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

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

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

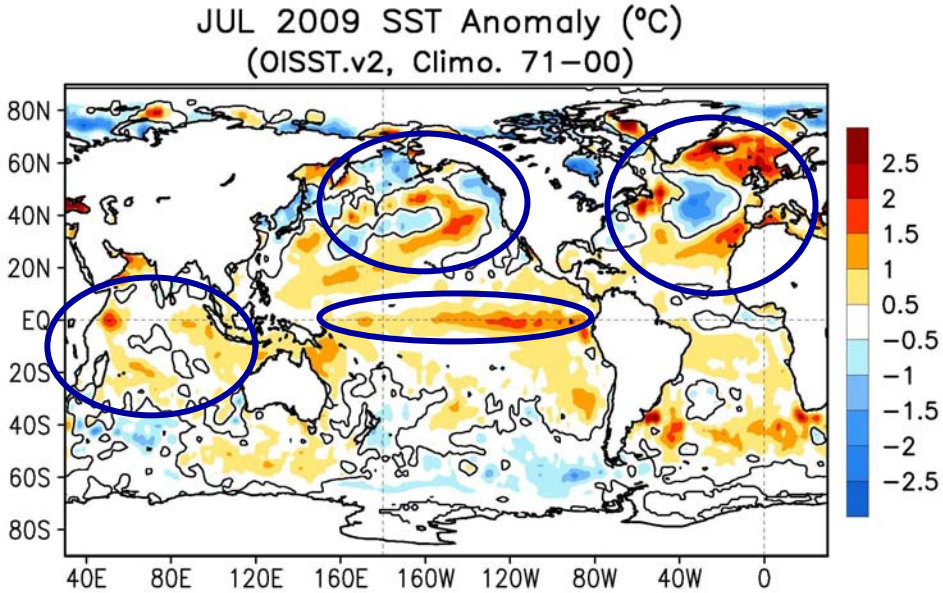
Outline

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

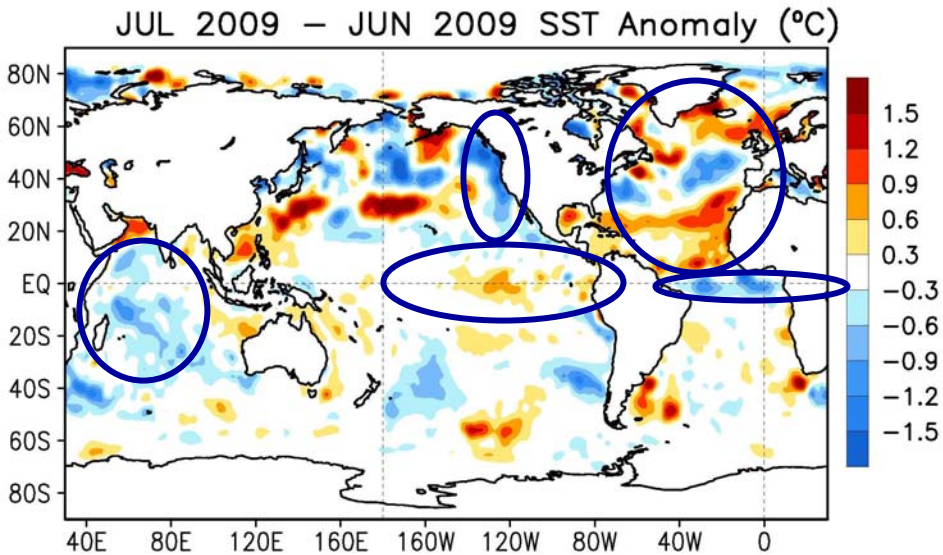
Overview

- **Pacific Ocean**
  - El Niño conditions (NINO 3.4 > 0.5 ^{o}C) established in June 2009, and further strengthened in July 2009.
  - Negative PDO phase since September 2007 has persisted for 23 months; but it weakened and remained weakly below-normal in June-July 2009.
  - Upwelling along west coast North America was near-normal in July 09.
- **Indian Ocean**
  - Since mid-April 09, zonal wind anomalies were persistently easterly and easterly winds strengthened in July 2009.
  - SST was 1.5^{o}C (1 ^{o}C) above-normal in the western (eastern) tropical Indian Ocean, and Dipole Mode Index became weakly below-normal in July 2009.
- **Atlantic Ocean**
  - Tropical North Atlantic SST (TNA) increased and became weakly above-normal in July 2009.
  - ITCZ shifted northward, that was consistent with the warming in TNA and the cooling in the equatorial Atlantic.
  - NAO was the lowest (-2.2) since October 2006.
- **Arctic Ocean**
  - Sea ice extent was near a historical low in July 09.

Global SST Anomaly (ºC) and Anomaly Tendency



- El Nino conditions (NINO 3.4 > 0.5ºC) continued in the tropical Pacific.
- Weak negative PDO-like SST pattern in North Pacific persisted.
- Positive SSTA in the western and eastern tropical Indian Ocean continued.
- A tripole SSTA pattern presented in North Atlantic.

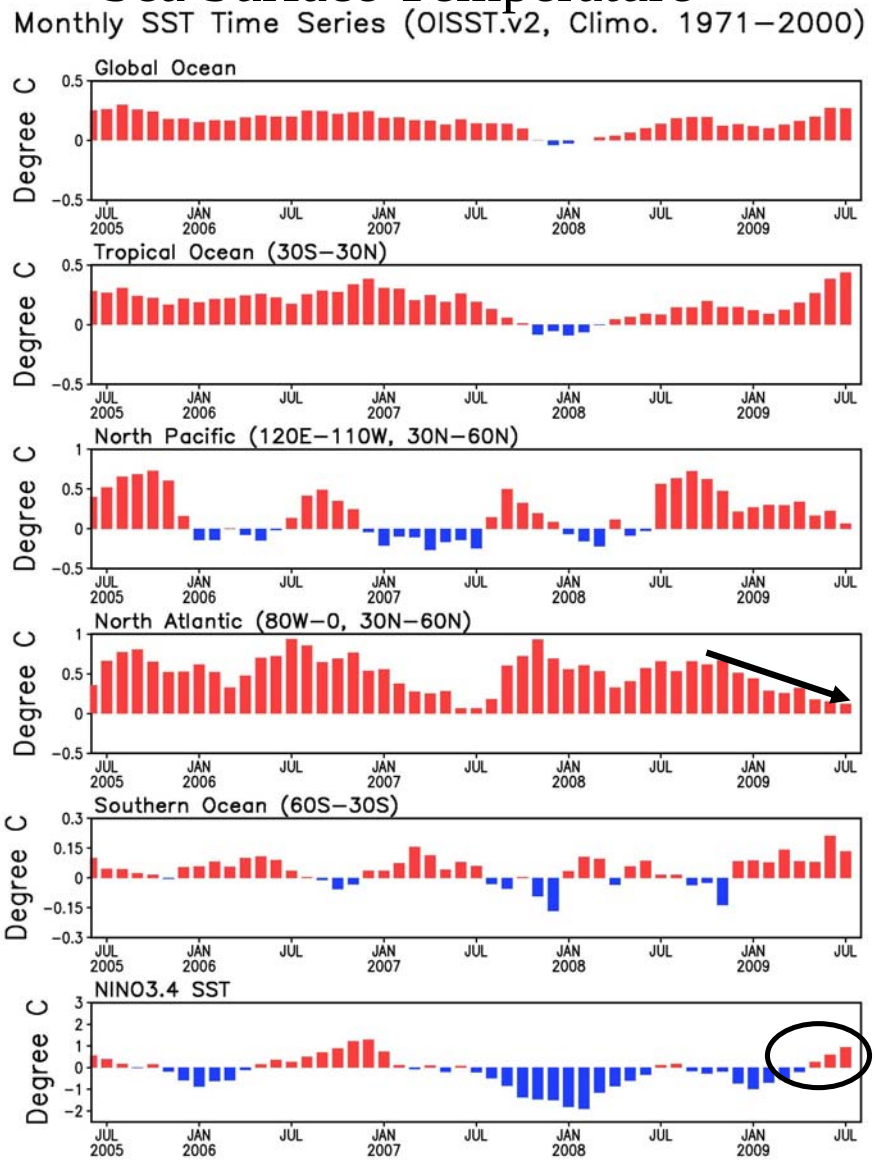


- Positive SSTA in the central-eastern equatorial Pacific strengthened.
- SSTA decreased along the west coast of North America.
- Positive SSTA in the central and western tropical Indian Ocean weakened.
- SSTA tendency in North Atlantic has a tripole pattern.
- SSTA decreased along the equatorial Atlantic.

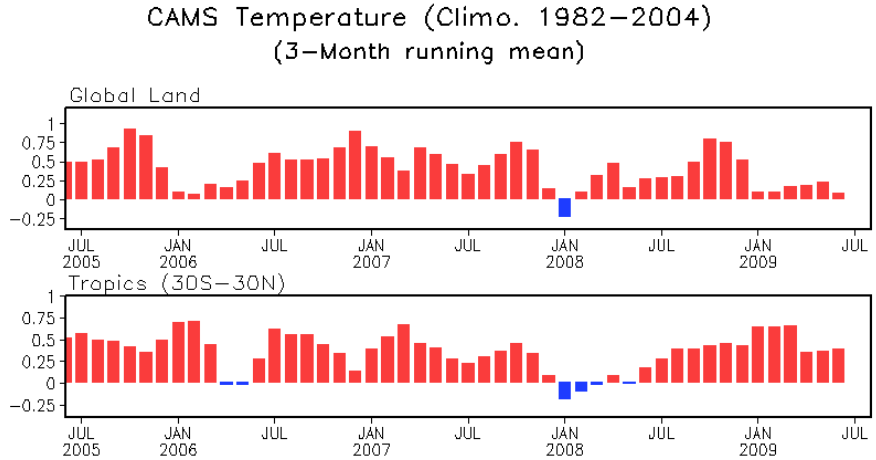
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1971-2000 base period means.

Monthly Time Series

Sea Surface Temperature



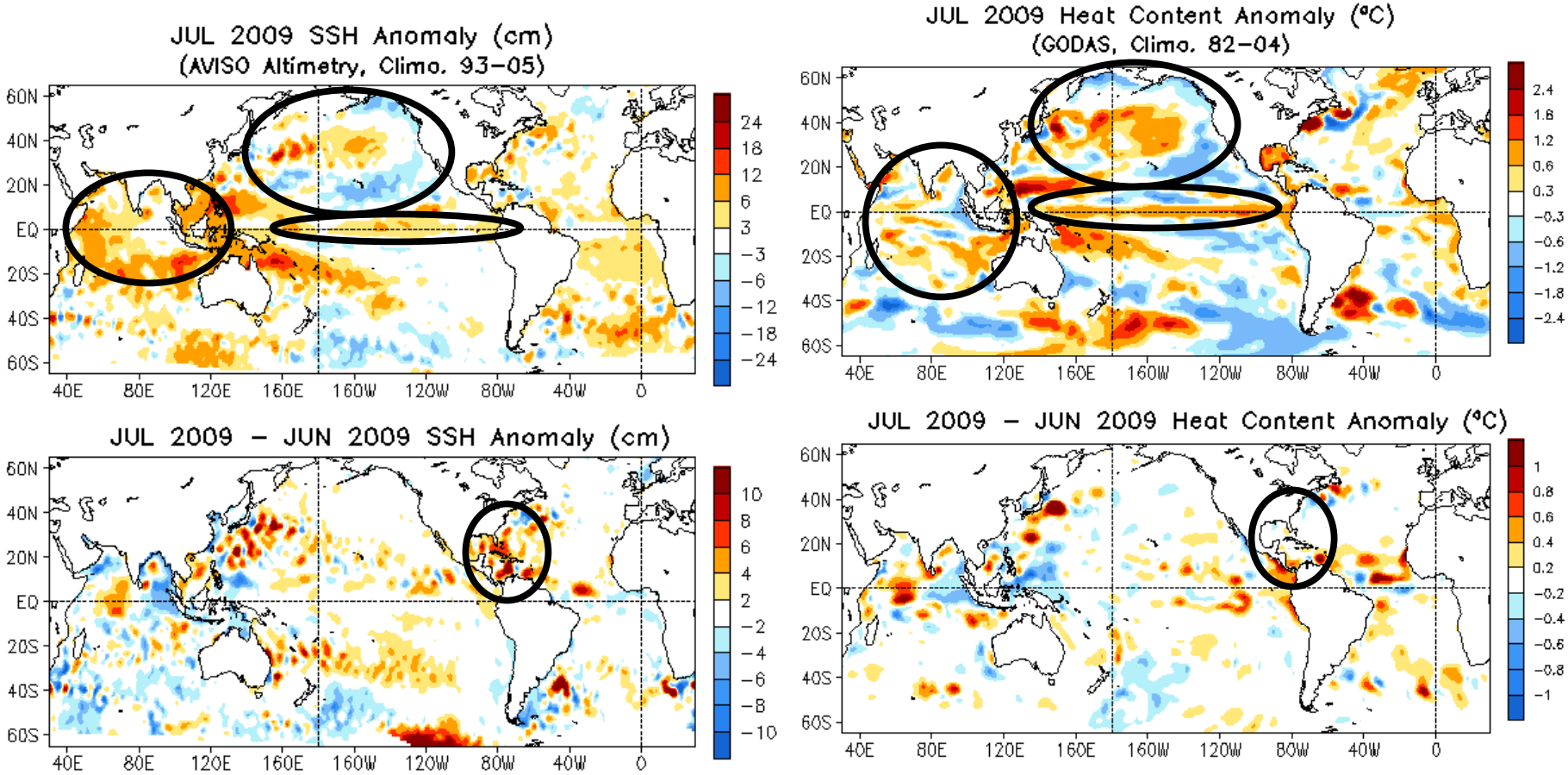
CAMS Land Temperature



- **Positive global mean SSTA persisted.**
- **Global mean seasonal land temperature became near-normal.**
- **Positive tropical land temperature anomalies persisted.**
- **SSTA in North Atlantic continued a downward trend since November 08.**
- **Positive Southern Oceans SSTA weakened slightly.**
- **NINO 3.4 SST became 0.9ºC above-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.

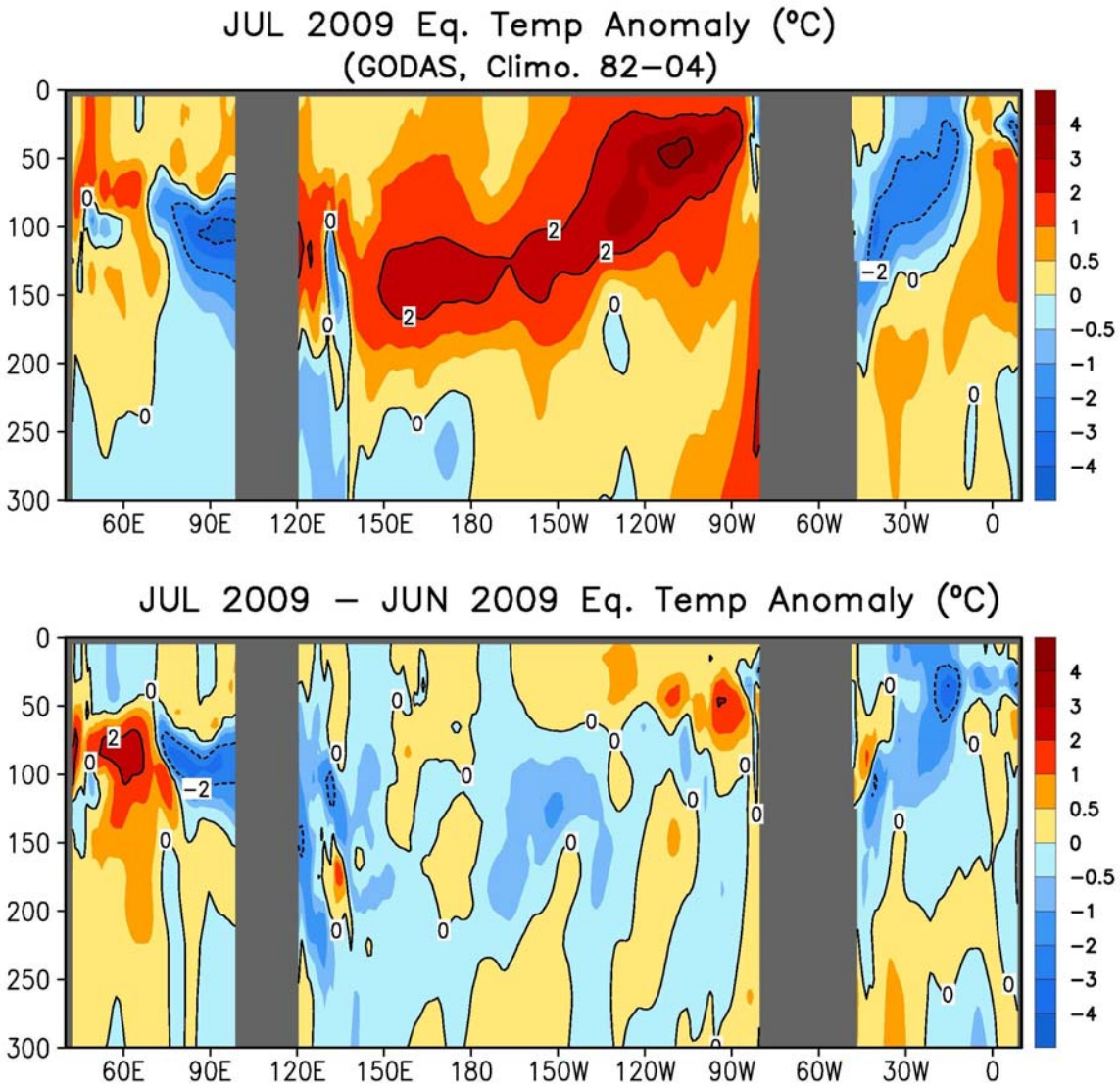
Global SSH / HC Anomaly (cm / ºC) and Anomaly Tendency



- **Negative PDO-like pattern presented in SSHA and HCA in the North Pacific.**
- **Positive SSHA and HCA presented along a narrow equatorial belt, consistent with the weak El Nino conditions.**
- **SSHA and HCA were largely consistent except in the tropical Indian Ocean where biases in GODAS HC climatology were large (not shown).**
- **Tendency of SSHA and HCA was largely consistent except in the Gulf of Mexico where observations were sparse.**

Fig. G2. Sea surface height anomalies (SSHA, top left), SSHA tendency (bottom left), top 300m heat content anomalies (HCA, top right), and HCA tendency (bottom right). SSHA are derived from http://www.aviso.oceanobs.com, and HCA from GODAS.

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



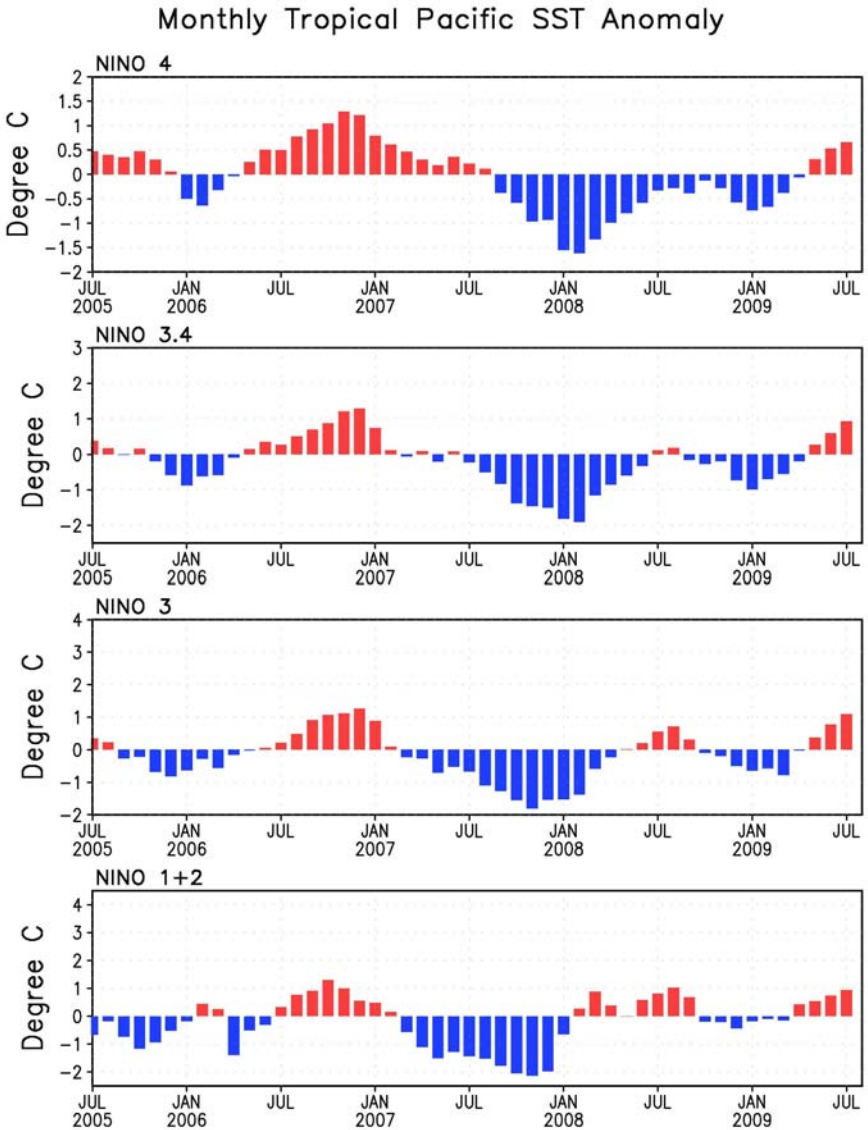
- Positive subsurface temperature anomalies about 2-4°C presented near the thermocline in the equatorial Pacific, consistent with the El Nino conditions.

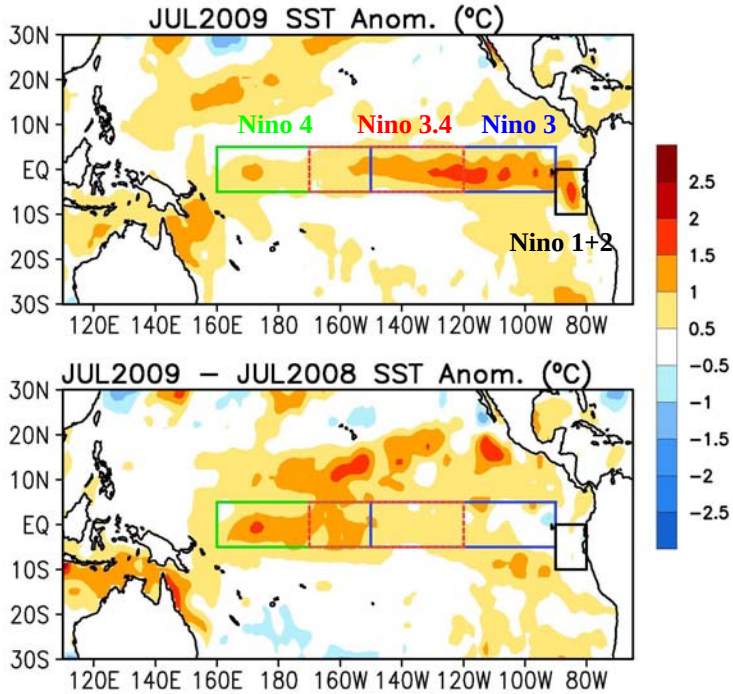
- Tropical Atlantic temperature anomaly decreased substantially.
- Subsurface temperature anomaly decreased (increased) near the thermocline in the eastern (western) tropical Indian Ocean.

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

Tropical Pacific Ocean

Evolution of Pacific NINO SST Indices

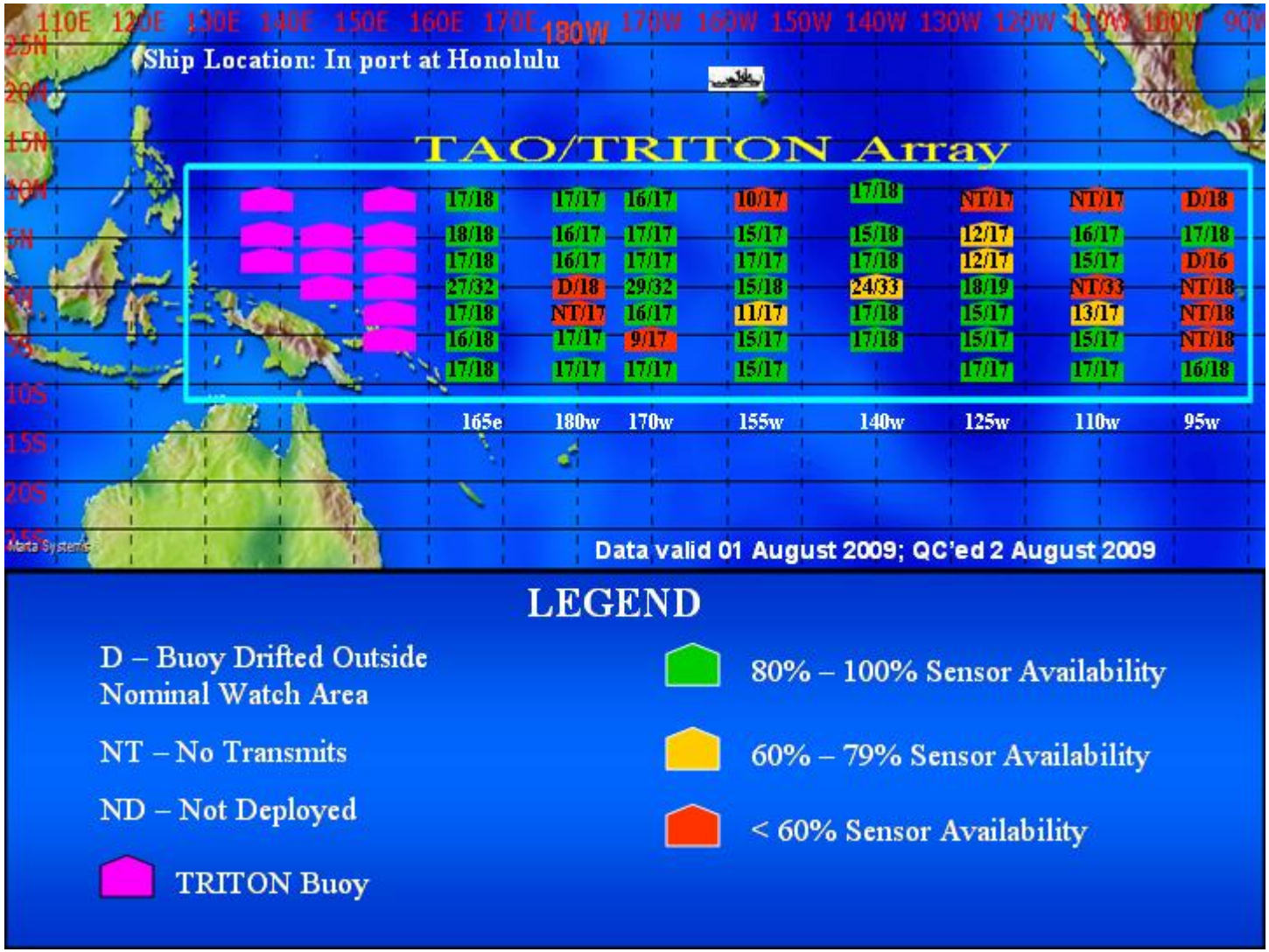




- **El Niño conditions (NINO 3.4 > 0.5°C) are expected to last through the Northern Hemisphere Winter – NOAA's "ENSO Diagnostic Discussion".**
- **All NINO indices increased in July 09.**

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.

TAO/TRITON Observing Status in July



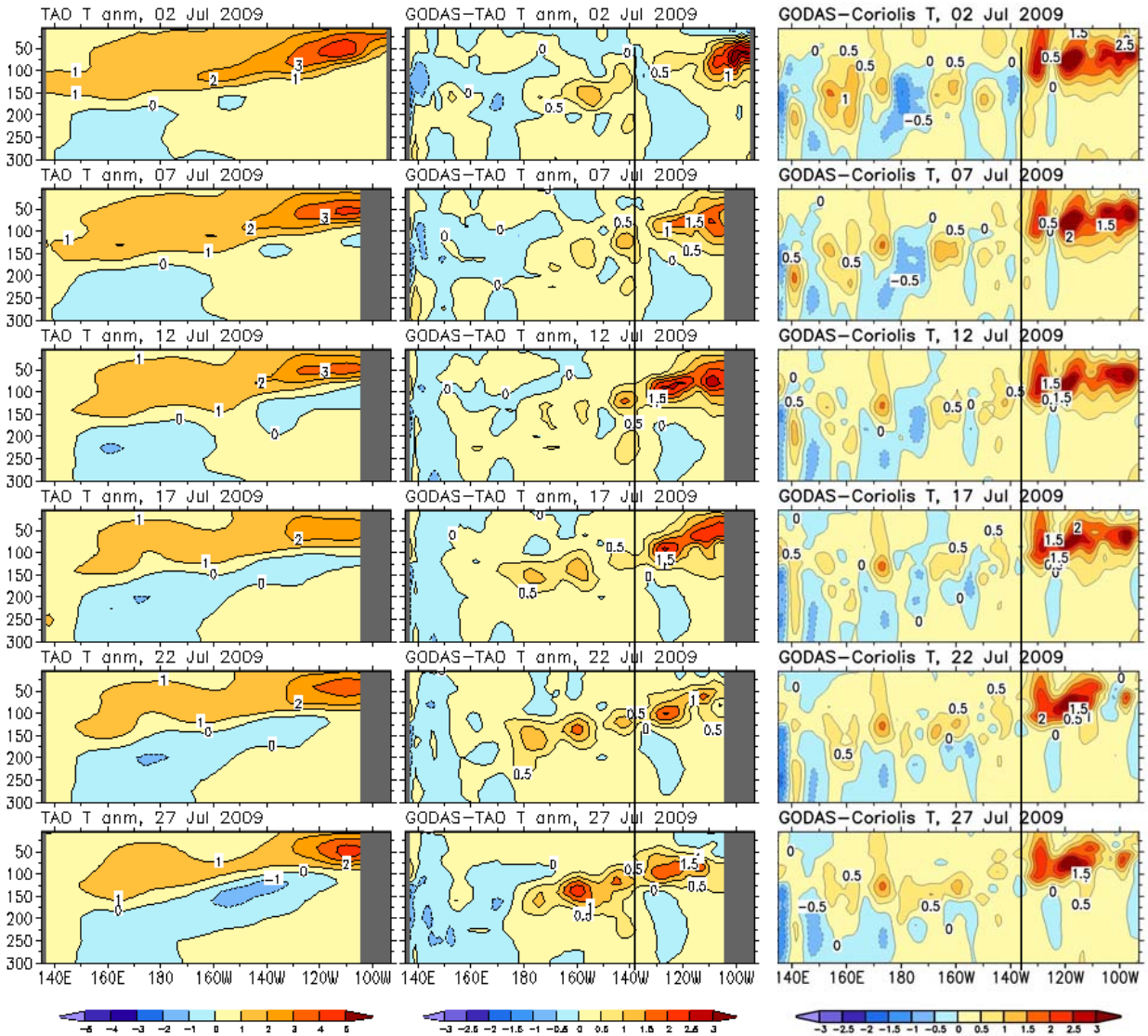
- TAO moorings had massive failures at 95W and 110W near the equator.

http://tao.noaa.gov/tao/status

Equatorial Pacific Temperature

http://tao.noaa.gov/tao/status
http://www.coriolis.eu.org/cdc

TAO Temp Anom | GODAS-TAO | GODAS-Coriolis



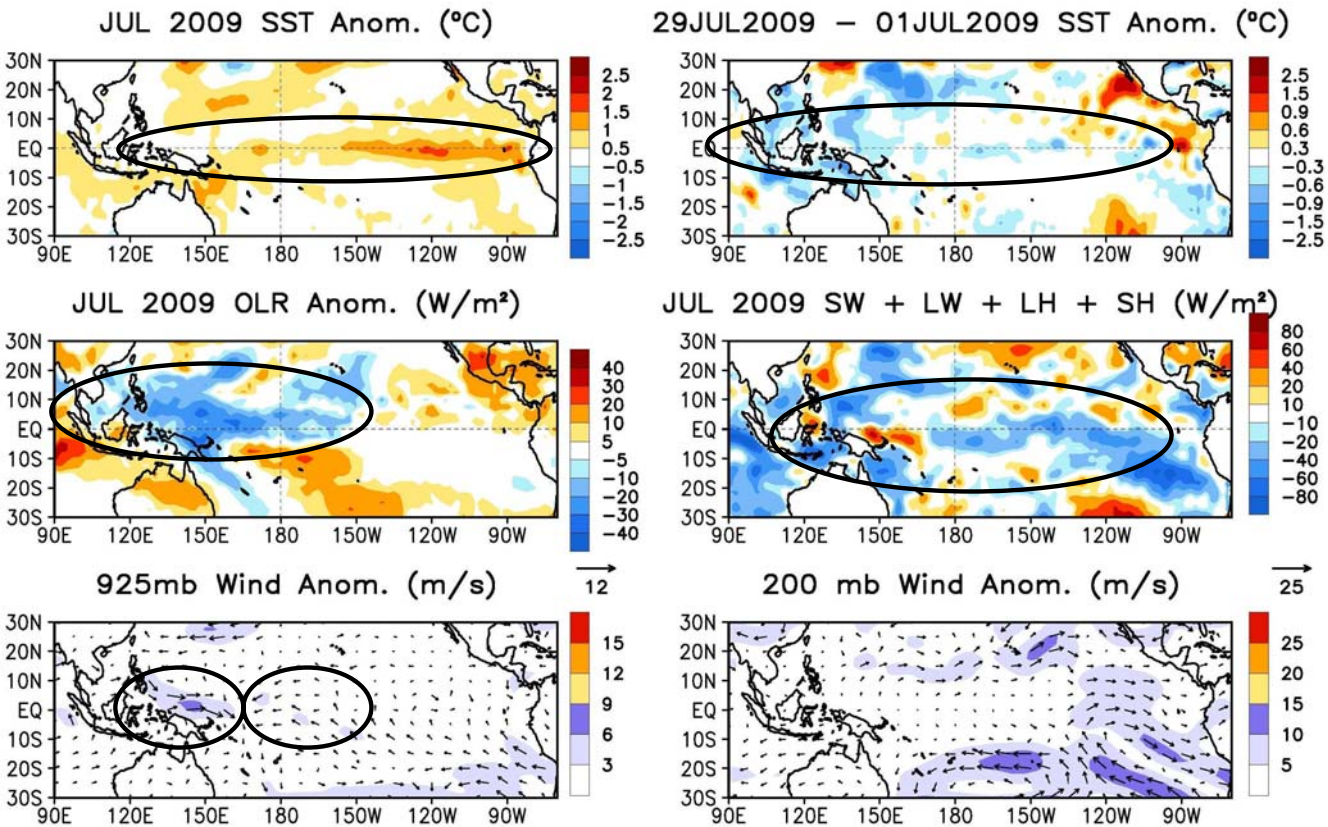
- **Equatorial temperature decreased at the surface and near the thermocline, probably forced by easterly wind anomalies in the central-eastern Pacific (slide 14).**

- **Temperature differences between GODAS and TAO, GODAS and Coriolis, were above 1C near the thermocline east of 135W.**

- **Those positive biases were consistent with warm biases in the control simulation in which observations were not included.**

- **Therefore, TAO mooring data at 95W and 110W played critical roles in constraining model biases.**

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



- **Positive SSTA presented along the equatorial Pacific.**
- **SSTA decreased in most of the tropical Pacific, consistent with net surface heat flux anomalies.**
- **Convection was enhanced in the west-central Pacific.**
- **Low-level westerly (easterly) wind anomalies presented in the western (central) tropical Pacific.**

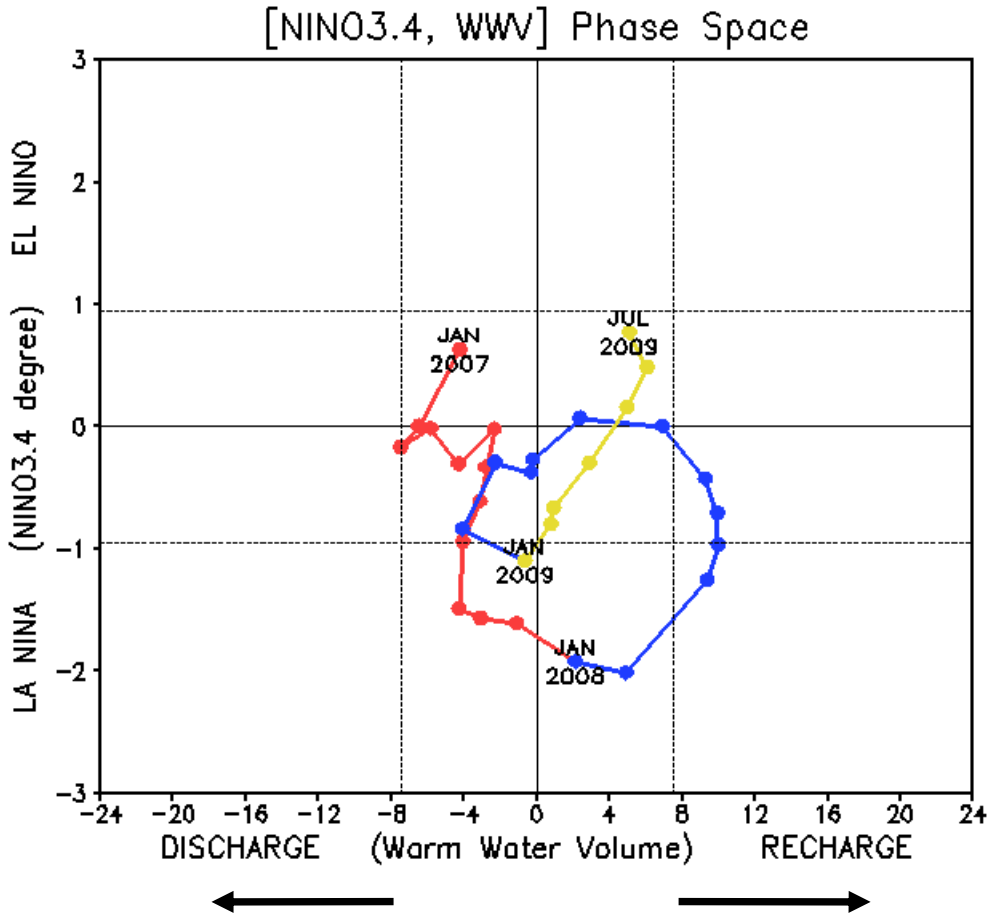
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Warm Water Volume (WWV) and NINO3.4 Anomalies

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

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

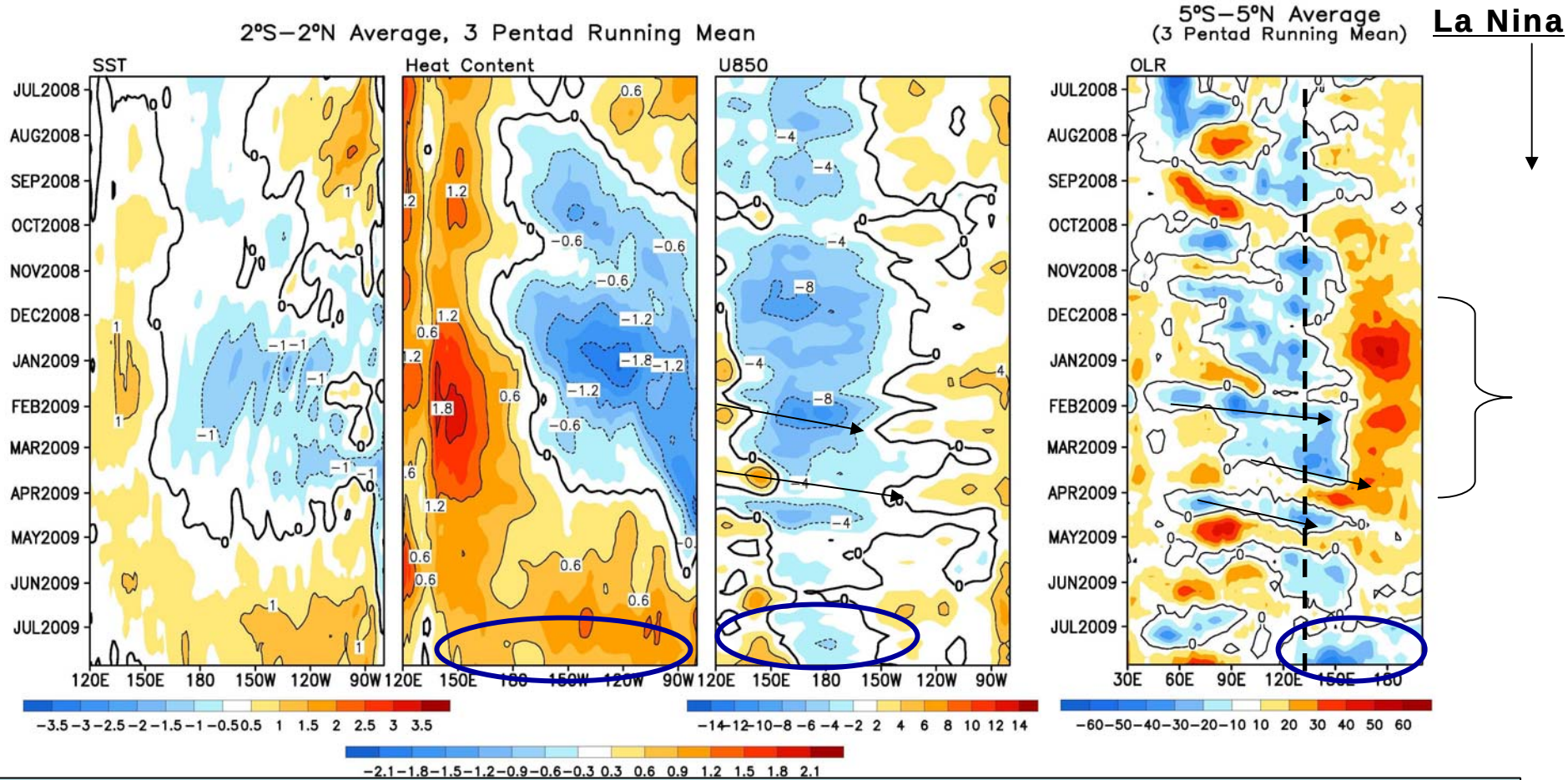
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



- NINO3.4 (WWV) increased (decreased) slightly in Jul 09.

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.

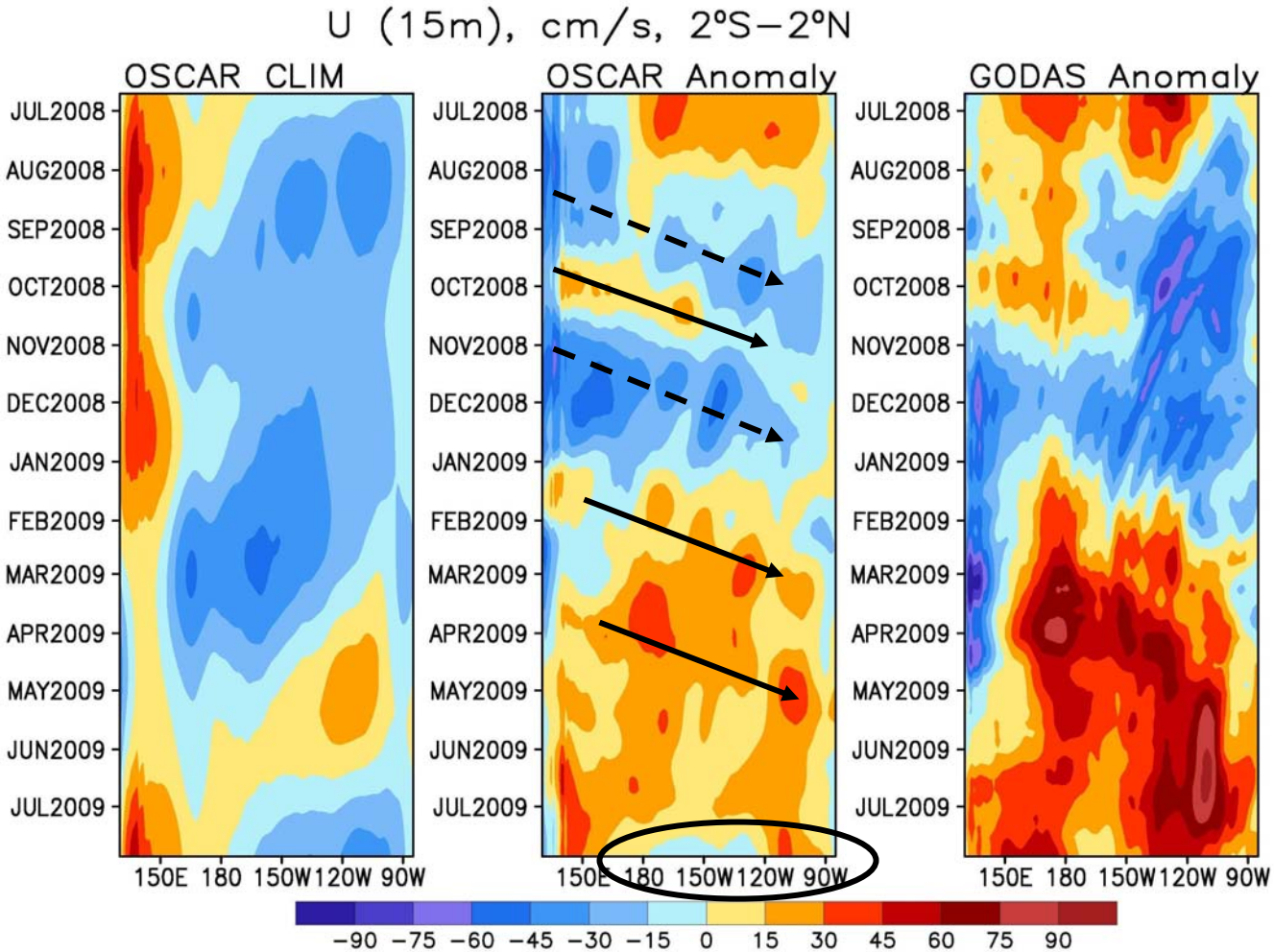
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m^2) Anomaly



- SST was about 1 C above-normal in the central-eastern equatorial Pacific.
- Positive heat content anomalies in the equatorial Pacific weakened in later Jul, probably forced by the recent easterly wind anomalies near the Dateline.
- Westerly (easterly) wind anomaly presented in the western (central) tropical Pacific, consistent with enhanced convection in the western 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.

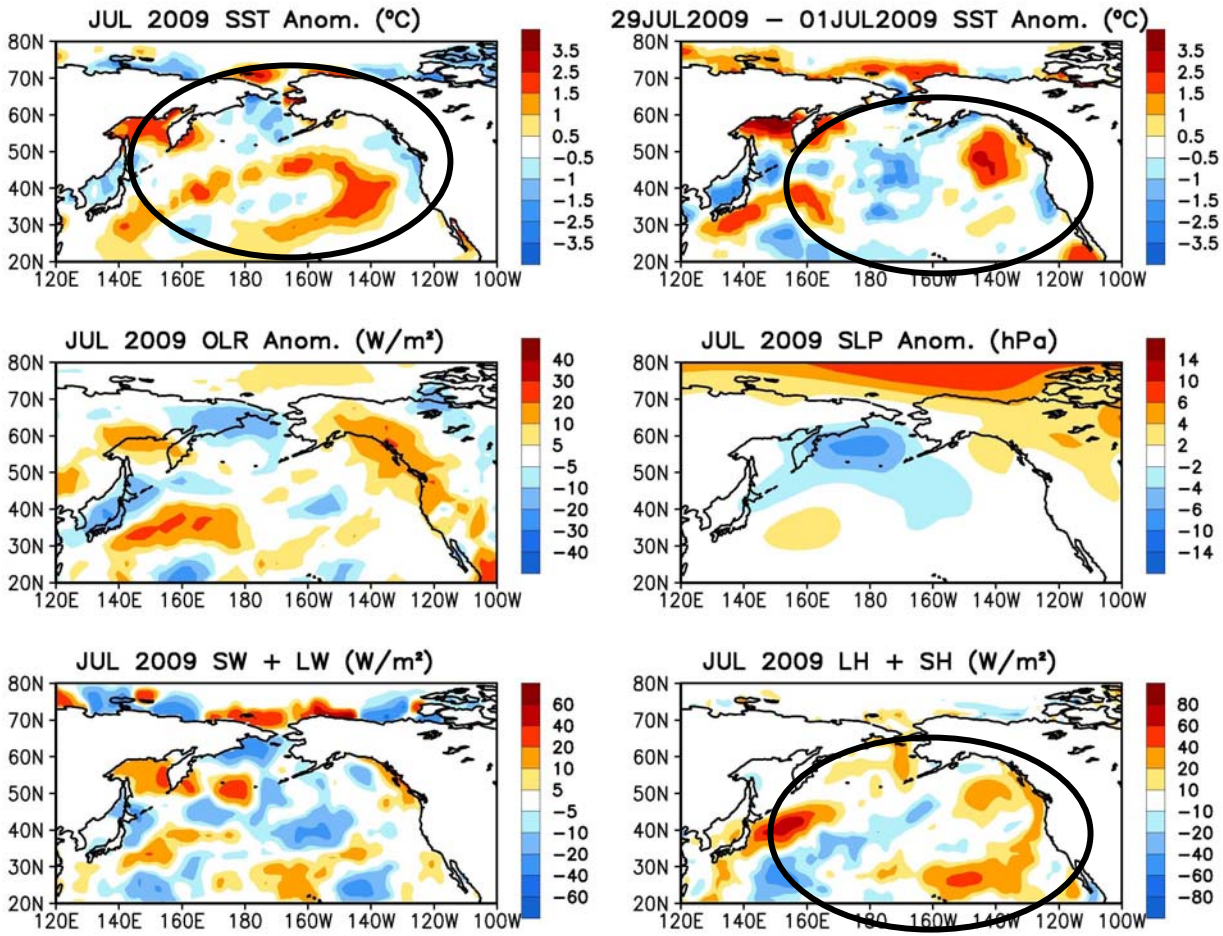
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- **Eastward propagation of negative (positive) surface zonal current anomalies were associated with upwelling (downwelling) oceanic Kelvin waves.**
- **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 anomalies simulated by GODAS were too strong compared with those of the OSCAR currents.**

North Pacific & Arctic Ocean

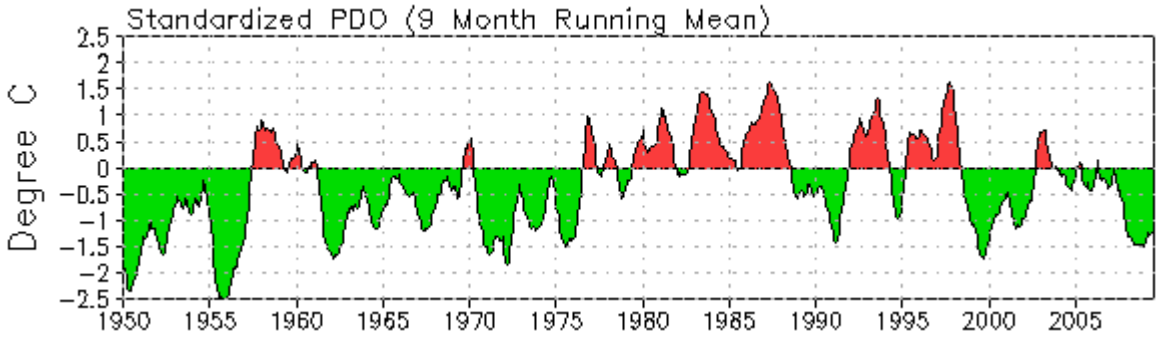
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

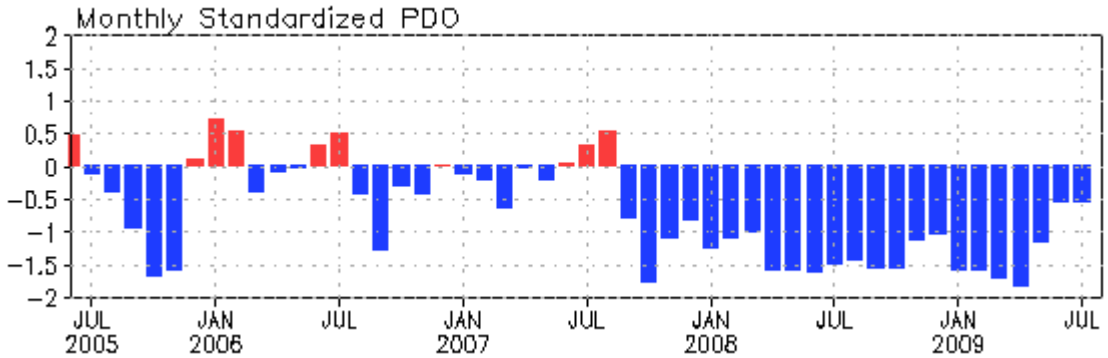


- Weak negative PDO-like SST pattern in the North Pacific persisted.
- SSTA tendencies were largely consistent with the net surface heat flux anomalies.
- Near-normal sea level pressure presented along the west coast of North America, consistent with near-normal coastal upwelling (slide 20).

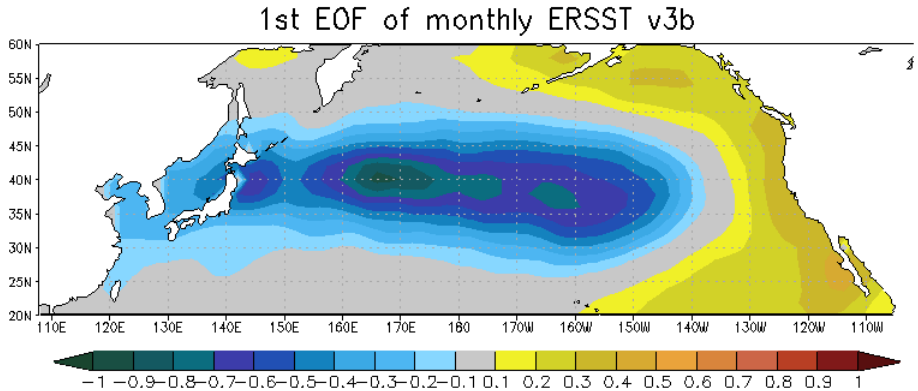
Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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





- **Negative PDO index started in September 2007, and has persisted for 23 months.**
- **Weak negative PDO index persisted.**

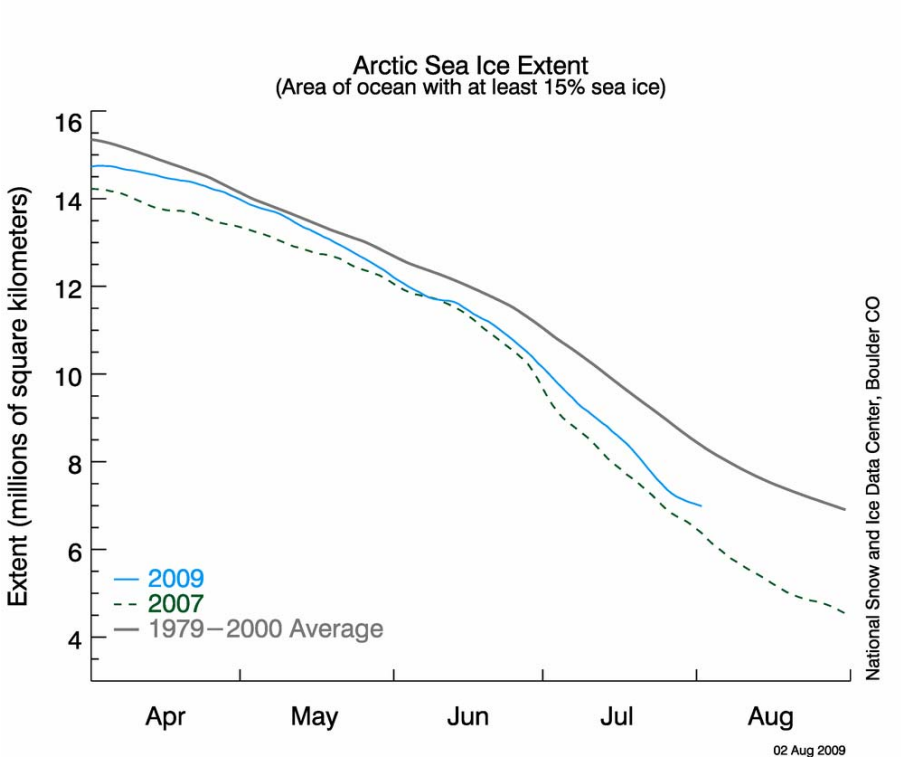


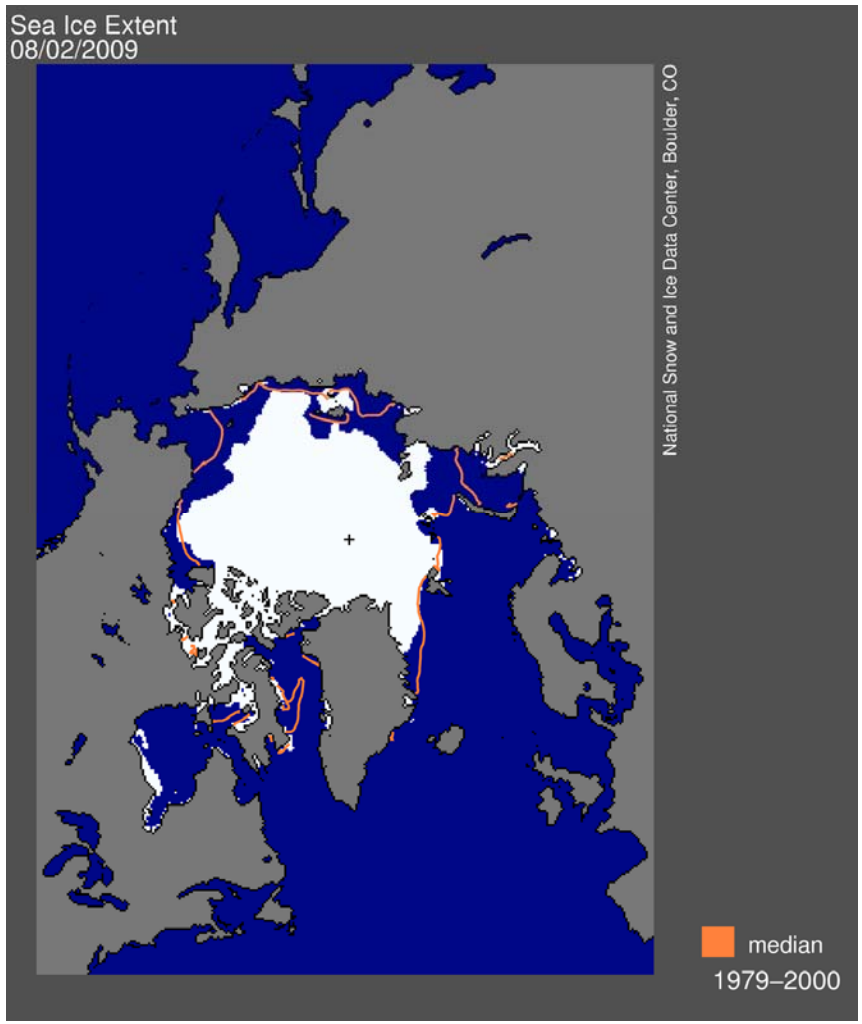
- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.**
- **The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.**

Arctic Sea Ice

National Snow and Ice Data Center

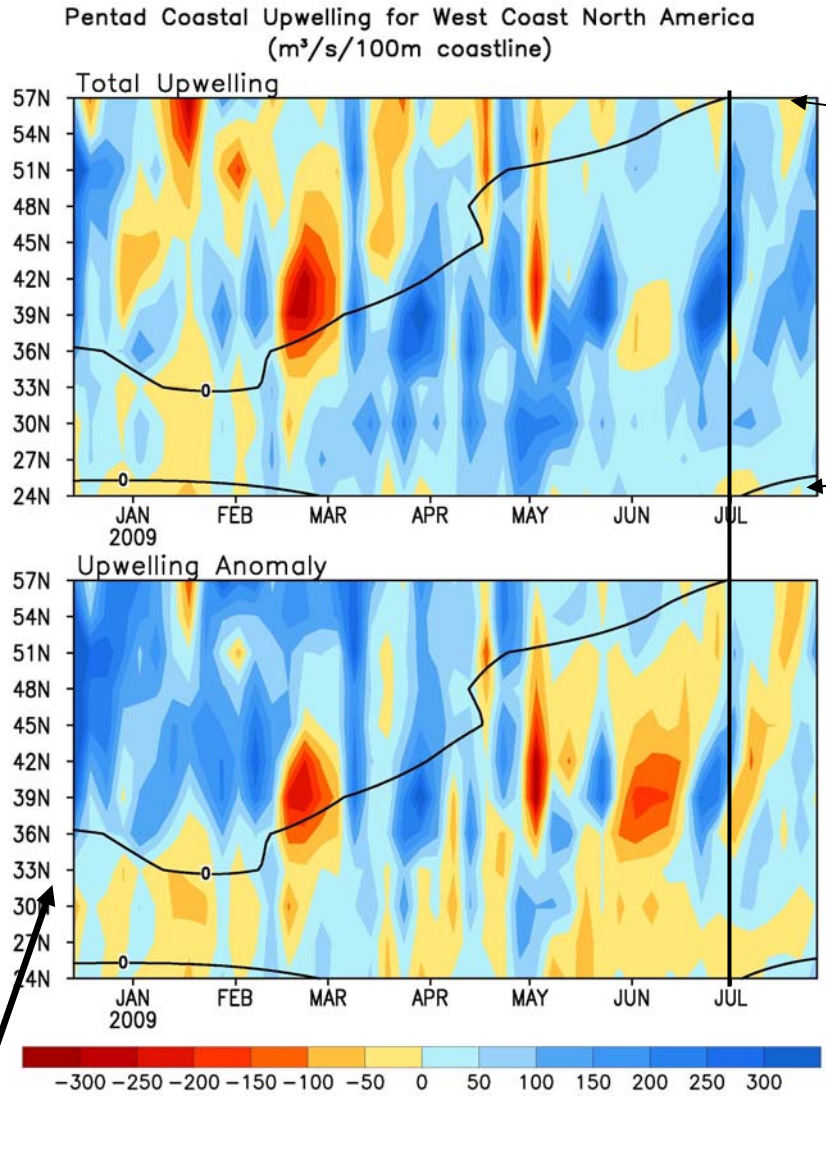
http://nsidc.org/arcticseaicenews/index.html

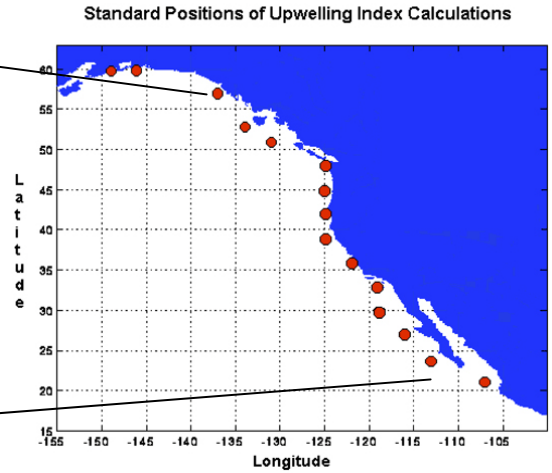




- **Sea ice extent decreased rapidly in July and was only slightly higher than the 2007 historical low.**

North America Western Coastal Upwelling





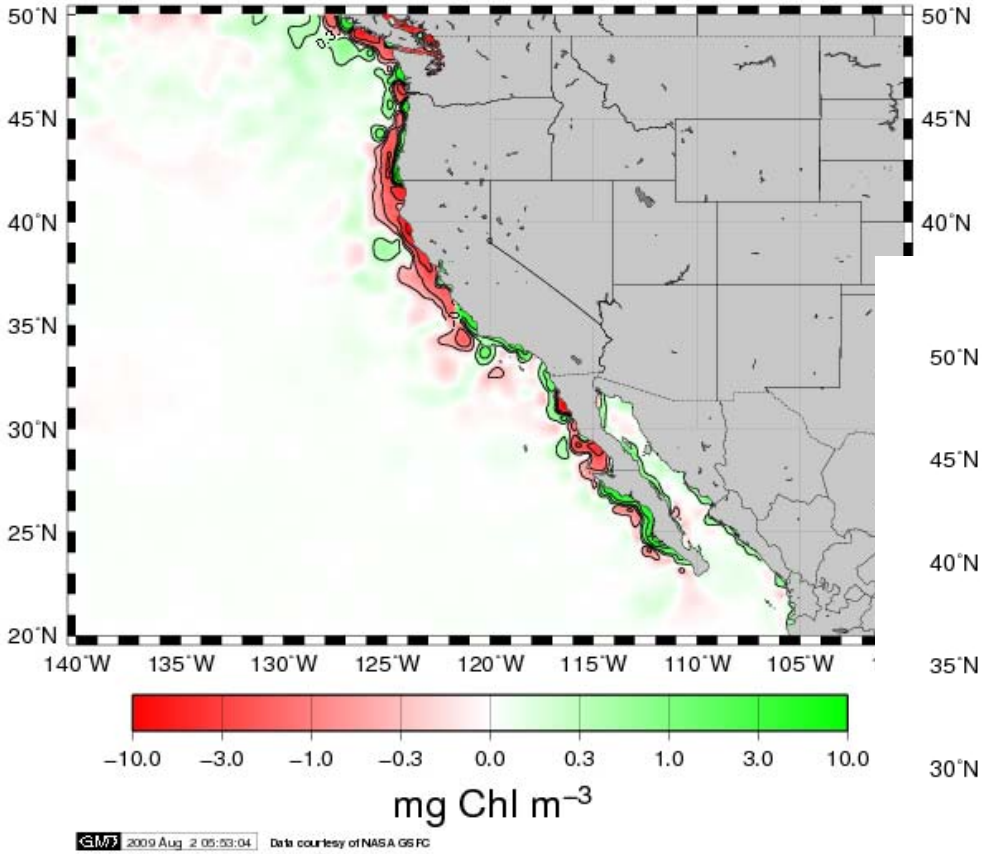
- **Upwelling had large week-to-week variability.**
- **The monthly mean was mostly near-normal in July 09.**

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

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

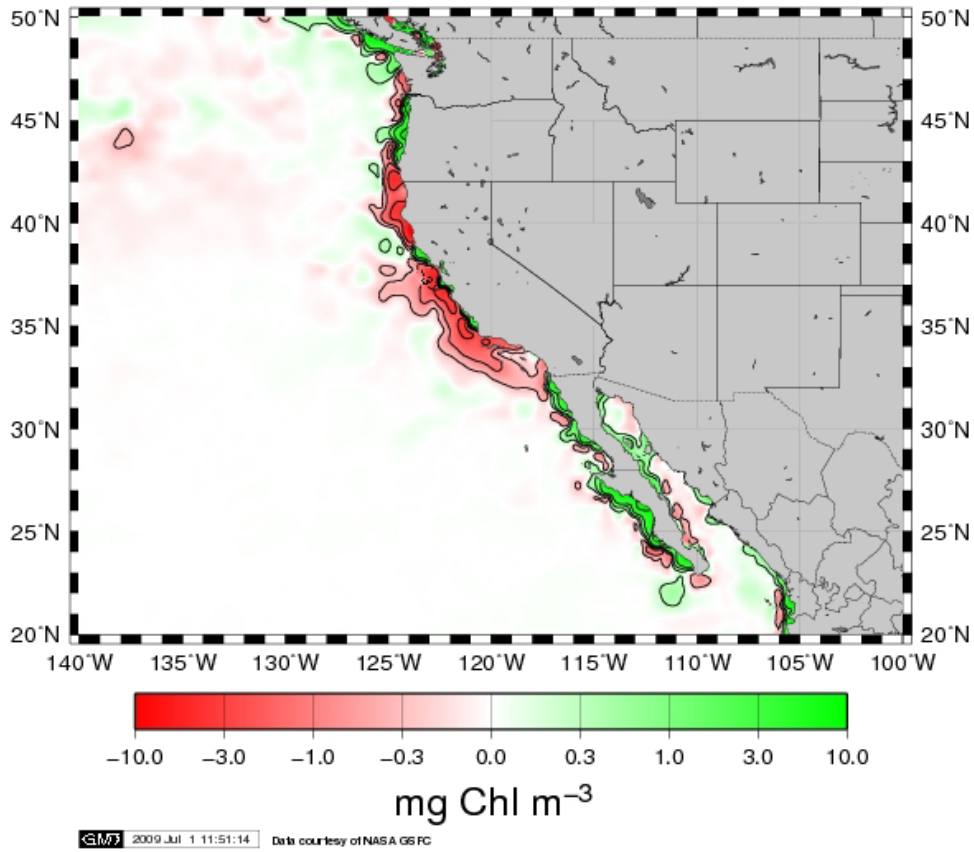
Monthly Chlorophyll Anomaly

MODIS Aqua Chlorophyll a Anomaly for July, 2009



- **Chlorophyll anomalies changed little from June to July 09.**

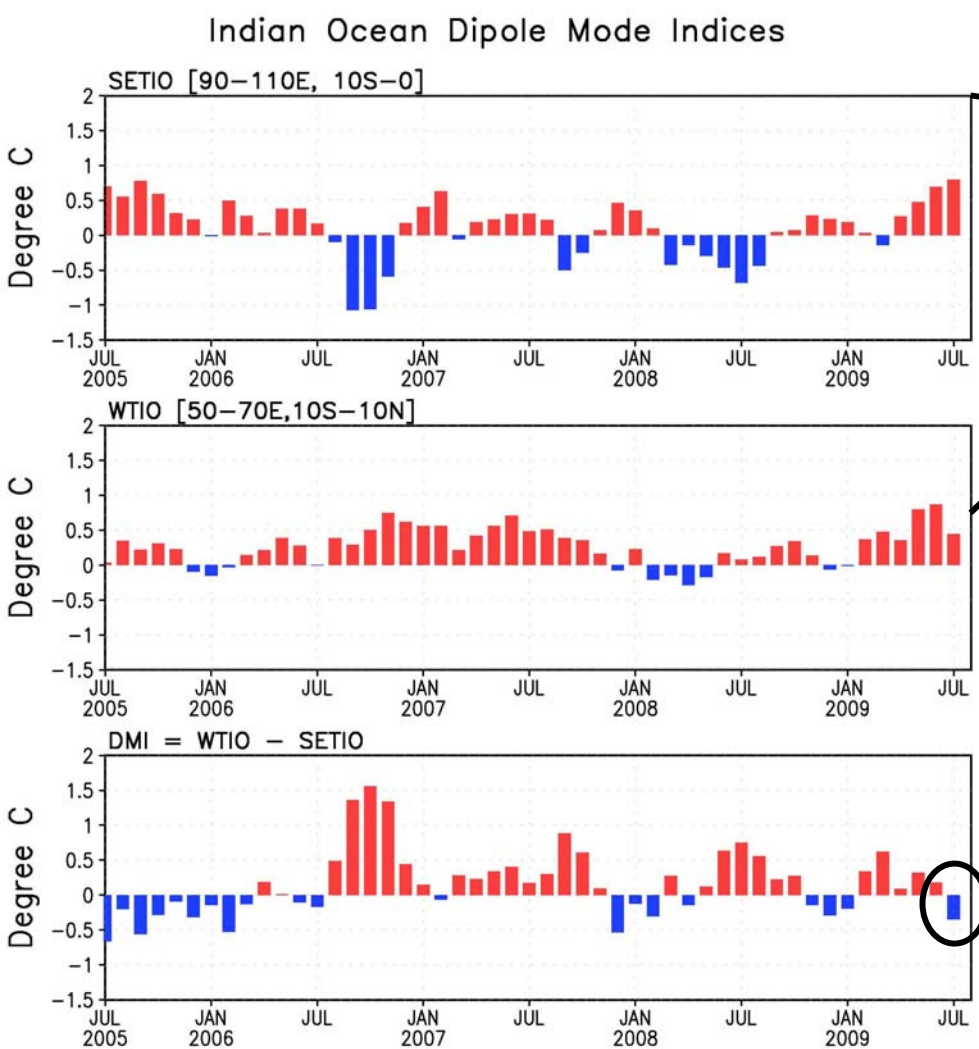
MODIS Aqua Chlorophyll a Anomaly for June, 2009

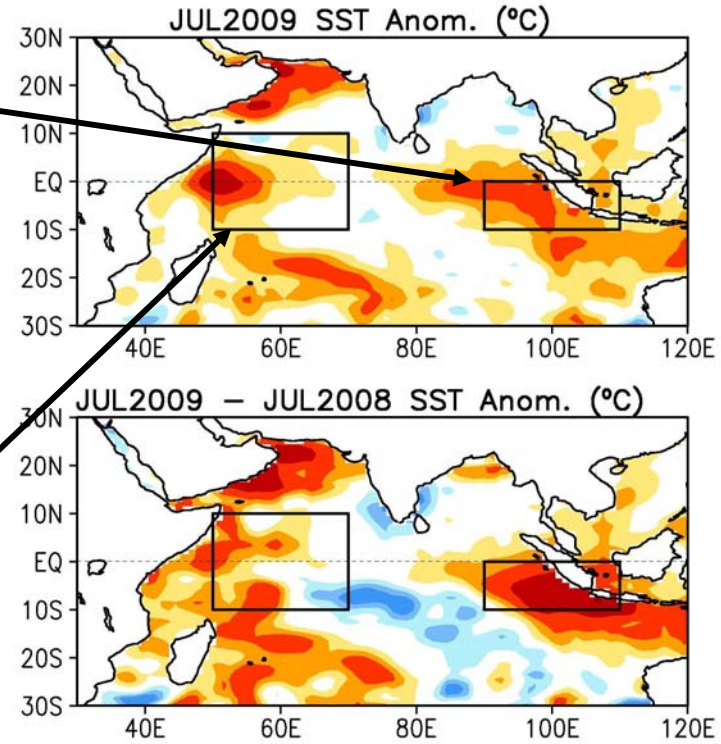


http://coastwatch.pfel.noaa.gov/FAST

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

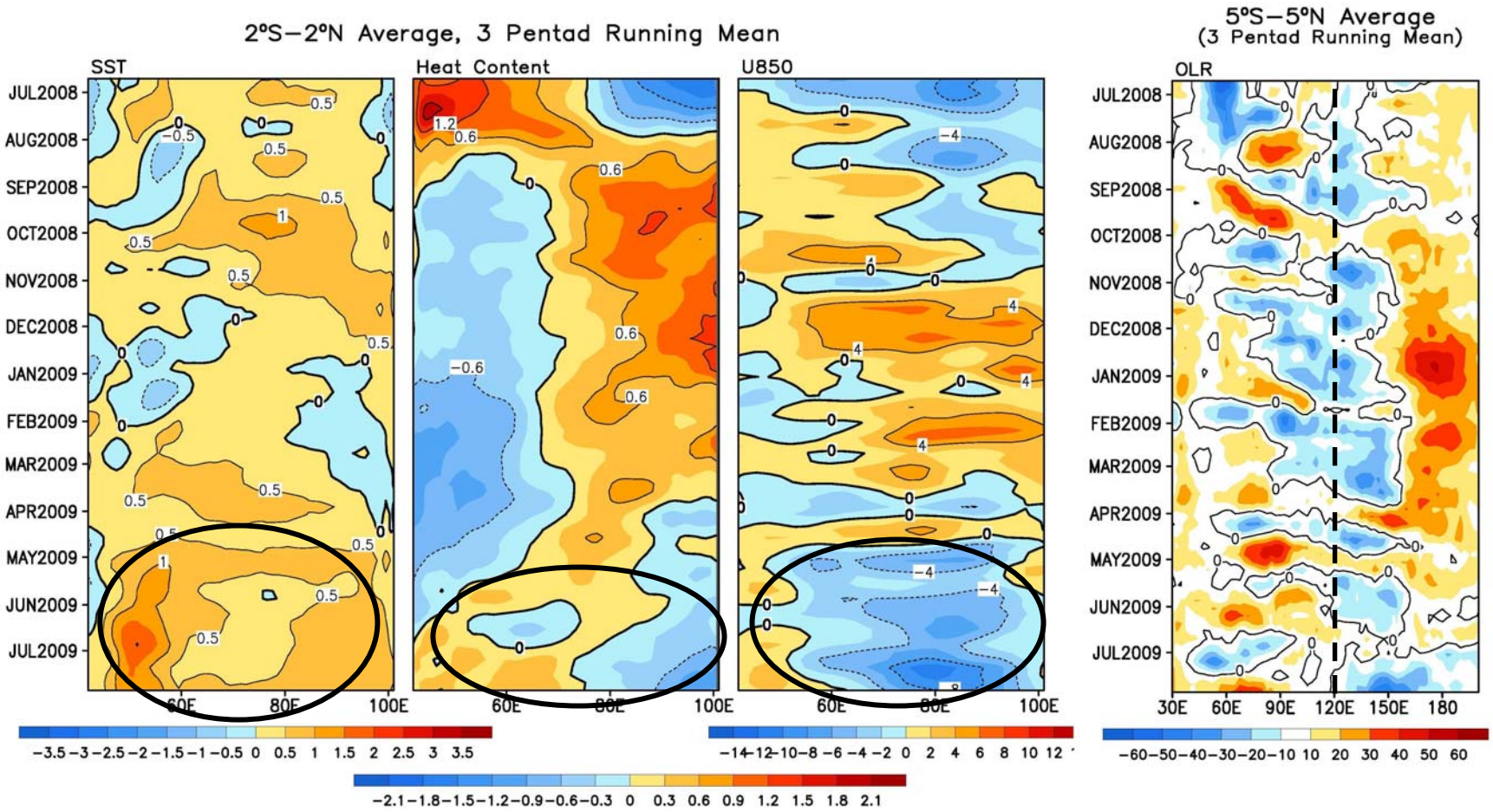




- **Positive eastern pole SSTA (SETIO) strengthened slightly.**
- **Positive western pole SSTA (WTIO) weakened.**
- **DMI decreased significantly, and became below-normal in July 09.**
- **SSTA in the eastern (western) tropical Indian Ocean was about 1.5 C (1 C) higher than that during last July.**

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

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

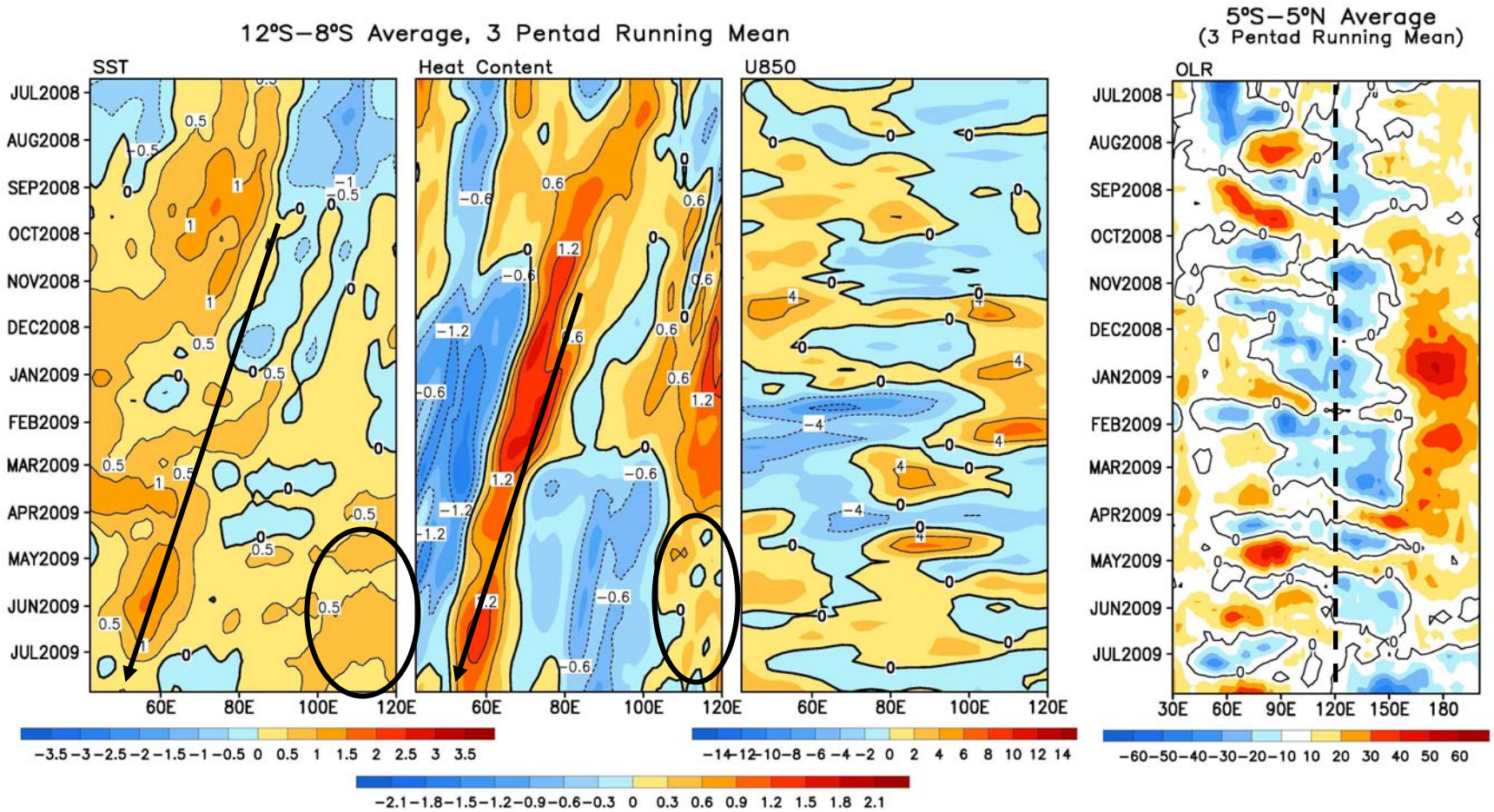


- **Easterly wind anomalies since mid-April 09, which were probably associated with the negative east-west SSTA gradient, strengthened in July.**

- **In response to the easterly wind anomalies, positive (negative) heat content anomaly was built up in the western (eastern) tropical Indian Ocean.**

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.

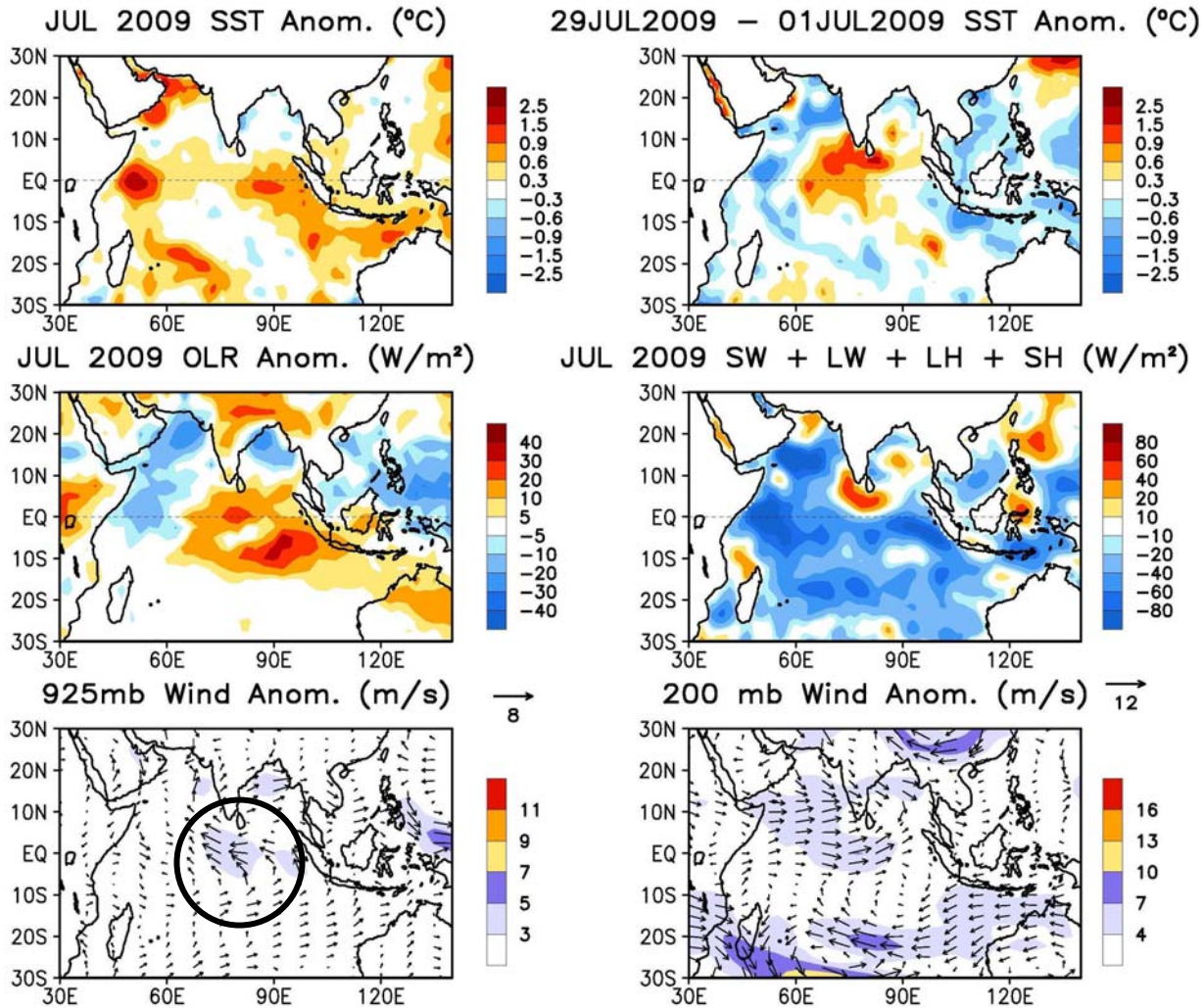
Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)



- Westward propagation of positive HCA near 10°S probably contributed to the recent warming in SST near 60°E.
- Positive SSTA east of 100°E was consistent with positive HCA there.

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.

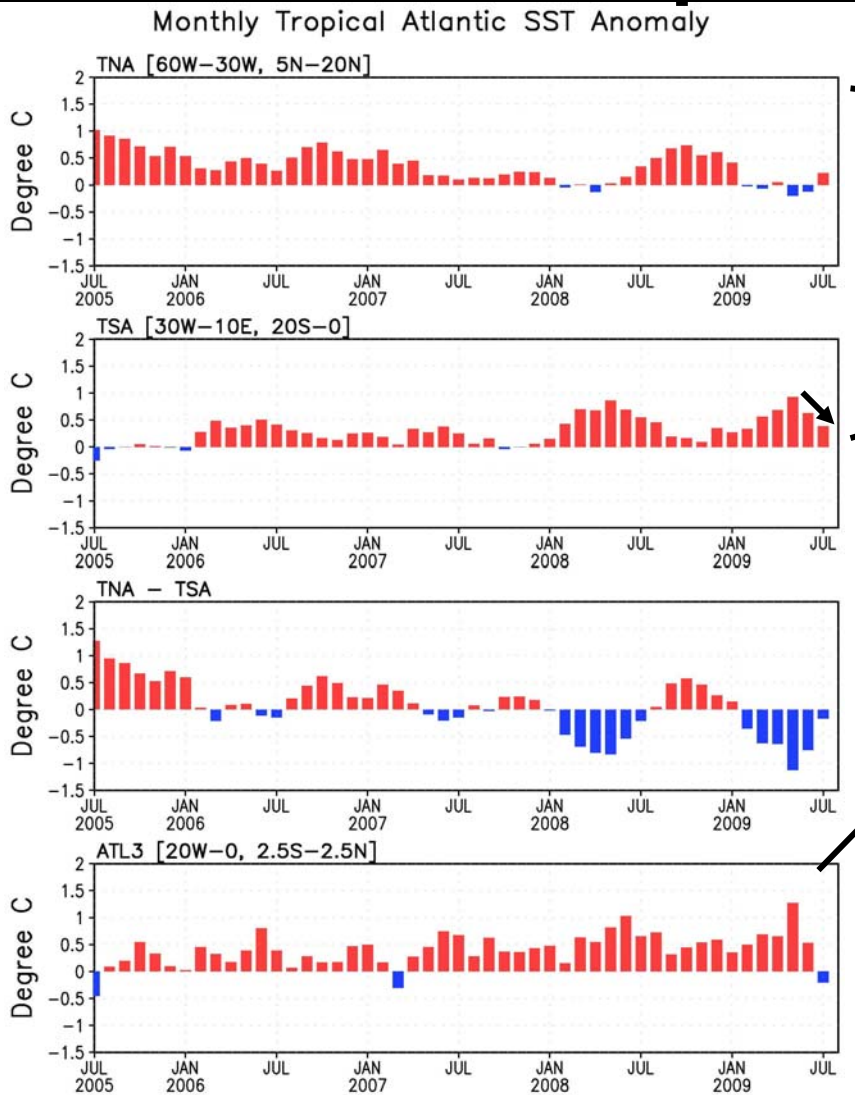


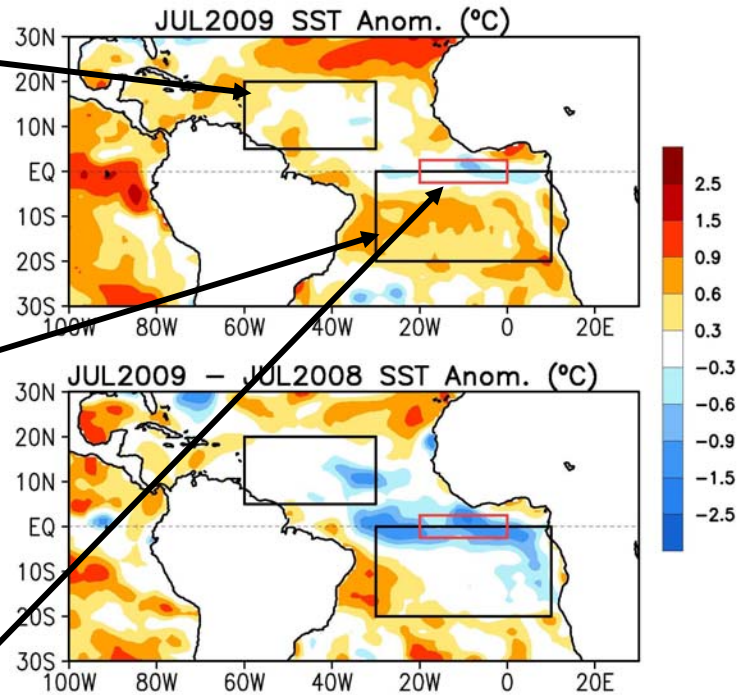
- Easterly wind anomalies presented in the central-eastern tropical Indian Ocean.
- Net surface heat flux anomalies cooled most of the tropical Indian Ocean.
- Convection was suppressed (enhanced) in the eastern tropical Indian Ocean (near Philippine).

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



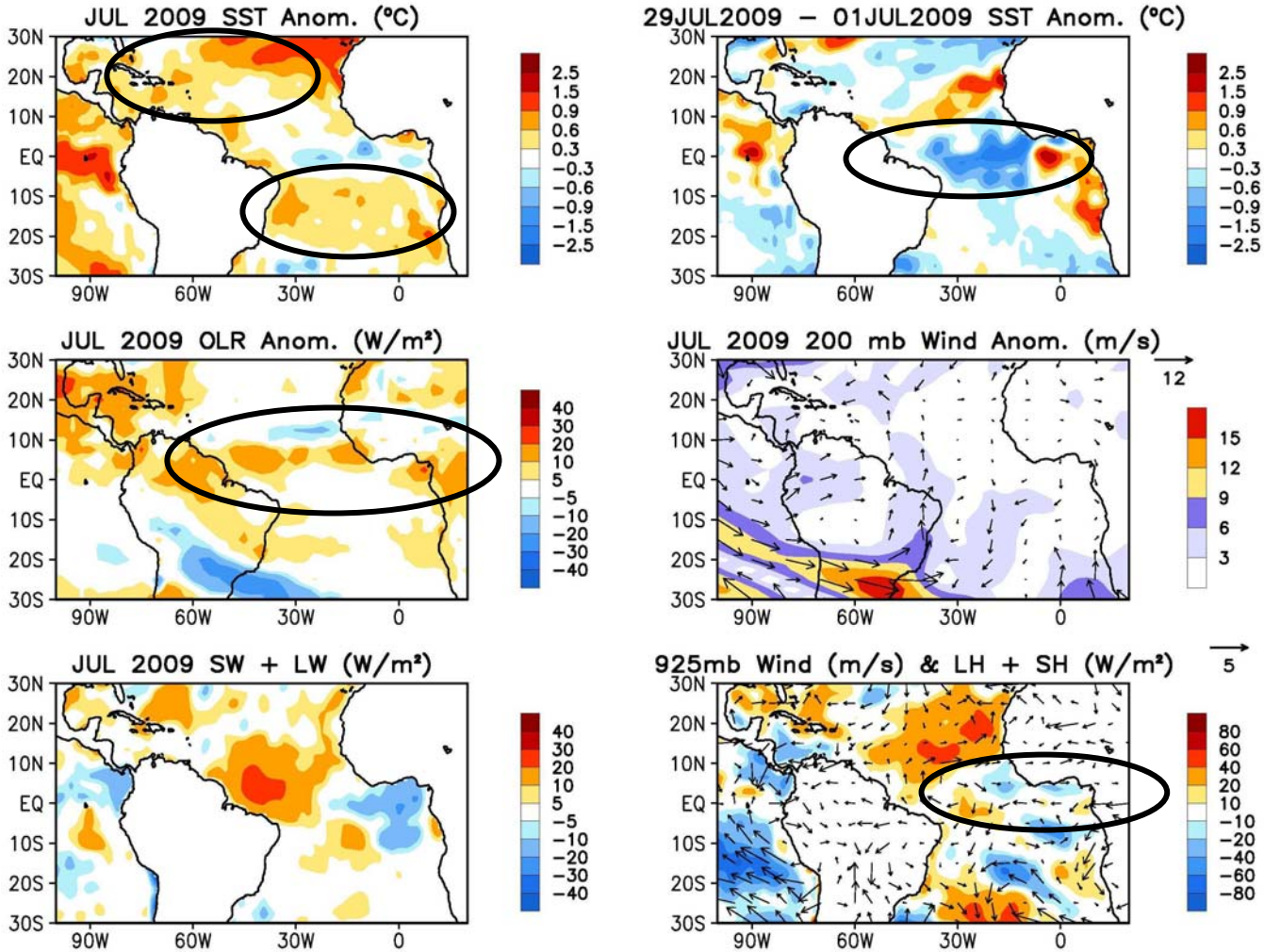


- **Tropical North Atlantic SST (TNA) increased and was slightly above-normal in July.**
- **Tropical South Atlantic SST (TSA) decreased, and remained weakly above-normal.**
- **Meridional Gradient Mode (TNA-TSA) became near-normal.**
- **ATL3 SST decreased significantly, and became negative for the first time since Mar 07.**

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



- **Positive SSTAs presented in the tropical North and South Atlantic.**
- **Strong negative SSTA tendency in the equatorial Atlantic was associated with easterly wind anomalies.**
- **Convection was suppressed (enhanced) along the equatorial Atlantic (tropical North Atlantic).**

North Atlantic Ocean

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

- Strong negative NAO pattern in SLP.
- SSTA tendencies were largely consistent with net surface heat flux anomalies.

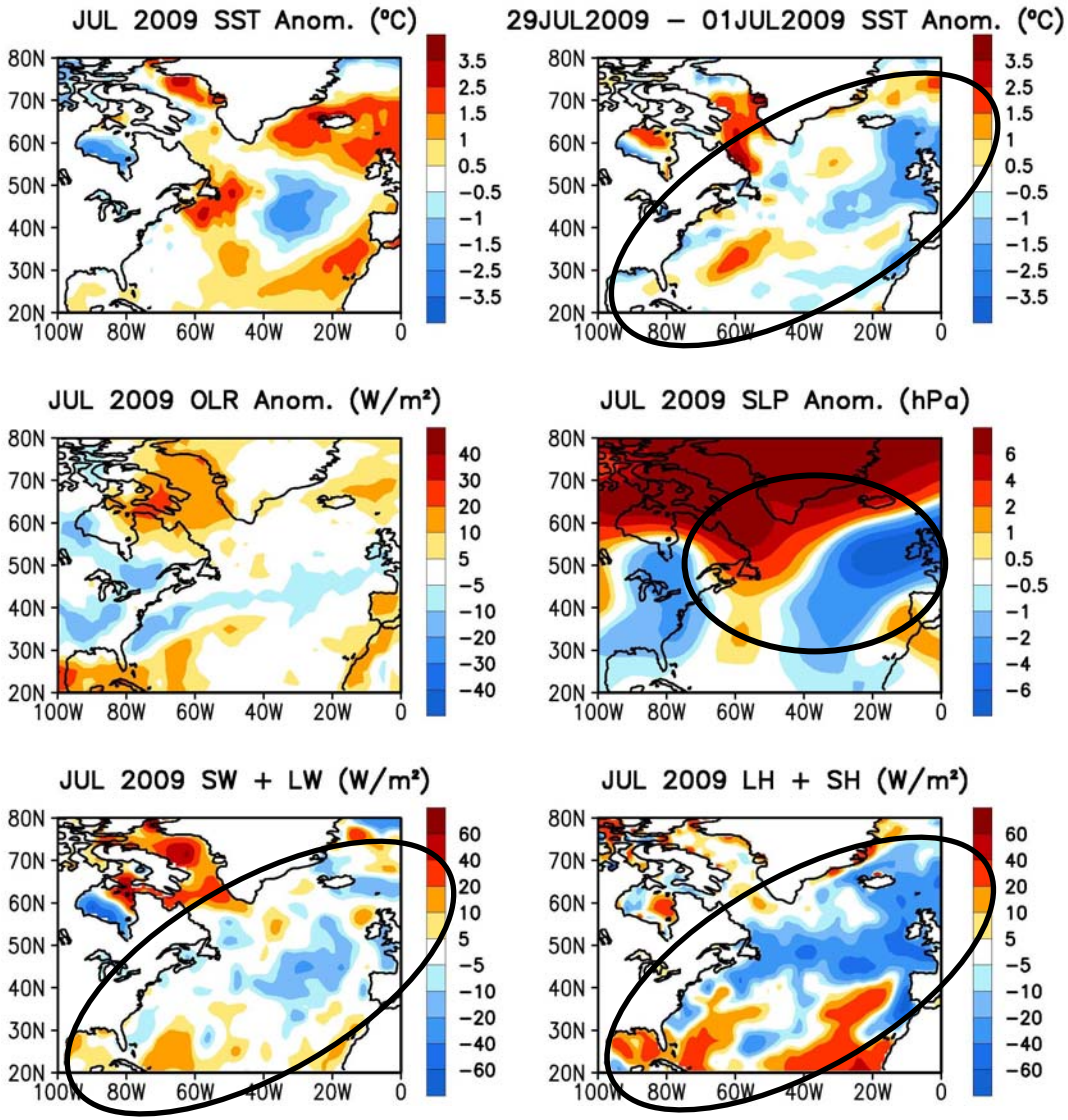
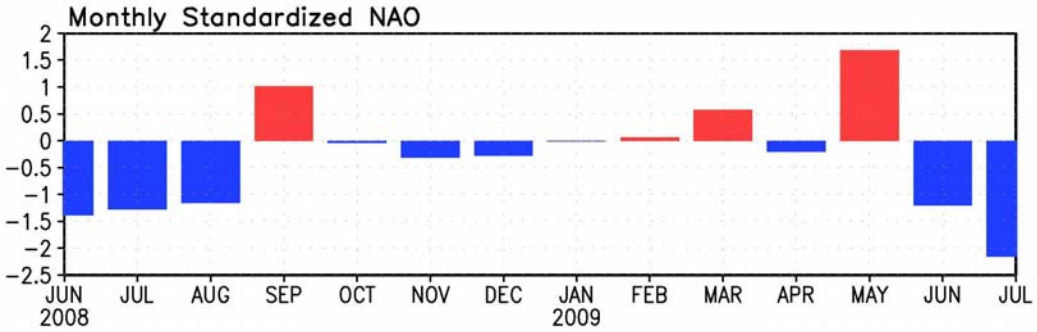
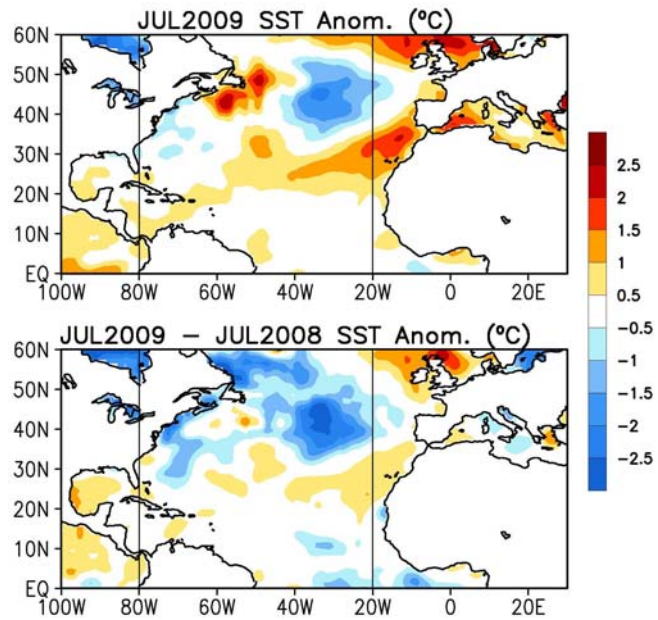
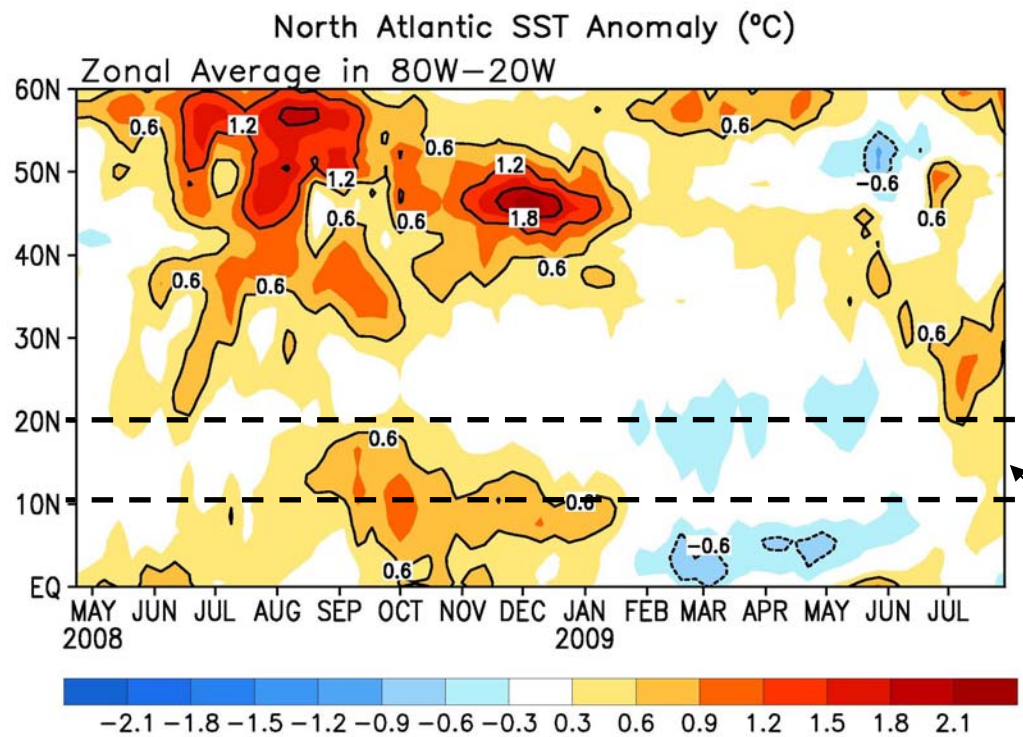


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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



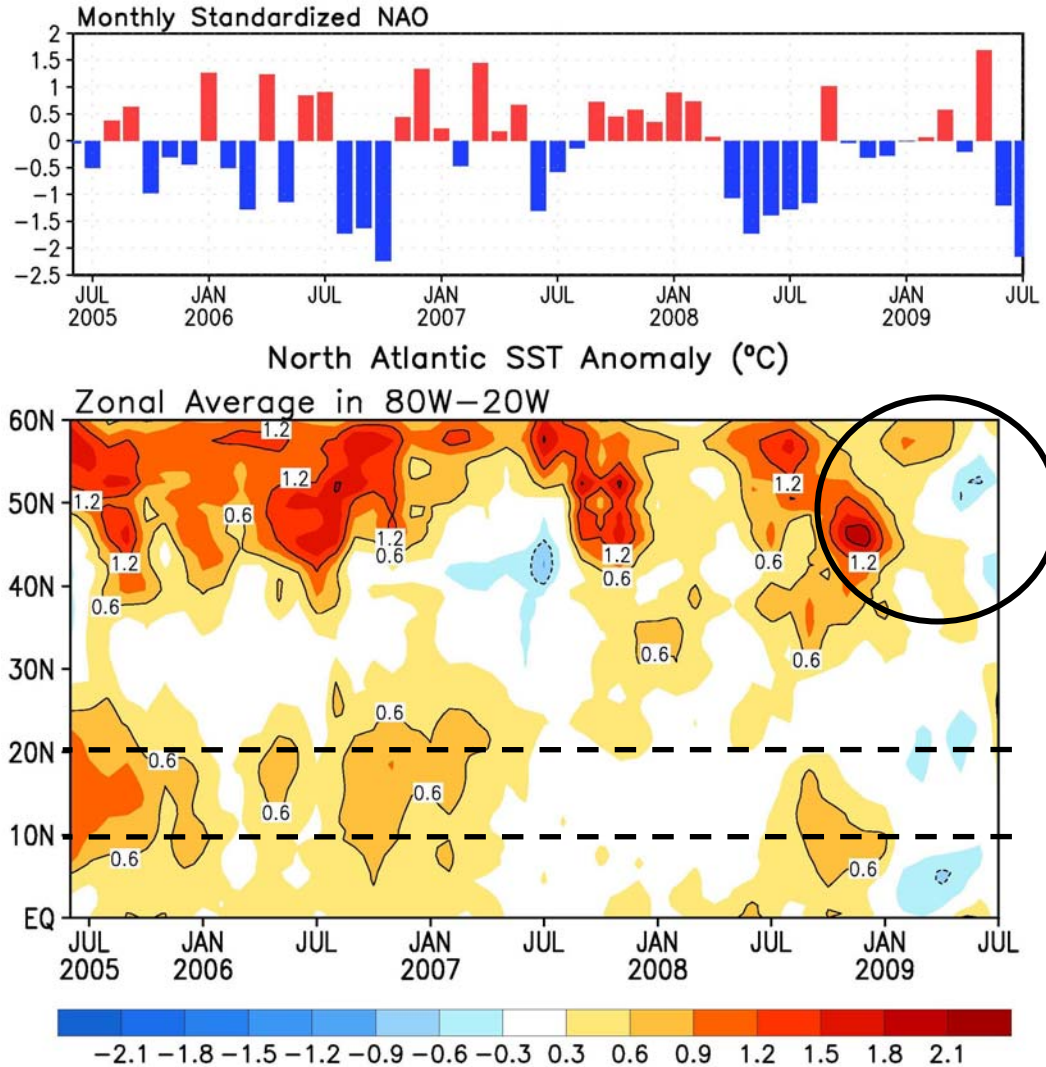


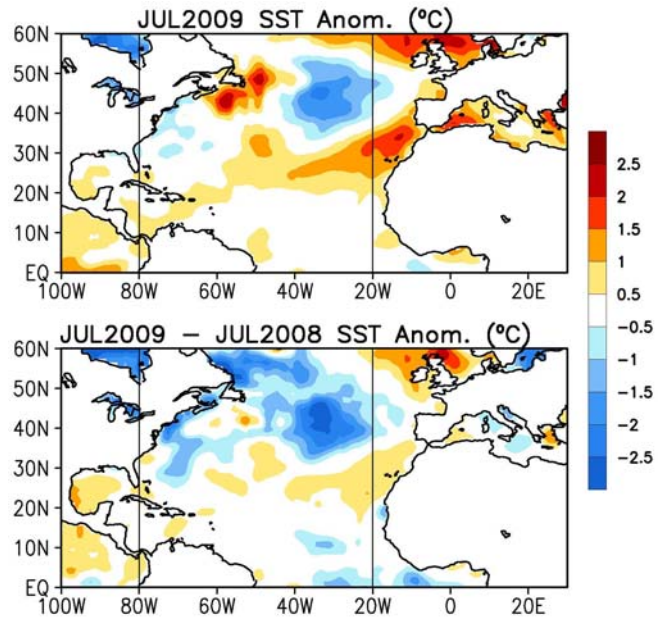


- **High-latitude North Atlantic SSTA are closely related to NAO index – negative (positive) NAO leads to SST warming (cooling).**
- **NAO was about -2.2 standard deviation in Jul 09.**
- **SST in the Hurricane Main Development Region was slightly above-normal in Jul 09.**

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

NAO and SST Anomaly in North Atlantic





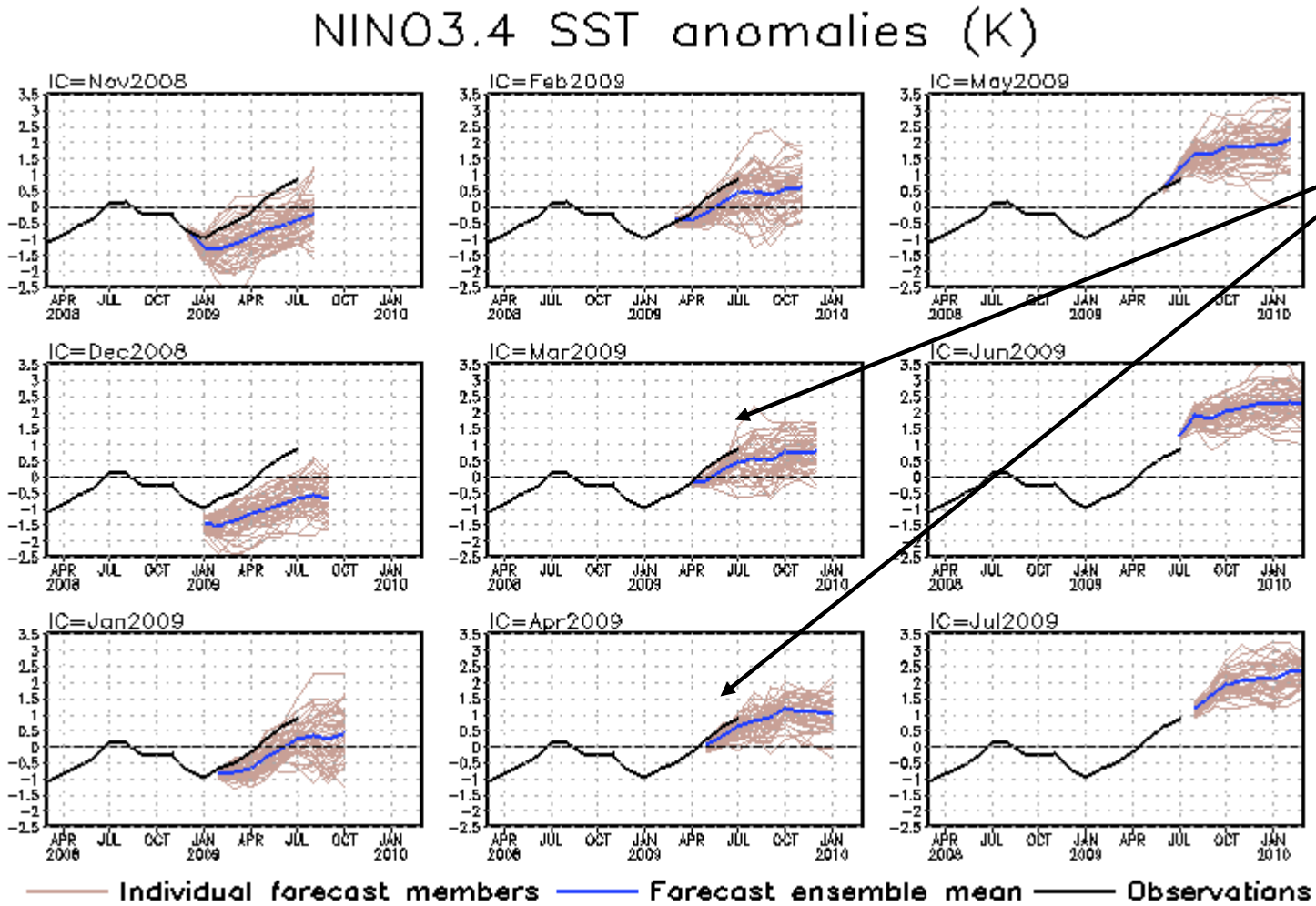
- North Atlantic SSTs cooled down and became slightly below-normal during the past few months due to near-normal or above-normal NAO index.

- Strong negative NAO in June-July suggests a positive SSTA tendency in North Atlantic in next few months.

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

CFS SST Predictions and Ocean Initial Conditions

CFS Niño3.4 SST Predictions from Different Initial Months

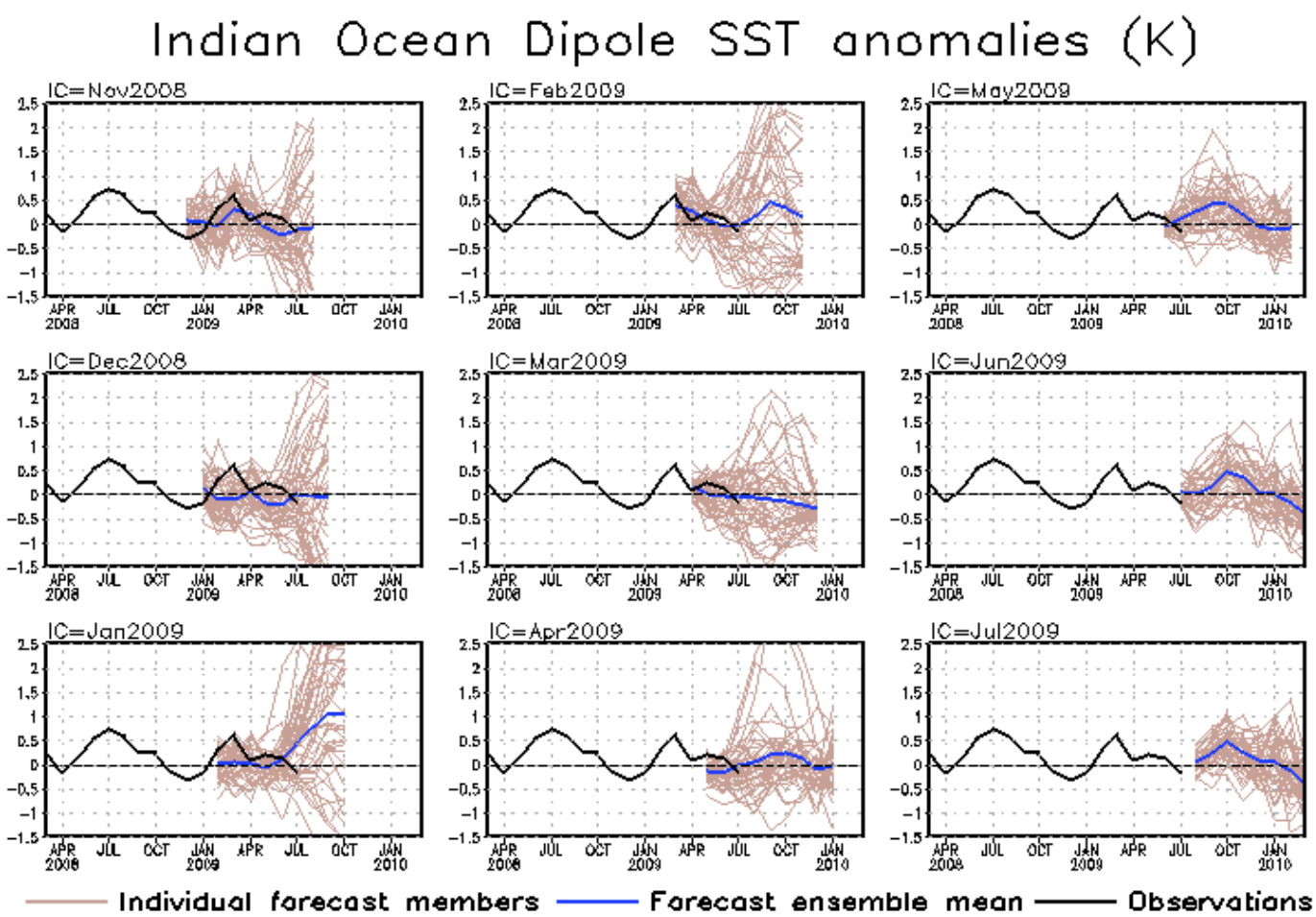


- Nice forecasts from Mar-Apr I.C..

- Latest forecasts suggested a strong El Nino (NINO 3.4 > 2C) would develop during fall/winter 2009.

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

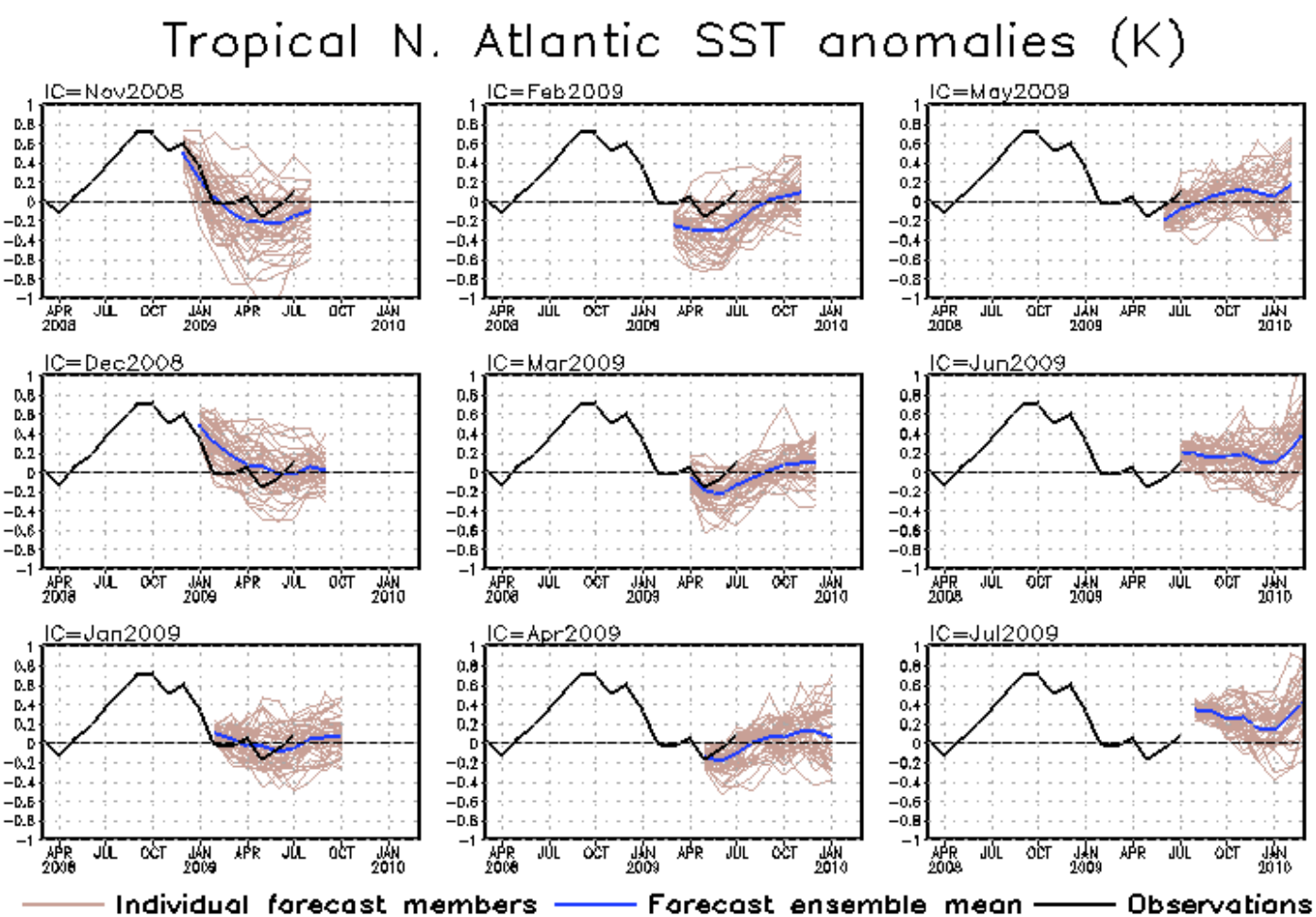
SETIO = SST anomaly in [90ºE-110ºE, 10ºS-0]

WTIO = SST anomaly in [50ºE-70ºE, 10ºS-10ºN]

- Latest forecasts called for a weakly above-normal Dipole Mode Index in the fall 09.

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

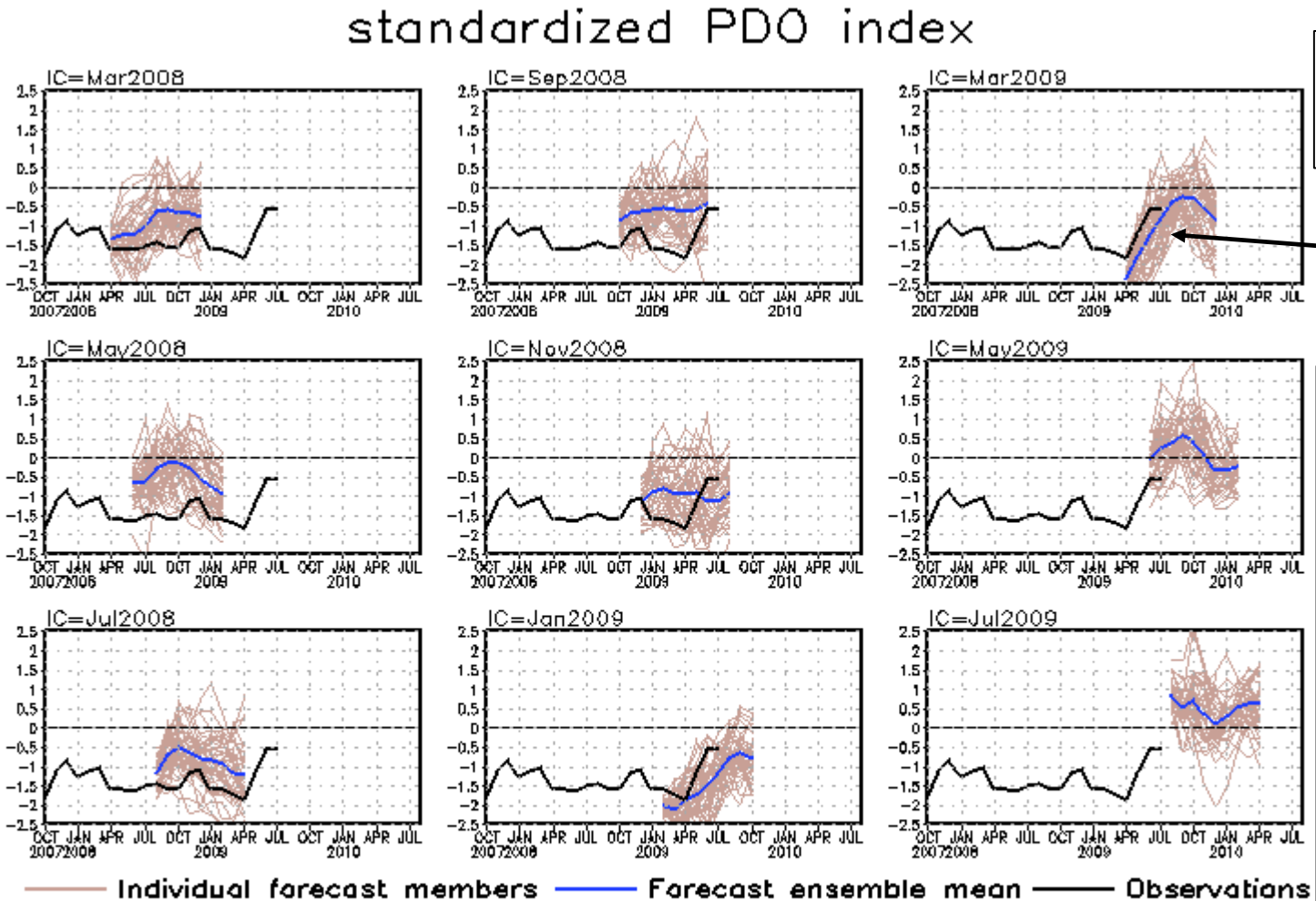


TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- Latest forecasts suggested that the tropical North Atlantic SST would be weakly above-normal in next 3-6 months.

Fig. M3. CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labeled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1971-2000 base period means.

CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



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

- Nice forecasts from Mar I.C..

- CFS SST anomalies are projected onto the PDO SST pattern (slide 16).

- CFS has forecasted the recent negative PDO phase since Dec 07 I.C.

- Latest forecasts suggested that the current negative PDO would weaken rapidly and became above-normal during summer/fall 09.

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) established in June 2009, and further strengthened in July 2009.
  - Negative PDO phase since September 2007 has persisted for 23 months; but it weakened and remained weakly below-normal in June-July 2009.
  - Upwelling along west coast North America was near-normal in July 09.
- **Indian Ocean**
  - Since mid-April 09, zonal wind anomalies were persistently easterly and easterly winds strengthened in July 2009.
  - SST was 1.5^{o}C (1 ^{o}C) above-normal in the western (eastern) tropical Indian Ocean, and Dipole Mode Index became weakly below-normal in July 2009.
- **Atlantic Ocean**
  - Tropical North Atlantic SST (TNA) increased and became weakly above-normal in July 2009.
  - ITCZ shifted northward, that was consistent with the warming in TNA and the cooling in the equatorial Atlantic.
  - NAO was the lowest (-2.2) since October 2006.
- **Arctic Ocean**
  - Sea ice extent was near a historical low in July 09.

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!