2016 Annual Ocean Review

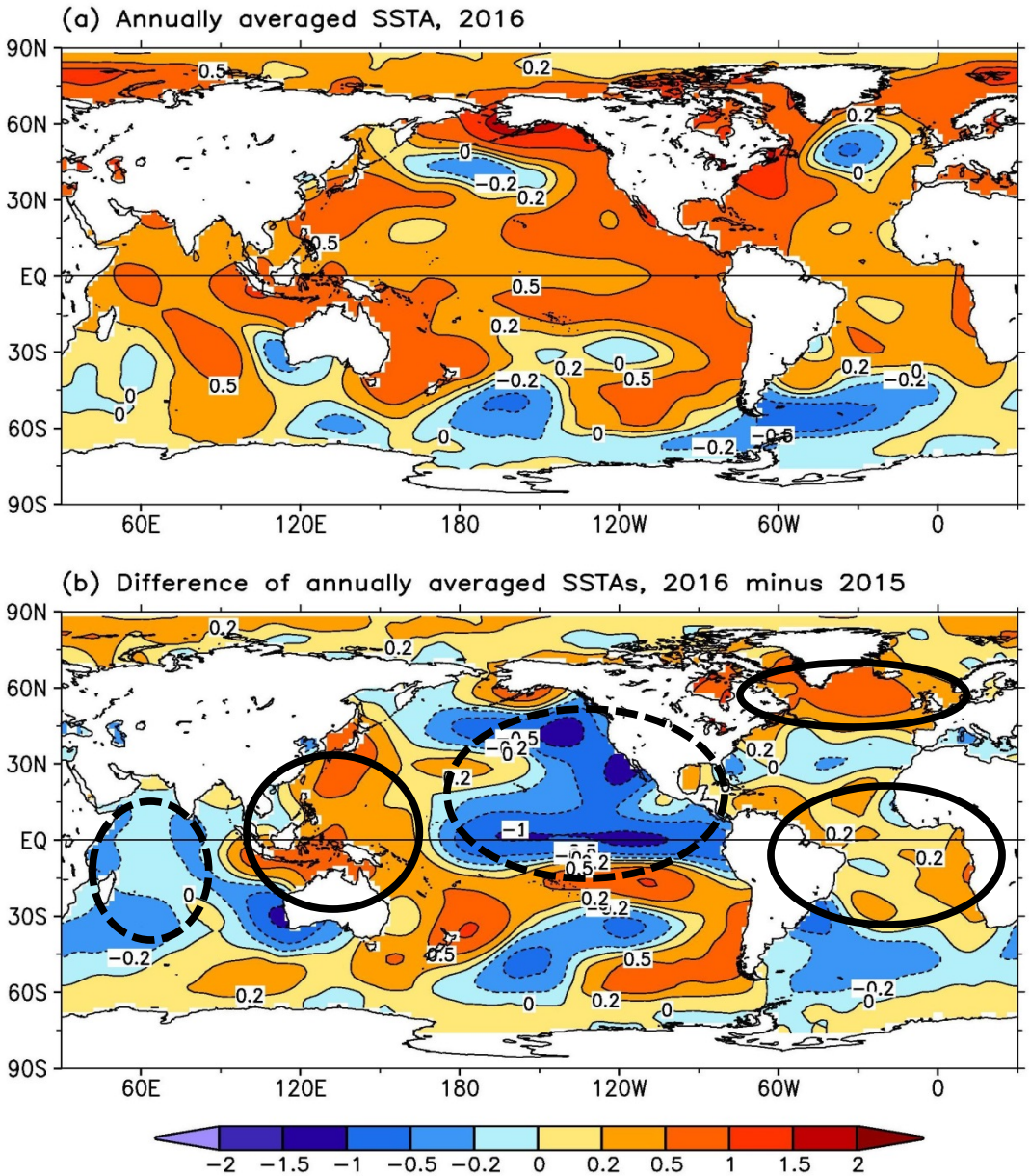
Prepared by
Climate Prediction Center, NCEP/NOAA

February 9, 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 NOAA Ocean Climate Observation Program (OCO)

2016 Yearly Mean SST Anomaly and Tendency



Global SST Section in the BAMS State of the Climate in 2016 by Huang et al.

- **Positive SSTA dominated in the global ocean with maximum warming over Maritime Continents, eastern subtropical Pacific, Western Boundary Current regions and Gulf of Alaska.**
- **Negative SSTA presented in central N. Pacific, south of Greenland, and high-latitude Southern Oceans.**
- **SST tendency was dominated by a cooling in the C.-E. tropical Pacific that extended to near the west coast of N. America and central North Pacific, consistent with the transition from El Nino to La Nina conditions.**
- **The cooling (warming) tendency in the tropical Indian Ocean (over Maritime Continents) was associated with the influences of the ENSO transition.**
- **There was a substantial warming in the subpolar N. Atlantic and a weak warming in the tropical Atlantic.**

Fig. 3.1. (a) Yearly mean ERSSTv4 anomaly (°C, relative to 1981-2010 average) in 2016, (b) 2016 minus 2015 ERSSTv4 anomaly.

Seasonal Mean SST Anomaly in 2016

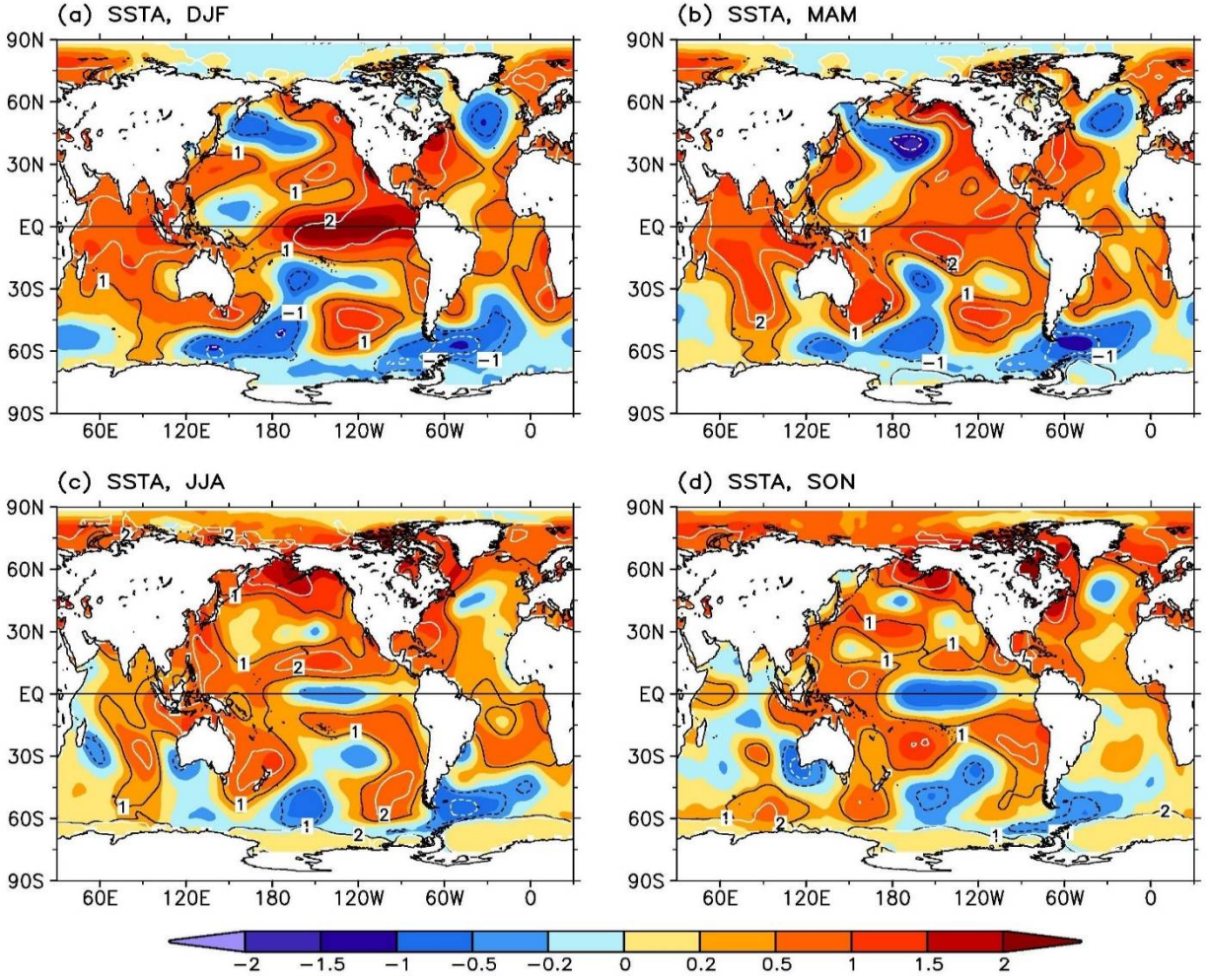


Fig. 3.2. Seasonal mean SSTA from ERSSTv4 (shading, ºC, relative to 1981-2010 average) for (a) December 2015 to February 2016, (b) March to May 2016, (c) June to August 2016 and (d) September to November 2016. The normalized seasonal mean SSTA based on seasonal mean standard deviation (STD) over 1981-2010 are indicated by contours of -2 (dashed white), -1 (dashed black), 1 (solid black), and 2 (solid white).

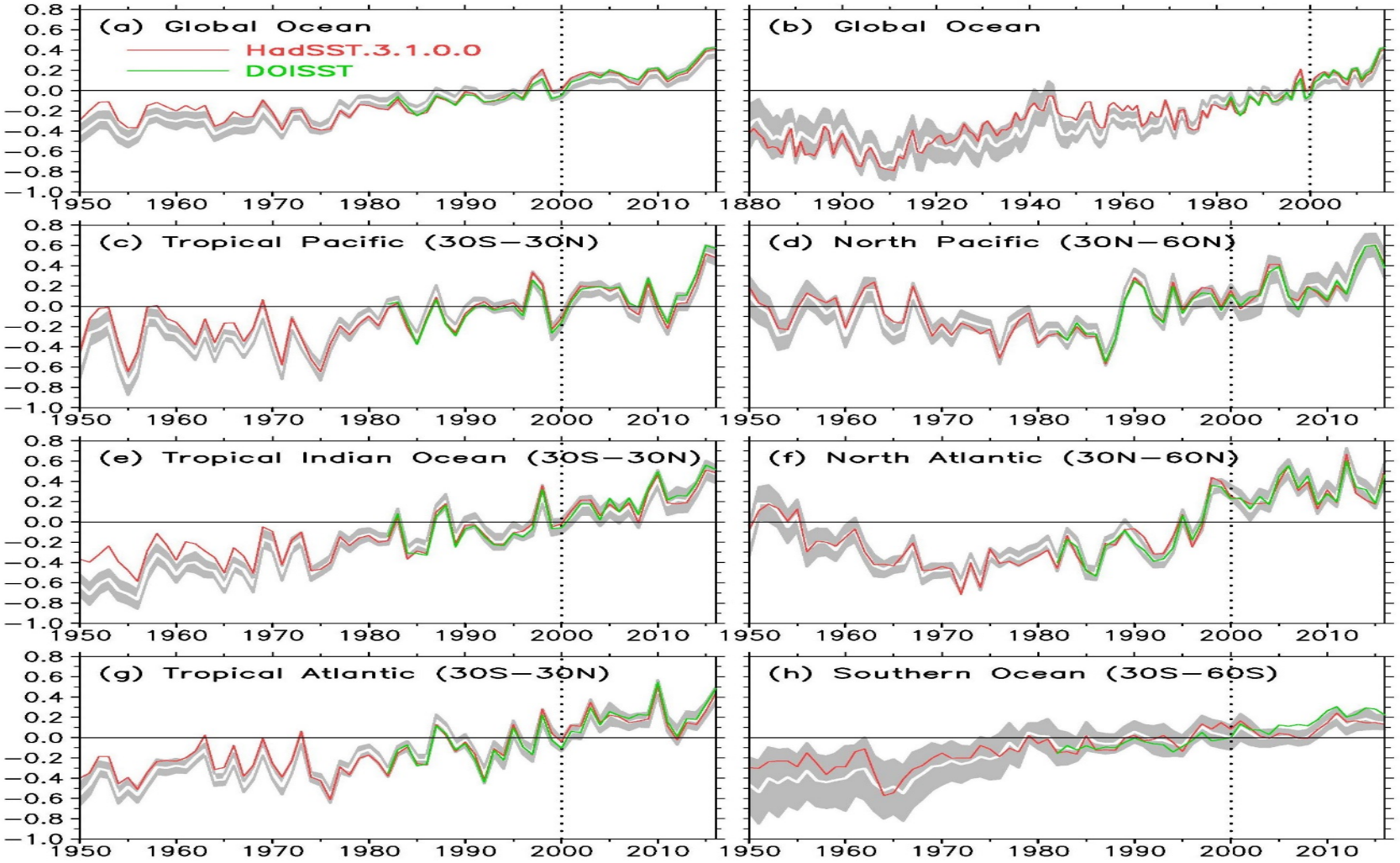
Global SST Section in the BAMS State of the Climate in 2016 by Huang et al.

- **Winter 2015/2016: positive SSTA exceeding +2 STD presented in C.-E. tropical Pacific, tropical Indian Ocean, and near the east coast of N. America, also featured positive PDO in N. Pacific, cold blob south of Greenland.**

- **Spring 2016: Positive SSTA weakened in C.-E. Pacific, SSTA persisted over other regions.**

- **Summer/fall 2016: SSTA transitioned to negative in C.-E. equatorial Pacific, SSTA returned to neutral in the tropical Indian Ocean, negative SSTA dissipated in central N. Pacific and south of Greenland.**

Yearly Mean SST Anomaly Indices

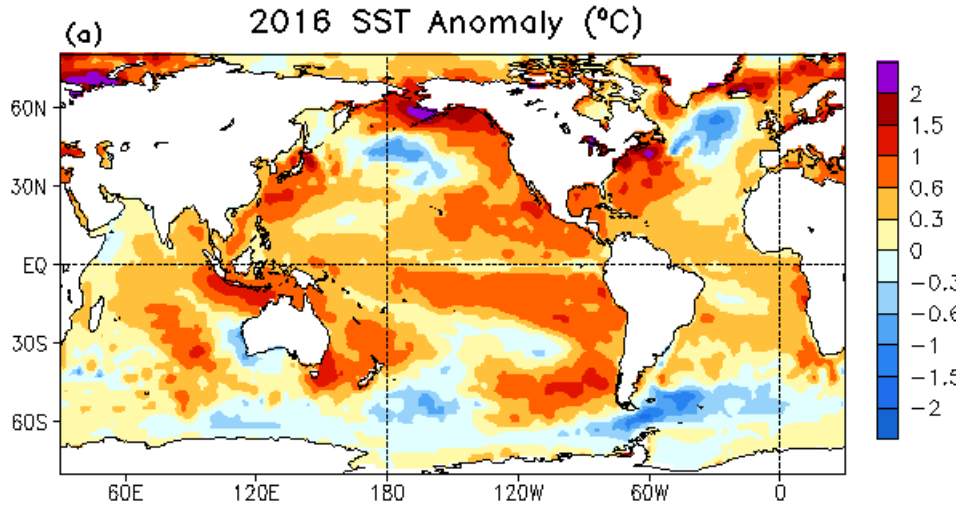


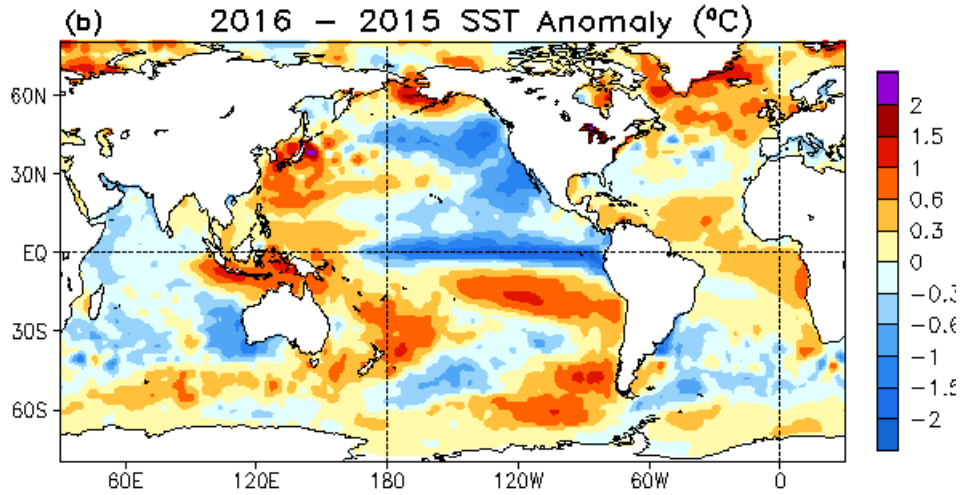
- **The ERSSTv4 is compared with daily OISST and HadSST.3.1.0.0. Differences are largely within the 2-σ STD (grey shading) of ERSSTv4.**

- **Linear trend of globally averaged SSTA based on ERSSTv4 (°C/century): 0.99±0.56 in 2000-2014; 1.36±0.71 in 2000–2015; 1.62±0.76 in 2000–2016; 1.00±0.11 in 1950–2016.**

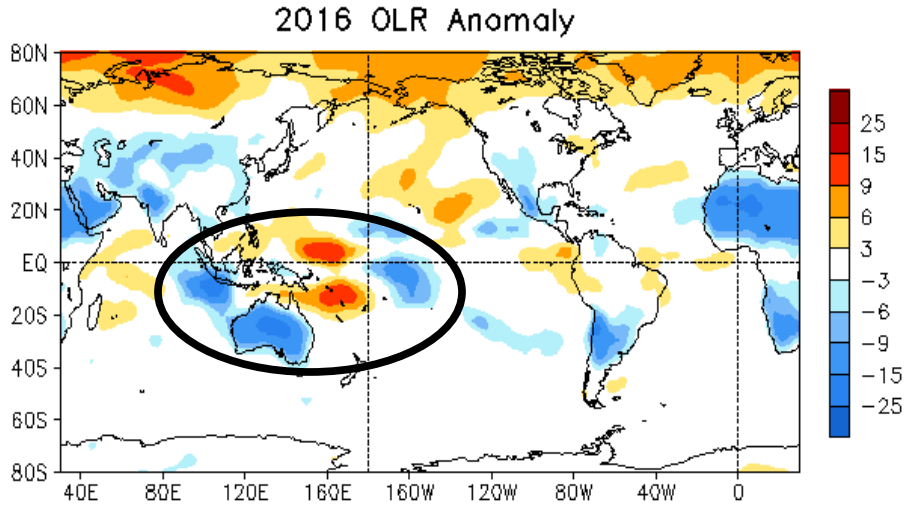
- **Largest warming trend was observed in the tropical Indian and tropical Atlantic Oceans.**

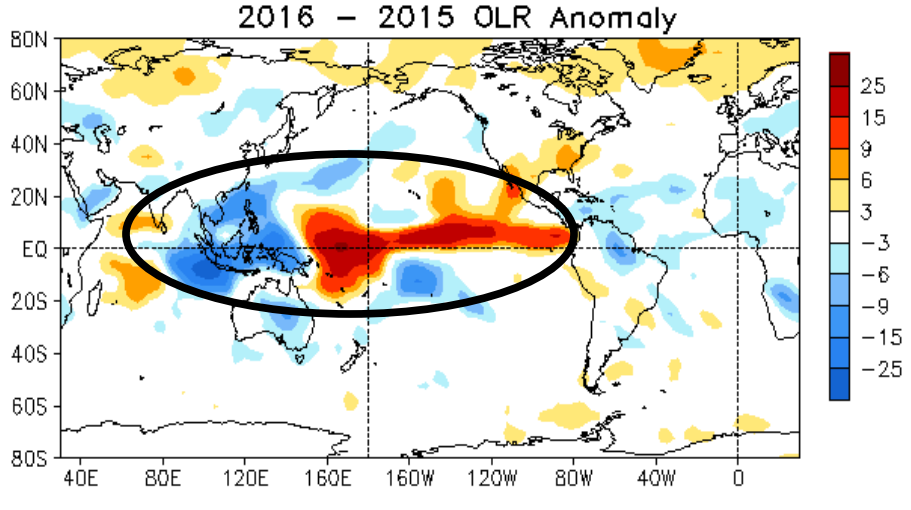
Weekly OISST





OLR

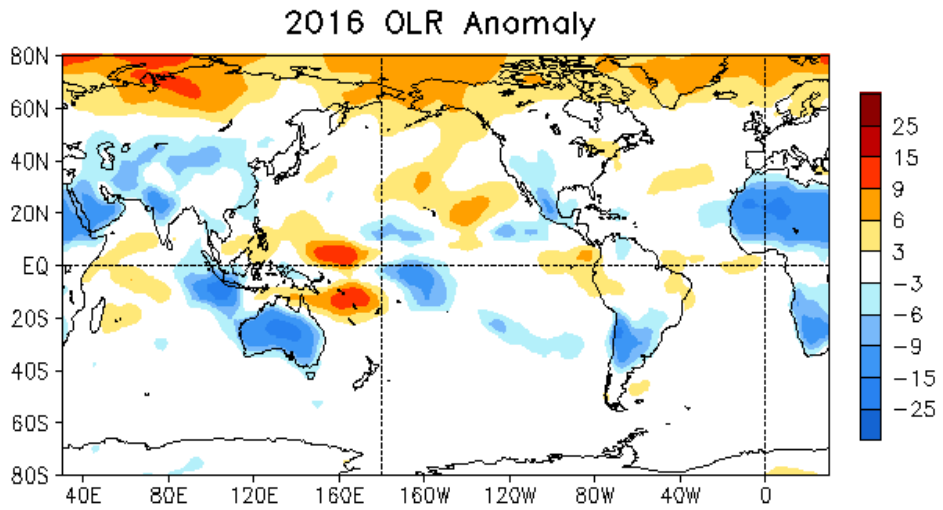


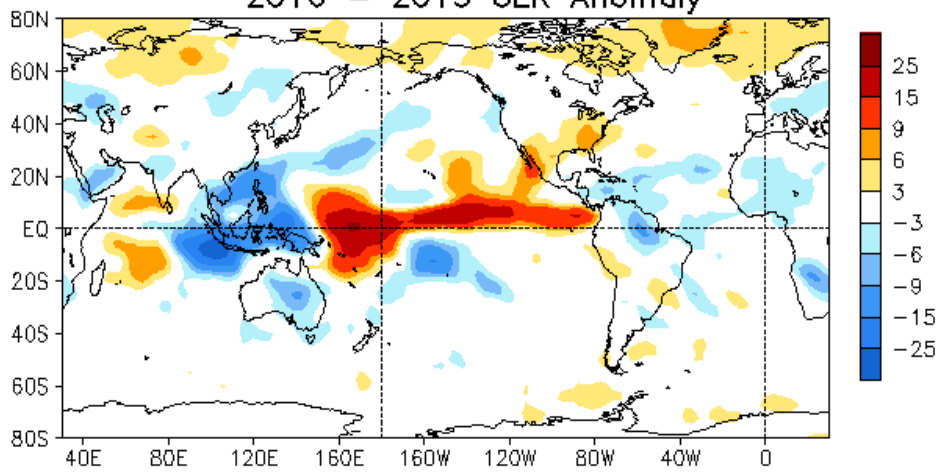


- **In 2016 the OLR anomaly pattern was characterized by a tripole pattern in the Indo-Pacific region. Convection was enhanced over North Africa and the Middle East.**

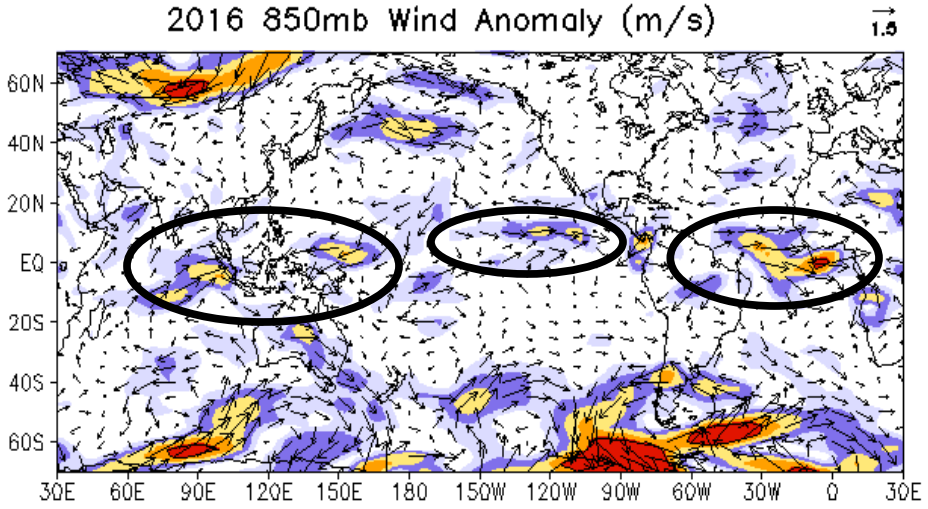
- **The 2016 minus 2015 OLR anomaly was dominated by the La Nina pattern.**

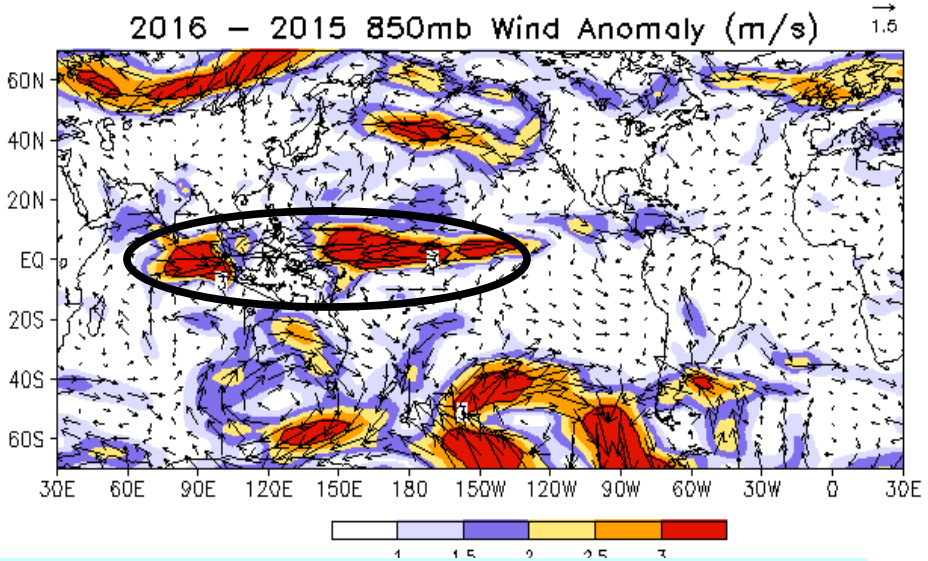
OLR





850mb Wind



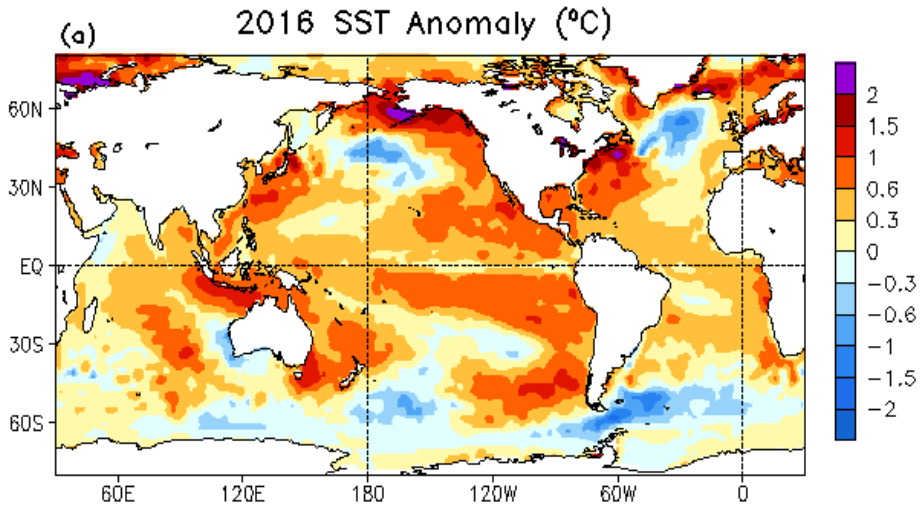


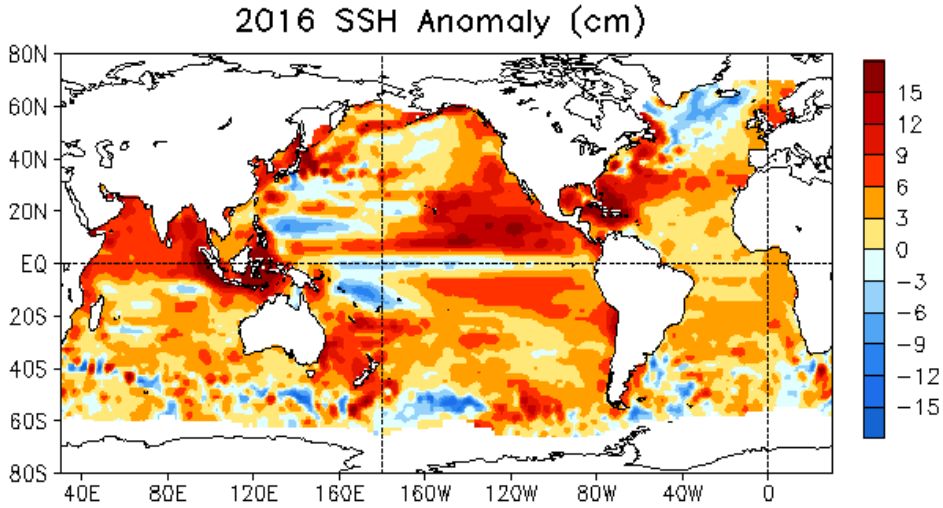
- **In 2016, convergence wind was observed over Maritime Continents and ITCZ. Low-level westerly wind anomaly presented over the eq. Atlantic consistent with enhanced convection over North Africa.**

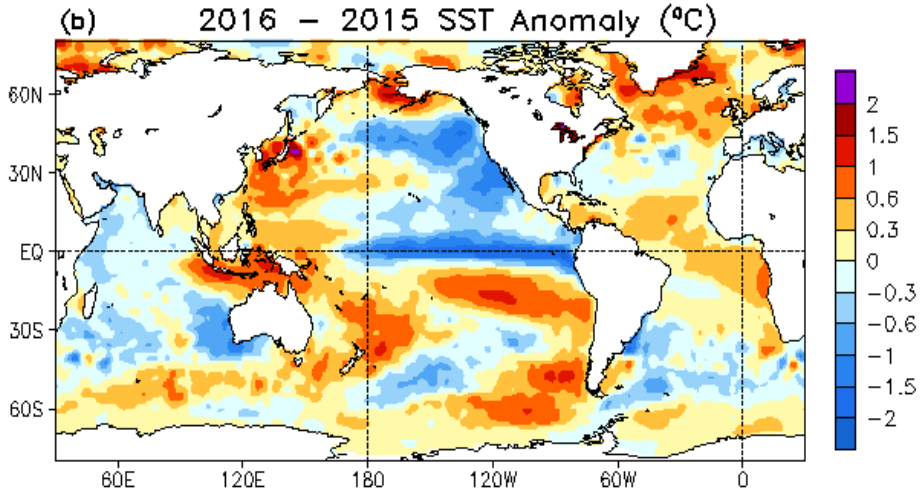
- **The 2016 minus 2015 wind anomaly showed strong convergence wind over Maritime Continents consistent with the transition from El Nino to La Nina.**

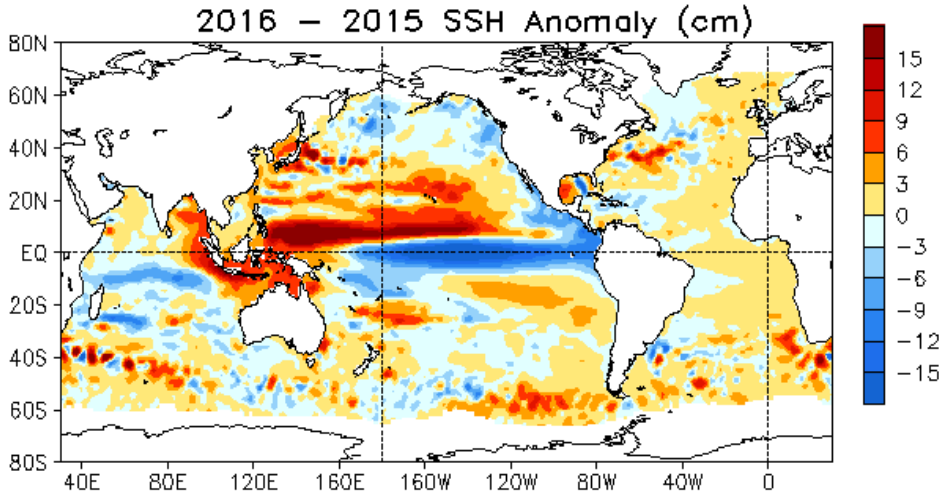
Weekly OISST (1981-2010 Clim)

AVISO SSH (1993-2013 Clim)







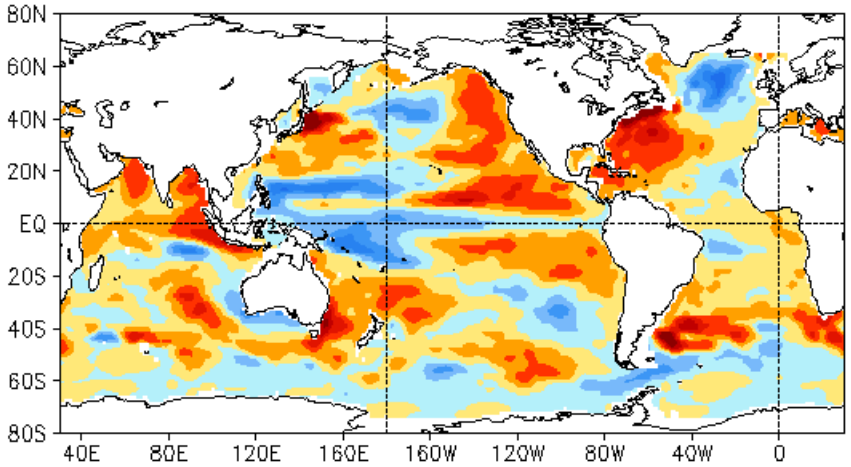


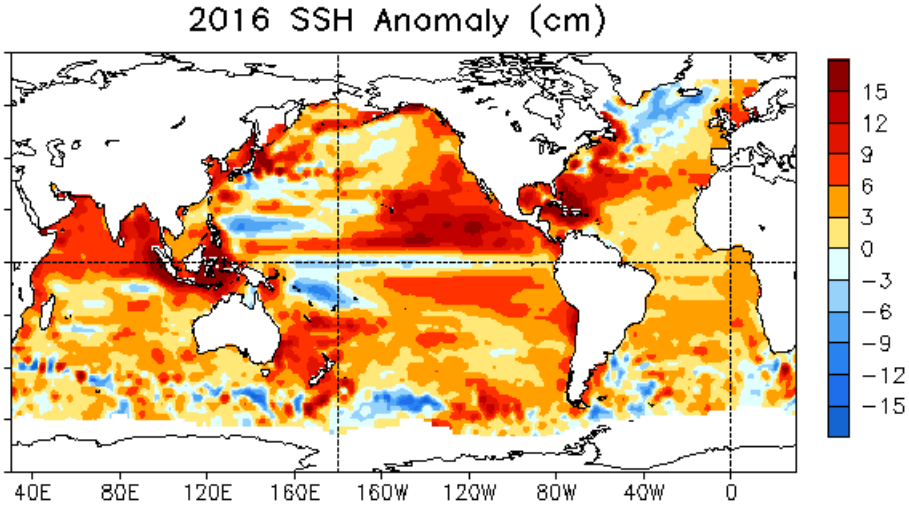
- **Pattern of SST and SSH anomalies were largely consistent despite different climatology periods.**

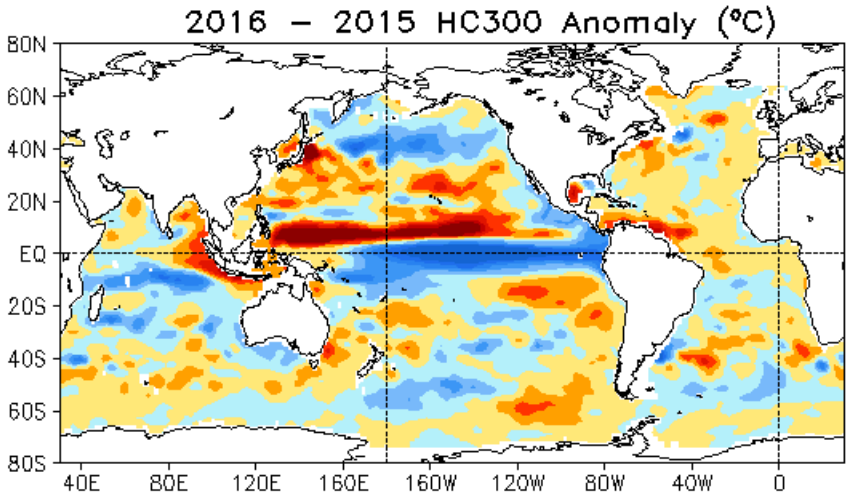
- **The tendency of SST and SSH anomalies were largely consistent except in subtropical North Pacific and mid-high latitude North Pacific.**

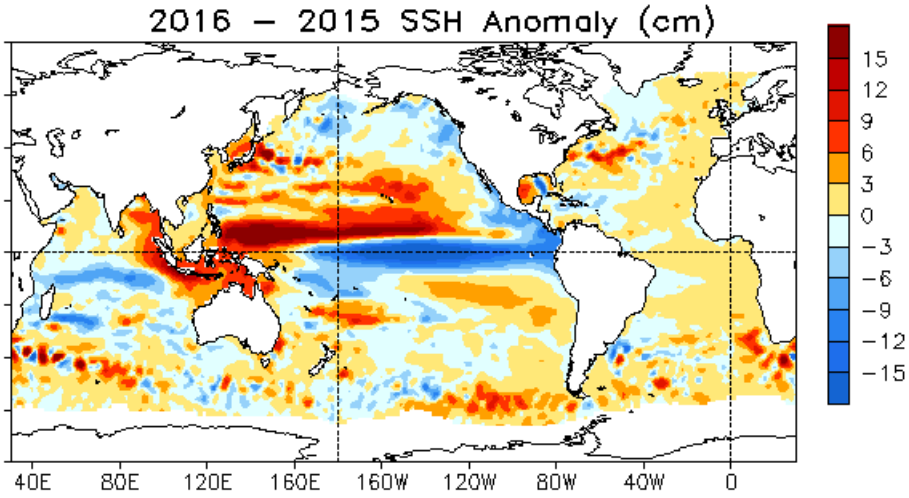
Ensemble Mean HC300

AVISO SSH





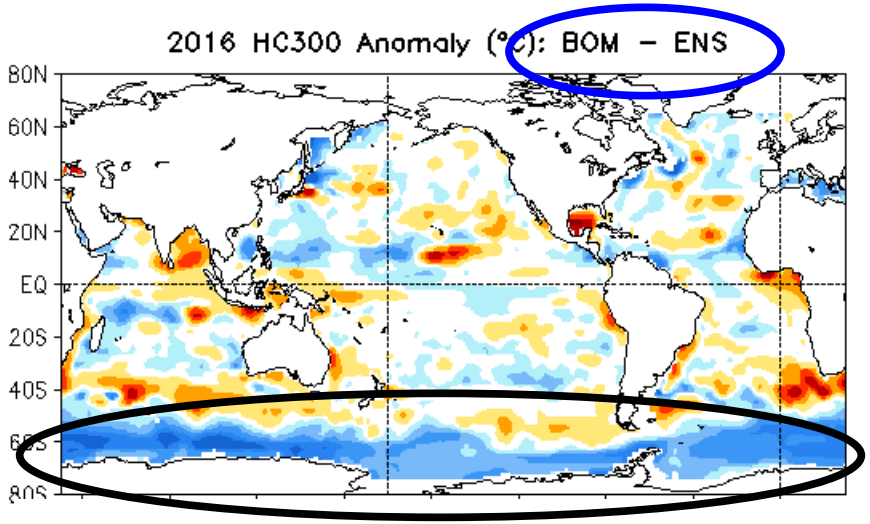


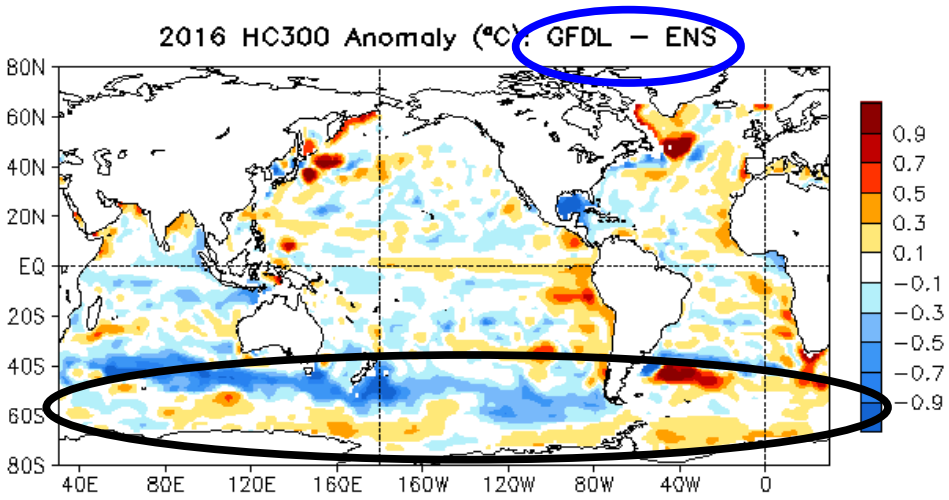


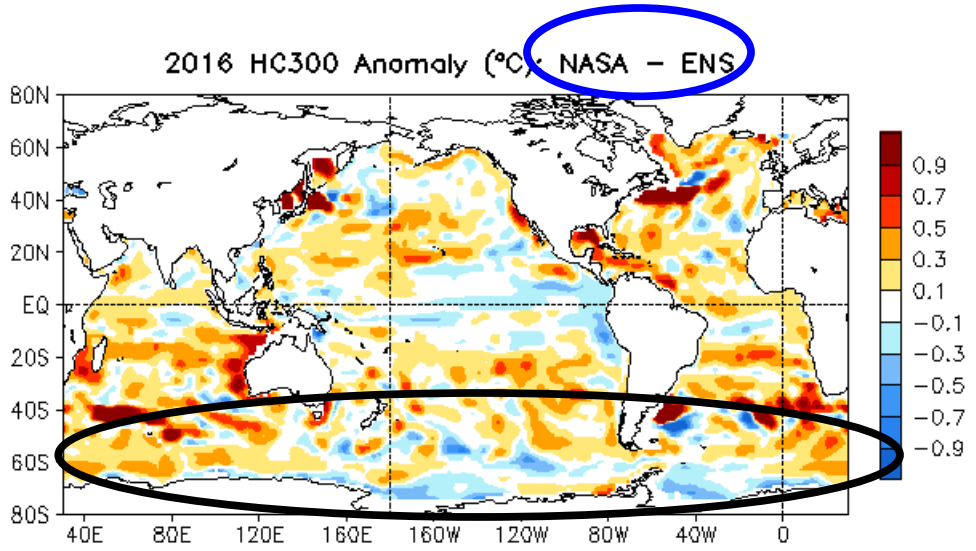
- **Pattern of HC300 (upper 300m temperature average) and SSH anomalies were largely consistent except some notable differences in the tropical Indian Ocean, western tropical Pacific and tropical Atlantic.**

- **The tendency of HC300 and SSH anomalies were largely consistent.**

Uncertainties in HC300 Anomalies







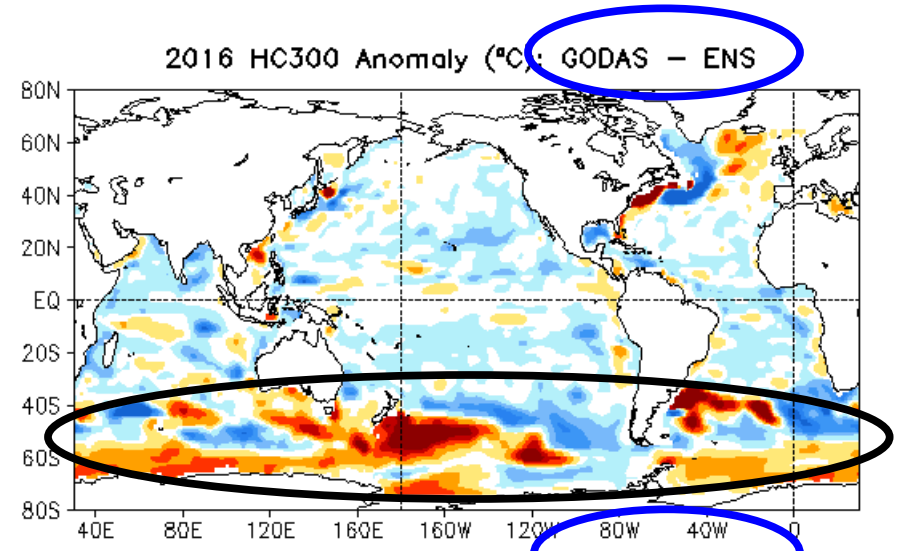
Real-time Ocean Reanalysis Intercomparison Project

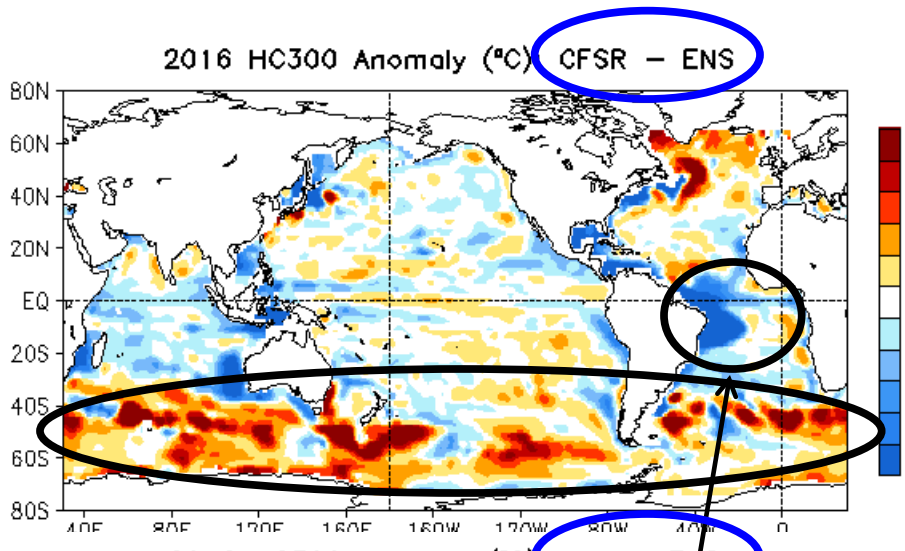
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)

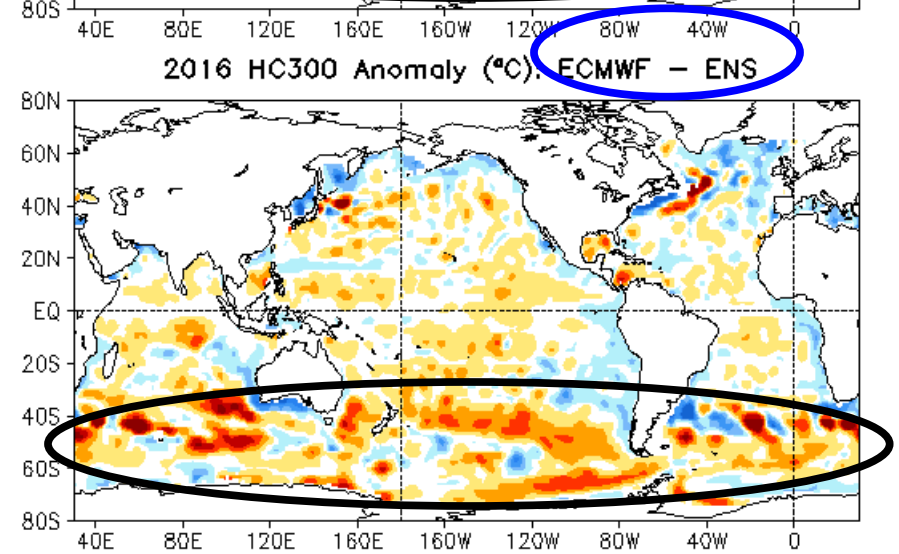
Xue et al. 2017 (see http://rdcu.be/o4wO)

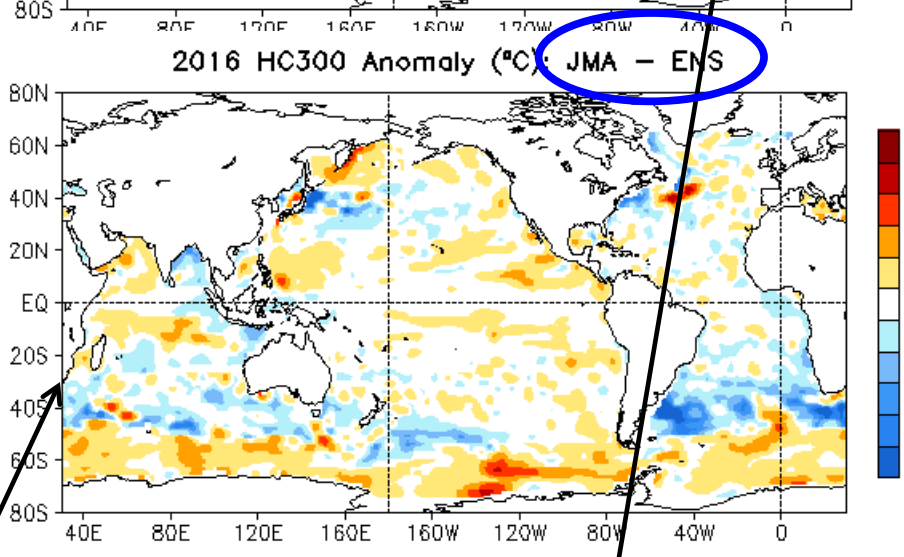
- **Uncertainties among HC300 analyses are high south of 40S.**
- **Departure from the ensemble mean is the largest in the NASA analysis.**

Differences of Individual Product from Ensemble Mean





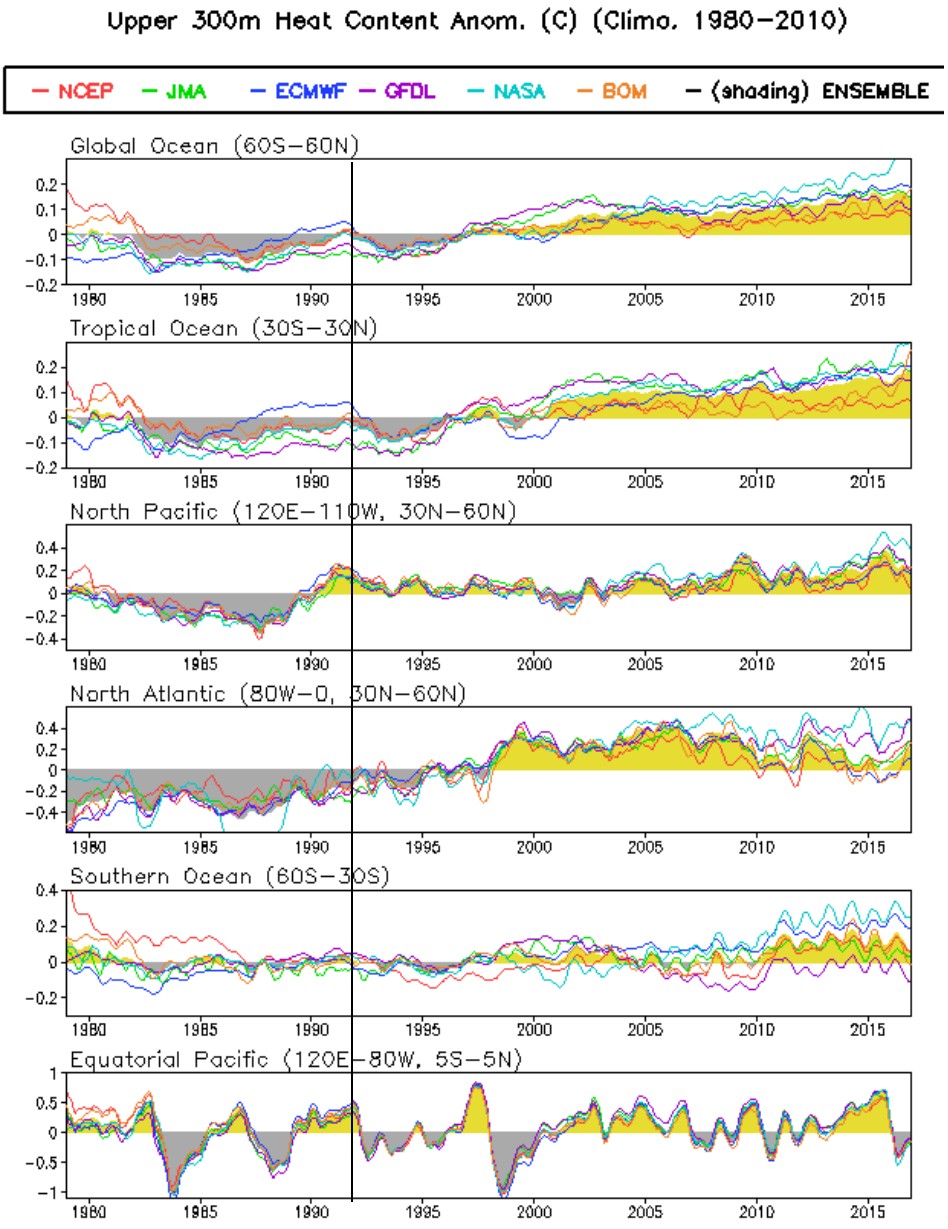


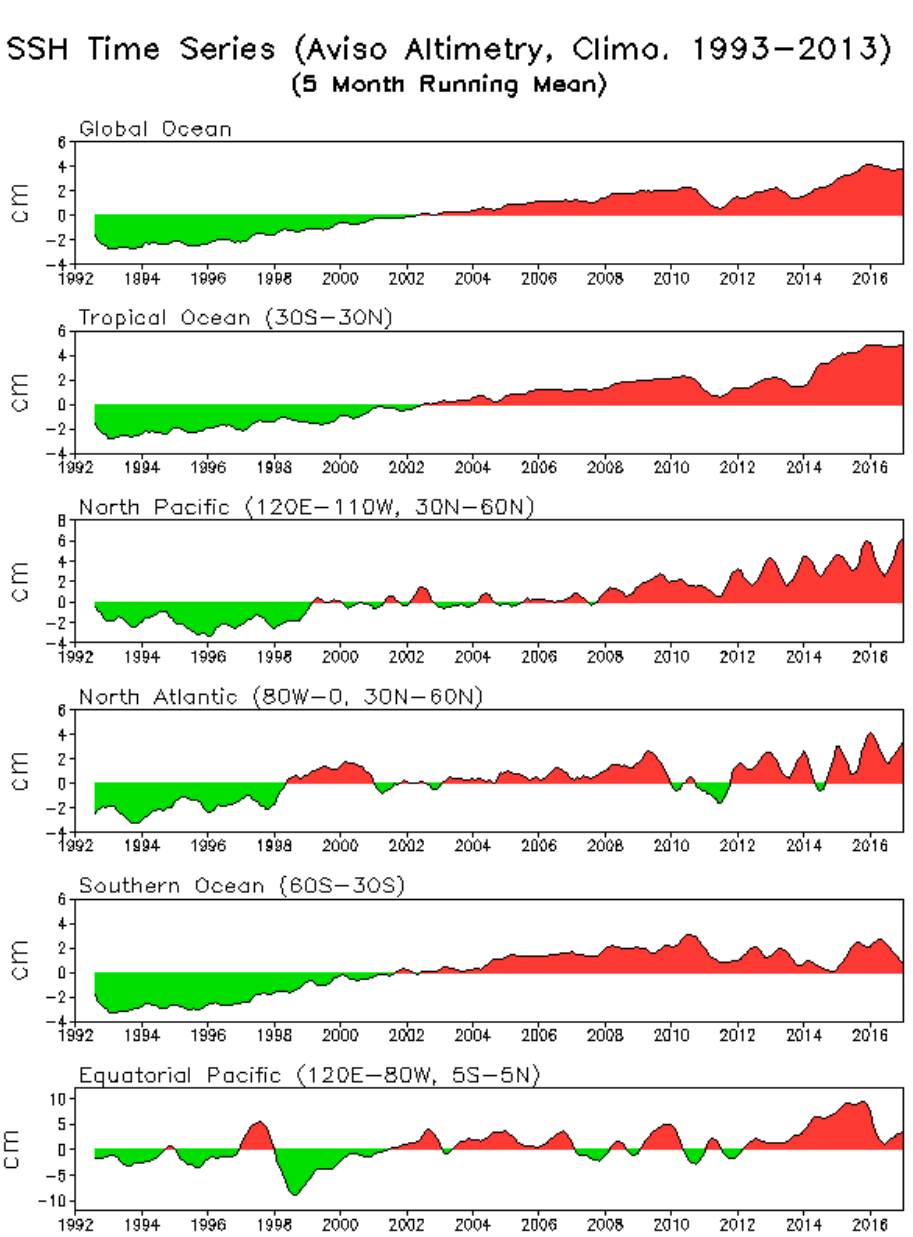


- Departure from the ensemble mean is the smallest in the JMA analysis.

- In CFSR, an emergency fix was implemented on Mar 29, 2016 to correct a large cold bias in the tropical Atlantic.

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

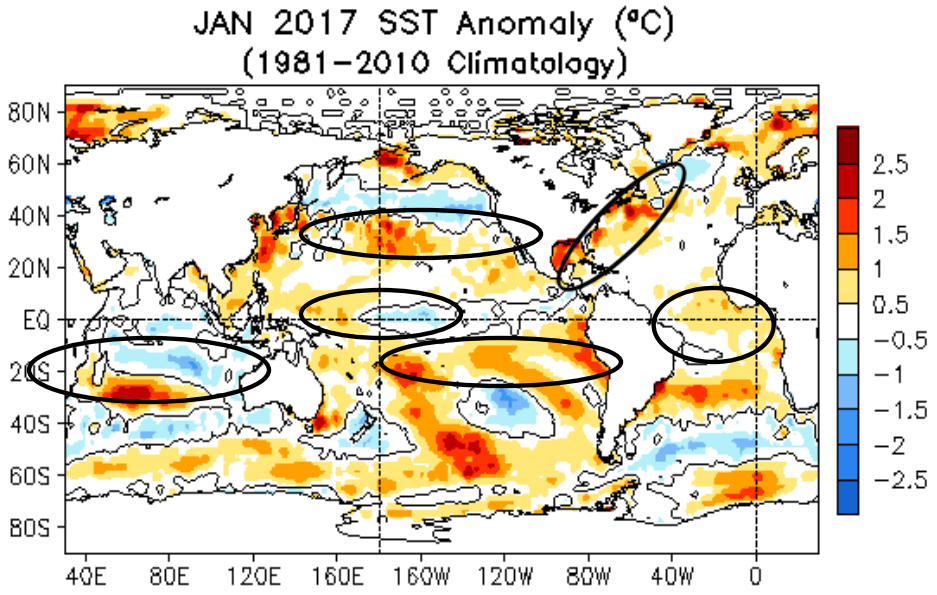


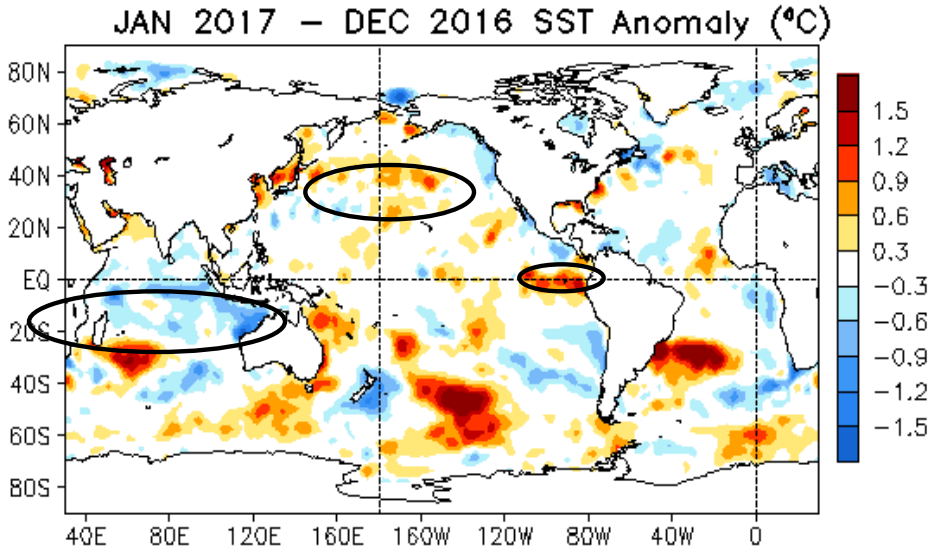


- **The linear trend in the global average and tropical ocean average of SSH and HC300 anomalies is consistent, but there are large uncertainties among HC300 analyses.**
- **However, there is a high consistency among HC300 analyses in the equatorial Pacific.**

Highlights in January 2017

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





- Weak negative (positive) SSTA was observed to east (west) of the dateline near the equator.

- Positive SSTA dominated in the subtropical South Pacific and North Pacific.

- A dipole SSTA pattern presented in the southern subtropical Indian Ocean.

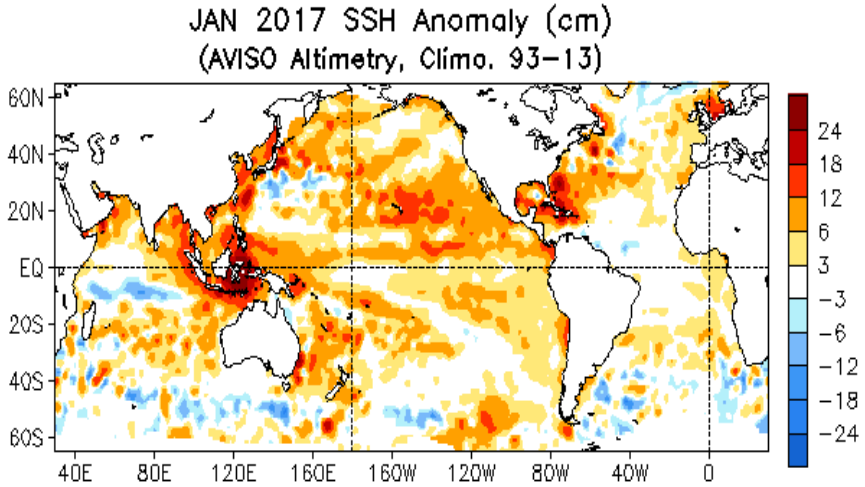
-Positive SSTA was observed along the E. coast of N. America, and tropical Atlantic.

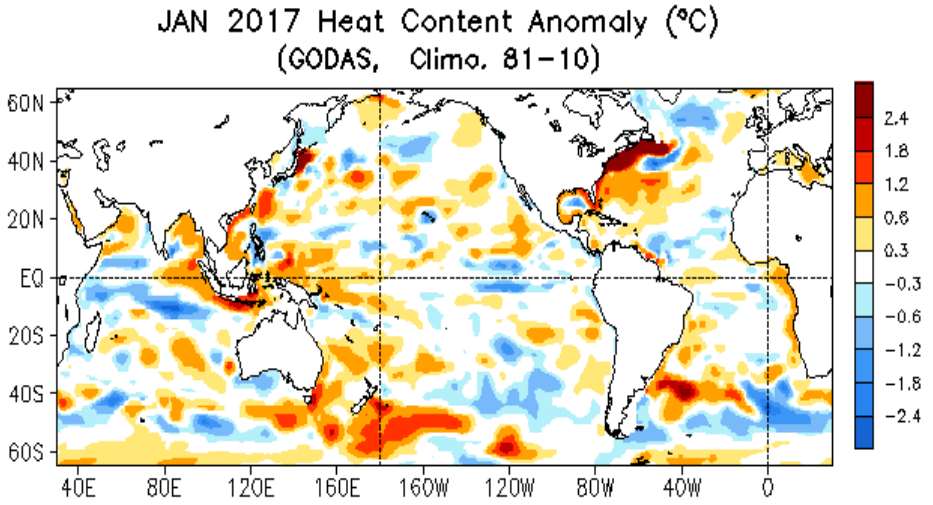
- Positive SSTA tendencies presented in the eastern equatorial Pacific and central North Pacific.

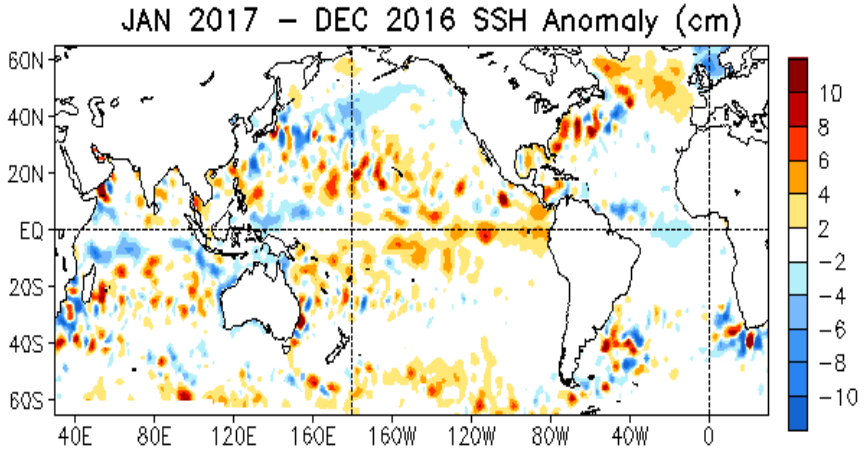
- Negative SSTA tendency presented in the southern tropical Indian Ocean.

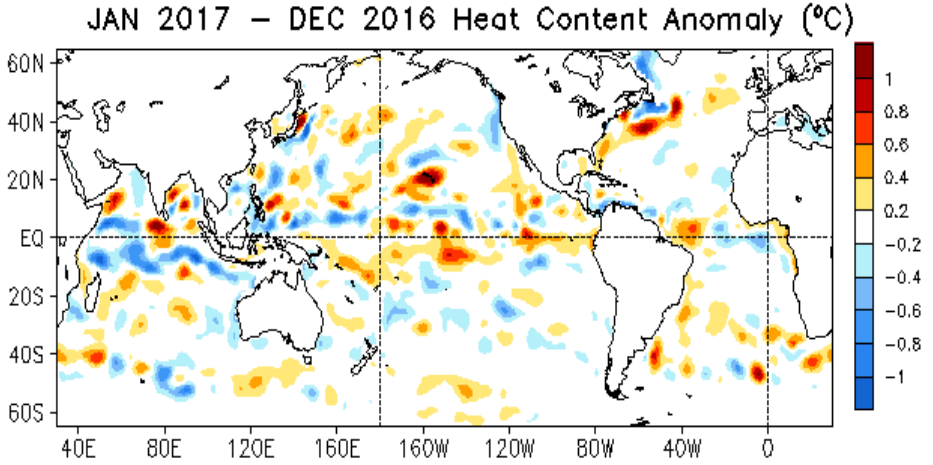
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

Global SSH and HC300 Anomaly & Anomaly Tendency







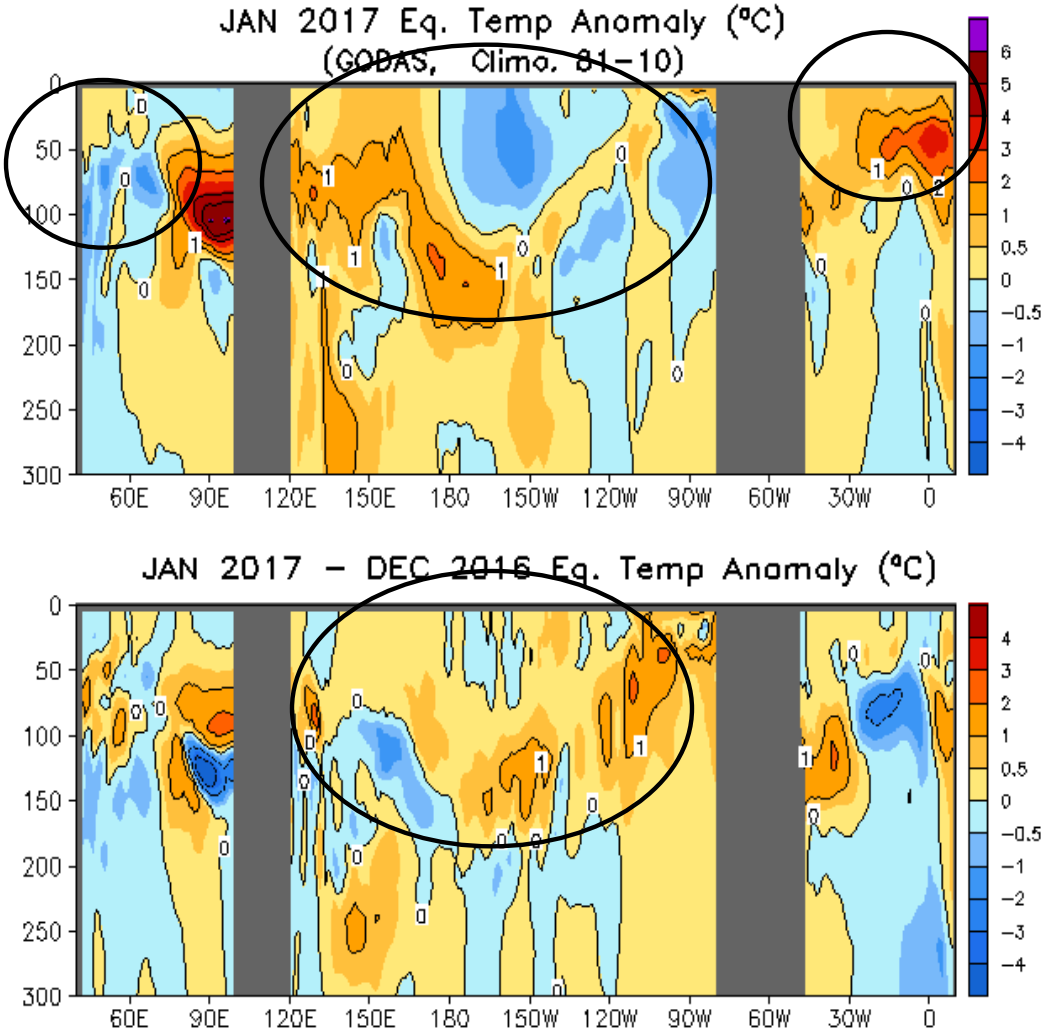


- **SSH was near-normal, but HC300 was below-normal in the central-eastern equatorial Pacific.**

-**SSH and HC300 were both above-normal over the Maritime Continents and near the E. coast of N. America.**

- **Positive SSHA and H300A tendency dominated in the central-eastern equatorial Pacific.**

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



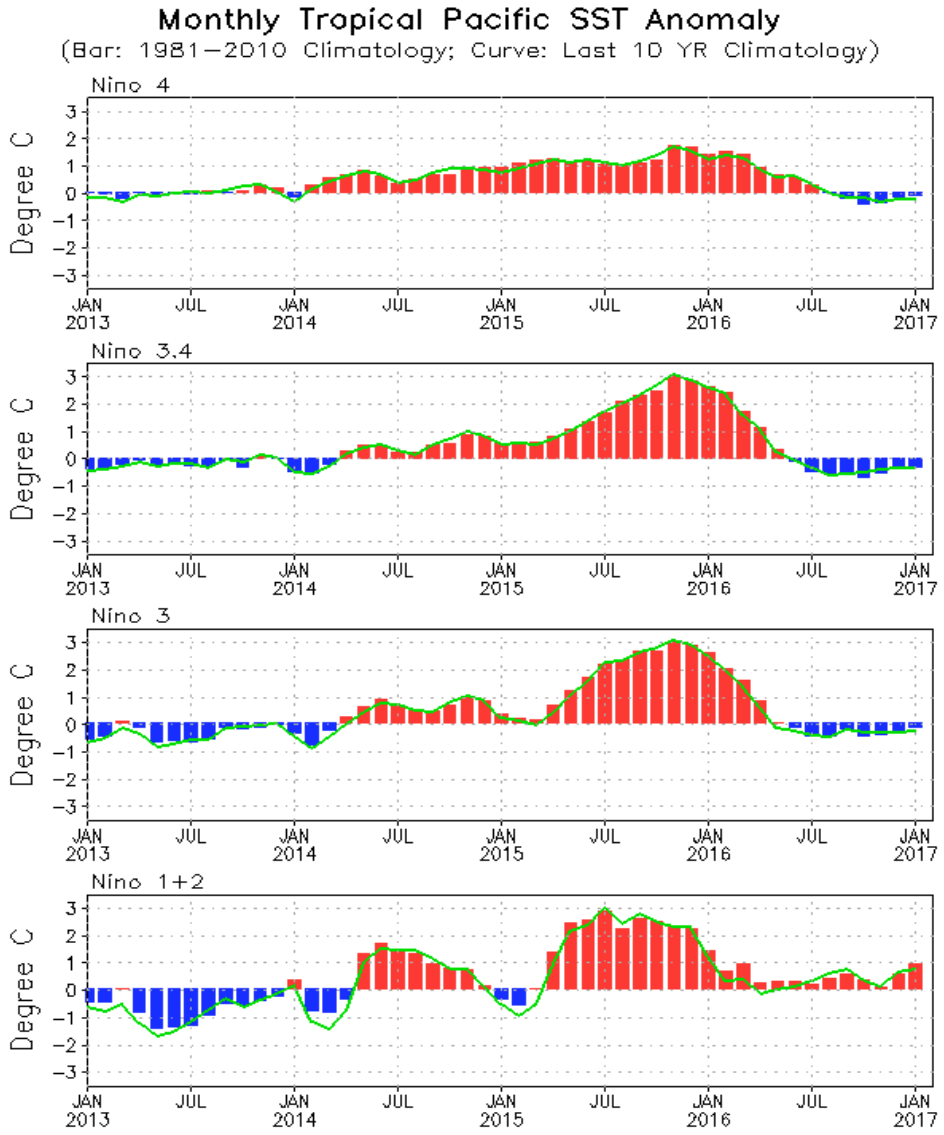
- **Positive (negative) temperature anomalies presented in the western (central-eastern) equatorial Pacific.**

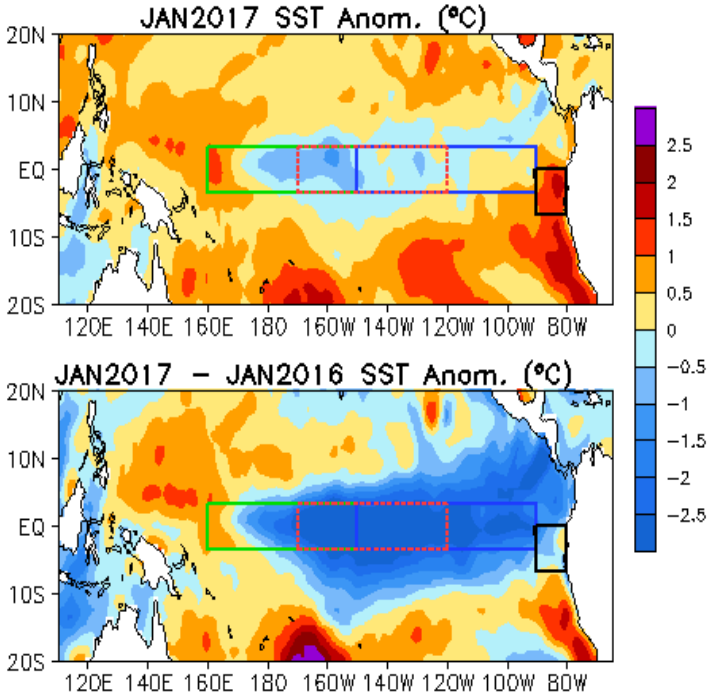
- **Positive temperature anomalies dominated in the equatorial Indian and Atlantic Ocean.**

- **Positive temperature anomaly tendency covered most of 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.

Evolution of Pacific NINO SST Indices

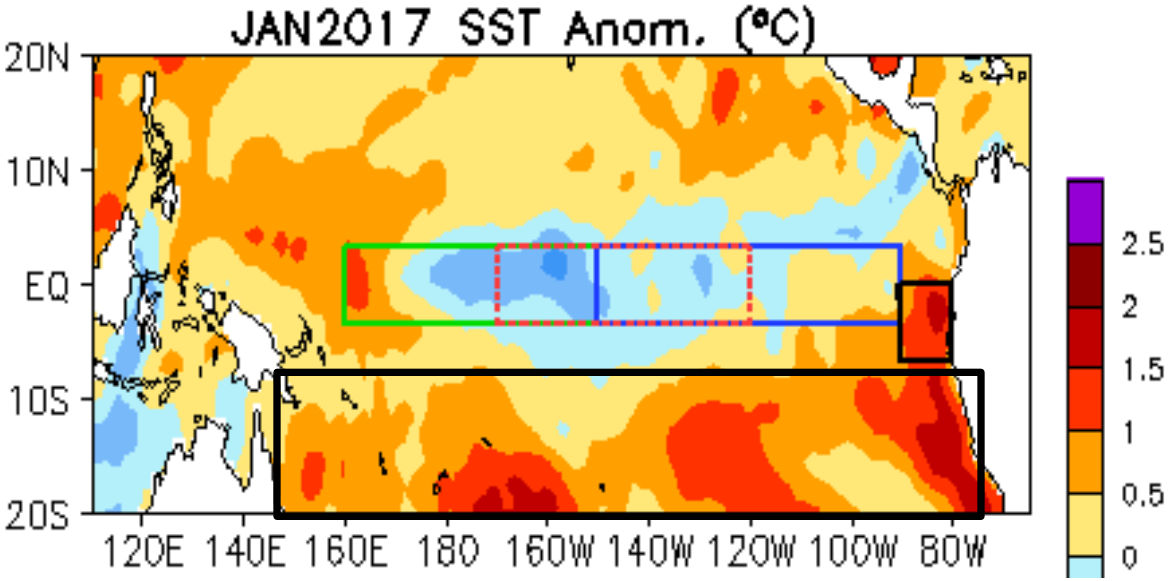


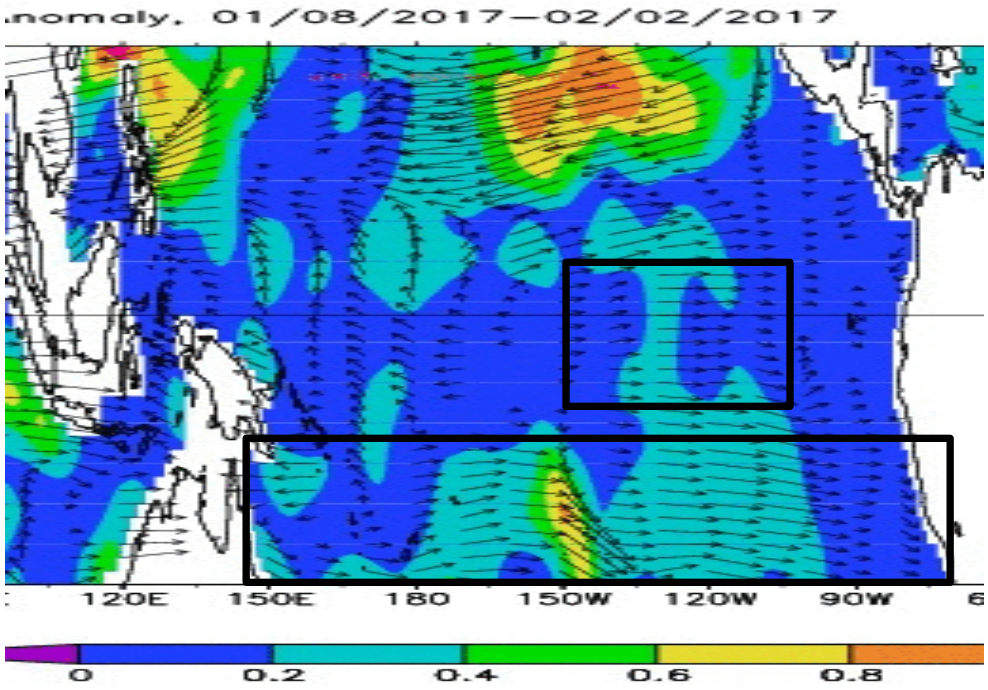


- **All NINO indices were negative except NINO1+2 (+1.2°C) in Jan 2017.**

- **Nino3.4 = -0.3°C in Jan 2017, which is based on weekly OI SST.**

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 (bar) and last ten year (green line) means.

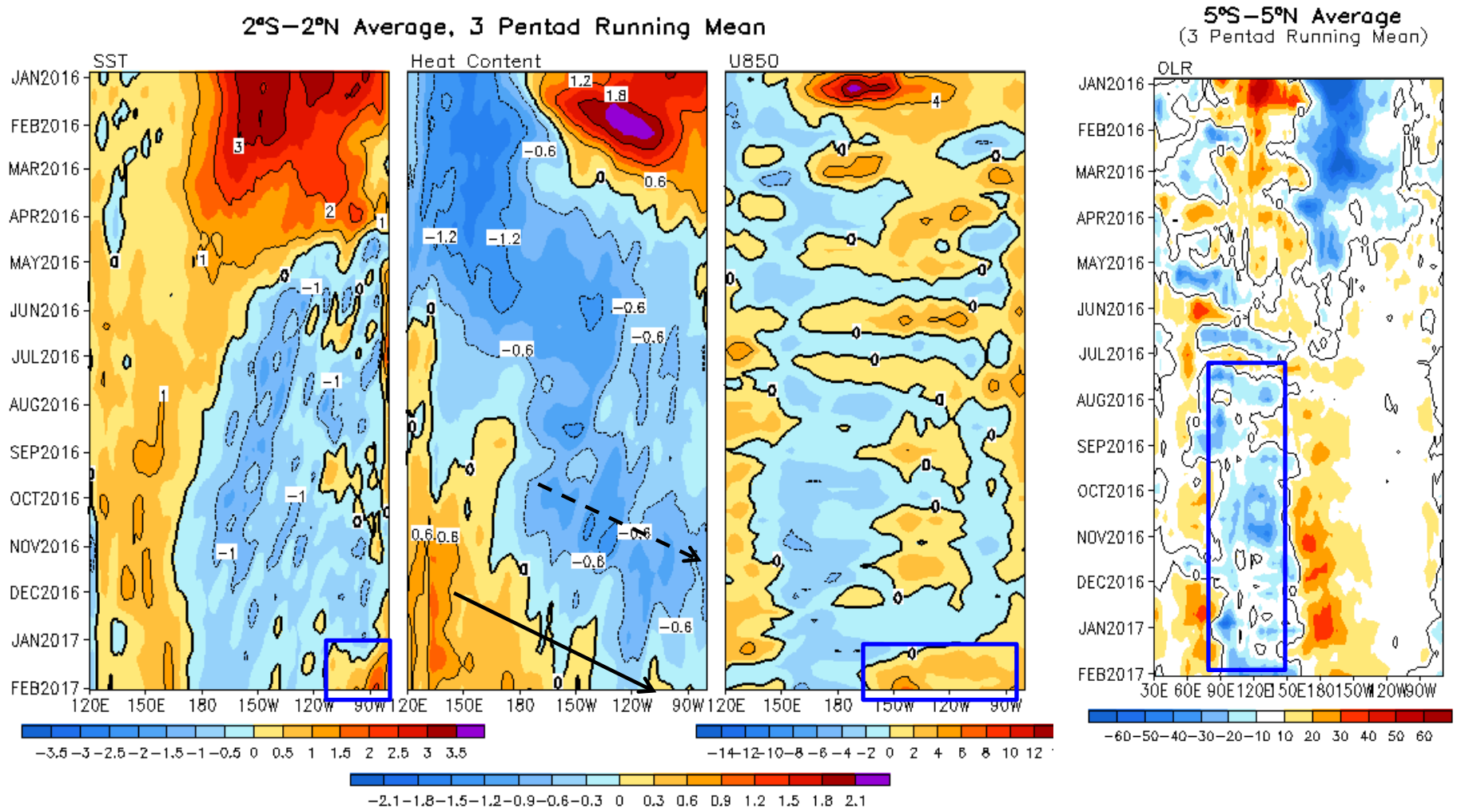




- **The warming in 10S-20S was associated with persistent westerly wind anomalies that extended to near the coast in the last two weeks.**

- **The rapid warming along the coast caused high air temperatures along the coast and the rain and mudslides being reported over the western slopes of the Andes (Courtesy of David Enfield).**

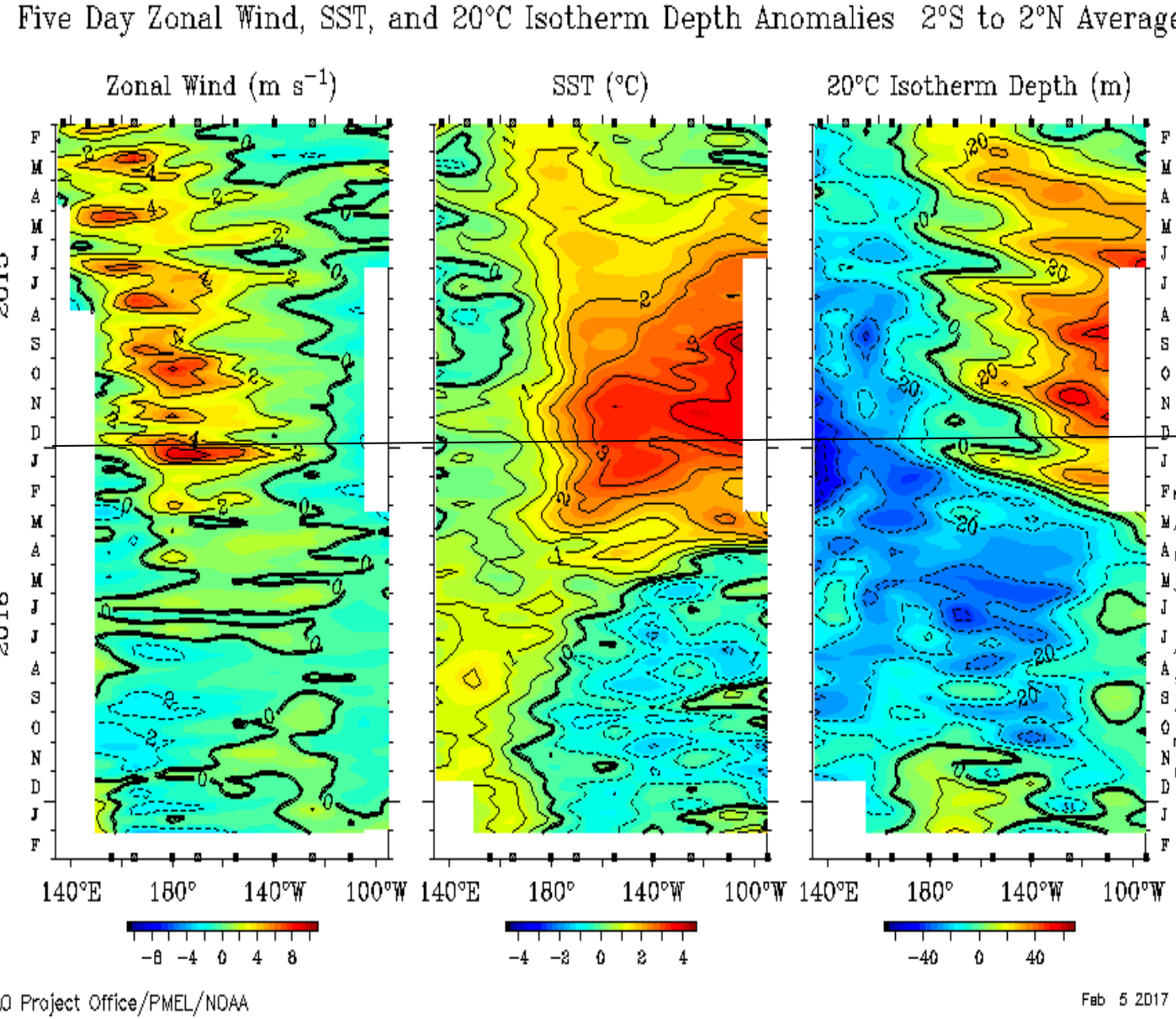
Equatorial Pacific SST (ºC), HC300 (ºC), u850 (m/s) and OLR(W/m²)Anomalies

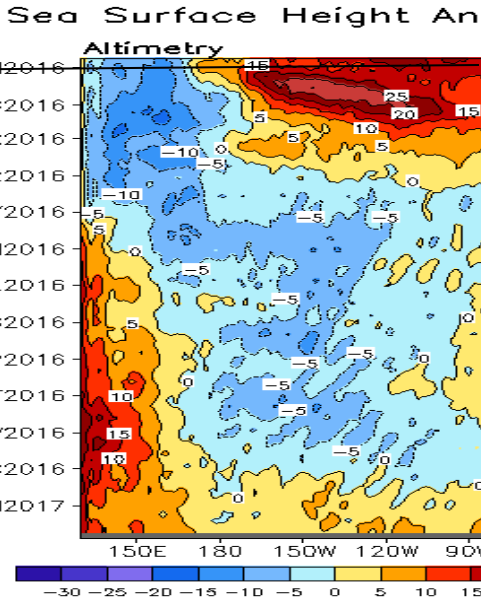


- **Positive SSTA emerged in the far eastern equatorial Pacific, which was coincident with the enhancement of westerly wind anomalies east of 160W.**

-**Positive HC300 anomalies extended to the eastern Pacific.**

Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2ºS-2ºN and Outgoing Long-wave Radiation (OLR, right) averaged in 5ºS-5ºN. SST is derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1981-2010 base period pentad means respectively.



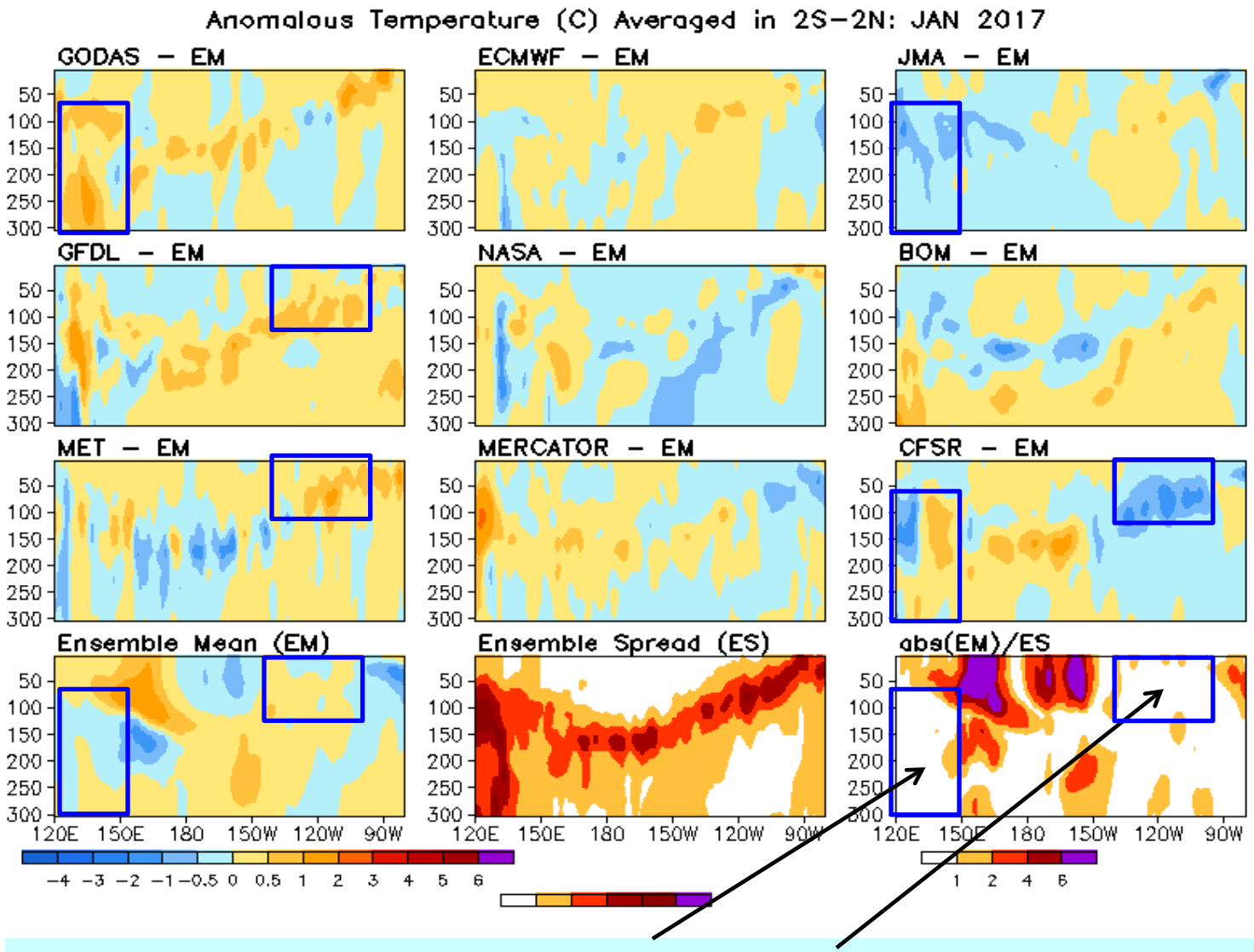


- **The TAO/TRITON data also suggested the warming in the far eastern Pacific was associated with the positive D20 anomalies and westerly wind anomalies in that region.**

- **The positive D20 anomalies covered most of the equatorial Pacific in Jan 2017, consistent with the positive SSH anomalies from AVISO.**

Real-Time Ocean Reanalysis Intercomparison: Eq. Temp. Anom.

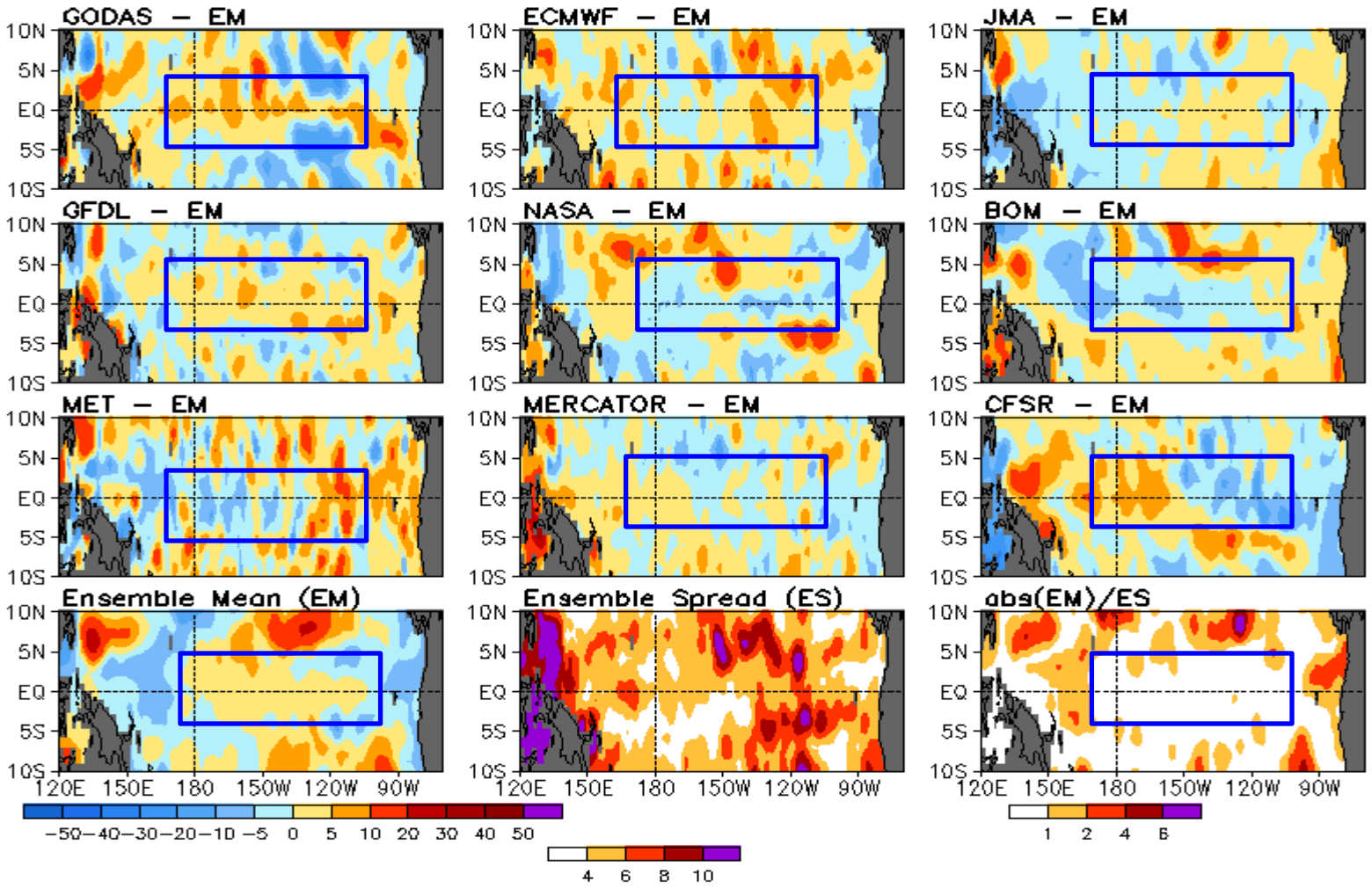
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html, **1993-2003 Climatology**)



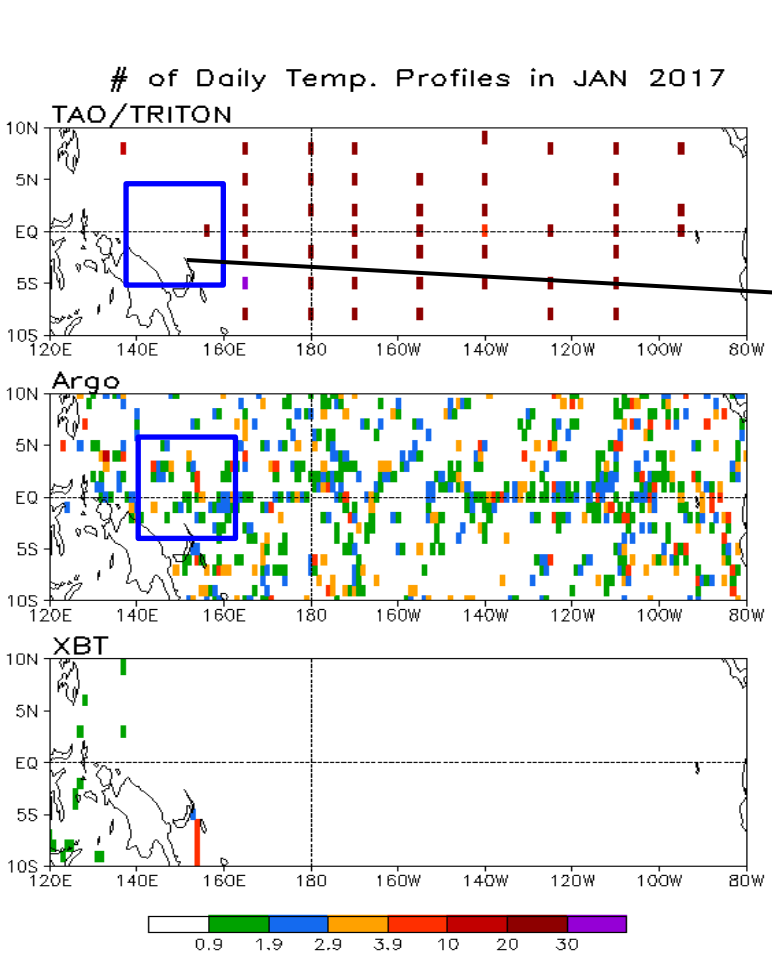
- **Signal to noise ratio is small in the far W. and E. equatorial Pacific.**

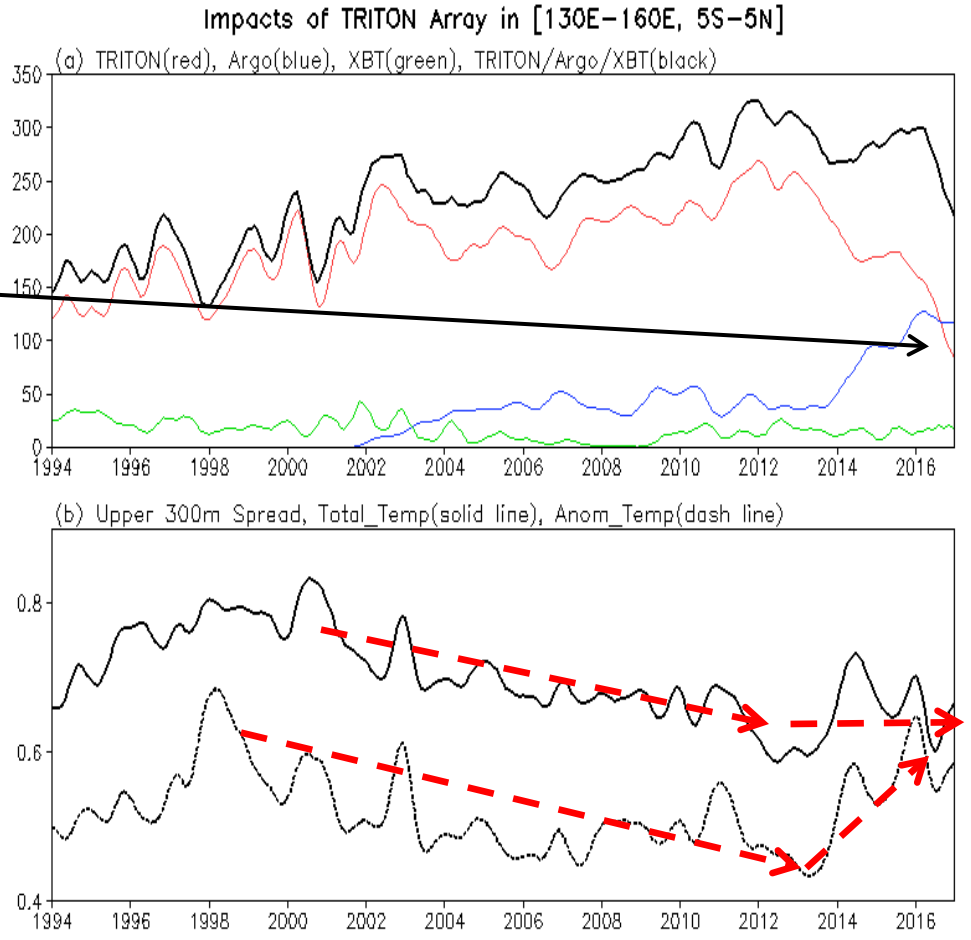
Real-Time Ocean Reanalysis Intercomparison: D20 Anom.

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



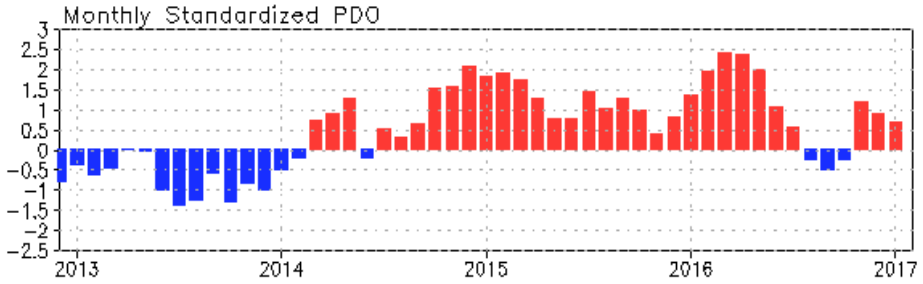
- **D20 anom. is weakly negative (-5m) in the far western and eastern Pacific.**
- **Signal is very weak in C.-E. equatorial Pacific, and contains large uncertainties.**
- **MERCATOR agrees with EM the best.**

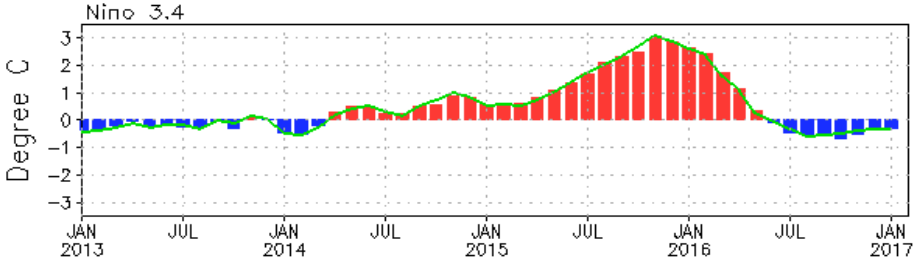


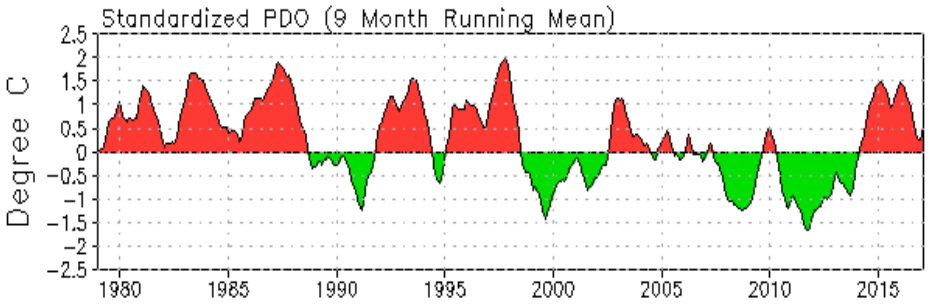


- **Averaged in the box of 130E-160E, 5S-5N, the spread of both total and anomalous temperature in upper 300m have decreased from 2000 to 2013, which can be attributed to the constrain of the TRITON and Argo data.**
- **However, the TRITON data declined rapidly since 2013. The loss of TRITON data seems partially compensated by the increase of the Argo data since 2014.**
- **Although the spread of total temperature returned to the pre-2013 value, the spread of anomalous temperature remained well above the 2013 value, indicating the importance of stability of ocean observing systems (see Xue et al. 2017, Climate Dynamics).**

Pacific Decadal Oscillation Index



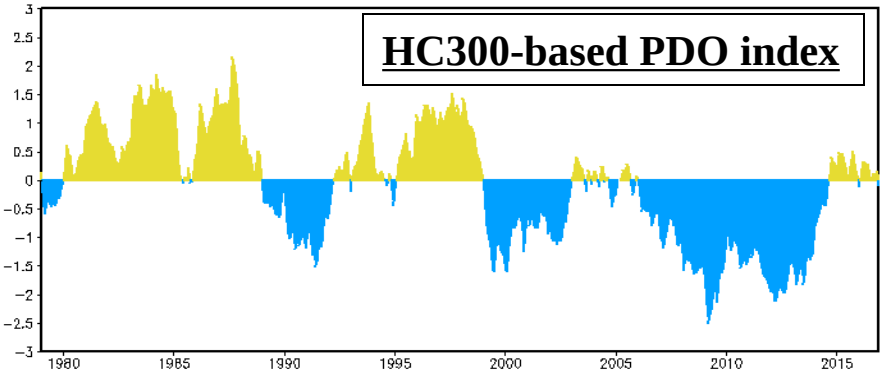




- **Previous CPC PDO index based on ERSSTv3b discontinued in Oct. 2016.**

- **Current CPC PDO index is based on ERSSTv4.**

- **Positive PDO weakened slightly in Jan 2017.**



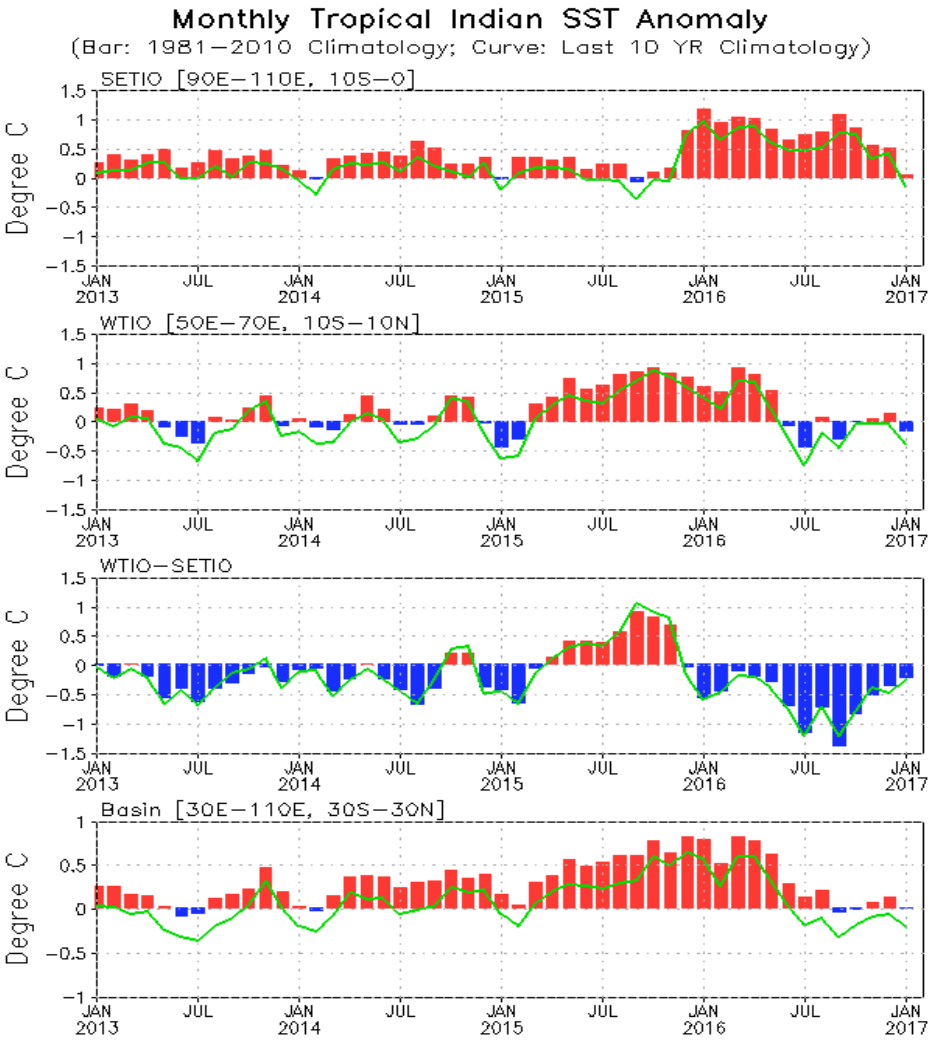
- **Upper 300m Ocean heat content(HC300) based PDO (HPDO) highlights the slower frequency variability in the SST-based PDO (Kumar and Wen 2016).**

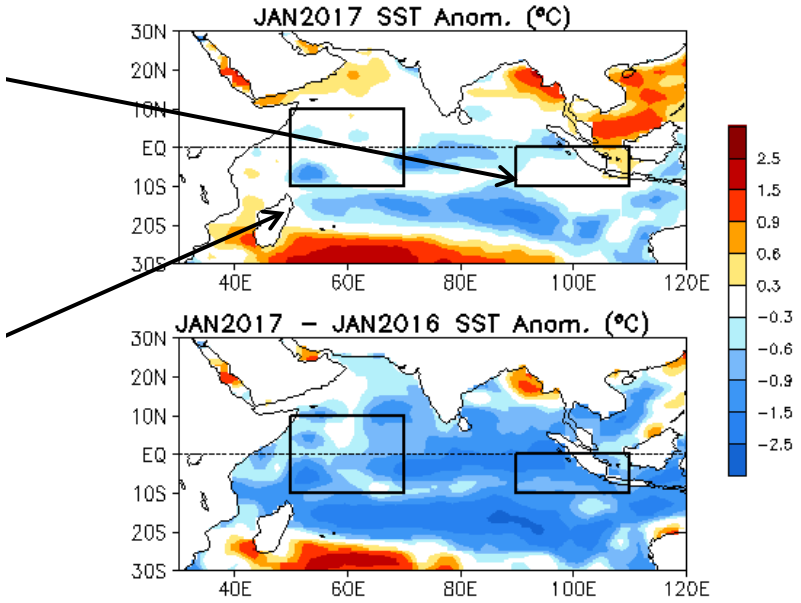
(http://www.cpc.ncep.noaa.gov/products/GODAS/PDO_body.html)

- **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.**

Evolution of Indian Ocean SST Indices

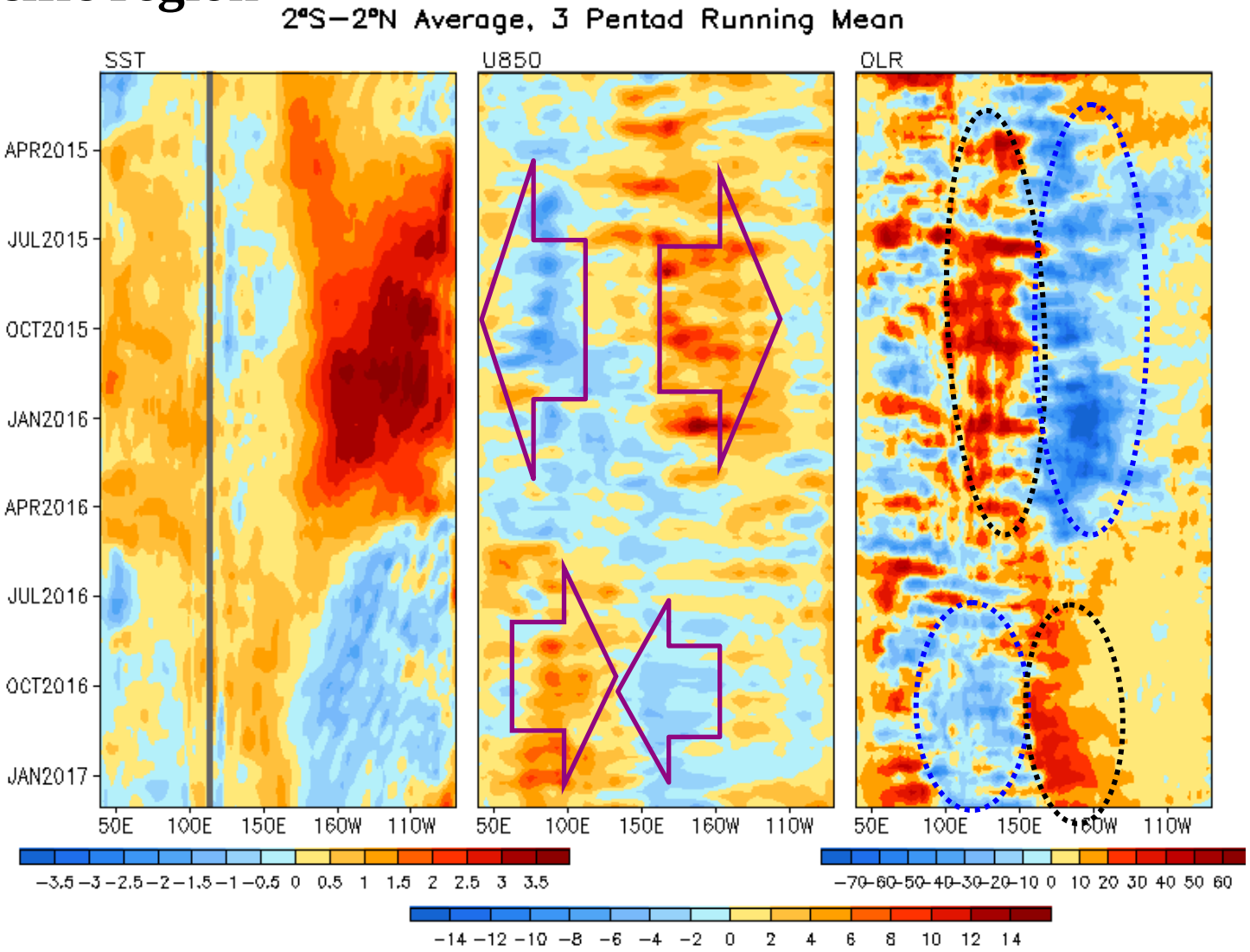




- **SETIO returned to near-normal in Jan 2017.**
- **WTIO has been near-normal since Jun 2016.**
- **DMI was near-normal.**
- **Basin-average index has been near-normal since Jun 2016.**

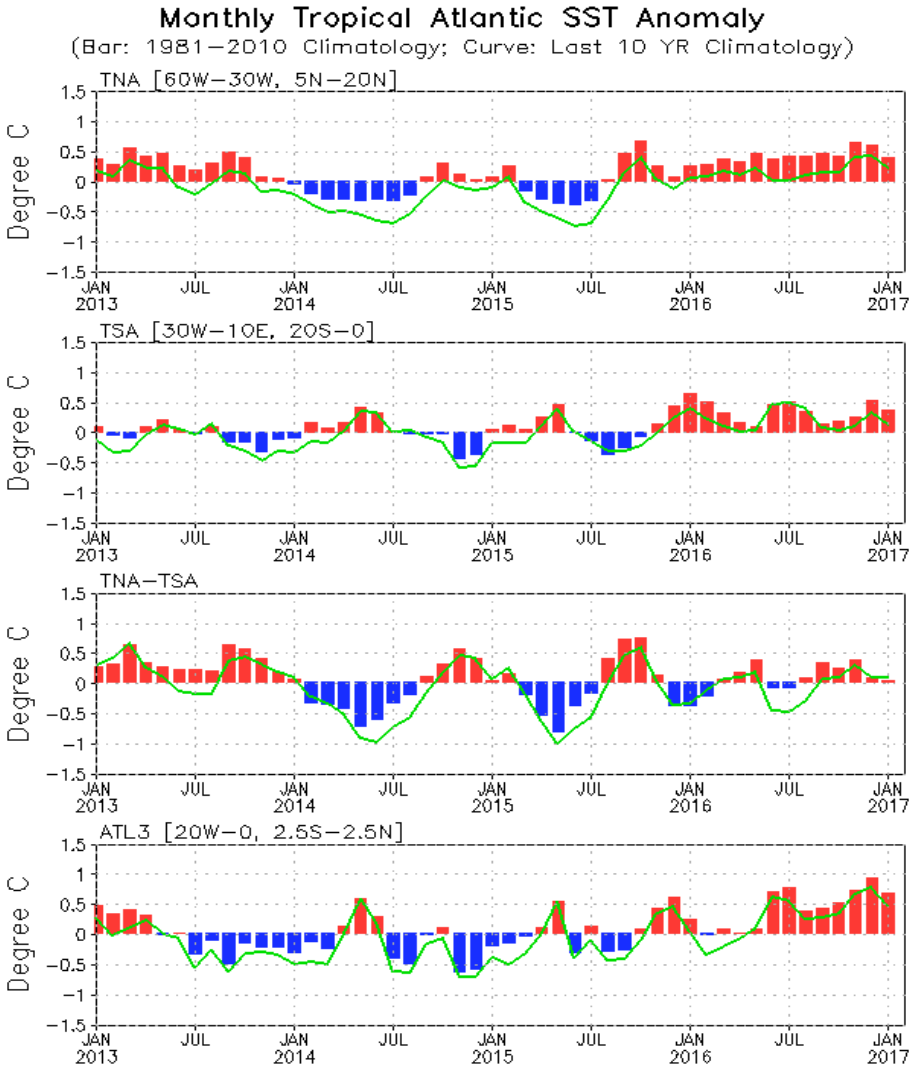
Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the SETIO [90°E-110°E, 10°S-0] and WTIO [50°E-70°E, 10°S-10°N] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

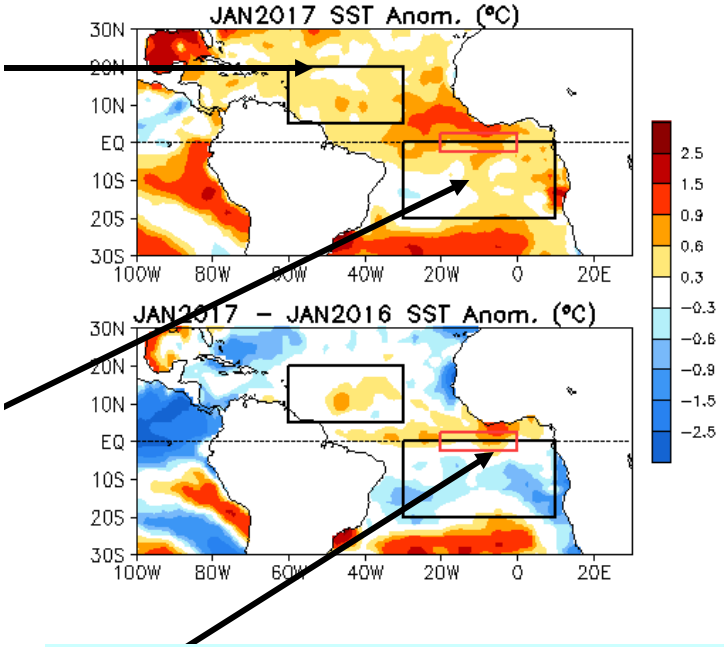
Indo-Pacific region



- **Surface zonal wind and OLR anomalies across the Indo-Pacific region were largely associated with the warm and cold phase of the tropical Pacific SSTA in 2015-16.**

Evolution of Tropical Atlantic SST Indices



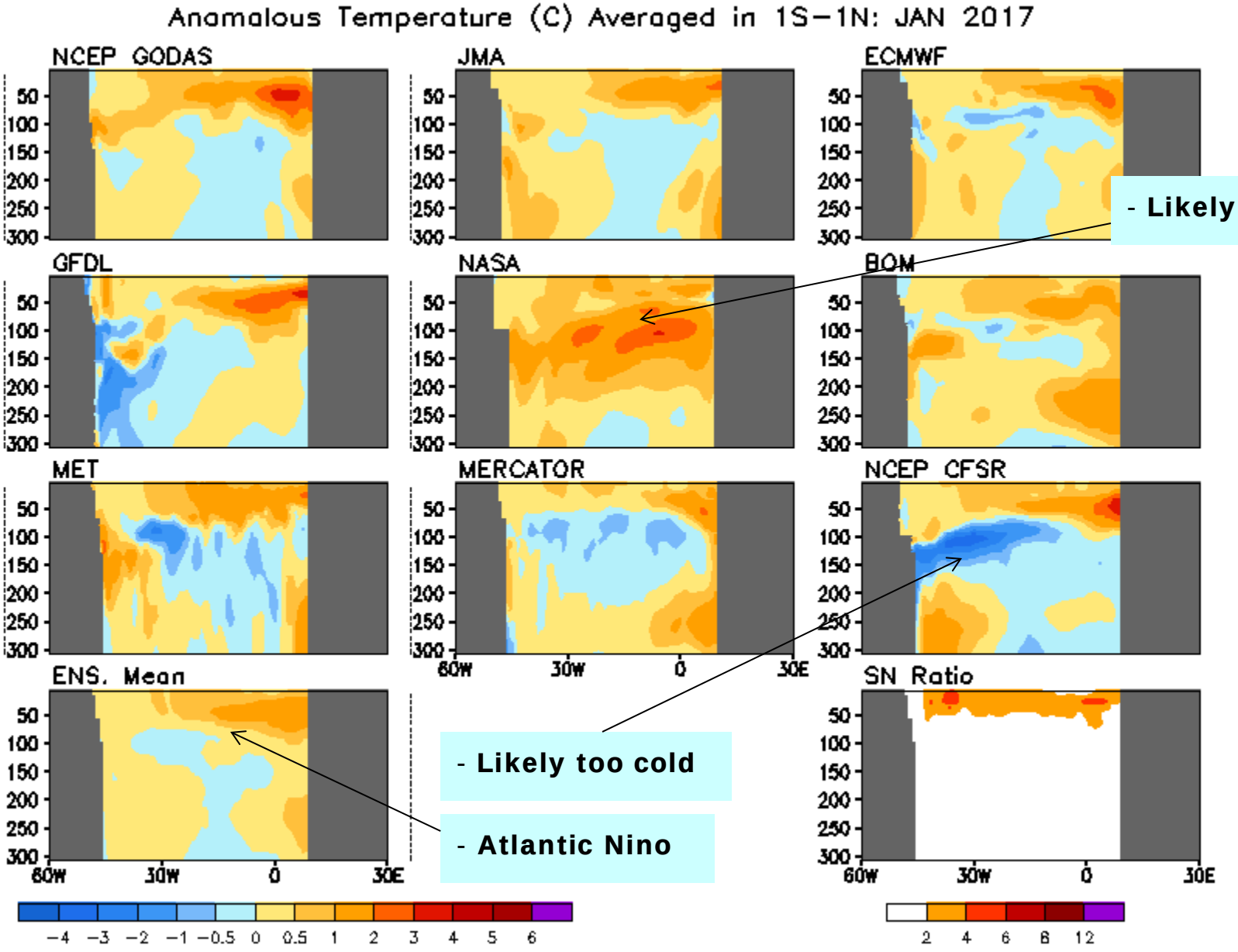


- **Positive SSTA in the tropical North Atlantic (TNA) weakened in Jan 2017.**
- **Meridional Gradient Mode index (TNA-TSA) was near-normal.**
- **Positive ATL3 SSTA persisted from Jun 2016 to Jan 2017.**

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 departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

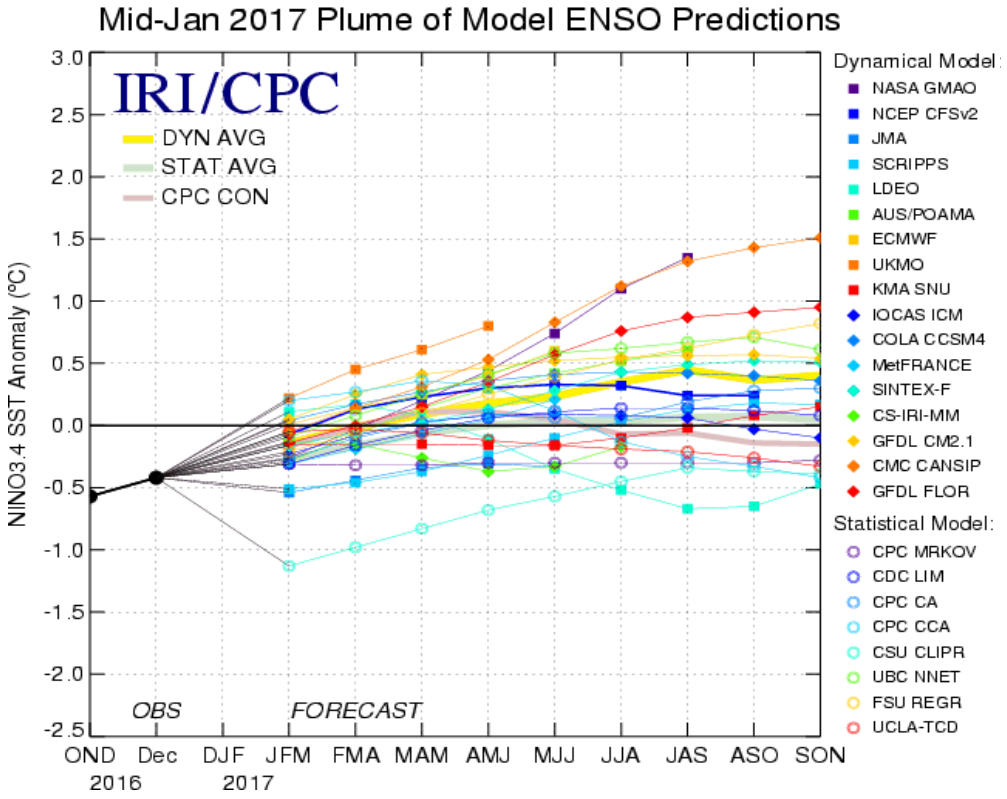
Real-Time Ocean Reanalysis Intercomparison: Eq. Temp. Anom. in Jan 2017

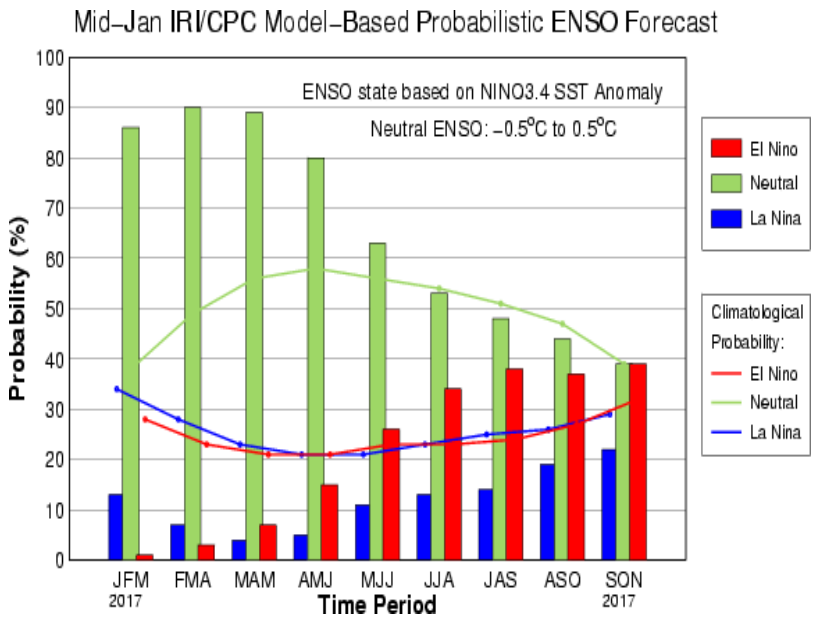
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)

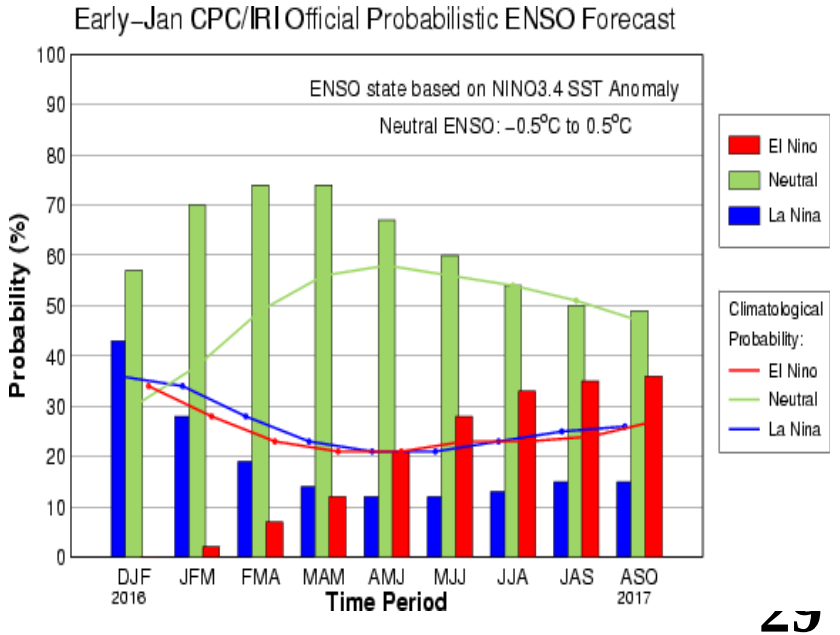


Global SST Predictions

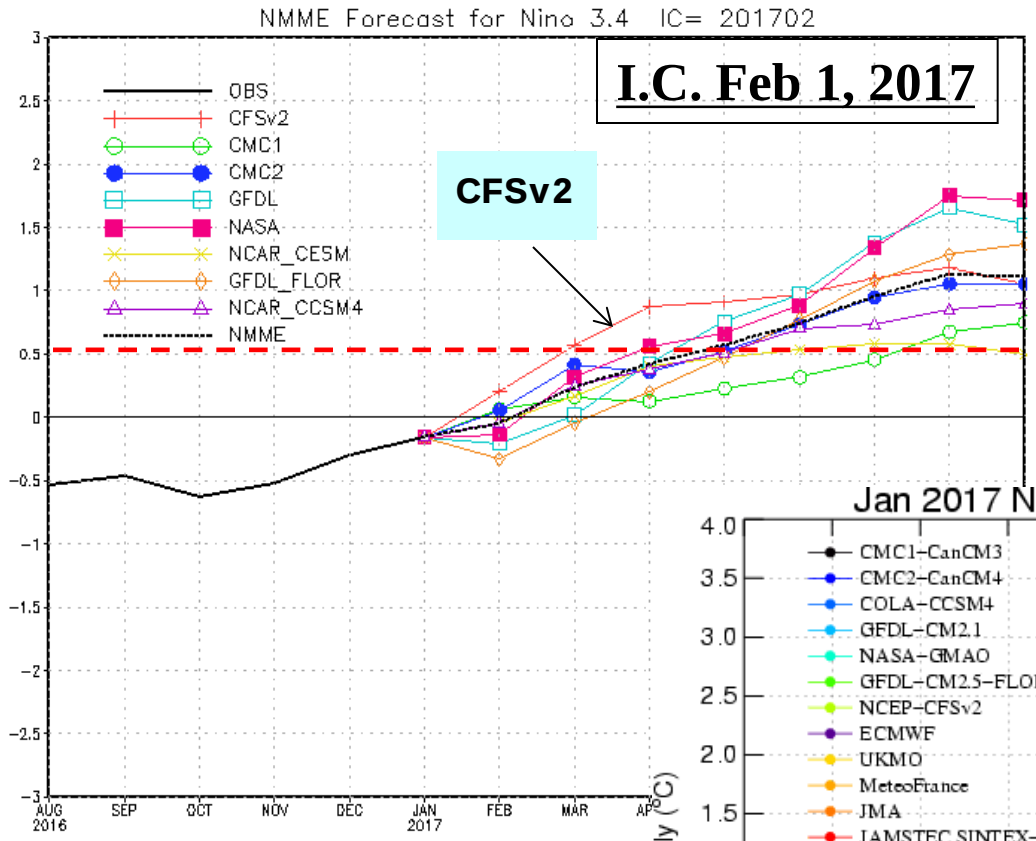
IRI NINO3.4 Forecast Plume





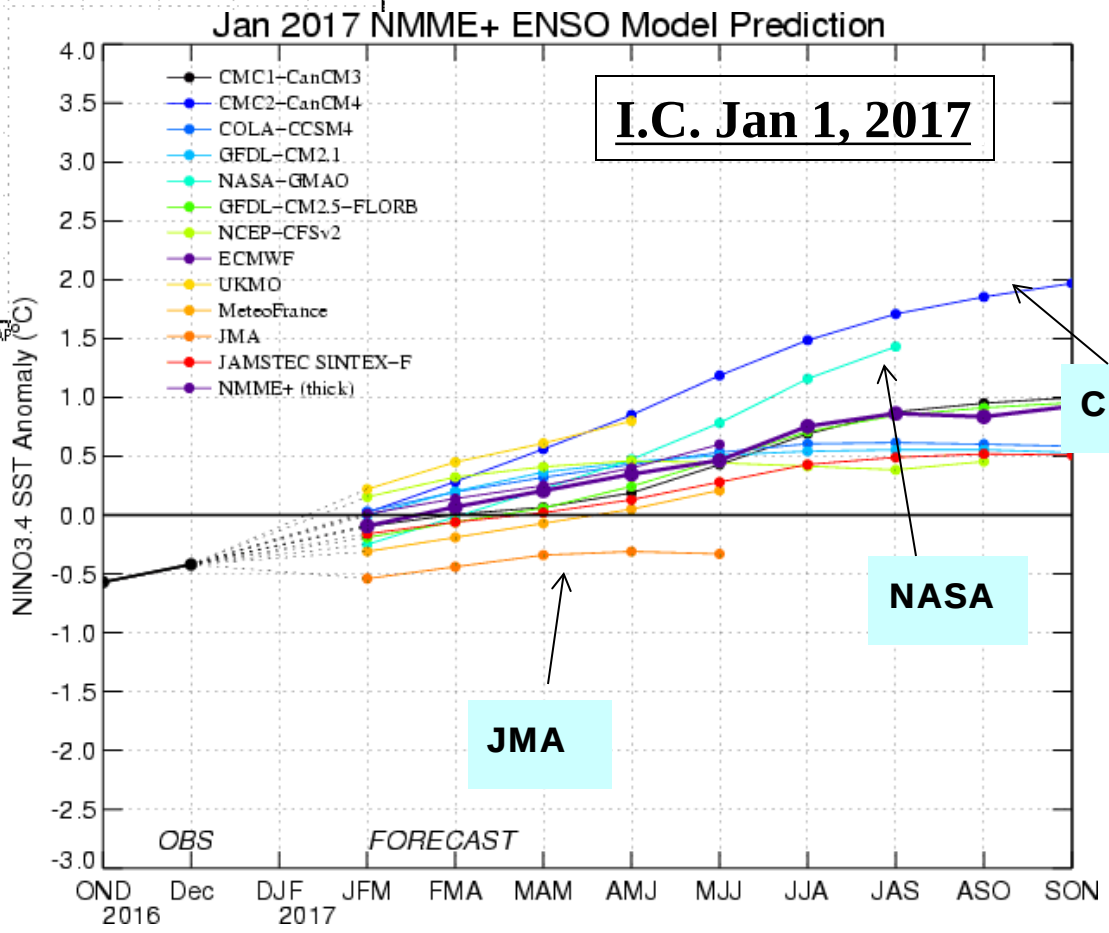


- **NOAA "ENSO Diagnostic Discussion" on Feburary 9, 2017 suggested that "ENSO-neutral conditions have returned and are favored to continue through at least the Northern Hemisphere spring 2017".**



CFSv2

NASA, GFDL reach 1.5C in Sep

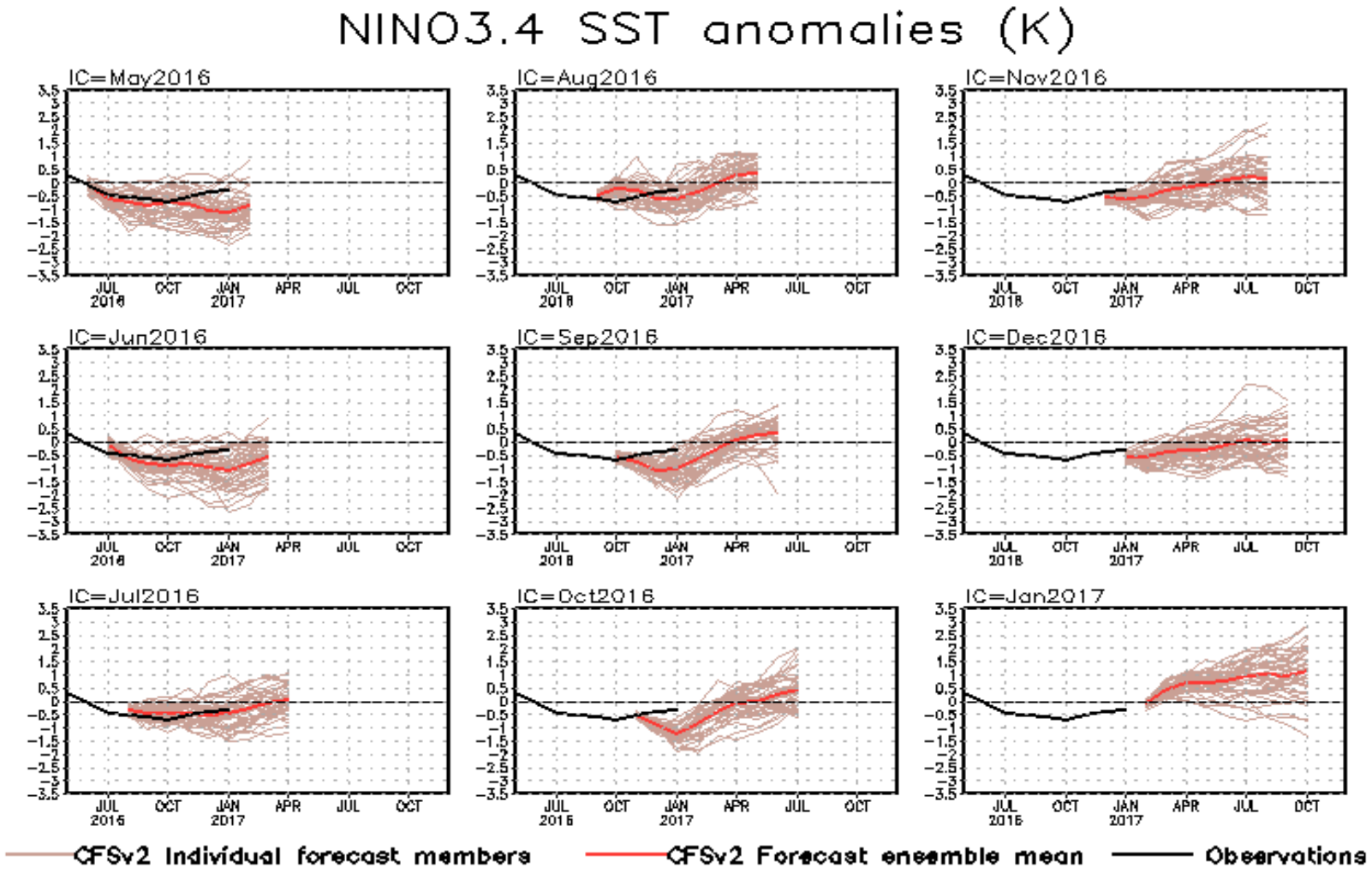


CMC2

NASA

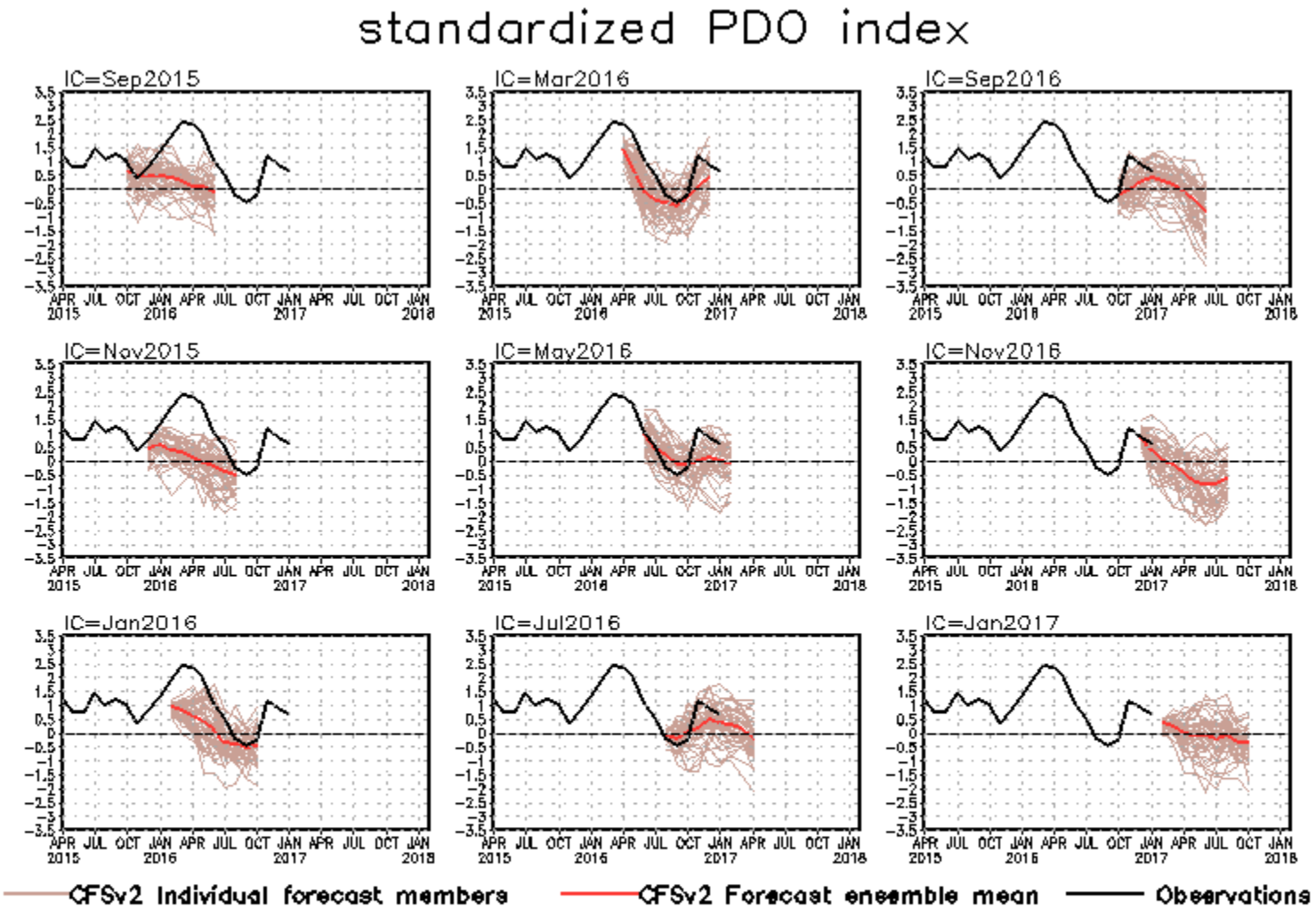
JMA

NCEP CFSv2 NINO3.4 Forecast



- **Latest CFSv2 predictions (initialized from the last ten days of Jan 2017) suggest El Nino conditions will emerge in spring 2017.**

NCEP CFSv2 Pacific Decadal Oscillation (PDO) Forecast

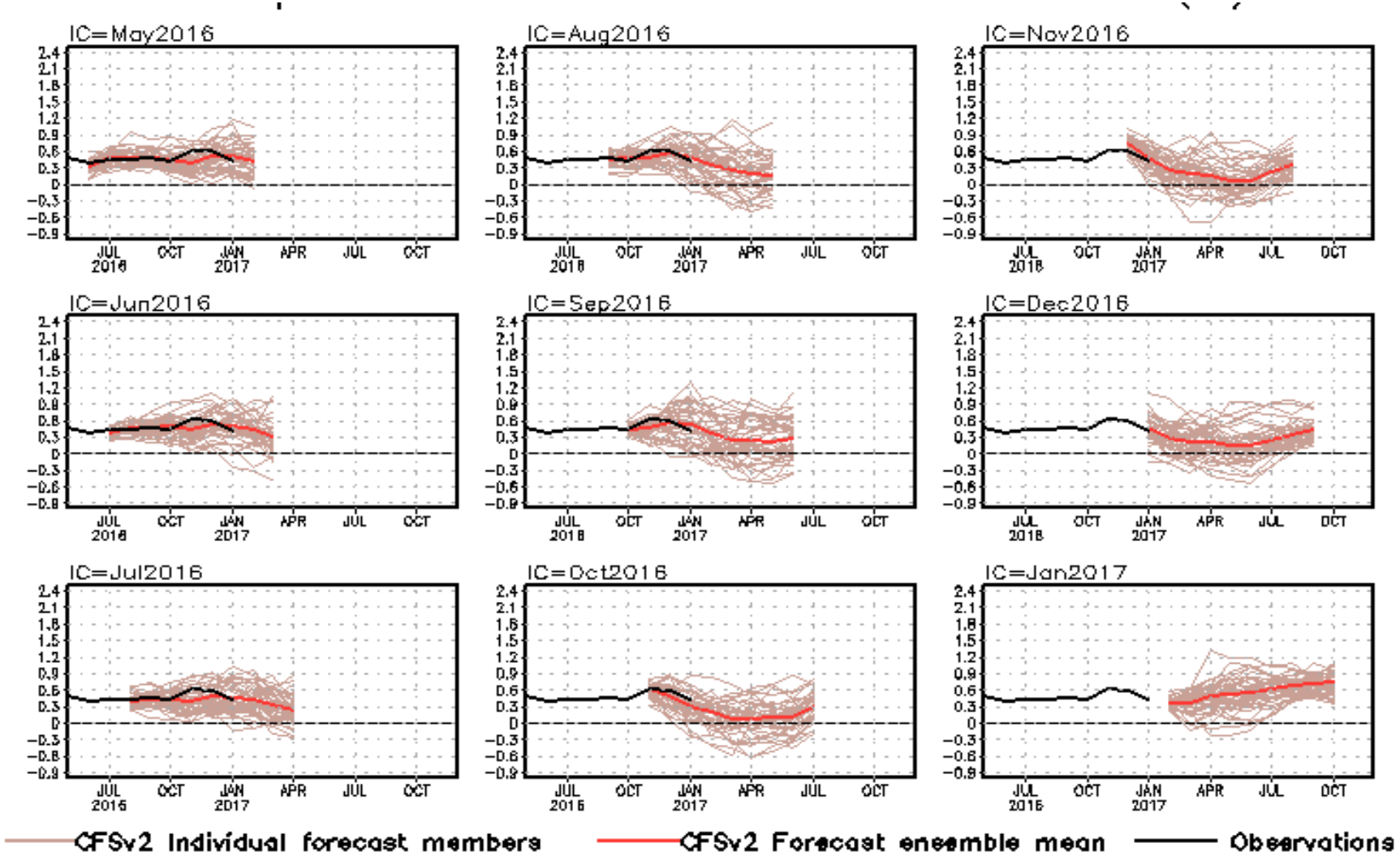


PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110ºE-100ºW, 20ºN-60ºN].

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

- Latest CFSv2 prediction suggests neutral PDO phase in spring and summer 2017.

NCEP CFSv2 Tropical North Atlantic SST Forecast



- **Latest CFSv2 prediction suggests tropical North Atlantic SST will remain above-normal and gradually increase from spring to fall 2017.**

Backup Slides

Global Sea Surface Salinity (SSS)

Anomaly for January 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!
- The positive SSS anomaly in the Pacific Ocean along the Equator continues this month along with the continuing negative precipitation anomaly. Off the equator, similar as last month, large scale of SSS decreasing appears in the North Pacific subtropics and west basin of South Pacific subtropics. Large scale freshening in the subarctic regions of both North Pacific and North Atlantic ocean in the storm track regions continues as well in this month, con-incident with increasing of precipitation. However, in this month, the SSS in the Bay of Bengal significantly decreased, while the evaporation increased and precipitation didn't show significant changes which led to a E-P increasing.

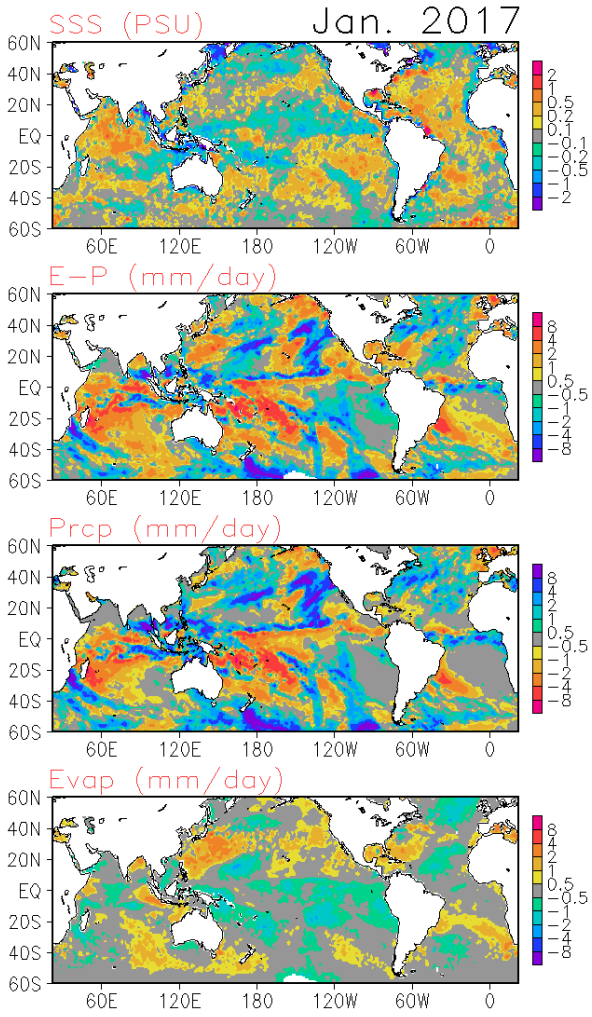
- **Data used**

  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

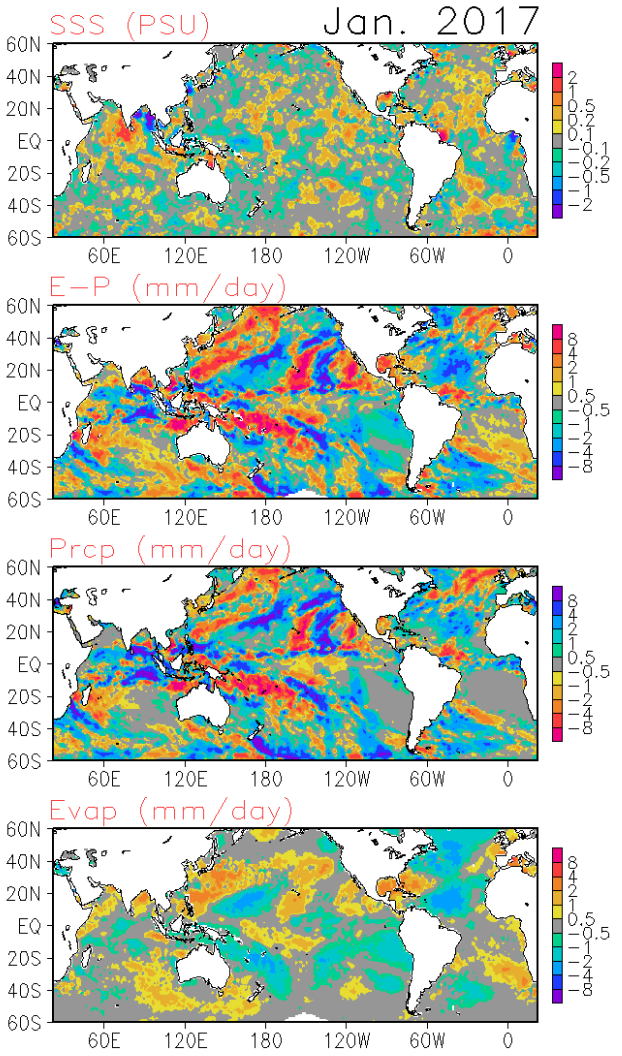
  Evaporation: CFS Reanalysis



Global Sea Surface Salinity (SSS)

Tendency for January 2017

Compared with last month, the salinity in the Pacific Ocean at the equatorial region doesn't show significant changes, except the SSS decreased between 150°E and 180°E. The SSS significantly decreased in the Bay of Bengal with no significant change of precipitation but increasing of evaporation, which suggests that the decrease of the SSS is primarily due to the oceanic advection which brings fresher water to this region.

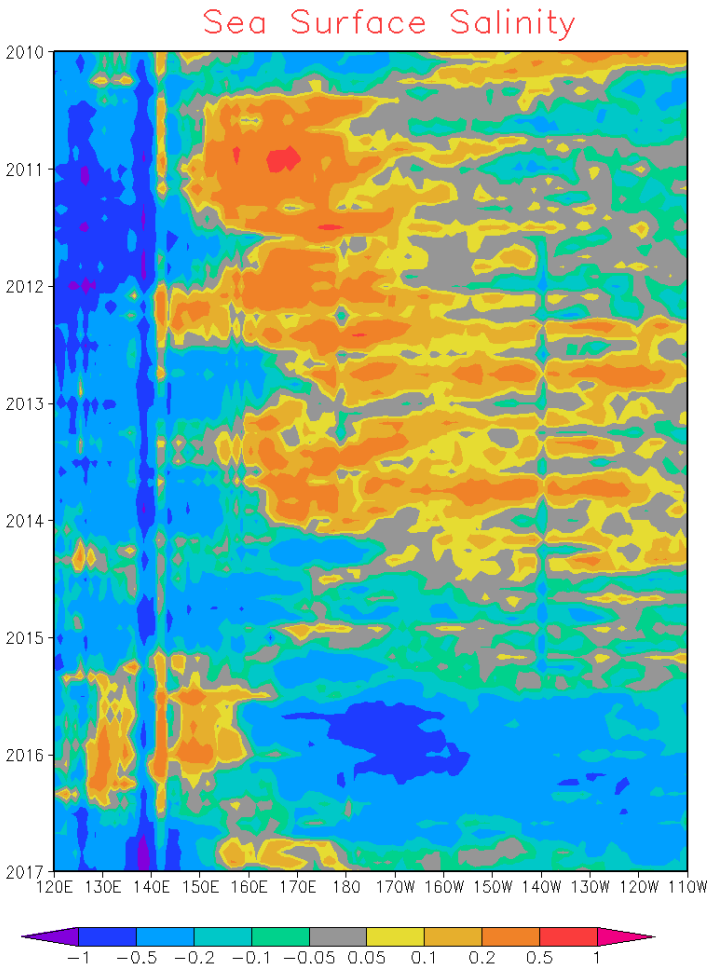


Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific

- Hovemoller diagram for equatorial SSS anomaly **(10ºS-10ºN);**

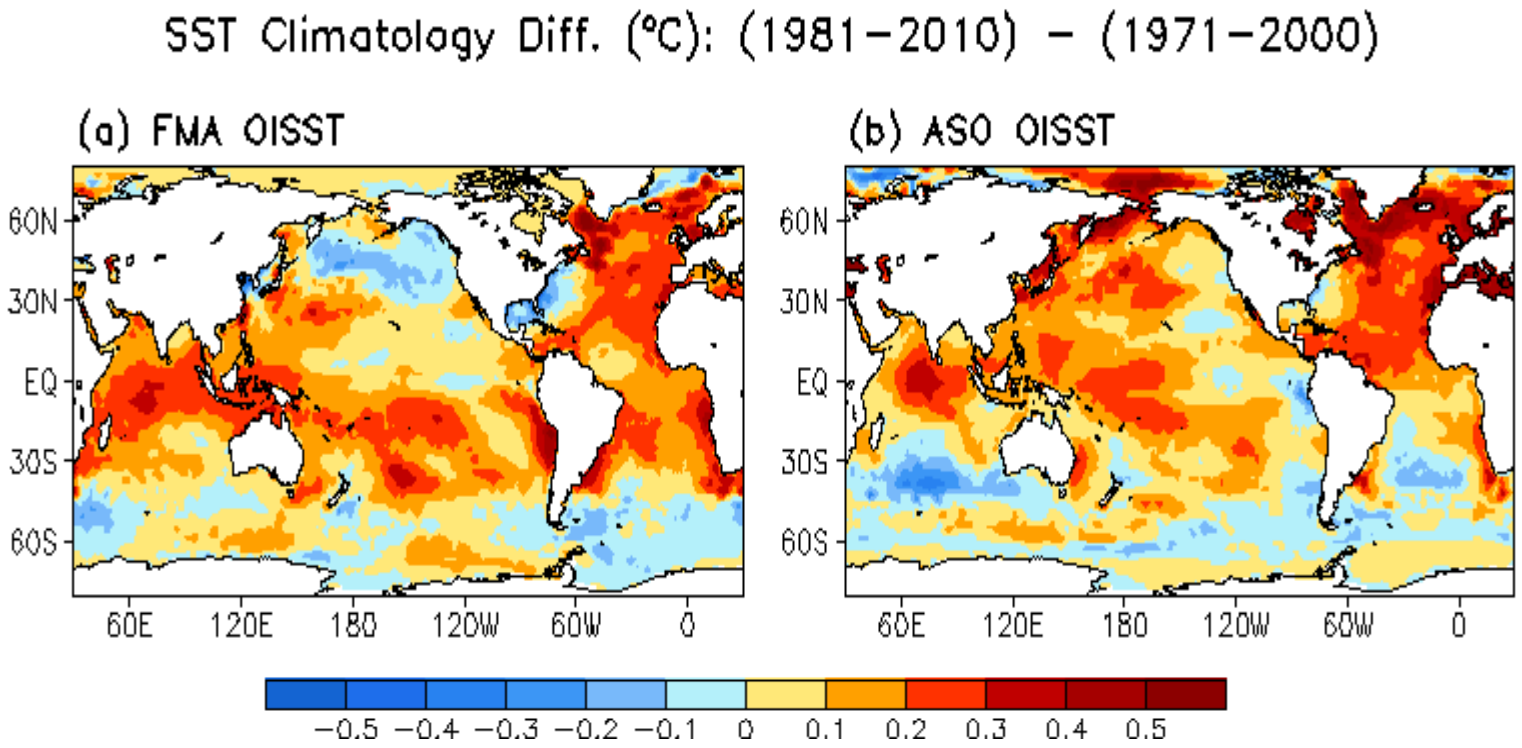
- The anomaly evolution in this region shows similar pattern as last month. In the western equatorial Pacific Ocean, from 120°E to 150°E, the negative SSS signal continues. At the meantime, the SSS anomaly over the eastern Pacific Ocean, between 150ºE and 180ºE, is continuing in its positive phase. There are no significant changes east of 170°W.



Switch to 1981-2010 Climatology

- **SST from 1971-2000 to 1981-2010**
  - **Weekly OISST.v2, monthly ERSST.3b**
- **Atmospheric fields from 1979-1995 to 1981-2010**
  - **NCEP CDAS winds, sea level pressure, 200mb velocity potential, surface shortwave and longwave radiation, surface latent and sensible fluxes, relative humidity**
  - **Outgoing Long-wave Radiation**
- **Oceanic fields from 1982-2004 to 1981-2010**
  - **GODAS temperature, heat content, depth of 20°C, sea surface height, mixed layer depth, tropical cyclone heat potential, surface currents, upwelling**
- **Satellite data climatology 1993-2005 unchanged**
  - **Aviso Altimetry Sea Surface Height**
  - **Ocean Surface Current Analyses – Realtime (OSCAR)**

Be aware that new climatology (1981-2010) was applied since Jan 2011



1971-2000 SST Climatology (Xue et al. 2003):
http://www.cpc.ncep.noaa.gov/products/predictions/30day/SSTs/sst_clim.htm

1981-2010 SST Climatology: http://origin.cpc.ncep.noaa.gov/products/people/yxue/sstclim/

- **The seasonal mean SST in February-April (FMA) increased by more than 0.2°C over much of the Tropical Oceans and N. Atlantic, but decreased by more than 0.2°C in high-latitude N. Pacific, Gulf of Mexico and along the east coast of U.S.**

- **Compared to FMA, the seasonal mean SST in August-October (ASO) has a stronger warming in the tropical N. Atlantic, N. Pacific and Arctic Ocean, and a weaker cooling in Gulf of Mexico and along the east coast of U.S.**

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.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!