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

Prepared by

Climate Prediction Center, NCEP/NOAA

November 8, 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 oceanic ENSO precursors**
- **Will Pacific 'Blob' be back?**

Overview

Pacific Ocean

- Negative SSTA persisted in the central-eastern Pacific with Nino3.4 = -0.7ºC.
- CFSv2 forecast La Nina conditions will continue through the Northern Hemisphere fall and winter 2016-17.
- SST warming weakened in the N. E Pacific (Pacific 'Blob').
- Negative PDO continued, with PDO = -0.4 in Oct 2016.
- Arctic sea ice extent in October hit the historical low in the Satellite record.

Indian Ocean

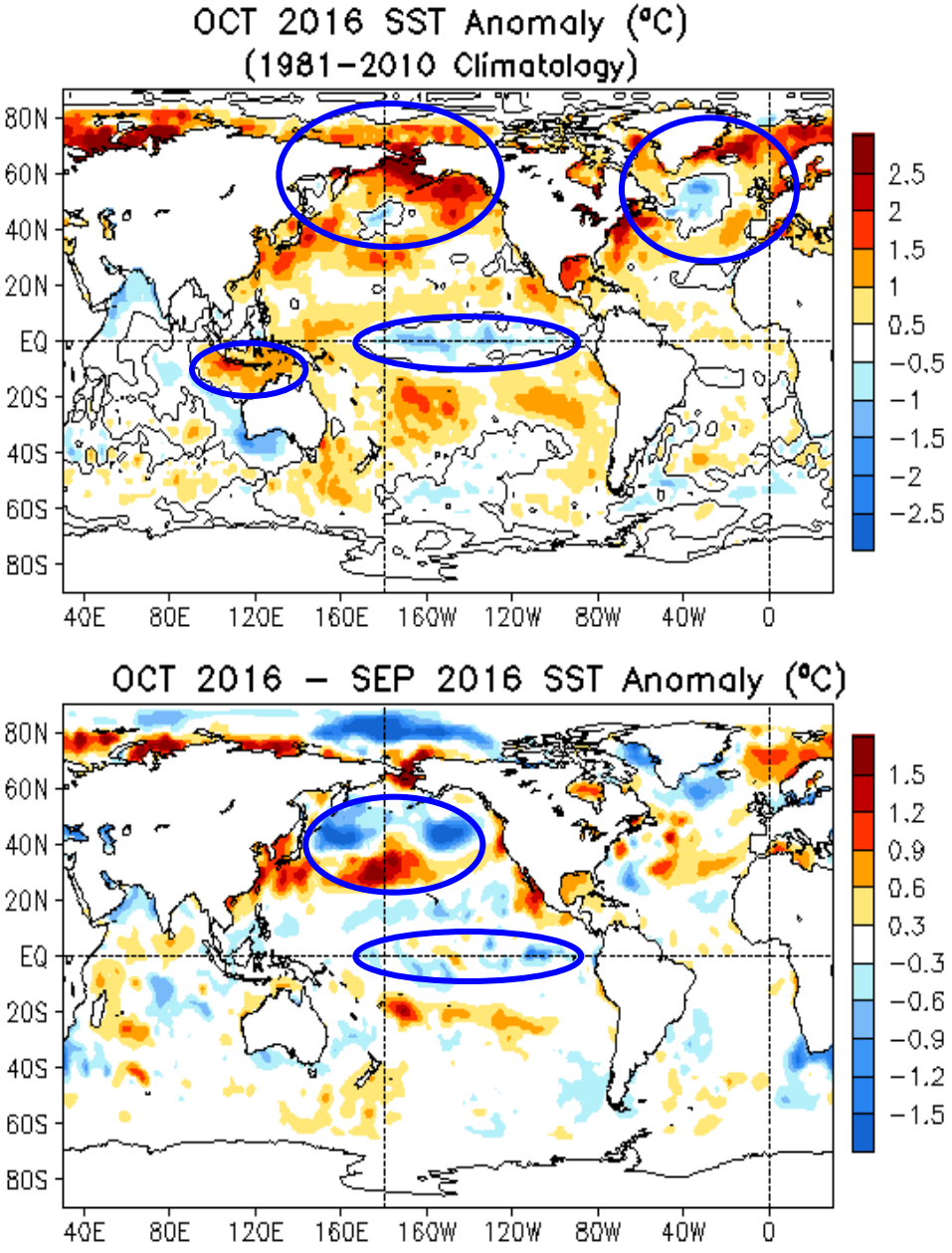
- Dipole Mode Index continued to be well-below average.
- SST warming persisted in the eastern Indian Ocean.

Atlantic Ocean

- Positive NAO increased slightly in Oct 2016, with NAOI =+1.
- SSTA were well above-average along the eastern coast of North America.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency

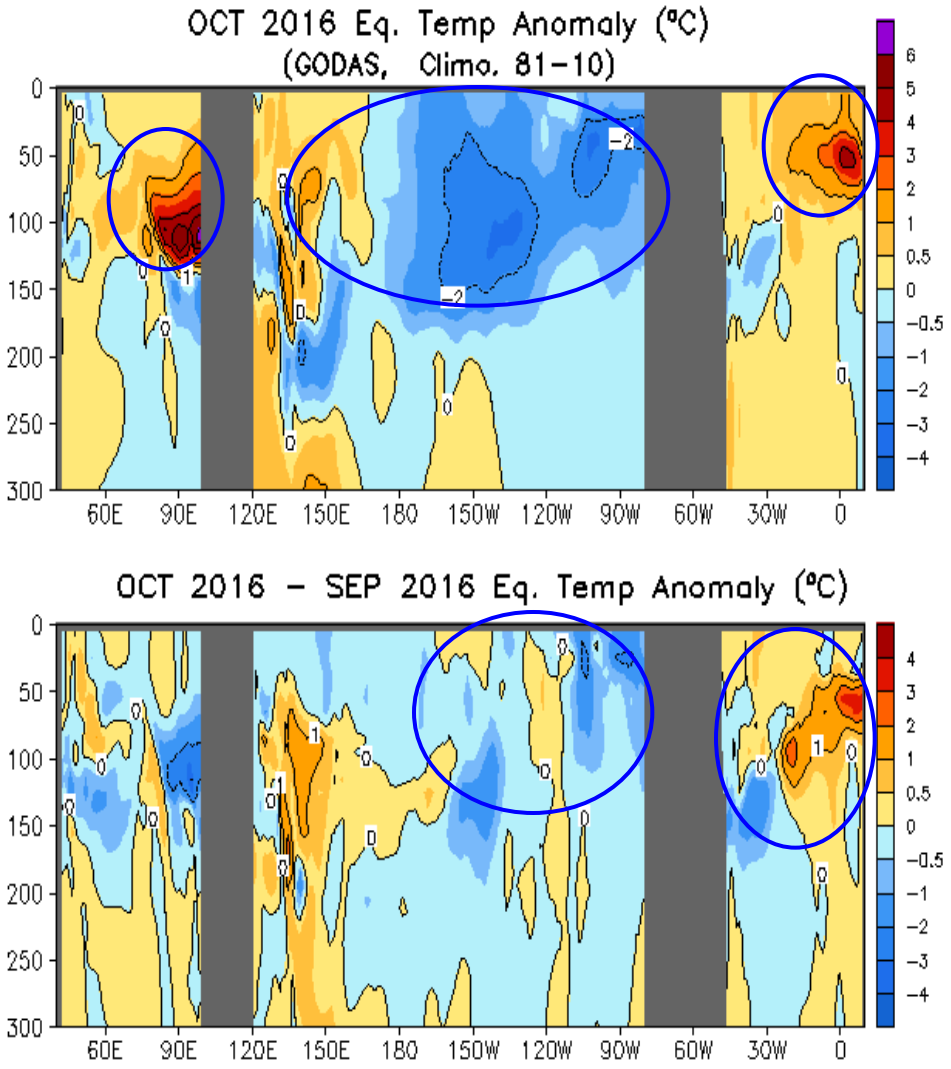


- **Negative SSTA continued in a narrow band along the C.-E. equatorial Pacific, and surrounded by positive SSTA in off-equatorial regions and the W.-C. Pacific.**
- **Strong positive SSTA presented near the Maritime Continent.**
- **Strong positive SSTA persisted in the high-latitude N. Pacific and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

- **Large SSTA tendencies presented in the North Pacific.**
- **Negative SSTA tendency dominated in the C-E. 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



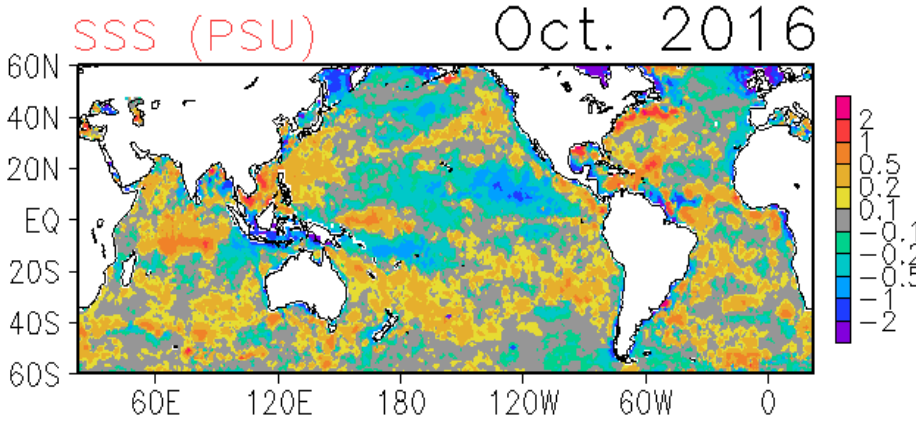
- **Negative temperature anomalies continued along the thermocline in the whole Pacific, while positive temperature anomalies were confined near the surface in the W.Pacific.**
- **Strong positive temperature anomalies persisted in the eastern Indian Ocean.**
- **Positive temperature anomalies occupied in the Atlantic Ocean.**

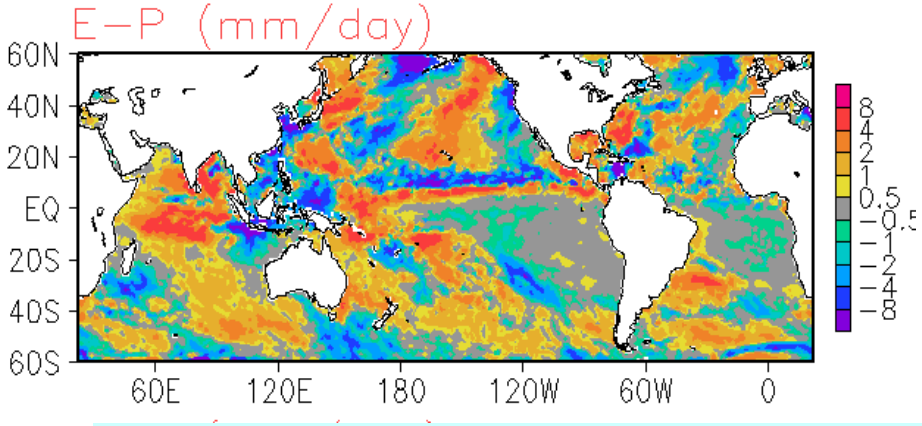
- **Negative temperature anomaly tendency dominated the C. Pacific near the thermocline and the far E. Pacific in the upper 50m.**
- **Positive temperature anomaly tendency dominated the Atlantic Ocean.**

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.

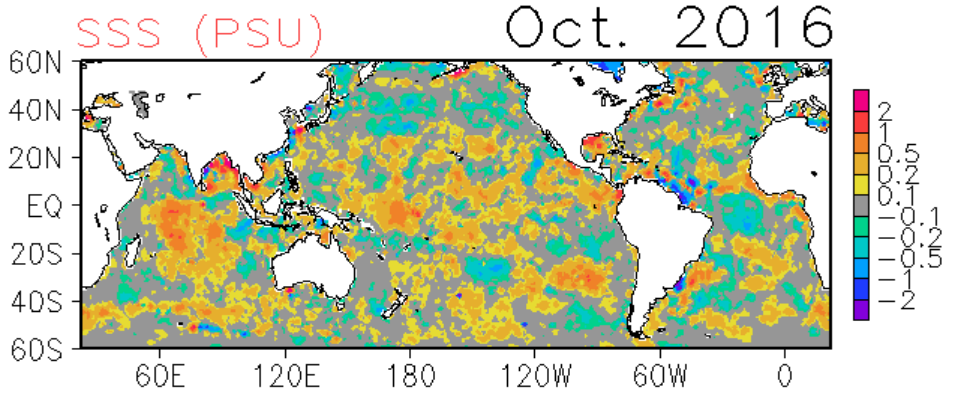
Global SSS Anomaly (⁰C) and Anomaly Tendency

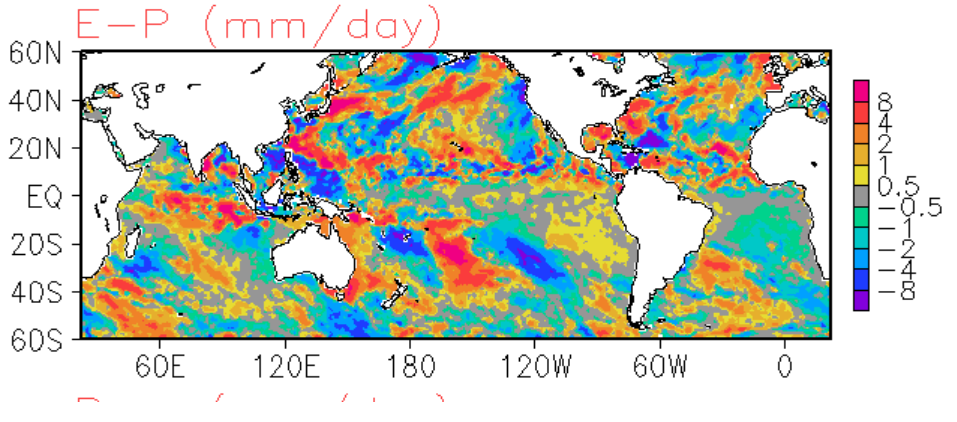
Anomaly





Anomaly Tendency





-**Positive (negative) SSS anomaly presented in the western(eastern) tropical Pacific.**

- **Positive SSS tendency dominated in the tropical Pacific and Indian Oceans.**

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

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

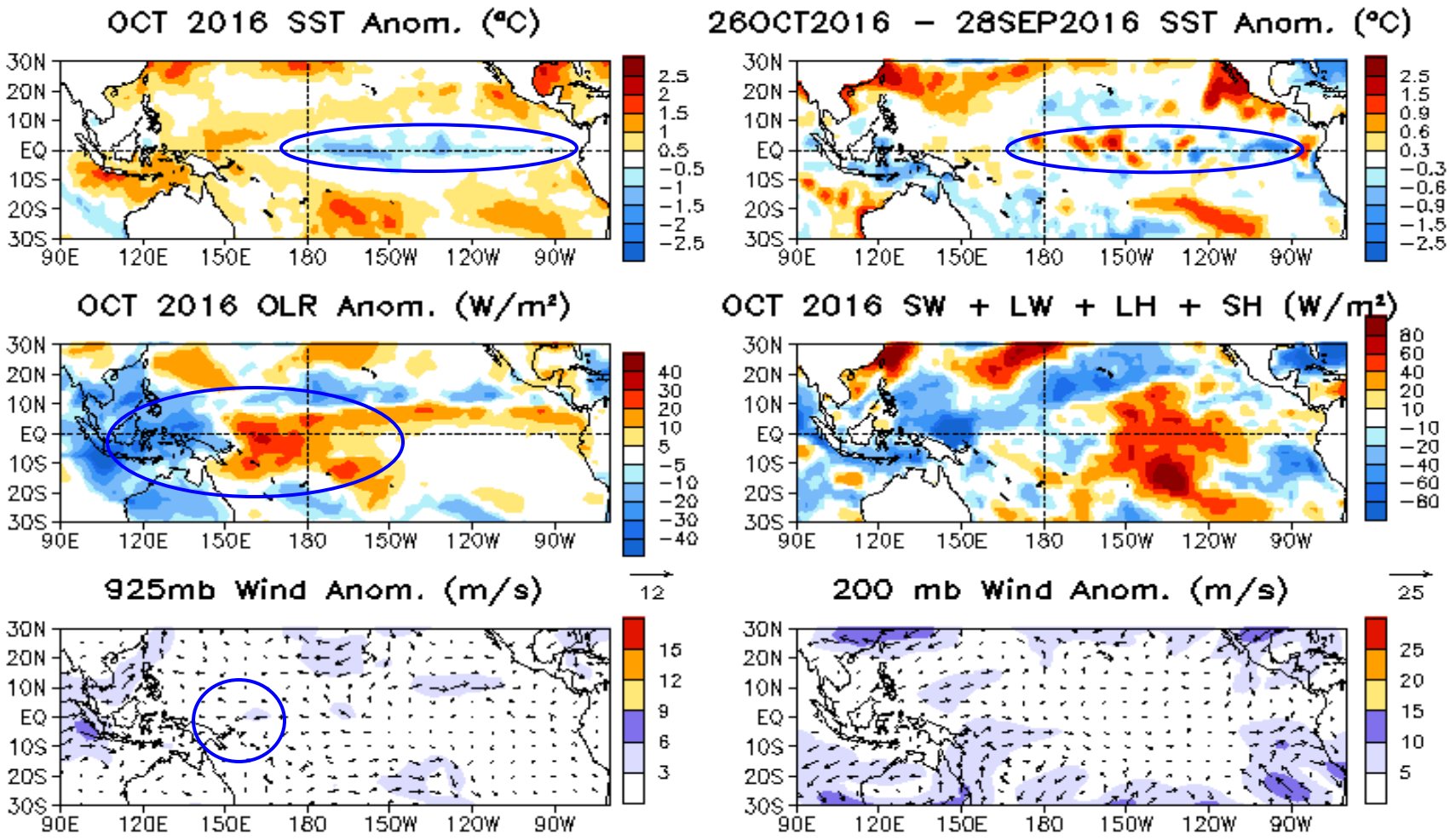
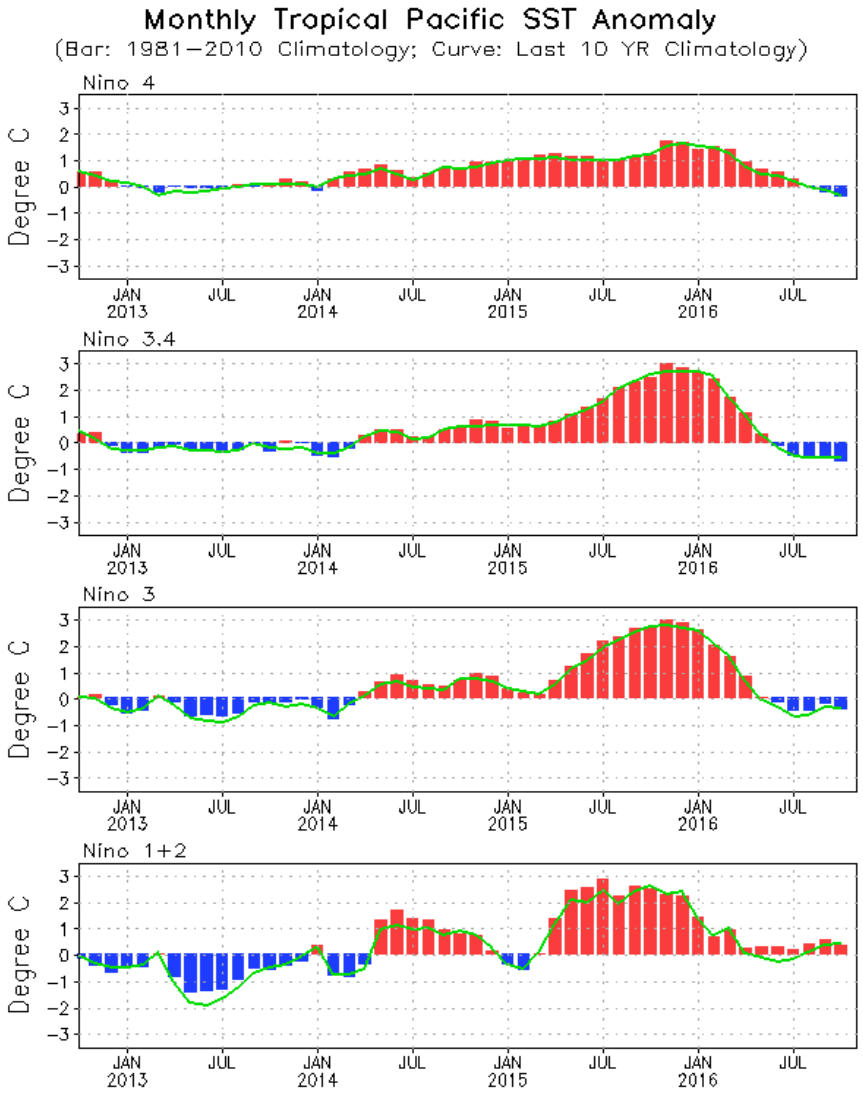
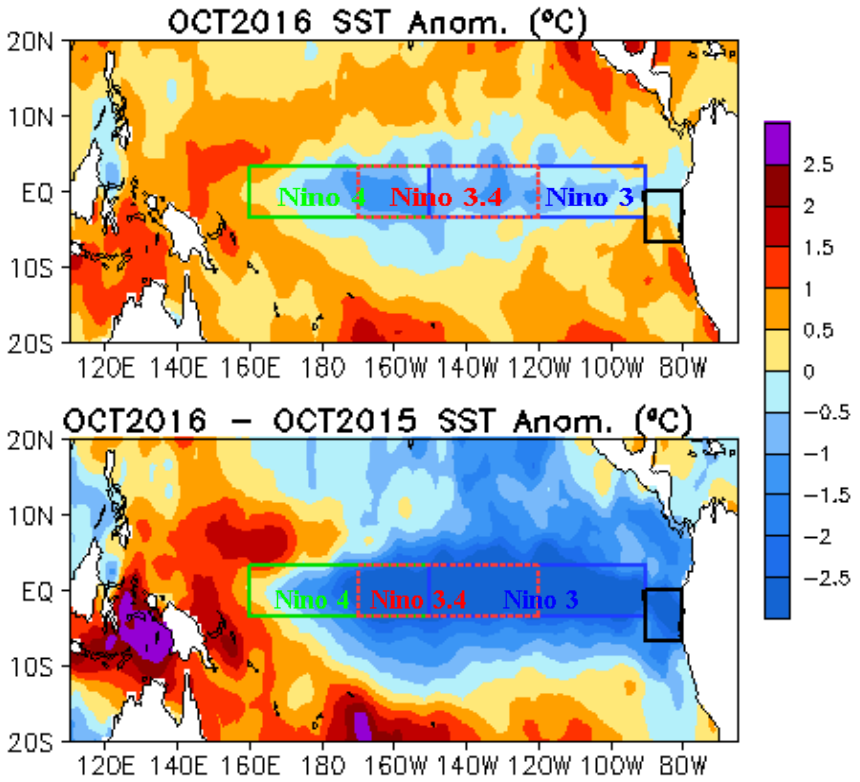


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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





– Nino4, Nino3 and Nino 3.4 cooled slightly, with Nino3.4 = -0.7°C in Oct 2016.

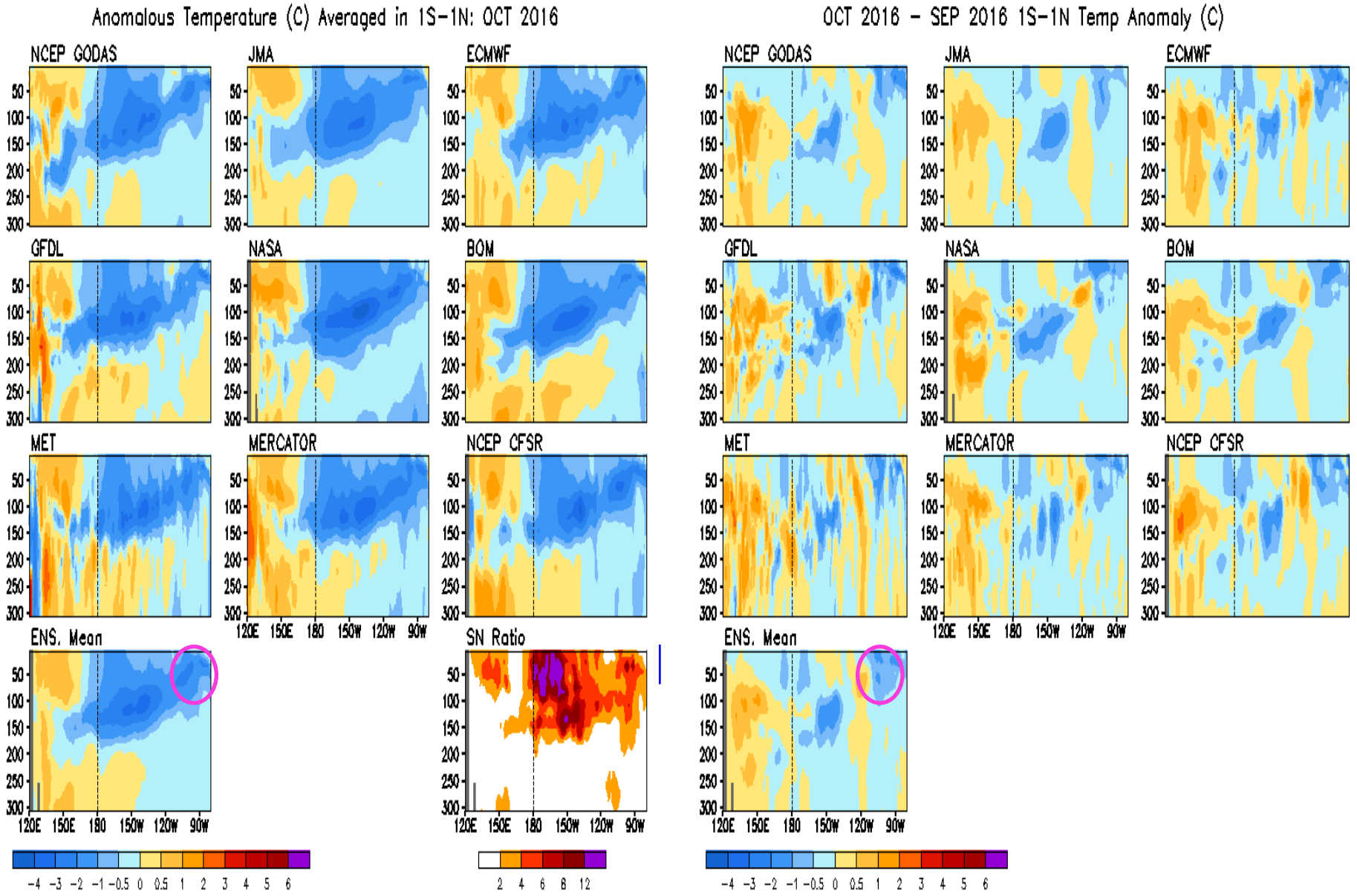
- The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v4.

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

Real-Time Ocean Reanalysis Intercomparison: Temperature

Climatology : 1993-2013

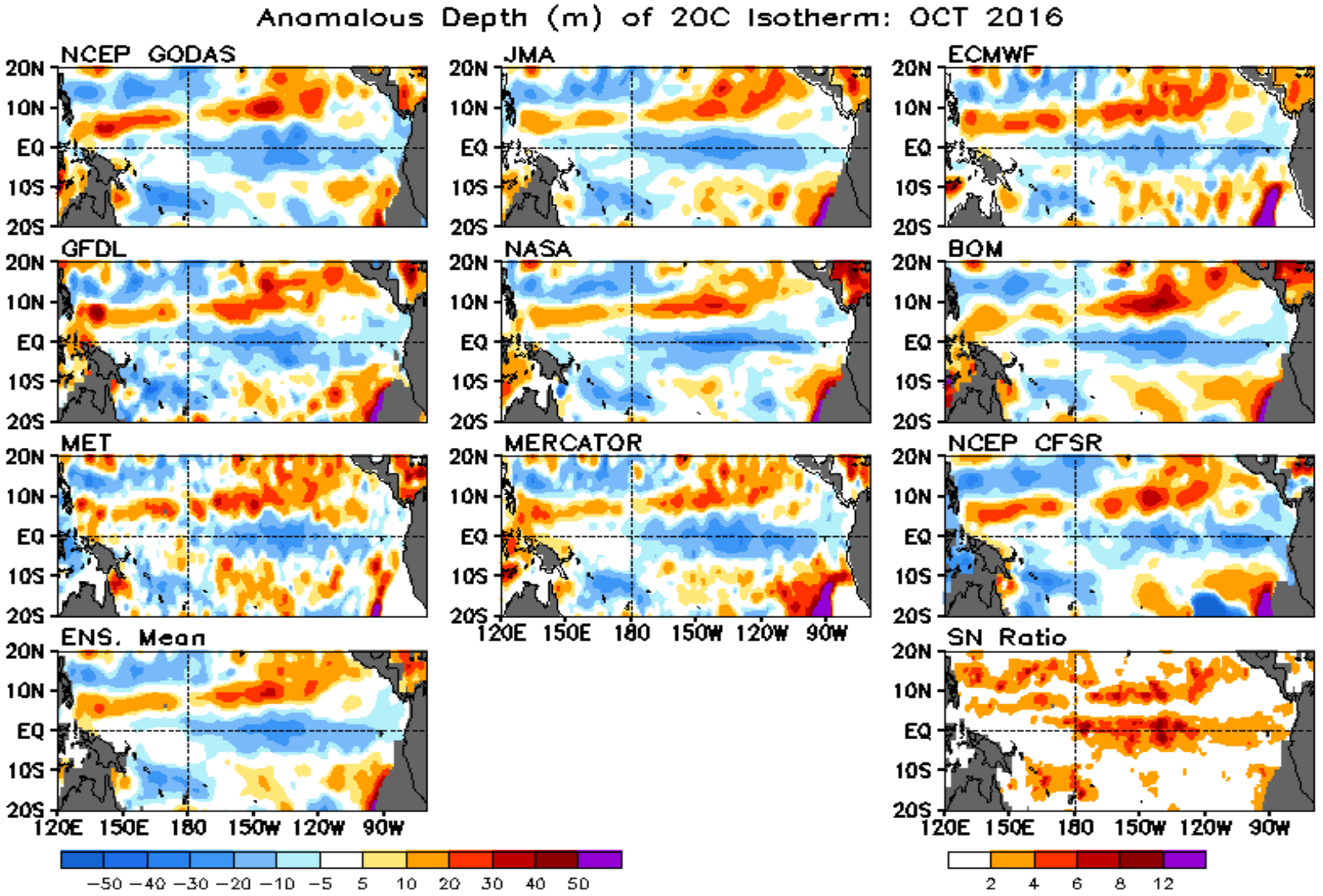
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)



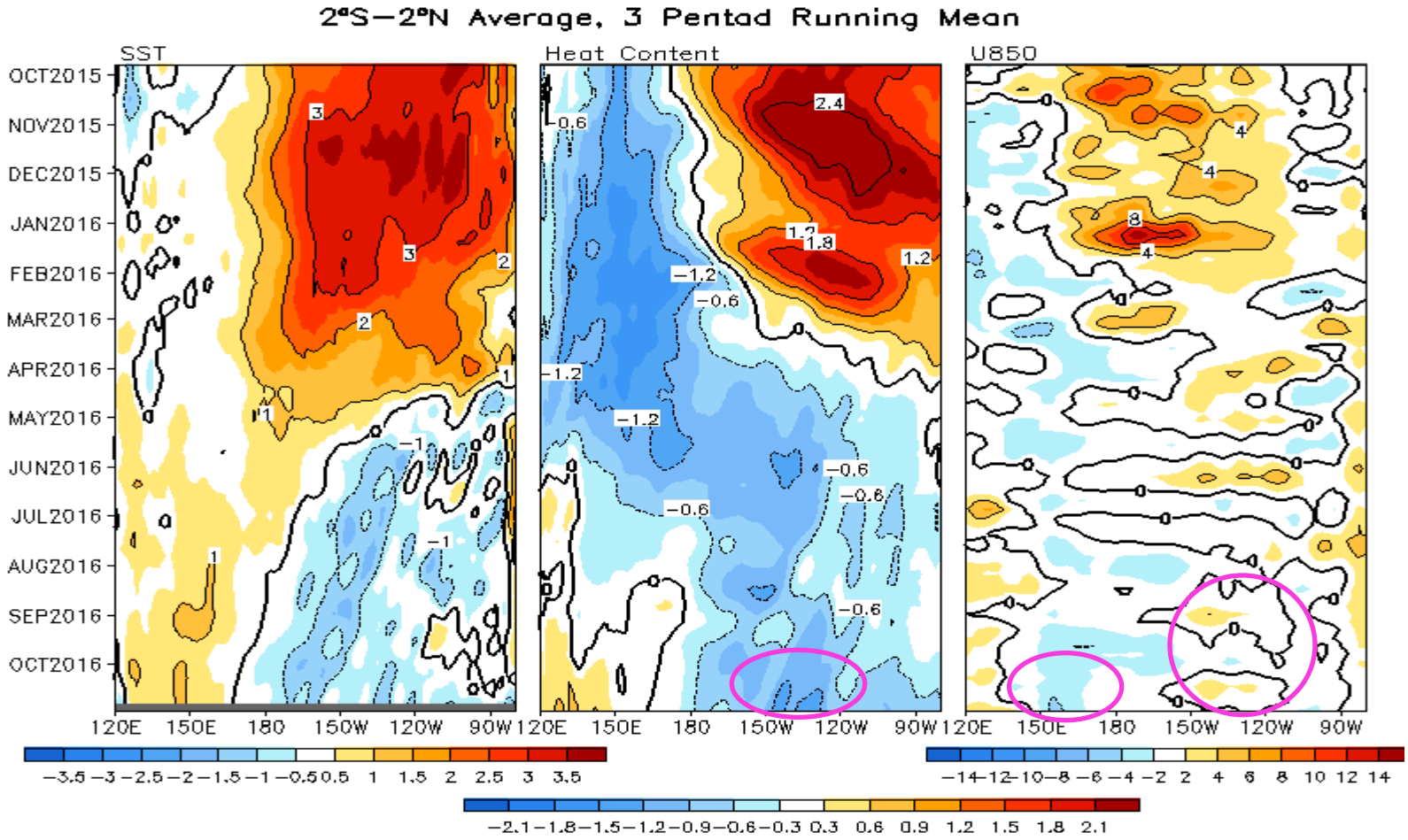
Real-Time Ocean Reanalysis Intercomparison: D20

Climatology : 1993-2013

(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)



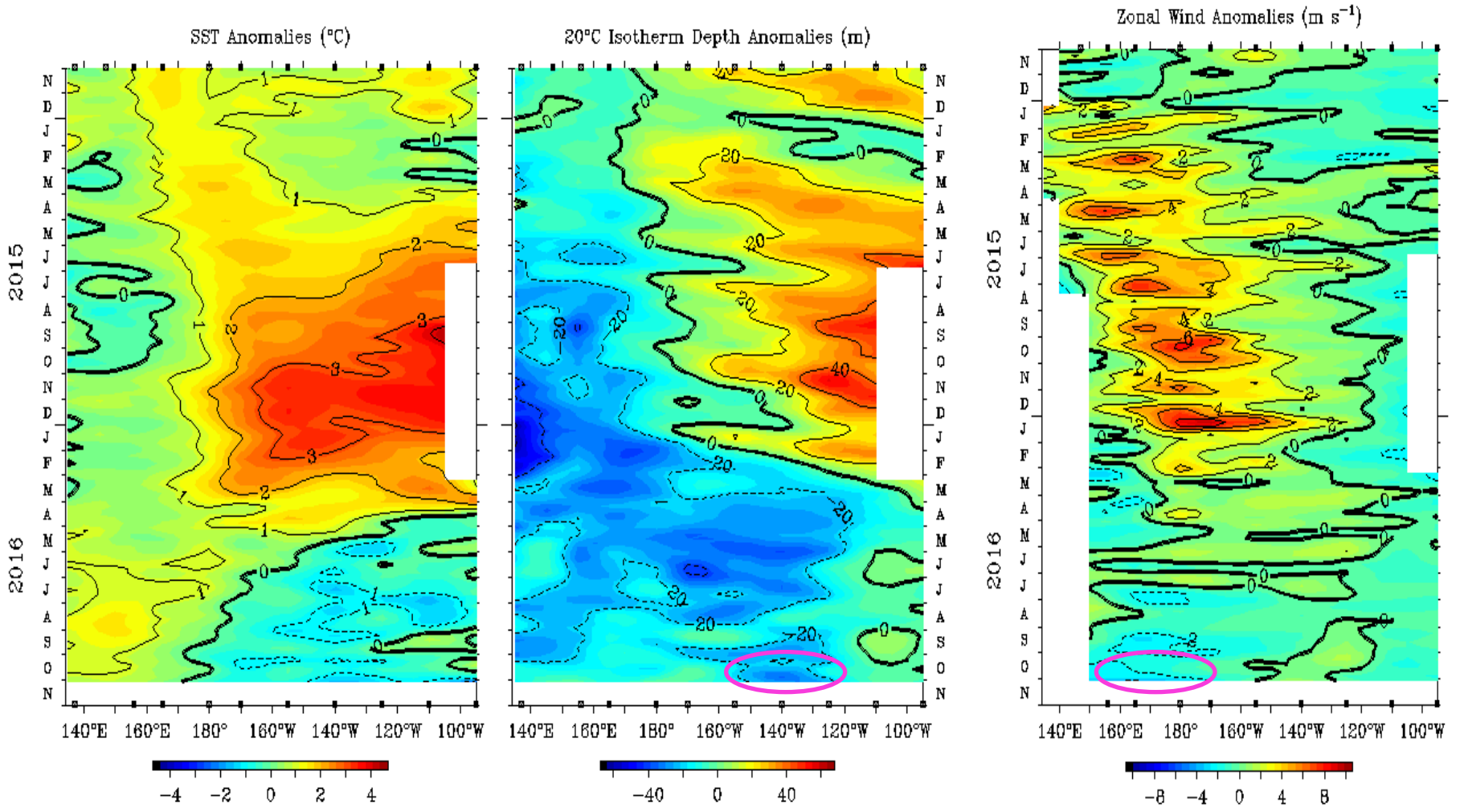
Equatorial Pacific SST (ºC), HC300 (ºC), U850 (m/s) Anomalies



- Negative SSTA persisted in the C-E. Pacific.
- Negative SSTA reemerged in the far E. Pacific in Oct 2016
- Negative H300 anomalies have strengthened slightly near [150W-120W] in Oct 2016.
- Easterly wind anomalies enhanced slightly west of Dateline.

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

Five Day SST, 20C Isotherm Depth and Zonal Wind Anomalies [2S-2N]

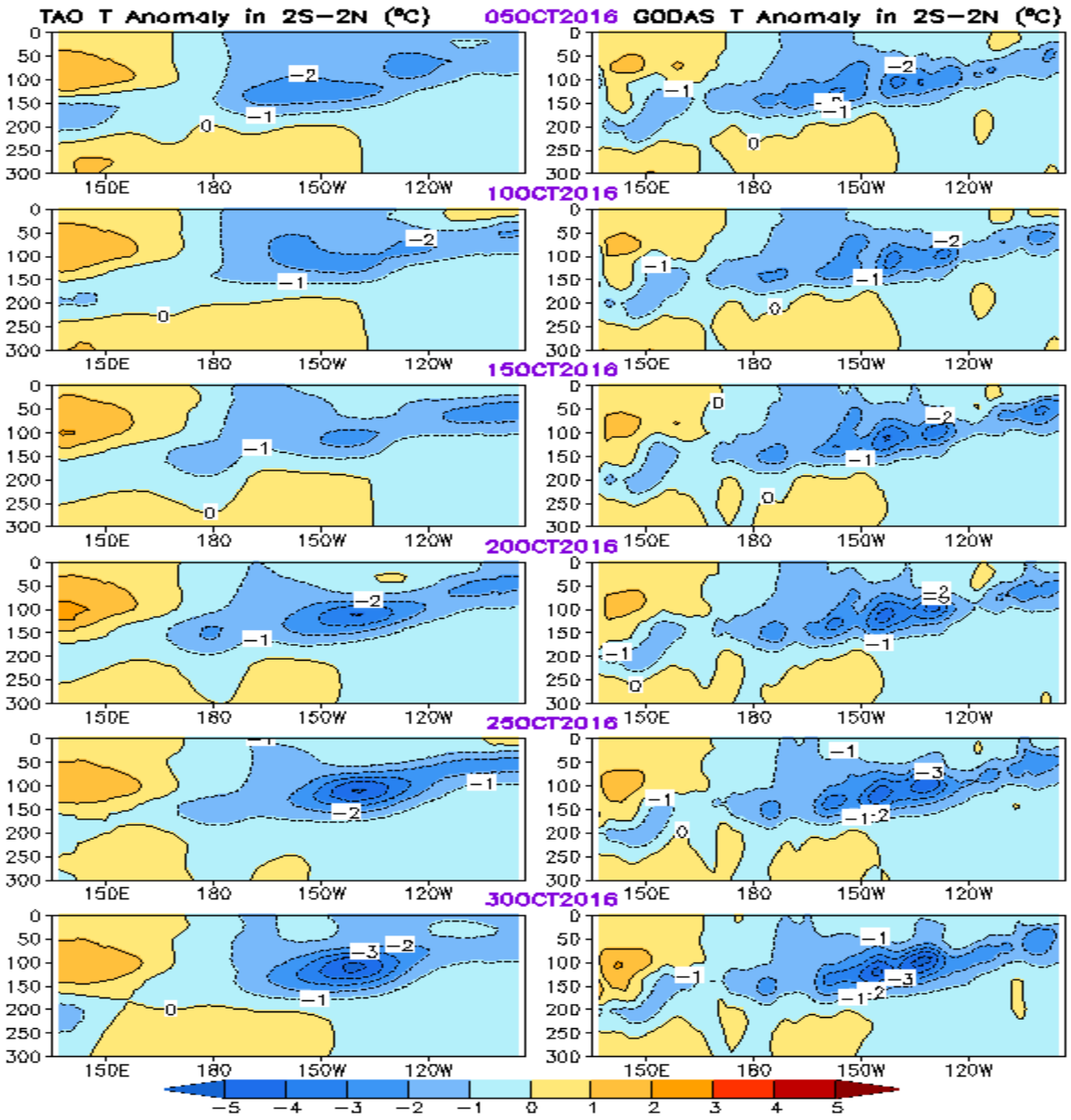


(http://www.pmel.noaa.gov/tao/jsdisplay/)

- **Negative D20 anomaly strengthened around 160w-120W in Oct 2016.**
- **Weak easterly wind anomaly presented over west of Dateline.**

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

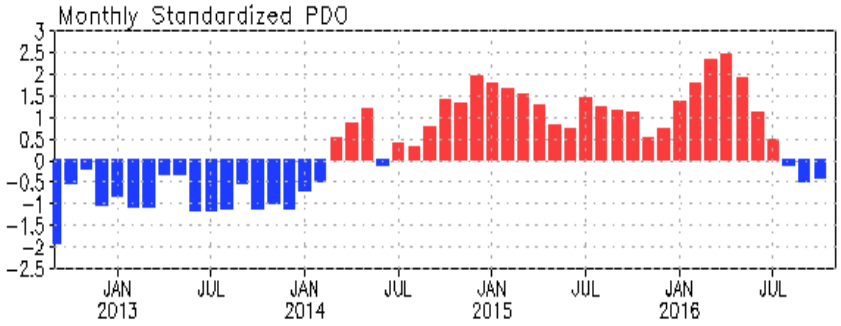
TAO GODAS

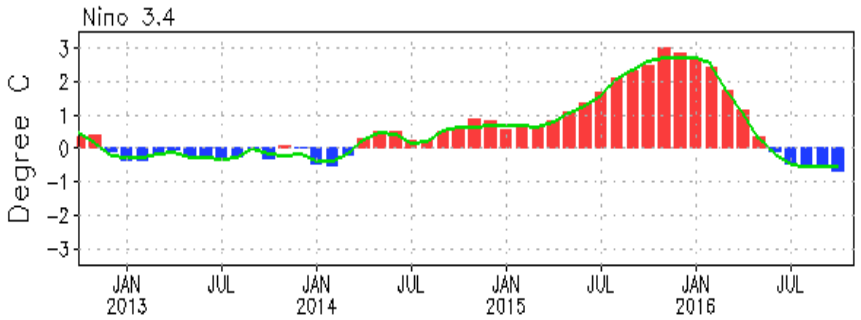


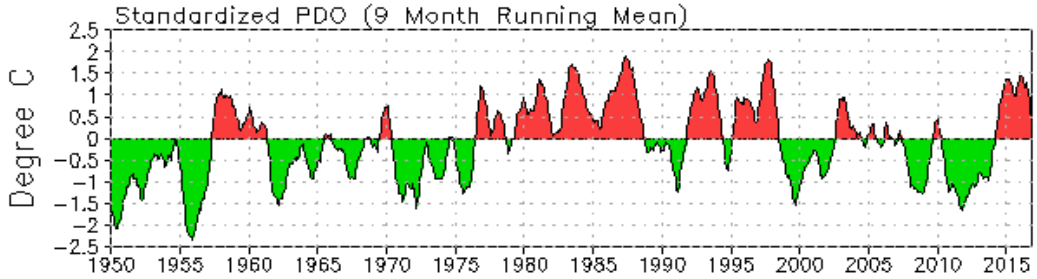
- **Negative temperature anomalies have strengthened east of dateline near the thermocline since mid-October.**

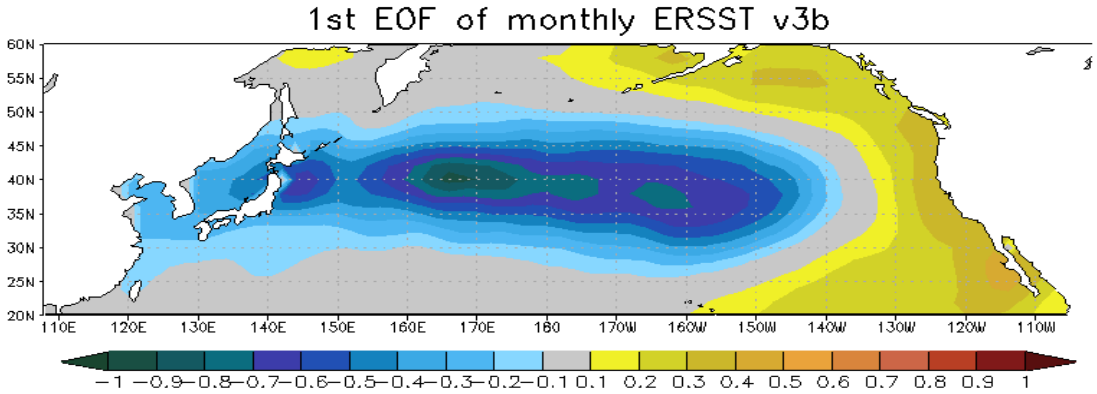
North Pacific & Arctic Oceans

Pacific Decadal Oscillation Index









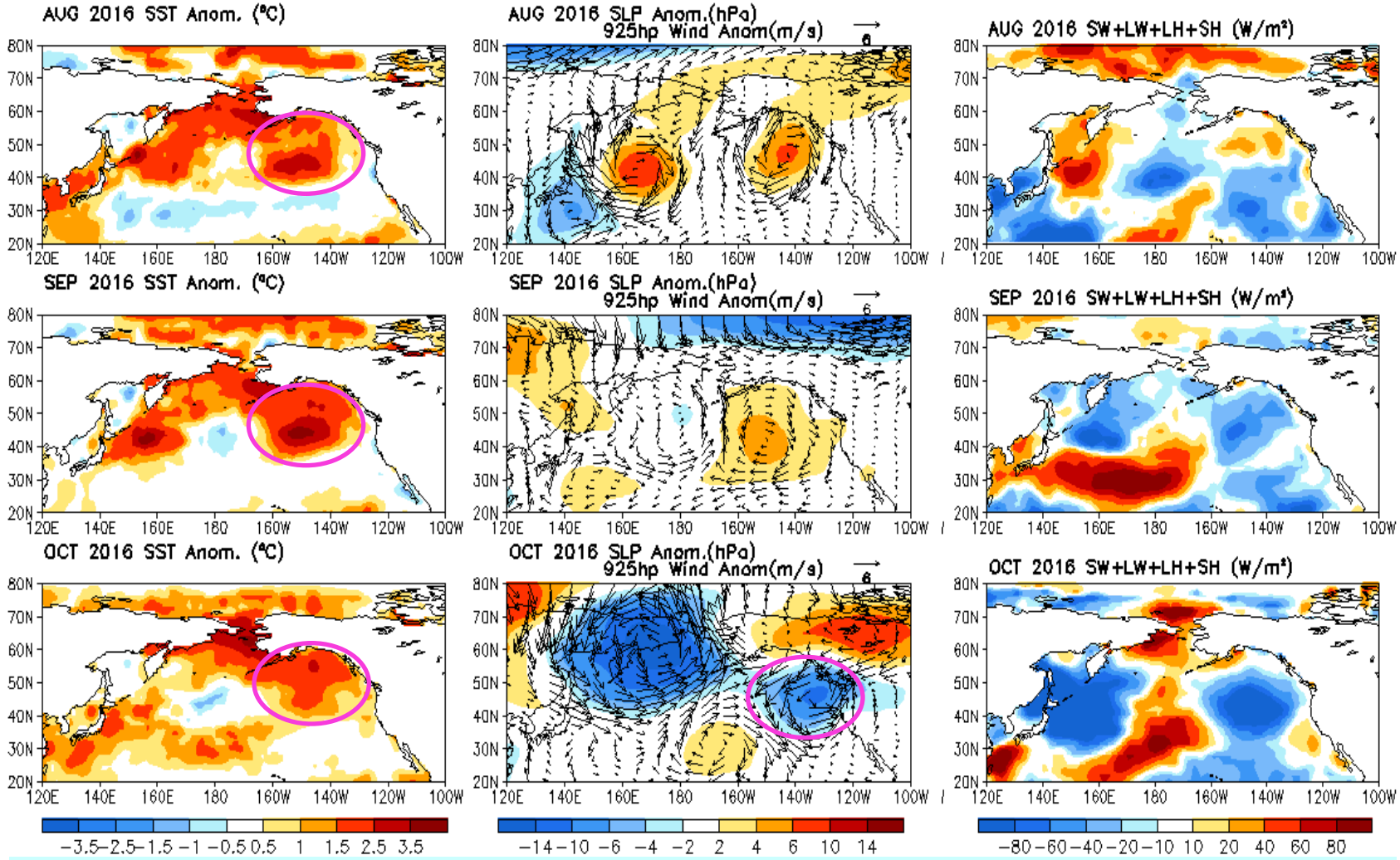
- Negative PDO persisted in Oct with PDO index = -0.4.

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

- 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 SST, SLP , 925hp Wind and Heat Flux Anom.



- **Positive SSTA in the NE Pacific weakened in Oct 2016.**
- **Anomalous cyclone presented near the western coast of U.S.A in Oct 2016.**

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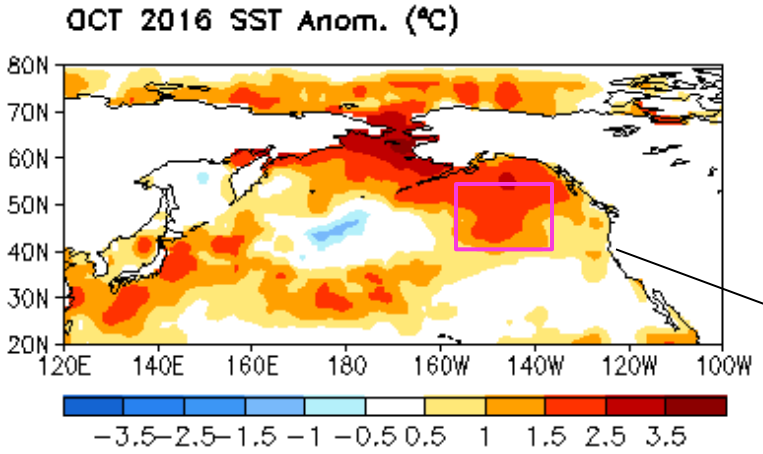
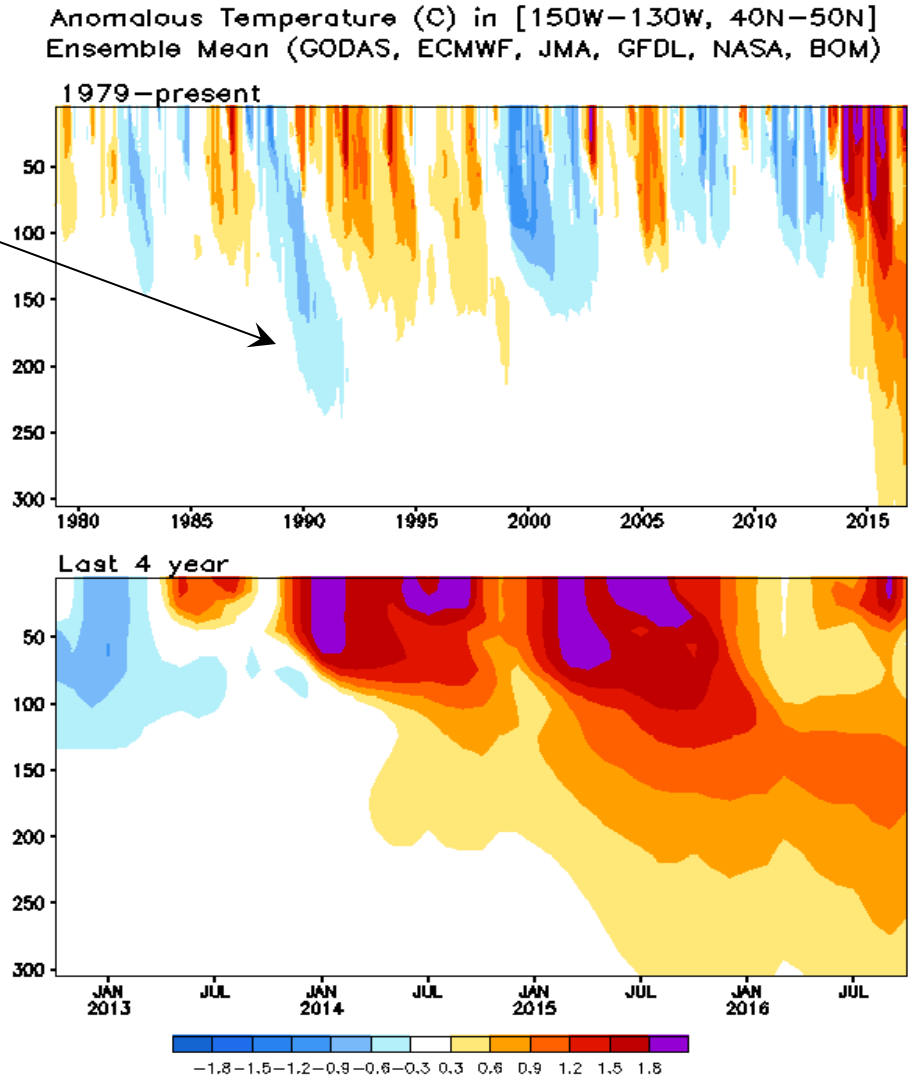
"Blob" in North Pacific

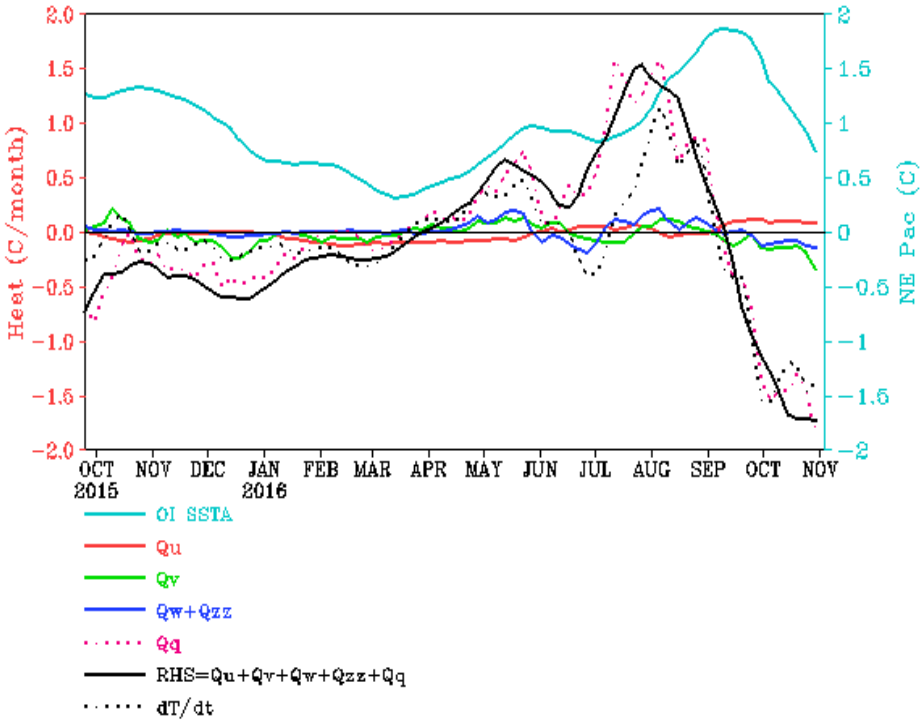




- **Between winters of 2013/14 and 2015/16, northeast Pacific experienced the strongest SST warming ever recorded, referred to as "Blob" by Bond et al. (2015)**
- **Warming has gradually extended to 300m since the late 2013.**
- **Near surface warming re-emerged since Jun 2016 and weakened slightly in October.**

NE Pac Heat Budget

[150W-130W,40N-50N]



- Strong negative SSTA tendency (dT/dt) in NE Pac region (dotted black line) presented in Oct 2016.

- Qq was the dominant factor modulating the SSTA tendency.

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

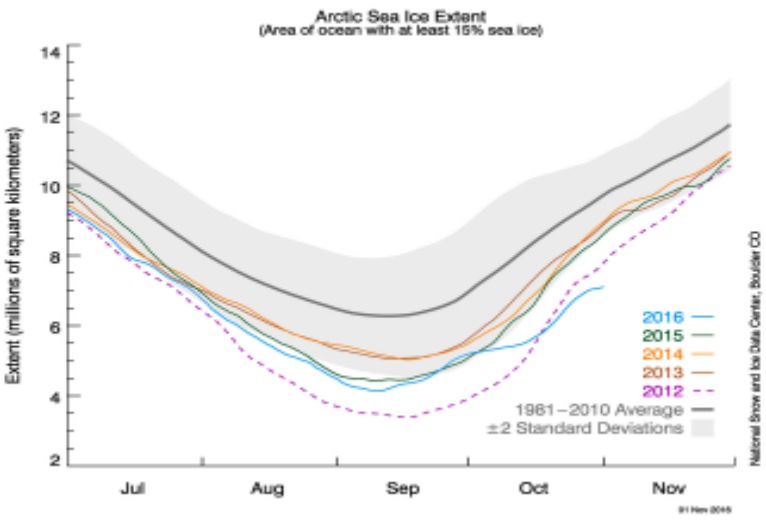
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

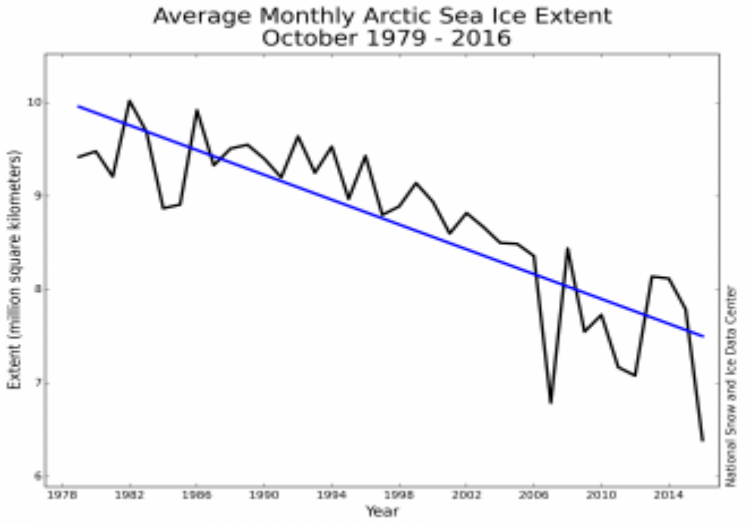
Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

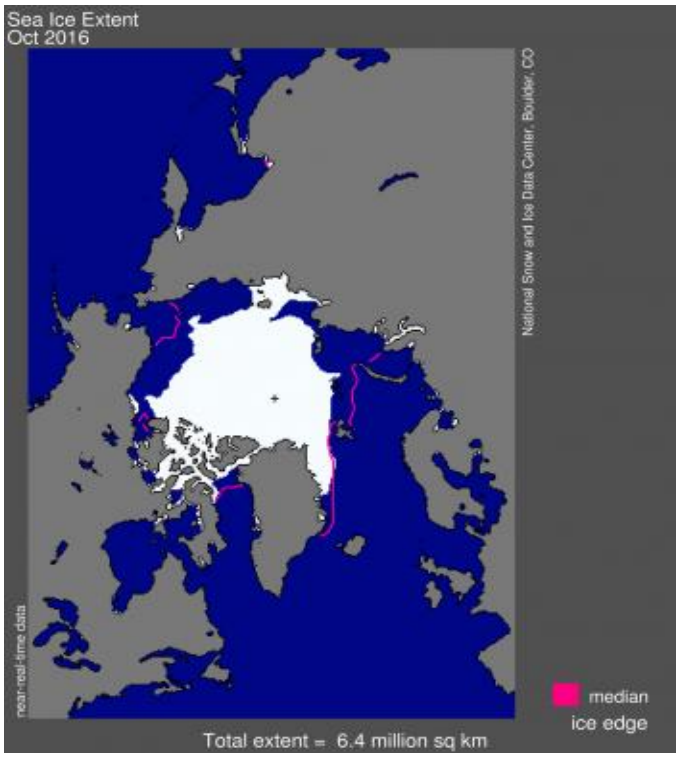
Arctic Sea Ice

National Snow and Ice Data Center

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







- Artic sea ice extent in Oct 2016 reached the historical low in the satellite record.

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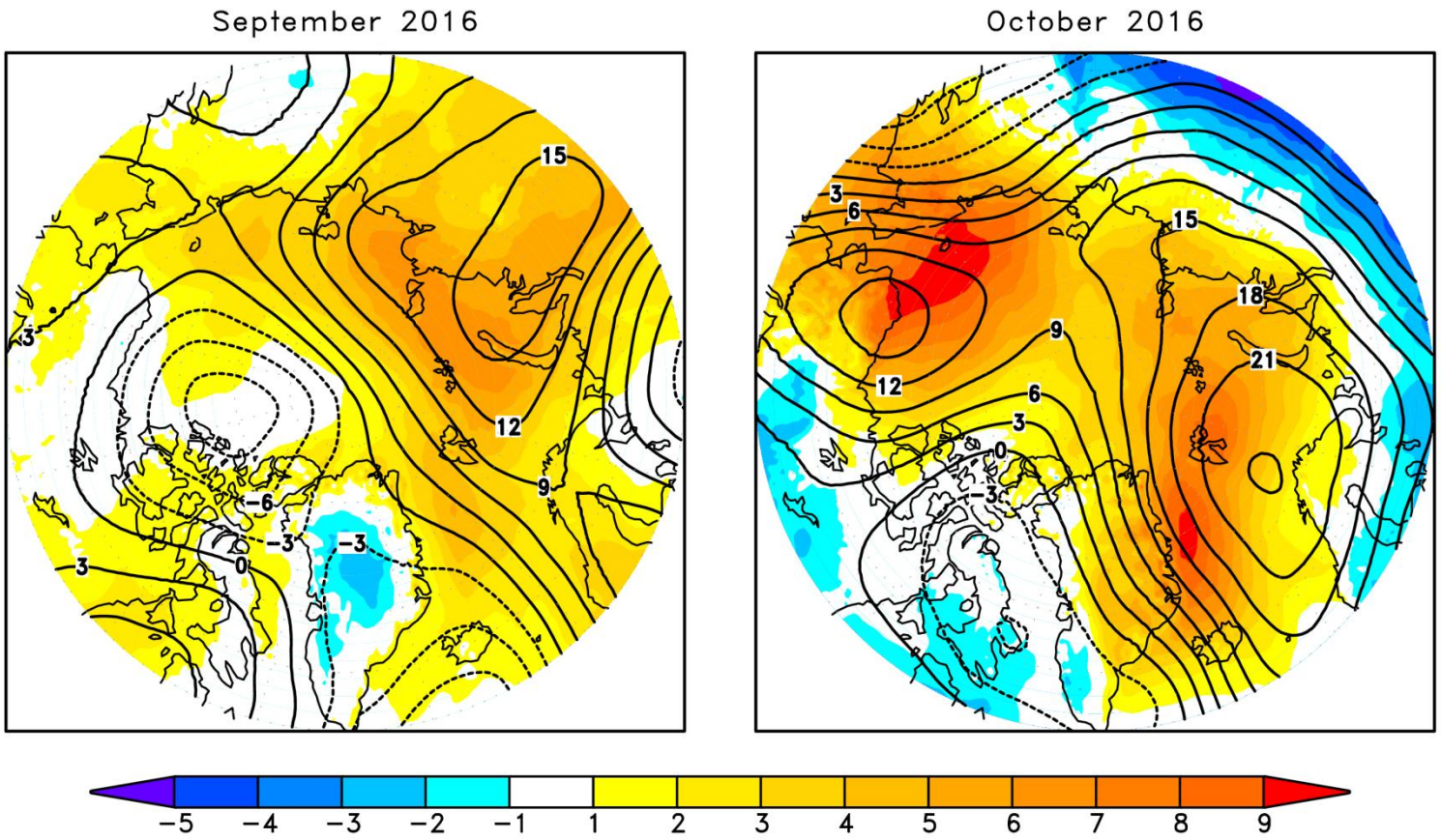
925 hpa temperature anomaly (K, shaded) and 500 hpa height anomaly (dm, contour) from CFSR with respect to the 1981–2010 period



-September generally featured cooler temperatures, especially in the second half of the month, which allowed melted ice near the poles to rapidly refreeze.

- A pattern shift in October created strong warming over both sides of the Arctic which worked to stunt ice growth. In addition, a build up of oceanic heat content from summer melting existed in regions further away from the poles which also acted to delay refreezing.

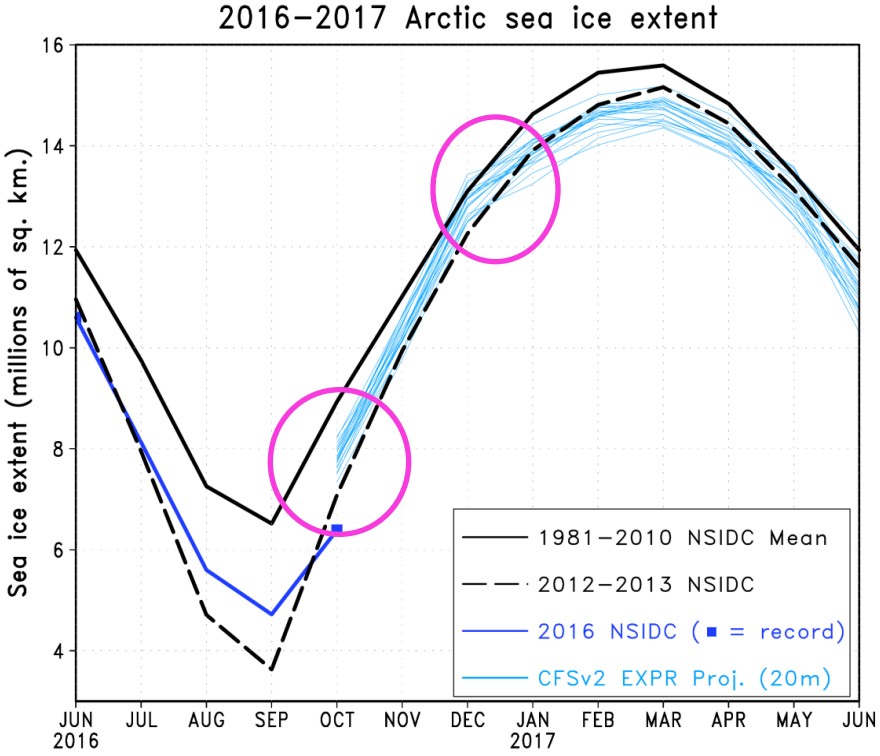
(Provided by Thomas W. Collow)

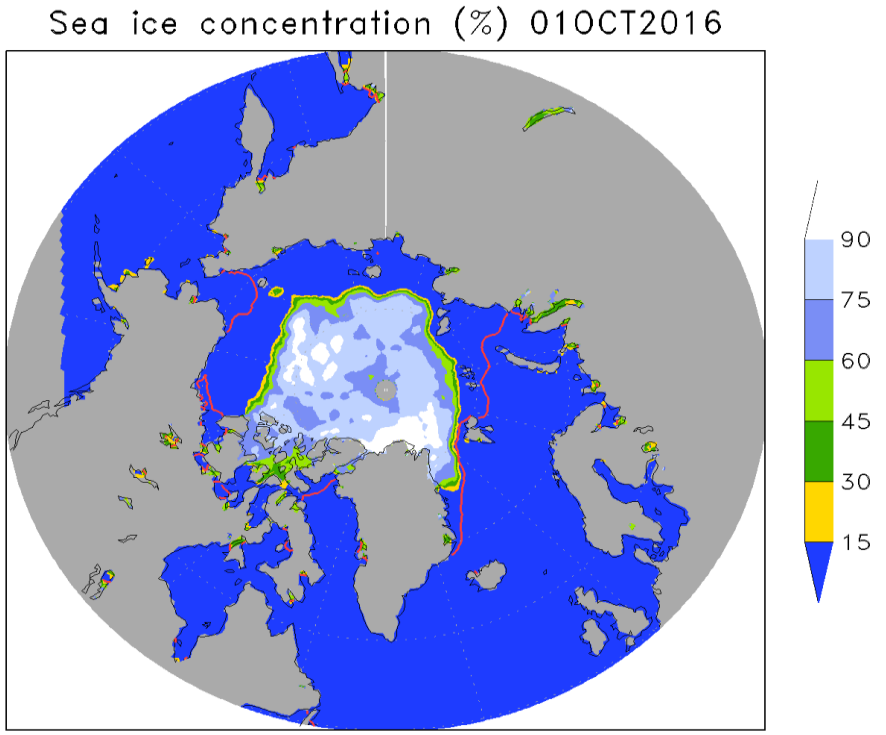
CPC Experimental Arctic Sea Ice Prediction

(Wanqiu Wang and Thomas Collow)

National Snow and Ice Data Center

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





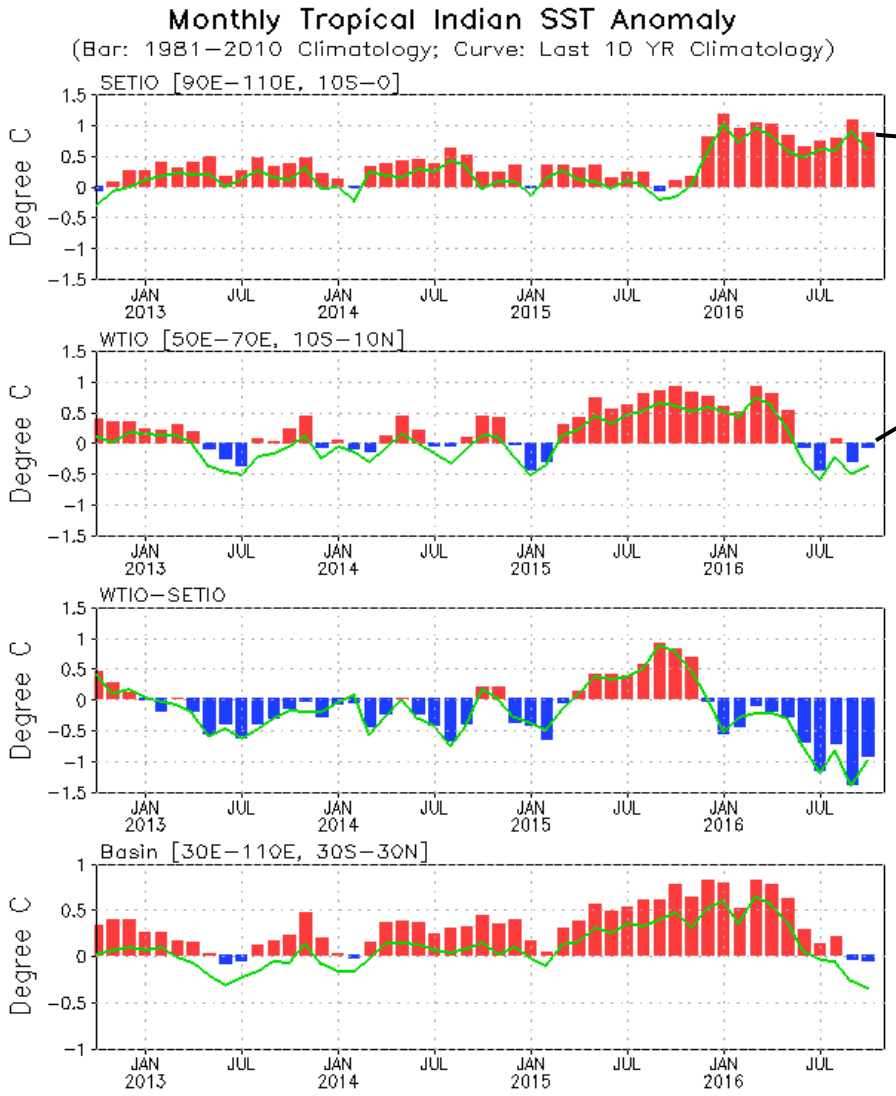
- After a rapid freeze-up in mid to late September, Arctic sea ice extent growth slowed down considerably in October.

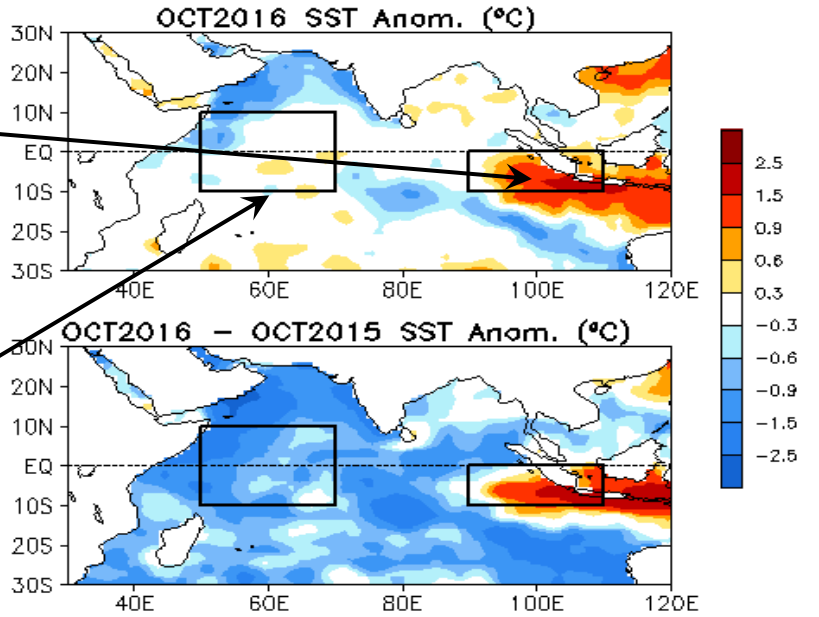
- Monthly mean sea ice extent in October was 6.39 * 10^6 km^2 setting a new record in the satellite era (Previous record was 6.79 * 106 km2 in 2007).

(Provided by Thomas W. Collow)

Indian Ocean

Evolution of Indian Ocean SST Indices





- **SETIO has been strong positive (> +0.7°C) since Dec 2015.**

- **DMI was well below average, with DMI = -0.9°C in Oct 2016.**

- **The long-persistent basin wide warming ended in Sep 2016.**

Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the SETIO [90°E-110°E, 10°S-0] and WTIO [50°E-70°E, 10°S-10°N] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

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

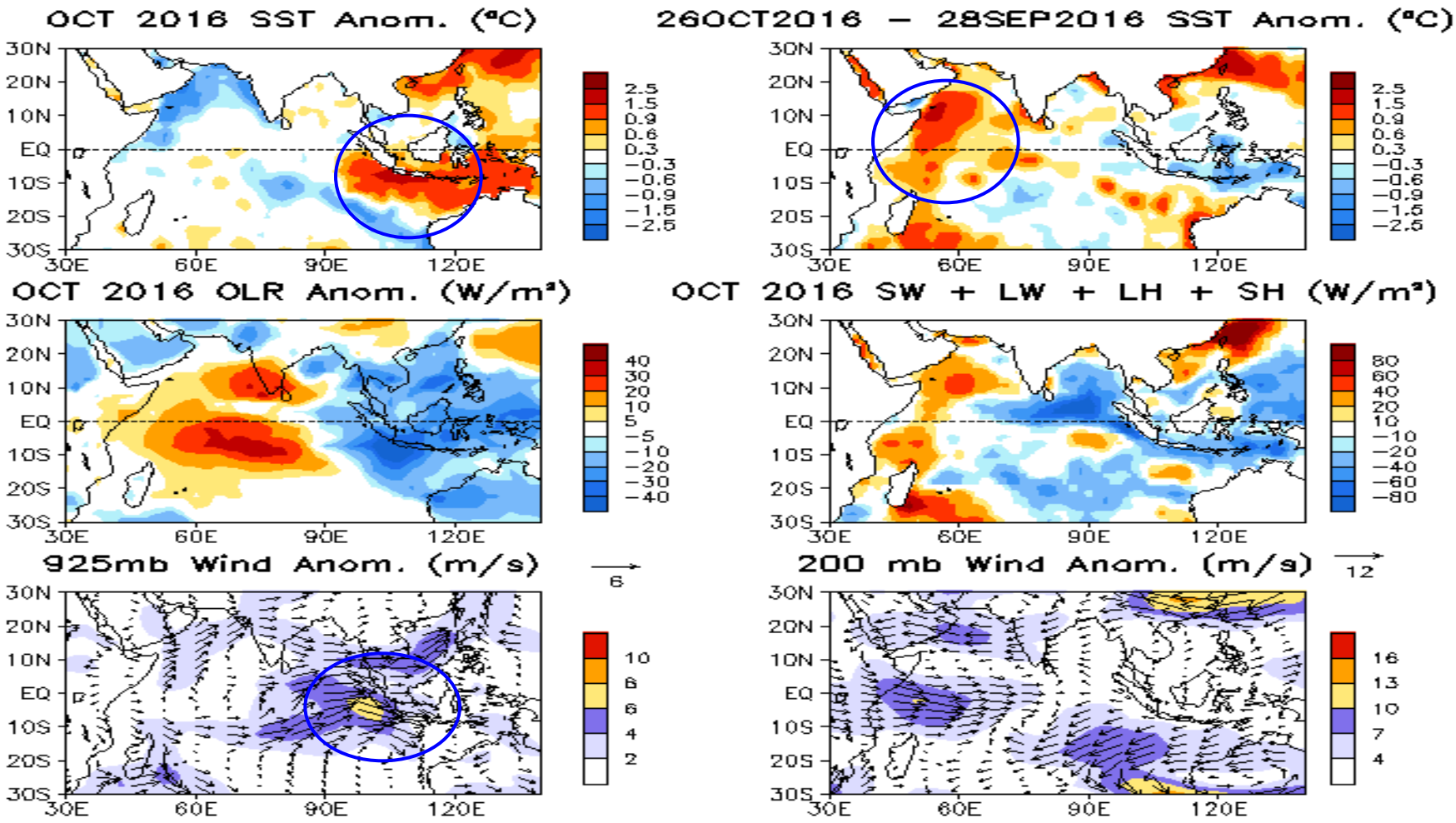
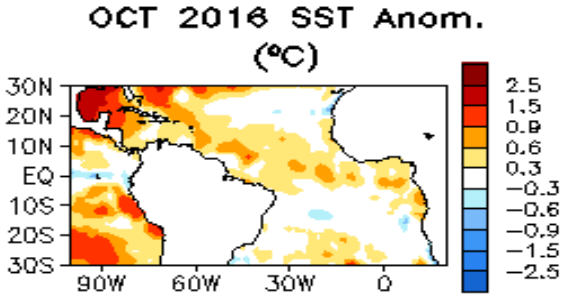


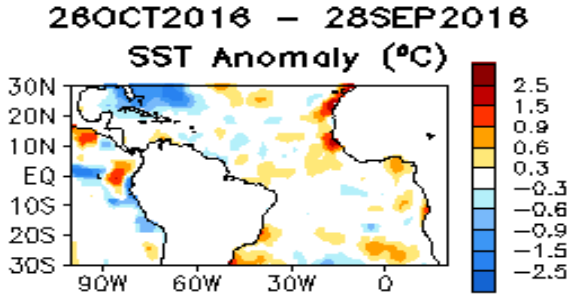
Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

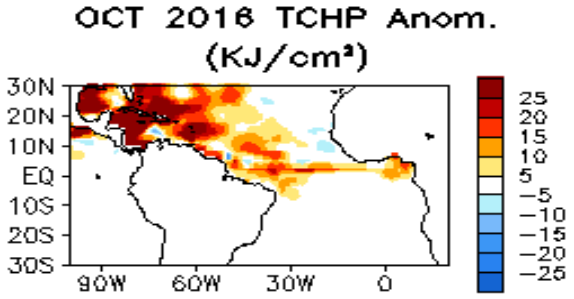
Tropical and North Atlantic Ocean

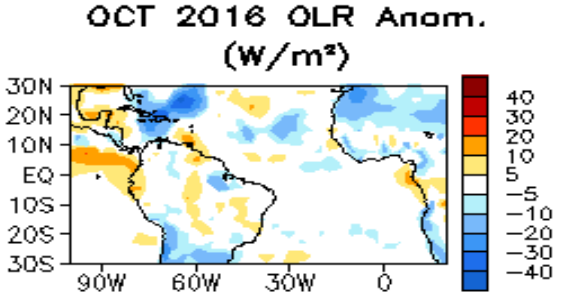
Tropical Atlantic:

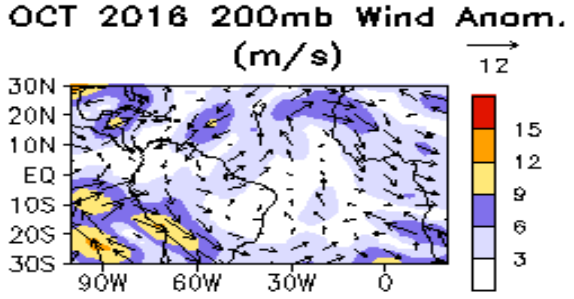
SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb/200-mb Winds

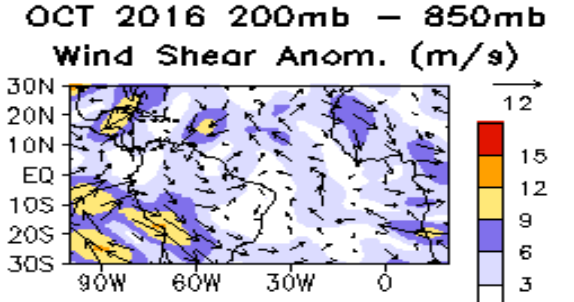


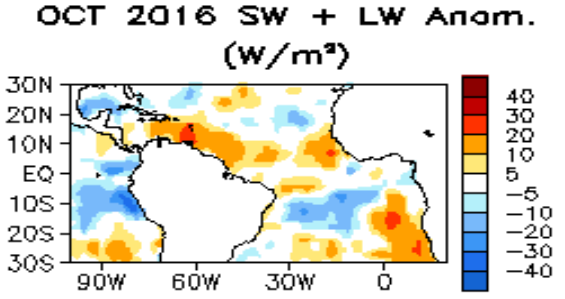


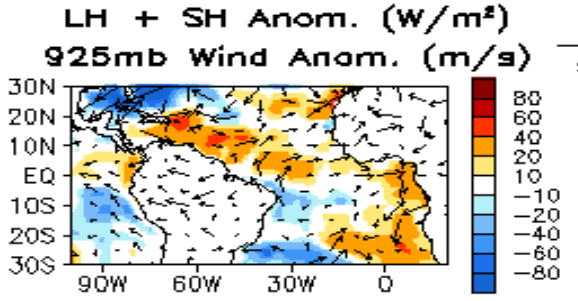


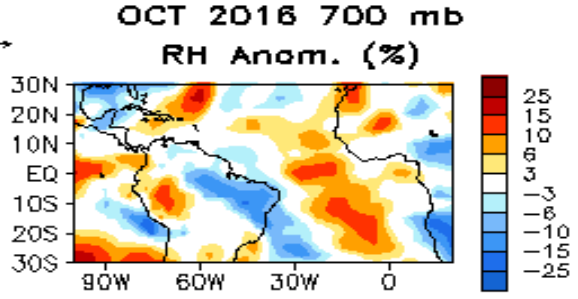








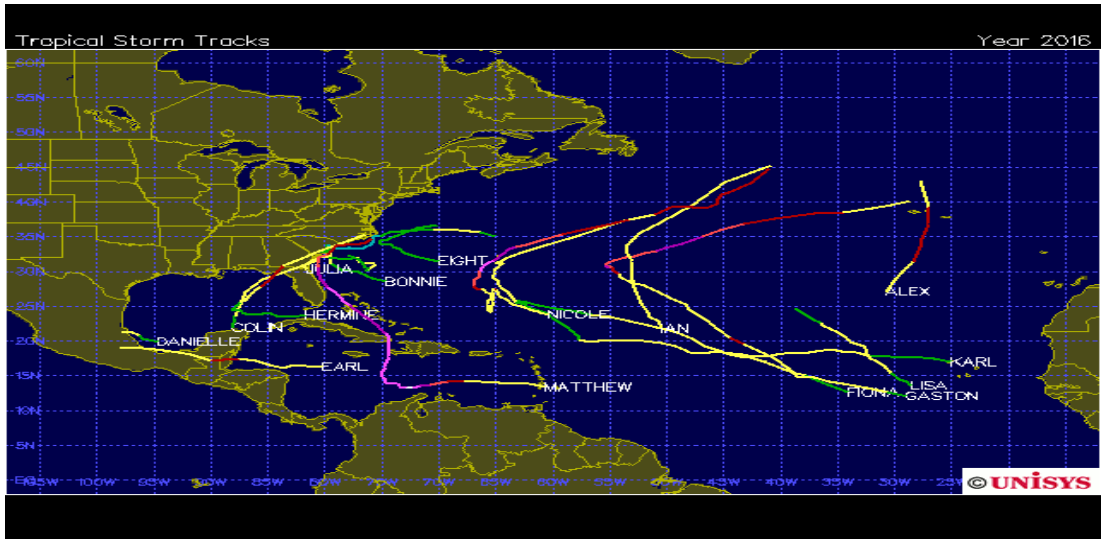




- **Above-normal SSTA and TCHP presented in the hurricane Main Development Region (MDR) .**
- **Westerly low-level wind blew towards the western Africa, indicating enhanced west African monsoon.**

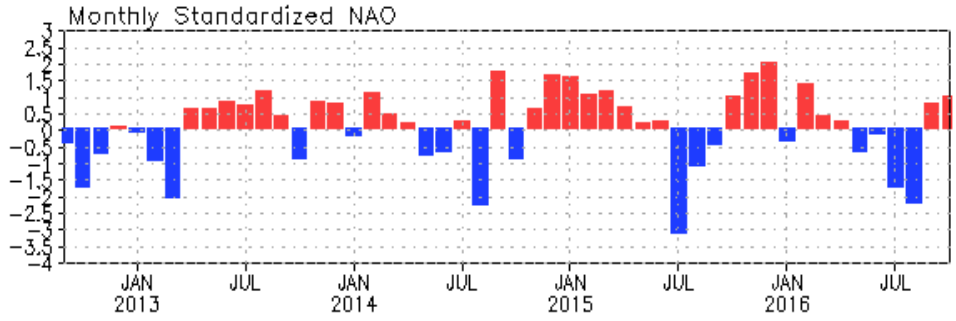
2016 Atlantic Hurricane Season

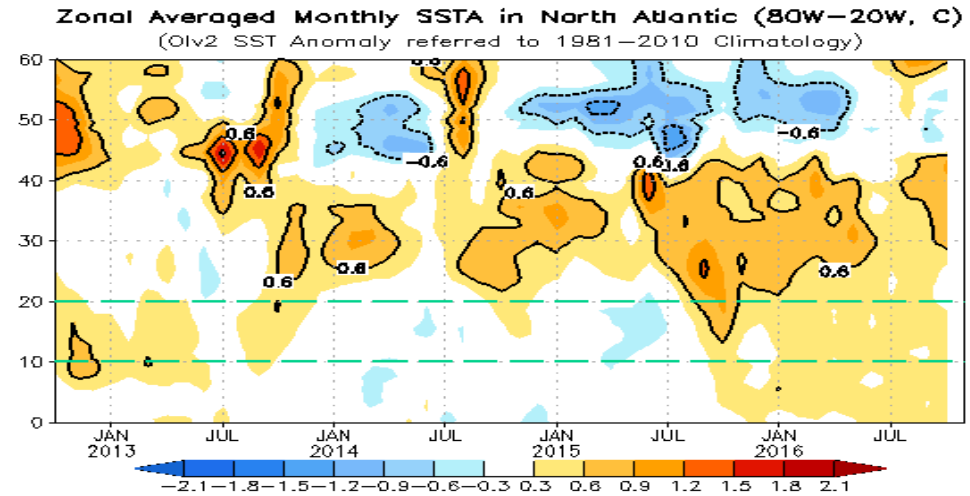
(http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.shtml)

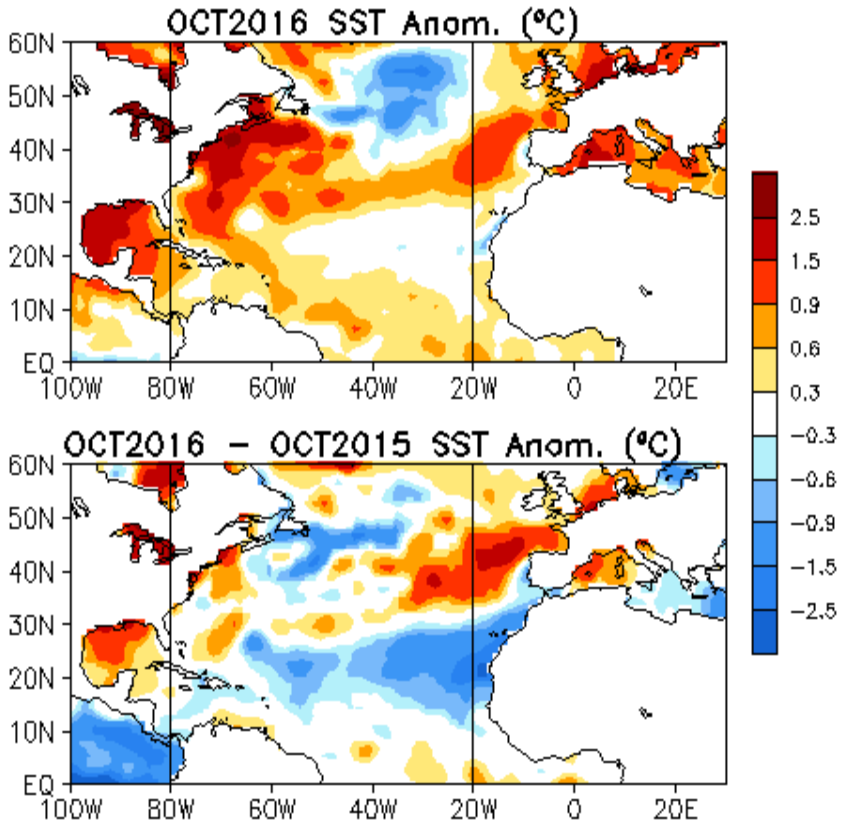


Atlantic	Observation by Nov 6, 2016	August Update	May outlook	1981-2010
Named storms	14	12-17	10-16	12.1
Hurricanes	6	5-8	4-8	6.4
Major hurricanes	3	2-4	1-4	2.7

NAO and SST Anomaly in North Atlantic





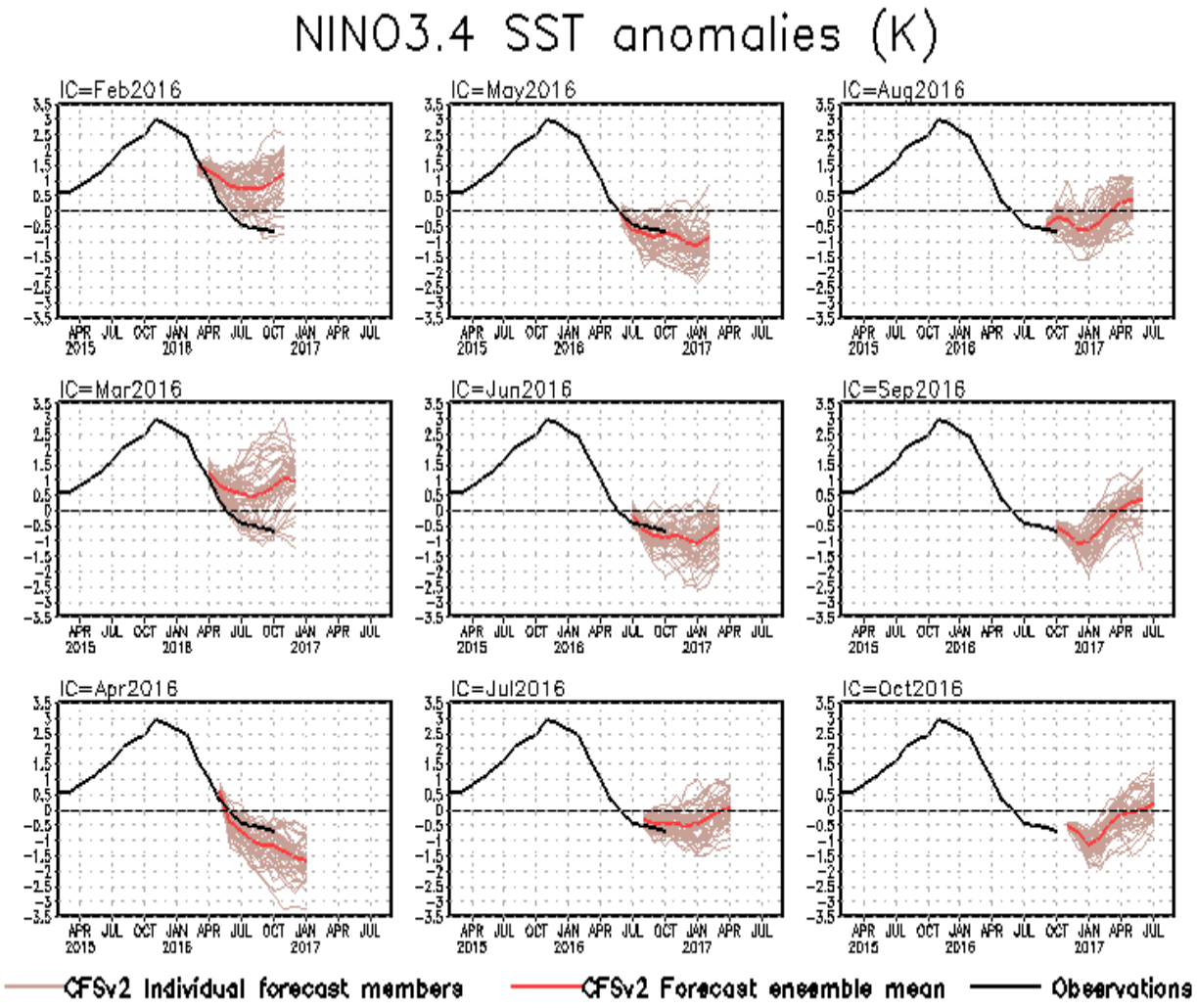


- **Positive NAO increased slightly, with NAOI=+1 in Oct 2016.**
- **Strong positive SSTA persisted along the Gulf of Mexico and E. coast of North America.**

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

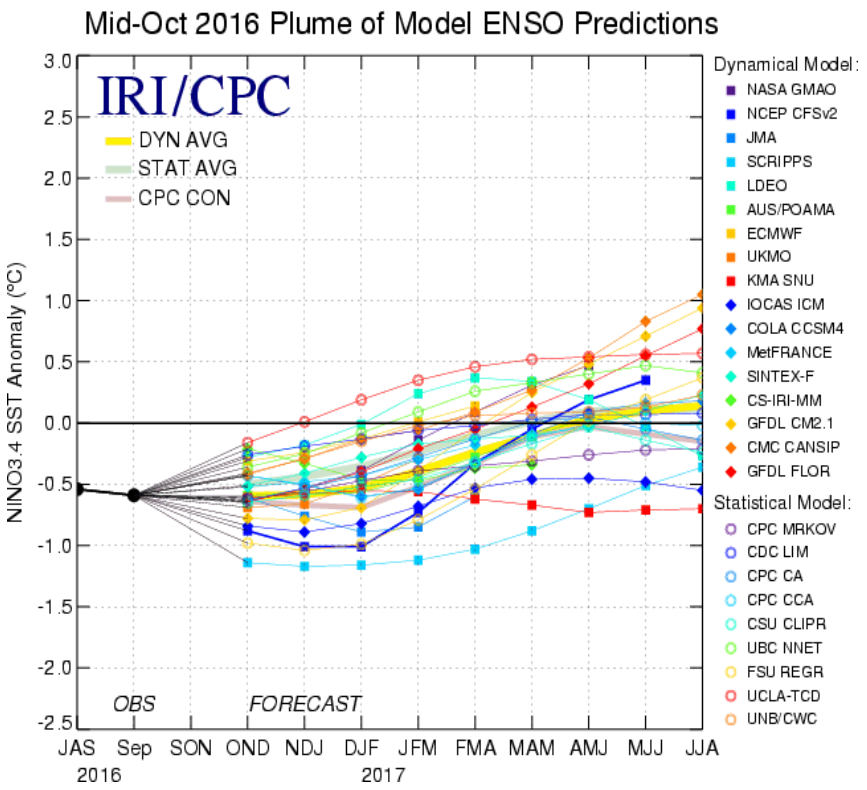
CFS Niño3.4 SST Predictions from Different Initial Months

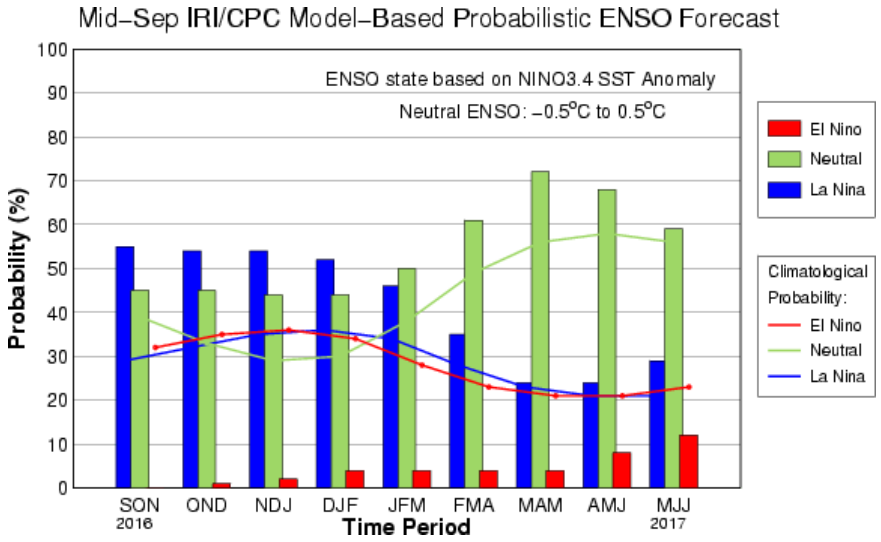


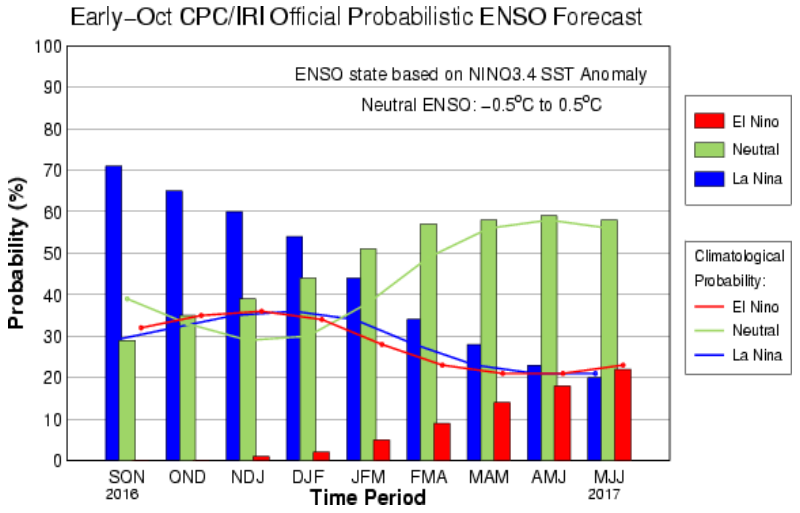
- **Latest CFSv2 predictions suggest La Nina conditions (NINO3.4 < -0.5C) would likely continue through fall/winter and then return to ENSO-neutral in spring/summer 2017.**

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







- **Multi-model ensemble forecasts suggest weak La Niña conditions would likely dominate in the fall/winter and then return to ENSO-neutral conditions in spring 2017.**
- **CPC/IRI Official probabilistic ENSO forecast calls a 50%-60% chance of La Nina conditions during the 2016/17 winter.**

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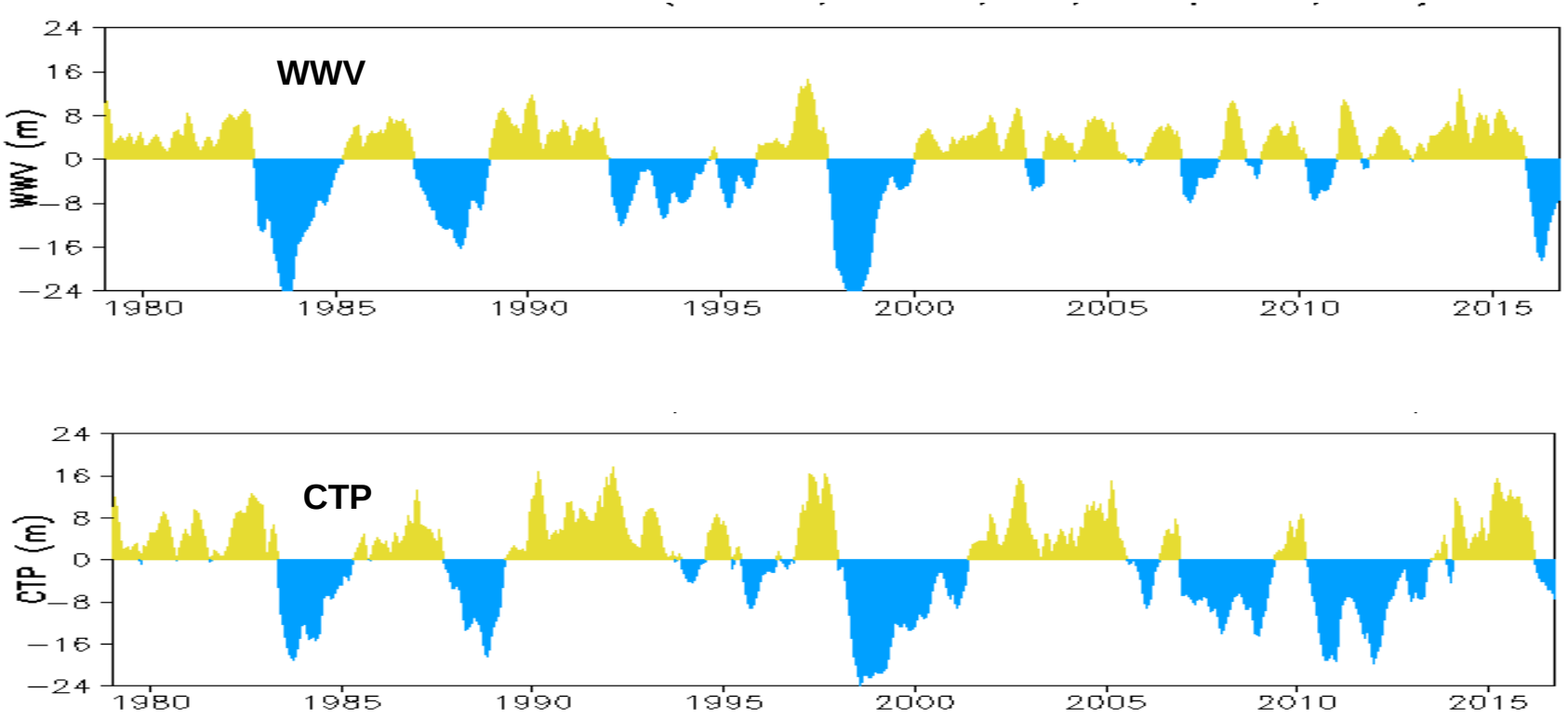
Two ENSO Precursors Based on Thermocline Anomaly



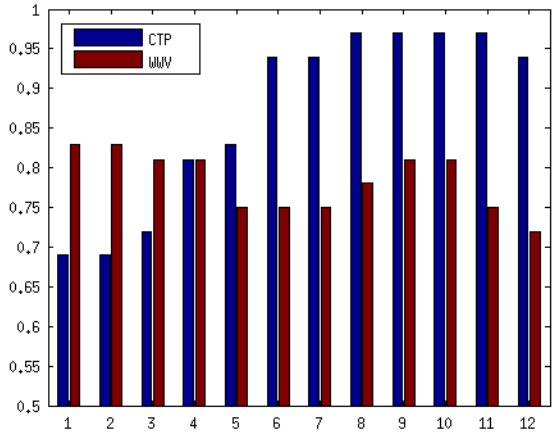
- **Warm Water Volume (WWV) index is defined as average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN]. It is inferred from the slow ocean adjustment via zonal mean heat content exchange between the equatorial and off-equatorial regions.**
- **Central tropical Pacific (CTP) index is defined as average of depth of 20ºC in [160ºW-110ºW, 10ºS-10ºN]. It includes equatorial thermocline variations involving the equatorial wave processes in response to the wind-stress-curl anomalies and off-equatorial thermocline variations related with Subtropical cells (STCs).**

Meinen, C. S., and M. J. McPhaden, 2000: Observations of warm water volume changes in the equatorial Pacific and their relationship to El Niño and La Niña. *J.Climate*, **13,** 3551-3559.

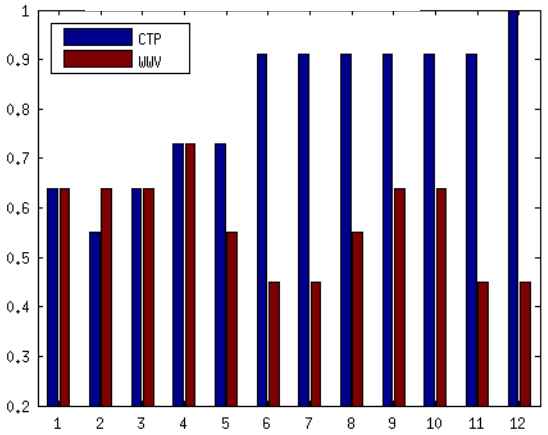
Wen C, Kumar A, Xue Y, McPhaden MJ (2014) Changes in tropical pacific thermocline depth and their relationship to ENSO after 1999. *J Climate* 27:7230–7249

2x2 contingency table for La Nina case

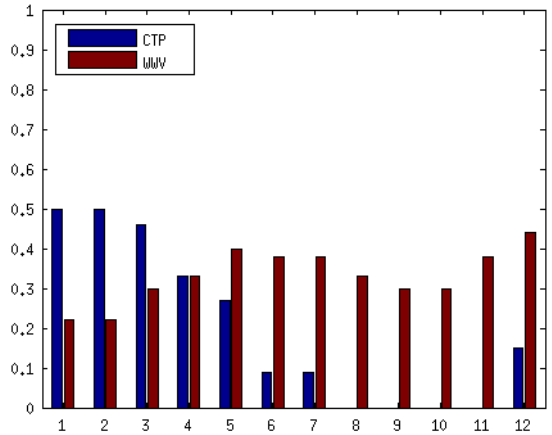
Percent correct

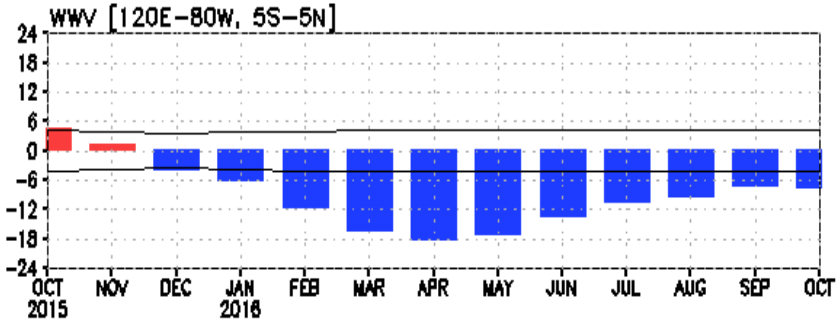


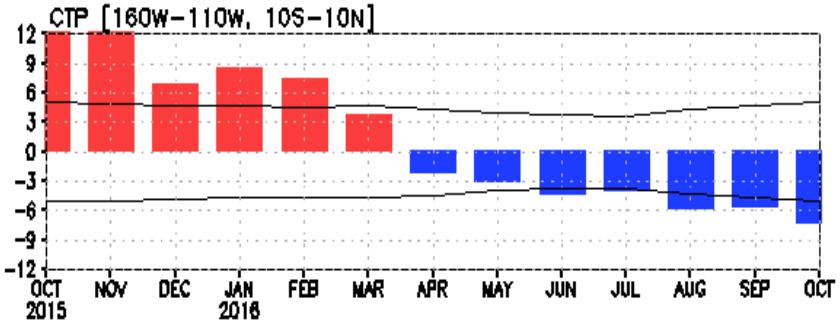
Hit Rate



False Alarm





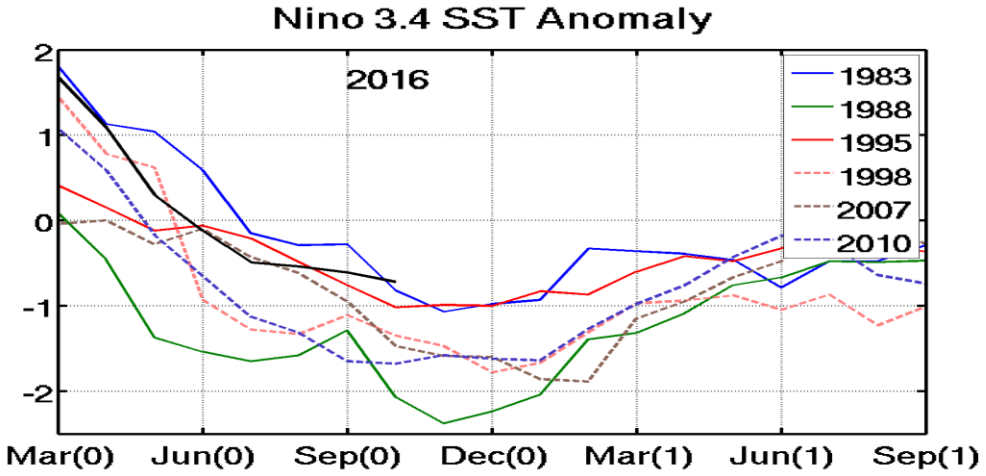


Forecast criterion: 0.5 monthly standard deviation (black lines)

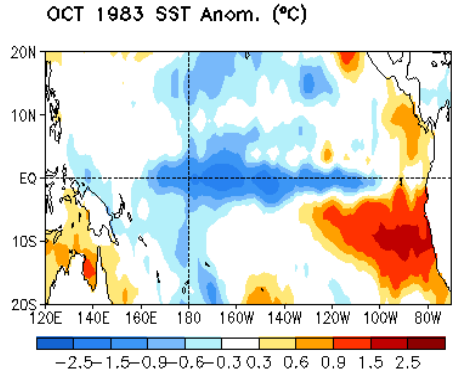
- For forecasting La Nina events (NINO3.4 < -0.5C in DJF), CTP has a very high hit rate (>90%) and low false alarm rate (<10%) after May when CTP is less than -0.5 STD, which beats WWV by a large margin.

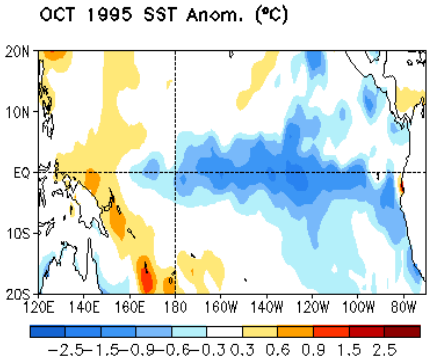
- CTP has been persistently lower than -0.5 STD since June 2016, indicating a high probability of La Nina conditions during winter 2016/17.

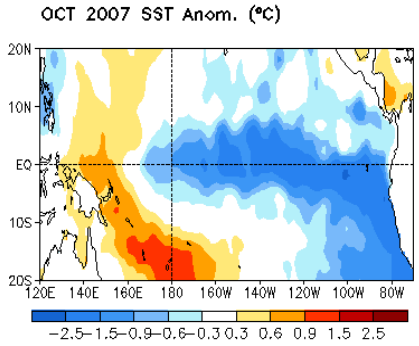
SST,D20 and 925hp Wind anomalies in October

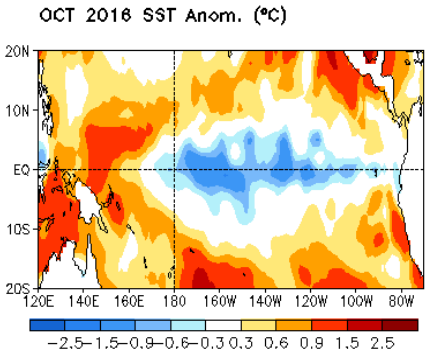


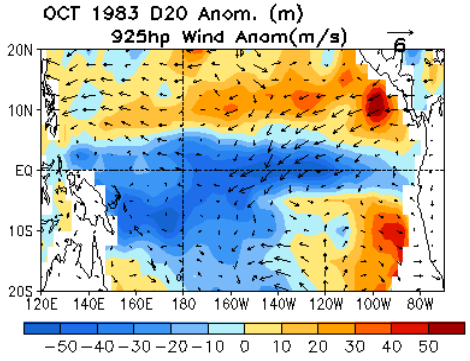
1983 1995 2007 2016

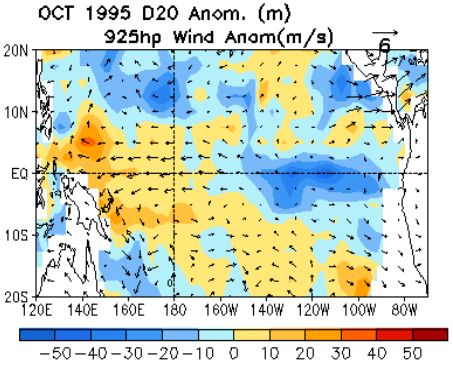


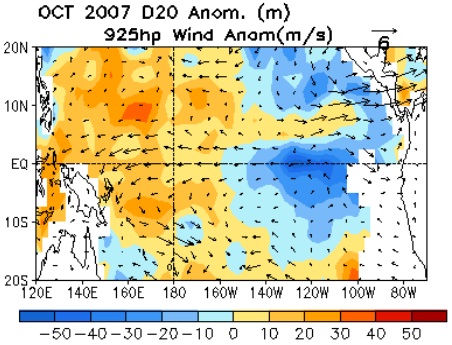


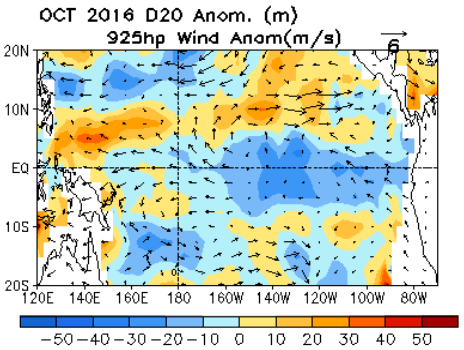




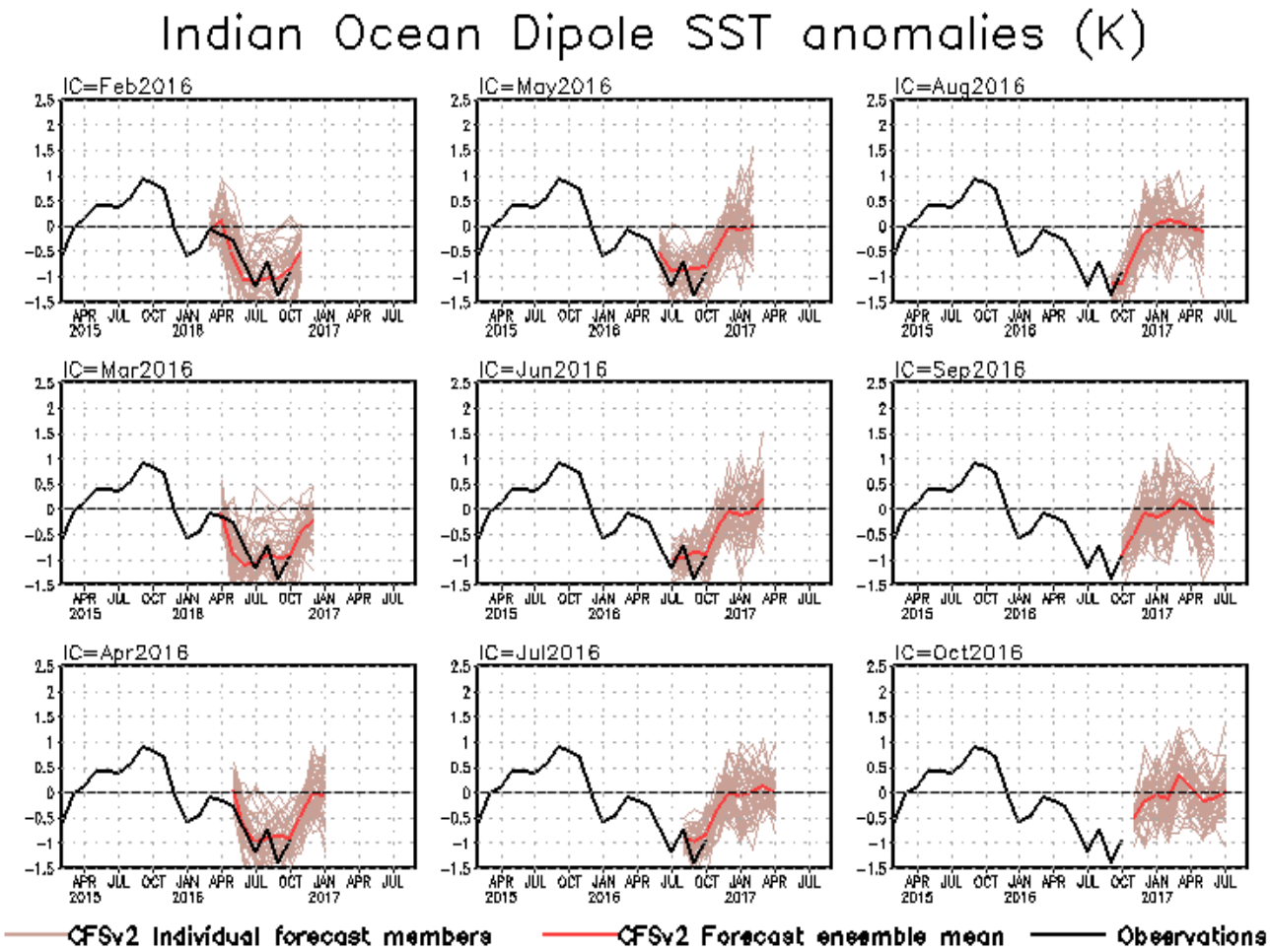








CFSv2 DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

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

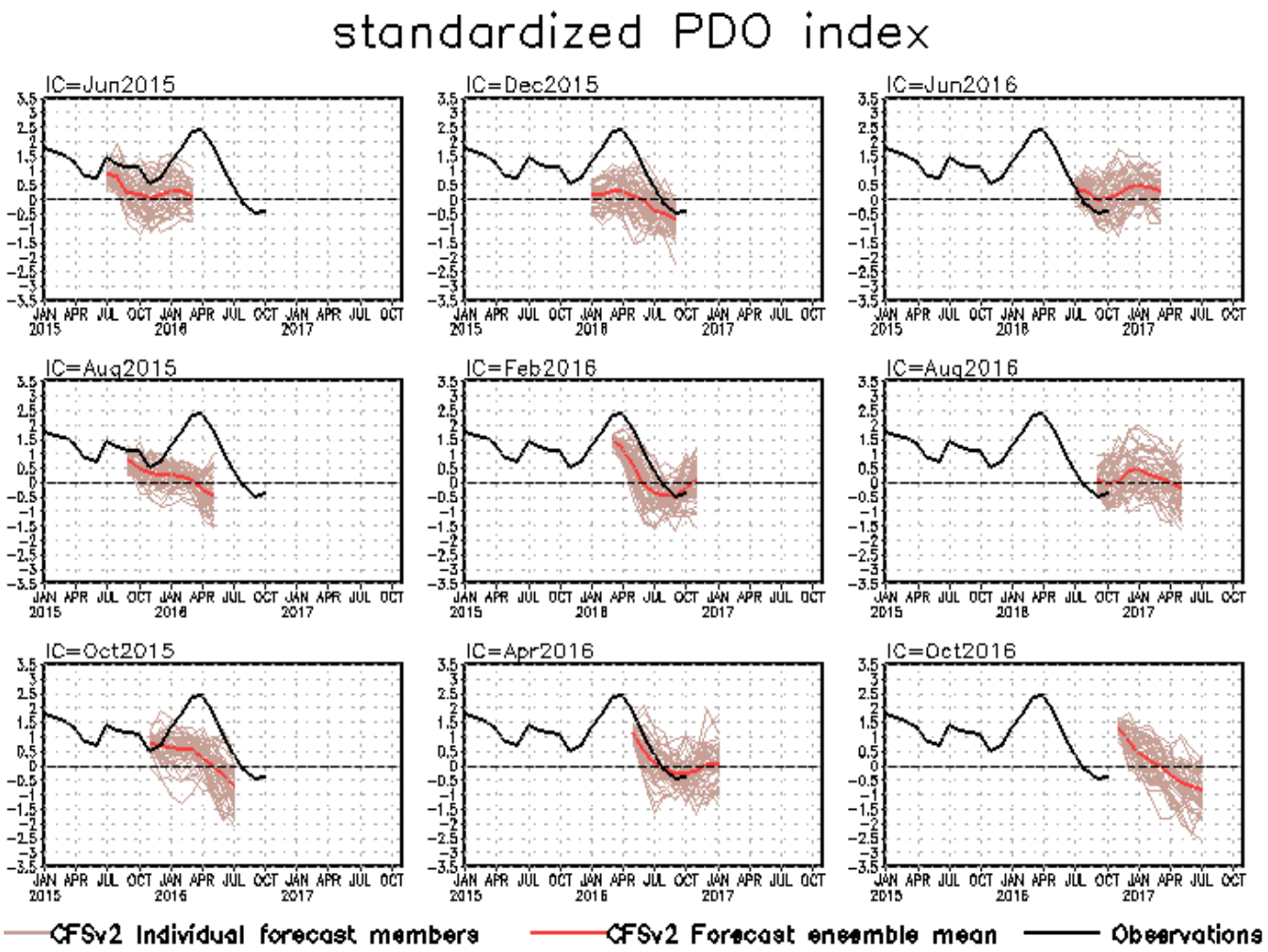
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

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

- Latest CFSv2 forecasts DMI will return to neutral in winter 2016.

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

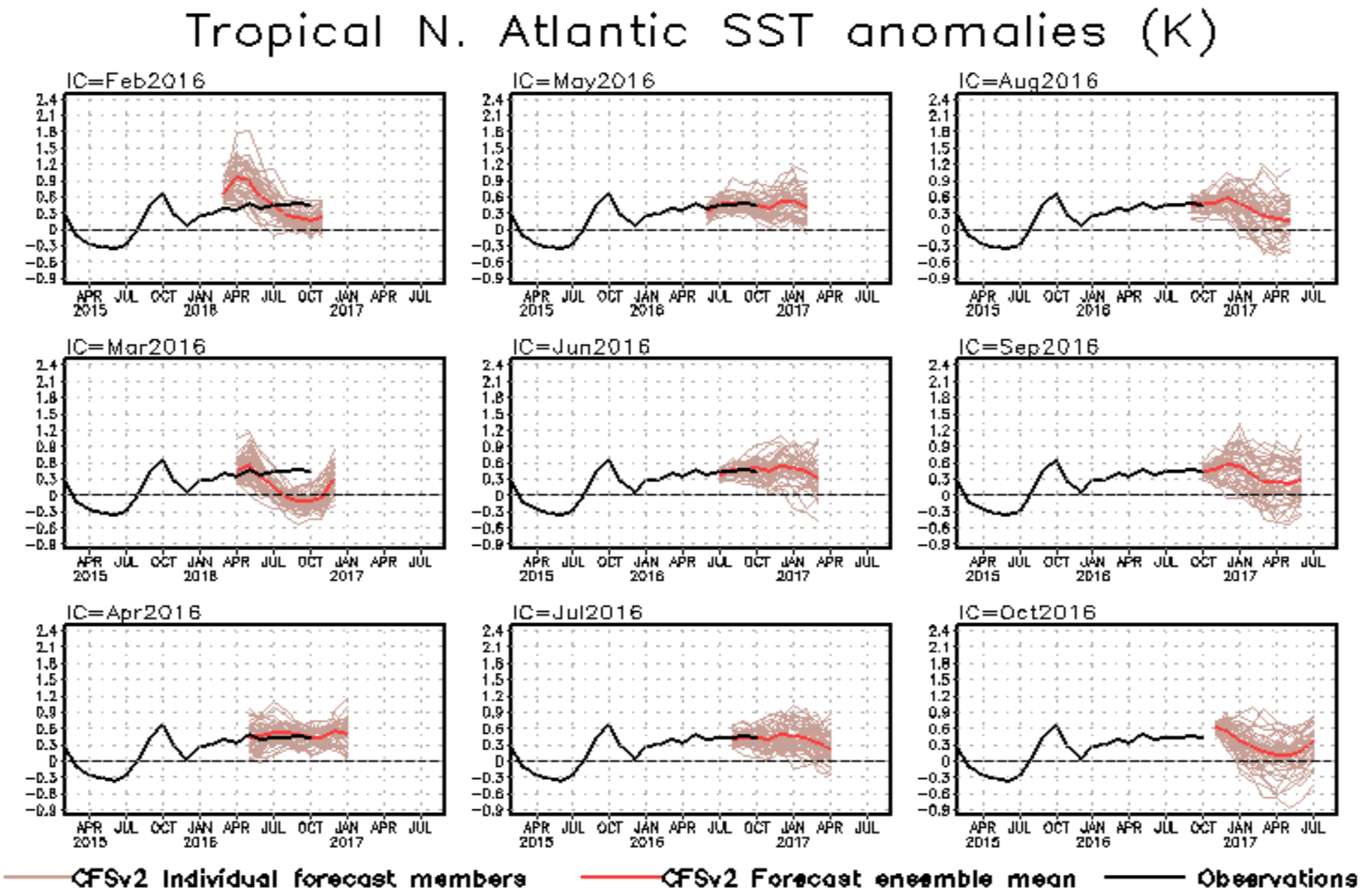


- CFSv2 forecasts PDO will be well above normal in Nov 2016 and return to neutral during winter 2016-17.

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



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

Overview

Pacific Ocean

- Negative SSTA persisted in the central-eastern Pacific with Nino3.4 = -0.7ºC.
- CFSv2 forecast La Nina conditions will continue through the Northern Hemisphere fall and winter 2016-17.
- SST warming weakened in the N. E Pacific (Pacific 'Blob').
- Negative PDO continued, with PDO = -0.4 in Oct 2016.
- Arctic sea ice extent in October hit the historical low in the Satellite record.

Indian Ocean

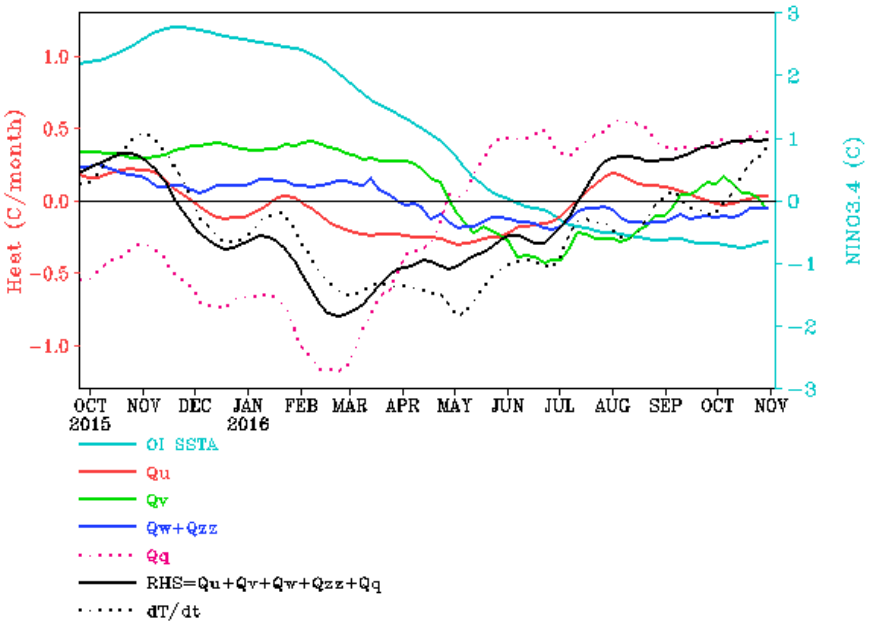
- Dipole Mode Index continued to be well-below average.
- SST warming persisted in the eastern Indian Ocean.

Atlantic Ocean

- Positive NAO increased slightly in Oct 2016, with NAOI =+1.
- SSTA were well above-average along the eastern coast of North America.

Backup Slides

NINO3.4 Heat Budget



- Observed SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) switched to positive in Oct 2016.

-Dynamical terms (Qv, Qw+Qzz, Qu) were near zero in October.

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.

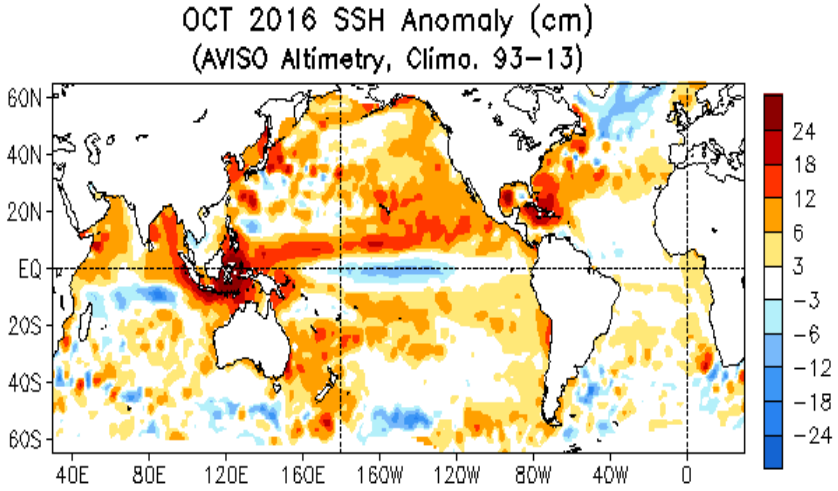
Qu: Zonal advection; Qv: Meridional advection;

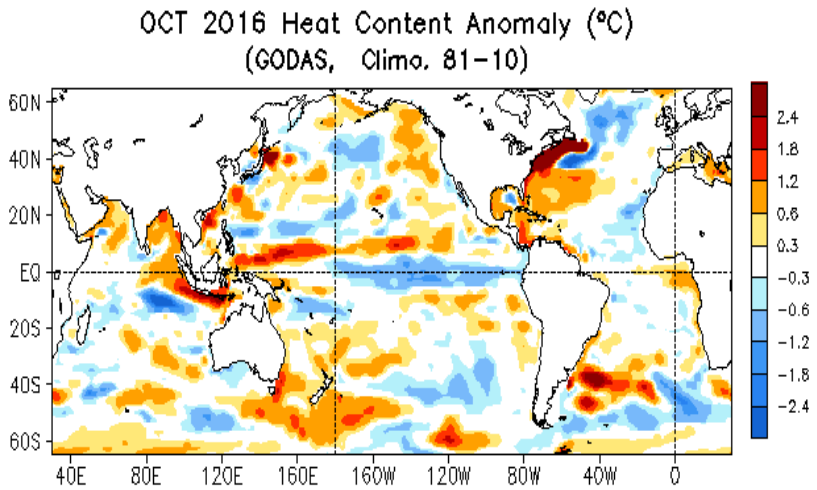
Qw: Vertical entrainment; Qzz: Vertical diffusion

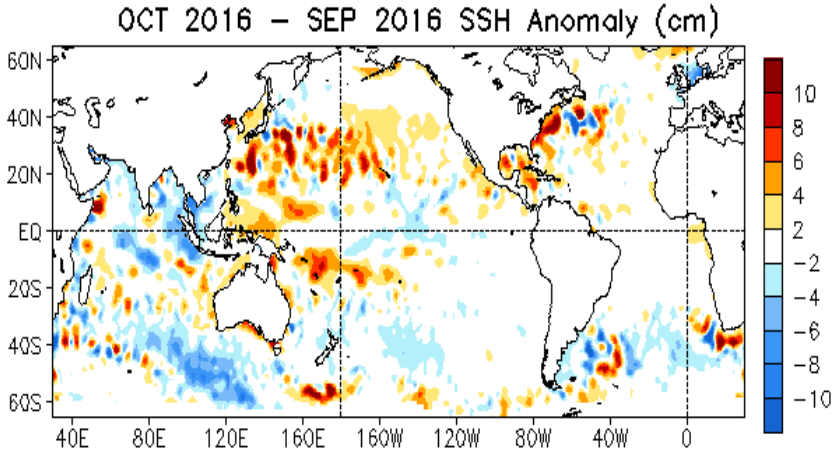
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

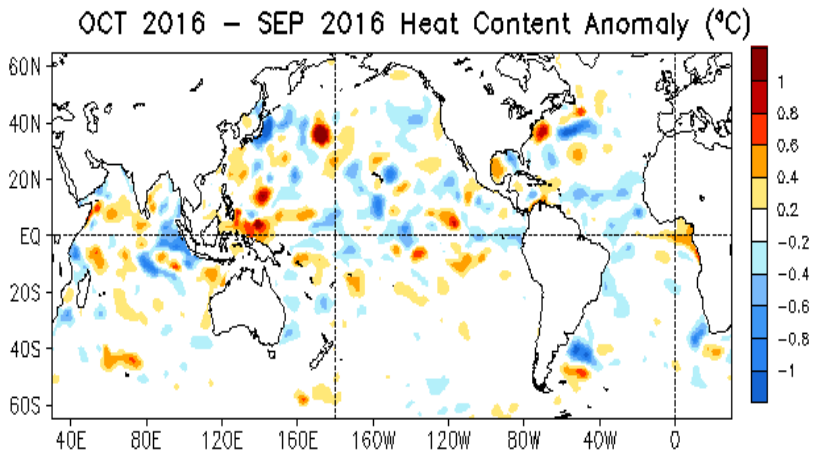
Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

Global SSH and HC300 Anomaly & Anomaly Tendency









- **The SSHA was overall consistent with HC300A: Positive (negative) HC300A is tied up with positive (negative) SSHA.**
- **Both SSHA and HC300A were negative along the equatorial Pacific.**
- **Negative SSHA and H300A tendency dominated in the C.-E. Pacific.**

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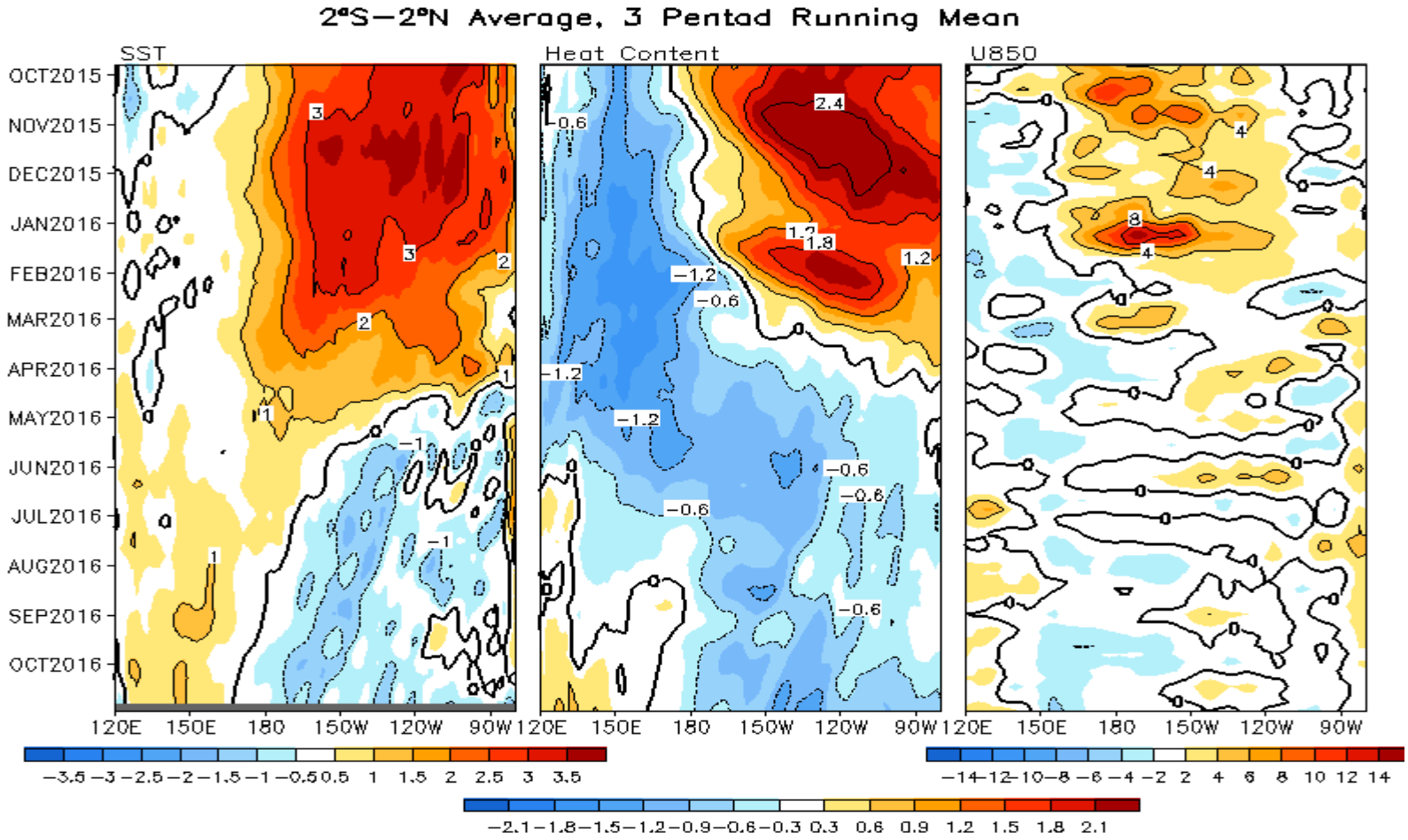
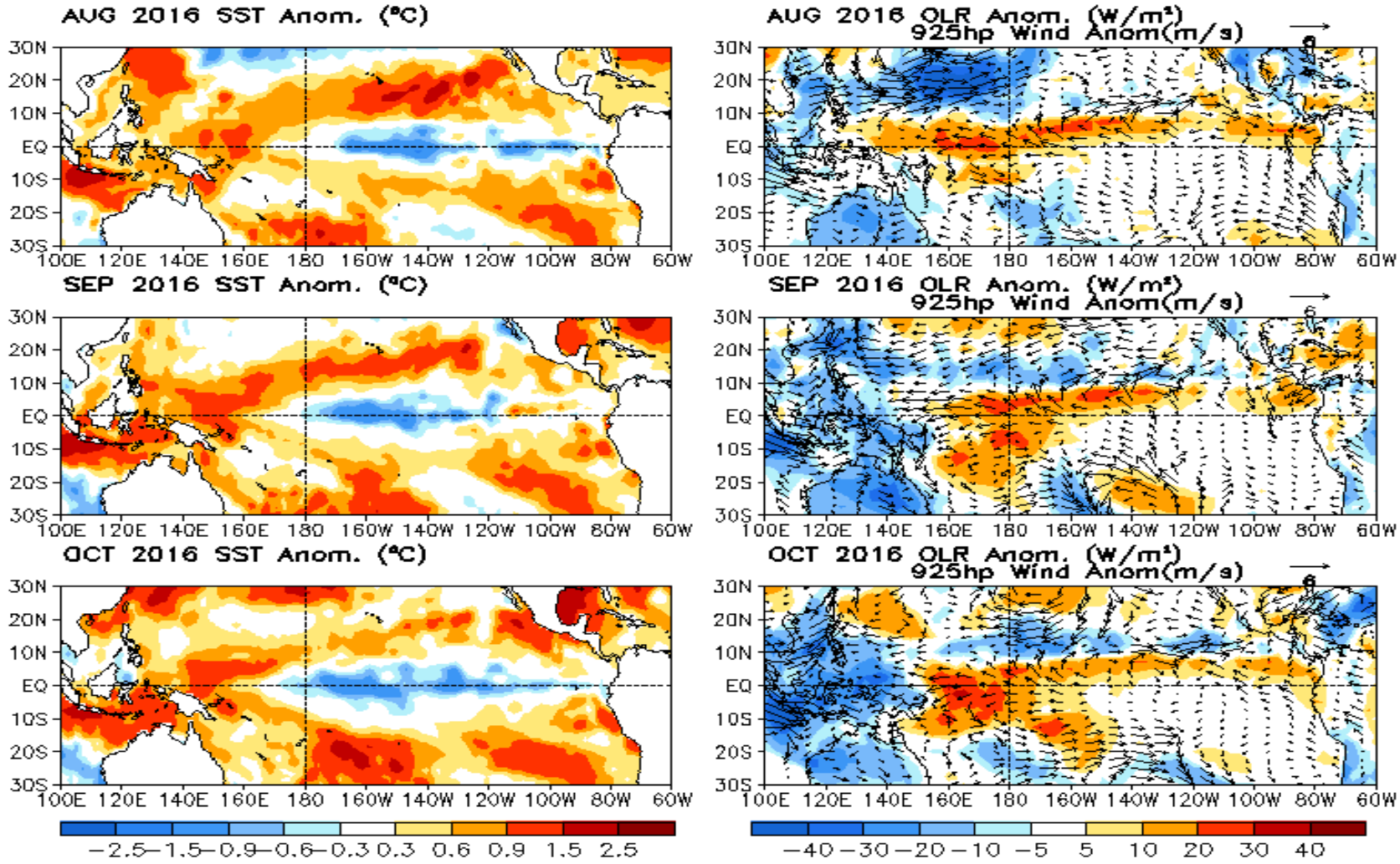
Equatorial Pacific SST (ºC), HC300 (ºC), U850 (m/s) Anomalies



- Negative SSTA persisted in the C-E. Pacific.
- Negative SSTA reemerged in the far E. Pacific in Oct 2016
- Negative H300 anomalies have strengthened slightly near [150W-120W] in Oct 2016.
- Easterly wind anomalies enhanced slightly west of Dateline.

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

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

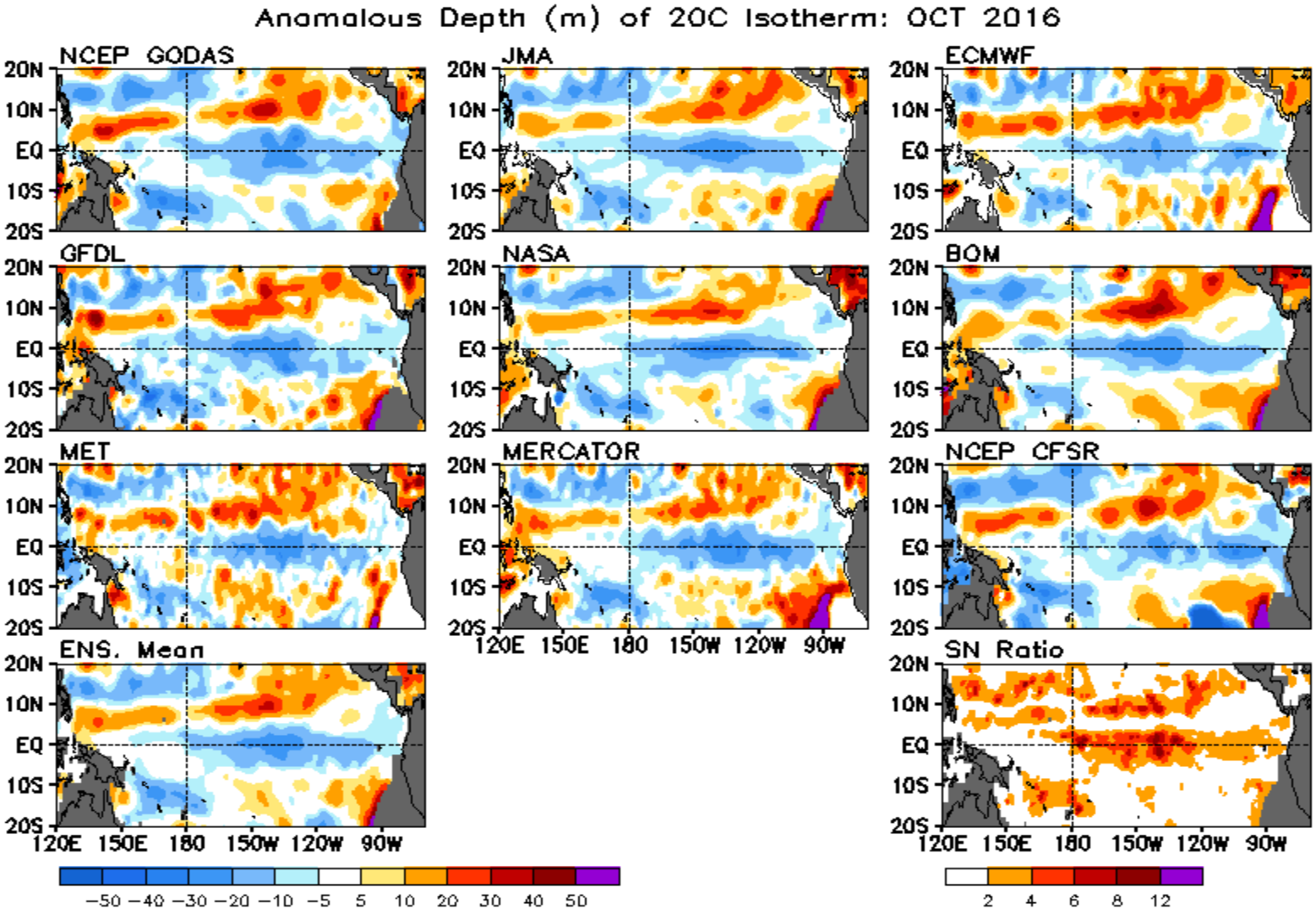


- **Negative SSTA enhanced slightly and extended westward gradually in the past three months.**
- **Positive SSTA and D20A persisted in the N.E tropical Pacific.**
- **Surface easterly wind anomalies persisted in the western Pacific, consistent with enhanced convection over the Maritime Continent and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

Real-Time Ocean Reanalysis Intercomparison: D20

Climatology : 1993-2013

(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)



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

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

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

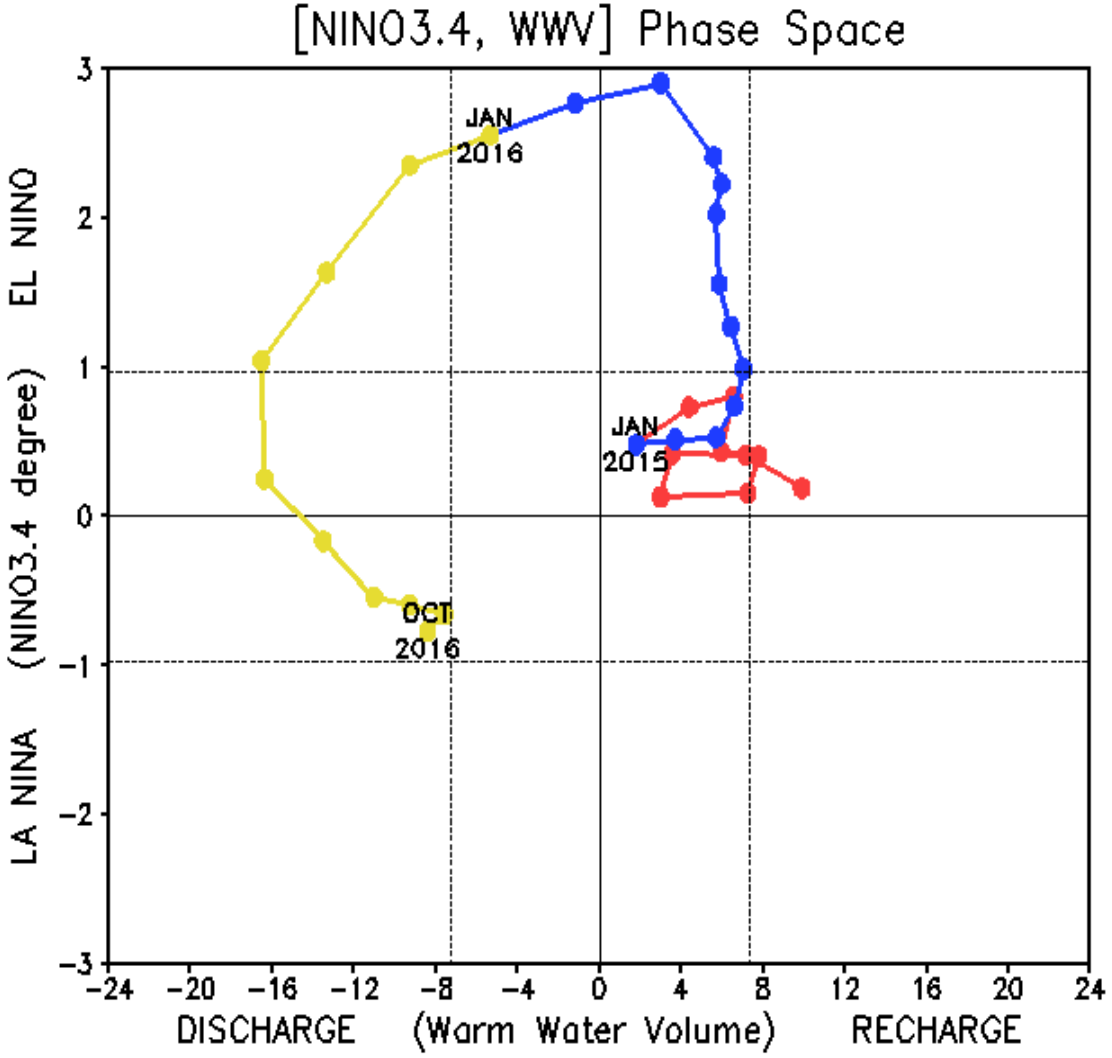


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

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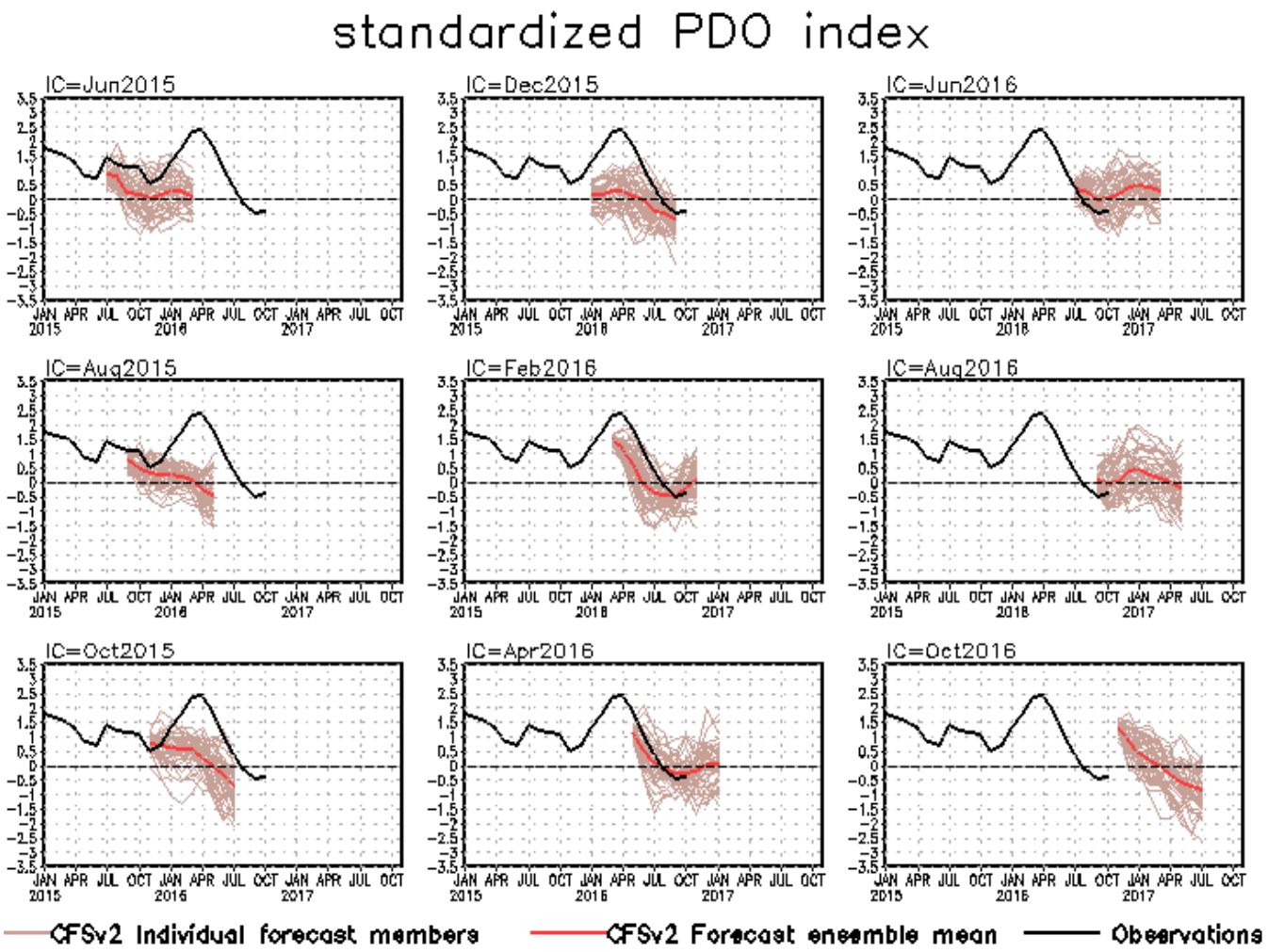
PDO Forecast by NCEP CFSv2

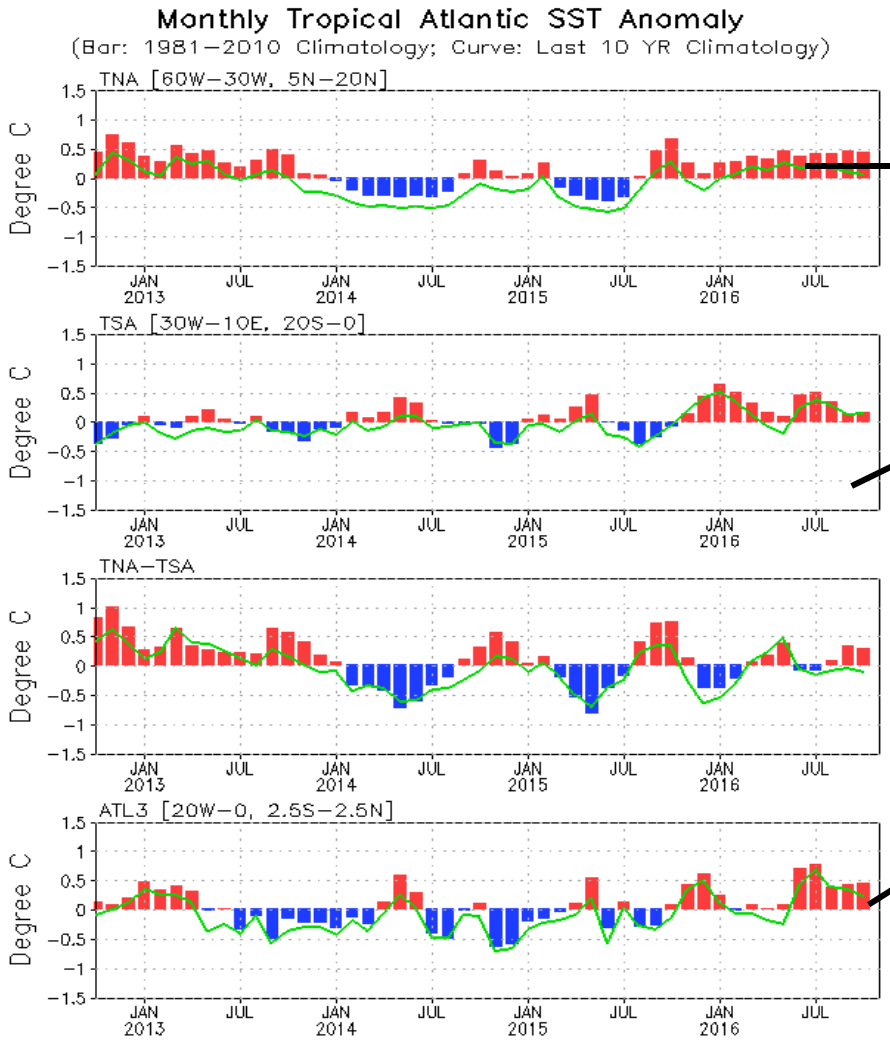


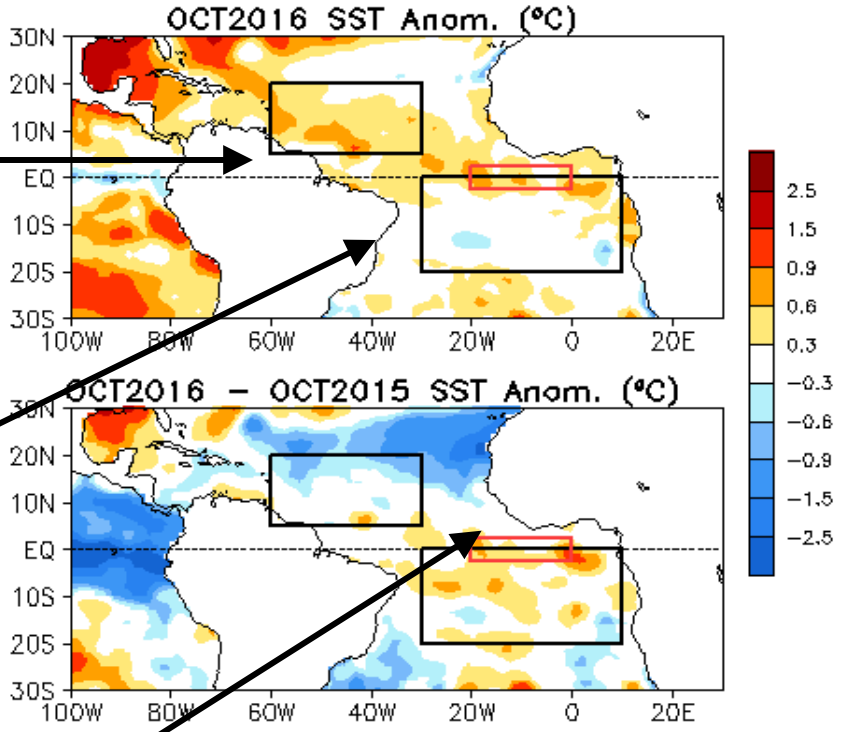
- CFSv2 forecasts PDO will be well above normal in Nov 2016 and return to neutral during winter 2016-17.

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.

Evolution of Tropical Atlantic SST Indices





- ATL3 index continued to be above-average in Oct 2016.

- SSTA in the TNA has been above-normal since Aug 2015.

- Positive Meridional Gradient Mode index continued in Oct 2016.

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.

Global Sea Surface Salinity (SSS)

Anomaly for October 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 in neutral condition in this month with no significant salinity changes along the Equator. Large scale of SSS decreasing was observed in the east basin of North Pacific subtropics and west basin of South Pacific subtropics. The SSS decrease in the South Pacific subtropics extends northwestward to the east basin of Indian ocean. However, there are no significant freshwater flux increase in both the east of N. Pacific subtropics and west of S. Pacific subtropics. Large scale freshening in the subarctic regions of both North Pacific and North Atlantic ocean was also observed con-incident with increasing of precipitation.

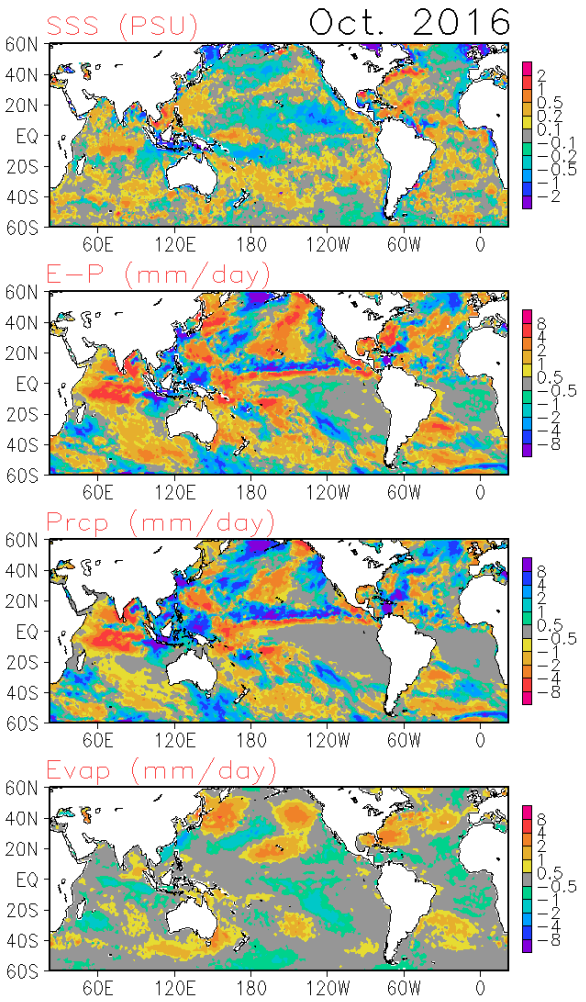
- **Data used**

  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

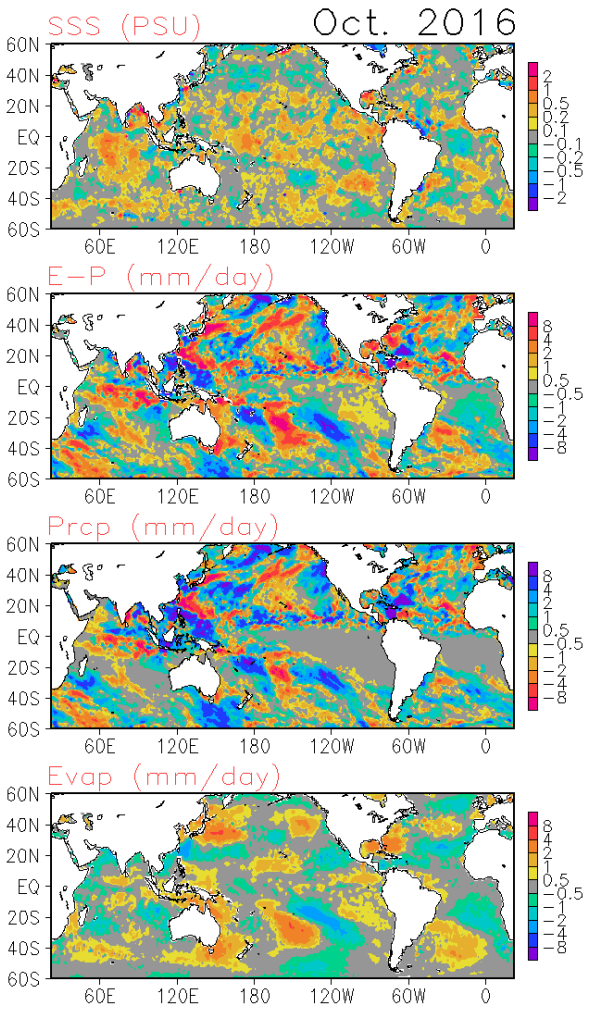
  Evaporation: CFS Reanalysis



Global Sea Surface Salinity (SSS)

Tendency for October 2016

Compared with last month, there are large area of SSS increasing in the Pacific ocean, except the subarctic North Pacific ocean. The salinity in the Bay of Bengal increased with increasing precipitation in the north/central regions and decreasing precipitation in the south region. The SSS in the Indian Ocean south of Equator within the longitude band of 60°E to 100°E was significantly increased. However, a strong reduction of freshwater flux into the ocean was identified, mainly due to the decrease of precipitation. Significant increase of precipitation was observed in the Caribbean sea and adjacent islands likely due to the hurricane Matthew but no significant SSS change was found in these areas.

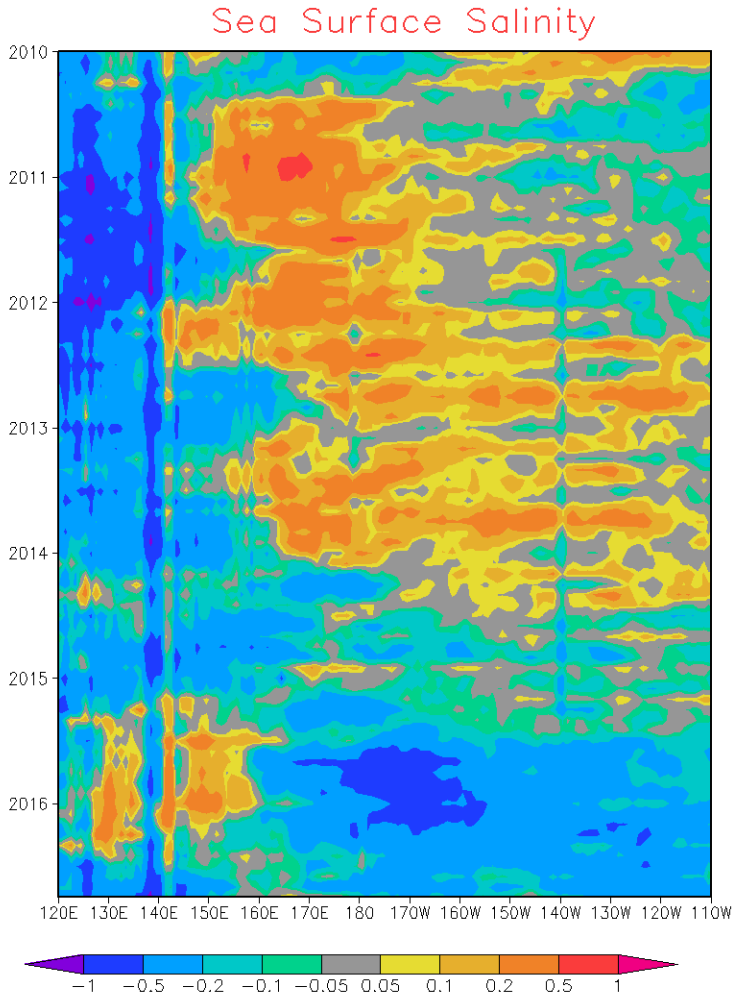


Global Sea Surface Salinity (SSS)

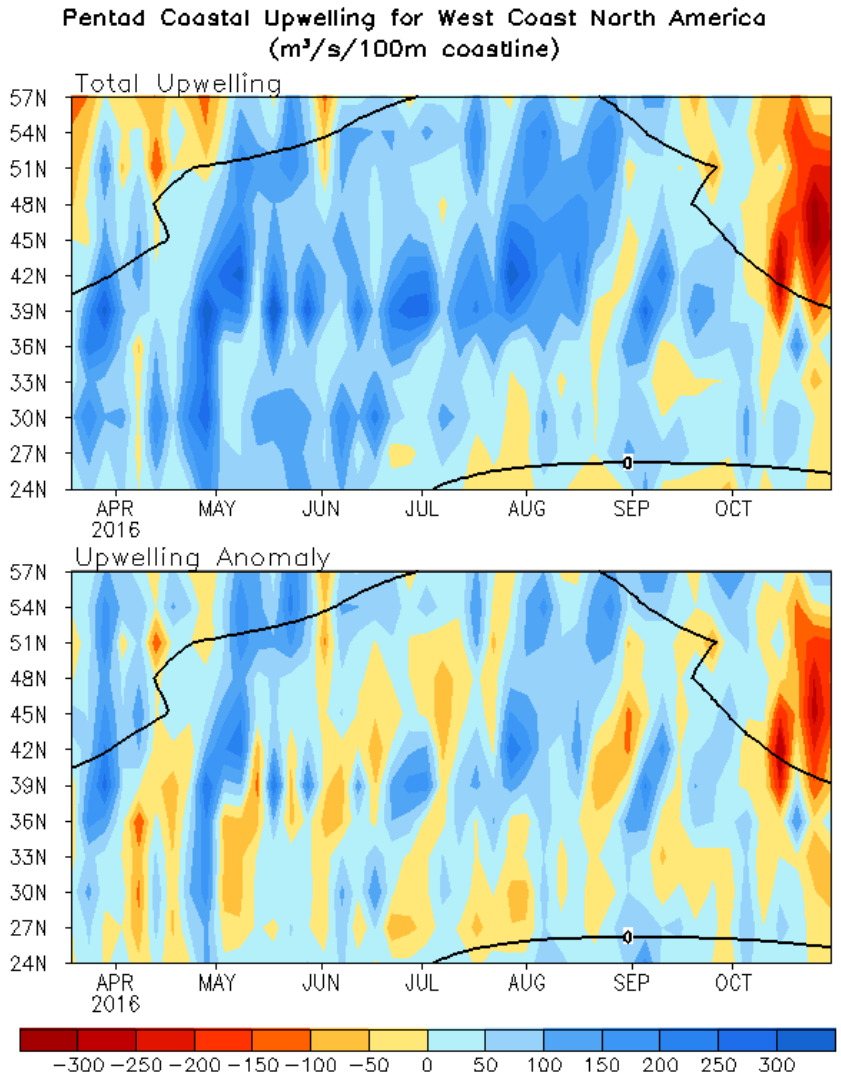
Anomaly Evolution over Equatorial Pacific

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

- The anomaly evolution in this region shows similar pattern as last month. The negative SSS in the Eastern Equatorial Pacific from 160ºE to 110ºW is continuing in its neutral condition. At the meantime, the positive SSS anomaly over the western Pacific from 130ºE – 160ºE is continuing in its negative phase.



North America Western Coastal Upwelling



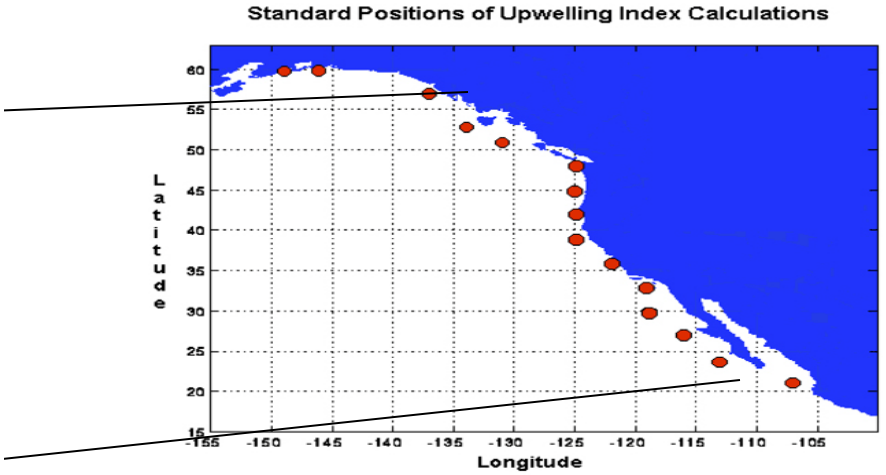


Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point (m³/s/100m coastline). Anomalies are departures from the 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 36ºN to 57ºN.**

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

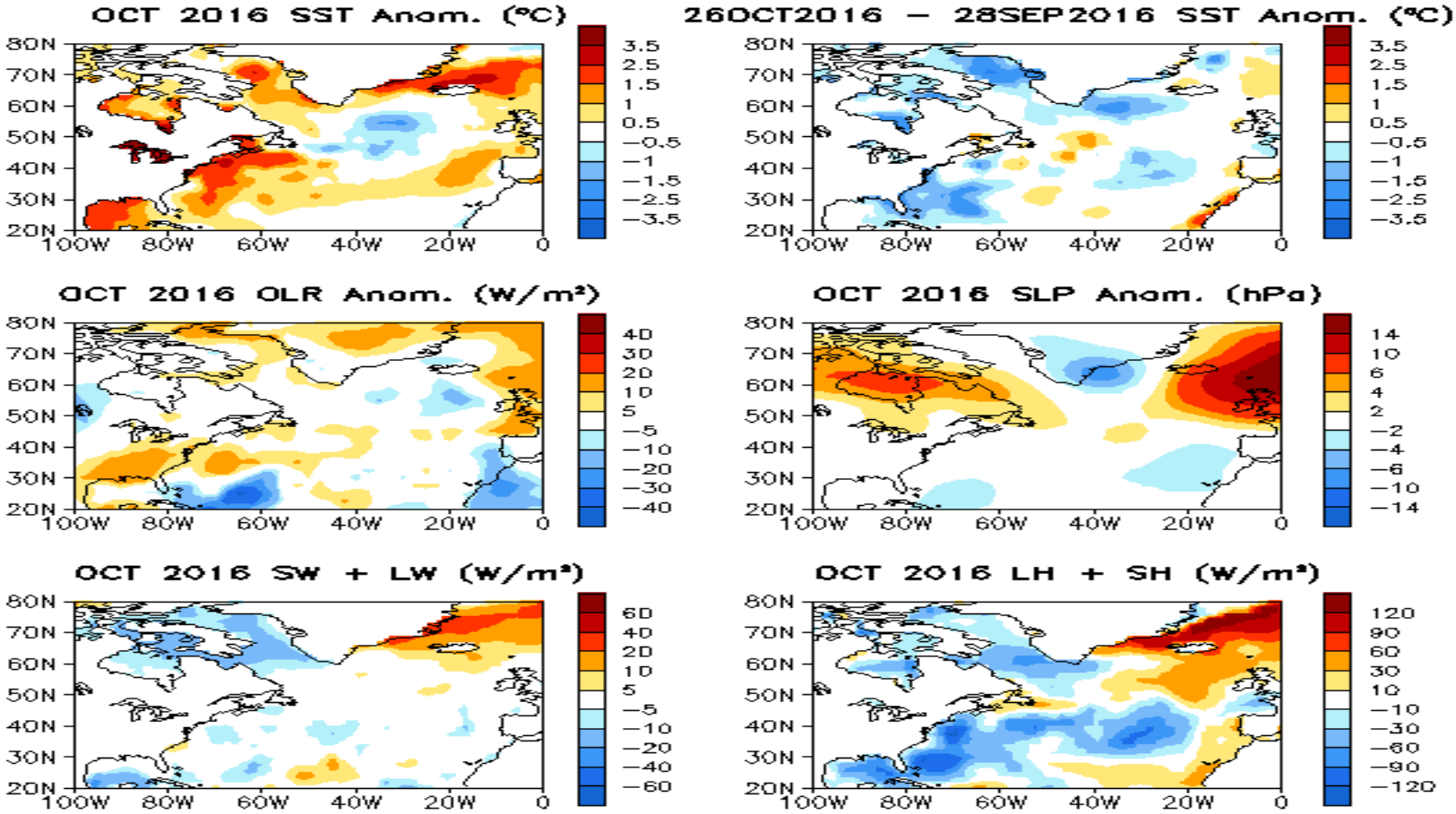
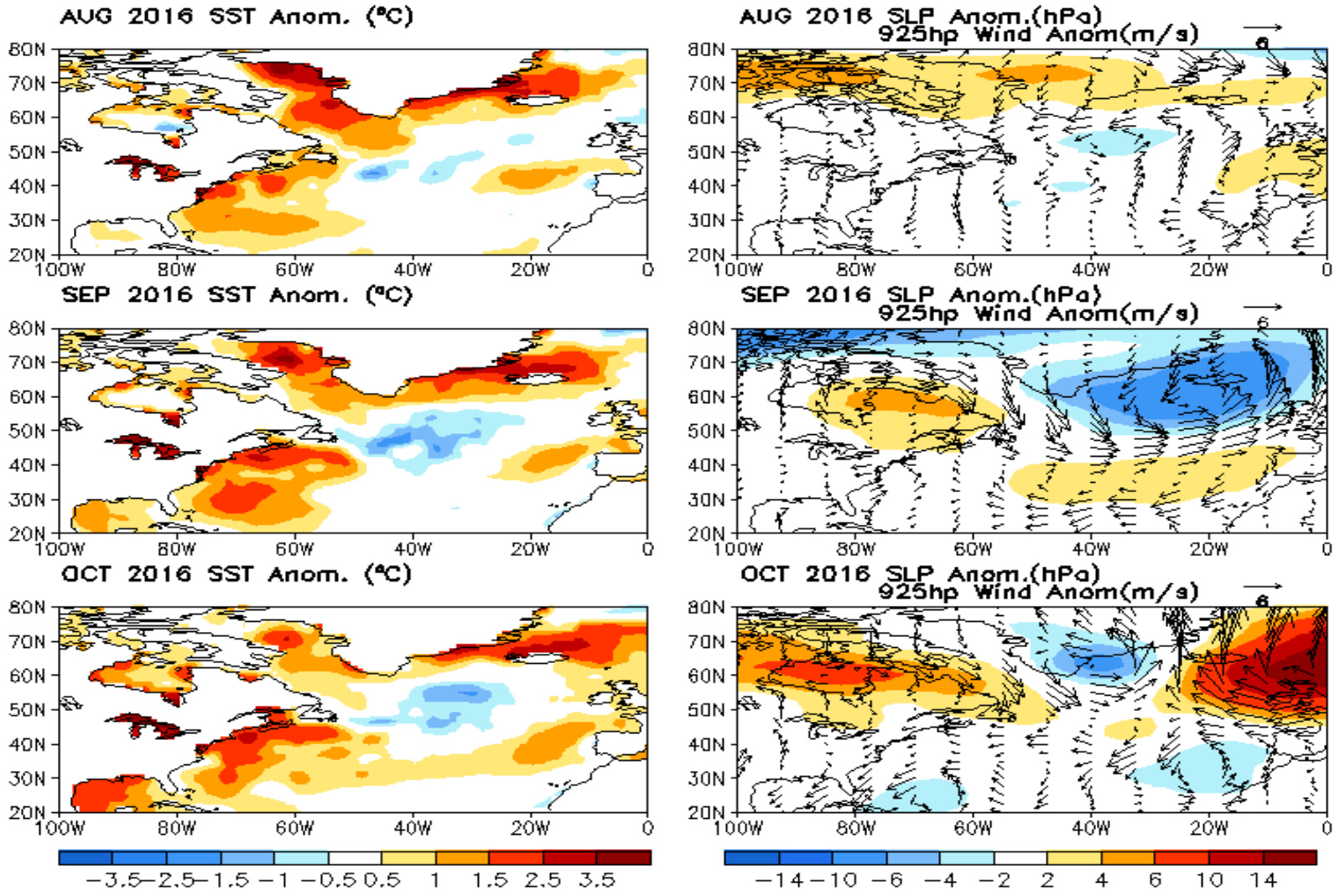


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

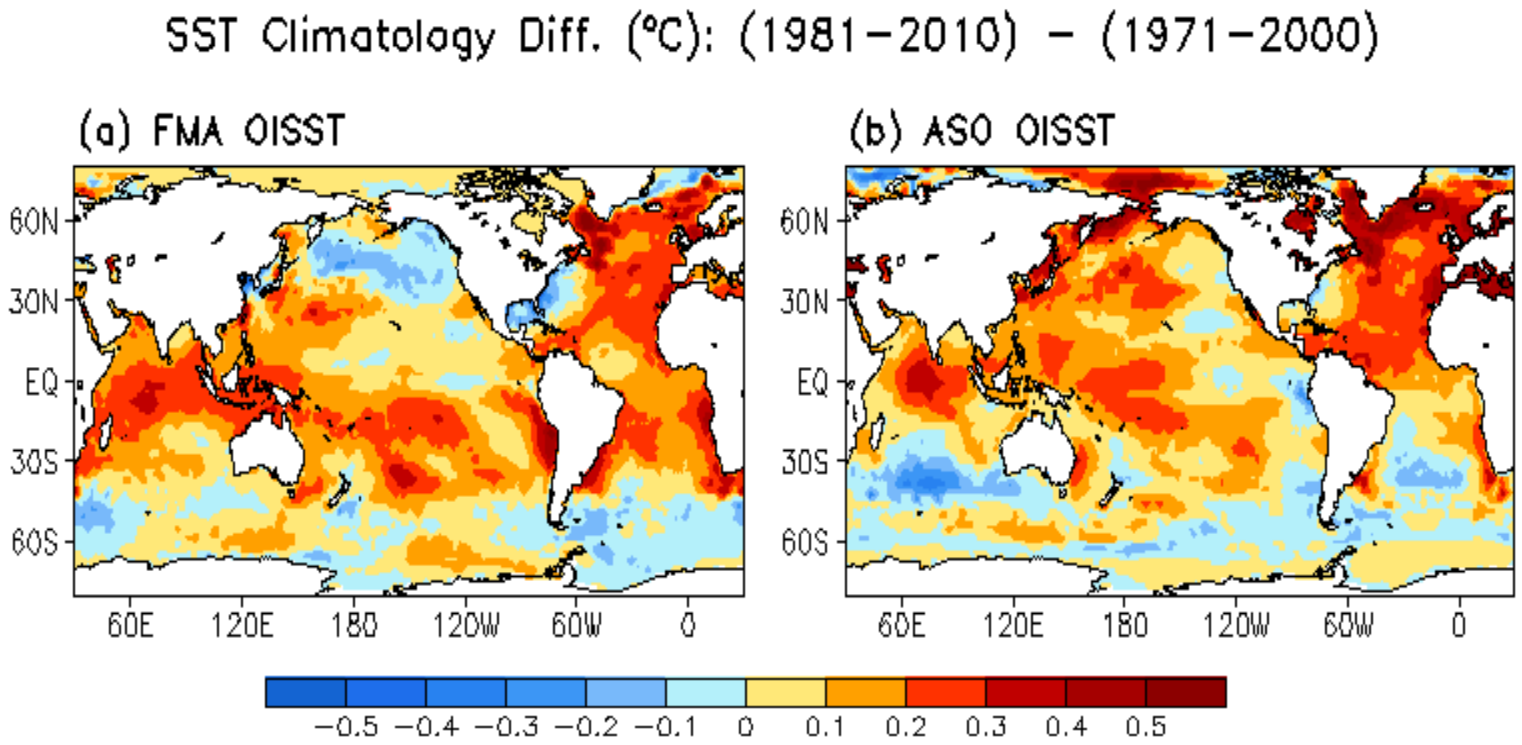
Last Three Month SST, SLP and 925hp Wind Anom.



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)**

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



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

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

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

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

Data Sources and References

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

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