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

Prepared by

Climate Prediction Center, NCEP/NOAA

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http://www.cpc.ncep.noaa.gov/products/GODAS/

This project to deliver real-time ocean monitoring products is implemented by CPC in cooperation with NOAA Ocean Climate Observation Program (OCO)

Outline

- **Overview**
- **Recent highlights**
  - **Pacific/Arctic Ocean**
  - **Indian Ocean**
  - **Atlantic Ocean**
- **Global SST Predictions**

- **Current ENSO status and ENSO forecast**
- **SST PDO index switched from ERSST v3b to ERSST v4**
- **A new PDO index based on HC300 data**

Overview

Pacific Ocean

- La Niña conditions presented in Nov 2016 and the atmospheric and oceanic anomalies reflect a weak La Niña.
- CPC/IRI consensus favors the continuation of weak La Niña conditions through December-February (DJF) 2016-17.
- SST PDO index switched to positive phase , with PDO = 0.9 in Nov 2016.
- Arctic sea ice extent in November hit the historical low in the satellite record.

Indian Ocean

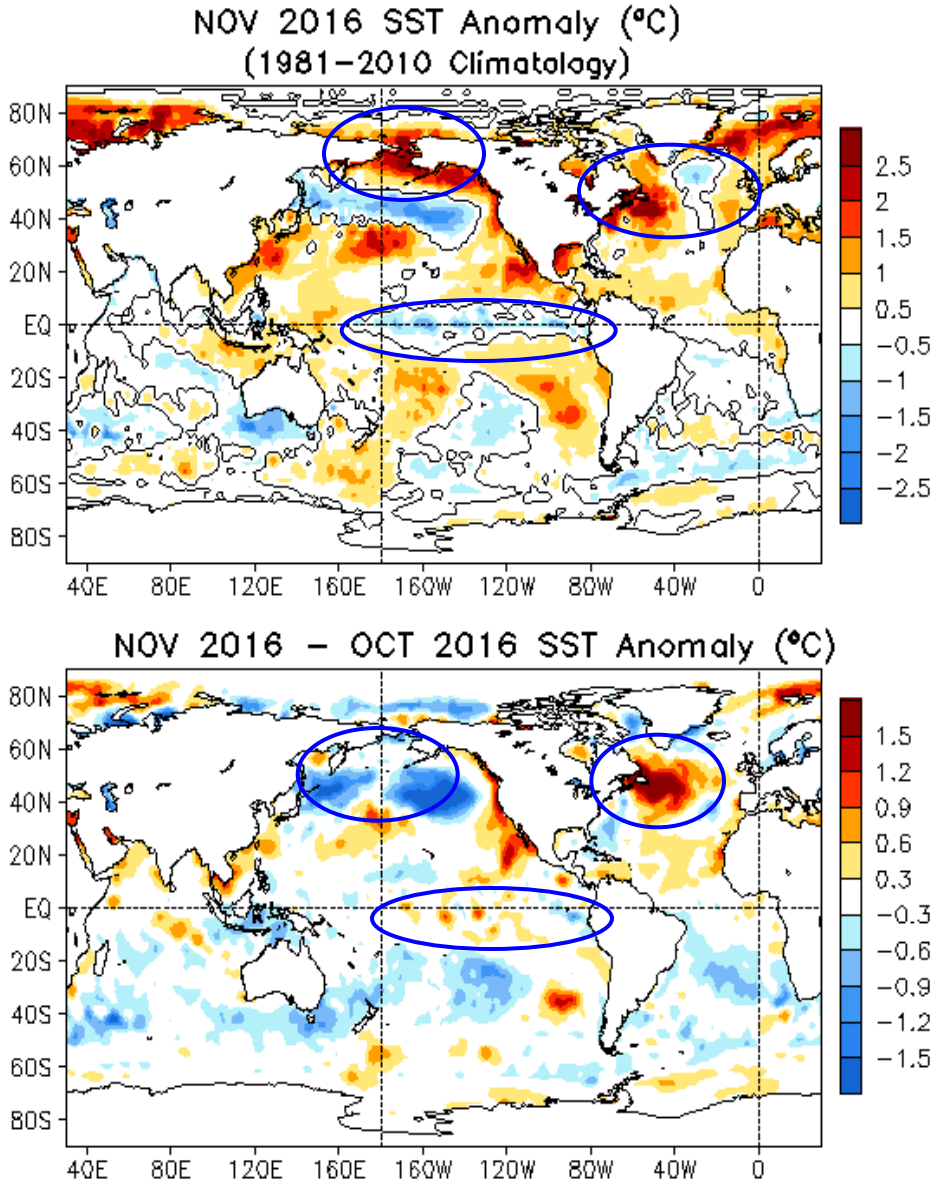
- Dipole Mode Index returned to neutral in Nov 2016.
- SST warming in the eastern Indian Ocean weakened in Nov 2016.

Atlantic Ocean

- NAO switched to negative phase in Nov 2016.
- Strong positive SSTA continued 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 persisted in the high-latitude N. Pacific and Artic Oceans.

- **Positive SSTA continued in the E. coast of N. America and subpolar north Atlantic.**

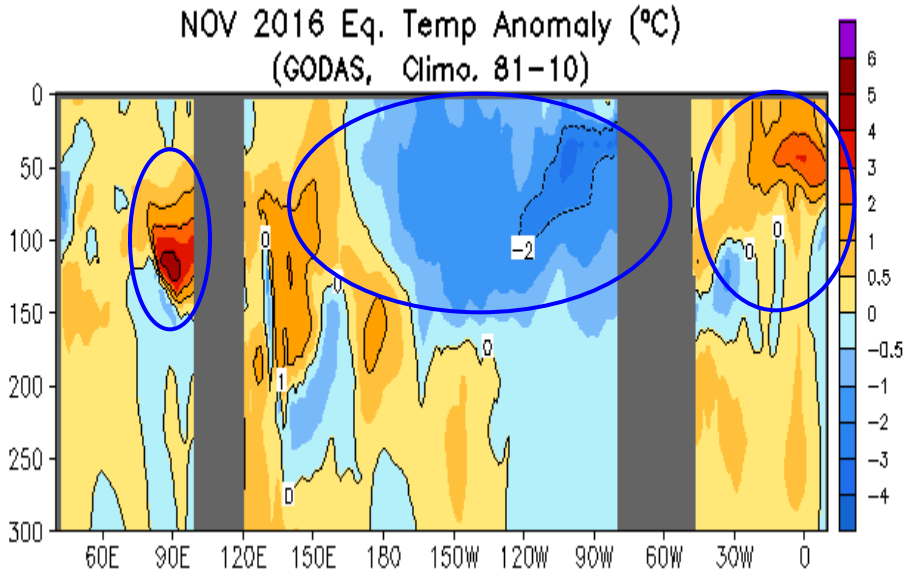
- **Negative SSTA tendency presented in the mid-latitude of N. Pacific.**

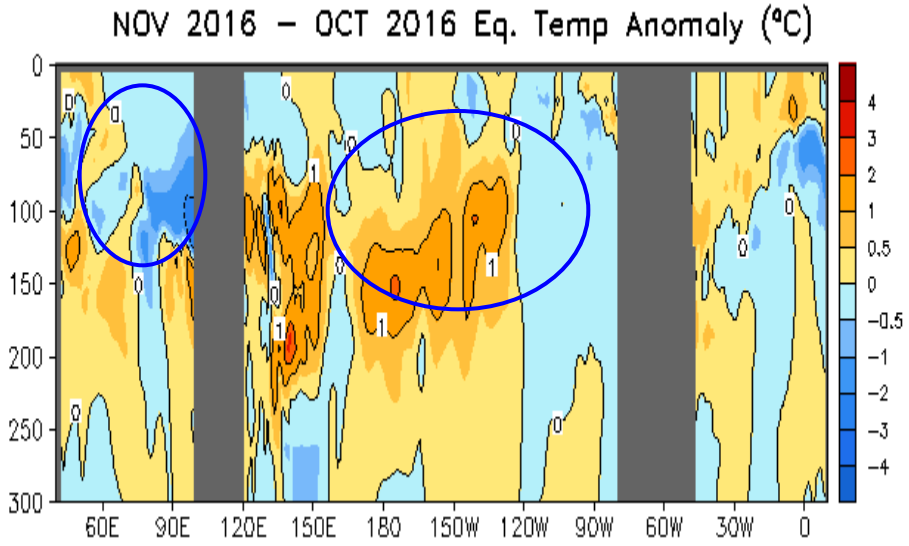
- **Positive SSTA tendency dominated in high-latitude of N. Atlantic Ocean.**

- **Positive (negative) SSTA tendencies presented in the C-E Pacific (far E. 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 (positive) temperature anomalies presented in the C-E. Pacific (W. Pacific) Ocean.**
- **Positive temperature anomalies persisted in the eastern Indian Ocean.**
- **Positive temperature anomalies occupied in the Atlantic Ocean.**

- **Positive temperature anomaly tendency dominated the W-C. Pacific near the thermocline.**
- **Negative temperature anomaly tendency dominated in the upper 100m of the Indian Ocean.**

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

Tropical Pacific Ocean and ENSO Conditions

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

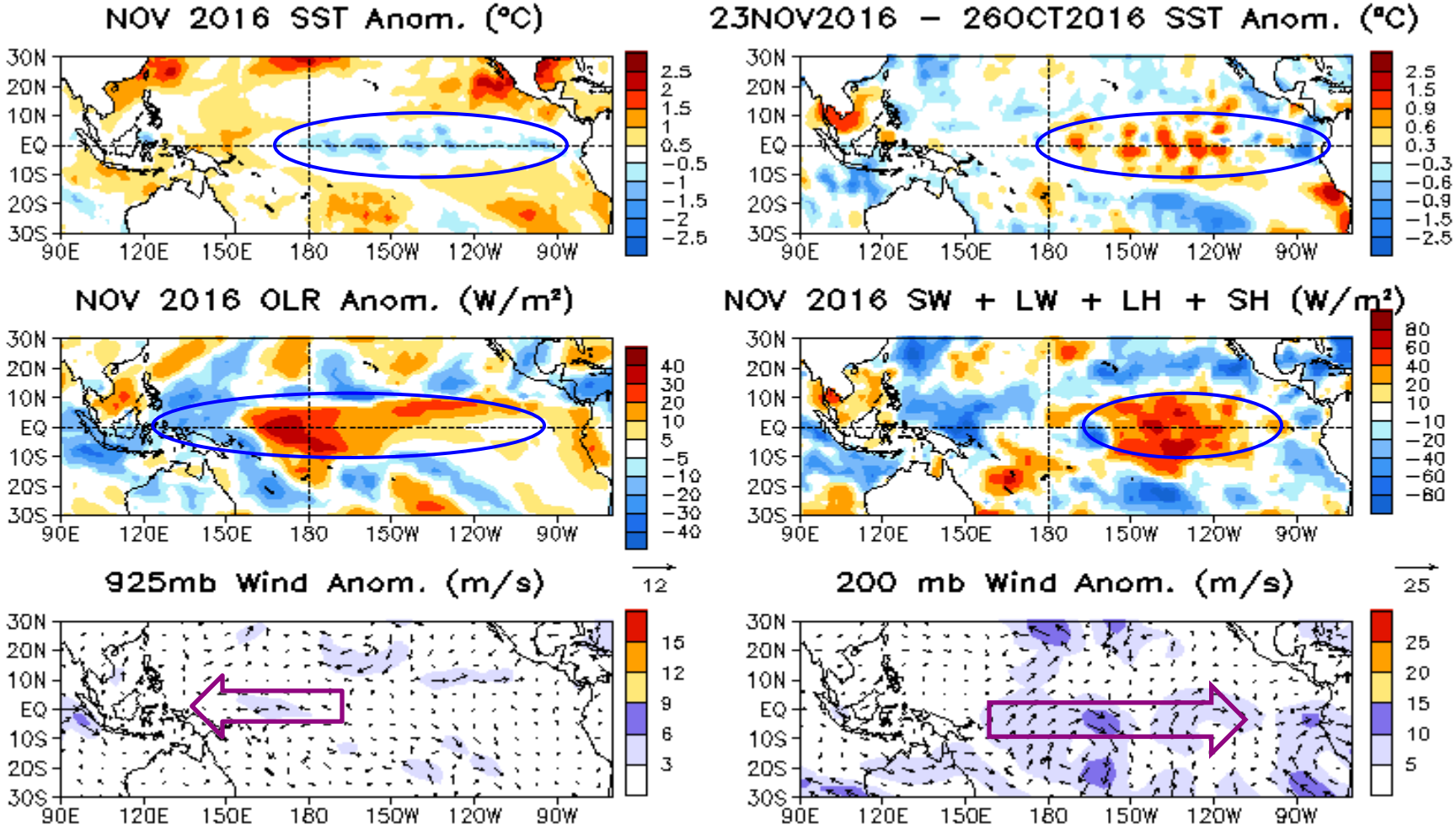


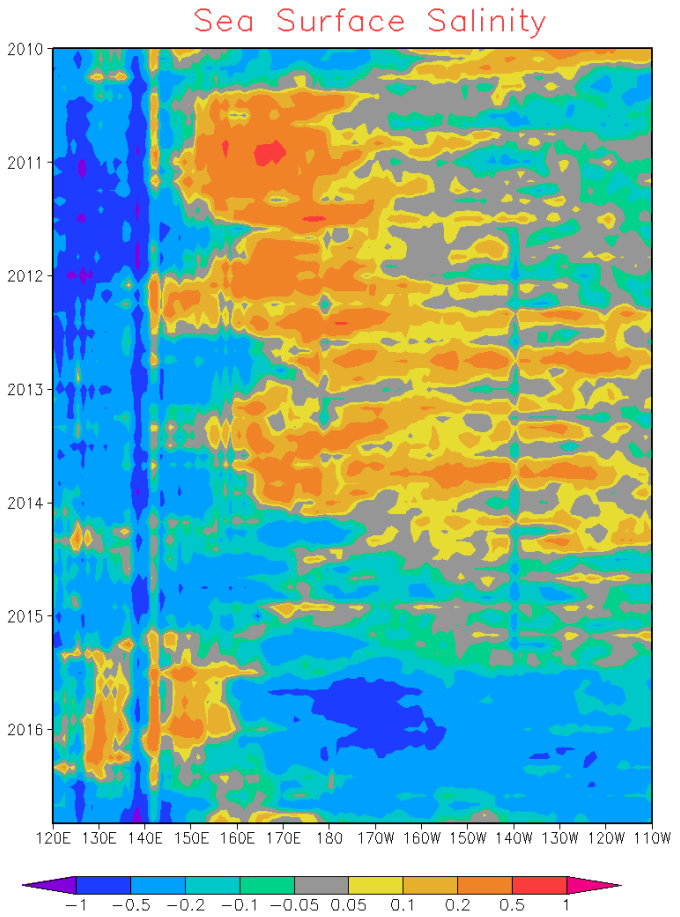
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific

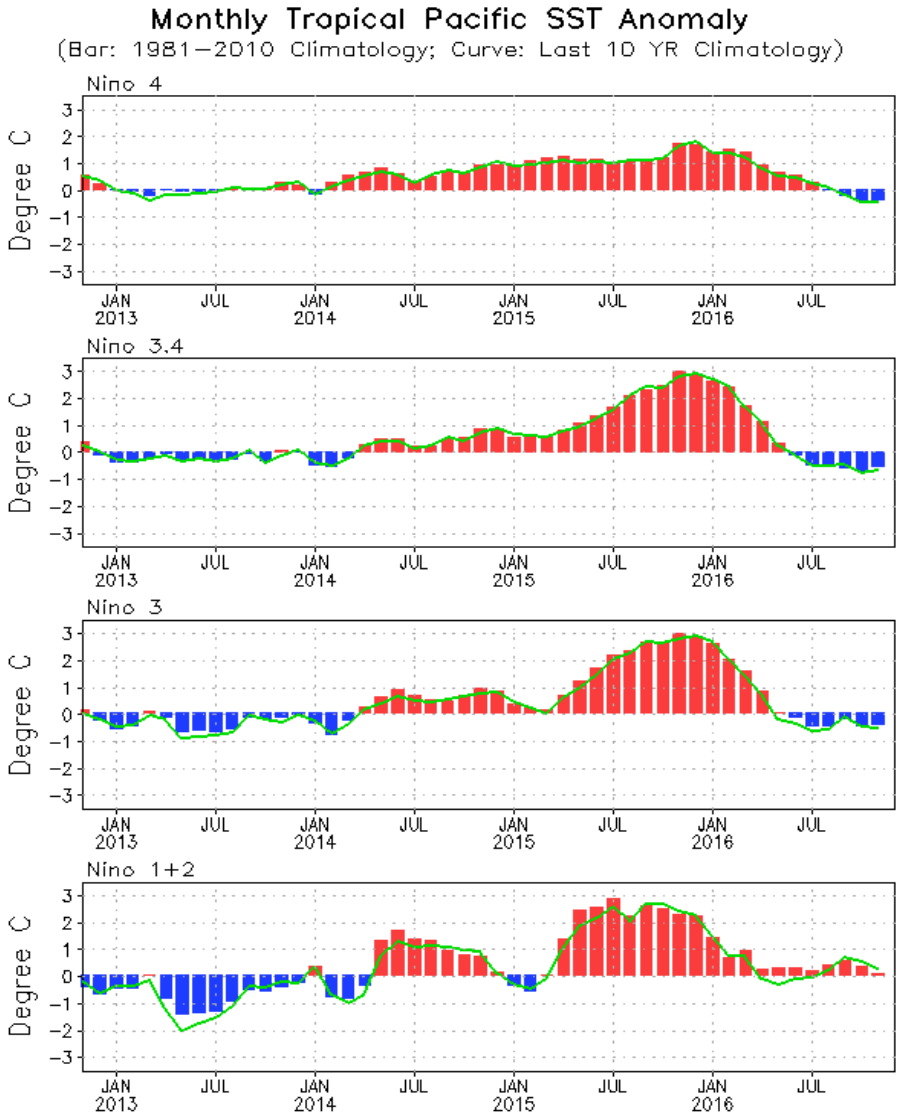
- Hovemoller diagram for equatorial SSS anomaly **(10°S-10°N);**

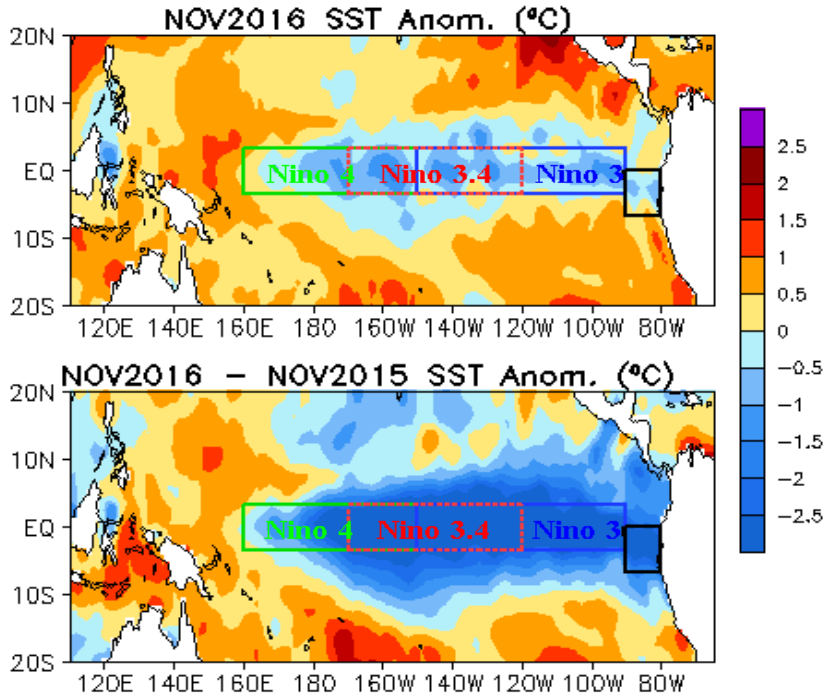
- The anomaly evolution in this region shows some changes in Nov 2016, particularly in the eastern equatorial Pacific region. The negative SSS anomaly in the C.-E. equatorial Pacific (155°E to 110°W) switched to positive signal. At the meantime, the SSS anomaly over the western Pacific from 130°E – 155°E is continuing in its negative phase. These SSS anomaly signals are consistent with La Nina conditions.



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

Evolution of Pacific NINO SST Indices





- **Negative Nino4, Nino3 and Nino3.4 weakened slightly, with Nino3.4 = -0.5°C in Nov 2016.**

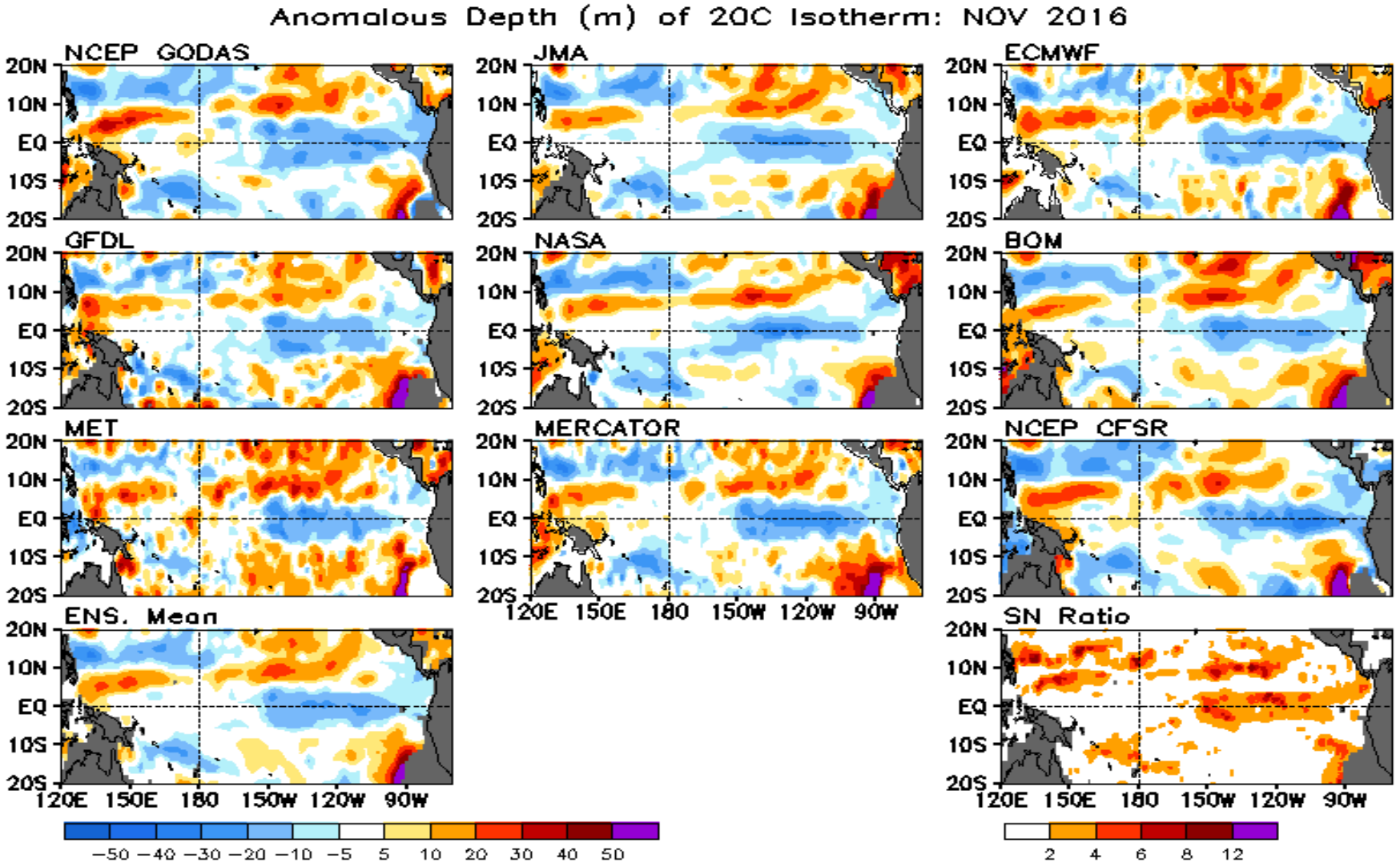
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v4.**

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.

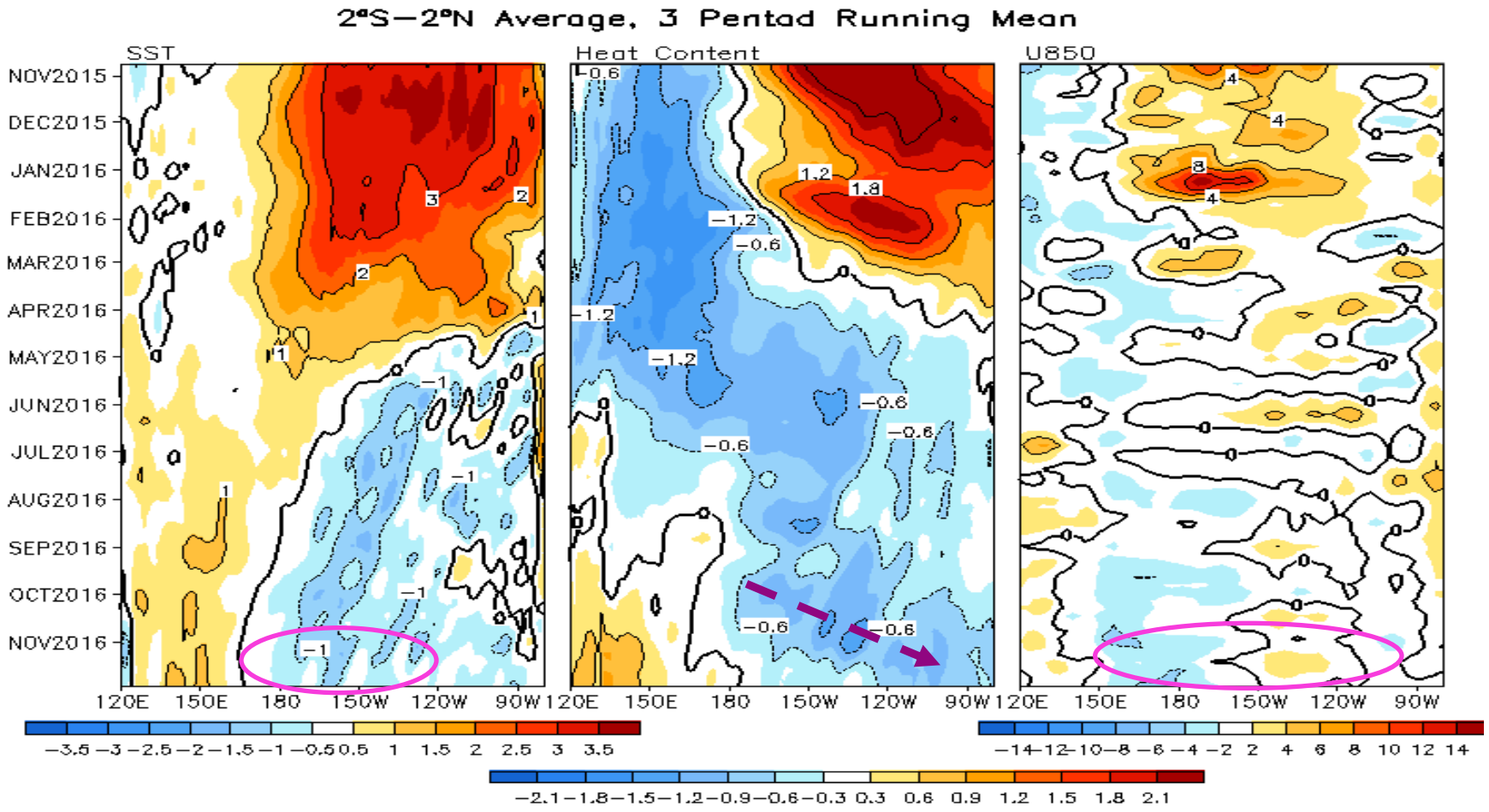
Real-Time Ocean Reanalysis Intercomparison: D20

Climatology : 1993-2013

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



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

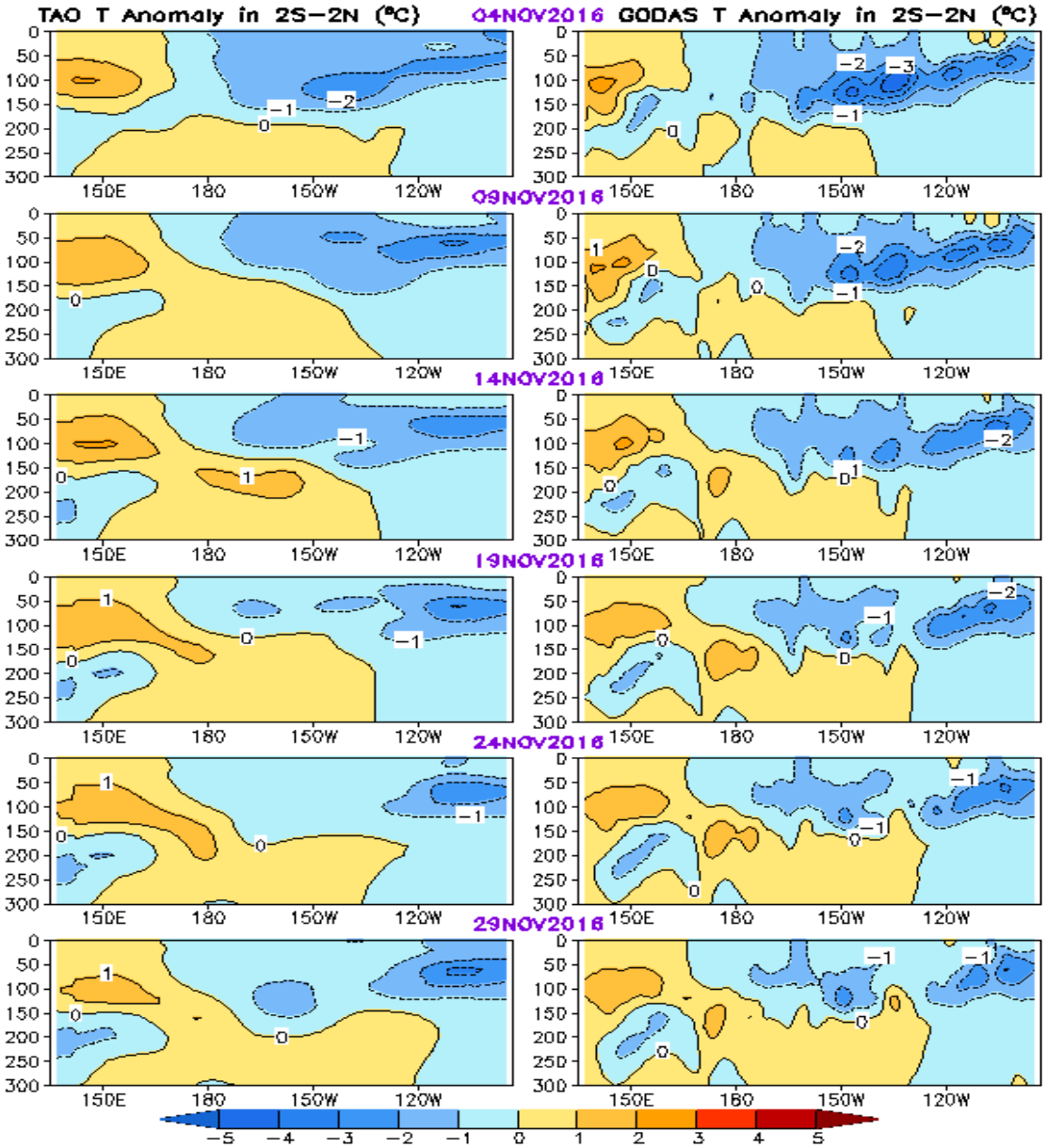


- **Negative SSTA persisted in the C-E. Pacific.**
- **Negative H300 anomalies weakened near the Dateline in Nov 2016, owing to the eastward propagation of upwelling Kelvin wave.**
- **Easterly wind anomalies enhanced slightly in the western Pacific, while westerly wind anomalies persisted in the E. Pacific.**

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.

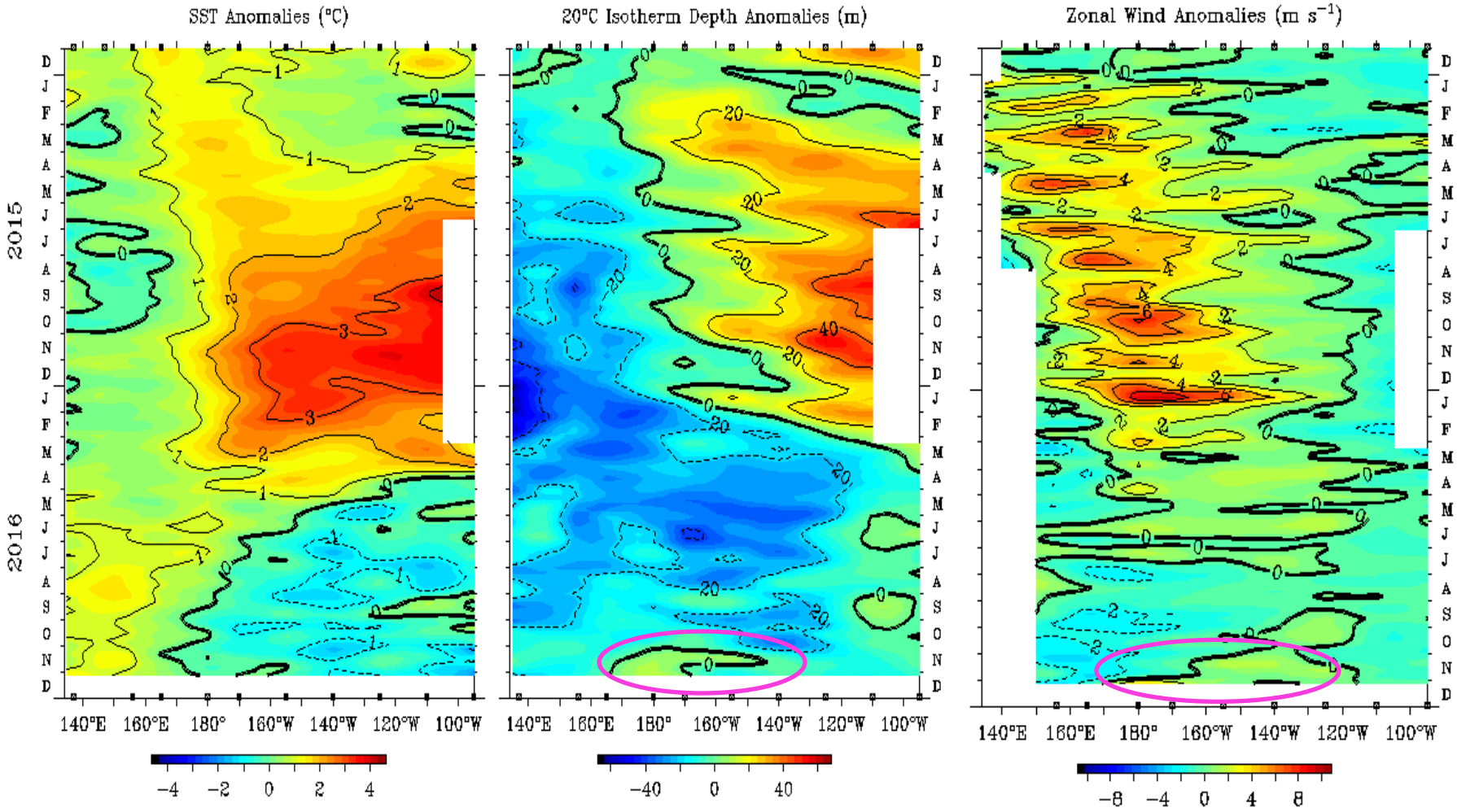
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

TAO GODAS



- **Negative temperature anomalies in the C. Pacific weakened in the last 6 pentads.**

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

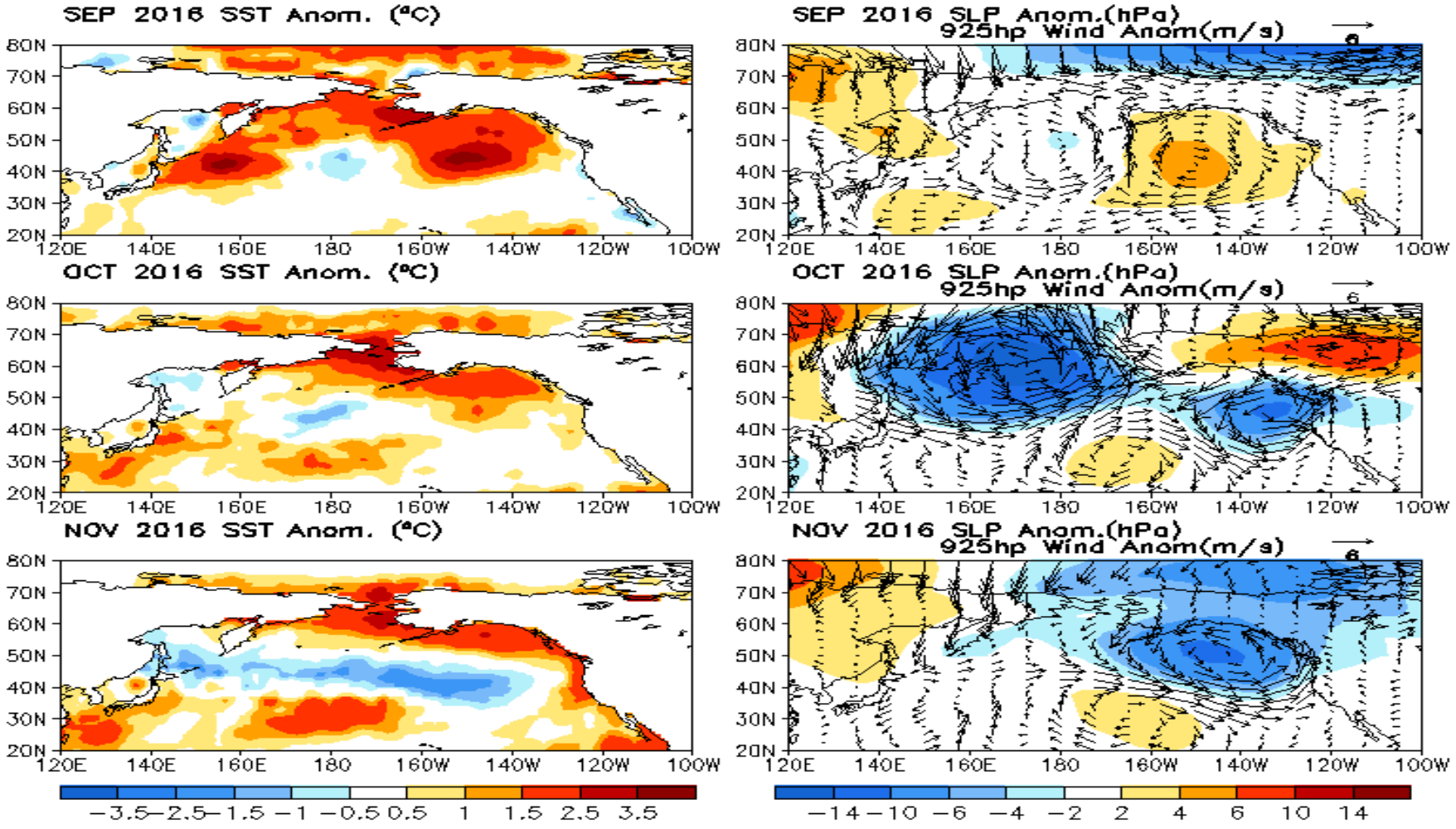


(http://www.pmel.noaa.gov/tao/jsdisplay/)

- **Positive D20 anomaly presented in the C. Pacific in Nov.**
- **Westerly wind anomaly emerged east of Dateline at the end of Nov 2016.**

North Pacific & Arctic Oceans

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



- **Negative SSTA emerged in the central N. Pacific in Nov 2016.**
- **Anomalous cyclone persisted near the western coast of U.S.A. in the last two months.**

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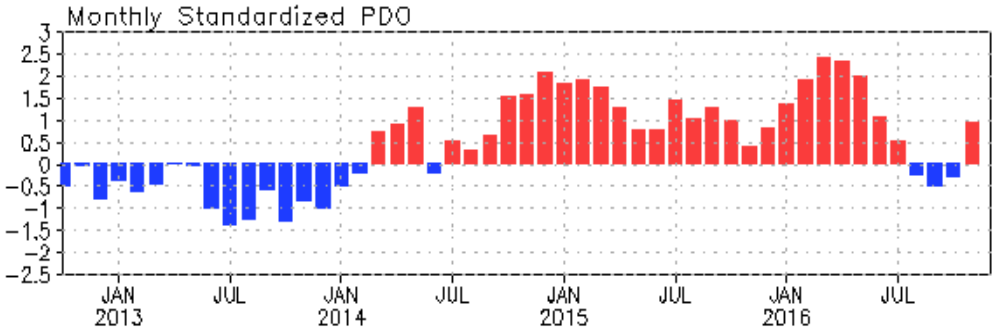
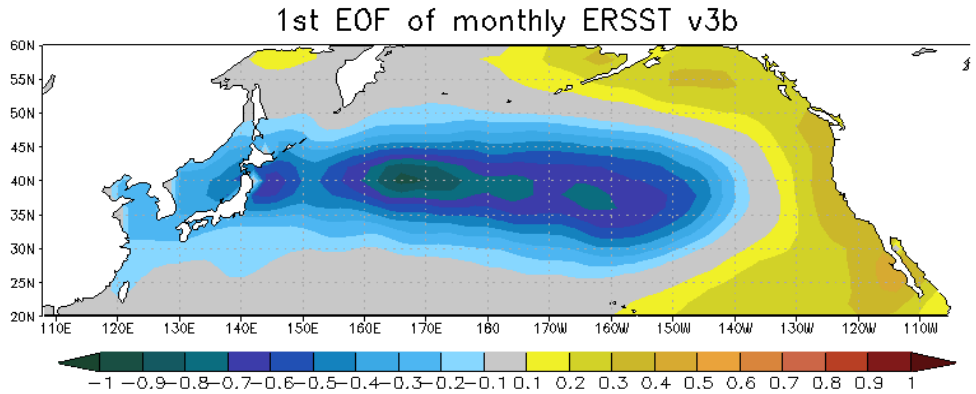
Pacific Decadal Oscillation Index Using ERSST v4



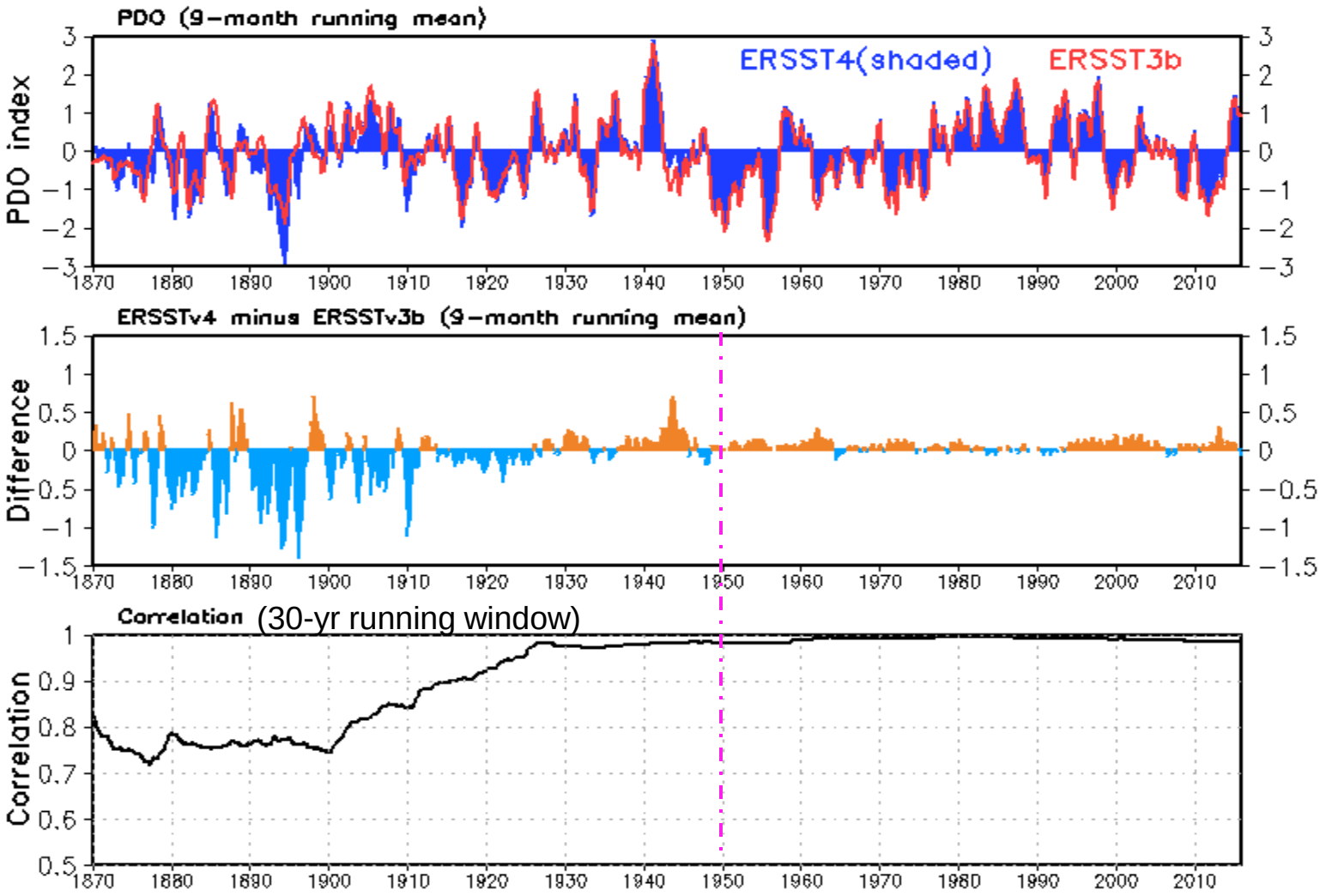


- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the ERSST v4 monthly SST anomalies onto the 1st EOF pattern.**

-ERSST v3b discontinued in Oct. 2016.
- Current CPC PDO index is defined based on ERSST v4.
- For uncertainty in PDO indices, choices of EOF vector and SST data set are important sources of uncertainty on seasonal to decadal time scales, while choice of climatology base period only contributes to uncertainty on seasonal time scale (Wen et al. 2014).
-To reduce uncertainty, EOF vector and climatology base period are the same between current PDO index and previous PDO index.
-PDO switched to positive phase in Nov 2016, with PDO index = 0.9.

Wen, C., A. Kumar, and Y. Xue (2014), Factors contributing to uncertainty in Pacific Decadal Oscillation index, Geophys. Res. Lett., 41, 7980–7986, doi:10.1002/2014GL061992.

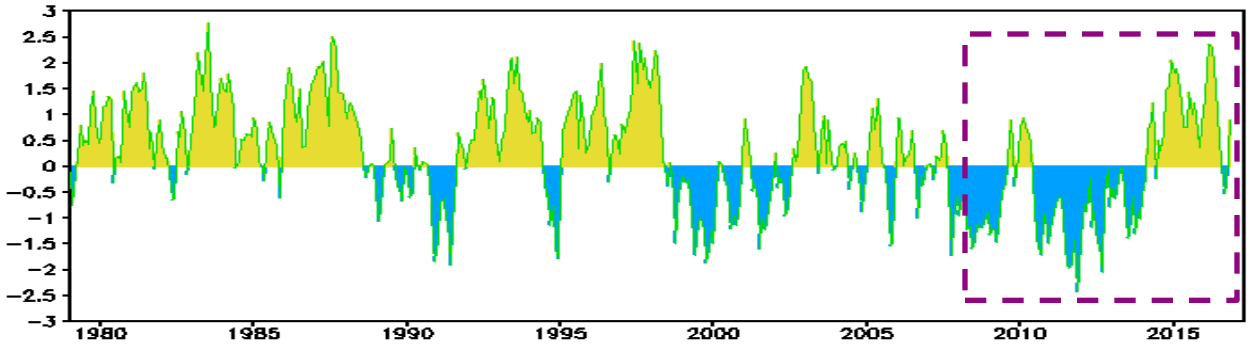
PDO based on ERSST v4 .vs. PDO based on ERSST v3b



-PDO index based on ERSST V4 is very similar with PDO index based on ERSST V3b after 1950.

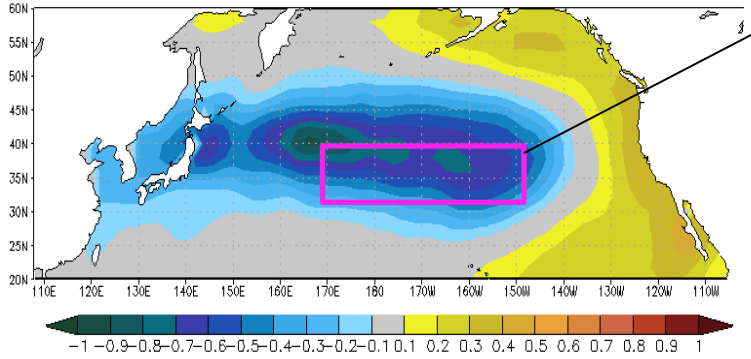
PDO index based on HC300 data

SST-based PDO index

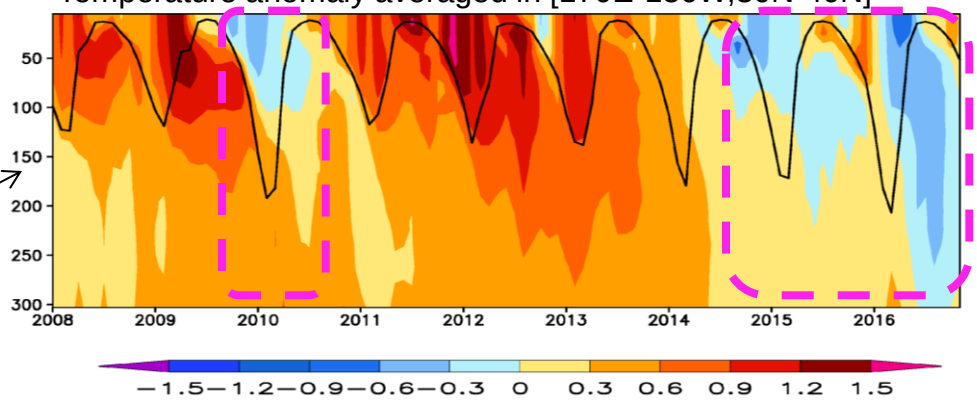


- **SST-based PDO index has considerable variability both on seasonal and decadal time scales.**

1st EOF of monthly ERSST v3b

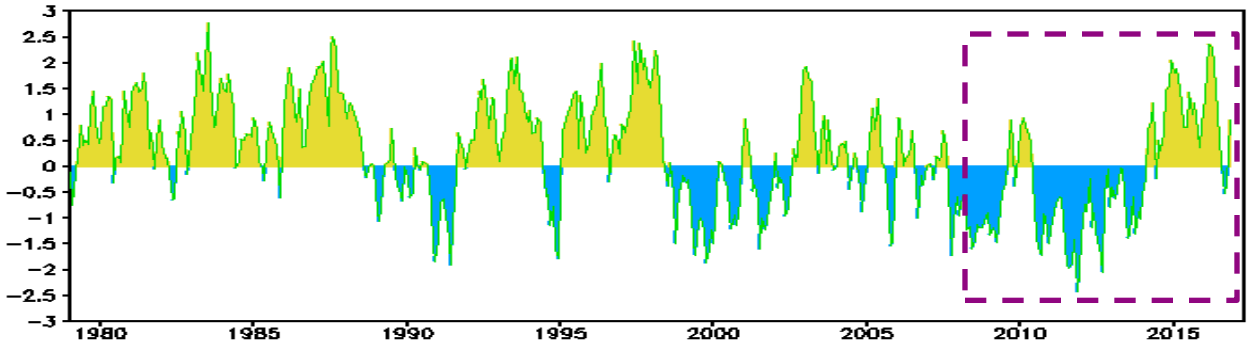


Temperature anomaly averaged in [170E-150W,30N-40N]



PDO index based on HC300 data

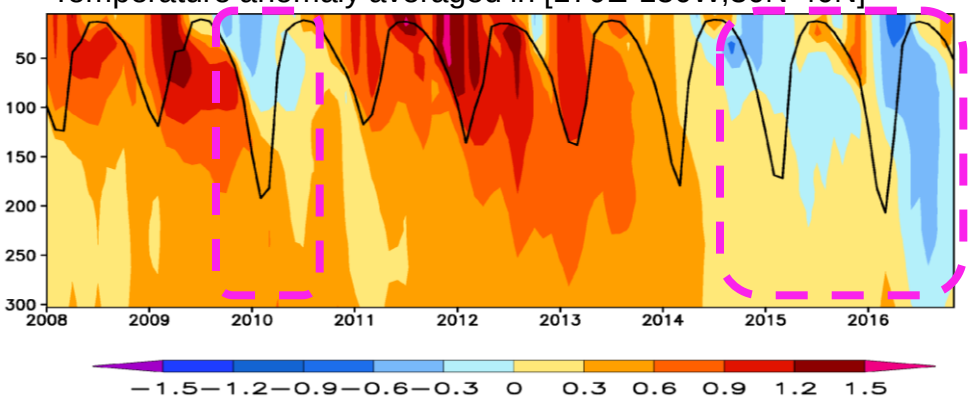
SST-based PDO index



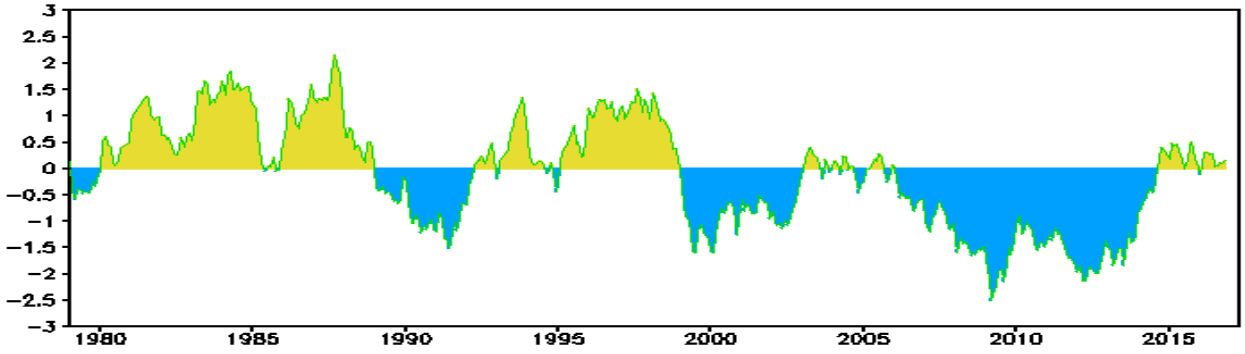
- **SST-based PDO index has considerable variability both on seasonal and decadal time scales.**

- **Upper 300m Ocean heat content(HC300) based PDO (HPDO) provides a natural way to highlight the slower frequency variability in the SST-based PDO and encapsulates an integrated view of temperature variability associated with the PDO in the upper ocean.**
- **HPDO index = 0.2 in Nov 2016.**

Temperature anomaly averaged in [170E-150W,30N-40N]



HC300-based PDO index



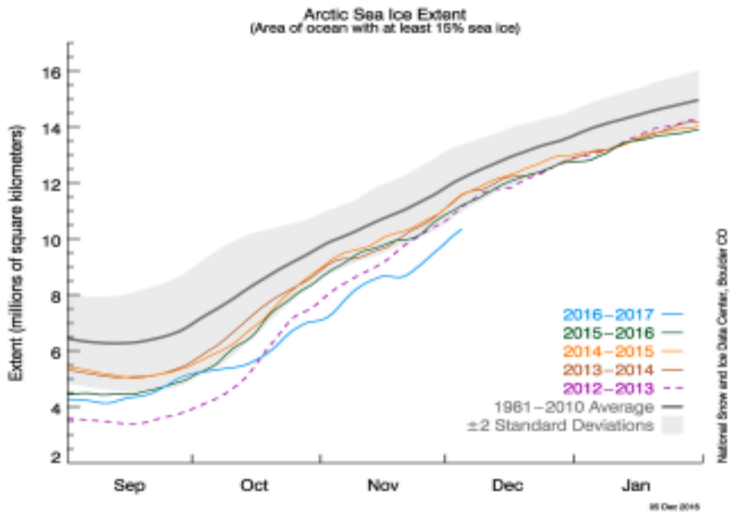
Kumar, A. and C. Wen, 2016: An Oceanic Heat Content-Based Definition for the Pacificc Decadal Oscillation. Mon. Wea. Rev., 144, 3977–3984, doi: 10.1175/MWR-D-16-0080.1.

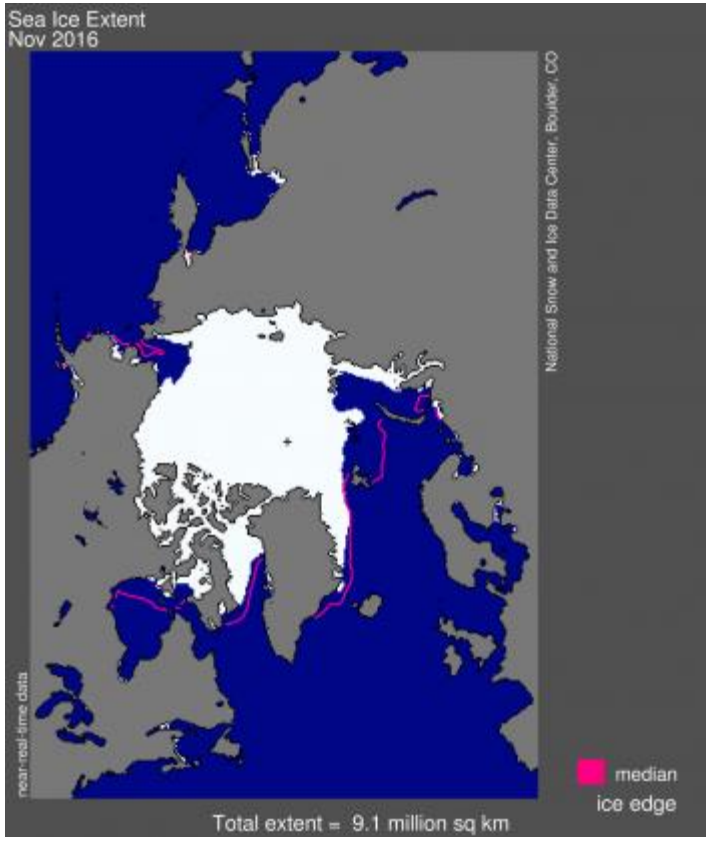
(http://www.cpc.ncep.noaa.gov/products/GODAS/PDO_body.html)

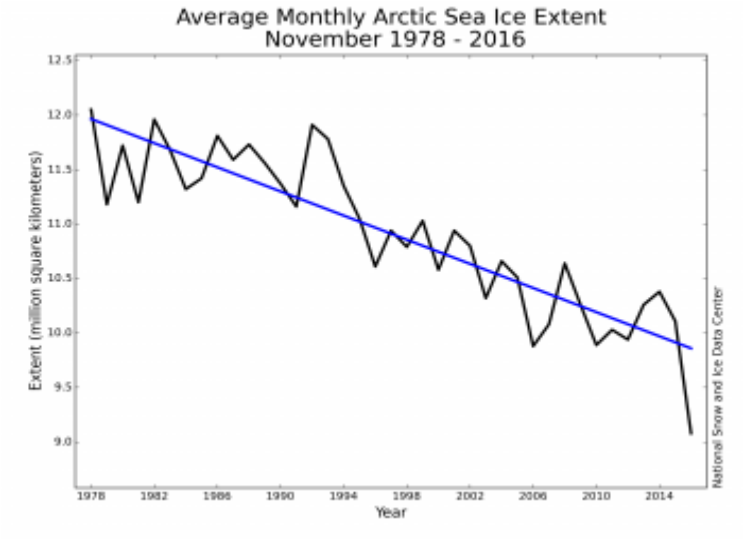
Arctic Sea Ice

National Snow and Ice Data Center

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



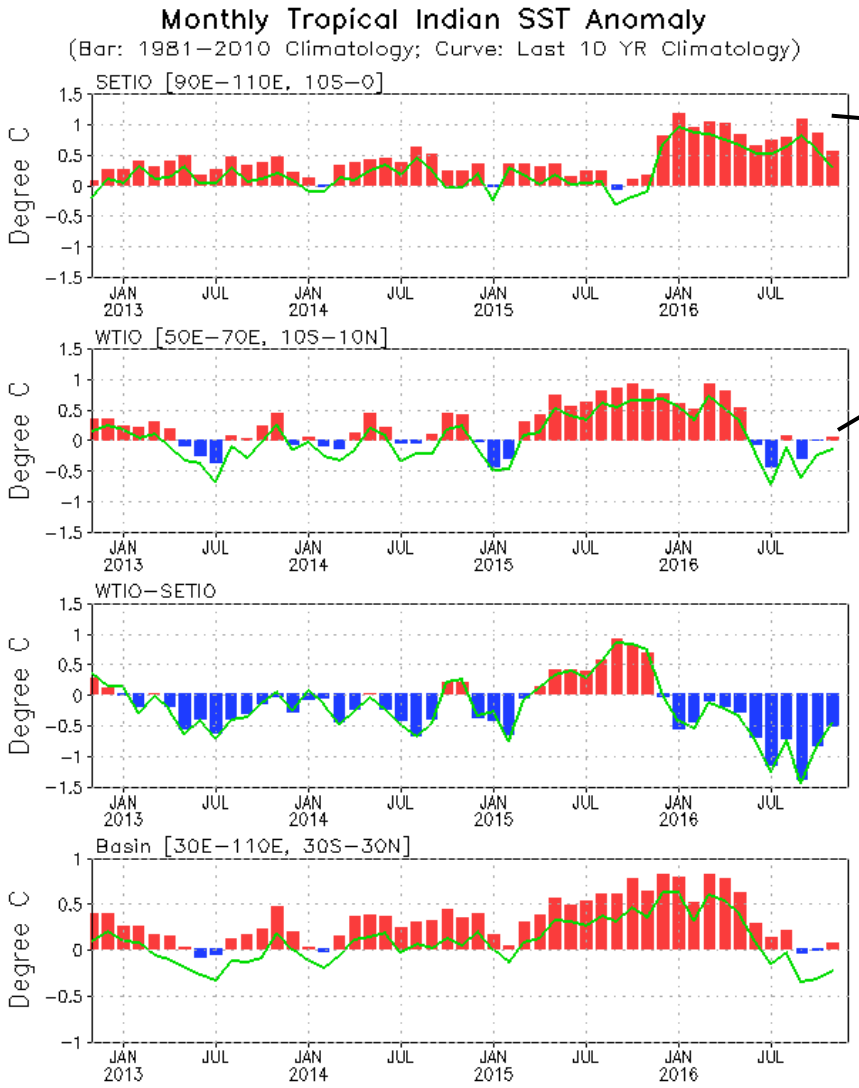


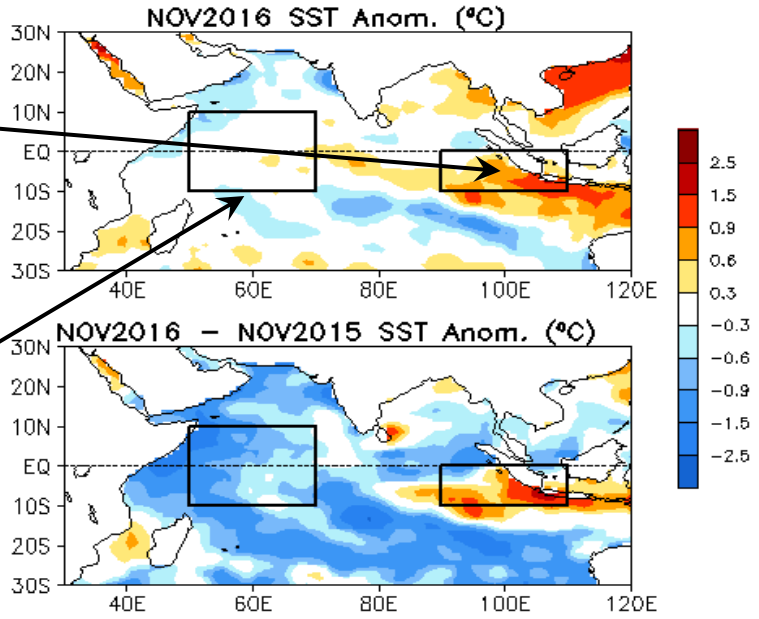


- Artic sea ice extent in Nov 2016 reached the historical low in the satellite record.

Indian Ocean

Evolution of Indian Ocean SST Indices





- **SETIO has been strong positive (> +0.7°C) since Dec 2015.**
- **Negative DMI returned to neutral, with DMI = -0.5°C in Nov 2016.**
- **WTIO and Basin indices were near-averaged in Nov. 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.

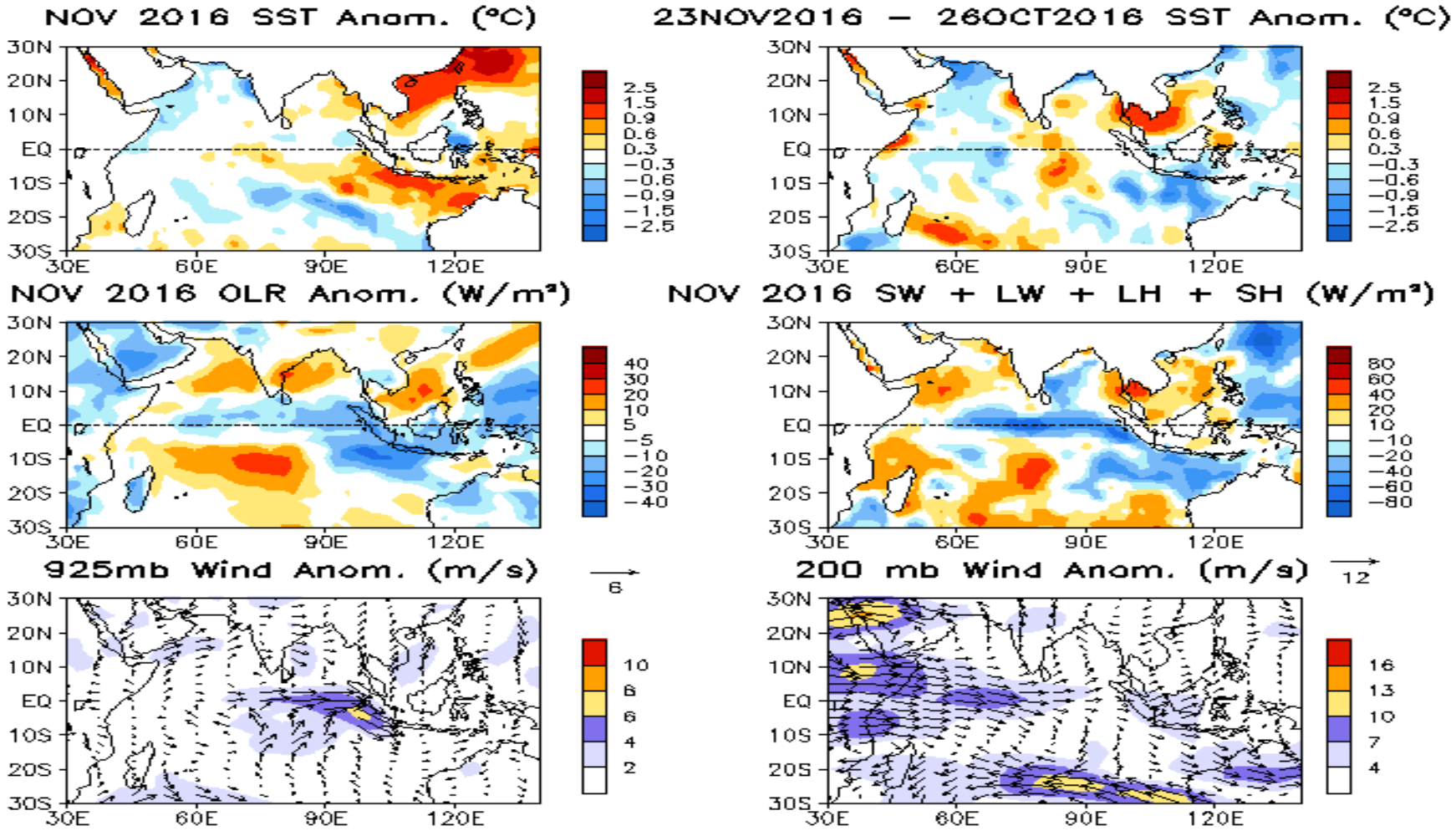
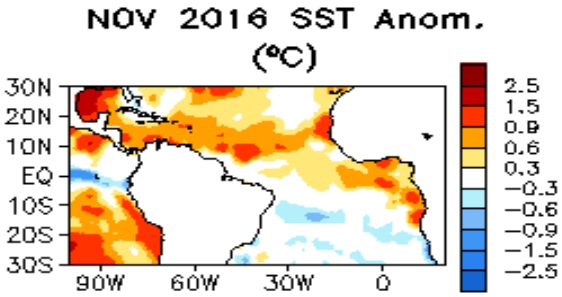


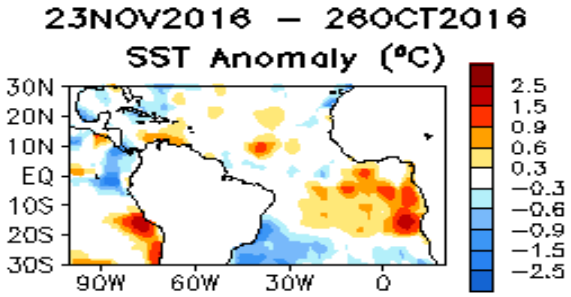
Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

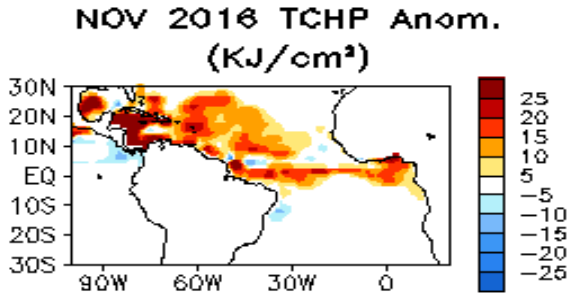
Tropical and North Atlantic Ocean

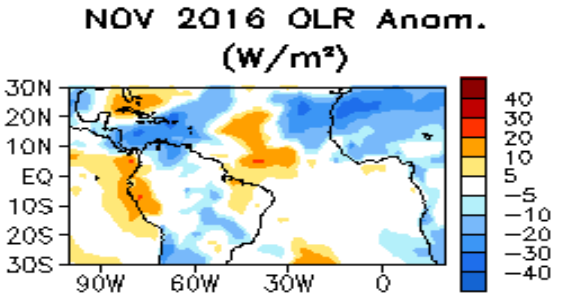
Tropical Atlantic:

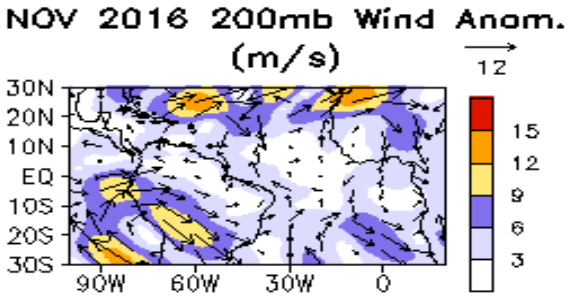
SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb/200-mb Winds

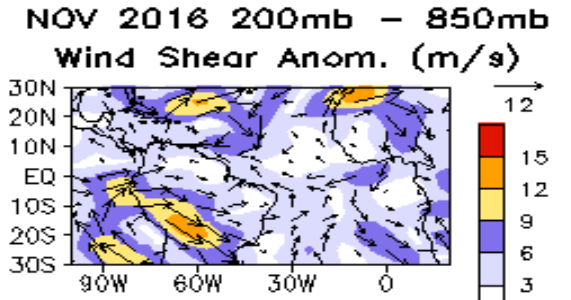


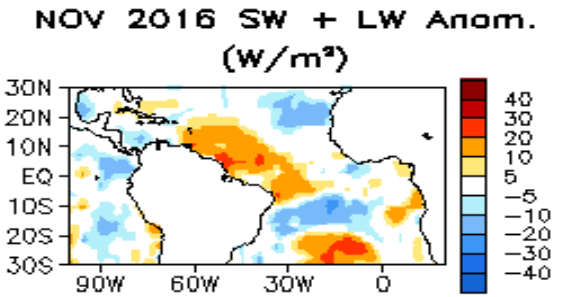


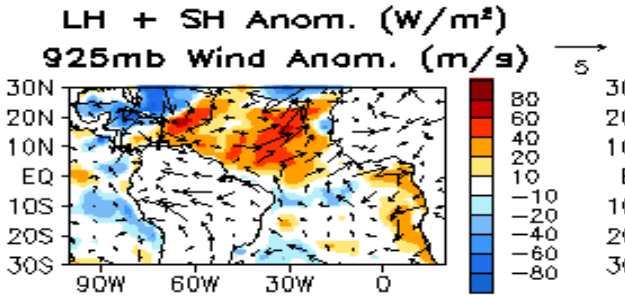


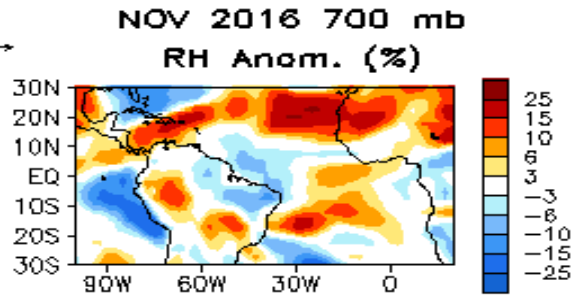








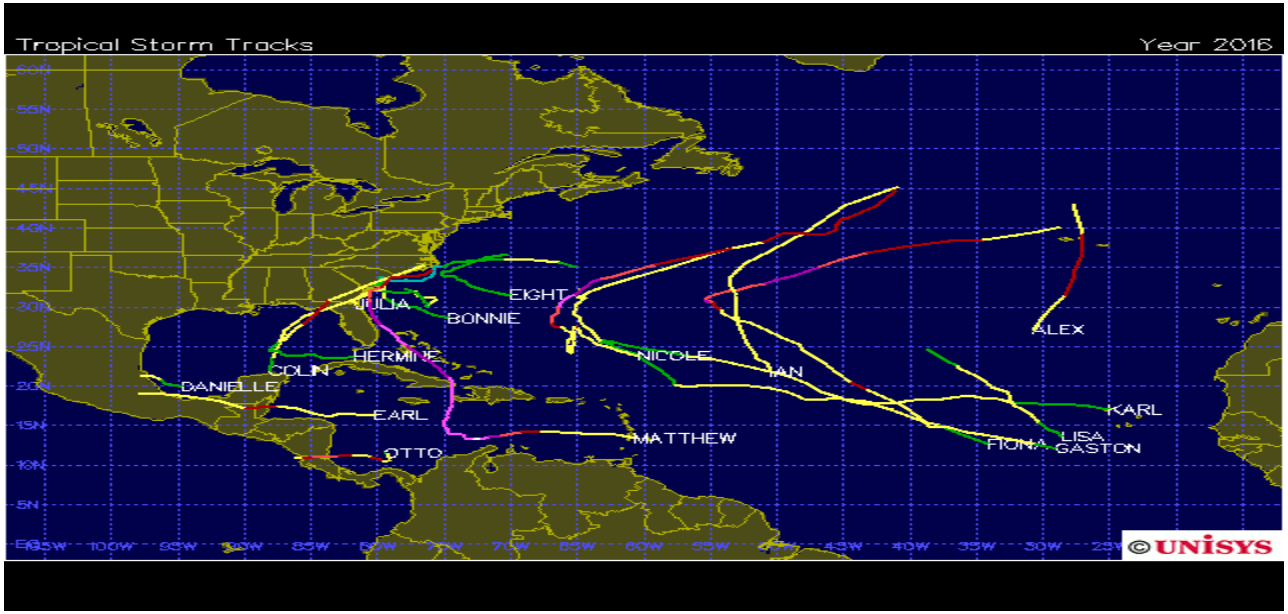




- **Above-normal SSTA and TCHP persisted in the hurricane Main Development Region (MDR).**
- **Westerly low-level wind blew towards the western Africa.**

2016 Atlantic Hurricane Season

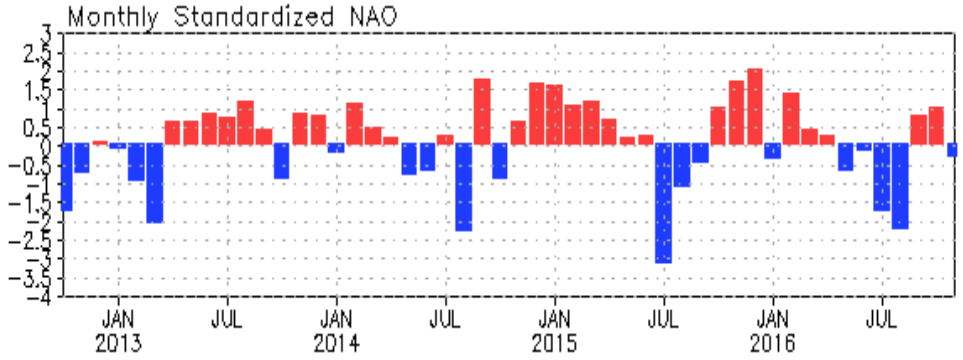
(http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.shtml)

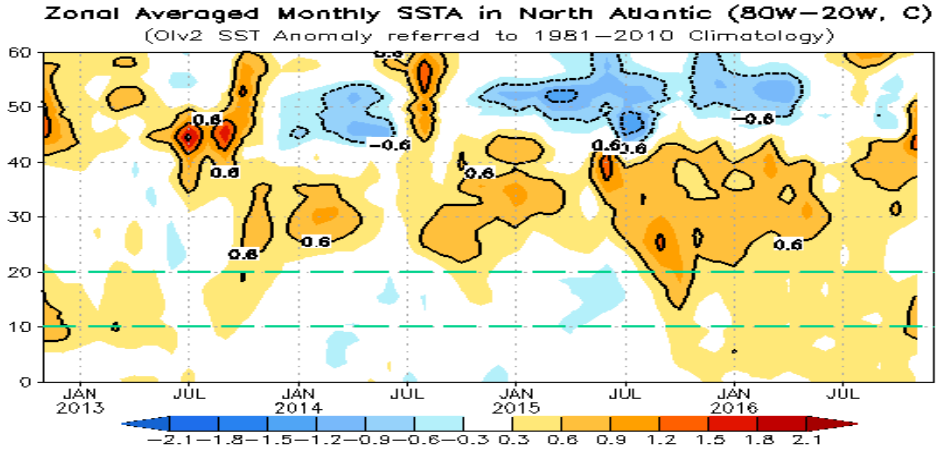


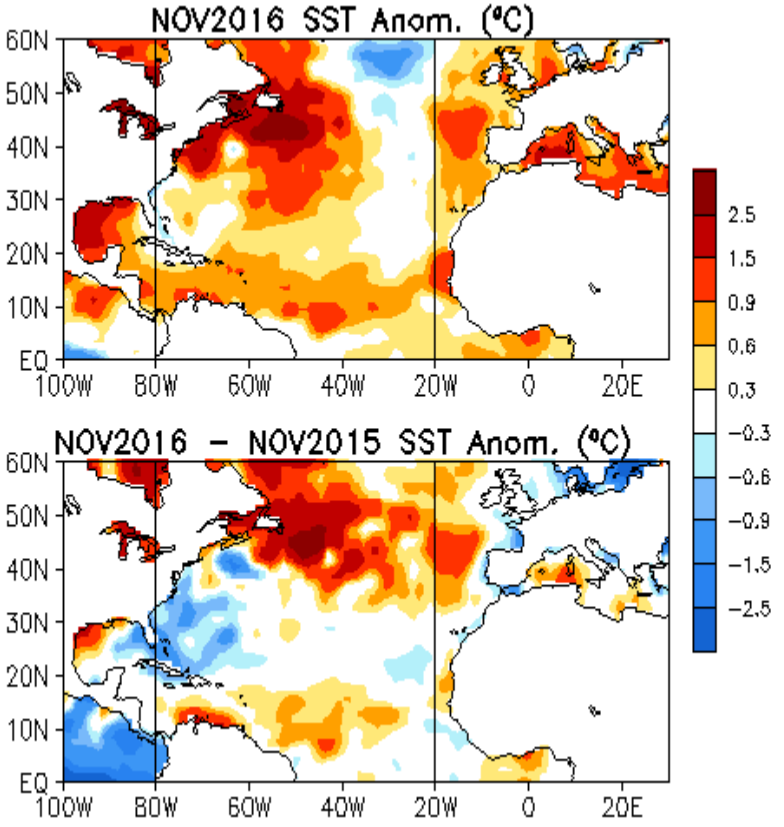
(http://weather.unisys.com/hurricane/)

Atlantic	Observation by Dec 8, 2016	August Update	May outlook	1981-2010
Named storms	15	12-17	10-16	12.1
Hurricanes	7	5-8	4-8	6.4
Major hurricanes	3	2-4	1-4	2.7

NAO and SST Anomaly in North Atlantic





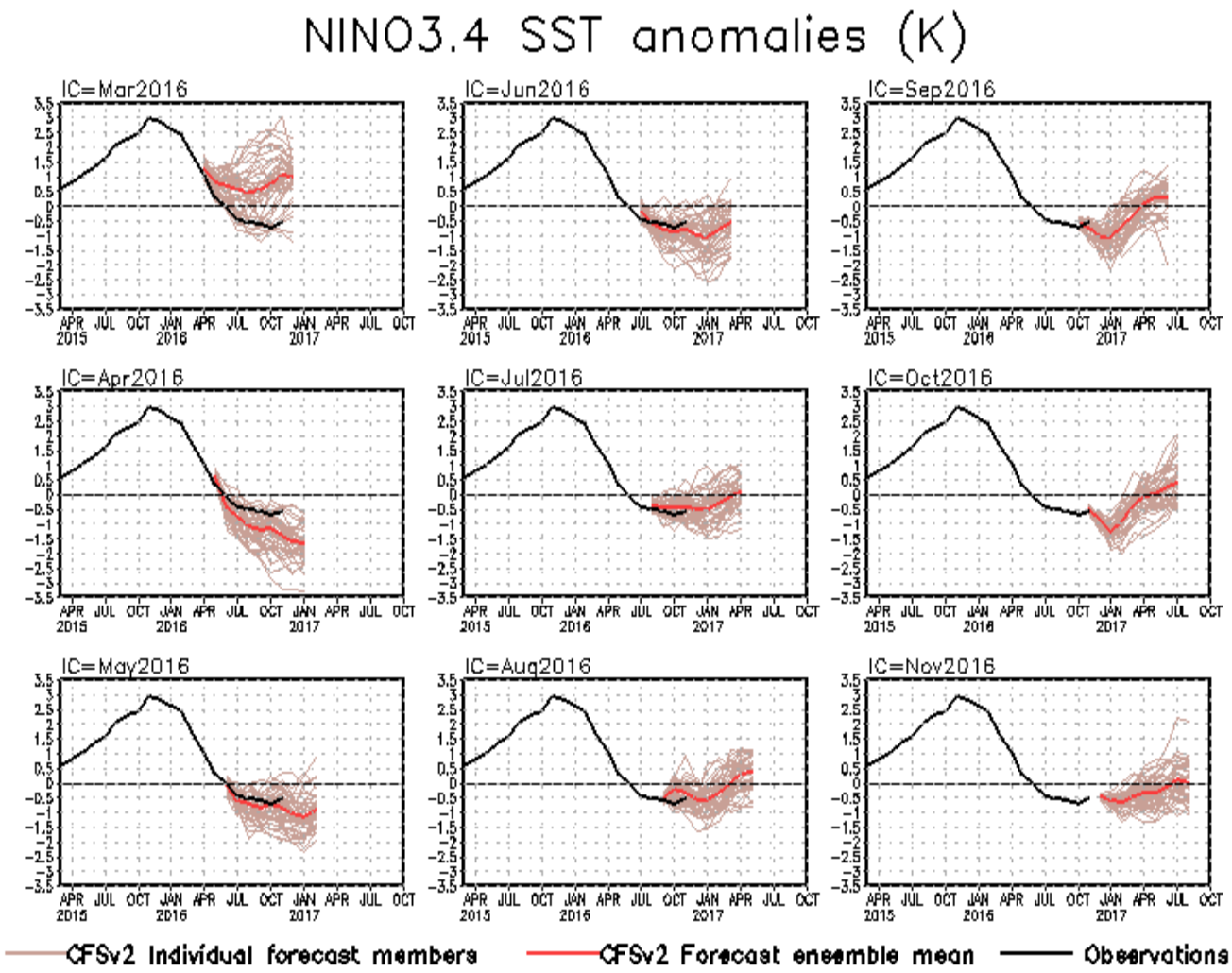


- **NAO switched to negative phase, with NAOI=-0.3 in Nov 2016.**
- **Strong positive SSTA persisted along the Gulf of Mexico and E. coast of North America.**

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

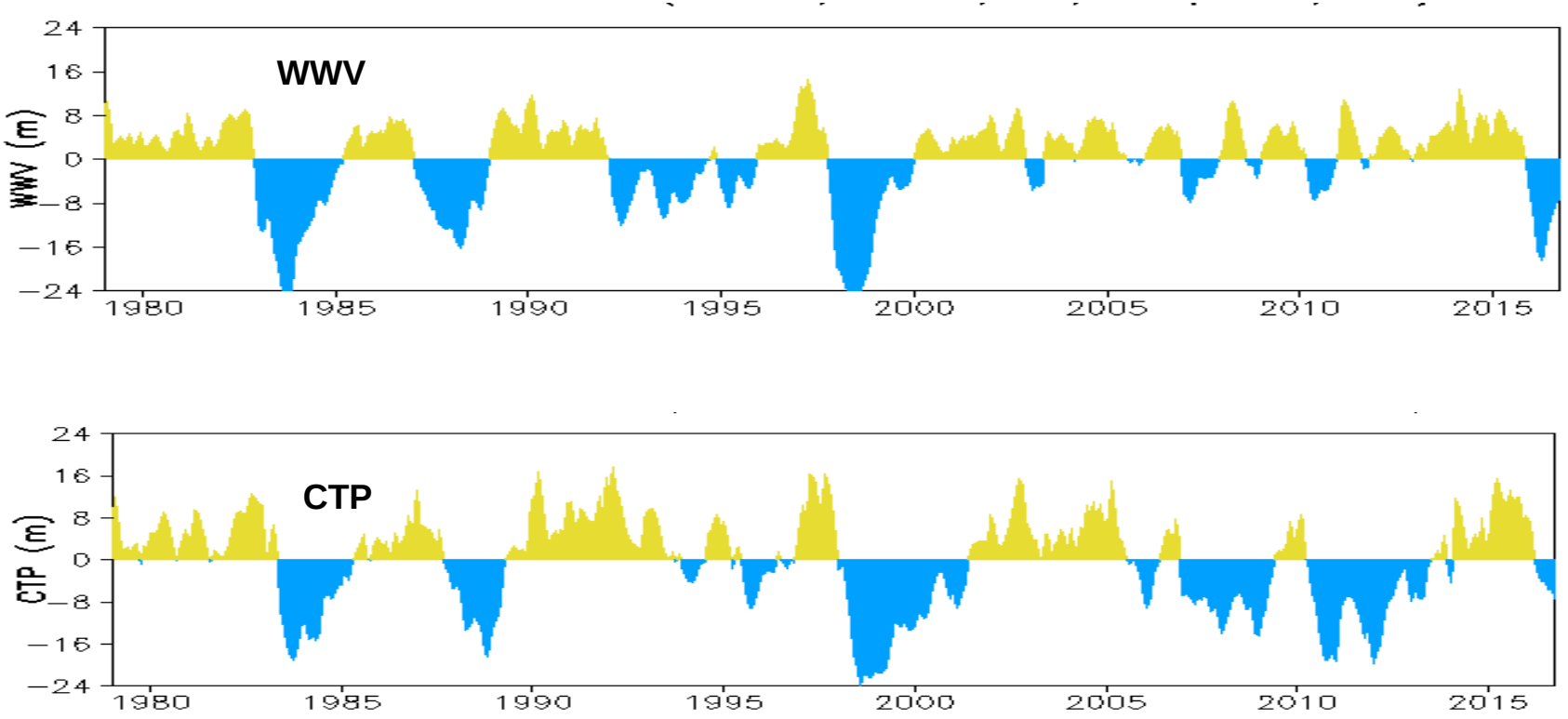
CFS Niño3.4 SST Predictions from Different Initial Months



Latest CFSv2 predictions suggest weak La Nina conditions (NINO3.4 < -0.5C) would continue through DJF and then return to ENSO-neutral in spring 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.

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).**

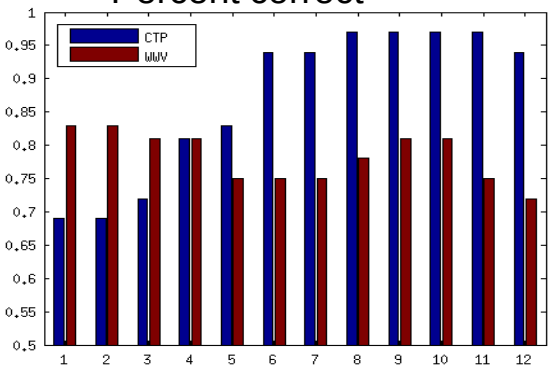
Meinen, C. S., and M. J. McPhaden, 2000: Observations of warm water volume changes in the equatorial Pacific and their relationship to El Niño and La Niña. *J.Climate*, **13,** 3551-3559.

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

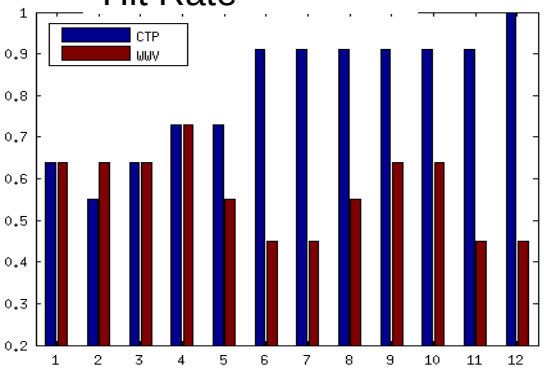
Two ENSO Precursors Based on Thermocline Anomaly

2x2 contingency table for La Nina case

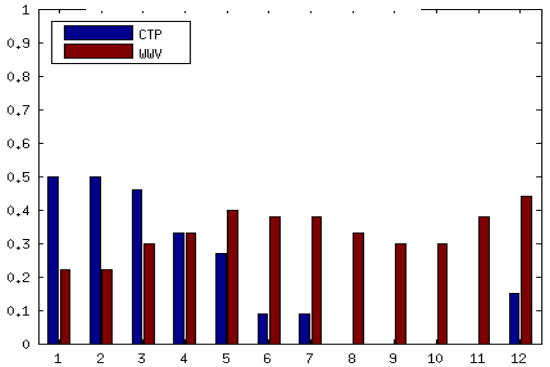
Percent correct

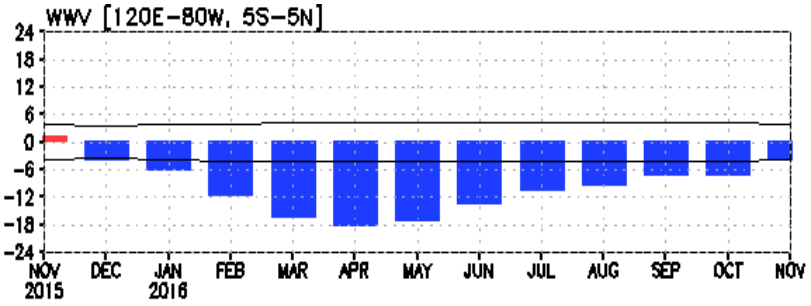


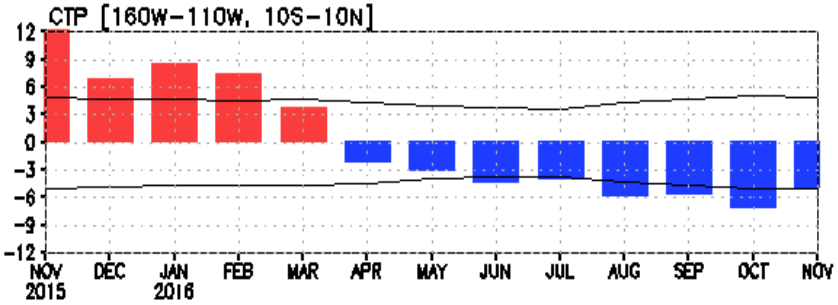
Hit Rate



False Alarm



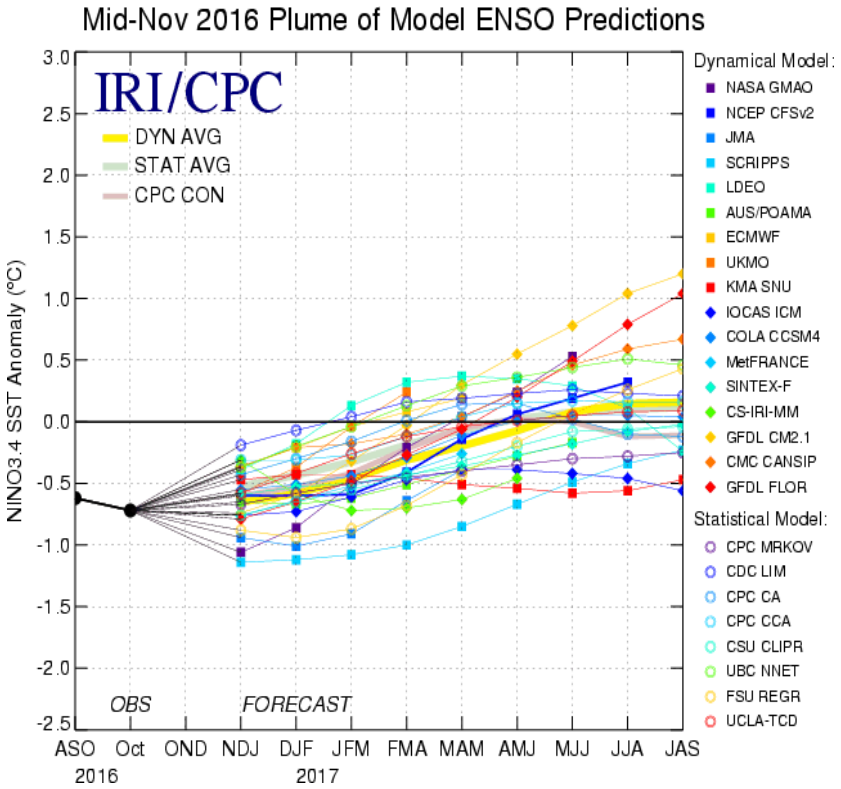


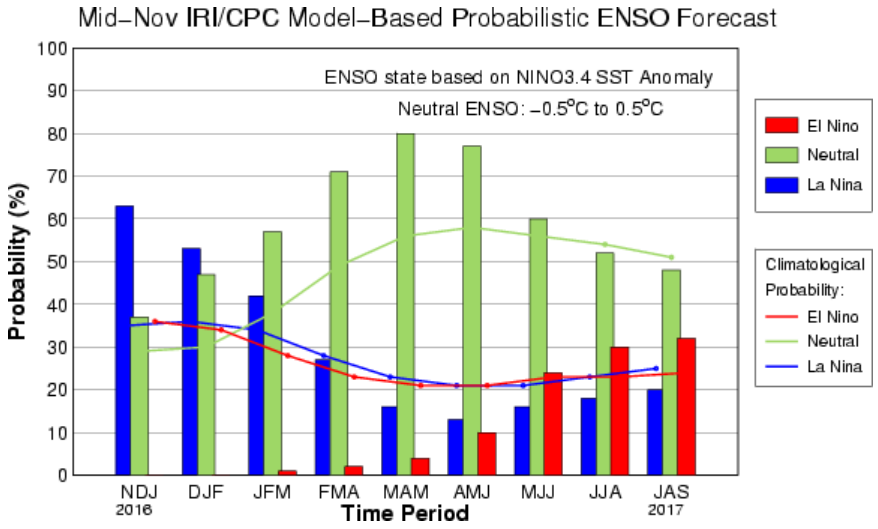


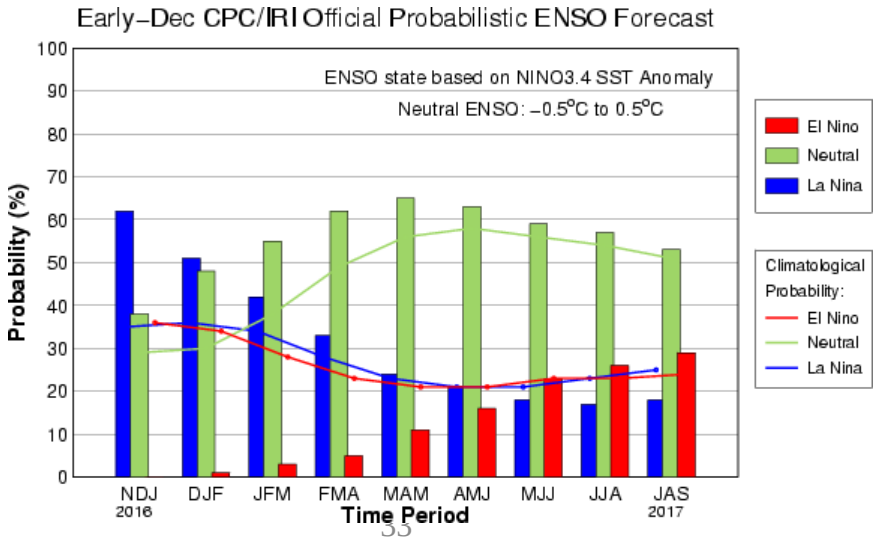
Forecast criterion: 0.5 monthly standard deviation (black lines)

- 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 duringJun-Oct 2016, indicating a high probability of La Nina conditions during DJF 2016-17.
- CTP was close to -0.5 STD in Nov 2016.

IRI NINO3.4 Forecast Plume

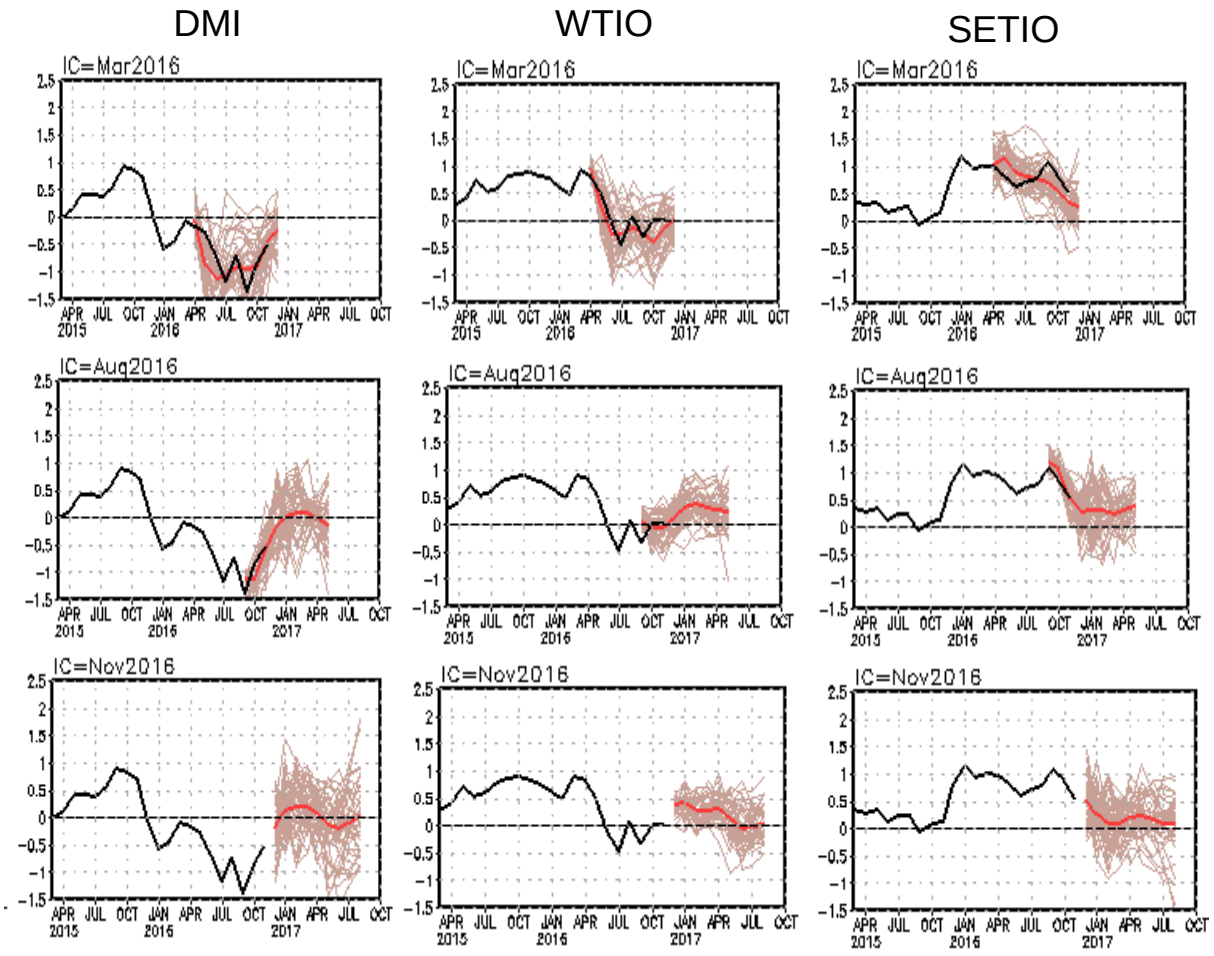






- **Multi-model ensemble forecasts suggest that La Niña conditions will continue through Dec-Feb (DJF) 2016-17.**
- **NOAA "ENSO Diagnostic Discussion" on 8 Dec 2016 suggested that "La Niña conditions are present, with a transition to ENSO-neutral favored during January-March 2017".**

CFSv2 DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

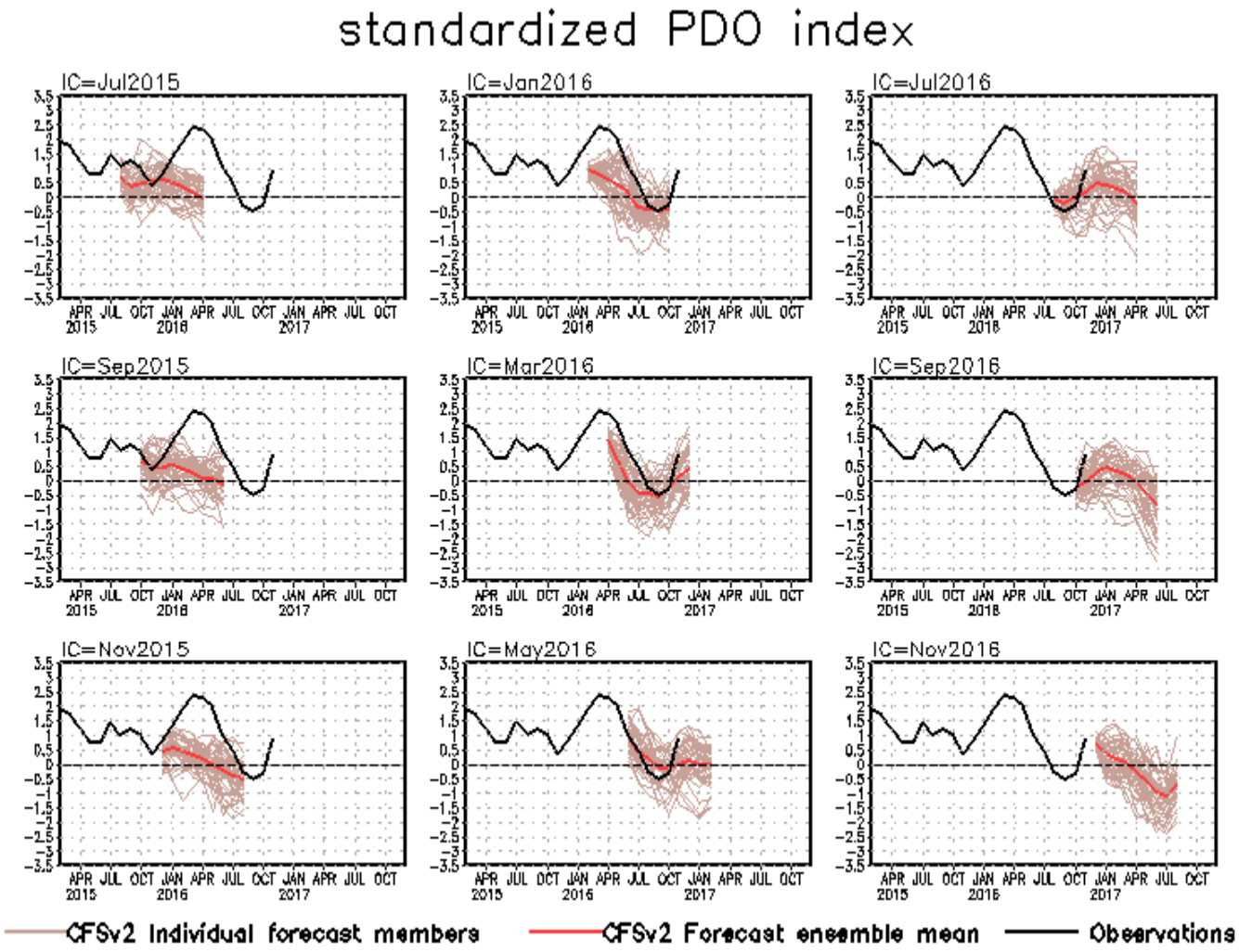
SETIO = SST anomaly in [90°E-110°E, 10°S-0]

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

- CFSv2 successfully forecast the 2016 negative DMI event since Nov 2015.
- Latest CFSv2 forecasts neutral DMI will persist through summer 2017.

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 above normal in Dec 2016 and shift to negative phase during spring 2017.

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.

Overview

Pacific Ocean

- La Niña conditions presented in Nov 2016 and the atmospheric and oceanic anomalies reflect a weak La Niña.
- CPC/IRI consensus favors the continuation of weak La Niña conditions through December-February (DJF) 2016-17.
- SST PDO index switched to positive phase , with PDO = 0.9 in Nov 2016.
- Arctic sea ice extent in November hit the historical low in the satellite record.

Indian Ocean

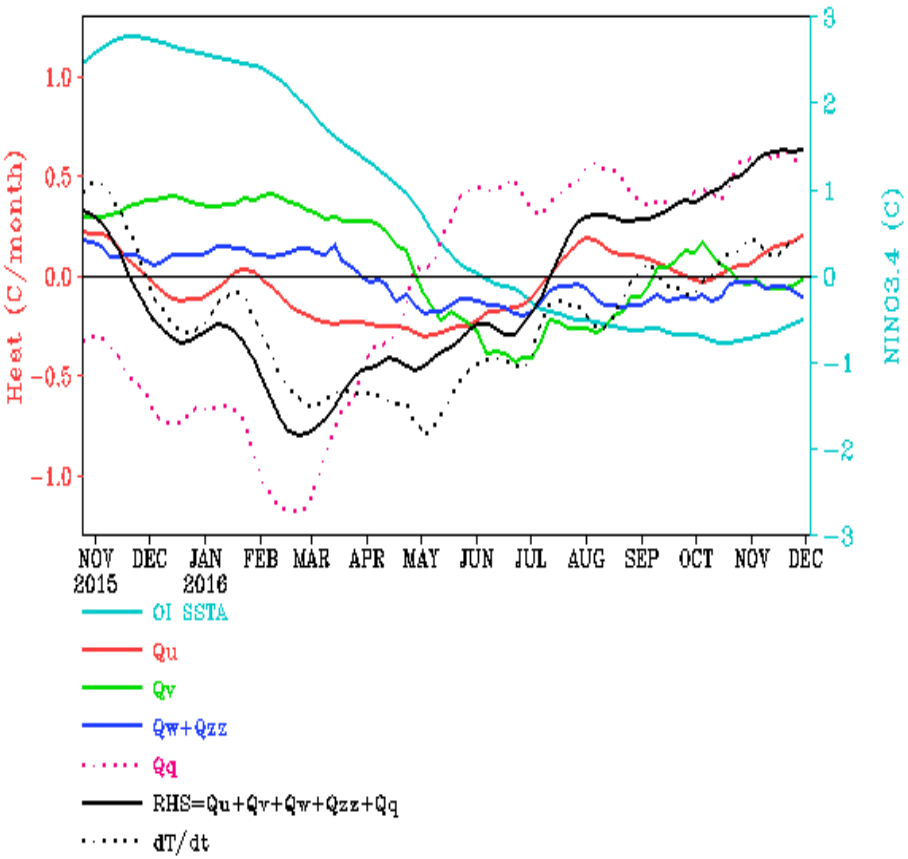
- Dipole Mode Index returned to neutral in Nov 2016.
- SST warming in the eastern Indian Ocean weakened in Nov 2016.

Atlantic Ocean

- NAO switched to negative phase in Nov 2016.
- Strong positive SSTA continued 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 Nov 2016.

-Dynamical terms (Qv, Qw+Qzz, Qu) were near zero in Nov 2016.

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.

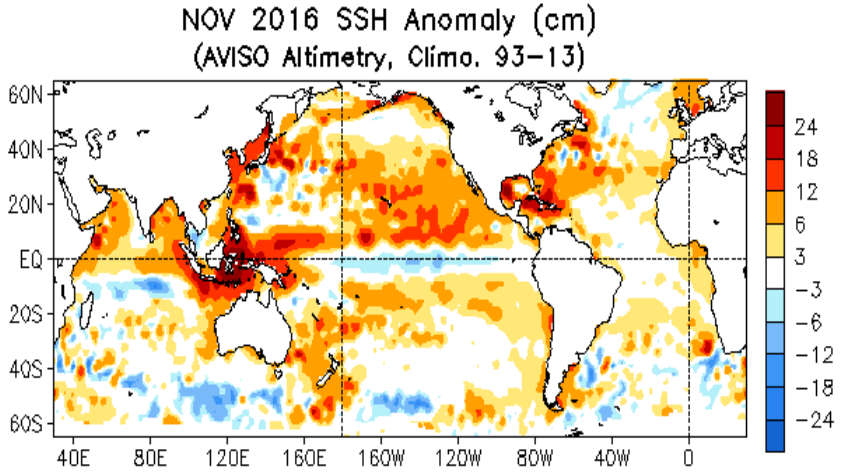
Qu: Zonal advection; Qv: Meridional advection;

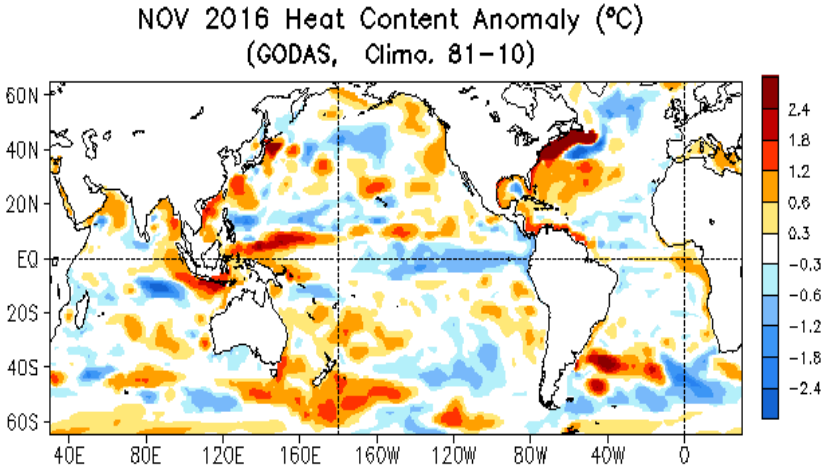
Qw: Vertical entrainment; Qzz: Vertical diffusion

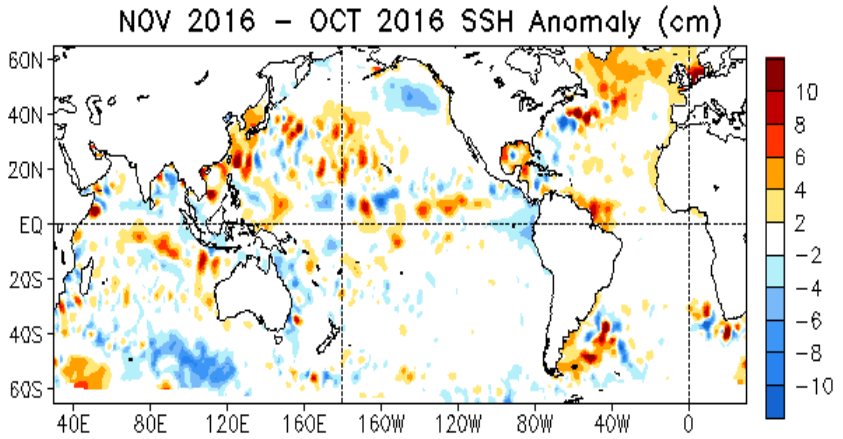
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

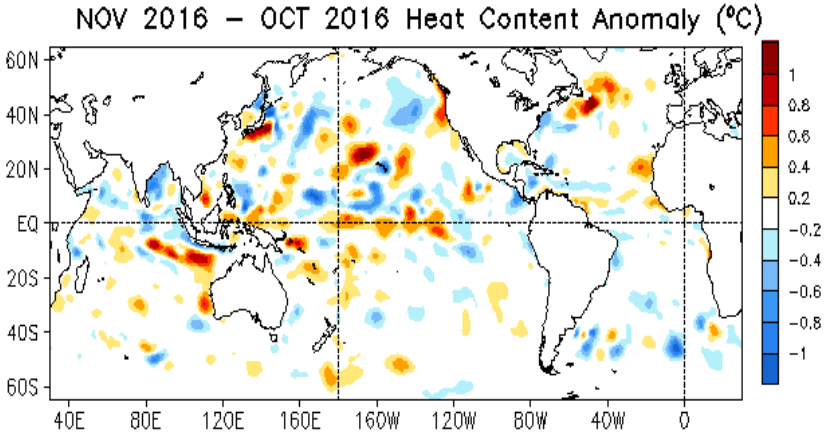
Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

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.**
- **Positive SSHA and H300A tendency dominated in the C.-E. Pacific.**

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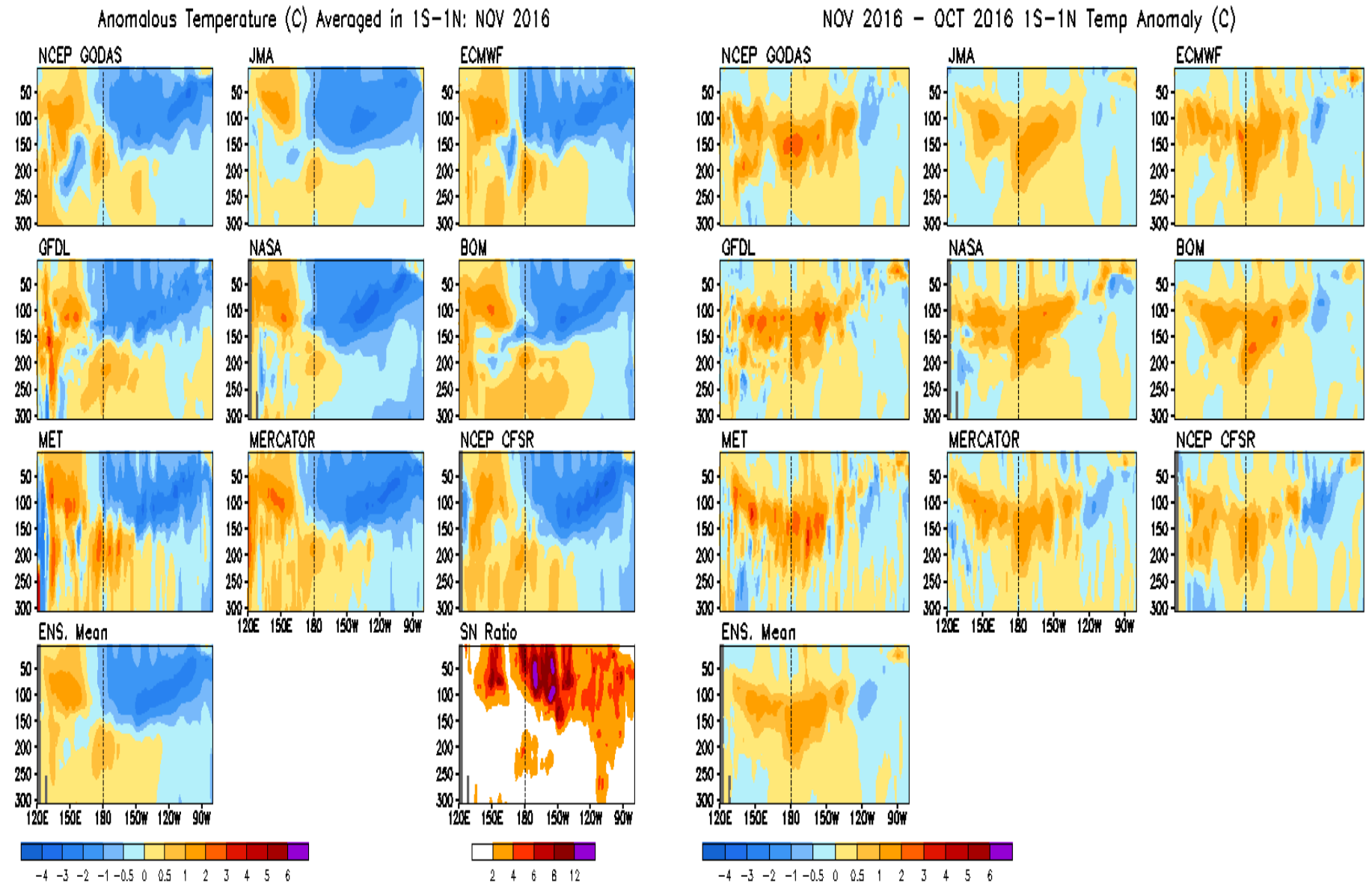
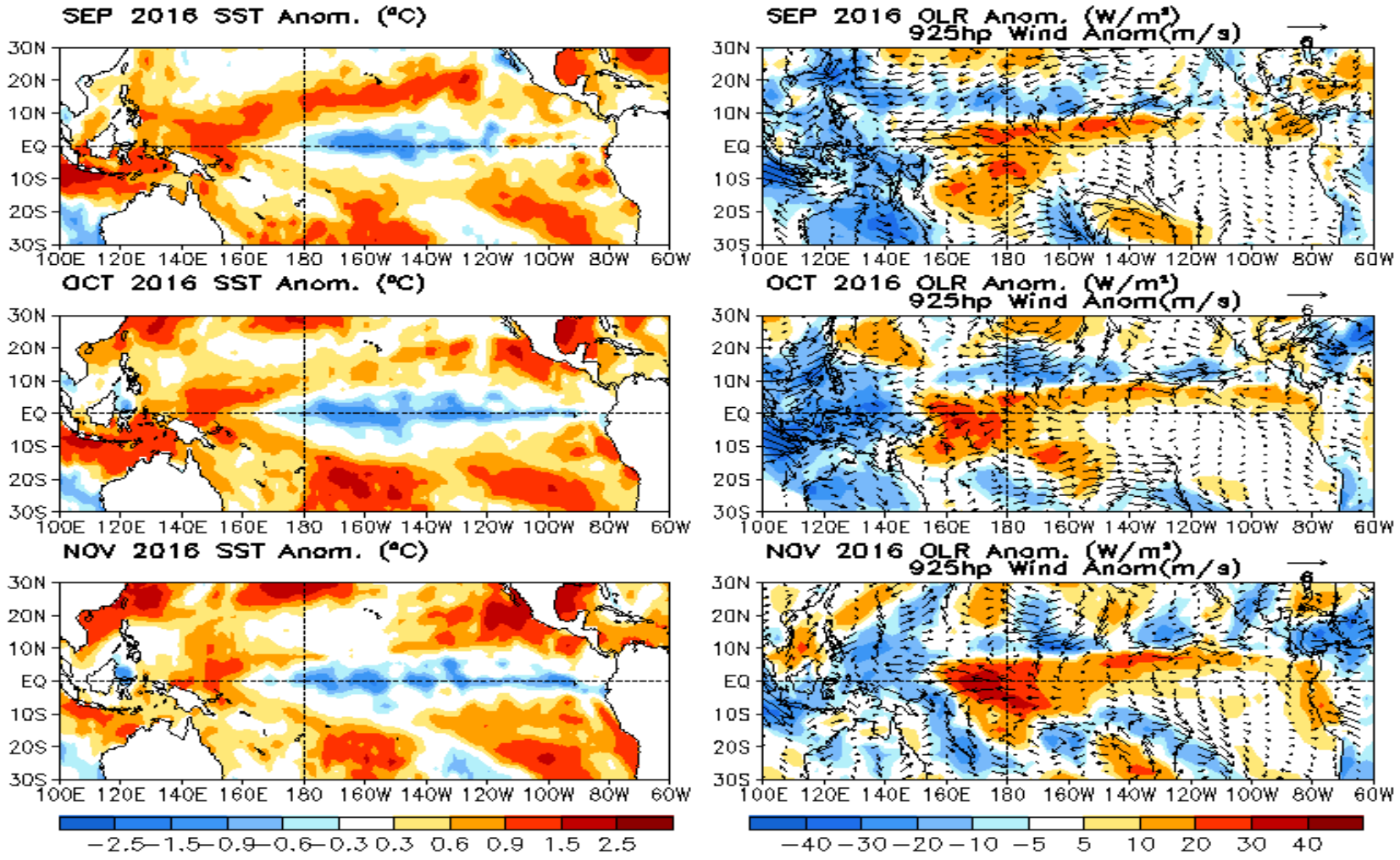
Real-Time Ocean Reanalysis Intercomparison: Temperature

Climatology : 1993-2013
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)



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.**

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.

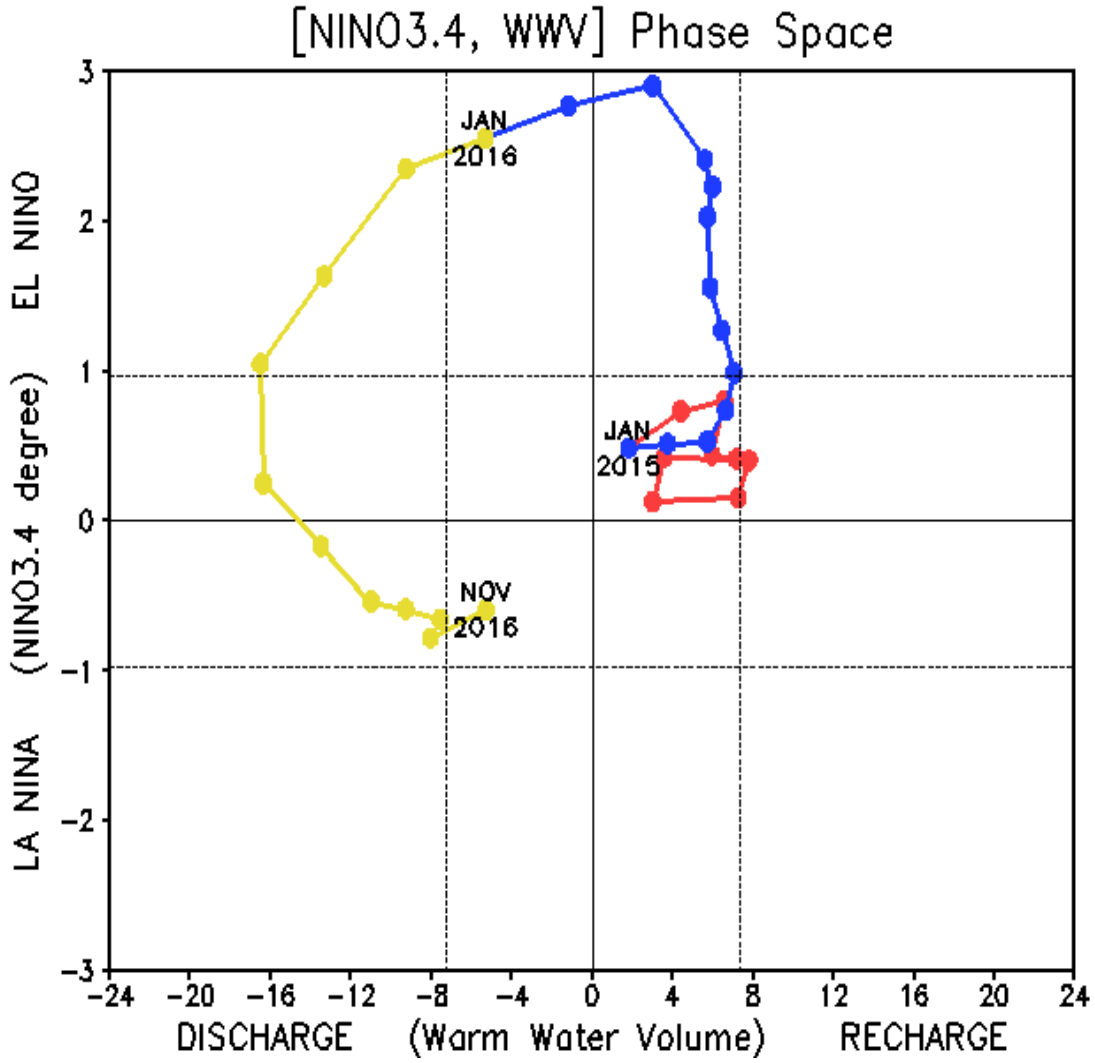


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

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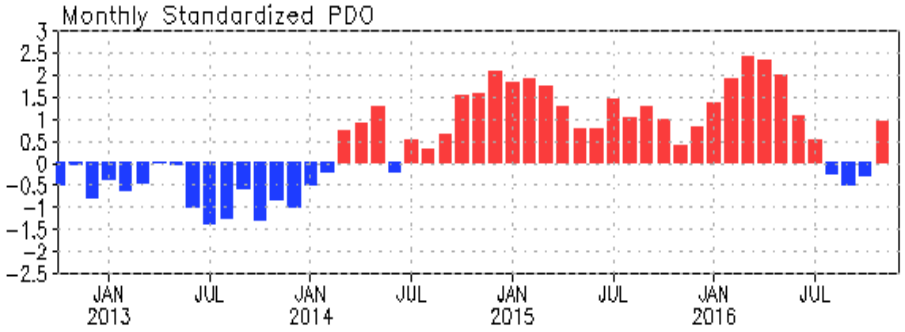
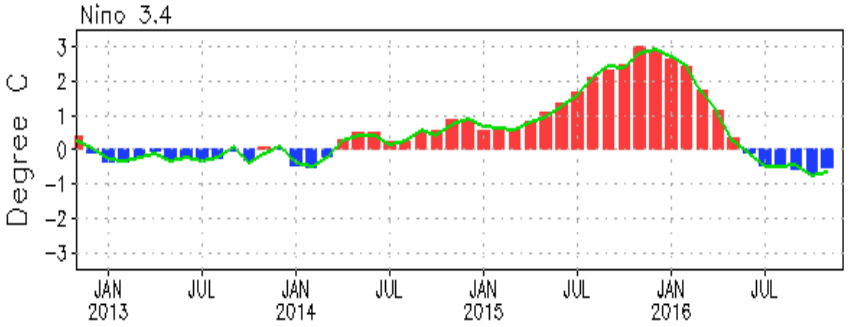
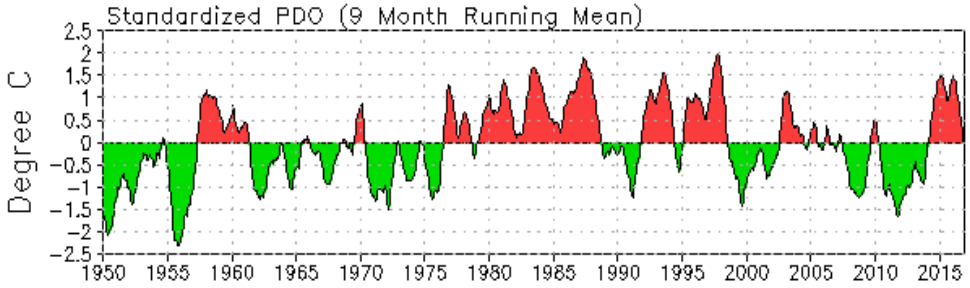
Pacific Decadal Oscillation Index

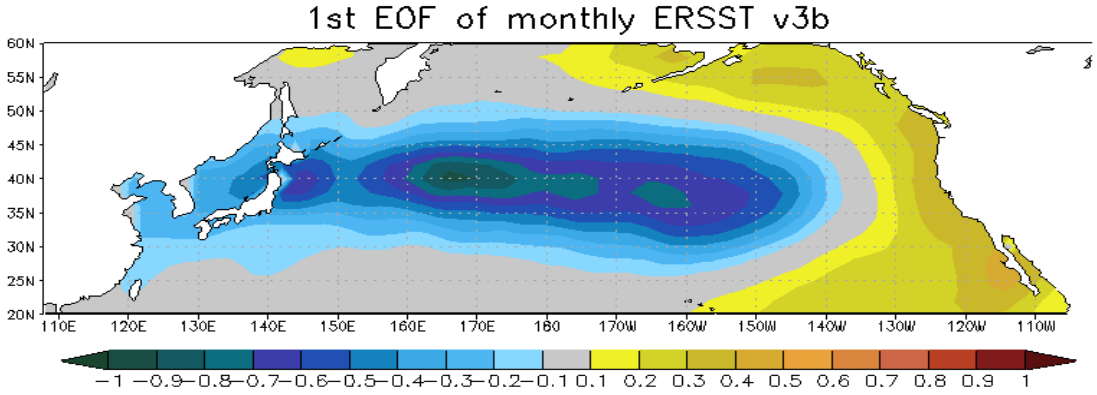






- **PDO switched to positive phase, with PDO index=0.9.**

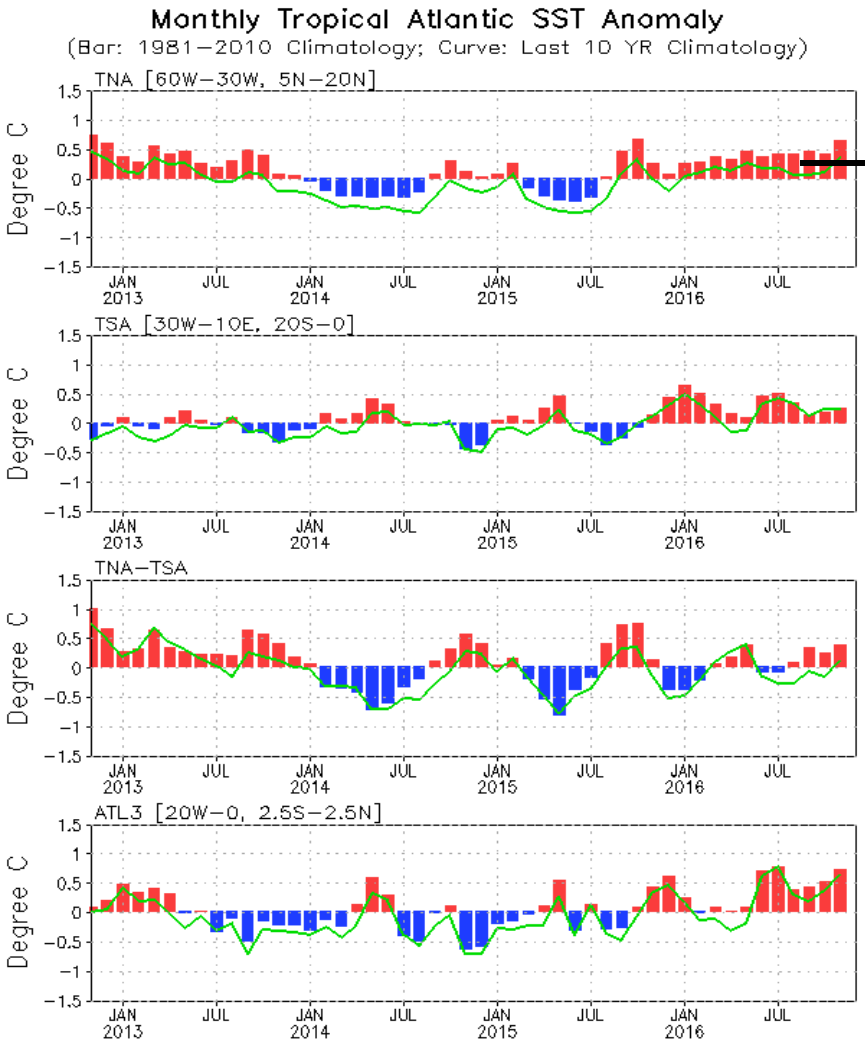
- **Statistically, ENSO leads PDO by 3-4 months, may through atmospheric bridge.**

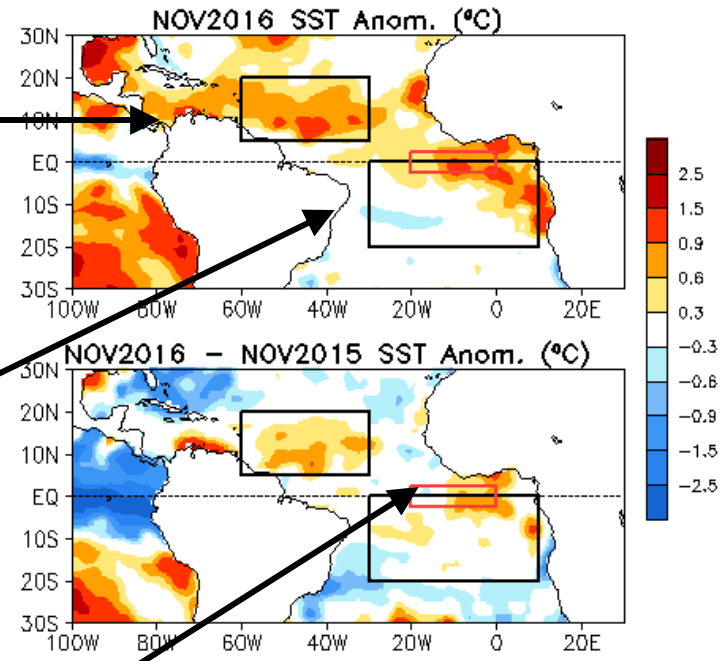


- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the ERSST v4 monthly SST anomalies onto the 1st EOF pattern.**

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

Evolution of Tropical Atlantic SST Indices





- ATL3 index increased in Nov 2016.

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

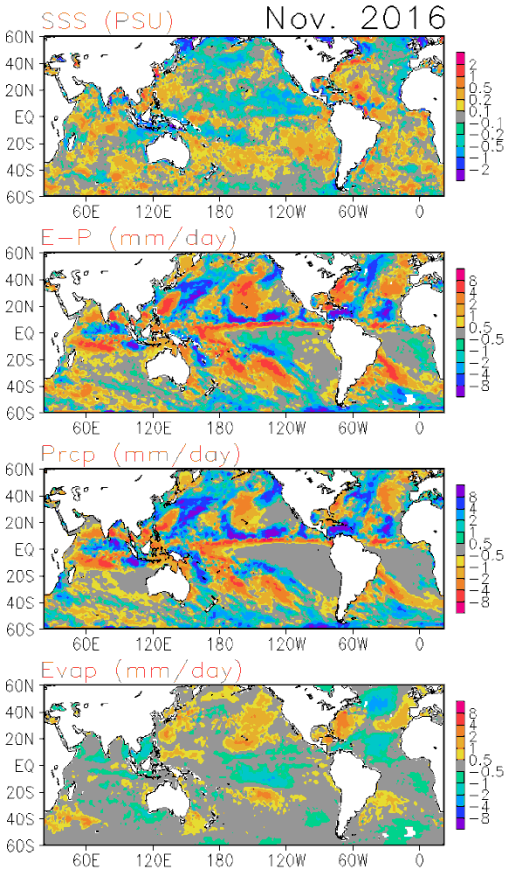
- Positive Meridional Gradient Mode index continued in Nov 2016.

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 November 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 SSS in the Pacific Ocean along the Equator generally increased, which indicates that La Nina condition is favoring. Continuous large scale of SSS decreasing appears in the east basin of North Pacific subtropics and west basin of South Pacific subtropics, but the signals are slightly weaker than last month. Large scale freshening in the subarctic regions of both North Pacific and North Atlantic ocean in the storm track regions was also observed con-incident with increasing of precipitation. The SSS in the Bay of Bengal increased with the decreasing of the precipitation in this 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

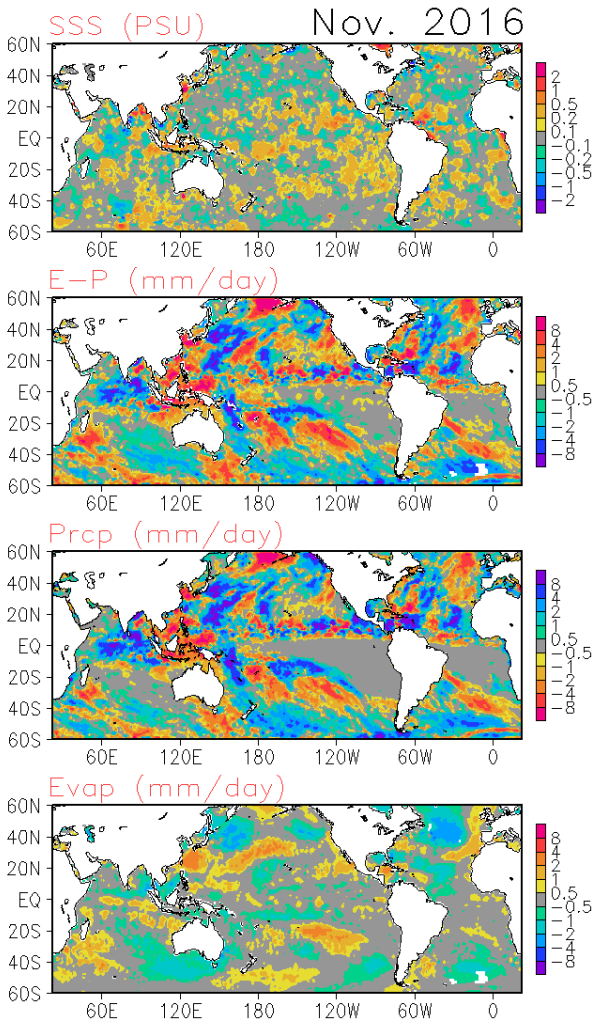
Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: CFS Reanalysis

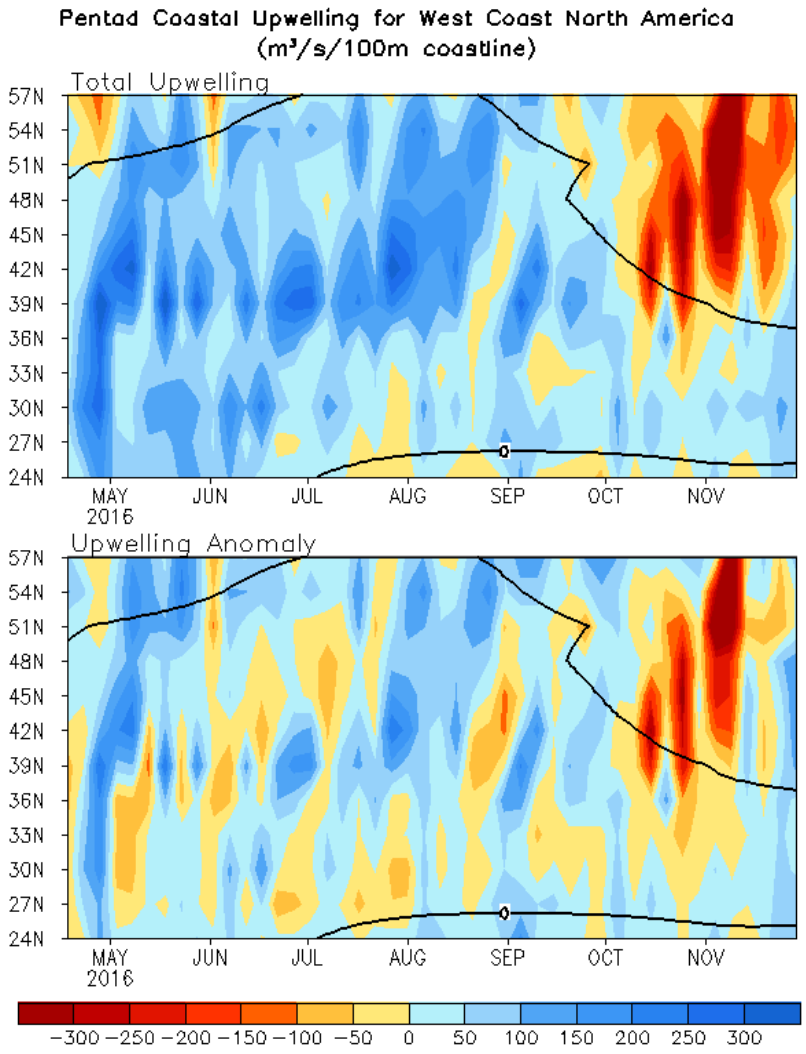
Global Sea Surface Salinity (SSS)

Tendency for November 2016

Compared with last month, the salinity in the Pacific Ocean around the equatorial region was increasing, particularly in the eastern basin, while it was decreasing in the subarctic North Pacific Ocean and poleward of 40°S South Pacific Ocean. The SSS continued increasing in the Bay of Bengal with decreasing precipitation. The SSS in the Indian Ocean south of Equator within the longitude band of 60°E to 100°E was decreased with a strong increase of freshwater flux into the ocean, which is primarily due to the increase of precipitation.



North America Western Coastal Upwelling



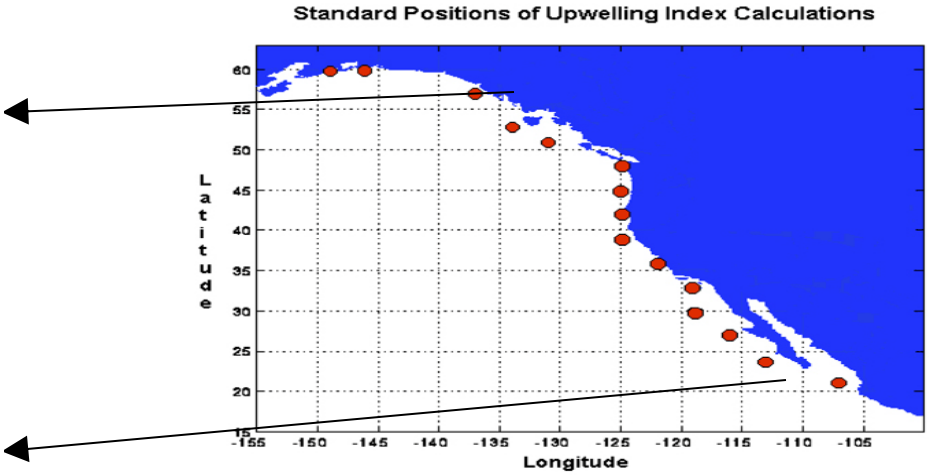


Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport 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

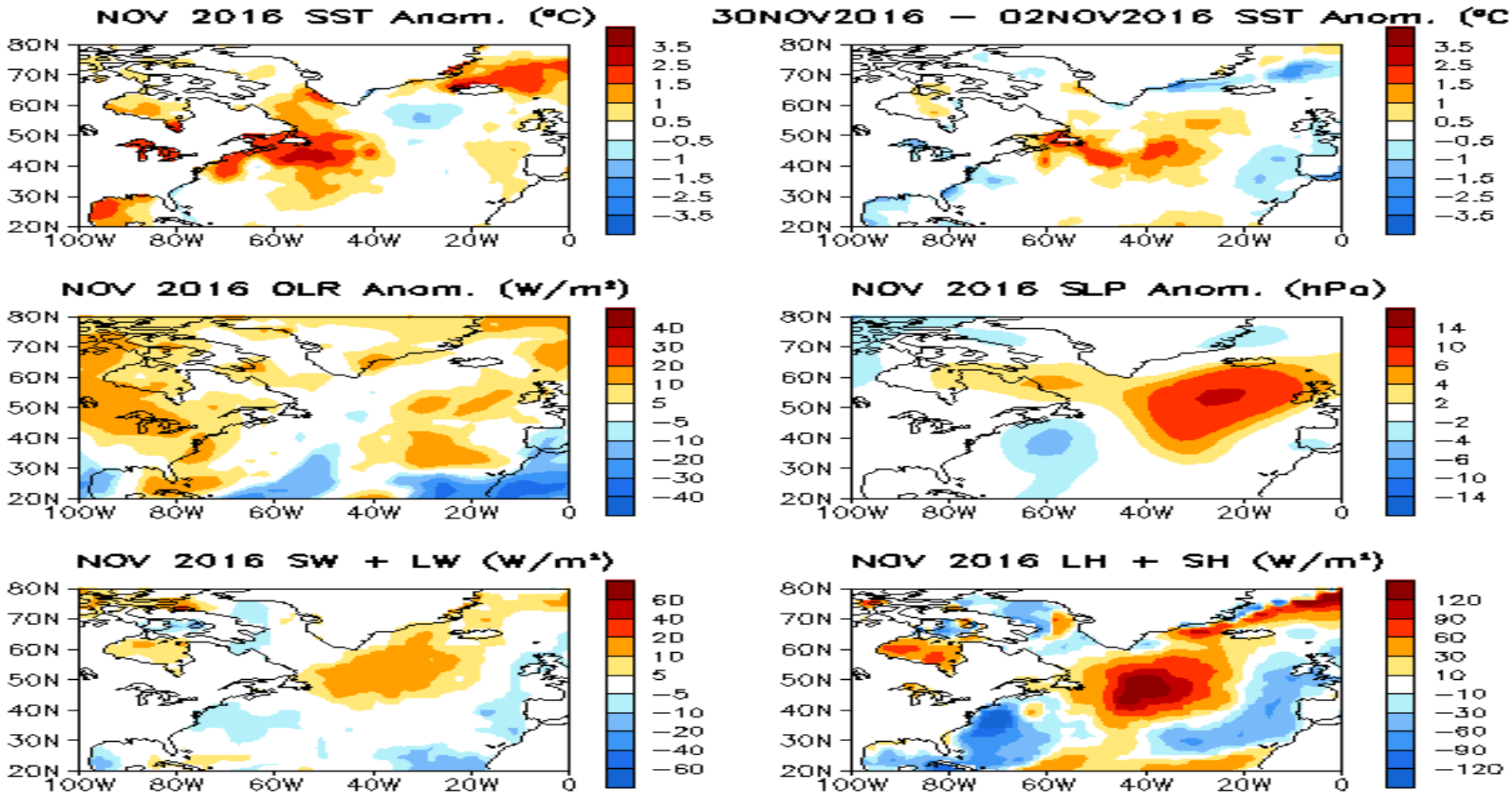
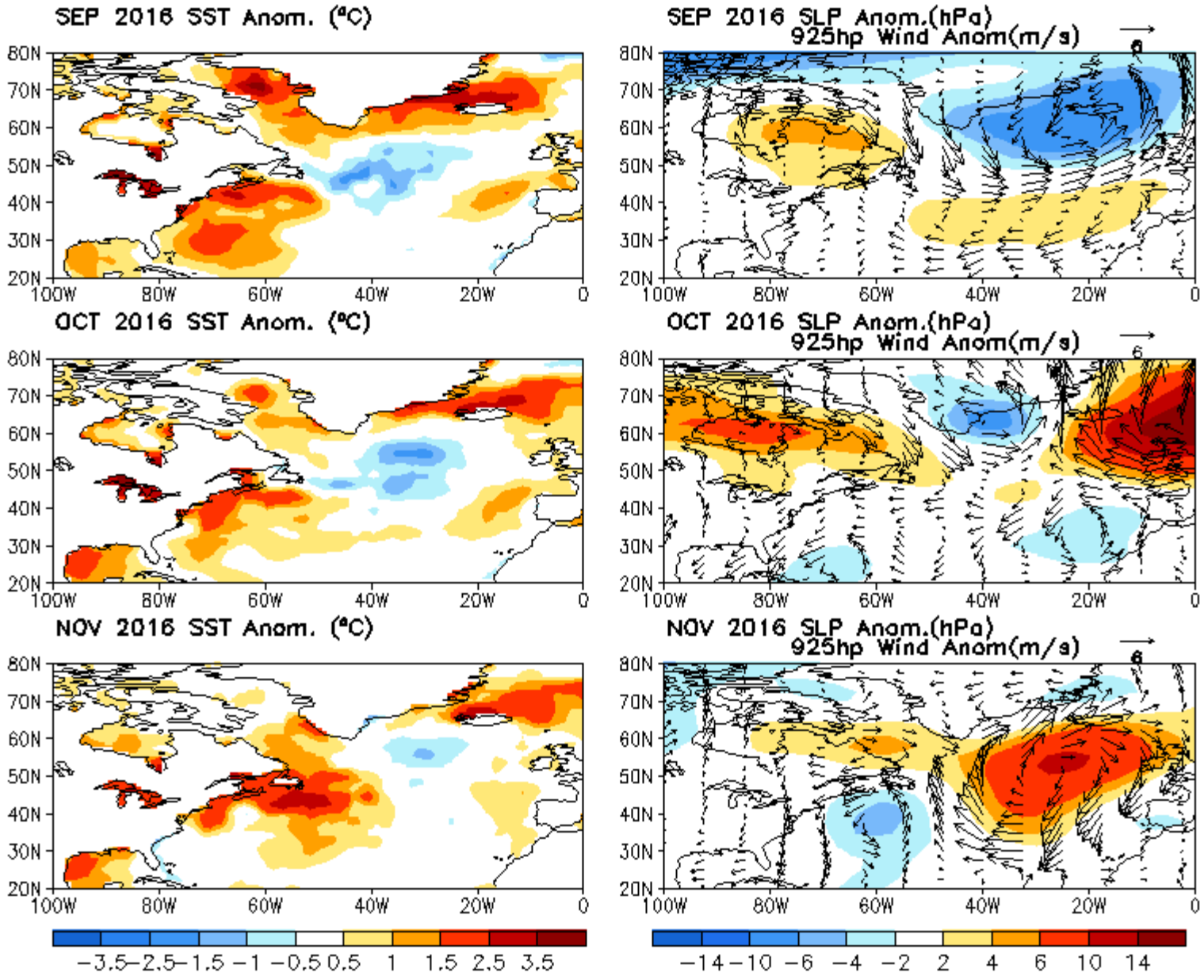
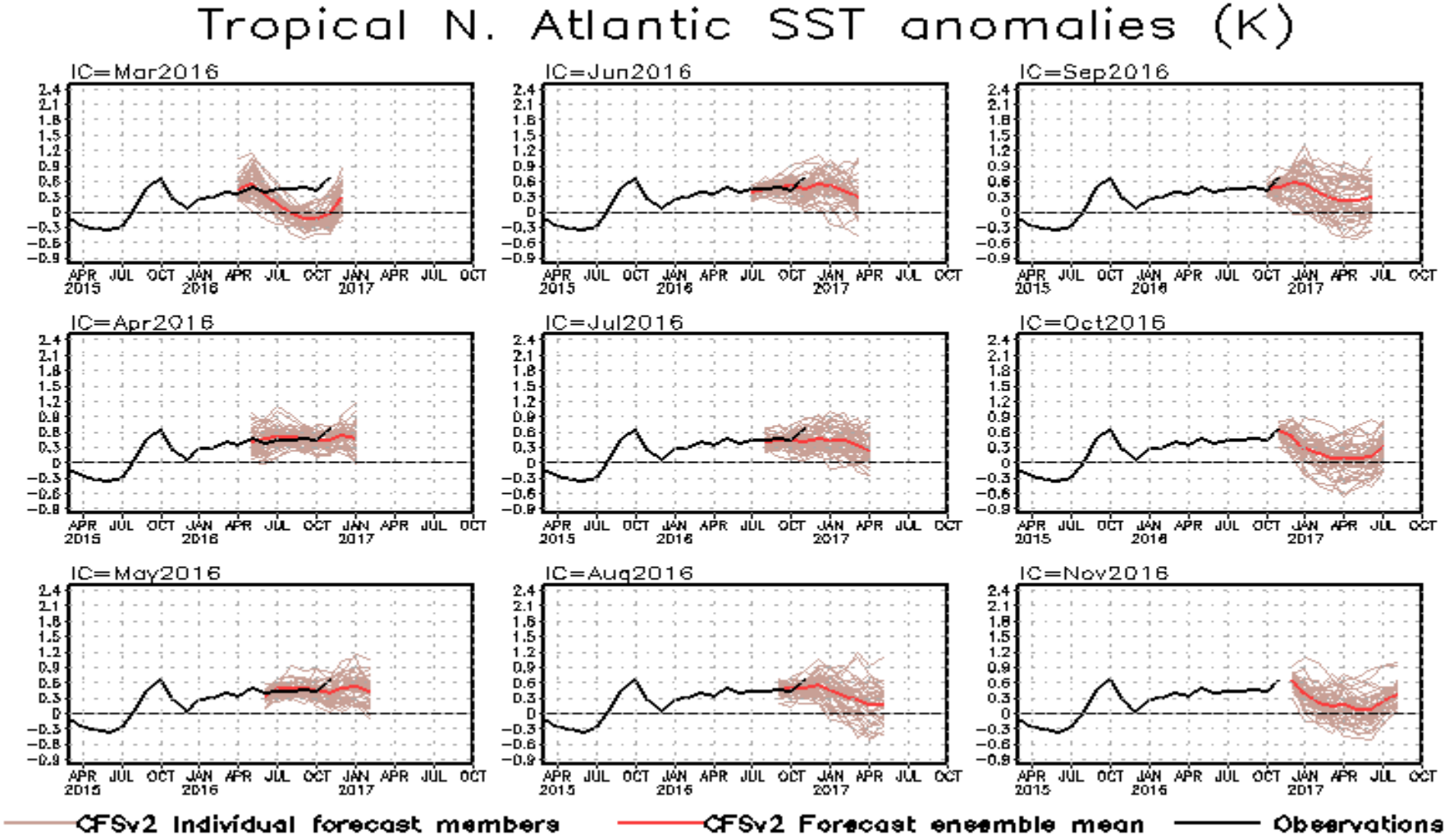


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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



Tropical North Atlantic SST Forecast by NCEP CFSv2

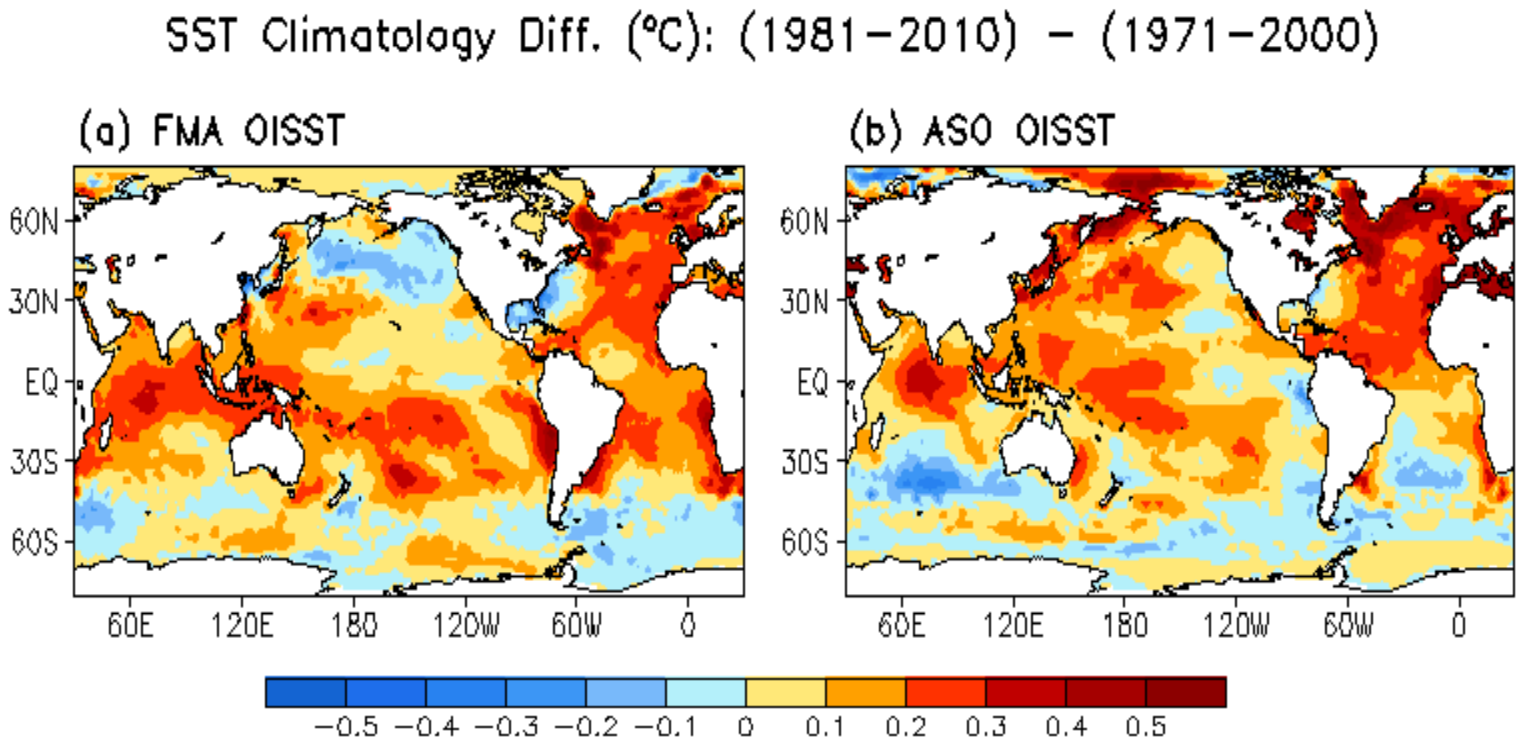


- **CFSv2 forecast the tropical North Atlantic SST will continue to be above-normal during the norther hemisphere winter 2016-17.**

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!