

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

Prepared by  
Climate Prediction Center, NCEP/NOAA  
**September 9, 2016**

**<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
  - Indian Ocean
  - Atlantic Ocean
- **Global SST Predictions**
  - ❖ **Current ENSO status and prediction**
  - ❖ **Experimental Arctic Sea Ice Prediction**

# Overview

## ➤ Pacific Ocean

- ❑ NOAA “ENSO Diagnostic Discussion” on 8 Sep 2016 suggested that “ENSO-Neutral conditions are slightly favored (between 55-60%) during the upcoming Northern Hemisphere fall and winter 2016-17.
- ❑ ENSO-neutral condition continued in Aug 2016.
- ❑ Negative SSTA persisted in the central-eastern Pacific with Nino3.4 =  $-0.5^{\circ}\text{C}$ .
- ❑ Negative subsurface anomaly weakened across the equatorial Pacific.
- ❑ Positive phase of PDO switched to negative phase in August.
- ❑ Arctic sea ice extent for Aug. 2016 ranked the fourth lowest in the Satellite record.

## ➤ Indian Ocean

- ❑ Positive SSTA continued in the eastern tropical Indian Ocean.
- ❑ Dipole Mode Index =  $-0.7^{\circ}\text{C}$  in Aug 2016.

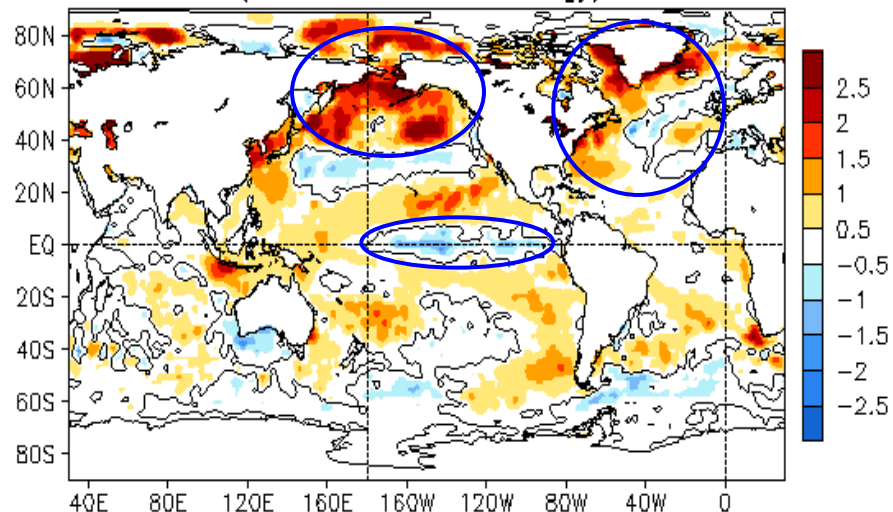
## ➤ Atlantic Ocean

- ❑ NAO strengthened with NAOI =  $-2.2$  in Aug 2016.
- ❑ NOAA updated Atlantic Hurricane outlook issued in Aug calls for 50% chance of a near-normal season, a 35% chance of an above-normal season, and a 15% chance of a below-normal season.

# Global Oceans

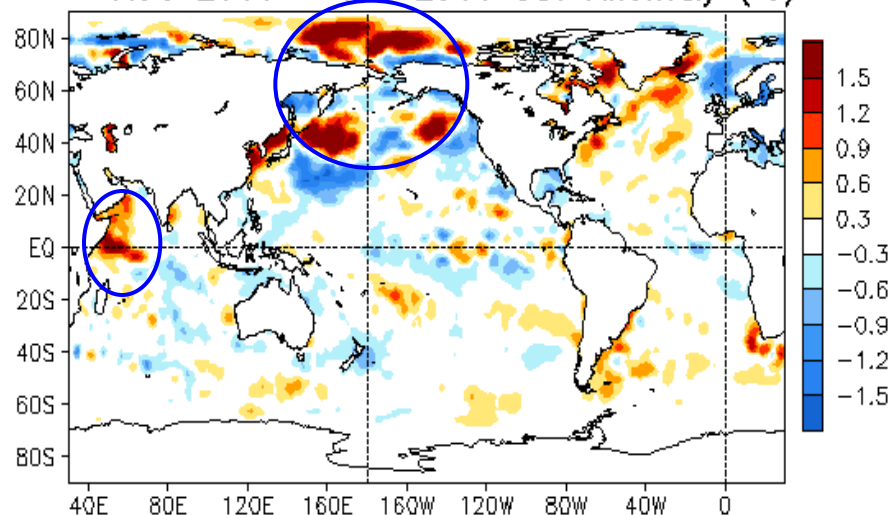
# Global SST Anomaly ( $^{\circ}\text{C}$ ) and Anomaly Tendency

AUG 2016 SST Anomaly ( $^{\circ}\text{C}$ )  
(1981–2010 Climatology)



- Negative SSTA were confined in a narrow band along the C.-E. equatorial Pacific, and surrounded by positive SSTA in off-equatorial regions and the W.-C. Pacific.
- Strong positive SSTA presented in the high-latitude N. Pacific and near the Bering strait.
- Positive SSTA occupied the E. coast of N. America and subpolar north Atlantic.

AUG 2016 – JUL 2016 SST Anomaly ( $^{\circ}\text{C}$ )

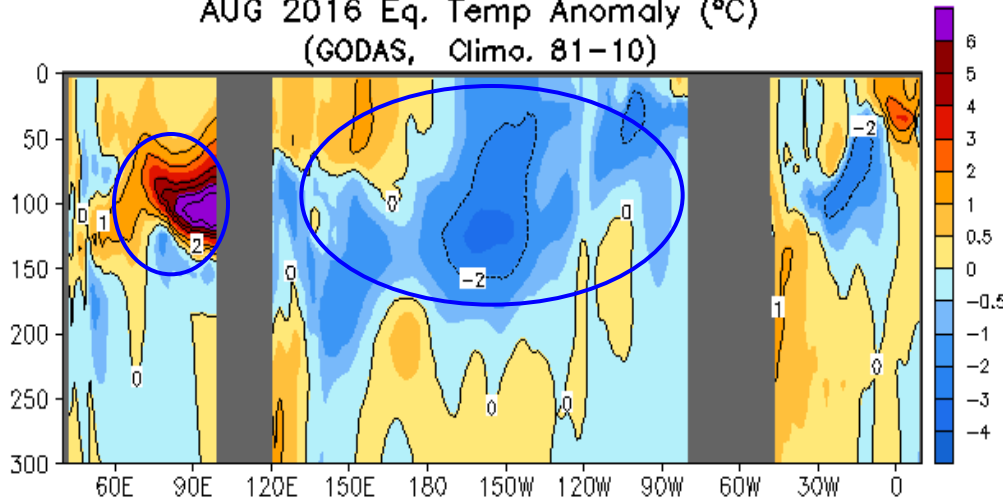


- Large SSTA tendencies presented in the North Pacific.
- Positive SSTA tendency was observed in the western Indian Ocean.

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

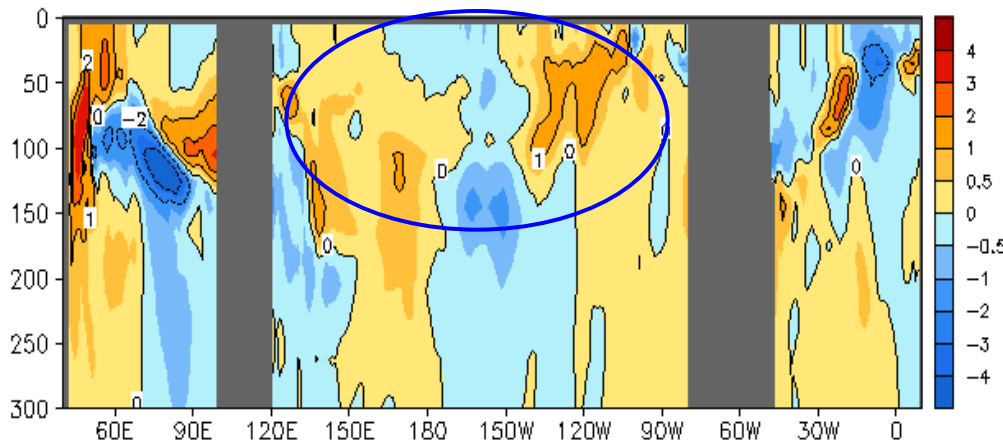
AUG 2016 Eq. Temp Anomaly (°C)  
(GODAS, Clima. 81-10)



- Negative temperature anomalies continued along the thermocline in the whole Pacific, while positive temperature anomalies were confined near the surface in the W.-C. Pacific.

- Strong positive temperature anomalies were observed in the eastern Indian Ocean.

AUG 2016 - JUL 2016 Eq. Temp Anomaly (°C)

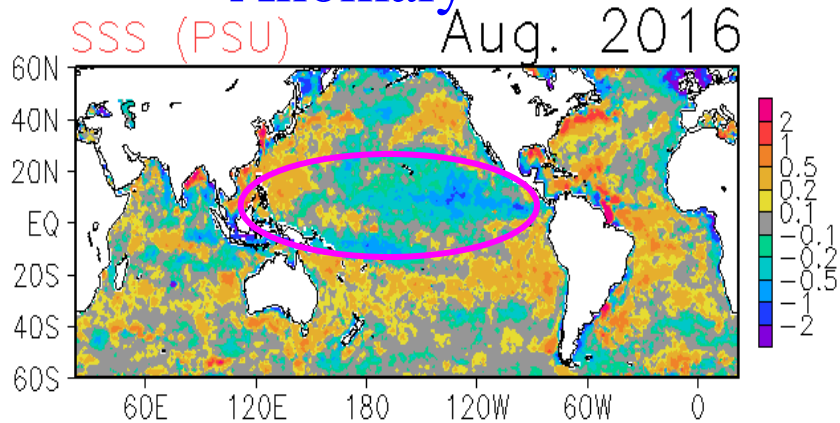


- Positive temperature anomaly tendency dominated the W. Pacific and E. Pacific.

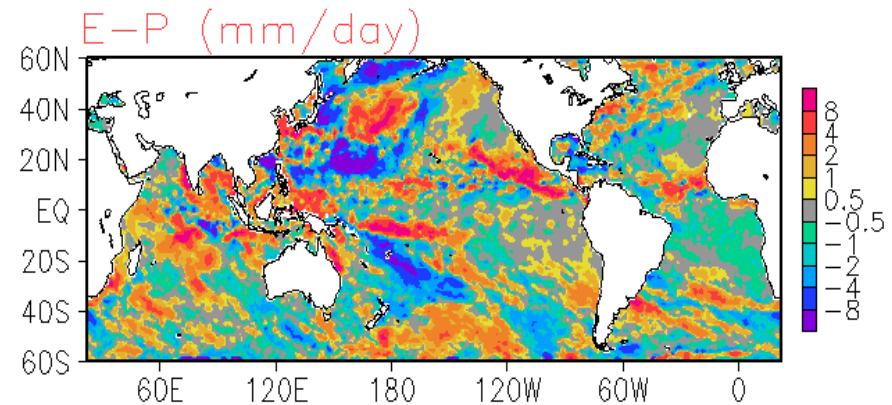
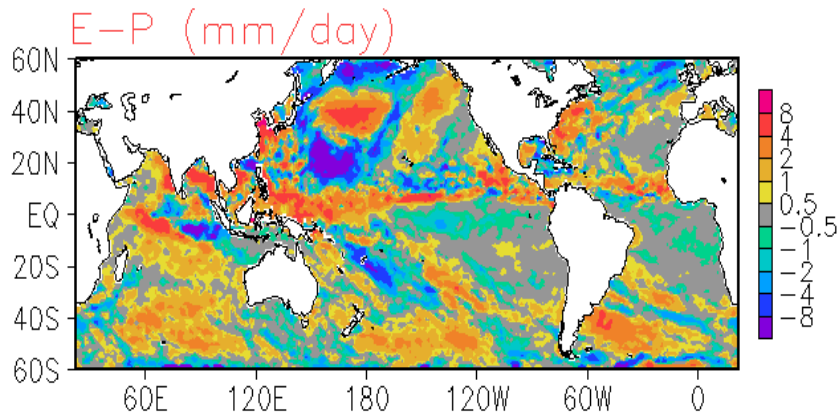
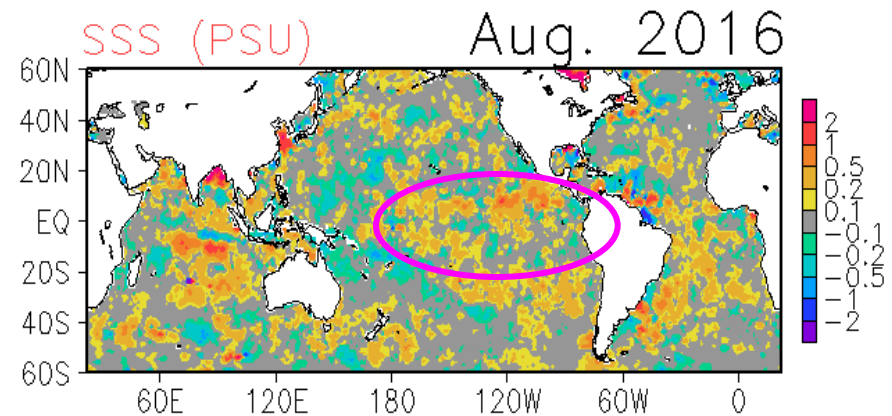
**Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1981-2010 base period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

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

Anomaly



Anomaly Tendency



- Positive (negative) SSS anomaly presented in the western(eastern) tropical Pacific.
- Positive SSS tendency was observed in the C.-E. tropical Pacific due to the reduction of freshwater flux.

SSS : Bended Analysis of Surface Salinity (BASS) based on in situ and satellite observation (Xie et al. 2014)  
( <ftp.cpc.ncep.noaa.gov/precip/BASS> )

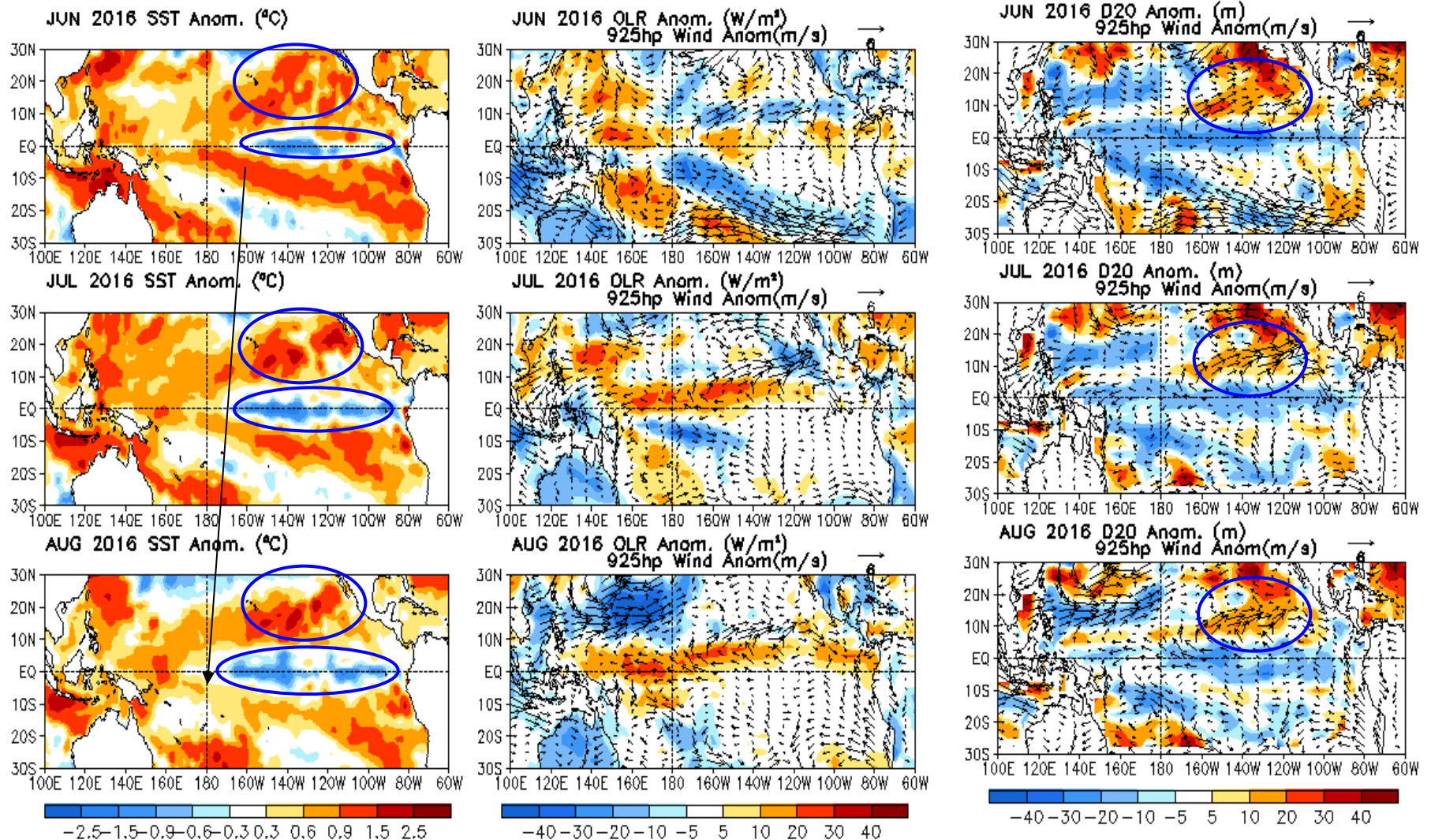
Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: CFSR

# Tropical Pacific Ocean and ENSO Conditions



# Last Three Month SST, OLR, D20 and 925hp Wind Anom.



- Negative SSTA enhanced slightly and extended westward in the past three months.
- Positive SSTA and D20A persisted in the N.E tropical Pacific.
- Surface easterly wind anomalies persisted in the western Pacific, consistent with enhanced convection over the Maritime Continent and in the eastern Indian Ocean.

# 2016 E. Pacific Hurricane Season

([http://www.cpc.ncep.noaa.gov/products/Epac\\_hurr/Epac\\_hurricane.html](http://www.cpc.ncep.noaa.gov/products/Epac_hurr/Epac_hurricane.html))

E.Pac	<u>Observation by 7 Sep, 2016</u>	Outlook issued on 27 May, 2016 <b>40% near-normal</b>	1981-2010
Named storms	<u>15</u>	13-20	15
Hurricanes	<u>8</u>	6-11	8
Major hurricanes	<u>4</u>	3-6	4

Scenario 1: competing factors: Near-normal or above-normal season most likely if La Niña is weaker and the global SST patterns of the last two active seasons are again present.

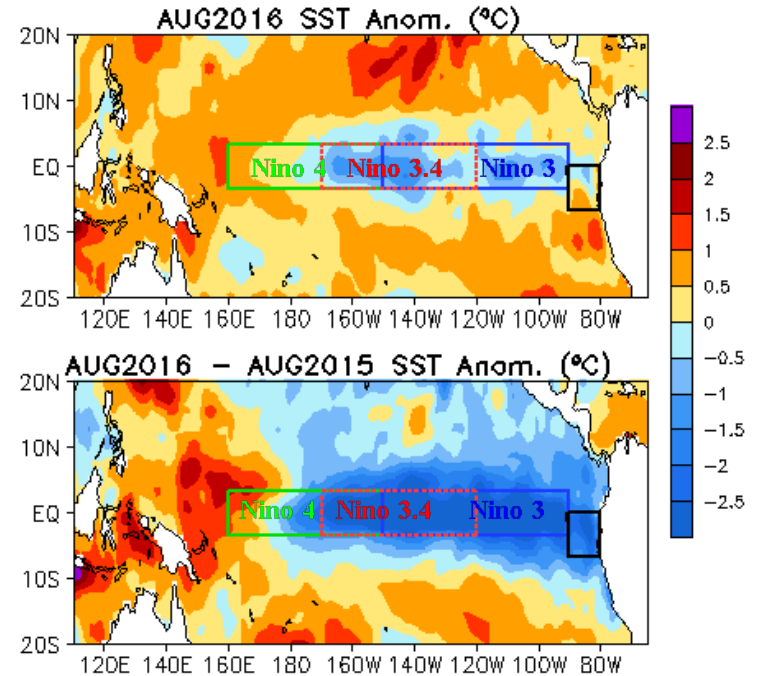
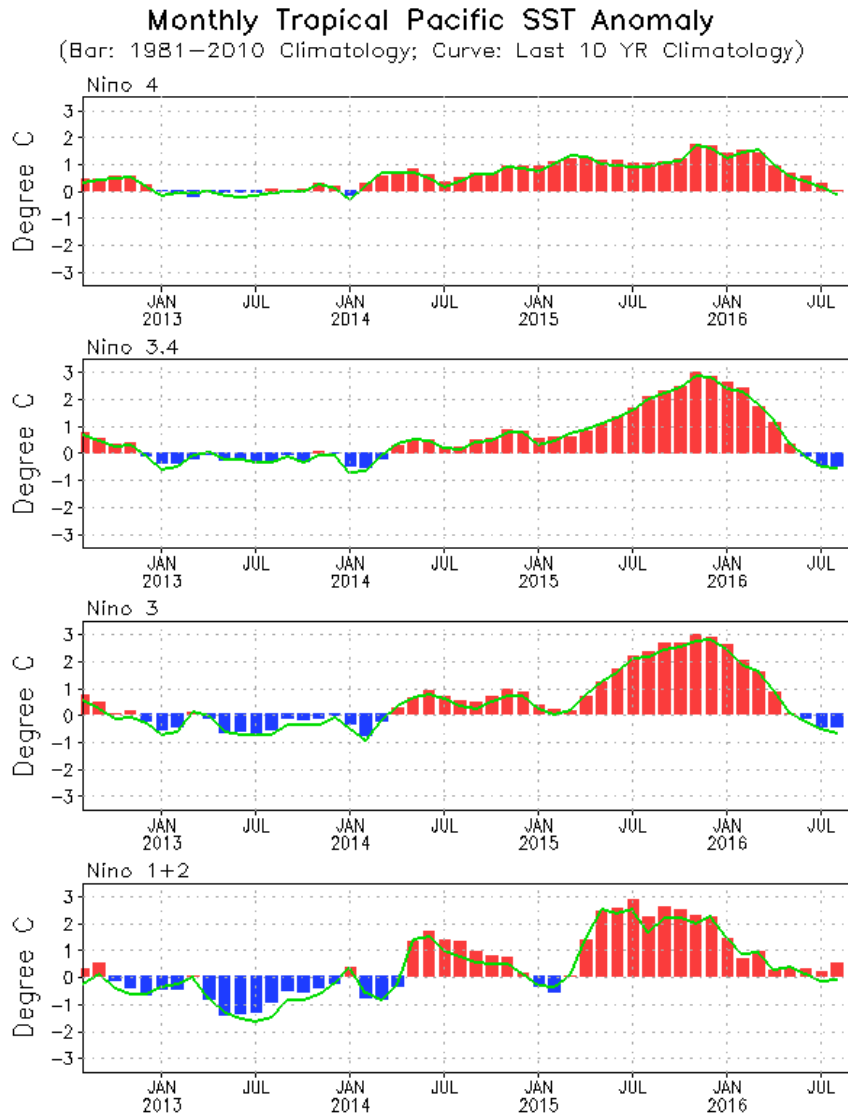
Scenario 2: competing factors: Near-normal season most likely if La Niña is stronger and the global SST patterns of the last two active seasons are again present this year.

Scenario 3: re-inforcing factors: Near-normal or below-normal season most likely if La Niña develops and the global SST patterns observed during the 1995-2013 low-activity era for eastern Pacific hurricanes re-emerge.



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

# Evolution of Pacific NINO SST Indices



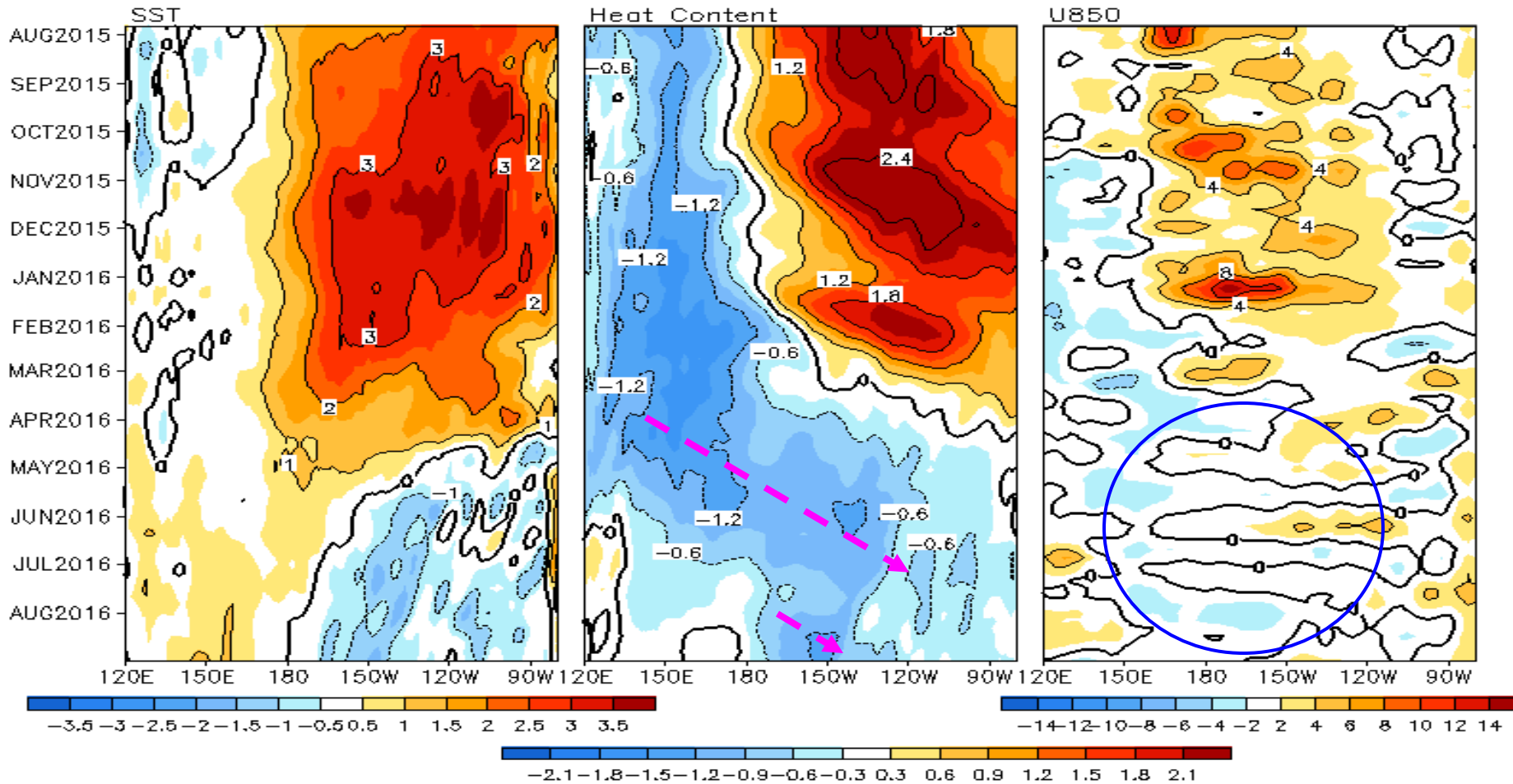
- Niño3 and Niño 3.4 were slightly below-average, with Niño3.4 = -0.5°C in Aug 2016.

- The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v4.

Fig. P1a. Niño 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.

# Equatorial Pacific SST (°C), HC300 (°C), U850 (m/s) Anomalies

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



- Negative SSTA developed in the far eastern Pacific in May 2016, and has extended westward since then.
- Negative HC300 anomalies strengthened east of dateline.
- Surface wind and OLR have been near-normal since May 2016, indicating ENSO-neutral conditions.

Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2°S-2°N and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST is derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1981-2010 base period pentad means respectively.

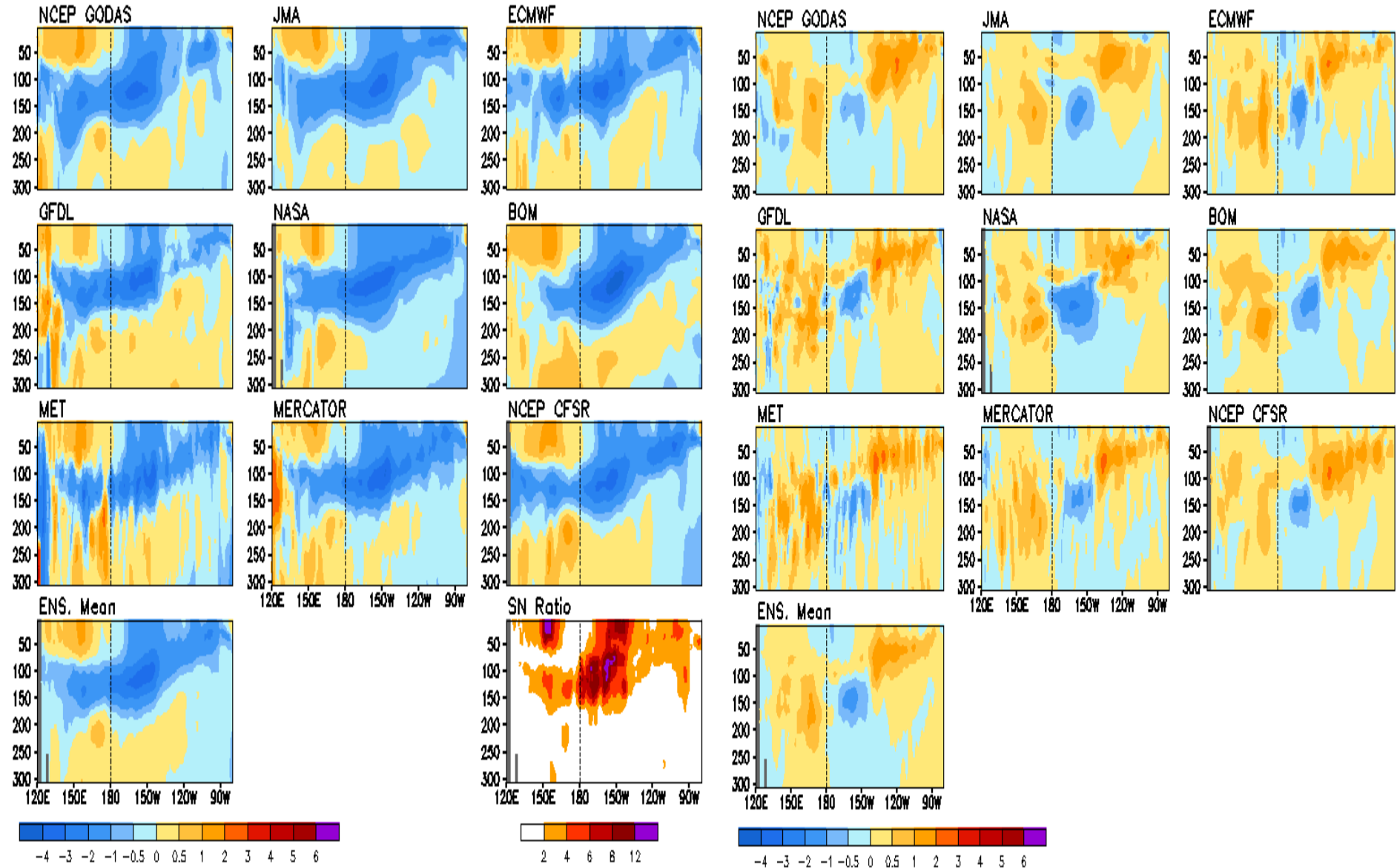
# Real-Time Ocean Reanalysis Intercomparison: [Temperature](#)

Climatology : 1993-2013

([http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93\\_body.html](http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html))

Anomalous Temperature (C) Averaged in 1S-1N: AUG 2016

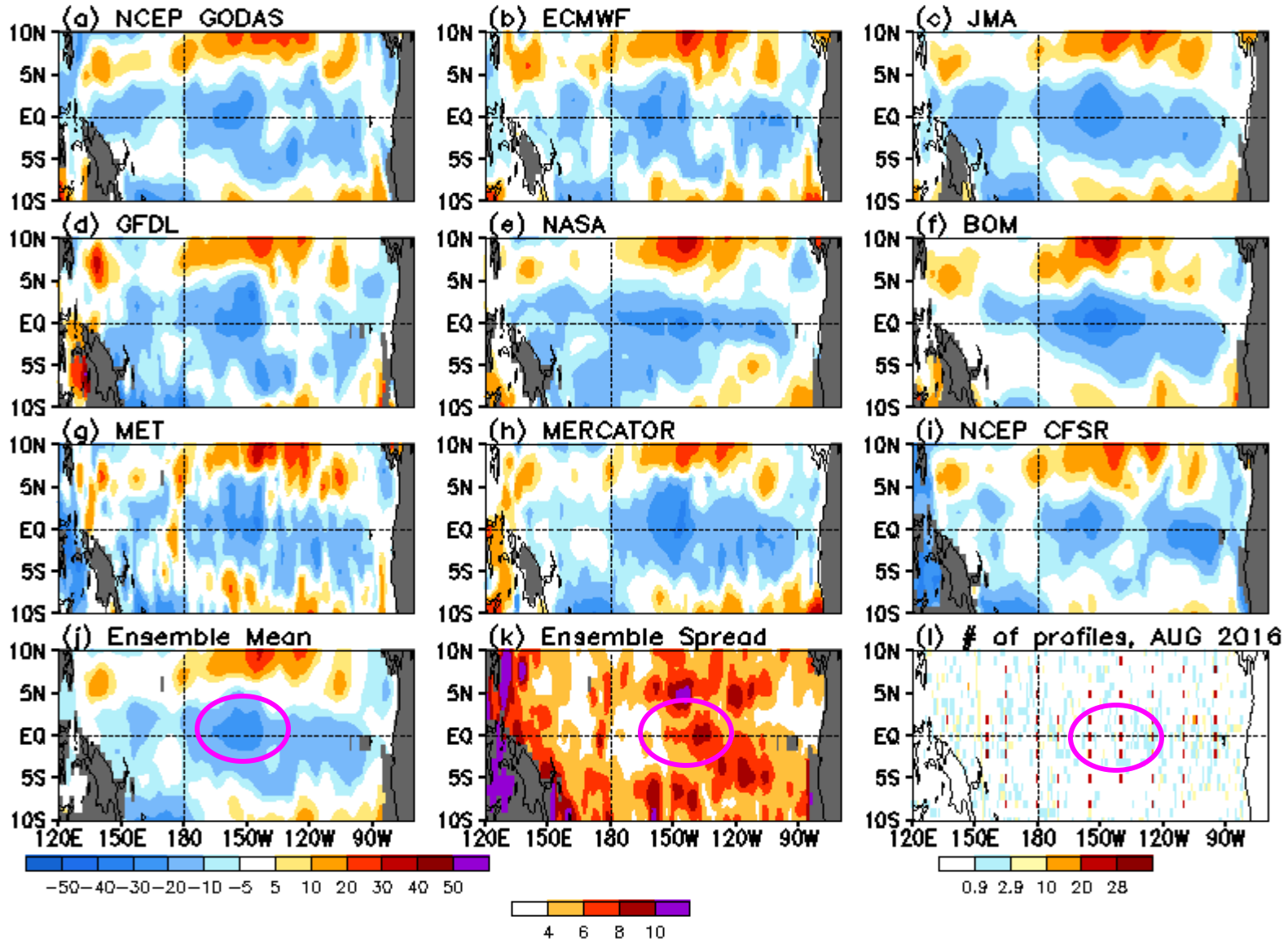
AUG 2016 - JUL 2016 1S-1N Temp Anomaly (C)



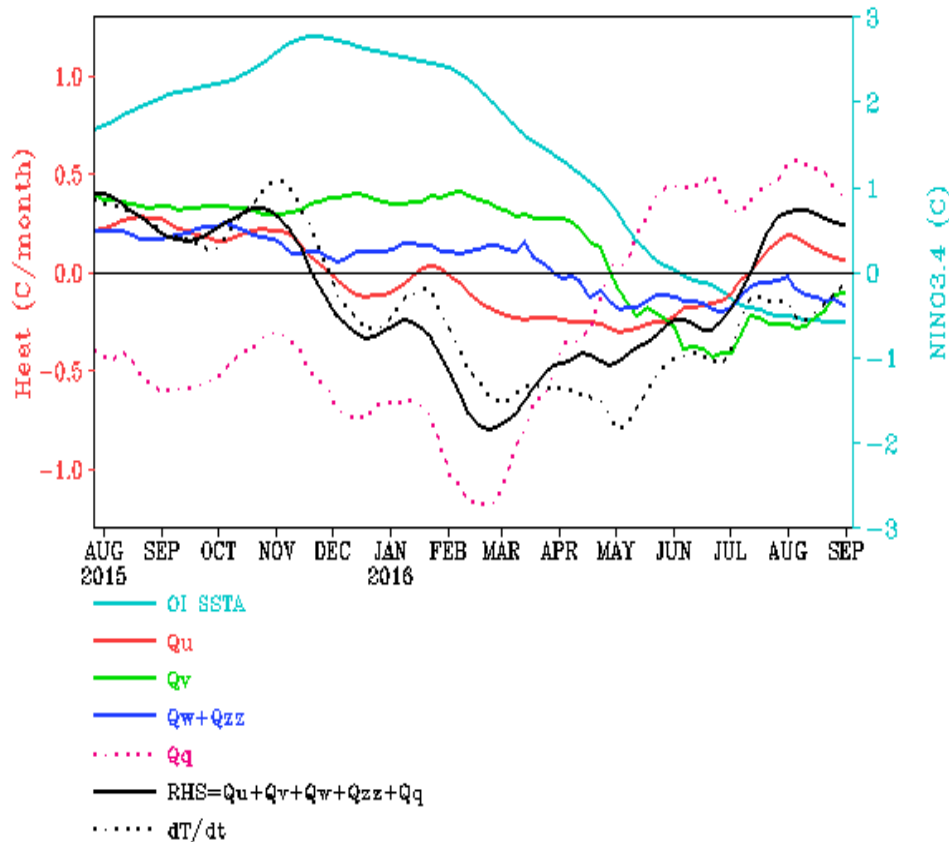
# Real-Time Ocean Reanalysis Intercomparison: [D20](#)

## Climatology : 1993-2013

([http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93\\_body.html](http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html))



# NINO3.4 Heat Budget



- Observed SSTA tendency ( $dT/dt$ ) in NINO3.4 region (dotted black line) was small in Aug 2016.

- Dynamical terms ( $Q_v$ ,  $Q_w+Q_{zz}$ ,  $Q_u$ ) were near zero in August..

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.

**$Q_u$ : Zonal advection;  $Q_v$ : Meridional advection;**

**$Q_w$ : Vertical entrainment;  $Q_{zz}$ : Vertical diffusion**

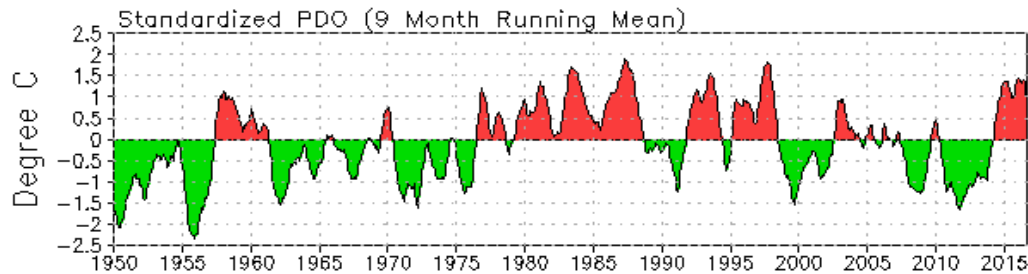
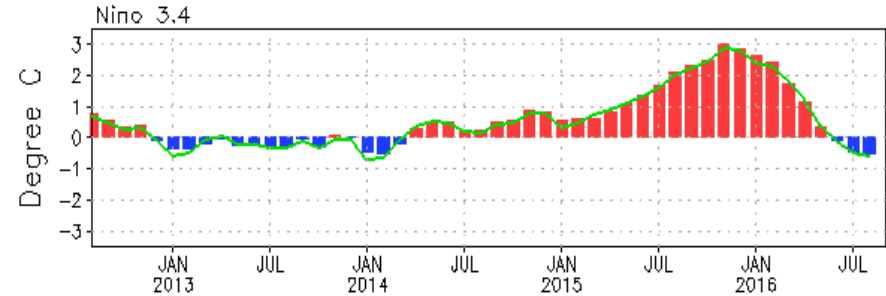
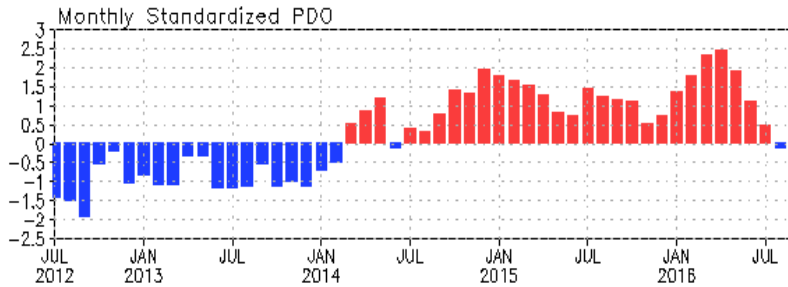
**$Q_q$ :  $(Q_{net} - Q_{open} + Q_{corr})/pcph$ ;  $Q_{net} = SW + LW + LH + SH$ ;**

**$Q_{open}$ : SW penetration;  $Q_{corr}$ : Flux correction due to relaxation to OI SST**

# North Pacific & Arctic Oceans



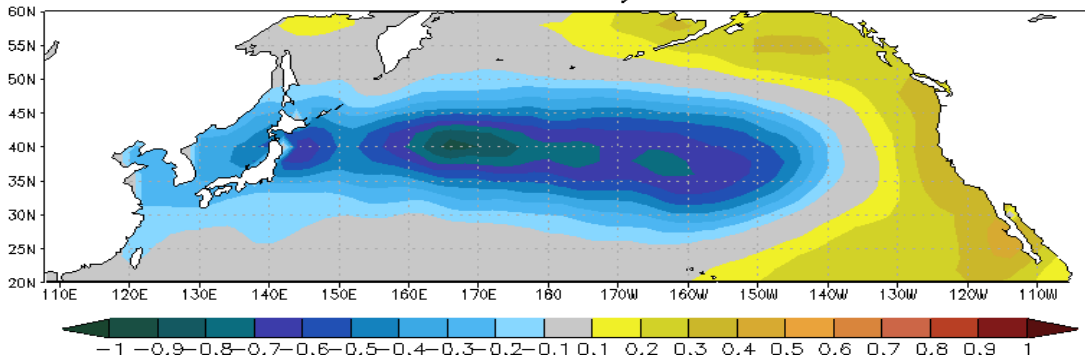
# Pacific Decadal Oscillation Index



- PDO switched to negative phase in Aug with PDO index = -0.1.

- Statistically, ENSO leads PDO by 3-4 months, may through atmospheric bridge.

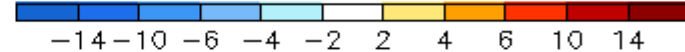
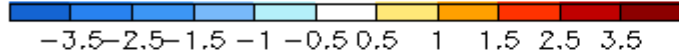
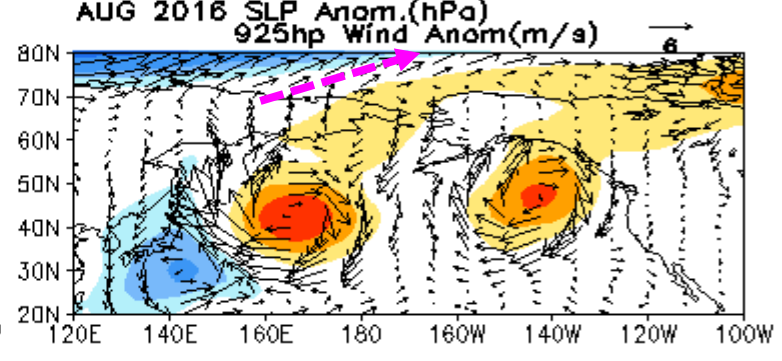
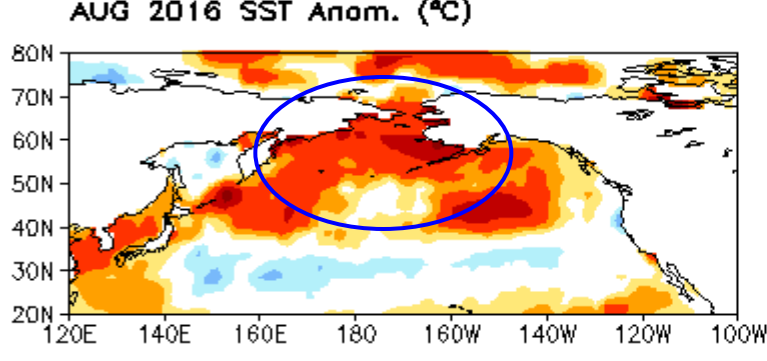
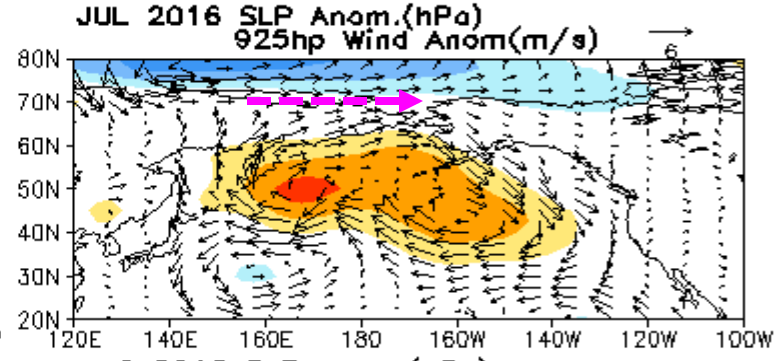
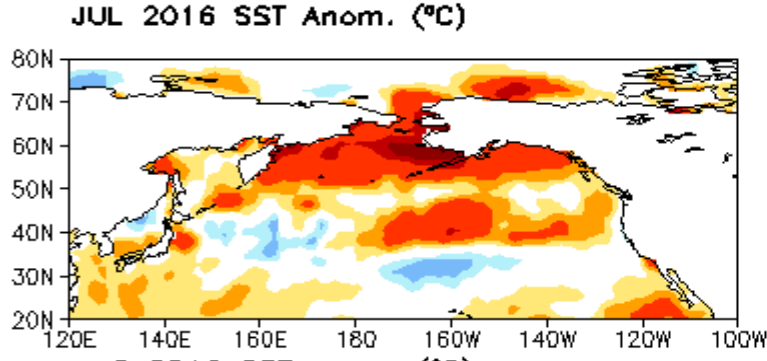
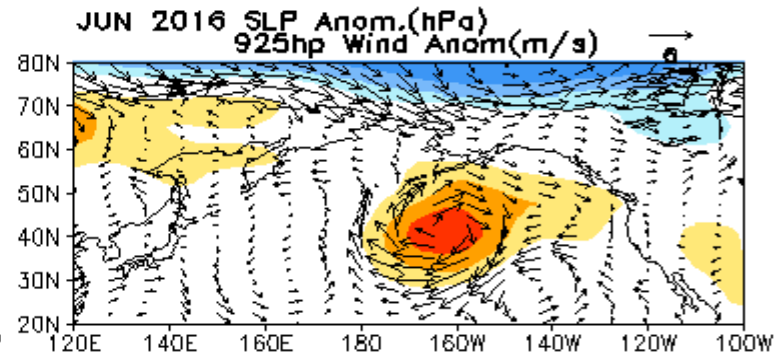
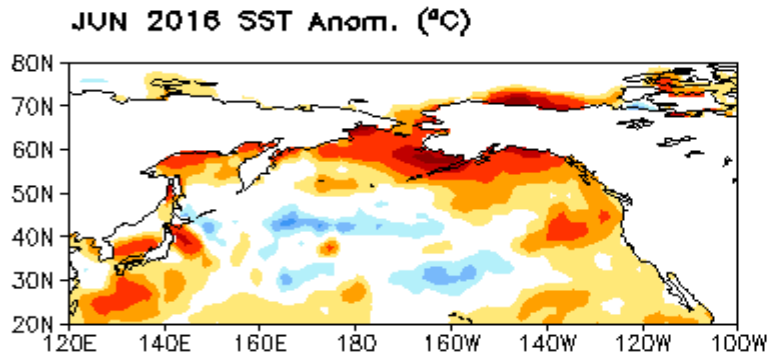
1st EOF of monthly ERSST v3b



- Pacific Decadal Oscillation is defined as the 1<sup>st</sup> 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.

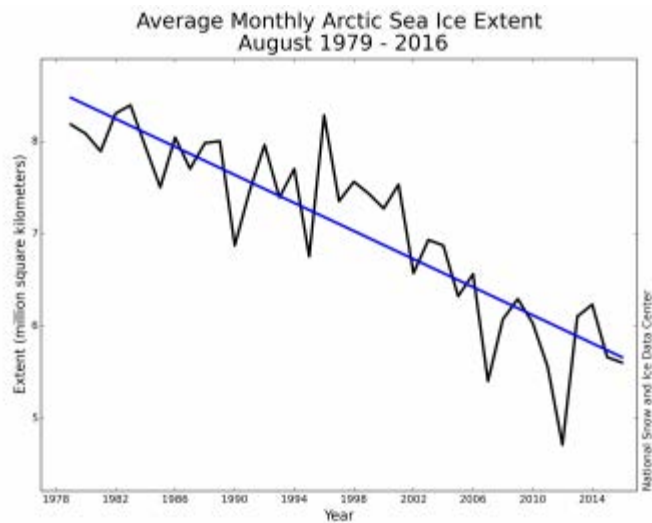
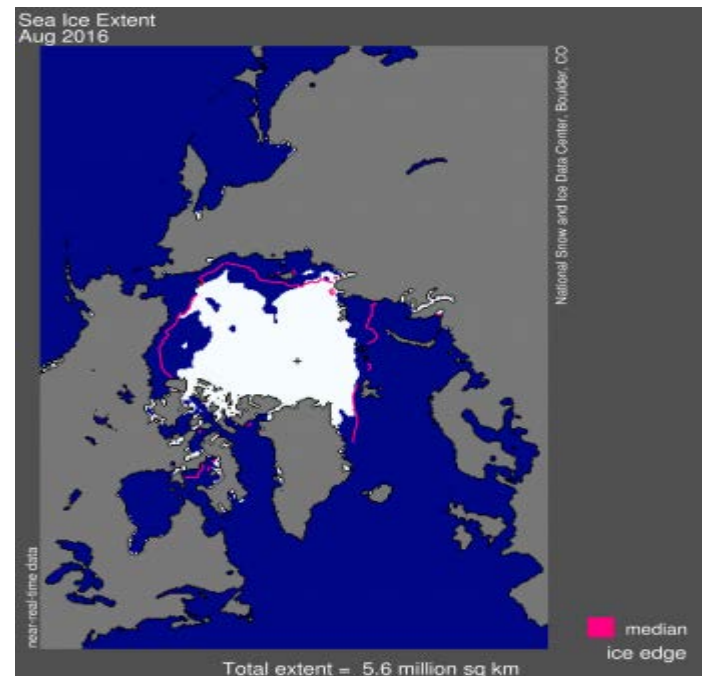
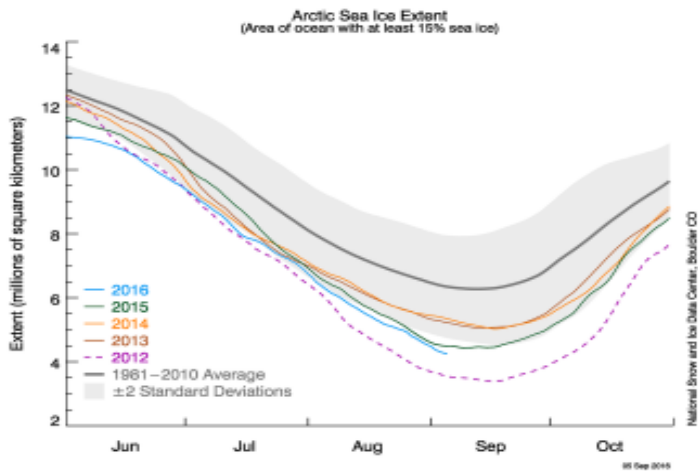
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

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



# Arctic Sea Ice

National Snow and Ice Data Center  
<http://nsidc.org/arcticseaicenews/index.html>

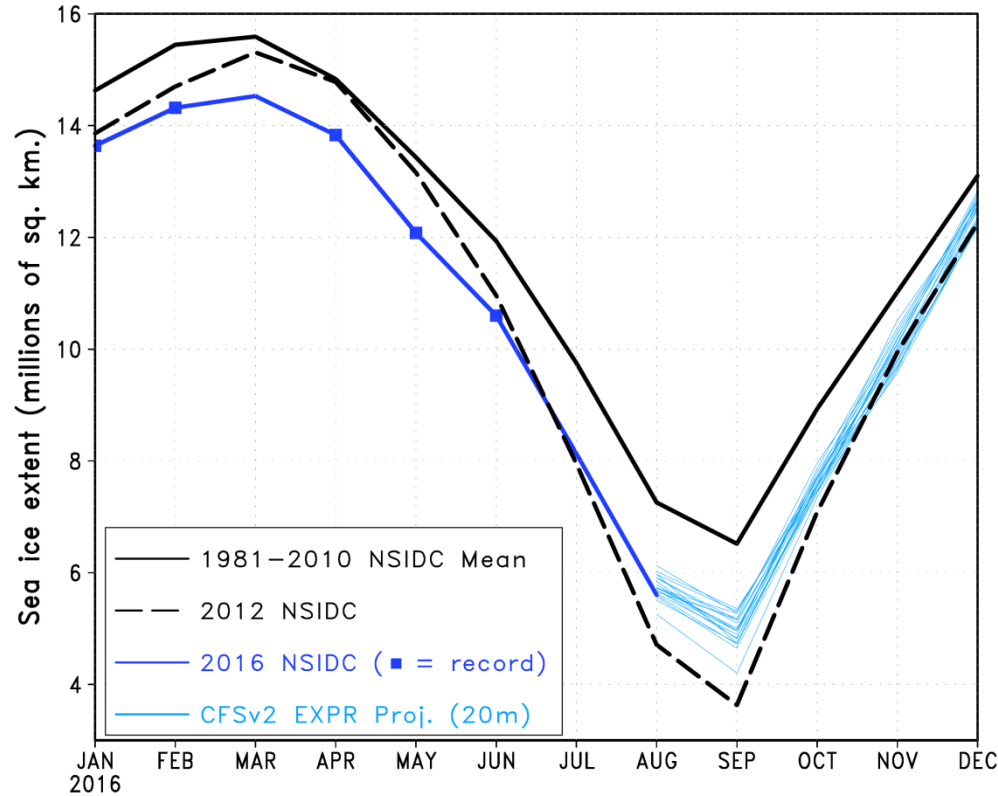


- Arctic sea ice extent for Aug. 2016 ranked the fourth lowest in the Satellite record.

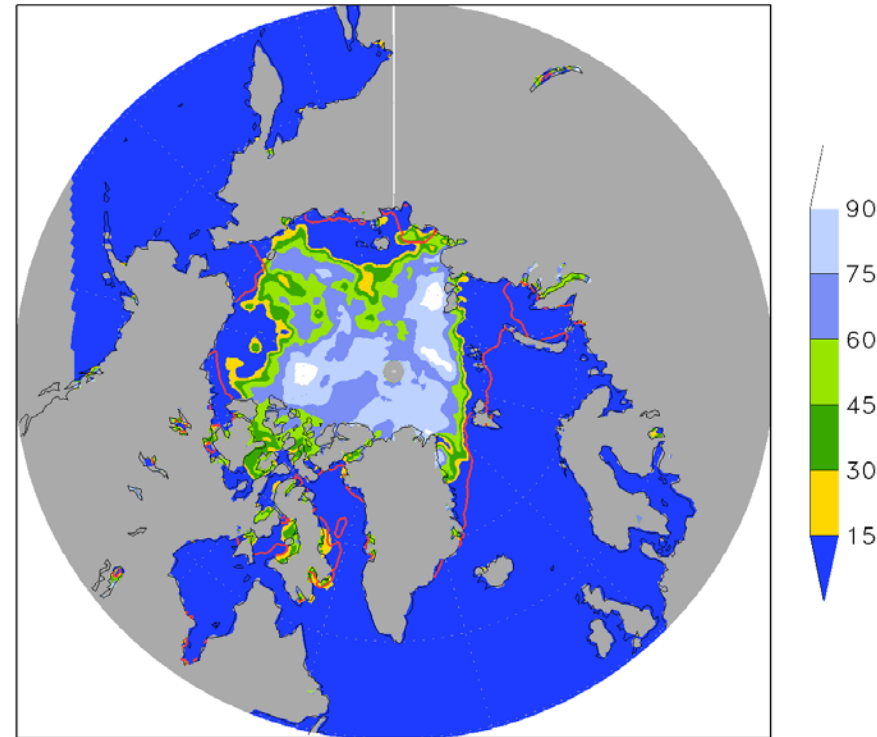
# Sea Ice Outlook

(Wang and Collwo)

2016 Arctic sea ice extent



Sea ice concentration (%) 01AUG2016



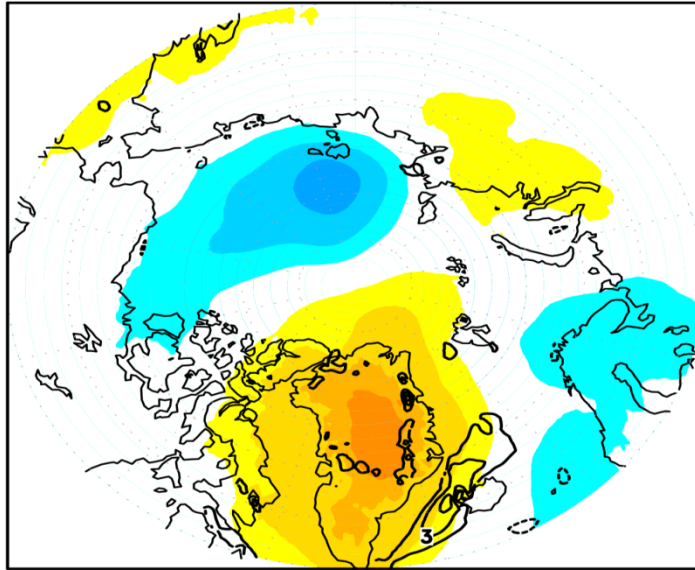
- Increased storminess in the Arctic throughout August resulted in an increased rate of sea ice melt. As a result, current melt is below most of our model projections but a new record low is still not anticipated.

- The monthly sea ice extent for September is on track to be the 2<sup>nd</sup> or 3<sup>rd</sup> lowest in the satellite era (1979-present)

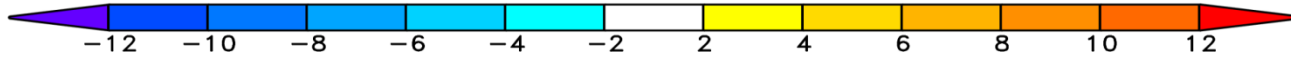
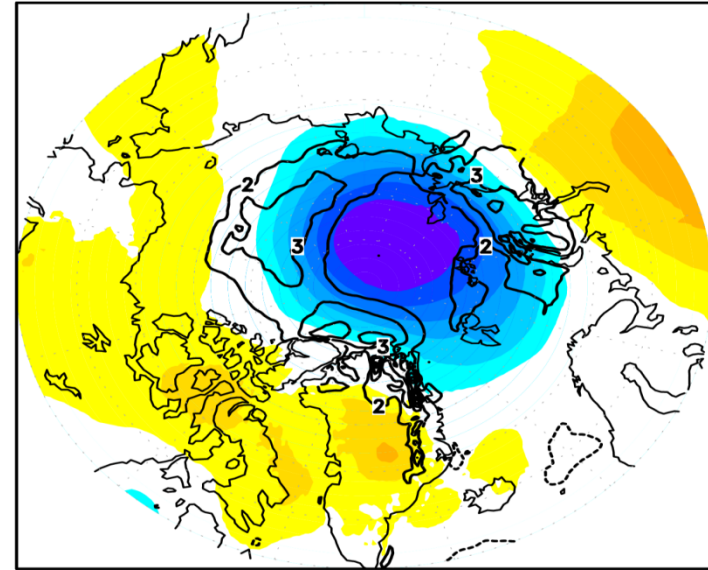
(Provided by Thomas W. Collwo)

MSL pressure anomaly (hpa, shaded) and 10 m wind anomaly (m/s, contour)  
from CFSR with respect to the 1981–2010 period

July 2016



August 2016

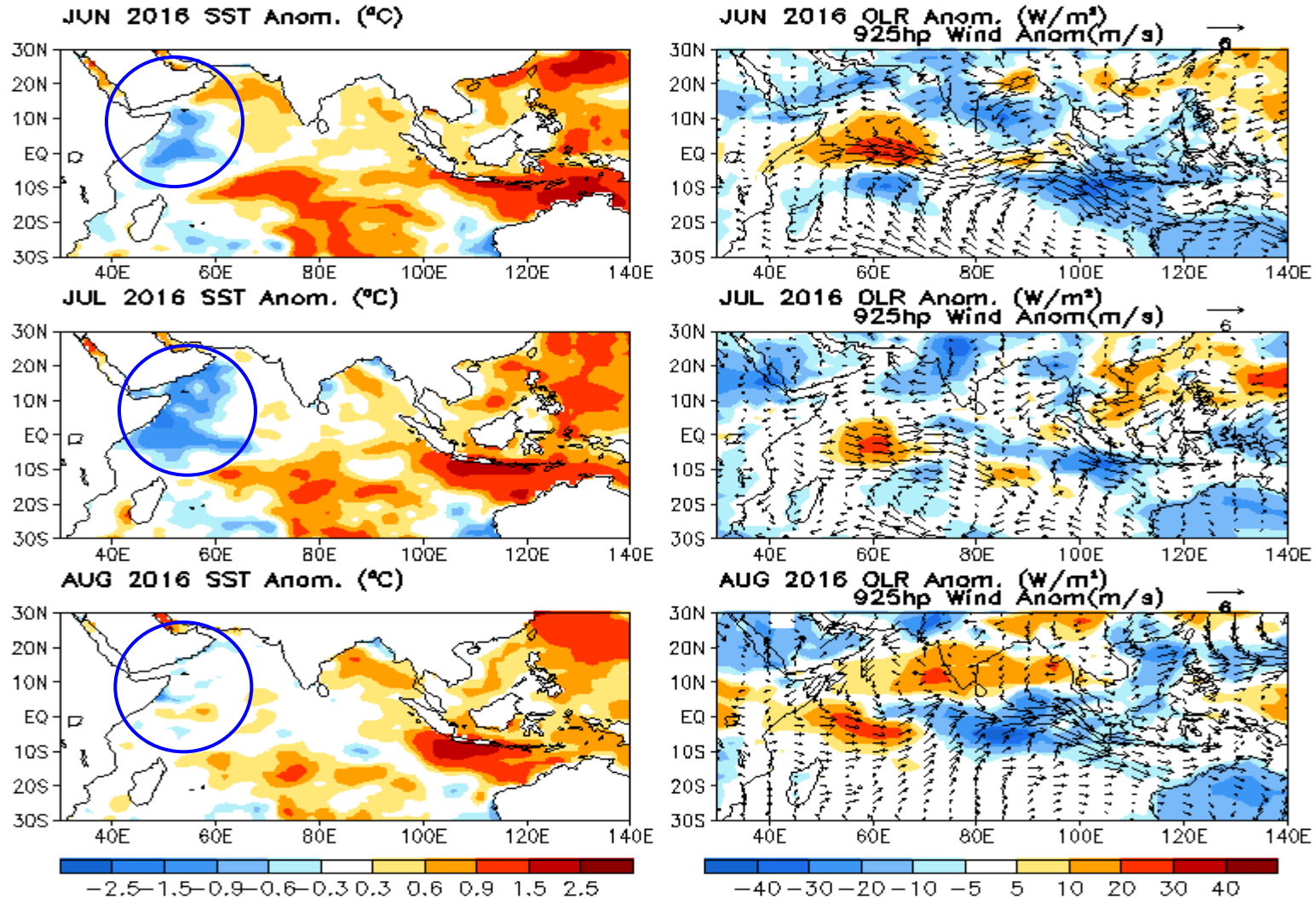


- July and August had different atmospheric patterns which impacted sea ice loss
- July featured a cyclonic pressure anomaly over the Laptev and Siberian Seas which allowed for cooler temperatures and slowed ice melt.
- On the other hand, August featured a very large cyclonic anomaly over the center of the Arctic which resulted in a strong pressure gradient and positive wind anomaly over ice covered regions. As a result of increased stress and compaction, faster melting occurred.

(Provided by Thomas W. Collow)

# Indian Ocean

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

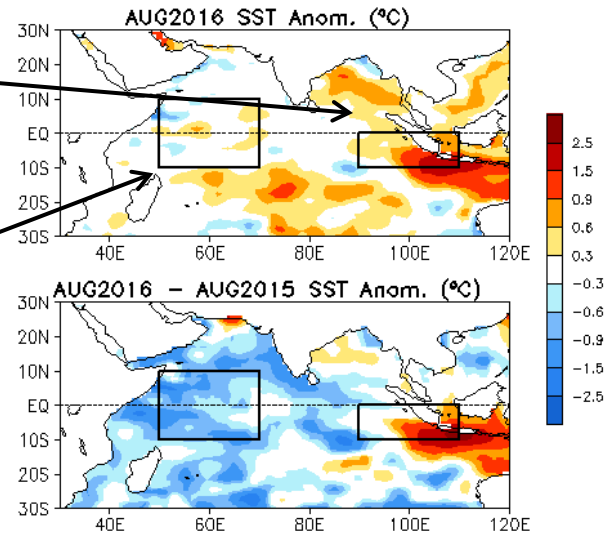
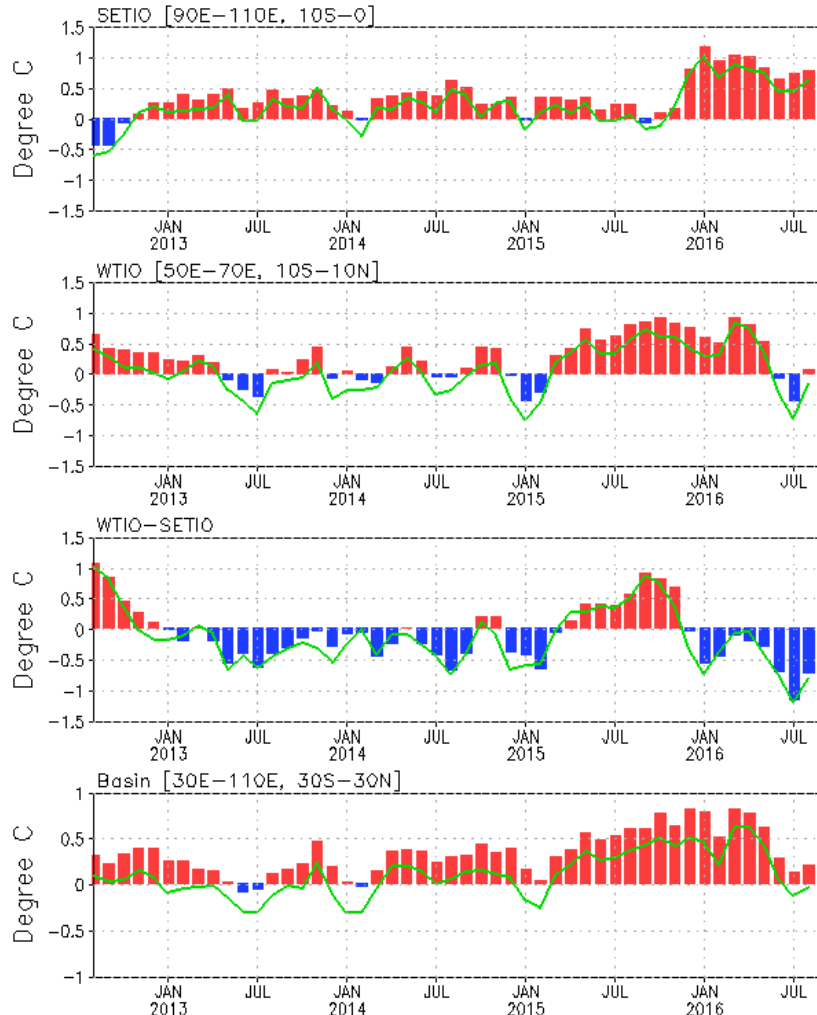


- Surface westerly wind anomalies persisted in the tropical Indian Ocean in the past three months.
- Positive SSTA persisted in the eastern and southern Indian Ocean, while negative SSTA dissipated in the western tropical Indian Ocean in Aug 2016.

# Evolution of Indian Ocean SST Indices

## Monthly Tropical Indian SST Anomaly

(Bar: 1981–2010 Climatology; Curve: Last 10 YR Climatology)



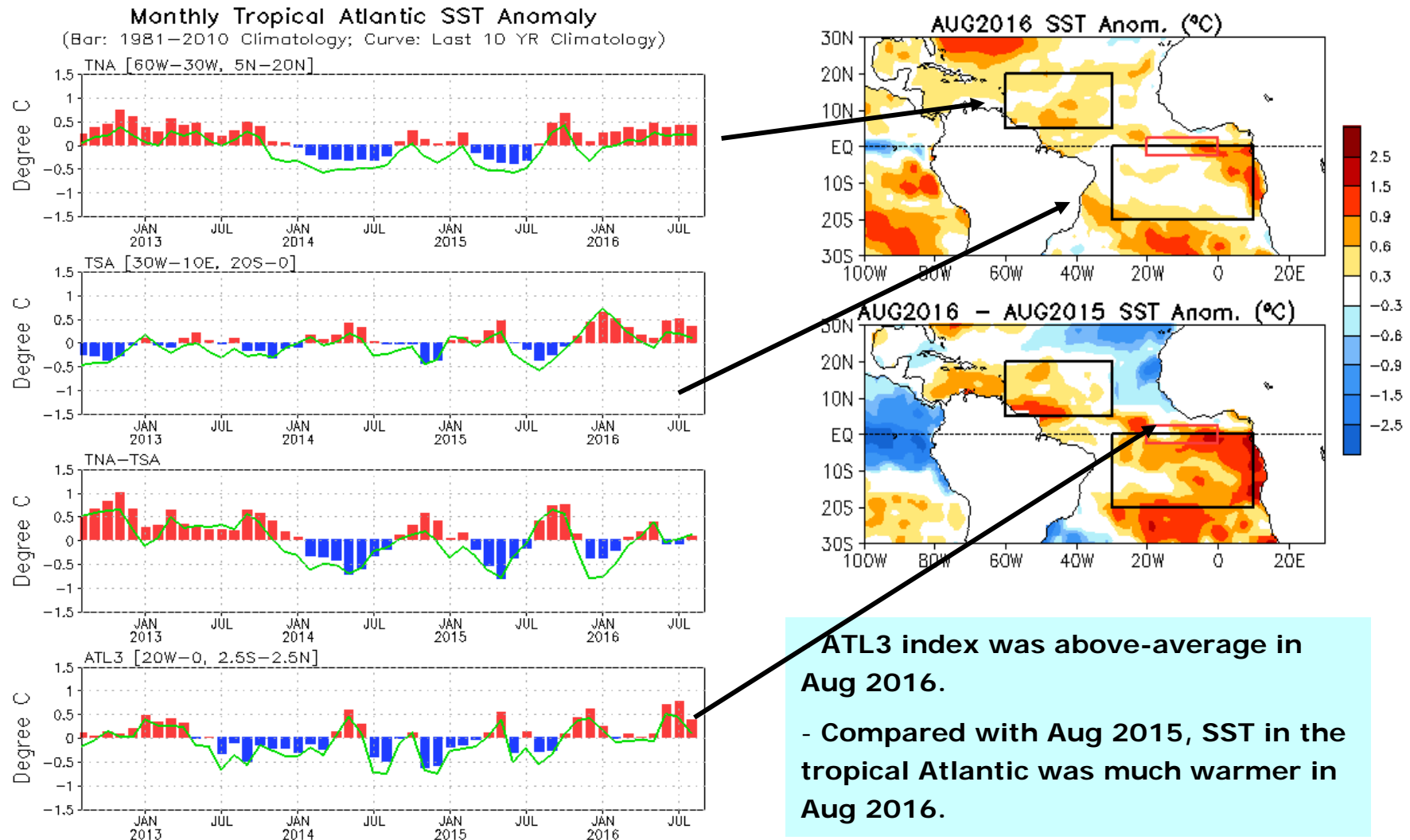
- SETIO has been strong positive ( $> +0.7^{\circ}\text{C}$ ) since Dec 2015.
- WTIO was near normal in Aug 2016.
- DMI weakened in Aug with  $\text{DMI} = -0.7^{\circ}\text{C}$ .
- The basin wide warming continued.

**Fig. 11a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies ( $^{\circ}\text{C}$ ) for the SETIO [90 $^{\circ}\text{E}$ -110 $^{\circ}\text{E}$ , 10 $^{\circ}\text{S}$ -0] and WTIO [50 $^{\circ}\text{E}$ -70 $^{\circ}\text{E}$ , 10 $^{\circ}\text{S}$ -10 $^{\circ}\text{N}$ ] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.**



# Tropical and North Atlantic Ocean

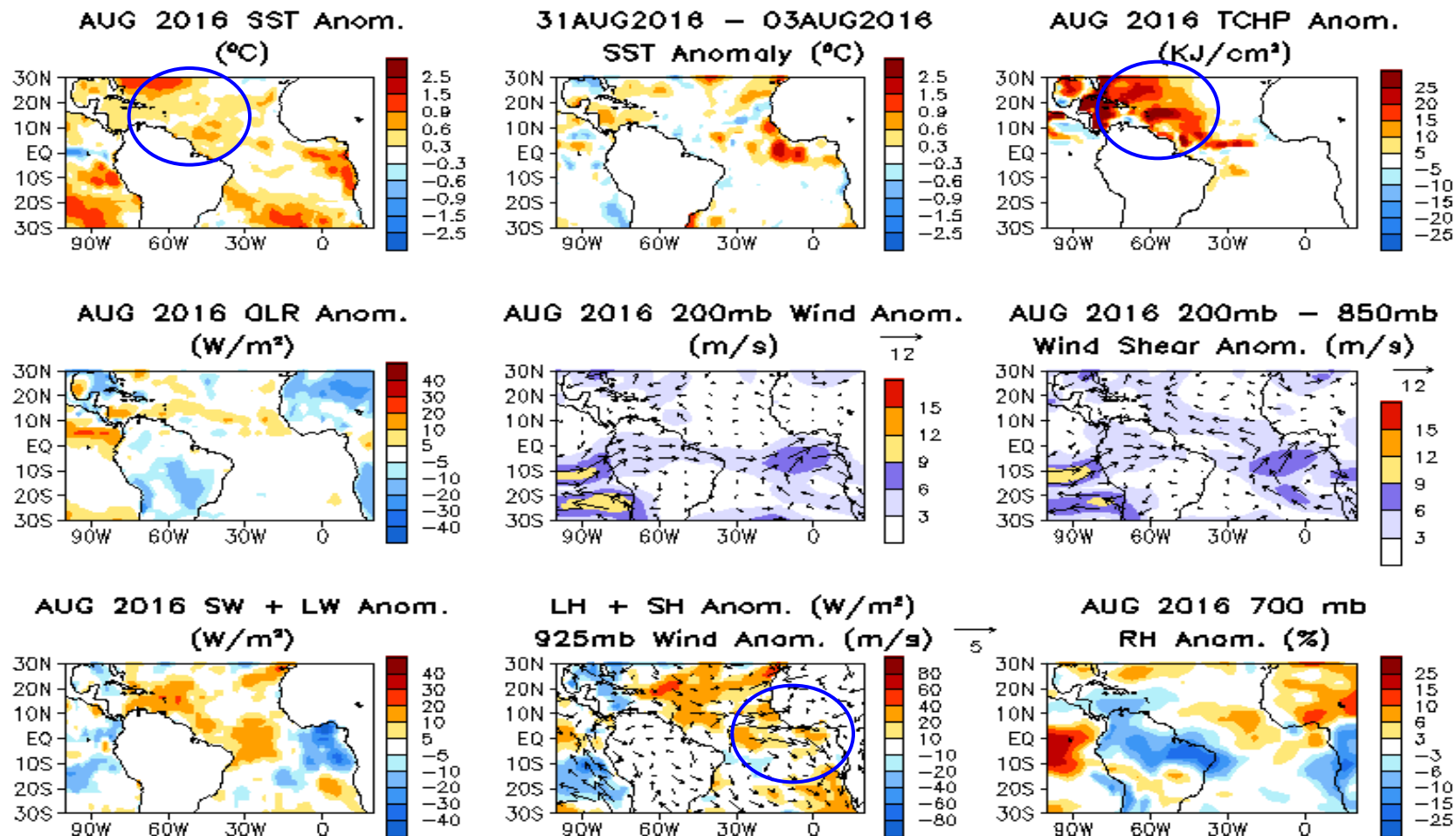
# Evolution of Tropical Atlantic SST Indices



**Fig. A1a.** Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W–30°W, 5°N–20°N], TSA [30°W–10°E, 20°S–0] and ATL3 [20°W–0, 2.5°S–2.5°N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the NCEP OI SST analysis, and 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., OLR, Sfc Rad, Sfc Flx, 925-mb/200-mb Winds



- Above-normal SSTA and TCHP presented in the hurricane Main Development Region (MDR) .
- Below-normal vertical wind shear presented in MDR, which is favourable for hurricane activity.
- Westerly low-level wind blew towards the western Africa, indicating enhanced west African monsoon.

# 2016 Atlantic Hurricane Season

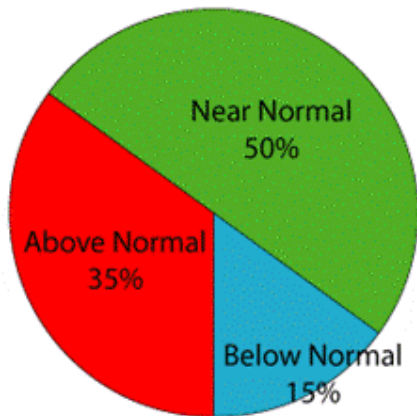
(<http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.shtml>)

## NOAA's Updated 2016 Atlantic Hurricane Season Outlook

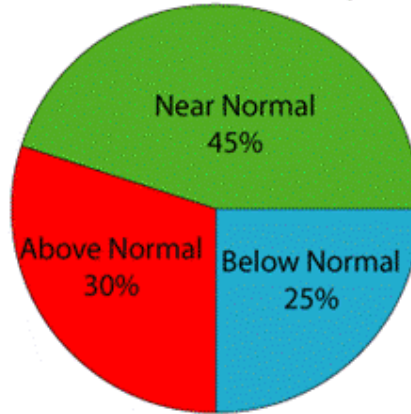
85% Chance of Near-Normal or Above-Normal Season

Probability of Season Type

August Update



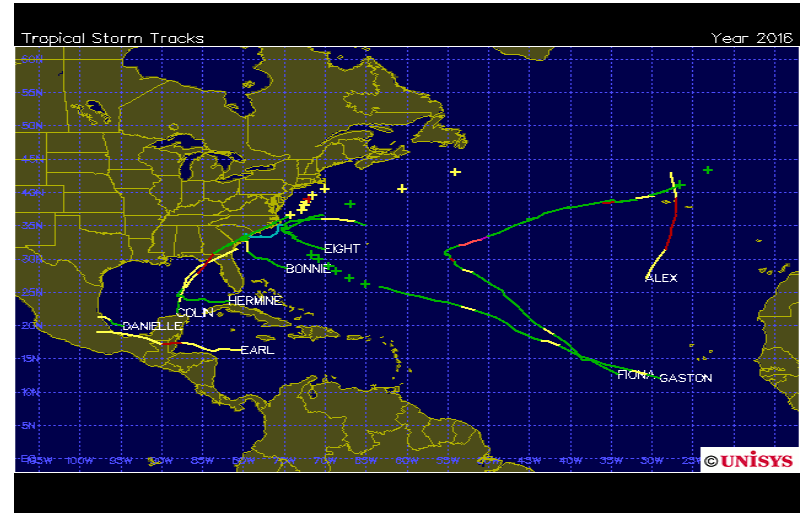
Outlook Issued 27 May



Predicted Activity

70% Probability For Each Range

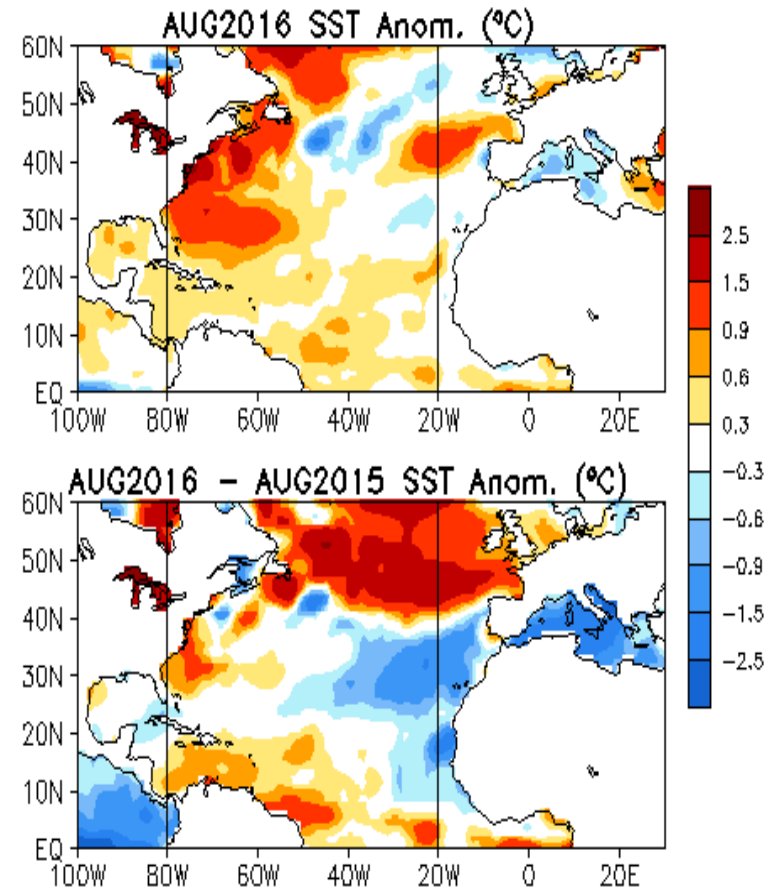
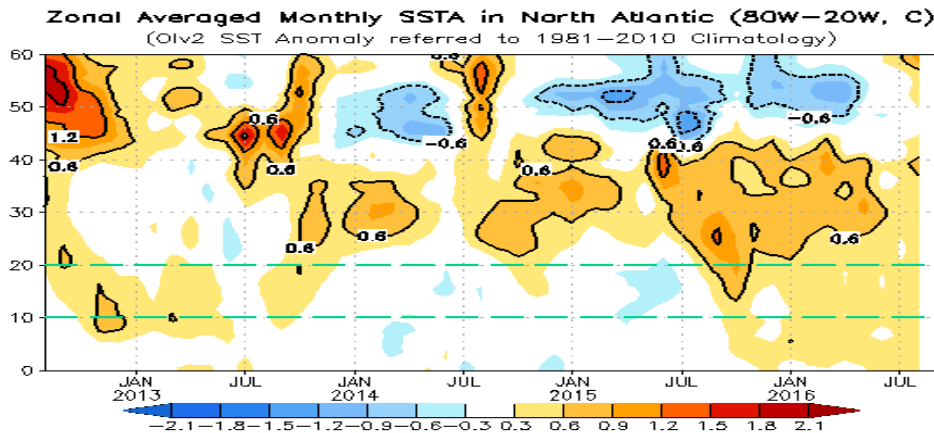
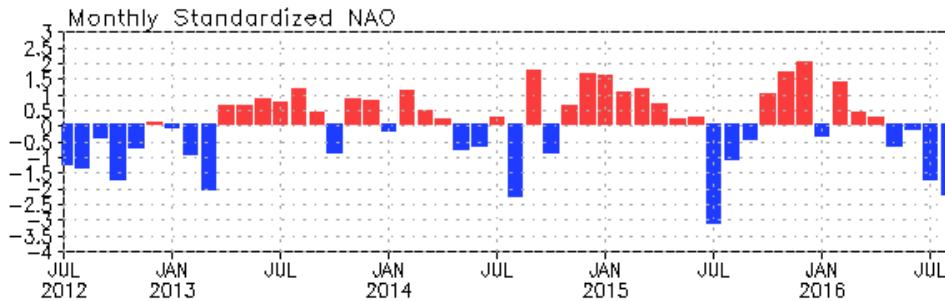
	August Update	May Outlook	Season Averages (1981-2010)
Named Storms	12-17	10-16	12
Hurricanes	5-8	4-8	6
Major Hurricanes	2-4	1-4	3



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

- Eight tropical storms with 4 reaching hurricane category formed in N. Atlantic by Sep.7.

# NAO and SST Anomaly in North Atlantic



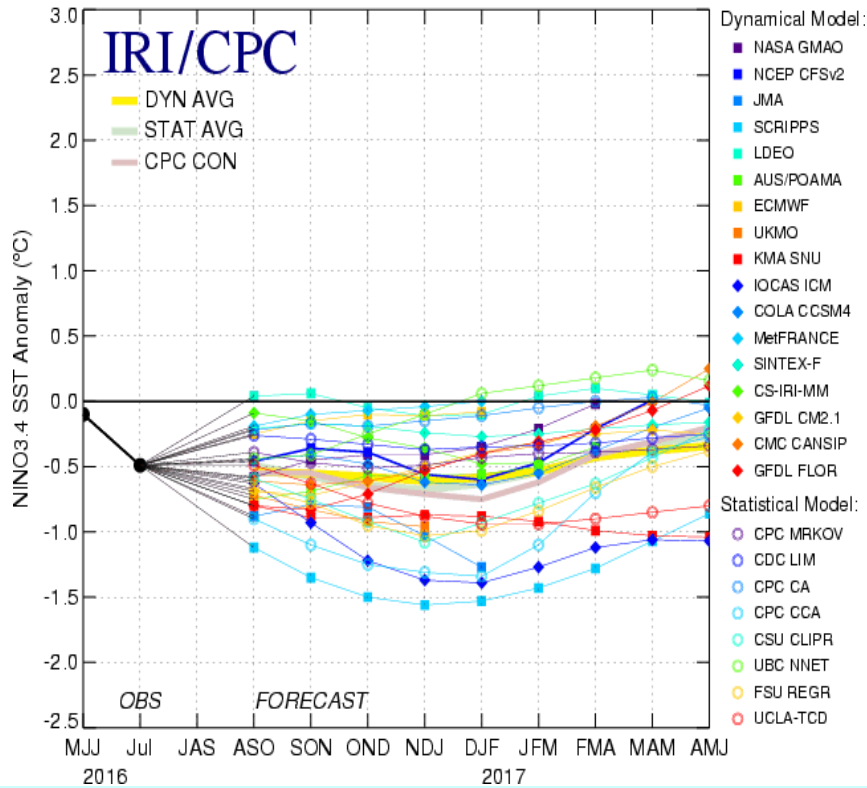
- Negative NAO strengthened with NAOI = -2.2 in Aug 2016.
- Strong positive SSTA presented along the E. coast of North America.

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.

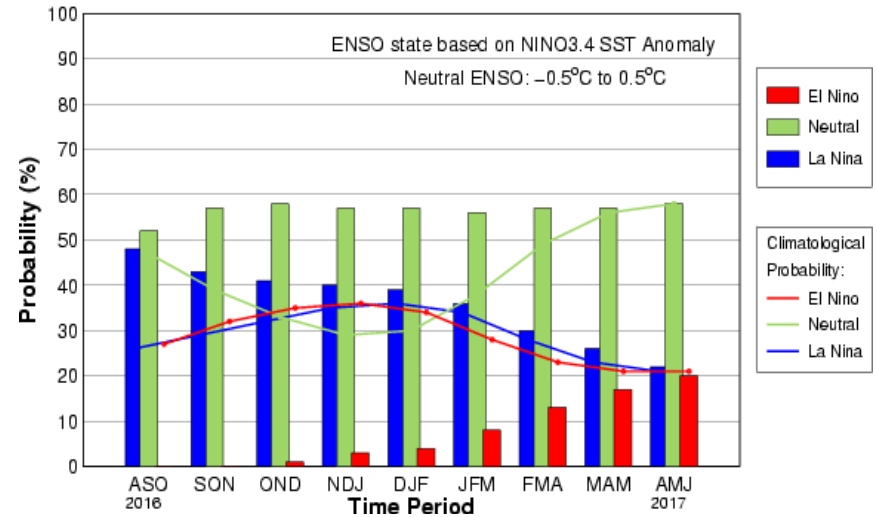
# Global SST Predictions

# IRI NINO3.4 Forecast Plum

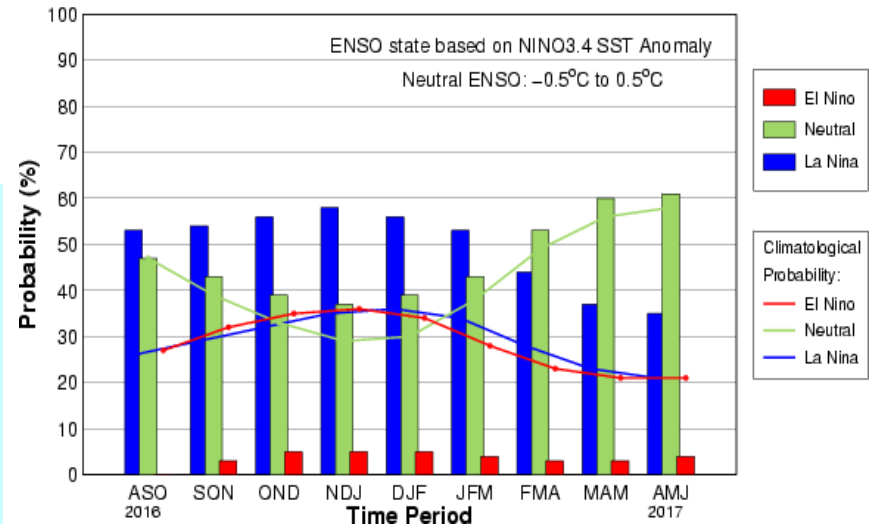
Mid-Aug 2016 Plum of Model ENSO Predictions



Early-Sep CPC/IRI Official Probabilistic ENSO Forecast



Mid-Aug IRI/CPC Model-Based Probabilistic ENSO Forecast

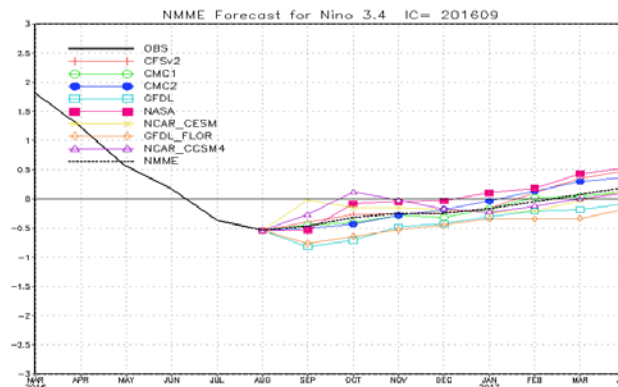
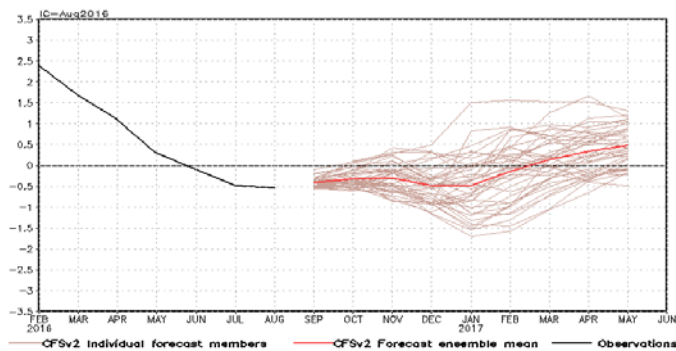
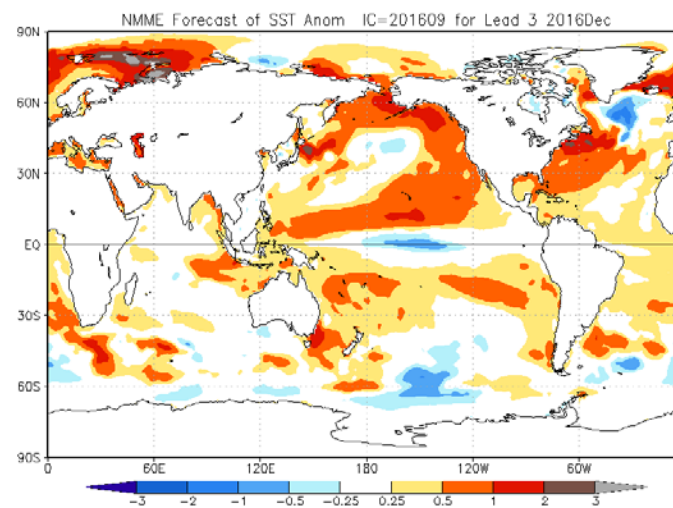
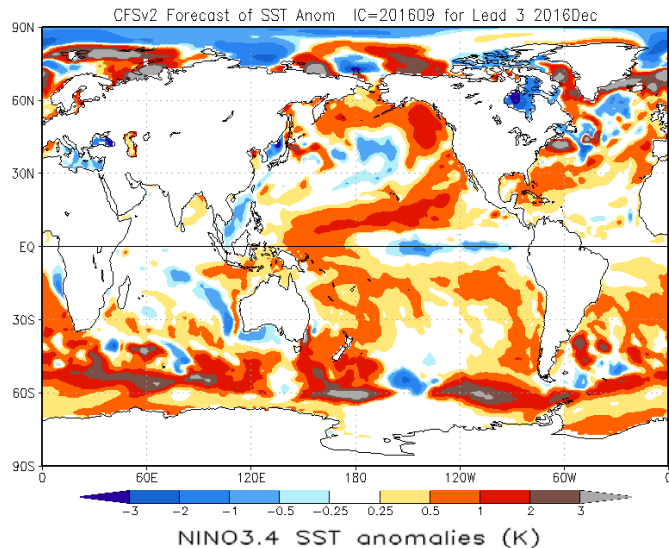


- Multi-model averages favor borderline Neutral-La Niña conditions.
- [NOAA "ENSO Diagnostic Discussion" on 8 Sep 2016](#) suggested that "ENSO-Neutral conditions are slightly favored (between 55-60%) during the upcoming Northern Hemisphere fall and winter 2016-17."

# NCEP CFSv2 & NMME SST Predictions

Dec 2016

Dec 2016



- Both CFSv2 and NMME forecast ENSO-neutral will continue in the fall and winter 2016-17.



# Constructed Analogue Prediction of Global SSTA

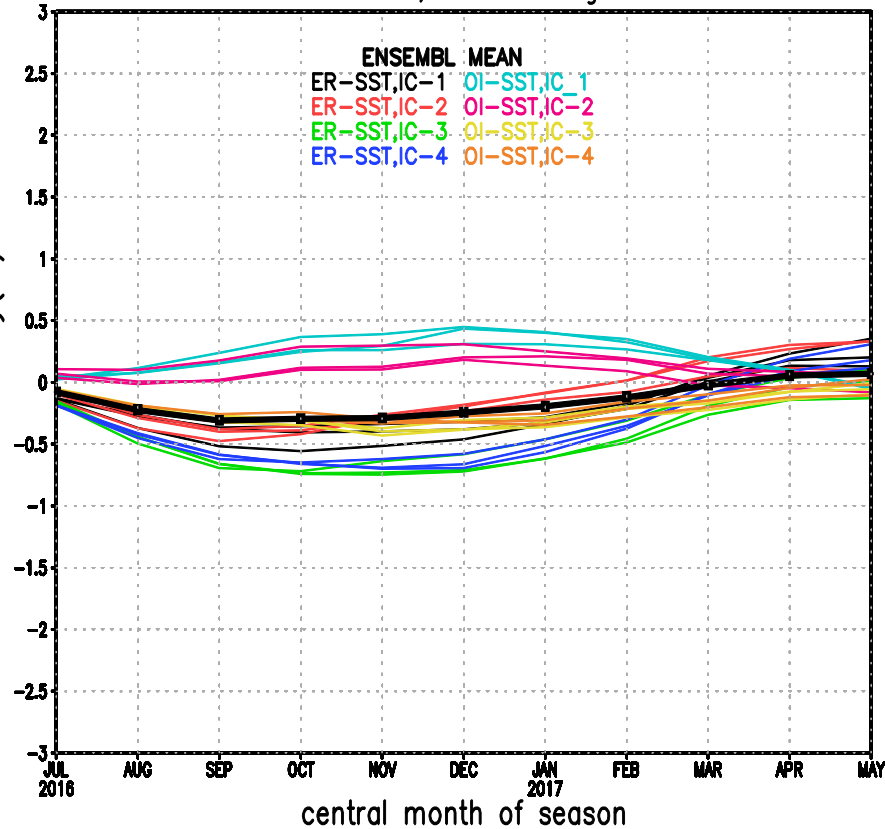
- ❑ Use weighted average of historical data to approximate current data (IC);
- ❑ The weights are obtained by minimizing the RMS error;
- ❑ Construct forecast by applying the weights to the lagged data in history

1. Use both HAD-OI SST and ERSST since 1948;
2. Choose EOF truncations at 15, 25, 40;
3. Have season number 1 to 4 in ICs;

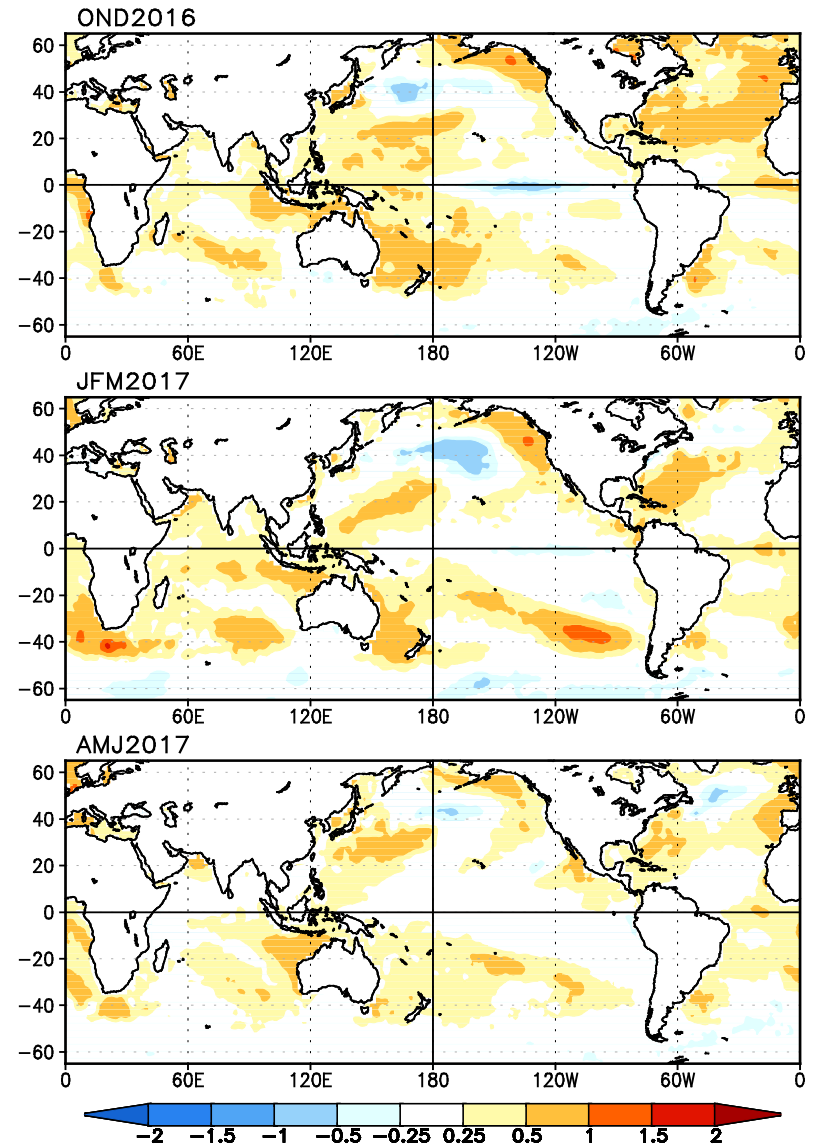
Combine 1-3 above to have a 24-member ensemble

# CA 24-member Ensemble Forecast for SST

CA Forecast for Nino3.4 SST Index  
24 members, data thru Aug2016



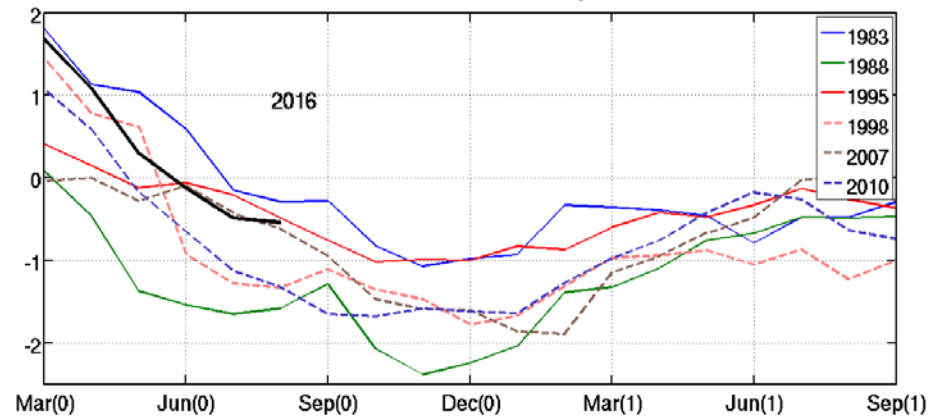
CA SST Forecast, ICs through Aug2016



ENSO-neutral is expected for 2016/17 winter

# SST, D20 and 925hp Wind anomalies in August

Nino 3.4 SST Anomaly



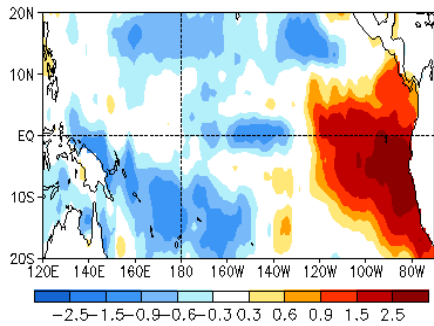
1983

1995

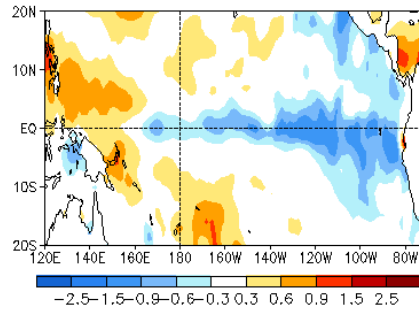
2007

2016

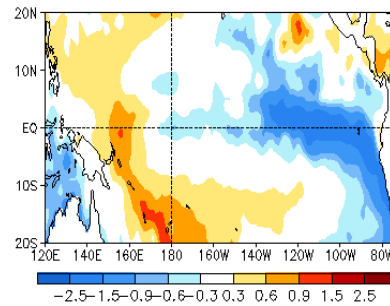
AUG 1983 SST Anom. (°C)



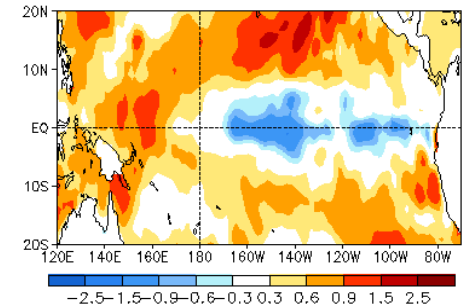
AUG 1995 SST Anom. (°C)



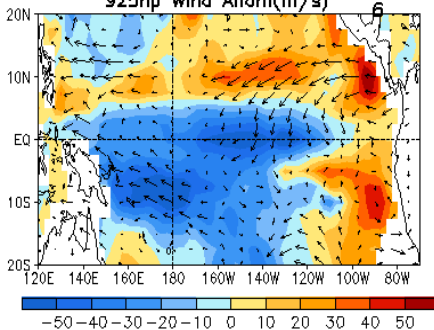
AUG 2007 SST Anom. (°C)



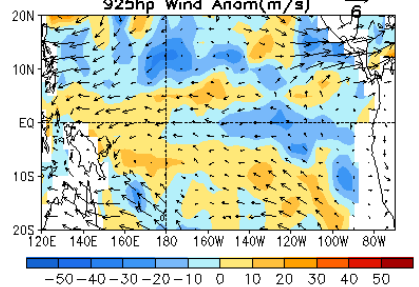
AUG 2016 SST Anom. (°C)



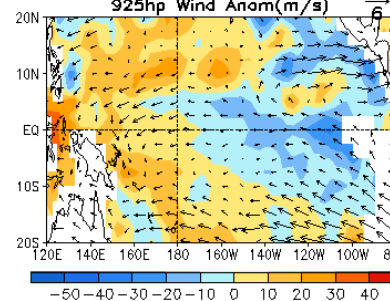
AUG 1983 D20 Anom. (m)  
925hp Wind Anom(m/s)



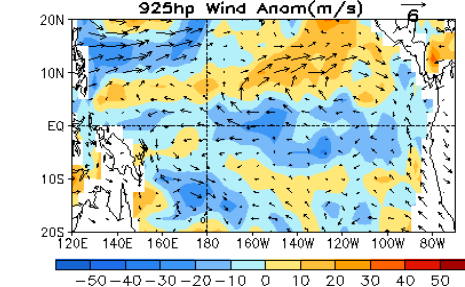
AUG 1995 D20 Anom. (m)  
925hp Wind Anom(m/s)



AUG 2007 D20 Anom. (m)  
925hp Wind Anom(m/s)

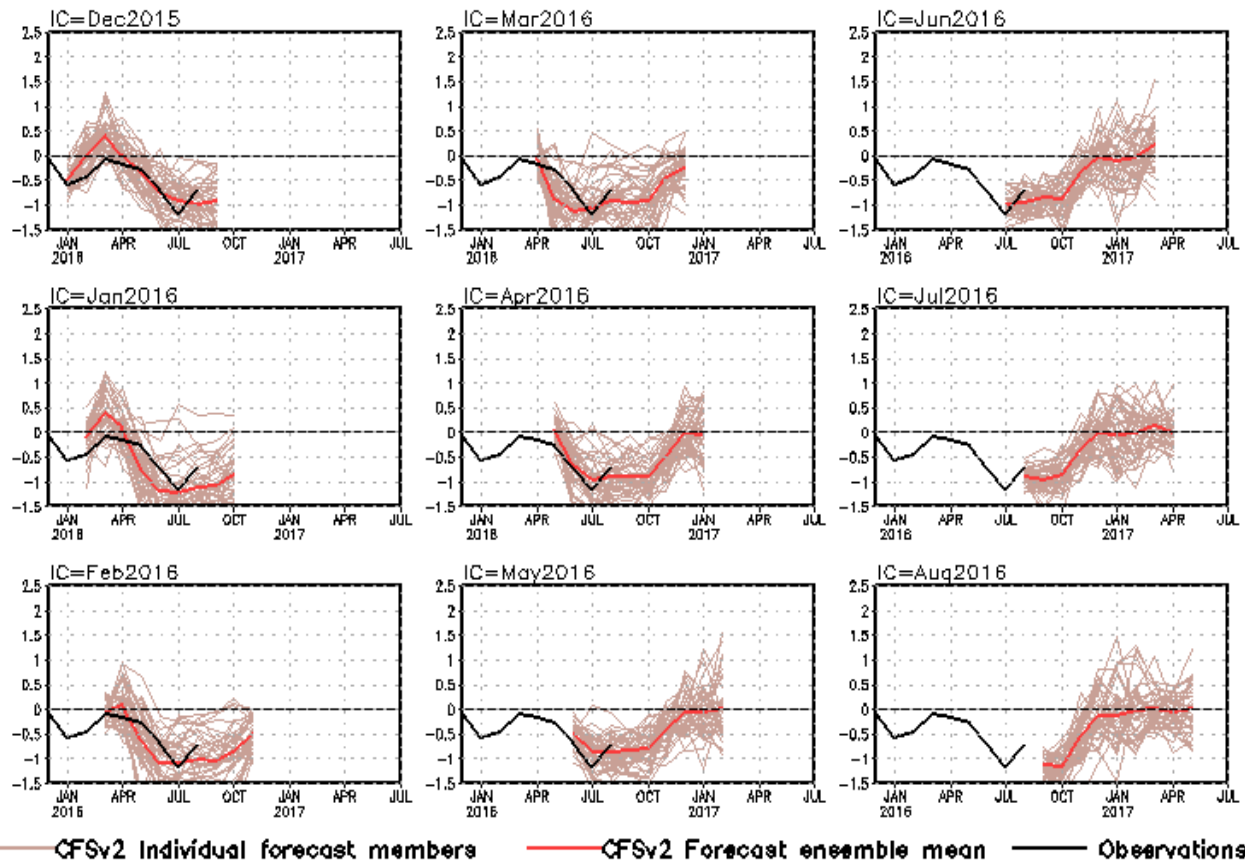


AUG 2016 D20 Anom. (m)  
925hp Wind Anom(m/s)



# CFSv2 DMI SST Predictions from Different Initial Months

## Indian Ocean Dipole SST anomalies (K)



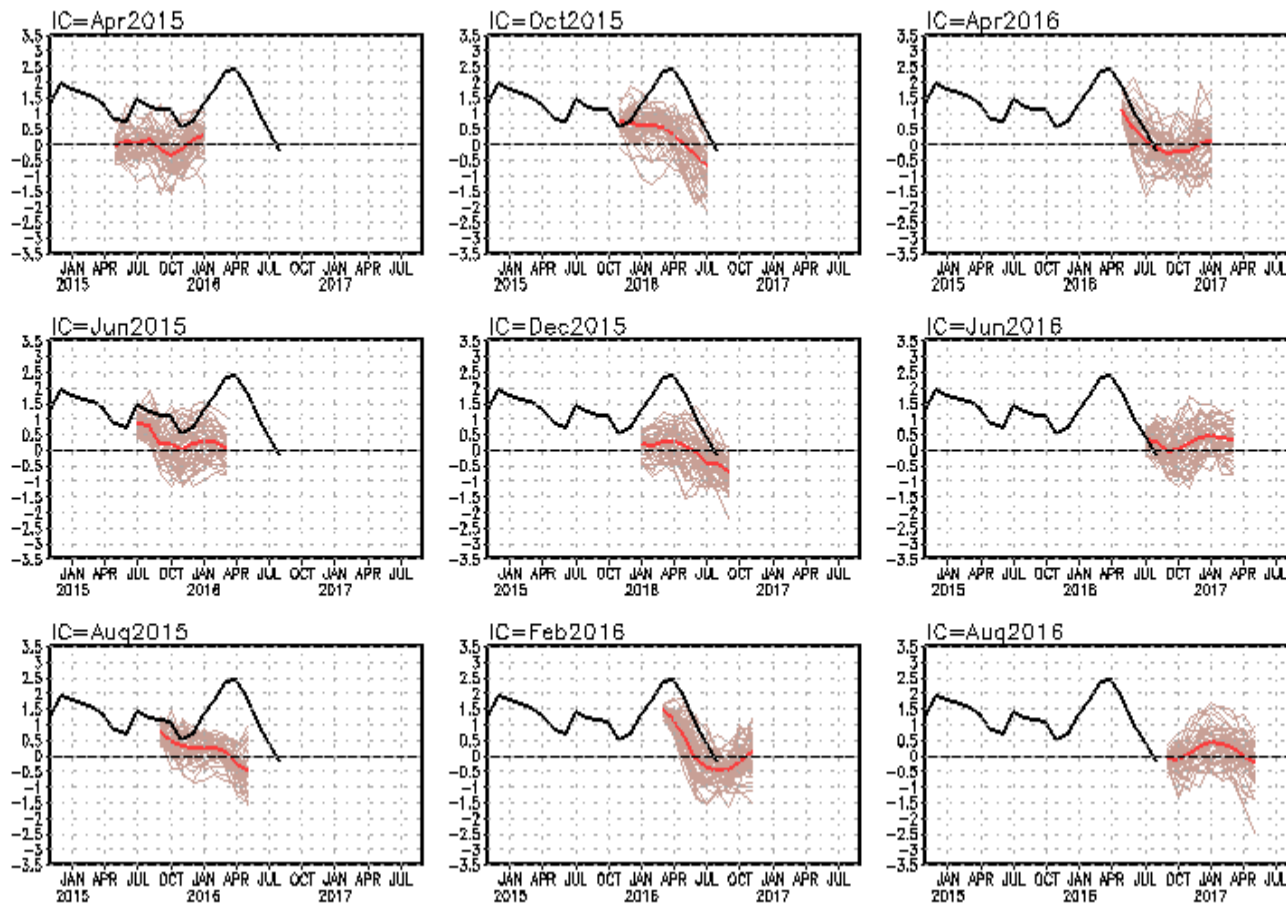
DMI = WTIO - SETIO  
 SETIO = SST anomaly in [90°E-110°E, 10°S-0]  
 WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

CFSv2 has persistently forecast negative DMI to develop during the northern hemisphere summer and fall 2016 since Nov 2015 I.C..

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.

# PDO Forecast by NCEP CFSv2

standardized PDO index



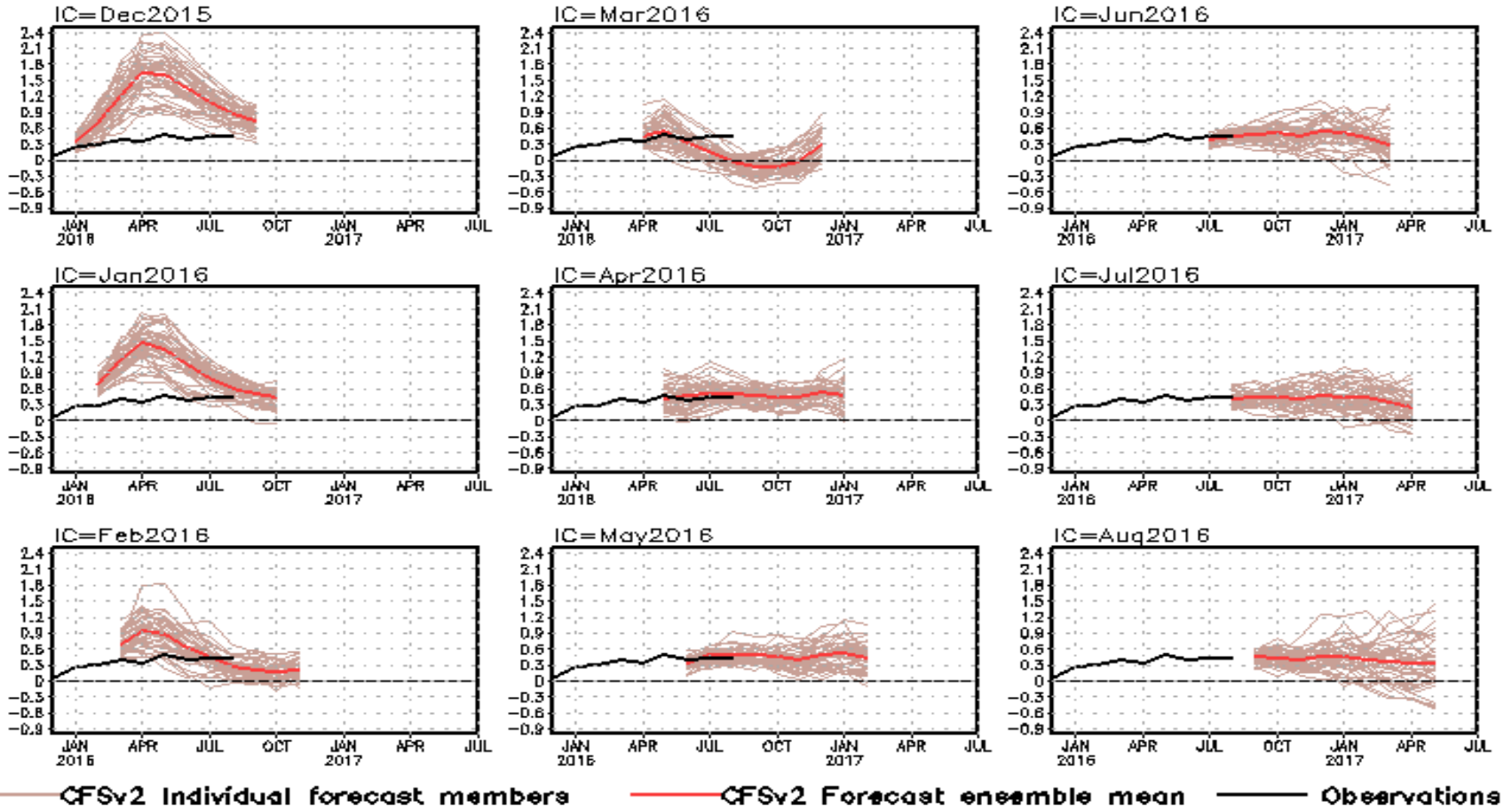
- CFSv2 forecasts PDO will remain near-neutral during the northern hemisphere fall and winter 2016-17.

— CFSv2 Individual forecast members    — CFSv2 Forecast ensemble mean    — Observations

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.

# Tropical North Atlantic SST Forecast by NCEP CFSv2

## Tropical N. Atlantic SST anomalies (K)



- CFSv2 forecast the tropical North Atlantic SST will be weakly above-normal during the northern hemisphere fall and winter 2016-17.

# Overview

## ➤ Pacific Ocean

- ❑ NOAA “ENSO Diagnostic Discussion” on 8 Sep 2016 suggested that “ENSO-Neutral conditions are slightly favored (between 55-60%) during the upcoming Northern Hemisphere fall and winter 2016-17.
- ❑ ENSO-neutral condition continued in Aug 2016.
- ❑ Negative SSTA persisted in the central-eastern Pacific with Nino3.4 =  $-0.5^{\circ}\text{C}$ .
- ❑ Negative subsurface anomaly weakened across the equatorial Pacific.
- ❑ Positive phase of PDO switched to negative phase in August.
- ❑ Arctic sea ice extent for Aug. 2016 ranked the fourth lowest in the Satellite record.

## ➤ Indian Ocean

- ❑ Positive SSTA continued in the eastern tropical Indian Ocean.
- ❑ Dipole Mode Index =  $-0.7^{\circ}\text{C}$  in Aug 2016.

## ➤ Atlantic Ocean

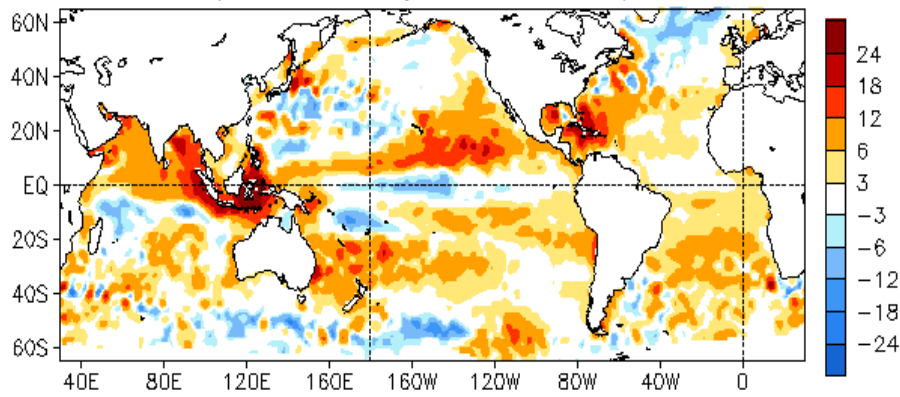
- ❑ NAO strengthened with NAOI =  $-2.2$  in Aug 2016.
- ❑ NOAA updated Atlantic Hurricane outlook issued in Aug calls for 50% chance of a near-normal season, a 35% chance of an above-normal season, and a 15% chance of a below-normal season.

# Backup Slides

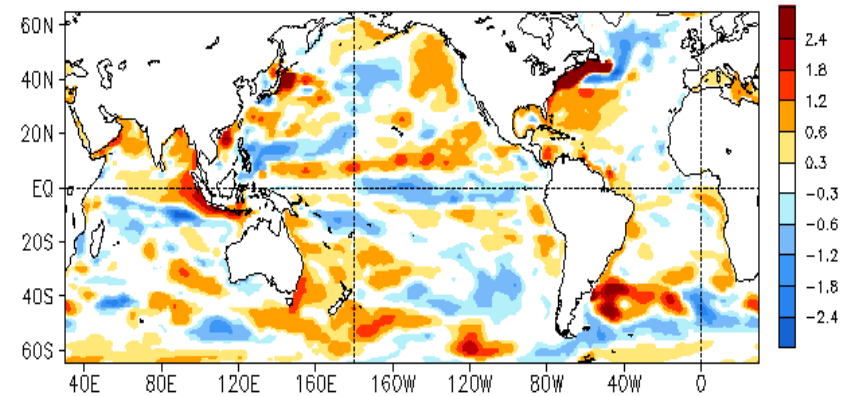


# Global SSH and HC300 Anomaly & Anomaly Tendency

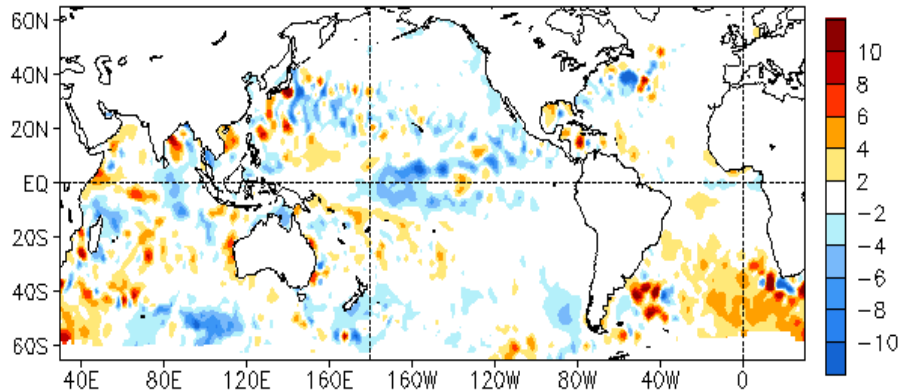
AUG 2016 SSH Anomaly (cm)  
(AVISO Altimetry, Climo. 93-13)



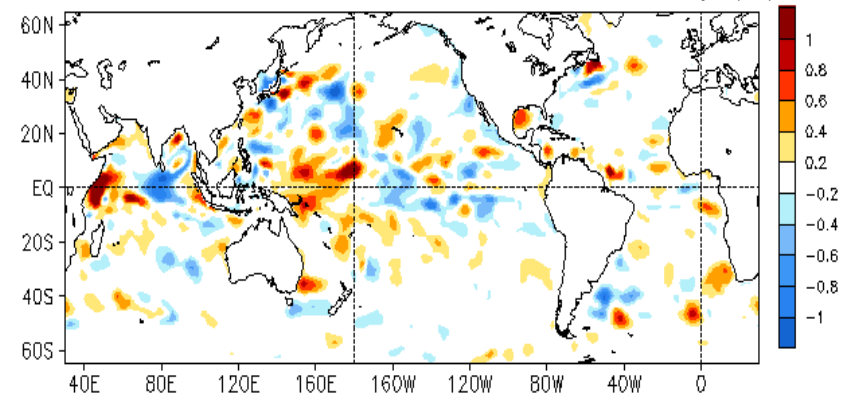
AUG 2016 Heat Content Anomaly (°C)  
(GODAS, Climo. 81-10)



AUG 2016 - JUL 2016 SSH Anomaly (cm)



AUG 2016 - JUL 2016 Heat Content Anomaly (°C)



- The SSHA was overall consistent with HC300A: Positive (negative) HC300A is tied up with positive (negative) SSHA.
- Both SSHA and HC300A were weakly negative along the equatorial Pacific, reflecting the neutral phase of ENSO.
- Negative SSHA tendency dominated in the C.-E. Pacific.

# Warm Water Volume (WWV) and NINO3.4 Anomalies

- WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N].

**Statistically, peak correlation of Nino3 with WWV occurs at 7 month lag** (Meinen and McPhaden, 2000).

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

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

- Equatorial Warm Water Volume (WWV) has started to recharge since May 2016.

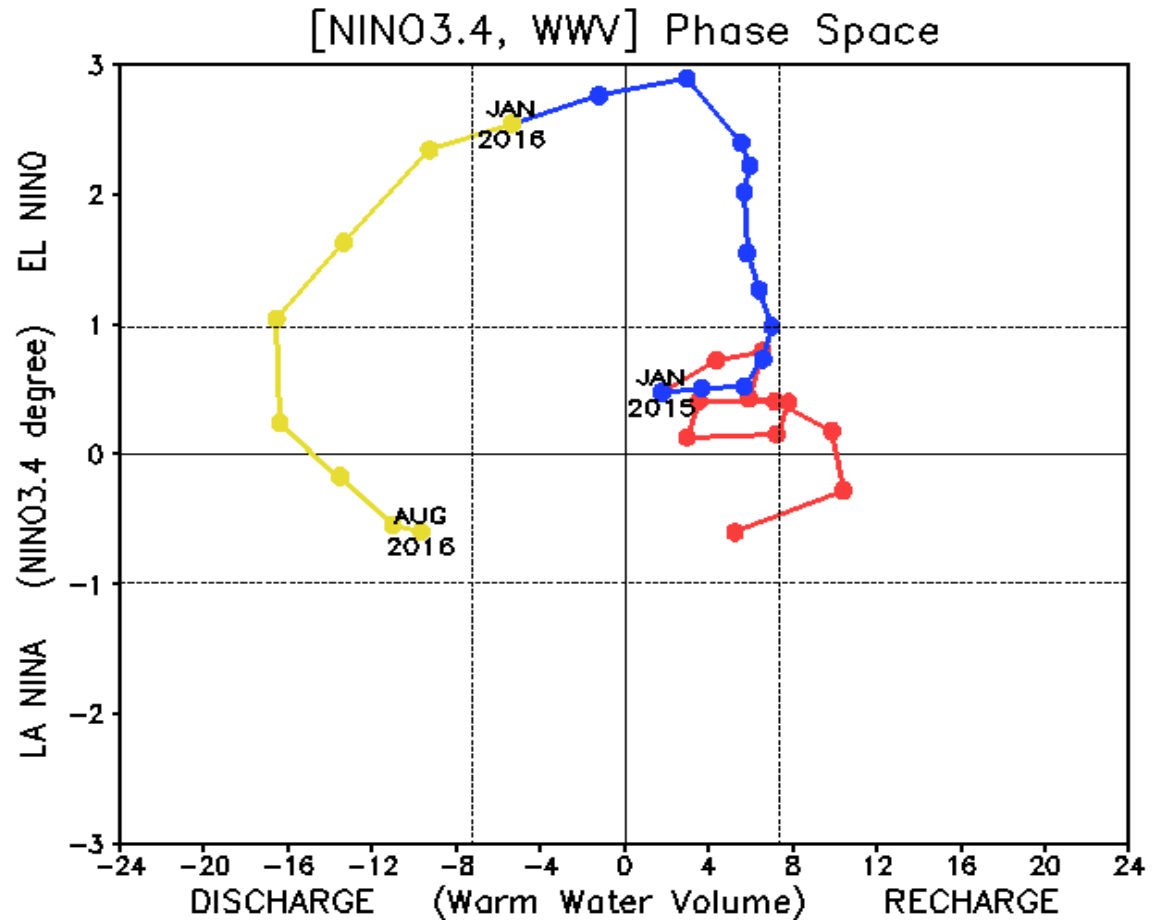
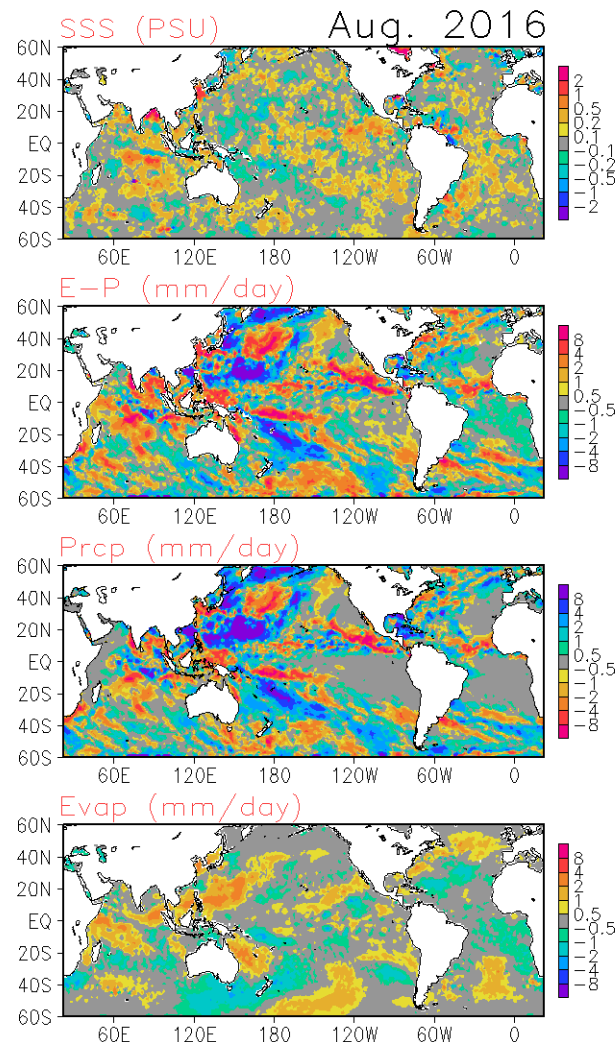


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

# Global Sea Surface Salinity (SSS)

## Tendency for August 2016

Compared with last month, SSS becomes saltier in the central-east equatorial Pacific Ocean, which is likely caused by the reduction of freshwater flux. The SSS in the northern part of Bay of Bengal increases with increasing precipitation suggests the oceanic current bring saltier water to this region. The precipitation shows little change in the western South Pacific and Atlantic Ocean. There is a significant precipitation decrease in the west Pacific Ocean between 20° N and 50° N, however, no significant increase of SSS was identified in this region indicating that the oceanic process plays important roles in the SSS changes in that region.



# Global Sea Surface Salinity (SSS) Anomaly for August 2016

- 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!
- The ENSO is continuing in neutral and favored to La Nino condition in this month with increased SSS in the equatorial Pacific caused by reduced fresh water flux. The fresh SSS anomaly in Bay of Bengal and Arabian Sea are still present in this month and is likely due to the oceanic advection as the E-P being increased in this region. The freshening of SSS in the east Pacific north of the Equator is caused by the enhanced precipitation. A similar SSS freshening pattern in the Western Pacific south of the Equator is also caused by the increasing of the precipitation in that region.

- Data used**

- SSS :**

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

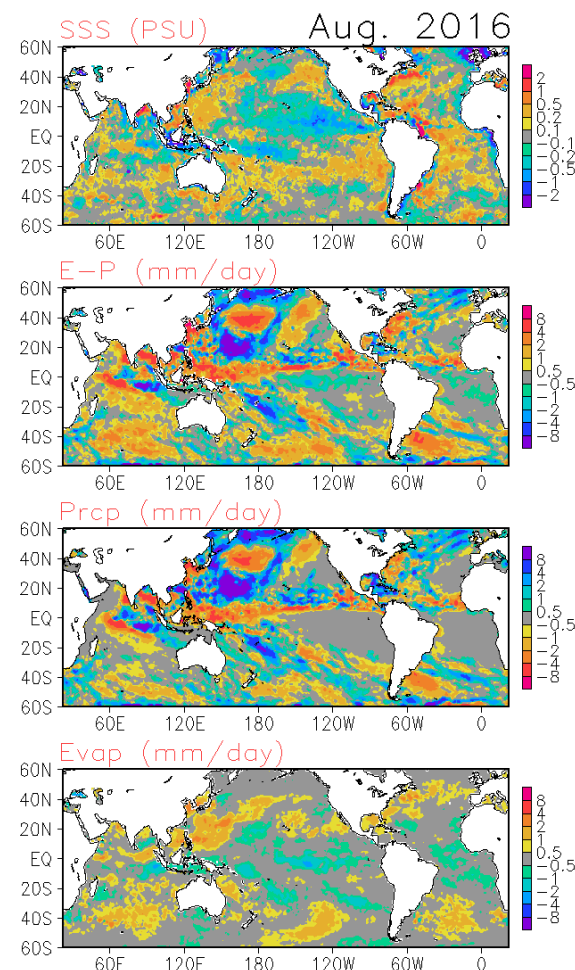
- <ftp.cpc.ncep.noaa.gov/precip/BASS>

- Precipitation:**

- CMORPH adjusted satellite precipitation estimates

- Evaporation:**

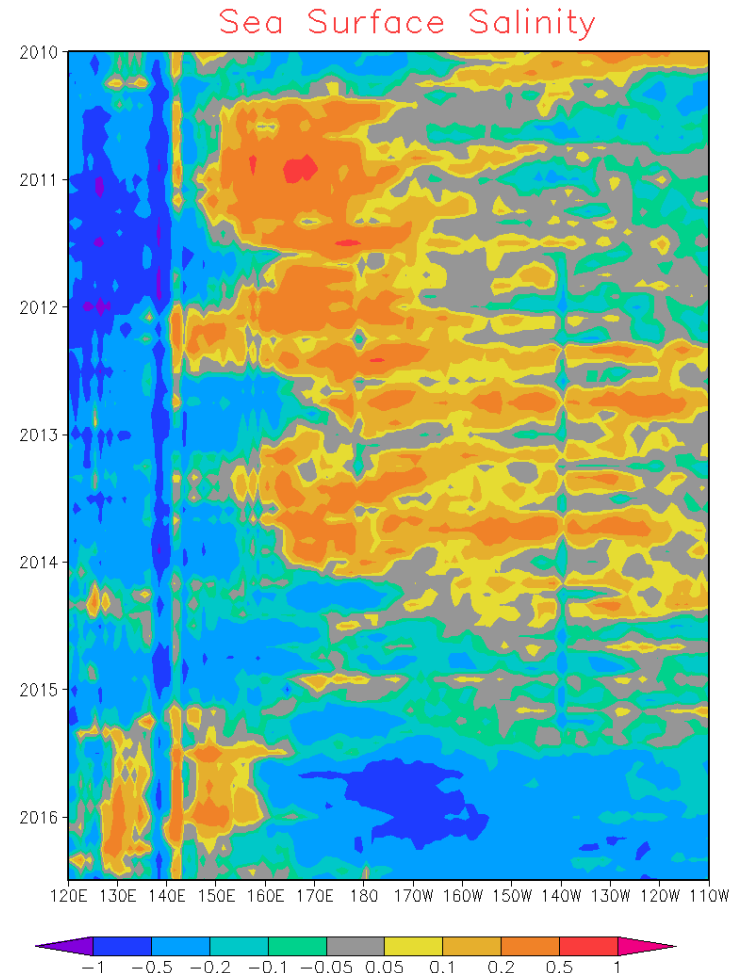
- CFS Reanalysis



# *Global Sea Surface Salinity (SSS)*

## *Anomaly Evolution over Equatorial Pacific*

- Hovemoller diagram for equatorial SSS anomaly (**10°S-10°N**);
- The anomaly evolution in this region shows similar pattern as last month. Negative SSS in the Eastern Equatorial Pacific from 160°E to 110°W has been present for more than a year, with its maximum anomalies appearing from August 2015 to the April 2016 centered from 180°E to 160°W. Such anomalies are propagating to the east. At the meantime, a stretch of positive SSS anomaly remains over the western Pacific from 130°E – 160°E.



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

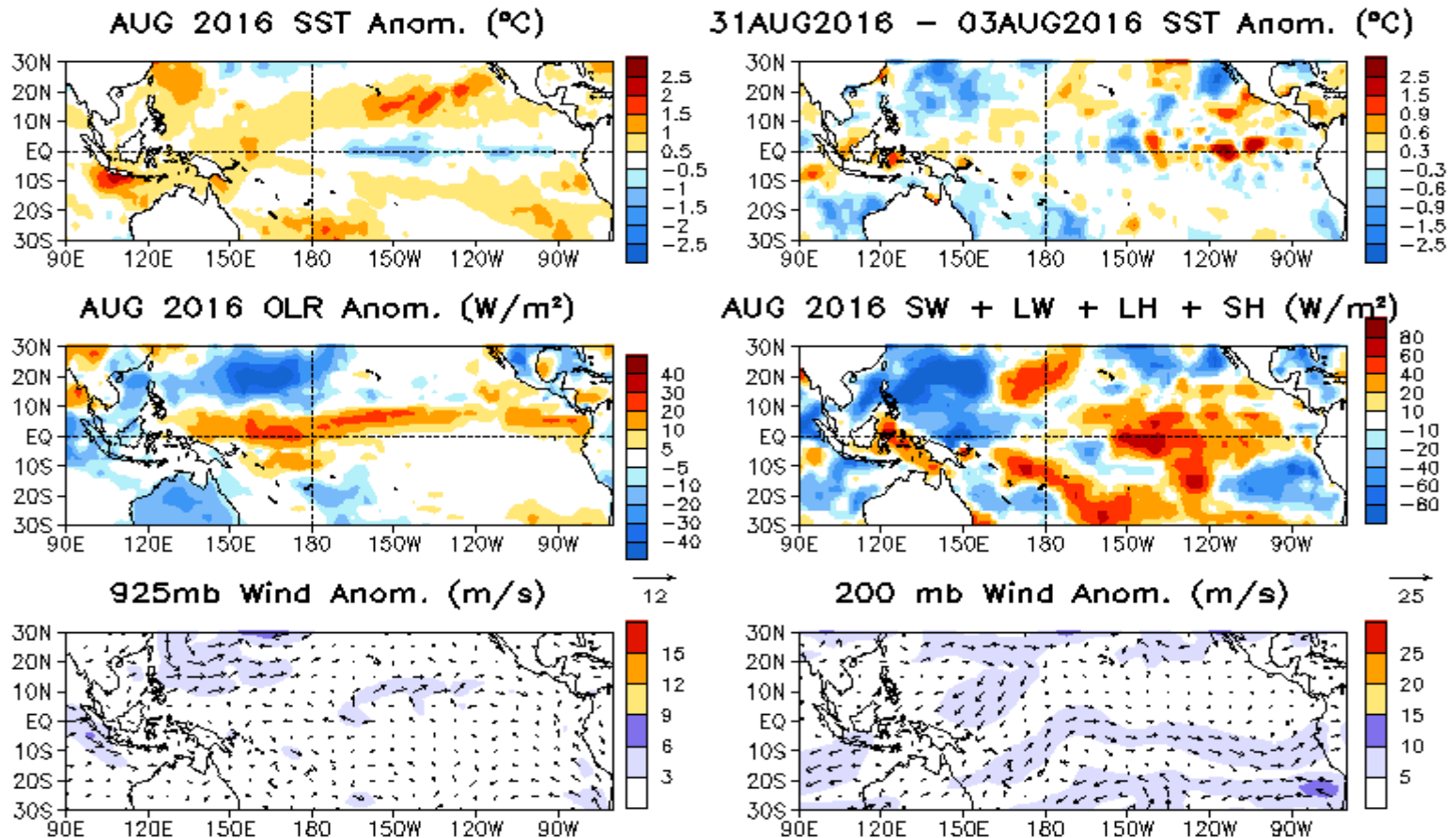
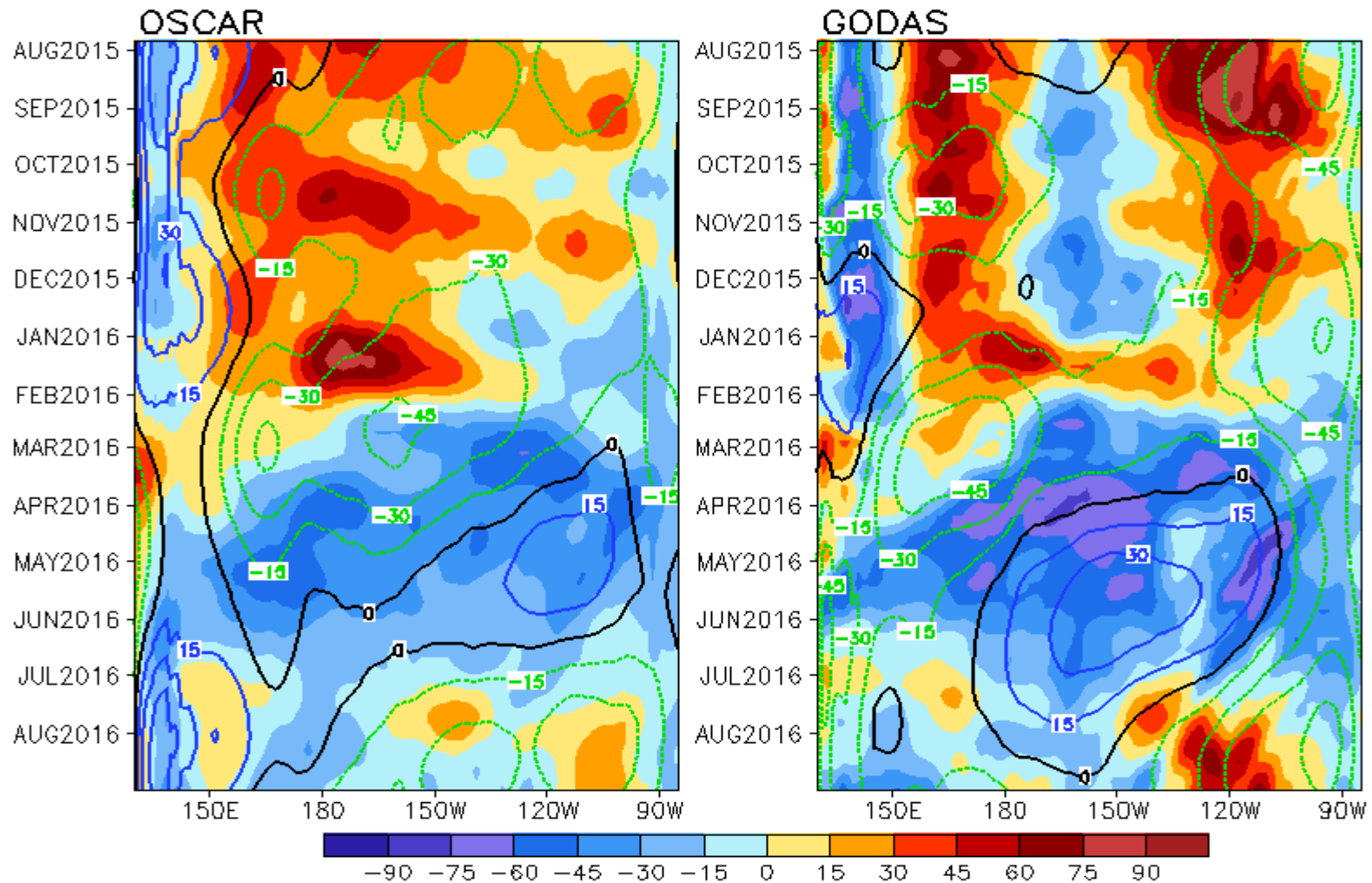


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

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

U (15m), cm/s, 2°S–2°N (Shading=Anomaly; Contour=Climatology)



- Eastward zonal current anomalies presented in the E. Pacific in Aug 2016, which were unfavorable for SST cooling.

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

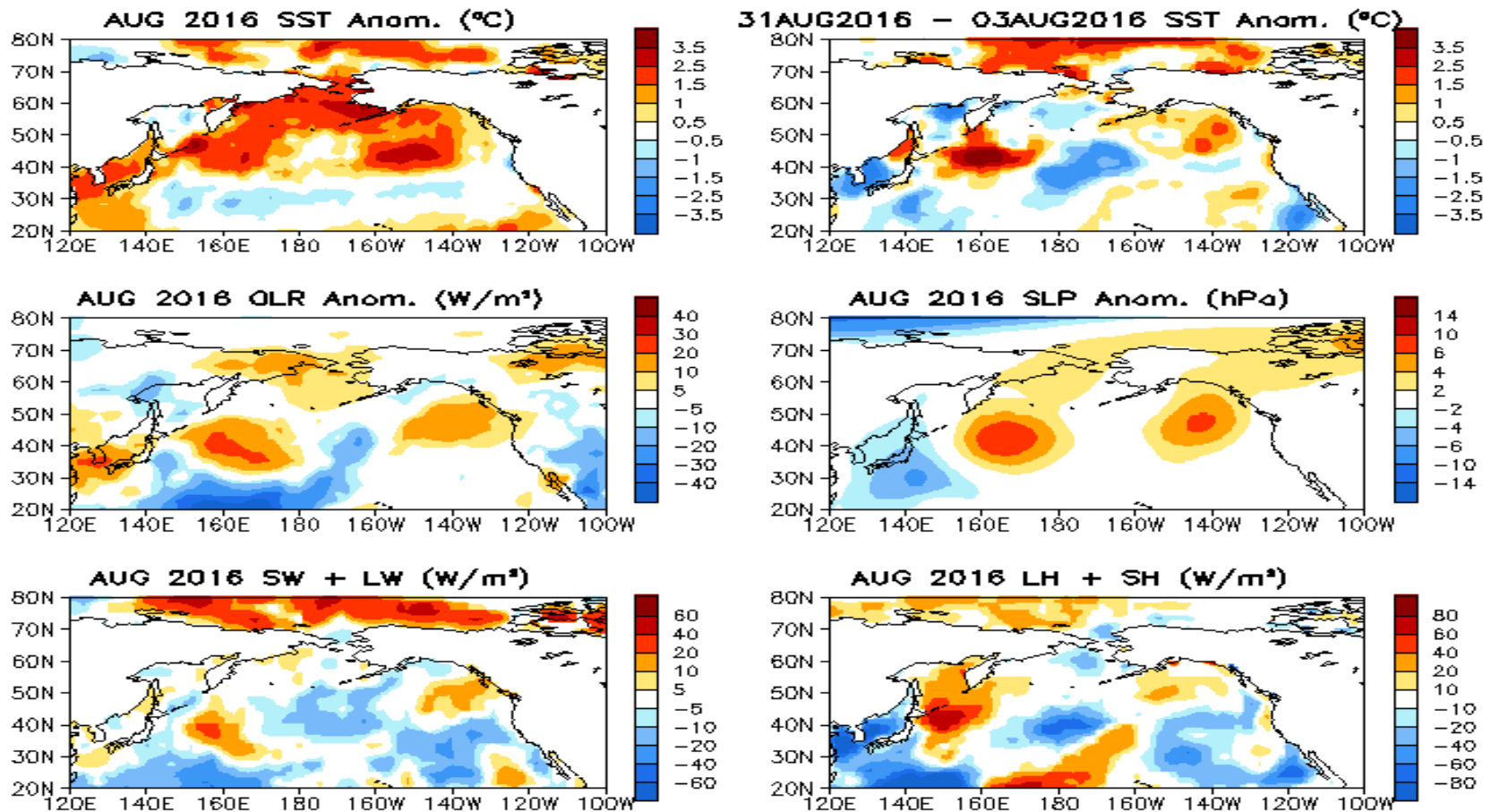
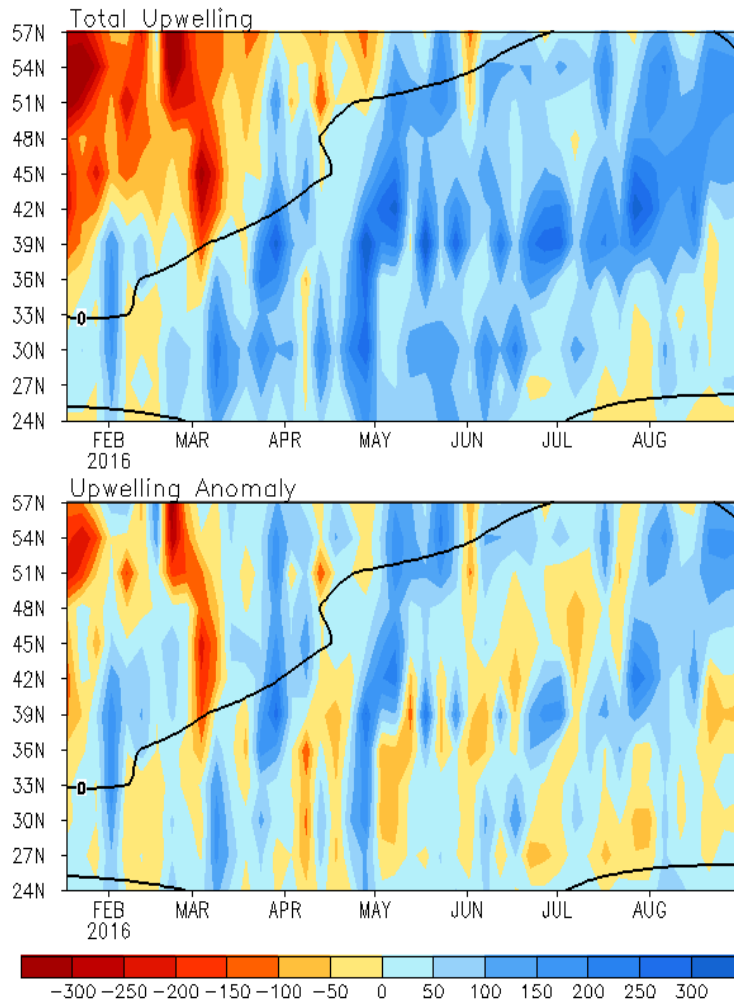


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

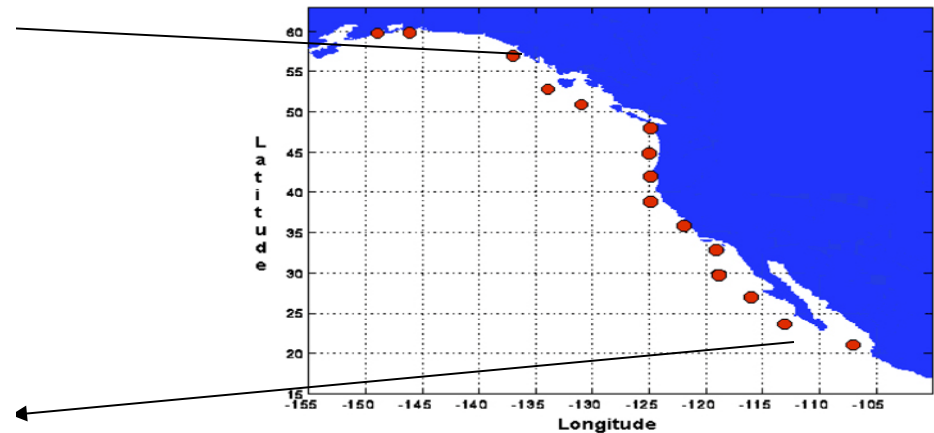


# North America Western Coastal Upwelling

Pentad Coastal Upwelling for West Coast North America  
(m<sup>3</sup>/s/100m coastline)



Standard Positions of Upwelling Index Calculations



- Upwelling near 42N-57N was above-average.

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<sup>3</sup>/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.

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

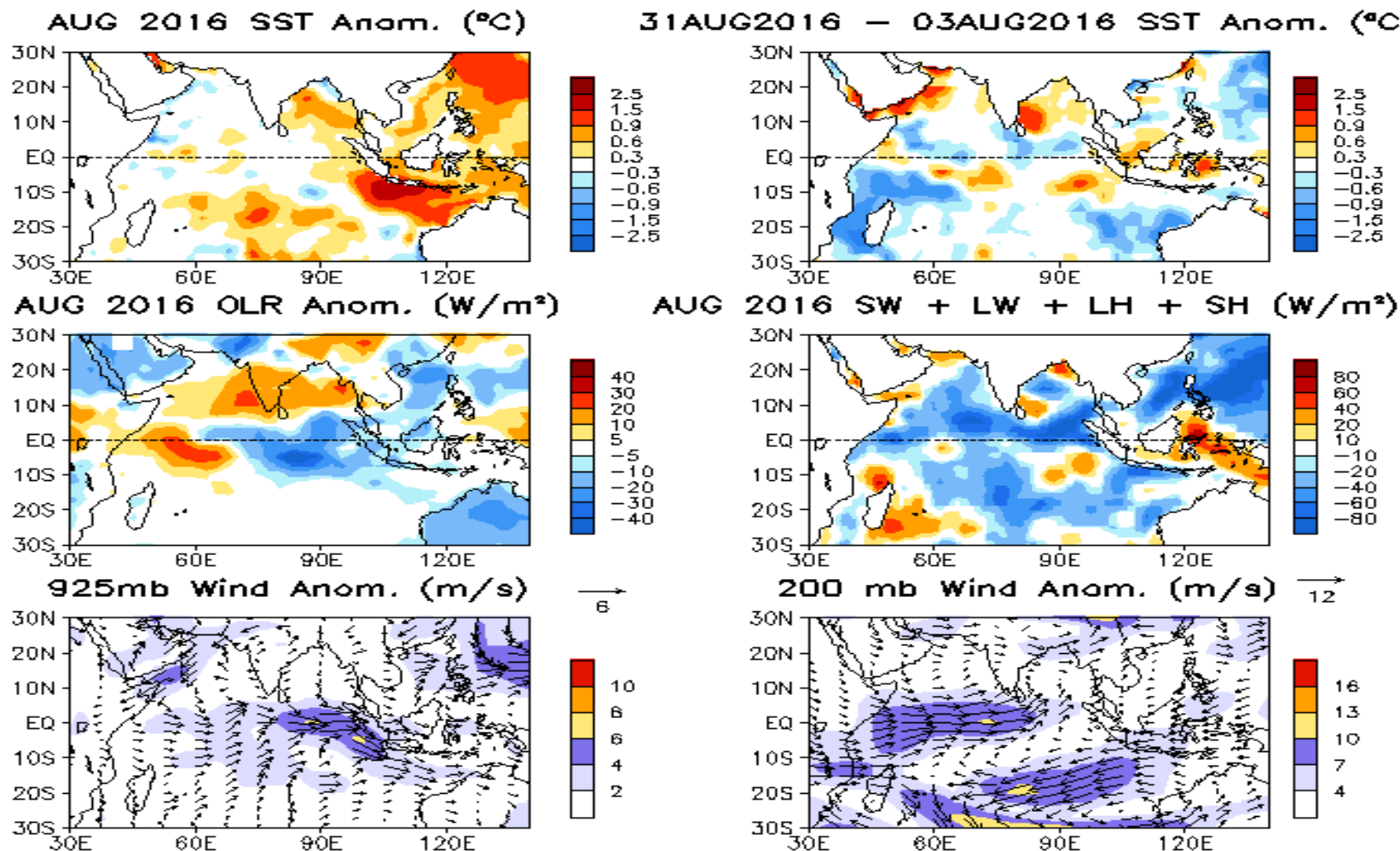


Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

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

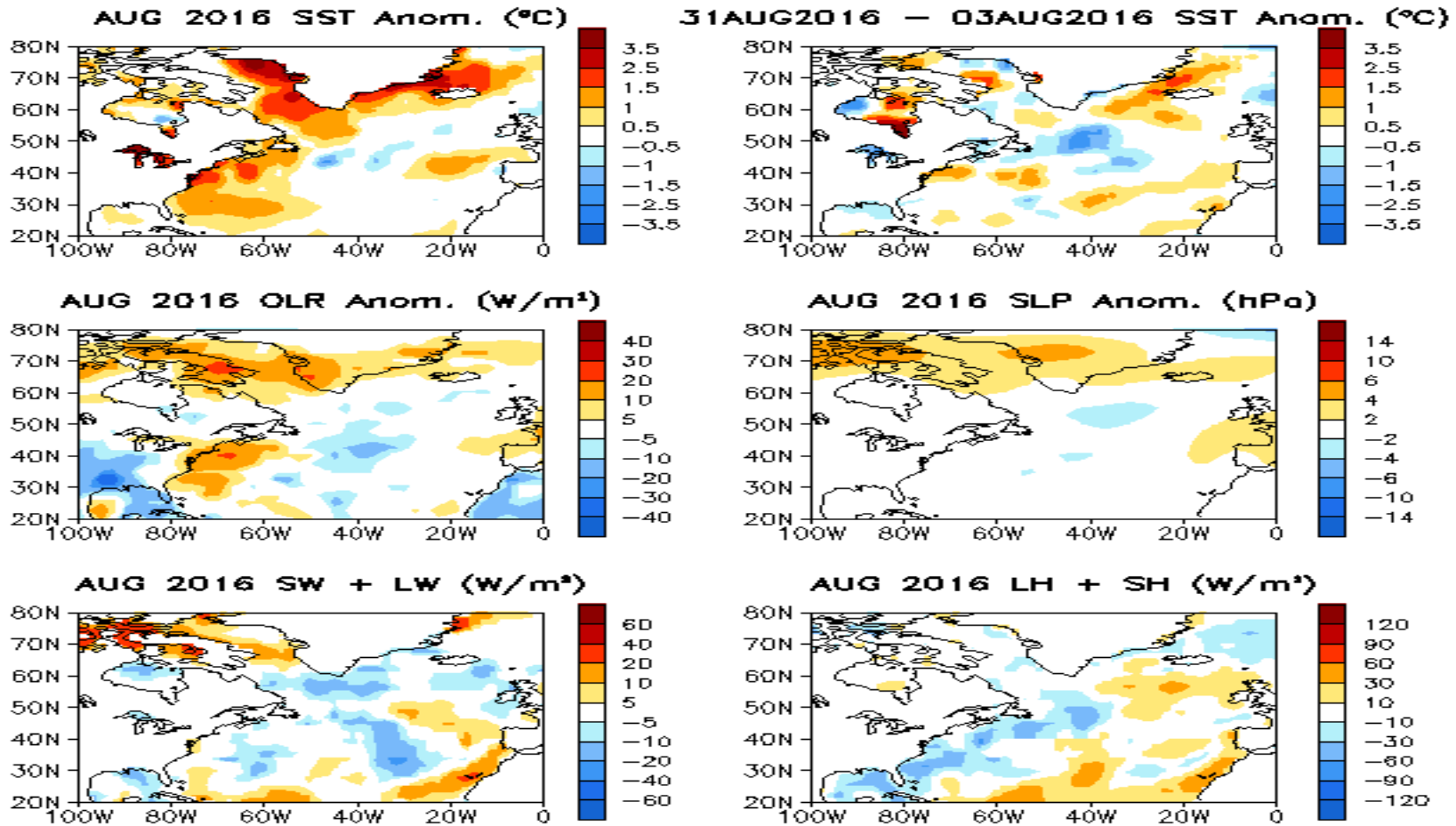


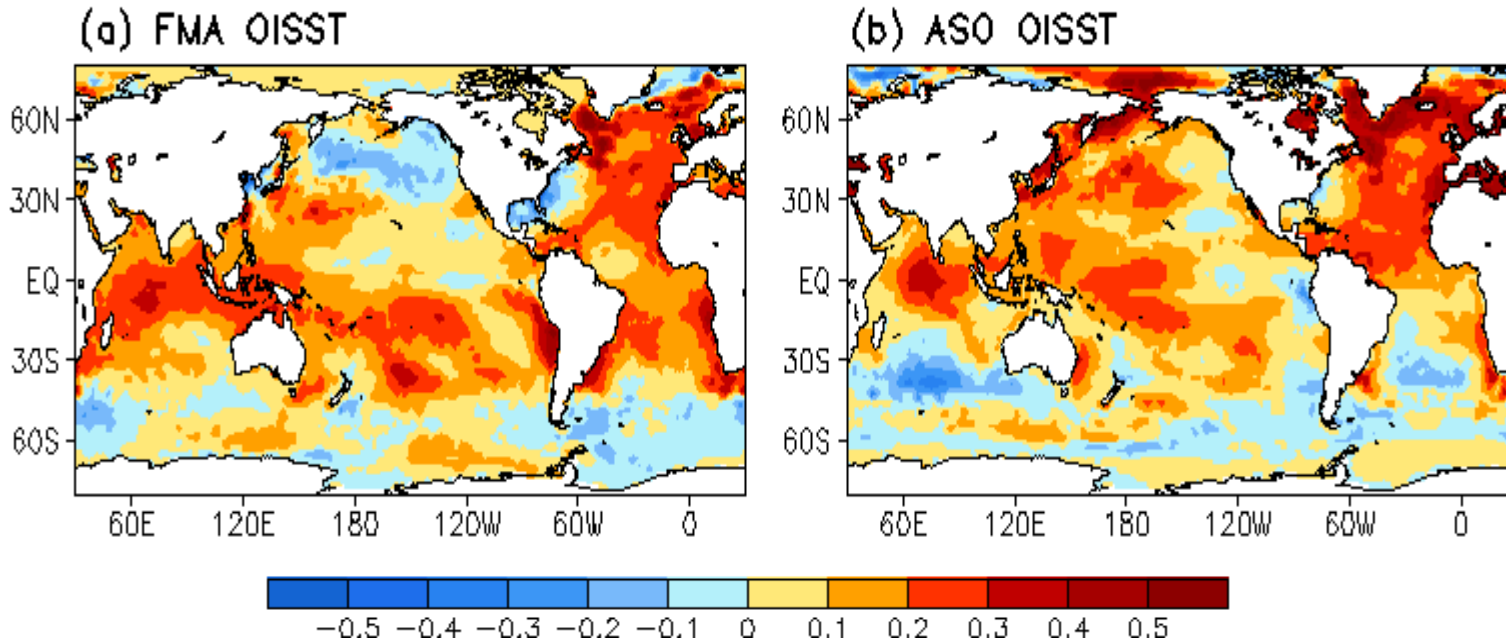
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

# 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

SST Climatology Diff. ( $^{\circ}\text{C}$ ): (1981–2010) – (1971–2000)



**1971-2000 SST Climatology (Xue et al. 2003):**

[http://www.cpc.ncep.noaa.gov/products/predictions/30day/SSTs/sst\\_clim.htm](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  $0.2^{\circ}\text{C}$  over much of the Tropical Oceans and N. Atlantic, but decreased by more than  $0.2^{\circ}\text{C}$  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](mailto:Yan.Xue@noaa.gov). Thanks!