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

Prepared by

Climate Prediction Center, NCEP/NOAA

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

This project to deliver real-time ocean monitoring products is implemented

by CPC in cooperation with NOAA's Ocean Observing and Monitoring Division (OOMD)

Outline

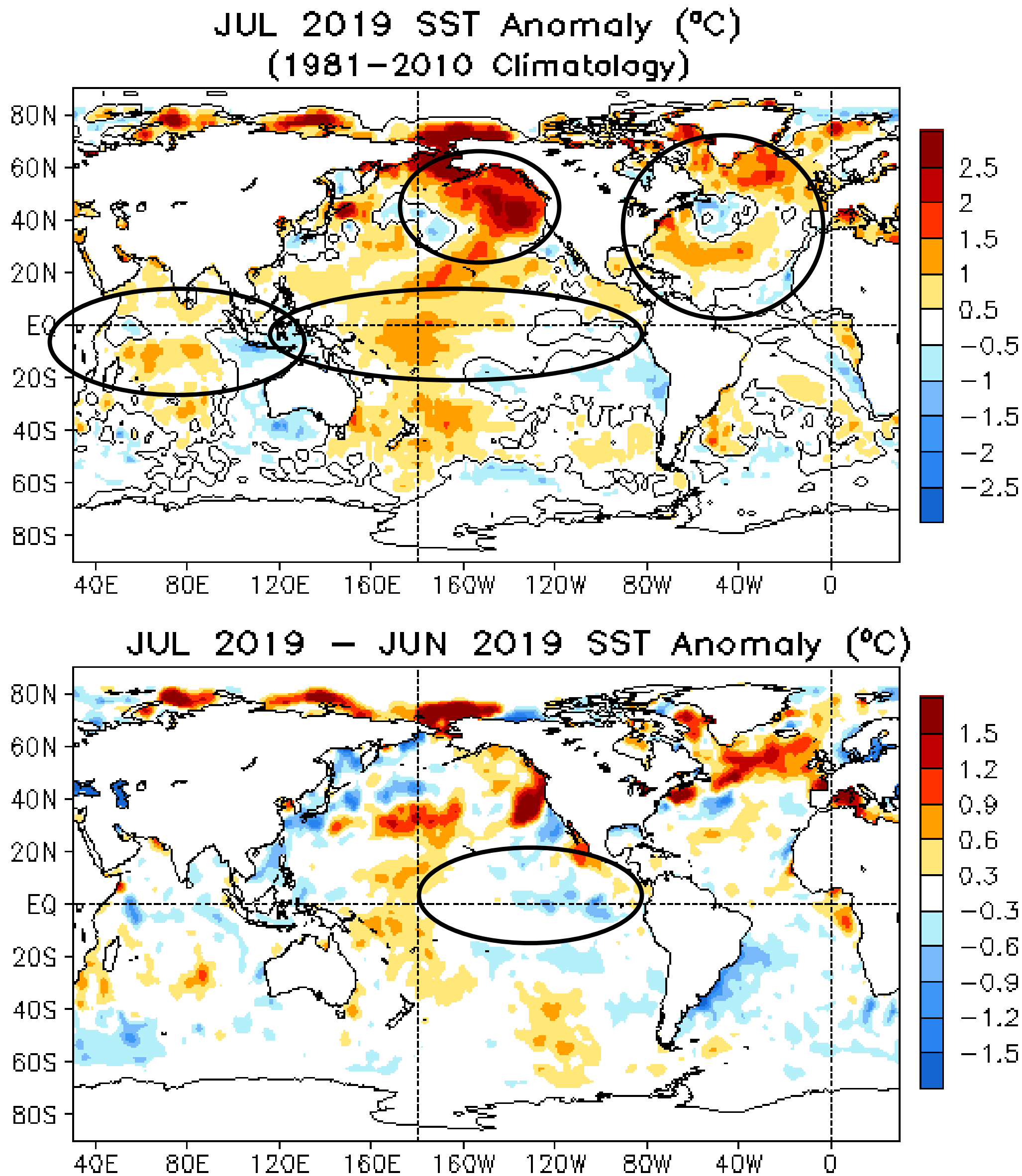
- **Overview**
- **Recent highlights**
  - **Pacific/Arctic Ocean**
  - **Indian Ocean**
  - **Atlantic Ocean**
- **Global SSTA Predictions**
- **Pacific "Blob" strengthened in Jul 2019**
- **NCEP/CPC Experimental Sea Ice Outlook**

Overview

- **Pacific Ocean**
  - **NOAA "ENSO Diagnostic Discussion" on 8 August 2019 issued "*Final El Nino Advisory*" and indicated that *"El Niño has transitioned to ENSO-neutral, which is most likely to continue through Northern Hemisphere winter 2019-20 (50-55% chance)."***
  - **Positive SSTAs weakened in the central and eastern tropical Pacific with NINO3.4=0.41^{o}C in Jul 2019.**
  - **Positive SSTAs dominated in the N. Pacific in Jul 2019. The PDO index switched to positive phase since March 2019 with PDOI= 0.8 in Jul 2019.**
- **Indian Ocean**
  - **IOD was in a strong positive phase in May-Jul 2019 with SSTAs generally positive (negative) in the west (far east).**
- **Atlantic Ocean**
  - **NAO was in a negative phase with NAOI=-1.4 in Jul 2019.**
  - **SSTAs were organized in a tripole/horseshoe pattern with positive anomalies in the middle latitudes of N. Atlantic during 2013-2019.**

Global Oceans

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



-SSTAs are Positive in the central, but near neutral in the eastern tropical Pacific.

- Positive SSTAs persisted in the Gulf of Alaska

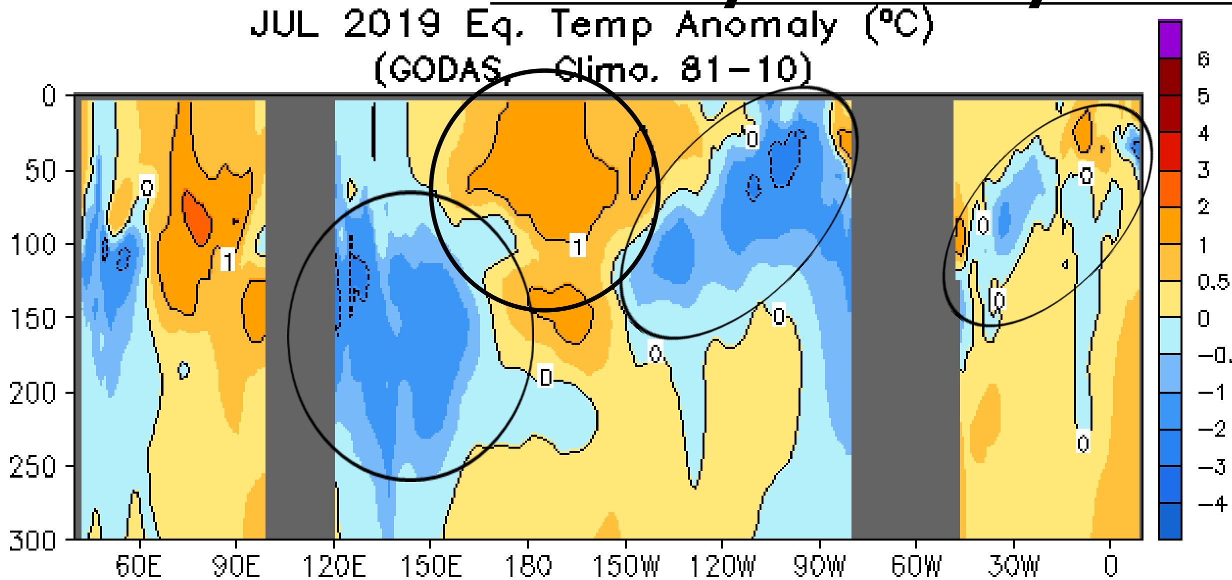
- Horseshoe/tripole-like SSTA pattern persisted in the North Atlantic.

- In the Indian Ocean, SSTAs were positive in the west and central and negative in the far east.

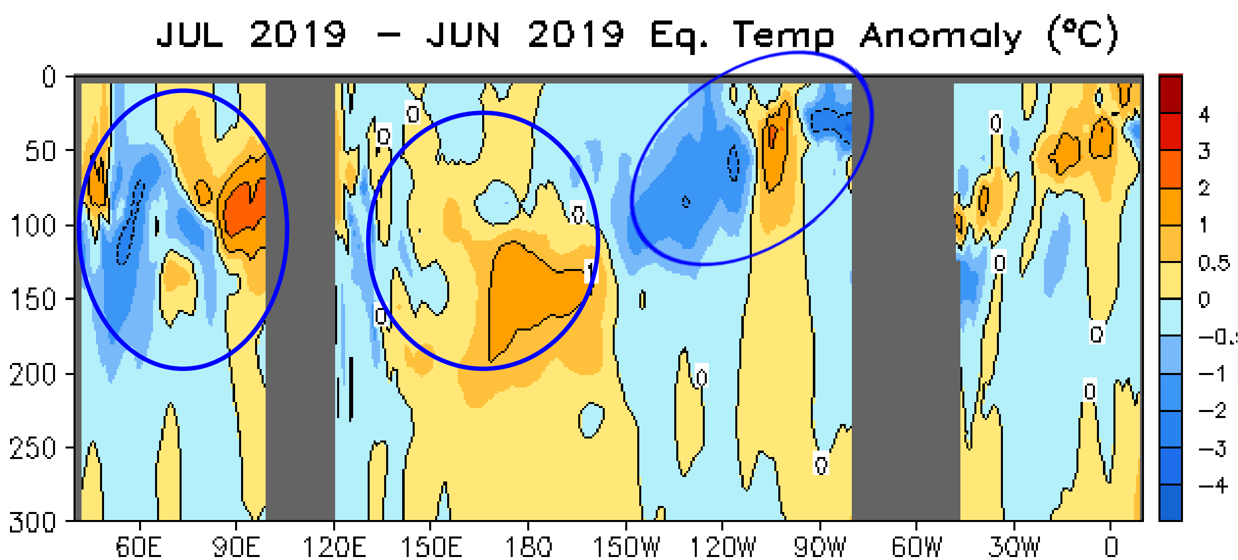
-Negative SSTA tendencies were observed in the eastern tropical Pacific.

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



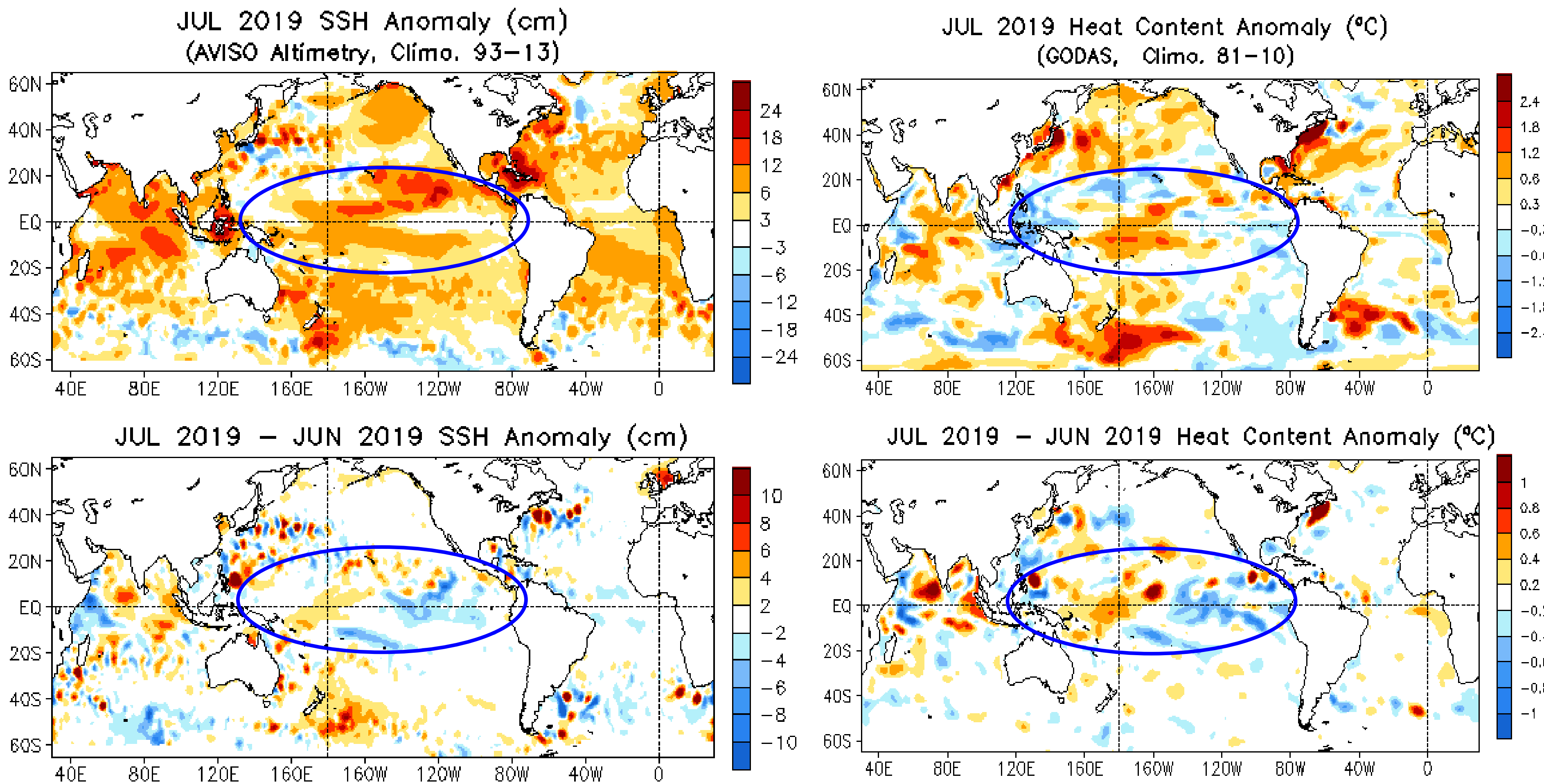
- **Positive (negative) temperature anomalies presented in the central (western and eastern) equatorial Pacific.**
- **Negative temperature anomalies persisted along the thermocline in the Atlantic Ocean.**



- **Temperature anomaly tendency was positive (negative) in the western (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.

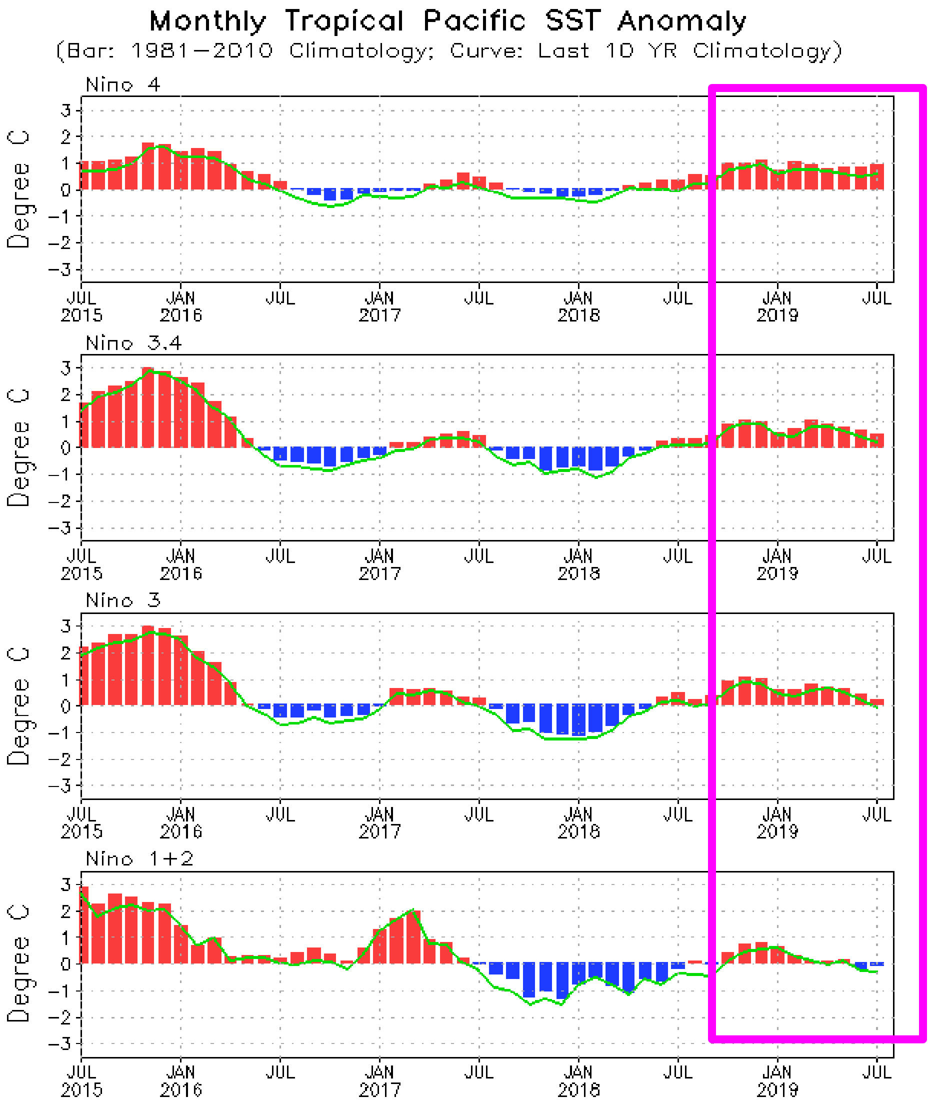
Global SSH and HC300 Anomaly & Anomaly Tendency

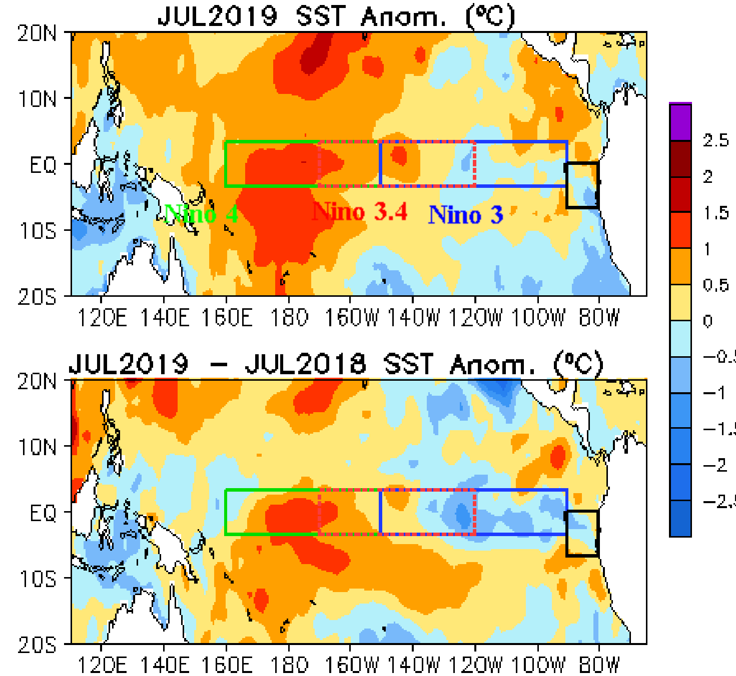


- **The SSHA pattern was overall consistent with the HC300A pattern, but with differences in details.**
- **Both SSHA and HC300A in the tropical Pacific were consistent with the ENSO-neutral state.**
- **Negative tendencies of SSHA and HC300A presented in the eastern tropical Pacific.**

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific NINO SST Indices

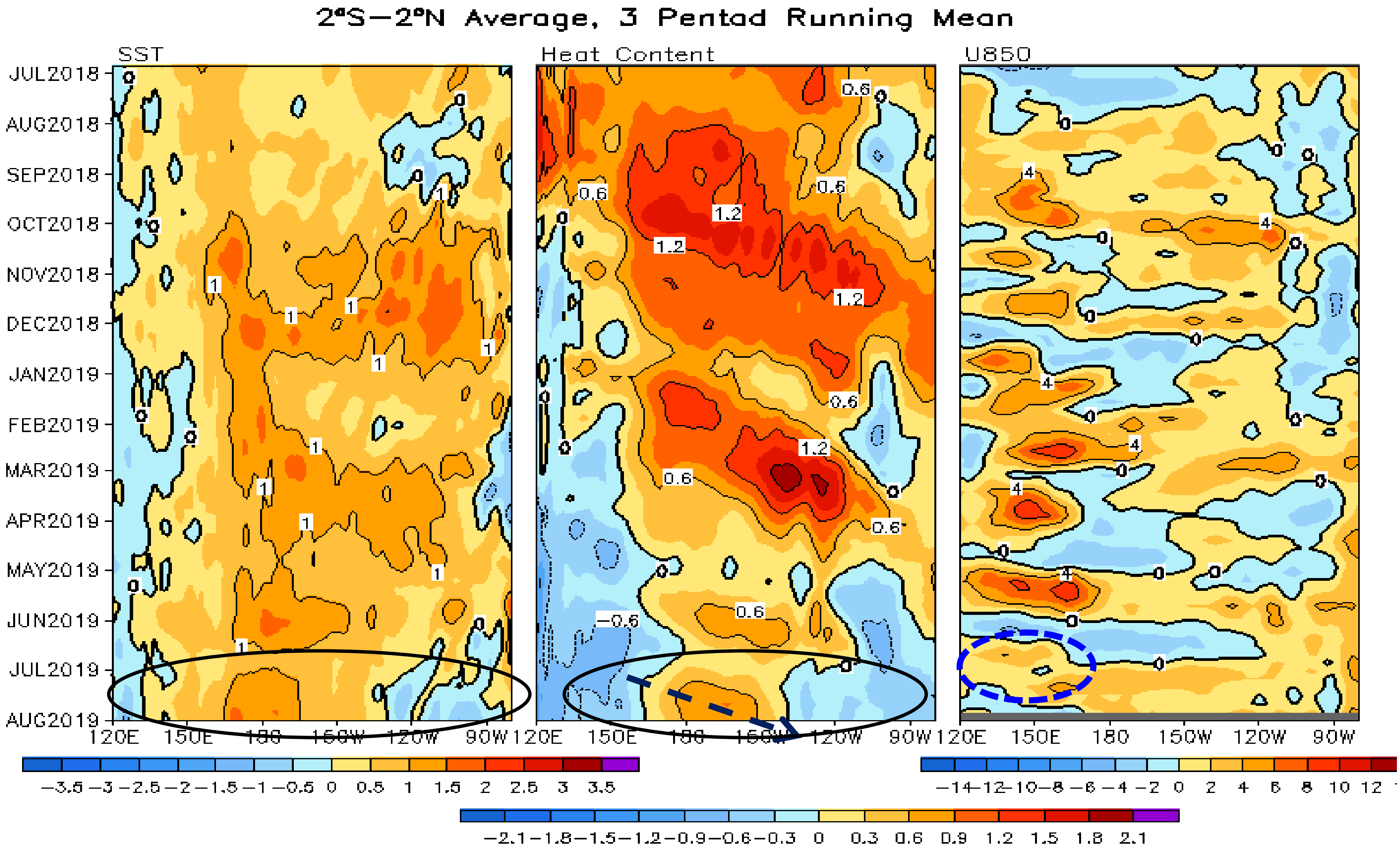




- **All indices, except Nino1+2, were positive in Jul 2019.**
- **Nino3.4 = 0.41 C in Jul 2019.**
- **Compared with Jul 2018, the central (eastern) equatorial Pacific was warmer (cooler) in Jul 2019.**
- **The indices were calculated based on OISST. They may have some differences compared with those 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



- **Positive SSTA in the central Pacific persisted, but SSTA in the eastern Pacific changed to negative in July 2019.**
- **Positive HC300A presented in the central Pacific, in association with a weak Kelvin wave.**
- **Negative SSTA/HC300A in the far eastern Pacific was partially related to meridional wind-induced Ekman pumping processes.**

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

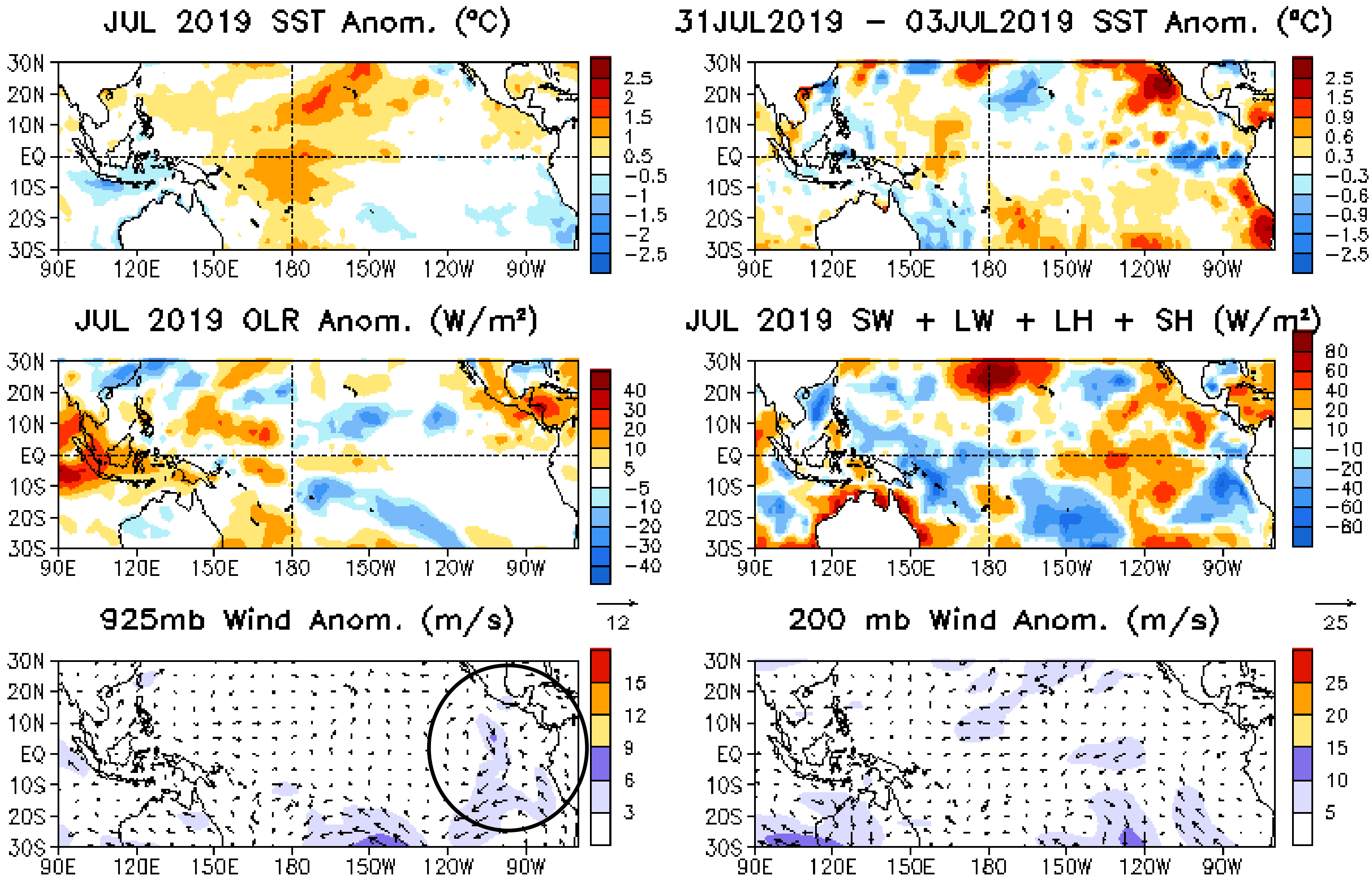
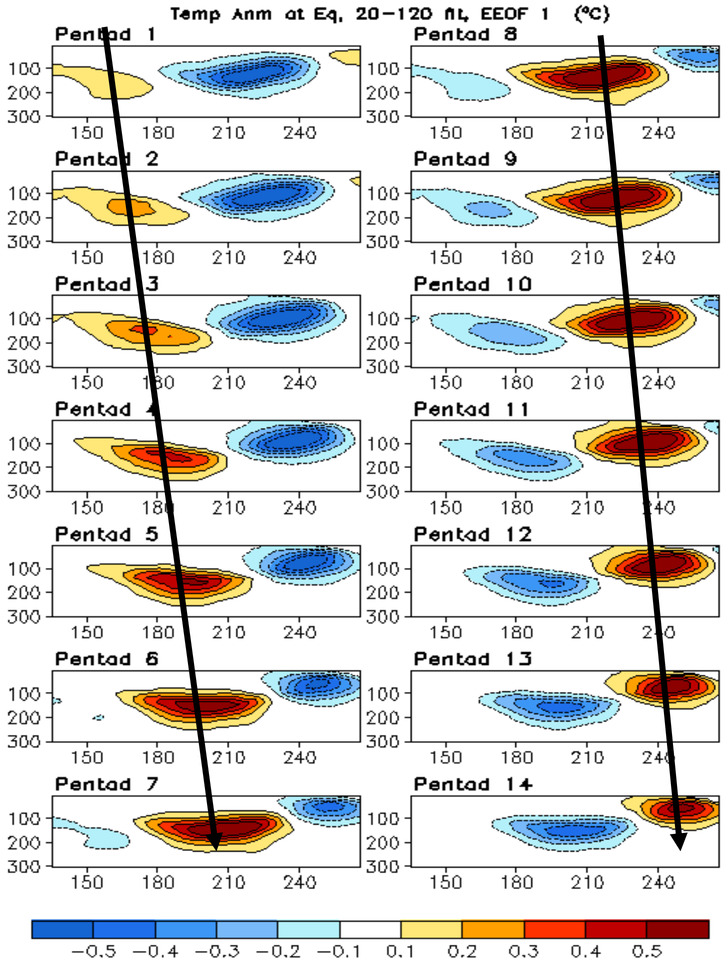
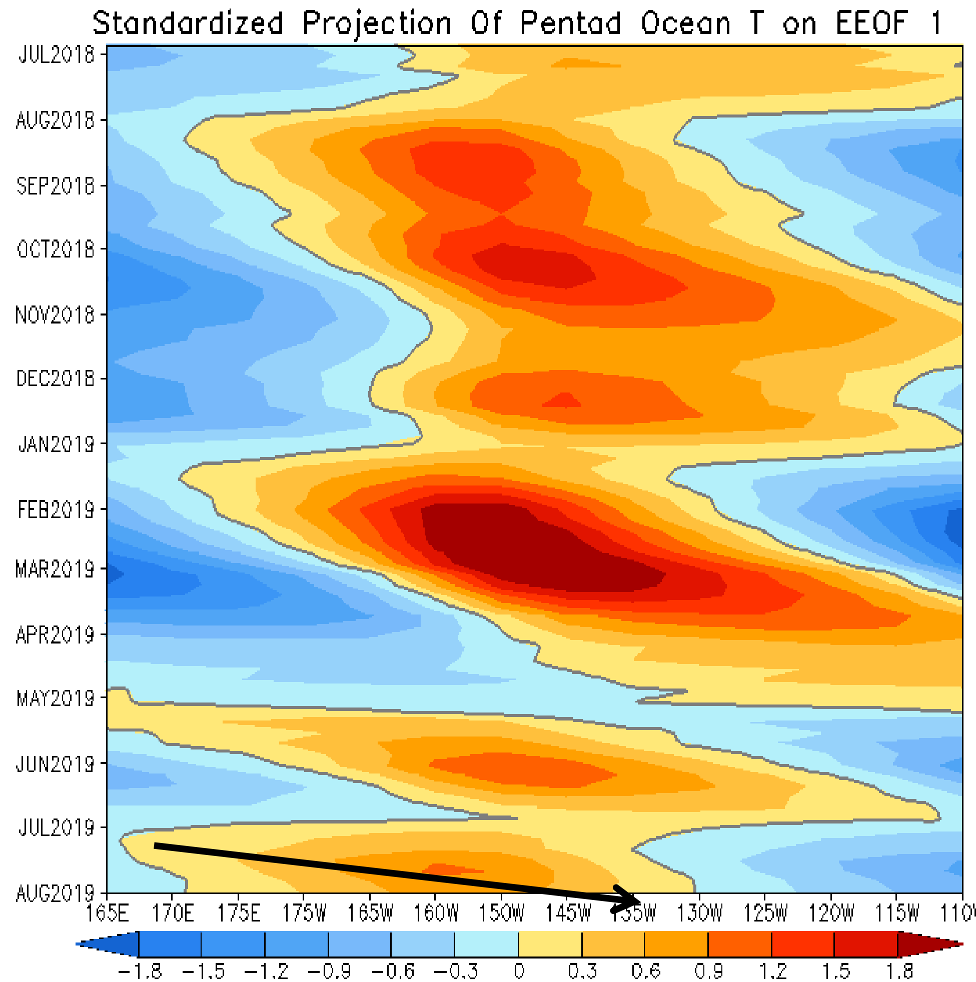


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Oceanic Kelvin Wave (OKW) Index





-A weak downwelling Kelvin wave initiated in early Jul 2019 and propagated eastward.

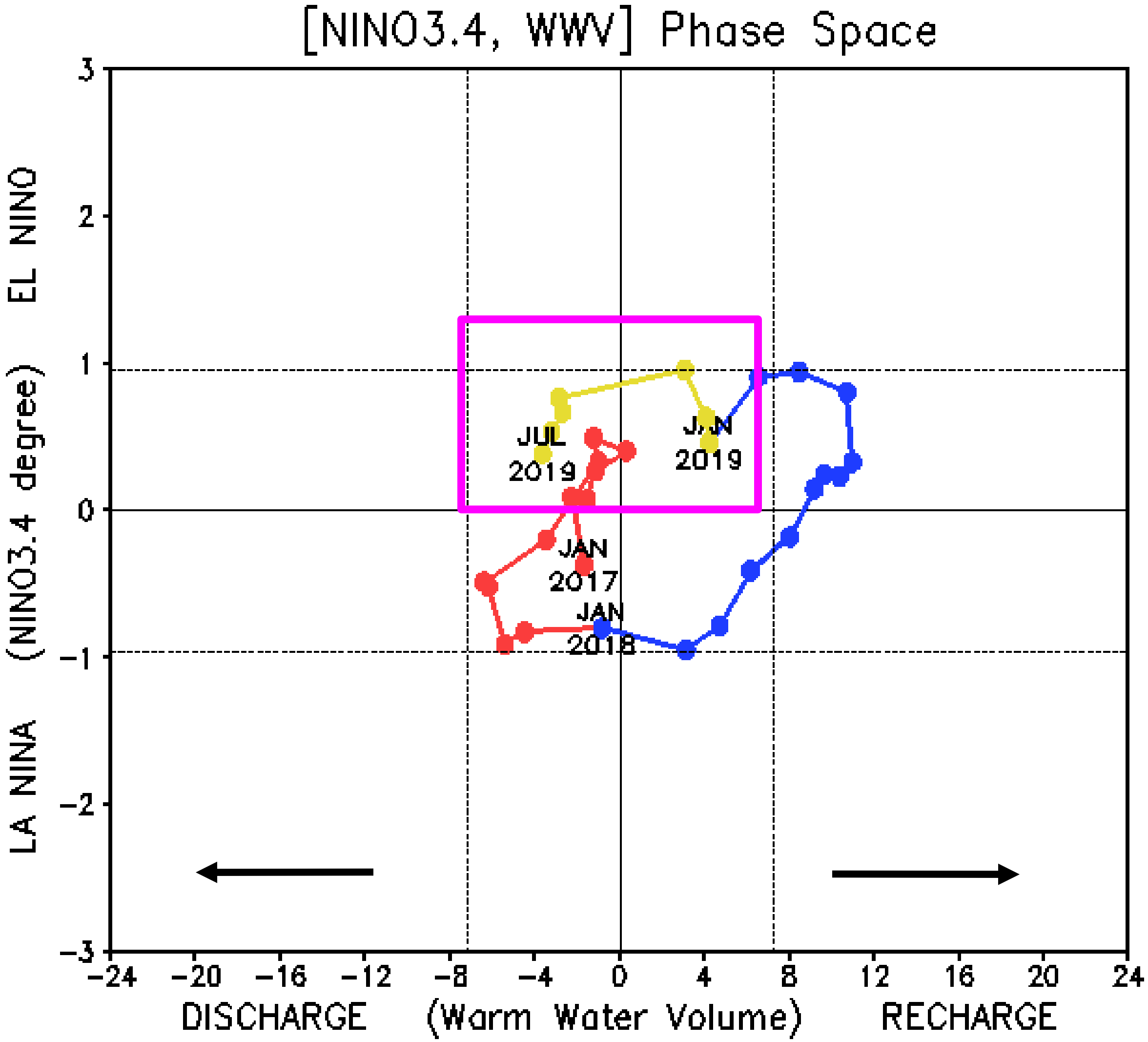
(OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)

Warm Water Volume (WWV) and NINO3.4 Anomalies

- WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N]. **Statistically, peak correlation of Nino3 with WWV occurs at 7 month lag** (Meinen and McPhaden, 2000).

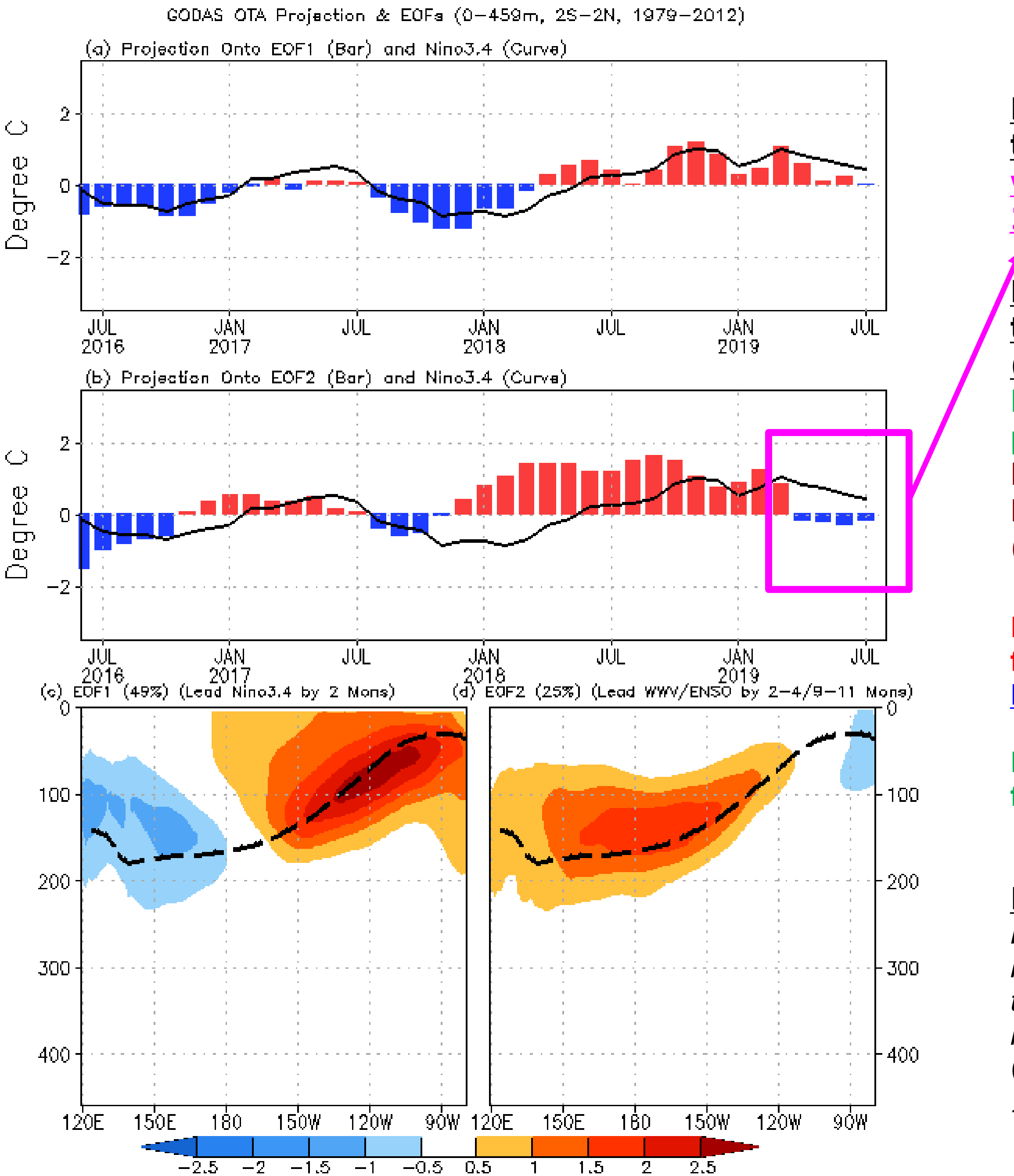
- Since WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and NINO3.4 (Kessler 2002).

- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



- **Equatorial Warm Water Volume (WWV) switched to a discharged phase since Apr 2019.**

Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.



Equatorial subsurface ocean temperature monitoring: ENSO was in a discharged phase in Jul 2019.

Projection of equatorial ocean temperature onto EOF1 and EOF2 (2S-2N, 0-459m, 1979-2010)

EOF1: Tilt mode (ENSO peak phase);

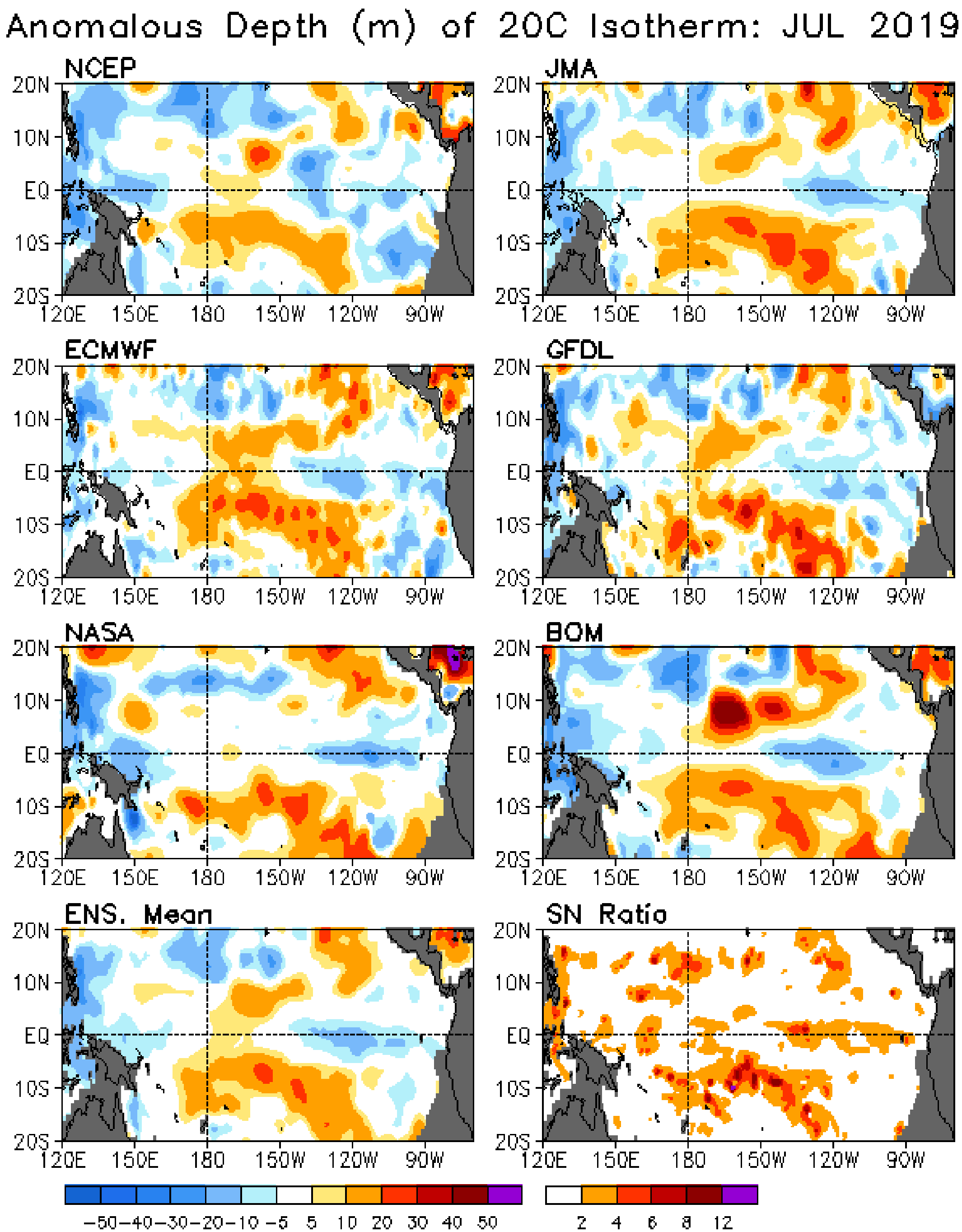
EOF2: WWV mode, Recharge/discharge oscillation (ENSO transition phase).

Recharge process: heat transport from outside of equator to equator : Negative -> positive phase of ENSO

Discharge process: heat transport from equator to outside of equator: Positive -> Negative phase of ENSO

For details, see:

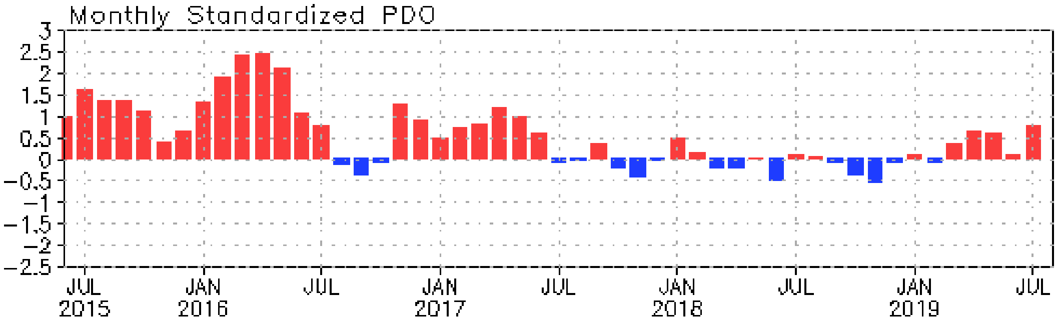
Kumar A, Z-Z Hu (2014) Interannual and interdecadal variability of ocean temperature along the equatorial Pacific in conjunction with ENSO. Clim. Dyn., 42 (5-6)**, 1243-1258.** *DOI: 10.1007/s00382-013-1721-0*.

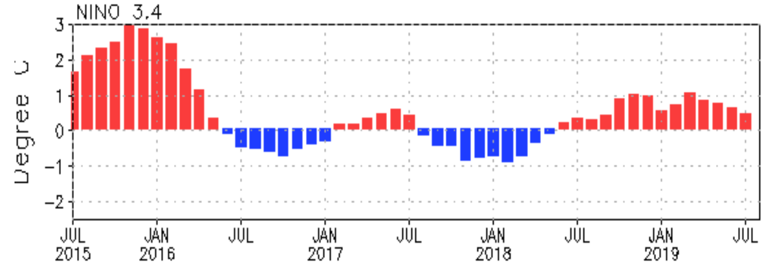


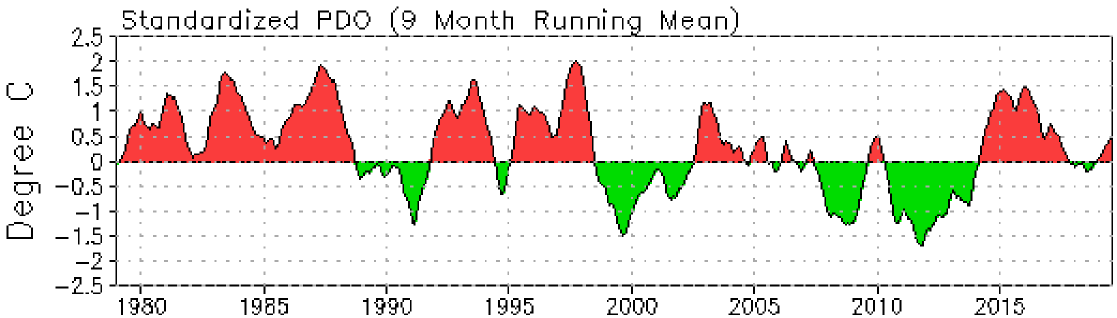
-Large scale feature is consistent among different products, but the noise level was larger compared to during ENSO peak phases.

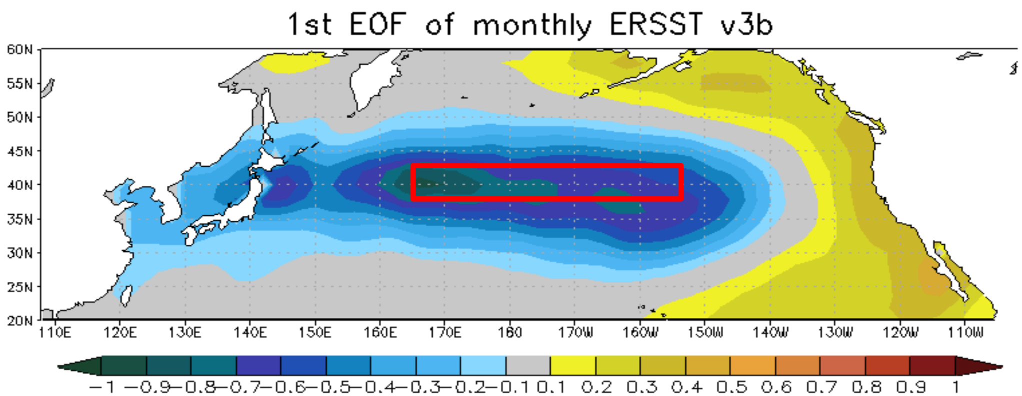
North Pacific & Arctic Oceans

PDO index









- The PDO index switched to positive phase since Mar 2019 with PDOI= 0.8 in Jul 2019.

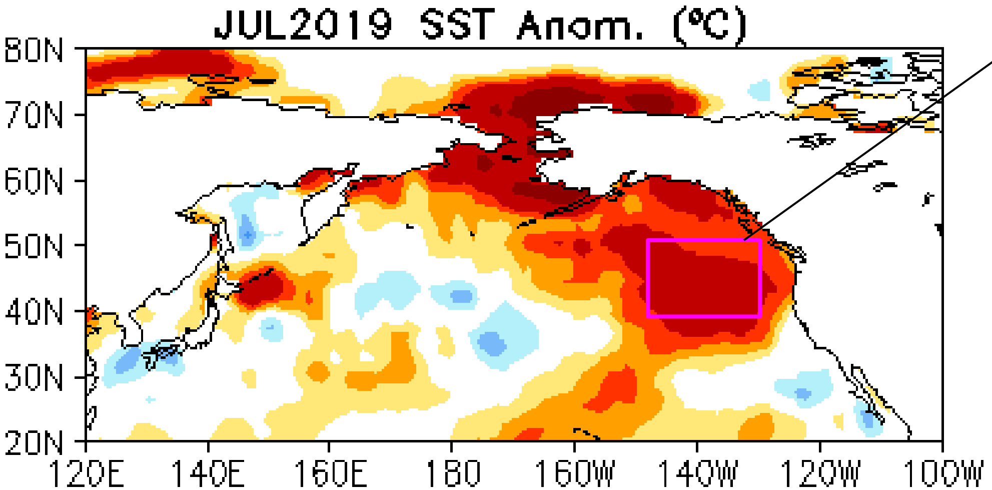
- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge.

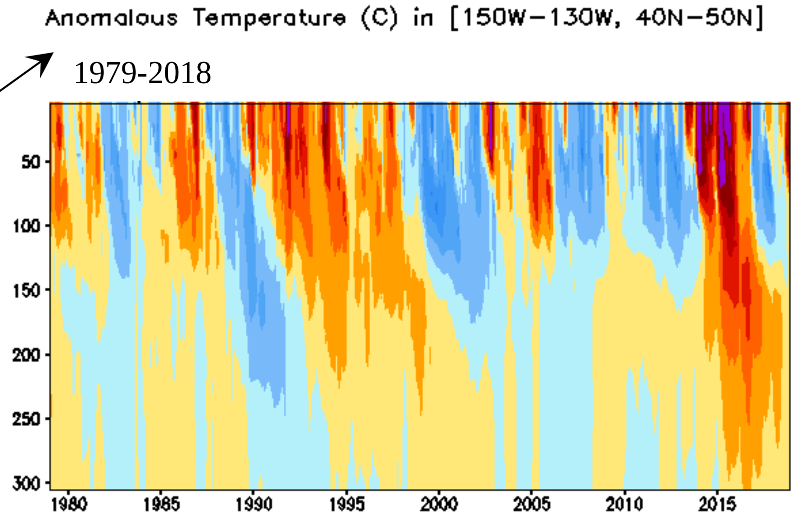
- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

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

The "Blob" in North Pacific

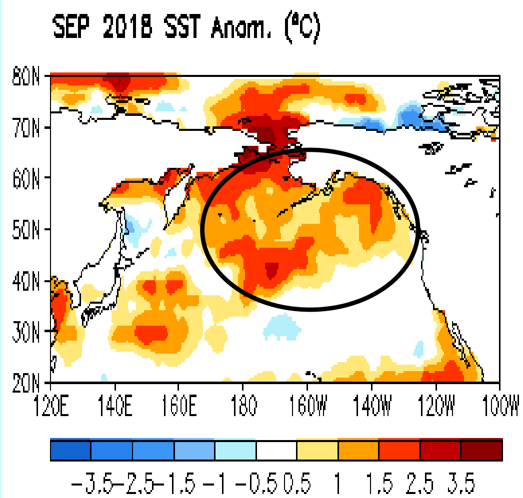
https://en.wikipedia.org/wiki/The_Blob_(Pacific_Ocean)

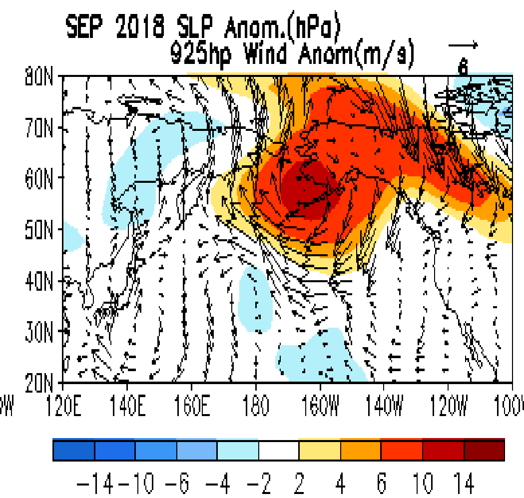


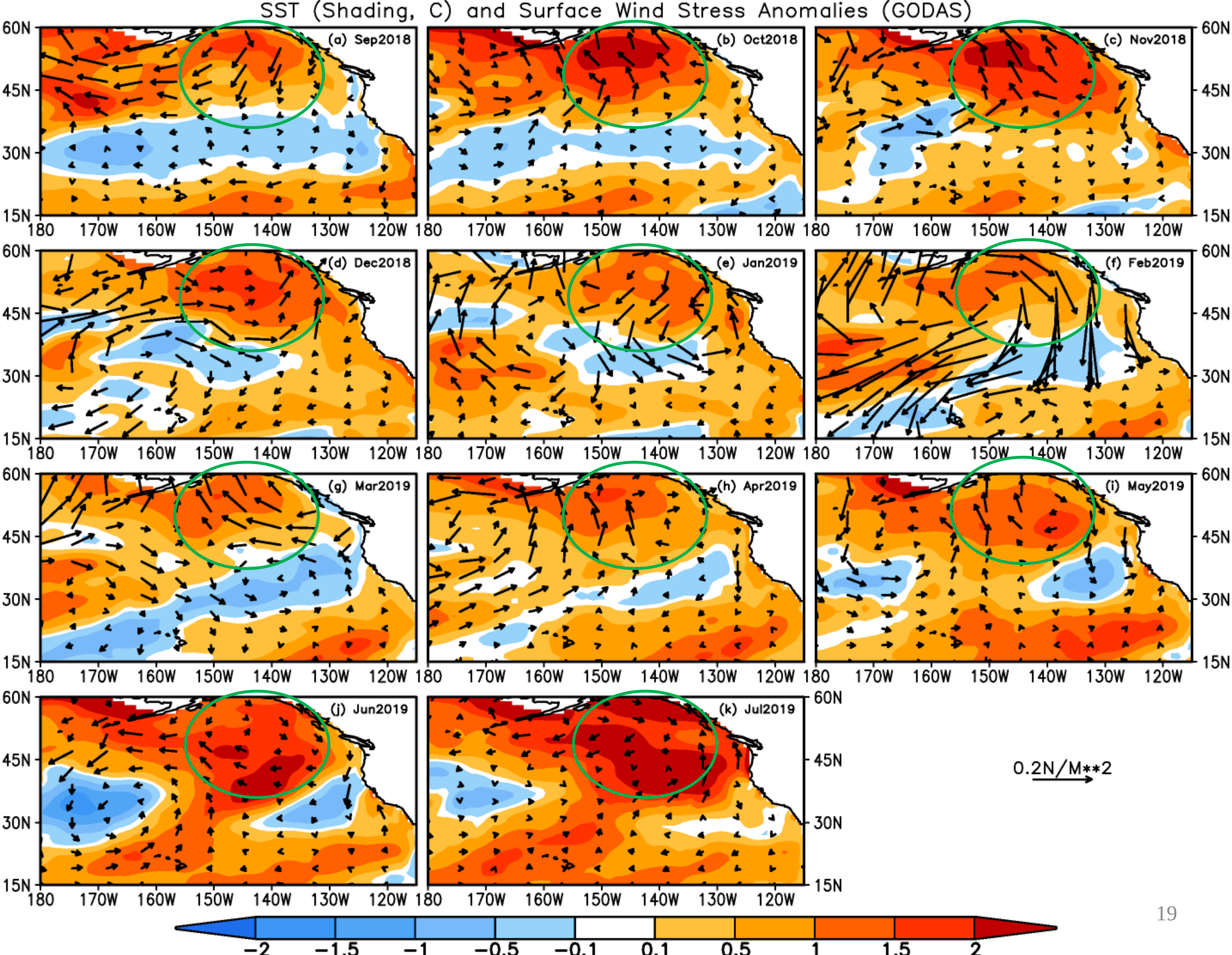


- **In 2014-2015, the northeast Pacific experienced the strongest SST warming on the record, referred to as "Pacific Blob" by Bond et al. (2015). The warming extended to 300m depth in late 2015 and the subsurface warming has lasted into 2018.**

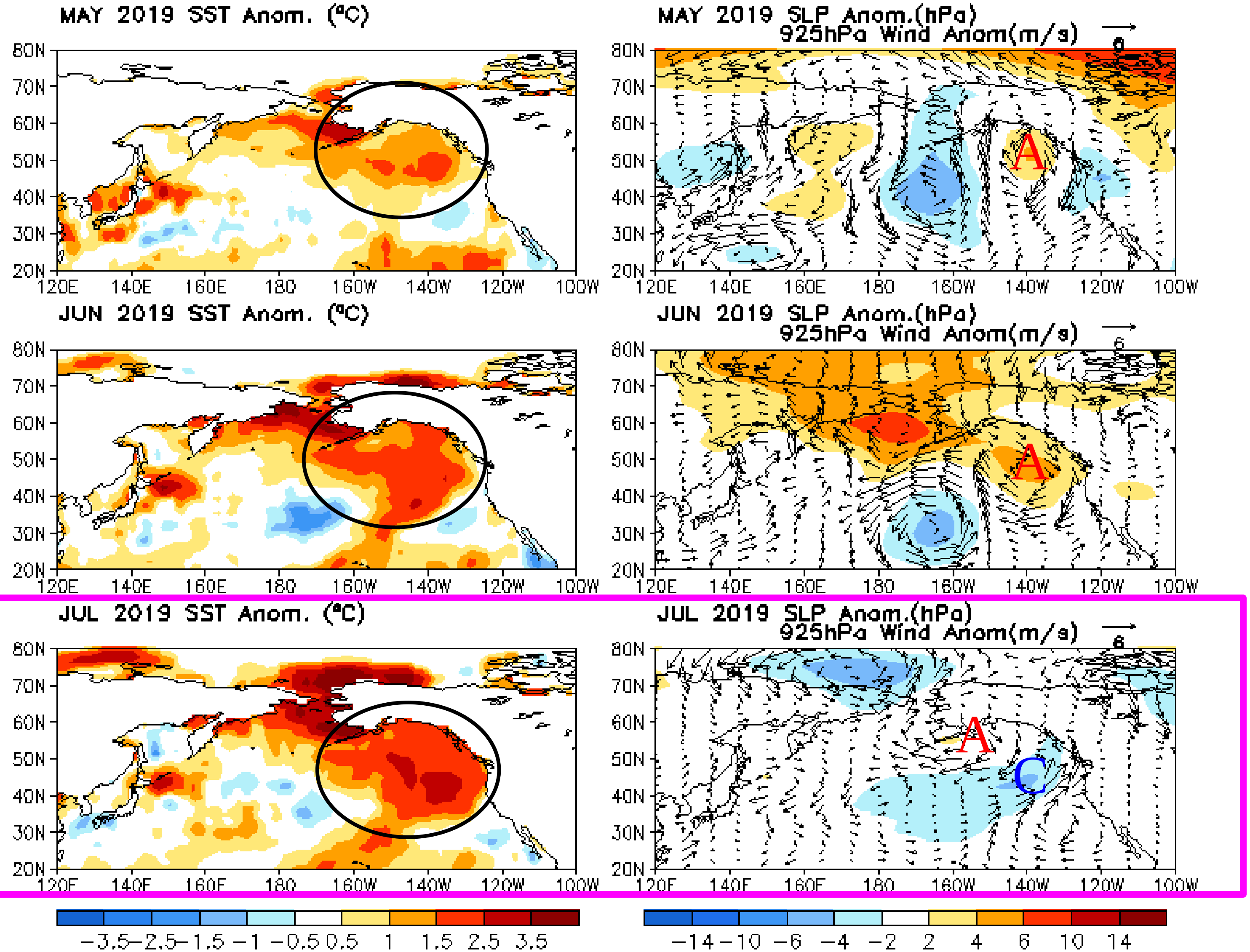
- **The current warming can be traced to Sep 2018.**






SST (Shading, C) and Surface Wind Stress Anomalies (GODAS)
(a) Sep2018
(b) Oct2018
(c) Nov2018
(d) Dec2018
(e) Jan2019
(f) Feb2019
(g) Mar2019
(h) Apr2019
(i) May2019
(j) Jun2019
(k) Jul2019
60N
45N
30N
15N
180
170W
160W
150W
140W
130W
120W
0.2N/M**2
−2
−1.5
−1
−0.5
−0.1
0.1
0.5
1
1.5
2

Last Three Month SST, SLP and 925hPa Wind Anomalies



- SST warming in the northeast Pacific (Pacific “Blob”) persisted in Jul 2019.
- The warming seems partially related to an anticyclone over the Gulf of Alaska.

North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

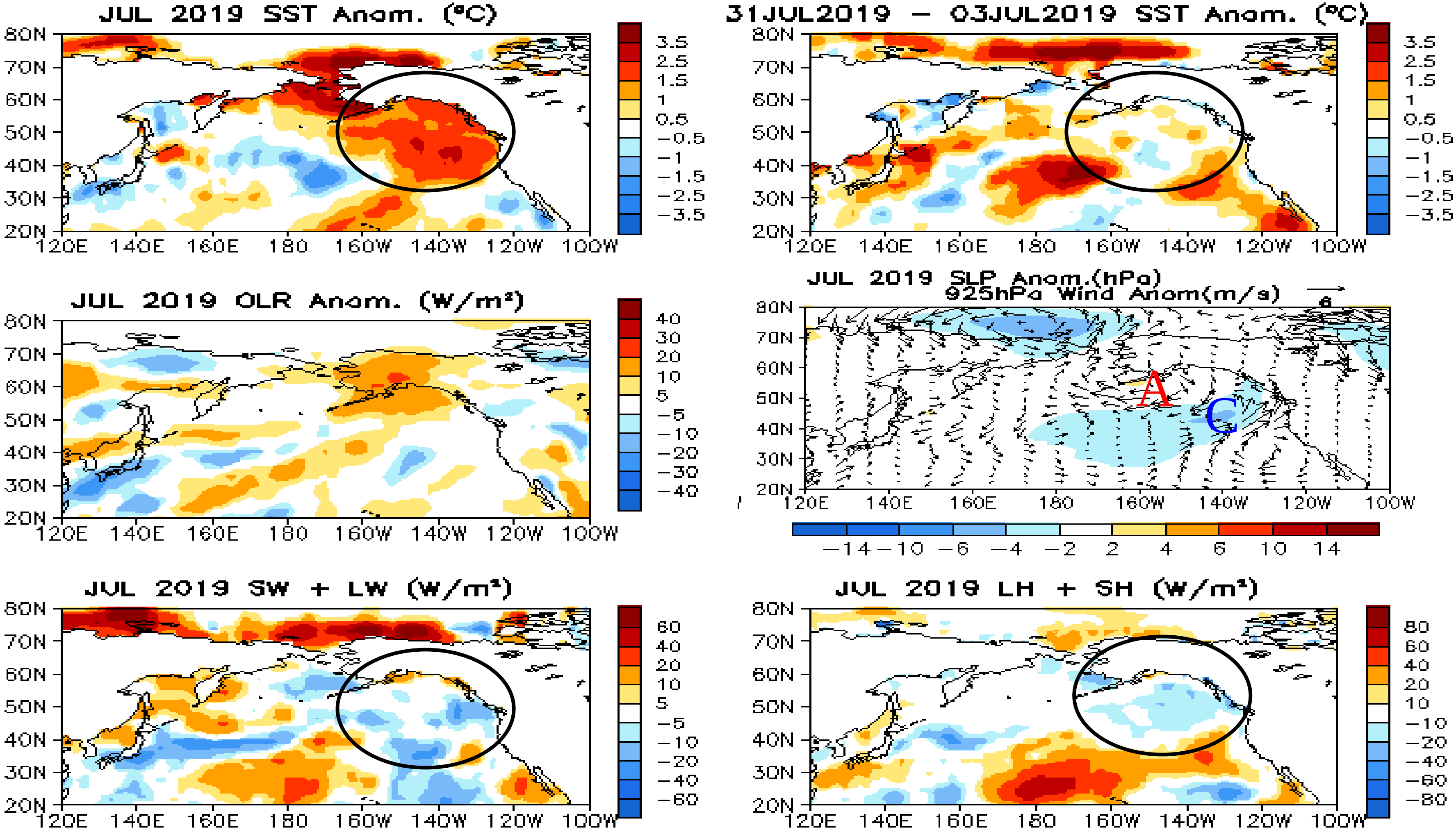
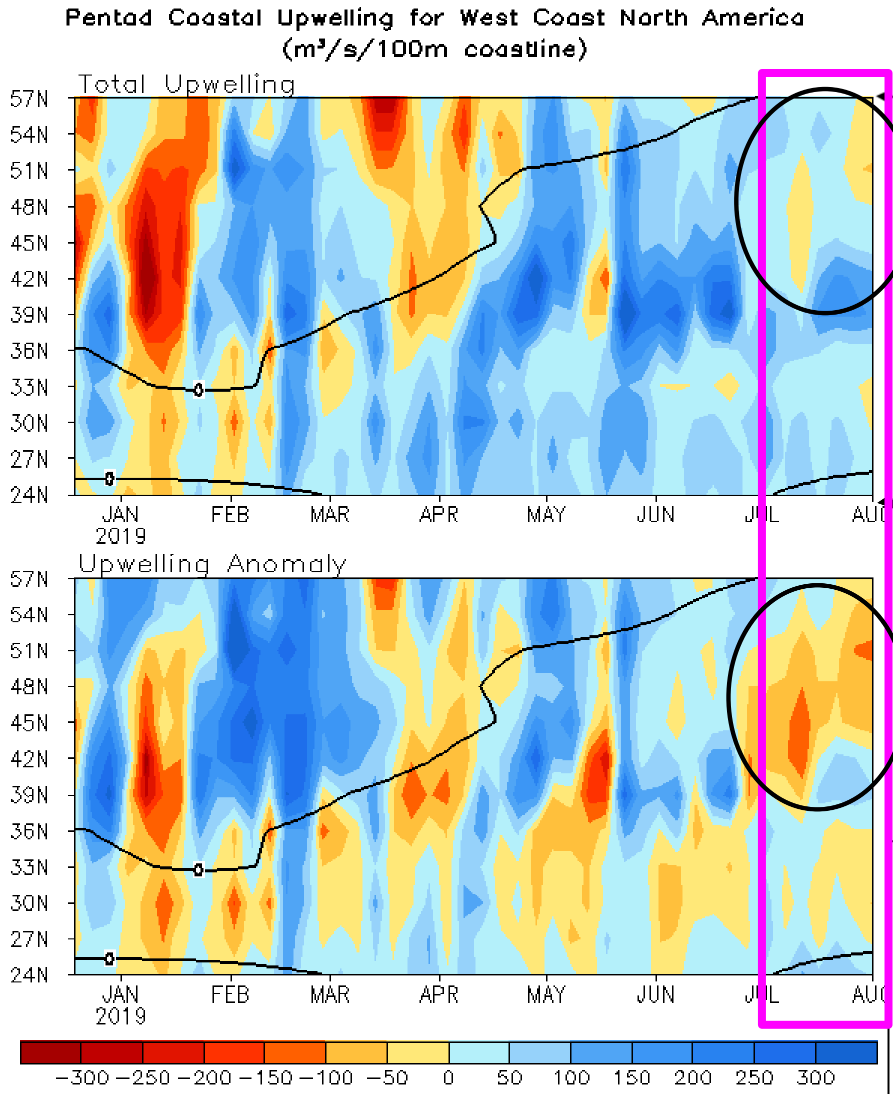
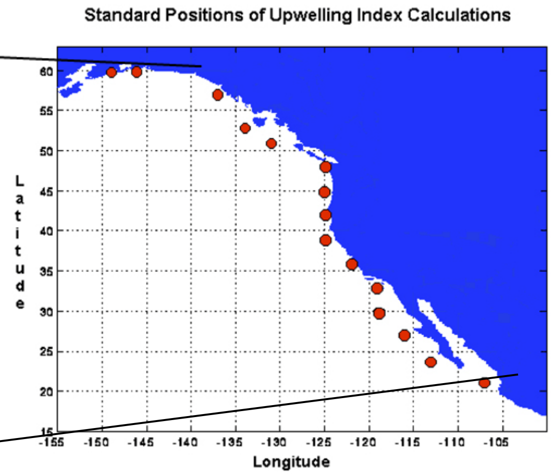


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

North America Western Coastal Upwelling





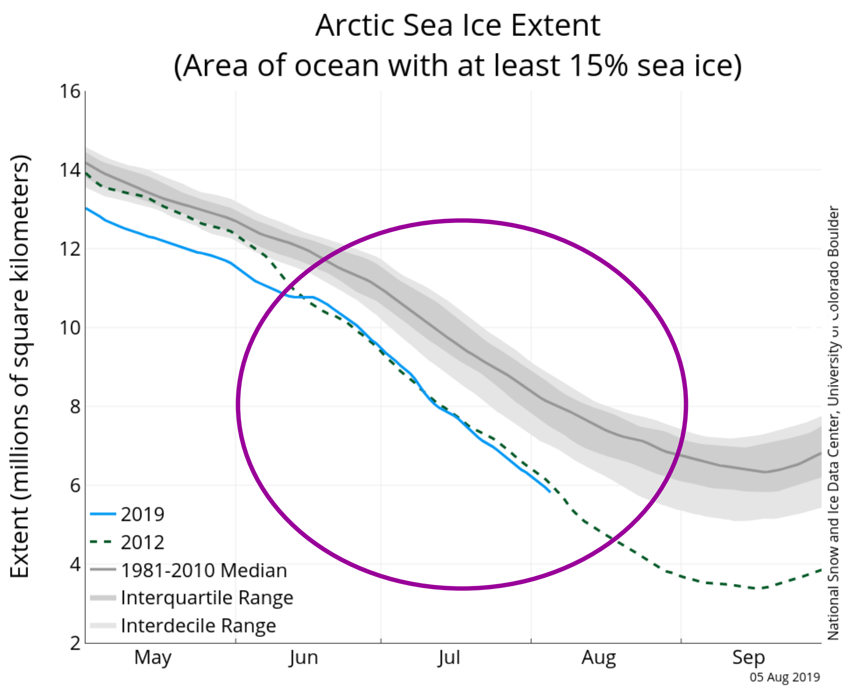
- **Upwelling was abnormally weak in July 2019.**

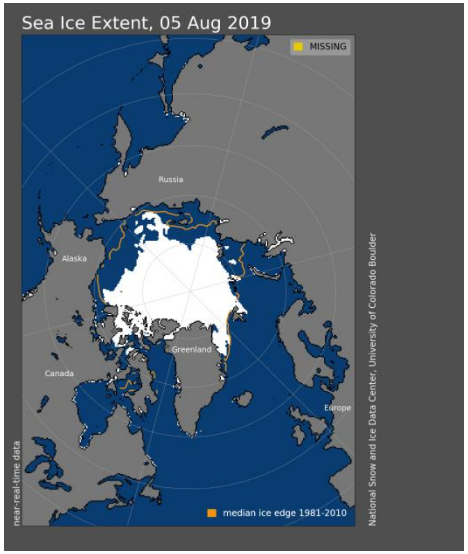
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

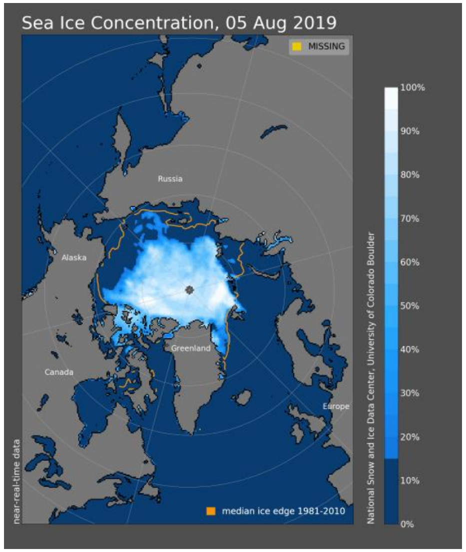
- **Area below (above) black line indicates climatological upwelling (downwelling) season.**
- **Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.**

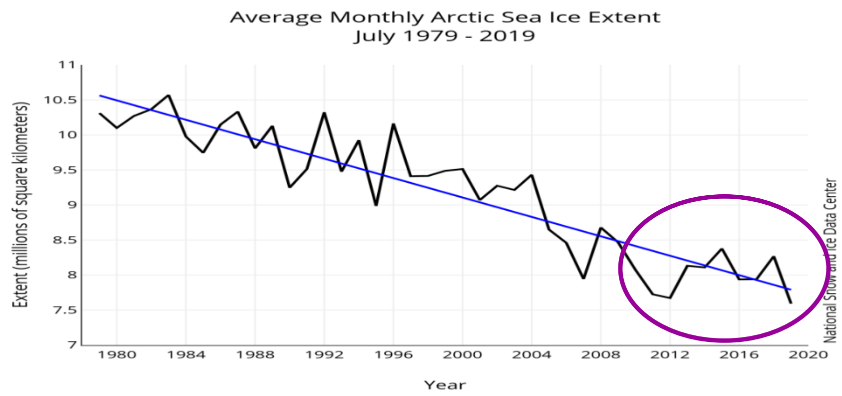
Arctic Sea Ice

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









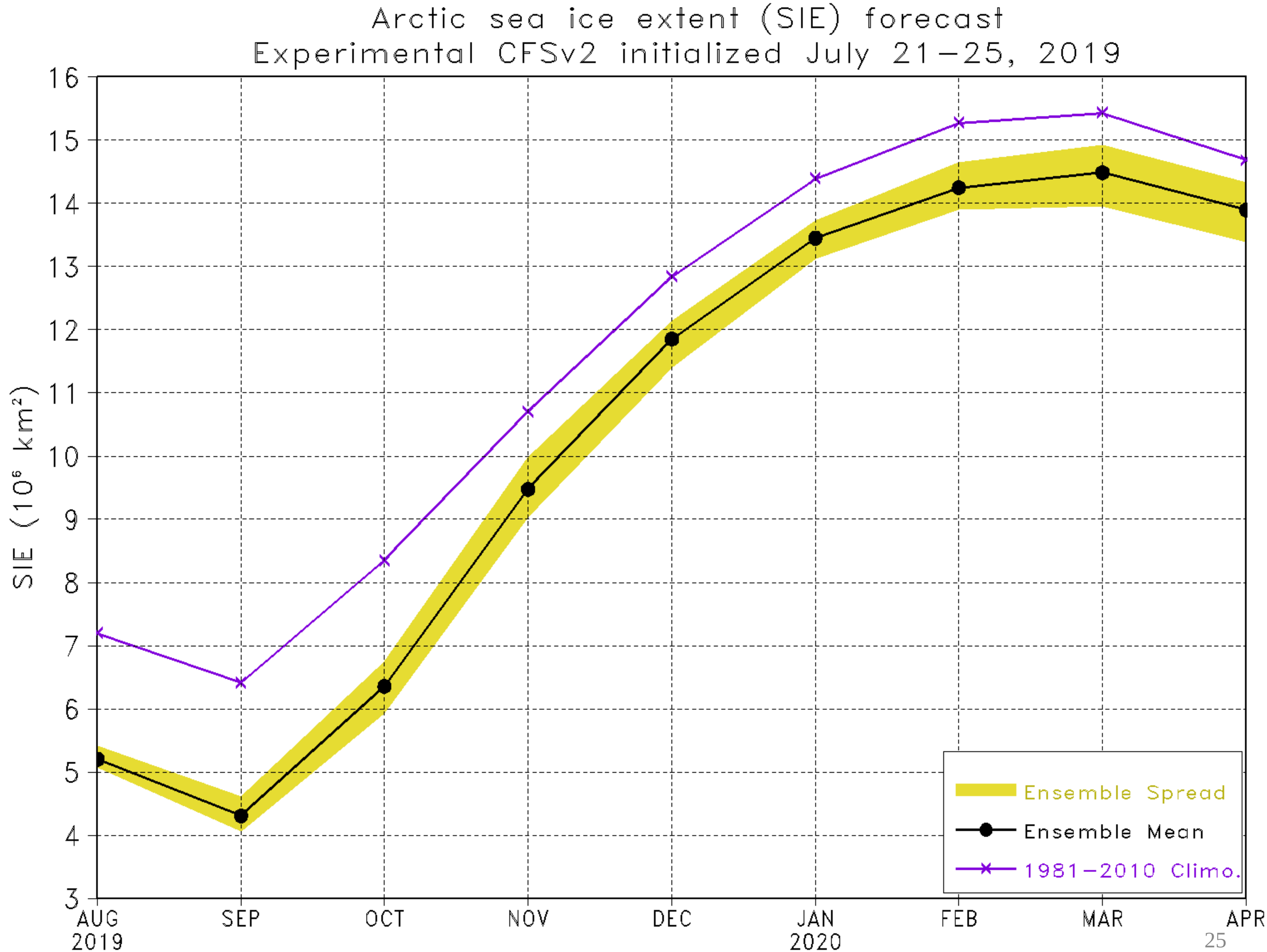
- Arctic sea ice extent was well below the normal in Jul 2019.

- The monthly average extent for Jul 2019 of 7.59 million square kilometers ended up as a new record low since satellite observations in 1979.

Procedure of Experimental Sea Ice Outlook in Jul 2019

(Provided by Dr. Wanqiu Wang's Team, Climate Prediction Center, NCEP/NWS/NOAA)

- Use Climate Forecast System (CFS) coupled model initialized with CPC Sea Ice Initialization System (CSIS) initial sea ice conditions (20 initializations: Jul 21-25, 2019).
- Correct biases using 2006-2018 mean error with respect to NSIDC observations
- Present unbiased results
- The following figures are included
  - SIE Monthly time series (mean and spread)
  - SIC Monthly forecast panels (Ensemble mean)
  - SIC Monthly standard deviation panels
  - Monthly ice cover probability
  - Mean first ice melt day/ standard deviation (Alaska region)


Arctic sea ice extent (SIE) forecast
Experimental CFSv2 initialized July 21–25, 2019
SIE (10⁶ km²)
16
15
14
13
12
11
10
9
8
7
6
5
4
3
AUG 2019
SEP
OCT
NOV
DEC
JAN 2020
FEB
MAR
APR
Ensemble Spread
Ensemble Mean
1981–2010 Climo.

September 2019 SIE forecast

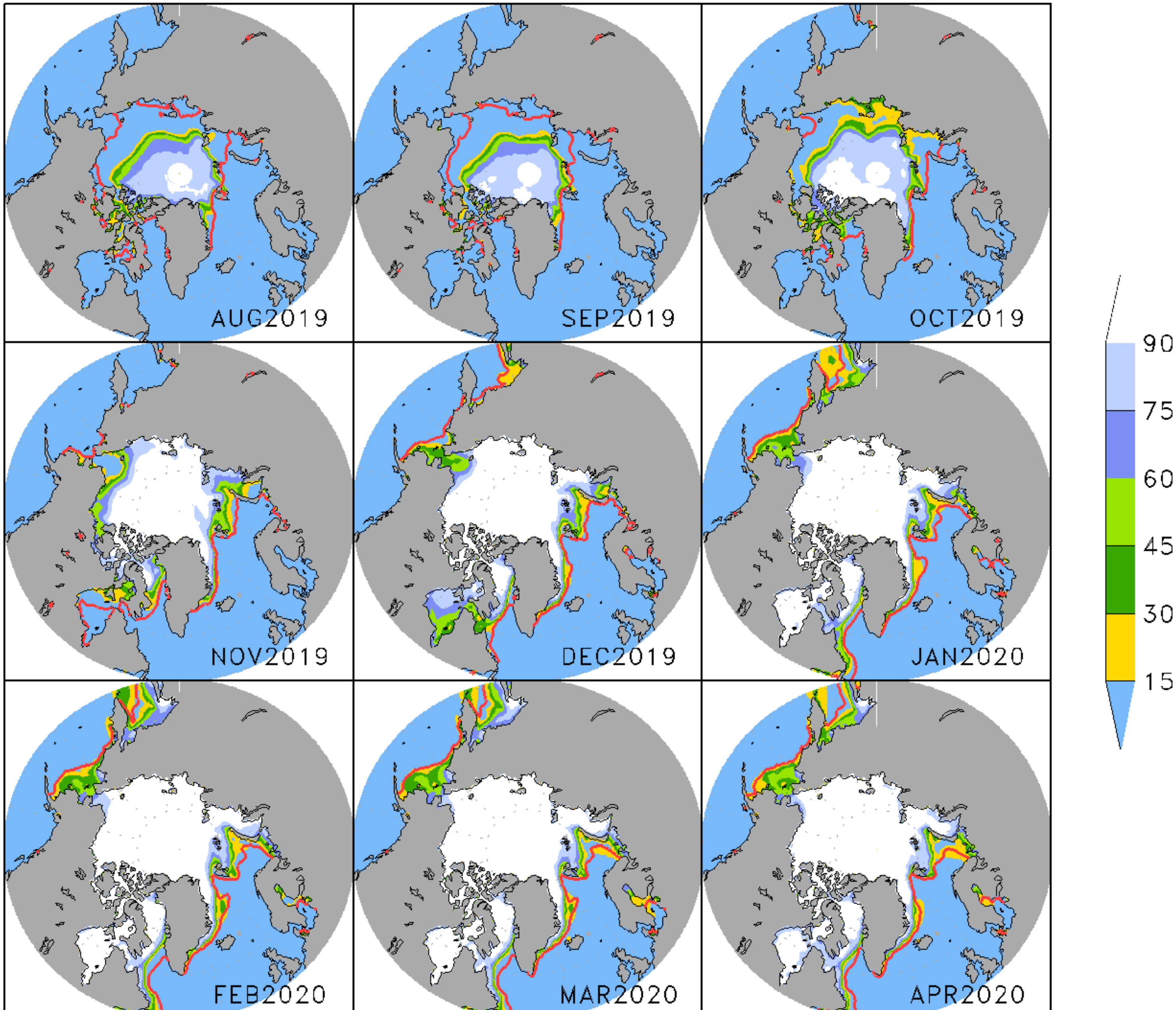
Source	SIE Value (10^6 km^2)
NSIDC 1981-2010 Climatology	6.41
NSIDC 2018	4.71
NSIDC 2012 (record low)	3.57
Experimental CFSv2 2019 forecast	**4.31**

Based on these simulations, the September 2019 sea ice extent is forecasted to be above the record minimum set in 2012 and slightly below last year's value.

Month to Month September Prediction for this year's forecasts

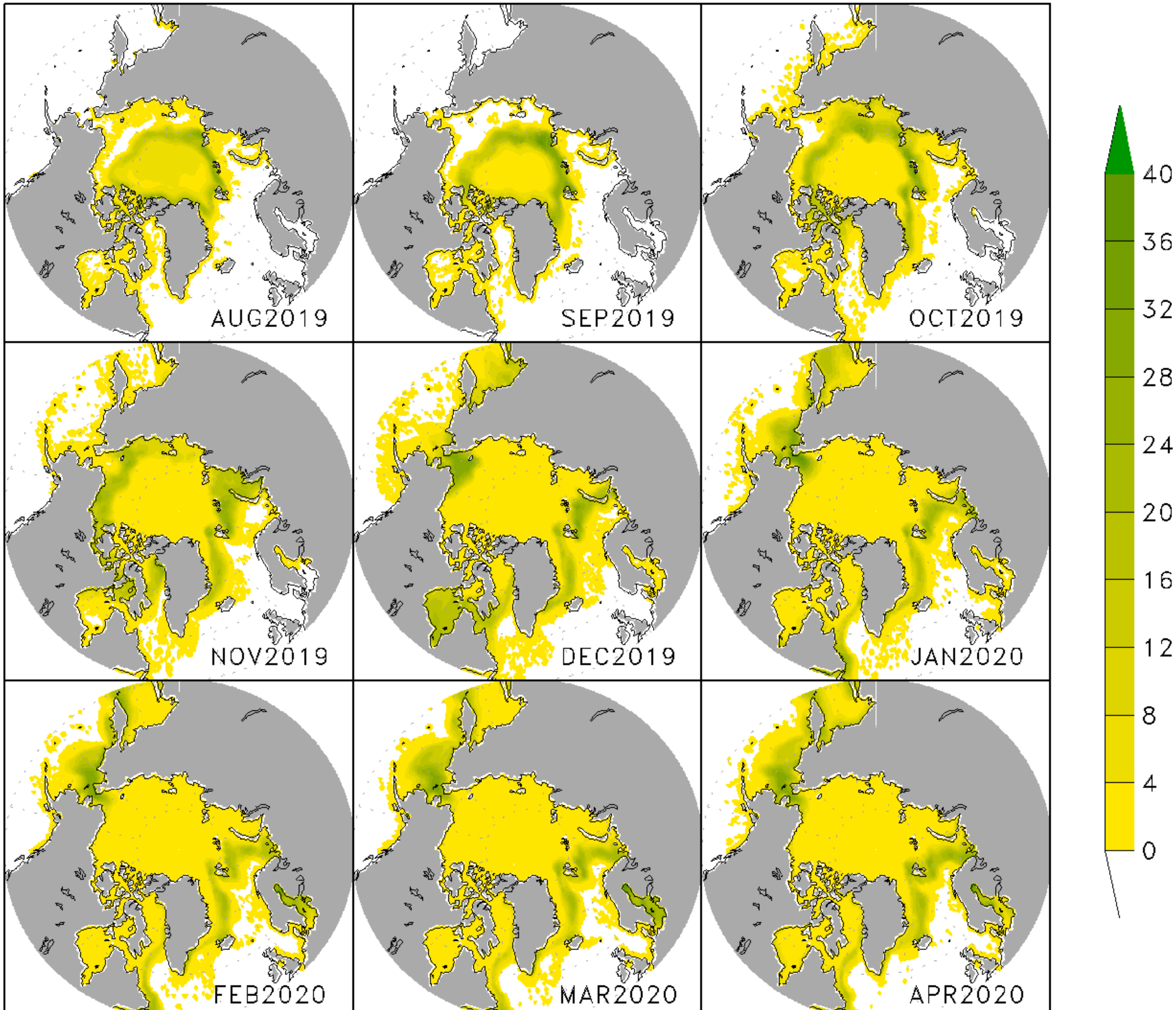
Month	March	April	May	June	July	August
Ens. Mean	4.87	4.71	4.62	4.55	4.31	
Ens. Spread	0.34	0.33	0.26	0.24	0.14	

Arctic sea ice concentration (SIC, %) forecast
Experimental CFSv2 initialized July 21-25, 2019

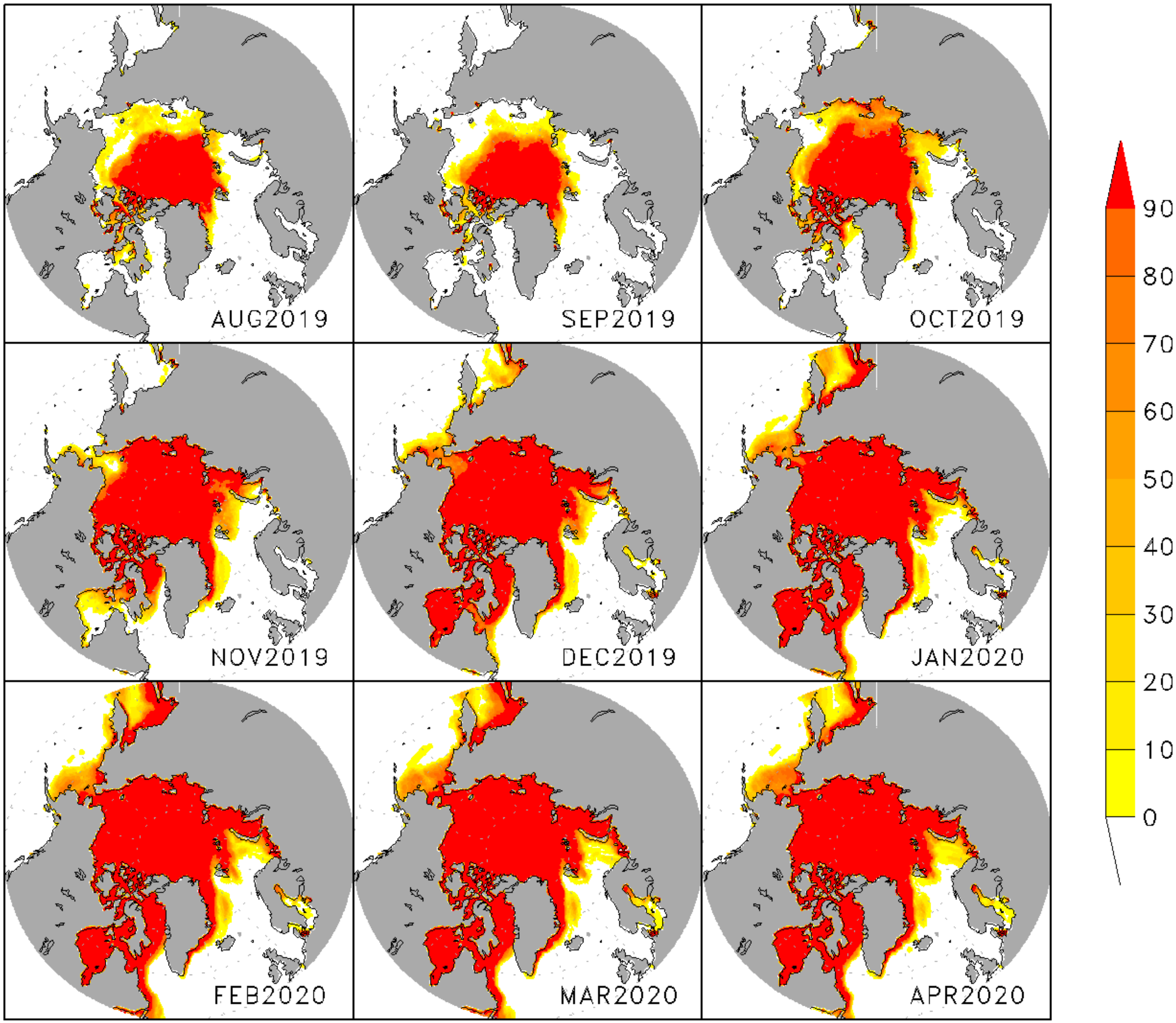


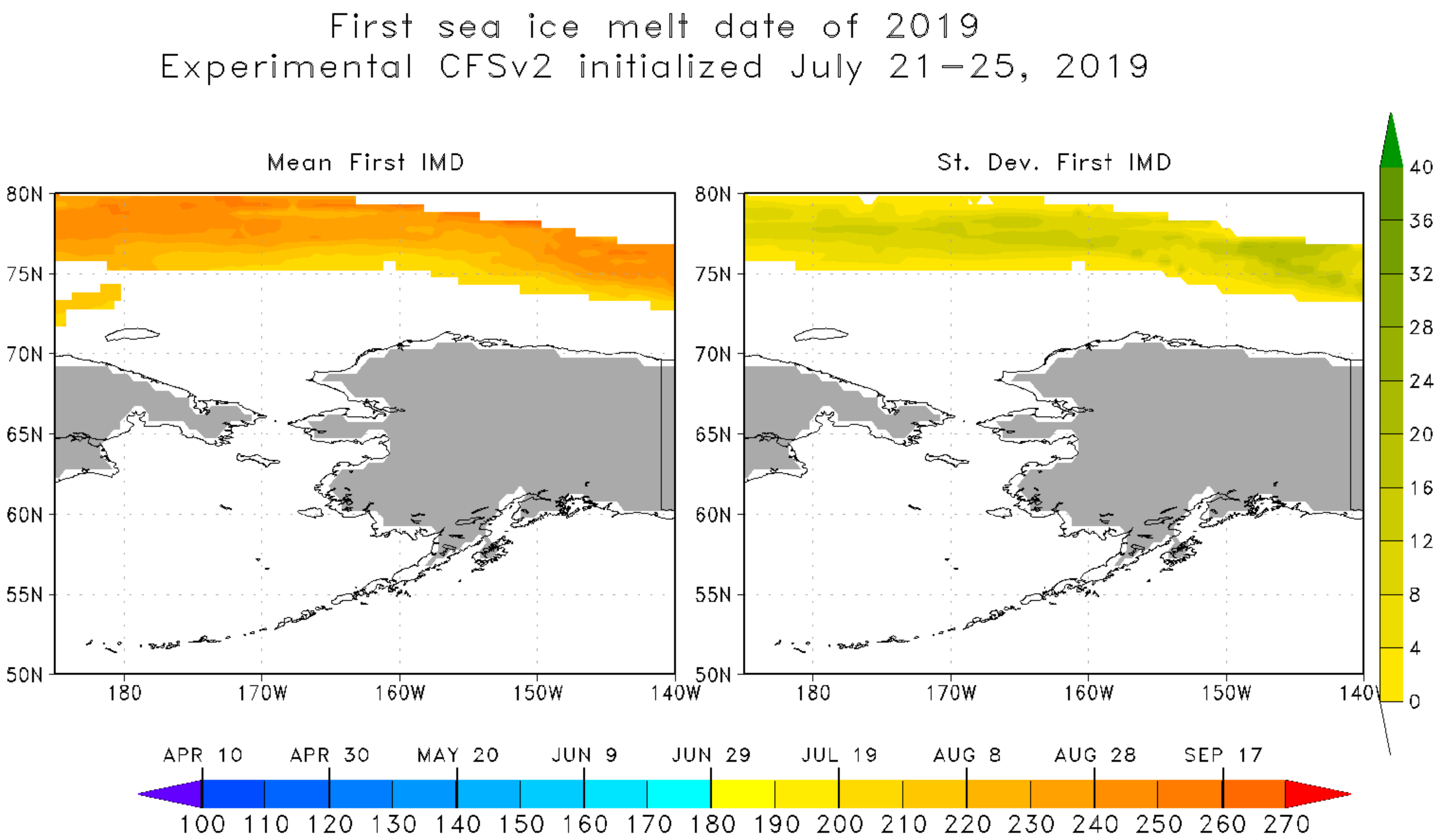
* 1981-2010 climatology of 15% NASA Team SIC countoured red *

Arctic sea ice concentration standard deviation (SICstd, %)
Experimental CFSv2 initialized July 21–25, 2019



Arctic sea ice concentration probability ≧ 15% (SIP)
Experimental CFSv2 initialized July 21–25, 2019

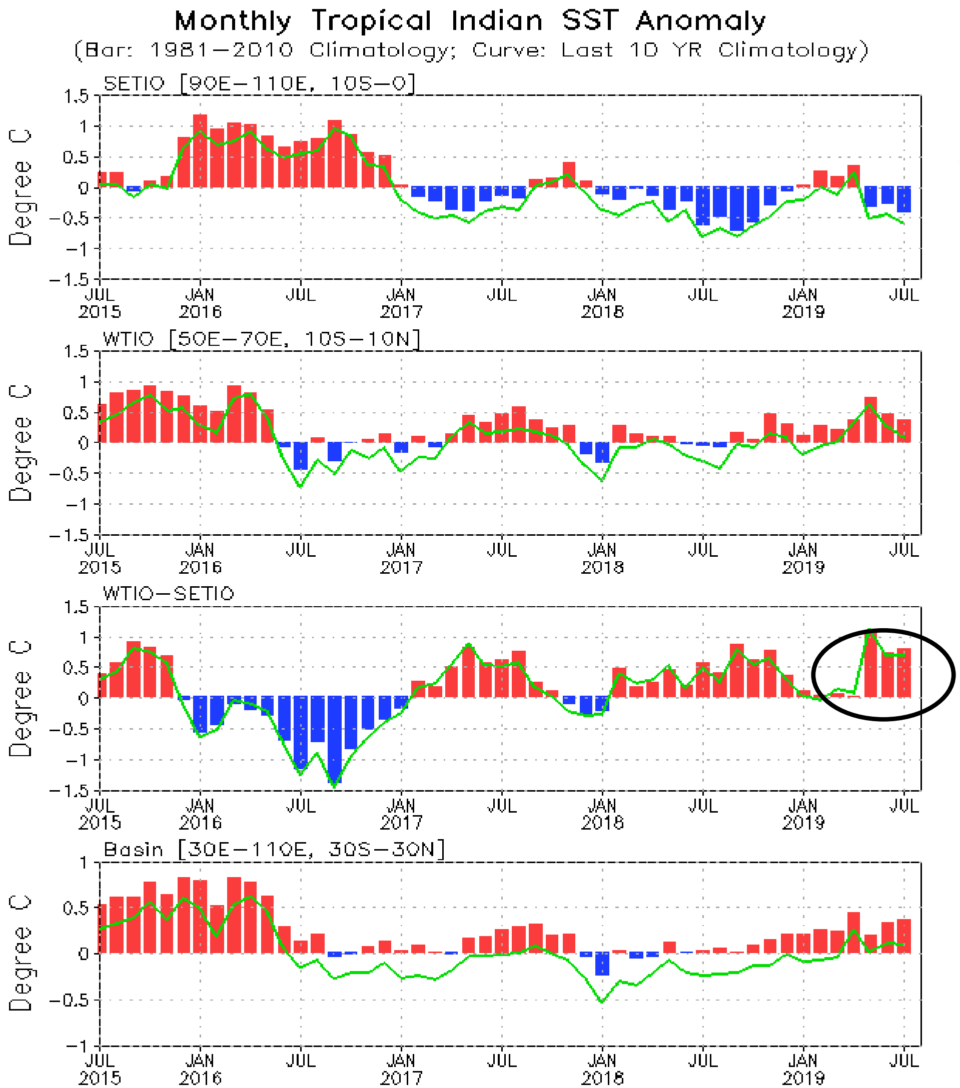


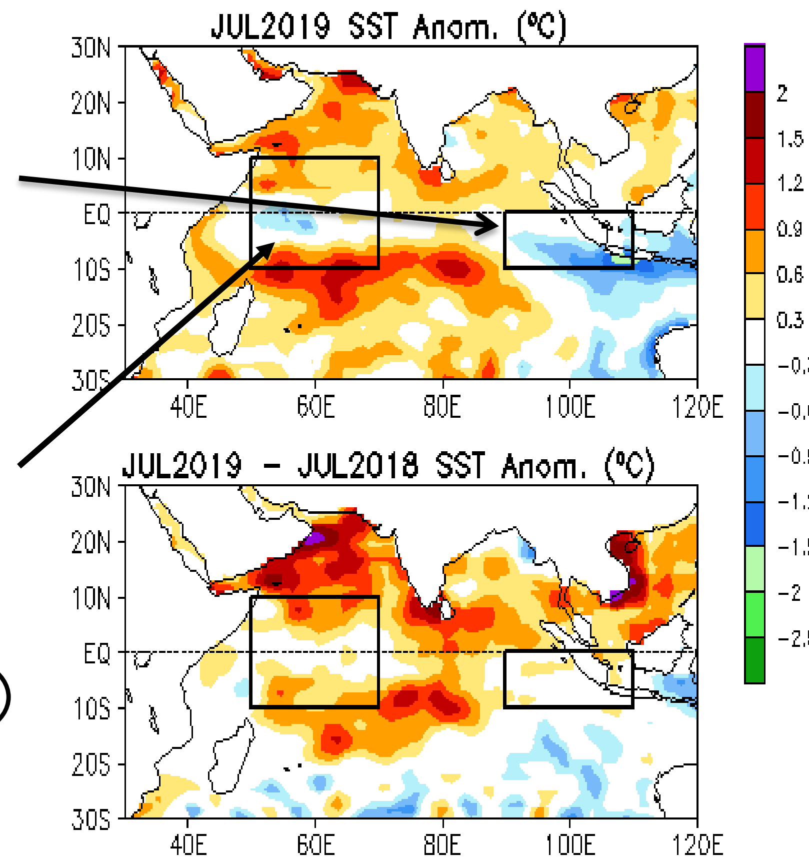


First sea ice melt date of 2019
Experimental CFSv2 initialized July 21–25, 2019
Mean First IMD
St. Dev. First IMD
80N
75N
70N
65N
60N
55N
50N
180
170W
160W
150W
140W
0
4
8
12
16
20
24
28
32
36
40
APR 10
APR 30
MAY 20
JUN 9
JUN 29
JUL 19
AUG 8
AUG 28
SEP 17
100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270

Indian Ocean

Evolution of Indian Ocean SST Indices





- IOD was in a strong positive phase in May-Jul 2019.

Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) for the SETIO [90ºE-110ºE, 10ºS-0] and WTIO [50ºE-70ºE, 10ºS-10ºN] 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.

- SSTAs were overall positive in the west and central, and negative in the far east.

- Convection was suppressed over the eastern Indian ocean and Indonesia.

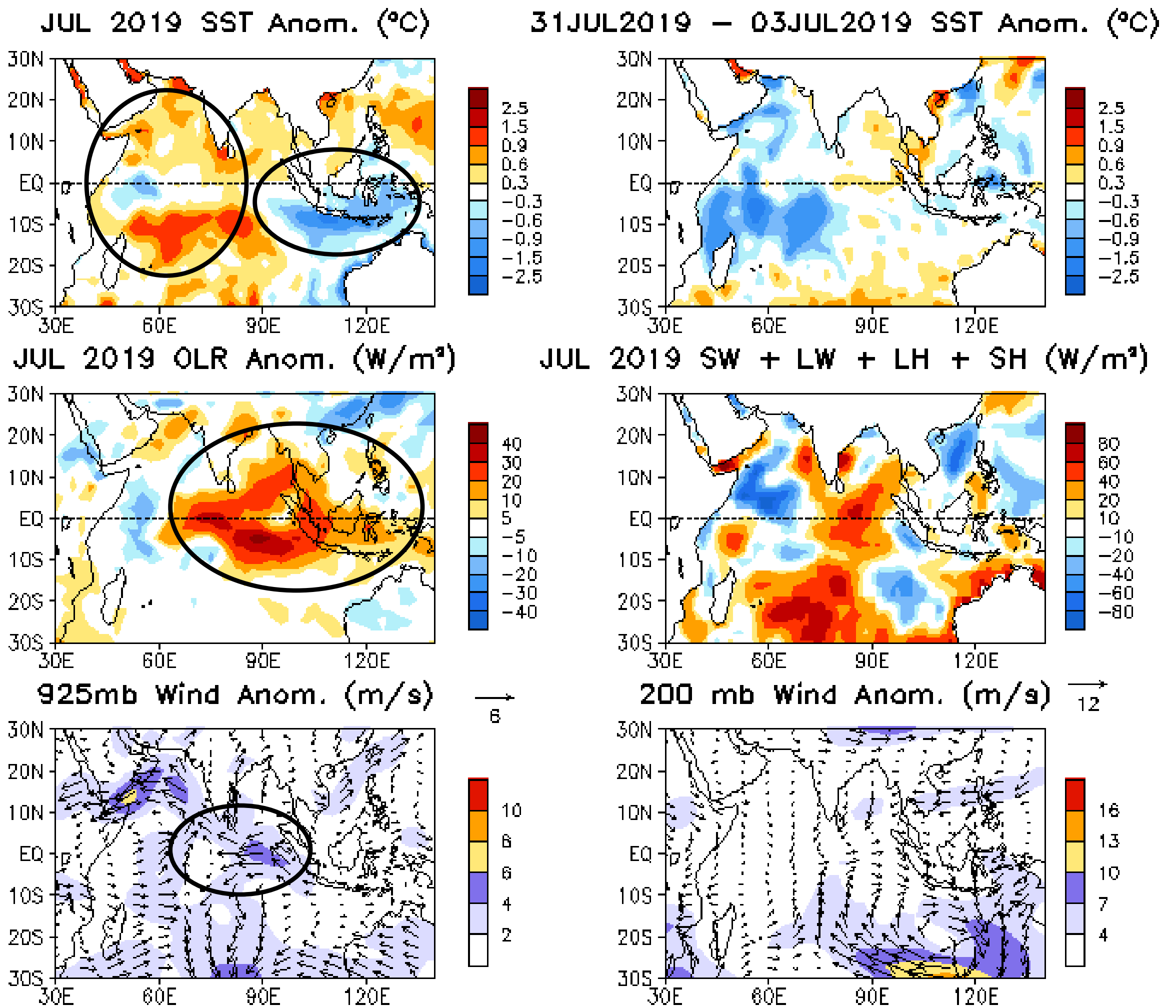


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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 Indian: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.

- Compared to Jun 2019, SST, Convection and low-level winds were better coupled in July.

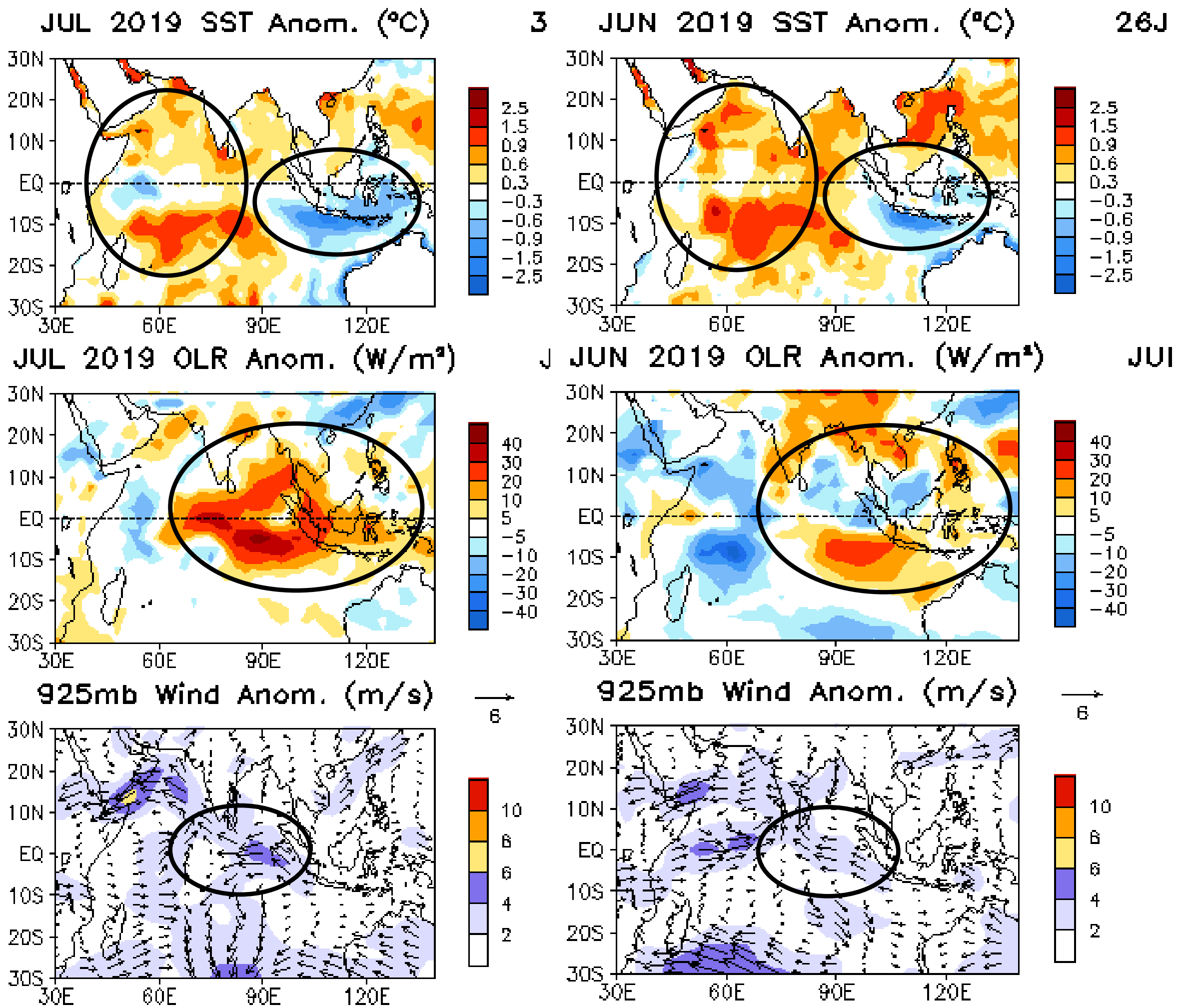
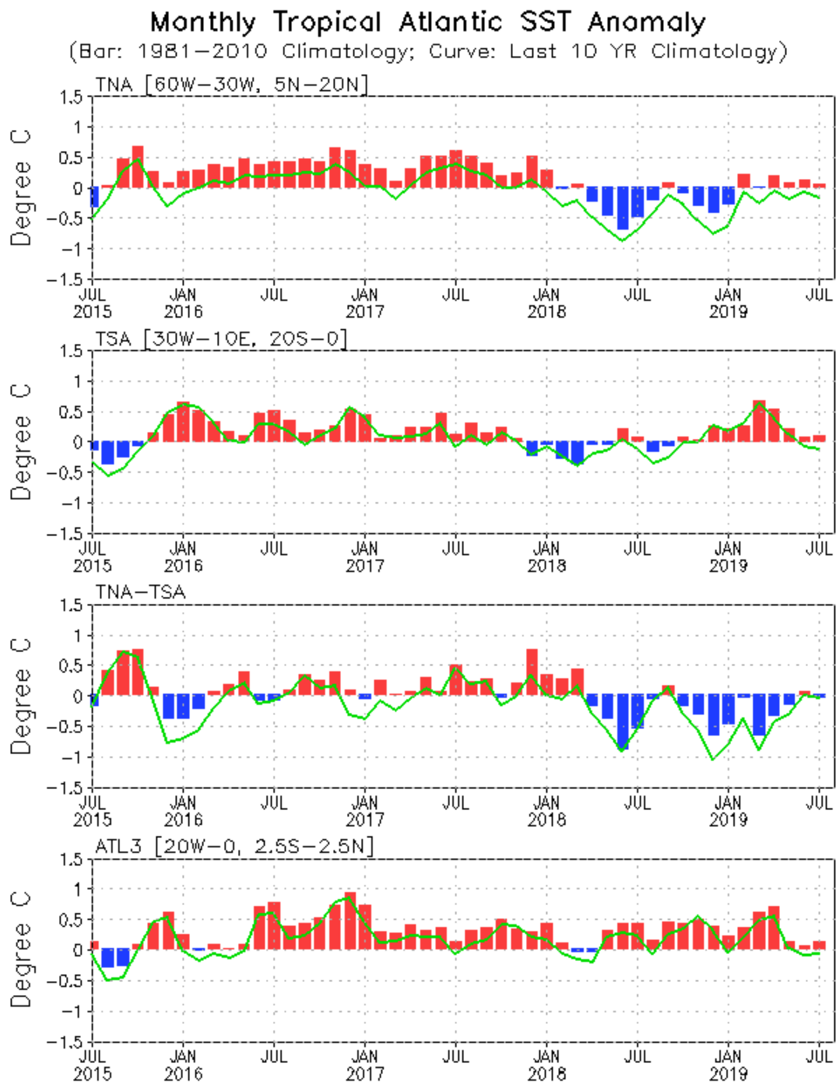
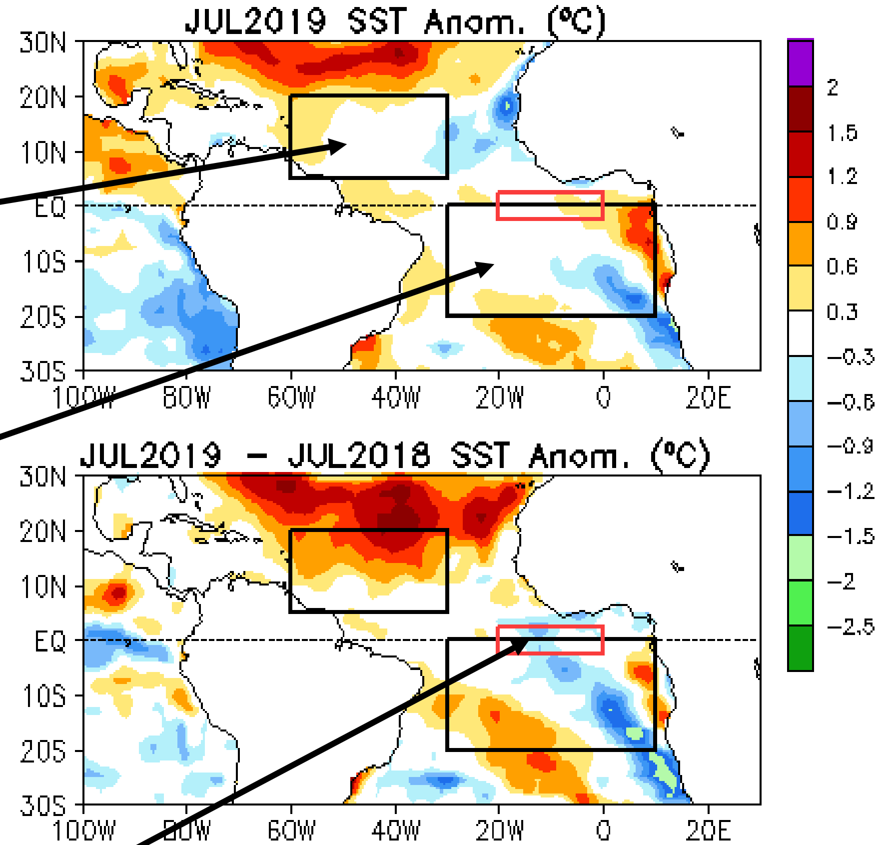


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

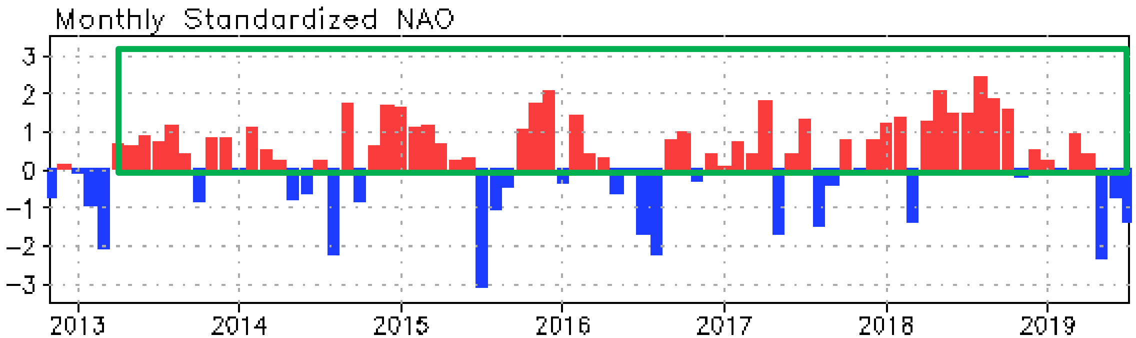


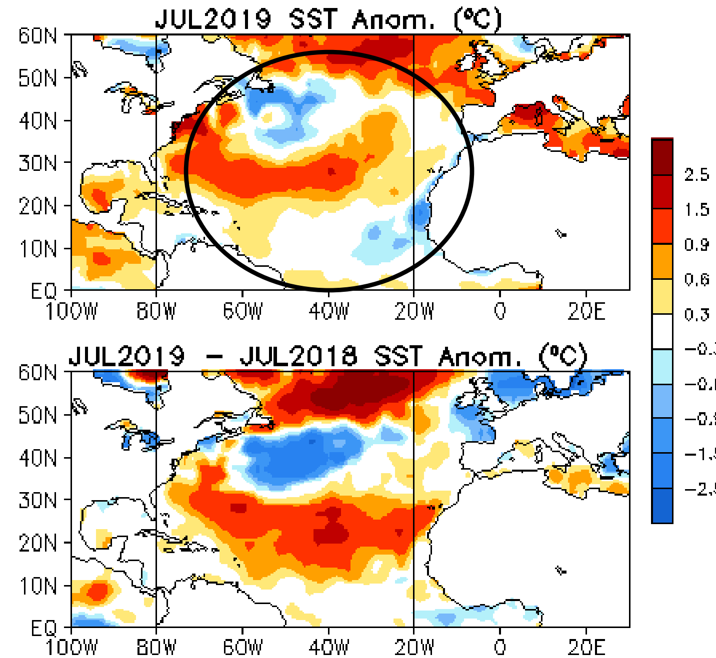


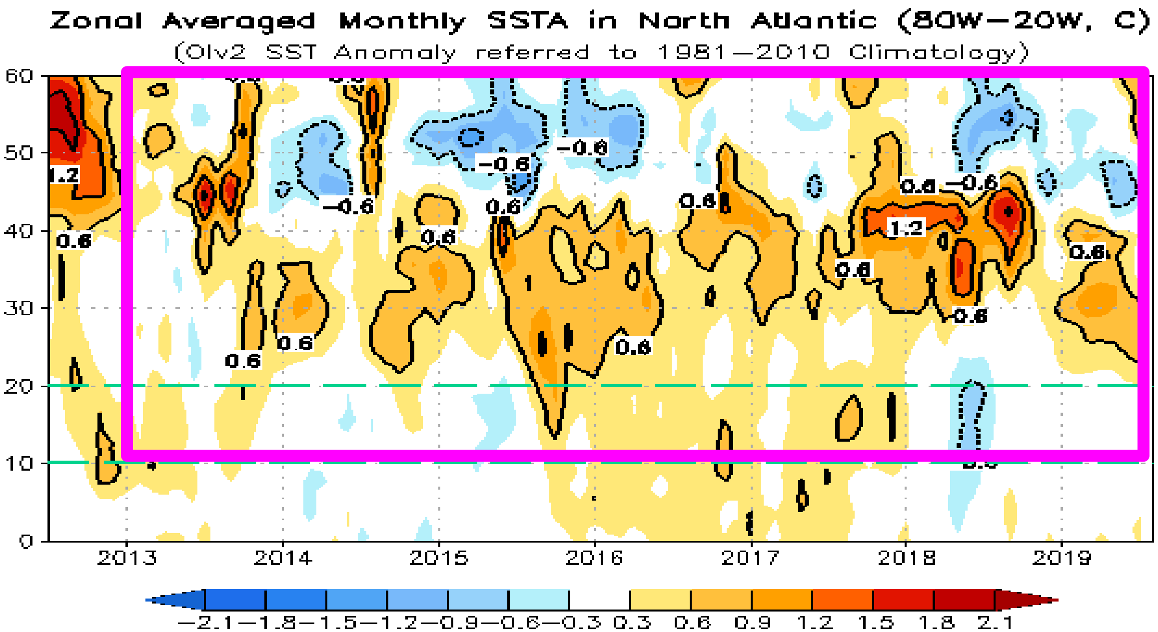
- **All indices were small in Jul 2019.**

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.

NAO and SST Anomaly in North Atlantic

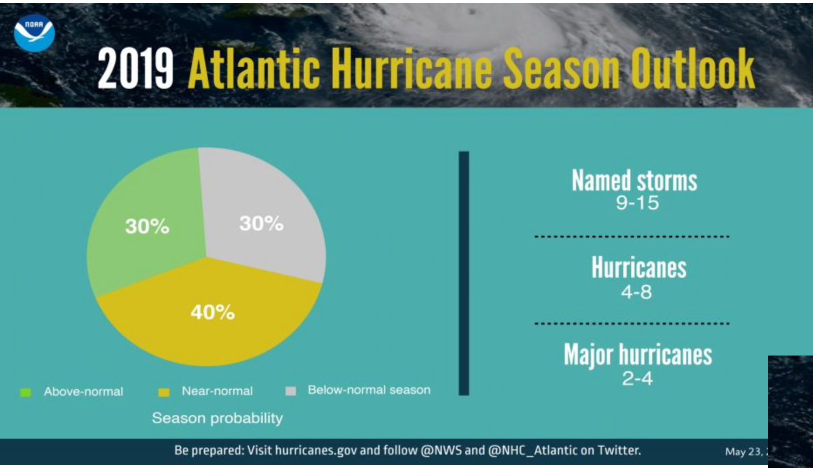


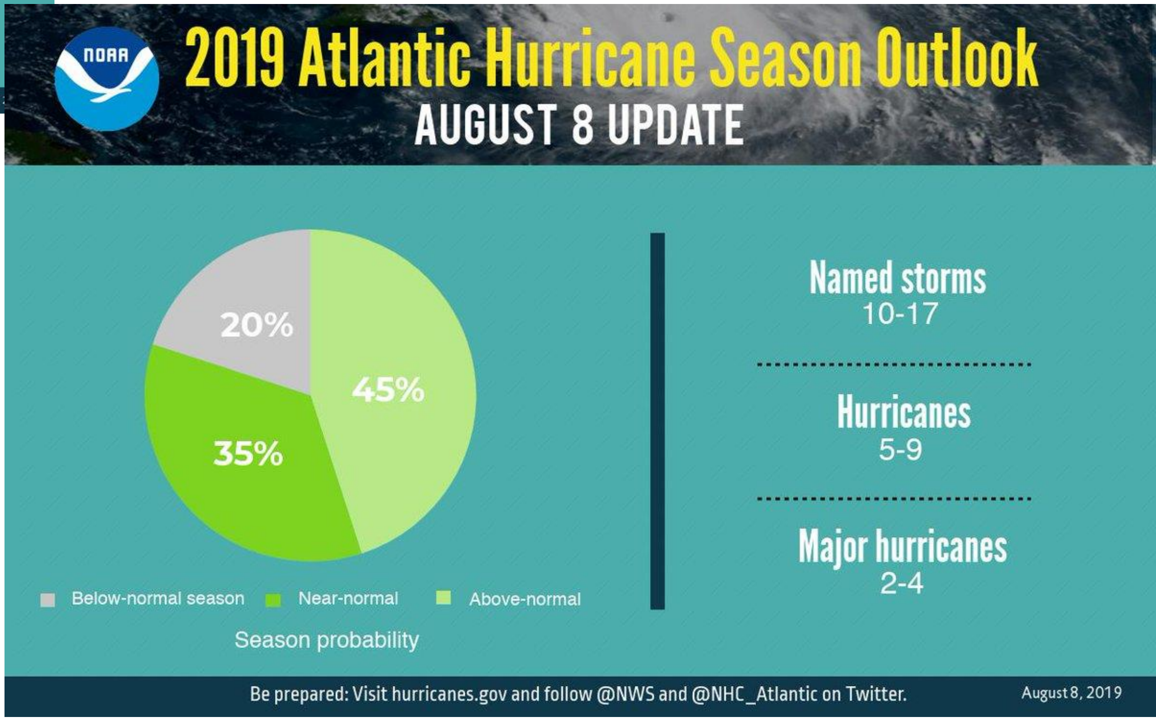




- NAO was still in a negative phase with NAOI= -1.4 in Jul 2019.
- SSTA was a tripole/horseshoe –like pattern with positive in the mid-latitudes and negative in the lower and higher latitudes, due to the long-term persistence of a positive phase of NAO.

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.

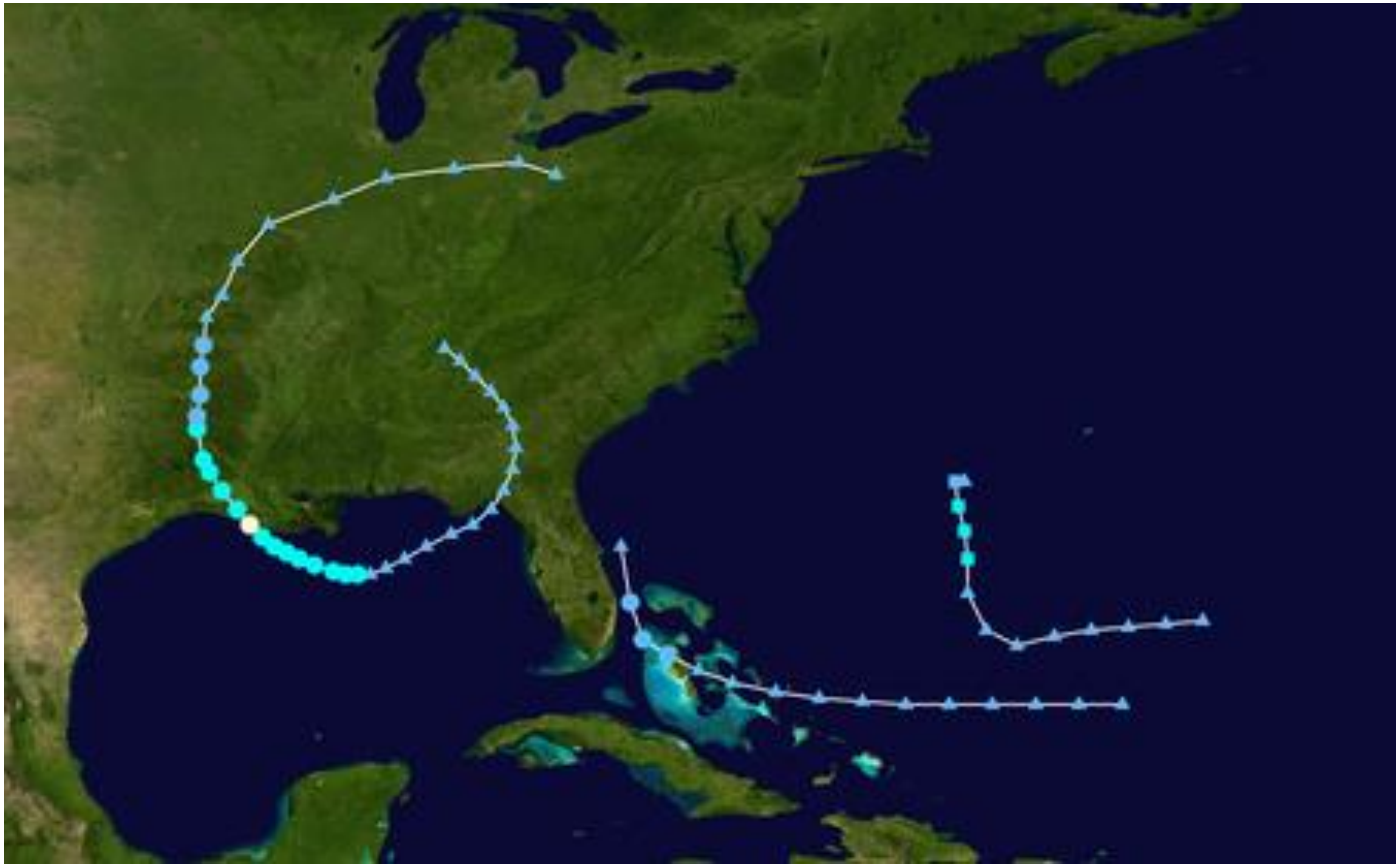




(August 8 update)

NOAA's updated outlook for the 2019 Atlantic Hurricane Season indicates that an above-normal season has the highest chance of occurring (45%), followed by a 35% chance for near-normal season and a 20% chance for a below-normal season.

https://www.noaa.gov/sites/default/files/thumbnails/image/2019%20Hurricane%20Numbers.png

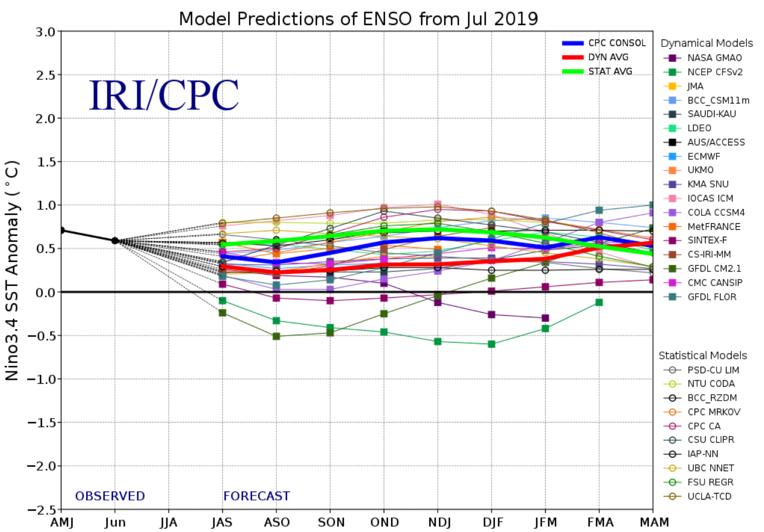


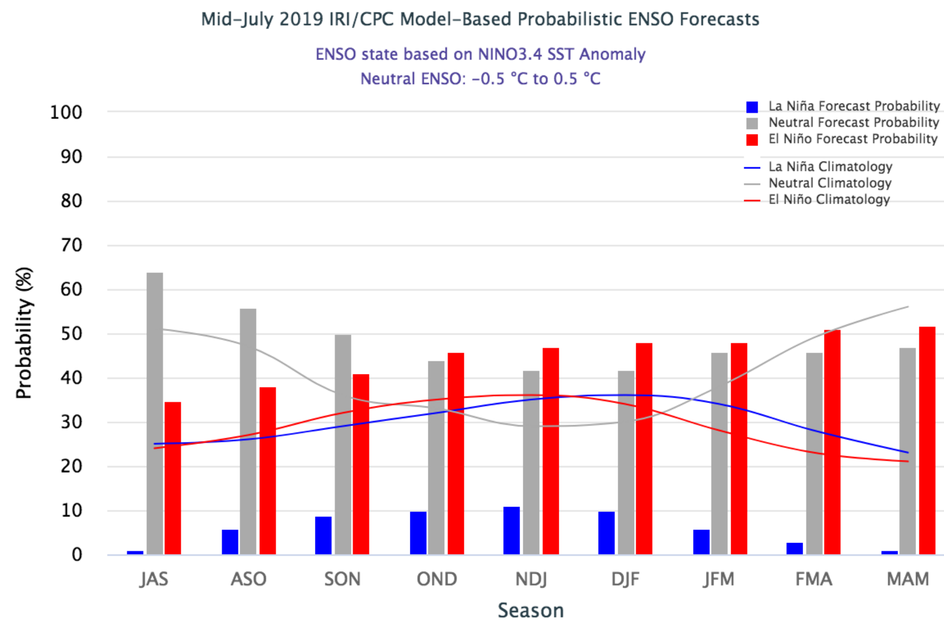
By August 12, 2019

2019		(1981-2010)
Total storms	2	12.1
Hurricanes	1	6.4
Major hurricanes (Cat. 3+)	0	2.7

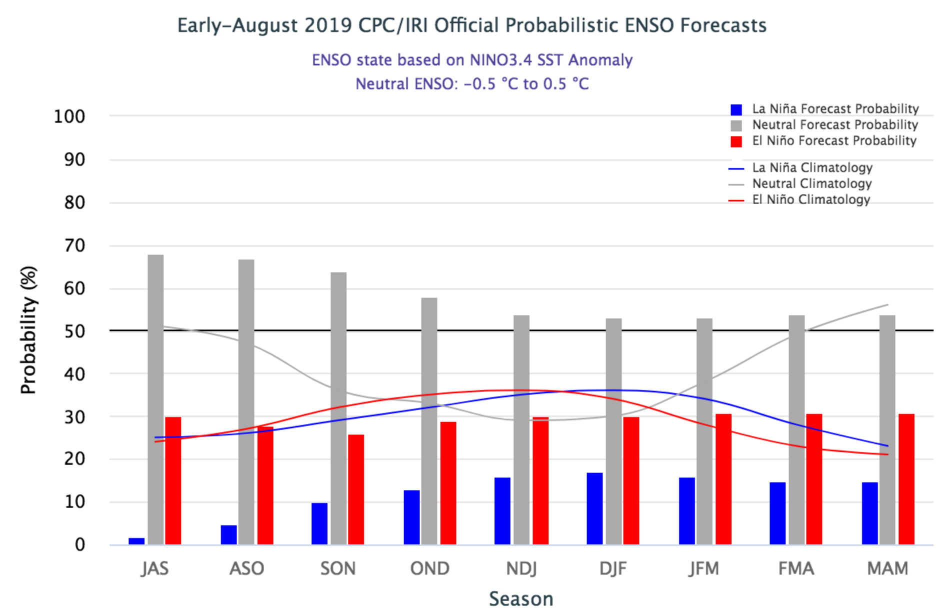
ENSO and Global SST Predictions

IRI NINO3.4 Forecast Plum



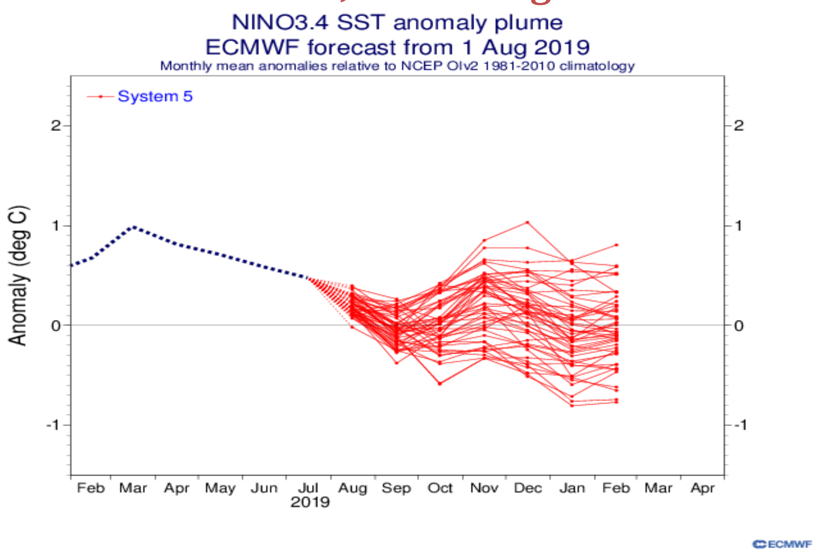


- **Most models predicted a ENSO-neutral with ICs in Jul 2019.**
- **NOAA "ENSO Diagnostic Discussion" on 8 August 2019 issued "*Final El Nino Advisory*" and indicated that** ***"El Niño has transitioned to ENSO-neutral, which is most likely to continue through Northern Hemisphere winter 2019-20 (50-55% chance)."***

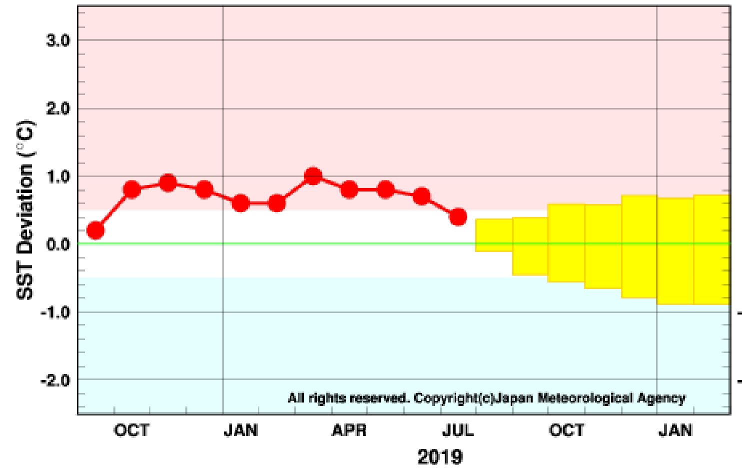


Individual Model Forecasts: ENSO-Neutral

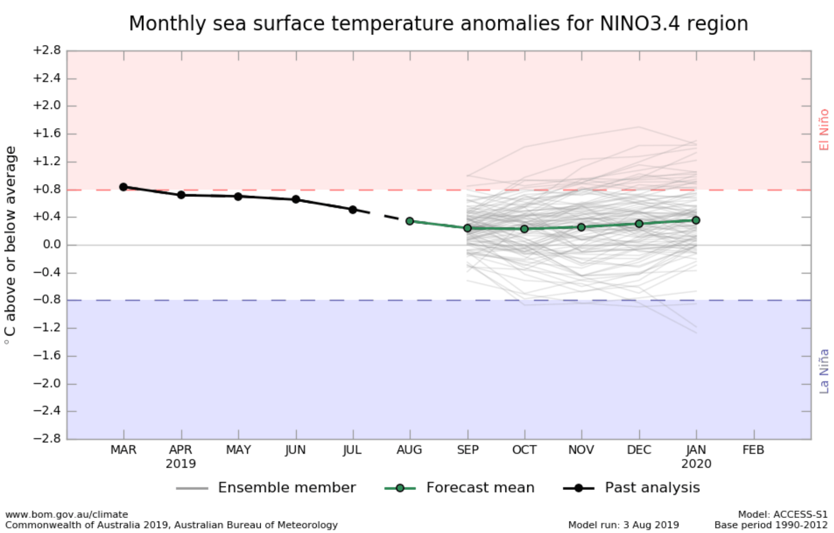
EC: Nino3.4, IC=01Aug 2019



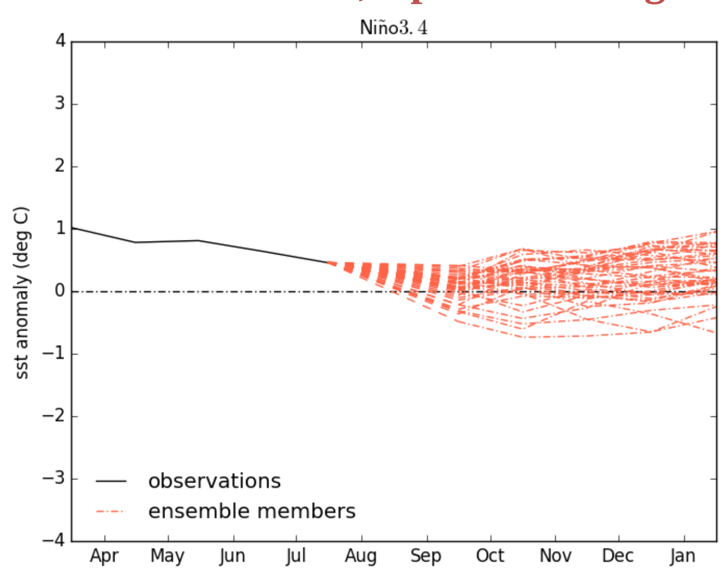
JMA: Nino3.4, Updated 9Aug2019

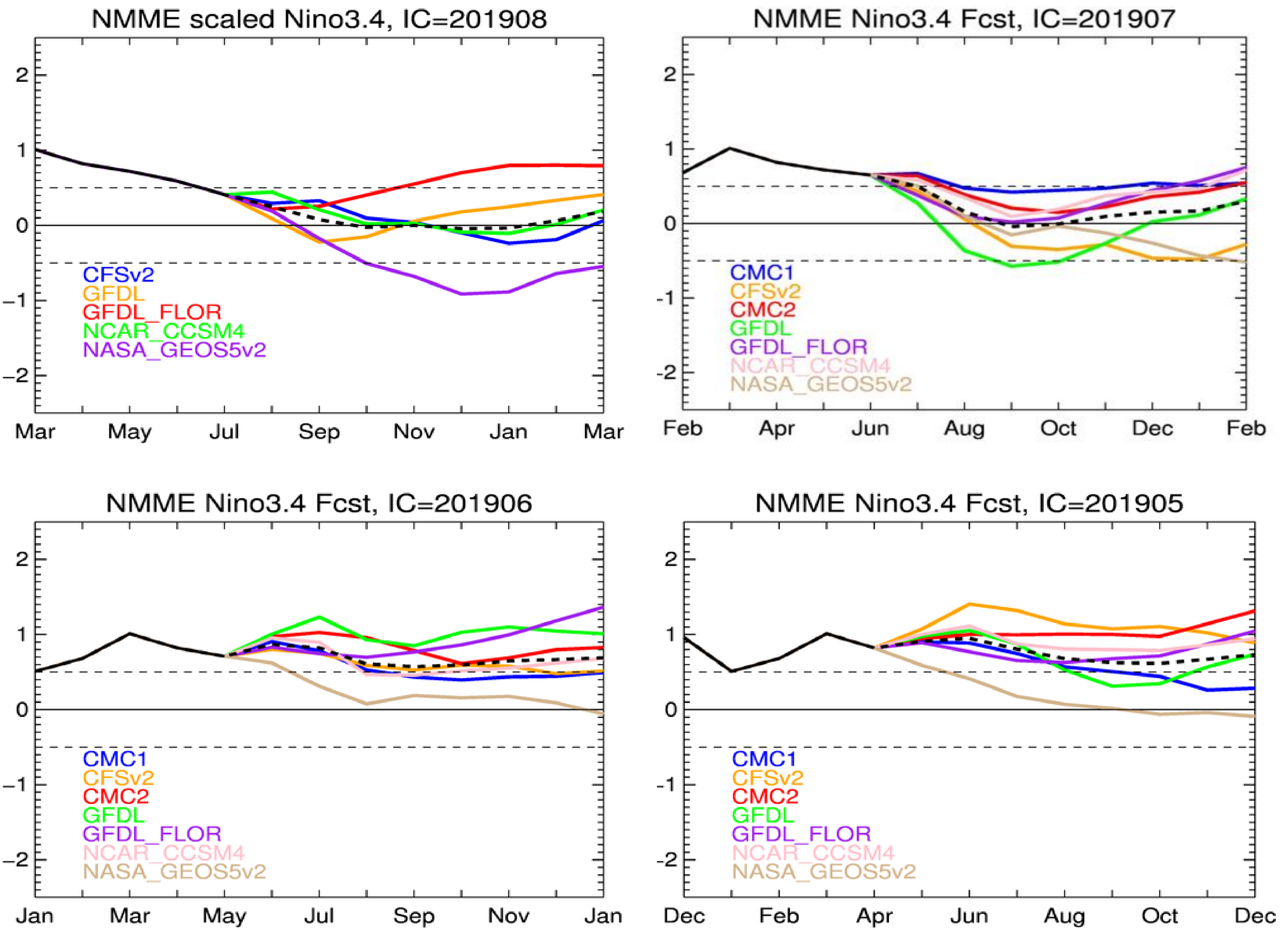


Australia: Nino3.4, Updated 3Aug 2019

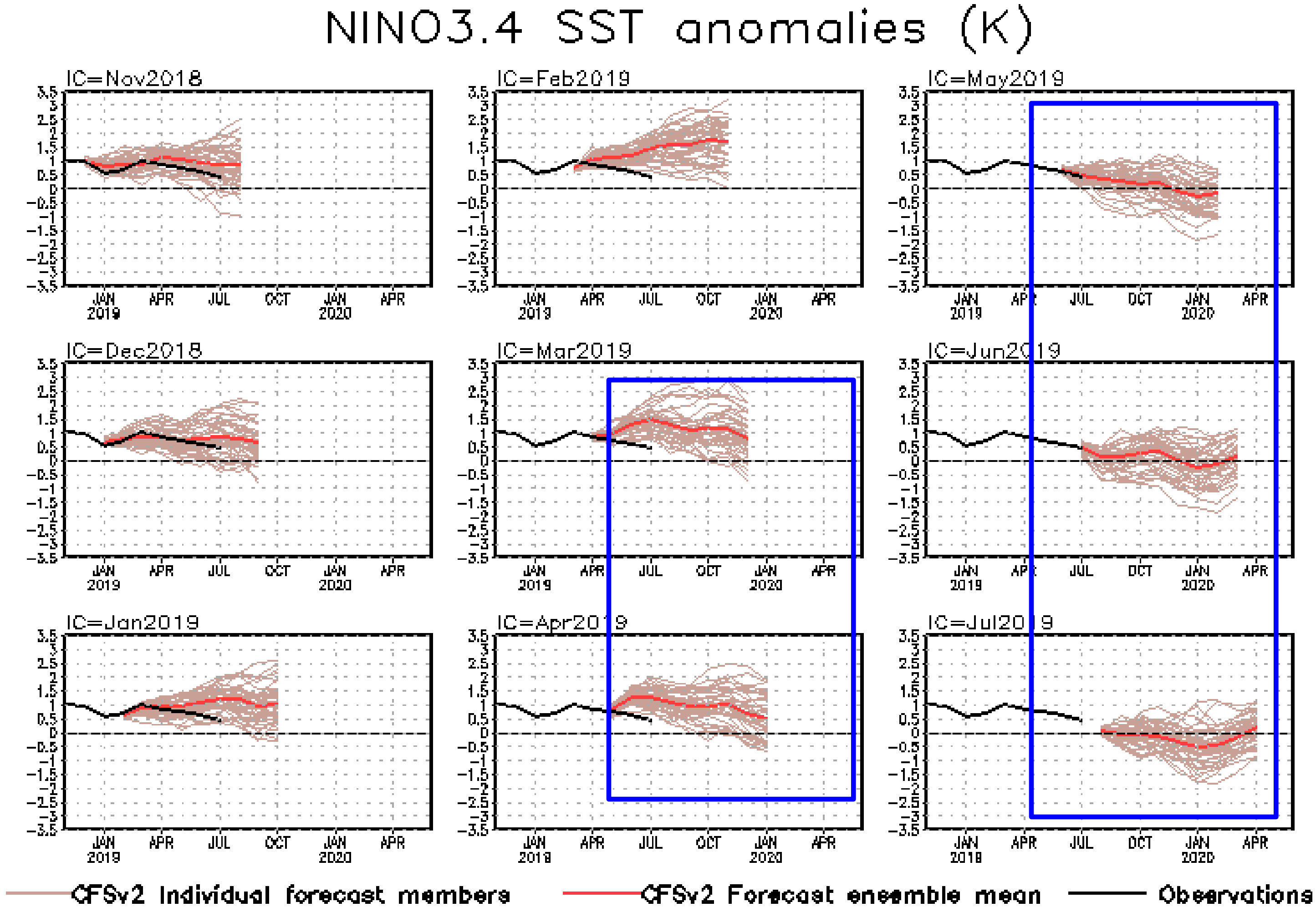


UKMO: Nino3.4, Updated 12Aug 2019




NMME scaled Nino3.4, IC=201908
CFSv2
GFDL
GFDL_FLOR
NCAR_CCSM4
NASA_GEOS5v2
Mar May Jul Sep Nov Jan Mar
NMME Nino3.4 Fcst, IC=201907
CMC1
CFSv2
CMC2
GFDL
GFDL_FLOR
NCAR_CCSM4
NASA_GEOS5v2
Feb Apr Jun Aug Oct Dec Feb
NMME Nino3.4 Fcst, IC=201906
CMC1
CFSv2
CMC2
GFDL
GFDL_FLOR
NCAR_CCSM4
NASA_GEOS5v2
Jan Mar May Jul Sep Nov Jan
NMME Nino3.4 Fcst, IC=201905
CMC1
CFSv2
CMC2
GFDL
GFDL_FLOR
NCAR_CCSM4
NASA_GEOS5v2
Dec Feb Apr Jun Aug Oct Dec

CFS Niño3.4 SST Predictions from Different Initial Months

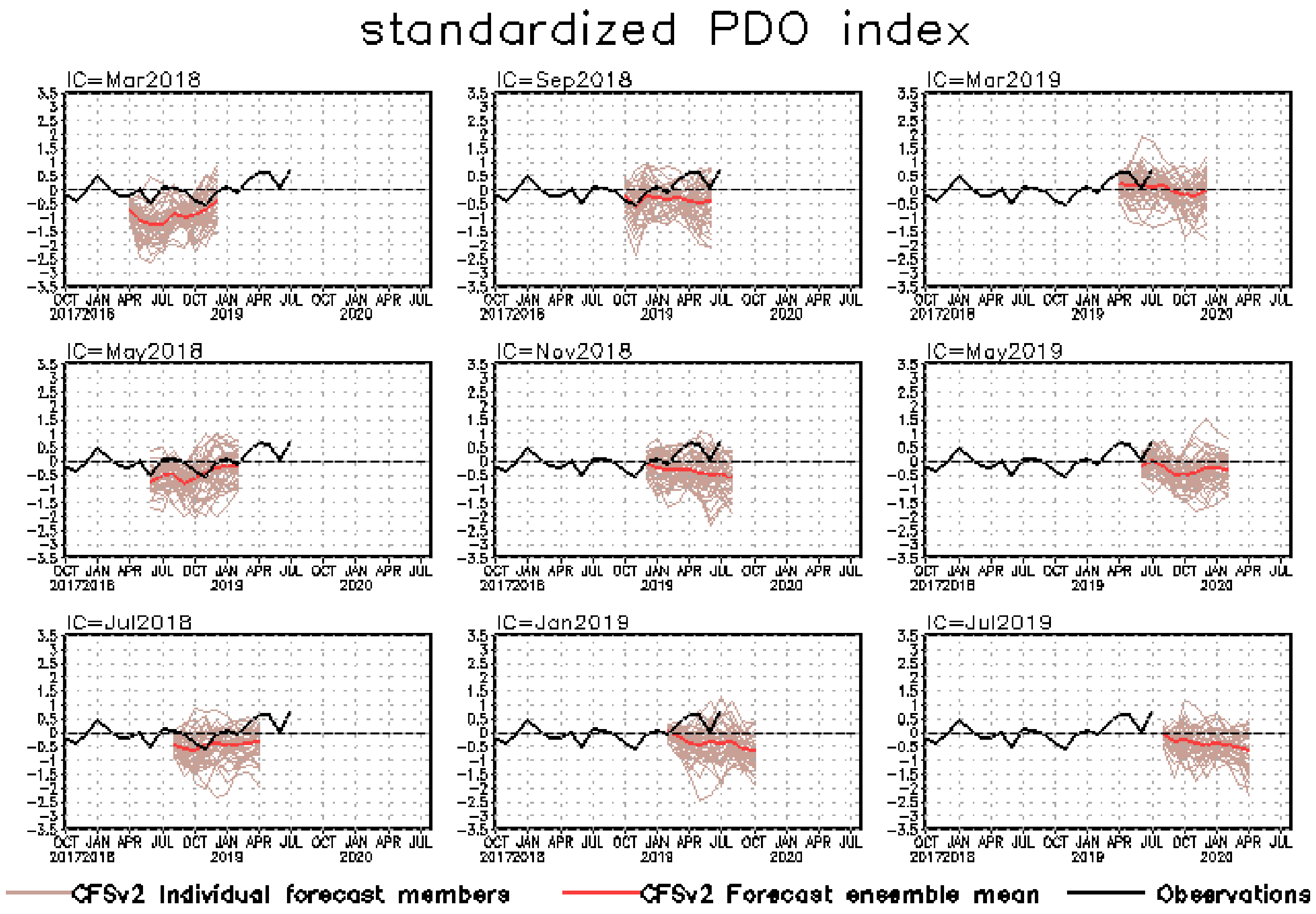


- CFSv2 predicted a decline of positive SSTAs with ICs since Mar 2019.

- The latest forecasts call for a ENSO-neutral state since summer 2019.

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 from Different Initial Months



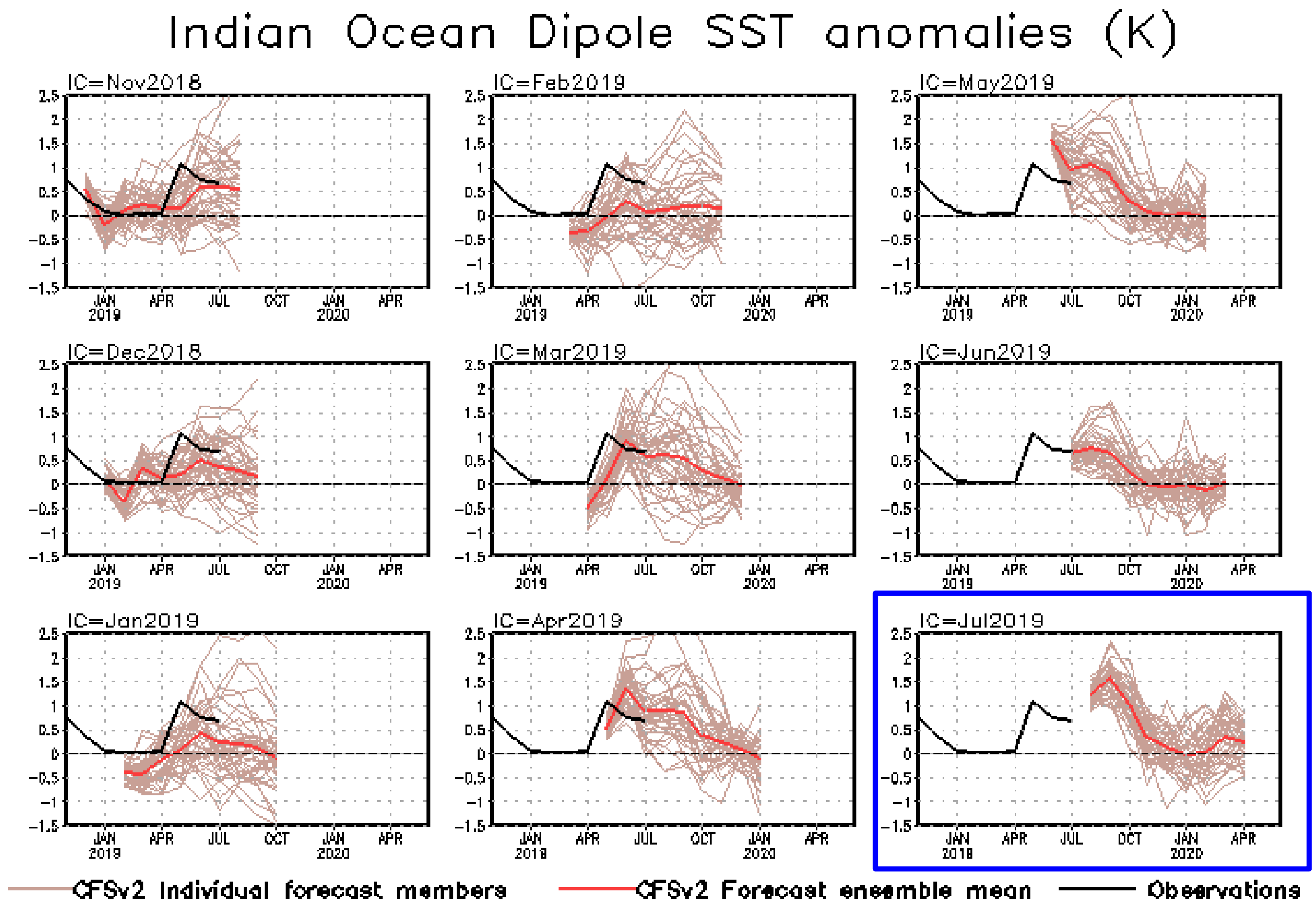
PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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 2019.

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.

NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

SETIO = SST anomaly in [90ºE-110ºE, 10ºS-0]

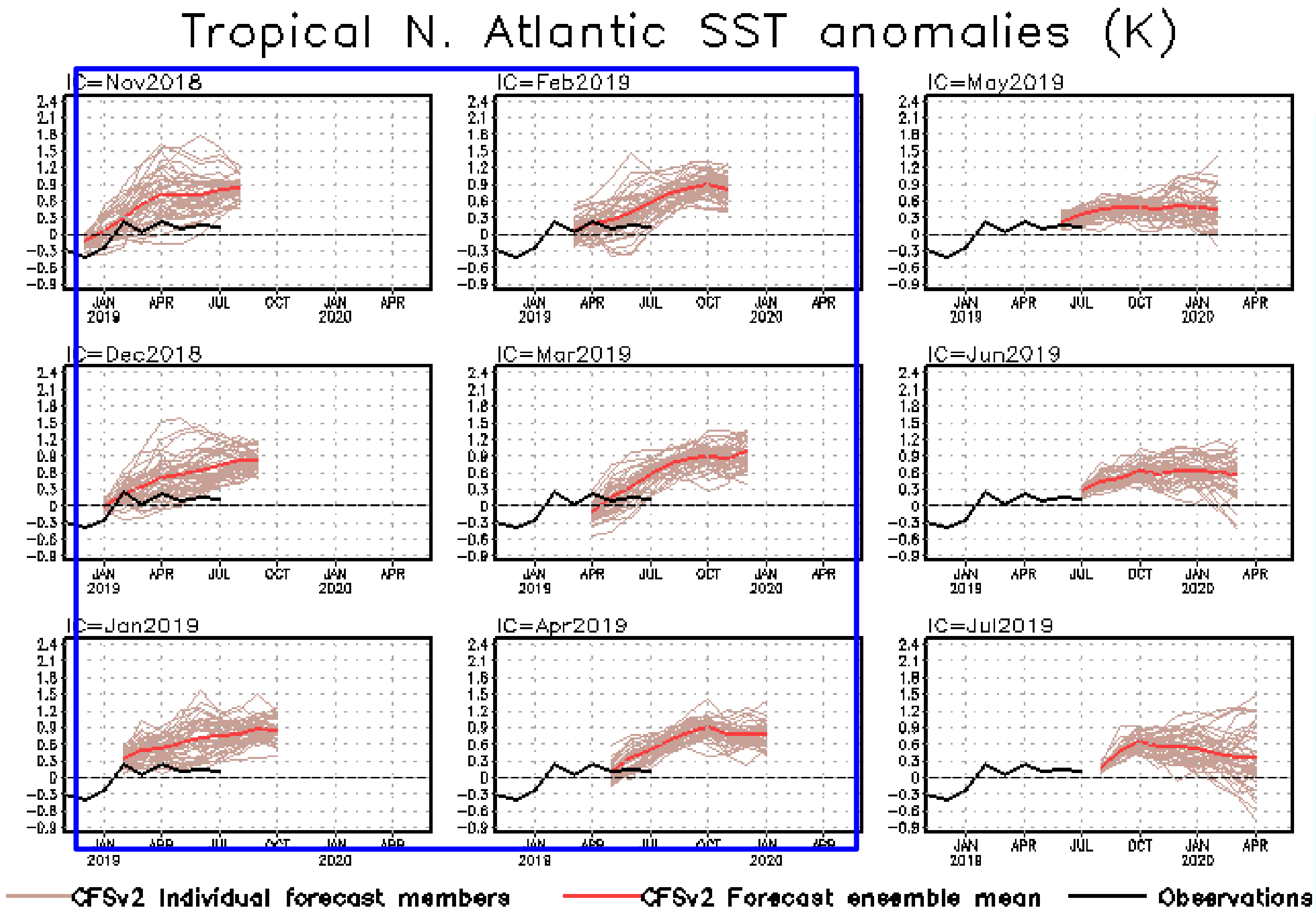
WTIO = SST anomaly in [50ºE-70ºE, 10ºS-10ºN]

- **CFSv2 predict a positive IOD phase in this fall.**

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.

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 may be partially associated with the warm bias in CFSR due to the decoding bug.**
- **Latest CFSv2 predictions call above normal SSTA in the tropical N. Atlantic in summer-autumn 2019, corresponding to the lag impact of the 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.

Acknowledgements

❖ Drs. Zeng-Zhen Hu, Caihong Wen, and Arun Kumar: reviewed PPT, and provide insightful and constructive suggestions and comments

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

❖ Dr. Wanqiu Wang provided the sea ice forecasts and maintained the CFSv2 forecast achieve

Please send your comments and suggestions to:

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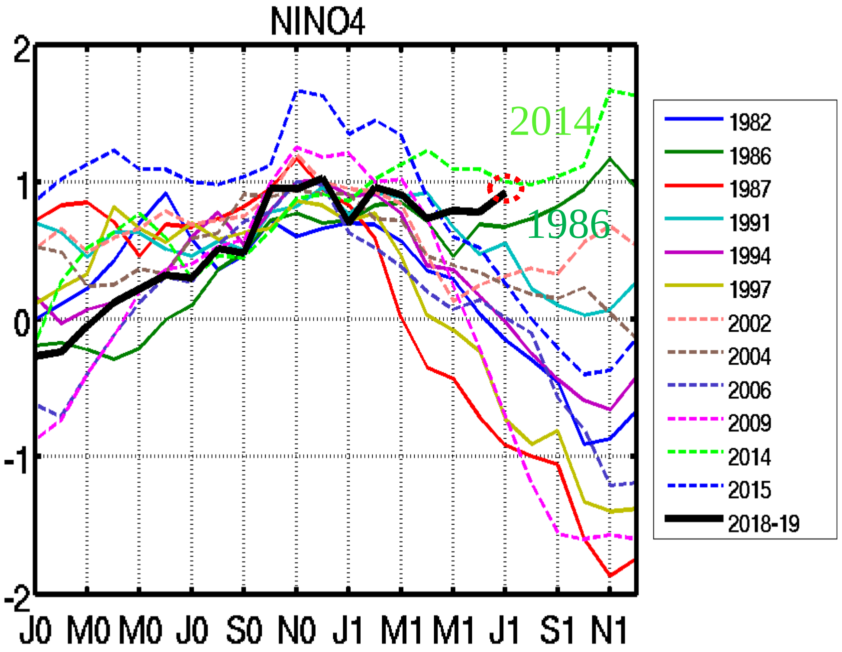
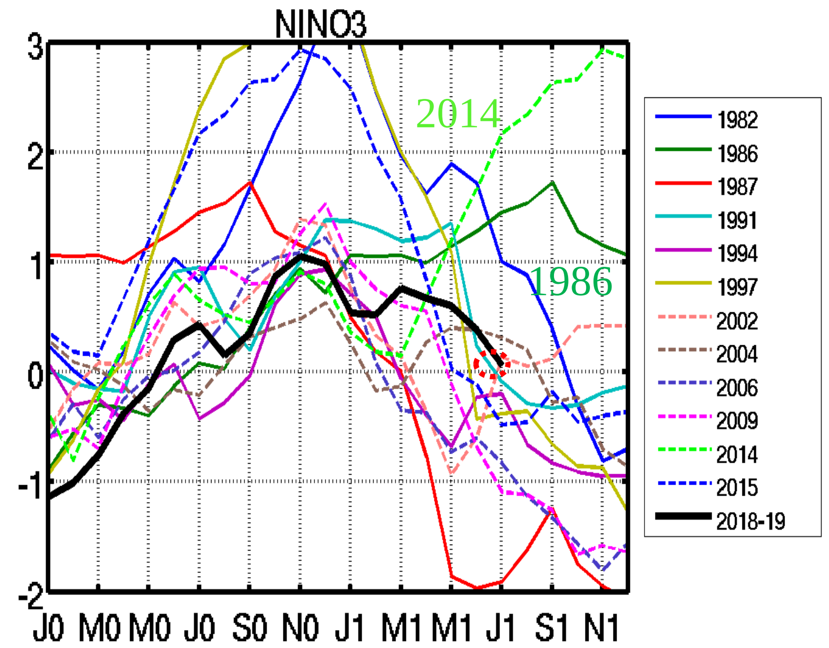
Arun.Kumar@noaa.gov
Caihong.Wen@noaa.gov
Jieshun.Zhu@noaa.gov

Backup Slides

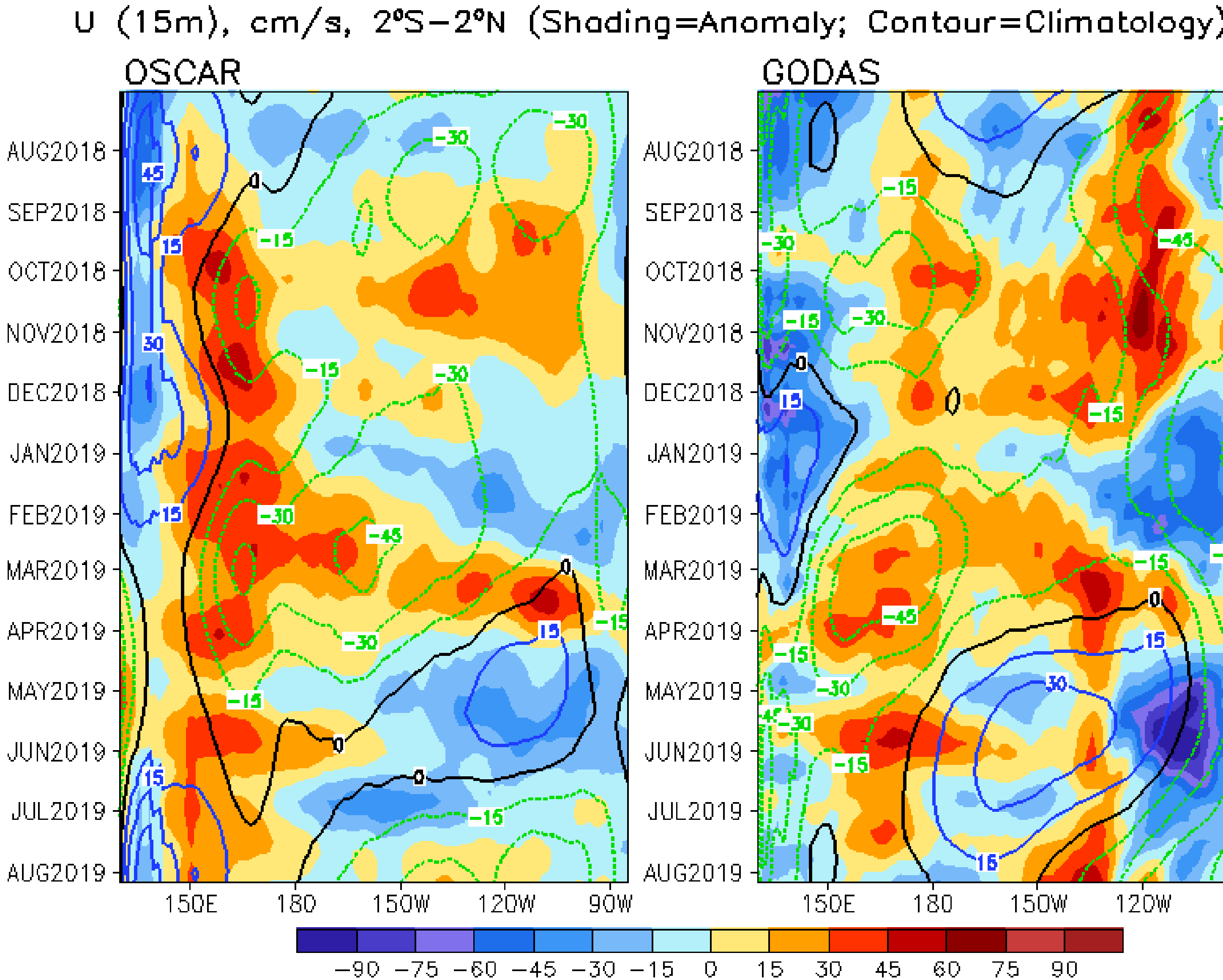
El Niño Composites



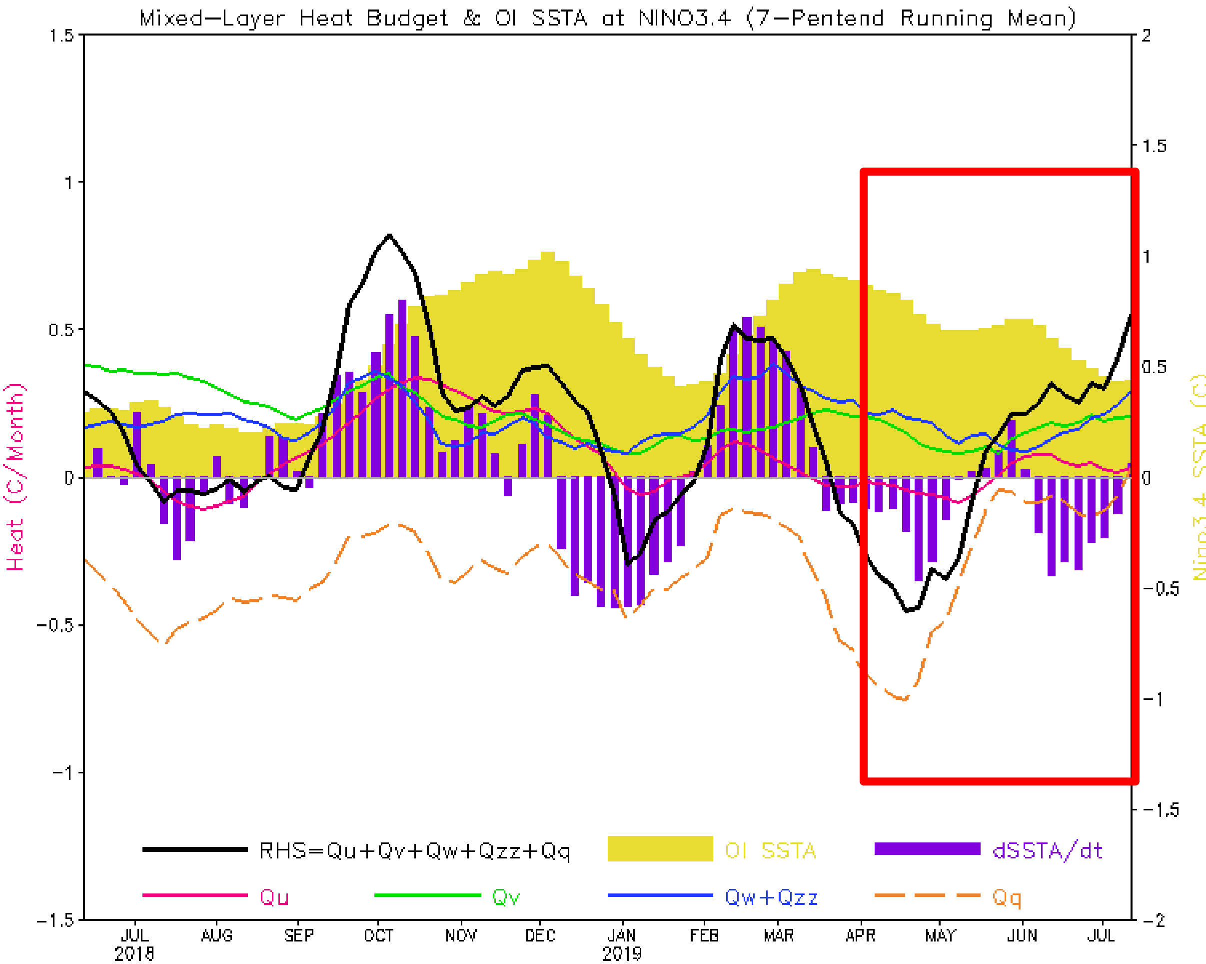


- Positive SSTAs were larger in the western-central Pacific than in the eastern Pacific for the 2018-19 El Niño event (Central-Pacific El Niño or Modoki El Niño).
- Compared to the historical El Niño events, the development of NINO4 in 2018-19 is similar to those in 2014-15 and 1986-87 events, while NINO3 in Jul,2019 is much cooler than those in Jul,1987 and Jul,2015.

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



NINO3.4 Heat Budget



- **Observed SSTA tendency (dSSTA/dt; bar) was negative in last a few pentads, and total heat budget (RHS; black line) was small since late Jun 2019.**

- **Dynamical terms (Qu, Qv, Qw+Qzz) were small positive or negative and heat-flux term (Qq) were negative in Jun 2019.**

Huang, B., Y. Xue, X. Zhang, A. Kumar, and M. J. McPhaden, 2010 : The NCEP GODAS ocean analysis of the tropical Pacific mixed layer heat budget on seasonal to interannual time scales, J. Climate., 23, 4901-4925.

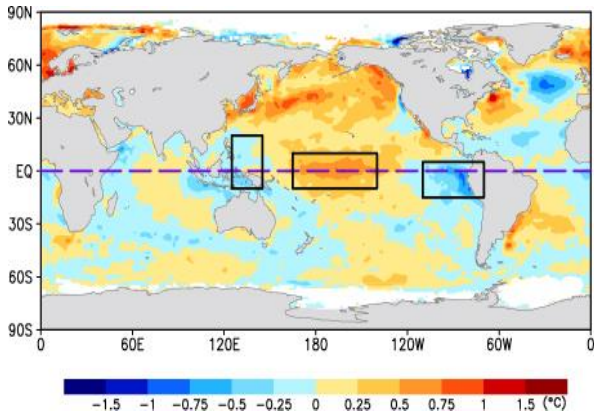
Qu: Zonal advection; Qv: Meridional advection;

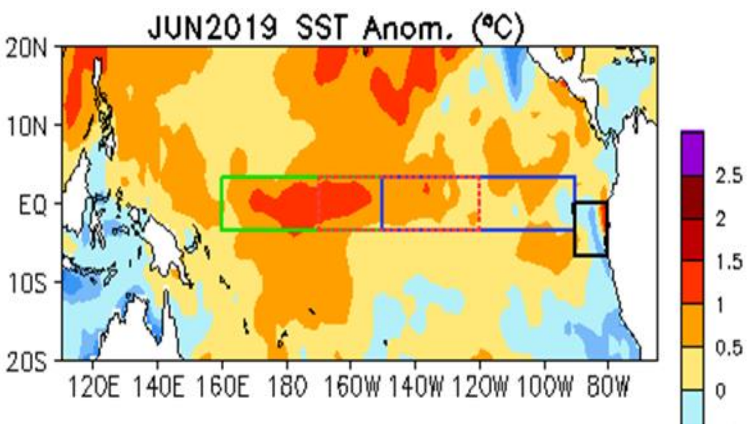
Qw: Vertical entrainment; Qzz: Vertical diffusion

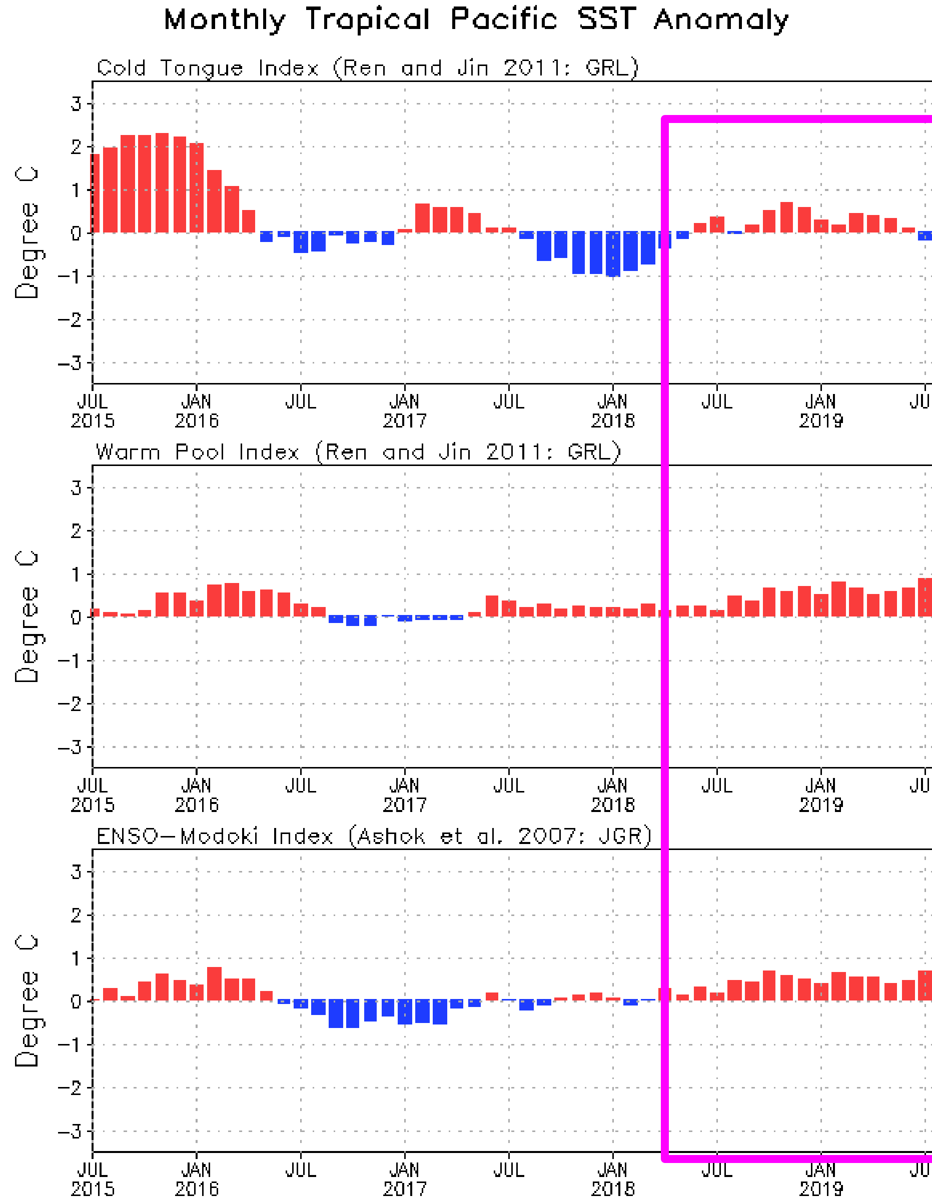
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

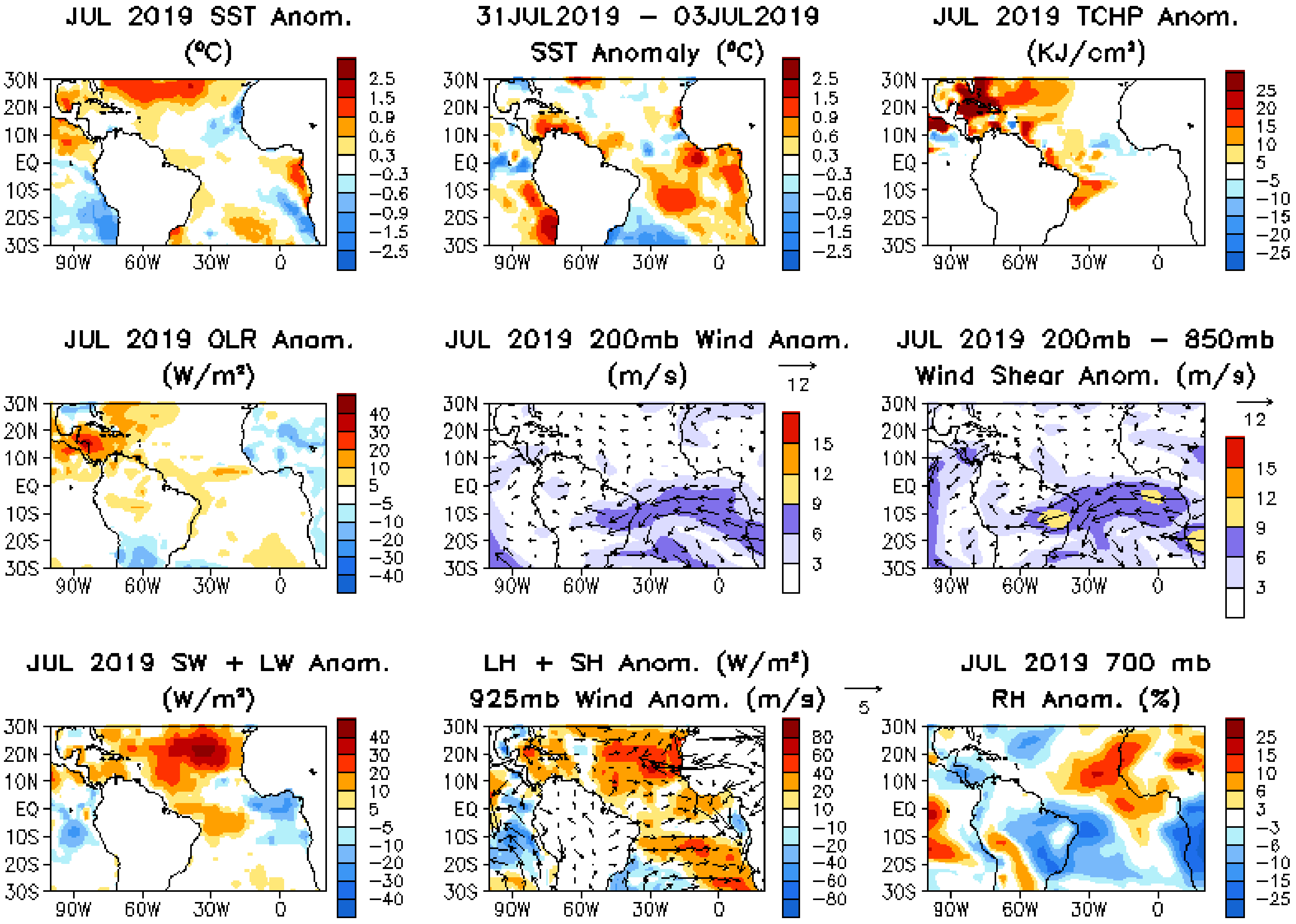
Positive SSTAs were larger in the warm pool than in the cold tongue.







Tropical Atlantic:



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

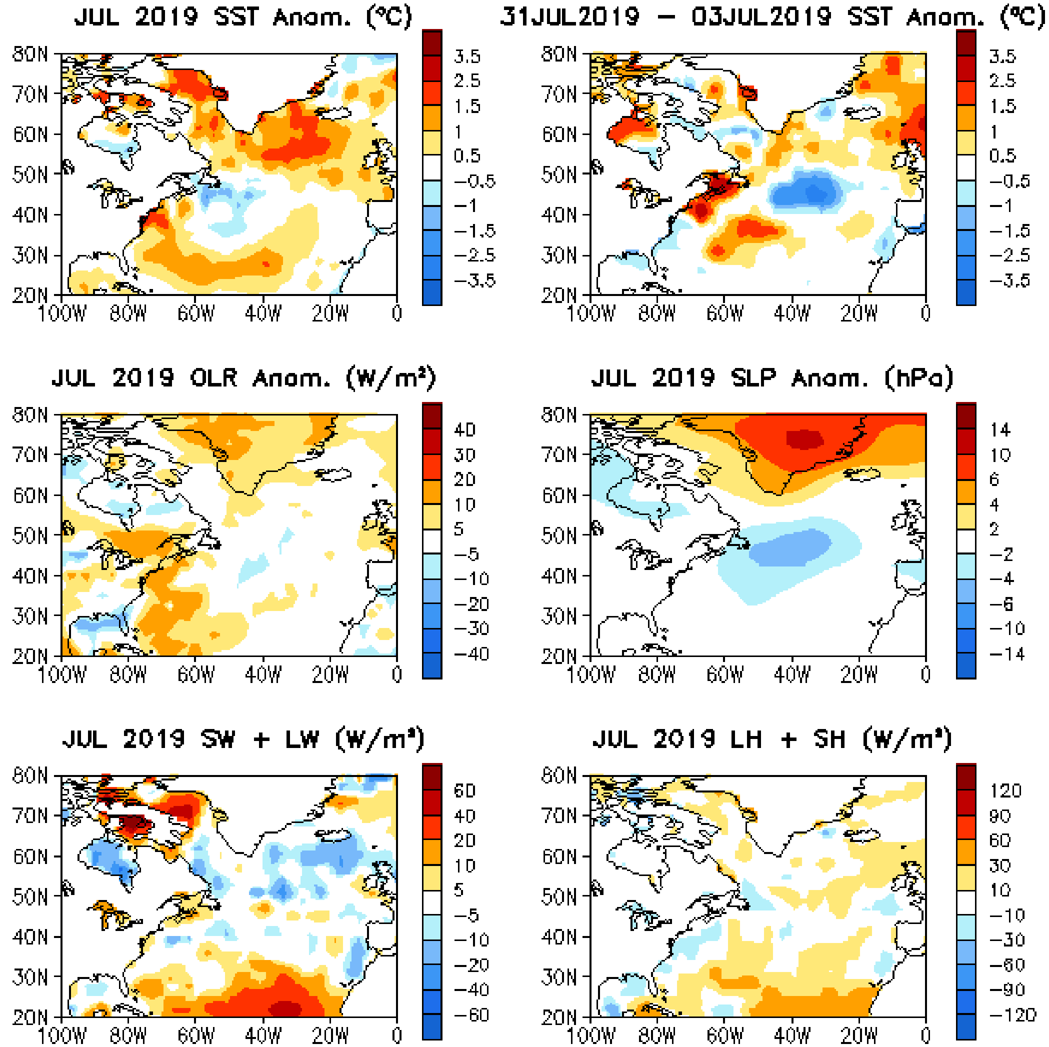
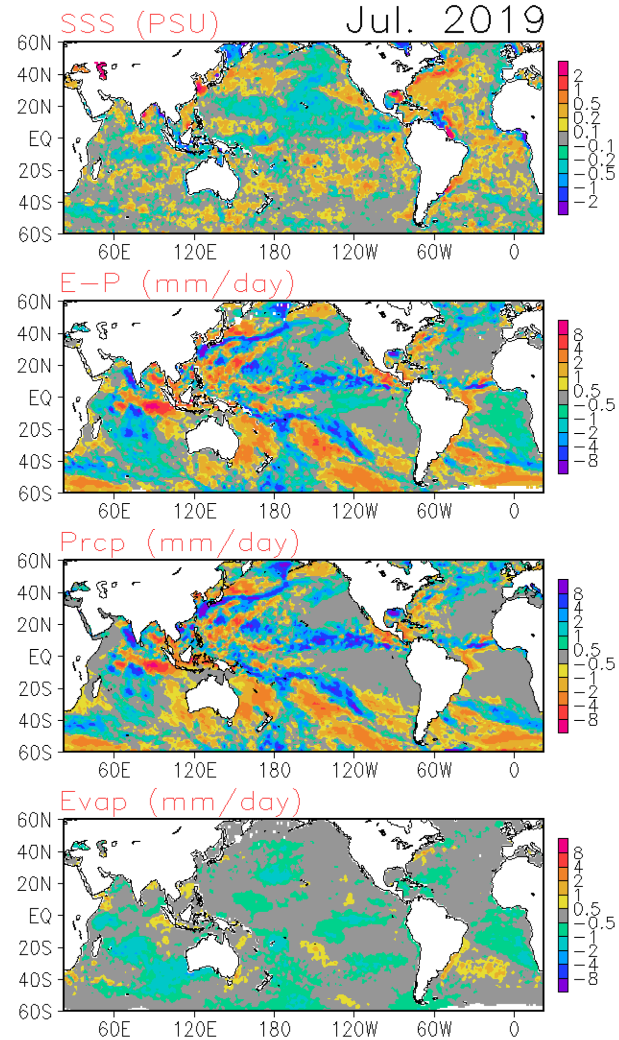


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

Global Sea Surface Salinity (SSS)

Anomaly for July 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: SMAP satellite resumed on 07/24/2019. For this month, SMAP SSS input is missing from 07/01/2019 to 07/23/2019.**
- In the equatorial Pacific ITCZ region, negative SSS anomalies are continually persistent, and it is enhanced in the east basin. Such signal is co-incident with increased precipitation, particularly in the east equatorial Pacific. Negative SSS anomalies appear in the subtropics of N. Pacific, which is likely due to the increased precipitation. The SSS anomaly is positive in the Bay of Bengal with stronger signal in the west basin. Meanwhile, in the Sea of Okhotsk, negative SSS anomaly continues/enhances which could be due to the river discharge.



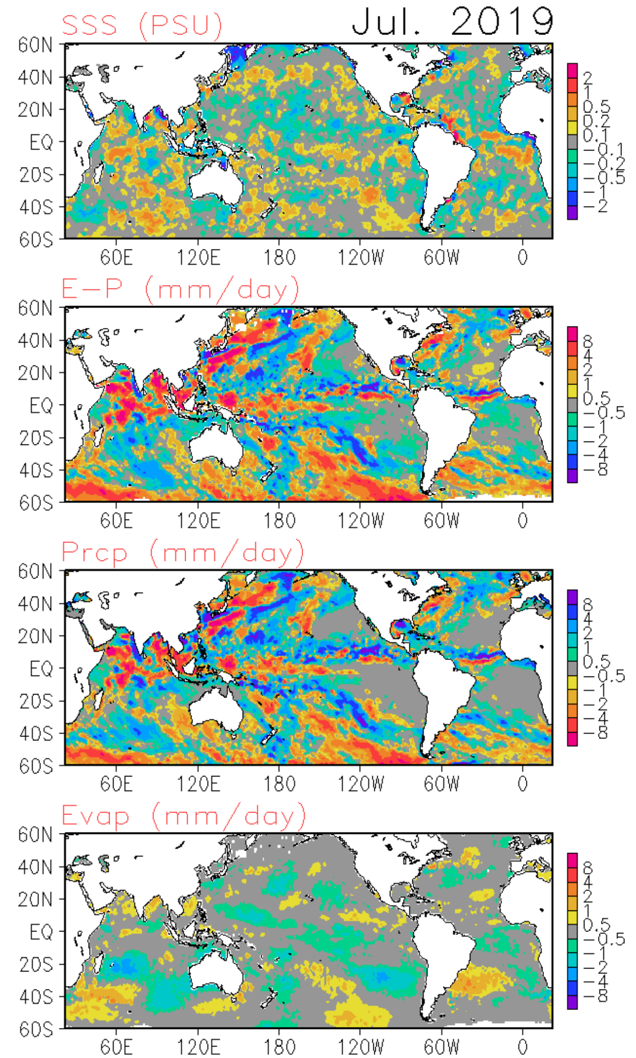
- **Data used**

  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 July 2019

Compared with last month, the SSS decreased in the east Equatorial Pacific and N. Pacific subtropical regions. Such SSS decreasing is co-incident with increased precipitation. The SSS increased in the Equatorial Atlantic ocean which is accompanied with reduced precipitation. The SSS continues decreasing in the Sea of Okhotsk with reduced precipitation in this area. However, the precipitation is enhanced in the Amur river path over the land. Therefore, such negative signal is possibly caused by increased Amur river discharge.

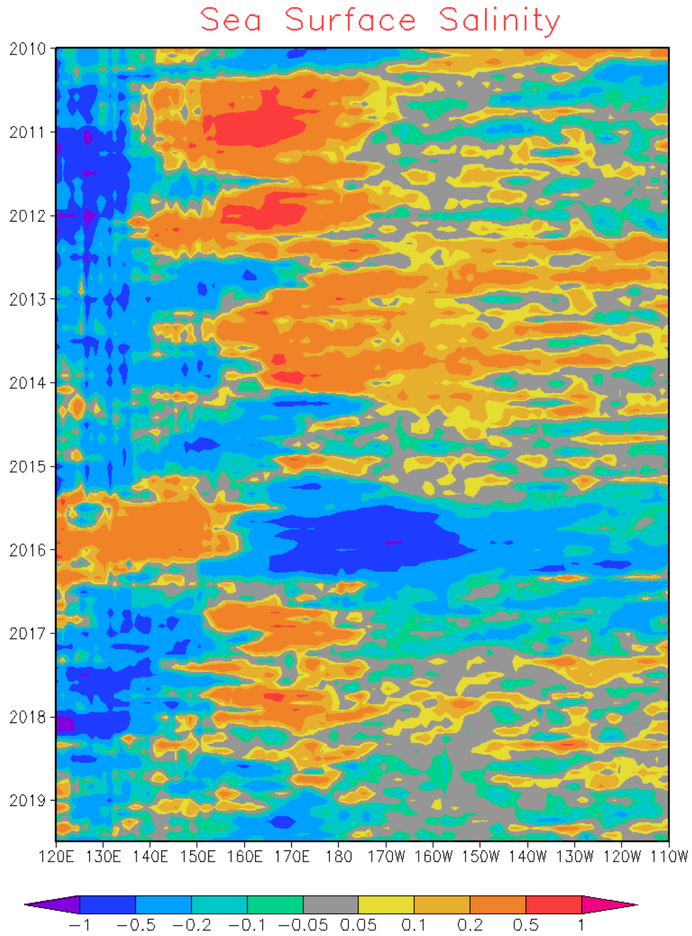


Global Sea Surface Salinity (SSS)

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.

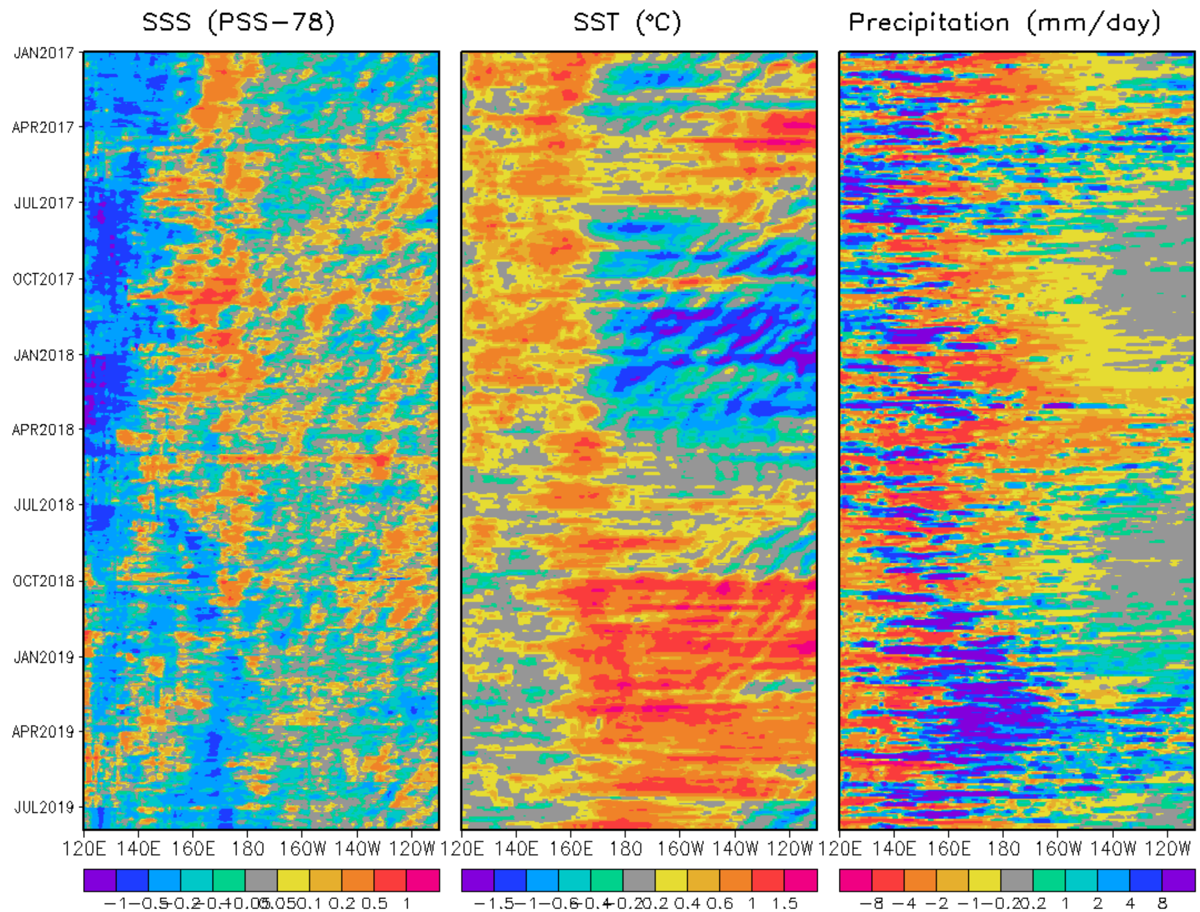
- Hovemoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- In the equatorial Pacific Ocean, the SSS signal continues in neutral west of 150°E; the SSS shows negative anomalies between 150°E and dateline; east of dateline, the SSS signal is in favor of neutral as well.



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