

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 Climate Observation Division (COD)**

Outline

- **Overview**
- **Recent highlights**
 - Pacific/Arctic Ocean
 - Indian Ocean
 - Atlantic Ocean
- **Global SST Predictions**
 - * Possibility of a La Nina developing in 2016-17
 - * Impact of Atlantic ocean cold bias problem on CFSv2 ENSO forecasting

Overview

➤ Pacific Ocean

- ❑ El Niño conditions weakened in March, but still at a strong El Niño level.
- ❑ Most model predictions suggest the El Niño will return to ENSO-neutral during late spring or early summer 2016.
- ❑ Positive phase of PDO strengthened with PDOI=2.3 in Mar 2016.
- ❑ Arctic sea ice have reached its annual maximum extent in March and is the lowest maximum in the satellite record

➤ Indian Ocean

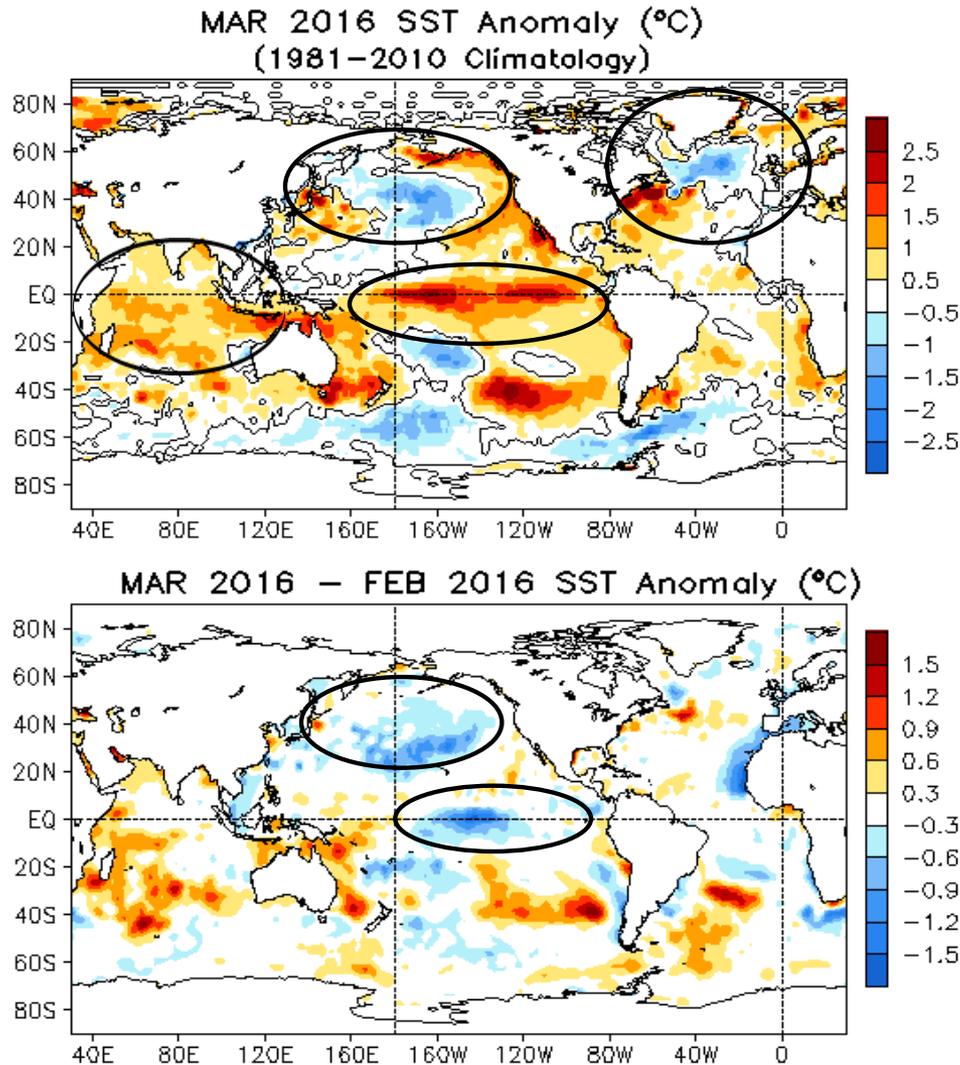
- ❑ Positive SSTA continued to cover much of the Indian Ocean, and Dipole Mode Index was near-normal.

➤ Atlantic Ocean

- ❑ ATL3 and Meridional Gradient indices were near-normal.
- ❑ Large uncertainty exhibited in tropical Atlantic among multiple Ocean Reanalyses.
- ❑ Positive NAO index weakened, with NAOI=1.35 in Mar 2016.

Global Oceans

Global SST Anomaly ($^{\circ}\text{C}$) and Anomaly Tendency



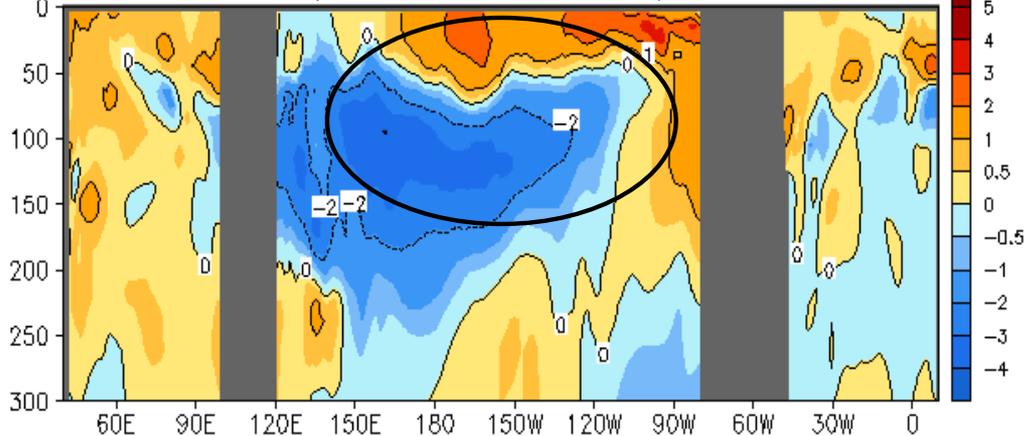
- Strong positive SSTA continued in the central-eastern tropical Pacific.
- SSTA pattern in N. Pacific was associated with positive phase of PDO.
- Horseshoe-like SSTA presented in N. Atlantic.
- Positive SSTA continued to cover much of the Indian Ocean.

- SSTA decreased across most of the central-eastern equatorial Pacific.
- Negative SSTA tendency dominated in N. Pacific Ocean.
- Positive SSTA tendency occupied the S. Indian Ocean.

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

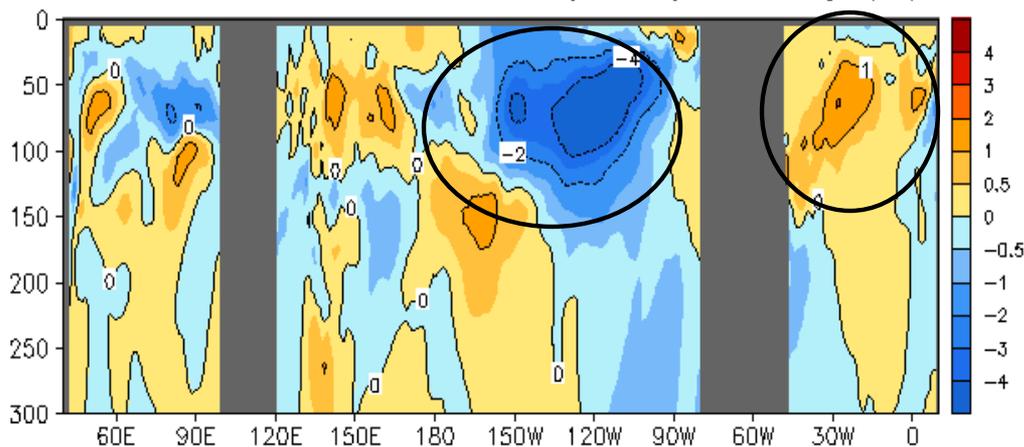
Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2°S-2°N

MAR 2016 Eq. Temp Anomaly (°C)
(GODAS, Clima. 81-10)



- Positive temperature anomalies were confined to the top 50m of the central-eastern Pacific.
- Negative subsurface temperature anomalies near the thermocline reached 110°W.
- Subsurface warming dominated the equatorial Indian Ocean.

MAR 2016 - FEB 2016 Eq. Temp Anomaly (°C)



- Large negative temperature anomaly tendencies presented in the central-eastern Pacific.
- Positive temperature anomaly tendency dominated in the equatorial Atlantic 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**

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

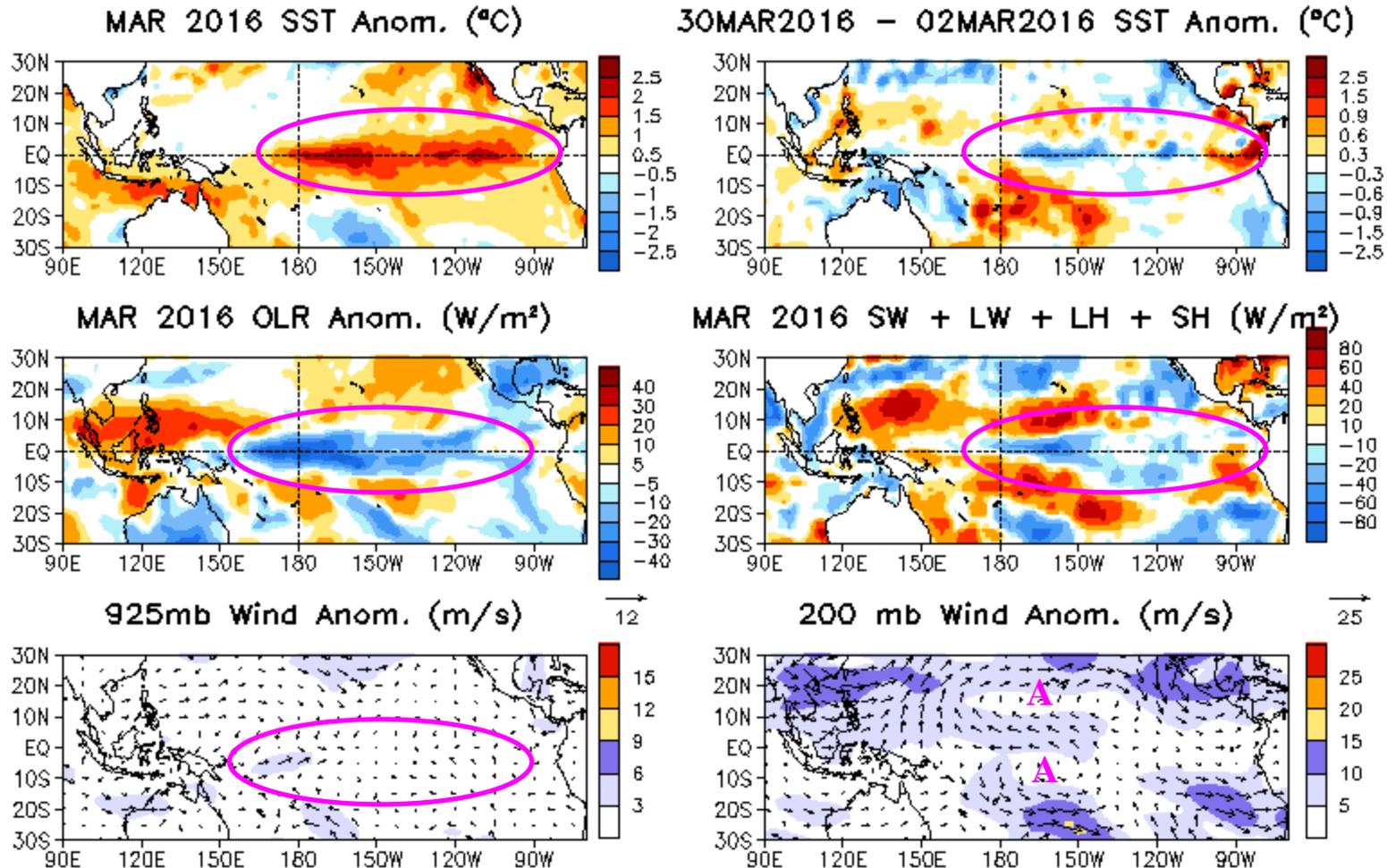
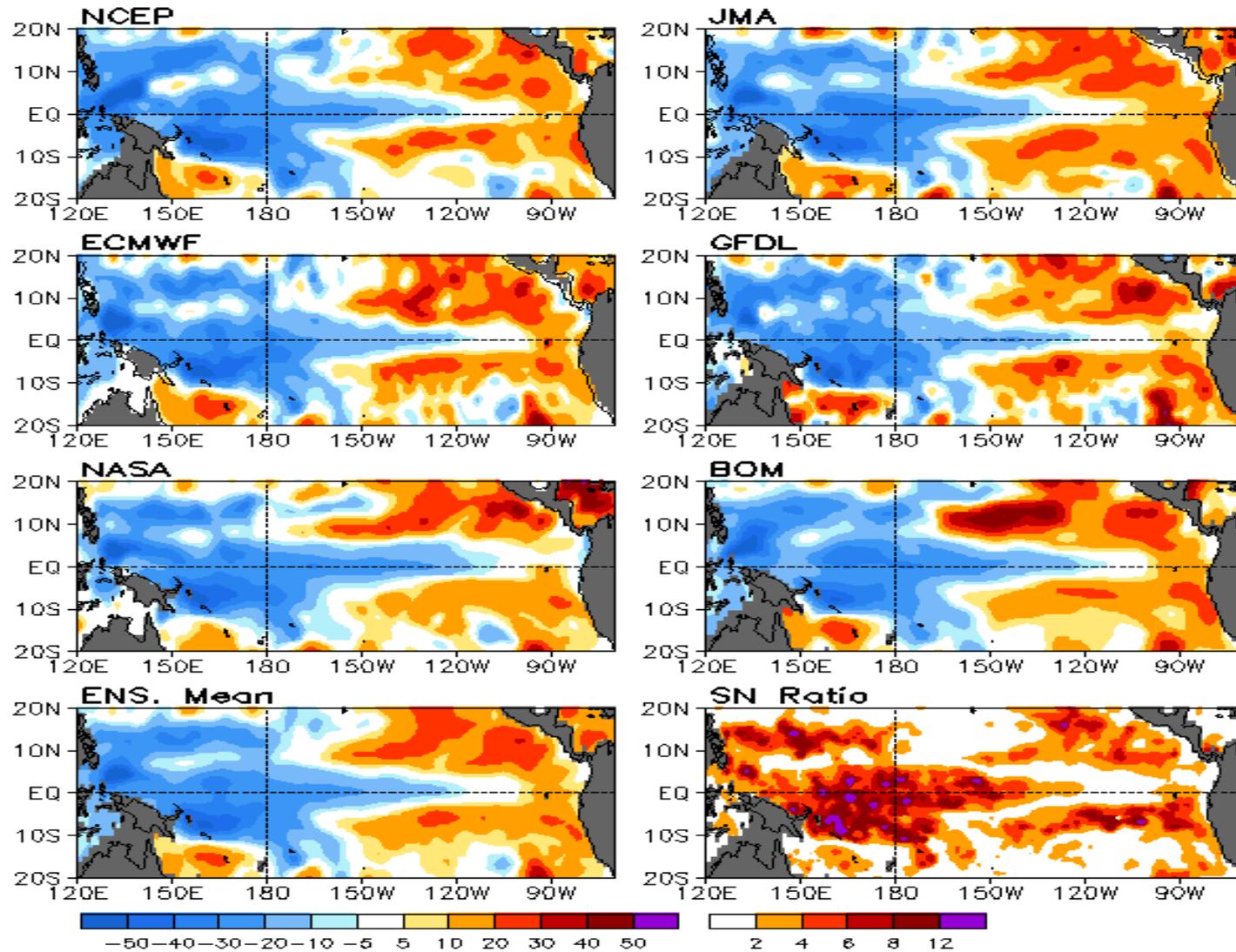


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

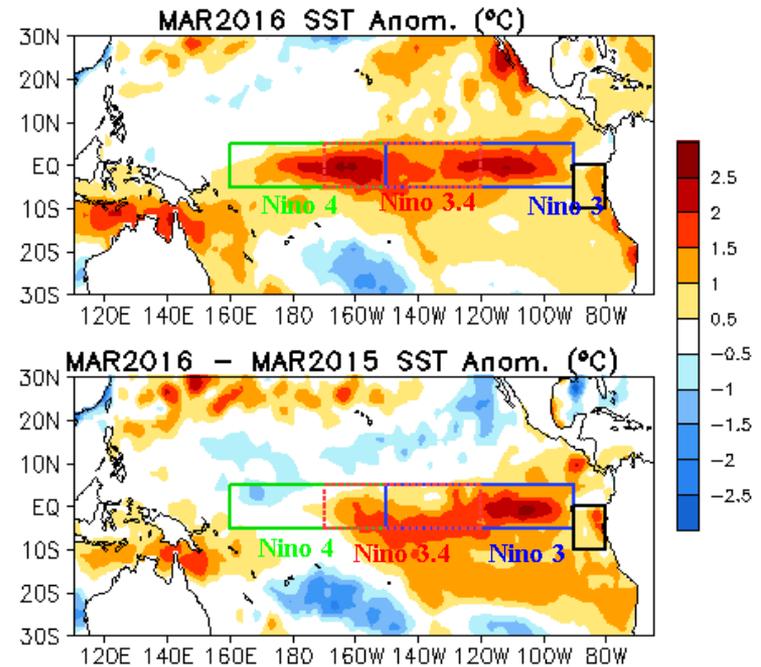
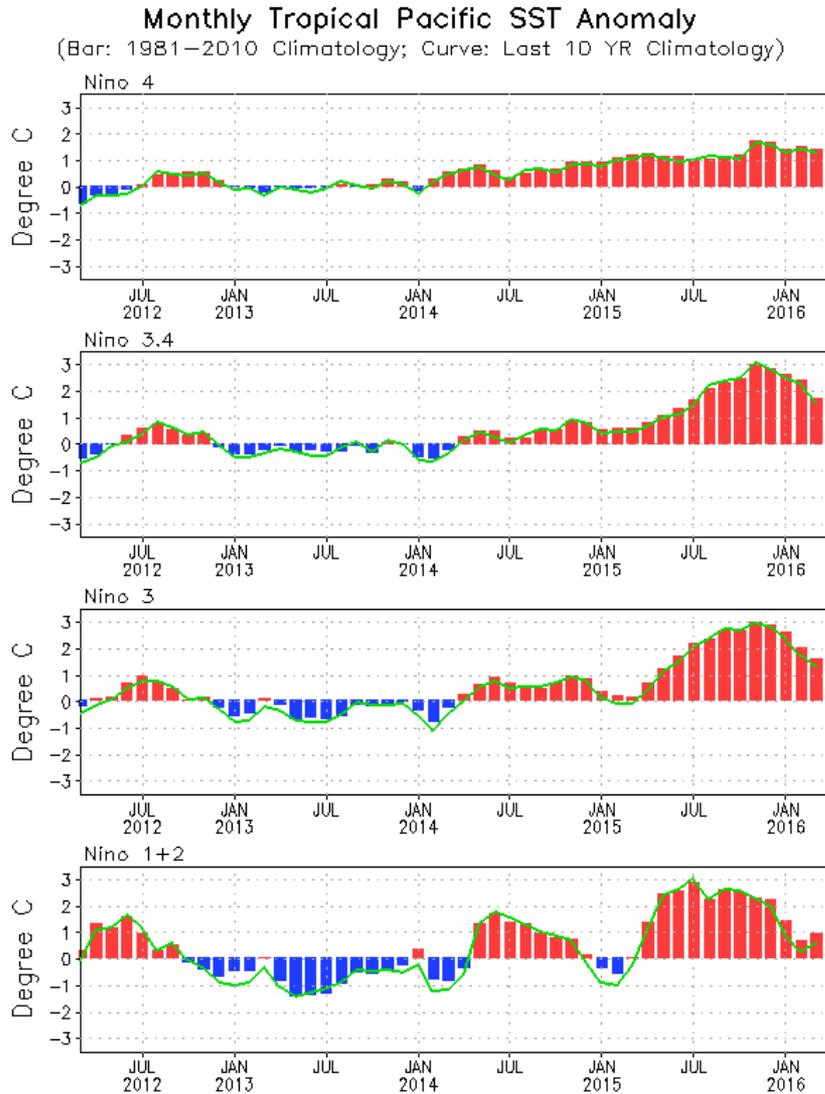
Real-Time Multiple Ocean Reanalyses Intercomparison

(http://origin.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)

Anomalous Depth (m) of 20C Isotherm: MAR 2016



Evolution of Pacific NINO SST Indices

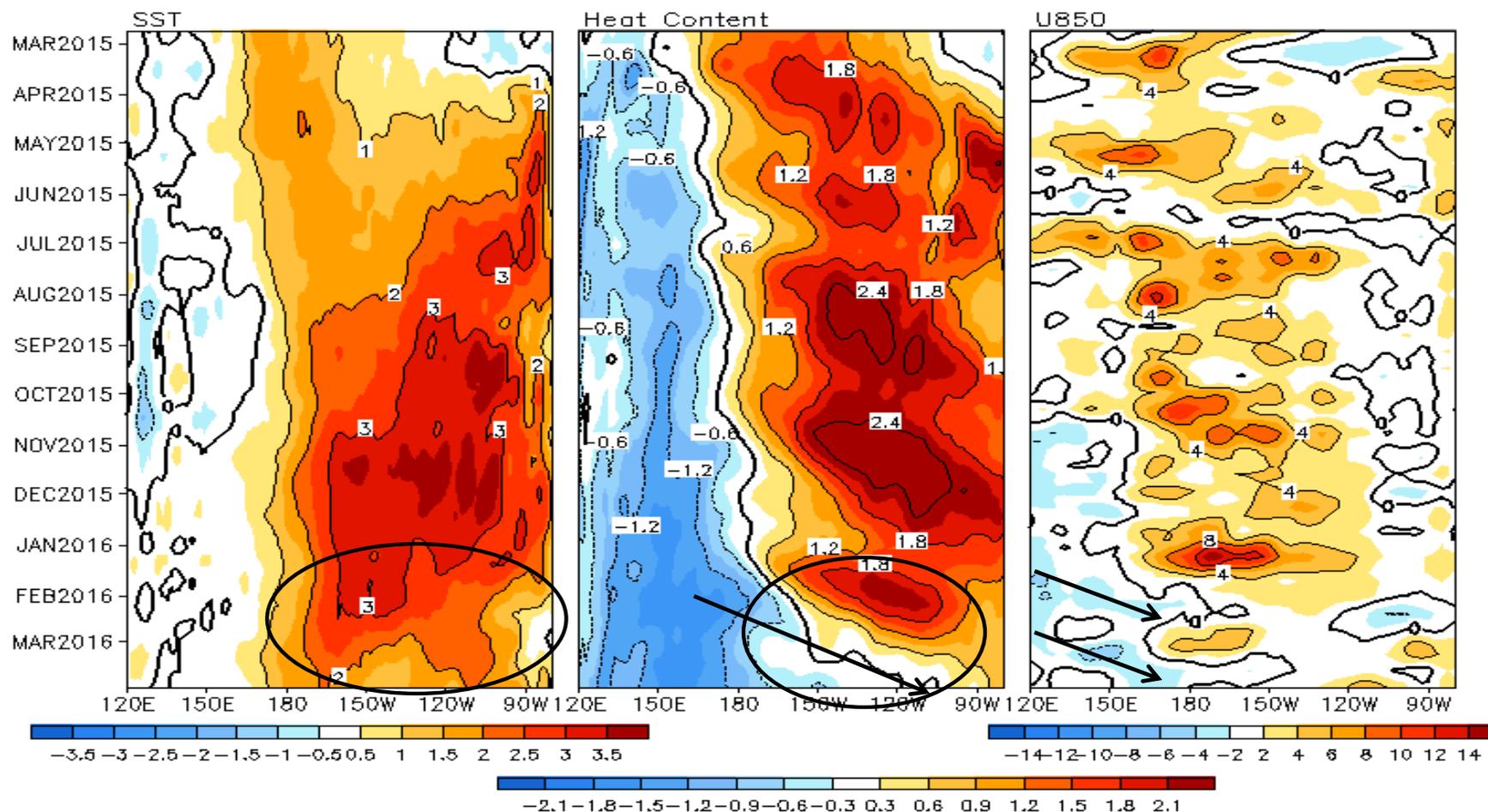


- Nino 4, 3.4, and 3 indices weakened in Mar. 2016.
- Nino3.4 = 1.7°C in Mar 2016.
- Oceanic and atmospheric features reflect continuing strong El Nino conditions in March.
- The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.

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

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

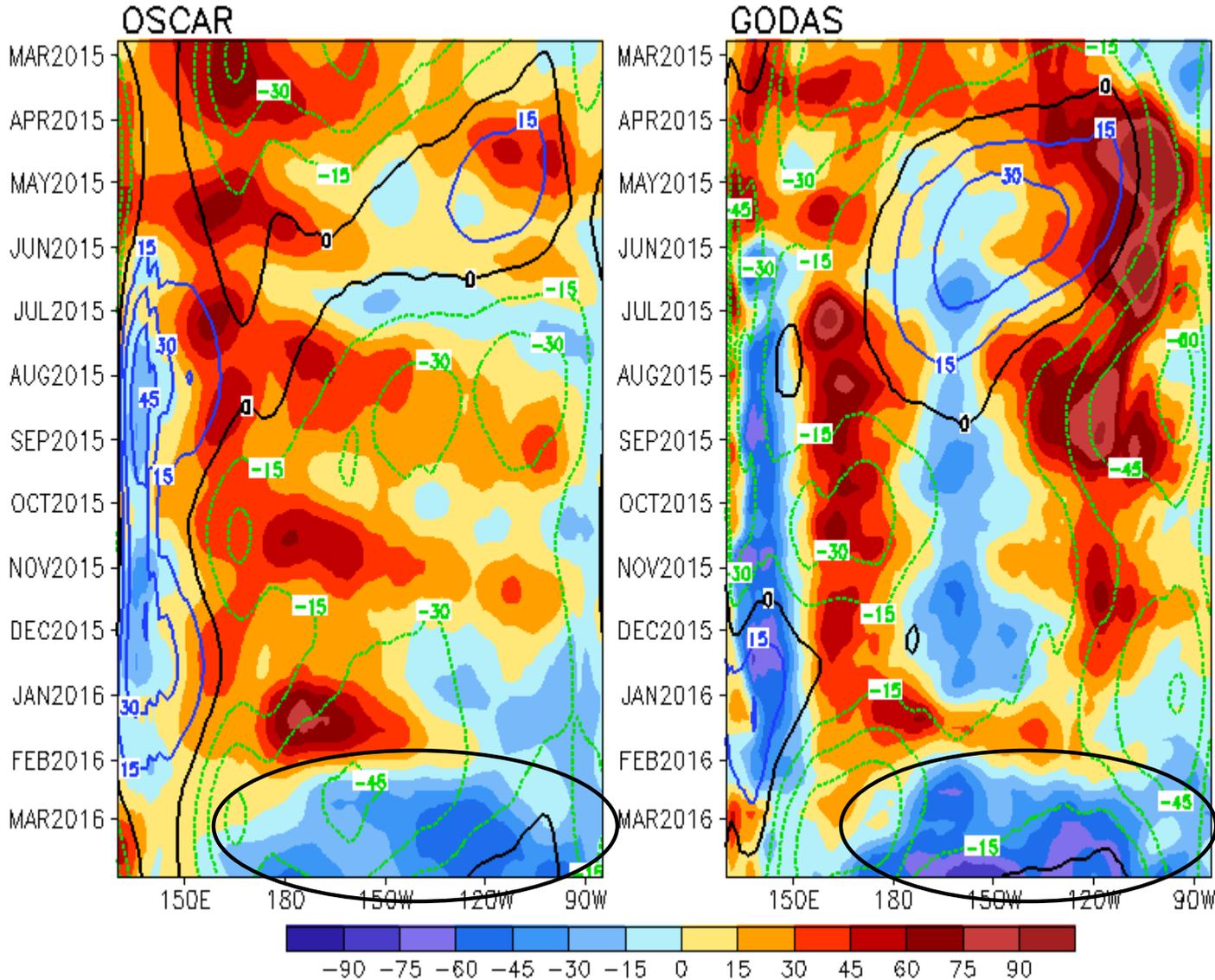
2°S–2°N Average, 3 Pentad Running Mean



- Positive SSTA in the central and eastern equatorial Pacific weakened since Dec 2015.
- Positive HC300A east of dateline weakened substantially since Feb. 2016 with negative phase appearing during March.
- The rapid decline of ocean heat content was probably forced by the two episodes of easterly wind anomalies that extended from far western Pacific to near the dateline in Feb-Mar.

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

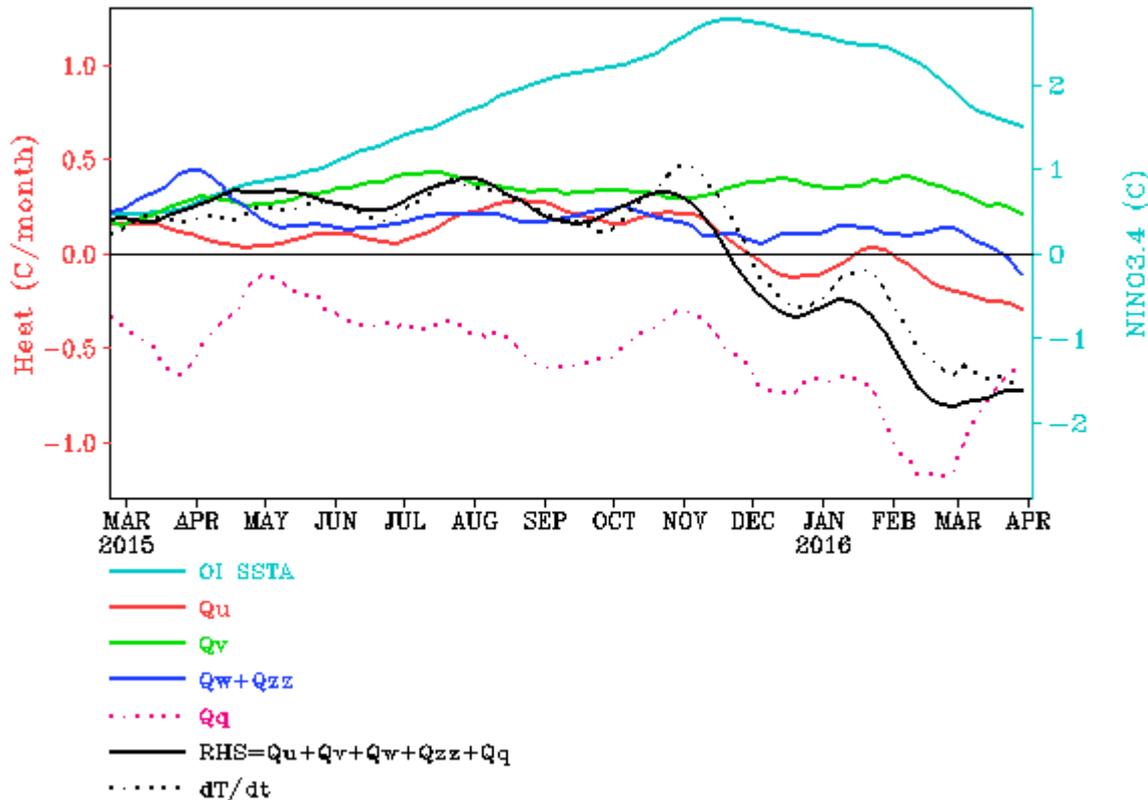
U (15m), cm/s, 2°S–2°N (Shading=Anomaly; Contour=Climatology)



- Anomalous current patterns were similar between OSCAR and GODAS.

- Anomalous westward current dominated across the central- eastern equatorial Pacific. It was favorable for a cooling tendency in the central-eastern Pacific SSTA

NINO3.4 Heat Budget



- Observed SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) became negative since Dec 2015.

- Zonal advection term (Q_u) and heat flux term (Q_q) were negative in Mar 2016, contributing to the decay of El Nino.

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.

Q_u : Zonal advection; Q_v : Meridional advection;

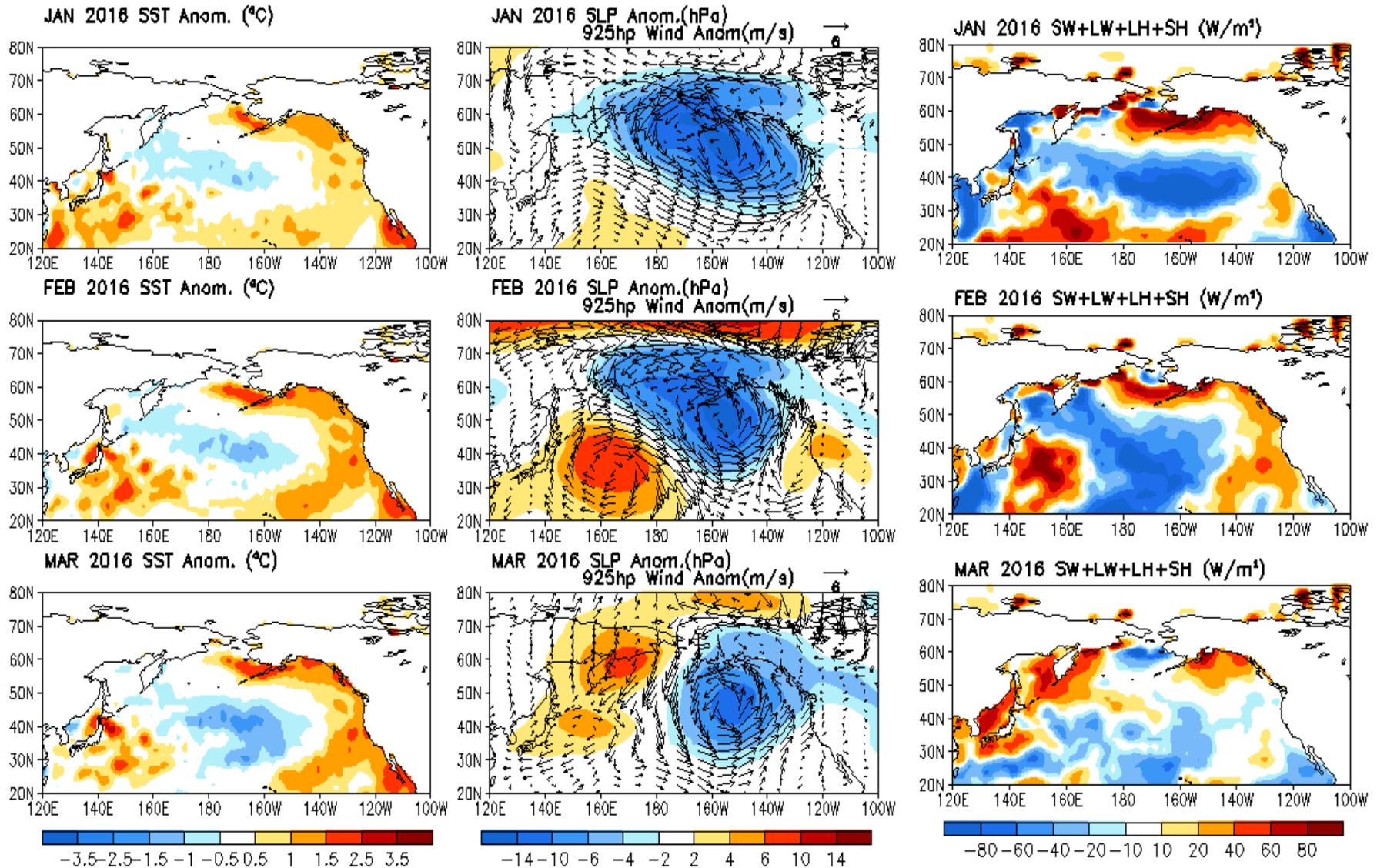
Q_w : Vertical entrainment; Q_{zz} : Vertical diffusion

Q_q : $(Q_{net} - Q_{open} + Q_{corr})/pcph$; $Q_{net} = SW + LW + LH + SH$;

Q_{open} : SW penetration; Q_{corr} : Flux correction due to relaxation to OI SST

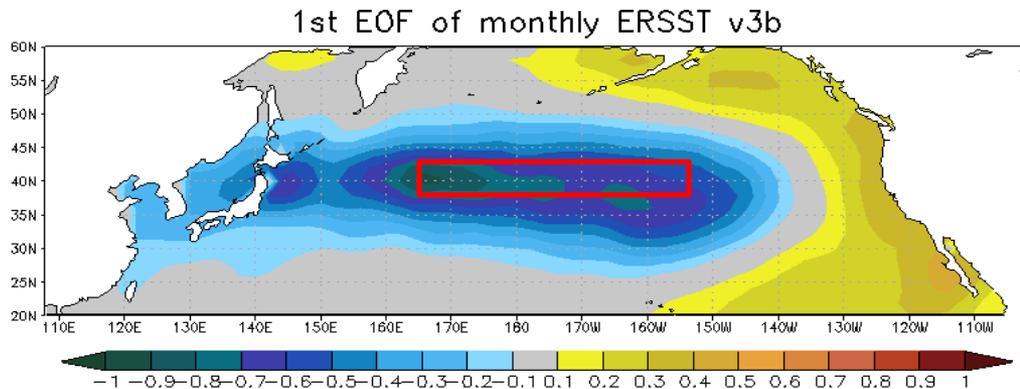
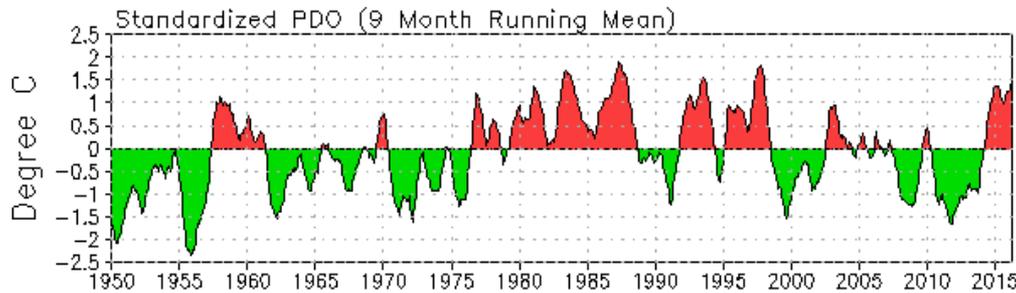
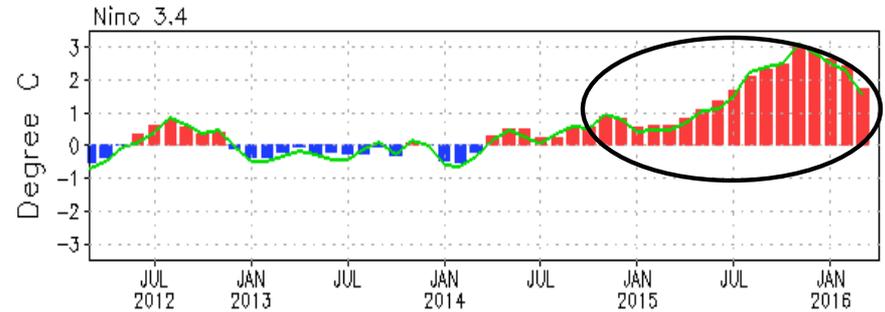
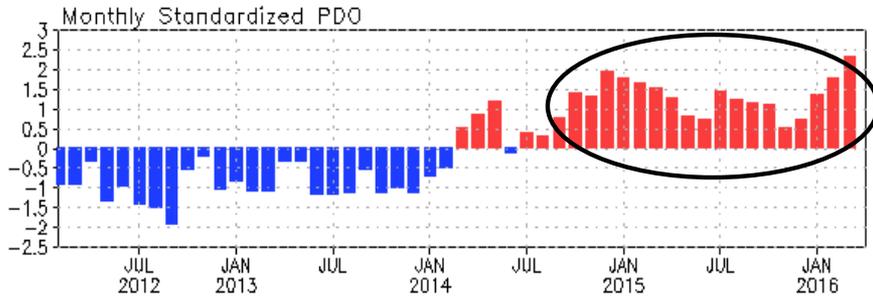
North Pacific & Arctic Oceans

Last Three Month SST, SLP, 925hp Wind and Net Heat flux Anom.



- SSTA, SLP, 925hp wind and net heat flux anomalies in the north Pacific resembled those typical ENSO-induced responses via atmospheric bridge.

PDO index



- The positive phase of PDO index has persisted 21 months since Jul 2014, and strengthened with PDO index = 2.3 in Mar 2016.

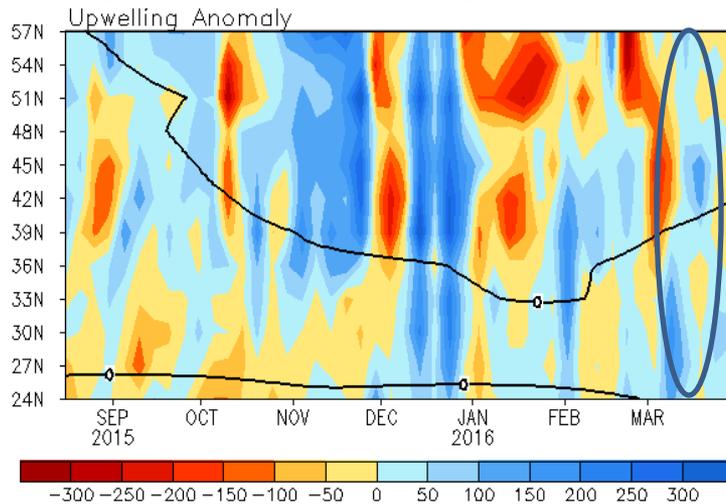
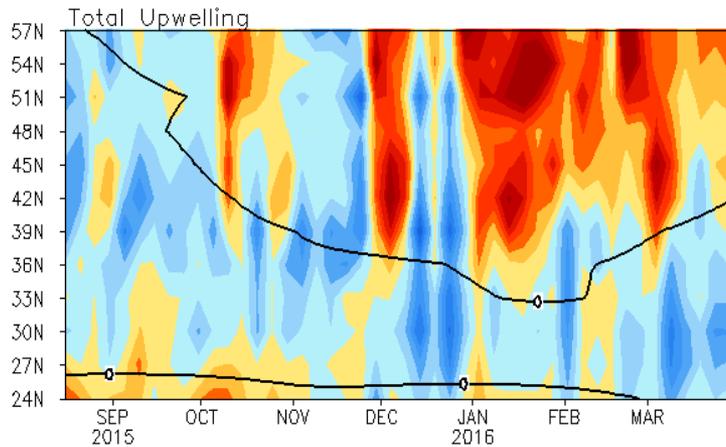
- Strengthening of PDO since Nov 2015 is related with ENSO forcing via atmospheric bridge.

- 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.

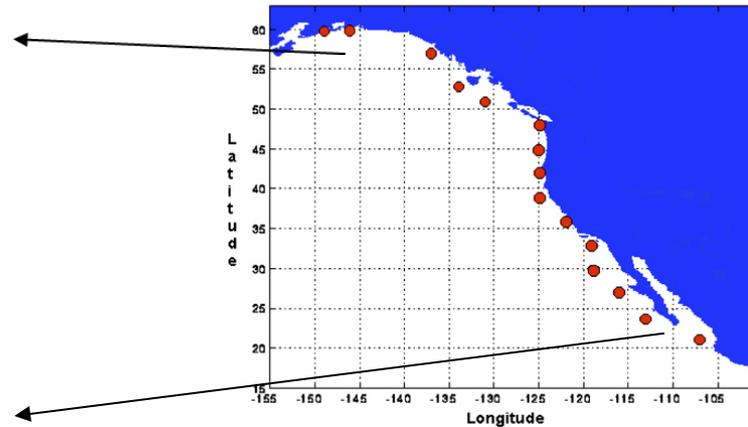
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

North America Western Coastal Upwelling

Pentad Coastal Upwelling for West Coast North America
($\text{m}^3/\text{s}/100\text{m}$ coastline)



Standard Positions of Upwelling Index Calculations



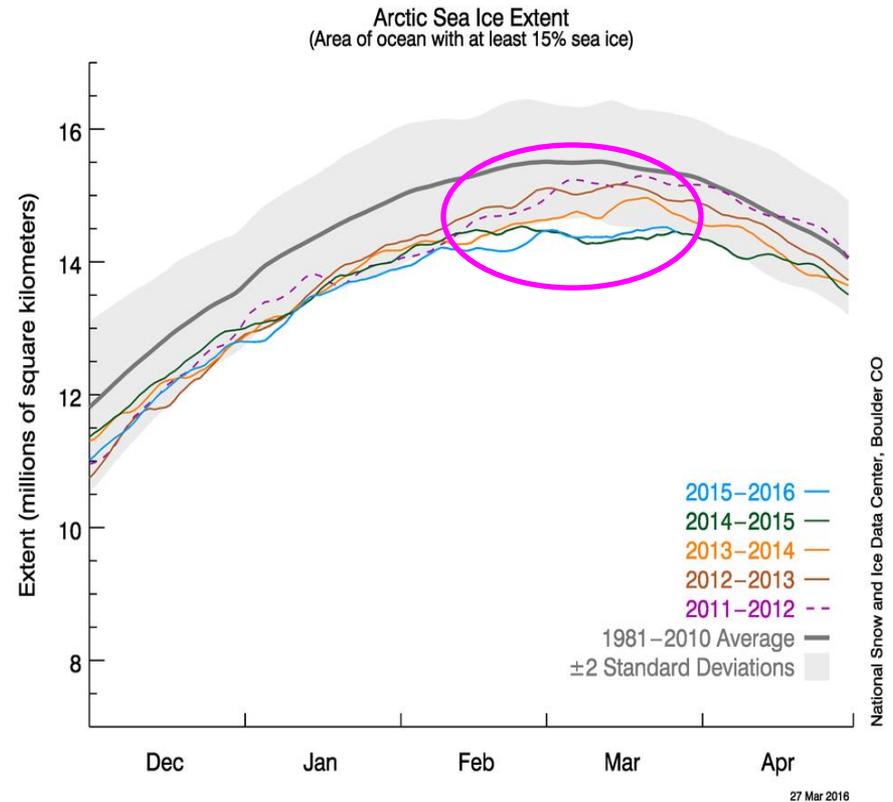
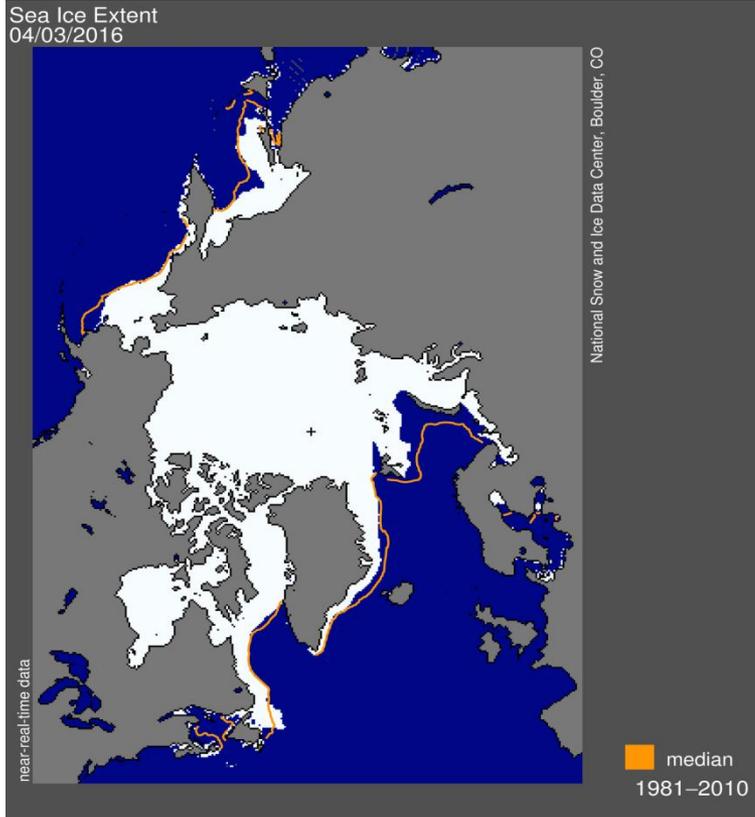
- Both anomalous upwelling and downwelling presented in Mar 2016.

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 ($\text{m}^3/\text{s}/100\text{m}$ 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 36°N to 57°N .

Arctic Sea Ice

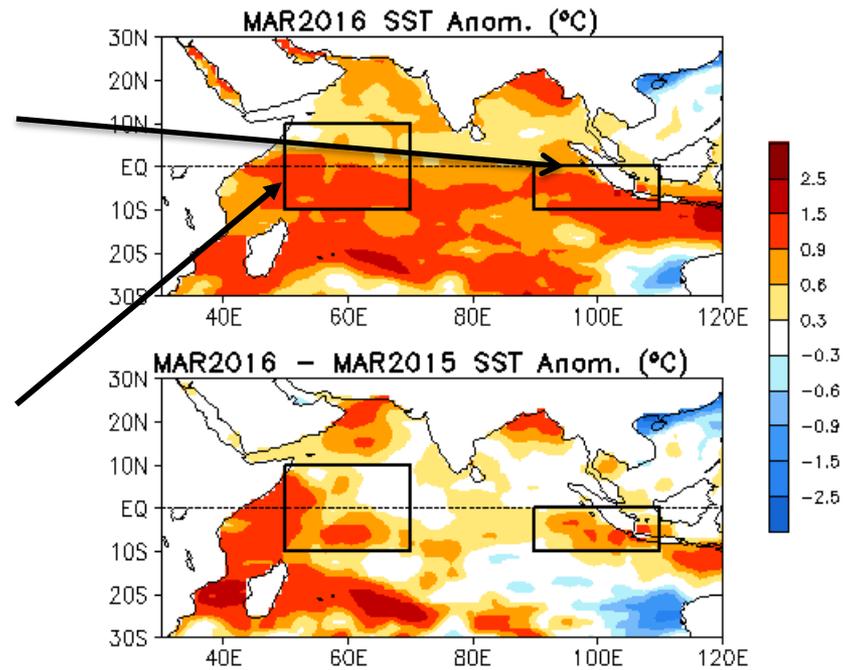
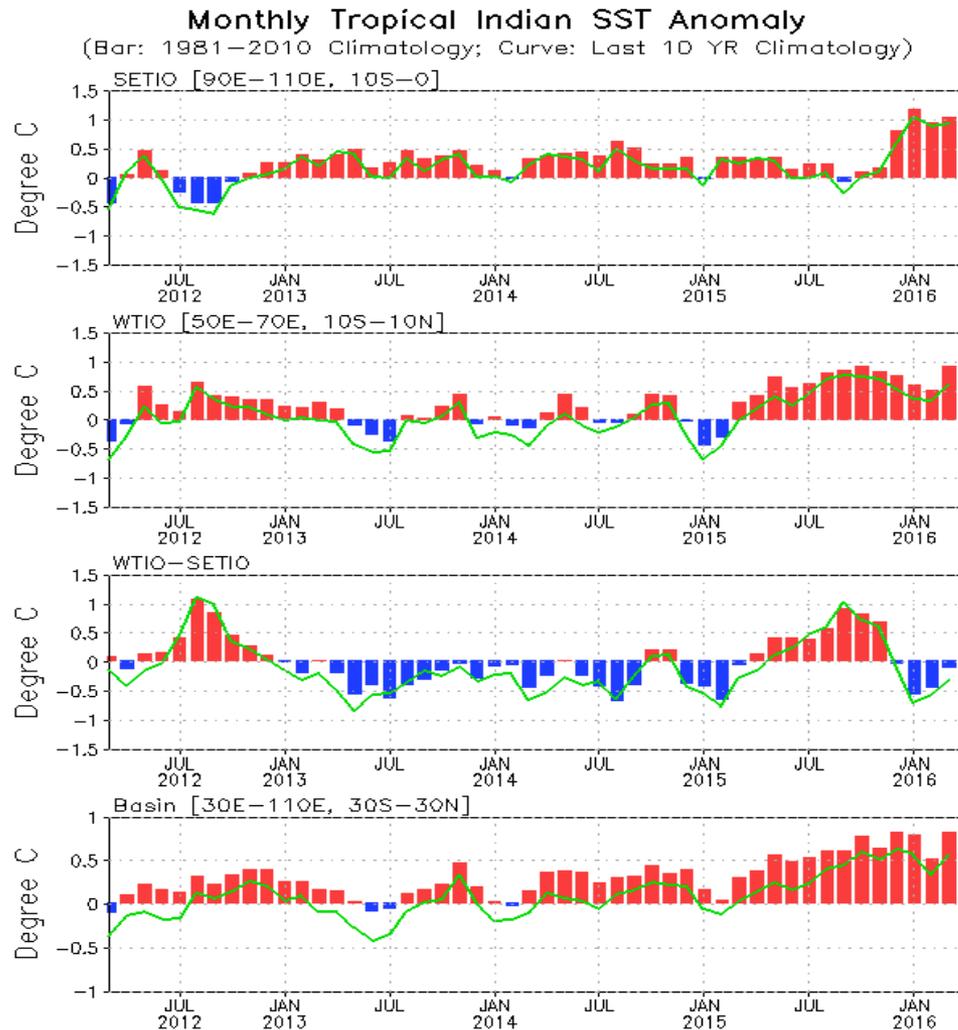
National Snow and Ice Data Center
<http://nsidc.org/arcticseaicenews/index.html>



- Arctic sea ice have reached its annual maximum extent in March and is the lowest maximum in the satellite record.

Indian Ocean

Evolution of Indian Ocean SST Indices



- Positive SSTA continued to cover much of the Indian Ocean.
- DMI was neutral in Mar 2016.

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.

- Positive SSTA continued to cover much of the Indian Ocean
- SSTA tendency was largely determined by heat flux.

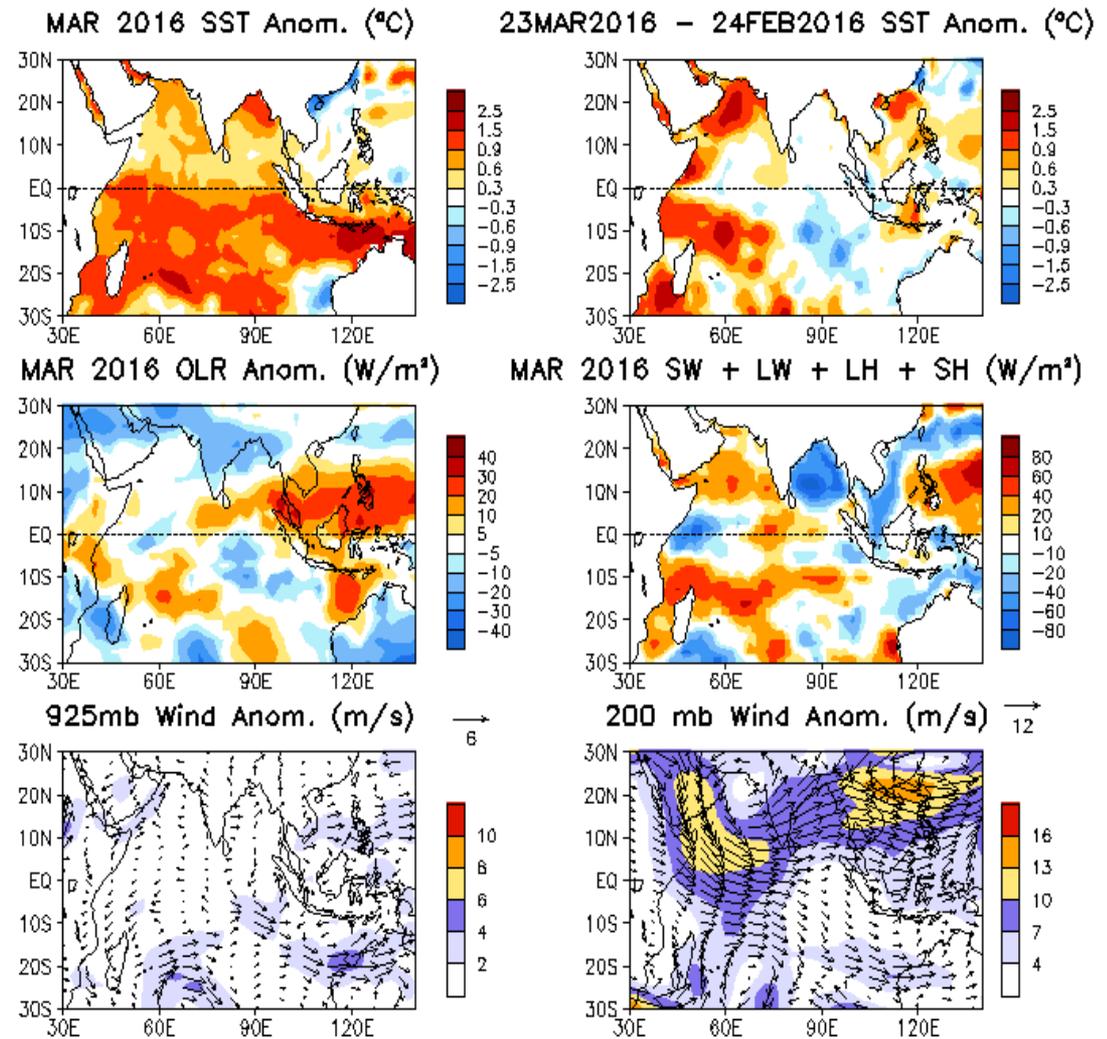
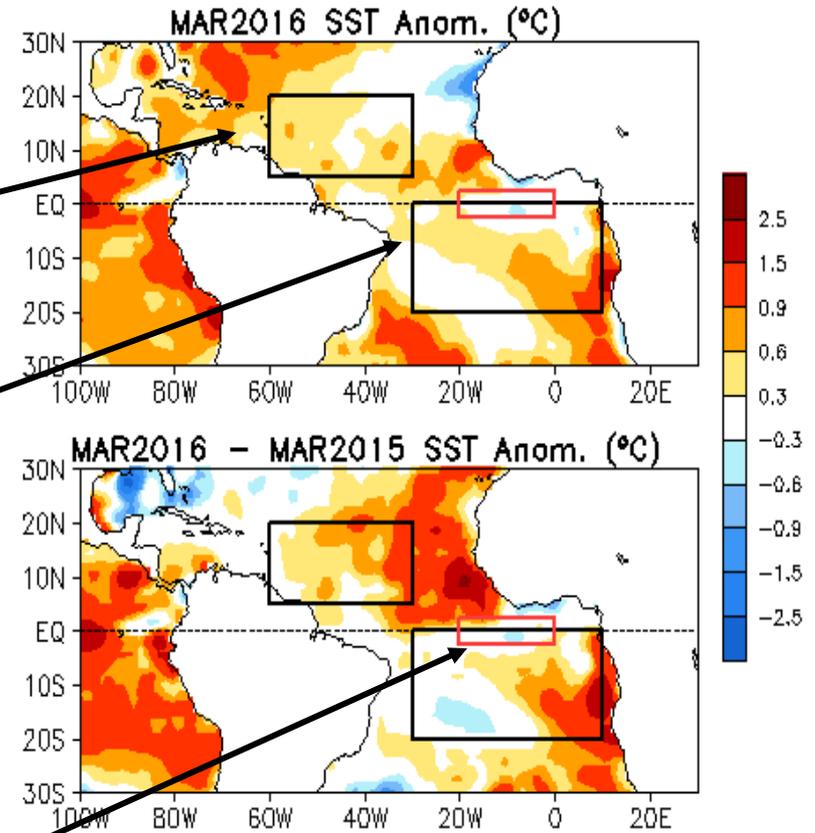
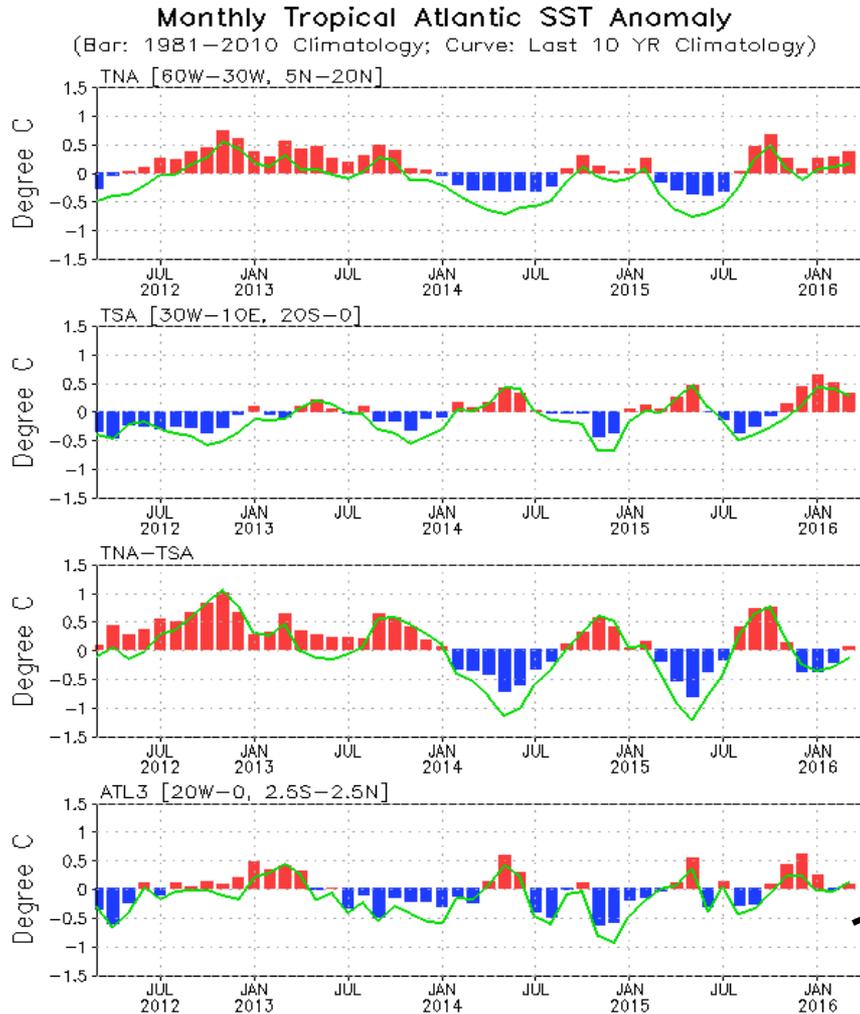


Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices



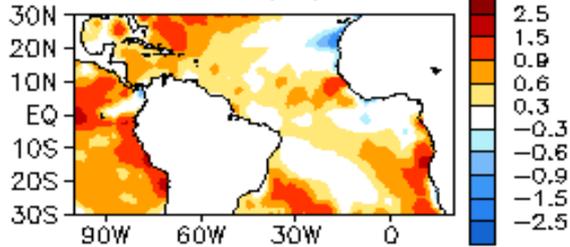
- **ATL3 and Meridional Gradient indices were near-normal in Mar. 2016.**

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.

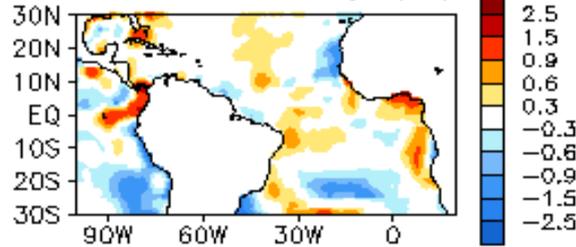
Tropical Atlantic:

SST Anom., SST Anom. Tend., TCHP OLR, Sfc Flx, 925-mb/200-mb Winds and RH

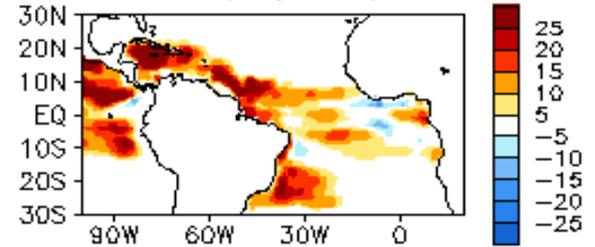
MAR 2016 SST Anom.
(°C)



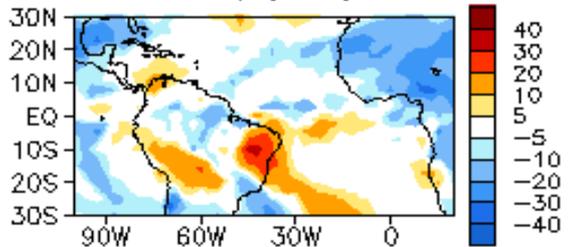
23MAR2016 – 24FEB2016
SST Anomaly (°C)



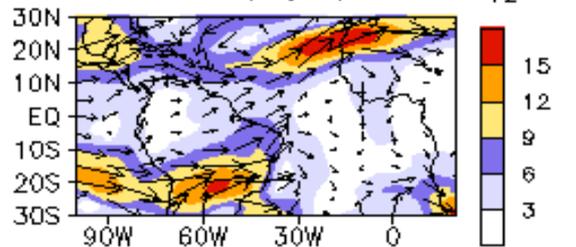
MAR 2016 TCHP Anom.
(KJ/cm²)



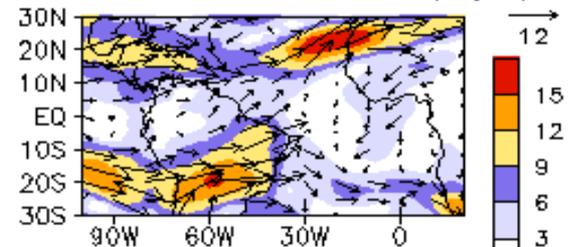
MAR 2016 OLR Anom.
(W/m²)



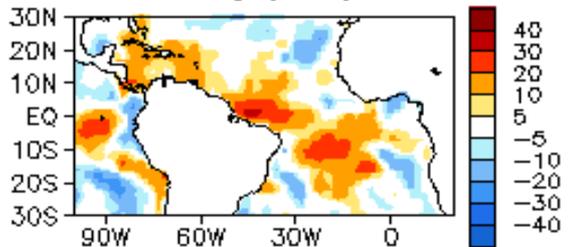
MAR 2016 200mb Wind Anom.
(m/s)



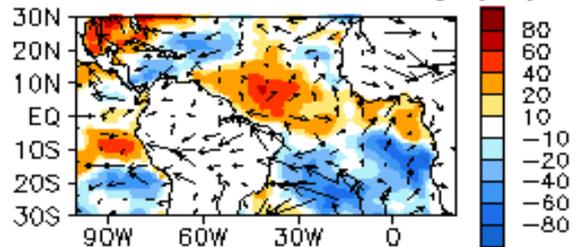
MAR 2016 200mb – 850mb
Wind Shear Anom. (m/s)



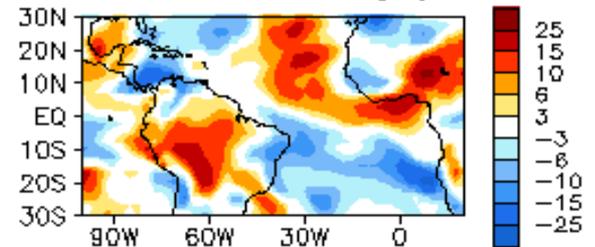
MAR 2016 SW + LW Anom.
(W/m²)



LH + SH Anom. (W/m²)
925mb Wind Anom. (m/s)

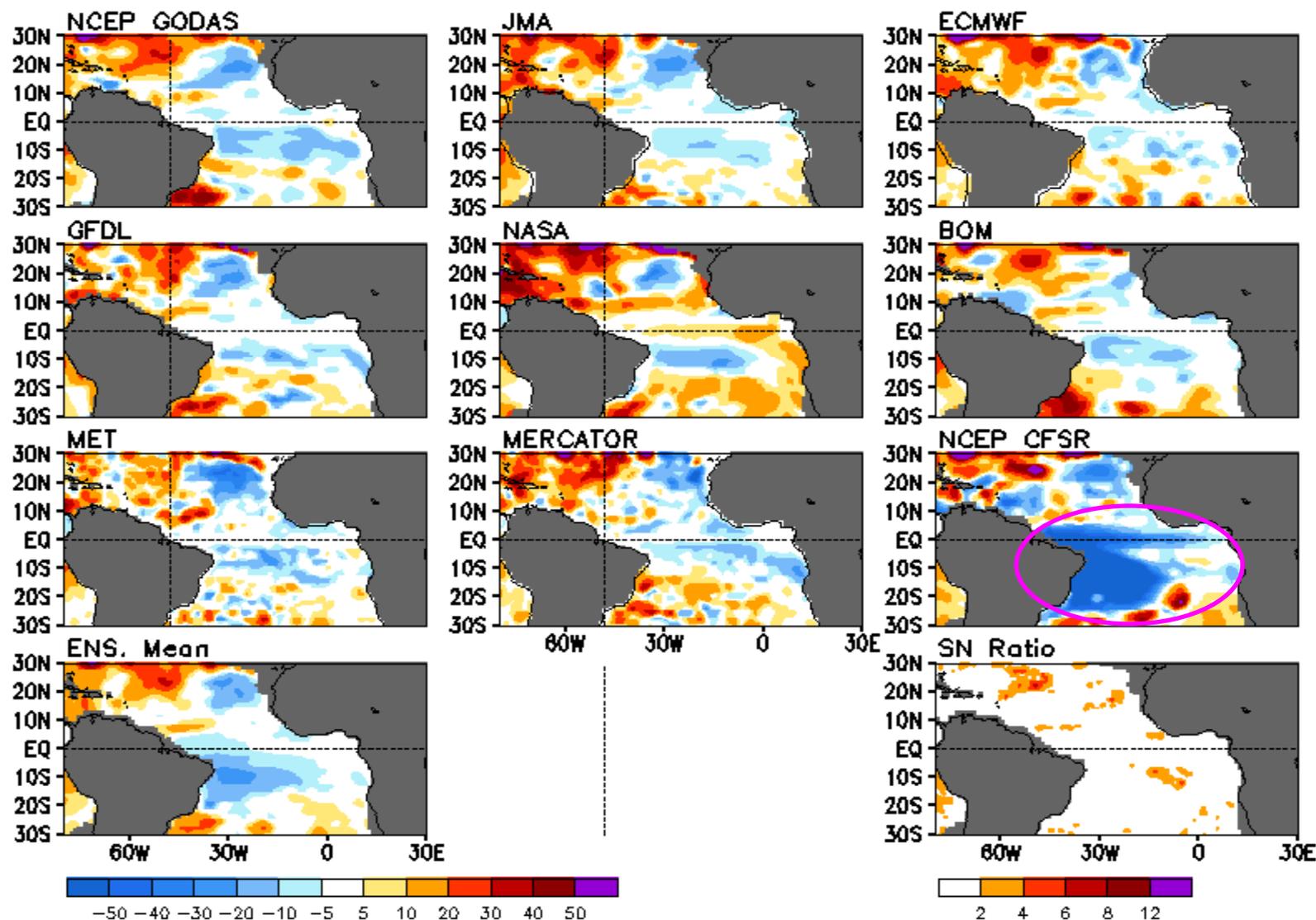


MAR 2016 700 mb
RH Anom. (%)

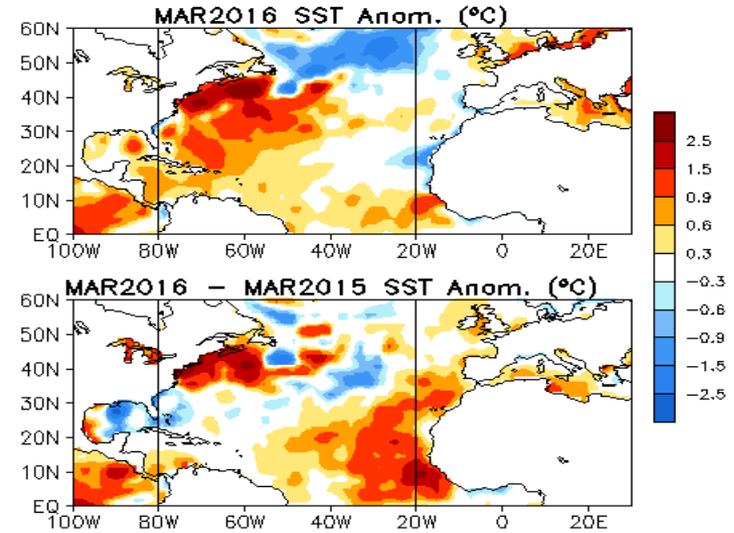
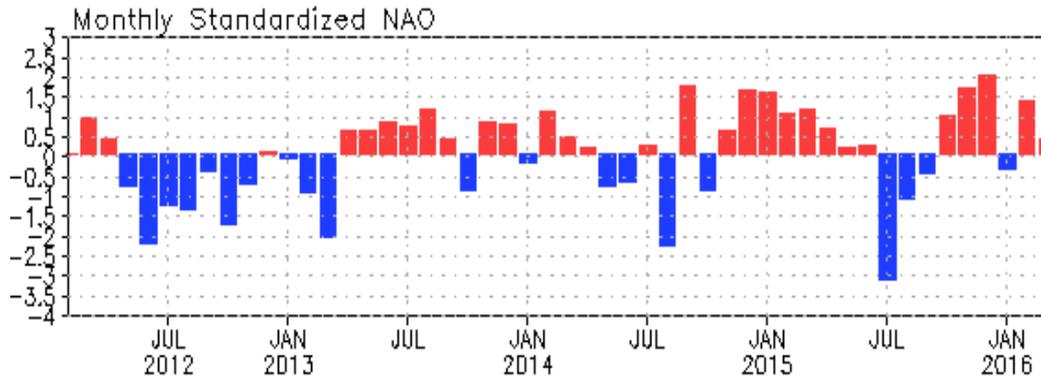


Real-Time Multiple Ocean Reanalyses Intercomparison (1993-2013 Climatology)

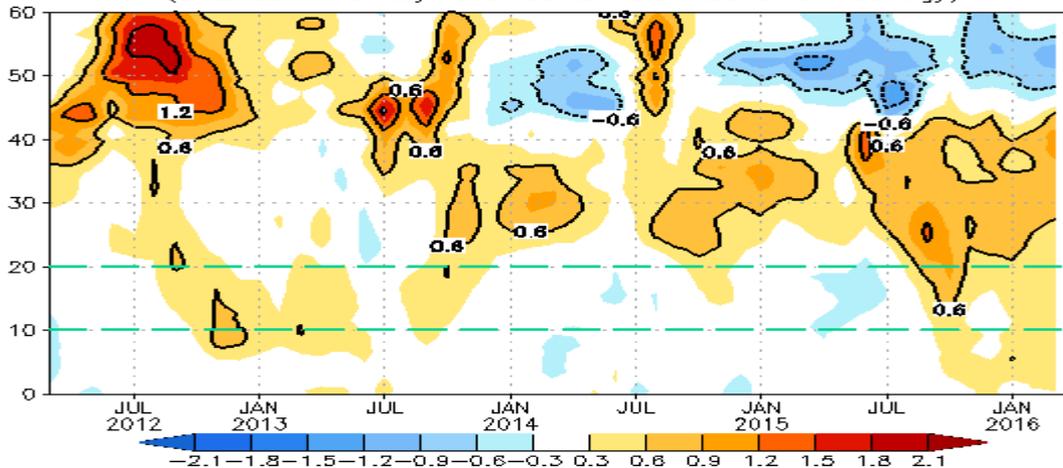
Anomalous Depth (m) of 20C Isotherm: MAR 2016



NAO and SST Anomaly in North Atlantic



Zonal Averaged Monthly SSTA in North Atlantic (80W-20W, C)
(OIv2 SST Anomaly referred to 1981-2010 Climatology)



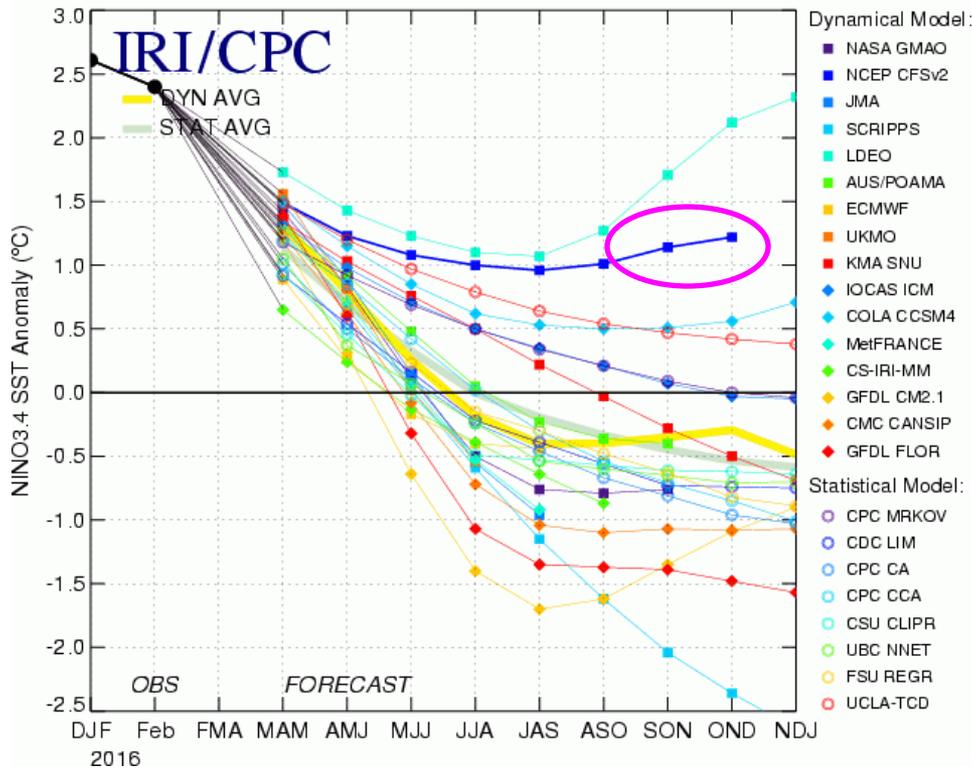
- Positive NAO weakened with NAOI=0.4 in Mar 2016.
- SSTA was positive in the middle latitudes and negative in the high latitudes, may be due to the influence of positive phase of NAO.

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

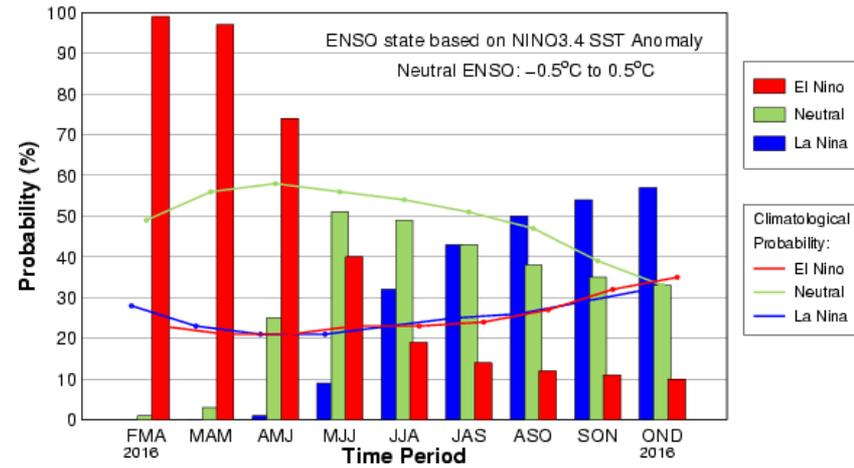
ENSO and Global SST Predictions

IRI NINO3.4 Forecast Plum

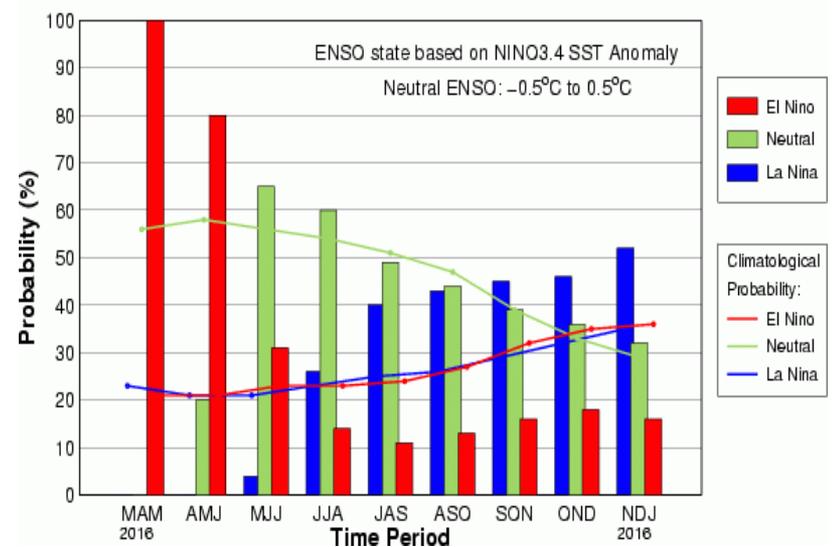
Mid-Mar 2016 Plume of Model ENSO Predictions



Early-Mar CPC/IRI Consensus Probabilistic ENSO Forecast



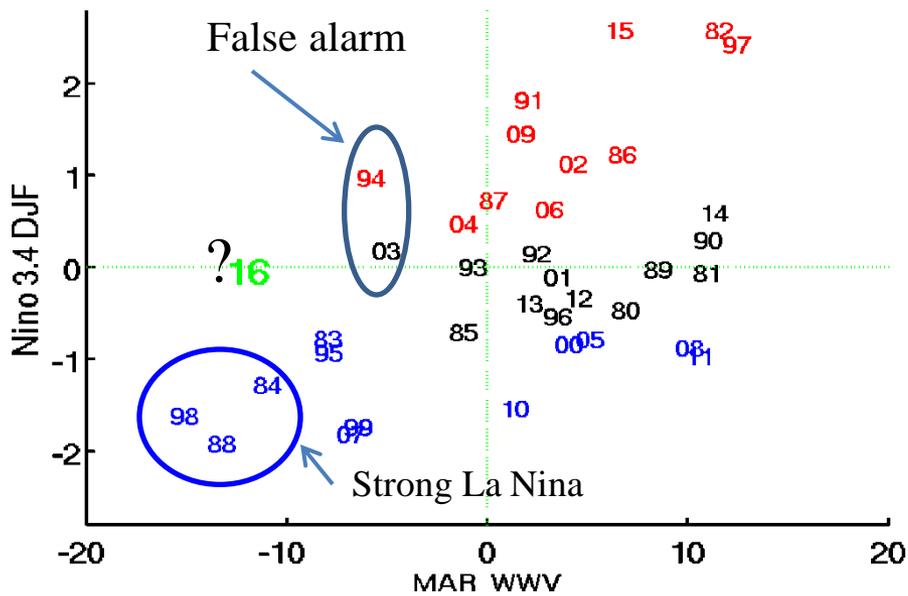
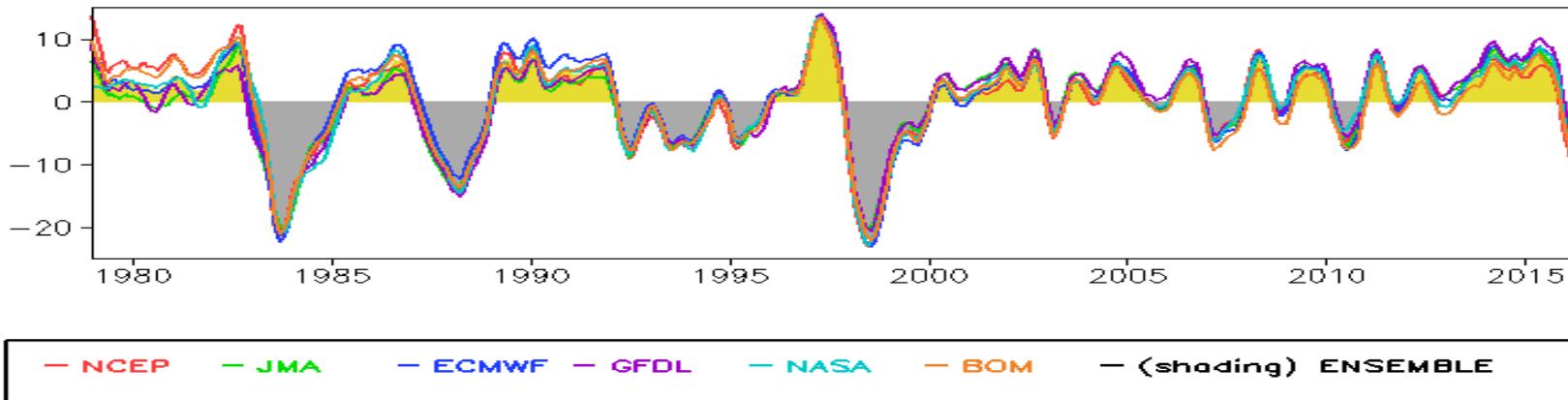
Mid-Mar IRI/CPC Model-Based Probabilistic ENSO Forecast



- All models indicate continued weakening El Nino conditions over the coming several months.
- Most models predict a transition to ENSO-neutral by late spring or early summer, and high possibility of La Nina conditions during the northern hemisphere fall 2016.

Warm Water Volume (WWV) and NINO3.4 Anomalies

Anomalous Depth (m) of 20C Isotherm Averaged in [120E-80W, 5S-5N]

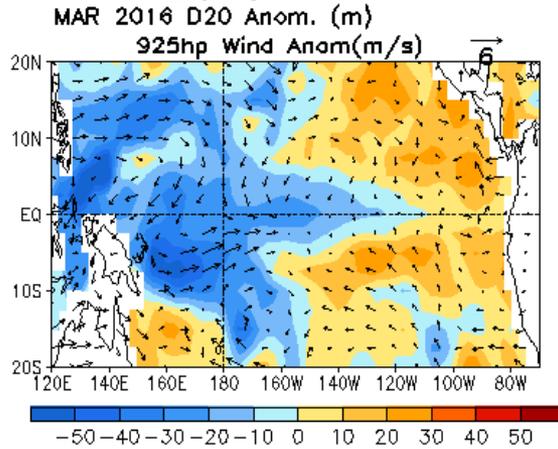


- WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N]. **Statistically, WWV leads Nino 3.4 by 6-9 months** (Meinen and McPhaden, 2000).
- Historical record indicates that high possibility of a La Niña event will develop when WWV is strong negative in Mar.
- WWV in Mar 2016 ranked the third lowest, indicating a very high chance of a La Niña in the coming winter.

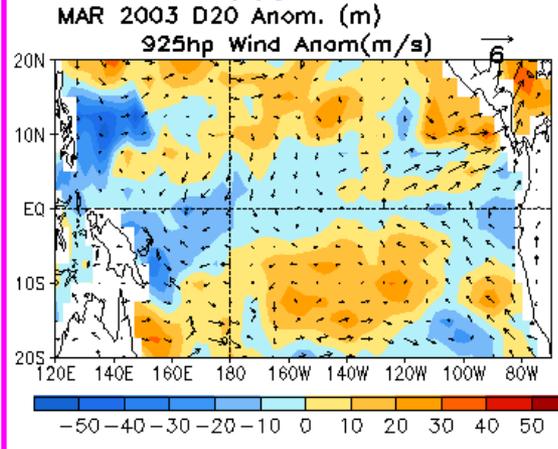
Scatter plot of WWV in March .VS. Nino 3.4 index in the following winter (DJF)

False Alarm

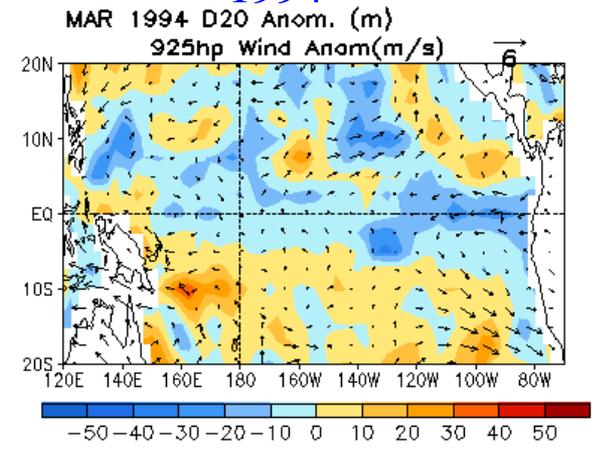
2016



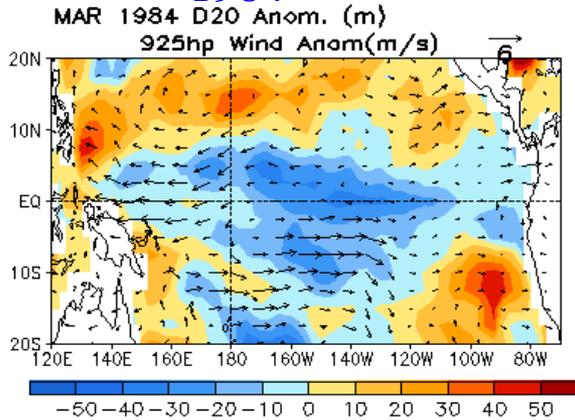
2003



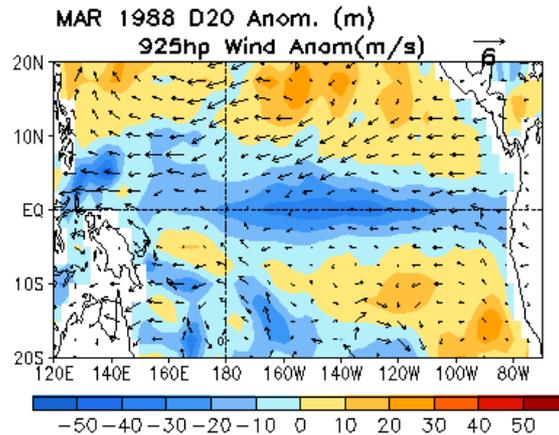
1994



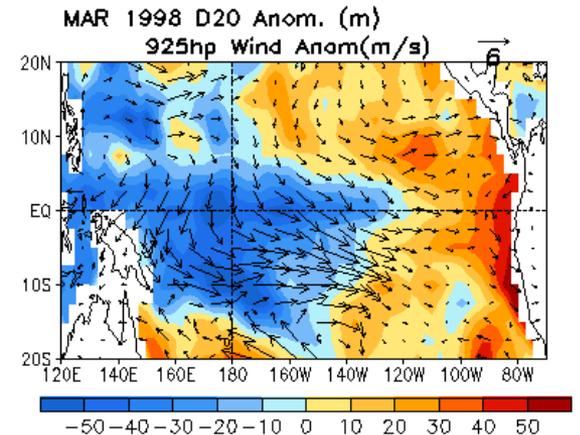
1984



1988



1998



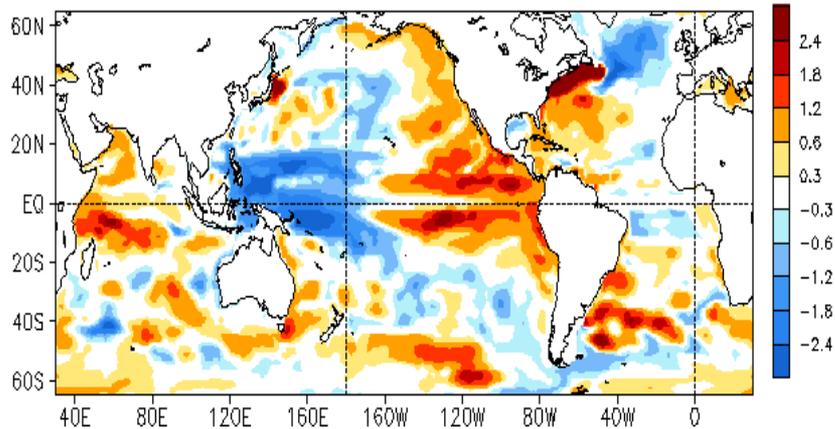
La Niña start: SON

La Niña start: AMJ

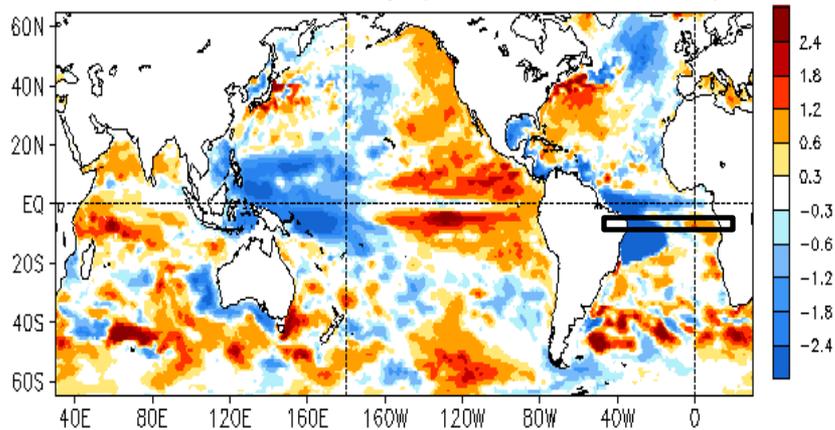
La Niña start: JJA 30

Recent CFSv2 Cold Biases in Tropical South Atlantic

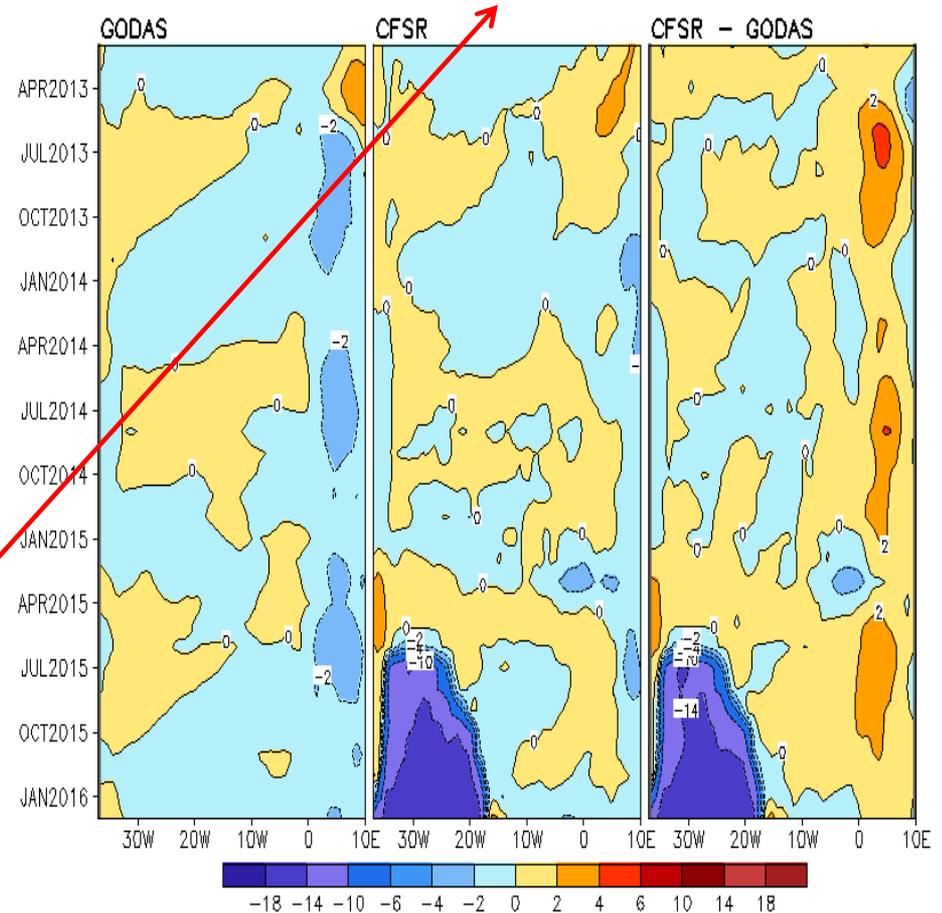
MAR 2016 HC300 Anomaly (°C, Clim. 1999–2010): GODAS



MAR 2016 HC300 Anomaly (°C, Clim. 1999–2010): CFSR



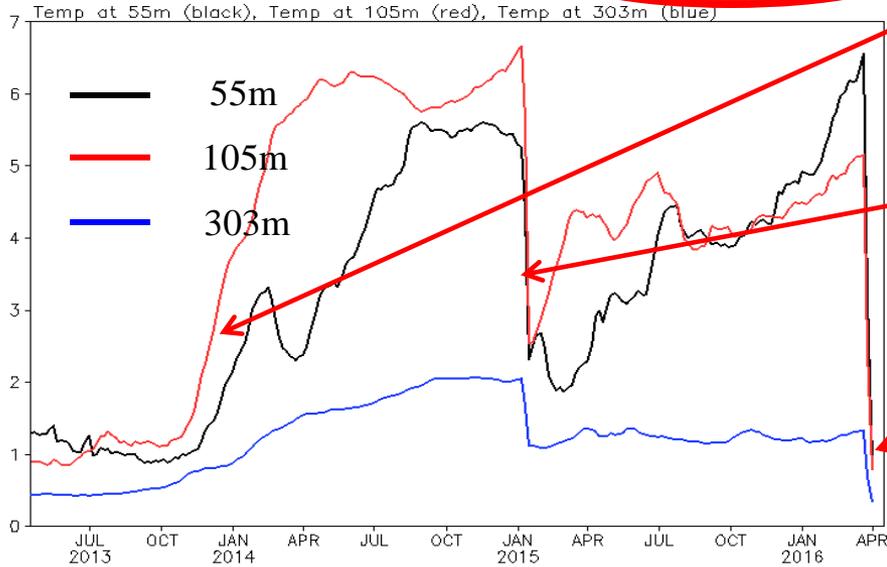
Temperature Anomaly at z=55m in 9°S–11°S (°C, Clim. 1999–2010)



- A cold bias emerged around 10S in the South Atlantic around **Jul 2015** and enhanced quickly with time.
- It reached **-18 degree at 55m depth** since Oct 2015.

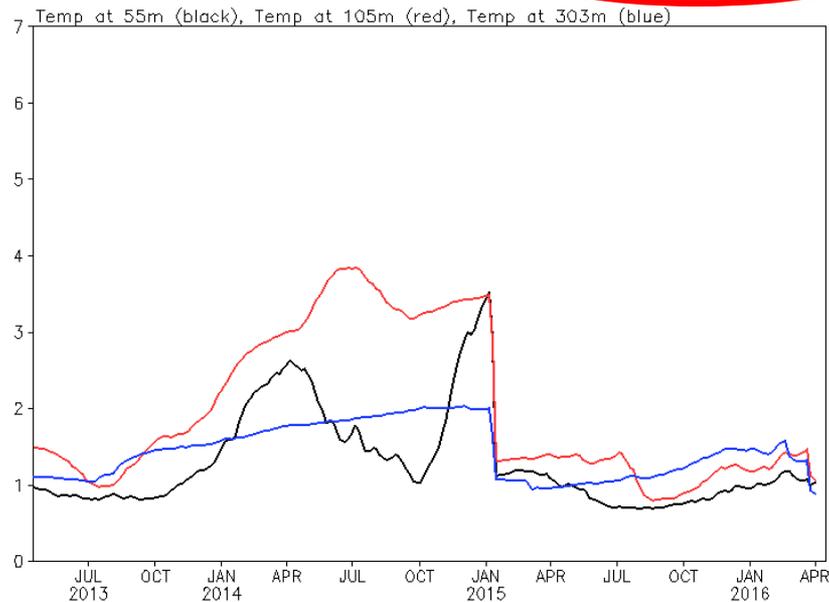
Pentad Temperature

RMSD of CFSR minus GODAS Pentad Temp in [80W-20E, 20S-20N]

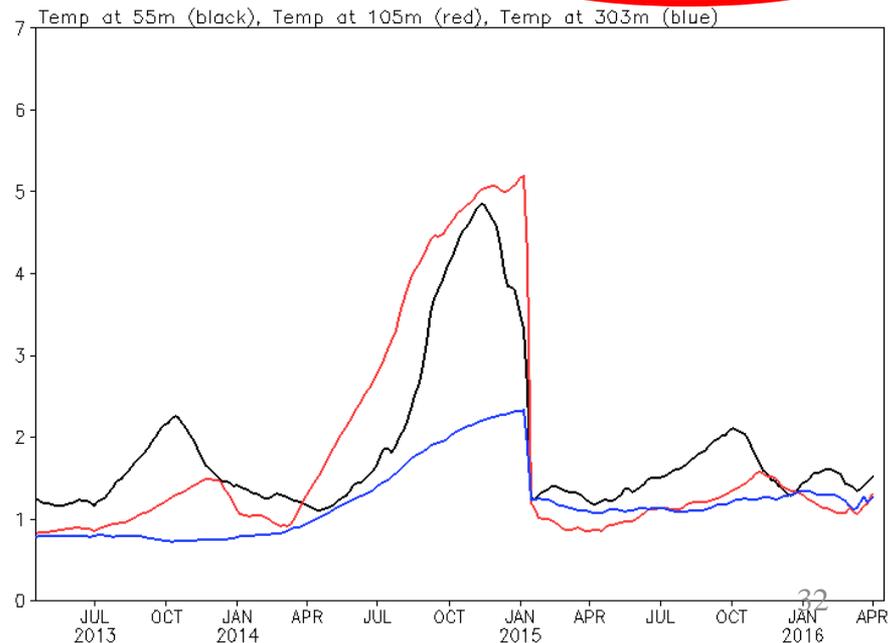


- The cold bias in 2014 started from the tropics and extended to extra-tropics. The RMSD from GODAS grew fastest at 105m depth (red line).
- The emergency fix implemented in Jan 2015 removed the error in the extra-tropics but not completely in the tropics, which grew rapidly after the fix.
- The fix implemented on Mar 29 has brought RMSD back to the pre-2014 value.

RMSD of CFSR minus GODAS Pentad Temp in [70W-20E, 60S-20S]



RMSD of CFSR minus GODAS Pentad Temp in [80W-0E, 20N-60N]

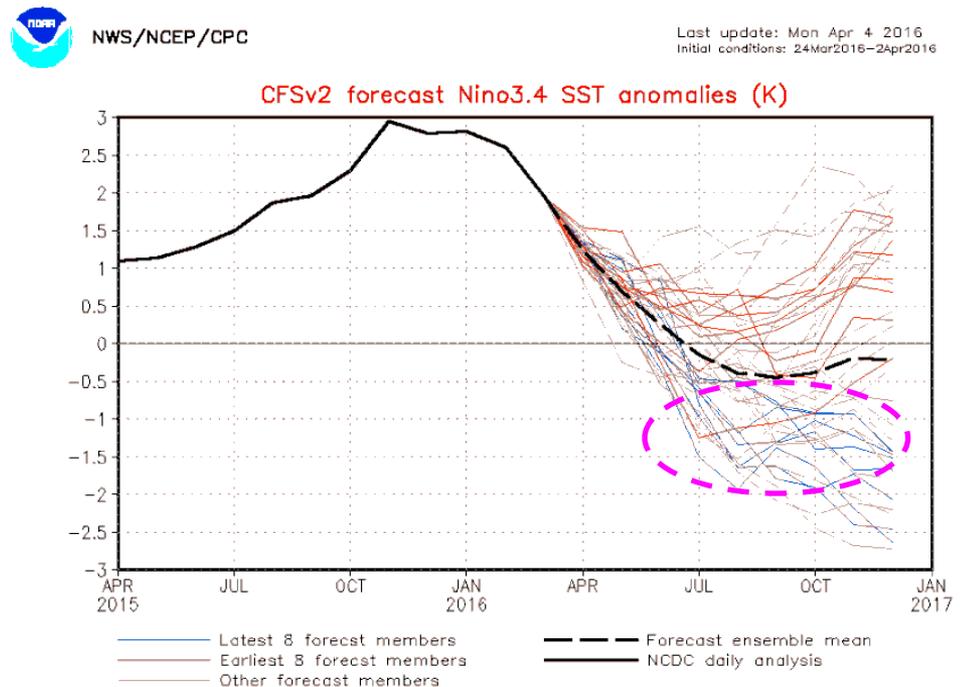
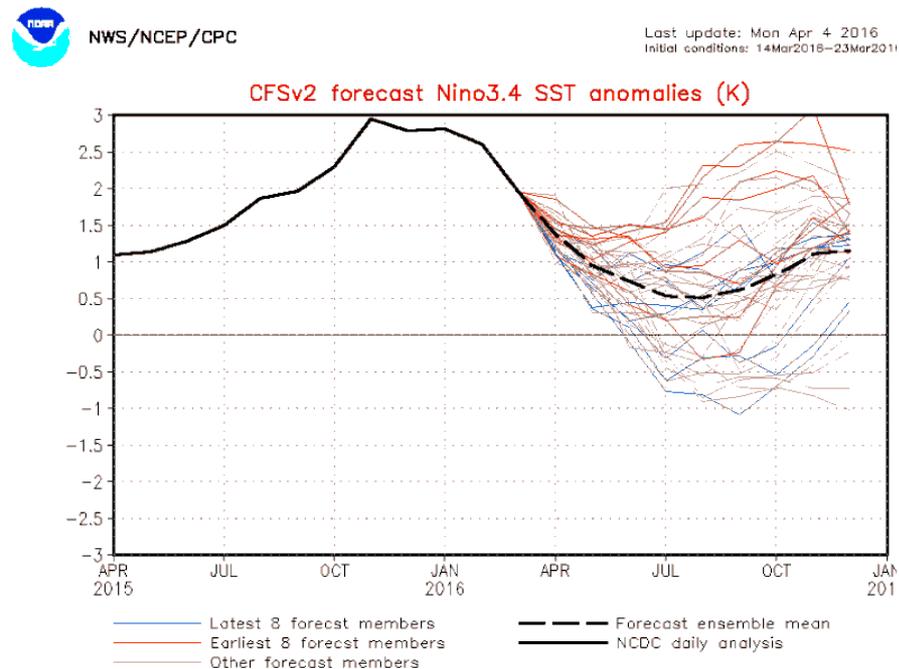


- NCEP EMC implemented a fix to the CFSv2 operations on Mar 29, 2016 to address a large erroneous cold bias in the equatorial and South Atlantic Ocean temperatures.
- CFSv2 was re-initialized by replacing the ocean initial states with those from an off-line GODAS.

(<http://cfs.ncep.noaa.gov/cfsv2/news.html>)

Before Mar 29

After Mar 29



Before Mar 29



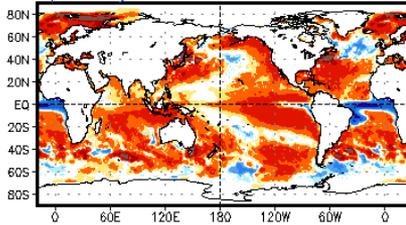
NWS/NCEP/CPC

Initial conditions: 7Mar2016–16Mar2016

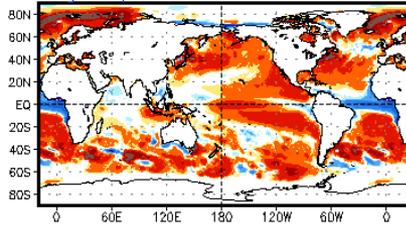
Last update: Thu Apr 7 2016

CFSv2 seasonal SST (K)

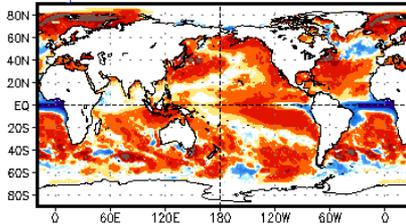
Apr-May-Jun 2016



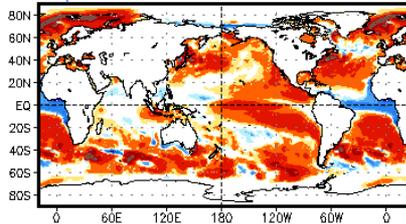
Aug-Sep-Oct 2016



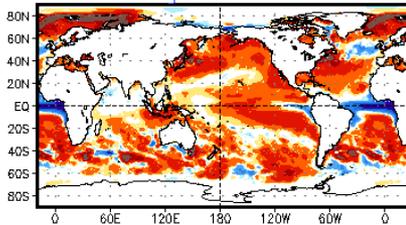
May-Jun-Jul 2016



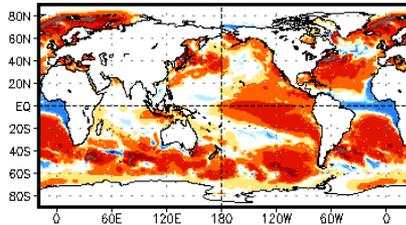
Sep-Oct-Nov 2016



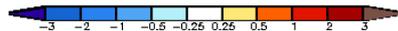
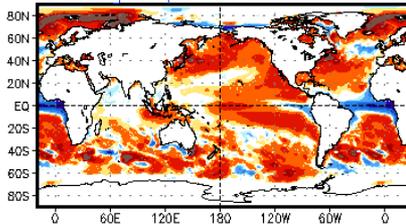
Jun-Jul-Aug 2016



Oct-Nov-Dec 2016



Jul-Aug-Sep 2016



(Model bias correction base period: 1999–2010; Climatology base period: 1982–2010)

After Mar 29



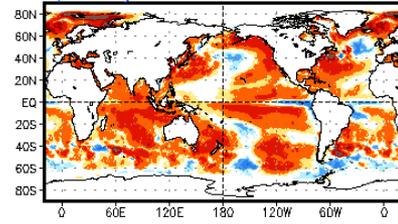
NWS/NCEP/CPC

Initial conditions: 27Mar2016–5Apr2016

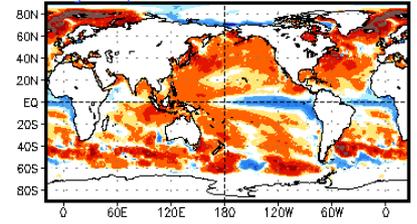
Last update: Thu Apr 7 2016

CFSv2 seasonal SST (K)

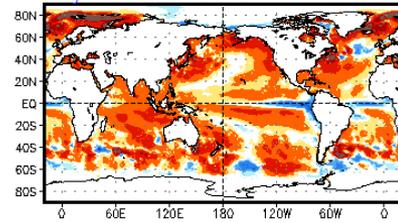
Apr-May-Jun 2016



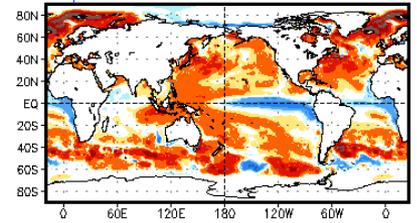
Aug-Sep-Oct 2016



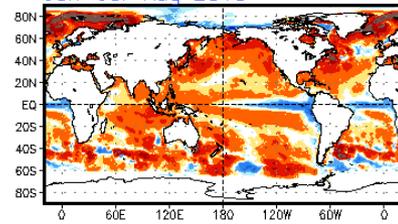
May-Jun-Jul 2016



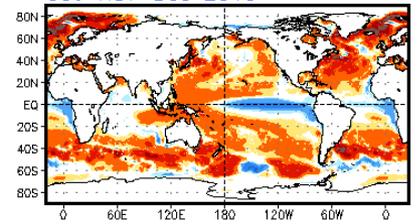
Sep-Oct-Nov 2016



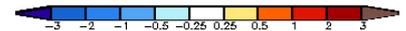
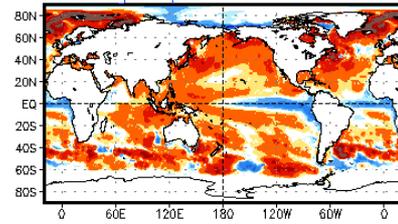
Jun-Jul-Aug 2016



Oct-Nov-Dec 2016



Jul-Aug-Sep 2016



(Model bias correction base period: 1999–2010; Climatology base period: 1982–2010)

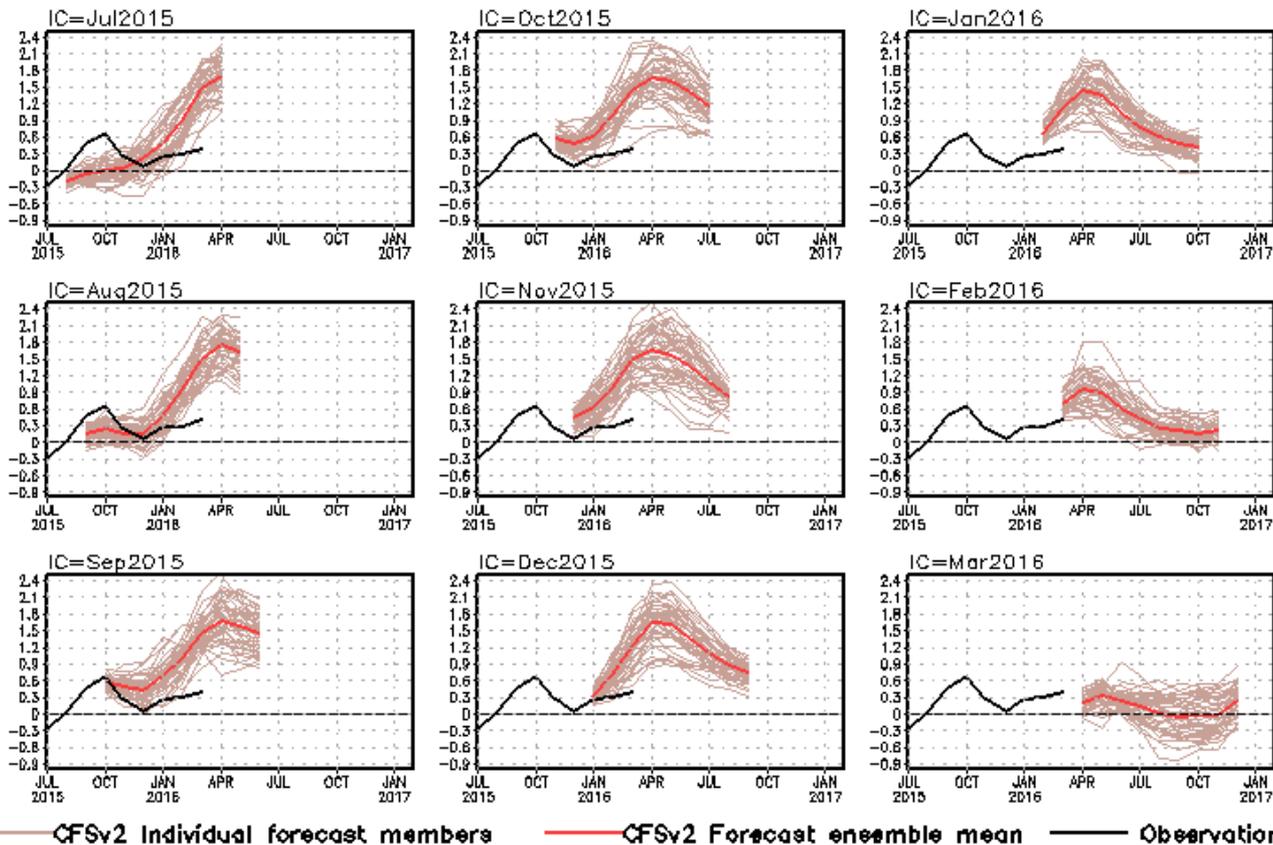
- After the fix, CFSv2 forecast was noticeably warmer in the tropical Indian Ocean, western tropical Pacific and tropical Atlantic, while colder in the central-eastern Pacific.

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].

Tropical N. Atlantic SST anomalies (K)



- Latest CFSv2 predictions suggest neutral conditions in tropical N. Atlantic in summer and autumn 2016.

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

- ❑ El Niño conditions weakened in March, but still at a strong El Niño level.
- ❑ Most model predictions suggest the El Niño will return to ENSO-neutral during late spring or early summer 2016.
- ❑ Positive phase of PDO strengthened with PDOI=2.3 in Mar 2016.
- ❑ Arctic sea ice have reached its annual maximum extent in March and is the lowest maximum in the satellite record

➤ Indian Ocean

- ❑ Positive SSTA continued to cover much of the Indian Ocean, and Dipole Mode Index was near-normal.

➤ Atlantic Ocean

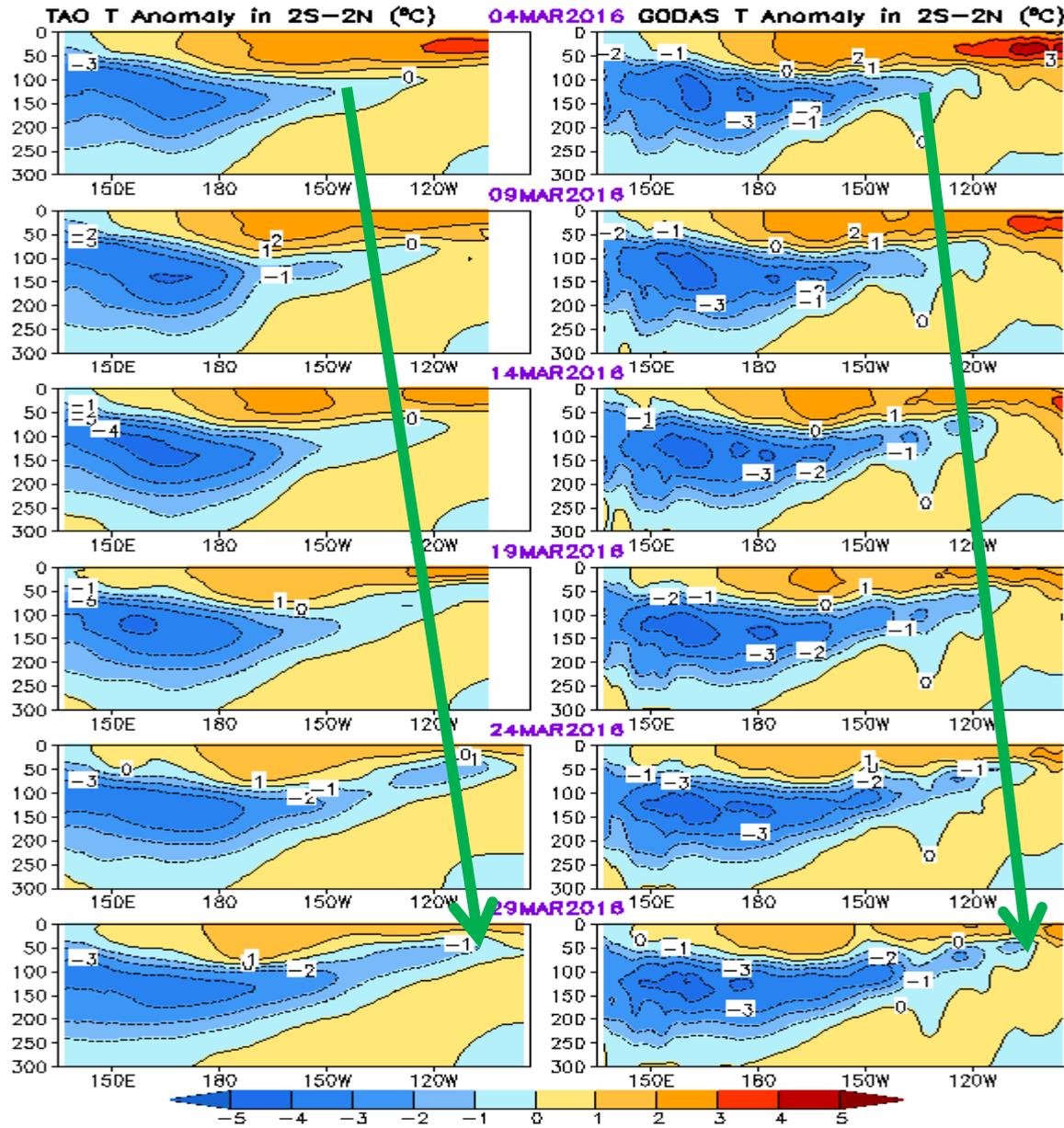
- ❑ ATL3 and Meridional Gradient indices were near-normal.
- ❑ Large uncertainty exhibited in tropical Atlantic among multiple Ocean Reanalyses.
- ❑ Positive NAO index weakened, with NAOI=1.35 in Mar 2016.

Backup Slides

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

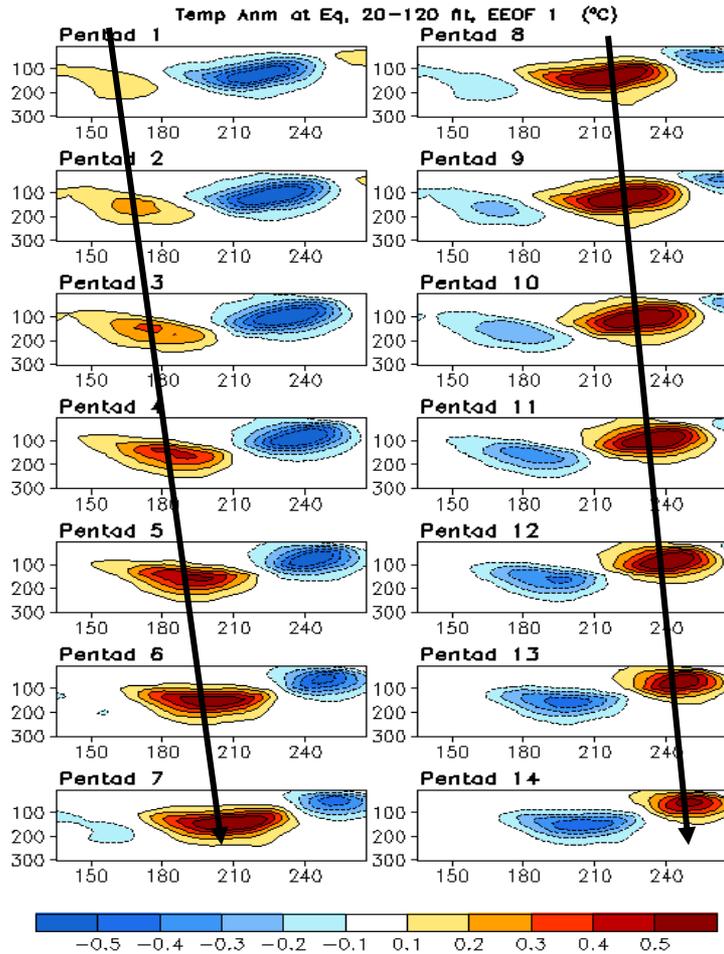
TAO

GODAS

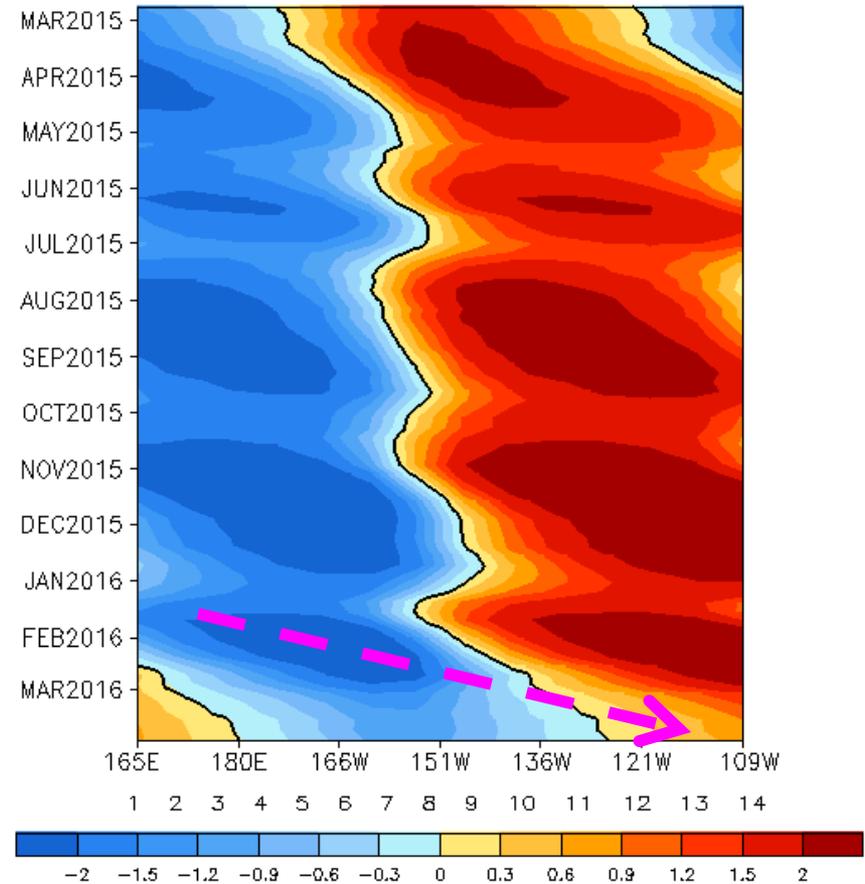


- Negative temperature anomalies near the thermocline gradually extended to 110°W at the end of March.
- Positive temperature anomalies were confined to the upper 50m and decreased slowly with time.

Oceanic Kelvin Wave (OKW) Index



Standardized Projection on EEOF 1



- A upwelling OKW (dashed line) was initiated in the western Pacific since Jan. 2016 and then reached the far eastern Pacific in March. The upwelling contributed to the observed eastward propagation of subsurface cooling.

- (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 (Wyrтки 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 rapidly discharged since Nov 2015.

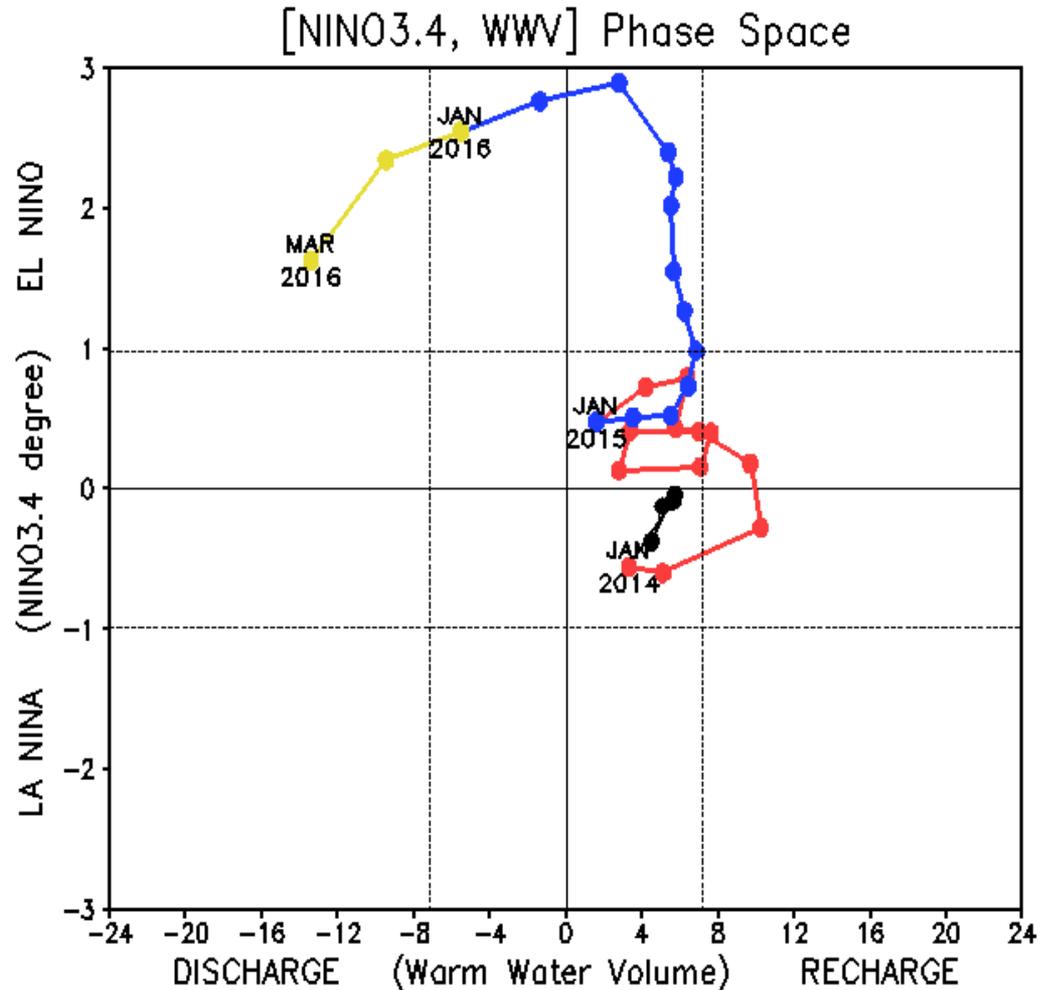
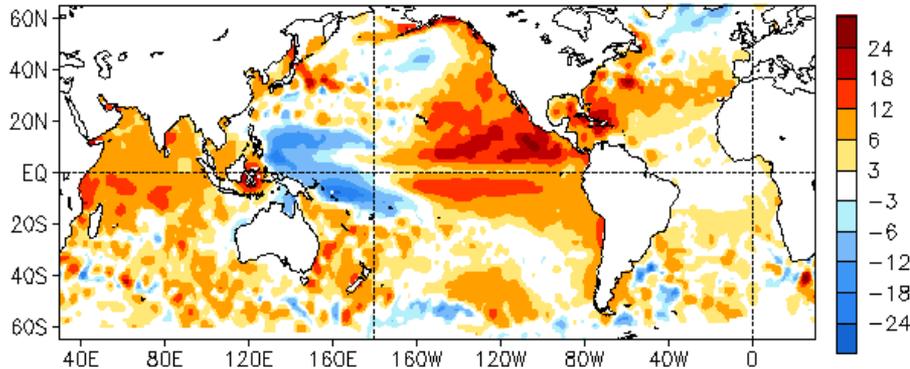


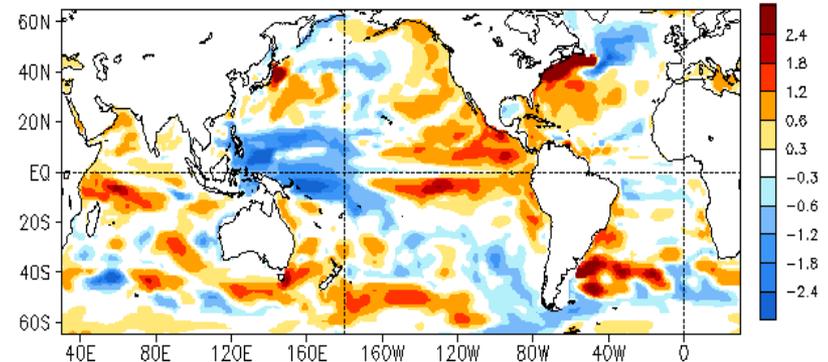
Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

Global SSH and HC300 Anomaly & Anomaly Tendency

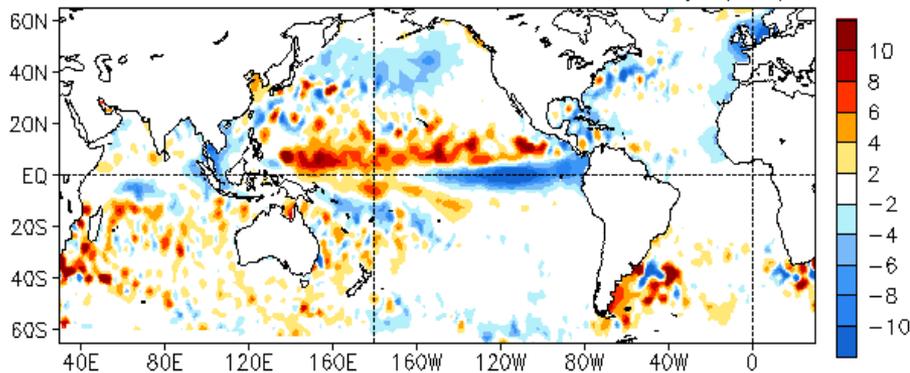
MAR 2016 SSH Anomaly (cm)
(AVISO Altimetry, Climo. 93-13)



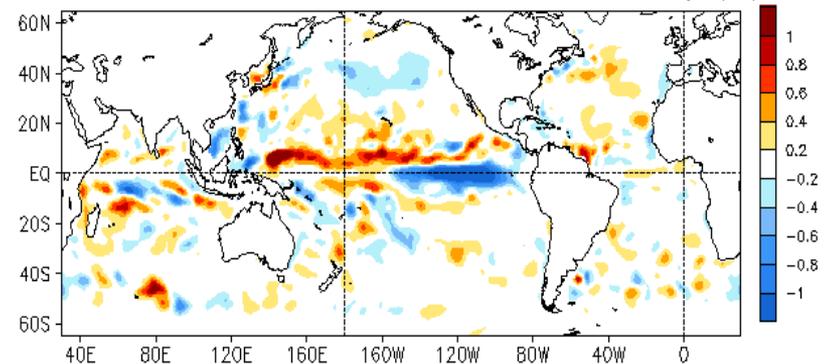
MAR 2016 Heat Content Anomaly (°C)
(GODAS, Climo. 81-10)



MAR 2016 - FEB 2016 SSH Anomaly (cm)

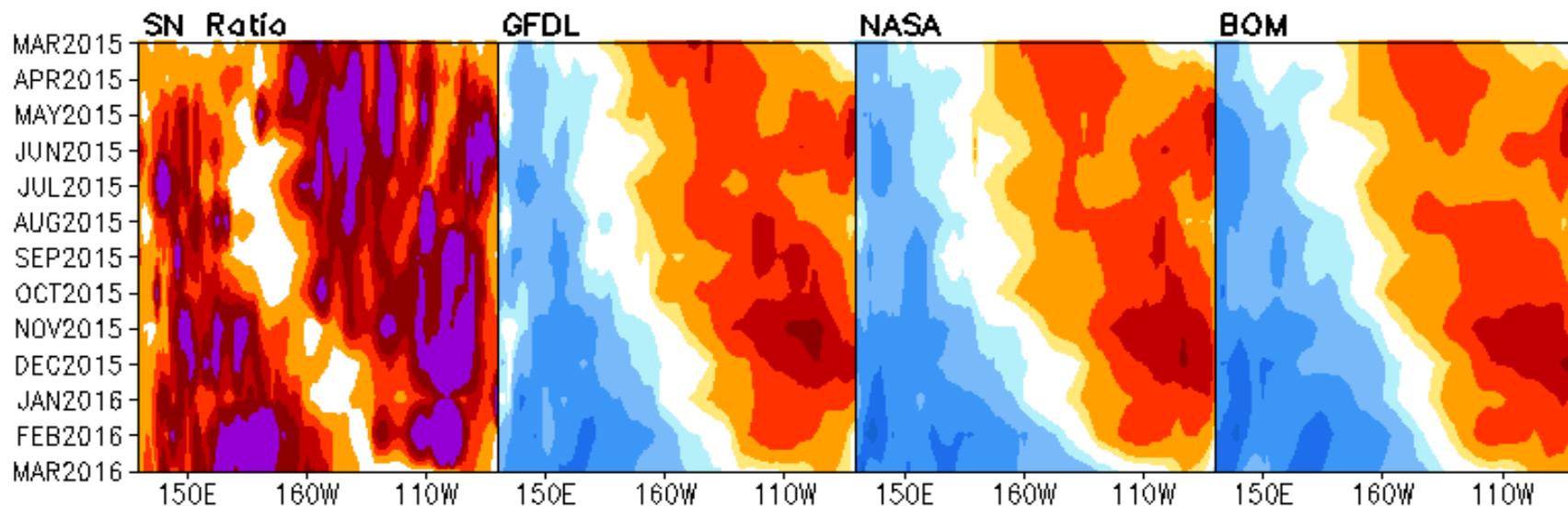
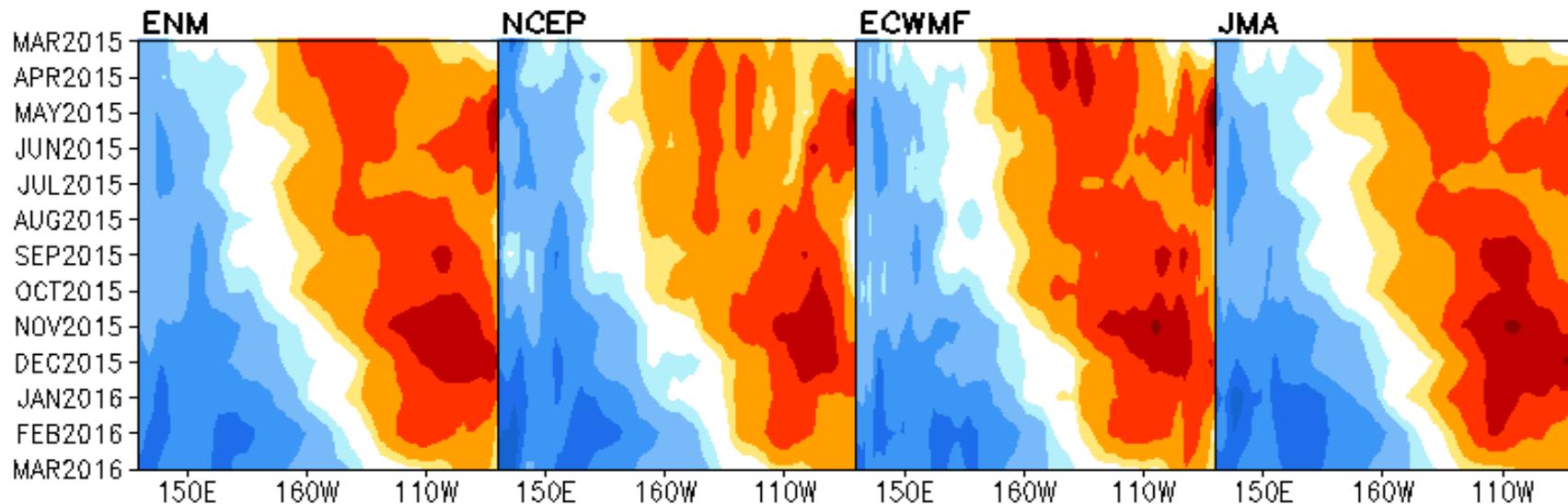


MAR 2016 - FEB 2016 Heat Content Anomaly (°C)



- The SSHA was overall consistent with HC300A: Positive (negative) HC300A is tied up with positive (negative) SSHA.
- Positive SSHA(HC300A) decreased substantially in equatorial eastern Pacific.
- Negative tendencies of SSHA and HC300A presented in the eastern equatorial Pacific, indicating a decay tendency of El Nino.

Depth of 20C Isotherm Anomaly Averaged in 5S-5N (m)



Global Sea Surface Salinity (SSS)

Anomaly for Mar. 2016

- 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!

- The El Nino condition continues in this month producing positive precipitation anomaly over the eastern and central tropical Pacific Ocean and negative anomaly in the western tropical Pacific Ocean. The enhanced flux water flux maintains the fresh SSS anomaly across most of the tropical Pacific. Positive precipitation anomaly in the central South Indian Ocean likely causes the SSS fresher in the region.

- Data used**

- SSS :**

- Blended Analysis of Surface Salinity (BASS) V0.Y**
(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
(Xie et al. 2014)

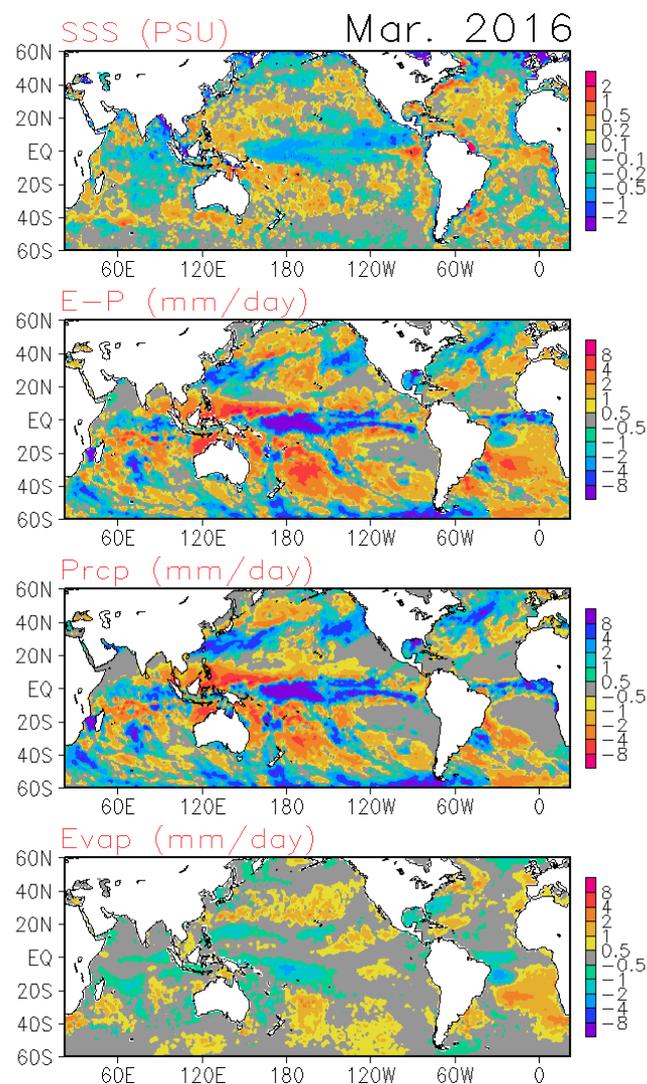
- <ftp.cpc.ncep.noaa.gov/precip/BASS>

- Precipitation:**

- CMORPH adjusted satellite precipitation estimates

- Evaporation:**

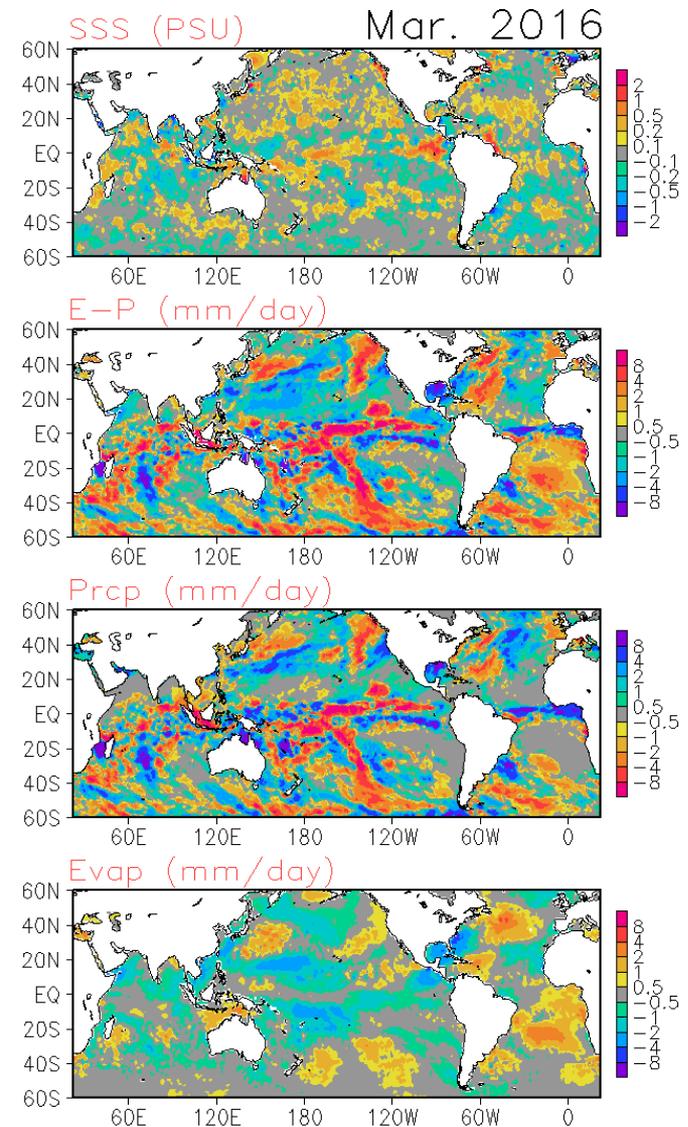
- CFS Reanalysis



Global Sea Surface Salinity (SSS)

Tendency for Mar. 2016

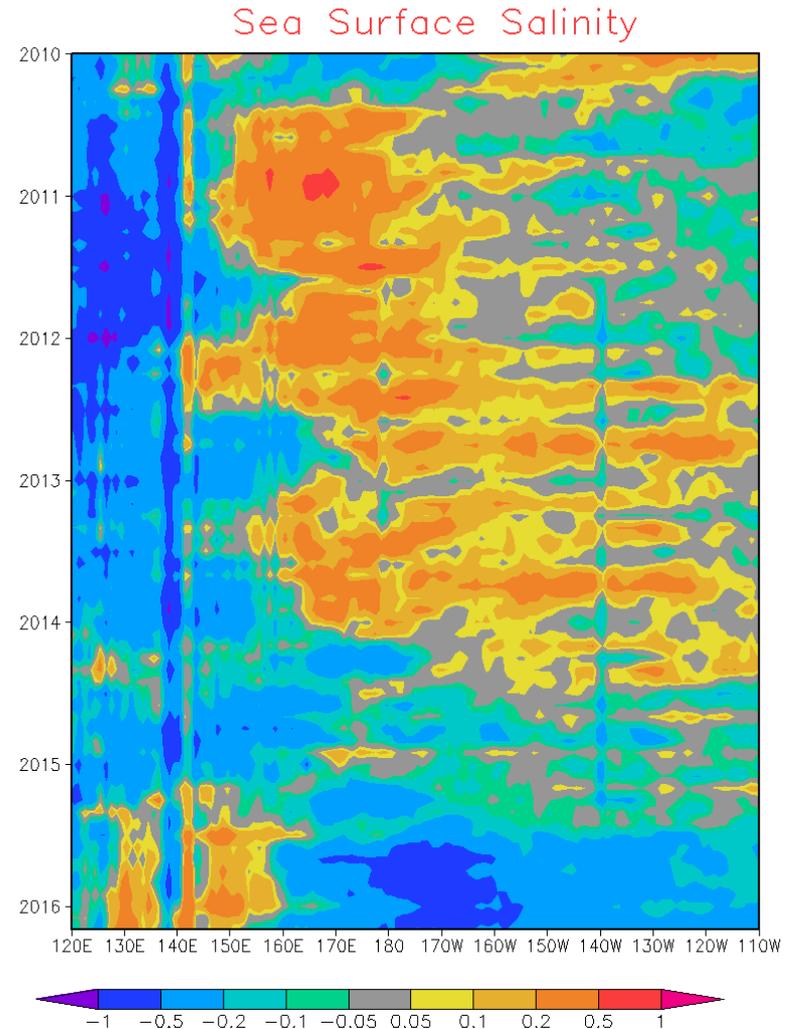
- Compared with last month, positive SSS anomalies appear in the central and eastern equatorial Pacific Ocean due to less enhanced precipitation, which likely indicates the weakening of the El Niño. SSS becomes fresher in the central South Indian Ocean (20°S to 40°S), which is likely caused by positive precipitation anomalies in this region. Negative SSS was also observed in the equatorial Atlantic Ocean being accompanied with enhanced precipitation.



Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific

- Hovemoller diagram for equatorial SSS anomaly (**10°S-10°N**);
- Negative SSS anomaly continues over the central and eastern Pacific, with the center of the maximum SSS anomaly moving slightly westward. The longitude position of the maximum fresh SSS anomaly moved to 170°W in this month. At the meantime, a stretch of positive SSS anomaly remains over the western Pacific and eastern Indian Ocean from 130°E – 160°E;



CFS Niño3.4 SST Predictions from Different Initial Months

NINO3.4 SST anomalies (K)

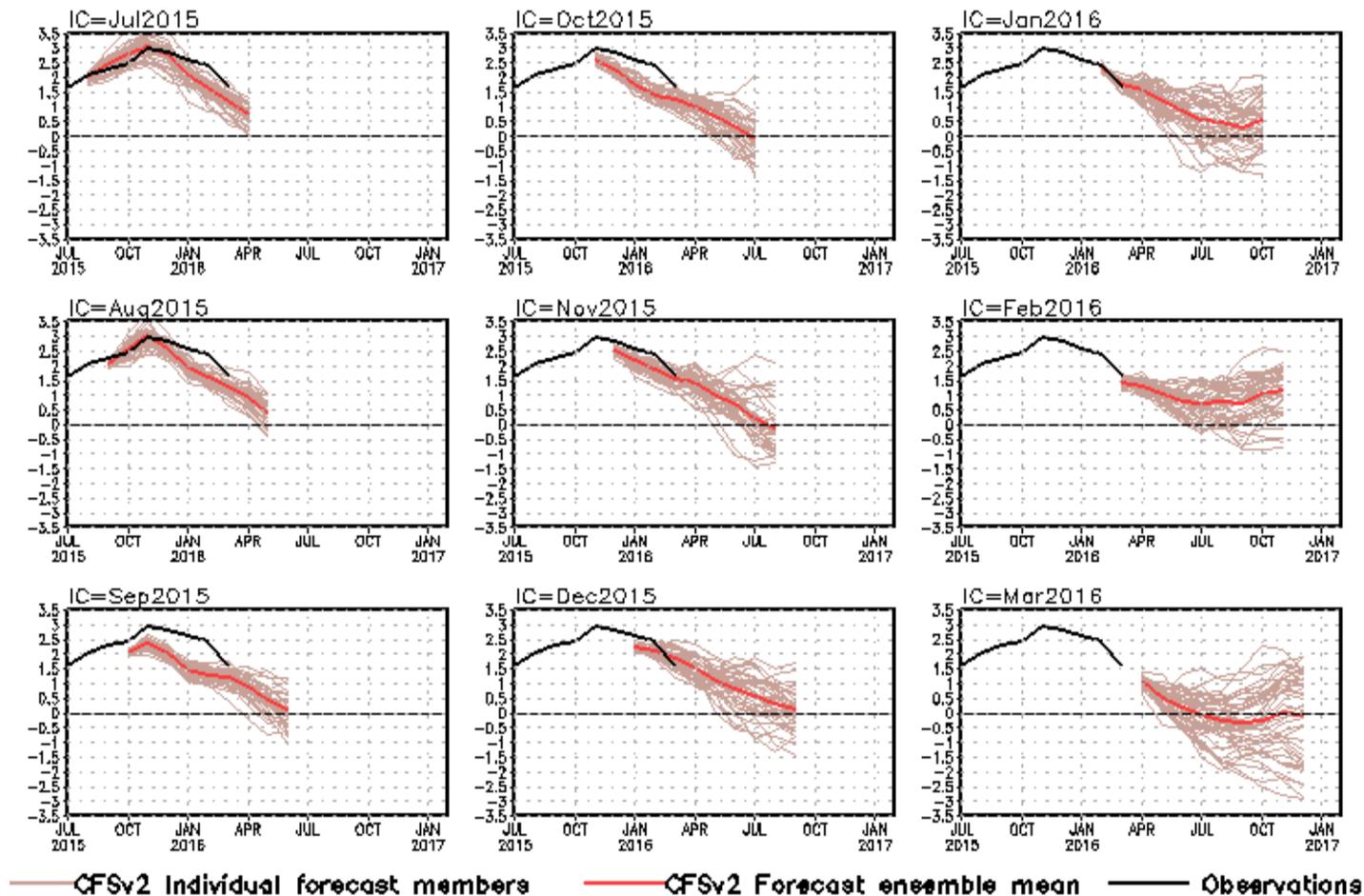
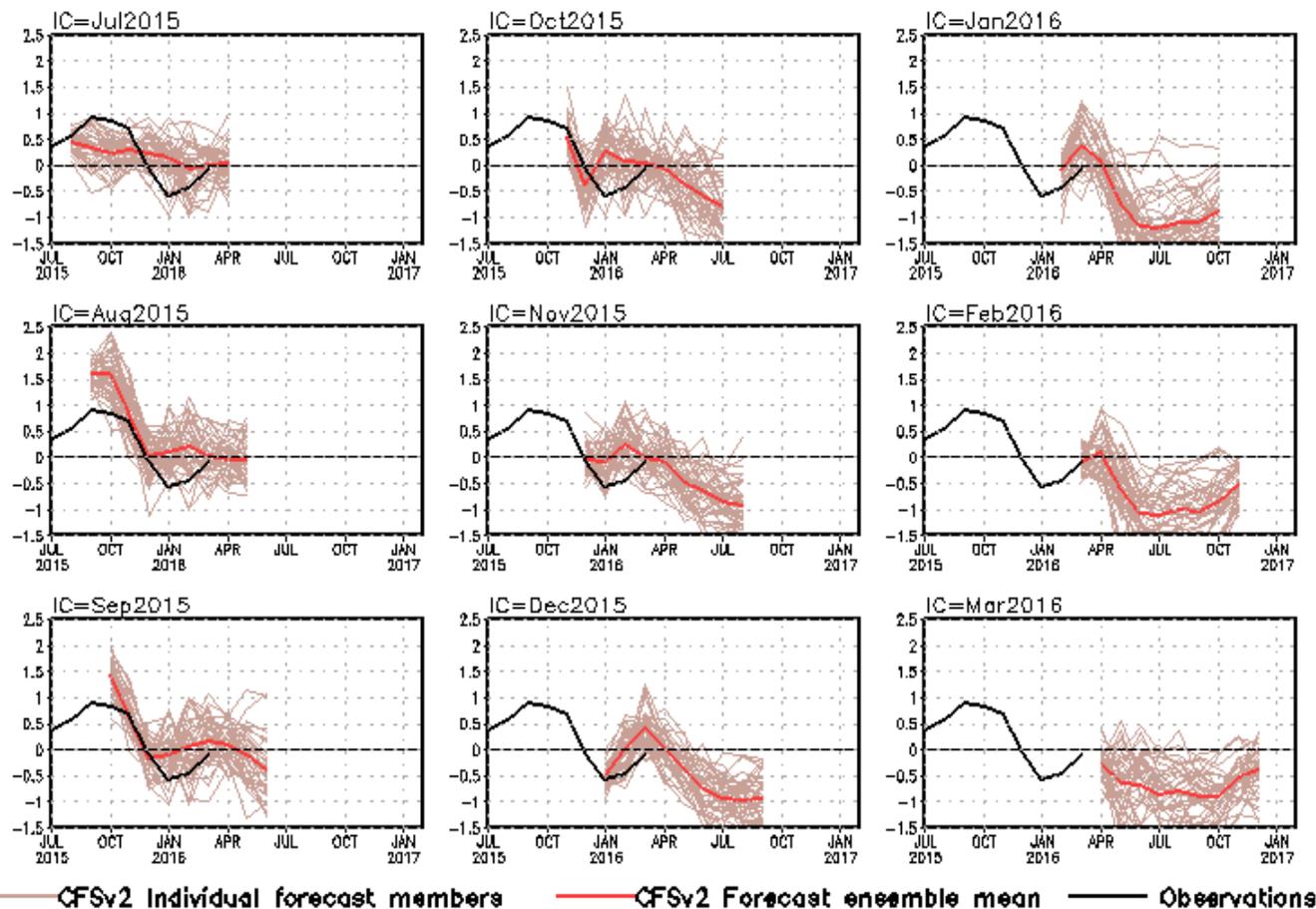


Fig. M1. CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

NCEP CFS DMI SST Predictions from Different Initial Months

Indian Ocean Dipole SST anomalies (K)



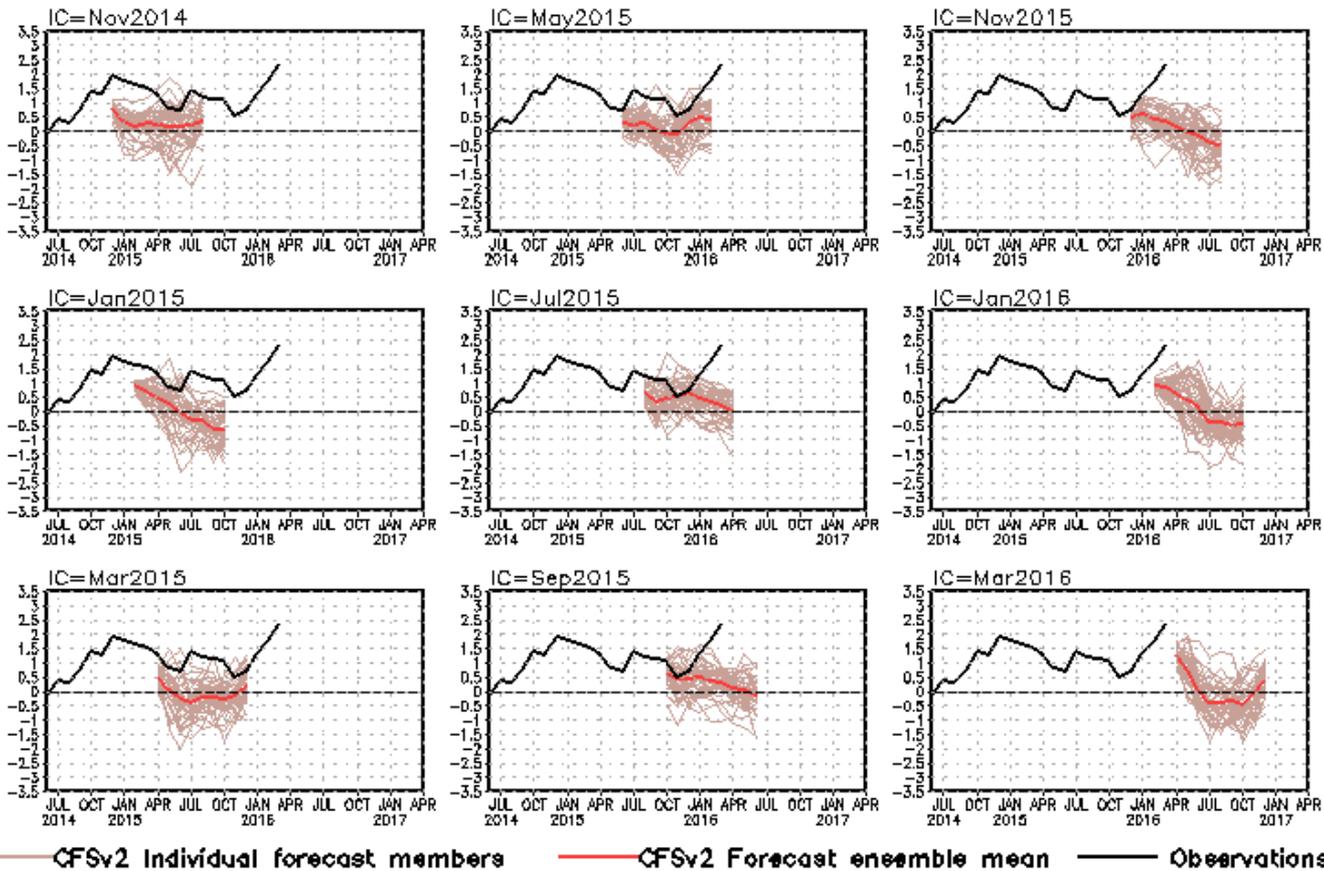
DMI = WTIO - SETIO
SETIO = SST anomaly in [90°E-110°E, 10°S-0]
WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]

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.

CFS Pacific Decadal Oscillation (PDO) Index Predictions

from Different Initial Months

standardized PDO index



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 downward tendency of PDO, and neutral phase since summer 2016.

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.

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

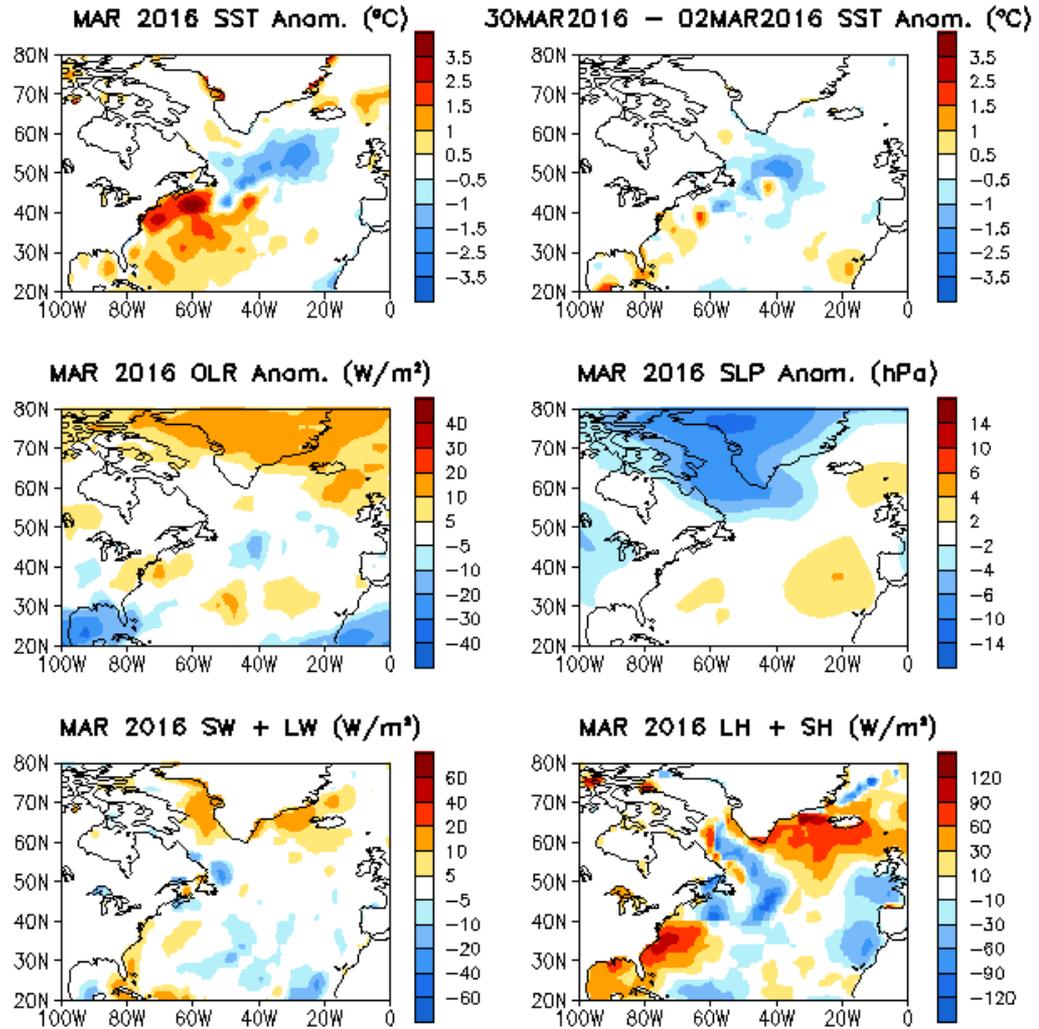


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

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!