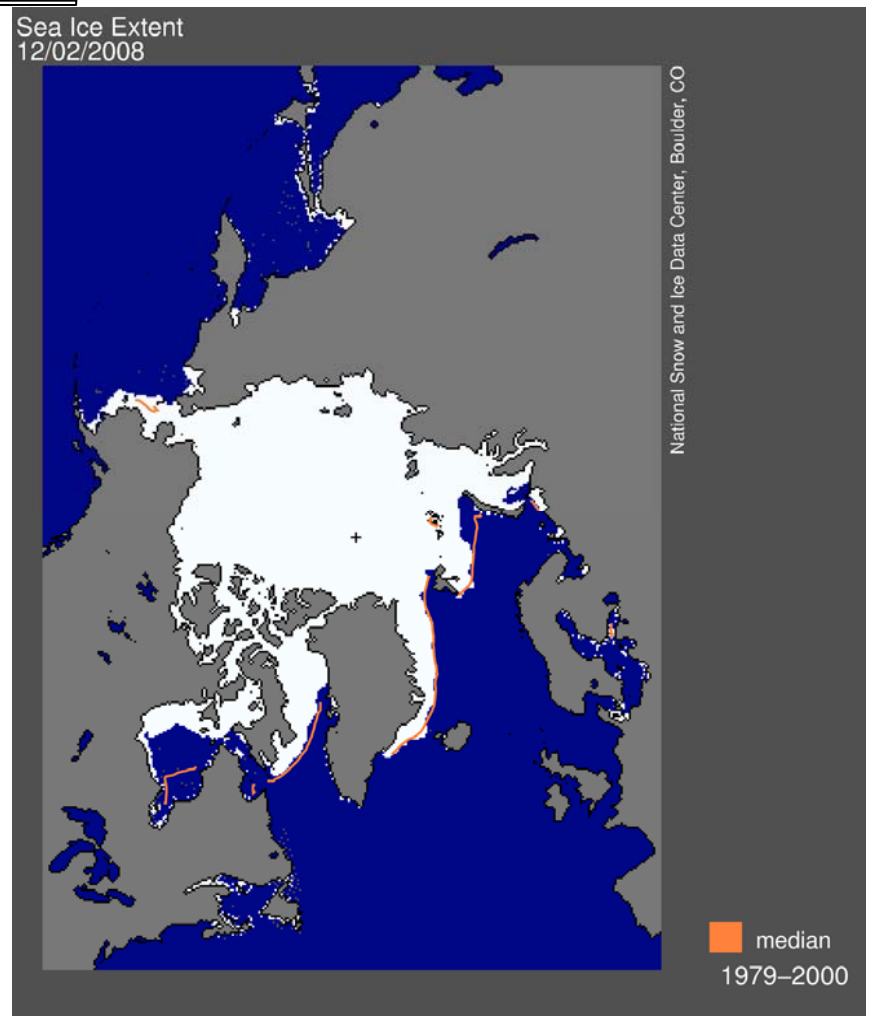
- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly SST in the North Pacific.**
- **Index is the standardized projection of the monthly SST anomalies on this pattern.**

Arctic Sea Ice

National Snow and Ice Data Center

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

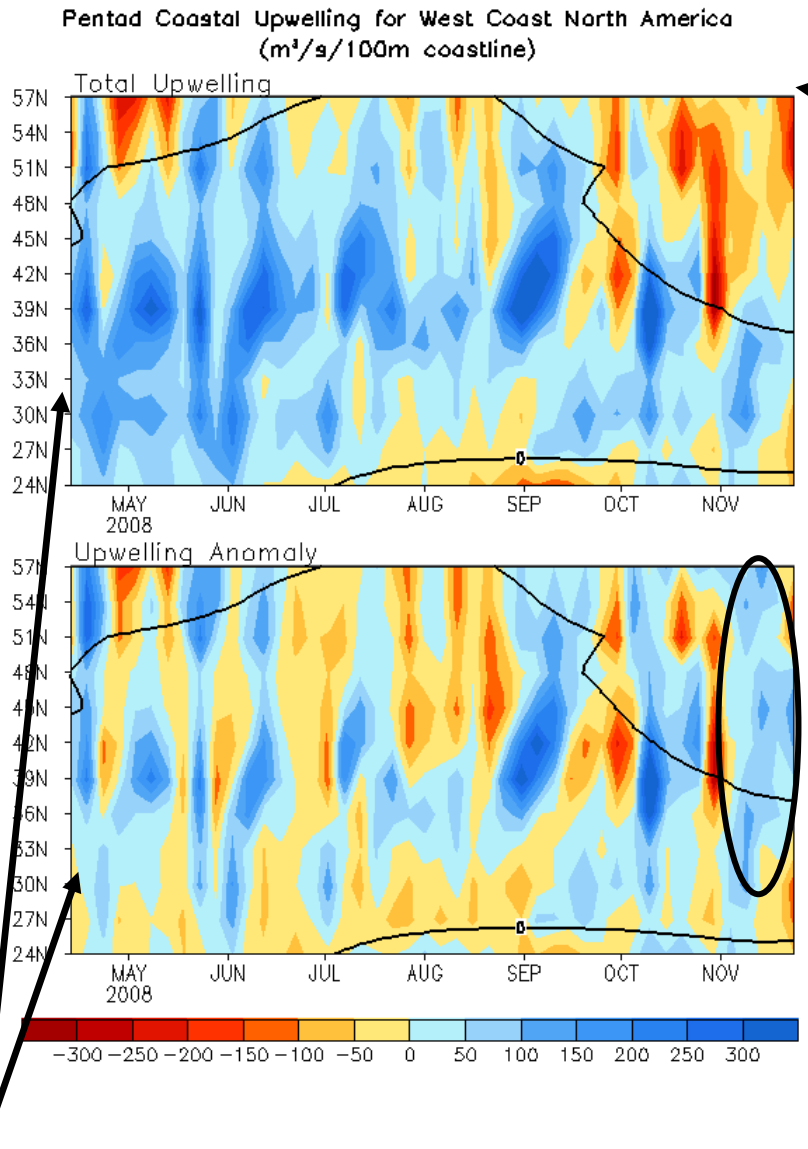


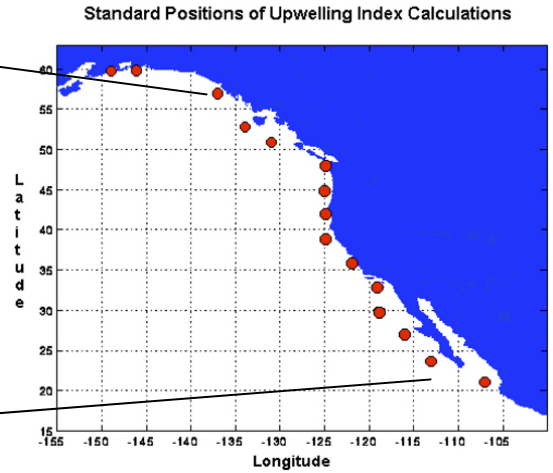


-Sea ice extent remains well below normal.

-Most of Hudson's Bay remained ice free during November.

North America Western Coastal Upwelling





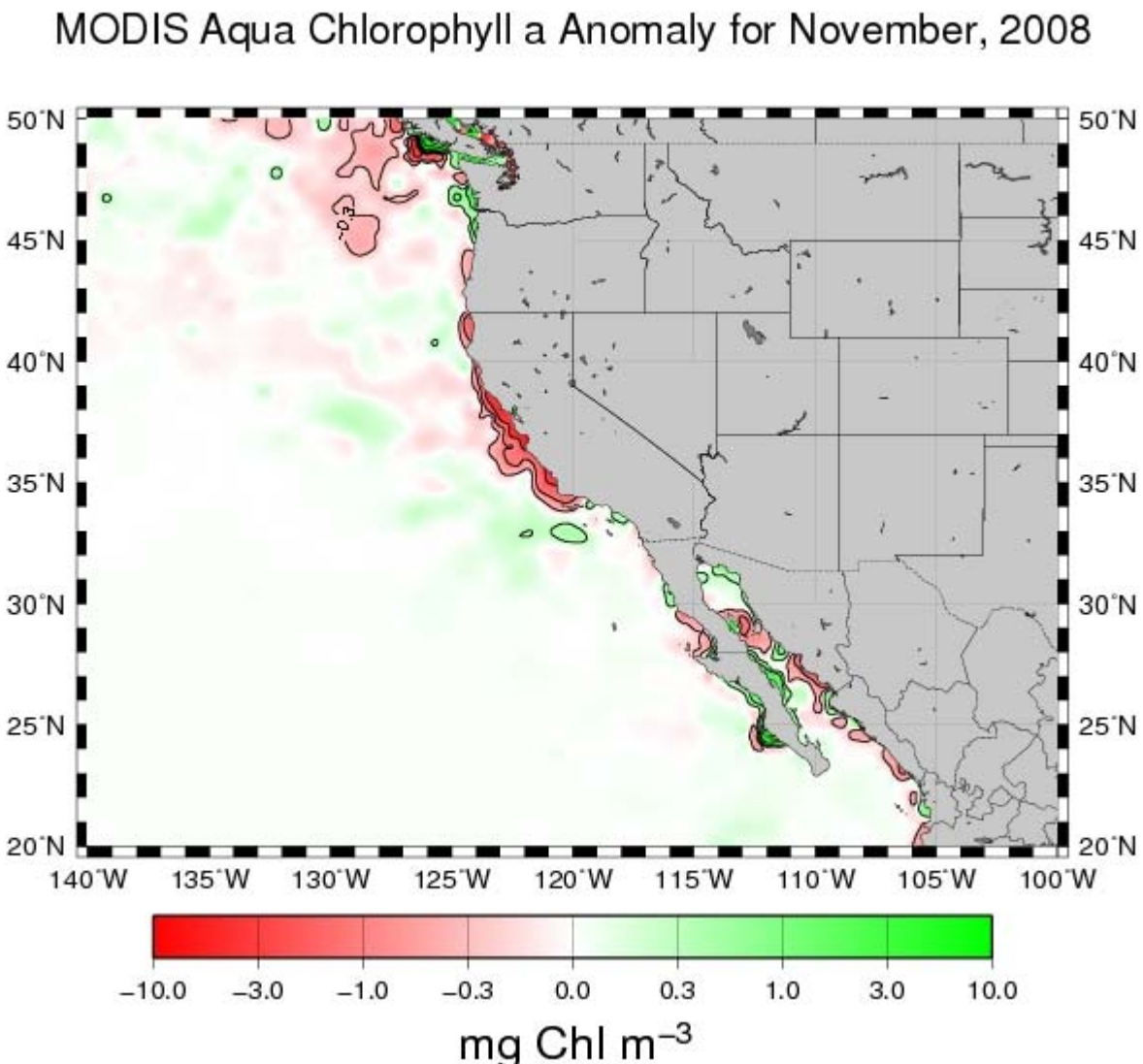
- **Positive upwelling anomaly for most of the Pacific cost for the month of November.**
- **Approaching minimum upwelling in annual cycle**

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

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

Monthly Chlorophyll Anomaly

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

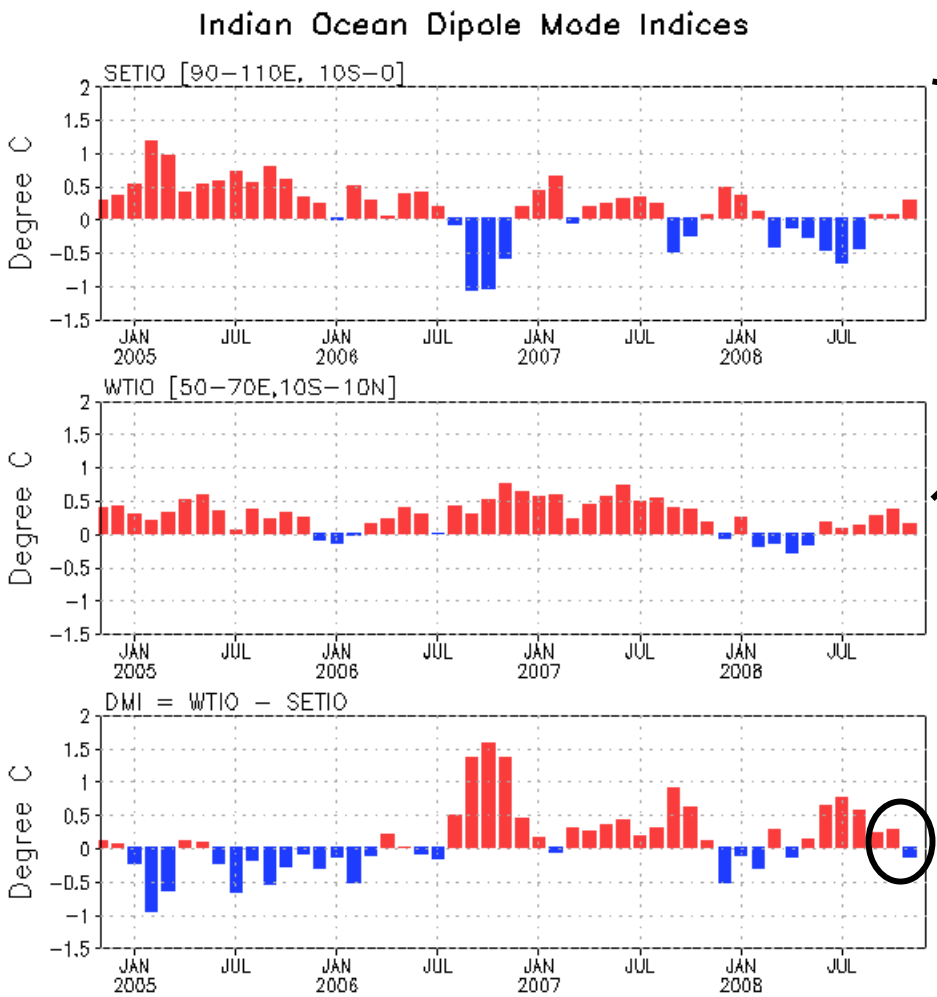


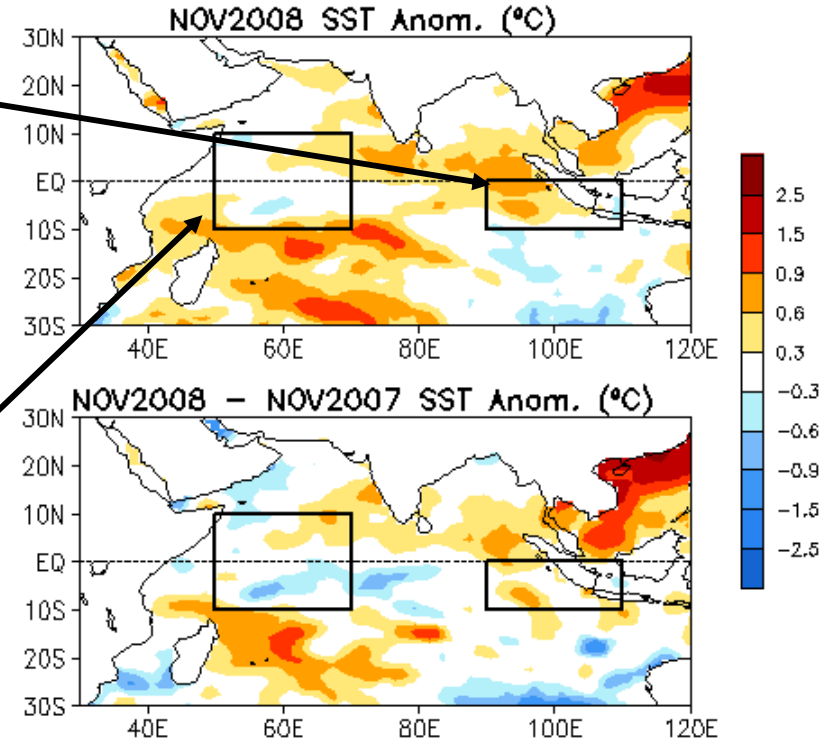
Mixed chlorophyll anomalies away from the coast

Negative anomalies right along the coast of California.

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

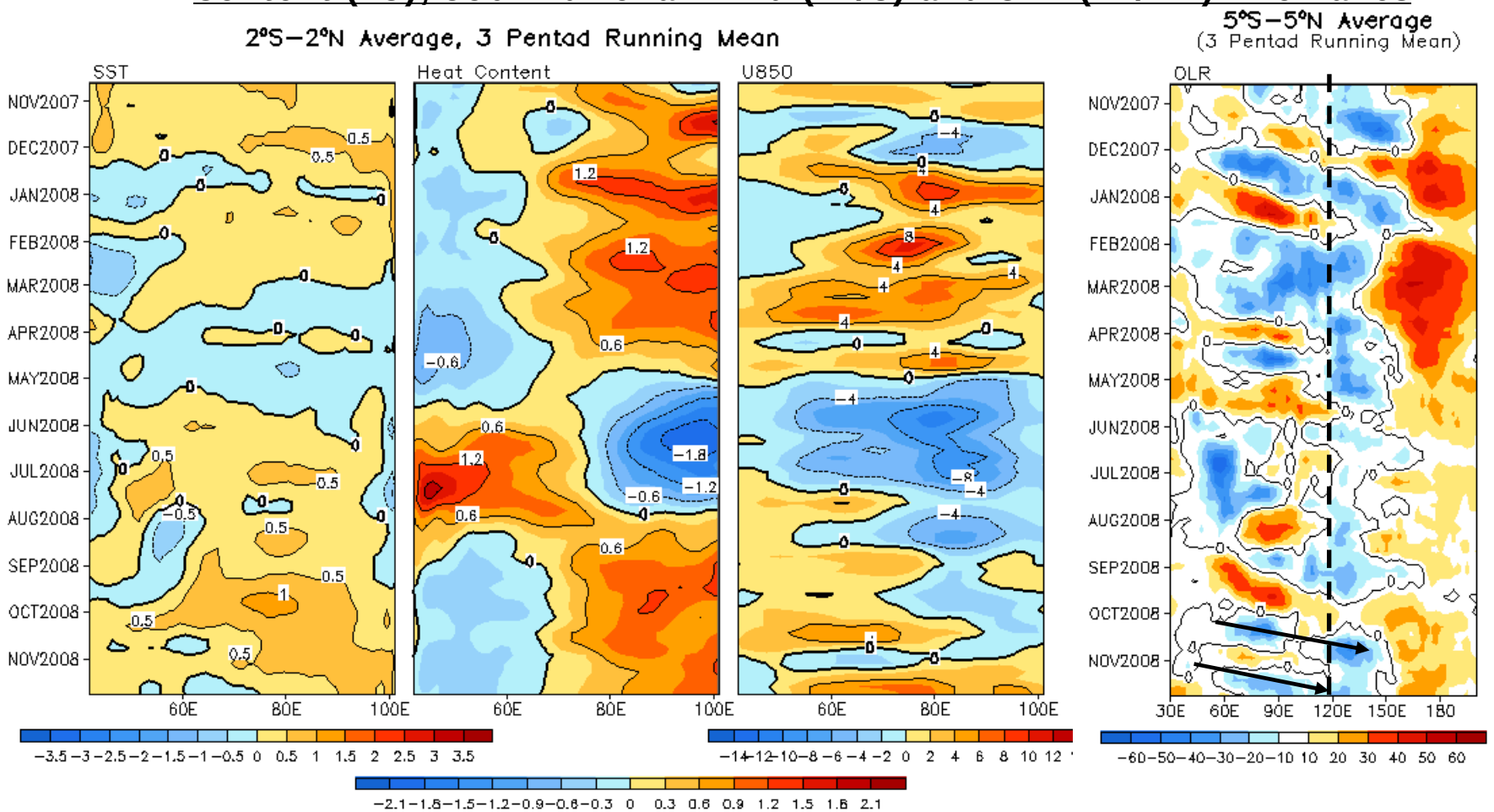




- **Dipole Mode Index (DMI) and its eastern and western pole indices were near-normal in September-November 08.**
- **Eastern Indian Ocean has warmed since July.**
- **Large warm anomalies in southern Indian Ocean.**

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.

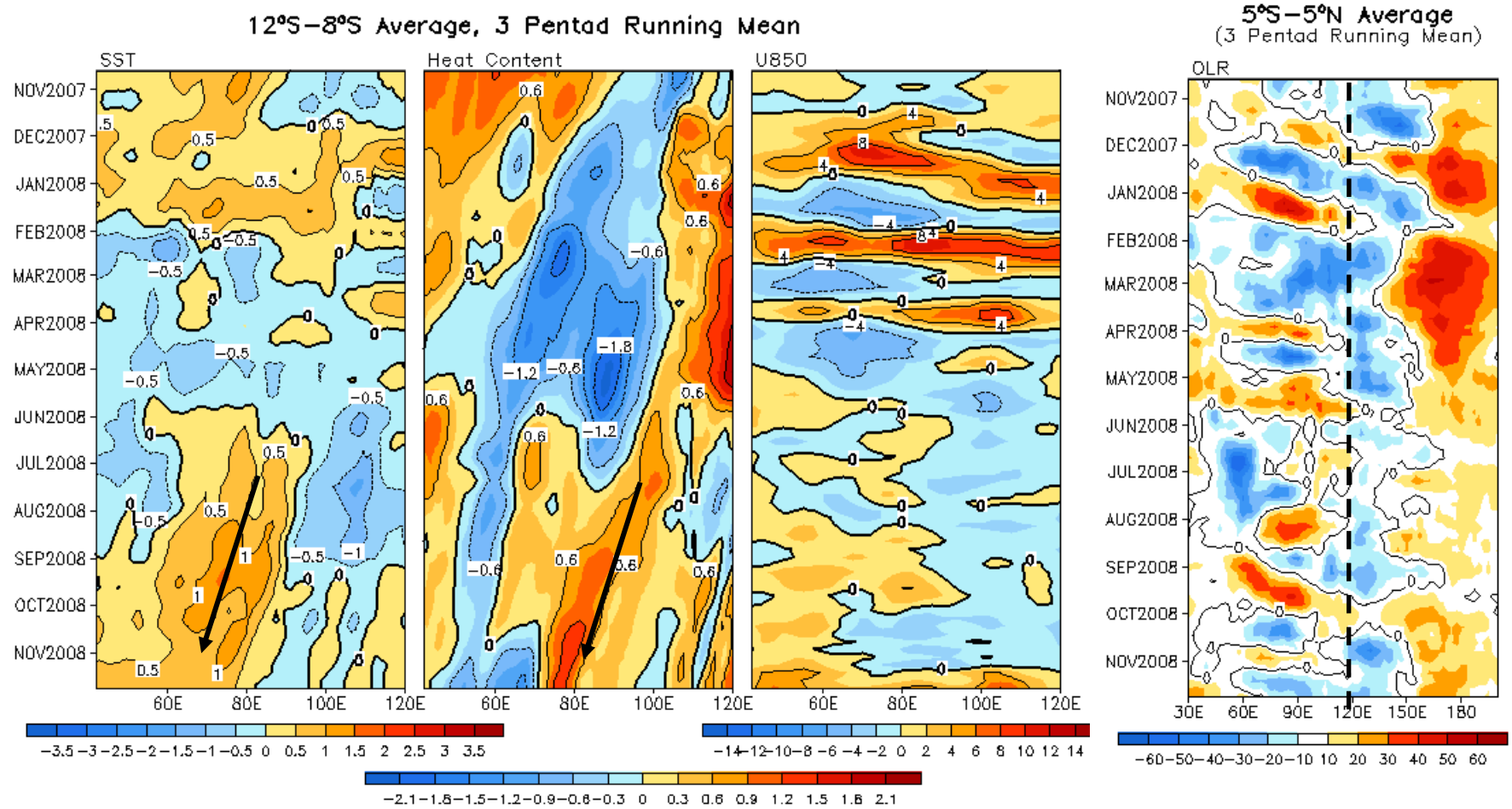
Recent Evolution of Equatorial Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies



- **Recent westerly wind anomalies in the tropical Indian Ocean were associated with persistent convection over the maritime continent.**
- **SST in the western Tropical Indian Ocean cooled down since early October, possibly 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 2°S-2°N 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.

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



- **Westward propagation of positive SSTA and heat content anomalies continued in November 08.**
- **Maximum of positive SSTA was located to the west of maximum of positive heat content anomalies.**
- **Westerly wind anomalies appeared in mid-November**

Fig. I4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 12°S-8°S and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST are derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, and U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1971-2000, 1982-2004, 1979-1995 base period pentad means respectively.

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

- **Positive SSTA in the central tropical Indian Ocean.**
- **Convection was enhanced in the central-eastern tropical Indian Ocean and Indonesia.**
- **Westerly surface wind anomalies in the tropical Indian Ocean and easterly winds east of the Philippines are associated with the anomalous convection over the Maritime Continent.**

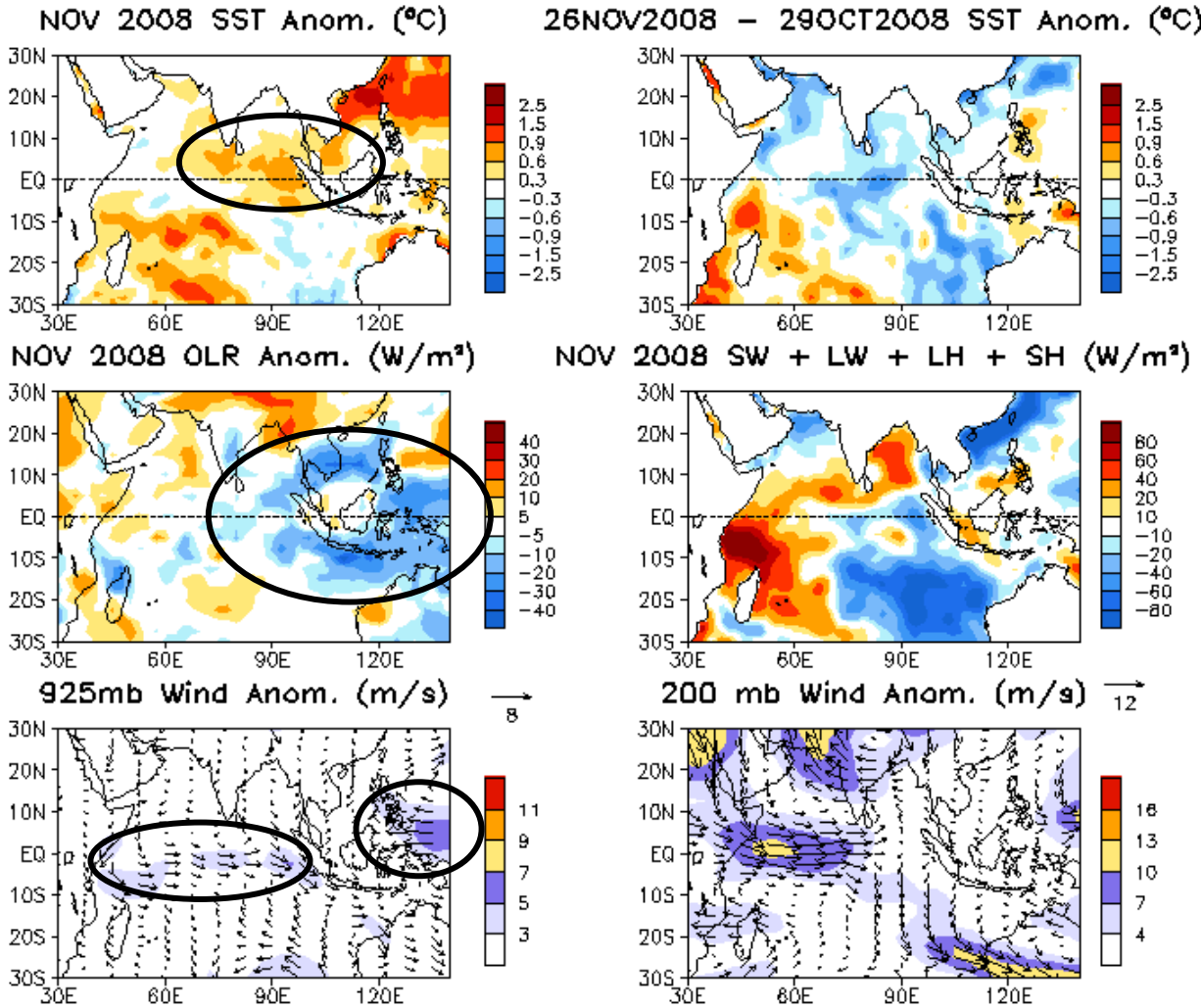
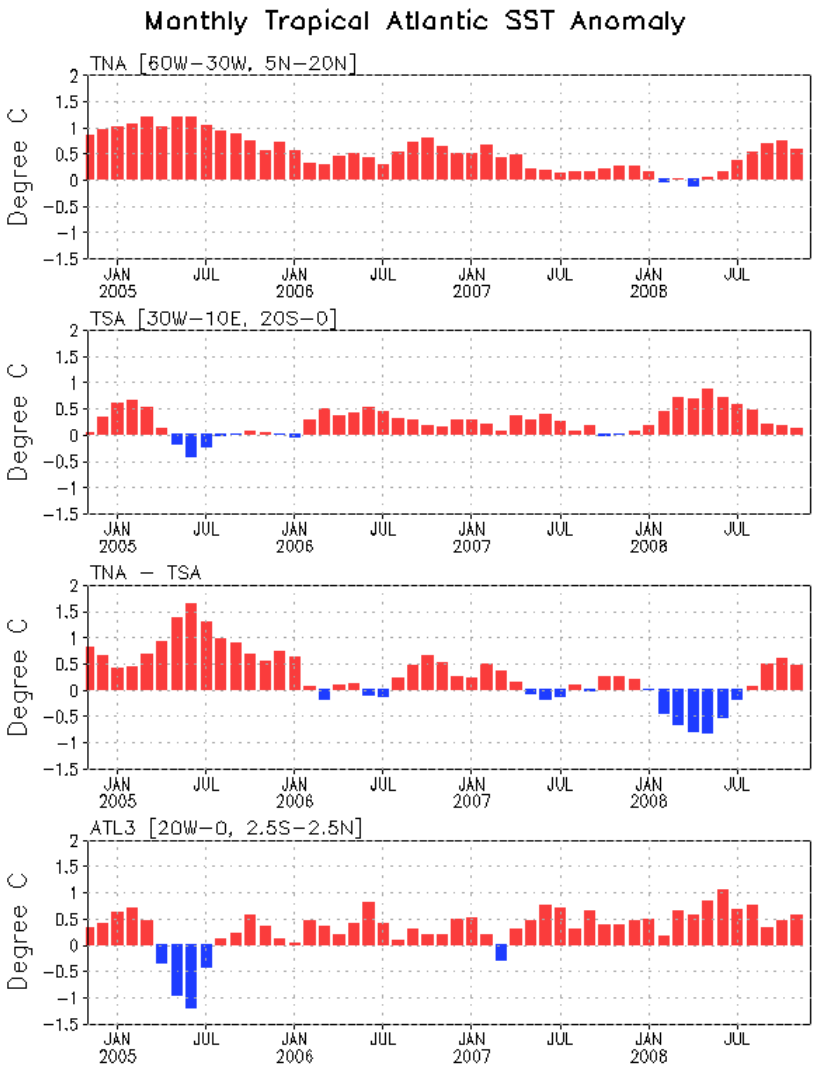
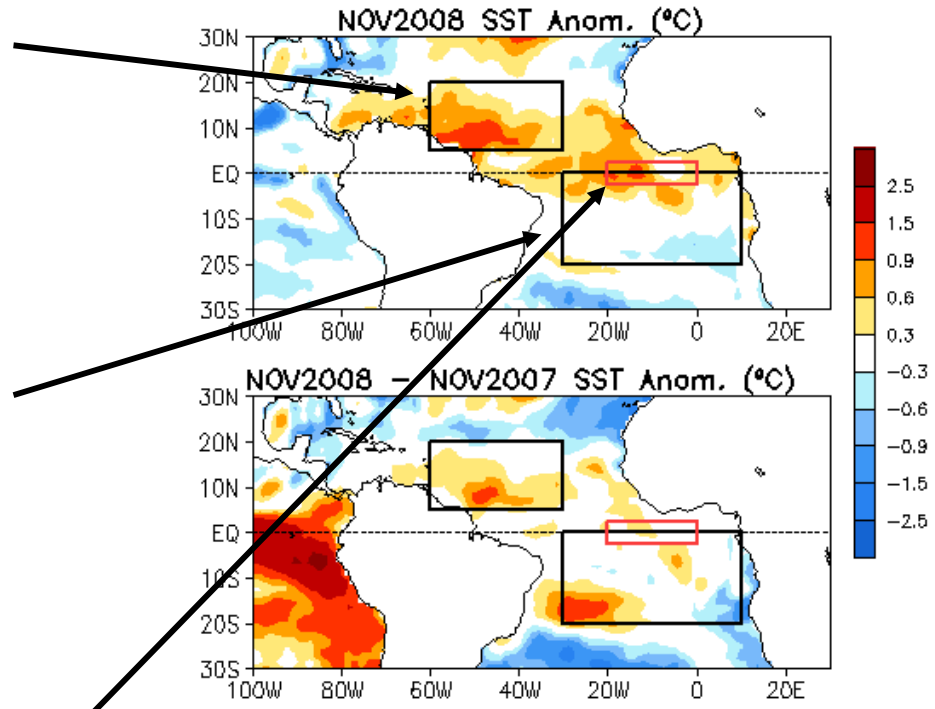


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Tropical Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

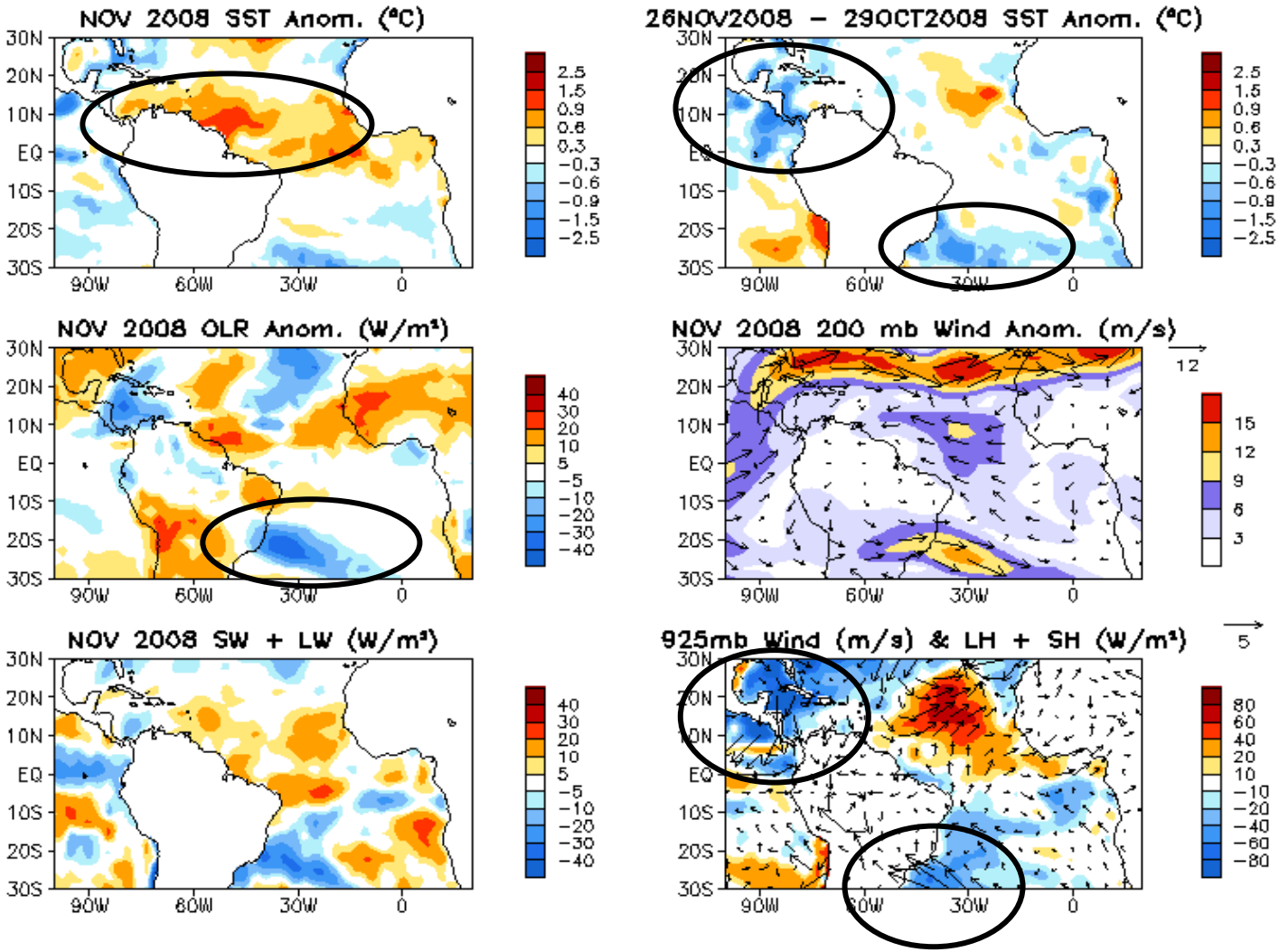




- **Positive SST anomalies across the basin from 5S to 15N.**
- **All Atlantic indices are above average.**

Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

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



- **SSTs cooled in the far eastern North Pacific and portions of Caribbean Sea.**
- **South Atlantic Convergence Zone has been enhanced during November.**
- **Several Mid-latitude fronts have produce strong northerly flow in the Gulf of Mexico and western Caribbean.**

North Atlantic Ocean

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

- North Atlantic SST remains above-normal.
- Anomalous high pressure over North Atlantic contributed to clear skies and light winds.

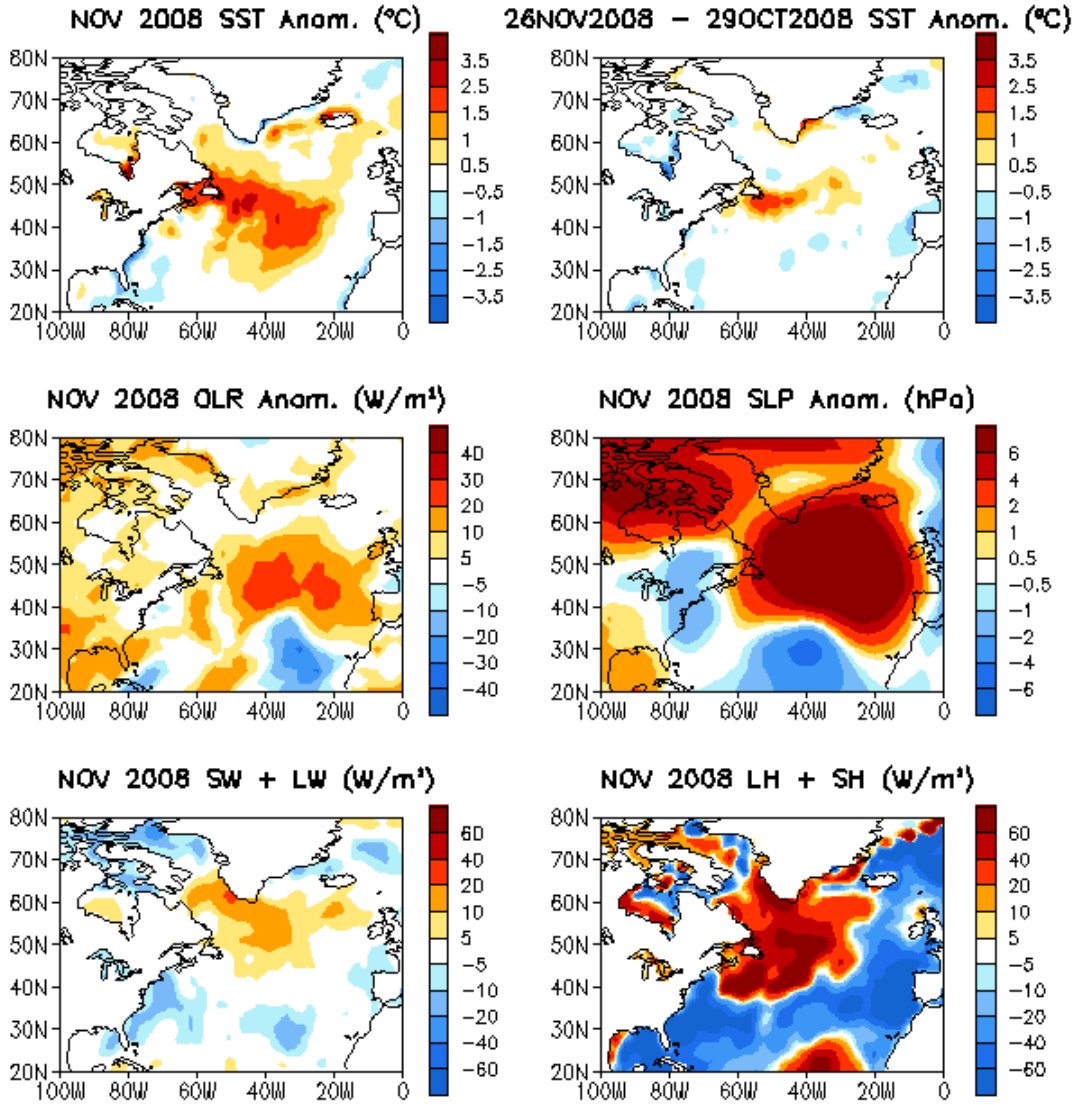
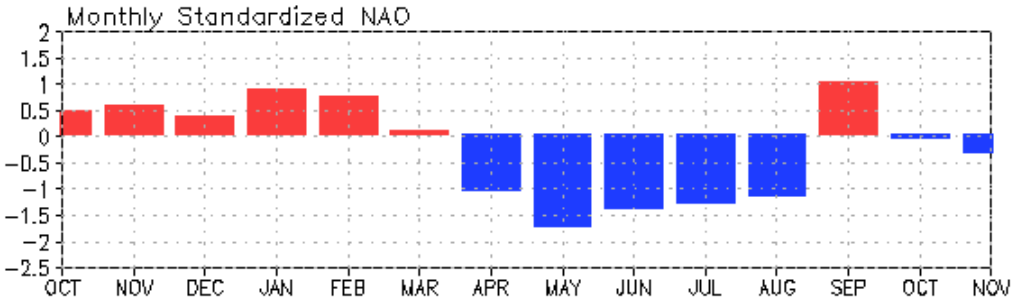
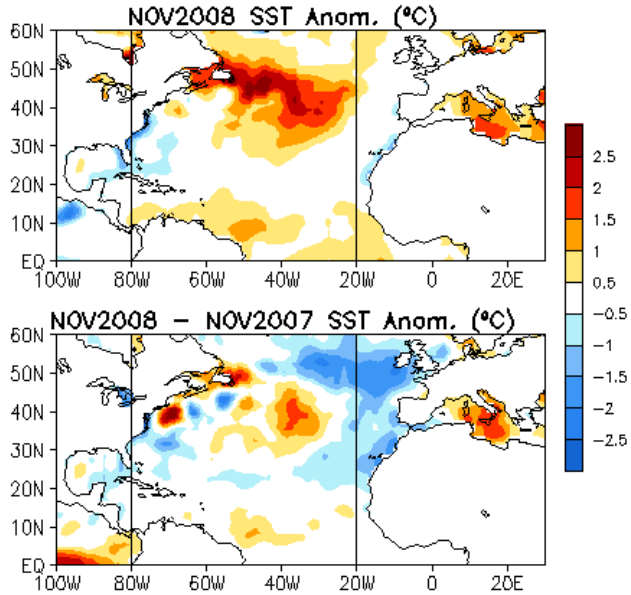
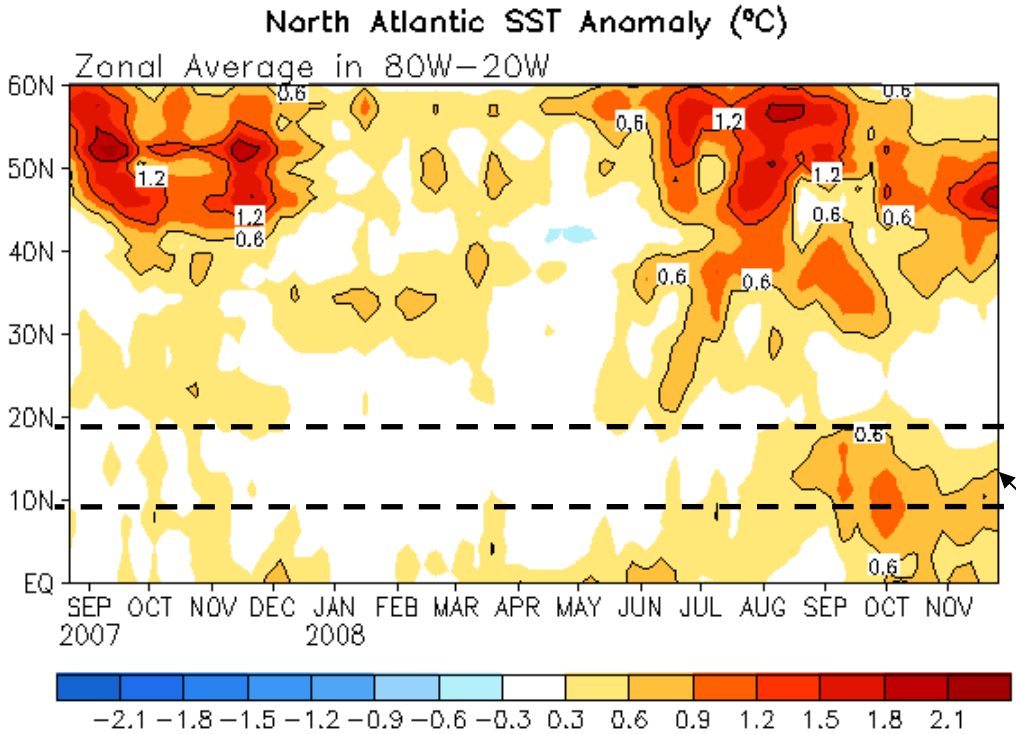


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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



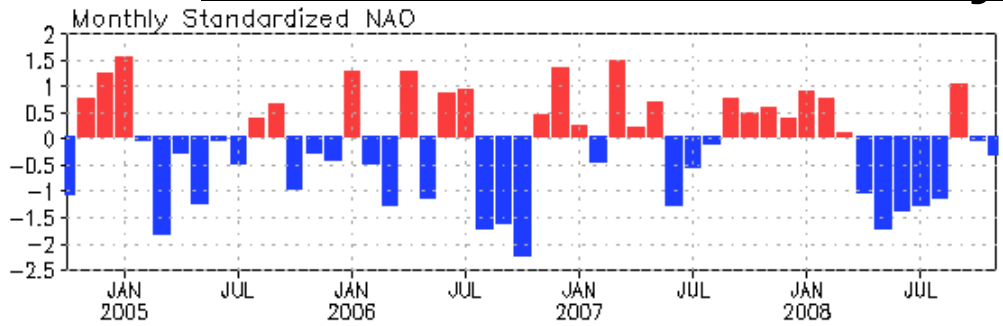


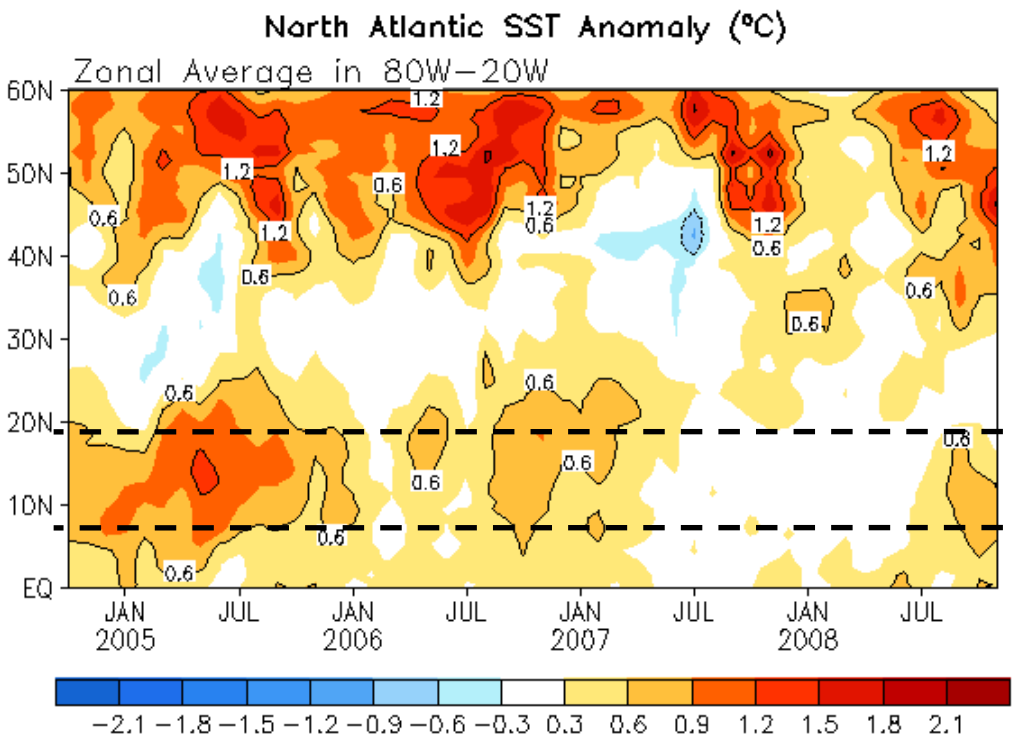


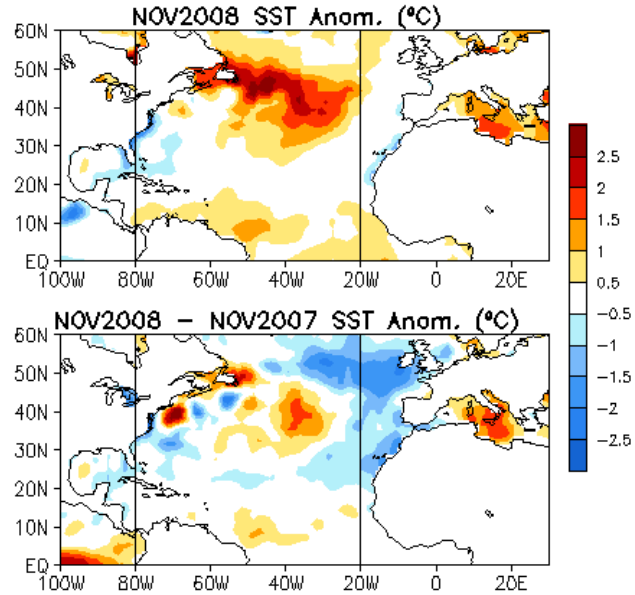
- **High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).**
- **NAO was near-normal in November 08.**
- **Positive SSTA in the Hurricane Main Development Region remained in November 08.**

Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

NAO and SST Anomaly in North Atlantic



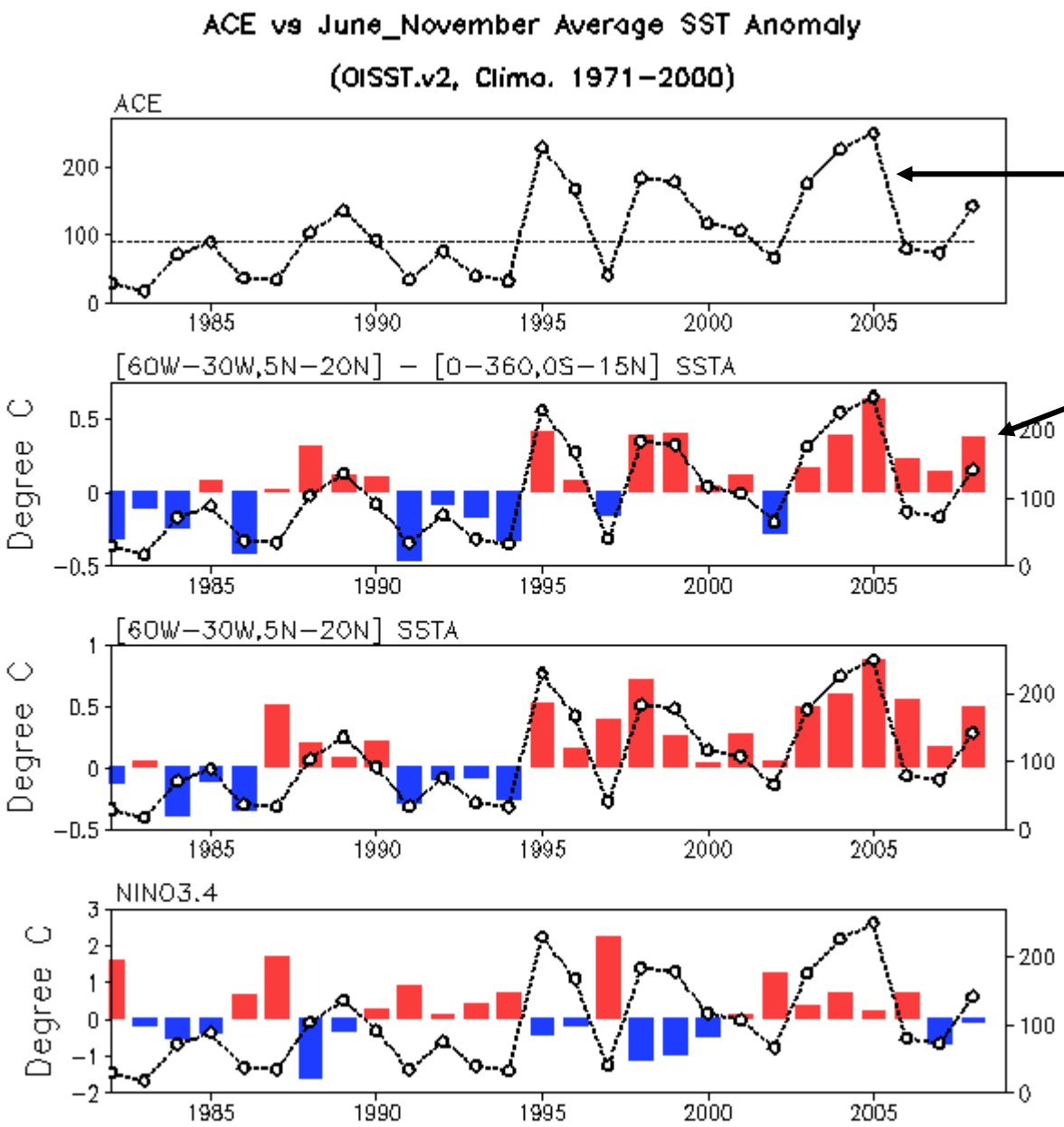




- **North Atlantic SSTs have warmed since July 2008.**

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.

Atlantic Hurricane Activity & SST Anomaly



Accumulated Cyclone Energy (ACE) downloaded from http://en.wikipedia.org

Non-local SST index used by Swanson (2008); Vecchi & Soden (2007)

Correlation with ACE of detrended time series:

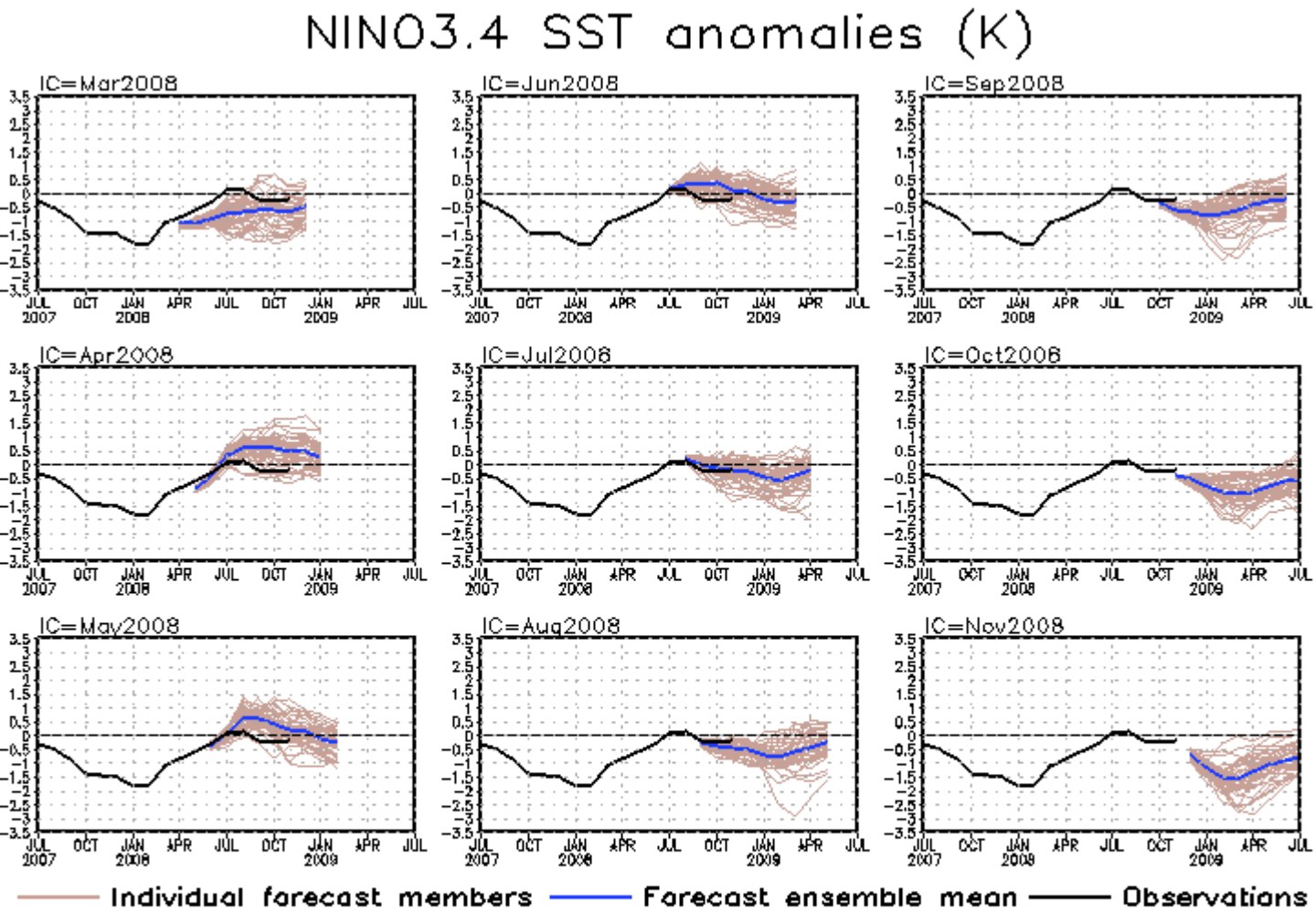
TNA_nolocal	**0.77**
TNA	**0.54**
NINO3.4	**-0.48**

- **SSTA in the tropical North Atlantic relative to the global tropical mean (non-local SSTA) describes 59% variance of ACE, while the local SSTA describes only 29% variance.**

- **Non-local SSTA in 08 was much higher than that of 06-07, consistent with the fact that ACE in 08 was much higher than that of 06-07.**

CFS SST Predictions and Ocean Initial Conditions

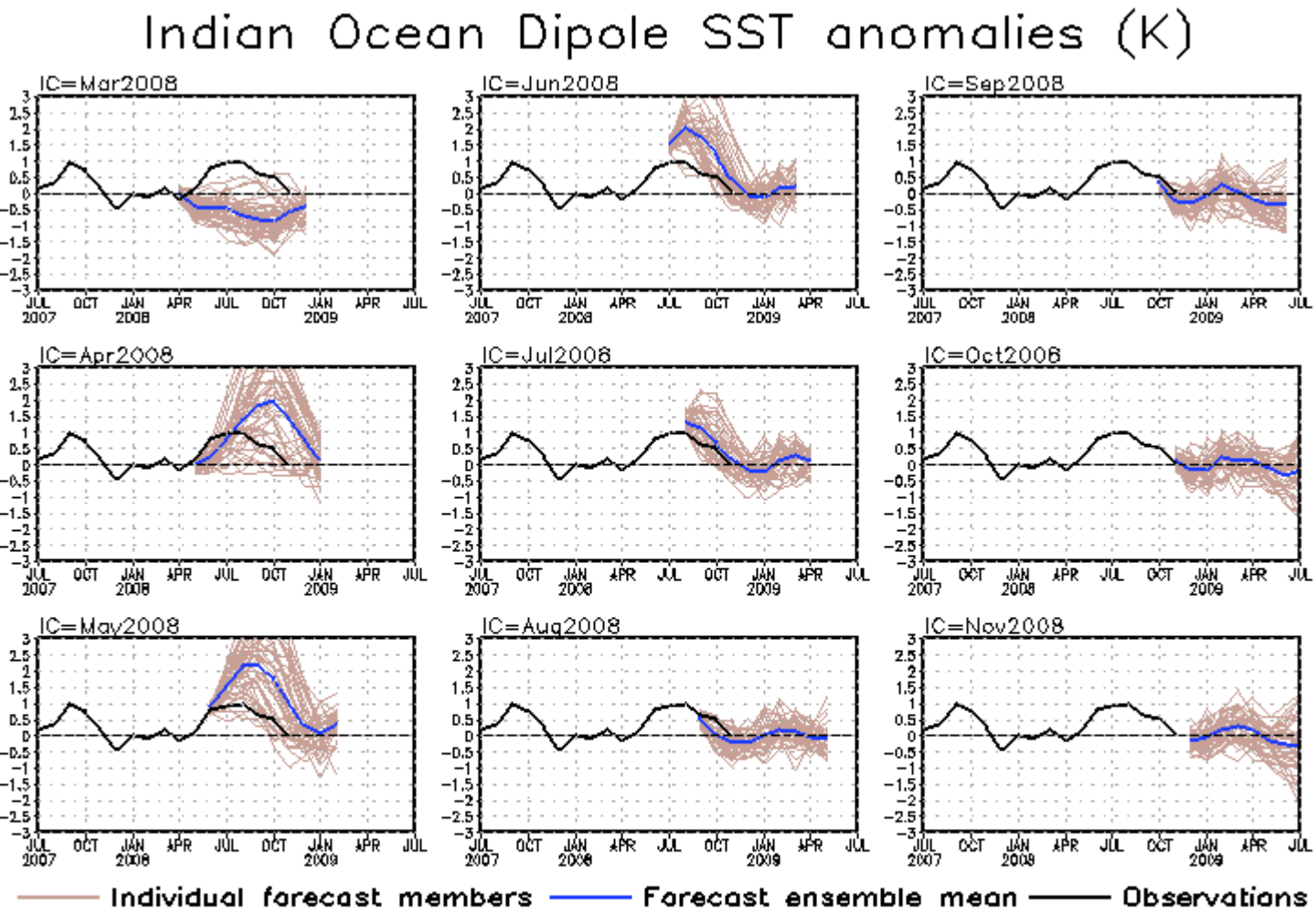
CFS Niño3.4 SST Predictions from Different Initial Months



- **Latest forecasts suggest that a moderate La Nina will develop in the winter 08/09.**

Fig. M1. CFS Nino3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

SETIO = SST anomaly in [90°E-110°E, 10°S-0]

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

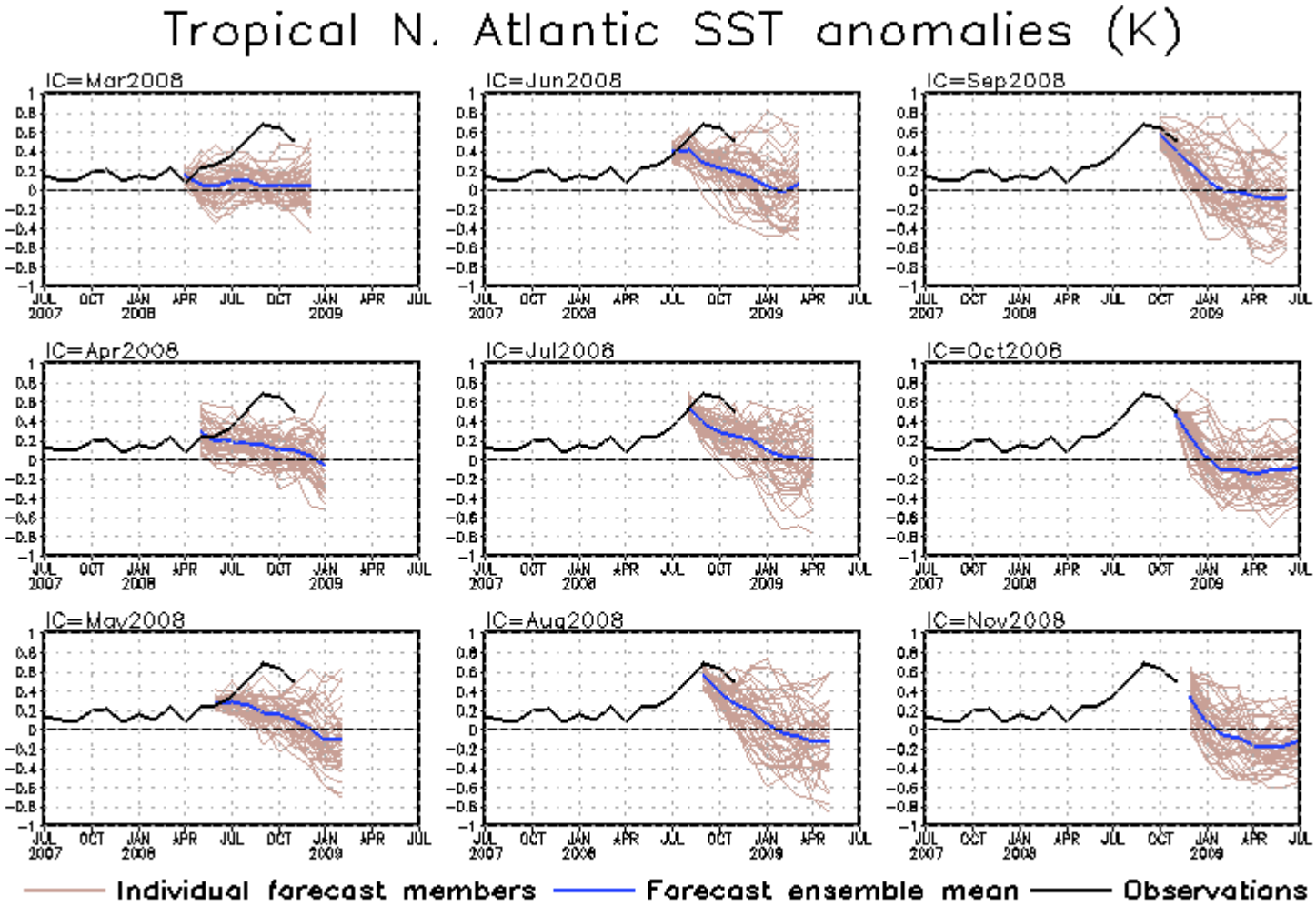
- CFS overestimated the amplitude of the positive IOD.

- CFS called for a strong negative IOD event from Jan-Mar I.C., which indicates that the IOD has a low predictability of about 1-2 month lead times.

- Latest forecasts call for near-normal conditions in next 6-9 months.

Fig. M2. CFS Dipole Model Index (DMI) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months



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

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

-Latest forecasts suggest that the current positive SSTA will dissipate quickly and return to near-normal conditions in next two 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.

Summary

- **Pacific Ocean**
  - Current ENSO-neutral conditions are expected to continue into early 2009.
  - Persistent convection over the Maritime continent is producing anomalous easterlies over the central and western Pacific ocean maintaining the below normal SST near the dateline.
  - PDO index is hovering around -1.5 since April 2008, the lowest values since 1999.
- **Indian Ocean**
  - Positive SST anomalies across much of the tropical Indian ocean.
- **Atlantic Ocean**
  - Positive SST anomalies extend from the eastern Caribbean sea to the coast of equatorial Africa.
  - North Atlantic SST is much above average.
- **Arctic Ocean**
  - Ice concentration remains below normal.

Backup Slides

Data Sources and References

- Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
- SST 1971-2000 base period means (Xue et al. 2003)
- NCEP CDAS winds, surface radiation and heat fluxes
- NESDIS Outgoing Long-wave Radiation
- PMEL TAO equatorial temperature analysis
- NCEP's Global Ocean Data Assimilation System temperature, heat content, currents (Behringer and Xue 2004)
- Aviso Altimetry Sea Surface Height
- Ocean Surface Current Analyses – Realtime (OSCAR)

Please send your comments and suggestions to Yan.Xue@noaa.gov. Thanks!