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**
  - ***CPC Arctic Sea Ice Predictions***
  - ***Will the Pacific "Blob" return in 2018?***

Overview

Pacific Ocean

- ENSO-neutral conditions continued in Oct 2018.
- Positive subsurface temperature anomalies strengthened in the central-eastern Pacific.
- NOAA Continued El Niño Watch in Nov 2018 and stated that El Niño is expected to form and continue through the Northern Hemisphere winter 2018-19 (80% chance).
- 2018 E. Pacific hurricane season had the historical high Accumulated Cyclone Energy (ACE) value since 1971.
- Arctic sea ice extent in Oct 2018 ranked the third lowest Oct value since 1979.

Indian Ocean

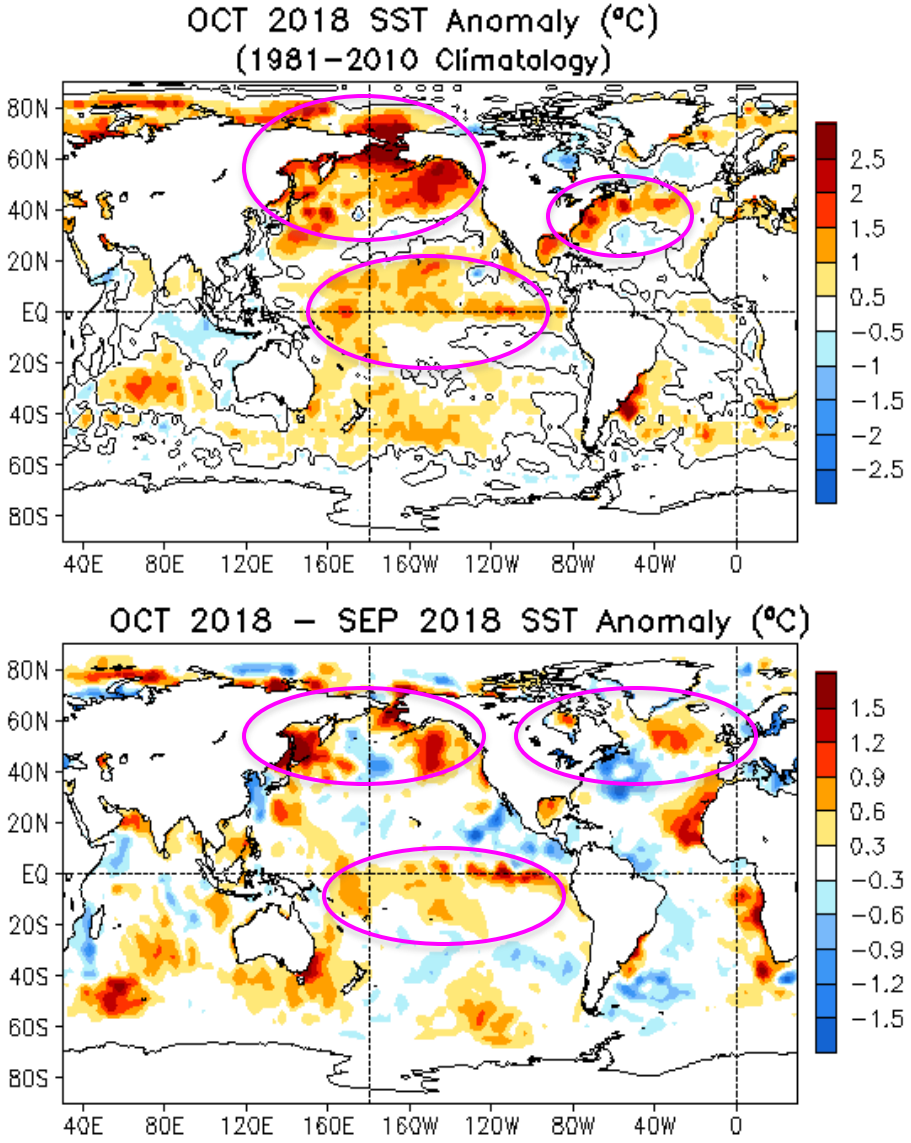
- Indian Ocean dipole index continued to be above-average in Oct 2018.

Atlantic Ocean

- Atlantic hurricane season had a quite Oct.
- Positive phase of NAO continued in Oct 2018, with NAOI=+1.5.

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 and Artic Oceans.

- **Strong positive SSTAs presented in the Gulf of Mexico and along the Gulf Stream.**

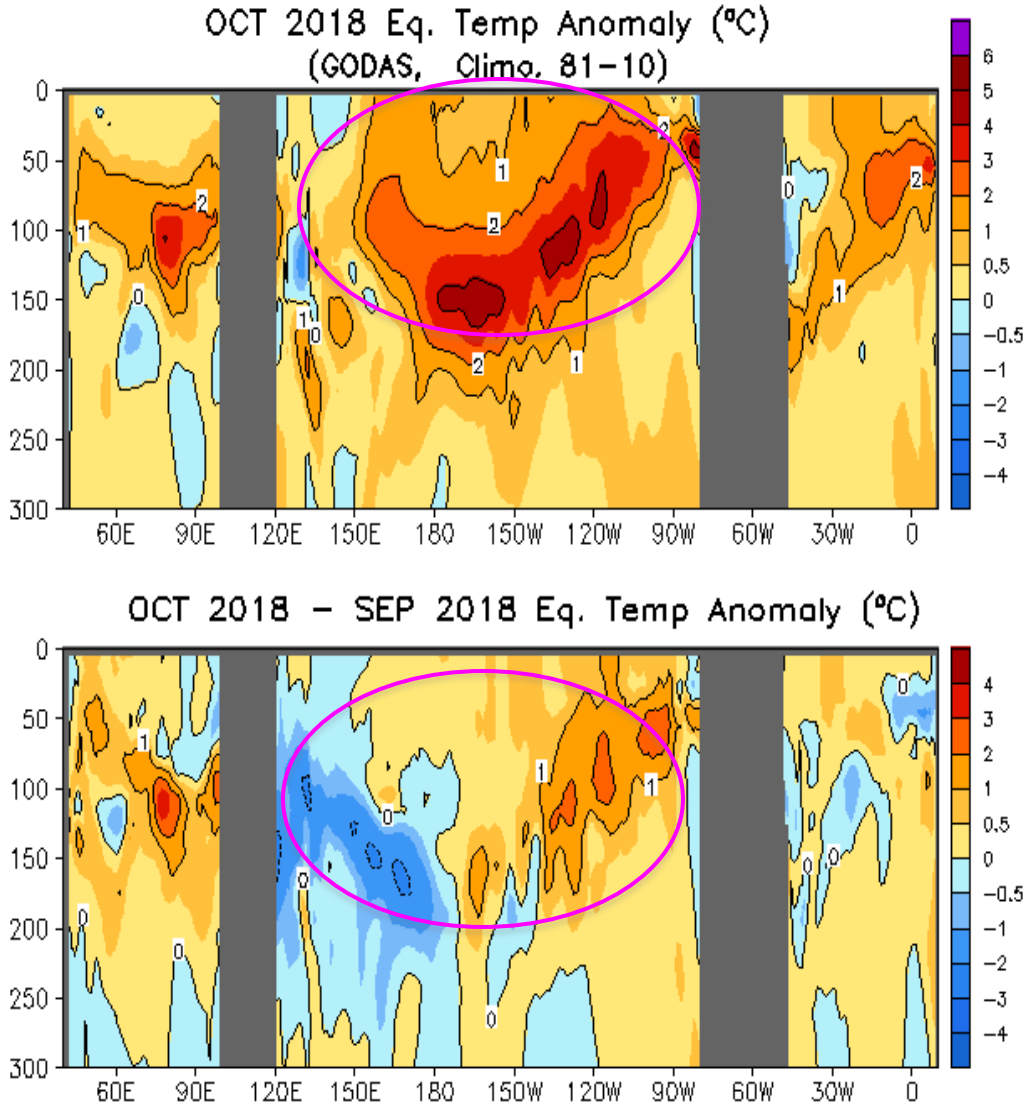
- **SST warming dominated in the Southern Oceans.**

- **Positive SSTA tendencies strengthened across much of the equatorial Pacific Ocean.**

- **Large SSTA tendencies were observed in the mid-high latitude of N. Pacific and N. Atlantic.**

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 Oct 2018.**

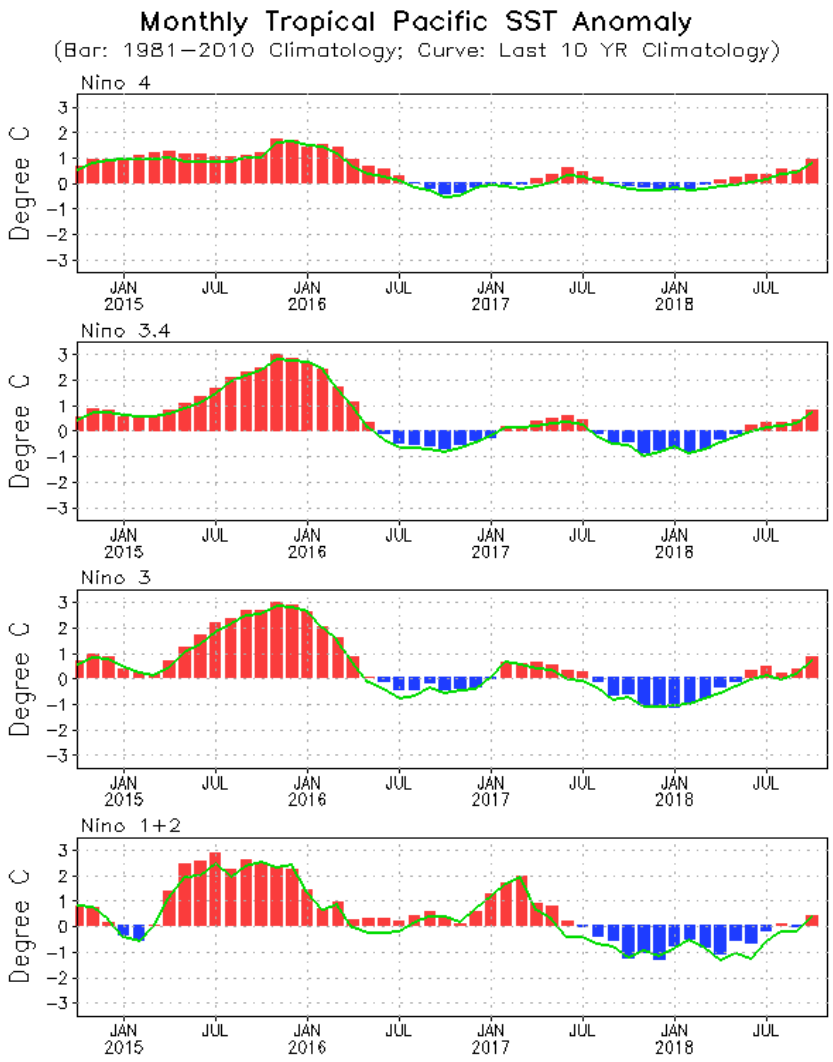
- **Positive temperature anomaly presented along the thermocline in the Atlantic and Indian Oceans.**

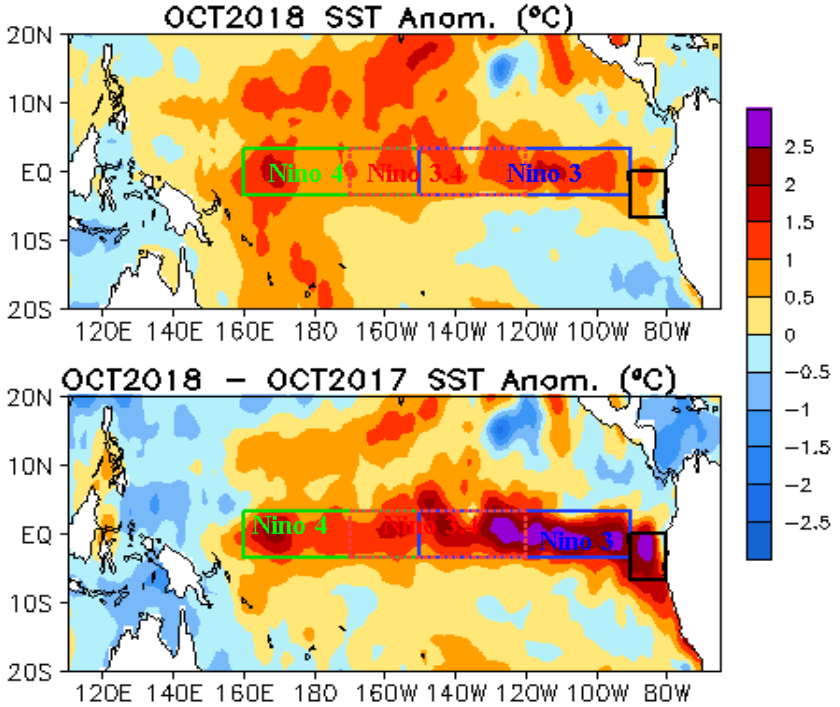
- **Positive (negative) temperature tendency presented in the central-eastern (western) equatorial thermocline in the Pacific Ocean.**

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



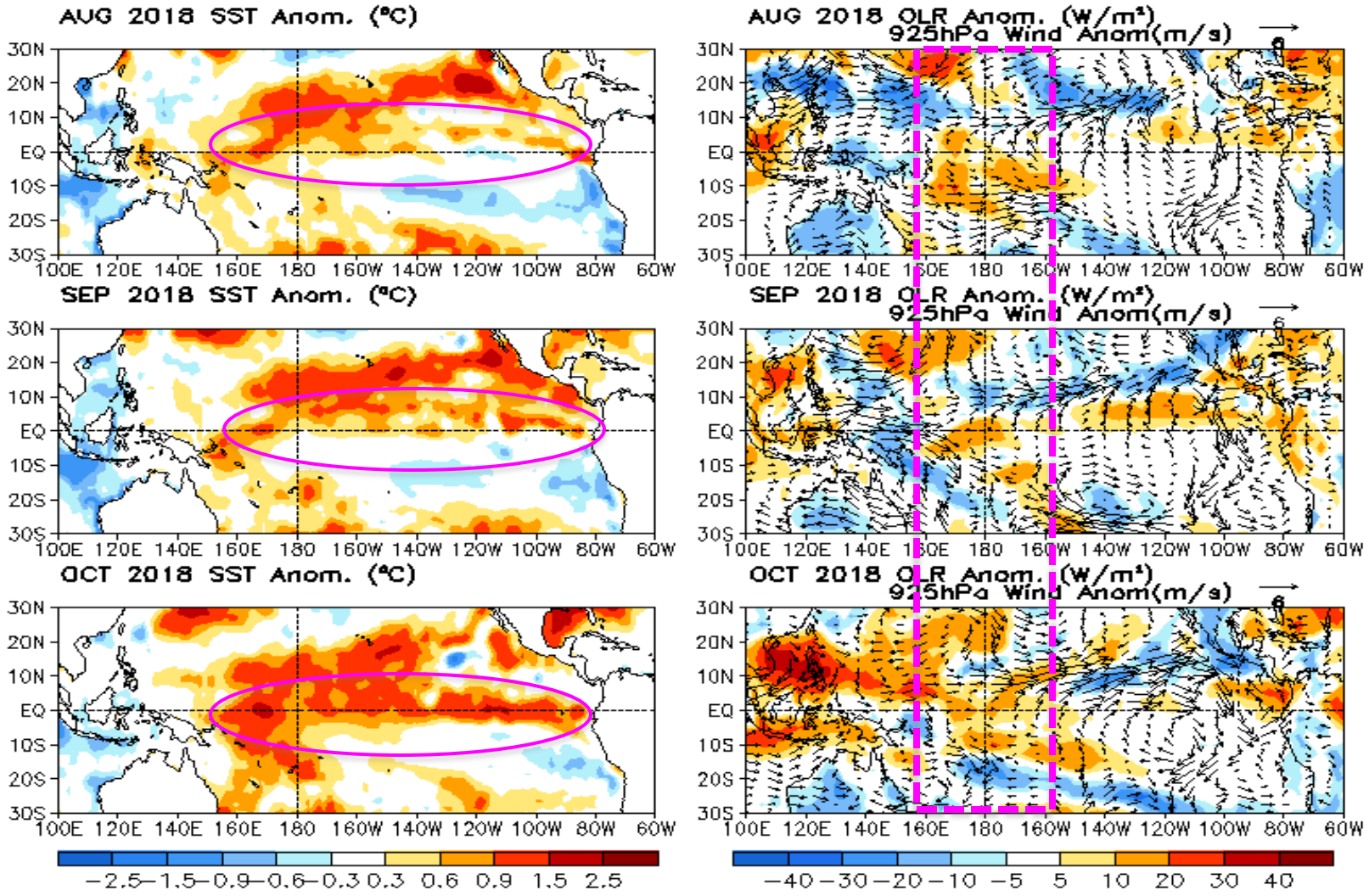


- **All NINO indices strengthened in Oct 2018, with Niño 3.4 = 0.9 C.**

-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.

Last Three Month SST, OLR and 925hPa Wind Anomalies



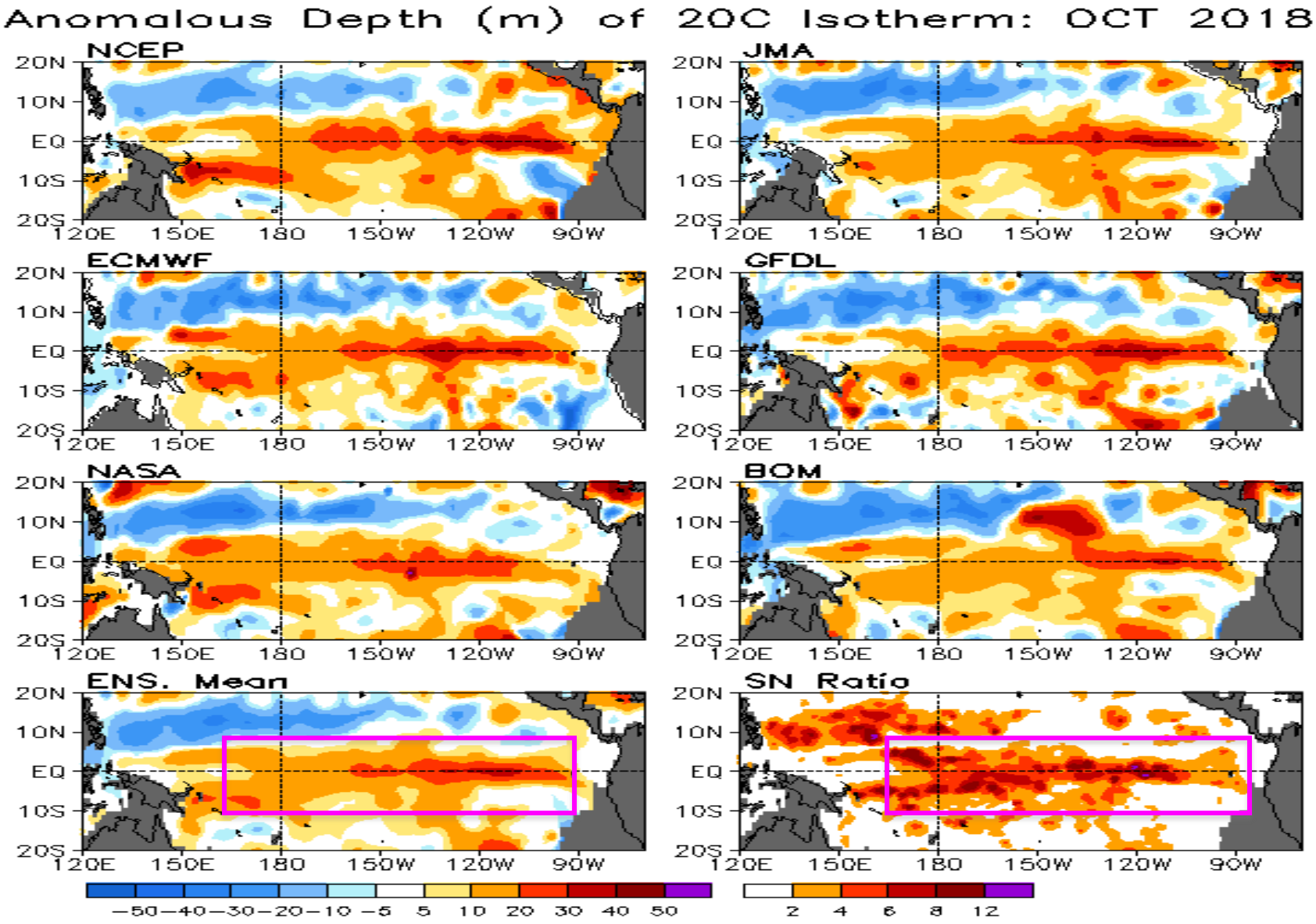
- **Positive SSTAs strengthened across most of the equatorial Pacific in the last three months.**

- **Convection remained suppressed near the Dateline in Oct 2018.**

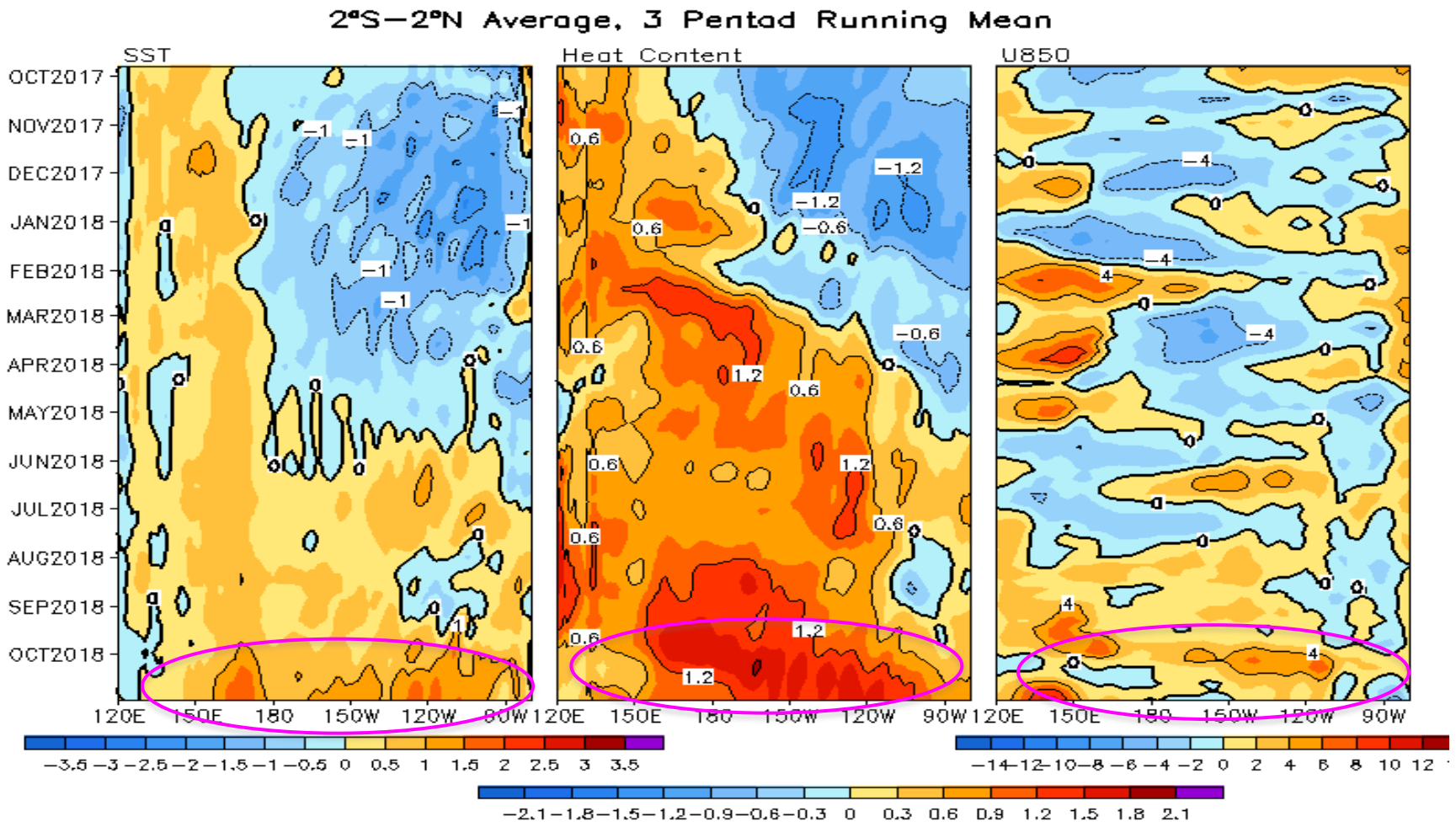
Real-Time Ocean Reanalysis Intercomparison: D20

Climatology : 1981-2010

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

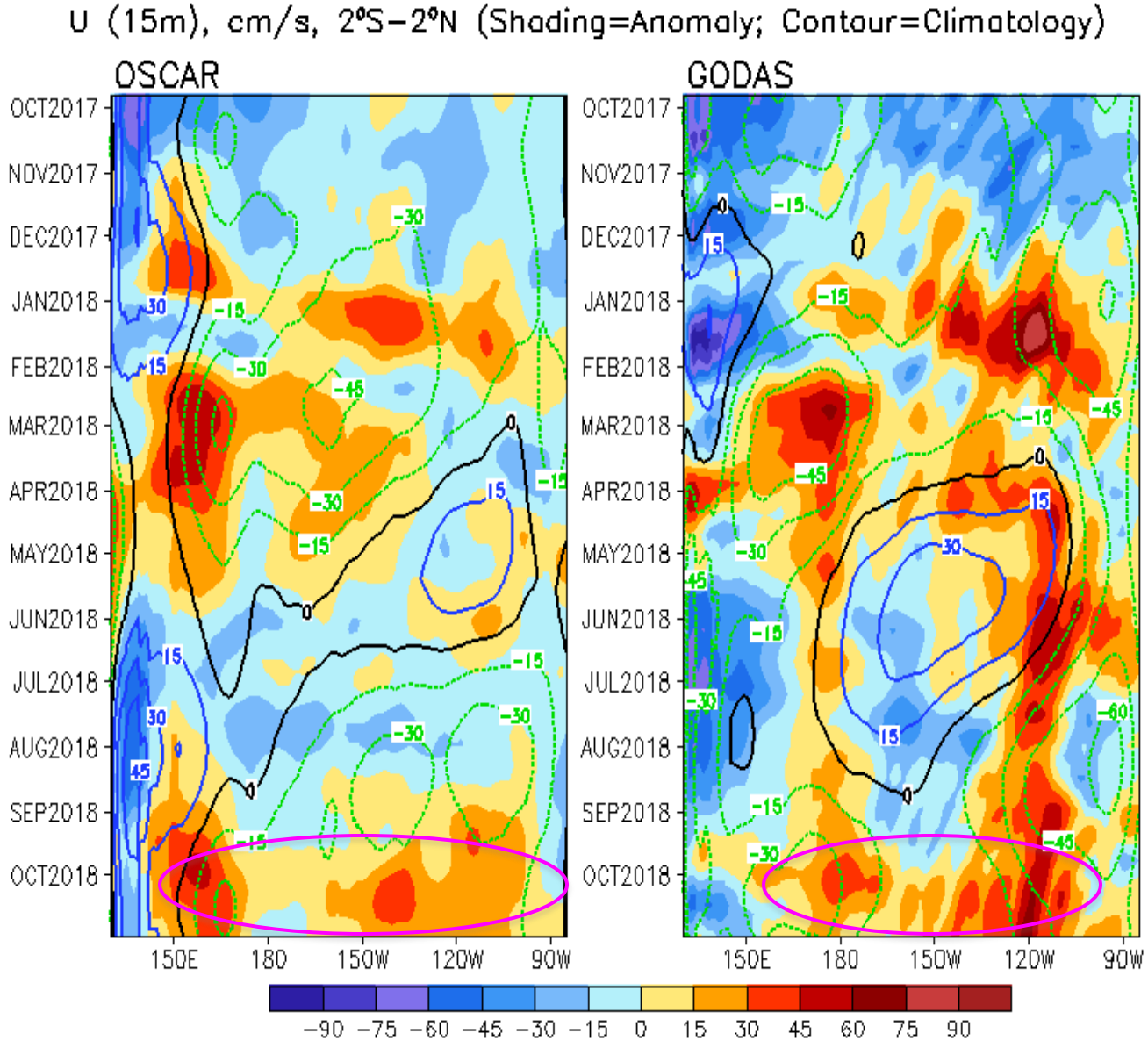


Equatorial (2S-2N) Pacific SST (°C), Surface Zonal Wind (m/s) and HC300 (°C) Anomalies



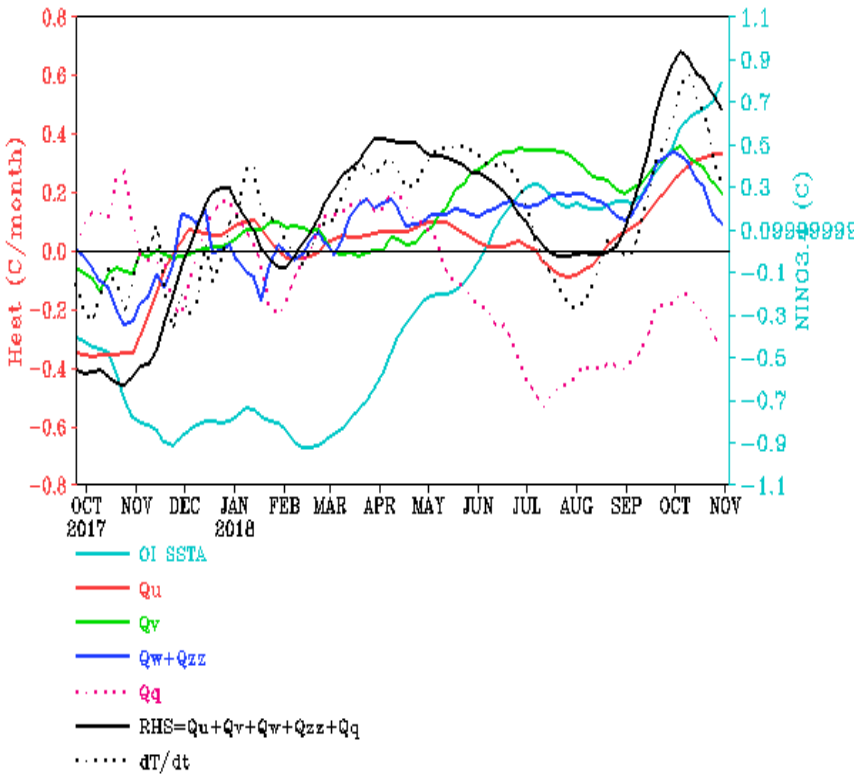
- **Positive SSTA strengthened in much of the equatorial Pacific in Oct 2018, consistent with the eastward extension of positive subsurface anomalies.**
- **Westerly wind anomalies prevailed over the equatorial Pacific in Oct 2018.**

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



-Positive zonal current anomalies dominated across much of the equatorial Pacific in Oct 2018.

NINO3.4 Heat Budget



- Positive observed SSTA tendencies (dT/dt; dotted black line) weakened in the second half of Oct 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.

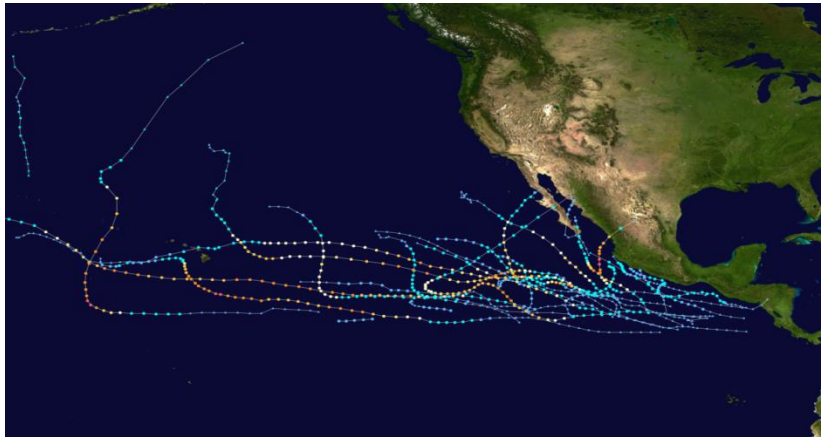
Qu: Zonal advection; Qv: Meridional advection;

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

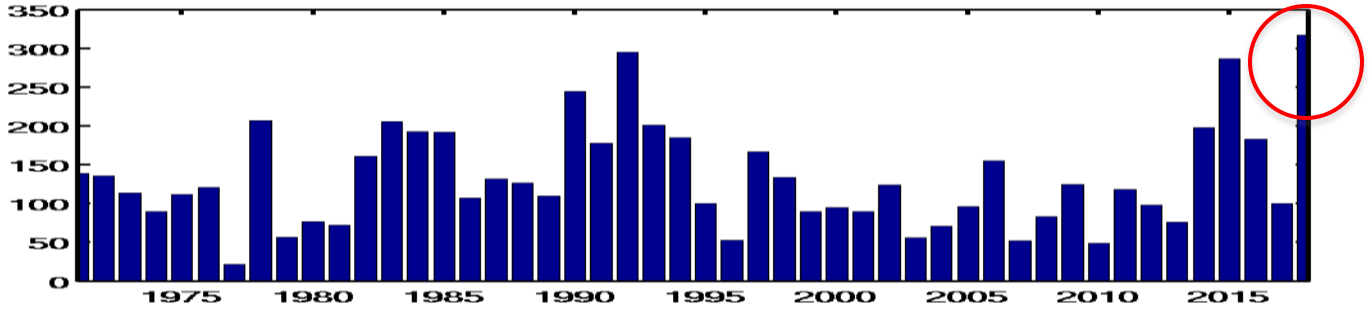
2018 E. Pacific Hurricane Season



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

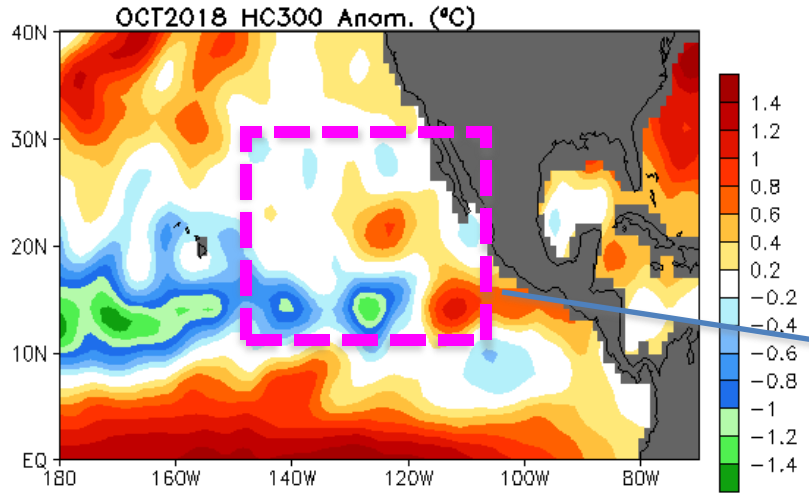
- 23 tropical storms formed by Nov 6, with 13 developing into hurricanes and 10 becoming major hurricanes.
- 2018 E. Pacific hurricane season produced the highest ACE since 1971, and is the fourth most active season based on storm number.

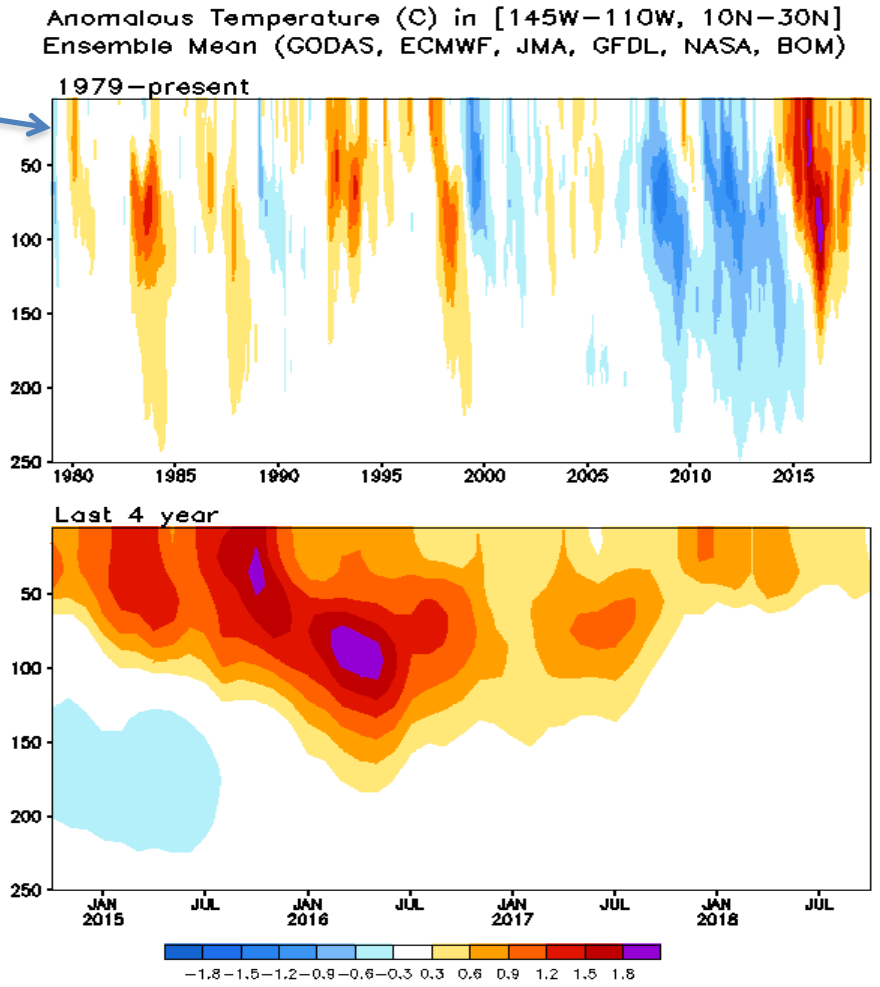
E. Pac Accumulated Cyclone Energy



E.Pac	2018 prediction (issued on May 24) 80% near or above normal	1981-2010	Observations (By Nov 6)
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

Subsurface warming in eastern subtropical Pacific



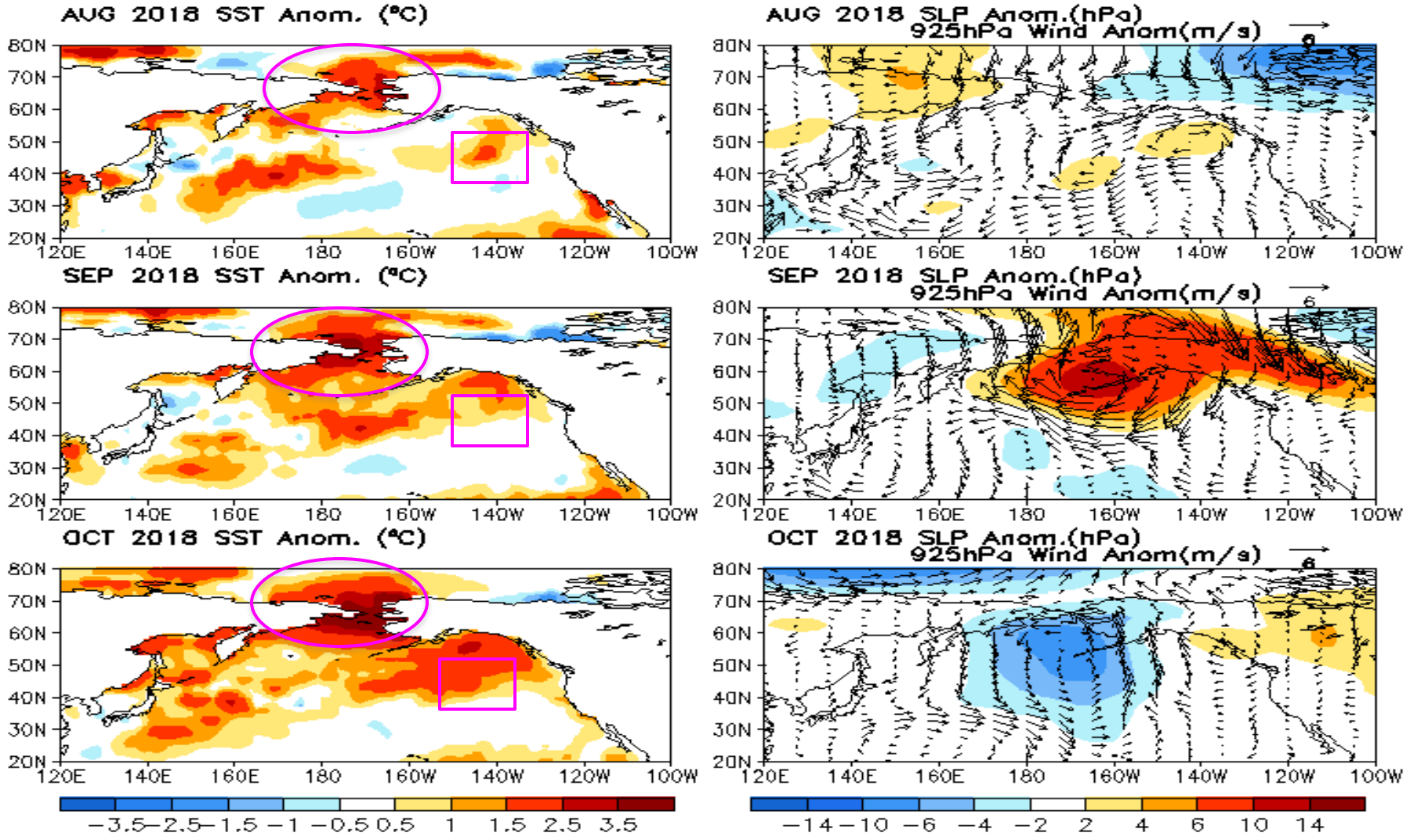


- **Subsurface temperature variation in the eastern subtropical Pacific is tightly connected with ENSO.**

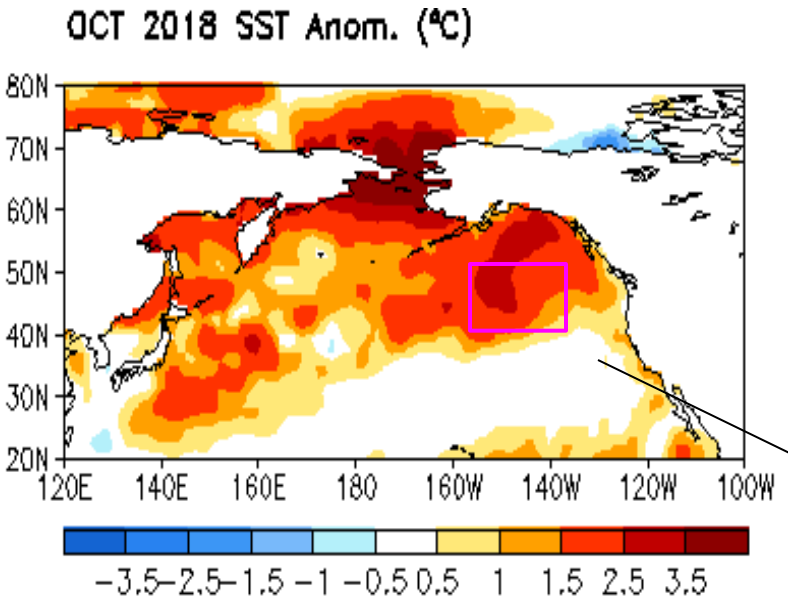
- **Subsurface warming reached its maximum during 2014-15, and then weakened gradually in recent years.**

North Pacific & Arctic Oceans

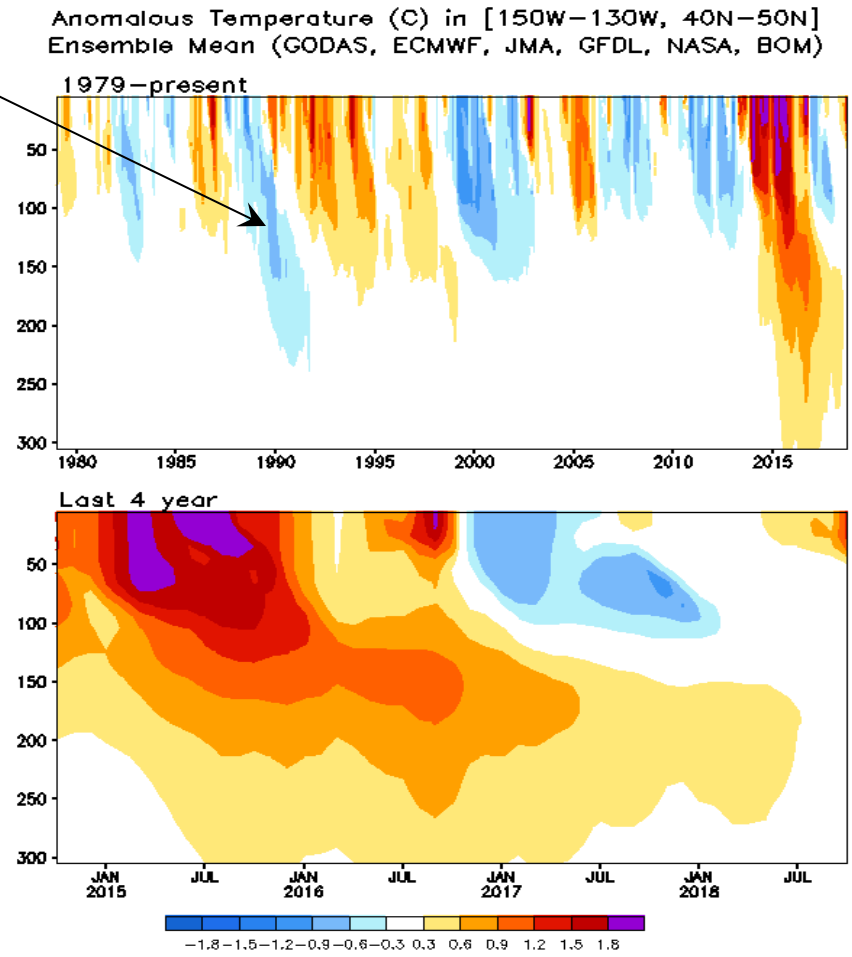
Last Three Month SST, SLP and 925hp Wind Anomalies



- **SST warming in the northeast Pacific (Pacific "Blob") and the Arctic Ocean enhanced in the last three months.**
- **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

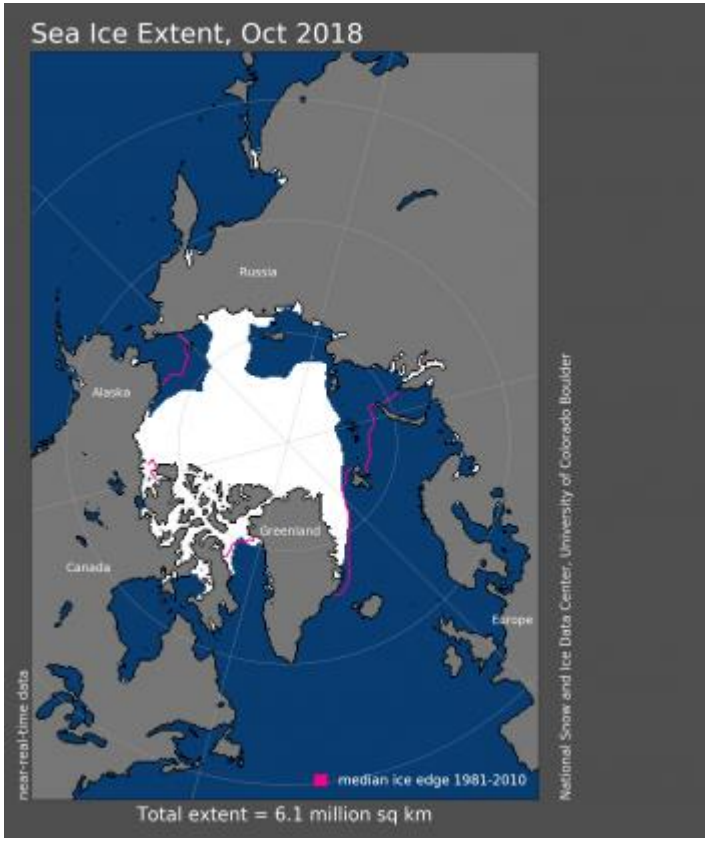


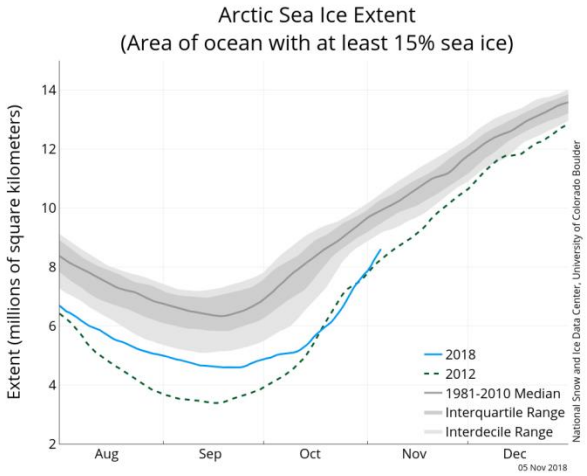
- **Between winters of 2013/14 and 2015/16, northeast Pacific experienced the strongest SST warming ever recorded, referred to as "Blob" by Bond et al. (2015)**
- **Warming has gradually extended to 300m since the late 2013.**
- **Near surface warming re-emerged since May 2018, while the warming is only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

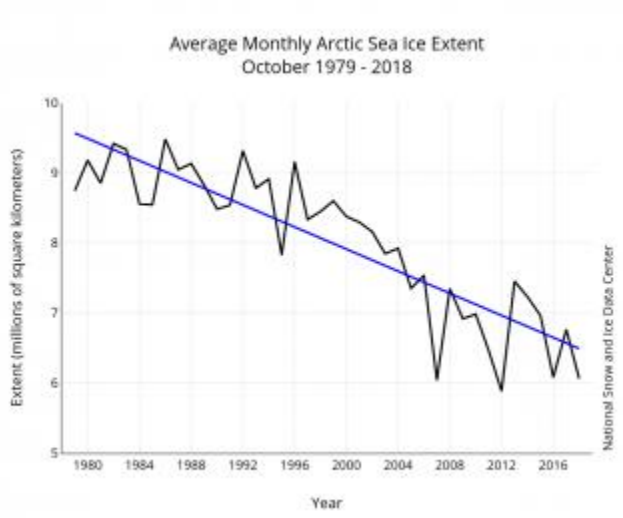
Arctic Sea Ice

National Snow and Ice Data Center

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







-Arctic sea ice extend in Oct 2018 ranked the third lowest Oct since 1979.

CPC Arctic Sea Ice Predictions

1. Seasonal prediction

- **Forecast frequency**: Monthly
- **Target**: 9 months
- **Hindcast**: Most recent 12 years
- **Ensemble size**: 20

2. Week 3-4 prediction

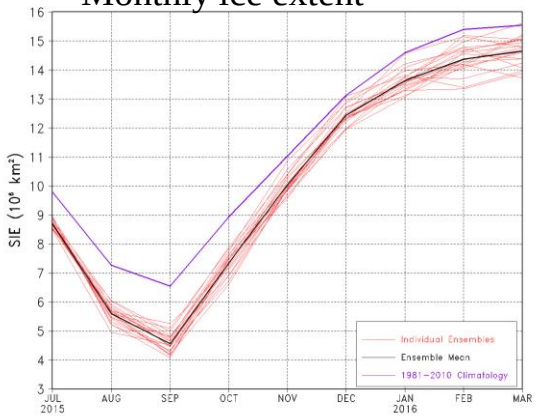
- **Forecast frequency**: Weekly
- **Target**: 45 days
- **Hindcast**: Most recent 6 years
- **Ensemble size**: 16

3. Forecast System

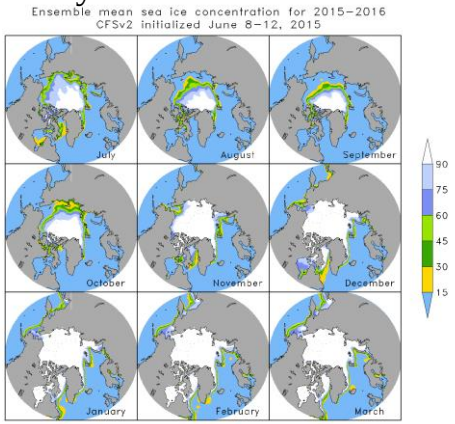
- **Model**: CFSm5 (coupled GFS/MOM5)
- **Initial conditions**
  - Sea ice and Ocean: CSIS (CPC Sea ice Initialization System)
  - Atmosphere and land: CFSR (Climate Forecast System Analysis)

CPC Seasonal Sea Ice Prediction

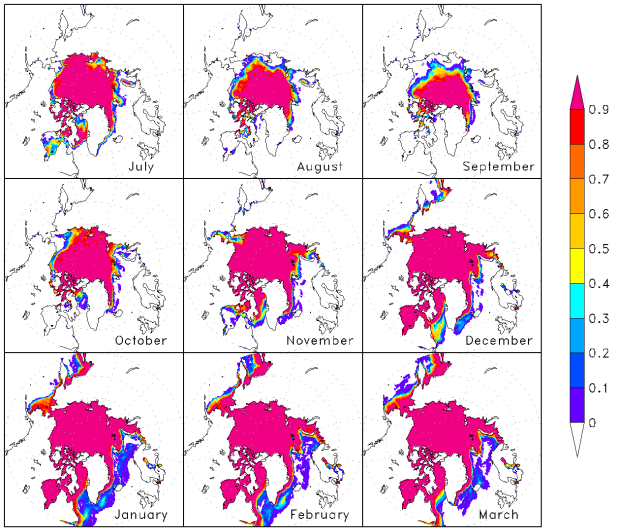
Monthly ice extent



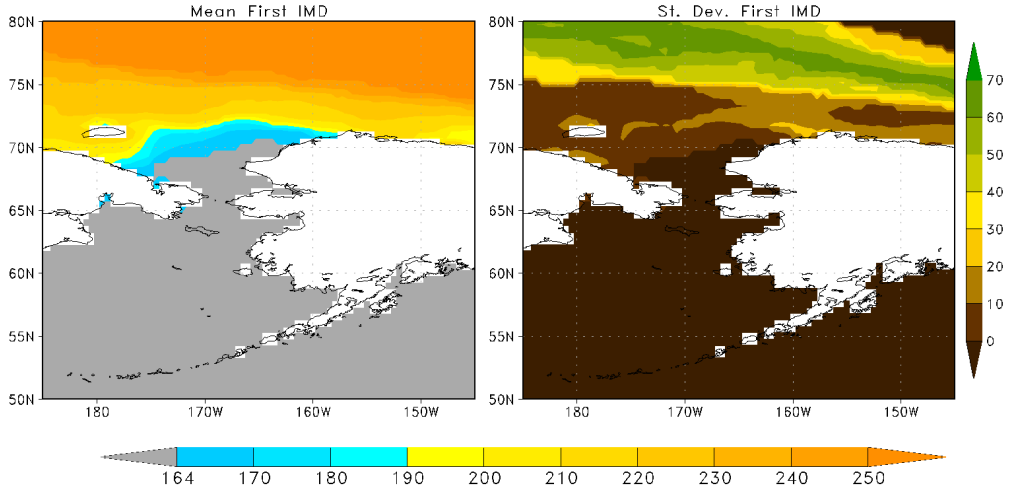
Monthly sea ice concentration



Monthly Sea Ice Probability

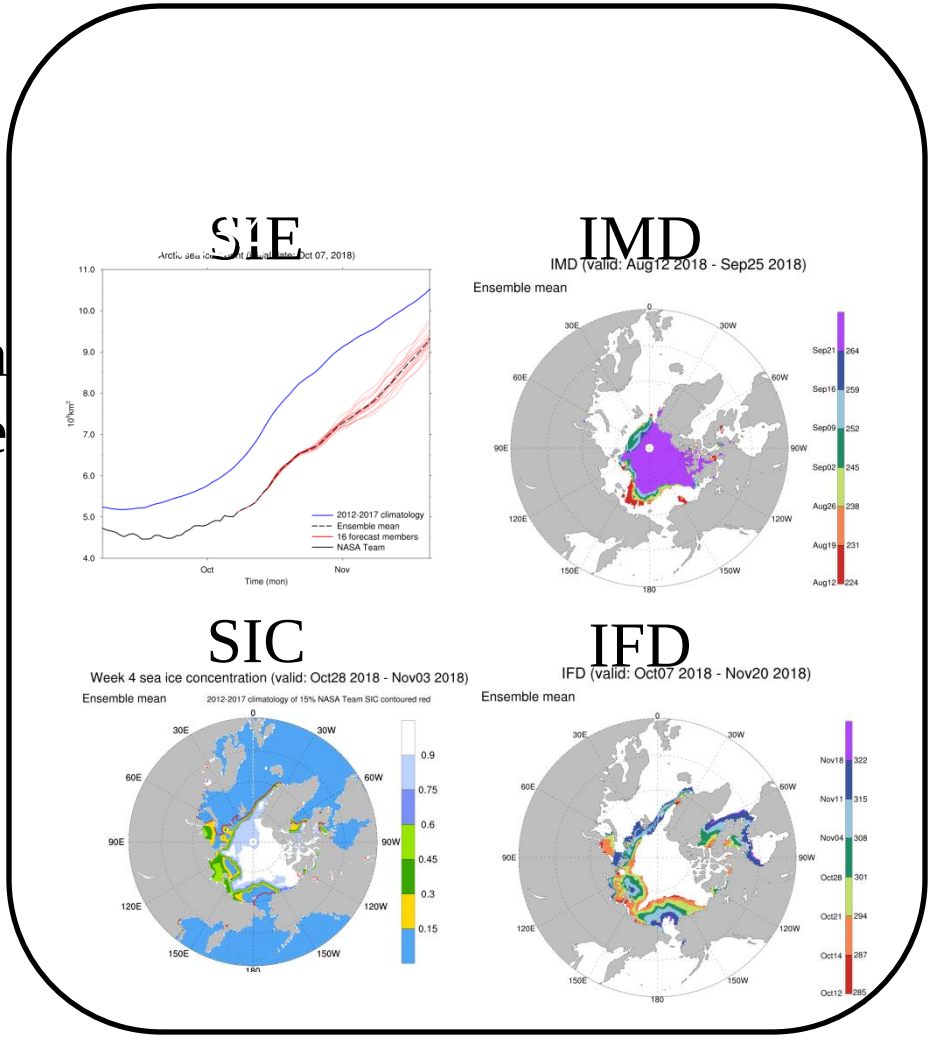


Ice melt-out day (IMD) and Ice freeze-up day (IFD)



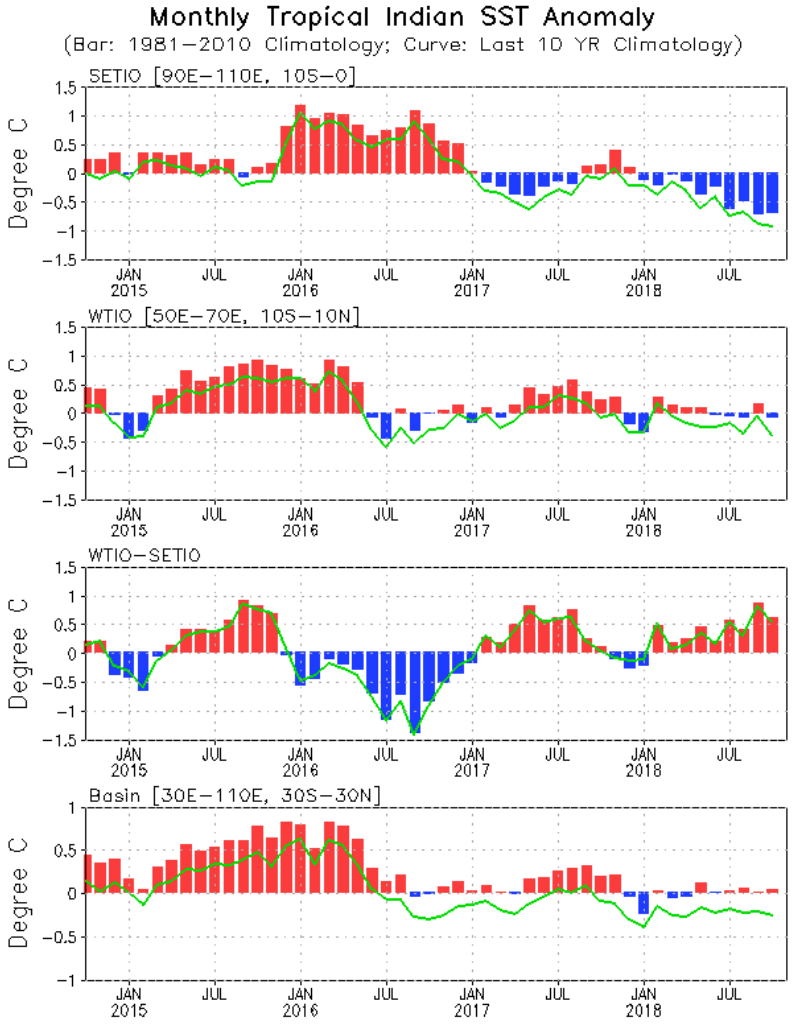
CPC Week 3-4 Sea Ice Prediction

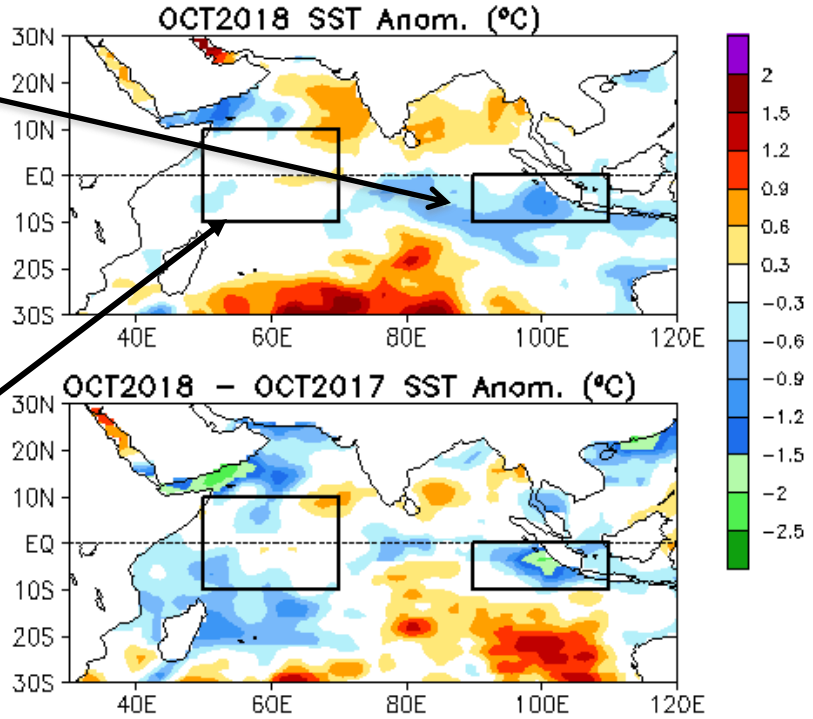
SIE: Sea ice extent
SIC: Sea ice concentration
IMD: Sea ice melt-out date
IFD: Sea ice freeze-up date



Indian Ocean

Evolution of Indian Ocean SST Indices





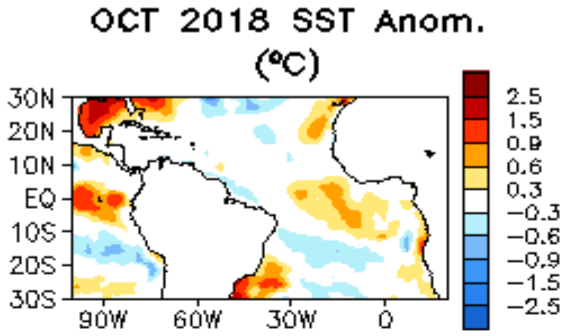
- **Positive Indian Ocean Dipole continued to be above average in Oct 2018,with IOD index = 0.6 C.**

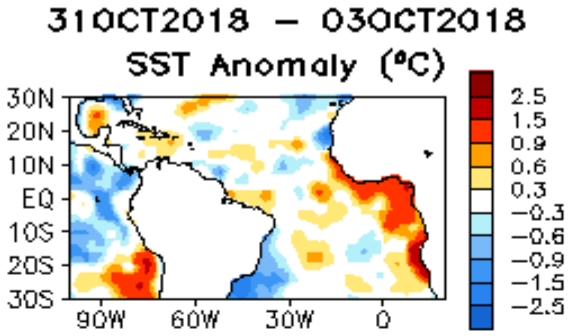
Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the SETIO [90°E-110°E, 10°S-0] and WTIO [50°E-70°E, 10°S-10°N] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the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

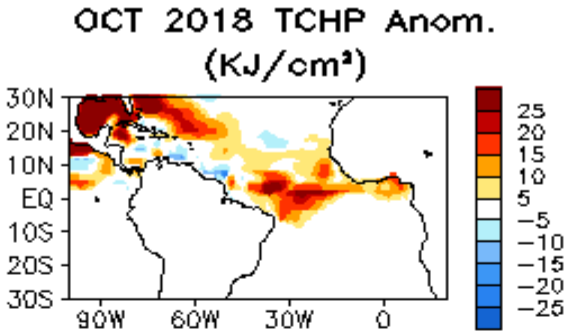
Tropical and North Atlantic Ocean

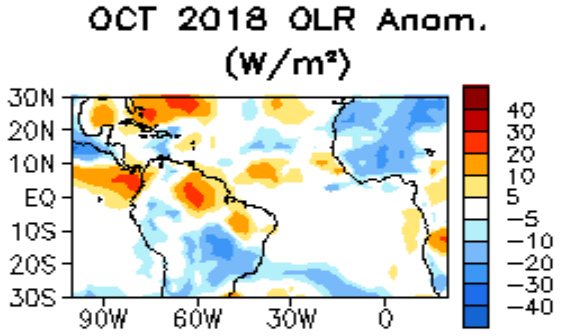
Tropical Atlantic:

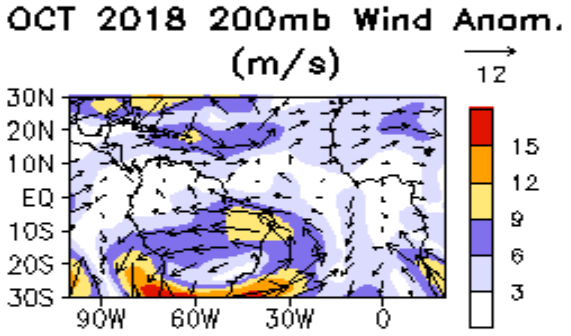
SST, SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, TCHP, 925-mb/200-mb Winds anom.

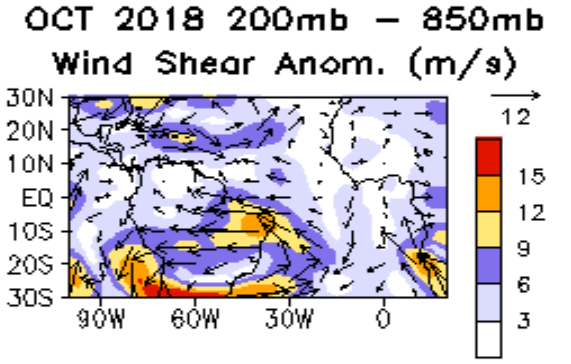


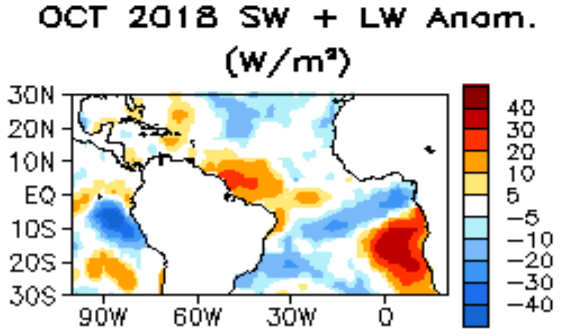


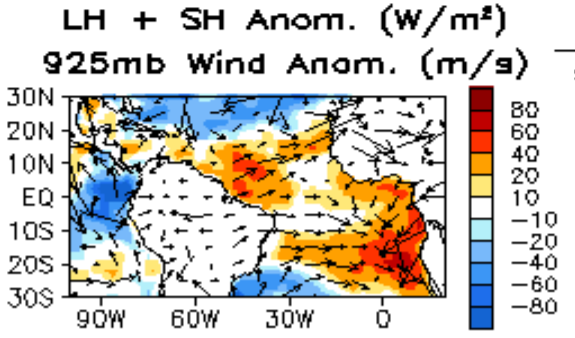


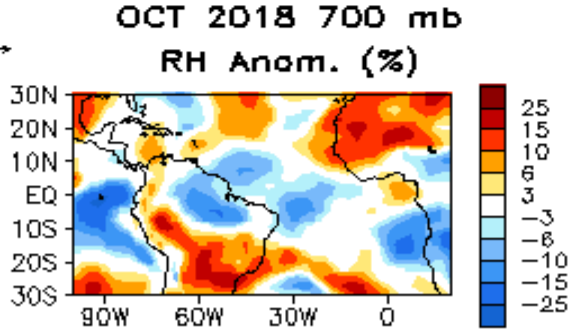




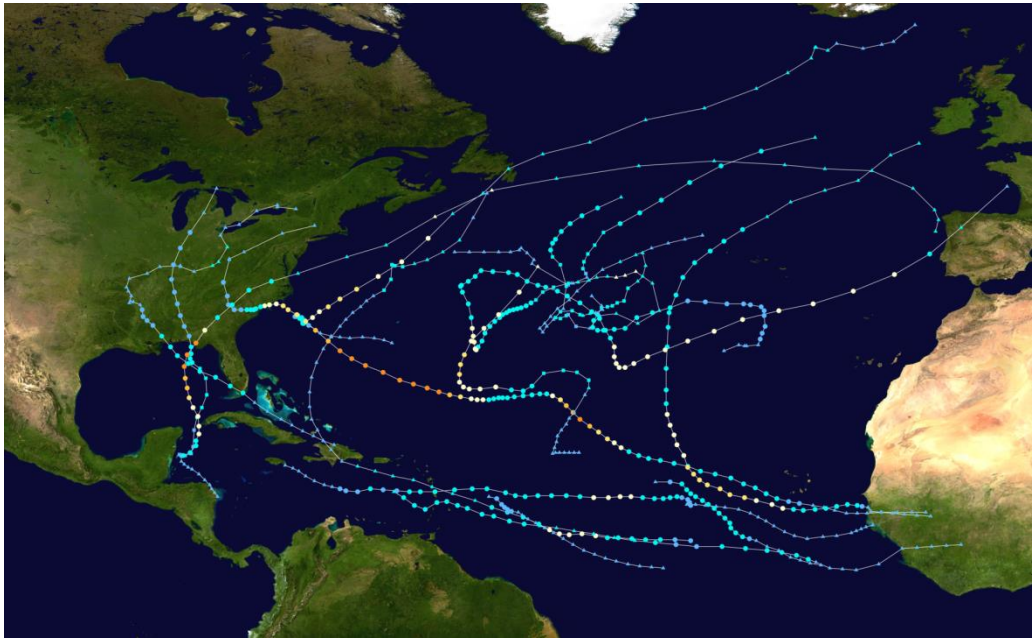








2018 Atlantic Hurricane Season Activities

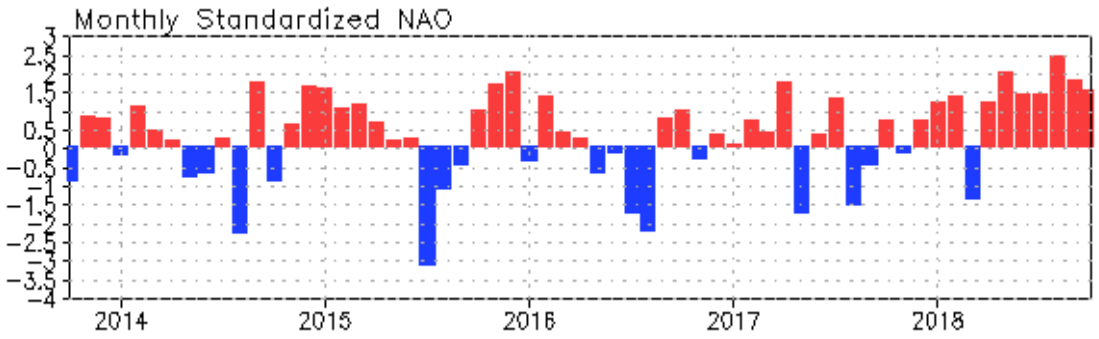


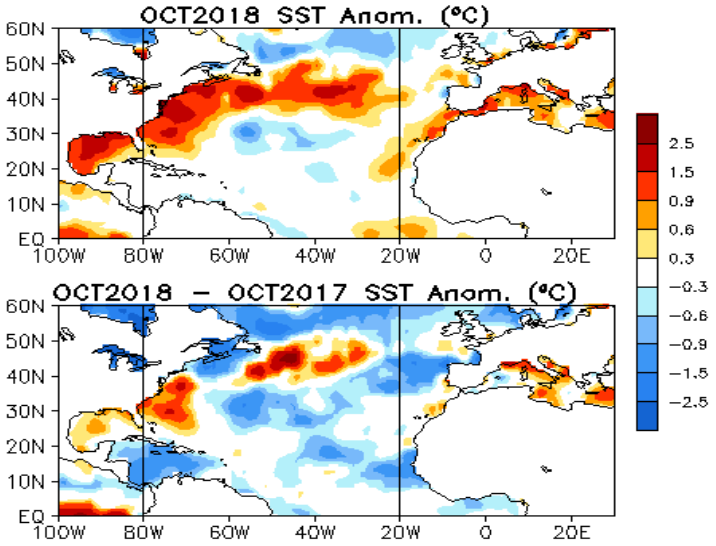
https://en.wikipedia.org/wiki/2018_Atlantic_hurricane_season

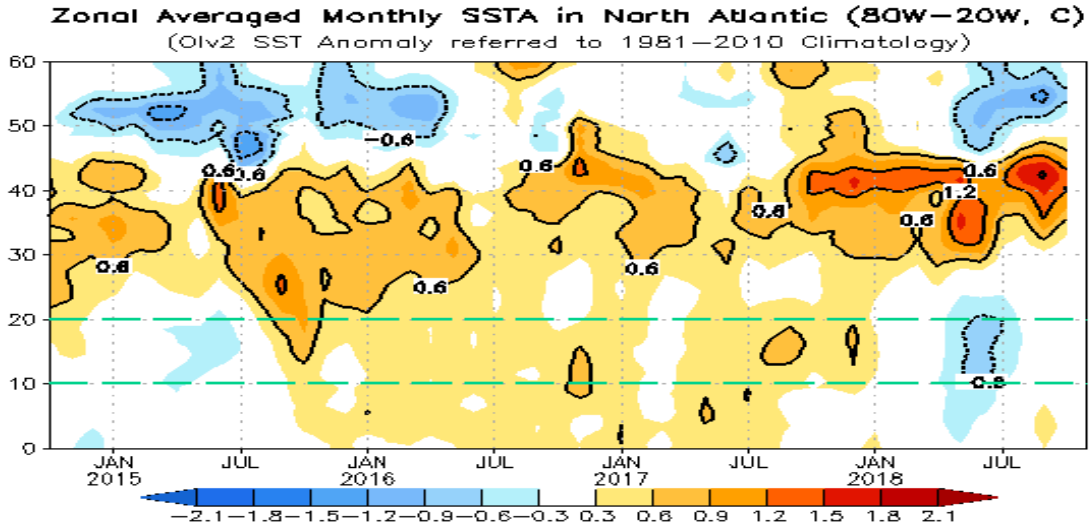
- **Fifteen tropical storms has formed by Nov 5, with eight developing into hurricanes and two became major hurricanes.**

Atlantic	2018 prediction (issued on May 24) Updated on Aug 9 60% below average	1981-2010	Observations (By Nov 5)
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



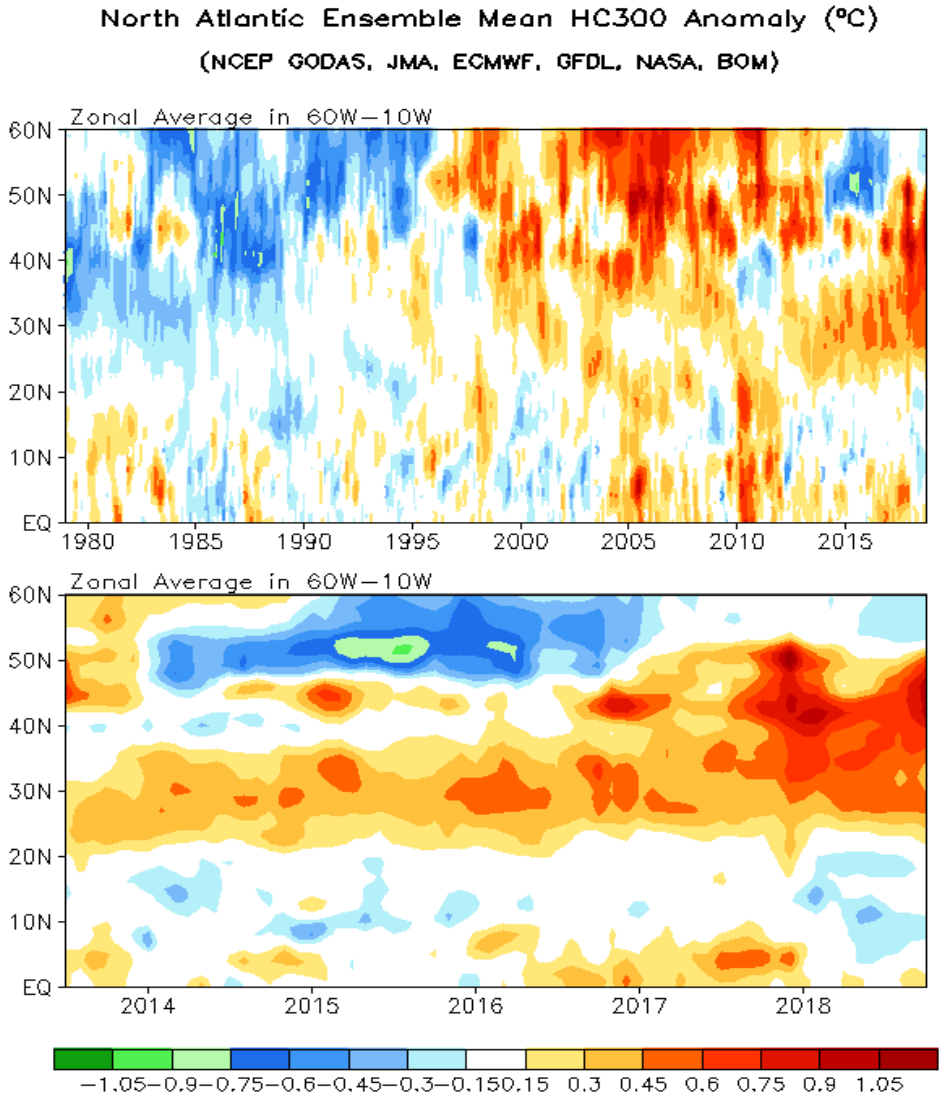


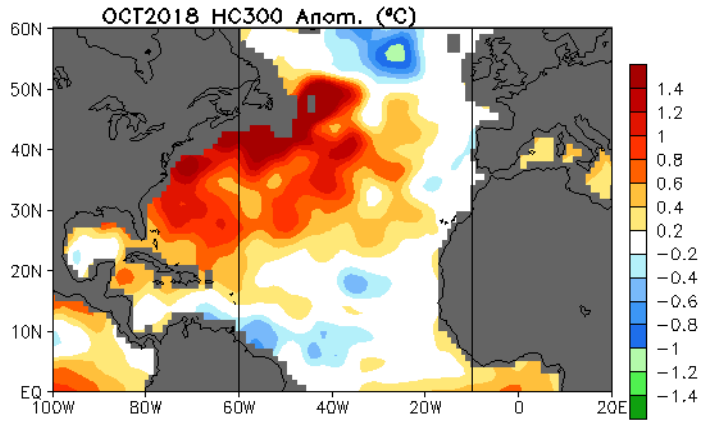


- **Positive NAO index continued to be well above average, with NAOI= +1.5 in Oct 2018.**

- **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 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.



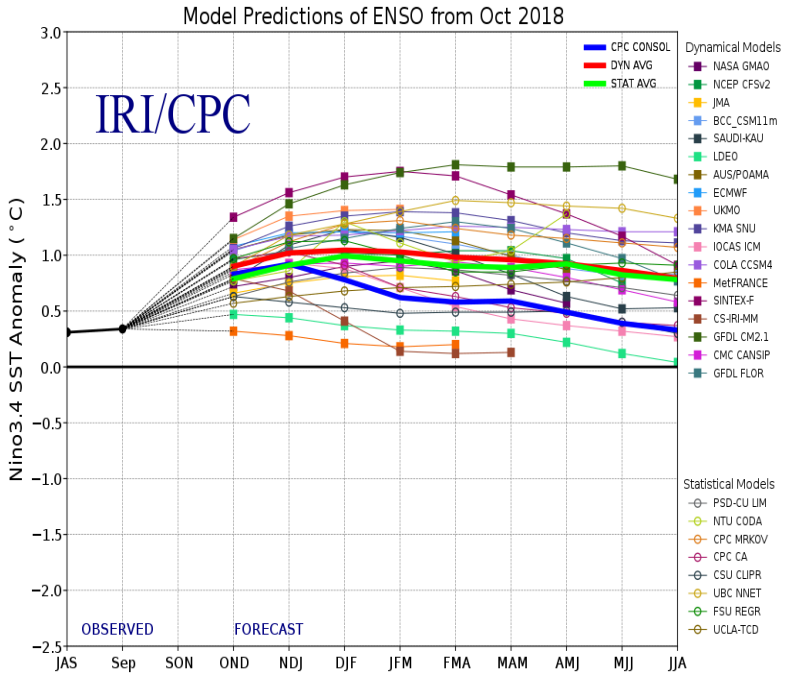


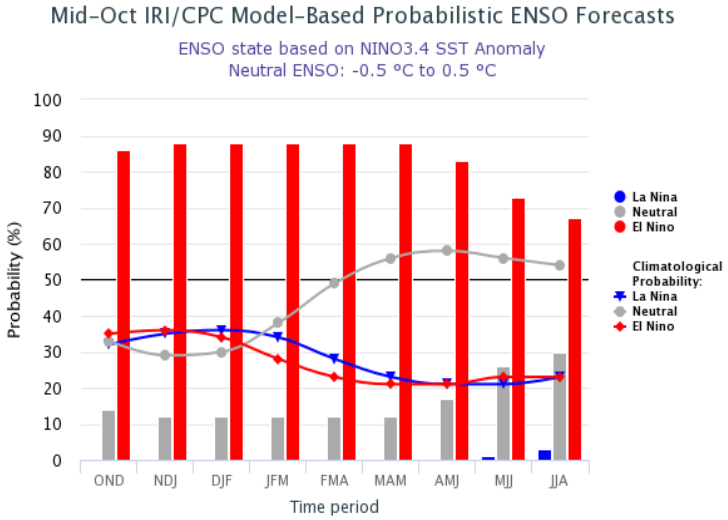
- HC300 anomaly has a tripole/horseshoe pattern with positive in the mid- latitudes and negative in lower and higher latitudes.

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

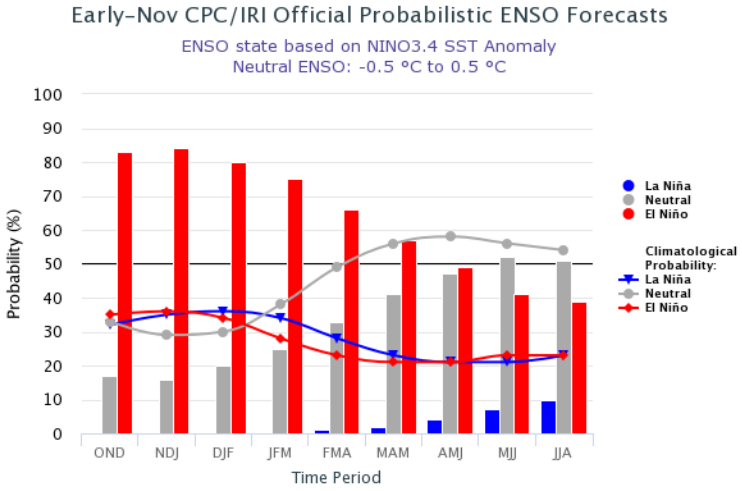
- The "cold blob" weakened substantially during 2017-2018, while warming in the mid-latitude enhanced in the last couple years.

ENSO and Global SST Predictions



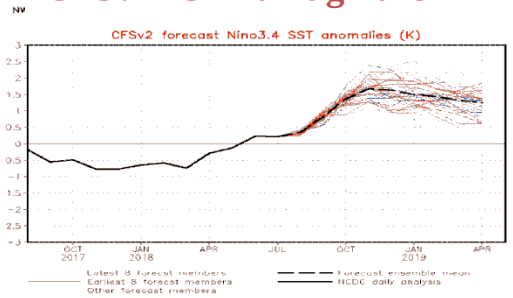


- **NOAA Continuously issued El Niño Watch in Nov 8 2018 and stated that El Niño is expected to form and continued continue through the Northern Hemisphere winter 2018-19 (80% chance).**

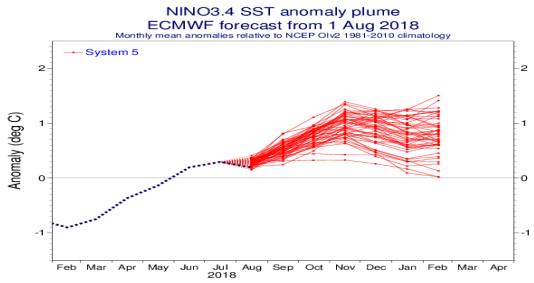


Changes in NINO3.4 predictions

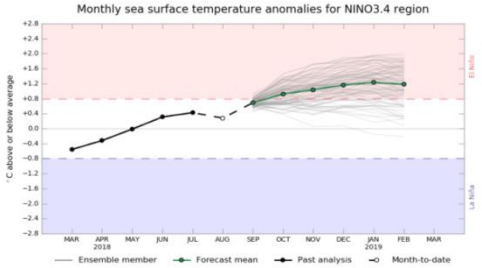
CFSv2 IC= 10 Aug 2018



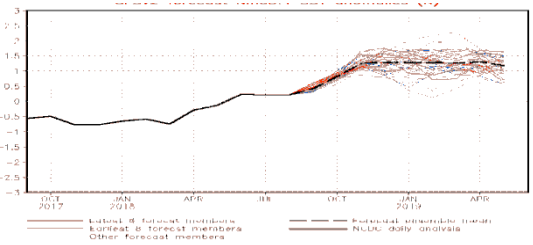
ECMWF IC= 1 Aug 2018



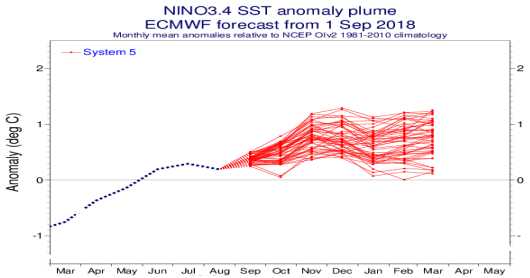
BOM, IC= 25 Aug 2018



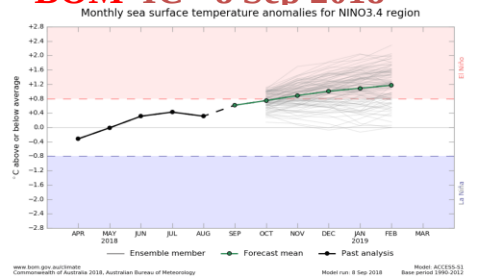
CFSv2 IC= 10 Sep 2018



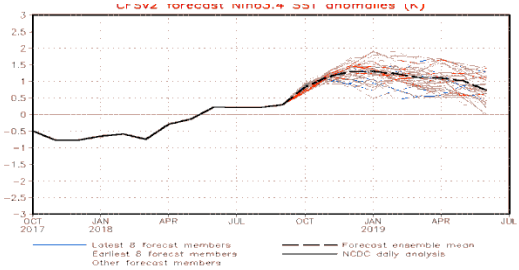
ECMWF IC= 1 Sep 2018



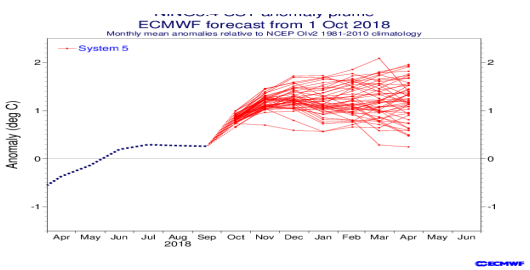
BOM IC= 8 Sep 2018



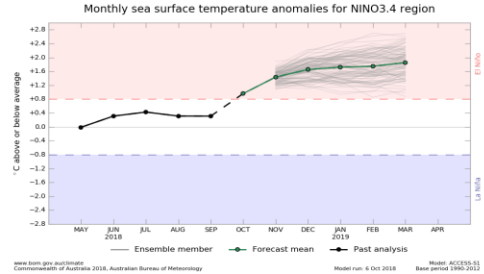
CFSv2 IC= 9 Oct 2018



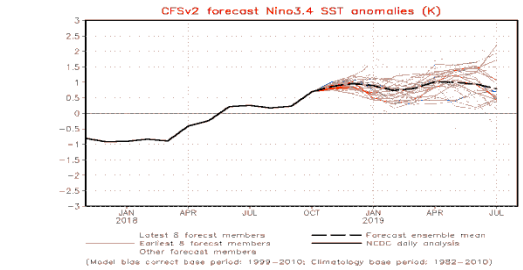
ECMWF IC= 1 Oct 2018



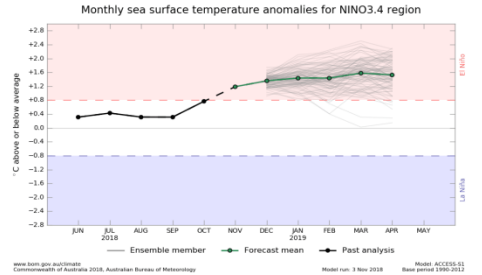
BOM IC= 6 Oct 2018



CFSv2 IC= 6 Nov 2018

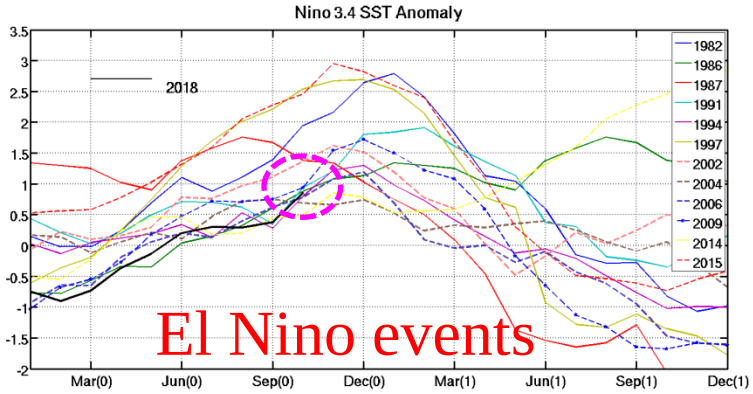


BOM IC= 3 Nov2018



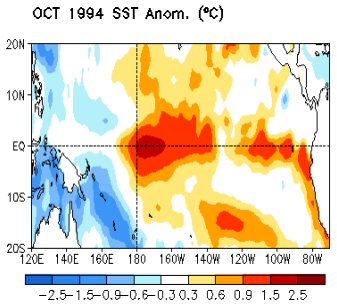
SST,D20 and 925hPa Wind anomalies in October

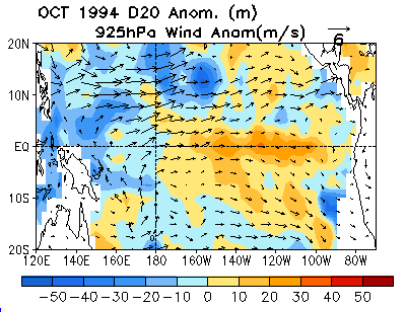
NINO3.4 Anomaly



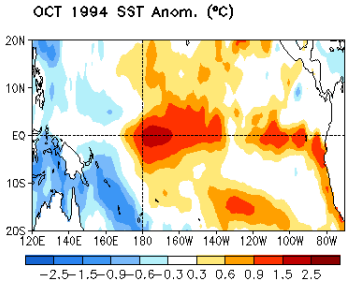
Weak El Niños

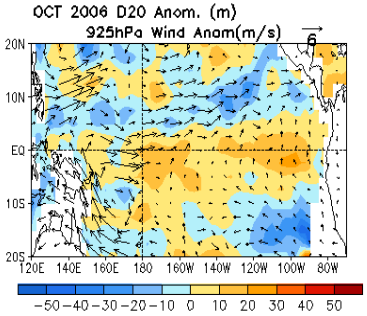
1994





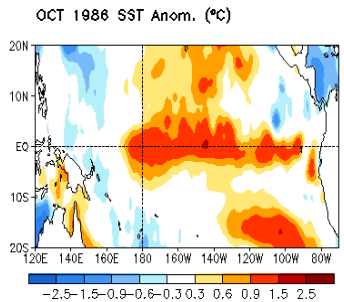
2006

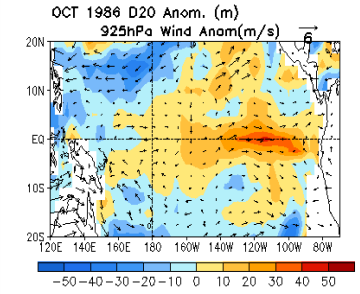




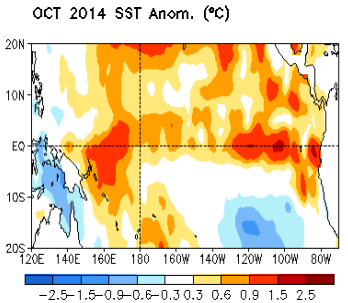
Strong El Niños

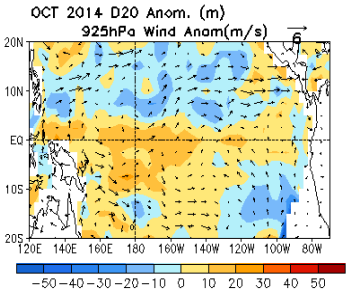
1986



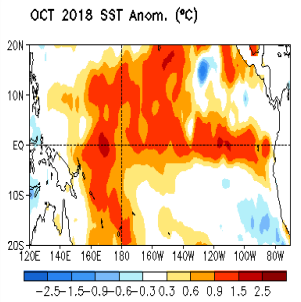


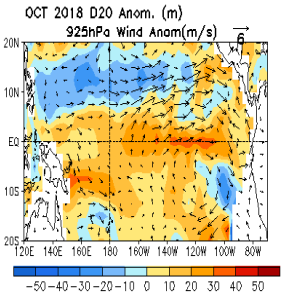
2014





2018

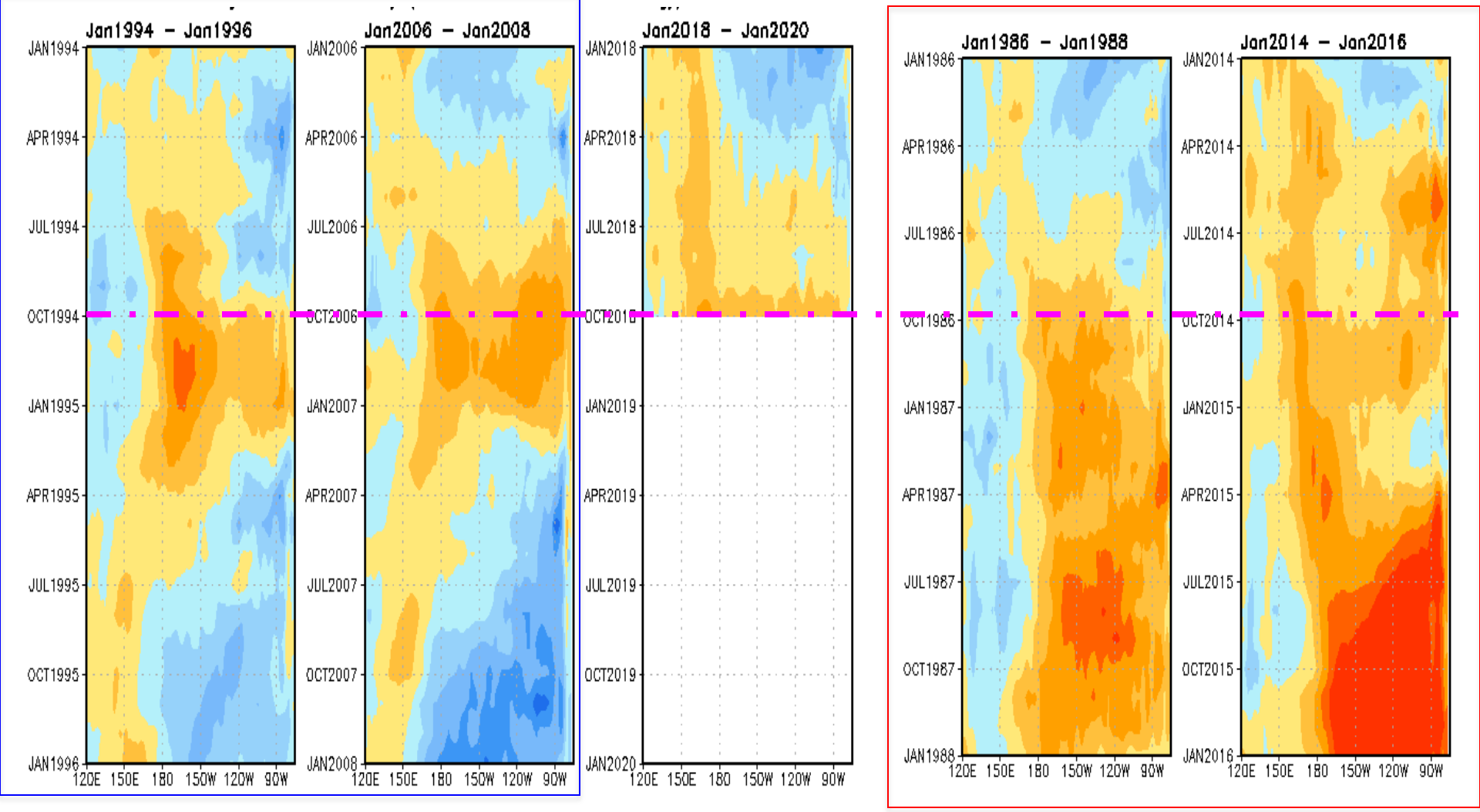




Monthly Mean SST Anomaly across [5S-5N]

Weak El Niños

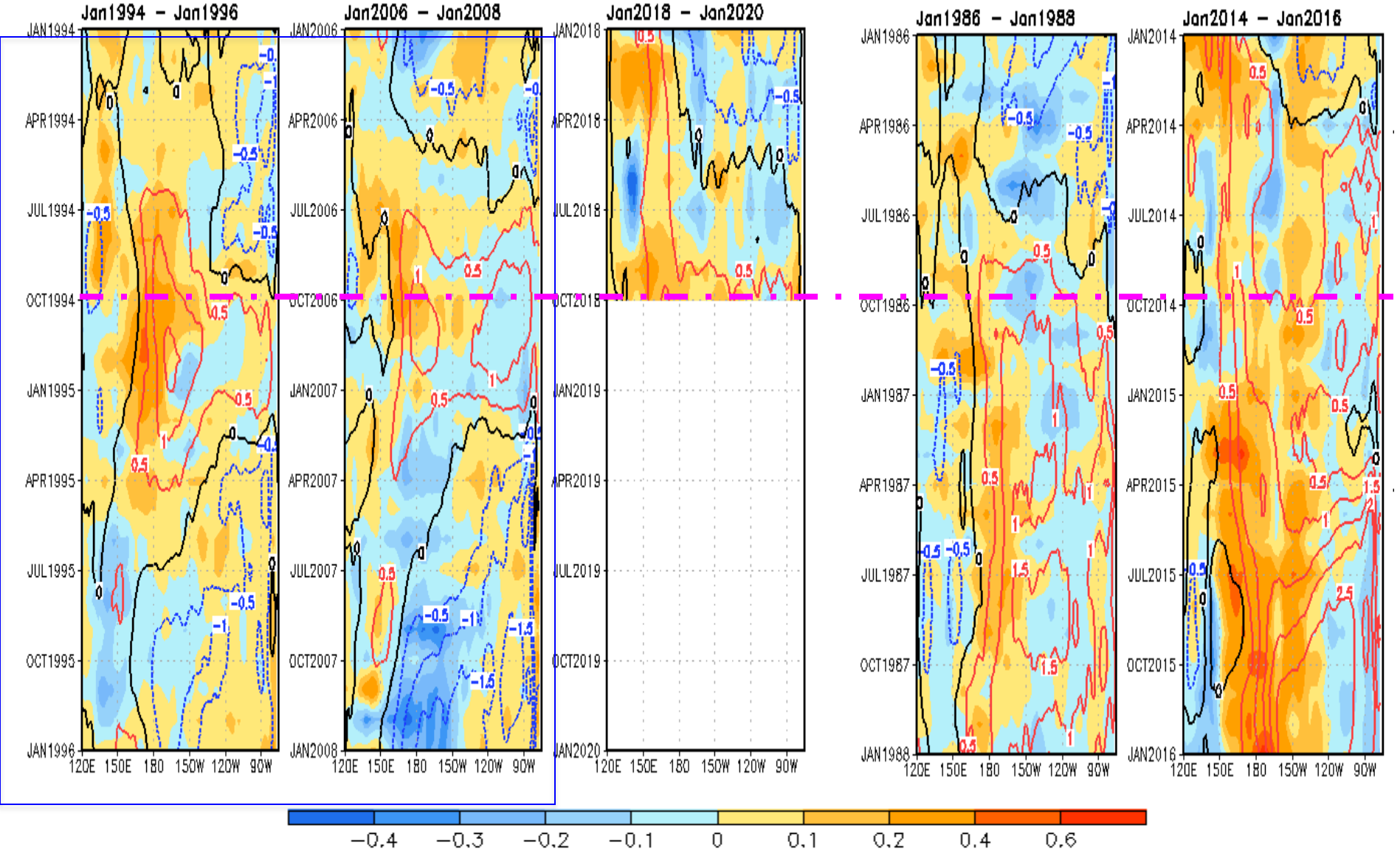
Strong El Niños



Monthly Mean Zonal Wind Stress Anomaly across [5S-5N]

Weak El Niños

Strong El Niños

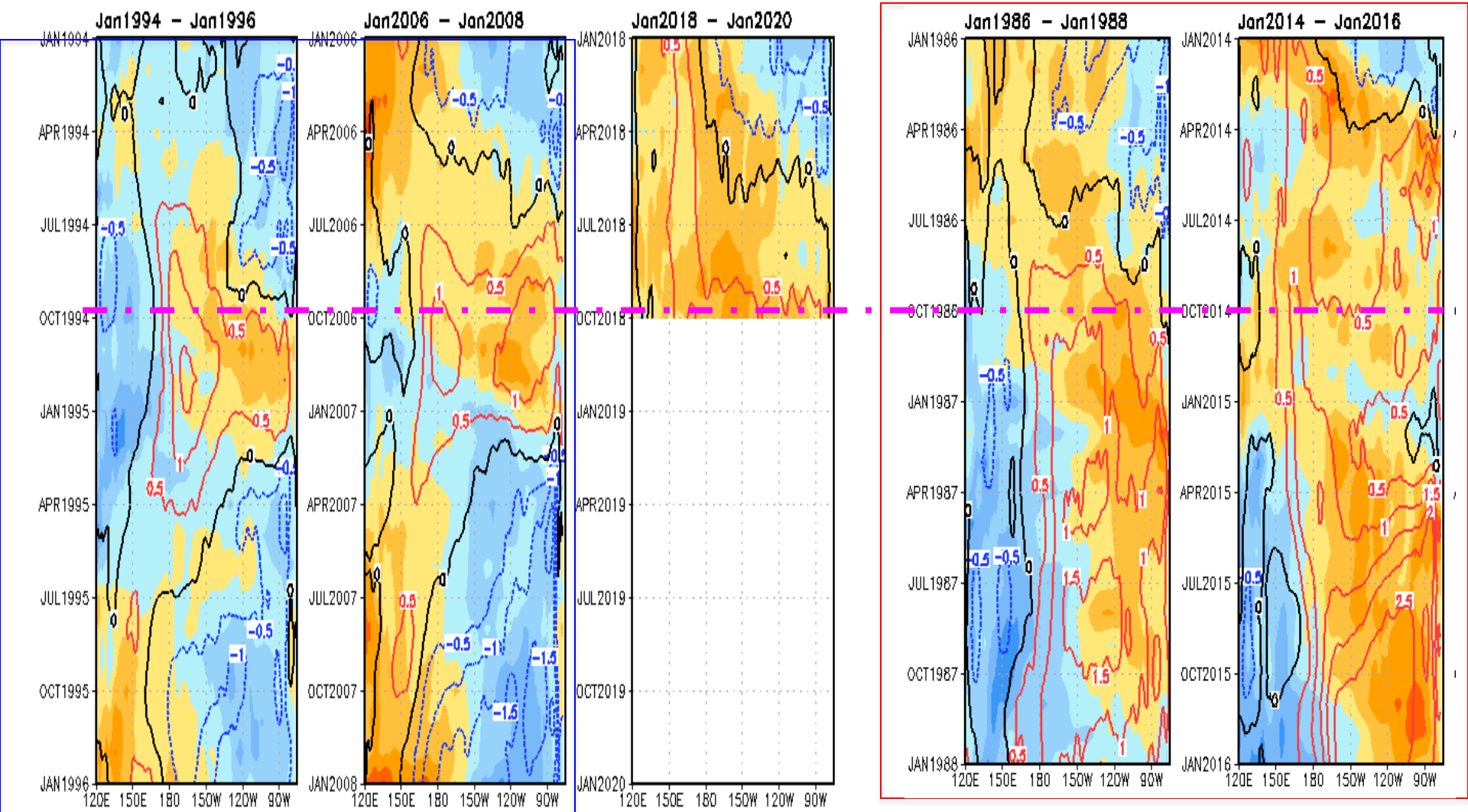


Shaded: zonal wind stress anomaly Contour: SSTA

Monthly Mean D20 Anomaly across [5S-5N]

Weak El Niños

Strong El Niños



Shaded: D20 anomaly Contour: SSTA

Acknowledgements

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

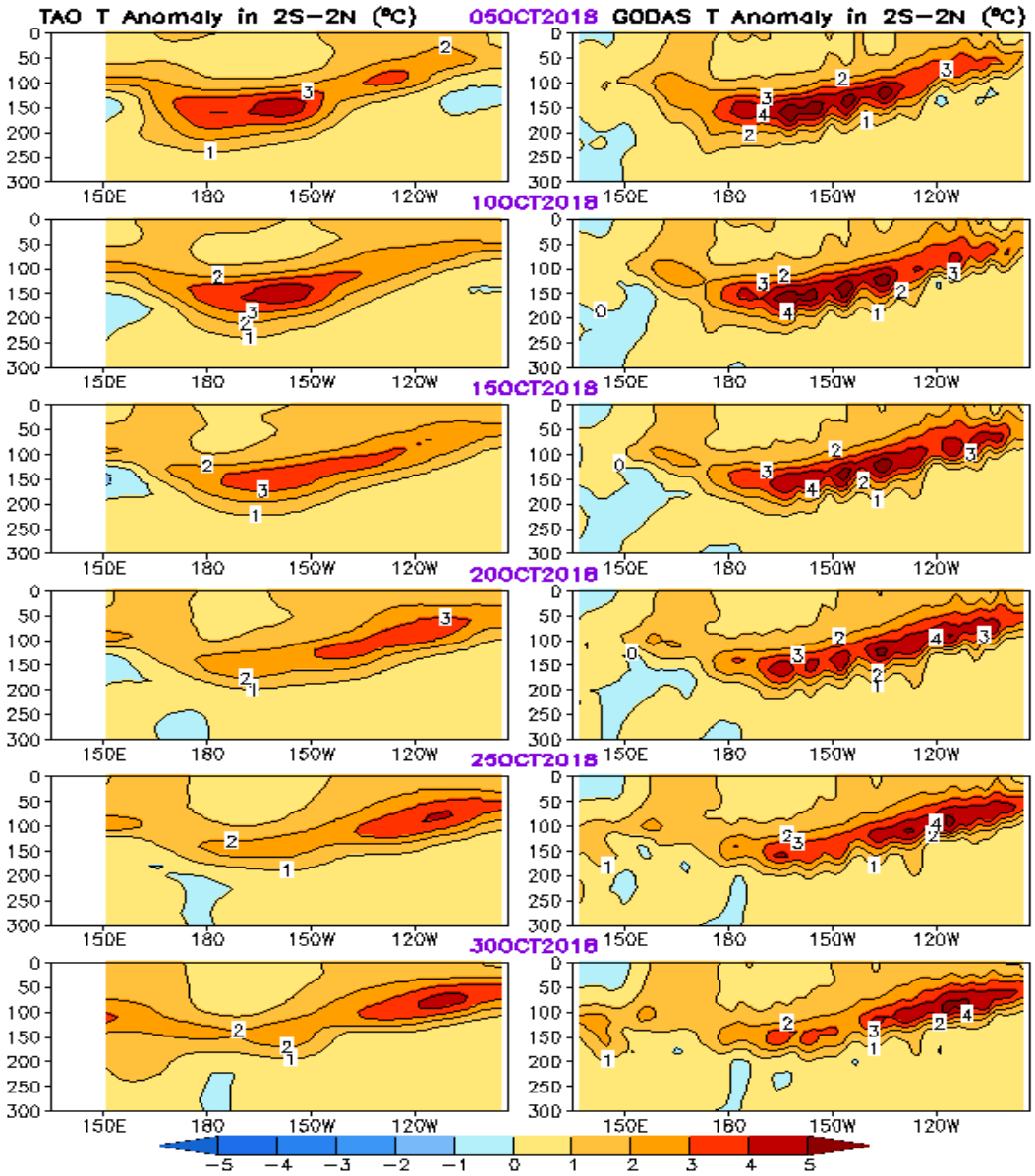
- Dr s. Li Ren and Pingping Xie: Provided SSS slides

- Dr Wanqiu Wang provided Sea Ice slides.

Back up

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

TAO GODAS



- **Positive subsurface temperature anomaly strengthened in the central-eastern Pacific, and extended eastward in the last six pentads.**

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

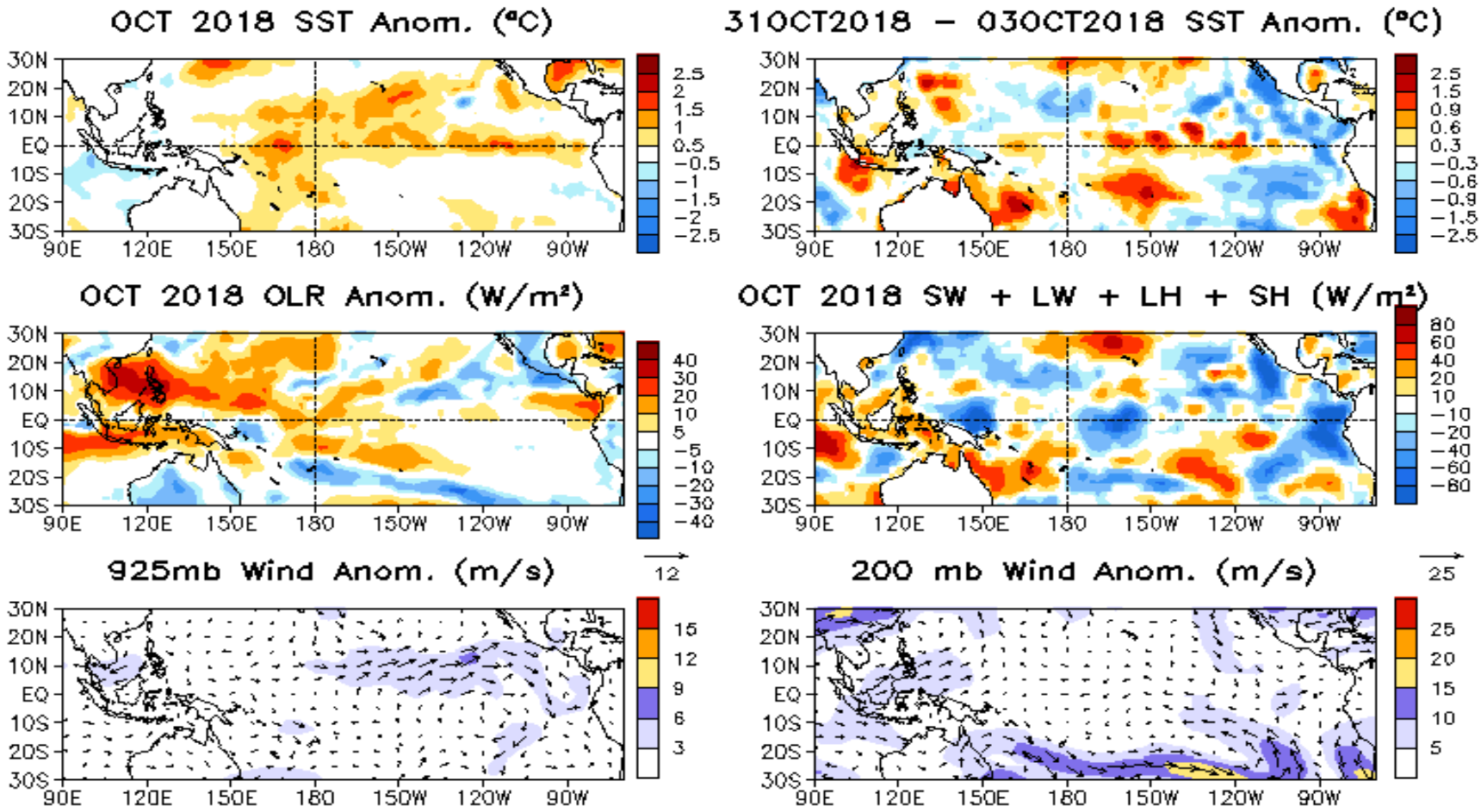
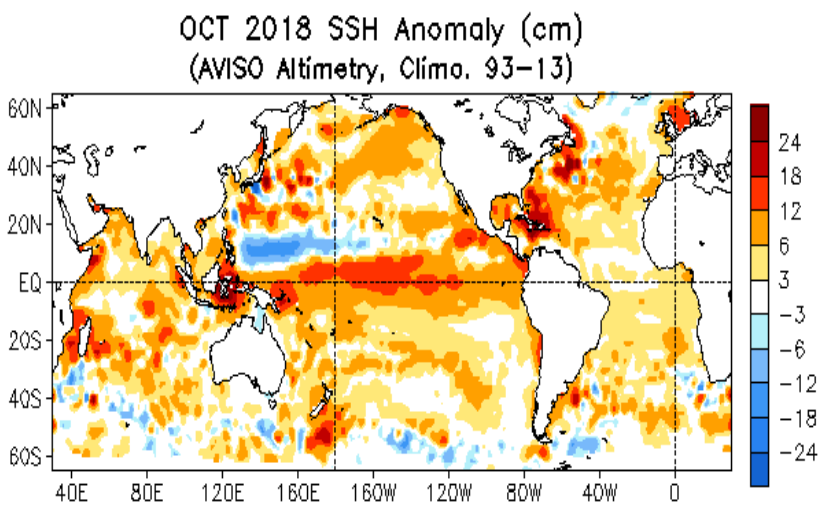
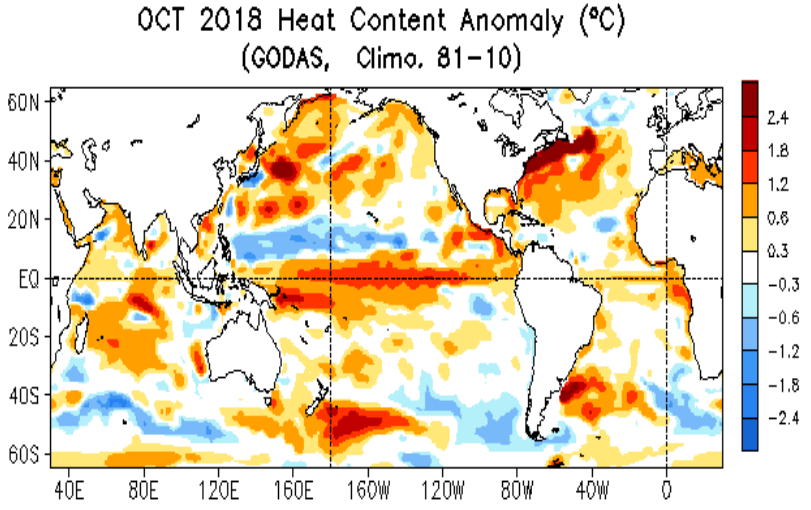
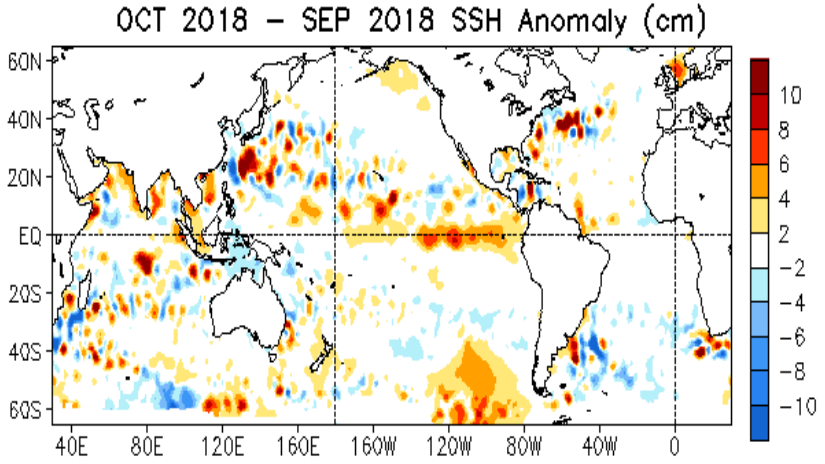


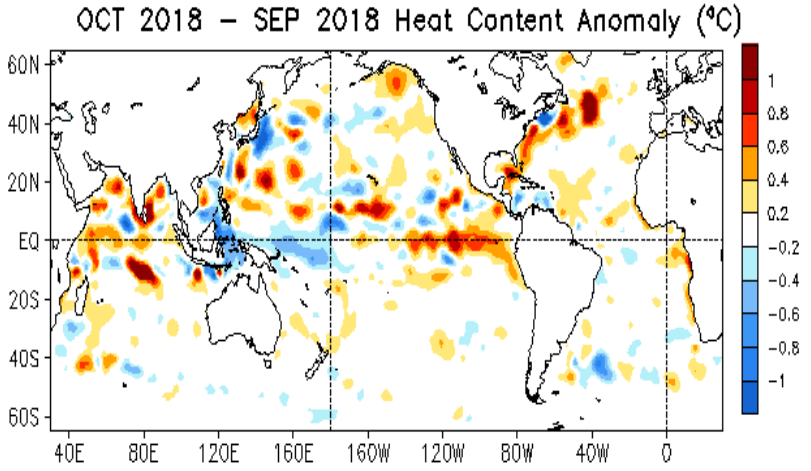
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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



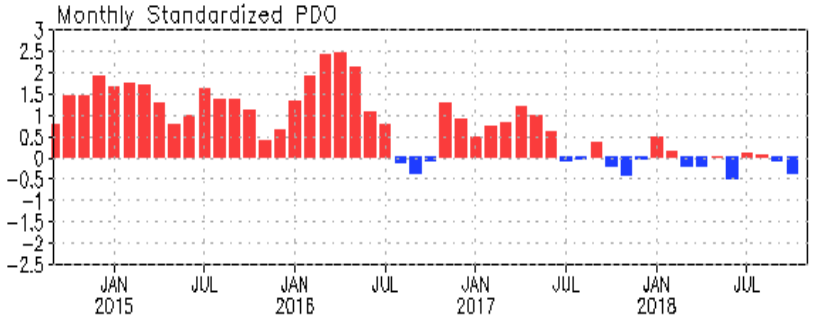


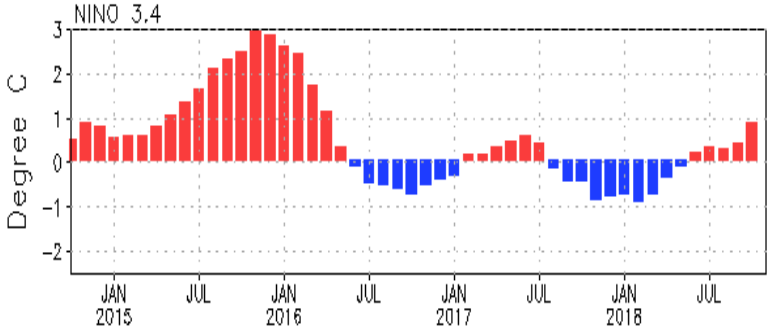


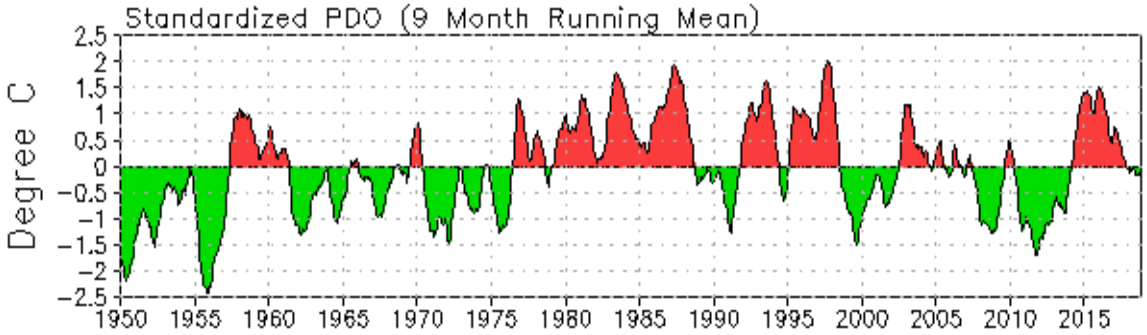


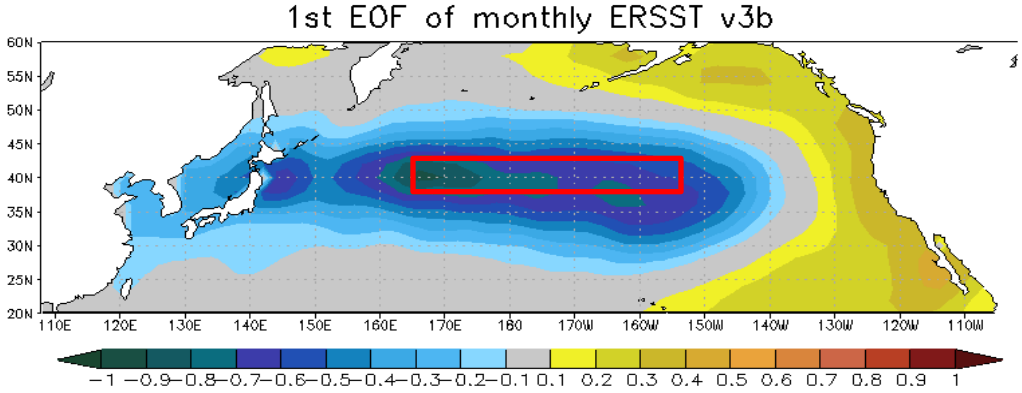
- **SSHA pattern was overall consistent with H300A pattern in the Pacific Ocean.**

PDO index









-PDO index = -0.4 in Oct 2018.

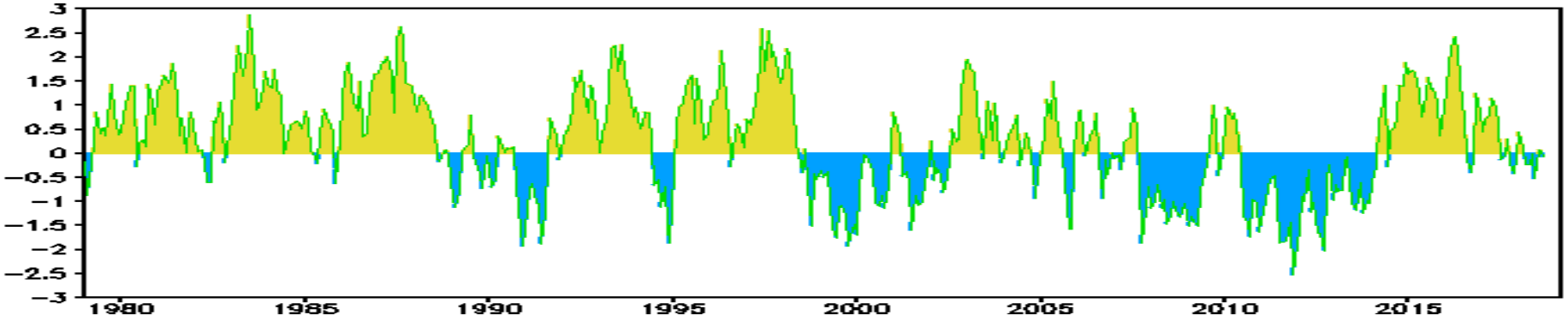
- Statistically, ENSO leads PDO by 3-4 months, may through atmospheric bridge.

- 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.

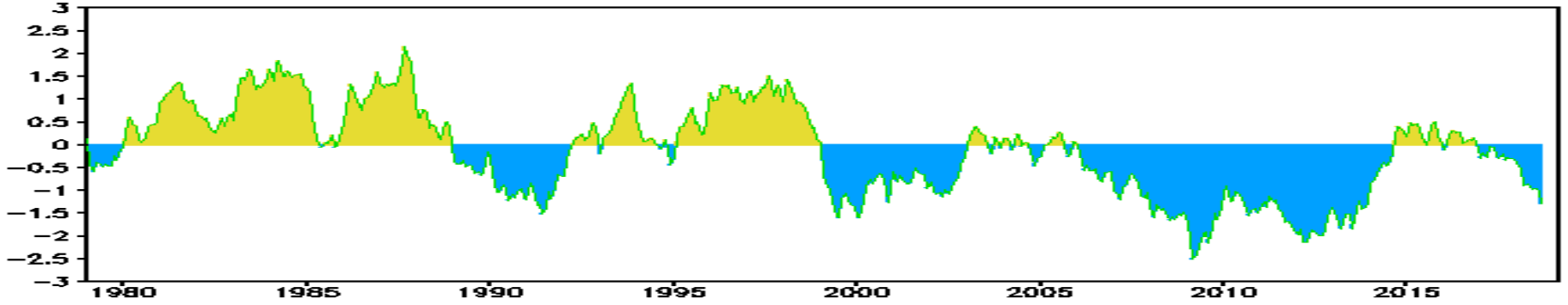
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

Two Oceanic PDO indices

SST-based PDO



H300-based PDO

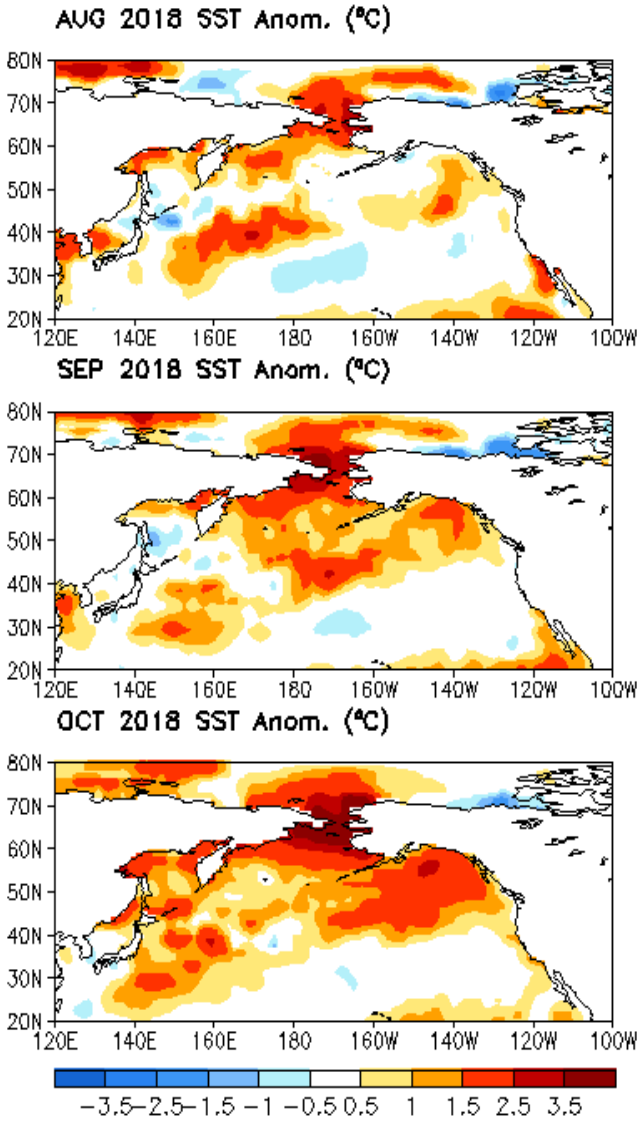


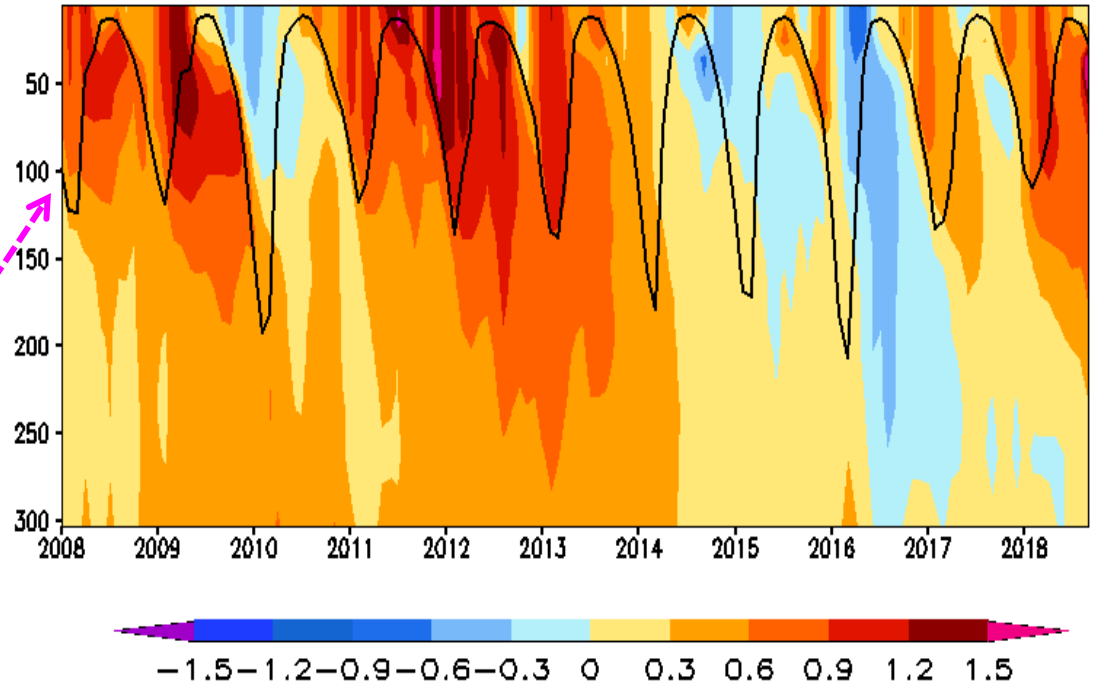
- **Negative SST-based PDO index enhanced in Oct 2018, with PDO index =-0.4.**
- **Negative H300-based PDO index has persisted 13 months since Nov 2016, with HPDO = -1. in Oct 2018.**
- **SST-based PDO index has considerable variability both on seasonal and decadal time scales.**

(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.

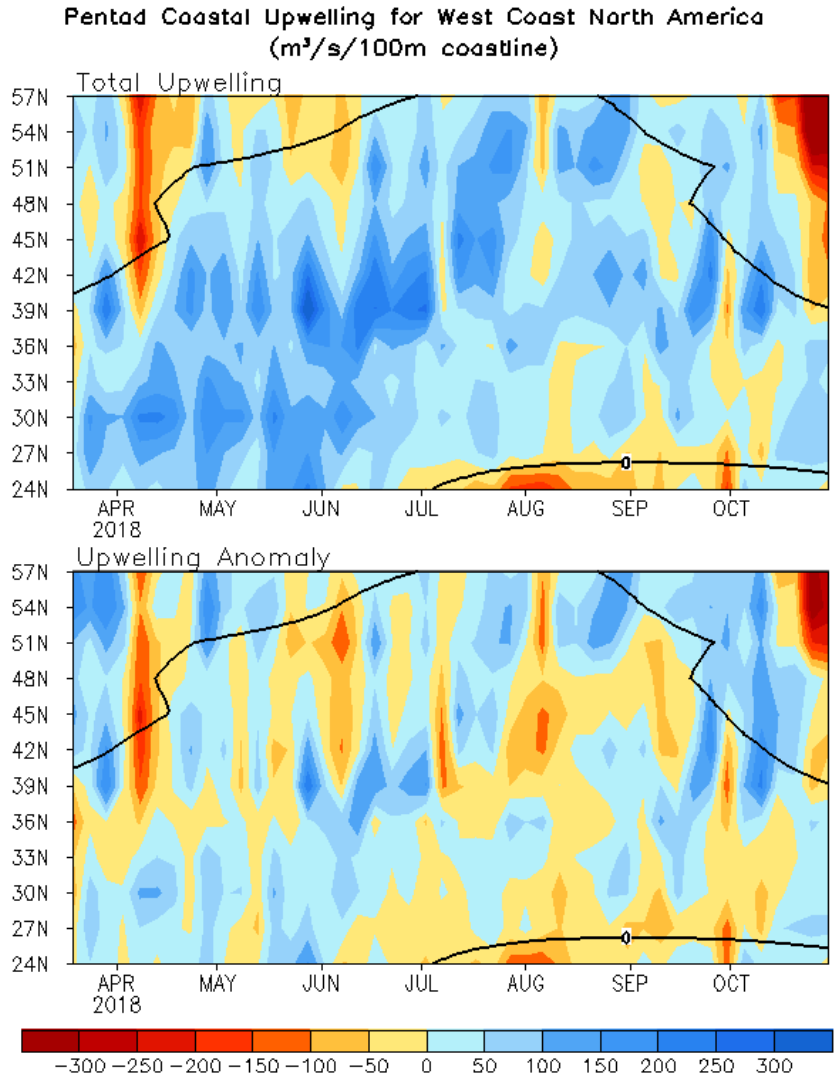
Subsurface Temperature Anomaly in the C. N Pacific





- **Positive subsurface temperature anomaly in the central North Pacific has persisted since 2016.**

North America Western Coastal Upwelling



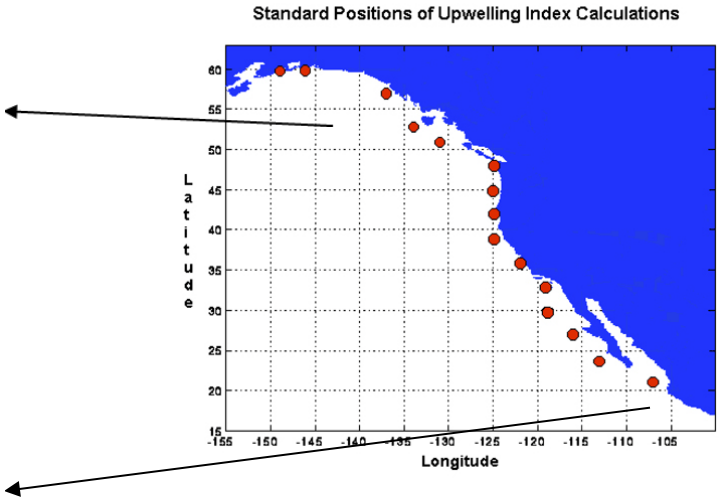


Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport 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 36ºN to 57ºN.**

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

- **Negative SSTA weakened in the eastern Indian Ocean.**

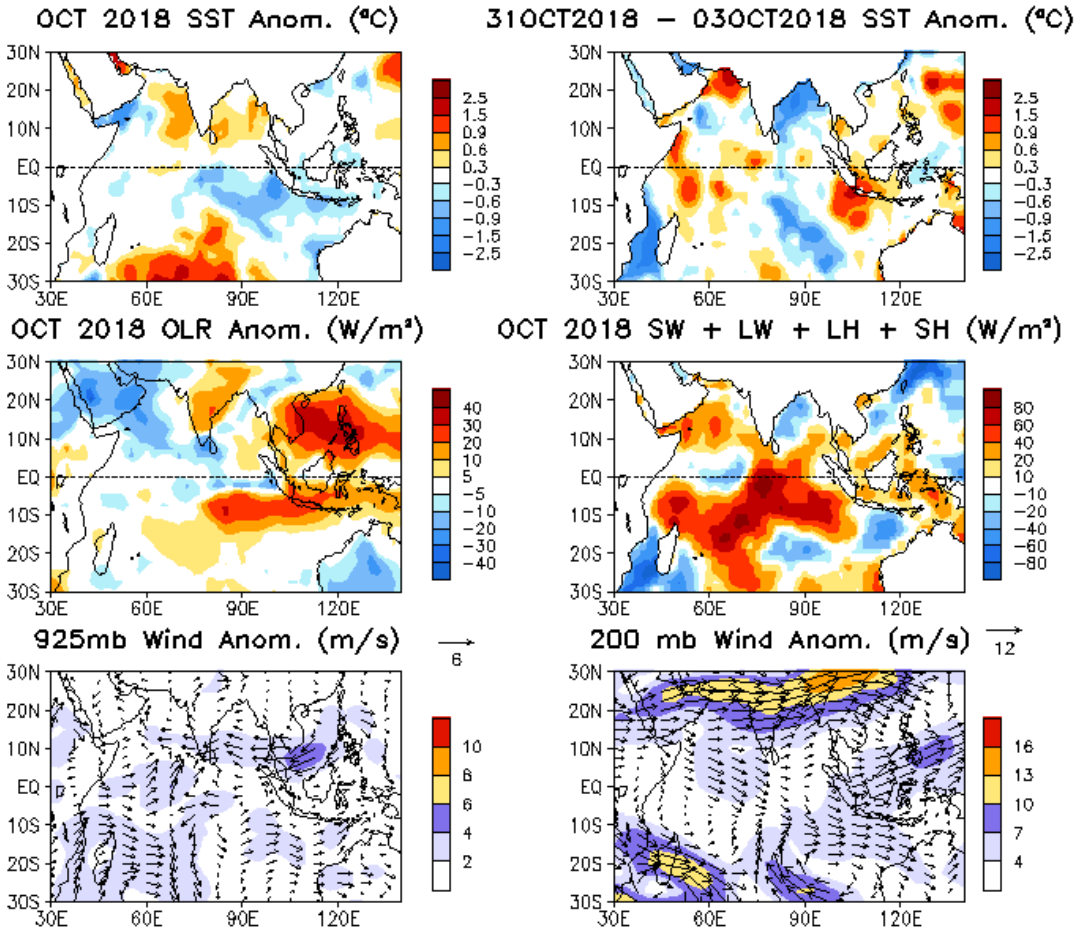
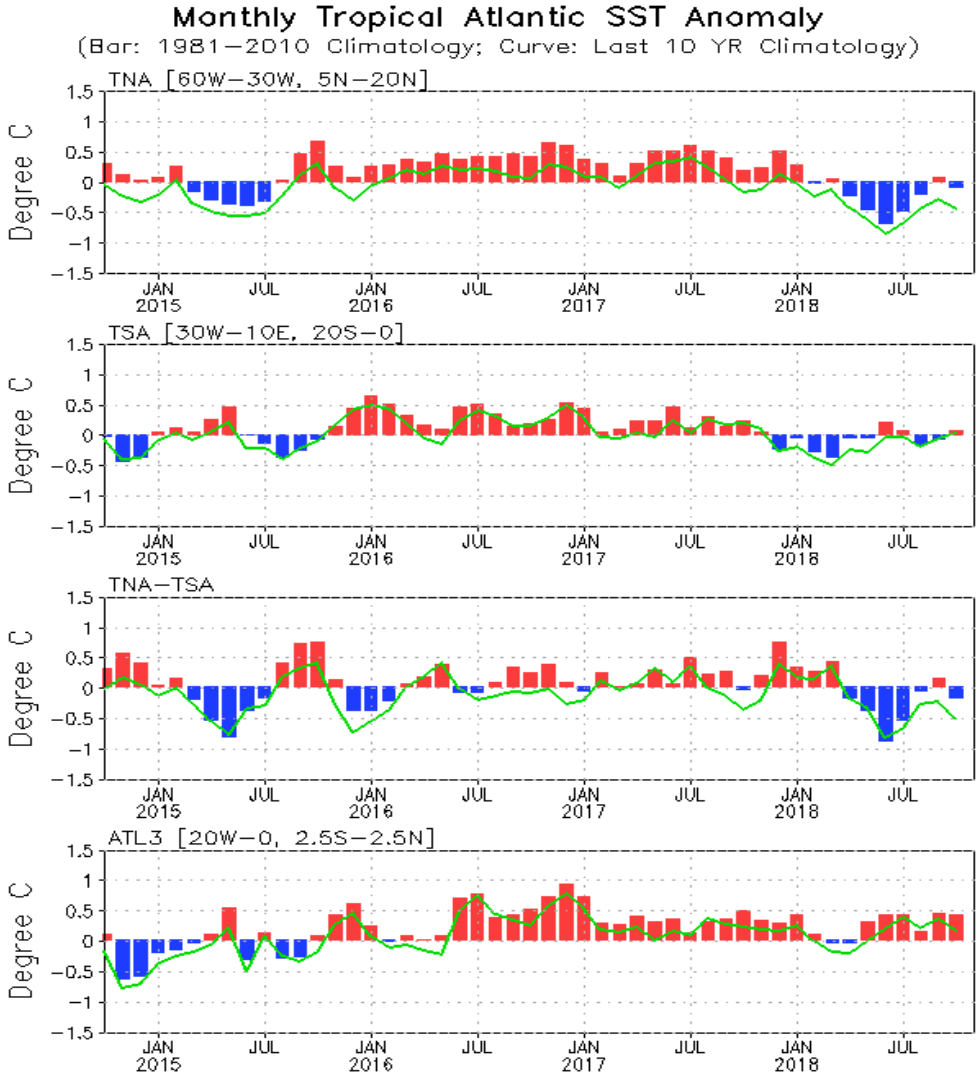
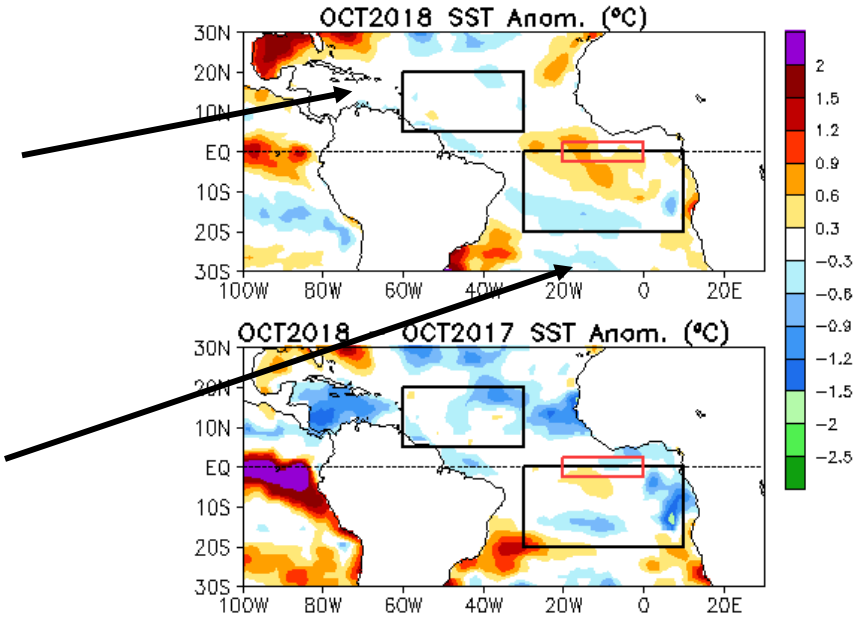


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Evolution of Tropical Atlantic SST Indices



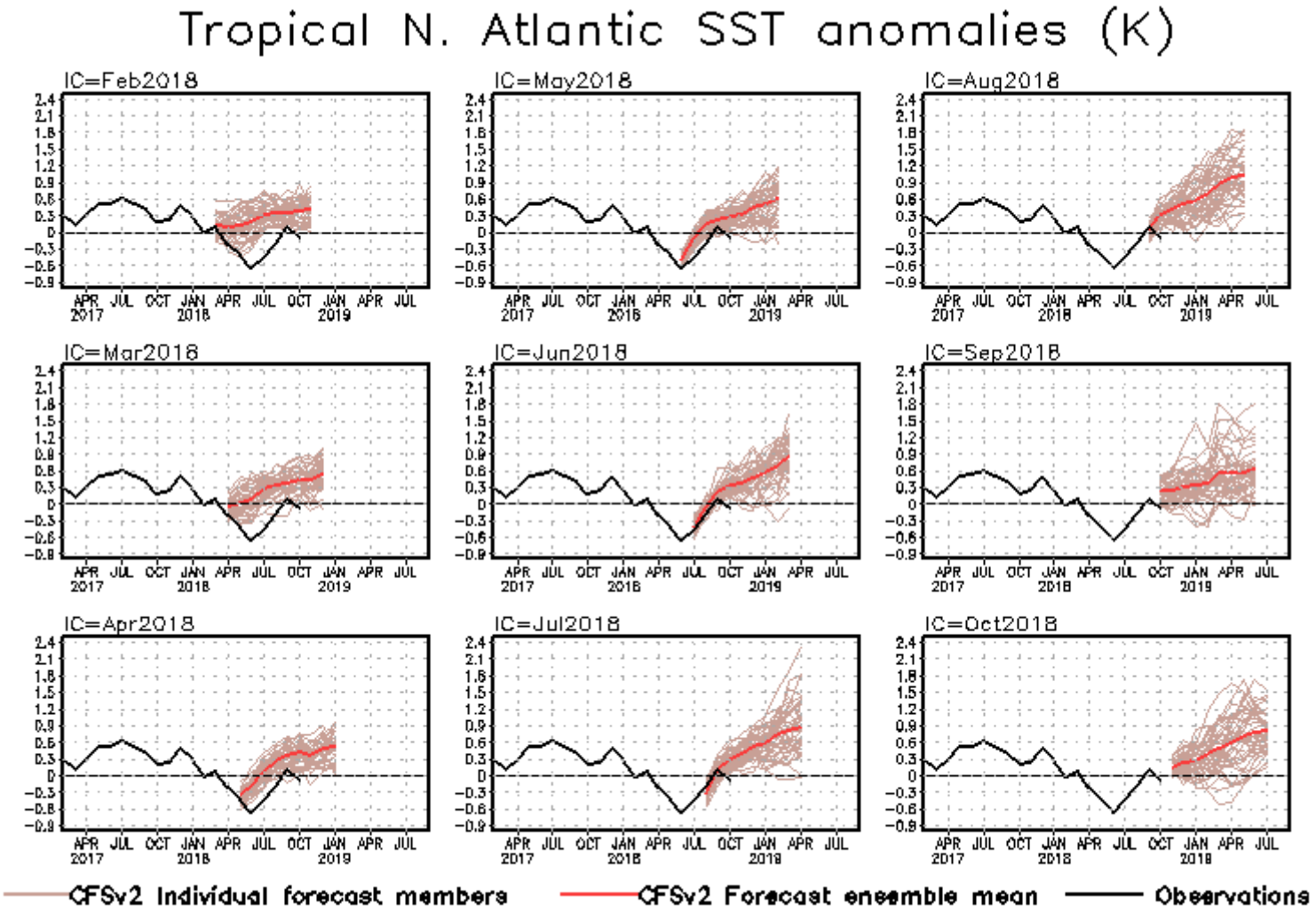


- **Positive Atl 3 continued in Oct 2018.**

- **The SST in the eastern tropical N Atlantic in Sep 2018 was about 2 degree colder than that in Sep 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.

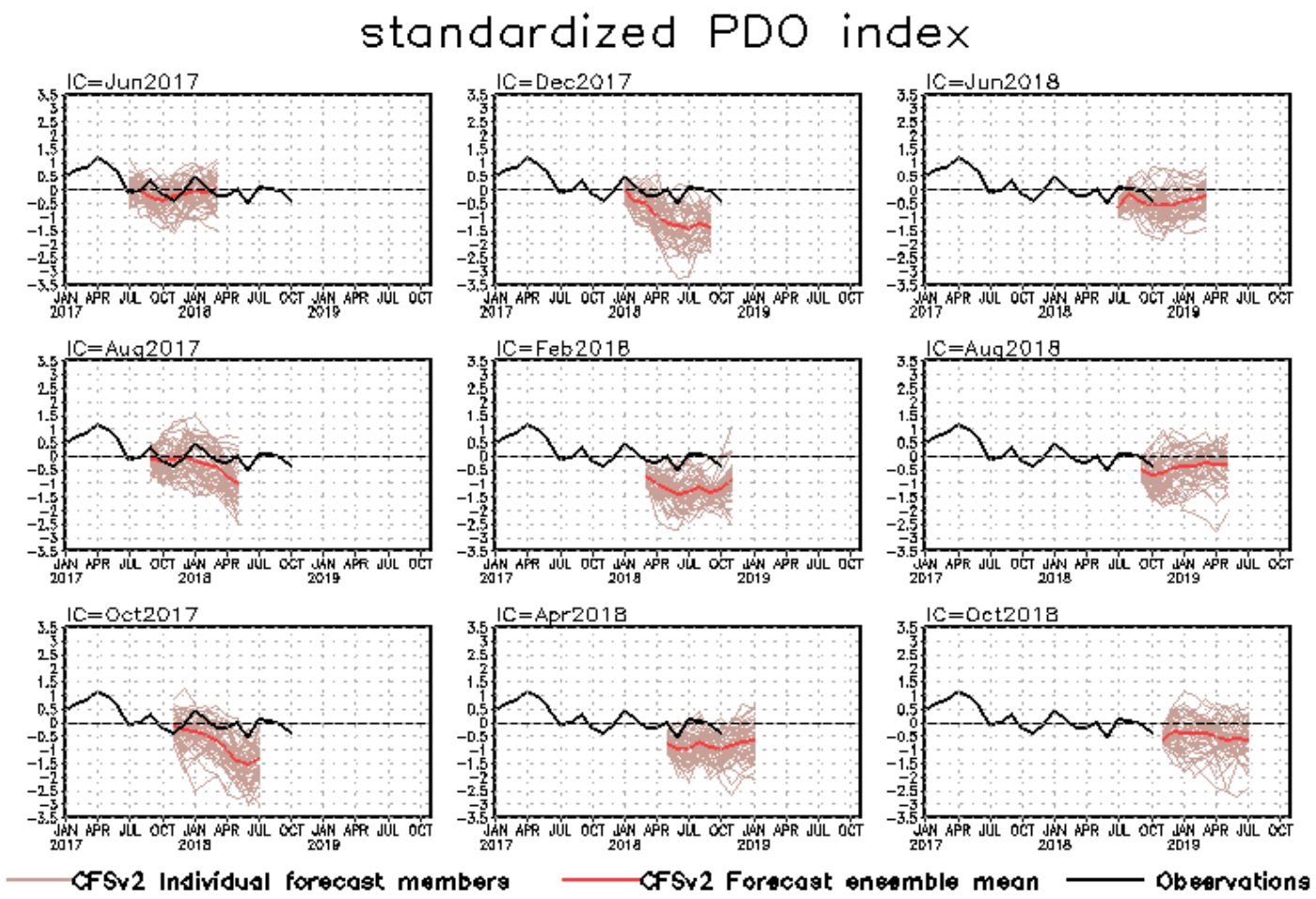
CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months



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.

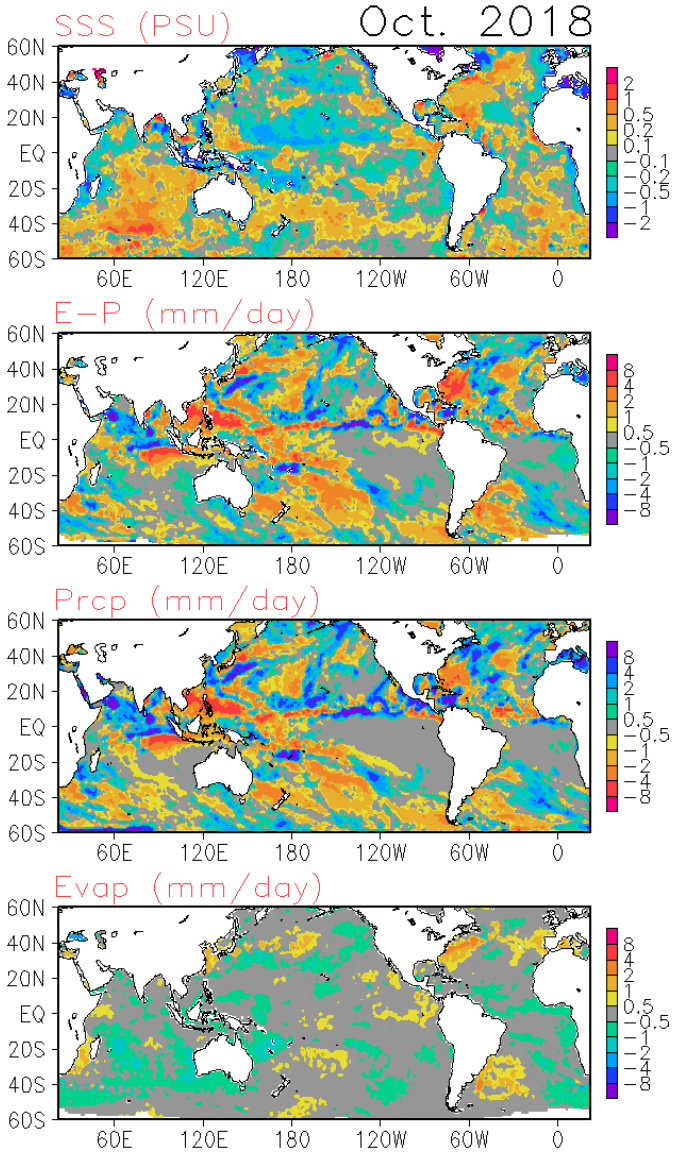
Global Sea Surface Salinity (SSS)

Anomaly for October 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 this month. A large scale of freshening continues in the subarctic region of N. Pacific between 35˚ N and 50˚ N as well. Most of the Indian ocean north of equator became fresher this month, which is possibly due to increased precipitation. The positive SSS along the Gulf Stream continues. Meanwhile, the negative SSS in the central N. Atlantic ocean is co-incident with a strong positive precipitation signal.

- **Data used**

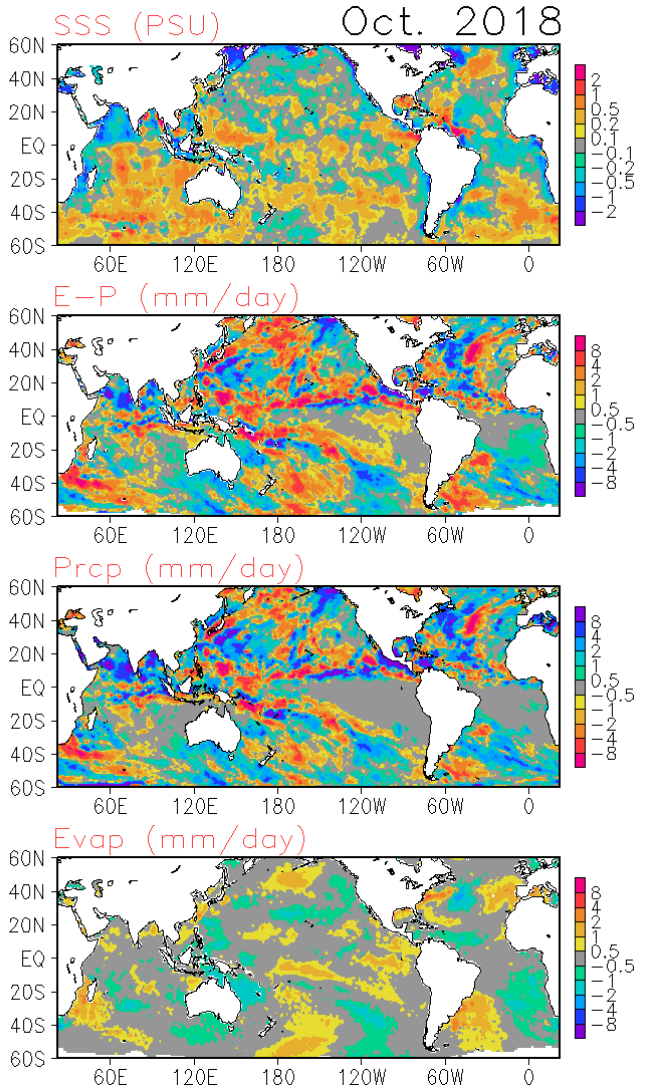
  SSS : Blended Analysis of Surface Salinity (BASS) V0.Z
  (a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
  (Xie et al. 2014)
  ftp.cpc.ncep.noaa.gov/precip/BASS
  Precipitation: CMORPH adjusted satellite precipitation estimates
  Evaporation: Adjusted CFS Reanalysis



Global Sea Surface Salinity (SSS)

Tendency for October 2018

Compared with last month, the decreasing of SSS in the ITCZ and SPCZ region became weaker. The SSS in both the Arabian and Bay of Bengal decreased, especially the Arabian Sea, which is likely due to the increasing of the precipitation in these regions. The SSS in the middle of the North Atlantic ocean decreases which is accompanied with increasing precipitation.

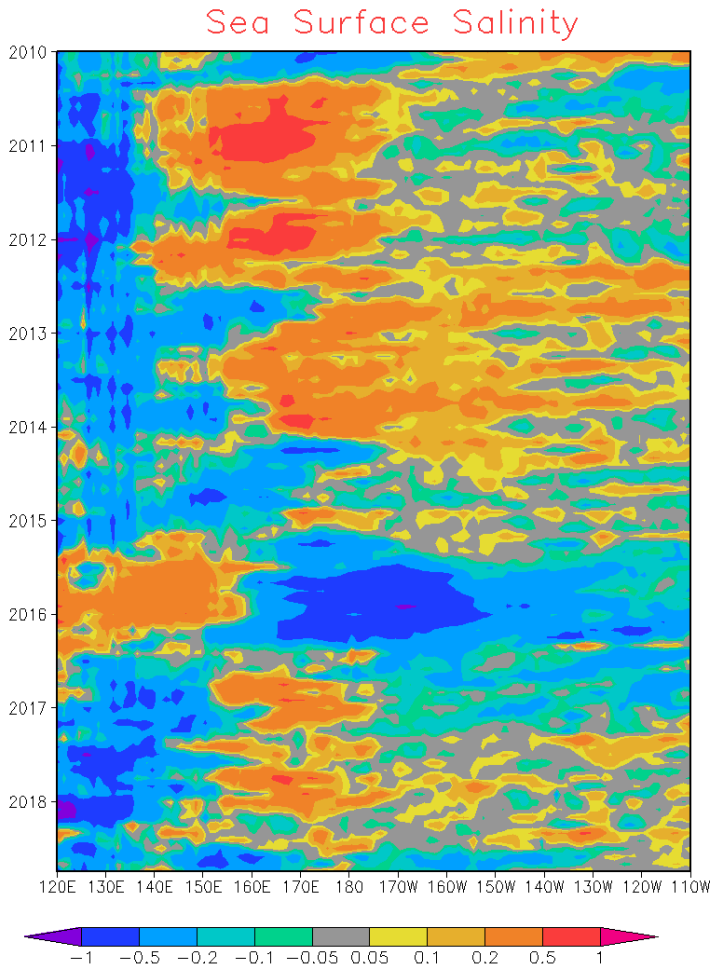


Global Sea Surface Salinity (SSS)

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.

- Hovemoller diagram for equatorial SSS anomaly **(5˚ S-5˚ N);**
- In the equatorial Pacific Ocean, the negative SSS signal almost spreads the whole basin from 120˚ E to 130˚ W, with stronger signals appearing in the west basin.



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.