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

Prepared by

Climate Prediction Center, NCEP/NOAA

September 12, 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

- **Overview**
- **Recent highlights**
  - **Pacific/Arctic Ocean**
  - **Indian Ocean**
  - **Atlantic Ocean**
- **Global SSTA Predictions**

➢ **Missing of TAO Mooring Observations and Ocean Temperature Anomalies in TAO and GODAS**

➢ **A Strong Positive Phase of an IOD event in 2019**

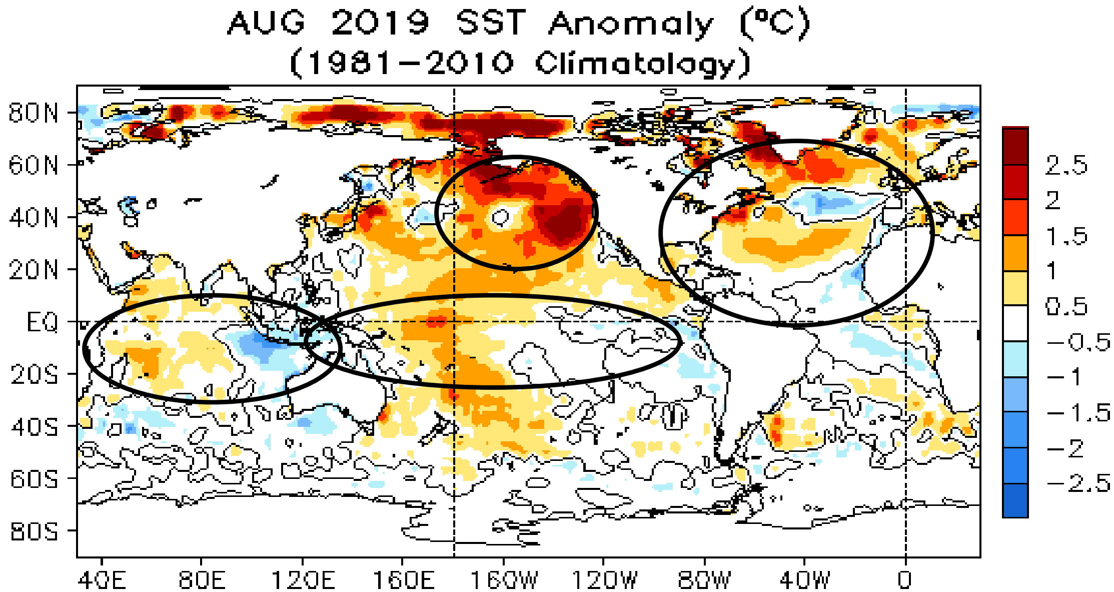
➢ **Marine Heat Waves in 2018/19 and 2014/16**

Overview

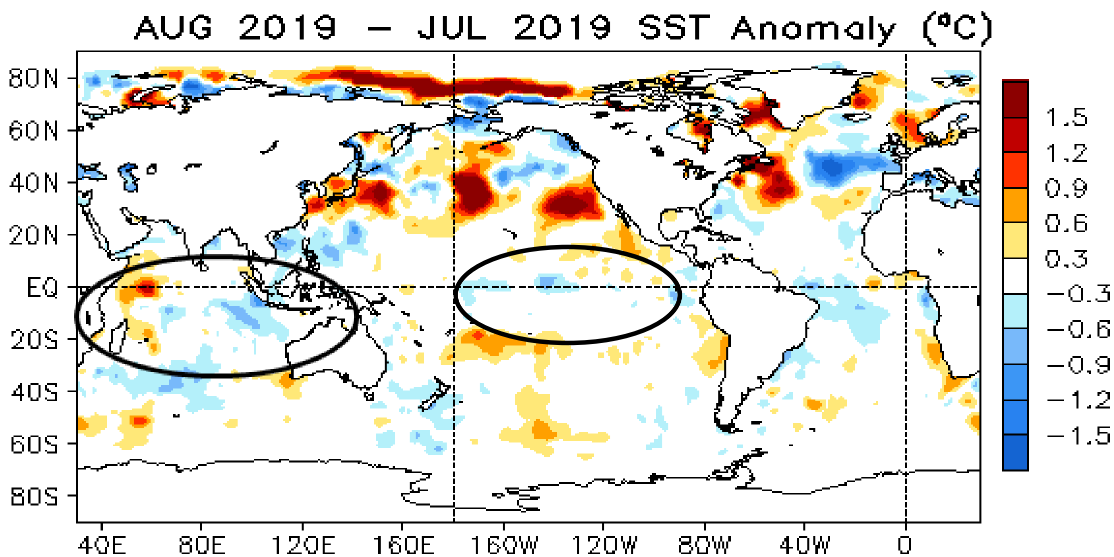
- **Pacific Ocean**
  - **NOAA "ENSO Diagnostic Discussion" on 12 September 2019 indicated that** ***"ENSO-neutral is favored during the Northern Hemisphere fall 2019 (~75% chance), continuing through spring 2020 (55-60% chance)."***
  - **Positive SSTAs were persistent in the central tropical Pacific and small negative SSTAs in the eastern tropical Pacific with NINO3.4=0.20^{o}C in Aug 2019.**
  - **Strong positive SSTAs dominated in the N. Pacific in Aug 2019. PDO switched to a positive phase since Mar 2019 with PDOI= 0.45 in Aug 2019.**
- **Indian Ocean**
  - **IOD was in a strong positive phase in May-Aug 2019 with positive (negative) SSTAs in the west and central (east) and IODI=1.3, which is comparable to 2006.**
- **Atlantic Ocean**
  - **NAO was in a negative phase with NAOI=-1.6 in Aug 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



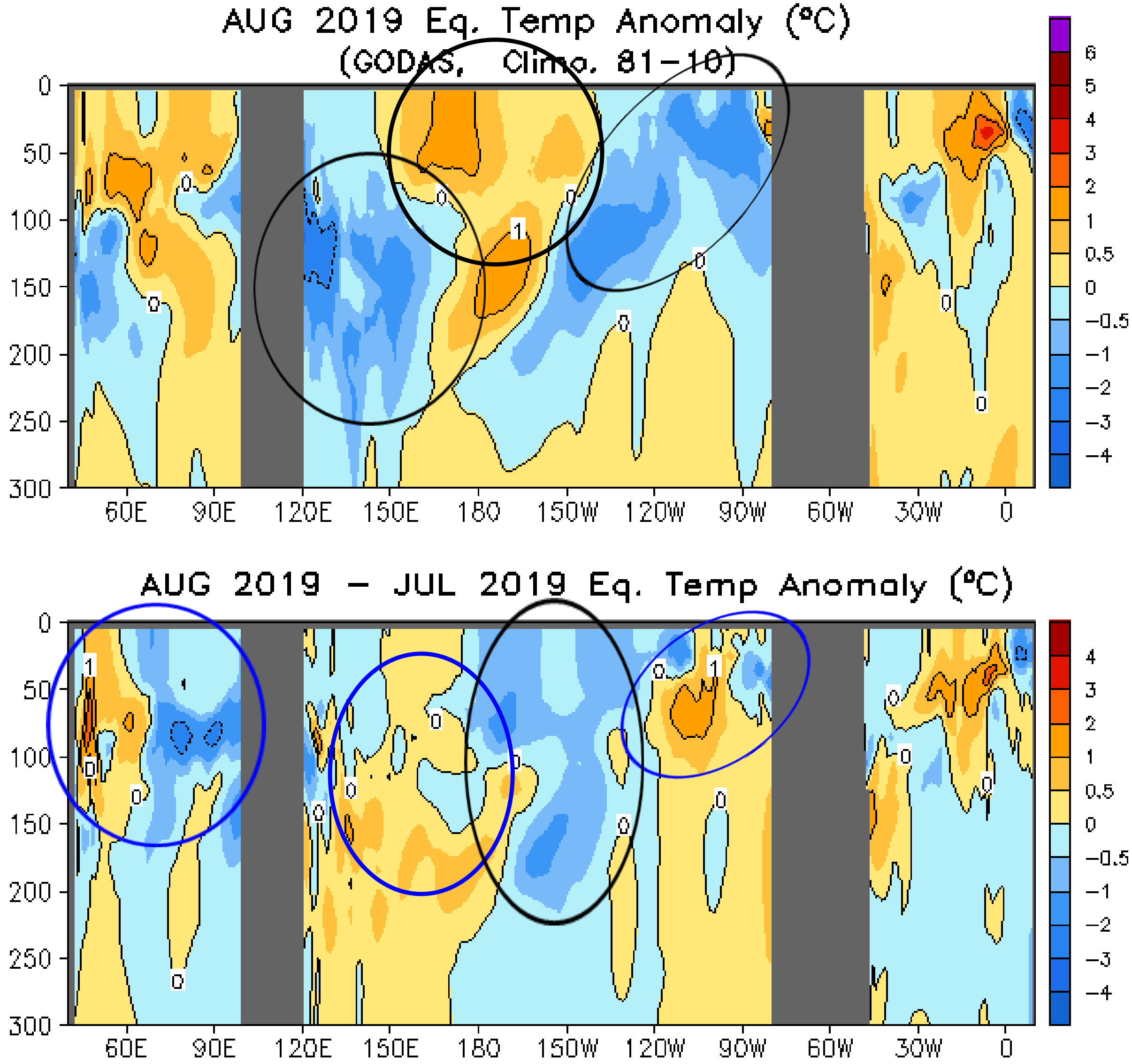
- SSTAs were positive in the central, and small negative in the eastern tropical Pacific.
- Strong positive SSTAs persisted in the Gulf of Alaska
- Horseshoe/tripole-like SSTA pattern persisted in the North Atlantic.
- In the Indian Ocean, dipole-like SSTAs were present with positive in the west and central and negative in the east.



- Negative SSTA tendencies were observed in the eastern tropical Pacific.
- Dipole-like tendencies were present in the Indian Ocean, suggesting a strengthening of the positive phase of IOD.

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



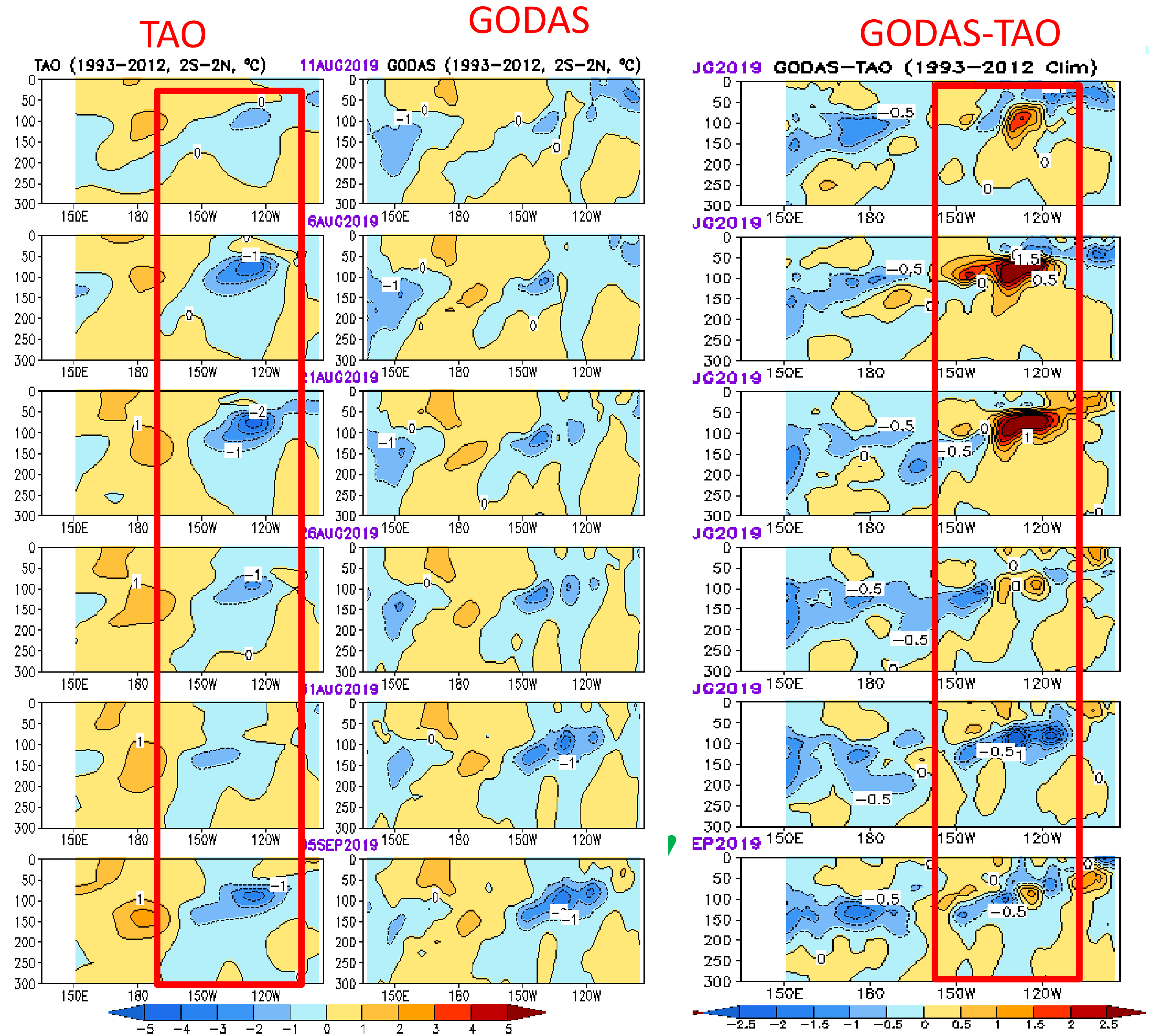
- **Positive (negative) temperature anomalies persisted in the central (western and eastern) equatorial Pacific.**

- **Temperature anomaly tendency pattern was opposite to the anomaly pattern, suggesting an overall weakening of both the positive and negative anomalies.**
- **The tendencies in the Indian Ocean were consistent with the strengthening of the positive phase of IOD.**

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

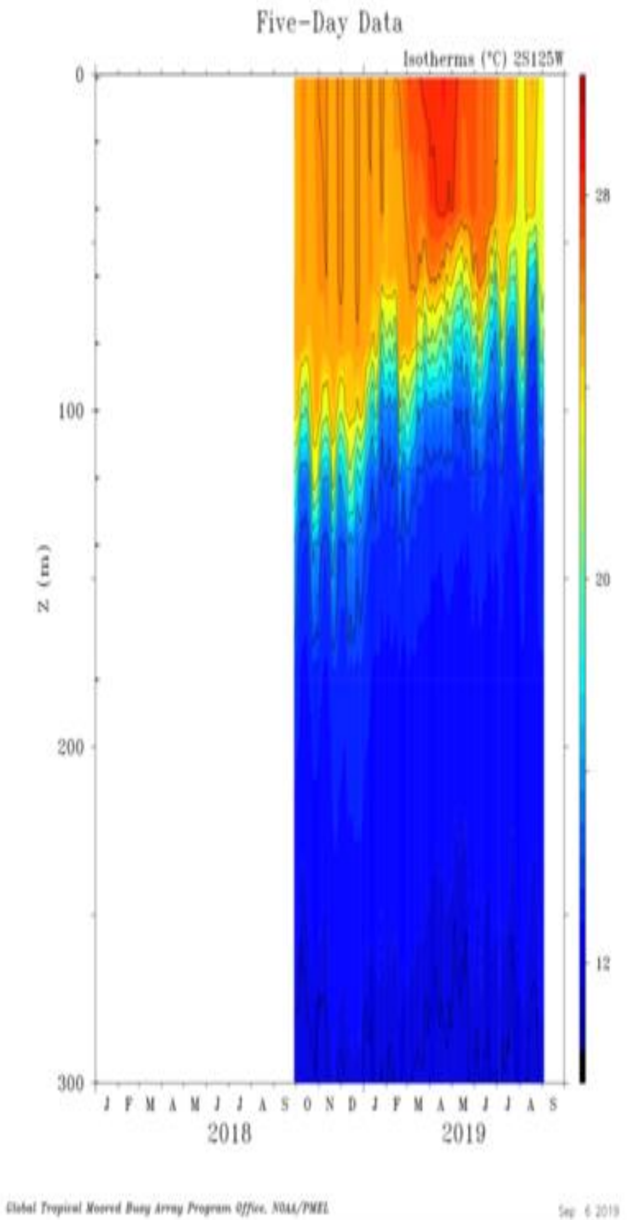
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

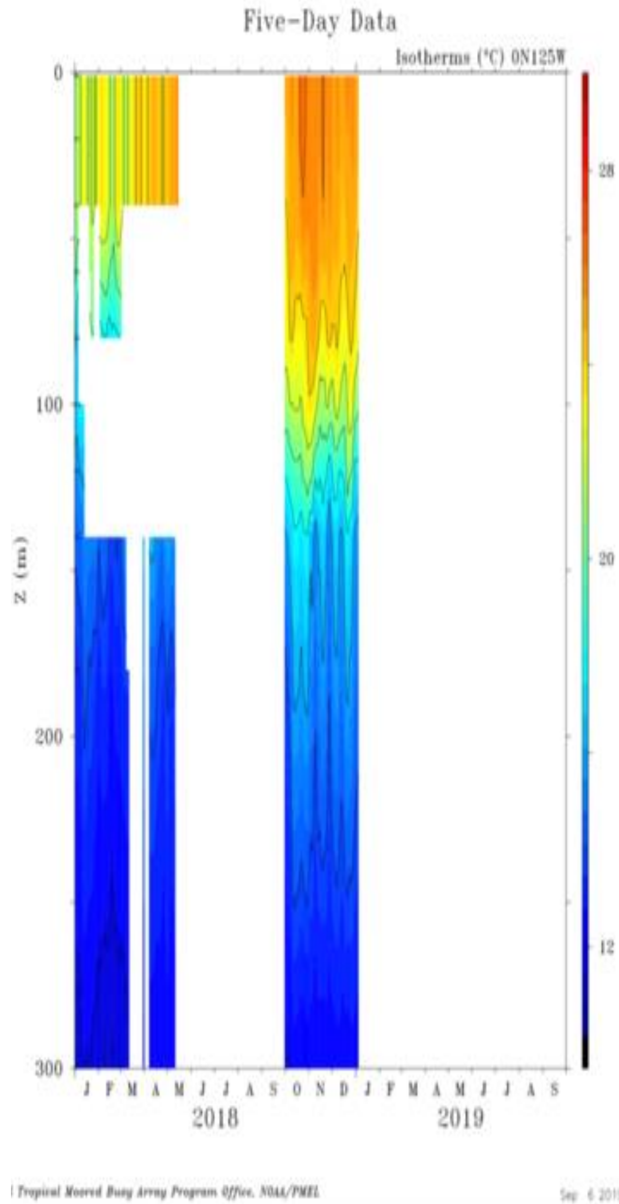


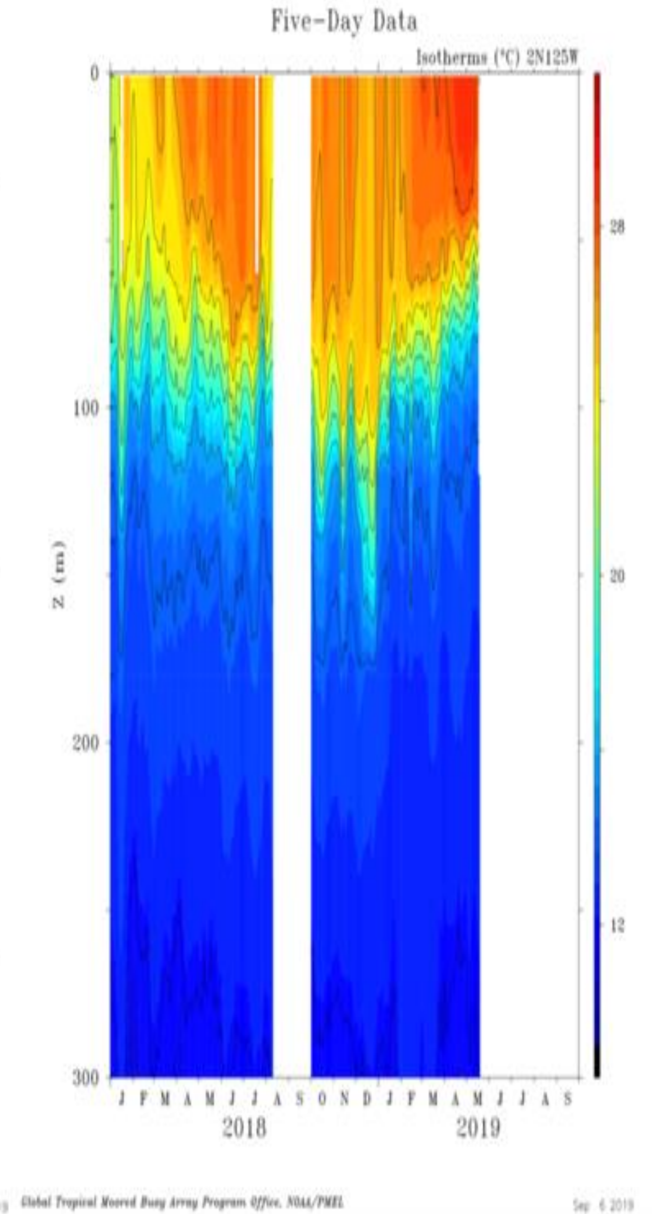
- Negative anomalies were in the east-central Pacific.

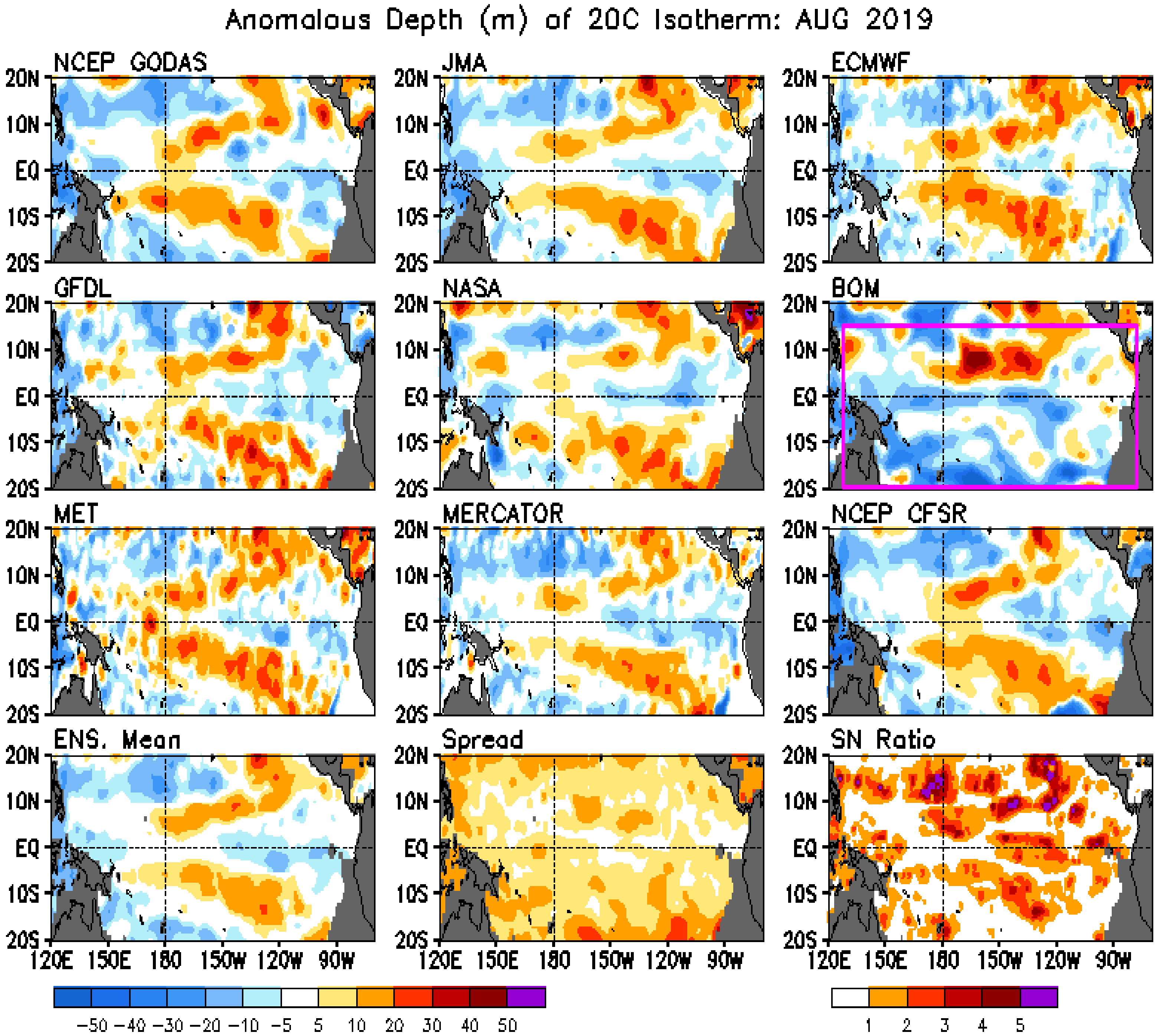
- The differences between GODAS and TAO were large in the eastern Pacific, and fluctuated between negative and positive difference.

-Large Differences between TAO and GODAs may partially due to missing TAO mooring observations along 125W



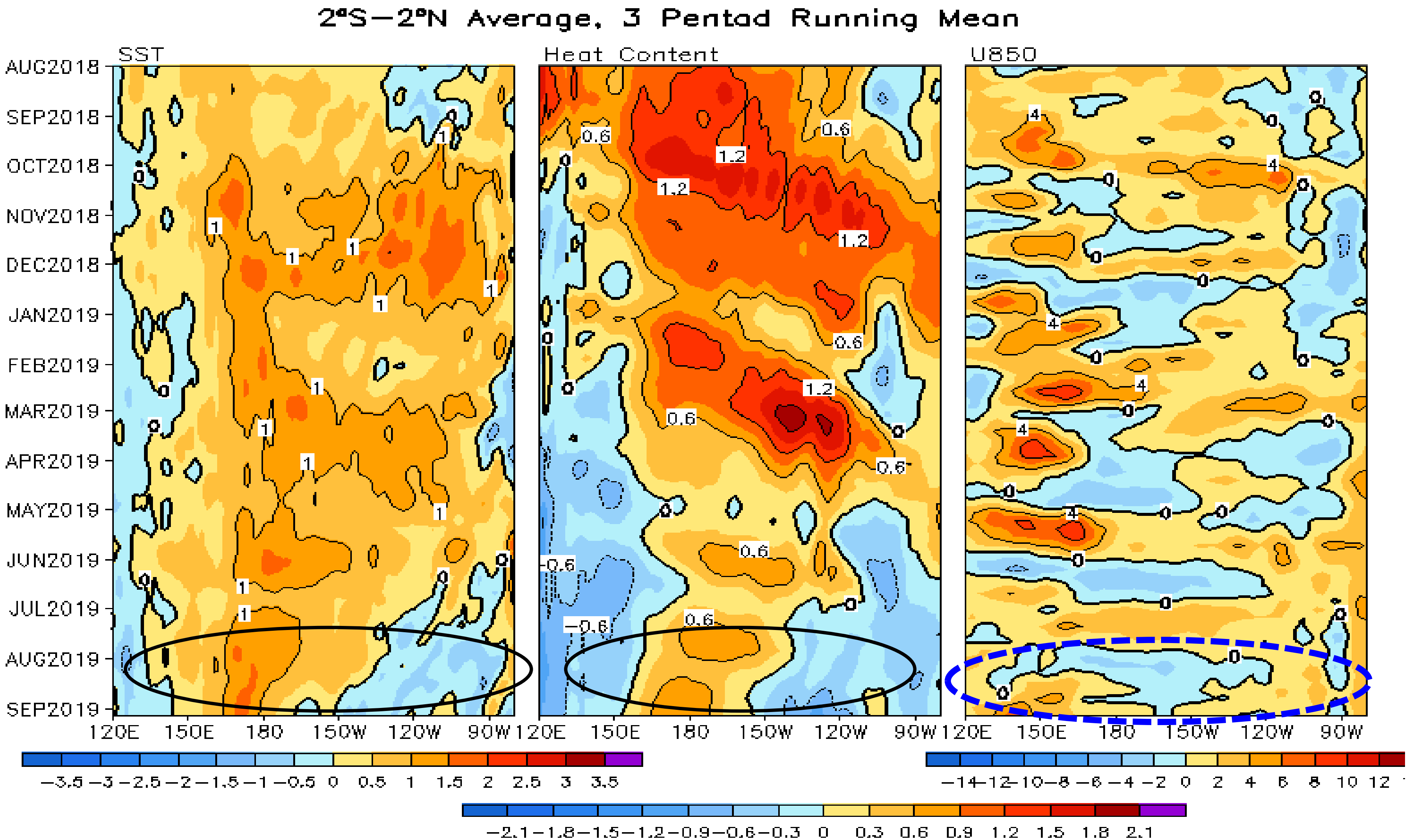






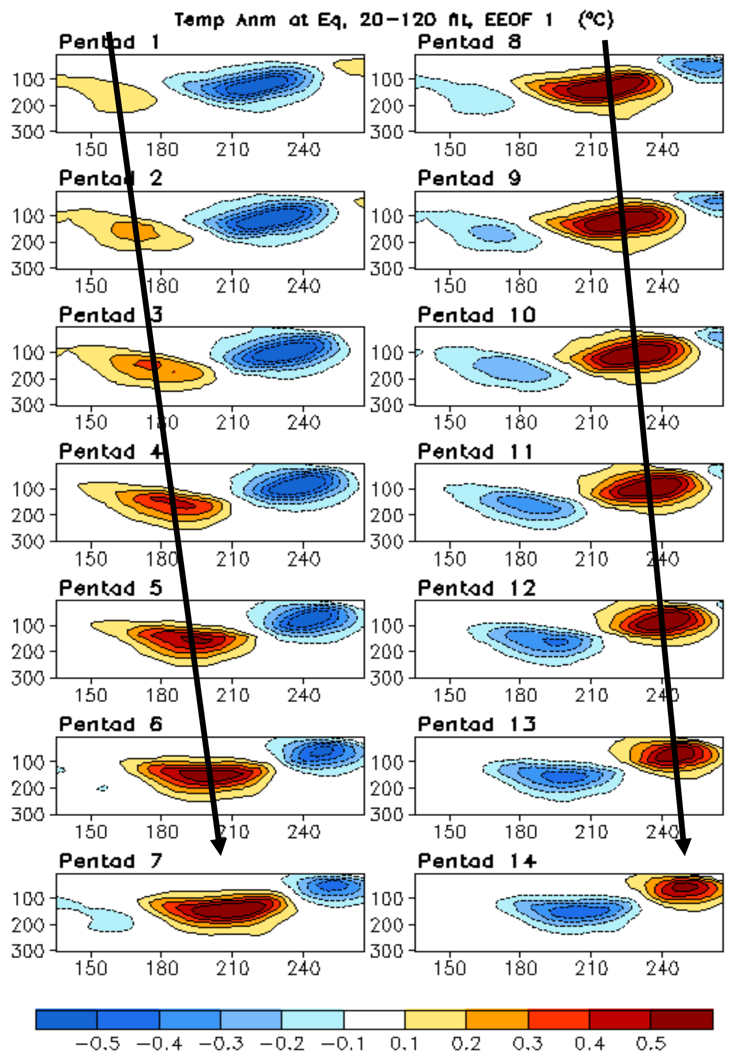
- **Large scale feature is consistent among different products.**
- **Only BOM shows large negative anomaly in the SH.**

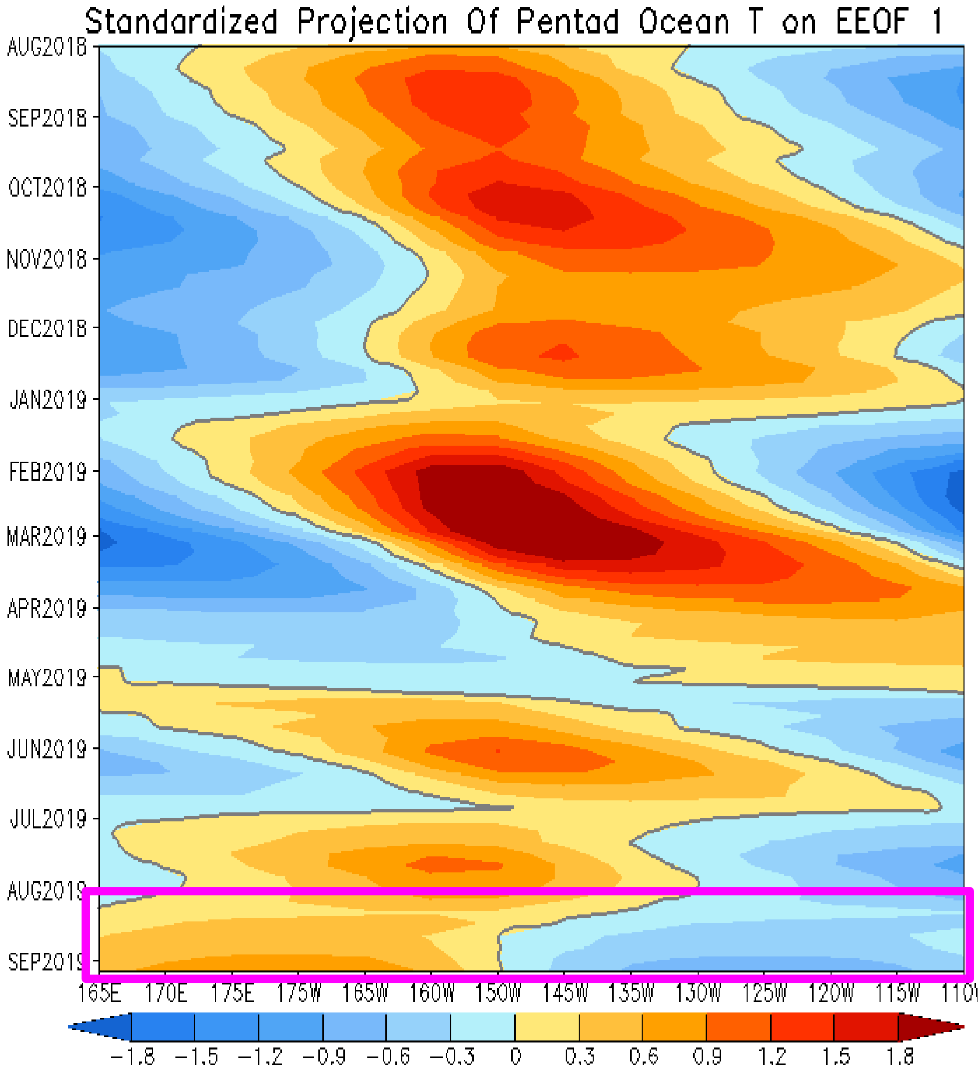
Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies



- SSTA was positive in the central Pacific, and negative in the eastern Pacific in Aug 2019.
- Positive (negative) HC300A persisted in the central (far eastern) Pacific.

Oceanic Kelvin Wave (OKW) Index

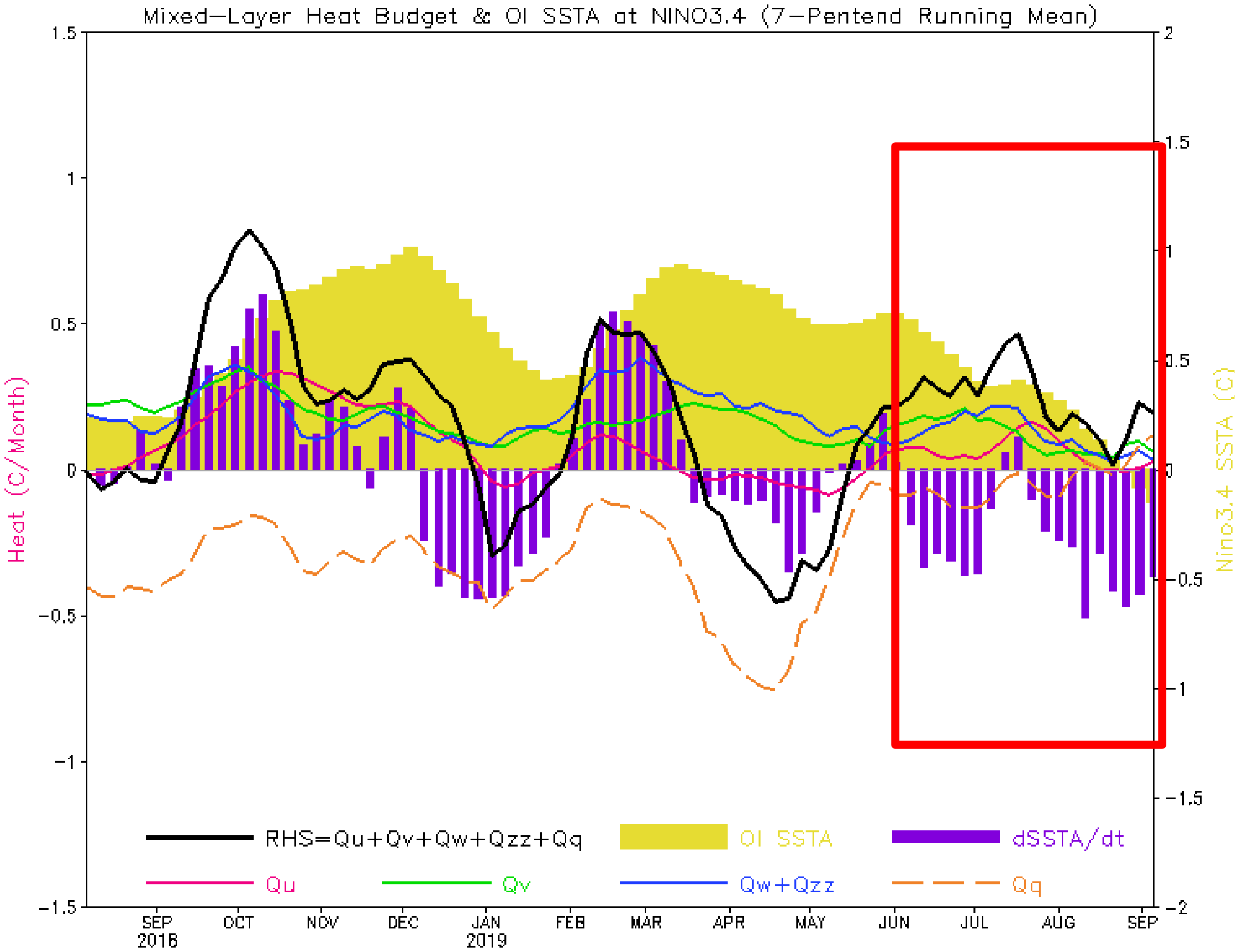




- Since August, Kelvin wave activity was weak and stationary variations were dominated.

(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).)

NINO3.4 Heat Budget



- Observed SSTA tendency (dSSTA/dt; bar) was mostly negative in last a few months, but the total heat budget (RHS; black line) was positive, showing *inconsistency* between them.

- Both dynamical (Qu, Qv, Qw+Qzz) and heat-flux (Qq) terms were small positive or negative in Aug 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.

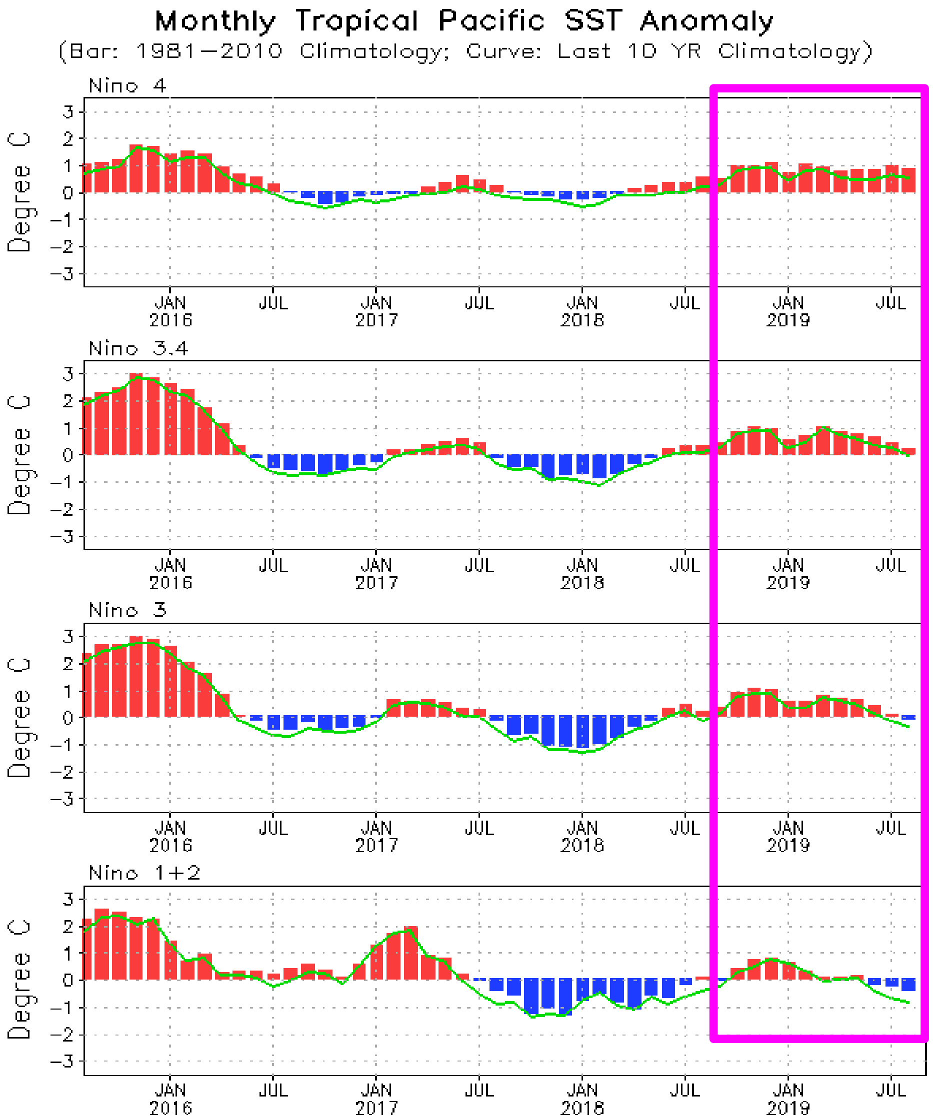
Qu: Zonal advection; Qv: Meridional advection;

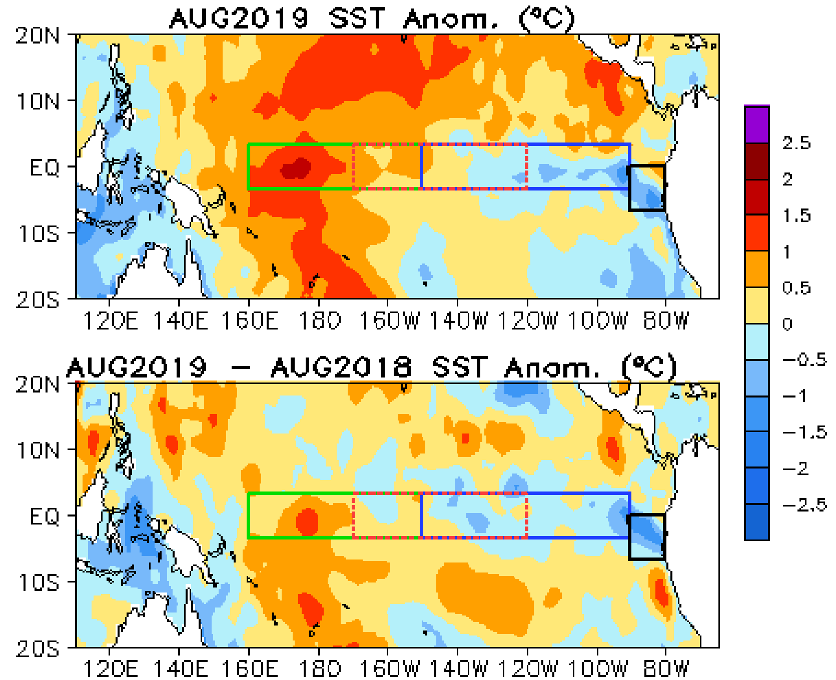
Qw: Vertical entrainment; Qzz: Vertical diffusion

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

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

Evolution of Pacific NINO SST Indices

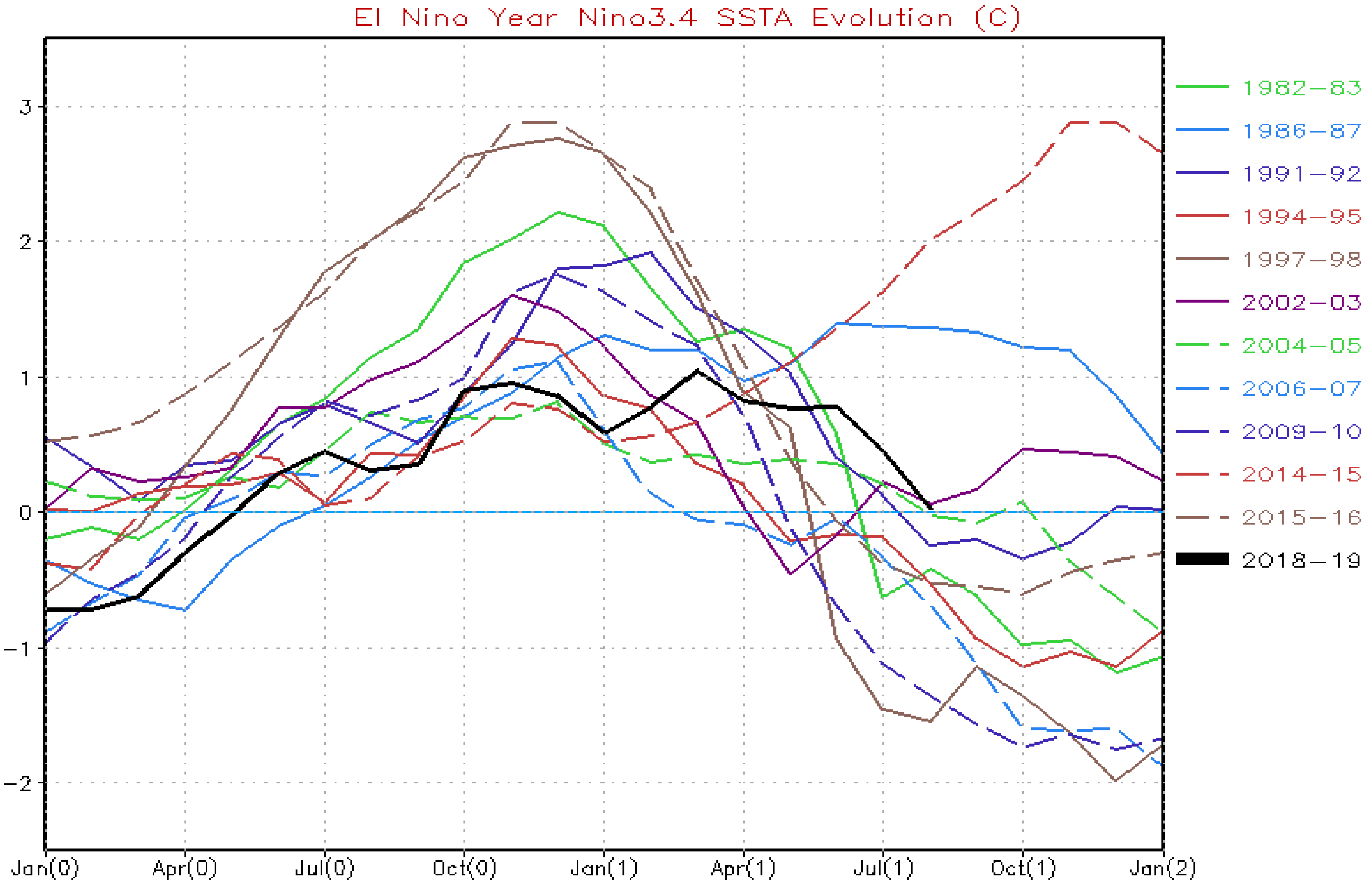




- **All indices decreased, and Nino4 and Nino3.4 were positive, and Nino3 and Nino1+2 negative in Aug 2019.**
- **Nino3.4 = 0.20 C in Aug 2019.**
- **Compared with Aug 2018, the central (eastern) equatorial Pacific was warmer (cooler) in Aug 2019.**
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v5.**

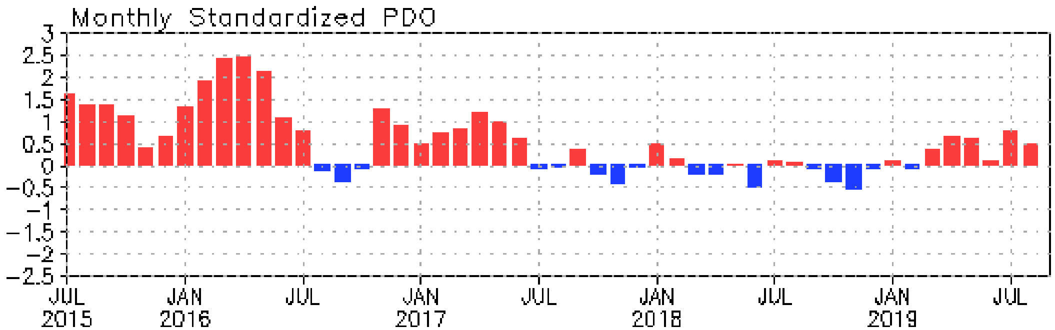
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

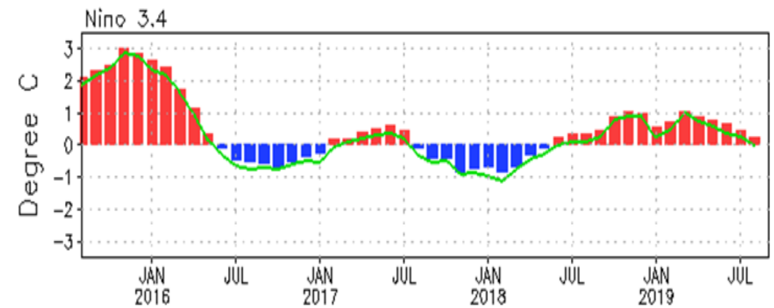
2018-19 is a weak El Nino event

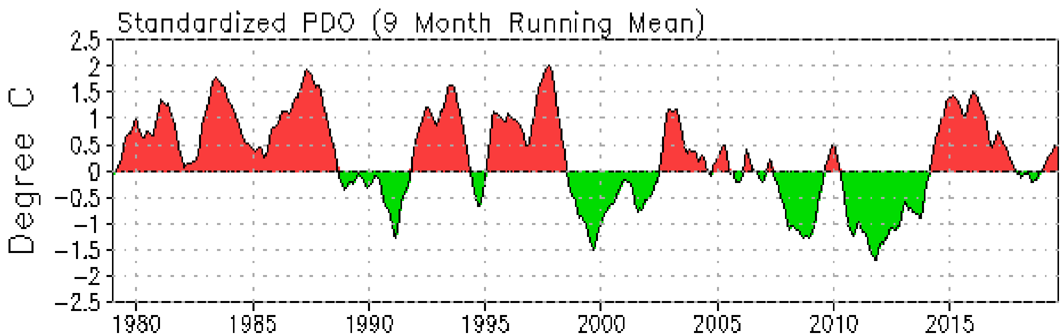


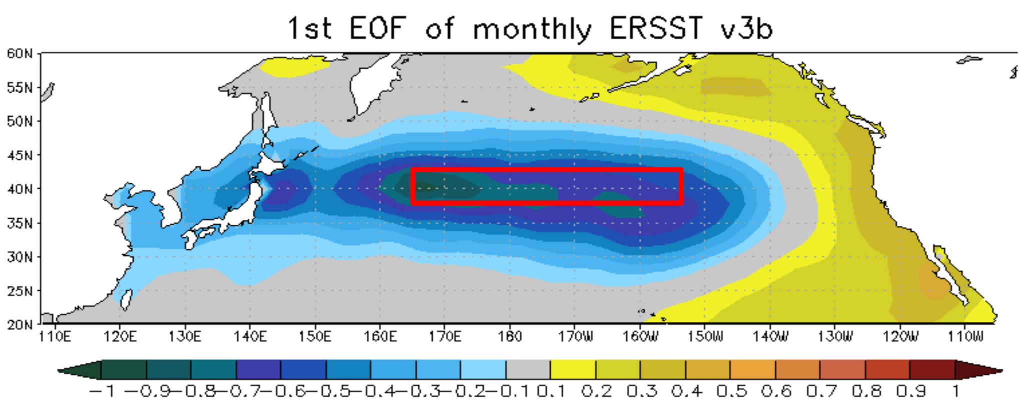
North Pacific & Arctic Oceans

PDO index









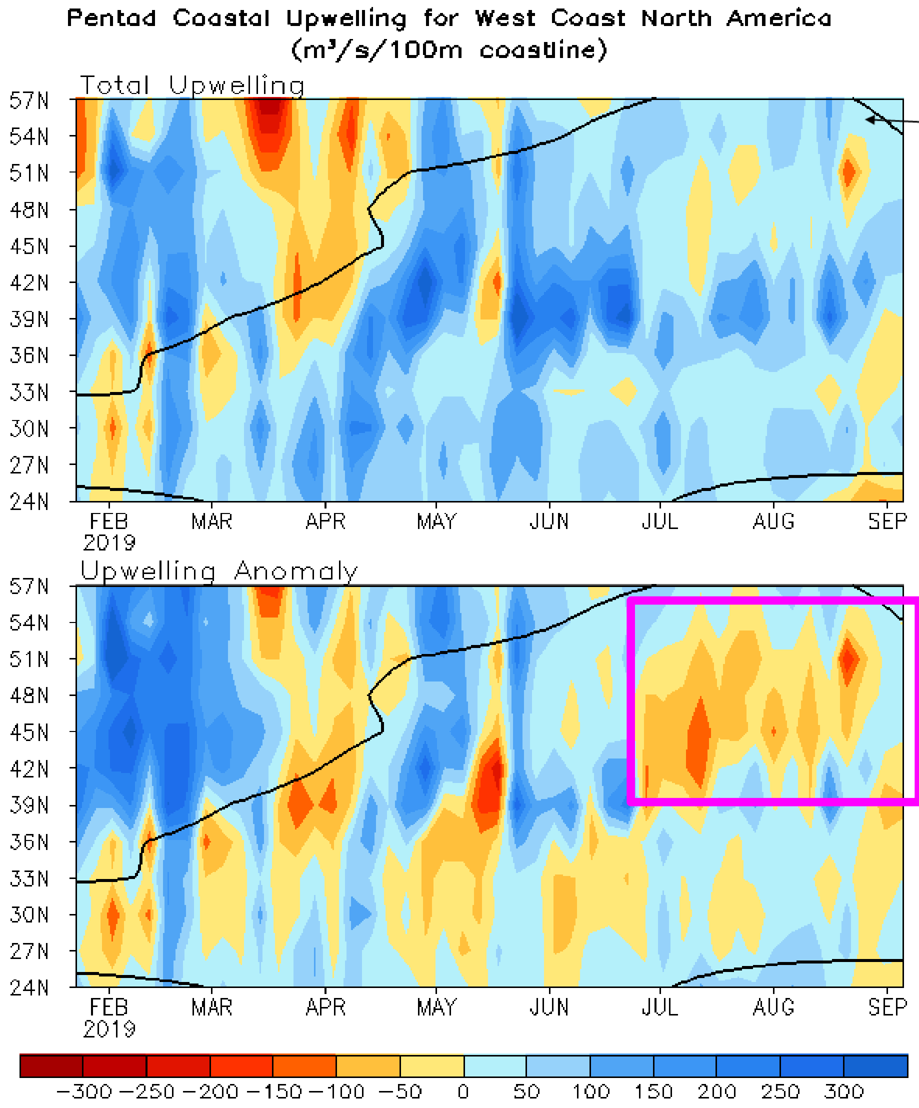
- The PDO index switched to a positive phase since Mar 2019 with PDOI= 0.45 in Aug 2019.

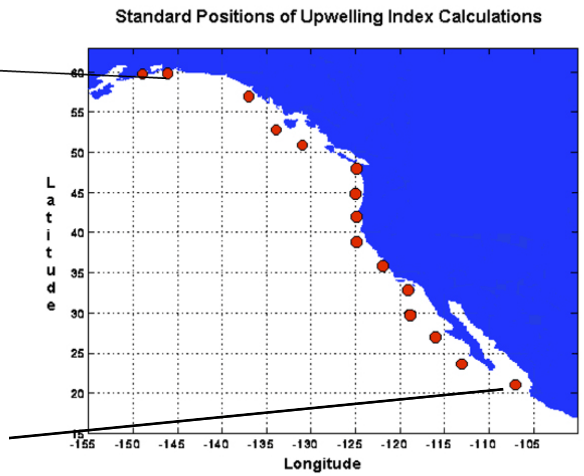
- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge.

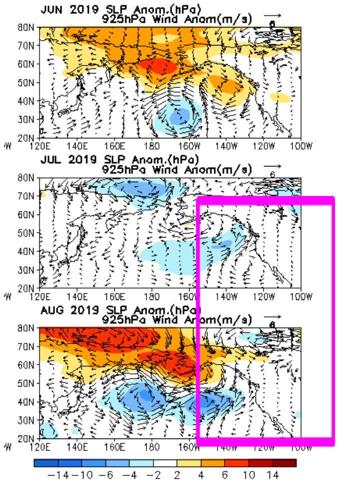
- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

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

North America Western Coastal Upwelling







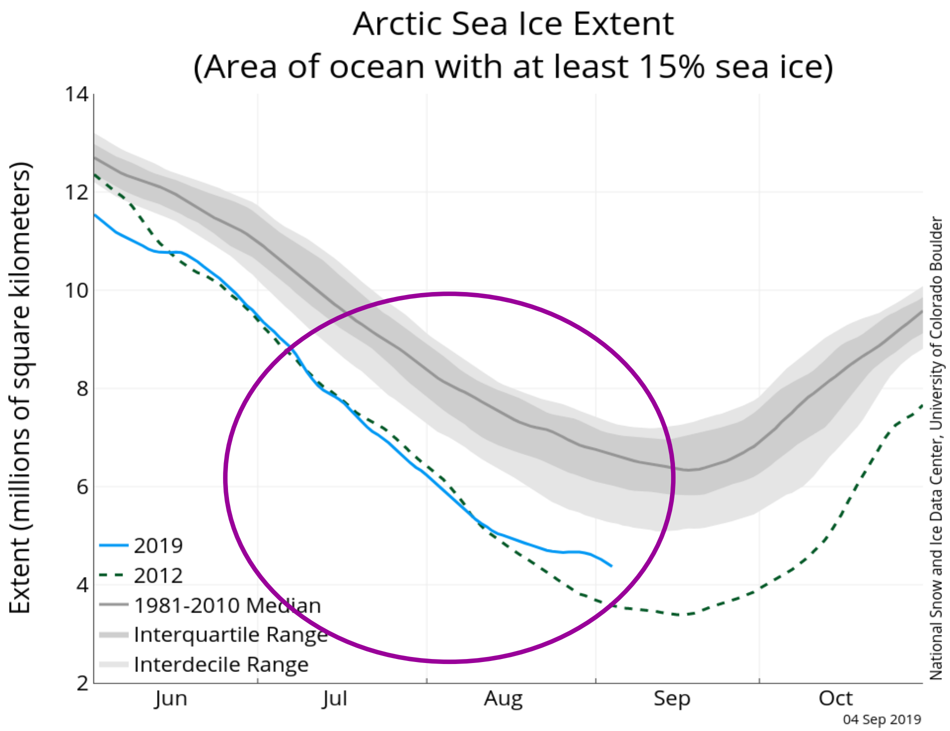
- **Anomalous downwelling was present in 39~54N since Jul 2019, which may be associated with anomalous southerly wind along the coast.**

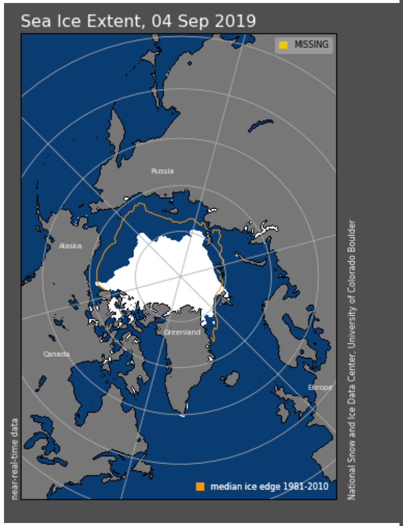
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

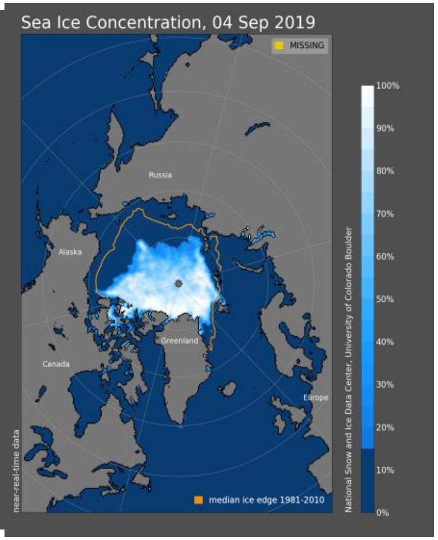
- **Area below (above) black line indicates climatological upwelling (downwelling) season.**
- **Climatologically upwelling season progresses from Mar to Aug along the west coast of North America from 36ºN to 57ºN.**

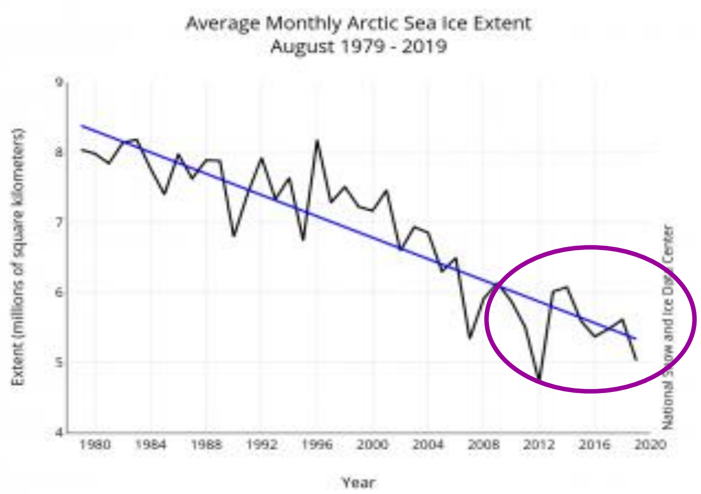
Arctic Sea Ice

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



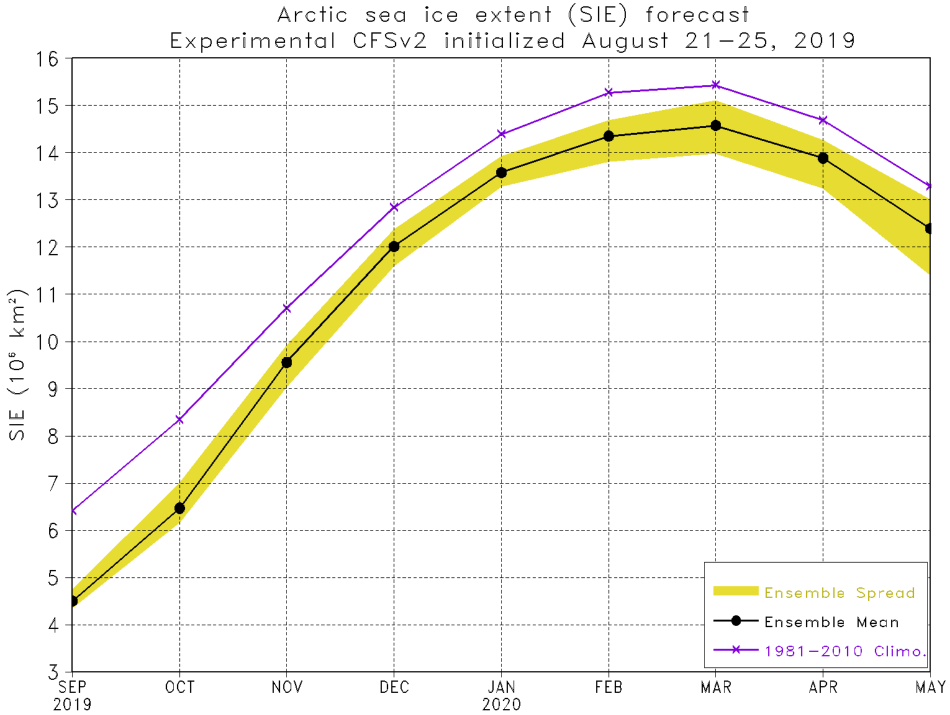


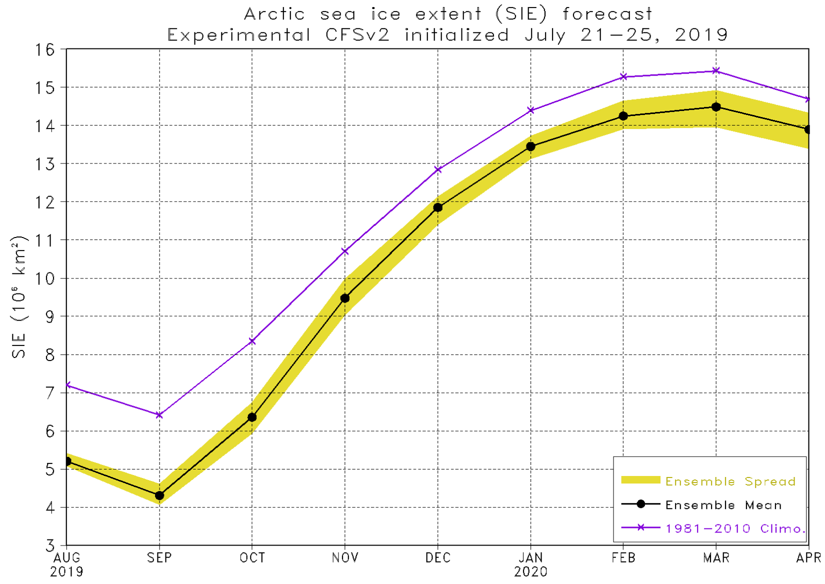




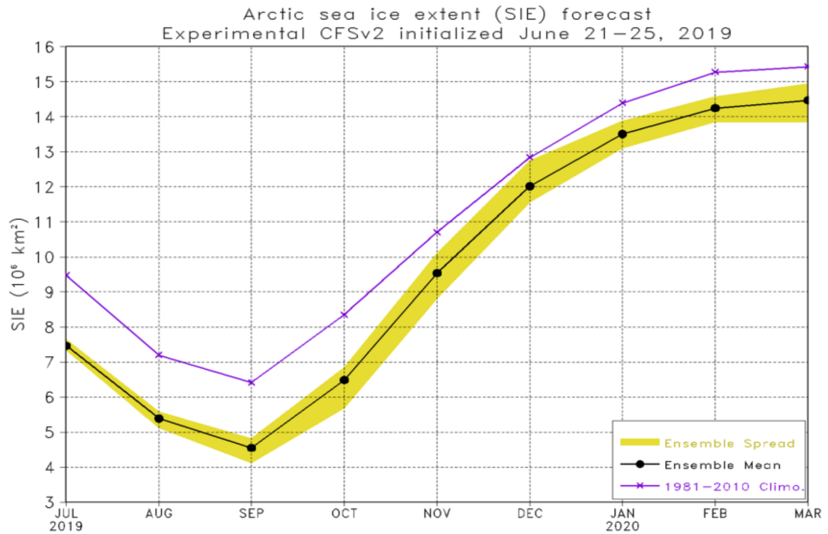
- **Arctic sea ice extent was well below the normal in Aug 2019.**

- **Aug 2019 was the second lowest extent since satellite observations in 1979.**



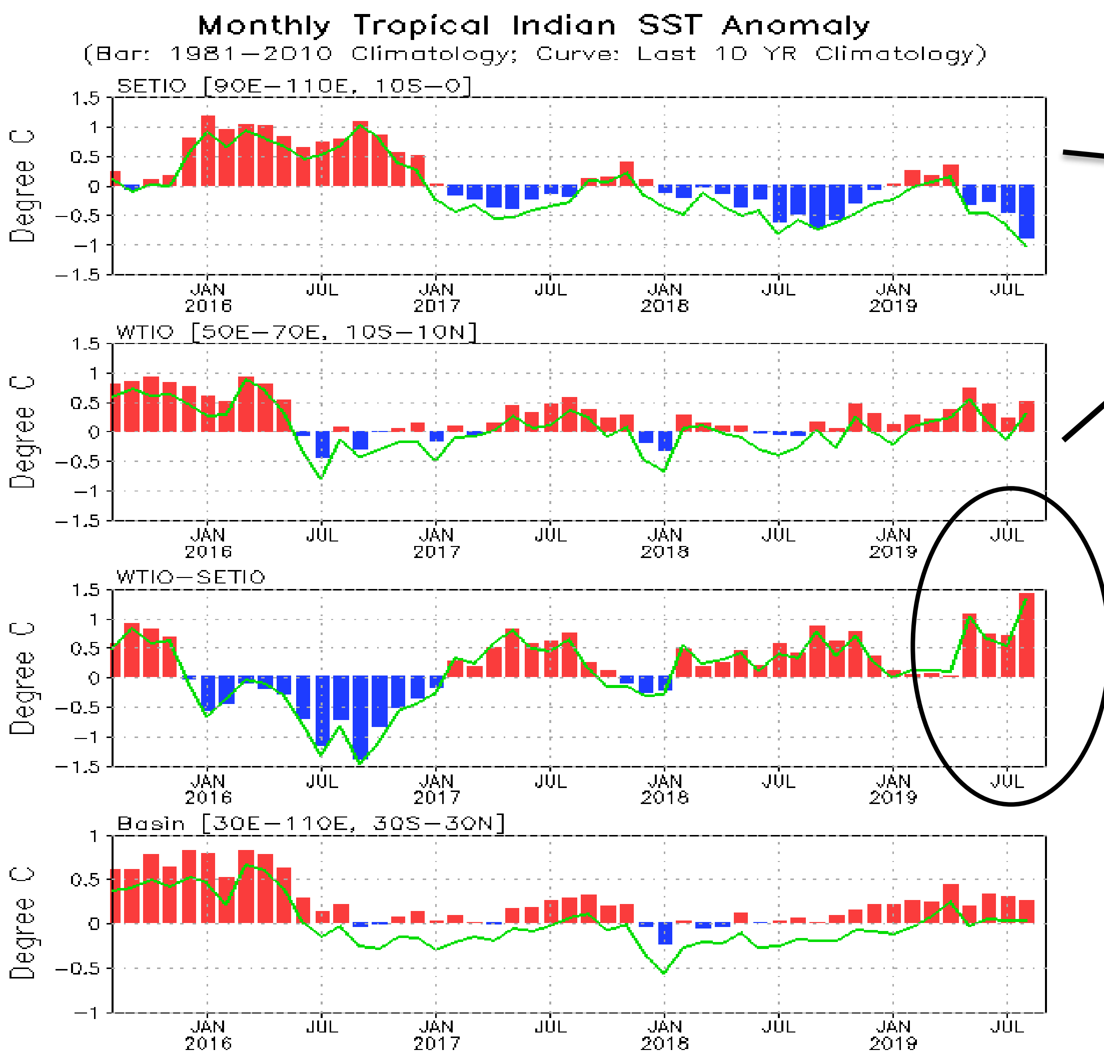


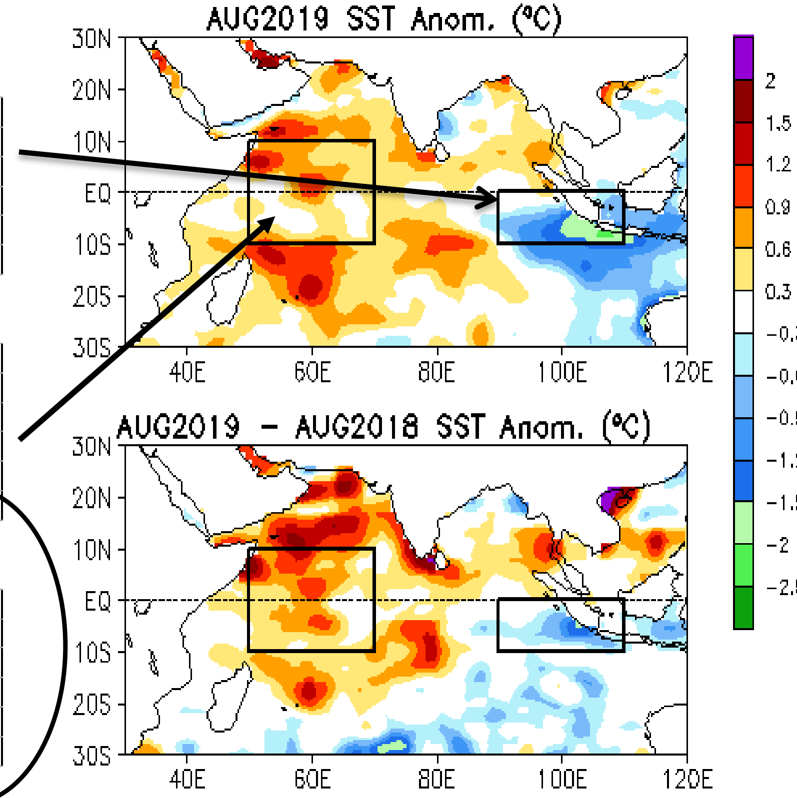
Experimental Sea Ice Outlook
Climate Prediction Center,
NCEP/NWS/NOAA
Provided by Dr. *Wanqiu Wang*



Indian Ocean

Evolution of Indian Ocean SST Indices





- IOD was in a strong positive phase during May-Aug 2019 with IODI=1.3 in Aug 2019, which is comparable to 2006.

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.

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

- The dipole pattern strengthened in Aug 2019, which seems not driven by the heat flux.

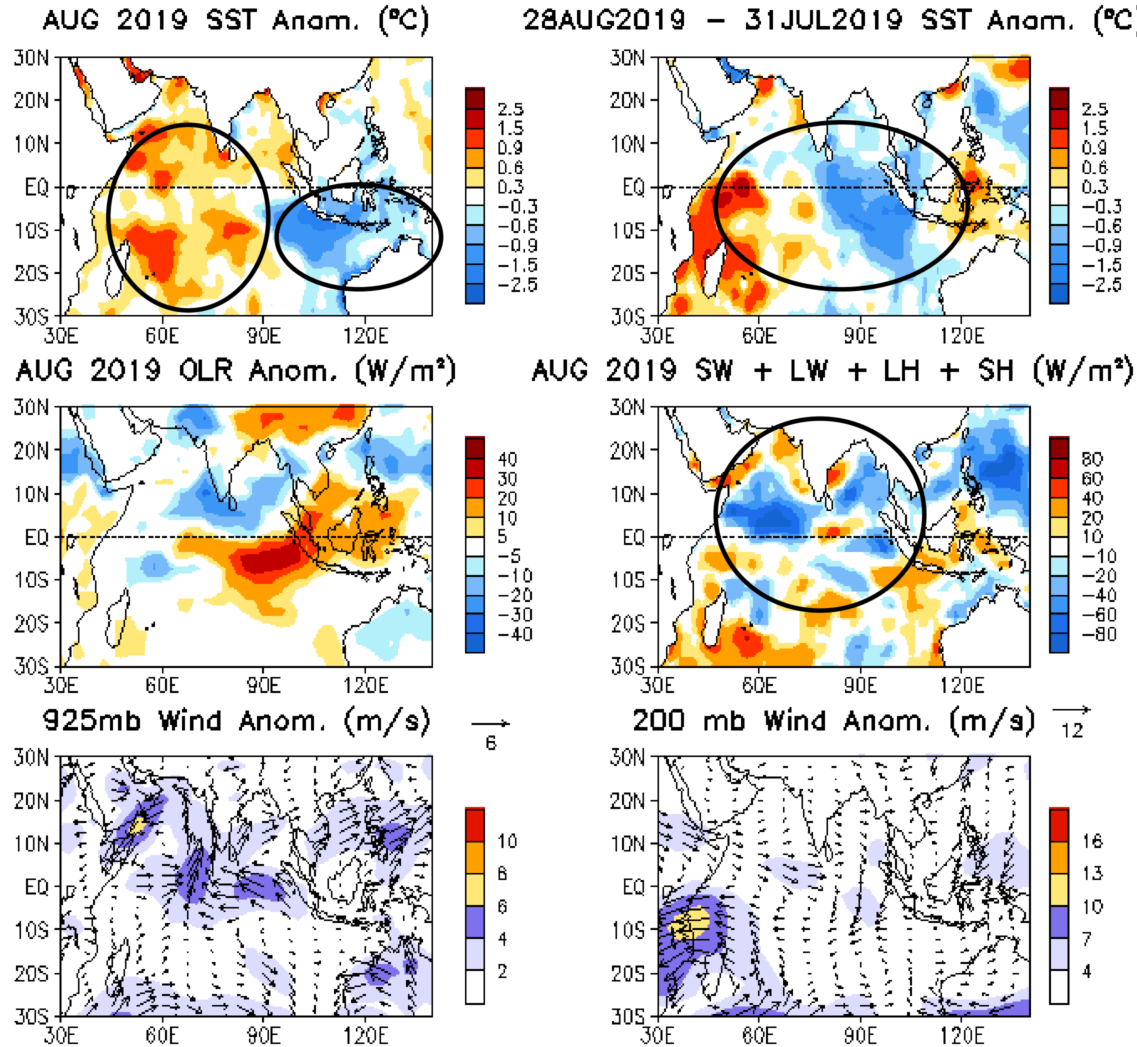
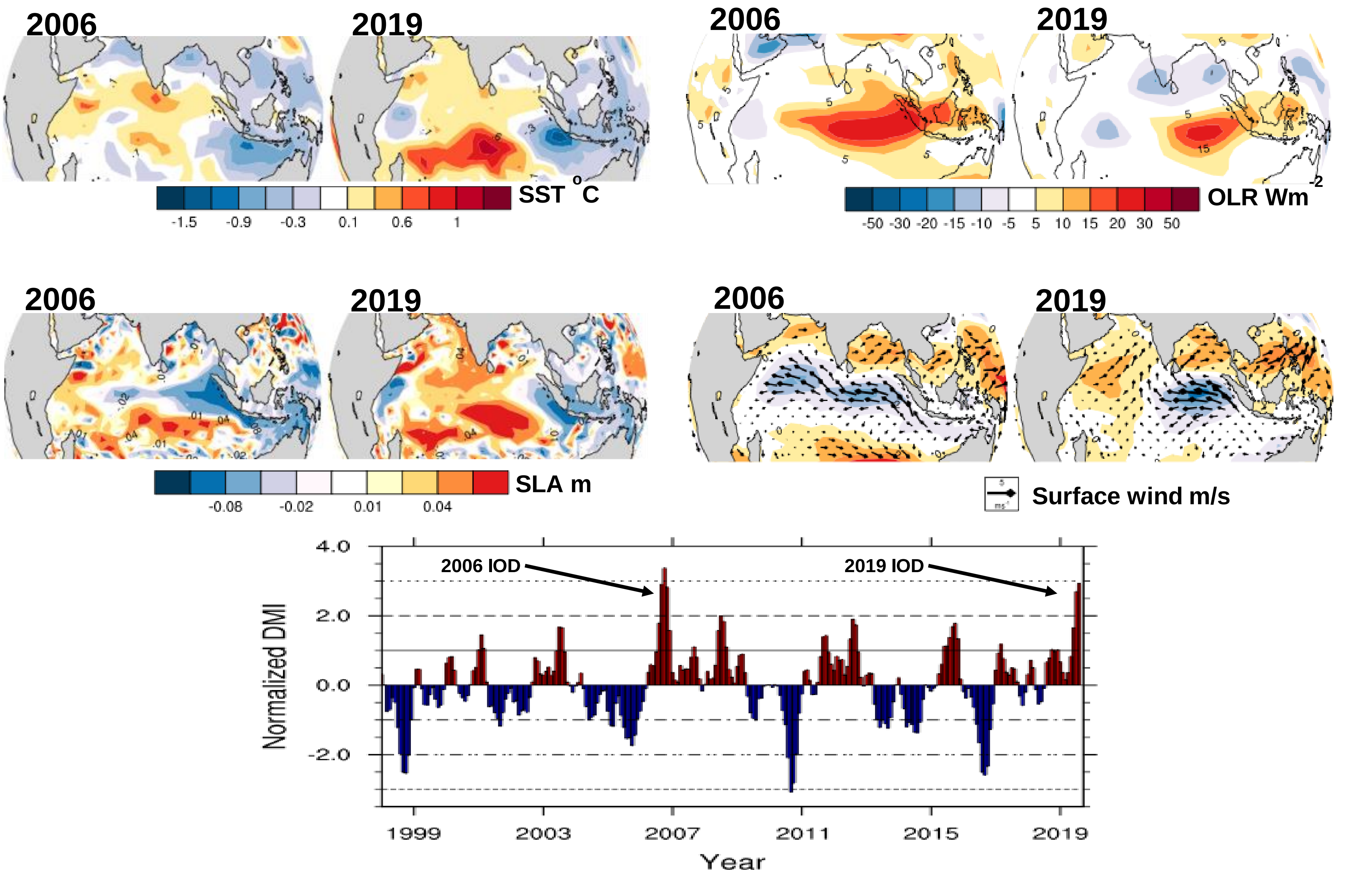


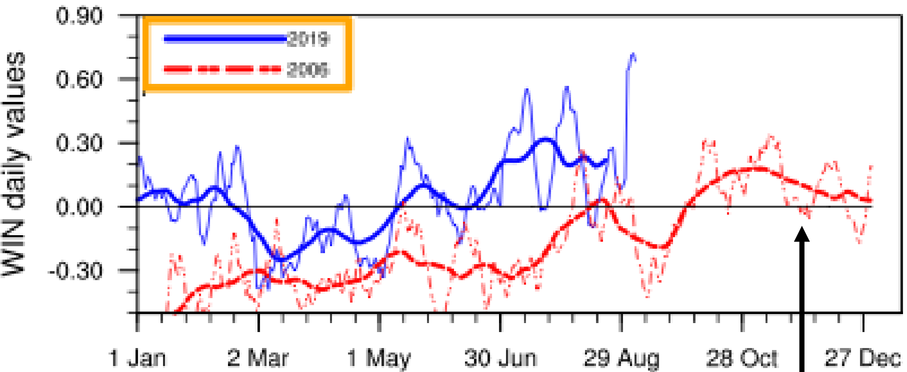
Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

During August, the 2019 IOD is comparable in strength to the 2006 event (**provided by Prof. Saji N Hameed**)

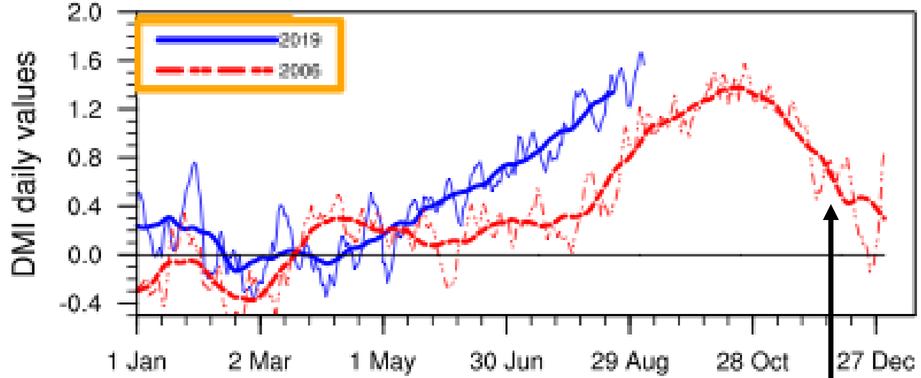


During August, the 2019 IOD compares in strength to the 2006 event (**provided by Prof. Saji N Hameed**)

WIN = SST anomaly (10S-10N, 60-80E)



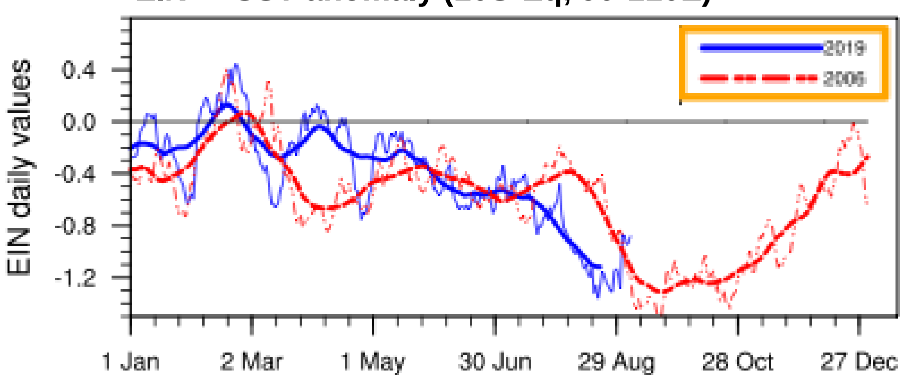
DMI = WIN-EIN



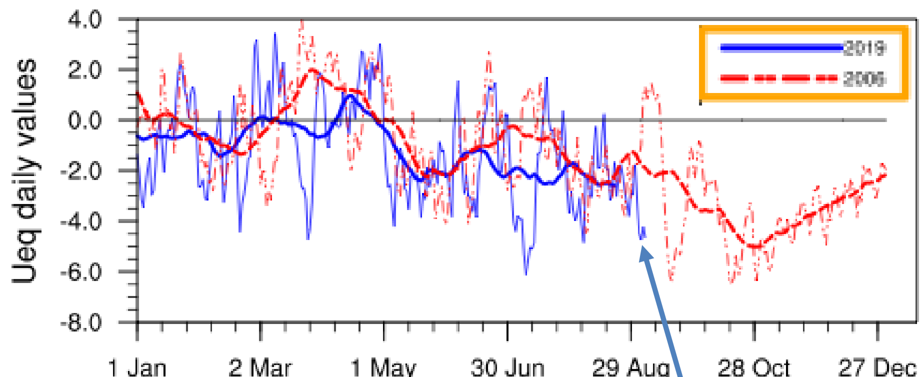
Thin line - daily time series

Thick line - smoothed with 31-day running average

EIN = SST anomaly (10S-Eq, 90-110E)



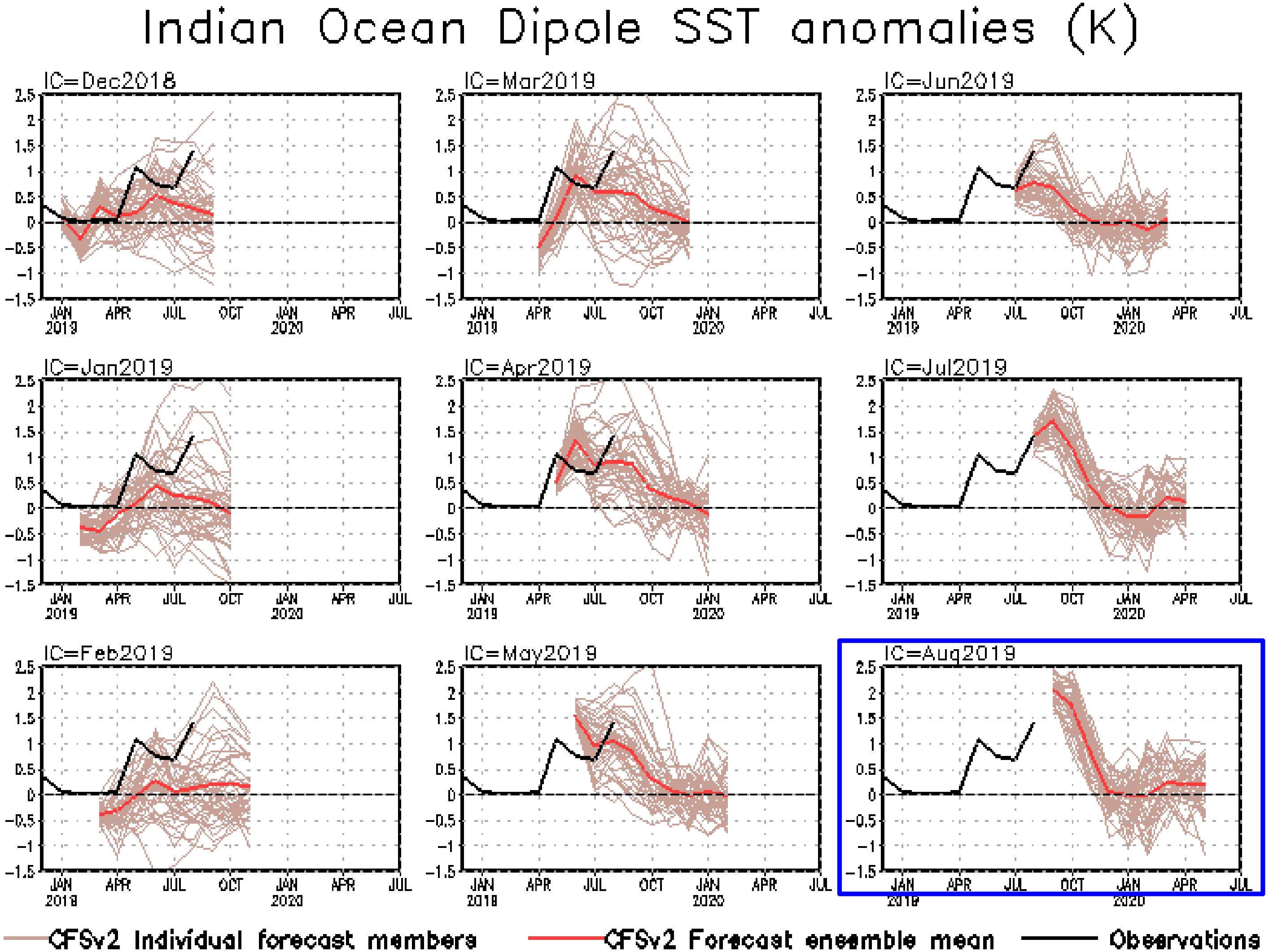
UEQ = surface zonal wind anom. (5S-5N, 70-90E)



IOD indices reference: Saji and Yamagata, 2003 (J. Climate)
Images from IOD monitoring pages at
http://enformtk.u-aizu.ac.jp

strong easterly wind anomalies suggest IOD will further strengthen during September

NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

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

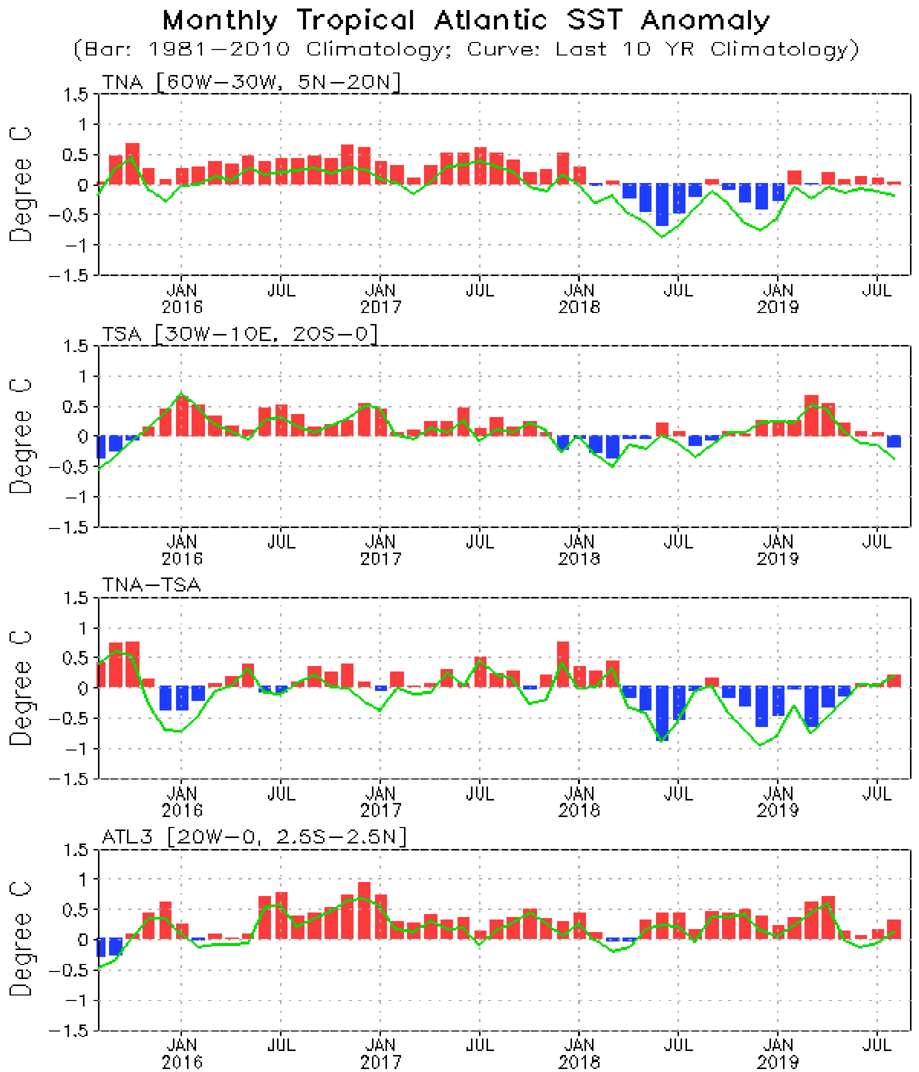
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

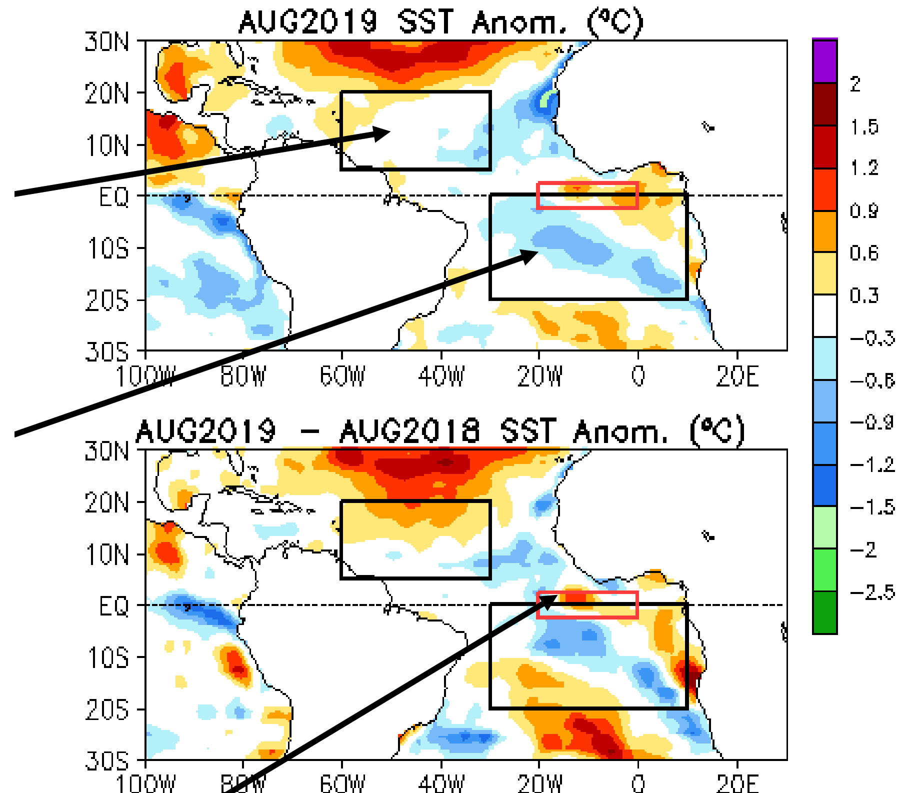
- **CFSv2 predict weakening of the positive phase of IOD during 2nd half of 2019.**

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.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

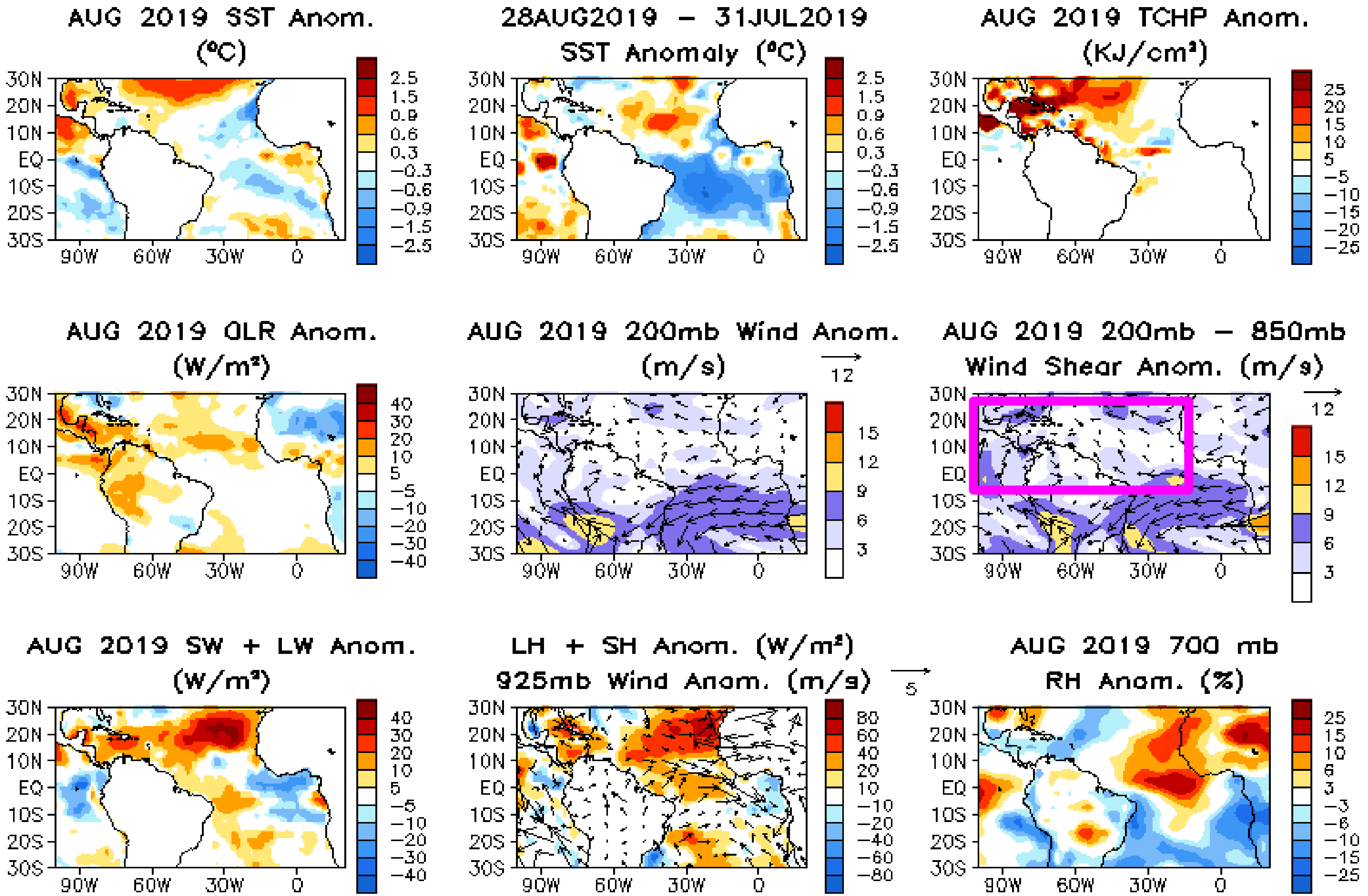




- All indices were small in Aug 2019.

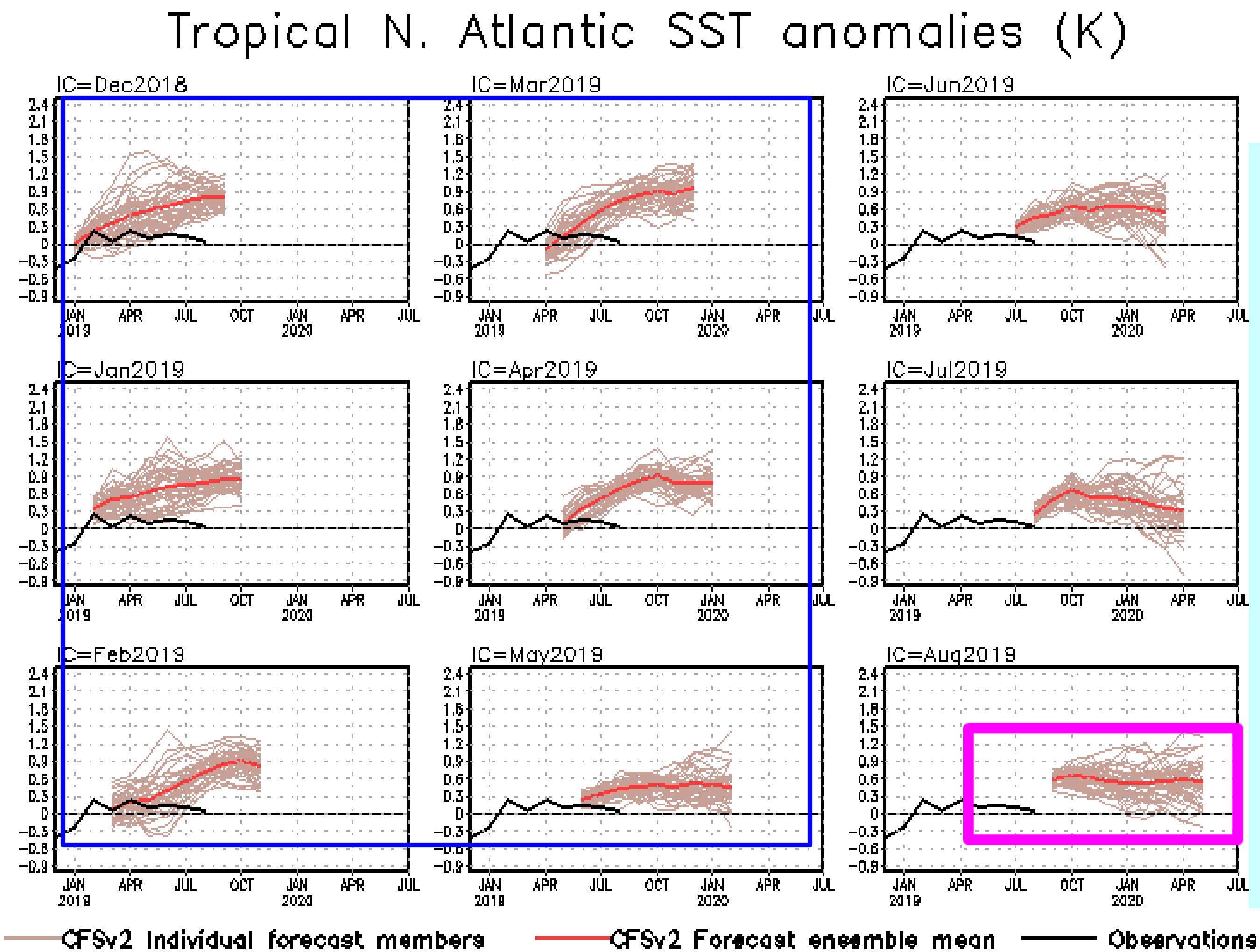
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) for the TNA [60ºW-30ºW, 5ºN-20ºN], TSA [30ºW-10ºE, 20ºS-0] and ATL3 [20ºW-0, 2.5ºS-2.5ºN] regions, and Meridional Gradient Index, defined as differences between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

Tropical Atlantic:



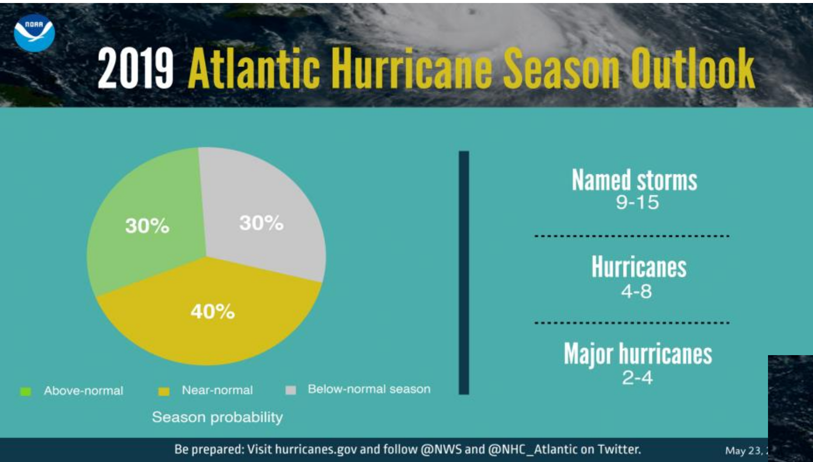
CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months

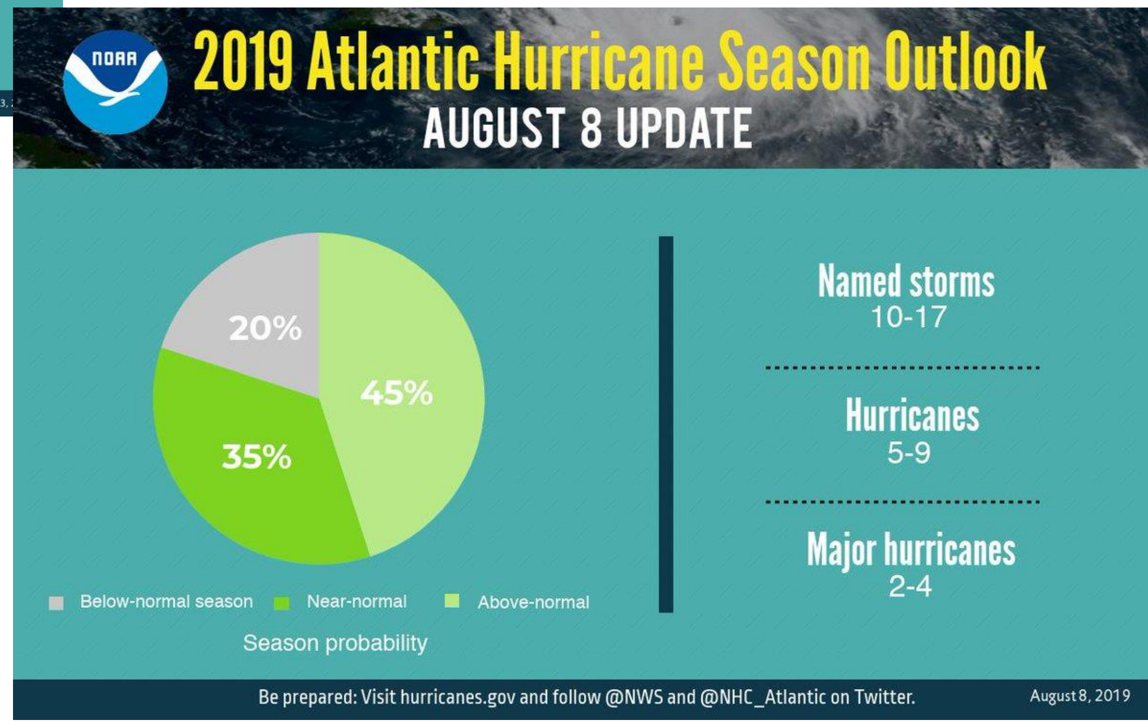
TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].



- Predictions had warm biases for ICs since Sep 2018. 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 autumn and winter 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.

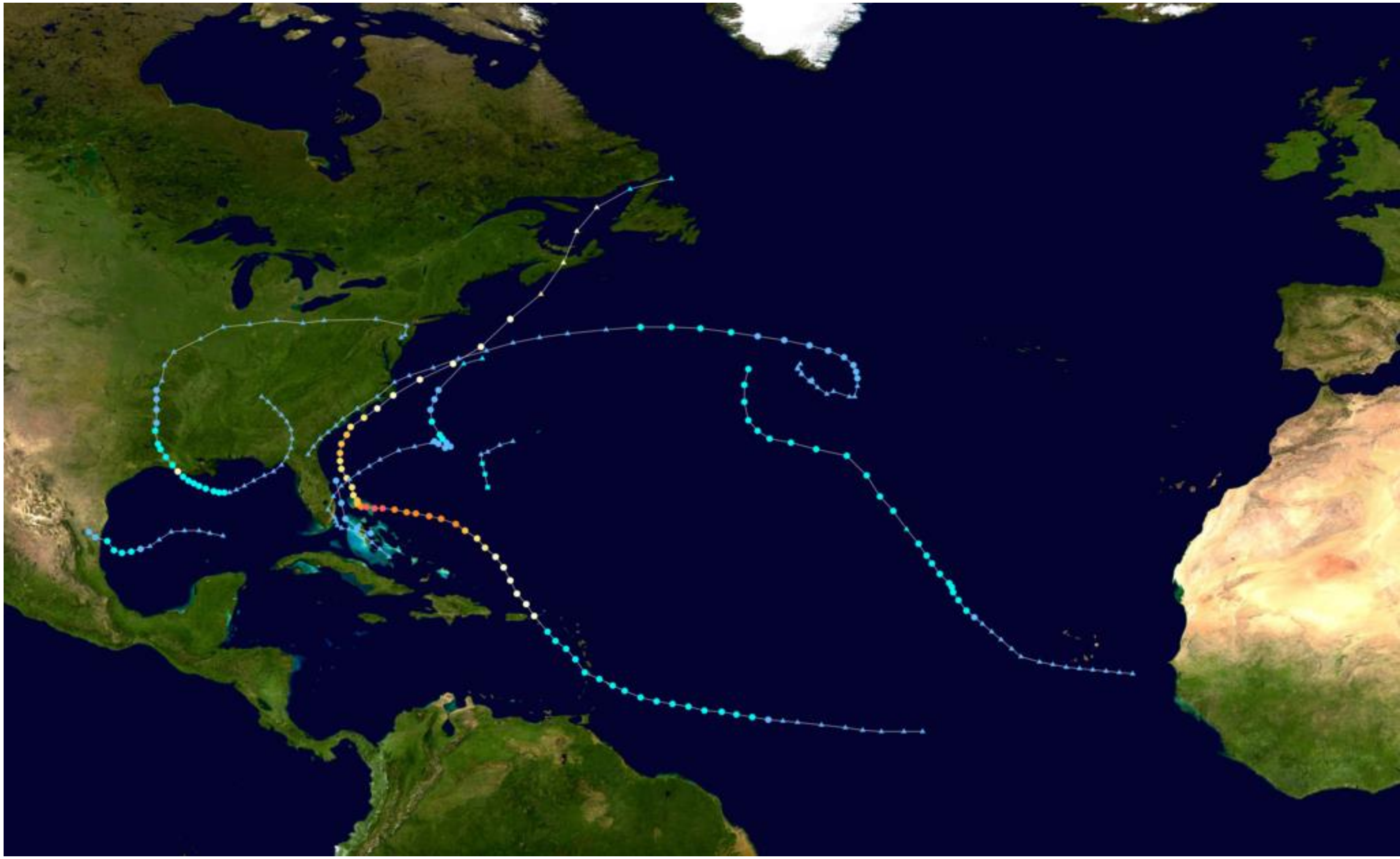




(August 8 update)

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.

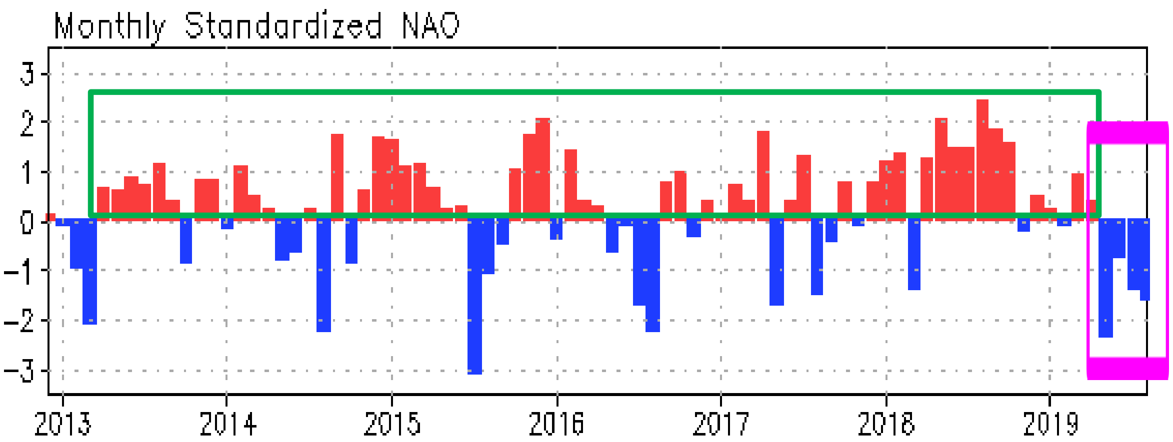
https://www.noaa.gov/sites/default/files/thumbnails/image/2019%20Hurricane%20Numbers.png

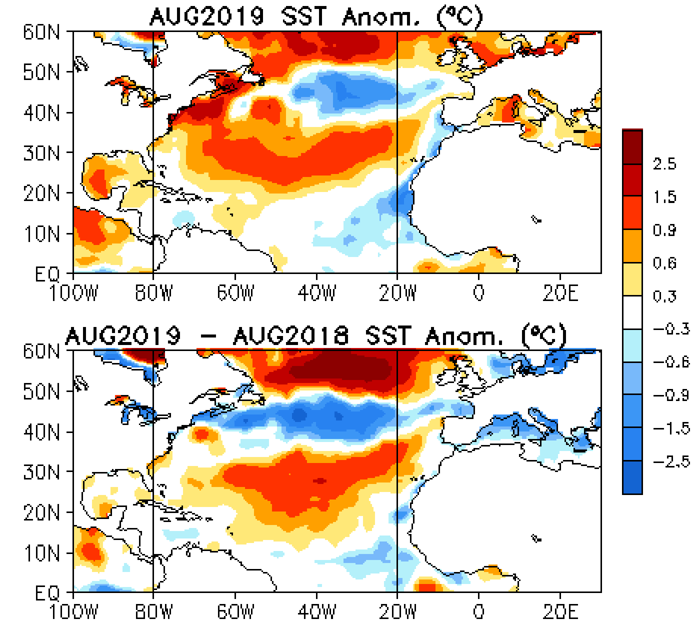


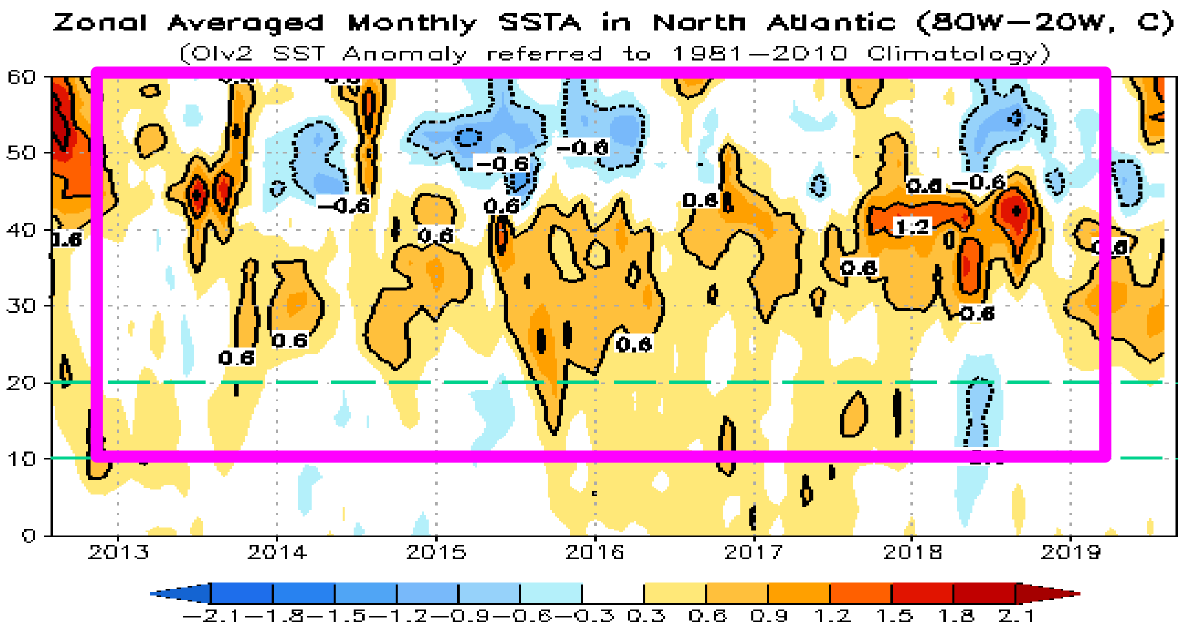
By Sep 11, 2019

2019	Observation	Outlook Aug 8 & May 23	(1981-2010)
Total storms	7	10-17 & 9-15	12.1
Hurricanes	2	5-9 & 4-8	6.4
Major hurricanes (Cat. 3+)	1	2-4 & 2-4	2.7

NAO and SST Anomaly in North Atlantic





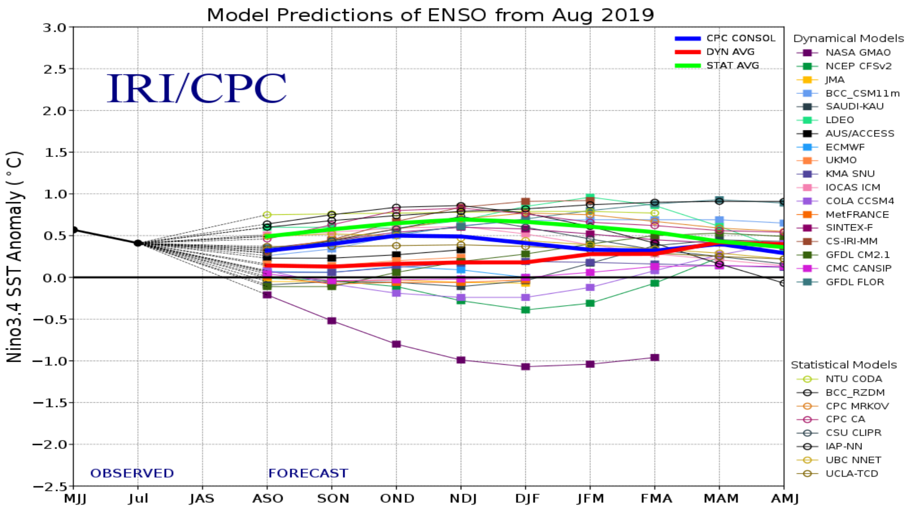


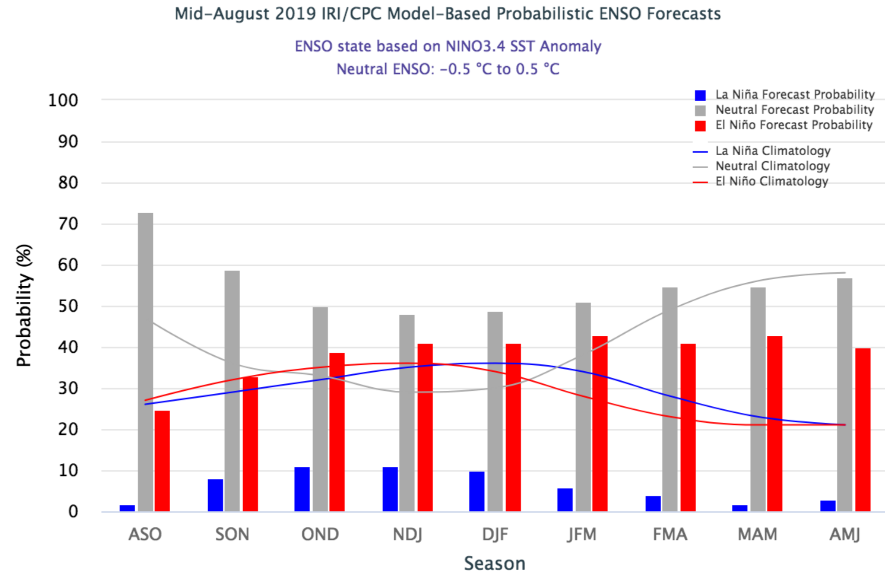
- **NAO was still in a negative phase with NAOI= -1.6 in Aug 2019.**
- **SSTA was overall a tripole/horseshoe –like pattern with positive in the mid-latitudes and negative in the lower and higher latitudes during 2013-2019, may due to the long-term persistence of a positive phase of NAO.**

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.

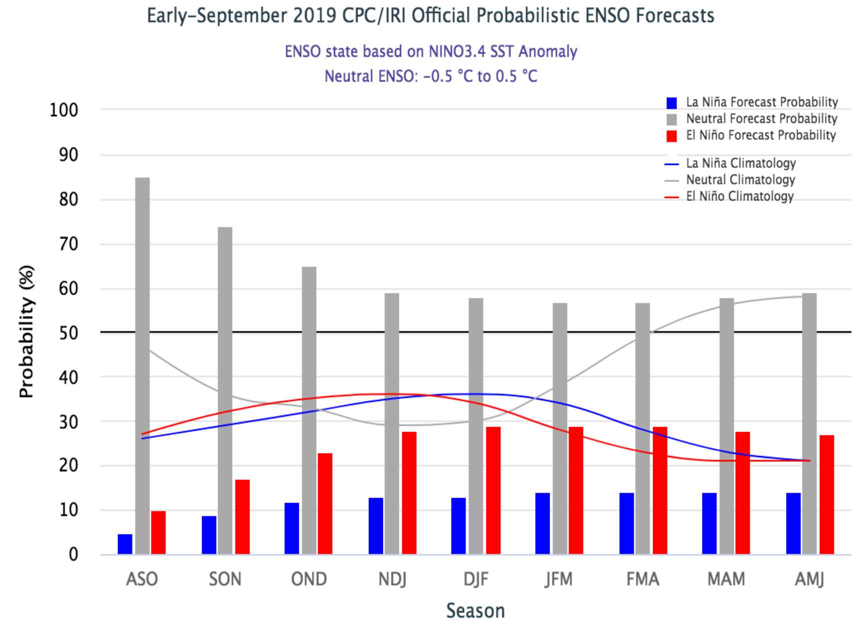
ENSO and Global SST Predictions

IRI NINO3.4 Forecast Plum



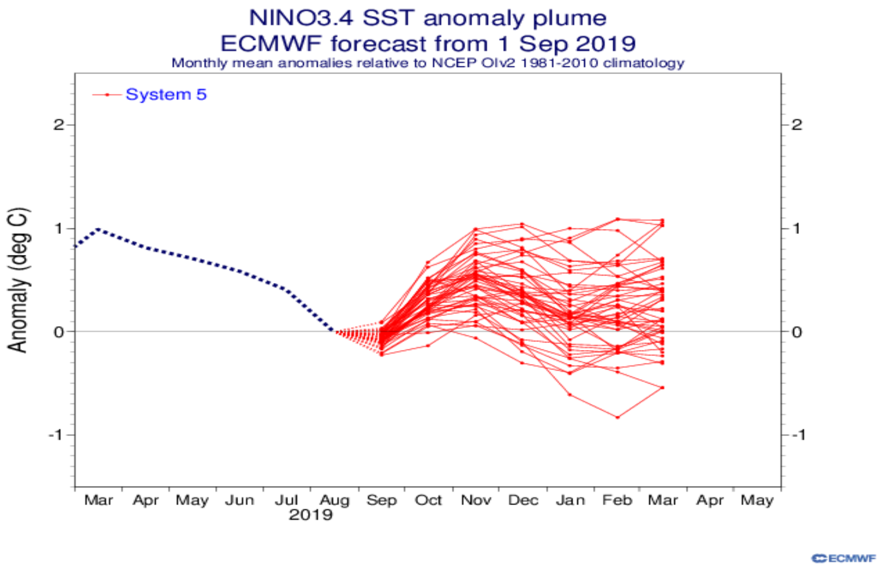


- **The average of the dynamical models (thick red line) predicts ENSO-neutral, while the average of the statistical models (thick green line) predicts a weak El Niño through the NH winter 2019-20.**
- **NOAA "ENSO Diagnostic Discussion" on 12 Sep 2019 indicated that** ***"ENSO-neutral is favored during the Northern Hemisphere fall 2019 (~75% chance), continuing through spring 2020 (55-60% chance)."***

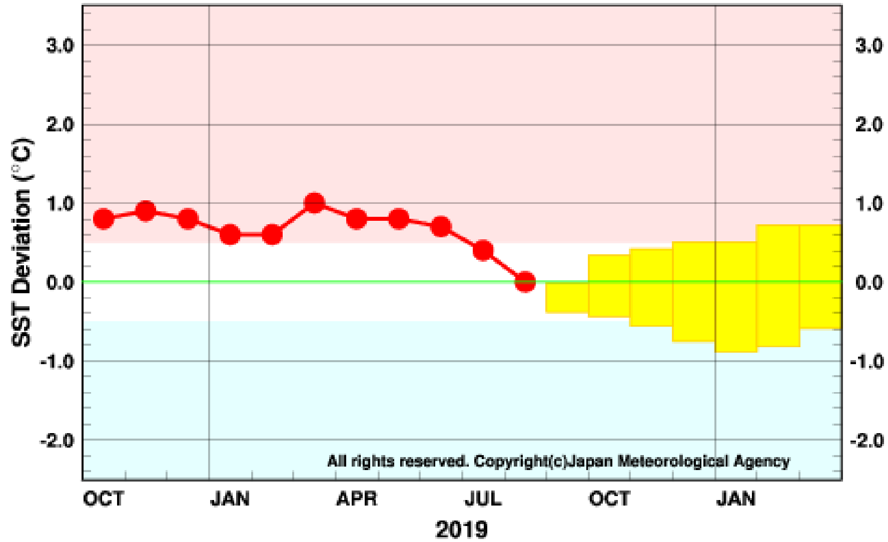


Individual Model Forecasts: ENSO-Neutral

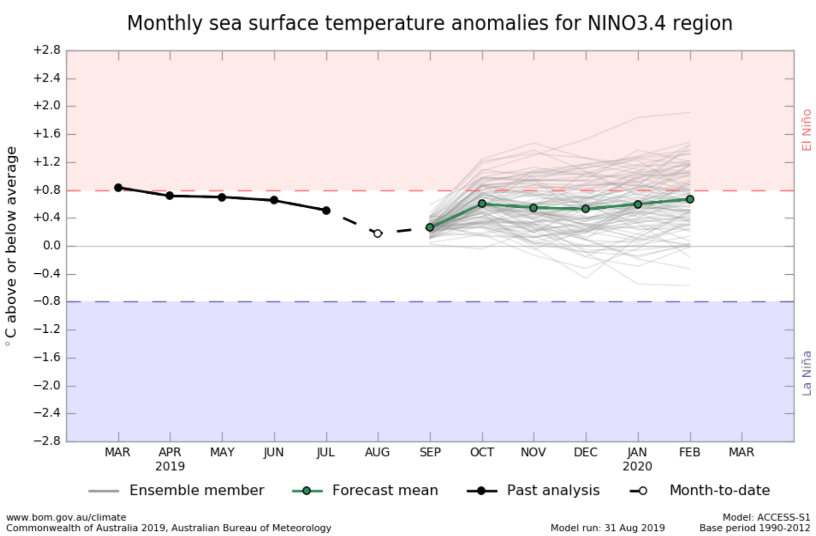
EC: Nino3.4, IC=01Sep 2019



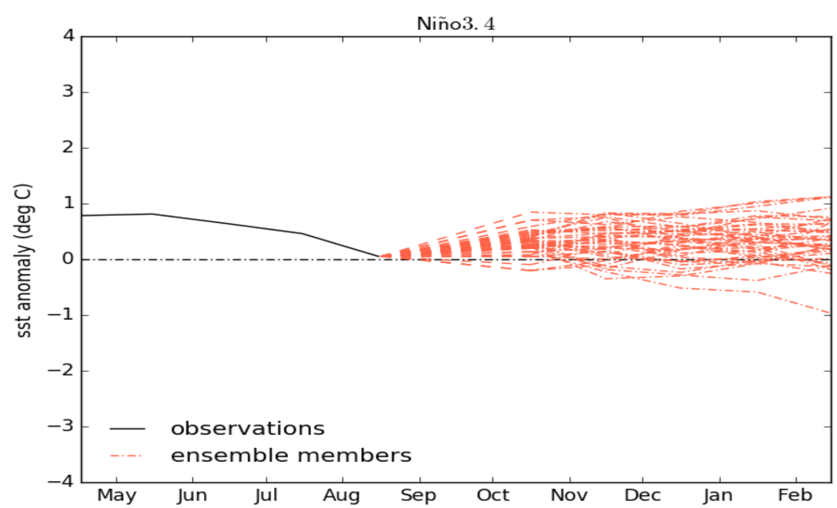
JMA: Nino3.4, Updated 10Sep2019

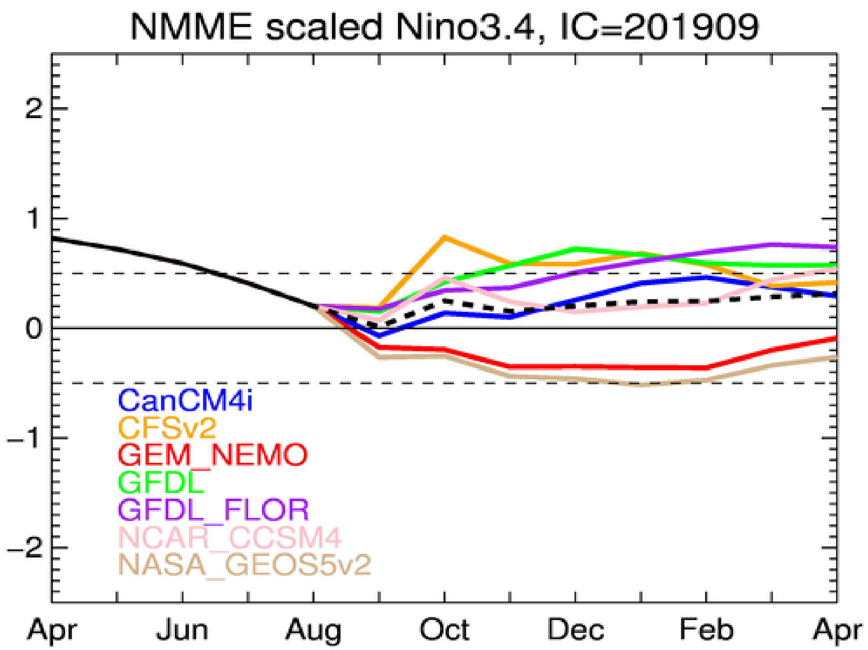


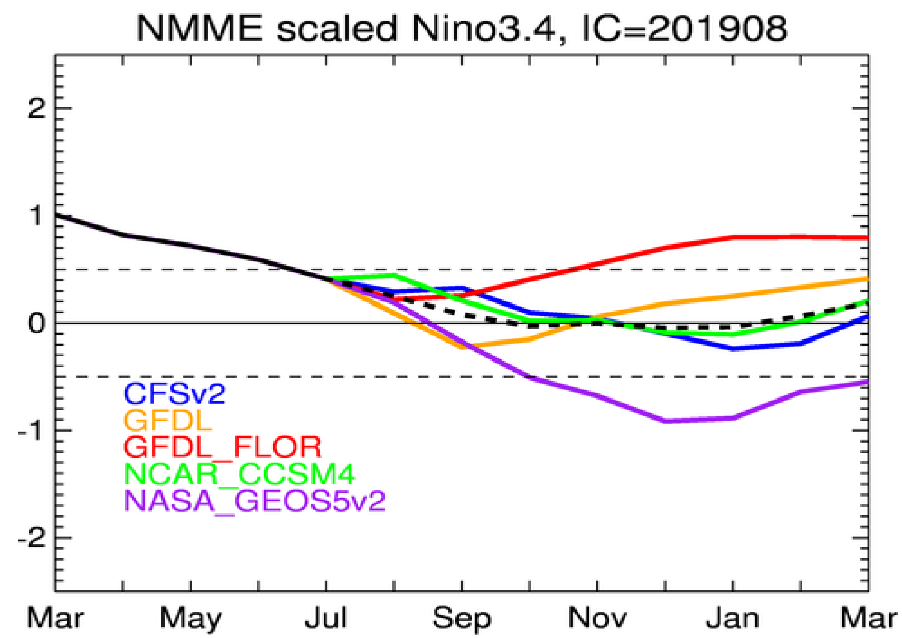
Australia: Nino3.4, Updated 31 Aug 2019

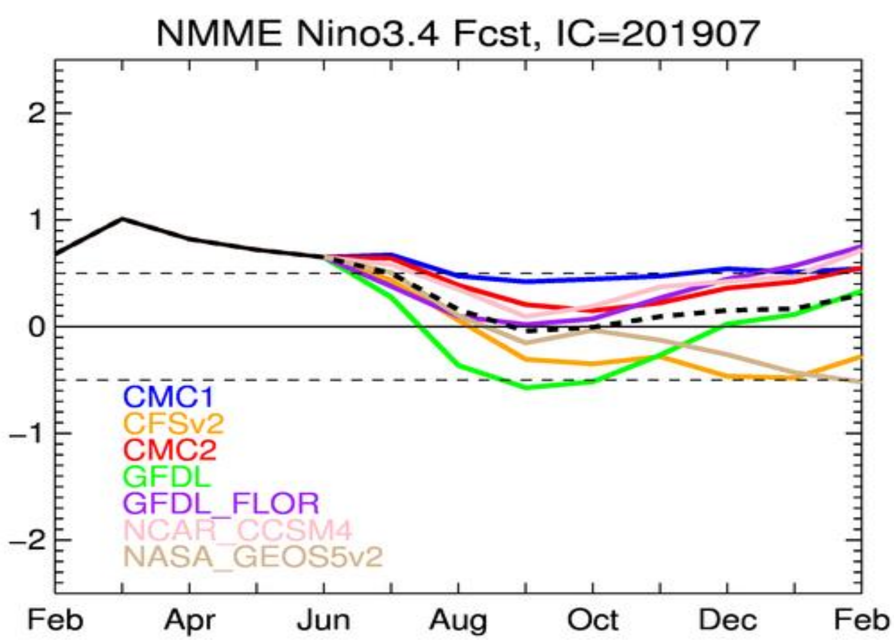


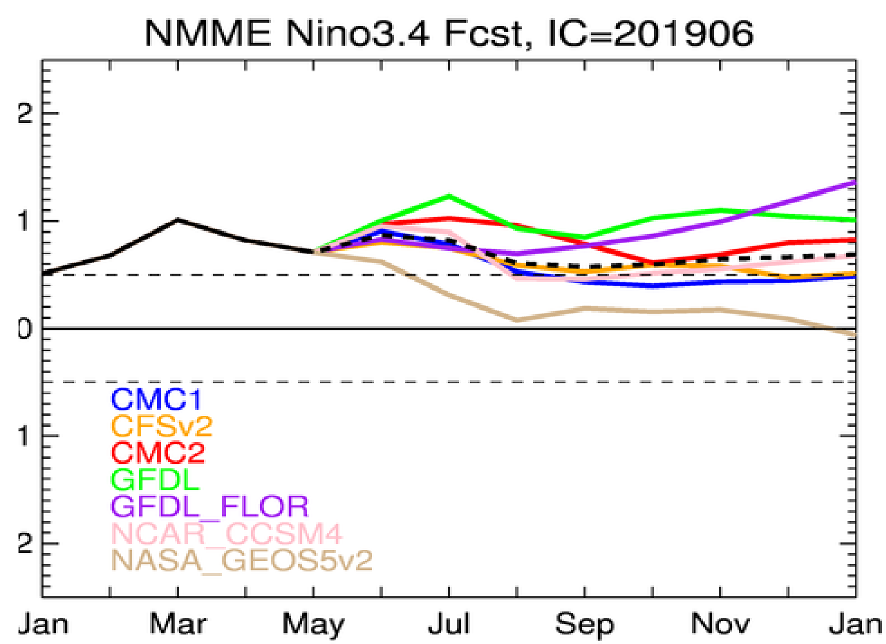
UKMO: Nino3.4, Updated 11Sep 2019



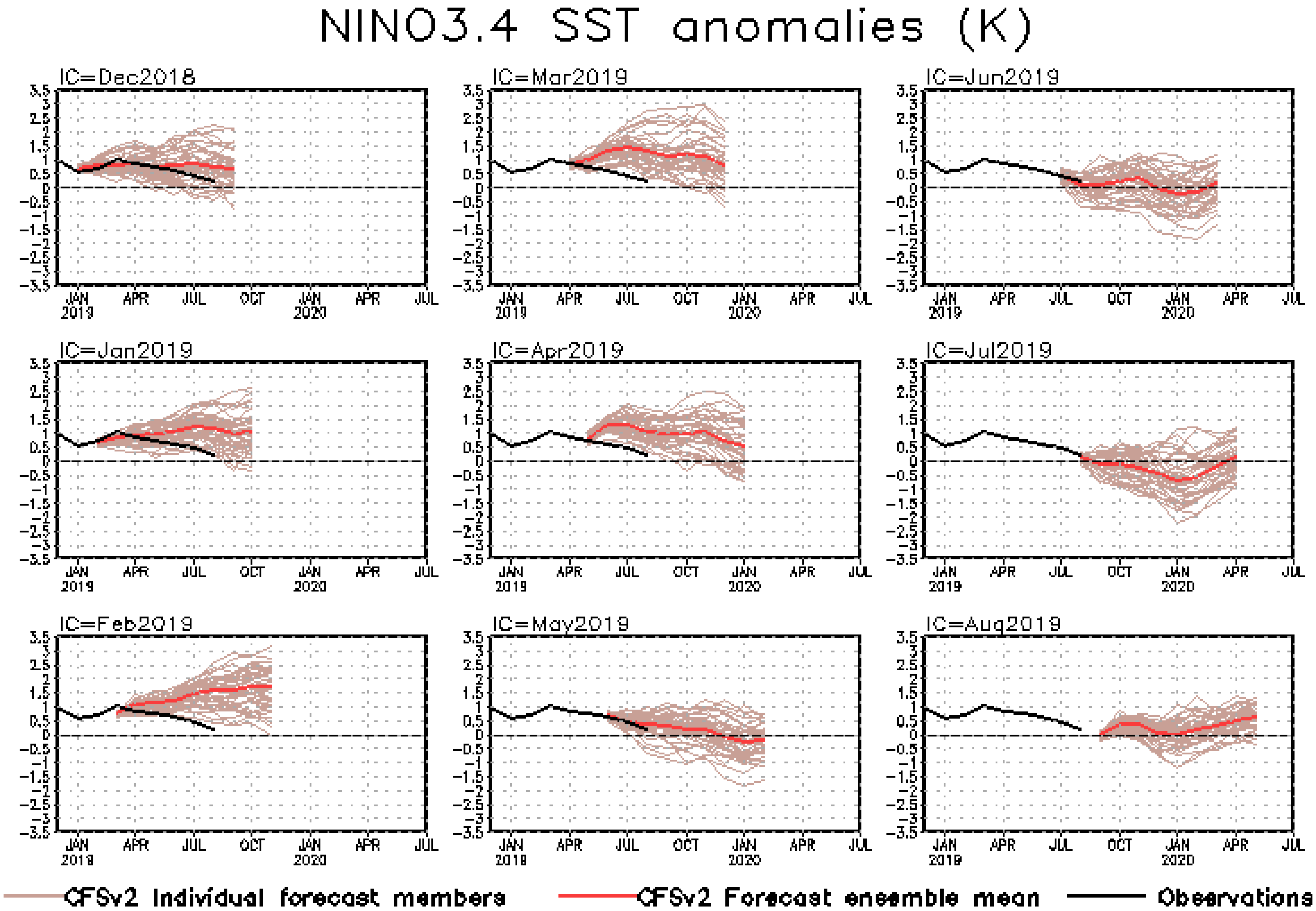

NMME scaled Nino3.4, IC=201909
2
1
0
−1
−2
Apr
Jun
Aug
Oct
Dec
Feb
Apr
CanCM4i
CFSv2
GEM_NEMO
GFDL
GFDL_FLOR
NCAR_CCSM4
NASA_GEOS5v2


NMME scaled Nino3.4, IC=201908
2
1
0
-1
-2
Mar
May
Jul
Sep
Nov
Jan
Mar
CFSv2
GFDL
GFDL_FLOR
NCAR_CCSM4
NASA_GEOS5v2


NMME Nino3.4 Fcst, IC=201907
2
1
0
−1
−2
Feb
Apr
Jun
Aug
Oct
Dec
Feb
CMC1
CFSv2
CMC2
GFDL
GFDL_FLOR
NCAR_CCSM4
NASA_GEOS5v2


NMME Nino3.4 Fcst, IC=201906
2
1
0
1
2
Jan
Mar
May
Jul
Sep
Nov
Jan
CMC1
CFSv2
CMC2
GFDL
GFDL_FLOR
NCAR_CCSM4
NASA_GEOS5v2

CFS Niño3.4 SST Predictions from Different Initial Months

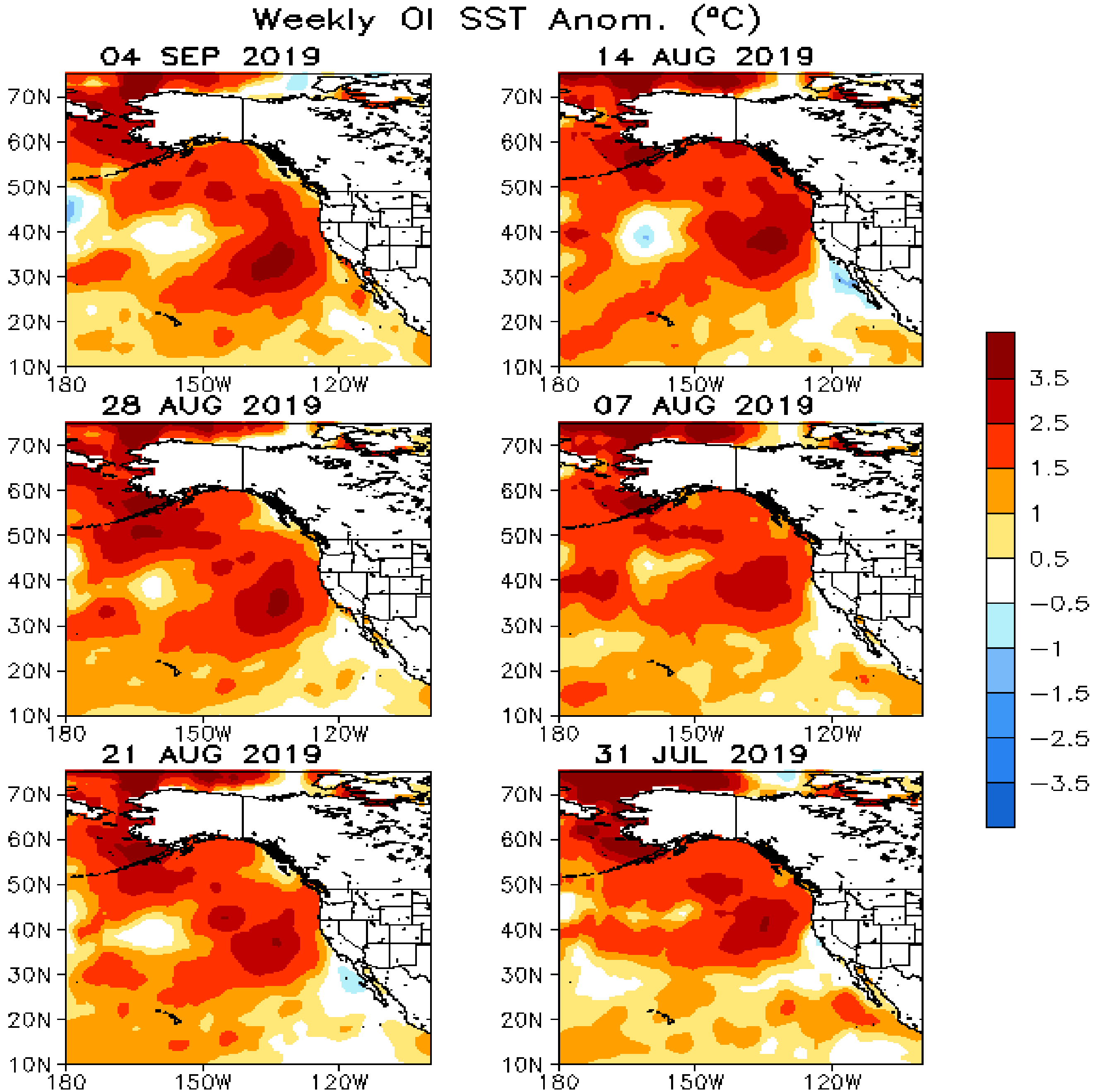


- CFSv2 predicted a decline of positive SSTAs with ICs since Mar 2019.

- The latest forecasts call for a ENSO-neutral state since autumn and winter 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.

Marine Heatwaves in 2018/19 and 2014/16

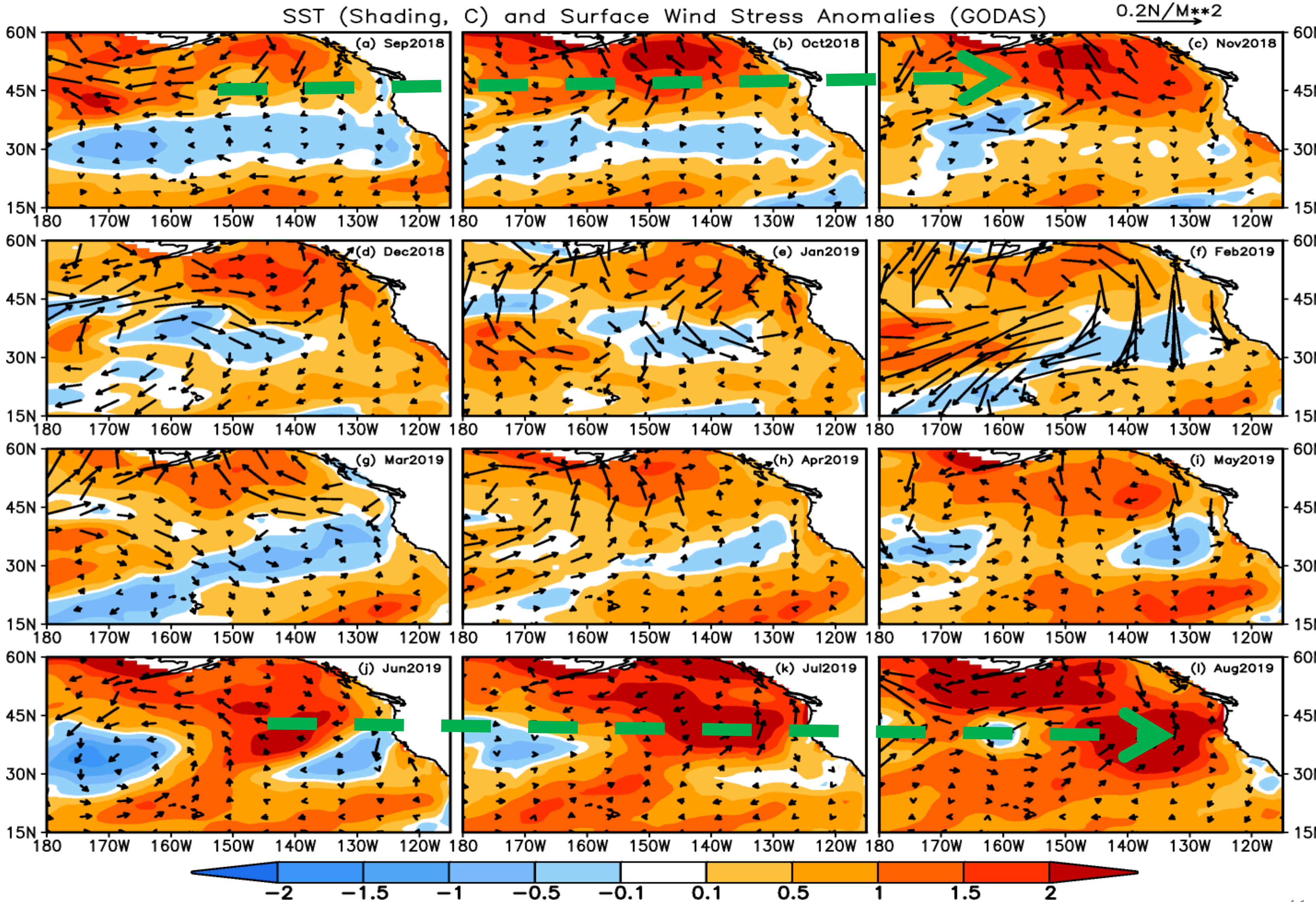


"Marine heatwaves, or MHWs, occur when ocean temperatures are much warmer than usual for an extended period of time; ..."

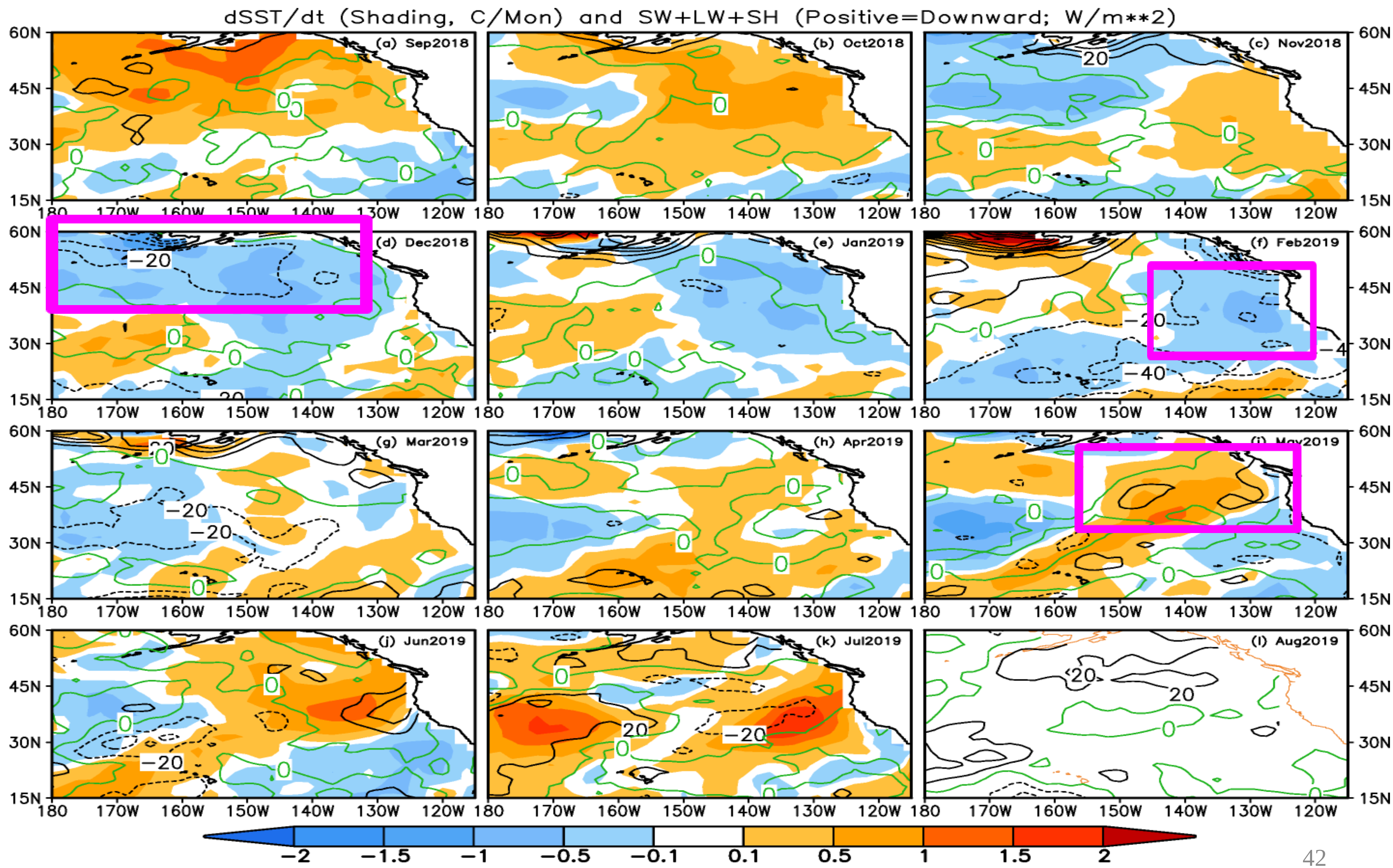
(Hobday, A. J., et al., 2016: A hierarchical approach to defining marine heatwaves. Progress in Oceanography, 141, 227-238.)

Persistent mainly southerly wind anomalies in NE Pacific

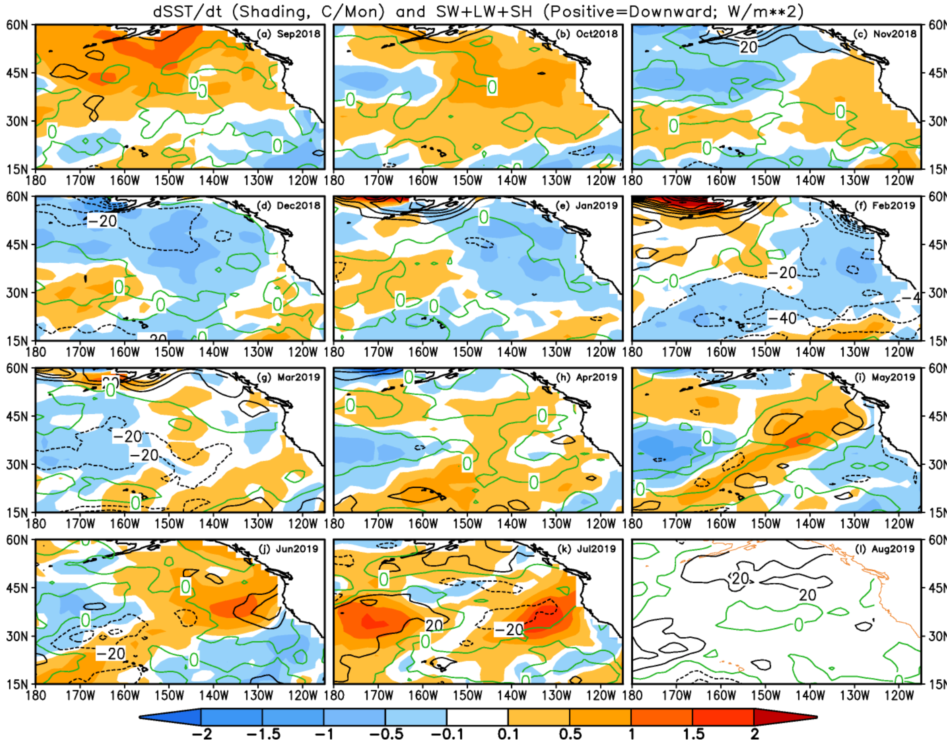
(Southerly wind anomaly favors warm advection in addition to the WES feedback)

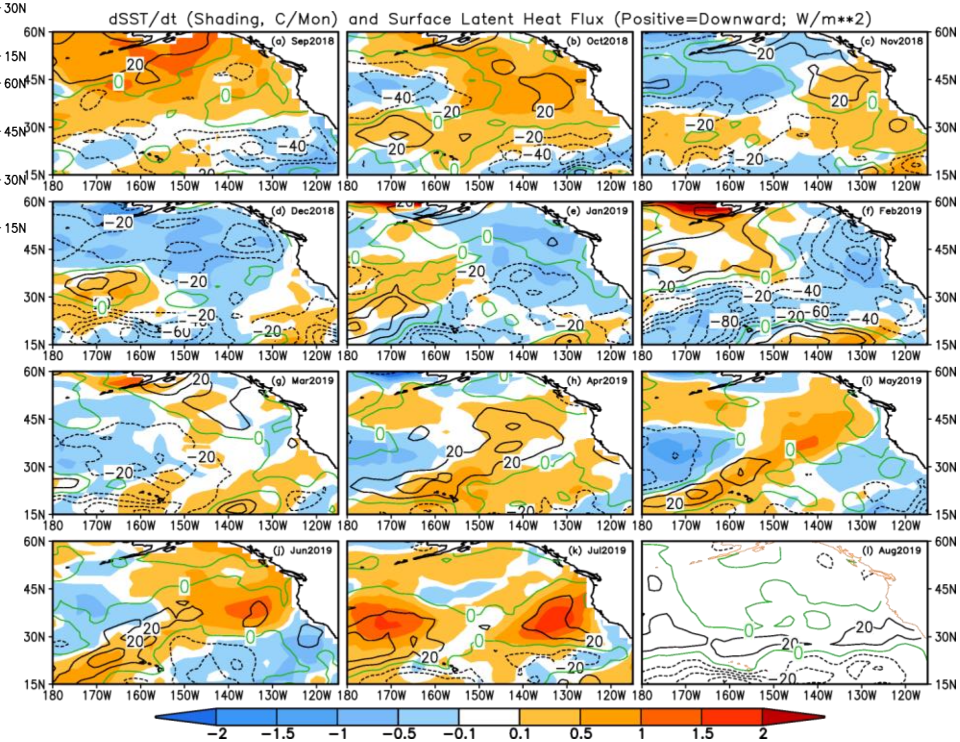


Total heat flux plays a role in dSSTA/dt, and dynamical processes may also have significant contributions.



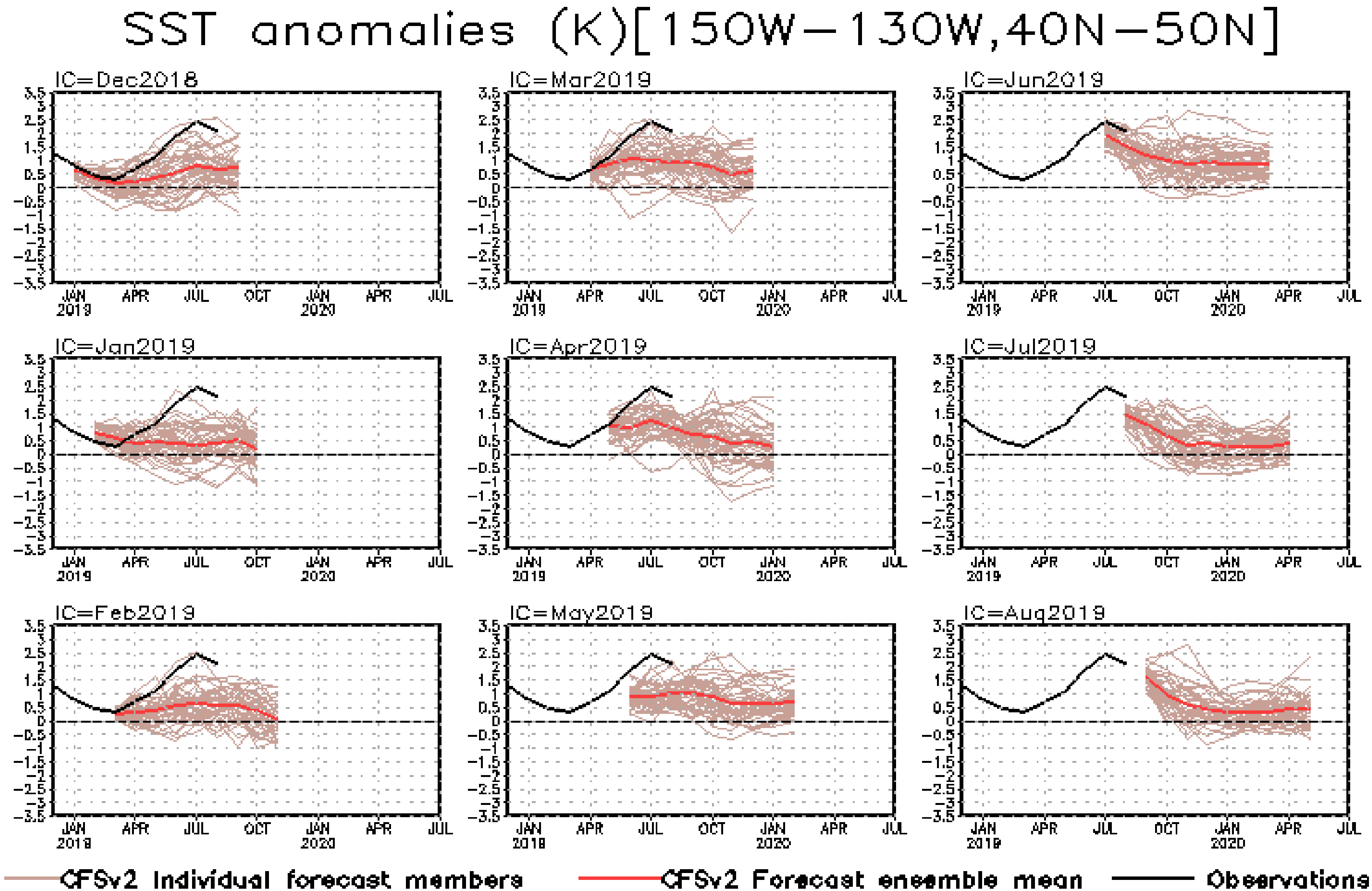
Total heat flux is largely determined by latent heat



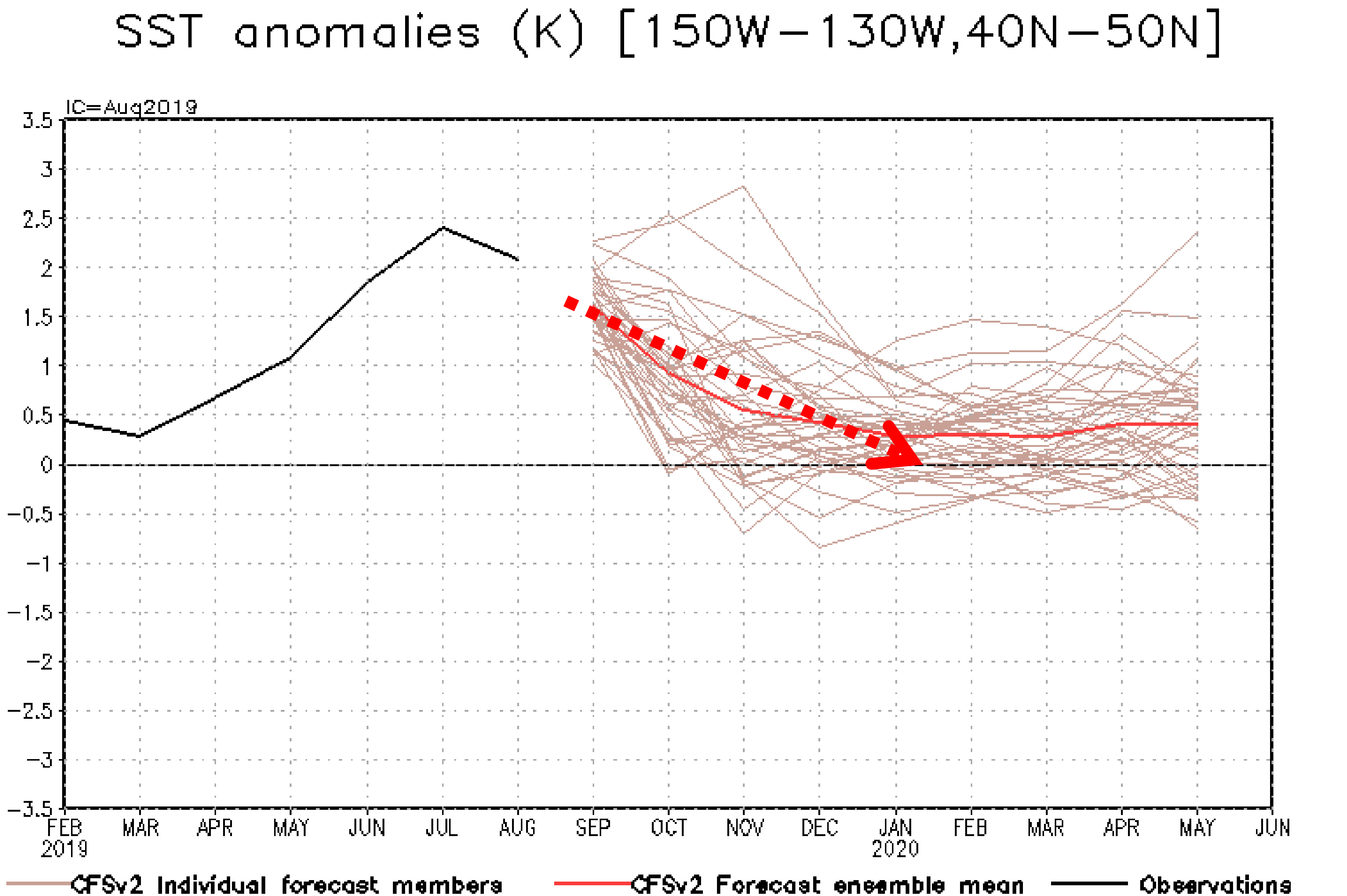


CFSv2 forecasts

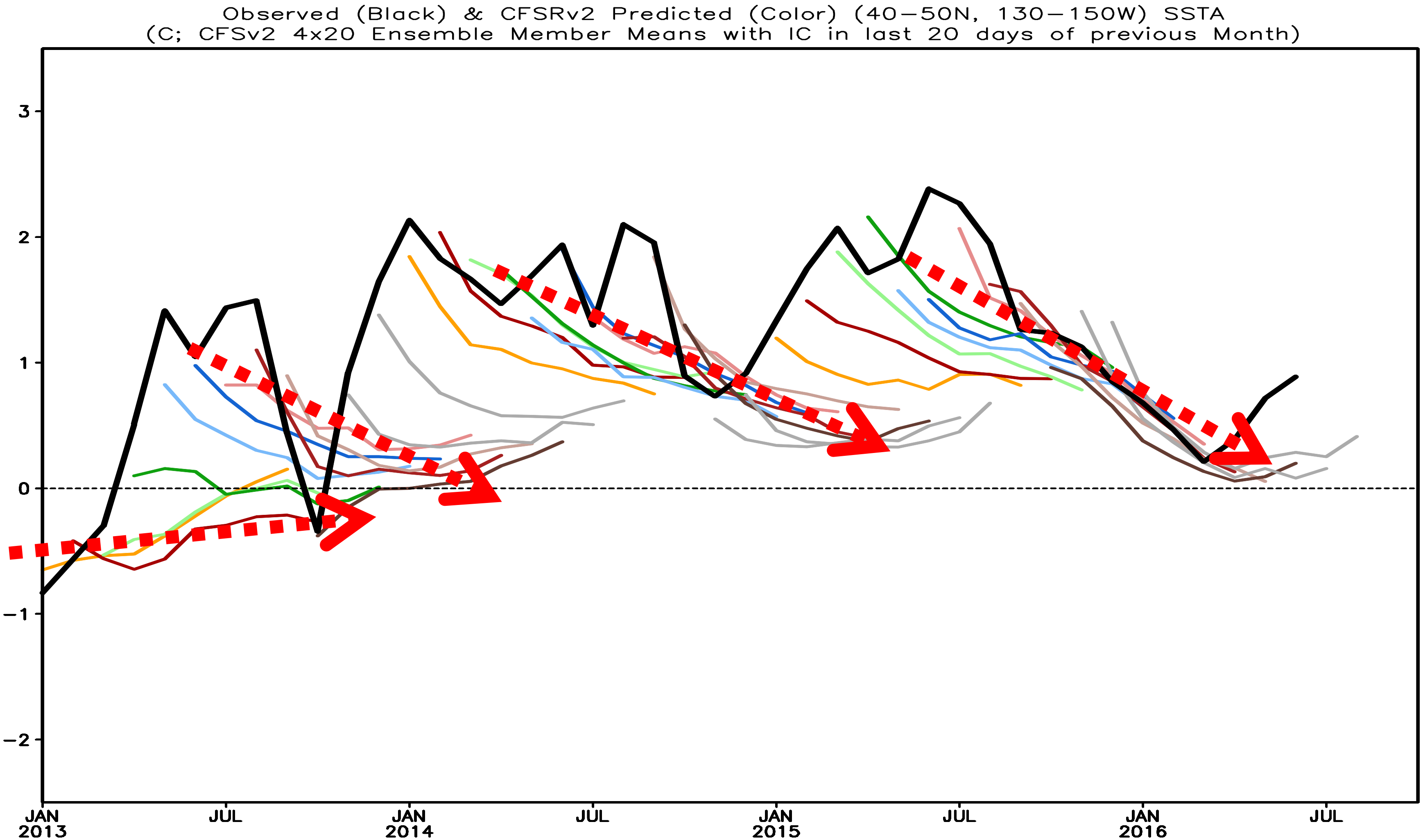
Cold Biases: Underestimated the warming intensity



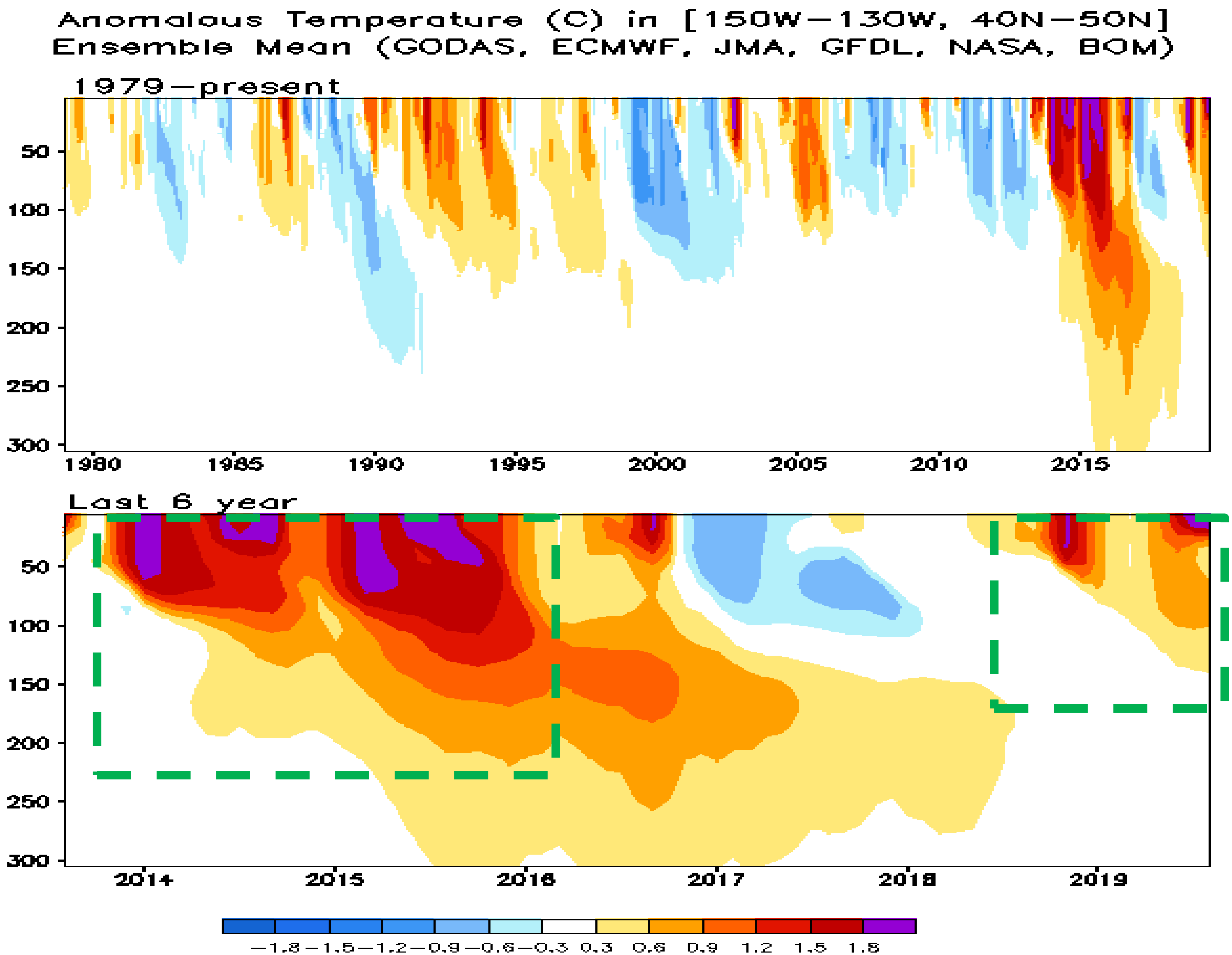
CFSv2 forecasts



CFSv2 predictions damped the IC anomaly in NE Pacific (30-50N, 150W-130W)

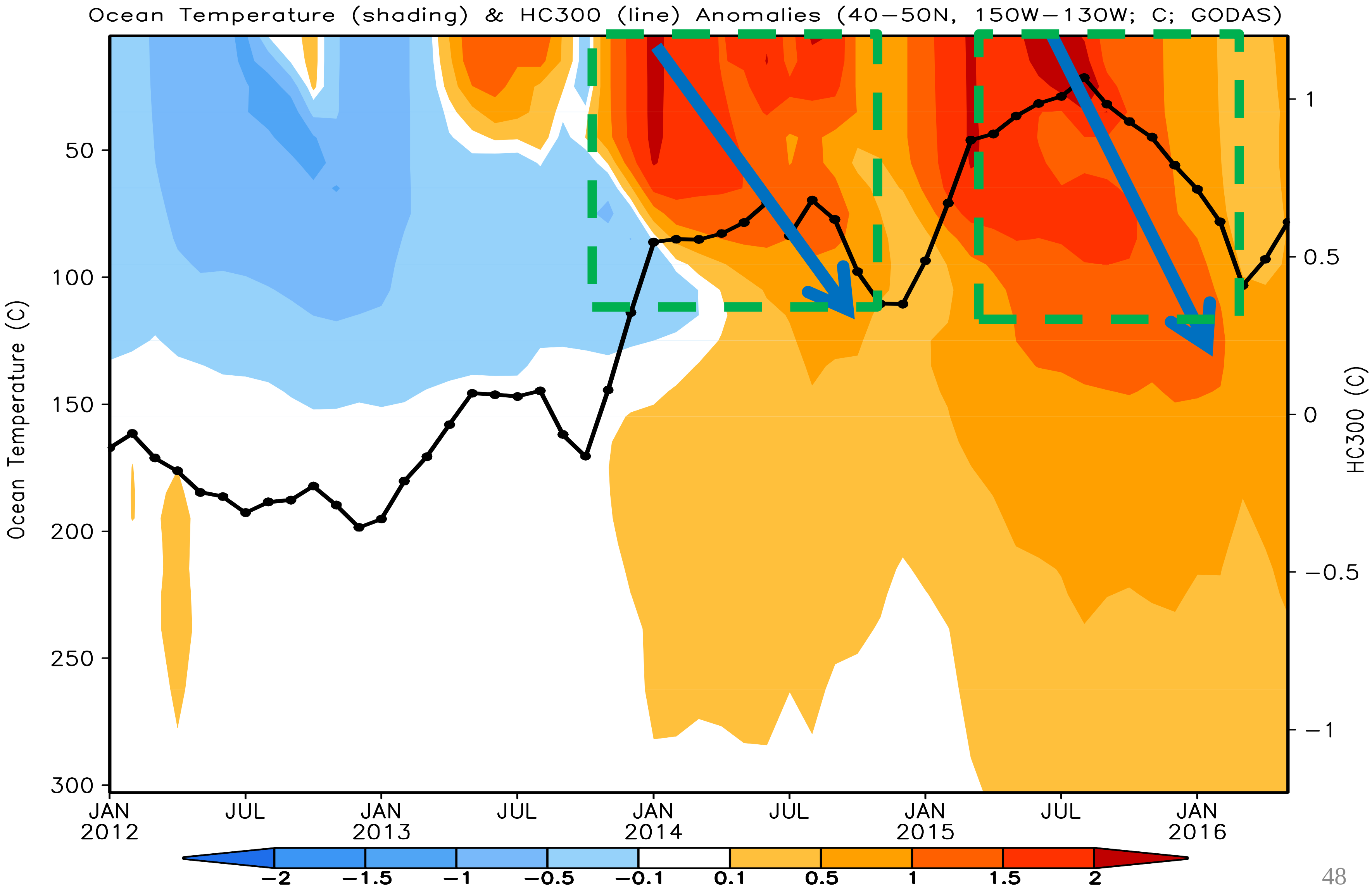


Hu, Z.-Z., A. Kumar, B. Jha, J. Zhu, and B. Huang, 2017: Persistence and predictions of the remarkable warm anomaly in the northeastern Pacific Ocean during 2014-2016. J. Climate, 30 (2), 689–702. DOI: 10.1175/JCLI-D-16-0348.1.


Anomalous Temperature (C) in [150W–130W, 40N–50N]
Ensemble Mean (GODAS, ECMWF, JMA, GFDL, NASA, BOM)
1979–present
50
100
150
200
250
300
1980
1985
1990
1995
2000
2005
2010
2015
Last 6 year
2014
2015
2016
2017
2018
2019
–1.8 –1.5 –1.2 –0.9 –0.6 –0.3 0.3 0.6 0.9 1.2 1.5 1.8

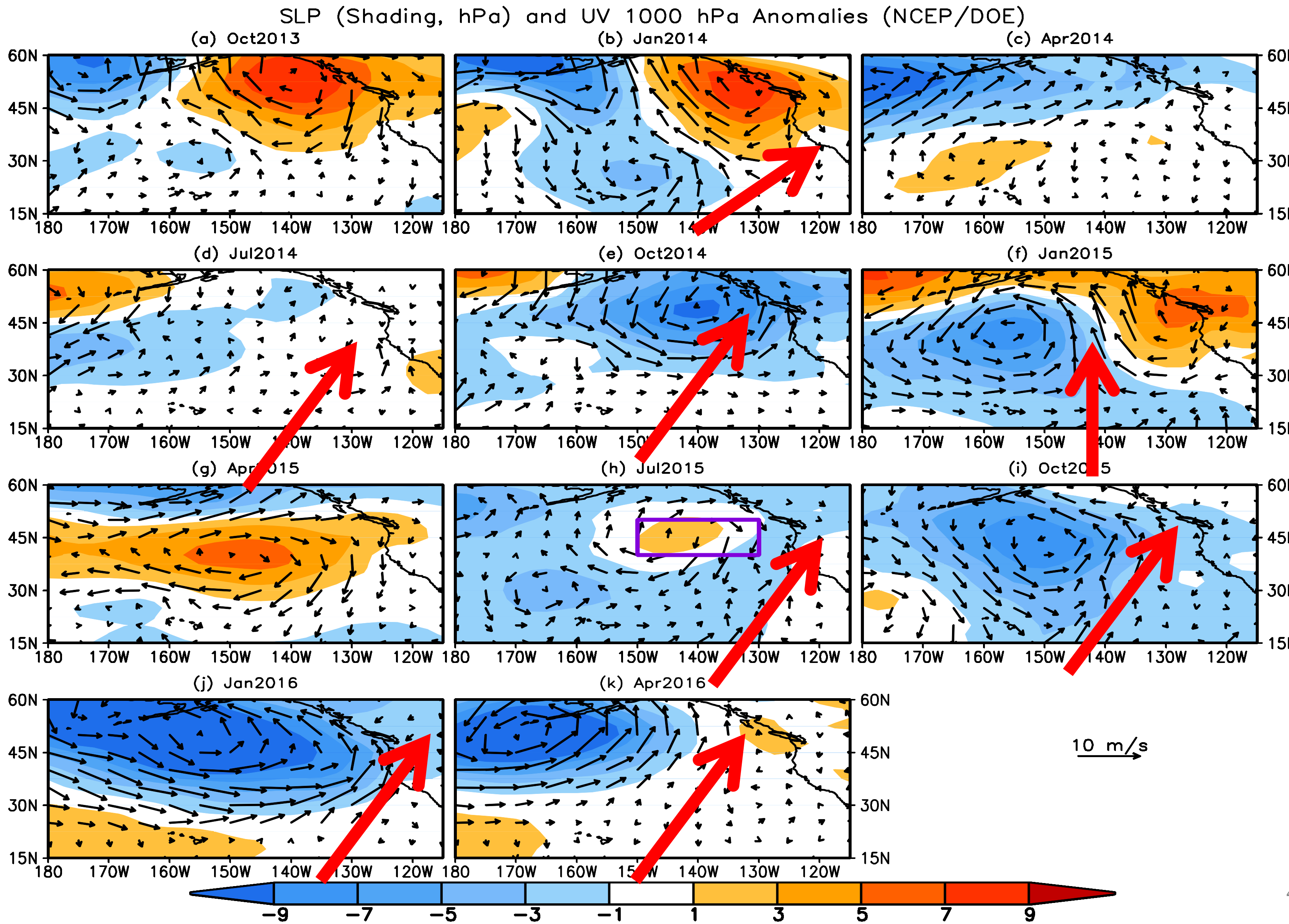
Persistent positive OTA in NE Pacific

(a) Two peaks in Jan 2014 and Jul 2015; (b) Downward propagation.



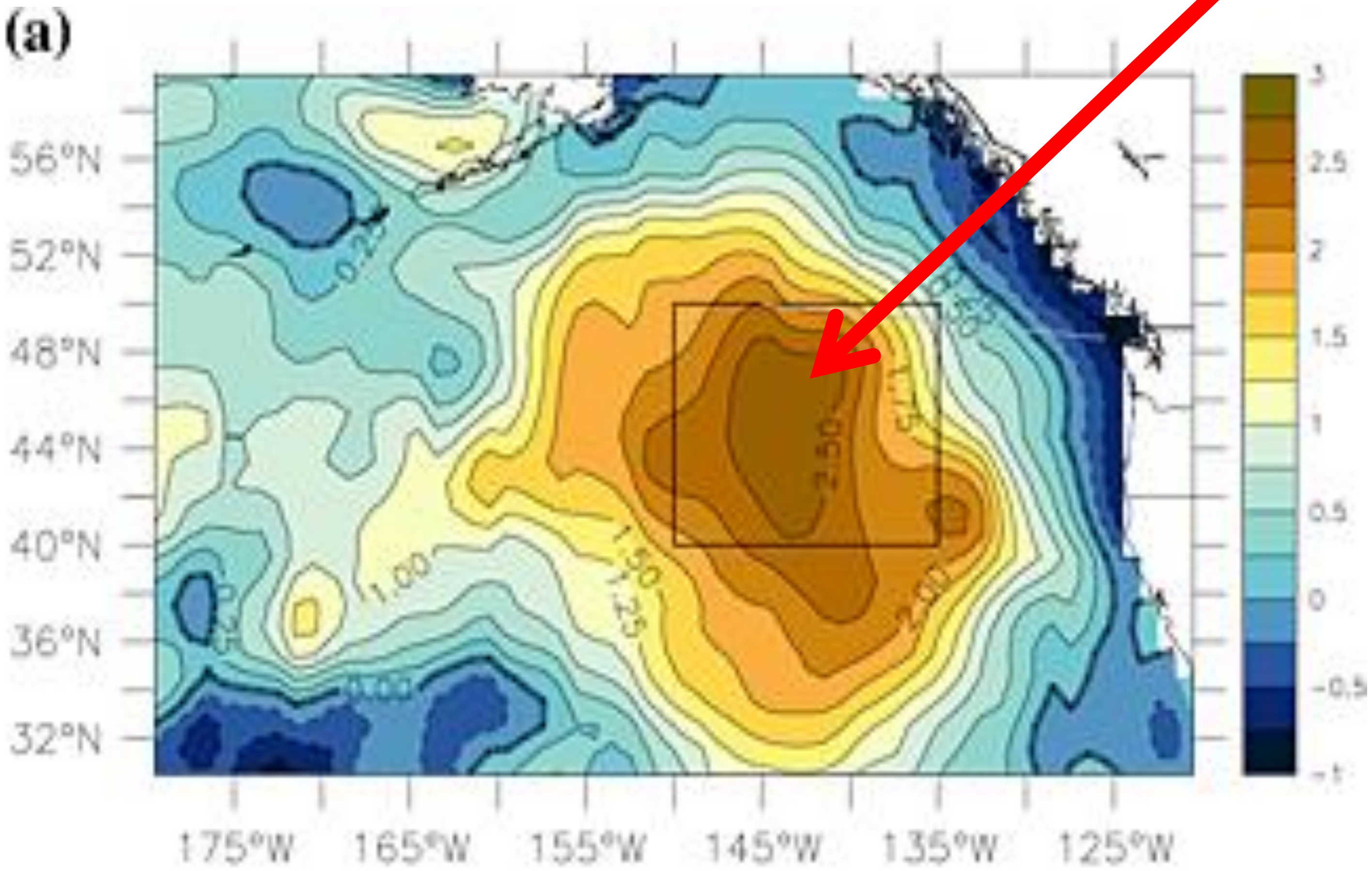
Persistent mainly southerly wind anomalies in NE Pacific

(Southerly wind anomaly favors warm advection in addition to the WES feedback)



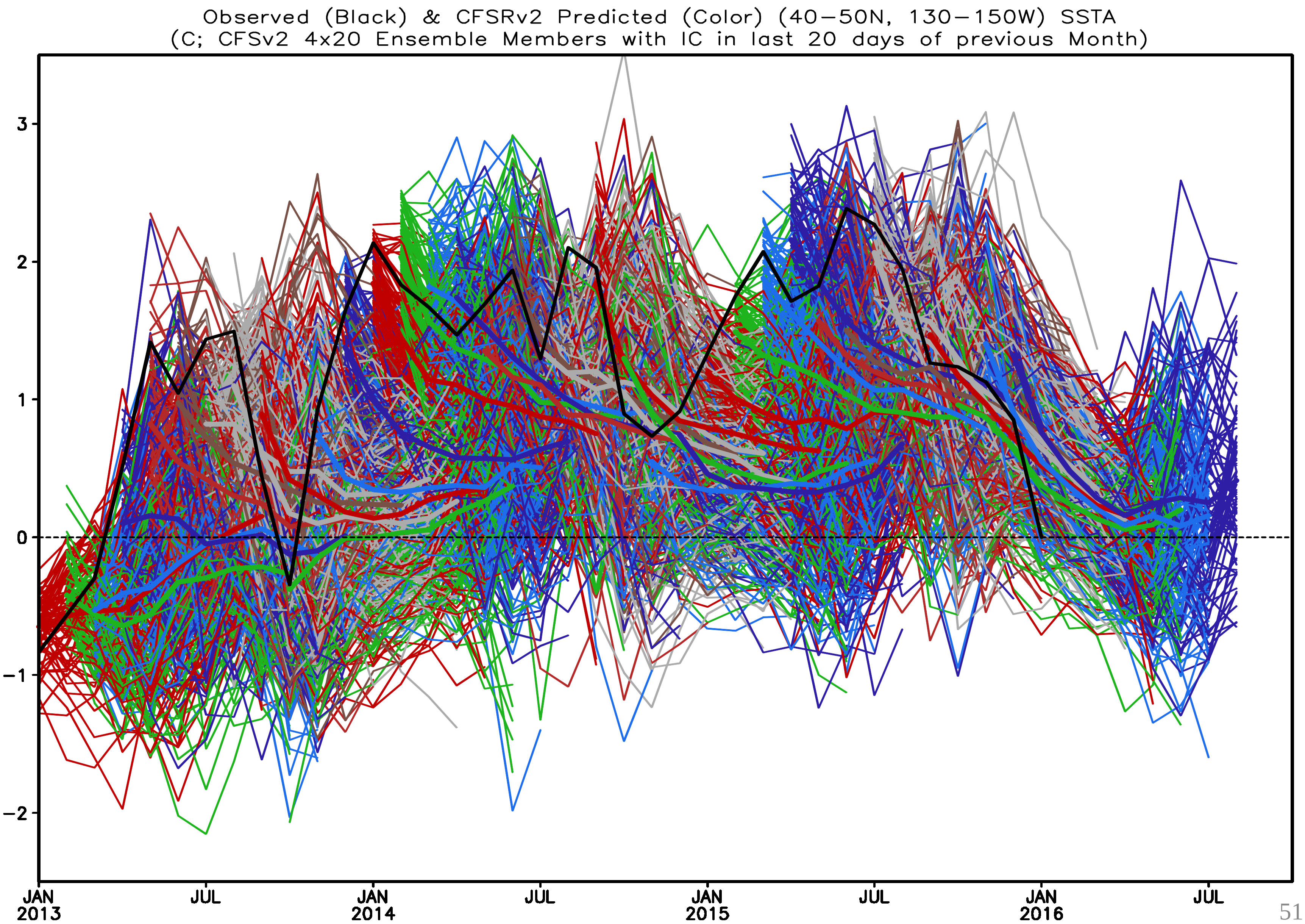
What is “Blob”?

Persistent warm water mass in NE Pacific during 2013-2015 (Bond et al. 2015).



Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua (2015), Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophys. Res. Lett., ***42****, 3414–3420, doi:10.1002/2015GL063306.*

CFSv2 predictions of SSTA in NE Pacific (30-50N, 150W-130W)



Acknowledgements

- Drs. Caihong Wen, Jieshun Zhu, 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
- Prof. Saji N. Hameed provided the IOD slides and relevant information

Please send your comments and suggestions to:

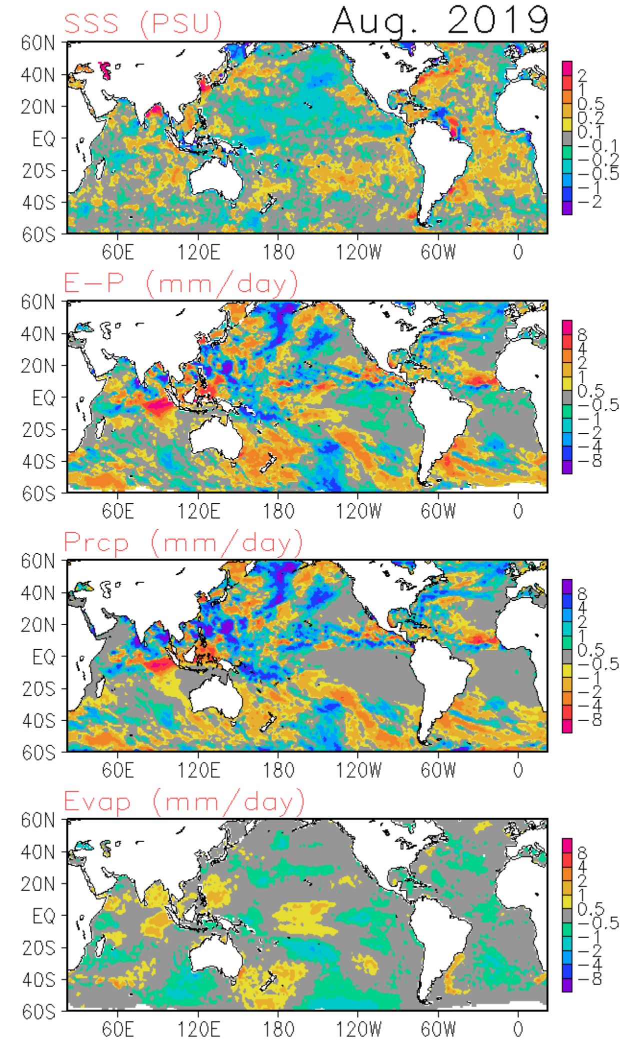
Zeng-Zhen.Hu@noaa.gov
Arun.Kumar@noaa.gov
Caihong.Wen@noaa.gov
Jieshun.Zhu@noaa.gov

Backup Slides

Global Sea Surface Salinity (SSS)

Anomaly for August 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.
- In the equatorial Pacific ITCZ region, negative SSS anomalies are continually persistent. Such signal is co-incident with increased precipitation. In the SPCZ region, negative SSS anomalies appear and it is accompanied with enhanced precipitation. Negative SSS anomalies is continuing in the subtropics of the north Pacific Ocean, which is likely due to the combination of increased precipitation and oceanic advection/entrainment. 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

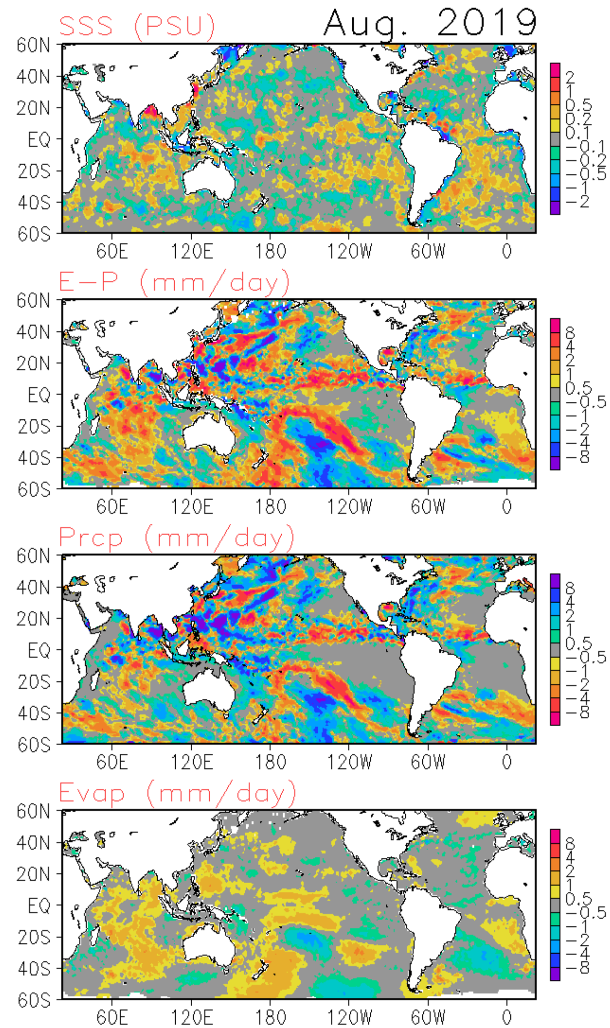
  Precipitation: CMORPH adjusted satellite precipitation estimates

  Evaporation: Adjusted CFS Reanalysis

Global Sea Surface Salinity (SSS)

Tendency for August 2019

Compared with last month, the SSS decreased in the SPCZ regions. Such SSS decreasing is co-incident with increased precipitation. The SSS decreased between 30° N and 40° N in the Pacific Ocean which is likely due to the oceanic advection/entrainments and increased precipitation. The SSS continues decreasing in the Sea of Okhotsk with reduced precipitation in this area. The SSS increased in the Bay of Bengal with no significant freshwater flux change.

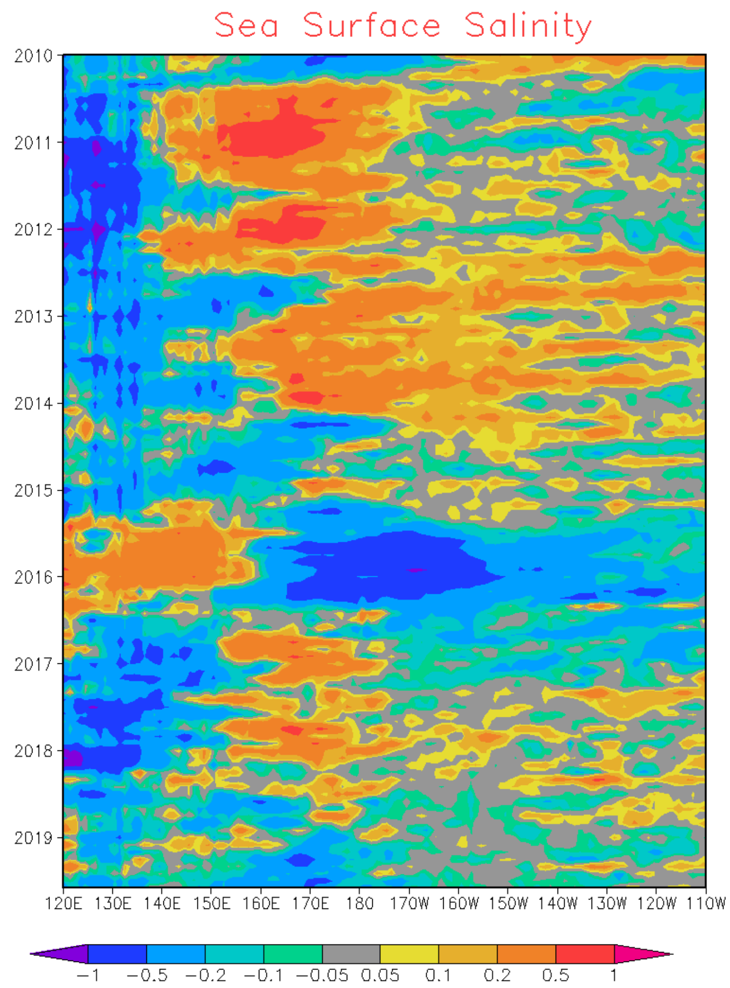


Global Sea Surface Salinity (SSS)

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.

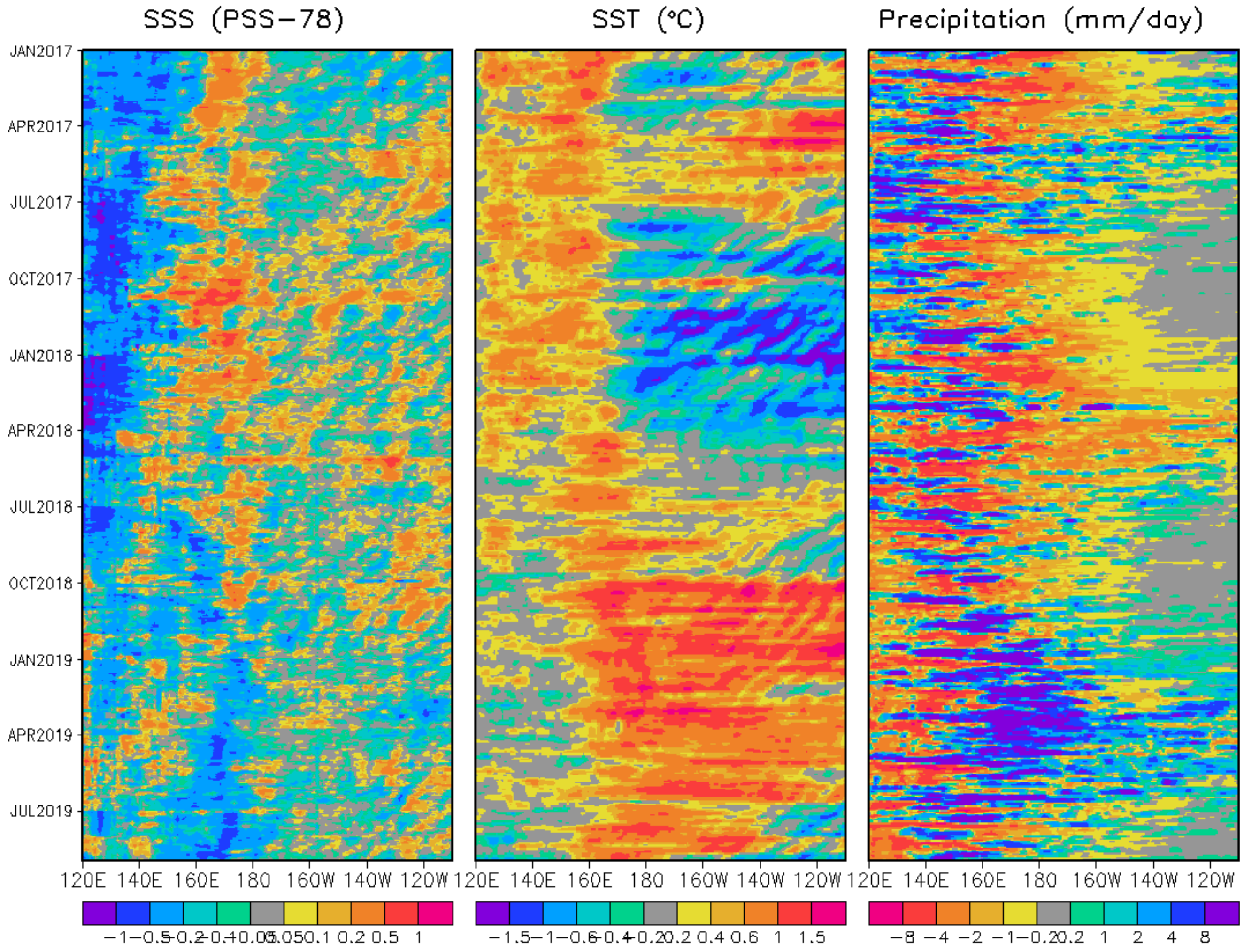
- Hovemoller diagram for equatorial SSS anomaly **(5° S-5° N);**
- In the equatorial Pacific Ocean, the SSS signal becomes negative between 120° E to 140° E; the SSS shows enhanced negative anomalies between 150° E and dateline; east of dateline, the SSS does not show strong signals.



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.



August 2019 Experimental Sea Ice Outlook

Climate Prediction Center, NCEP/NWS/NOAA

Acknowledgments: Both hindcasts and forecasts were produced on NOAA GAEA computer.

Procedure

- Use Climate Forecast System (CFS) coupled model initialized with CPC Sea Ice Initialization System (CSIS) initial sea ice conditions (20 initializations: August 21-25, 2019).
- Correct biases using 2006-2018 mean error with respect to NSIDC observations
- Present unbiased results
- The following maps 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)
  - First ice melt day prediction difference from previous month
  - Mean first ice freeze day/ standard deviation (Alaska region)

September 2019 SIE forecast

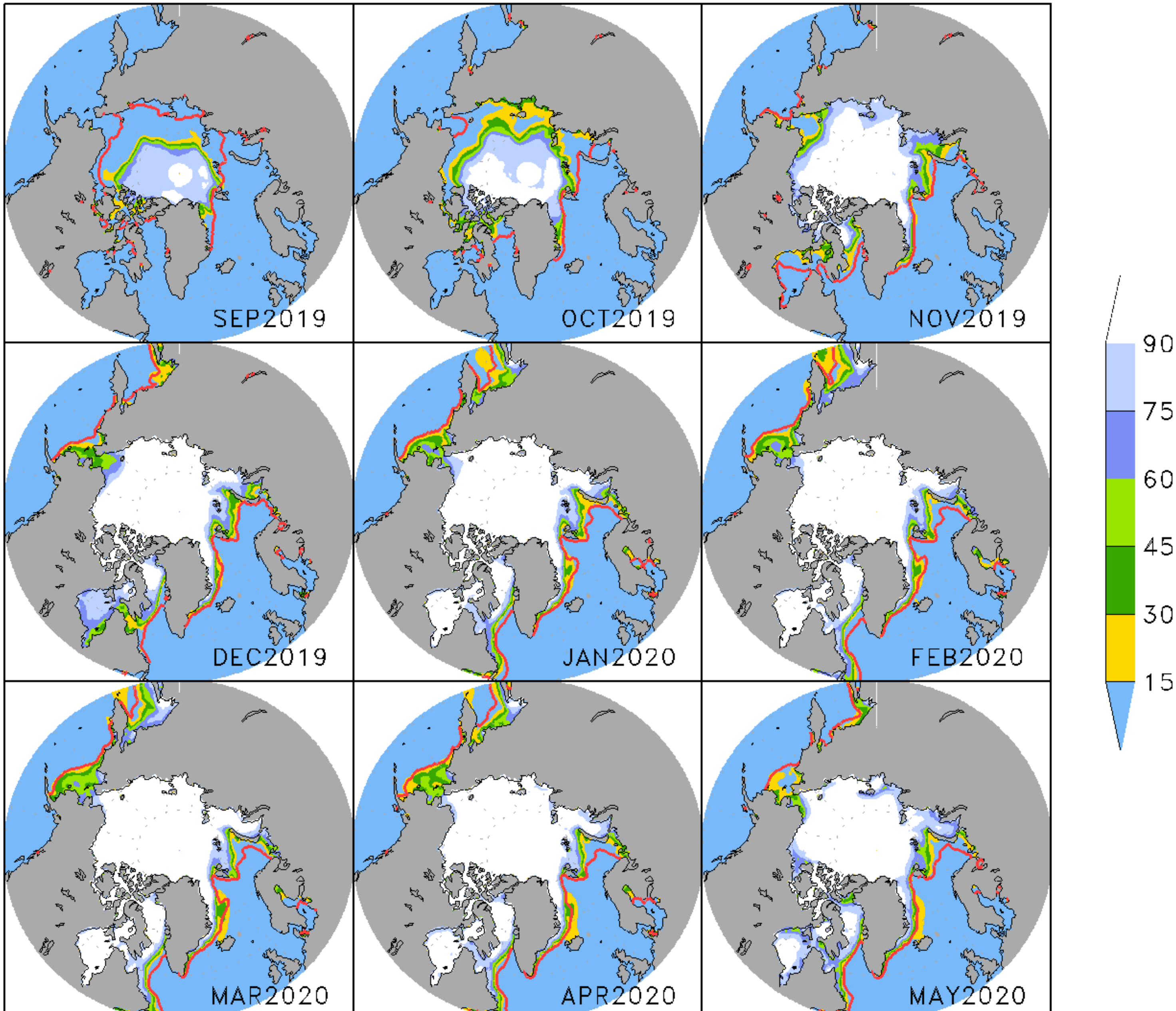
Source	SIE Value (10^6 km^2)
NSIDC 1981-2010 Climatology	6.41
NSIDC 2018	4.71
NSIDC 2012 (record low)	3.57
Experimental CFSv2 2019 forecast	**4.50**

Based on these simulations, the September 2019 sea ice extent minimum 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

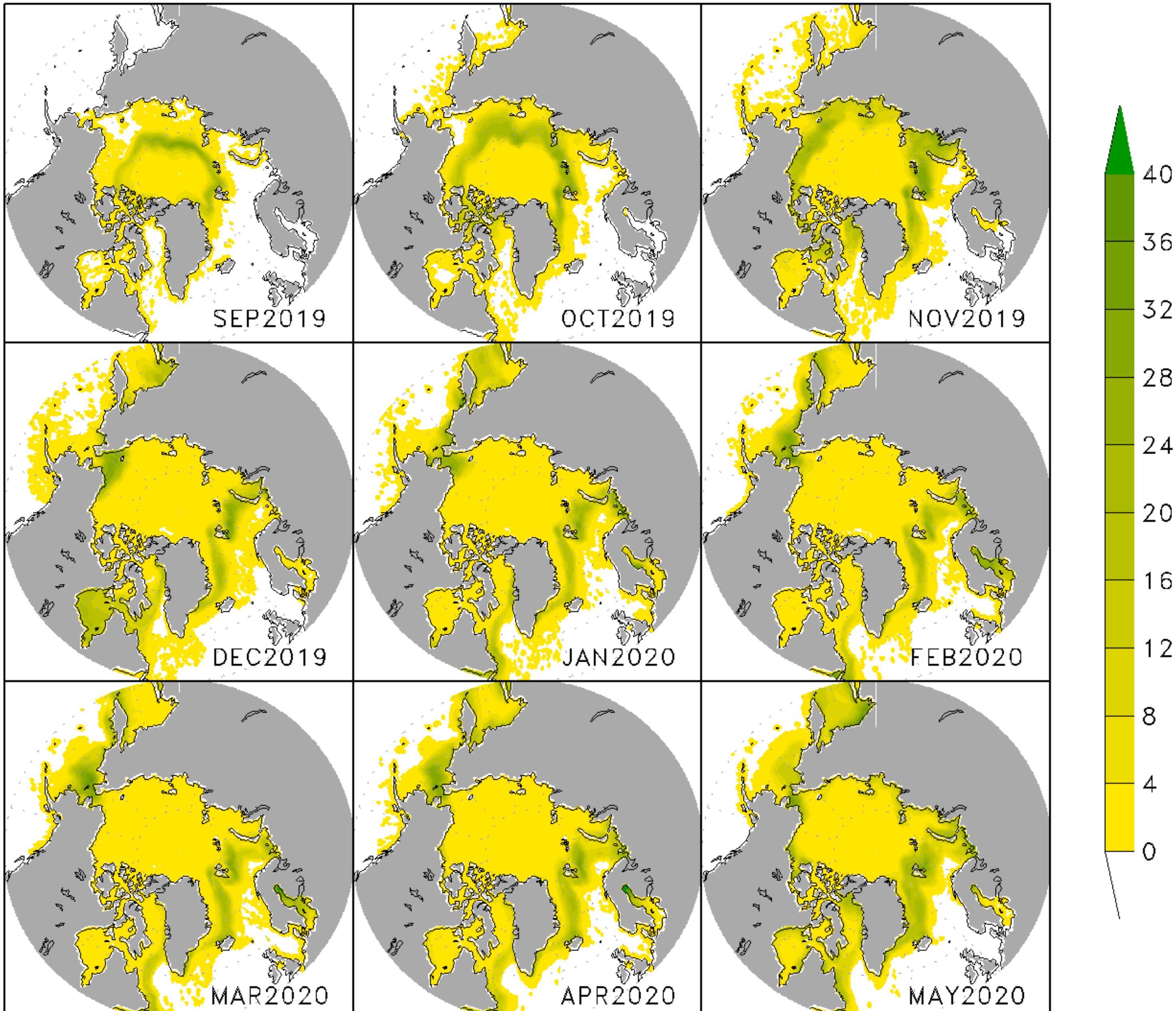
Month	March	April	May	June	July	August
Ens. Mean	4.87	4.71	4.62	4.55	4.31	4.50
Std. Dev.	0.34	0.33	0.26	0.24	0.14	0.11

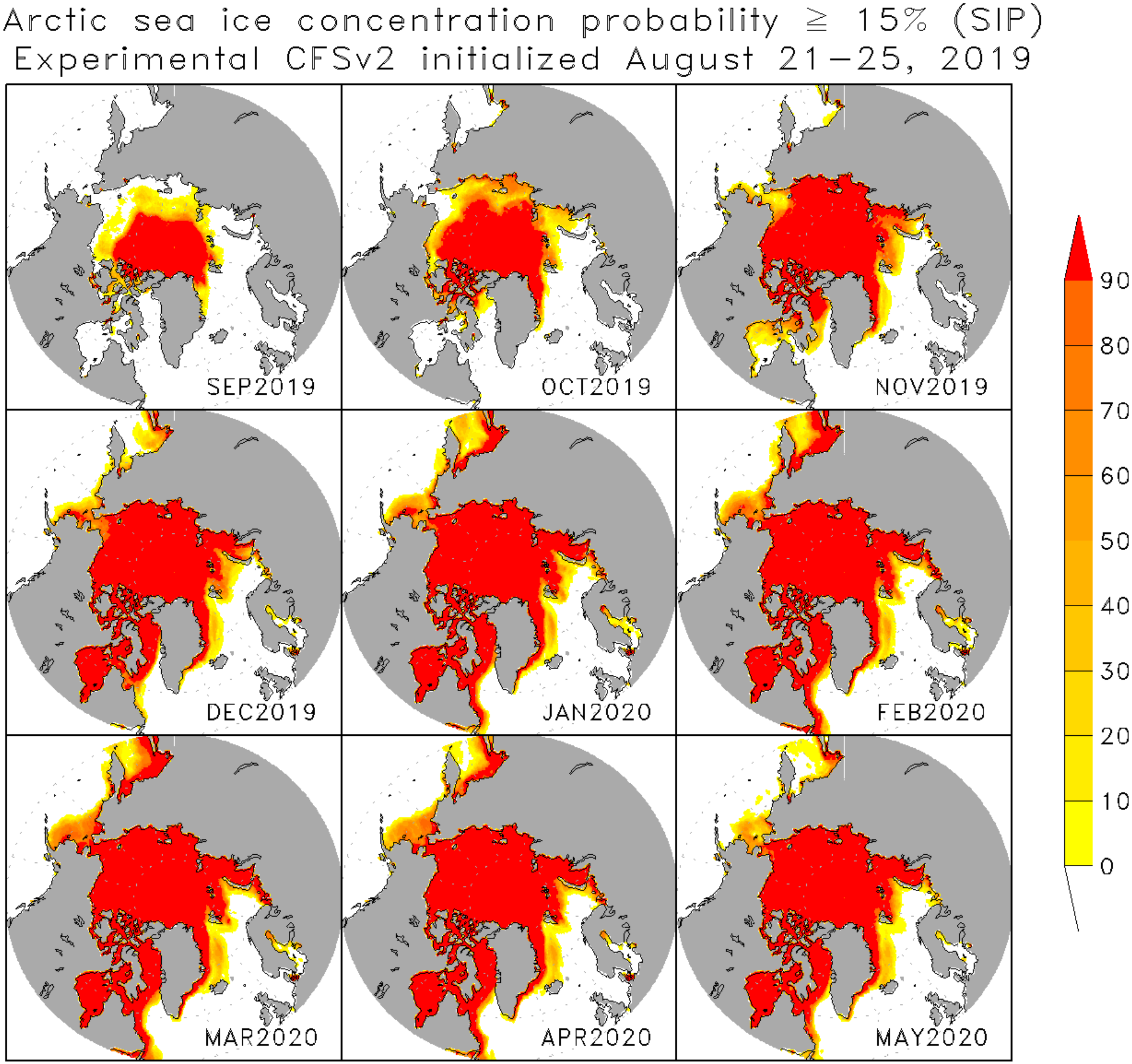
Arctic sea ice concentration (SIC, %) forecast
Experimental CFSv2 initialized August 21–25, 2019



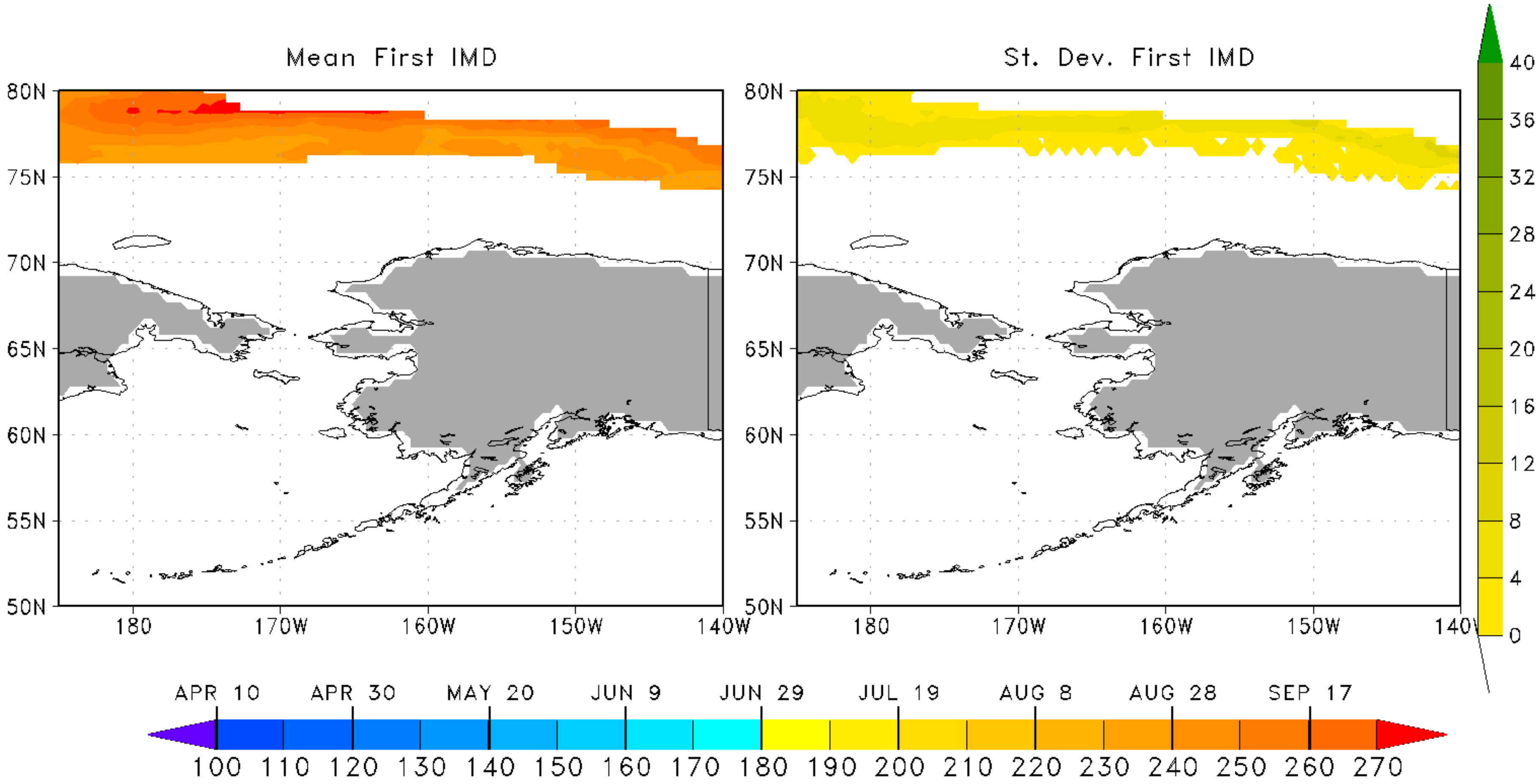
* 1981–2010 climatology of 15% NASA Team SIC countoured red *

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

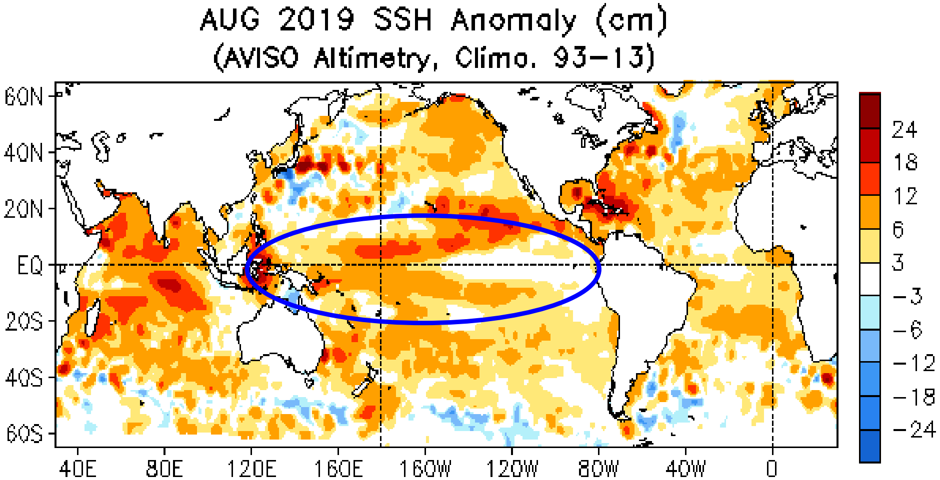


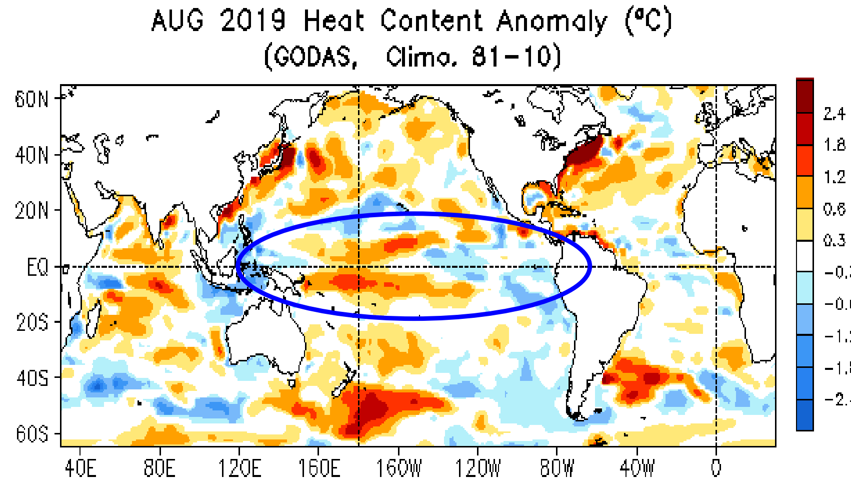

Arctic sea ice concentration probability ≧ 15% (SIP)
Experimental CFSv2 initialized August 21–25, 2019
SEP2019
OCT2019
NOV2019
DEC2019
JAN2020
FEB2020
MAR2020
APR2020
MAY2020
90
80
70
60
50
40
30
20
10
0

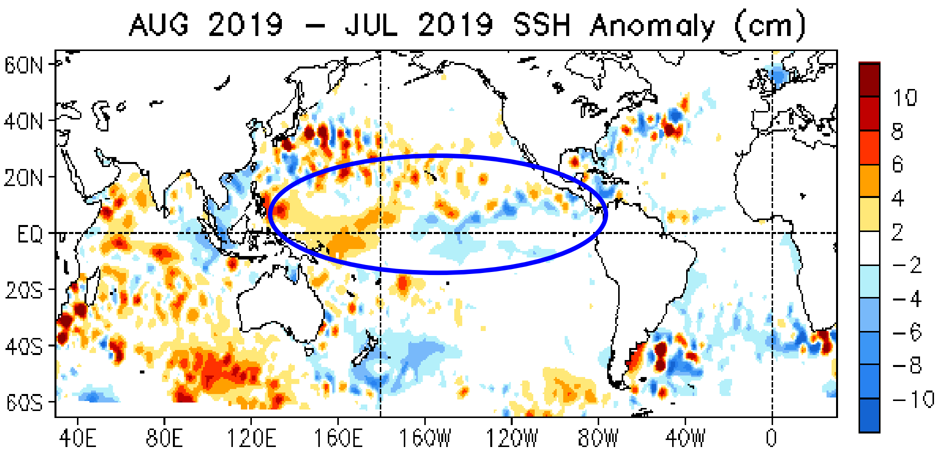
First sea ice melt date of 2019
Experimental CFSv2 initialized August 21–25, 2019

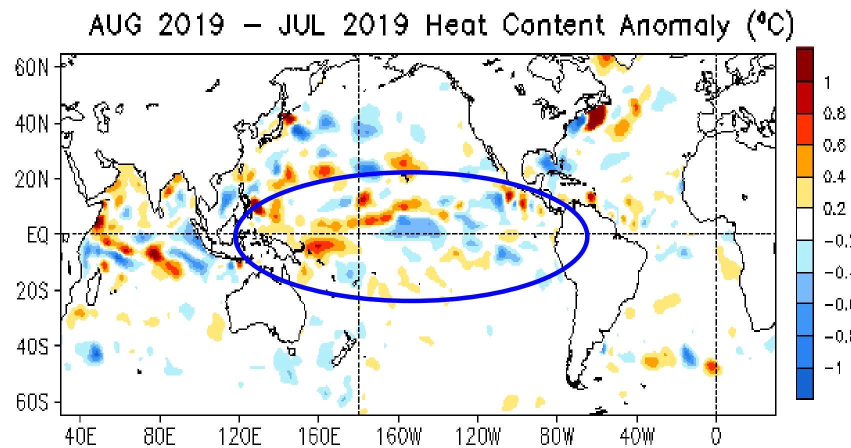


Global SSH and HC300 Anomaly & Anomaly Tendency









- **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 conditions.**
- **Positive (negative) tendencies of SSHA and HC300A presented in the western (eastern) tropical Pacific.**

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.**

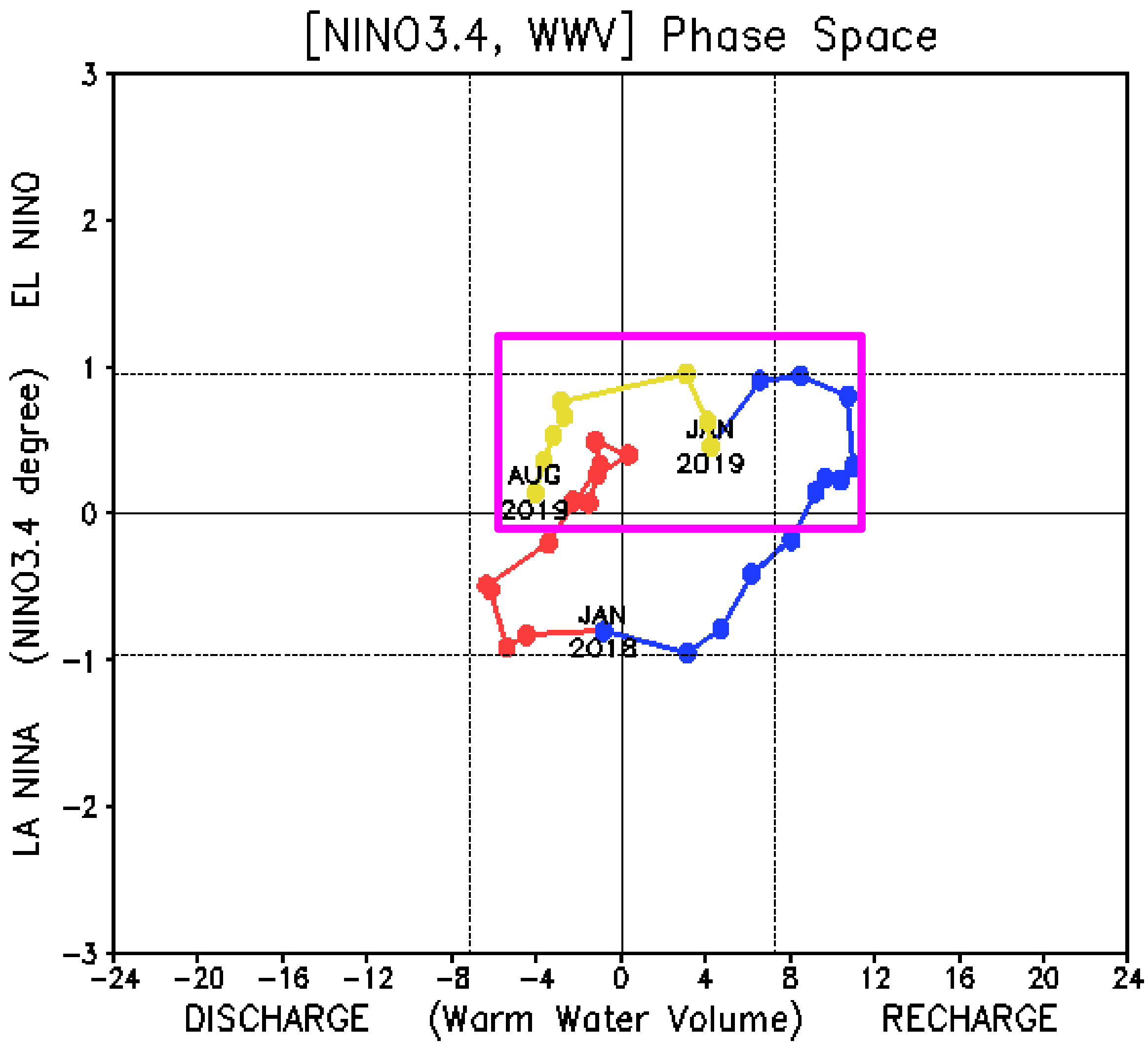
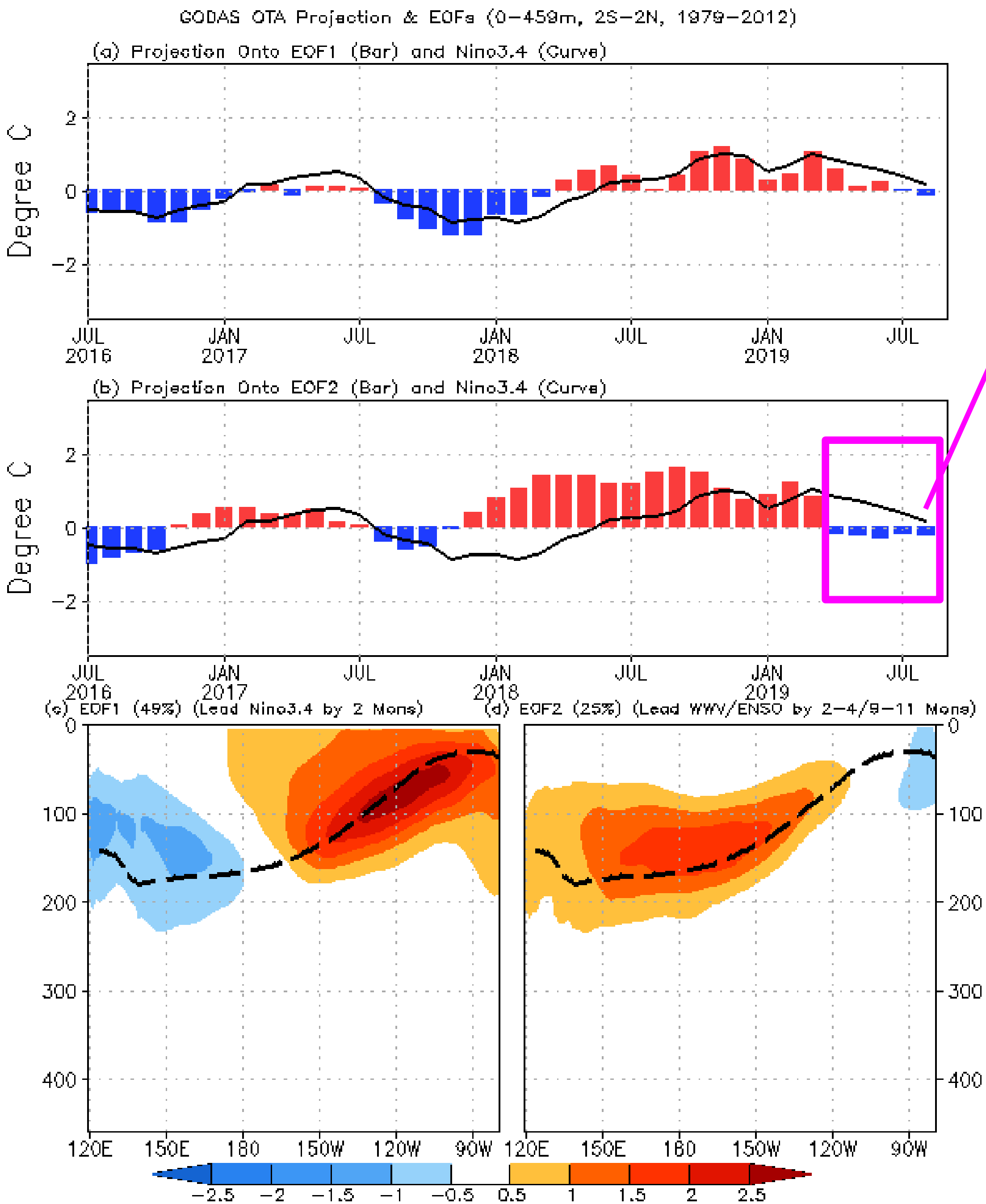


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.



Equatorial subsurface ocean temperature monitoring: ENSO was in a discharged phase in Aug 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).

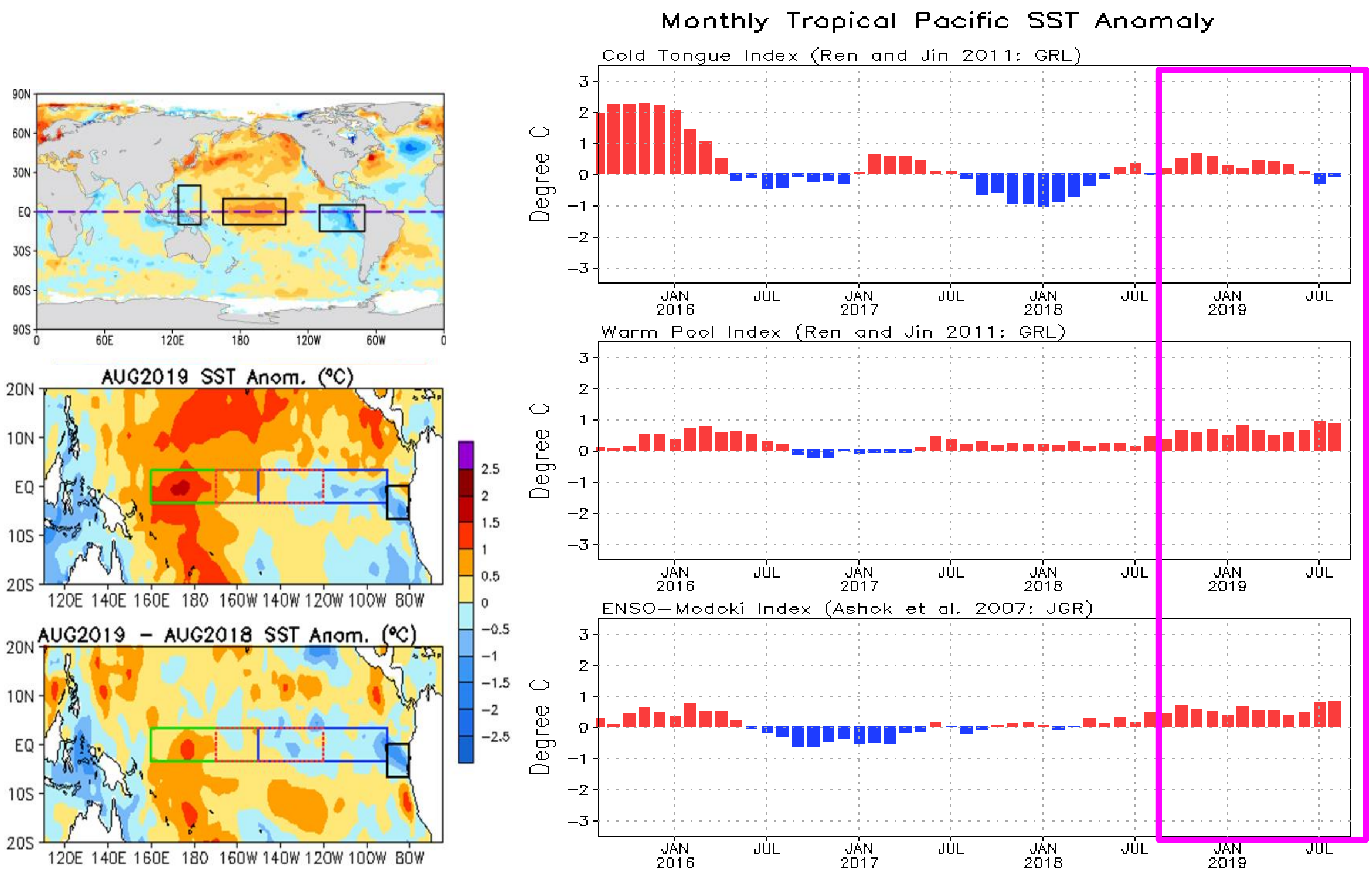
Recharge process: heat transport from outside of equator to equator : Negative -> A positive phase of ENSO

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

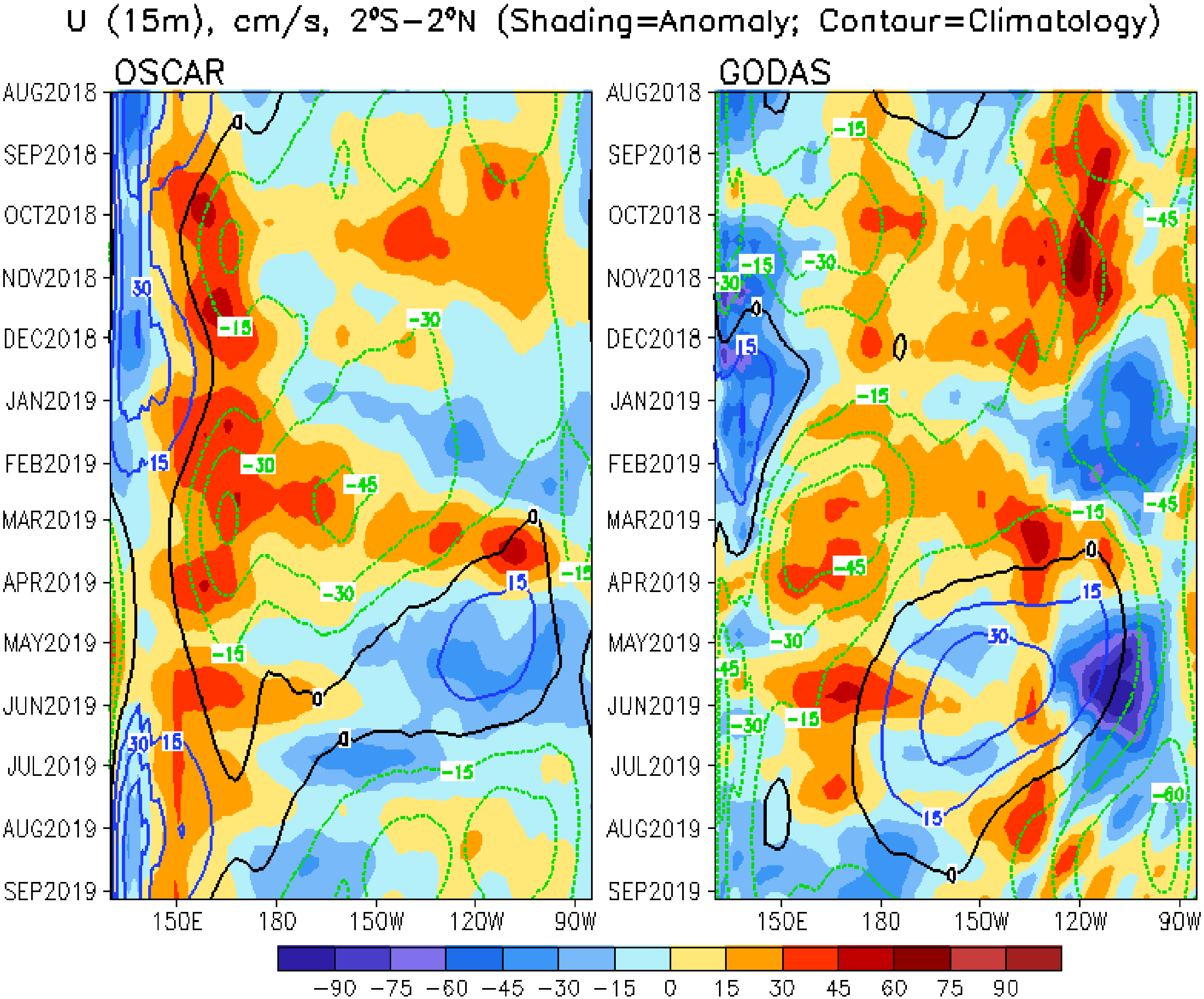
For details, see:

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*.

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



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



- **Westward anomalous current was observed in the central Pacific since Aug 2019, consistent with the decay of the El Nino.**

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

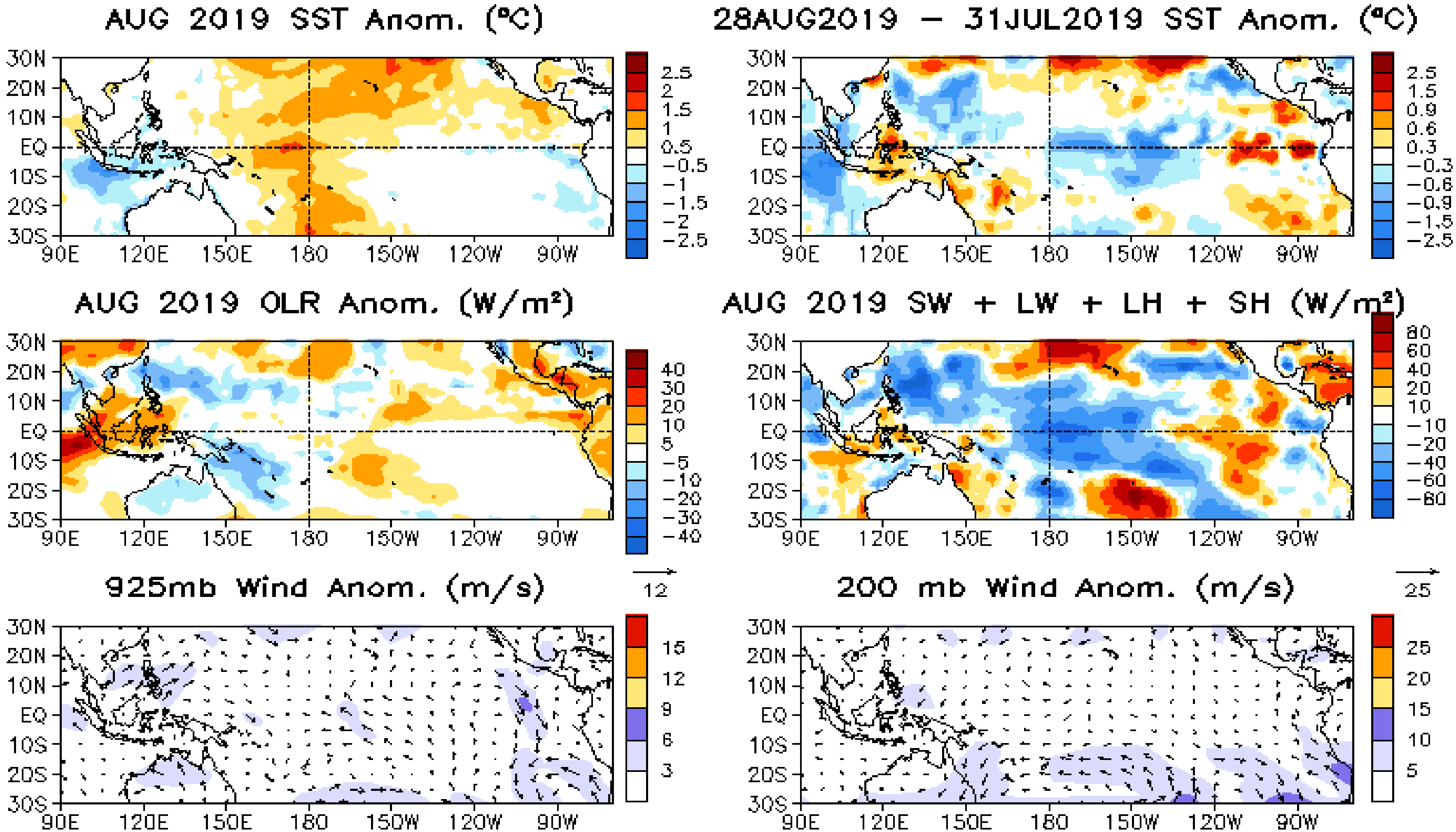


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

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

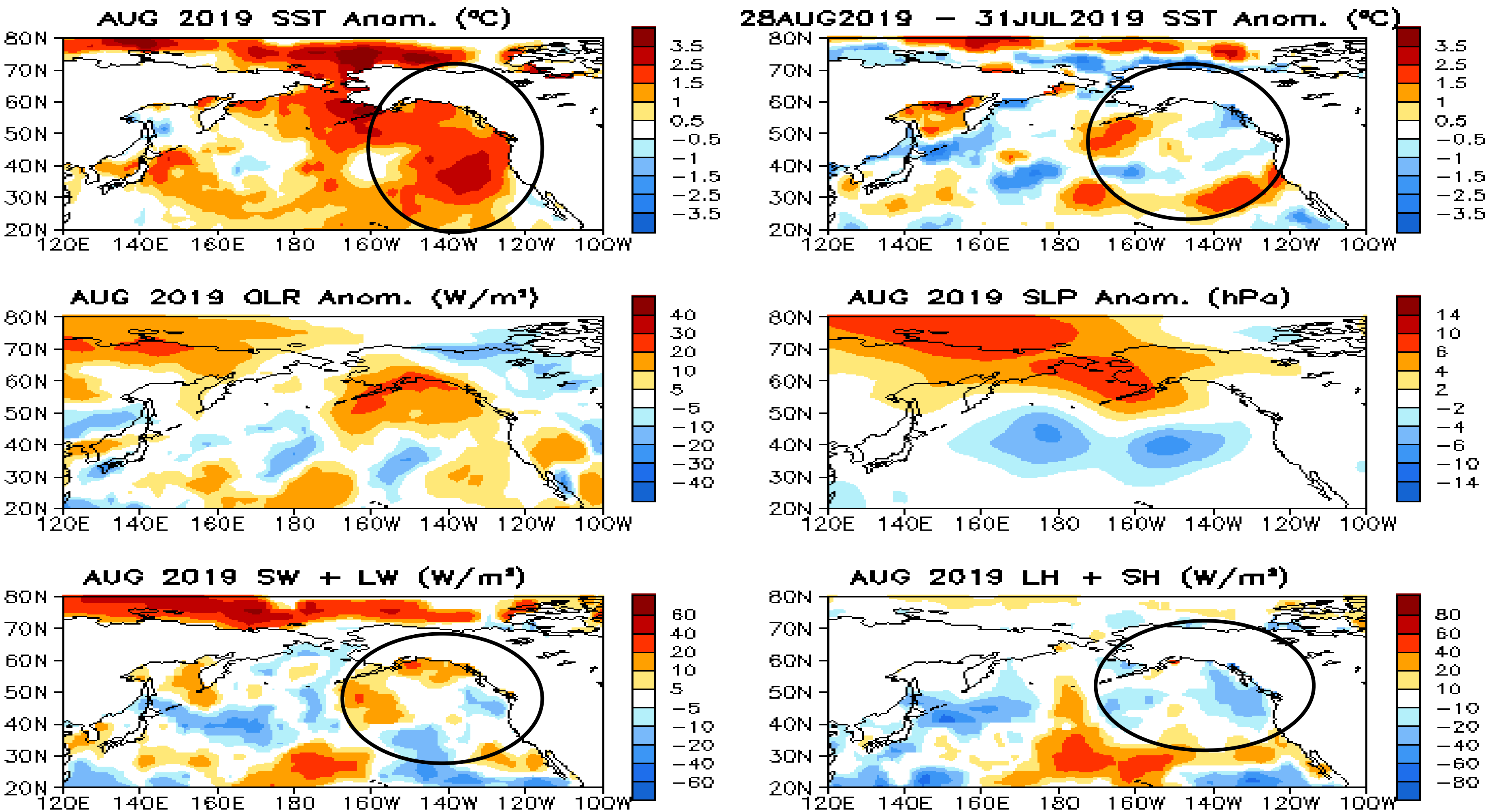


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

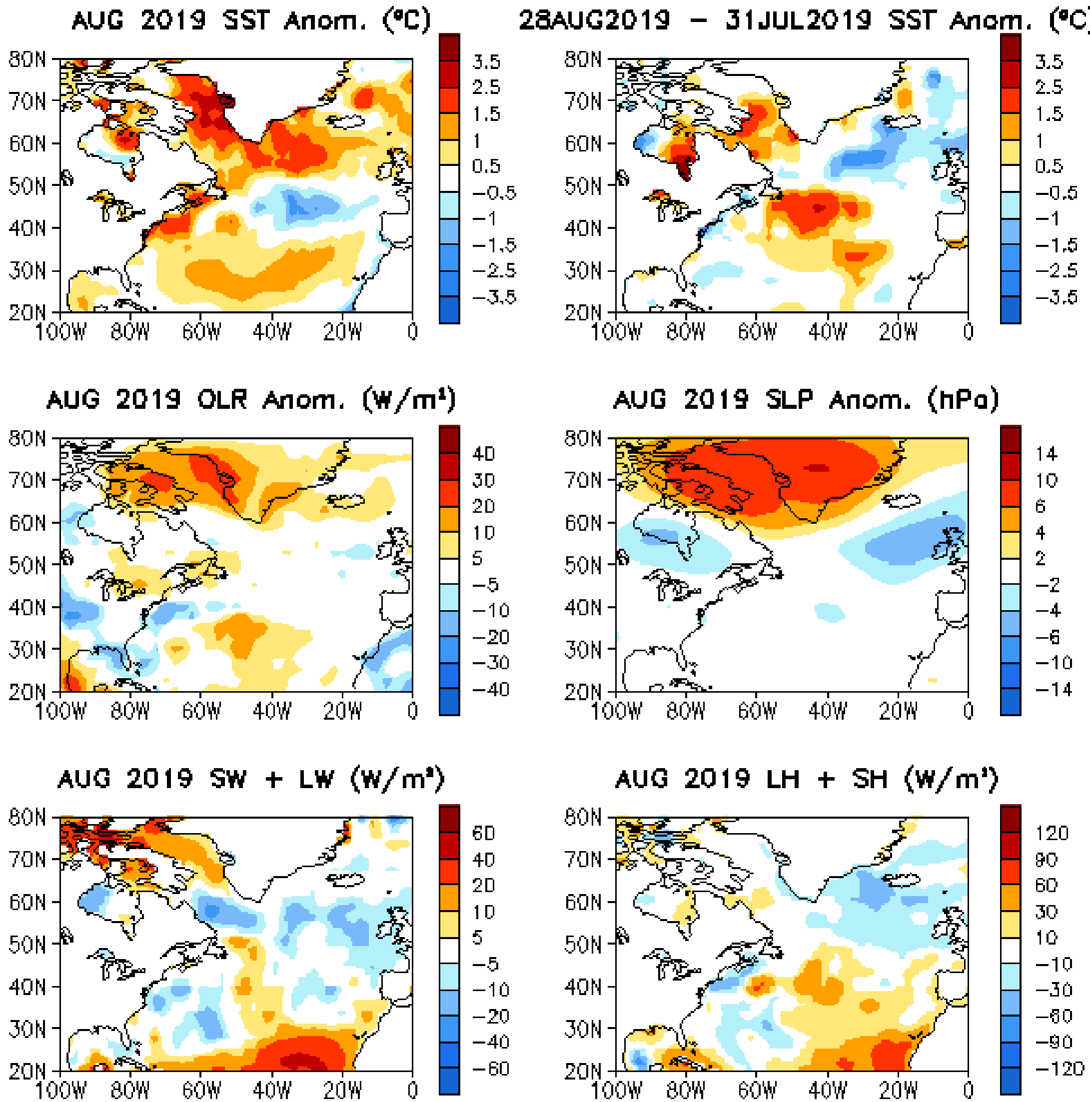
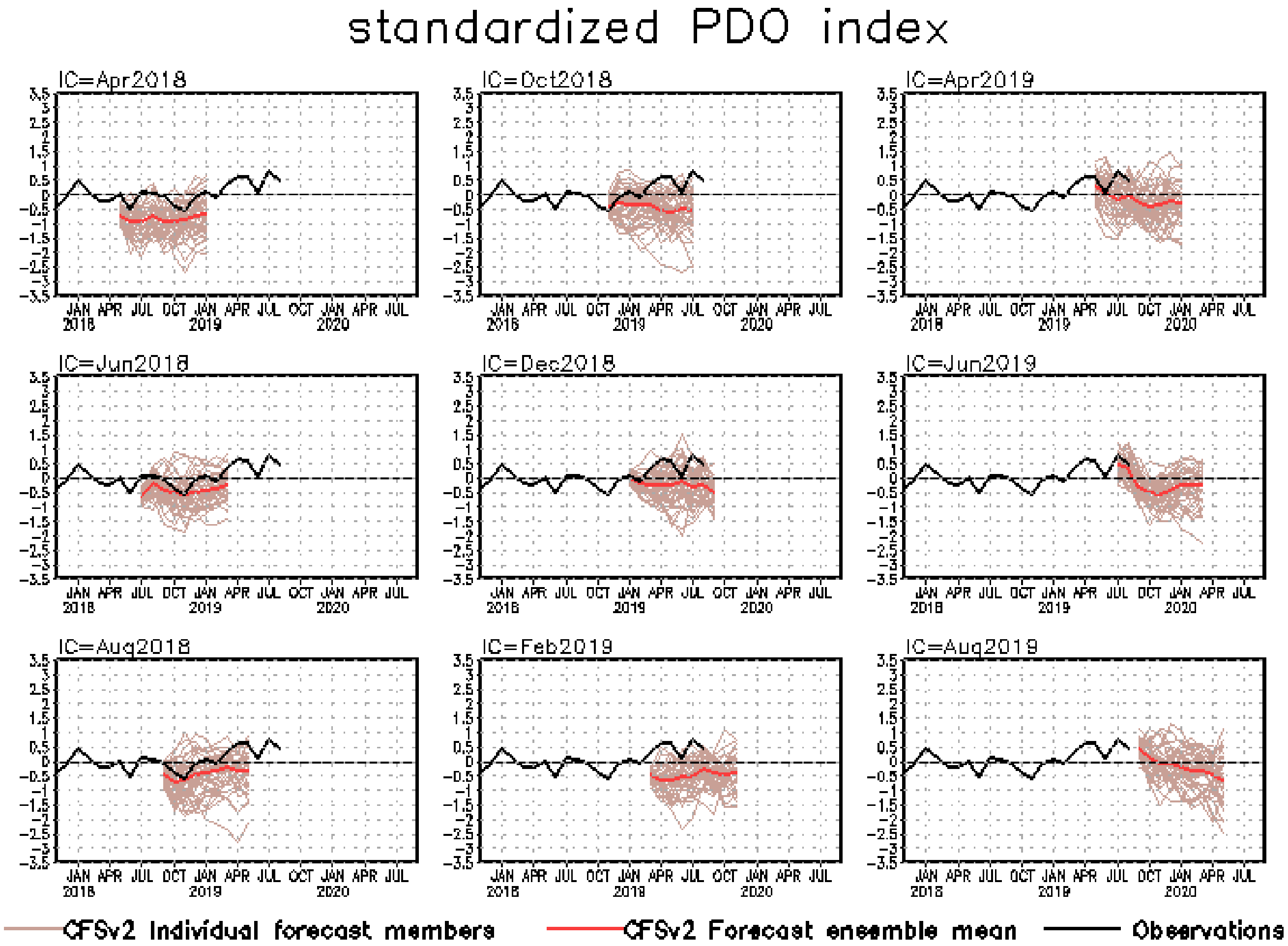


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



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

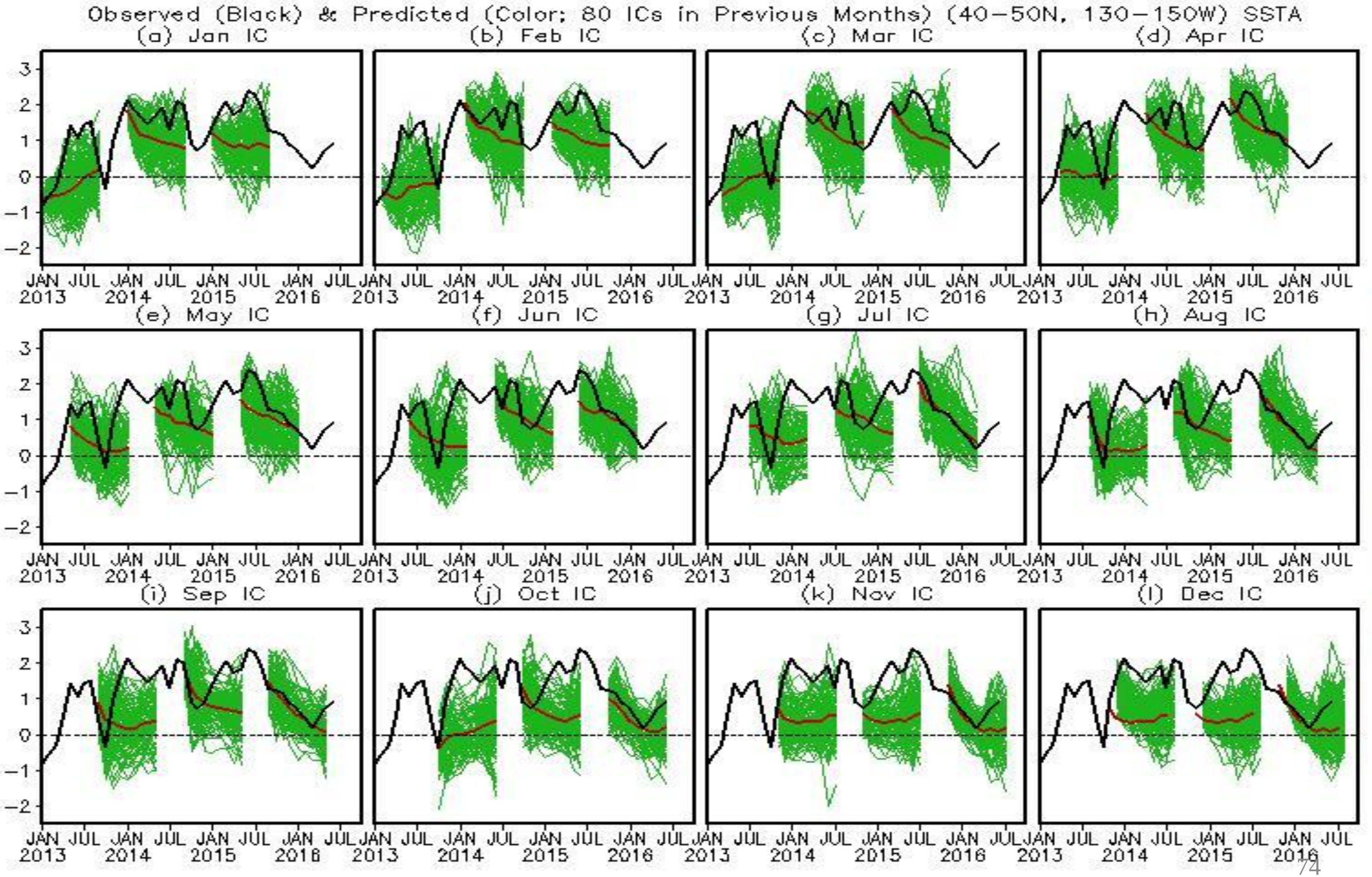
CFS PDO index is the standardized projection of CFS SST forecast anomalies onto the PDO EOF pattern.

- **CFSv2 predicts a decline of PDO with ICs in Aug 2019.**

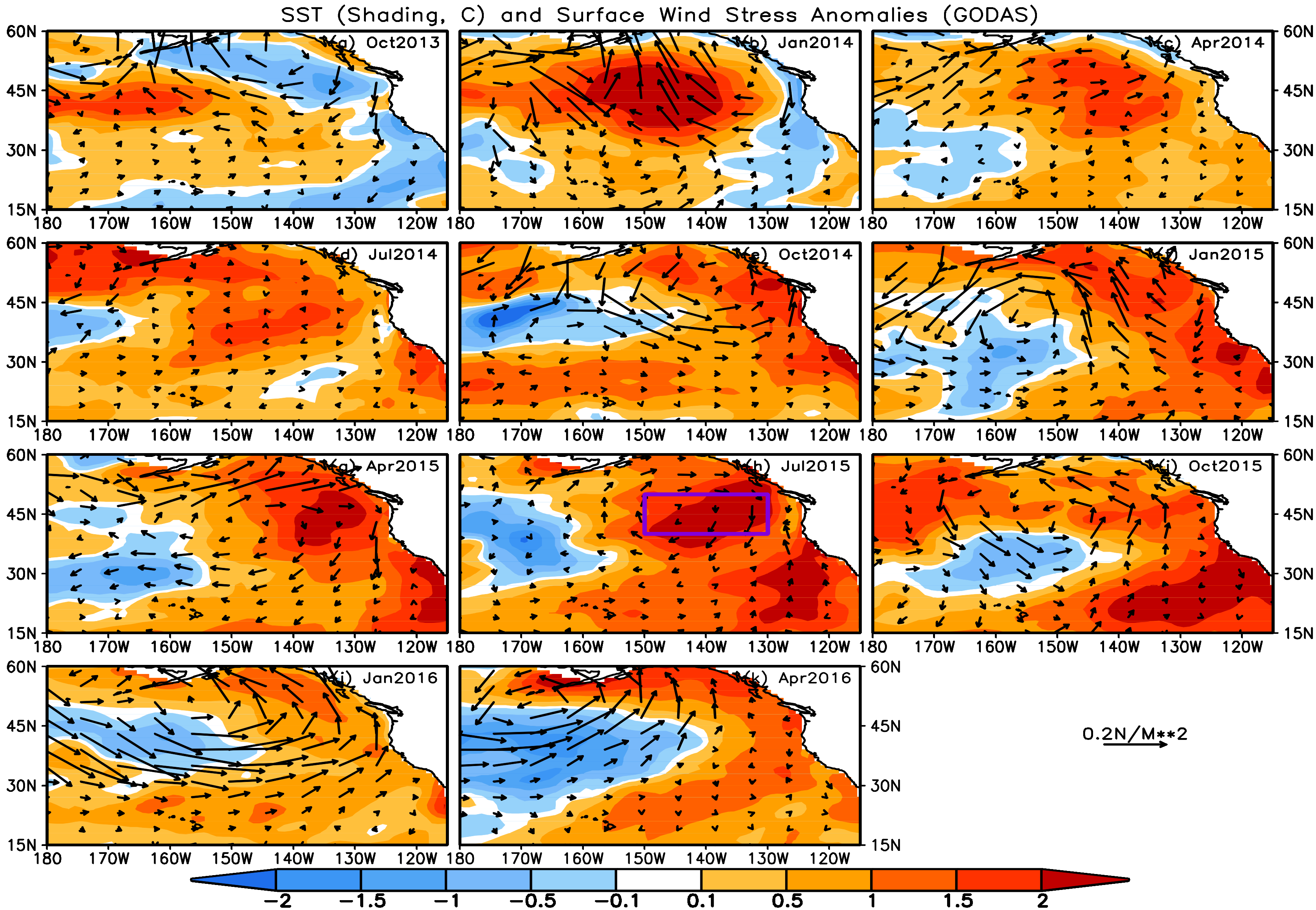
Fig. M4. CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

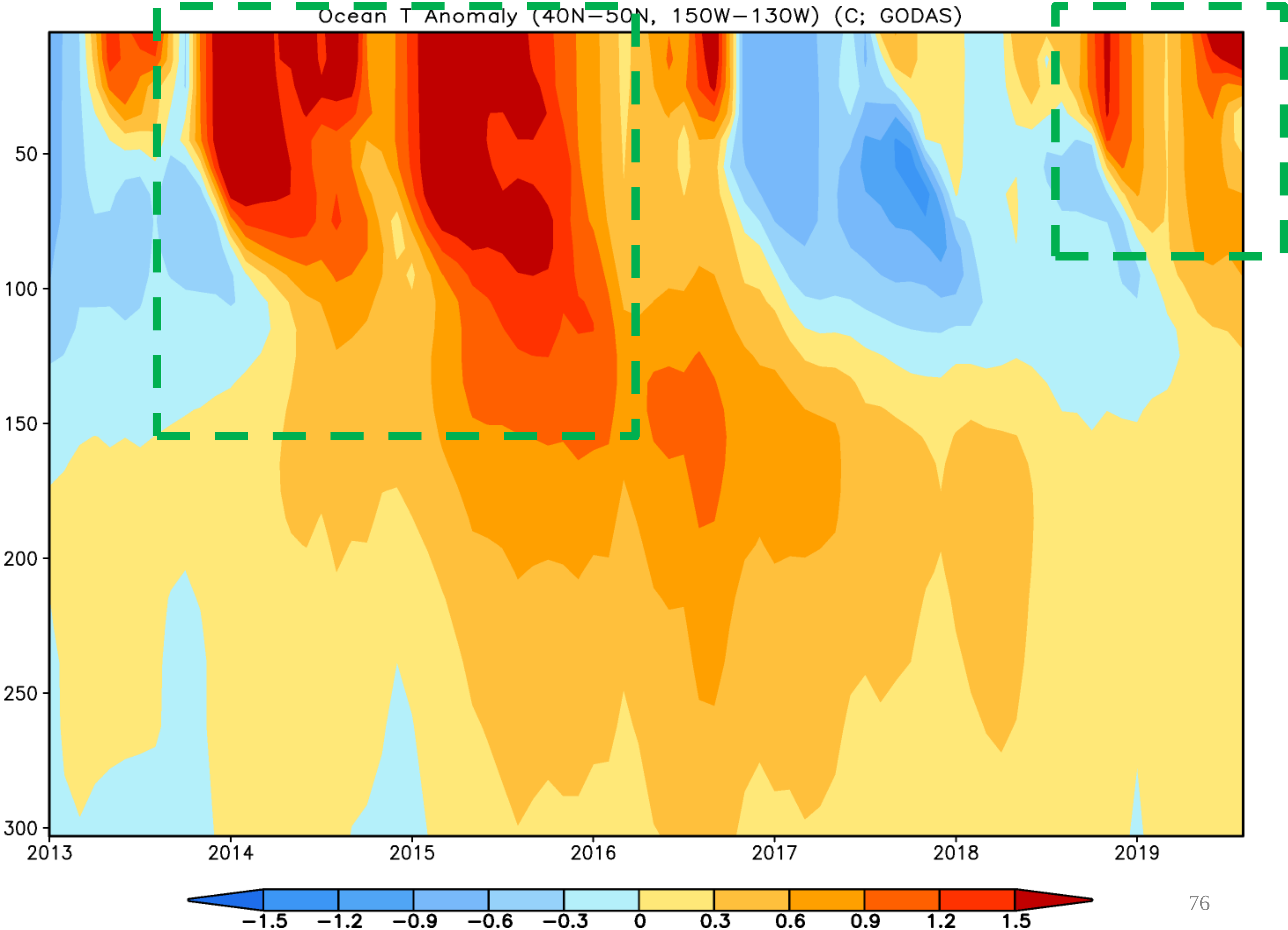
CFSv2 predicted SSTA in NE Pacific (30-50N, 150W-130W) with IC from each Month

(very large spread among individual ensemble member, even at the initial conditions of 20 days window



Persistent positive SSTA in NE Pacific during Jan2014-Apr 2016





Ocean T Anomaly (40N–50N, 150W–130W) (C; GODAS)
50
100
150
200
250
300
2013
2014
2015
2016
2017
2018
2019
−1.5
−1.2
−0.9
−0.6
−0.3
0
0.3
0.6
0.9
1.2
1.5

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 2007)**
- **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

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