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

Prepared by

Climate Prediction Center, NCEP/NOAA

July 9, 2015

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 Climate Observation Division (COD)

Outline

- **Overview**
- **Recent highlights**
  - **Pacific/Arctic Ocean**
    - **El Niño conditions**
    - **NE Pacific warming**
  - **Indian Ocean**
  - **Atlantic Ocean**
- **Global SST Predictions**
  - **Is an extreme El Niño coming in 2015/2016?**

Overview

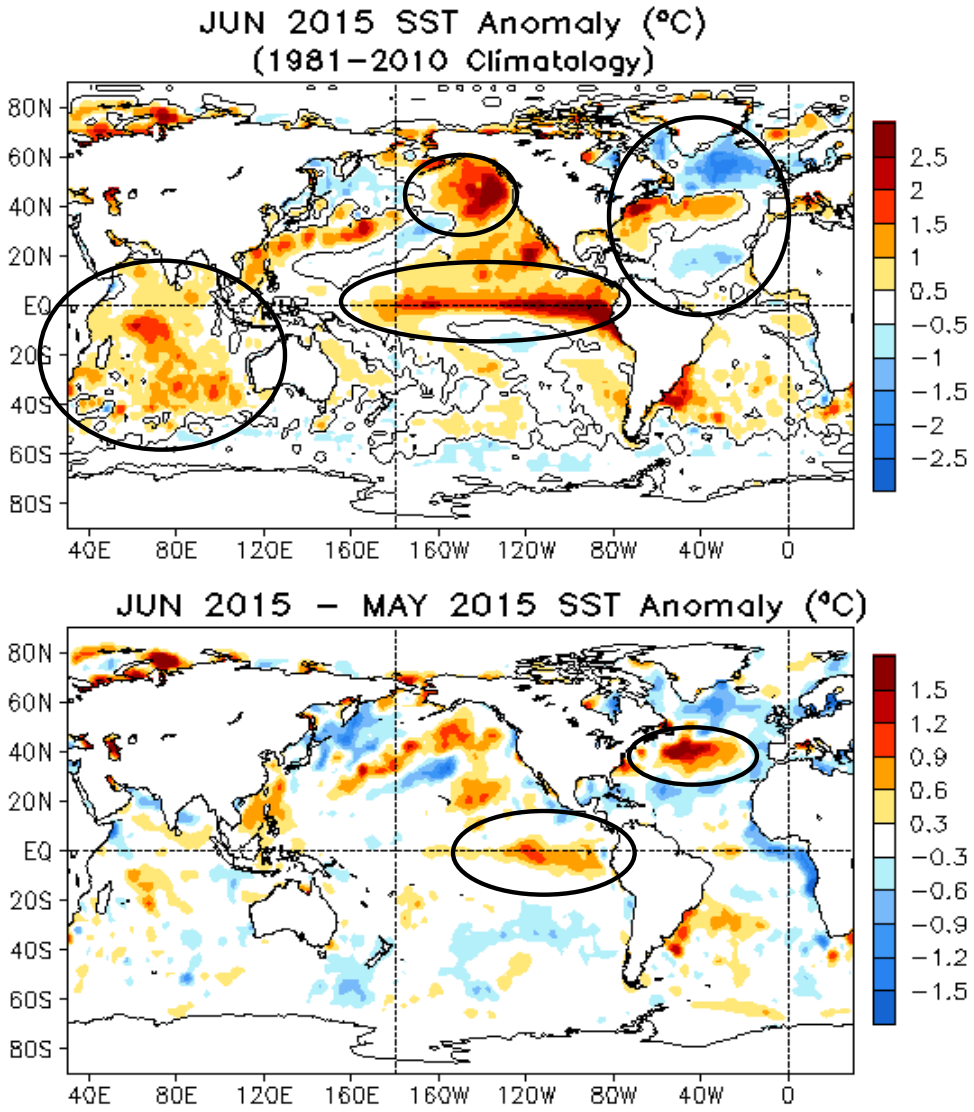
- **Pacific Ocean**
  - **El Niño conditions strengthened in June 2015.**
  - **NOAA "ENSO Diagnostic Discussion" on 09 Jul.2015 suggested " There is a greater than 90% chance that El Niño will continue through Northern Hemisphere winter 2015-16.**
  - **Strong SST warming in the NE Pacific has persisted since 2013 winter.**
  - **PDO continued to be above-normal, with PDOI=0.7 in June 2015.**

- **Indian Ocean**
  - **Positive SSTAs dominated the whole Indian Ocean.**

- **Atlantic Ocean**
  - **Horseshoe-like pattern of SSTA continued in N. Atlantic.**

Global Oceans

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

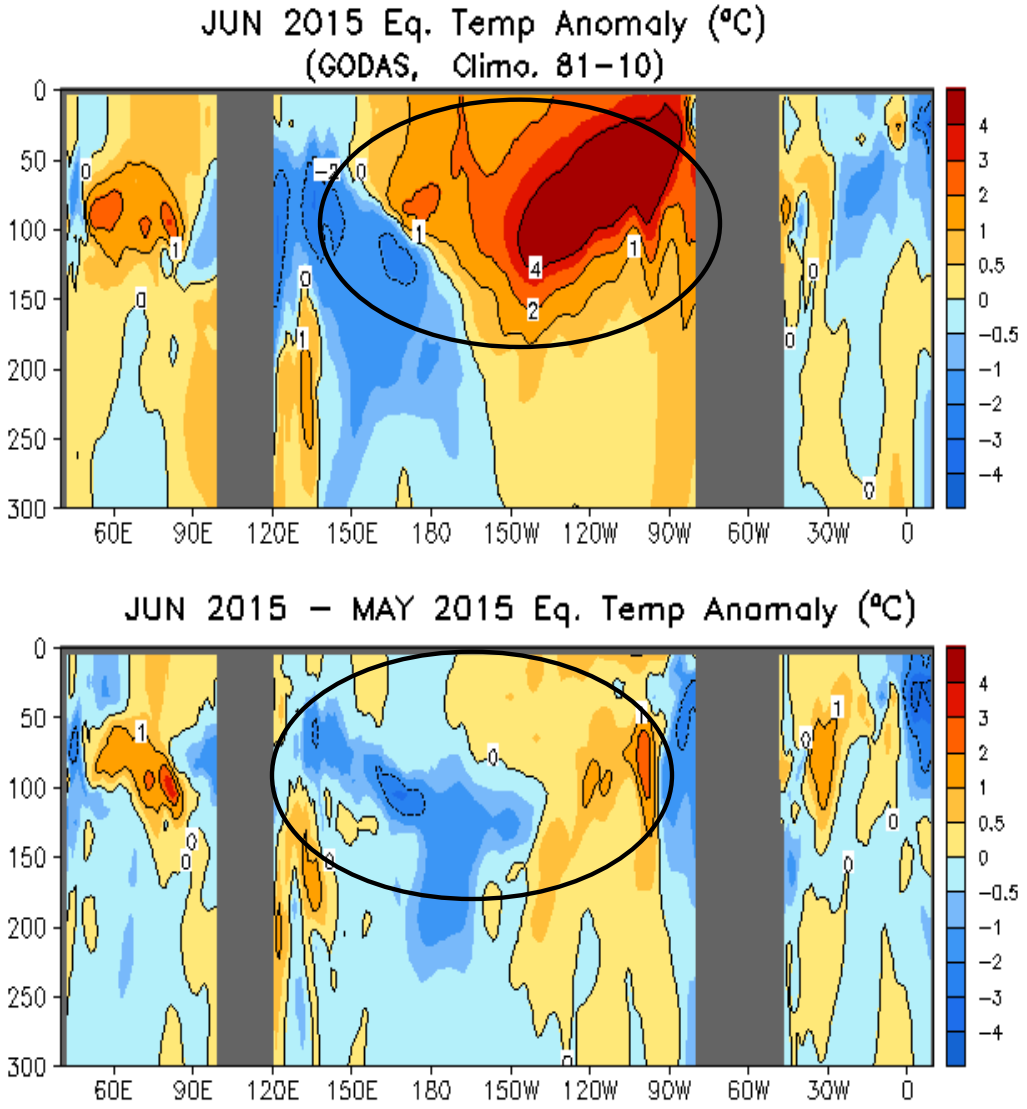


- **SSTA exceeded +1.°C across the central and eastern equatorial Pacific Ocean.**
- **Strong positive SSTA continued in the NE Pacific Ocean.**
- **Horseshoe-like SSTA pattern persisted in the North Atlantic.**
- **Positive SSTA presented in the Indian and Southern Oceans.**

- **A strong warming tendency was observed in the central North Atlantic.**
- **Positive SSTA tendency continued in the eastern equatorial 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 1981-2010 base period means.

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



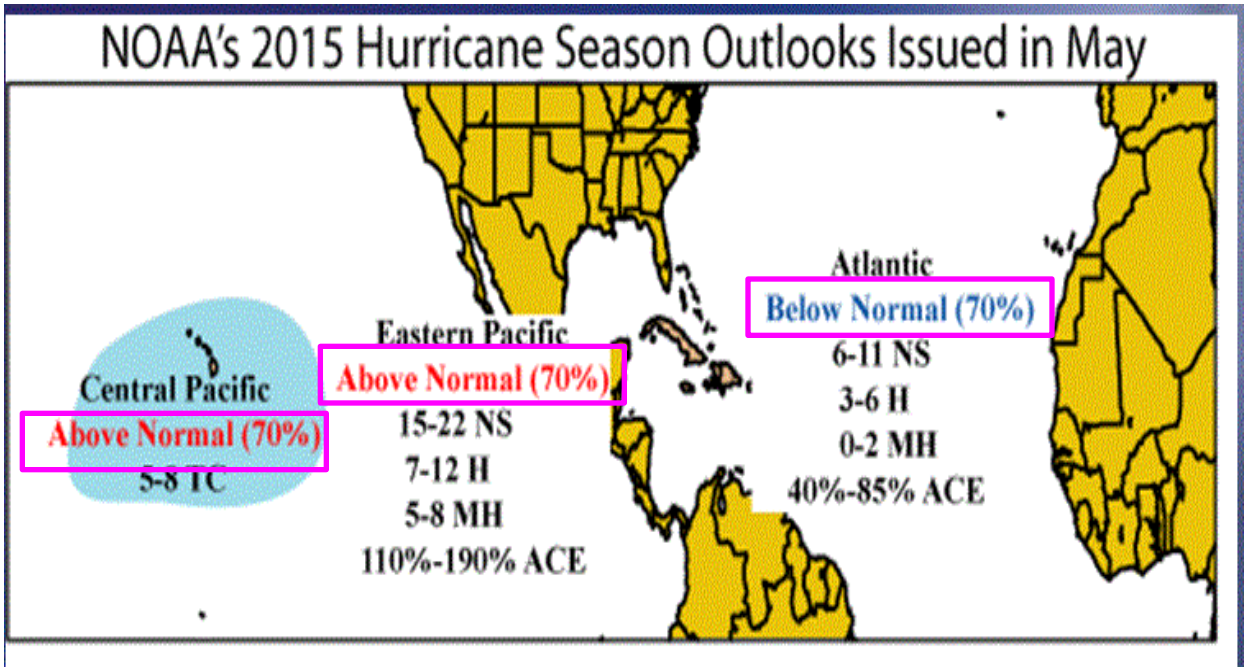
- Strong positive ocean temperature anomalies persisted in the central-eastern equatorial Pacific.
- Positive temperature anomalies occupied most of the Indian Ocean.

- A warming (cooling) tendency presented in the eastern (western) Pacific.

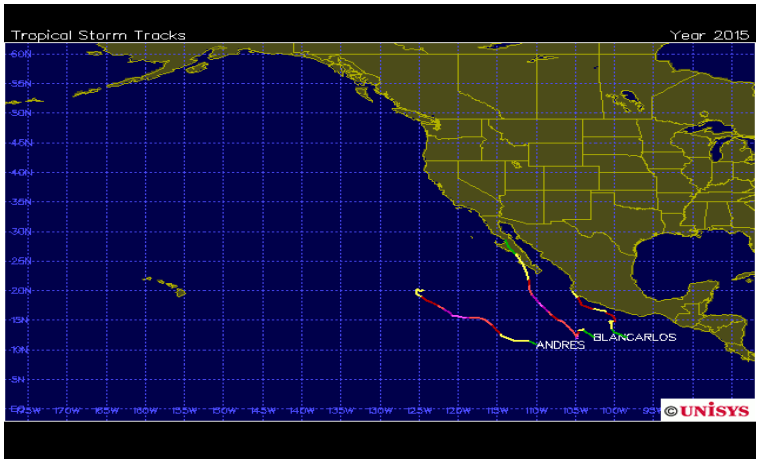
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1981-2010 base period means.

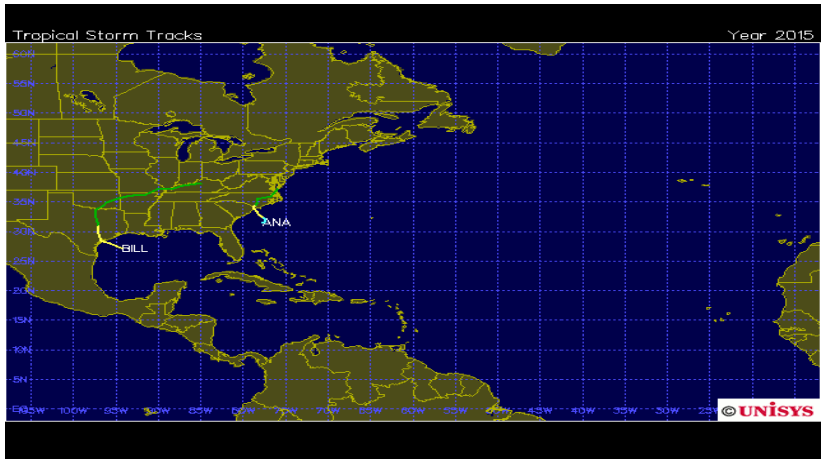
NOAA Outlooks of Hurricane Season issued on May 2015

(http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane2015/)



Two tropical storms were formed in North Atlantic by Jul. 6.
Three hurricanes were formed in E. Pacific by Jul.6.



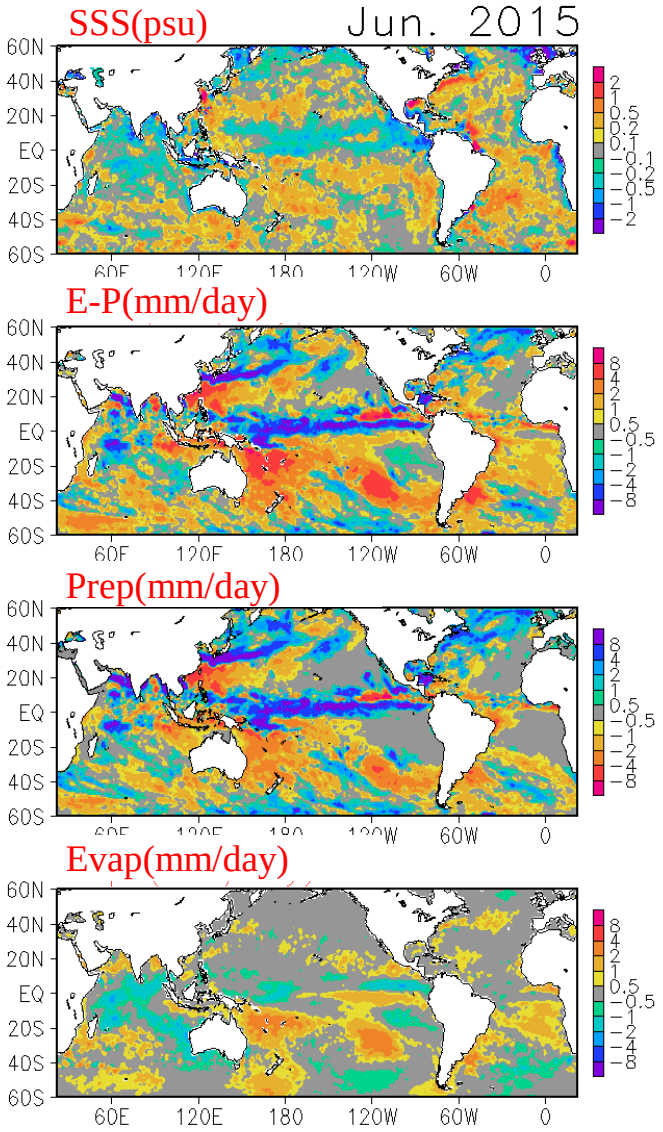


(http://weather.unisys.com/hurricane/)

Global Sea Surface Salinity (SSS)

Anomaly for June 2015

- NOTE: Since Aquarius terminated operations, the blended SSS analysis is from in situ and SMOS only from June 2015. Please report to us any suspicious data issues!
- Global SSS pattern is characterized by zonally oriented belts of negative / positive anomalies across the equatorial Pacific in the north / south sides, and the positive anomalies over SW Pacific.



- Data used

SSS :

Blended Analysis of Surface Salinity (BASS) V0.Y

(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)

(Xie et al. 2014)

ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation:

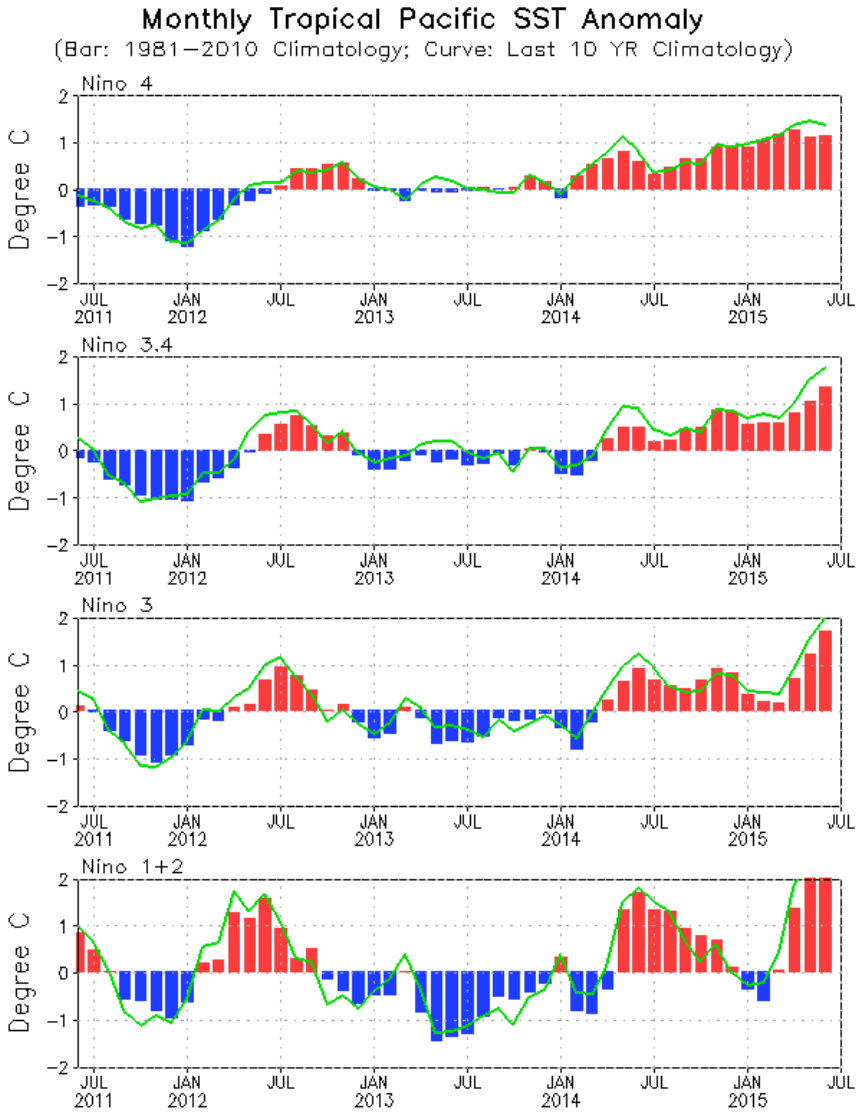
CMORPH adjusted satellite precipitation estimates

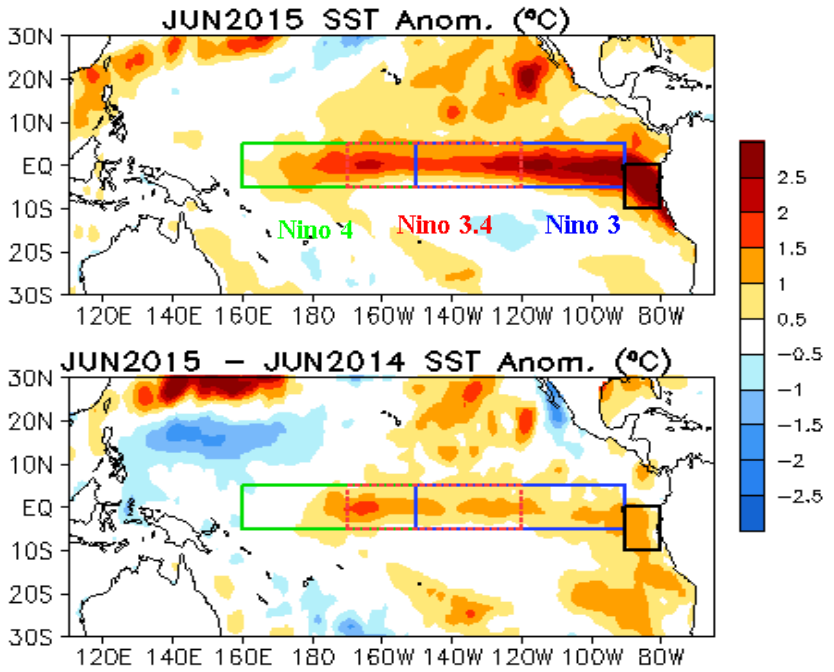
Evaporation:

CFS Reanalysis

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific NINO SST Indices





- **All NINO indices exceeded +1°C in June 2015.**

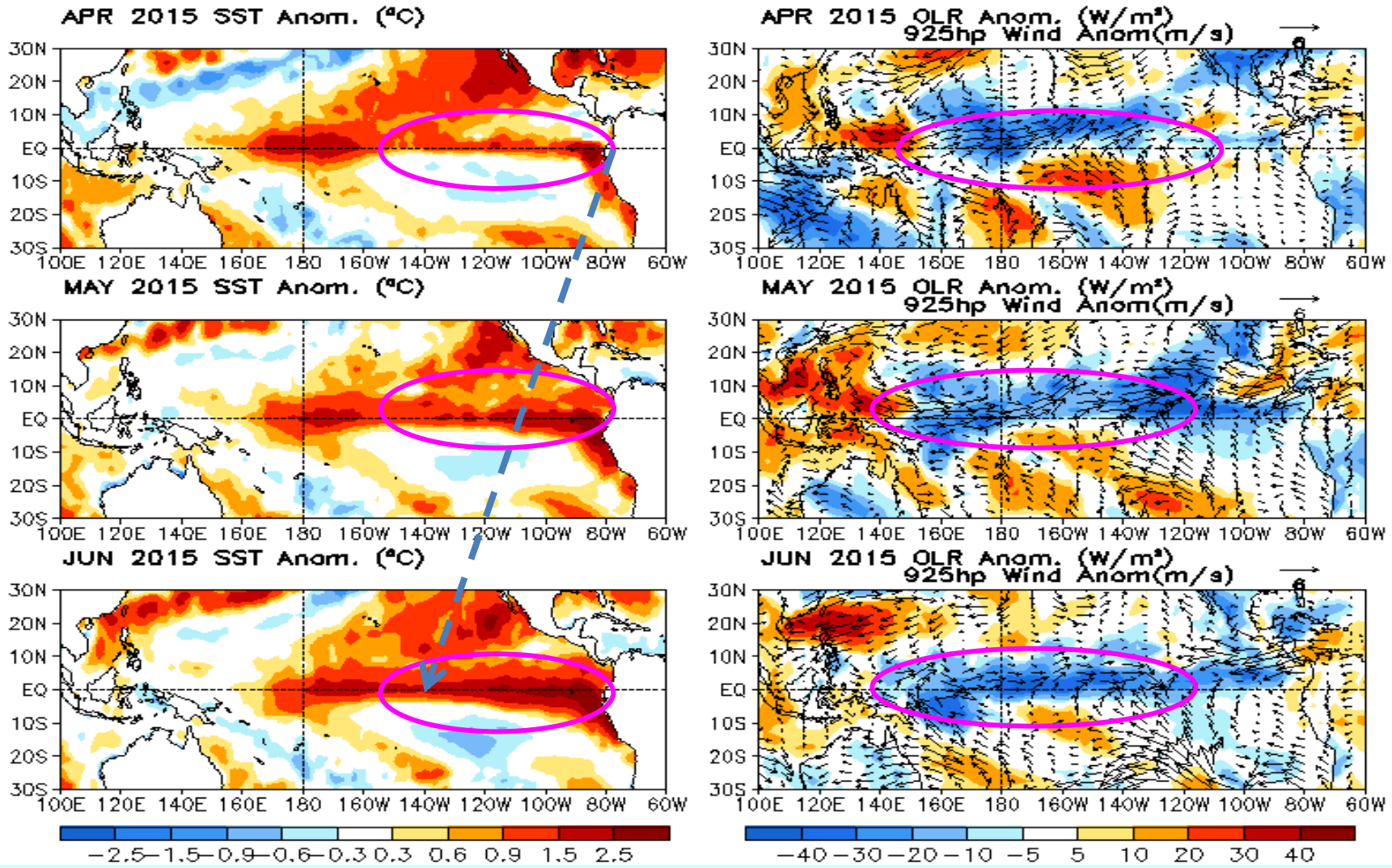
- **Nino3.4 = 1.3 °C in June 2015 and ranks the second warmest June since 1982.**

- **Compared with last June, the central-eastern equatorial Pacific and the central and southern American coast were warmer in June 2015.**

- **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 base period means.

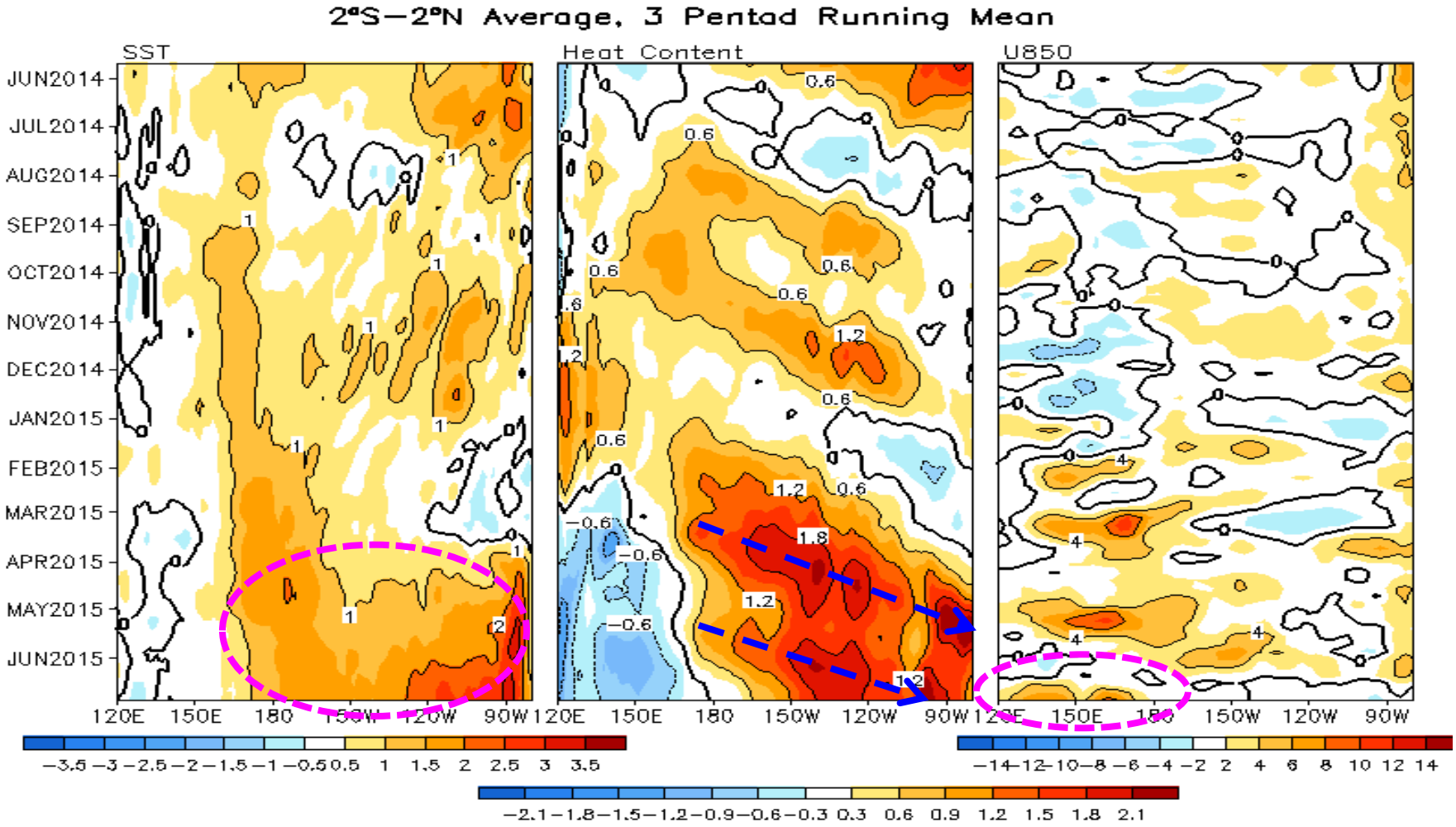
Last Three Month SST, OLR and 925hp Wind Anom.



- **From April to June, positive SSTA strengthened and extended from the South American coast line to the central equatorial Pacific.**

- **During the last three months, negative OLR anomalies persisted over the central and eastern Pacific and westerly low-level winds prevailed across the east-central equatorial Pacific.**

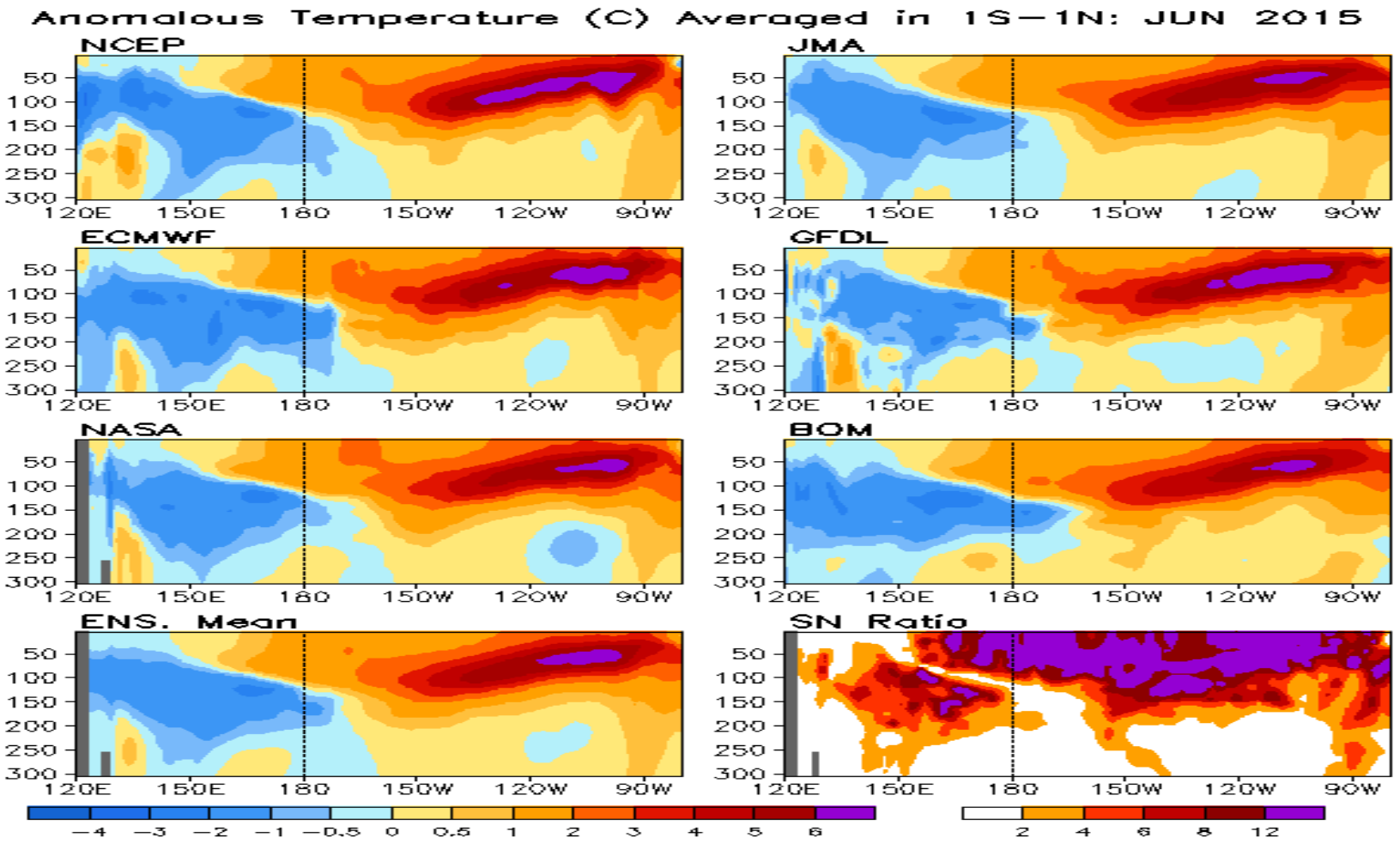
Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies



- **Strength of SST warm anomalies has increased in the eastern equatorial Pacific and extended to the central Pacific since Apr. 2015 .**
- **The downwelling Kelvin wave initiated in late May has propagated to the eastern Pacific.**
- **Low-level westerly wind anomalies in the western Pacific reemerged since mid June.**

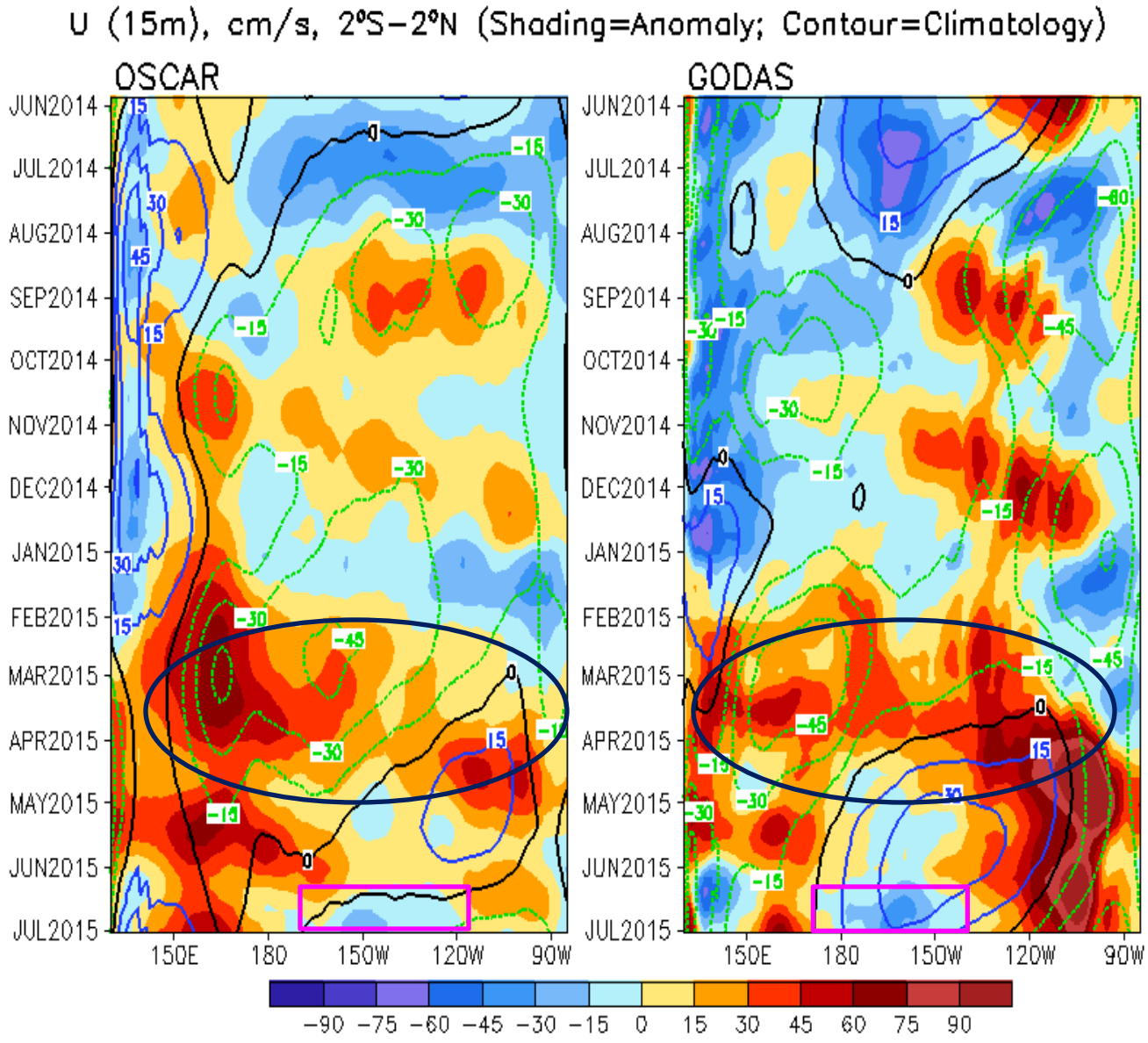
Multiple Ocean Reanalyses: Ocean Temperature along the equator

(http://origin.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)



- **Six operational ocean reanalysis showed a similar pattern and comparable amplitudes of subsurface temperature anomalies.**

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

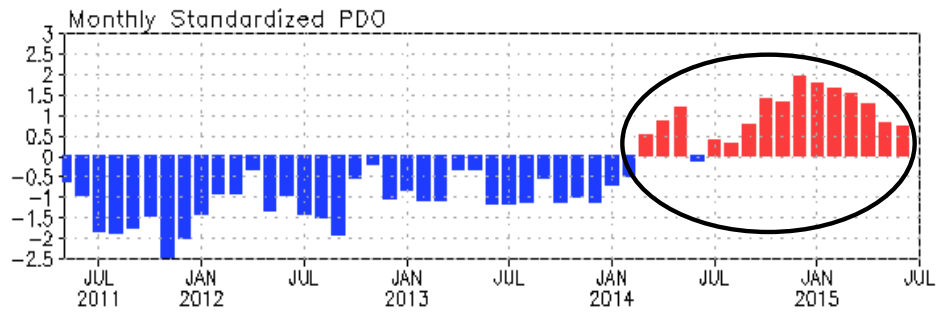


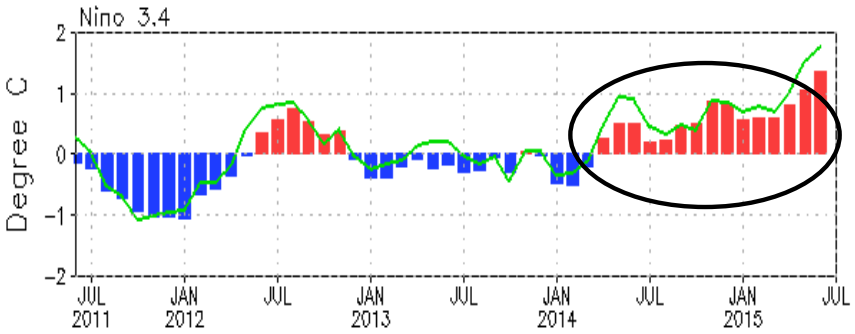
-Anomalous eastward current initiated in Jan 2015 and slightly strengthened in Feb-Mar 2015, leading to positive zonal advective feedback.

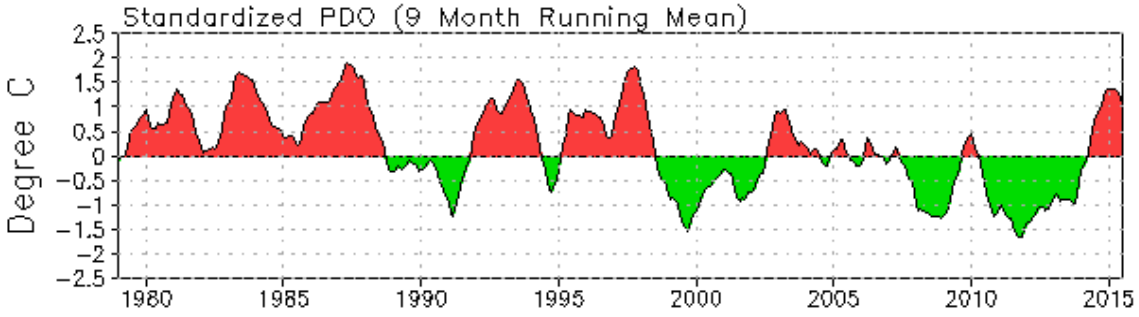
- Anomalous westward current dominated the central-eastern Pacific in June 2015.

North Pacific & Arctic Oceans

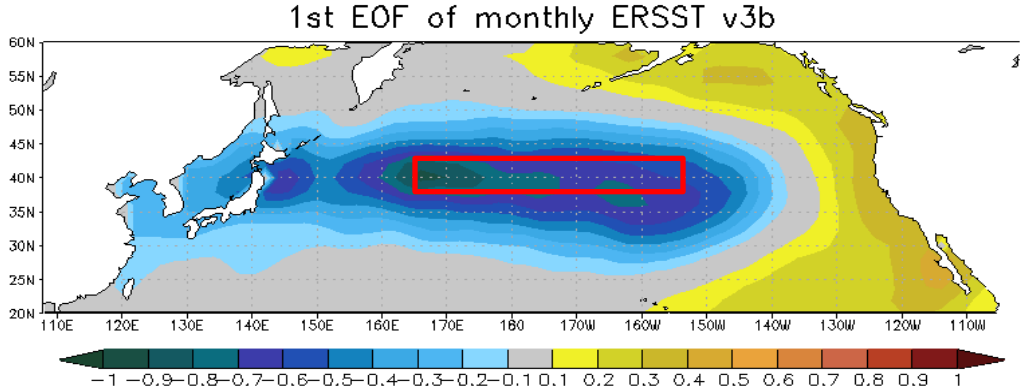
PDO index





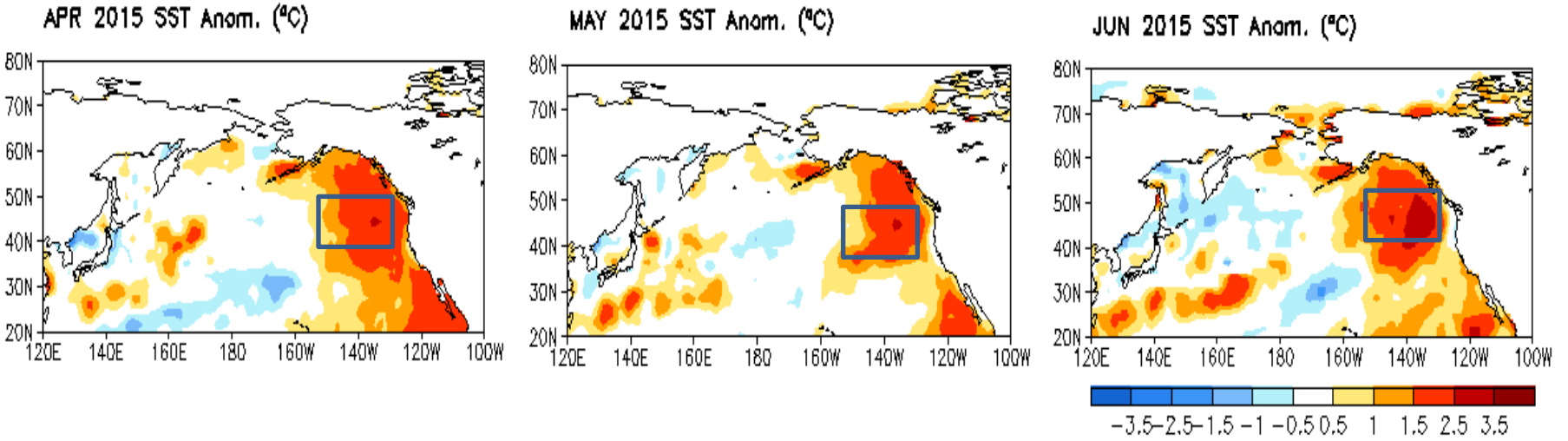


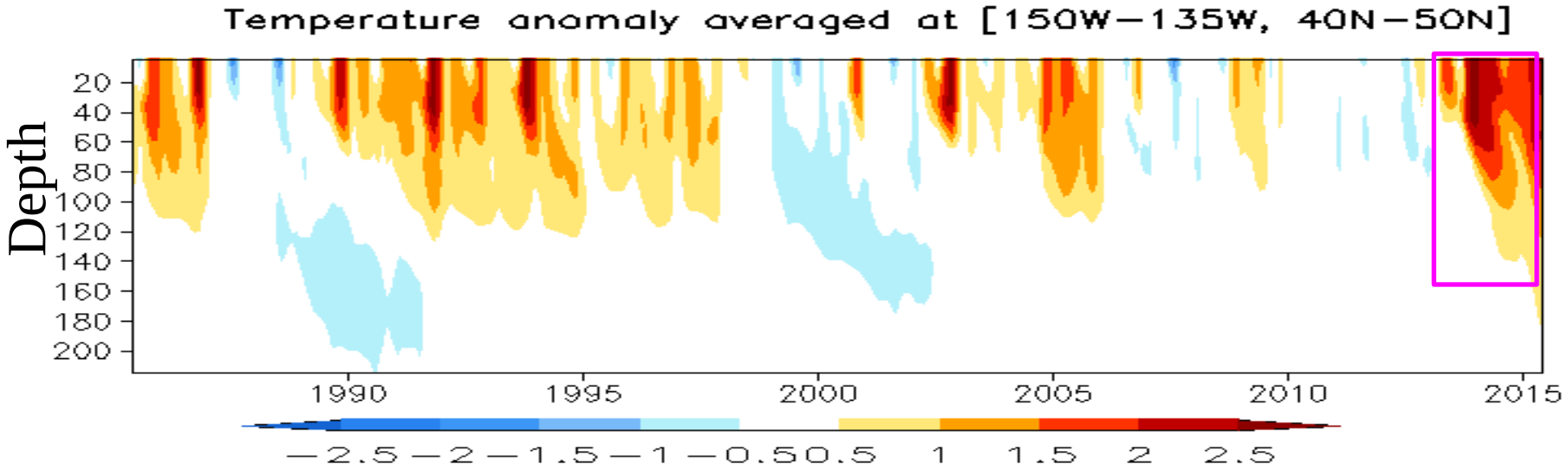
- **Positive PDO has persisted 12 months since Jul 2014 and PDO index =0.7 in Jun 2015.**



- **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.**

Last Three Month SSTA of North Pacific



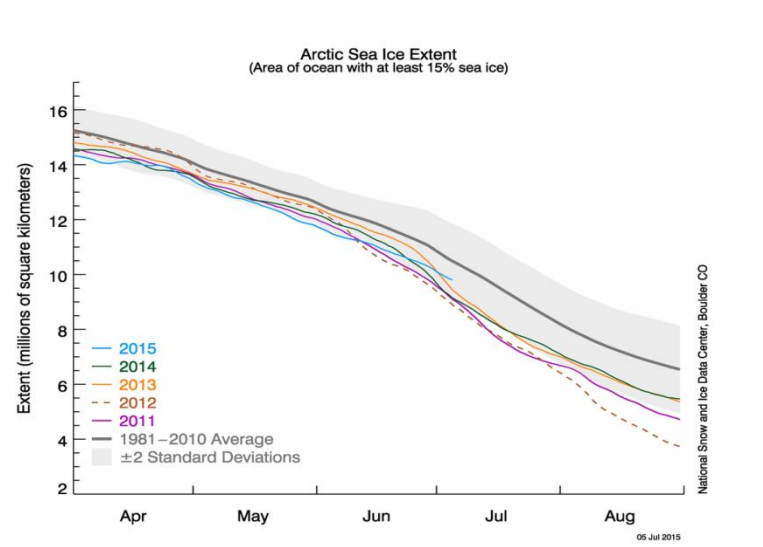


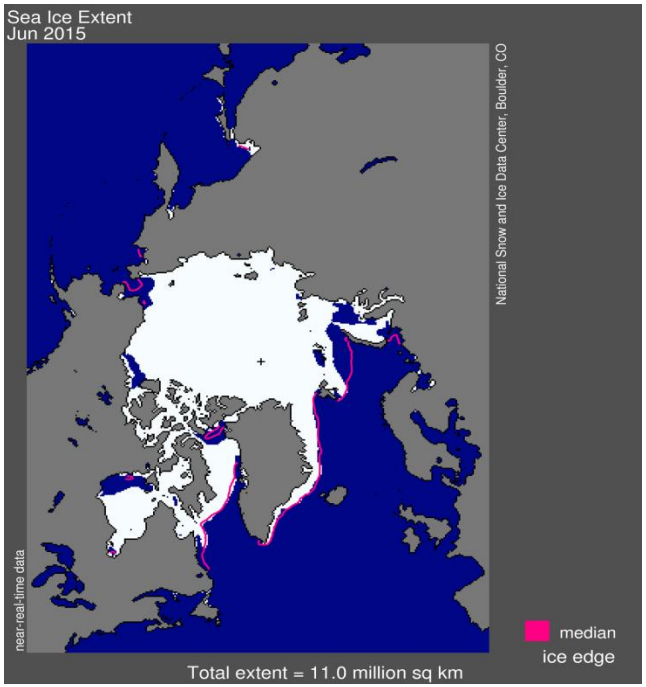
- **Strong positive SSTA persisted in the NE Pacific in the last three months .**
- **Strong subsurface temperature warming in the NE Pacific [150°w-135°w, 40°-50°N] persisted since 2013 winter.**

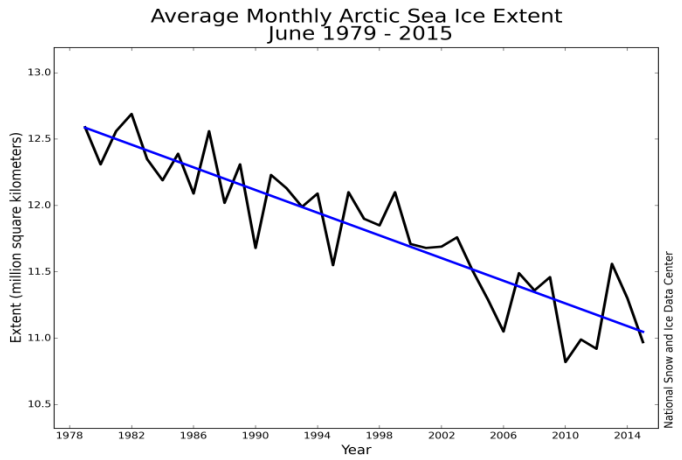
Arctic Sea Ice

National Snow and Ice Data Center

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



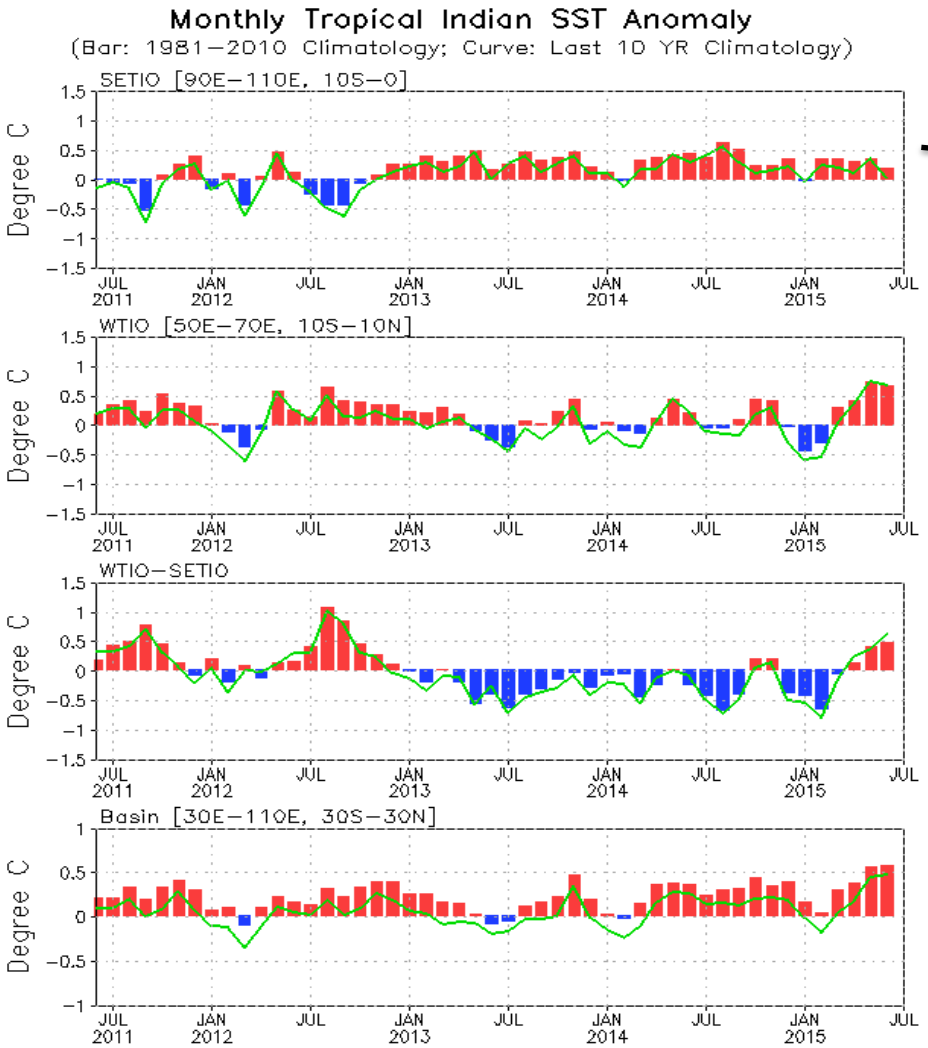


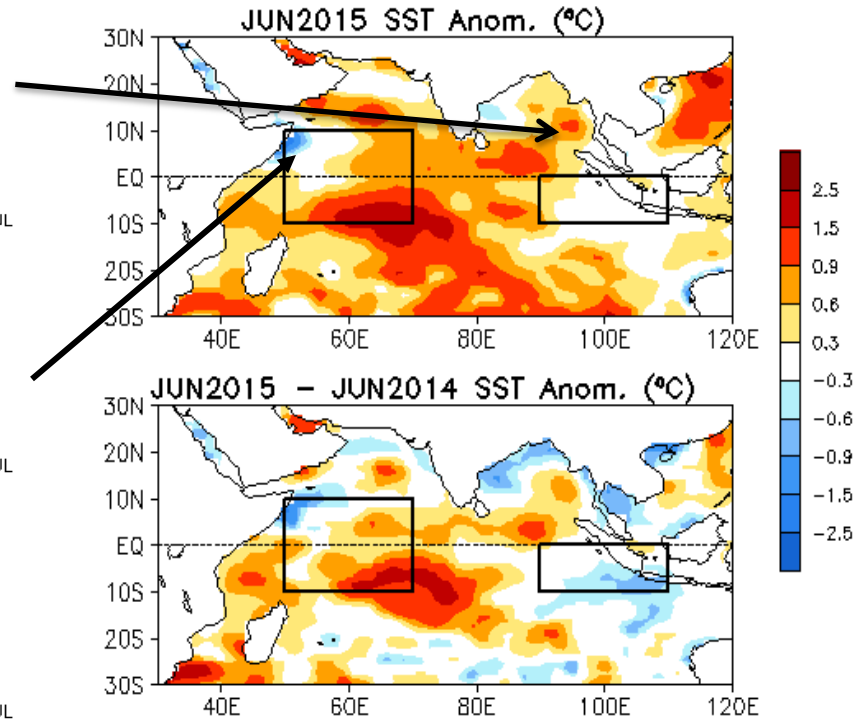


- **Arctic sea ice extent for June 2015 was the third lowest in the satellite record.**

Indian Ocean

Evolution of Indian Ocean SST Indices





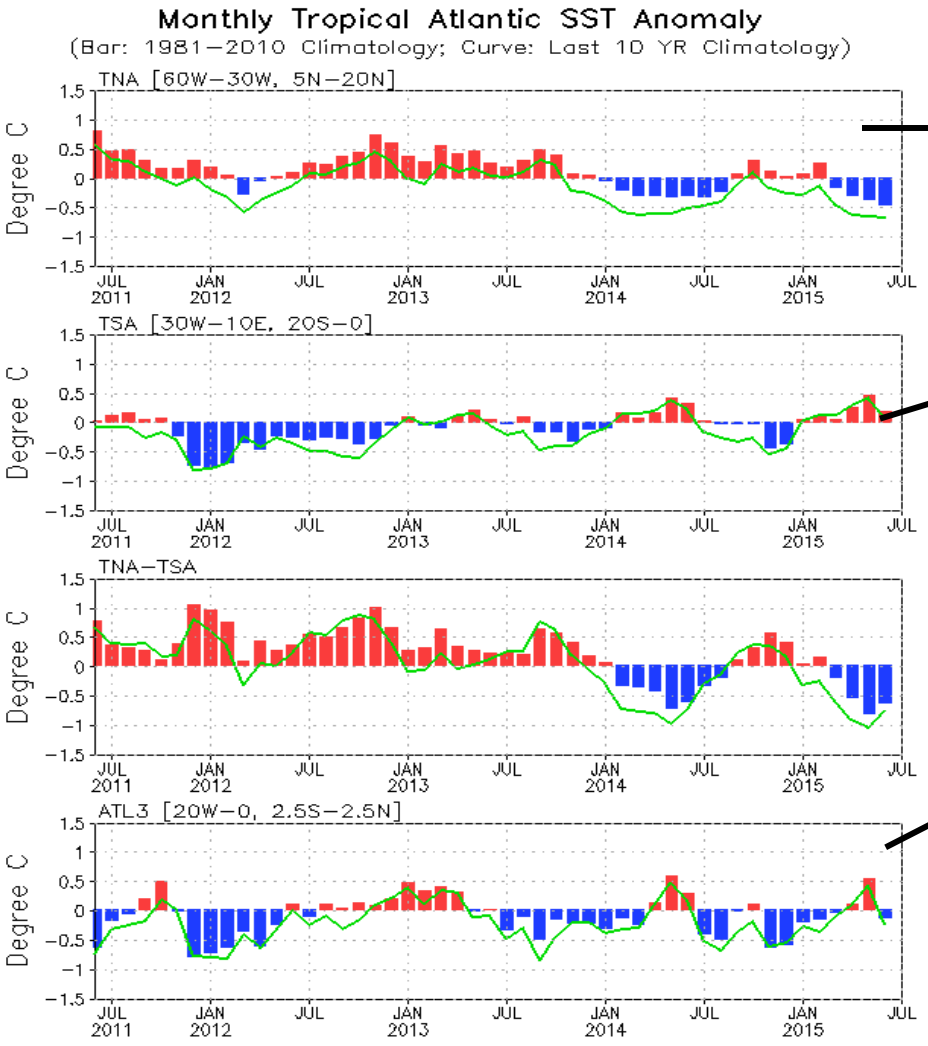
- **Positive SSTA dominated the Indian Ocean.**

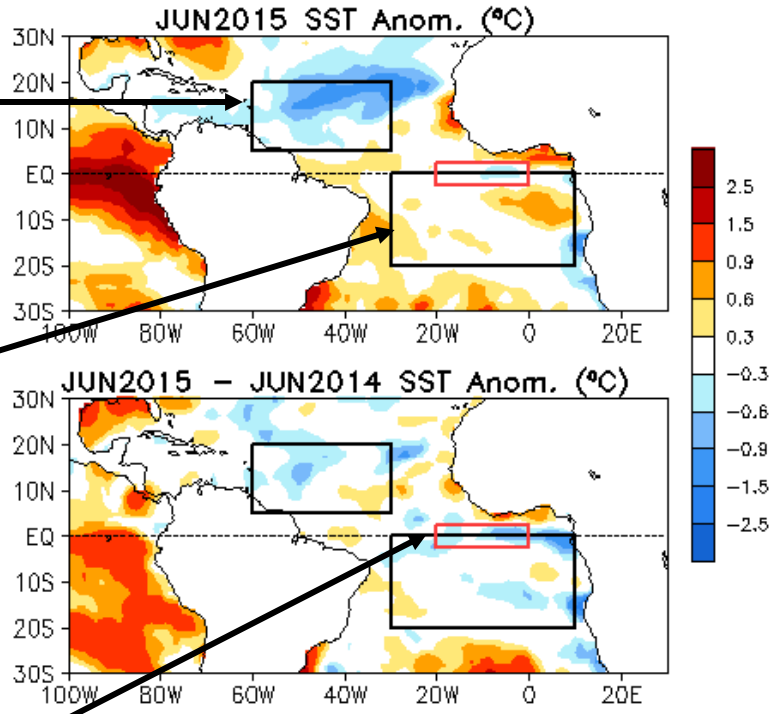
- **Above-average DMI continued in June 2015.**

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 1981-2010 base period means.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices





- **Negative SSTA dominated in the North subtropical Atlantic.**

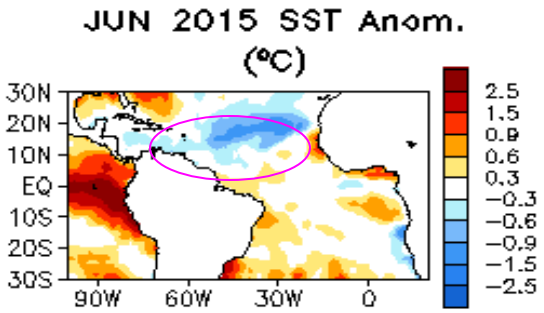
-**ATL3 switched to below normal in June.**

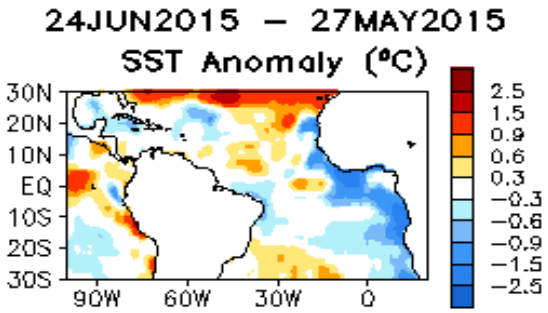
- **Dipole index has been negative since Mar. 2015.**

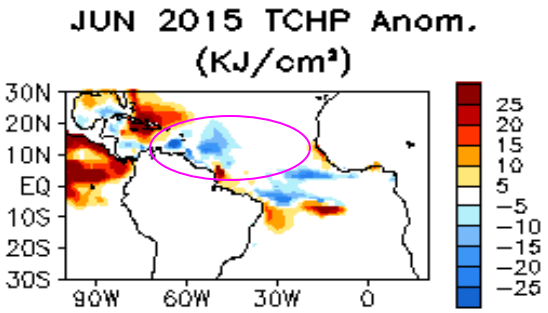
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between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

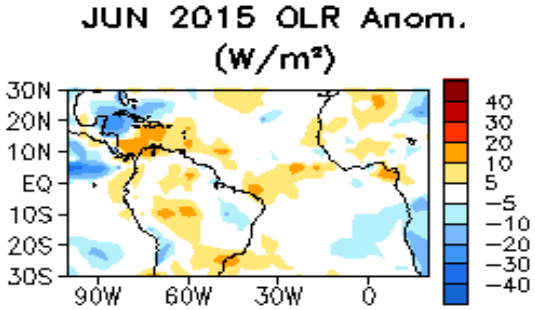
Tropical Atlantic:

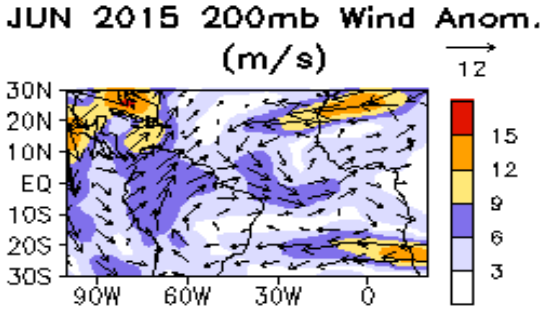
SST Anom., SST Anom. Tend., TCHP OLR, Sfc Flx, 925-mb/200-mb Winds and RH

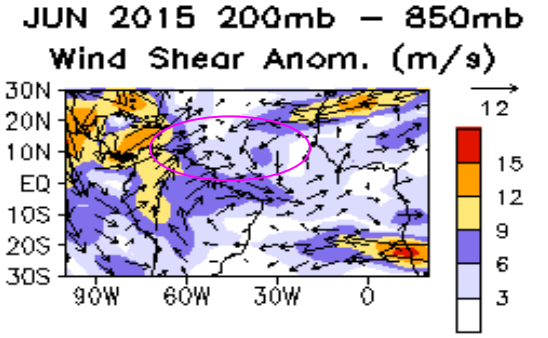


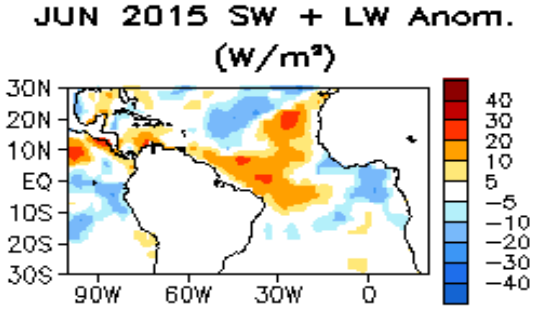


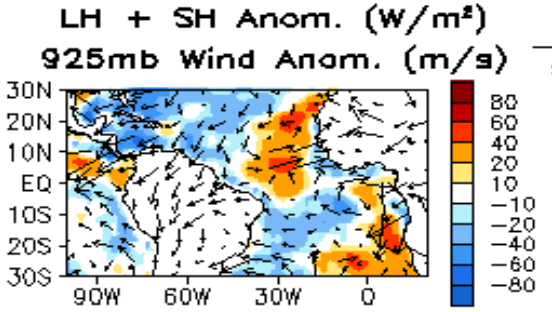


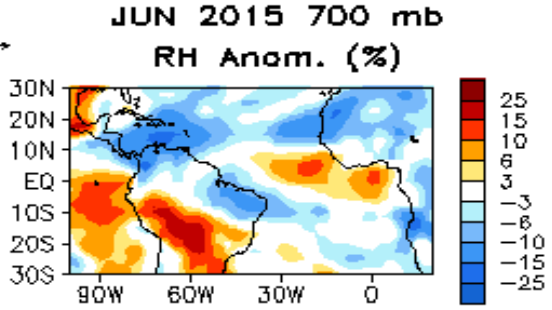












- **Negative SSTA and TCHP continued in the hurricane Main Development Region (MDR) .**
- **Above-normal vertical wind shear was observed in MDR in June 2015.**

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

-A horseshoe like SST pattern presented in North Atlantic.

- SSTA tendency was largely consistent with surface flux anomalies.

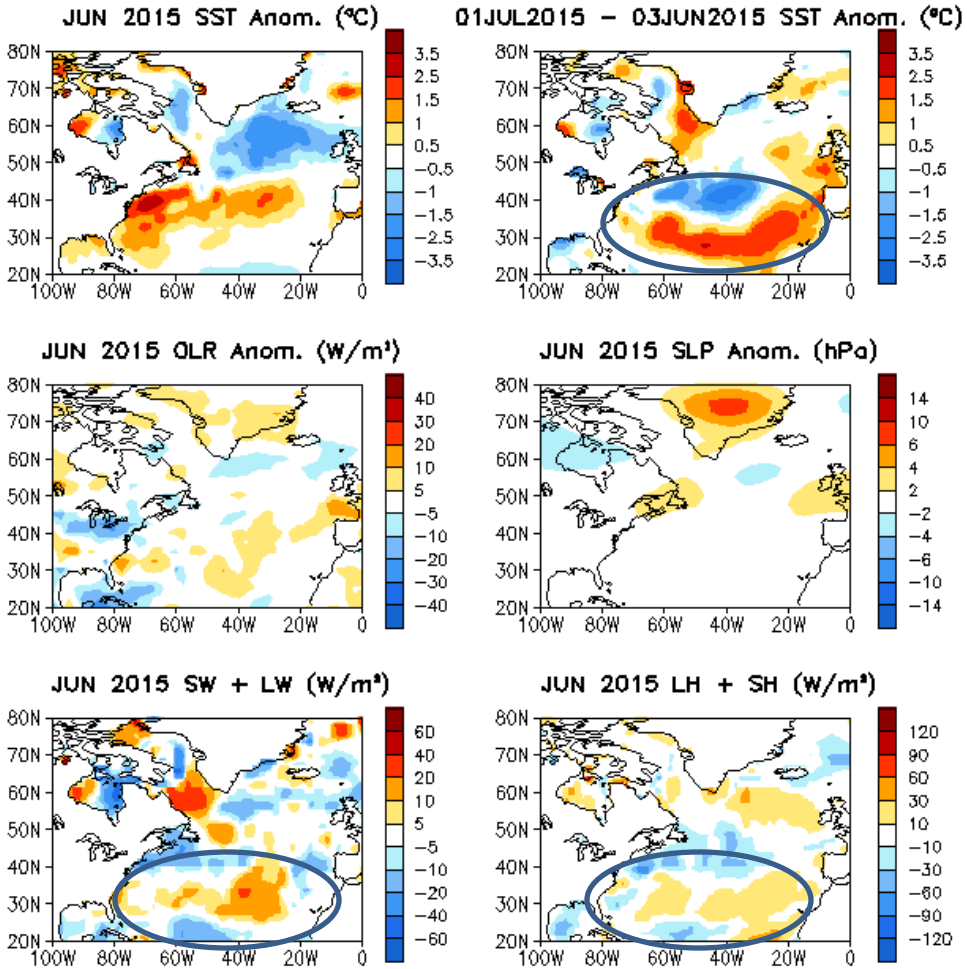
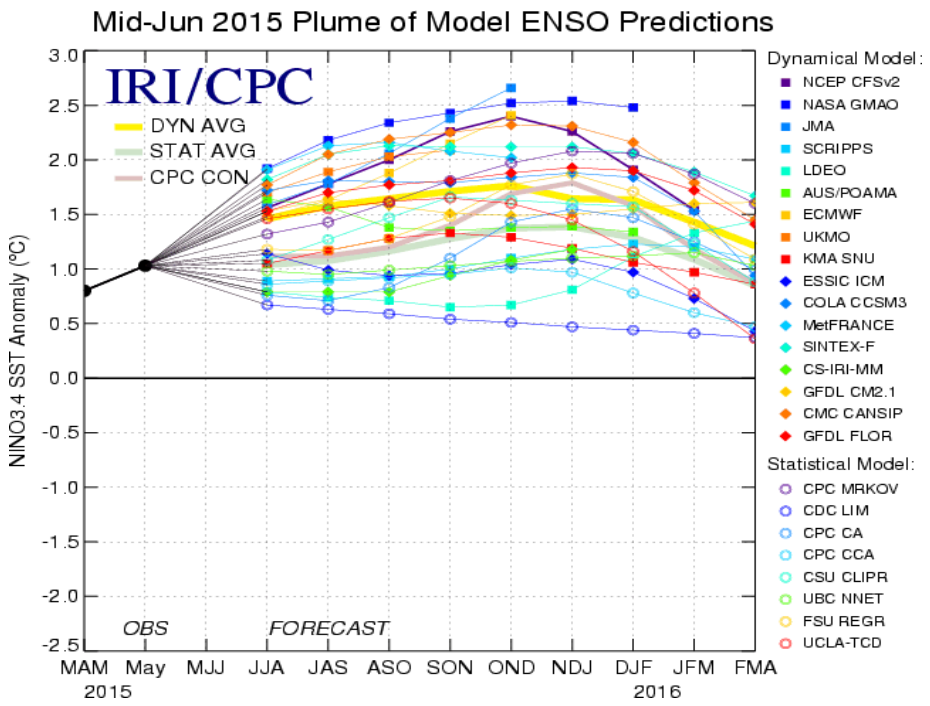
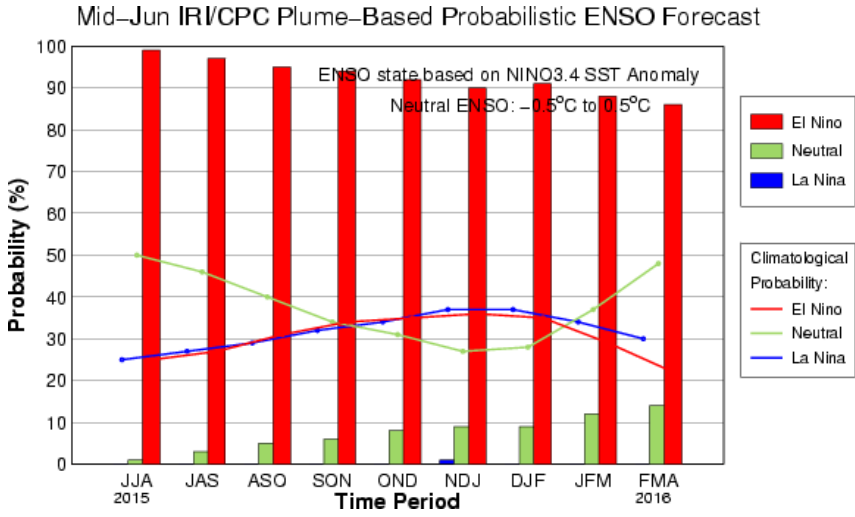


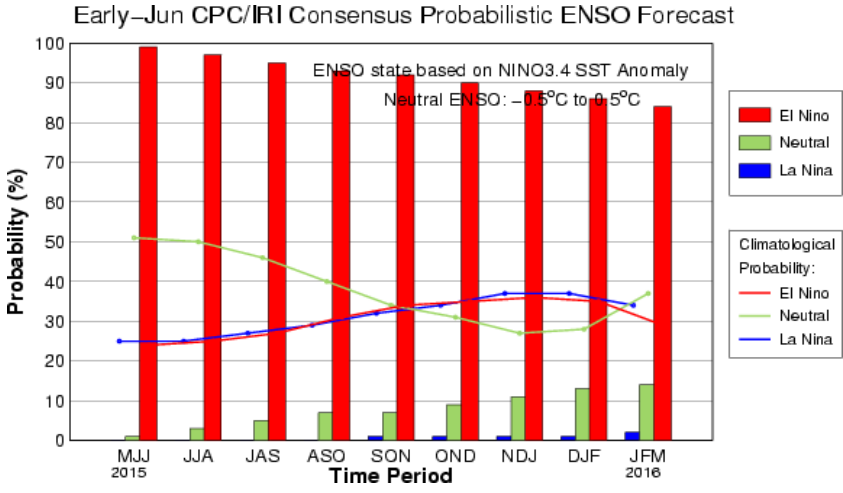
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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 1981-2010 base period means.

ENSO and Global SST Predictions

IRI NINO3.4 Forecast Plum

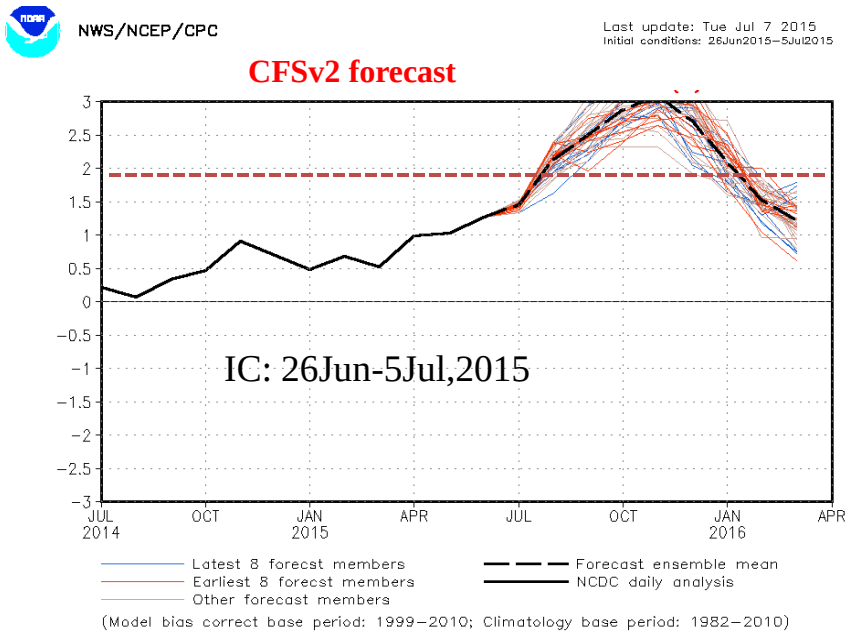


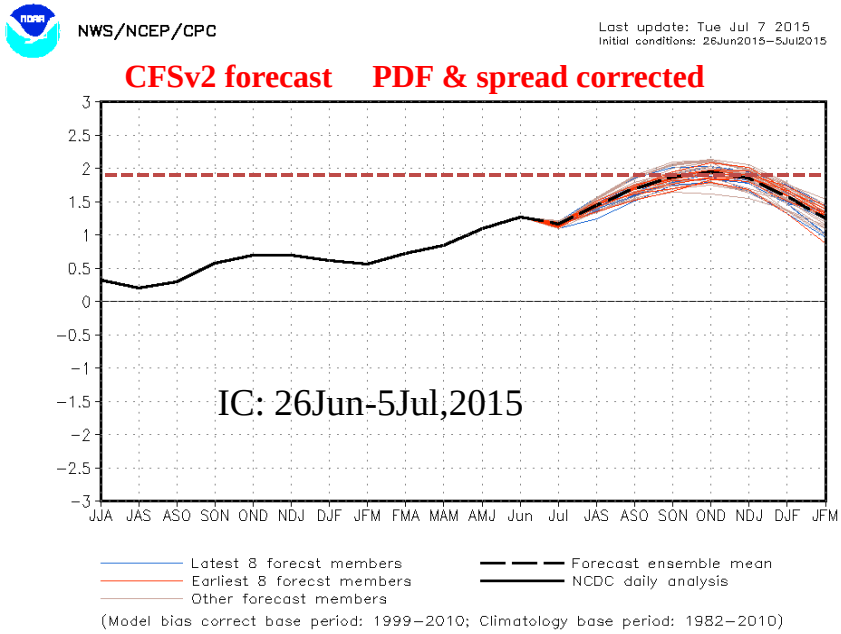


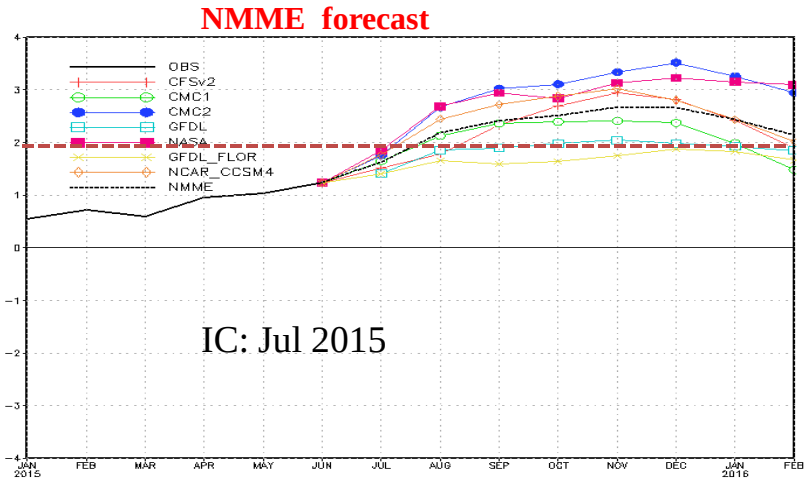


- **Most models predict a moderate to strong El Niño (>1.5°C) at its peak strength.**
- **NOAA "ENSO Diagnostic Discussion" on 09 July 2015 suggested that "There is a greater than 90% chance that El Niño will continue through Northern Hemisphere winter 2015-16, and around an 80% chance it will last into early spring 2016."**

NCEP CFSv2 & NMME NINO 3.4 forecast

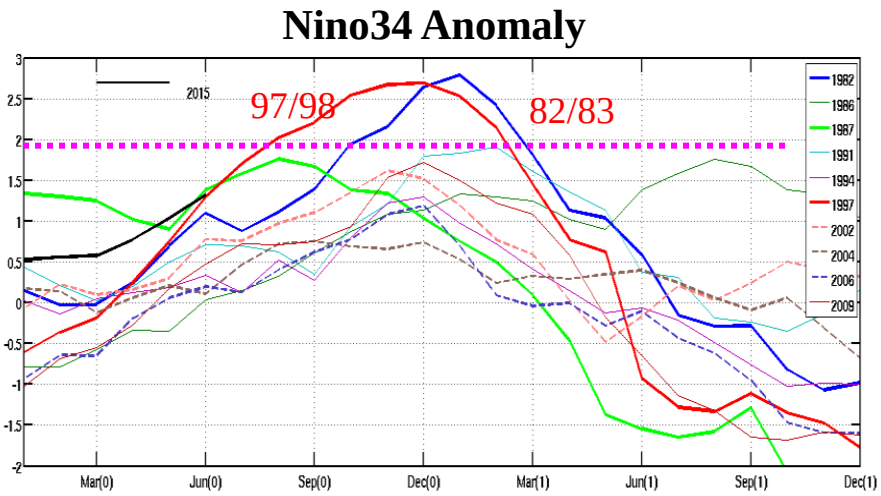




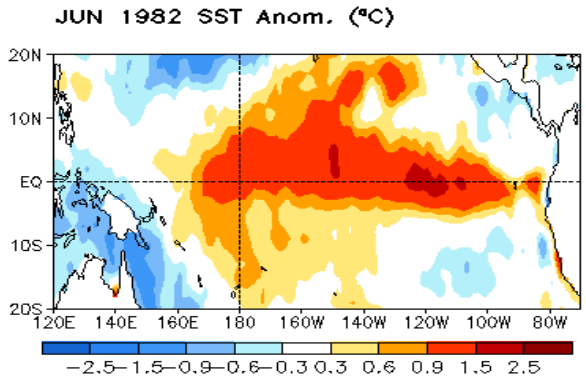


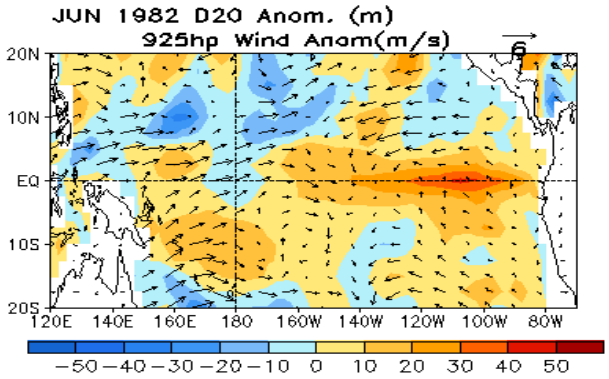
- Latest CFSv2 and NMME forecast called for a significant strong El Niño event (>2°C) throughout the Northern Hemisphere fall-winter 2015.

SST,D20 and 925hp Wind anomalies in June

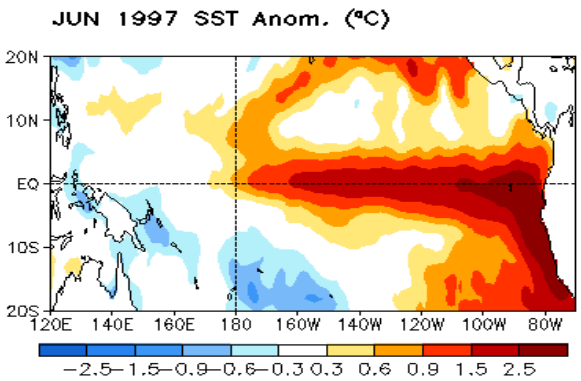


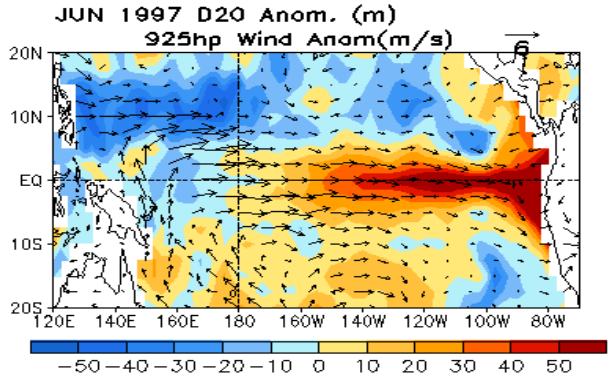
1982



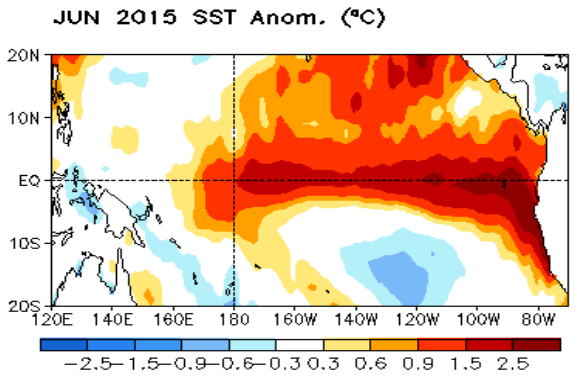


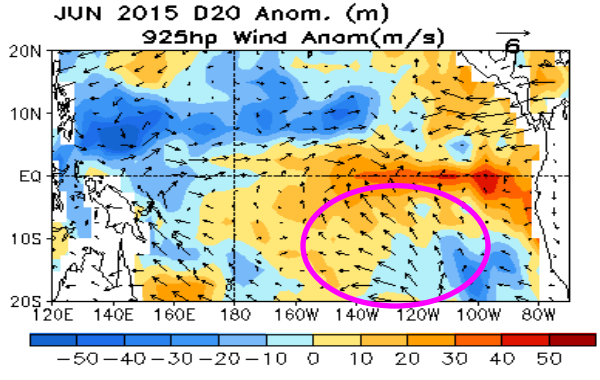
1997



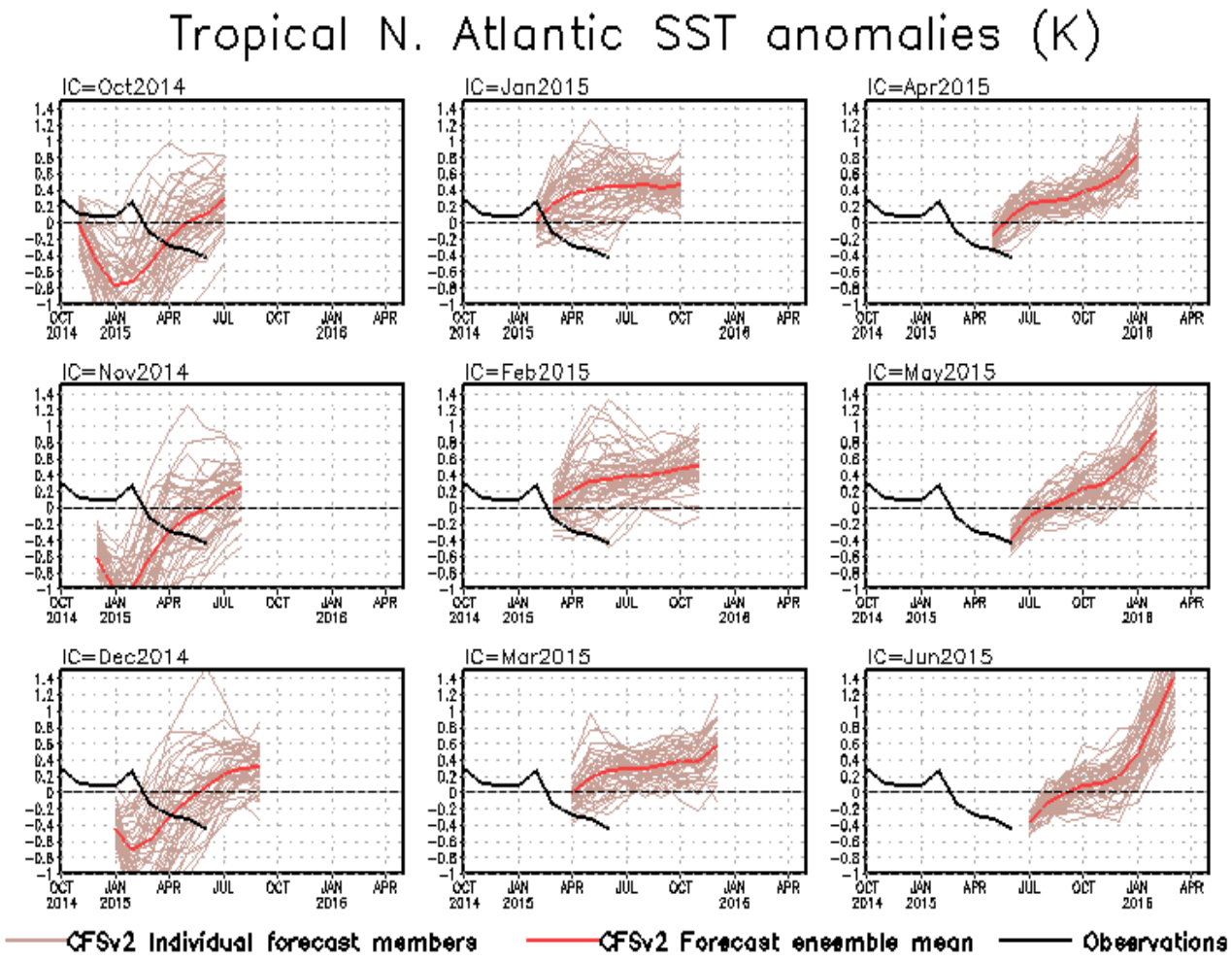


2015





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



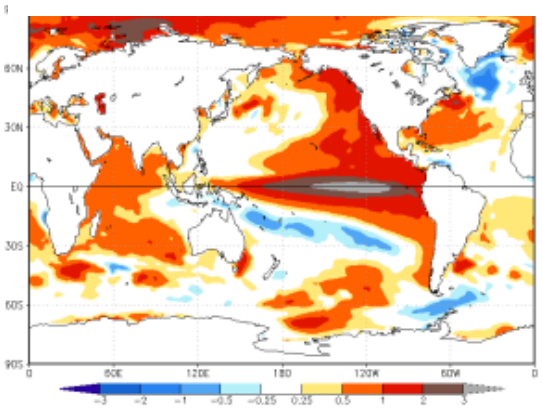
TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- **Predictions initiated in Oct-Dec 2004 may be biased by errors in the Atlantic in CFSR.**
- **Latest CFS2 prediction calls a warming tendency in North Atlantic during summer-winter 2015.**

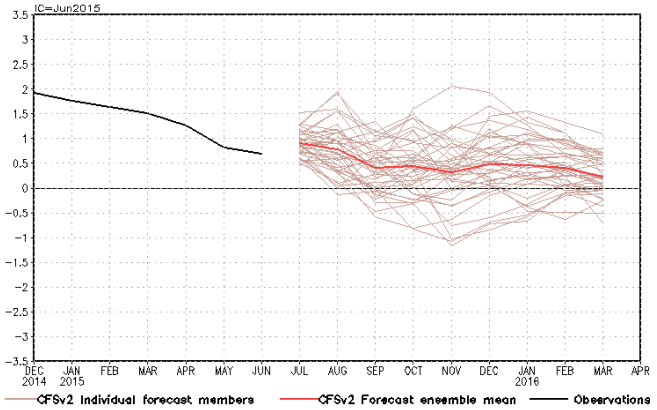
Fig. M3. CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

Global SST and CFS Pacific Decadal Oscillation (PDO) Index Predictions

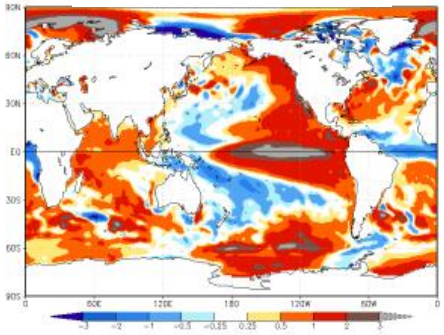
NMME IC=201507 4-mon lead



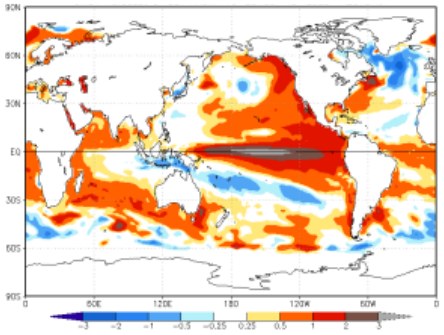
NCEP CFSv2 PDO



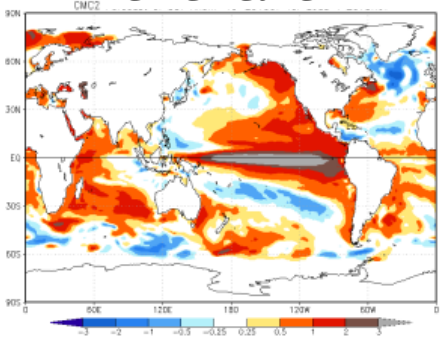
NCEP CFSv2



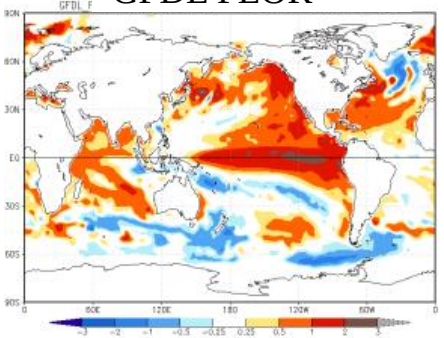
CMC1 CanCM3



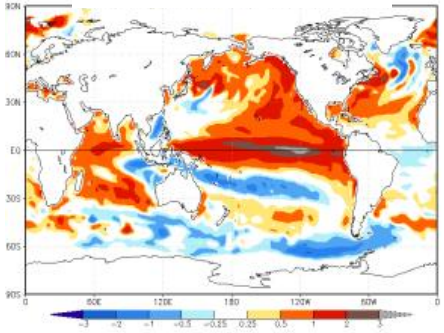
CMC2 CanCM4



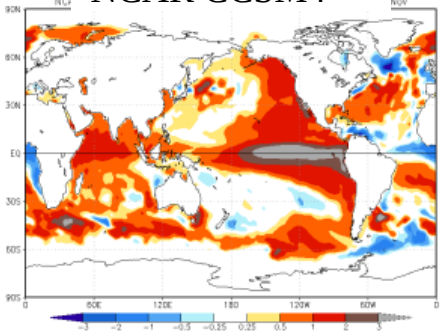
GFDL FLOR



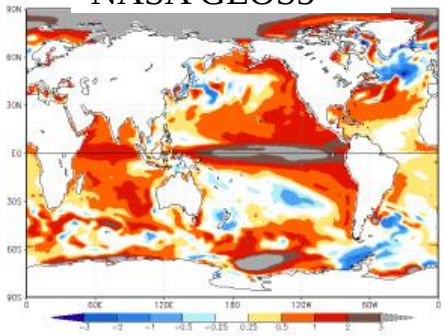
GFDL CM2.1



NCAR CCSM4



NASA GEOS5



Overview

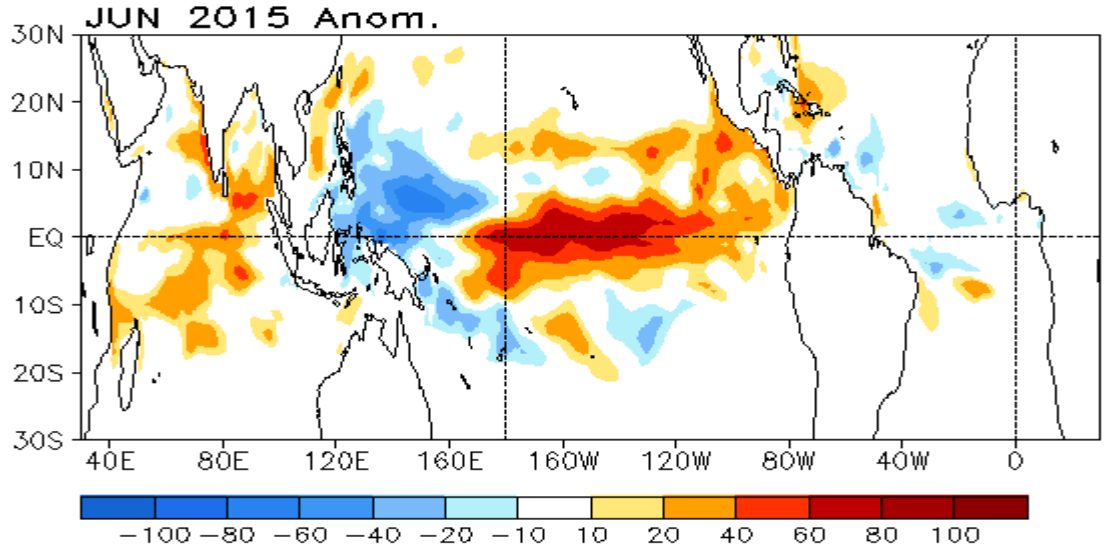
- **Pacific Ocean**
  - **El Niño conditions strengthened in June 2015.**
  - **NOAA "ENSO Diagnostic Discussion" on 09 Jul.2015 suggested " There is a greater than 90% chance that El Niño will continue through Northern Hemisphere winter 2015-16.**
  - **Strong SST warming in the NE Pacific has persisted since 2013 winter.**
  - **PDO continued to be above-normal, with PDOI=0.7 in June 2015.**

- **Indian Ocean**
  - **Positive SSTAs dominated the whole Indian Ocean.**

- **Atlantic Ocean**
  - **Horseshoe-like pattern of SSTA continued in N. Atlantic.**

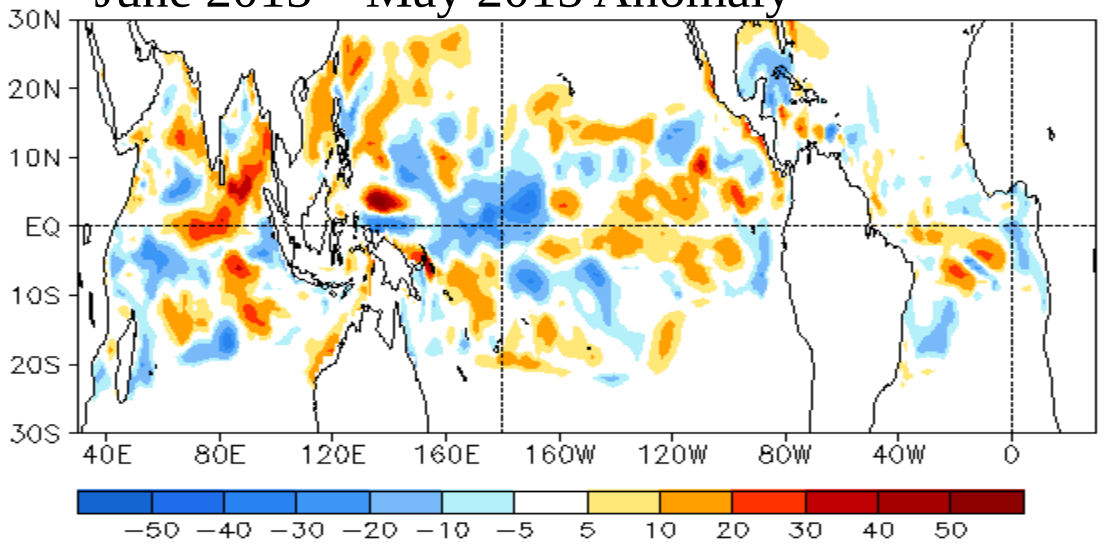
Backup Slides

Tropical Cyclone Heat Potential Anomaly and Tendency (KJ/cm^2]



- **Strong positive TCHP anomalies presented in the central and eastern equatorial Pacific.**
- **TCHP anomalies were near normal over the tropical Atlantic Ocean.**

June 2015 – May 2015 Anomaly



- **Positive TCHP anomaly tendency was observed in the eastern equatorial Pacific .**

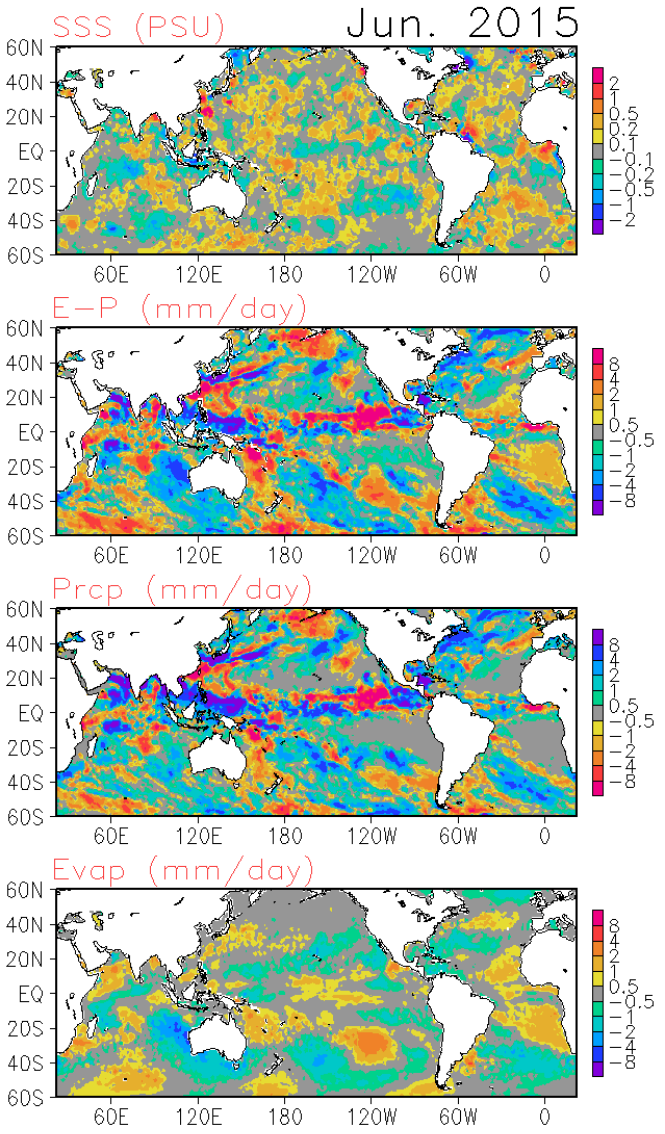
TCHP field is the anomalous heat storage associated with temperatures larger than 26 ℃.

Global Sea Surface Salinity (SSS)

Tendency for June 2015

- Though not as organized as in the anomaly maps, zonally oriented belts of negative / positive SSS tendency is observed over the equatorial Pacific in response to the changes in the E-P fields;

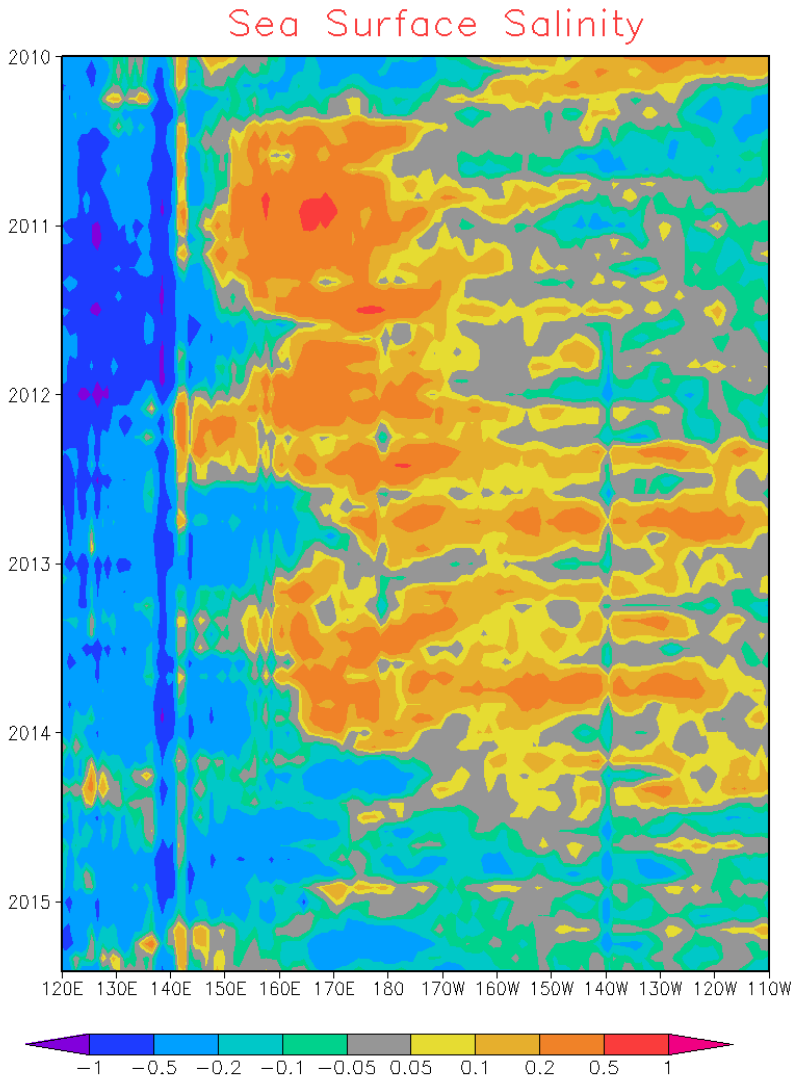
- Positive SSS tendencies are also noticed over SW Pacific over regions of SPCZ.



Global Sea Surface Salinity (SSS)

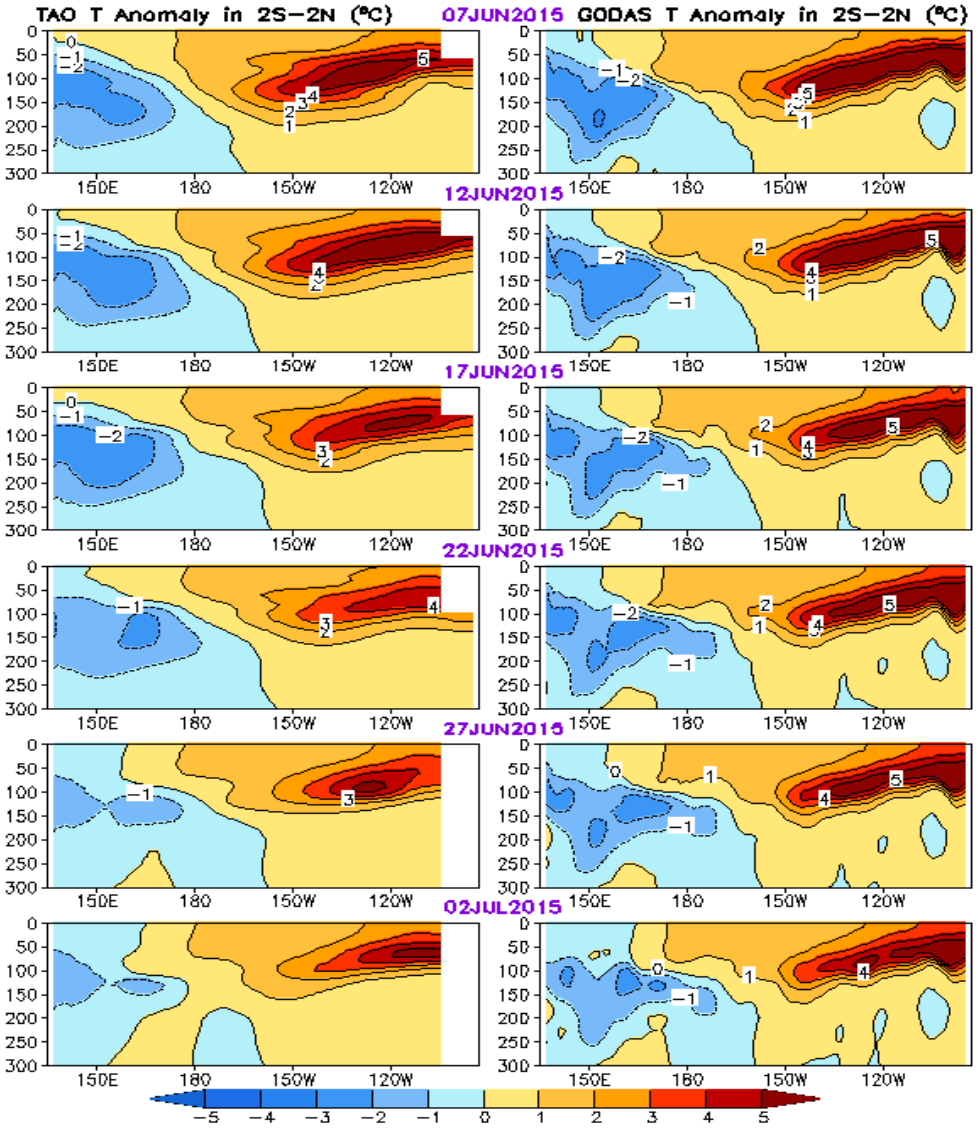
Anomaly Evolution over Equatorial Pacific

- Hovemoller diagram for equatorial SSS anomaly **(10°S-10°N);**
- Negative SSS anomaly continued to cover the majority the entire equatorial Pacific, though the intensity of negative SSS anomaly near the dateline appears weaker than the previous months;



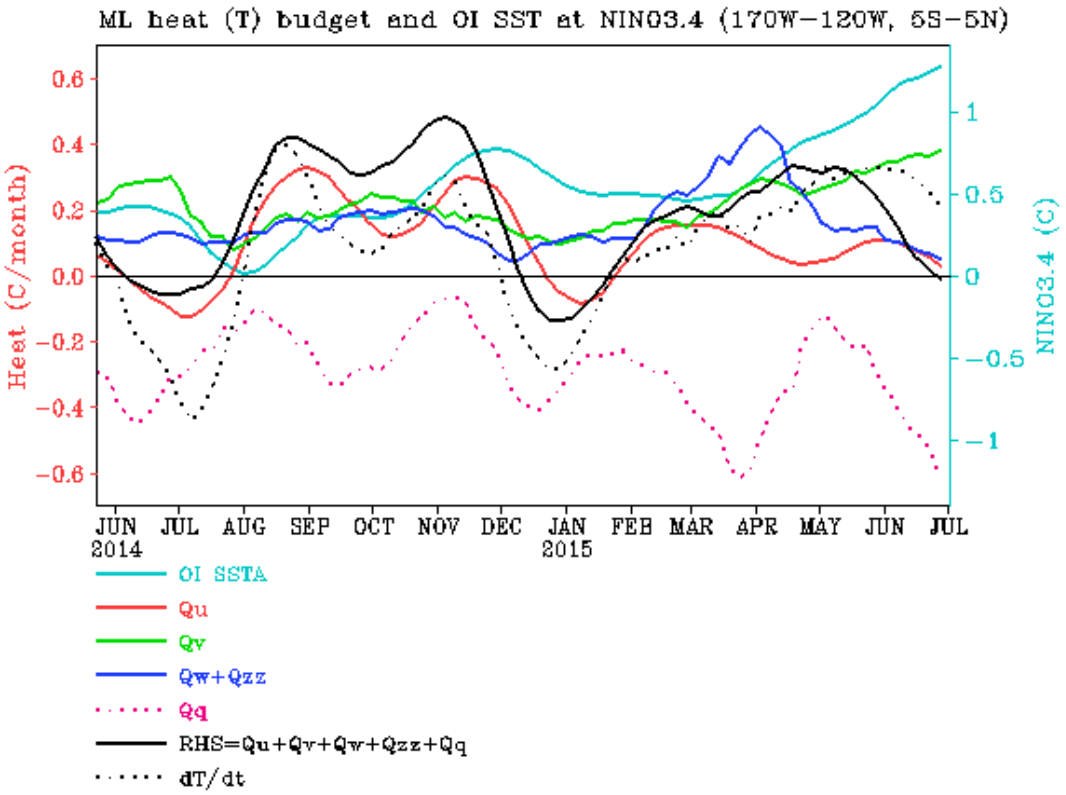
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

TAO GODAS



- **Strong positive ocean temperature anomalies persisted in the eastern Pacific.**
- **Area with negative temperature anomaly in the western Pacific contracted in the last two pentads.**

NINO3.4 Heat Budget



- Observed SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) was positive since mid-Jan 2015.

-All dynamical terms (Qu, Qv, Qw+Qzz) were positive since Feb 2015, and heat flux term (Qq) was negative.

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

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

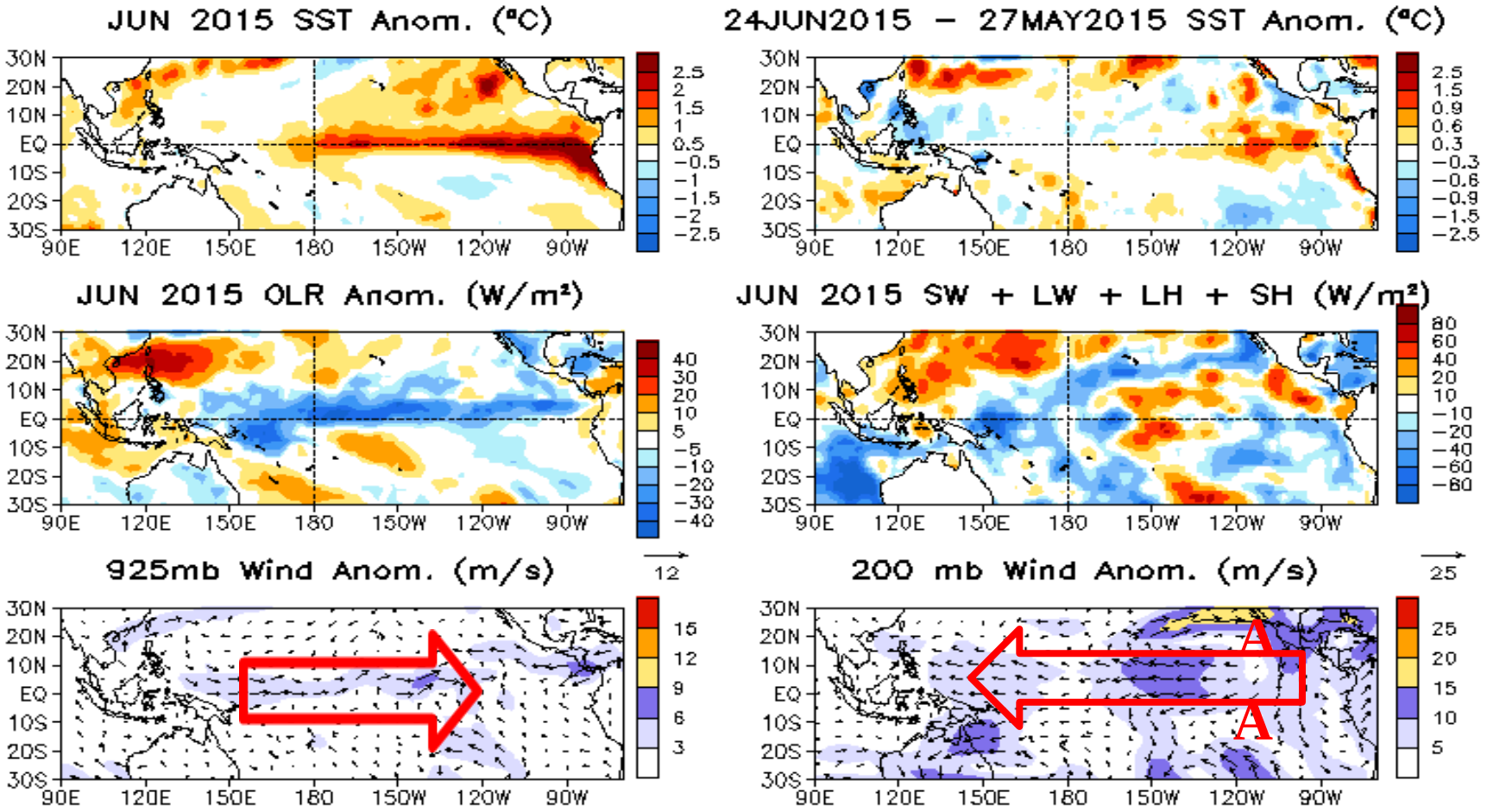
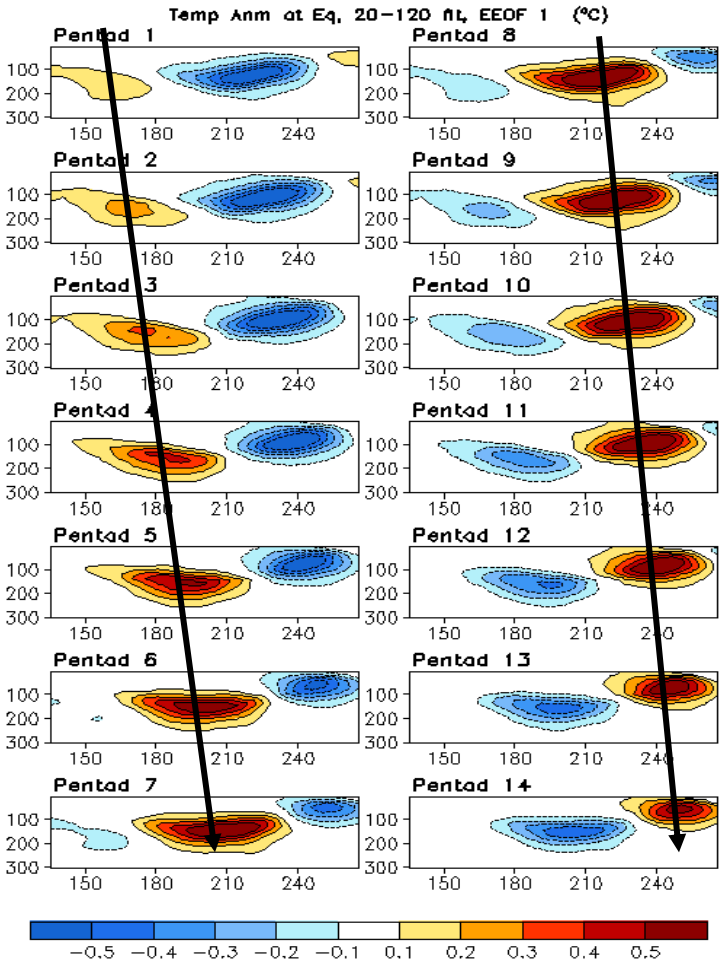
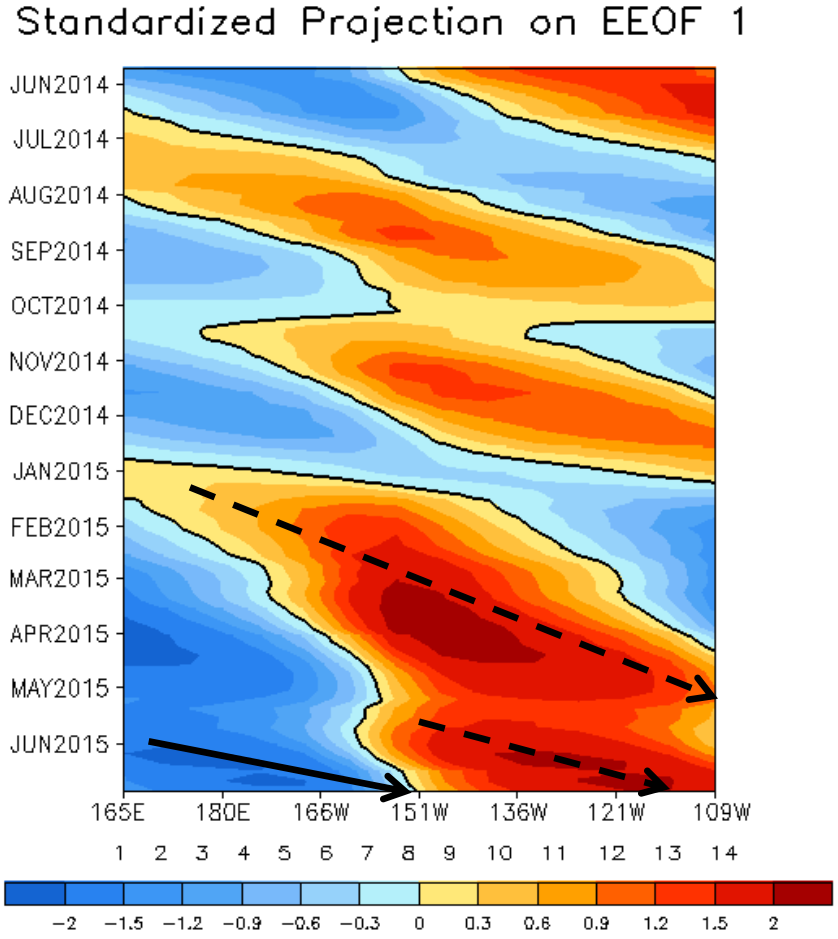


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Oceanic Kelvin Wave (OKW) Index





- **Downwelling OKW (dash line) initiated in May has propagated to far eastern Pacific.**
- **A upwelling OKW (solid line) initiated in the western Pacific since early June.**

(OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)

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

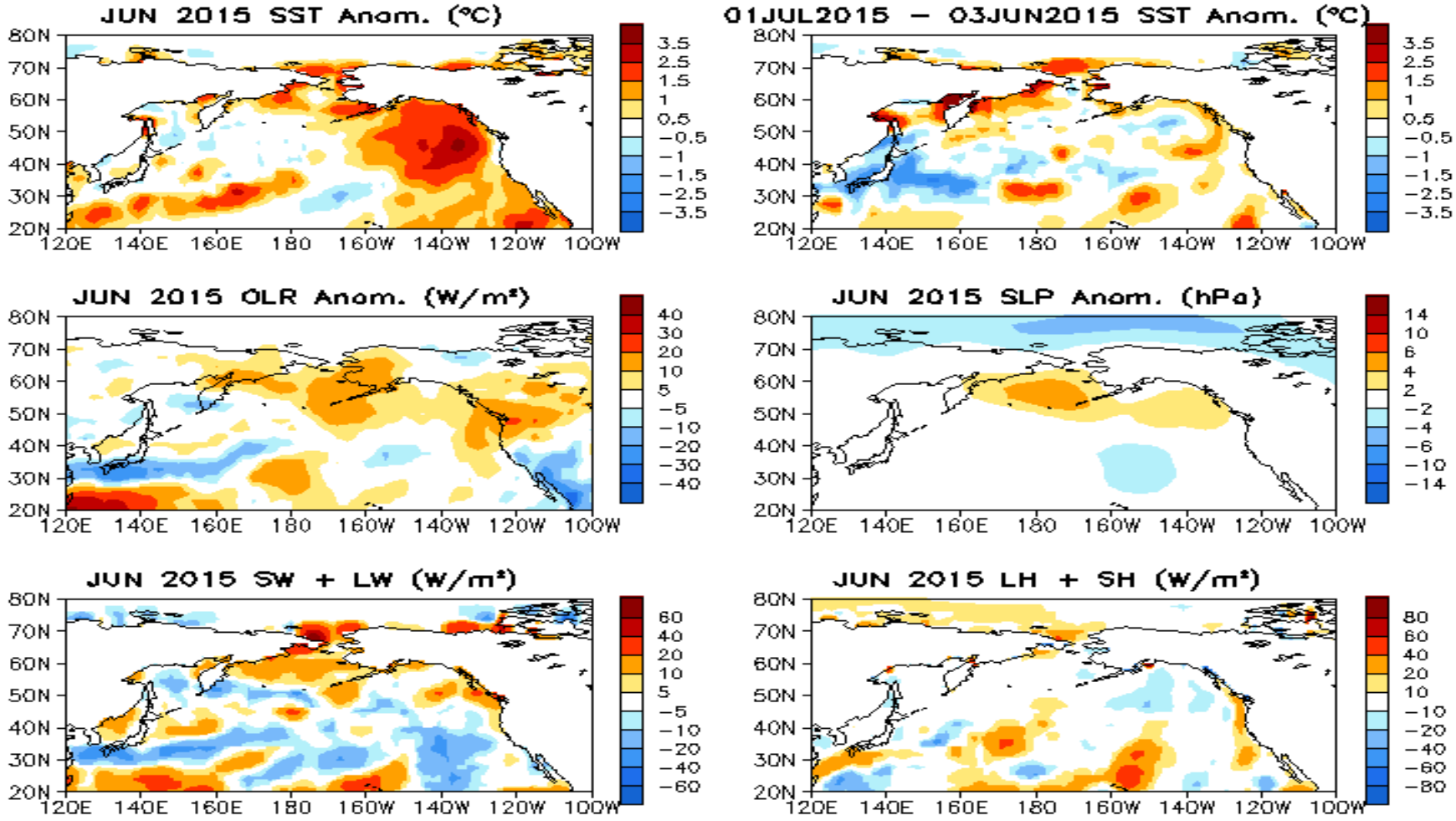
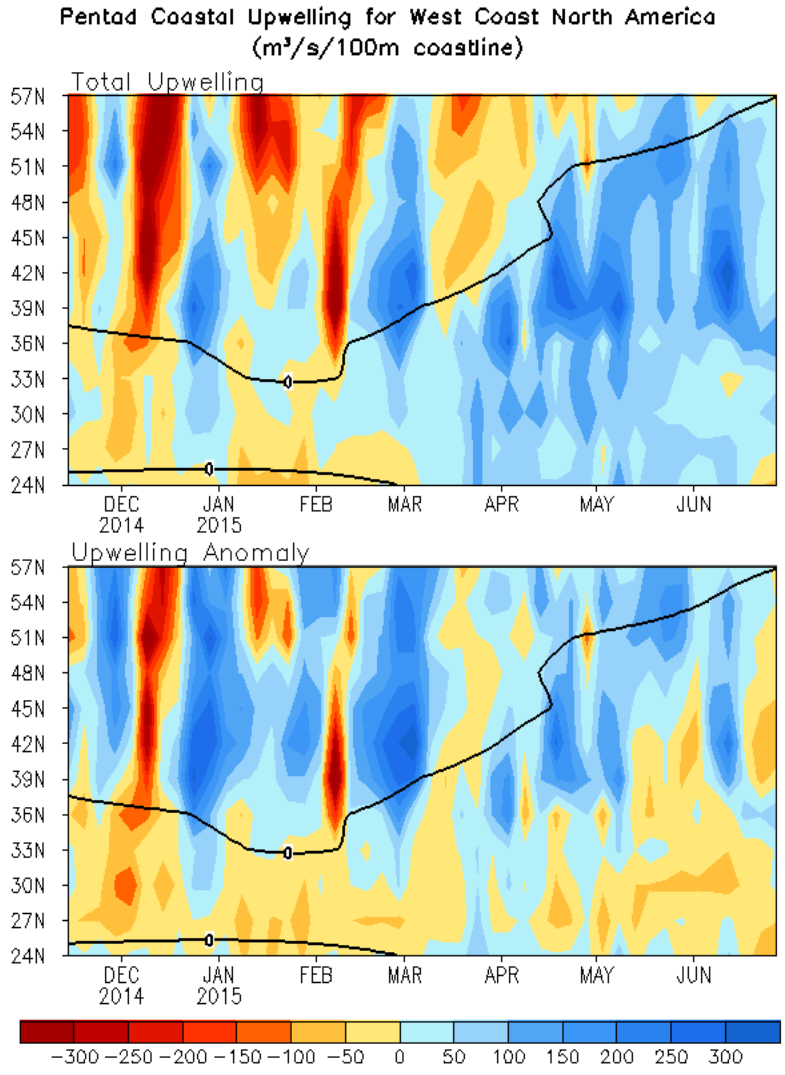
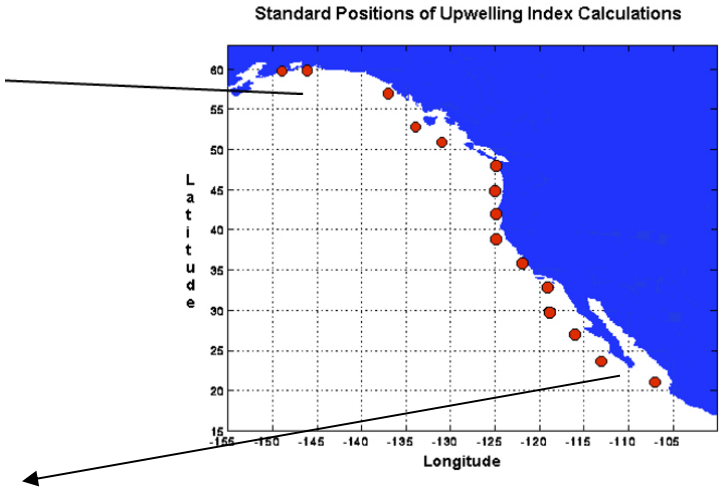


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

North America Western Coastal Upwelling



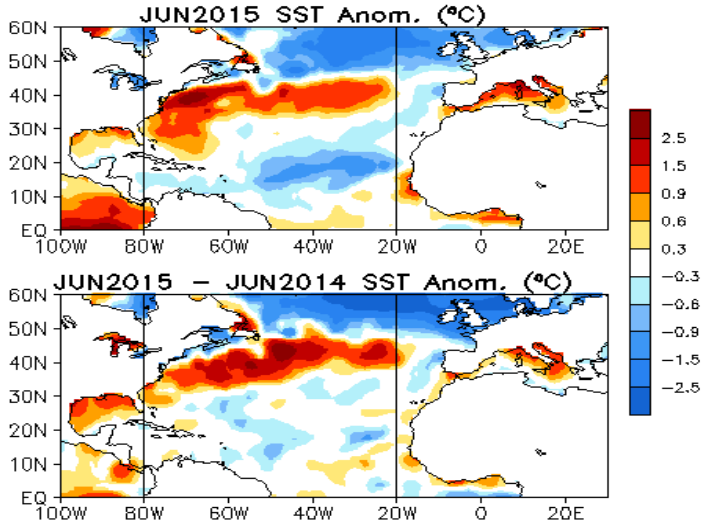


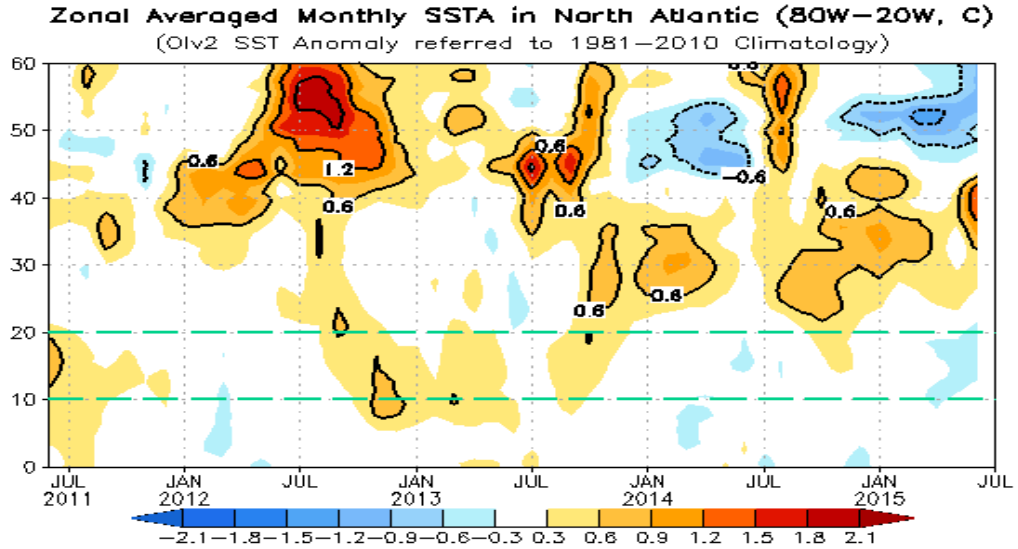
• **Both anomalous upwelling and downwelling were observed in Jun. 2015.**

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 Mar to Jul along the west coast of North America from 36ºN to 57ºN.**

NAO and SST Anomaly in North Atlantic





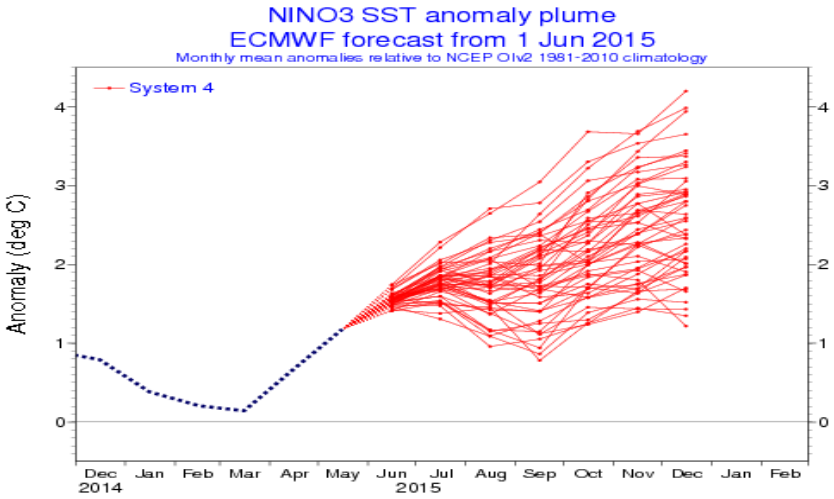
- **Positive phase of NAO has persisted 7 months and weakened with NAOI=XXXX in June 2015.**

-Horseshoe-like pattern continued in N. Atlantic Ocean.

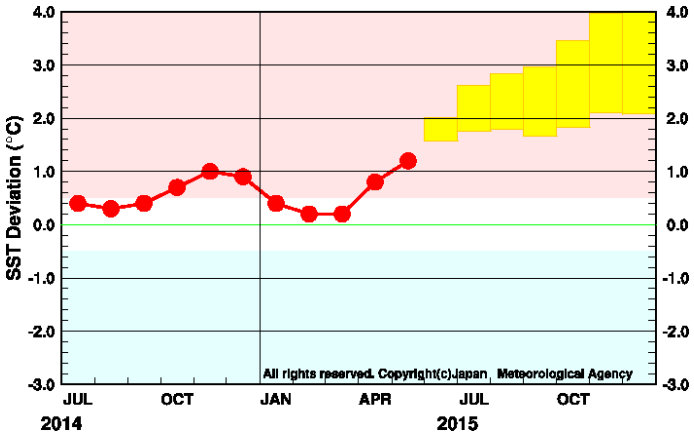
Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

Individual Model Forecasts: strong warming or little tendency

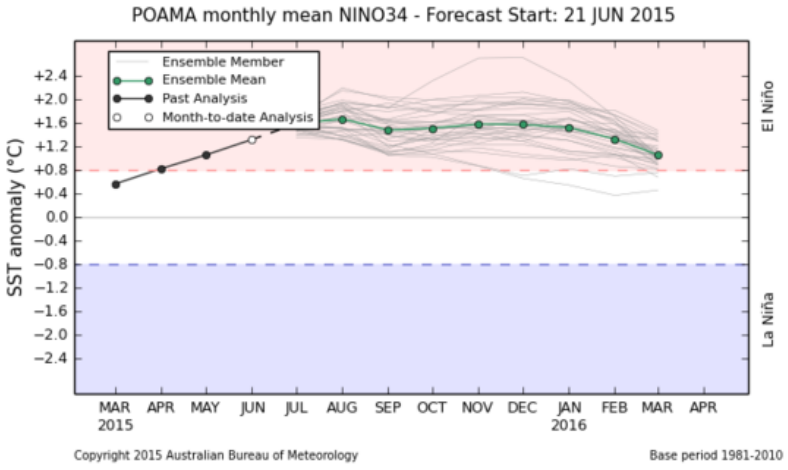
EC: Nino3.4, IC=01 June 2015



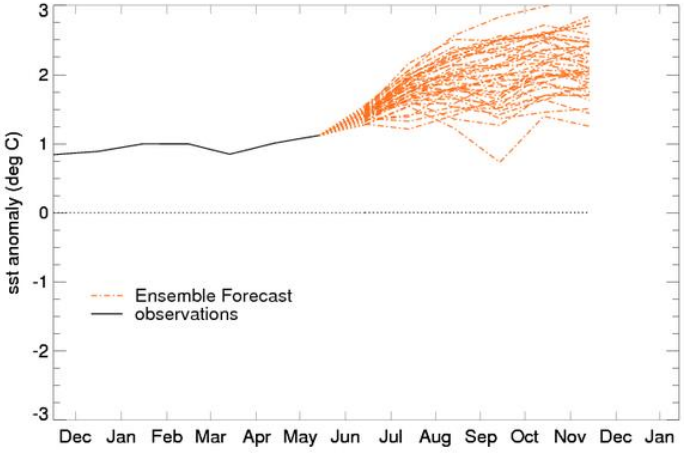
JMA: Nino3, IC=May2015



Australia: Nino3.4, IC= 21Jun 2015



UKMO: Nino3.4, IC=June 2015



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

- **SST warming occupied the whole basin.**

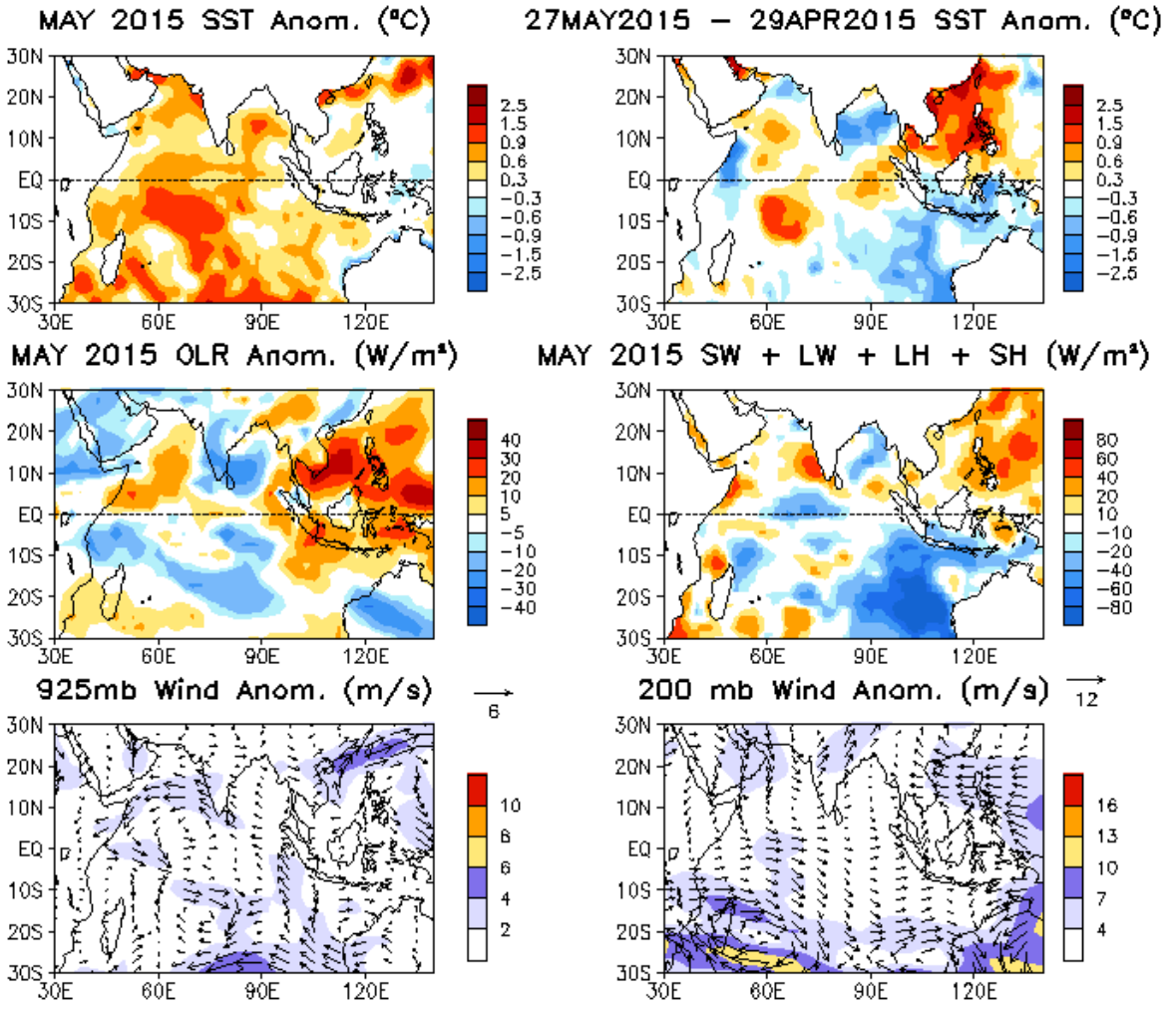
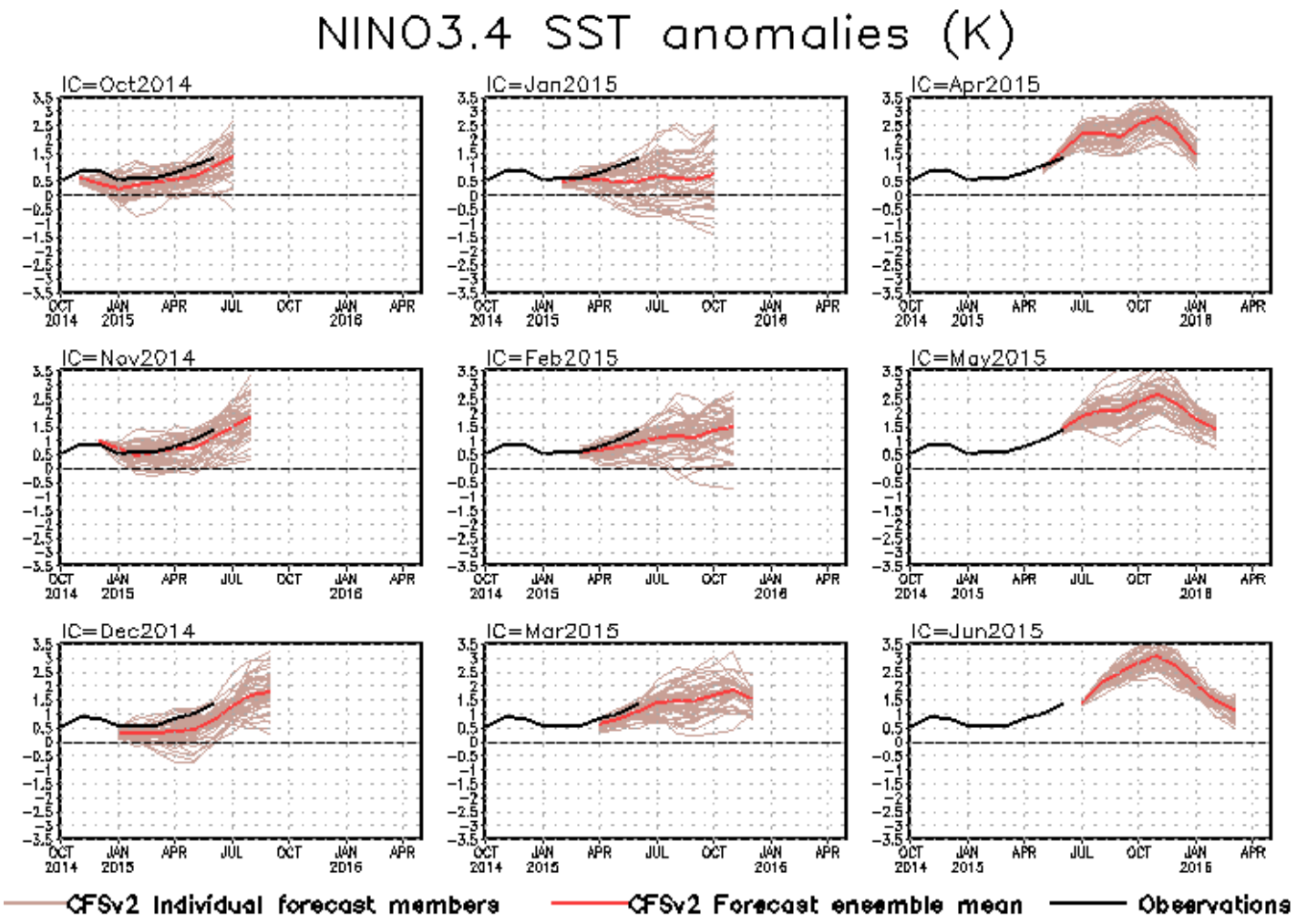


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

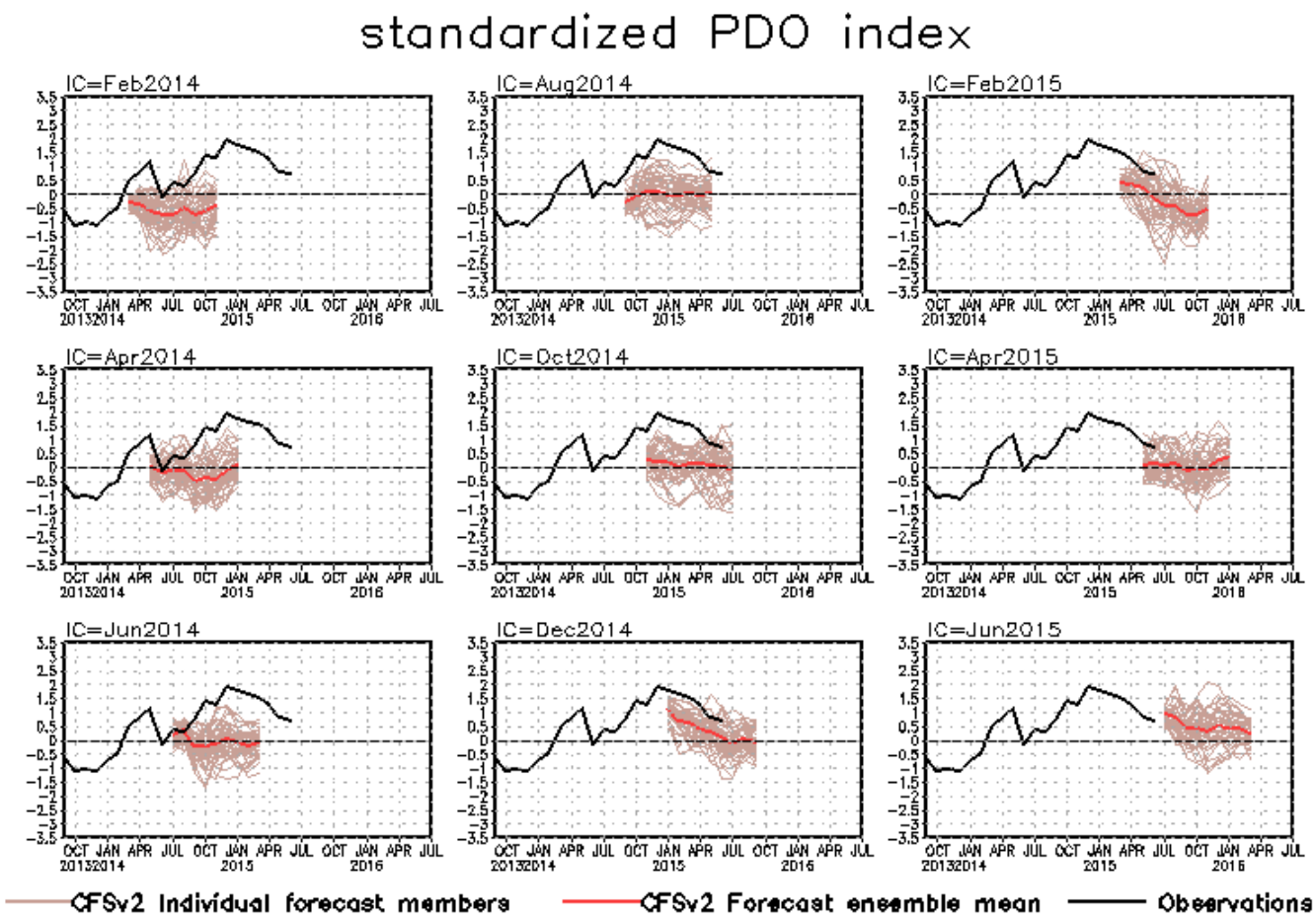
CFS Niño3.4 SST Predictions from Different Initial Months



- CFSv2 predicts a strong El Nino event through out the fall-winter 2015.

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 (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

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



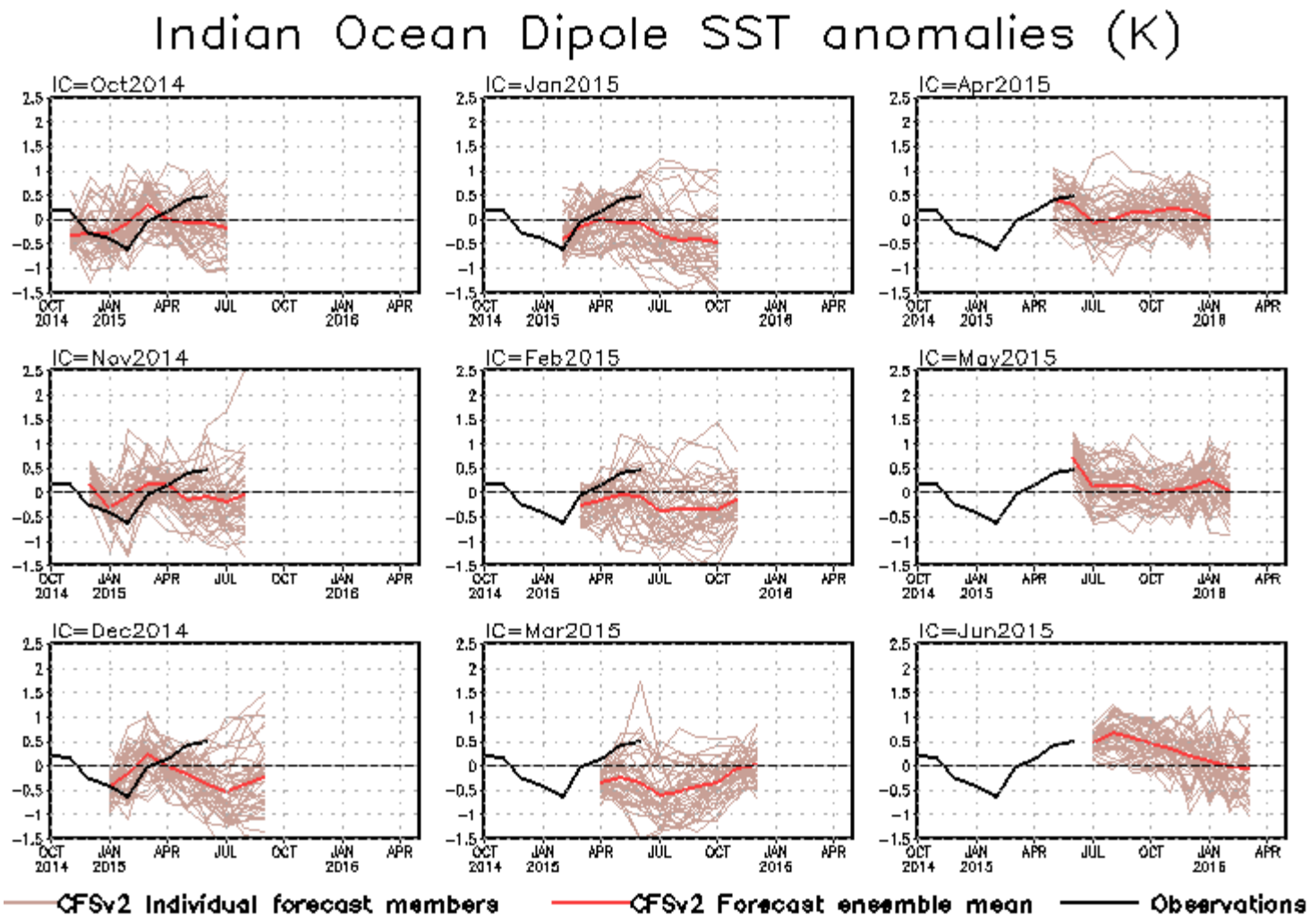
PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

- Forecast from Jun IC calls for above-normal PDO through out northern hemisphere fall-winter 2015.

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 (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

NCEP CFS DMI SST Predictions from Different Initial Months



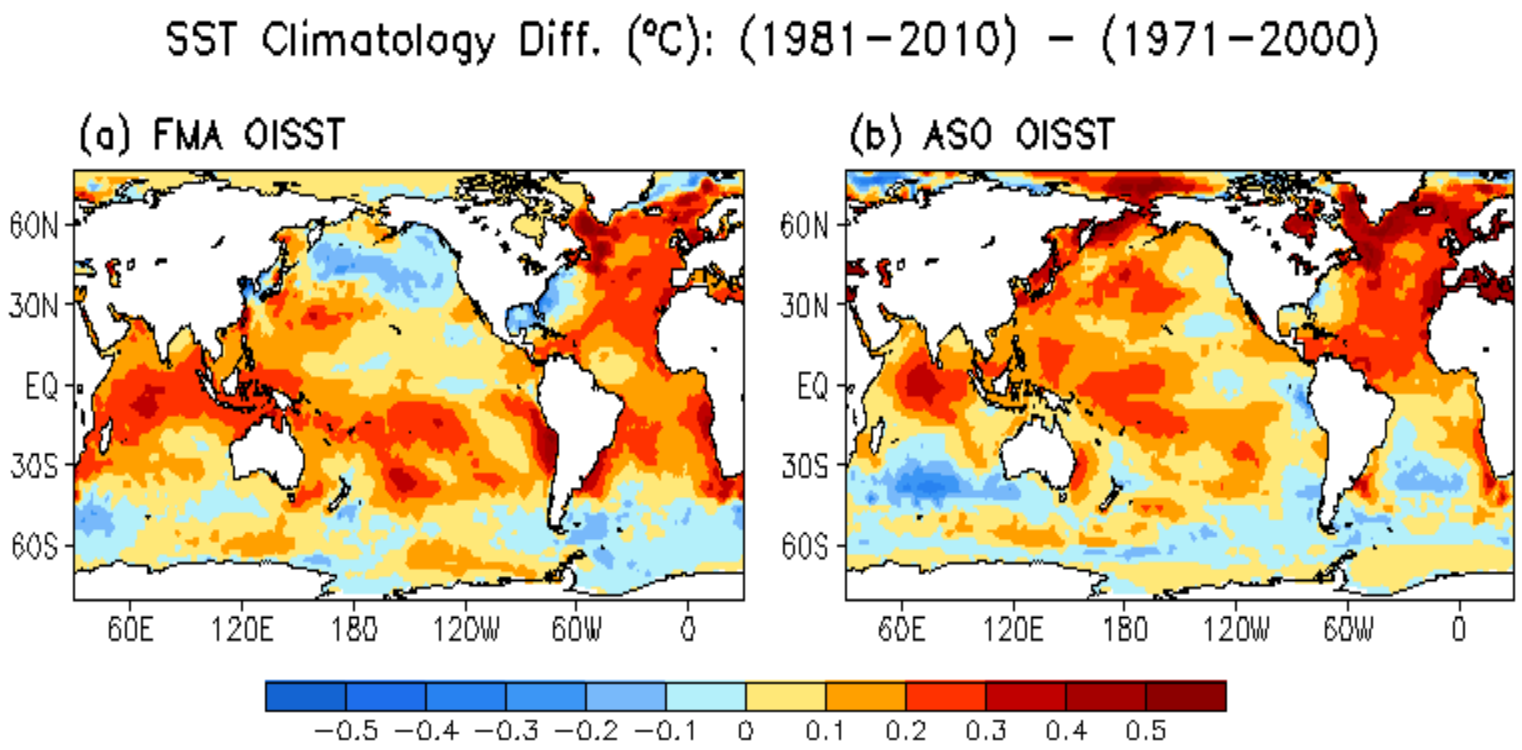
DMI = WTIO- SETIO

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.

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.**

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)**

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!