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

Prepared by
Climate Prediction Center, NCEP/NOAA

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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 Ocean Climate Observation Program (OCO)

Outline

- **Overview**
- **Recent highlights**
  - **Pacific/Arctic Ocean**

    (Uncertainty in equatorial sub-surface temperature anomalies)
  - **Indian Ocean**
  - **Atlantic Ocean**

    (NOAA's 2013 updated Atlantic Hurricane Seasonal Outlook)
- **Global SST Predictions**

Overview

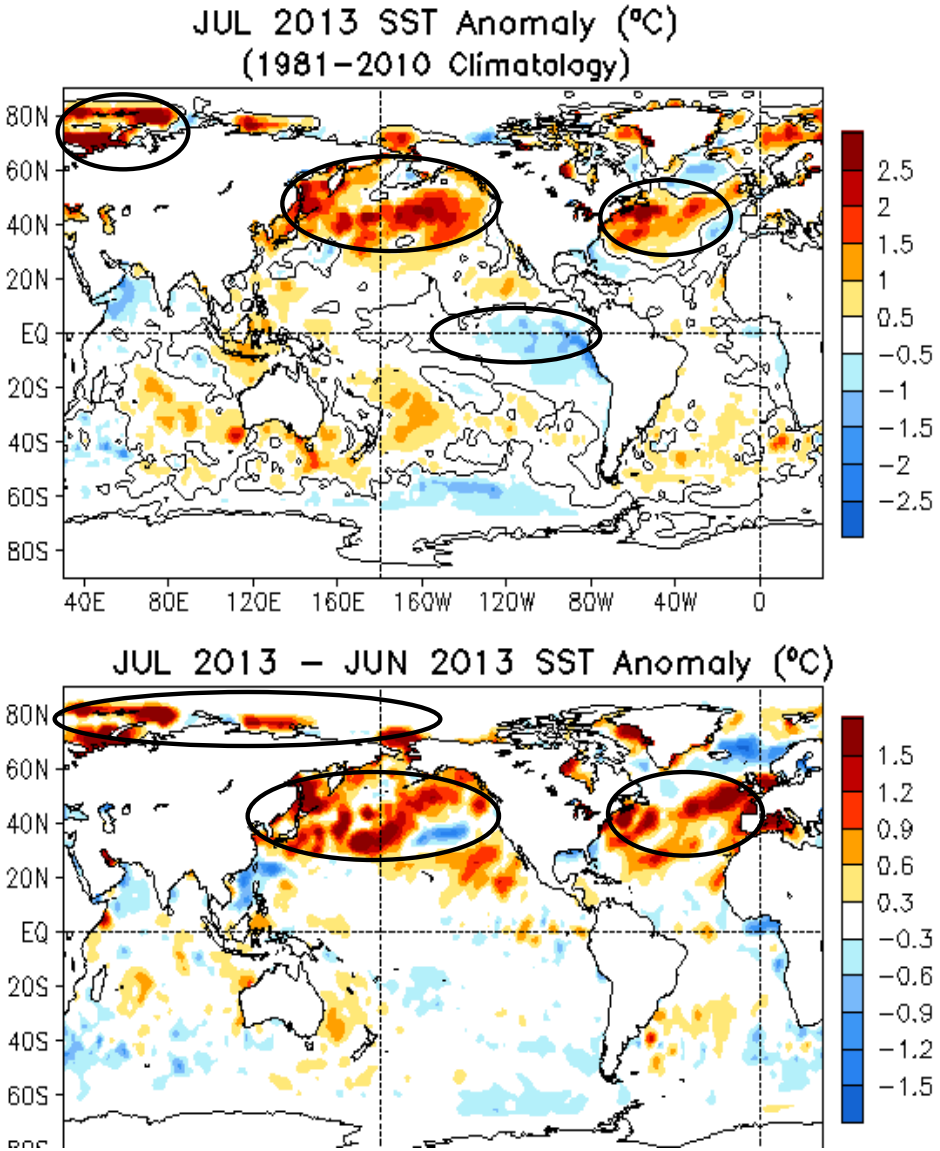
- **Pacific and Arctic Oceans**
  - **ENSO-neutral conditions continued during July 2013.**
  - **The consensus forecast favors ENSO-neutral conditions to continue into the Northern Hemisphere Spring 2014.**
  - **Negative PDO phase strengthened with PDO=-1.5 in July 2013, and NCEP CFSv2 predicted negative PDO phase would continue into next spring.**
  - **Strong positive SSTA dominated the high latitudes of the North Pacific and Arctic Oceans in July 2013**

- **Indian Ocean**
  - **SSTs were above-normal in the east and slightly below-normal in the west, and negative Indian Ocean Dipole index continued in July 2013.**

- **Atlantic Ocean**
  - **Above-normal SST continued in the hurricane main development region.**
  - **NOAA's updated hurricane outlook continued to predict above-normal condition of hurricane activity in 2013.**
  - **Positive NAO index persisted in the past four months.**

Global Oceans

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

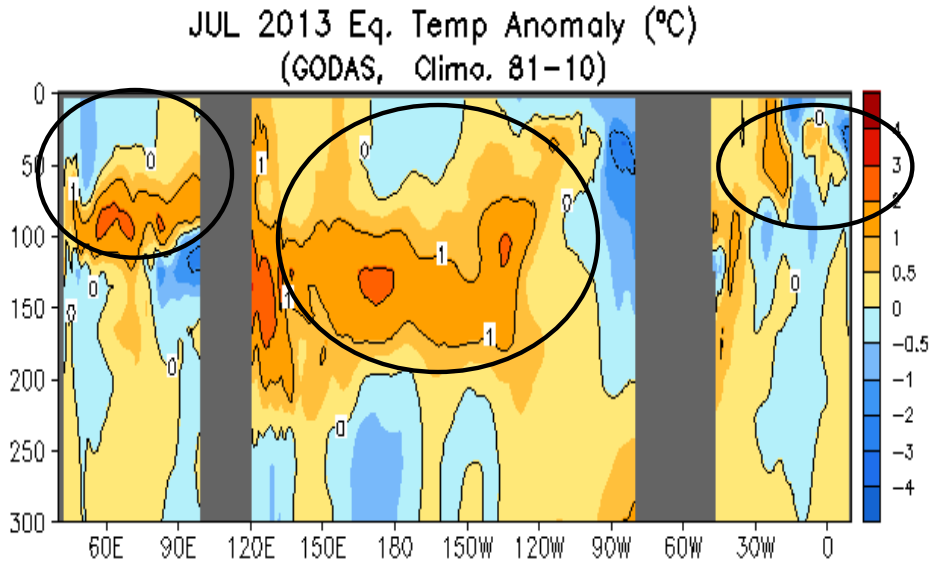


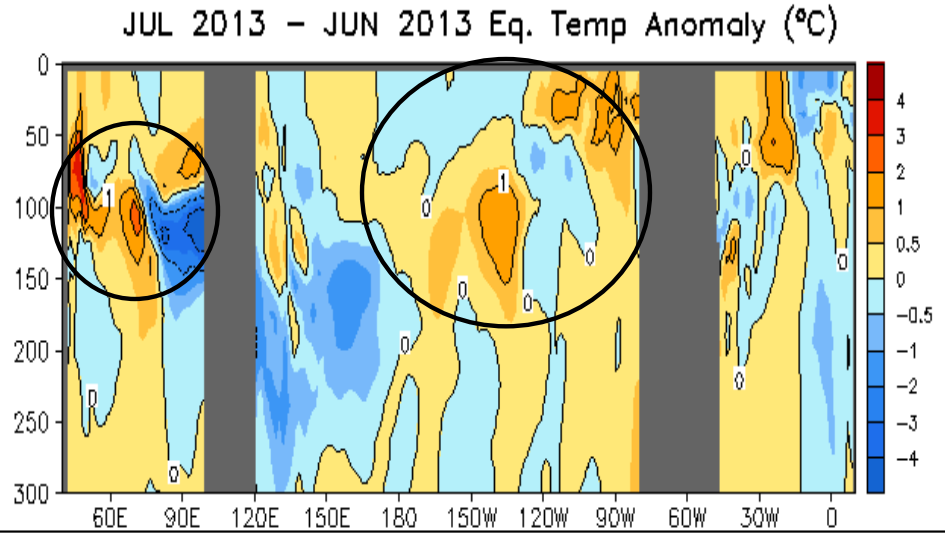
- **SST was near-normal across the western-central tropical Pacific and below average across the eastern Pacific.**
- **Strong positive SST anomalies were observed in the high latitudes of North Pacific, North Atlantic, and Arctic Oceans.**

- **A strong warming tendency was observed in the high latitudes of North Pacific, North Atlantic and Artic Oceans.**

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 1981-2010 base period means.

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





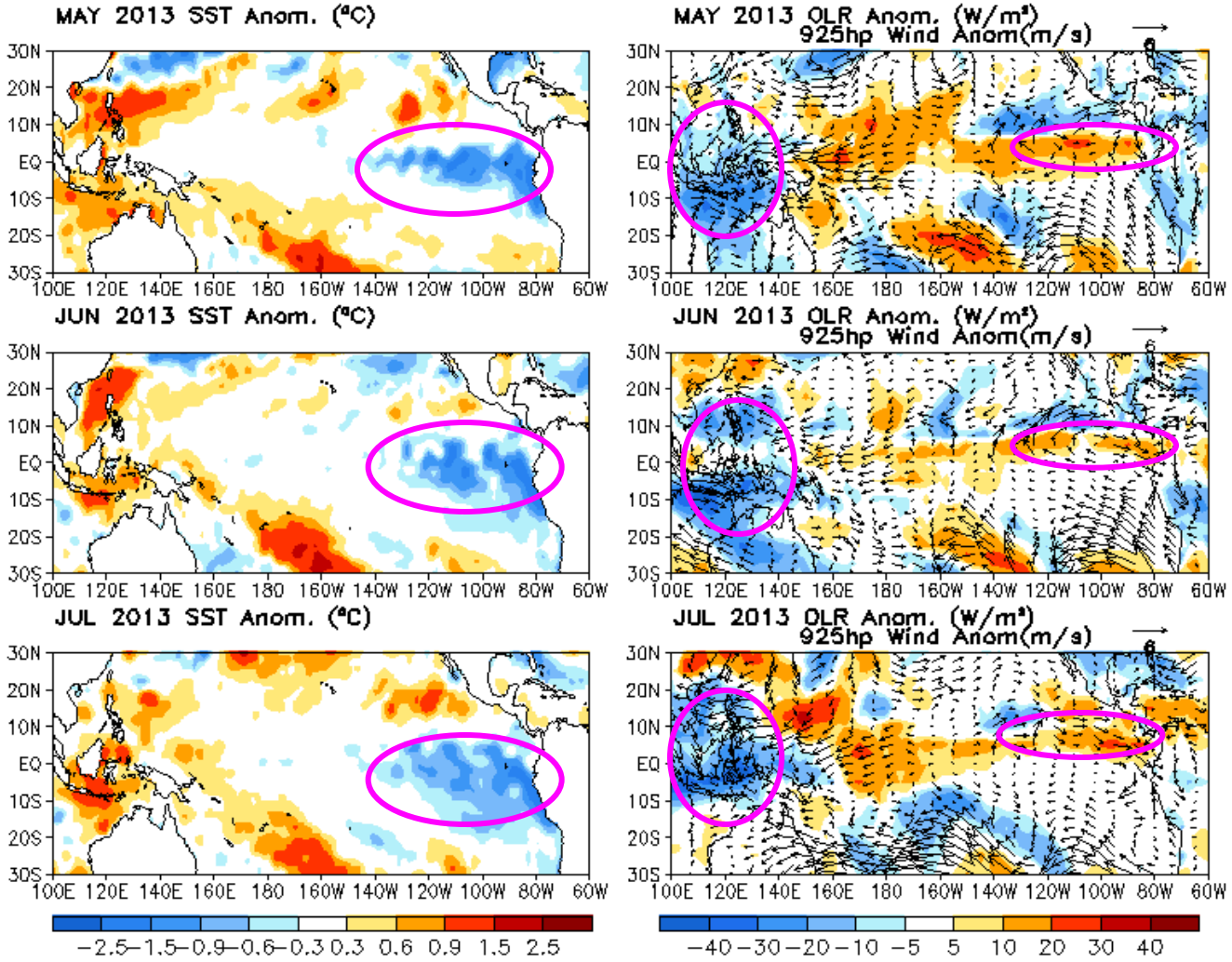
- **Positive temperature anomalies continued to occupy near the thermocline in the western-central equatorial Pacific Ocean.**
- **Positive anomalies continued to dominate at the upper 100m of equatorial Indian Ocean.**

- **A warming (cooling) tendency was observed in the east-central (western) Pacific near the thermocline**
- **A cooling (warming) tendency presented in the upper 120m of eastern (western) 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 1981-2010 base period means.

Tropical Pacific Ocean and ENSO Conditions

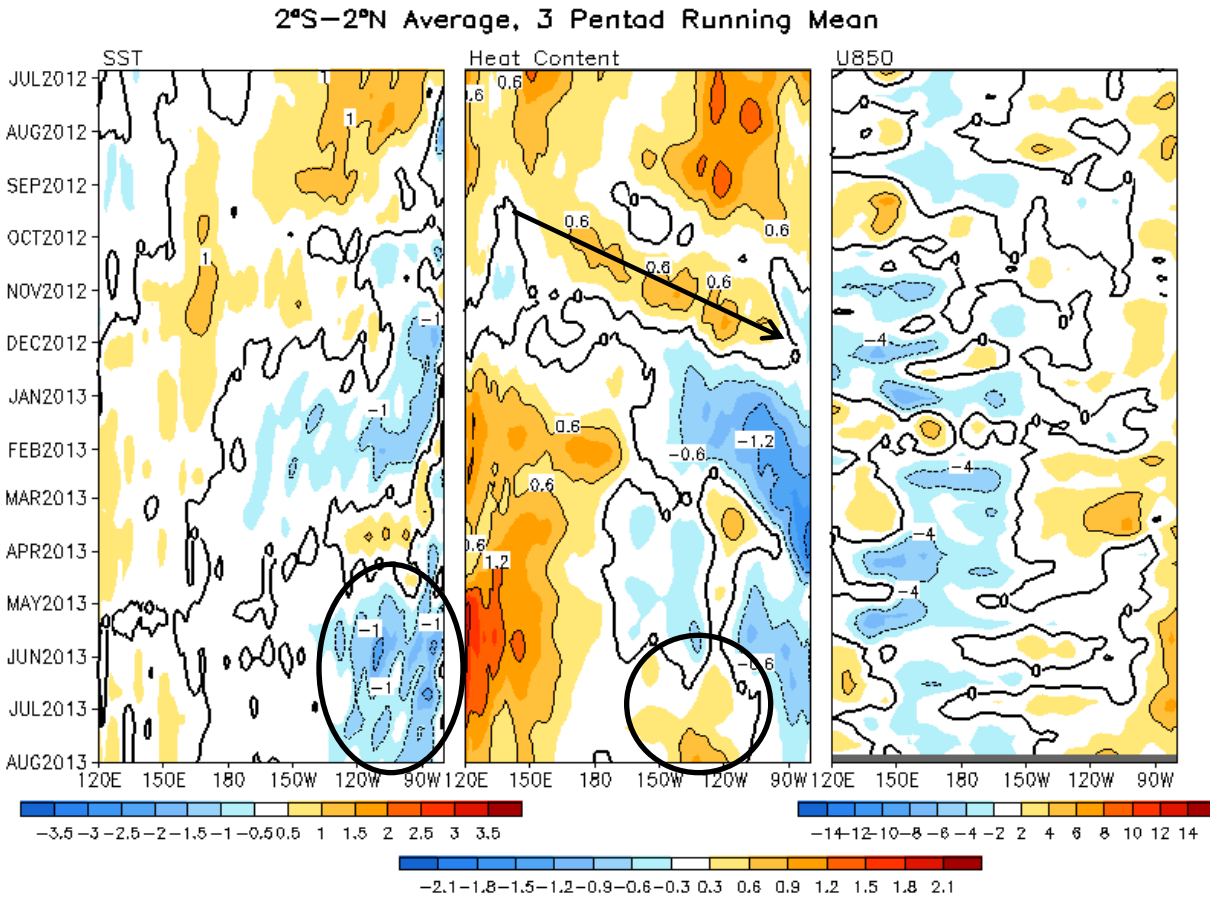
Last Three Month SST, OLR and 925hp Wind Anom.



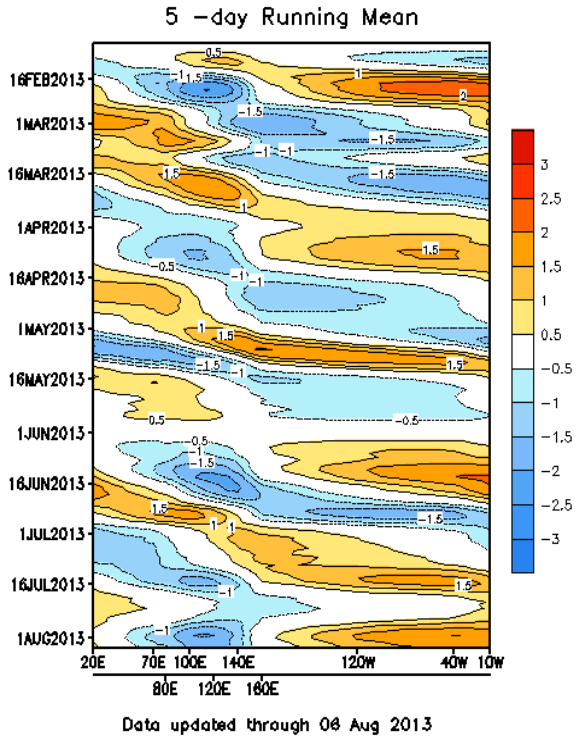
- **During the last three months, equatorial SSTs were near average in the central and western Pacific, and below average in the eastern Pacific.**

- **During the last three months, negative(positive) OLR anomalies persisted over Indonesia and Malaysia (north of the equator in the eastern Pacific).**

Equatorial Pacific SST (ºC), HC300 (ºC), u850 (m/s) and OLR(W/m²)Anomalies



CPC MJO Indices

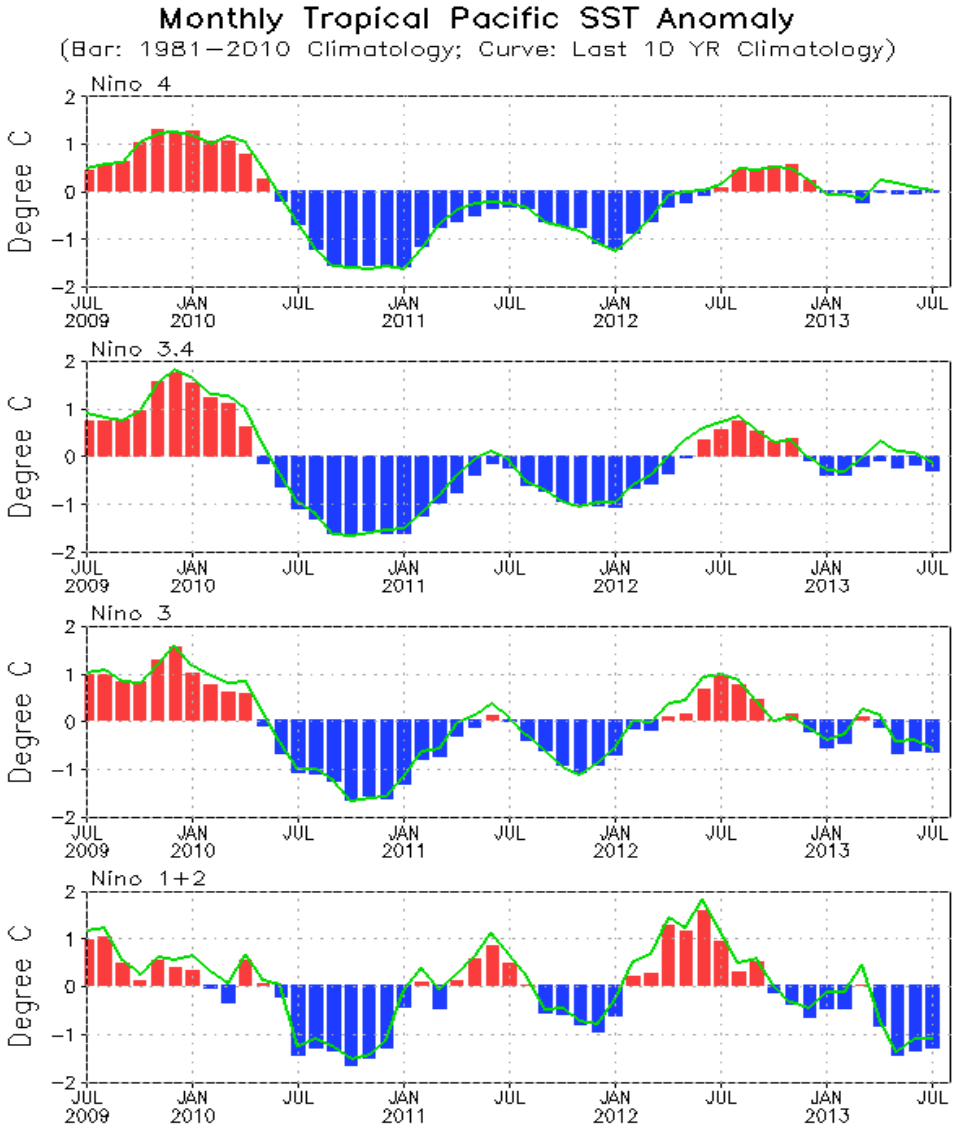


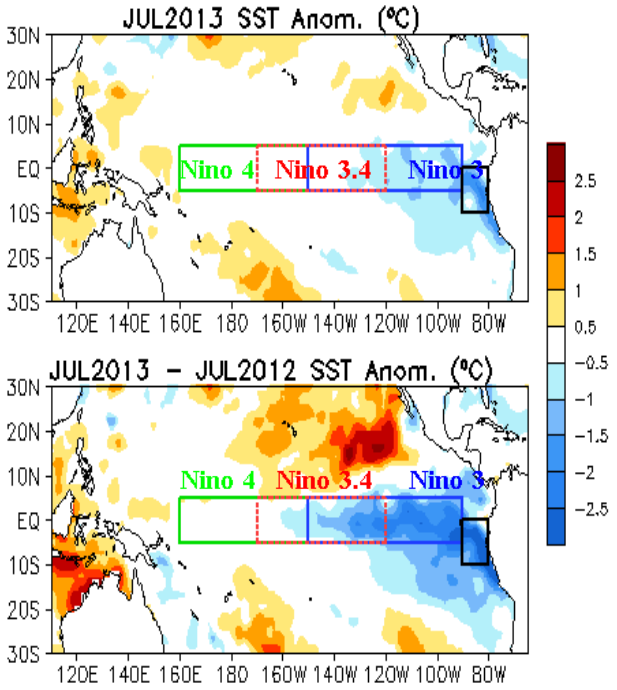
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/mjo_index.shtml

- **Below average SSTs were observed in the eastern Pacific since May 2013.**
- **Positive HC300 anomalies in the east-central Pacific continued in July 2013.**
- **Low-level zonal wind anomalies were near normal in July 2013.**

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 2ºS-2ºN and Outgoing Long-wave Radiation (OLR, right) averaged in 5ºS-5ºN. 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 1981-2010 base period pentad means respectively.

Evolution of Pacific NINO SST Indices





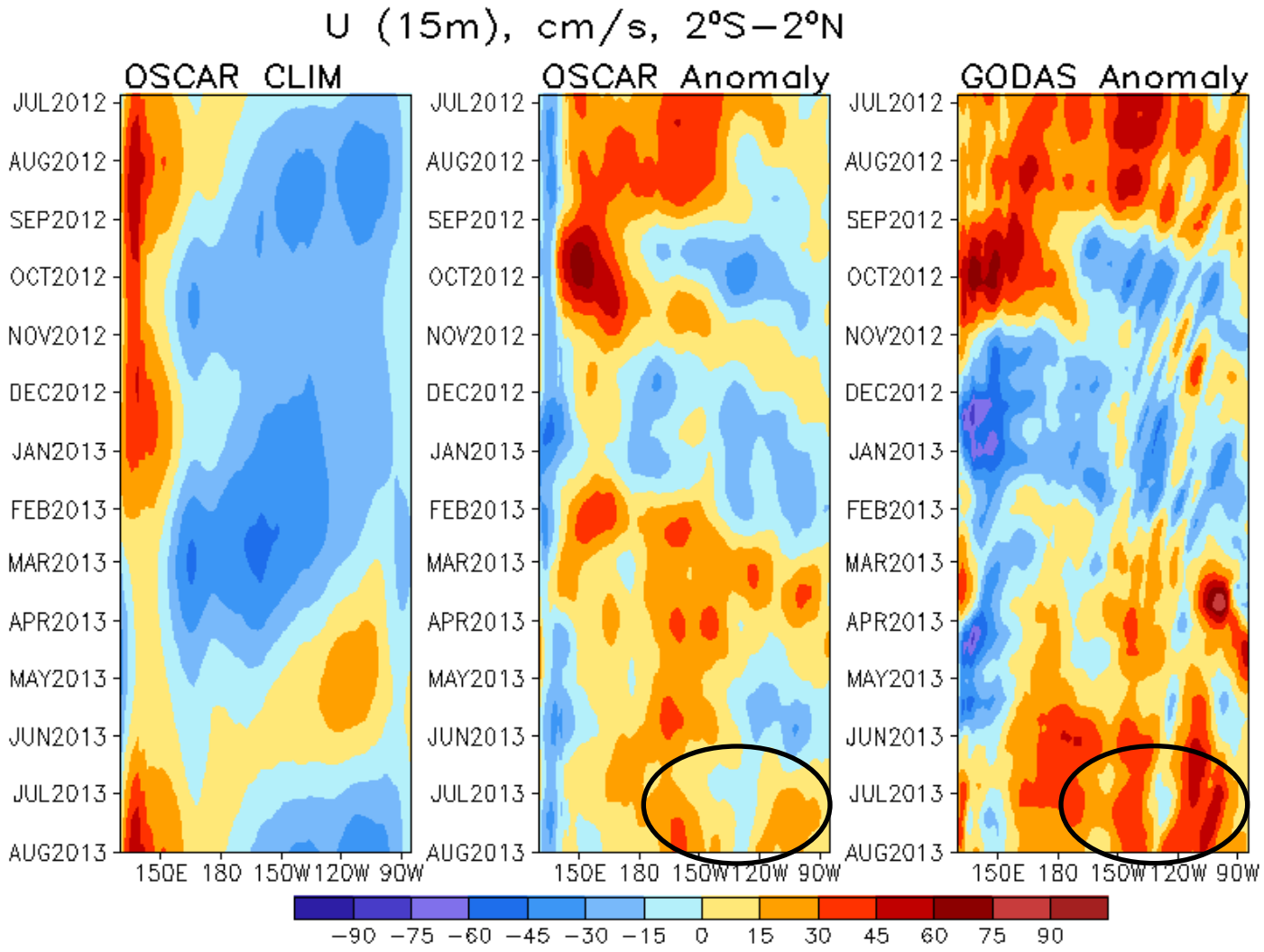
All Nino indices were below average with NINO 3.4 =-0.3 °C. .

ENSO-neutral conditions continued in July 2013.

The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.

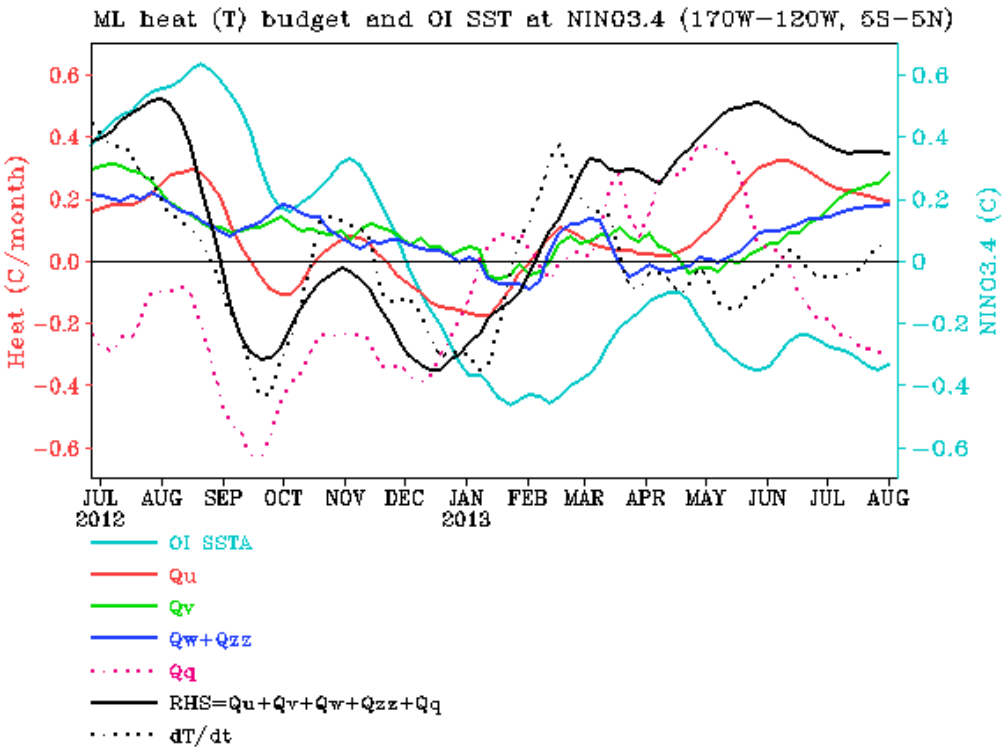
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 (bar) and last ten year (green line) means.

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



- **Positive zonal current anomalies dominated in the central-eastern Pacific in July 2013.**
- **Westerly zonal current anomalies from GODAS were stronger than those from OSCAR.**

NINO3.4 Heat Budget



- SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) was near zero in Jul 2013, indicating a persistence in NINO3.4.

- All the dynamical terms were positive, while the thermodynamical term (Qq) was negative.

-The RHS and dT/dt had large differences since March 2013. This indicates the heat budget analysis based on GODAS is limited during the period.

Huang, B., Y. Xue, X. Zhang, A. Kumar, and M. J. McPhaden, 2010 : The NCEP GODAS ocean analysis of the tropical Pacific mixed layer heat budget on seasonal to interannual time scales, J. Climate., 23, 4901-4925.

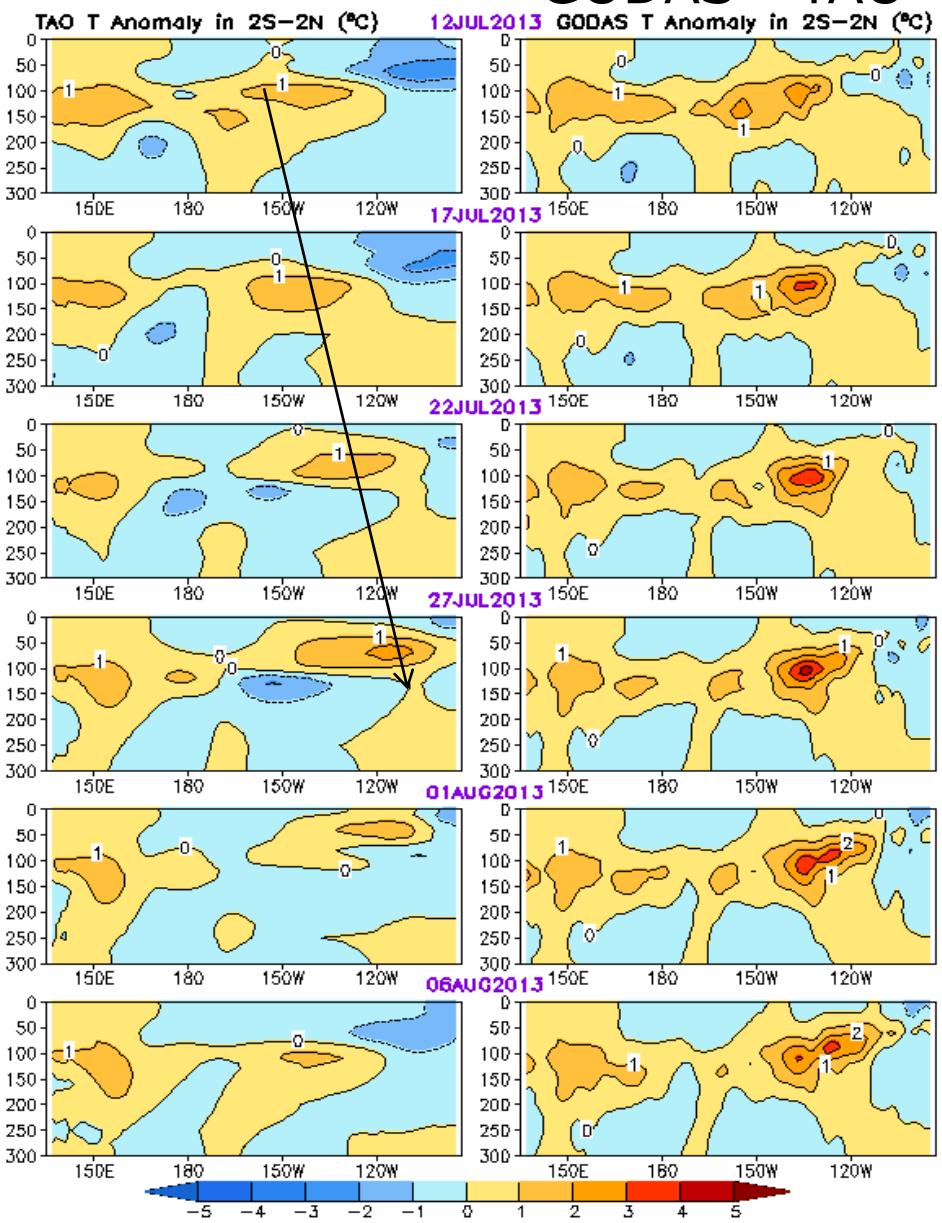
Qu: Zonal advection; Qv: Meridional advection;

Qw: Vertical entrainment; Qzz: Vertical diffusion

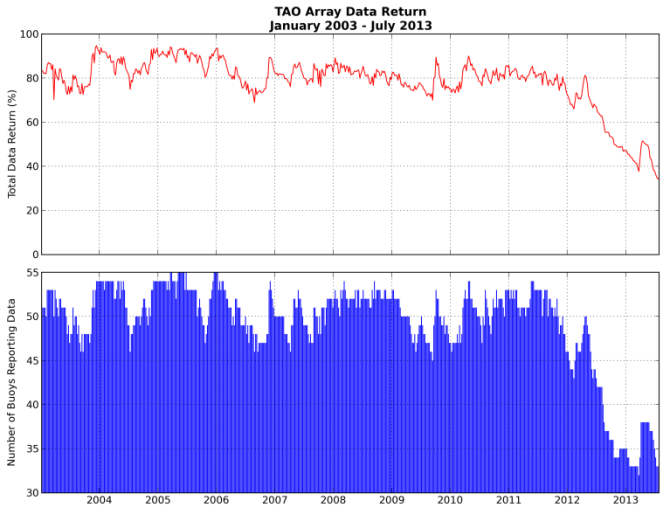
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

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

Equatorial Pacific Temperature Anomaly



- **The TAO data showed a warming in the far eastern Pacific in late July 2013, which seems be associated with an eastward propagation of the warm anomalies from the central Pacific.**
- **However, there were large uncertainties in subsurface temperature anomalies : discrepancies between GODAS and TAO temperature anomalies were as large as 2 degree in the past three pentads.**
- **The TAO/TRITON array has encountered significant outages since summer 2012, particularly in the eastern part of the array.**



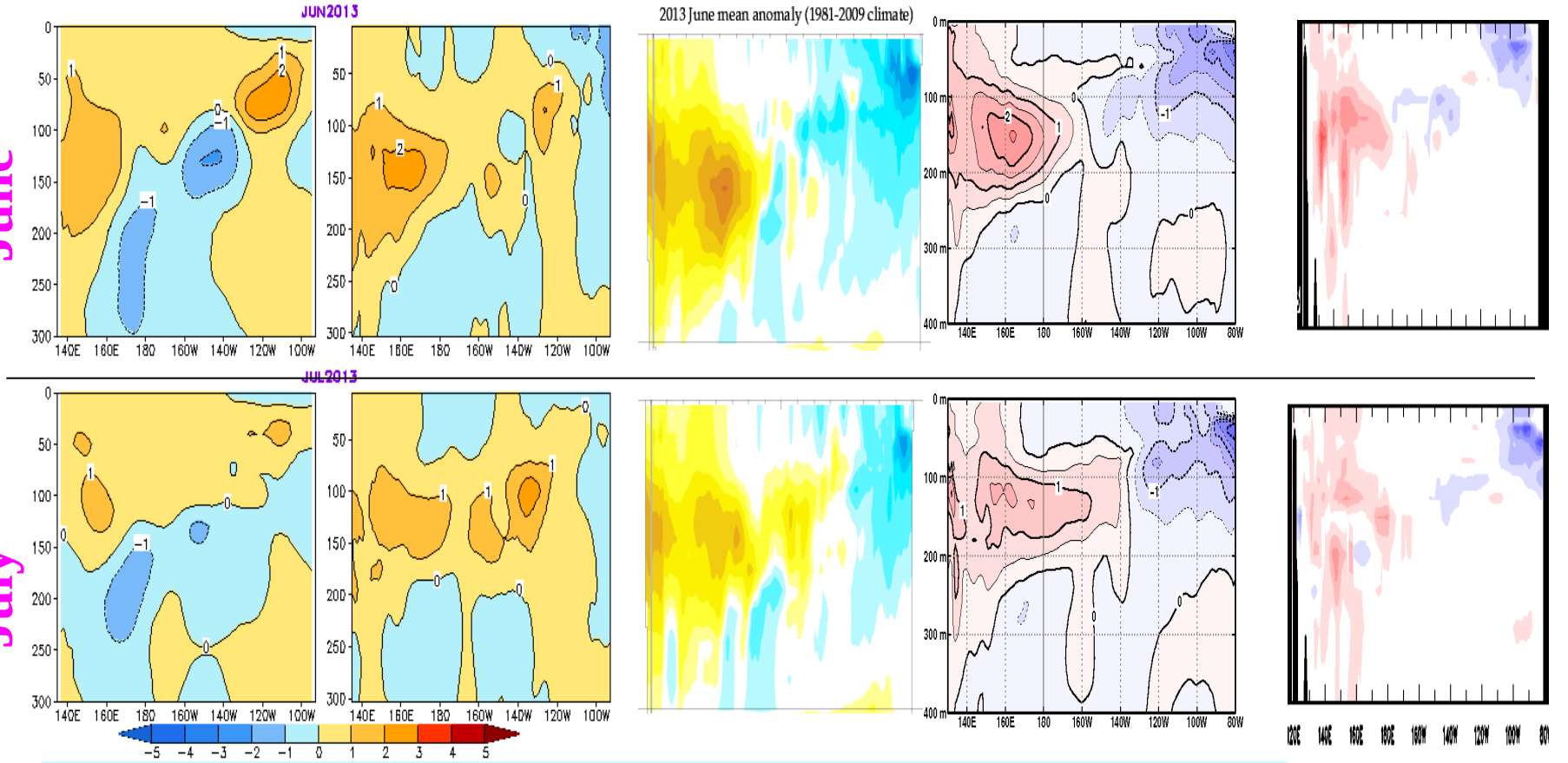
Source: Michael Mcphaden PMEL

Subsurface Temperature Anomalies along Equator

TAO GODAS ECMWF S4 JMA BOM

June

July

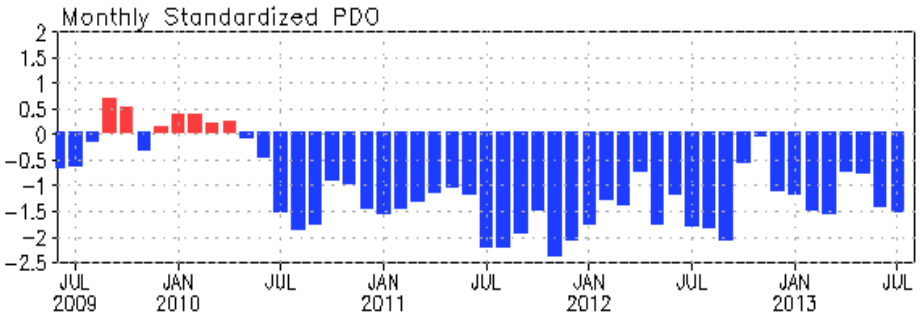


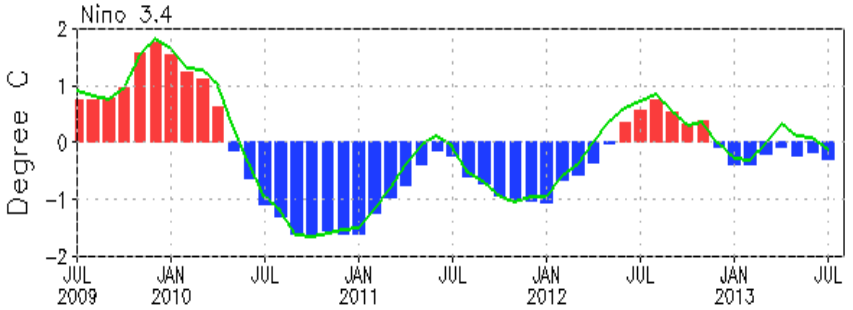
- **Subsurface temperature distribution in the last two months exhibited large uncertainty among ocean reanalysis products**

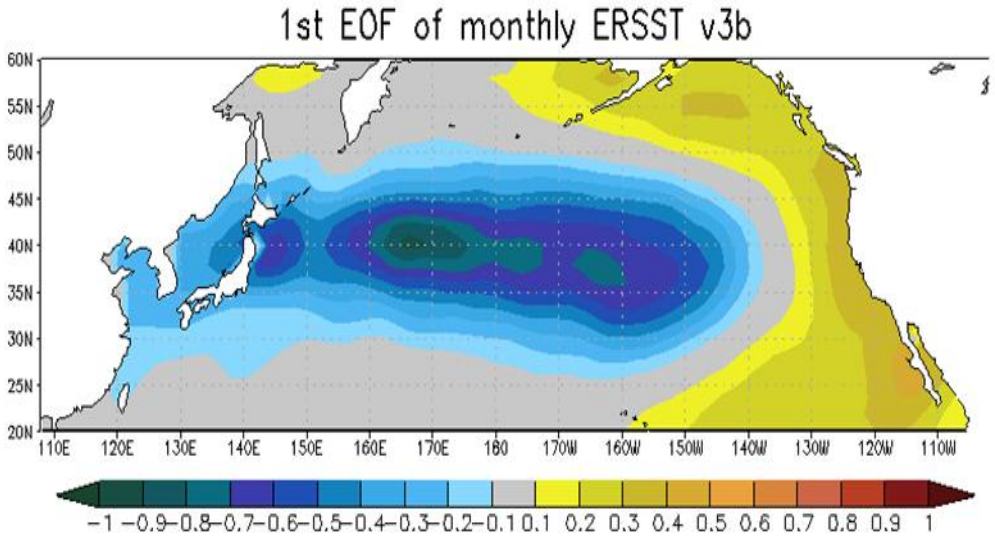
ECMWF S4: http://www.ecmwf.int/products/forecasts/d/charts/oras4/reanalysis/sections/xzmaps/1m!1m!201306!Anomaly!Temperature!/
JMA :http://ds.data.jma.go.jp/tcc/tcc/products/elnino/outlook.html
BOM:http://www.bom.gov.au/climate/enso/

North Pacific & Arctic Oceans

Pacific Decadal Oscillation Index







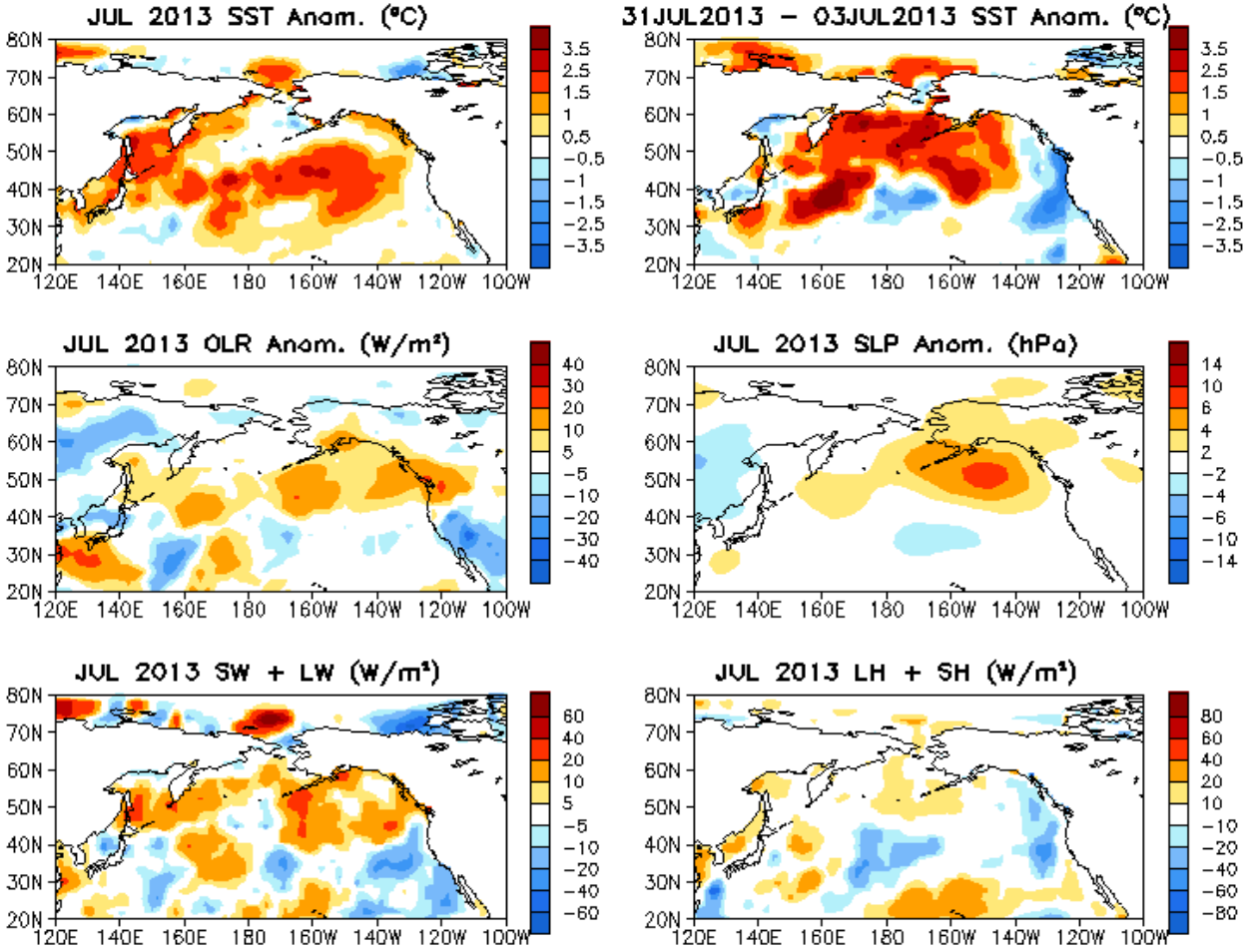
-Negative PDO phase since May 2010 has persisted for more than 3 years (39 months) now, and the PDO index slightly strengthened in July 2013 with PDO index = -1.5.

- The apparent connection between NINO3.4 and PDO index suggest connections between tropics and extratropics.

- 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.

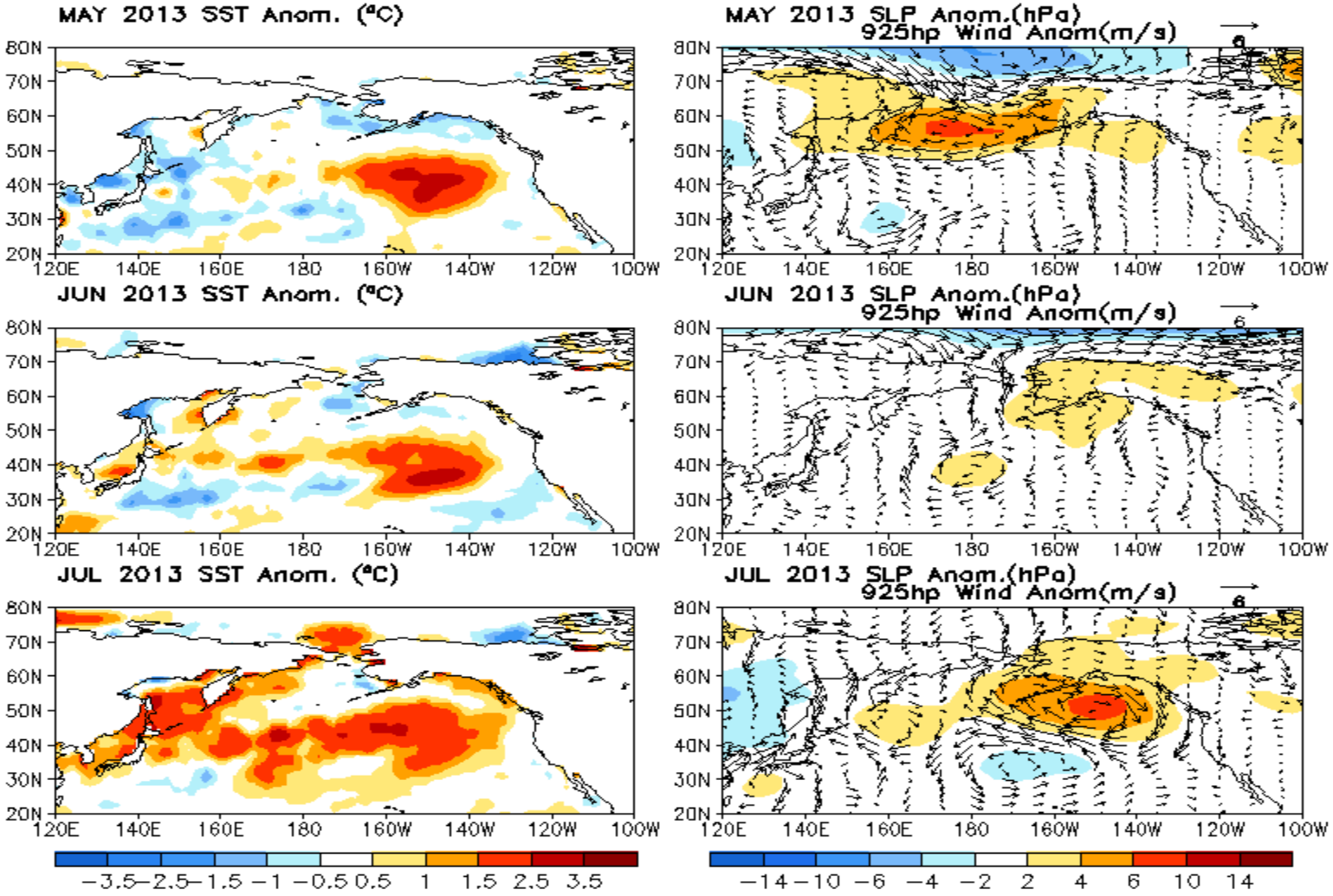
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tendency, OLR, SLP, Sfc Rad, Sfc Flx



- **Large positive SSTA were observed in the North Pacific and Artic Oceans.**
- **Large positive SW+LW anomalies were observed in the Artic Ocean and the high latitudes of North Pacific, leading to significant warming in these regions.**

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 1981-2010 base period means.

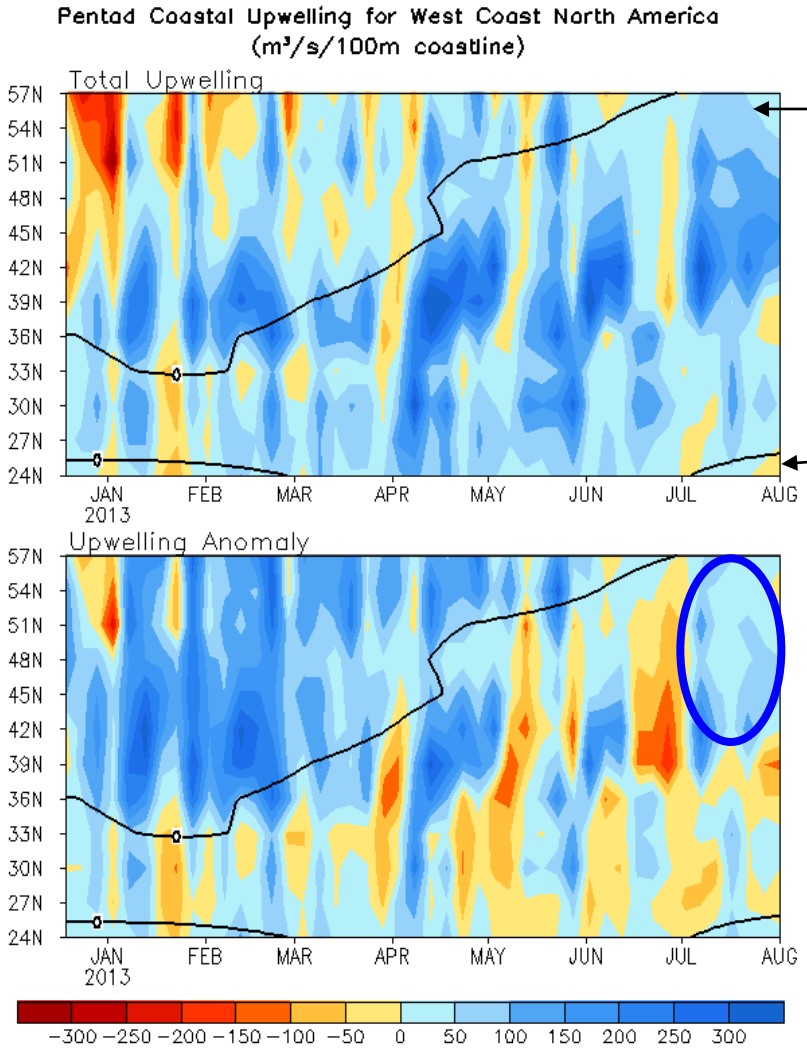
Last Three Month SST, SLP and 925hp Wind Anom.

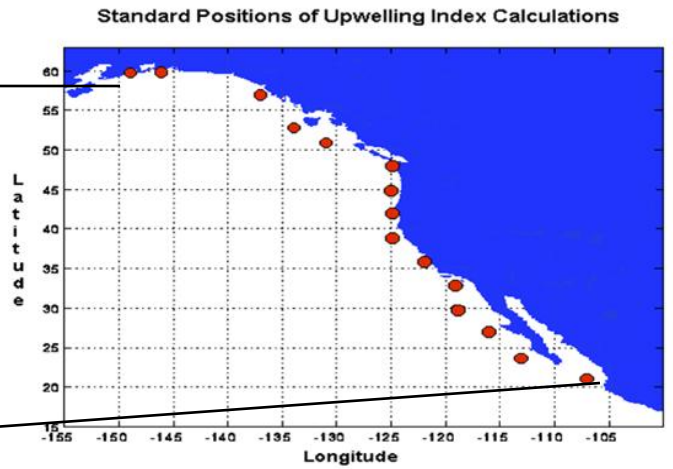


-**Strong positive temperature anomalies presented in the far western Pacific, leading to strengthening of negative PDO-like pattern.**

- **Anomalous anticyclone was observed near the coast of Alaska .**

North America Western Coastal Upwelling





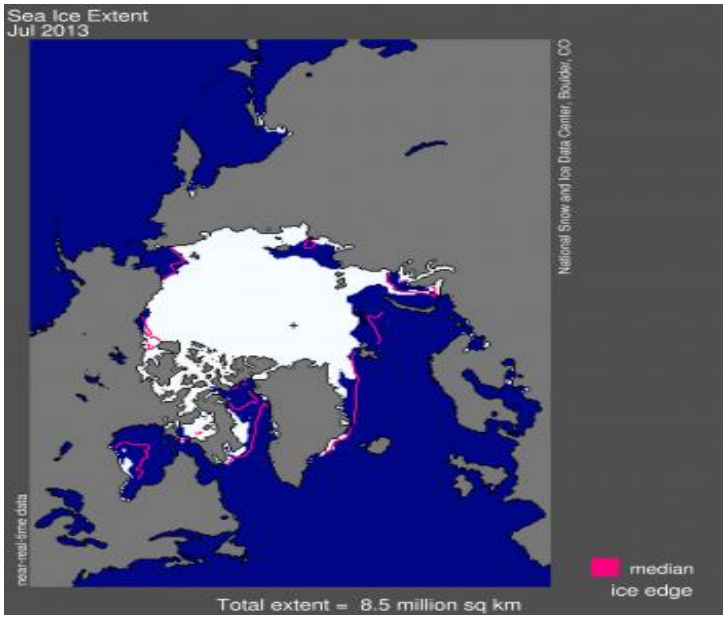
- Upwelling north of 36N enhanced in Jul 2013, consistent with anomalous northerly winds.

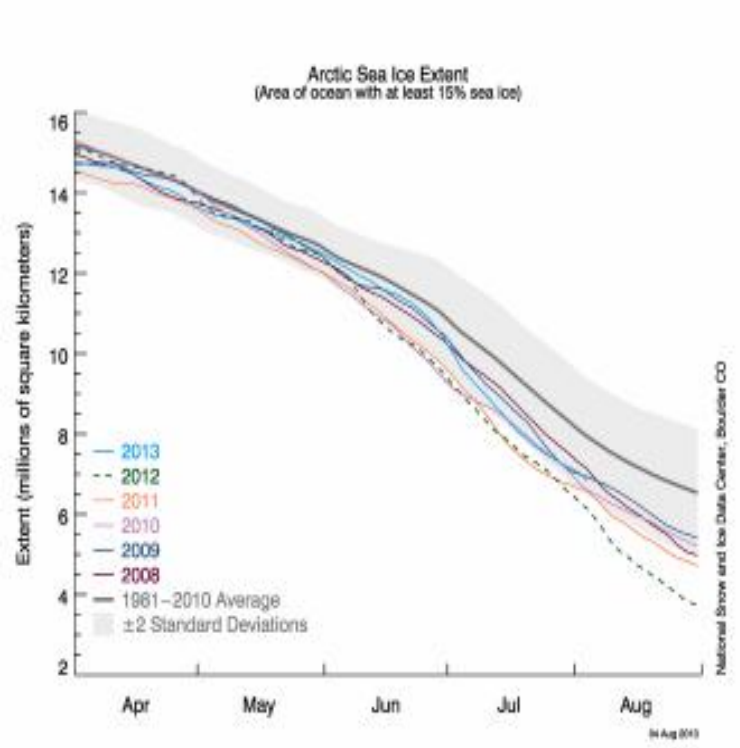
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1981-2010 base period pentad means.

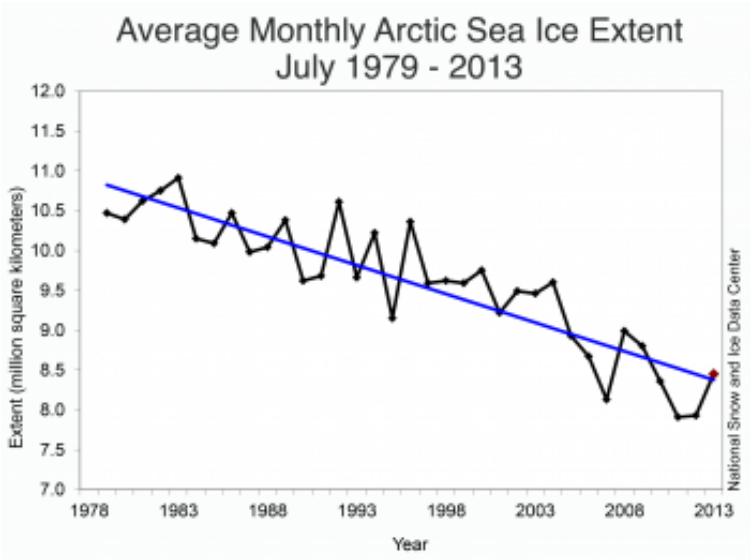
- **Area below (above) black line indicates climatological upwelling (downwelling) season.**
- **Climatologically upwelling season progresses from March to July along the west coast of North America from 36°N to 57°N.**

Arctic Sea Ice

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



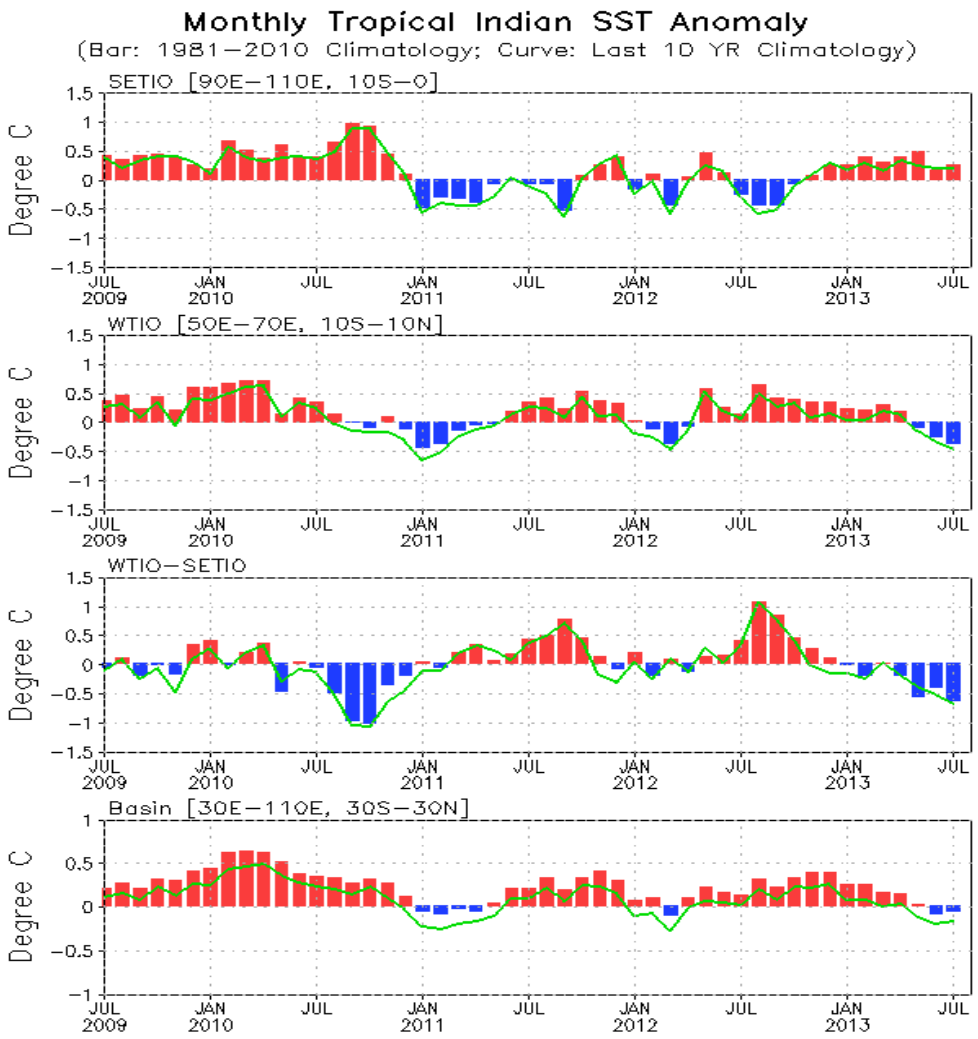


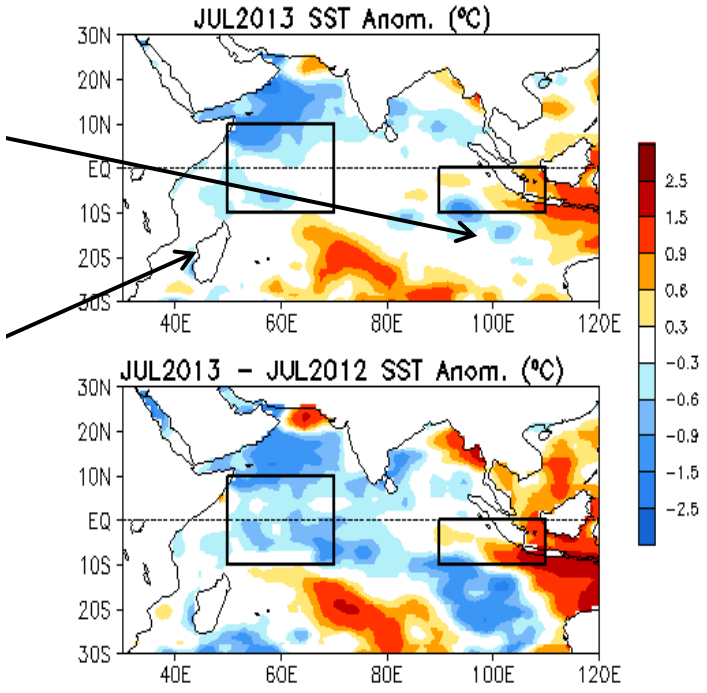


- **Ice extent remained below average on the Atlantic side of the Artic ocean in July 2013.**
- **July 2013 was the fifth lowest July during the 1979-2013 satellite record.**

Indian Ocean

Evolution of Indian Ocean SST Indices

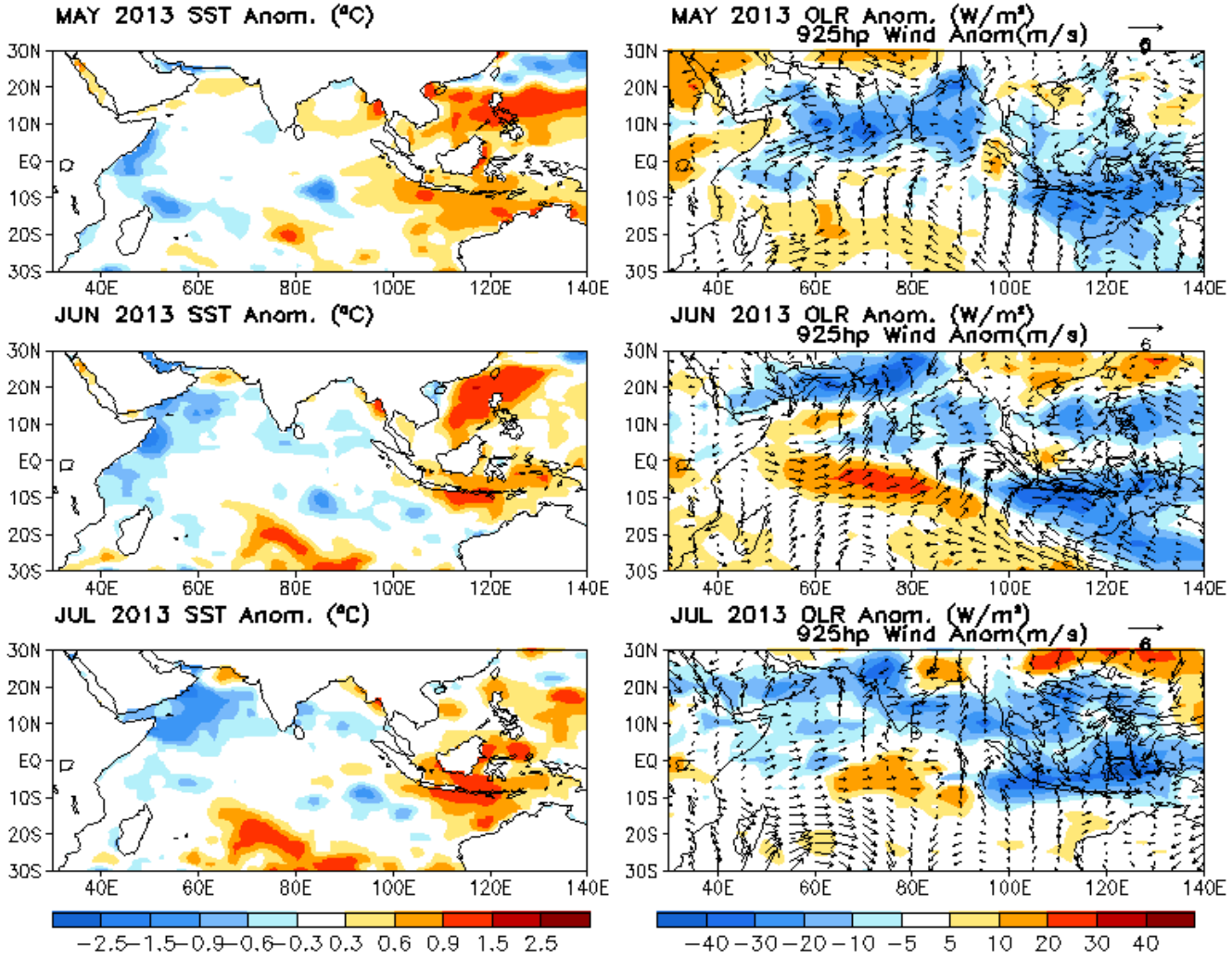




- **Negative DMI continued in July 2013.**
- **The basin mean SST was below-normal in July 2013.**

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 departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

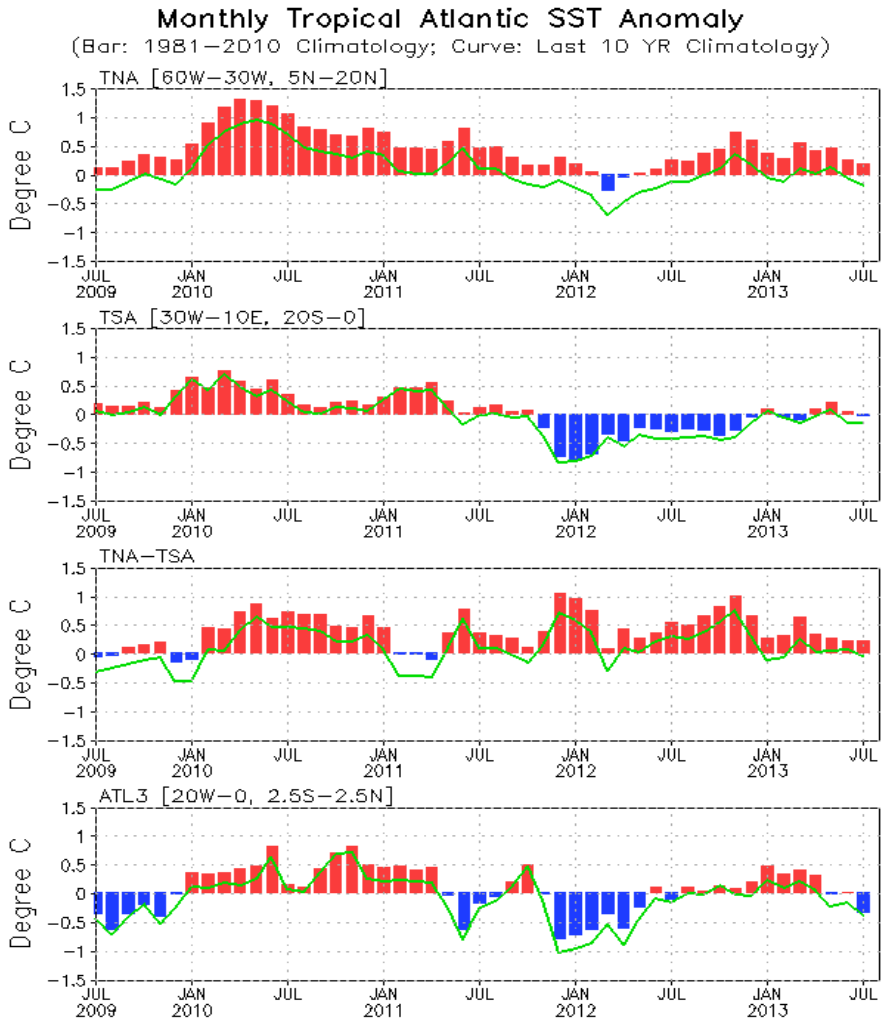
Last Three Month SST, SLP and 925hp Wind Anom.

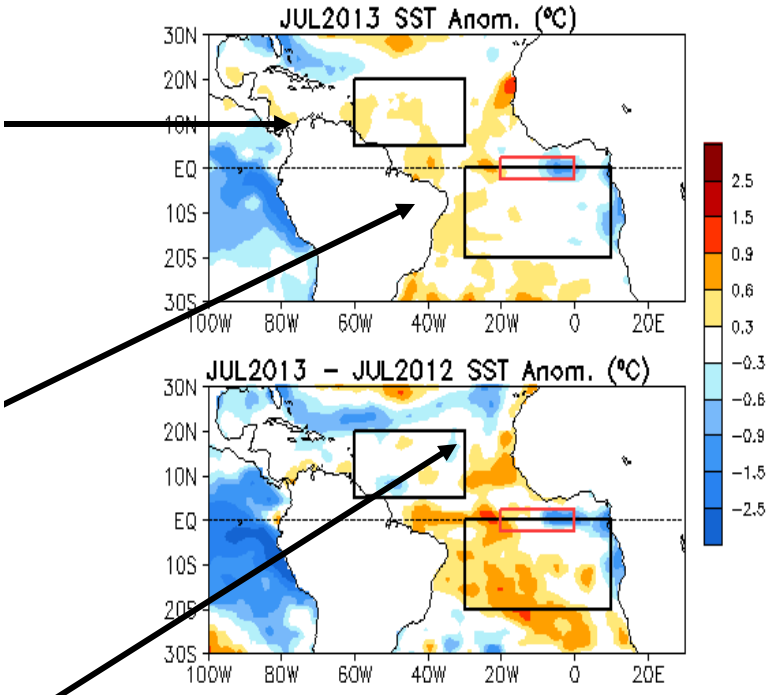


- **Negative SSTA strengthened in Arabian Sea in July 2013.**
- **Negative OLR anomalies (enhanced convection) continued over the tropical North Indian Ocean.**

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices



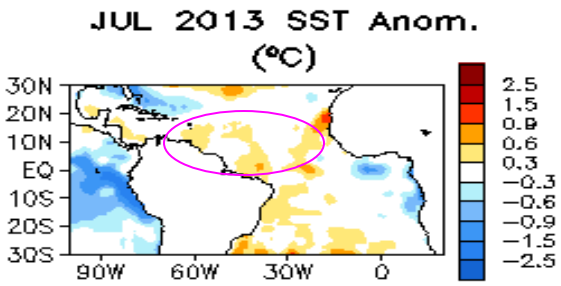


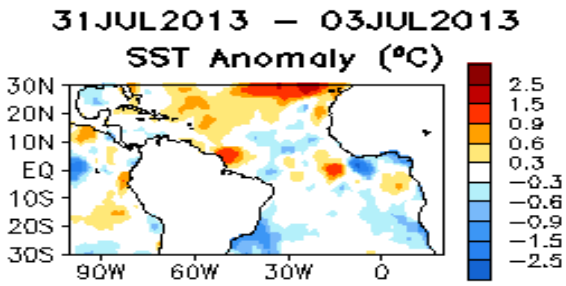
- **Positive TNA weakened in July 2013.**
- **Meridional Gradient Mode index (TNA-TSA) was above-normal since May 2011.**
- **ATL3 SST was below average in July 2013.**

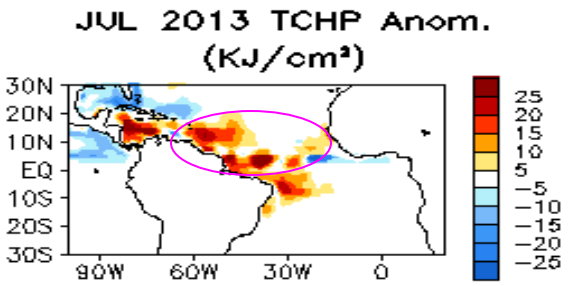
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the NCEP OI SST analysis, and departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

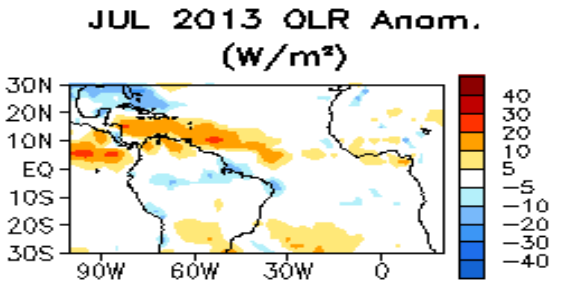
Tropical Atlantic:

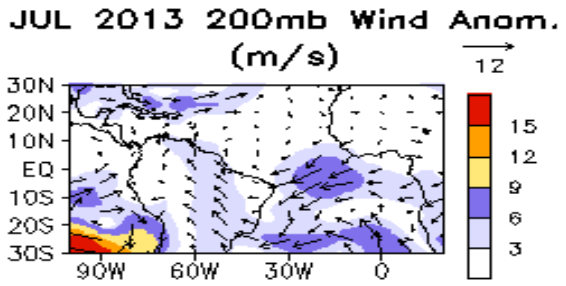
SST Anom., SST Anom. Tend., TCHP OLR, Sfc Flx, 925-mb/200-mb Winds and RH

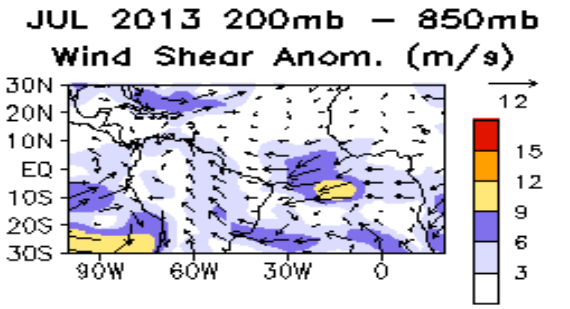


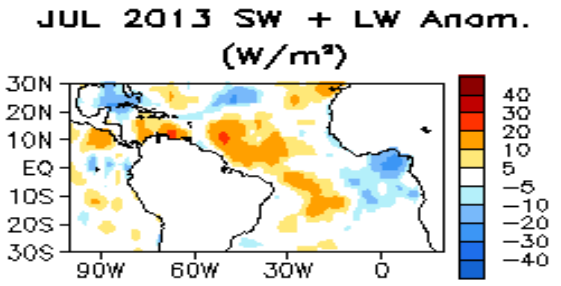


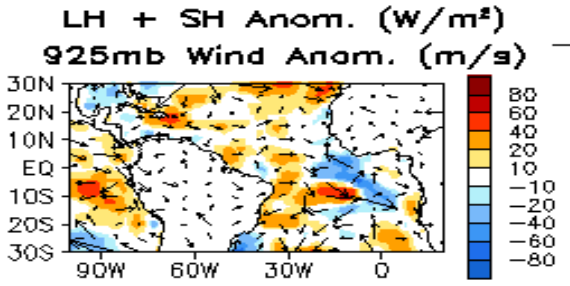


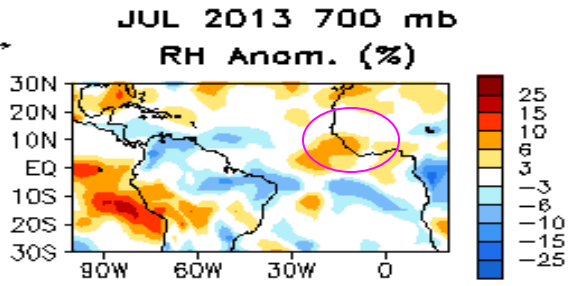












- **Above-normal SSTA and TCHP continued in the hurricane Main Development Region (MDR) .**
- **Below-normal vertical wind shear was observed in MDR.**
- **Positive RH anomalies were observed over the eastern tropical Atlantic.**

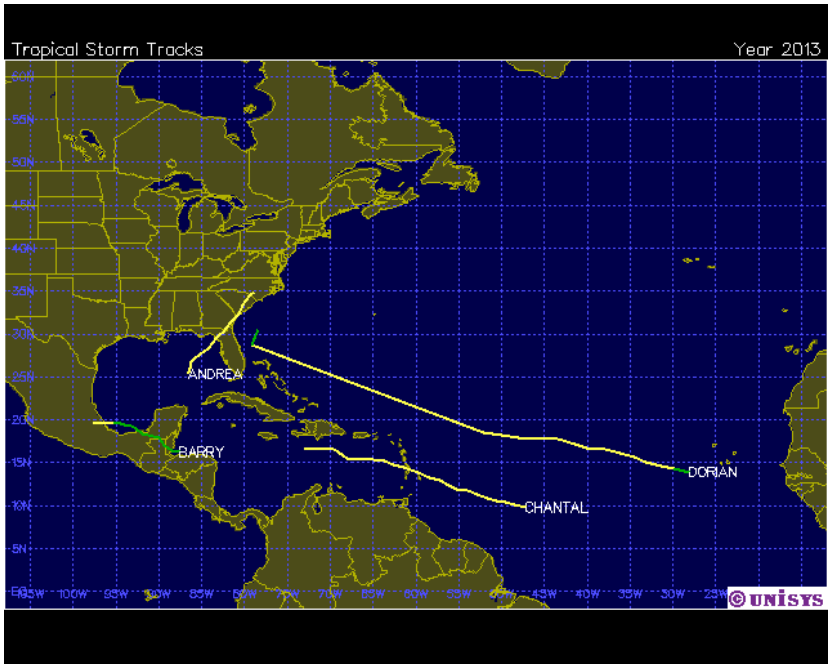
NOAA Predict an Above-Normal Atlantic Hurricane Season in 2013

(http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.shtml
http://weather.unisys.com/hurricane/atlantic/2013/index.html)

NOAA 2013 Atlantic Hurricane Season Outlooks

Activity Type	August Update	May 23 Outlook	NHC 1981-2010 Normals
Chance Above Normal	70%	70%	
Chance Near Normal	25%	25%	
Chance Below Normal	5%	5%	
Named Storms*	13-19	13-20	12
Hurricanes*	6-9	7-11	6
Major Hurricanes	3-5	3-6	3
ACE (% Median)	120-190	120-205	71-120**

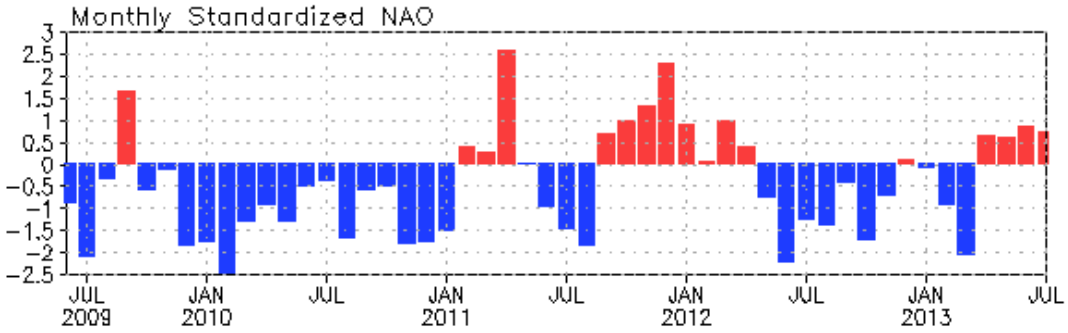
The outlooks indicate a 70% probability for each range of activity.
* Includes all such storms regardless of strength
**A near-normal season has ACE values of 71%-120% of the median.

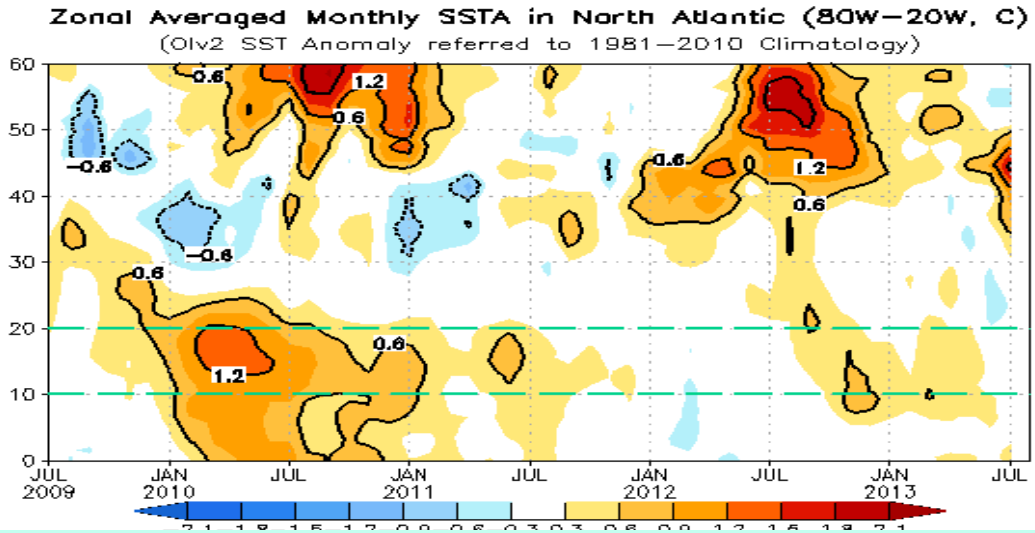


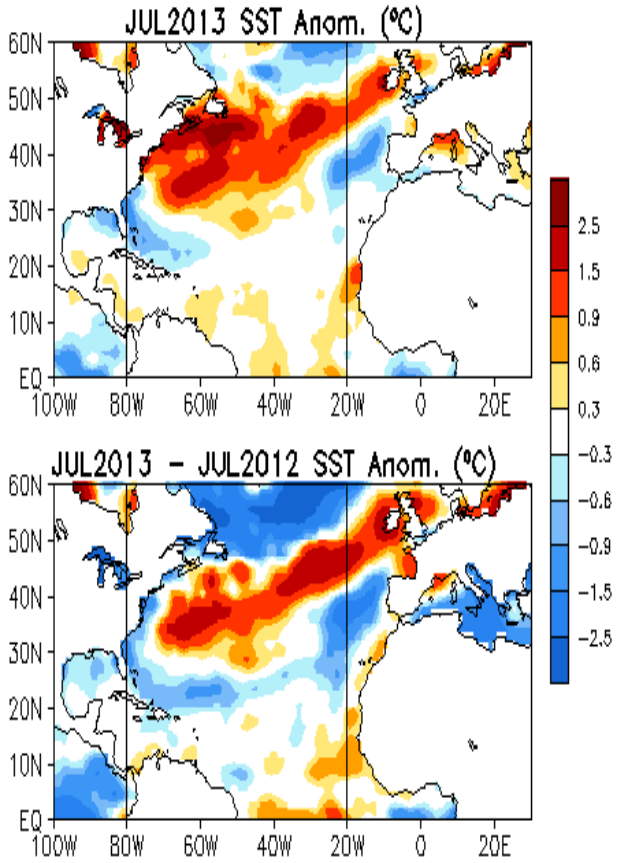
- NOAA's updated Atlantic hurricane outlook continued to call for an above-normal season, while the predicted ranges of activity are slightly lower and narrower than the May outlook.

-Four tropical storms were formed in North Atlantic by August 8.

NAO and SST Anomaly in North Atlantic







- **High-latitude North Atlantic SSTA is generally closely related to NAO index (negative NAO leads to SST warming and positive NAO leads to SST cooling).**

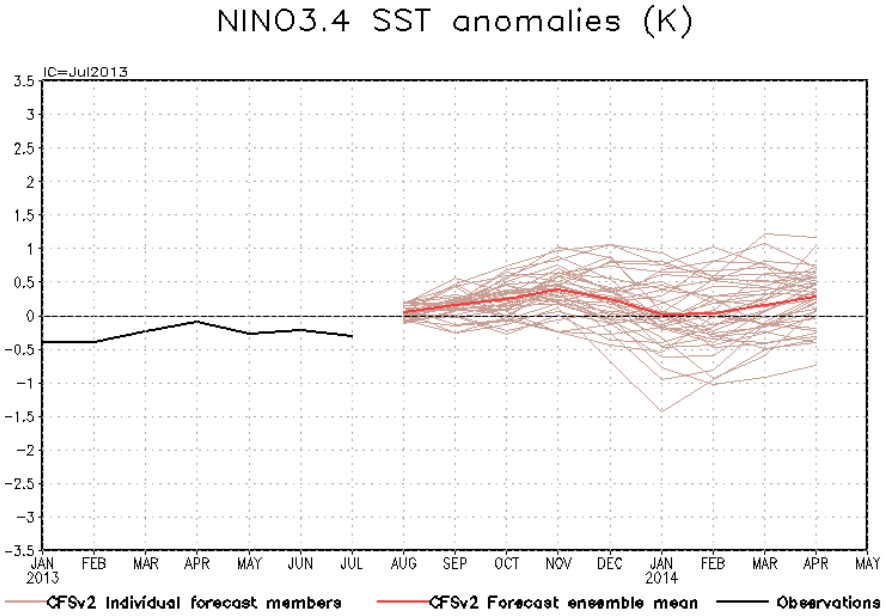
- **NAO continued to be positive in July 2013.**

-**In the past three hurricane seasons, positive SSTA in MDR was strong in 2010, and became weakening in subsequent two years.**

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 1981-2010 base period means.

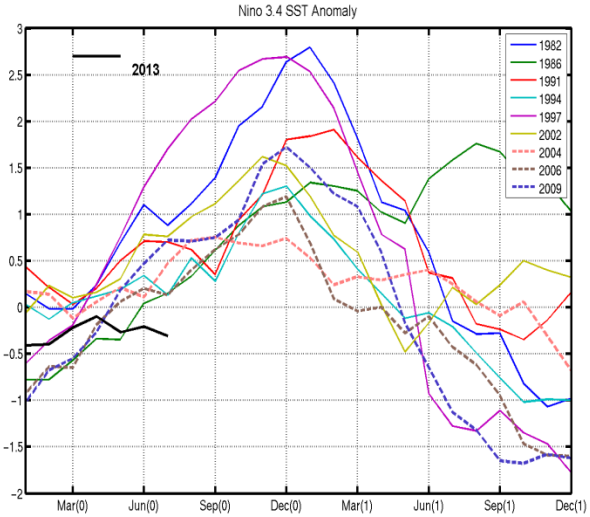
Global SST Predictions

NCEP CFSv2 NINO3.4 Forecast

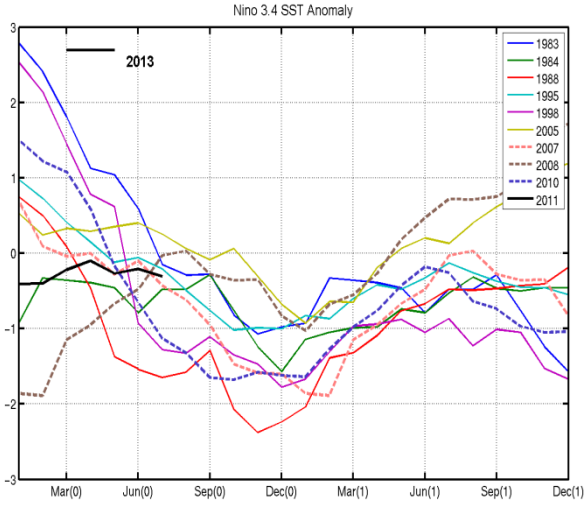


- **Latest NCEP CFSV2 continued to forecast ENSO-neutral condition into the spring 2014.**
- **Historical record (1980-2012) shows similar condition in July either continued ENSO neutral condition or developed La Nina event in the following winter.**

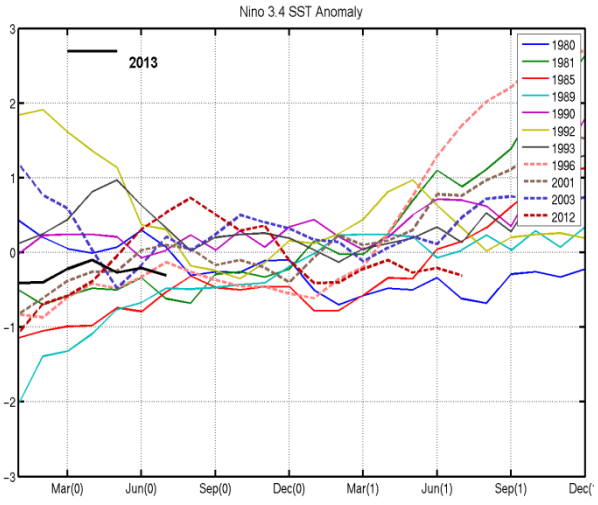
Nino3.4 El Nino Composite



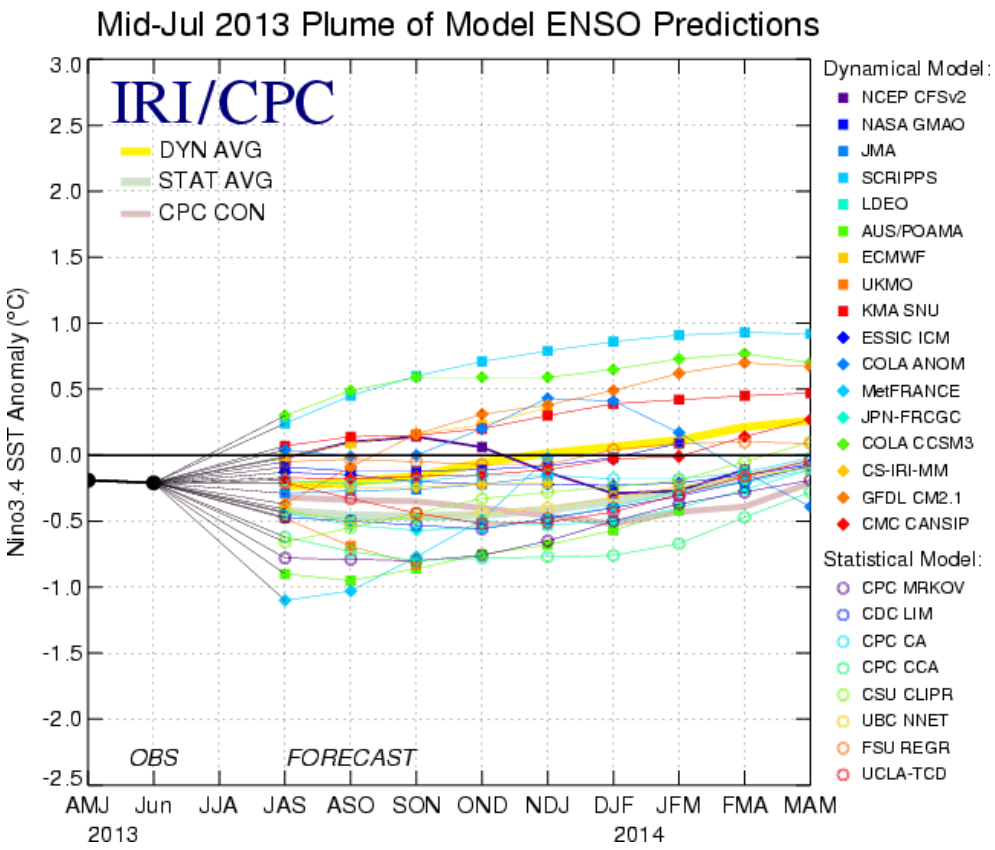
Nino3.4 La Nina Composite

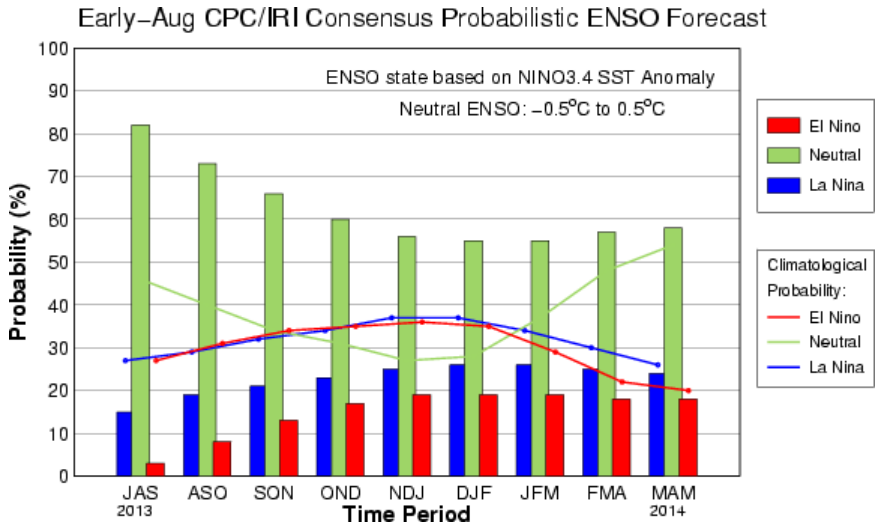


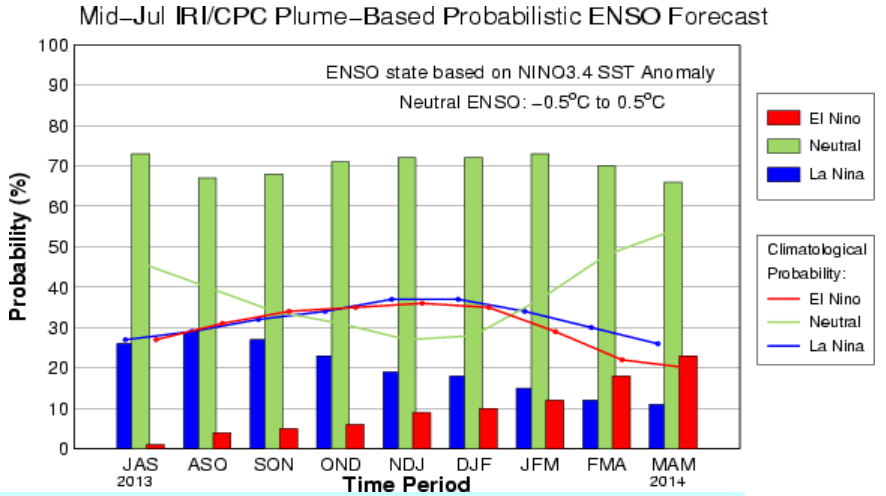
Nino 3.4 Neutral Composite



IRI/CPC NINO3.4 Forecast Plume

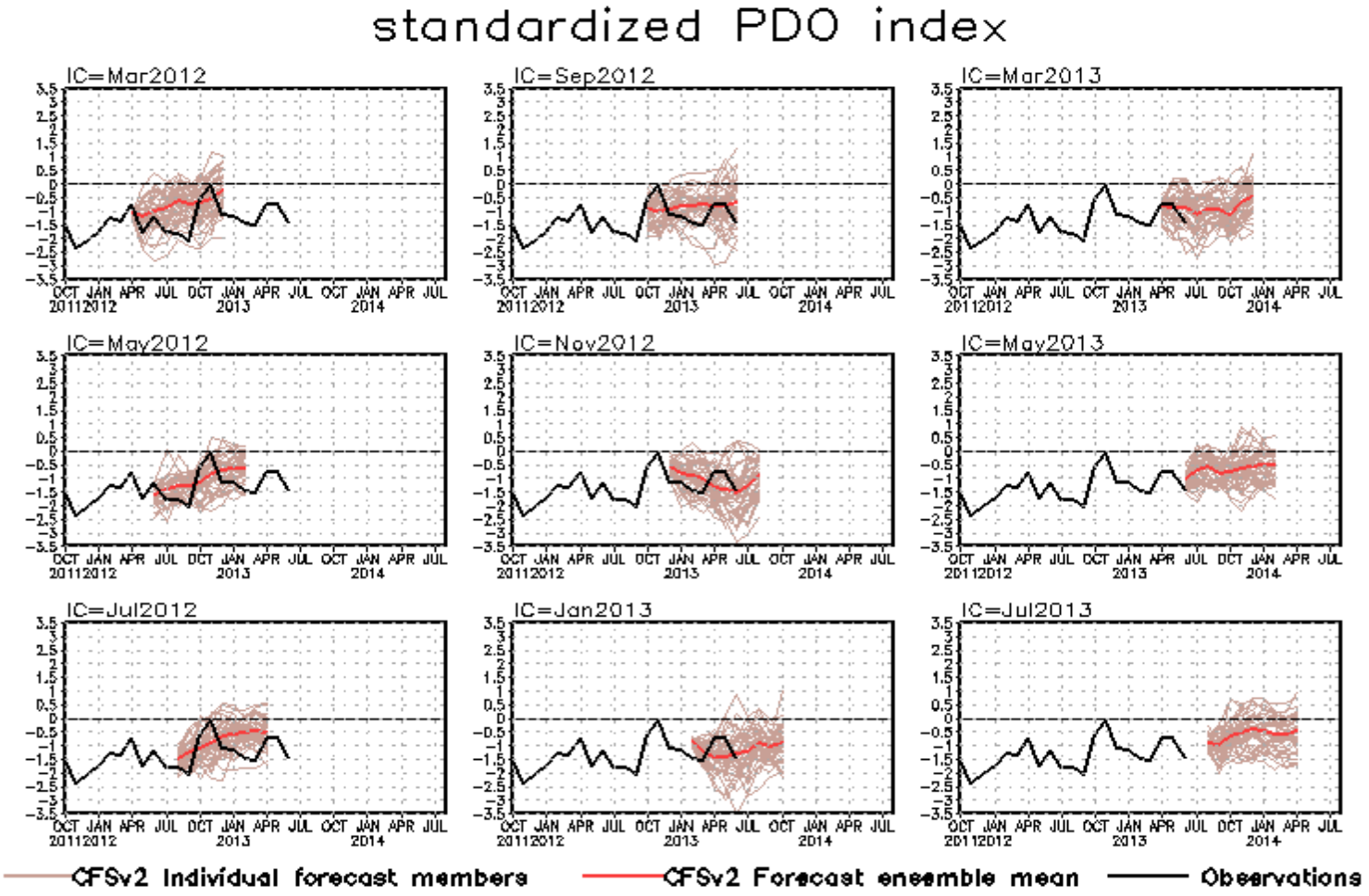






- **Most of the models predicted ENSO-neutral to continue into the Northern Hemisphere spring 2014.**
- **The consensus forecast favors ENSO-neutral conditions in the winter and next spring.**

NCEP CFSv2 Pacific Decadal Oscillation (PDO) Forecast

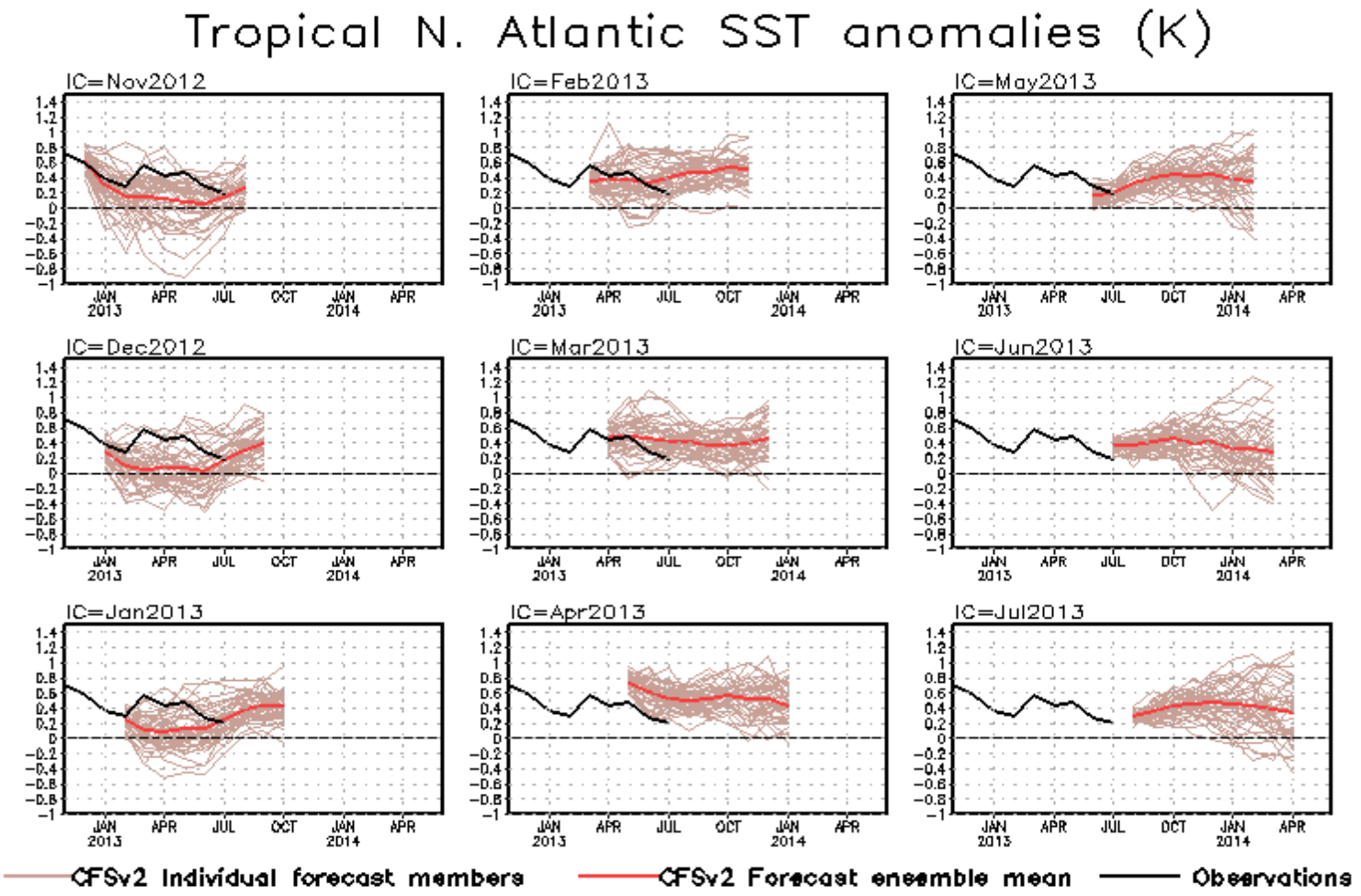


PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

- Latest CFSv2 prediction suggests negative PDO phase will likely continue into the northern hemisphere spring 2014.

NCEP CFSv2 Tropical North Atlantic SST Forecast



- **Latest CFSv2 prediction suggests that above-normal SST in the tropical N. Atlantic will continue into the northern hemisphere spring 2014.**

Overview

- **Pacific and Arctic Oceans**
  - **ENSO-neutral conditions continued during July 2013.**
  - **The consensus forecast favors ENSO-neutral conditions to continue into the Northern Hemisphere Spring 2014.**
  - **Negative PDO phase strengthened with PDO=-1.5 in July 2013, and NCEP CFSv2 predicted negative PDO phase would continue into next spring.**
  - **Strong positive SSTA dominated the high latitudes of the North Pacific and Arctic Oceans in July 2013**

- **Indian Ocean**
  - **SSTs were above-normal in the east and slightly below-normal in the west, and negative Indian Ocean Dipole index continued in July 2013.**

- **Atlantic Ocean**
  - **Above-normal SST continued in the hurricane main development region.**
  - **NOAA's updated hurricane outlook continued to predict above-normal condition of hurricane activity in 2013.**
  - **Positive NAO index persisted in the past four months.**

Backup Slides

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

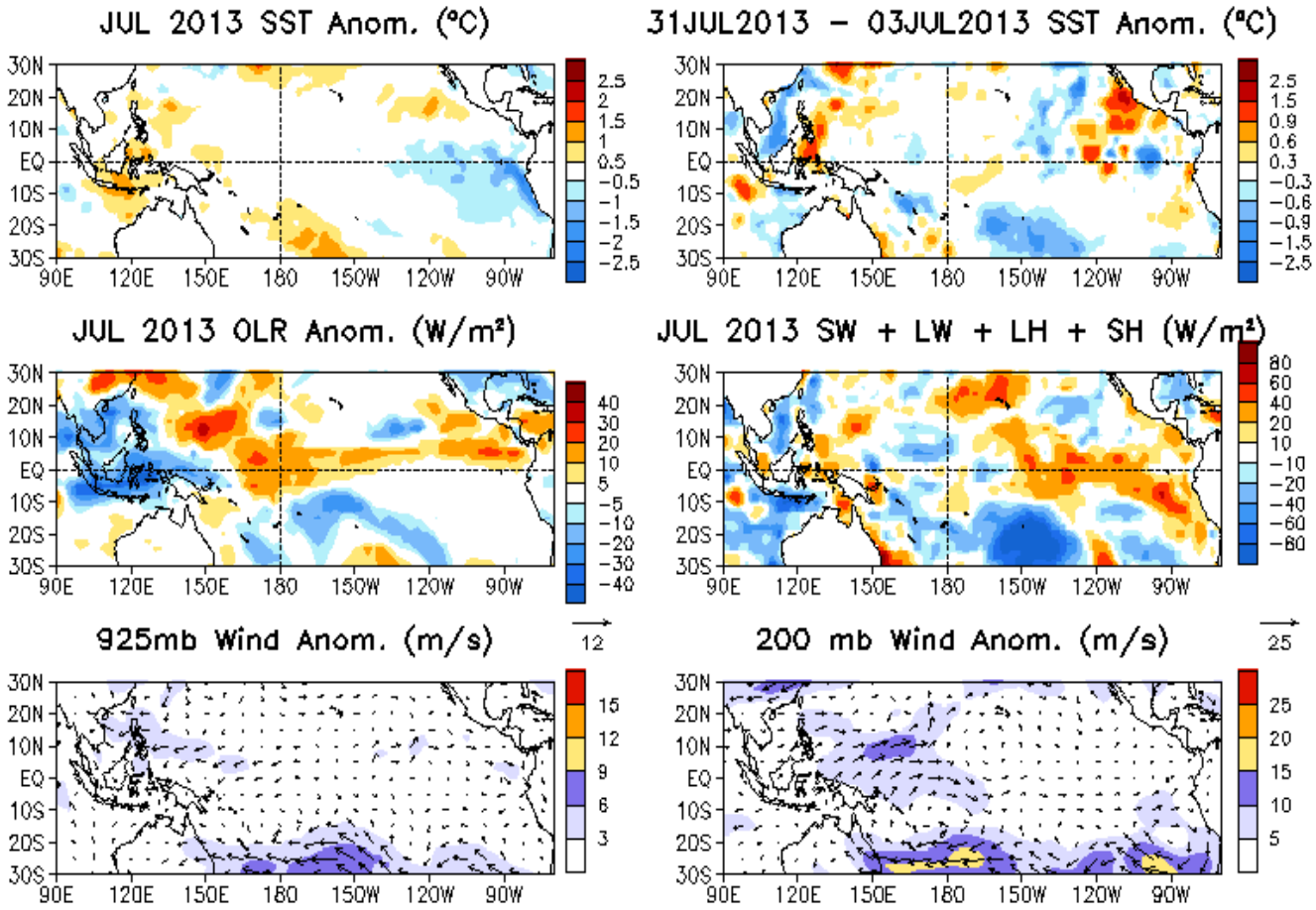


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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 1981-2010 base period means.

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

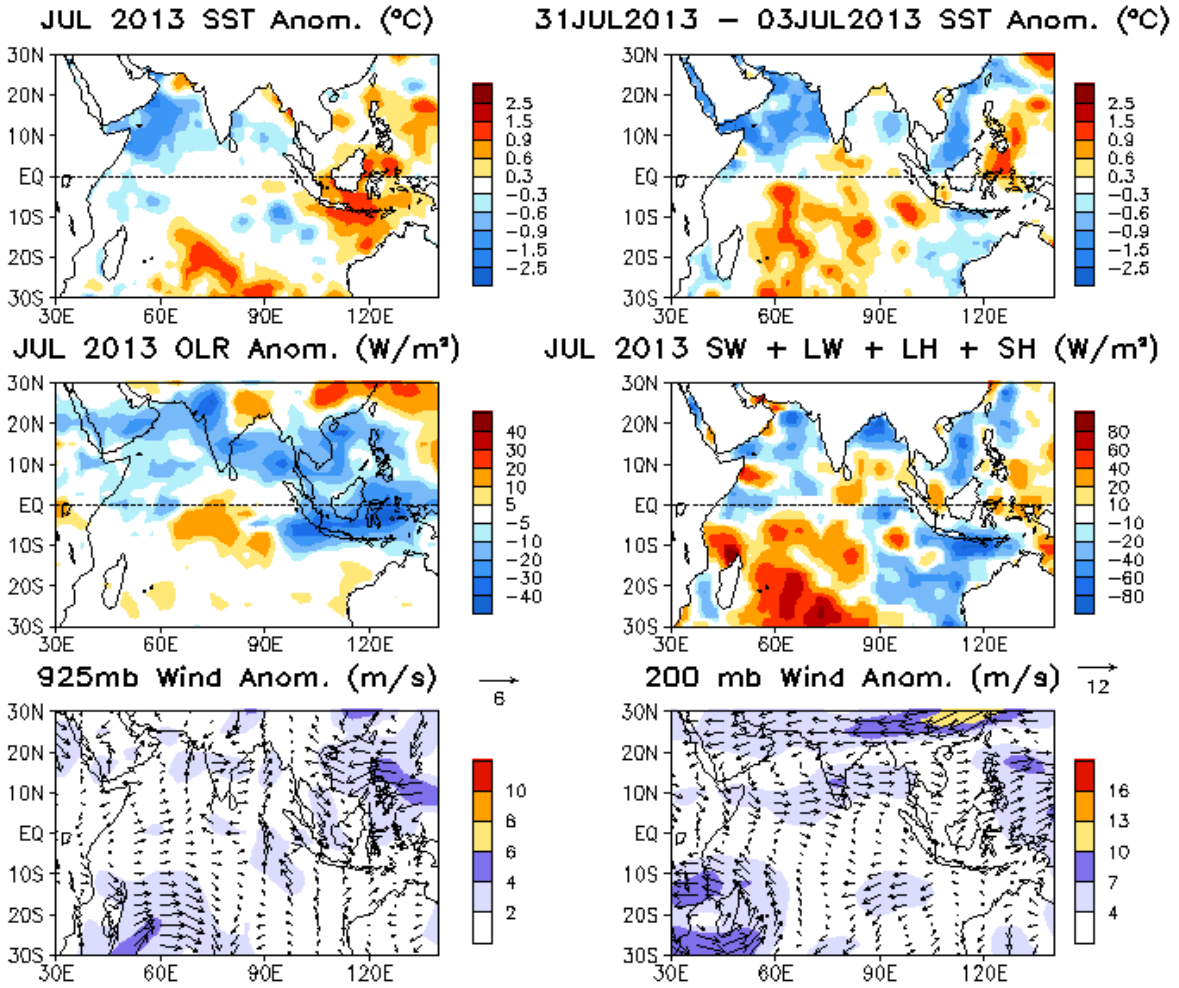


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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 1981-2010 base period means.

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

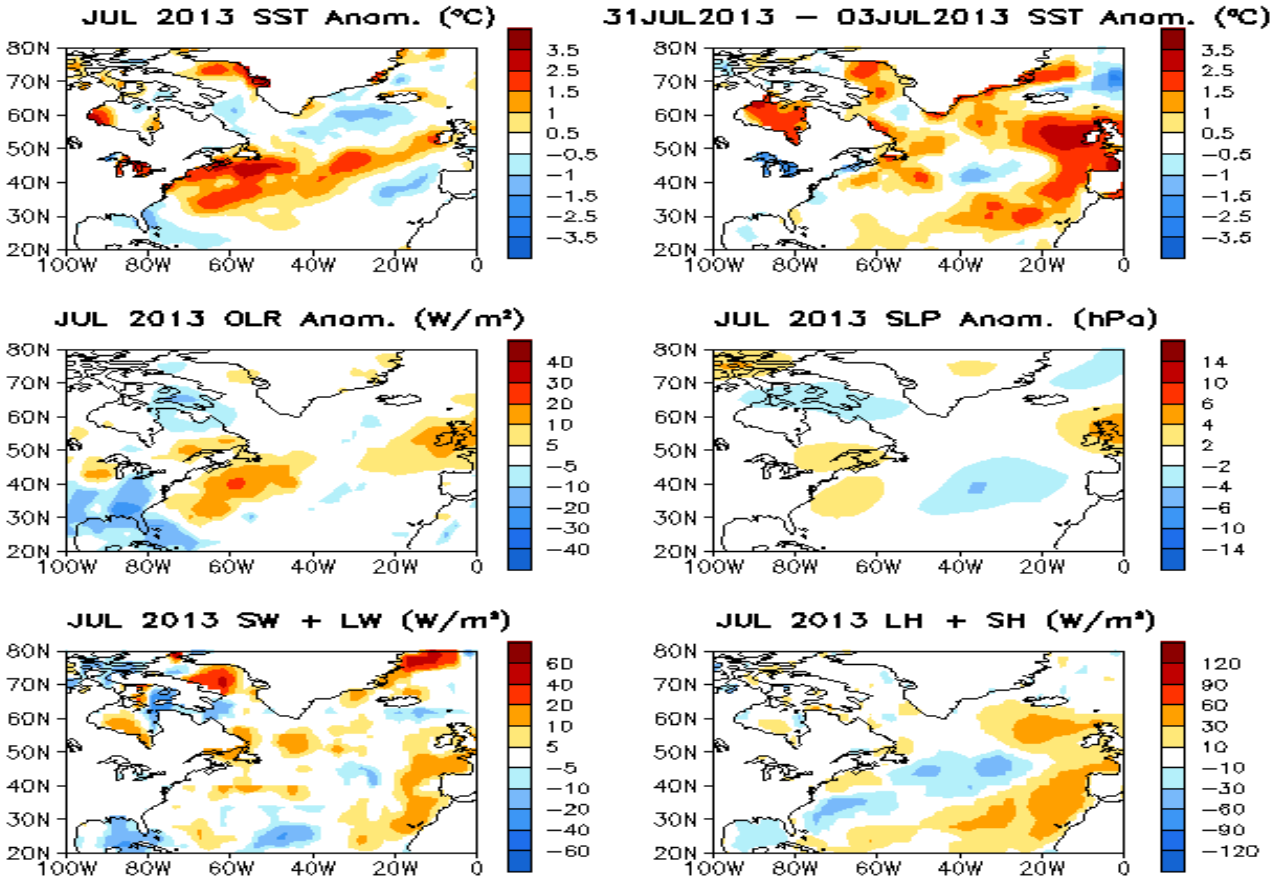
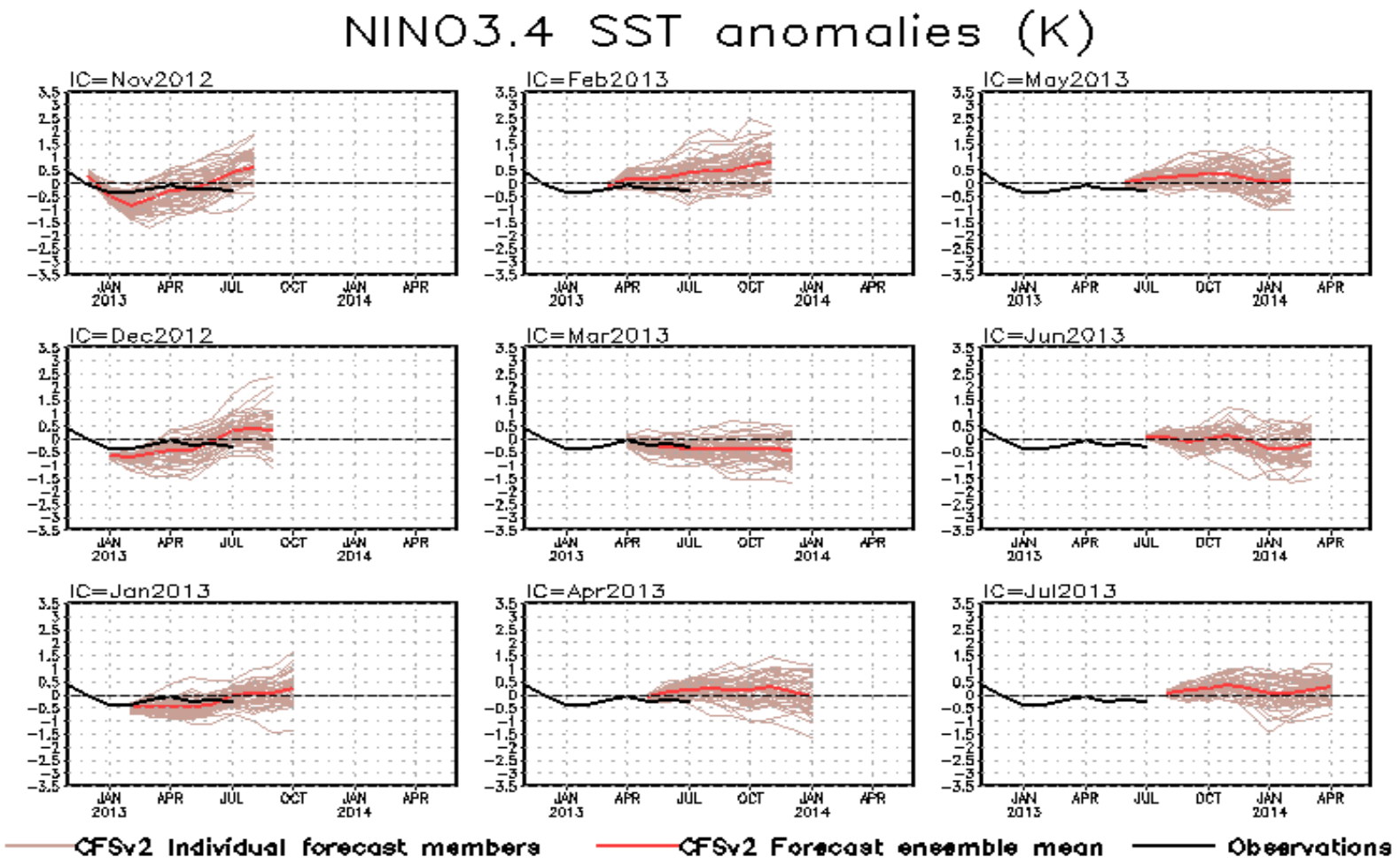


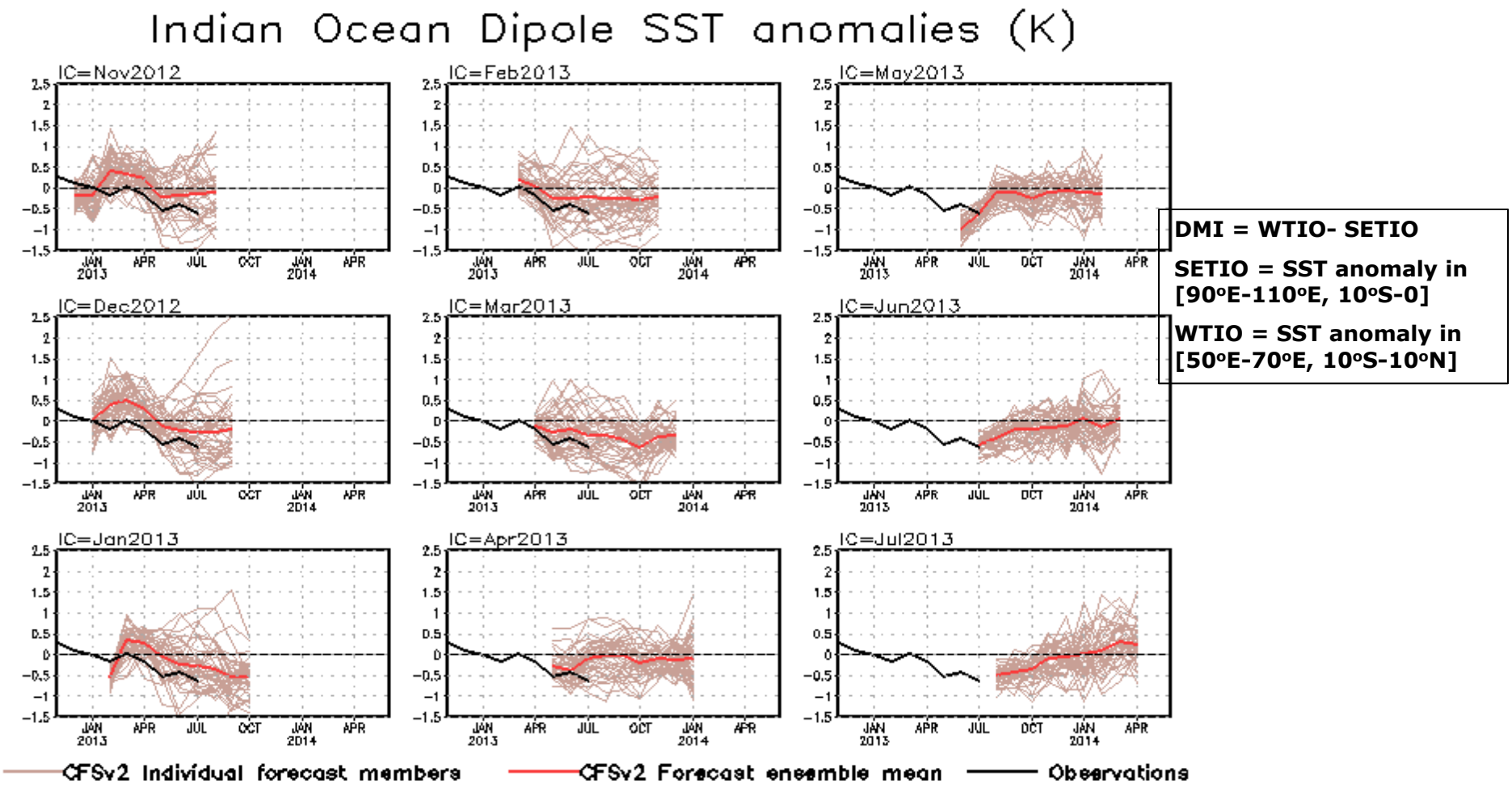
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

NCEP CFSv2 NINO3.4 Forecast



- CFSv2 successfully forecast the ENSO-neutral phase in summer 2013 starting from November 2012

NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

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

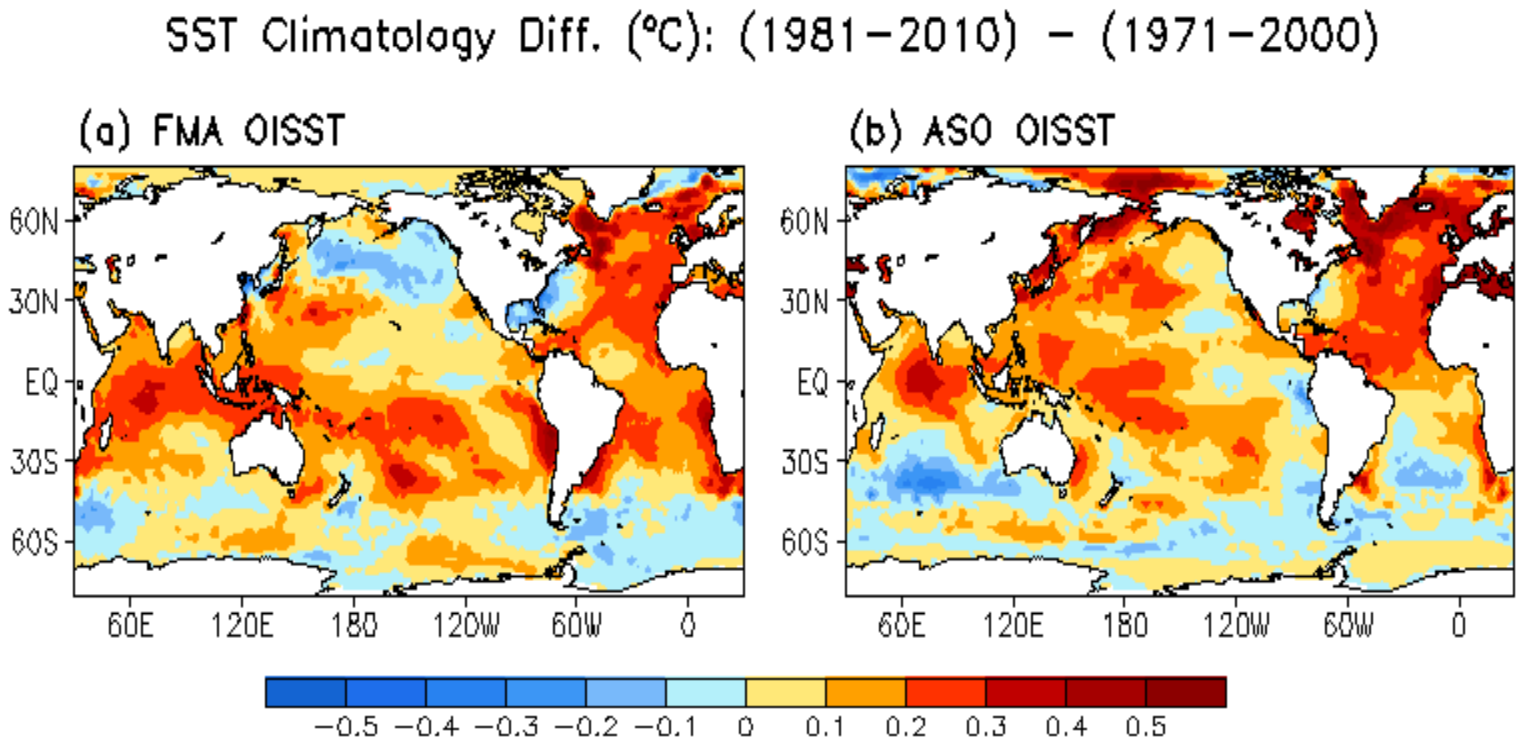
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

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 (labelled 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 1981-2010 base period means.

Switch to 1981-2010 Climatology

- **SST from 1971-2000 to 1981-2010**
  - **Weekly OISST.v2, monthly ERSST.3b**
- **Atmospheric fields from 1979-1995 to 1981-2010**
  - **NCEP CDAS winds, sea level pressure, 200mb velocity potential, surface shortwave and longwave radiation, surface latent and sensible fluxes, relative humidity**
  - **Outgoing Long-wave Radiation**
- **Oceanic fields from 1982-2004 to 1981-2010**
  - **GODAS temperature, heat content, depth of 20°C, sea surface height, mixed layer depth, tropical cyclone heat potential, surface currents, upwelling**
- **Satellite data climatology 1993-2005 unchanged**
  - **Aviso Altimetry Sea Surface Height**
  - **Ocean Surface Current Analyses – Realtime (OSCAR)**

Be aware that new climatology (1981-2010) was applied since Jan 2011



1971-2000 SST Climatology (Xue et al. 2003):
http://www.cpc.ncep.noaa.gov/products/predictions/30day/SSTs/sst_clim.htm

1981-2010 SST Climatology: http://origin.cpc.ncep.noaa.gov/products/people/yxue/sstclim/

- **The seasonal mean SST in February-April (FMA) increased by more than 0.2°C over much of the Tropical Oceans and N. Atlantic, but decreased by more than 0.2°C in high-latitude N. Pacific, Gulf of Mexico and along the east coast of U.S.**

- **Compared to FMA, the seasonal mean SST in August-October (ASO) has a stronger warming in the tropical N. Atlantic, N. Pacific and Arctic Ocean, and a weaker cooling in Gulf of Mexico and along the east coast of U.S.**

Data Sources and References

- **Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)**
- **NCEP CDAS winds, surface radiation and heat fluxes**
- **NESDIS Outgoing Long-wave Radiation**
- **NDBC TAO data (http://tao.noaa.gov)**
- **PMEL TAO equatorial temperature analysis**
- **NCEP's Global Ocean Data Assimilation System temperature, heat content, currents (Behringer and Xue 2004)**
- **Aviso Altimetry Sea Surface Height**
- **Ocean Surface Current Analyses – Realtime (OSCAR)**

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