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

Prepared by

Climate Prediction Center, NCEP/NOAA

December 11 , 2018

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**
  - **comparison among 1986,2014 and 2018 conditions**

Overview

Pacific Ocean

- ALL NINO indices strengthened in Nov 2018, with Niño34 = +1.0C.
- Positive subsurface temperature anomalies strengthened in the central-eastern Pacific.
- Most of the models suggest El Niño conditions will develop and last through the Northern Hemisphere spring 2019.
- 2018 E. Pacific hurricane season produced the highest ACE since 1971.
- Arctic sea ice extent in Nov 2018 ranked the ninth lowest Nov value since 1979.

Indian Ocean

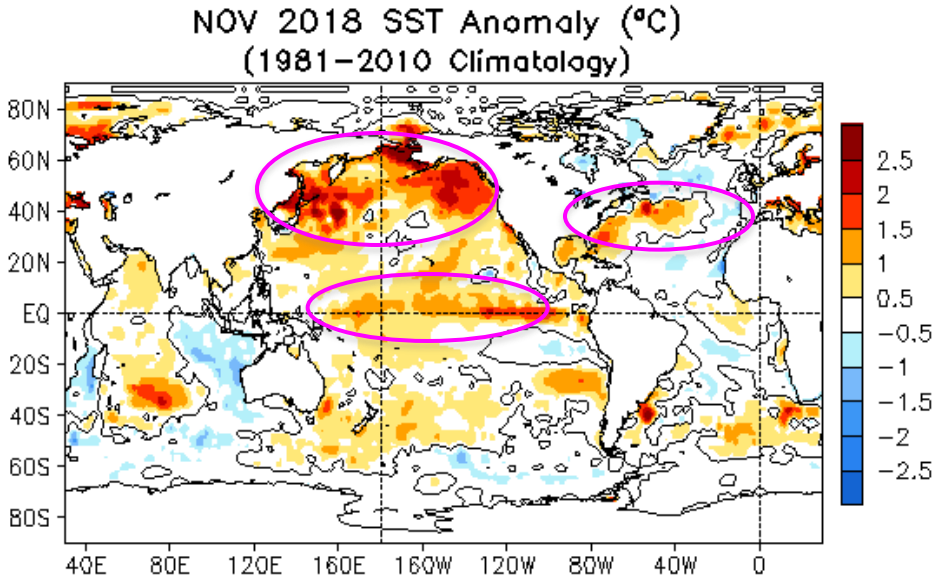
- A positive Indian Ocean dipole event was observed during Sep-Nov 2018.

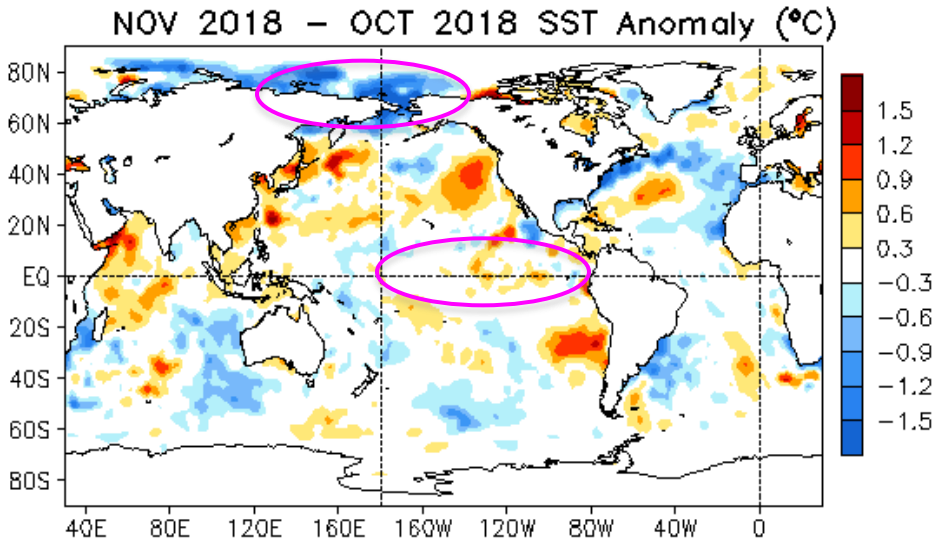
Atlantic Ocean

- 2018 Atlantic hurricane season was the third in a consecutive series of above-average and damaging Atlantic hurricane seasons.
- Positive phase of NAO switched to negative phase in Nov.

Global Oceans

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





- SSTs were above average across most of the tropical Pacific Ocean.

- Strong positive SSTAs continued in the mid-high latitudes of N. Pacific.

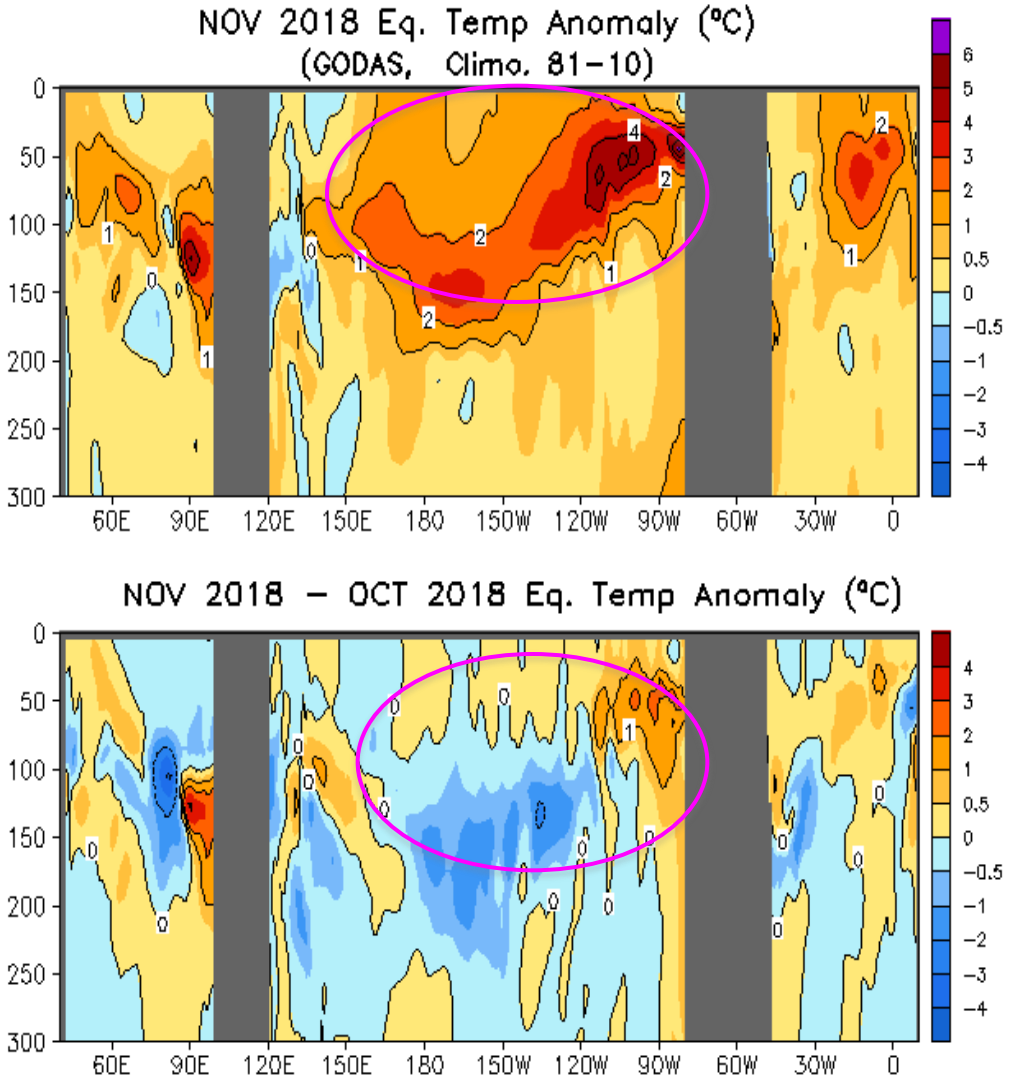
- Positive SSTAs persisted in the Gulf of Mexico and along the Gulf Stream.

- Positive SSTA tendencies presented across central-eastern equatorial Pacific Ocean.

- Strong negative SSTA tendencies were observed in the Arctic Ocean.

Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2°S-2°N



- **Positive temperature anomalies continued along the thermocline in the equatorial Pacific in Nov 2018, and temperature were more than 4°C warmer than average in the far eastern Pacific.**

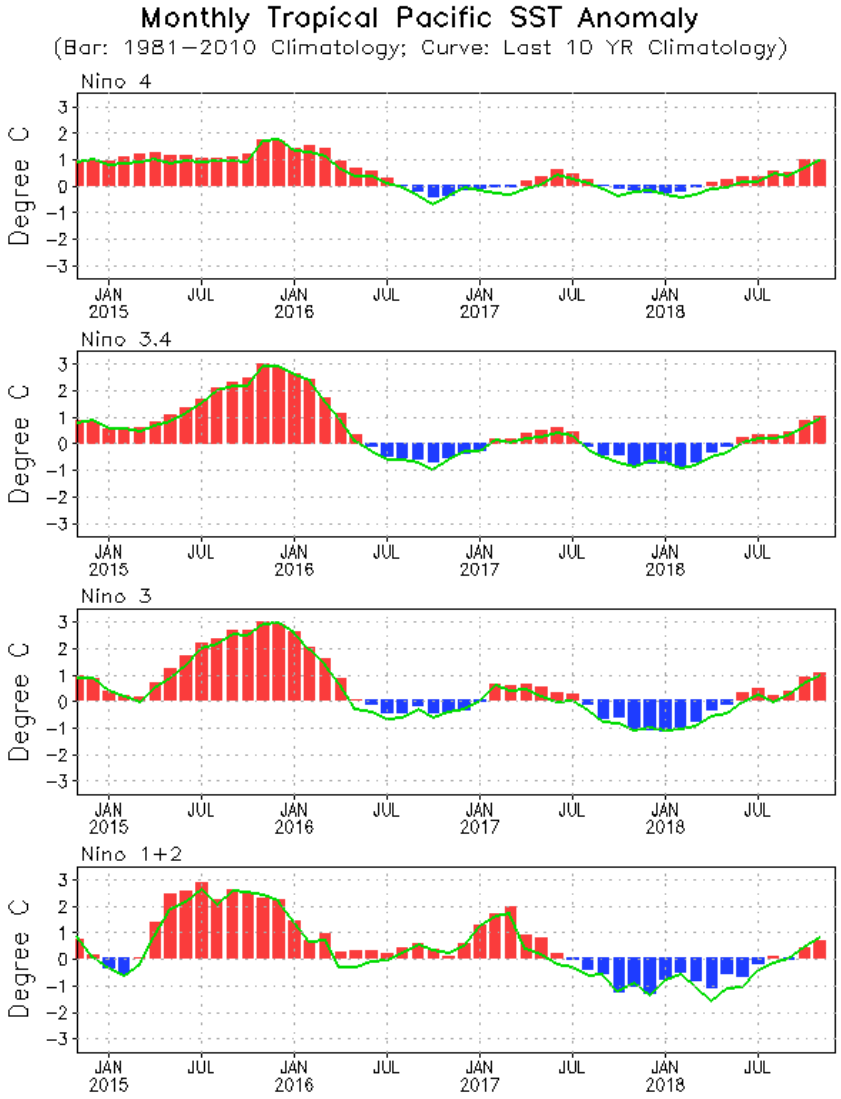
- **Positive temperature anomaly persisted along the thermocline in the Atlantic and Indian Oceans.**

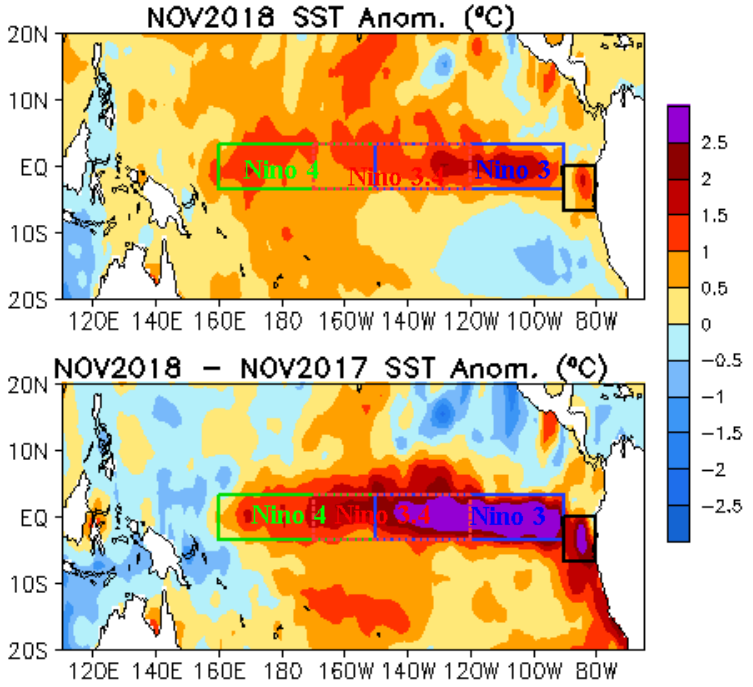
- **Positive (negative) temperature anomaly tendency presented in the eastern (central) equatorial thermocline in the Pacific Ocean.**

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 strengthened in Nov2018, with Niño 3.4 = 1.0 C.**

-The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v5.

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.

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

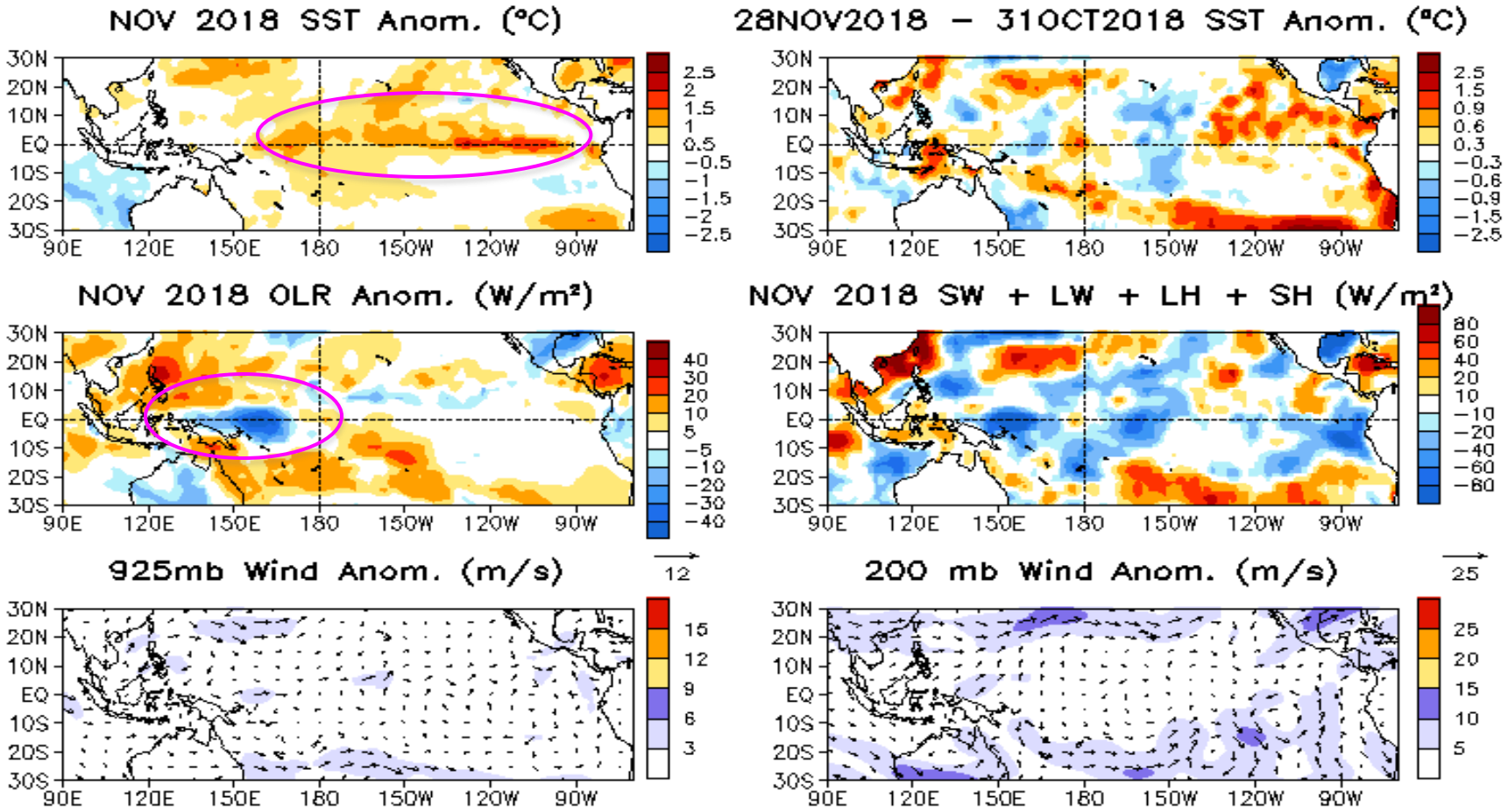
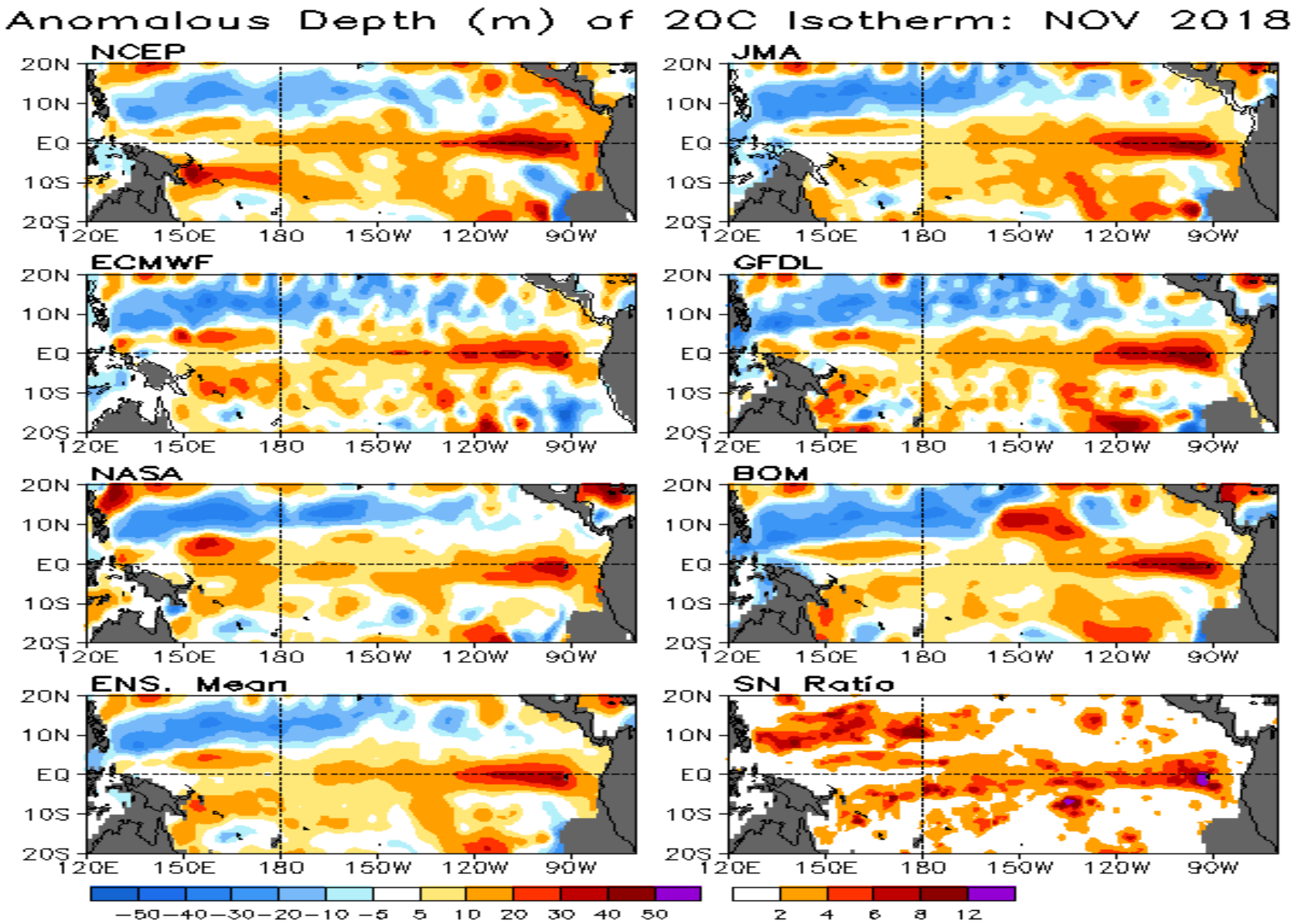


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

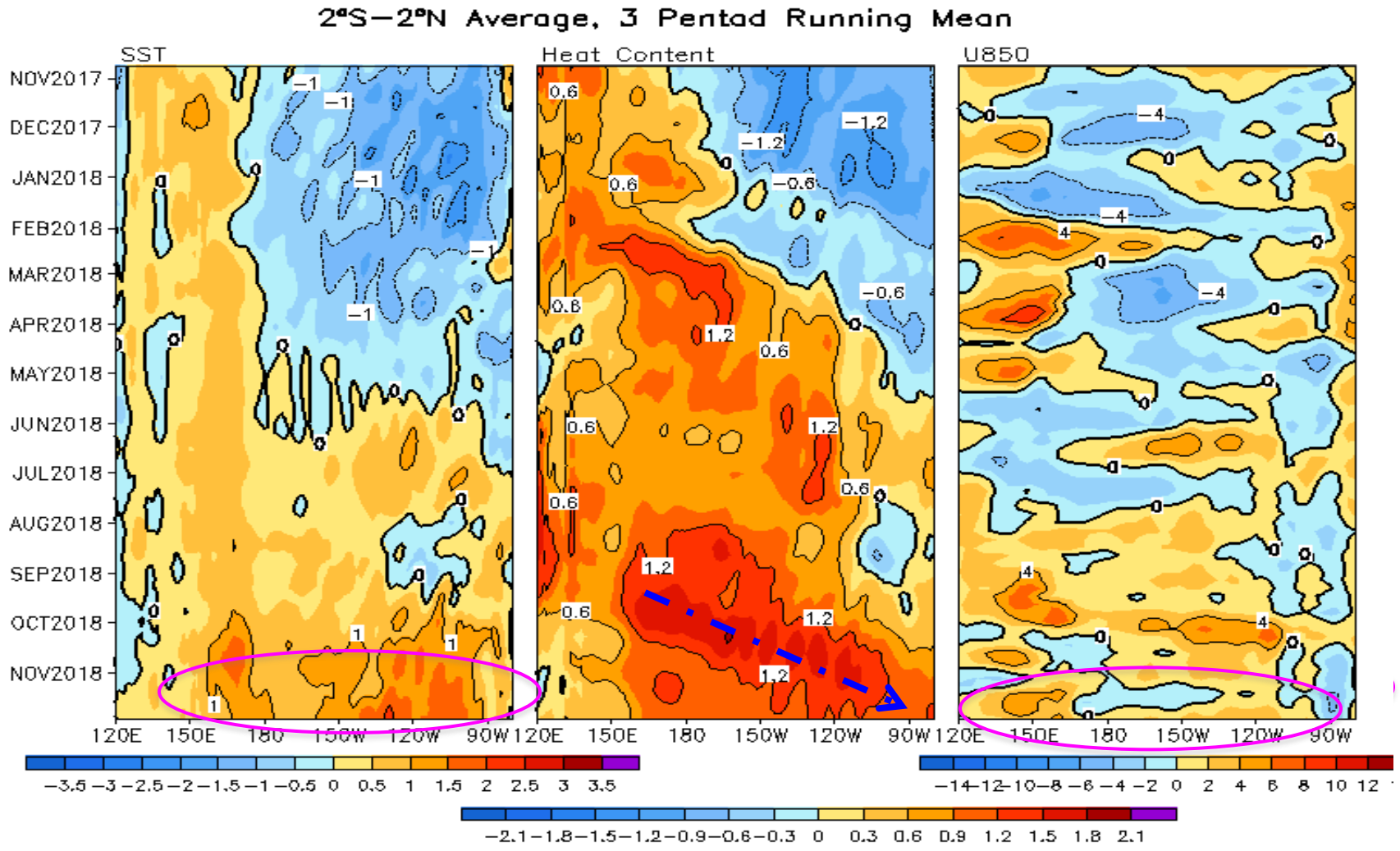
Real-Time Ocean Reanalysis Intercomparison: D20

Climatology : 1981-2010

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



Equatorial (2S-2N) Pacific SST (°C), Surface Zonal Wind (m/s) and HC300 (°C) Anomalies



- **Positive SSTA strengthened in much of the equatorial Pacific in Nov 2018, consistent with the eastward extension of positive subsurface temperature anomalies.**

- **Westerly wind anomalies prevailed over the equatorial Pacific in the 2nd half of Nov 2018.**

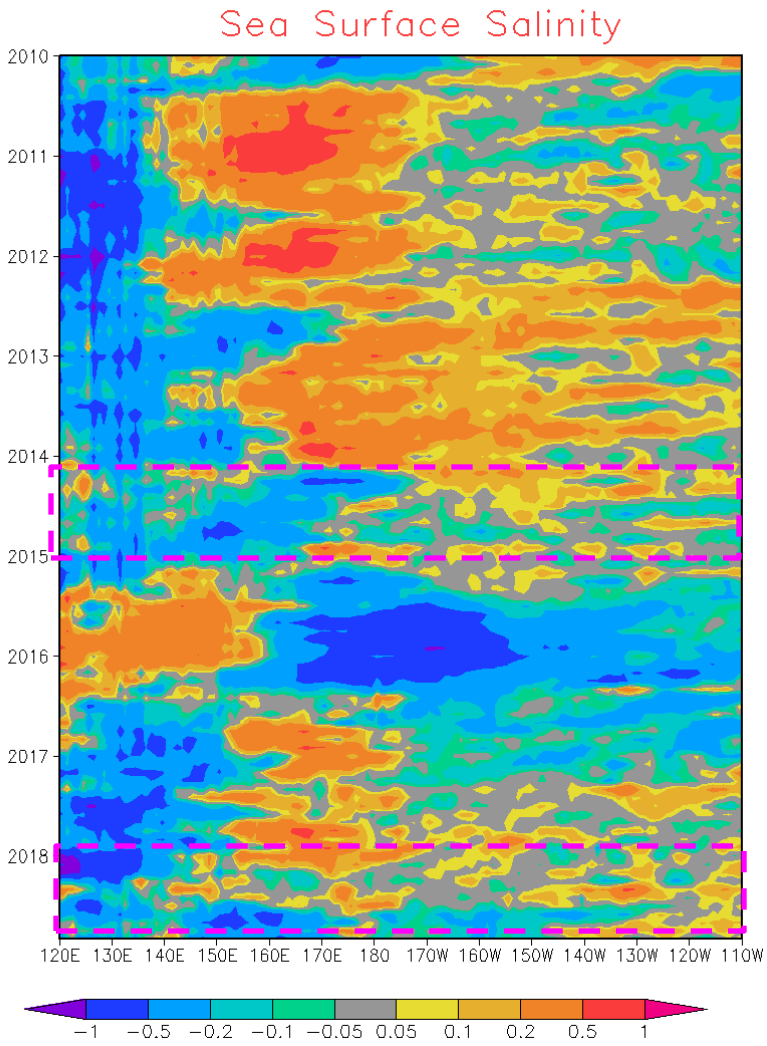
Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific from Monthly SSS

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.

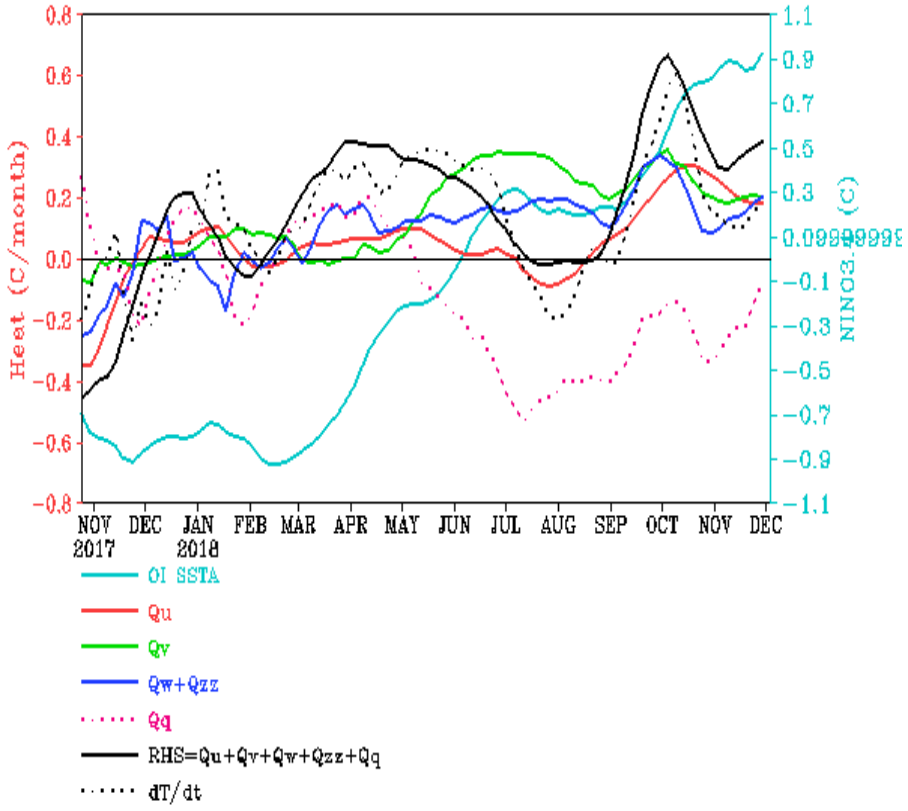
- **Negative SSS anomalies dominated across the western-central equatorial Pacific ocean since Oct 2018.**

- **Evolution of SSS anomalies in 2018 is similar with that of 2014.**



Hovemoller diagram for equatorial SSS anomaly (5° S-5° N)

NINO3.4 Heat Budget



- Positive observed SSTA tendencies (dT/dt; dotted black line) continued in Nov 2018.

- All dynamical terms(Qv, Qu, Qw+Qzz) contributed to the warming 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

2018 E. Pacific Hurricane Season

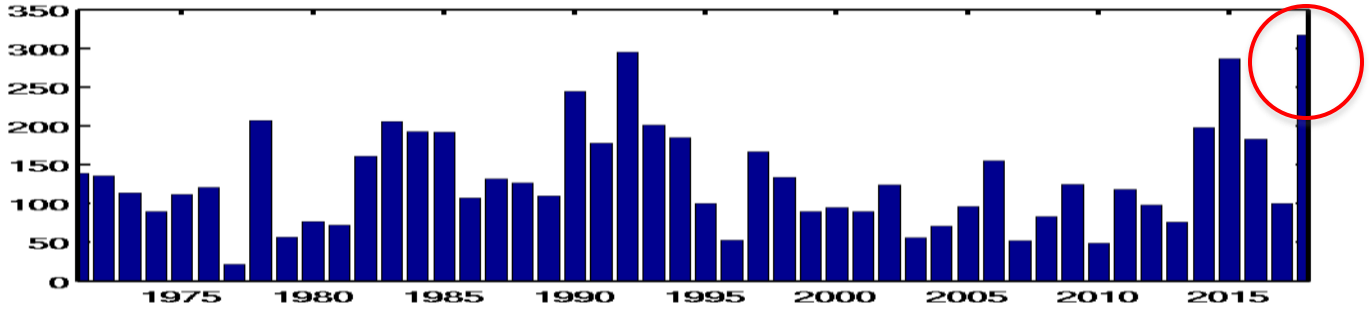
(https://en.wikipedia.org/wiki/2018_Pacific_hurricane_season)

- 2018 E. Pacific hurricane season has ended in Nov, with last system dissipating on Nov 6.

-23 tropical storms formed during 2018 hurricane season, with 13 developing into hurricanes and 10 becoming major hurricanes.

- 2018 E. Pacific hurricane season produced the highest ACE since 1971, and is the fourth most active season based on storm number.

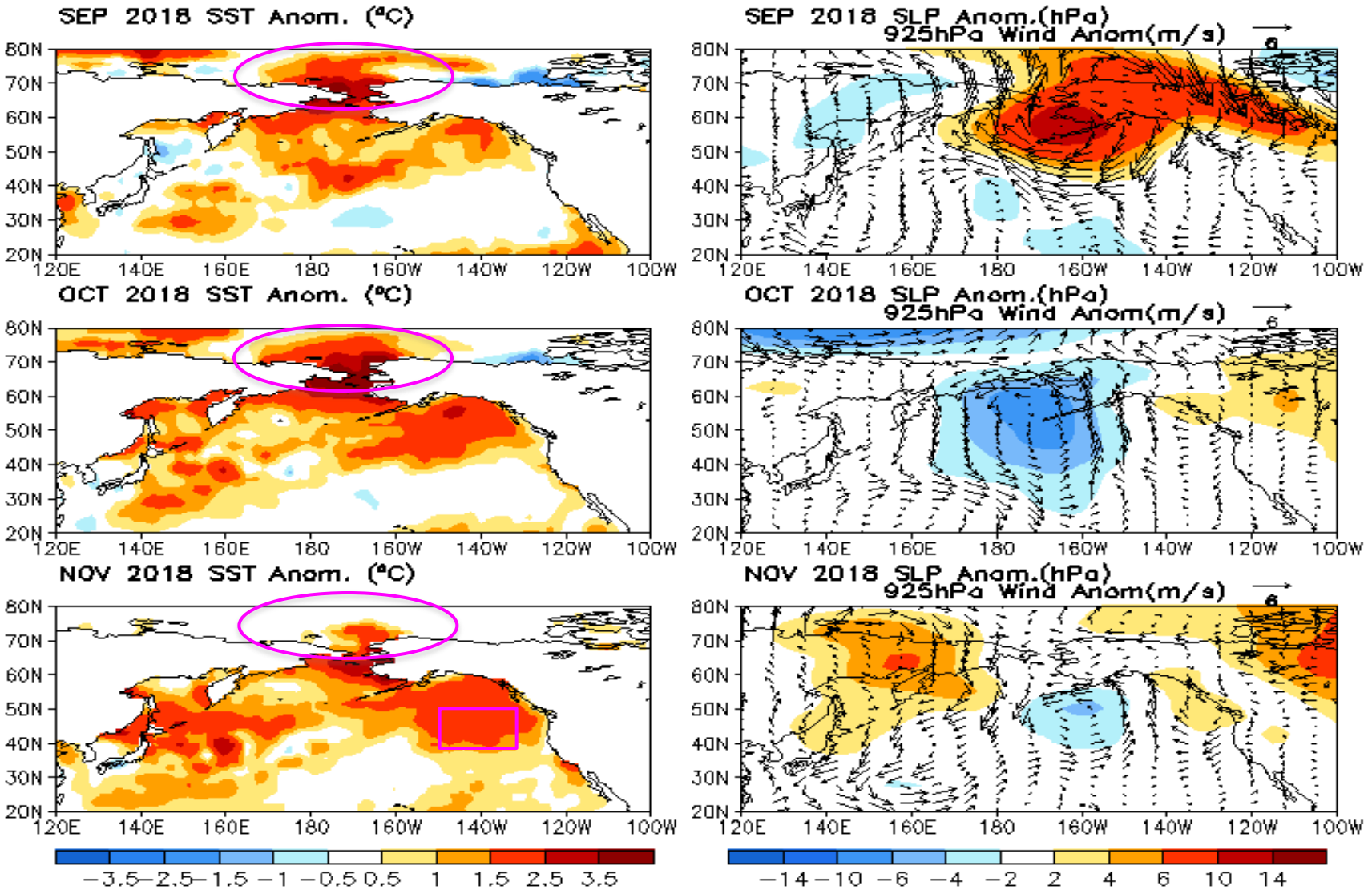
E. Pac Accumulated Cyclone Energy



E.Pac	2018 prediction (issued on May 24) 80% near or above normal	1981-2010	Observations (By Dec 10)
Named storms	14-20	15	23
Hurricanes	7-12	8	13
Major hurricanes	3-7	4	10
ACE	80%-160% median	100.4×10^4 kt^2	317

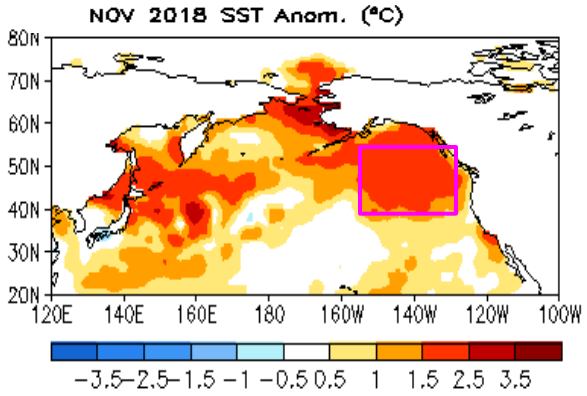
North Pacific & Arctic Oceans

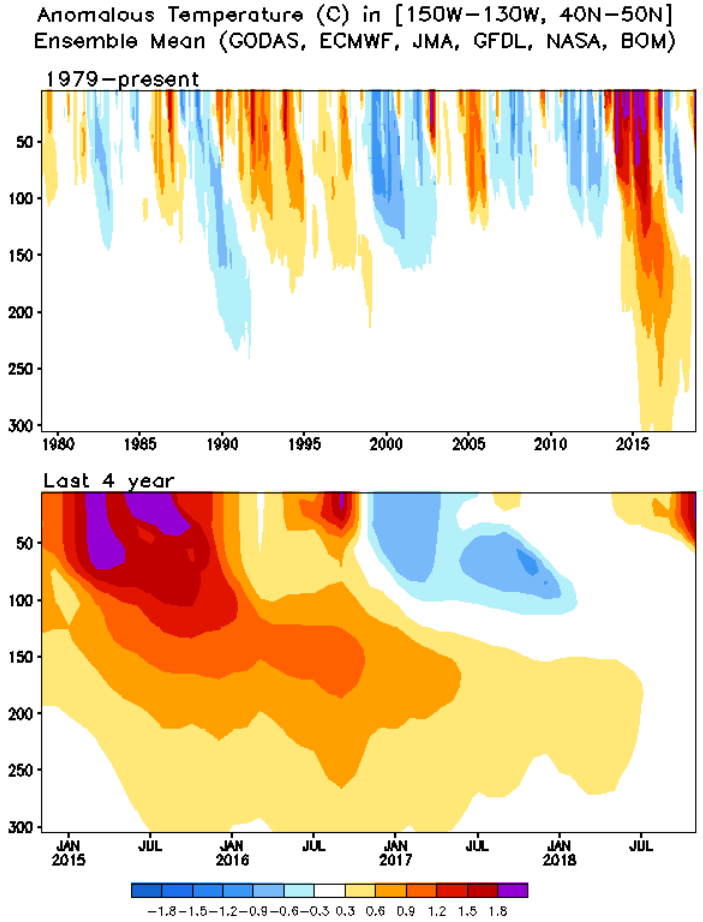
Last Three Month SST, SLP and 925hPa Wind Anomalies



- **SST warming continued in the northeast Pacific (Pacific "Blob").**
- **Positive SSTA weakened substantially in the Arctic Ocean.**
- **Distribution of SST anomalies between 20 - 50N varied month by month, owing to the high frequency changes in the atmospheric circulation.**

"Blob" in North Pacific

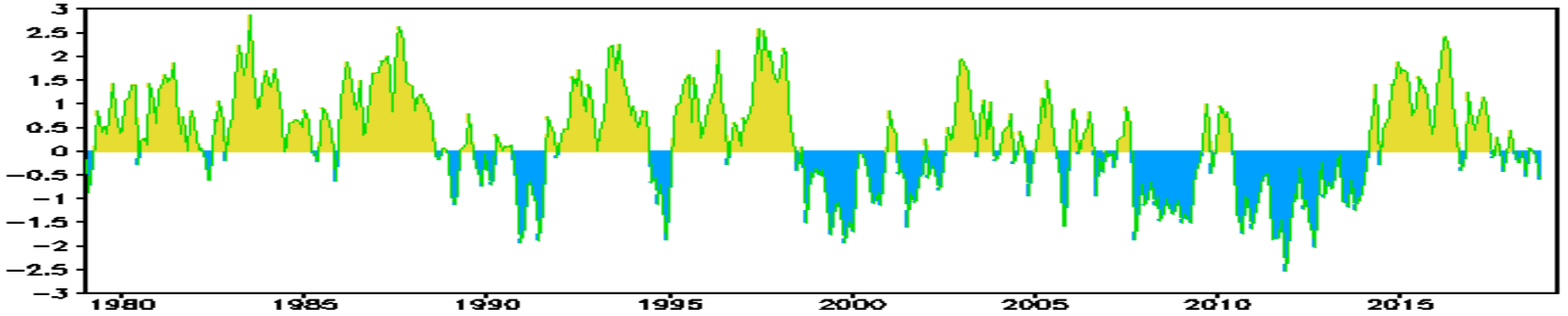




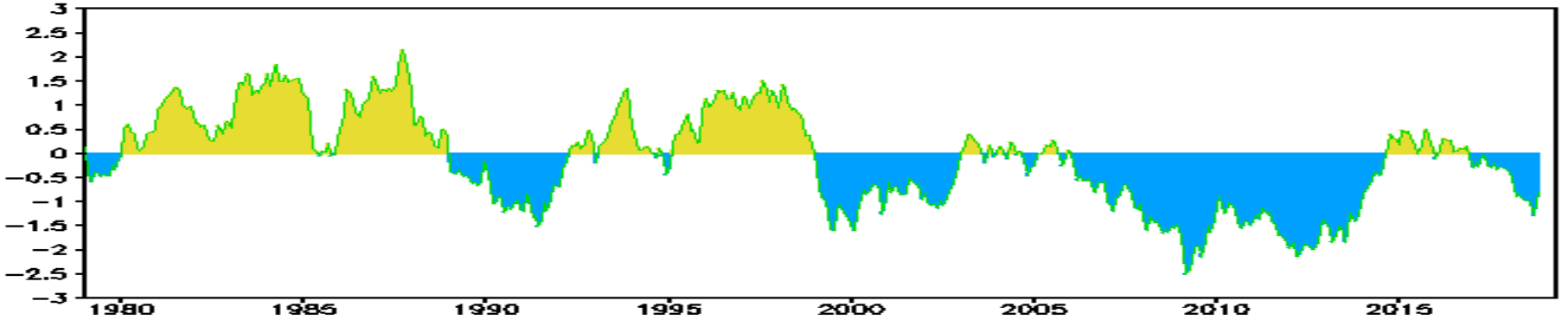
- **Between winters of 2013/14 and 2015/16, northeast Pacific experienced the strongest SST warming ever recorded, referred to as "Blob" by Bond et al. (2015)**
- **Warming has gradually extended to 300m since the late 2013.**
- **Near surface warming re-emerged since May 2018, while the warming is only confined within the upper 50m.**

Two Oceanic PDO indices

SST-based PDO



H300-based PDO

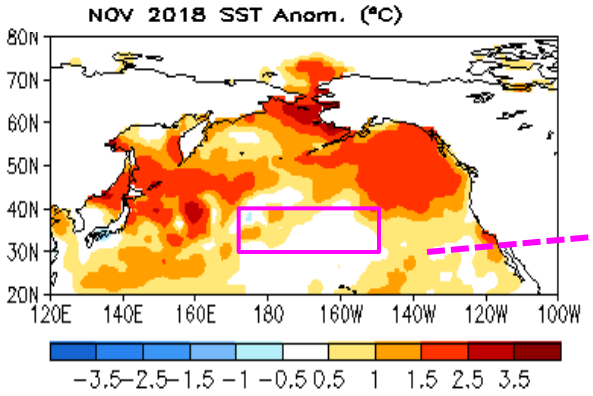


- **Negative SST-based PDO index enhanced in Nov 2018, with PDO index =-0.6.**
- **Negative H300-based PDO index has persisted 13 months since Nov 2016, with HPDO = -0.8 in Nov 2018.**
- **SST-based PDO index has considerable variability both on seasonal and decadal time scales.**

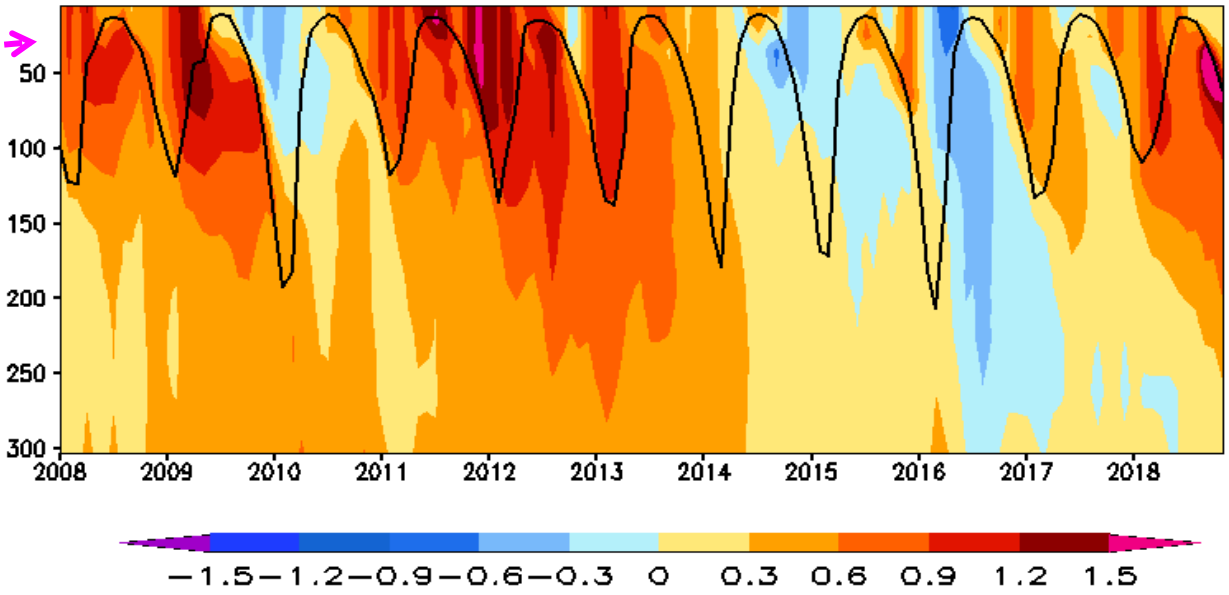
(H300-based PDO index is downloadable from http://www.cpc.ncep.noaa.gov/products/GODAS/PDO_body.html)

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.

Subsurface Temperature Anomaly in the C. N Pacific



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

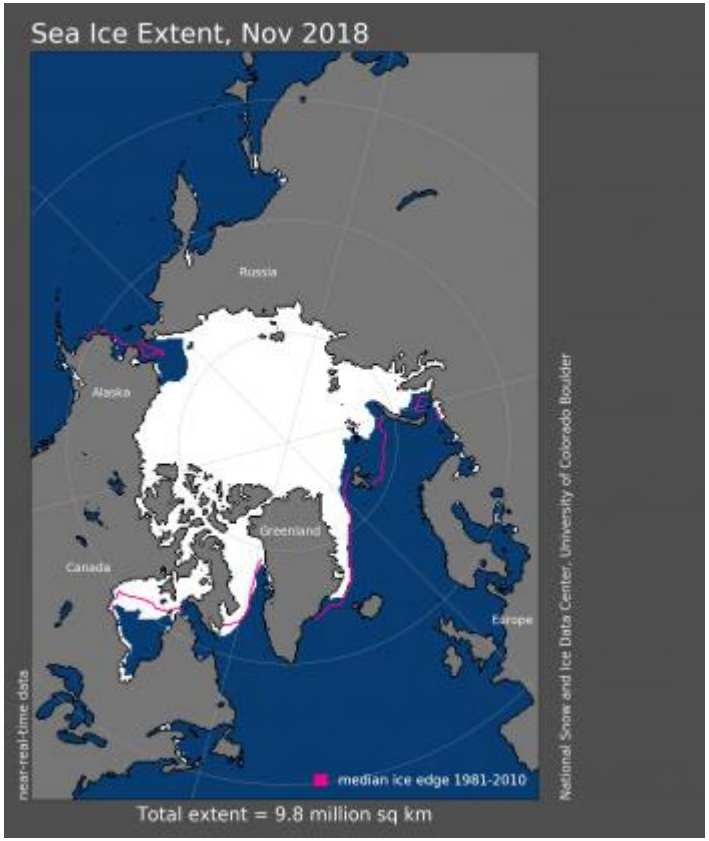


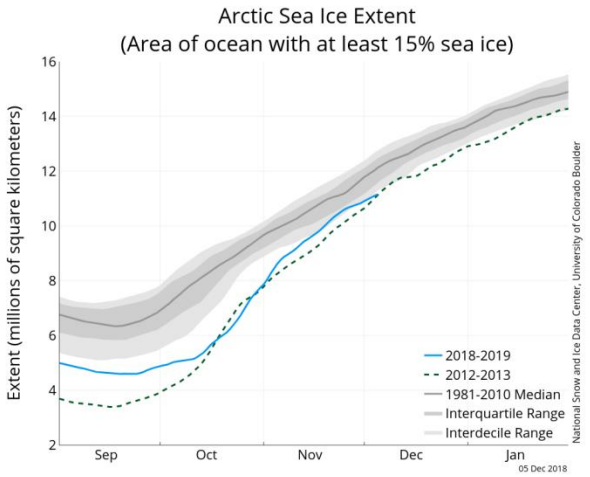
- **Strong subsurface warm water tend to warm up the surface when the mixed layer deepens during the winter season.**

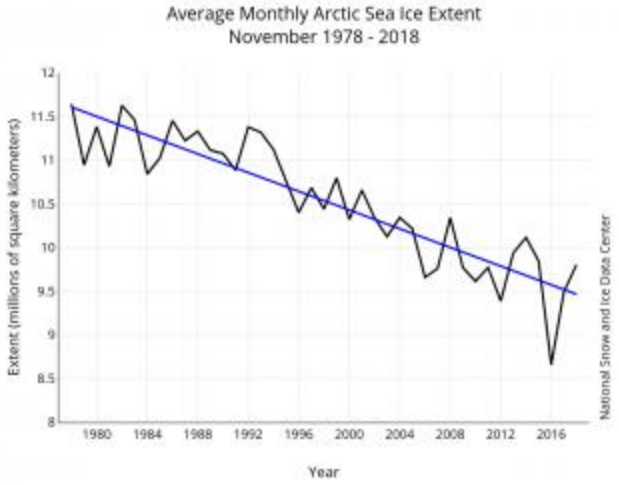
Arctic Sea Ice

National Snow and Ice Data Center

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



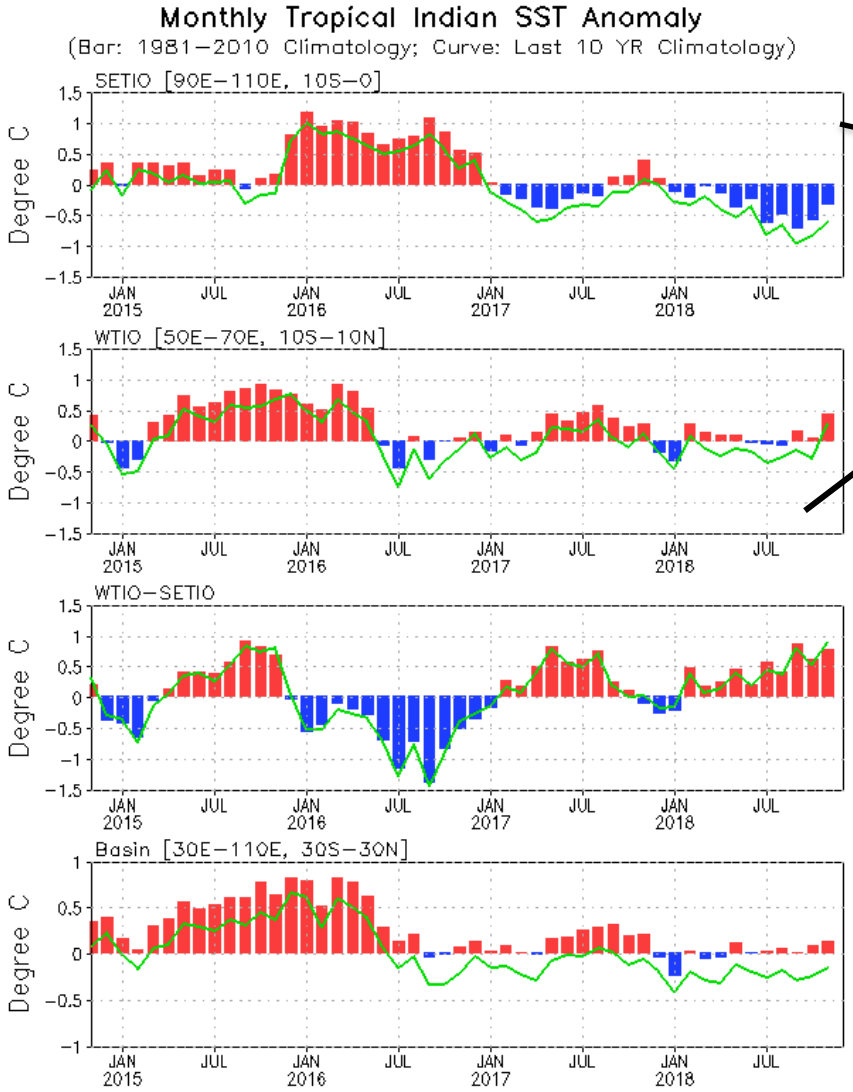


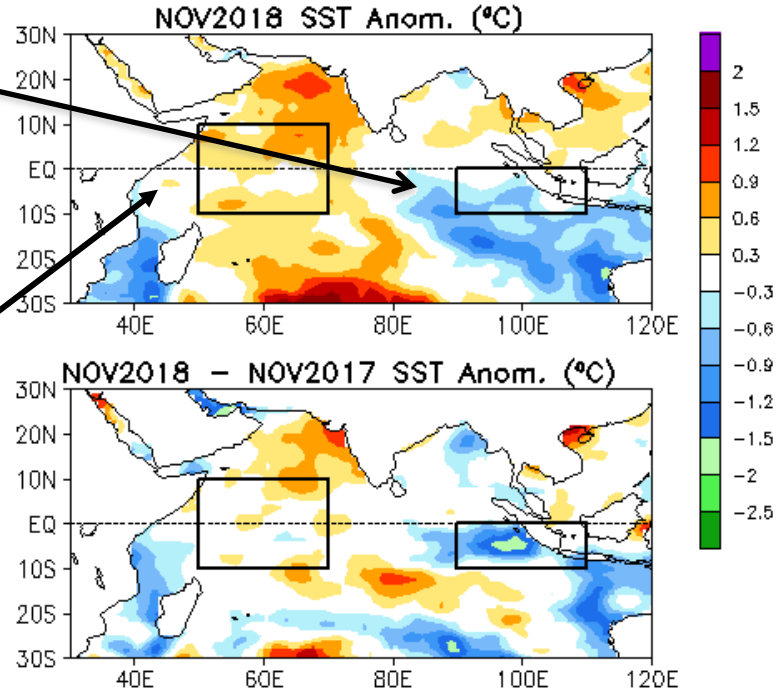


-Arctic sea ice extend in Nov 2018 ranked the ninth lowest Nov since 1979.

Indian Ocean

Evolution of Indian Ocean SST Indices





- **Positive Indian Ocean Dipole strengthened in Nov 2018,with IOD index = 0.8 C.**

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.

- **Positive (negative) SSTA enhanced (weakened) in the western (eastern) Indian Ocean.**

- **Surface net heat flux was the dominant factor modulating the SST anomaly tendency.**

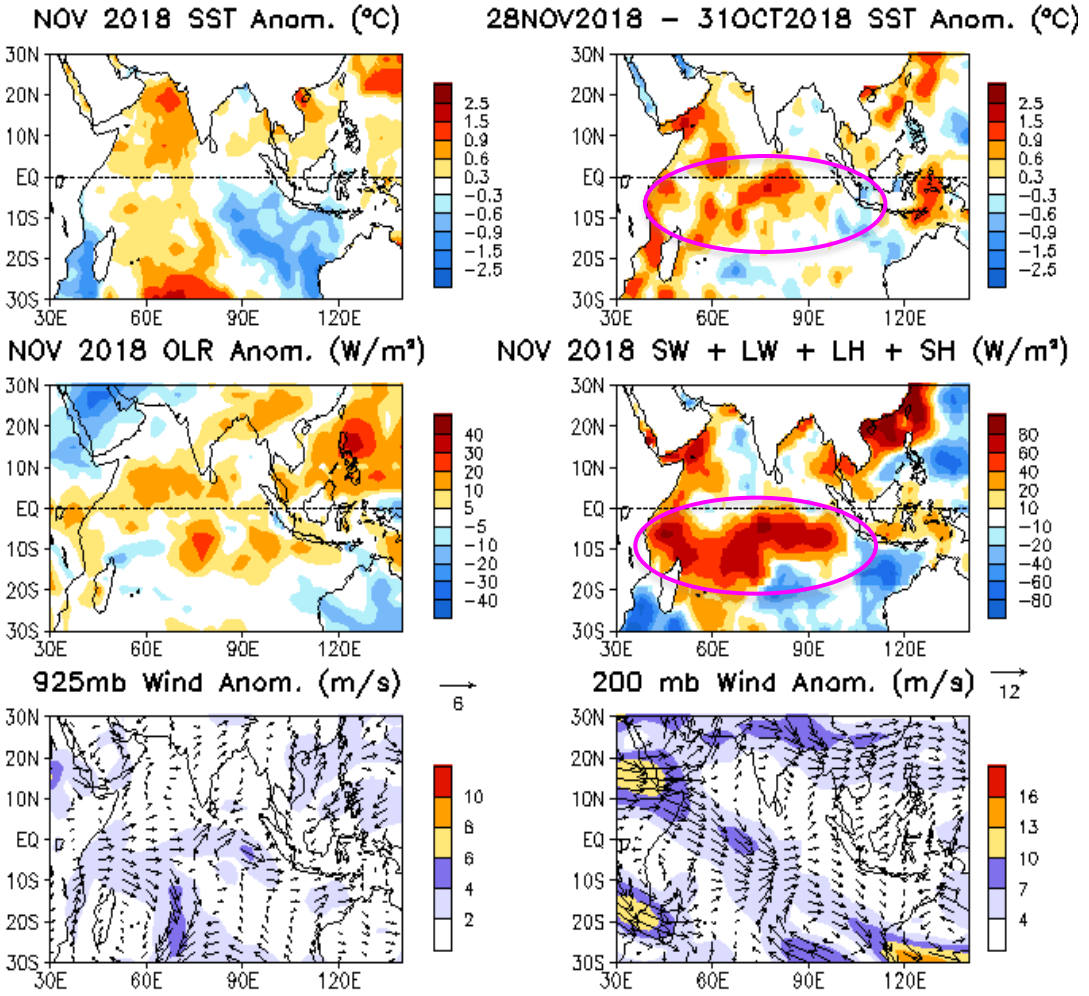
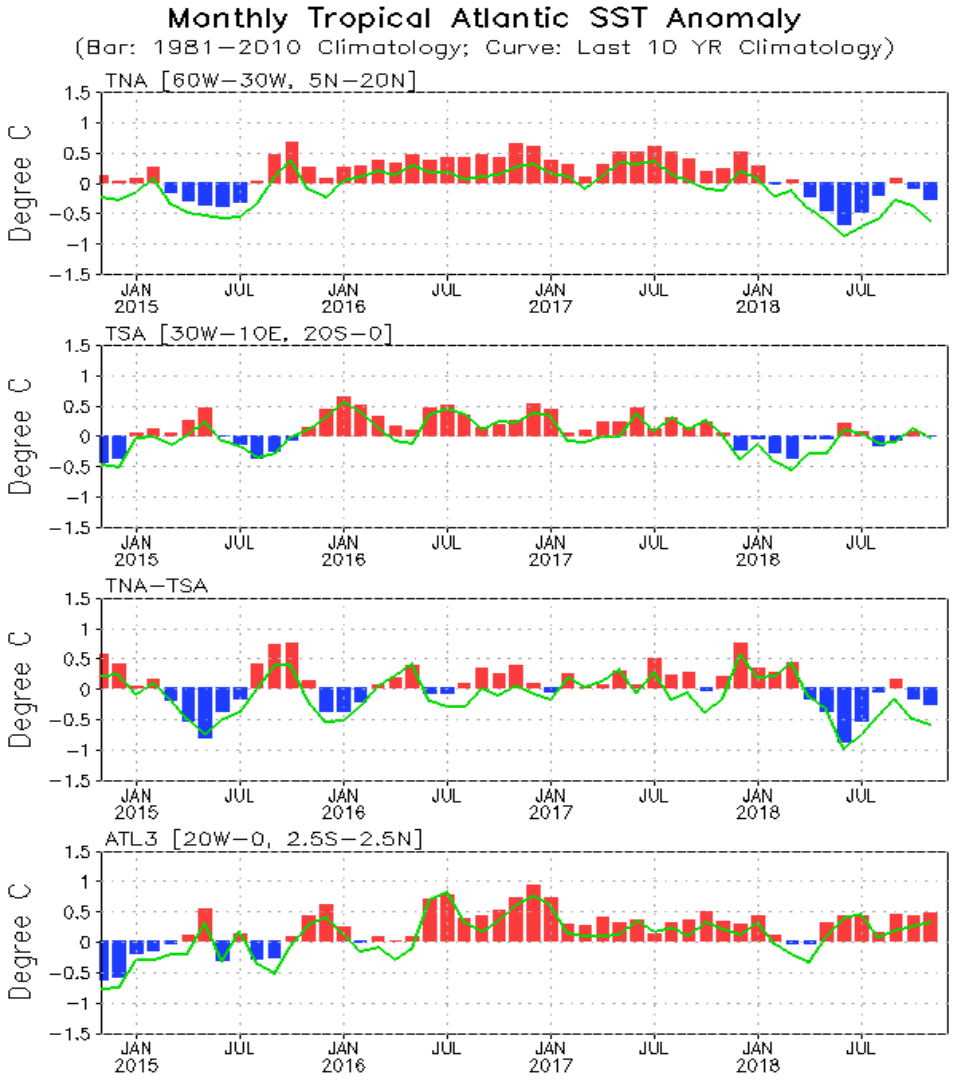
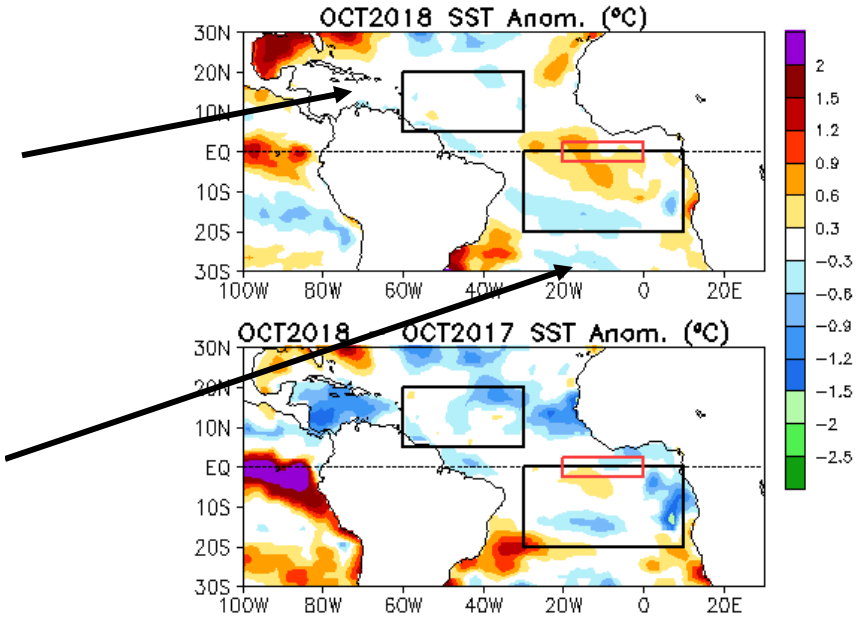


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices





- **Negative TNA strengthened in Nov 2018.**
- **Positive Atl 3 continued in Nov 2018.**

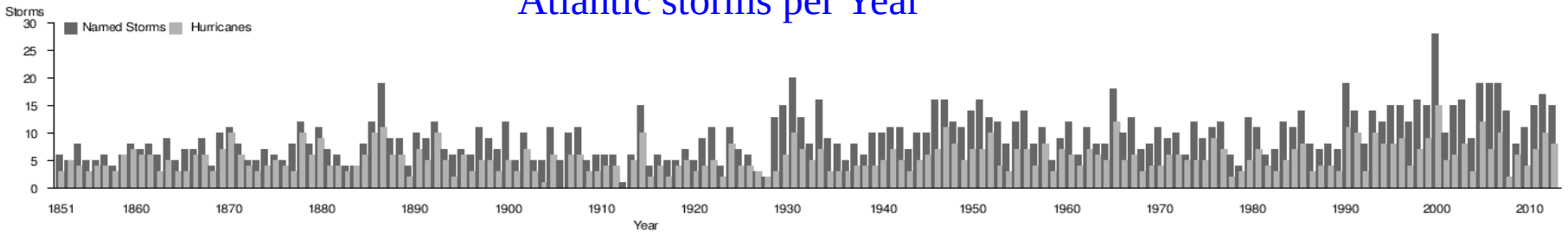
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between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

2018 Atlantic Hurricane Season Activities

- Last system dissipated in Oct 31, 2018.

- 2018 Atlantic hurricane season was the third in a consecutive series of above-average and damaging Atlantic season, with fifteen tropical storms, eight developing into hurricanes and two becoming major hurricanes.

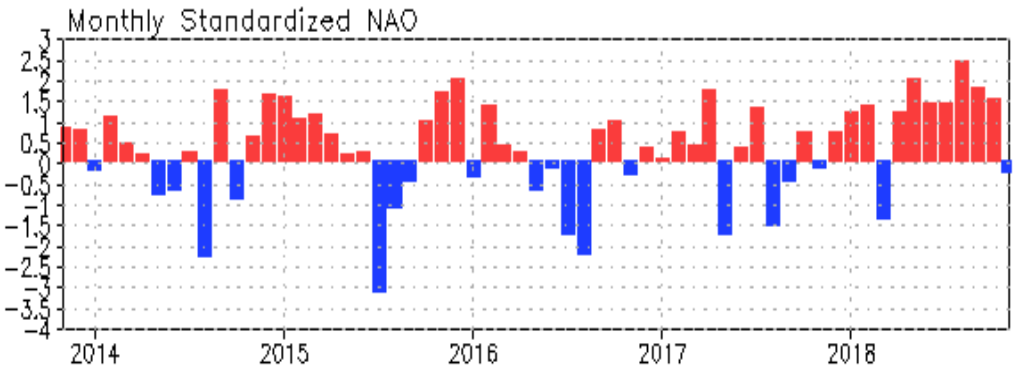
Atlantic storms per Year

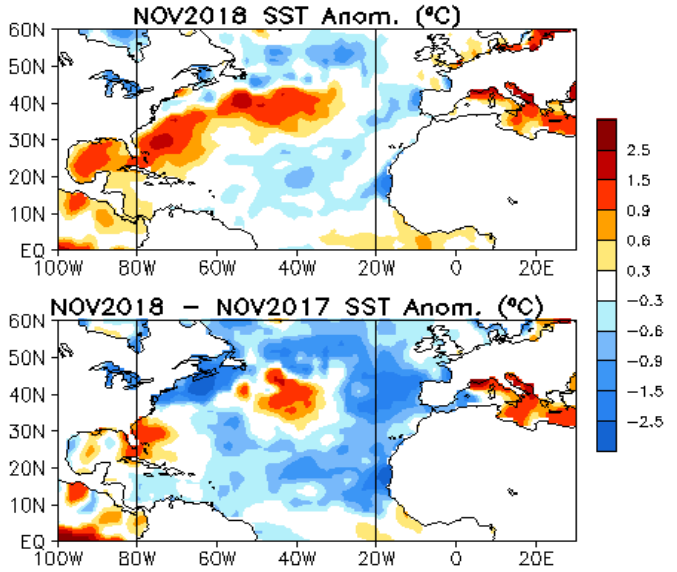


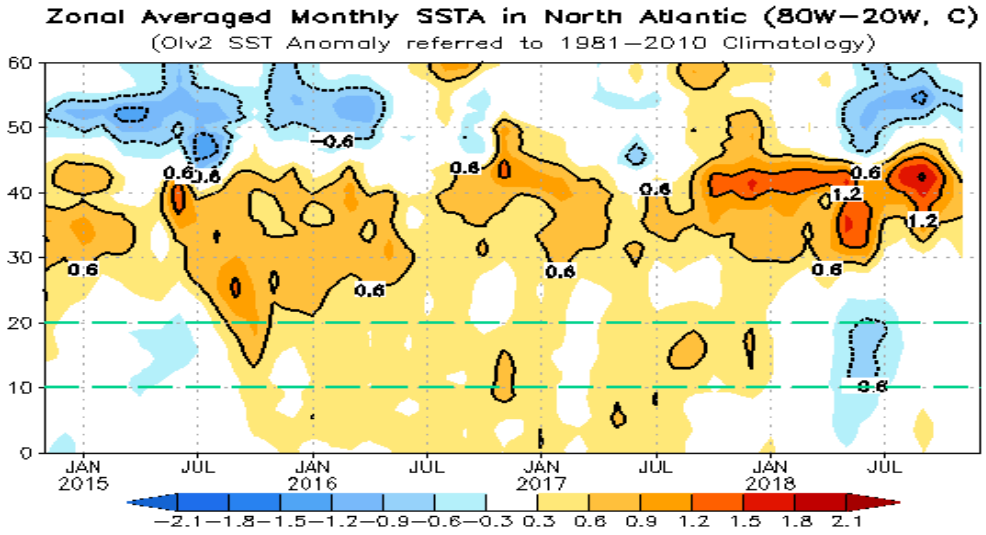
(https://en.wikipedia.org/wiki/2018_Atlantic_hurricane_season)

Atlantic	2018 prediction (issued on May 24) Updated on Aug 9 60% below average	1981-2010	Observations (By Dec 10)
Named storms	(10-16) 9-13	12	15
Hurricanes	(5-9) 4-7	6	8
Major hurricanes	(1-4) 0-2	3	2

NAO and SST Anomaly in North Atlantic



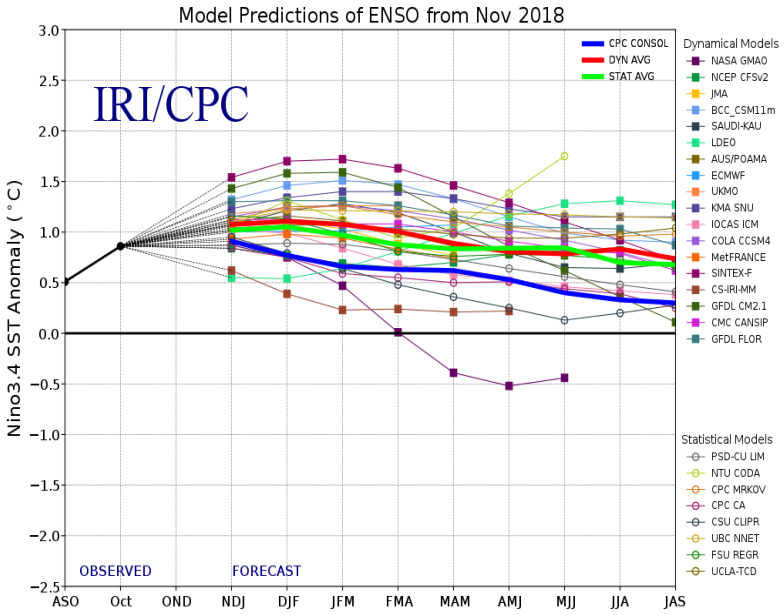


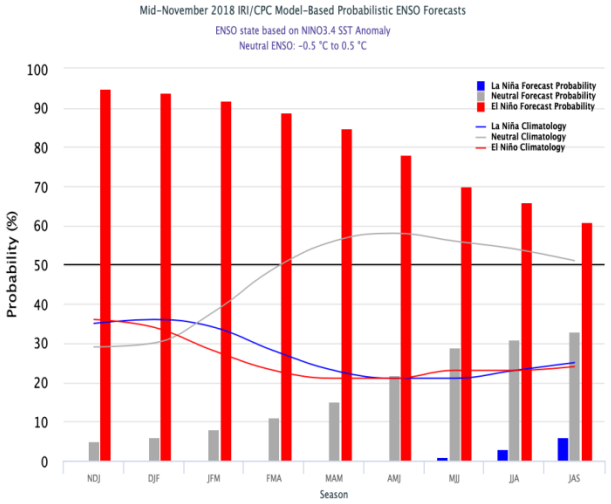


- NAO index switched to negative phase , with NAOI= -0.3 in Nov 2018.
- SSTA has a tripole/horseshoe pattern with positive in the mid- latitudes and negative in lower and higher latitudes, which resembled the late 2014 and 2015 period.

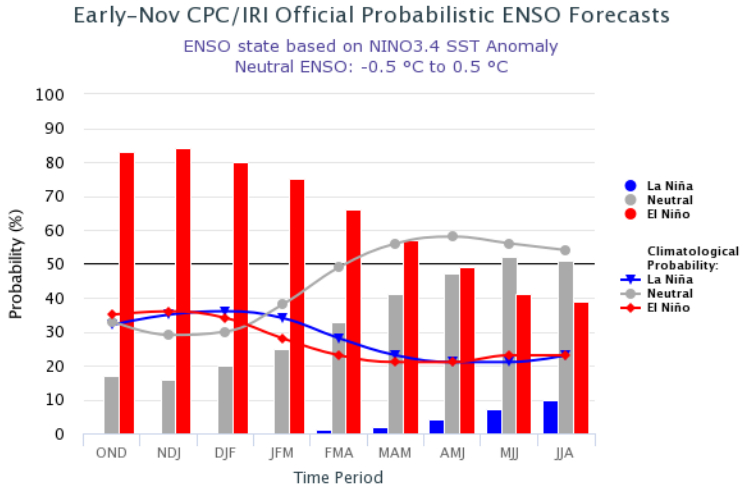
Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis,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

ENSO and Global SST Predictions

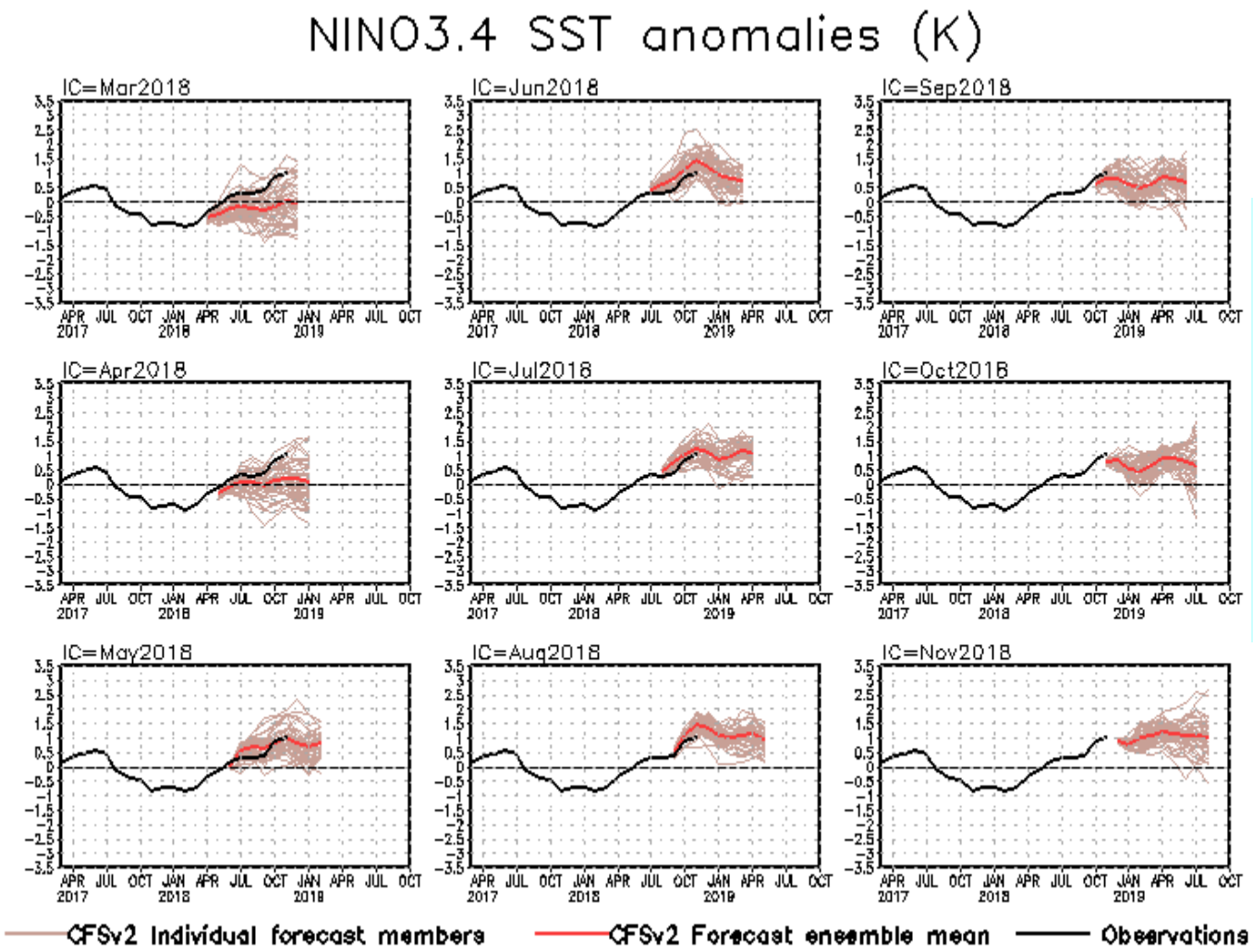




- **Most of statistical and dynamical models suggest an El Nino will develop and continue through the Northern Hemisphere 2019 summer.**



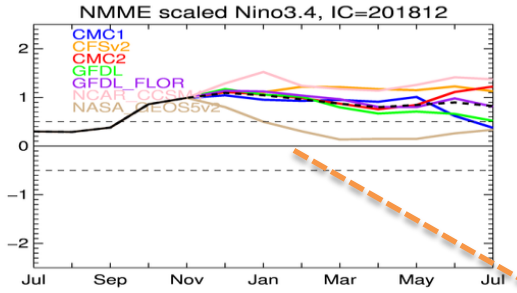
CFS Niño3.4 SST Predictions from Different Initial Months

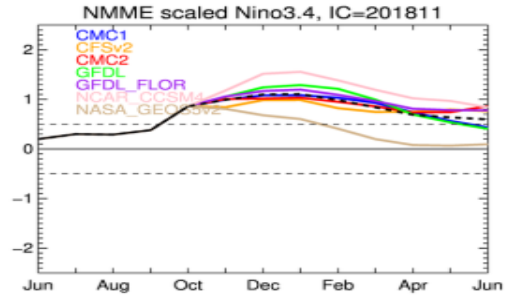


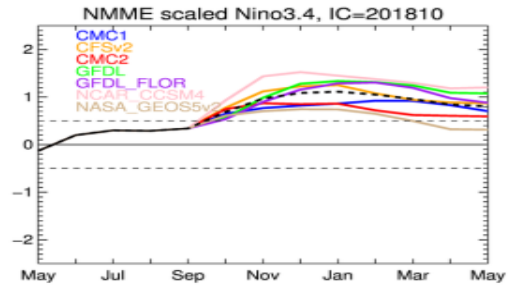
- CFSv2 predictions called for an El Nino since May IC.
- Latest CFSv2 forecasts suggest El Nino condition will continue through 2018/19 winter.

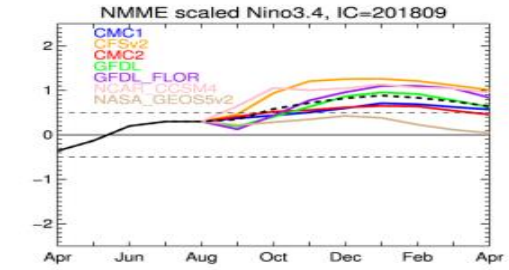
Fig. M1. CFS Nino3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with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

NMME Forecasts from different initial months

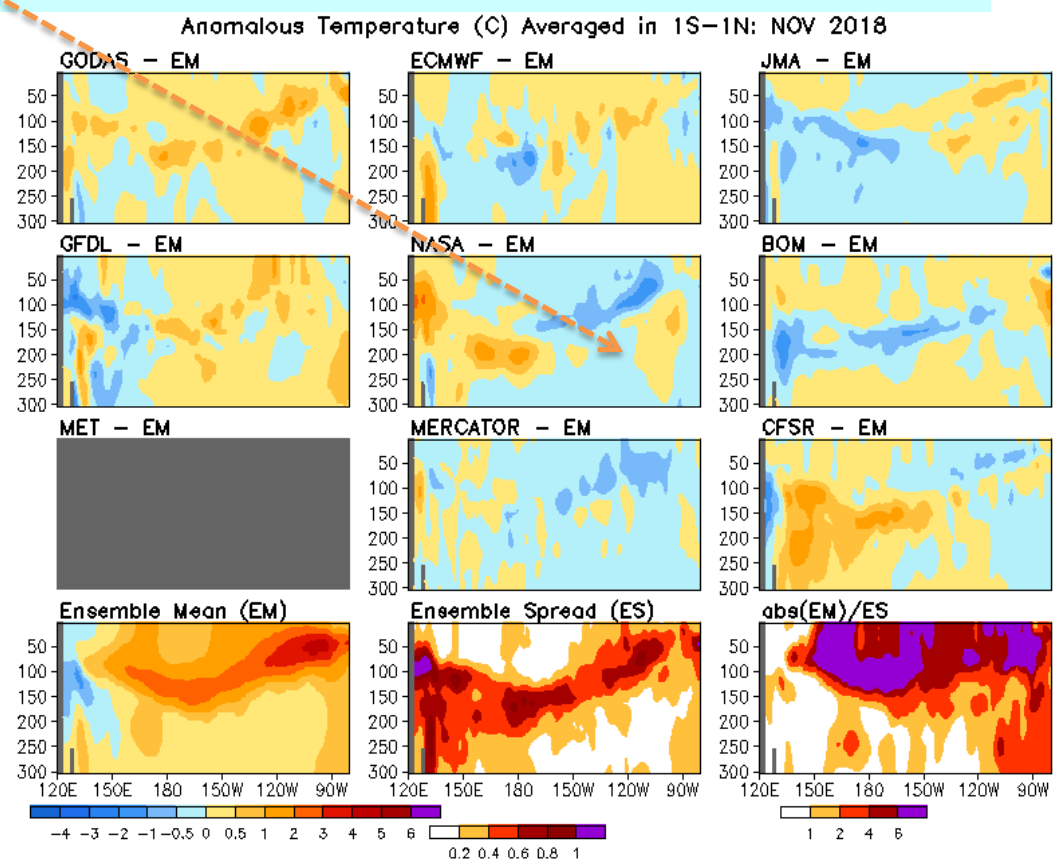




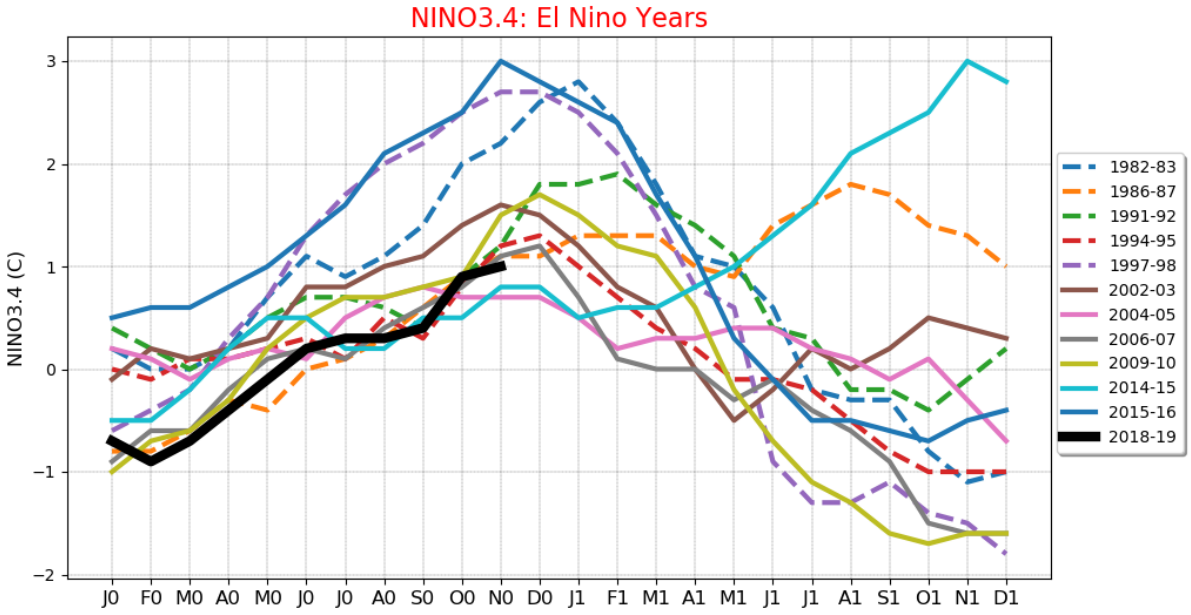




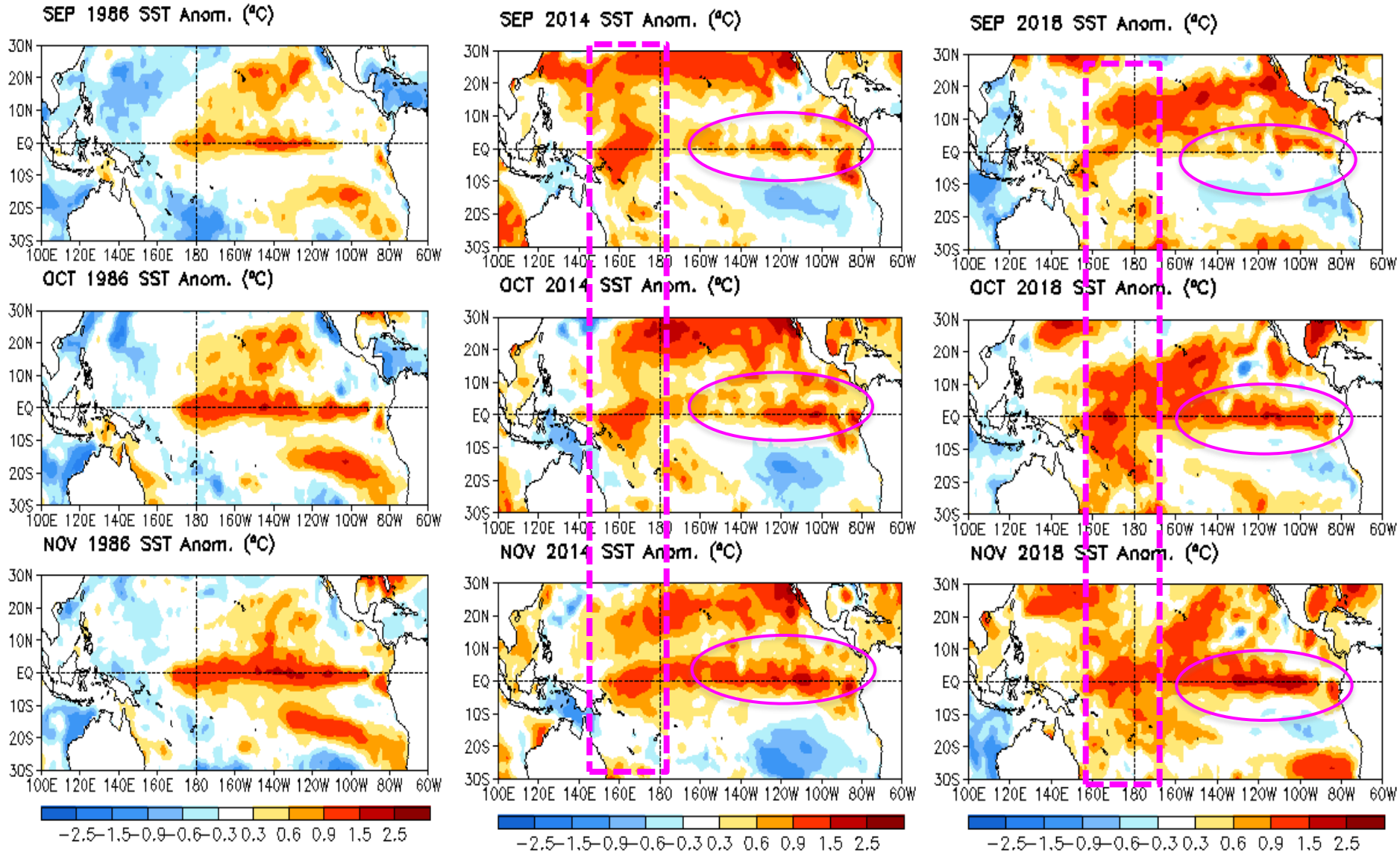
- **NMME continuously favors an El Nino will develop through 2019 spring.**
- **Compared to the ensemble mean of nine ocean reanalyses, the NASA had a cold bias near the surface in the eastern Pacific. This is consistent with the relatively colder NINO3.4 forecast by NASA_GEOS5v2**



Nino 34 El Nino composites

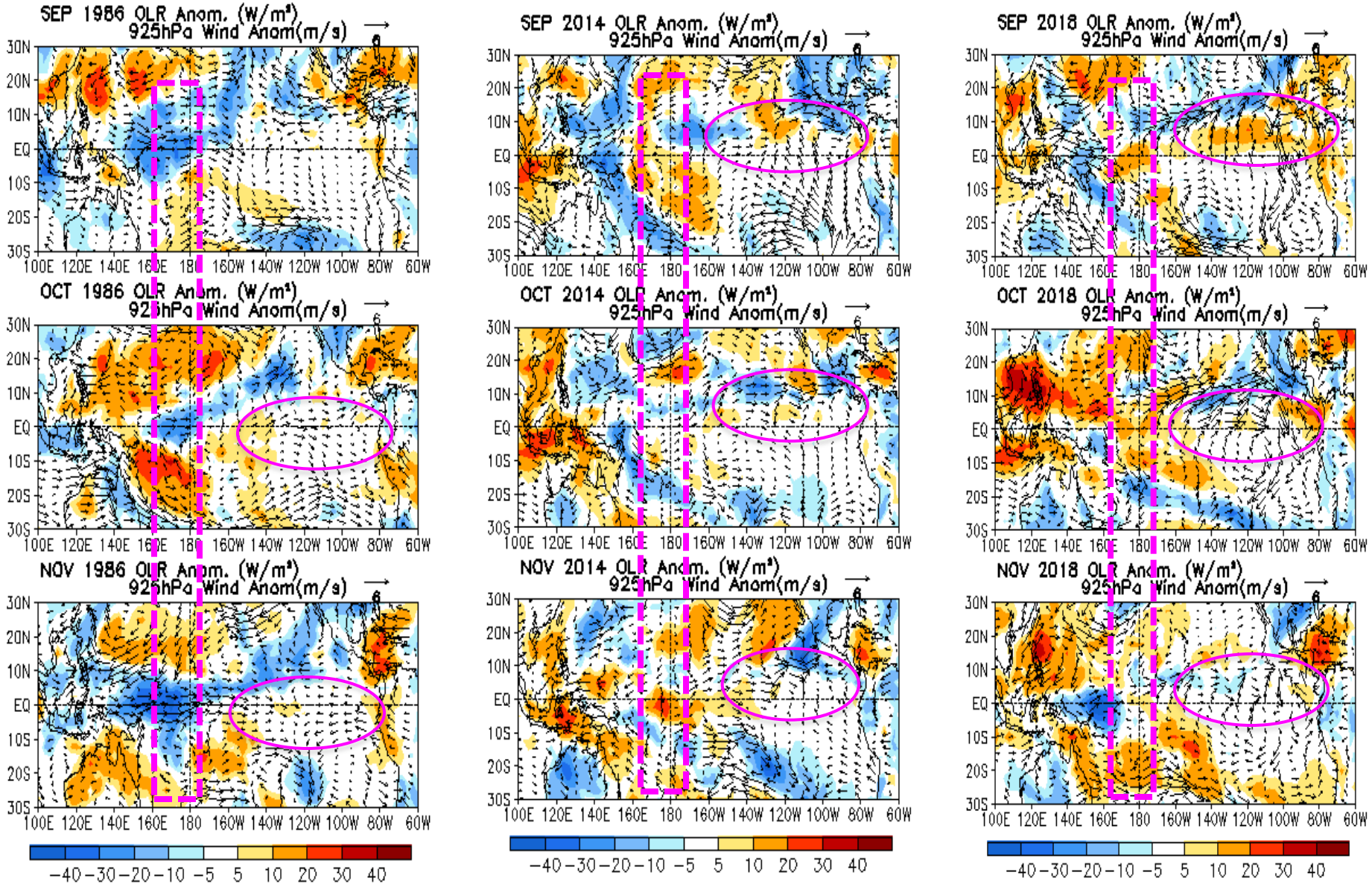


Last Three Month SSTA for 1986, 2014 and 2018



- **Positive SST anomaly persisted in the western Pacific for both 2014 and 2018.**
- **2018 SSTs during Oct-Nov were slightly warmer than those in 2014.**

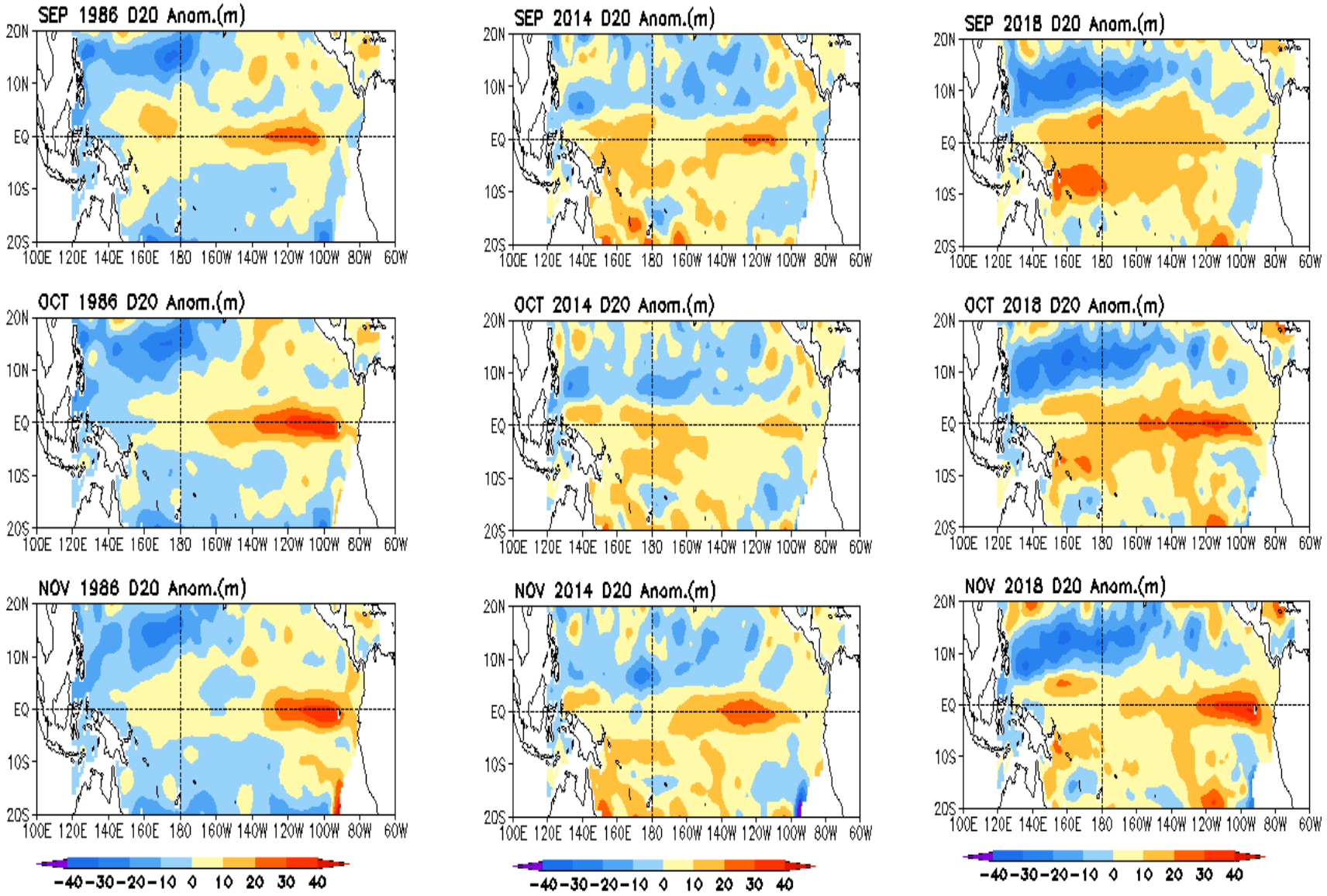
Last Three Month OLR and 925hPa wind anomaly for 1986, 2014 and 2018



- **Positive OLR anomalies persisted near the Date Line in 2014 and 2018 years.**

- **Maximum westerly wind anomalies presented on the northern side of the equator, while the maximum westerly wind anomalies were centered around the equator.**

Last Three Month D20 anomaly for 1986, 2014 and 2018



- **Positive d20 anomalies persisted across most of the equatorial Pacific during Sep-Nov in 2014 and 2018 years, while positive d20 anomalies in 1986 were confined in the central-eastern Pacific. .**

- **Positive D20 anomalies in 2018 were stronger than those in 2014.**

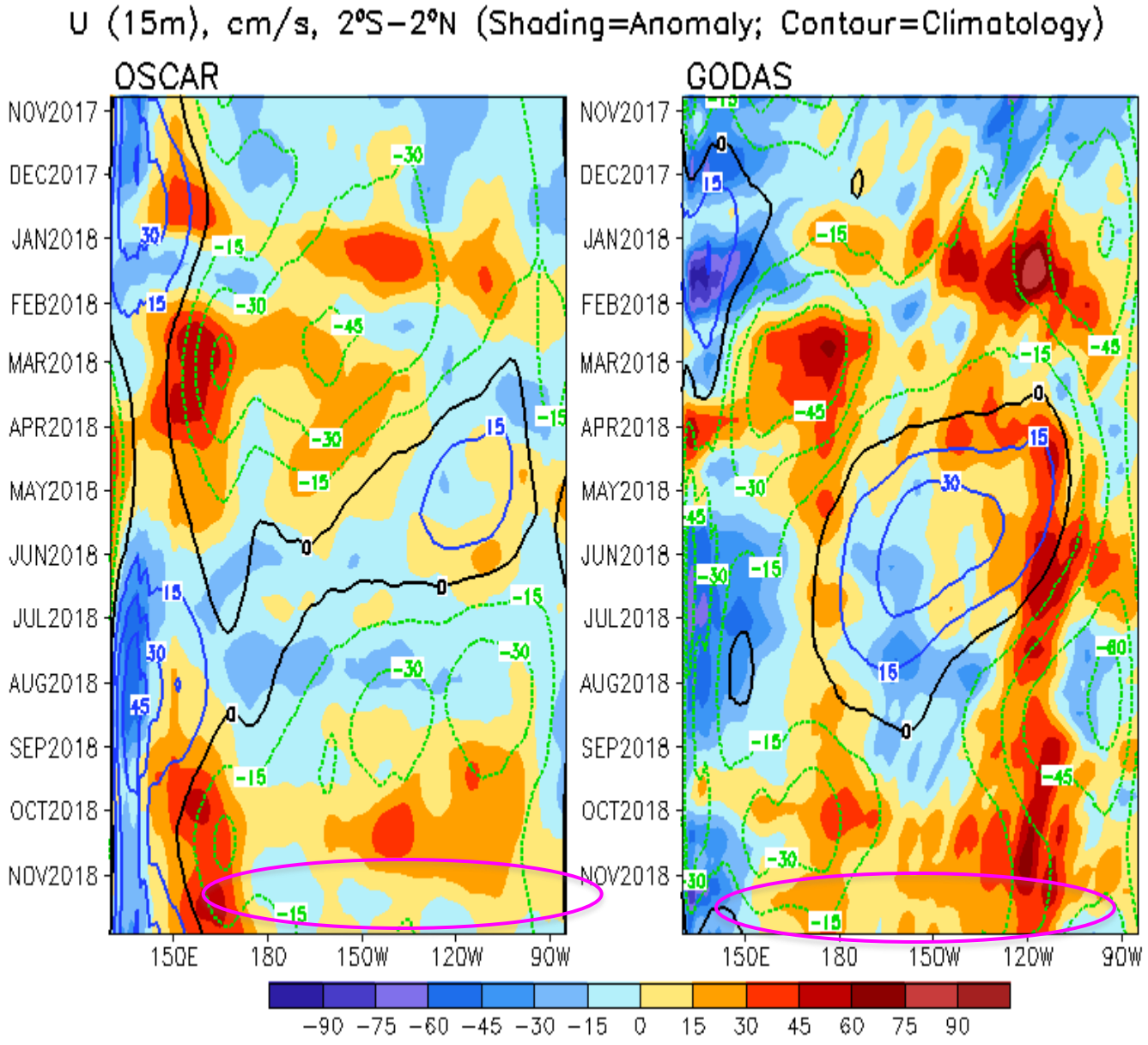
Acknowledgements

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

- Dr s. Li Ren and Pingping Xie: Provided SSS slides

Back up

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

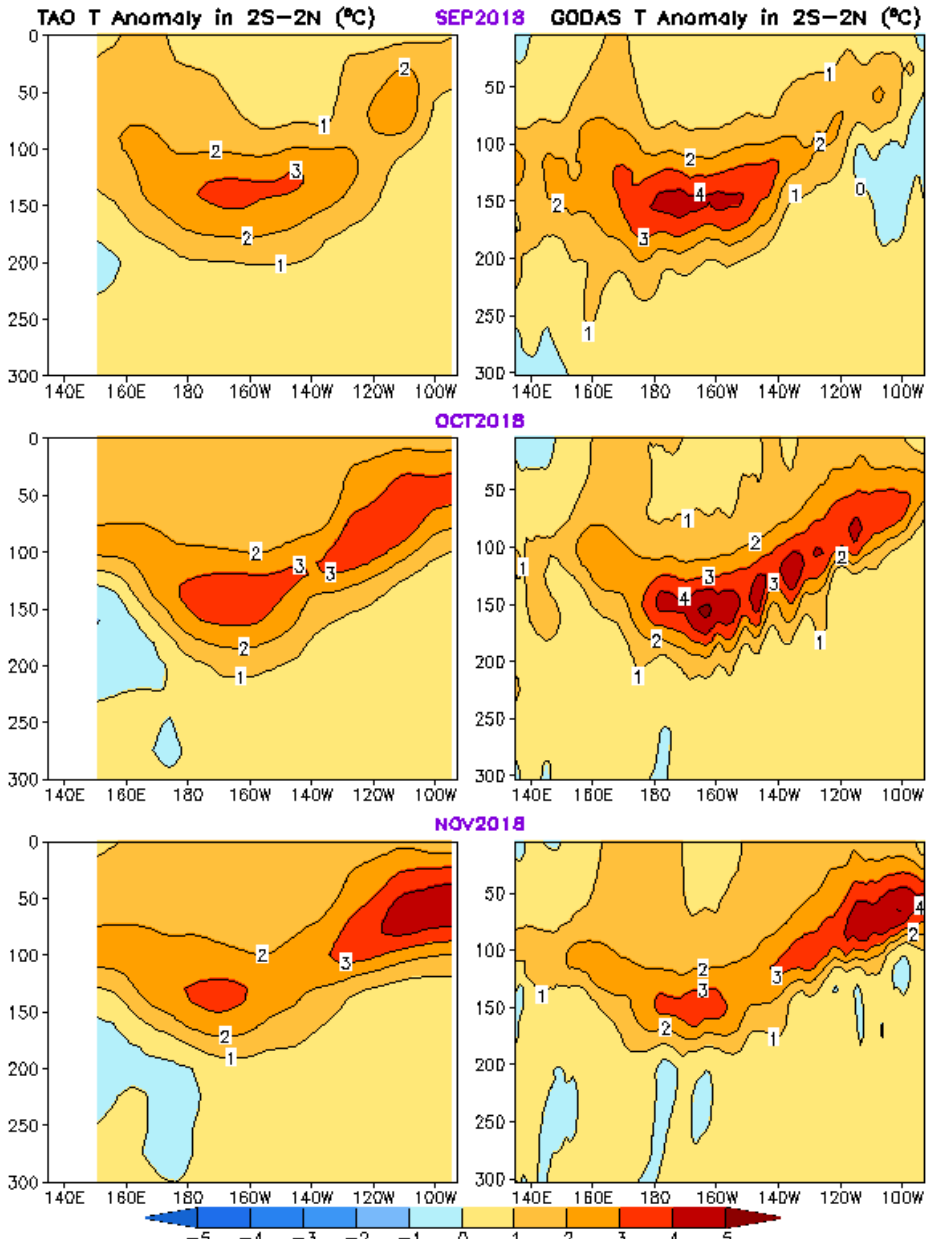


-Positive zonal current anomalies weakened across the equatorial Pacific in Nov 2018.

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

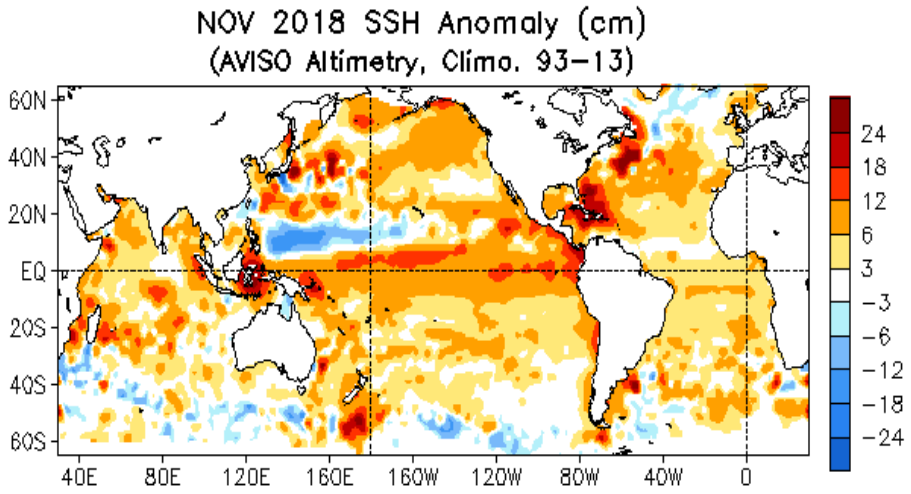
TAO

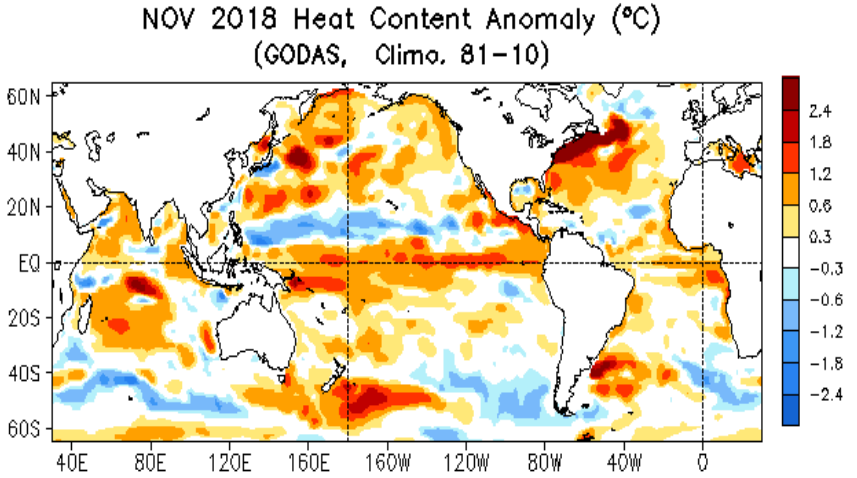
GODAS

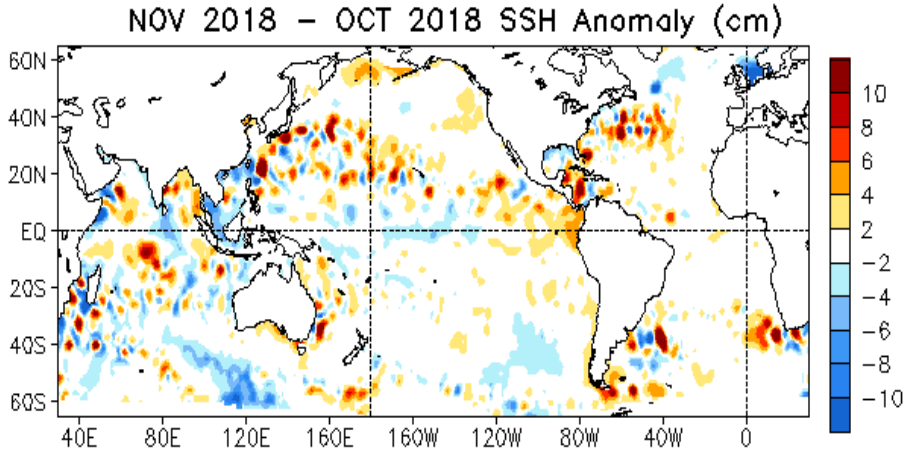


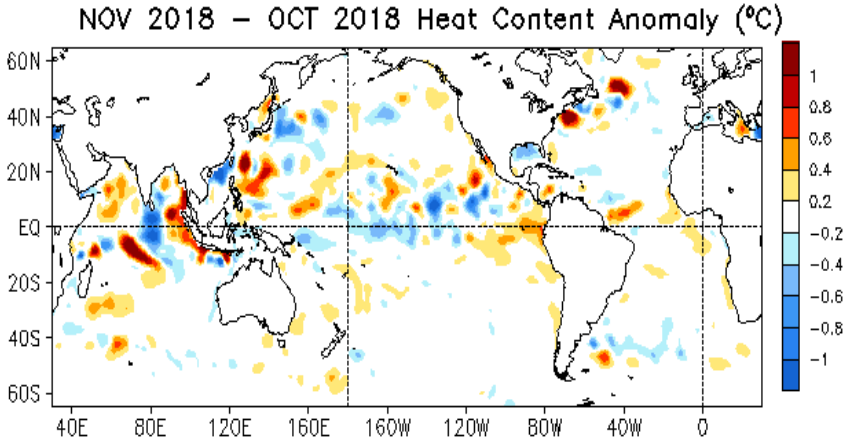
- **Positive subsurface temperature anomaly persisted in the last three months.**

Global SSH and HC300 Anomaly and Anomaly Tendency



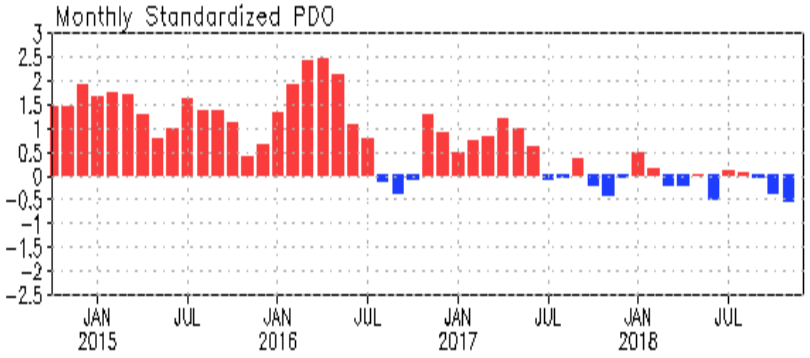


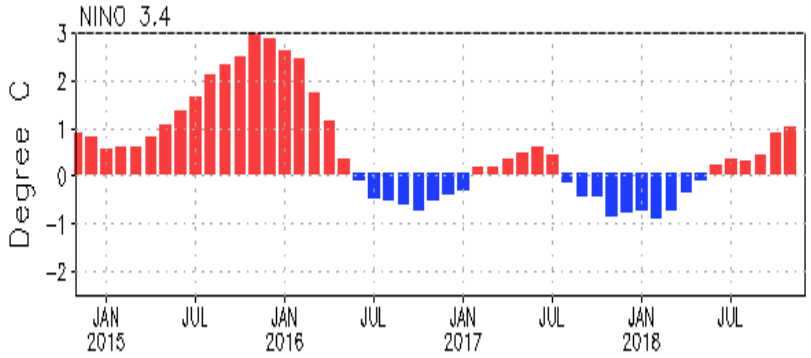


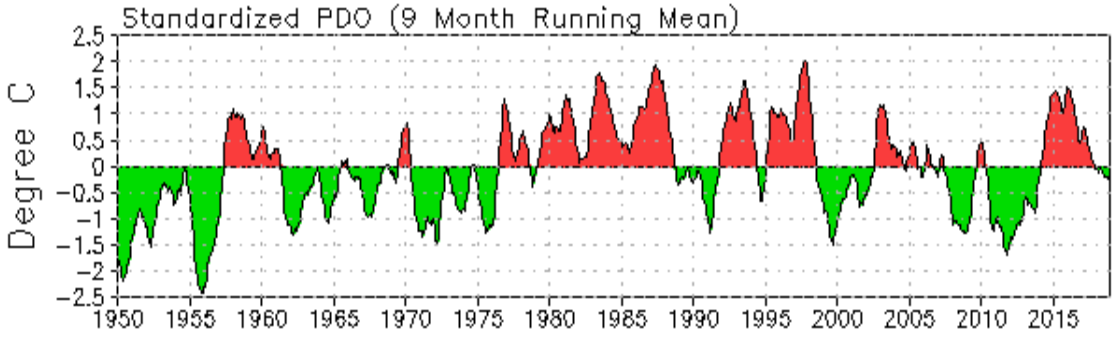


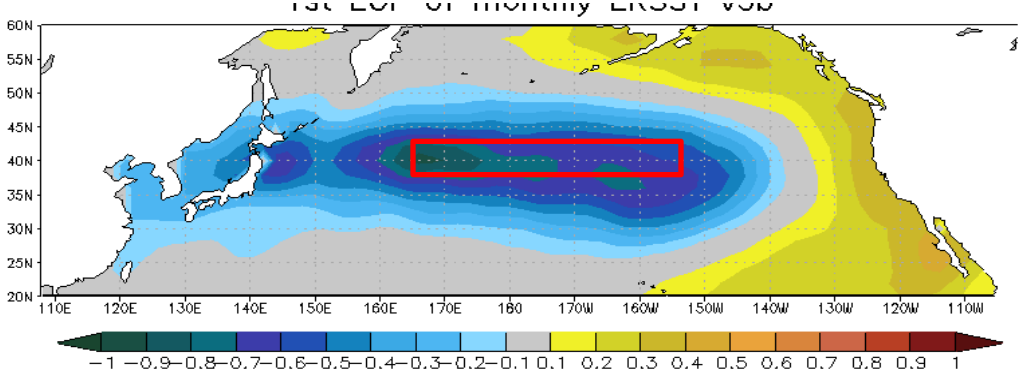
- **SSHA pattern was overall consistent with H300A pattern in the Pacific Ocean.**

PDO index









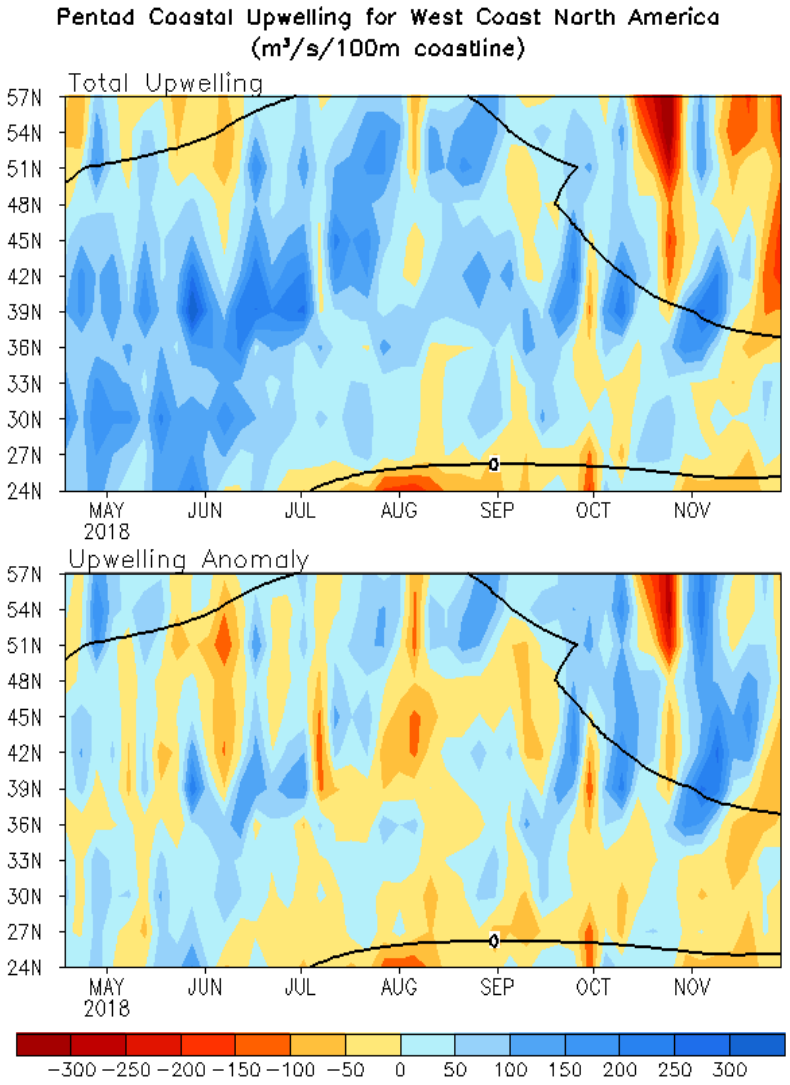
-PDO index = -0.6 in Nov 2018.

- 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.

North America Western Coastal Upwelling



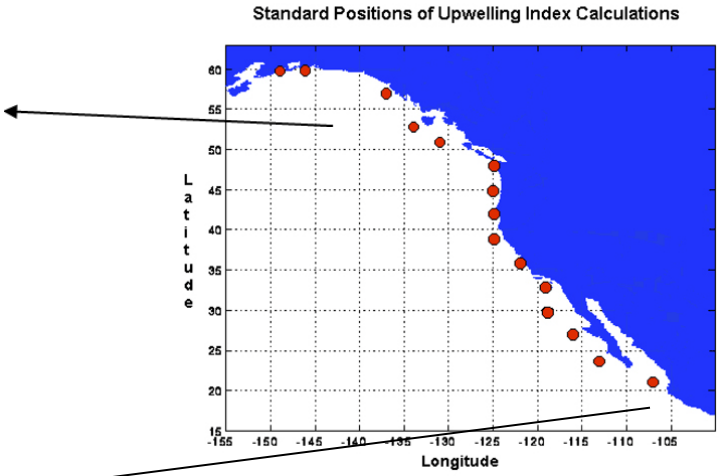
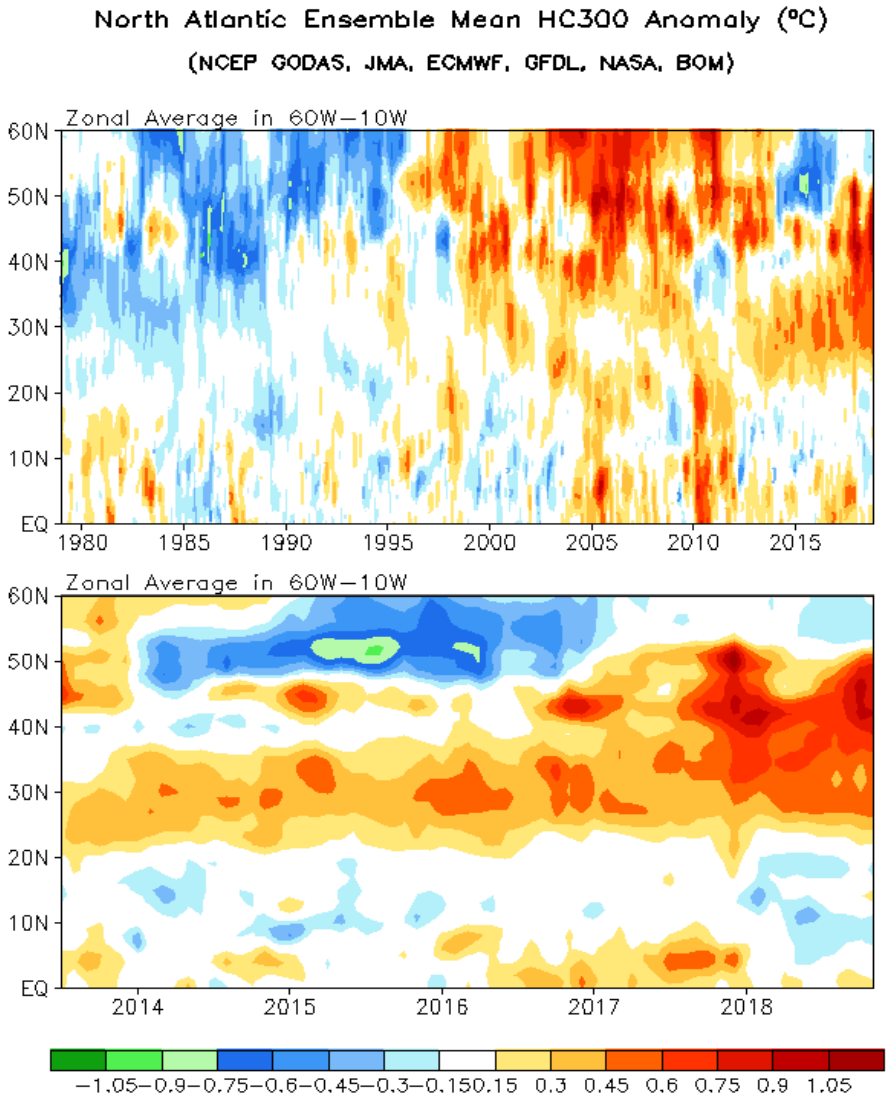
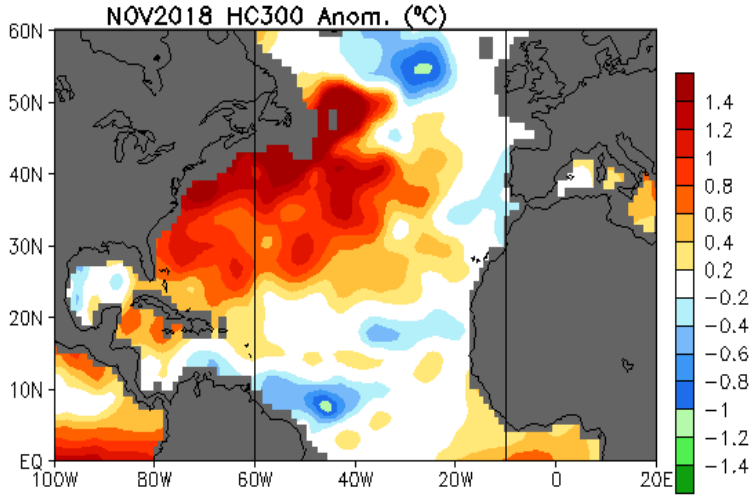


Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point ($m^3/s/100m$ 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 Mayil to July along the west coast of North America from 36°N to 57°N.**





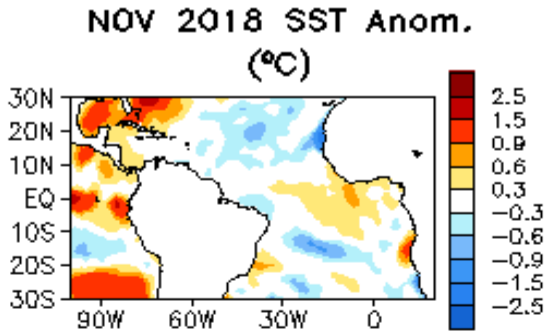
- HC300 anomaly has a tripole/horseshoe pattern with positive in the mid- latitudes and negative in lower and higher latitudes.

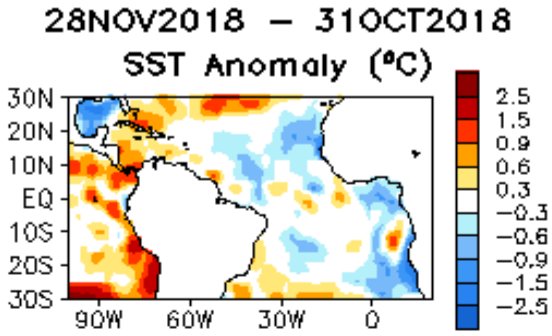
-The "cold blob" in the subpolar gyre in 2014-2016 was comparable to that before 1996.

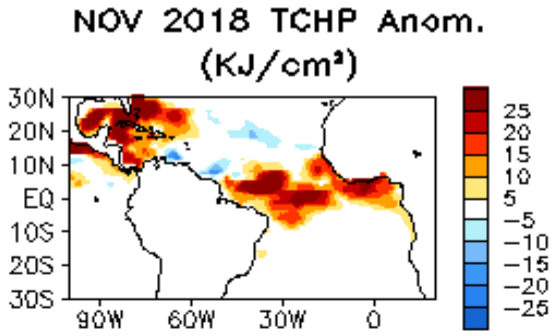
- The "cold blob" weakened substantially during 2017-2018, while warming in the mid-latitude enhanced in the last couple years.

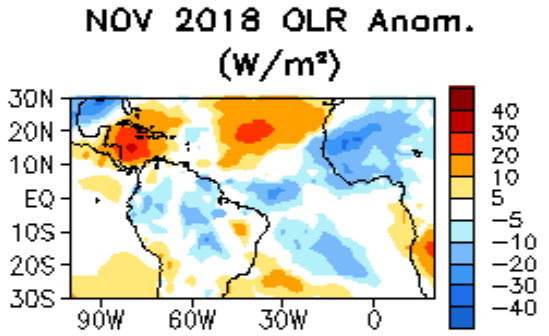
Tropical Atlantic:

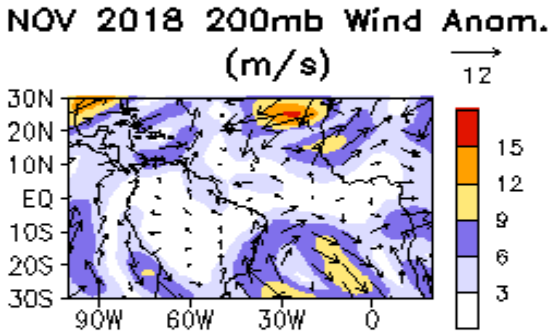
SST, SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, TCHP, 925-mb/200-mb Winds anom.

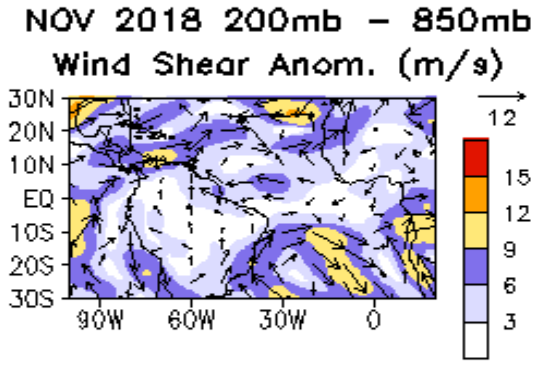


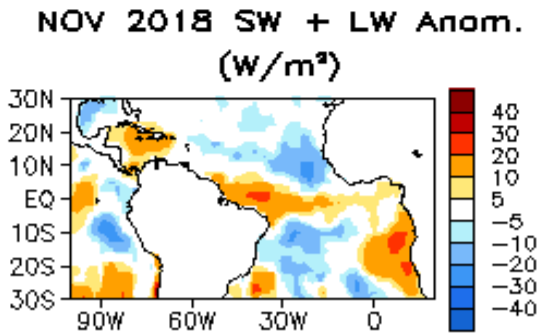


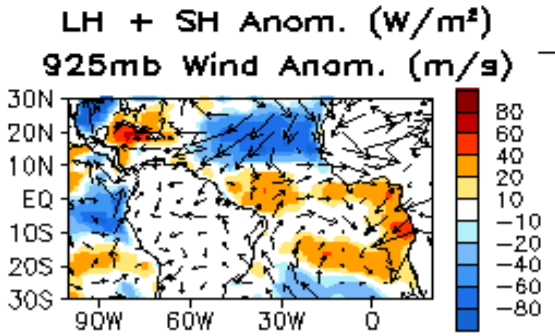


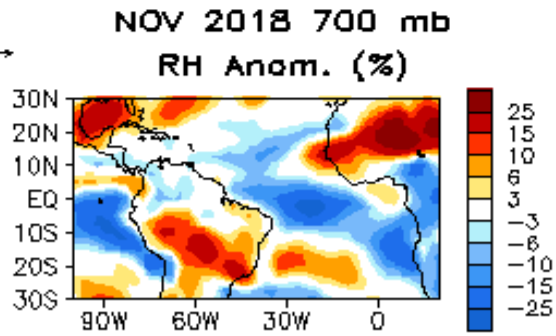




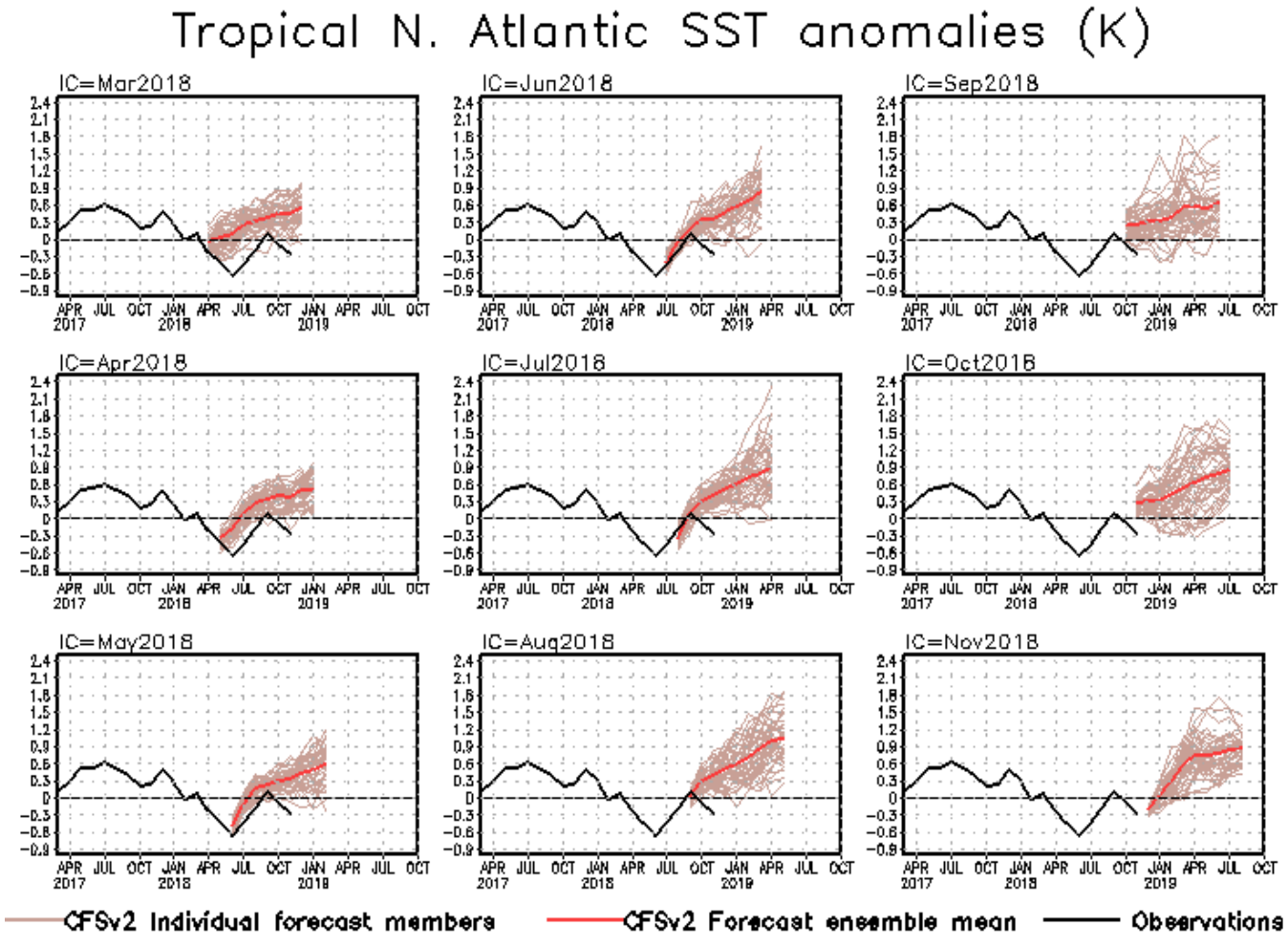








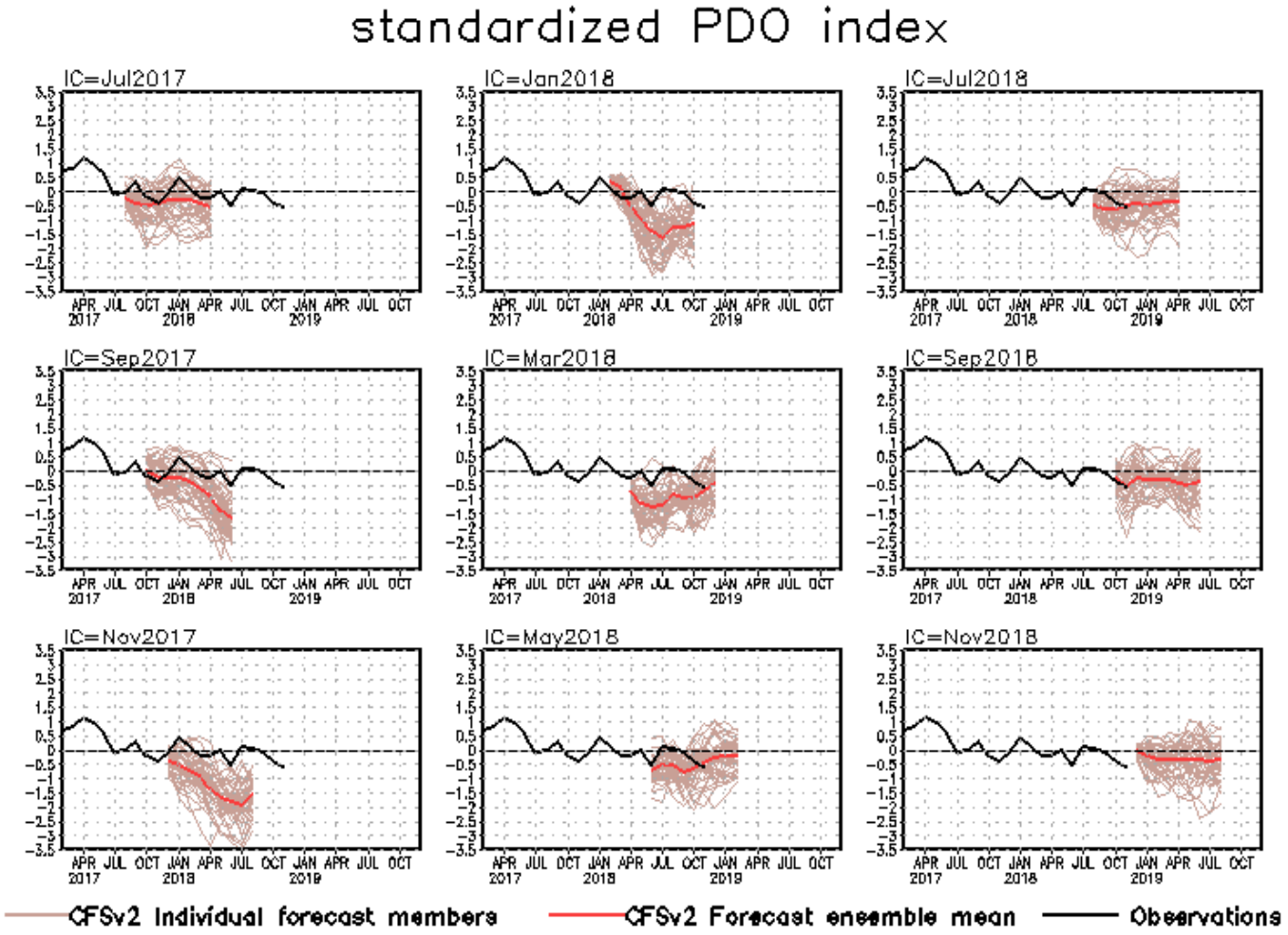
CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months



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.

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.

Global Sea Surface Salinity (SSS)

Anomaly for November 2018

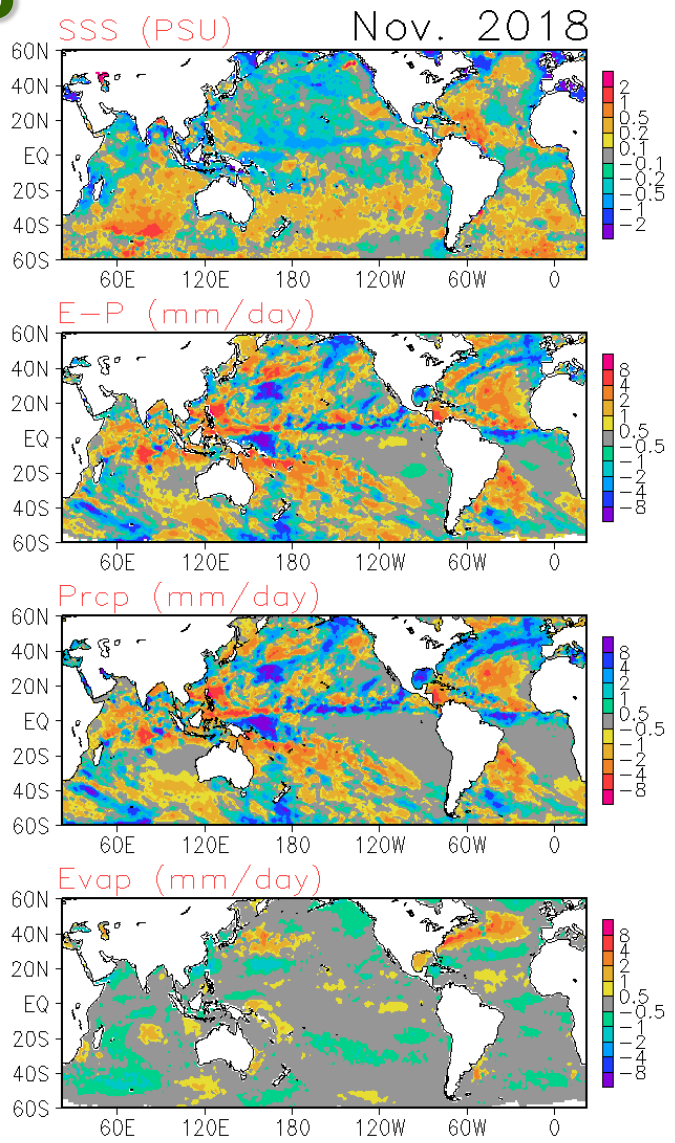
- **New Update: The input satellite sea surface salinity of SMAP from NSAS/JPL was changed from Version 4.0 to Near Real Time product in August 2018.**
- **Attention: There is no SMAP SSS available in July 2018**
- A large scale of negative SSS signal between equator and 20° N in the N. Pacific Ocean continues and the signal becomes stronger nearby the equator. A large scale of freshening continues in the subarctic region of N. Pacific between 35° N and 50° N as well. The west basin of the N. Indian Ocean became fresher this month. The SSS along the Gulf Stream became fresher which is likely due to heavier precipitation. Meanwhile, the negative SSS along the equatorial Atlantic Ocean is co-incident with a strong positive precipitation signal.

- **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

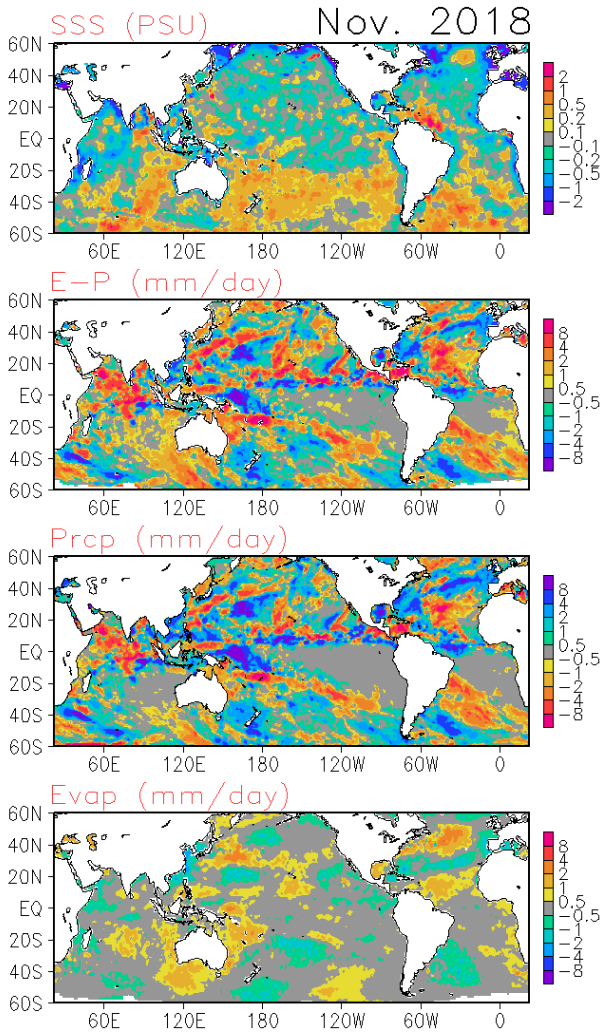
  Evaporation: Adjusted CFS Reanalysis



Global Sea Surface Salinity (SSS)

Tendency for November 2018

Compared with last month, the SSS decreases in the majority of the N. Pacific Ocean. The SSS in the west basin of N. Indian Ocean decreases, as well as the Arabian Sea. The SSS in most of the region north of 20° N in the North Atlantic ocean decreases. The SSS decreases along the equator in the Atlantic Ocean which is likely due to the increased precipitation.



Global Sea Surface Salinity (SSS)

Anomaly Evolution over N. of Equatorial Pacific from Pentad SSS

Figure caption: Hovemoller diagram for equatorial (5° S-5° N) 5-day mean SSS, SST and precipitation anomalies. The climatology for SSS is Levitus 1994 climatology. The SST data used here is the OISST V2 AVHRR only daily dataset with its climatology being calculated from 1985 to 2010. The precipitation data used here is the adjusted CMORPH dataset with its climatology being calculated from 1999 to 2013.