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

Prepared by

Climate Prediction Center, NCEP/NOAA

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

This project to deliver real-time ocean monitoring products is implemented

by CPC in cooperation with NOAA's Ocean Observing and Monitoring Division (OOMD)

Outline

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

❖ ***Impact of observing system on uncertainty in Tropical Cyclone Heat Potential in Atlantic MDR.***

❖ ***Review of prediction skill of IRI/CPC plume models and oceanic precursors for the 2017 La Niña.***

Overview

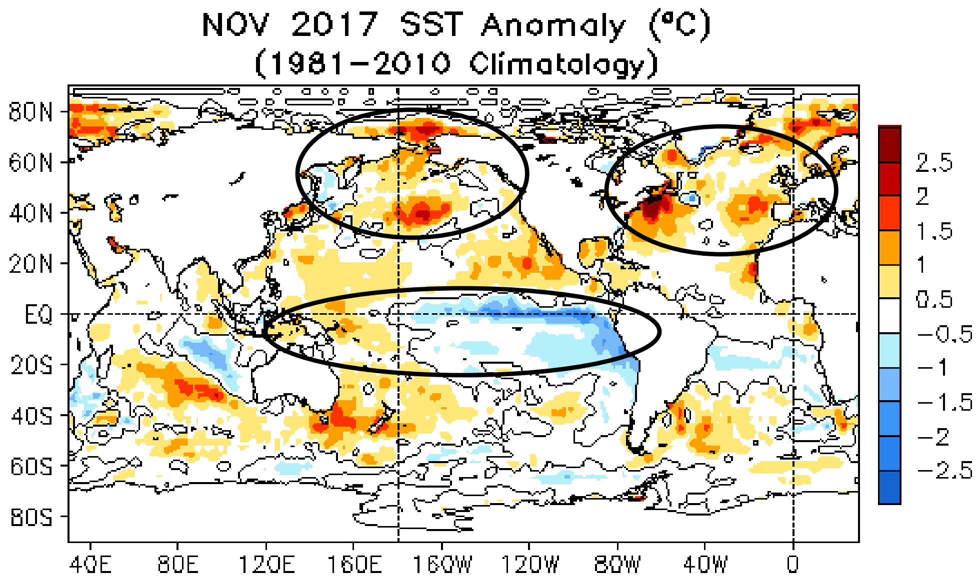
- **Pacific Ocean**
  - **La Niña conditions continued to develop in Nov 2017, and 2016-2017 are the fifth "double-dip" La Niña since 1950.**
  - **Most of models suggested La Niña conditions will continue at least through the early 2018.**
  - **Negative PDO persisted, with PDO = -0.2.**
  - **Arctic sea ice extent in Nov 2017 ranked the third lowest since 1979.**

- **Indian Ocean**
  - **Indian dipole index was near average in Nov 2017.**

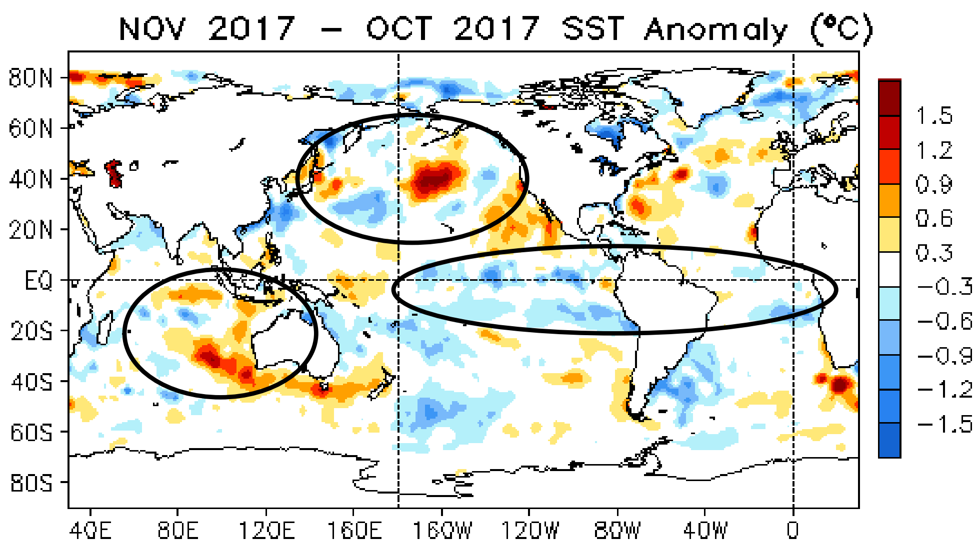
- **Atlantic Ocean**
  - **Extremely active 2017 Atlantic hurricane season ends in Nov.**
  - **Increased Argo data help to constrain the total Tropical Cyclone Heat Potential in the Atlantic MDR.**

Global Oceans

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



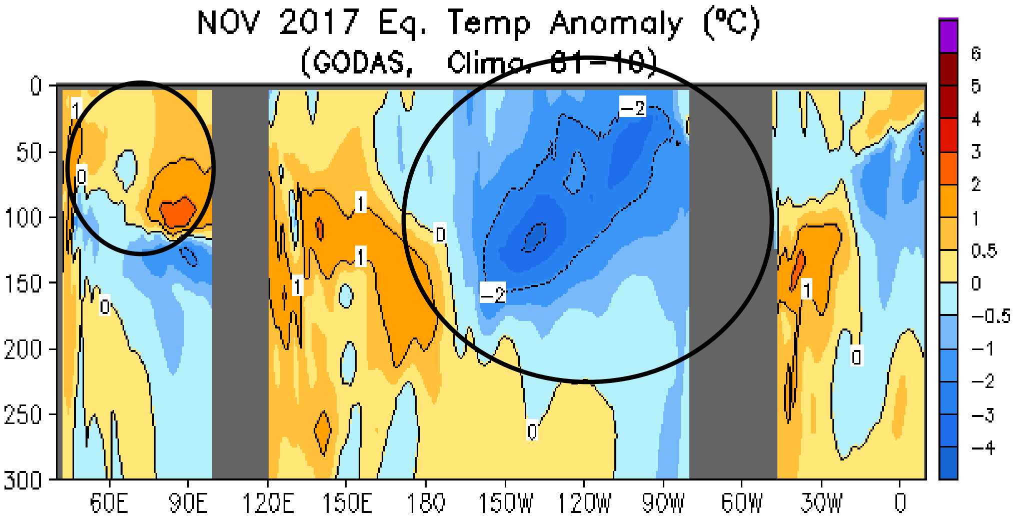
- Negative(positive) SSTA persisted in the central-eastern (western) equatorial Pacific.
- Positive SSTA continued in N. Pacific and N. Atlantic Oceans.



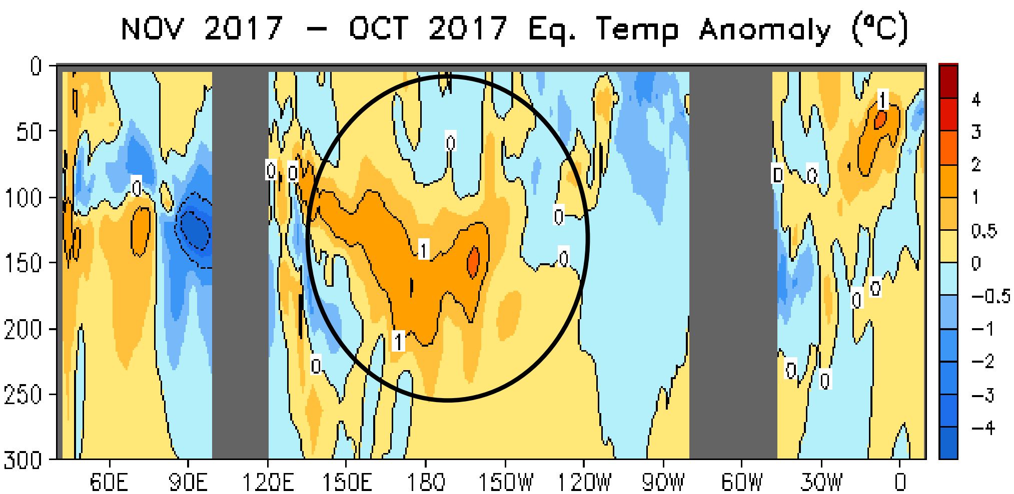
- SSTA tendency were mostly negative across the equatorial Pacific and Atlantic Oceans.
- Strong SSTA tendencies presented in the N. Pacific Ocean.
- Positive SSTA tendencies were observed in the eastern tropical Indian Ocean.

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^{O}S-2^{O}N



- Negative (positive) temperature anomalies persisted in the central-eastern (western) Pacific.
- Positive ocean temperature anomalies continued in upper 100m of Indian Ocean.

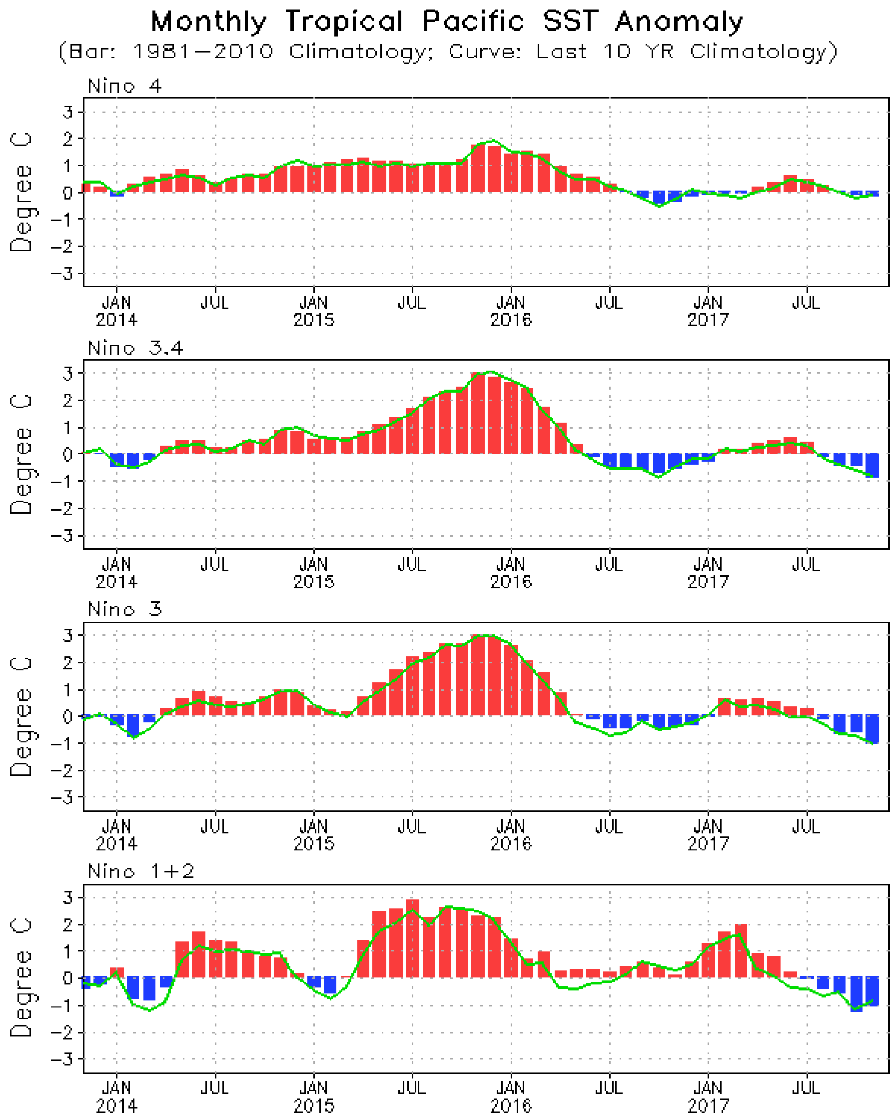


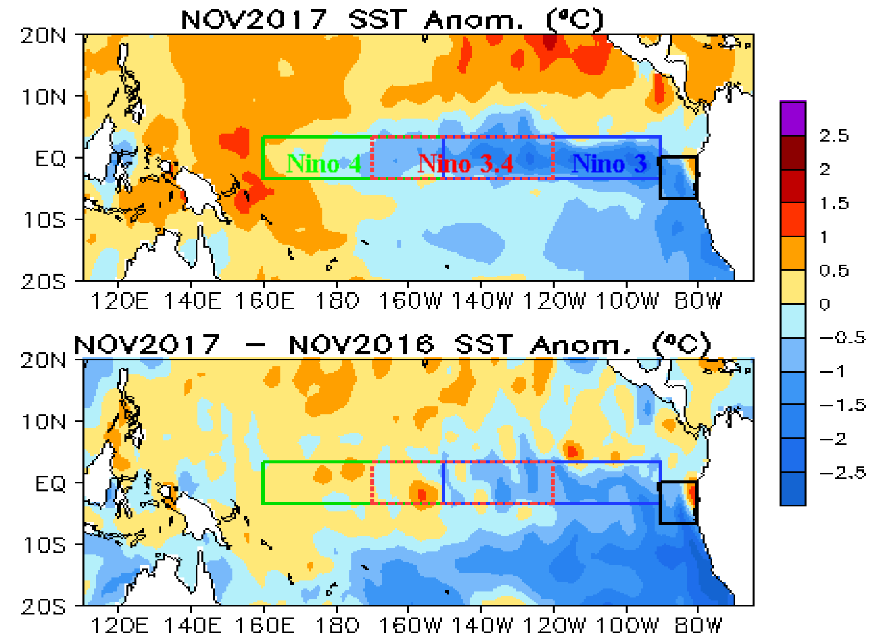
- Subsurface temperature tendencies were mostly positive across the western-central equatorial Pacific.
- Negative tendencies dominated in the equatorial eastern Indian Ocean.

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

Evolution of Pacific NINO SST Indices





- **All Nino indices were below-average in Nov 2017.**

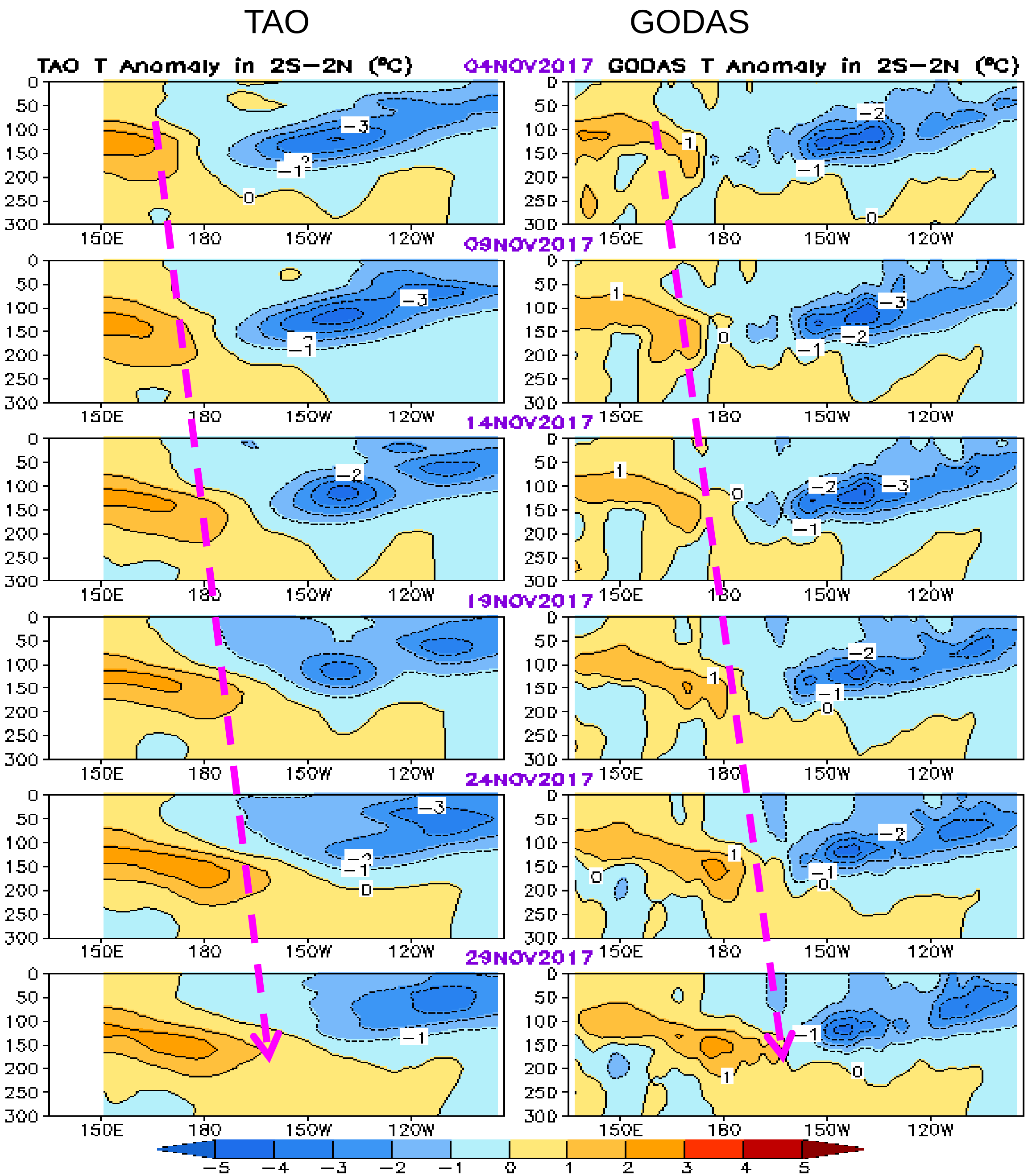
- **Nino3.4 strengthened substantially in Nov 2017, with Nino34 = -0.9°C.**

- **Compared with last Nov, the central (eastern) equatorial Pacific was warmer (colder) in Nov 2017.**

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

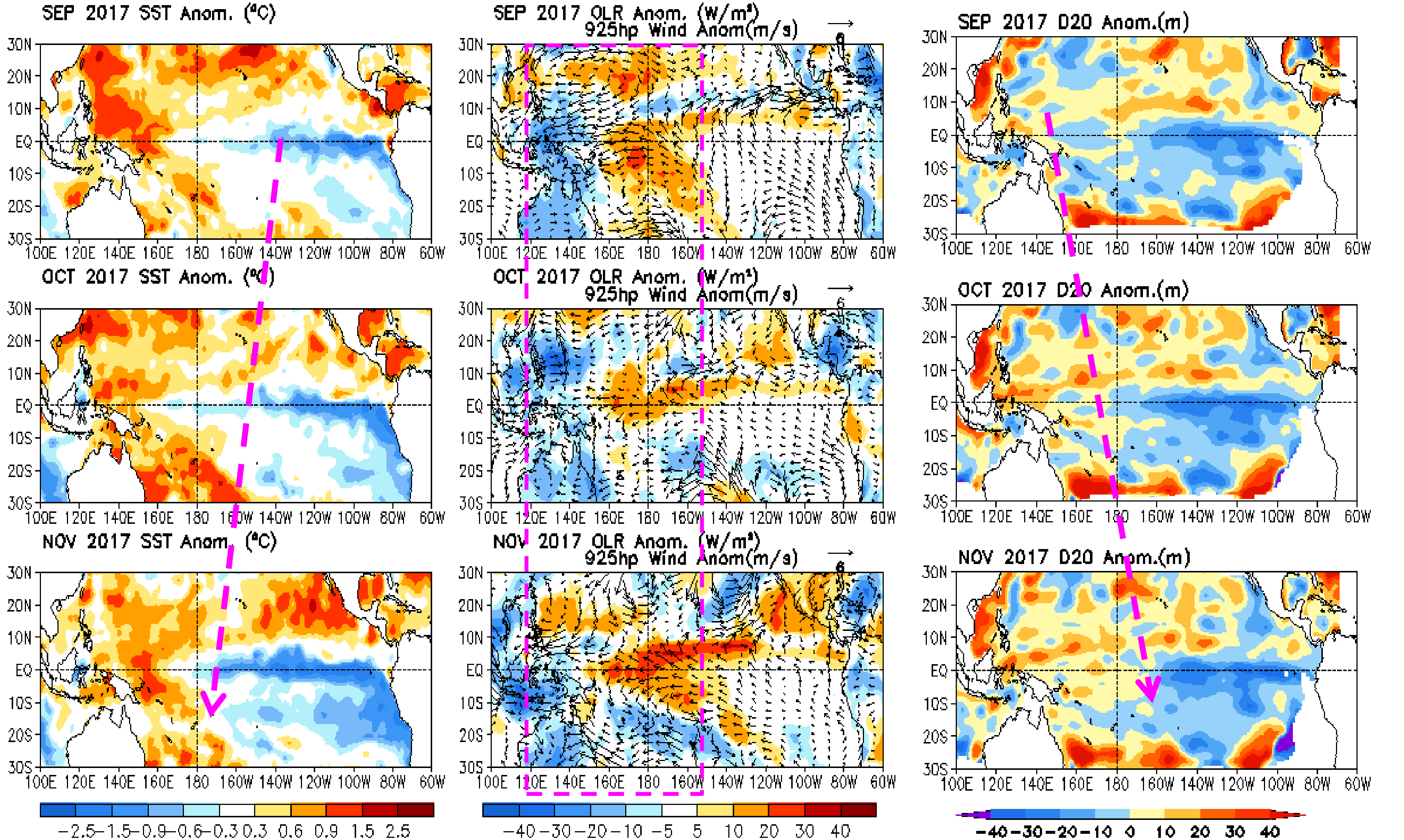
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



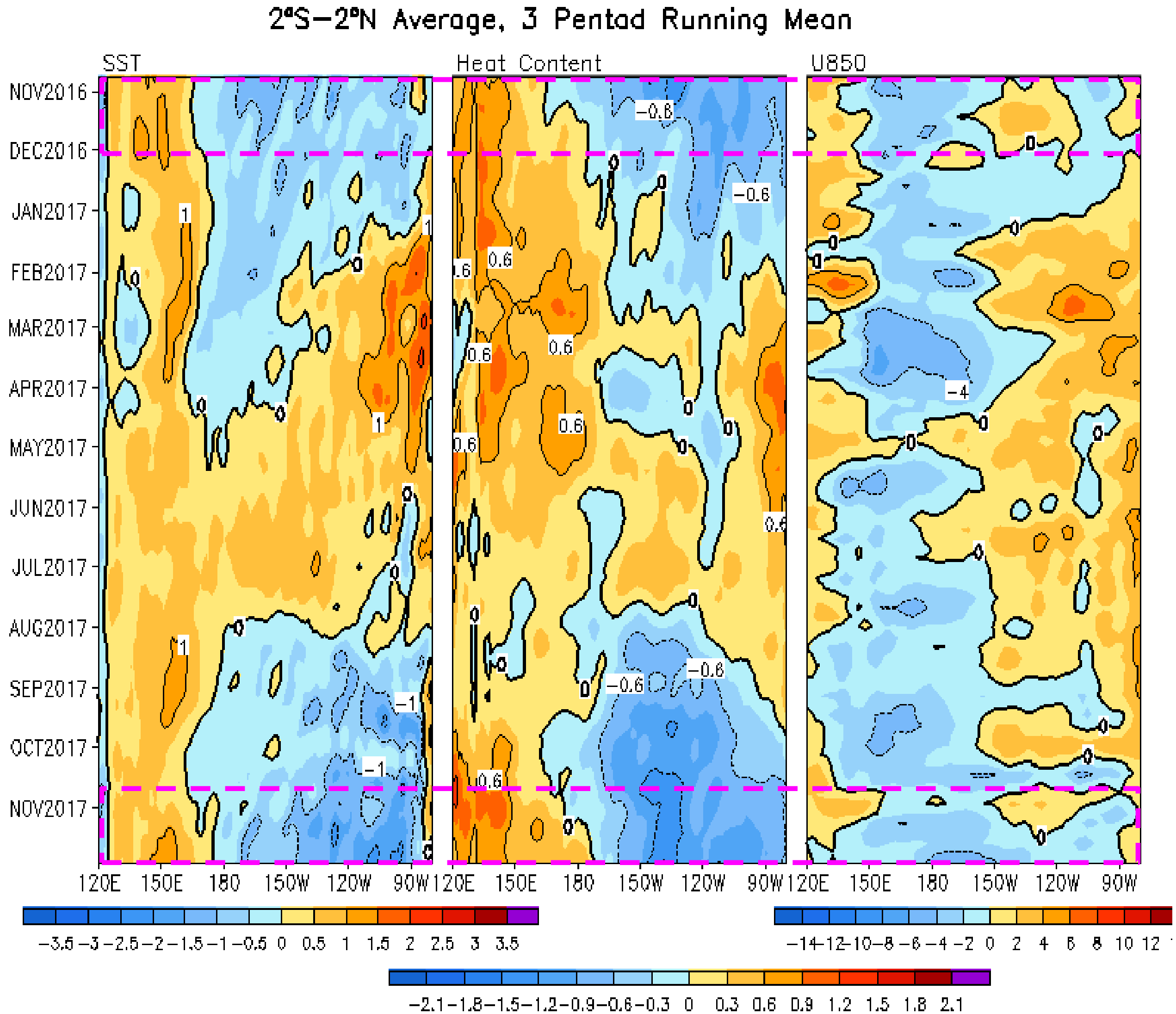
- Subsurface warming in the western Pacific steadily propagated eastward in the last six pentads.
- The extent and strength of negative temperature anomalies have declined slightly in the last three pentads.

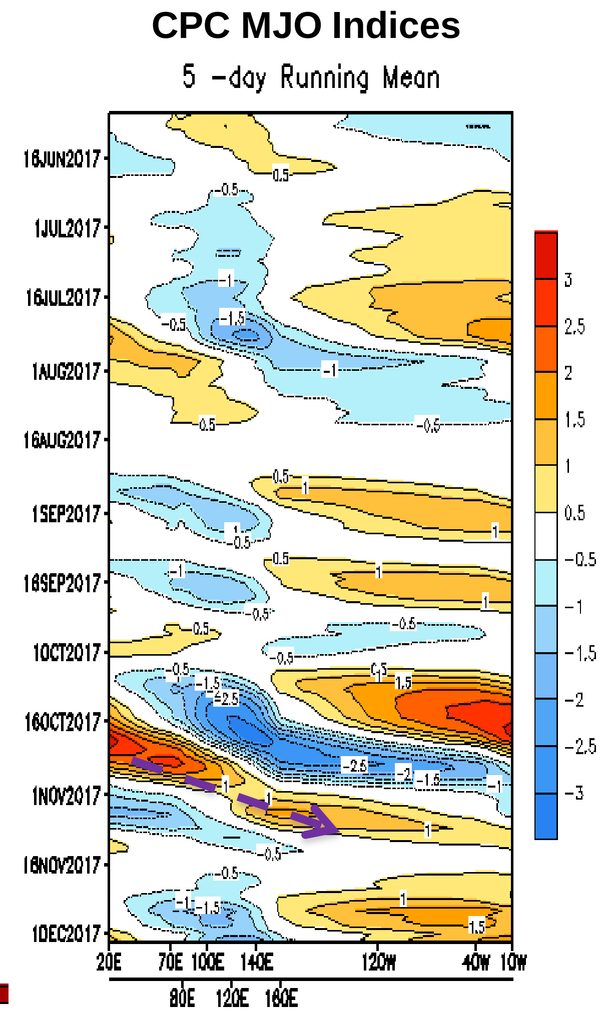
Last Three Month SST, OLR&925hp Wind, and D20 Anomalies



- Negative SSTAs strengthened and propagated westward in the last three months.
- Positive ORA anomalies strengthened in the central Pacific.
- Negative D20 anom. persisted in the central-eastern equatorial Pacific, while positive D20 anom. in the W.Pac propagated eastward.

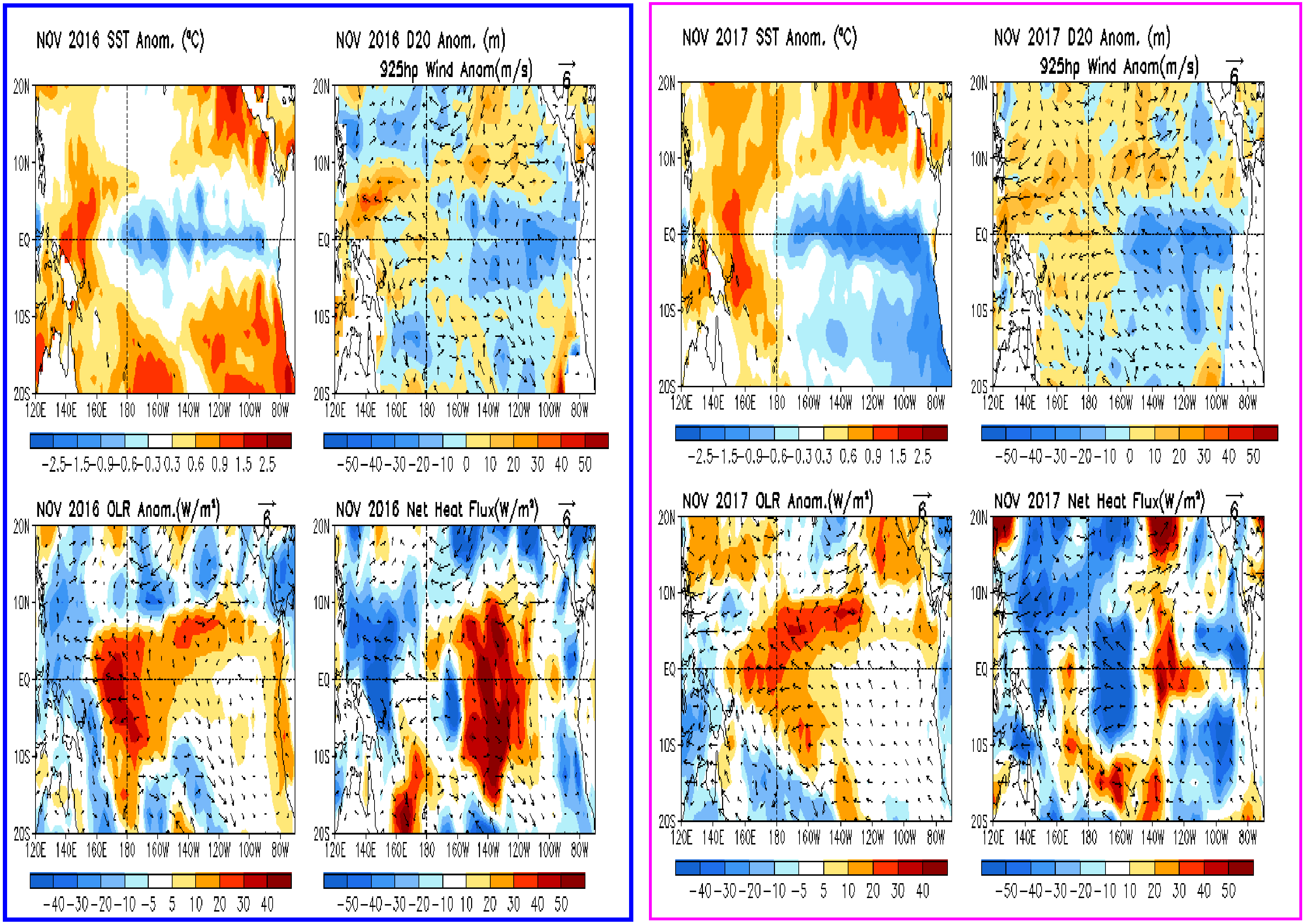
Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies





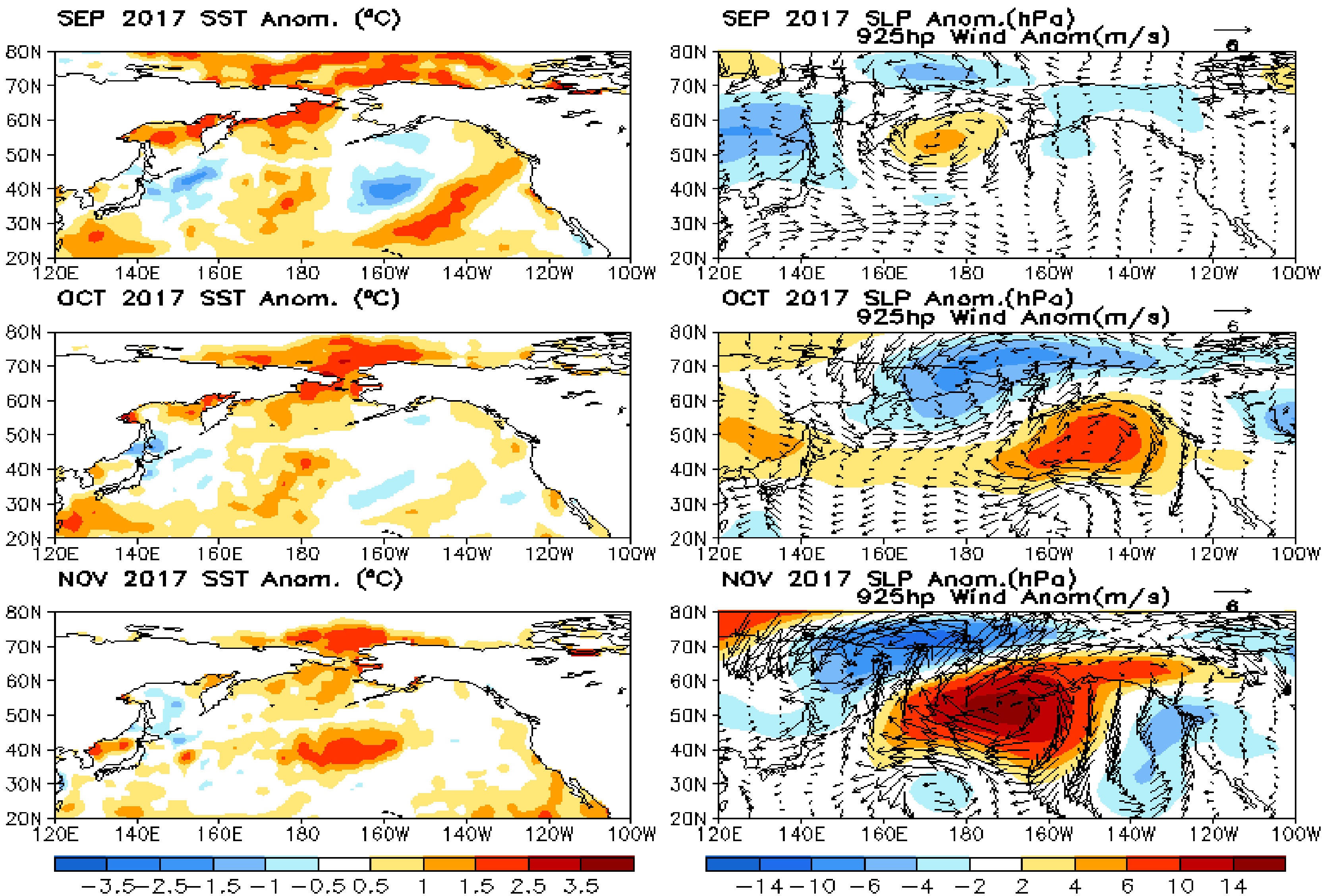
- **Negative SSTAs and HC300A persisted in the central-eastern equatorial Pacific in Nov 2017.**
- **Easterly wind anomalies enhanced in the late Nov 2017.**
- **2016-2017 is the fifth "double dip" La Niña since 1950 (http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php).**

2016-2017 "double dip" La Niña



North Pacific & Arctic Oceans

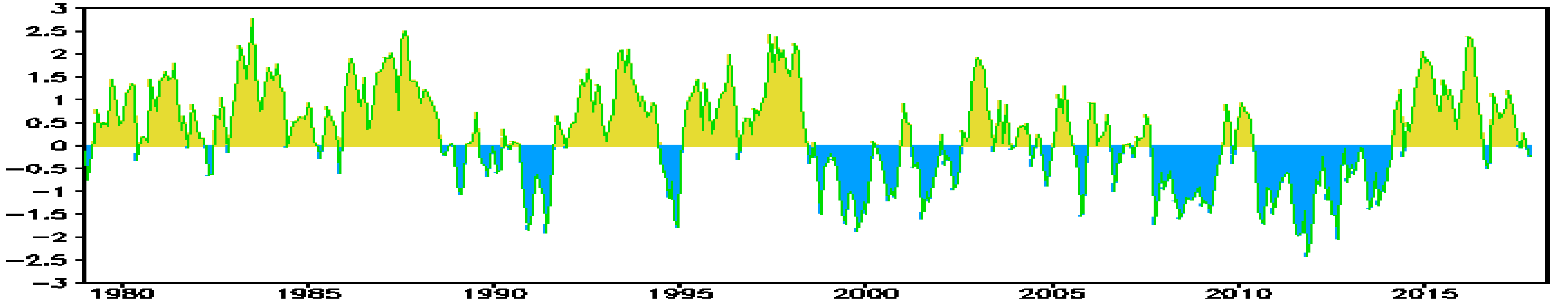
Last Three Month SST, SLP and 925hPa Wind Anomalies



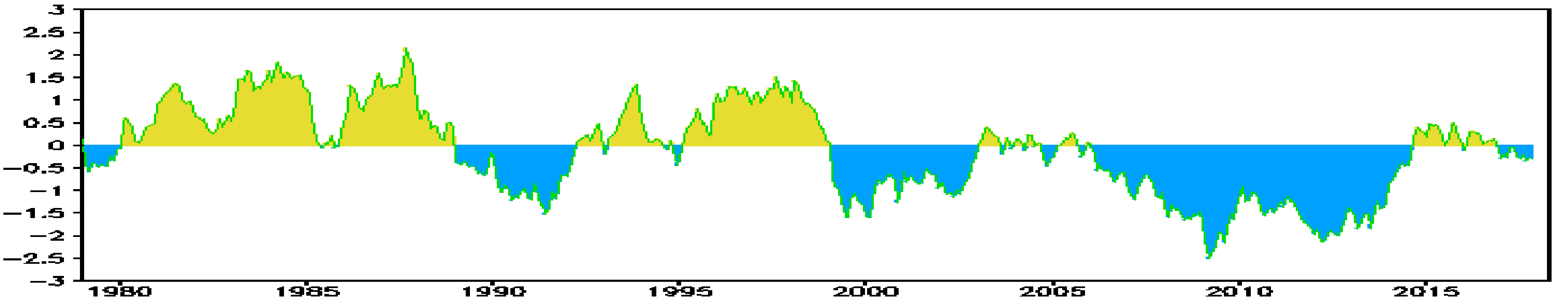
- **SST warming persisted in the Artic Ocean and the high latitudes of North Pacific.**
- **SST anomalies between 20-50N varied month by month, owing to the high frequency changes in the atmospheric circulation.**

Two Oceanic PDO indices

SST-based PDO



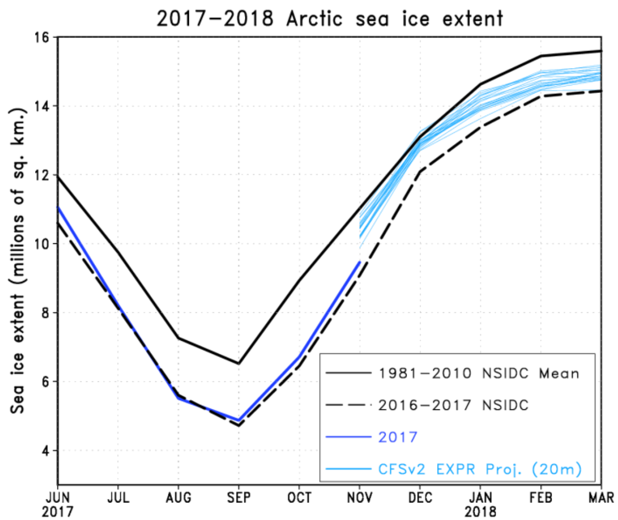
H300-based PDO



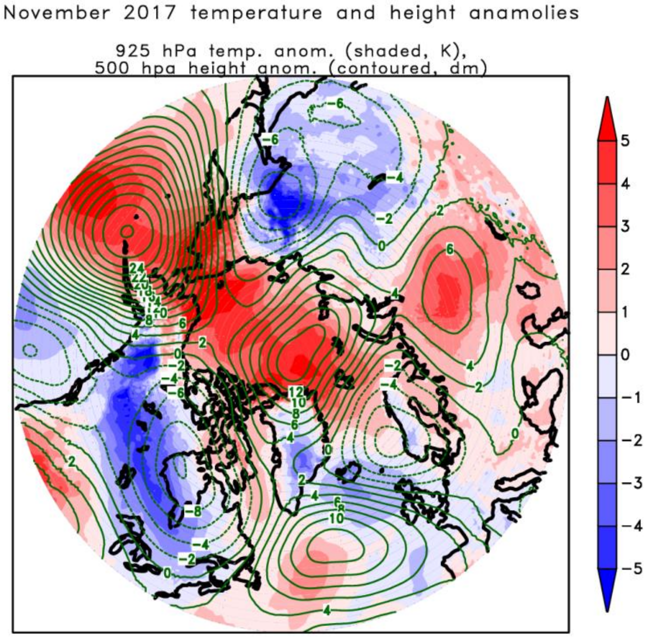
- SST-based PDO index switched to negative phase in Oct 2017, with PDO index =-0.2 in Nov 2017.
- Negative H300-based PDO index has persisted 12 months since Nov 2016, with HPDO = -0.3 in Nov 2017.

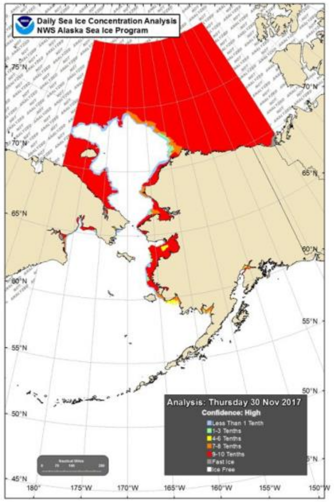
- SST-based PDO index has considerable variability on both seasonal and decadal time scales.

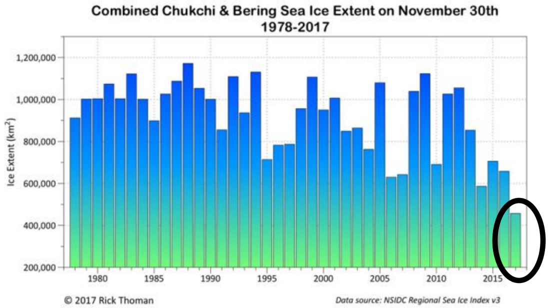
SST-based Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the ERSST v4 monthly SST anomalies onto the 1st EOF pattern. H300-based Pacific Decadal Oscillation is defined as the projection of monthly mean H300 anomalies from NCEP GODAS onto their first EOF vector in the North Pacific.



December 4, 2016, 2017 ice cover comparison





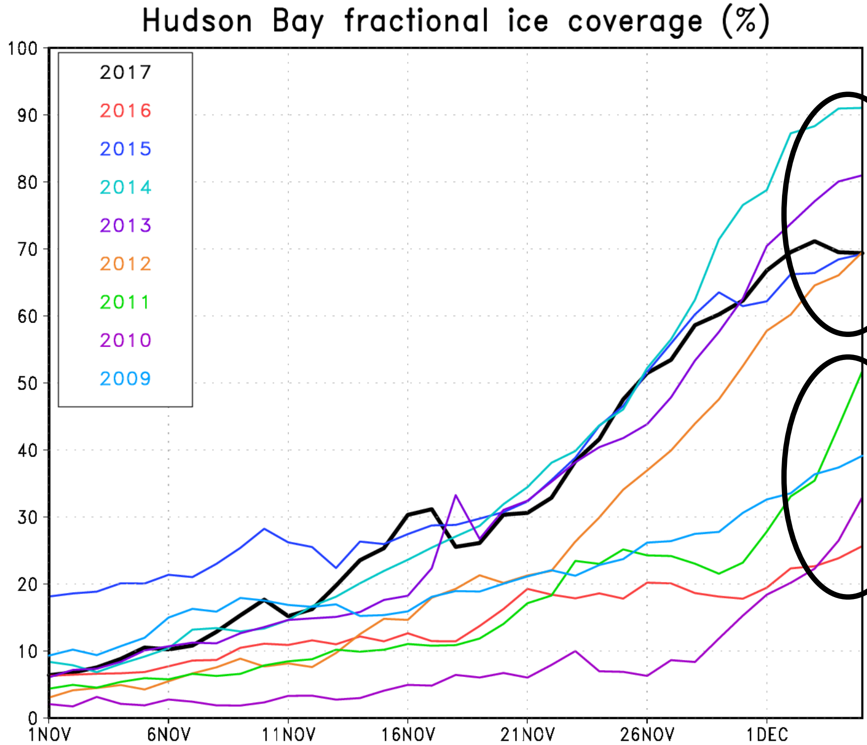


-Arctic sea ice extent for November was 9.46 million km^2 making it 3rd lowest November in the satellite record extending back to 1979

-Sea ice extent in the Chukchi Sea was at a record low this year due to persistent very warm temperature anomalies

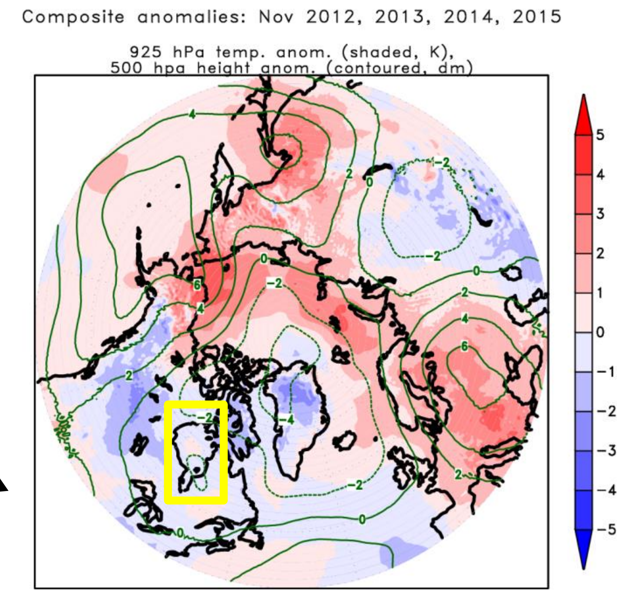
-The largest difference is the earlier freeze-up in Hudson Bay this year compared to last, which can be explained by the cool temperature anomalies seen across Canada

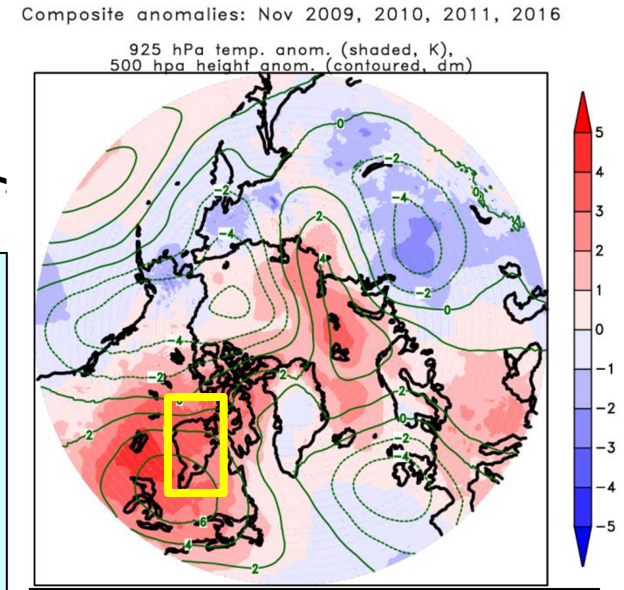
Hudson Bay sea ice freeze-up



2012, 2013, 2014, 2015, (2017)

2009, 2010, 2011, 2016





-Hudson Bay sea ice freeze-up is shown to be about 2 weeks later during the 2000-2014 period compared to the 1980-1994 period in Collow, Wang, and Kumar (2016, Clim. Dyn.).

-However, there is still year to year variability with faster freezing years (2017) and slower freezing years (2016) in the recent period

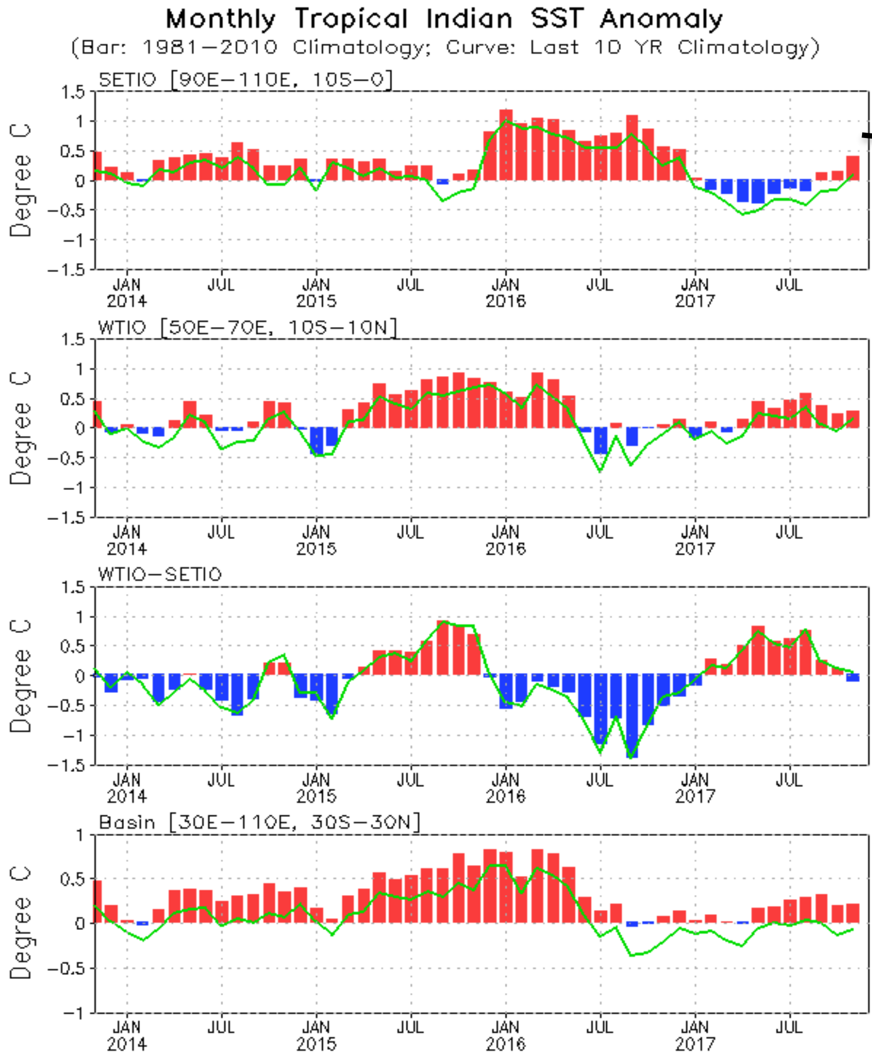
-Earlier freeze: associated with ridge over the North Pacific and associated downstream toughing over North America and neutral to cool temperature anomalies locally

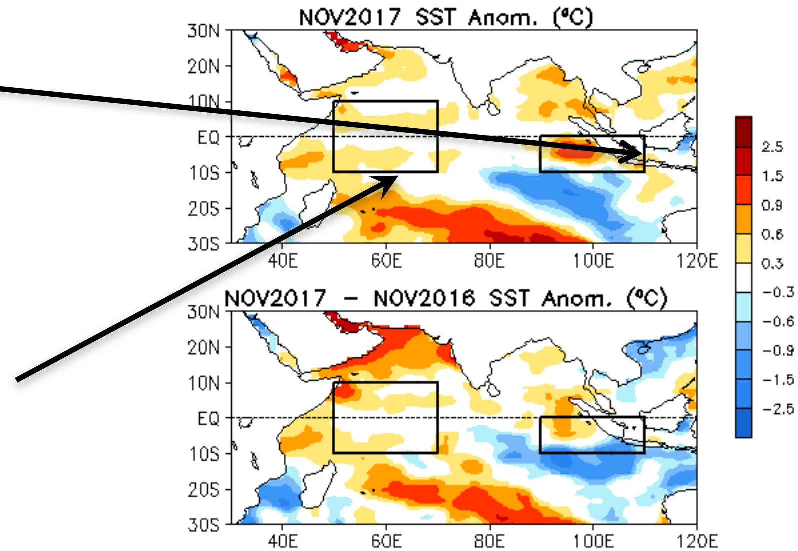
-Later freeze: ridge/warmth centered over eastern North America

Bottom line: Single extent value does not yield any info. for specific regions (ex. Chukchi Sea, Hudson Bay)

Indian Ocean

Evolution of Indian Ocean SST Indices





- SST warming in the SE. tropical Indian strengthened in Nov 2017.

- Dipole index was near normal in Nov 2017.

- Basin index was positive since May 2017.

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

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

- **Strong negative SSTA observed in the southeastern Indian Ocean.**

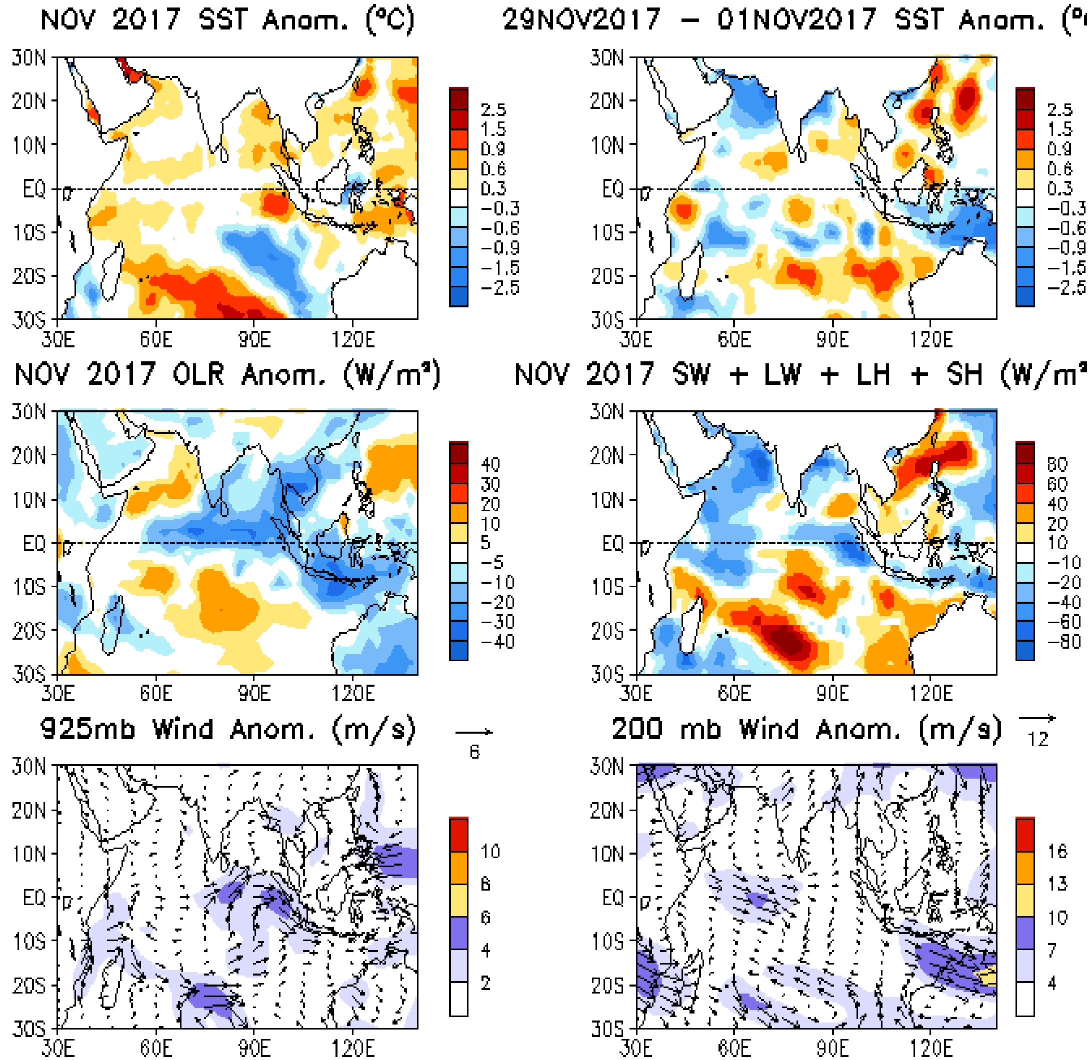
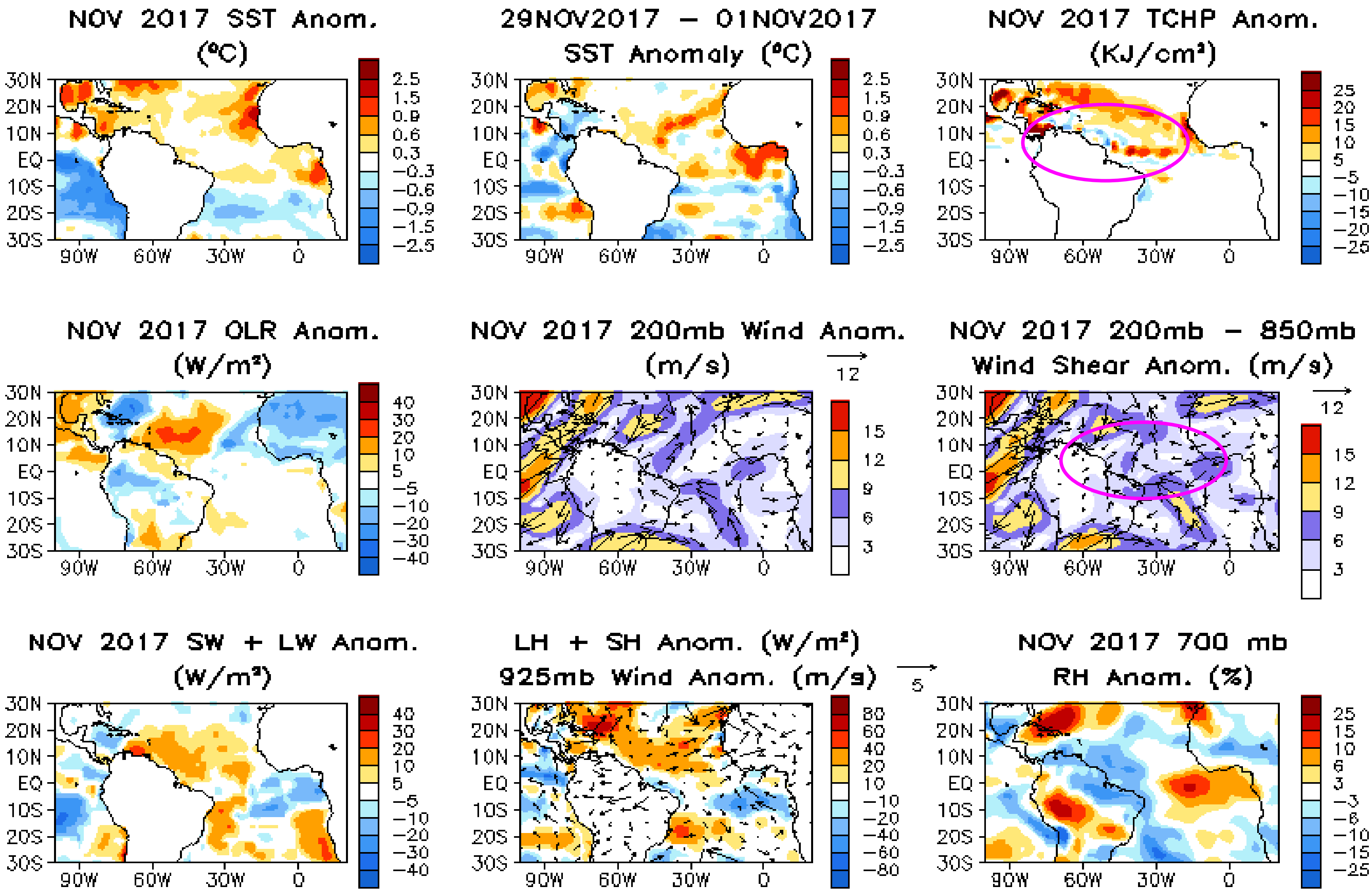


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Tropical and North Atlantic Ocean

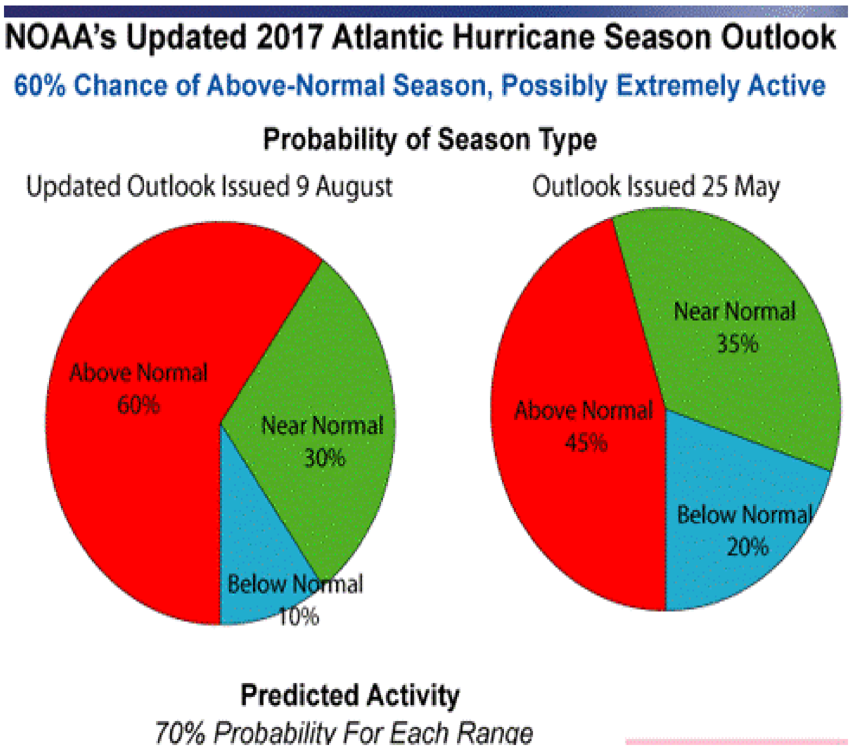
Tropical Atlantic:

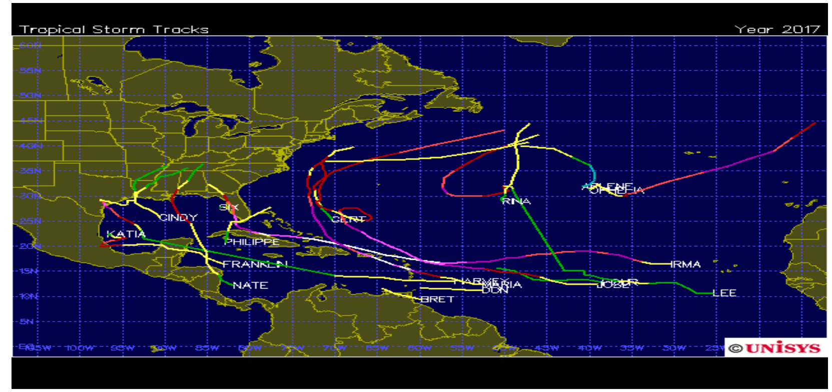
SST, SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, TCHP, 925-mb/200-mb Winds anom.



2017 Atlantic Hurricane Season

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



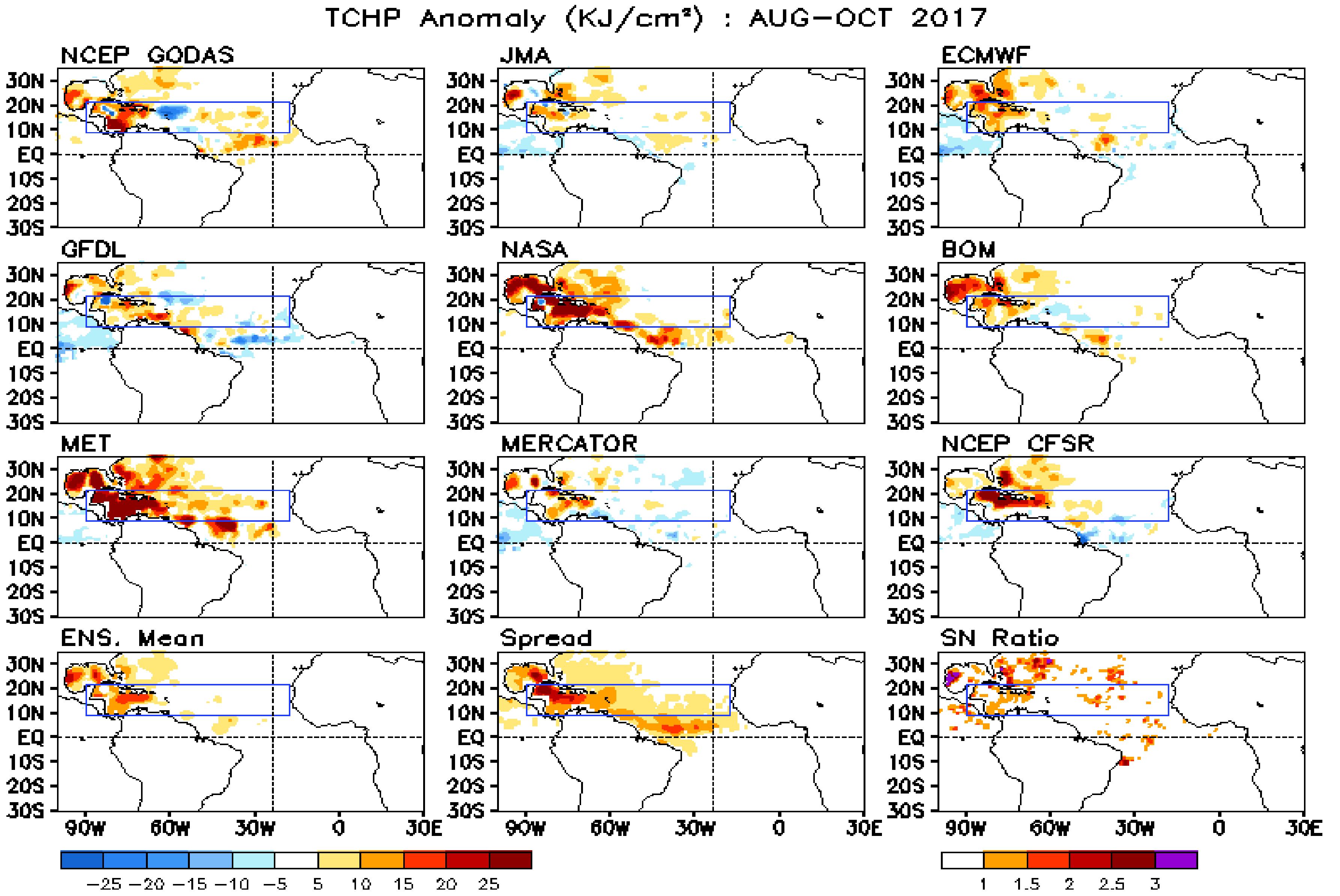


(http://weather.unisys.com/hurricane)

- **Extremely active 2017 Atlantic hurricane season ended in Nov.**
- **Three devastating major Hurricanes (Harvey, Irma and Maria) made landfall.**

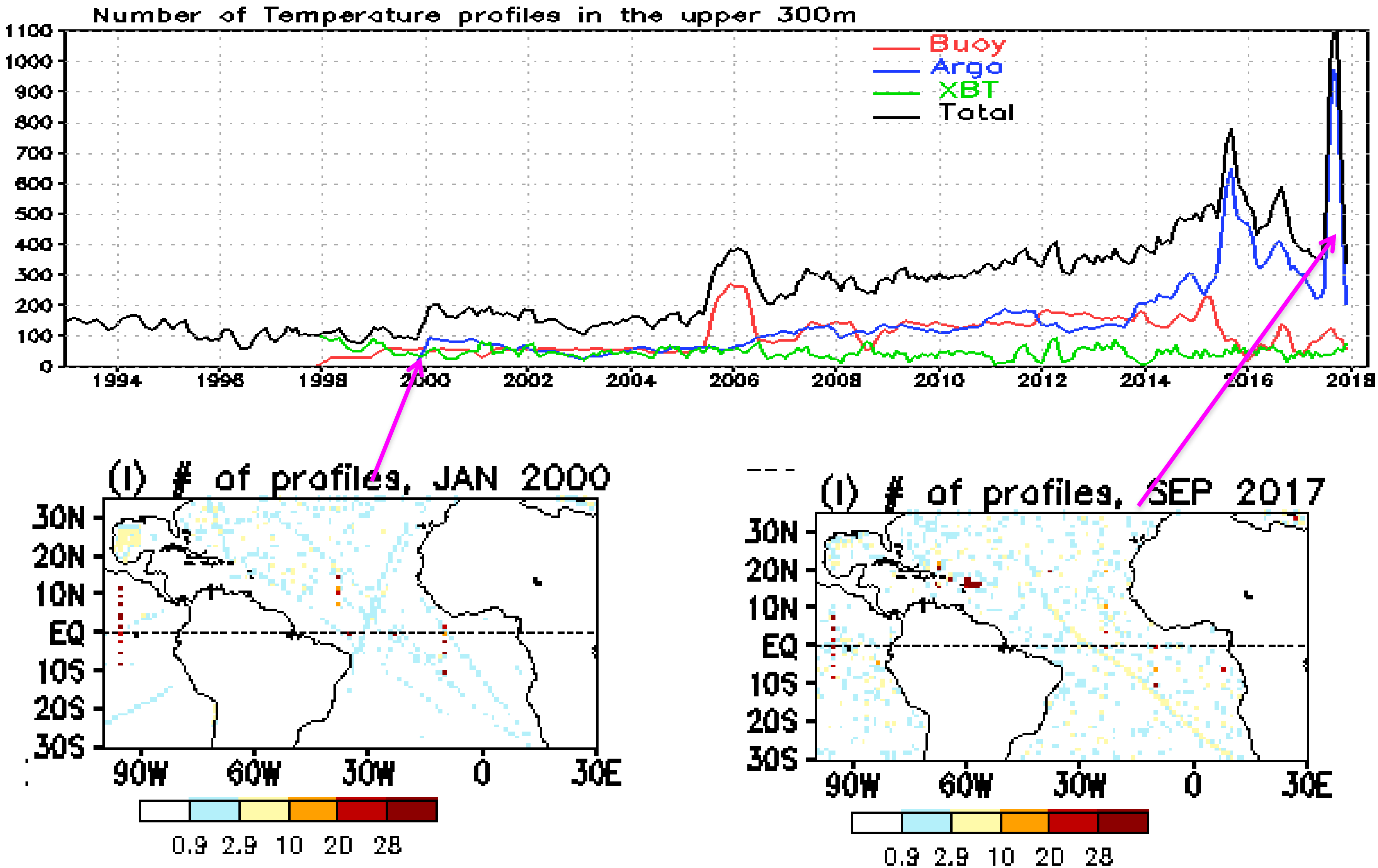
N. Atlantic	**Observation by Dec 8, 2016**	**August Update 60% Above normal**	May Outlook **45% above-normal**	**Season Average 1981-2010**
Named storms	17	14-19	11-17	**12**
Hurricanes	10	5-9	5-9	**6**
Major hurricanes	6	2-5	2-4	**3**
ACE(% median)	**225%**	100-170%	75-155%	**66-103%**

Tropical Cyclone Heat Potential (TCHP) Anomaly (KJ/cm**2)



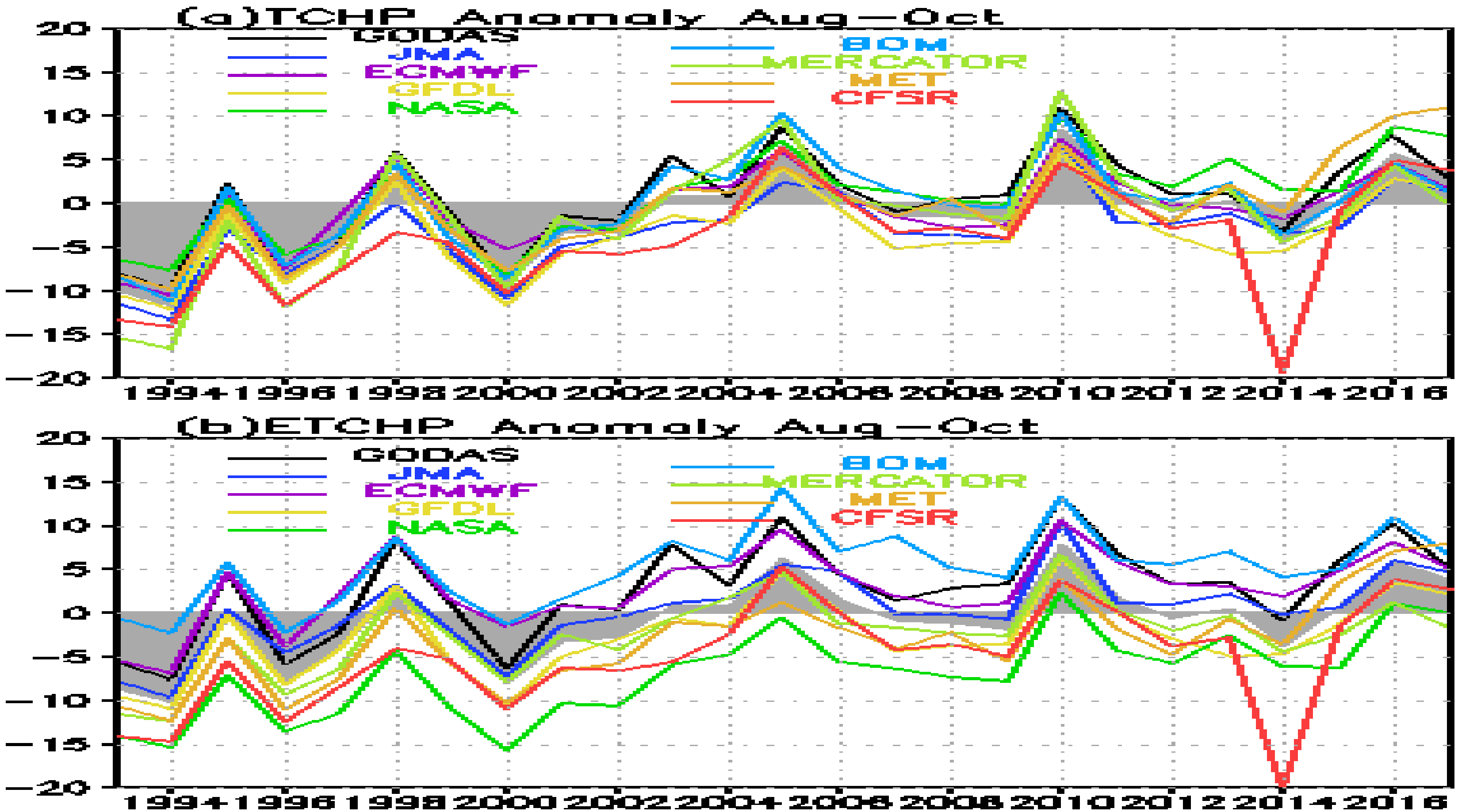
- Strong positive TCHP anom. observed in the hurricane MDR during the 2017 hurricane season.

Evolving observing system in Atlantic Hurricane MDR



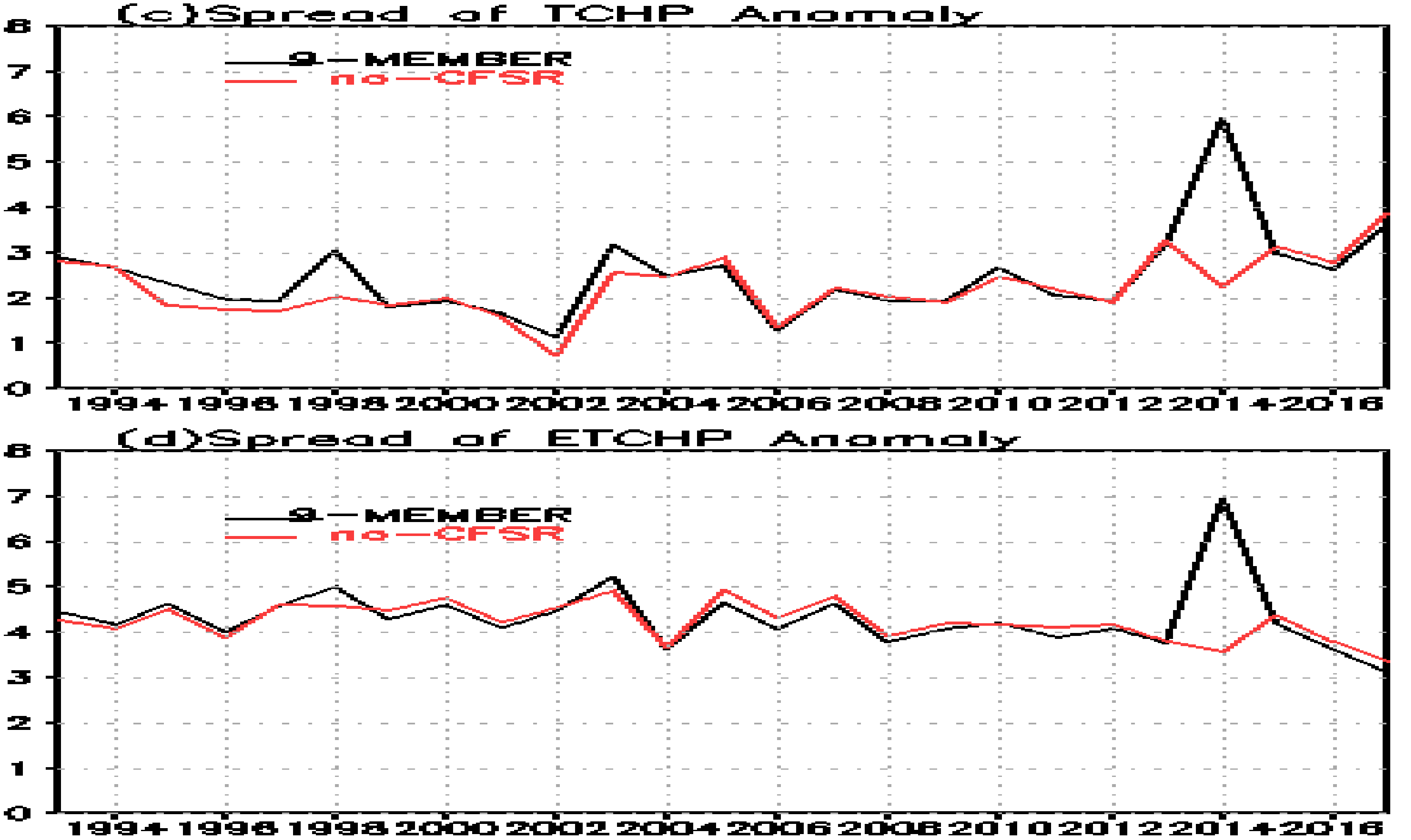
- **Argo data increased substantially after 2014 and reached a maximum during the 2017 Hurricane season.**

August-October TCHP Anomaly



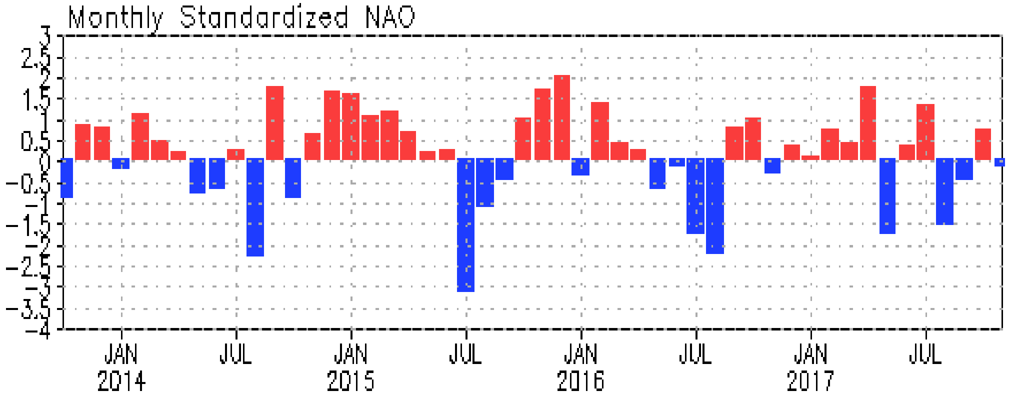
- TCHP Anomaly is defined as departures of TCHP from individual climatology in MDR .
- ETCHP Anomaly is defined as departures of TCHP from ensemble mean climatology.
- Both Aug-Oct 2017 TCHP anomaly and ETCHP anomaly in MDR ranked the fourth strongest since 1993.

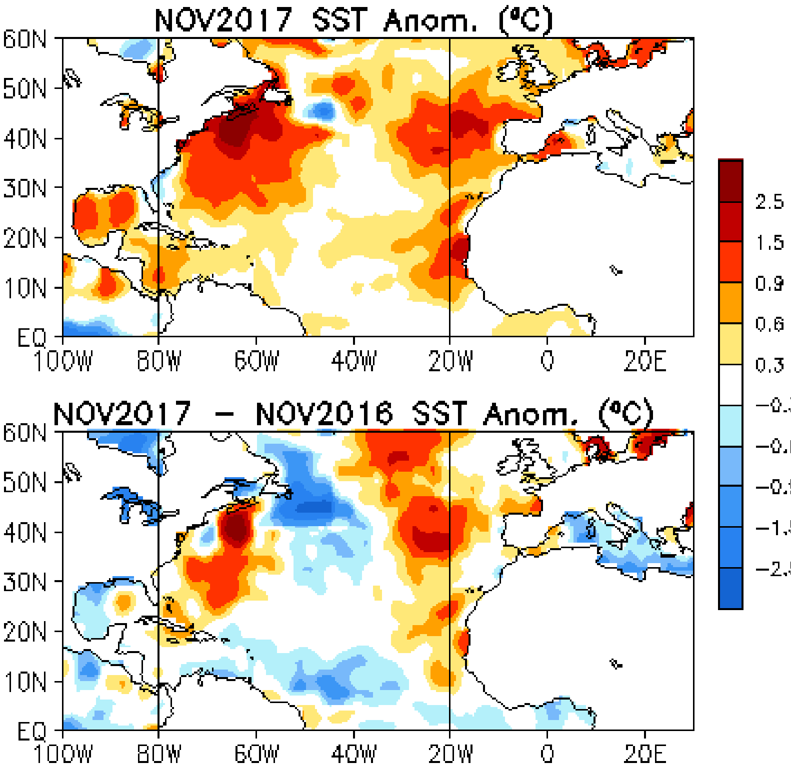
Spread of Aug-Oct TCHP Anomaly

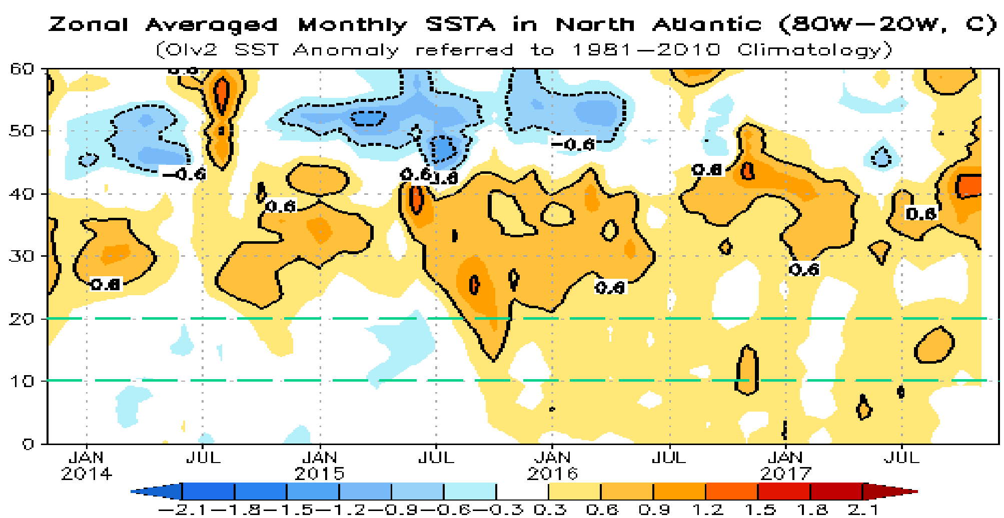


- The spread of ETCHP anomaly among nine members shows a decrease trend, while the spread of TCHP anomaly display an increasing trend. It indicates that total TCHP actually converge in recent years.

NAO and SST Anomaly in North Atlantic





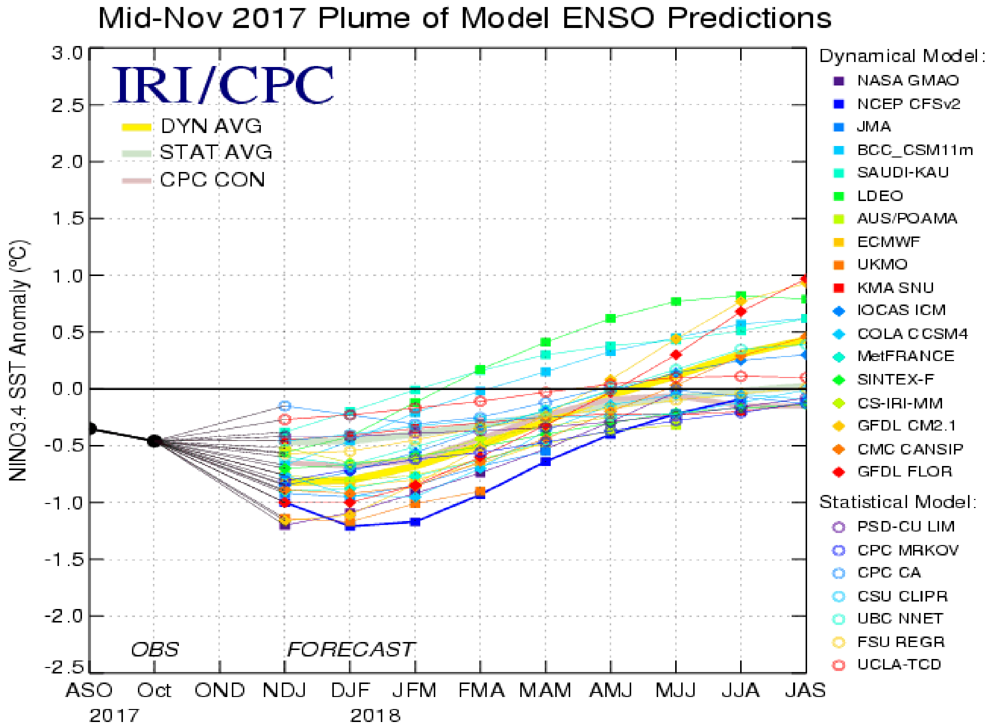


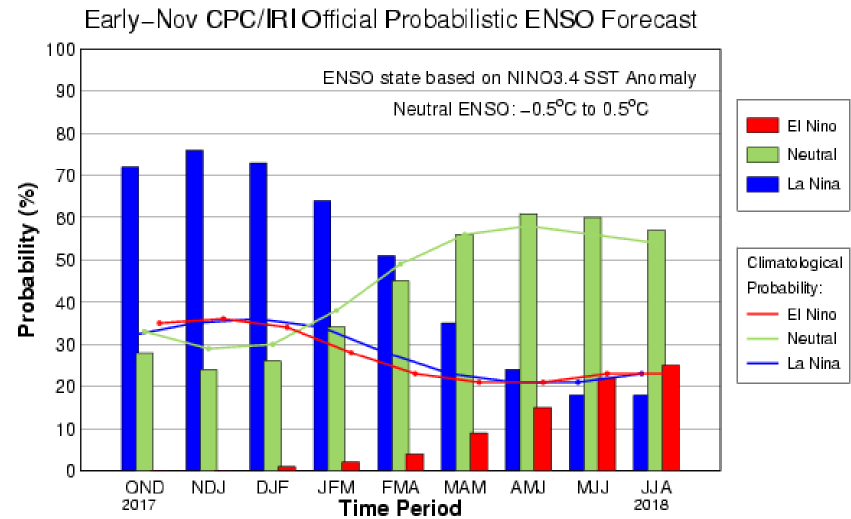
- NAO index switched to negative phase, with NAOI = -0.14 in Nov 2017.

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

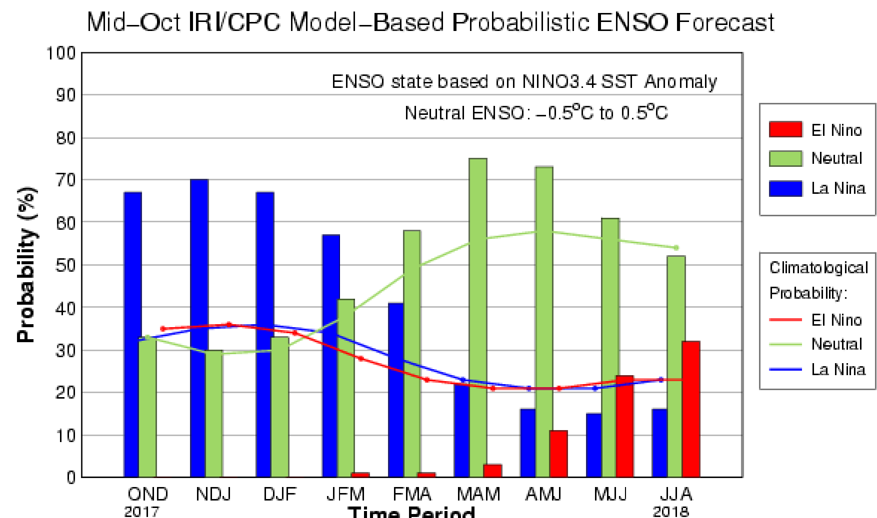
ENSO and Global SST Predictions

IRI NINO3.4 Forecast Plume



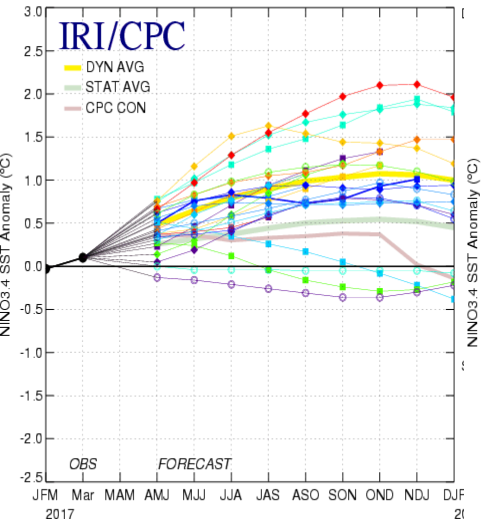


- Most of models predict a weak La Nina conditions will continue through early 2018.

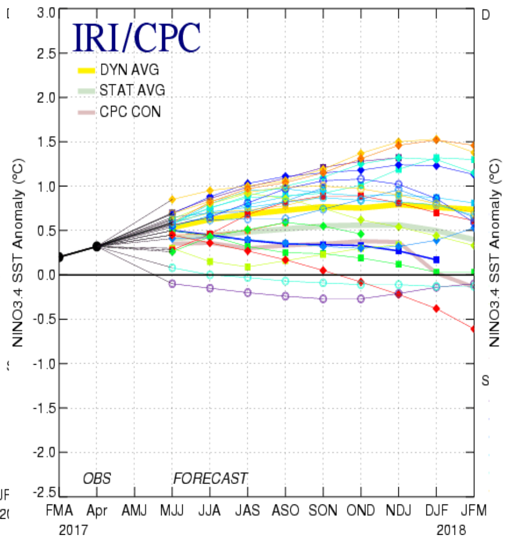


Large Uncertainty in IRI/CPC Plume of Models with IC in Apr-Oct

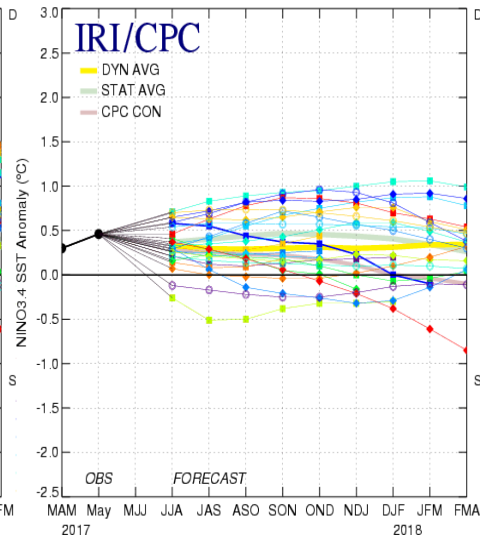
Mid-Apr 2017 Plume of Model ENSO Predictions



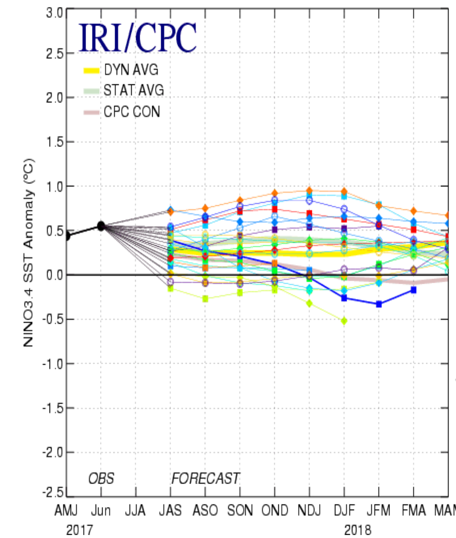
Mid-May 2017 Plume of Model ENSO Predictions



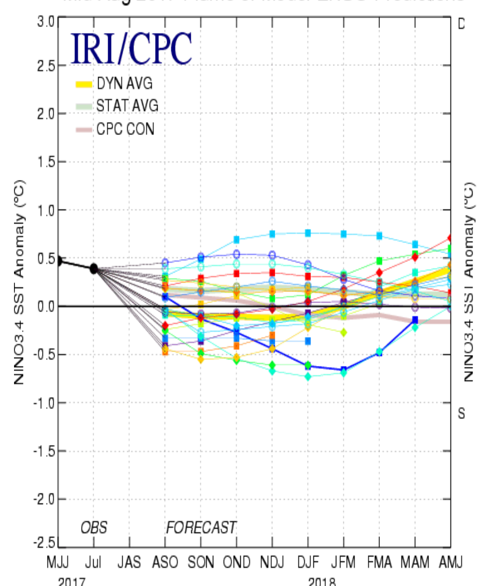
Mid-Jun 2017 Plume of Model ENSO Predictions



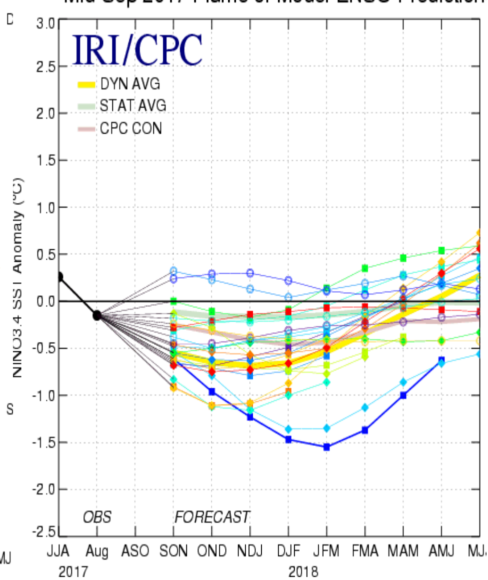
Mid-Jul 2017 Plume of Model ENSO Predictions



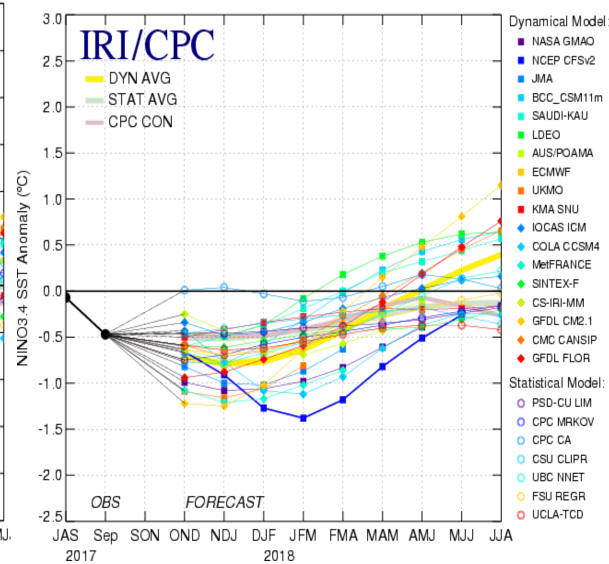
Mid-Aug 2017 Plume of Model ENSO Predictions



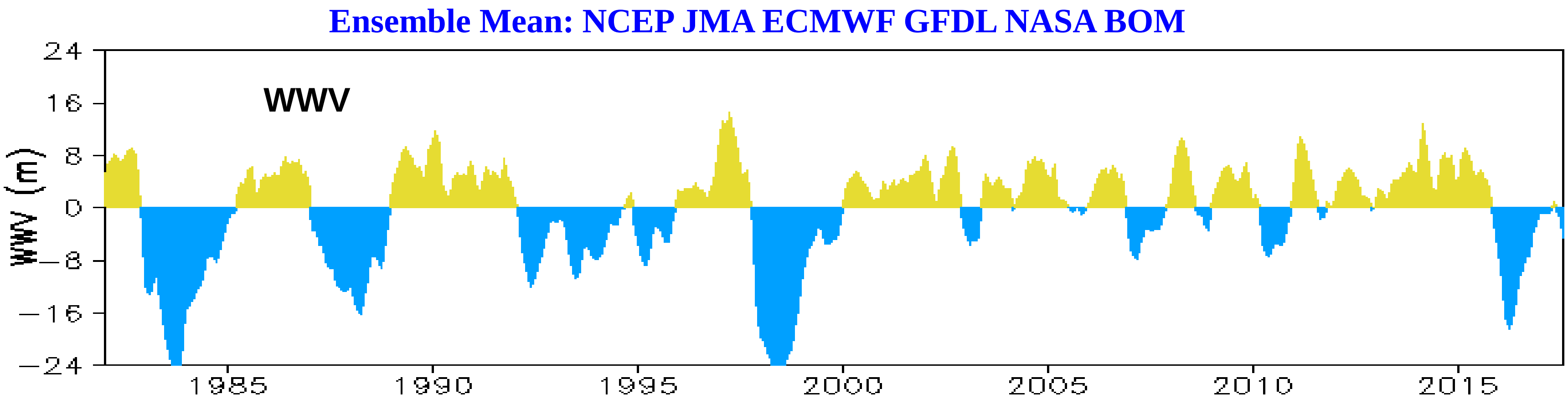
Mid-Sep 2017 Plume of Model ENSO Prediction

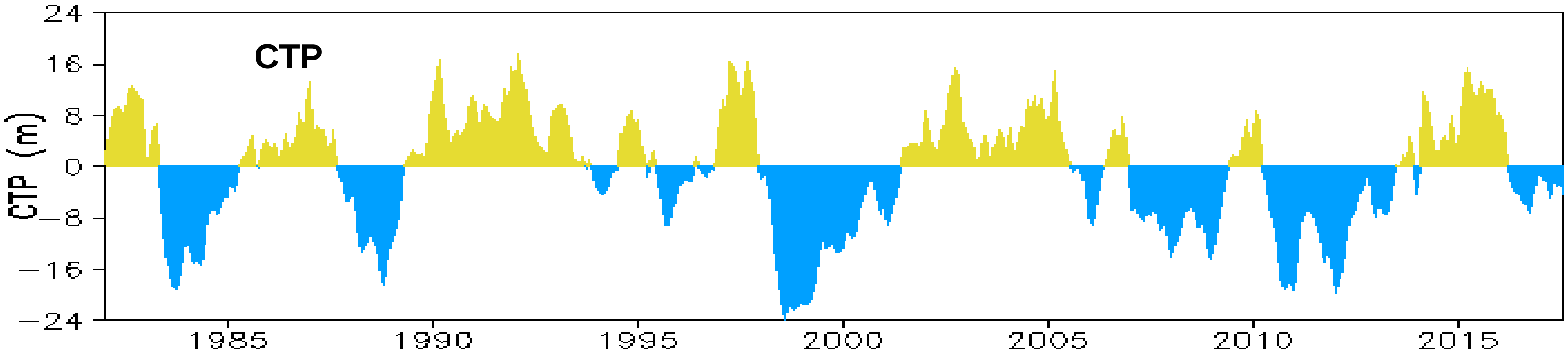


Mid-Oct 2017 Plume of Model ENSO Predictions



Two ENSO Precursors Based on Thermocline Anomaly





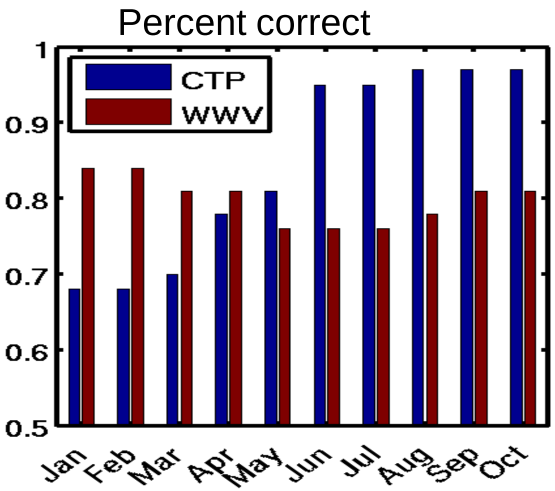
- **Warm Water Volume (WWV) index is defined as average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN]. It is inferred from the slow ocean adjustment via zonal mean heat content exchange between the equatorial and off-equatorial regions.**
- **Central tropical Pacific (CTP) index is defined as average of 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.*

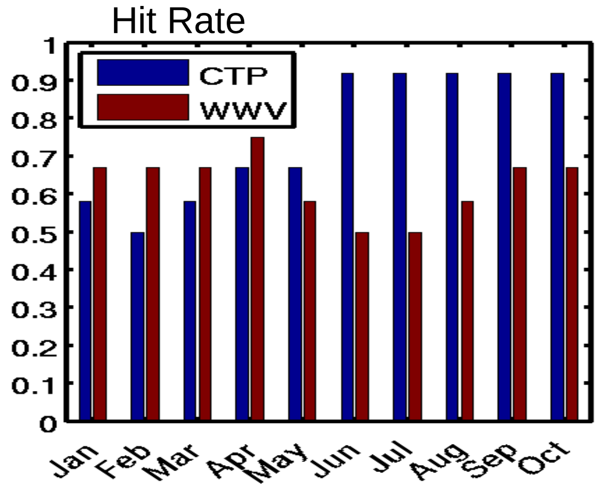
Wen C, Kumar A, Xue Y, McPhaden MJ (2014) Changes in tropical pacific thermocline depth and their relationship to ENSO after 1999. J Climate 27:7230–7249

2x2 contingency table for La Nina case

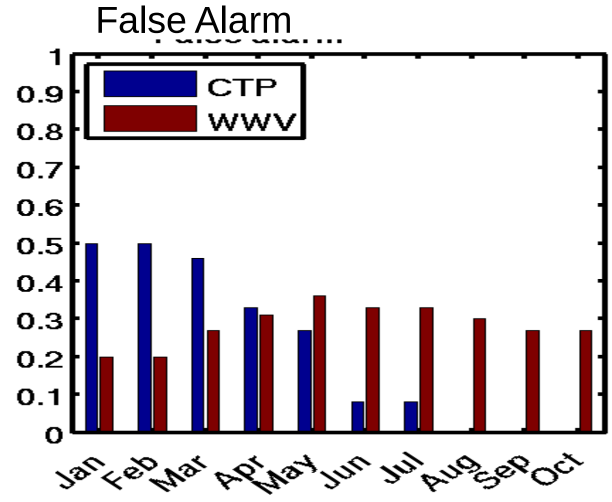
NINO34 Target season: DJF



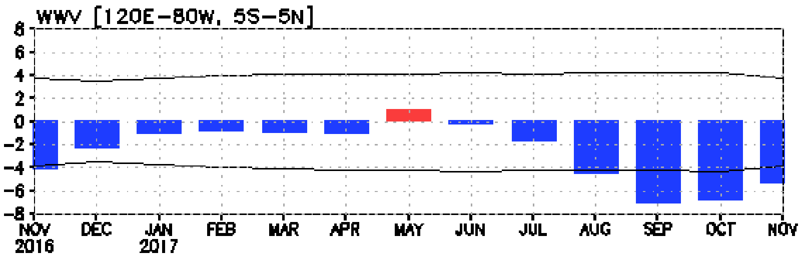
IC month

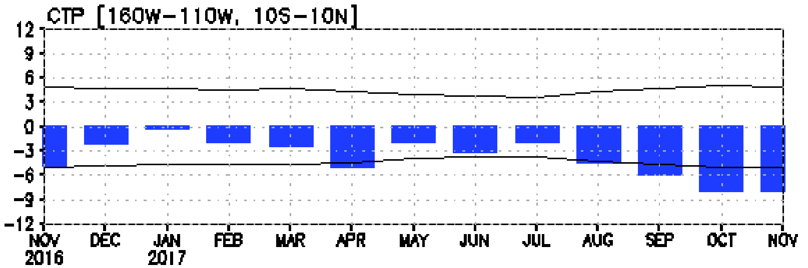


IC month



IC month





Forecast criterion: 0.5 monthly standard deviation (black lines)

- CTP index predicted La Niña condition as early as Apr 2017. It persistently projected La Niña condition from IC Aug-Oct with more than 90% chance.

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

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

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

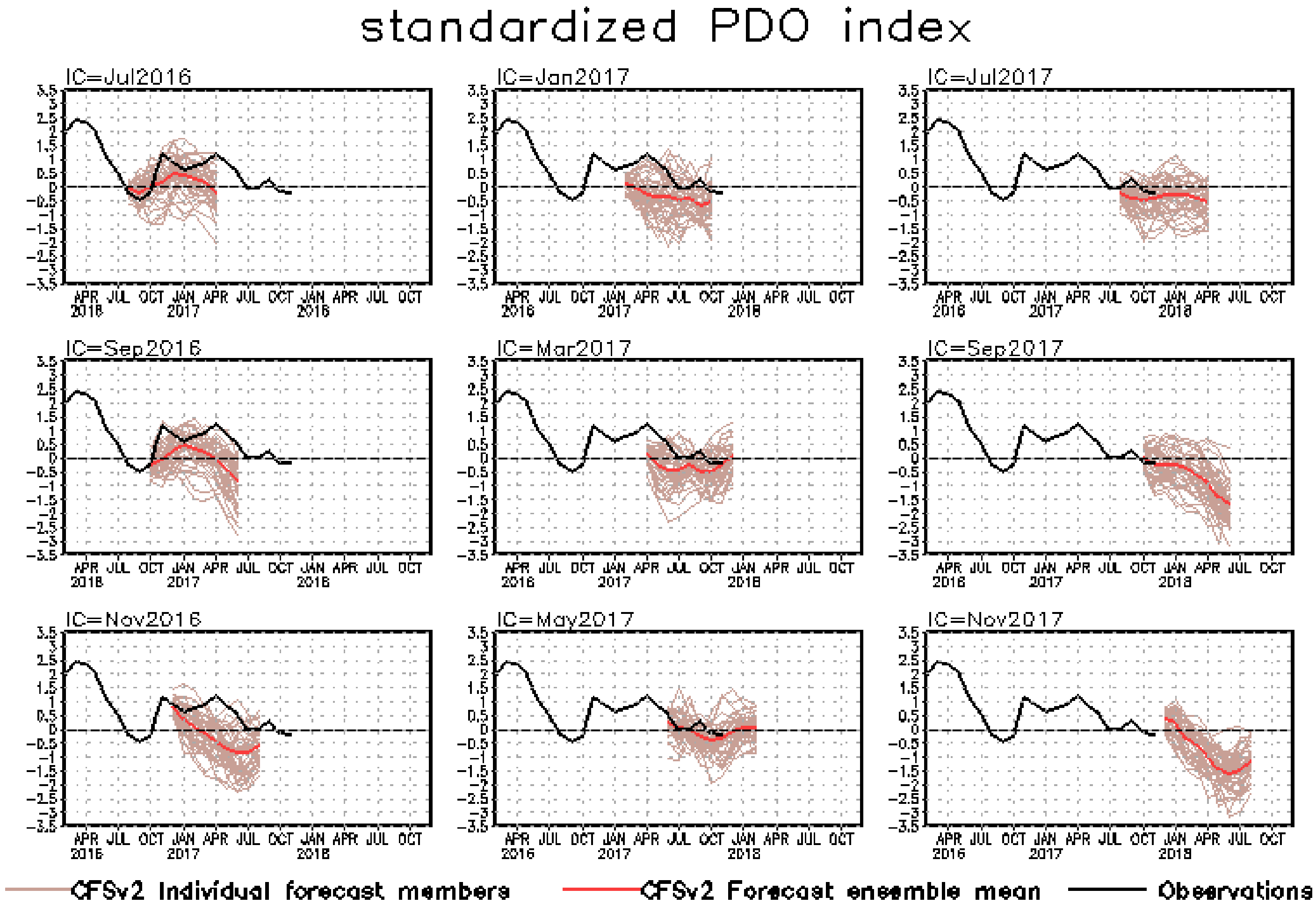


Fig. M4. CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

Acknowledgements

- Drs. Yan Xue ,Zeng-Zhen Hu and Arun Kumar: reviewed PPT, and provided insight and constructive suggestions and comments

- Drs. Thomas Collow and Wanqiu Wang: Provided sea ice prediction slides

- Drs. Li Ren and Pingping Xie: Provided SSS slides

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.ndbc.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!

Backup Slides

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

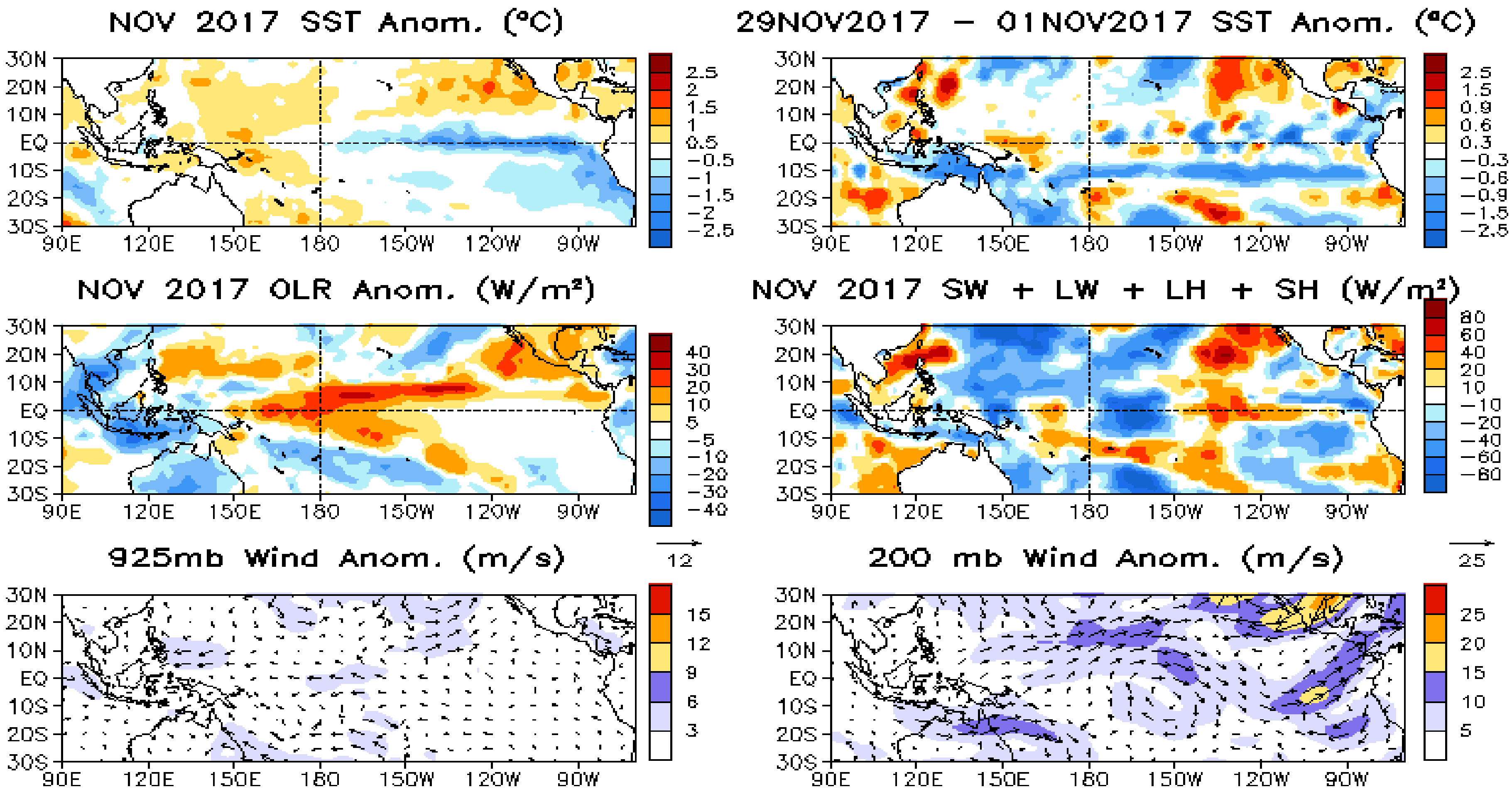
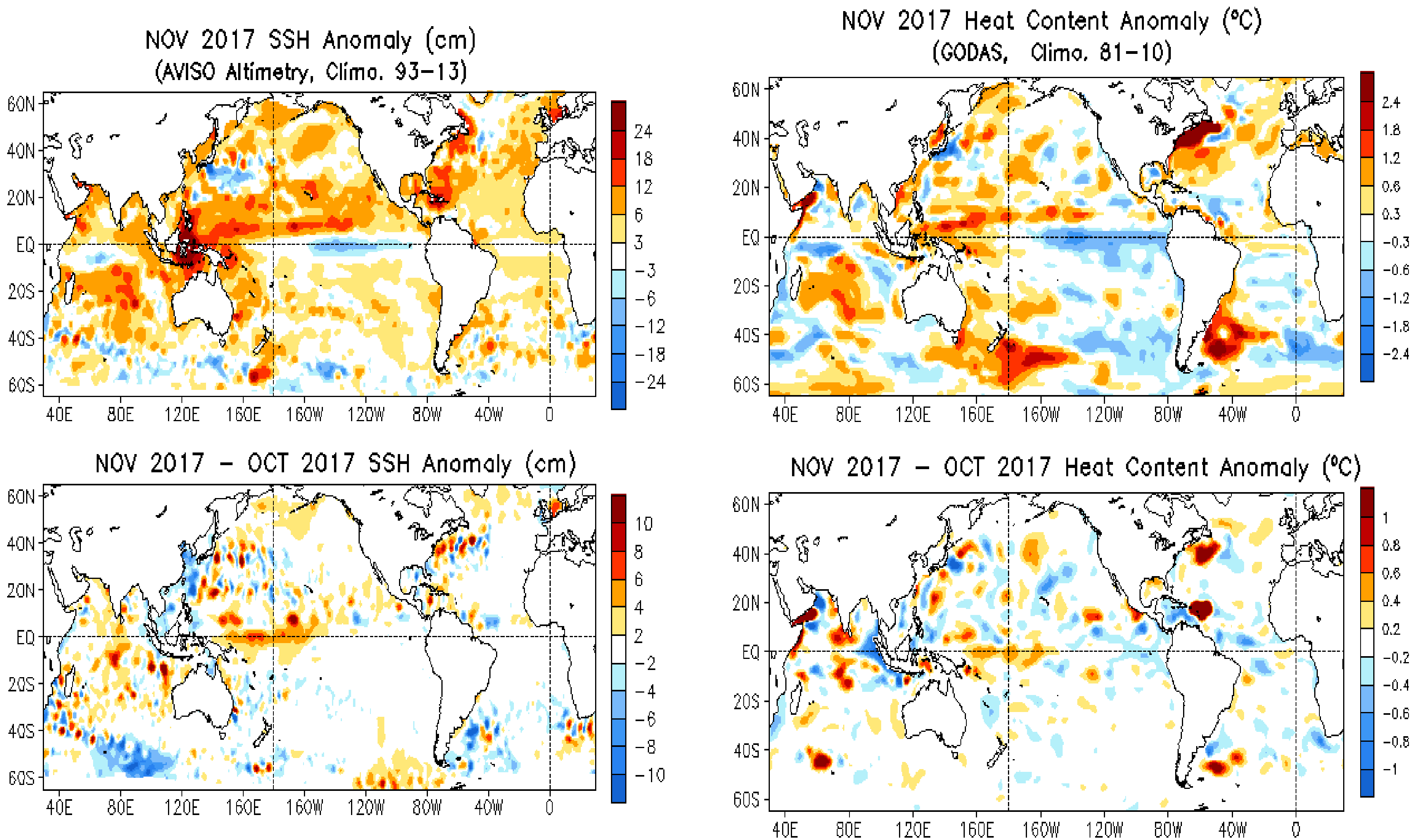


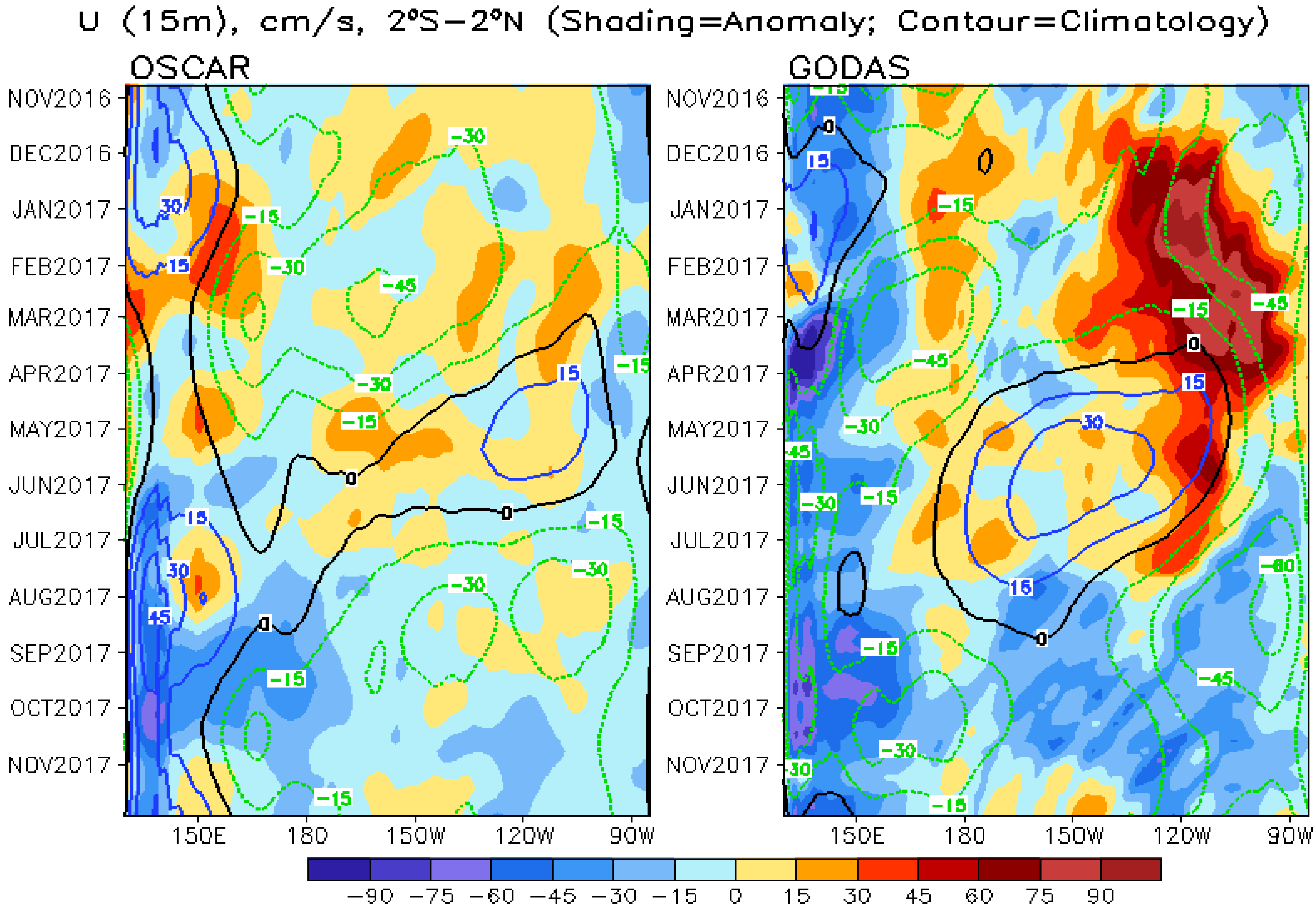
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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 SSH and HC300 Anomaly & Anomaly Tendency

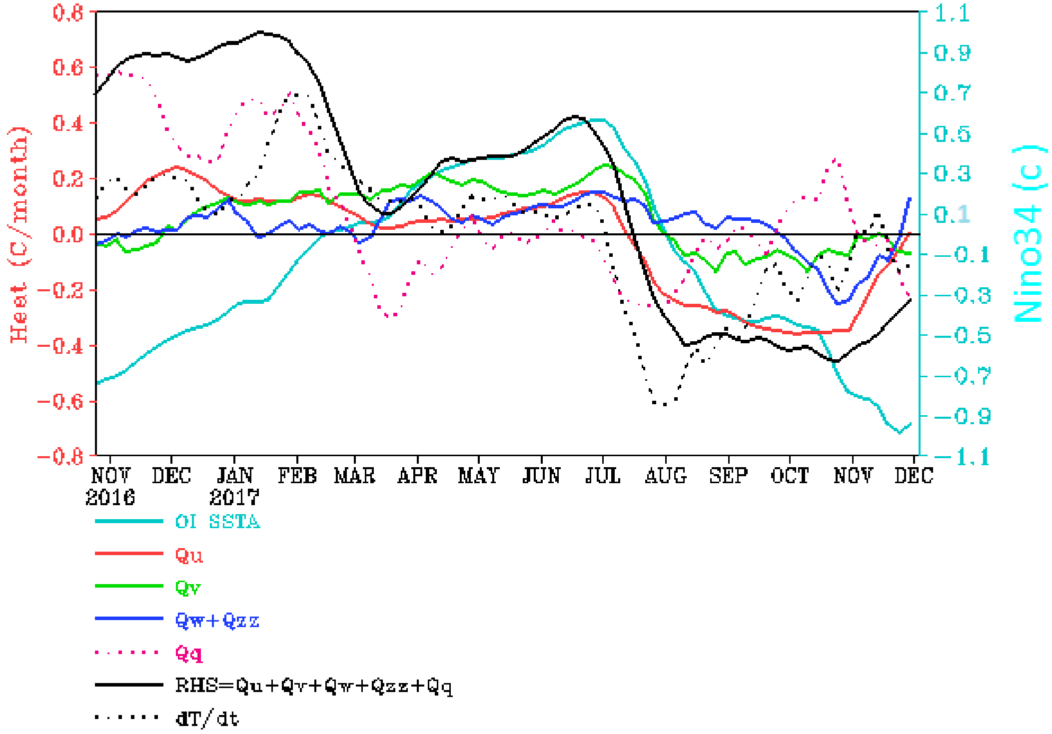


-Negative tendency was observed in both SSHA and HC300A in the central-eastern equatorial Pacific.

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



NINO3.4 Heat Budget



- Both observed SSTA tendency (dT/dt; dotted black line) and total budget tendency (RHS; solid black line) in Nino3.4 region became negative in Jul 2017.

- Zonal advection Qu and meridional advection Qv were the major factors contributing to the negative 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

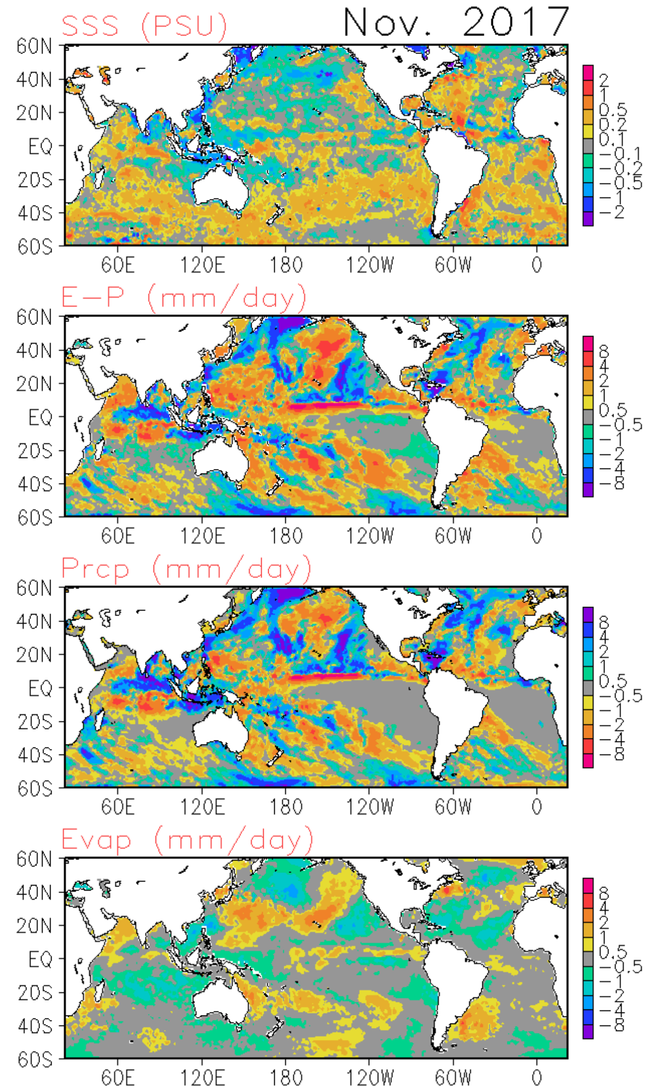
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

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

Global Sea Surface Salinity (SSS)

Anomaly for November 2017

- **New Update: The BASS 0.Z is released in July 2017 with the SSS from recently launched SMAP being integrated into the system. In BASS 0.Z, since June 2015, the blended SSS analysis is from in situ, SMOS and SMAP. Please report to us any suspicious data issues!**
- The positive SSS anomaly in the western equatorial Pacific Ocean continues with reduced precipitation in the area. Strong negative SSS anomaly appeared in the Indonesian equatorial Pacific with an increasing precipitation. Positive SSS anomalies continued in the west basin of Atlantic Ocean, while the precipitation increased. The negative SSS in the subarctic North pacific continues. In the Bay of Bengal, the negative SSS became weaker with little change in the freshwater input. Positive SSS is generally over the entire southern Ocean between 20˚ S and 50˚ S. Such large scale positive SSS anomaly is probably caused by less freshwater input and/or ocean advection.

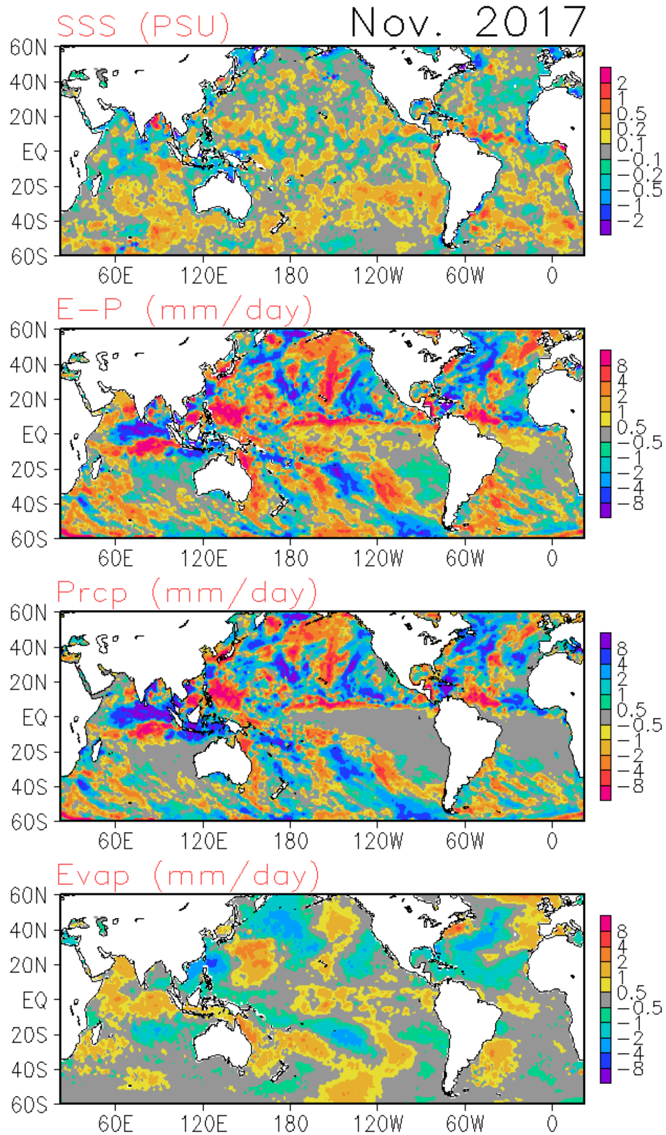


- **Data used**

SSS : Blended Analysis of Surface Salinity (BASS) V0.Z
(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 2017

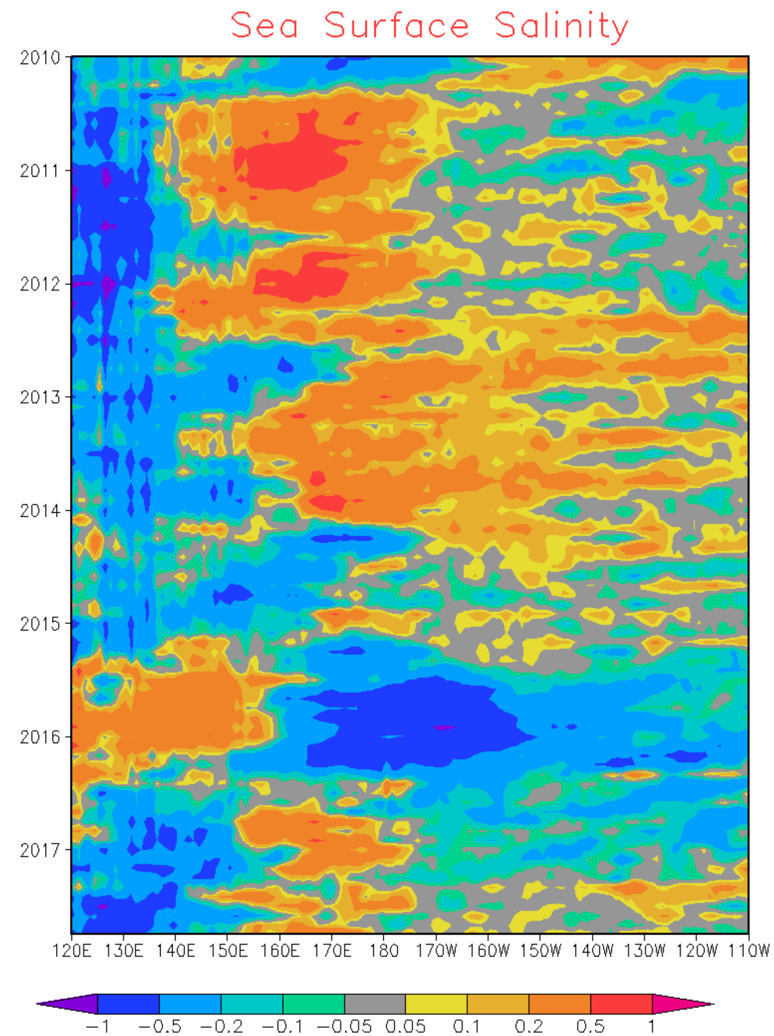
Compared with last month, the SSS in the Bay of Bengal increased with a decreasing freshwater input. The SSS in the central Indonesian equatorial Pacific significantly decreased, meanwhile, the precipitation in this region is increasing. The SSS in the Sea of Okhotsk continues decreasing. The increase of SSS in the east basin of South pacific Ocean is very likely due to the precipitation reduction. The SSS increases in the west basin of North Atlantic Ocean, while the precipitation increases as well. Therefore, such SSS increase is probably due to the ocean advection/mixing.



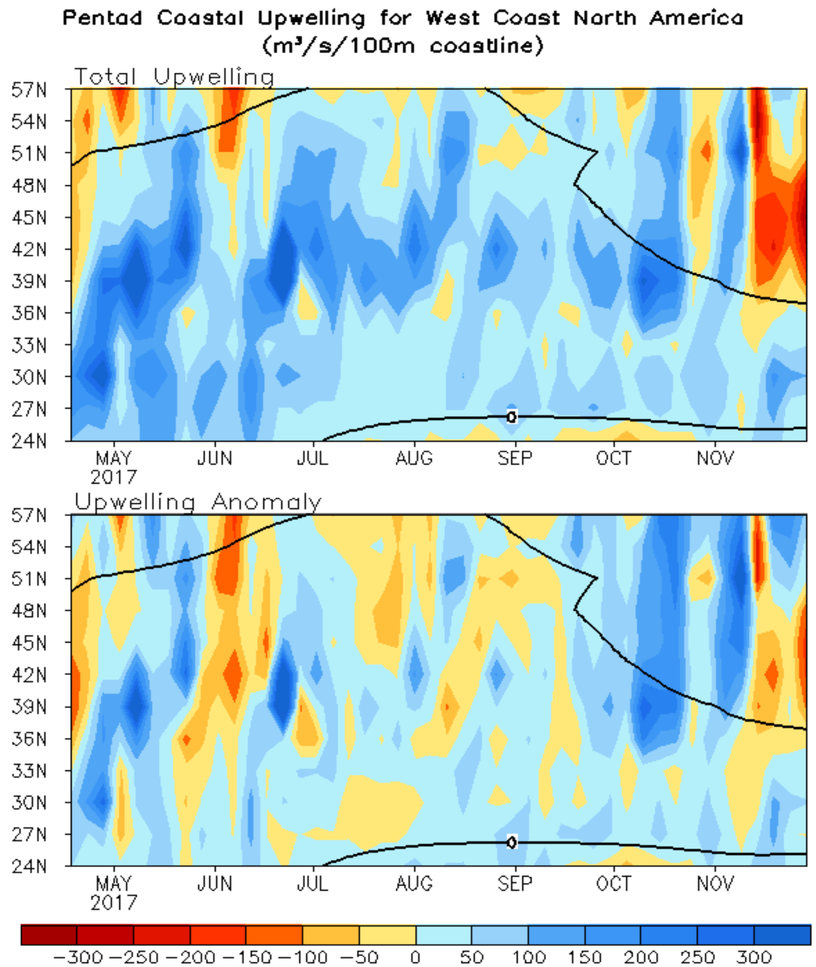
Global Sea Surface Salinity (SSS)
Anomaly Evolution over Equatorial Pacific

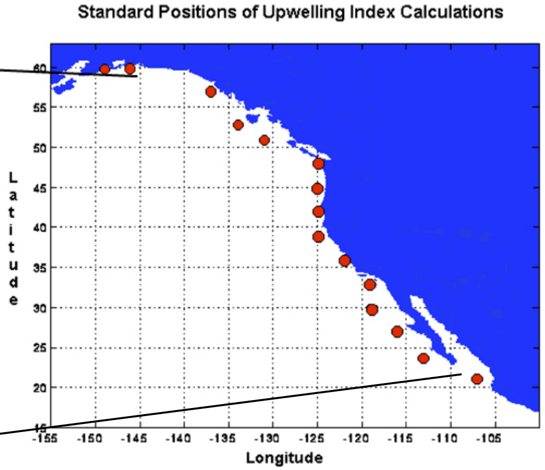
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

- Hovemoller diagram for equatorial SSS anomaly **(10˚ S-10˚ N);**
- In the equatorial Pacific Ocean, from 120˚ E to 150˚ E, the negative SSS signal continues in this month. The positive SSS anomaly signal between 150˚ E and 180˚ becomes stronger. East of 150˚ E, positive SSS anomaly signals started to build up. In sum, the SSS signal is negative west of 150˚ E and positive east of 150˚ E.



North America Western Coastal Upwelling



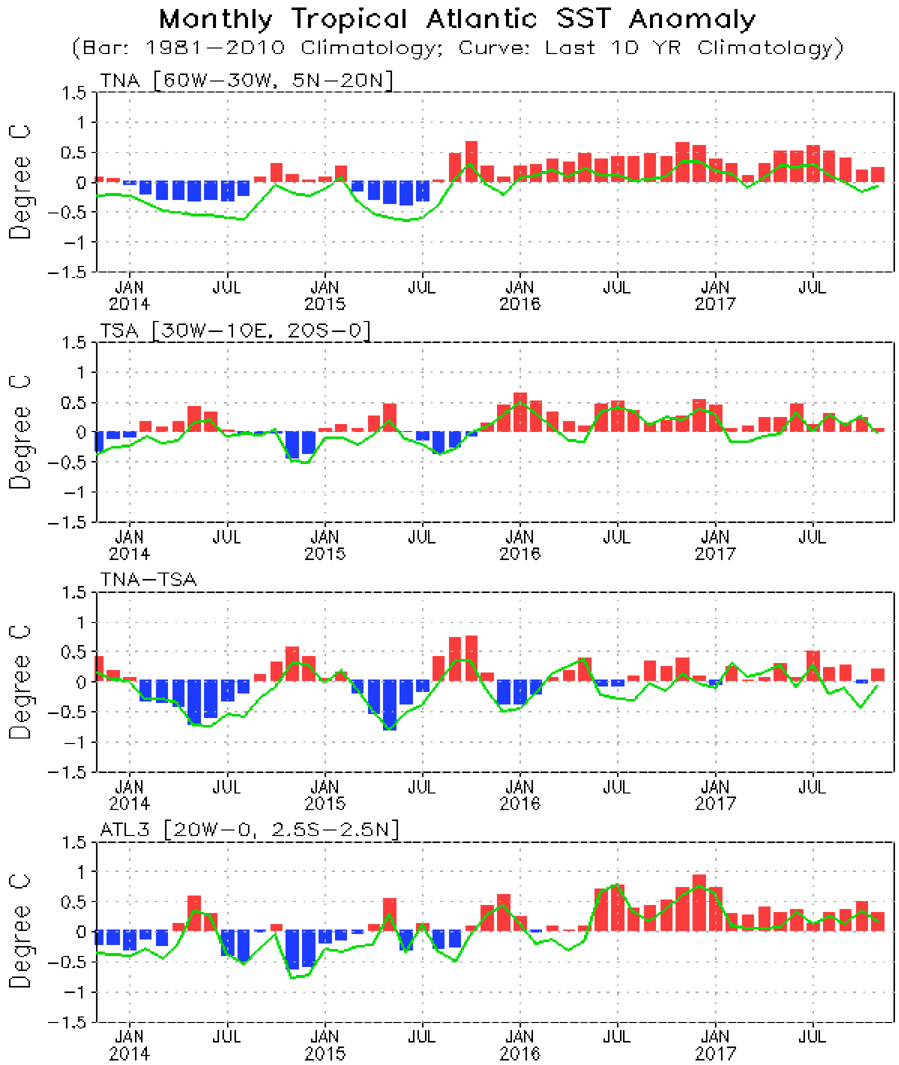


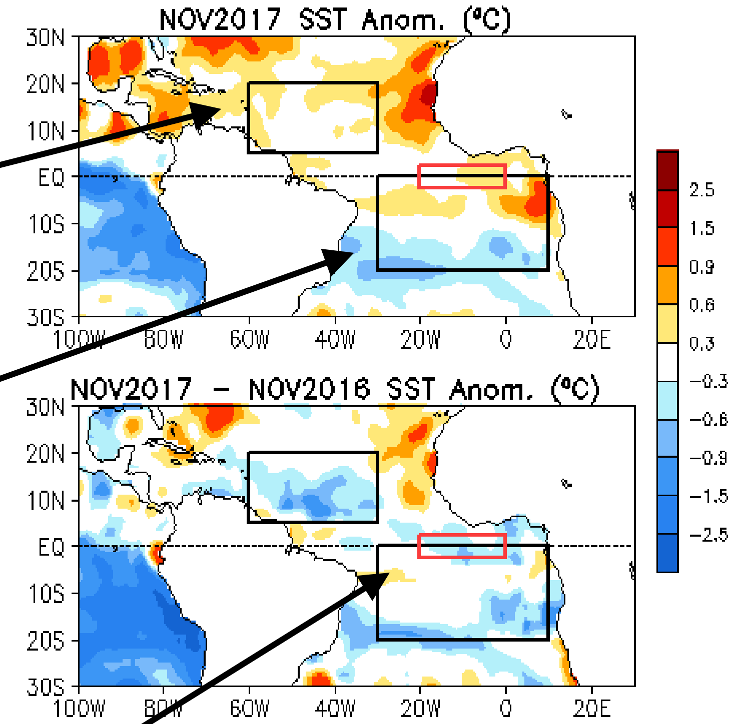
- Anomalous downwelling dominated along the coast in Nov 2017, owing to the southwesterly winds.

Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1981-2010 base period pentad means.

- **Area below (above) black line indicates climatological upwelling (downwelling) season.**
- **Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.**

Evolution of Tropical Atlantic SST Indices





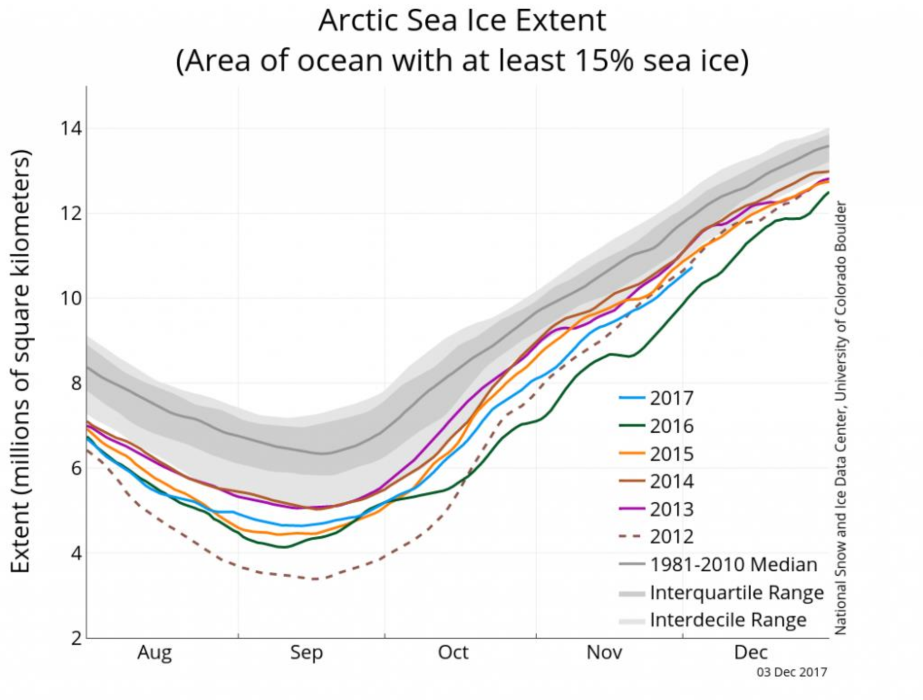
- Overall, SSTAs in the tropical Atlantic Ocean were positive.

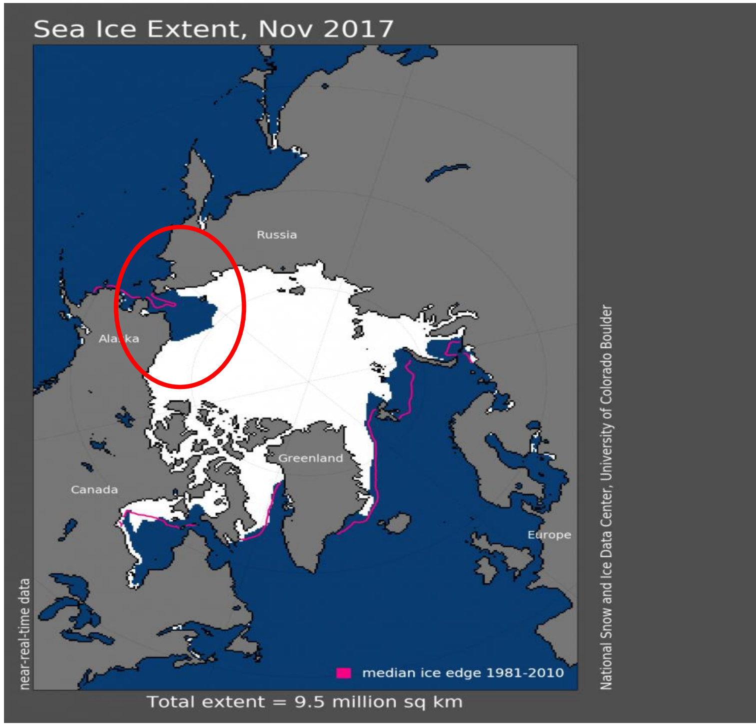
- All indices were positive in Nov 2017.

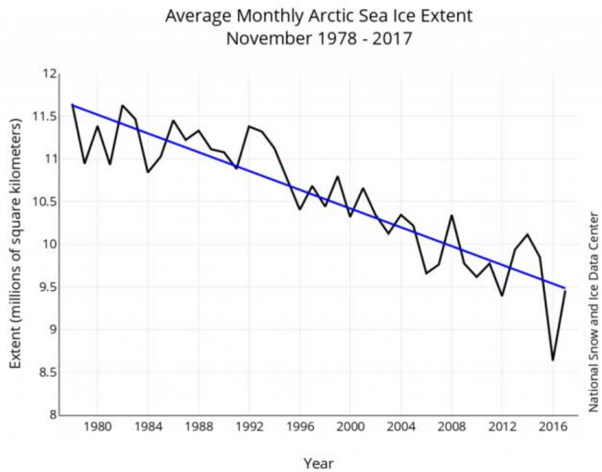
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between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

Arctic Sea Ice

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







- **Extent in the Chukchi Sea reached historical low in Nov 2017.**
- **Arctic sea ice extent averaged for Nov 2017 ranks the third lowest in the satellite record.**

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

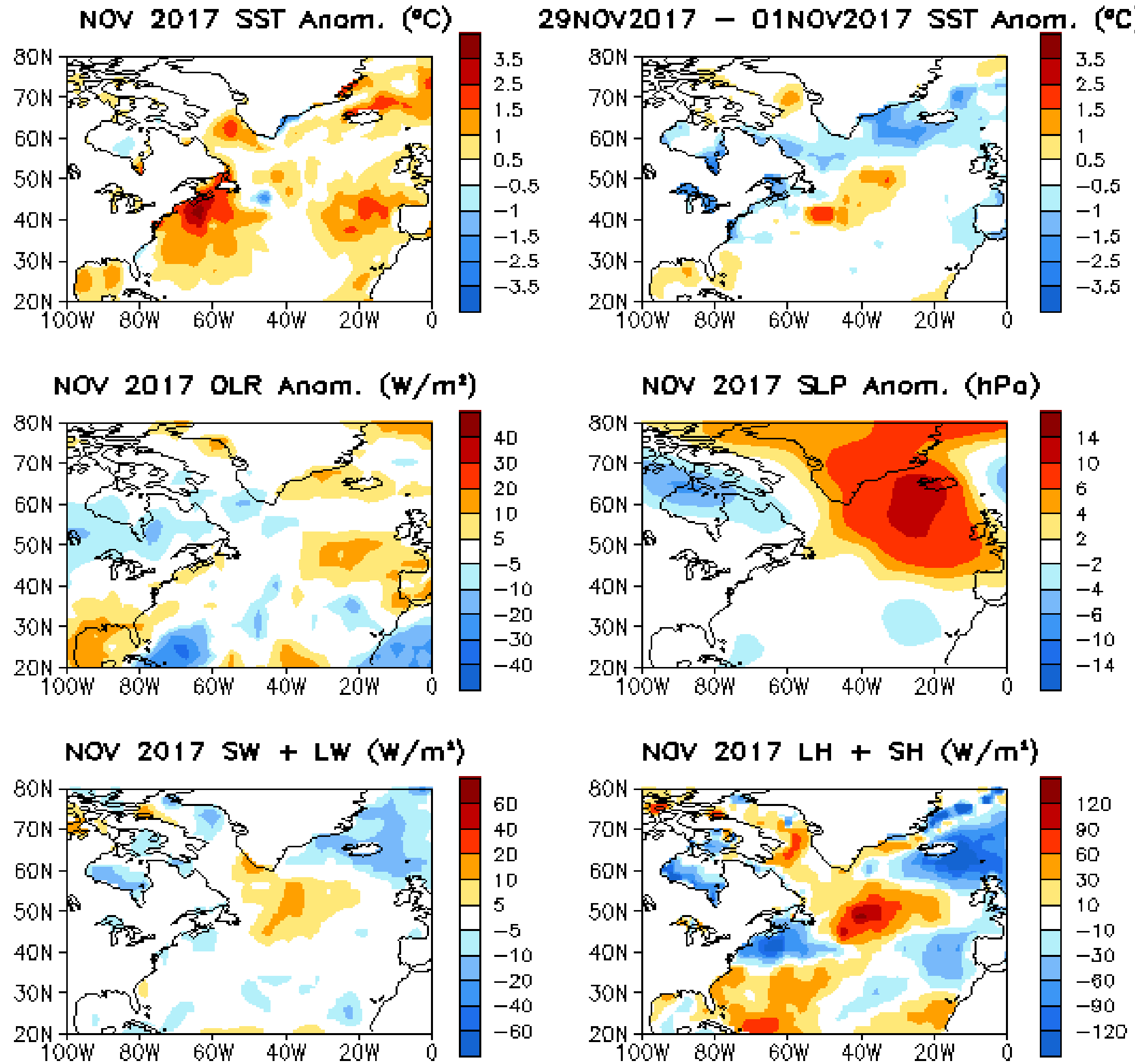


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

CFS Niño3.4 SST Predictions from Different Initial Months

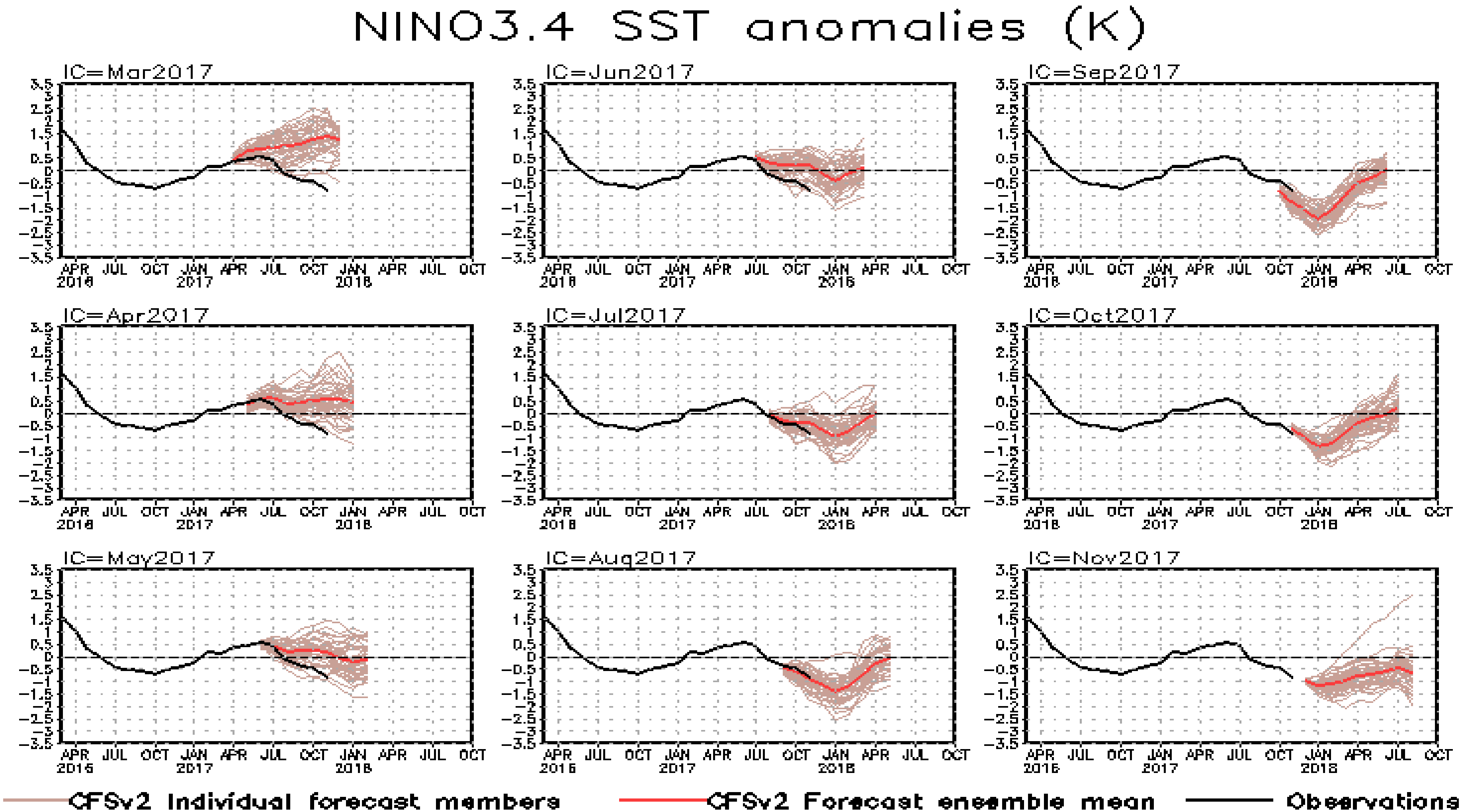
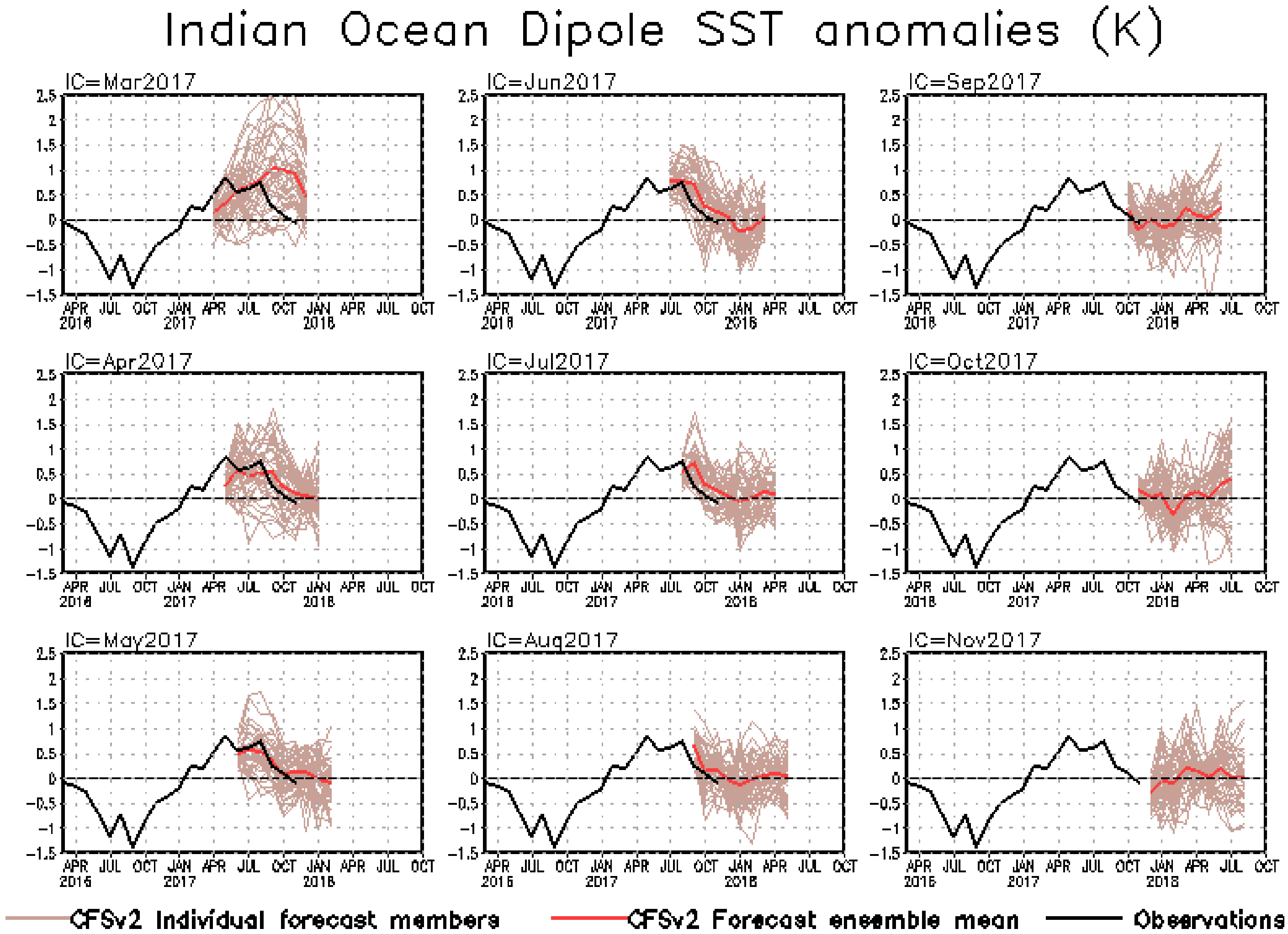


Fig. M1. CFS Nino3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

NCEP CFS DMI SST Predictions from Different Initial Months



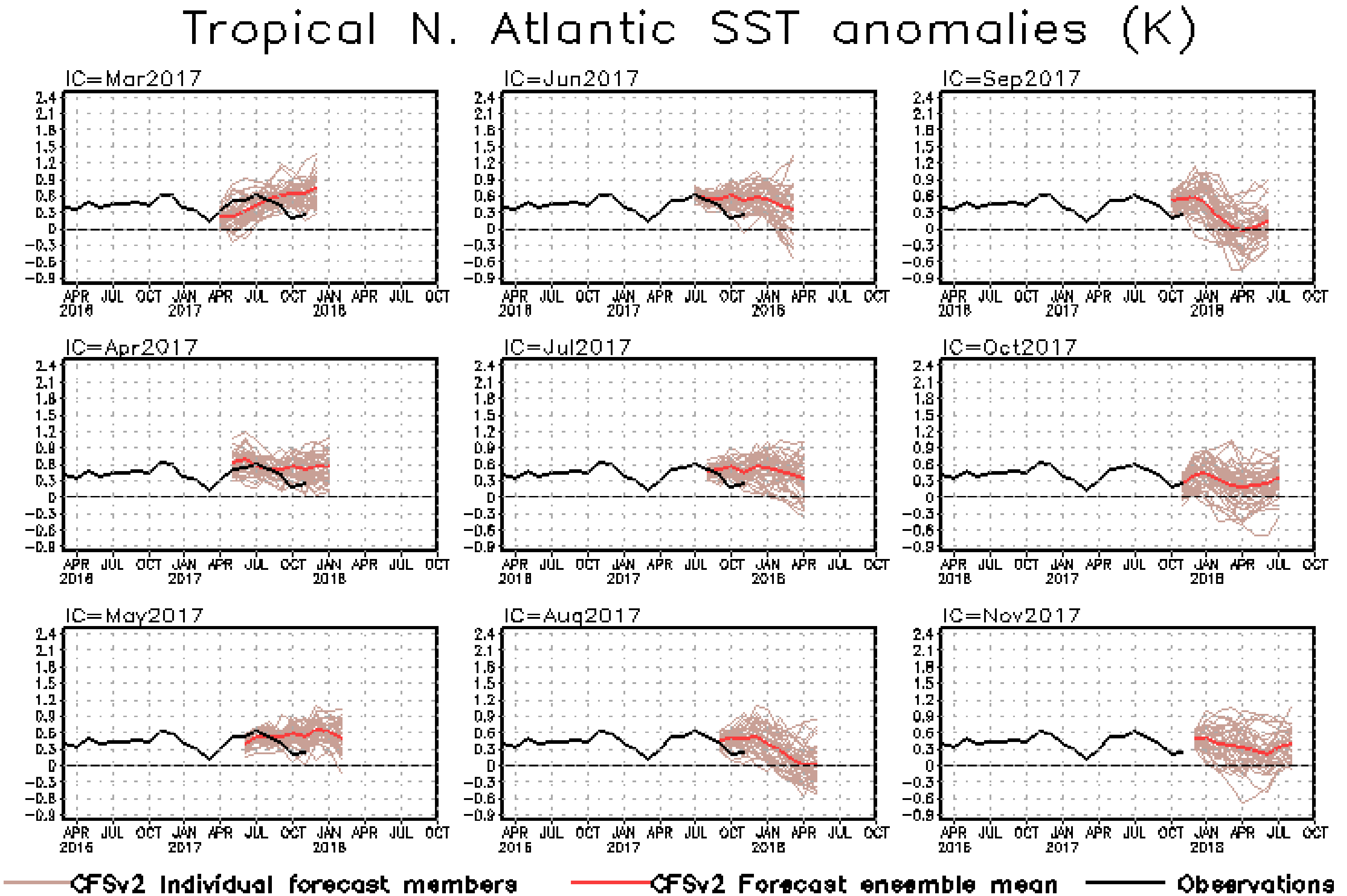
DMI = WTIO- SETIO

SETIO = SST anomaly in [90ºE-110ºE, 10ºS-0]

WTIO = SST anomaly in [50ºE-70ºE, 10ºS-10ºN]

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.

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



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

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