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

Prepared by

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November 12, 2019

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

https://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing.shtml

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 SSTA Predictions**

  - **2019 Marine Heatwave in the North Pacific and predictions**

Overview

Pacific Ocean

- ENSO neutral conditions continued in Oct 2019, with NINO34=0.6 ^{o}C.
- Positive SSTAs persisted in the NE Pacific in Oct 2019. The PDO switched to negative phase, with PDOI = - 0.7 in Oct 2019.
- Arctic sea ice extent in Oct 2019 reached the lowest record since 1979.

Indian Ocean

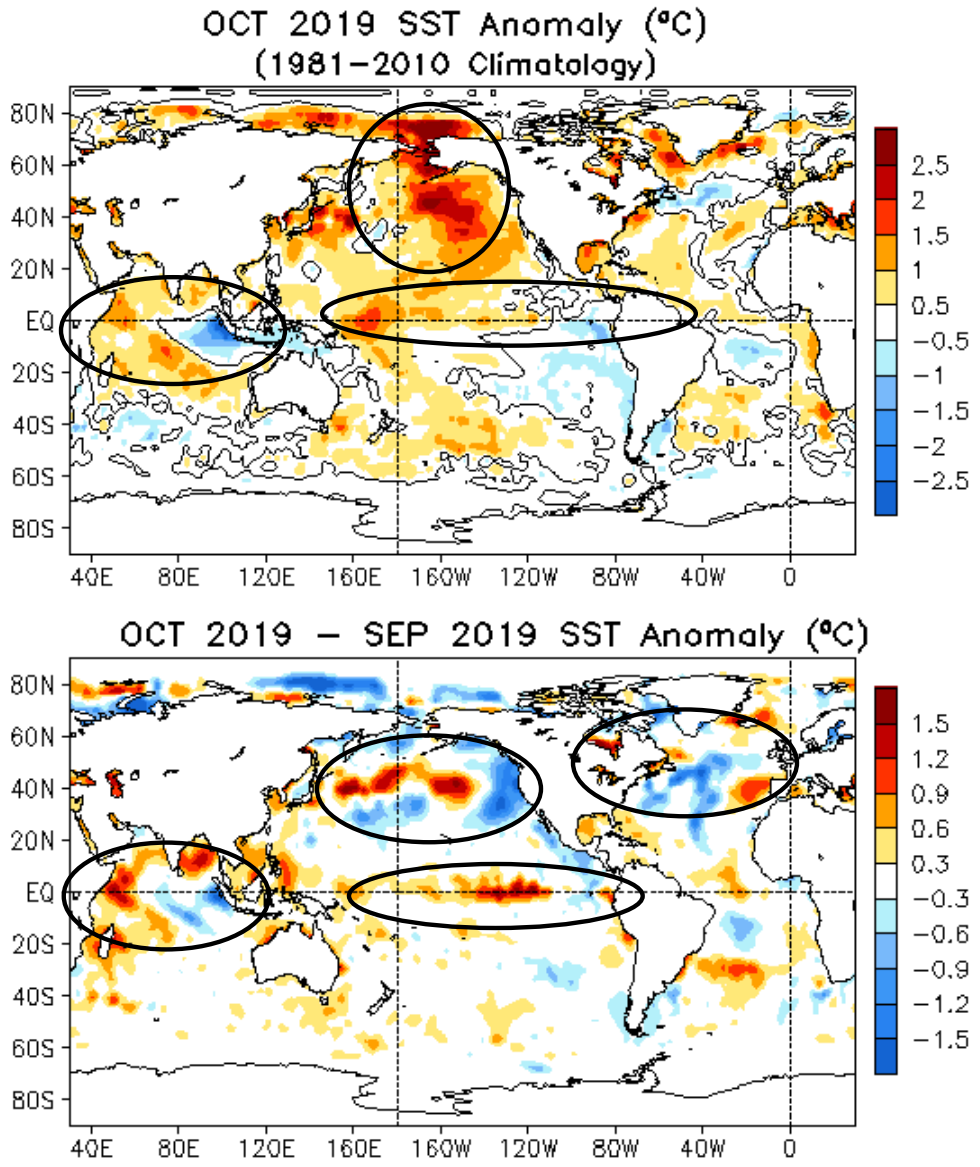
- The strong positive IOD event continued in Oct 2019.
- IOD index = 2 ^{o}C in Oct 2019, ranking the largest value since 1950.

Atlantic Ocean

- NAO switched to negative phase in Oct 2019.
- 2019 Atlantic hurricane season is the fourth consecutive year of above-average and damaging seasons since 2016.

Global Oceans

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



-SSTs were above normal across most of the equatorial Pacific.

- Strong positive SSTAs persisted in the NE Pacific and Arctic Oceans.

- SSTAs were positive in the west and central and negative in the far eastern Indian Ocean, featuring the positive IOD structure.

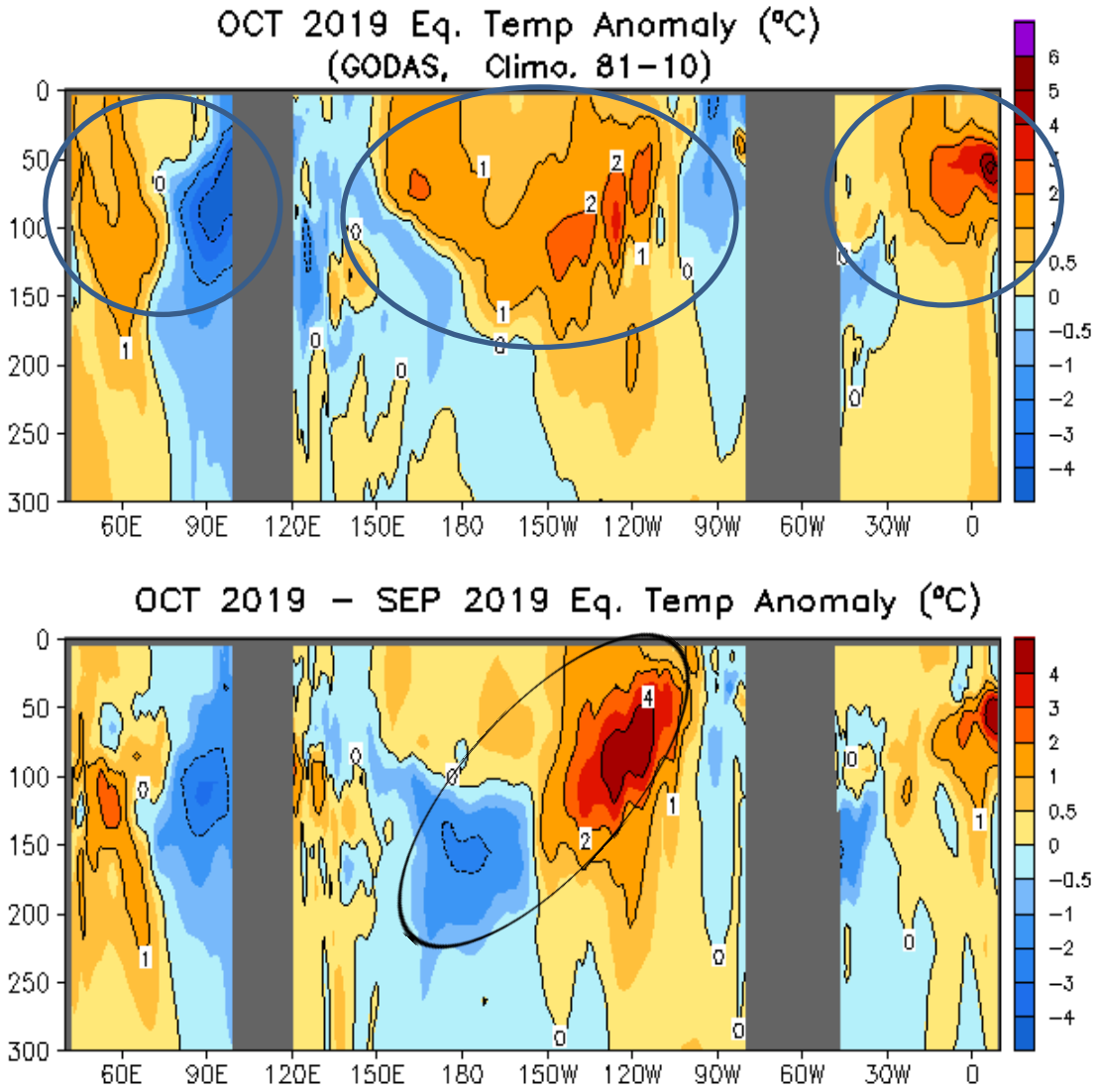
- Positive SSTA tendencies dominated in the equatorial Pacific.

- Horseshoe/tripole-like SSTA tendencies presented in the N. Pacific.

- Negative (positive) SSTA tendencies presented in the eastern (western) 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°S-2°N



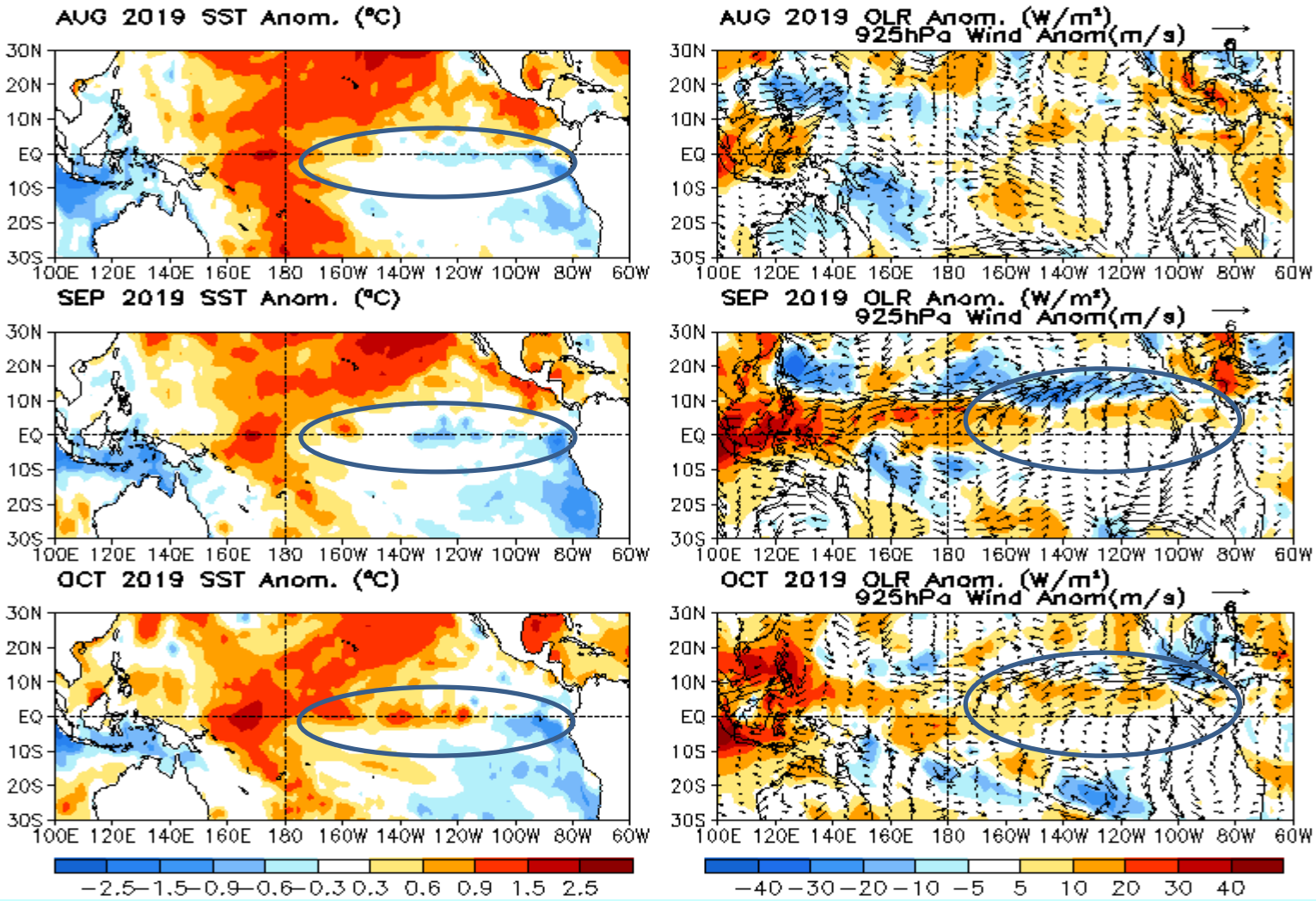
- **Positive temperature anomalies dominated the equatorial Pacific.**
- **Positive temperature anomalies continued in the Atlantic Ocean.**
- **Positive (negative) anomalies presented in the Indian Ocean.**

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

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.

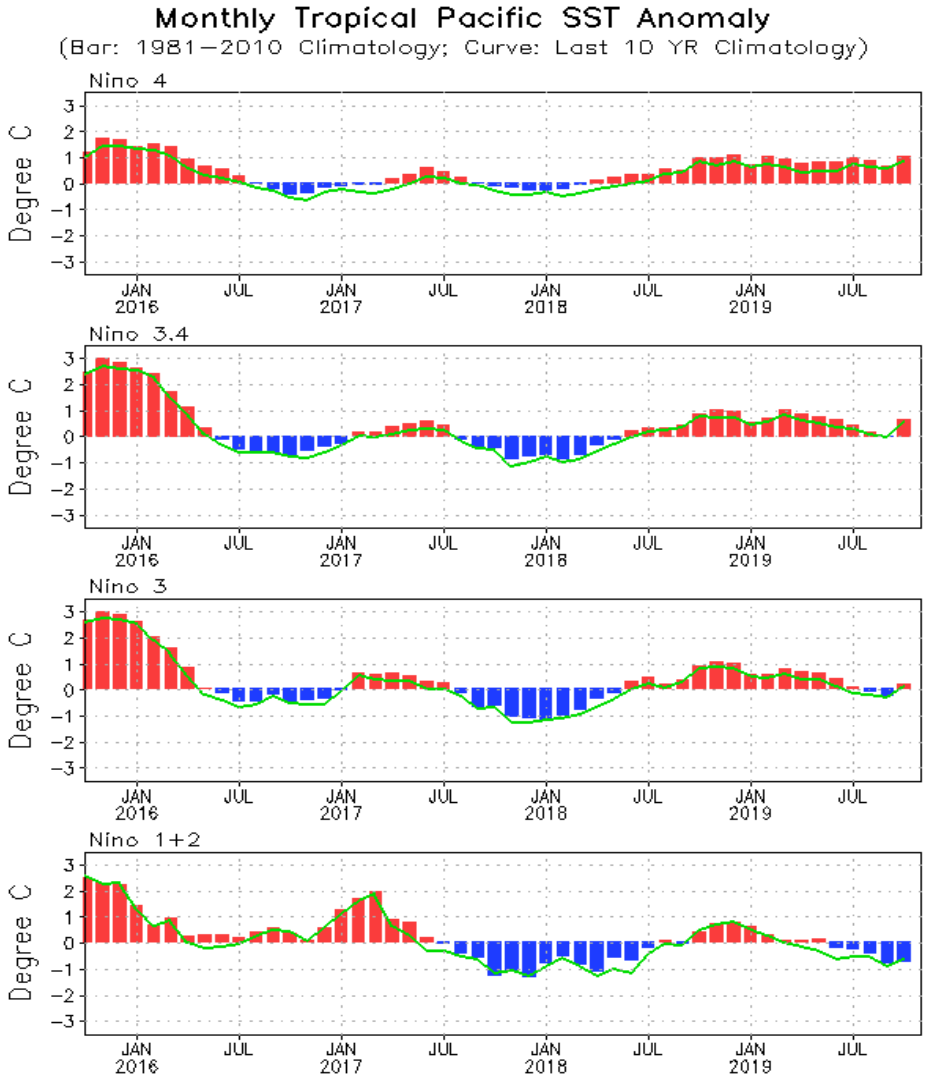
Tropical Pacific Ocean and ENSO Conditions

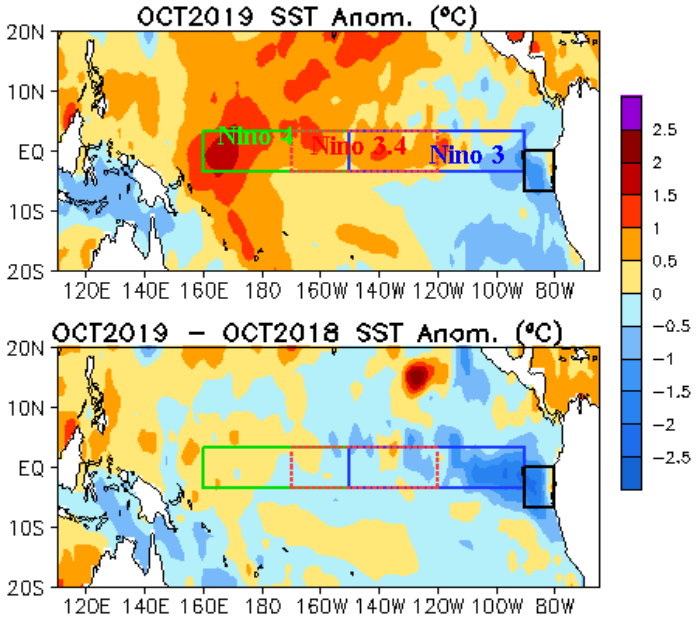
Last three month SST, OLR and 925hPa wind anomalies



- **During the last couple months, positive SST anomaly strengthened in the central-eastern Pacific, and below-average SSTs weakened in the far E. Pacific.**
- **Positive OLR anomalies have presented over the Date Line since Sep 2019.**
- **Low-level cross equatorial wind anomalies were evident during the last couple months.**

Evolution of Pacific NINO SST Indices





- **Positive NINO 4 and NINO3.4 increased in Oct 2019.**

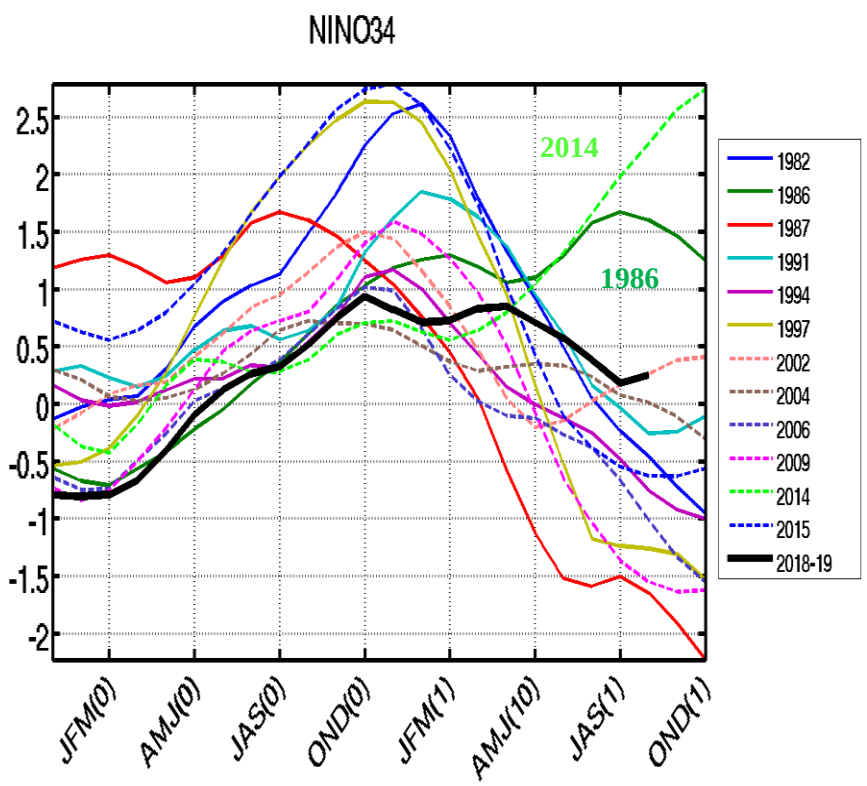
- **Nino3.4 = 0.6 C in Oct 2019.**

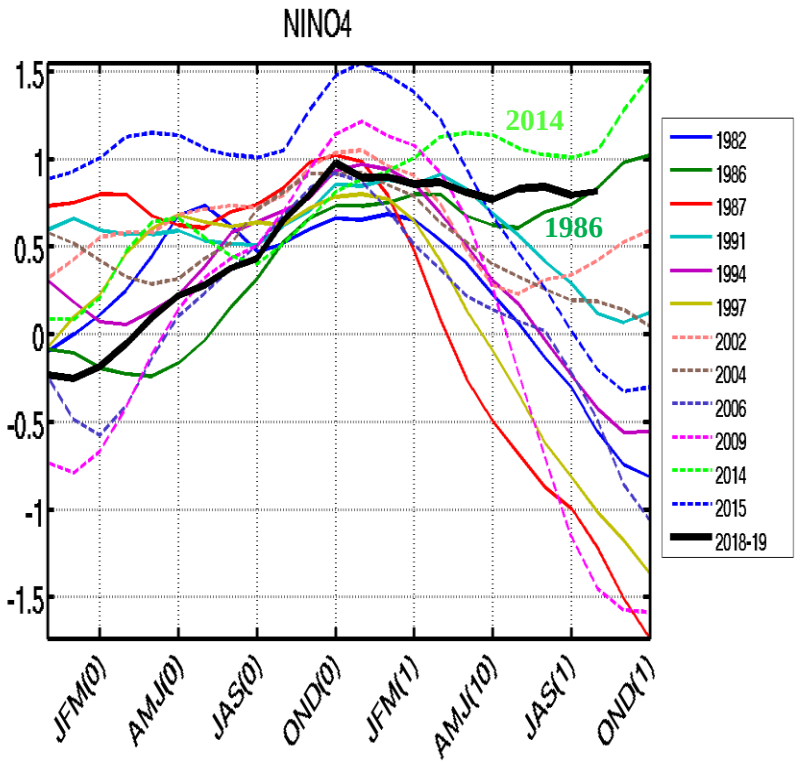
- **Compared with Oct 2018, the eastern equatorial Pacific was cooler in Oct 2019.**

- **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.

El Niño Composites



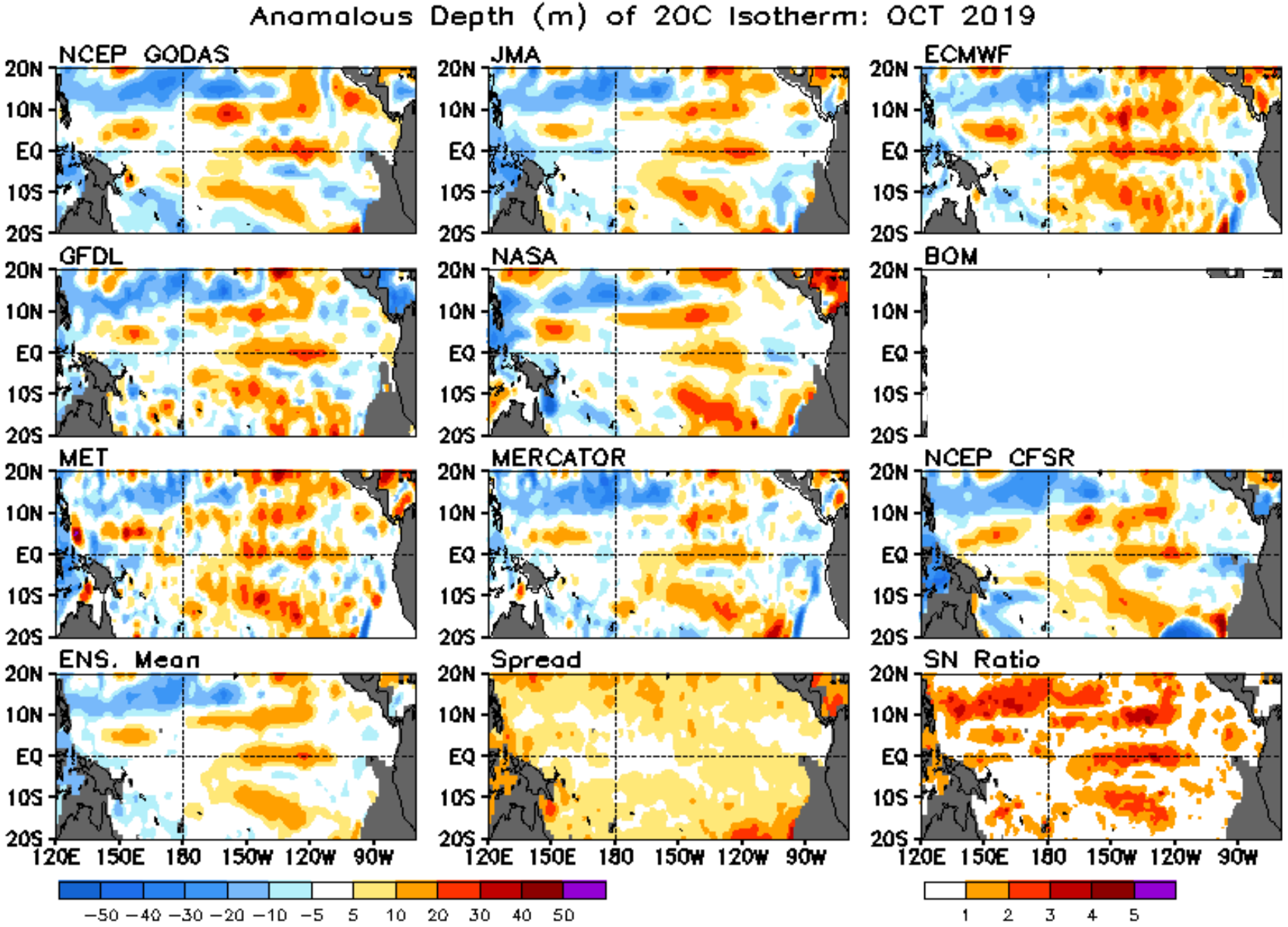


- **Compared to the historical El Niño events, 2018-19 is a weak El Niño.**
- **The evolution of NINO4 in 2018-19 is similar to those in 2014-15 and 1986-87 events.**

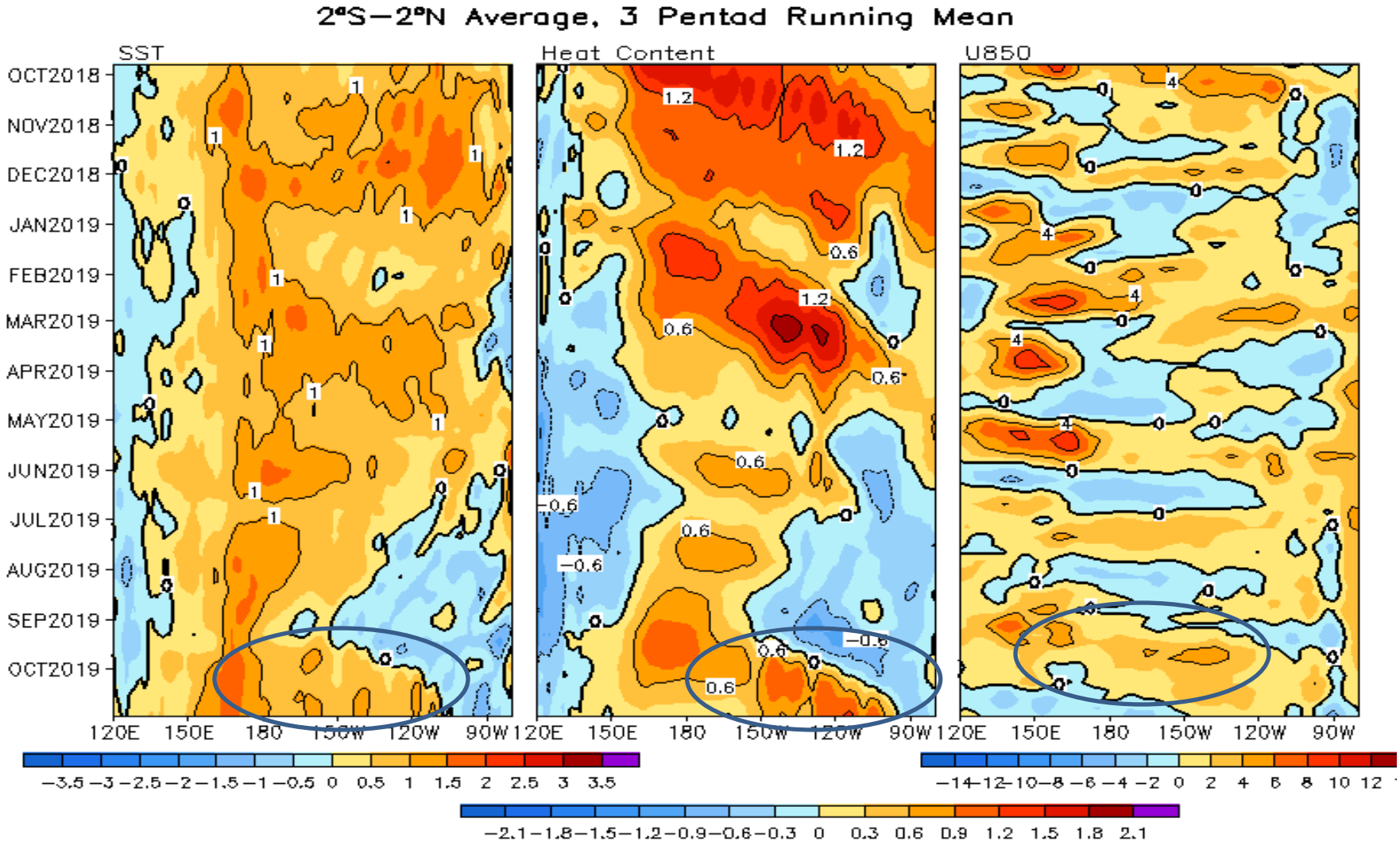
Real-Time Ocean Reanalysis Intercomparison: D20

Climatology : 1993-2013

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



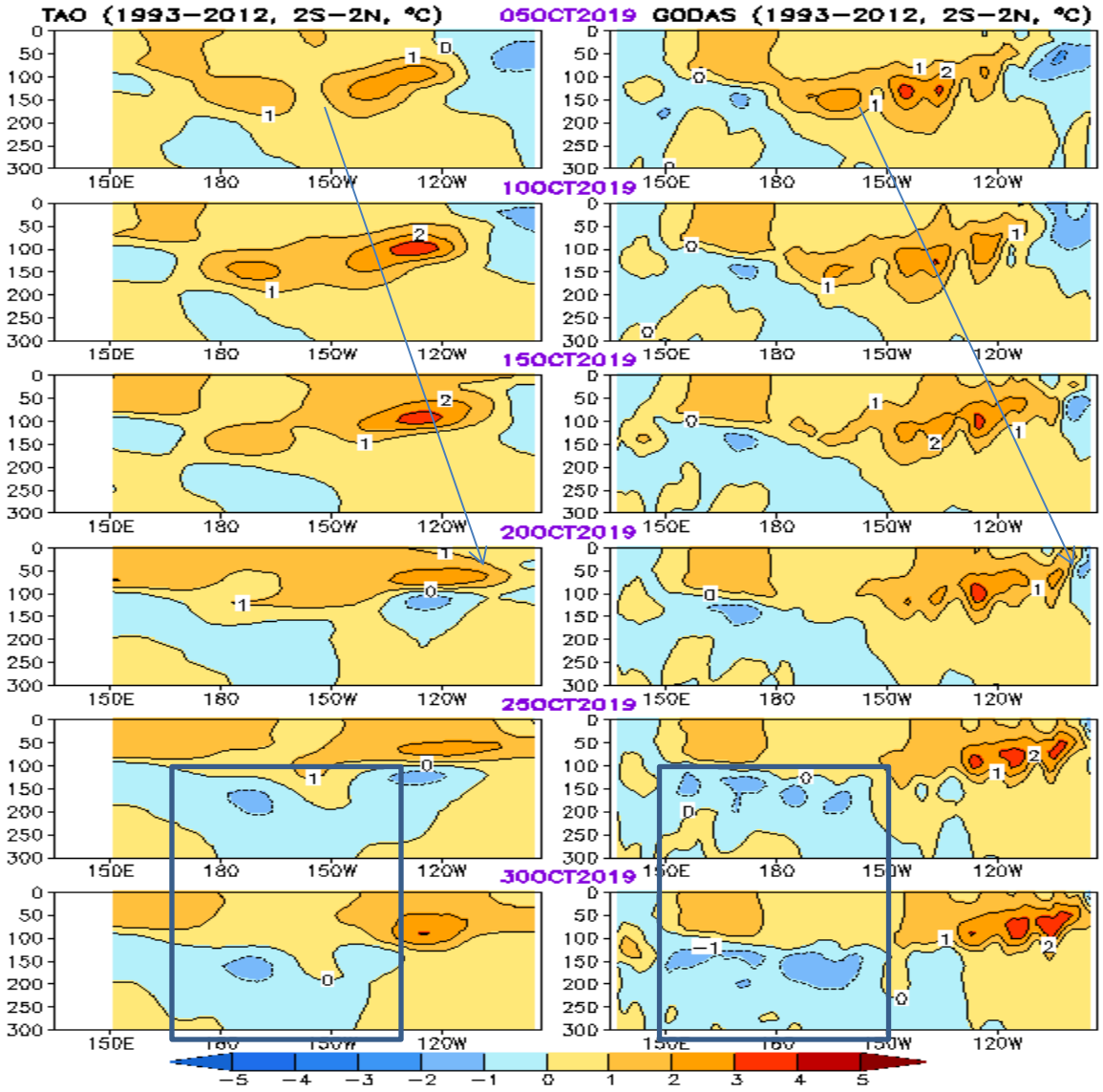
Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies



- MJO-related westerlies initiated a downwelling Kelvin wave in the central Pacific in Sep, 2019, contributing to the re-emergence of surface warming in the east-central Pacific.

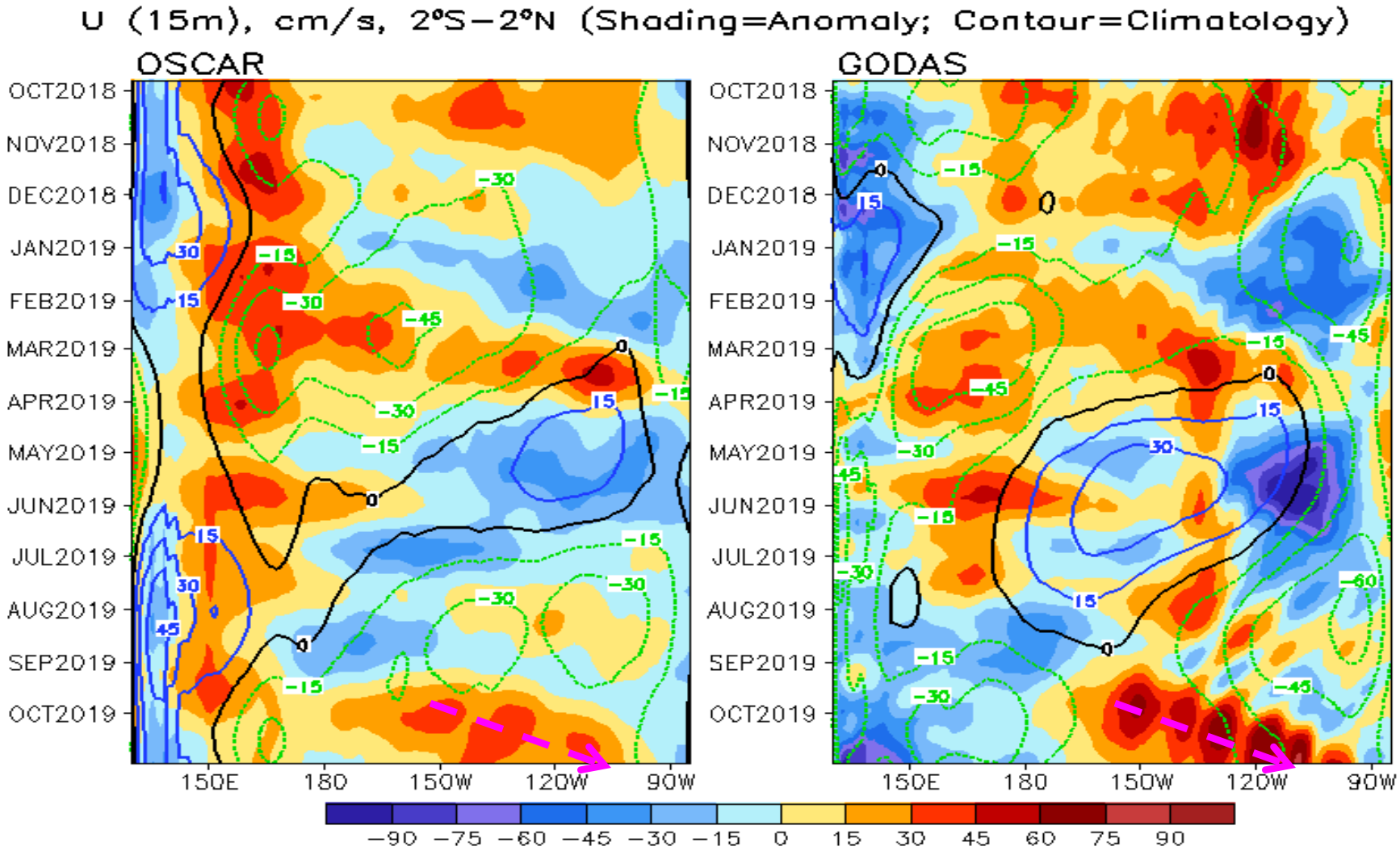
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

TAO GODAS



- **Positive ocean temperature anomalies expanded to the far eastern Pacific during the mid of Oct 2019.**
- **Negative temperature emerged near the thermocline in the western-central Pacific during the last two pentads.**

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



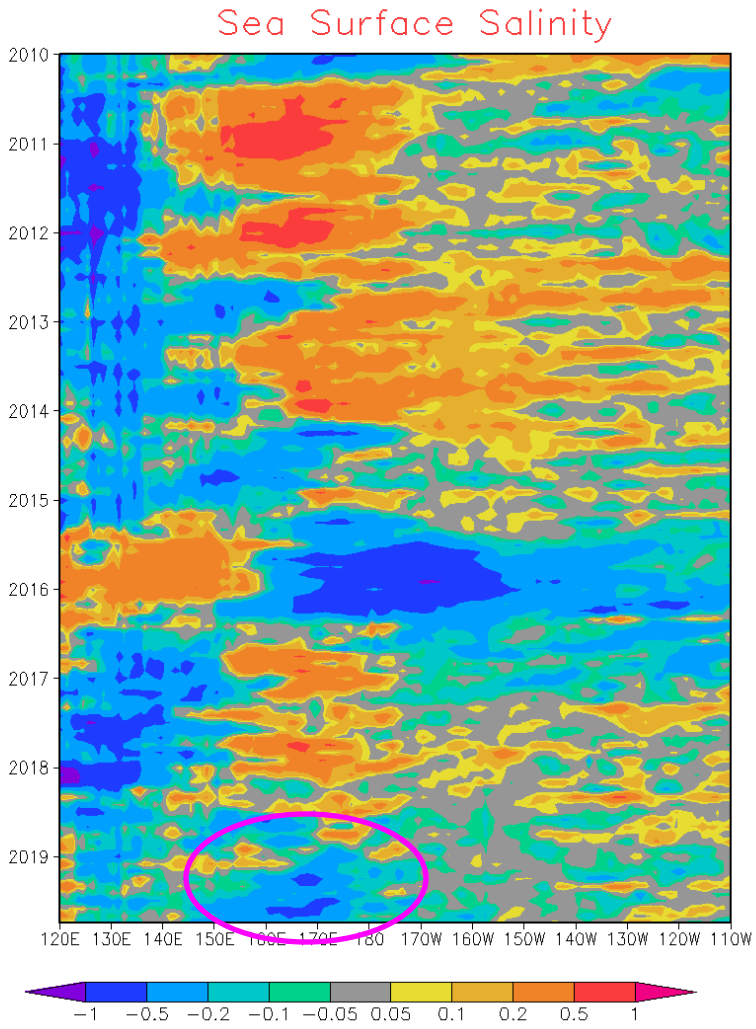
- **Anomalous eastward currents in the central Pacific propagated eastward since Sep 2019, contributing to the recent SST warming.**

Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific from Monthly SSS

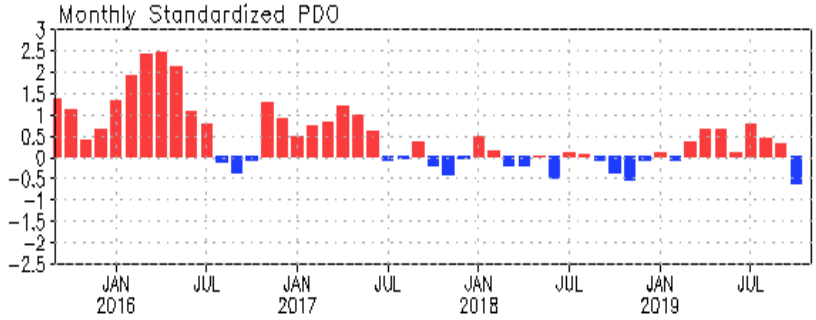
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

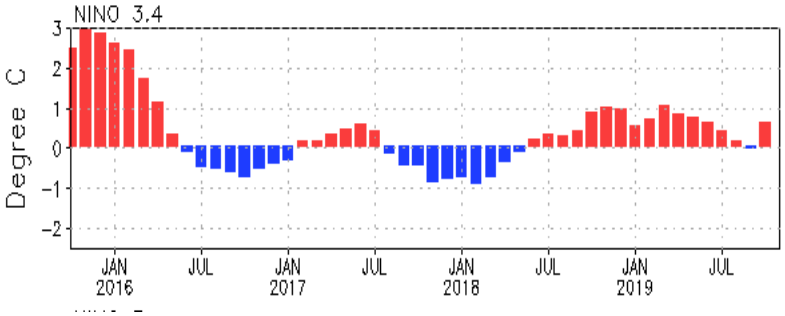
- Hovemoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- In the equatorial Pacific Ocean, the SSS signal is continually negative west of dateline with stronger signals between 160°E and 175°E; the SSS anomalies show positive signals east of 130°W.

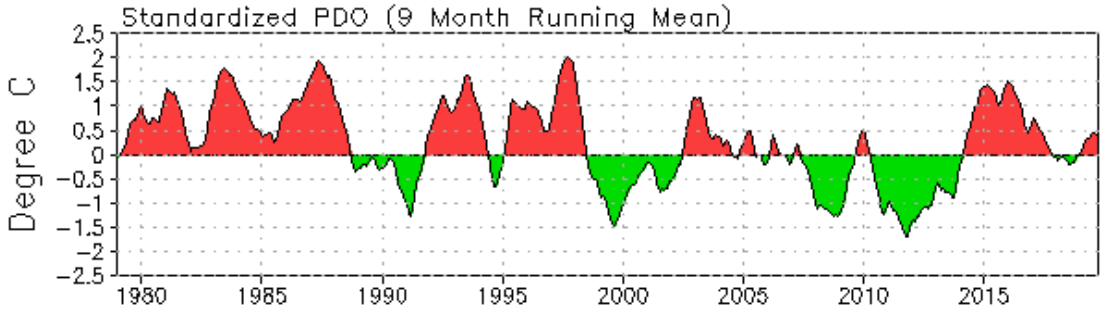


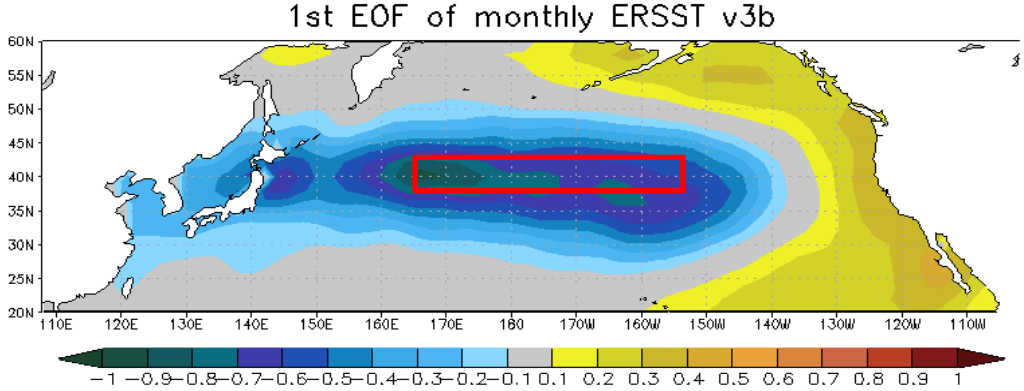
North Pacific & Arctic Oceans

PDO index









- The PDO switched to negative phase in Oct 2019 with PDOI = -0.7 in Oct 2019.

- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via 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 Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

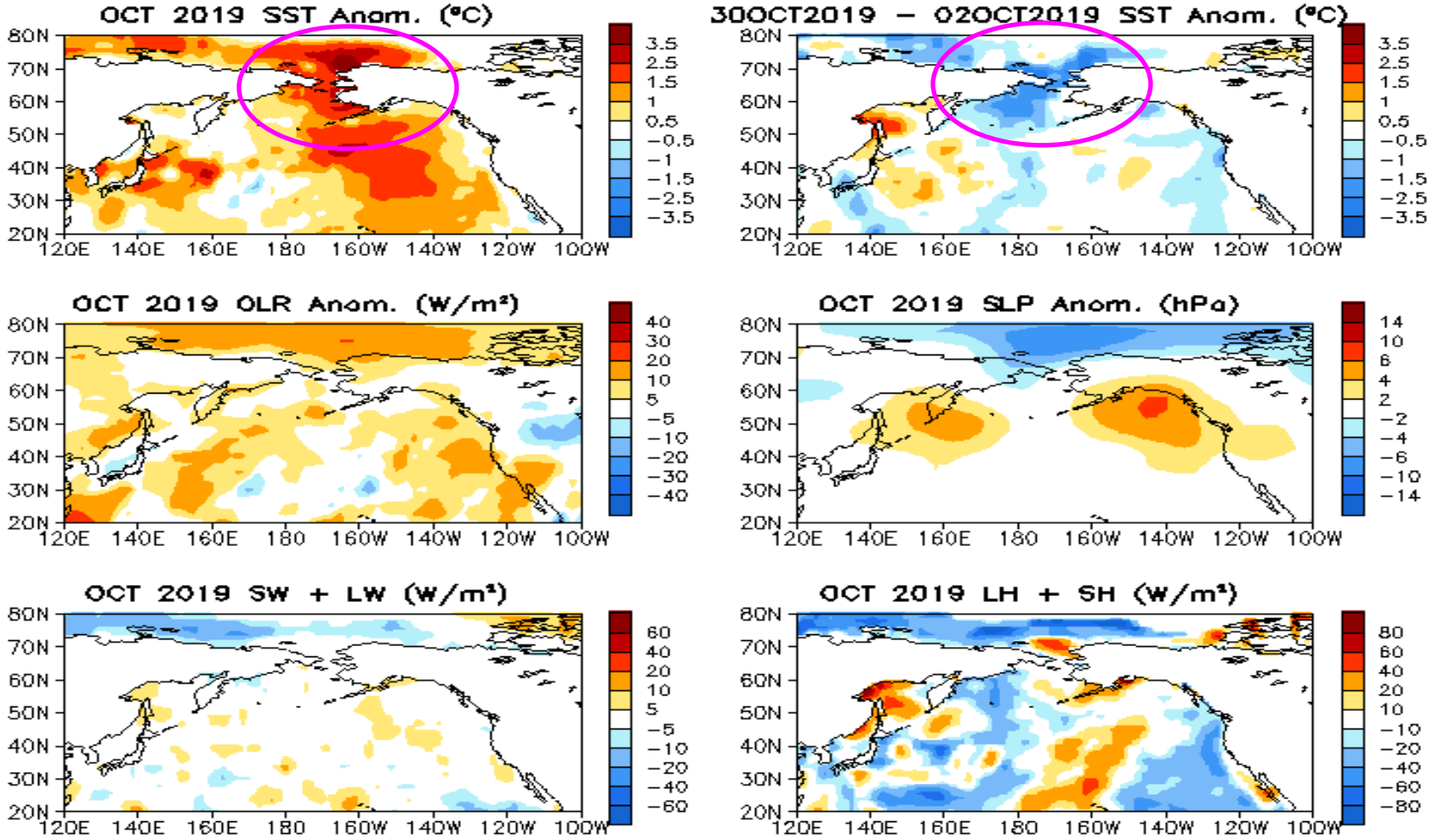
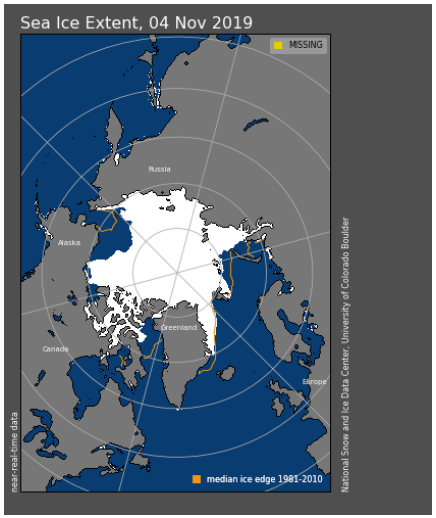
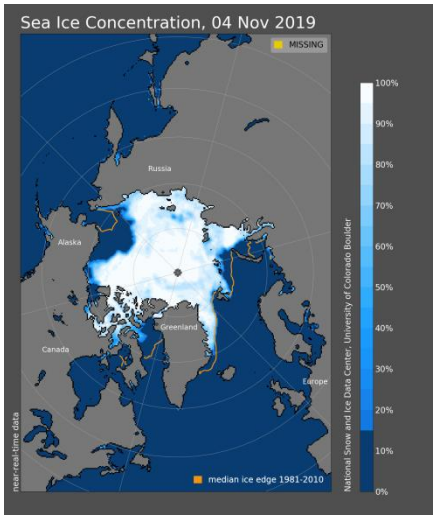


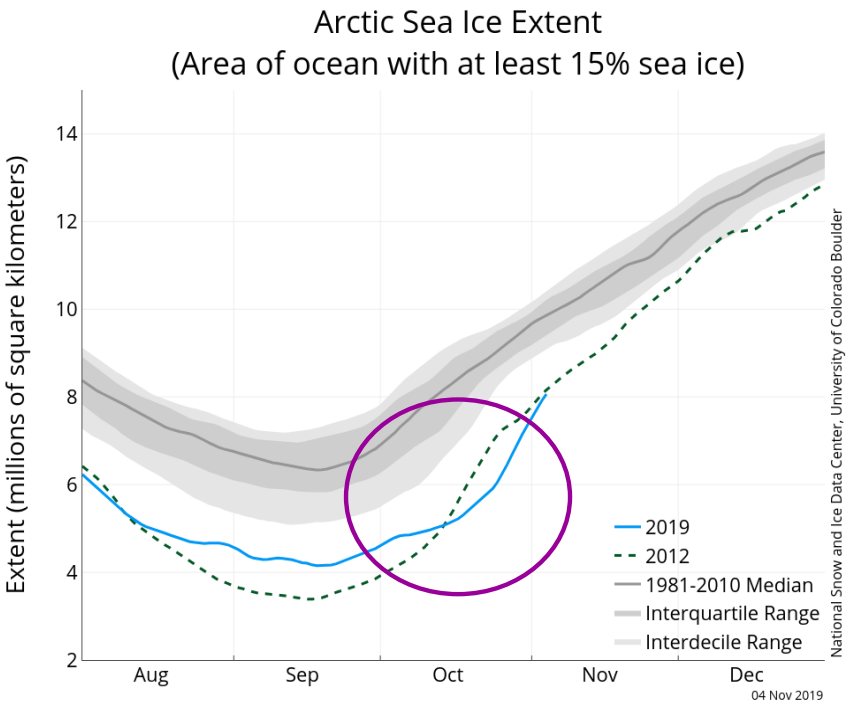
Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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.

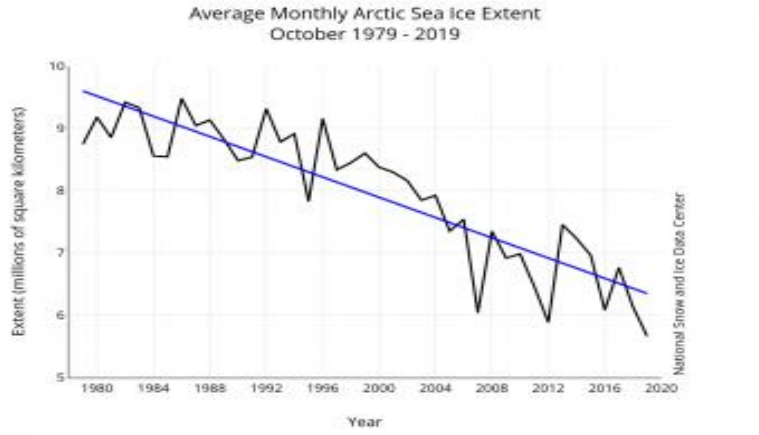
Arctic Sea Ice

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





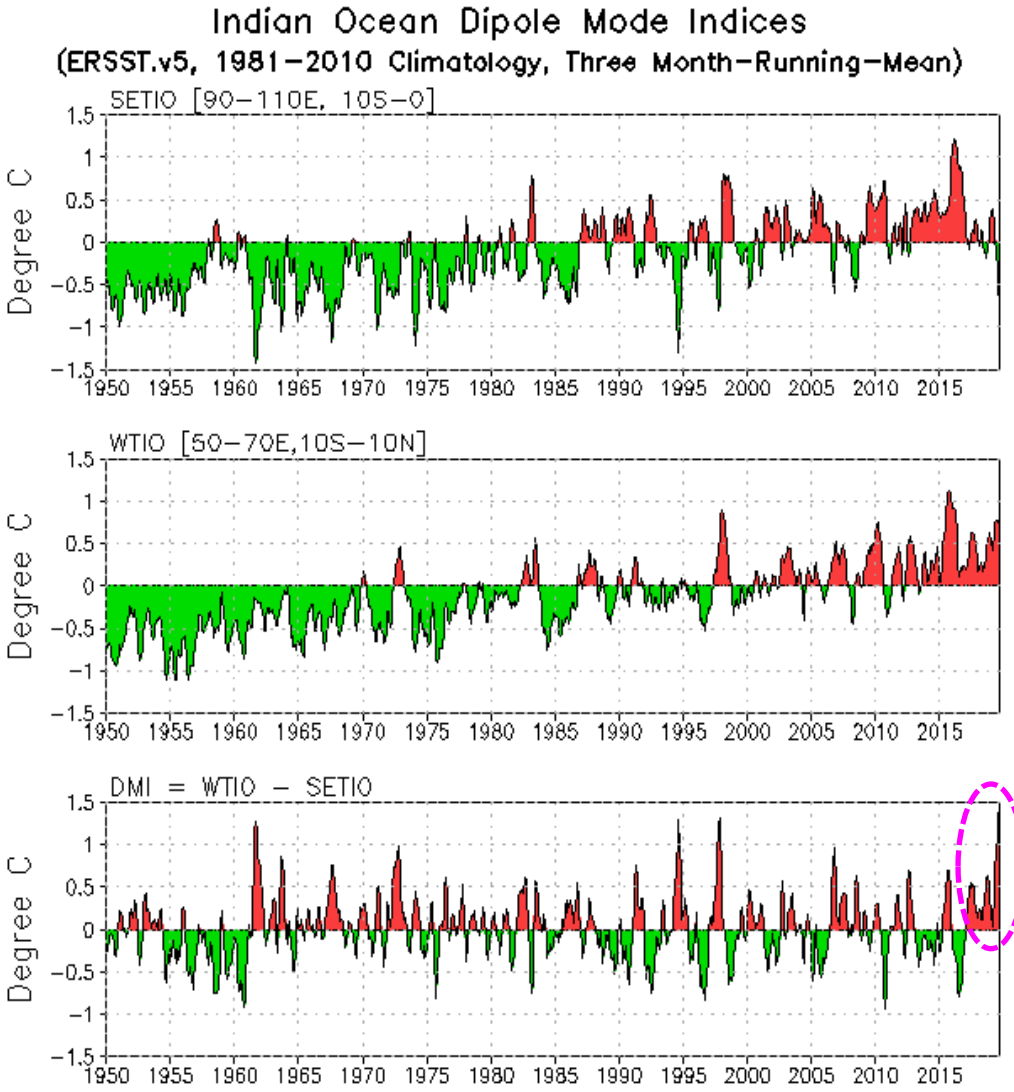


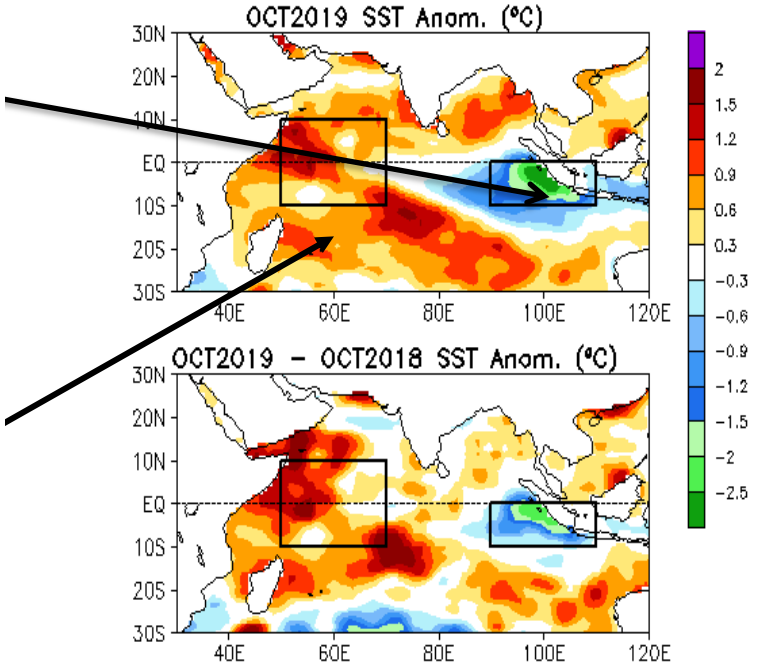


-The monthly average extent for Oct 2019 of 5.66 million square kilometers, hitting the lowest record since 1979.

Indian Ocean

Evolution of Indian Ocean SST Indices





- **Strong positive phase IOD strengthened in Oct 2019, reaching the historical high since 1950.**
- **IOD =2C in Oct 2019.**

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) SSTAs in the west and central (eastern) Indian Ocean.
- Convection was suppressed over the eastern Indian Ocean and Indonesia.
- Anomalous easterlies prevailed over the equatorial Indian Ocean.

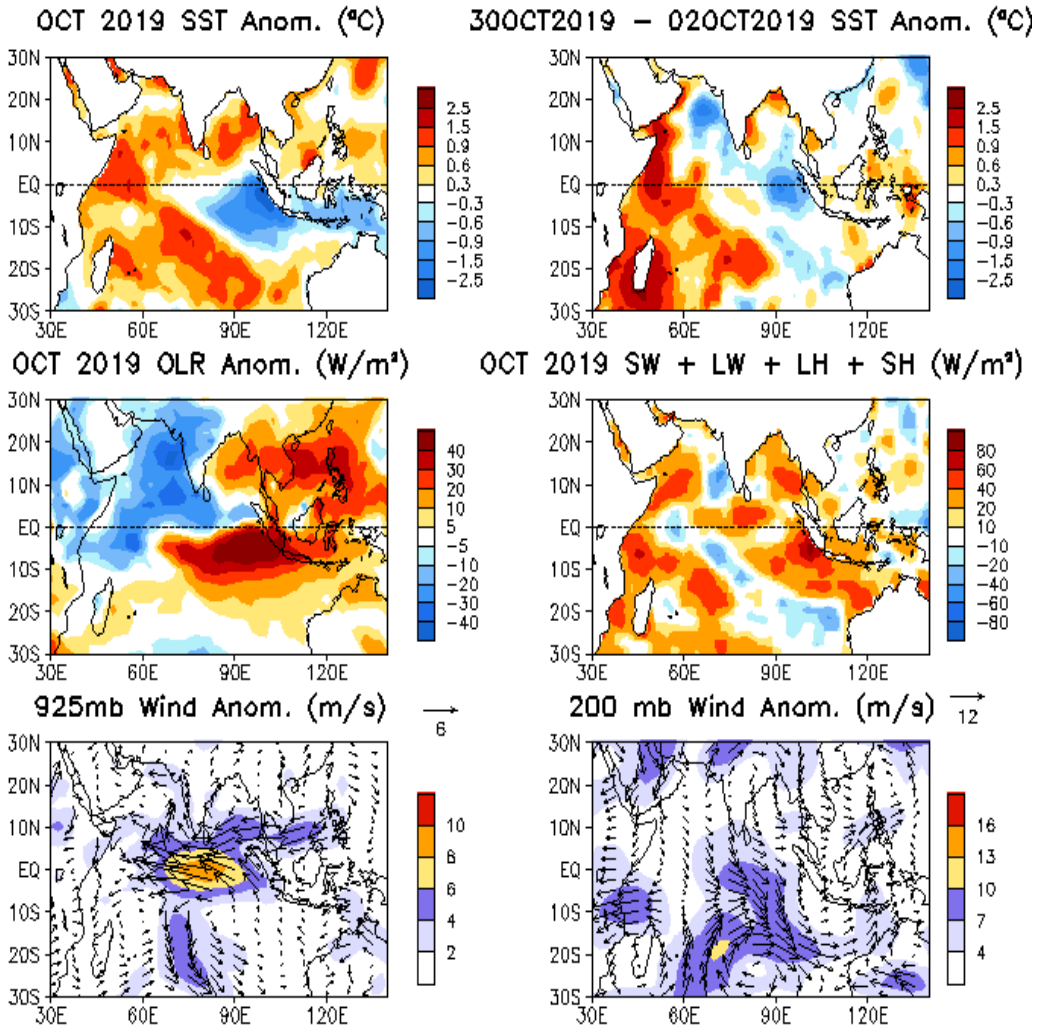
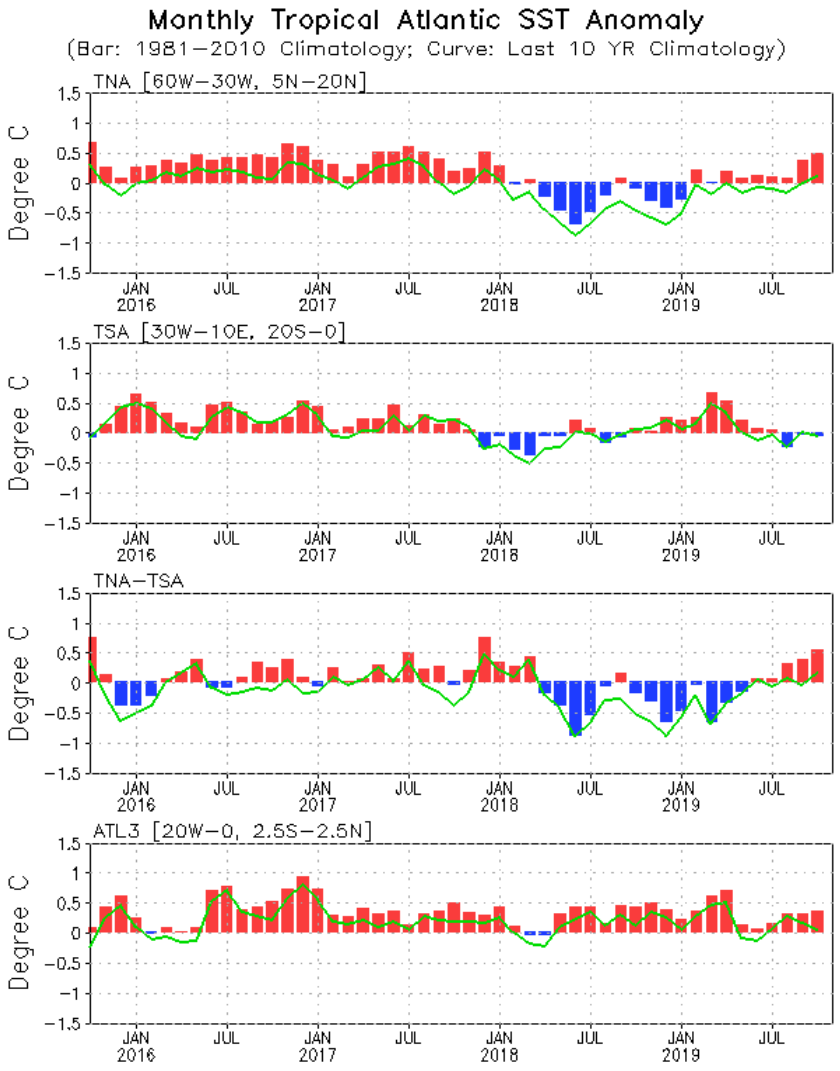
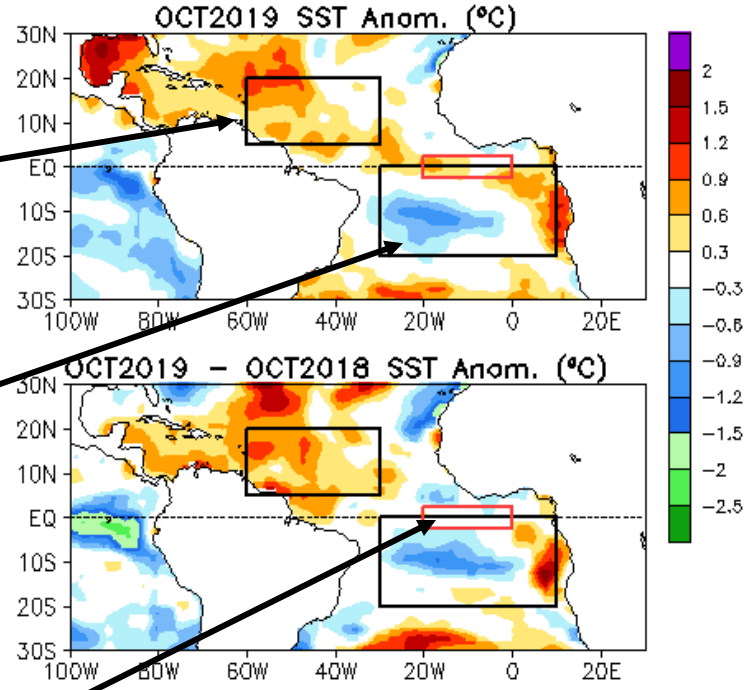


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Evolution of Tropical Atlantic SST Indices

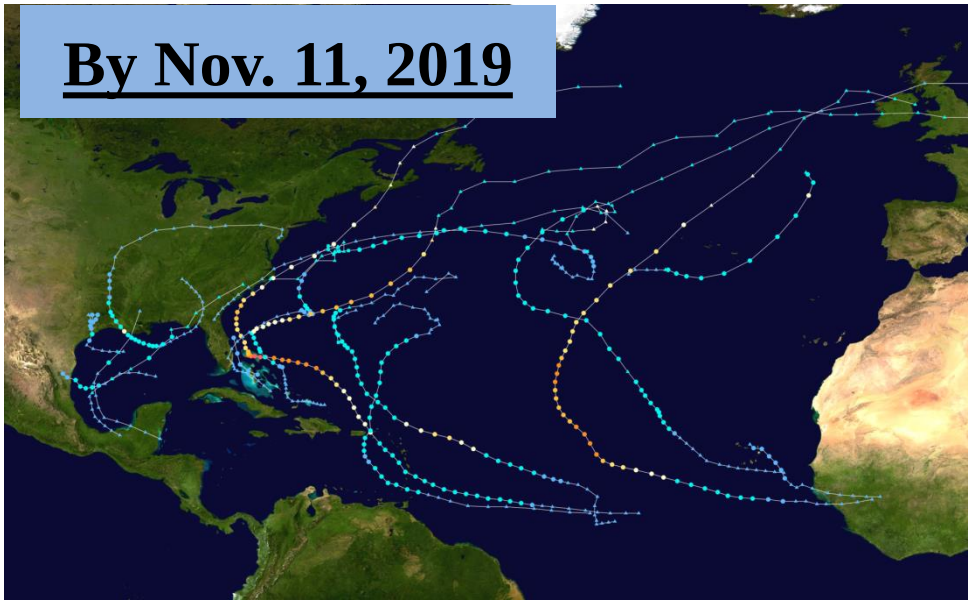




- TNA and Meridional Gradient Indices increased slightly in Oct 2019.

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.

2019 Atlantic Hurricane Season Activities

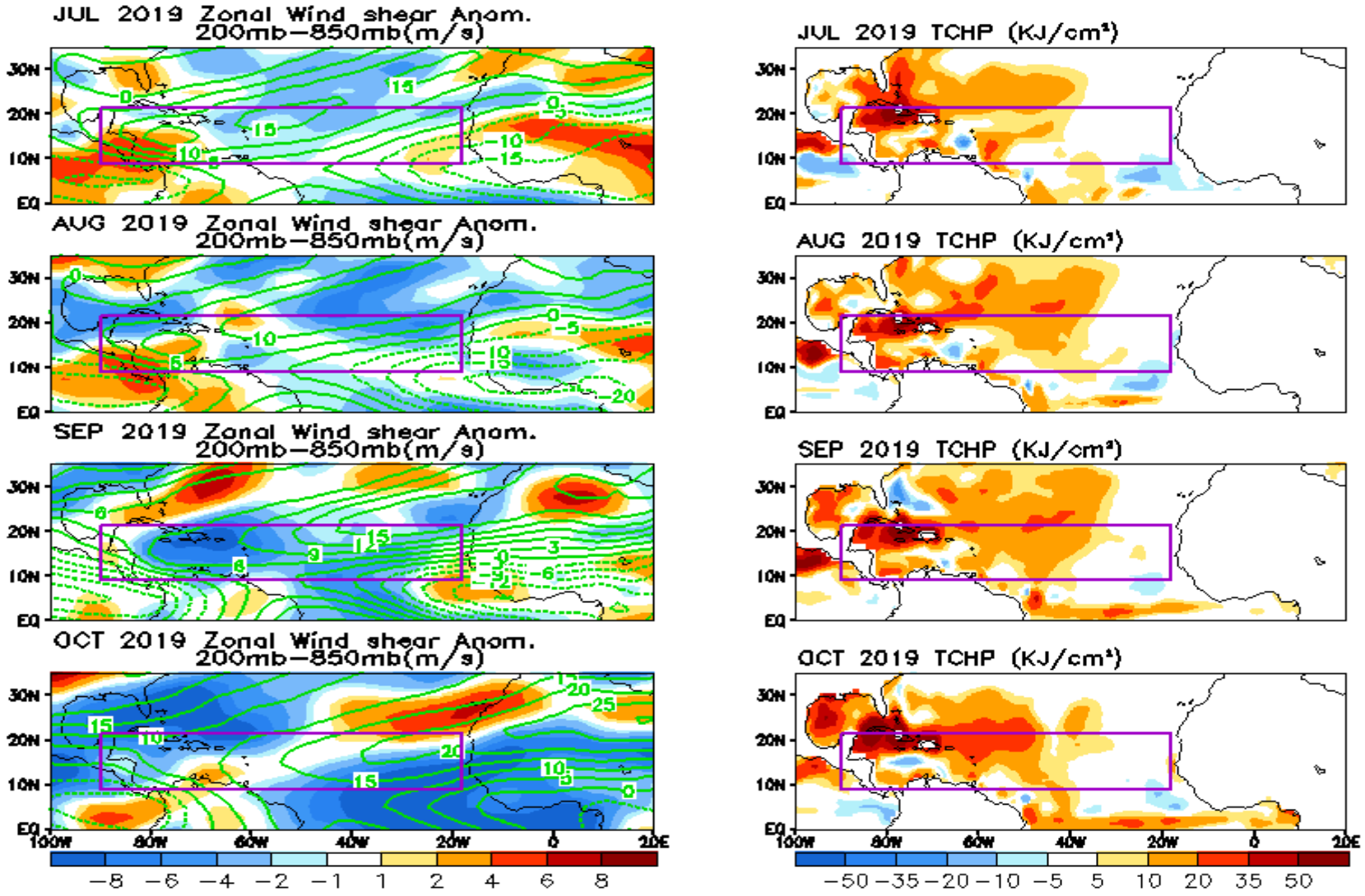


https://en.wikipedia.org/wiki/2019_Atlantic_hurricane_season

- **Seventeen tropical storms has formed by Nov 6, with six developing into hurricanes and three becoming major hurricanes.**

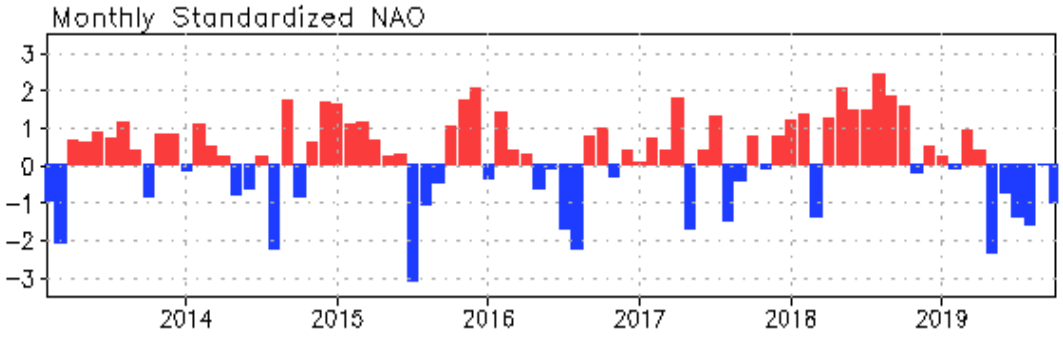
Atlantic	2019 prediction (issued on May 23) Updated on Aug 8 45% above normal	1981-2010	Observations (By Nov 6)
Named storms	(9-15) 10-17	12	17
Hurricanes	(4-8) 5-9	6.4	6
Major hurricanes	(2-4) 2-4	2.7	3

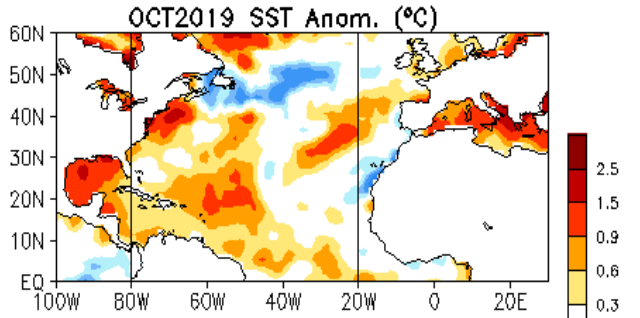
Last Four Months Zonal Wind Shear, and TCHP Anomalies

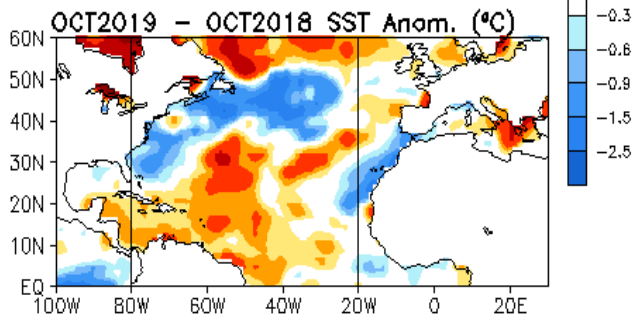


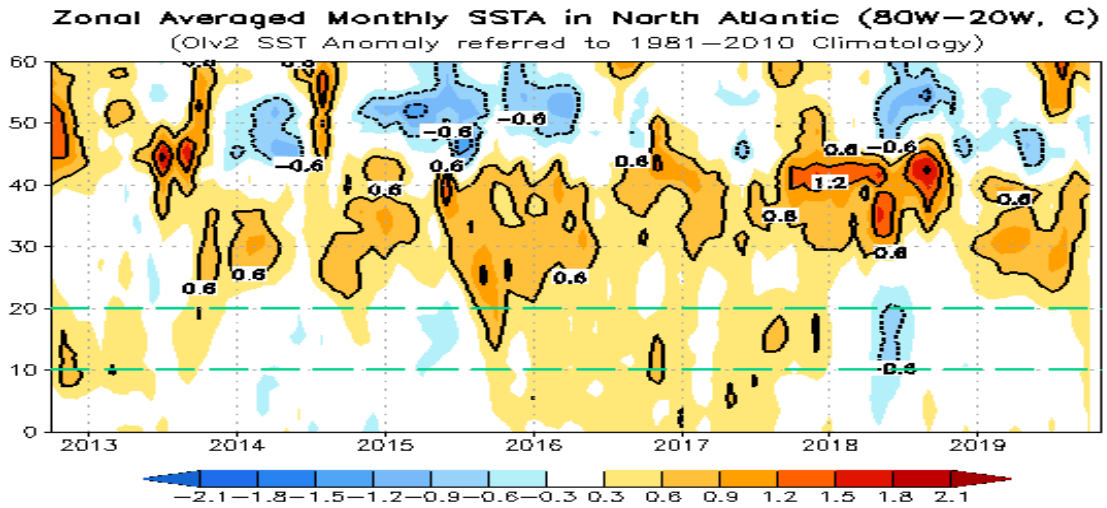
- **Weakened wind shear and positive Tropical Cyclone Heat Potential (TCHP) anomalies in the Hurricane main developing region favoured the development of Tropical storms.**

NAO and SST Anomaly in North Atlantic









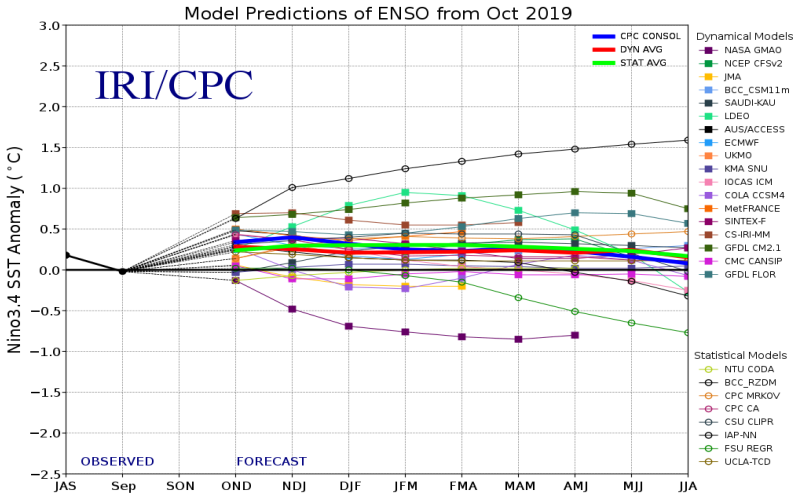
- Negative **NAO strengthened in Oct 2019 with NAOI= -1**

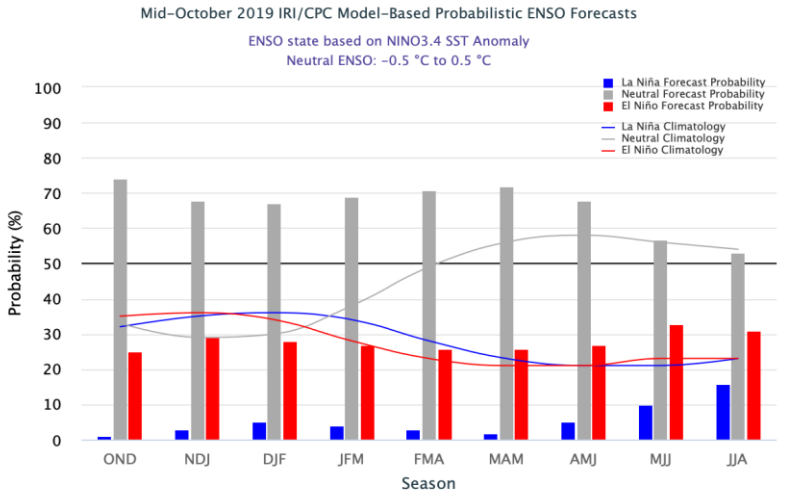
- **Tripole/horseshoe-like pattern with positive in the midl-latitudes and negative in the lower and higher latitudes , has been less evident since May 2019.**

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

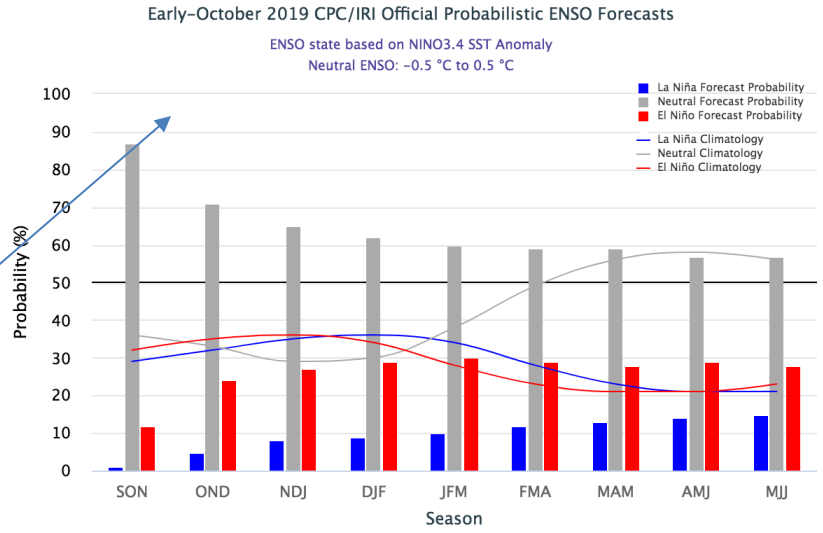
IRI/CPC NINO3.4 Forecast Plume



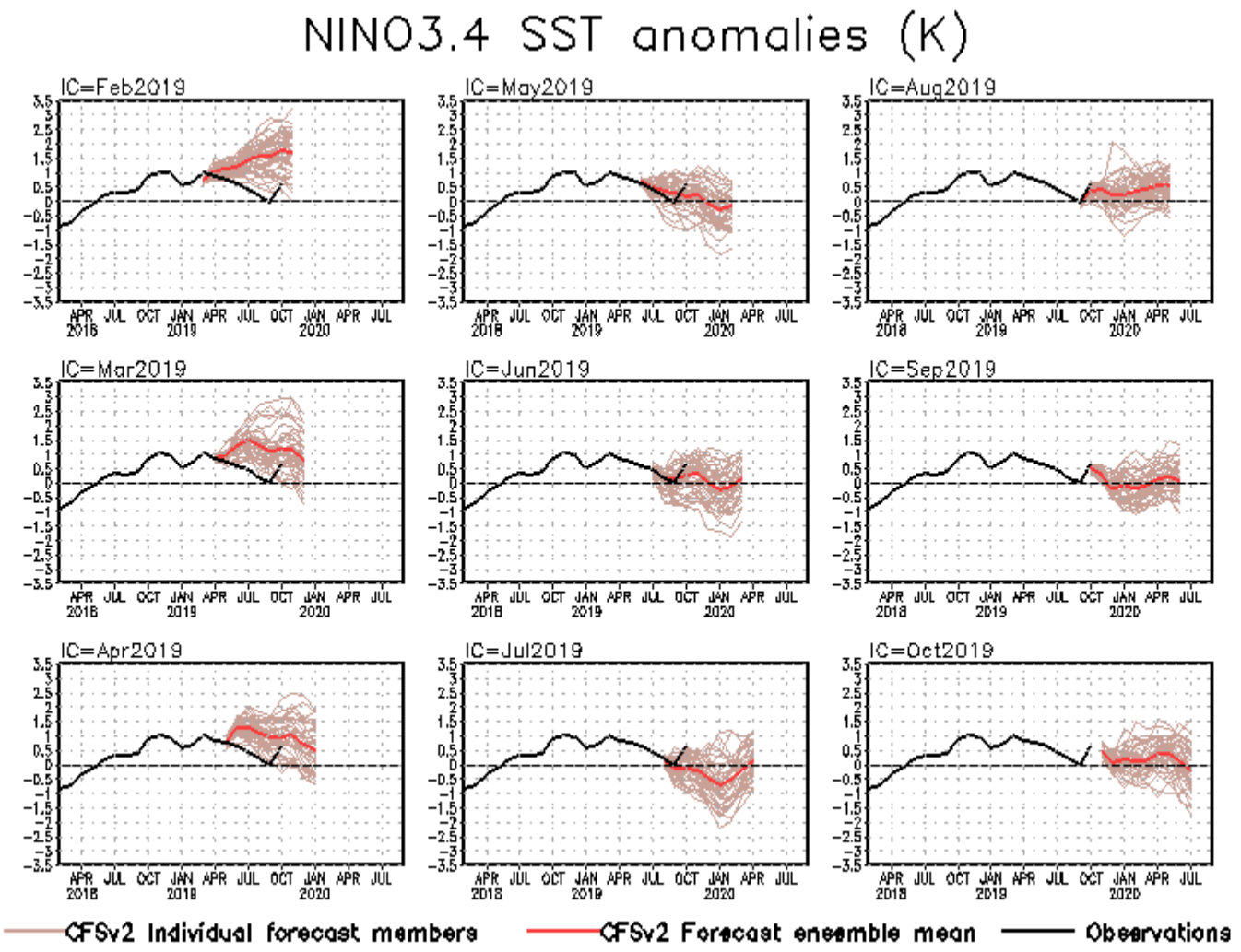


- **A majority of models favor ENSO-neutral through Northern Hemisphere spring 2020.**

- **NOAA "ENSO Diagnostic Discussion" on 10 Oct 2019 indicated that "ENSO-neutral is favored during the Northern Hemisphere fall 2019 (~85% chance), continuing through spring 2020 (55-60% chance)"**



CFS Niño3.4 SST Predictions from Different Initial Months



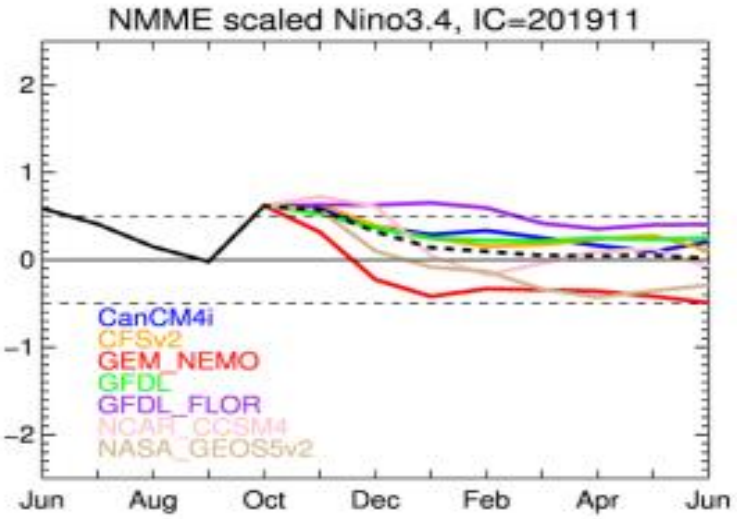
- CFSv2 predicted a decline of positive SSTAs with ICs since Mar 2019.

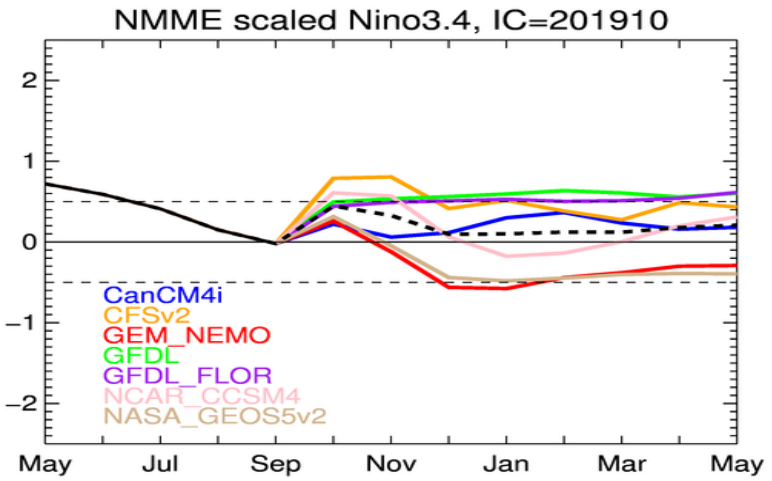
- The latest forecasts call for a ENSO-neutral state in coming seasons.

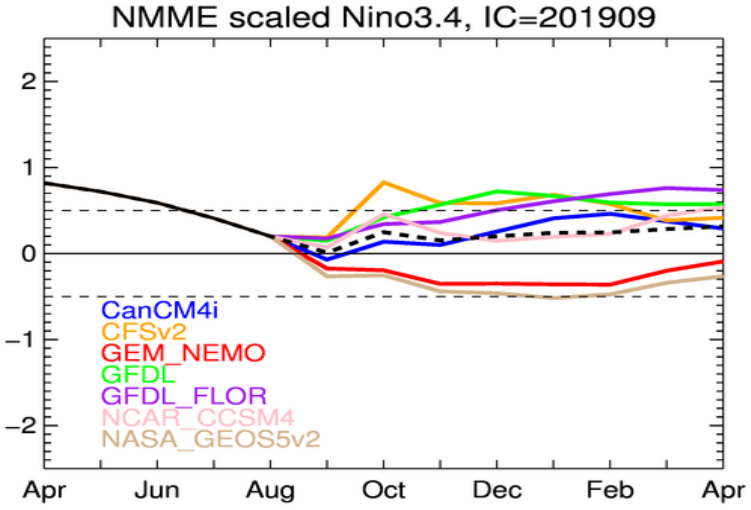
Fig. M1. CFS Nino3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with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

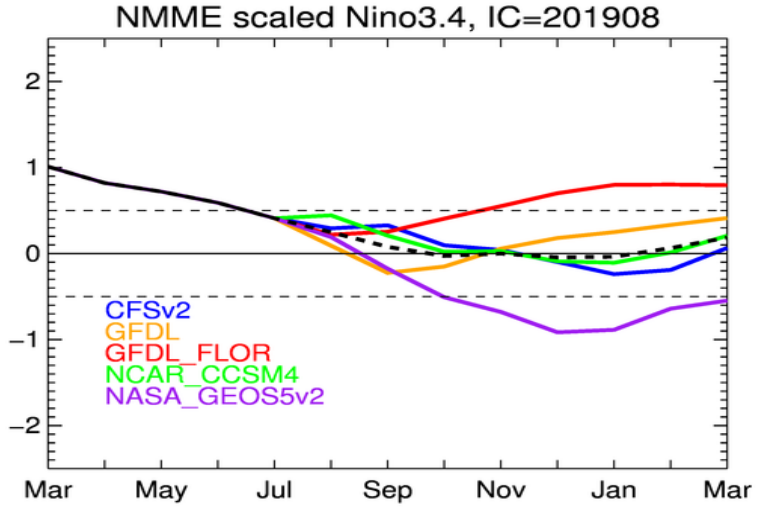
NMME Niño3.4 SST Predictions: ENSO neutral

(https://www.cpc.ncep.noaa.gov/products/NMME/)

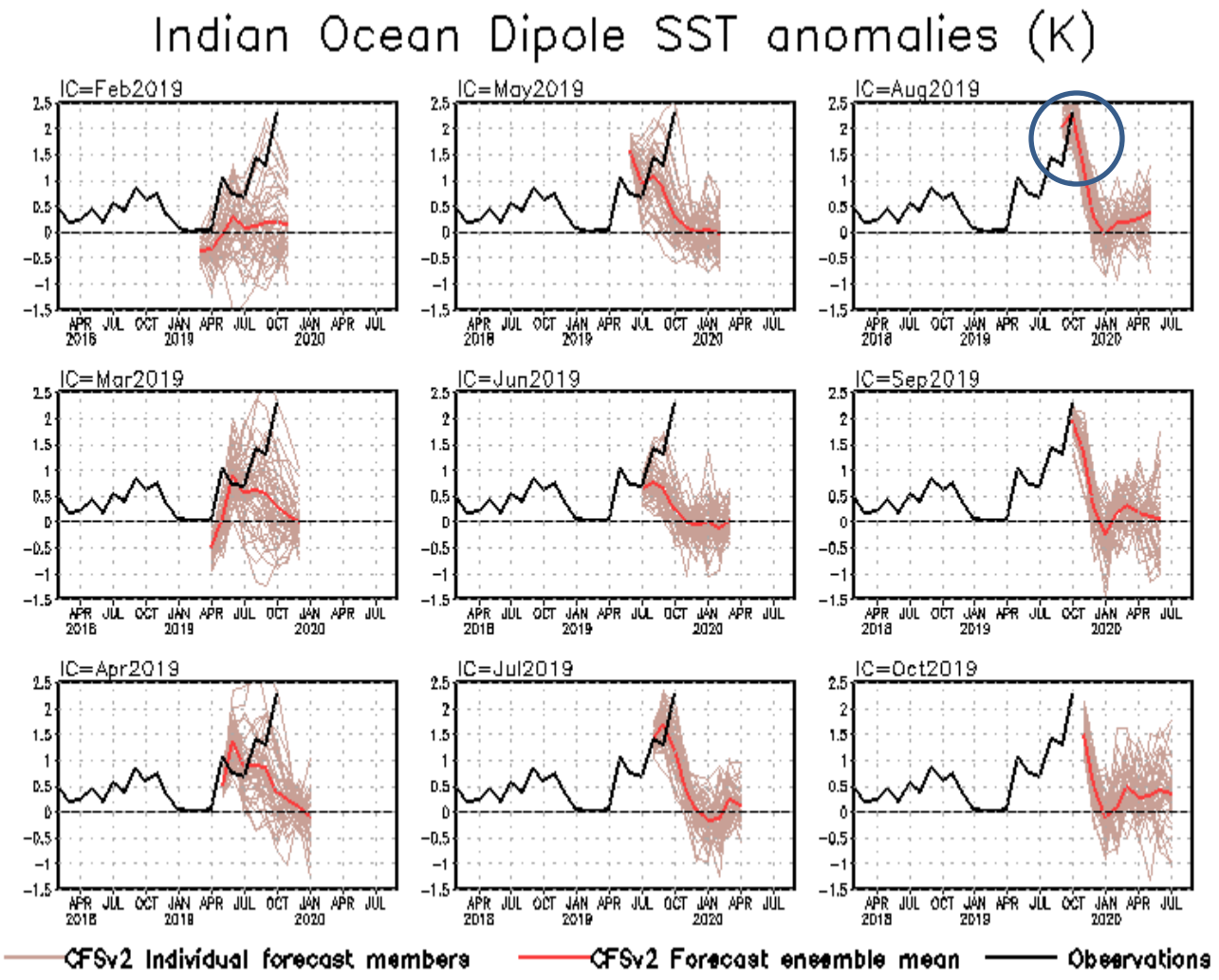








NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

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

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

- **CFSv2 predicts the current positive IOD event will decay to neutral during northern hemisphere winter 2019/20.**

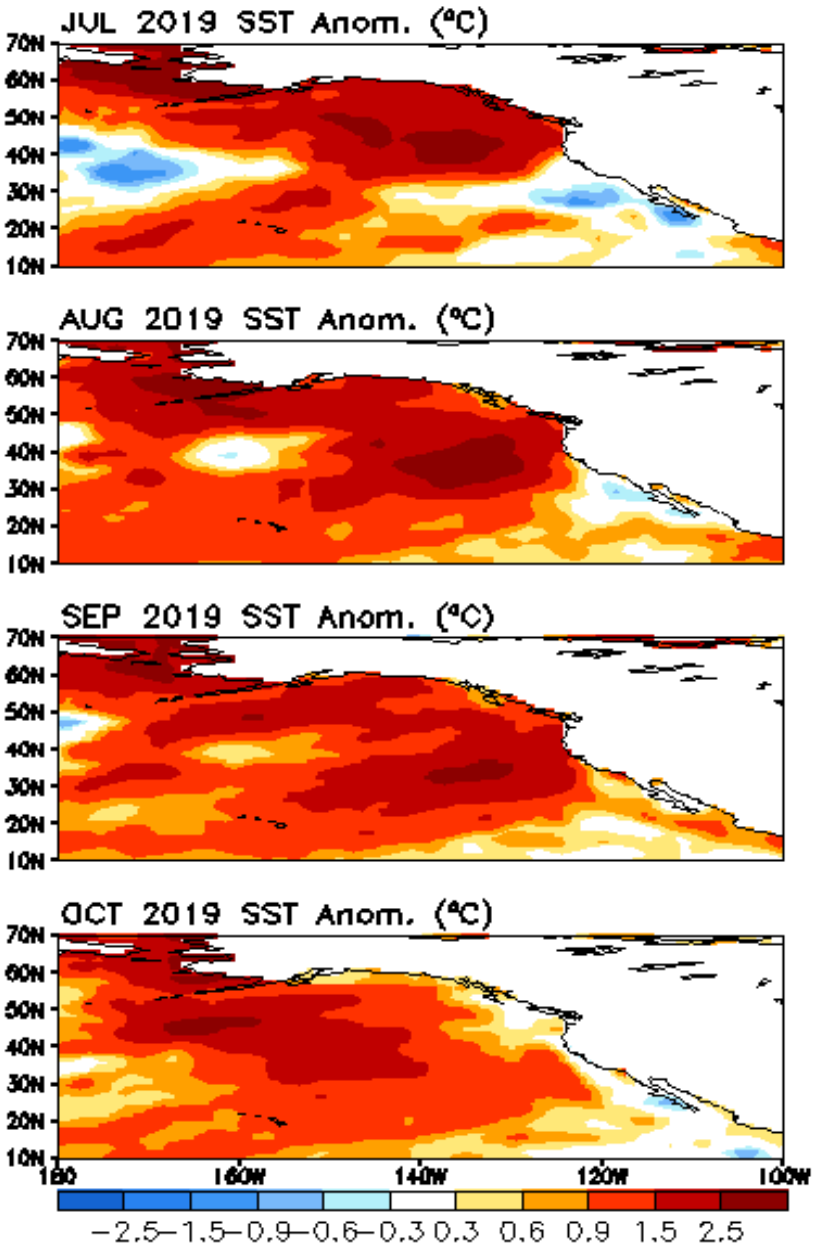
Fig. M2. CFS Dipole Model Index (DMI) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast 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.

2019 Marine Heatwave in the N.E Pacific and predictions

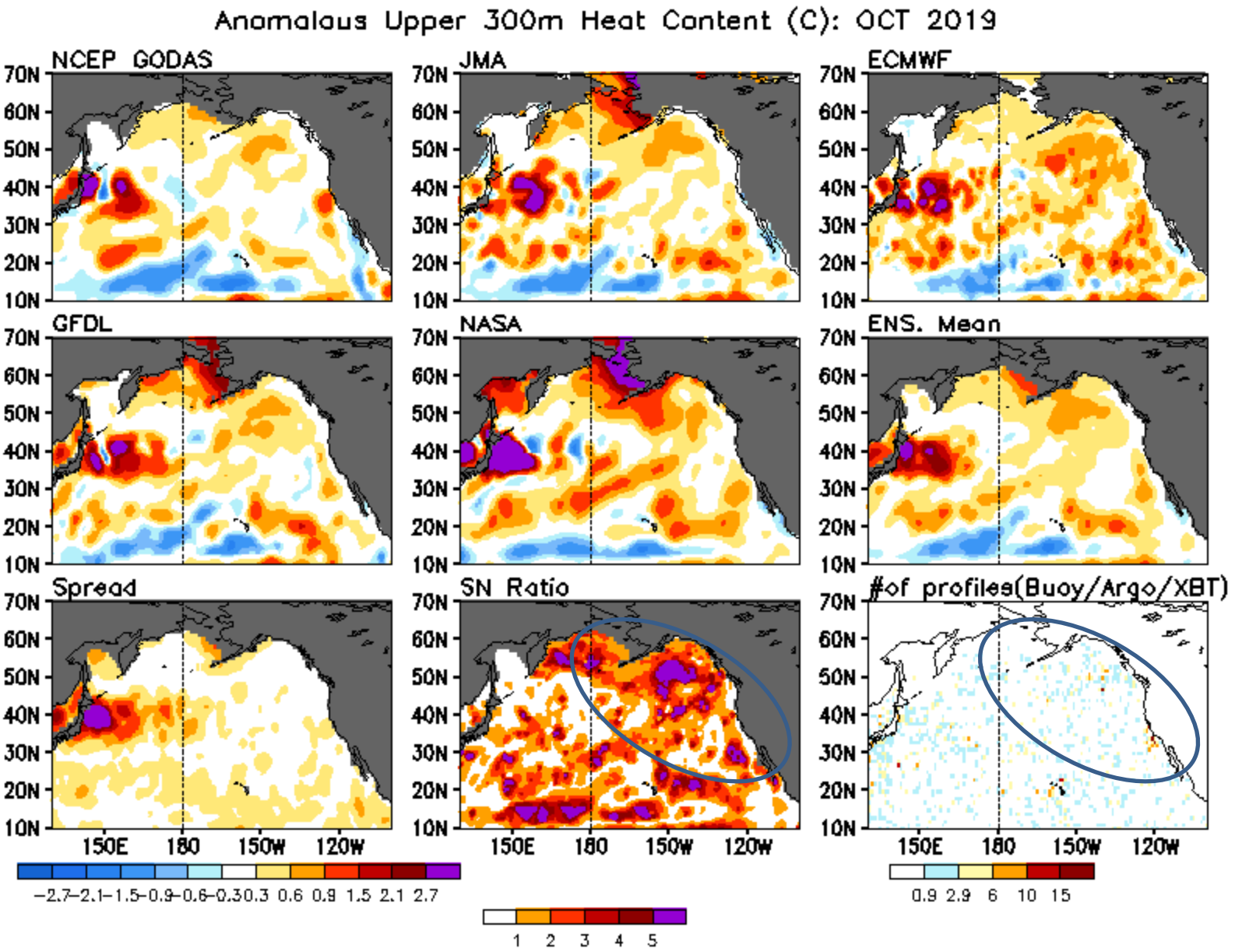
2019 Marine Heatwave (MHW)

- A MHW is define as a prolonged discrete anomalously warm water event that can be described by its duration, intensity, rate of evolution, and spatial extent." (Hobday et al. 2016)

- MHWs emerged off west coast of North America stretching from Alaska south to California over the past few months.



Real-Time Ocean Reanalysis Intercomparison: H300



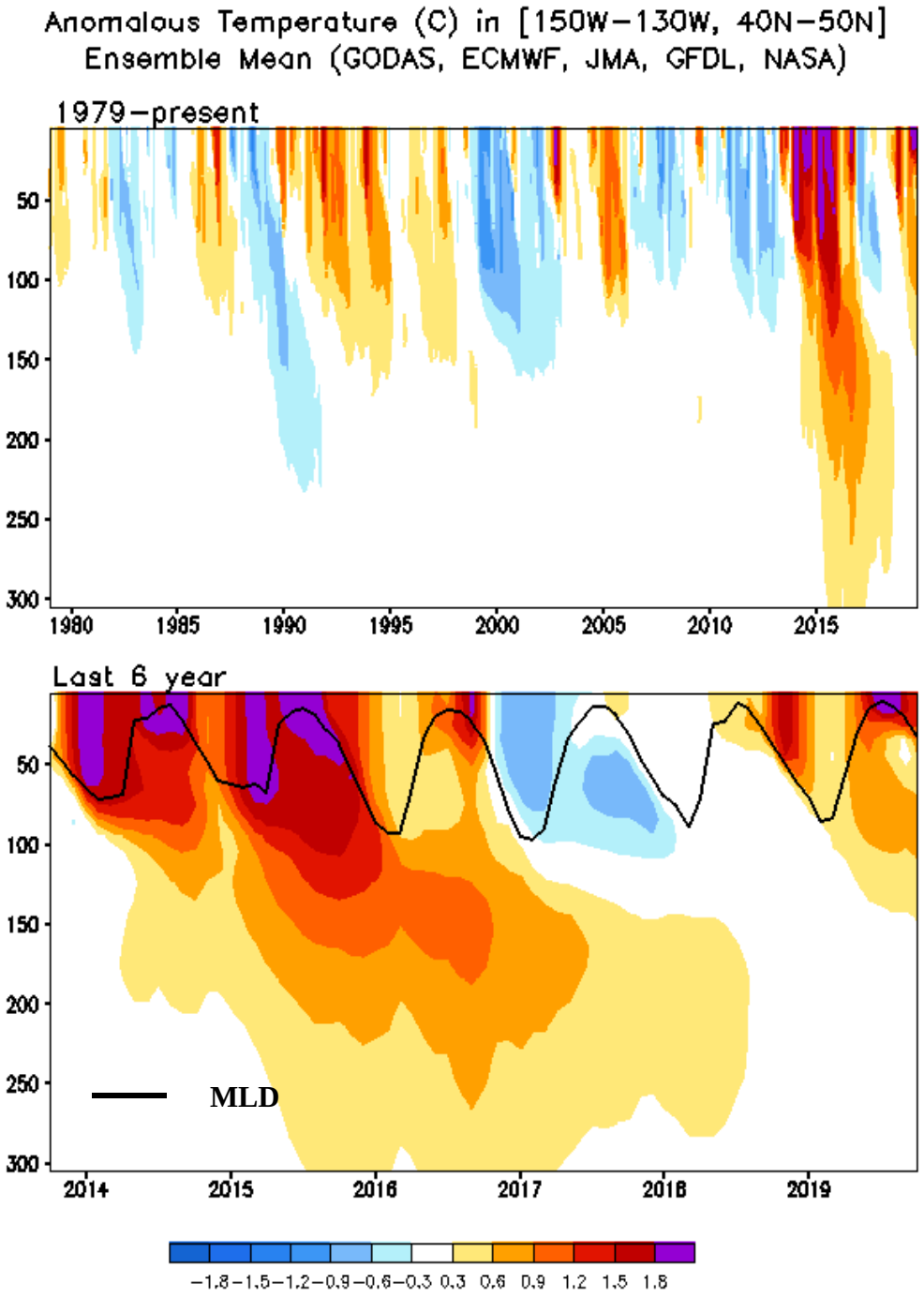
MHW 2014-16. VS. 2019

- 2014-16 MHW (Pacific Blob) lasted for multiple years and the warming extended to 300 meters.

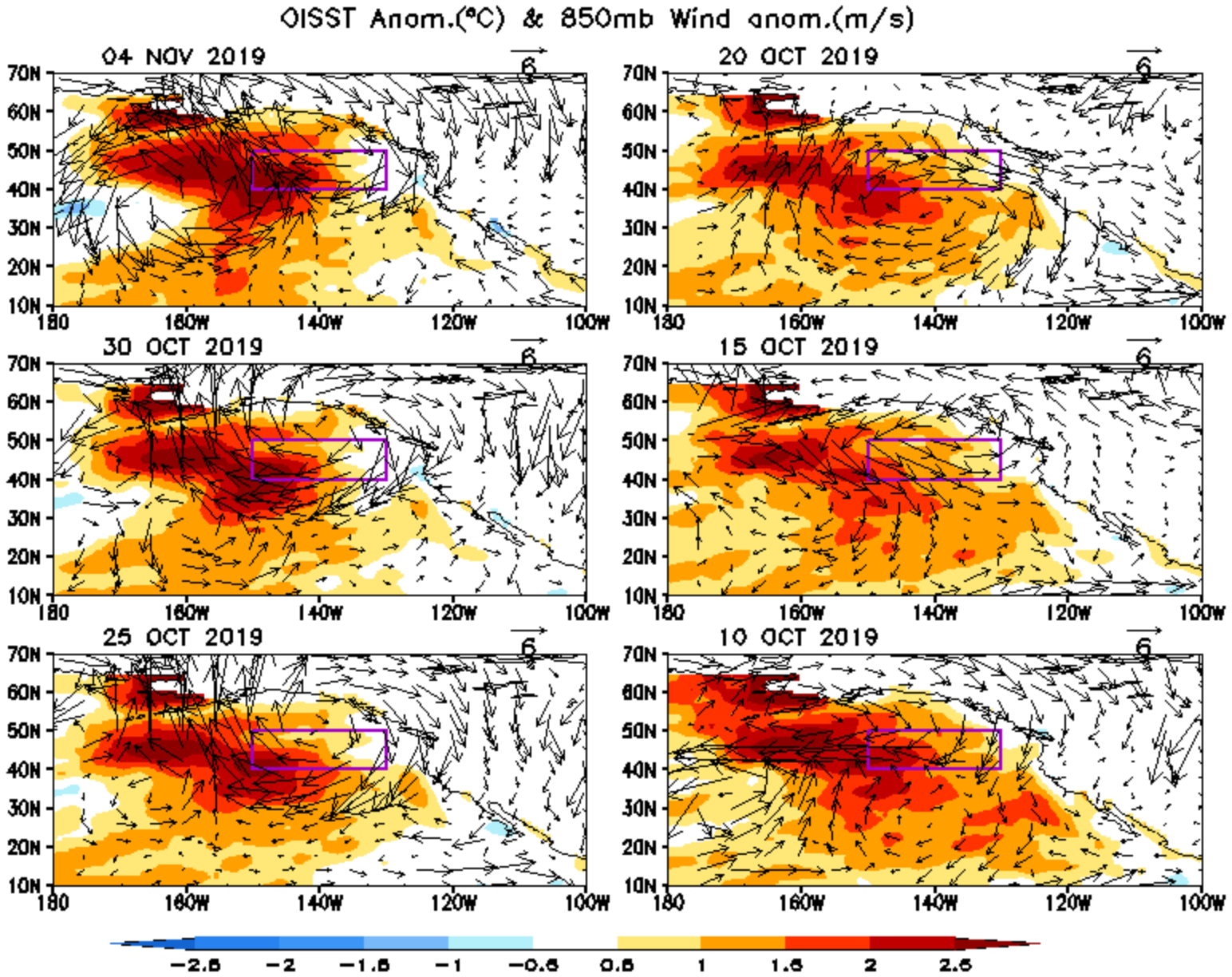
- 2019 MHW lasted a few months, and the extreme warming is confined to the top 30 -50 meters.

(ENSO Blog Oct 23,2019)

https://www.climate.gov/news-features/blogs/enso/seeing-red-across-north-pacific-ocean

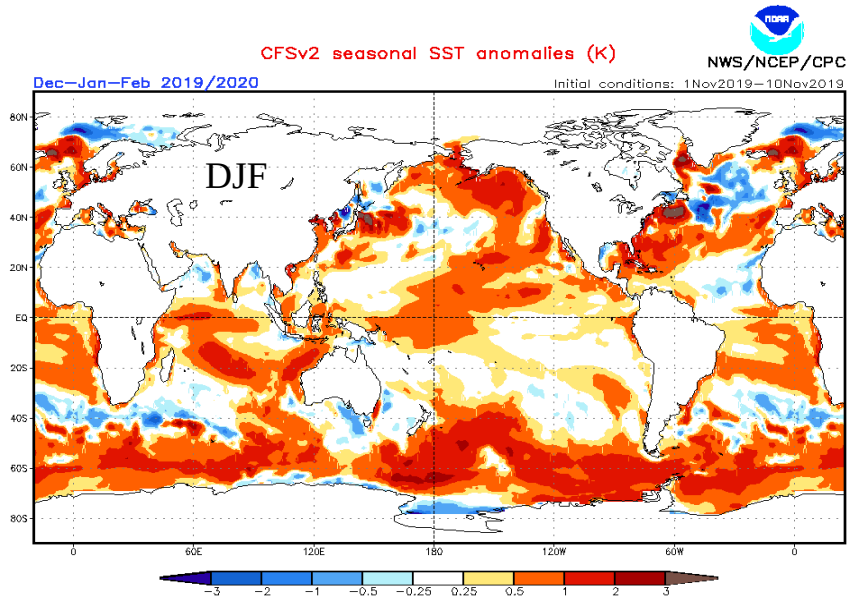


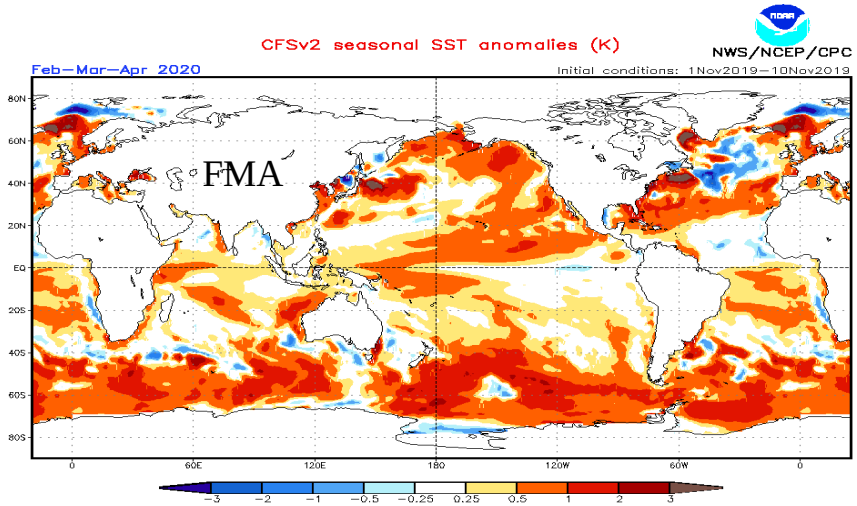
Last six pentad SST and 850mb wind Anomalies



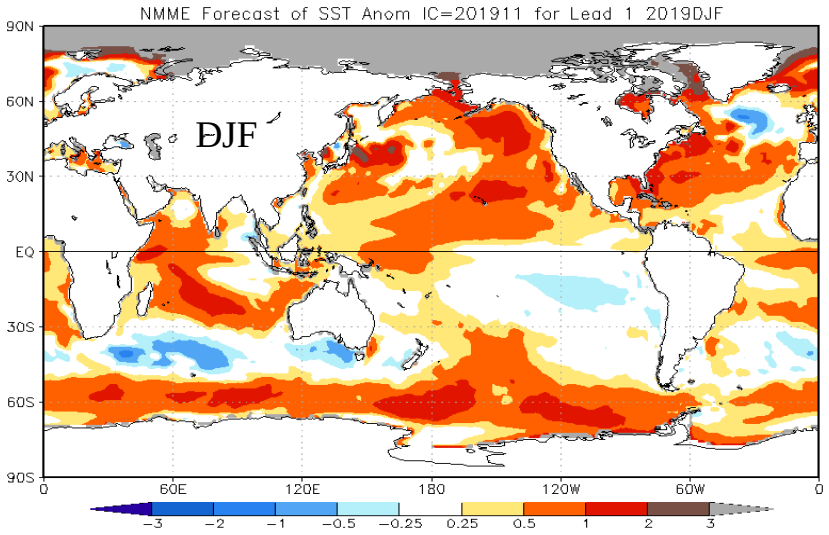
SST Predictions

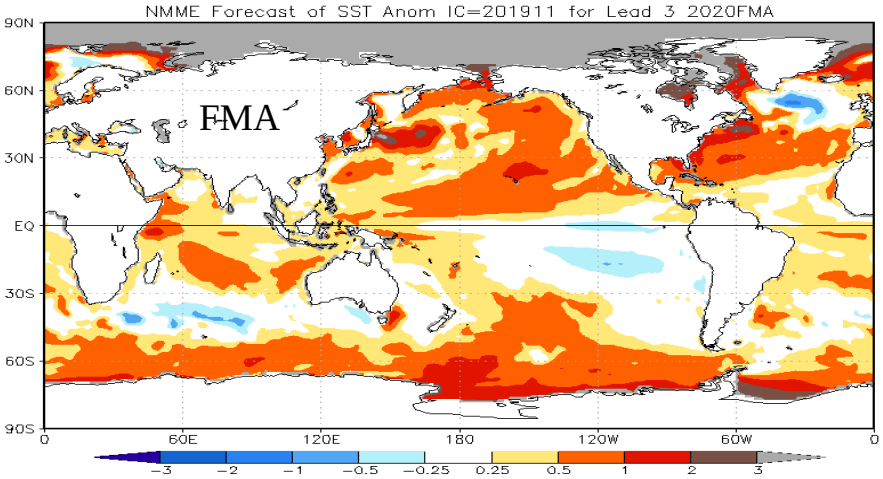
CFSv2





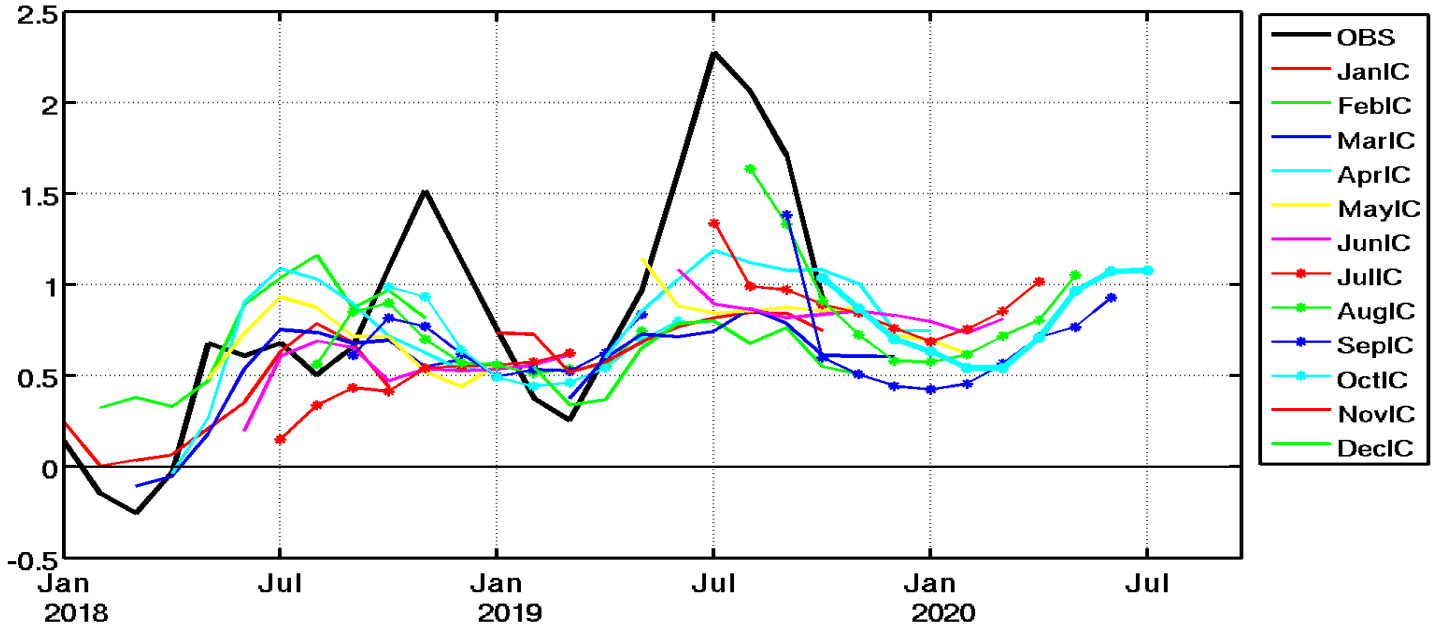
NMME

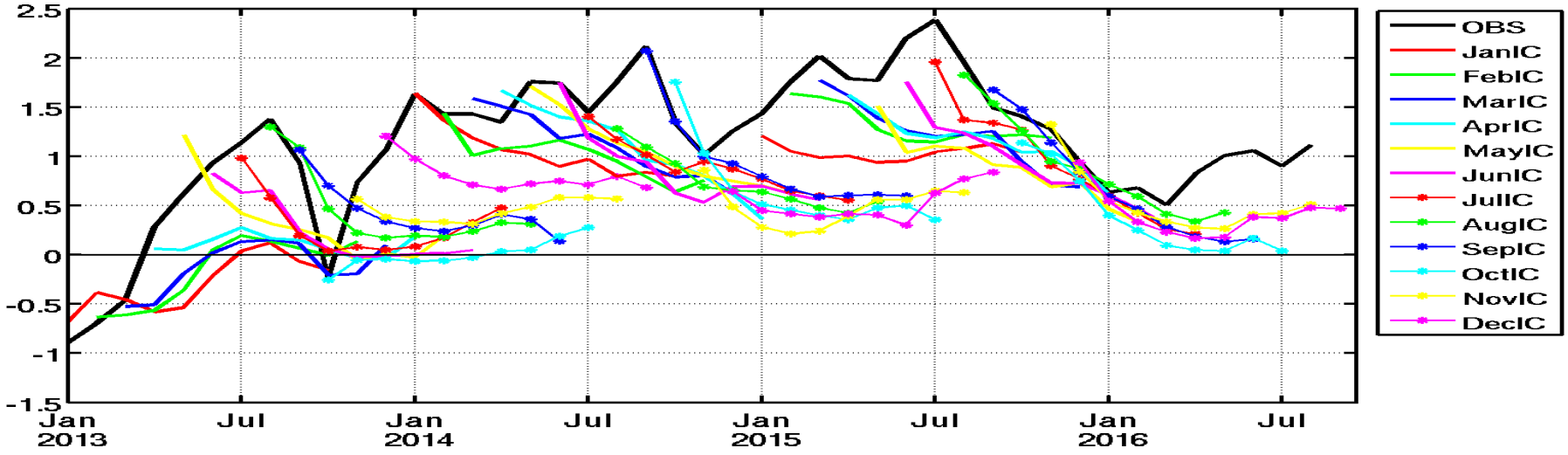




https://www.cpc.ncep.noaa.gov/products/CFSv2/htmls/glbSSTe3Sea.html
https://www.cpc.ncep.noaa.gov/products/NMME/seasanom.shtml

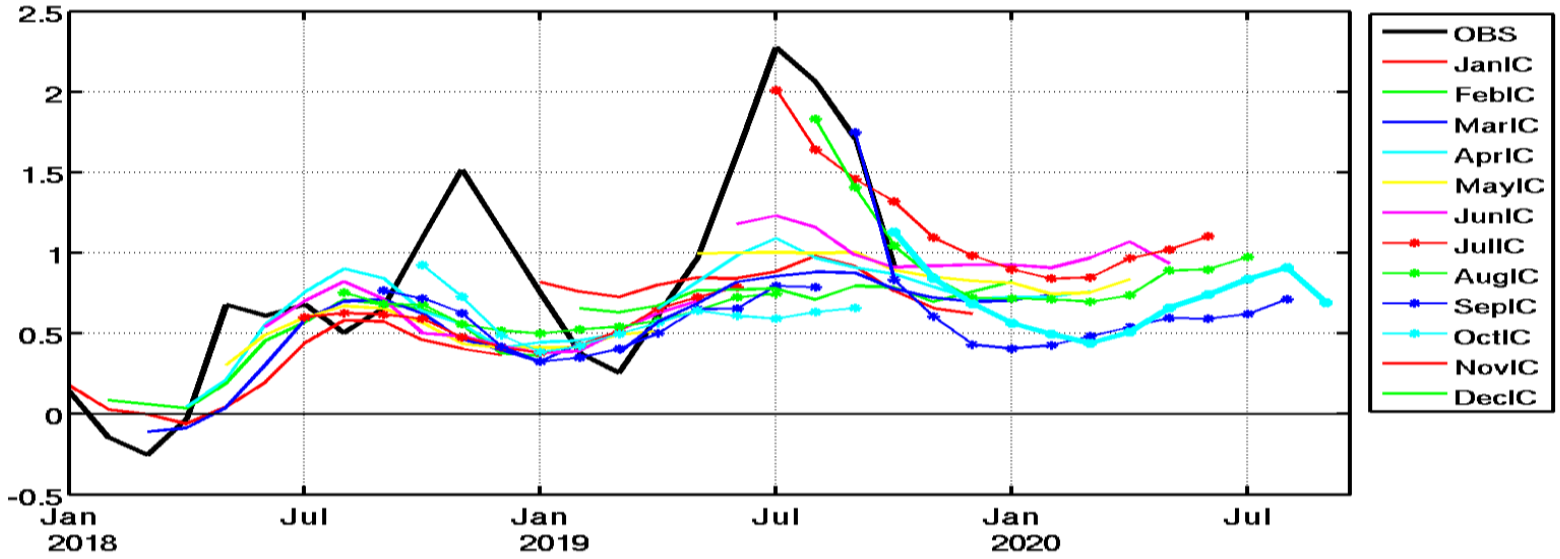
SST predictions in NEPac [150W-130W, 40N-50N] : CFSv2

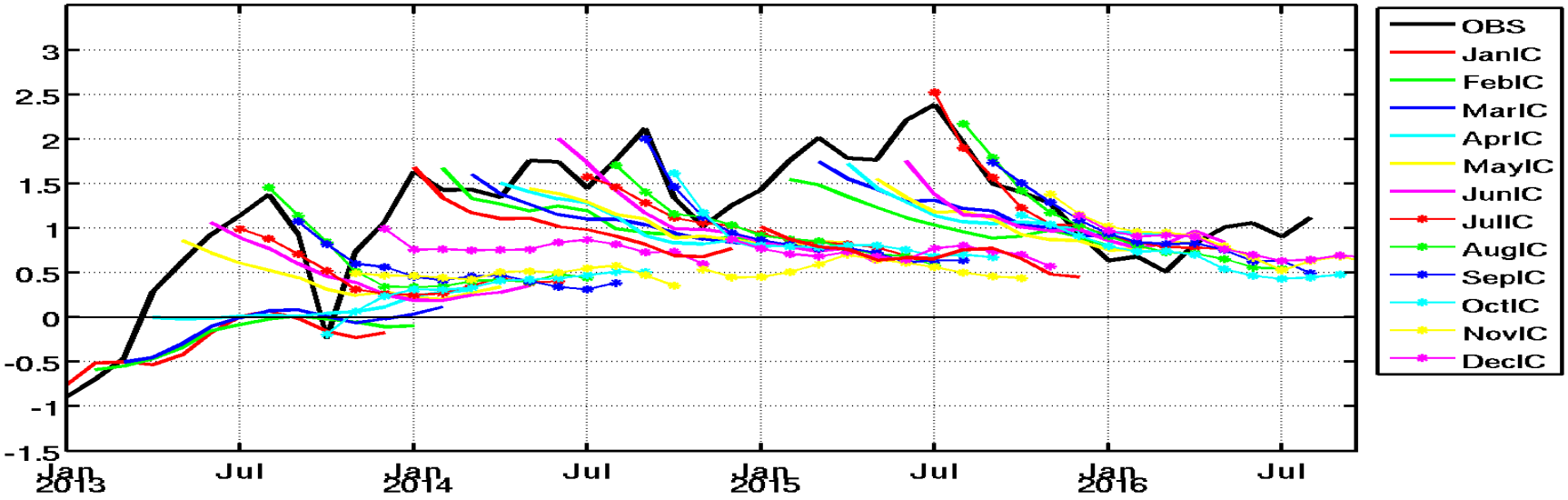




SST predictions in NEPac [150W-130W, 40N-50N] : NMME

(CanCM4i, CFSv2, GEM_NEMO, GFDL, GFDL_FLOR,NCAR_CCSM4, NASA_GEOS5v2)





Acknowledgements

- Drs. Zeng-Zhen Hu, Jieshun Zhu, and Arun Kumar: reviewed PPT, and provide insightful suggestions and comments

- Drs. Li Ren and Pingping Xie provided the BASS/CMORPH/CFSR EVAP package

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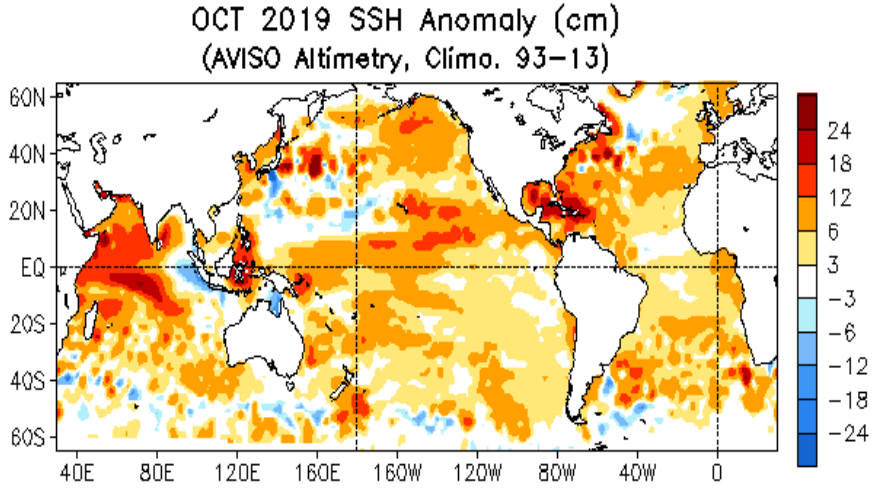
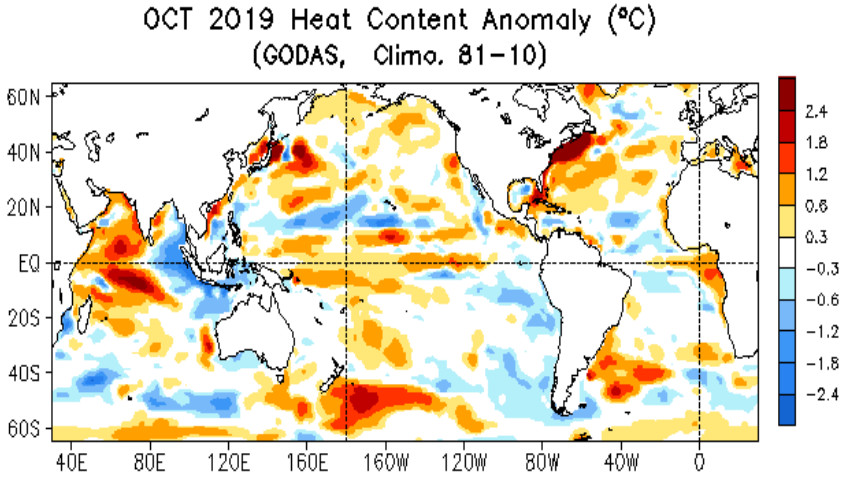
Caihong.Wen@noaa.gov

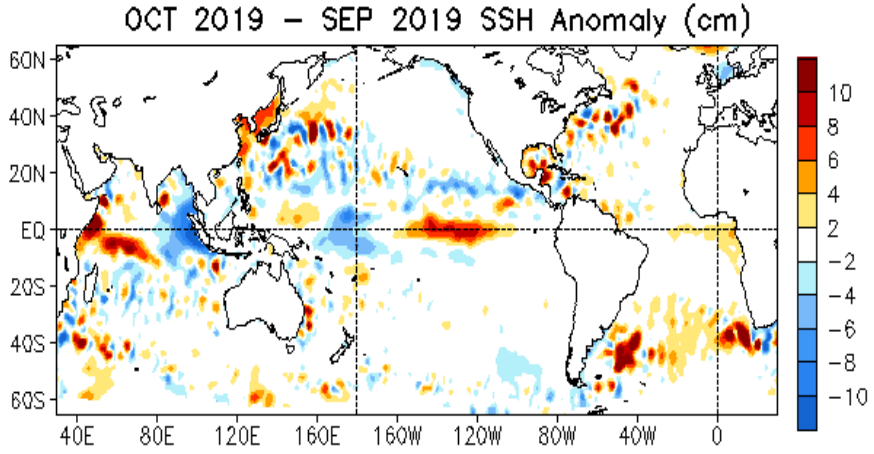
Jieshun.Zhu@noaa.gov

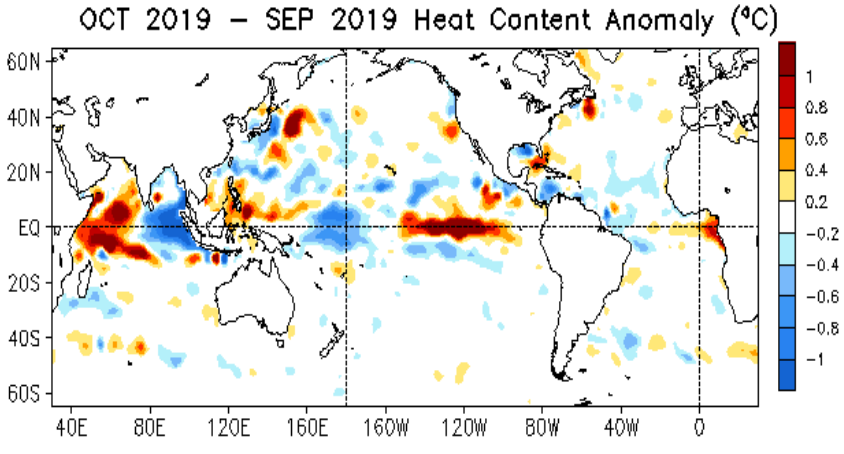
Backup Slides

Global SSH and HC300 Anomaly & Anomaly Tendency









- **The SSHA pattern was overall consistent with the HC300A pattern.**
- **Both SSHA and HC300A in the tropical Indian were consistent with the positive IOD state.**

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

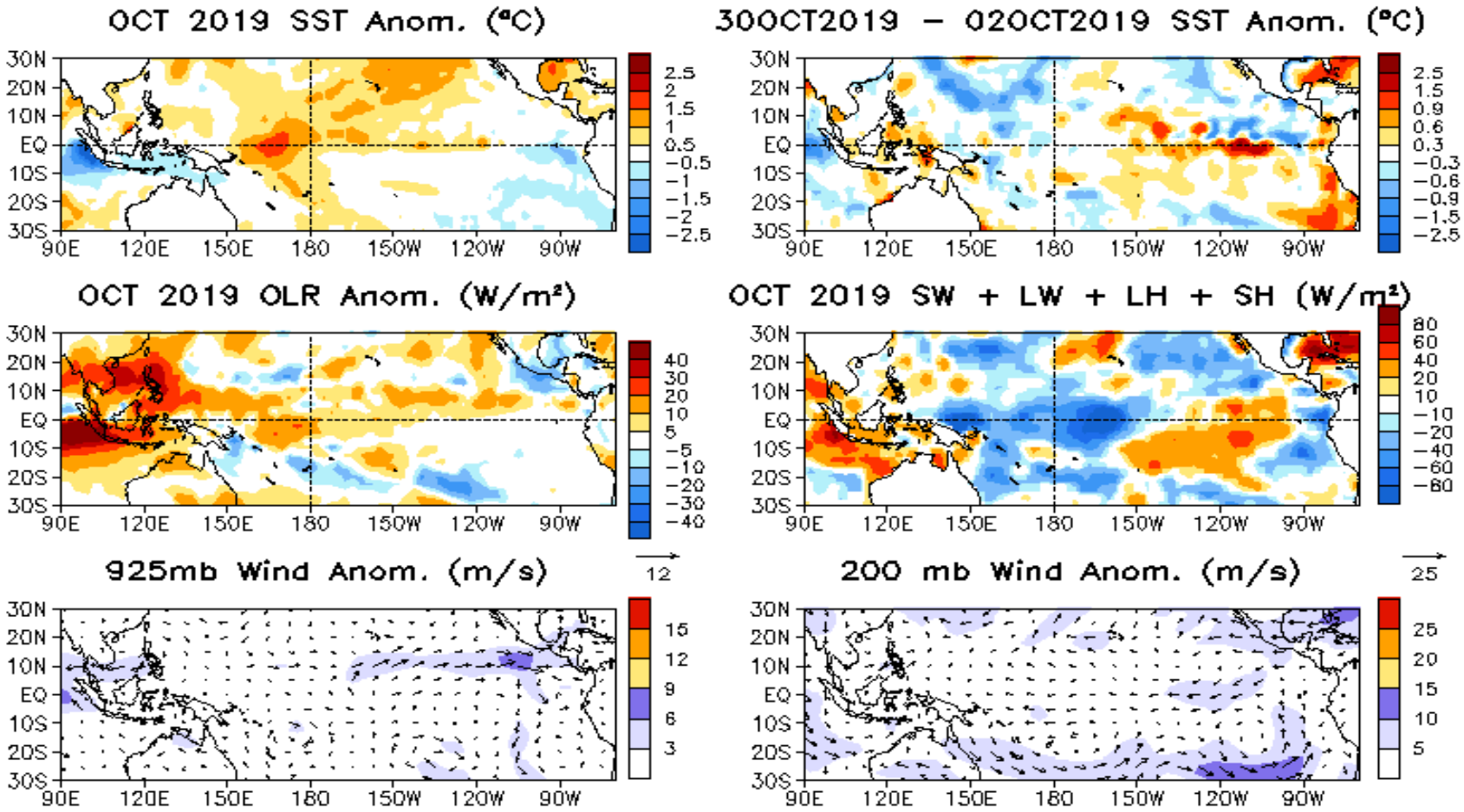
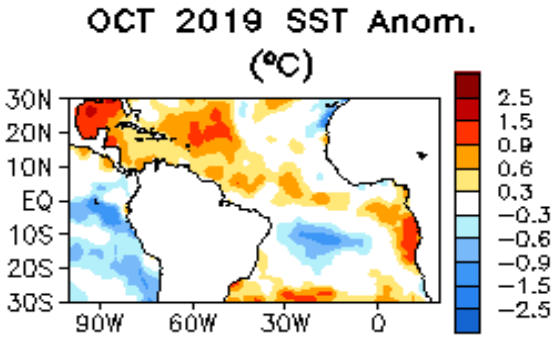
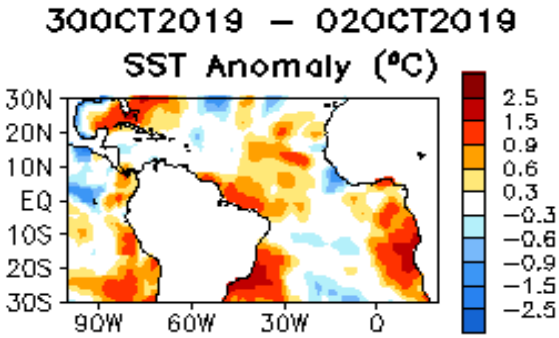


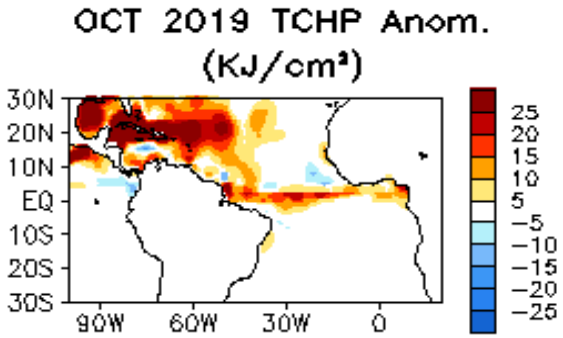
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

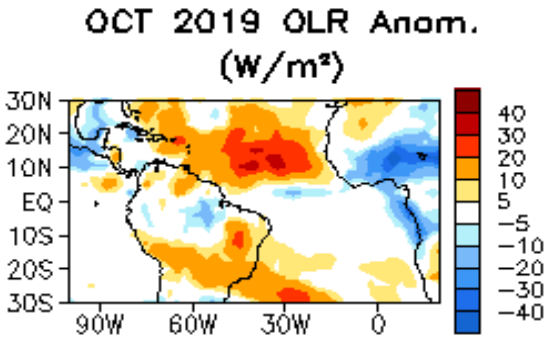
Tropical Atlantic:

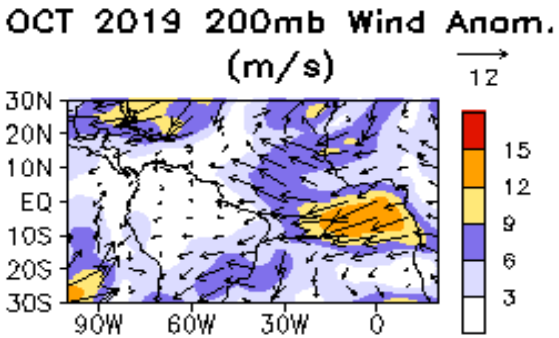
SST, SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, TCHP, 925-mb/200-mb Winds anom.

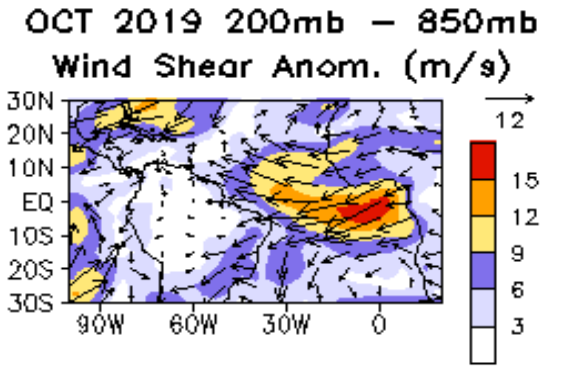


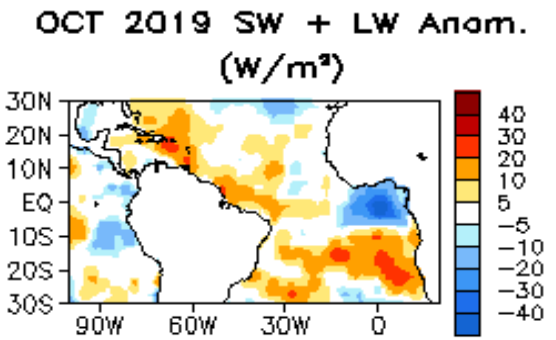


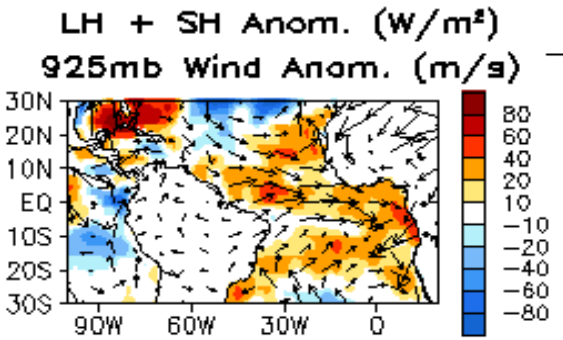


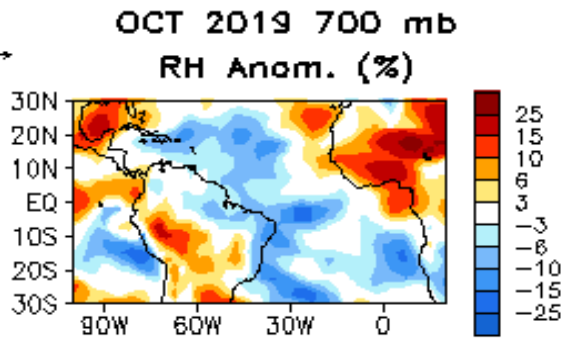




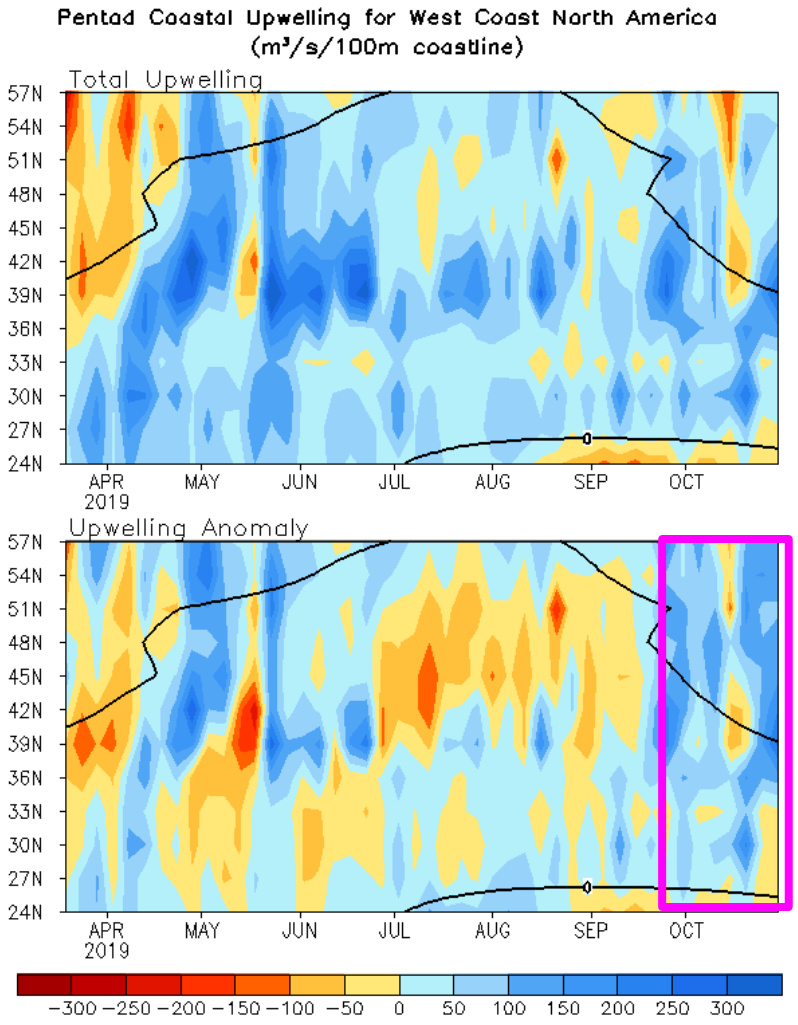


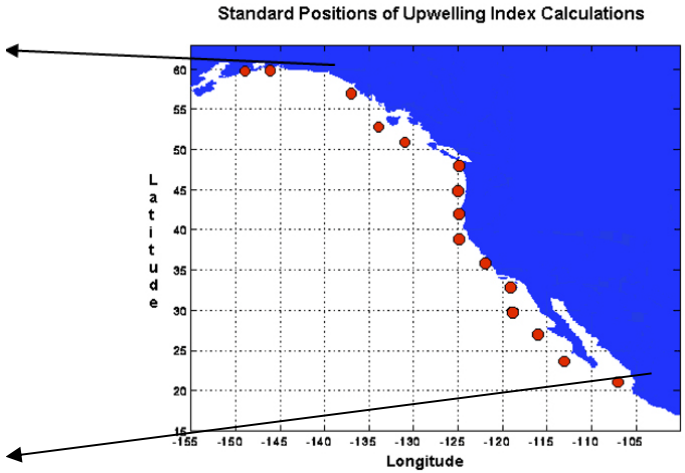






North America Western Coastal Upwelling





- **Anomalous upwelling dominated along the coastal line in Oct 2019.**

Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point (m³/s/100m coastline). Anomalies are departures from the 1981-2010 base period pentad means.

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

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

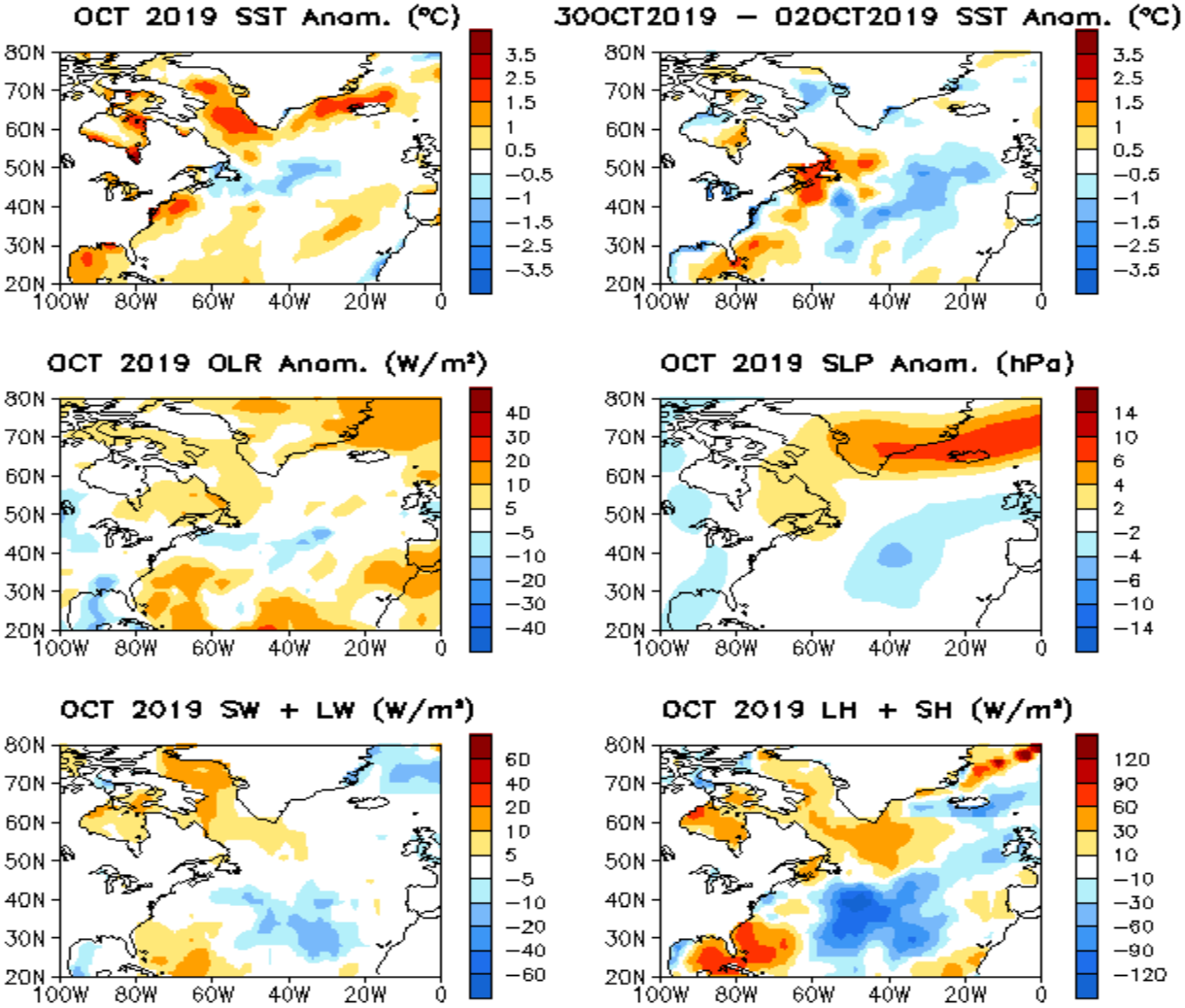
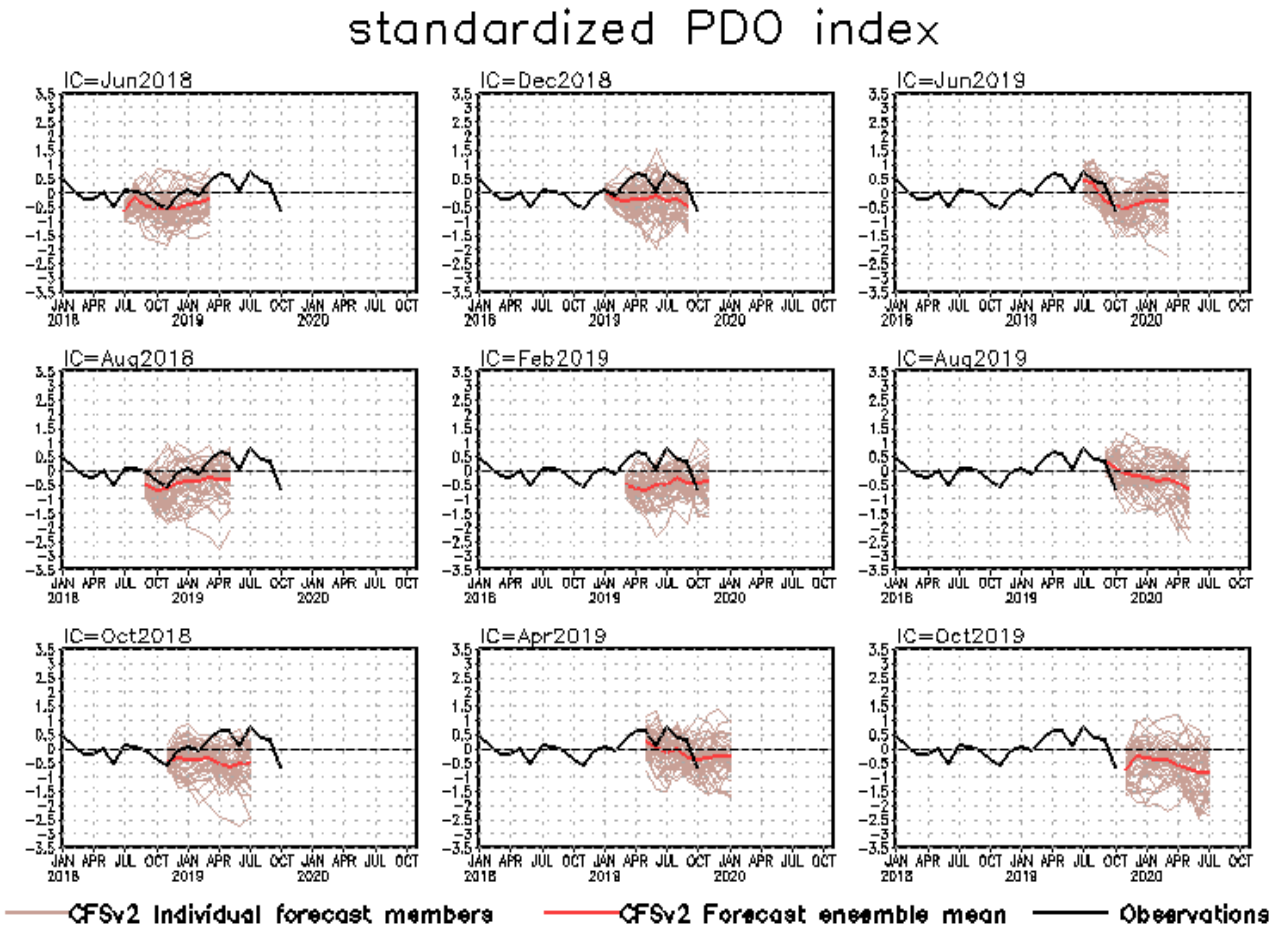


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

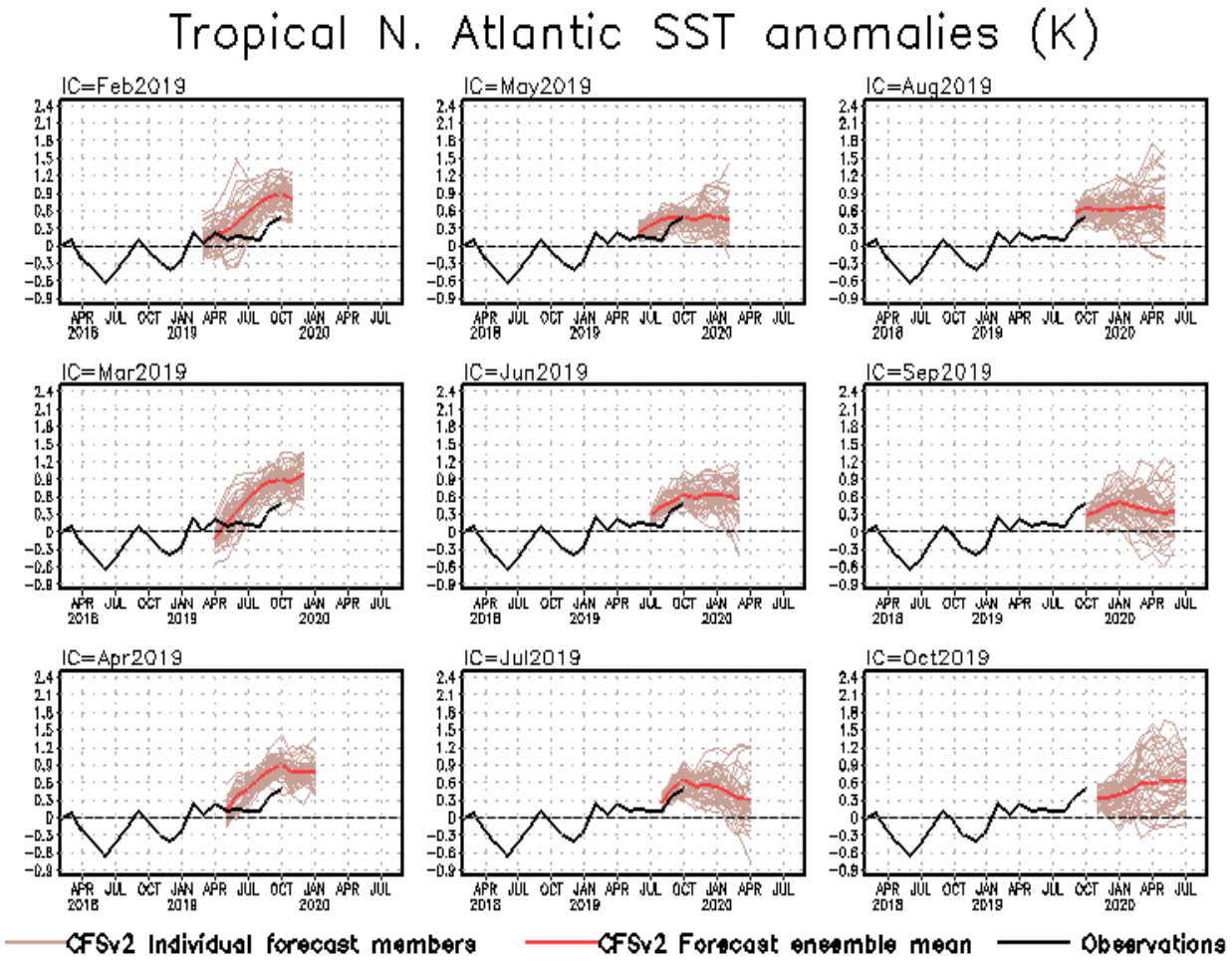
CFS PDO index is the standardized projection of CFS SST forecast anomalies onto the PDO EOF pattern.

- CFSv2 predicts a neutral phase of PDO in coming seasons.

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.

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].



- **Predictions had warm biases for ICs in Sep 2018-Apr 2019. The warm bias was partially associated with the warm bias in CFSR I.C. due to a decoding bug.**

- **Latest CFSv2 predictions call above normal SSTA in the tropical N. Atlantic in fall and winter 2019, a lag response to El Nino.**

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.

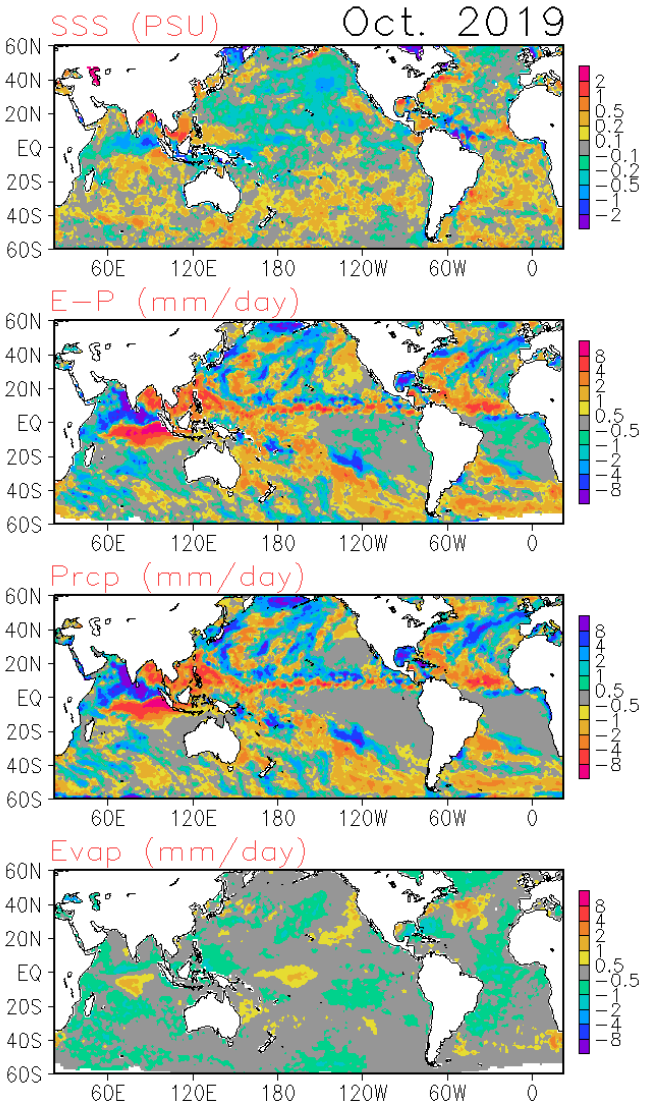
Global Sea Surface Salinity (SSS)

Anomaly for October 2019

- 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.
- Negative SSS anomalies are still continuing in the northeast Pacific ocean, which is likely due to the enhanced precipitation and oceanic advection/entrainment. Negative SSS signal across the central N. Atlantic Ocean from equator to 60^0N is accompanied with increased precipitation. In the Indian Ocean, a dipole pattern of negative/positive SSS signal is co-incident with similar pattern of the precipitation.

- **Data used**

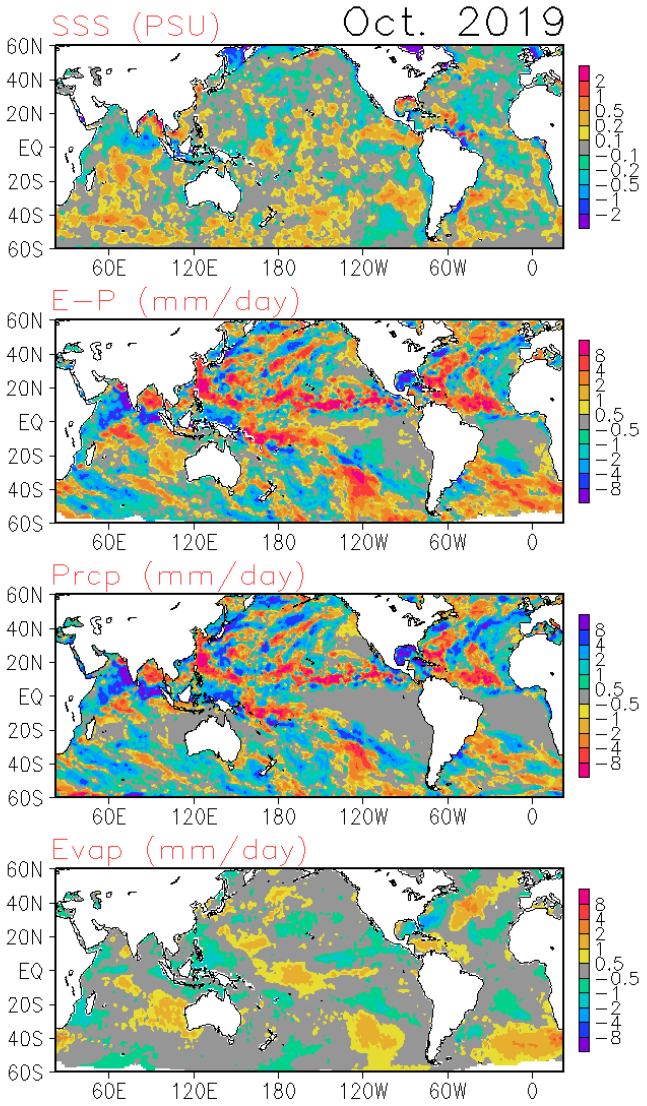
SSS : Blended Analysis of Surface Salinity (BASS) V0.Z
(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
(Xie et al. 2014)
ftp.cpc.ncep.noaa.gov/precip/BASS
Precipitation: CMORPH adjusted satellite precipitation estimates
Evaporation: Adjusted CFS Reanalysis



Global Sea Surface Salinity (SSS)

Tendency for October 2019

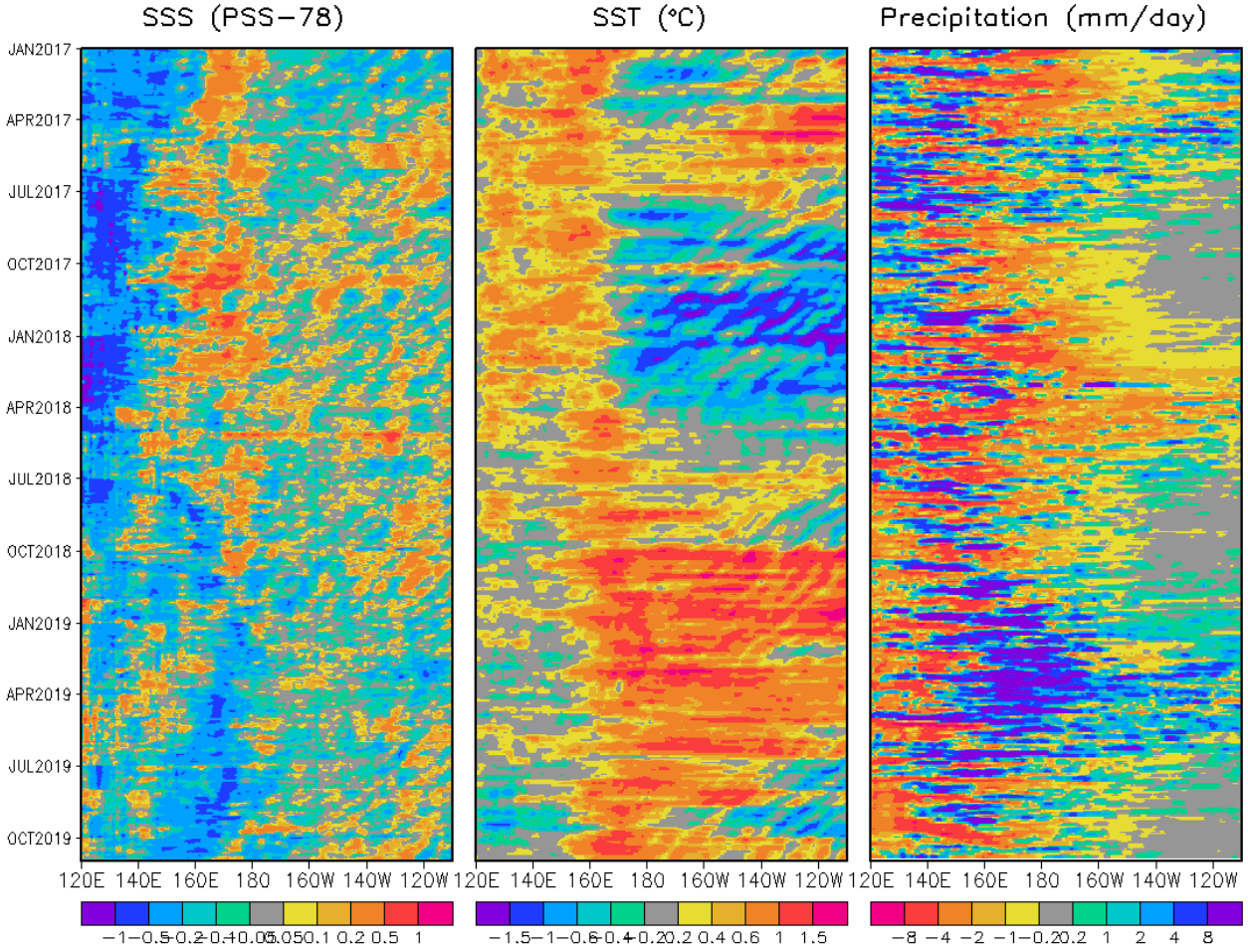
Compared with last month, in the Indian ocean, the SSS significantly decreased north of Equator with precipitation increasing, while the SSS increased between 0^0 and 20^0S with precipitation decreasing. The SSS decreased across the central N. Atlantic Ocean with heavy precipitation in the area. In Bay of Bengal, the reduced precipitation likely causes the SSS increasing.



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.



Data Sources (climatology is for 1981-2010)

- Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
- Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)
- Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)
- CMORPH precipitation (Xie et al. 2017)
- CFSR evaporation adjusted to OAFlux (Xie and Ren 2018)
- NCEP CDAS winds, surface radiation and heat fluxes (Kalnay et al. 1996)
- NESDIS Outgoing Long-wave Radiation (Liebmann and Smith 1996)
- NCEP's GODAS temperature, heat content, currents (Behringer and Xue 2004)
- Aviso altimetry sea surface height from CMEMS
- Ocean Surface Current Analyses – Realtime (OSCAR)
- In situ data objective analyses (IPRC, Scripps, EN4.2.1, PMEL TAO)
- Operational Ocean Reanalysis Intercomparison Project

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

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