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's Climate Observation Division (COD)

Outline

- **Overview**

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

  El Niño conditions

  NE Pacific conditions
  - Indian Ocean

  IOD conditions
  - Atlantic Ocean

- **Global SST Predictions**

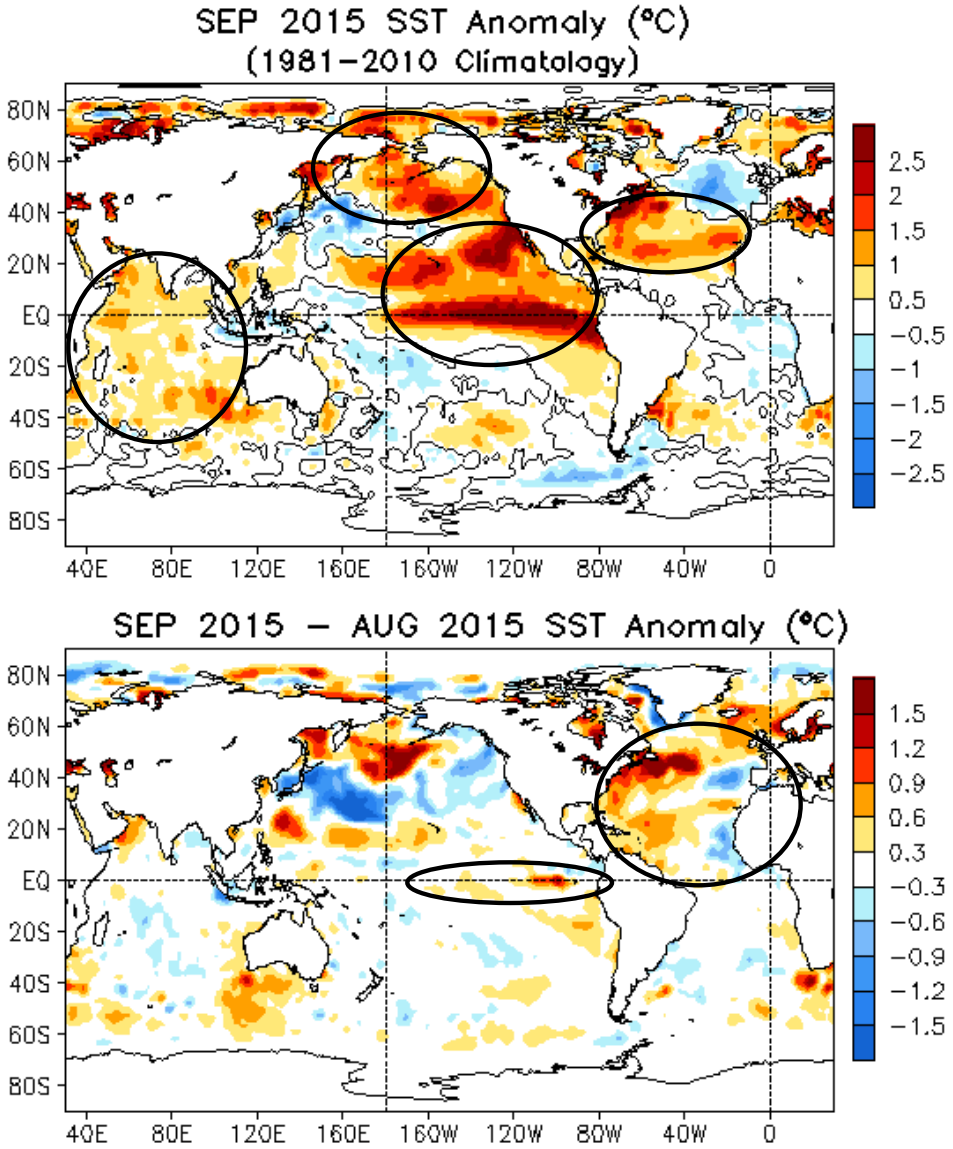
Is the amplitude of NINO3.4 going to exceed 2°C in winter 2015/2016?

Overview

- **Pacific Ocean**
  - **El Niño conditions further strengthened in Sep. 2015 and the atmospheric and oceanic anomalies reflect a strong El Niño.**
  - **Most model predictions called for a strong El Niño through the Northern Hemisphere fall-winter 2015.**
  - **Upper ocean warming associated with the "Blob" has persisted since winter 2013/2014.**
  - **Positive PDO weakened, with PDOI = 1.1 in Sep. 2015.**
- **Indian Ocean**
  - **Positive SSTAs continued in the whole Indian Ocean.**
  - **India Dipole Mode index increased to about 1°C above-normal.**
  - **NCEP CFSv2 predicted a positive India Dipole event through Nov.2015.**
- **Atlantic Ocean**
  - **SSTA were well above-average along the eastern coast of North America.**

Global Oceans

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

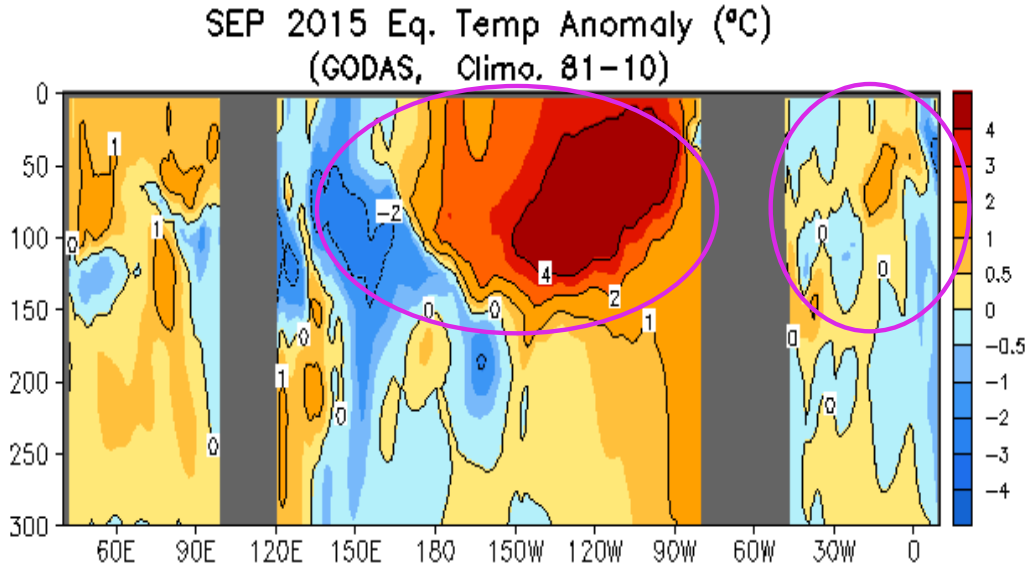


- **SSTA exceeded +2°C across the central and eastern equatorial Pacific Ocean.**
- **Strong positive SSTA persisted in the high-latitude of the North Pacific Ocean and Artic Ocean.**
- **SSTA were well above-average along the eastern coast of North America.**
- **Positive SSTA continued in the Indian Ocean.**

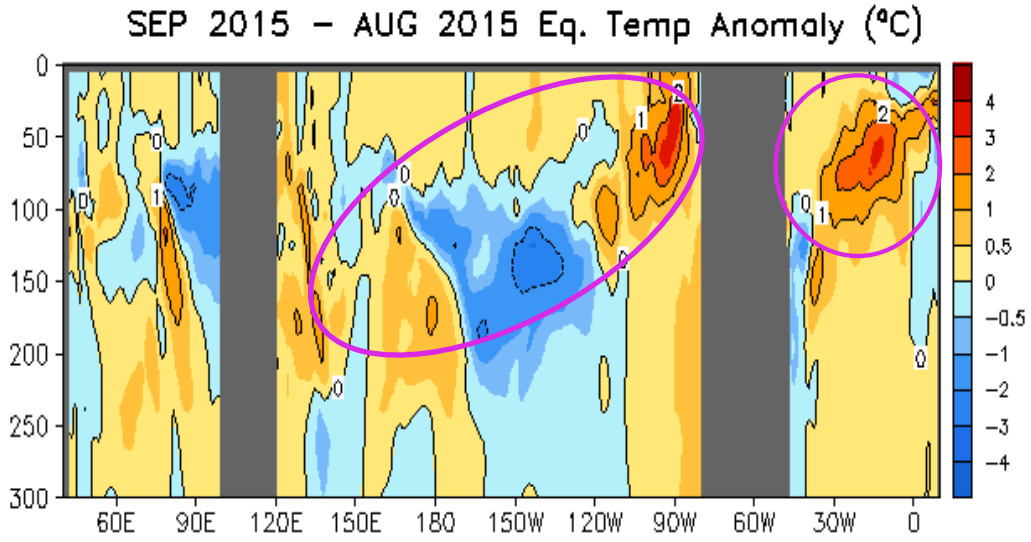
- **Positive SSTA tendency presented in the eastern equatorial Pacific.**
- **SST tendencies were large in the North Pacific.**
- **Positive SSTA tendency dominated much of the north Atlantic Ocean.**

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



- **Subsurface temperature anomalies were well above average across the central-eastern equatorial Pacific.**
- **Subsurface warming conditions persisted in the Indian Ocean.**
- **Positive temperature anomalies dominated in the upper Atlantic Ocean.**

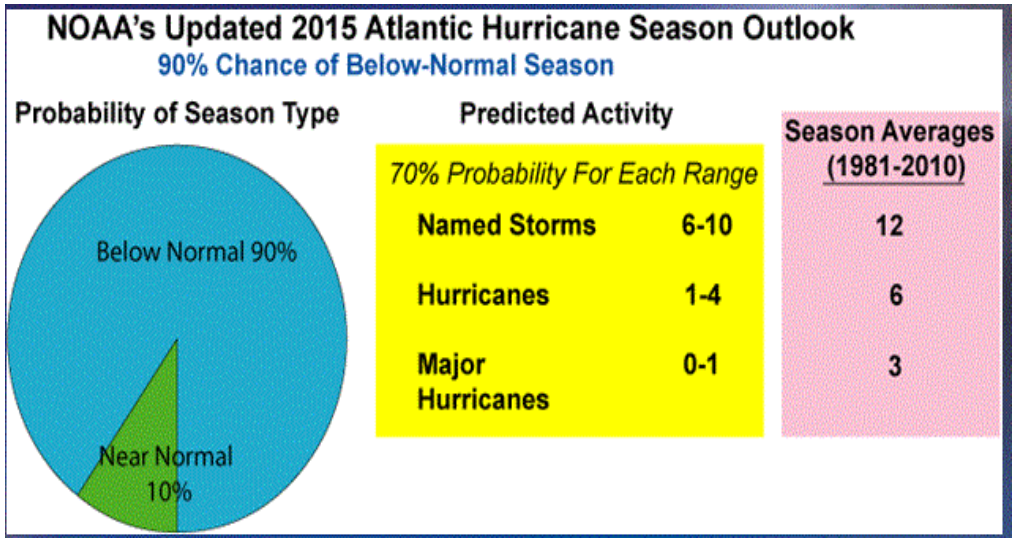


- **Warming (cooling) tendency presented in the western and far eastern Pacific (central Pacific).**
- **Positive subsurface temperature tendency dominated the upper Atlantic Ocean.**

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.

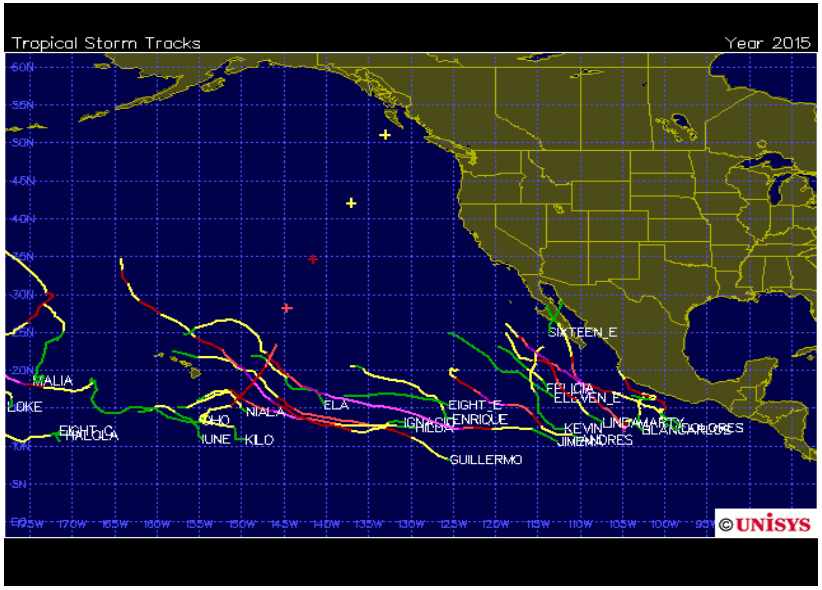
NOAA's Updated 2015 Atlantic Hurricane Season Outlook

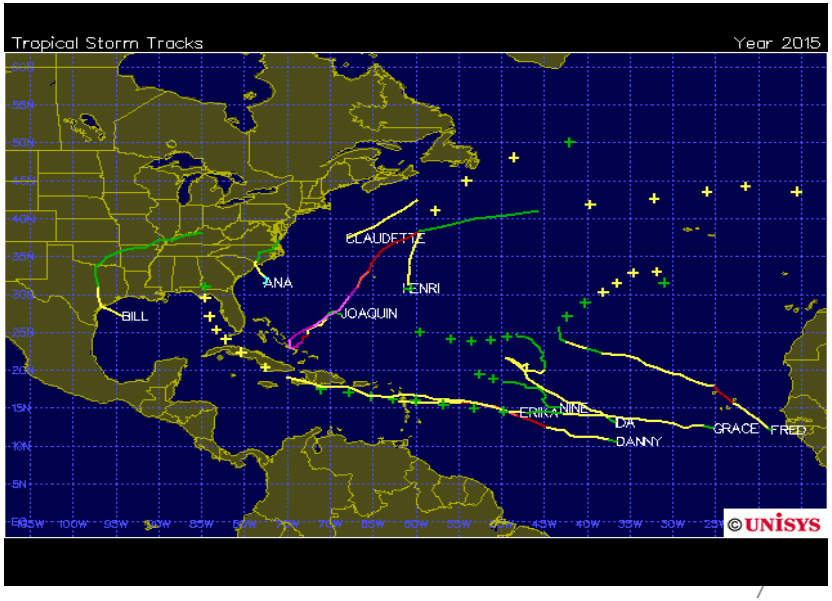
(http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane2015/)



- 10 tropical storms with 3 reaching hurricane category formed in the tropical North Atlantic by Oct. 7.

- 21 tropical storms with 13 reaching hurricane category formed in the eastern Pacific by Oct. 7.

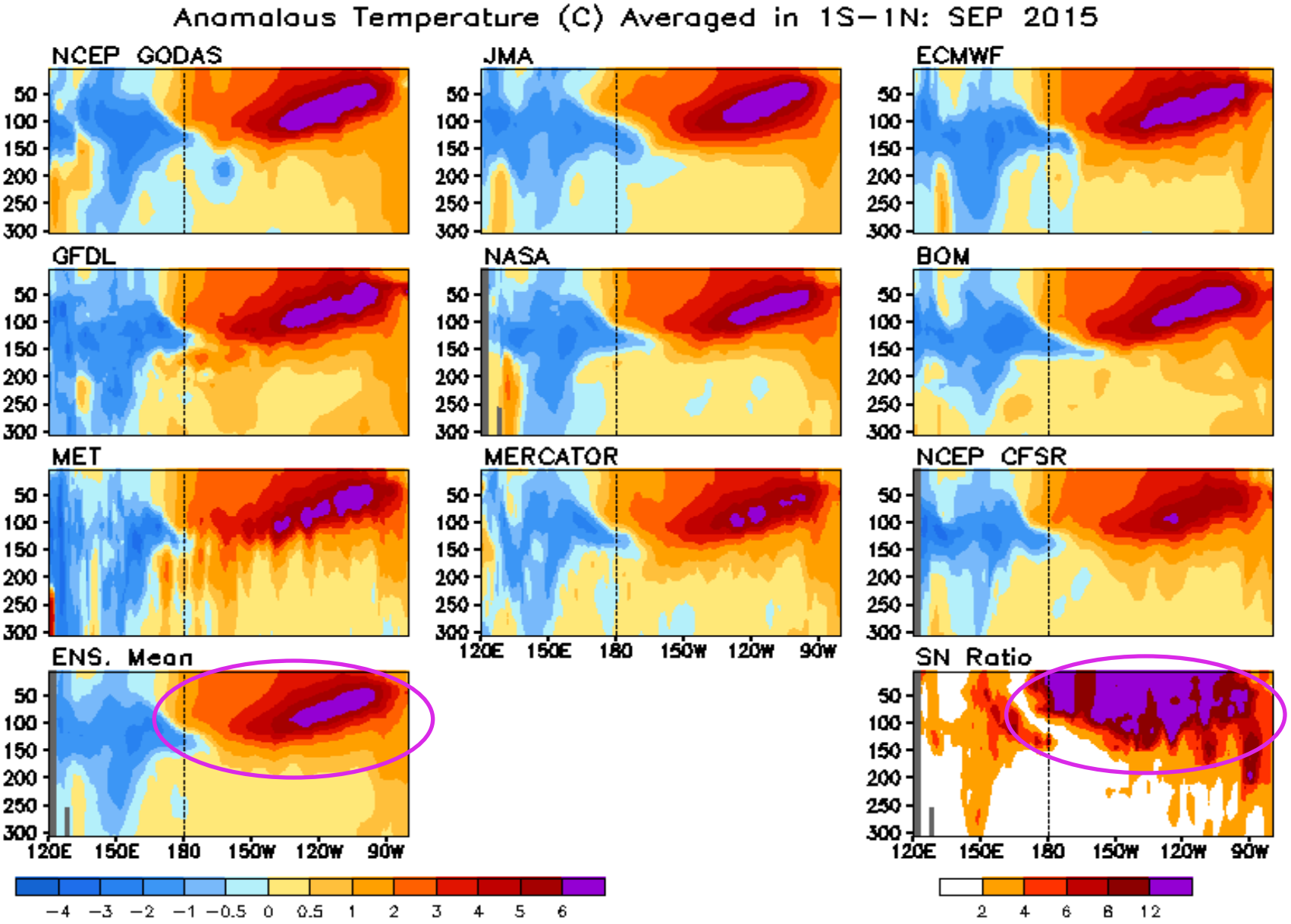




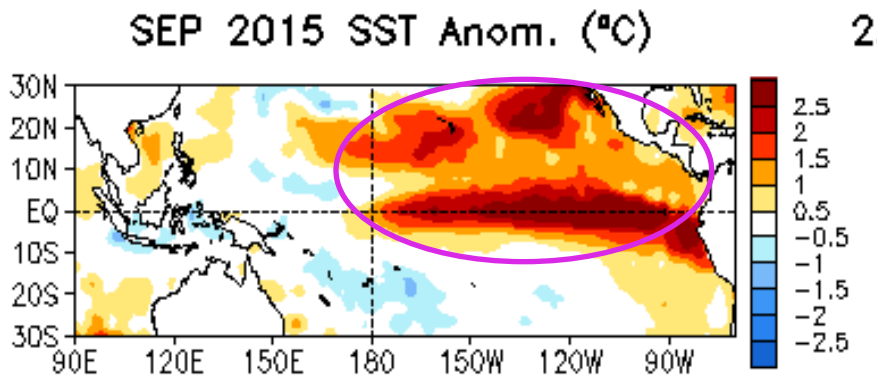
(http://weather.unisys.com/hurricane/)

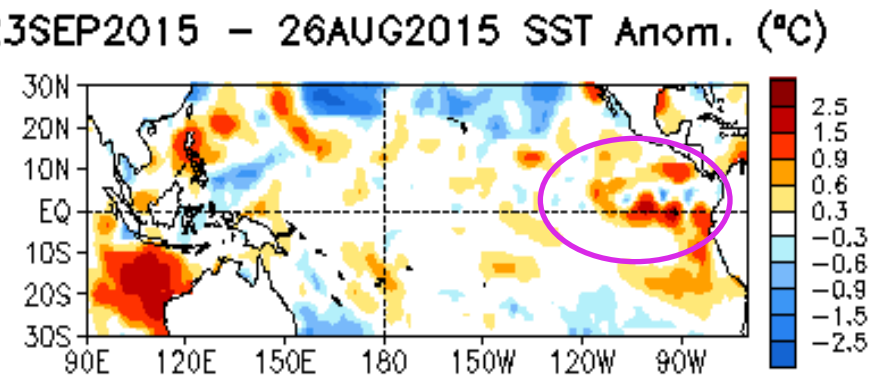
Tropical Pacific Ocean and ENSO Conditions

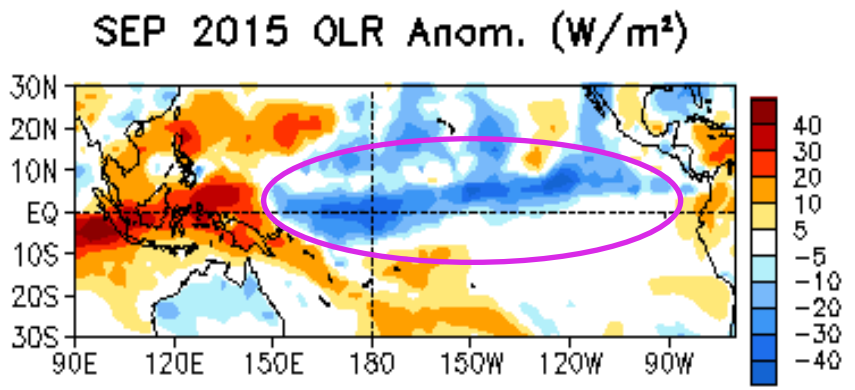
Real-Time Multiple Ocean Reanalyses Intercomparison
(1993-2013 Climatology)

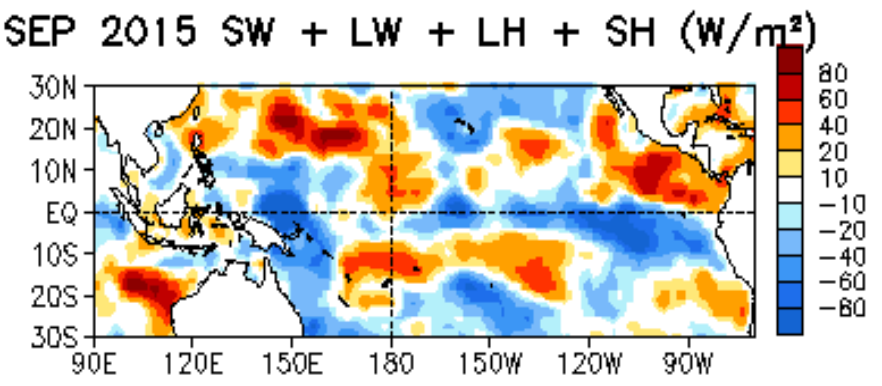


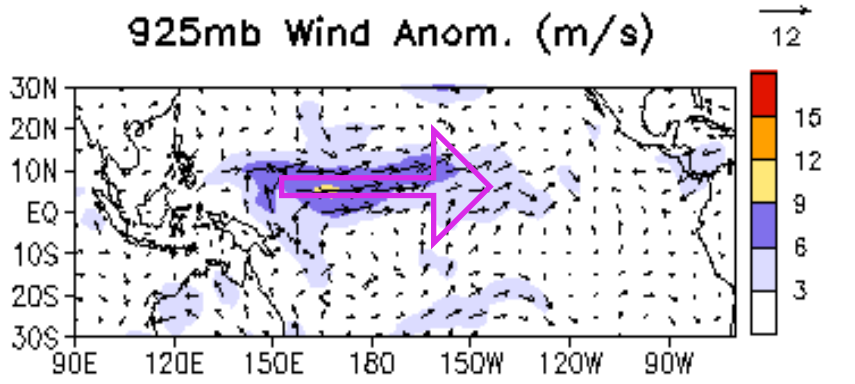
Tropical Pacific: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds

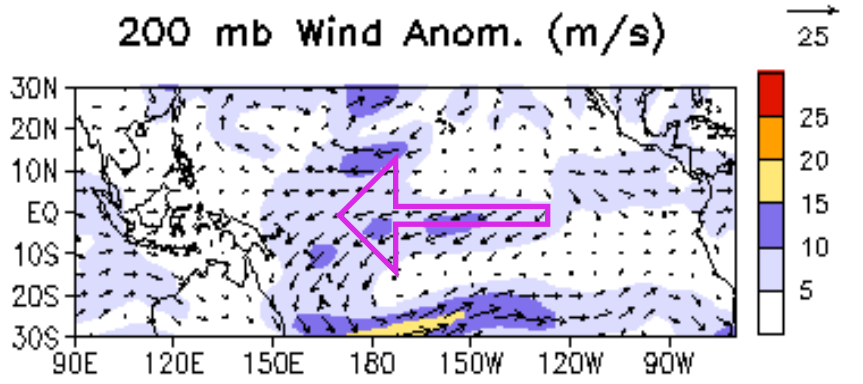










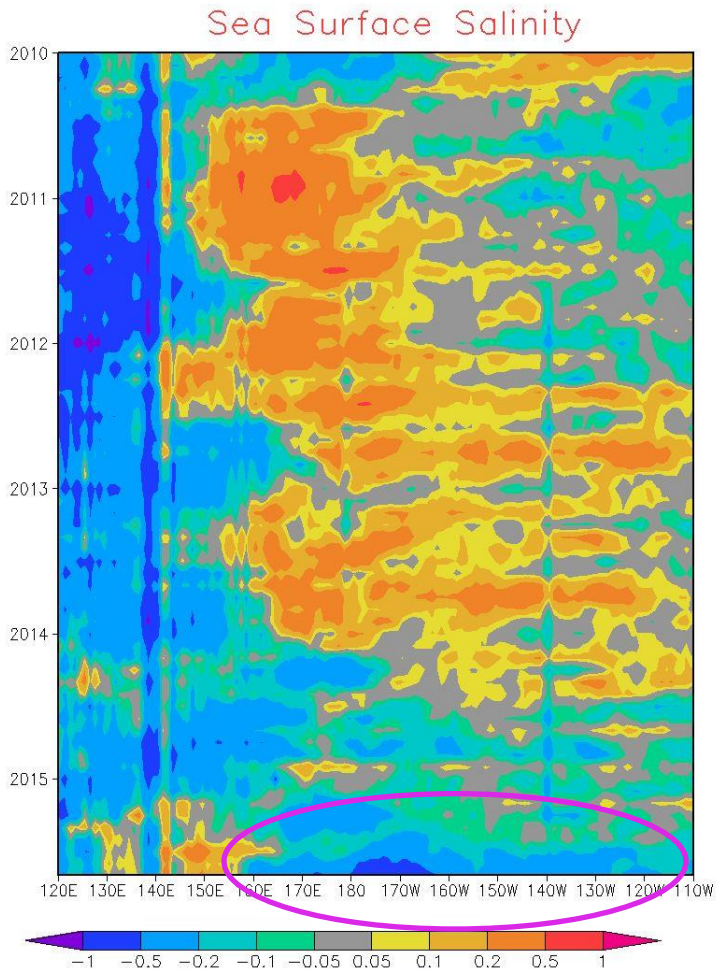


Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific

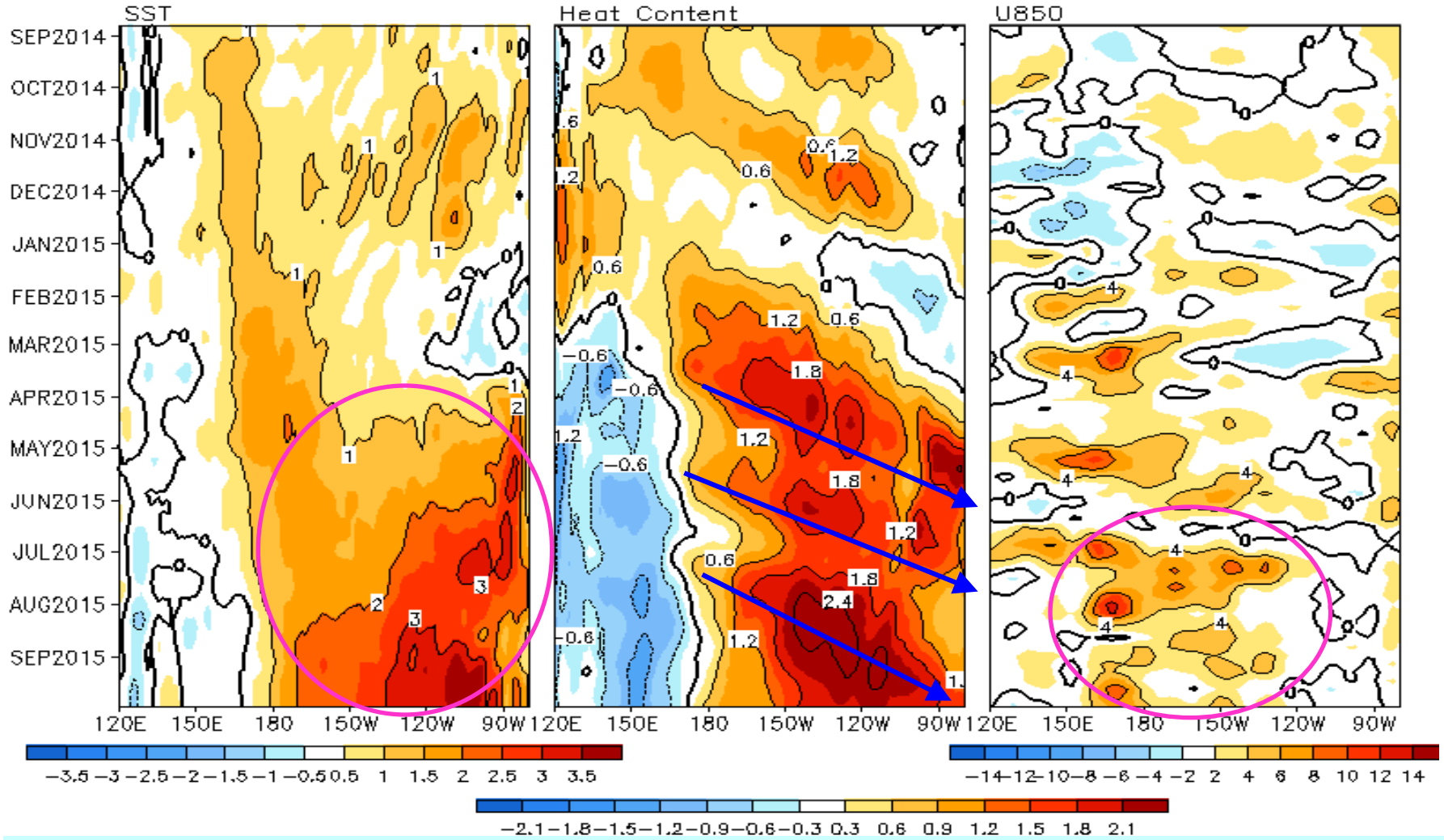
- Hovemoller diagram for equatorial SSS anomaly **(10ºS-10ºN);**

- Negative SSS anomaly continues to strengthen over the central and eastern Pacific, with the maximum SSS anomaly around 170ºW enhanced during this month. At the meantime, a stretch of positive SSS anomaly continues over the western Pacific from 130ºE – 160ºE;



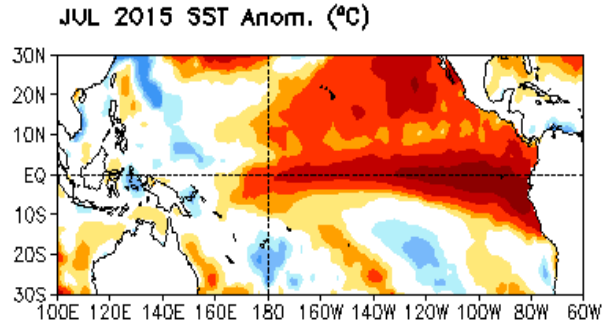
Equatorial Pacific SST (°C). HC300 (°C). u850 (m/s) Anomalies

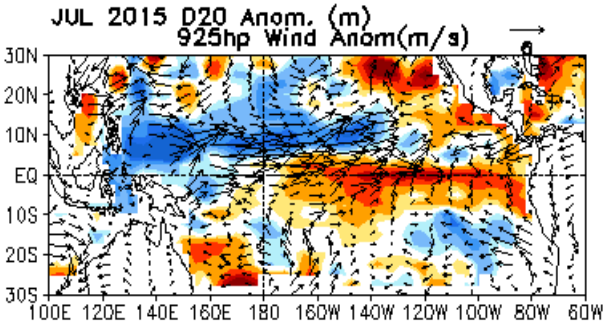
2°S–2°N Average, 3 Pentad Running Mean

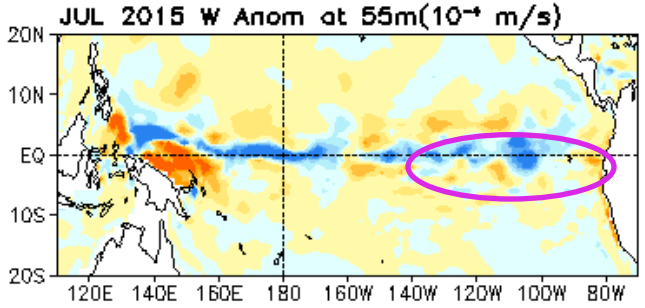


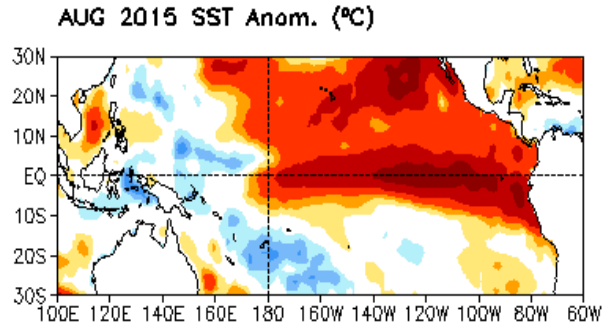
- **Positive SST anomalies in the eastern Pacific have strengthened significantly in Aug-Sep. 2015, which were associated with the strong downwelling Kelvin wave initiated in July.**
- **Westerly wind anomalies in the central-eastern Pacific were strongest in July and weakened somewhat since then.**

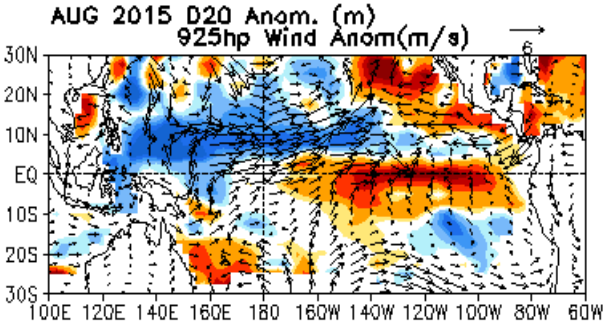
Last Three Month SST, D20&925hp Wind and Vertical Velocity Anomalies at 55m

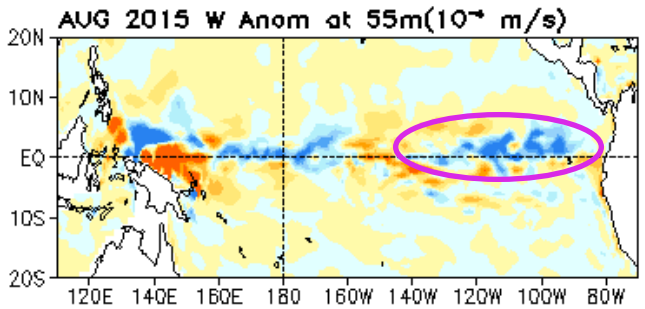


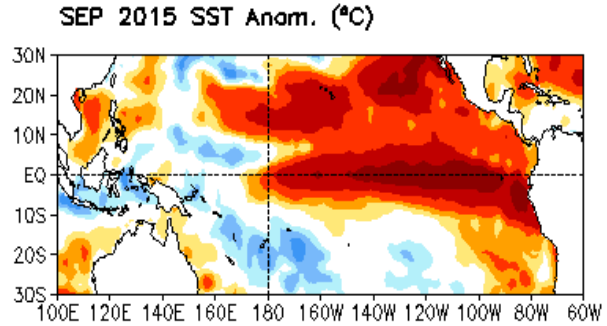


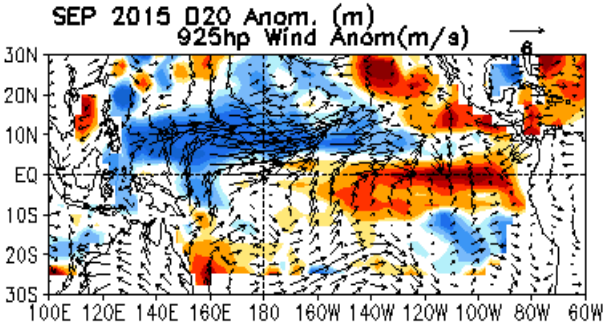


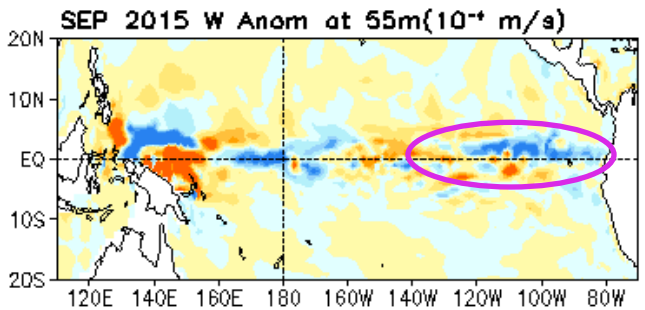






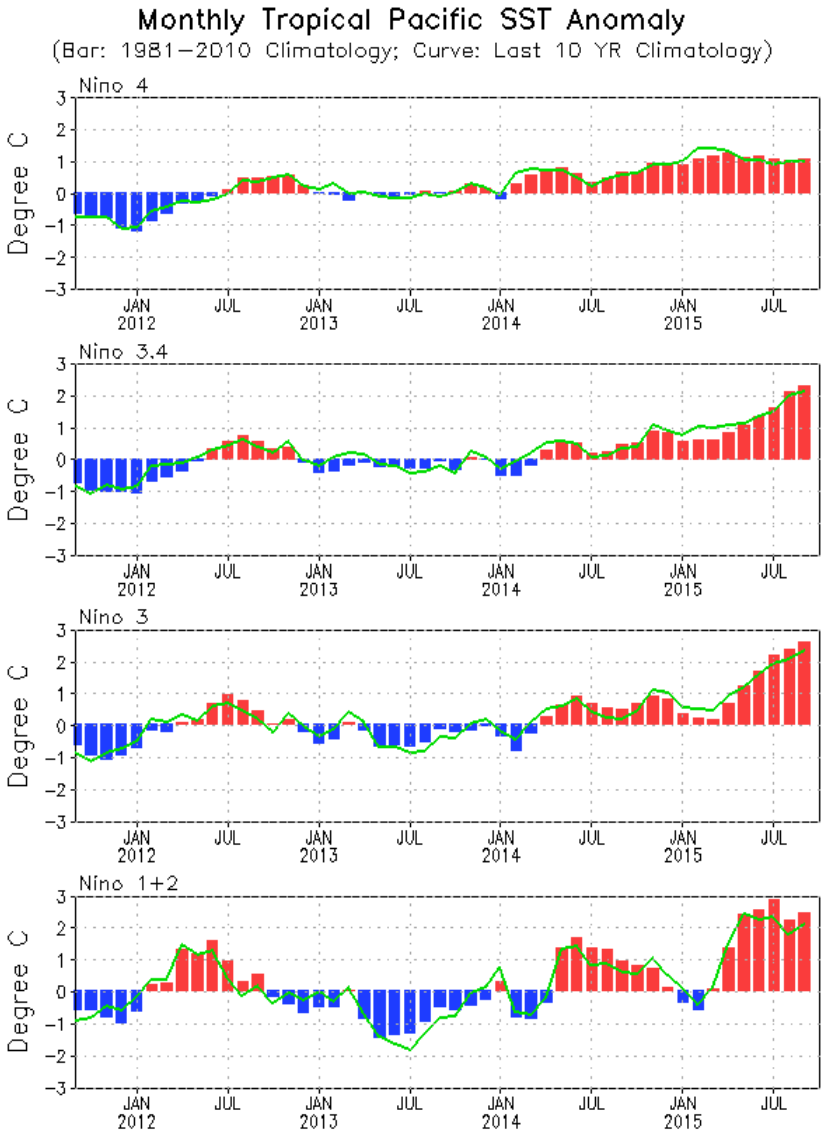


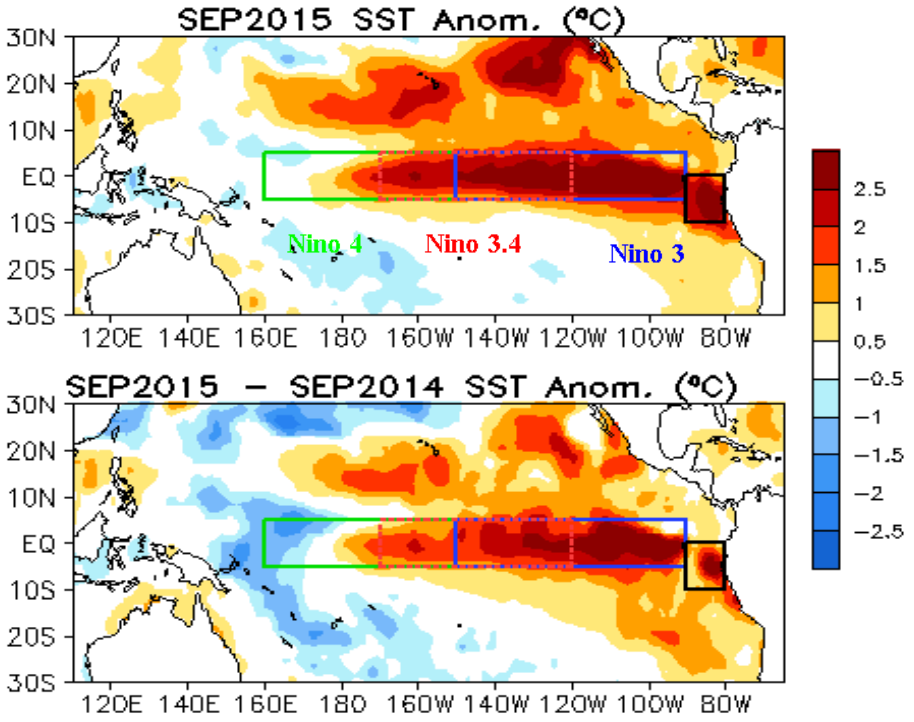




- **Area covered by strong positive anomalies (>1.5°C) has increased in the past three months.**
- **Westerly low-level wind anomalies persisted over the central and eastern Pacific.**
- **Strong positive d20 anomalies persisted in the central-eastern Pacific, and negative d20 anomalies existed north of the equator. This dipole pattern resembled the typical features of ENSO development.**
- **Ocean vertical velocity anomalies at 55m were below-averaged across much of the central-eastern equatorial Pacific since Jul. 2015, consistent with the strengthening of equatorial SST warming.**

Evolution of Pacific NINO SST Indices





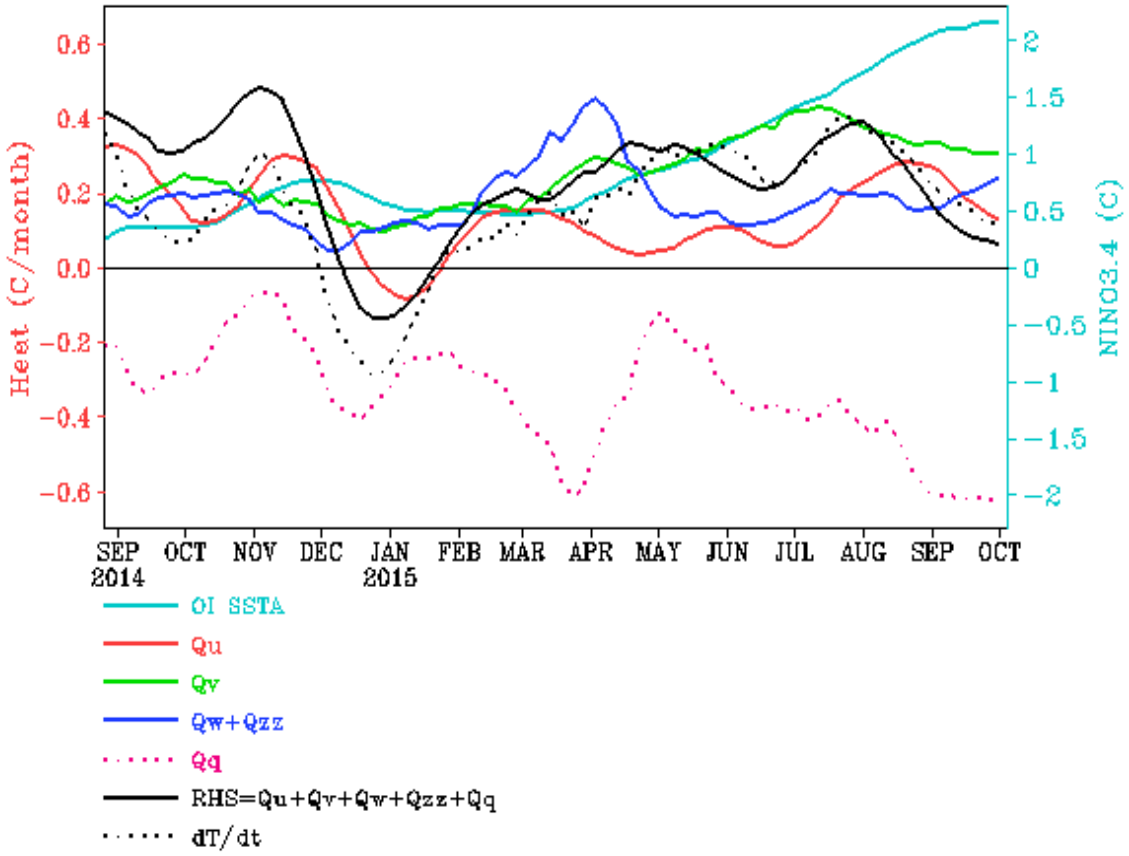
- **Nino 3.4, Nino 3 and Nino 1+2 indices exceeded 2.°C in Sep. 2015.**

- **Nino3.4 = 2.3 °C in Sep. 2015 and ranks the warmest September since 1982.**

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

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.

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;

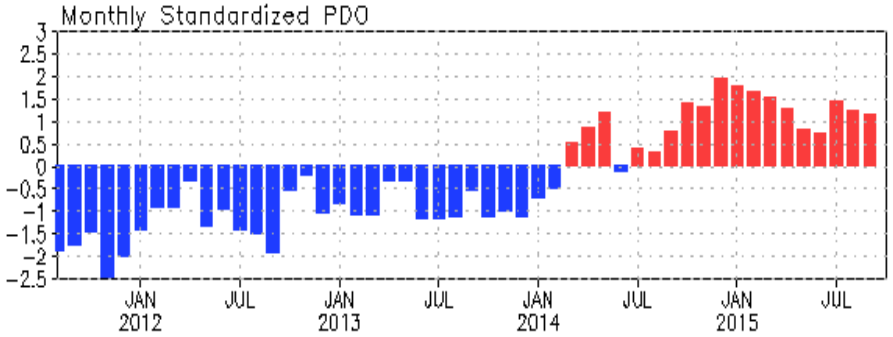
Qw: Vertical entrainment; Qzz: Vertical diffusion

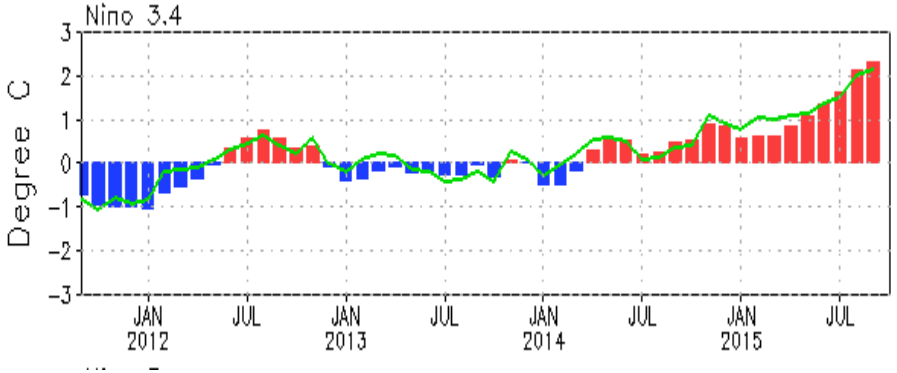
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

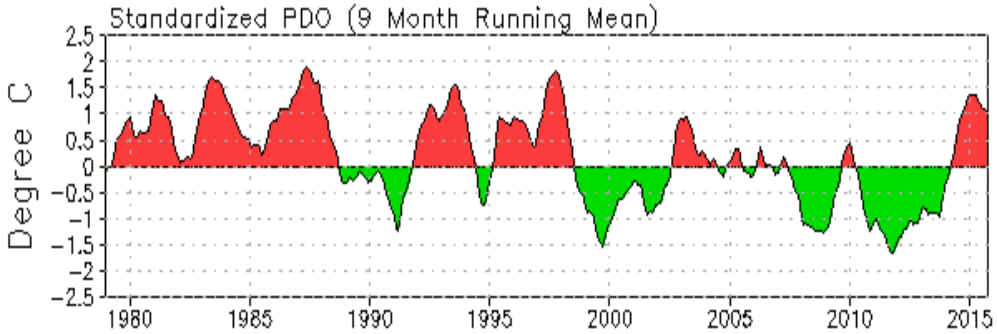
Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

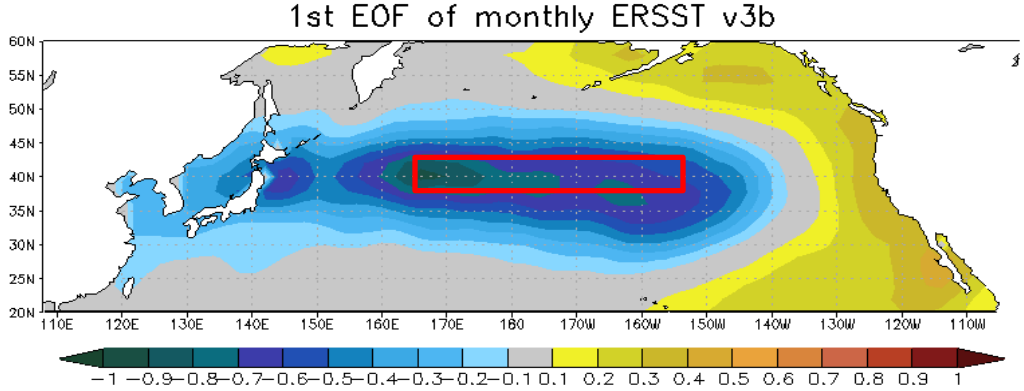
North Pacific & Arctic Oceans

PDO index









- Positive PDO has persisted 15 months since July 2014 and PDO index =1.1 in Sep. 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.

North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, 925hp wind, Sfc Rad, Sfc Flx

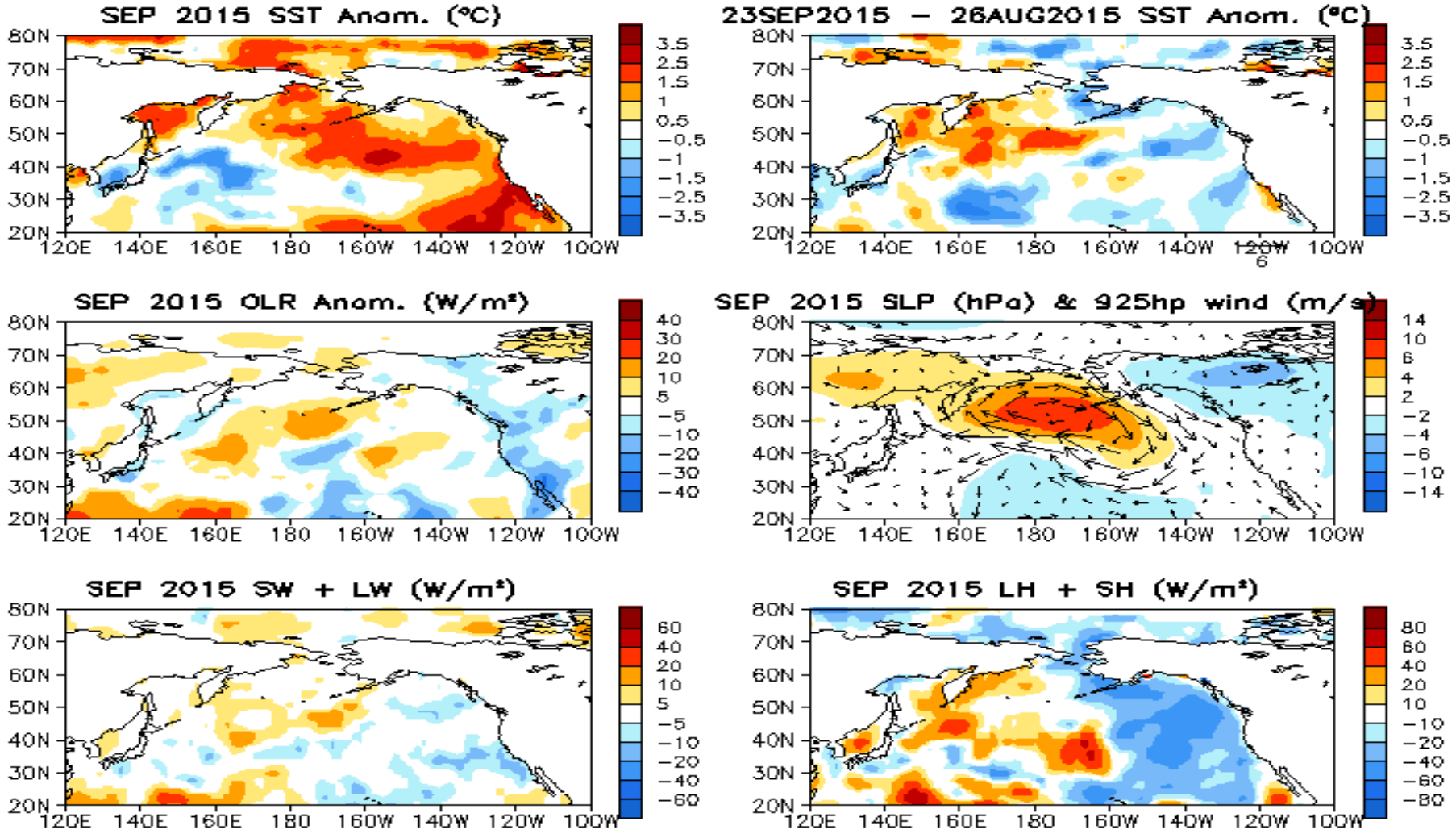
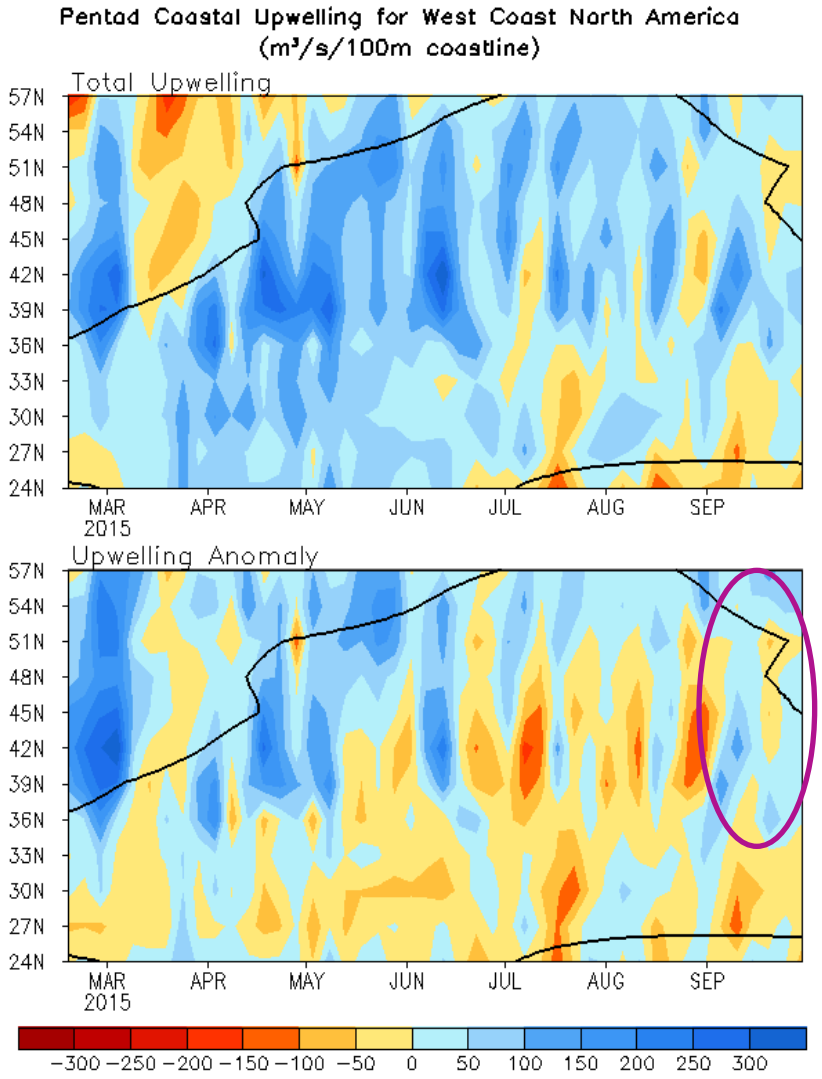
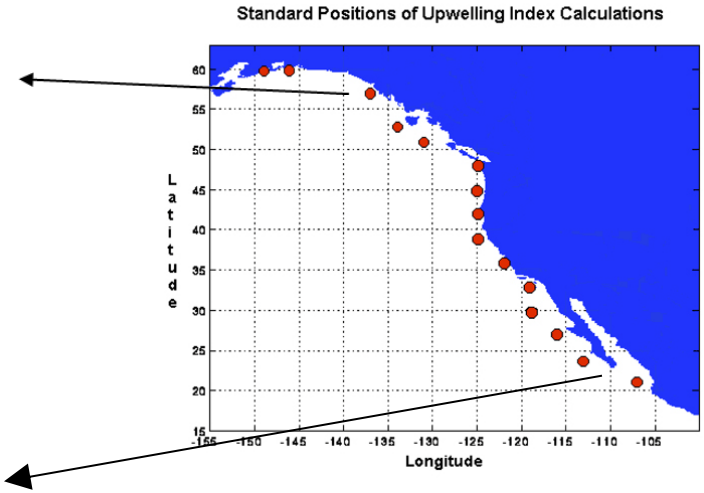


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure and 925hp wind anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent 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





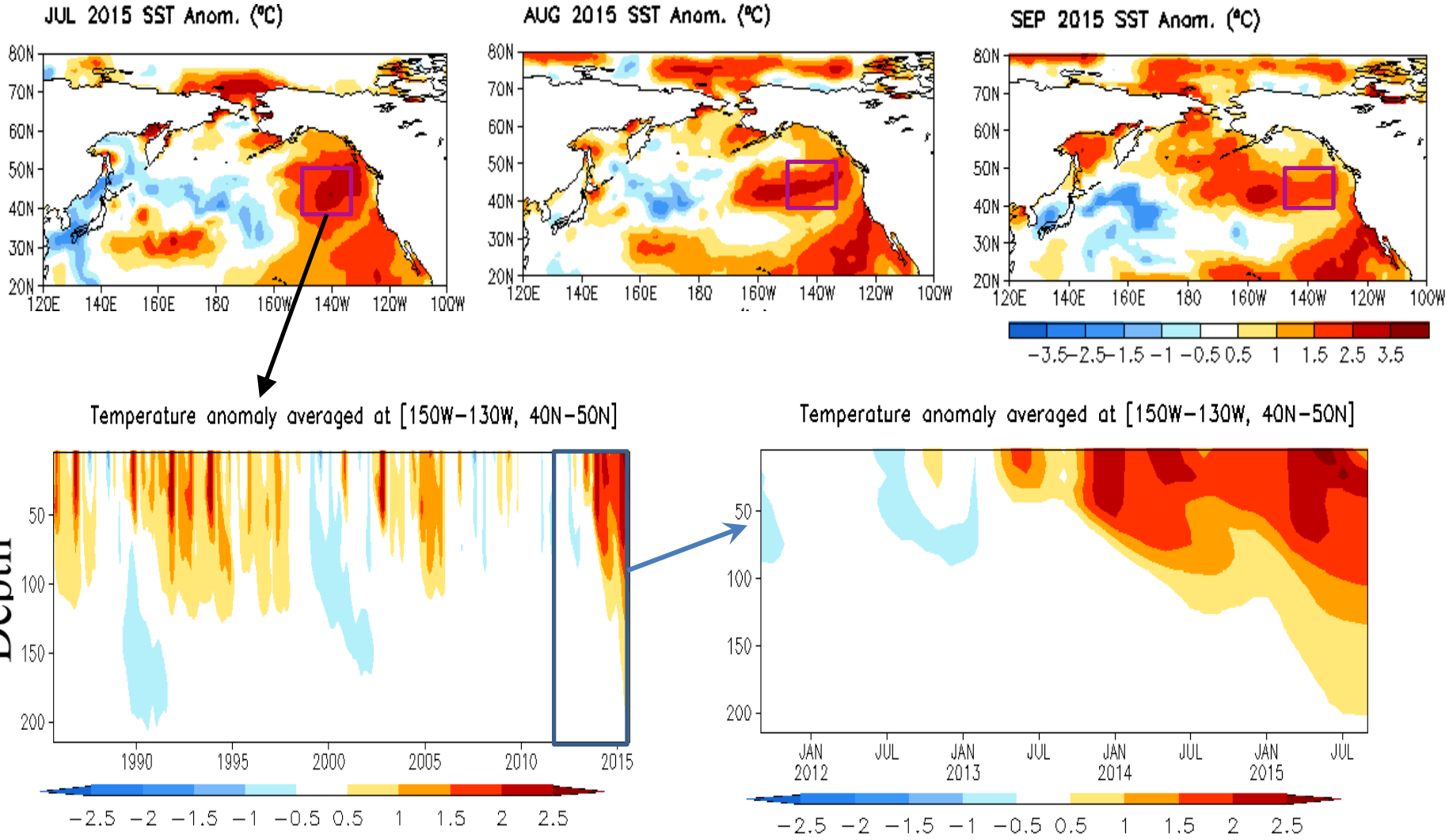
- Anomalous upwelling dominated north of 36°N in Sep. 2015 , consistent with the northwestly wind anomalies along the coast.

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.

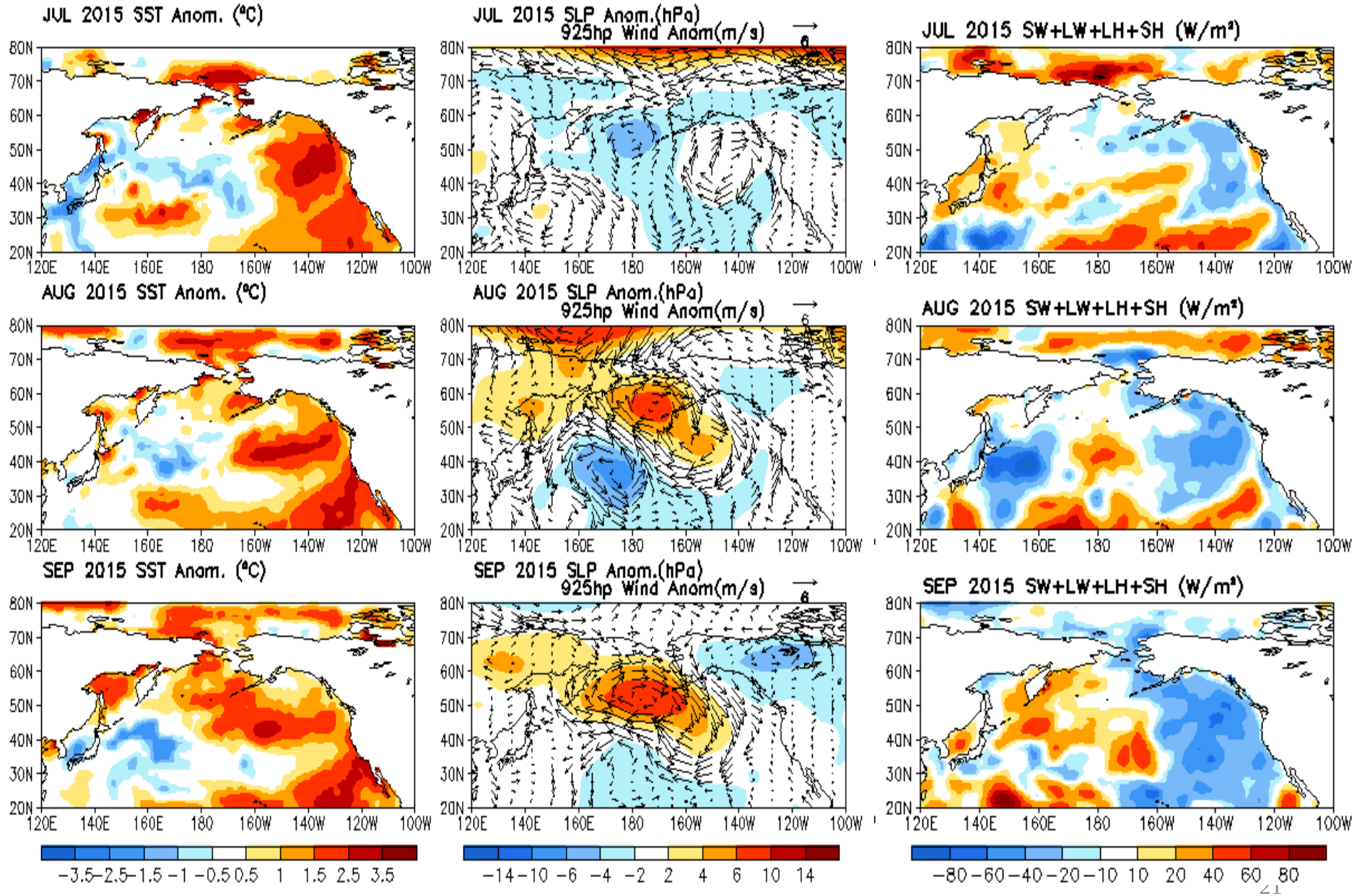
- Climatologically upwelling season progresses from Mar to Jul along the west coast of North America from 36ºN to 57ºN.

Last Three Month SSTA of North Pacific



- Strong subsurface temperature warming in the NE Pacific [150°w-135°w, 40°-50°N] persisted since winter 2013/14.

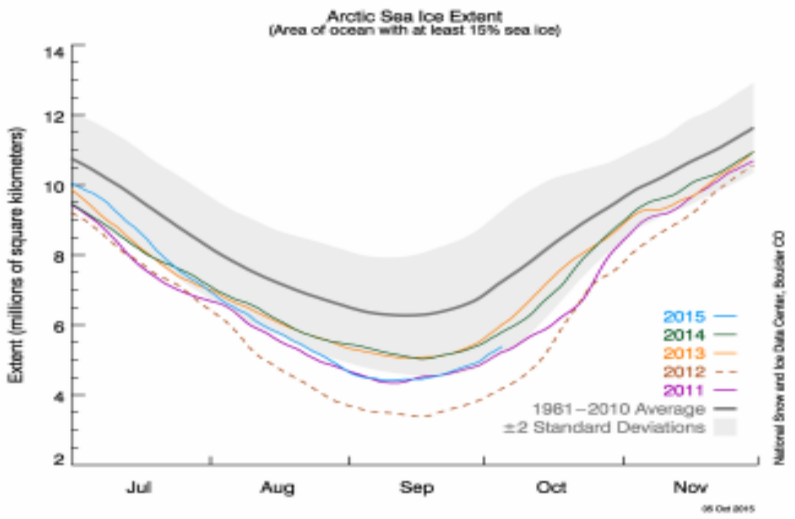
Last Three Month SSTA , SLP, 925p Wind and Net Heat flux Anomalies

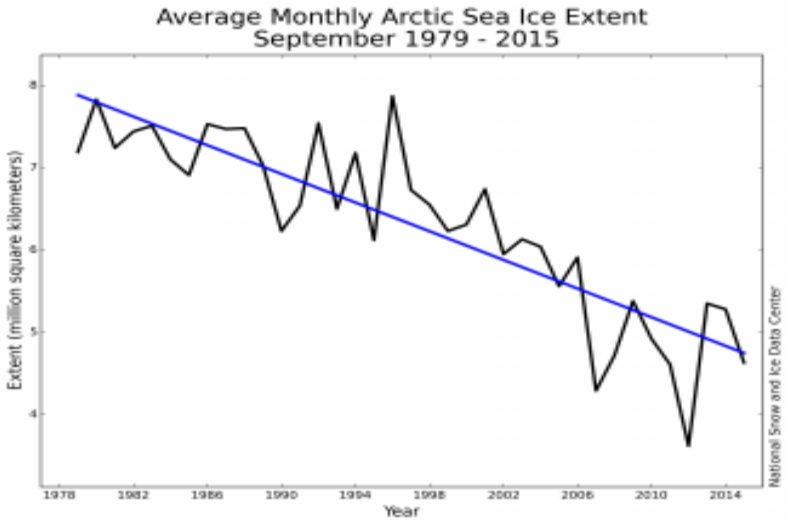


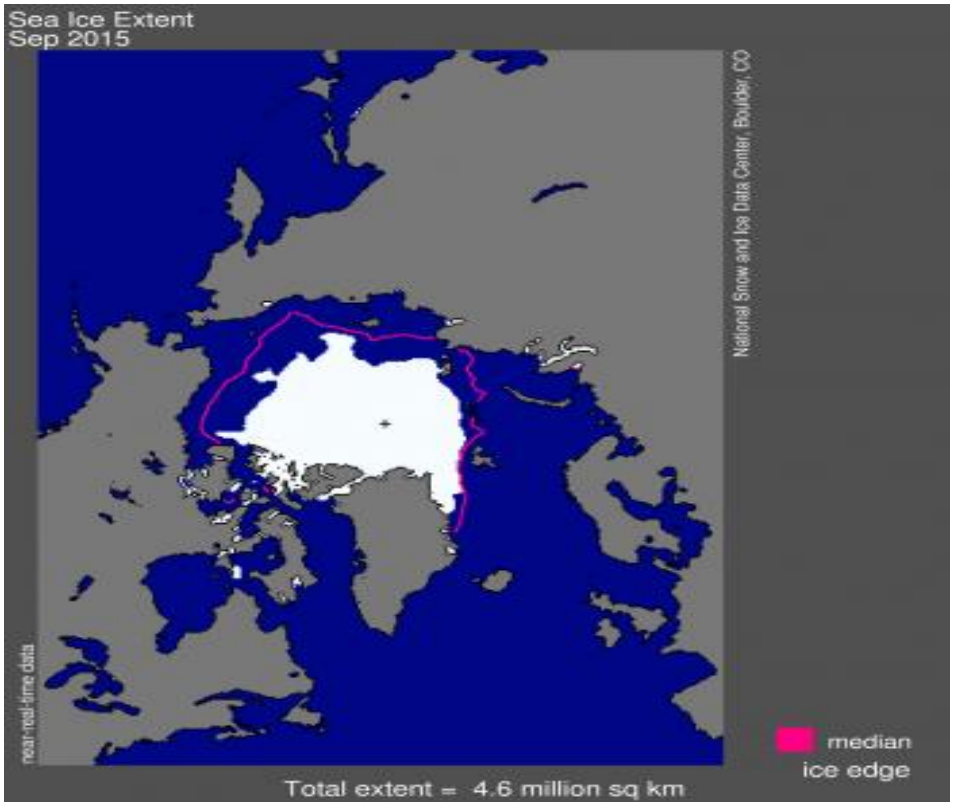
Arctic Sea Ice

National Snow and Ice Data Center

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



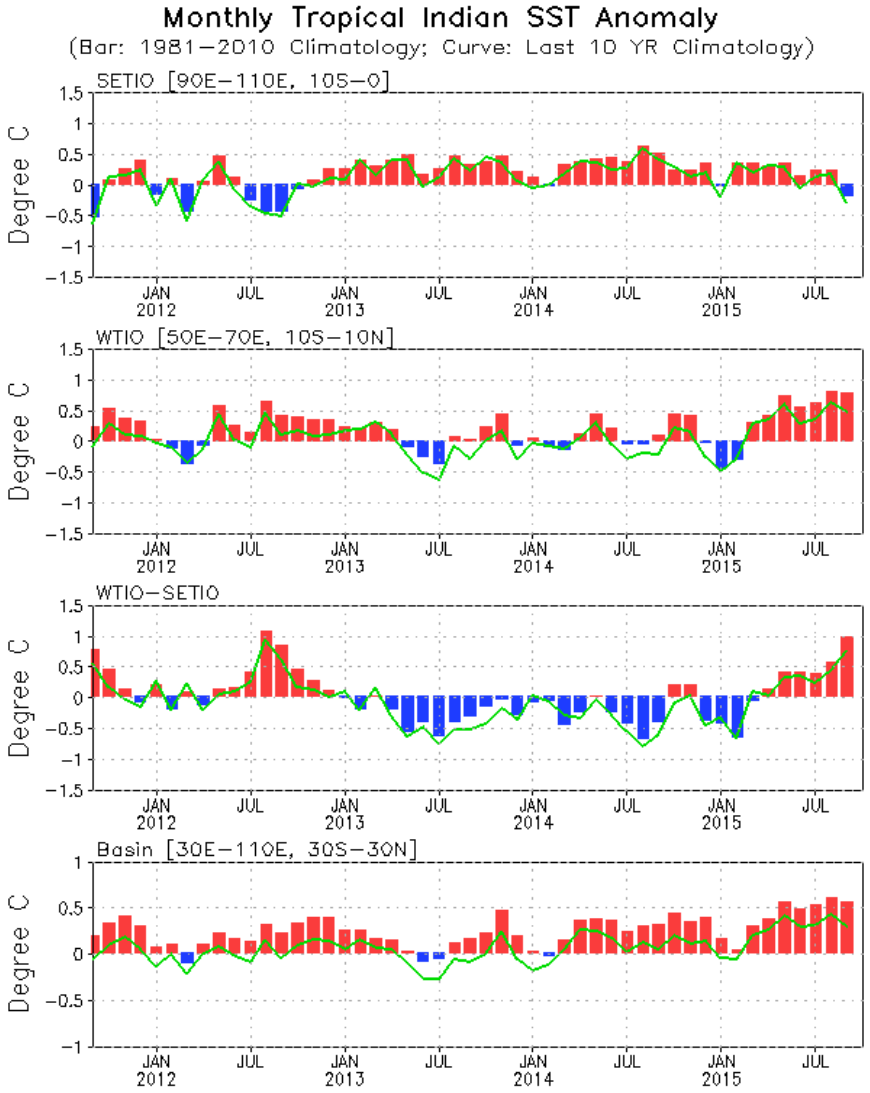


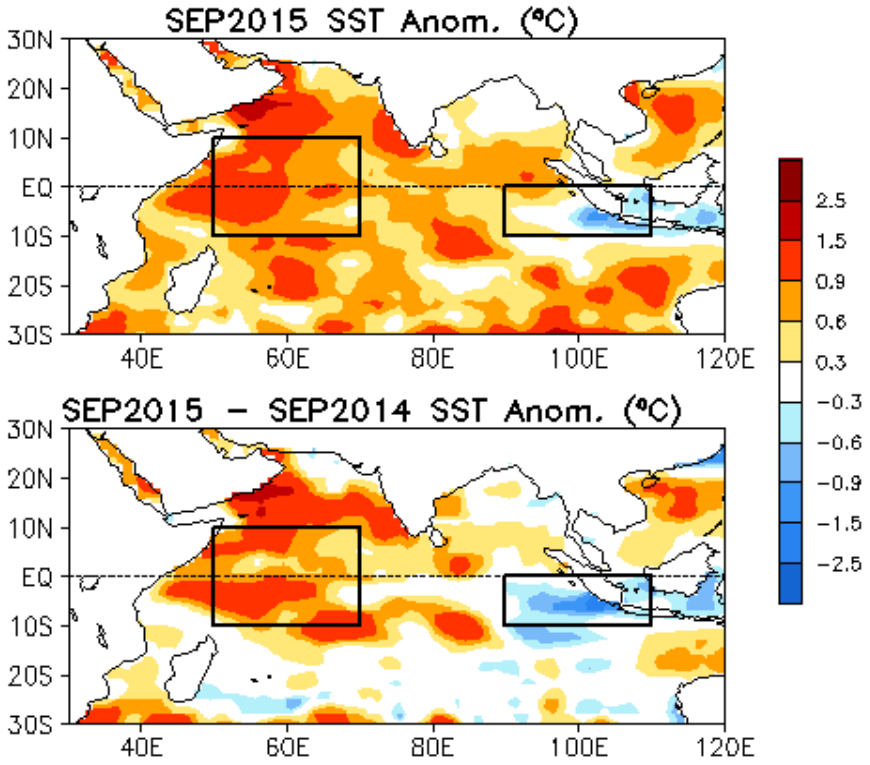


- Arctic sea ice extent reached the fourth lowest minimum in the satellite record.

Indian Ocean

Evolution of Indian Ocean SST Indices





- **Positive SSTA persisted in the Indian Ocean.**
- **DMI strengthened in Sep. 2015, with DMI = 0.9.**

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

- **SST warming occupied most of basin.**

- **Convection was suppressed (enhanced) in the eastern (western) tropical Indian Ocean.**

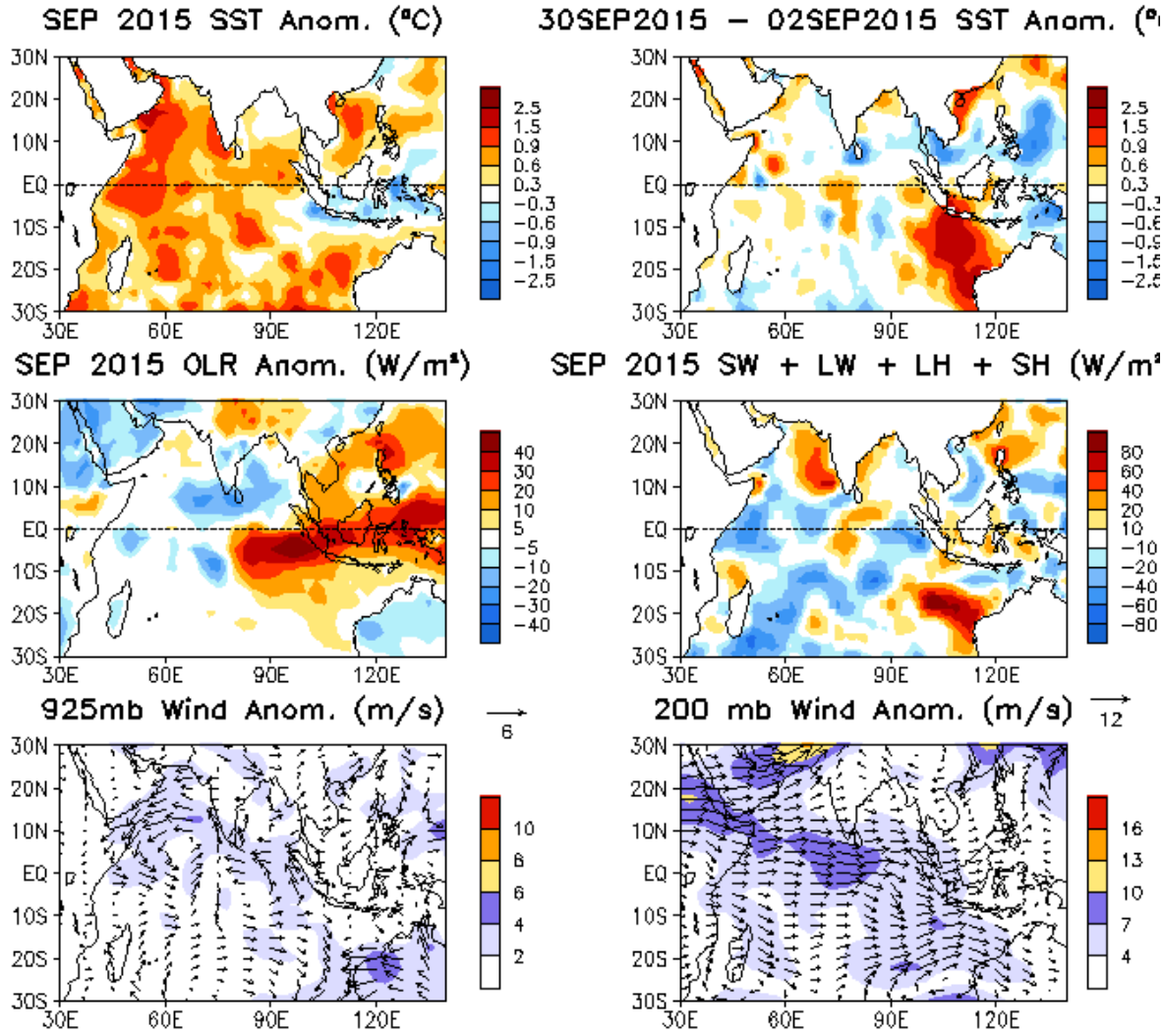
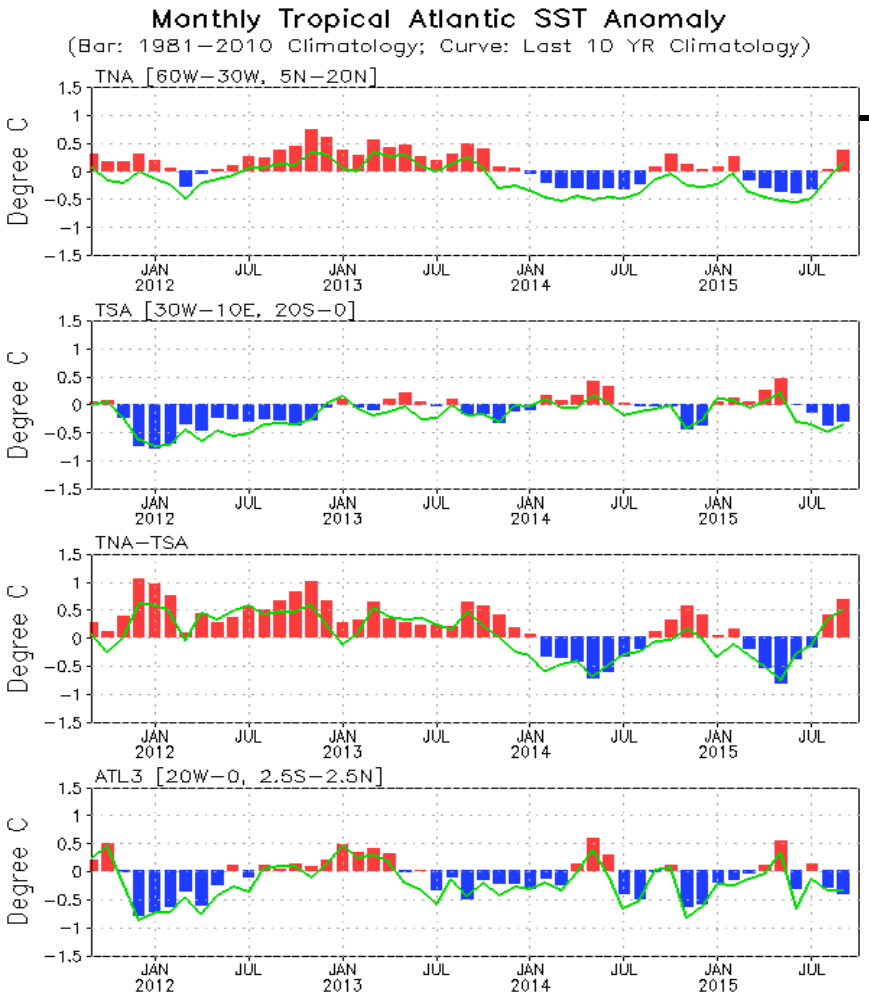
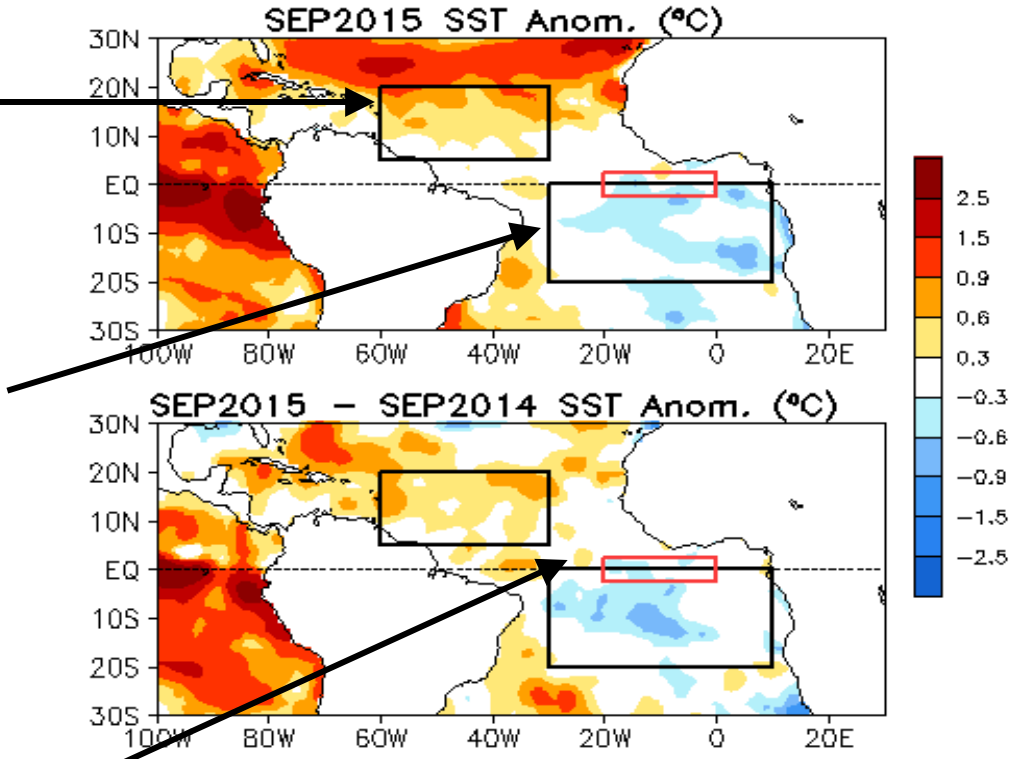


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices



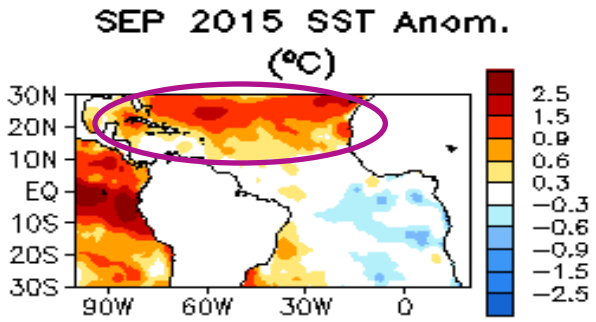


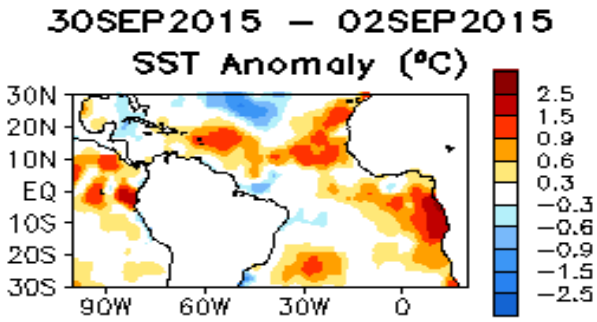
- **Positive SSTA dominated in the northern tropical Atlantic.**
- **ATL3 was below-average.**
- **Positive dipole index strengthened in Sep. 2015.**

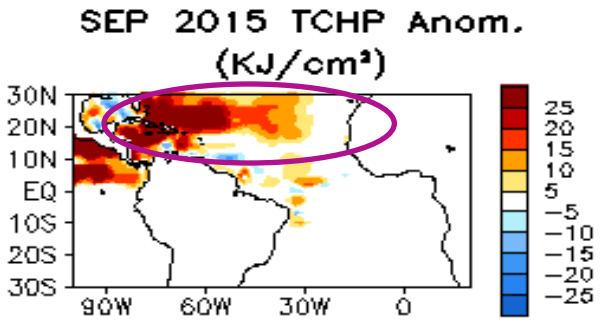
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between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

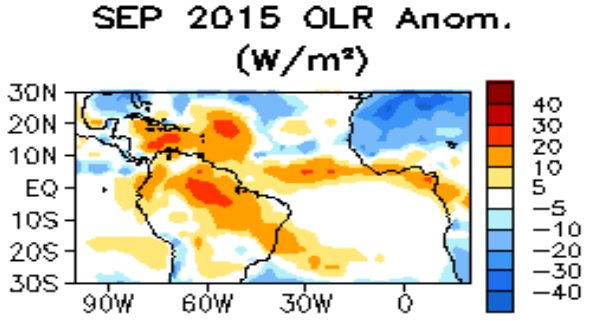
Tropical Atlantic:

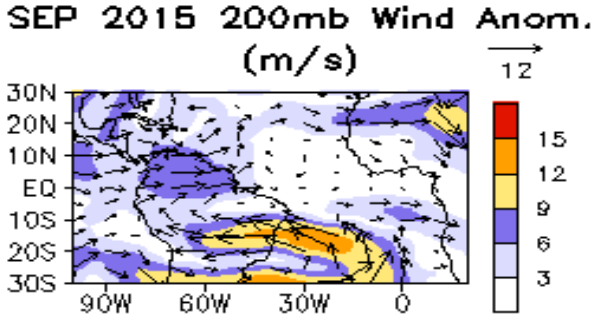
SST Anom., SST Anom. Tend., TCHP OLR, Sfc Flx, 925-mb/200-mb Winds and RH

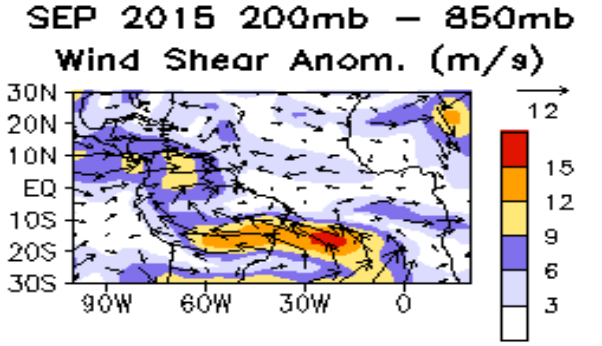


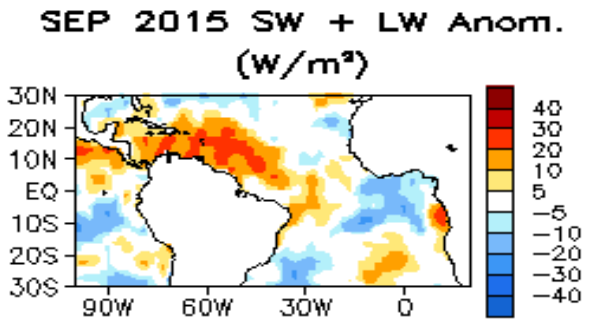


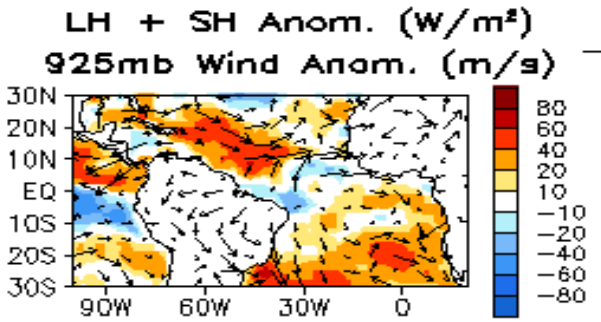


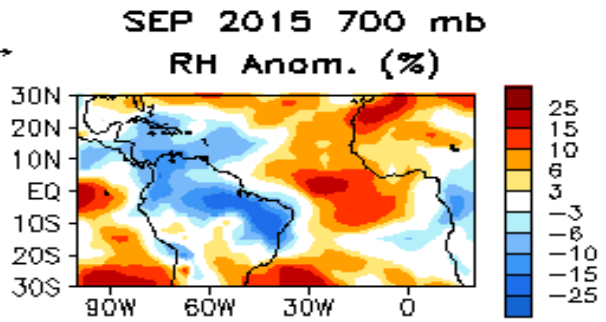








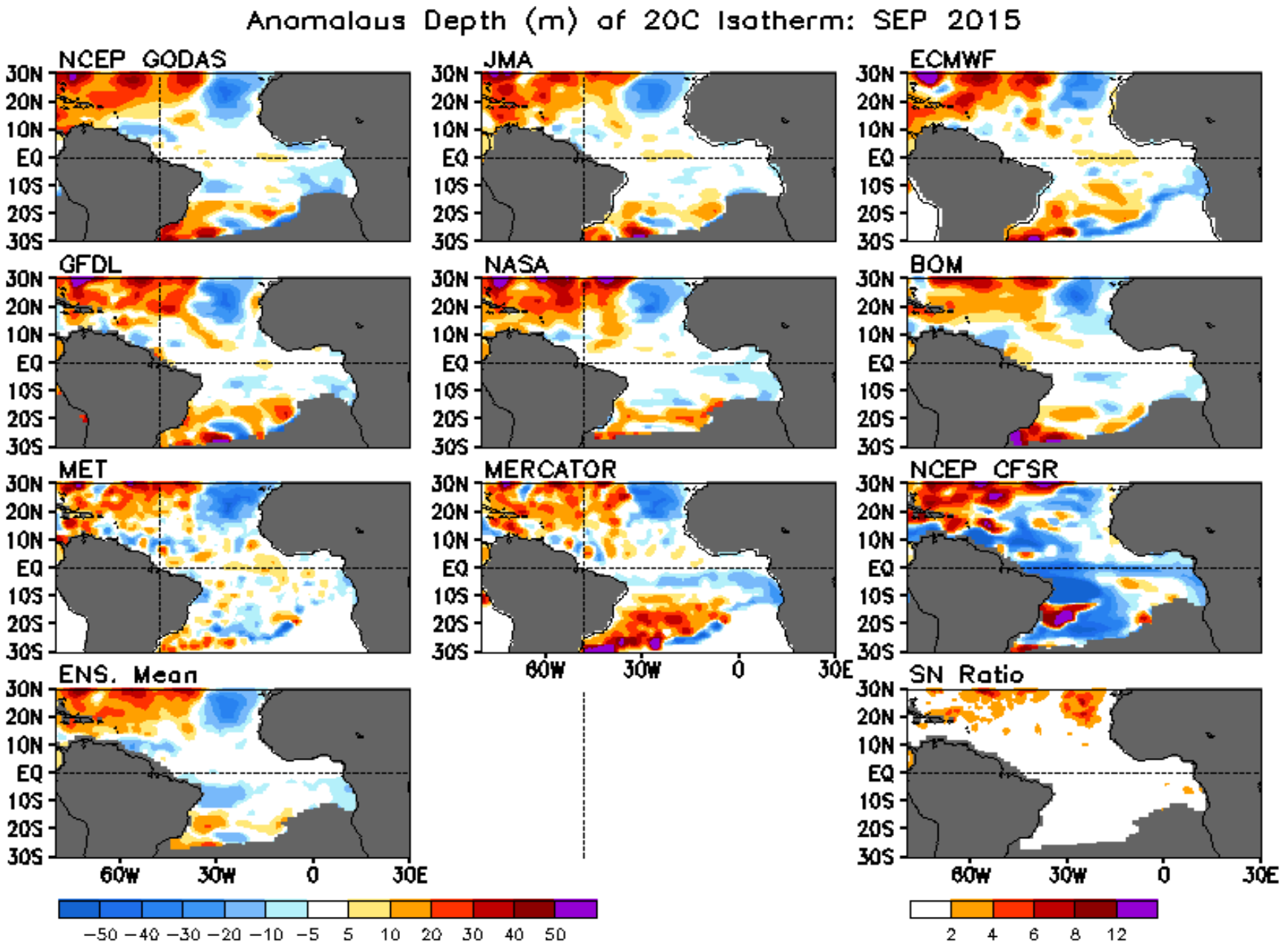




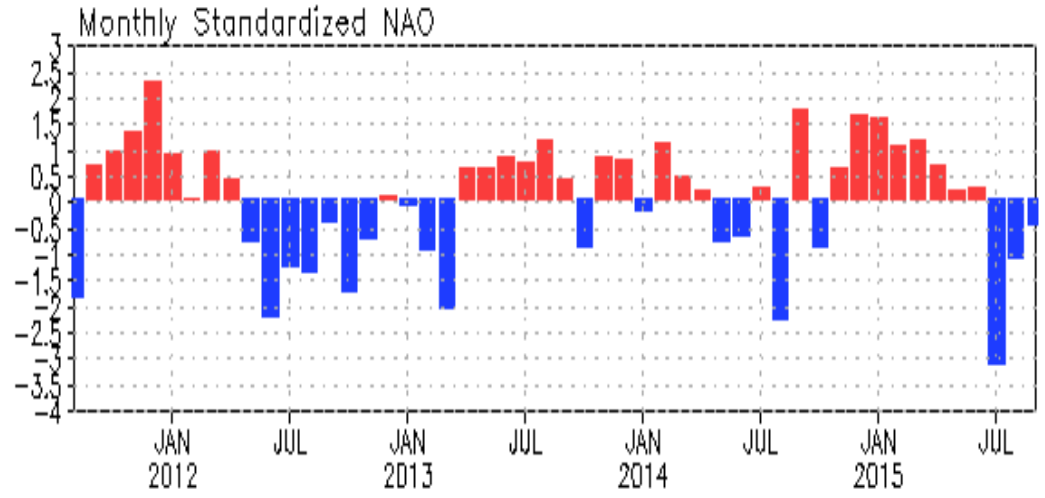
- **Positive SSTA and TCHP anomaly presented in the north subtropical Atlantic**
- **Warming tendency dominated the tropical Atlantic in Sep. 2015.**

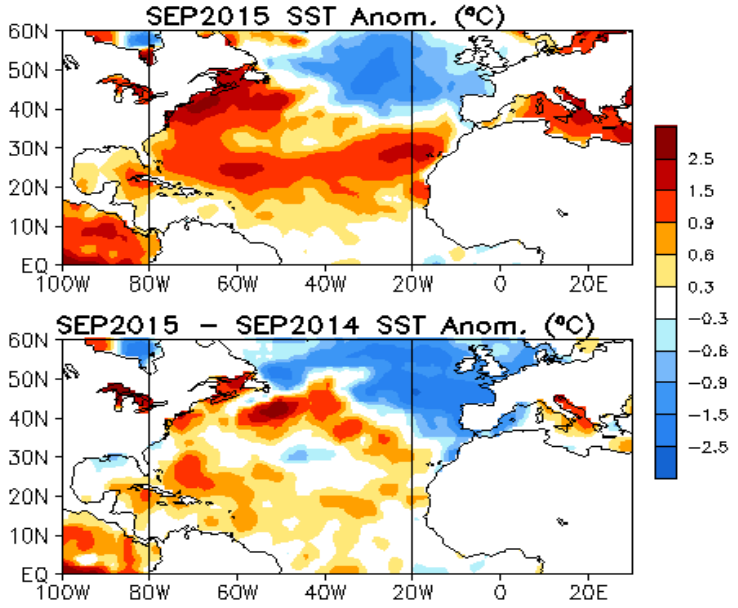
Real-Time Multiple Ocean Reanalyses Intercomparison

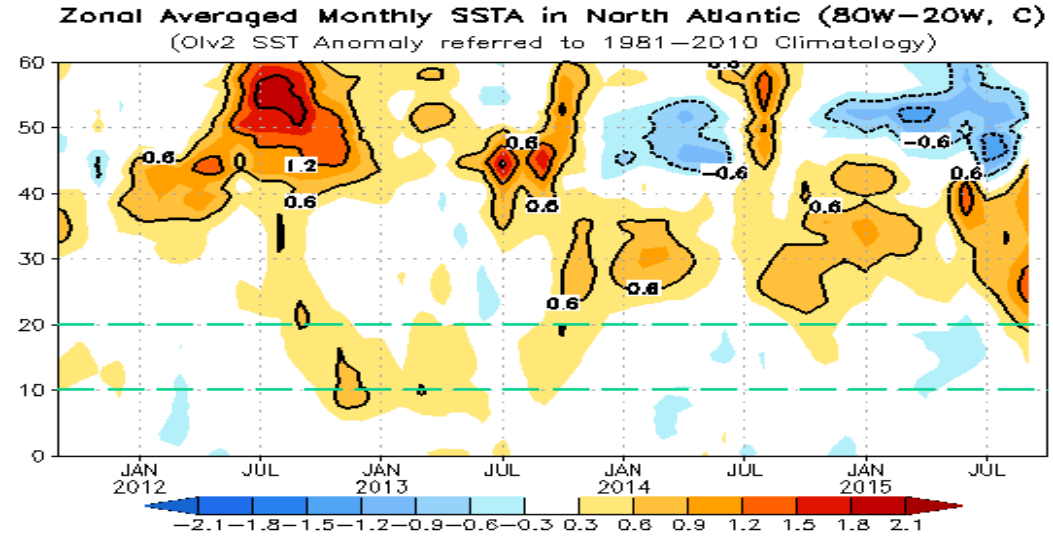
(1993-2013 Climatology)



NAO and SST Anomaly in North Atlantic





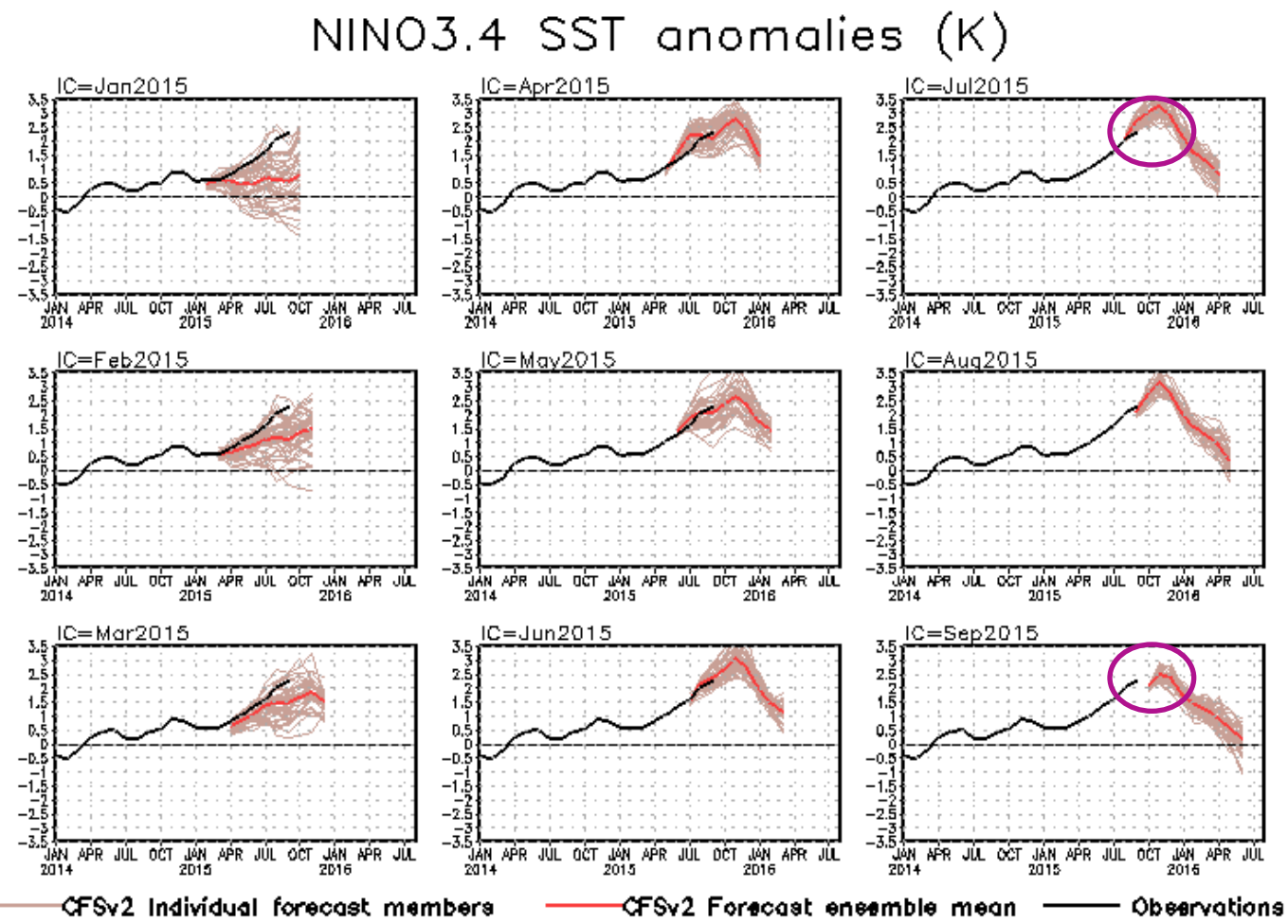


- Negative NAO weakened and NAOI=-0.5 in Sep. 2015.
- Dipole pattern presented in N. Atlantic Ocean.

Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 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.

ENSO and Global SST Predictions

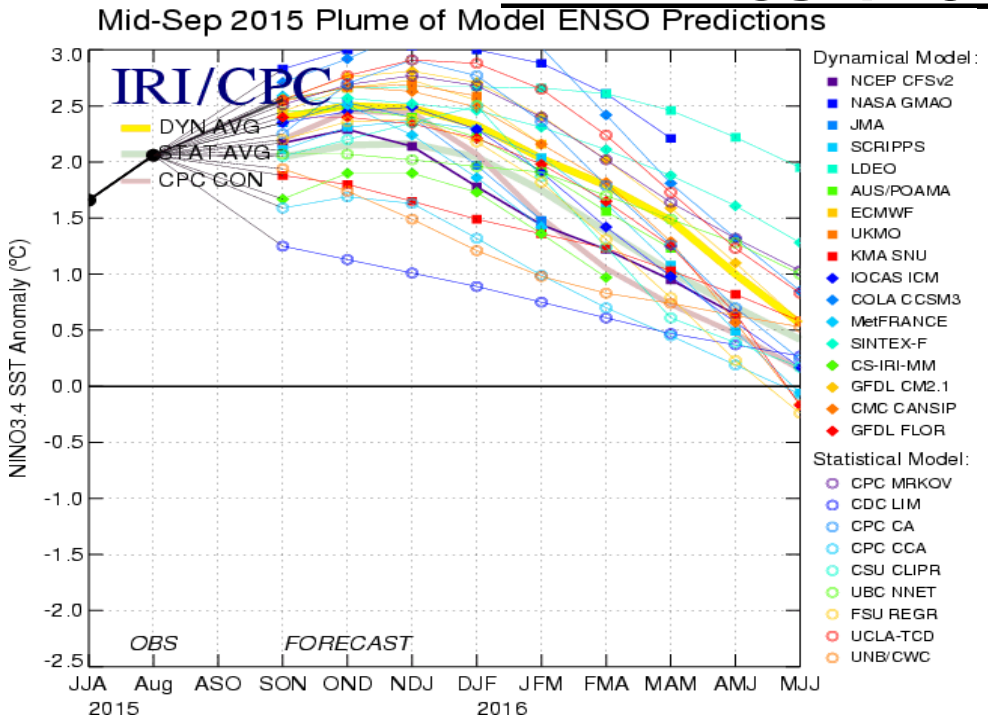
CFS Niño3.4 SST Predictions from Different Initial Months

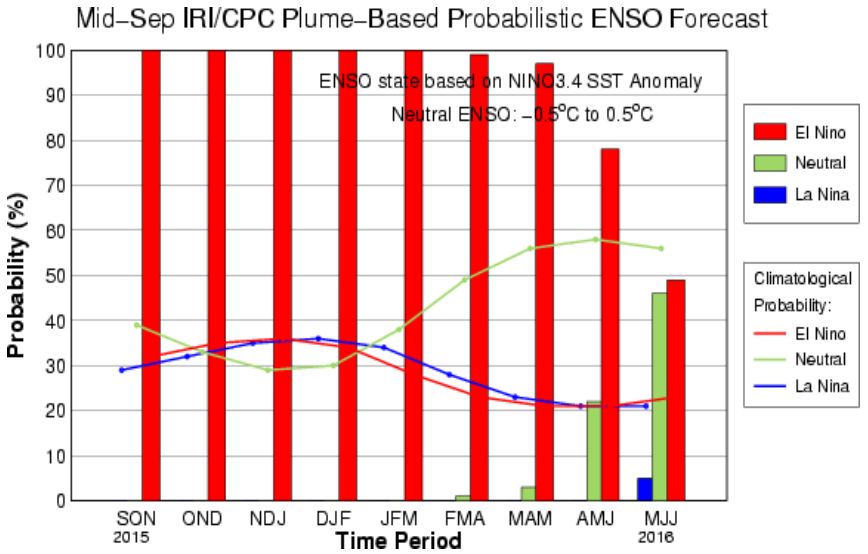


- Latest CFSv2 predicts Nino 34 will peak at Nov.2015 (2.5°C) and decrease gradually through northern hemisphere spring 2016.
- Peak of Nino 34 at Sep IC drop by 1°C compared with Jul. IC.

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.

IRI NINO3.4 Forecast Plum





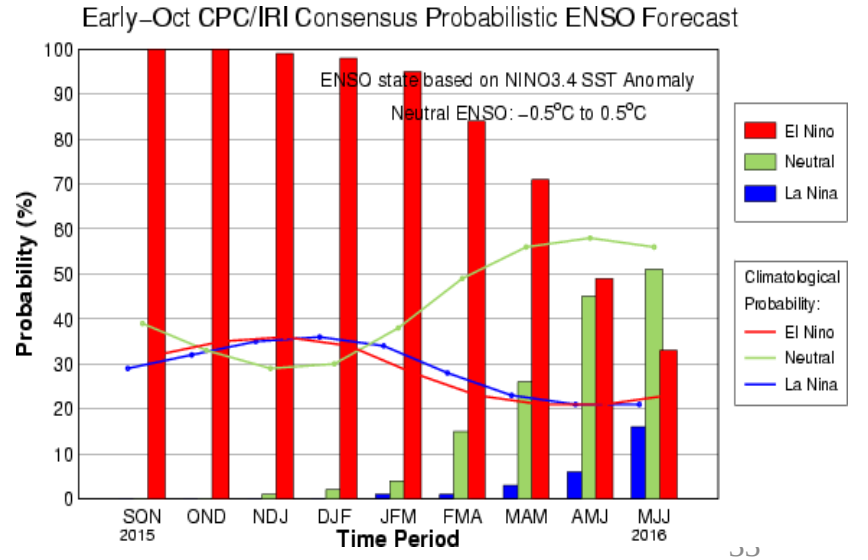
- **NOAA "ENSO Diagnostic Discussion" on 8 Oct. 2015 suggested that "There is 95% chance that El Niño will continue through Northern Hemisphere winter 2015-16.**

- **Both dynamical and statistical model ensemble means favored a strong (NINO3.4>=1.5C) El Niño in winter2015/2016.**

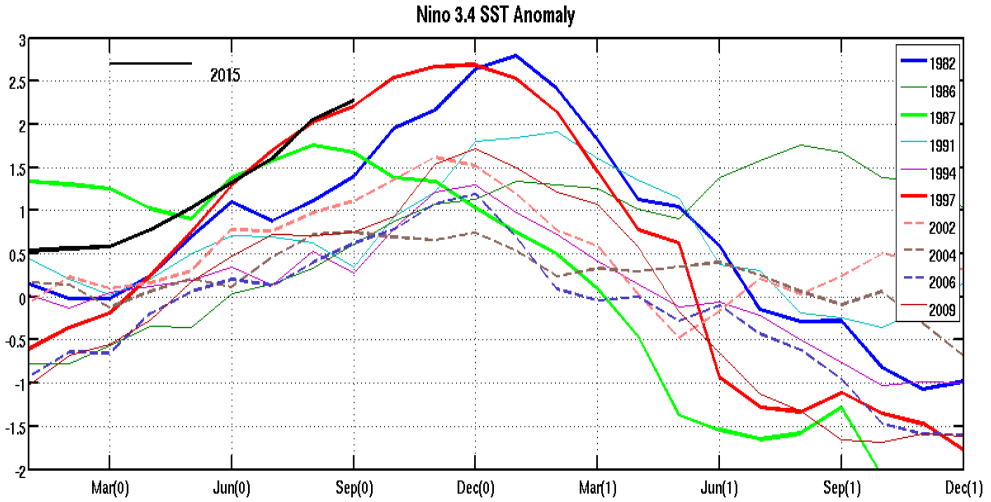
- **Models predicted NINO3.4 in consecutive five seasons exceeding +2°C (IRI web site):**

Dynamical Models (13/17): NASA GMAO, JMA, Scripps, LDEO, AUS/POAMA,ECMWF, UKMO, CHINA/IOCAS, COLA CCSM3, ,SINTEX-F, GFDL CM2.1, CMC CANSIP, GFDL FLOR

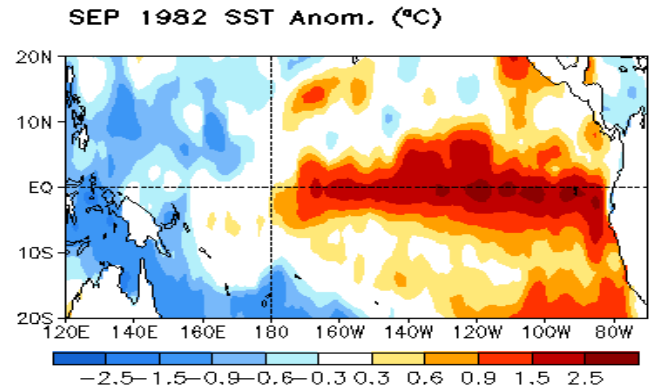
Statistical Models(6/9): CPC Markov, CPC CA, CSU CLIPR, UBC NNET, FSU-REGR, TCD-UCLA

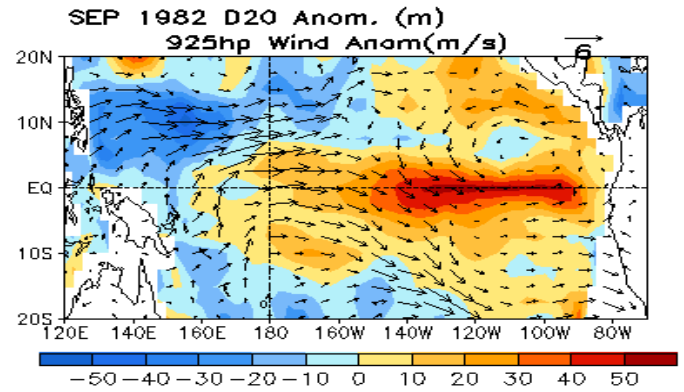


SST,D20 and 925hPa Wind anomalies in September

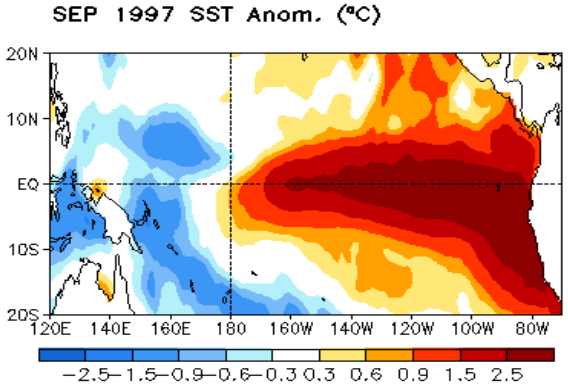


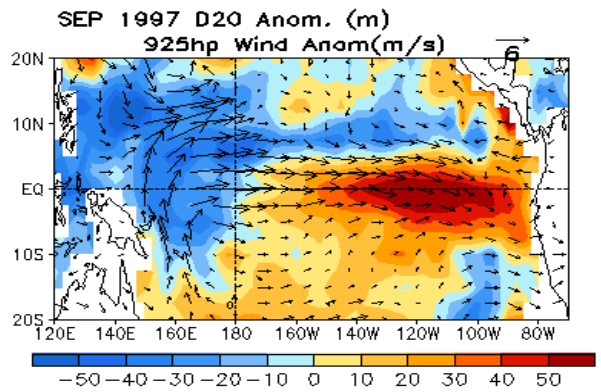
1982



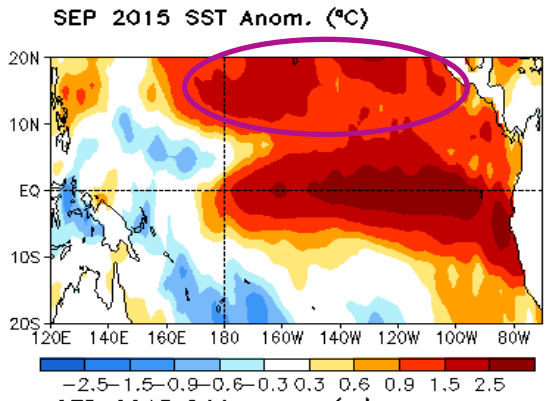


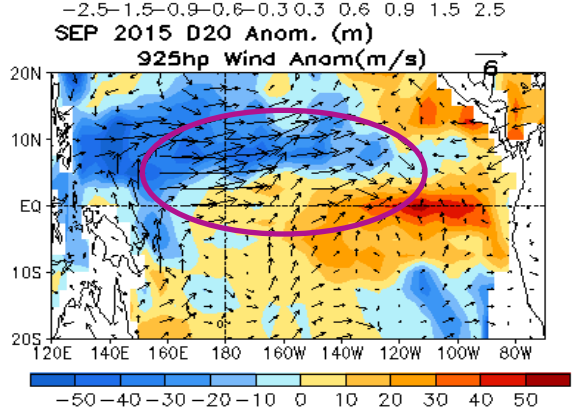
1997





2015

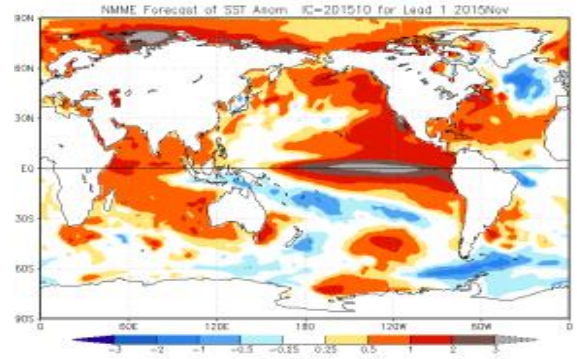




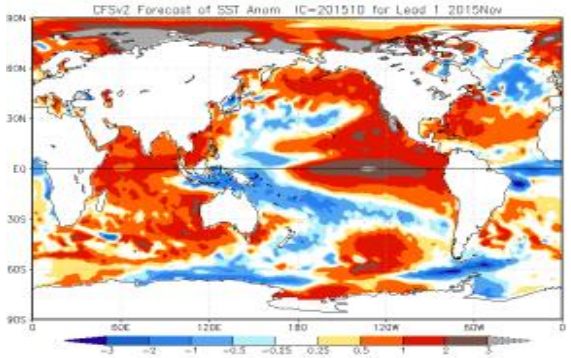
NCEP CFSv2 & NMME North Pacific SST Predictions

IC= 201509

NMME 2015Nov

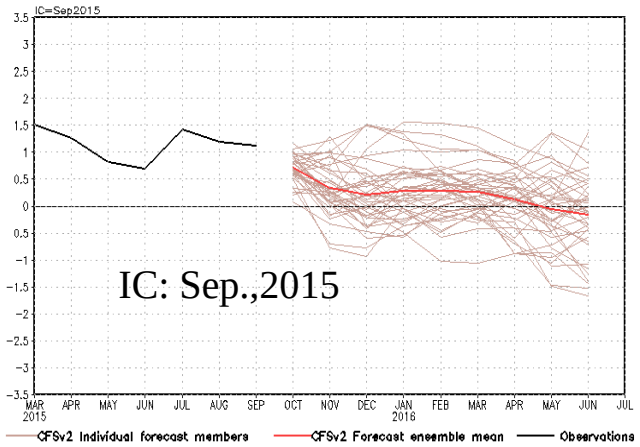


CFSv2 2015Oct

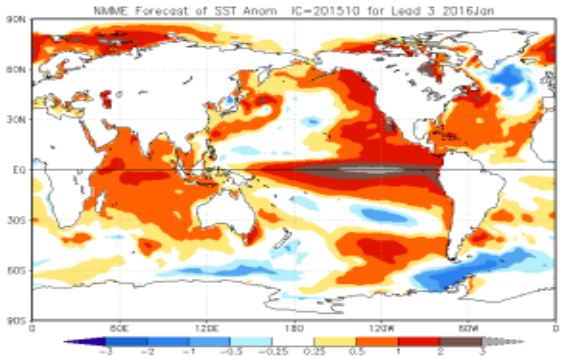


NCEP CFSv2 PDO

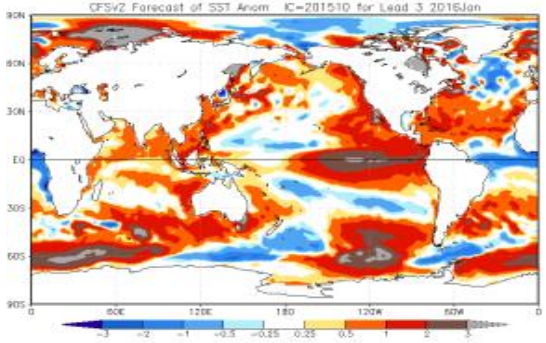
standardized PDO index



NMME 2016Jan

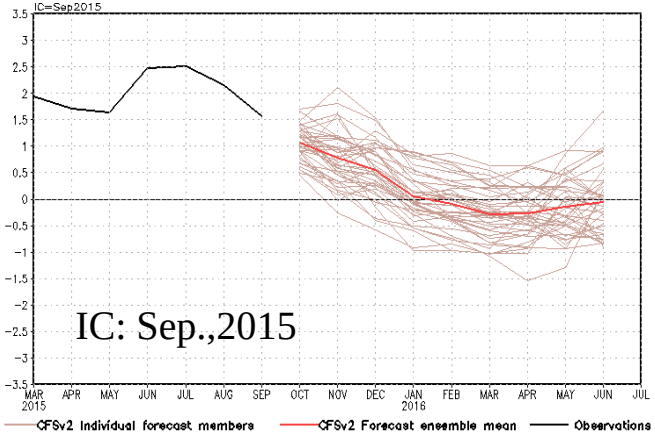


CFSv2 2016Jan

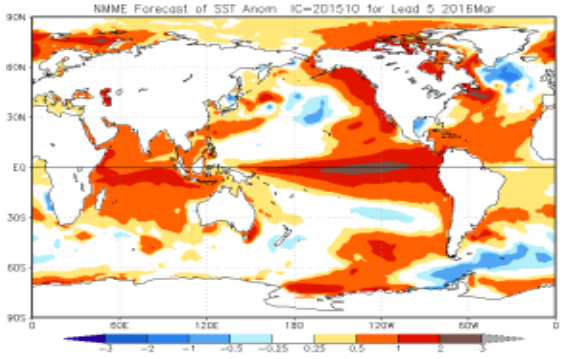


NCEP CFSv2 NPAC[150W-130W,40N-50N]

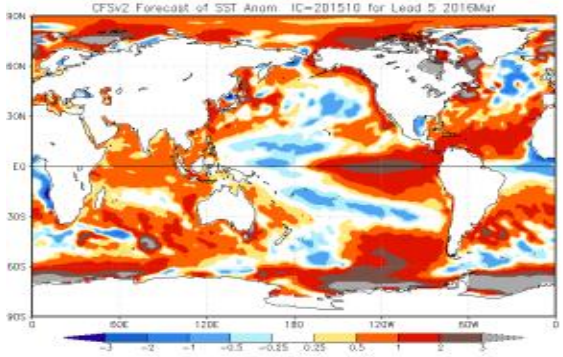
SST anomalies (K) [150W−135W,40N−50N]



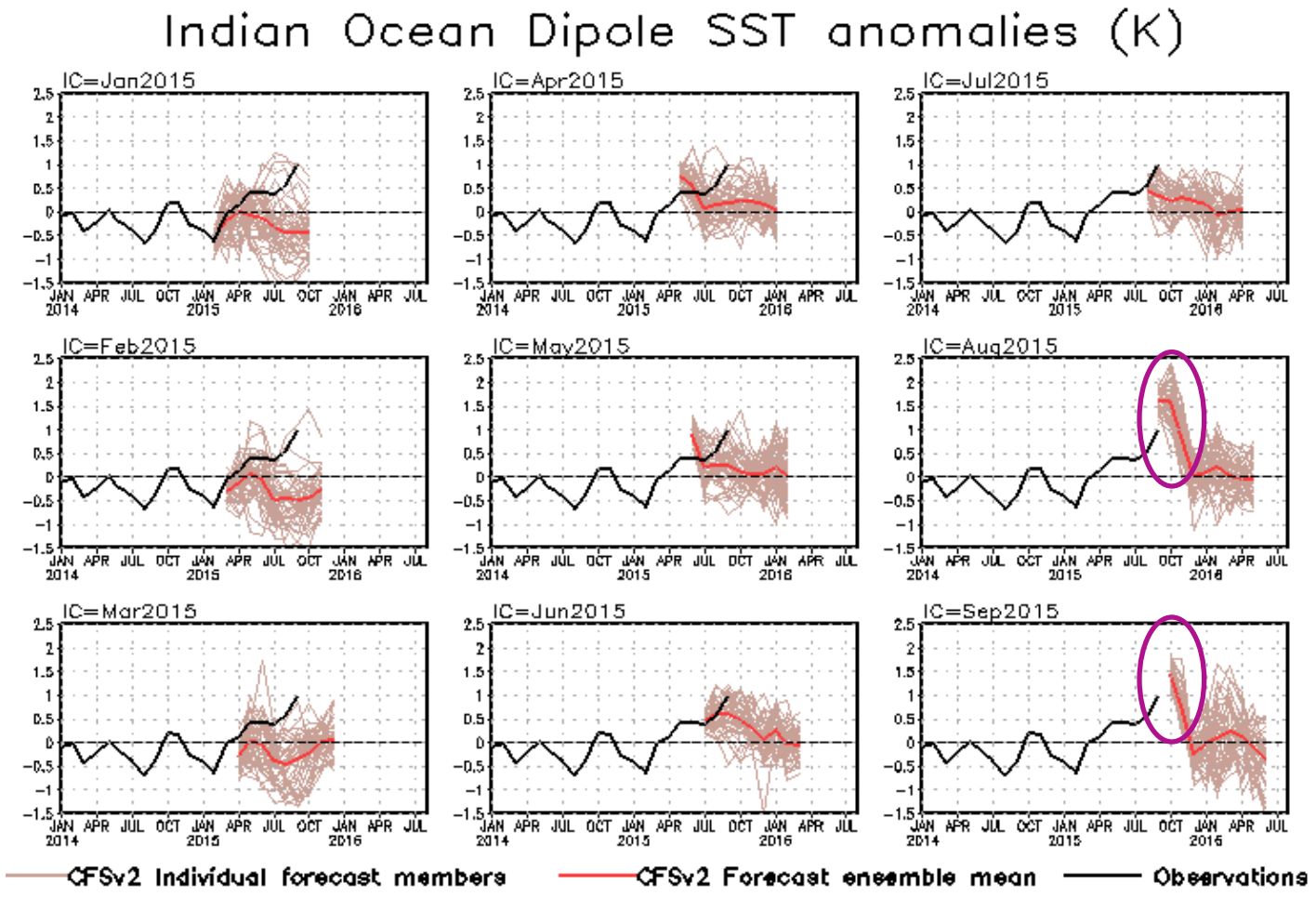
NMME 2016Mar



CFSv2 2016Mar



CFS DMI SST Predictions



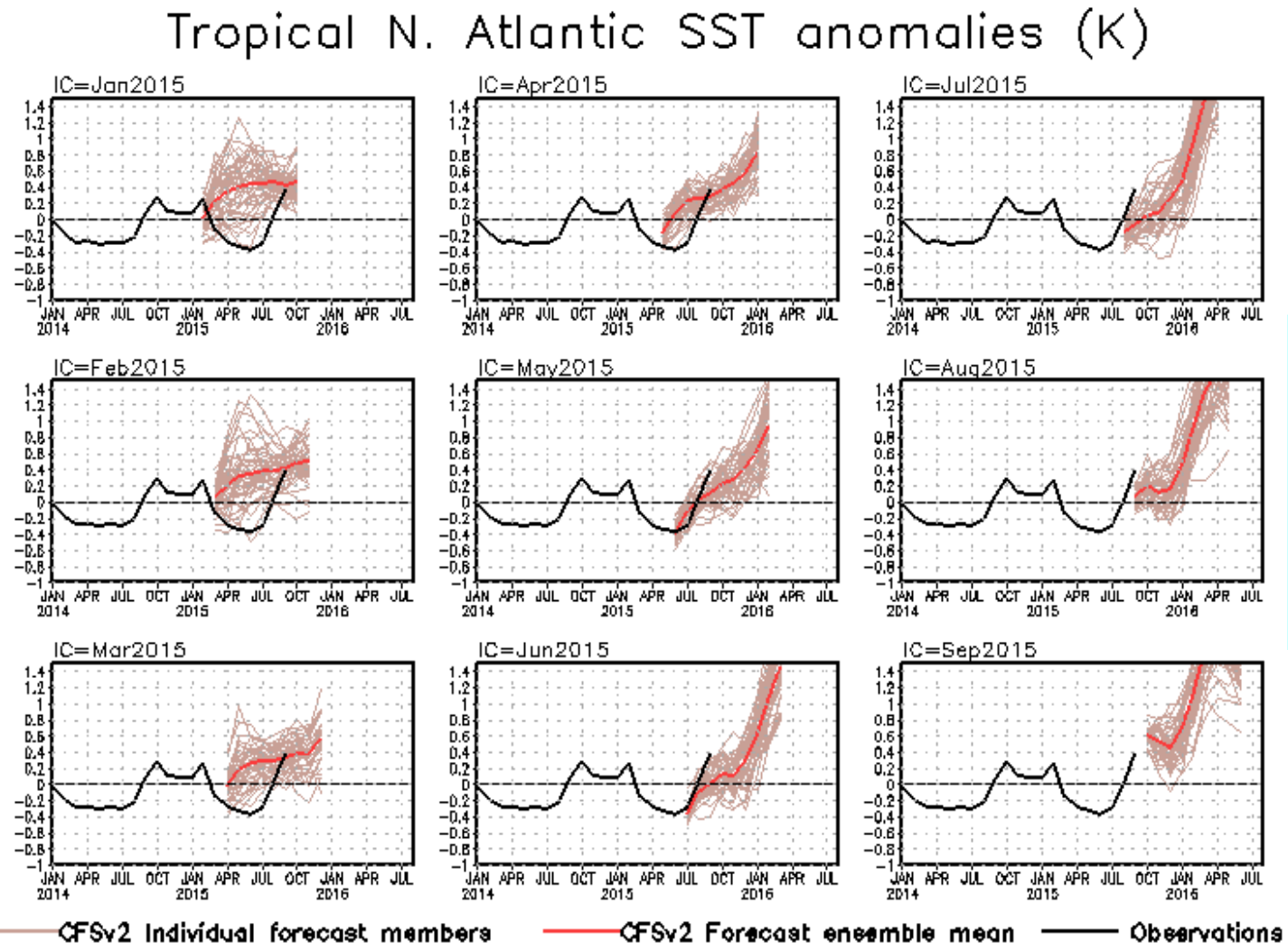
DMI = WTIO- SETIO

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

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

- **Latest CFS2 predict a positive Indian Ocean Dipole event through Nov. 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].

- **Latest CFS2 prediction calls a above-normal SSTA in North Atlantic throughout Fall 2015-Spring 2016.**

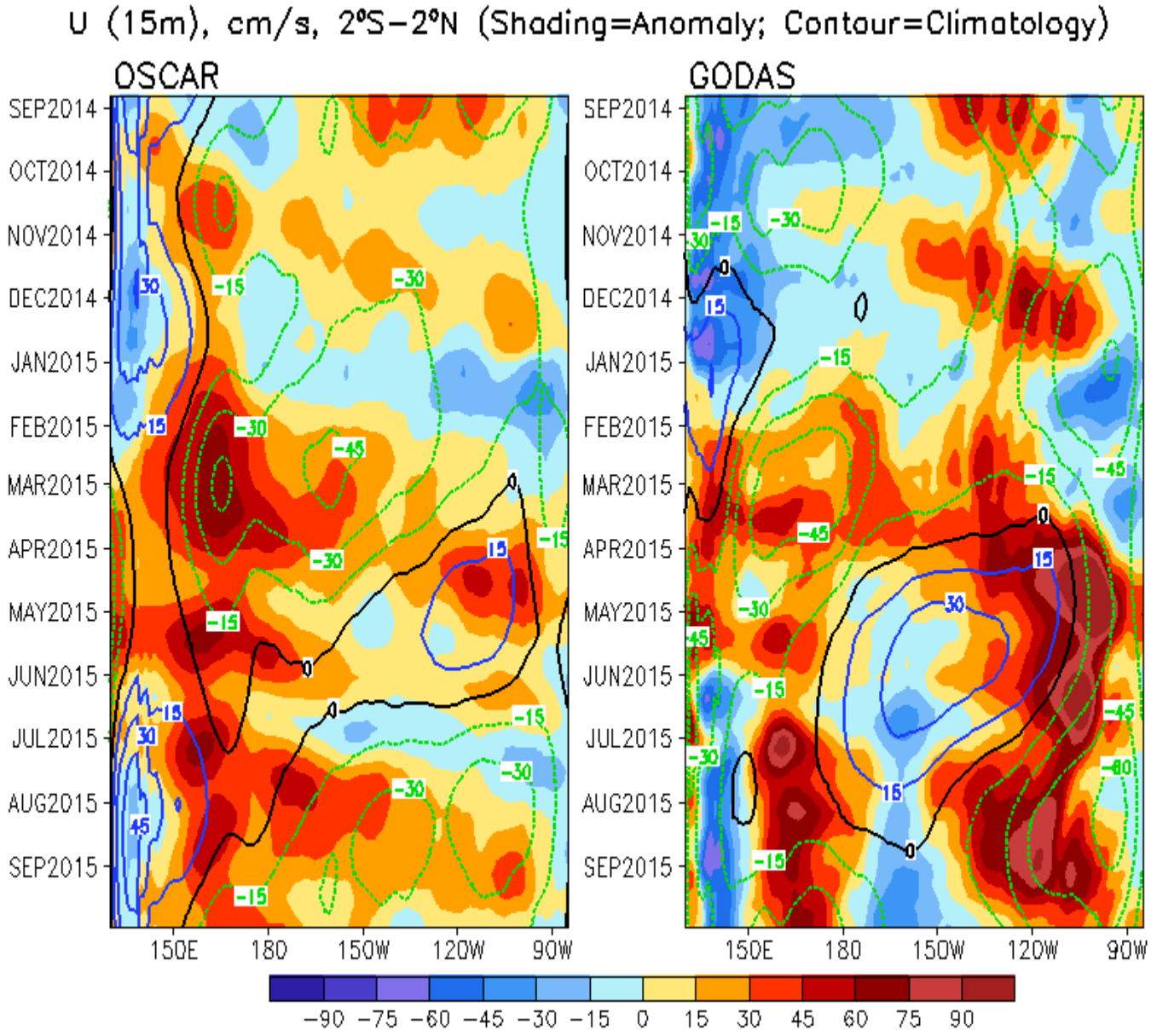
Fig. M3. CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies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

Overview

- **Pacific Ocean**
  - **El Niño conditions further strengthened in Sep. 2015 and the atmospheric and oceanic anomalies reflect a strong El Niño.**
  - **Most model predictions called for a strong El Niño through the Northern Hemisphere fall-winter 2015.**
  - **Upper ocean warming associated with the "Blob" has persisted since winter 2013/2014.**
  - **Positive PDO weakened, with PDOI = 1.1 in Sep. 2015.**
- **Indian Ocean**
  - **Positive SSTAs continued in the whole Indian Ocean.**
  - **India Dipole Mode index increased to about 1°C above-normal.**
  - **NCEP CFSv2 predicted a positive India Dipole event through Nov.2015.**
- **Atlantic Ocean**
  - **SSTA were well above-average along the eastern coast of North America.**

Backup Slides

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

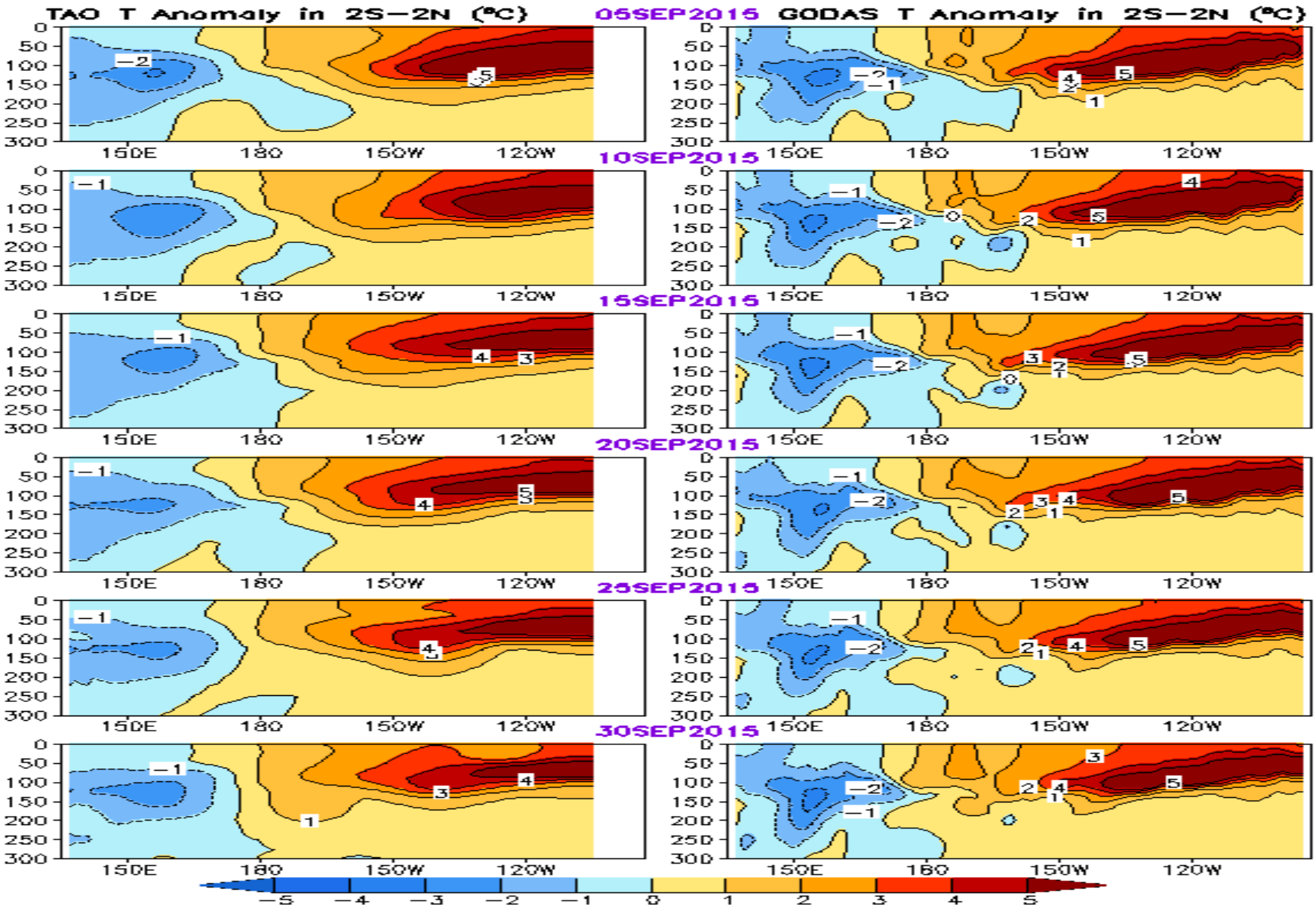


-Anomalous eastward current extended from the western Pacific to central-eastern Pacific since late June, partially attributed to the downwelling Kelvin wave.

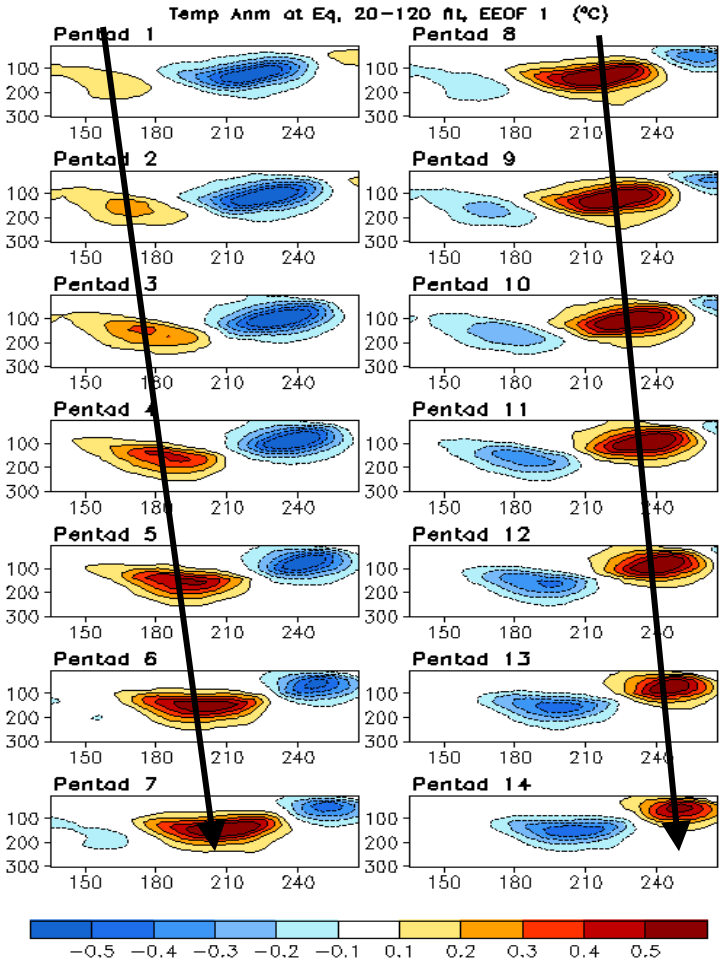
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

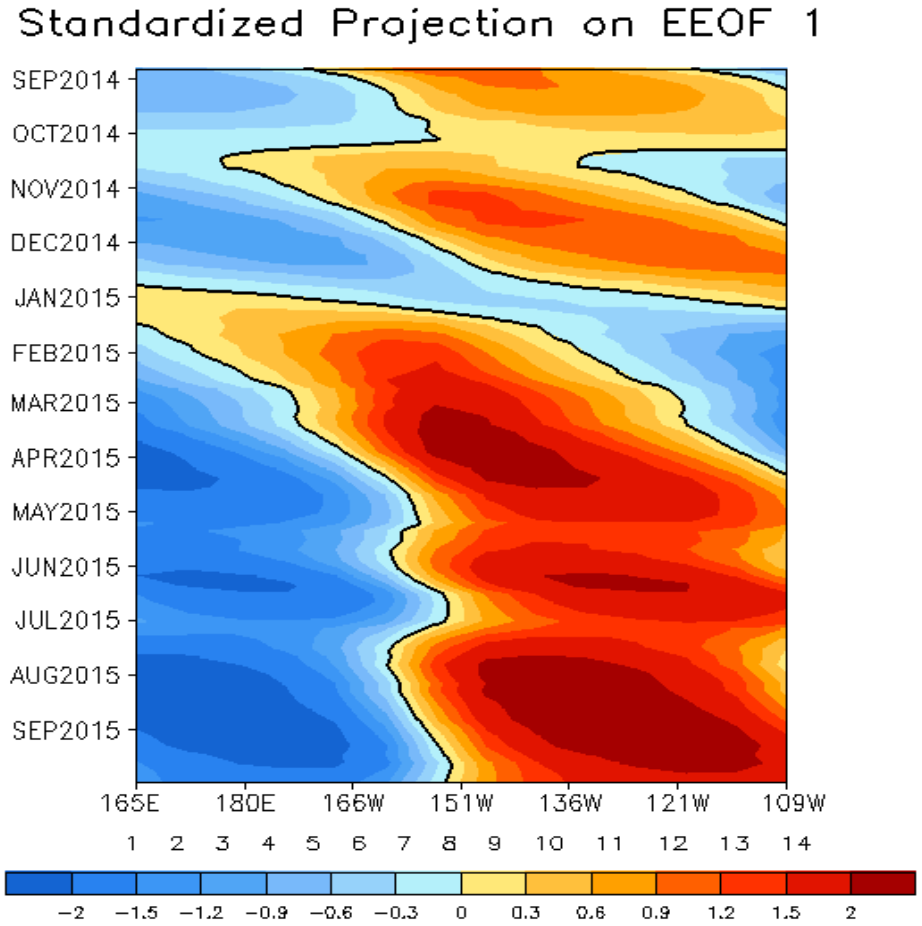
TAO

GODAS



Oceanic Kelvin Wave (OKW) Index





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

-A dipole like SST pattern continued in North Atlantic.

- SSTA tendency was largely consistent with surface flux anomalies.

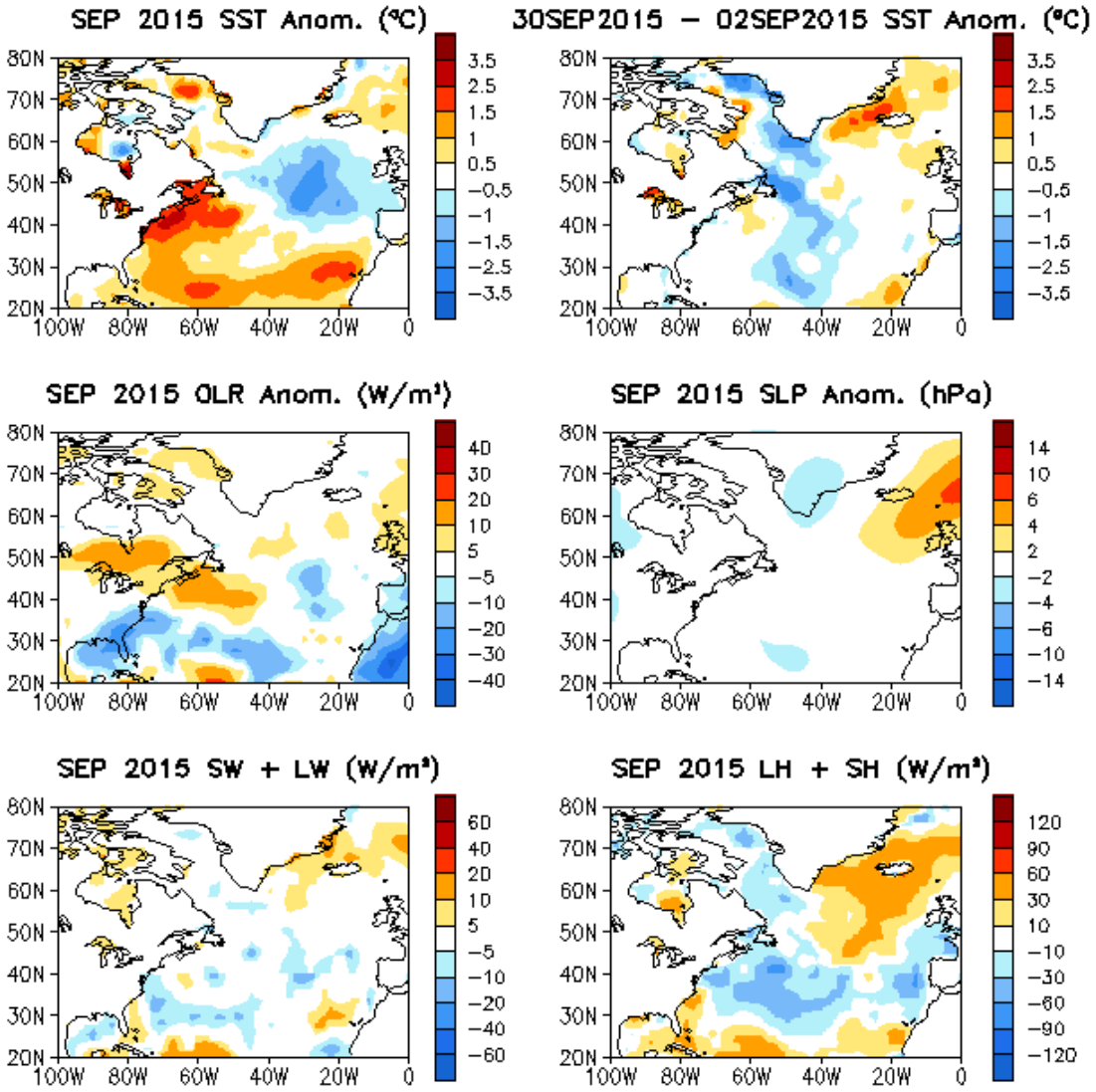
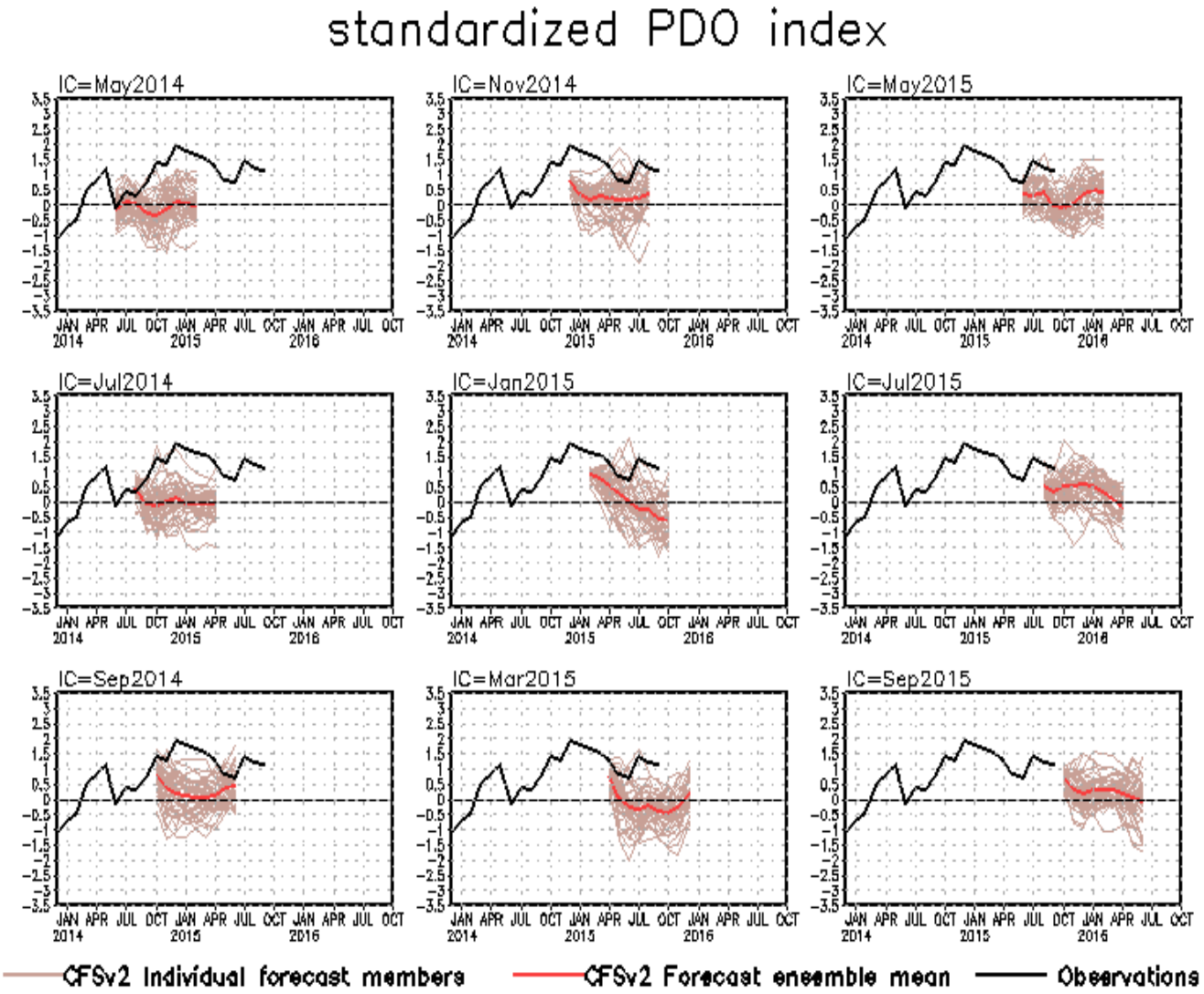


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

CFS Pacific Decadal Oscillation (PDO) Index Predictions



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 Sep. 2015 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.

Global Sea Surface Salinity (SSS)
Anomaly for September 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 dat issues!
- Negative SSS anomaly enhanced slightly over central and eastern Pacific as El Nino continues, with stronger precipitation and depressed evaporation over the regior Positive SSS anomaly, meanwhile, is observed over the western and southwestern Pacific, a reflection of E-P anomaly there.

- Data used

SSS :

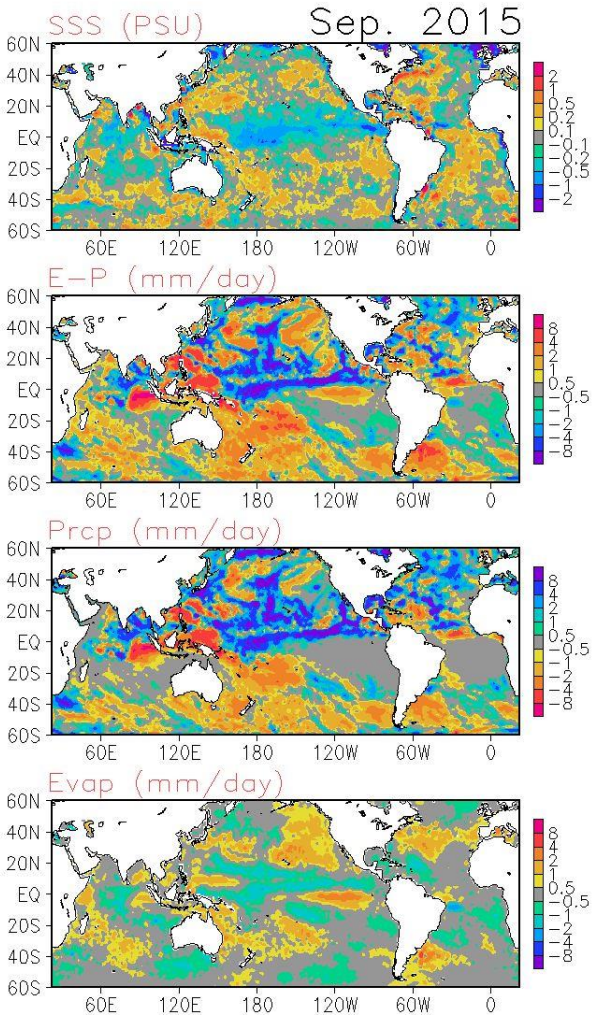
Blended Analysis of Surface Salinity (BASS) V0.Y
(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
(Xie et al. 2014)
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation:

CMORPH adjusted satellite precipitation estimates

Evaporation:

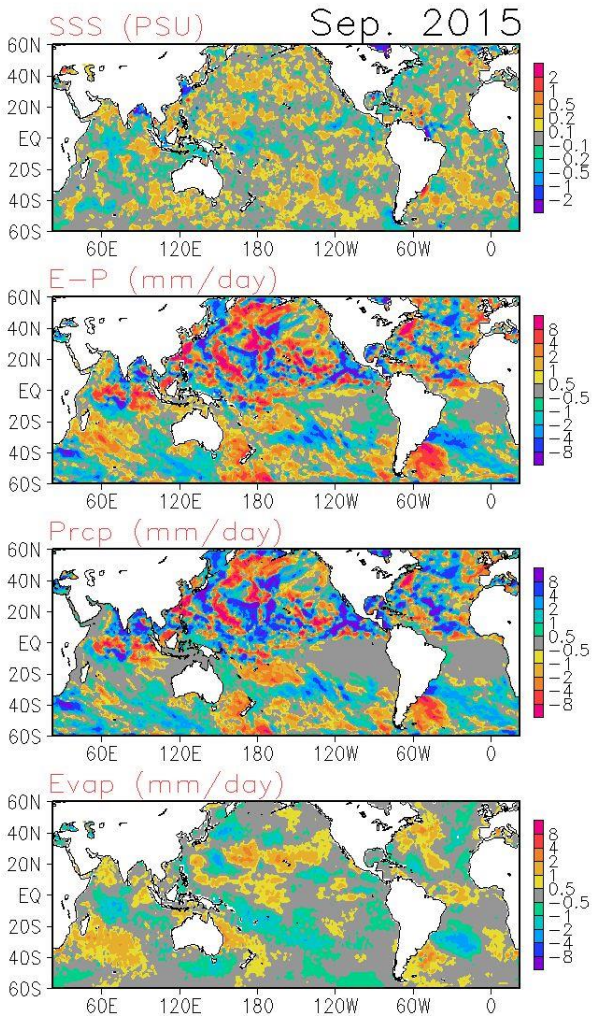
CFS Reanalysis



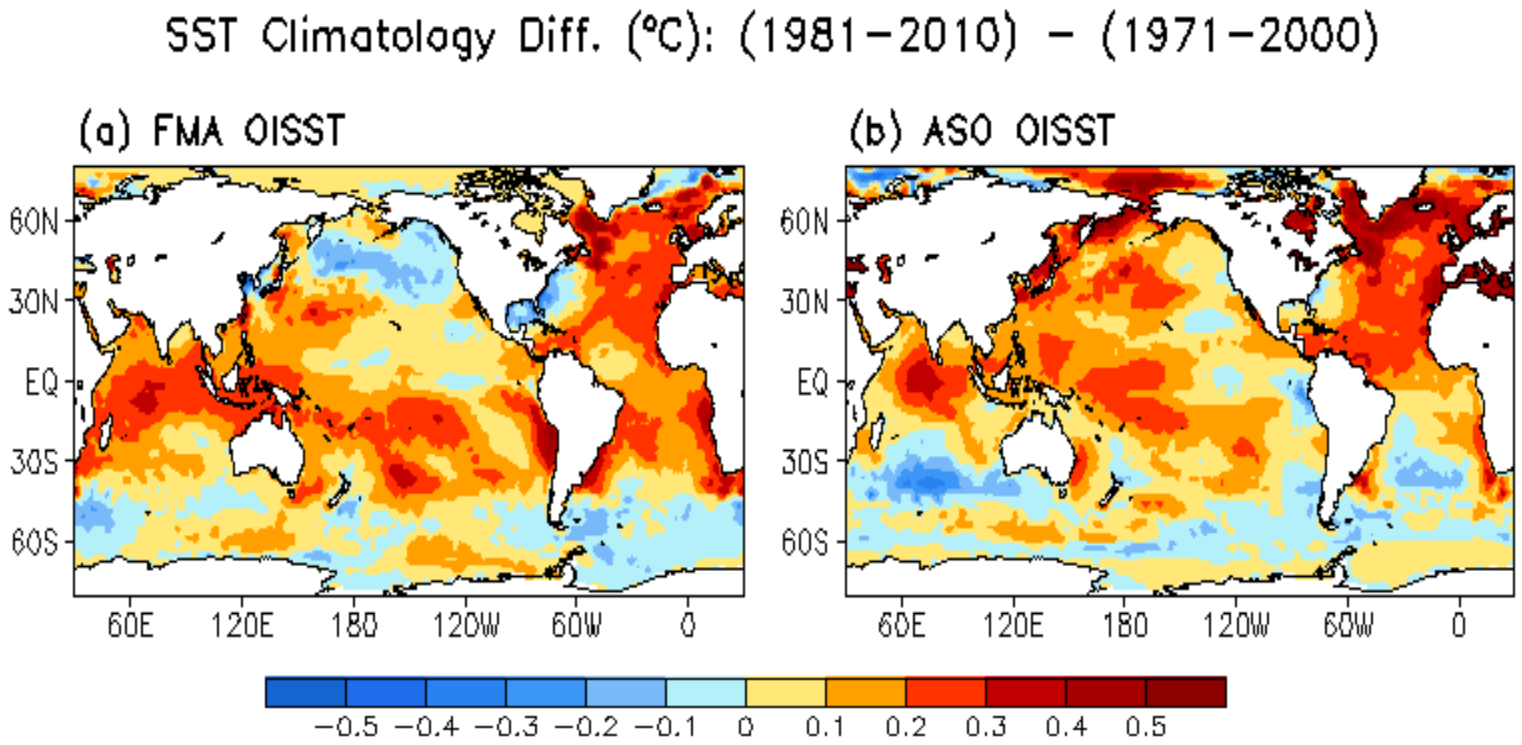
Global Sea Surface Salinity (SSS)

Tendency for September 2015

- SSS anomaly patterns for September are very similar to those for the previous month, with a slight enhanced negative SSS tendency over the central and eastern Pacific. However, the SSS tendency exhibit relatively small magnitude.



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^{o}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!