

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**

- La Niña conditions ($\text{NINO3.4} < -0.5\text{C}$) developed in December 08, and are expected to continue into early 2009.
- Typical La Nina signals presented in the tropical convection, atmospheric circulations, surface ocean currents and subsurface ocean temperature.
- Negative PDO SST pattern continued in North Pacific.
- Extremely strong upwelling has transitioned the climatological downwelling into upwelling along most of the west coast of North America in Dec 08.

- **Indian Ocean**

- Positive SST anomalies covered most of the extra-tropical Indian ocean.
- The tropical Indian Ocean SSTs are close to normal.

- **Atlantic Ocean**

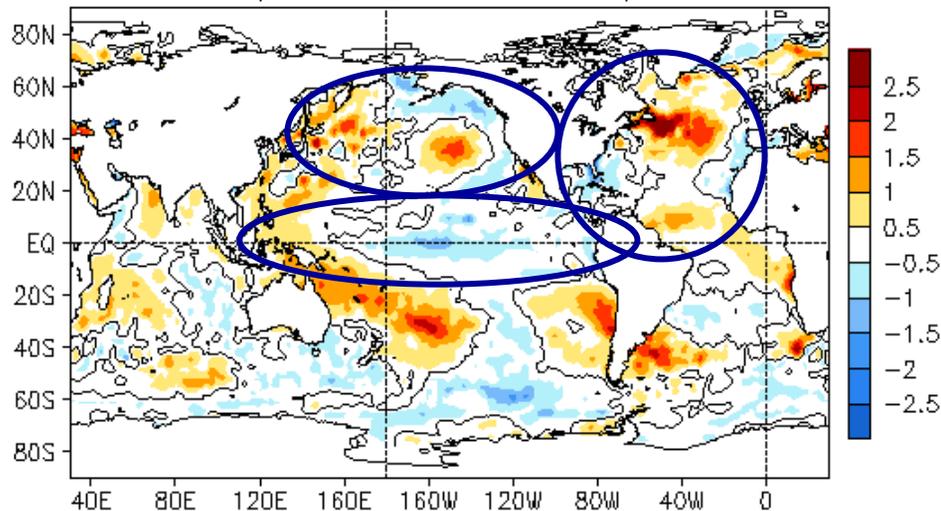
- Positive SST anomalies presented in mid-latitude North Atlantic and tropical North Atlantic.

- **Arctic Ocean**

- Ice concentration remains much below normal, with the ice growth slowing down during December.

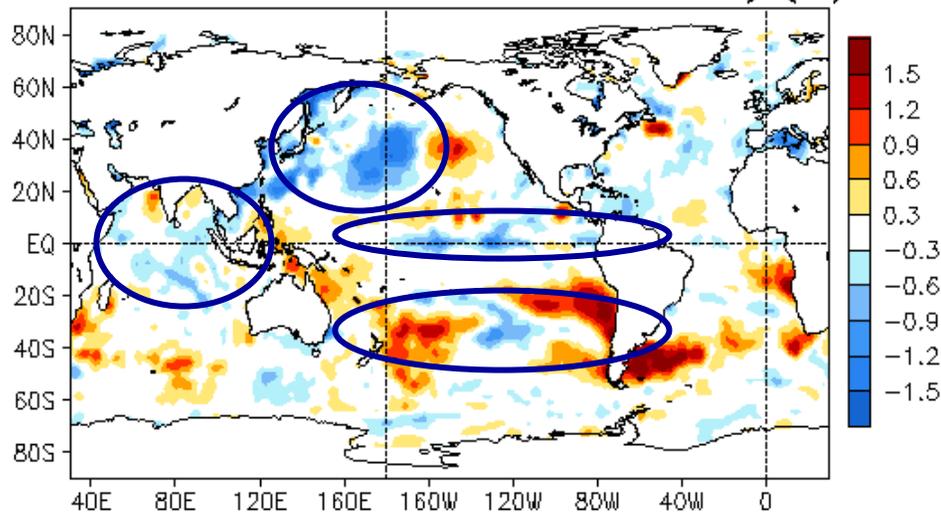
Global SST Anomaly ($^{\circ}\text{C}$) and Anomaly Tendency

DEC 2008 SST Anomaly ($^{\circ}\text{C}$)
(OISST.v2, Clima. 71-00)



- Negative PDO SST pattern in North Pacific.
- Positive SSTA in the northern and tropical North Atlantic.
- La Niña Conditions in the tropical Pacific.

DEC 2008 - NOV 2008 SST Anomaly ($^{\circ}\text{C}$)

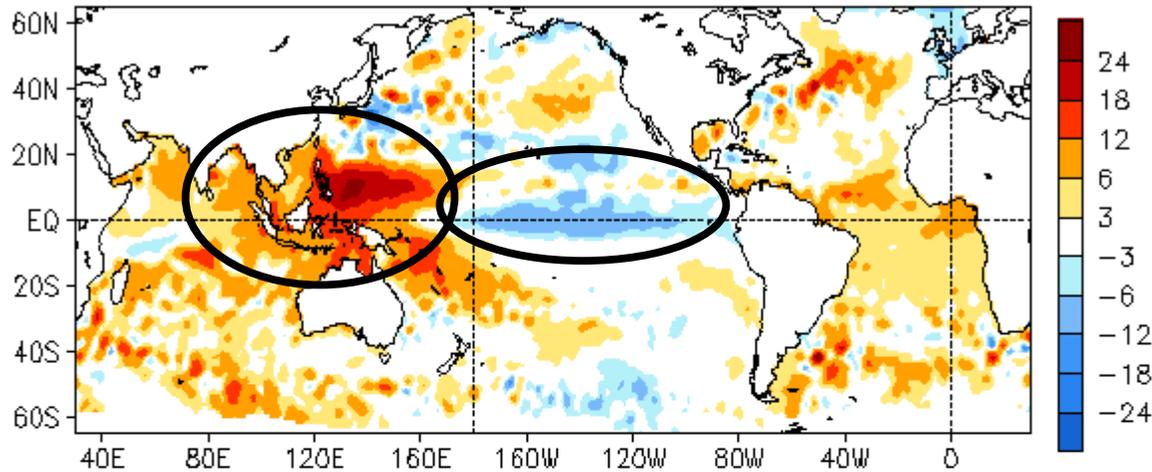


- SST cooled down in the central-eastern tropical Pacific, tropical Indian Ocean and central-western North Pacific.
- SST warmed up across much of the South Pacific.

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.

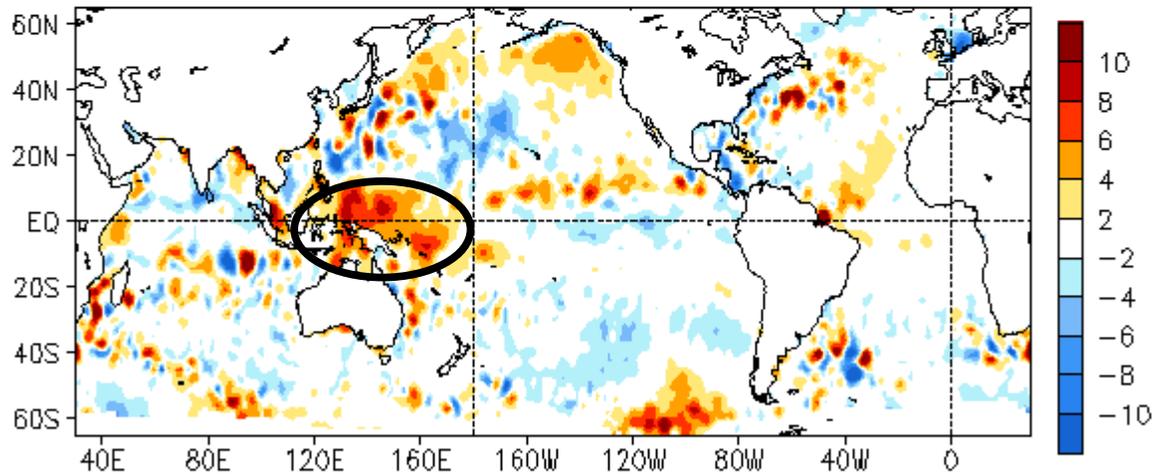
Global SSH Anomaly (cm) and Anomaly Tendency

DEC 2008 SSH Anomaly (cm)
(AVISO Altimetry, Climo. 93-05)



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

DEC 2008 – NOV 2008 SSH Anomaly (cm)

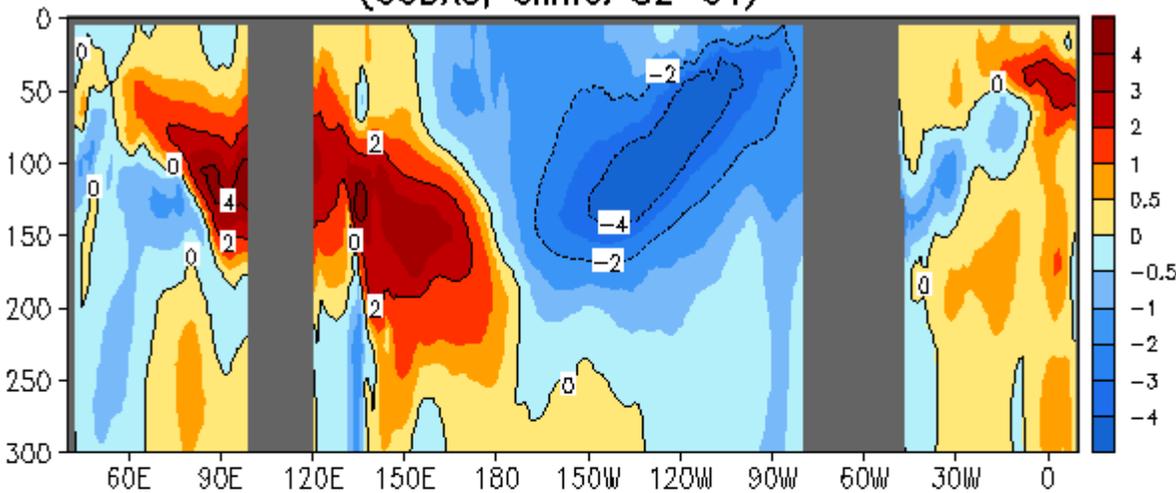


- SSH increased in the western tropical Pacific.

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.

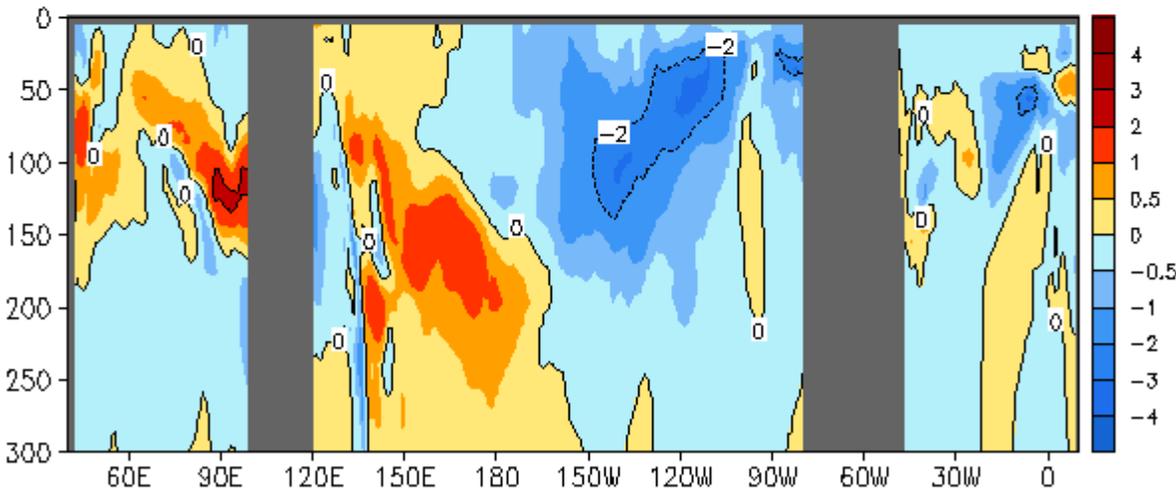
Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2°S-2°N

DEC 2008 Eq. Temp Anomaly (°C)
(GODAS, Clima. 82-04)



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

DEC 2008 – NOV 2008 Eq. Temp Anomaly (°C)



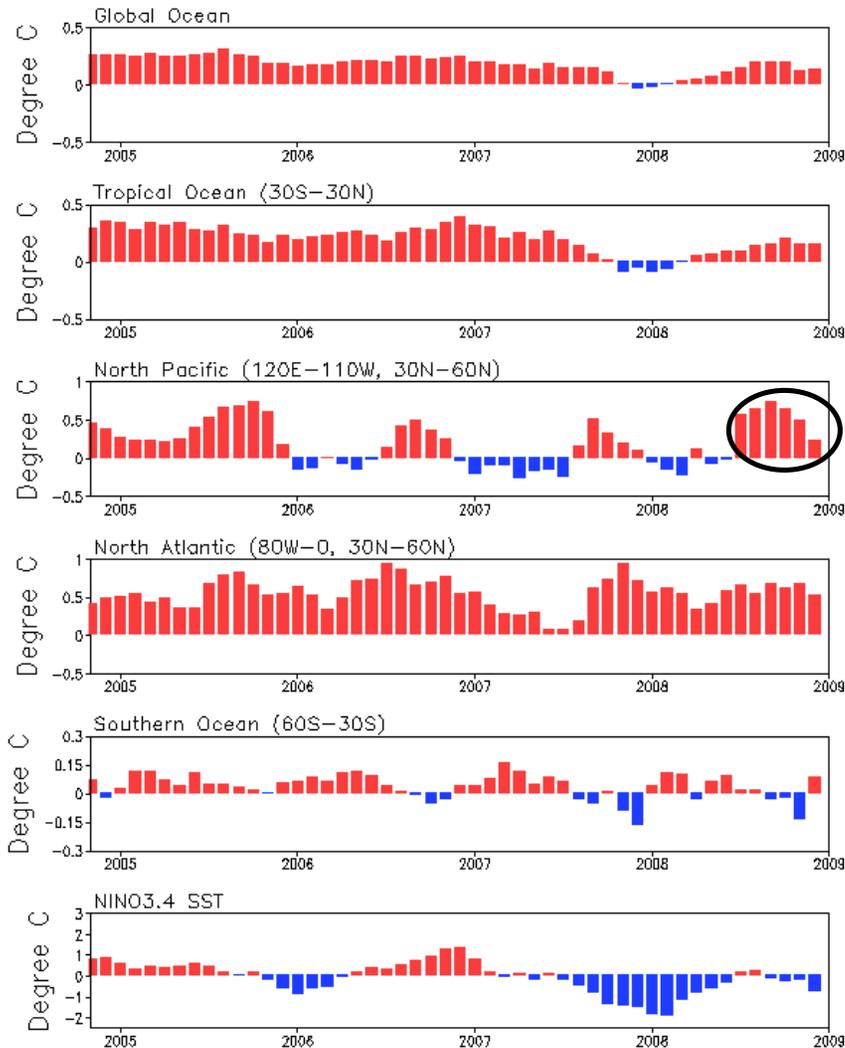
- Temperature tendency shows an amplification of the anomalies in the equatorial Indian and Pacific Oceans.

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

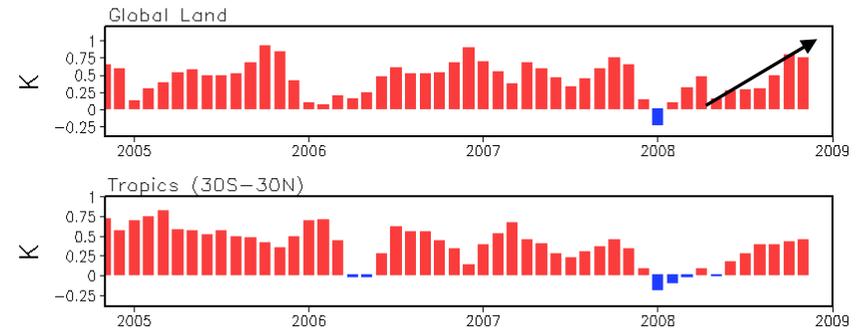
Sea Surface Temperature

Monthly SST Time Series (OISST.v2, Climo. 1971–2000)



CAMS Land Temperature

CAMS Temperature (Climo. 1982–2004)
(3–Month running mean)

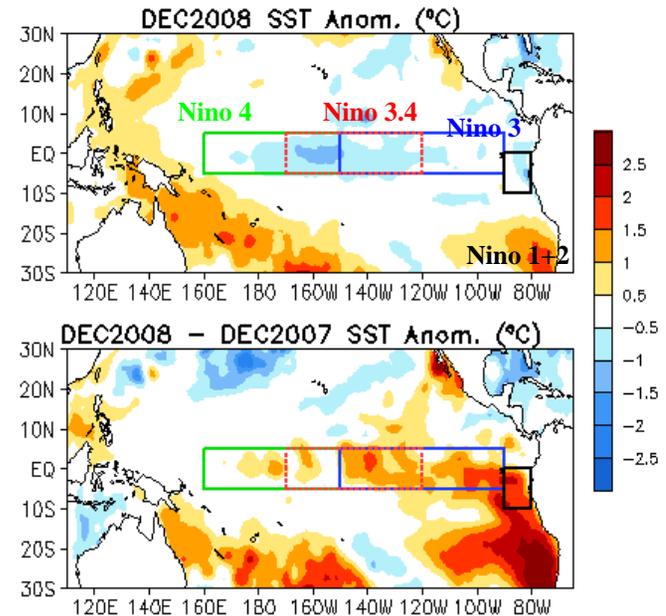
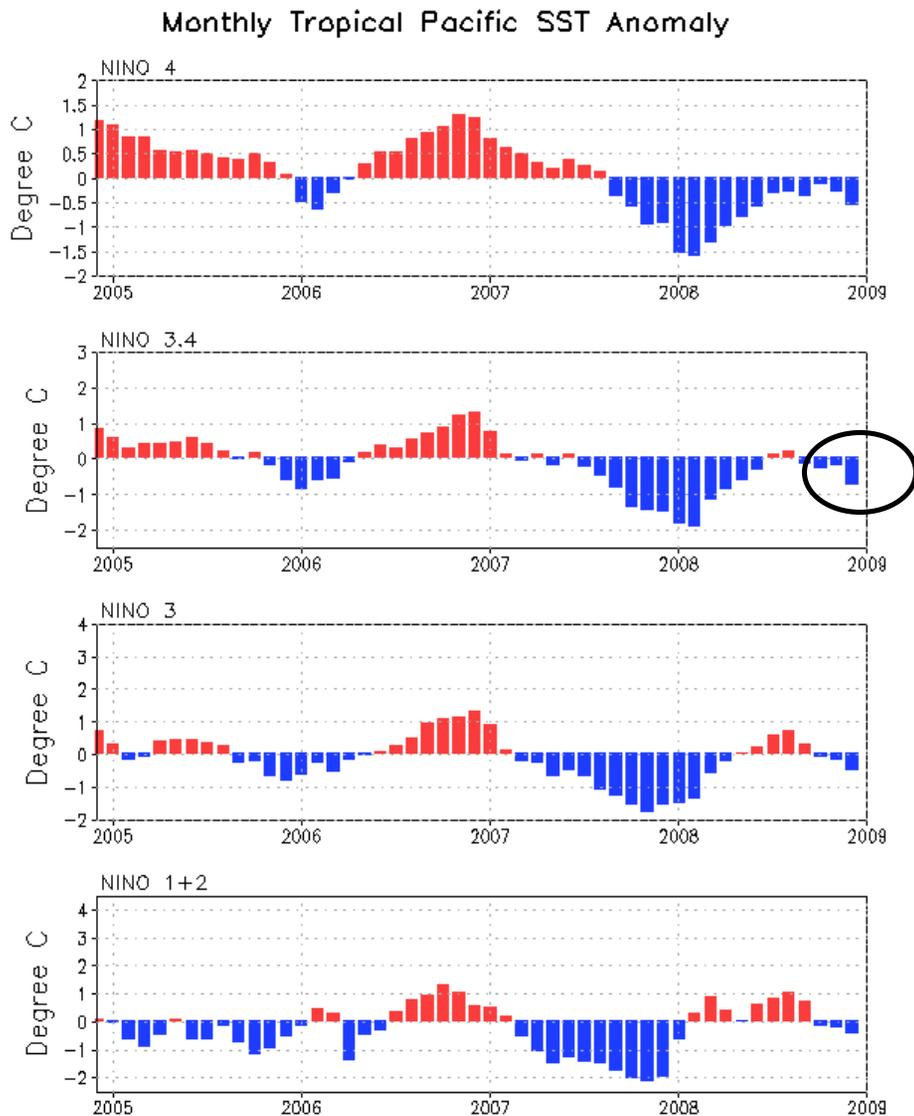


- Global mean SSTA and land temperature anomalies persisted.
- Tropical land temperature continues to be above-normal in response to the above-normal tropical ocean SST.
- Positive SSTA in North Pacific continued its downward trend since Sept. 08, and became near-normal in Dec. 08.
- Large positive SSTA in North Atlantic has persisted from September 07 to present.
- Negative NINO3.4 SST strengthened in Dec. 08, and met NOAA's La Nina definition (NINO3.4 < - 0.5C).

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

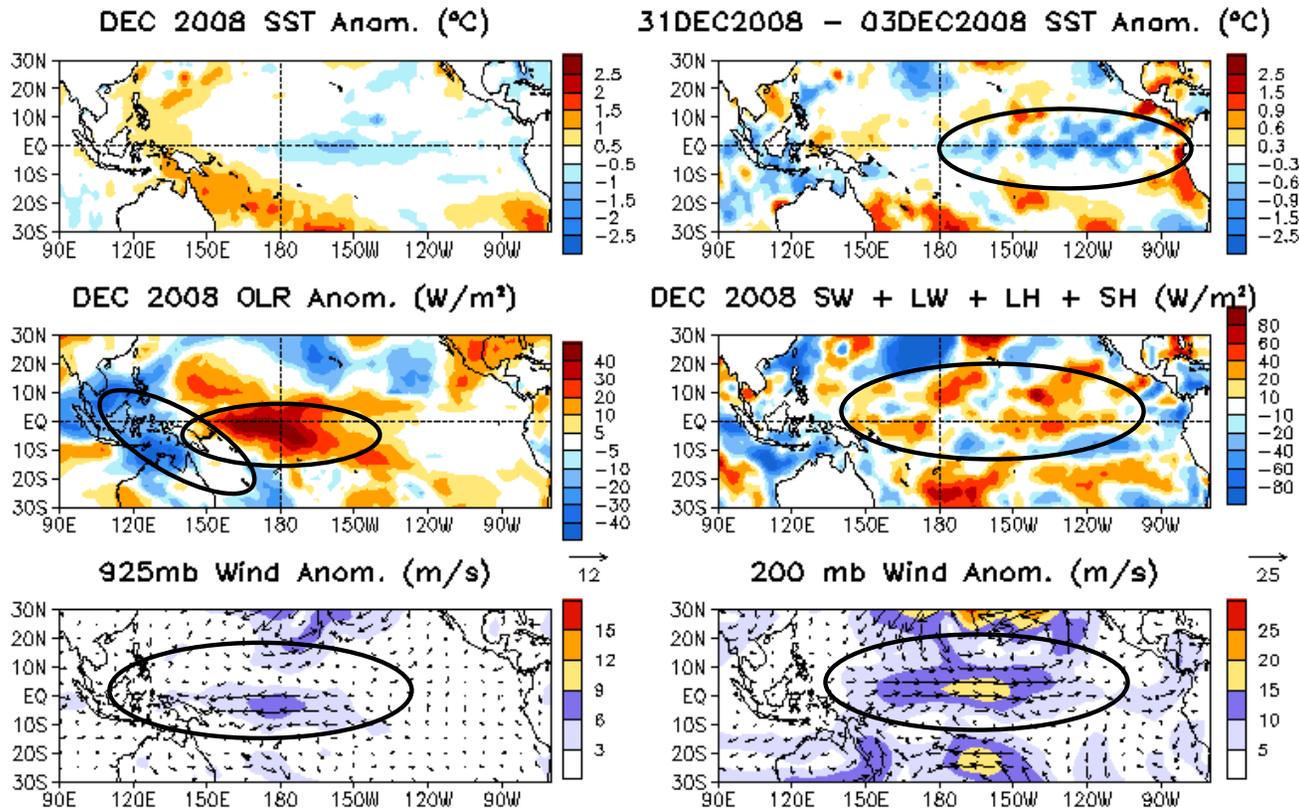
Evolution of Pacific NINO SST Indices



- La Niña conditions (NINO3.4 < -0.5C) developed during December 2008, and are expected to continue into spring 2009 – NOAA's "ENSO Diagnostic Discussion".
- All NINO indices are 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 the central tropical Pacific (Maritime Continent).
- Low-level (upper-level) easterly (westerly) wind anomalies in the central tropical Pacific.
- Negative SSTA tendency in the central-eastern tropical Pacific was not driven by surface fluxes.

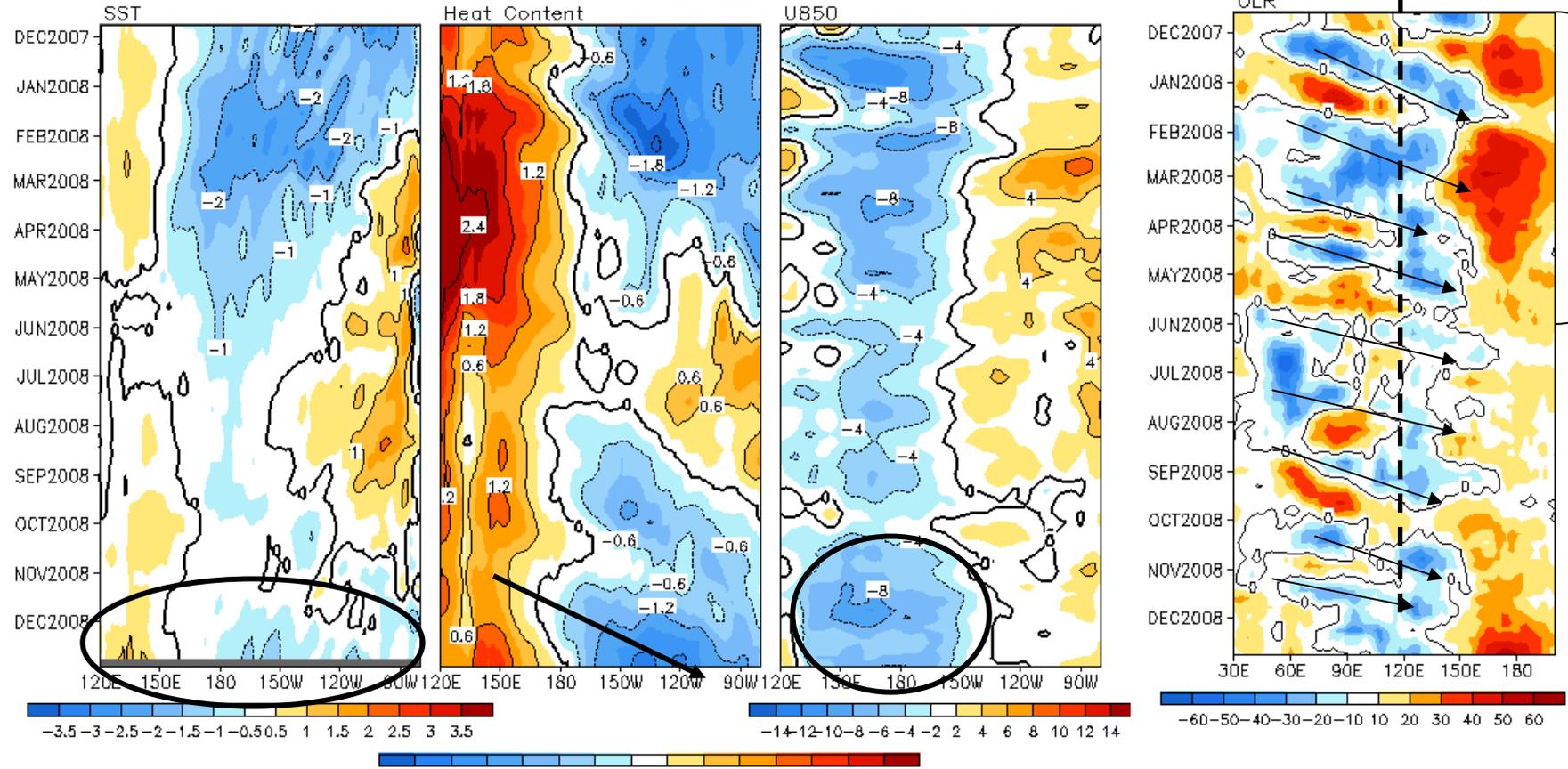
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Evolution of Equatorial Pacific SST ($^{\circ}\text{C}$), 0-300m Heat Content ($^{\circ}\text{C}$),

850-mb Zonal Wind (m/s), and OLR (W/m^2) Anomaly

2 $^{\circ}\text{S}$ -2 $^{\circ}\text{N}$ Average, 3 Pentad Running Mean

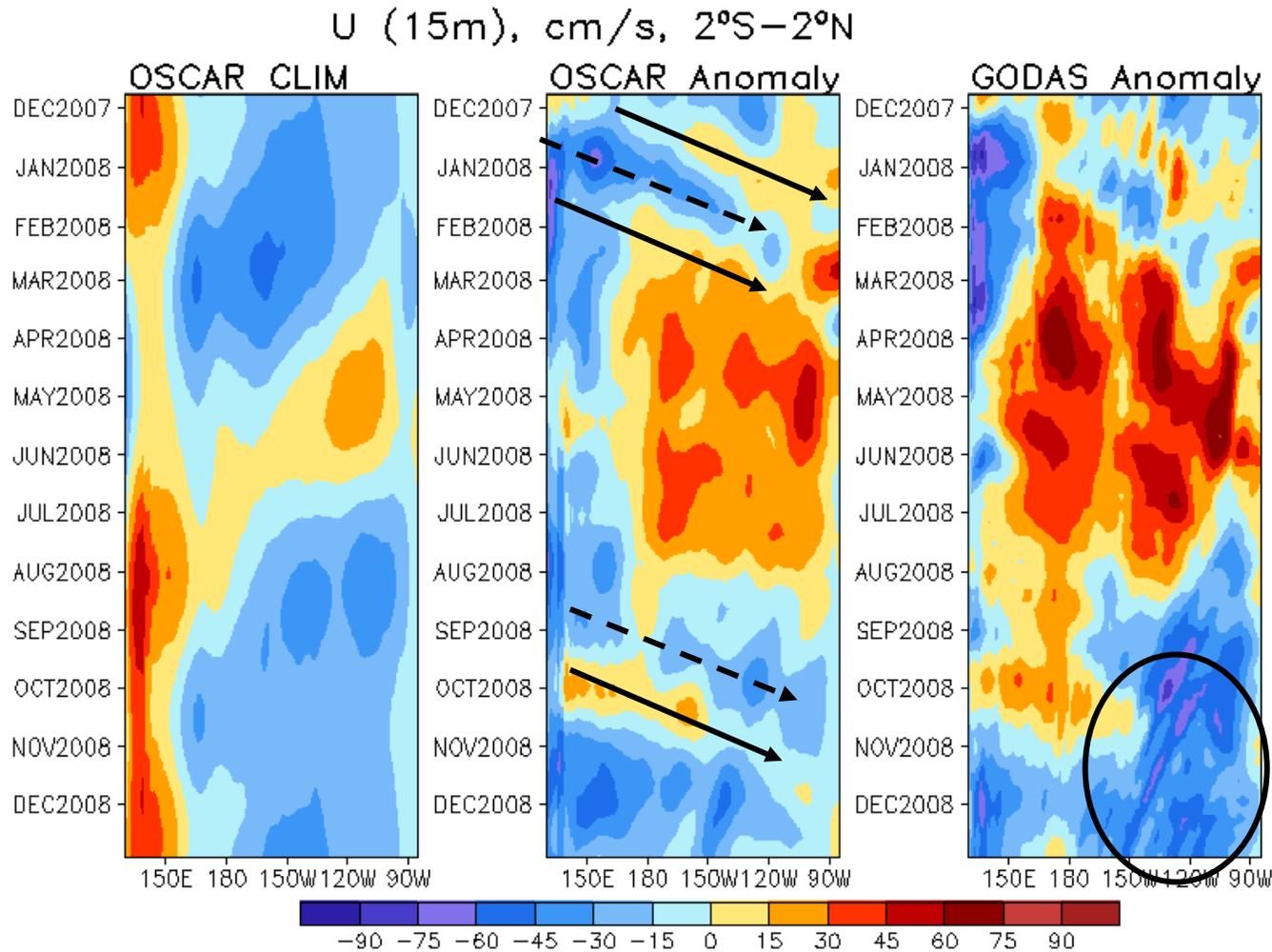
5 $^{\circ}\text{S}$ -5 $^{\circ}\text{N}$ Average (3 Pentad Running Mean) **La Nina**



- Below-normal SST in the tropical Pacific east of the Dateline.
- Negative heat content anomalies east of the Dateline have strengthened since early November.
- They were likely forced by strong easterly wind anomaly persisted 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 $^{\circ}\text{S}$ -2 $^{\circ}\text{N}$ and Outgoing Long-wave Radiation (OLR, right) averaged in 5 $^{\circ}\text{S}$ -5 $^{\circ}\text{N}$. 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.

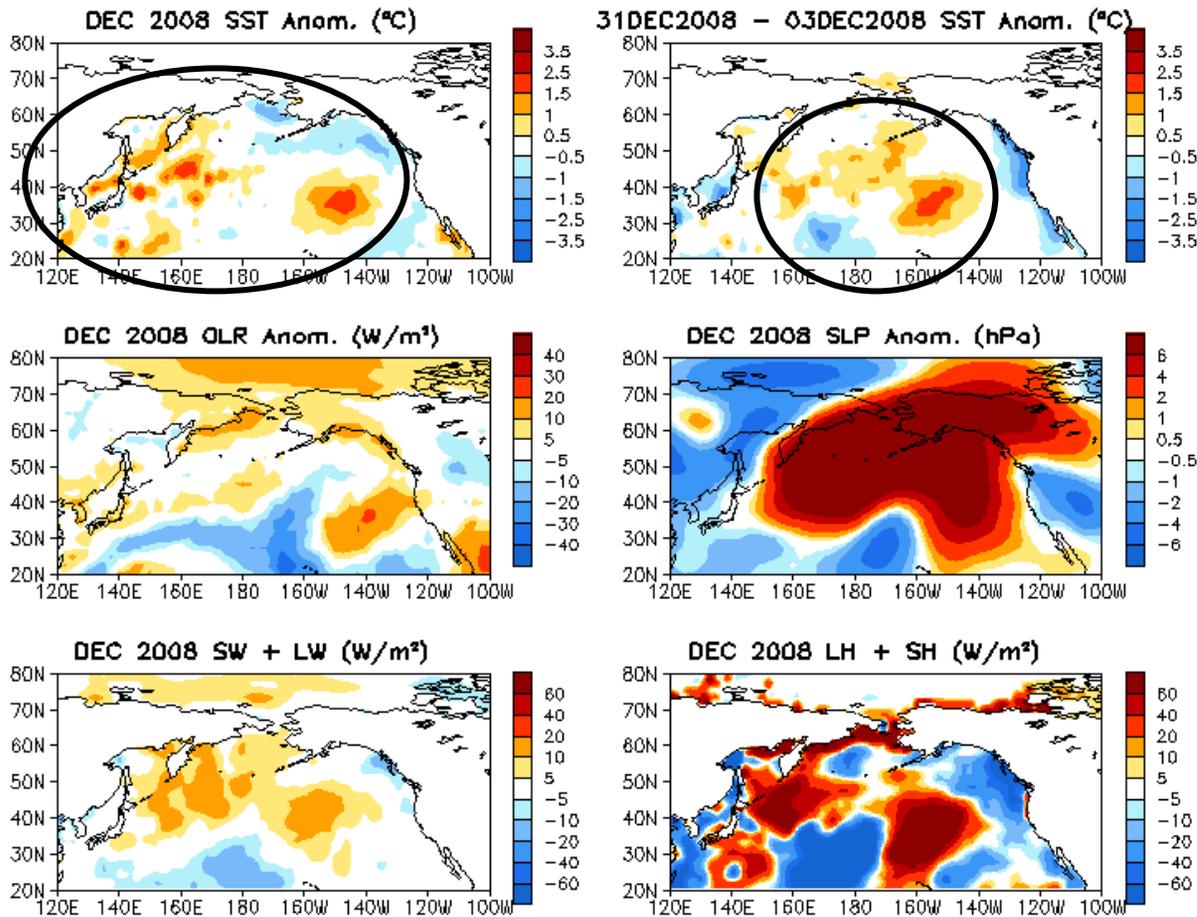
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- Eastward propagation of negative (dashed line) (positive, solid line) surface zonal current anomalies were associated with upwelling (downwelling) oceanic Kelvin waves.
- Surface zonal current anomaly switched from positive to negative after a downwelling oceanic Kelvin wave in late October.
- Negative surface zonal current anomalies of GODAS in E. tropical Pacific were too strong compared to OSCAR currents.

North Pacific & Arctic Ocean

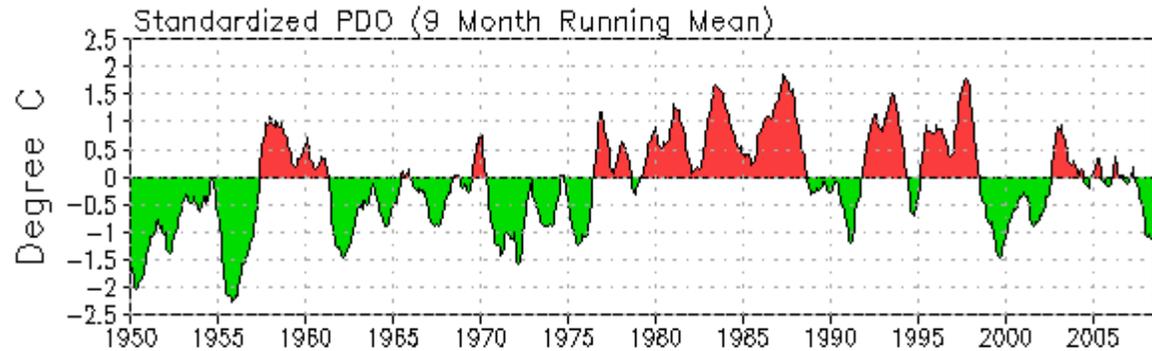
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx



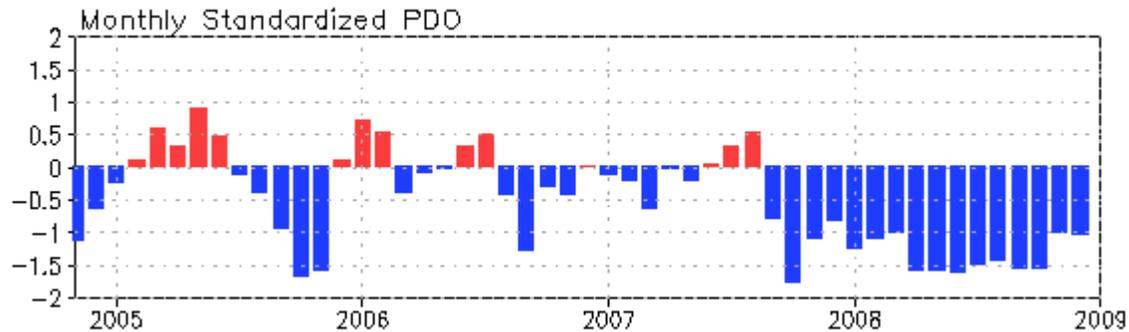
- Negative PDO SST pattern presented in North Pacific.
- SSTA increased in the central North Pacific, consistent with the turbulent flux anomalies and anomalous high sea level pressure.
- SST cooled down significantly along the west coast of North America, probably due to along-shore anomalous northerly winds associated with above-normal sea level pressure in 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.

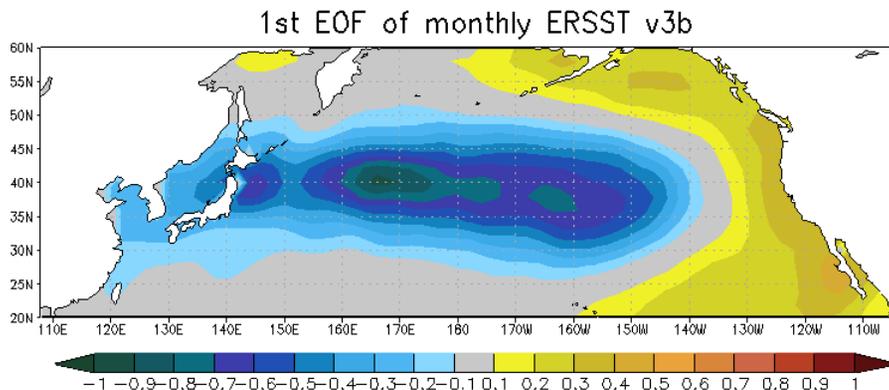
PDO index



PDO index at the lowest value since 1999.



PDO index below average since September 2007.



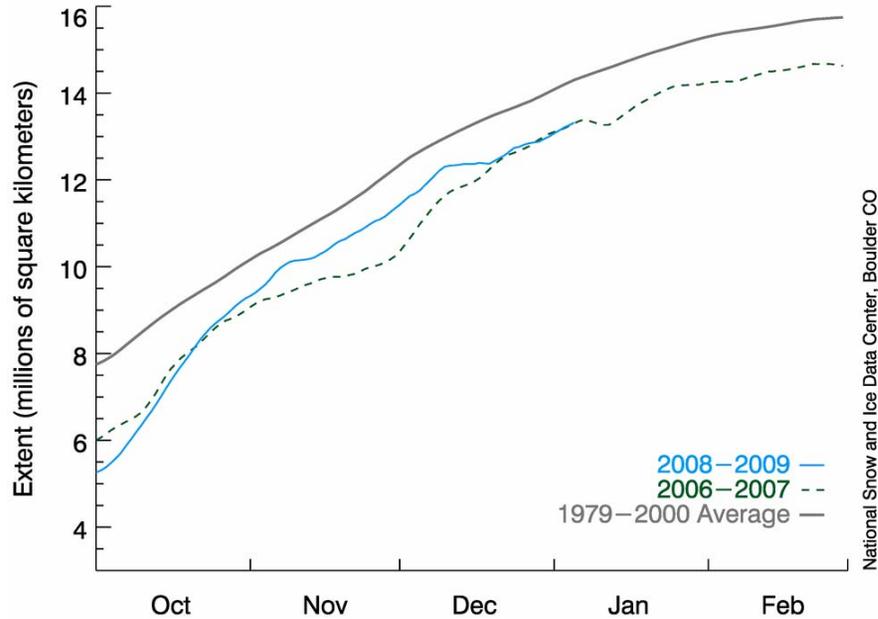
- Pacific Decadal Oscillation is defined as the 1st EOF of monthly SST in the North Pacific for the period 1900-1993.
- Based on ERSST v3b data. JISAO uses a blend of UKMET and OIv1 and OIv2 SST.
- PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

Arctic Sea Ice

National Snow and Ice Data Center

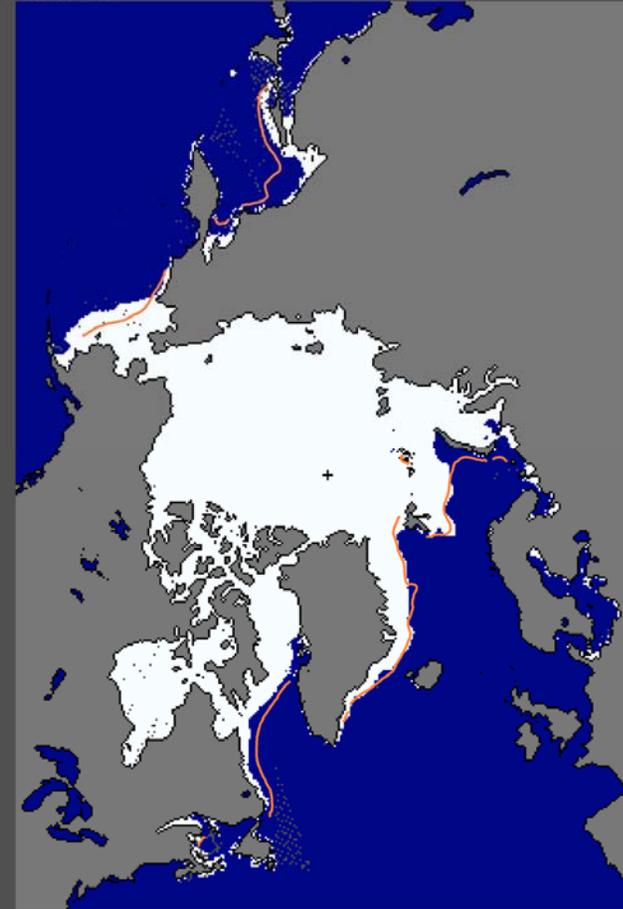
<http://nsidc.org/arcticseaicenews/index.html>

Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)



- Sea ice extent remains well below-normal.
- Arctic sea ice growth slowed during mid-December.

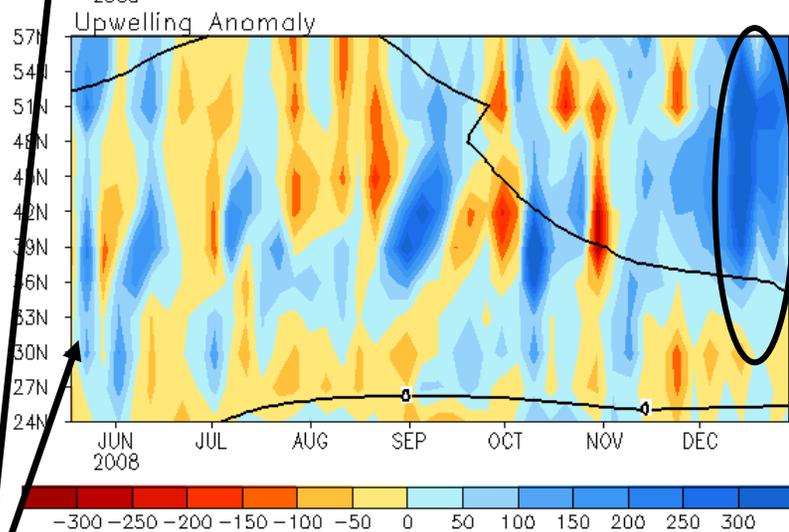
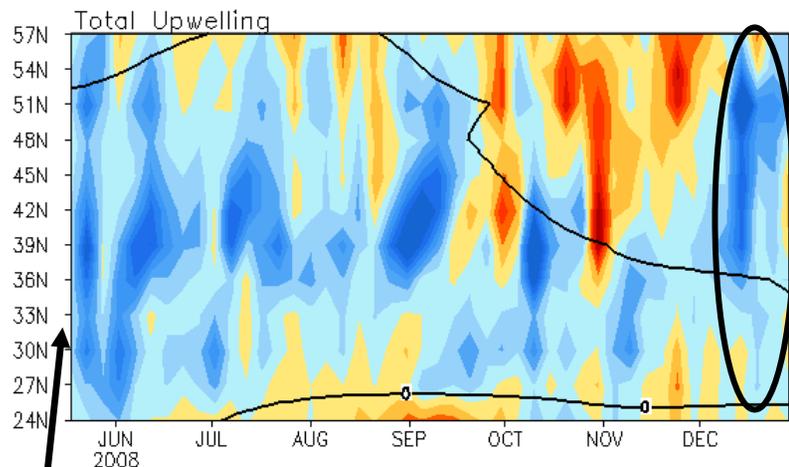
Sea Ice Extent
01/05/2009



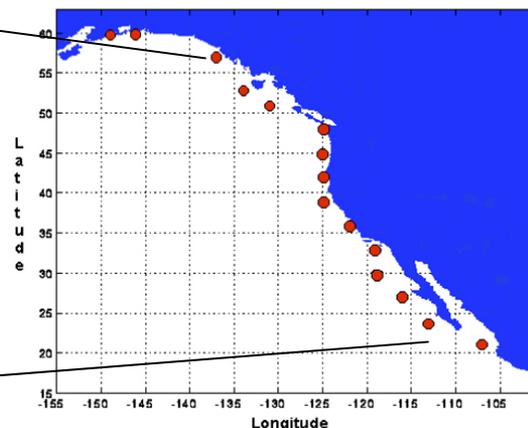
median
1979-2000

North America Western Coastal Upwelling

Pentad Coastal Upwelling for West Coast North America
($m^3/s/100m$ coastline)



Standard Positions of Upwelling Index Calculations



- Extremely strong upwelling has transitioned the climatological downwelling into upwelling along most of the west coast of North America in December 08.

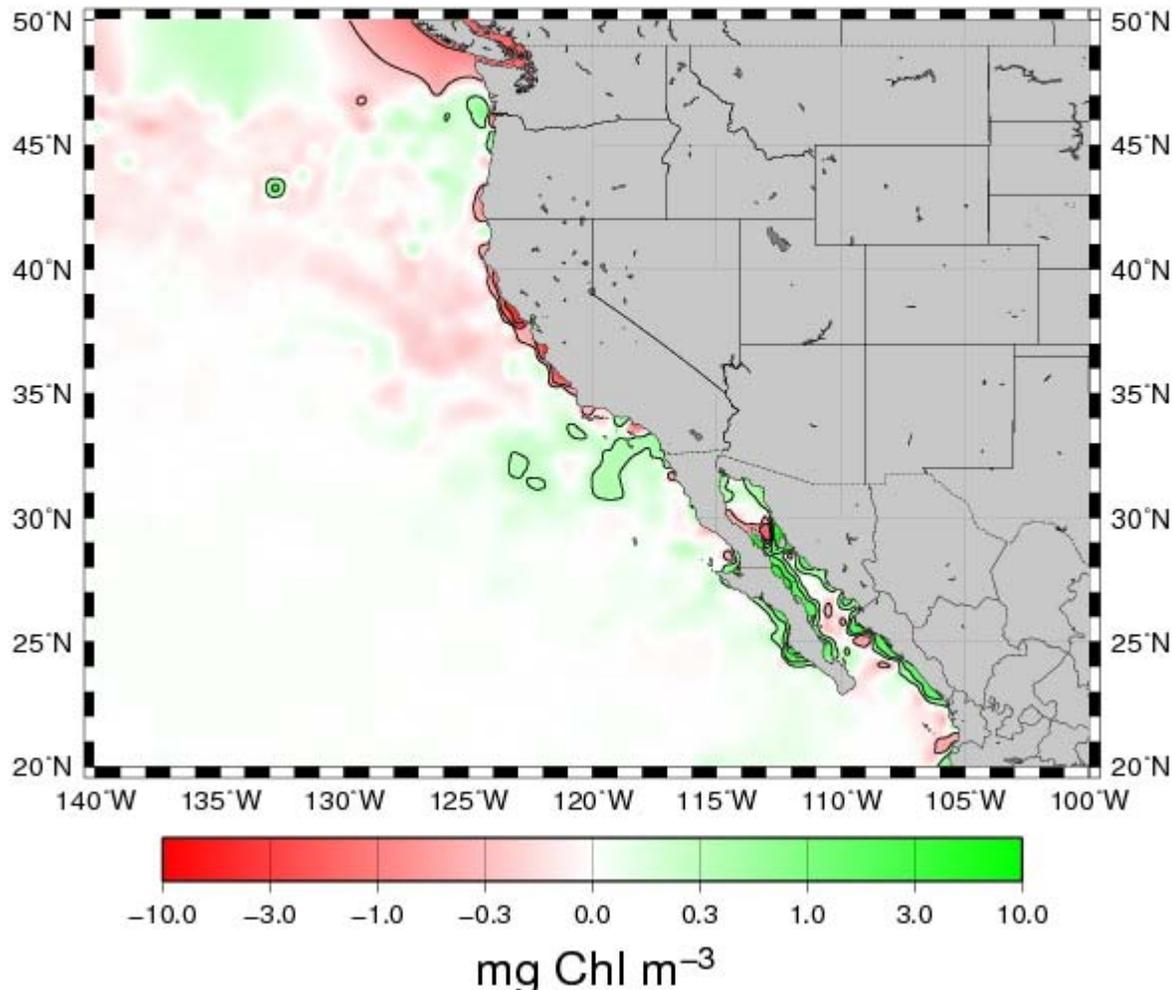
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport 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>

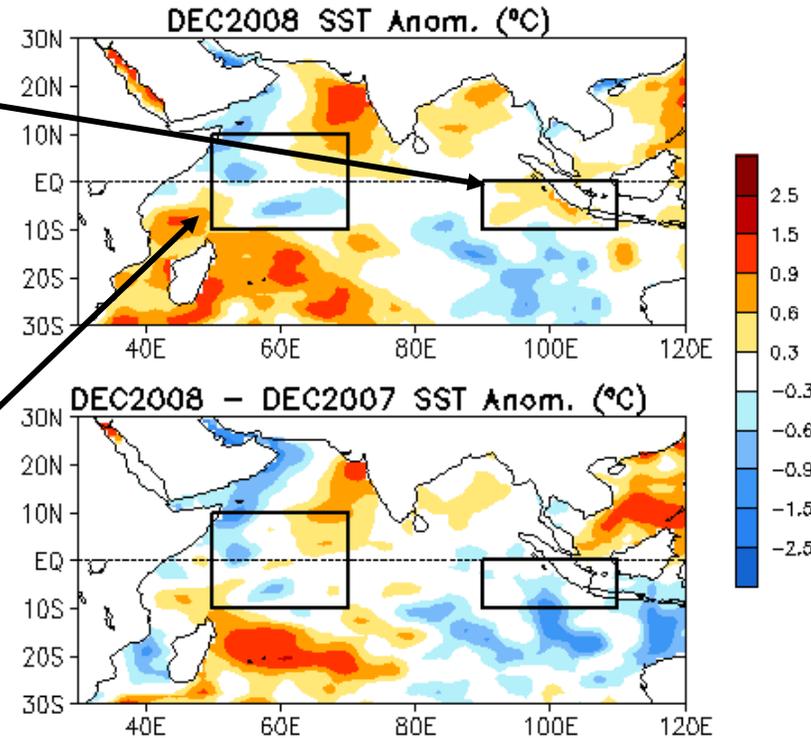
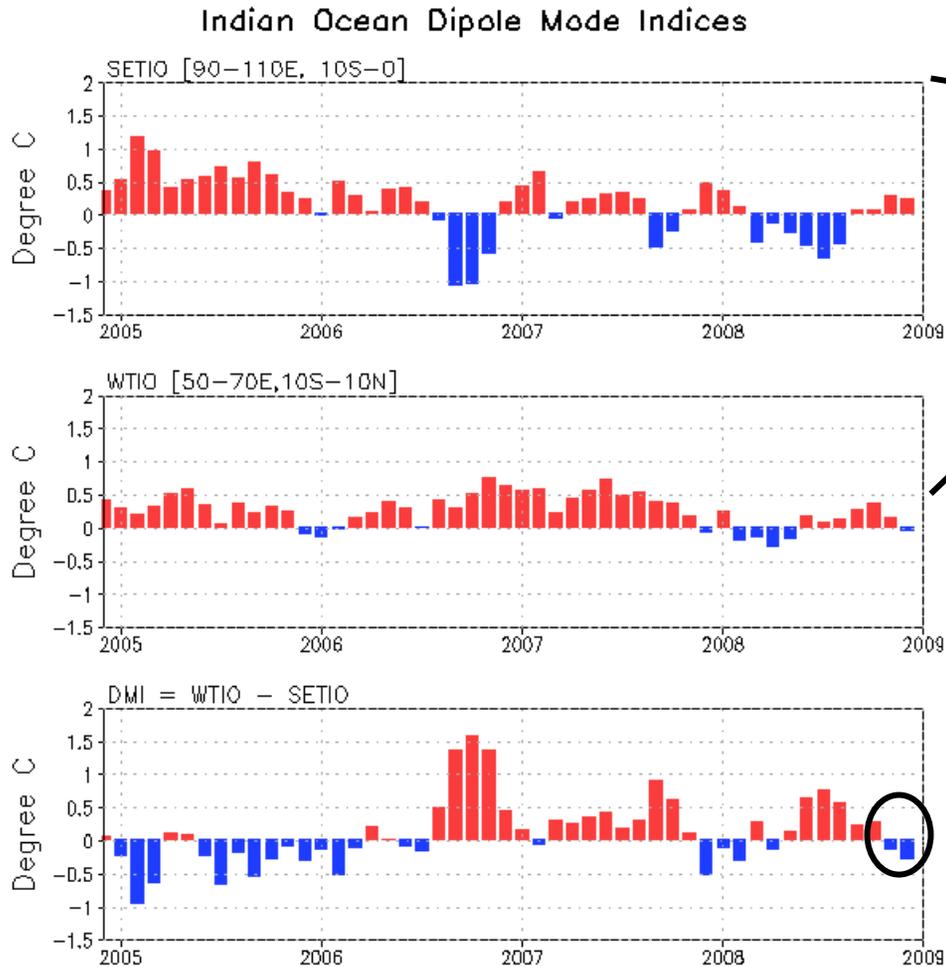
MODIS Aqua Chlorophyll a Anomaly for December, 2008



- Negative Chlorophyll anomalies near the Central and Northern California coast.
- Positive anomalies near the Baja California.

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices



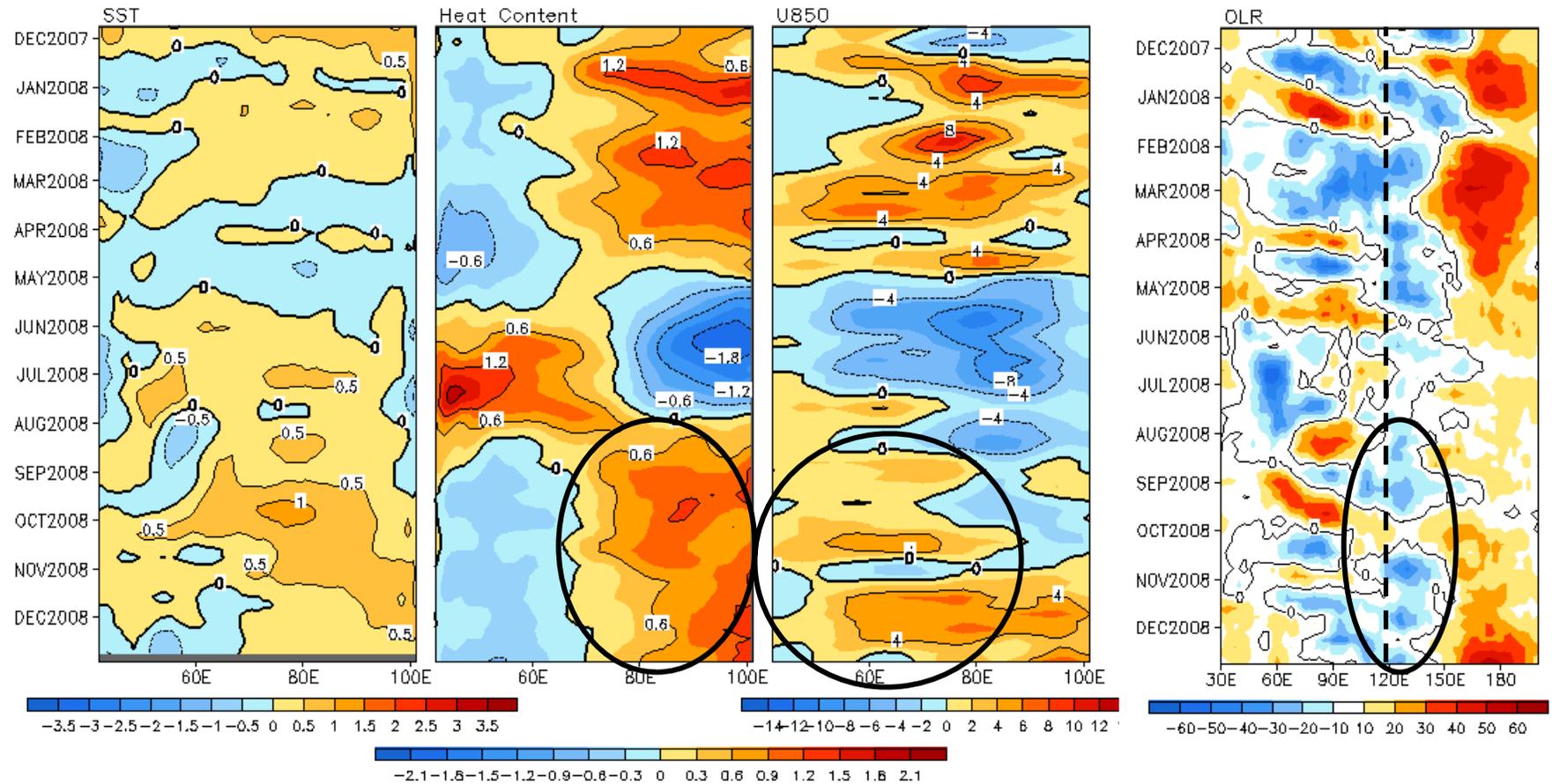
- Dipole Mode Index (DMI) and its eastern and western pole indices were near-normal in September-December 08.
- Eastern Indian Ocean has warmed up since July.
- Western Equatorial Indian Ocean has cooled down since October.
- Large positive anomalies in the south-western Indian Ocean.

Fig. 11a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies ($^{\circ}\text{C}$) for the SETIO [90 $^{\circ}\text{E}$ -110 $^{\circ}\text{E}$, 10 $^{\circ}\text{S}$ -0] and WTIO [50 $^{\circ}\text{E}$ -70 $^{\circ}\text{E}$, 10 $^{\circ}\text{S}$ -10 $^{\circ}\text{N}$] 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 ($^{\circ}\text{C}$), 0-300m Heat Content ($^{\circ}\text{C}$), 850-mb Zonal Wind (m/s) and OLR (W/m^2) Anomalies

2 $^{\circ}\text{S}$ –2 $^{\circ}\text{N}$ Average, 3 Pentad Running Mean

5 $^{\circ}\text{S}$ –5 $^{\circ}\text{N}$ Average
(3 Pentad Running Mean)



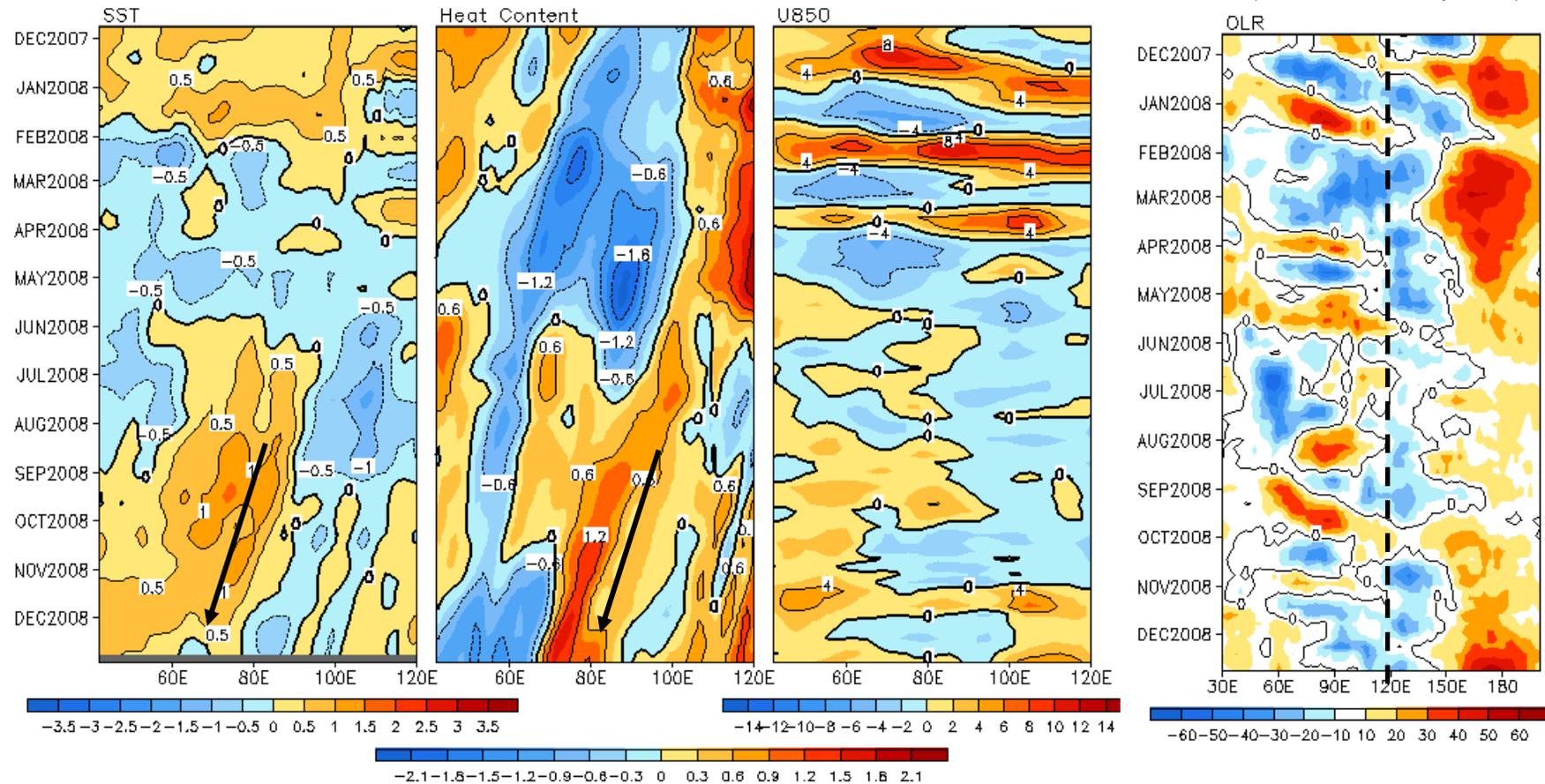
- Westerly wind anomalies since August are associated with the persistent enhanced-convection over the Maritime Continent.
- These westerly wind anomalies have killed off the positive IOD that occurred in the early Northern Summer.

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 $^{\circ}\text{S}$ -2 $^{\circ}\text{N}$ and Outgoing Long-wave Radiation (OLR, right) averaged in 5 $^{\circ}\text{S}$ -5 $^{\circ}\text{N}$. 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)

12°S–8°S Average, 3 Pentad Running Mean

5°S–5°N Average
(3 Pentad Running Mean)



- Westward propagation of positive SSTA and heat content anomalies continued in December 08.
- Maximum of positive SSTA was located to the west of maximum of positive heat content anomalies.

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 SSTA in the south-western and sub-tropical northern Indian Ocean.
- Convection was enhanced in the eastern tropical Indian Ocean and Maritime Continents, which cooled the SST in that region.

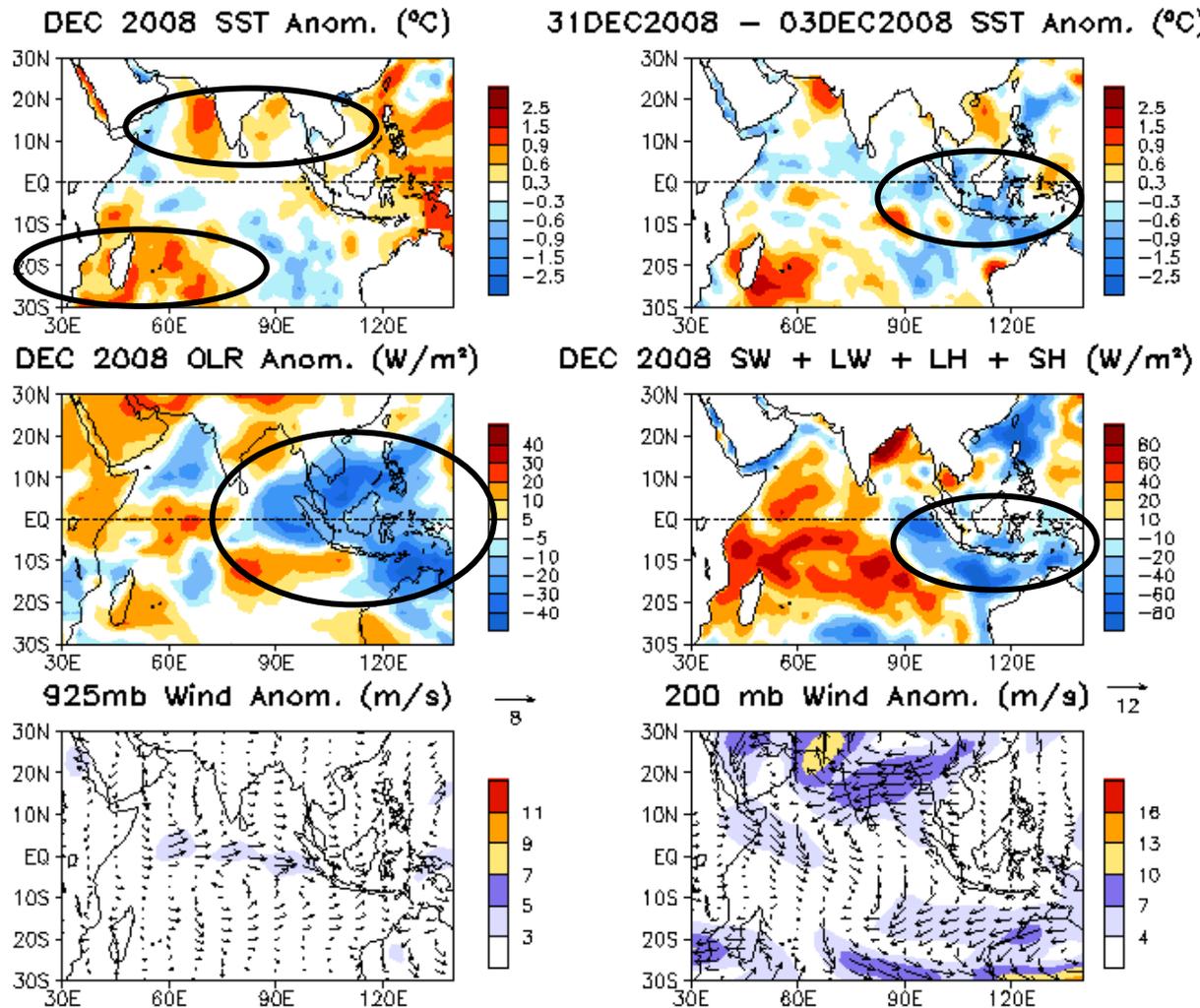


Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

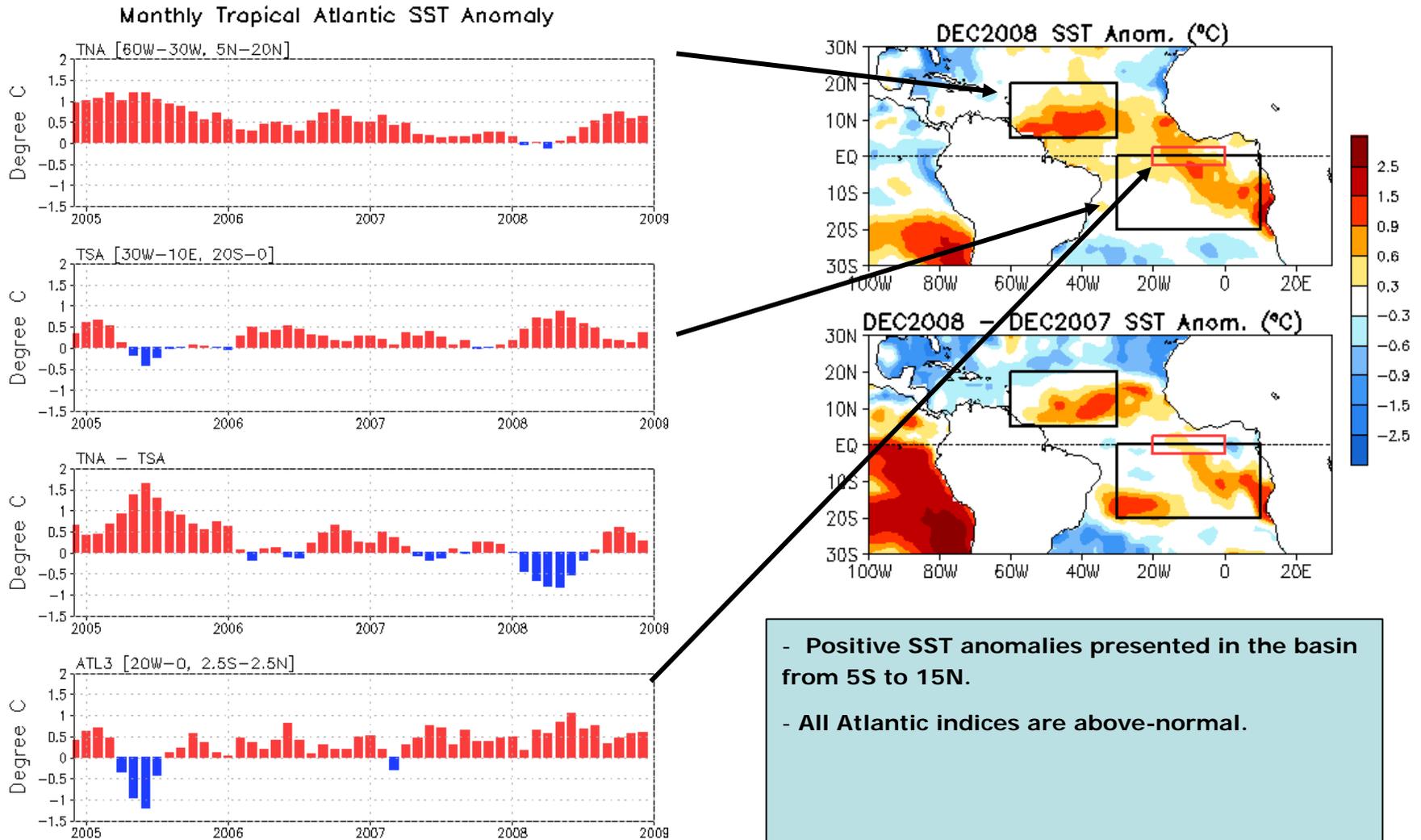
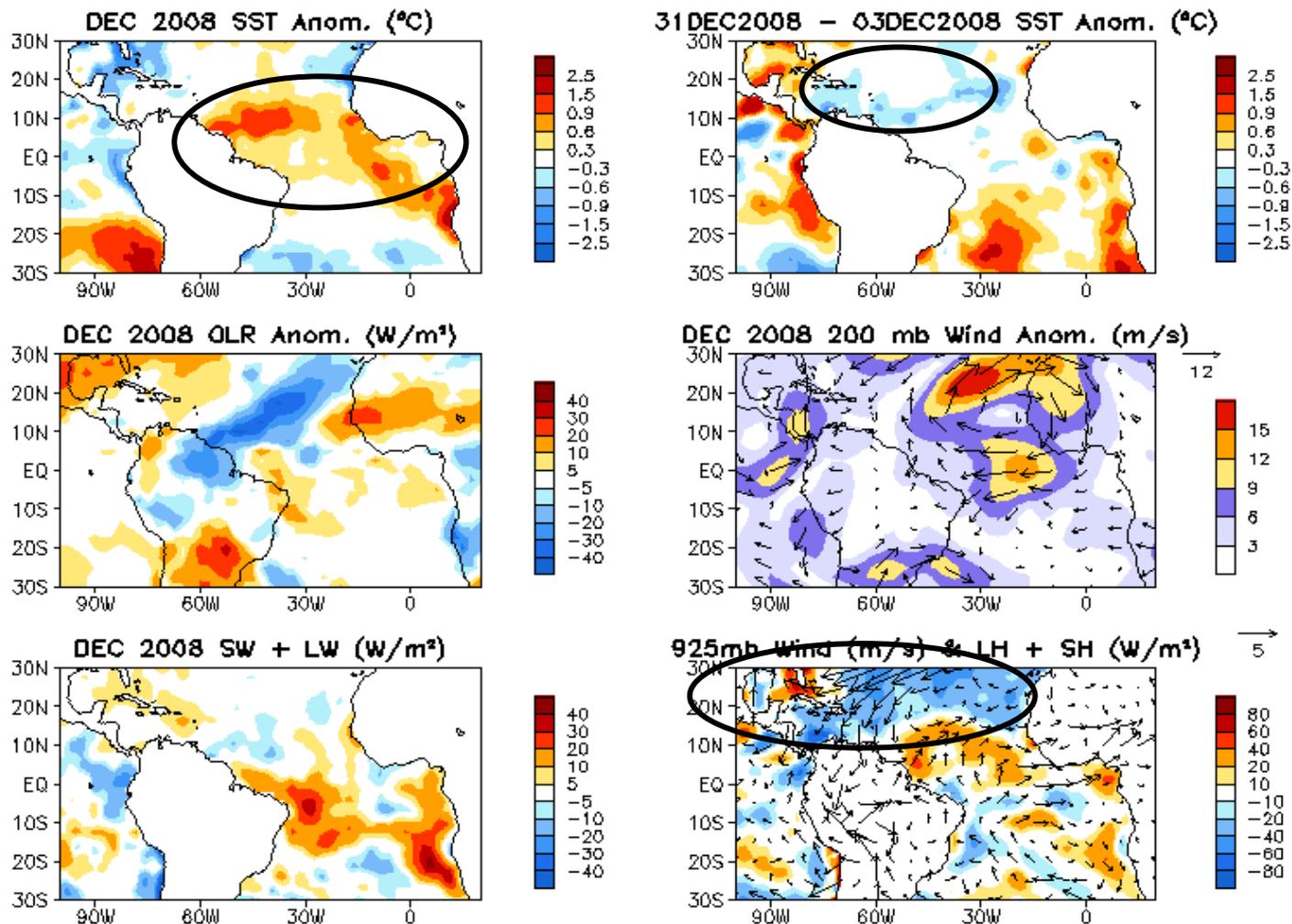


Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between 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 down in the tropical North Atlantic.
- Strong northerly wind anomalies induced negative surface fluxes in the tropical North Atlantic, contributing to the SST cooling there.

North Atlantic Ocean

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

- North Atlantic SST remains above-normal.
- Little change in SSTA since last month.

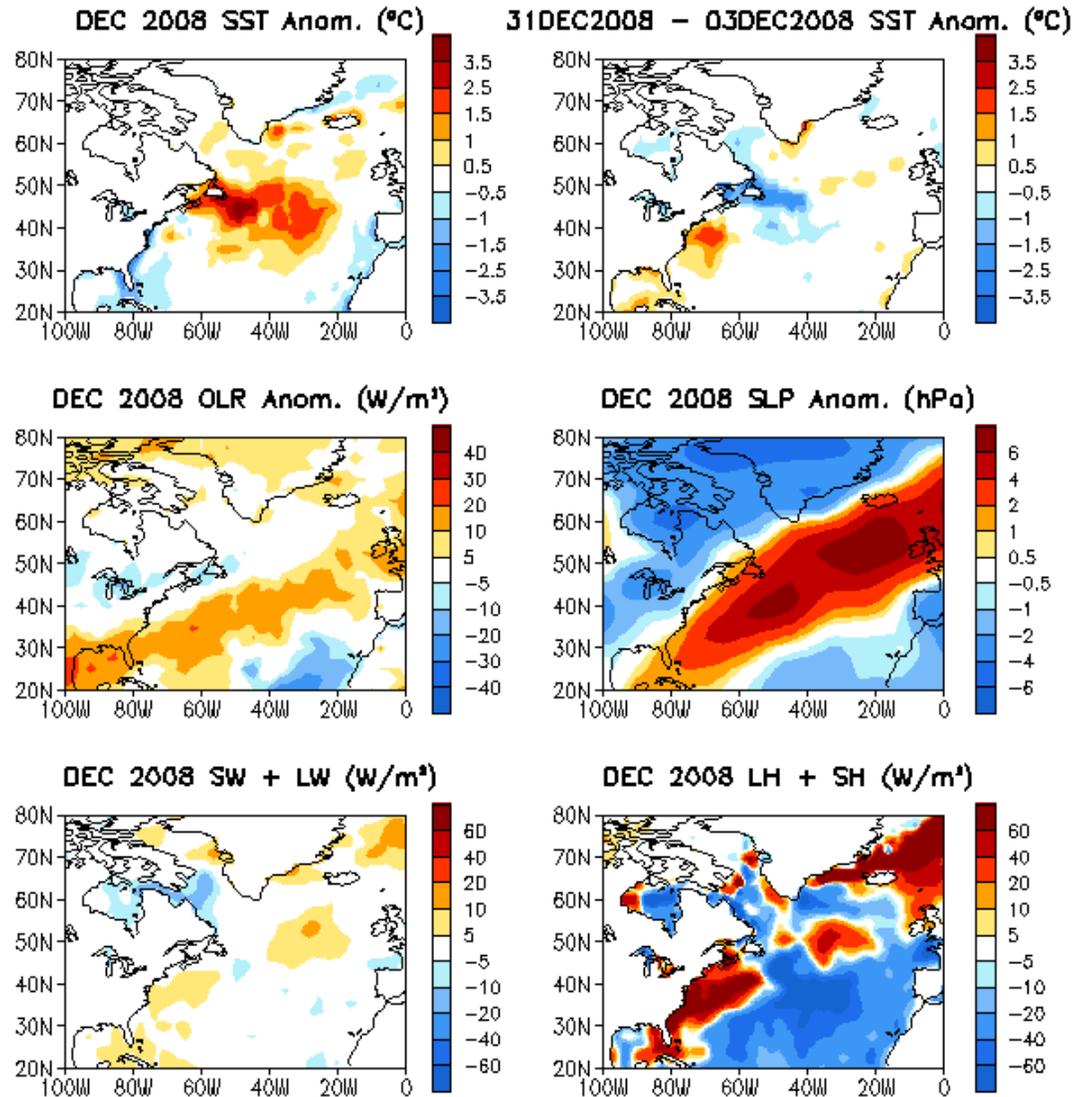
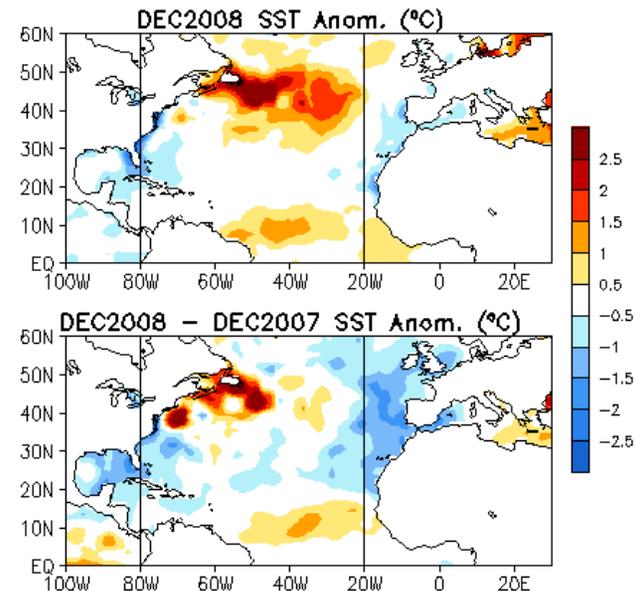
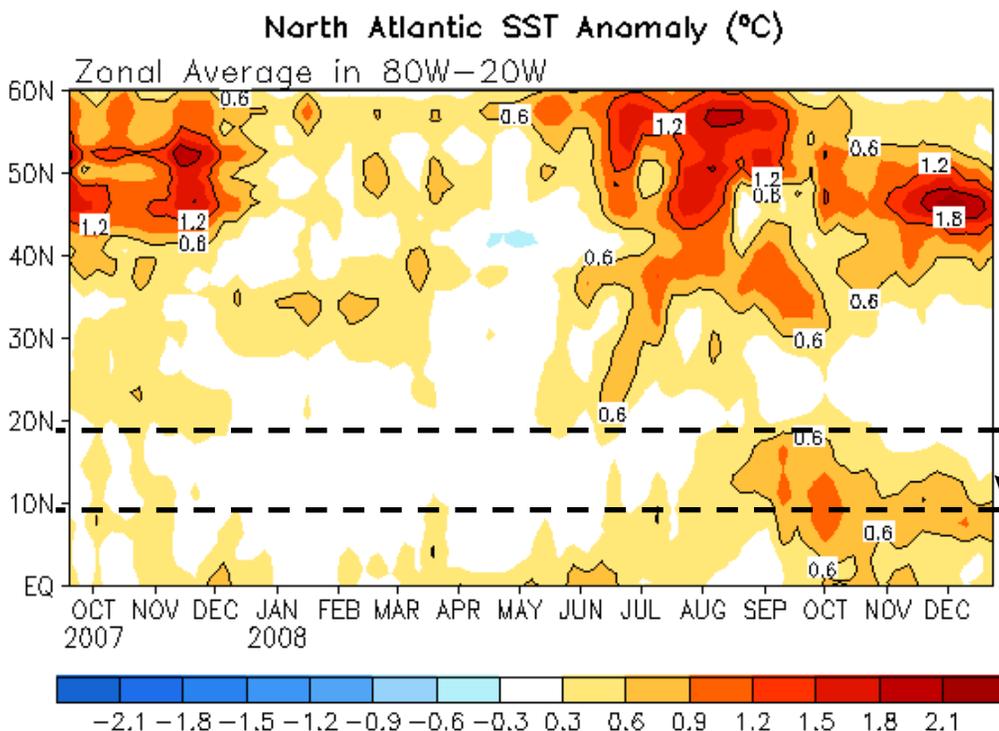
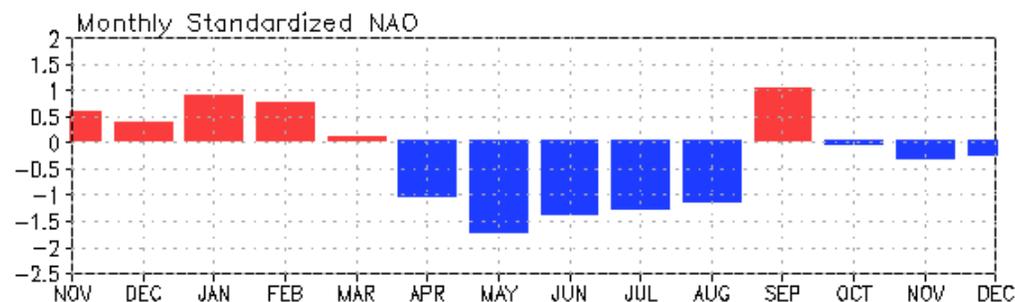


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

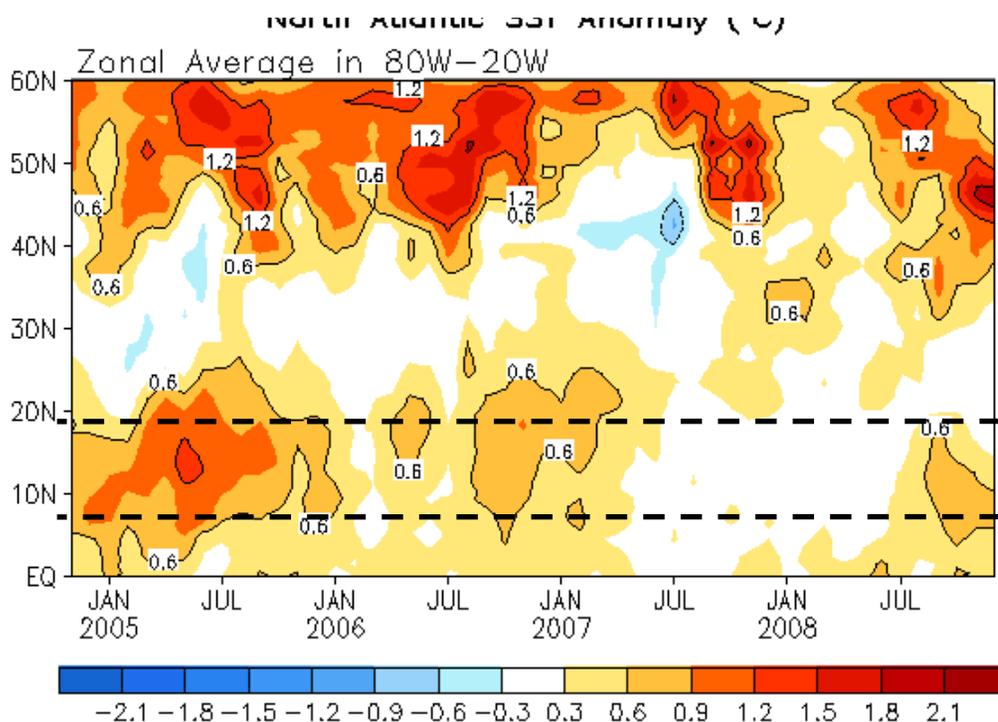
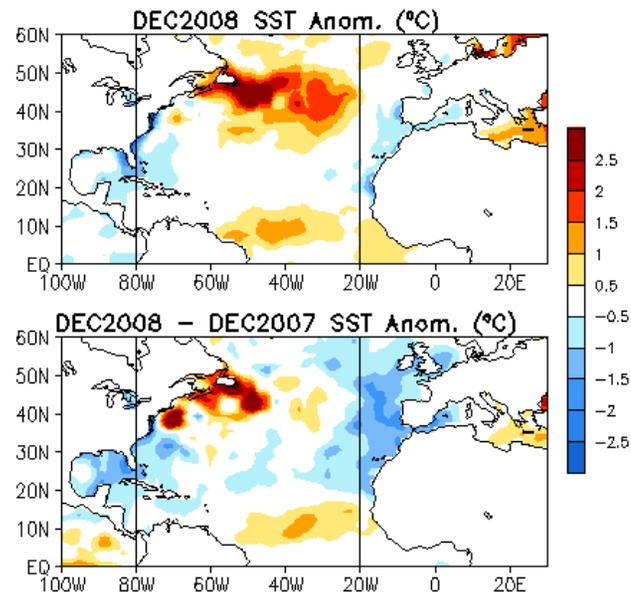
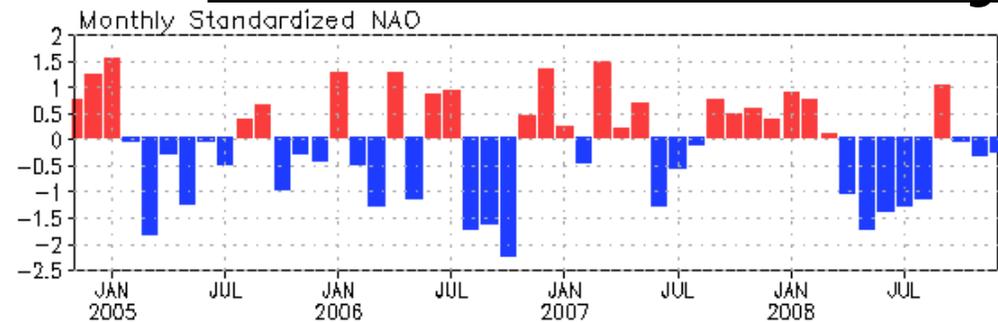
NAO and SST Anomaly in North Atlantic



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



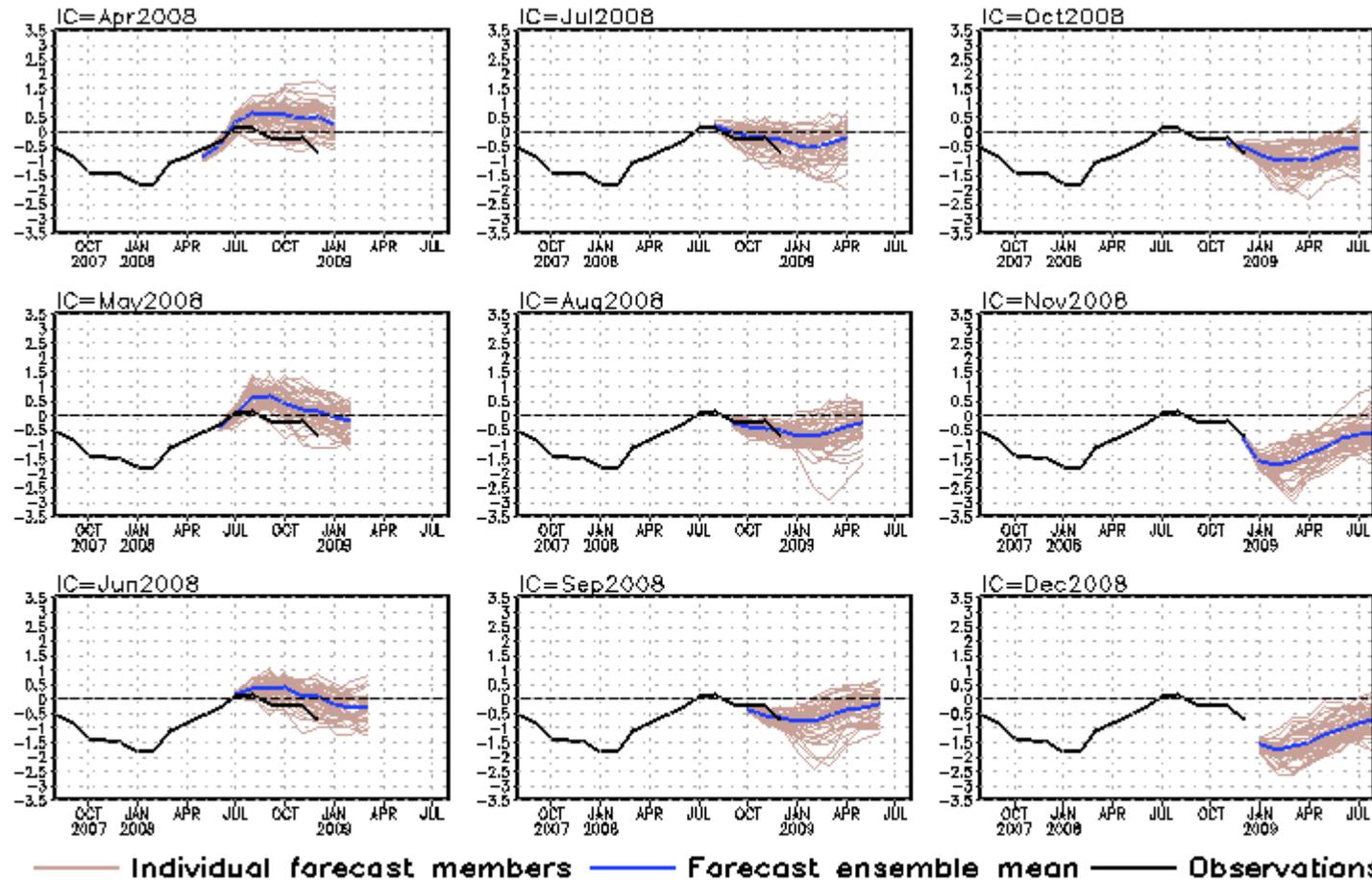
- North Atlantic SSTs have warmed up since June 2008.

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.

CFS SST Predictions and Ocean Initial Conditions

CFS Niño3.4 SST Predictions from Different Initial Months

NINO3.4 SST anomalies (K)

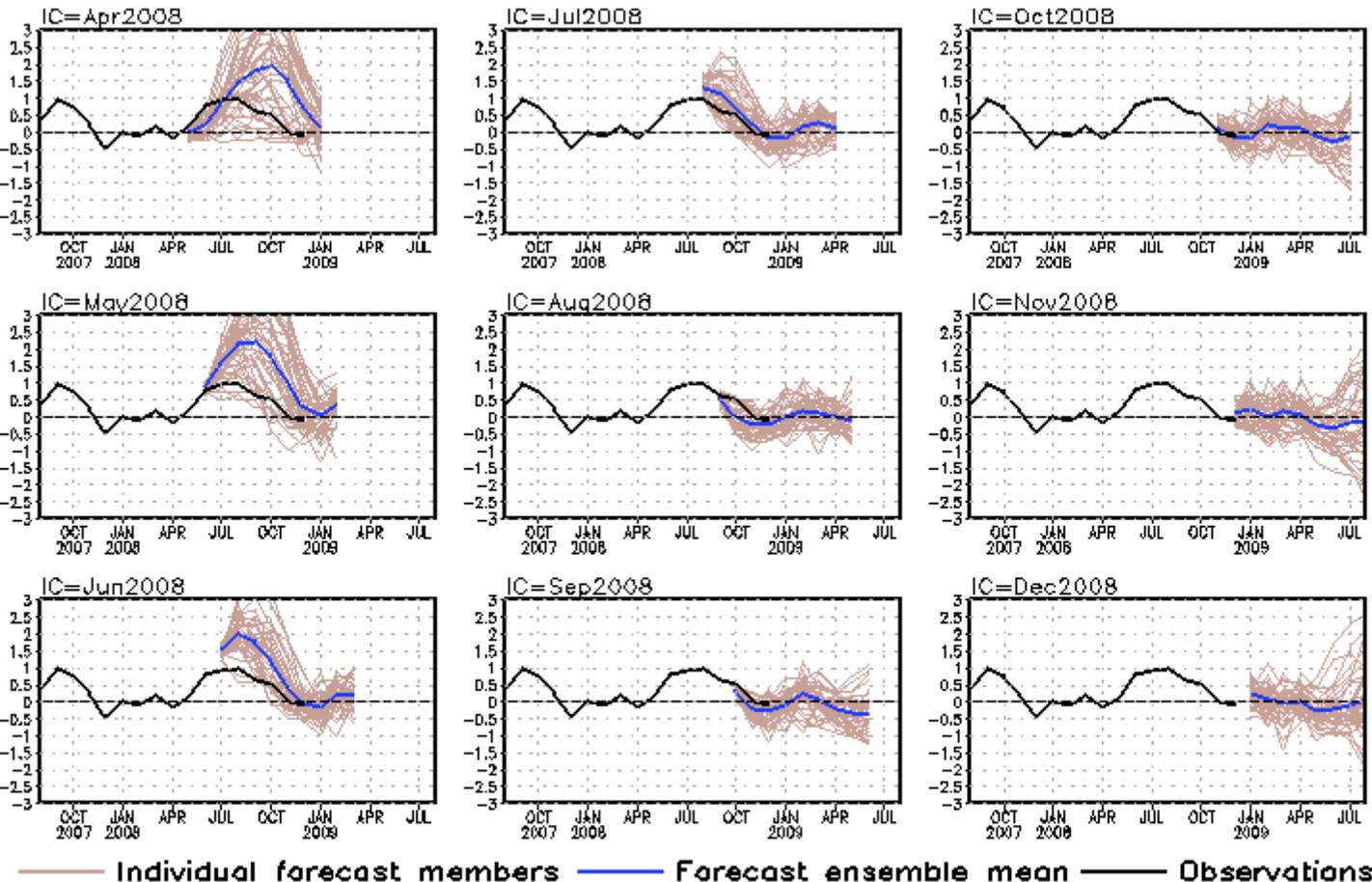


- Latest forecasts suggest that a moderate La Niña will develop in the winter 08/09 and continue through spring.

Fig. M1. CFS Niño3.4 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

Indian Ocean Dipole SST anomalies (K)



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]

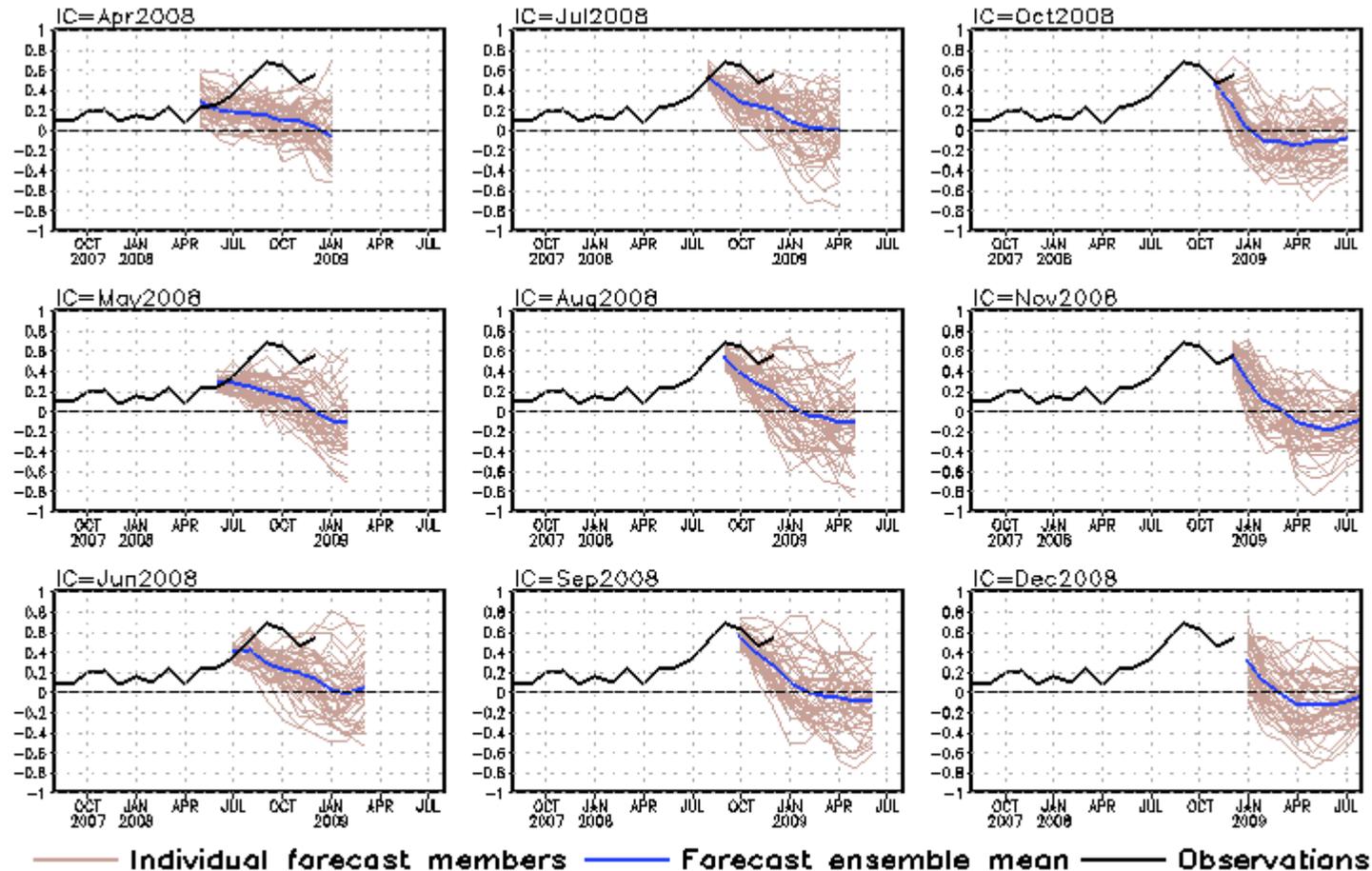
- CFS overestimated the amplitude of the positive IOD.
- CFS called for a strong negative IOD event from Jan-Mar I.C., which indicates that the IOD has a low predictability of about 1-2 month lead times.
- Latest forecasts call for near-normal conditions in next 6-9 months.

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

Tropical N. Atlantic SST anomalies (K)



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.

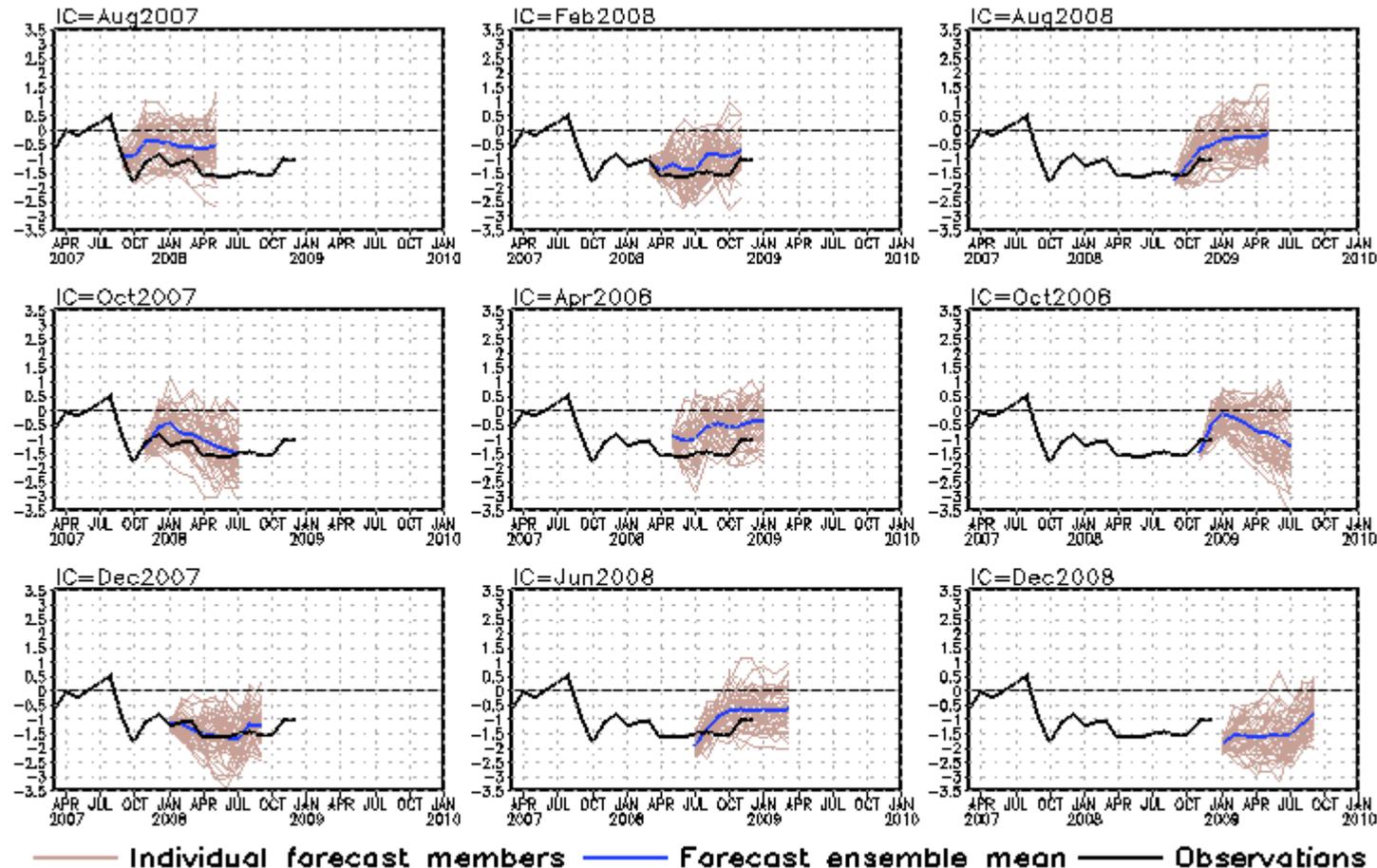
- Latest forecasts suggest that the current positive SSTA will dissipate quickly and return to near-normal conditions in next two months.

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.

CFS Pacific Decadal Oscillation (PDO) Index Predictions

from Different Initial Months

standardized PDO index



PDO is the first EOF of monthly SST in the region of [110°E-100°W, 20°N-60°N].

- CFS SST anomalies are projected onto the PDO SST pattern.

-CFS has forecast the recent negative PDO phase from Aug-Oct 08 I.C..

- Latest forecasts suggest that the current negative PDO will persist through next summer.

Fig. M3. CFS Pacific Decadal Oscillation (PDO) 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**

- La Niña conditions ($\text{NINO3.4} < -0.5\text{C}$) developed in December 08, and are expected to continue into early 2009.
- Typical La Nina signals presented in the tropical convection, atmospheric circulations, surface ocean currents and subsurface ocean temperature.
- Negative PDO SST pattern continued in North Pacific.
- Extremely strong upwelling has transitioned the climatological downwelling into upwelling along most of the west coast of North America in Dec 08.

- **Indian Ocean**

- Positive SST anomalies covered most of the extra-tropical Indian ocean.
- The tropical Indian Ocean SSTs are close to normal.

- **Atlantic Ocean**

- Positive SST anomalies presented in mid-latitude North Atlantic and tropical North Atlantic.

- **Arctic Ocean**

- Ice concentration remains much below normal, with the ice growth slowing down during December.

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!