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

Prepared by

Climate Prediction Center, NCEP

September 8, 2008

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

Outline

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

Overview

- **Global Ocean**
  - Global mean SST anomaly continues to rise.

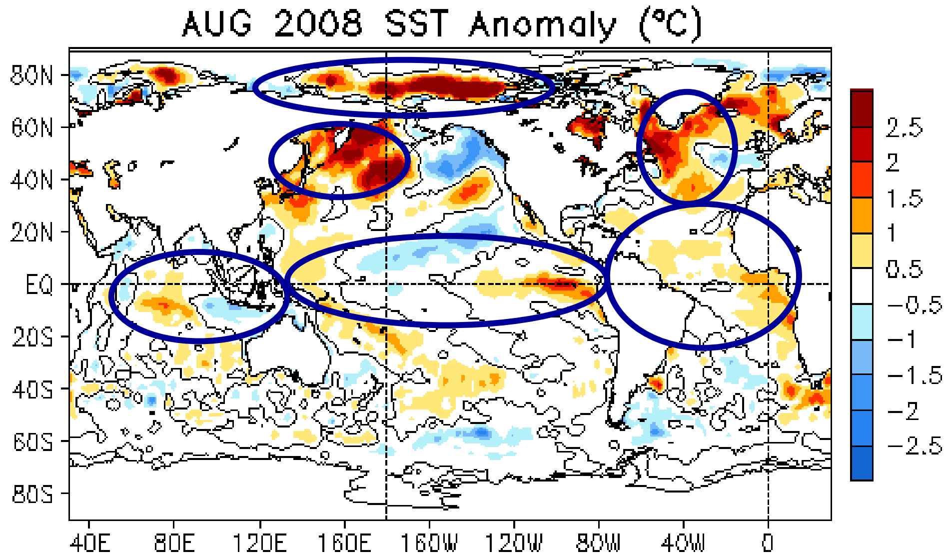
- **Pacific Ocean**
  - ENSO-neutral conditions will continue through winter.
  - Lingering La Nina signal in atmospheric circulations.

- **Indian Ocean**
  - Dipole Mode Index was above 0.5ºC in three consecutive months from June to August.

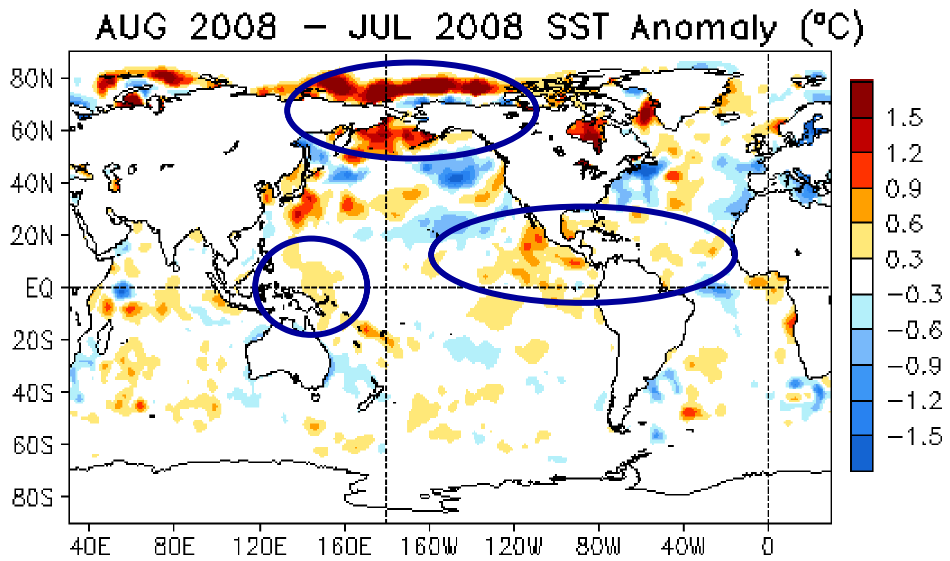
- **Atlantic Ocean**
  - Tropical North Atlantic SST continues to rise, favourable for hurricane development.

- **Active Ocean**
  - Arctic Ocean was not as warm as it was last August.
  - But sea ice extent is close to the 2007 low level.

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



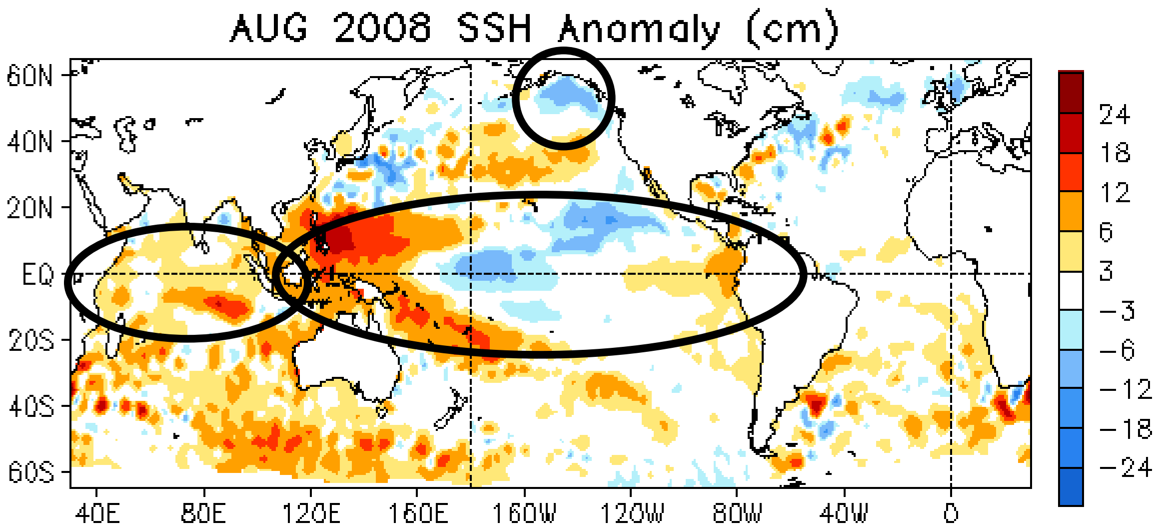
- Positive SSTA in W. North Pacific and W. North Atlantic.
- Positive SSTA in Arctic Ocean.
- Tripole SSTA pattern in tropical Pacific (negative in C. Pacific and positive in W. and E. Pacific) → Negative El Nino Modoki?
- Positive IOD SSTA in tropical Indian.
- Positive SSTA in tropical Atlantic.



- SST warmed up in W. Pacific.
- SST warmed up in Arctic Ocean.
- SST warmed up in tropical E. Pacific and W. 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.

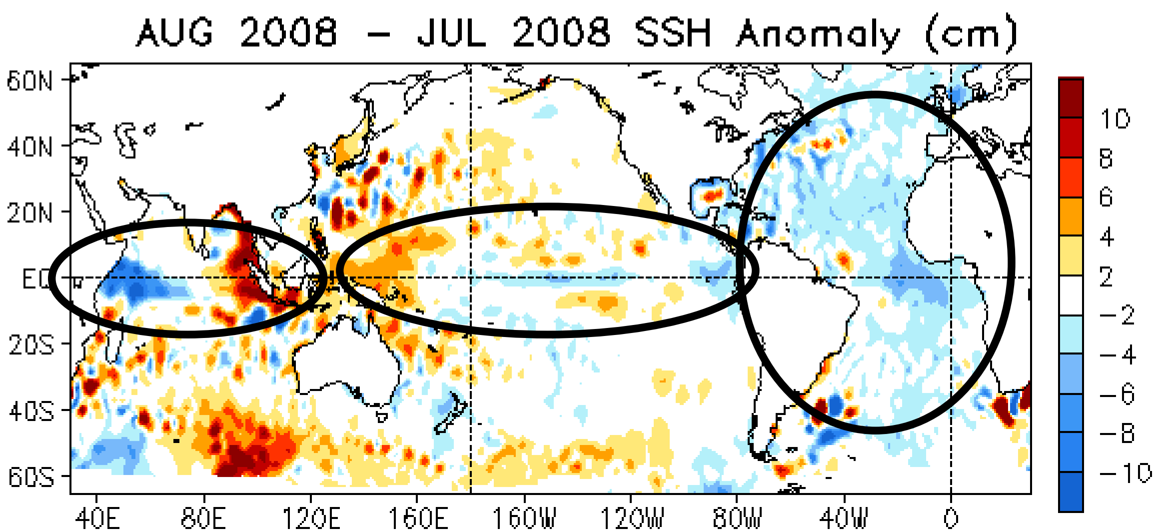
Global SSH Anomaly (cm) and Anomaly Tendency



- Tripole SSHA pattern in tropical Pacific (negative in C. Pacific and positive in W. and E. Pacific), consistent with tripole SSTA pattern.

- Positive SSHA in most of tropical Indian.

- Negative SSHA in Gulf of Alaska.



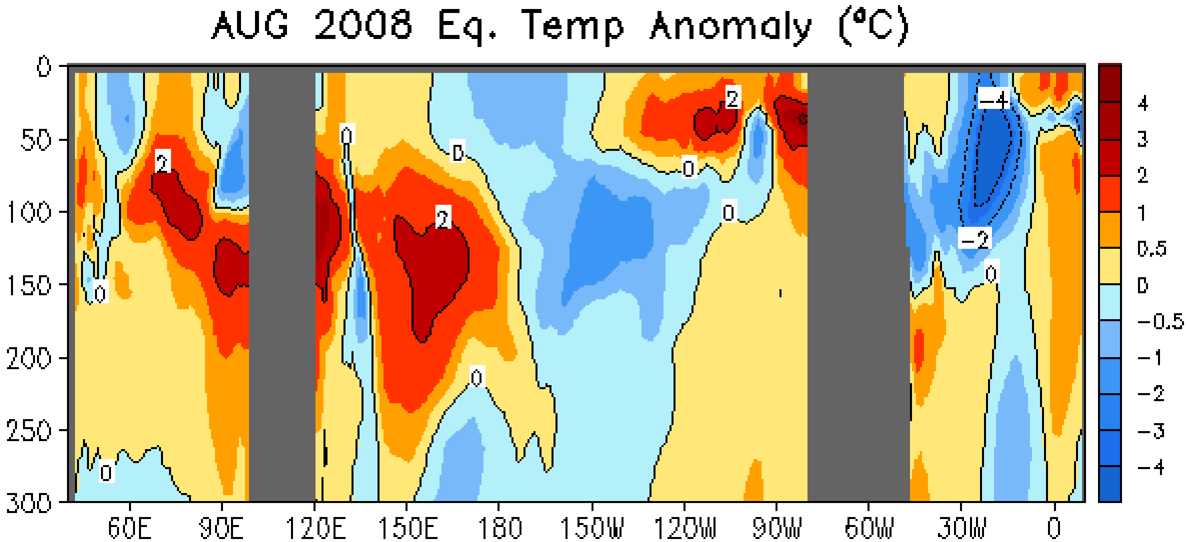
- SSH decreased in most of Atlantic Ocean.

- SSH increased (decreased) in W. Pacific (C.-E. Pacific).

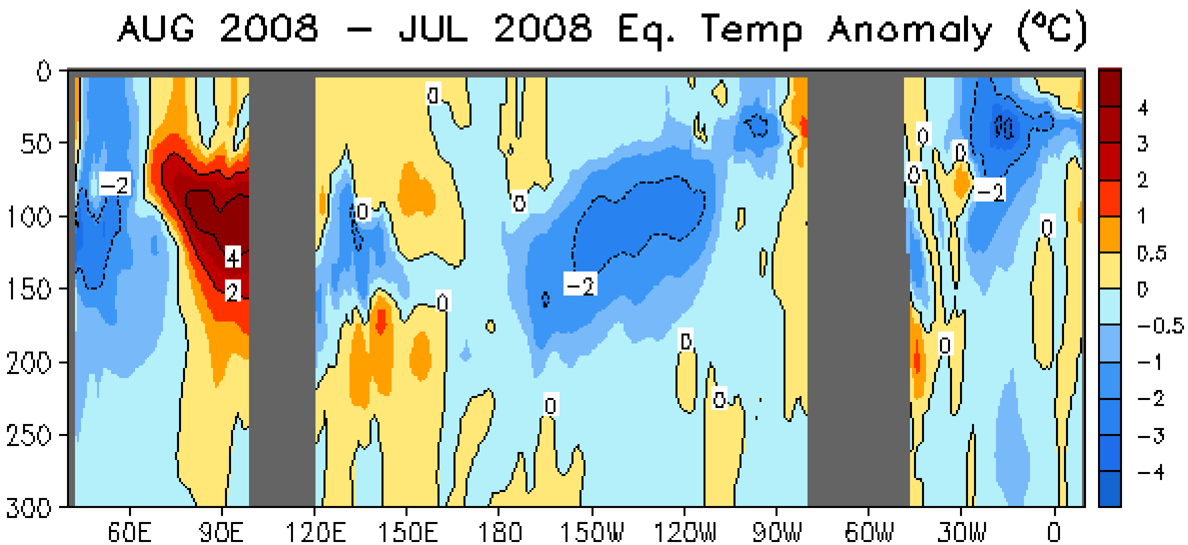
- SSH increased (decreased) in E. (W.) Indian Ocean.

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



- Tripole temperature anomalies near the thermocline(negative in C. Pacific and positive in W. and E. Pacific).

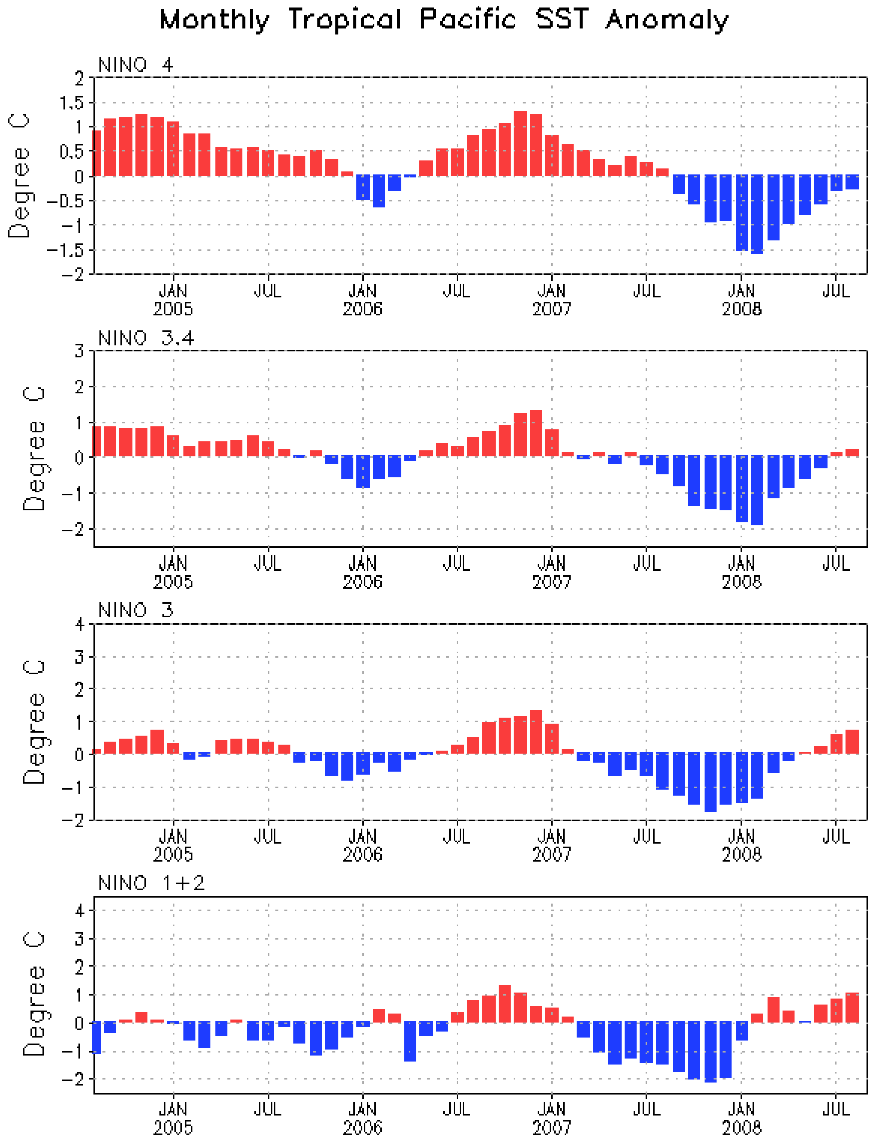


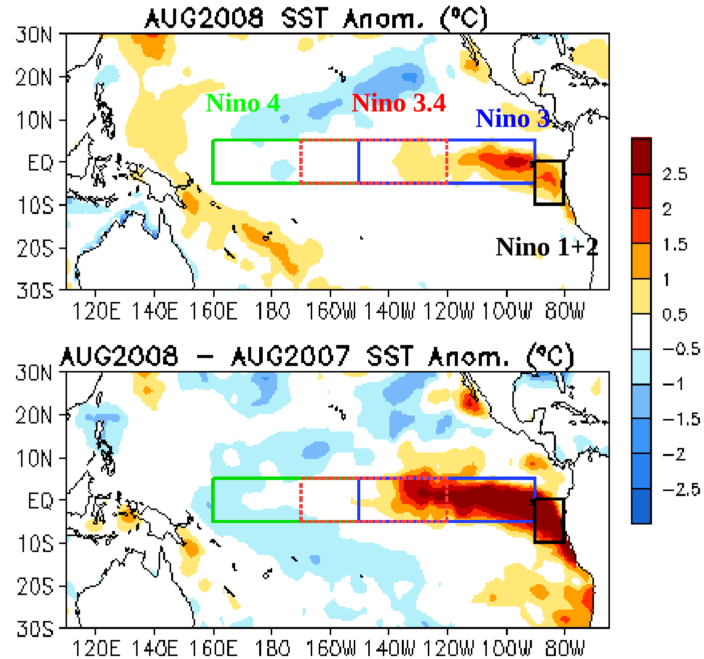
- Temperature decreased in C.-E. Pacific near the thermocline.
- Temperature increased (decreased) in E. (W.) Indian Ocean near the thermocline.

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.

Tropical Pacific Ocean

Evolution of Pacific NINO SST Indices



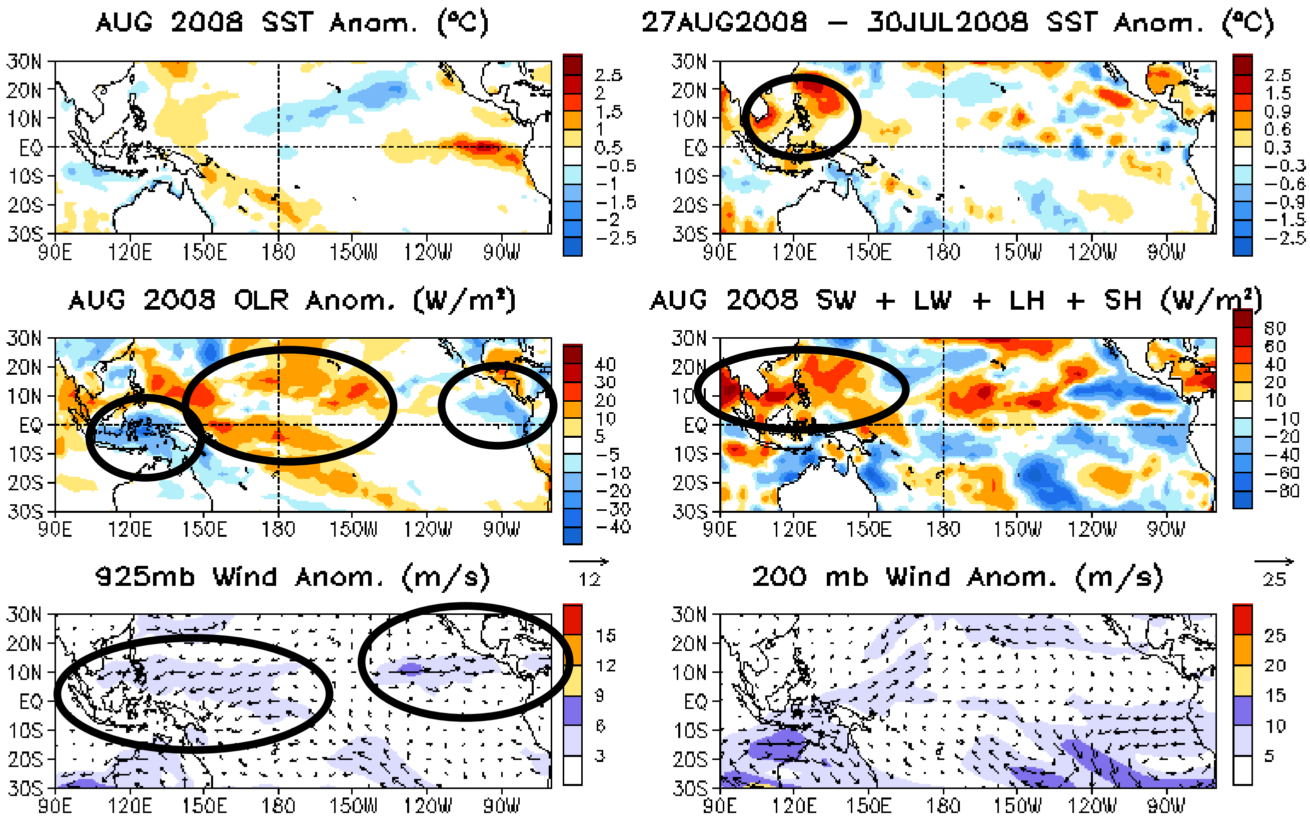


- **ENSO-neutral conditions will continue into winter – NOAA's "ENSO Diagnostic Discussion".**

- **Tripole SSTA pattern in tropical Pacific (negative in C. Pacific and positive in W. and E. Pacific).**

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

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



- **Convection suppressed (enhanced) in C. Pacific (Maritime Continent and far E. Pacific).**
- **Low-level easterly (westerly) wind anomalies presented in tropical W. Pacific (north-eastern Pacific).**
- **SST increased in South China Sea and N.-W. Pacific due to net heat flux into the ocean.**

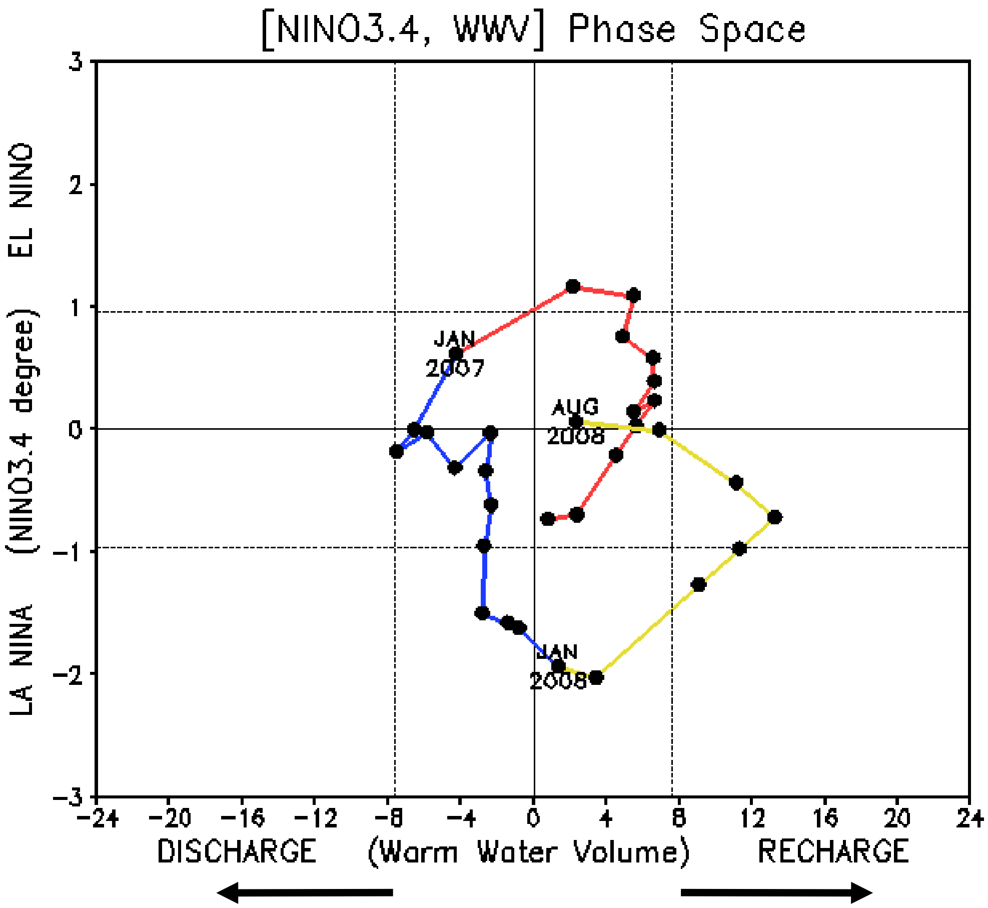
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

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

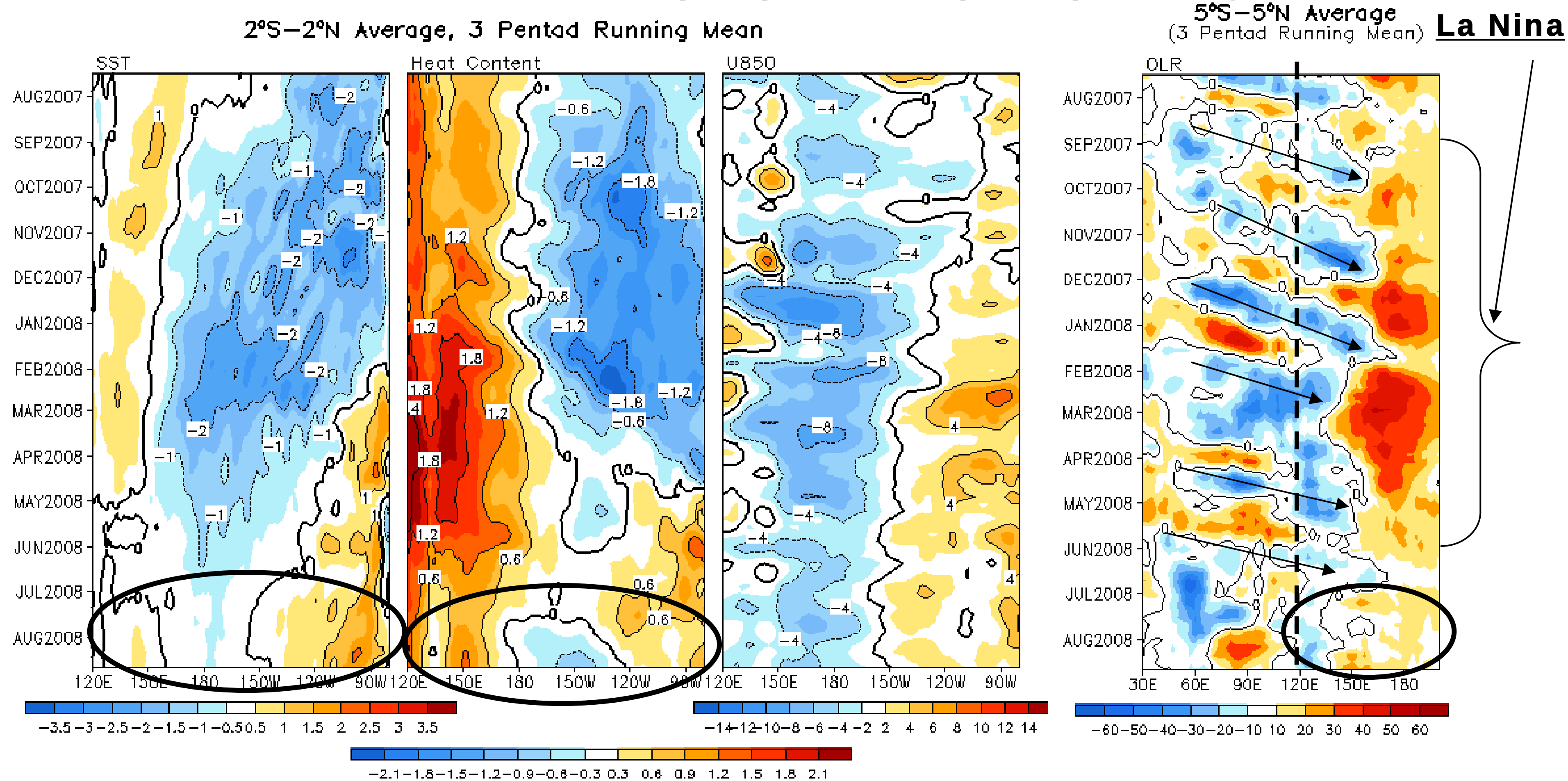


- Warm Water Volume(WWV) has increased rapidly from February to May, but has decreased since then.

- 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

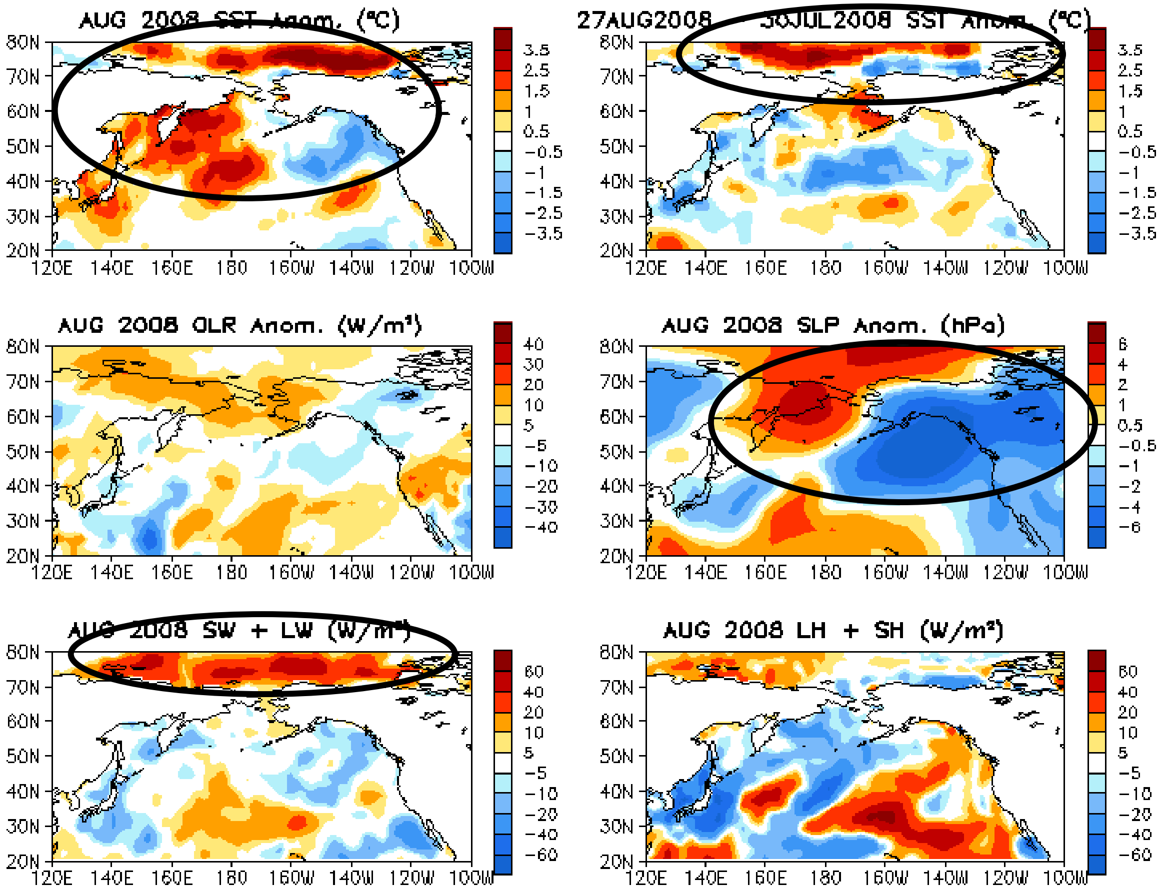


- **Tripole SSTA and SSHA patterns in tropical Pacific.**
- **Lingering La Nina convection (suppressed near the Dateline and enhanced in far W. Pacific).**

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.

North Pacific & Arctic Ocean

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



- Positive (negative) SSTA in Arctic Ocean and W. North Pacific (Gulf of Alaska).

- SST increased in W. Arctic Ocean, largely due to radiative warming.

- SST decreased along the northern coast of Alaska.

- Negative (positive) SLP anomalies over the Alaska and North Pacific (Seberia and Arctic Ocean).

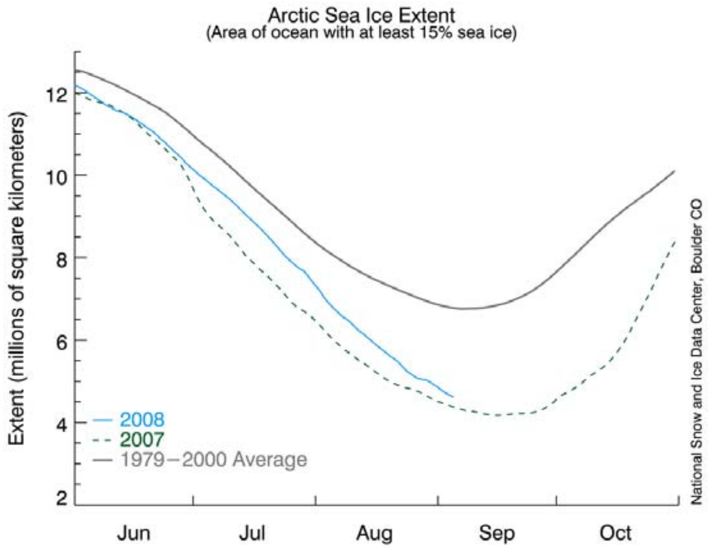
- Cyclonic wind anomalies west of the western North American coast were unfavourable for coastal upwelling.

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.

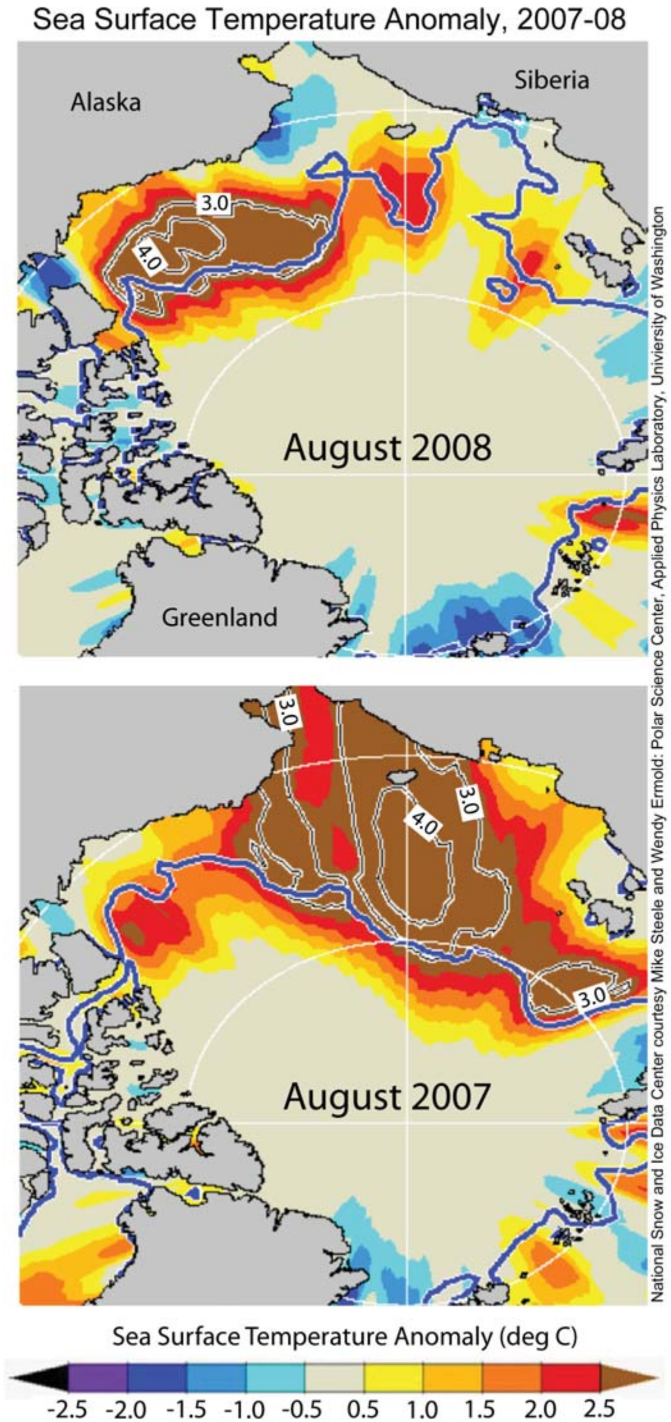
Arctic Sea Ice & SST Anomaly

National Snow and Ice Data Center

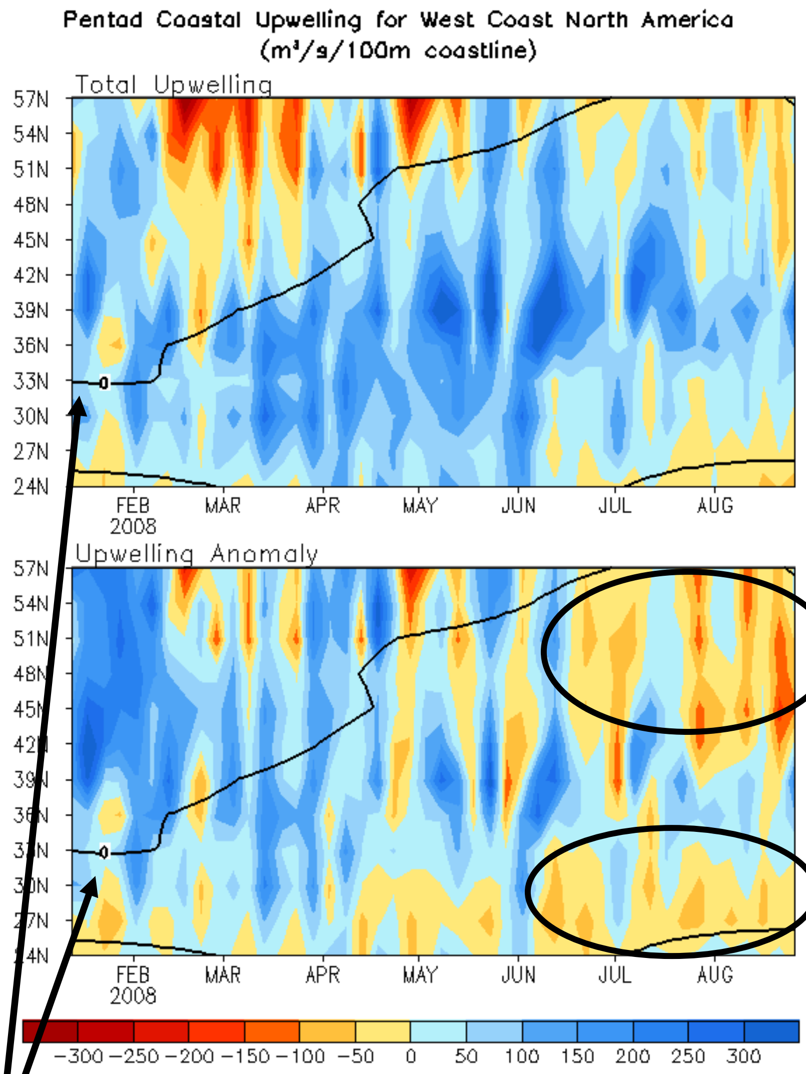
http://nsidc.org/arcticseaicenews/index.html

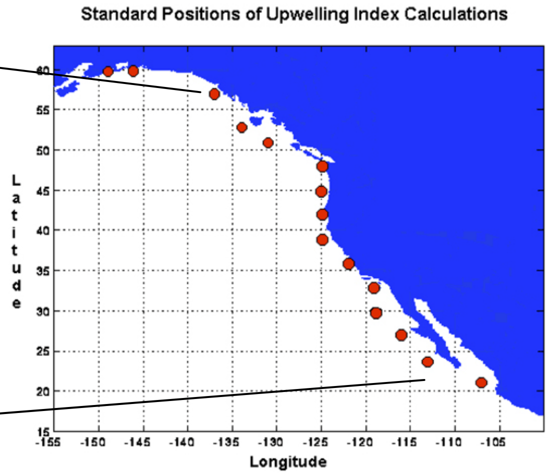


- Positive SSTA about 3-4ºC presented in W.-N. Arctic Ocean in August 08.
- SSTA (shaded) matches well the sea ice edge (blue line).
- Despite of the smaller coverage of positive SSTA than that in last year, the Arctic sea ice extent is close to the 2007 low level.



North America Western Coastal Upwelling





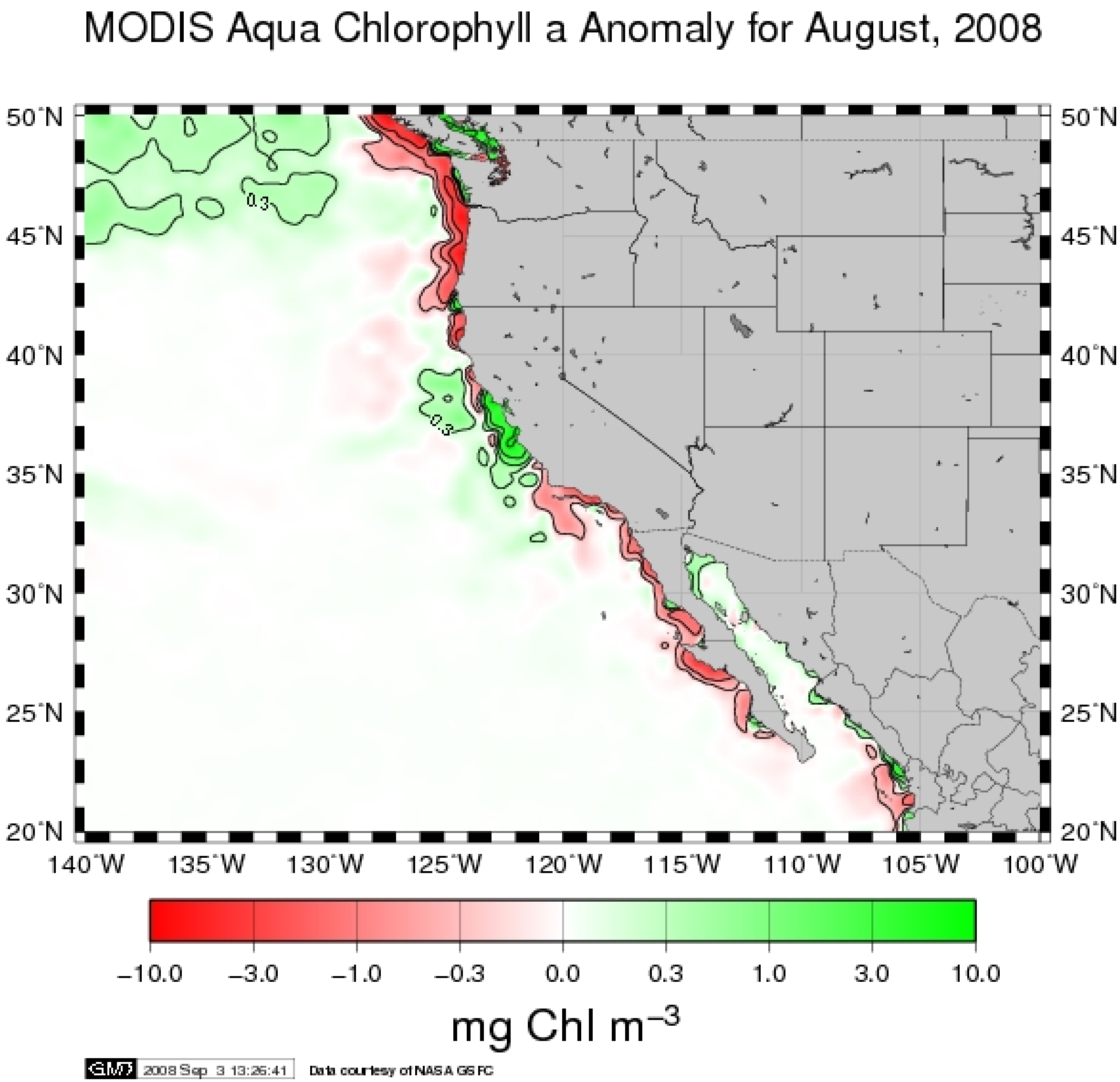
- Upwelling was suppressed along most of the western North America coast since June 2008.

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

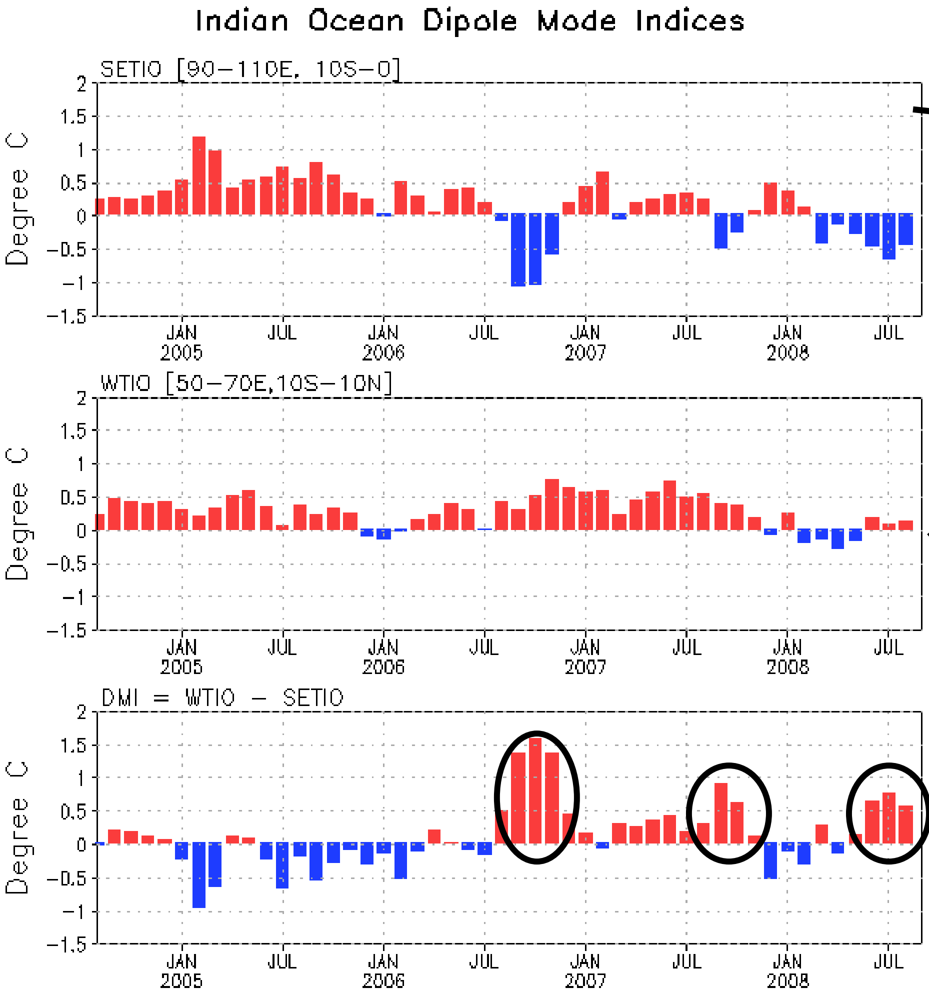
http://coastwatch.pfel.noaa.gov/FAST

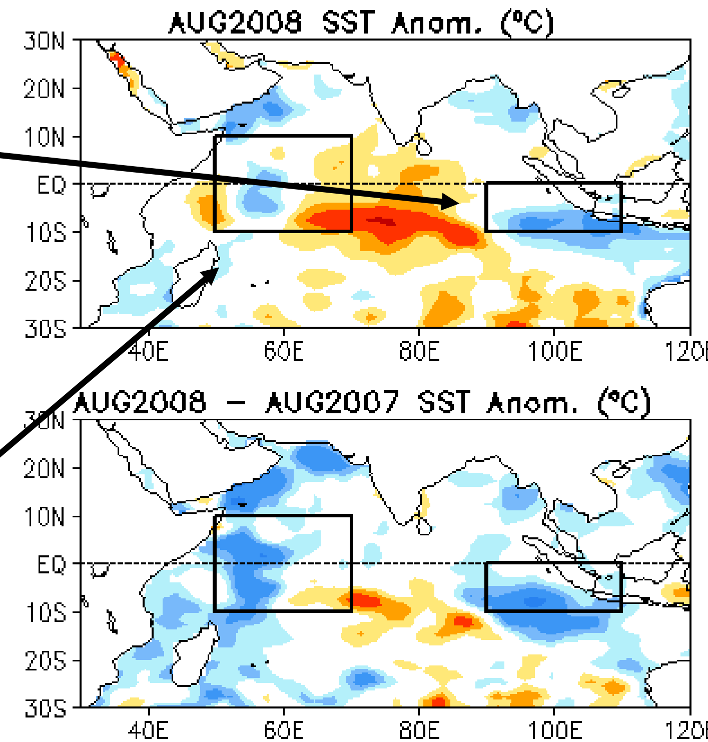


Negative Chlorophyll anomalies were consistent with suppressed upwelling.

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices





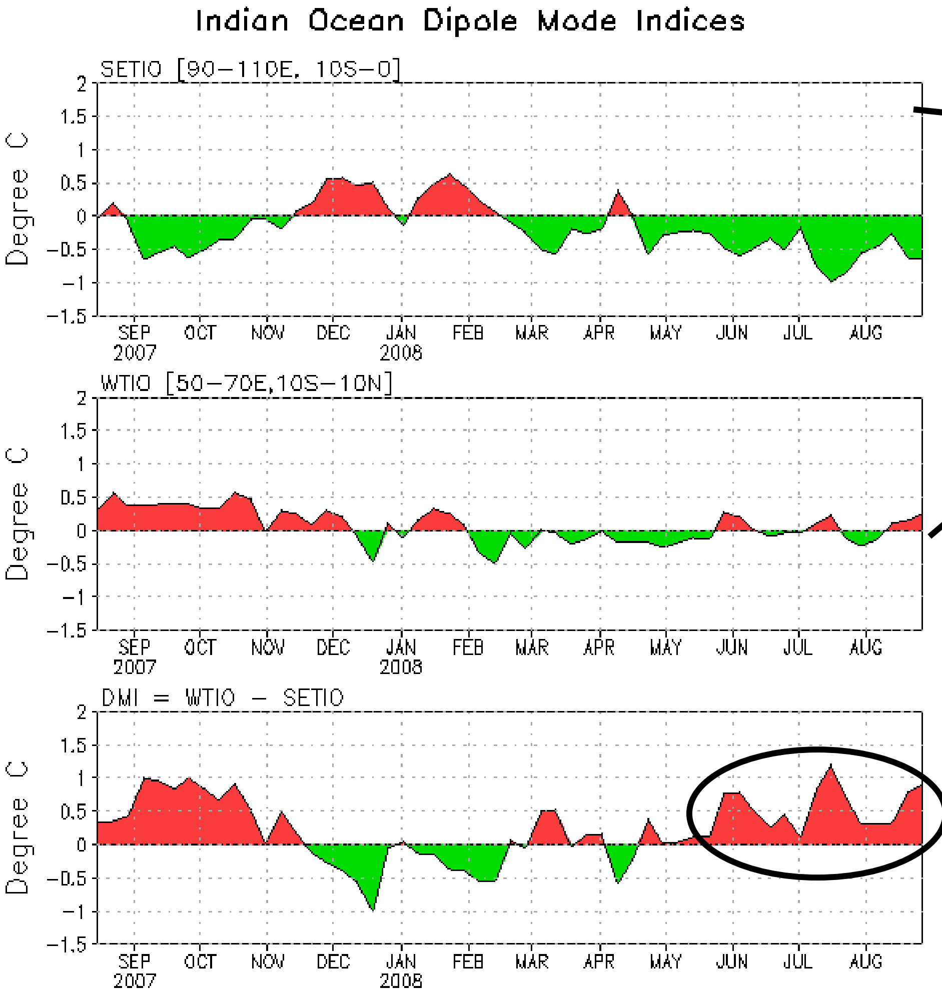
- Tropical Indian Ocean SST is mostly cooler than that last August.

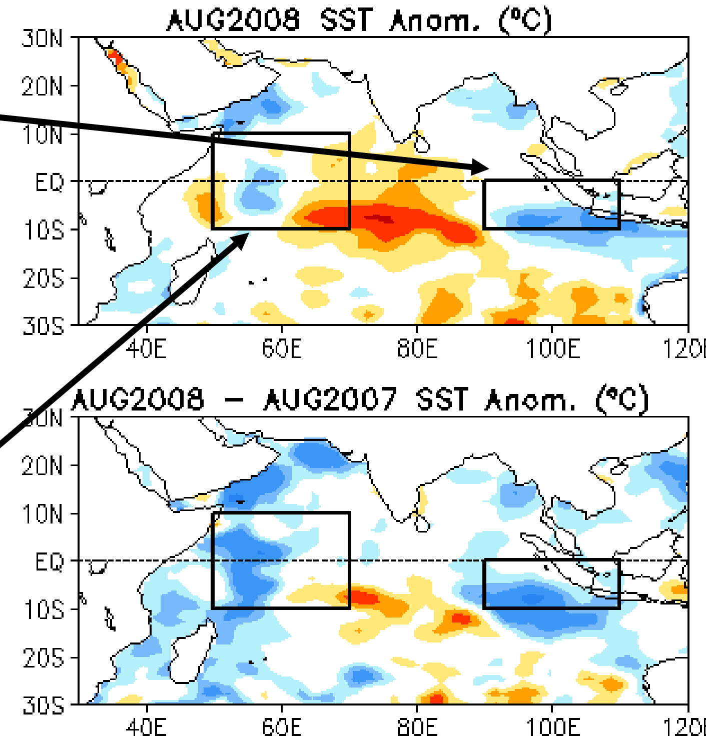
- Dipole Mode Index (DMI) was above 0.5°C in June-August.

- A third-in-a-row positive IOD event following two consecutive IOD events of 2006 and 2007 (http://www.jamstec.go.jp/frsgc/research/d1/iod).

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.

Evolution of Indian Ocean SST Indices

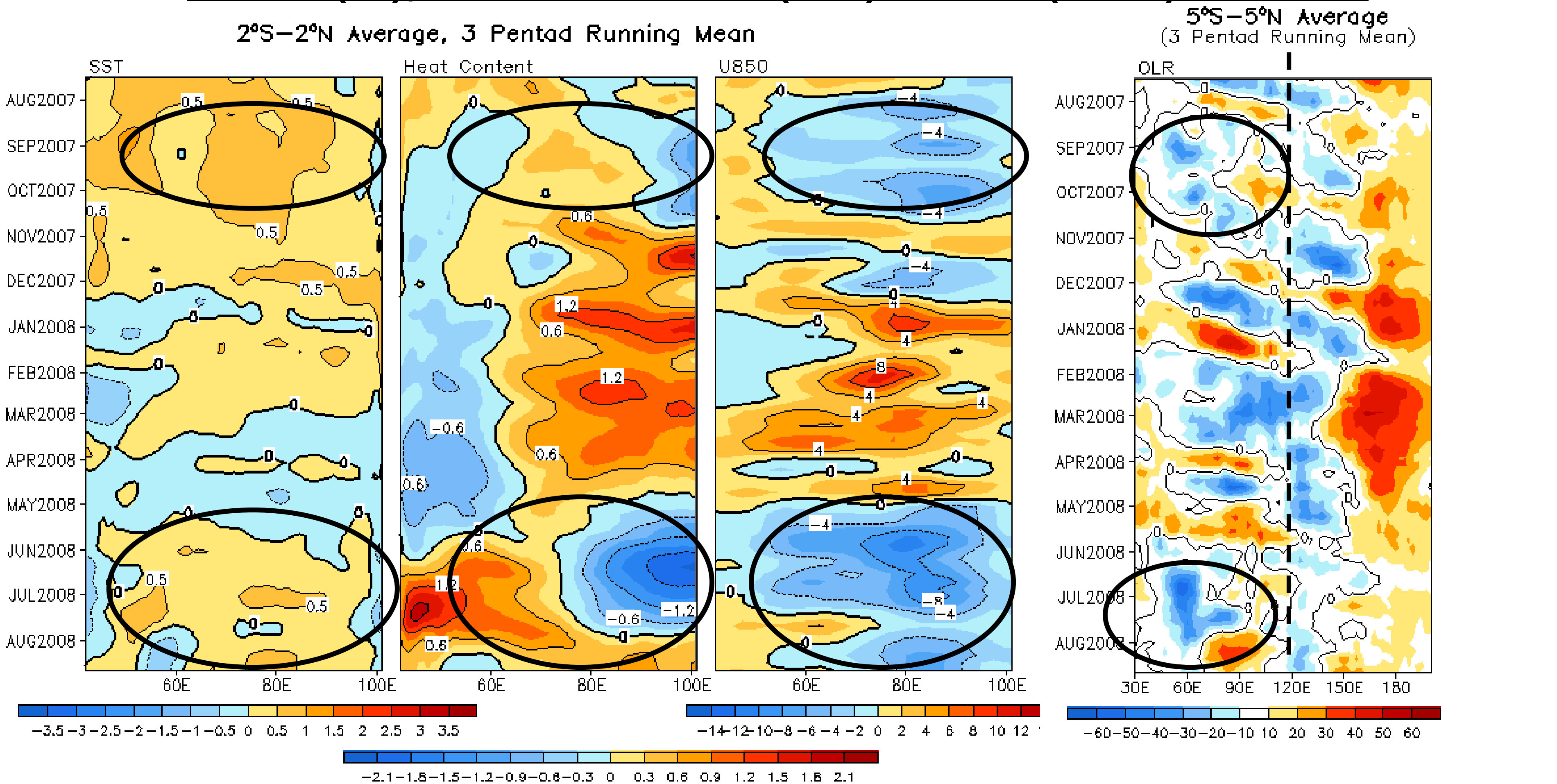




- **Dipole Mode Index (DMI) was significantly modulated by intraseasonal variability.**
- **DMI peaked in early June, mid-July and late August.**

Fig. I1b. Indian Ocean Dipole region indices, calculated as the area-averaged weekly 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.

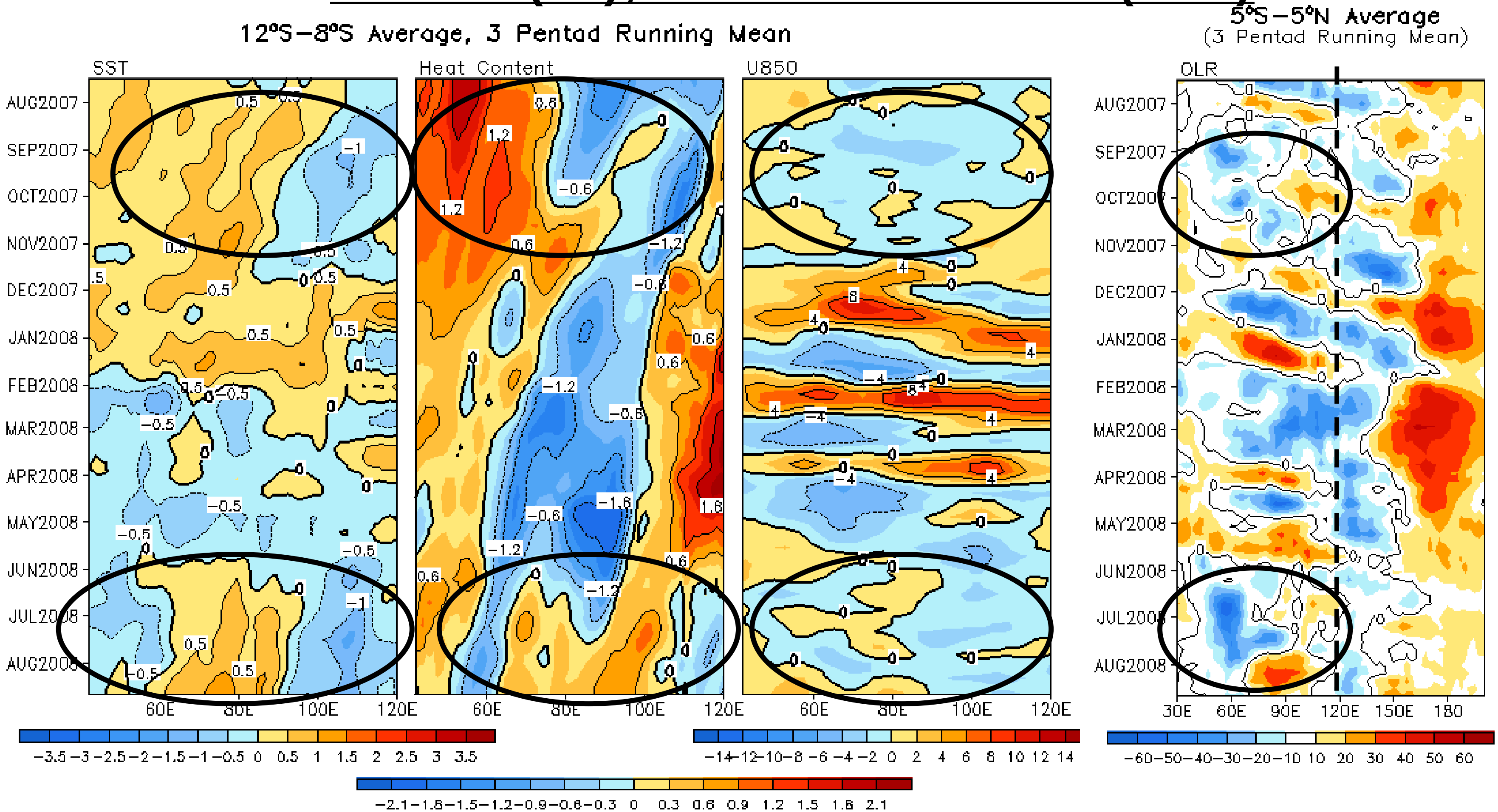
Recent Evolution of Equatorial Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies



- Easterly wind anomalies presented in tropical Indian Ocean in May-August were modulated by intraseasonal fluctuations.
- Negative heat content anomalies in E. Indian Ocean switched sign due to westerly wind bursts in mid-July.
- Enhanced (suppressed) convection in W. (E.) Indian Ocean persisted from June to August.
- Compared to last year mini-IOD, the west-east SST (heat content) gradient was weaker (stronger).

Fig. 13. 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)



- Tripole SST and heat content anomaly patterns persisted from June to August in 2008 along 10°S.
- In contrast, dipole SST and heat content anomaly patterns persisted from August to October in 2007 along 10°S.

Fig. 14. 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 IOD SSTA pattern.
- But convection anomaly does not match SSTA?
- North-south dipole convection anomalies presented in Maritime Continent.

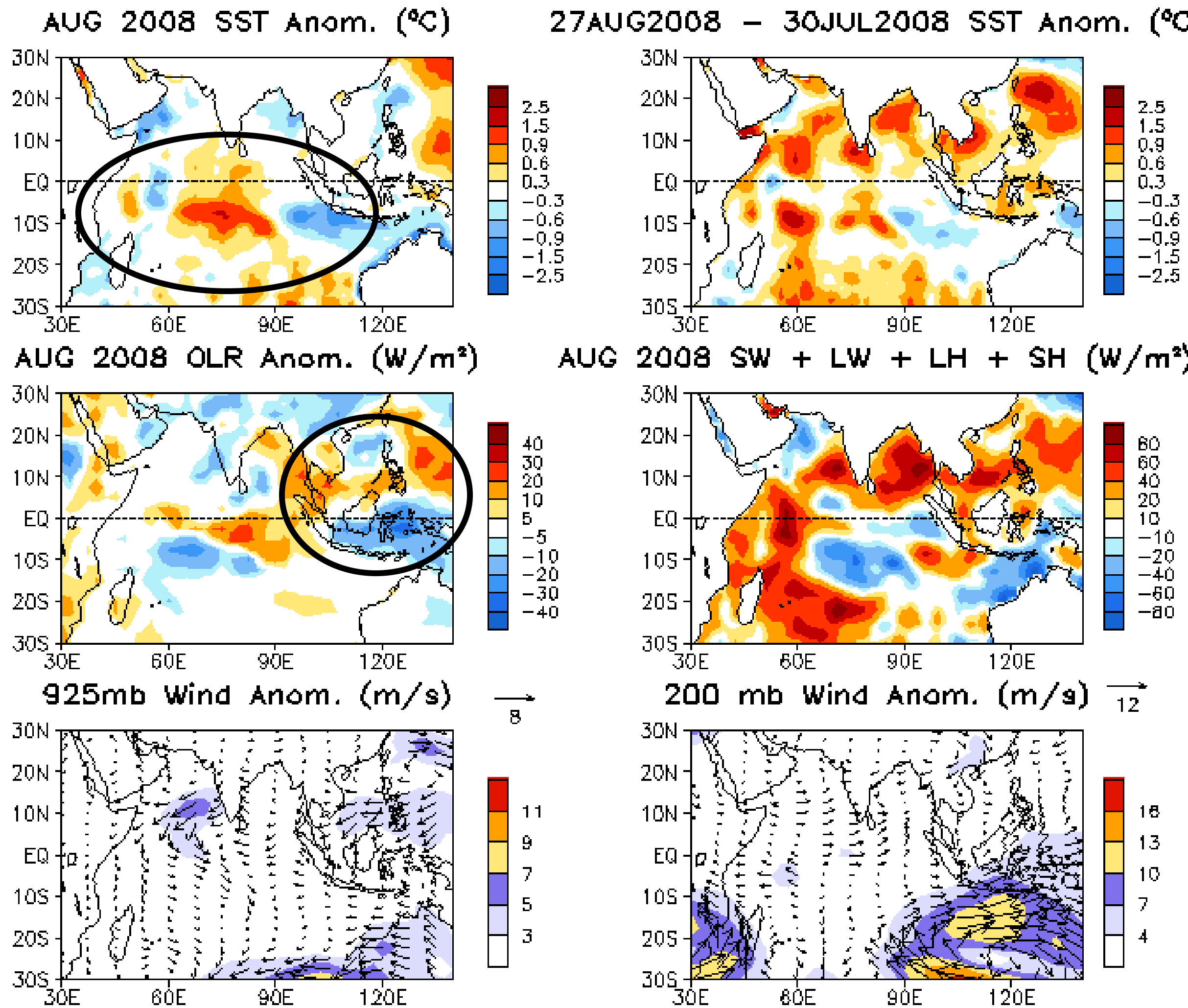
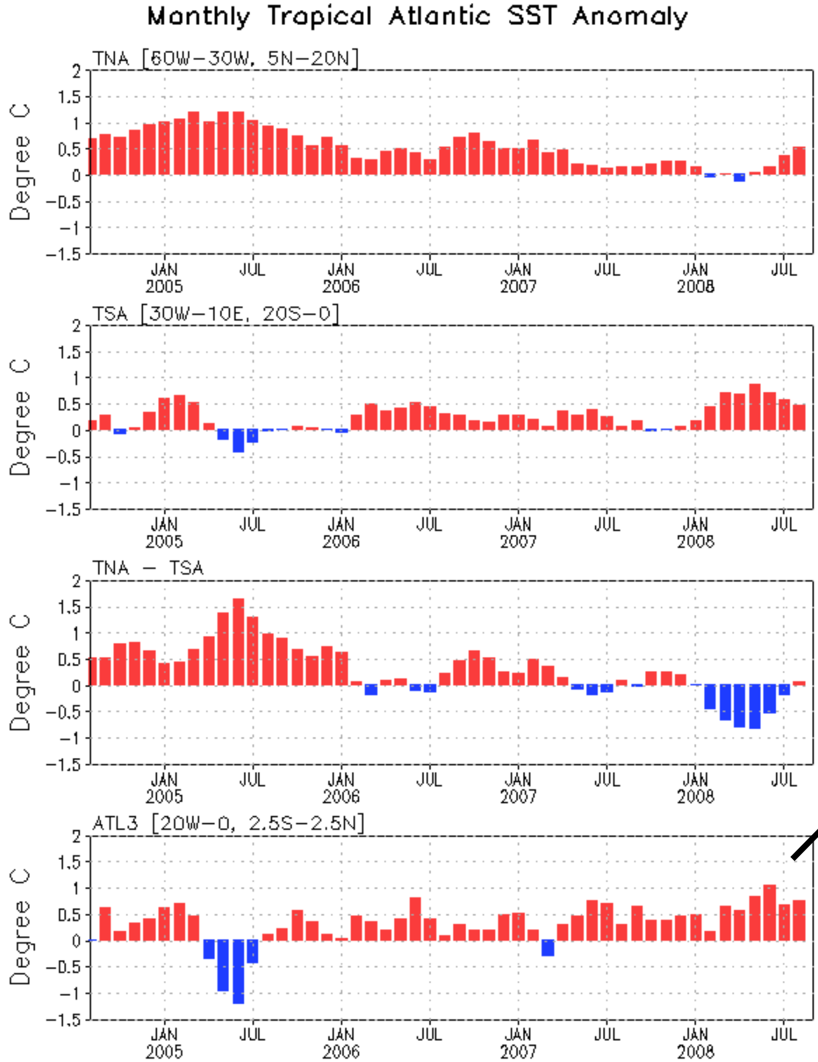
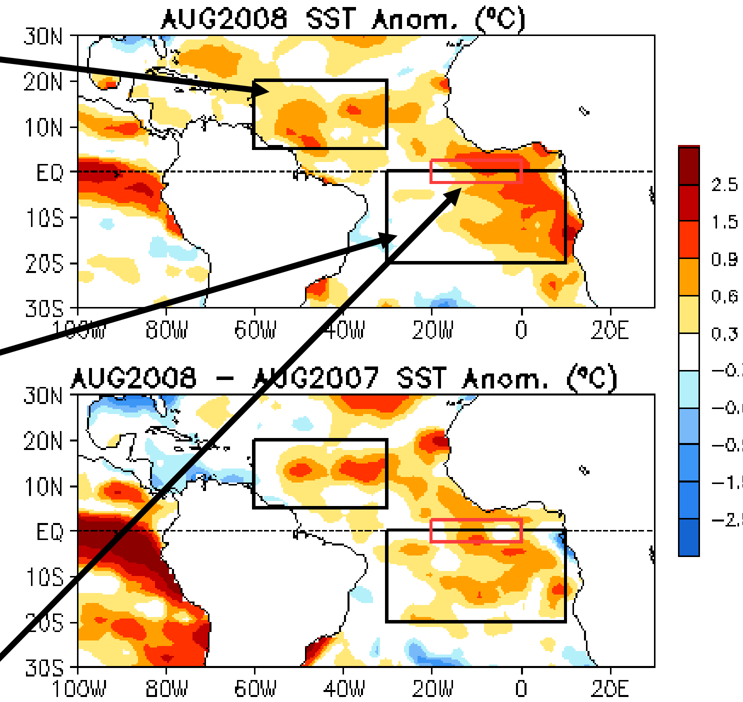


Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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



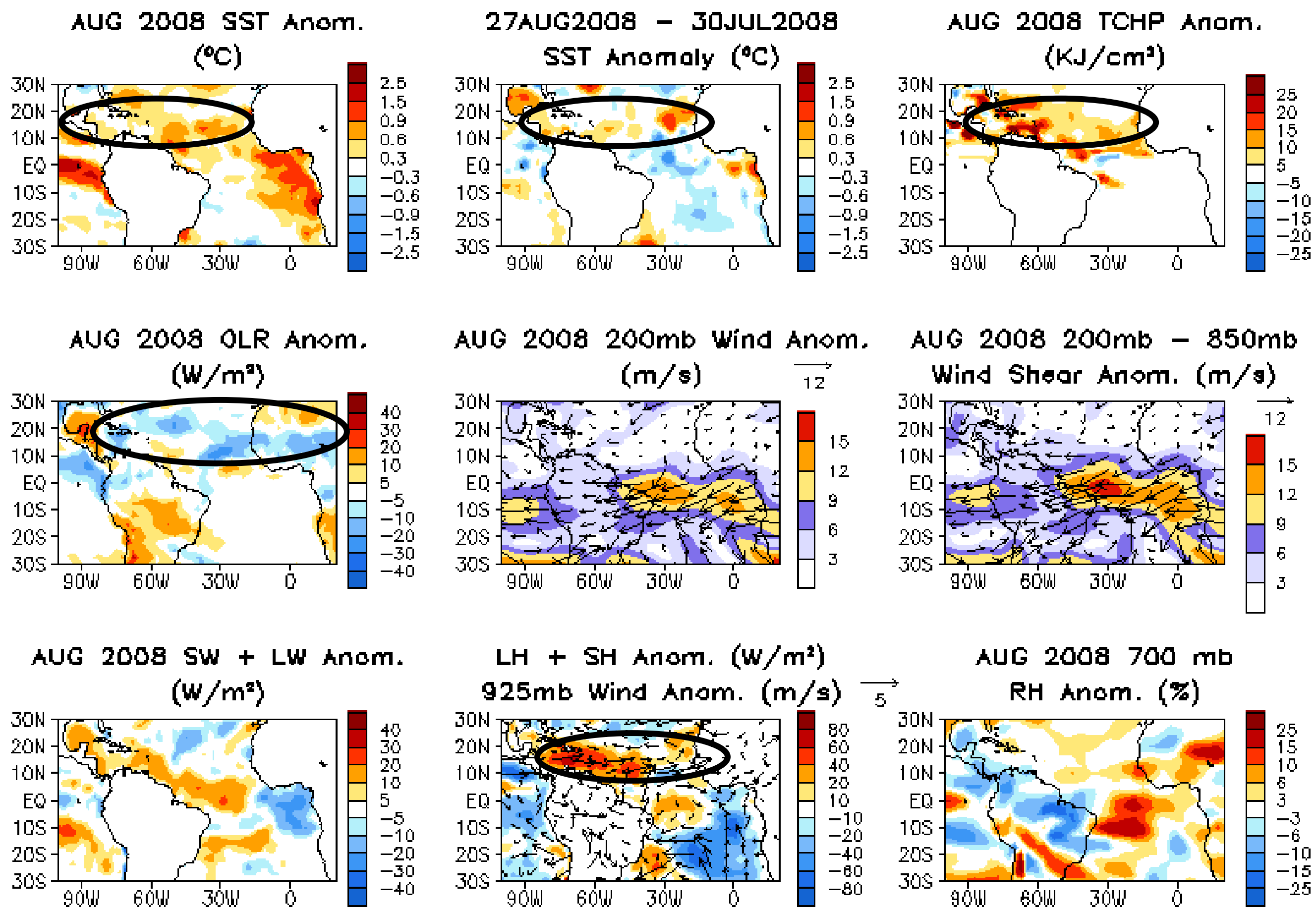


- Tropical North Atlantic SST has been steadily increasing since April, and reached above 0.5°C in August 08.

- Tropical Atlantic SST was much warmer than that last August except it was cooler in Caribbean Sea and Gulf of Mexico.

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, Windshear, TCHP, RH Anomaly



- SSTs increased in the hurricane Main Development Region (MDR).
- Low-level westerly (upper-level near-normal conditions) wind anomalies resulted in below-average wind shear in MDR.
- Tropical Cyclone Heat Potential (TCHP) was above-average in MDR, favourable for hurricane development.

North Atlantic Ocean

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

- SST cooled substantially near the Gulf Stream.
- Negative NAO pattern persisted.

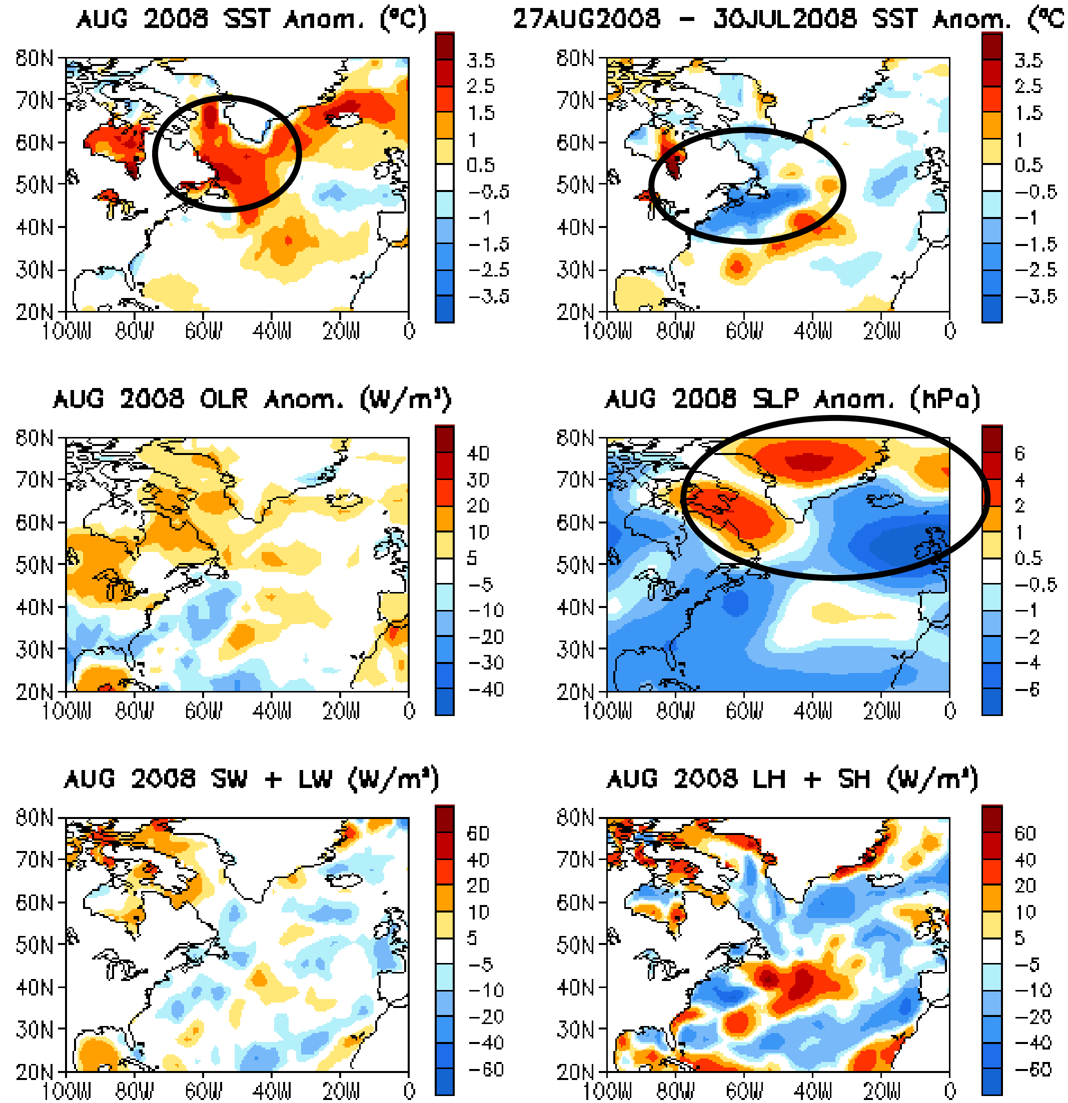
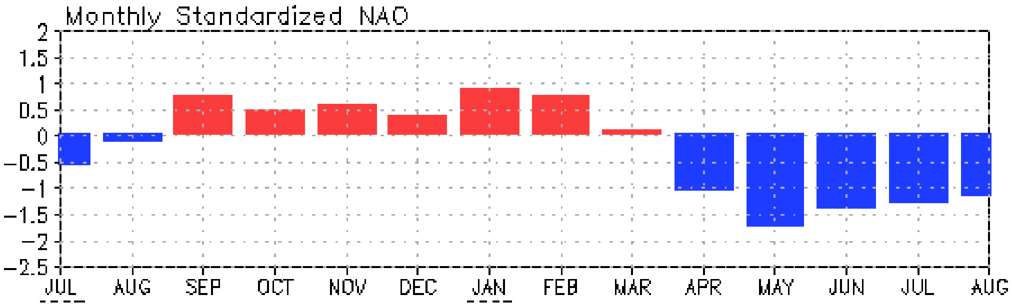
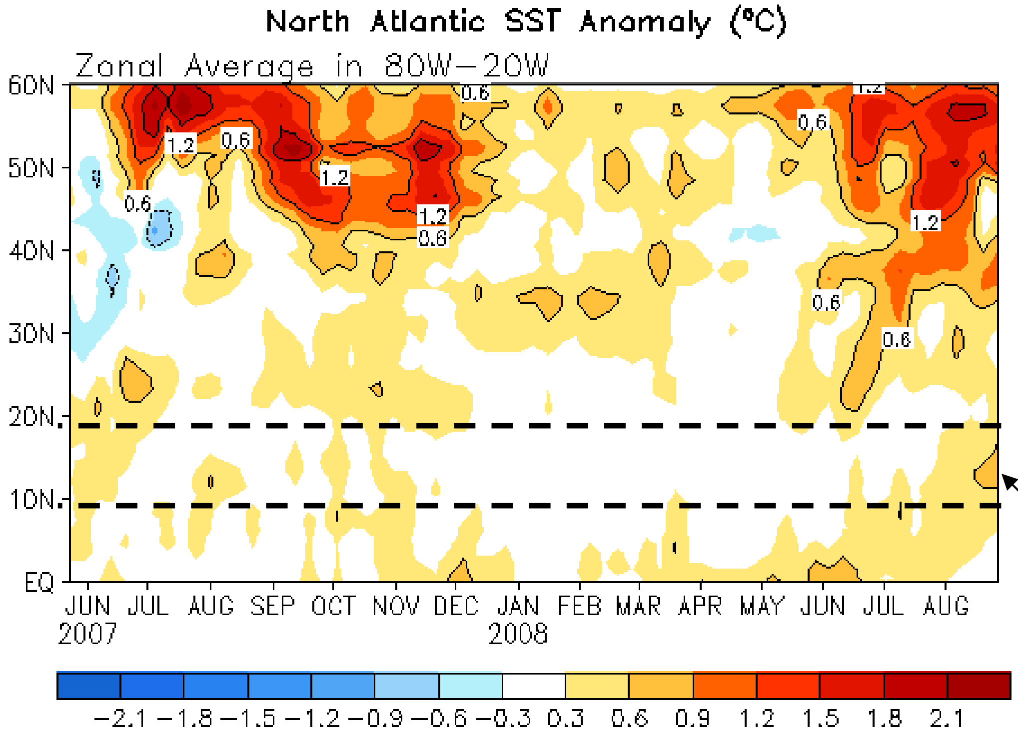
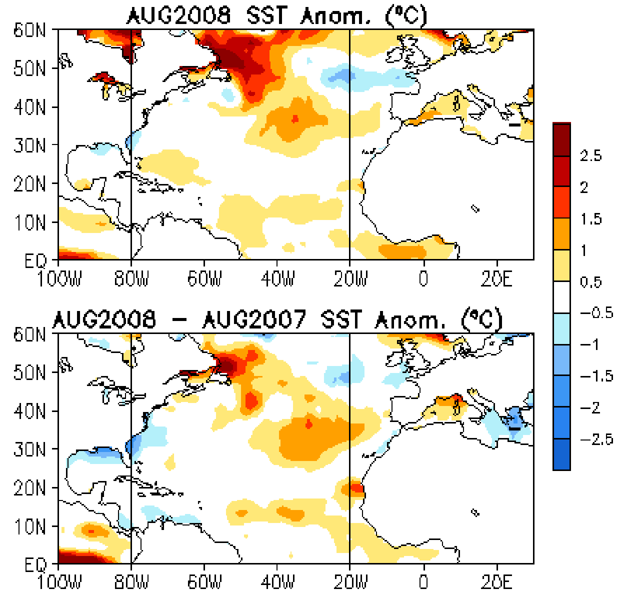


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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





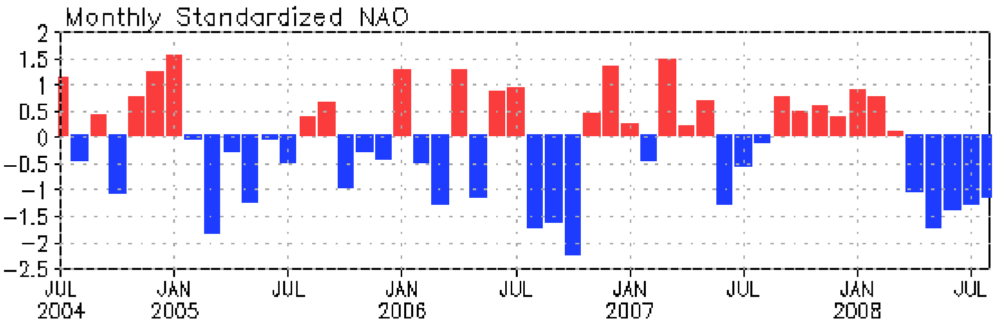


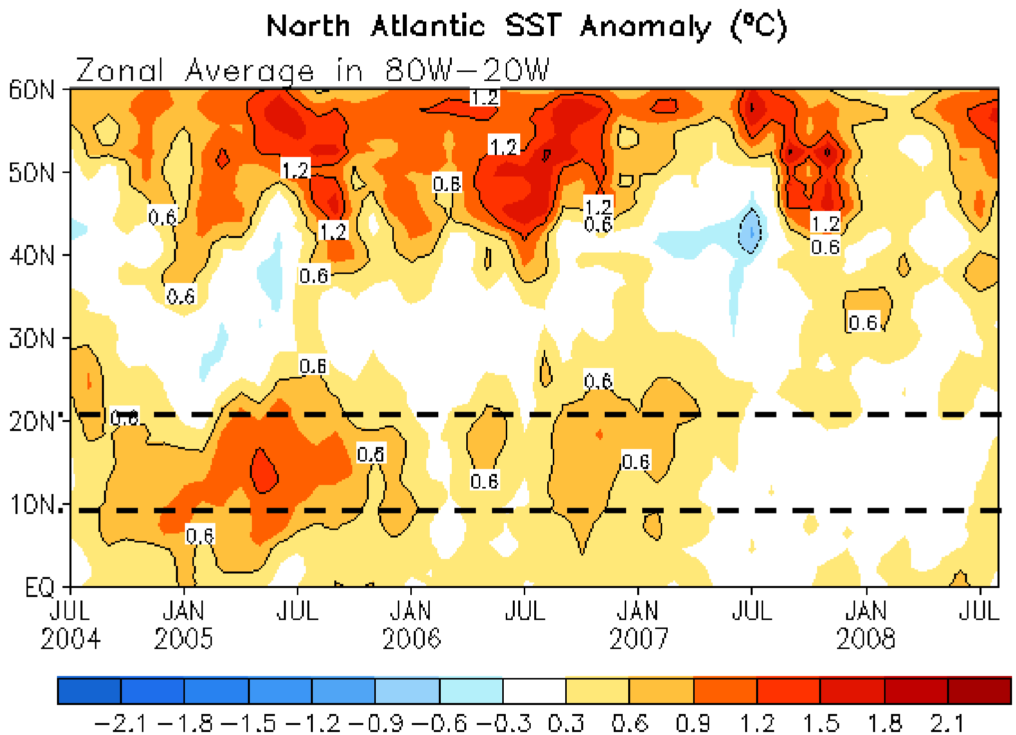
- High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).

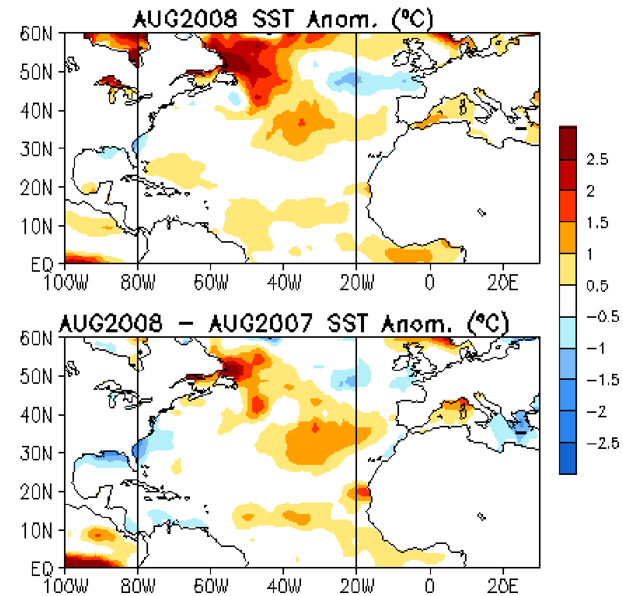
- Negative NAO index persisted over last 5 months has caused large warming in high-latitude North Atlantic, and possibly also the recent warming in hurricane main development region.

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





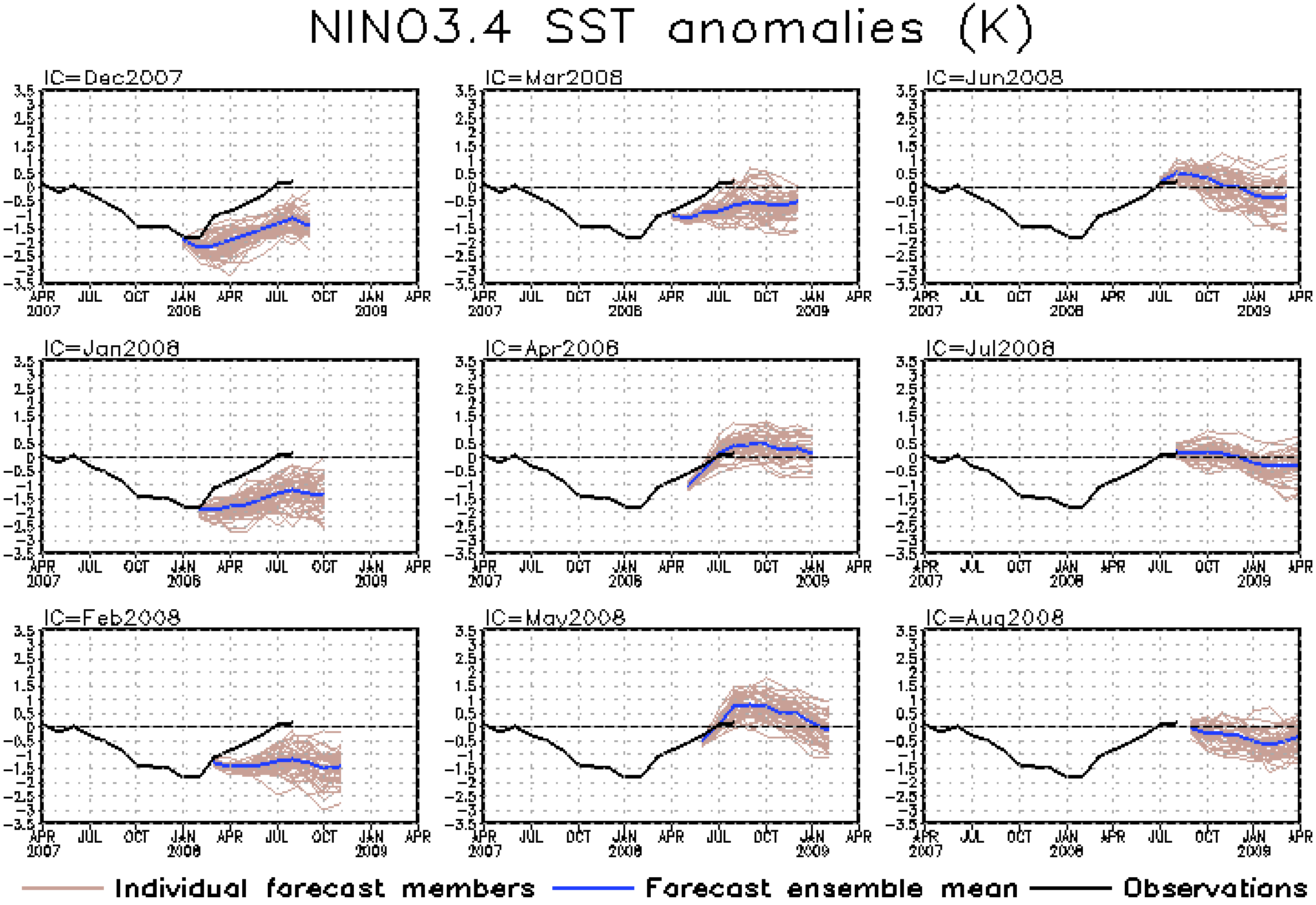


- SSTA in hurricane main development region was slightly warmer than in 2007, but still cooler than in 2006.

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

CFS SST Predictions and Ocean Initial Conditions

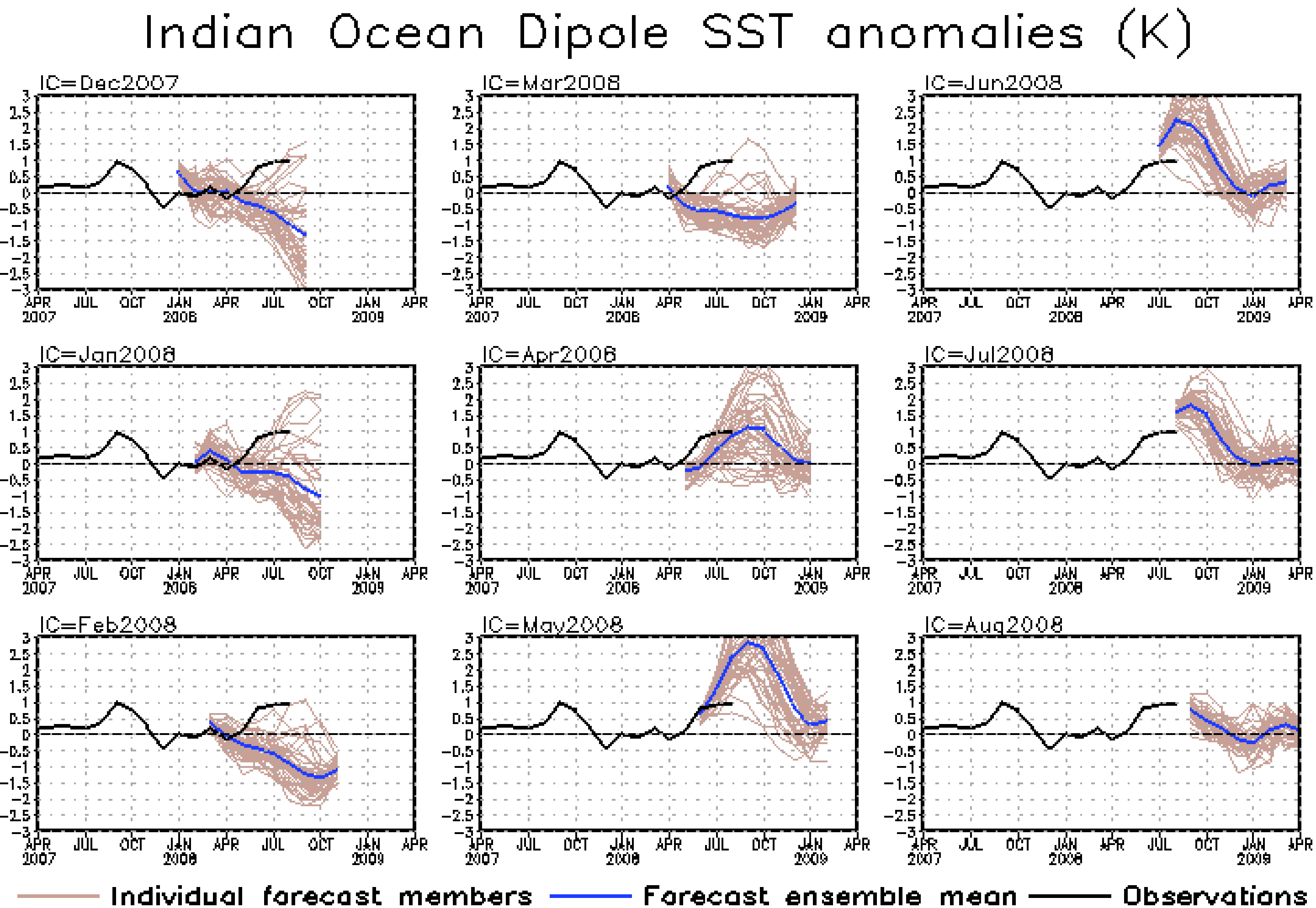
CFS Niño3.4 SST Predictions from Different Initial Months



- Latest forecasts are calling for ENSO-neutral to weak La Nina conditions.

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

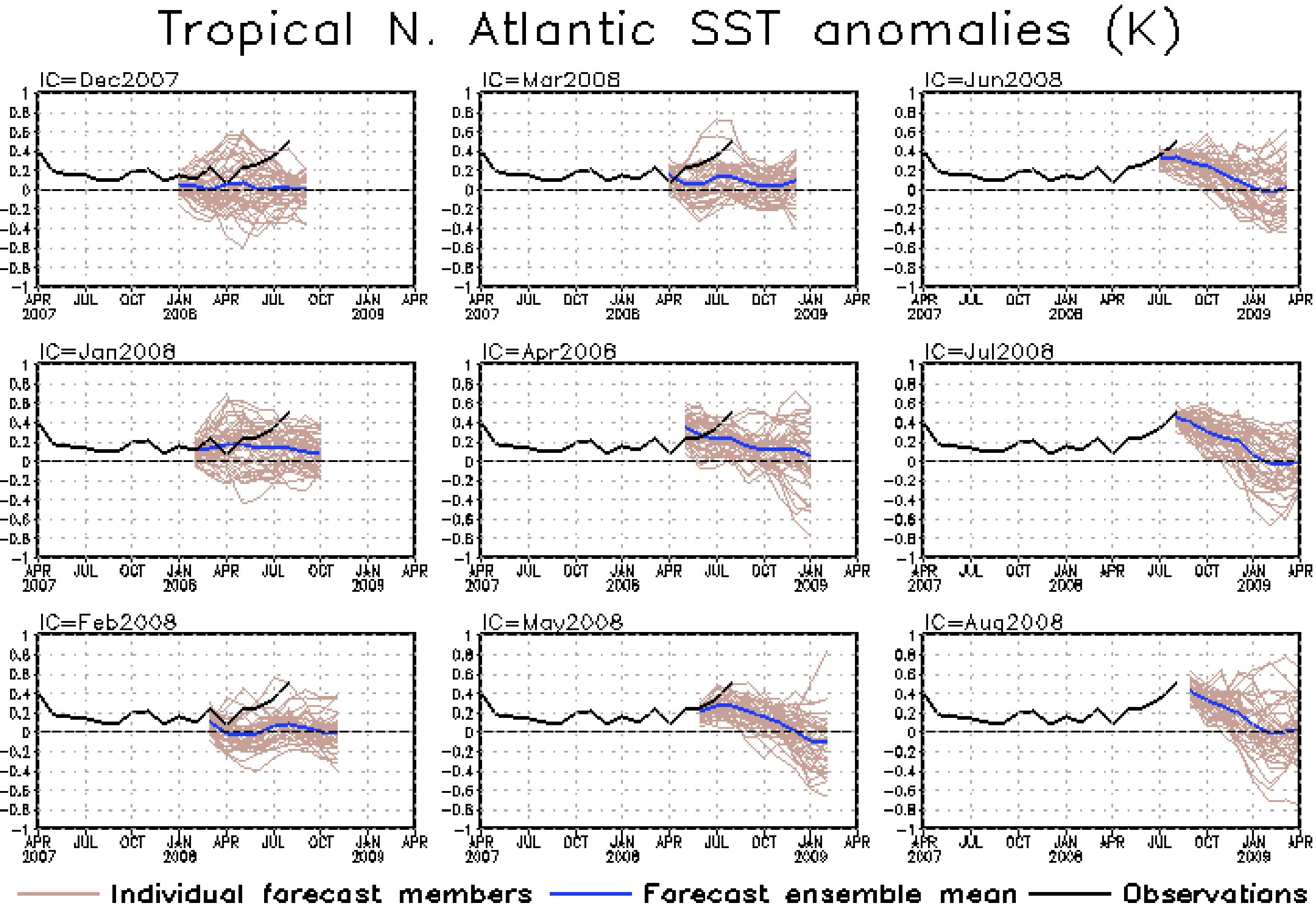
SETIO = SST anomaly in [90°E-110°E, 10°S-0]

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

- **Starting from May I.C., CFS has been predicting a positive IOD event.**
- **CFS overestimated the amplitude of IOD.**
- **CFS called for a strong negative IOD event from Jan-Apr I.C., suggesting that IOD has a low predictability of about 1-2 month lead times.**

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 SSTA in hurricane main development region.

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

- **Global Ocean**
  - Global mean SST anomaly continues to rise.

- **Pacific Ocean**
  - ENSO-neutral conditions will continue through winter.
  - Lingering La Nina signal in atmospheric circulations.

- **Indian Ocean**
  - Dipole Mode Index was above 0.5ºC in three consecutive months from June to August.

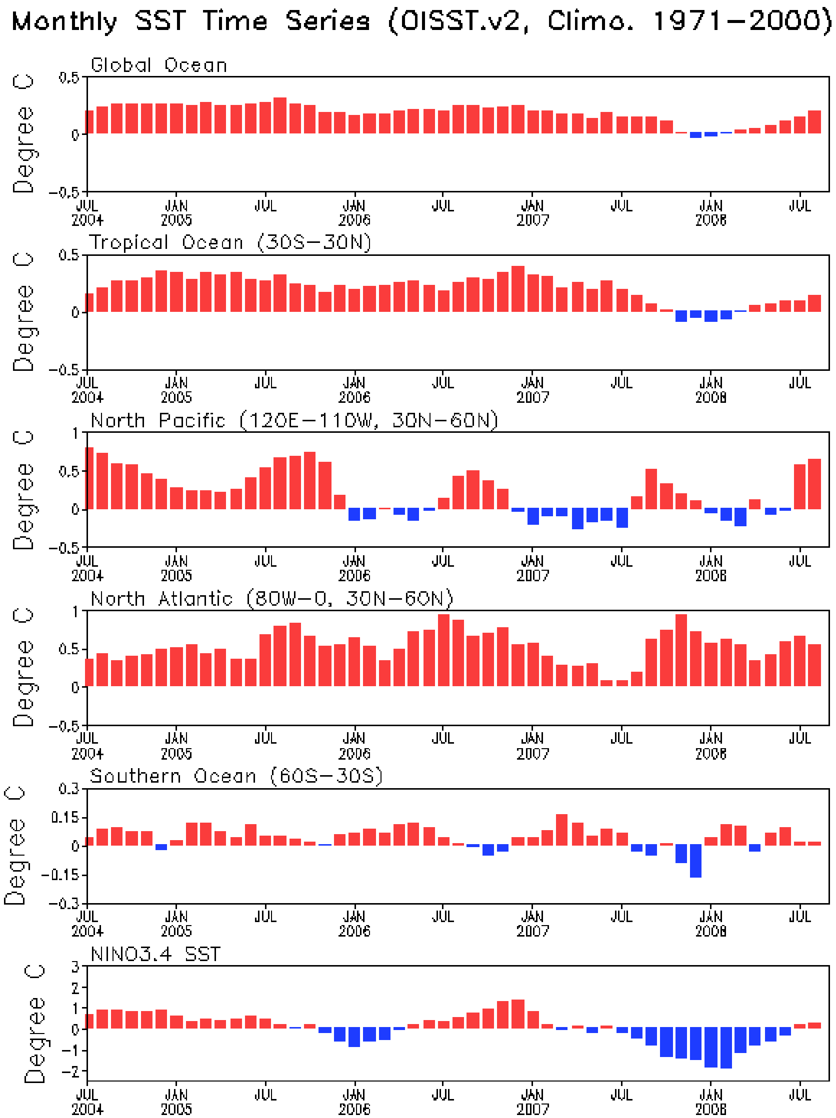
- **Atlantic Ocean**
  - Tropical North Atlantic SST continues to rise, favourable for hurricane development.

- **Active Ocean**
  - Arctic Ocean was not as warm as it was last August.
  - But sea ice extent is close to the 2007 low level.

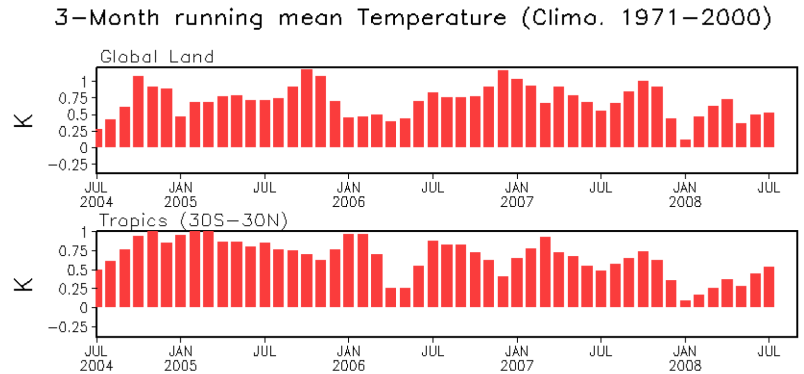
Backup Slides

Monthly Time Series

Sea Surface Temperature



CAMS Land Temperature



- **Tropical land temperature tracks the tropical ocean temperature well.**
- **Land temperature variability is larger than SST variability.**

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.

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!