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

Prepared by

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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

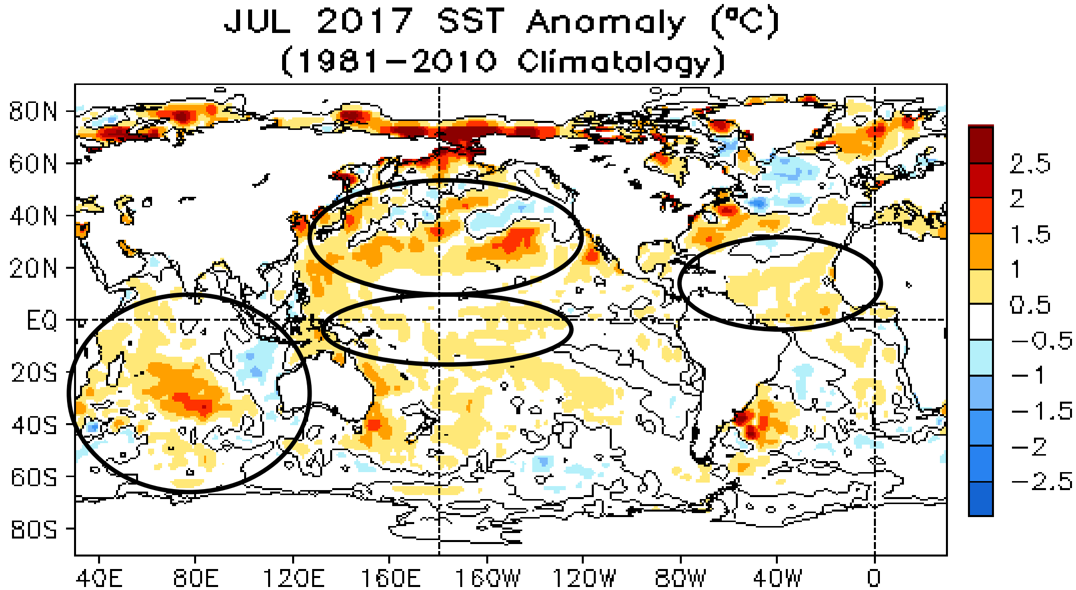
- **Overview**
- **Recent highlights**
  - ❖ Pacific/Arctic Ocean
  - ❖ Indian Ocean
  - ❖ Atlantic Ocean
- **Global SST Predictions**
  - ❖ *Potential Impact of failure of TAO buoys at 155W, 2S-2N on ocean temperature analysis and reanalysis*
  - ❖ *A possible factor leads to unsuccessful prediction of ENSO in 2017 in some models*

Overview

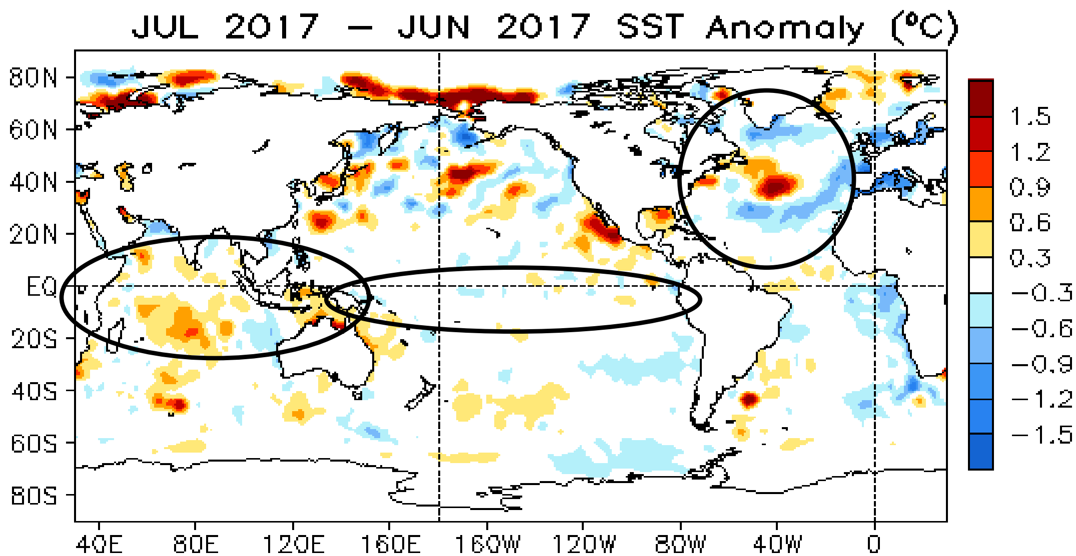
- **Pacific Ocean**
  - **NOAA "ENSO Diagnostic Discussion" on 10 August 2017 indicated *"ENSO-neutral is favored (~85% chance during Jul-Sep, decreasing to ~55% during Dec-Feb) through the Northern Hemisphere winter 2017-18."***
  - **Positive SSTAs presented in the tropical Pacific with NINO3.4=0.4^{o}C in Jul 2017.**
  - **Positive (negative) ocean temperature anomalies were small and presented above (along) the thermocline in the equatorial Pacific in Jul 2017.**
  - **Positive phase of PDO index has persisted 9 months since Nov 2016, and its intensity has weakened significantly during last 3 months with PDO index =0.1 in Jul 2017.**
- **Indian Ocean**
  - **SSTAs were positive in the west and negative in the east in Jul 2017.**
- **Atlantic Ocean**
  - **Positive phase of NAO strengthened with NAOI=1.28 in Jul 2017, and SSTAs were positive in the tropical N. Atlantic.**

<u>Global Oceans</u>

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



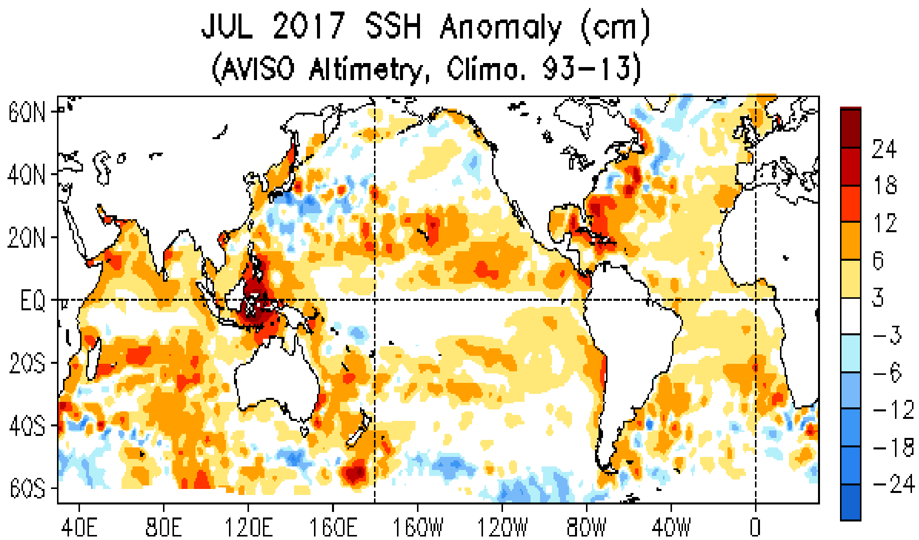
- Small positive SSTAs persisted in the tropical Pacific associated with ENSO neutral.
- SSTAs in N. Pacific were not the typical pattern of PDO.
- Positive SSTAs were observed in the tropical N. Atlantic.
- In the Indian Ocean, SSTAs were positive in the west and central and negative in the east.

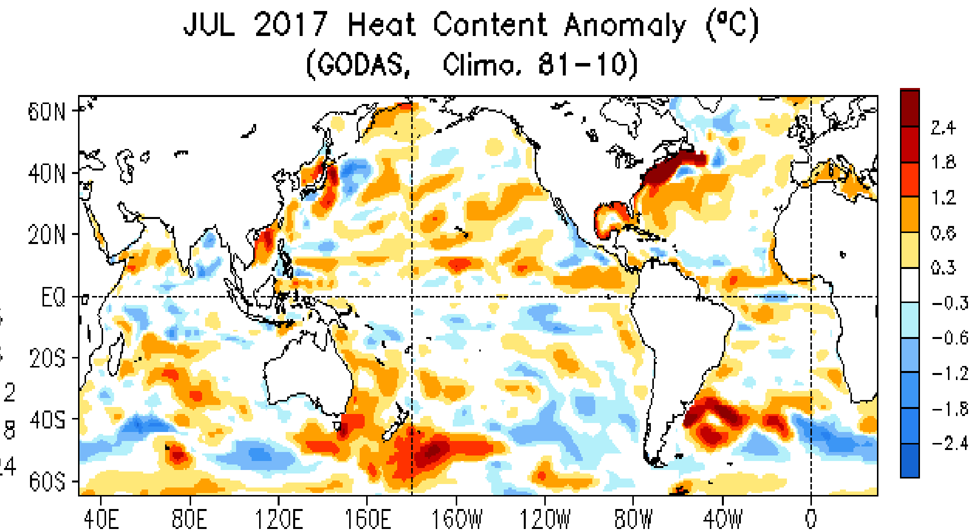


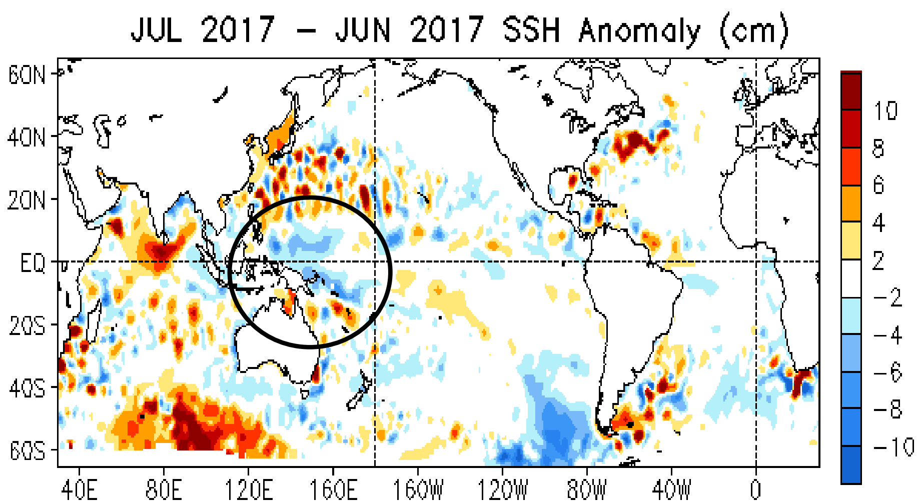
- SSTA tendencies were small in the tropical Pacific.
- SSTA tendencies were mostly positive in the Indian Ocean.
- Both positive and negative SSTA tendencies presented in the N. Atlantic, which may be associated the positive phase of NAO in the last 2 months.

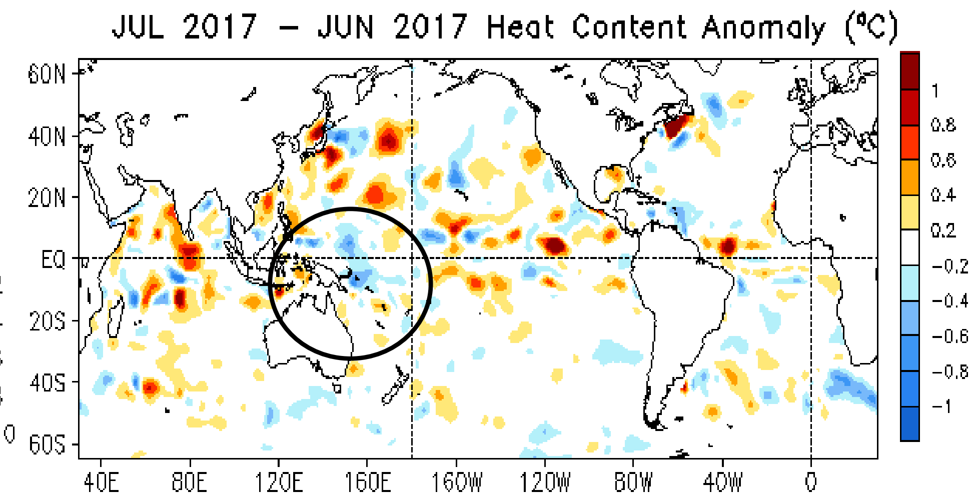
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

Global SSH and HC300 Anomaly & Anomaly Tendency



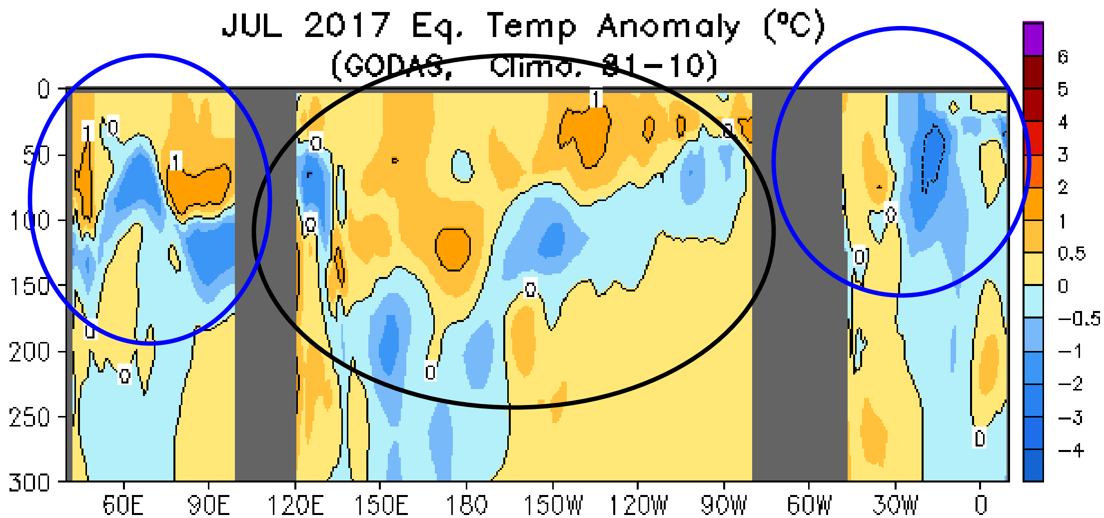




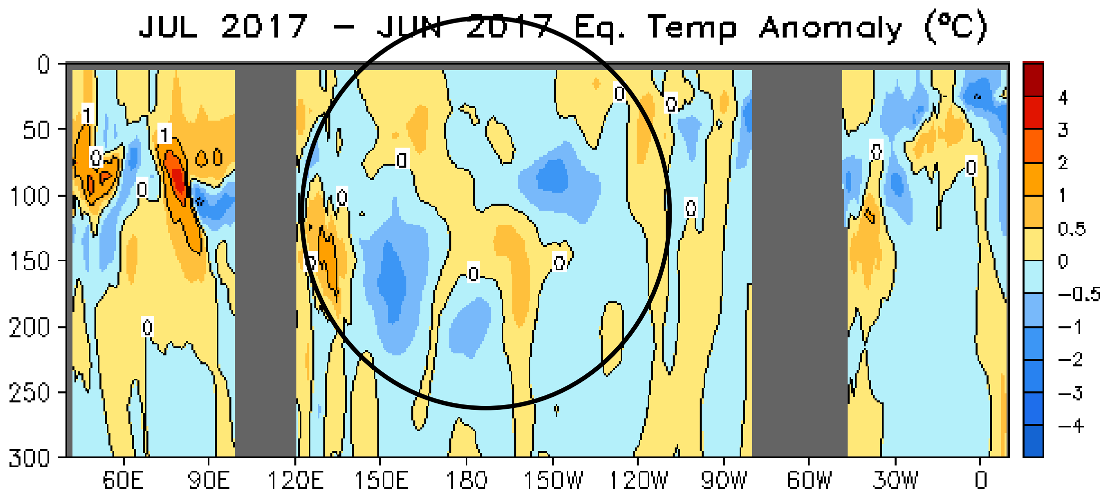


- Overall, both SSHA and HC300A were small in the tropical Pacific, consisting with neutral phase of ENSO.
- Negative tendency was observed in both SSHA and HC300A in the western equatorial Pacific.

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



- **Positive (negative) ocean temperature anomalies were small and presented above (along) the thermocline.**
- **Both positive and negative ocean temperature anomalies were observed in the Indian and Atlantic Oceans.**

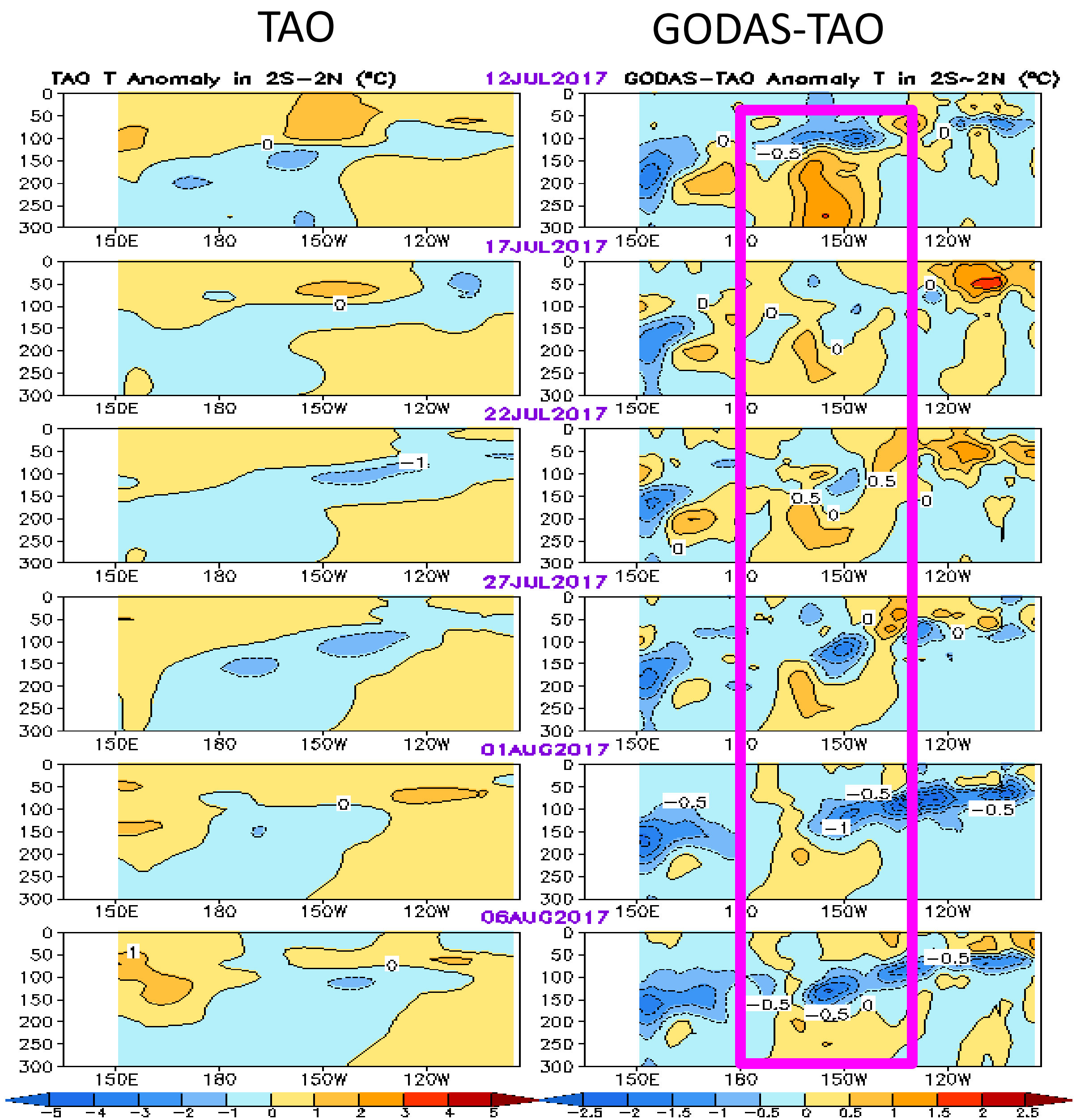


- **Both positive and negative tendencies of ocean temperature anomaly presented along the equatorial Pacific.**

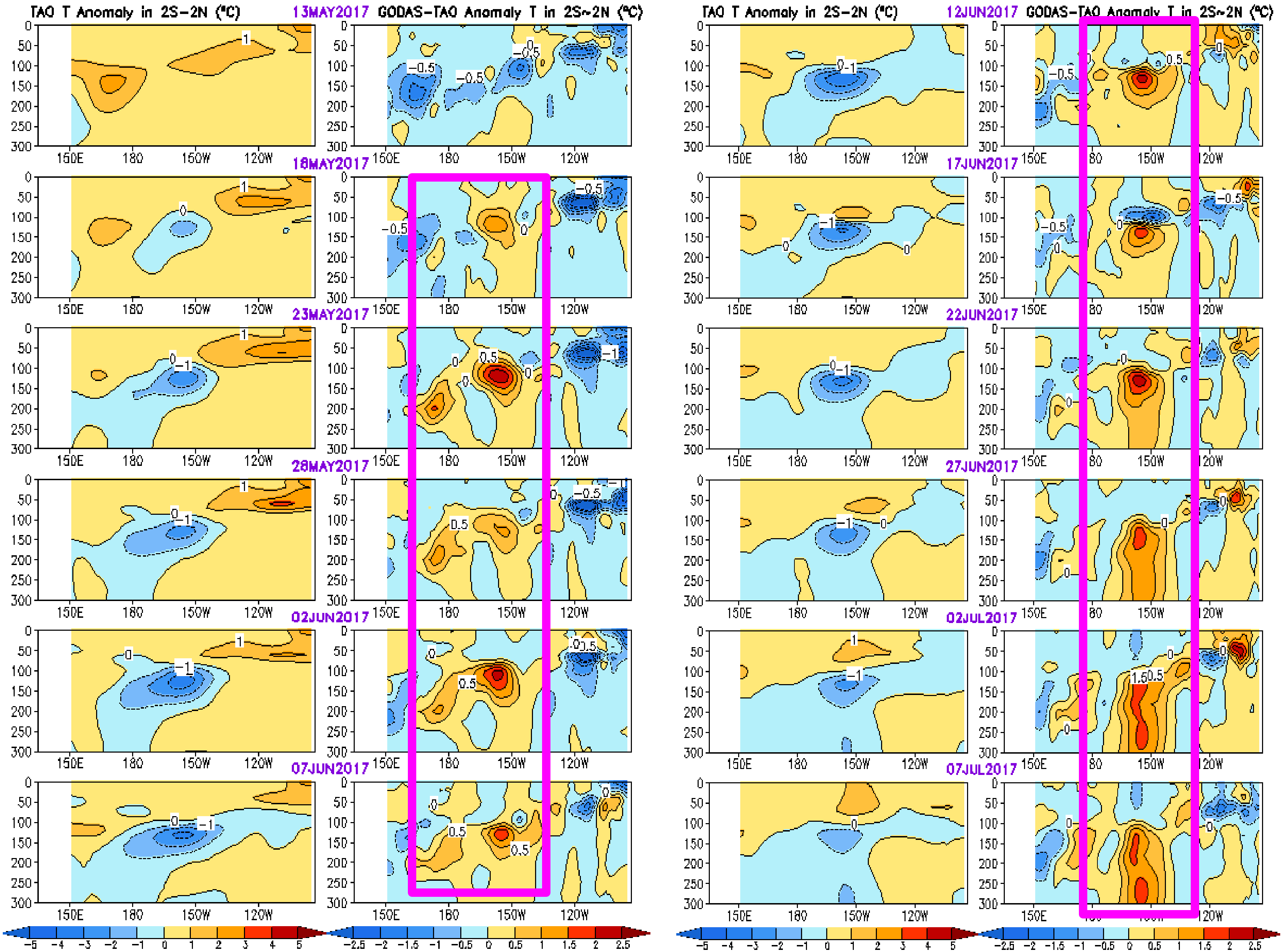
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1981-2010 base period means.

Tropical Pacific Ocean and ENSO Conditions

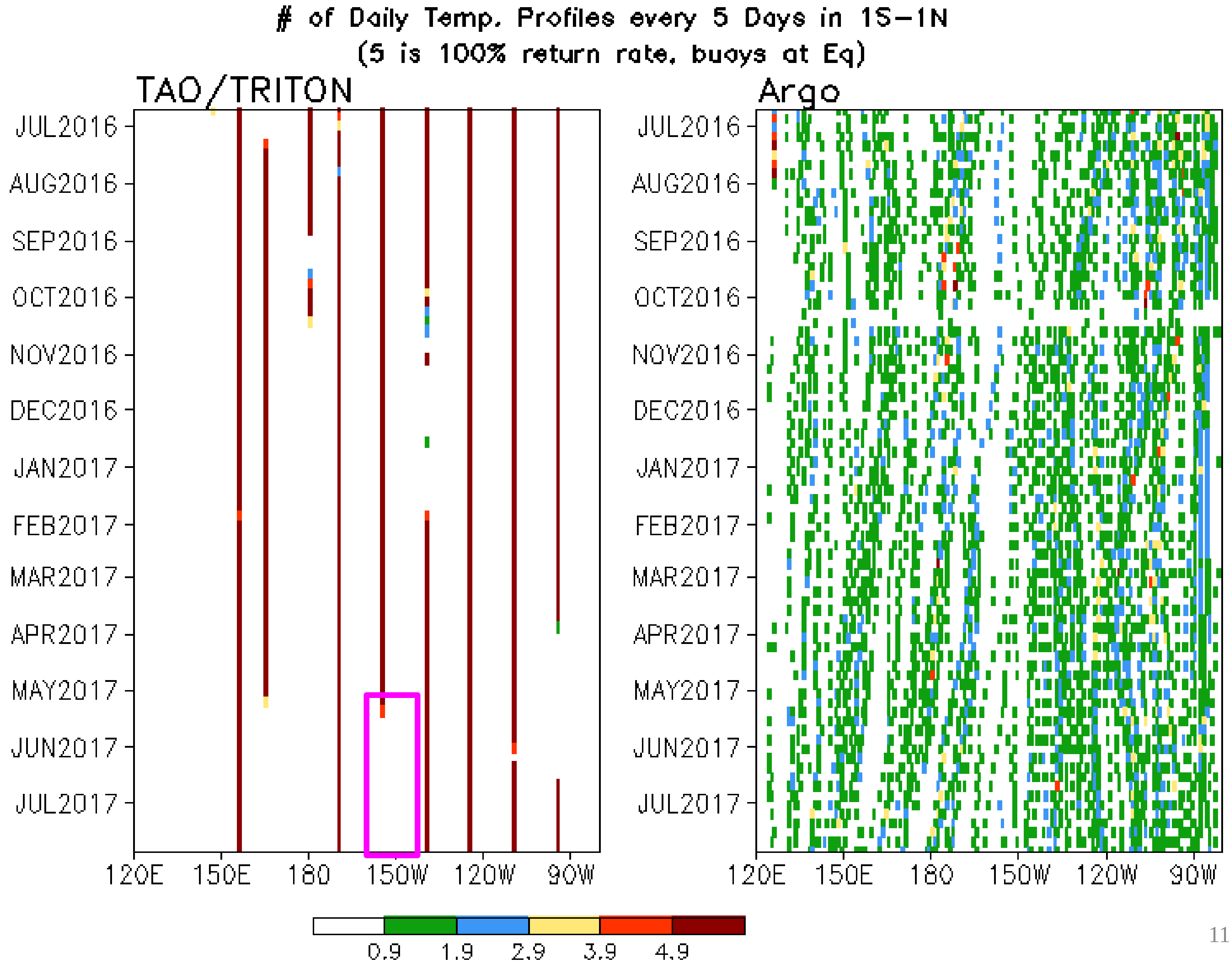
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



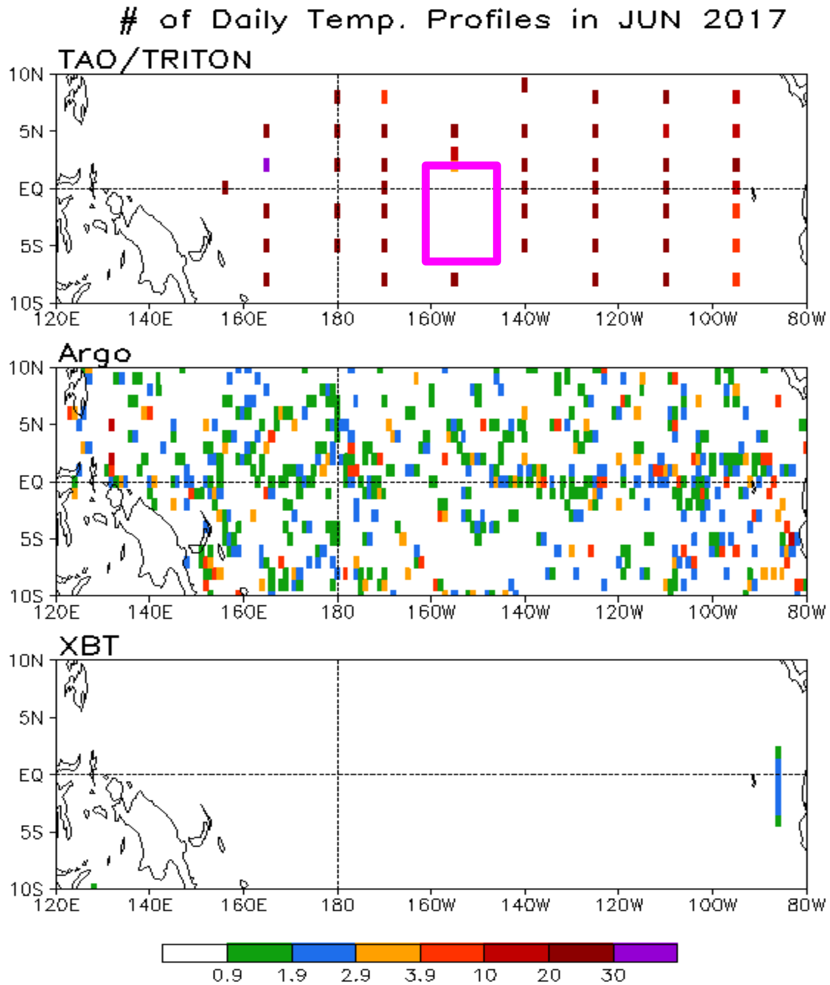
- Ocean temperature anomalies were small negative in the Pacific without propagation.
- The differences between TAO and GODAS along 150W presented.

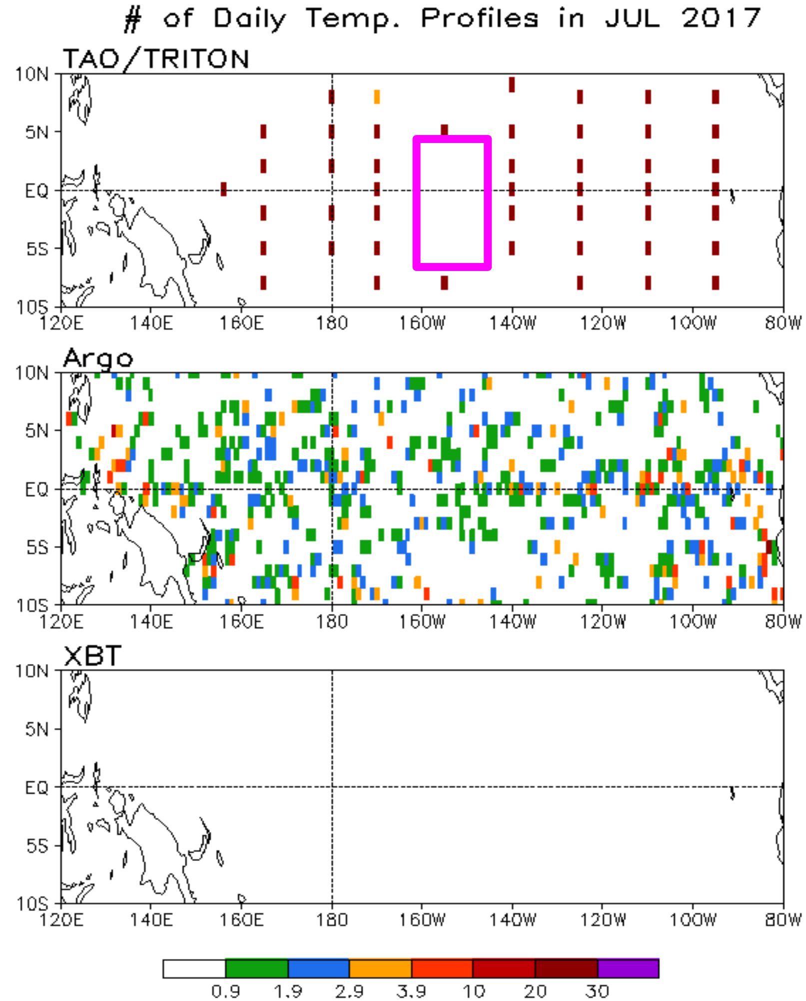


TAO T Anomaly in 2S-2N (°C)
GODAS-TAO Anomaly T in 2S~2N (°C)
13MAY2017
18MAY2017
23MAY2017
28MAY2017
02JUN2017
07JUN2017
12JUN2017
17JUN2017
22JUN2017
27JUN2017
02JUL2017
07JUL2017
150E
180
150W
120W
0
50
100
150
200
250
300
-5 -4 -3 -2 -1 0 1 2 3 4 5
-2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5



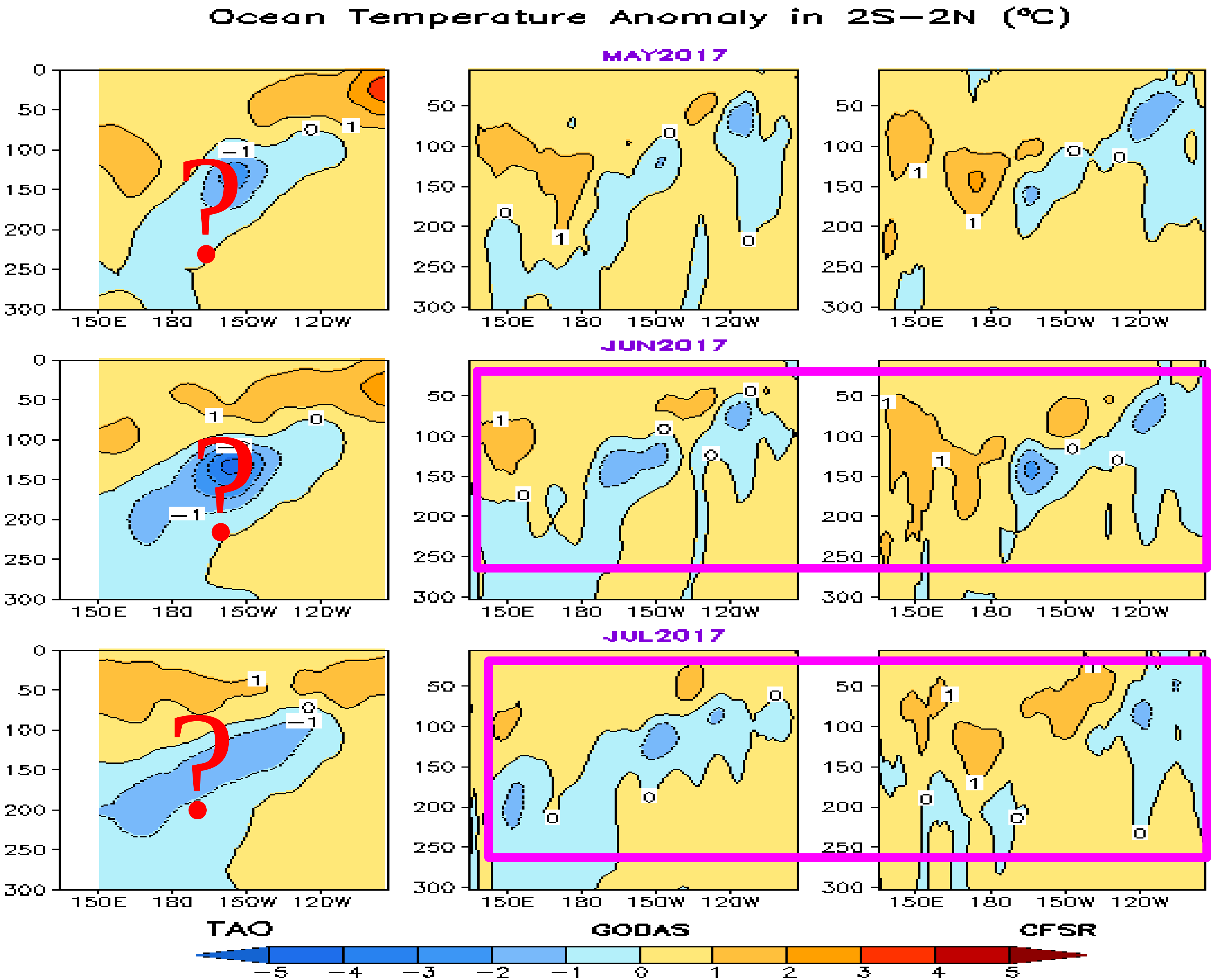
# of Daily Temp. Profiles every 5 Days in 1S-1N
(5 is 100% return rate, buoys at Eq)
TAO/TRITON
Argo
JUL2016
AUG2016
SEP2016
OCT2016
NOV2016
DEC2016
JAN2017
FEB2017
MAR2017
APR2017
MAY2017
JUN2017
JUL2017
120E
150E
180
150W
120W
90W
0.9
1.9
2.9
3.9
4.9





- **According to Karen Grissom at NDBC , the buoy at 155W, 2N started to drift on May 29. When it drifted outside its data grid (160W - 150W by 3N - 1N) on June 20, NDBC stopped releasing data to the GTS.**

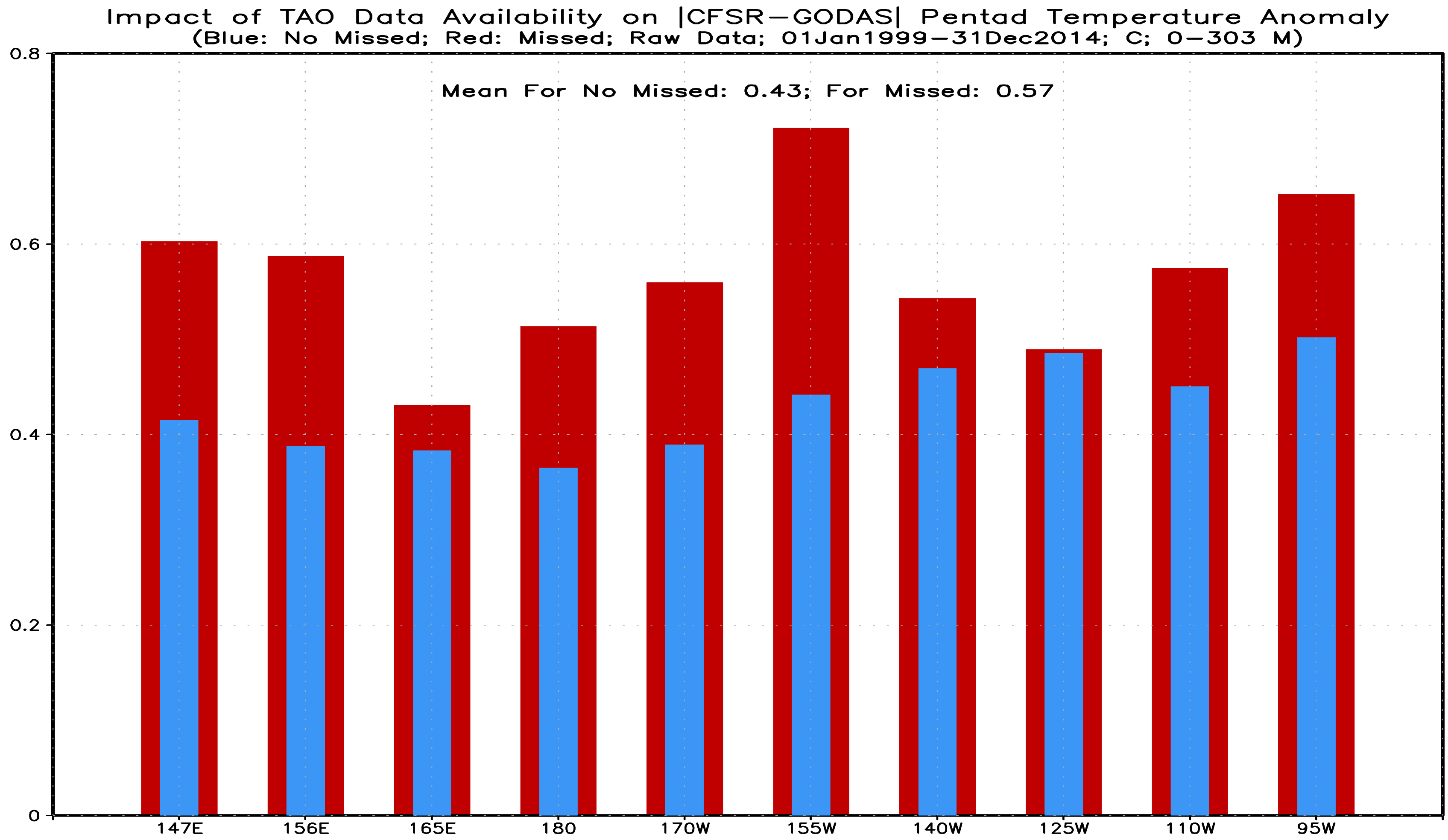
- **Since the three buoys at 155W (0, 2N, 2S) had lots of missing data in the last two months, the TAO analysis may not be reliable since it was calculated as the average of the buoy temperature in nearby buoys according to Dai Mcclurg (NOAA/PMEL).**



Ocean Temperature Anomaly in 2S-2N (°C)
MAY2017
JUN2017
JUL2017
TAO
GODAS
CFSR
150E
180
150W
120W
0
50
100
150
200
250
300
-5
-4
-3
-2
-1
0
1
2
3
4
5

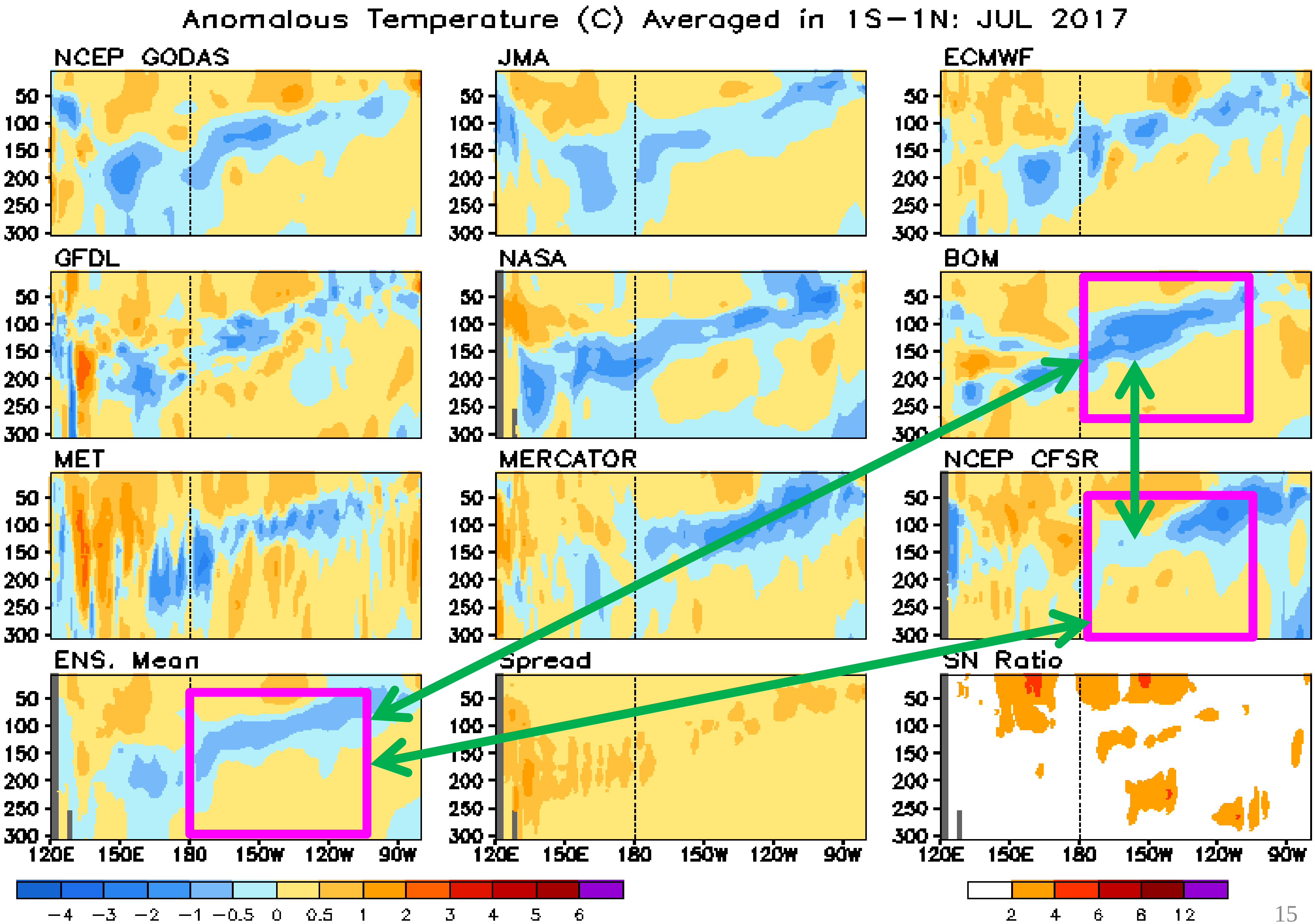
Impact of availability of TAO observations on pentad mean OTA differences |CFSR-GODAS| averaged 5-303m: Differences are mainly along the thermocline

Differences are larger when TAO observations unavailable than available

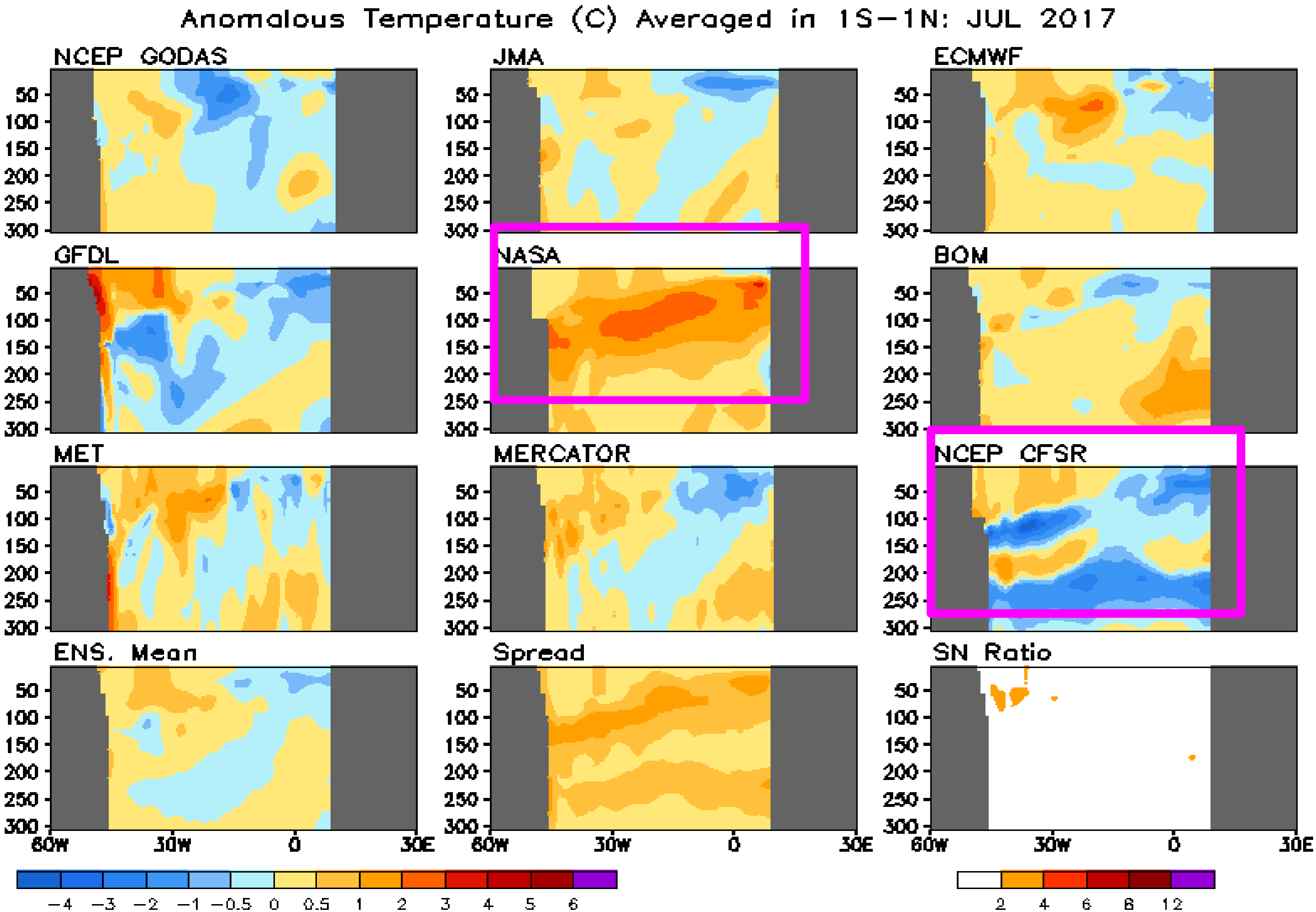


Hu, Z.-Z. and A. Kumar, 2015: Influence of availability of TAO data on NCEP ocean data assimilation systems along the equatorial Pacific. *J. Geophys. Res. (Ocean)*, **120**, 5534-5544. DOI: 10.1002/2015JC010913.

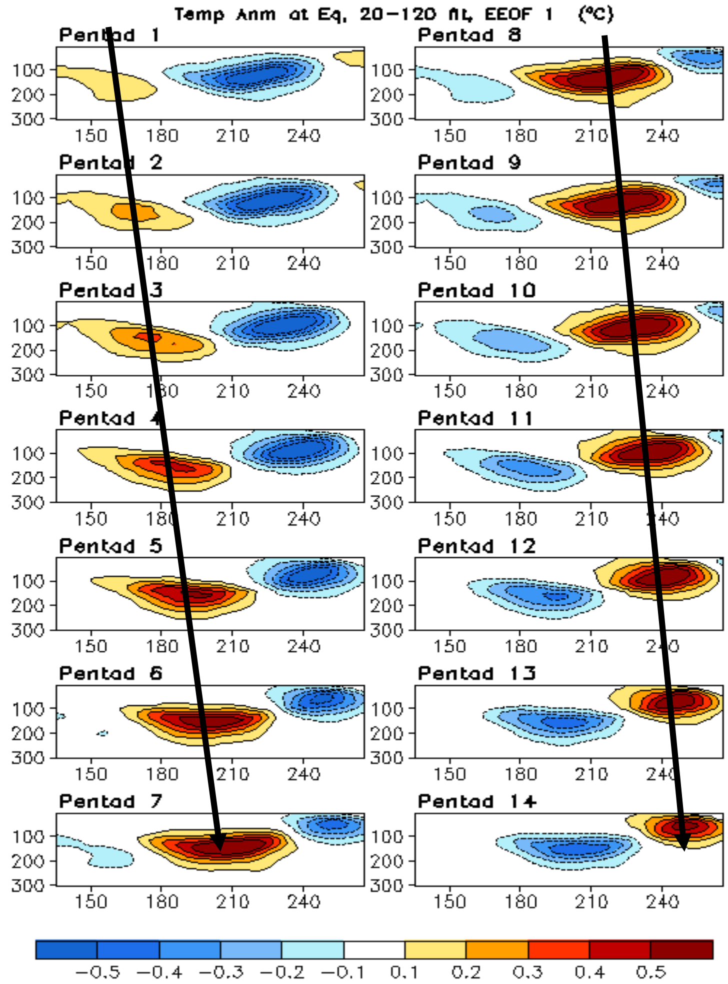
CFSR (NASA) was warmer (cooler) than the ensemble mean along the thermocline of the central and western Pacific

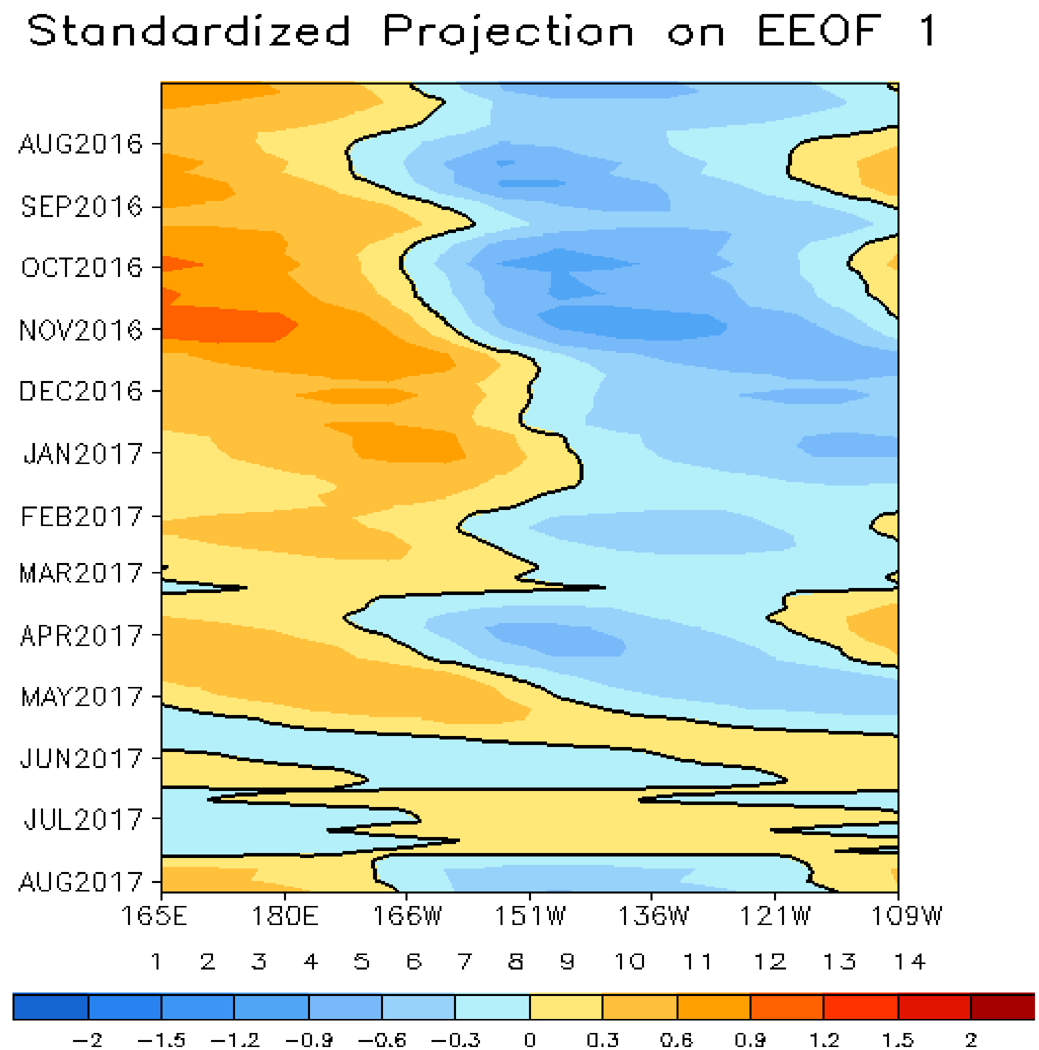


CFSR (NASA) was much cooler (warmer) than the ensemble mean in Atlantic



Oceanic Kelvin Wave (OKW) Index

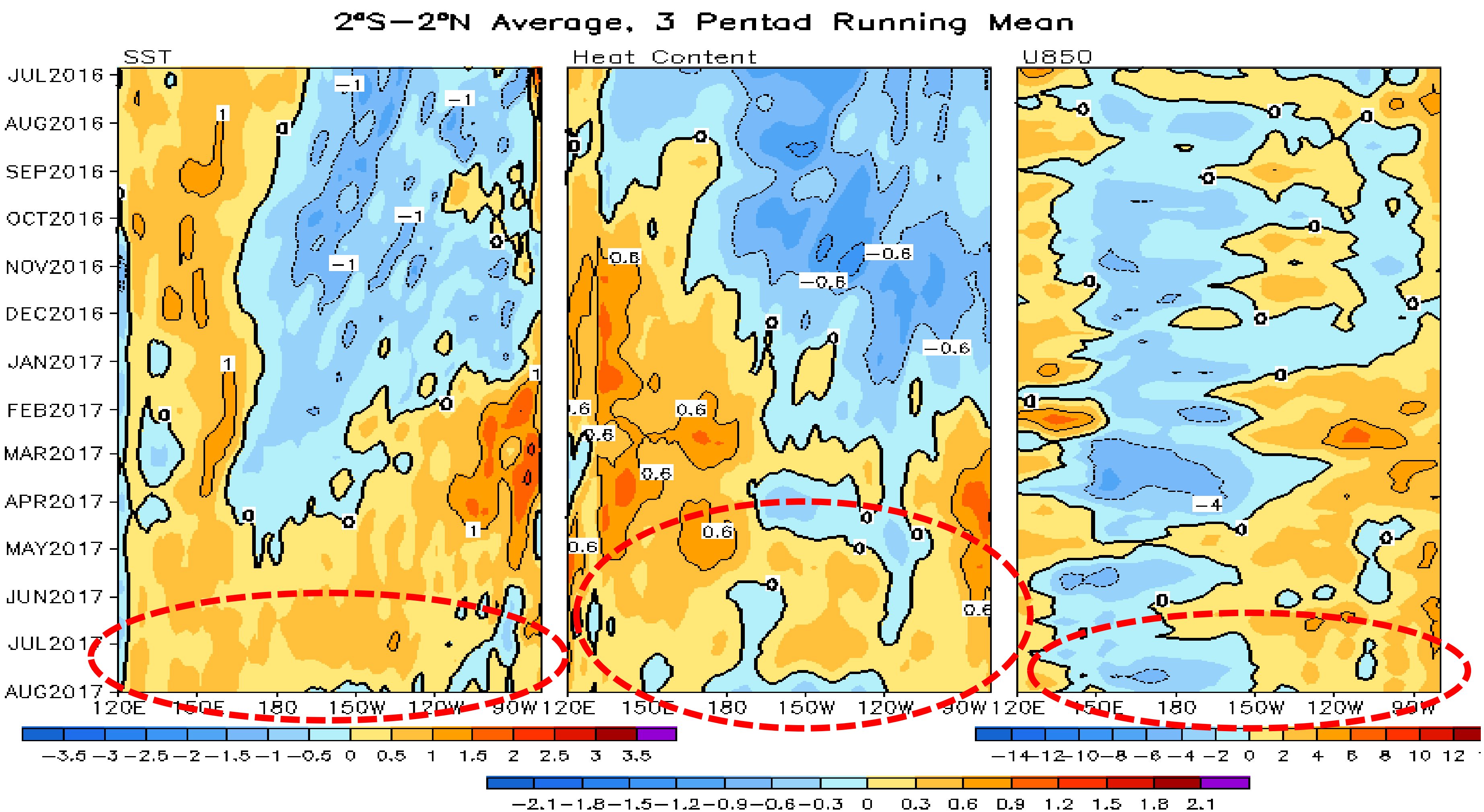




- **OKW activity was weak during last two months.**

- *(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).)*

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



- **Positive SSTAs weakened in the central and eastern equatorial Pacific in last month.**
- **Positive HC300A weakened in last month. Negative HC300A emerged in late July, which may be associated with enhanced easterly wind anomalies.**
- **Low-level wind anomalies were weak westerly in the eastern equatorial Pacific and easterly in the central Pacific in Jul 2017.**

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

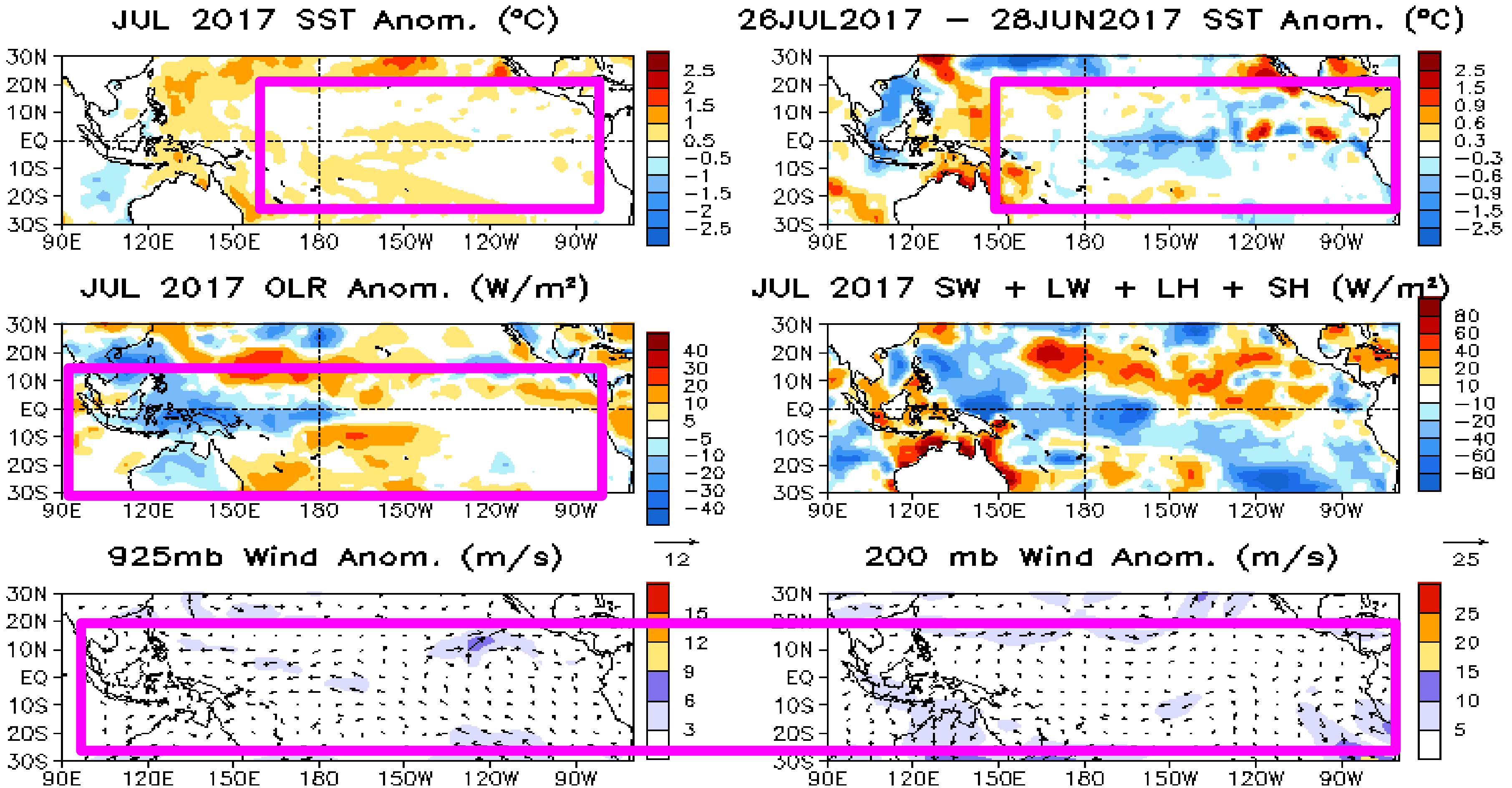
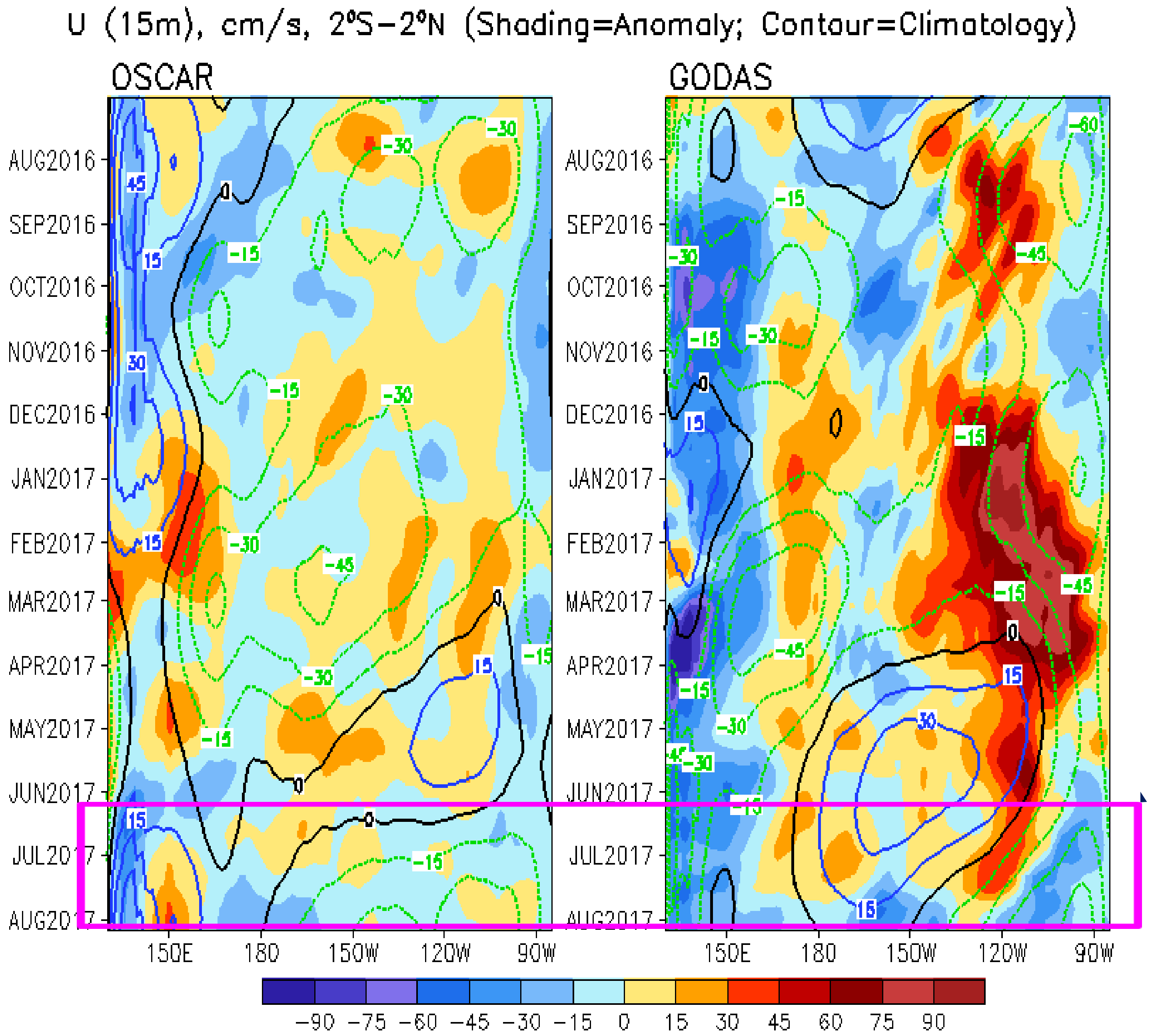


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

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



- The anomalous currents shifted from eastward to westward in Jul 2017.

- There were large differences between OSCAR and GODAS during Nov 2016 – Jul 2017.

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) has been small since Dec 2016.**

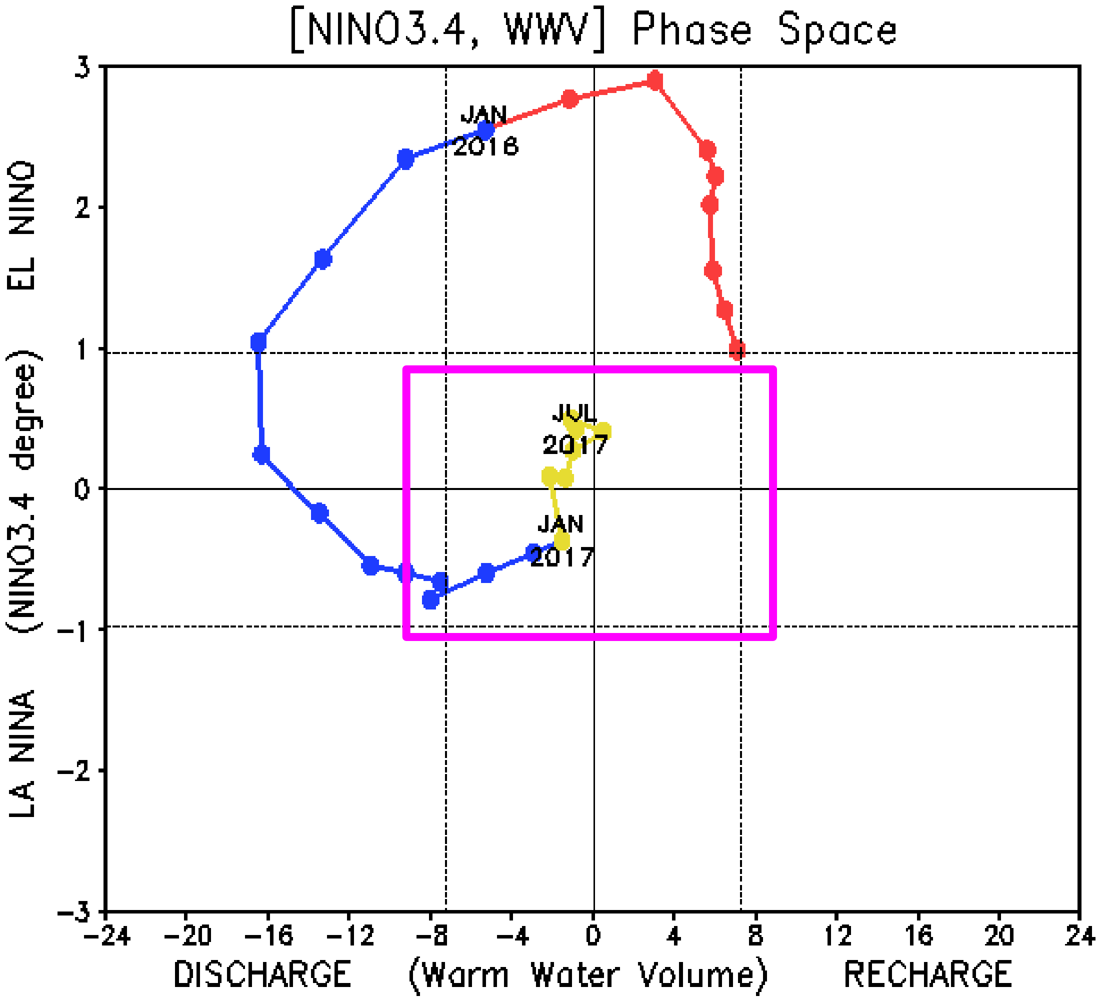
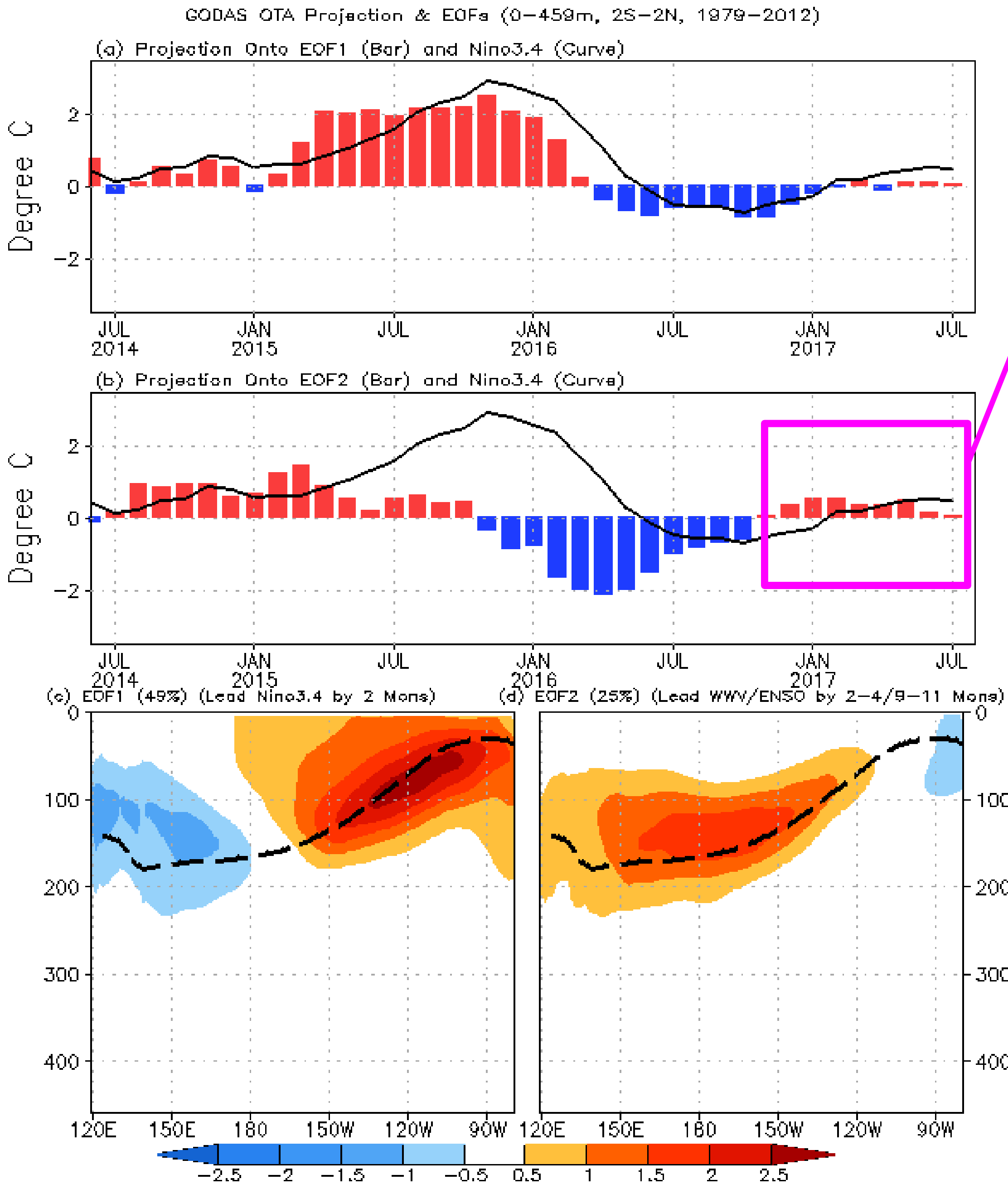


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.



Equatorial subsurface ocean temperature monitoring: Right now, ENSO was in weak recharge phase since Nov 2016.

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

EOF1: Tilt mode (ENSO peak phase);

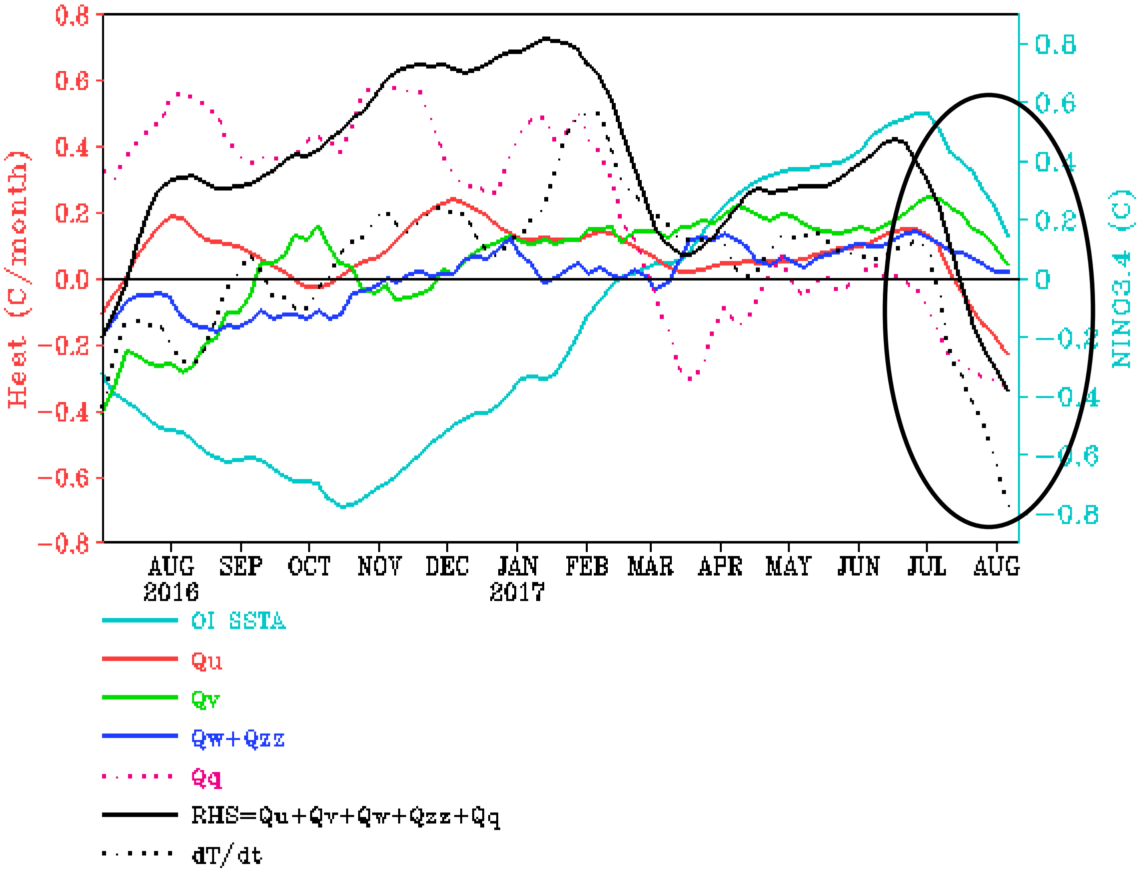
EOF2: WWV mode, Recharge/discharge oscillation (ENSO transition phase).

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 conJulction with ENSO. Clim. Dyn., 42 (5-6), **1243-1258.** *DOI: 10.1007/s00382-013-1721-0*.

NINO3.4 Heat Budget



- **Both observed SSTA tendency (dT/dt; dotted black line) and total budget tendency (RHS; solid black line) in Nino3.4 region became negative in Jul 2017.**

- **All dynamical terms (zonal advection Qu, meridional advection Qv, vertical terms Qw+Qzz), as well as heat flux term (Qq) showed a decrease tendency in Jul 2017.**

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.

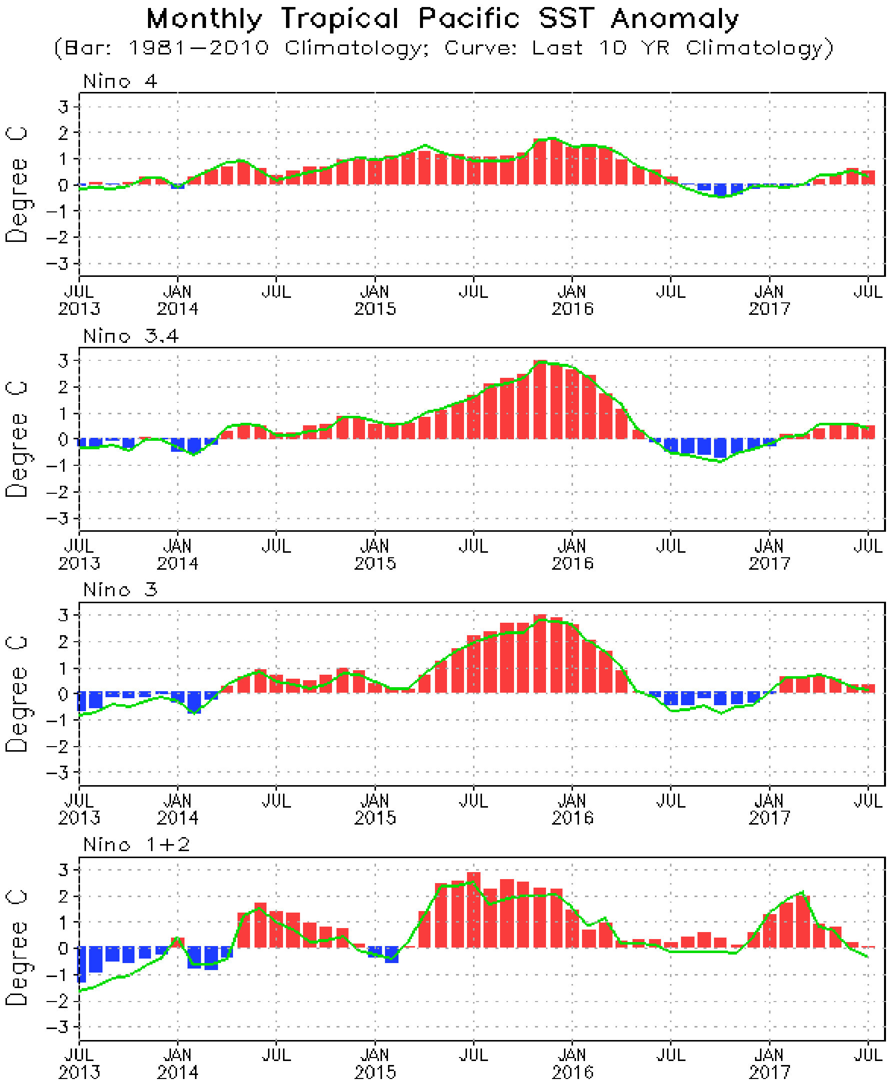
Qu: Zonal advection; Qv: Meridional advection;

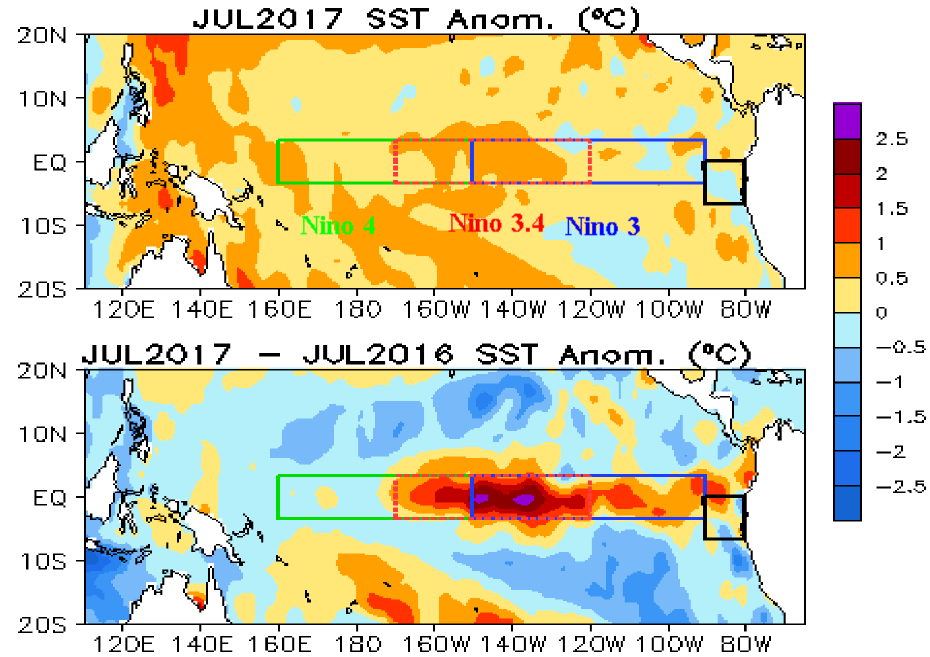
Qw: Vertical entrainment; Qzz: Vertical diffusion

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 Nino indices were still positive , but decreased or persisted in Jul 2017.**

- **Nino3.4 = 0.4°C in Jul 2017.**

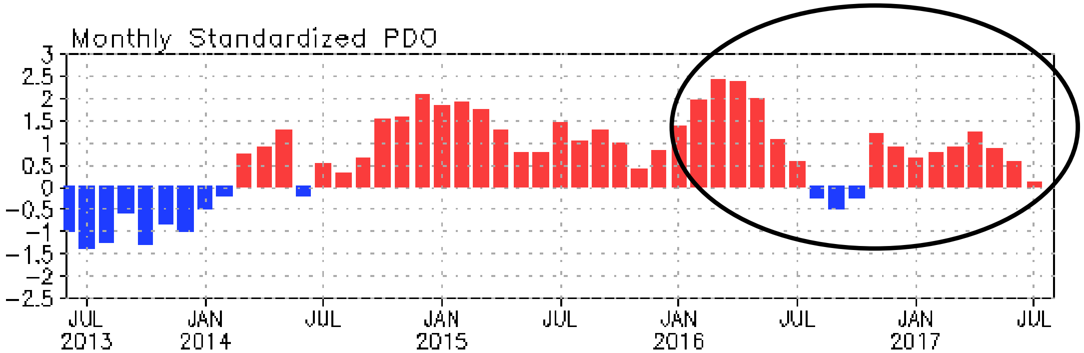
- **Compared with last Jul, the central and eastern equatorial Pacific was much warmer in Jul 2017.**

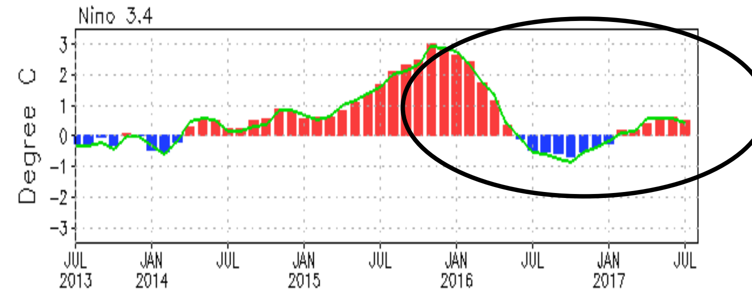
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v4.**

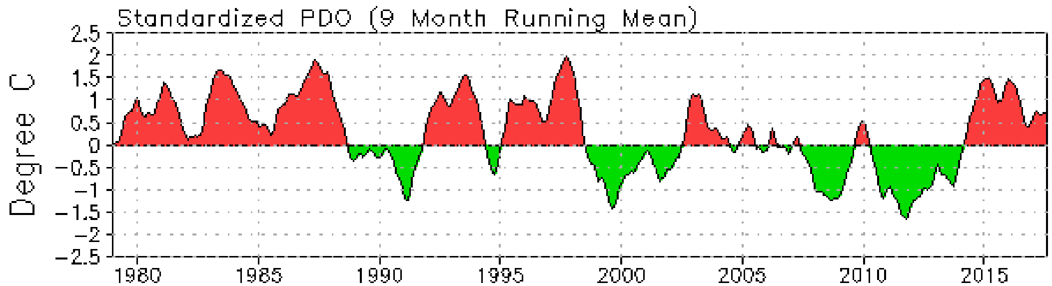
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

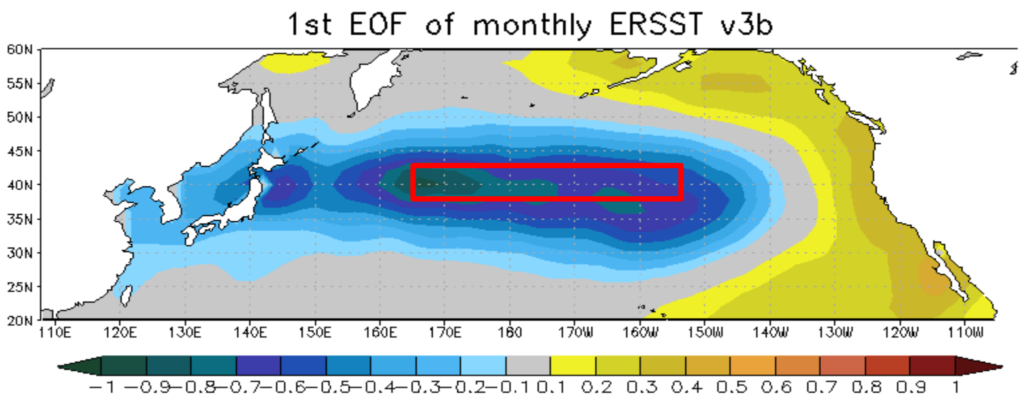
North Pacific & Arctic Oceans

PDO index









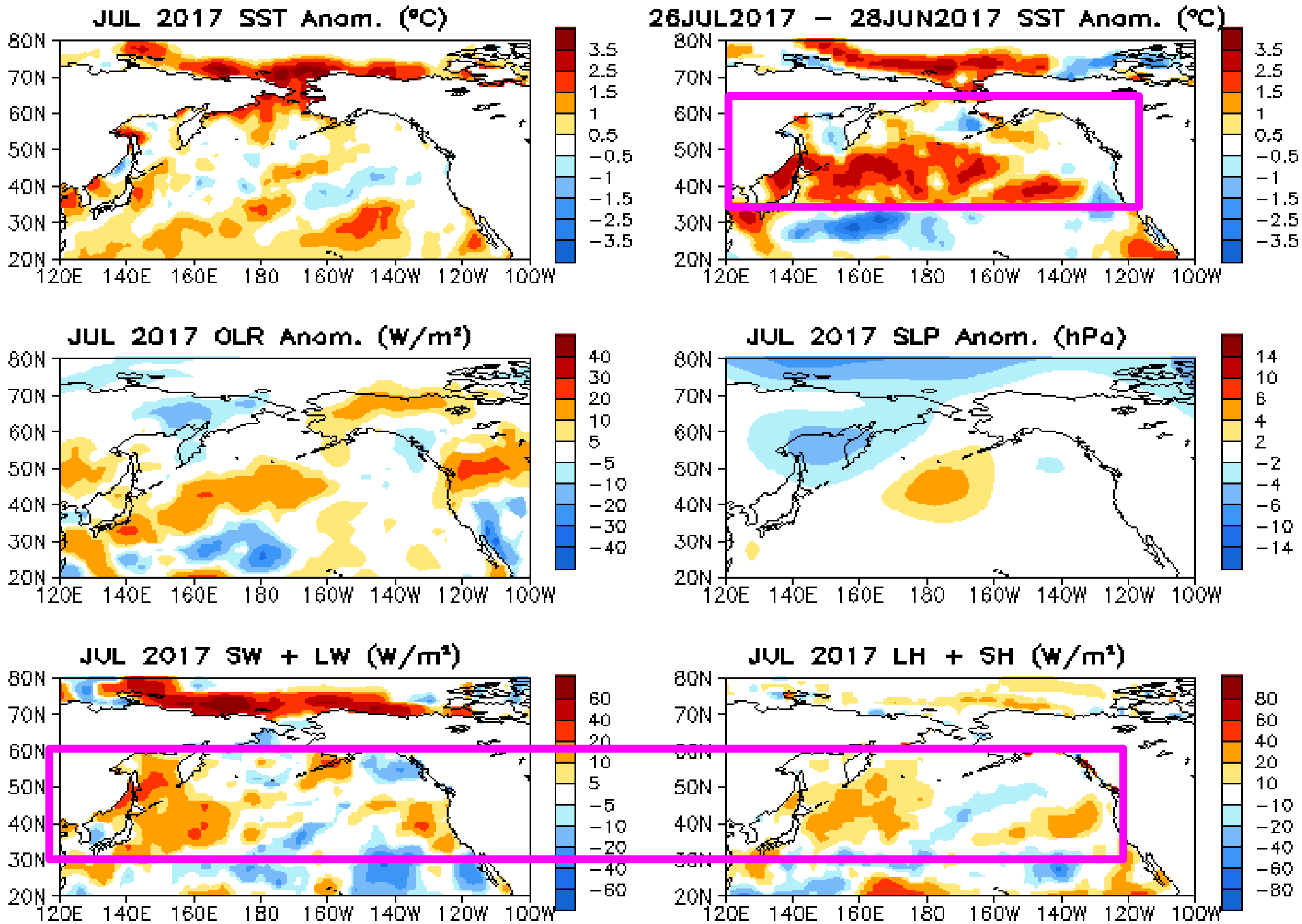
- Positive phase of PDO index has persisted 9 months since Nov 2016, and its intensity has weakened significantly during last 3 months with PDO index =0.1 in Jul 2017.

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

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

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

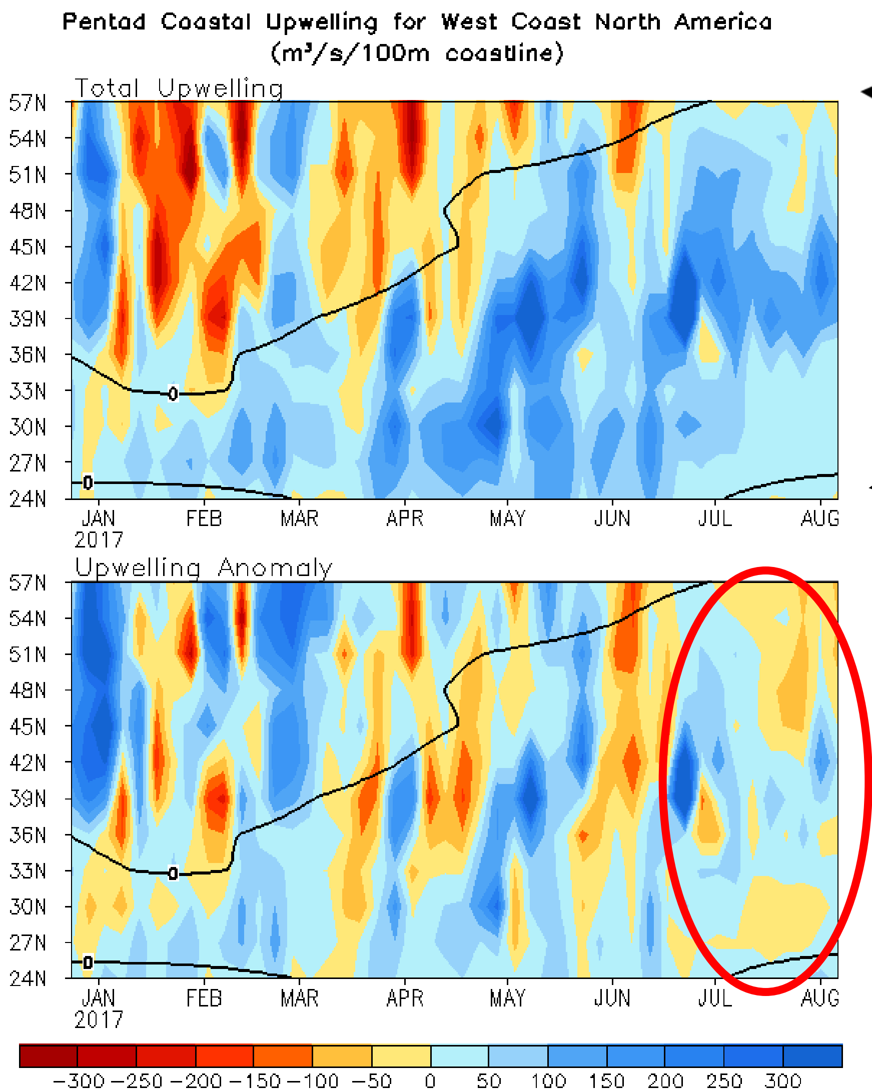
North Pacific & Arctic Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx

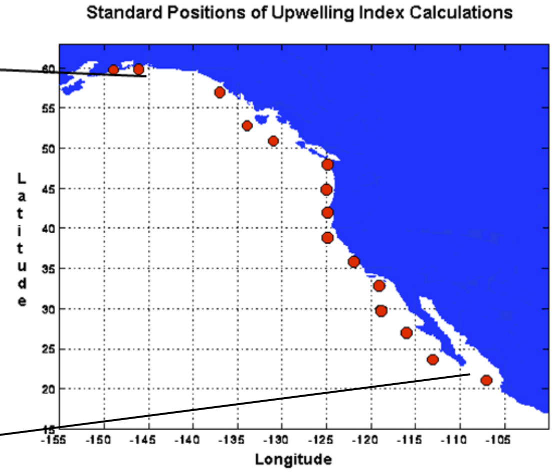


- Strong positive tendencies of SSTA presented along 35-50°N of the N. Pacific, which seems partially associated with heat flux anomalies.

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





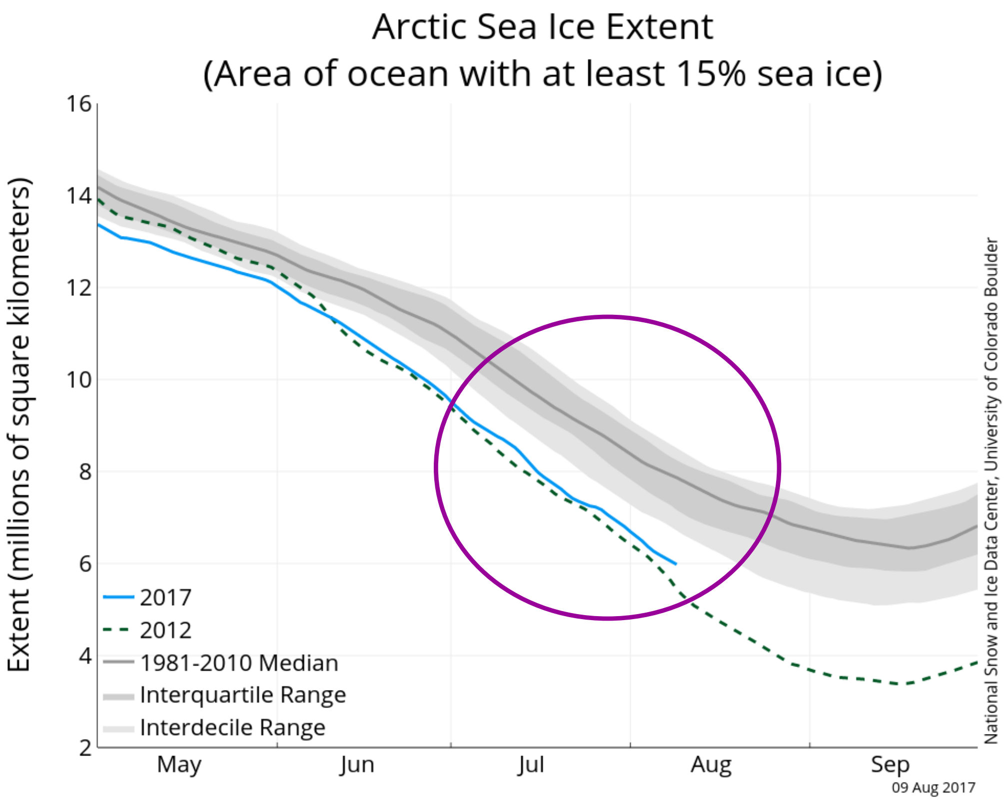
- **Both anomalous downwelling and upwelling were small along the coast in Jul 2017.**

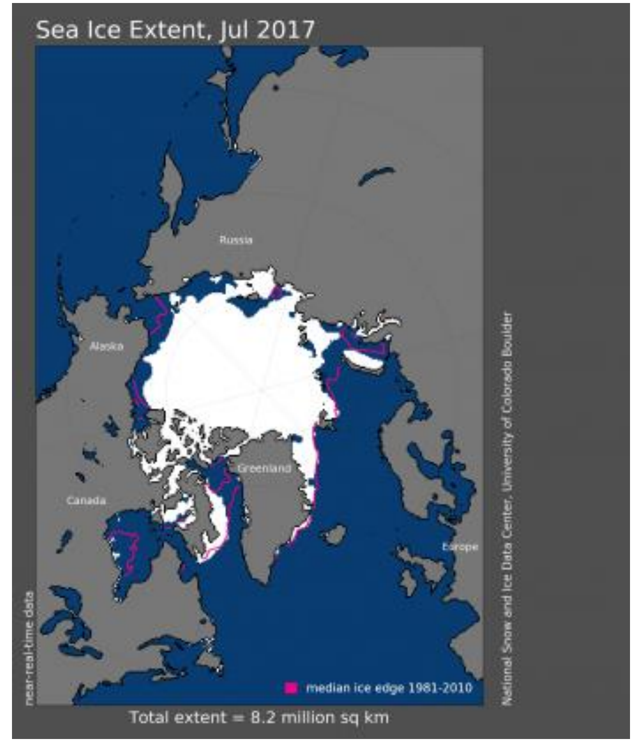
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1981-2010 base period pentad means.

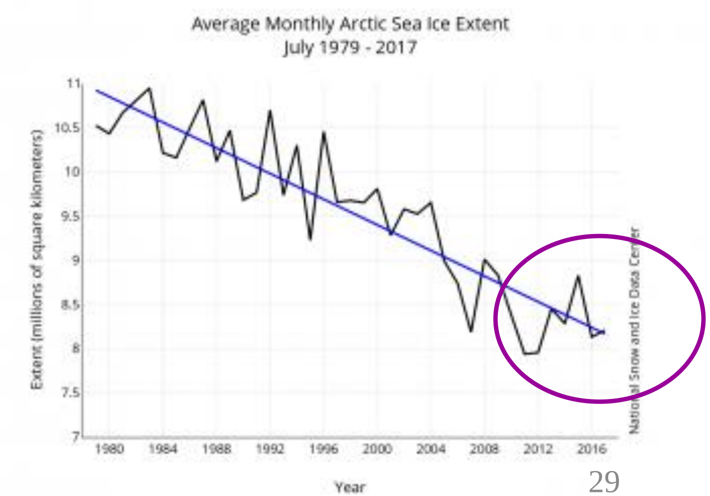
- **Area below (above) black line indicates climatological upwelling (downwelling) season.**
- **Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.**

Arctic Sea Ice

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



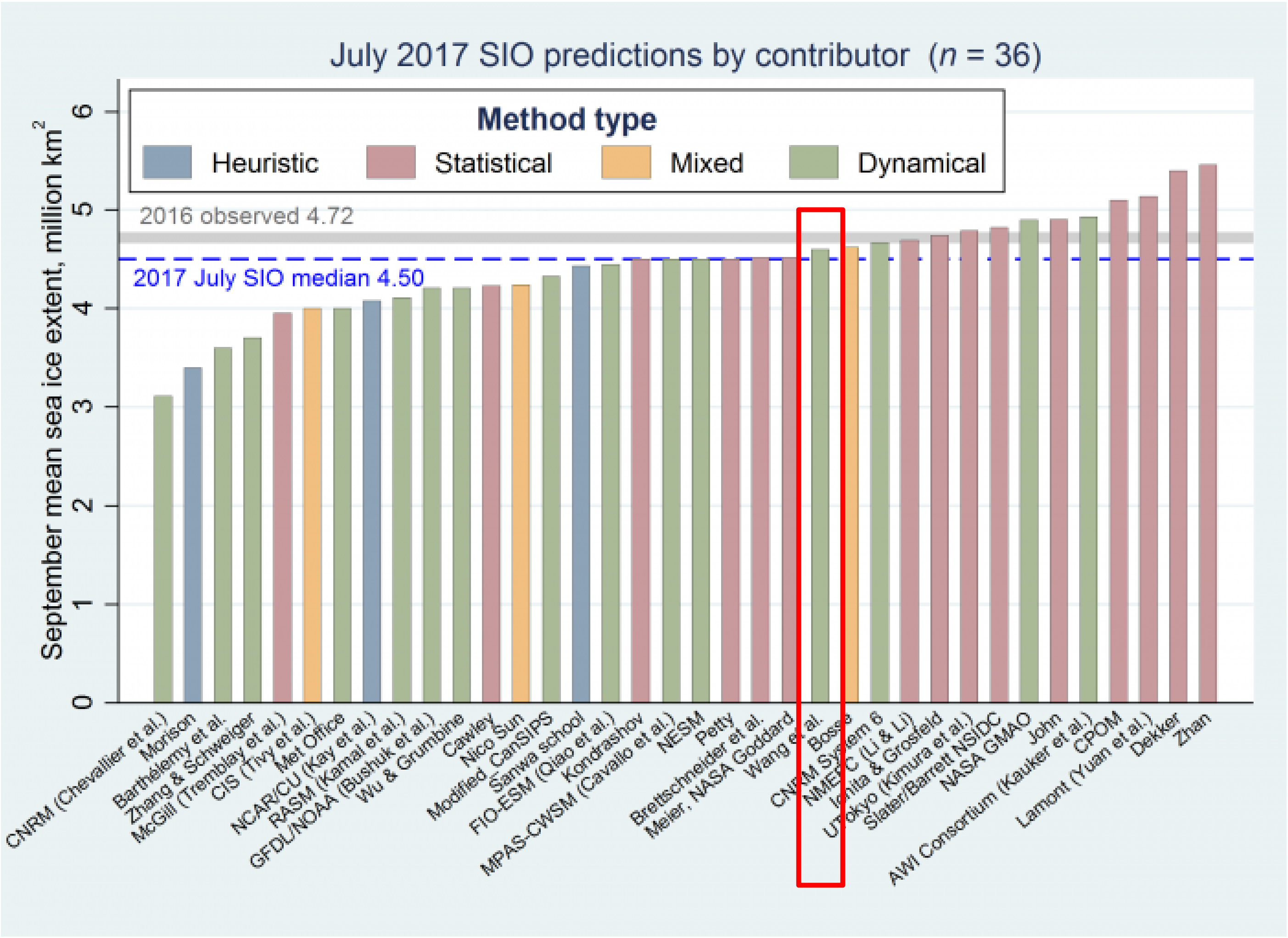




- Arctic sea ice extent averaged for July 2017 was 8.21 million square kilometers, the fifth lowest July in the 1979 to 2017 satellite record.

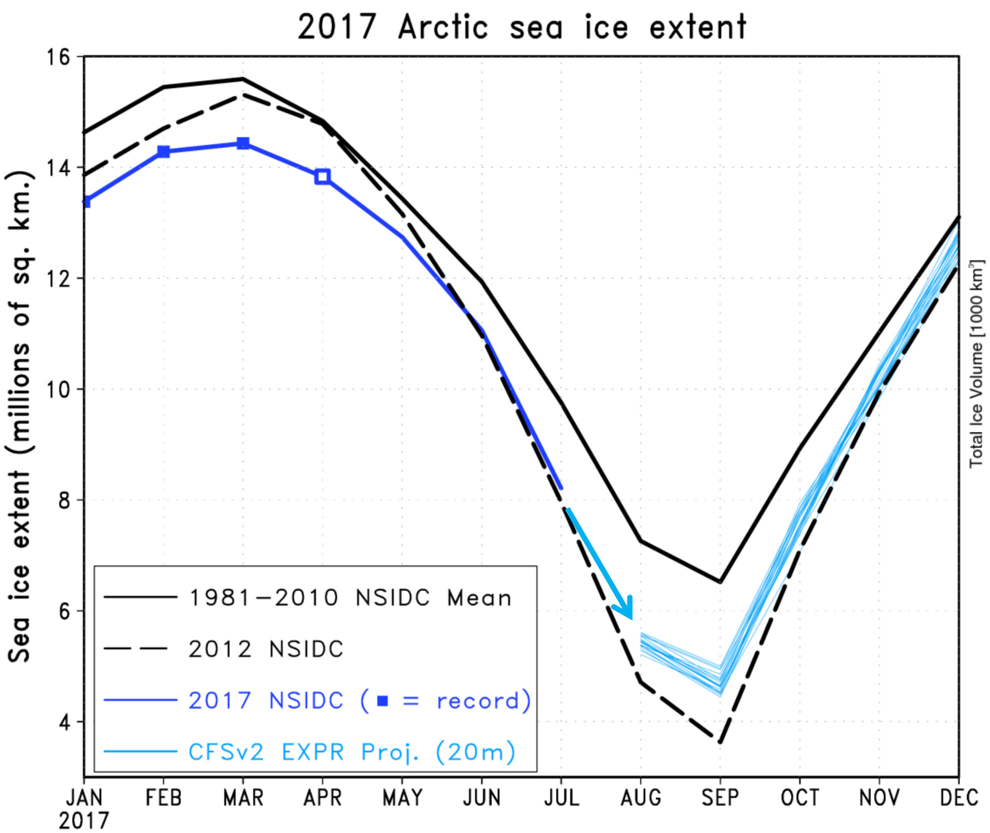
- Current sea ice extent was close to 2012.

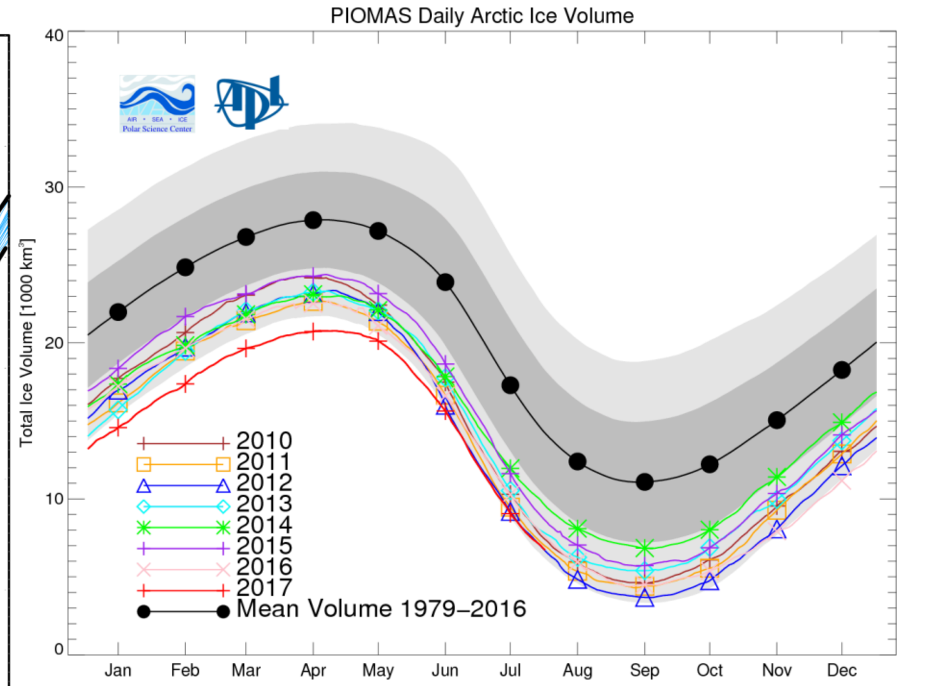
Arctic Sea Ice



- **Outlooks above are based on June data. Our September sea ice extent forecast from June of 4.60 million km^2 is close to the median of all outlooks (4.50 million km^2).**

- **June SIPN median was 4.43 million km^2, so both our forecast and the median adjusted up slightly**

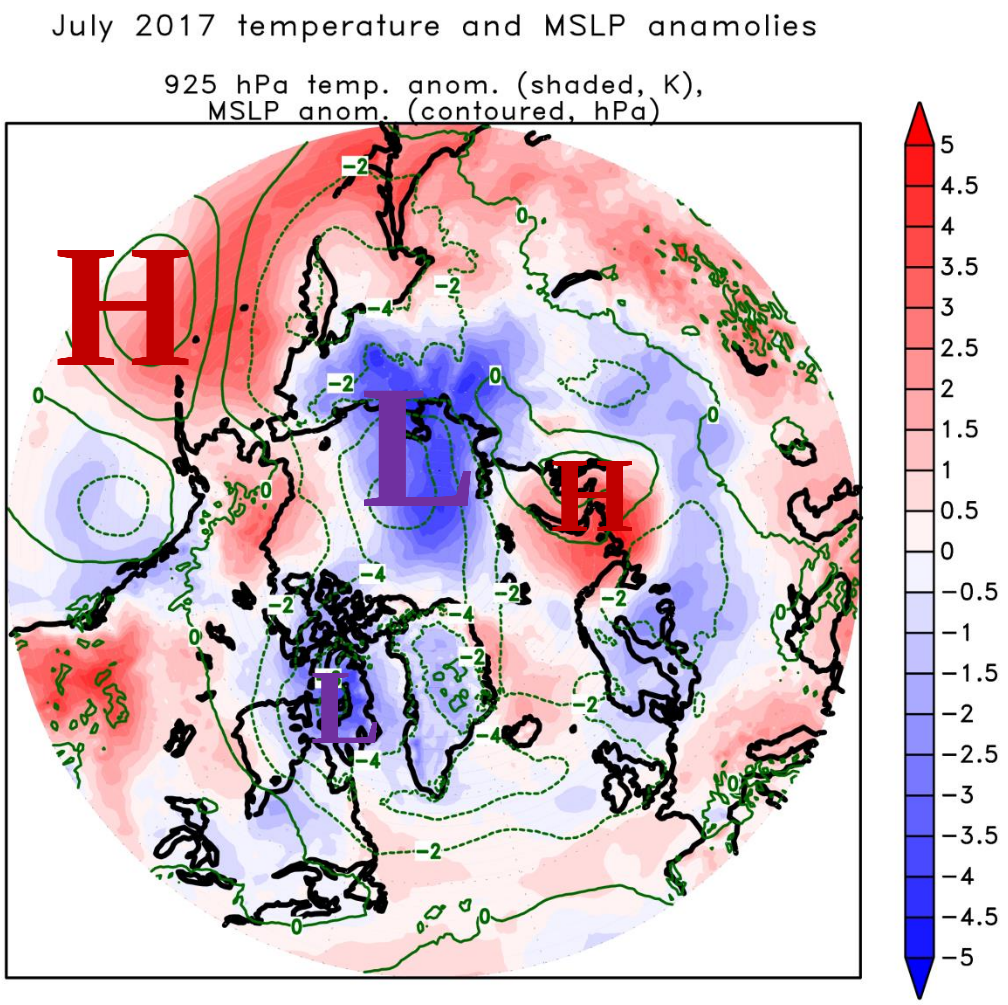




- Arctic sea ice has experienced steady decline throughout the month of July, with the rate of decline being slightly faster than the long term average

- Experimental July sea ice forecast slightly adjusted upward to an ensemble mean prediction of 4.68 million km^2

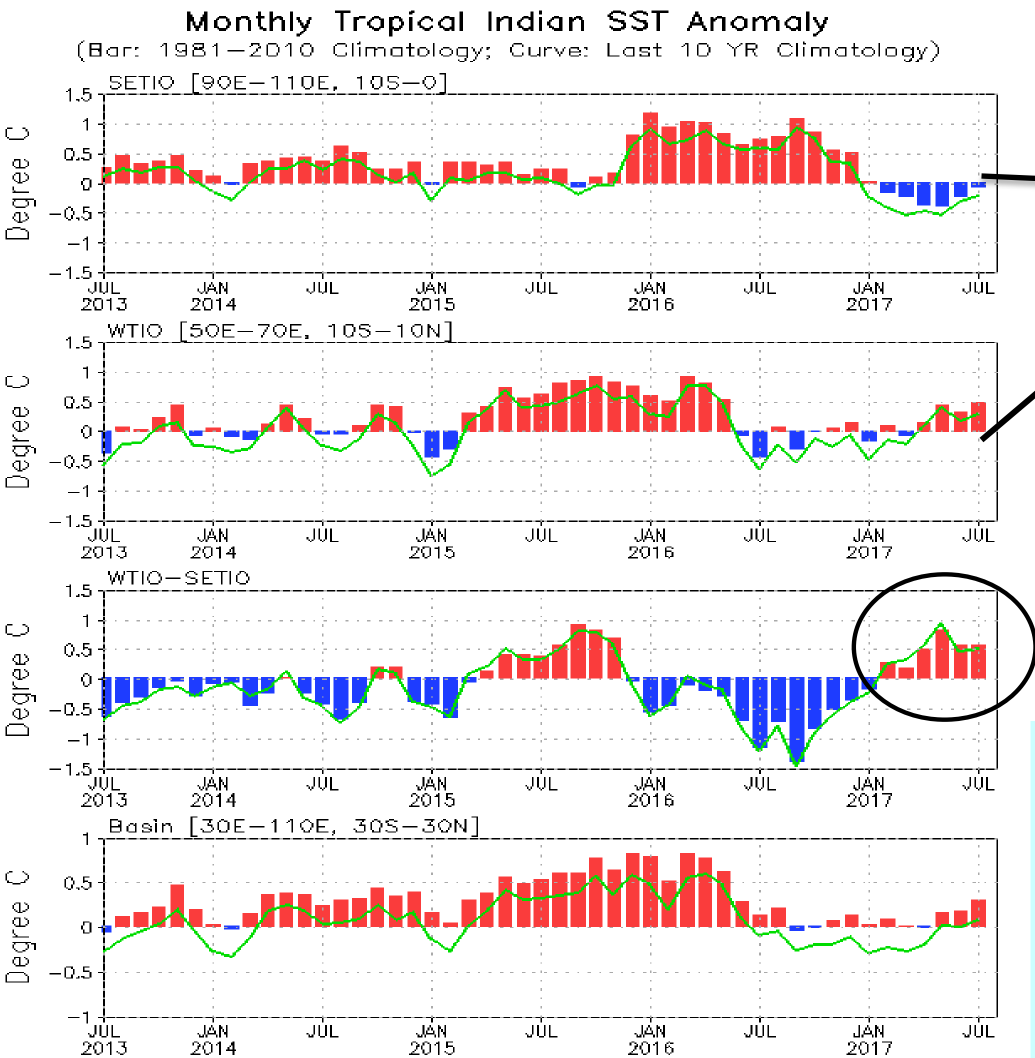
- Sea ice volume remains less of an outlier (still on the low end of the 2010-2016 spectrum)

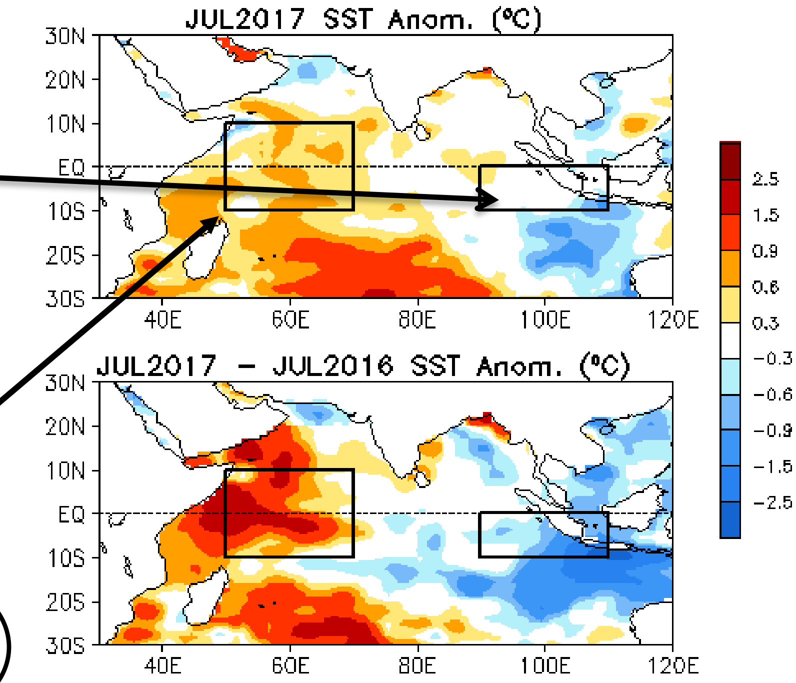


- Complex temperature pattern over Arctic in July
- Ridge over Alaska with positive temperature anomalies extending into the Beaufort Sea.
- Positive temperature anomalies over Barents/Kara Seas.
- Low pressure and negative temperature anomalies over the Canadian Archipelago and north Siberian coast
- Generally lower pressure in the Central Arctic is unfavorable for rapid sea ice loss

Indian Ocean

Evolution of Indian Ocean SST Indices





- **SSTAs were positive in the western and negative in the eastern Indian Ocean, respectively.**
- **Dipole index was positive during last 6 months, and Basin index was positive since May 2017.**

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.

- Overall, SSTAs were positive in the west and negative in the east.
- SSTA tendency was small in the tropics, which may not be mainly determined by heat flux anomalies.
- Convections were suppressed over the tropical N. Indian Ocean.

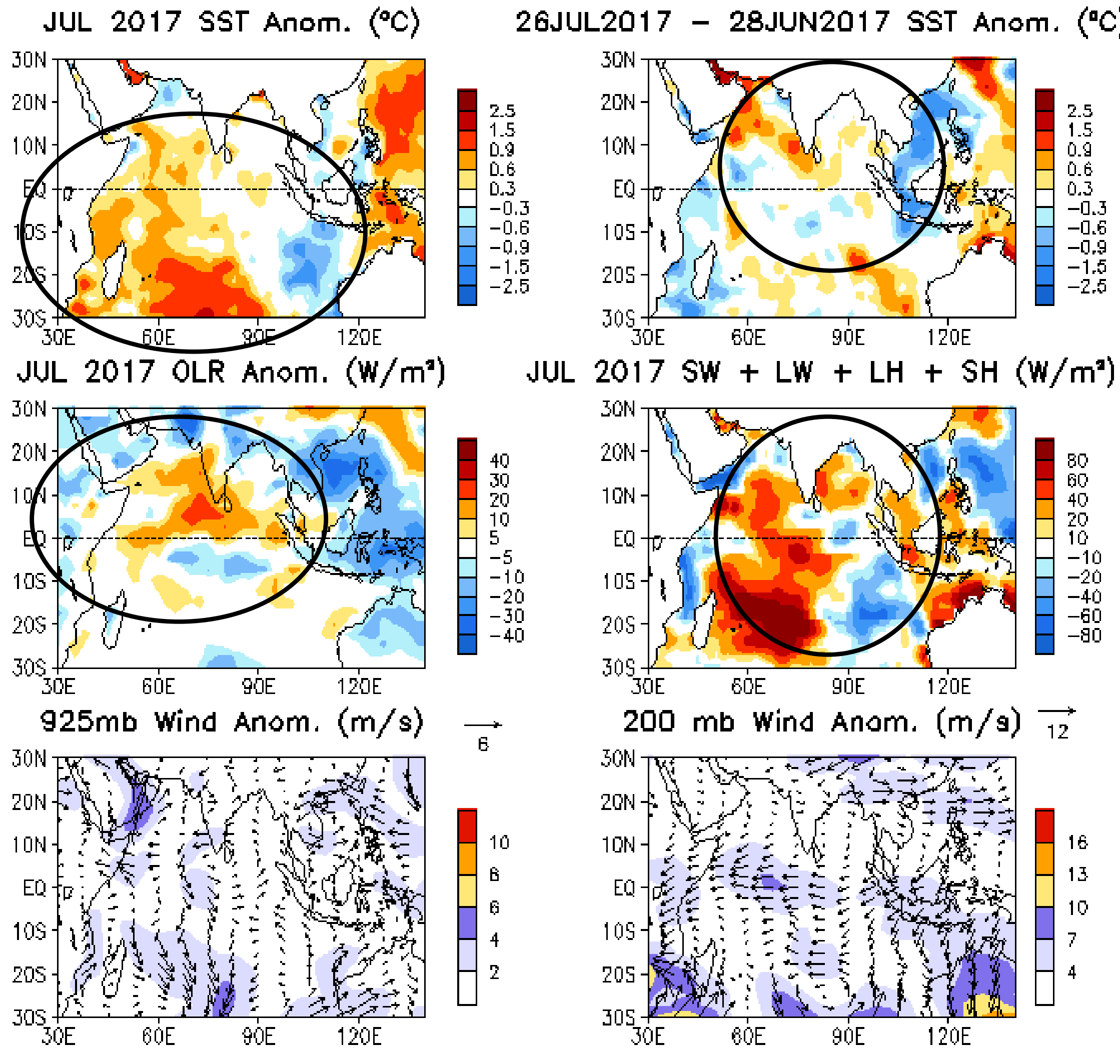
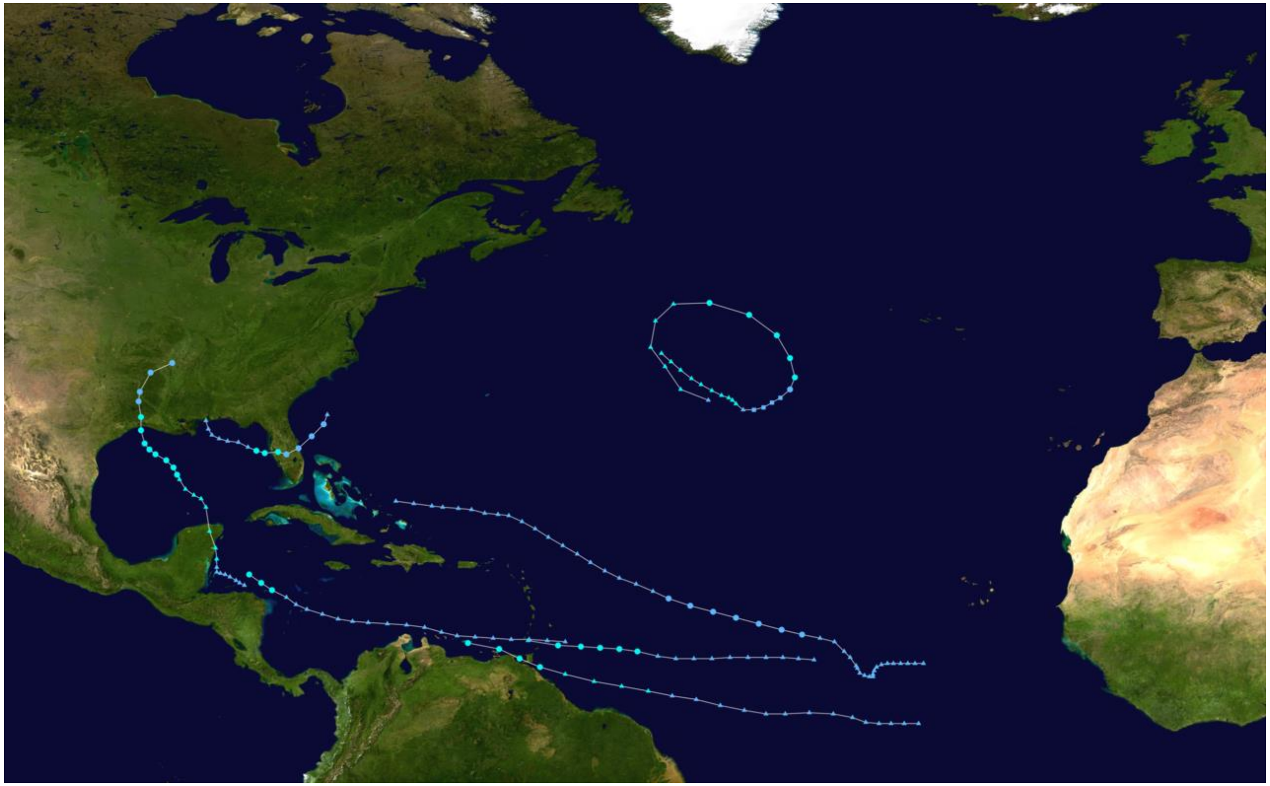


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

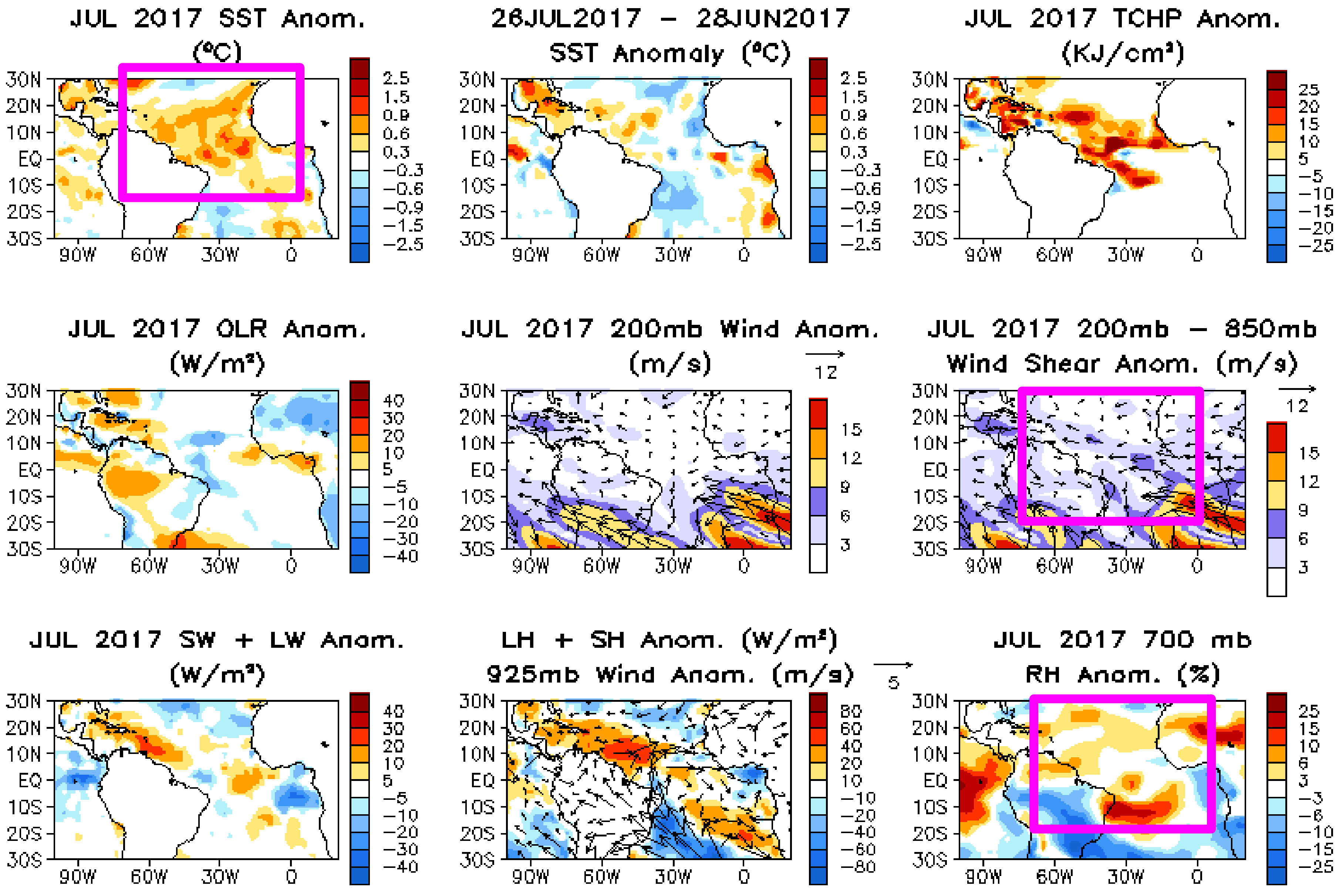
Tropical and North Atlantic Ocean

Atlantic Hurricane Activity *(https://en.wikipedia.org/wiki/2017_Atlantic_hurricane_season)*

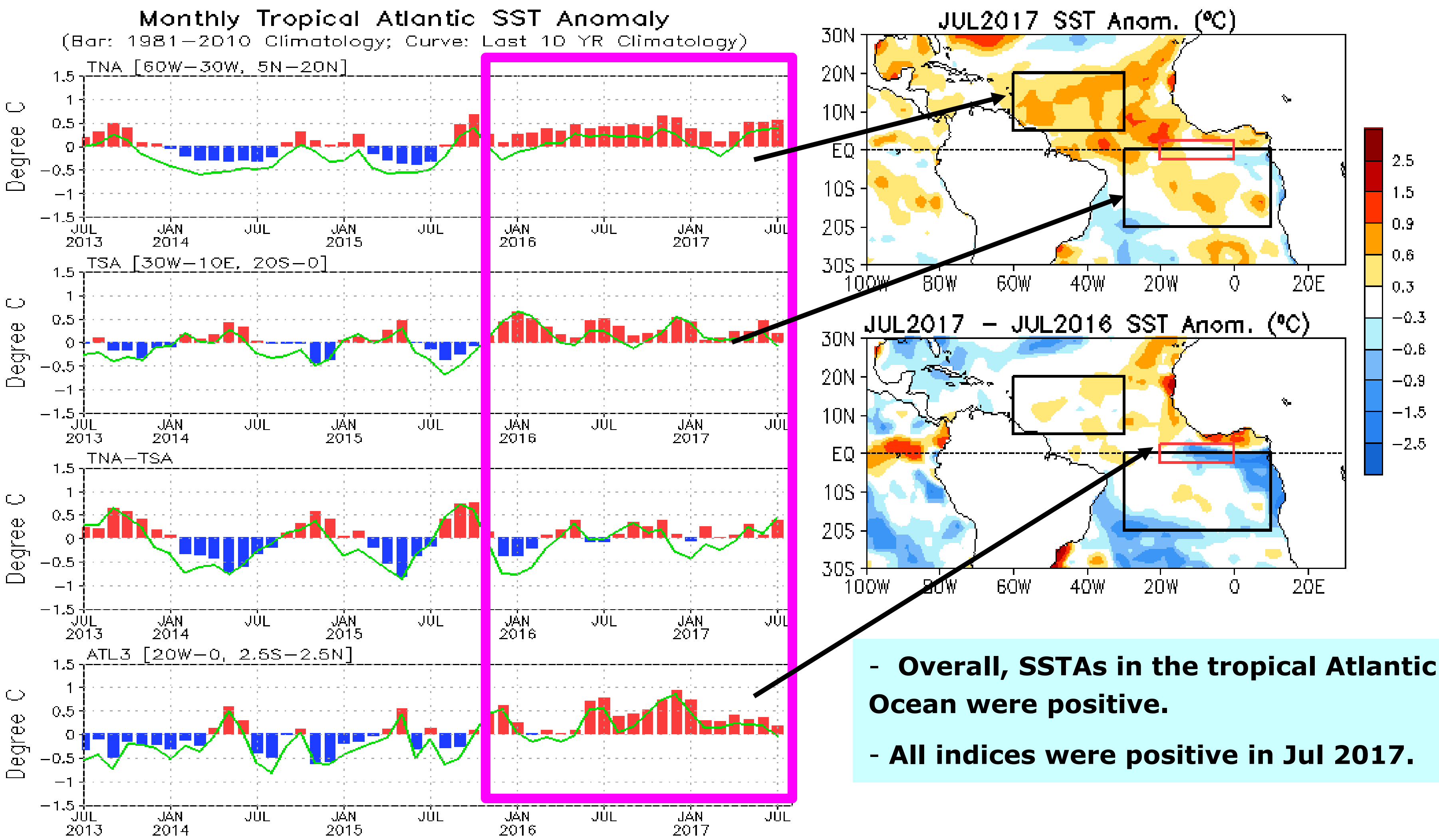


Atlantic	2017 prediction issued on May 25 (updated on Aug 9)	1981-2010	Observations (By Aug 10)
Named storms	11-17 (14-19)	12.1	6
Hurricanes	5-9 (5-9)	6.4	1
Major hurricanes	2-4 (2-5)	2.7	0
ACE range of the median, which includes Arlene in Apr	75%-155% (100-170%)		

Tropical Atlantic:



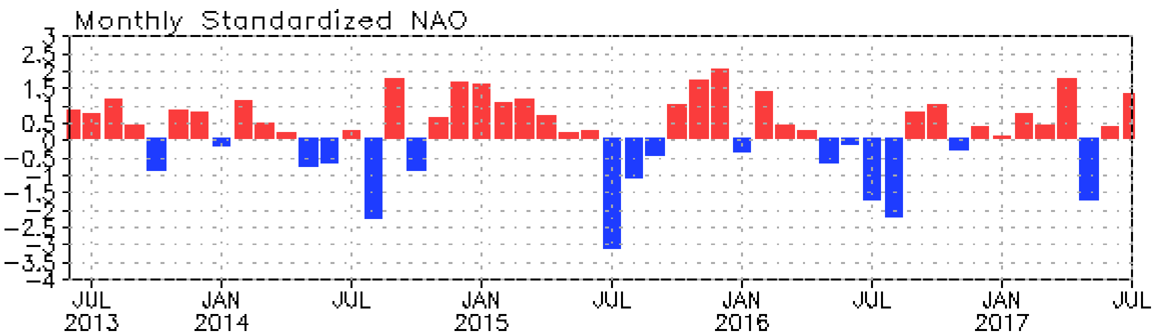
Evolution of Tropical Atlantic SST Indices

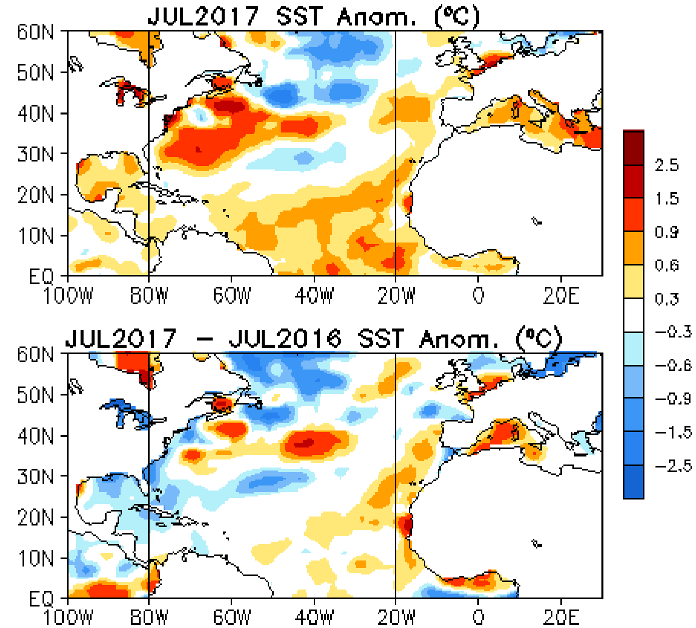


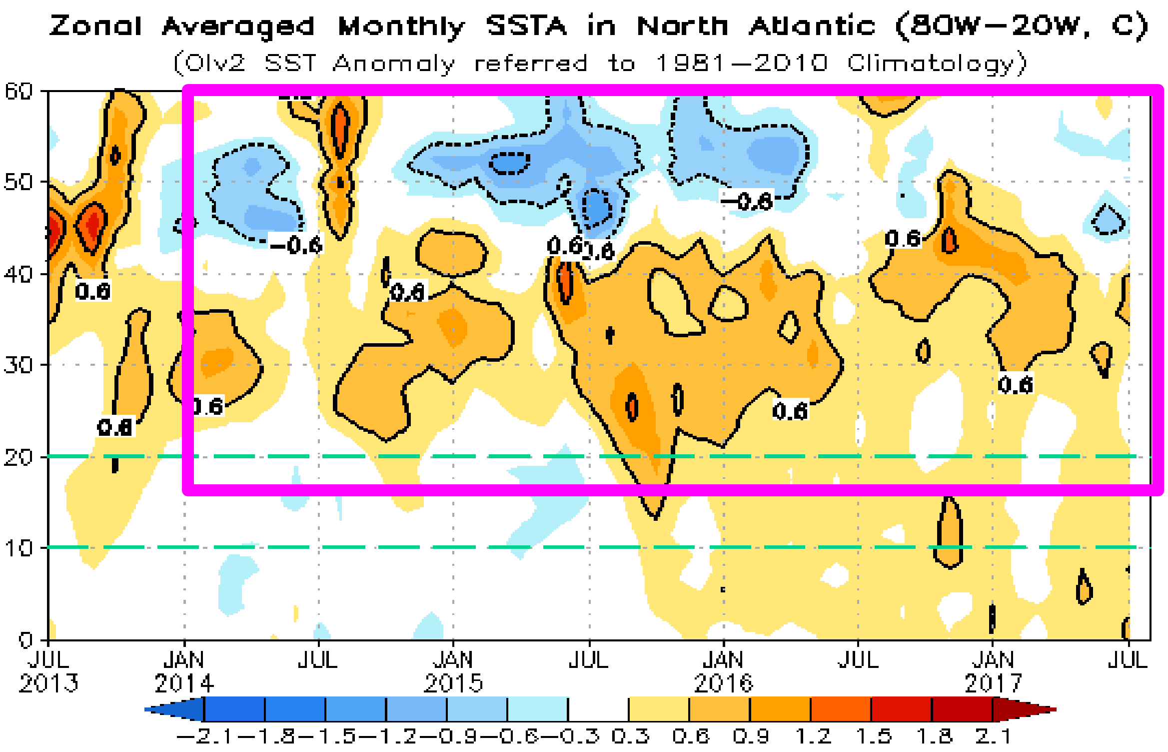
- Overall, SSTAs in the tropical Atlantic Ocean were positive.
- All indices were positive in Jul 2017.

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







- Positive phase of NAO strengthened with NAOI=1.28 in Jul 2017.

- SSTA was positive in the middle latitudes and negative in the high latitudes during last 3 years, probably due to the impact of dominated 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.

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

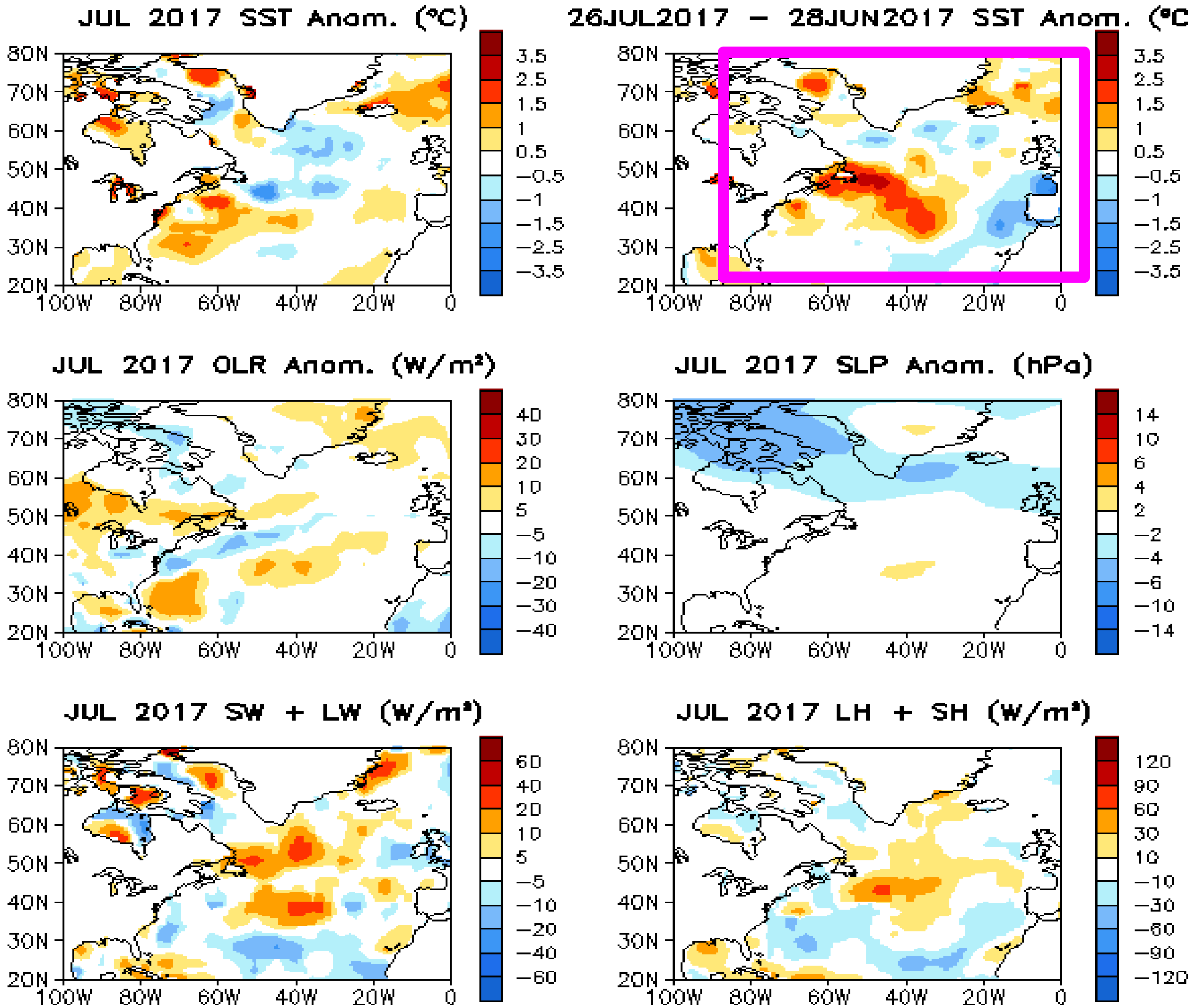
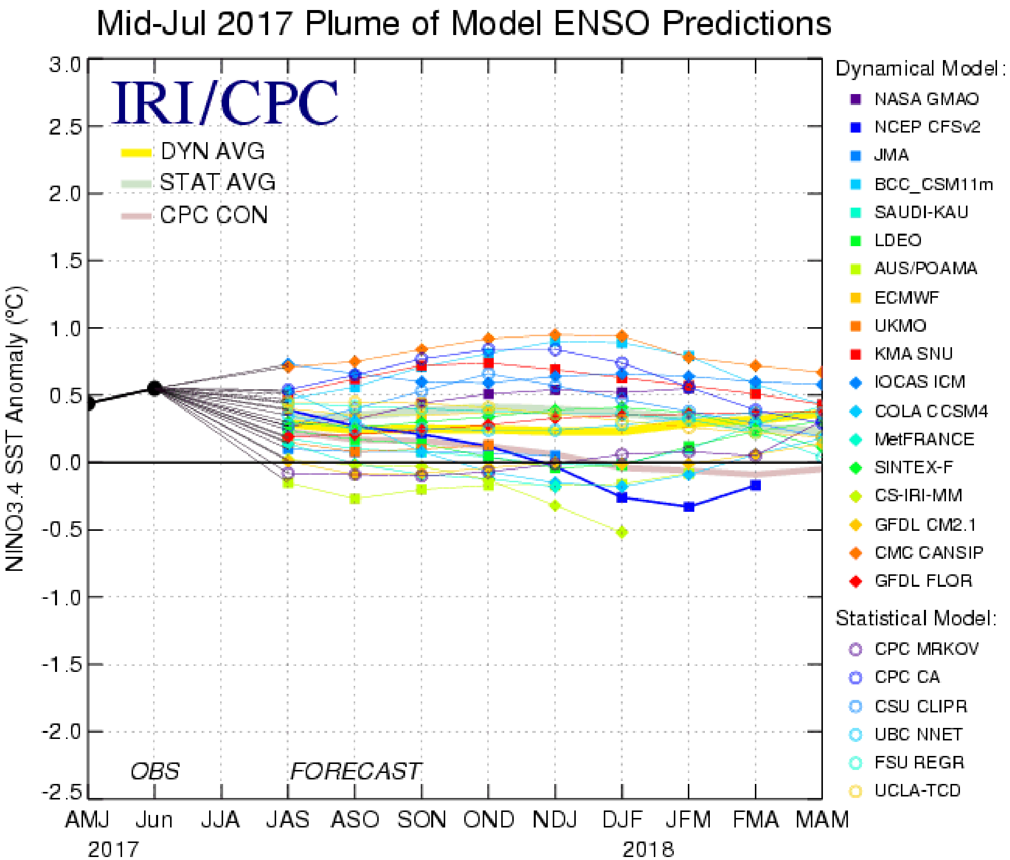
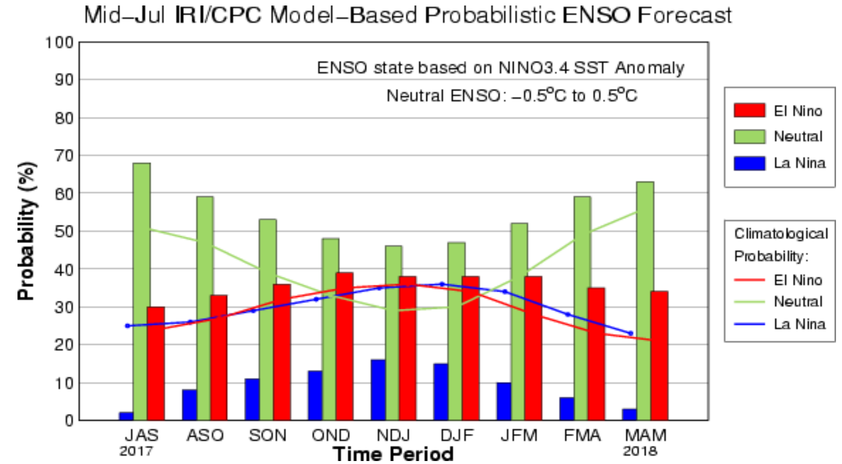


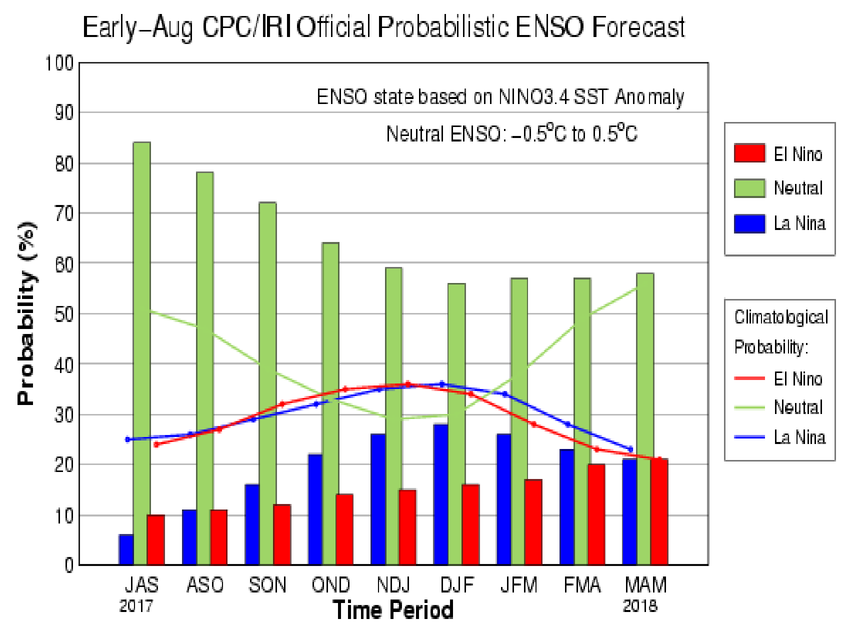
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

ENSO and Global SST Predictions

IRI NINO3.4 Forecast Plum

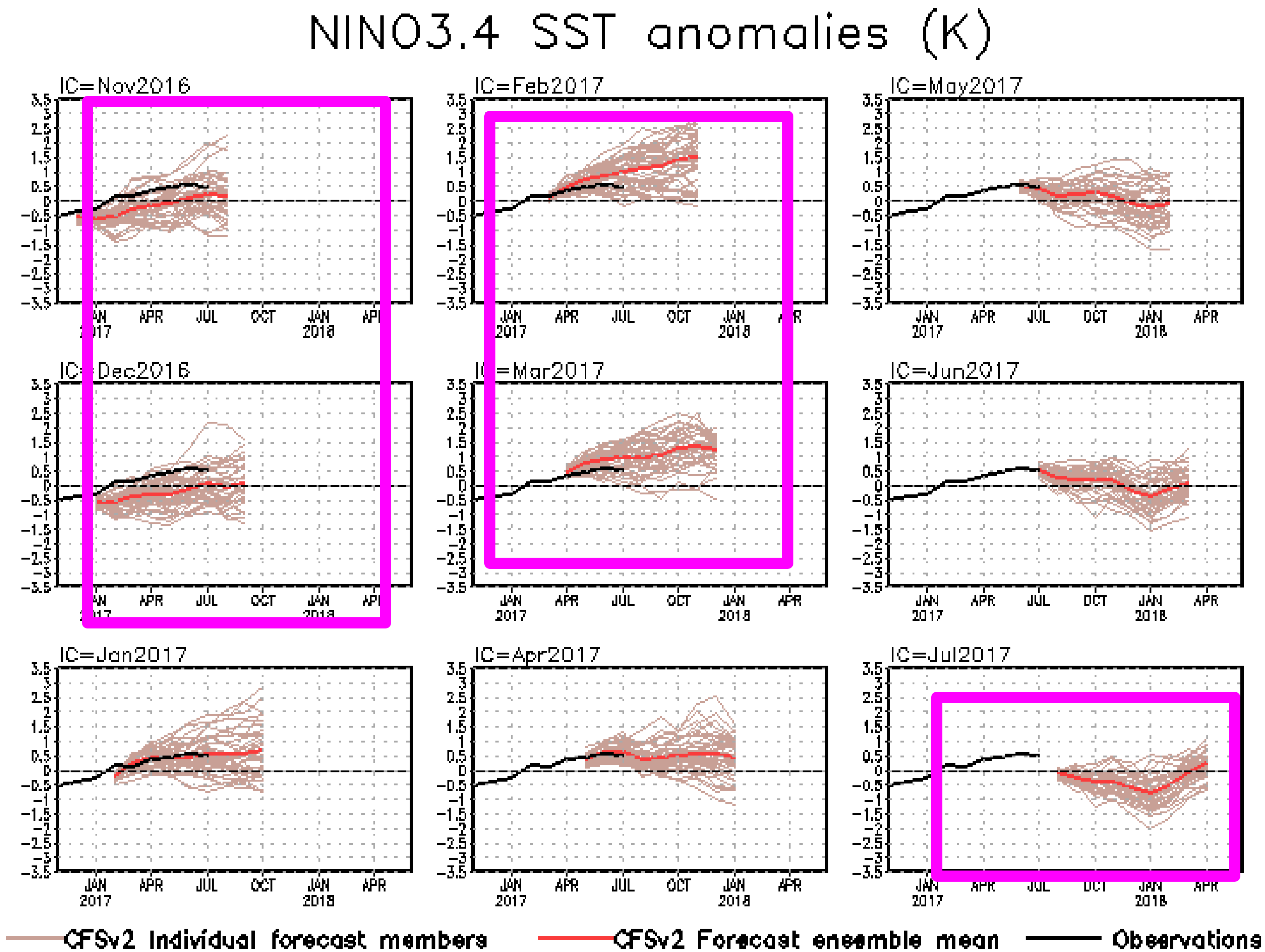






- **The majority of models favor ENSO-neutral through the Northern Hemisphere winter 2017-18 .**
- **NOAA "ENSO Diagnostic Discussion" on 10 Aug 2017 suggested that *"ENSO-neutral is favored (~85% chance during Jul-Sep, decreasing to ~55% during Dec-Feb) through the Northern Hemisphere winter 2017-18."***

CFS Niño3.4 SST Predictions from Different Initial Months

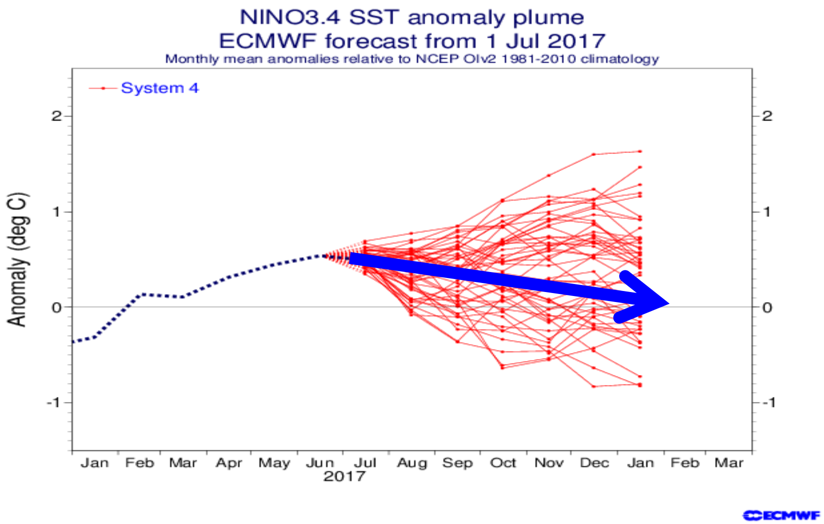


- CFSv2 predictions had cold biases with ICs in Jul-Dec 2016 and warm biases with ICs in Feb-Mar 2017.
- Latest CFSv2 forecasts call for ENSO neutral or boardline La Nina in wind 2017/18.

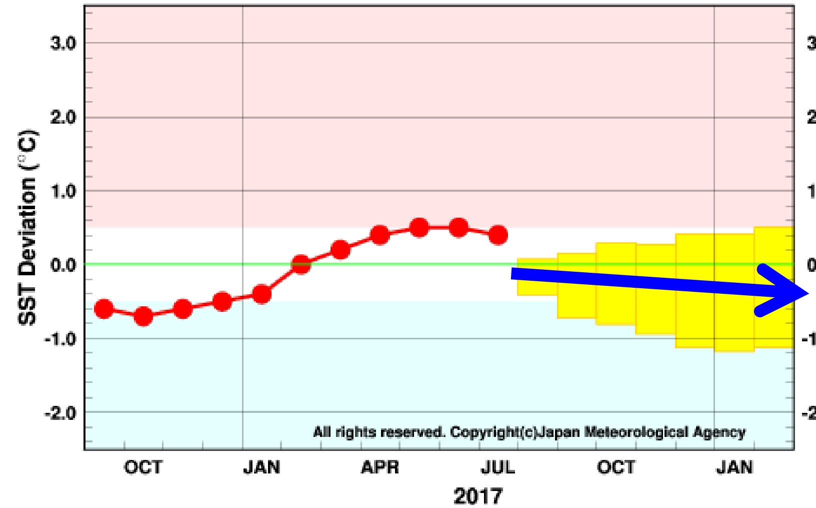
Fig. M1. CFS Nino3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with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

Individual Model Forecasts of Nino3.4: neutral

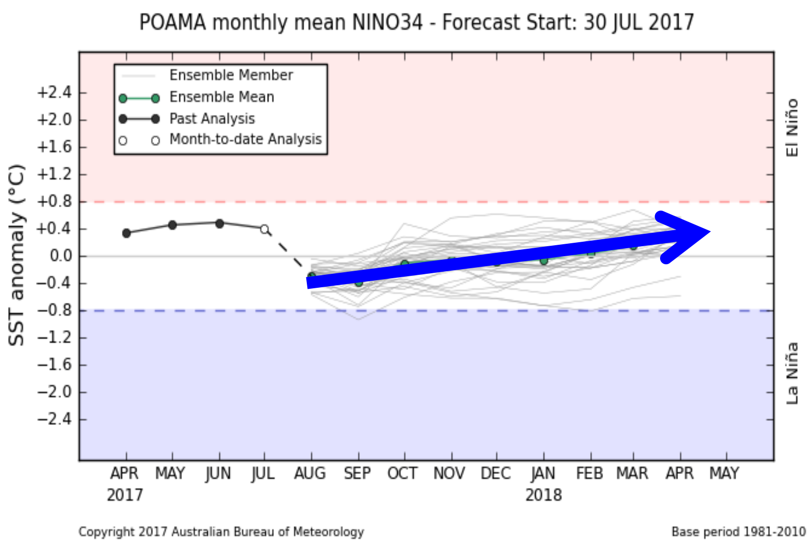
EC: IC=01Jul 2017



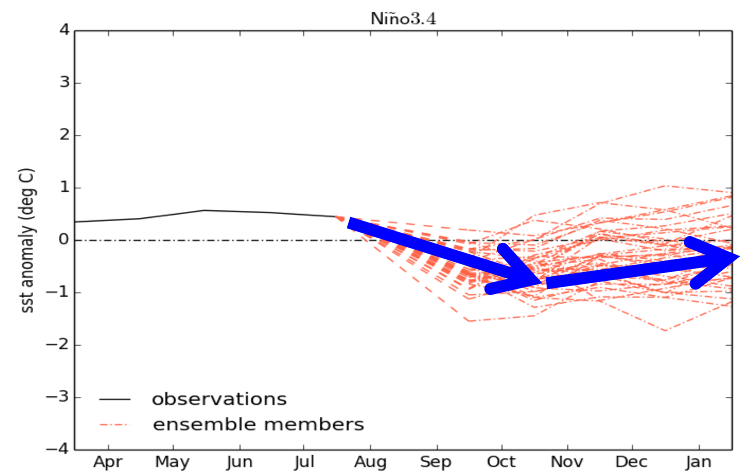
JMA: IC=Aug 2017

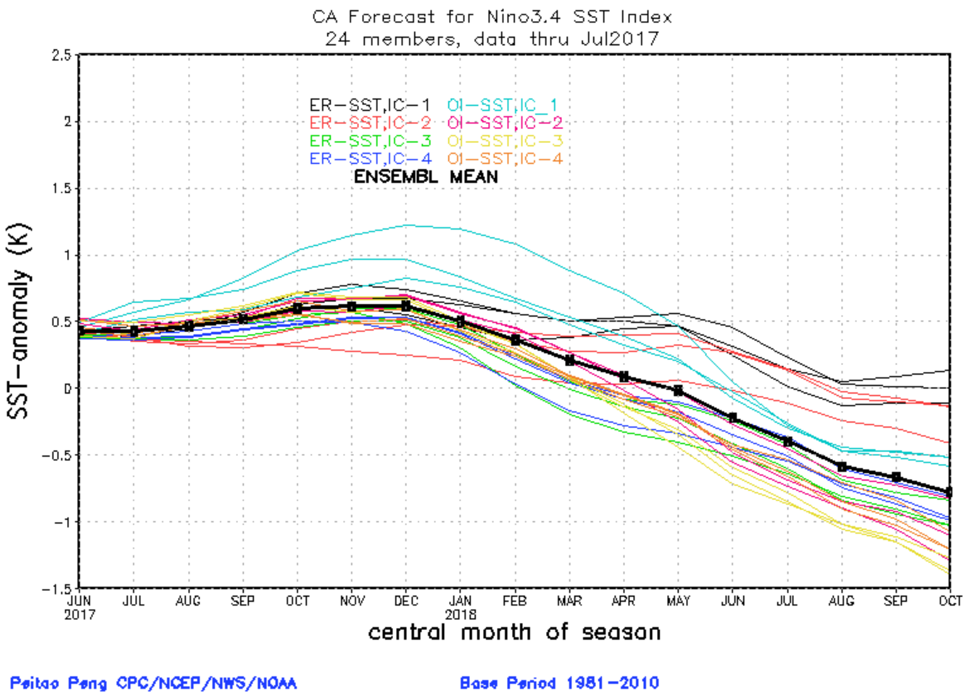


Australia: IC= 30 Jul 2017



UKMO: IC=Aug 2017

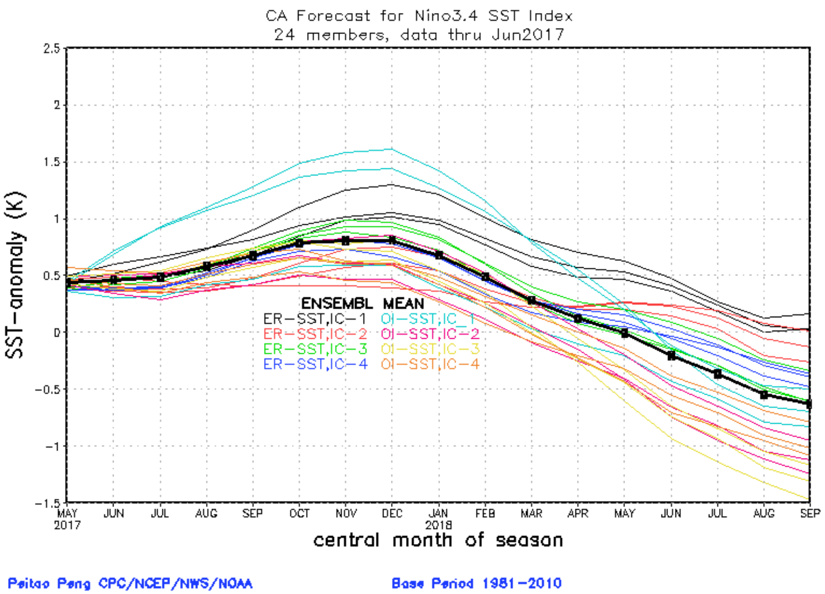


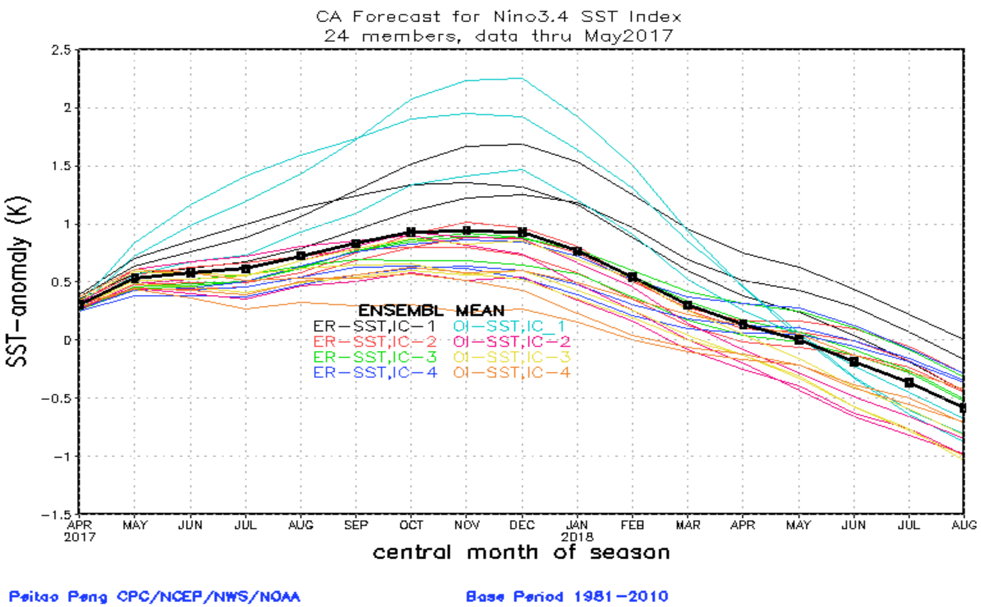


Analog forecasts:

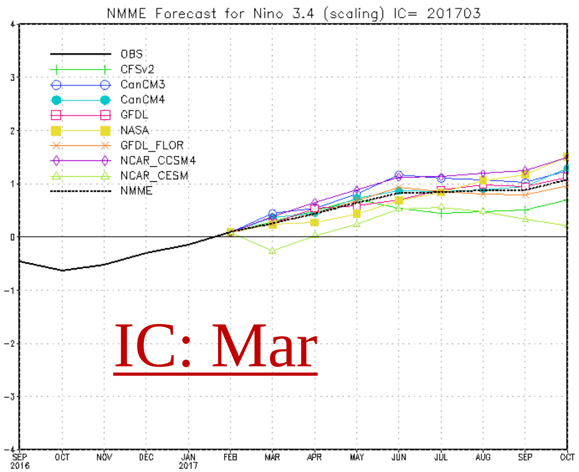
Nino3.4 amplitude declined in forecast with IC in Jul 2017, compared with that with IC in May and Jun 2017. Forecasts with Jul IC call for a La Nina in winter of 2018/19.

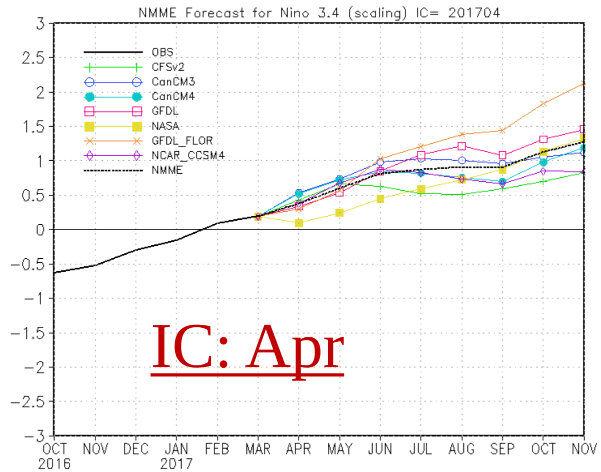
(From Dr. Peitao Peng)

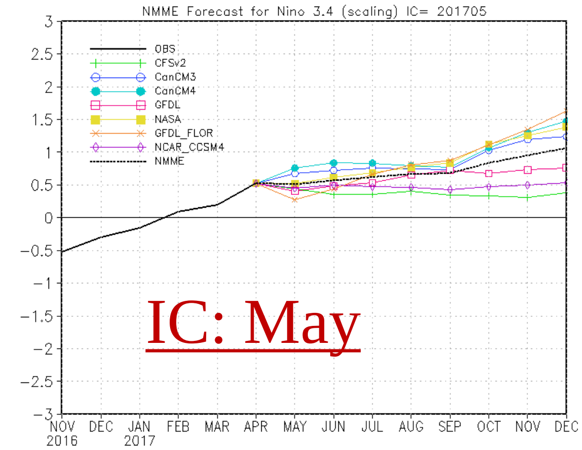


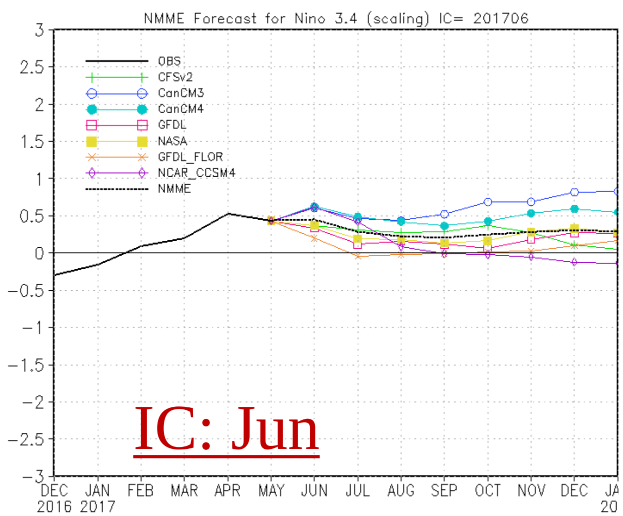


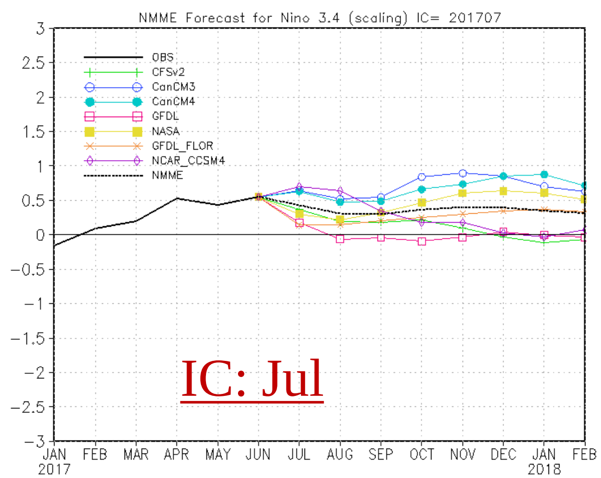
Large Uncertainty: 7 NMME Models with ICs in Mar-Aug 2017

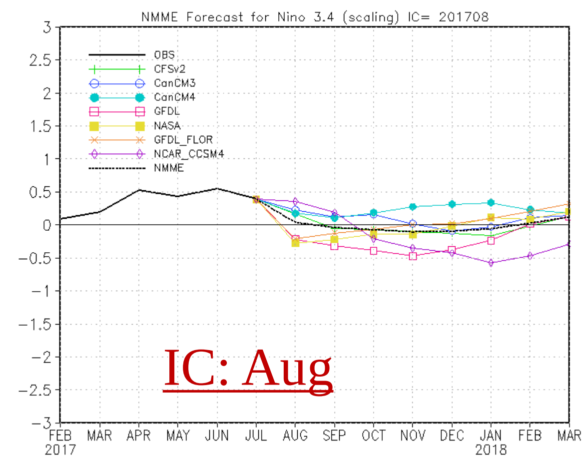


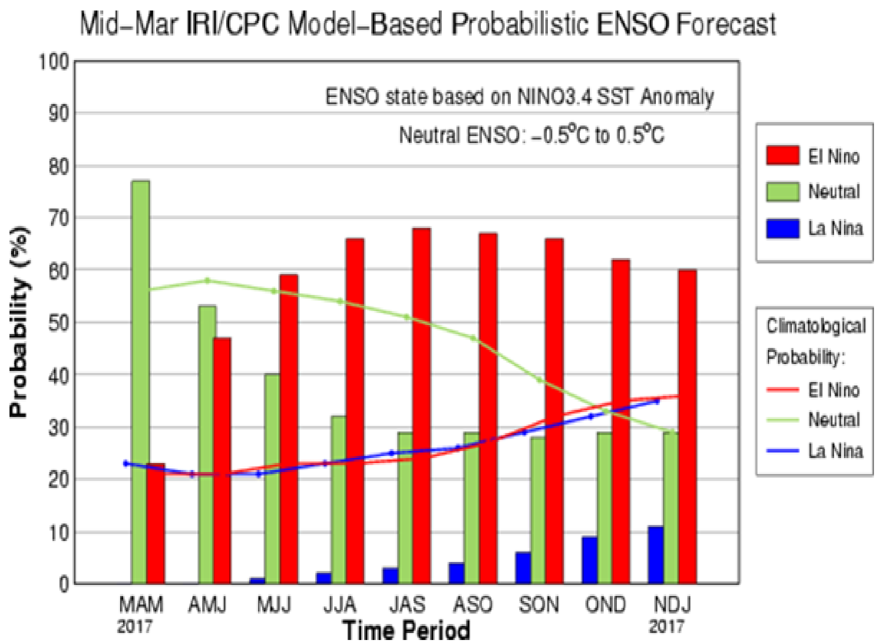


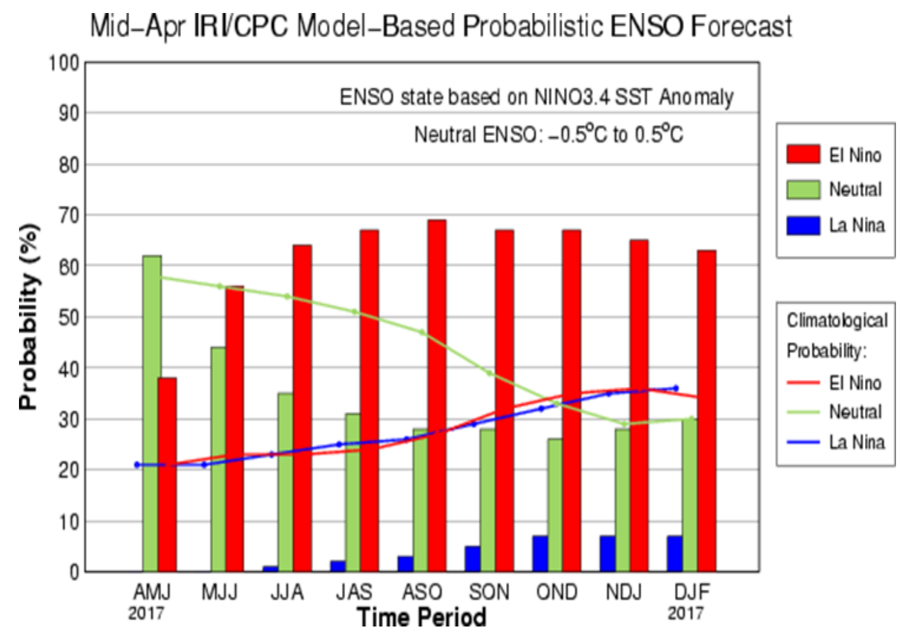


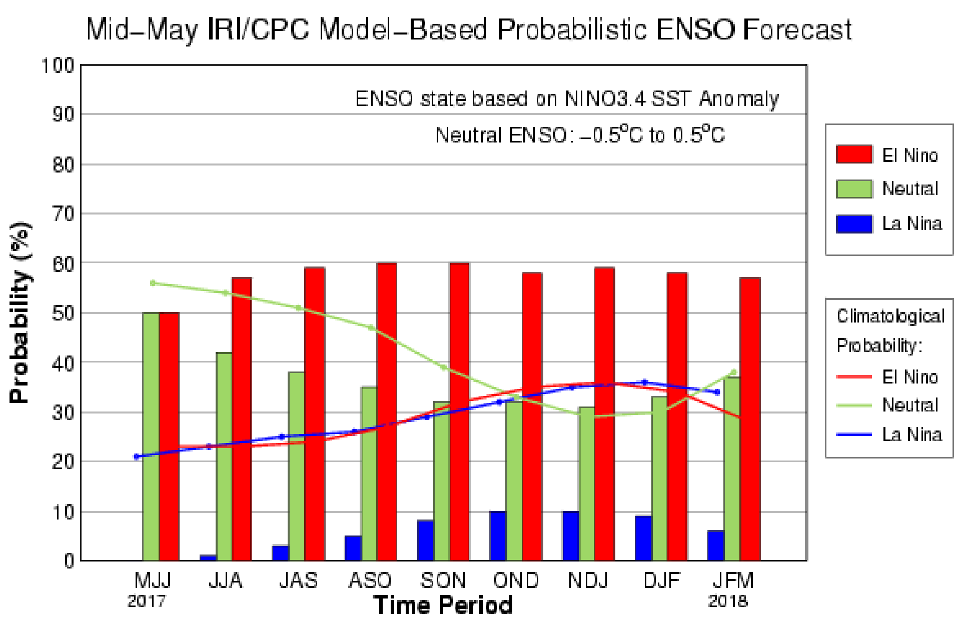


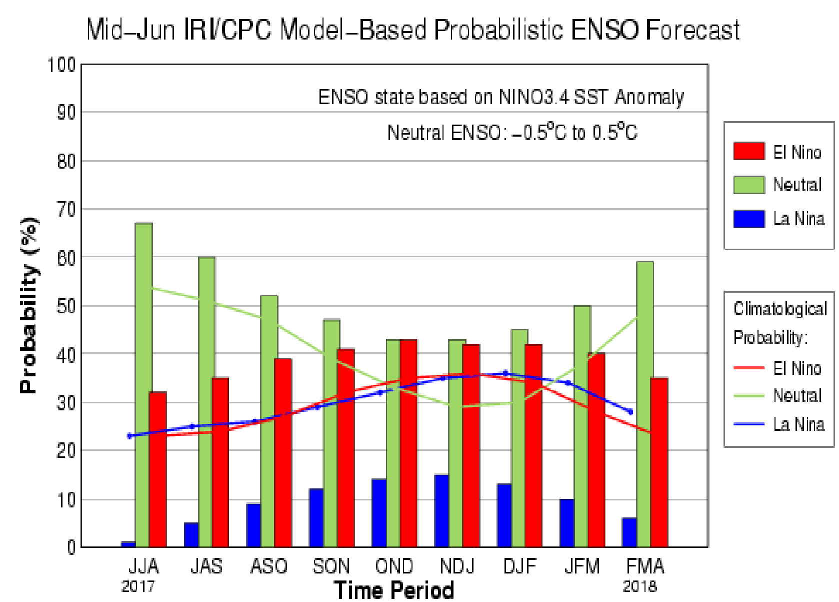





Mid–Mar IRI/CPC Model–Based Probabilistic ENSO Forecast
ENSO state based on NINO3.4 SST Anomaly
Neutral ENSO: –0.5°C to 0.5°C
El Nino
Neutral
La Nina
Climatological Probability:
El Nino
Neutral
La Nina
Probability (%)
MAM 2017
AMJ
MJJ
JJA
JAS
ASO
SON
OND
NDJ 2017
Time Period

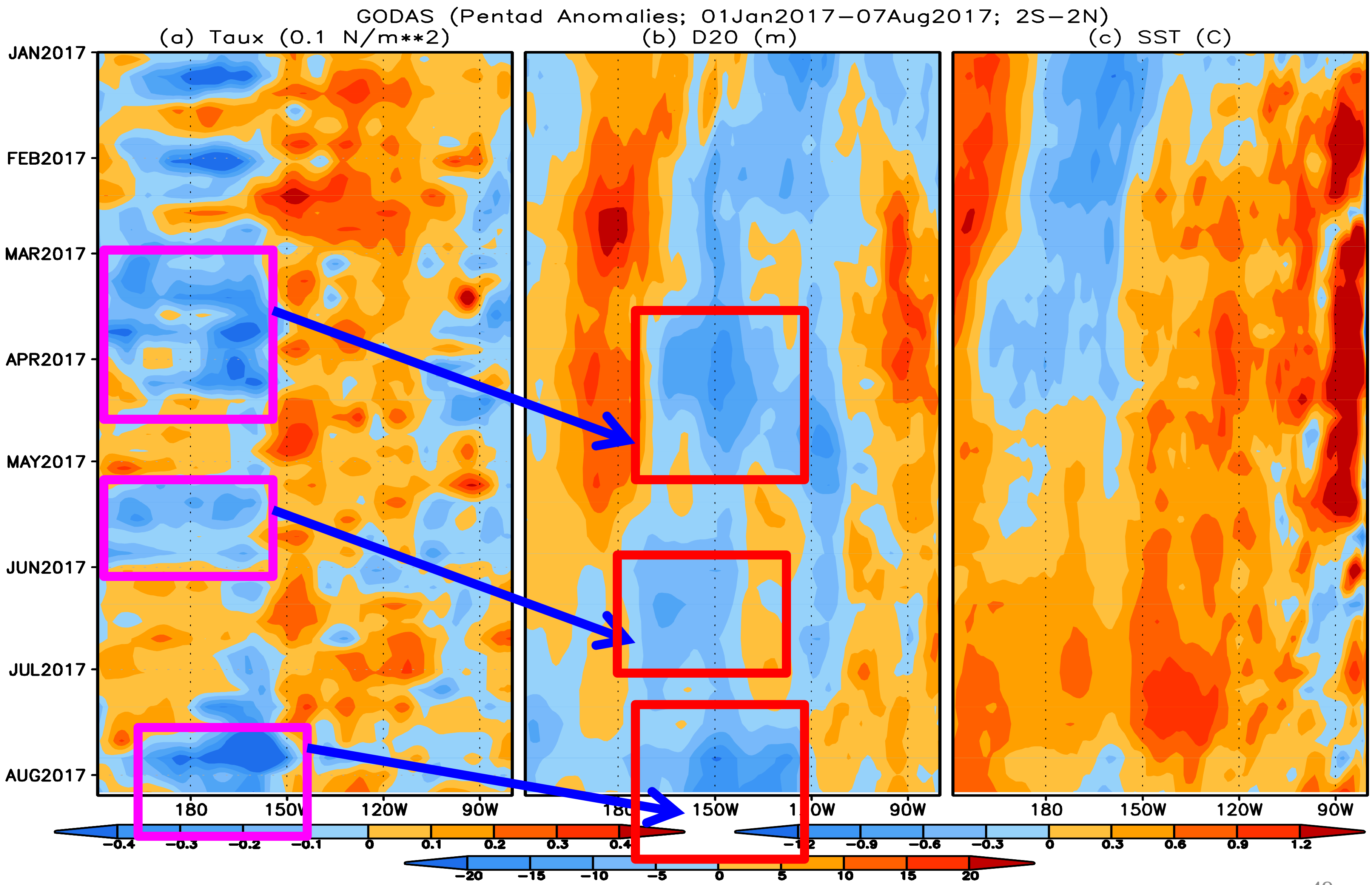

Mid–Apr IRI/CPC Model–Based Probabilistic ENSO Forecast
ENSO state based on NINO3.4 SST Anomaly
Neutral ENSO: –0.5°C to 0.5°C
El Nino
Neutral
La Nina
Climatological Probability:
El Nino
Neutral
La Nina
Probability (%)
AMJ 2017
MJJ
JJA
JAS
ASO
SON
OND
NDJ
DJF 2017
Time Period


Mid–May IRI/CPC Model–Based Probabilistic ENSO Forecast
ENSO state based on NINO3.4 SST Anomaly
Neutral ENSO: –0.5°C to 0.5°C
El Nino
Neutral
La Nina
Climatological Probability:
El Nino
Neutral
La Nina
Probability (%)
MJJ 2017
JJA
JAS
ASO
SON
OND
NDJ
DJF
JFM 2018
Time Period


Mid–Jun IRI/CPC Model–Based Probabilistic ENSO Forecast
ENSO state based on NINO3.4 SST Anomaly
Neutral ENSO: –0.5°C to 0.5°C
El Nino
Neutral
La Nina
Climatological Probability:
El Nino
Neutral
La Nina
Probability (%)
JJA 2017
JAS
ASO
SON
OND
NDJ
DJF
JFM
FMA 2018
Time Period

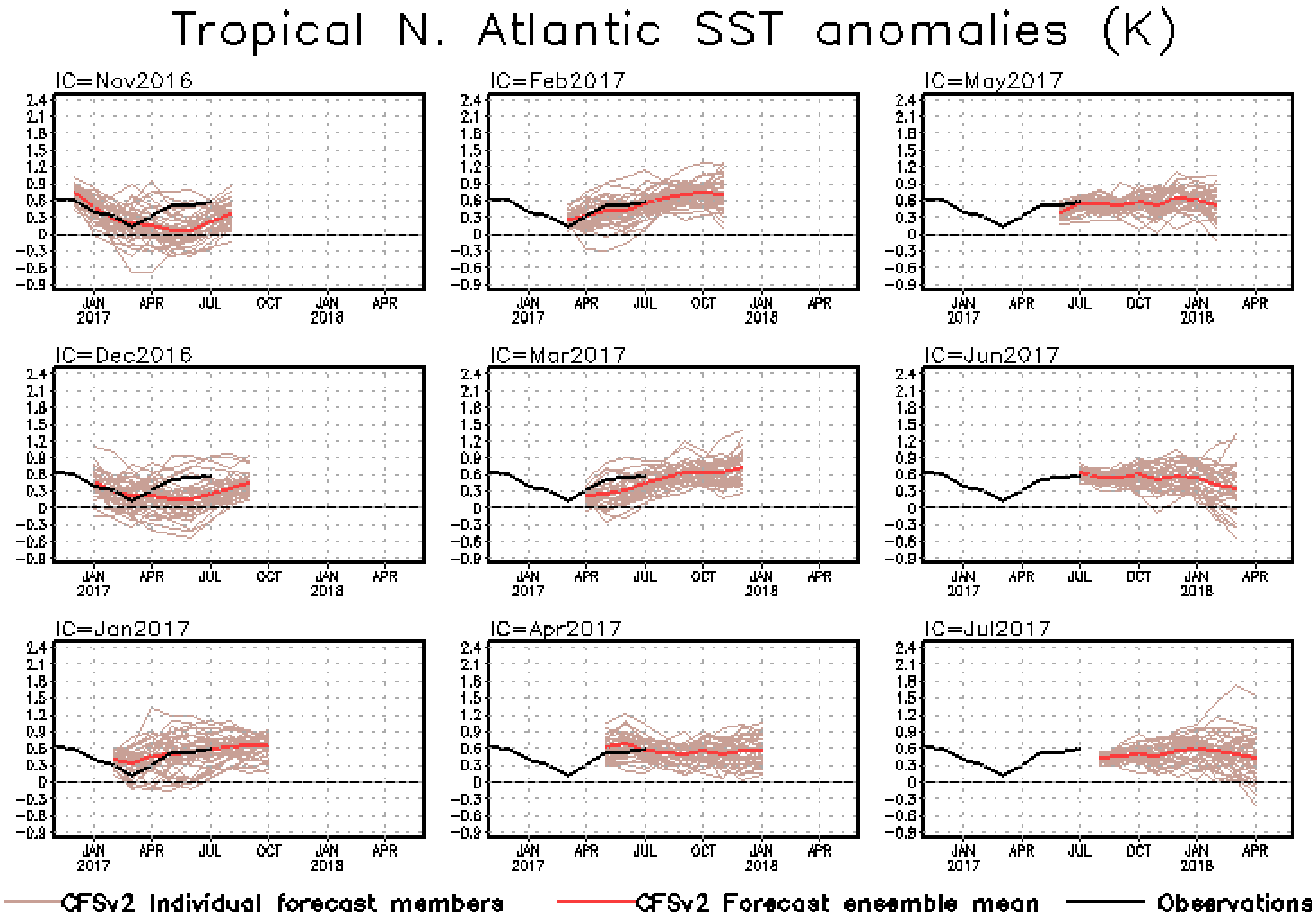
Why wasn't successful for model predictions?

May be the impact of unpredictable part: surface wind disturbance



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].

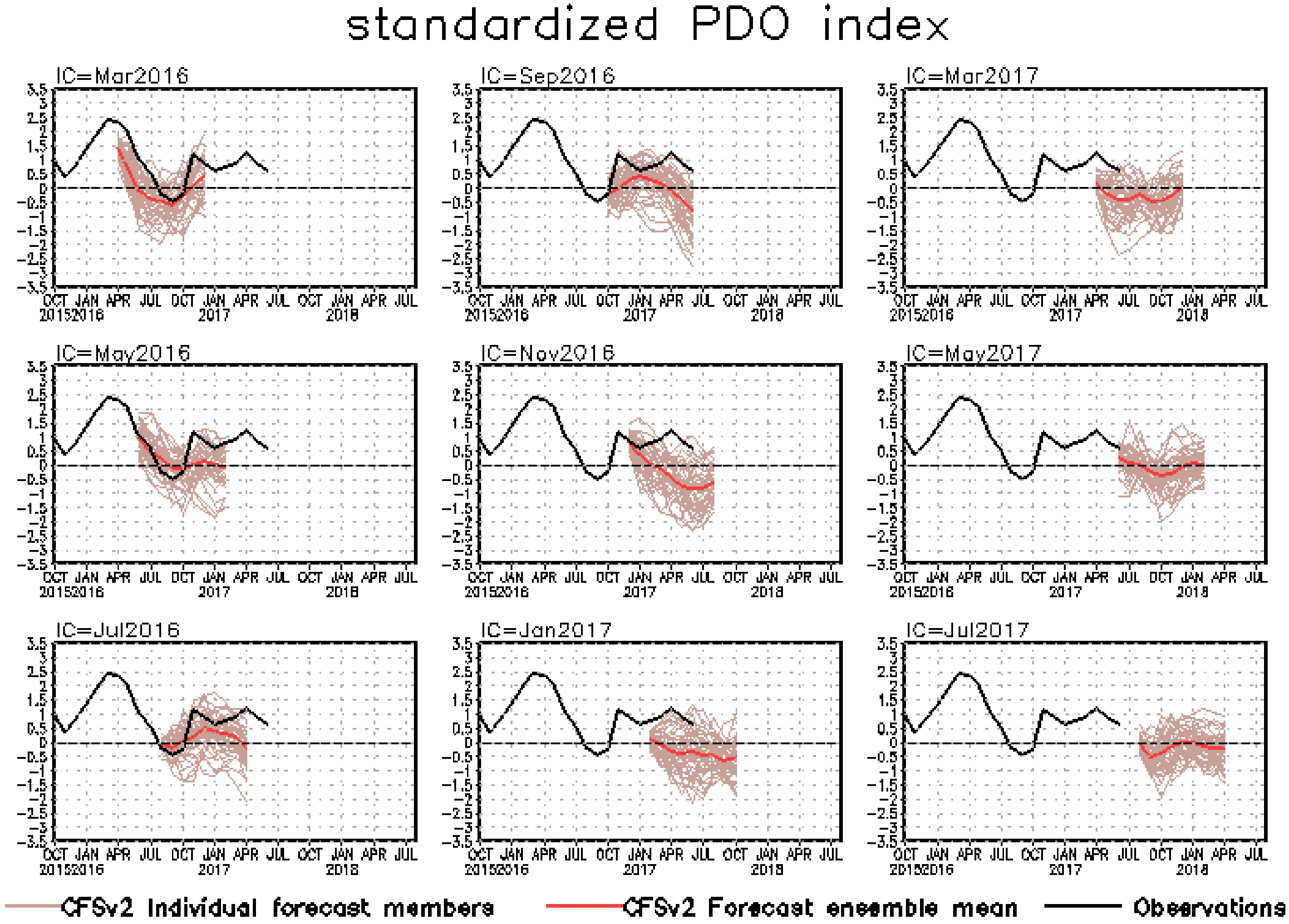


- Latest CFSv2 predictions call persistently above normal SST in the tropical N. Atlantic in 2017/18.

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.

CFS Pacific Decadal Oscillation (PDO) Index Predictions

from Different Initial Months



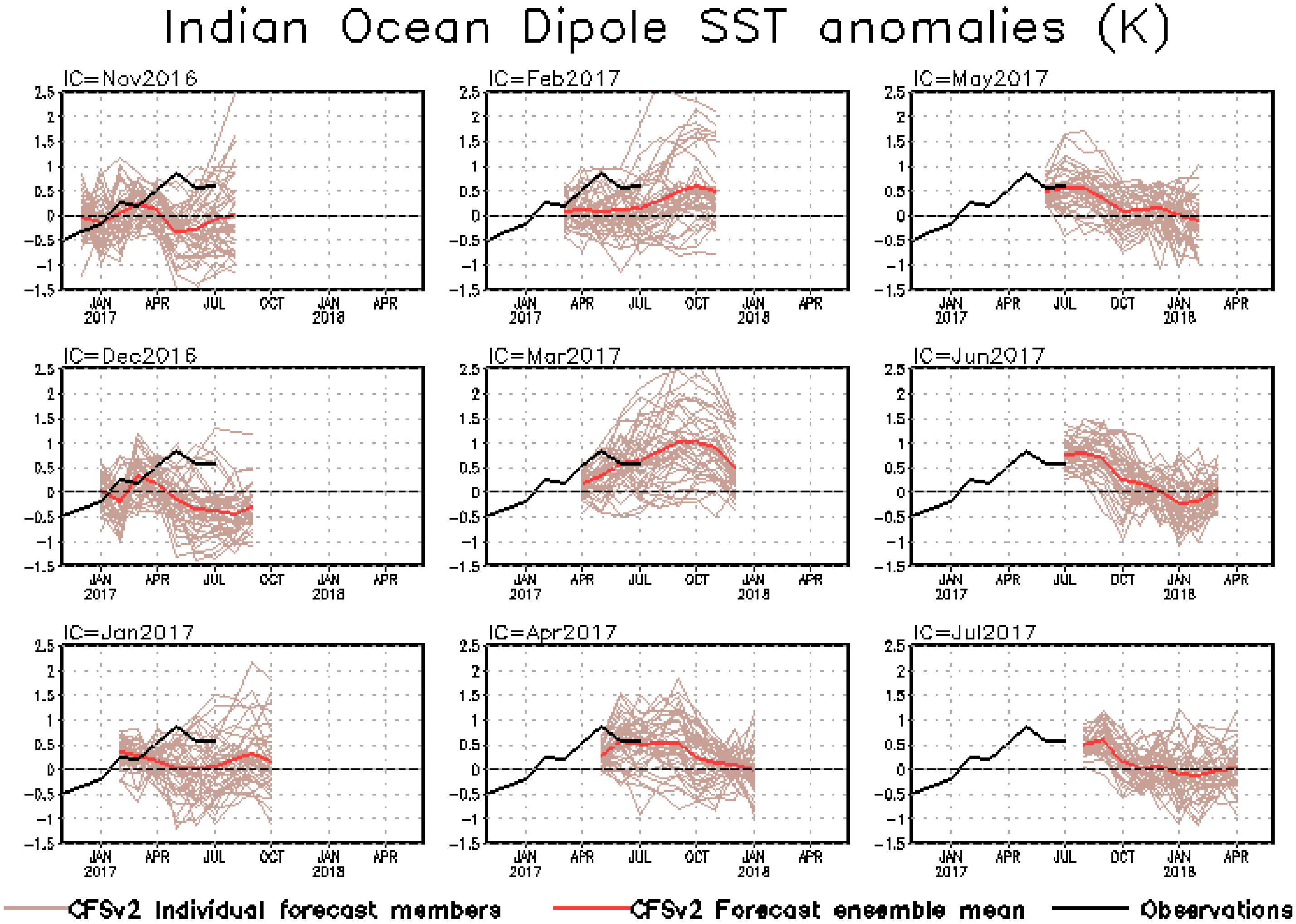
PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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 2017/18.

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 [90°E-110°E, 10°S-0]

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

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.

Acknowledgements

- Drs. Caihong Wen, Arun Kumar, and Yan Xue: reviewed PPT, and provide insight and constructive suggestions and comments
- Drs. Li Ren and Pingping Xie: Provided SSS slides
- Dr. Emily Becker: Provided NMME plots
- Dr. Peitao Peng: Provided analog forecast plots
- Dr. Caihong Wen: Provided slides of WWV and CTP
- Drs. Thomas Collow and Wanqiu Wang: Supplied sea ice slides
- Dai Mcclurg (NOAA/PMEL): Clarified the TAO analysis interpolation
- Karen Grissom (NDBC): Provided information about TAO buoy status
- Dr. Kathleen Dohan (ESR): Updated OSCAR current

Data Sources and References

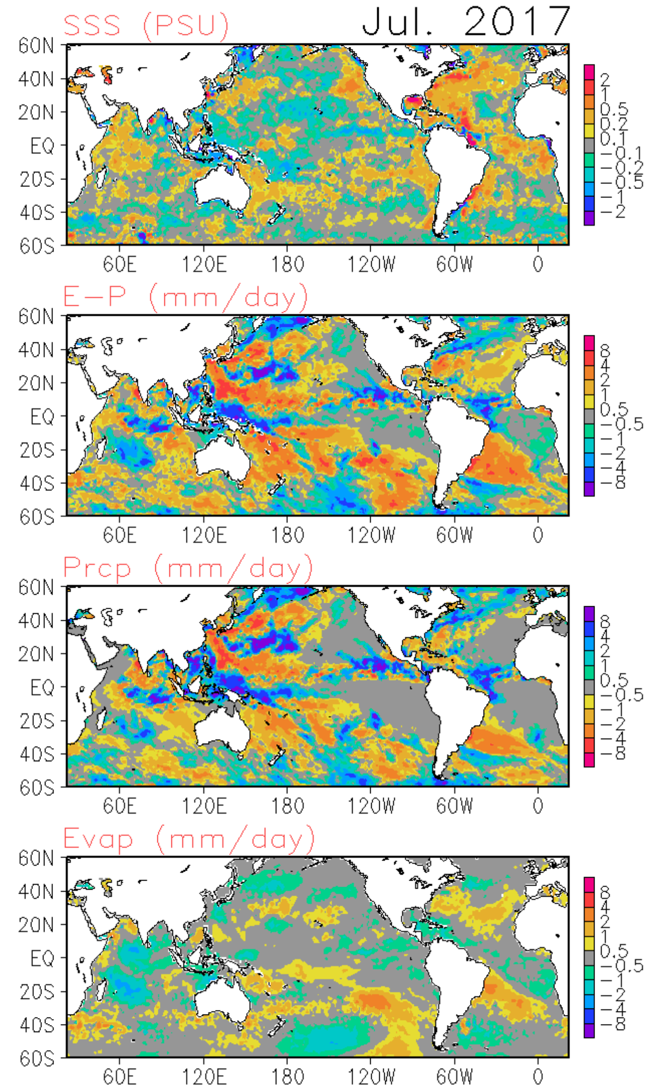
- **Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)**
- **NCEP CDAS winds, surface radiation and heat fluxes**
- **NESDIS Outgoing Long-wave Radiation**
- **NDBC TAO data (http://tao.ndbc.noaa.gov)**
- **PMEL TAO equatorial temperature analysis**
- **NCEP's Global Ocean Data Assimilation System temperature, heat content, currents (Behringer and Xue 2004)**
- **Aviso Altimetry Sea Surface Height**
- **Ocean Surface Current Analyses – Realtime (OSCAR)**

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

Backup Slides

Global Sea Surface Salinity (SSS)

Anomaly for July 2017



- **New Update: The BASS 0.Z is released this month with the SSS from recently launched SMAP being integrated into the system. Since June 2015, the blended SSS analysis is from in situ, SMOS and SMAP. Please report to us any suspicious data issues!**
- The SSS anomaly nearby 20°S/20°N, particularly in the west region, is negative. Such negative anomalies are co-incident with the increase of the precipitation. The less precipitation in the South Pacific (20°S to 40°S) likely contributes to the positive SSS anomalies there. The positive SSS anomaly continues in the Atlantic ocean from 40°S to 40°N with the SSS anomalies in the eastern N. Atlantic Ocean between 0 and 30°N being negative. In the South Atlantic ocean, the SSS anomaly is negative in the latitude band between 40°S and 60°S.

- **Data used**

SSS :

Blended Analysis of Surface Salinity (BASS) V0.Y

(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)

(Xie et al. 2014)

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

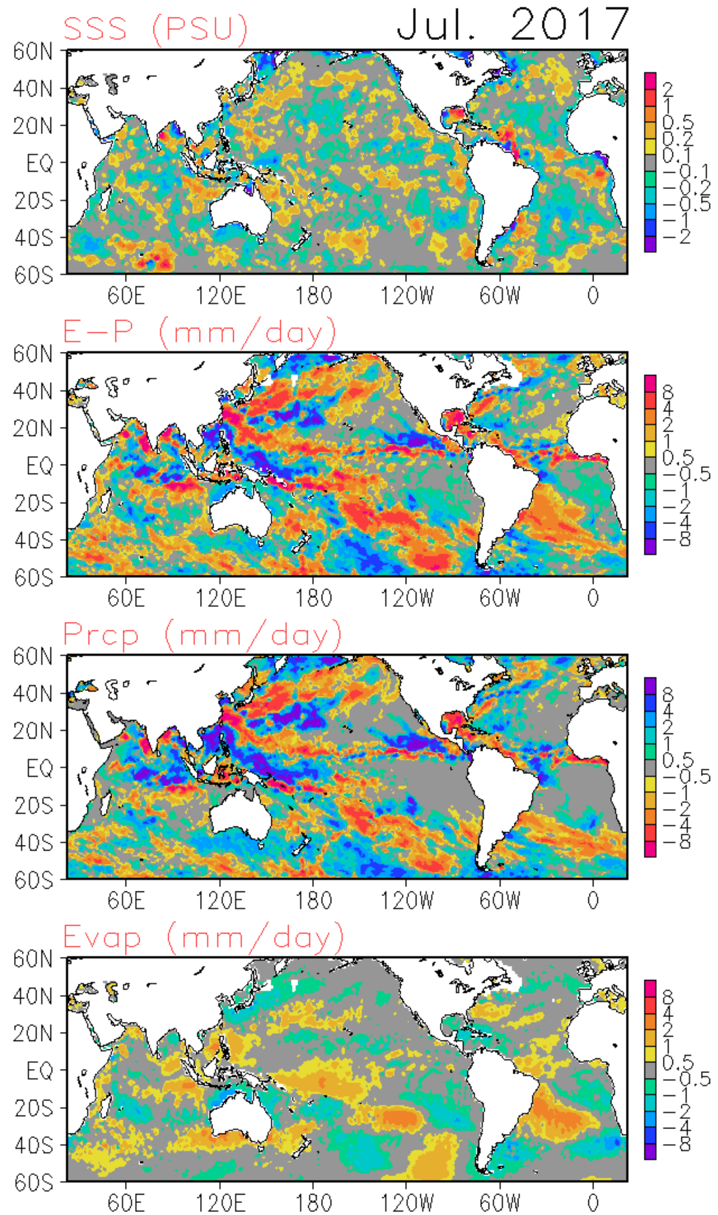
Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: CFS Reanalysis

Global Sea Surface Salinity (SSS)

Tendency for July 2017

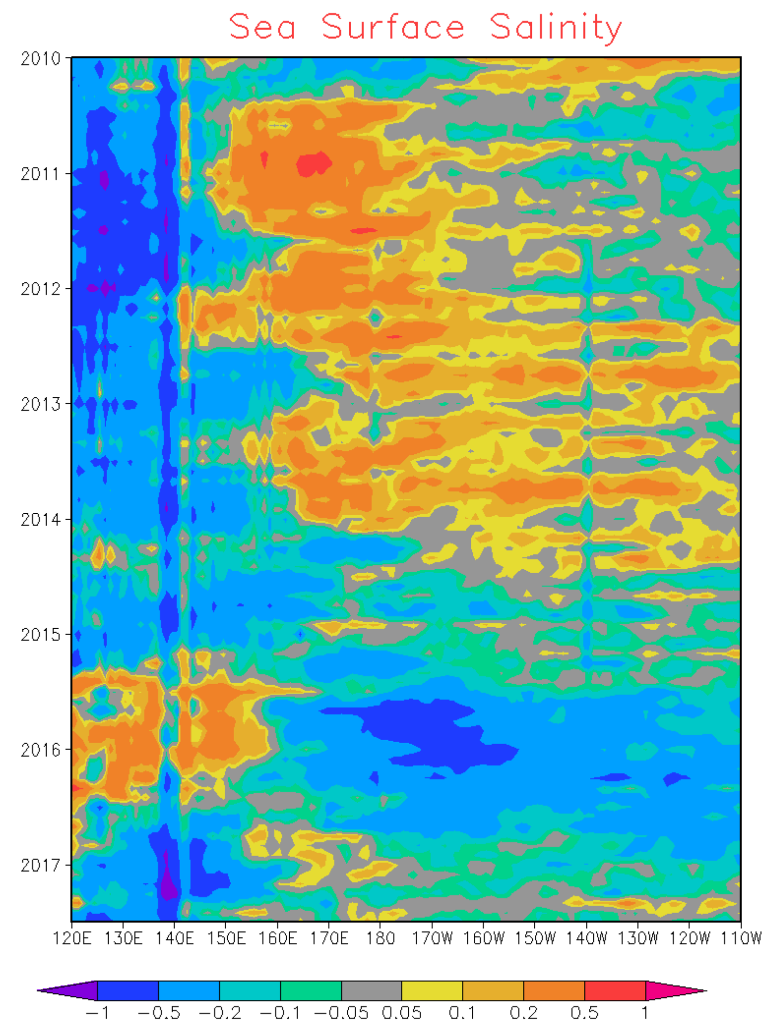
Compared with last month, the SSS in the west of equatorial Pacific Ocean significantly decreased due to the heavy rainfall. The salinity in most area of the N. Atlantic Ocean (south of 40°N) shows decreases, which is likely caused by the increase of precipitation, particularly in the west region. However, the SSS decrease in the S. Atlantic Ocean is probably mainly caused by the ocean advection/mixing. In the east of Bay of Bengal, a strong increase of net freshwater flux input may contribute to the SSS decrease, while in the west of Bay of Bengal, the reduction of the precipitation likely causes the SSS increase.



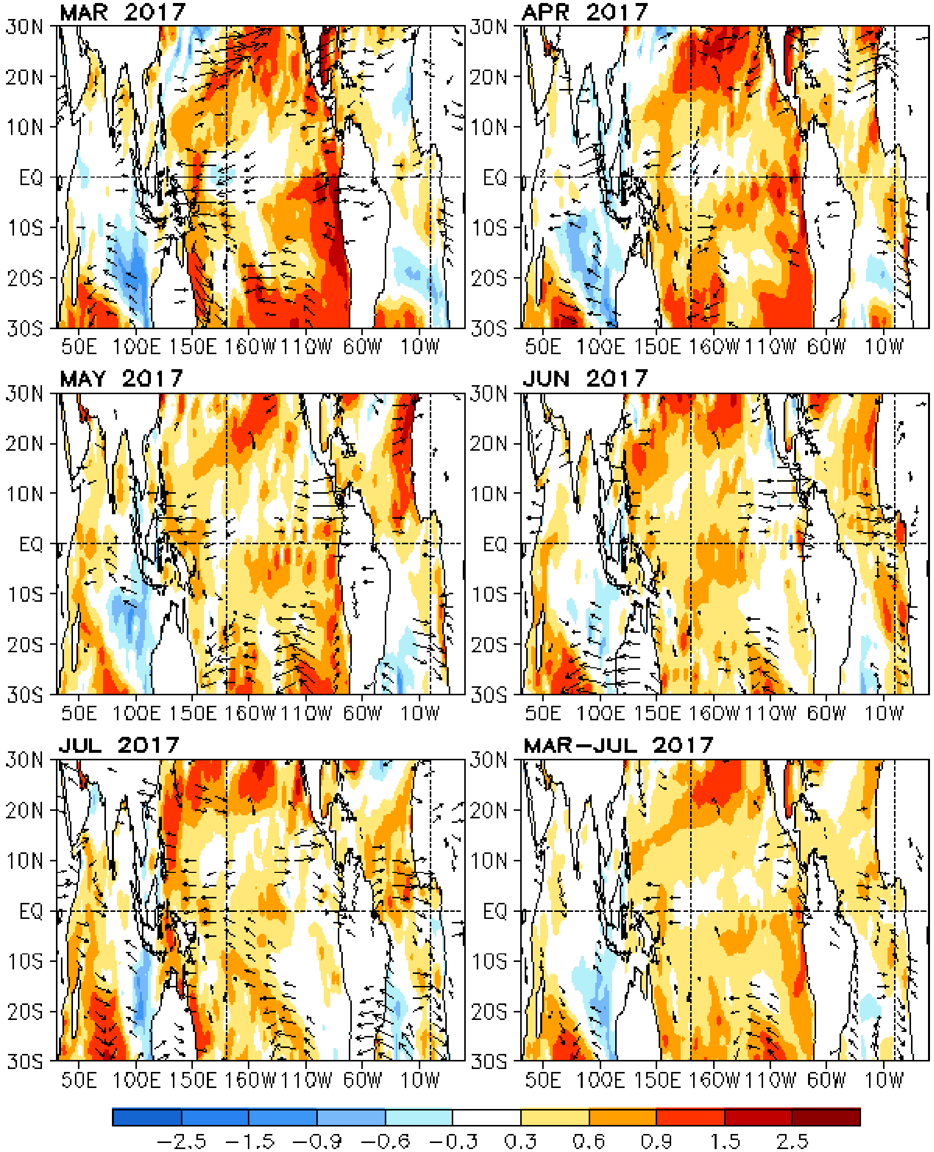
Global Sea Surface Salinity (SSS)
Anomaly Evolution over Equatorial Pacific

NOTE: Since June 2015, in the new version the blended SSS analysis is from in situ, SMOS and SMAP; while, in the old version, the blended SSS analysis is from in situ and SMOS only.

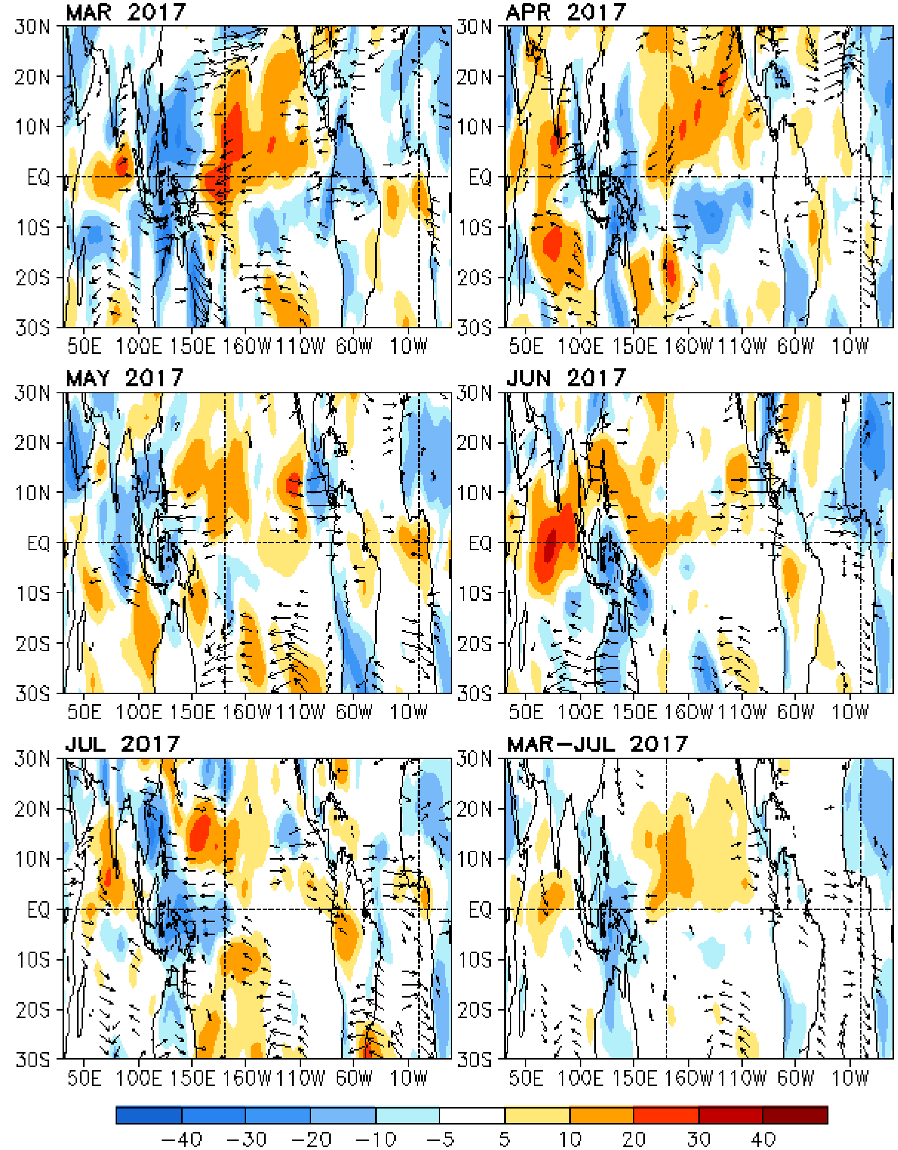
- Hovemoller diagram for equatorial SSS anomaly **(10ºS-10ºN);**
- In the western equatorial Pacific Ocean, from 120°E to 150°E, the strong negative SSS signal continues in this month. The SSS anomaly signals in the central and eastern equatorial Pacific region are weaker compared with that in the western region and the SSS anomalies continue negative east of 175°W.

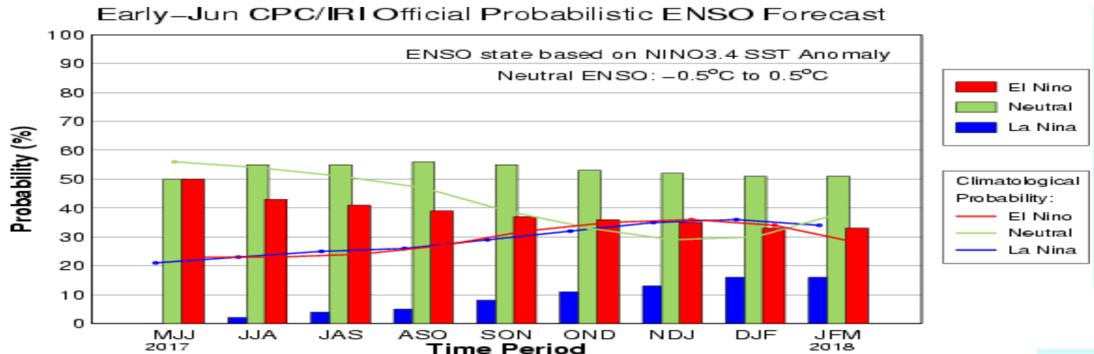


SST and uv850

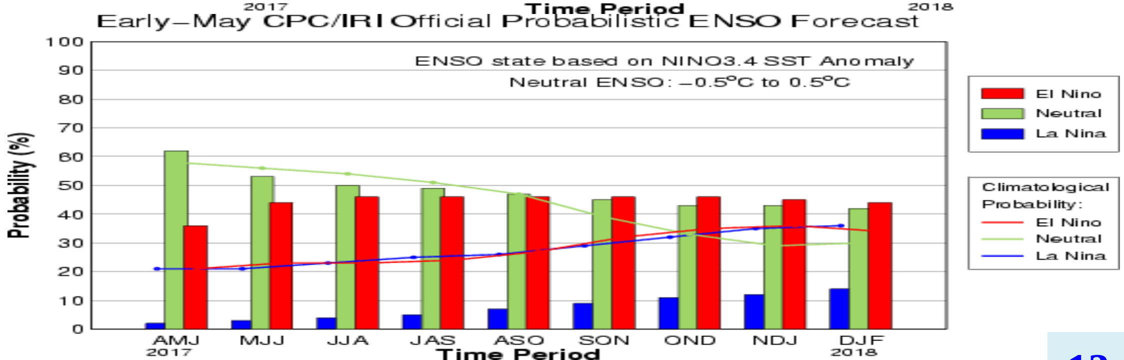


OLR and uv850

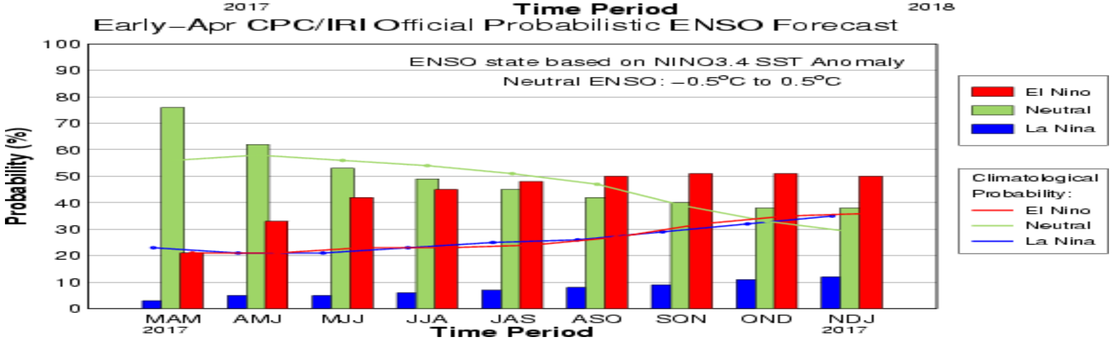




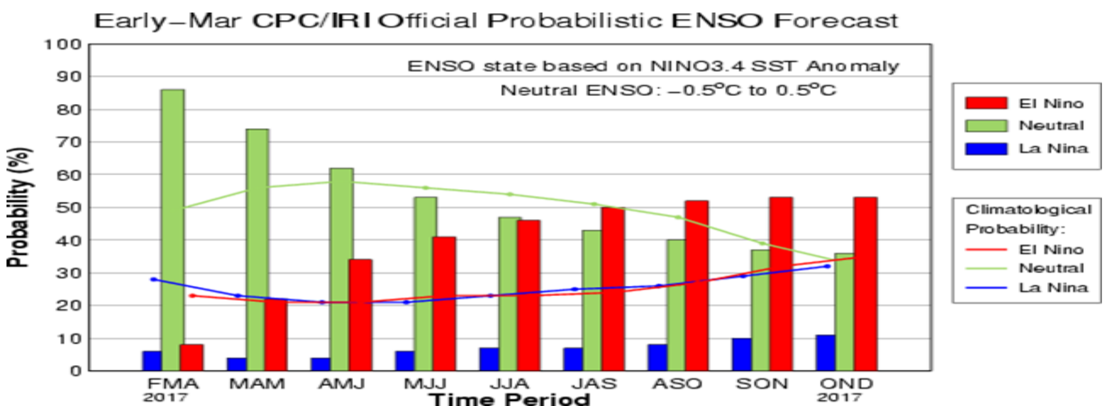
8 June 2017: "ENSO-neutral is favored (50 to ~55% chance) through the Northern Hemisphere fall 2017."



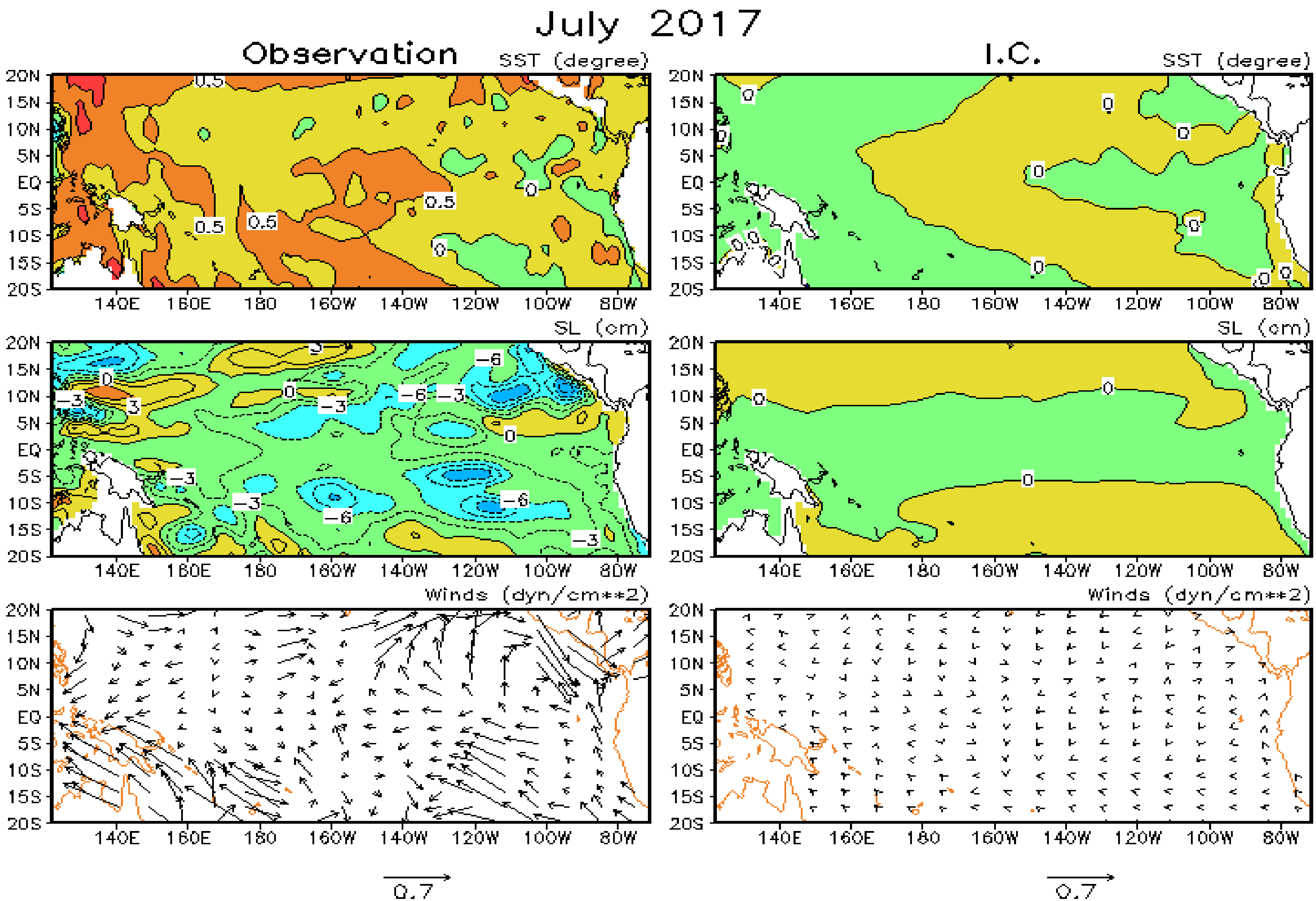
11 May 2017: "ENSO-neutral and El Niño are nearly equally favored during the Northern Hemisphere summer and fall 2017."



13 Apr 2017: "ENSO-neutral conditions are favored to continue through at least the Northern Hemisphere spring 2017, with increasing chances for El Niño development by late summer and fall."



09 Mar 2017: "ENSO-neutral conditions are favored to continue through at least the Northern Hemisphere spring 2017, with increasing chances for El Niño development into the fall."



http://www.cpc.ncep.noaa.gov/products/people/yxue/MKmodel_ellfb_clim81-10_godas/i.c._check/

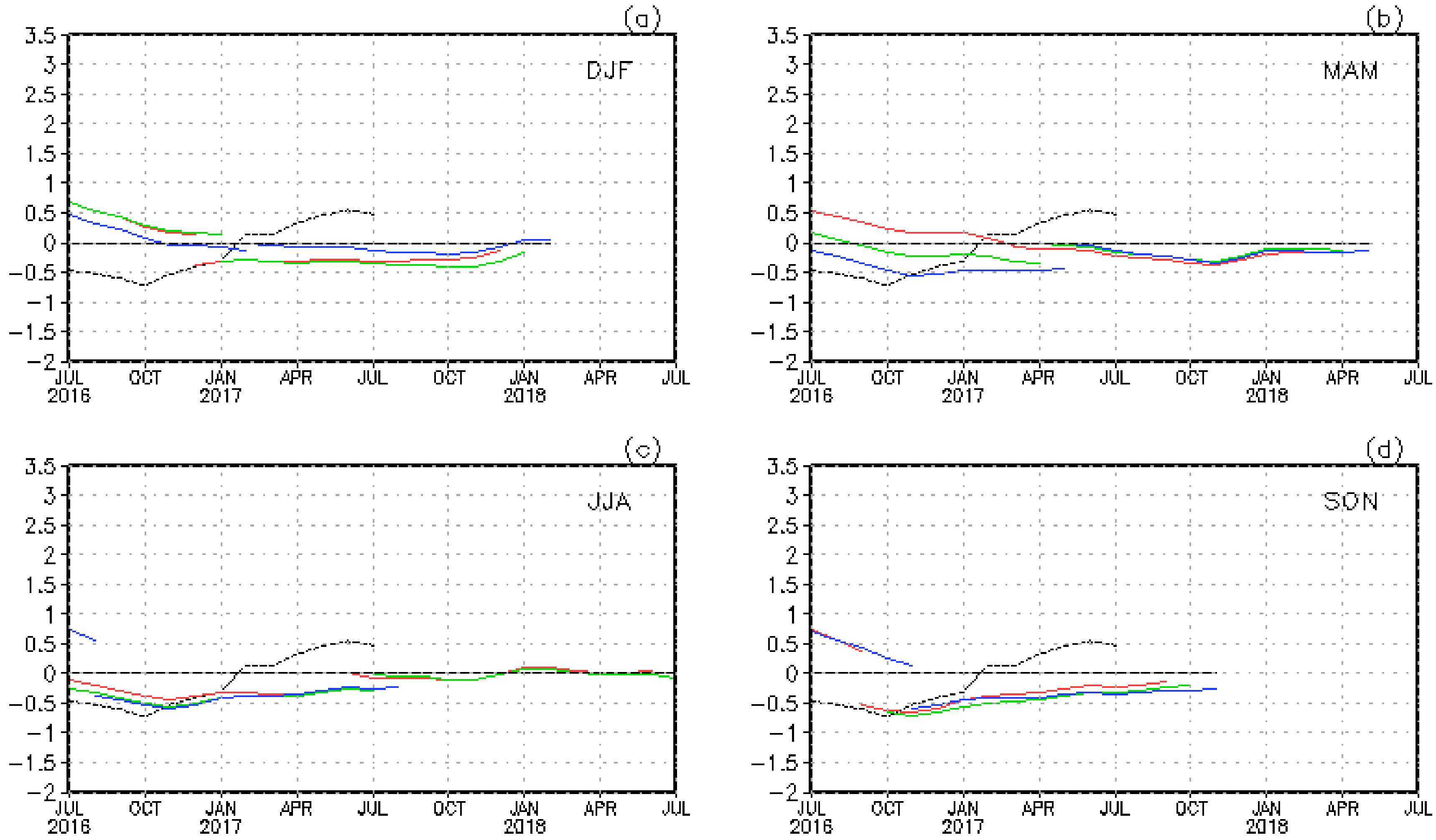
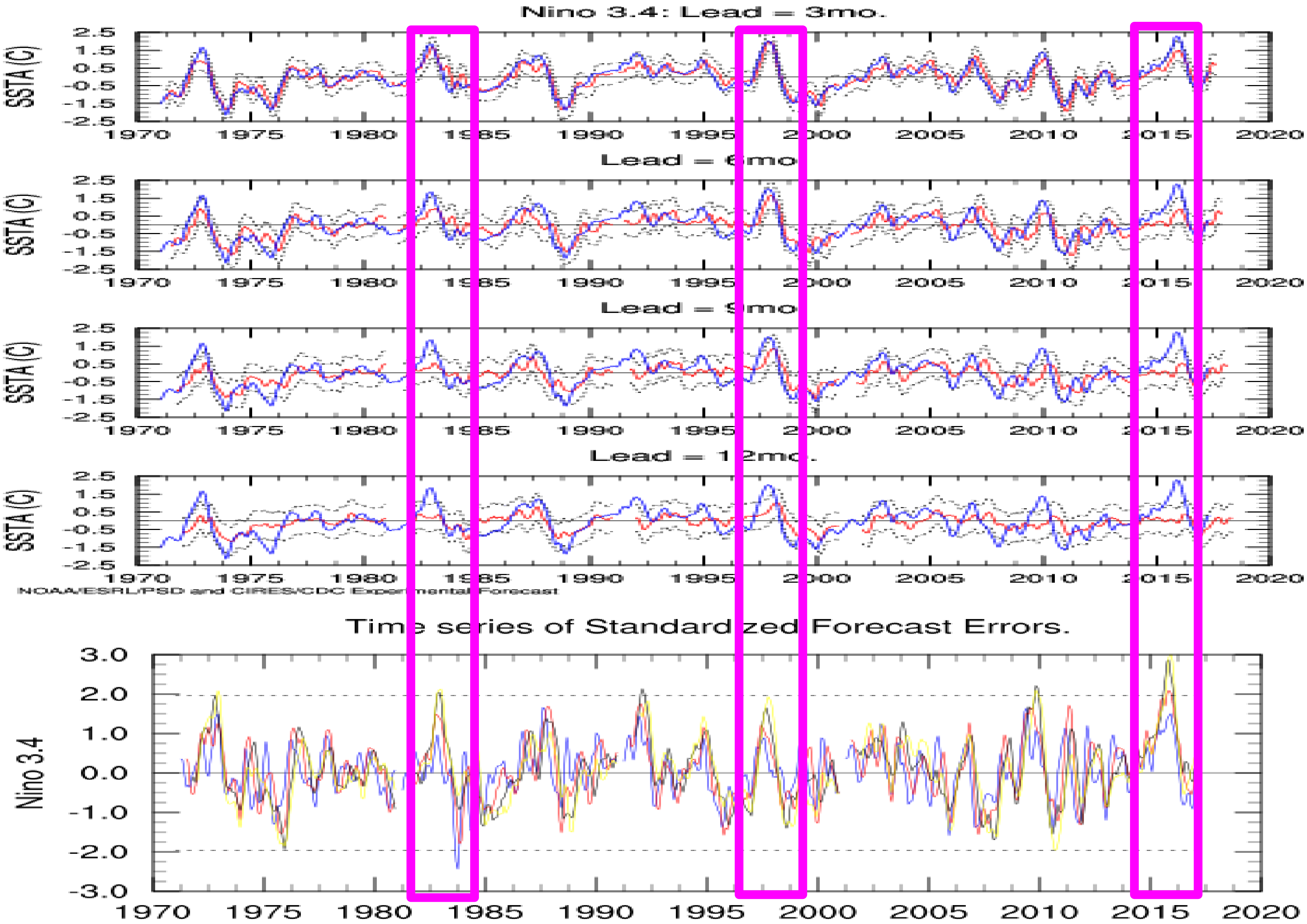


Fig. 4. Time evolution of NINO3.4 forecasts up to 12 lead months by the Markov model initiated monthly up to July 2017 . Shown in each panel are the forecasts grouped by three consecutive starting months: (a) is for December, January and February, (b) is for March, April and May, (c) is for June, July and August and (d) is for September, October and November. The observed NINO3.4 SST anomalies are shown in the heavy−dashed lines.

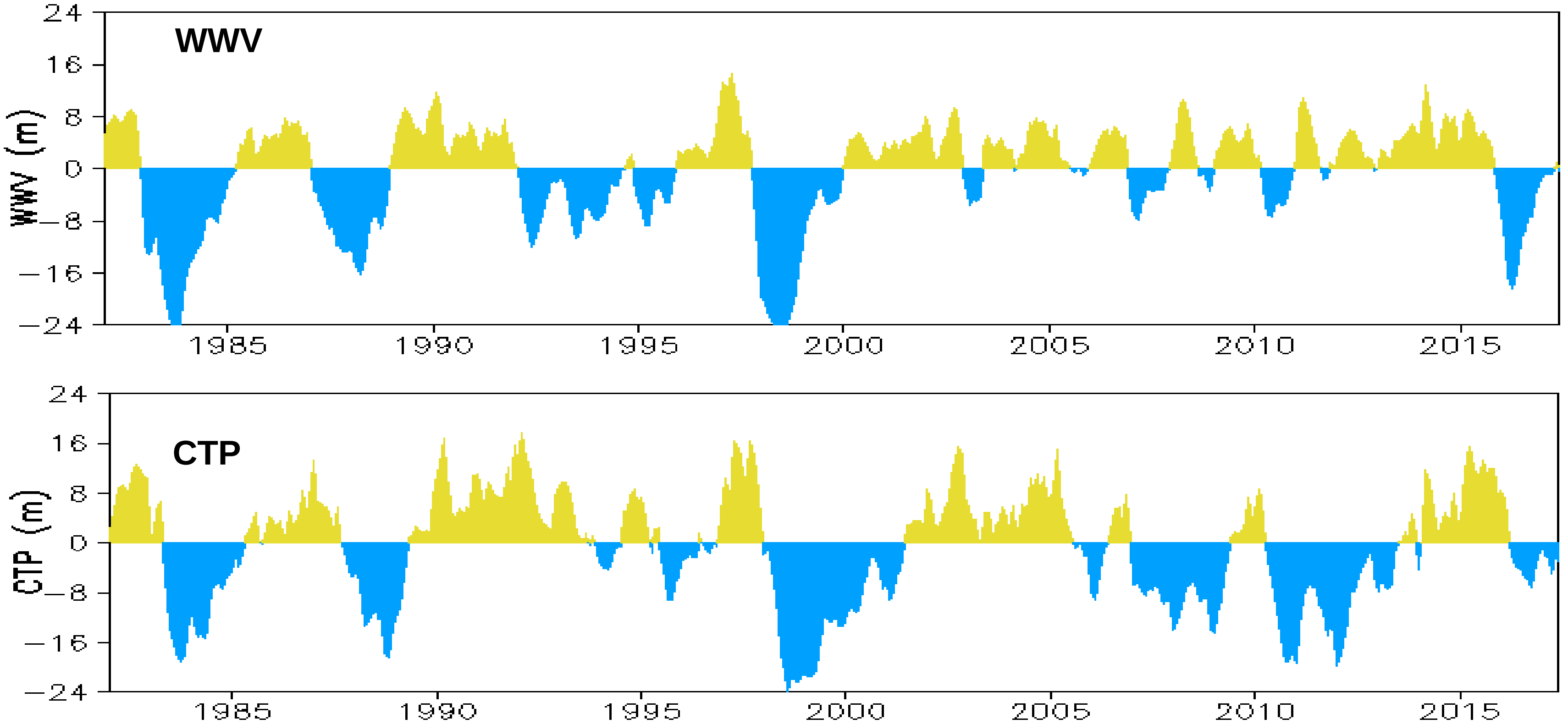
http://www.cpc.ncep.noaa.gov/products/people/yxue/MKmodel_ellfb_clim81-10_godas/fig4.gif



Linear Inverse Modeling (LIM):

https://www.esrl.noaa.gov/psd/forecasts/sstlim/for1gl.html

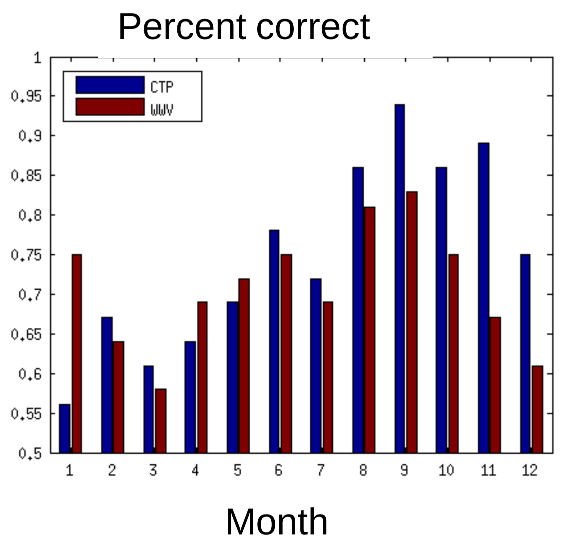
Two ENSO Precursors Based on Thermocline Anomaly

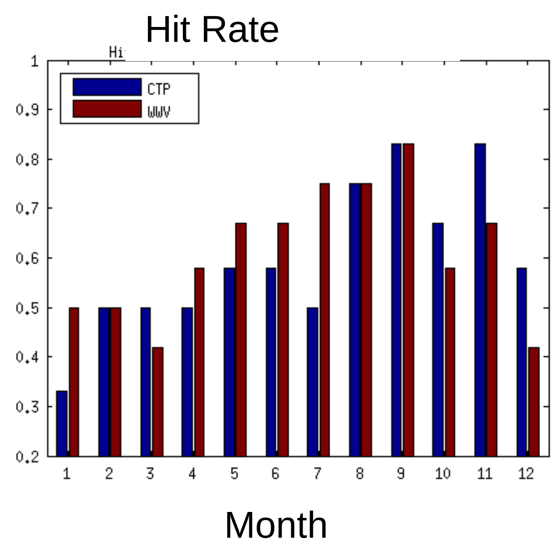


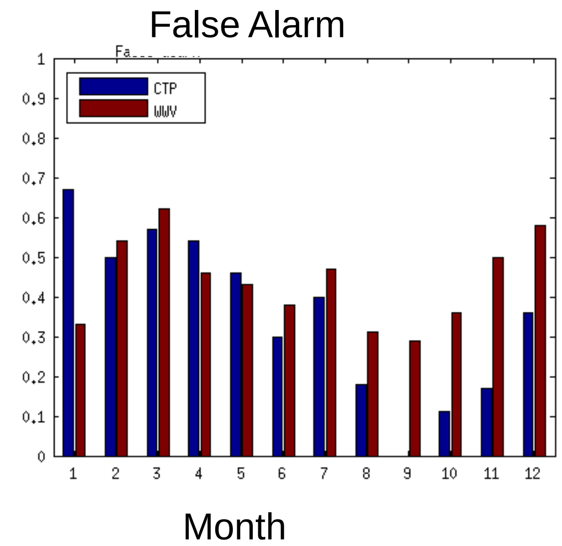
- **Warm Water Volume (WWV) index is defined as average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN]. It is inferred from the slow ocean adjustment via zonal mean heat content exchange between the equatorial and off-equatorial regions.**
- **Central tropical Pacific (CTP) index is defined as average of depth of 20ºC in [160ºW-110ºW, 10ºS-10ºN]. It includes equatorial thermocline variations involving the equatorial wave processes in response to the wind-stress-curl anomalies and off-equatorial thermocline variations related with Subtropical cells (STCs).**

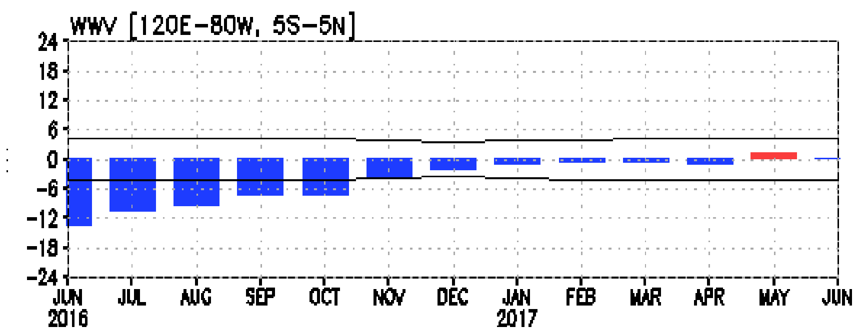
Meinen, C. S., and M. J. McPhaden, 2000: Observations of warm water volume changes in the equatorial Pacific and their relationship to El Niño and La Niña. *J.Climate*, **13,** 3551-3559.
Wen C, Kumar A, Xue Y, McPhaden MJ (2014) Changes in tropical pacific thermocline depth and their relationship to ENSO after 1999. *J Climate* 27:7230–7249

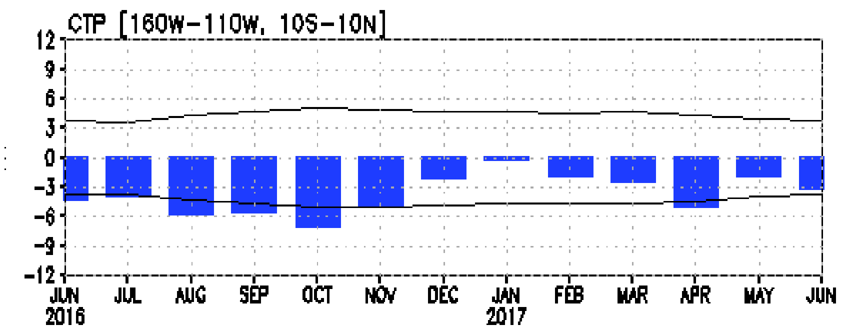
2x2 contingency table for El Nino case











Forecast criterion: 0.5 monthly standard deviation (black lines)

- Both WWV and CTP indices are within 0.5 STD in Jun 2017, indicating a high probability of neutral conditions during winter 2017/18.