2018 Annual Ocean Review

Prepared by
Climate Prediction Center, NCEP/NOAA

February 14, 2019

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

- Annual Ocean Review for 2018

- Highlights in January 2019
  - Pacific/Arctic Ocean
  - Indian Ocean
  - Atlantic Ocean

- Global SST Predictions

- Tools for monitoring salinity and freshwater flux variability

Data Sources and References

(climatology is for 1981-2010)

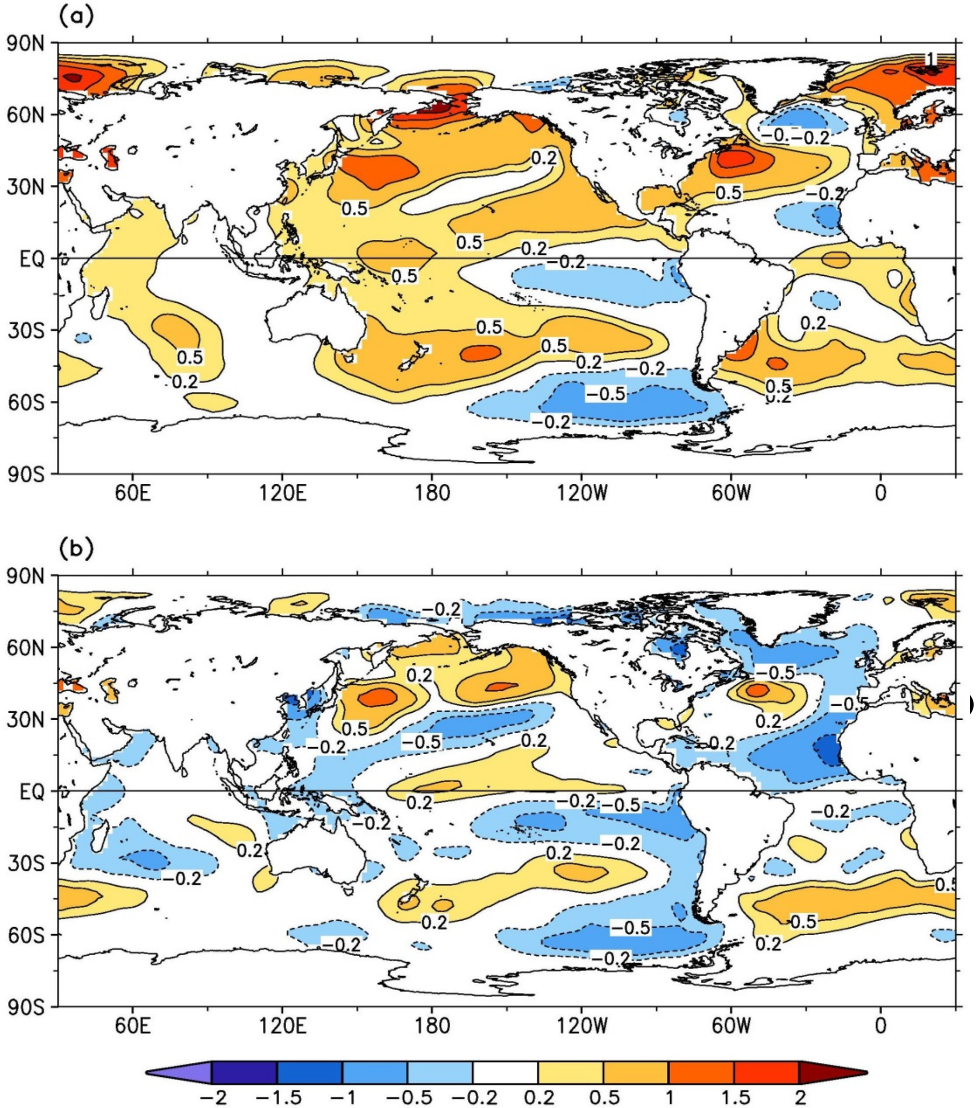
- **Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)**
- **Extended Reconstructed Sea Surface Temperature (ERSST) v5 (Huang et al. 2017)**
- **Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)**
- **CMORPH precipitation (Xie et al. 2017)**
- **CFSR evaporation adjusted to OAFlux (Xie and Ren 2018)**
- **NCEP CDAS winds, surface radiation and heat fluxes (Kalnay et al. 1996)**
- **NESDIS Outgoing Long-wave Radiation**
- **NCEP's Global Ocean Data Assimilation System 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 reanalyses from Real-time 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

Please send your comments and suggestions to Yan.Xue@noaa.gov. Thanks!

2018 Yearly Mean SST Anomaly and Tendency



- Positive SSTA dominated in the global ocean with maximum warming in the western North Pacific, the western North Atlantic, the Arctic and mid-latitude South Oceans.
- Negative SSTA presented in limited regions, including the southeastern tropical Pacific, south of Greenland, near the coast of North Africa, and high-latitude South Pacific Ocean.

- There was a cooling tendency over most of the global ocean except a warming tendency in the mid- and high-latitude North Pacific, the central equatorial Pacific, the western North Atlantic and mid-latitude South Ocean.

Fig. 3.1. (a) Yearly mean ERSSTv5 anomaly (°C, relative to 1981-2010 average) in 2018, (b) 2018 minus 2017 ERSSTv5 anomaly.

Global SST Section in the BAMS State of the Climate in 2018 by Huang et al.

Seasonal Mean SST Anomaly in 2018

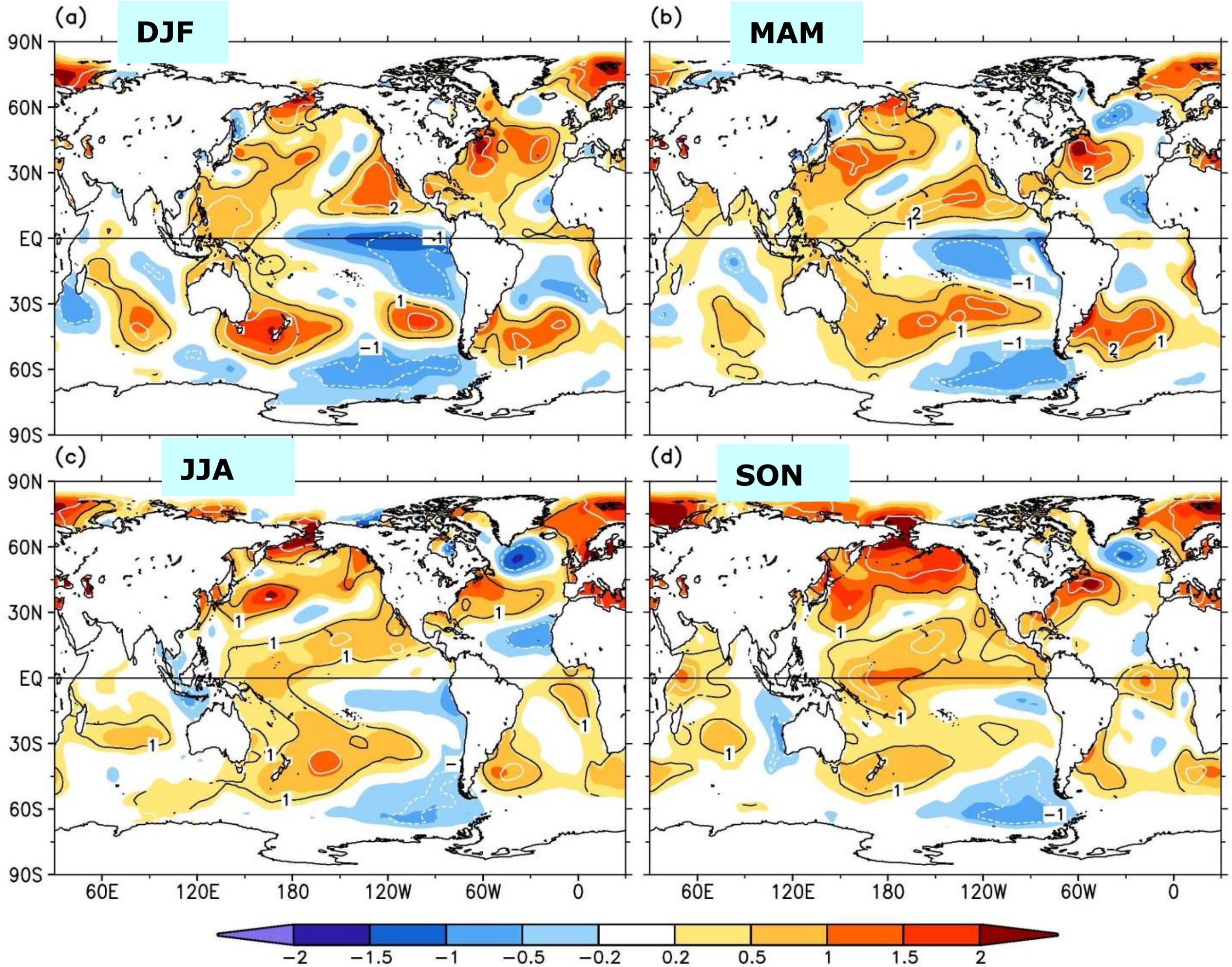


Fig. 3.2. Seasonal mean SSTA from ERSSTv5 (shading, ºC, relative to 1981-2010 average) for (a) December 2017 to February 2018, (b) March to May 2018, (c) June to August 2018 and (d) September to November 2018. The normalized seasonal mean SSTA based on seasonal mean standard deviation (STD) over 1981-2010 are indicated by contours of -2 (dashed white), -1 (dashed black), 1 (solid black), and 2 (solid white).

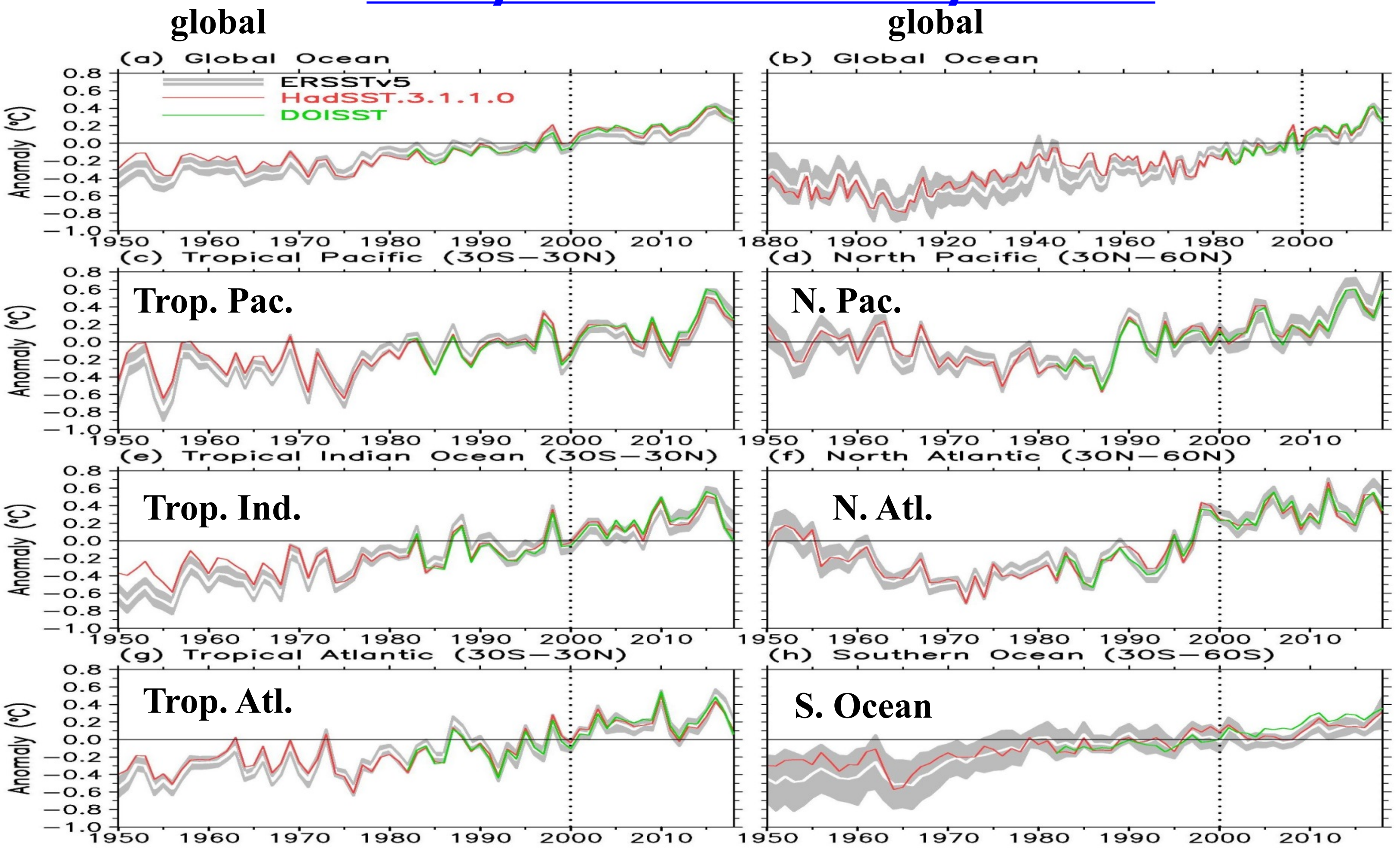
Global SST Section in the BAMS State of the Climate in 2018 by Huang et al.

- **Winter 2017/2018: A moderate negative SSTA presented in eq. Pacific associated with the La Nina of 2017/18, flanked by positive SSTA exceeding +1 STD in the western tropical Pacific and northeastern subtropical Pacific. Positive SSTA exceeding +1 STD dominated in the North Atlantic, Arctic Ocean and mid-latitude South Oceans.**

- **Spring/summer2018: Negative SSTA in the eq. Pacific weakened while positive SSTA in the western tropical Pacific, North and South Pacific largely persisted. Negative SSTA emerged south of Greenland and near the coast of North Africa.**

- **Fall 2018: Positive SSTA covered most of the tropical Pacific with maximum warming near the Dateline and north of the eq. around 10-20N. A positive Indian Ocean Dipole dominated the tropical Indian Ocean and a strong warming was observed in high-latitude North Pacific and Arctic Ocean.**

Yearly Mean SST Anomaly Indices

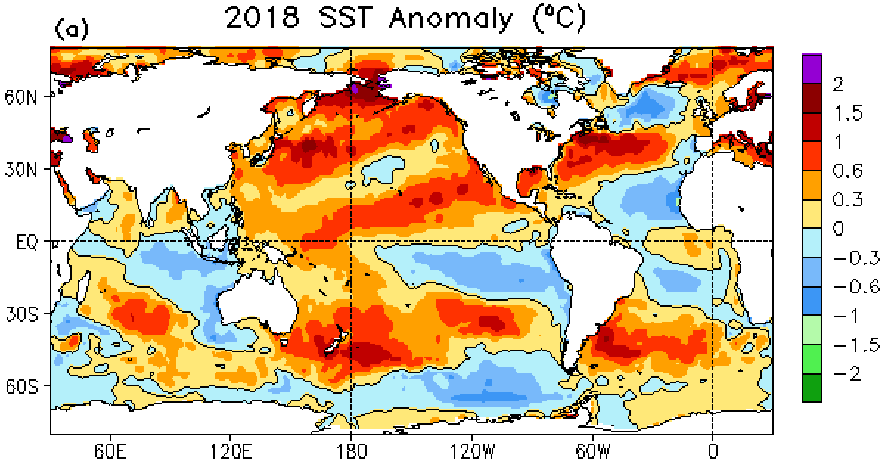


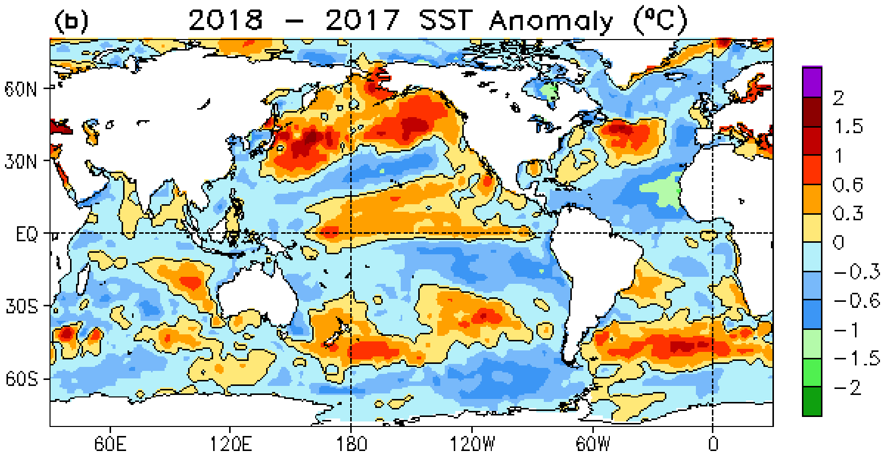
- **The ERSSTv5 (white line) is compared with daily OISST (DOISST) and HadSST.3.1.0.0. The differences are largely within the 2-σ STD (grey shading).**

- **There was a cooling from 2017 to 2018 in all ocean basins except in the North Pacific and South Ocean, which was probably associated with the impacts of the La Nina of 2017/18. The linear trend of globally averaged SSTA based on ERSSTv5 (°C/decade) is 0.16 in 2000-2018 and 0.1 in 1950–2018.**

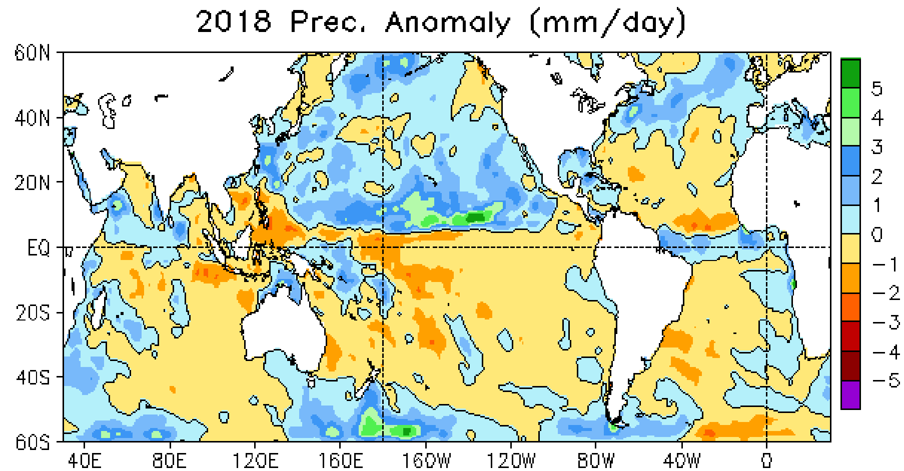
- **The largest warming trend (°C/decade) in 1950-2018 was observed in the tropical Indian (0.14), smallest warming in the North Pacific (0.07).**

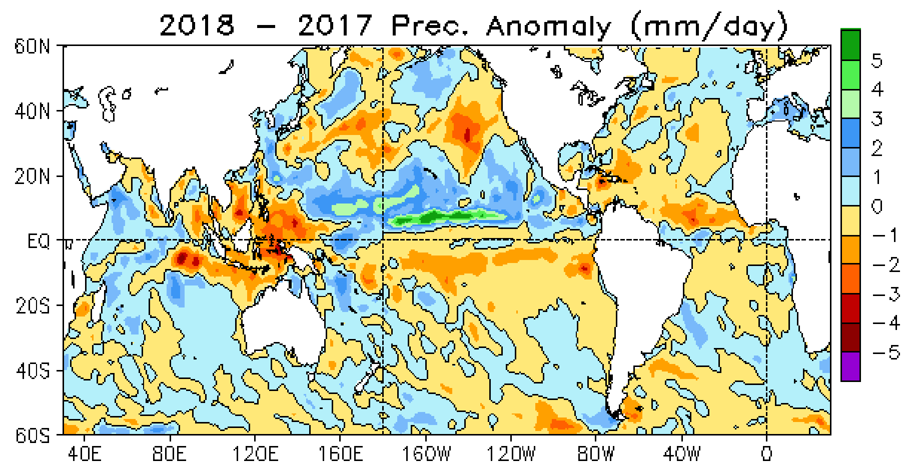
SST Anom.





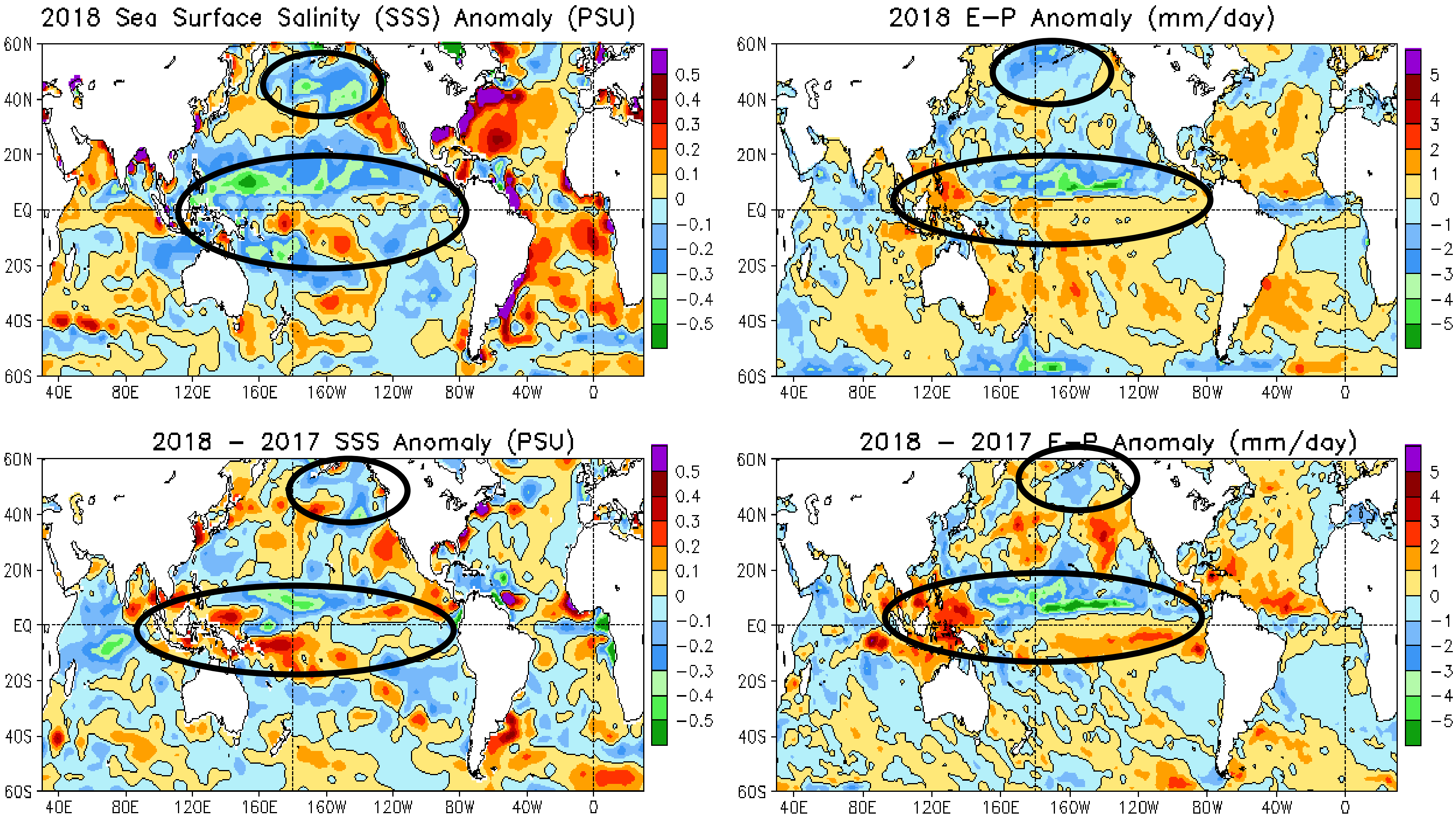
Prec. Anom.





- **In 2018, consistent with the positive SSTA, precipitation was mostly enhanced north of 5N in the North Pacific. In the tropical Indo-Pacific, there was a tripole pattern with suppressed (enhanced) precipitation over the Maritime Continent and central Pacific (western Pacific). Precipitation was enhanced in eq. Atlantic and subpolar N. Atlantic.**
- **The 2018 minus 2017 prec. anomaly was largely consistent with the 2018 prec. anom.**

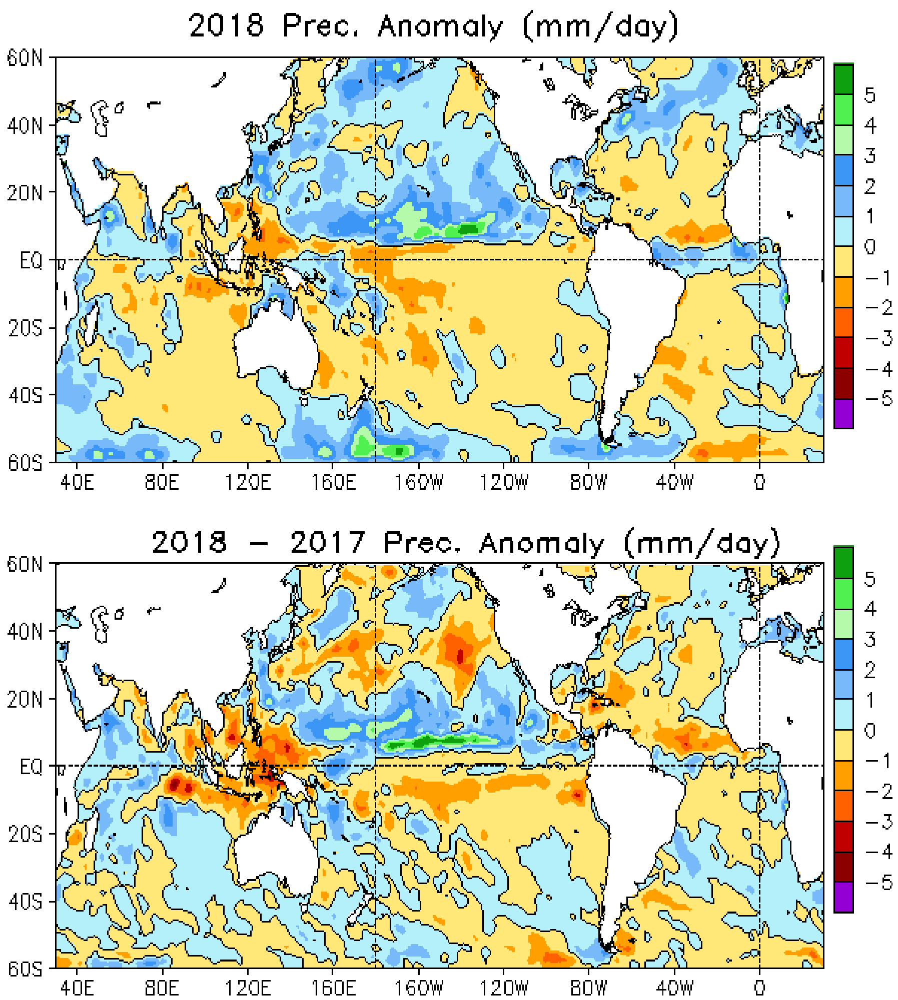
SSS Anom. **E-P Anom.**



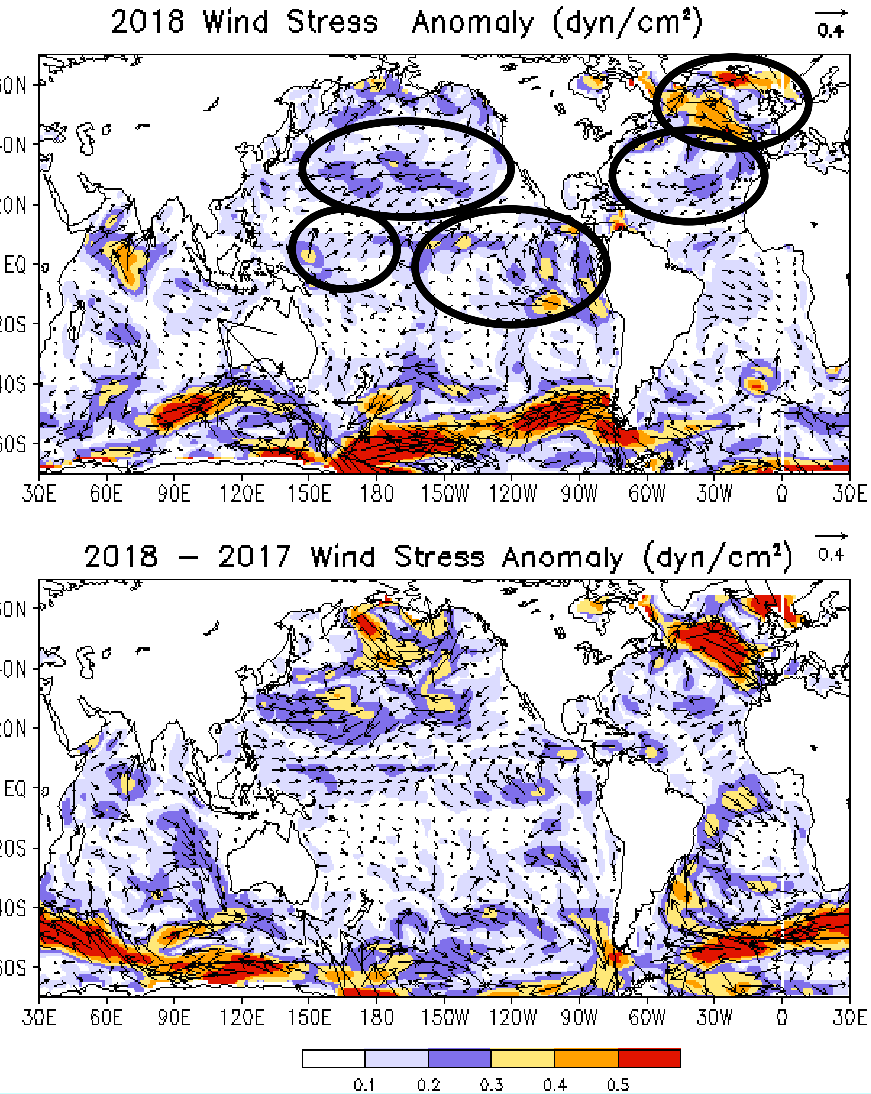
- **In 2018, SSS was mostly below-normal (above-normal) in the Pacific Ocean (Atlantic Ocean). The SSS anom. is well correlated with the E-P anom. in the tropical Pacific and North Pacific.**

- **The 2018 minus 2017 SSS anom. was well correlated with the E-P tendency in the tropical Indian and Pacific Ocean.**

Prec. Anom.



Wind Stress Anom.

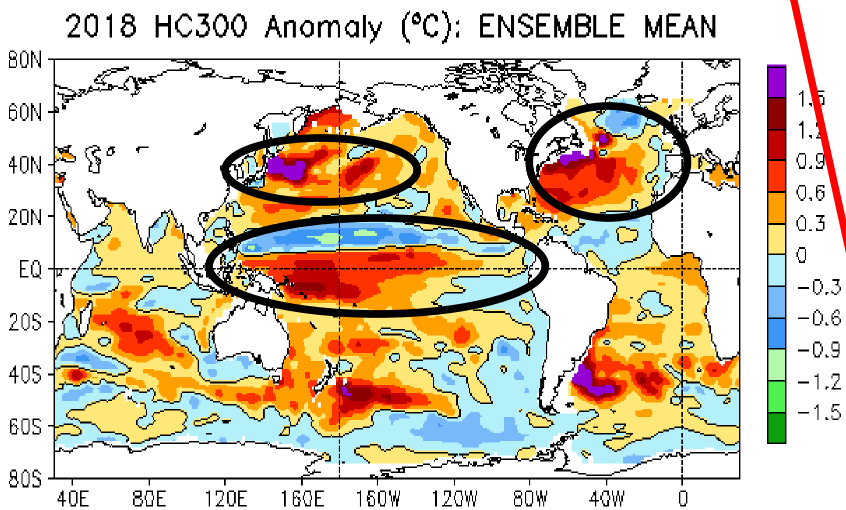


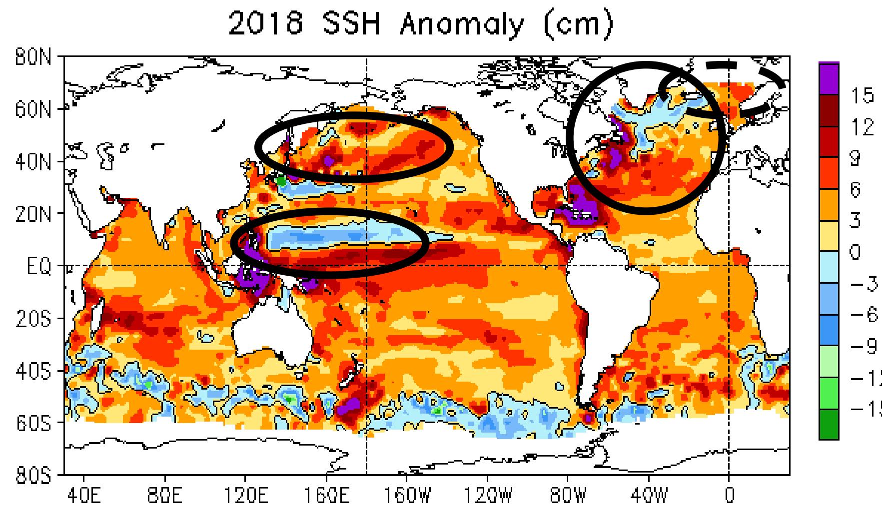
- In the Pacific, the north-south dipole pattern of prec. anom. was associated with convergence wind anom. towards the ITCZ along 5N and cross-equatorial wind anom. in the eastern Pacific.

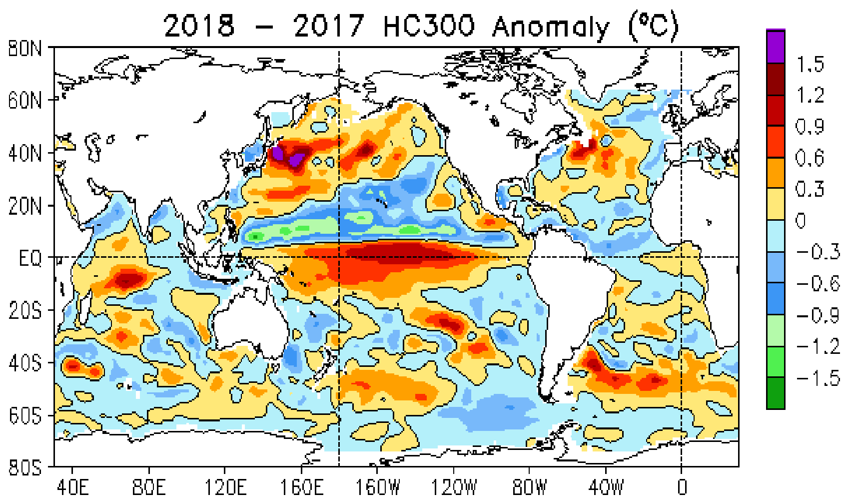
- In the North Atlantic, the prec. anom. dipole pattern was associated with cyclonic and anti-cyclonic circulation anom..

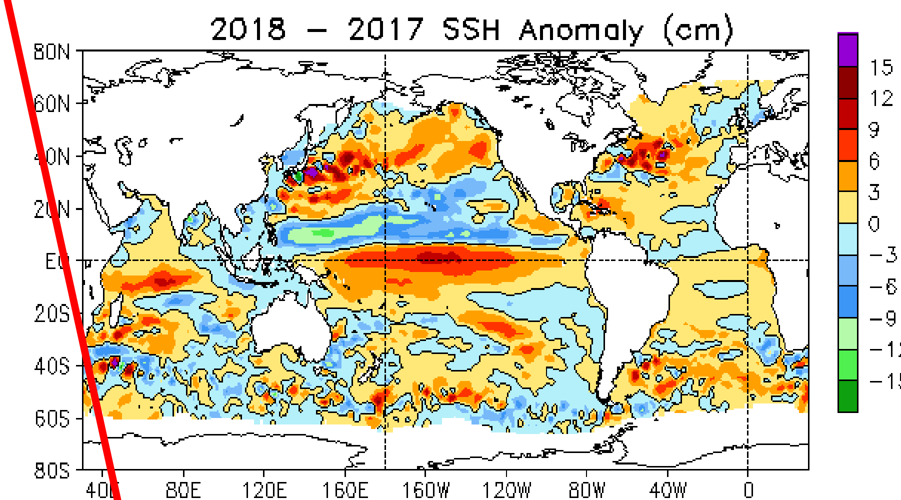
Ensemble Mean HC300 Anom.

AVISO SSH Anom.







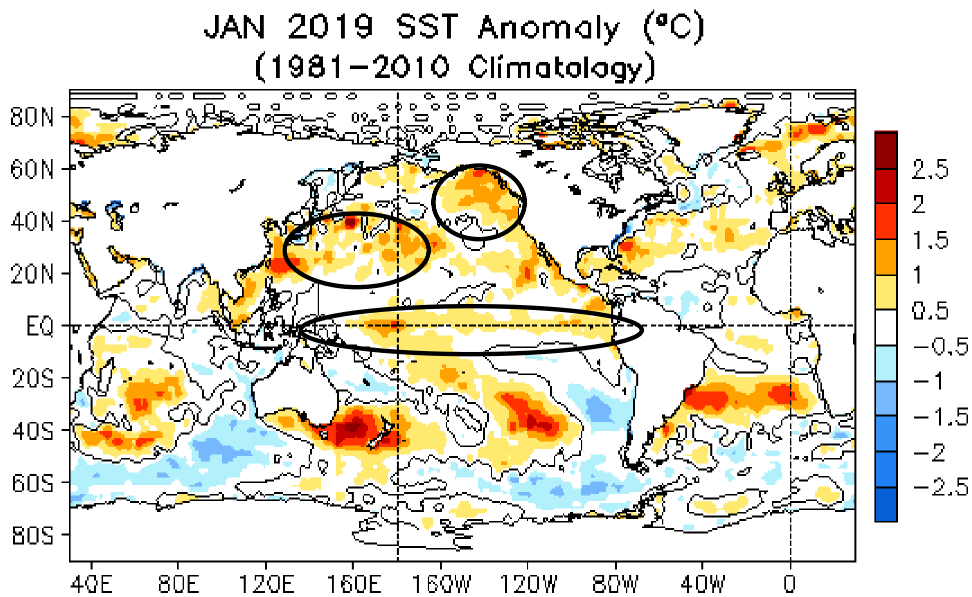


Real-time Ocean Reanalysis Intercomparison Project

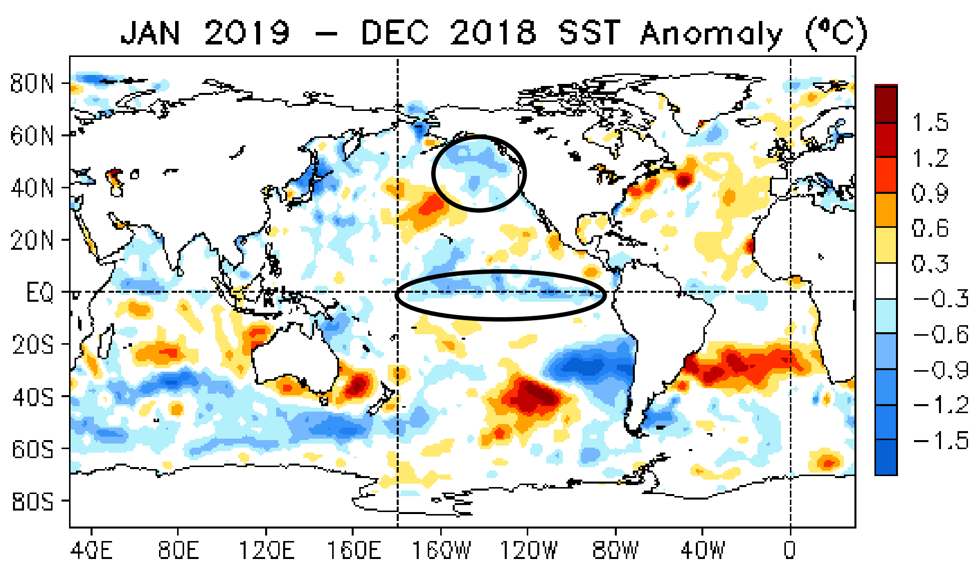
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html
http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)
Xue et al. 2017 (see http://rdcu.be/o4wO)

Highlights in January 2019

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



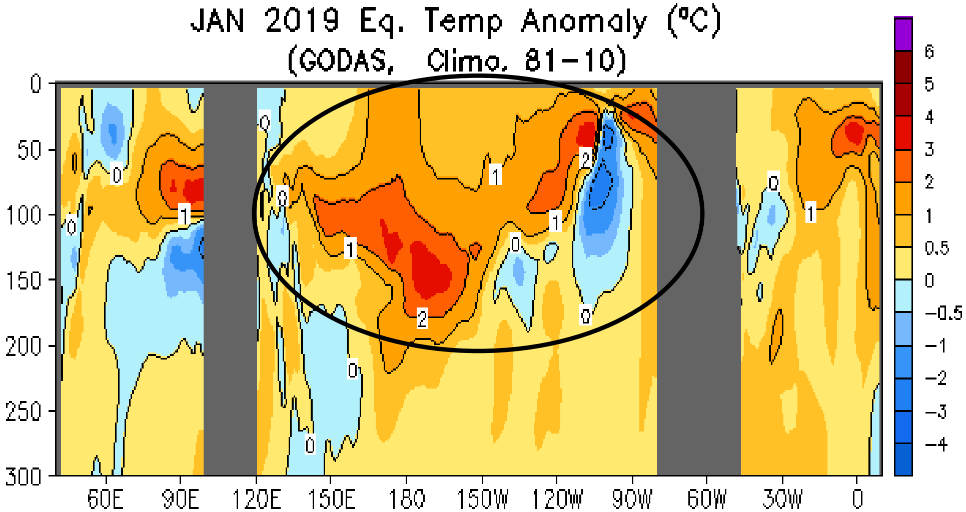
- SSTs were above-normal across the eq. Pacific.
- Positive SSTAs continued in the Gulf of Alaska and central-western N. Pacific.
- Positive (negative) SSTAs dominated in the mid- (high-) latitude South Ocean.



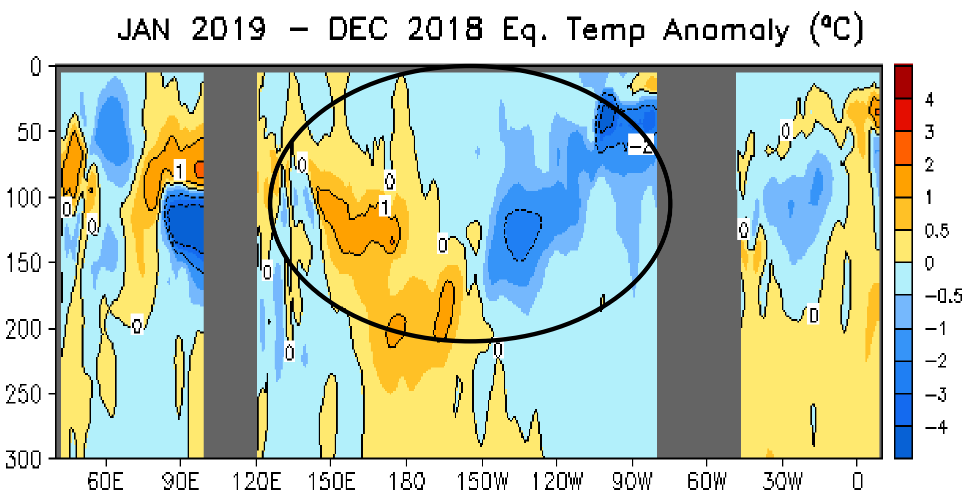
- SSTA tendencies were negative in the eq. Pacific and Gulf of Alaska.
- Large SSTA tendencies were observed in mid- and high-latitude South Ocean.

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

Longitude-Depth Temperature Anomaly and Anomaly Tendency in $2^{o}S-2^{o}N$



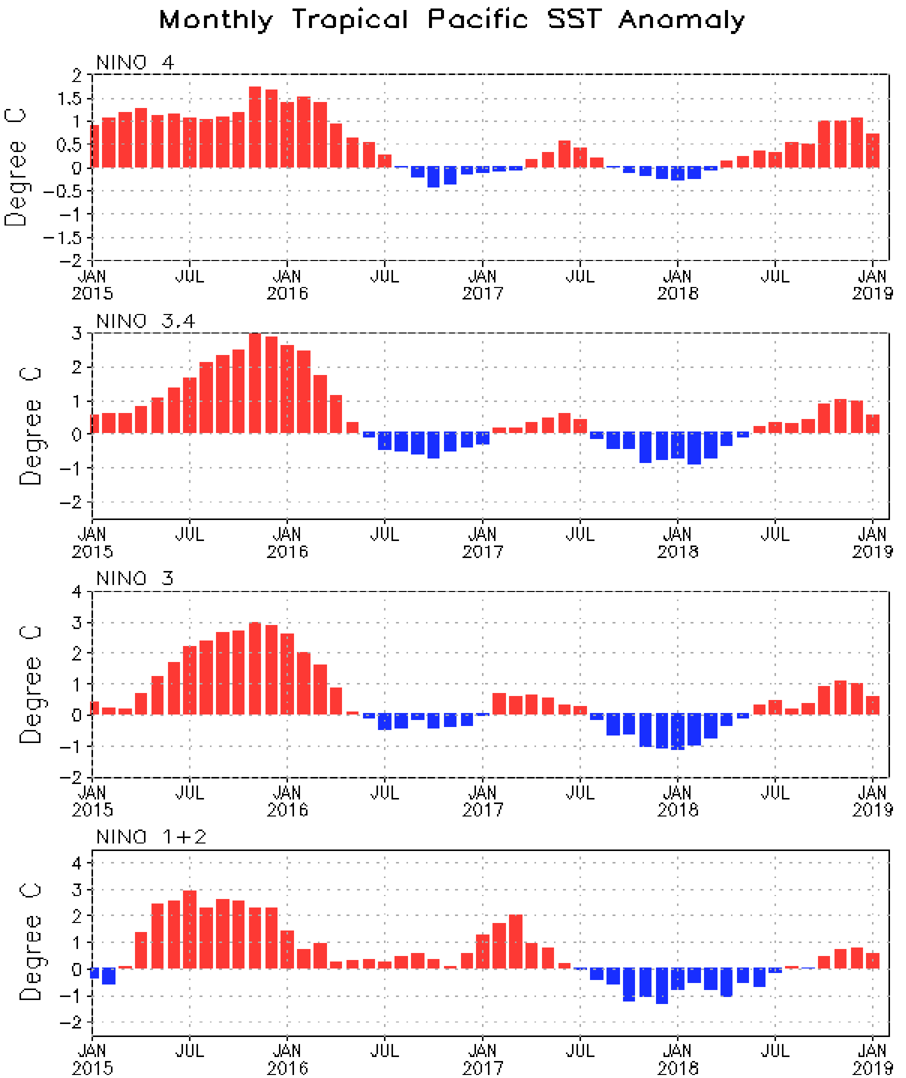
- **Positive temperature anom. covered most of the eq. Pacific except near 100W.**
- **Positive temperature anom. presented in the eq. Indian and Atlantic Ocean.**

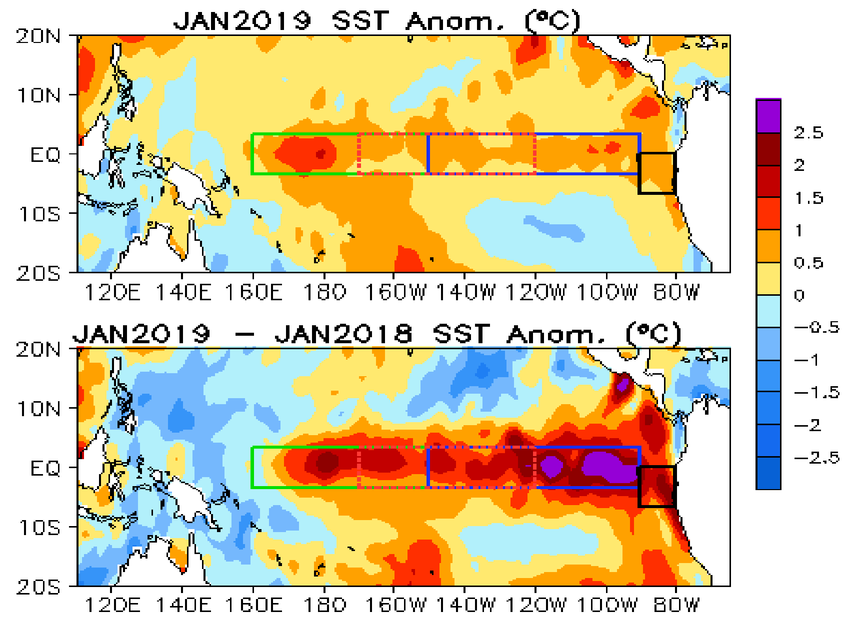


- **Subsurface temperature tendency was positive (negative) in the western (central-eastern) equatorial Pacific due to eastward propagation of upwelling Kelvin wave.**

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.

Evolution of Pacific NINO SST Indices



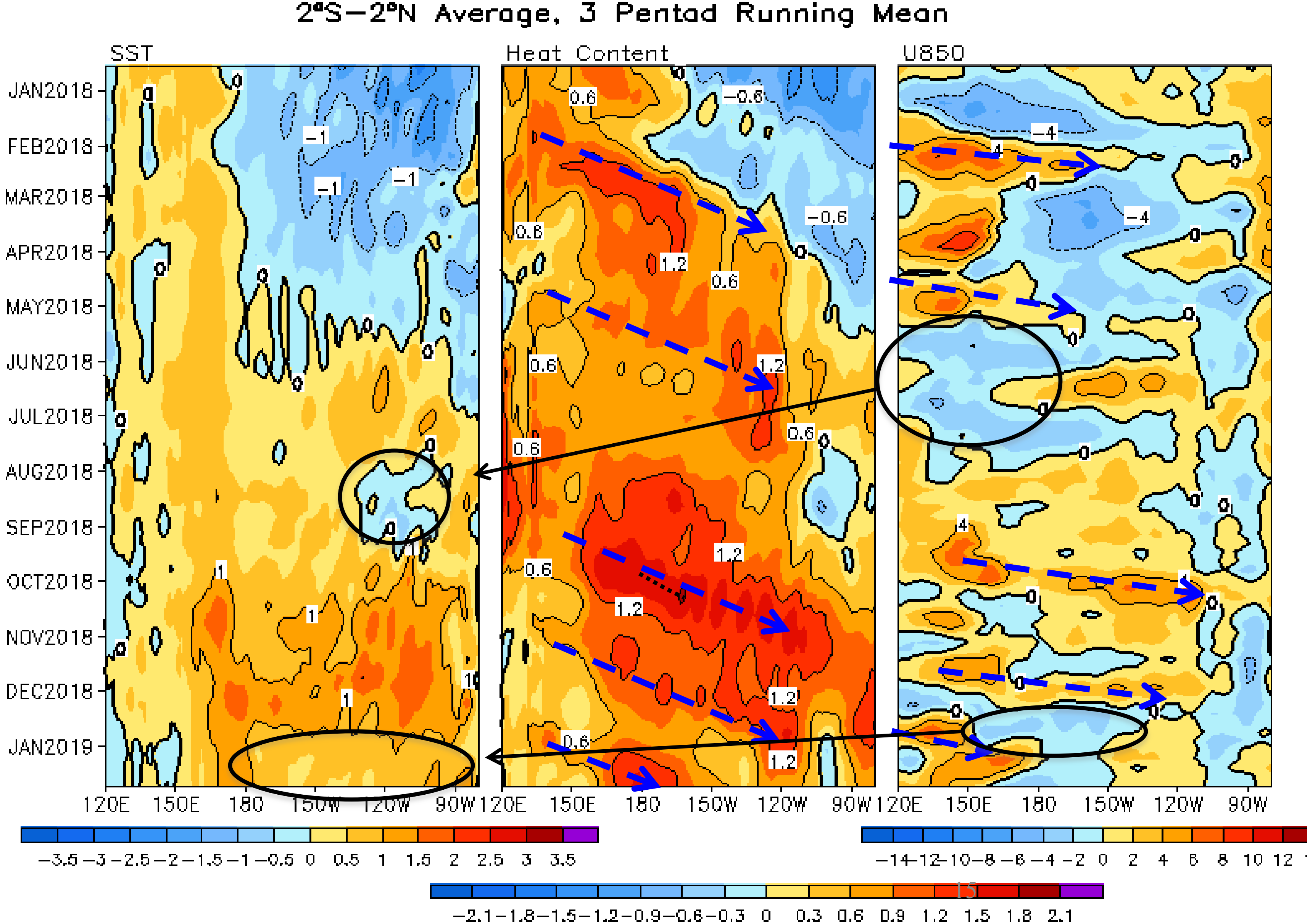


- All NINO indices weakened in Jan 2019, with Niño 3.4 = 0.52 C.

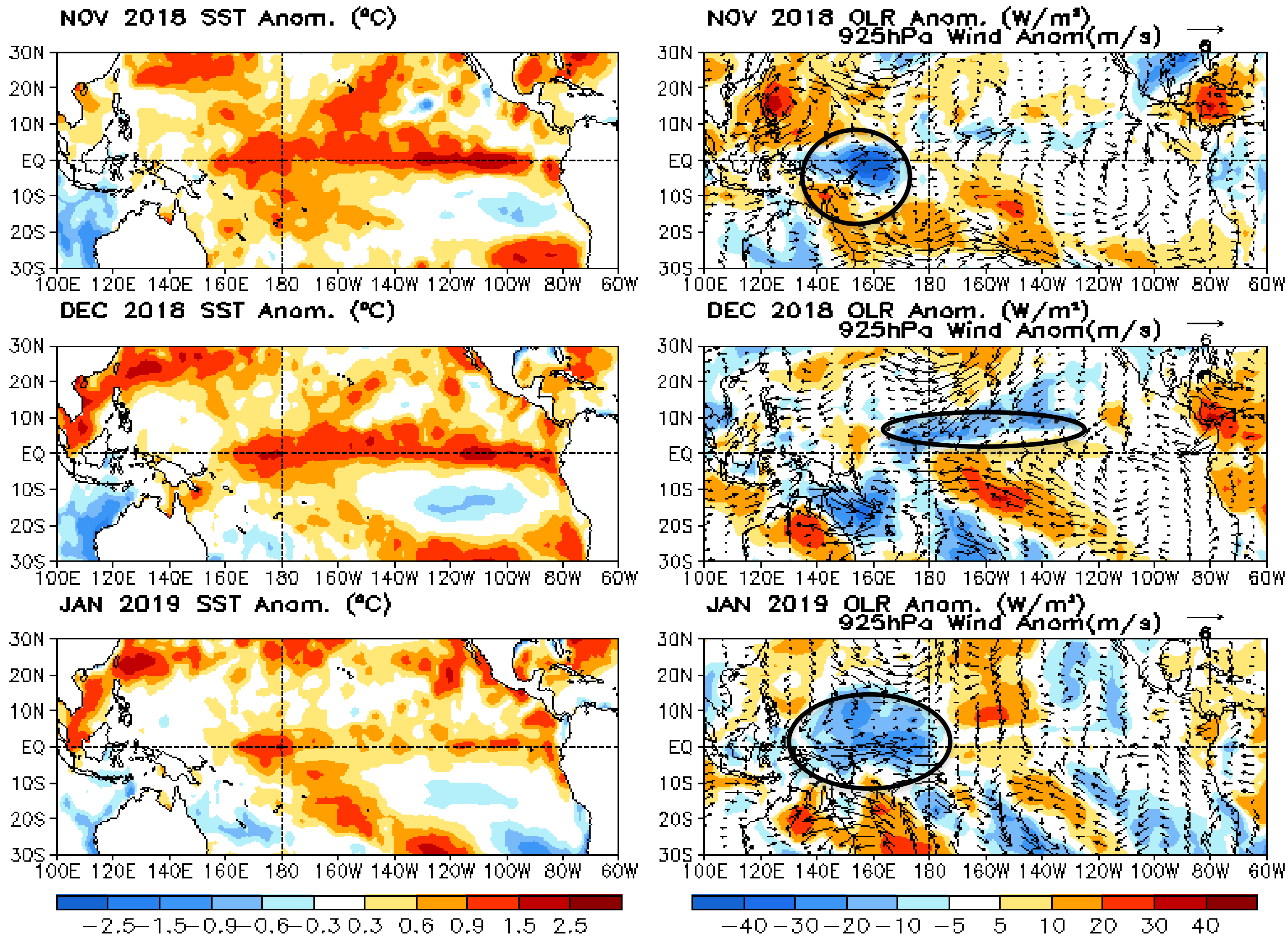
- The indices were calculated based on weekly OISST. They may have some differences compared with those based on ERSST.v5.

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 (bar) and last ten year (green line) means.

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

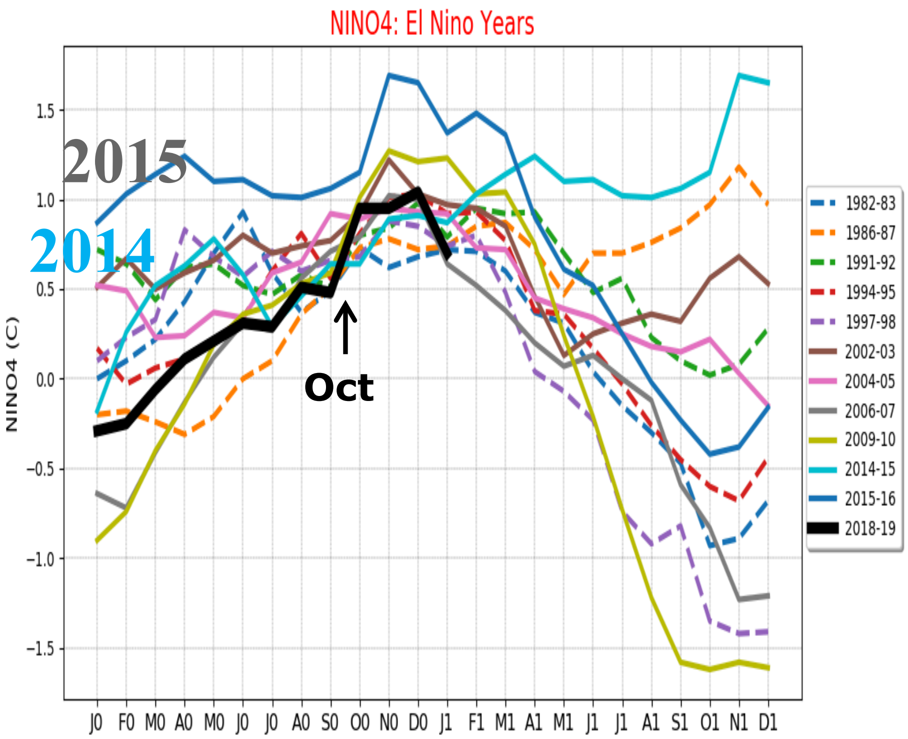


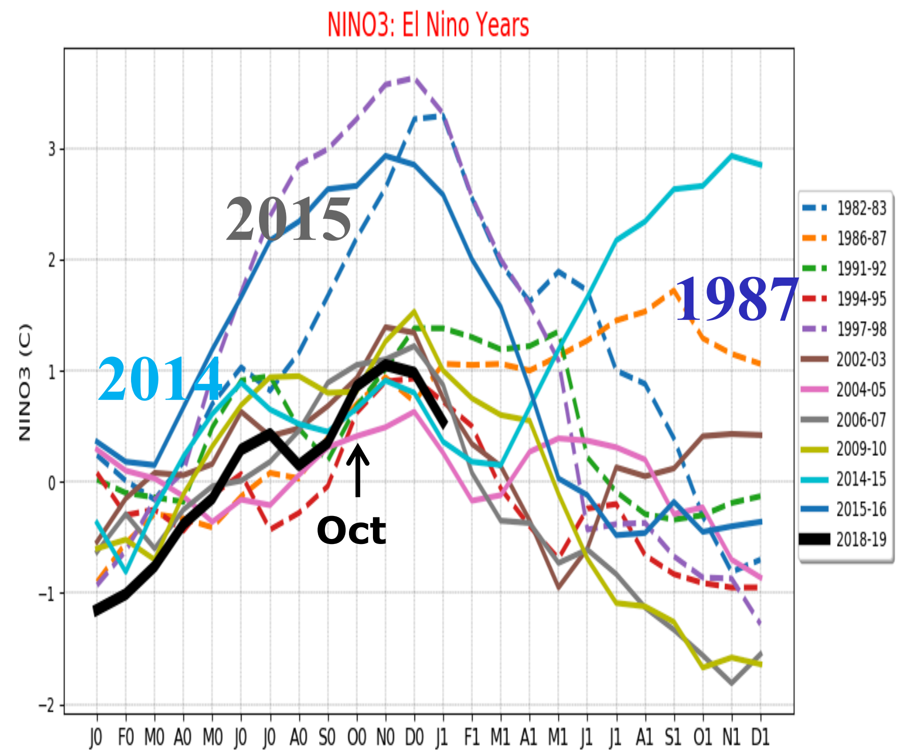
- Positive SSTA more than +1C has persisted since Oct 2018, but it reduced substantially in the central-eastern Pacific in Jan 2019, associated with the Easterly Wind Bursts in Dec 2018.
- A sequence of downwelling oceanic Kelvin waves were observed in spring and fall/winter, which were closely associated the sequence of Westerly Wind Bursts.



- According to ENSO Diagnostic Discussion released on Feb 14, 2019, ENSO- conditions presented in Jan 2019 since enhanced convection expanded near the Dateline and equatorial Southern Oscillation index was negative (-0.6 standard deviations).

El Nino Composites

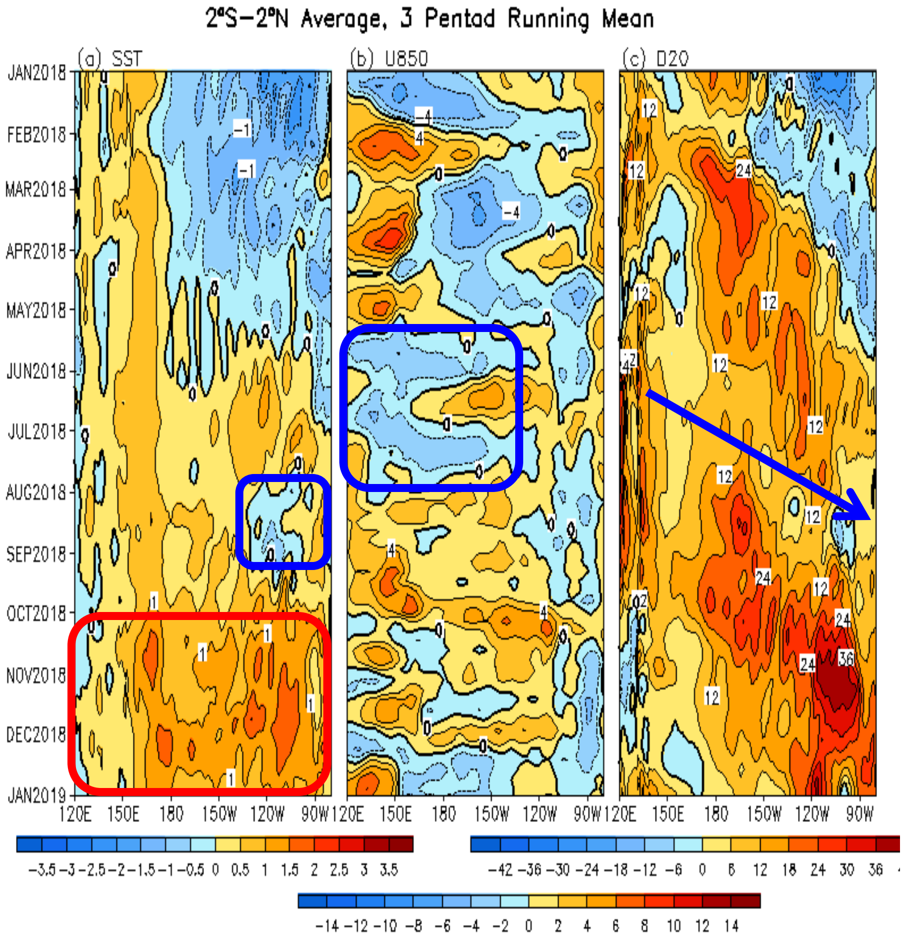




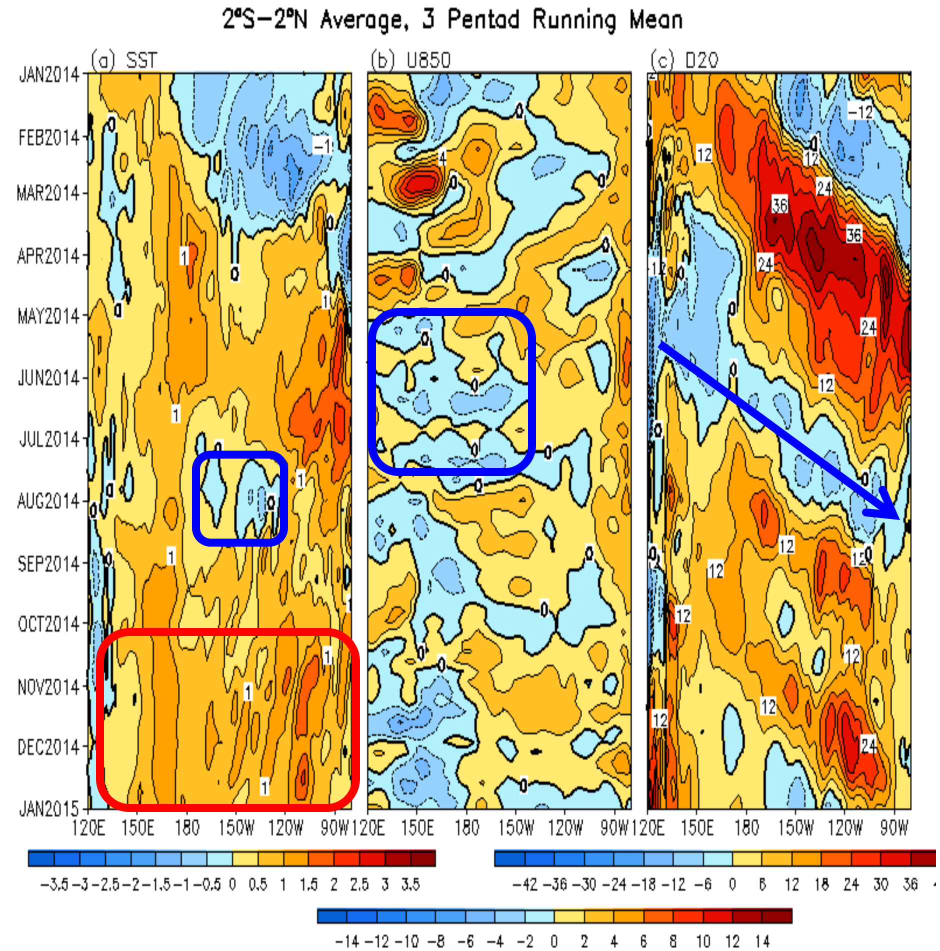
- Compared to the historical El Nino events since 1980, the El Nino development in 2018, measured by NINO3 and NINO4, started with cooler conditions, but cached up after summer, with an amplitude similar to other weak El Ninos.

- Although the evolution of NINO4 and NINO3 in 2018 is very different from that in 2014 in the first half of the year, the conditions in fall/winter are very similar in the two years.

2018



2014



The common features in the El Nino development in 2018 and 2014 include:

- easterly wind anom. and associated upwelling oceanic Kelvin waves in early summer, and SST cooling in the central-eastern Pacific in summer;

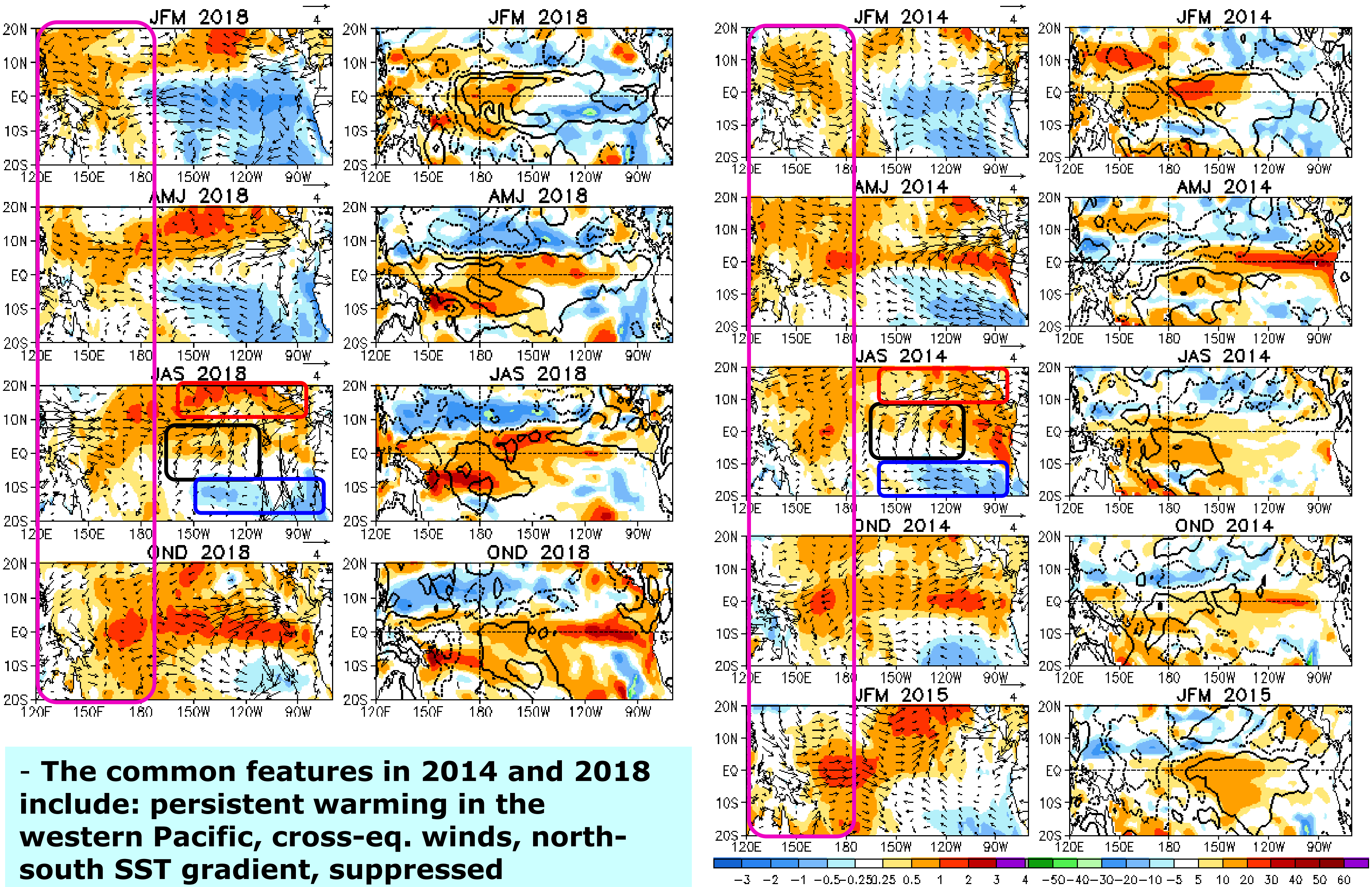
- a late onset of El Nino warming in Oct;

- absence of persistent westerly wind anom. associated with the warming

2018

SST (shade), Wind 850mb **OLR (contour), D20 (shade)**

2014

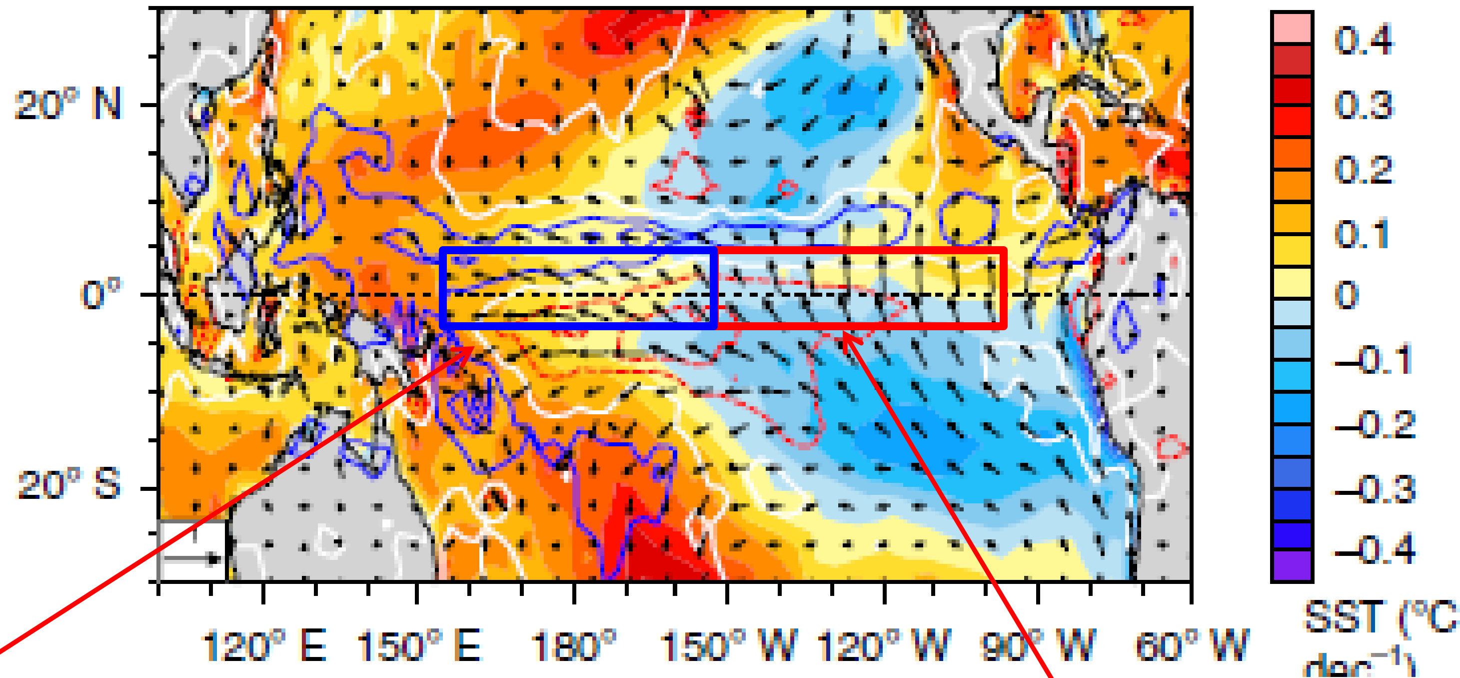


- The common features in 2014 and 2018 include: persistent warming in the western Pacific, cross-eq. winds, north-south SST gradient, suppressed convection near the Dateline and enhanced convection near 10N

Cross-Equatorial Winds Control El Nino Diversity and Change

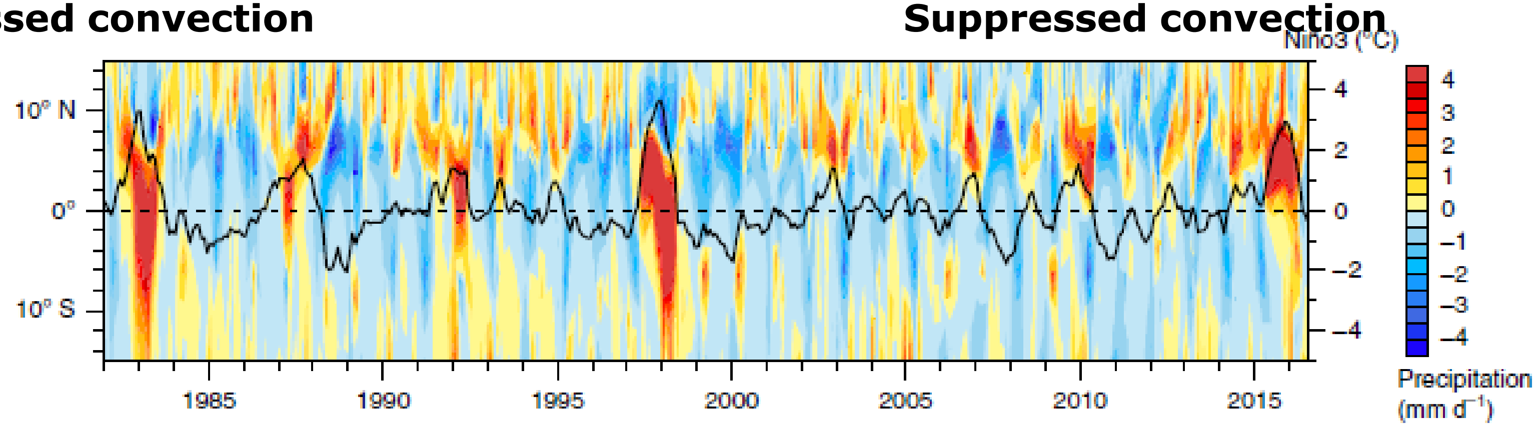
Hu and Fedorov, Nature Climate Change, 2018

Trend in 1982-2015



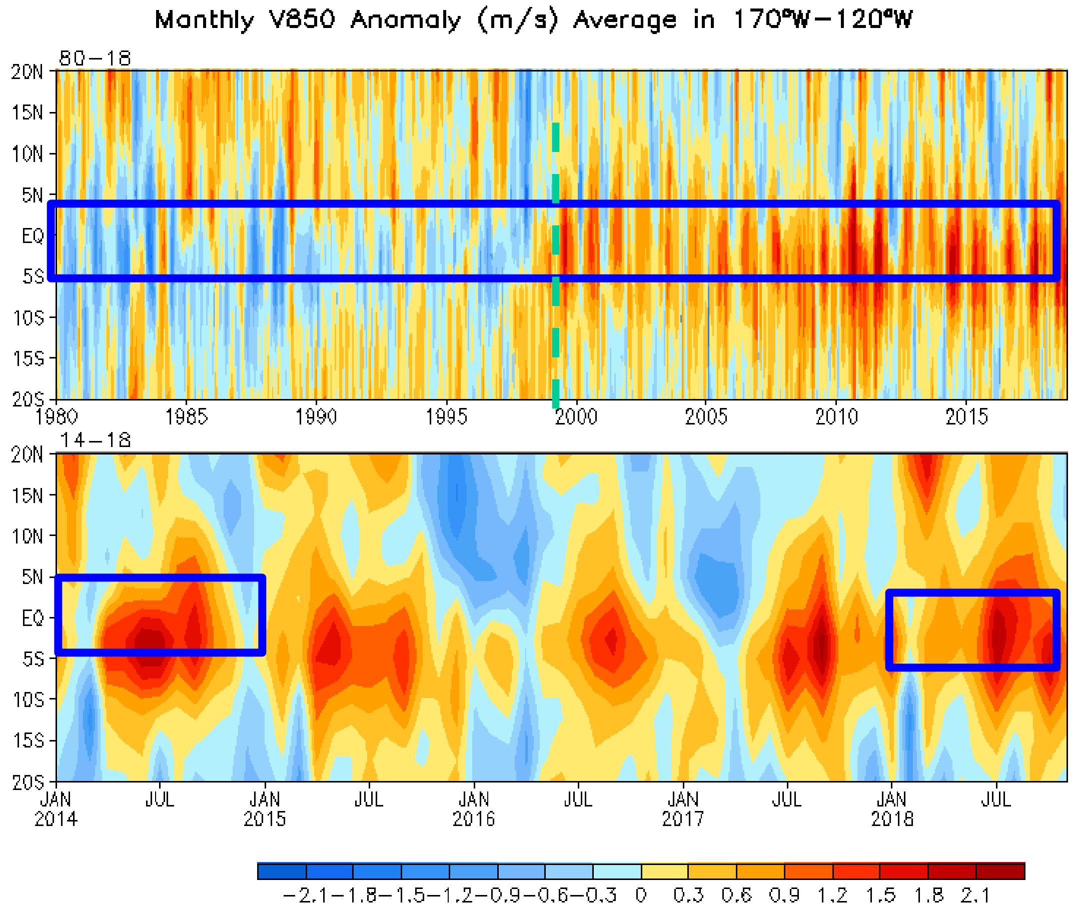
NINO4: Easterly wind anom.
Suppressed convection

NINO3: Cross-eq wind anom.
Suppressed convection



Positive precipitation anom. stayed north of the eq. since the 1997/98 El Nino.

V850mb Wind Anom. in the NINO3.4 Region

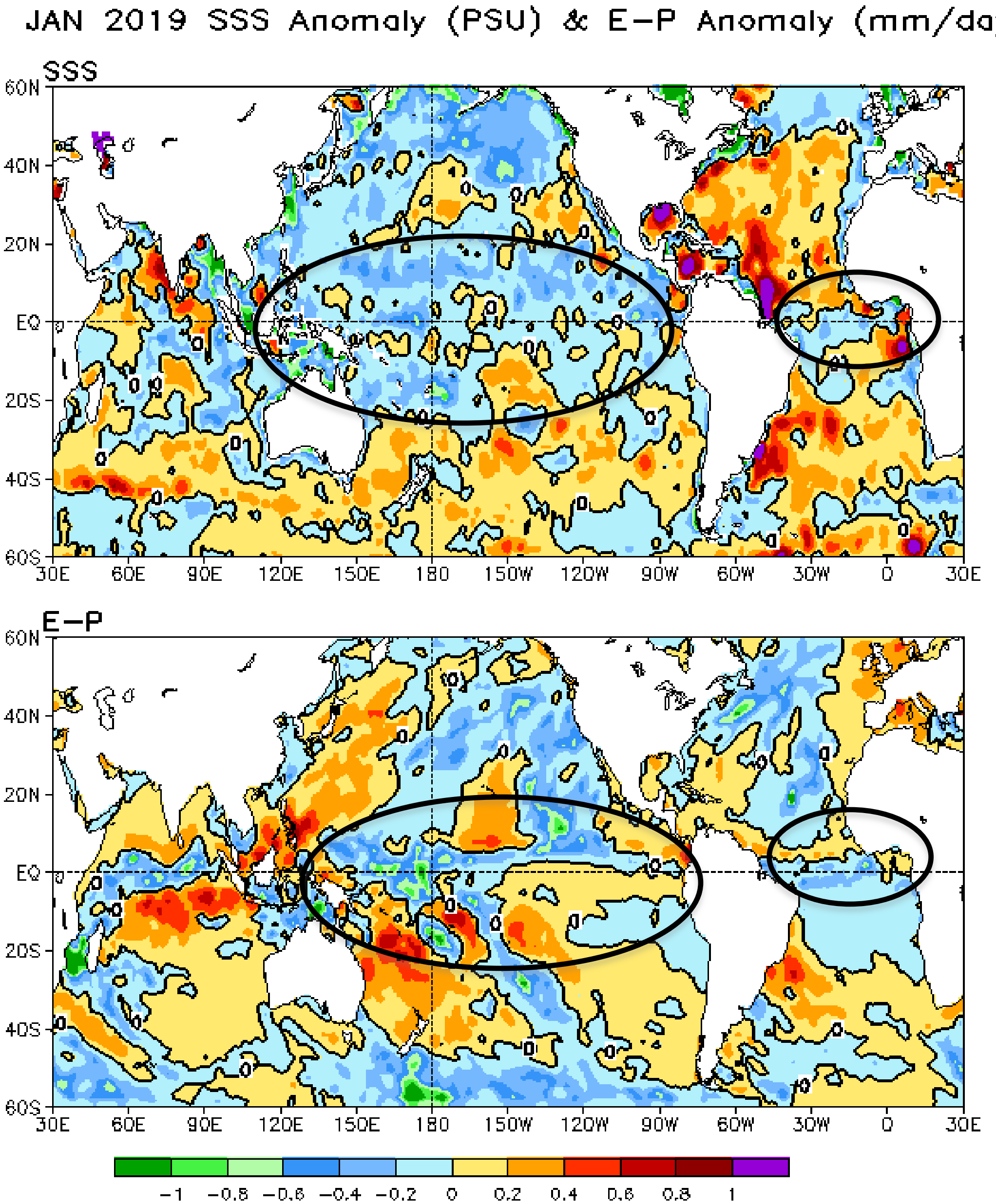


- **There was a shift towards enhanced northward cross-equatoriral wind around 2000, which have persisted since then.**

- **The enhanced cross-equatorial winds are unfavorable for development of the eastern Pacific El Nino (Hu and Fedorov 2018).**

- **The impacts of the cross-equatorial winds are largest during summer.**

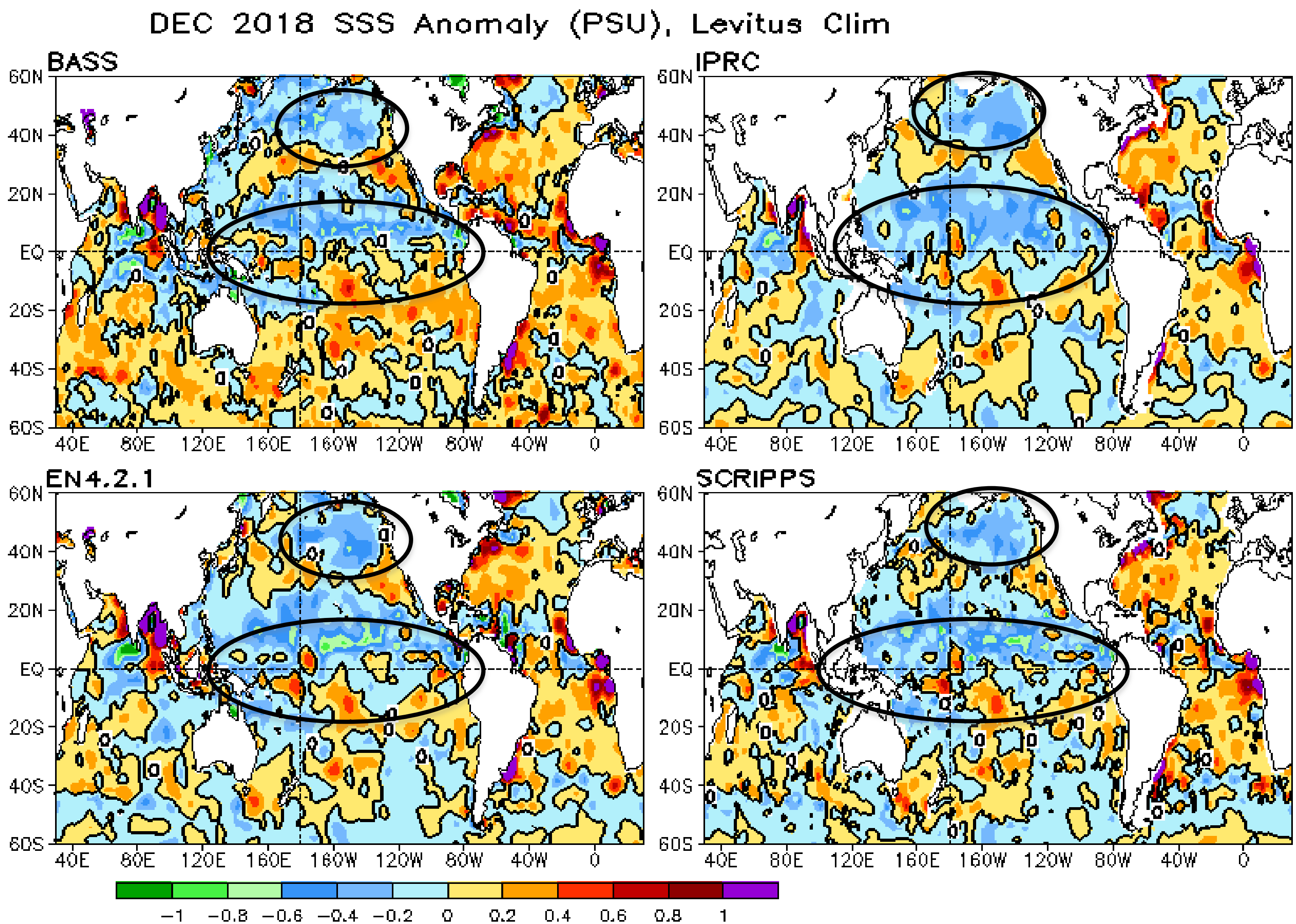
Monitoring SSS and Freshwater Flux Variability



- **Blended Analysis of Surface Salinity (BASS): In Situ, SMOS, Aquarius and SMAP**
- **2010-2018, Monthly and Pentad**
- **CPC/NODC/NESDIS joint effort (Xie et al. 2014)**

ftp.cpc.ncep.noaa.gov/precip/BASS

- **Precipitation: CMORPH**
- **Evaporation: CFSR adjusted to OAFlux**

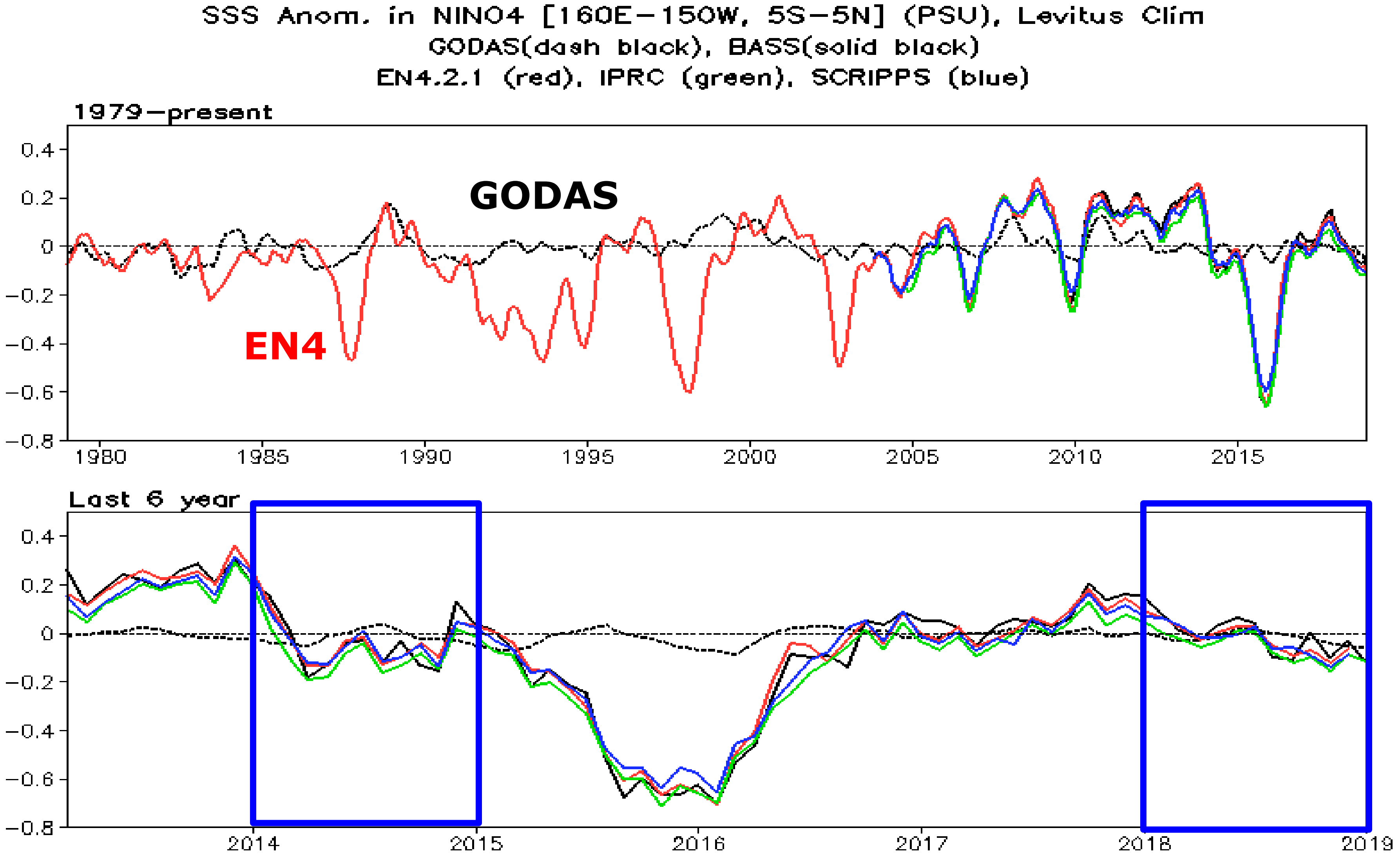


IPRC Argo (2005-present, real-time): http://apdrc.soest.hawaii.edu/projects/argo/

SCRIPPS Argo (2004-present, one-month delay): http://sio-argo.ucsd.edu/RG_Climatology.html

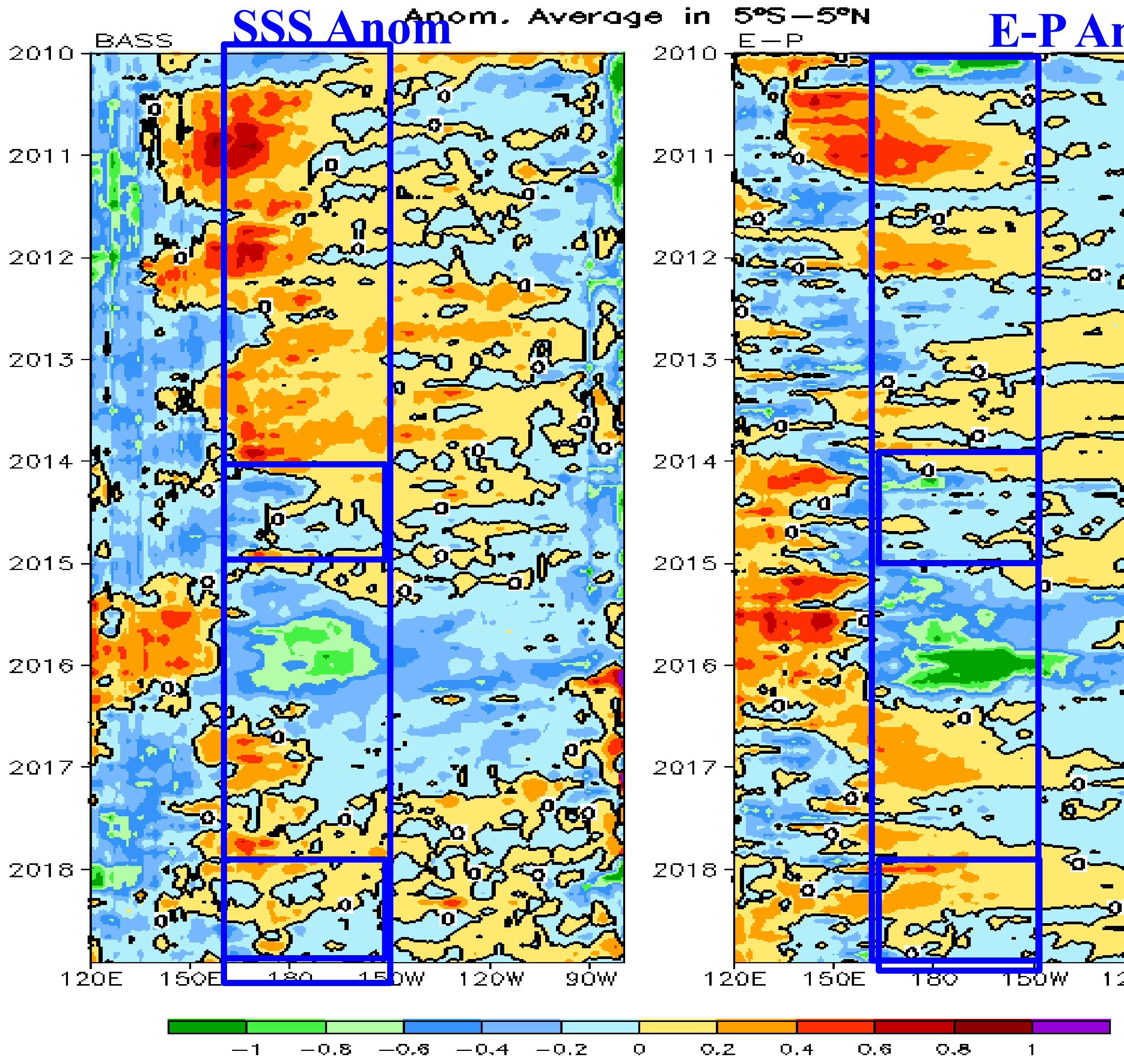
EN4.2.1 (1900-present, one-month delay): https://www.metoffice.gov.uk/hadobs/en4/download-en4-2-1.html

SSS Anom. in the NINO4 Region



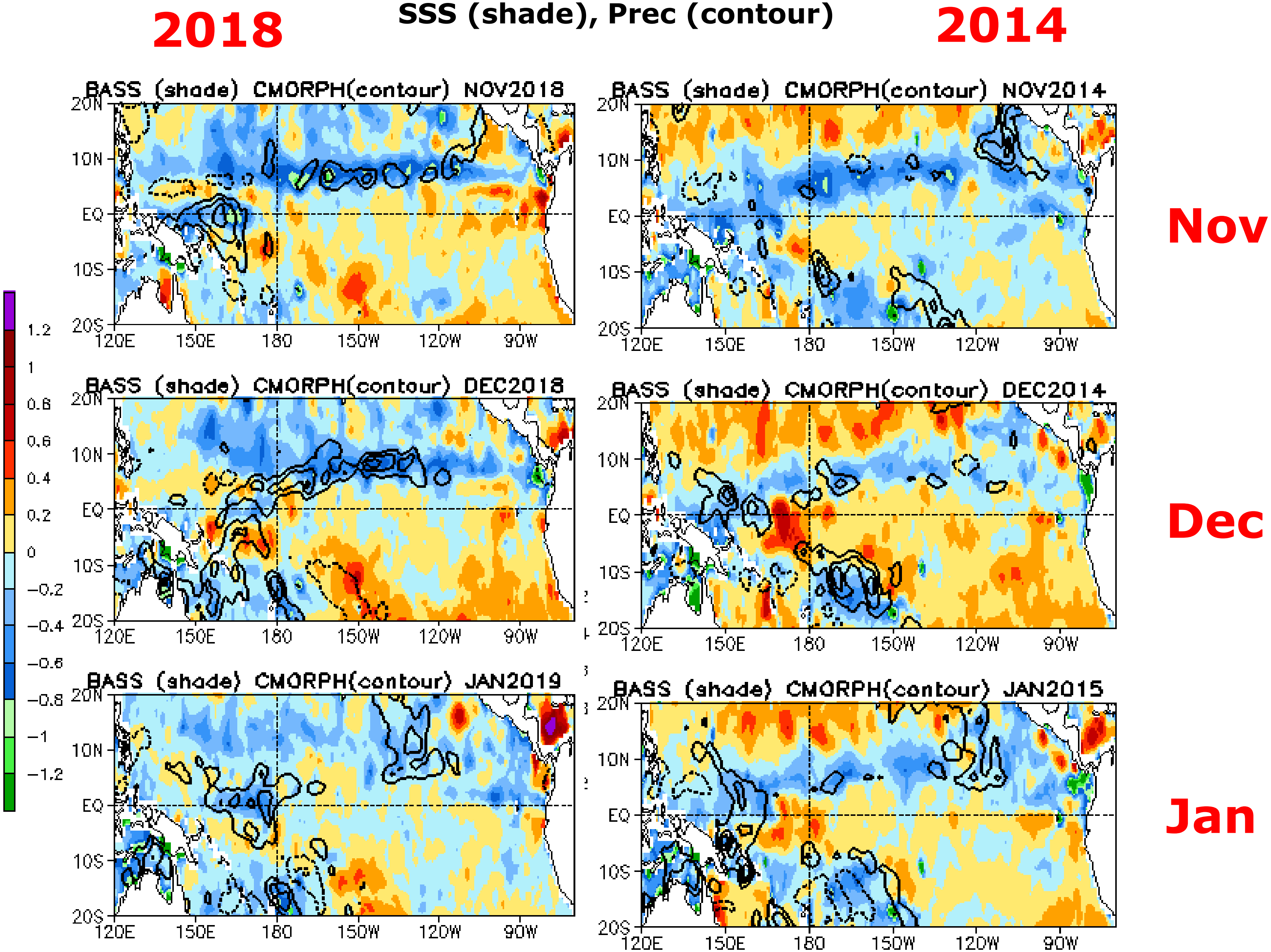
- **SSS anom. in the NINO4 region is consistent among the BASS and in situ data-based objective analyses (EN4.2.1, IPRC and Scripps Argo).**

- **GODAS severely underestimates SSS variability due to assimilation of synthetic salinity.**

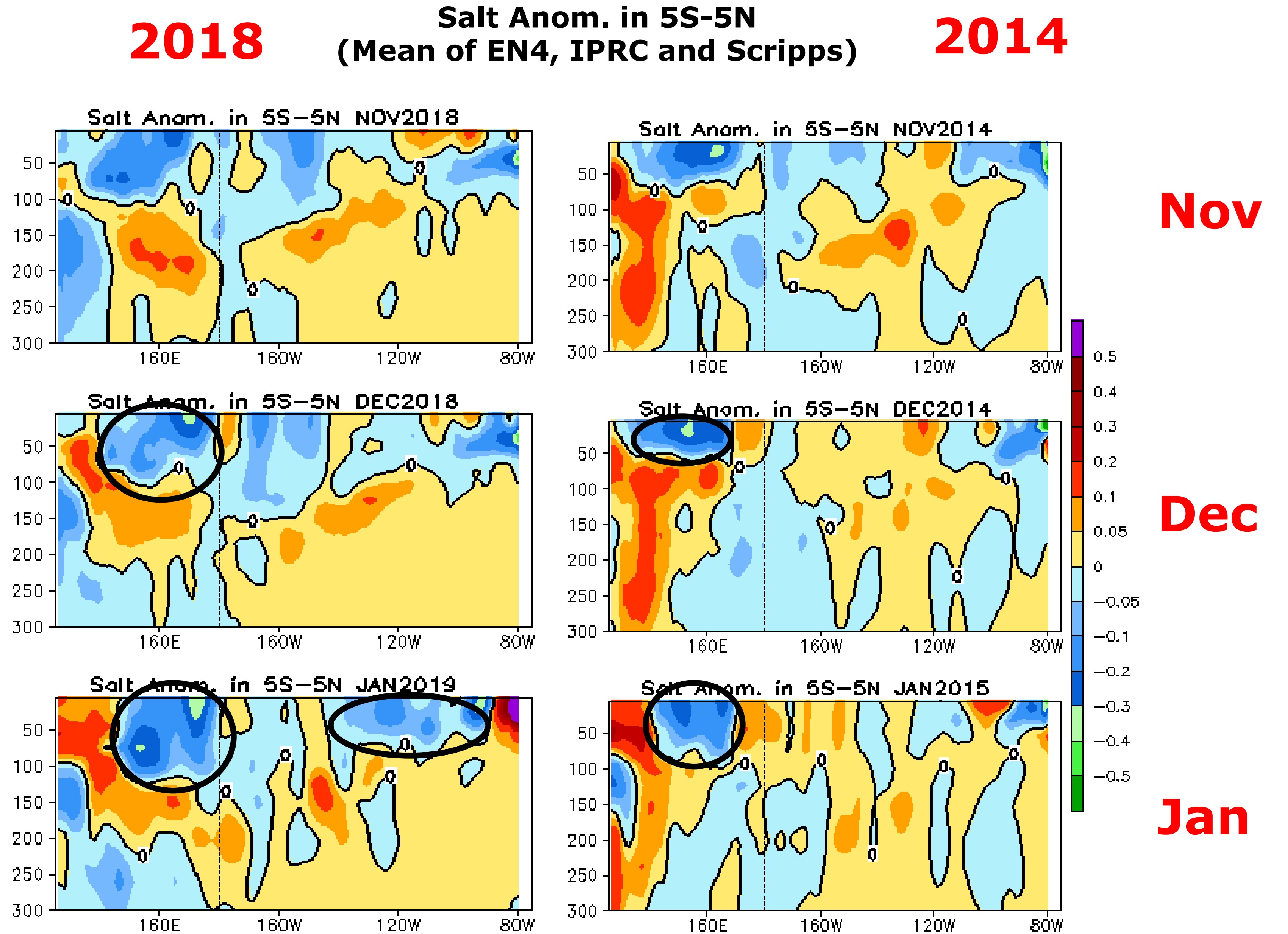


SSS Anom
Anom. Average in 5°S—5°N
E-P Anom
BASS
E—P
2010
2011
2012
2013
2014
2015
2016
2017
2018
120E
150E
180
150W
120W
90W
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1

SSS (shade), Prec (contour)

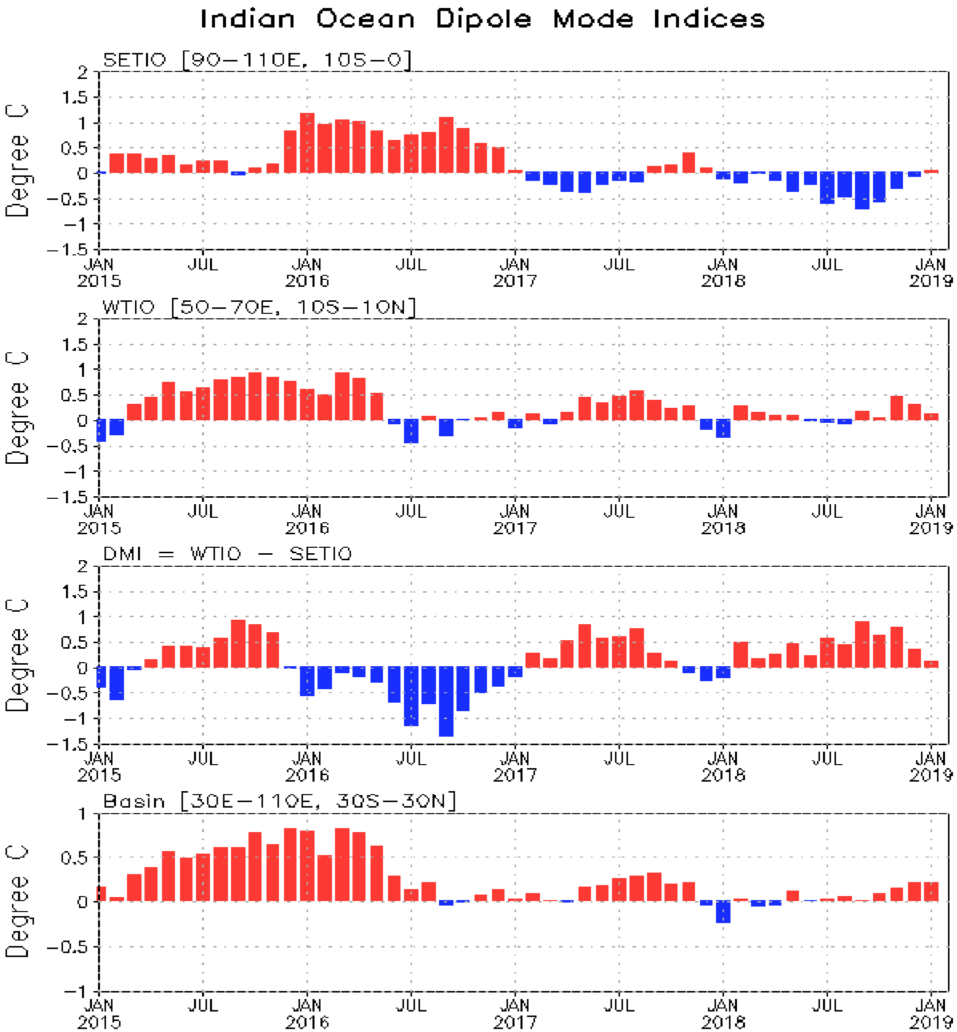


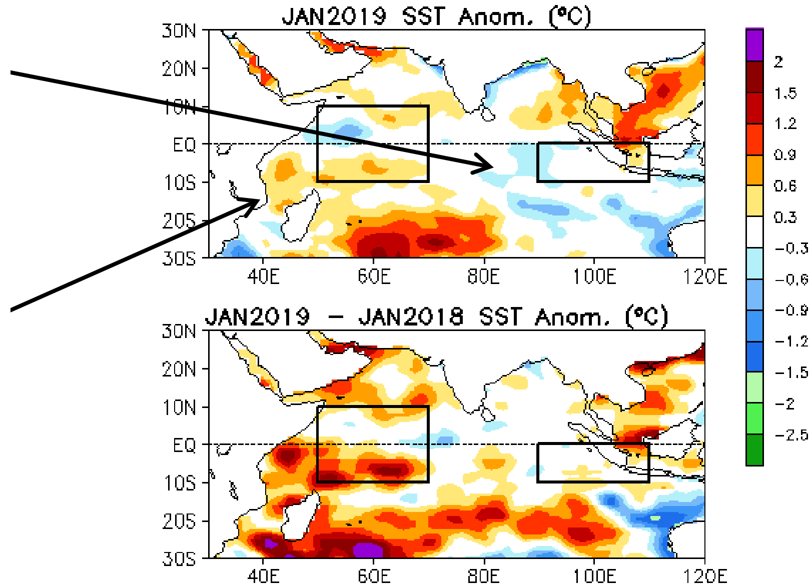
- **Compared to 2014/15, the negative SSS anom. and positive prec. anom. in the western eq. Pacific were somewhat stronger and expanded closer to the Dateline in 2018/19.**



- Compare to 2014/15, the negative salinity anom. was stronger and covered both the western and eastern eq. Pacific in 2018/19, which is potentially more favourable for air-sea coupling.

Evolution of Indian Ocean SST Indices

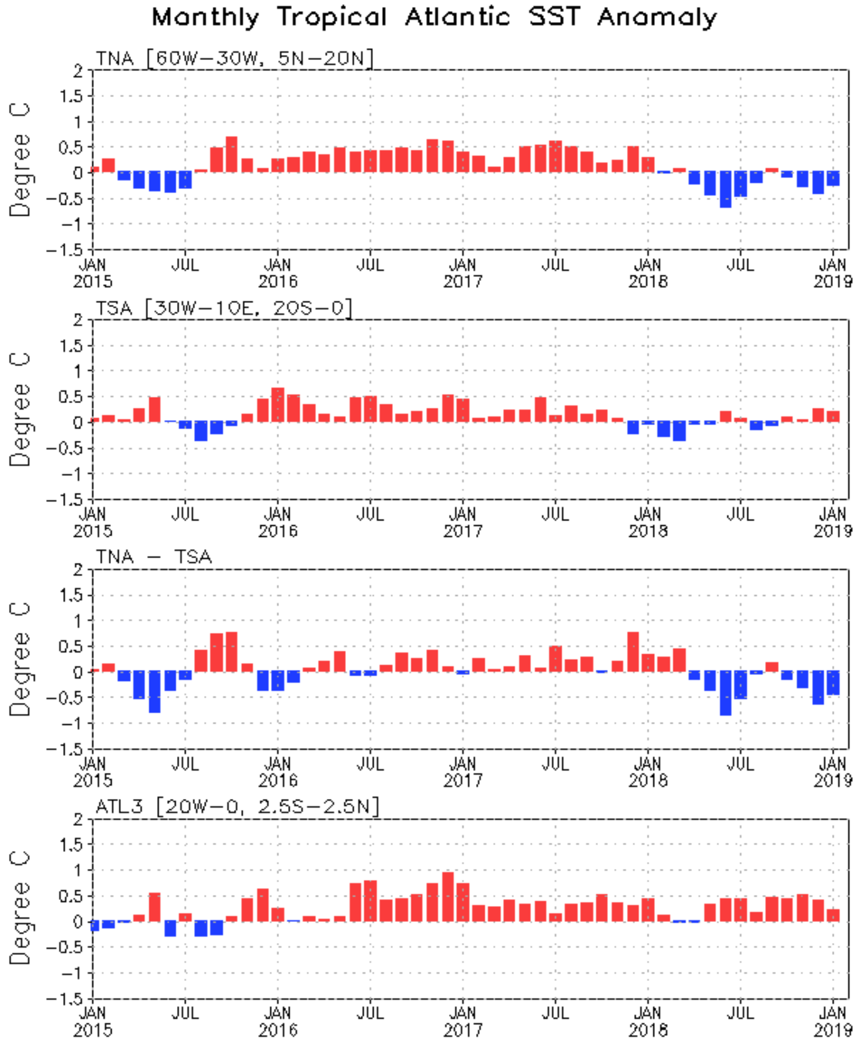


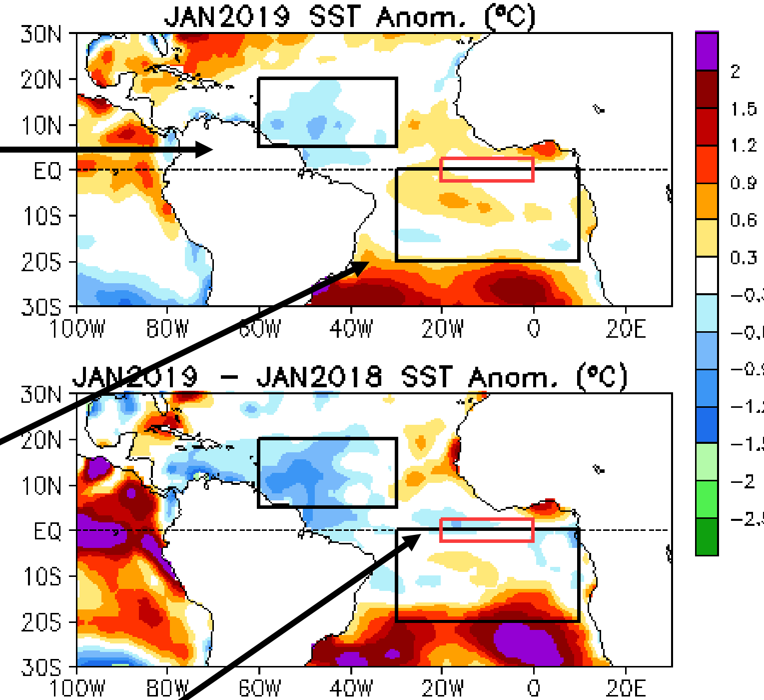


- SSTAs were weak in the tropical Indian Ocean in Jan 2019.

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 departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

Evolution of Tropical Atlantic SST Indices



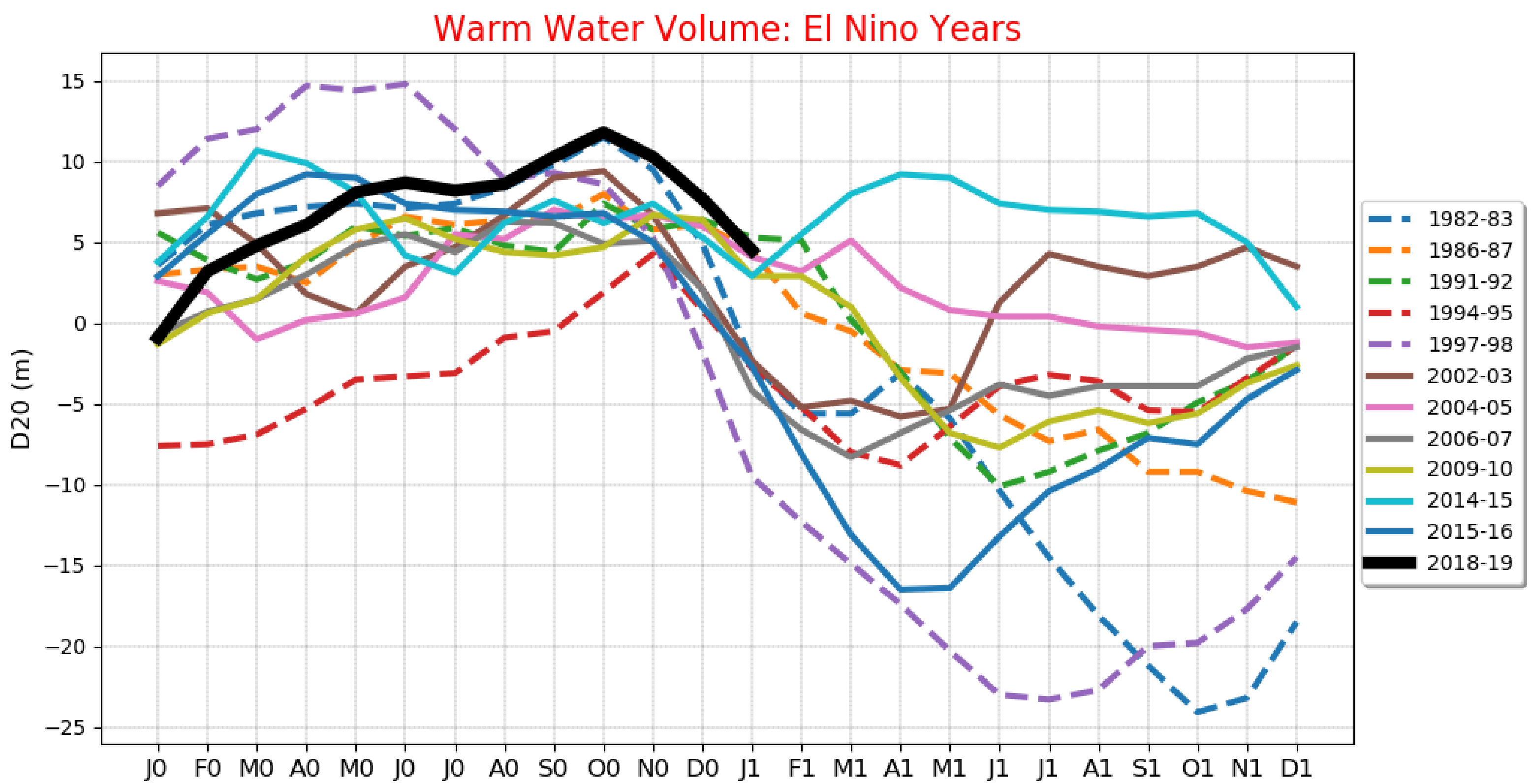


- **SSTAs were weakly negative (positive) in the subtropical North (South) Atlantic in Jan 2019.**

Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) for the TNA [60ºW-30ºW, 5ºN-20ºN], TSA [30ºW-10ºE, 20ºS-0] and ATL3 [20ºW-0, 2.5ºS-2.5ºN] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the NCEP OI SST analysis, and departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

Global SST Predictions

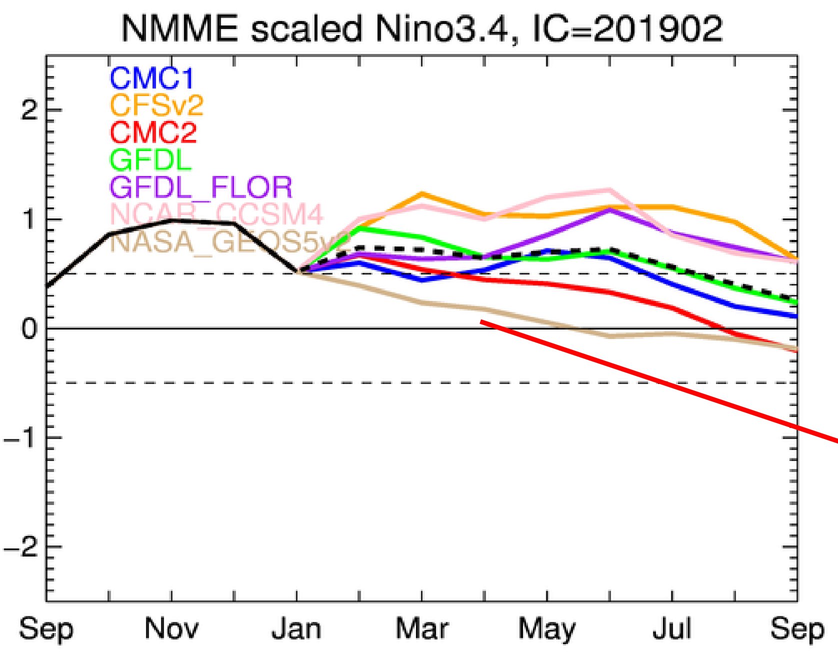
El Nino Composites



- Compared to other El Nino events, the WWV in 2018, based on the ensemble mean of 6 ocean reanalyses, was highest in the fall/winter of Year 0. But it has declined rapidly since Oct 2018 and became comparable to other weak warming events in Jan 2019. The current positive WWV provides the necessary conditions for development of a second year warming in 2019.

Ensemble ocean reanalyses in real-time:
http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

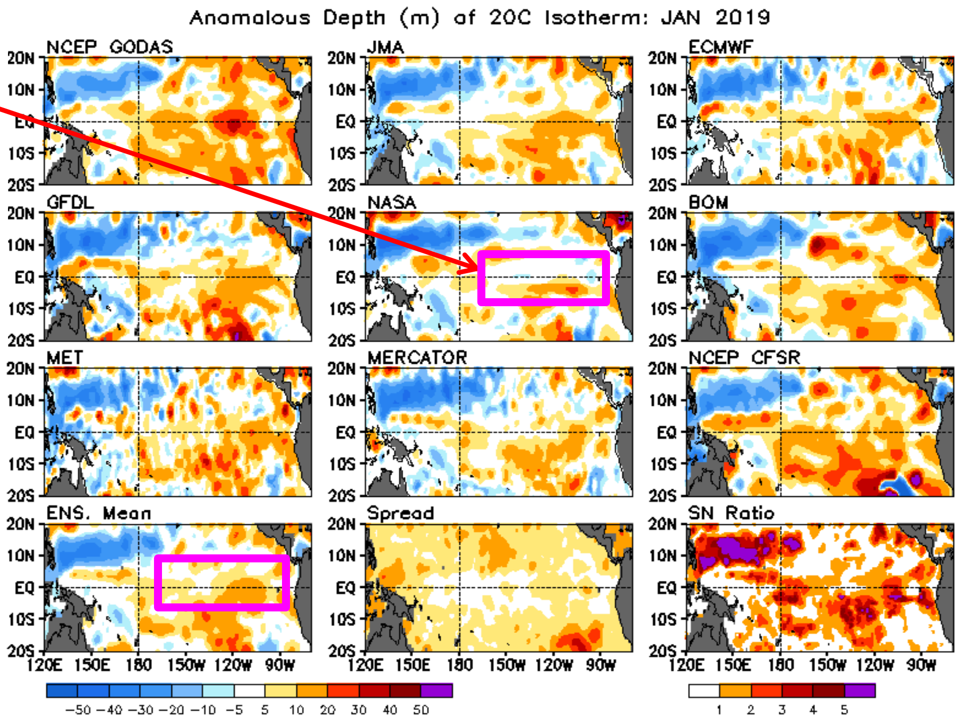
NMME NINO3.4 Forecast Plume



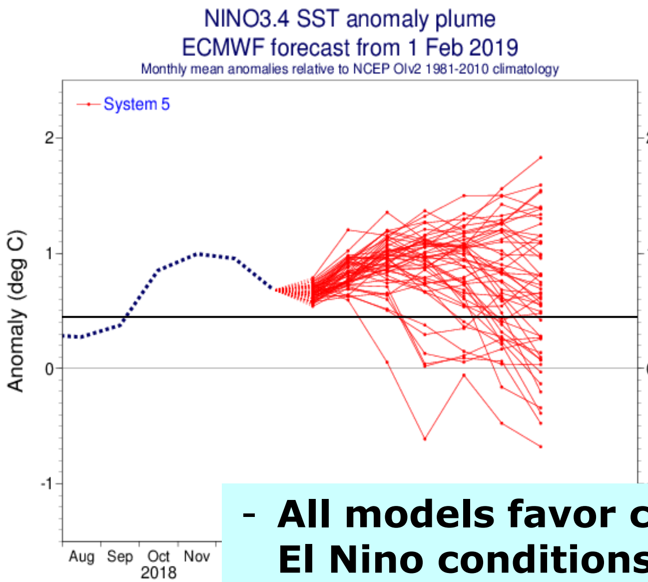
- The NASA ocean initial conditions had cold biases in the eq. thermocline in the central-eastern Pacific compared to the ensemble mean.
- The cold bias probably contributed to the colder NINO3.4 forecast relative to other NMME models.

Ocean Initial Conditions for Seasonal Forecast Models

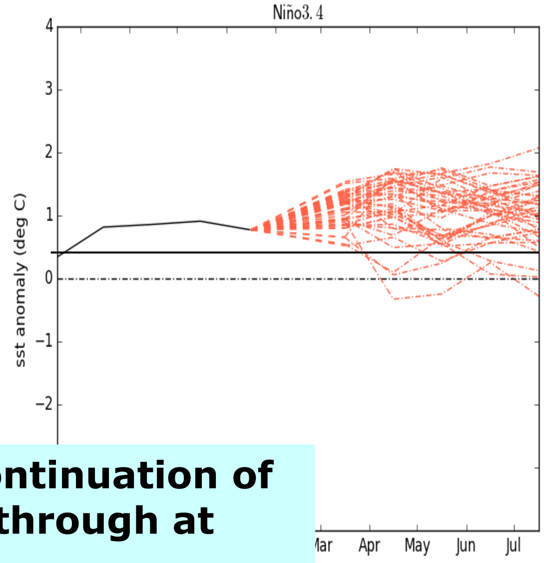
Real-Time Ocean Reanalysis Intercomparison:
D20
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html, clim. 1993-2013)



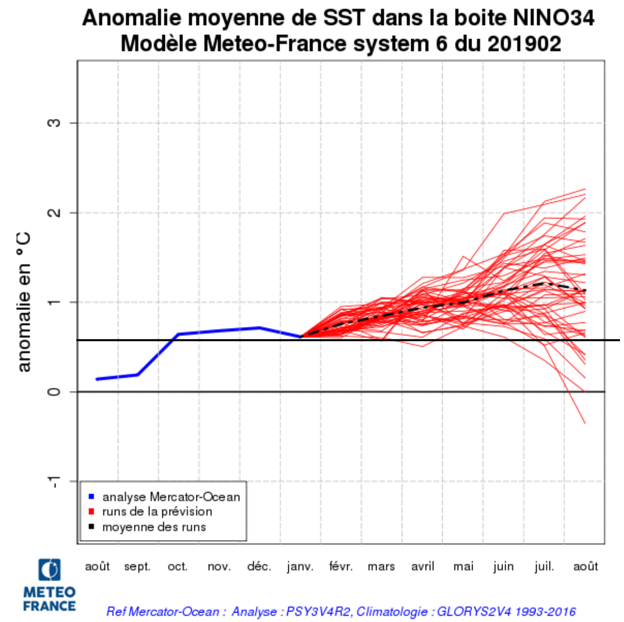
ECMWF



UK MET

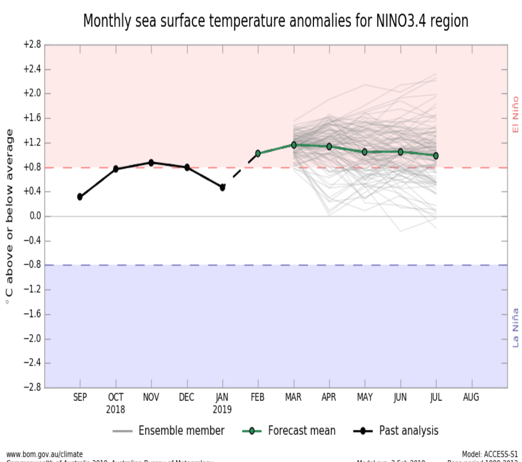


Meteo-France

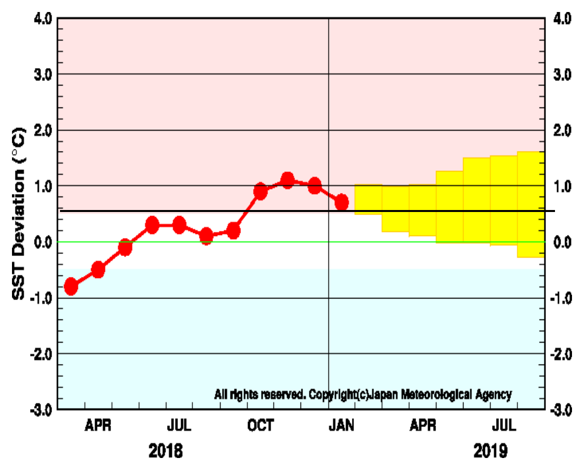


- All models favor continuation of El Nino conditions through at least spring 2019.

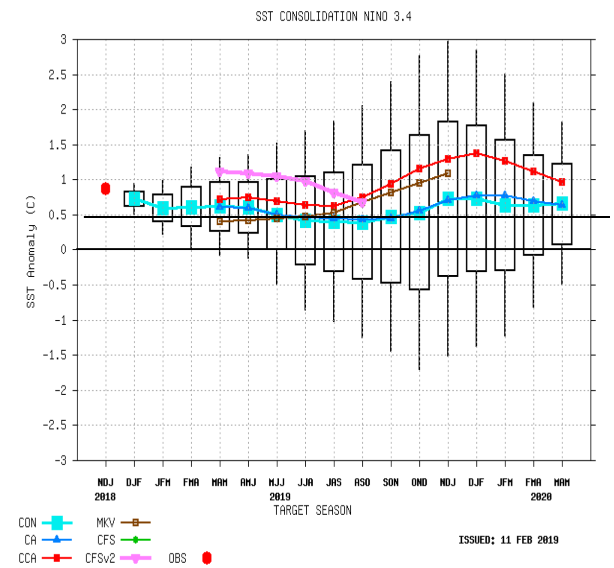
BOM

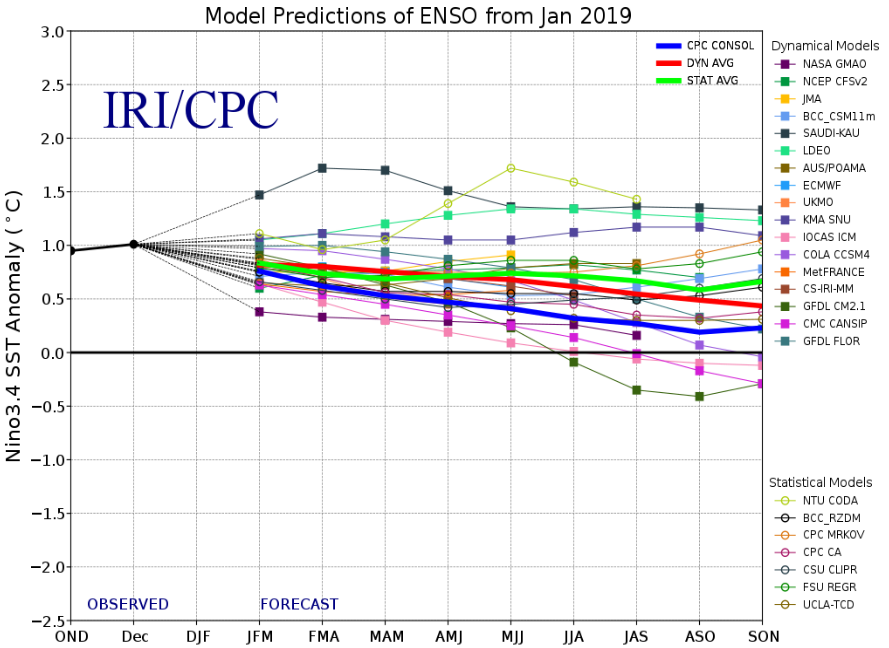


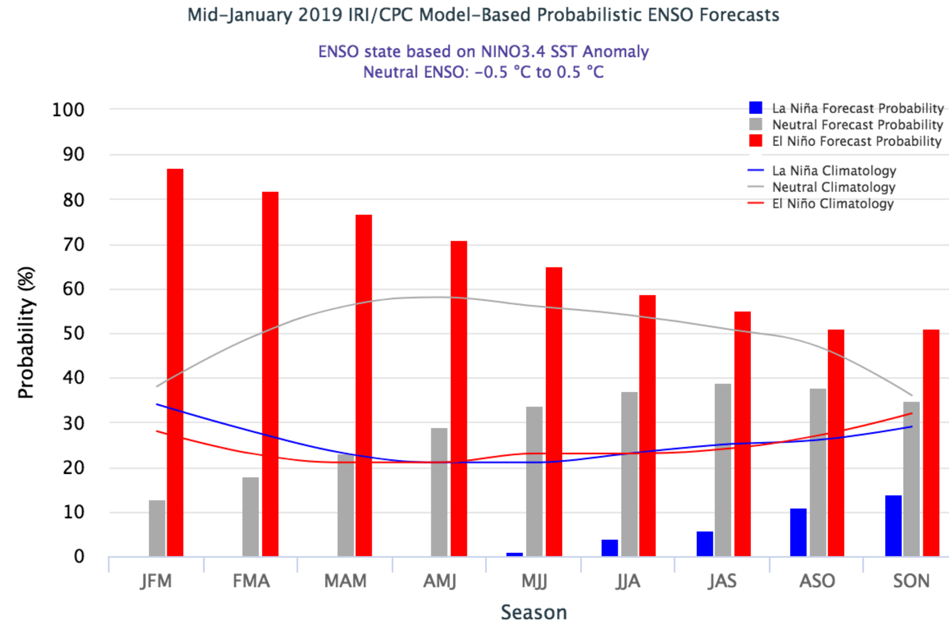
JMA



CPC Consolidation

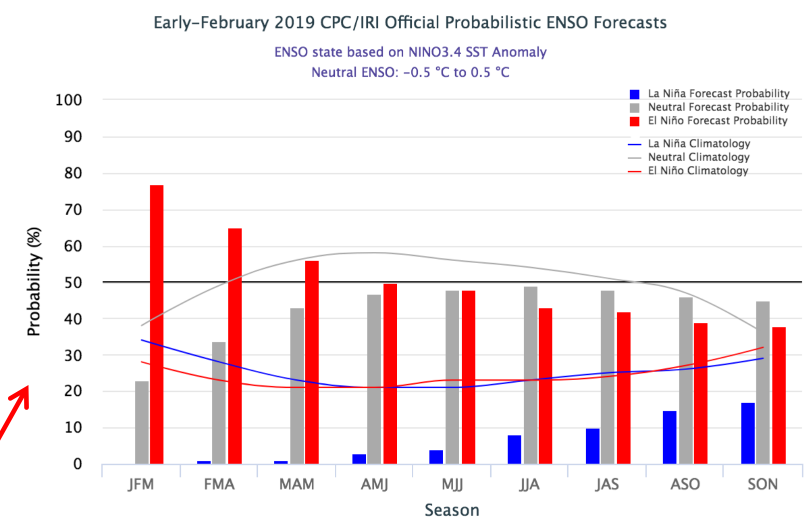






- **Most of statistical and dynamical models suggest the El Nino conditions will continue through the Northern Hemisphere summer 2019.**

- **ENSO Diagnostic Discussion on Feb 14, 2019: Weak El Niño conditions are present and are expected to continue through the Northern Hemisphere spring 2019 (~55% chance).**



Acknowledgements

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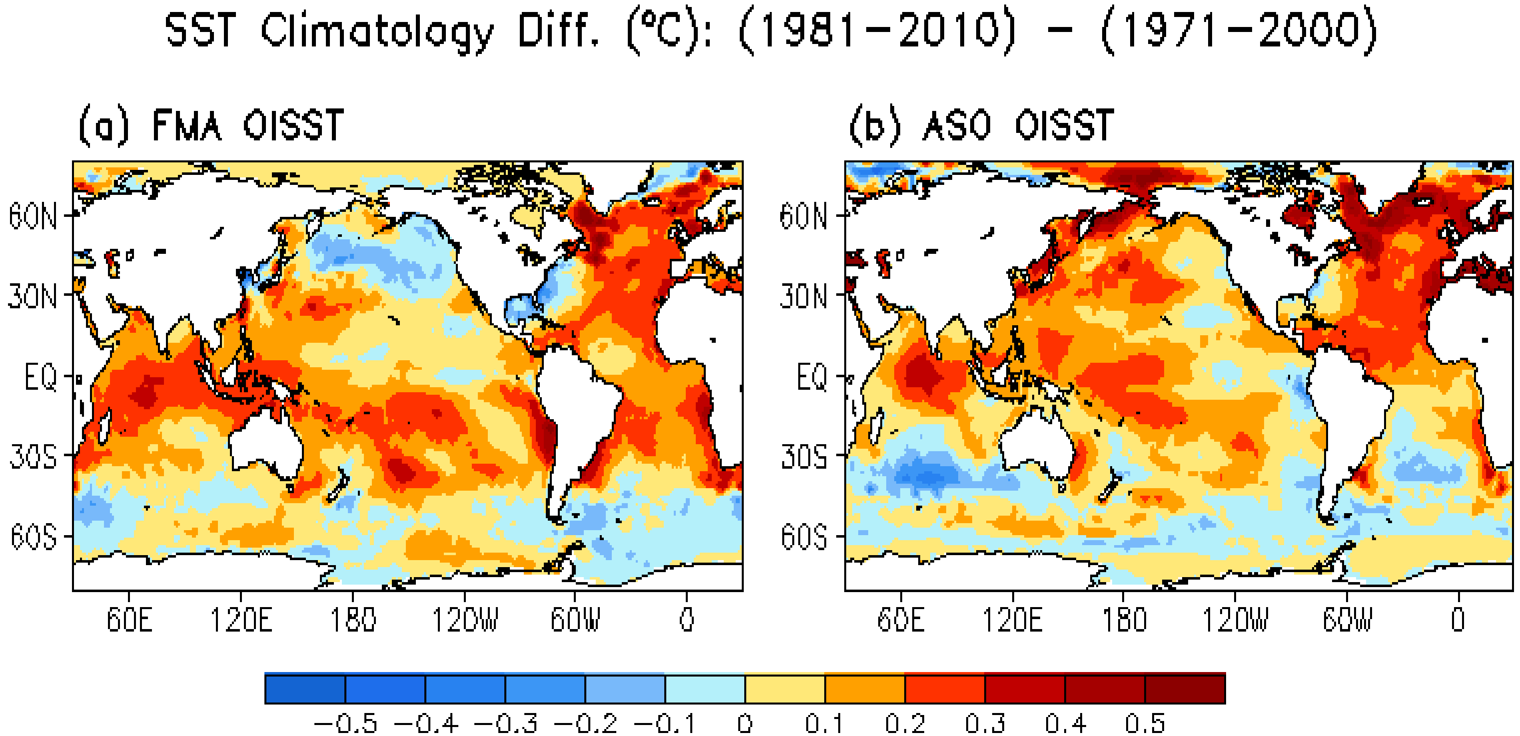
- Dr. Boyin Huang provided the BAMS SST plots
- Drs. Li Ren and Pingping Xie provided the BASS/CMORPH/CFSR EVAP package
- Dr. Emily Becker provided the NMME NINO3.4 plot
- Dr. Dan Collins provided the CPC ENSO consolidation plot

Backup Slides

Switch to 1981-2010 Climatology

- **SST from 1971-2000 to 1981-2010**
  - **Weekly OISST.v2, monthly ERSST.3b**
- **Atmospheric fields from 1979-1995 to 1981-2010**
  - **NCEP CDAS winds, sea level pressure, 200mb velocity potential, surface shortwave and longwave radiation, surface latent and sensible fluxes, relative humidity**
  - **Outgoing Long-wave Radiation**
- **Oceanic fields from 1982-2004 to 1981-2010**
  - **GODAS temperature, heat content, depth of 20^{o}C, sea surface height, mixed layer depth, tropical cyclone heat potential, surface currents, upwelling**
- **Satellite data climatology 1993-2005 unchanged**
  - **Aviso Altimetry Sea Surface Height**
  - **Ocean Surface Current Analyses – Realtime (OSCAR)**

Be aware that new climatology (1981-2010) was applied since Jan 2011



1971-2000 SST Climatology (Xue et al. 2003):
http://www.cpc.ncep.noaa.gov/products/predictions/30day/SSTs/sst_clim.htm

1981-2010 SST Climatology: http://origin.cpc.ncep.noaa.gov/products/people/yxue/sstclim/

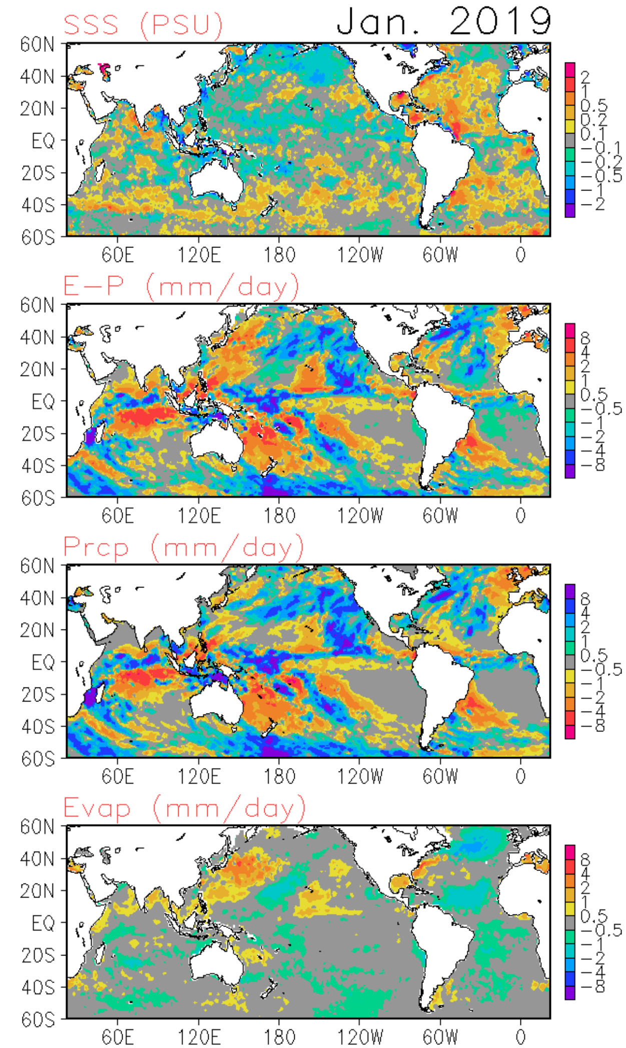
- The seasonal mean SST in February-April (FMA) increased by more than 0.2°C over much of the Tropical Oceans and N. Atlantic, but decreased by more than 0.2°C in high-latitude N. Pacific, Gulf of Mexico and along the east coast of U.S.

- Compared to FMA, the seasonal mean SST in August-October (ASO) has a stronger warming in the tropical N. Atlantic, N. Pacific and Arctic Ocean, and a weaker cooling in Gulf of Mexico and along the east coast of U.S.

Global Sea Surface Salinity (SSS)

Anomaly for January 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.**
- **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 and a large scale of freshening in the subarctic region of N. Pacific between 35°N and 50°N both continue this month. The SSS in the Bay of Bengal became fresher, especially in the east basin. The SSS in the majority of the N. Atlantic Ocean from equator to 40°N shows positive signals, which is likely due to oceanic advection and/or entrainments. Meanwhile, the positive SSS in the S. Atlantic ocean between 20°S and 40°S is co-incident with a reduced precipitation in some of the areas.



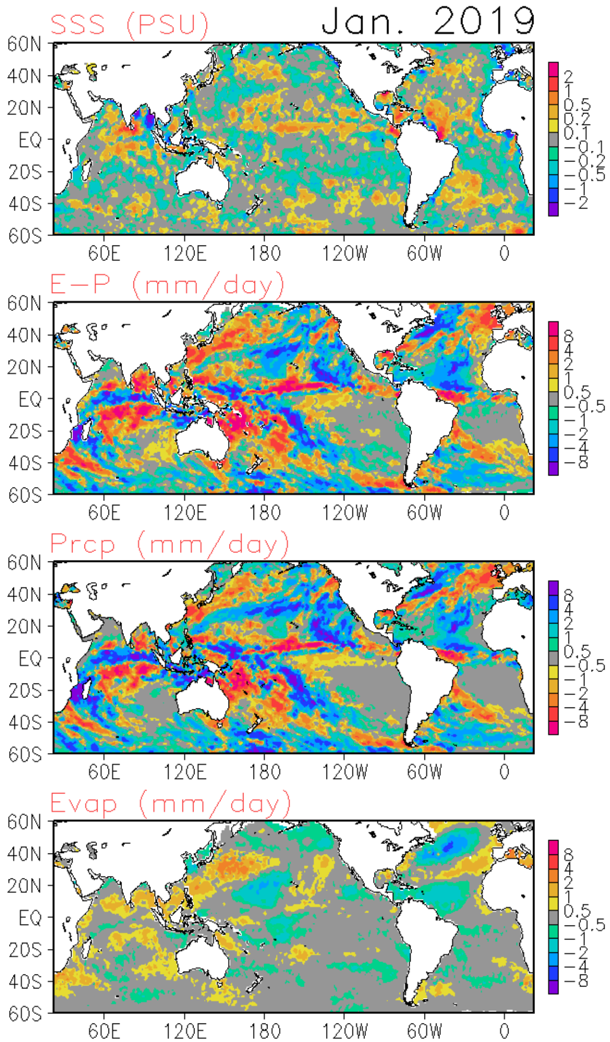
- **Data used**

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 January 2019

Compared with last month, the SSS increased in the ITCZ region with reduced precipitation in this area. A significant SSS decrease in the east basin of Bay of Bengal is likely due to the oceanic advection and/or entrainments as the precipitation decreased in this area. The SSS in the North Atlantic ocean between equator and 20°N increases with increased precipitation which suggests that such SSS change is likely due to the oceanic advection and/or entrainments.

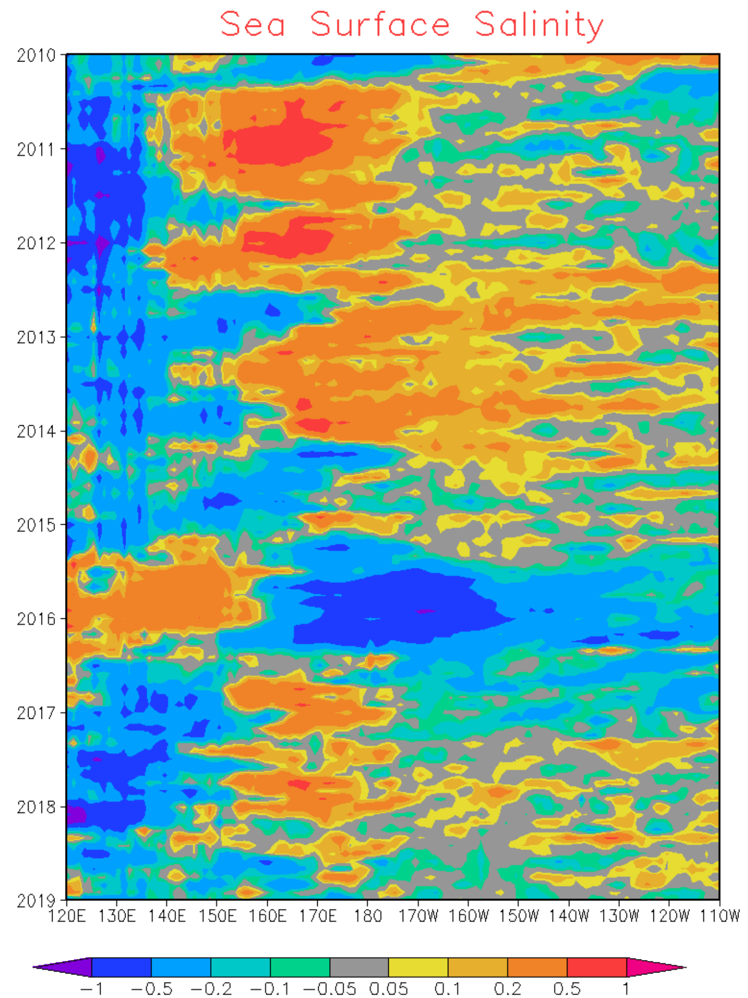


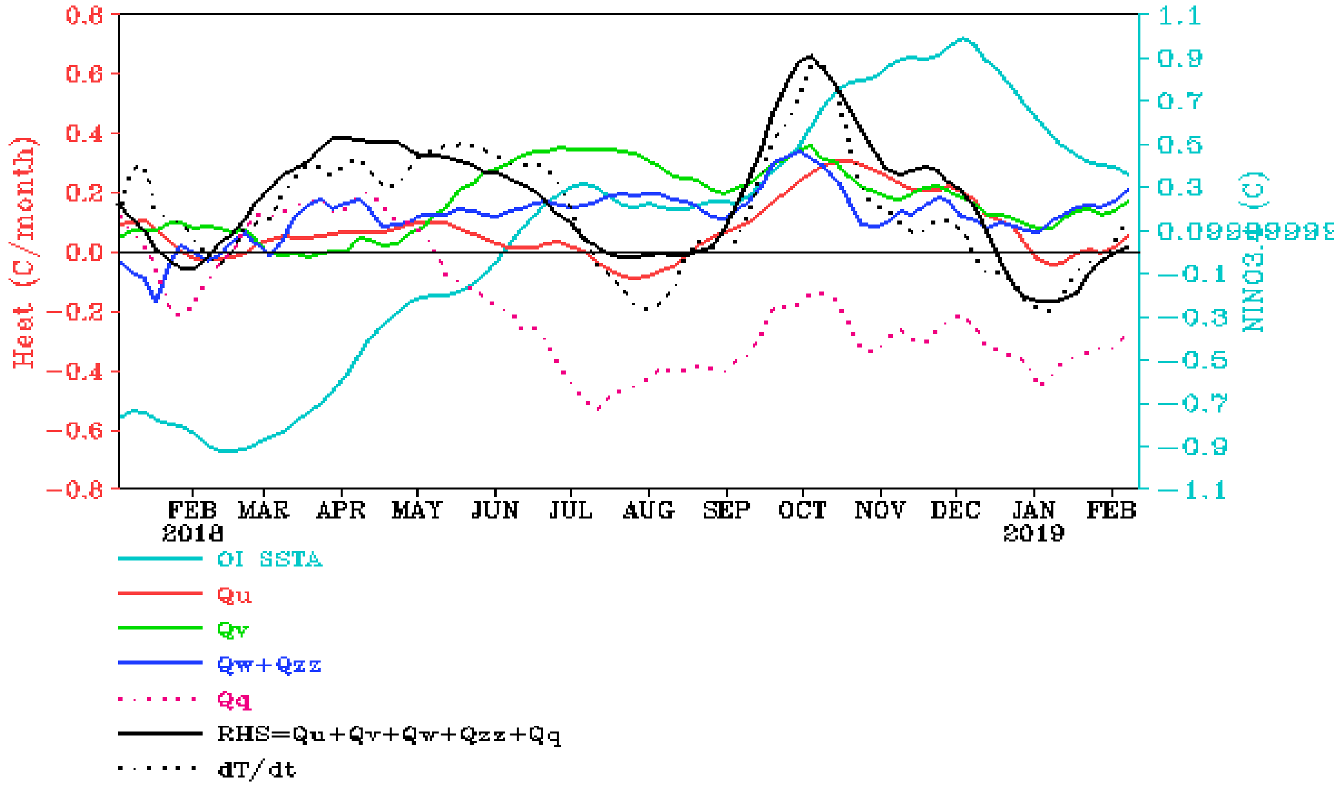
Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific from Monthly SSS

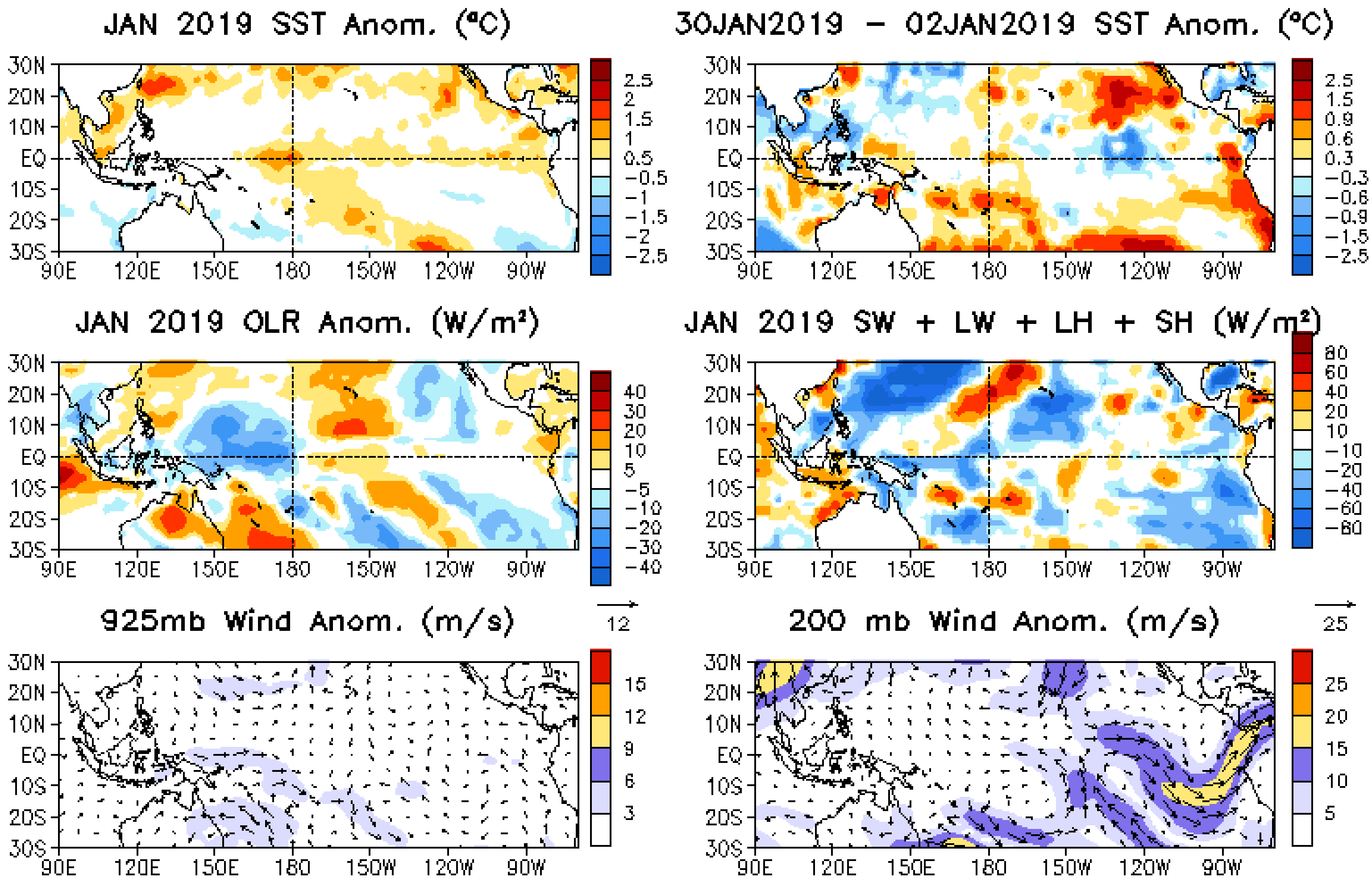
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

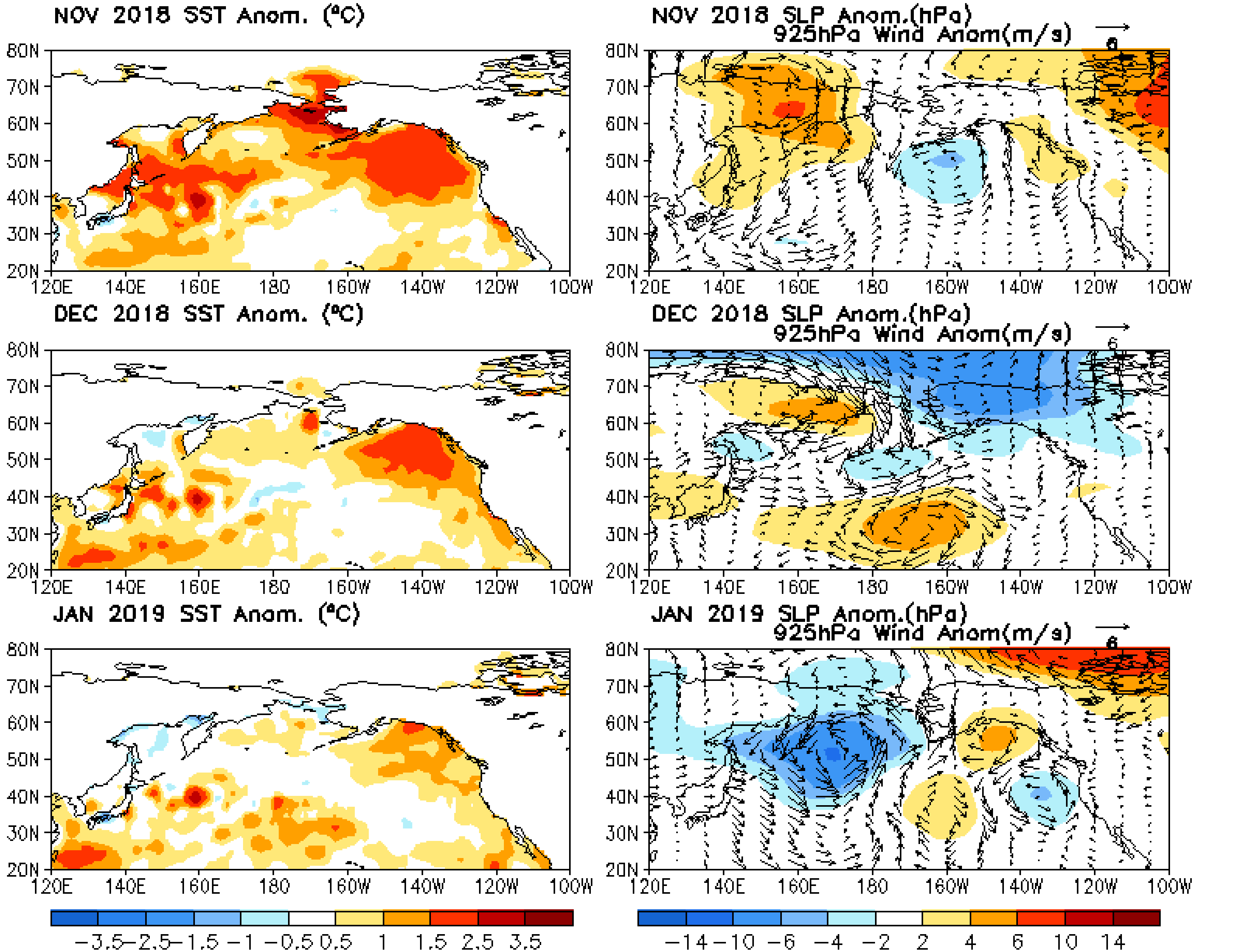
- Hovemoller diagram for equatorial SSS anomaly **(5°S-5°N);**
- In the equatorial Pacific Ocean, the negative SSS signal continues from 120°E to 170°E, while the negative SSS signal becomes weaker or neutral in some regions east of 170°E.

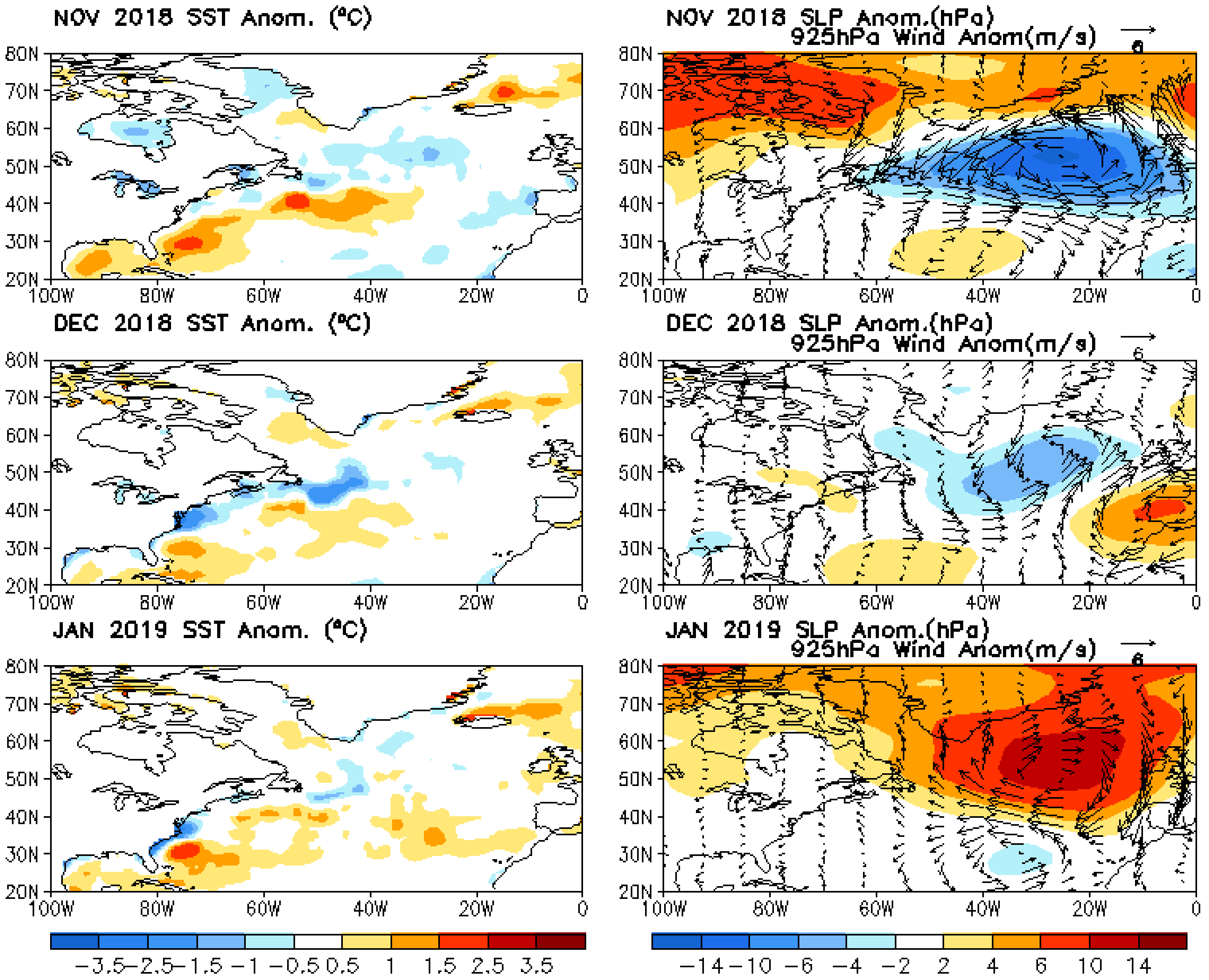




0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
Heat (C/month)
1.1
0.9
0.7
0.5
0.3
0.0999999
−0.1
−0.3
−0.5
−0.7
−0.9
−1.1
NINO3.4 (C)
FEB
2018
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
2019
FEB
OI SSTA
Qu
Qv
Qw+Qzz
Qq
RHS=Qu+Qv+Qw+Qzz+Qq
dT/dt


JAN 2019 SST Anom. (°C)
30JAN2019 – 02JAN2019 SST Anom. (°C)
JAN 2019 OLR Anom. (W/m²)
JAN 2019 SW + LW + LH + SH (W/m²)
925mb Wind Anom. (m/s)
200 mb Wind Anom. (m/s)
30N 20N 10N EQ 10S 20S 30S
90E 120E 150E 180 150W 120W 90W
2.5 2 1.5 1 0.5 −0.5 −1 −1.5 −2 −2.5
2.5 1.5 0.9 0.6 0.3 −0.3 −0.6 −0.9 −1.5 −2.5
40 30 20 10 5 −5 −10 −20 −30 −40
80 60 40 20 10 −10 −20 −40 −60 −80
12
15 12 9 6 3
25
25 20 15 10 5


NOV 2018 SST Anom. (°C)
NOV 2018 SLP Anom.(hPa)
925hPa Wind Anom(m/s)
DEC 2018 SST Anom. (°C)
DEC 2018 SLP Anom.(hPa)
925hPa Wind Anom(m/s)
JAN 2019 SST Anom. (°C)
JAN 2019 SLP Anom.(hPa)
925hPa Wind Anom(m/s)
6
80N
70N
60N
50N
40N
30N
20N
120E 140E 160E 180 160W 140W 120W 100W
−3.5 −2.5 −1.5 −1 −0.5 0.5 1 1.5 2.5 3.5
−14 −10 −6 −4 −2 2 4 6 10 14



NOV 2018 SST Anom. (°C)
NOV 2018 SLP Anom.(hPa)
925hPa Wind Anom(m/s)
DEC 2018 SST Anom. (°C)
DEC 2018 SLP Anom.(hPa)
925hPa Wind Anom(m/s)
JAN 2019 SST Anom. (°C)
JAN 2019 SLP Anom.(hPa)
925hPa Wind Anom(m/s)
80N
70N
60N
50N
40N
30N
20N
100W 80W 60W 40W 20W 0
−3.5 −2.5 −1.5 −1 −0.5 0.5 1 1.5 2.5 3.5
−14 −10 −6 −4 −2 2 4 6 10 14