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

Prepared by

Climate Prediction Center, NCEP/NOAA

December 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**

- **Conditions associated with above-normal 2019 Atlantic Hurricane season**
- **2019 MHW status and prediction**

Overview

Pacific Ocean

- ENSO neutral conditions continued in Nov 2019, with NINO34=0.6 ºC.
- NOAA "ENSO Diagnostic Discussion" on 12 Dec 2019 suggests ENSO-neutral will continue during the Northern Hemisphere winter 2019-20 with 70% chance.
- Positive SSTAs increased slightly in the NE Pacific in Nov 2019.
- Arctic sea ice extent in Nov 2019 reached the second lowest record since 1979.

Indian Ocean

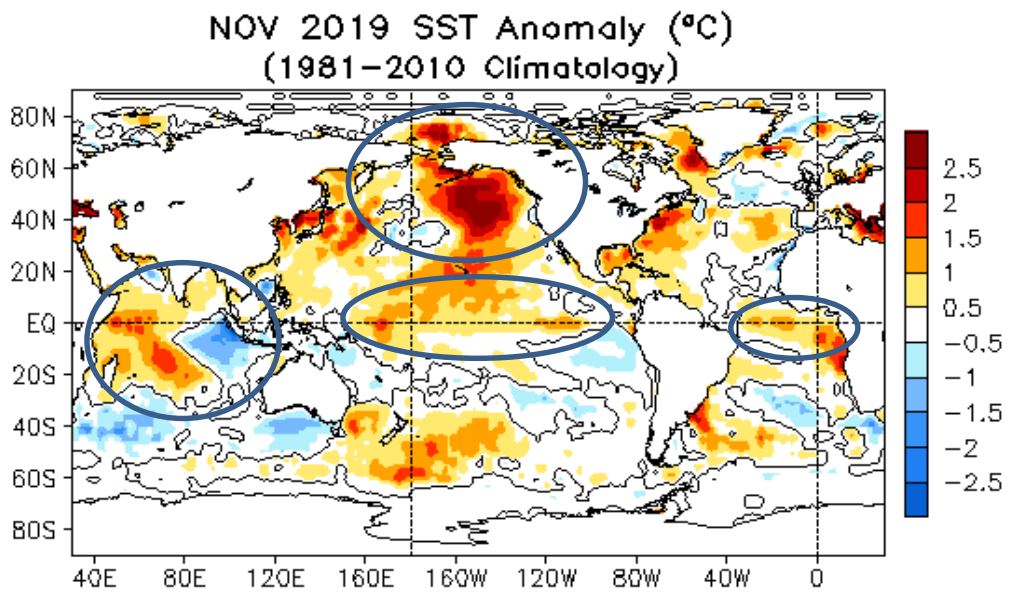
- The strong positive IOD event continued in Nov 2019.
- IOD index = 1.9 ºC in Nov 2019, ranking the second largest value since 1950.

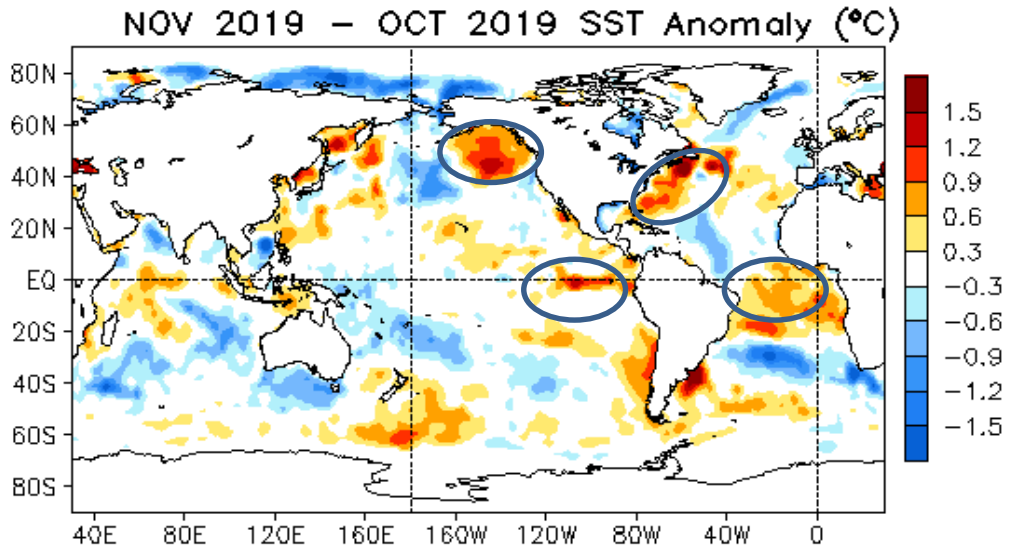
Atlantic Ocean

- 2019 Atlantic hurricane season was marked as 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 and Atlantic Oceans.

- 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.

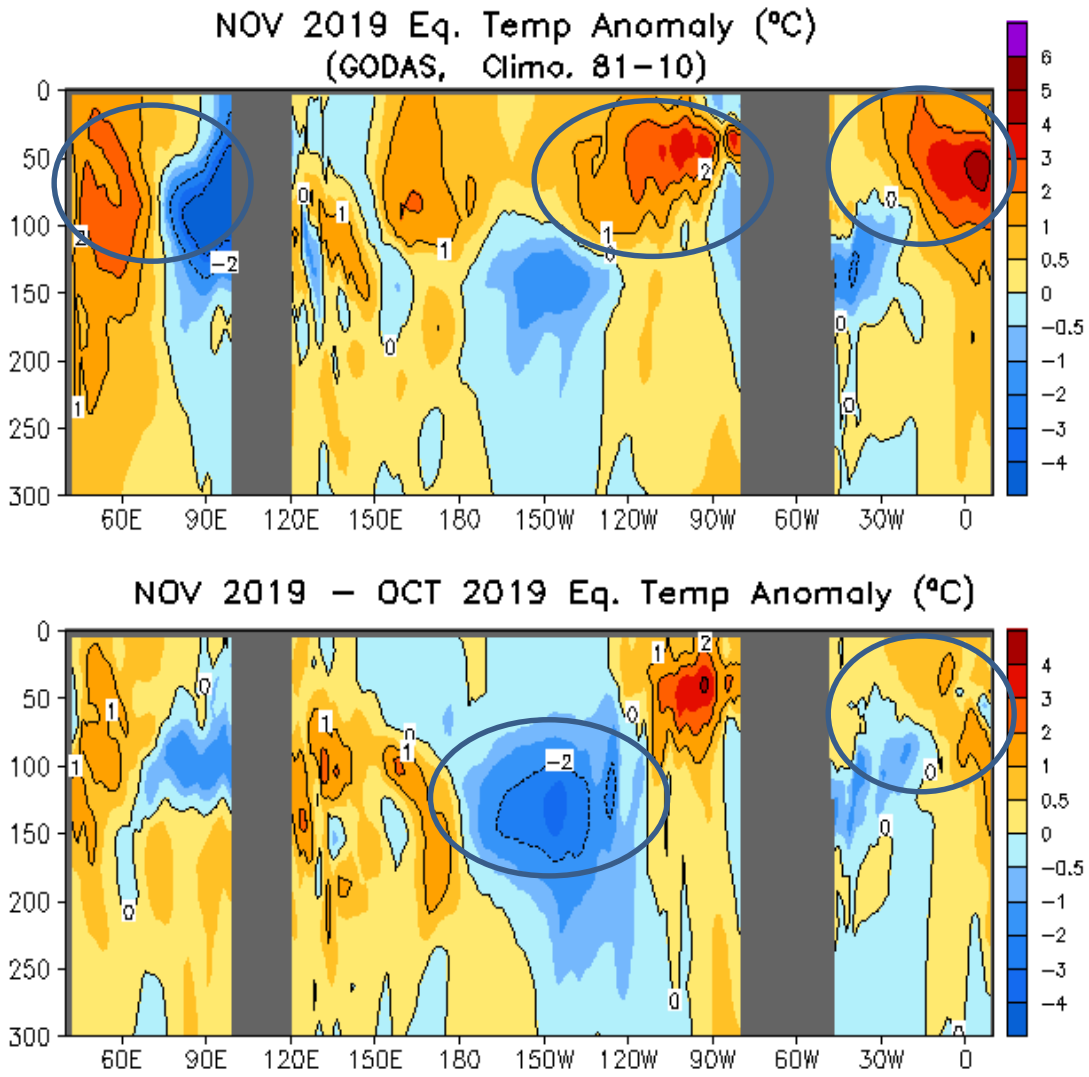
- Positive SSTA tendencies presented in the eastern equatorial Pacific and Atlantic Oceans.

- Strong positive tendencies presented in the NE Pacific.

- Positive tendencies were observed along the east coast of N. America.

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



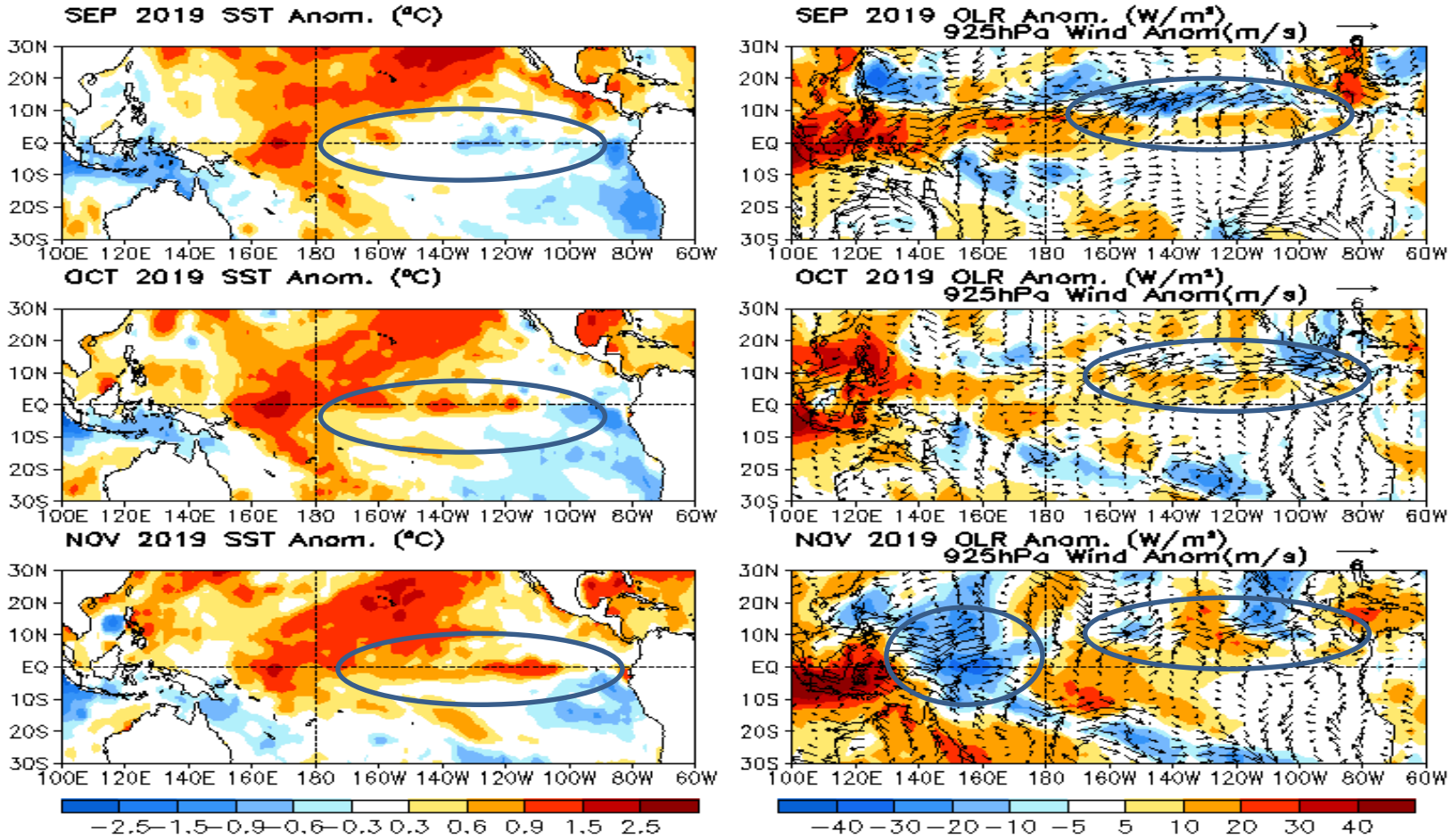
- **Positive subsurface temperature anomalies dominated in the upper 100m of the equatorial Pacific.**
- **Positive temperature anomalies continued in the Atlantic Ocean.**
- **Positive (negative) anomalies persisted in the Indian Ocean.**

- **Negative(positive) temperature anomaly tendency dominated in the central Pacific (western and eastern 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.

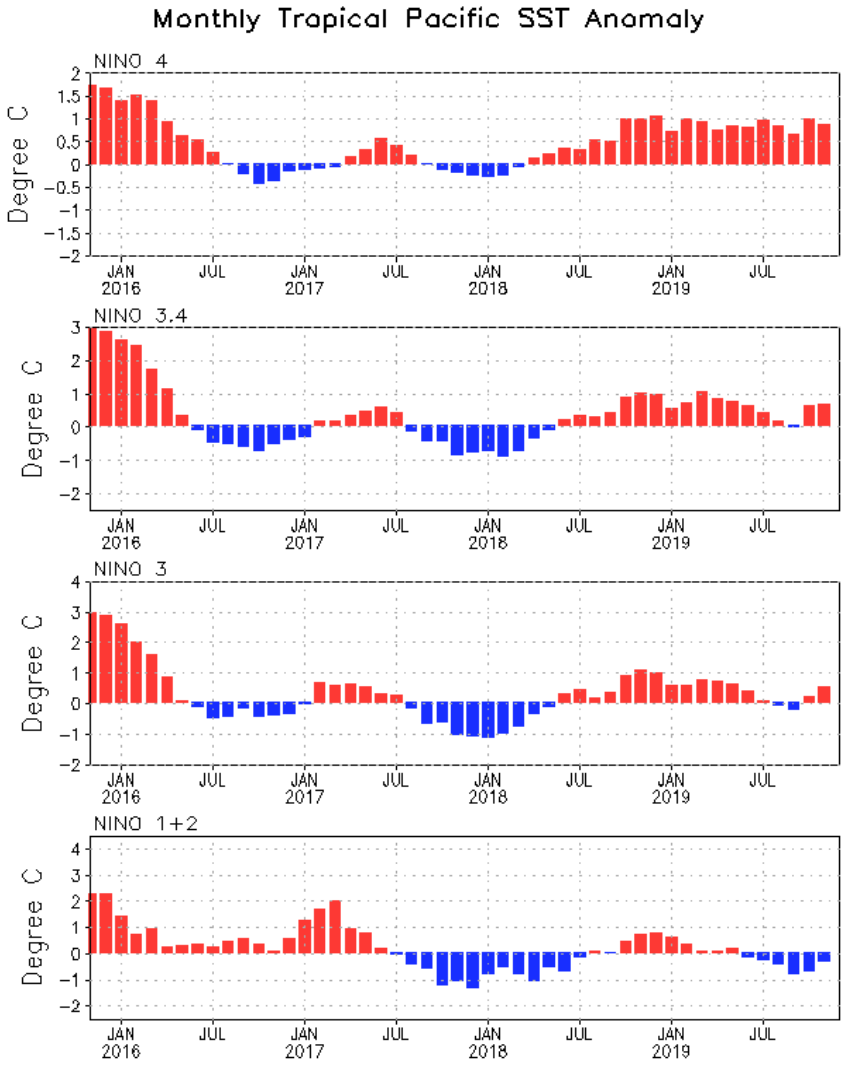
Tropical Pacific Ocean and ENSO Conditions

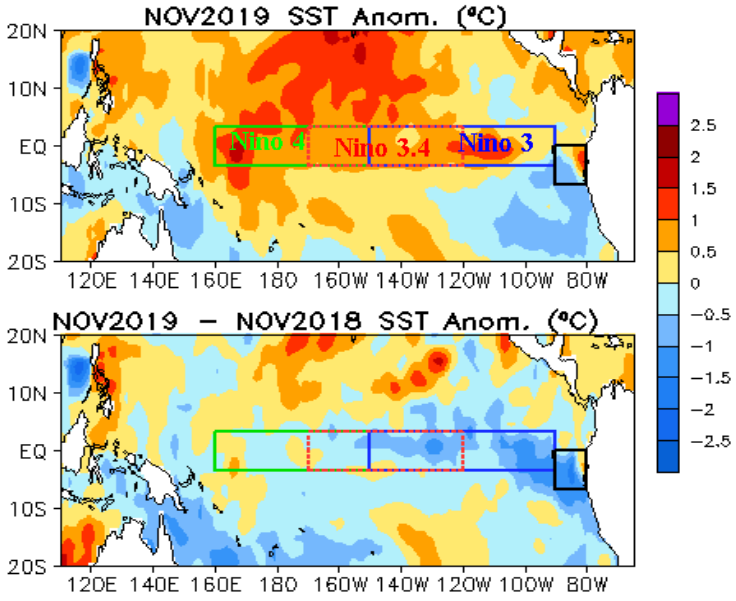
Last three month SST, OLR and 925hPa wind anomalies



- **During the last couple of months, positive SST anomaly strengthened in the central-eastern Pacific, and below-average SSTs weakened in the far E. Pacific.**
- **Negative OLR anomalies emerged west of the Date Line in Nov 2019.**
- **Low-level cross equatorial wind anomalies persisted during the last three months.**

Evolution of Pacific NINO SST Indices

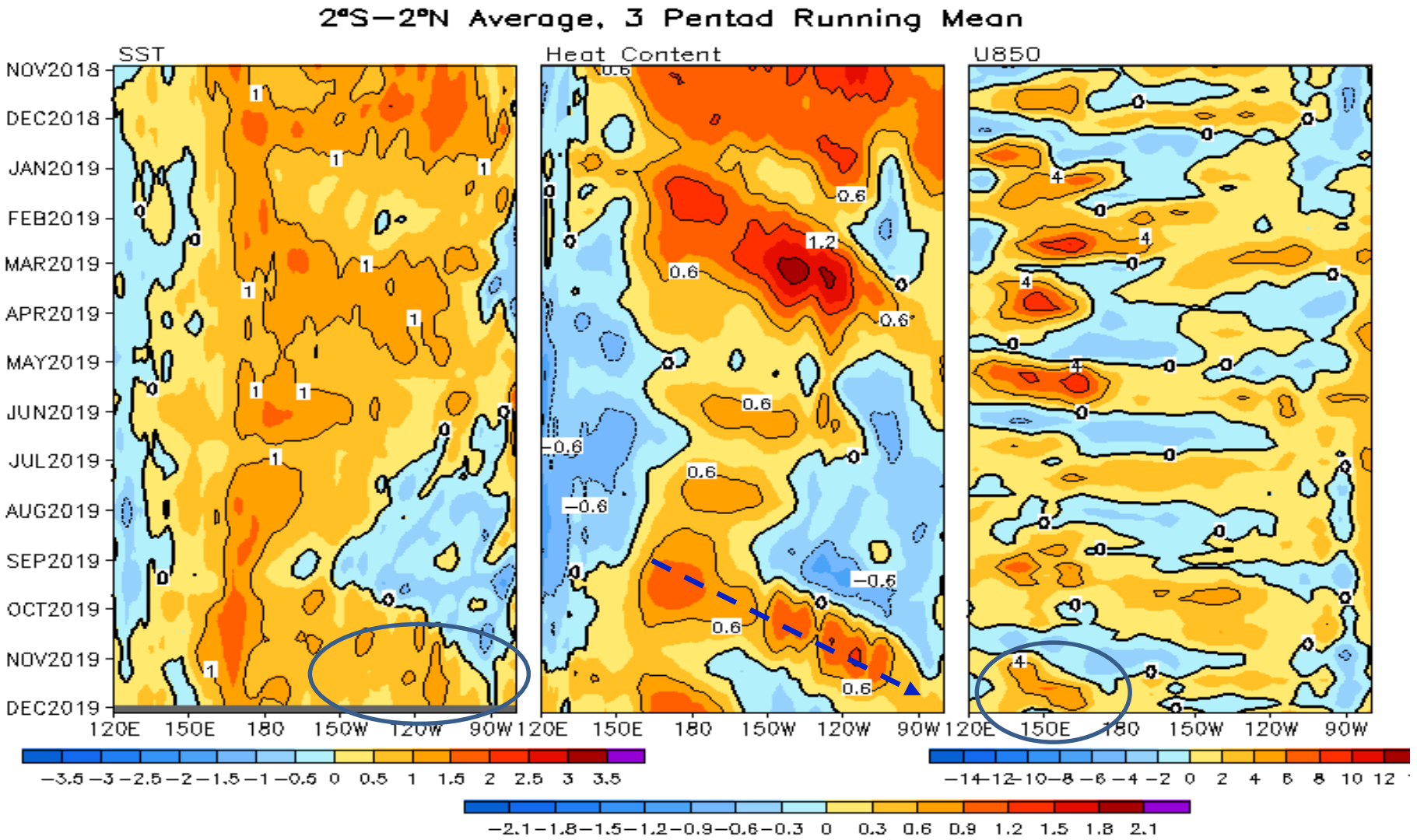




- **Both NINO 3.4 and NINO3 increased in Nov 2019.**
- **Nino3.4 = 0.6 C in Nov 2019.**
- **Compared with Nov 2018, the eastern equatorial Pacific was cooler in Nov 2019.**
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v5.**

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.

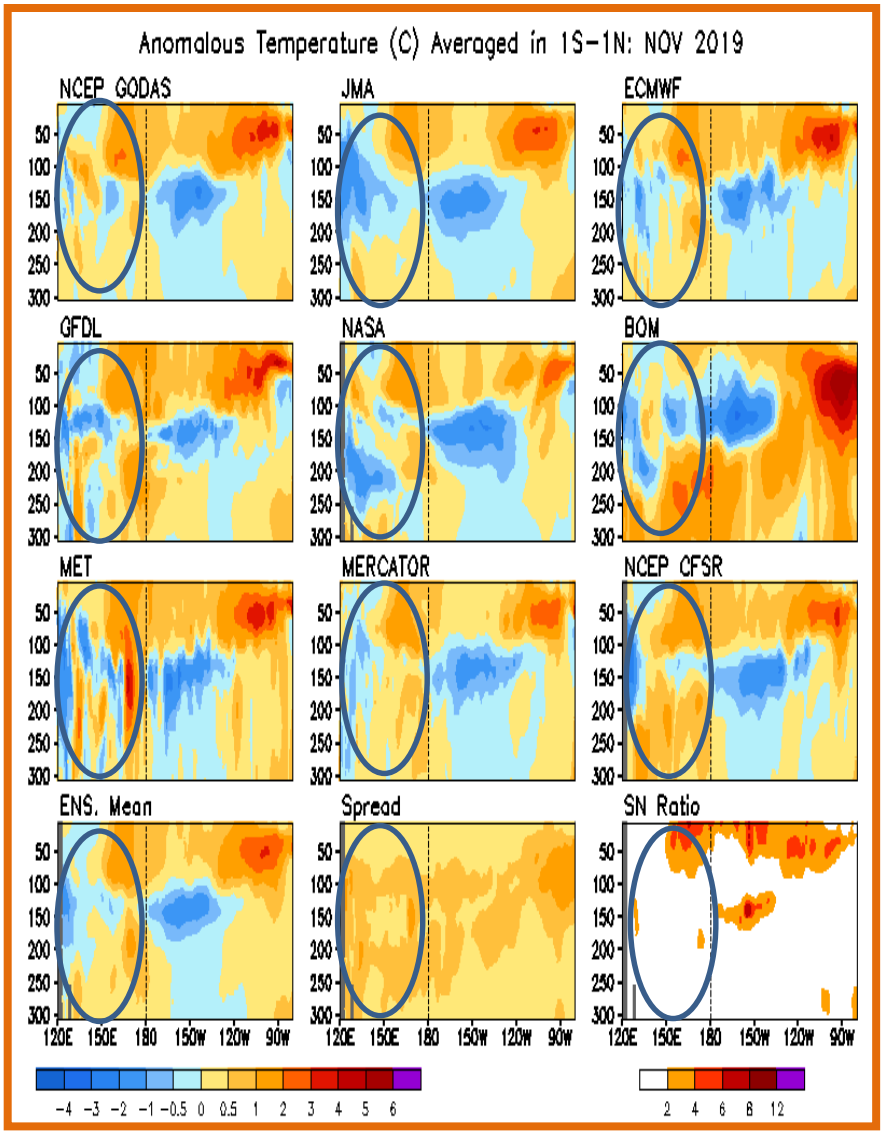
Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies

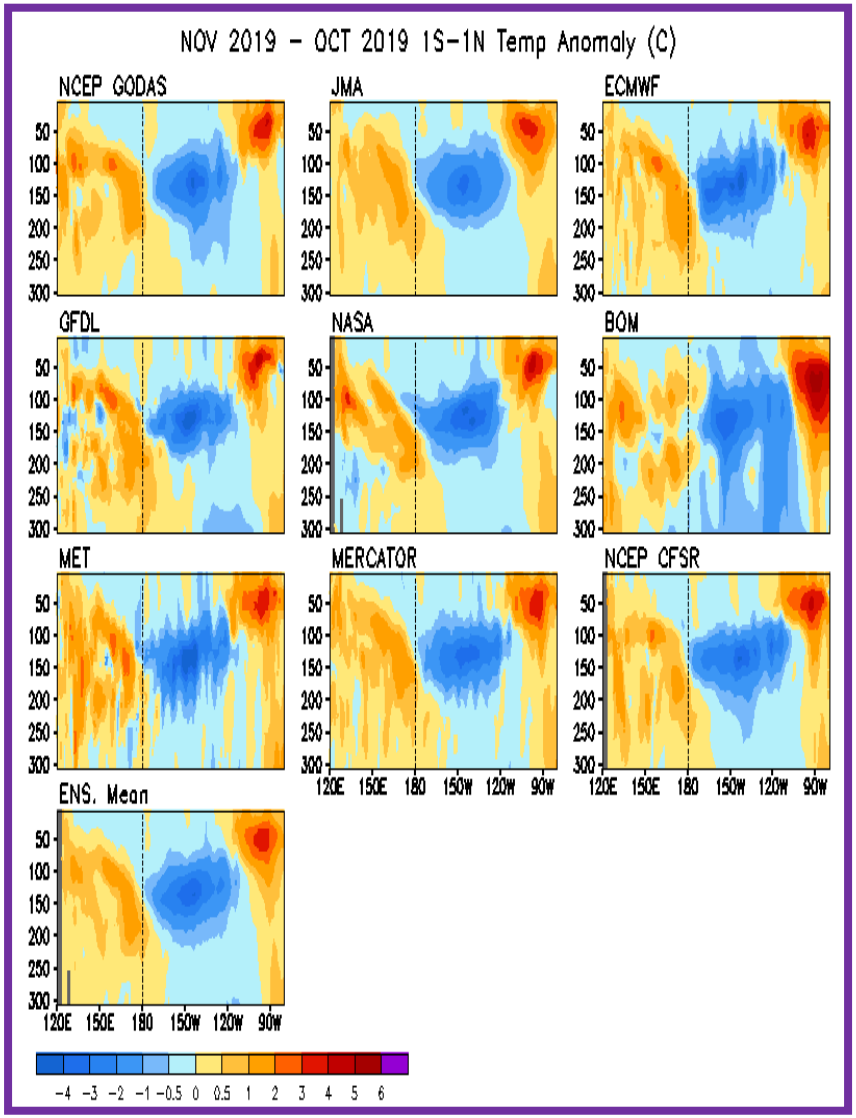


- **Enhanced positive SST anomaly in the eastern Pacific is consistent with eastward propagation of downwelling Kelvin wave.**
- **Westerly wind anomalies prevailed over the western Pacific.**

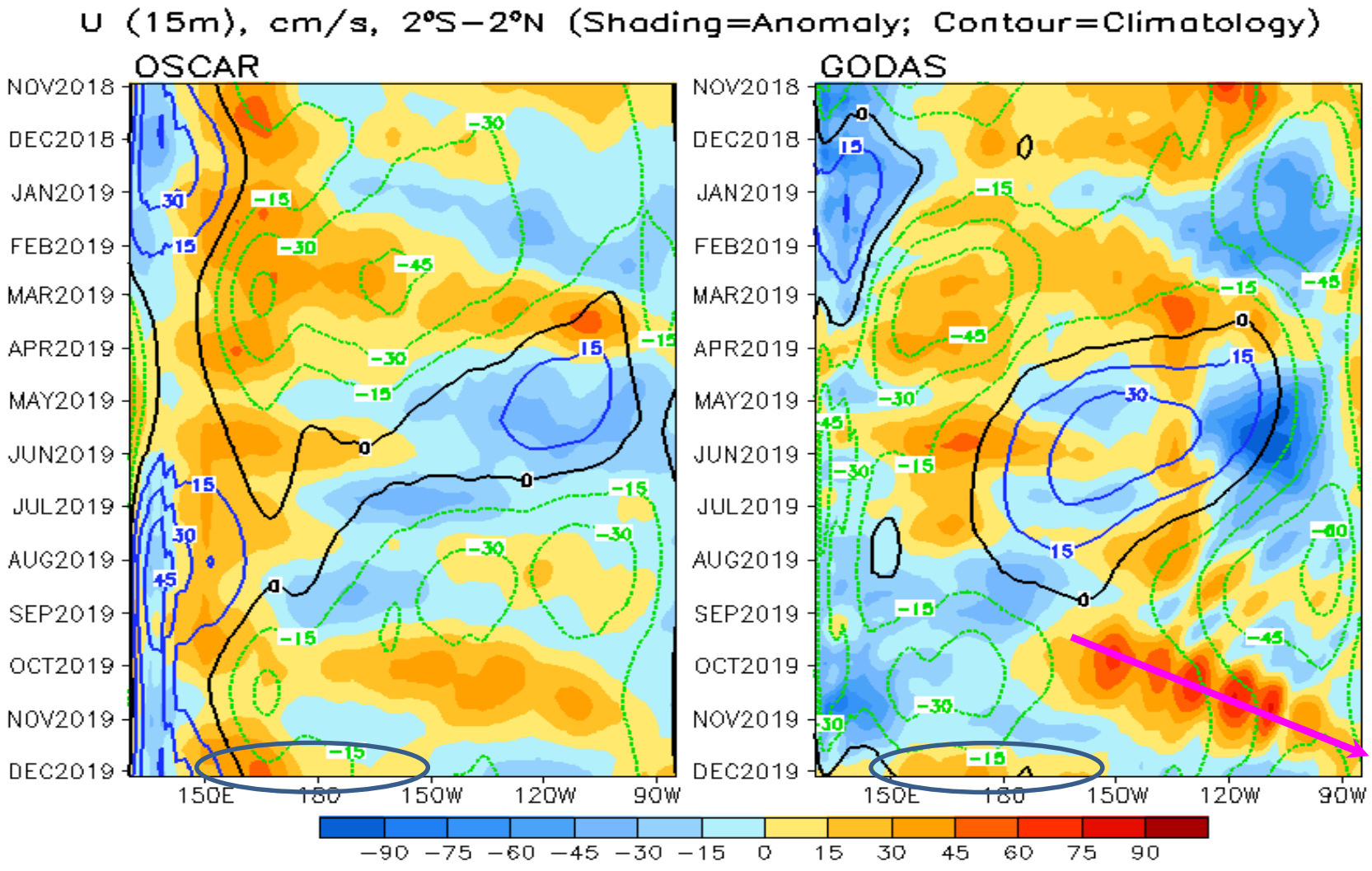
Real-Time Ocean Reanalysis Intercomparison: EQ temperature anomaly Climatology : 1993-2013

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





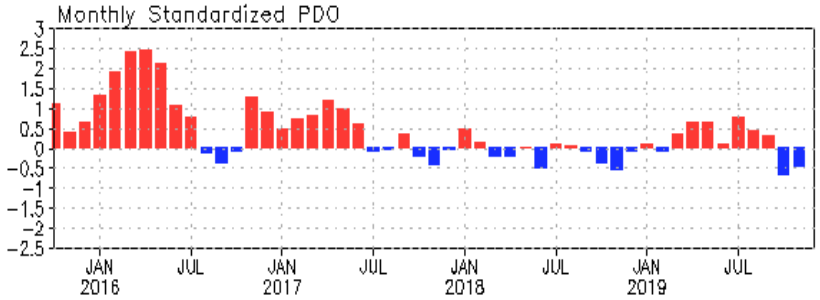
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)

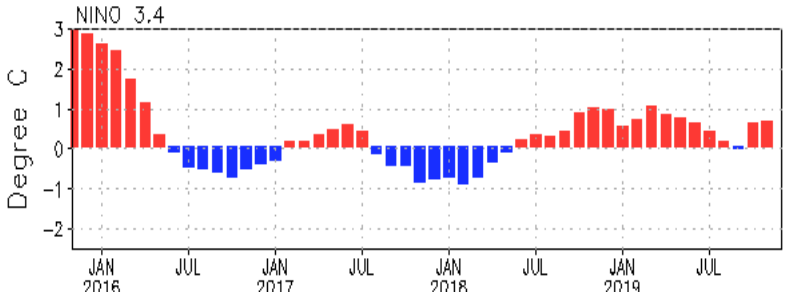


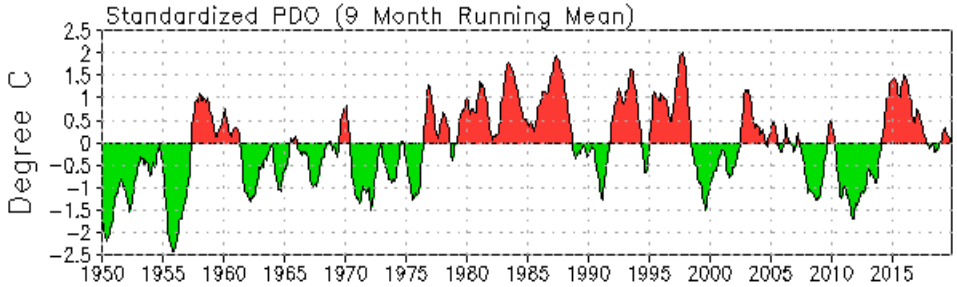
- Anomalous eastward currents in the central Pacific propagated eastward since Sep 2019, contributing to the SST warming in the eastern Pacific.
- Anomalous eastward currents emerged in the western-central Pacific.

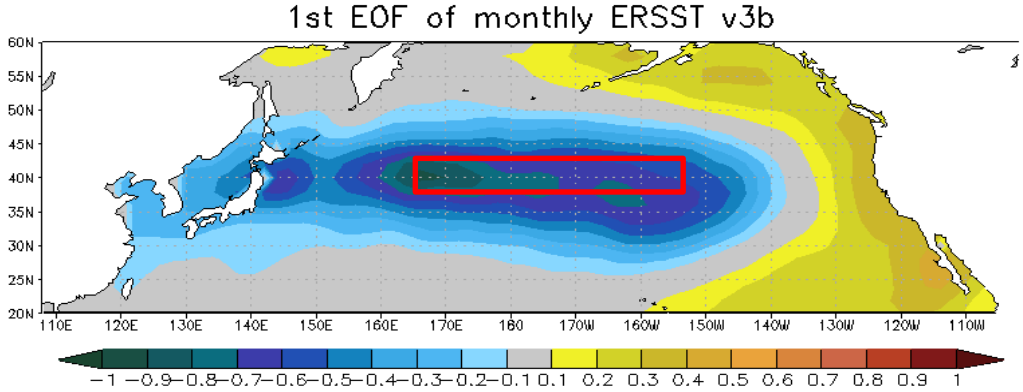
North Pacific & Arctic Oceans

PDO index









- Negative PDO weakened slightly in Nov 2019, with PDOI = -0.5.

- 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

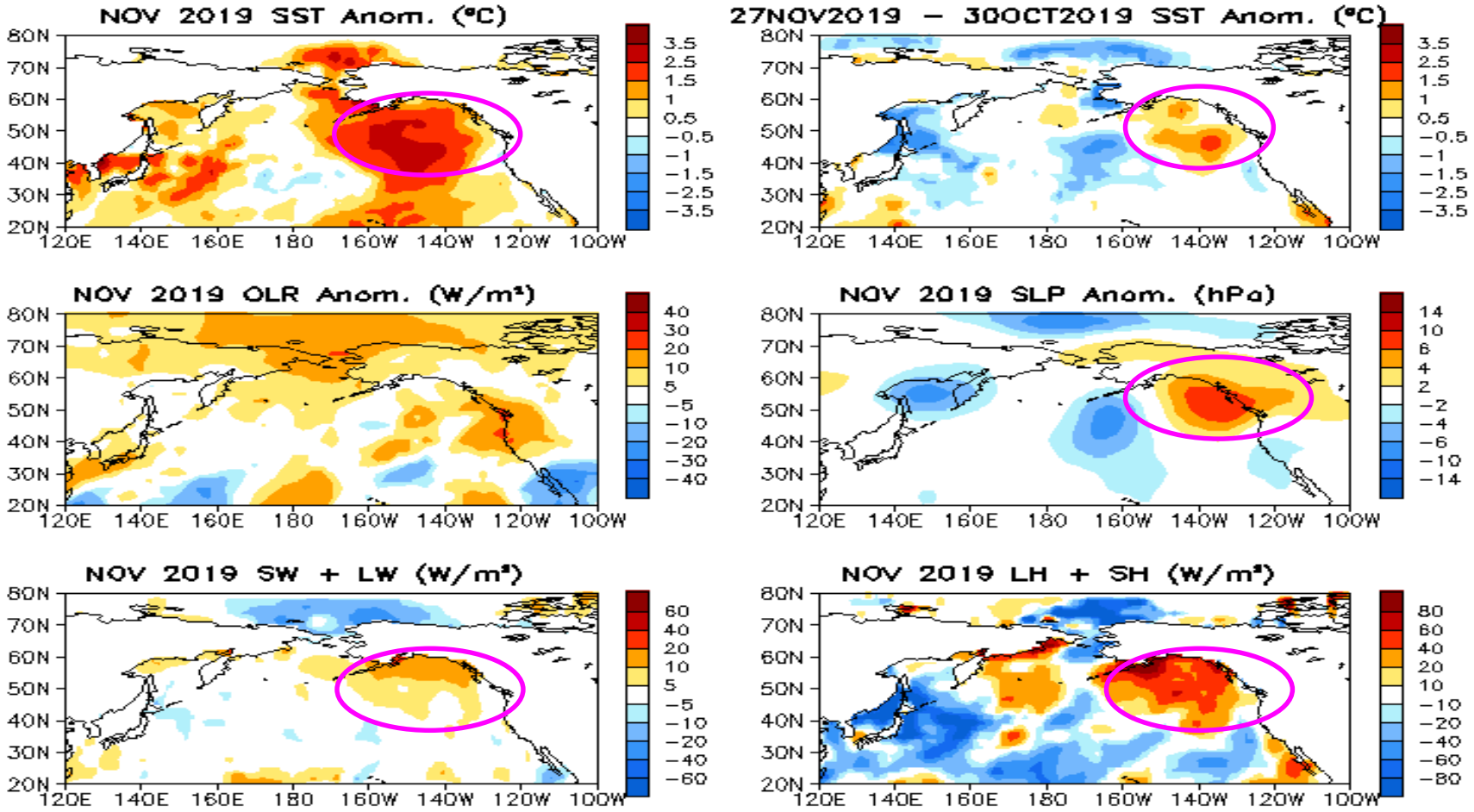
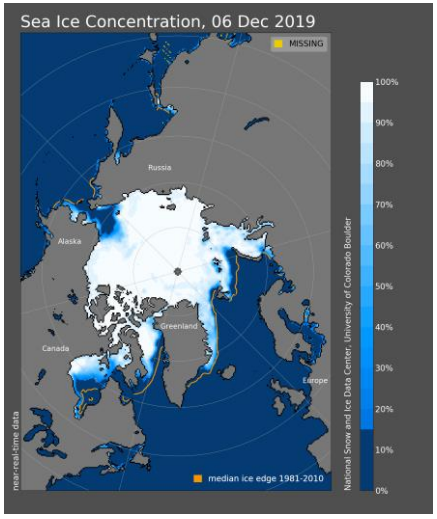
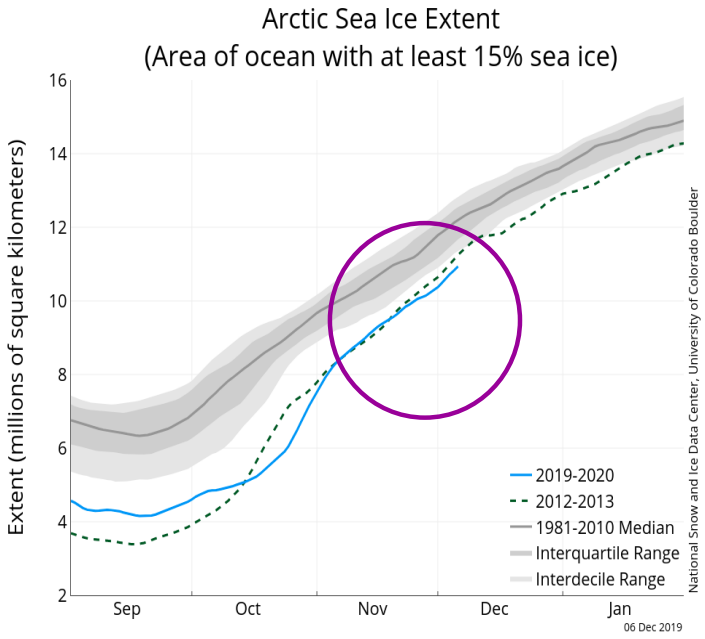


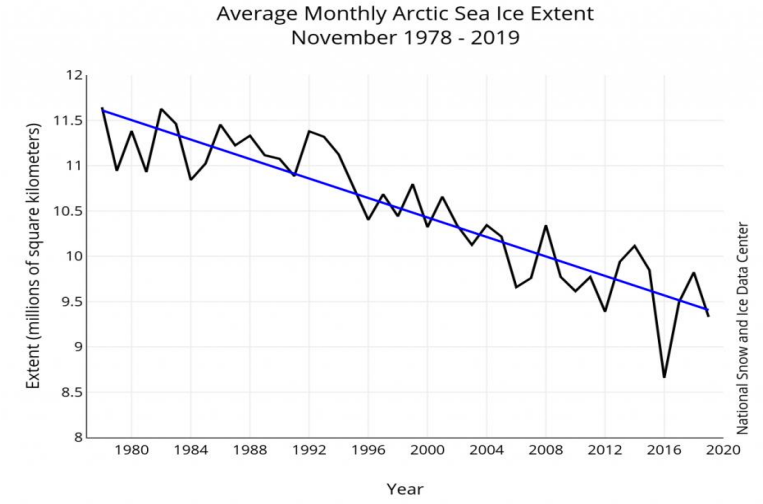
Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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





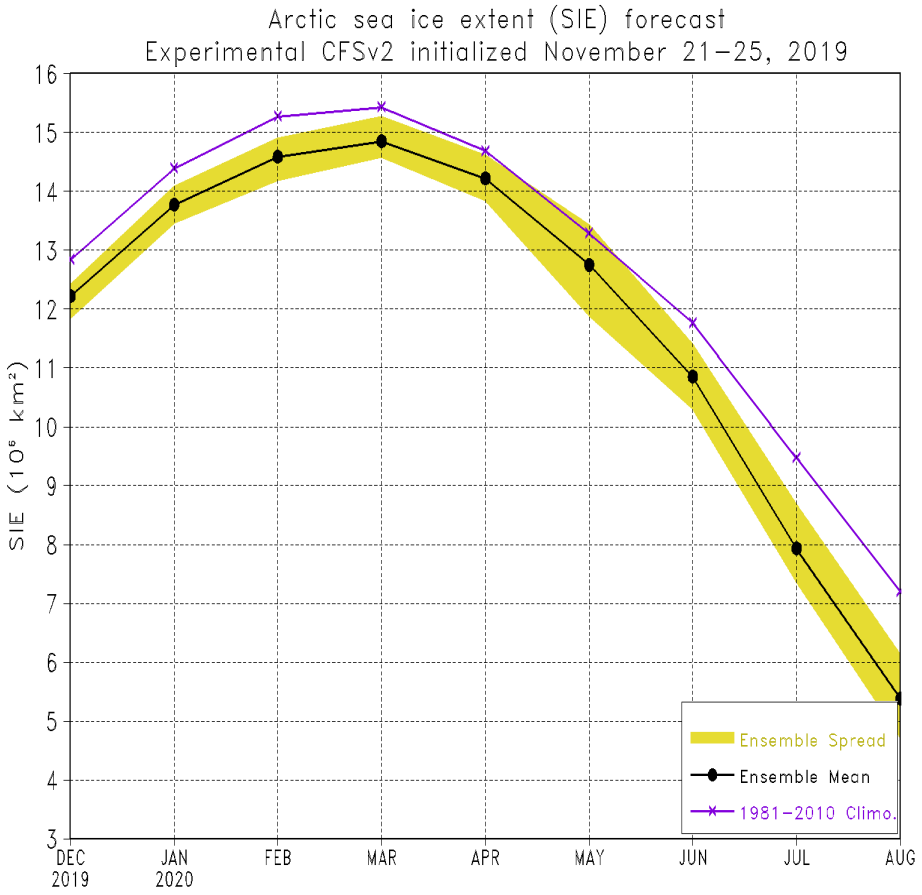


-The monthly average extent for Nov 2019 was 9.33 million square kilometers ranking the second lowest record since 1979.

Experimental Sea Ice Outlook

CPC/NCEP/NWS/NOAA

Provided by Dr. *Wanqiu Wang*



- **CPC Experimental Sea Ice Outlook suggests Arctic sea ice extend will continue to below average during 2019-20 winter.**

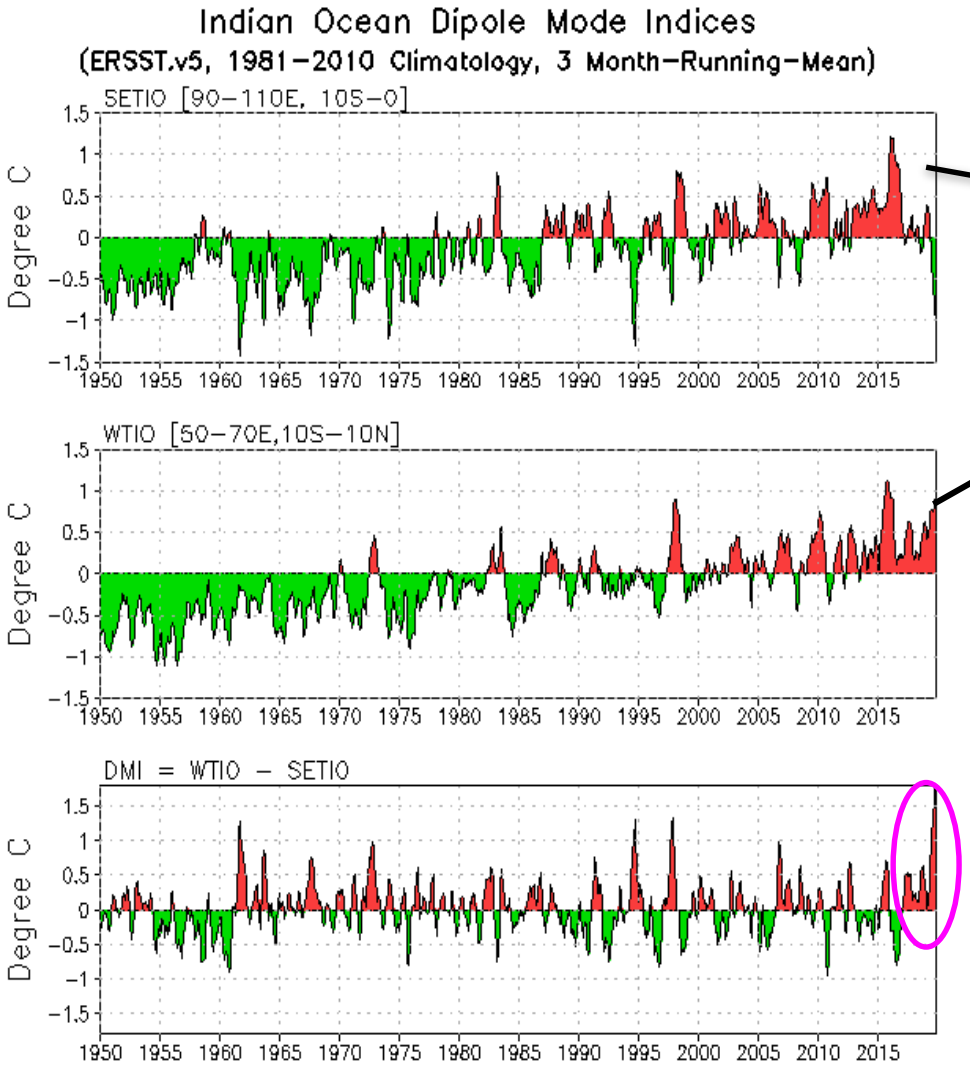
Procedure:

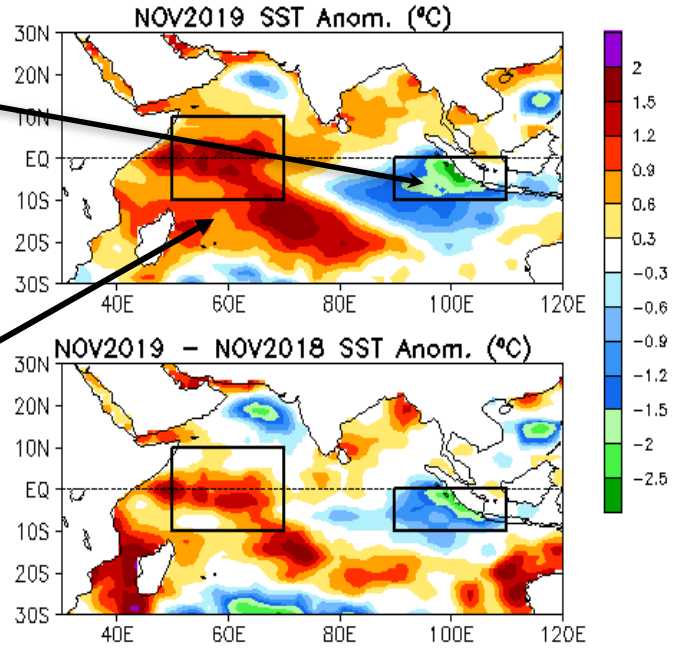
•Use Climate Forecast System (CFS) coupled model initialized with CPC Sea Ice Initialization System (CSIS) initial sea ice conditions (20 initializations: November 21-25, 2019).

•Correct biases using 2006-2018 mean error with respect to NSIDC observations

Indian Ocean

Evolution of Indian Ocean SST Indices





- **Strong positive phase IOD continued in Nov 2019, reaching the second historical high since 1950.**
- **IOD =1.9C in Nov 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 continued 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.

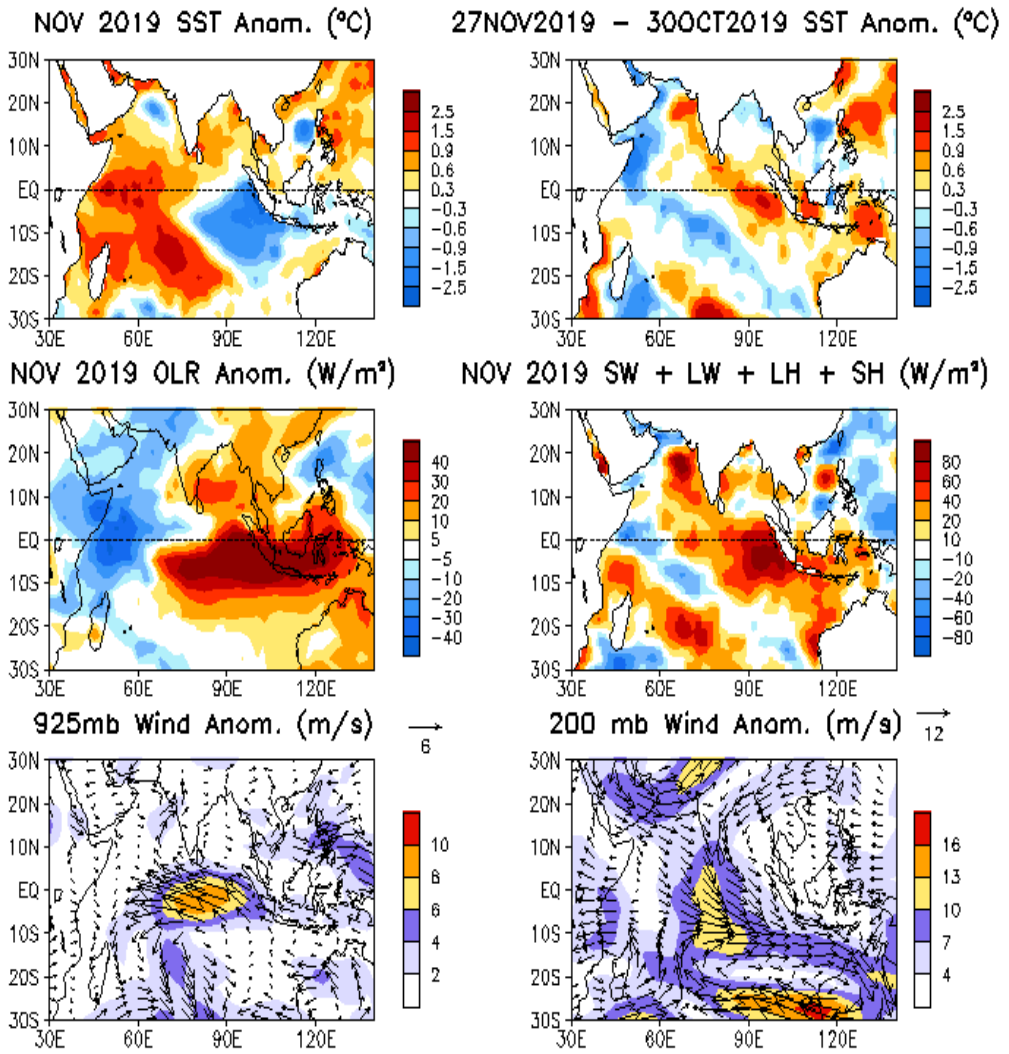
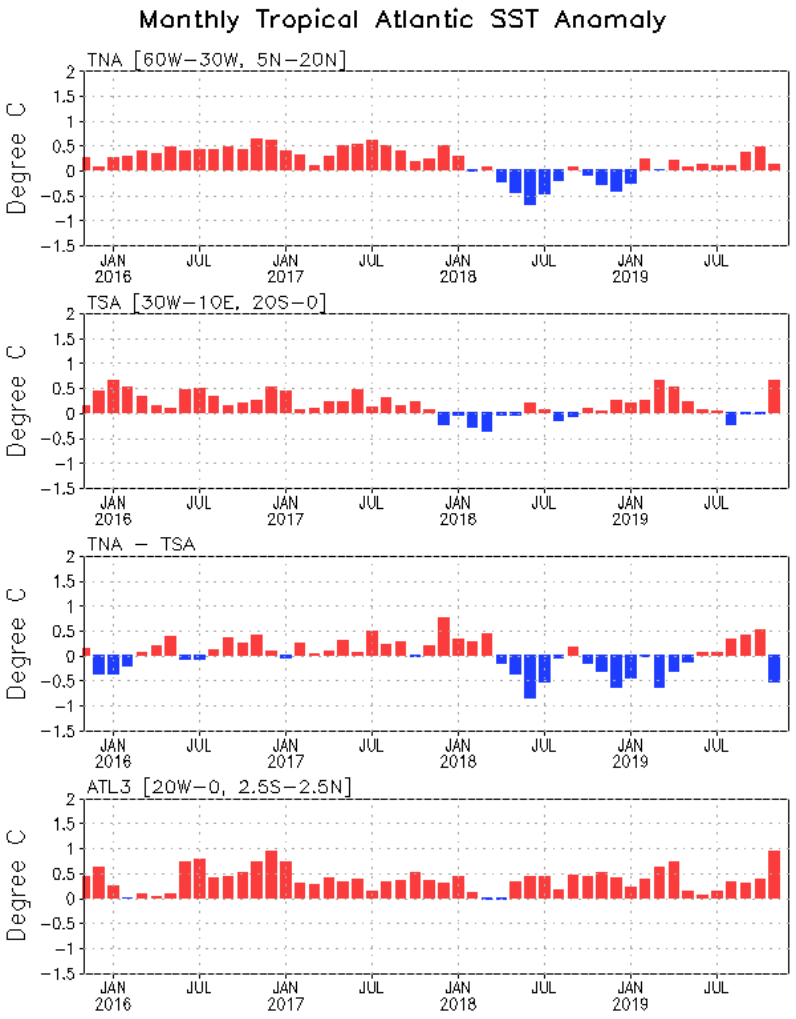
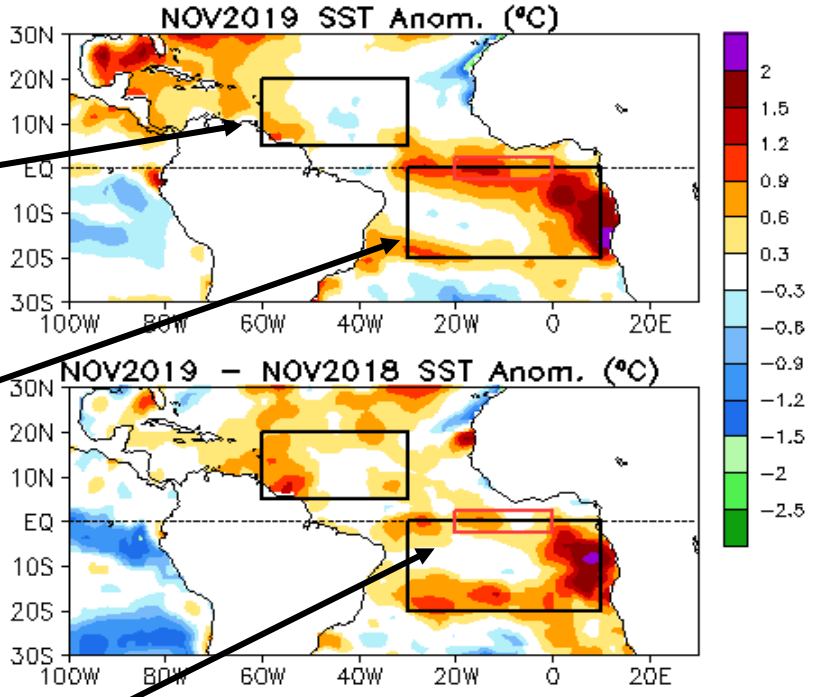


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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 decreased in Nov 2019.
- ATL3 increased substantially in Nov, 2019, with ATL3=1.1C.

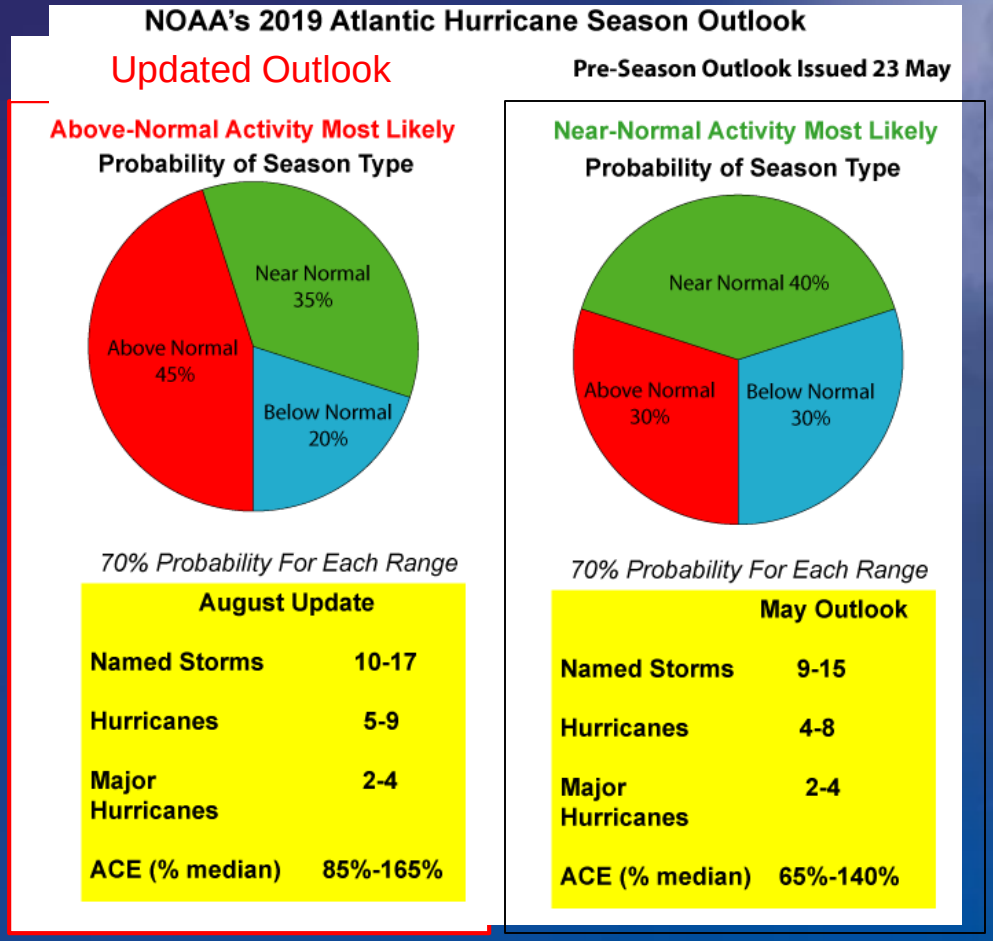
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between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

Conditions Associated with Above Normal 2019 Atlantic Hurricane Season

Dr. Gerry Bell

Lead Seasonal Hurricane Forecaster
Climate Prediction Center/ NOAA/NWS

NOAA's 2019 Atlantic Hurricane Season Outlooks



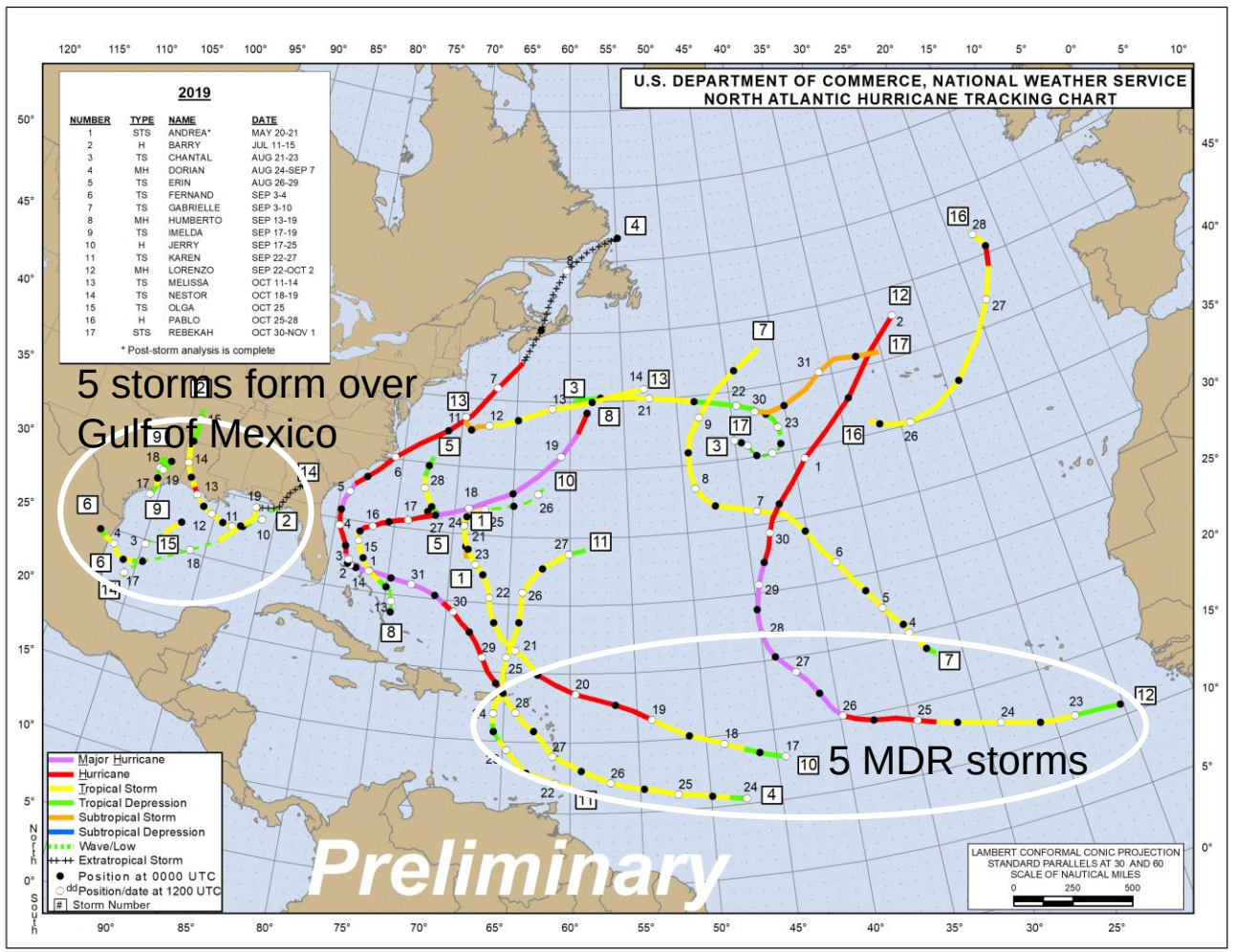
Observed

18 NS
6 H
3 MH

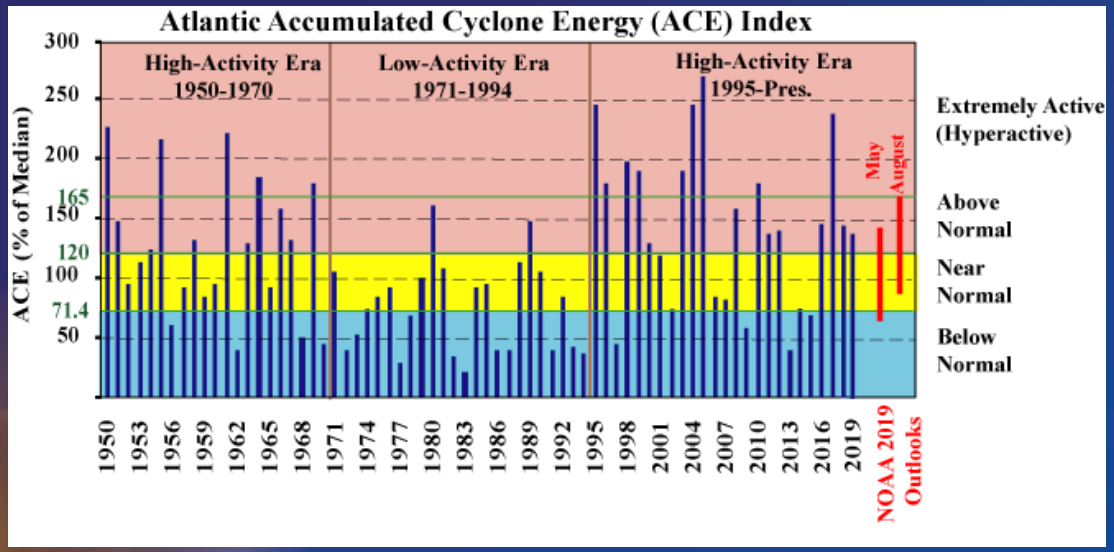
134% ACE

Both outlooks verified for H, MH, and ACE. The August update also verified for NS.

2019 Storm Tracks

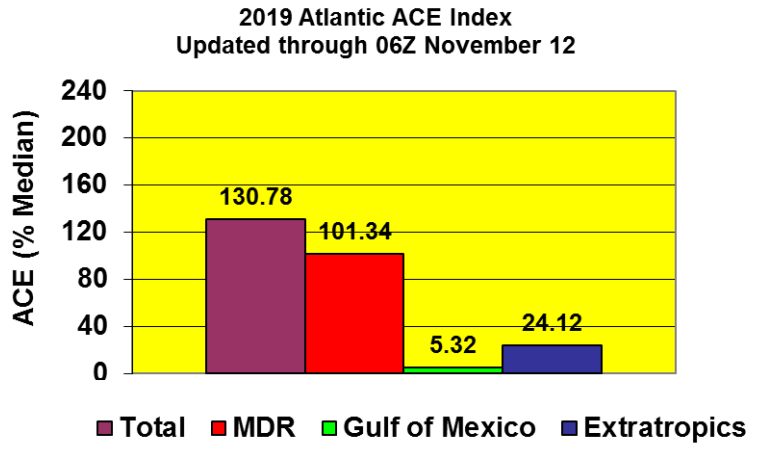


The 2019 Atlantic Outlook in a Historical Perspective



The 2019 seasonal ACE value is in the "above-normal" category.

ACE contribution from storms forming in different regions

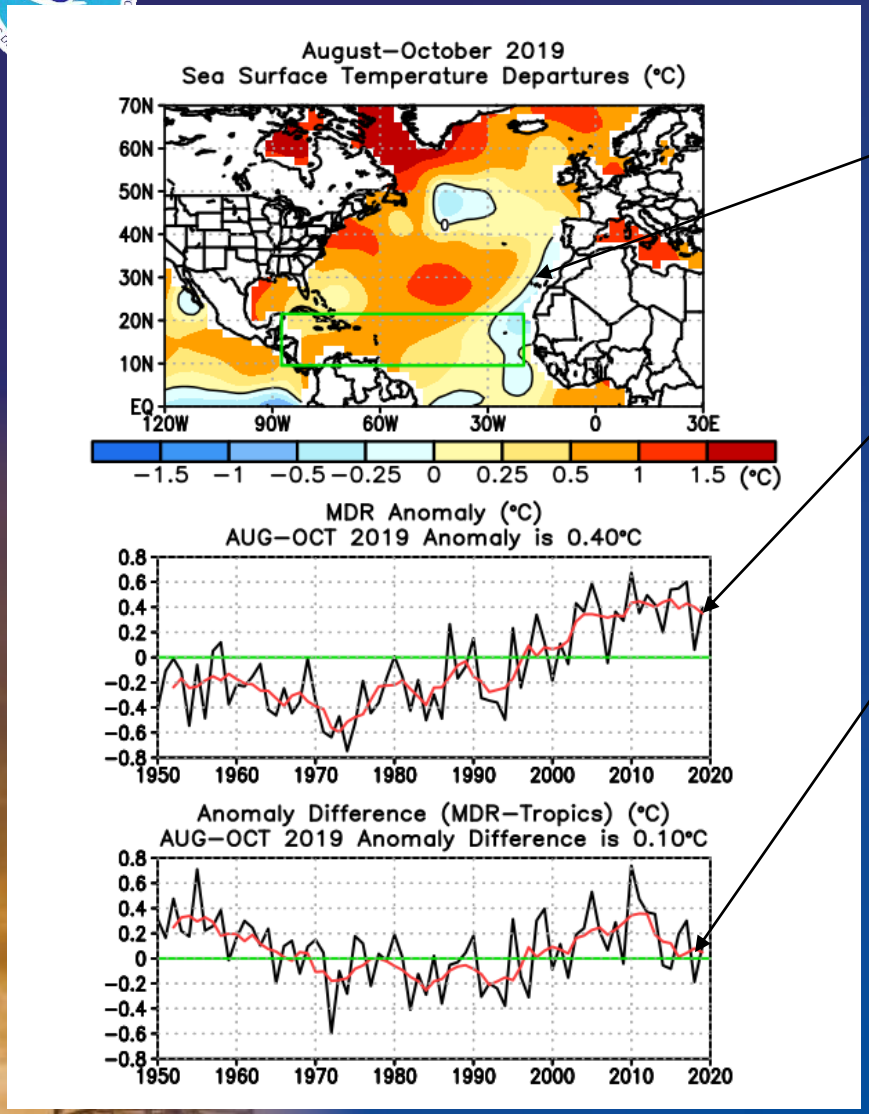


During 2019, storms first named in the MDR accounted for about 75% of the total ACE.

MHs Dorian and Lorenzo accounted for ~58% of the total ACE

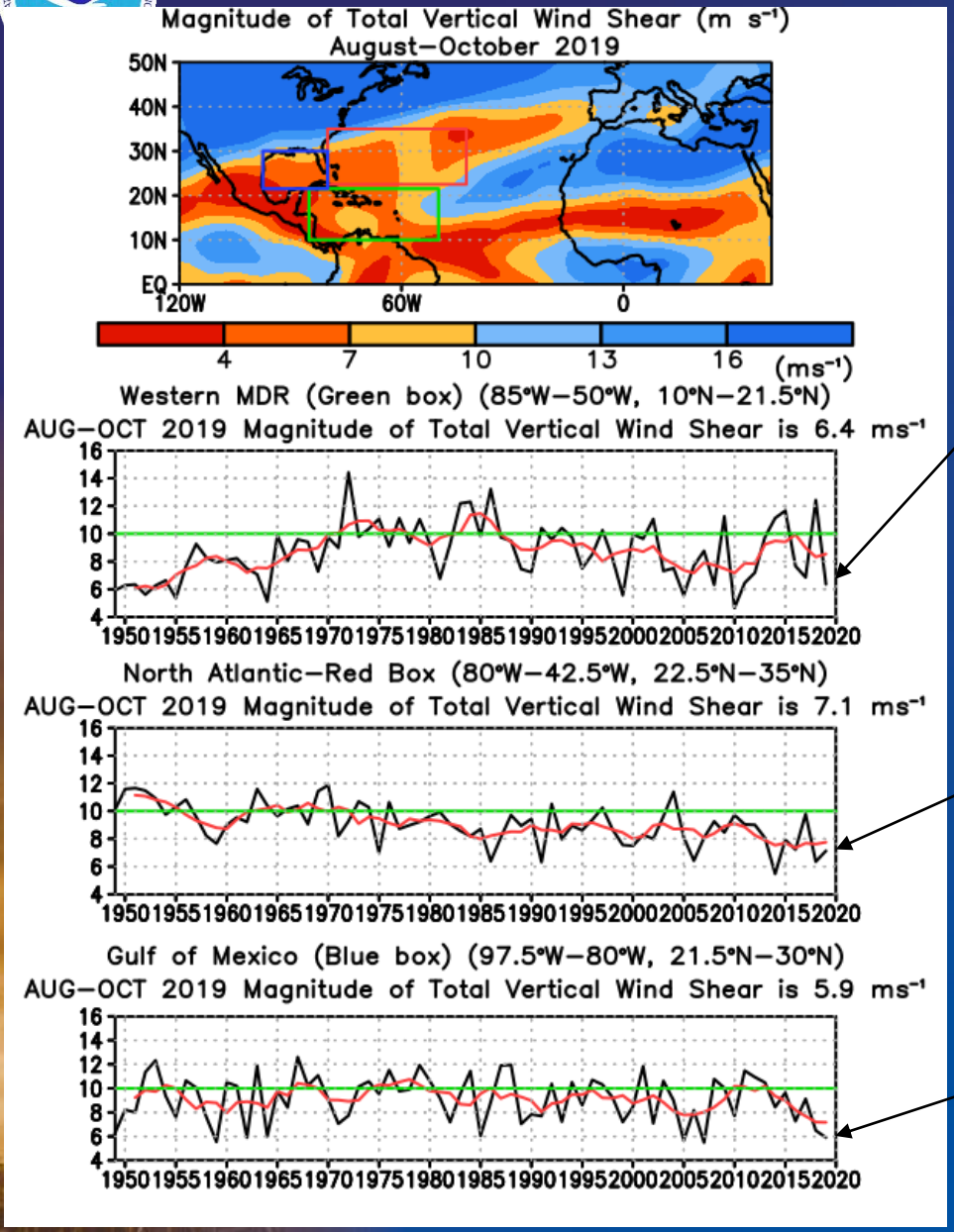
ACE index measures overall season strength by accounting for the combined intensity and duration of tropical storms and hurricanes.

MDR SST Anomalies During Aug-Oct 2019



- Above average SSTs in MDR during ASO 2019.
- The area-averaged SST anomaly in the MDR was +0.4 ºC.
- MDR was warmer (+0.10 ºC) than remainder of global Tropics.

Historical Time series of 200-850 hPa Vertical Wind Shear (m s^{-1})



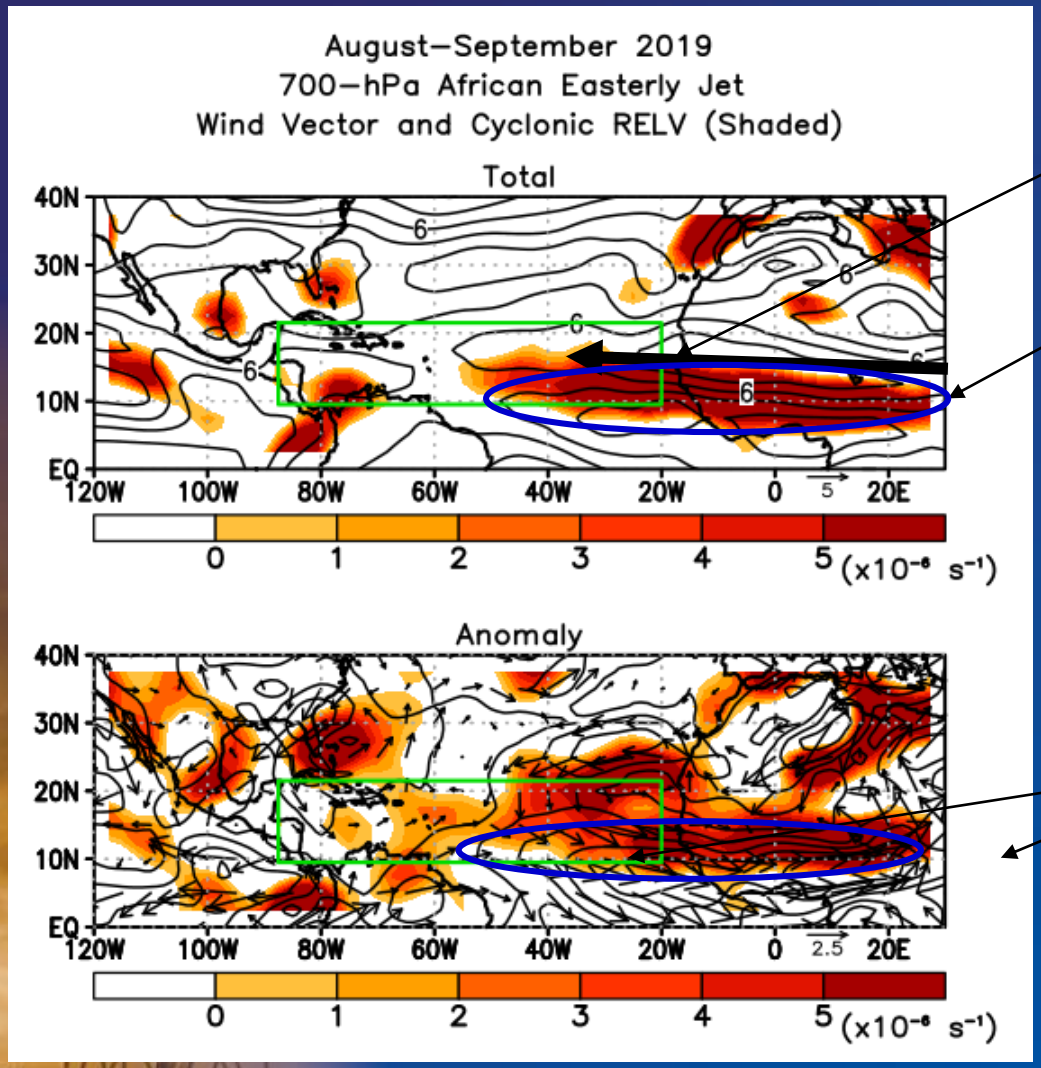
Weak vertical wind shear during ASO 2019 across western MDR, Gulf of Mexico, and subtropical western North Atlantic.

Western MDR (Blue Box)- Weak shear is typical of an above-normal season.

Western half of central North Atlantic (Red Box)- Weak shear in 2019 was also seen last year.

Gulf of Mexico (Green Box)— ASO 2019 was comparable to the weakest shear in the record

Aug-Sep 2019: 700-hPa Winds and African Easterly Jet Typify a more Active Season

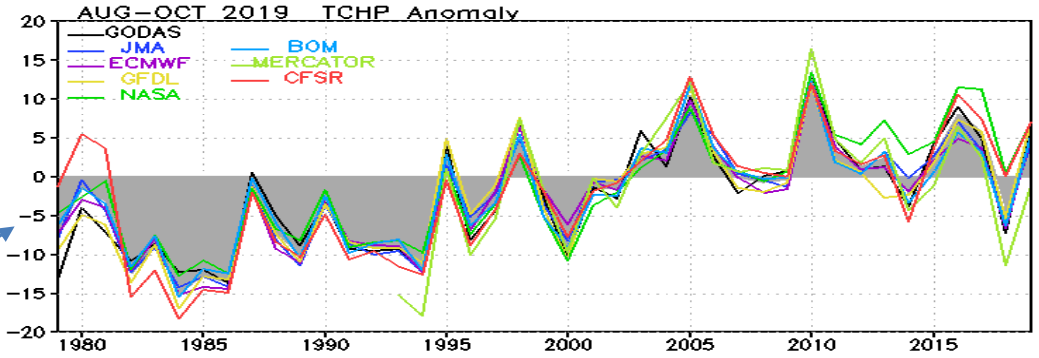


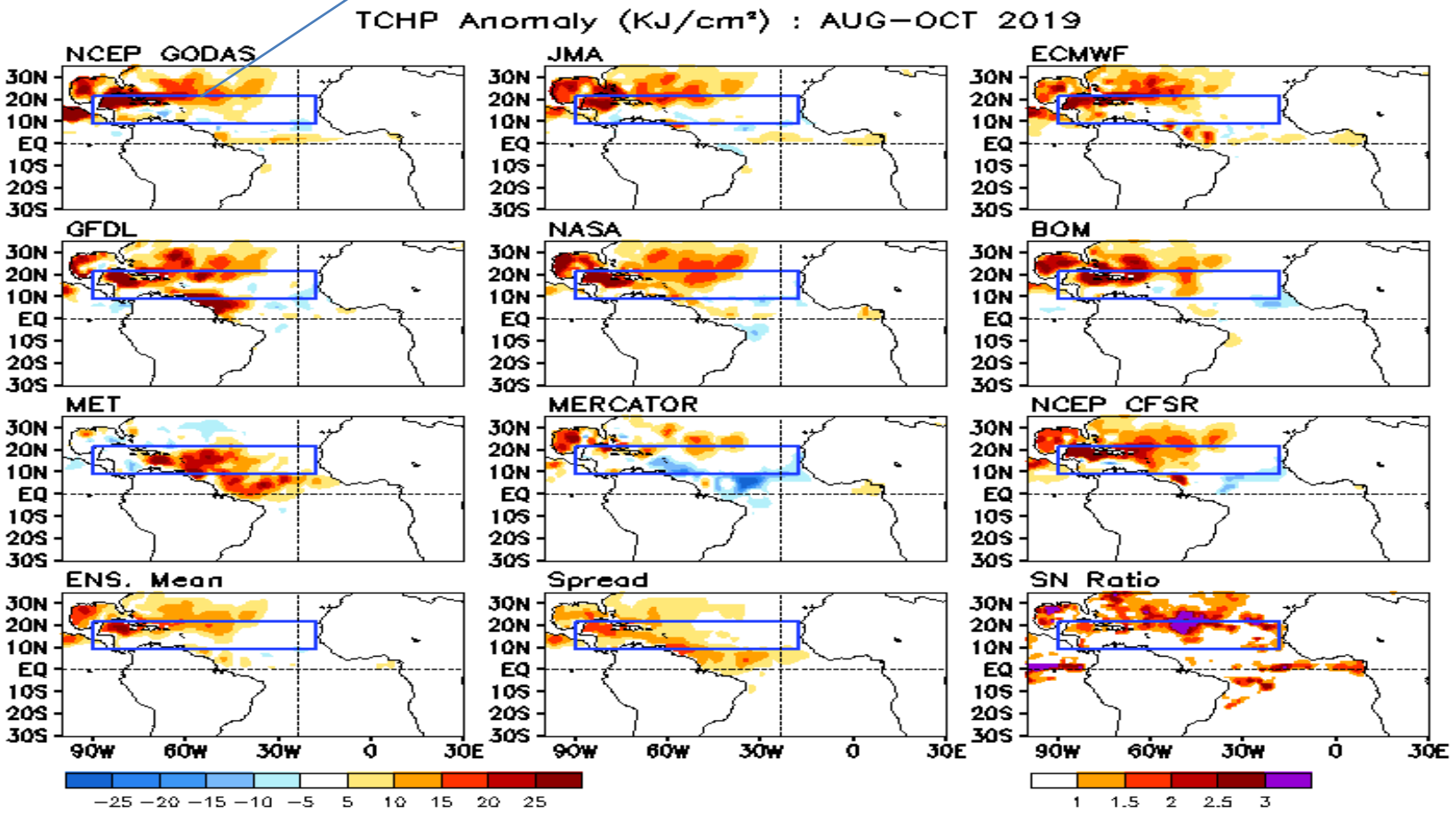
African Easterly Jet (AEJ) axis shifted north of normal.

Strong cyclonic relative vorticity (Red shading) along equatorward flank of AEJ extends across eastern MDR- typical of high-activity era for Atlantic hurricanes.

Weaker easterlies and increased cyclonic shear along equatorward flank of AEJ- typical of high-activity era for Atlantic hurricanes.

TCHP anomalies during ASO 2019

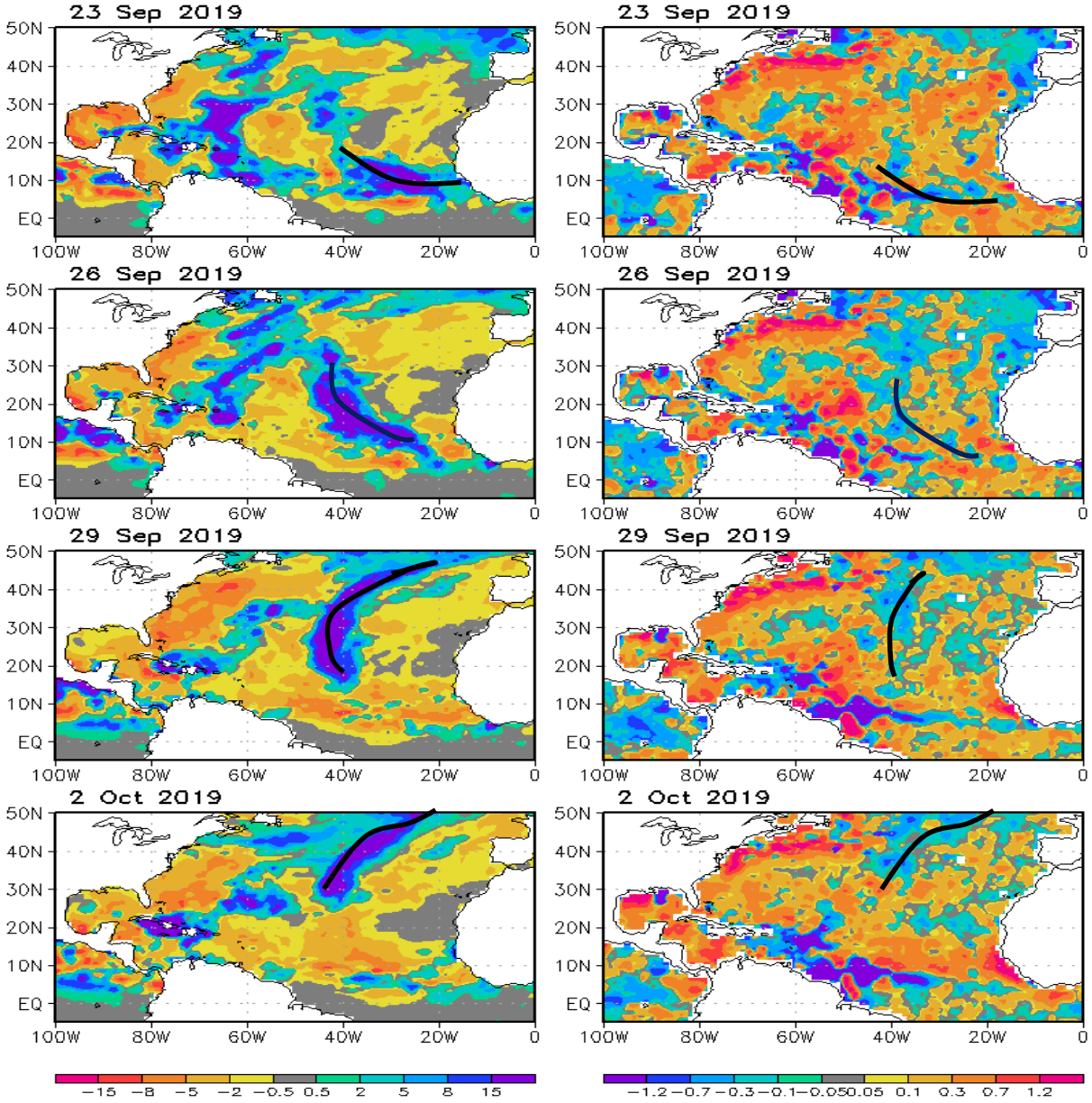


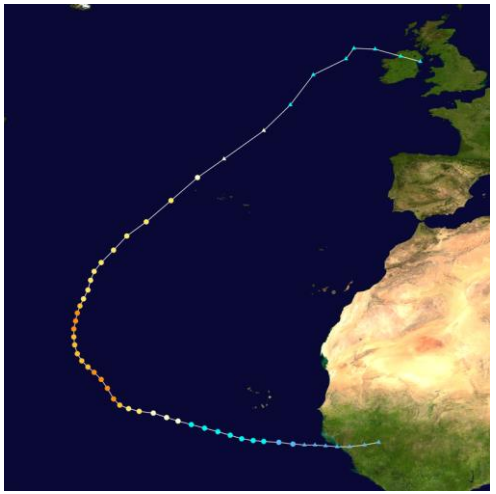


Footprints of Hurricane Lorenzo in precipitation and SSS anomalies

CMORPH Precipitation

BASS SSS

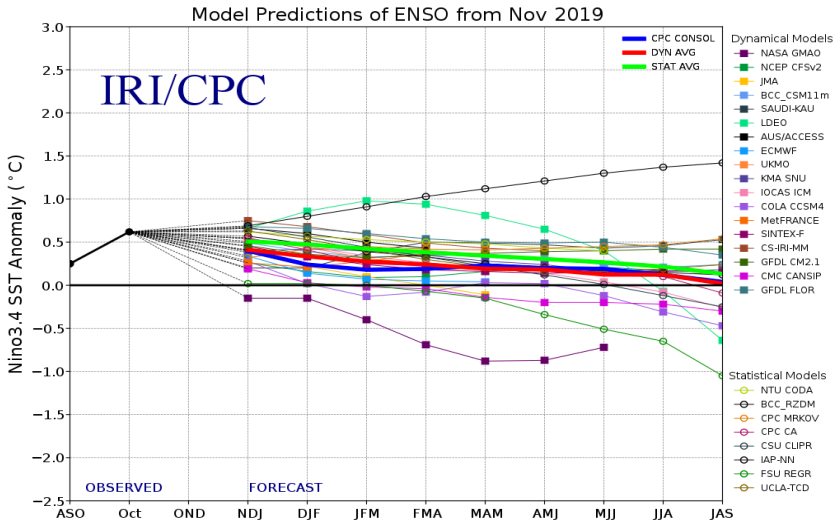


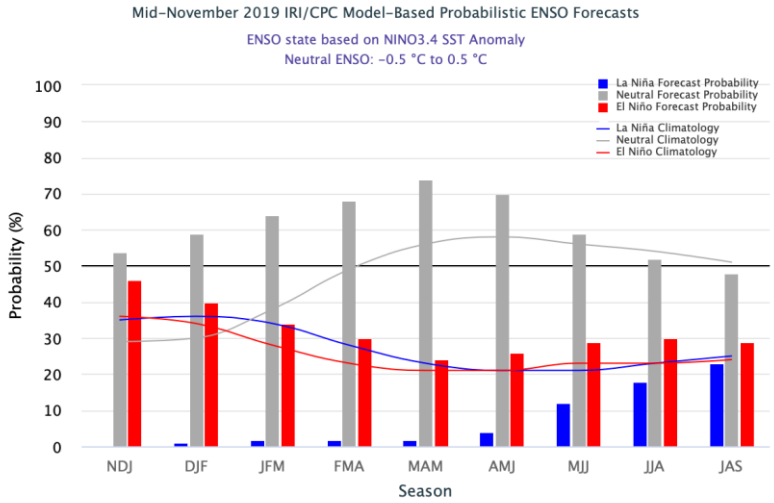


- **Lorenzo is the easternmost Category 5 Atlantic hurricane on record.**
- **Lorenzo left clear footprints in the pentad precipitation and SSS anomalies.**

ENSO and Global SST Predictions

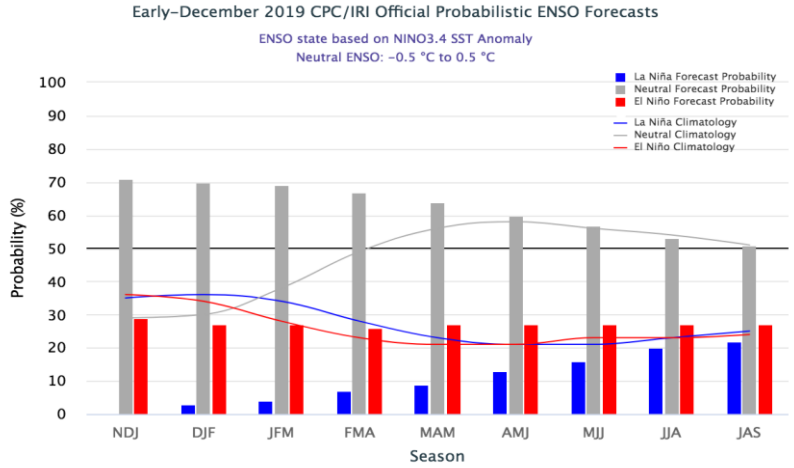
IRI/CPC NINO3.4 Forecast Plume





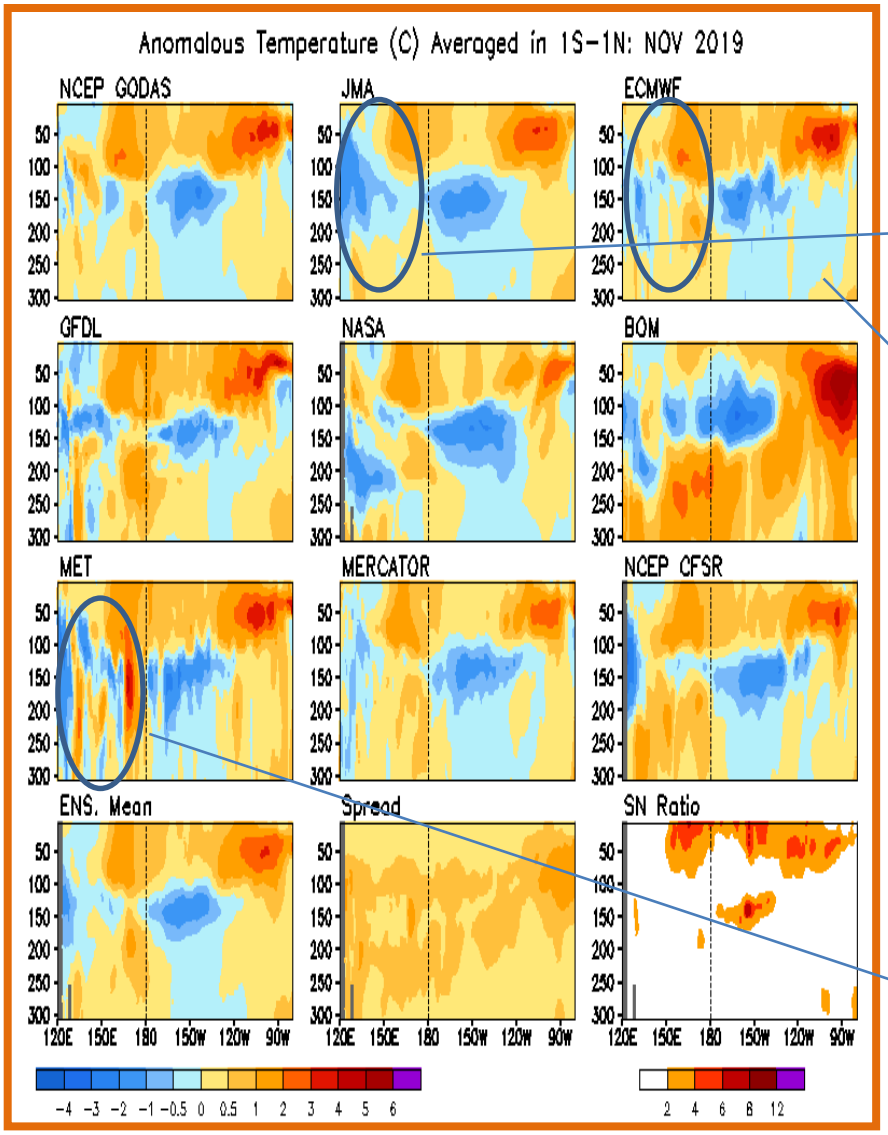
- **A majority of models favor ENSO-neutral through Northern Hemisphere spring 2020.**

- **NOAA "ENSO Diagnostic Discussion" on 12 Dec 2019 indicated that "ENSO-neutral is favored during the Northern Hemisphere winter 2019-20 (~70% chance), continuing through spring 2020 (~65% chance)"**

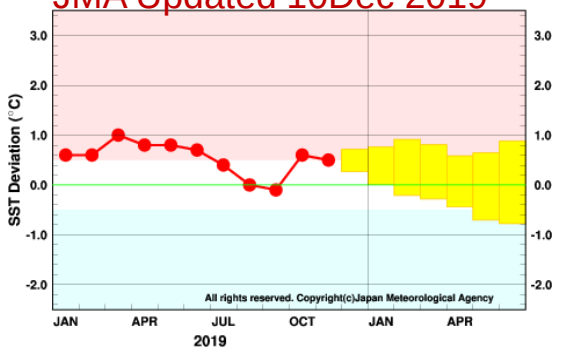


Individual Model Forecasts: ENSO neutral

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



JMA Updated 10Dec 2019



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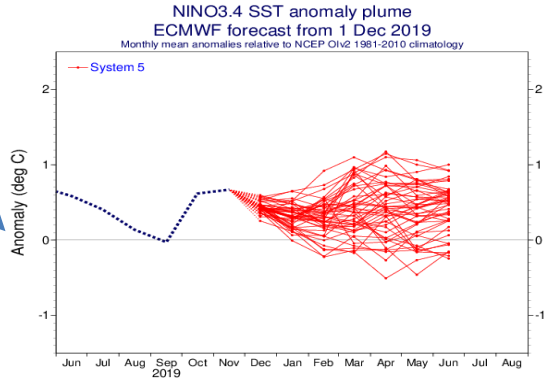
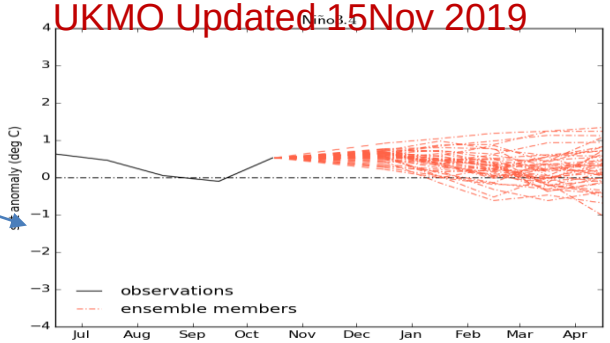
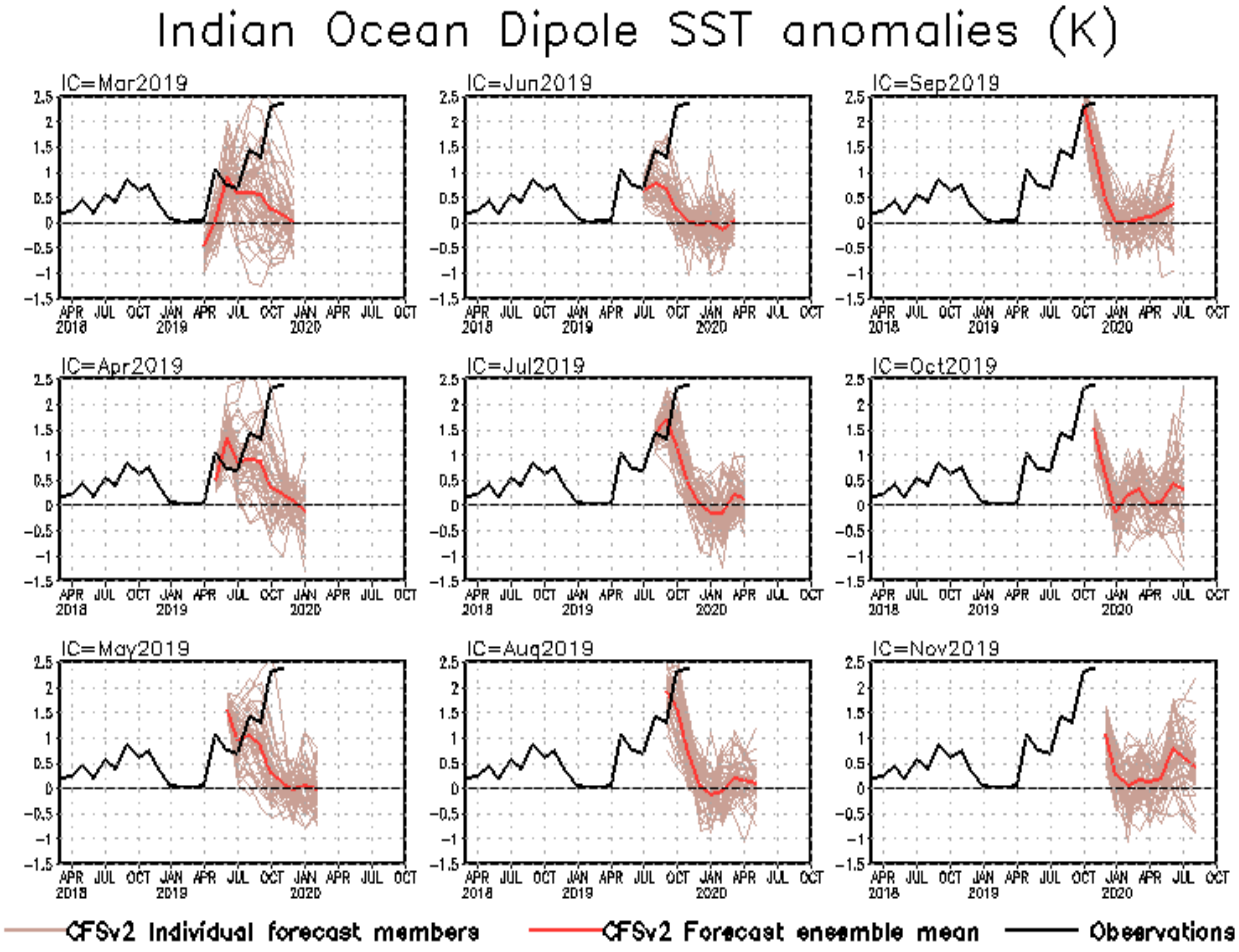


UKMO Updated 15Nov 2019



NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

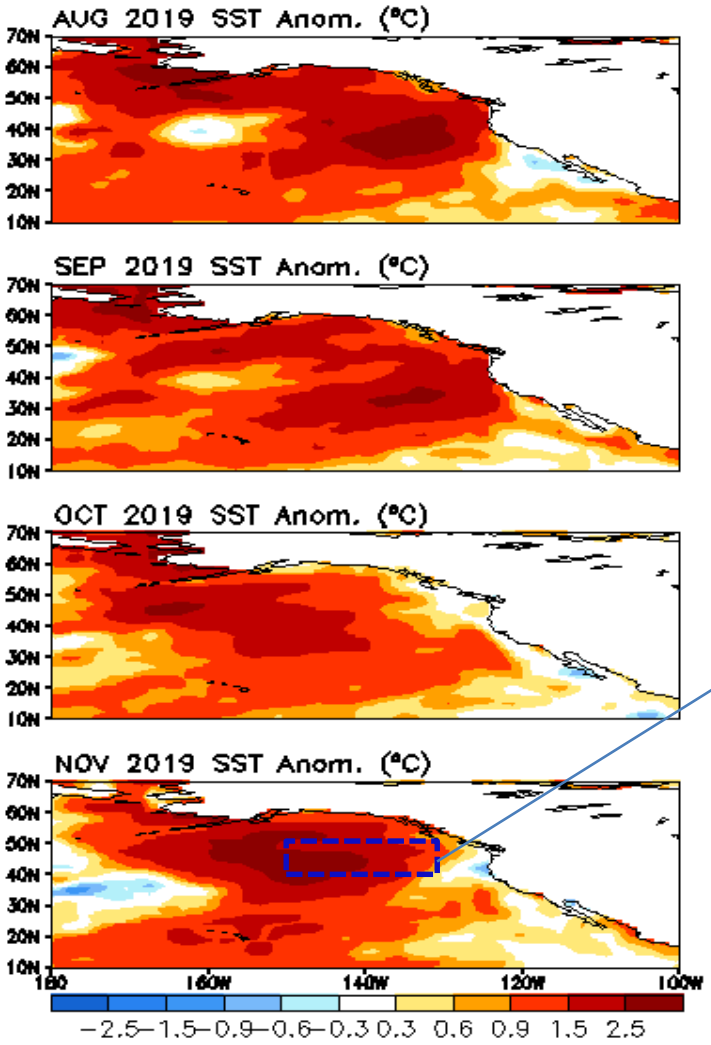
SETIO = SST anomaly in [90°E-110°E, 10°S-0]

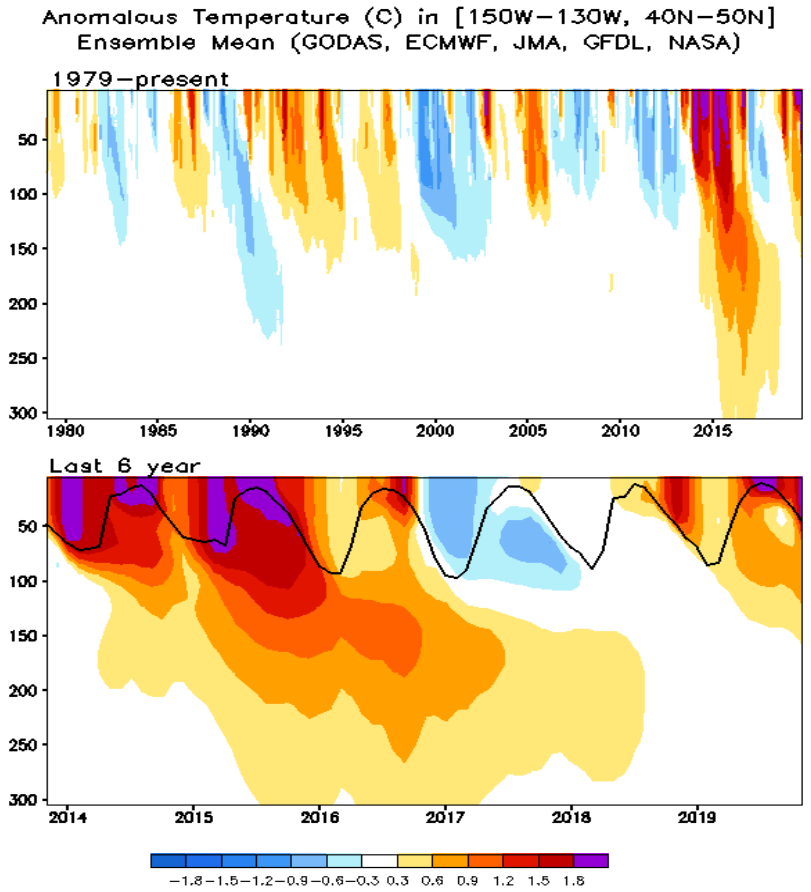
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

- **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 (MHW)

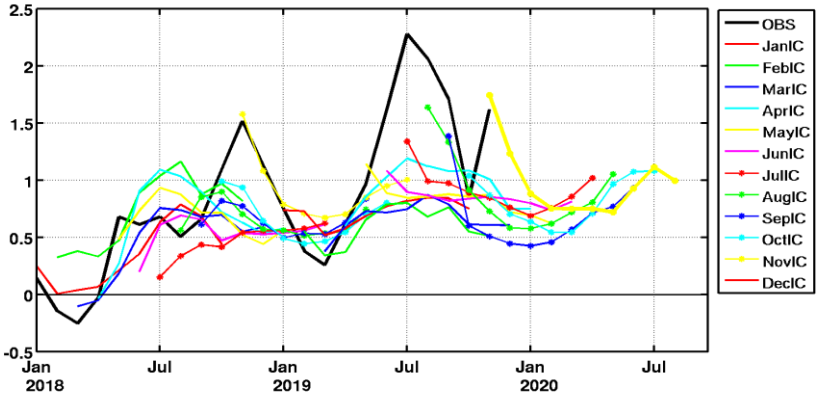




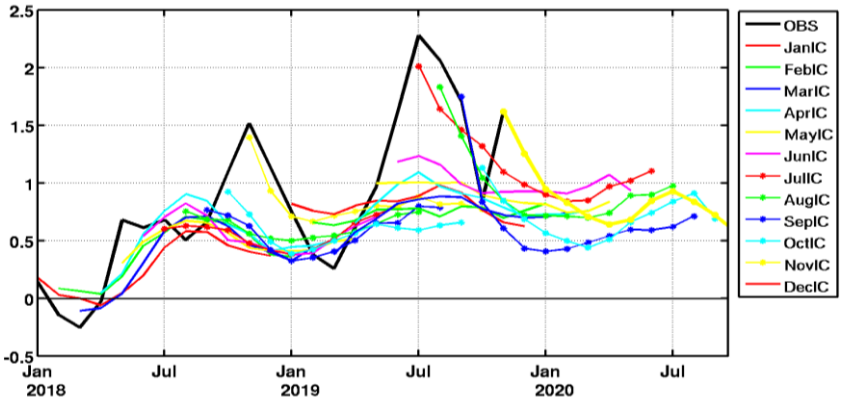
- **MHWs emerged off west coast of North America stretching from Alaska south to California over the past few months.**
- **Positive SST anomaly and subsurface warming in the NE Pac enhanced in Nov 2019.**

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

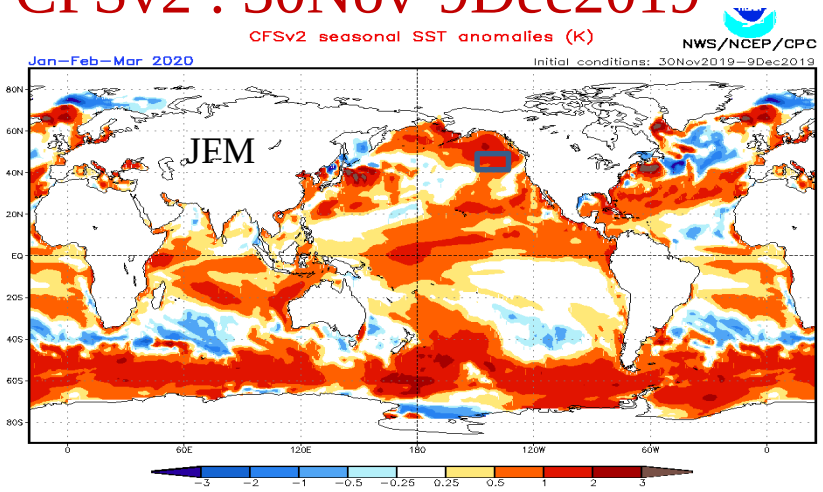
CFSv2



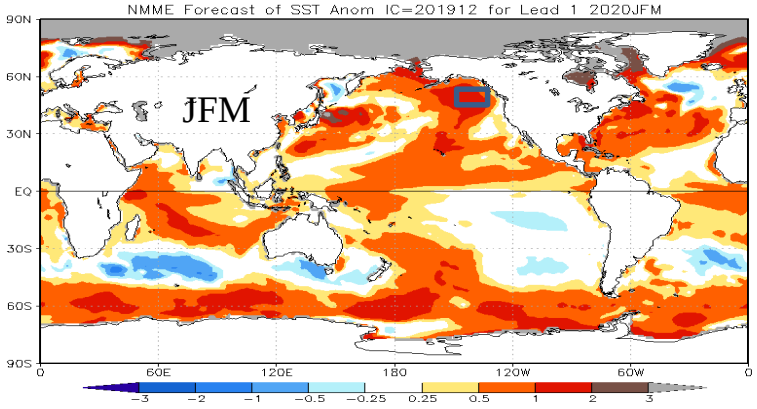
NMME



CFSv2 : 30Nov-9Dec2019



NMME: IC Dec2019



Acknowledgements

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

- Dr. Gerry Bell provided the summary about 2019 Atlantic hurricane season

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

- Dr. Wanqiu Wang provided the sea ice forecasts

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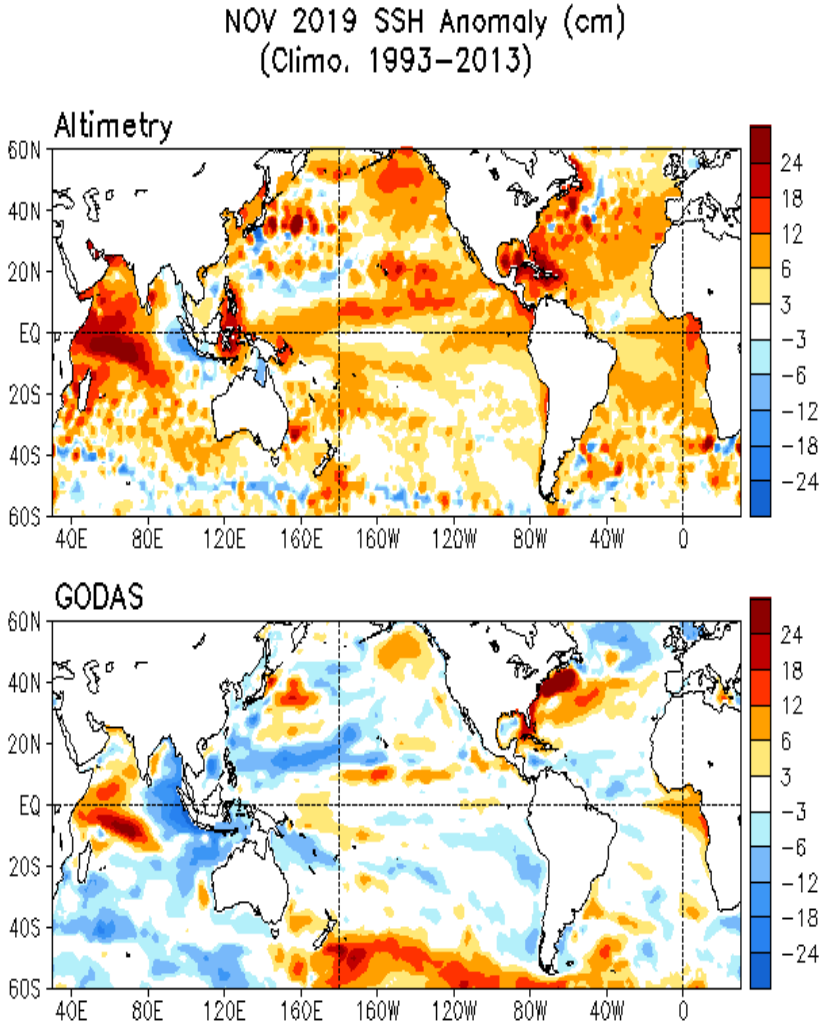
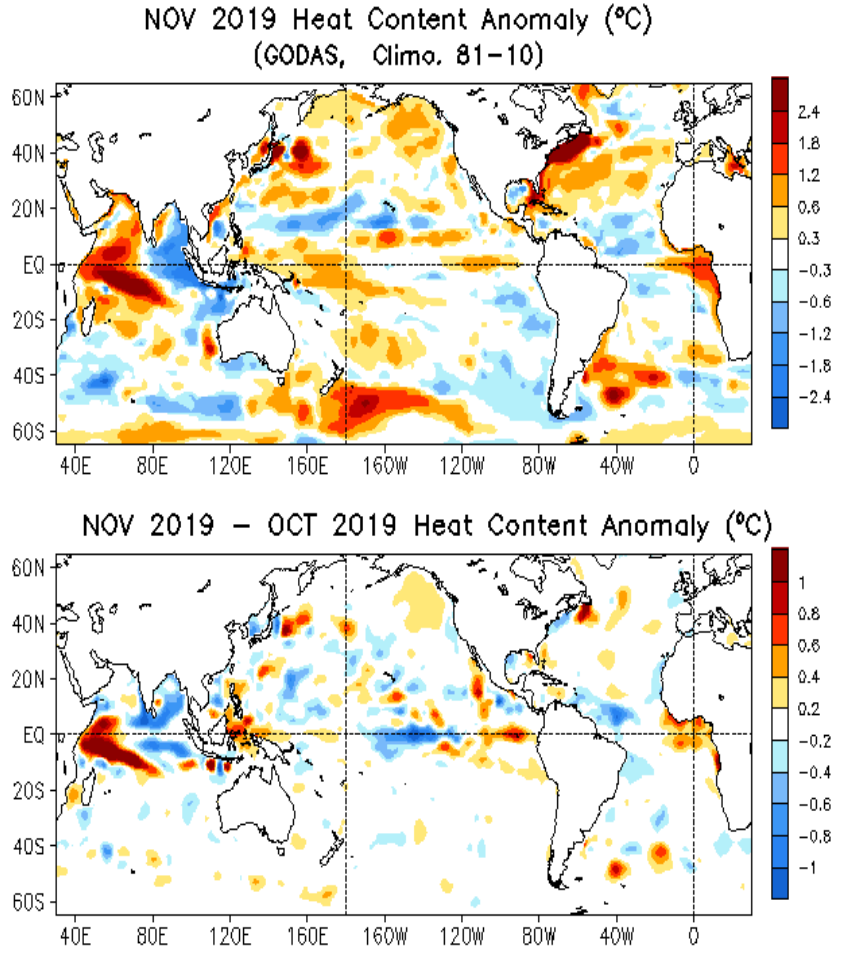
Jieshun.Zhu@noaa.gov

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

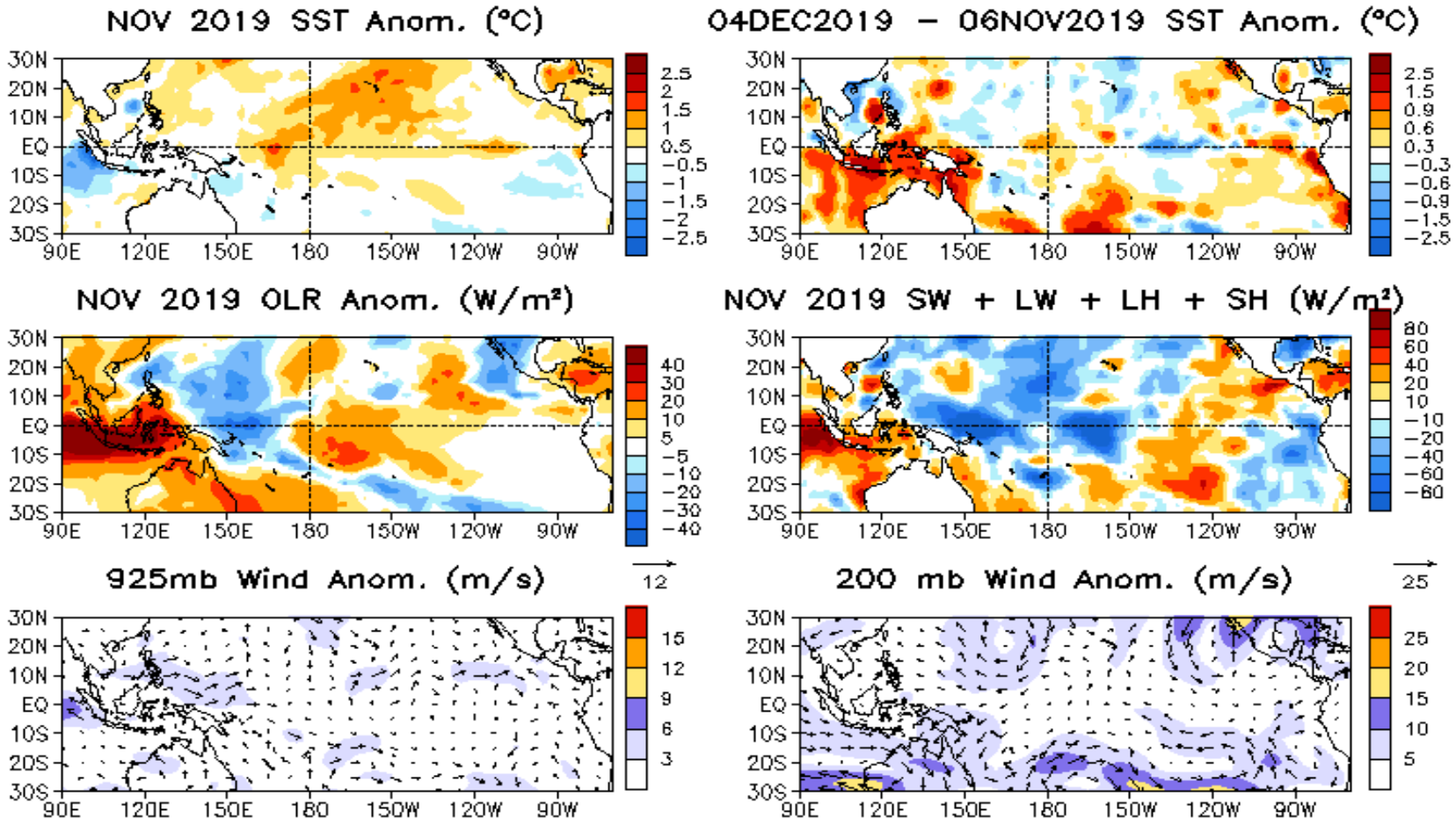
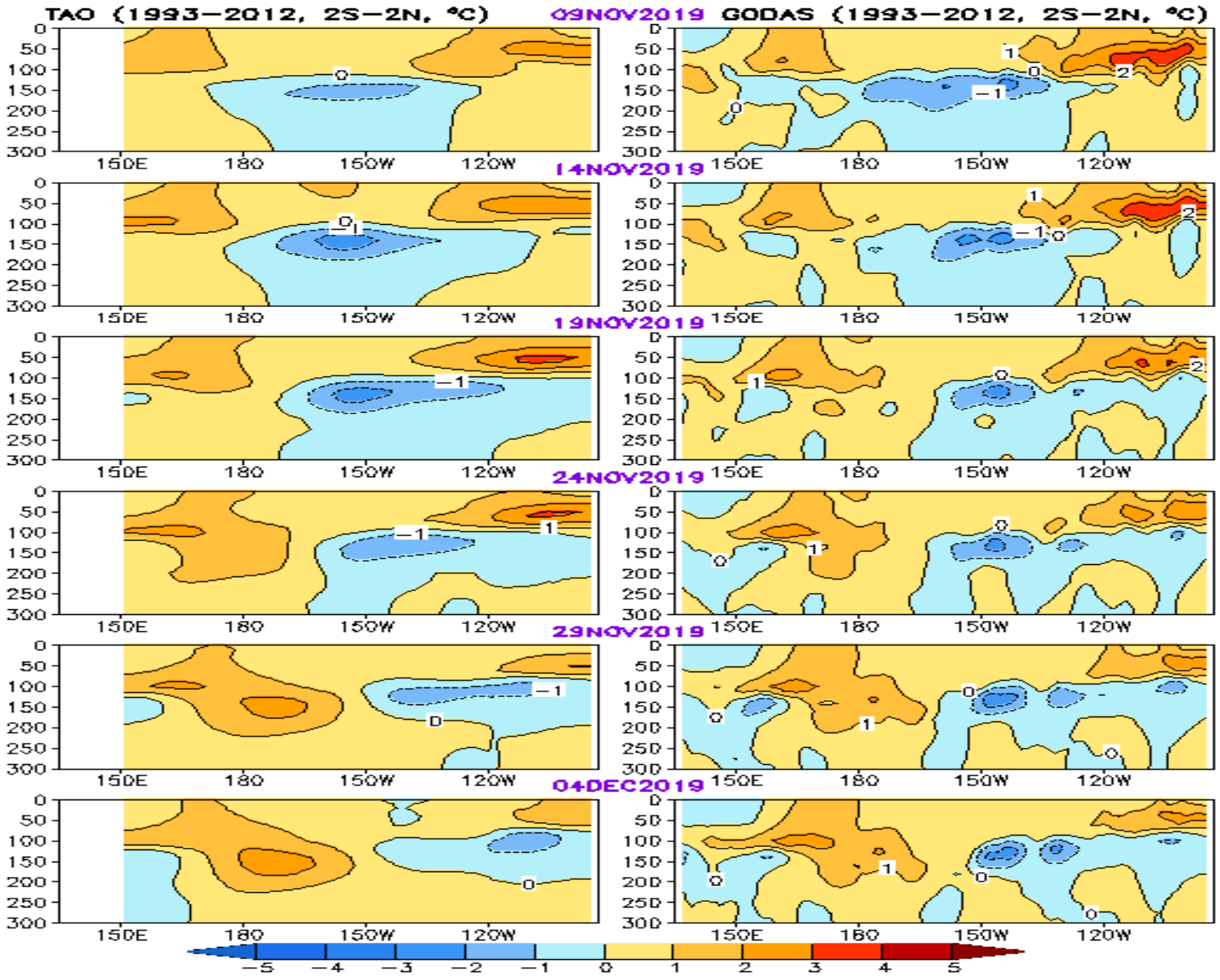


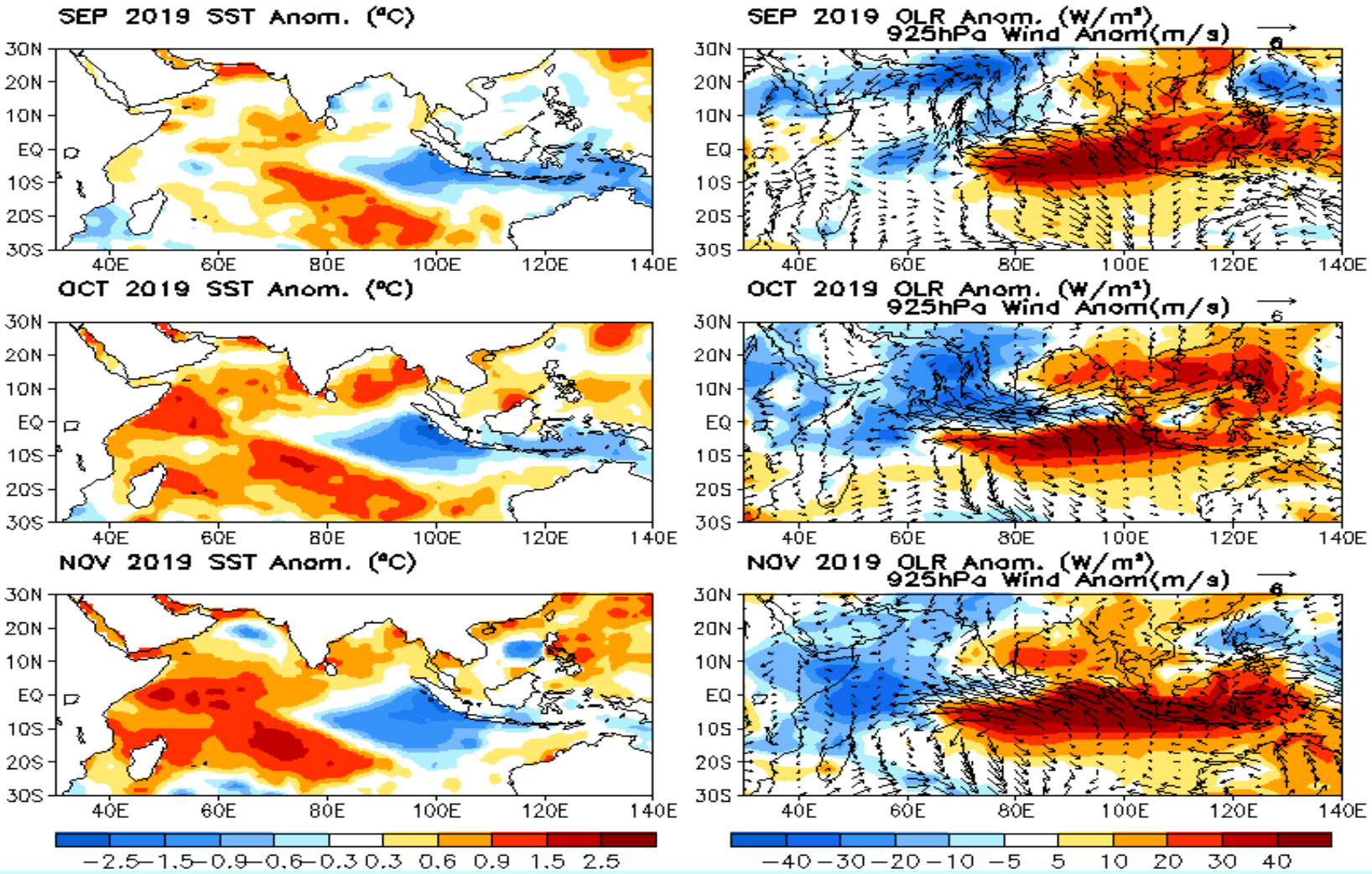
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

TAO GODAS



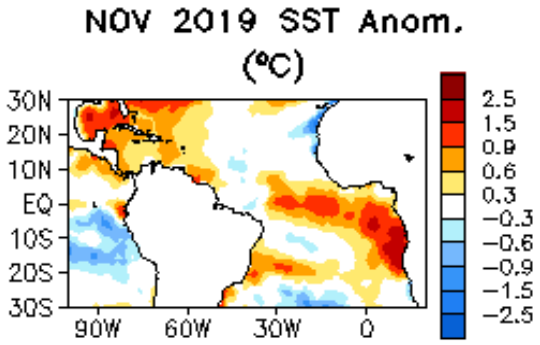
Last three month SST, OLR and 925hPa wind anomalies

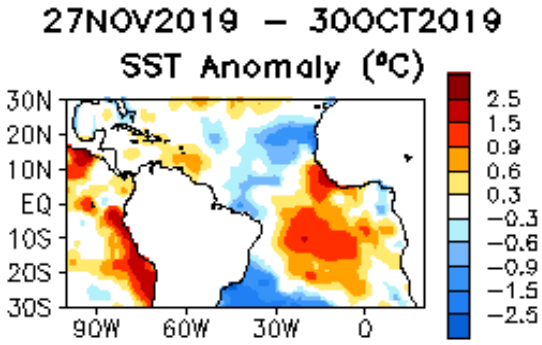


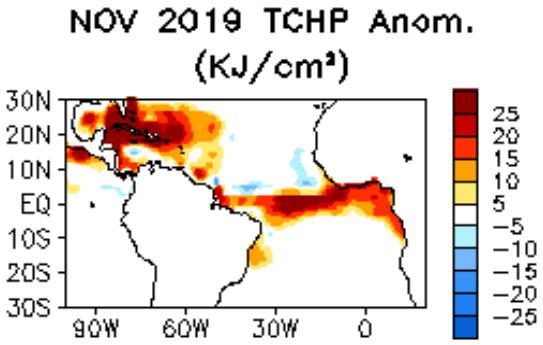
- Positive (negative) SSTAs persisted in the west and central (eastern) Indian Ocean during the last three months.
- Anomalous easterlies continued to prevail over the equatorial Indian Ocean in Nov 2019.

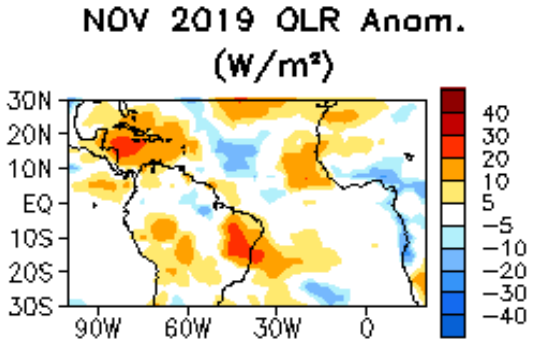
Tropical Atlantic:

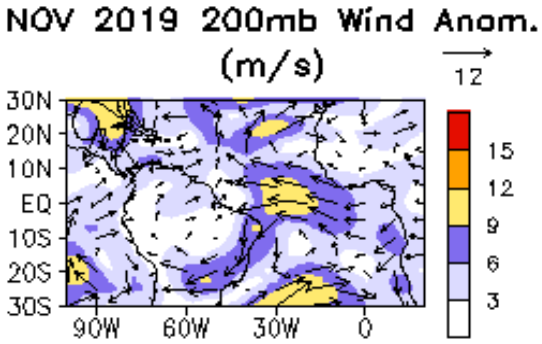
SST, SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, TCHP, 925-mb/200-mb Winds anom.

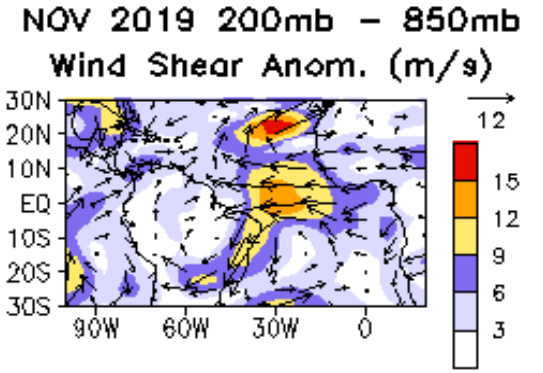


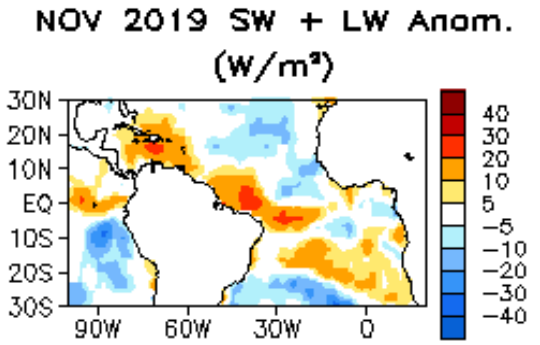


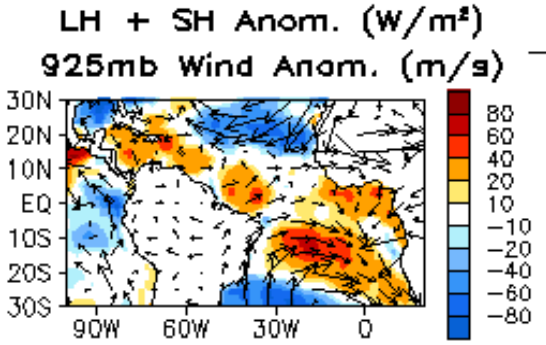


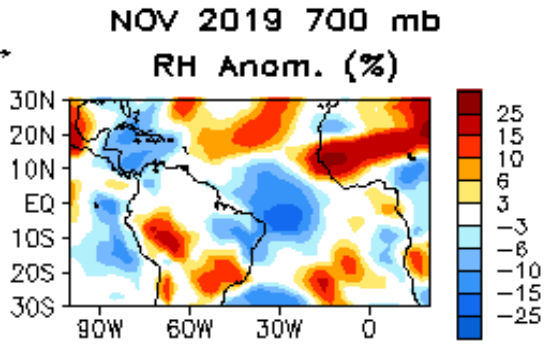




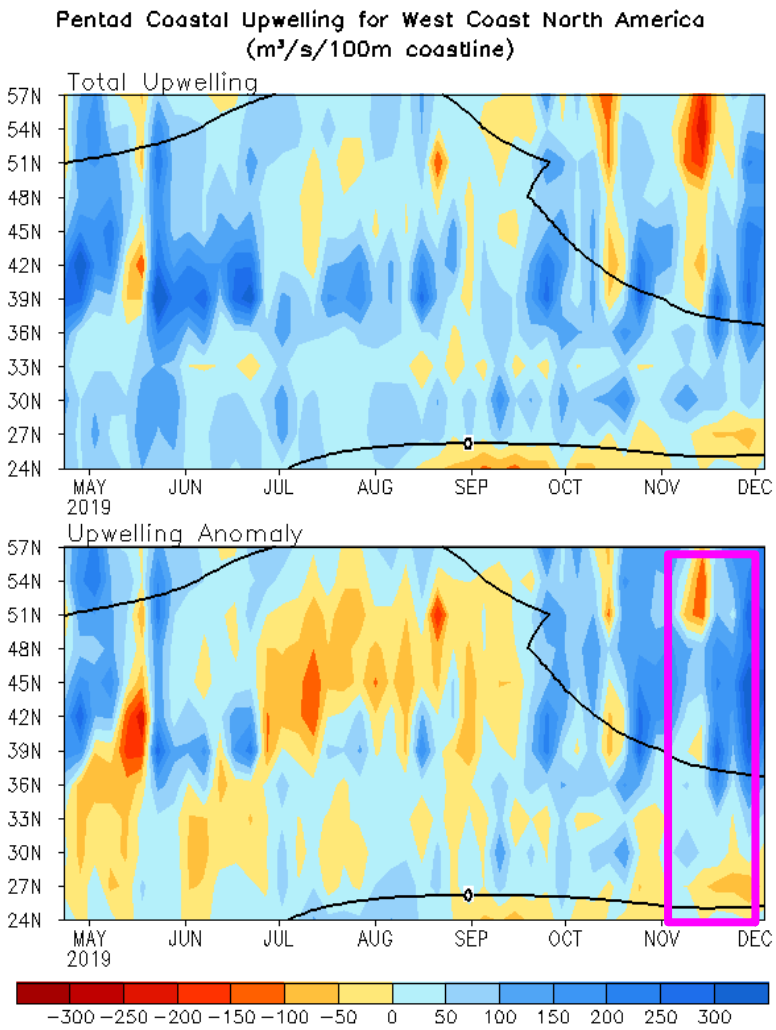


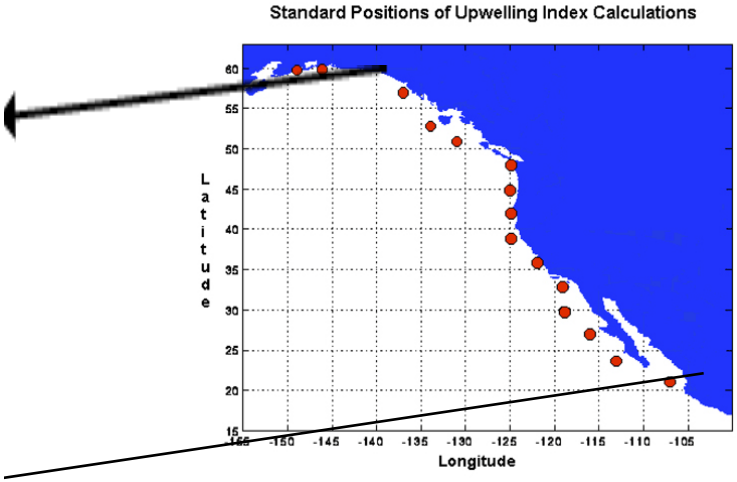






North America Western Coastal Upwelling



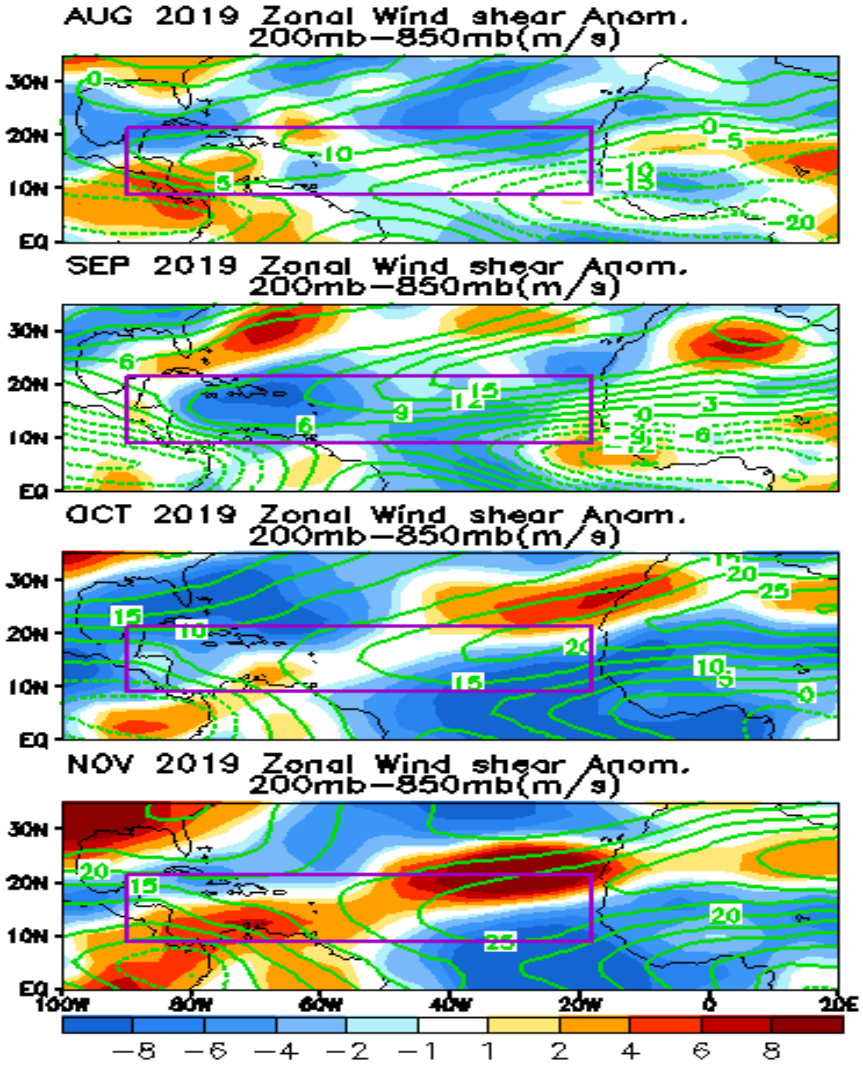


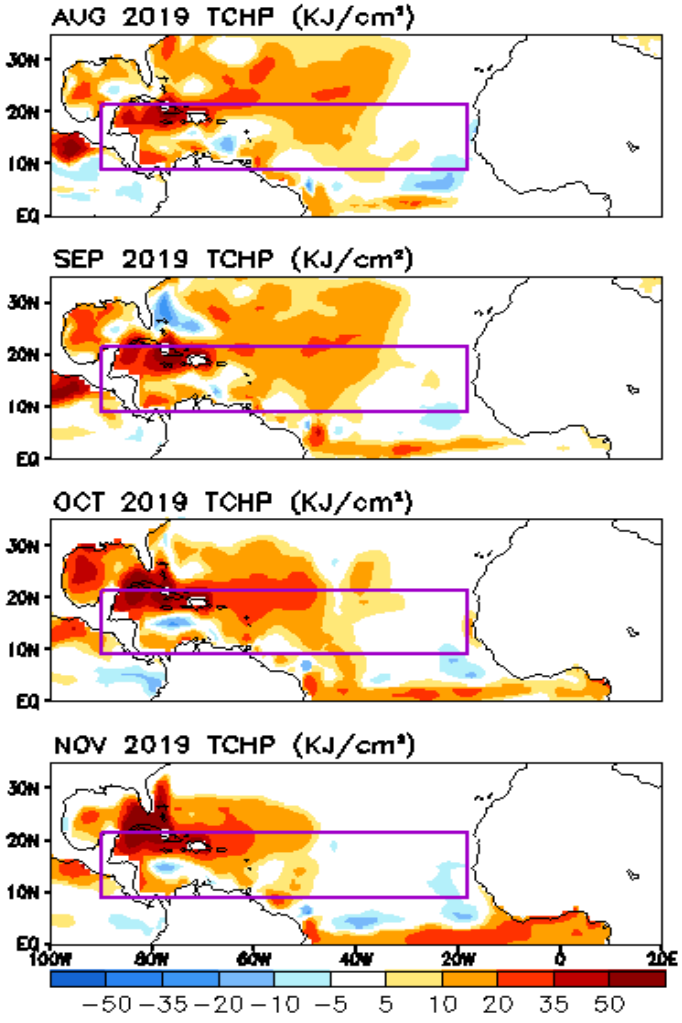
- Anomalous upwelling dominated along the coastal line in Nov 2019.

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 ($m^3/s/100m$ coastline). Anomalies are departures from the 1981-2010 base period pentad means.

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

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.**

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

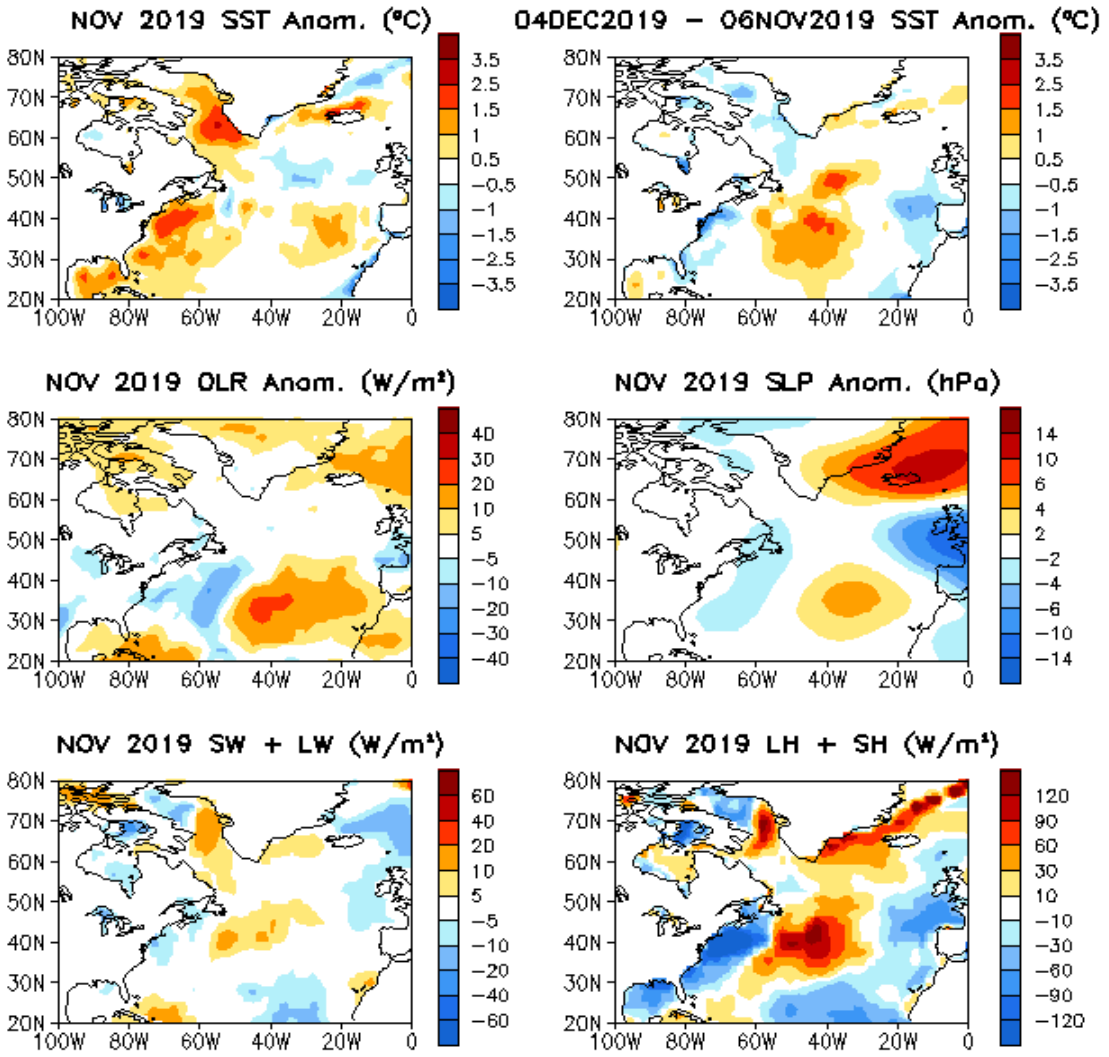
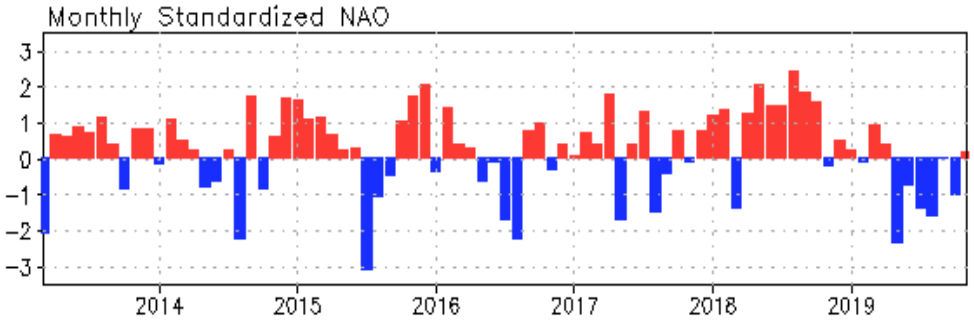
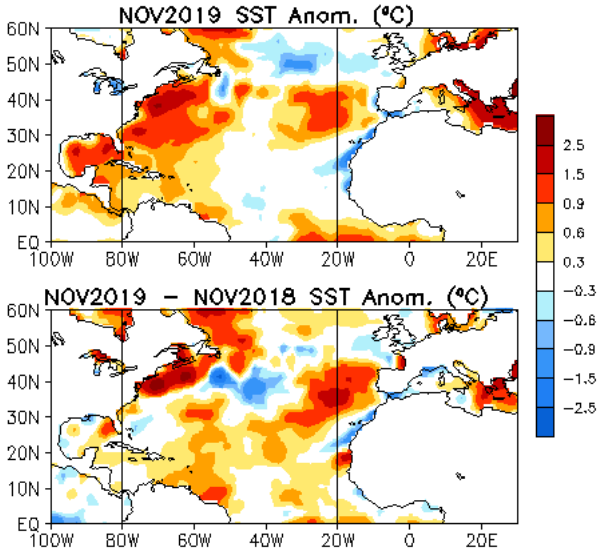
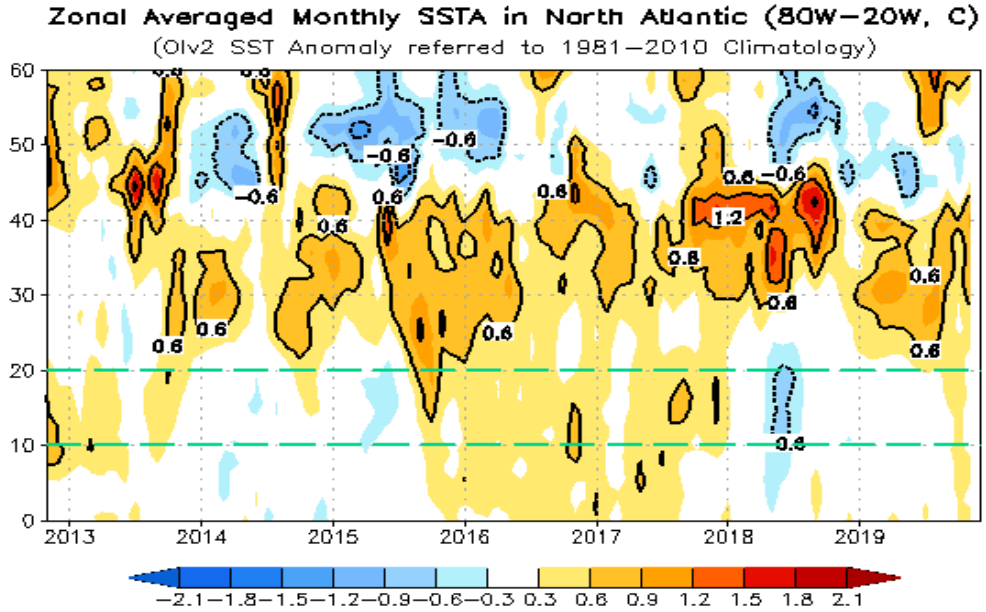


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

NAO and SST Anomaly in North Atlantic





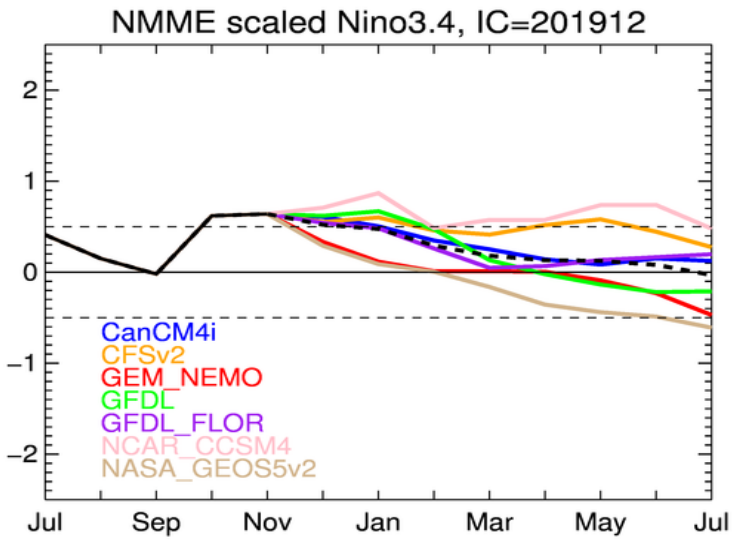


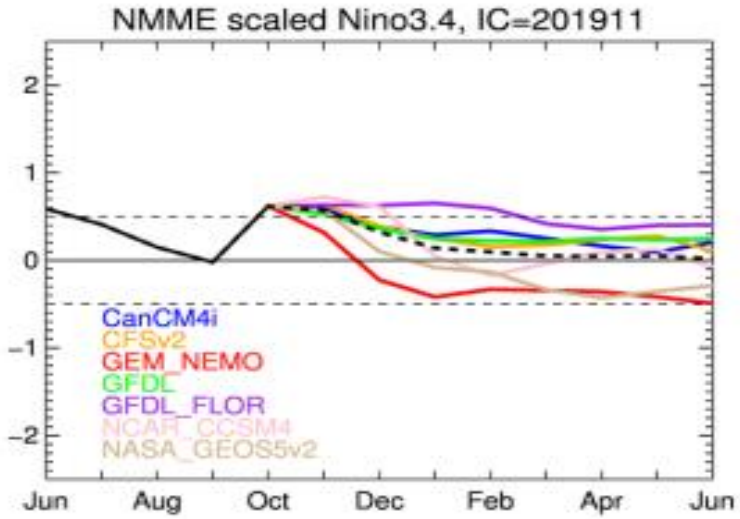
- **NAO switched to Positive phase in Nov 2019 with NAOI= 0.16**
- **Tripole/horseshoe-like pattern with positive in the midl-latitudes and negative in the lower and higher latitudes, has been less evident since May 2019.**

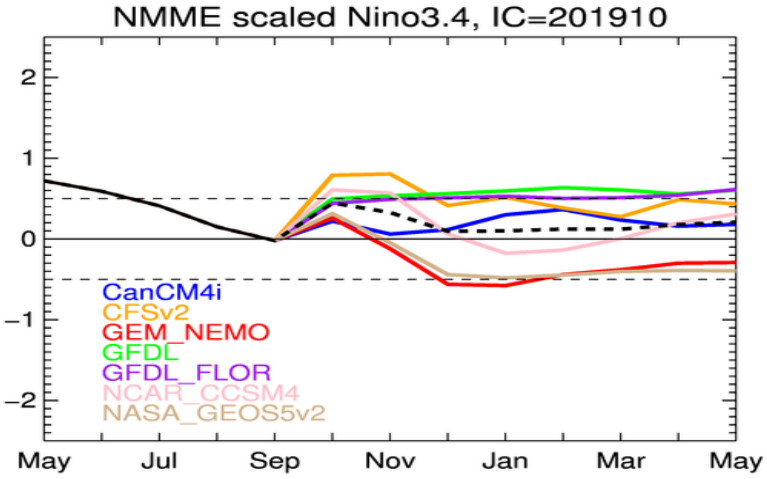
Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis,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

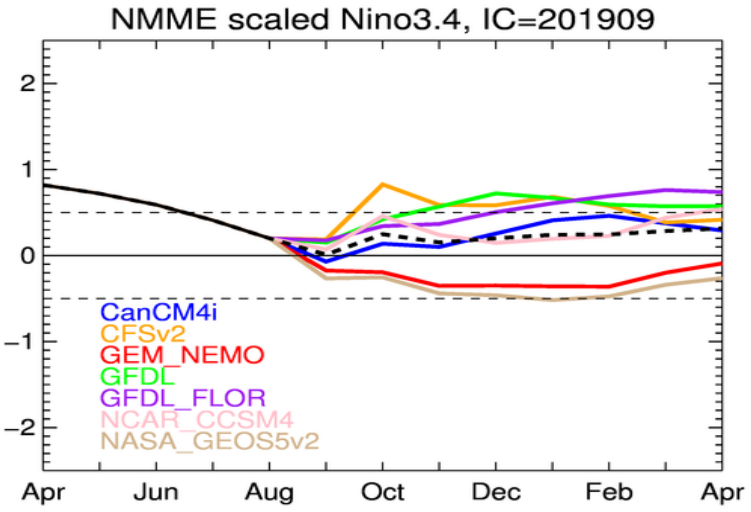
NMME Niño3.4 SST Predictions: ENSO neutral

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

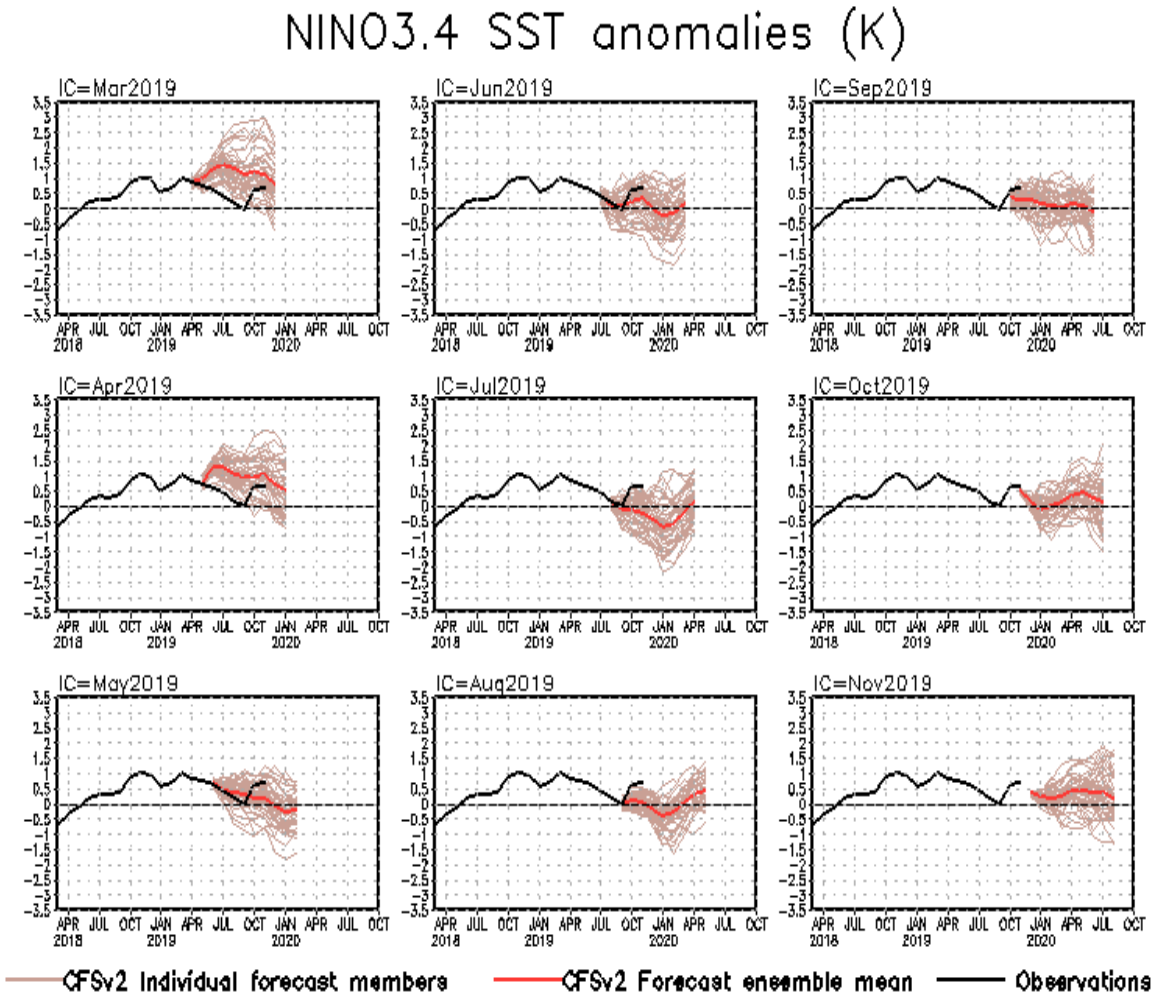








CFS Niño3.4 SST Predictions from Different Initial Months

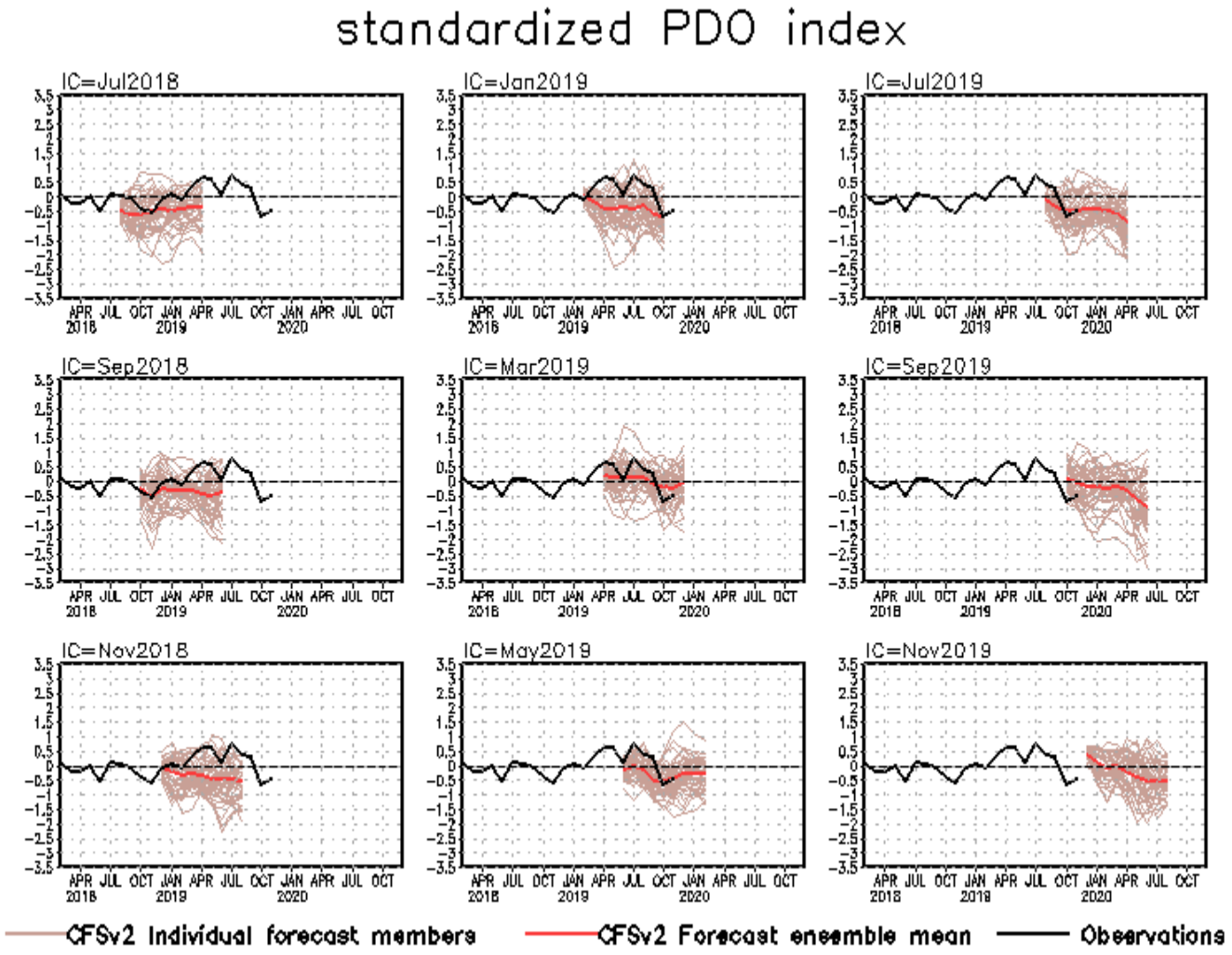


- CFSv2 predicted a decline of positive SSTAs with ICs since Mar 2019.

- 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.

CFS Pacific Decadal Oscillation (PDO) Index Predictions



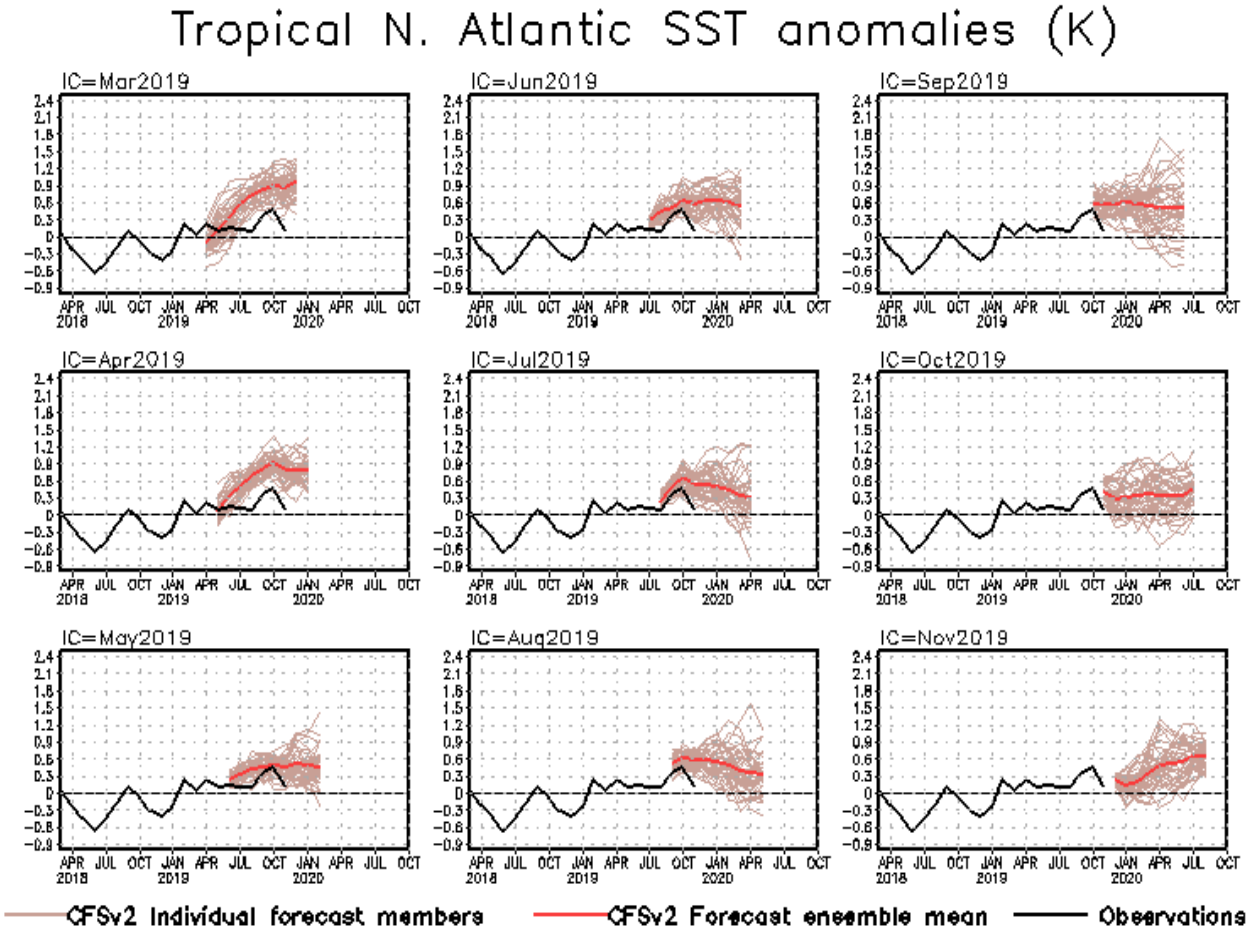
PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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.

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.

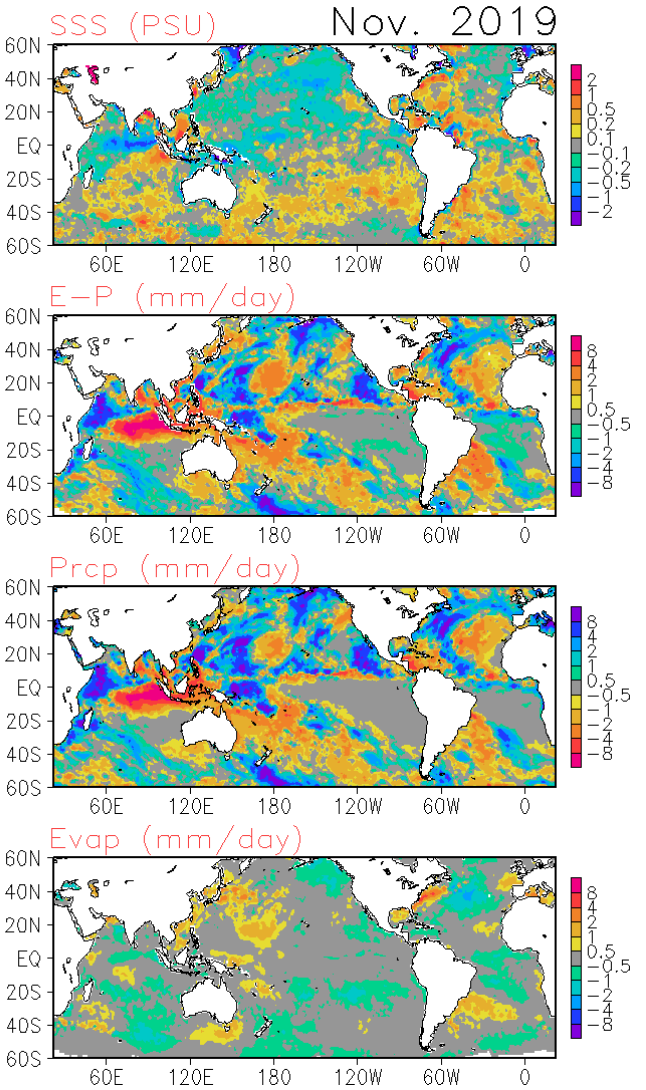
Global Sea Surface Salinity (SSS)

Anomaly for November 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 continuing in the northeast Pacific ocean and west basin of Equatorial Pacific ocean, both of which are co-incident with enhanced precipitation. Negative SSS signal shows in the east basin of N. Atlantic Ocean with reduced precipitation indicating that such anomalies are likely caused by oceanic advection/entrainments. In the Indian Ocean, the dipole pattern of negative/positive SSS signal is persistent, while the positive anomalies extends to the north.

- **Data used**

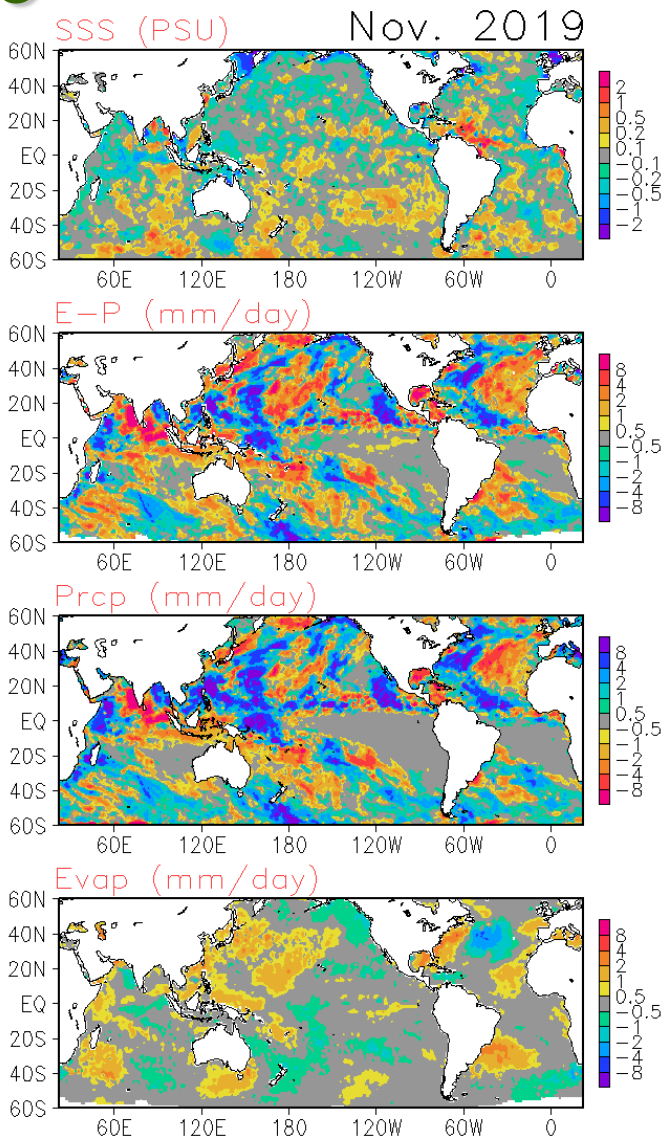
SSS : Blended Analysis of Surface Salinity (BASS) V0.Z
(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
(Xie et al. 2014)
ftp.cpc.ncep.noaa.gov/precip/BASS
Precipitation: CMORPH adjusted satellite precipitation estimates
Evaporation: Adjusted CFS Reanalysis



Global Sea Surface Salinity (SSS)

Tendency for November 2019

Compared with last month, the negative SSS signal in the west Equatorial Pacific ocean became stronger due to the enhanced precipitation in this area. In the Indian ocean, the SSS decreased in the west basin with increasing precipitation, and the SSS increased in the east basin south of equator with decreasing precipitation. The SSS significantly increased in the west basin nearby coast between equator and 20ºN in the Atlantic Ocean. However, the freshwater flux input is increased in this area suggesting that the change is caused by the oceanic advection.

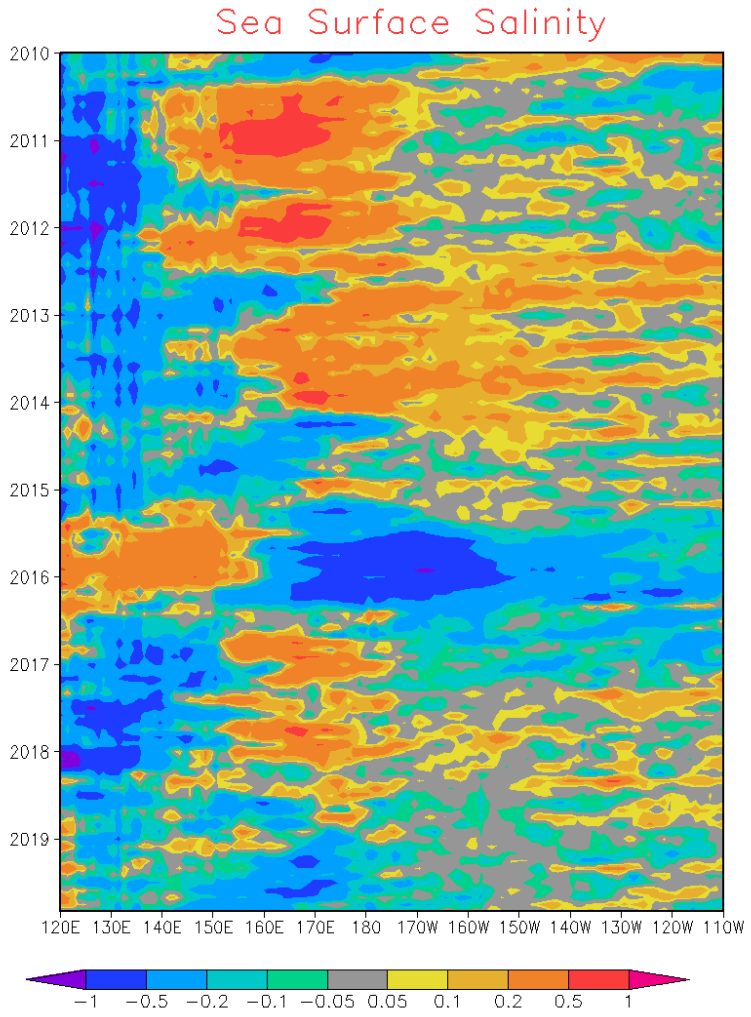


Global Sea Surface Salinity (SSS)

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.

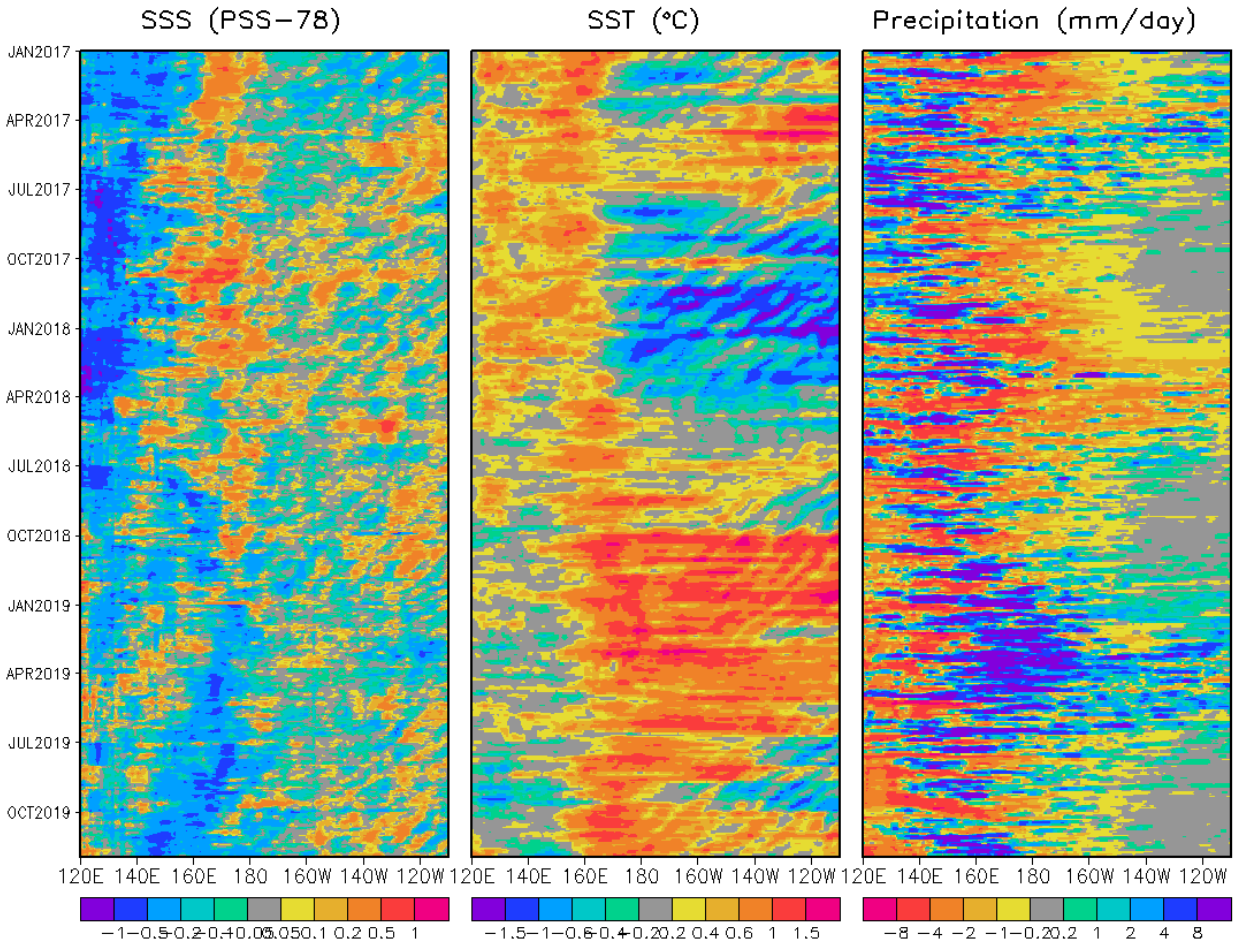
- Hovemoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- In the equatorial Pacific Ocean, the SSS signal is negative west of 160°W with stronger signals between 140°E and 180°E; the SSS anomalies show positive signals east of 150°W.



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