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

Prepared by

Climate Prediction Center, NCEP/NOAA

April 10, 2017

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

This project to deliver real-time ocean monitoring products is implemented by CPC in cooperation with Ocean Observing and Monitoring Division (OOMD)/Climate Program Office/NOAA

Outline

- **Overview**

- **Recent highlights**

  - **Pacific/Arctic Ocean**
  - **Indian Ocean**
  - **Atlantic Ocean**

- **Global SST Predictions**

➢ **Current ENSO status and prediction**

➢ **“Cold Blob” in the North Atlantic**

➢ **Warming in the Gulf of Mexico**

Overview

Pacific Ocean

- In March 2017, Nino3.4 SST anomaly remained in the neutral range.
- Negative temperature anomalies developed near the thermocline in the central equatorial Pacific.
- NINO1+2 index reached 2^{o}C in March 2017, with enhanced convection over Ecuador and Peru.
- Arctic sea ice reached its annual maximum extent in March, and the sea ice extent ranked the lowest since 1979.

Indian Ocean

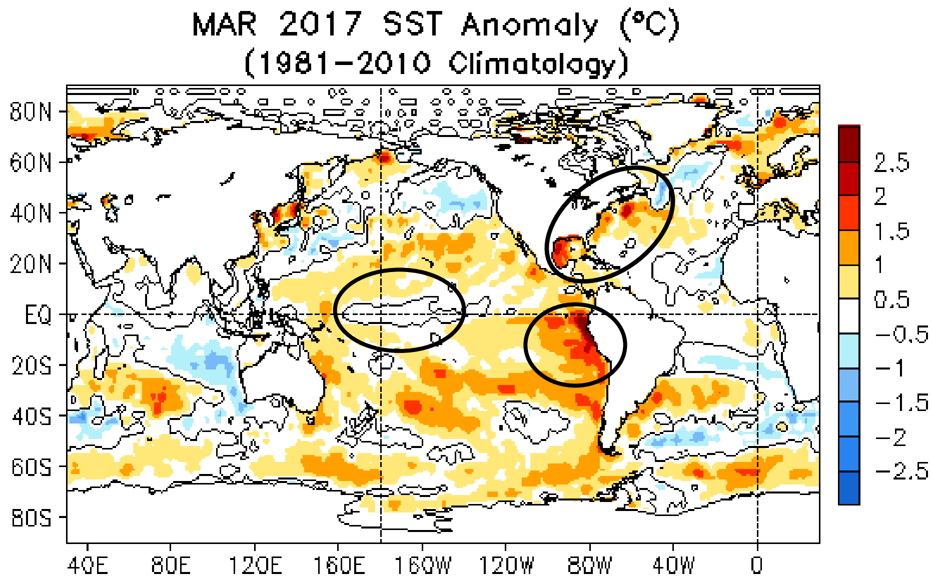
- SSTs continued to be near average in the tropical, and large positive in the SW Indian Ocean in March 2017.

Atlantic Ocean

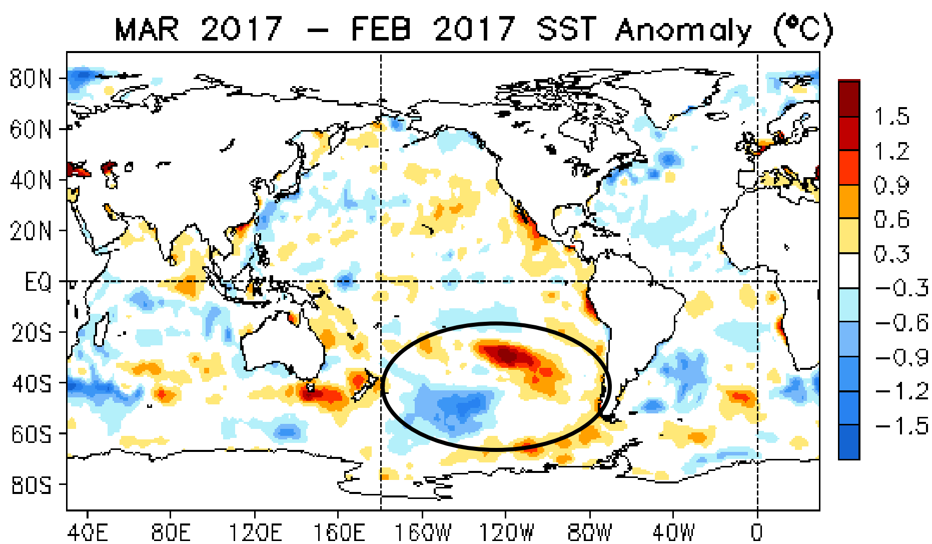
- NAO weakened slightly in March, with NAOI=0.4.
- Strong positive SSTA persisted in the Gulf of Mexico.
- Negative SSTA in the southeast of Greenland weakened in March.

Global Oceans

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



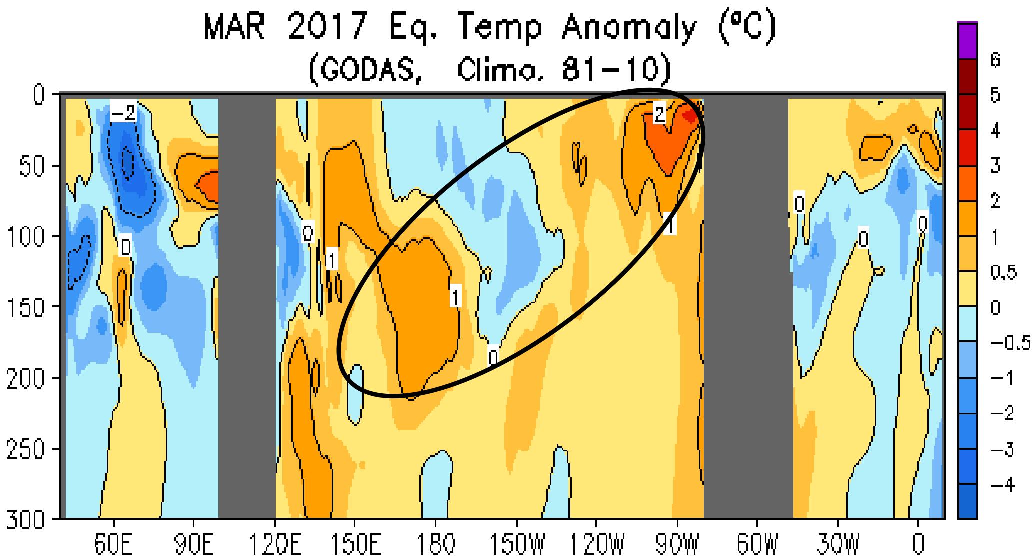
- -SSTs were near-average cross the central equatorial Pacific, while strong positive SSTA continued near the S. American coast.
- - Positive SSTA persisted in the Gulf of Mexico and East Coast of N. America.
- -SSTs were near average in the tropical Indian Ocean, while were well above-average (below-average) in the SW (SE) Indian Ocean.



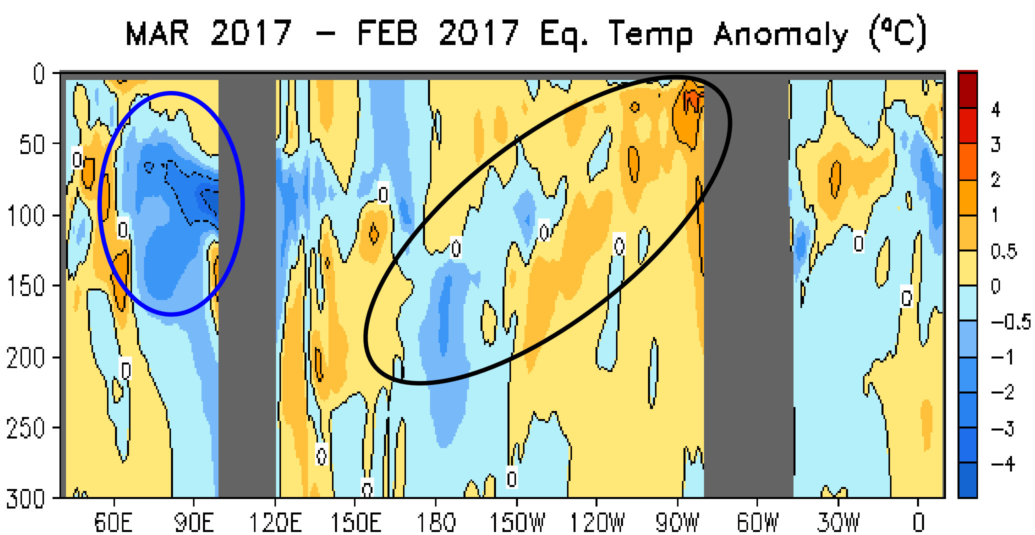
- - SSTA tendencies were close average in the tropical oceans.
- - Large SSTA tendencies were observed in southern Pacific and Indian Oceans.

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 ocean temperature anomalies continued in the western and eastern Pacific.
- Negative temperature anomalies developed near the thermocline in the central Pacific.
- Positive temperature anomalies presented in the upper 50m of Atlantic Ocean.

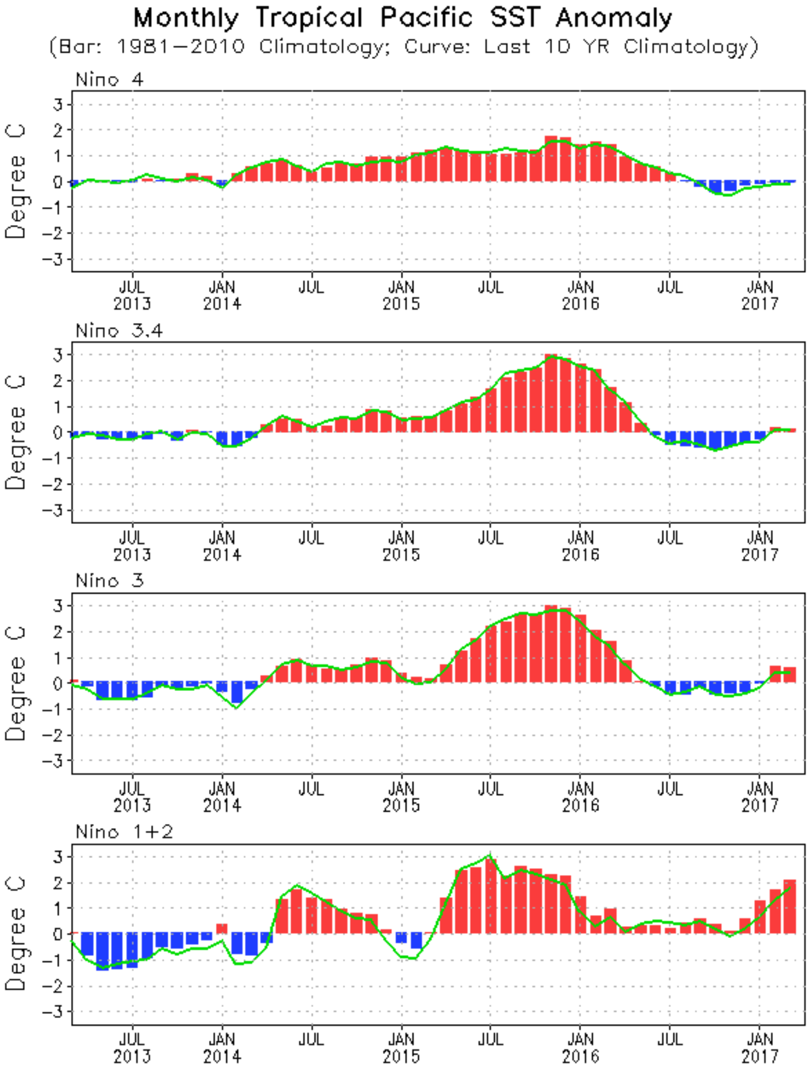


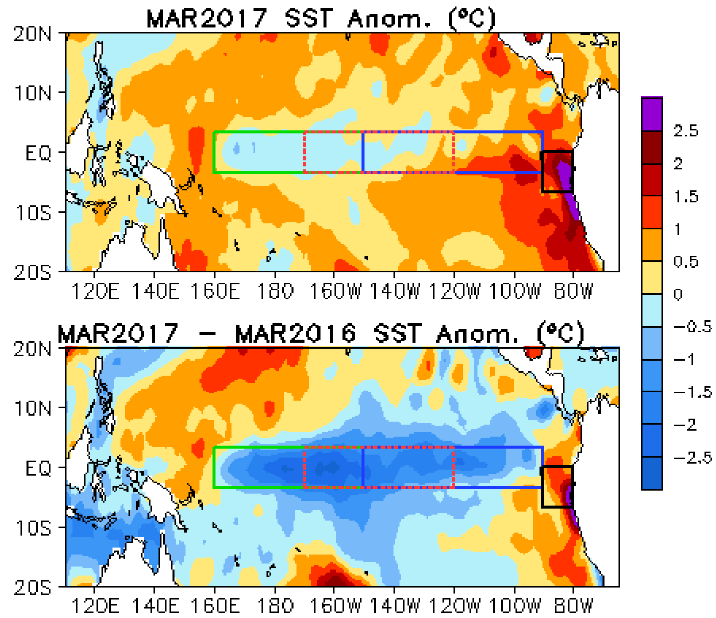
- Negative(positive) temperature anomaly tendency dominated along the thermocline in the central (eastern) Pacific.
- Strong negative temperature anomaly tendency presented in the eastern Indian Ocean.

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

Evolution of Pacific NINO SST Indices

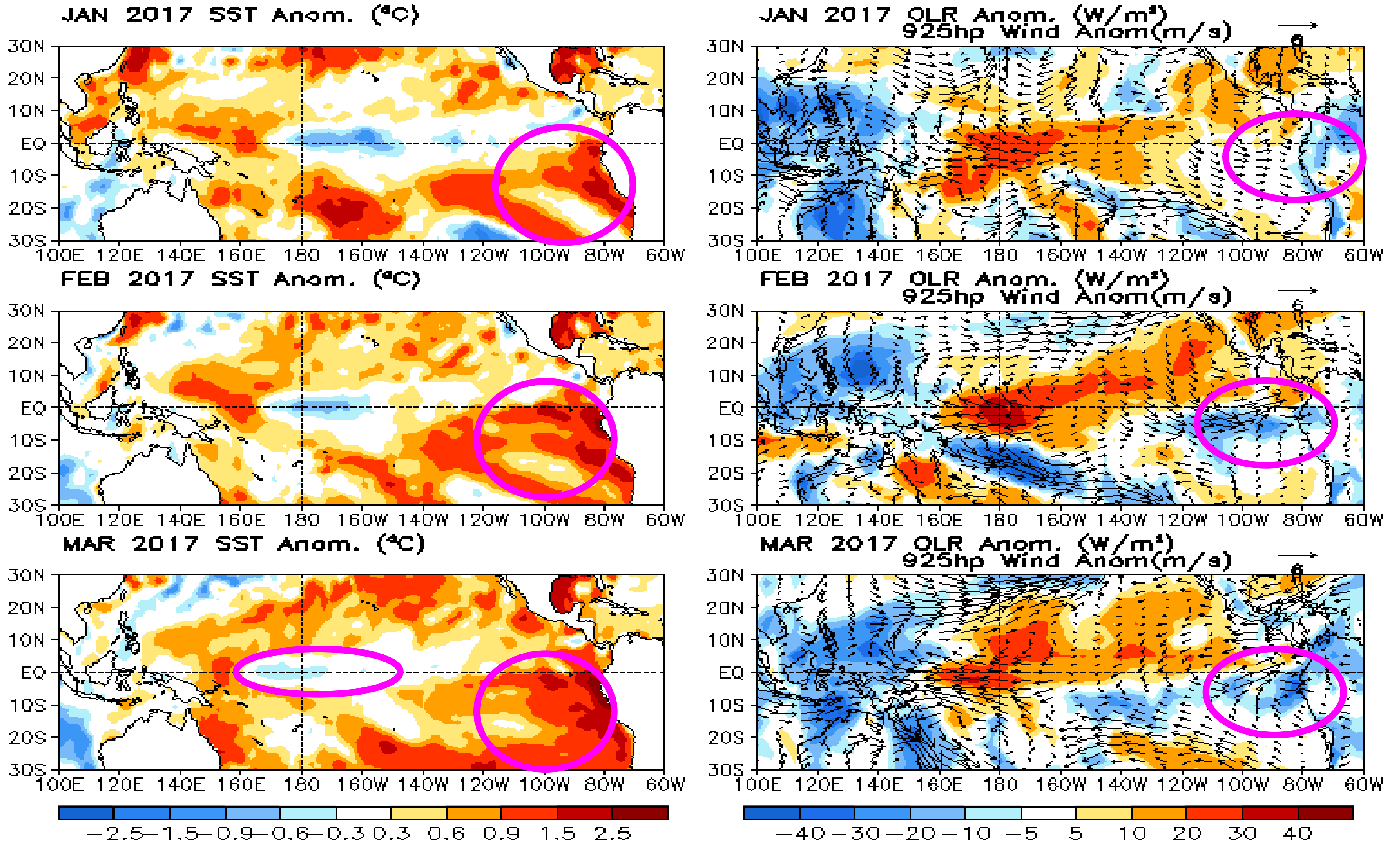




- Nino 4, and Nino 3.4 indices were close to average.
- Nino 1+2 index increased to 2°C in Mar 2017.
- Nino3.4 = 0.1°C in Mar 2017.
- Compared with last Mar, the central and eastern equatorial Pacific was much cooler in Mar 2017, associated with El Nino in 2015/16 transition to La Nina in 2016/17 .
- 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.

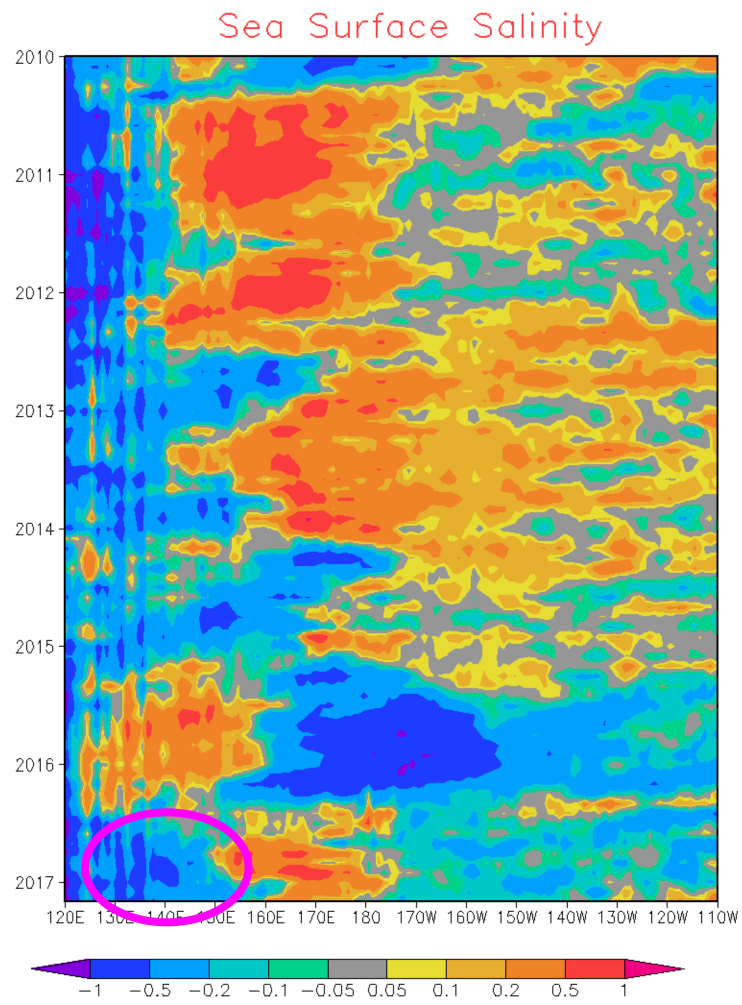
Last Three Month SST, OLR and 925hp Wind Anom.



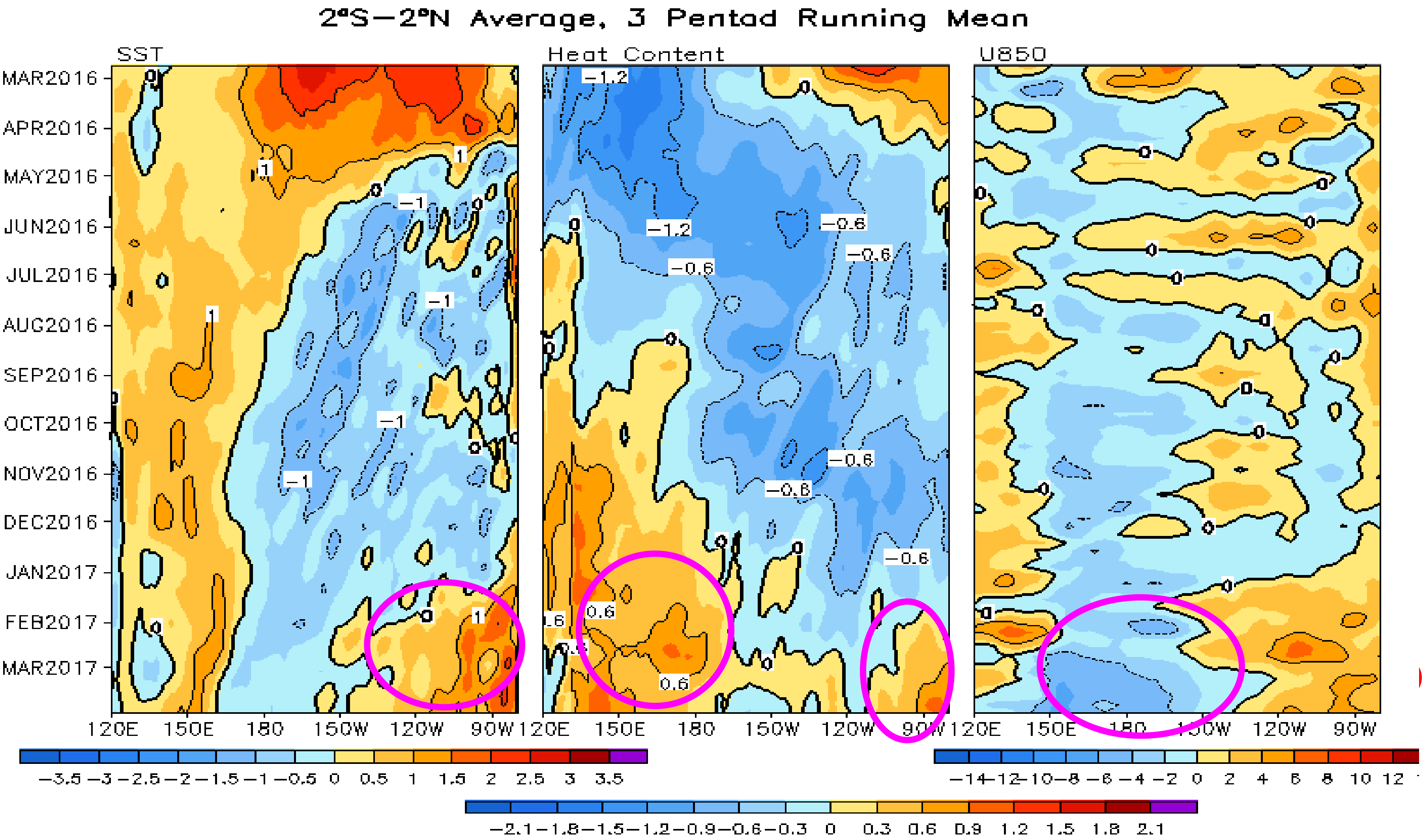
- Negative SSTA weakened to near average in the central Pacific in March.
- Negative (positive) OLR anomalies persisted over Maritime Continent (International Date line) in the last three months.
- SST off the coast of South America warmed considerably in the last three months, which were accompanied by persistent westerly wind anomalies in the SE.Pacific.
- Enhanced convection were observed over the Ecuador and Peru in the last three months, suggesting a coastal El Nino condition in these regions.

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

- Hovemoller diagram for equatorial SSS anomaly **(3ºS-3ºN);**
- In the western equatorial Pacific Ocean, from 120°E to 150°E, the negative SSS signal continues. At the meantime, the positive SSS anomaly in the central equatorial Pacific region between 150°E to 170°W continues as well. The SSS anomaly in the eastern basin (east of 130°W) is becoming positive.



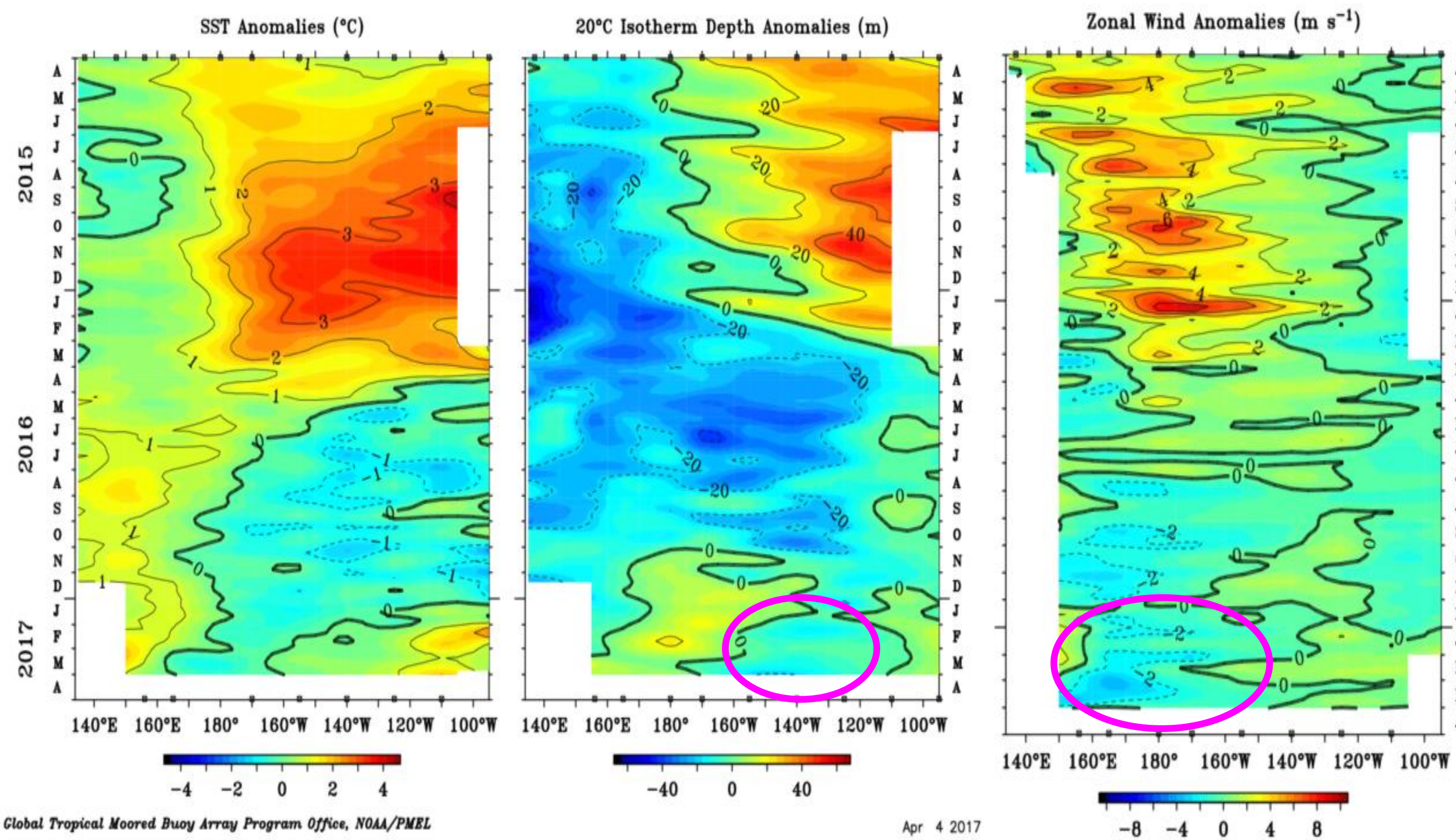
Equatorial Pacific SST (ºC), HC300 (ºC), u850 (m/s) Anomalies



- Positive SSTA in the eastern Pacific strengthened and expanded westward in last 3 months.
- Positive HC300A persisted in the western and eastern Pacific, while weakened in the central Pacific.
- Low-level easterly wind anomalies enhanced over the western-central Pacific.

Five Day SST, 20C Isotherm Depth and Zonal Wind Anomalies [2S-2N]

(http://www.pmel.noaa.gov/tao/jsdisplay/)

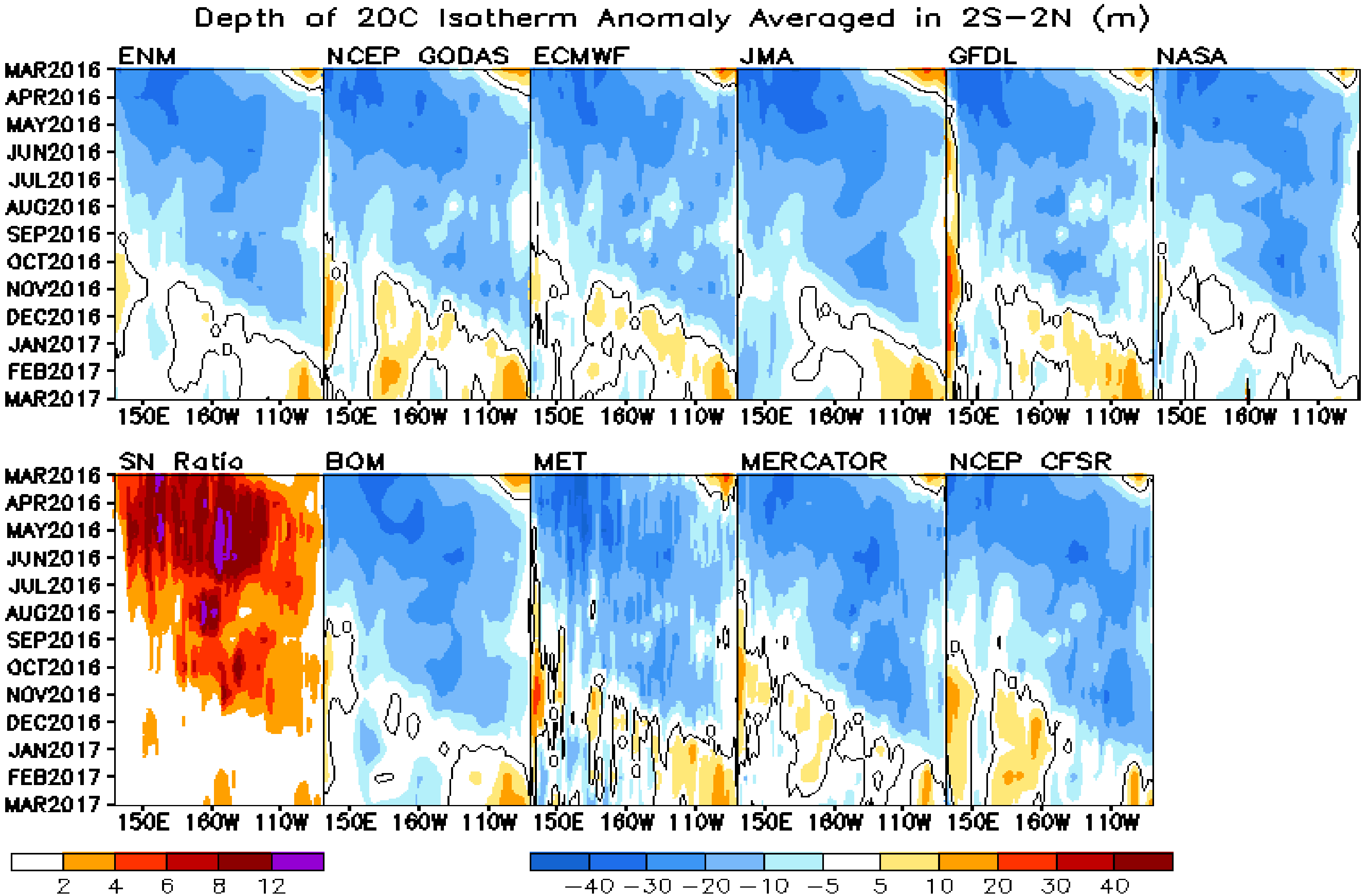


- Surface easterly wind anomalies enhanced in the W.-C. Pacific in March, giving rise to negative d20 anomalies across the central equatorial Pacific.

Real-Time Ocean Reanalysis Intercomparison: D20

Climatology : 1993-2013

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



Real-Time Ocean Reanalysis Intercomparison: D20

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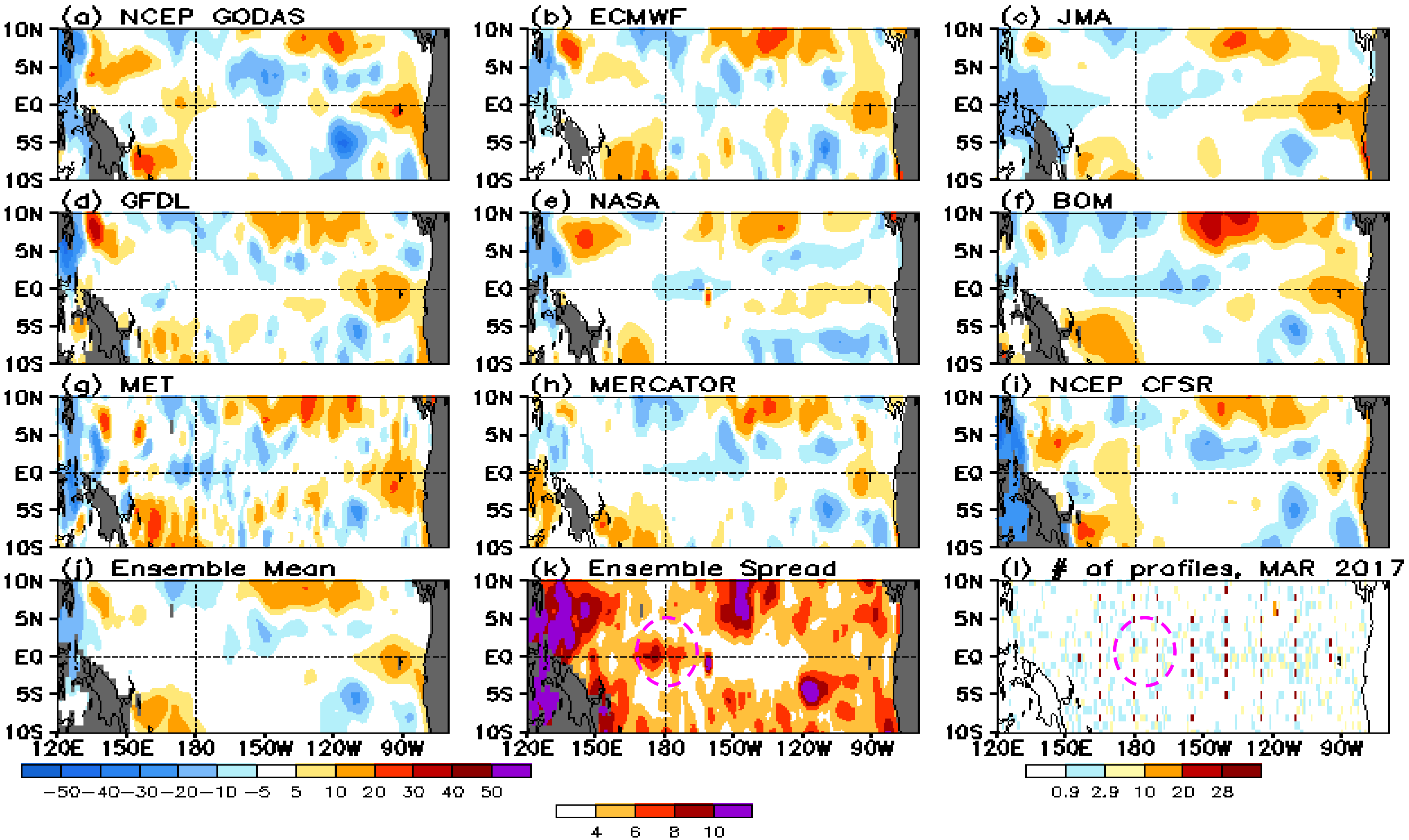
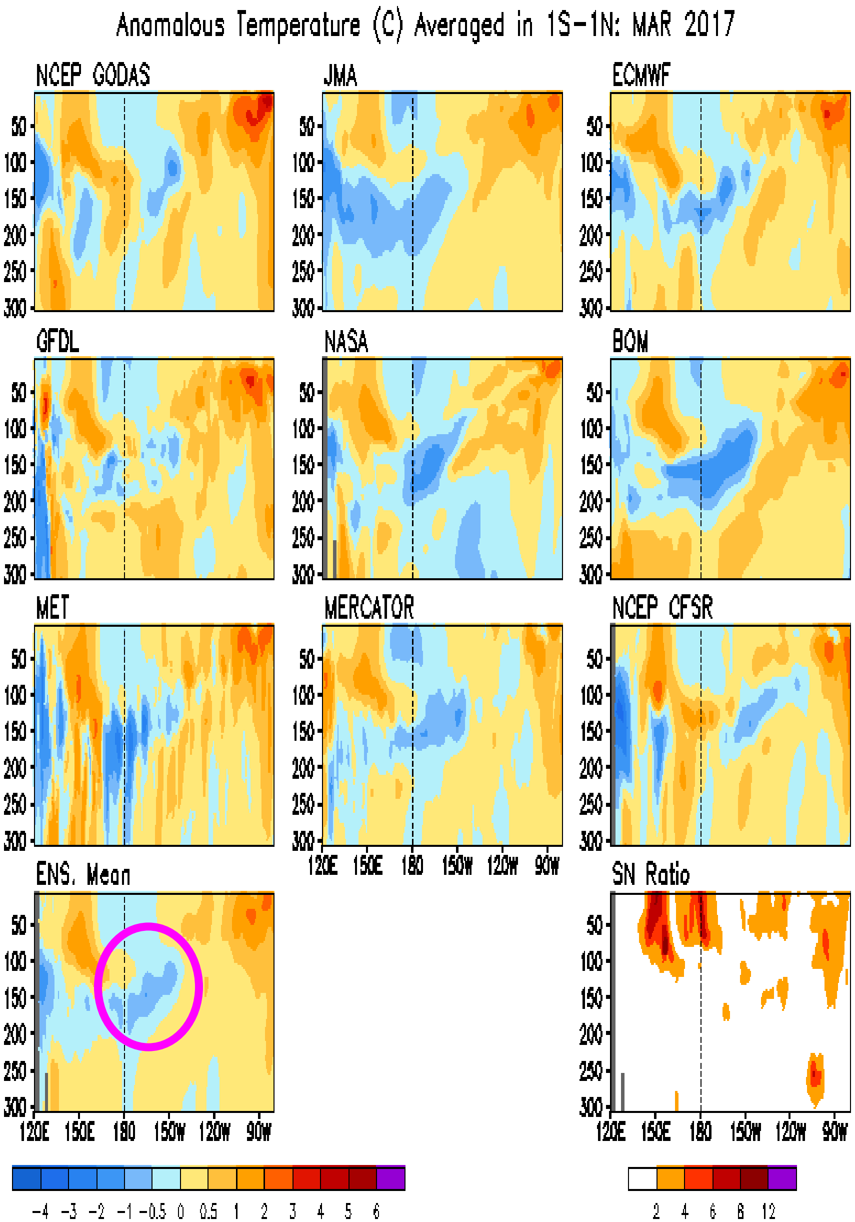


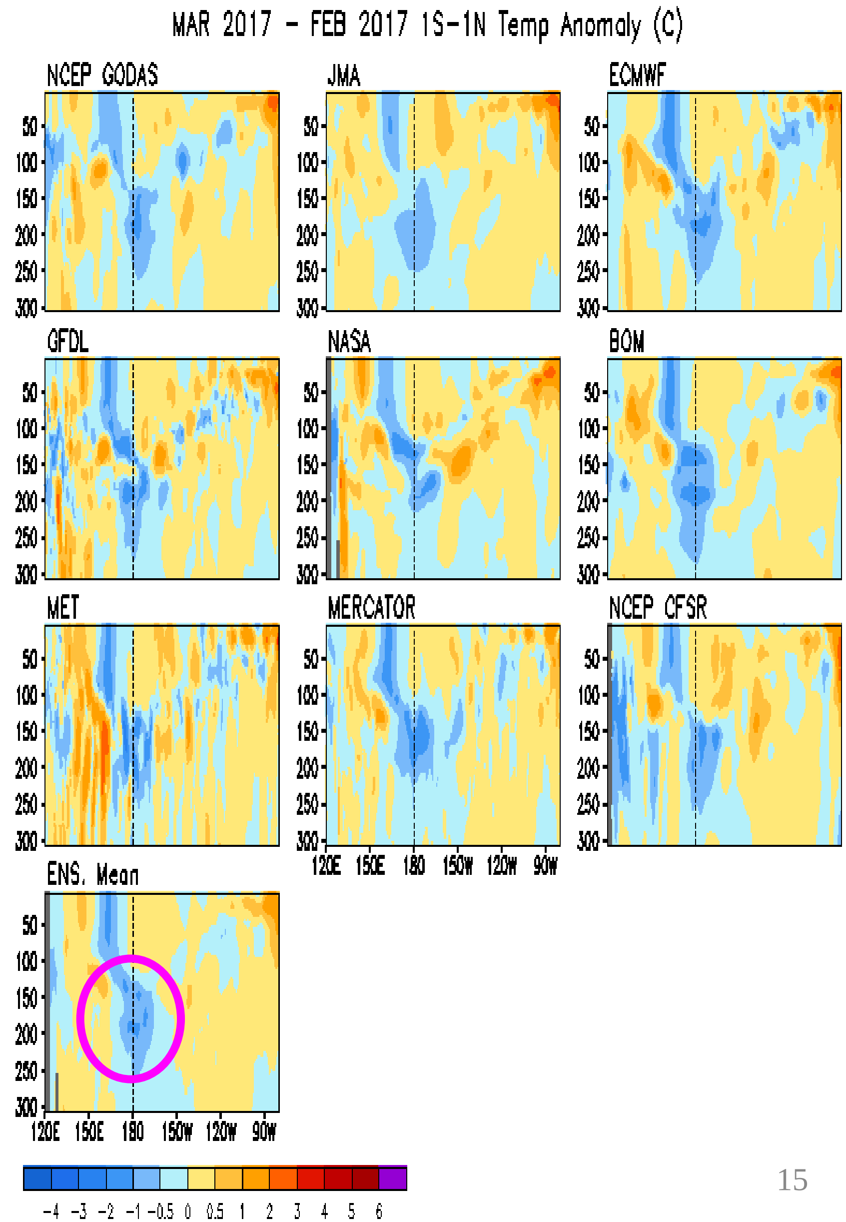
- **Spread was large near the dateline, which could be attributed to the missing buoy at [180W, 0N].**

Real-Time Ocean Reanalysis Intercomparison: Temperature

Climatology : 1993-2013

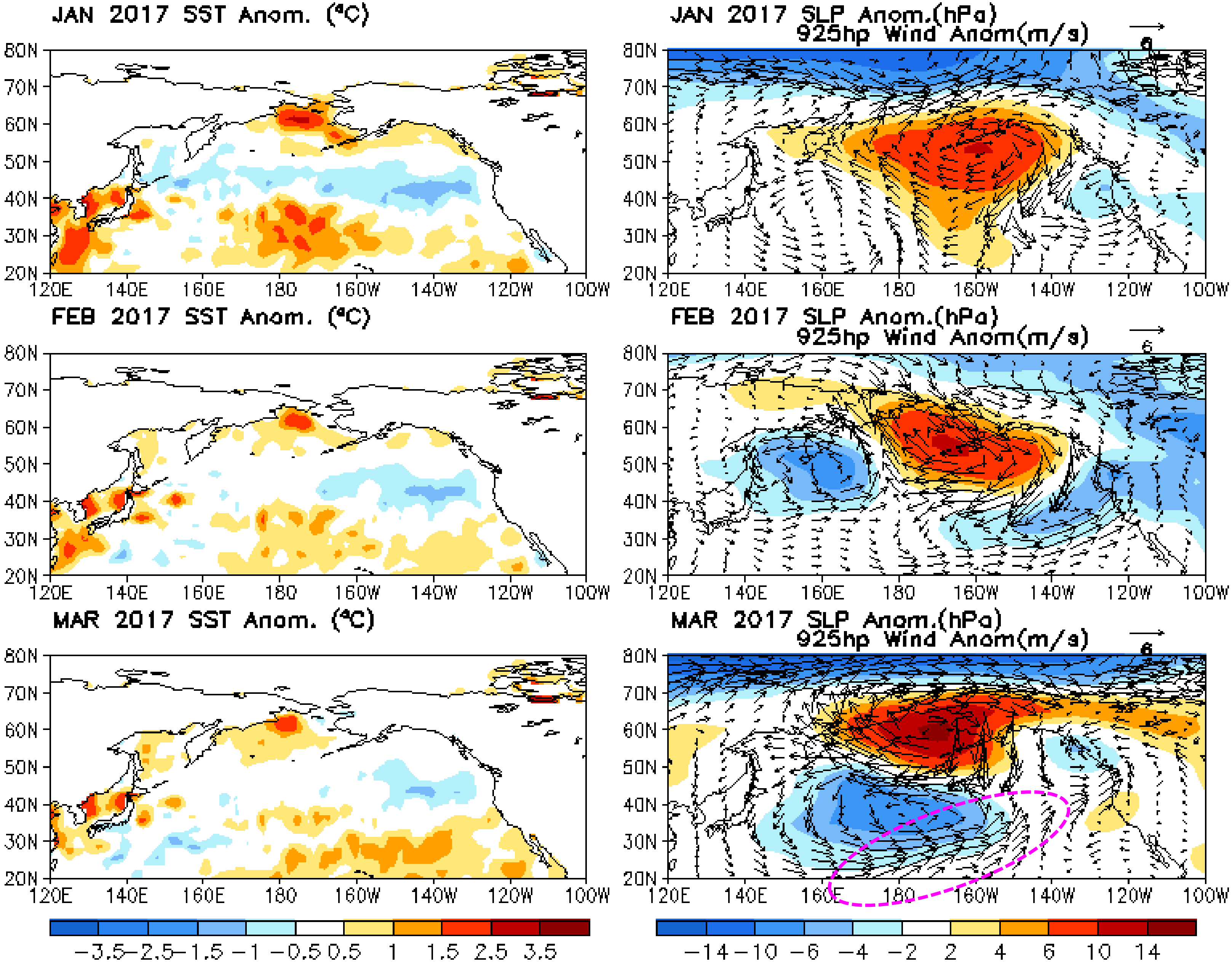
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)



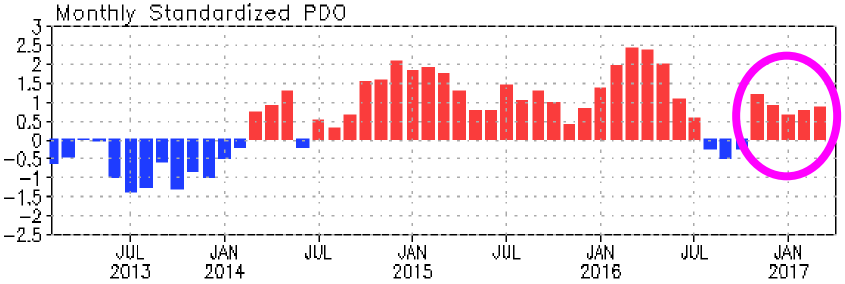


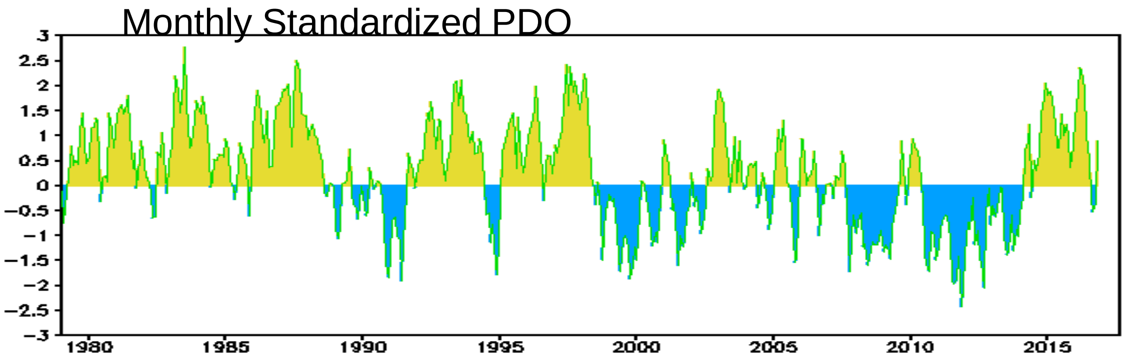
North Pacific & Arctic Oceans

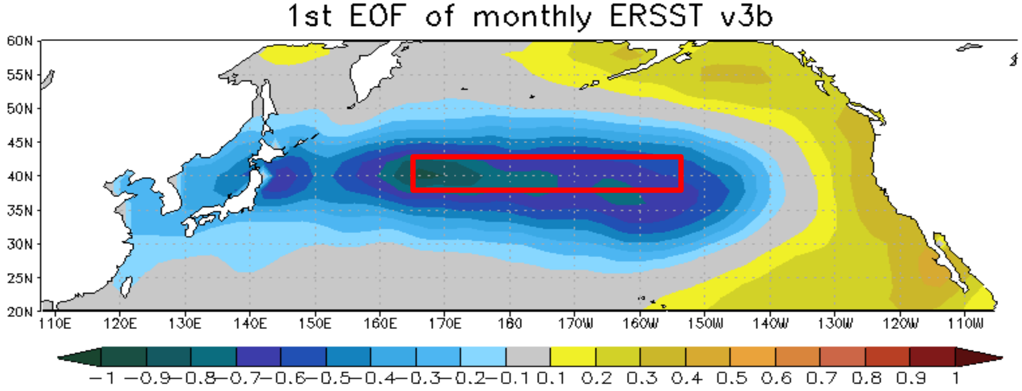
Last Three Month SST, SLP and 925hp Wind Anomalies



PDO index based on SST







- The positive phase of PDO index has persisted 5 months since Nov 2016 with PDO index =0.8 in Mar 2017.

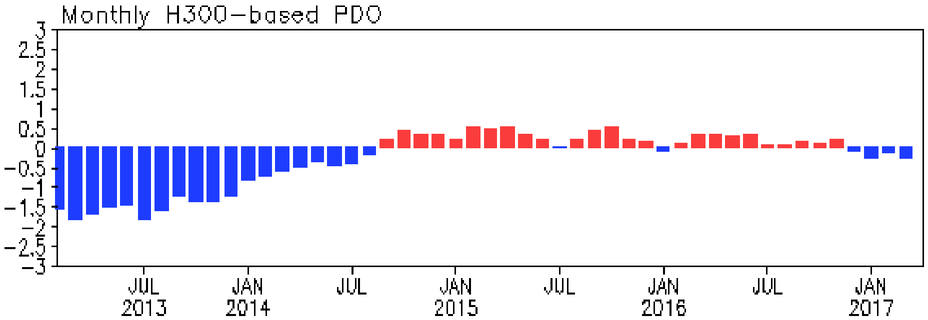
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

- 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 ERSST v4 monthly SST anomalies onto the 1st EOF pattern.

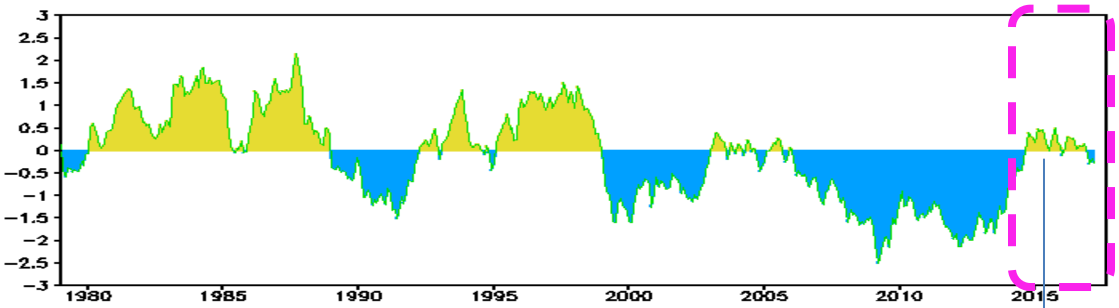
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

PDO index based on HC300 data

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

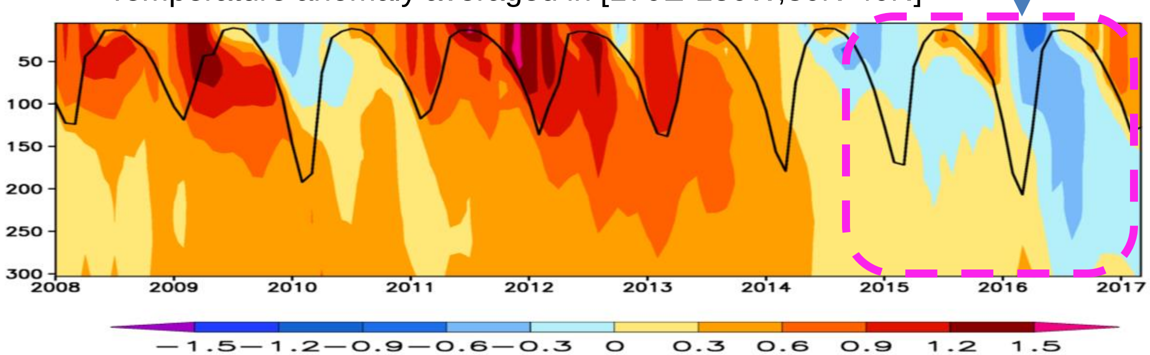


- HPDO index switched to negative phase in Nov 2016, with HPDO = -0.26 in Mar 2017.



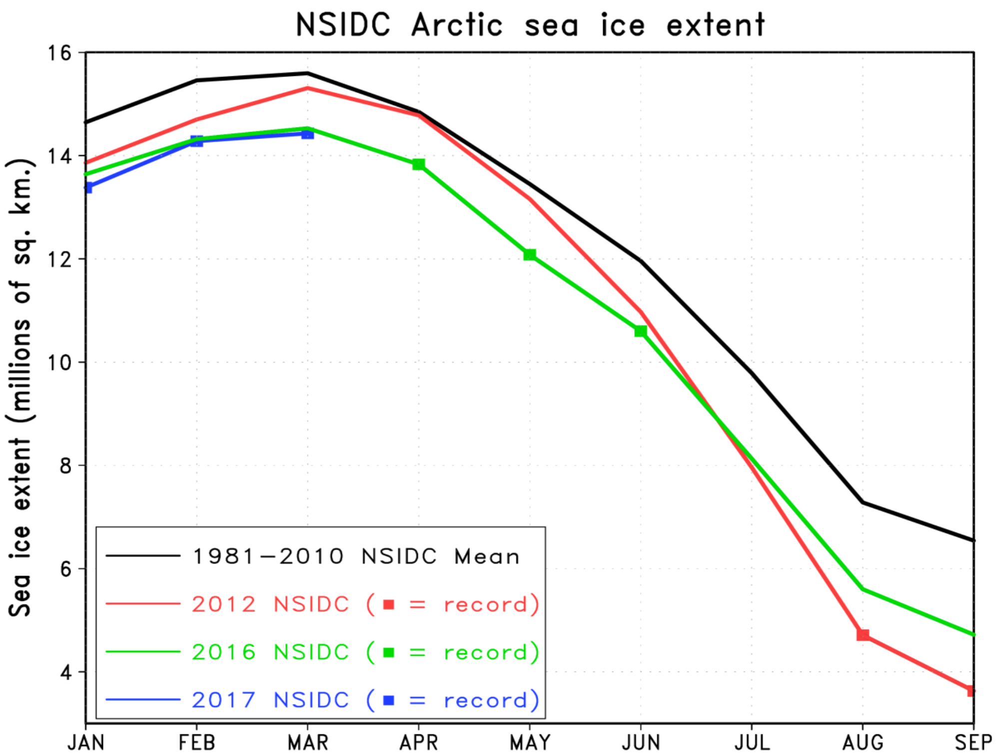
- Upper 300m Ocean Heat Content (HC300) based PDO index (HPDO) highlights the slower variability and encapsulates an integrated view of temperature variability in the upper ocean.

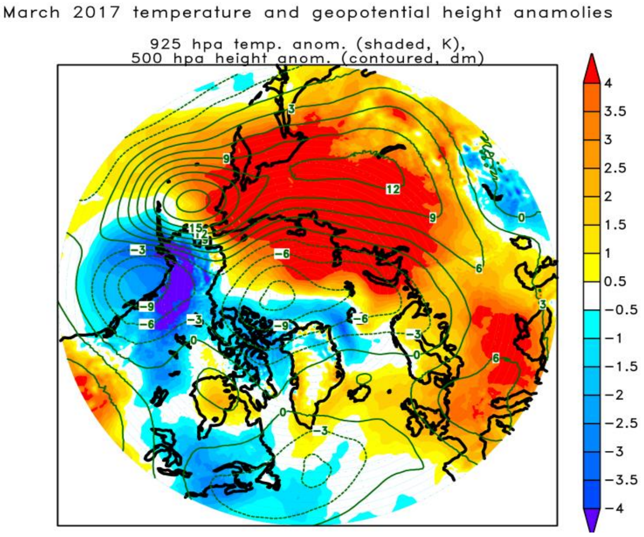
Temperature anomaly averaged in [170E-150W,30N-40N]

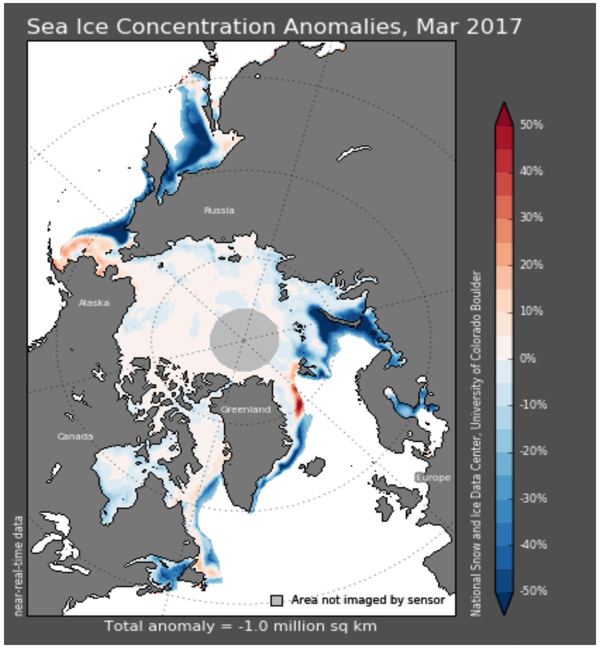


Kumar, A. and C. Wen, 2016: An Oceanic Heat Content-Based Definition for the Pacificc Decadal Oscillation. Mon. Wea. Rev., 144, 3977–3984, doi: 10.1175/MWR-D-16-0080.1.

Arctic Sea Ice





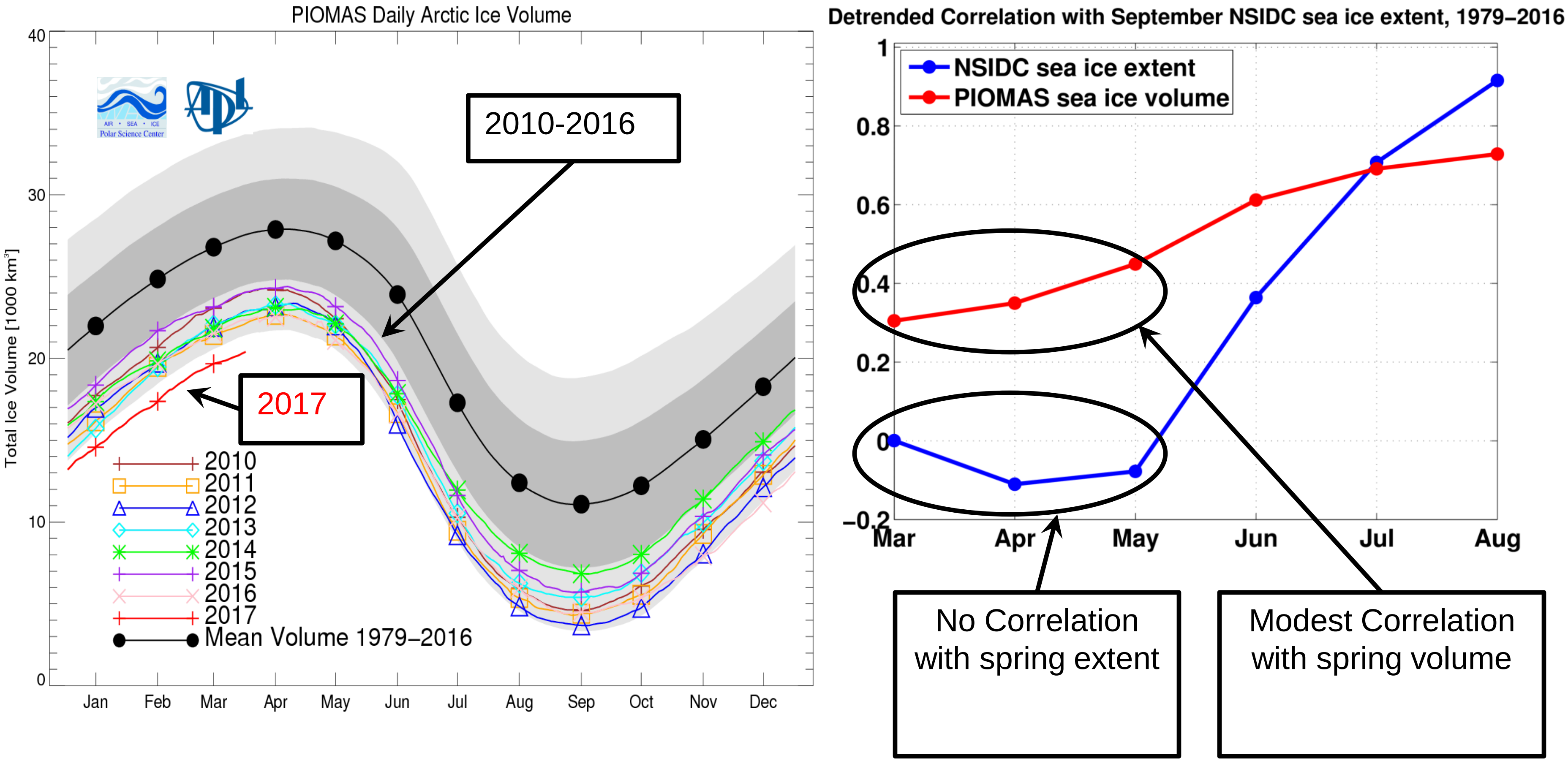


-Sea ice extent reached its seasonal maximum on Mar. 7, 2017

-Jan, Feb, and Mar 2017 set new records for lowest monthly sea ice extent in the satellite record due to persistence of warm temps.

-This does not necessary equate to low summer sea ice extent as 2012 experienced higher sea ice extent in March followed by record low extent in September (red line). Conversely, last year featured a very low March extent but a higher September extent (green line)

https://nsidc.org/data/seaice_index/



http://psc.apl.washington.edu/research/projects/arctic-sea-ice-volume-anomaly/

-Sea ice volume may be a better predictor of upcoming summer sea ice extent. 2017 sea ice volume is running considerably lower than in the 2010-2016 period based on daily PIOMAS data.

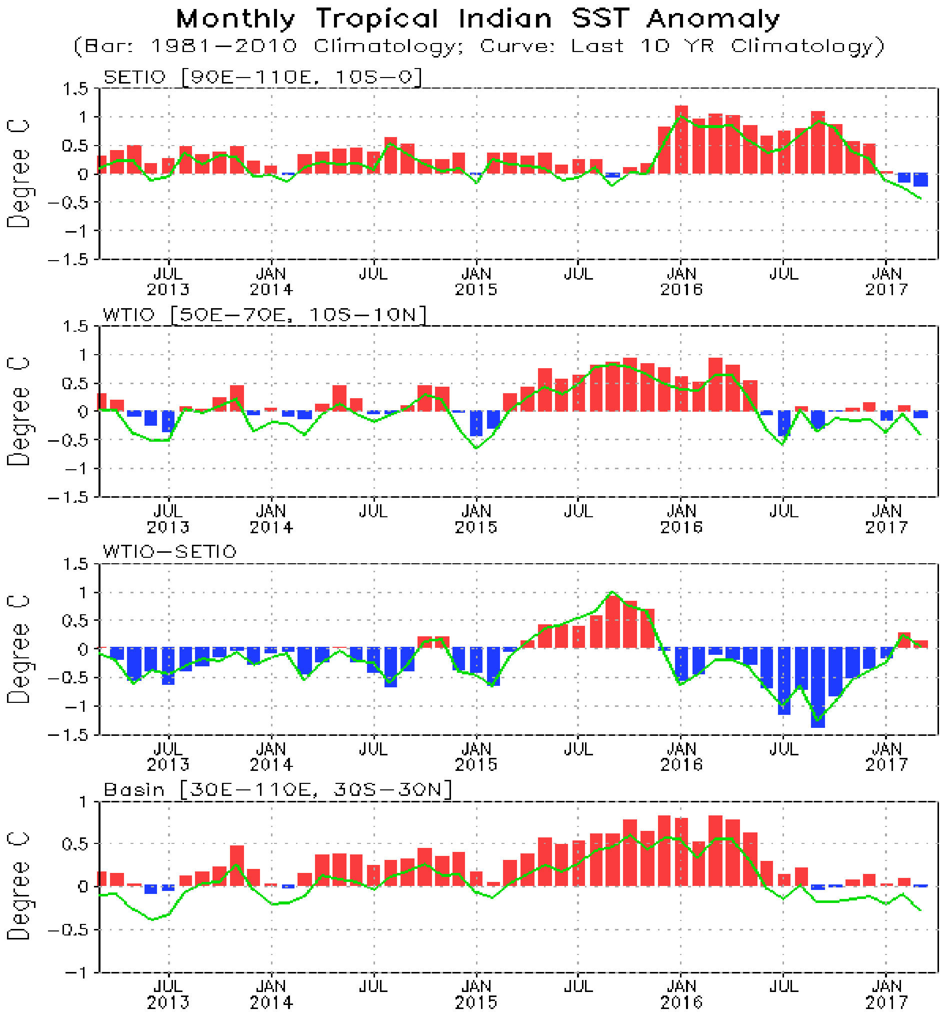
-Although 2016 and 2017 March sea ice extents are nearly the same, the sea ice volume is less this year, which suggests that sea ice will have an easier time melting this year then last year.

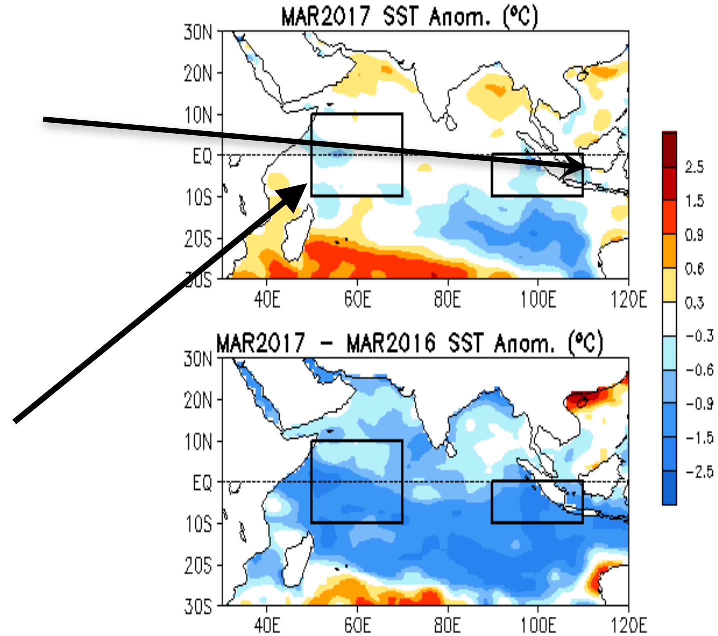
-As with last year, atmospheric conditions in the summer will likely determine whether or not the September 2012 record low will be broken, but a close call certainly looks possible.

(Provided by Thomas W. Collow)

Indian Ocean

Evolution of Indian Ocean SST Indices



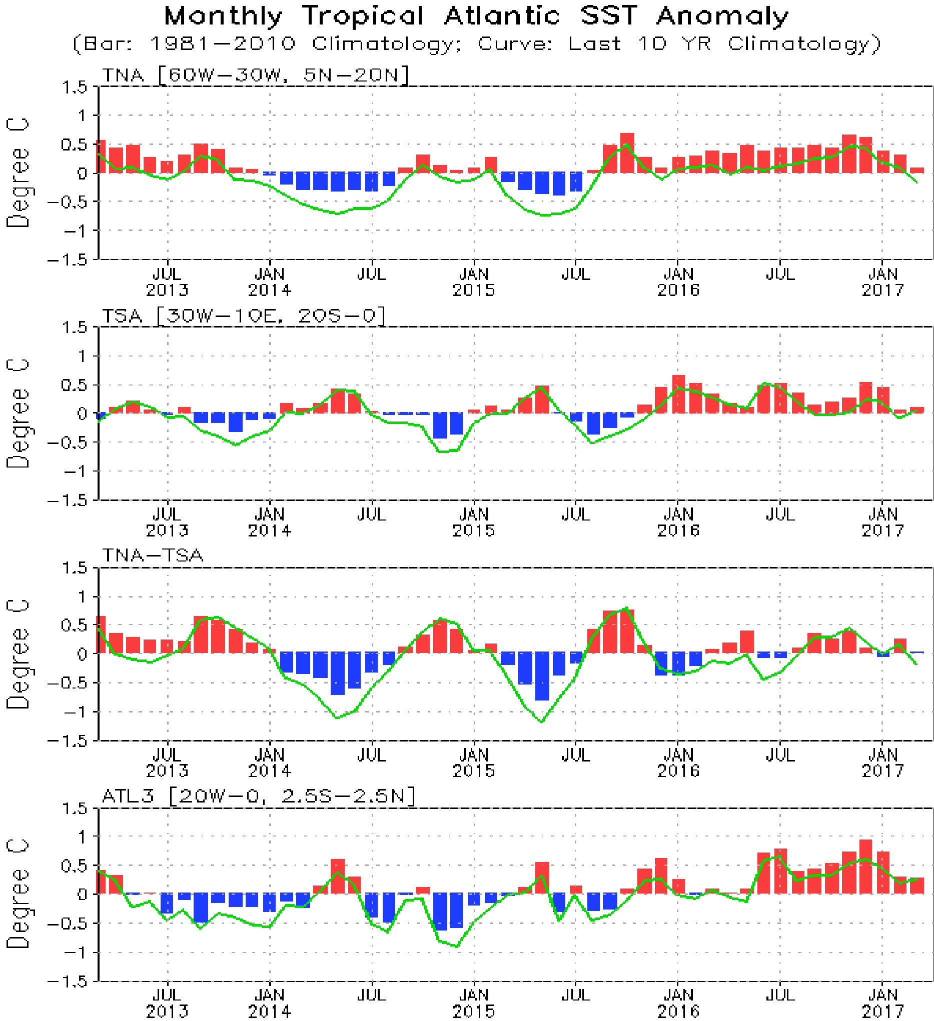


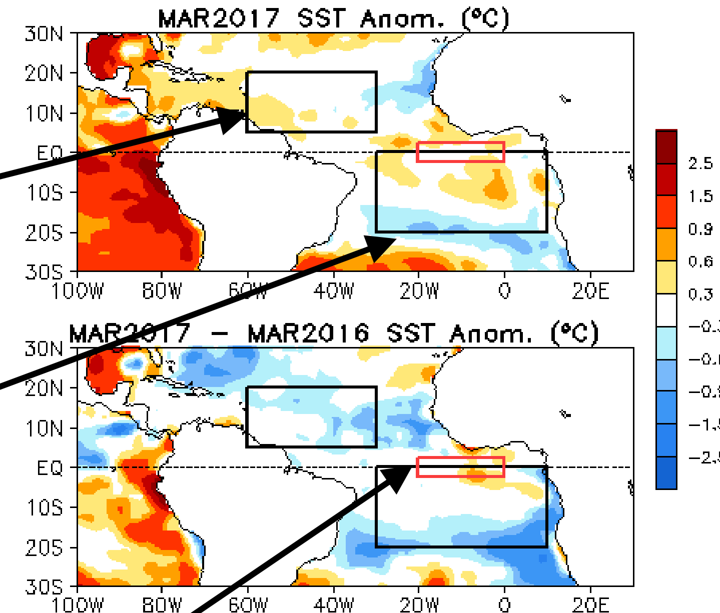
- **Near-average temperature dominated the tropical Indian Ocean.**

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 and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices



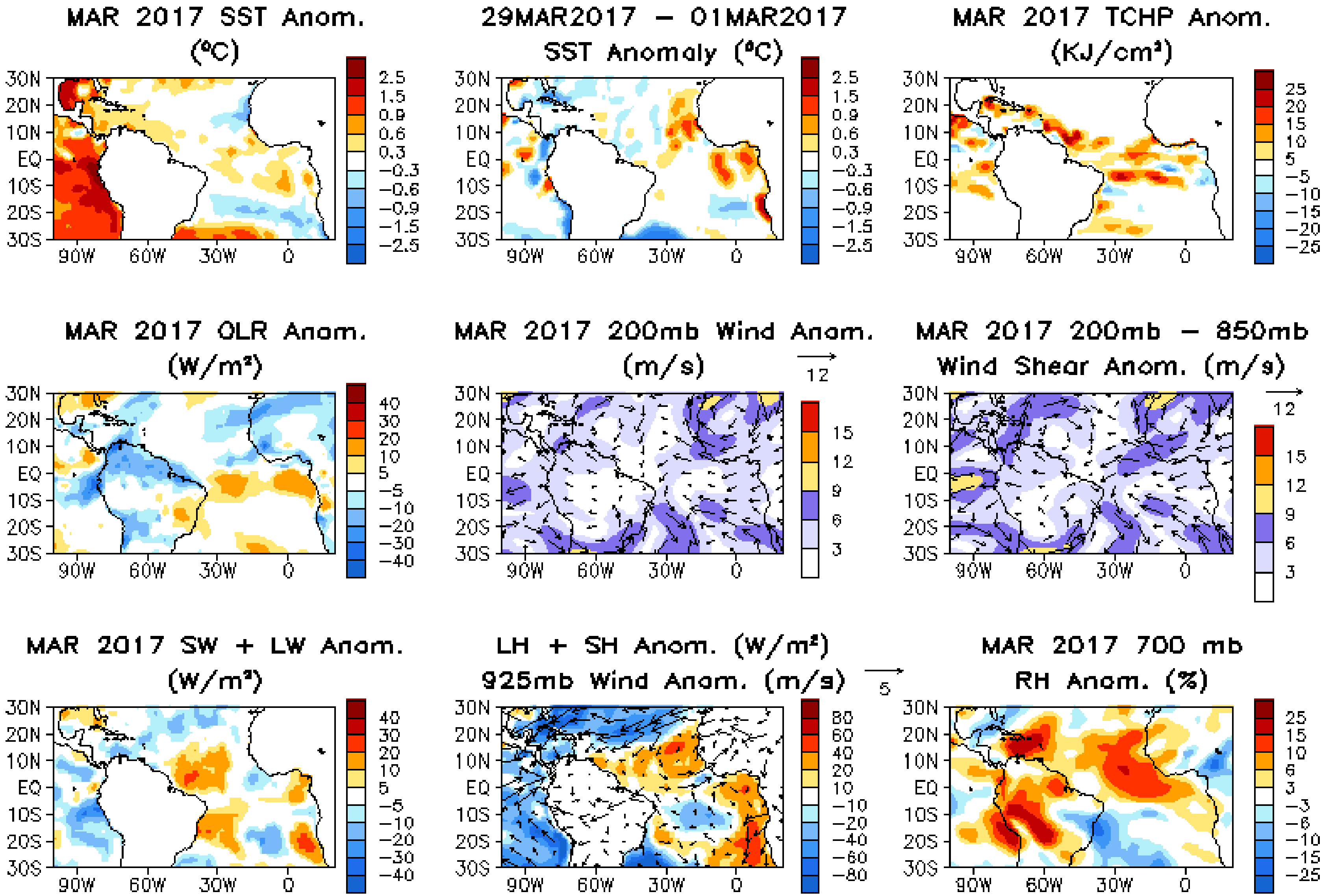


- **SSTs were near average in the tropical North Atlantic (TNA) and tropical South Atlantic(TSA).**

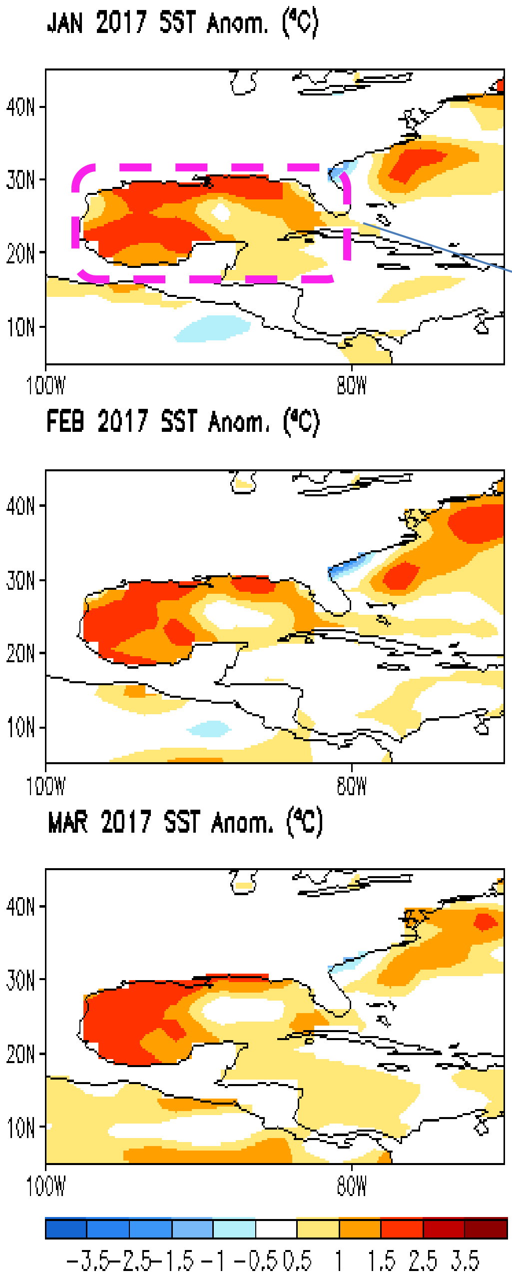
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) for the TNA [60ºW-30ºW, 5ºN-20ºN], TSA [30ºW-10ºE, 20ºS-0] and ATL3 [20ºW-0, 2.5ºS-2.5ºN] regions, and Meridional Gradient Index, defined as differences between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

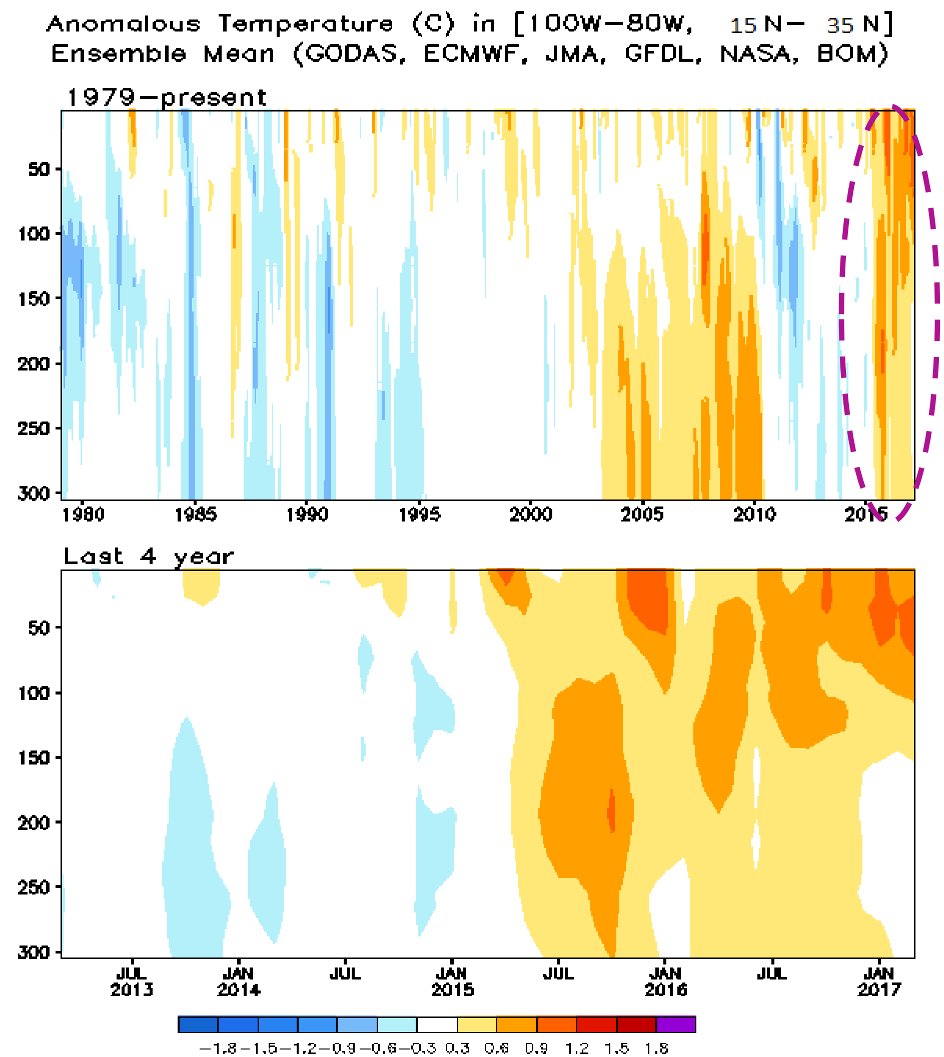
Tropical Atlantic:

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



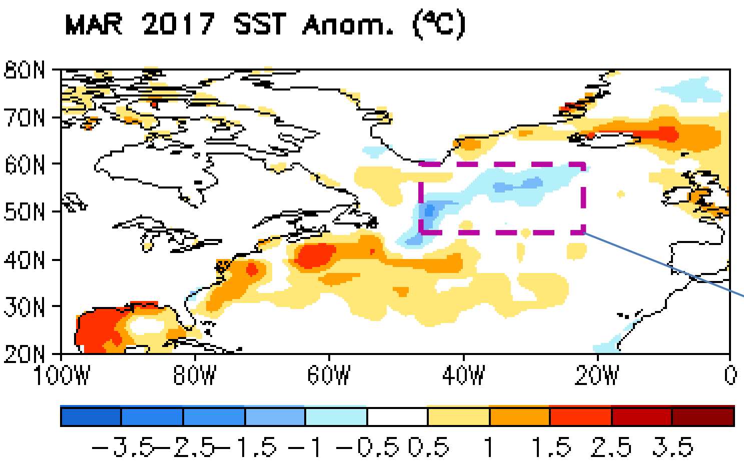
Warming in Gulf of Mexico

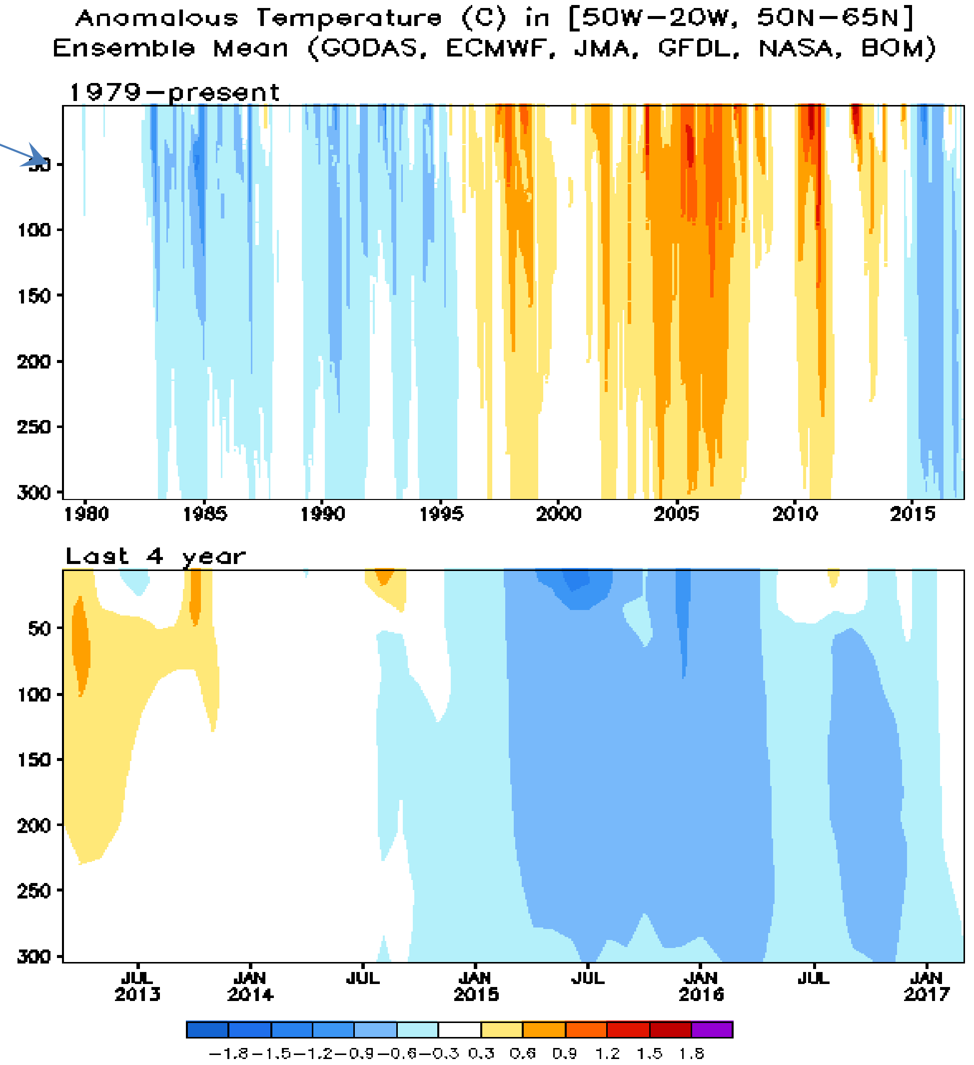




- **Gulf of Mexico experienced the strongest upper ocean warming since 1979.**

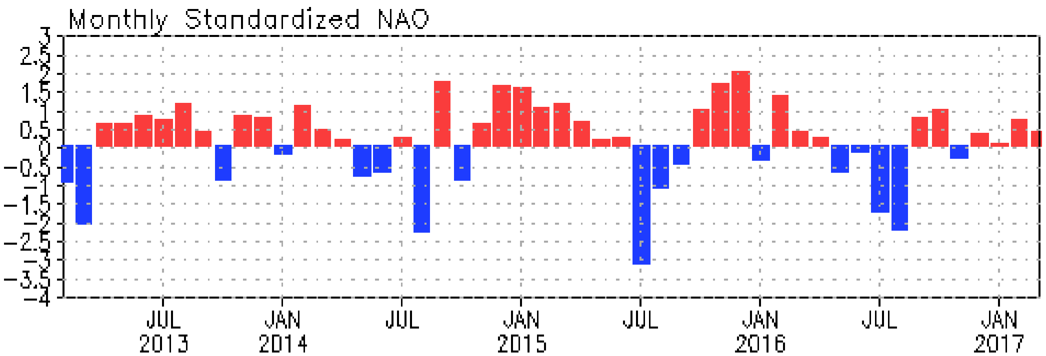
“Cold Blob” in the North Atlantic

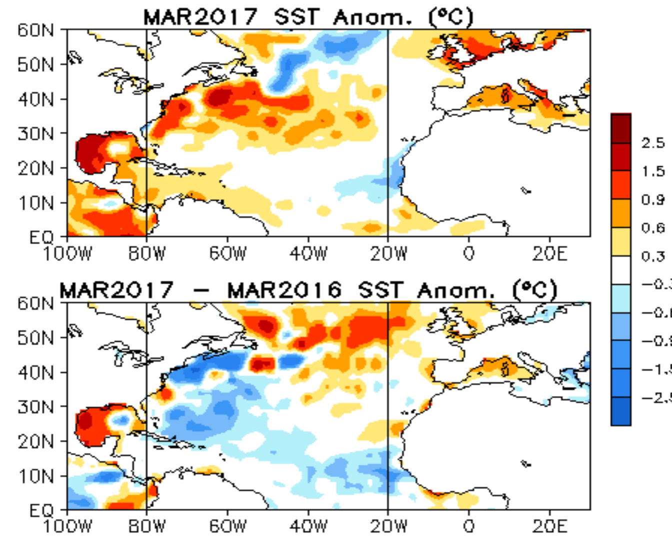


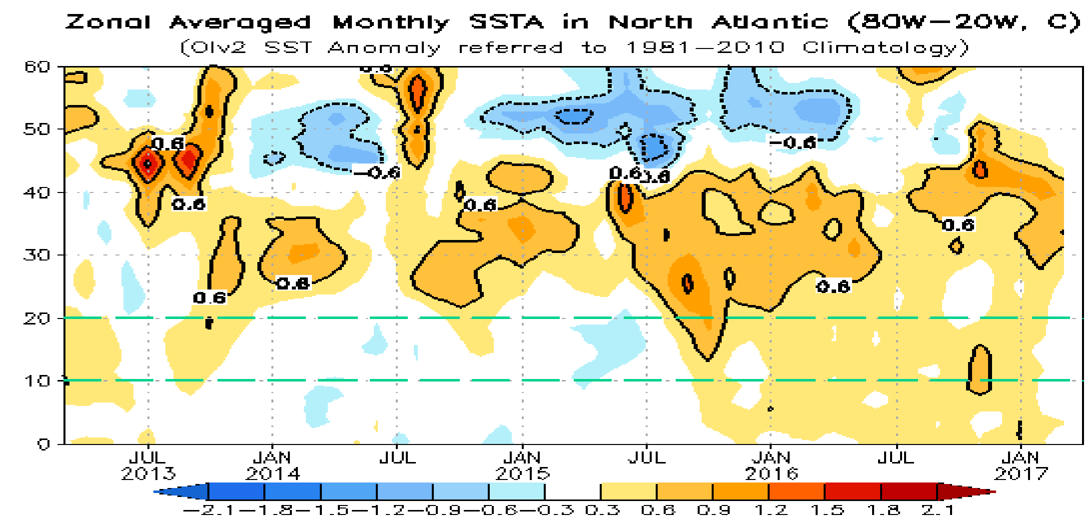


- **Below-average SSTs has persisted in the southeast of Greenland since late 2014, referred as “cold Blob” in the North Atlantic Ocean.**
- **Cooling has extended to 300m since the late 2014.**
- **Subsurface temperature anomalies in the “cold Blob” region exhibit decadal variability.**
- **Near surface cooling weakened in the last several months.**

NAO and SST Anomaly in North Atlantic







-NAO has been in positive phase since Dec 2016 with NAOI=0.4 in Mar 2017.

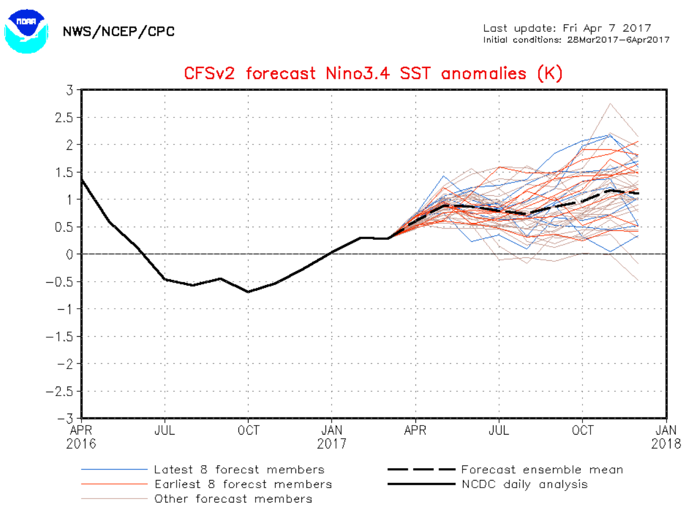
- SSTA was positive in the middle latitudes and negative in the high latitudes during last 3 years, probably due to the impact of positive phase of NAO.

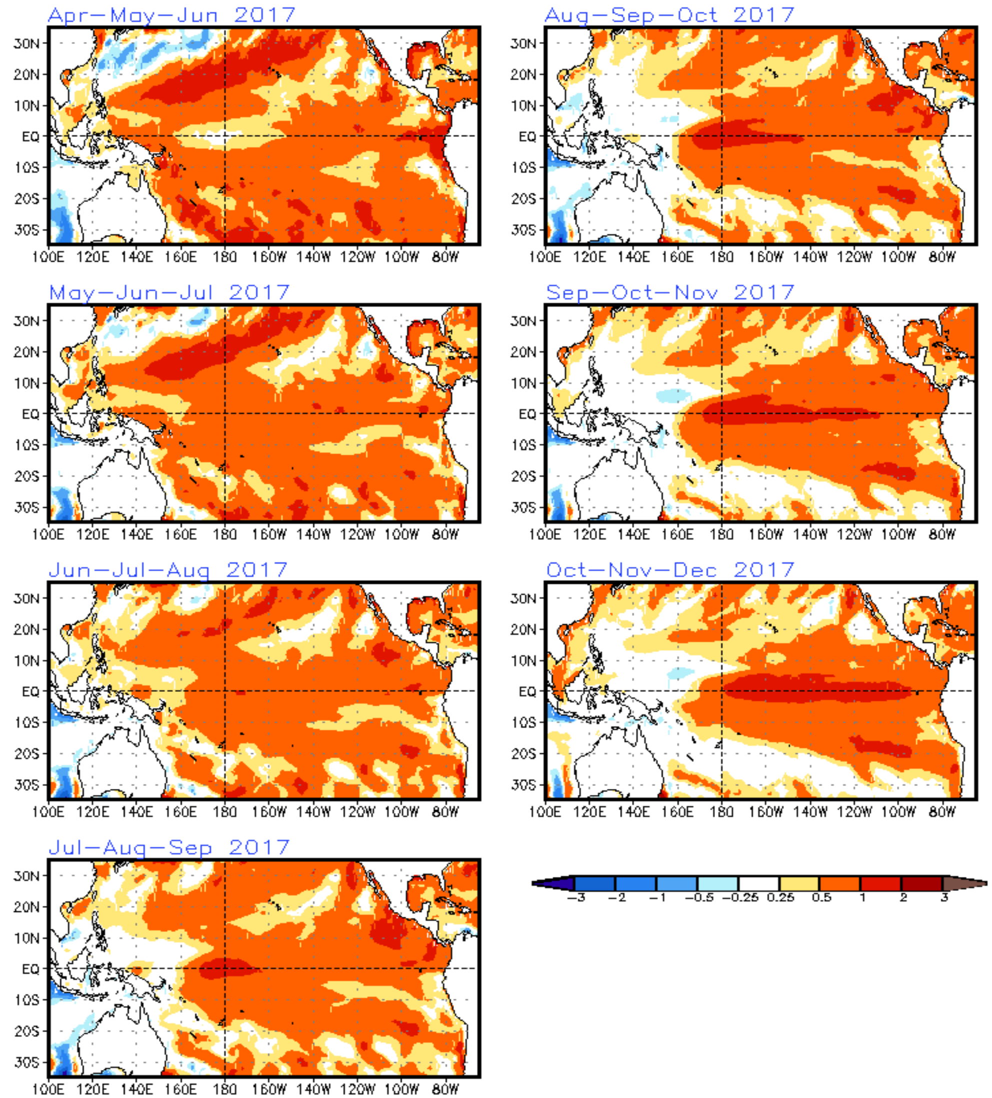
Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (bottom). SST are derived from the NCEP OI SST analysis,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

ENSO and Global SST Predictions

CFSv2 predictions

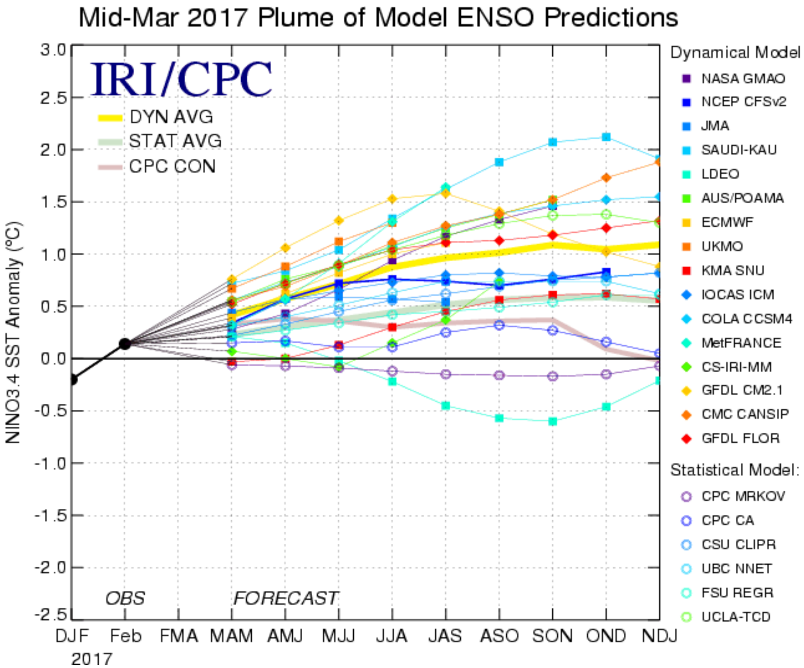
NCEP CFSv2 : Nino3.4, IC=Mar2017

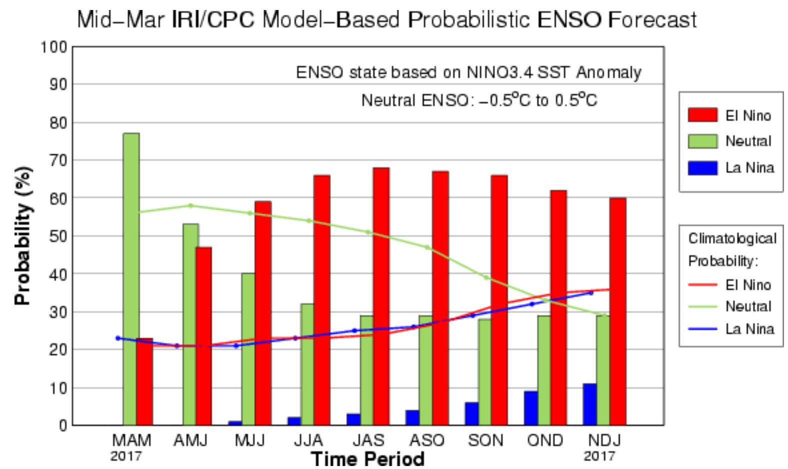




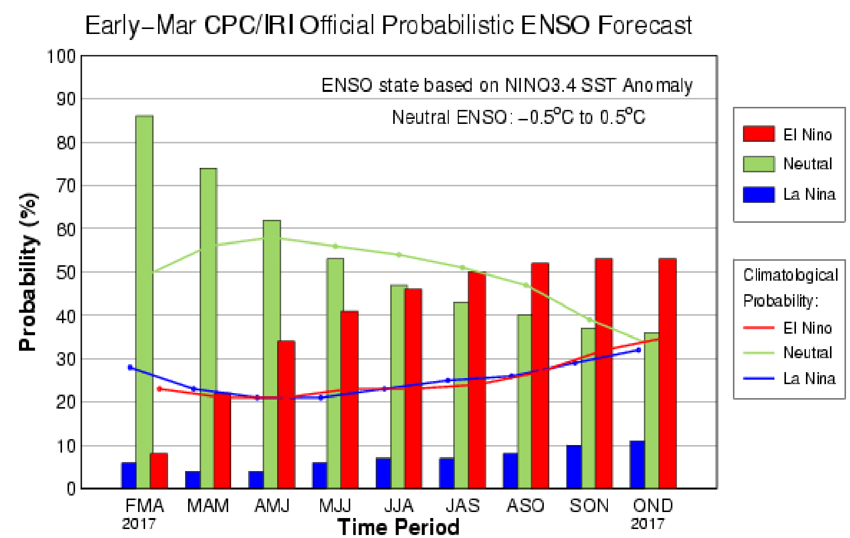
- CFSv2 forecasts suggest an El Nino will develop in early Northern Hemisphere summer 2017.

IRI NINO3.4 Forecast Plum



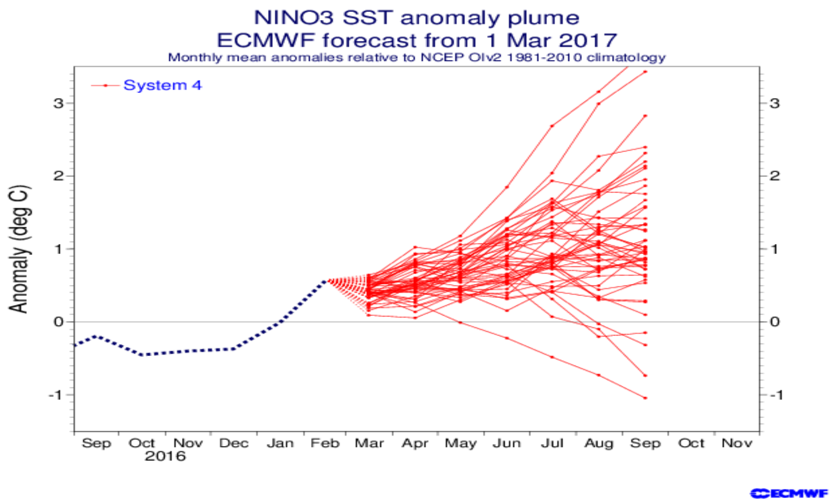


- **Majority of dynamical models call for El Nino development in early Northern Hemisphere summer 2017, while statistical models favor continuation of neutral conditions through fall 2017.**

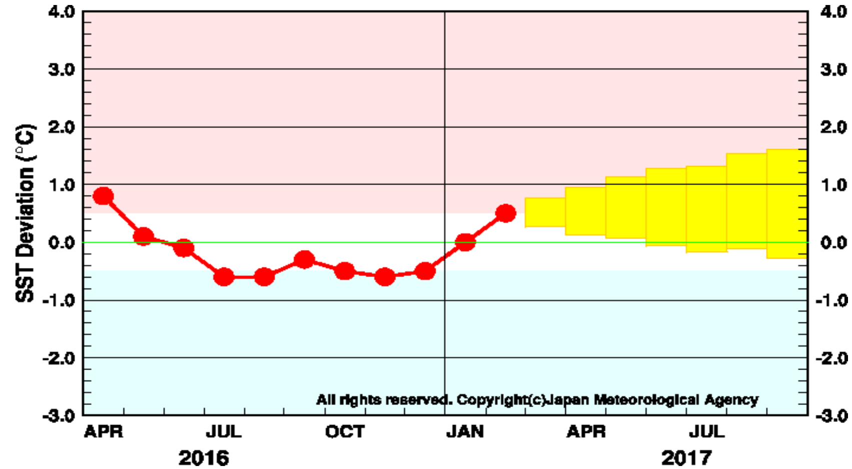


Individual Model Forecasts: neutral or El Nino

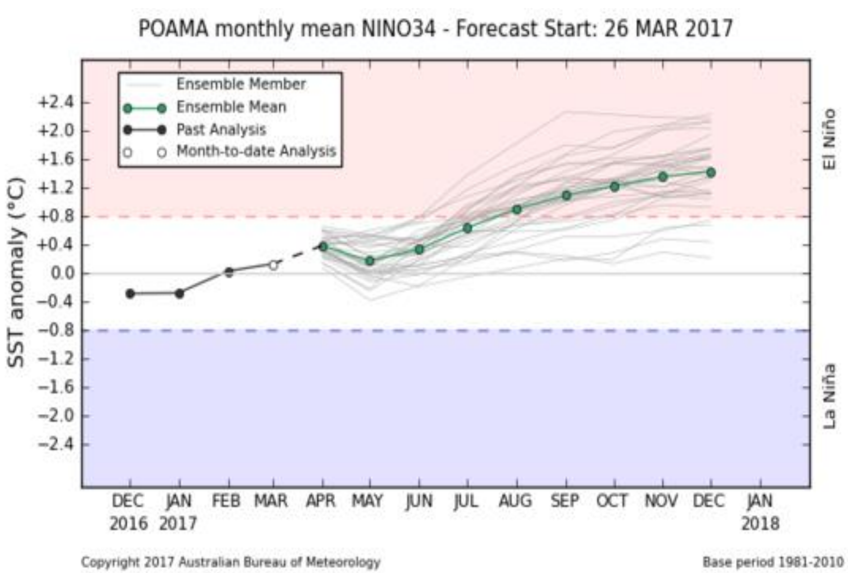
EC: Nino3.4, IC=01Mar 2017



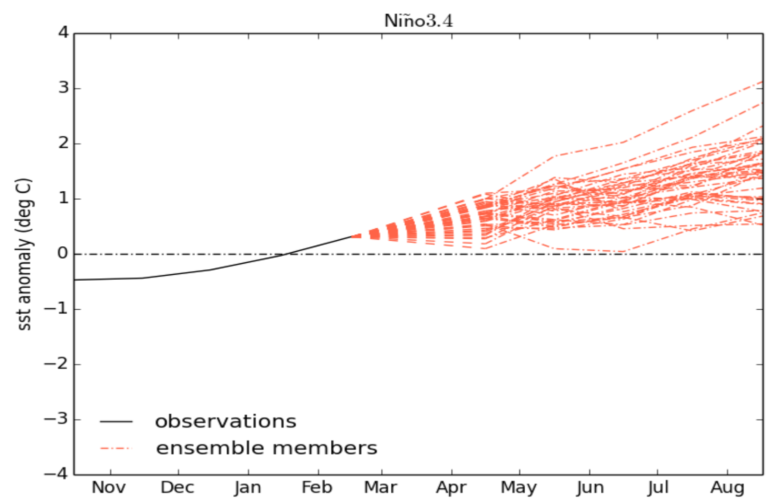
JMA: Nino3, IC=Mar 2017



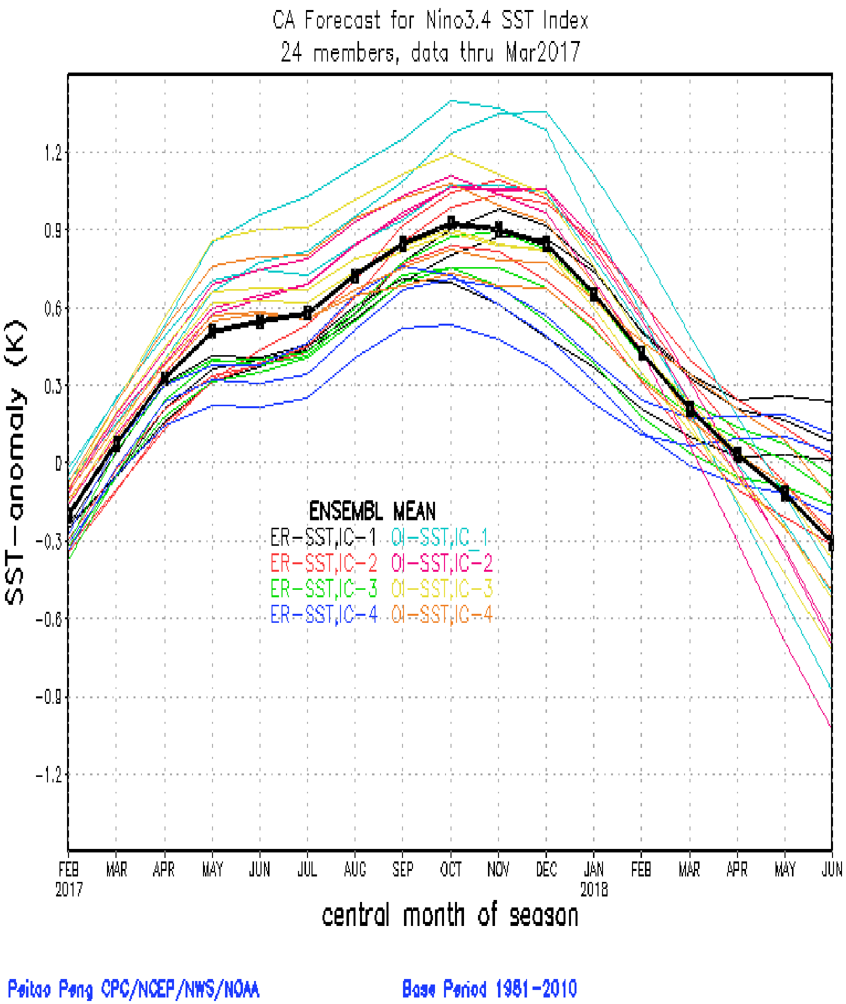
Australia: Nino3.4, IC=26Mar 2017

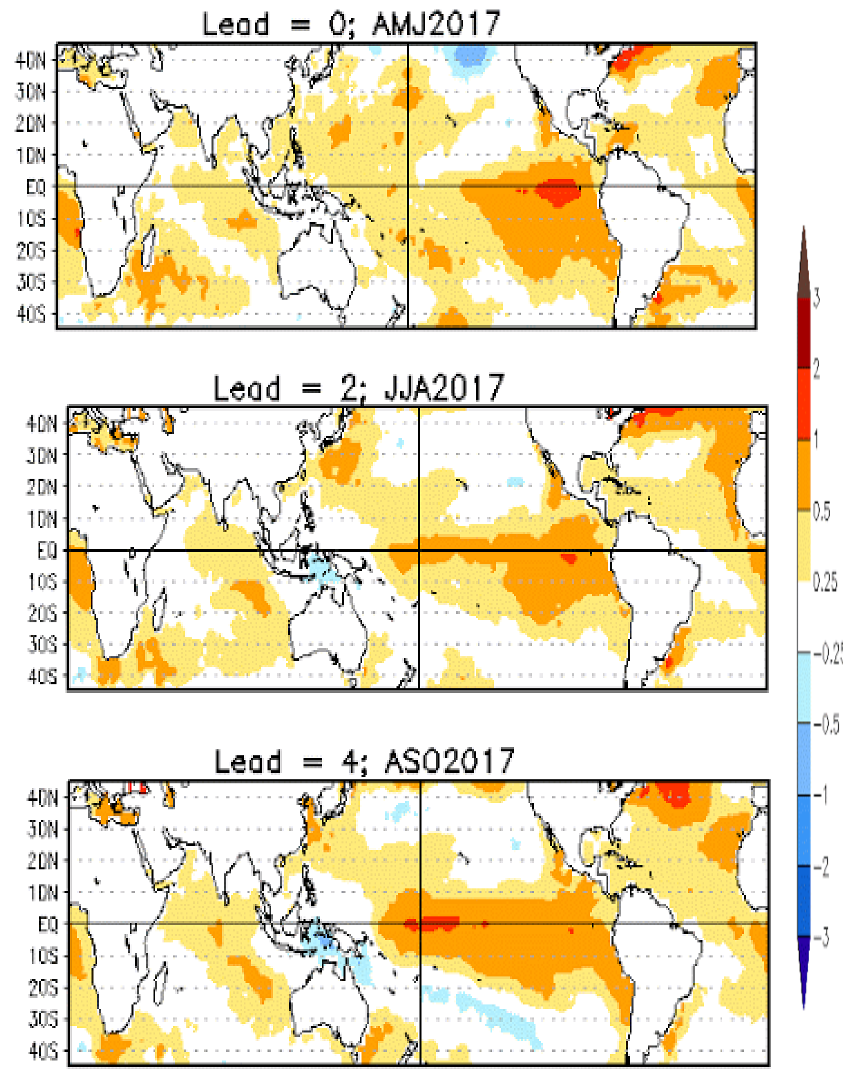


UK MET: Nino3.4, IC=Feb 2017



CA 24-member Ensemble Forecast for SST





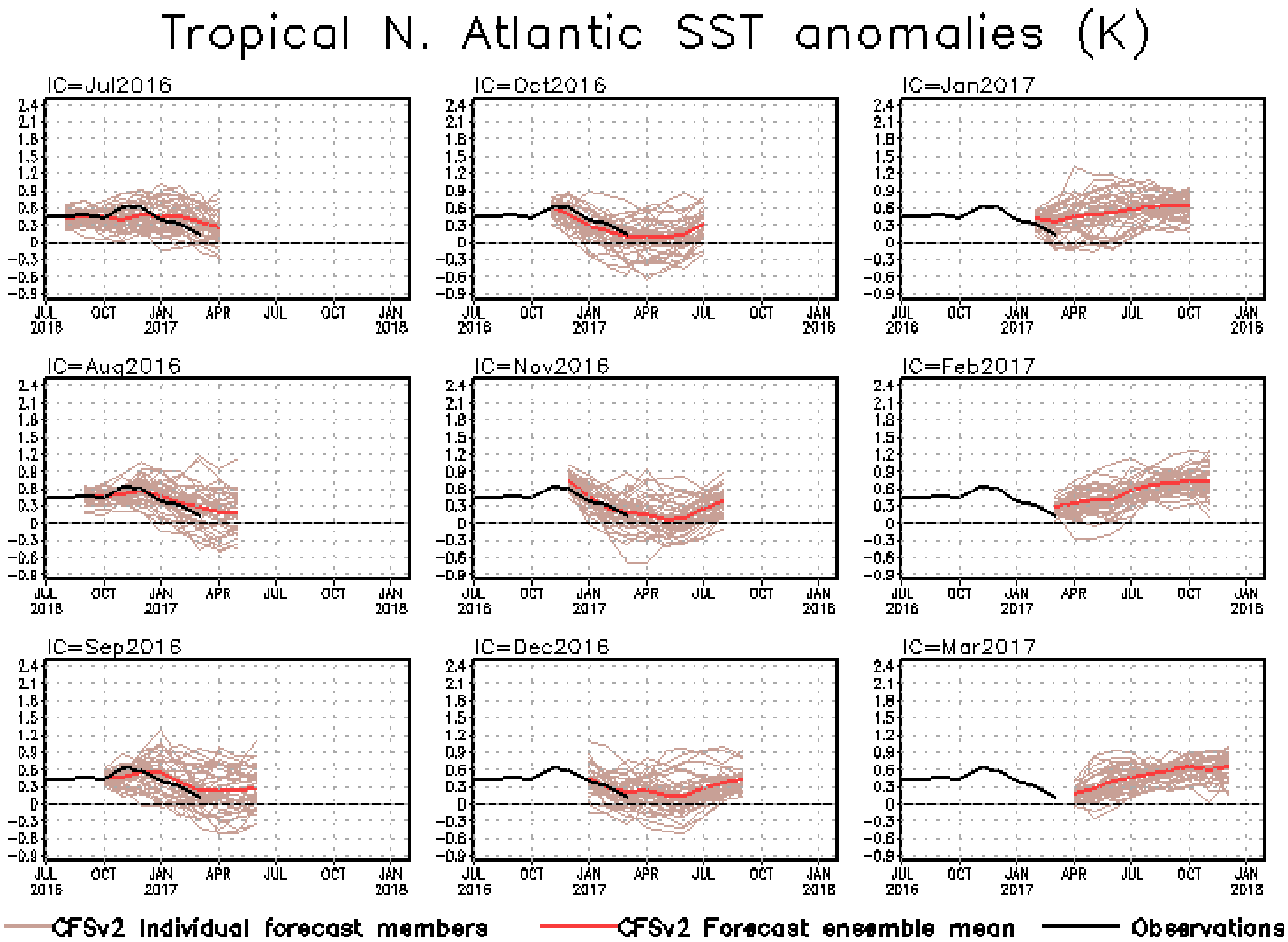
El Nino is expected in early Northern Hemisphere summer 2017

(Provided by Peitao Peng)

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 above normal SSTA in tropical N. Atlantic in spring-autumn 2017.**

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.

Overview

- **Pacific Ocean**
  - **In March 2017, Nino3.4 SST anomaly remained in the neutral range.**
  - **NINO1+2 index reached 2°C in March 2017, with enhanced convection over Ecuador and Peru.**
  - **Negative temperature anomalies developed near the thermocline in the central equatorial Pacific.**
  - **Arctic sea ice reached its annual maximum extent in March, and the sea ice extent ranked the lowest since 1979.**

- **Indian Ocean**
  - **SSTs continued to be near average in the tropical, and large positive in the SW Indian Ocean in March 2017.**

- **Atlantic Ocean**
  - **NAO weakened slightly in March, with NAOI=0.4.**
  - **Strong positive SSTA persisted in the Gulf of Mexico.**
  - **Negative SSTA in the southeast of Greenland weakened in March.**

Backup Slides

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

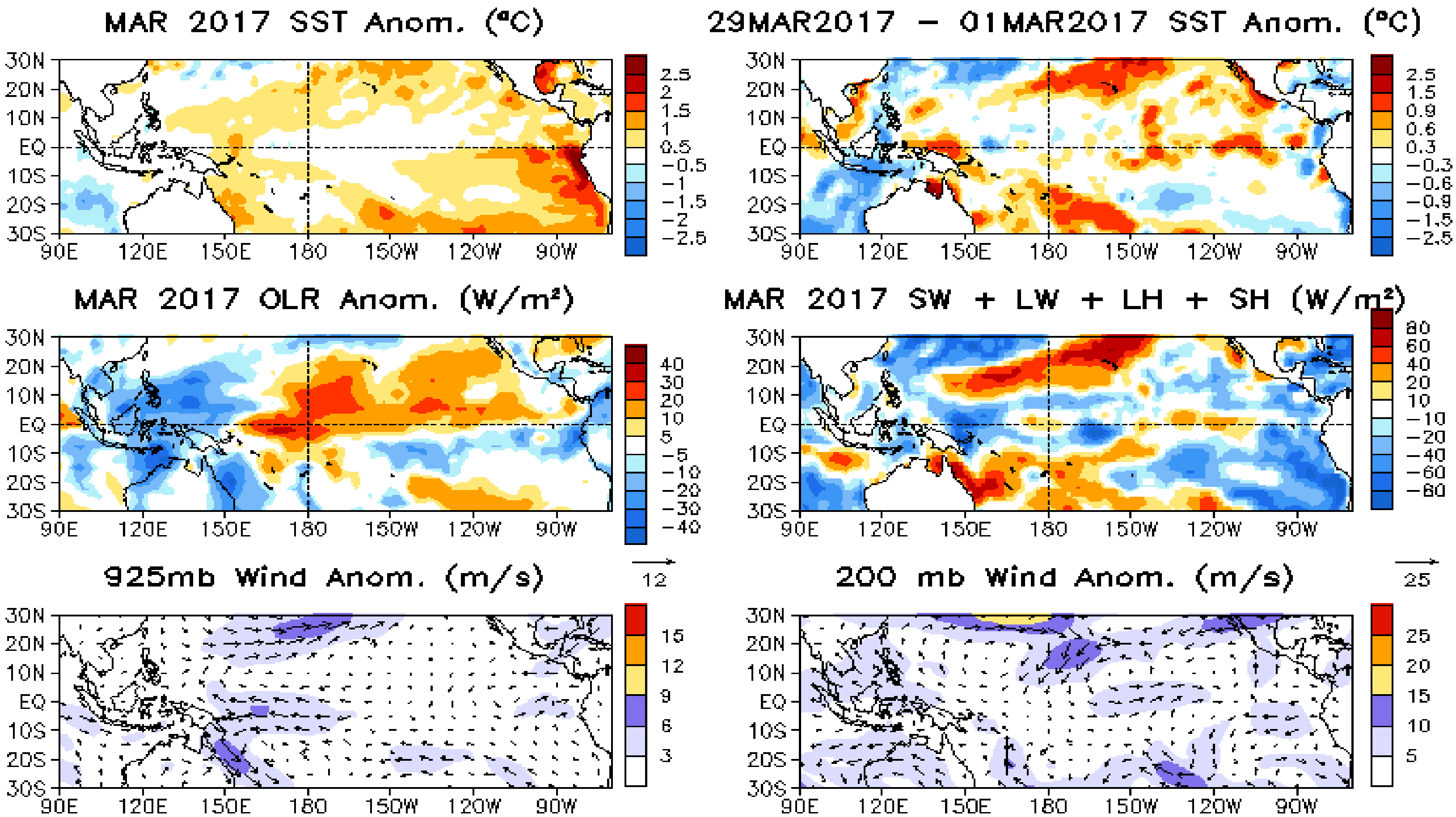
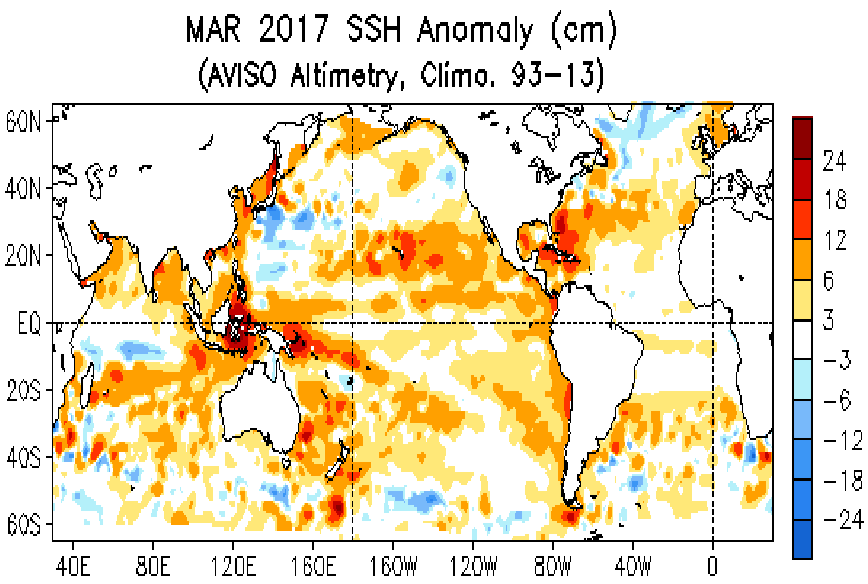
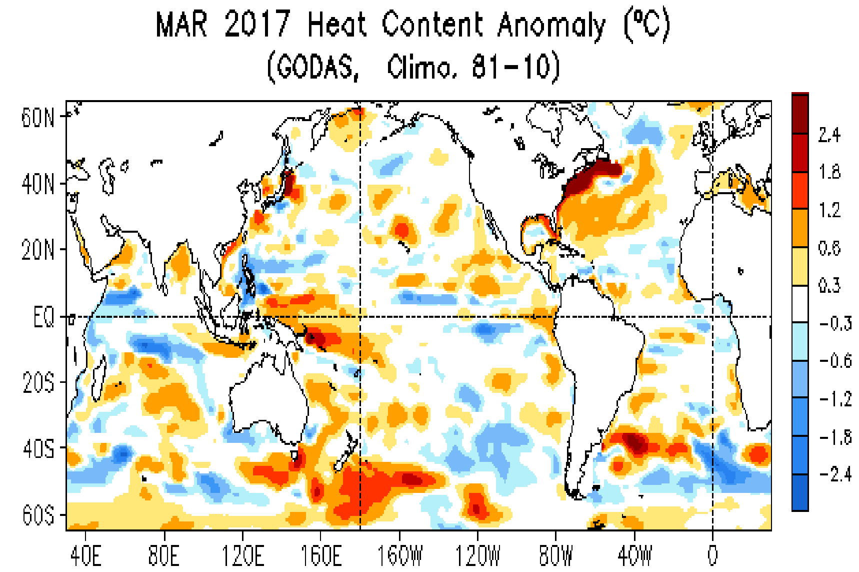
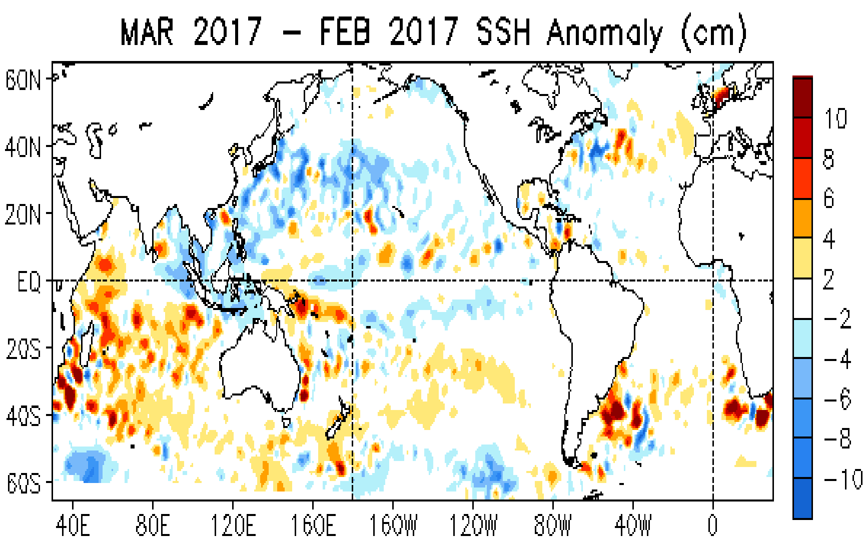


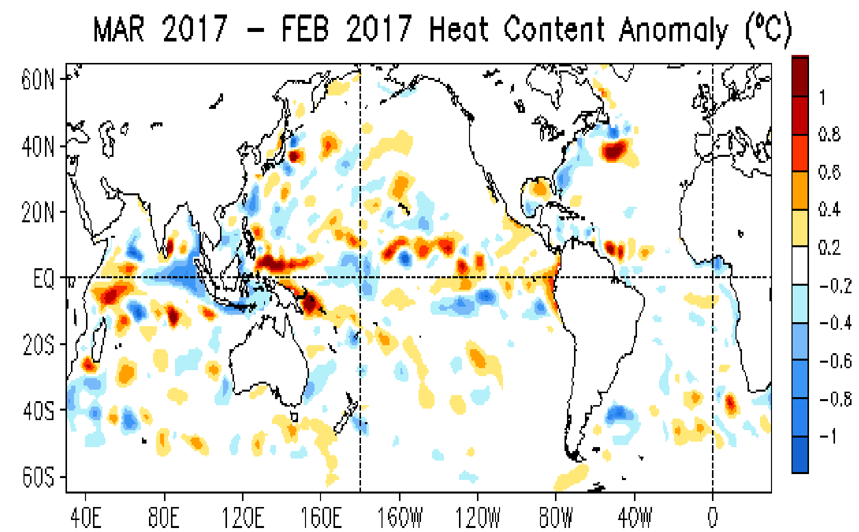
Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Global SSH and HC300 Anomaly & Anomaly Tendency

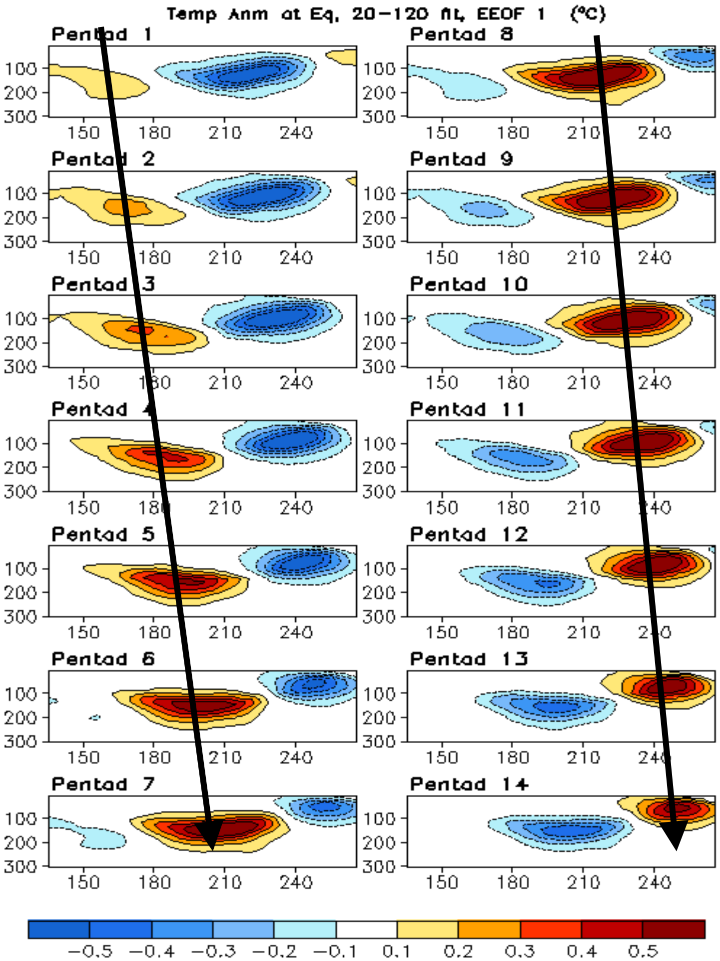


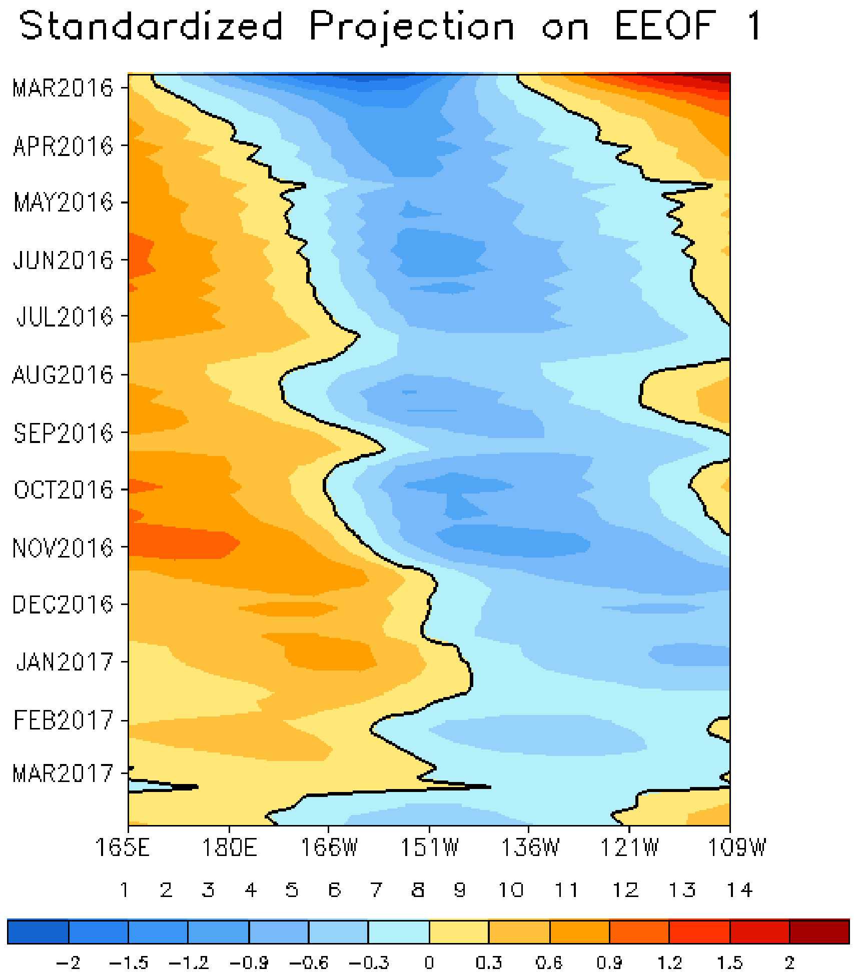






Oceanic Kelvin Wave (OKW) Index

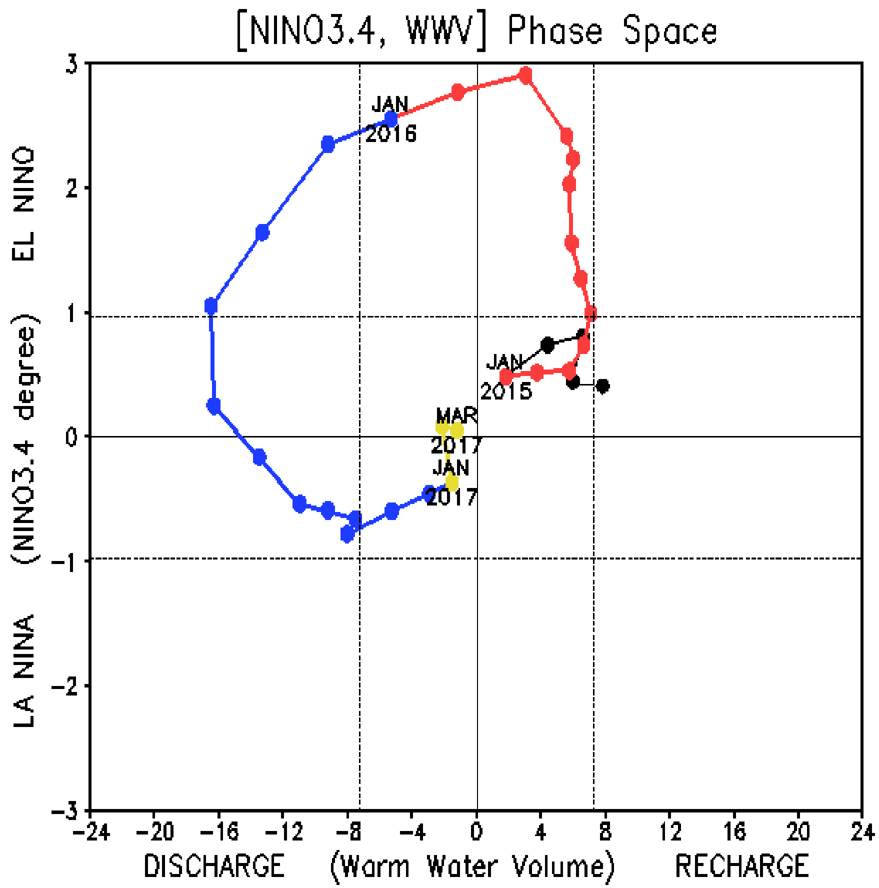




- *(OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)*

Warm Water Volume (WWV) and NINO3.4 Anomalies

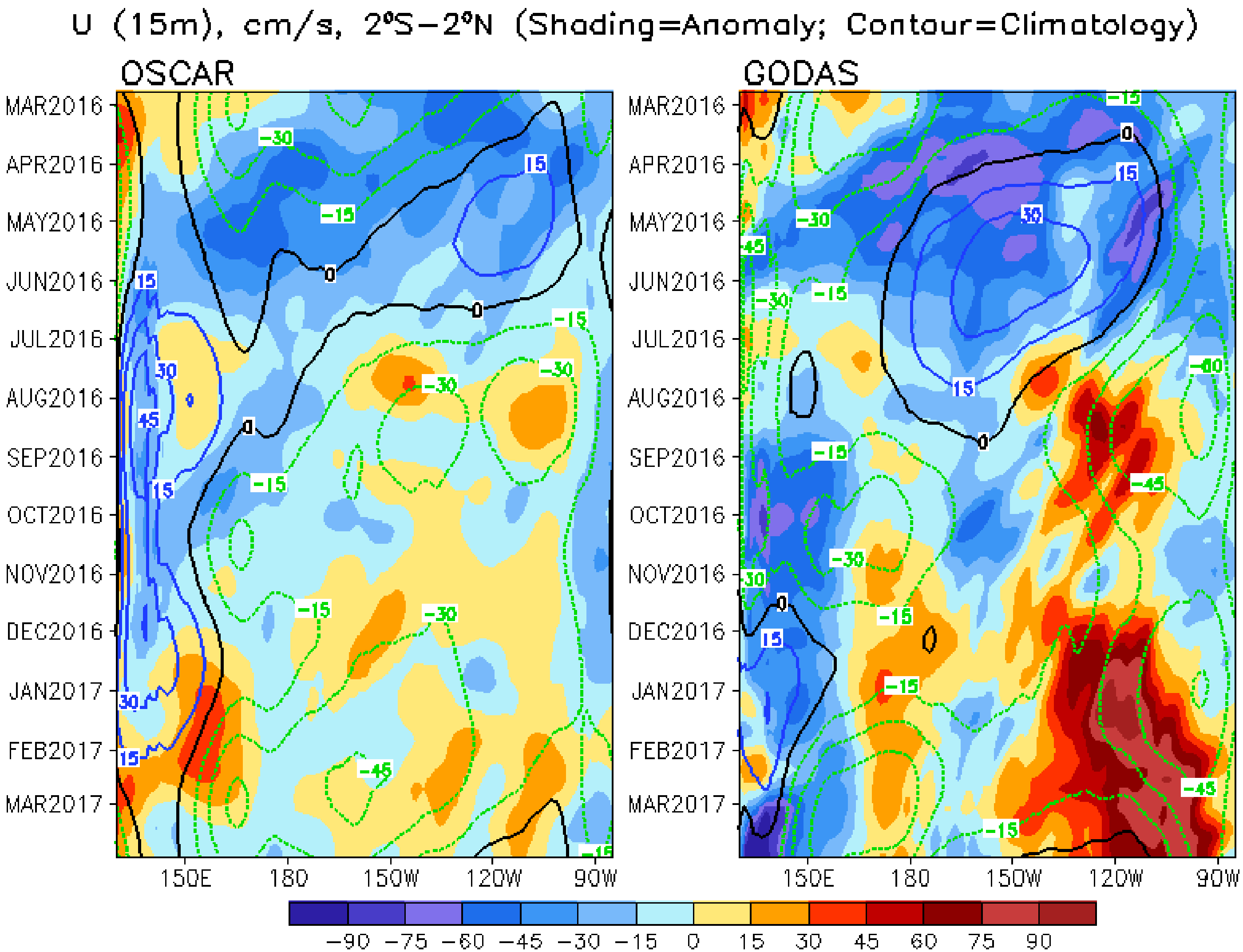
- WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N]. Statistically, peak correlation of Nino3 with WWV occurs at 7 month lag (Meinen and McPhaden, 2000).
- Since WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and NINO3.4 (Kessler 2002).
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



- **Equatorial Warm Water Volun (WWV) has been almost no change (small discharge) since Dec 2016.**

...olume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

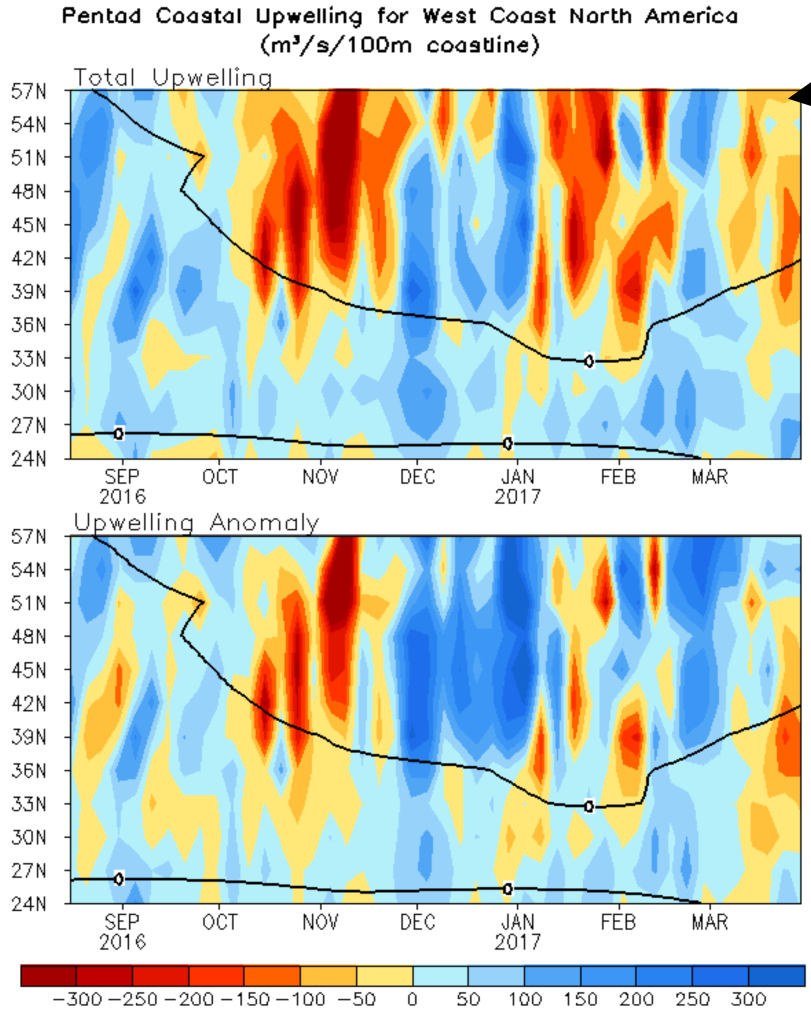
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)

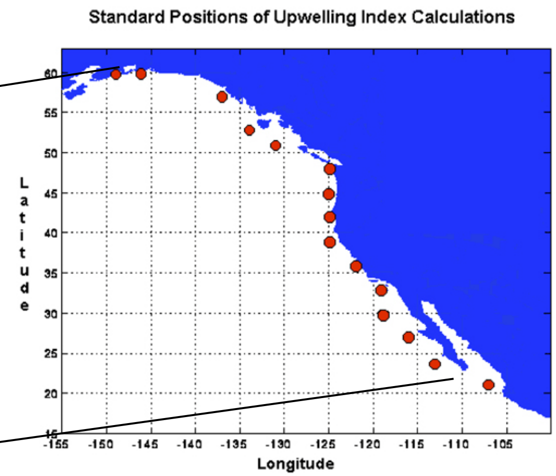


- The anomalous currents showed large differences between OSCAR and GODAS.

- Anomalous eastward currents were dominant in the last few months in OSCAR. That was favorable for a warming tendency in the central and eastern Pacific.

North America Western Coastal Upwelling



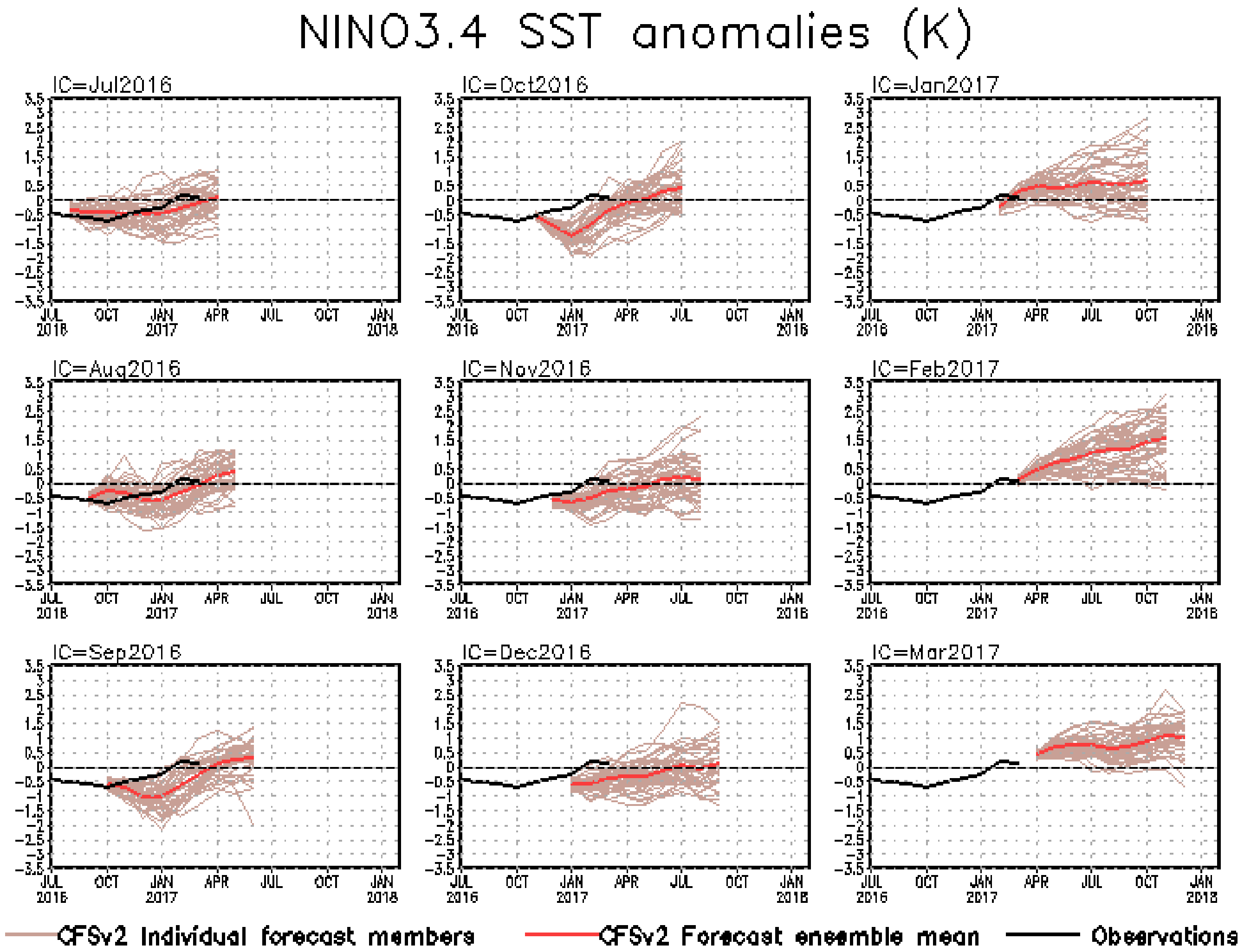


− Upper welling weakened south of 50N in Mar 2017.

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.**

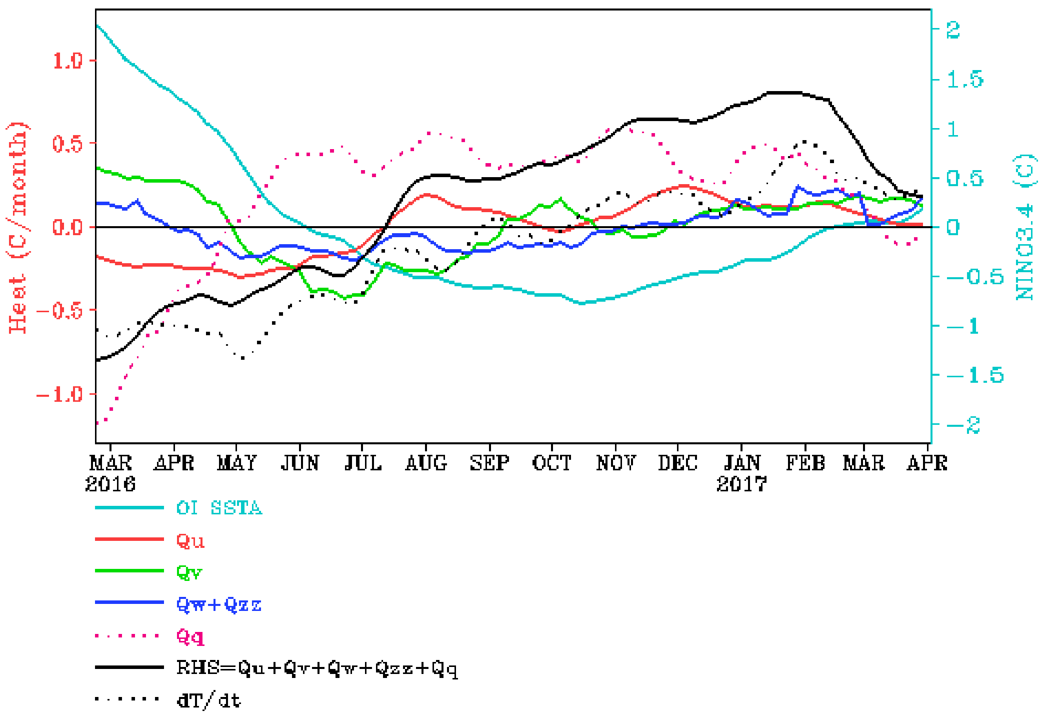
CFS Niño3.4 SST Predictions from Different Initial Months



- Latest CFSv2 forecasts call for an El Nino since summer 2017.
- CFSv2 predictions had cold biases with ICs in Jun-Dec 2016.

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.

NINO3.4 Heat Budget



- **Observed SSTA tendency (dT/dt) in Nino3.4 region (dotted black line) was positive since Oct 2016, consistent with the decay of La Nina.**

- **Dynamical terms (Qu, Qv, Qw+Qzz) were positive since Dec 2016.**

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

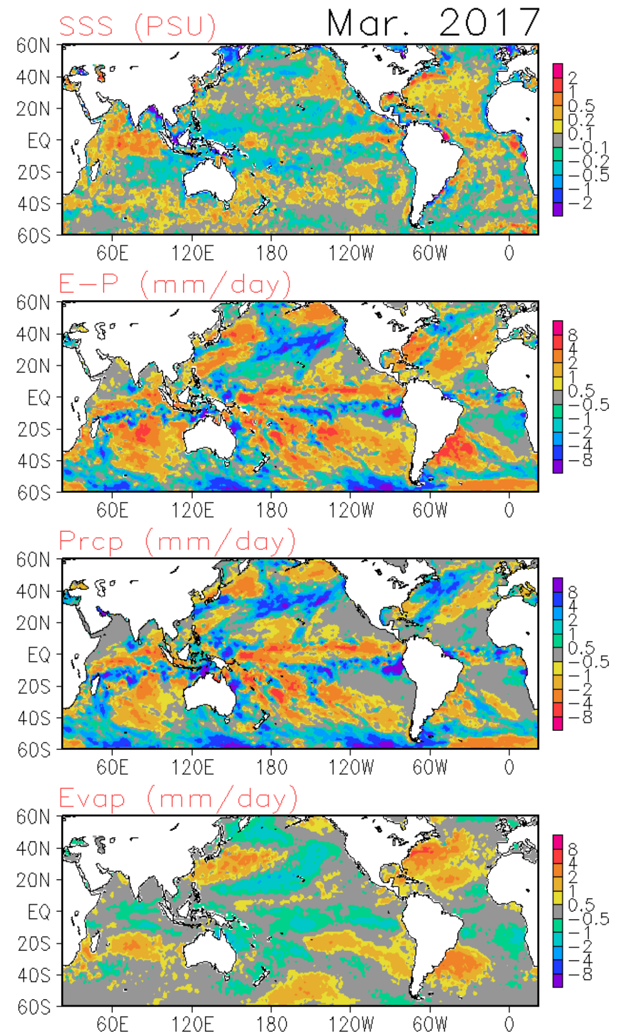
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

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

Global Sea Surface Salinity (SSS)

Anomaly for March 2017

- NOTE: Since Aquarius terminated operations, the blended SSS analysis is from in situ and SMOS only from June 2015. Please report to us any suspicious data issues!
- Positive SSS anomaly appear in the east Equatorial region of the Pacific Ocean, with the reduction of precipitation exits along the majority of the Equatorial Pacific Ocean. Large scale freshening in the subarctic regions of North Pacific and North Atlantic ocean continues in this month and such signal is centered in the west basin. The SSS in the north region of the Bay of Bengal continues decreasing, while both the evaporation and precipitation don't show significant changes. The SSS becomes fresher in the east basin of the subtropics of South Indian Ocean with an increase of precipitation in this region.



- **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

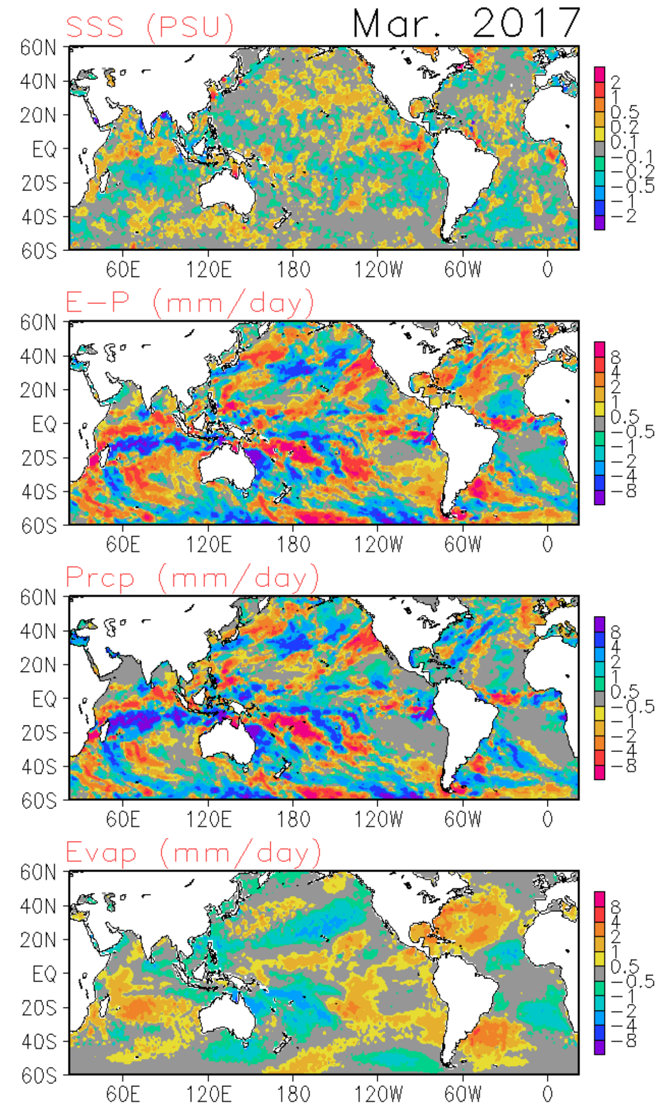
Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: CFS Reanalysis

Global Sea Surface Salinity (SSS)

Tendency for March 2017

Compared with last month, the salinity in the east equatorial Pacific Ocean region (east of 150°W) shows significant increase which is likely caused by the reduction of the freshwater flux in this region. The SSS continues decreasing in the north of Bay of Bengal with no significant change of precipitation/evaporation. A large area of SSS decrease appears in the subtropics of South Indian Ocean between 10°S and 30°S companying with an increase of precipitation.



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

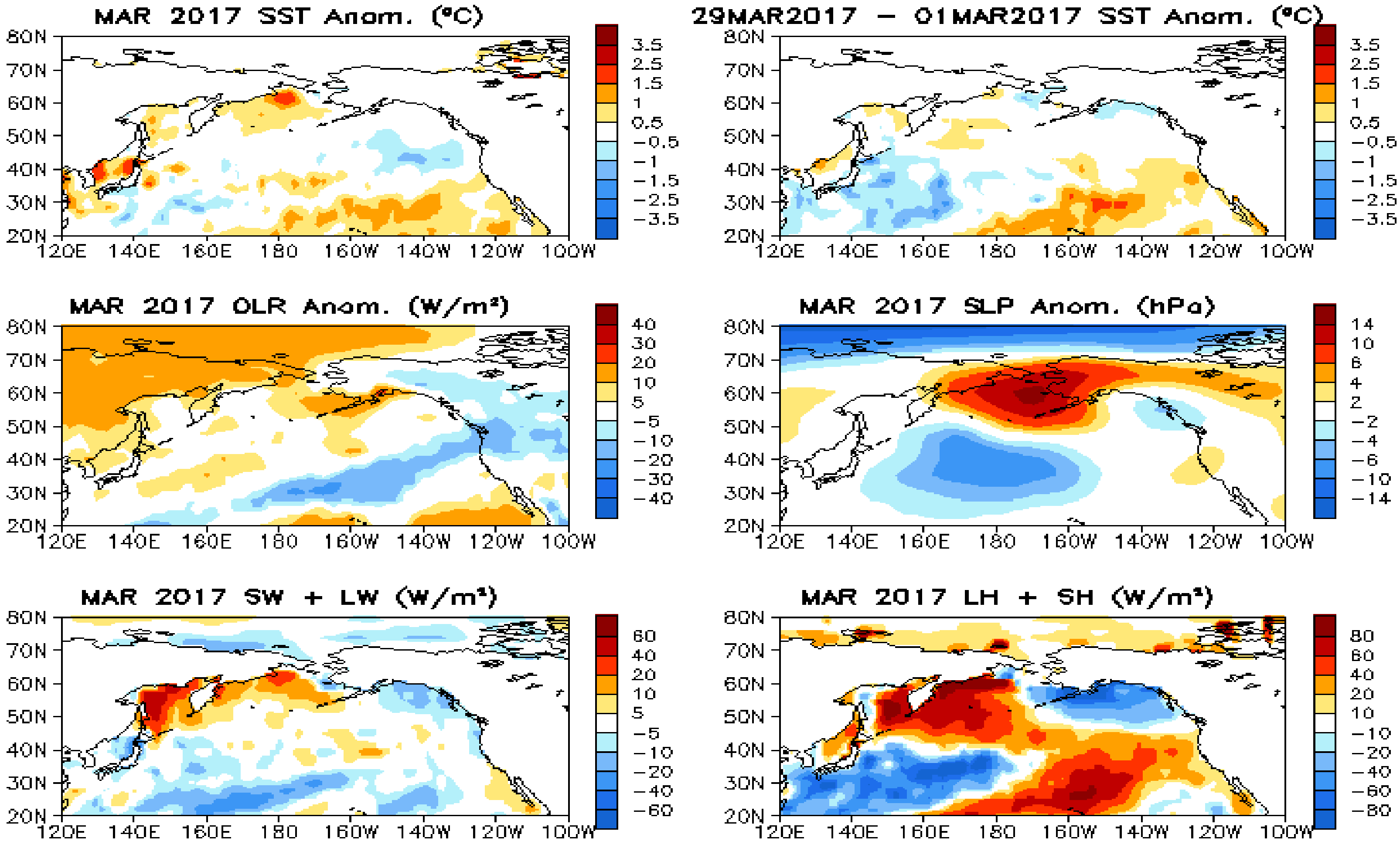


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

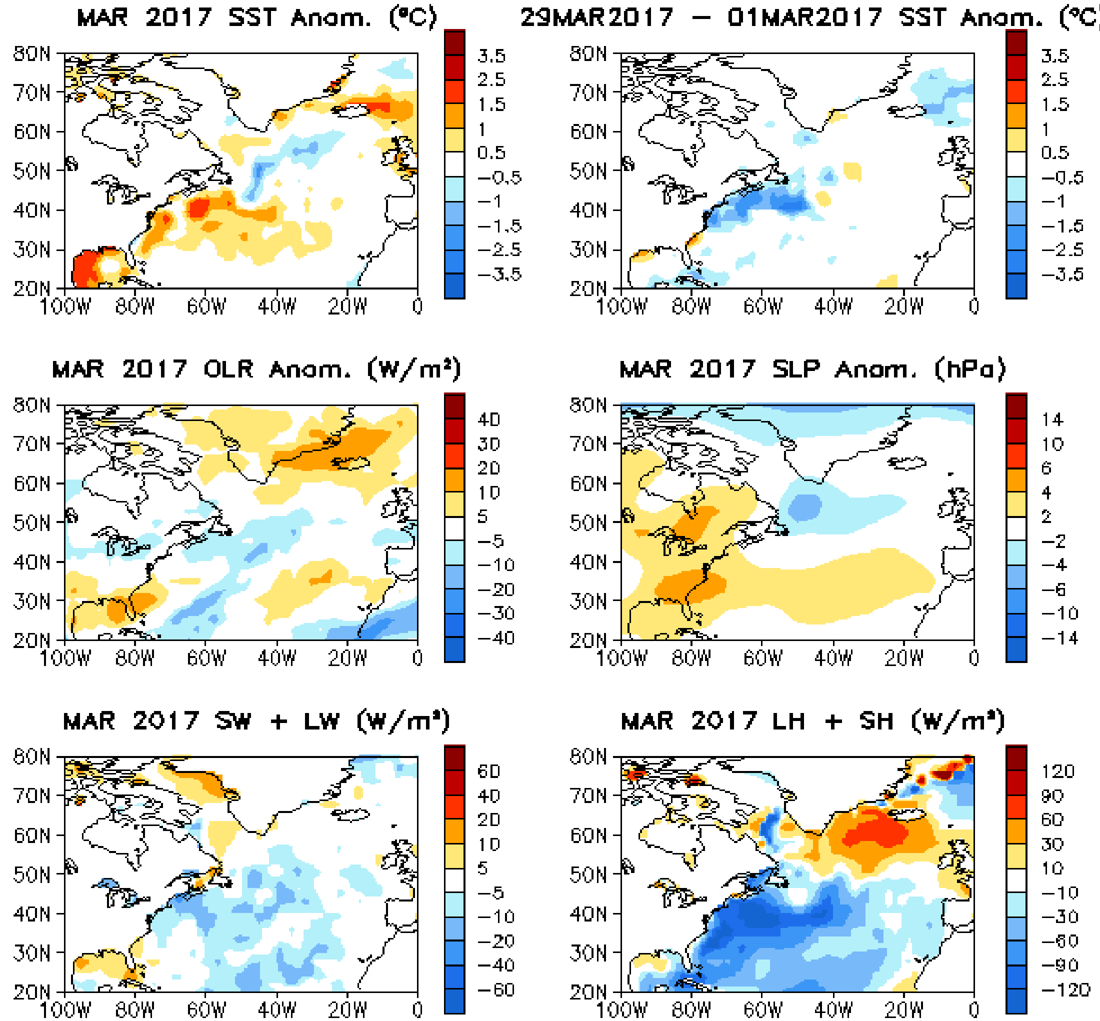
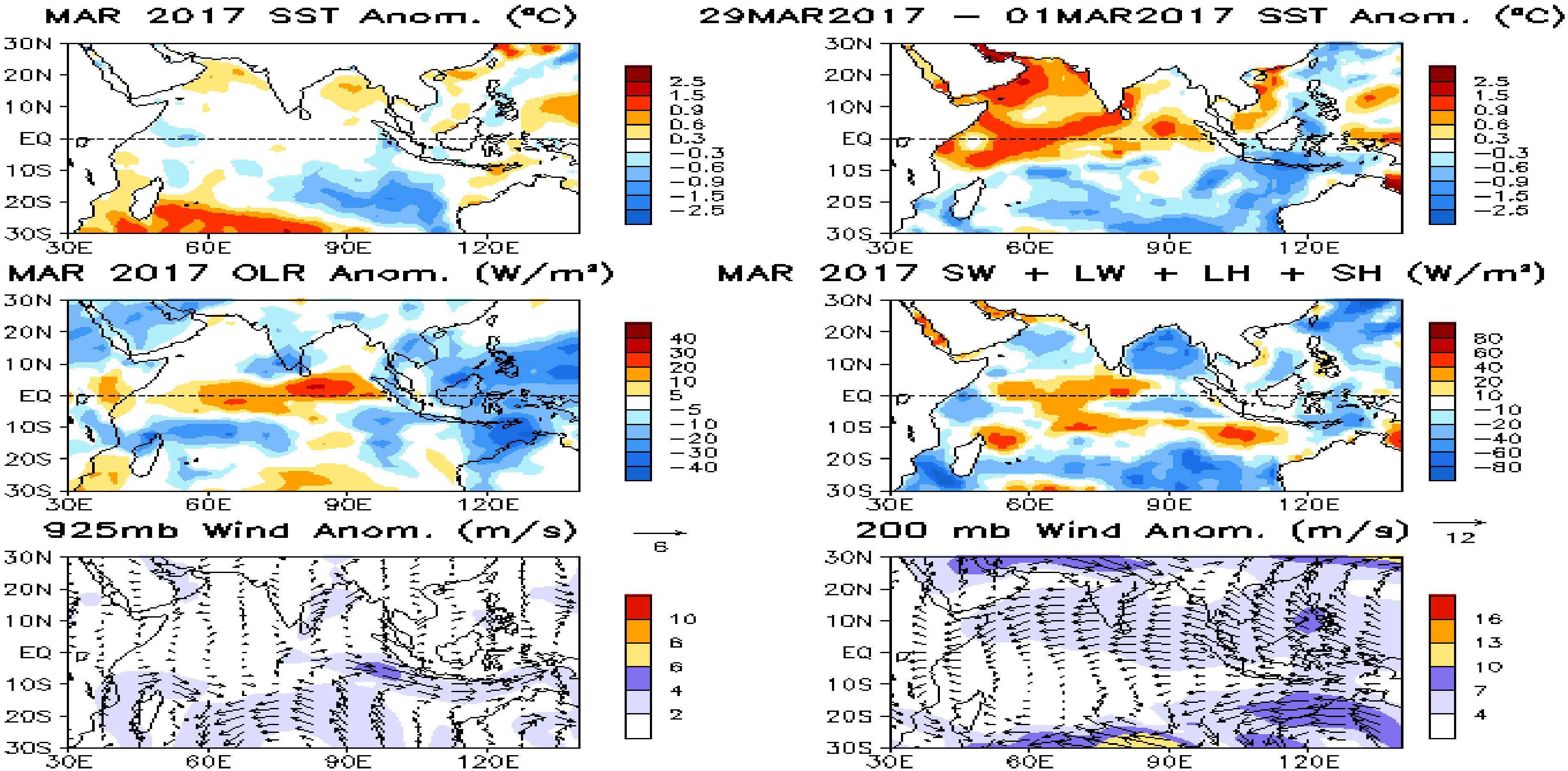


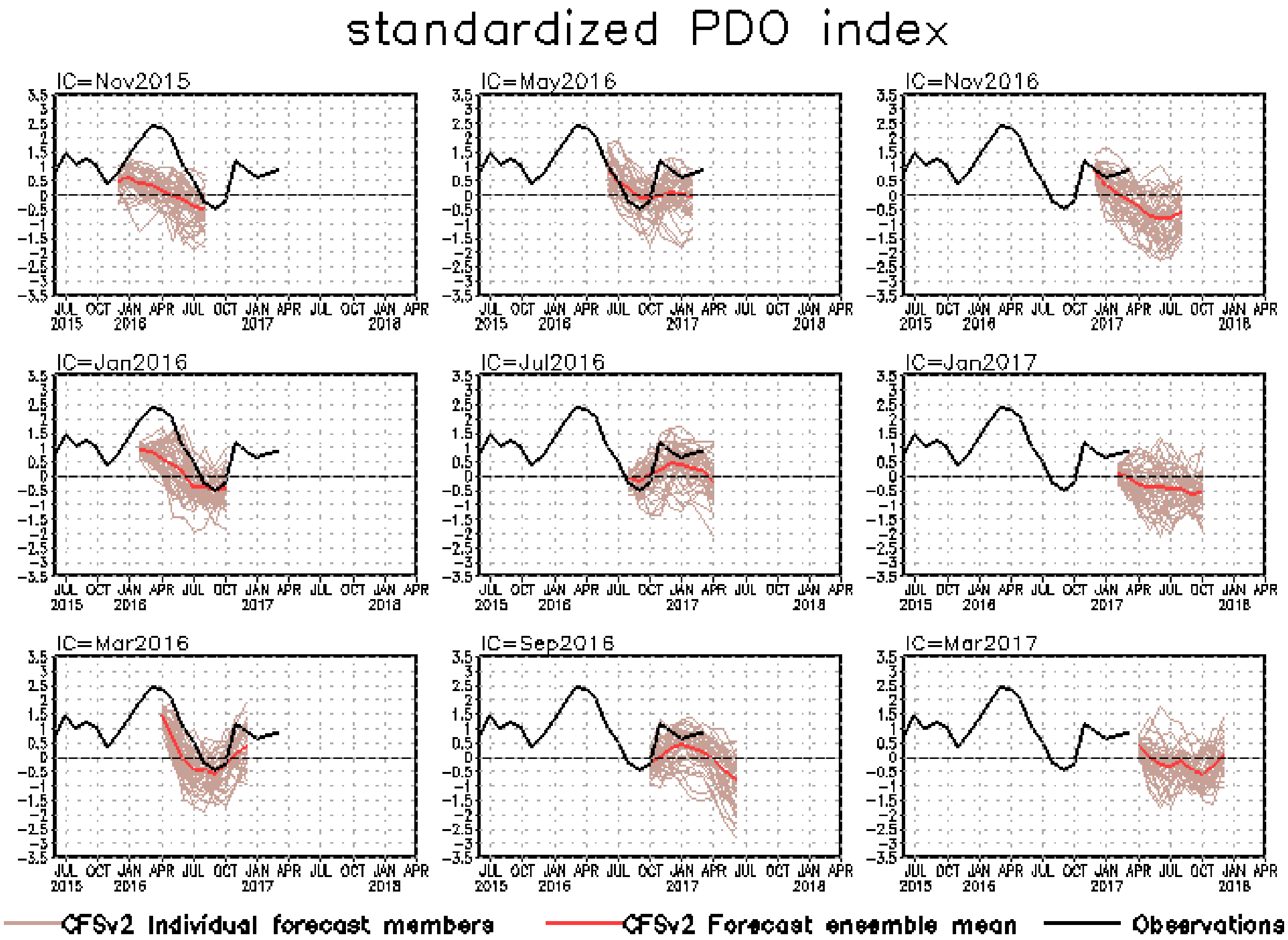
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

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



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.

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



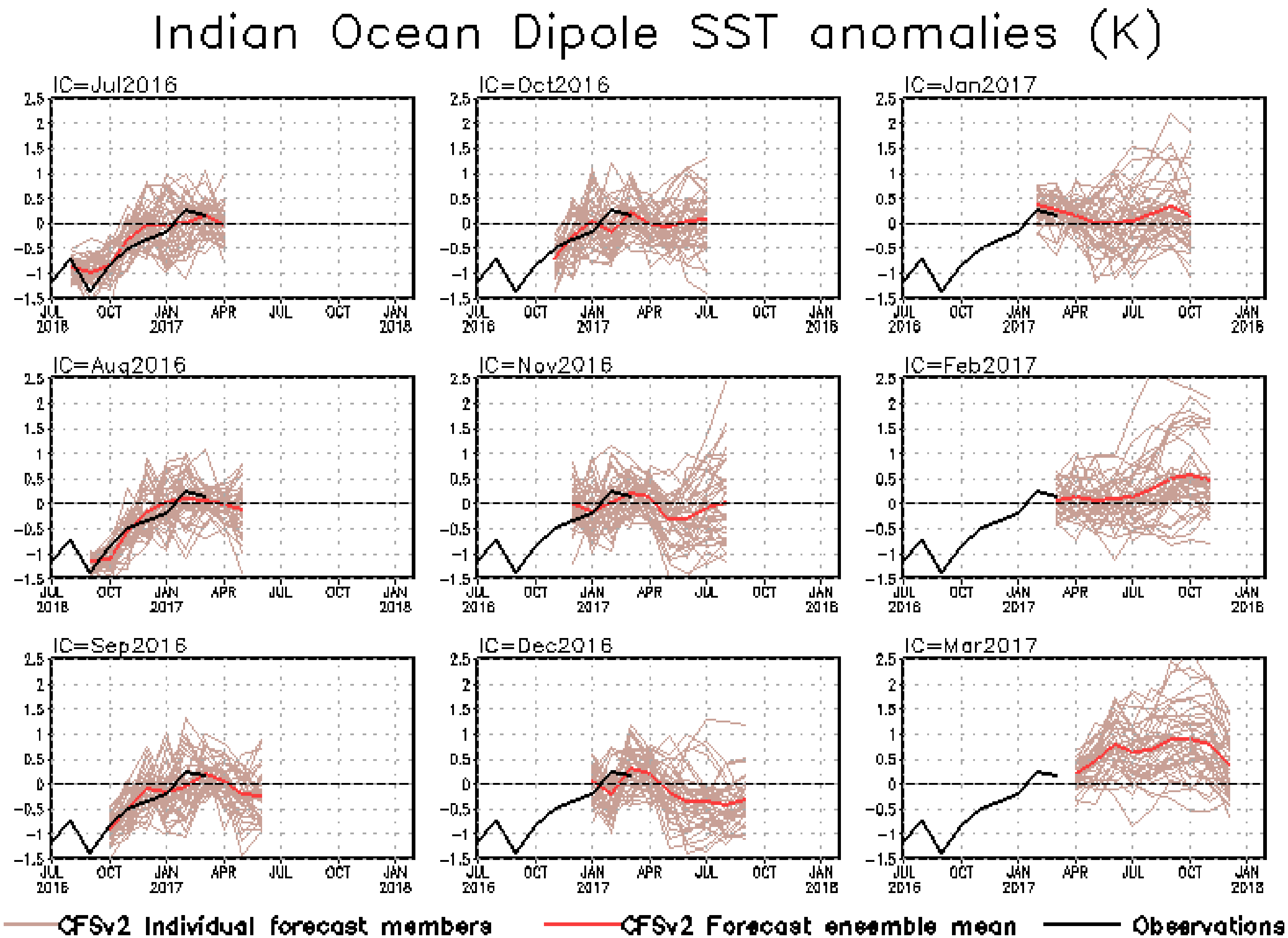
PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

- CFSv2 predicts PDO will switch to negative phase in early summer 2017.

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



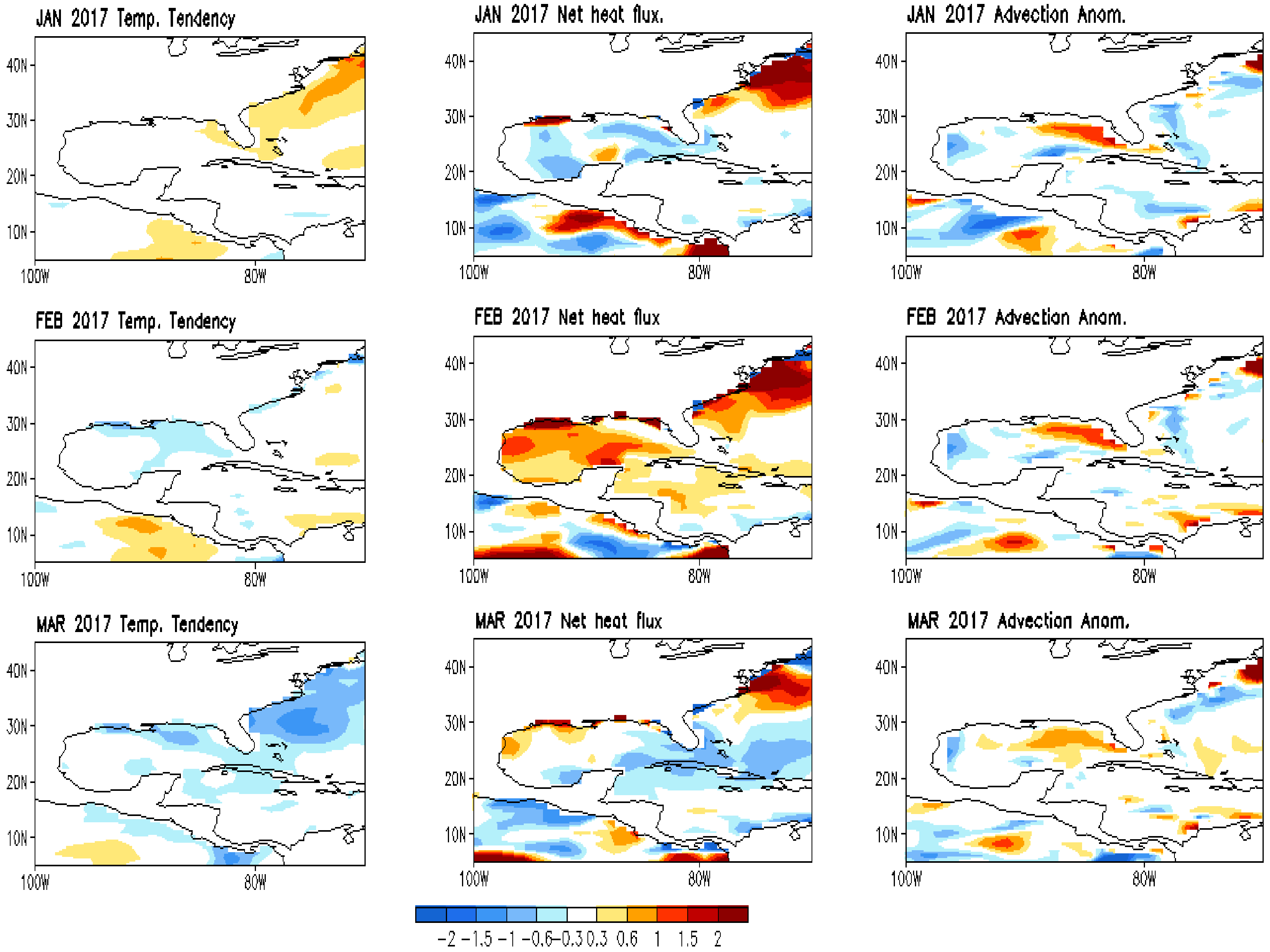
DMI = WTIO- SETIO

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.

Heat budget in the last three months



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!