2015 Annual Ocean Review

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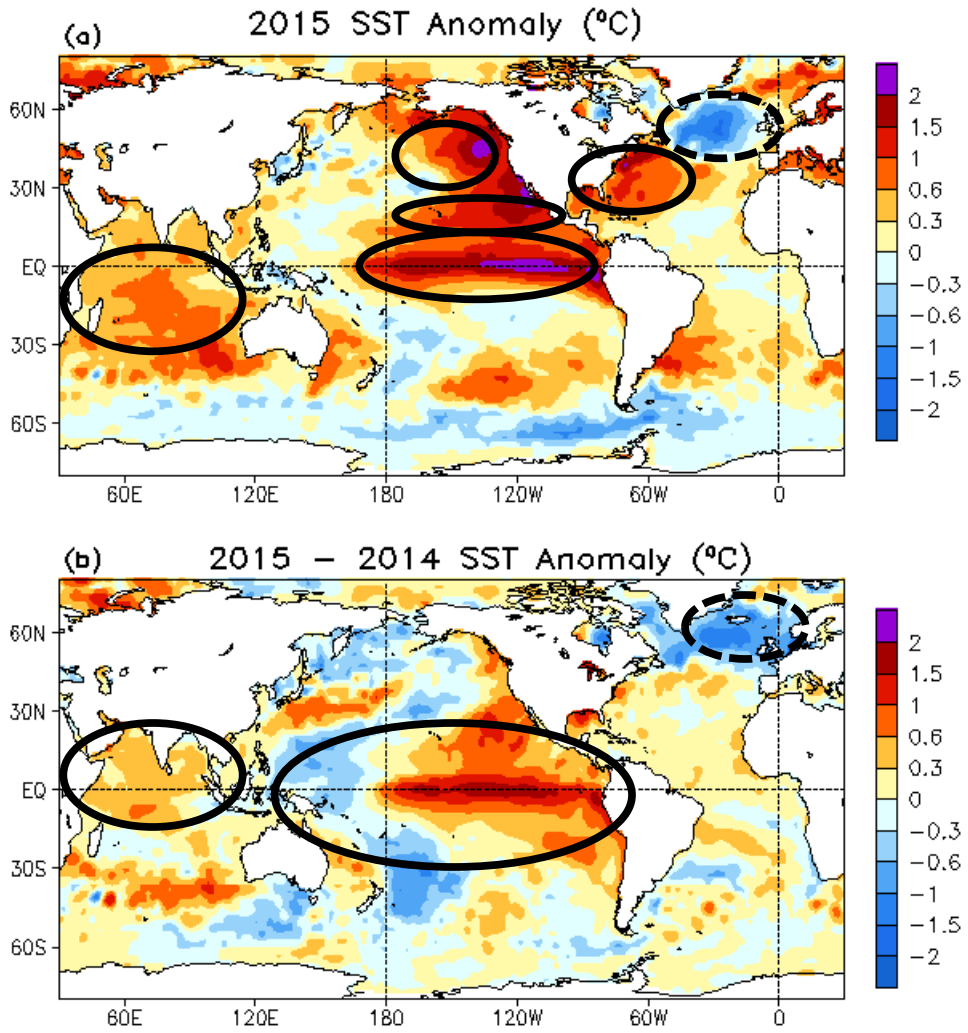
http://www.cpc.ncep.noaa.gov/products/GODAS/

This project to deliver real-time ocean monitoring products is implemented by CPC in cooperation with NOAA Ocean Climate Observation Program (OCO)

2015 Yearly Mean SST Anomaly and Tendency



- In the Pacific Ocean, positive SST anomaly (SSTA) exceeding 2°C was observed in C.-E. Pacific, near Baja California and off the coast of Pacific Northwest.
- In the North Atlantic, positive (negative) SSTA dominated along the east coast of North America (subpolar region).
- Positive SSTA exceeding 0.6°C dominated in the tropical Indian Ocean.

- The SST tendency was dominated by a dipole pattern in the tropical Pacific, reflecting the changes from central-Pacific warming in 2014 to eastern-Pacific warming in 2015.
- There was a substantial warming in the tropical Indian Ocean, partially due to influences of the 2015 El Nino.
- There was a substantial cooling in subpolar North Atlantic.

Global SST Section in the BAMS State of the Climate in 2015 by Xue et al.

Fig. 3.1. (a) Yearly mean OISST anomaly (°C, relative to 1981-2010 average) in 2015, (b) 2015 minus 2014 OISST anomaly.

Seasonal Mean SST Anomaly in 2015

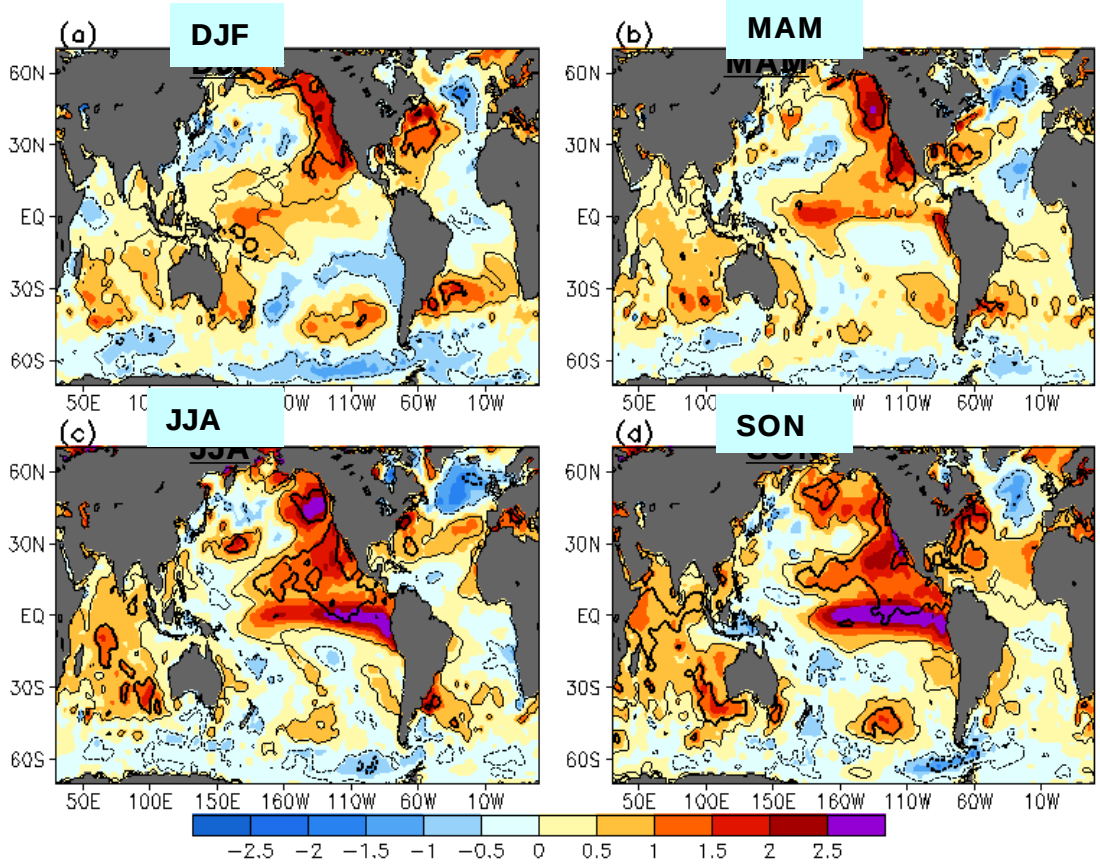


Fig. 3.2. Seasonal mean SSTA from OISST (shading, oC, relative to 1981-2010 average) for (a) December 2014 to February 2015, (b) March to May 2015, (c) June to August 2015 and (d) September to November 2015. The thin contours are +1 and -1 and the thick contours are +2.5 and -2.5 normalized seasonal mean SSTA based on seasonal mean standard deviation (STD) over 1981-2010.

Global SST Section in the BAMS State of the Climate in 2015 by Xue et al.

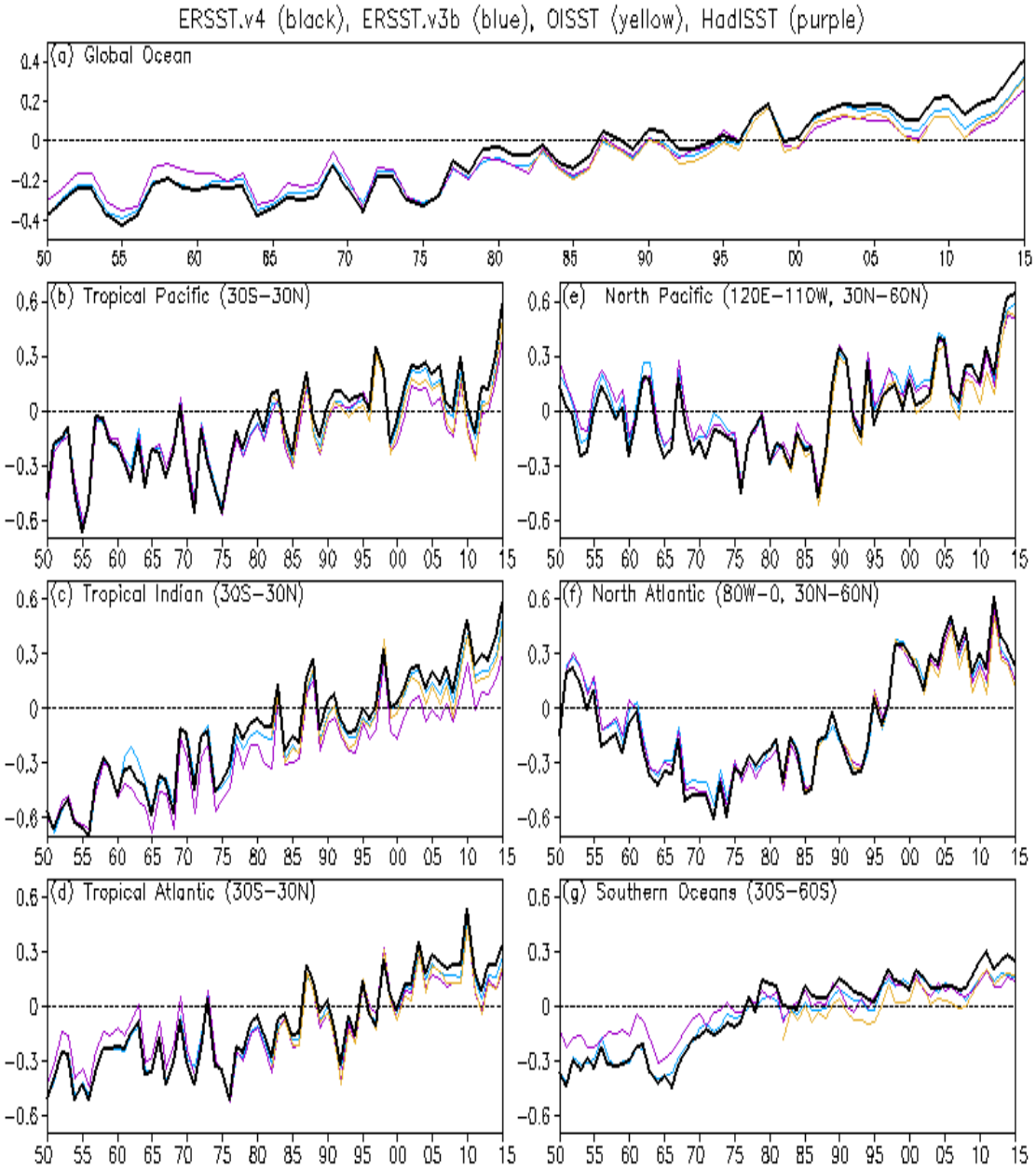
- **Winter 2014/2015: positive SSTA exceeding +1 STD in W. eq. Pac, exceeding+2.5 STD along west coast of N. America, negative SSTA exceeding -1 STD in S.E. Pac.**

- **Spring 2015: Positive SSTA shifted to near the Dateline, E. Pac. Warming, negative SSTA in S.E. Pac. diminished.**

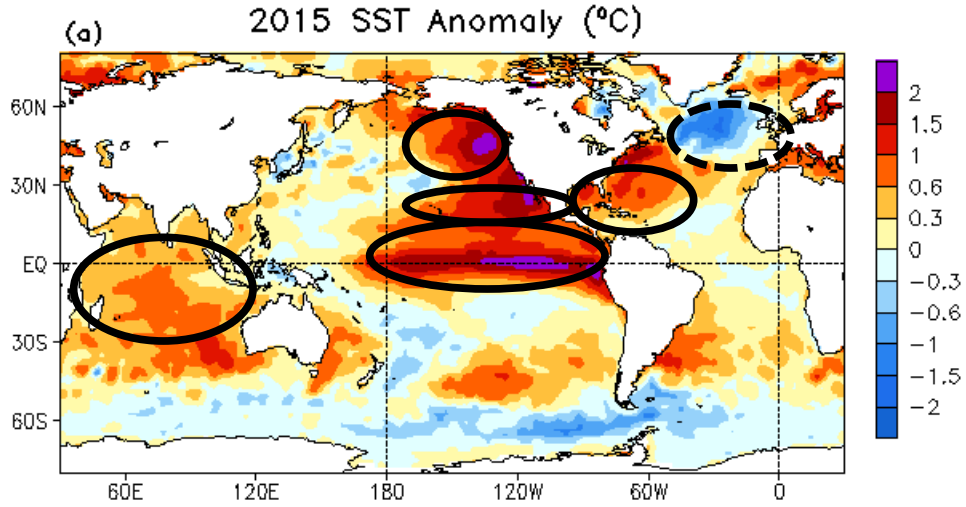
- **Summer 2015: SSTA exceeded +2.5ºC in E. eq. Pac., SSTA exceeded +2.5 STD from Baja California to Hawaii and in "Blob" region. Fall 2015: Positive SSTA increased in C. Pac. and persisted from Baja California to Hawaii**

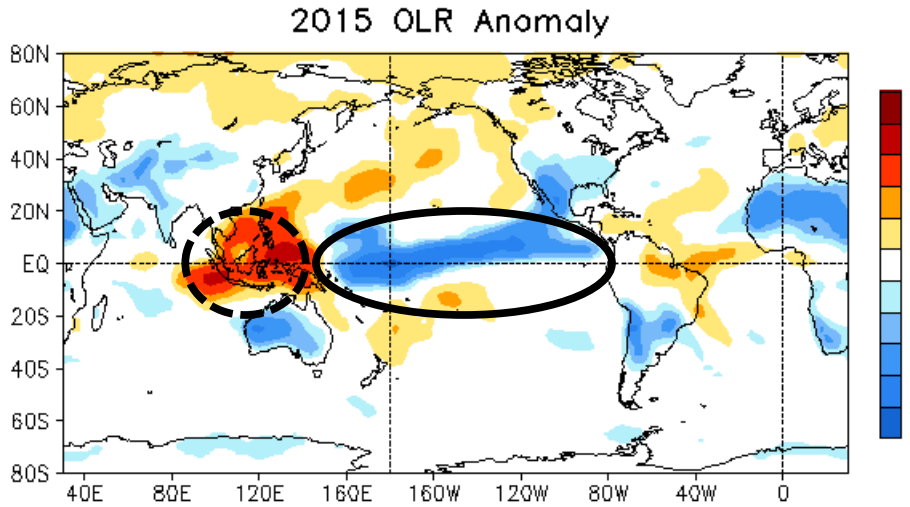
- **In the tropical Indian Ocean, SSTA exceeded +2.5 STD in fall. In the North Atlantic, positive SSTA along the east coast of N. America and negative SSTA in the subpolar region persisted through out the year.**

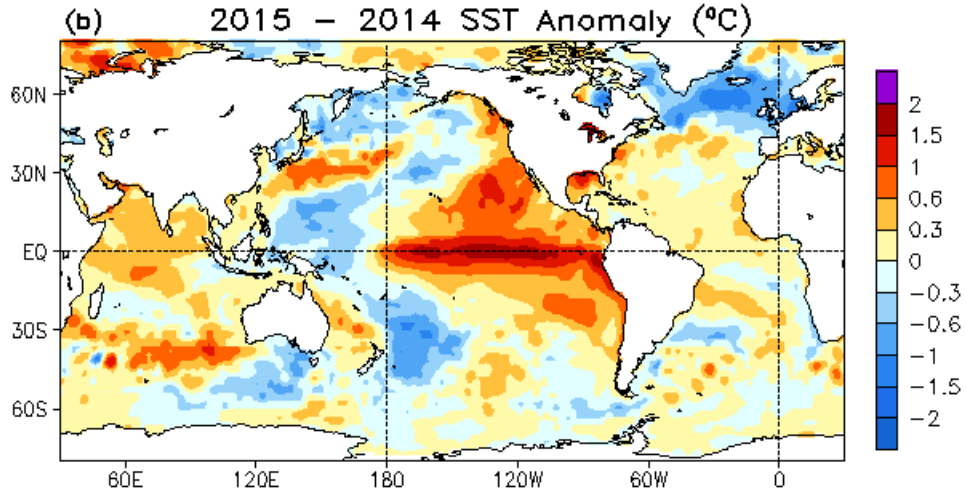
Yearly Mean SST Anomaly Indices

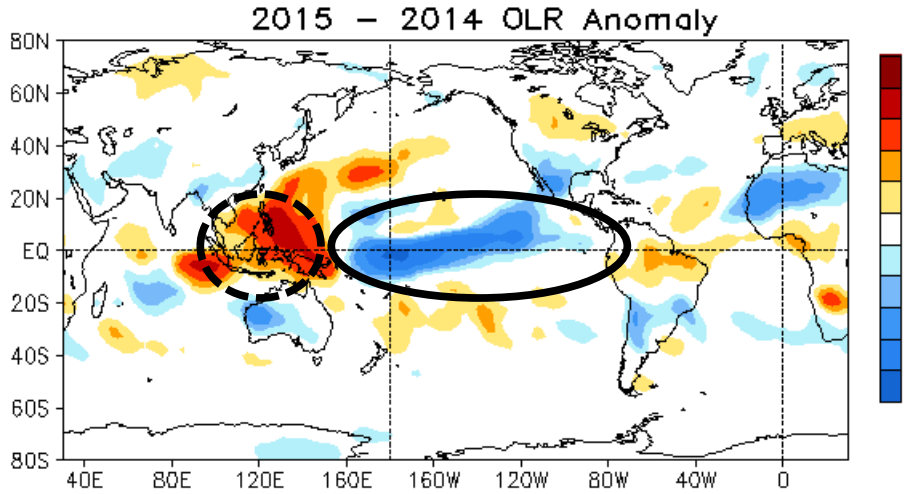


- **The global ocean SST increased by 0.08-0.11ºC in 2015, and 2015 surpassed 2014 becoming the warmest year since 1950.**
- **The warming trend in 2000-2015 (rising 0.13ºC, 0.07ºC, 0.08ºC and 0.08ºC decade^{-1} in ERSST.v4, ERSST.v3b, HadISST and OISST respectively) became comparable to the warming trend in 1950-1999 (rising 0.09ºC, 0.07ºC, and 0.06ºC decade^{-1} in ERSST.v4, ERSST.v3b and HadISST respectively).**
- **The mean SST in the tropical Pacific increased by 0.23-0.29ºC in 2015, and 2015 surpassed 1997 becoming the warmest year since 1950.**
- **The mean SST in the tropical Indian Ocean increased by 0.13-0.2ºC in 2015, becoming the warmest year since 1950.**
- **The North Pacific SSTA reached a historical high in 2014, and changed little from 2014 to 2015.**
- **The North Atlantic SSTA reached a historical high in 2012 and then cooled from 2012 to 2015.**

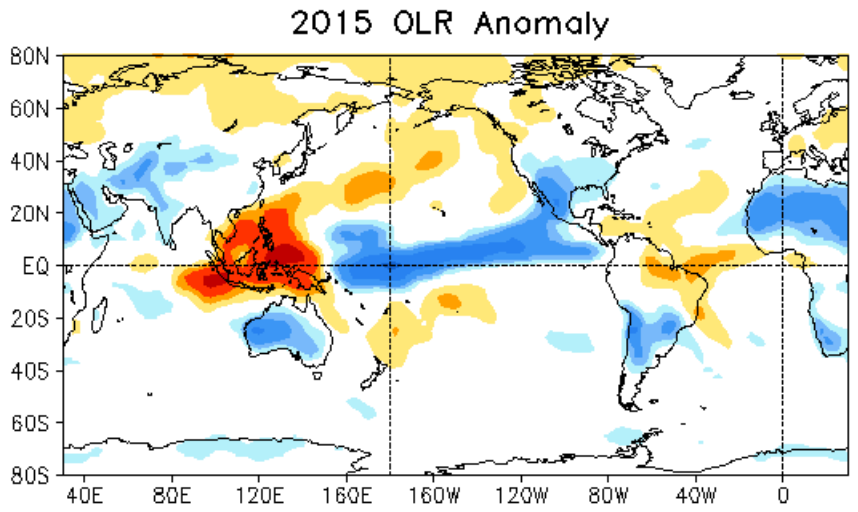


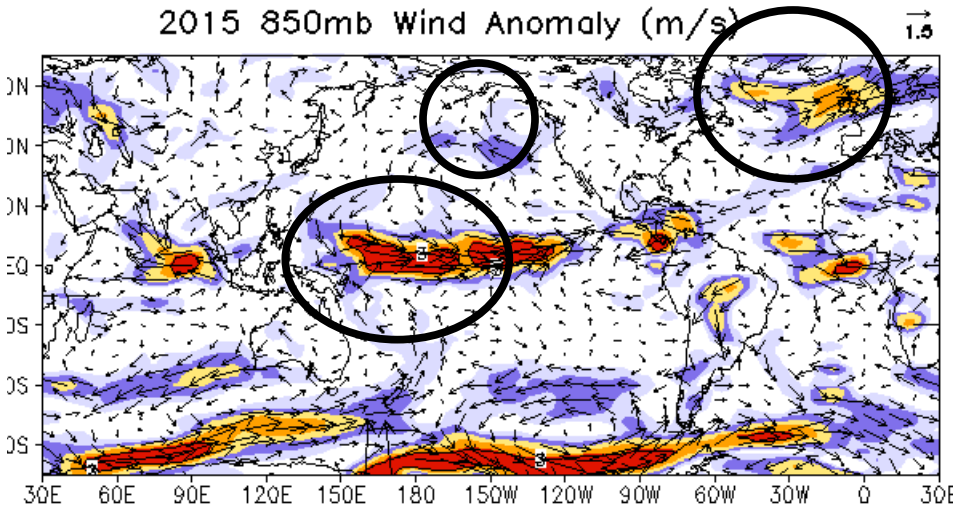


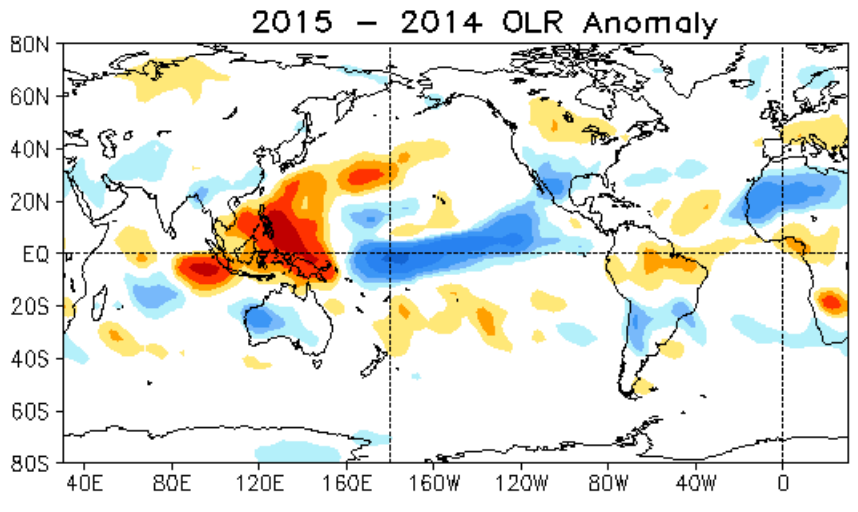


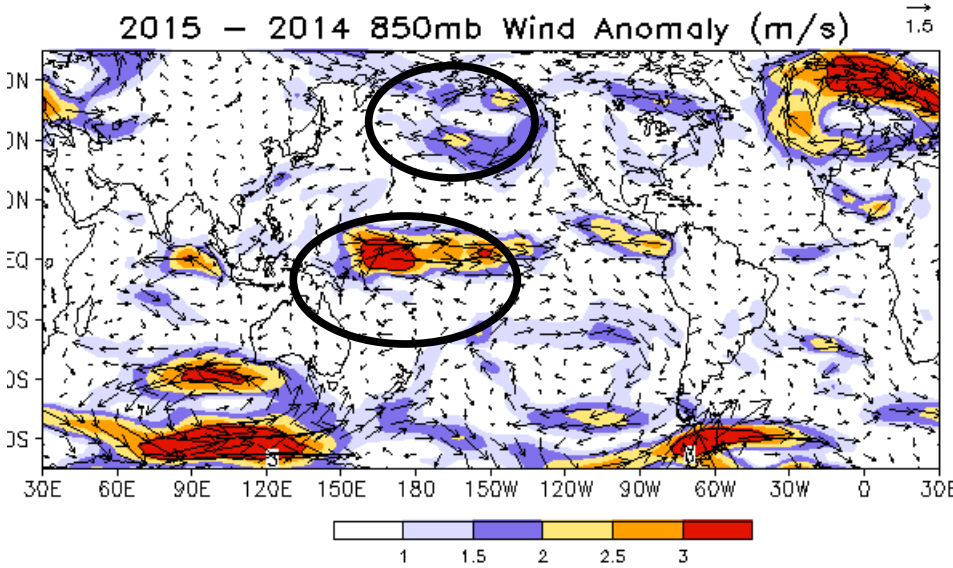


- **In 2015 the OLR anomaly pattern was characterized by enhanced (suppressed) convection in the central-eastern Pacific and ITCZ (Maritime Continents), indicating signature of the El Nino.**
- **The 2015 minus 2014 OLR anomaly was dominated by the 2015 anomaly pattern.**



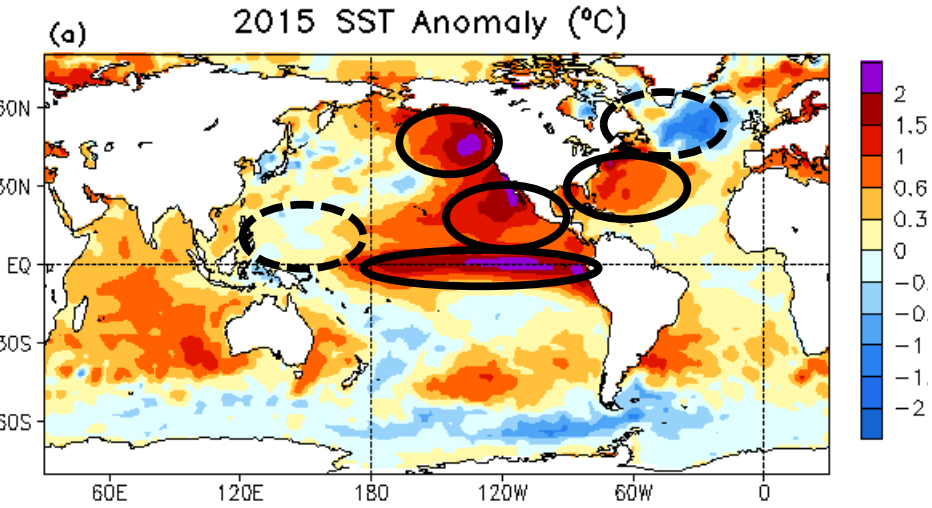


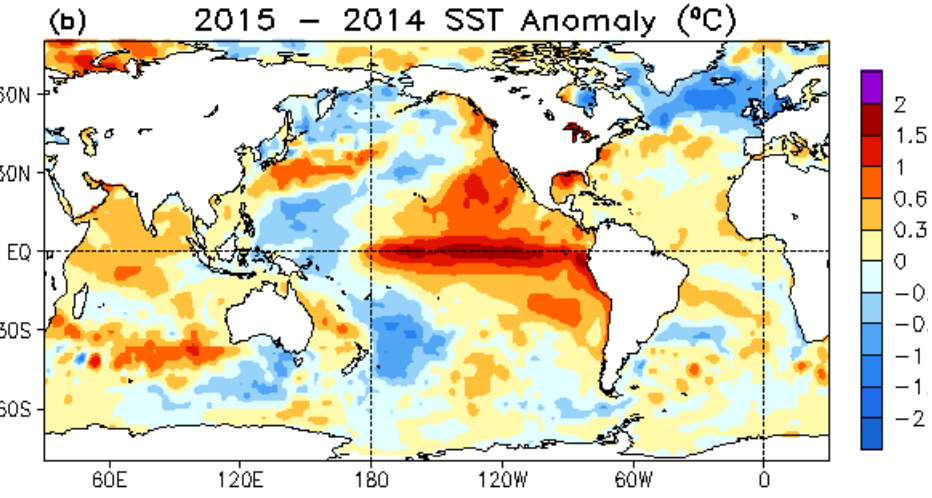




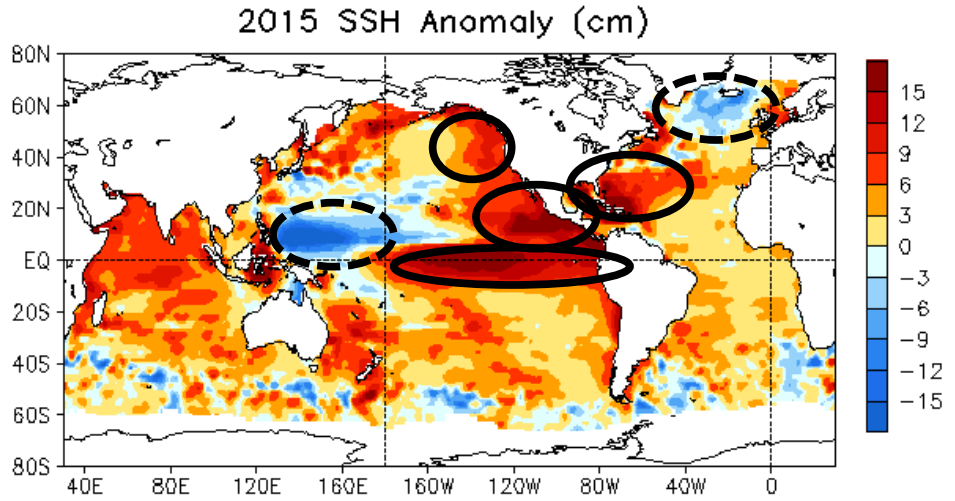
- **In 2015, the enhanced convection near the Dateline and along the ITCZ was associated with westerly wind anomalies centered north of the equator.**
- **Anticyclonic anomaly circulation dominated in Gulf of Alaska, while cyclonic anomaly circulation dominated in the subpolar North Atlantic.**

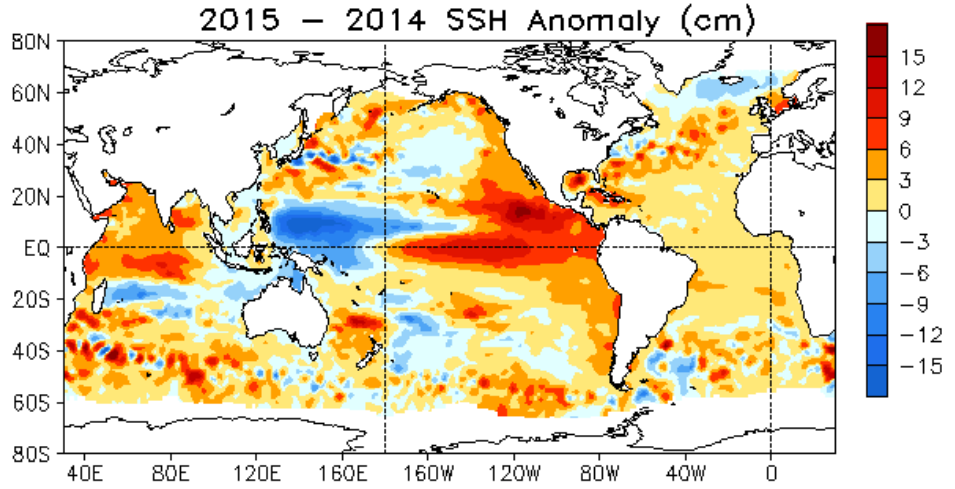
OI SST





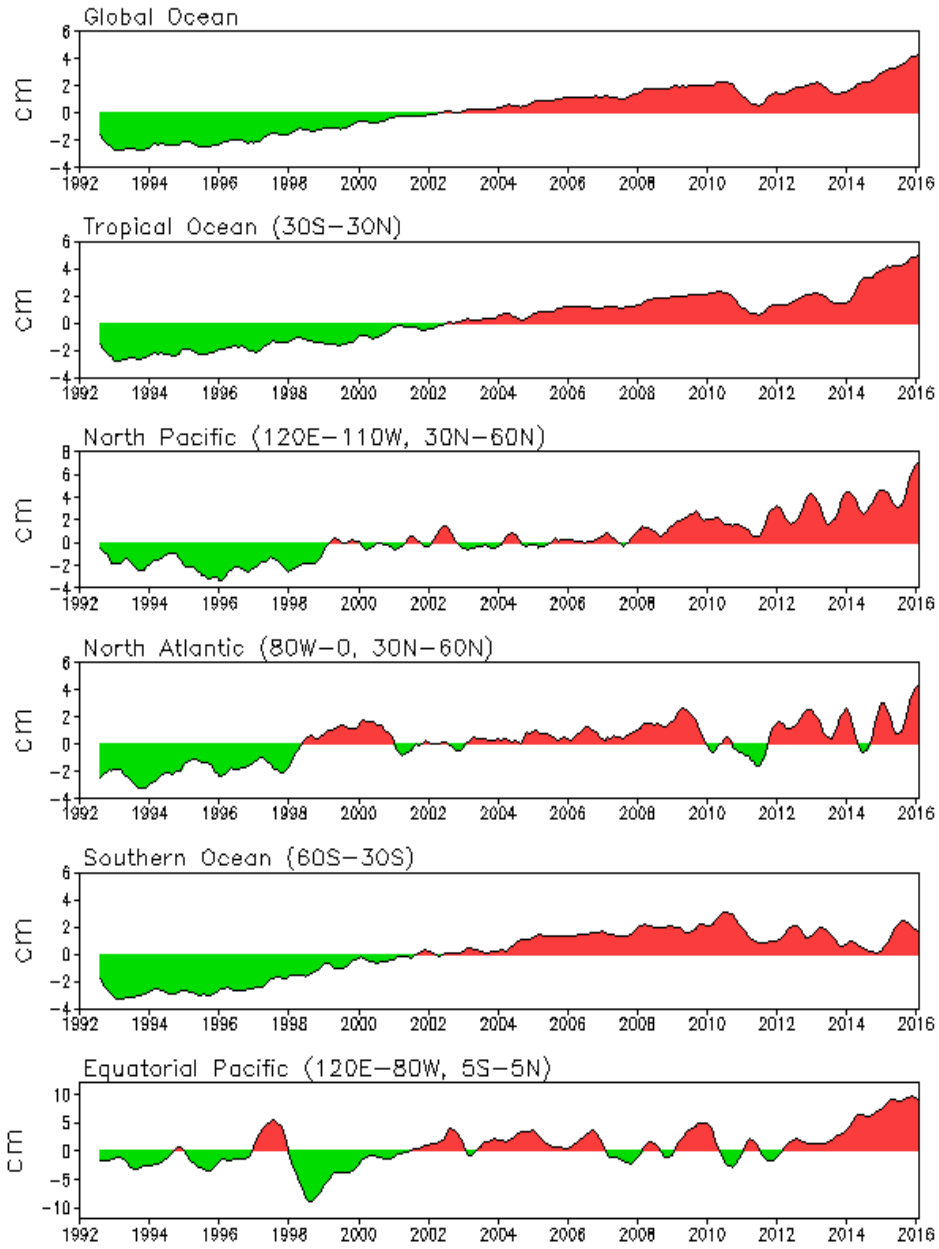
AVISO SSH





- **Pattern of SST and SSH anomalies were consistent except in the northwestern Pacific.**
- **The tendency of SST and SSH anomalies were also consistent.**

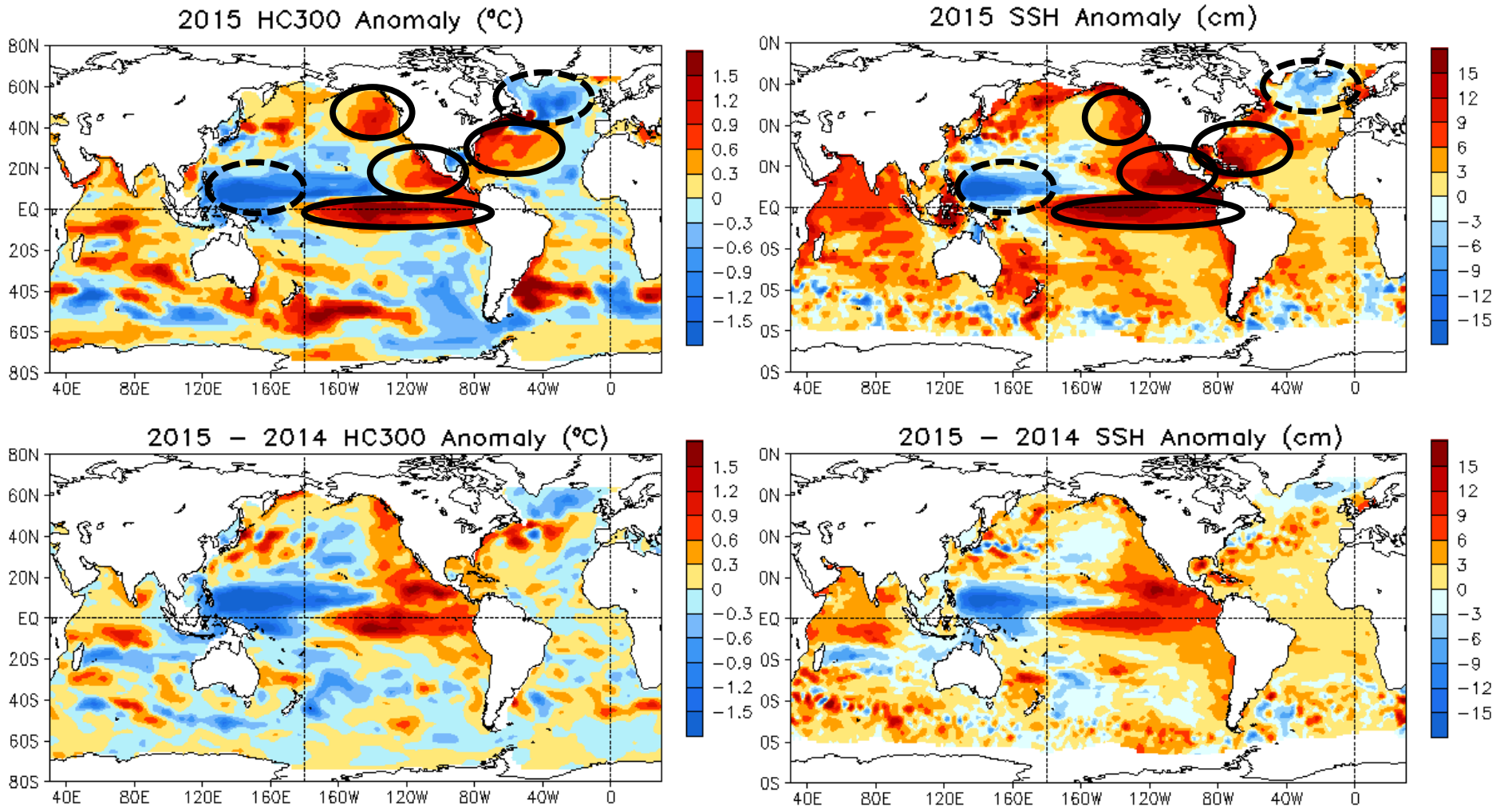
SSH Time Series (Aviso Altimetry, Climo. 1993–2013)
(5 Month Running Mean)



- **The mean SSH anomaly in the global ocean increased in 2015, reaching a historical high since 1992.**
- **The mean SSH anomaly in the tropical Ocean also increased in 2015, reaching a historical high since 1992.**
- **The mean SSH anomaly in North Pacific and North Atlantic also reached a historical high since 1992.**
- **The mean SSH anomaly in the Southern Oceans has increased in 2015.**
- **The mean SSH anomaly in the equatorial Pacific reached a historical high since 1992.**

GODAS HC300

AVISO SSH

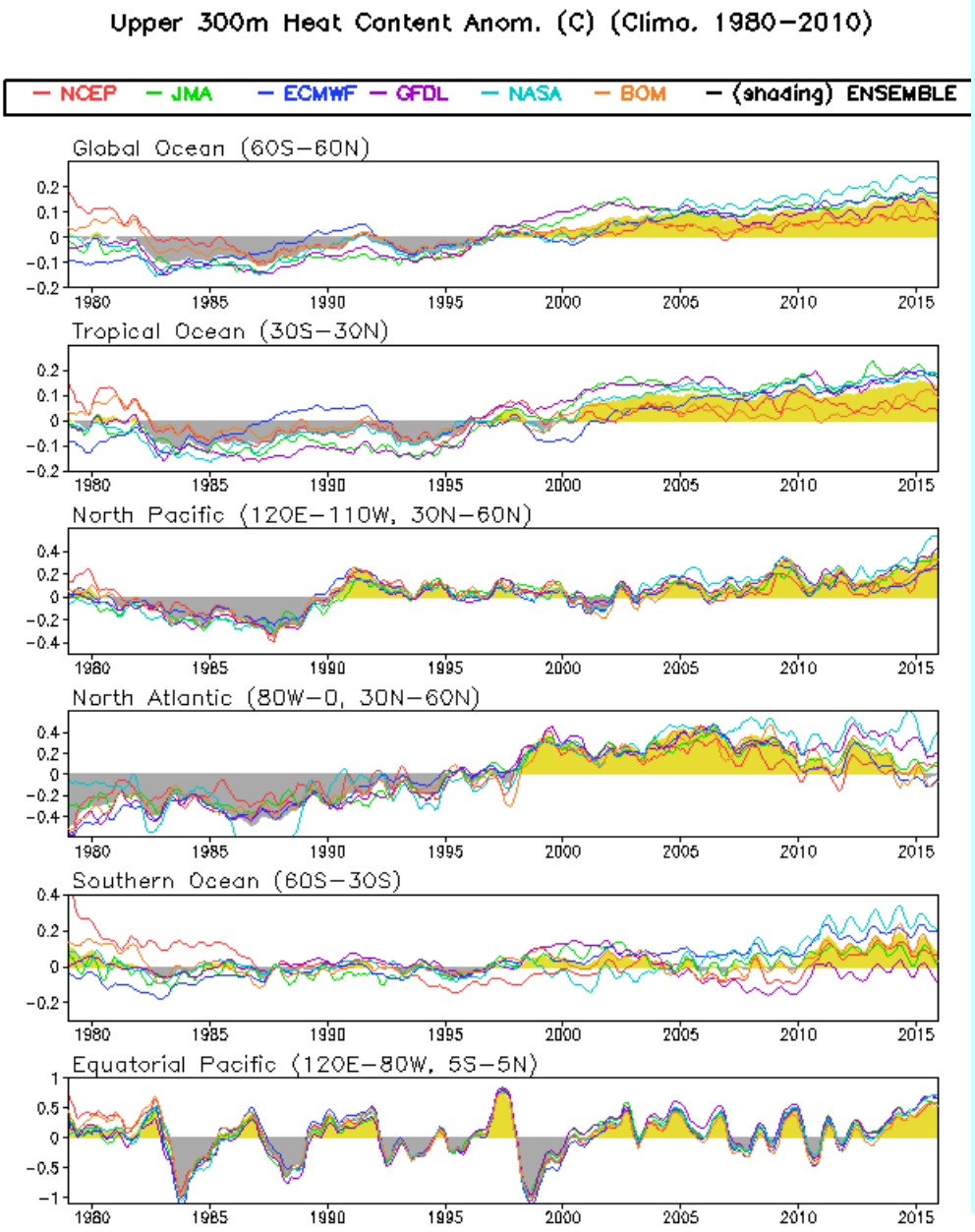


- **Pattern of HC300 and SSH anomalies were largely consistent except in the southeastern Pacific and tropical Atlantic Ocean.**

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

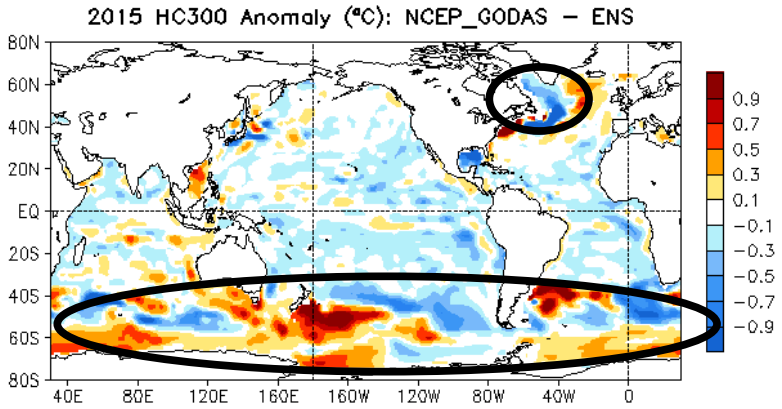
Real-time Ocean Reanalysis Intercomparison Project

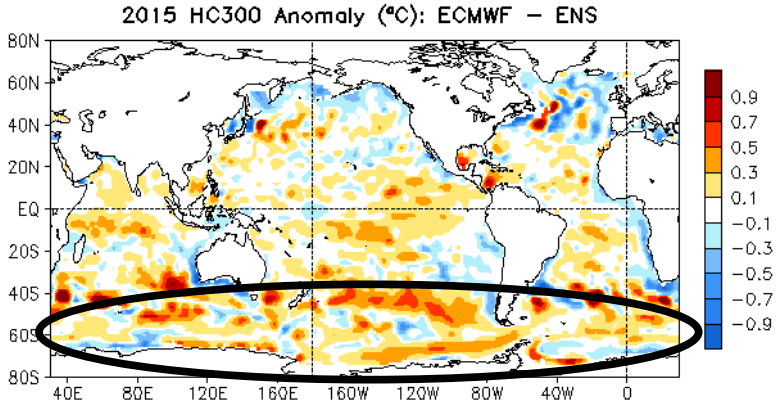
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)

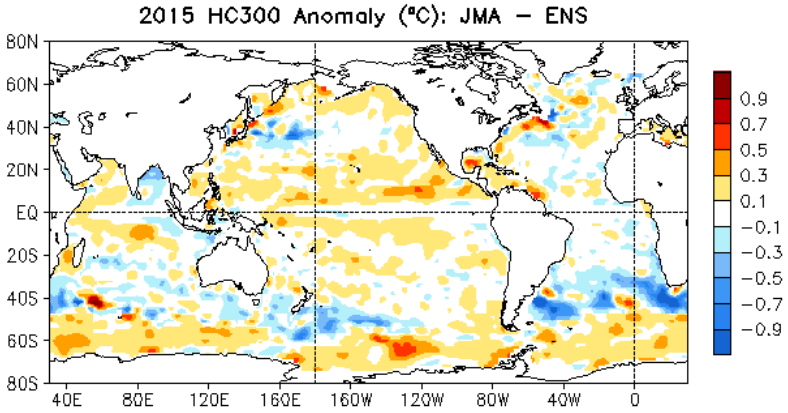


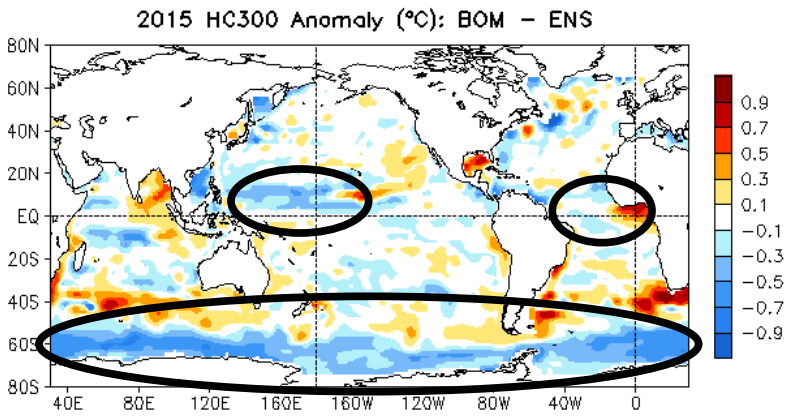
- **There were large uncertainties in the basin averages of HC300 anomalies.**
- **Based on the ensemble mean, the mean HC300 anomaly in the global ocean reached a historical high since 1979.**
- **The mean HC300 anomaly in the tropical Ocean and North Pacific also reached a historical high since 1979.**
- **The mean HC300 anomaly in North Atlantic returned to near-normal in 2015.**
- **There were large uncertainties in HC300 anomalies in Southern Oceans.**
- **The mean HC300 anomaly in the equatorial Pacific increased in 2015 and became the second highest behind 1997.**

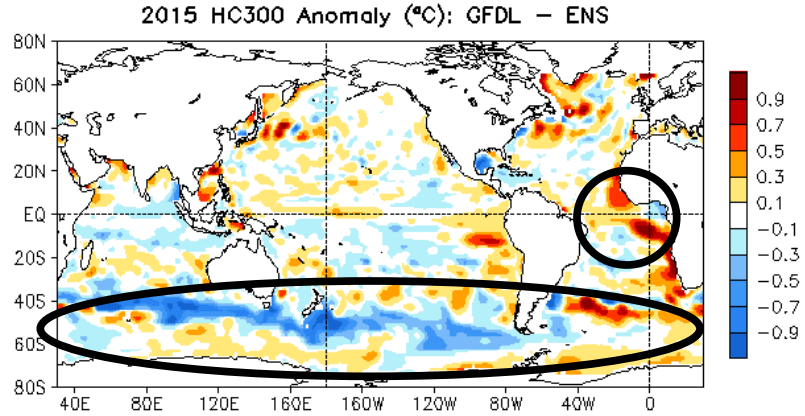
Differences of Individual Product from Ensemble Mean

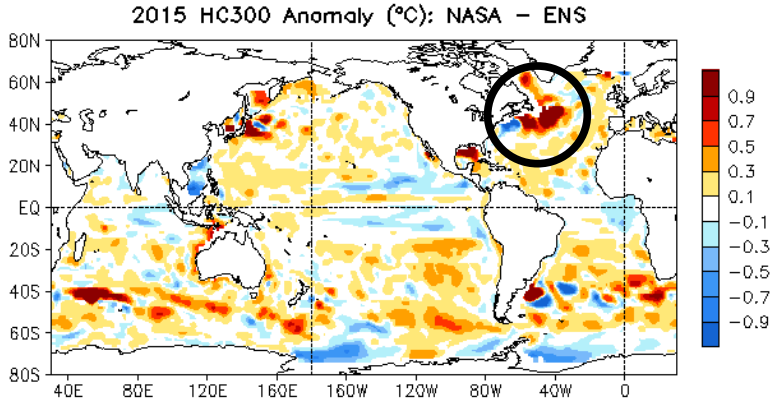






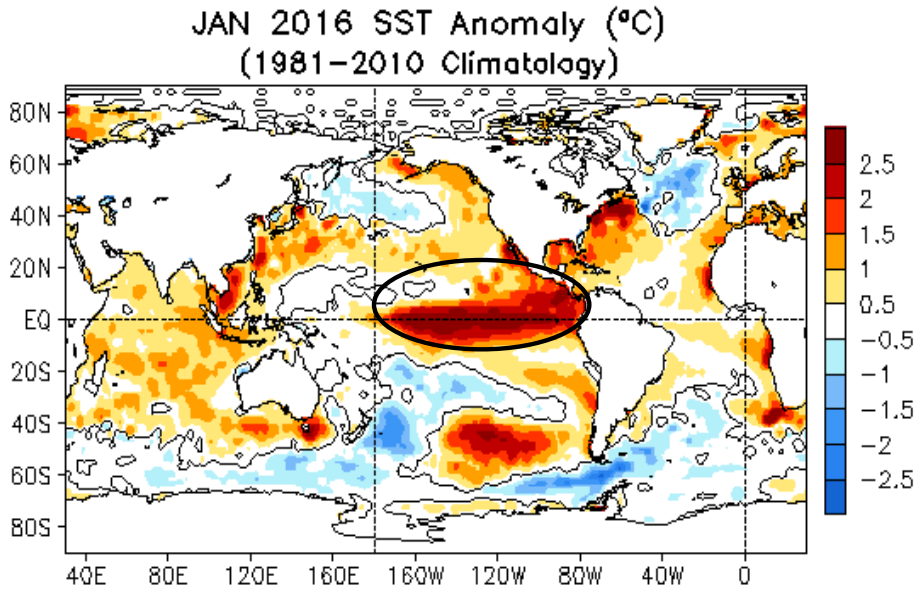


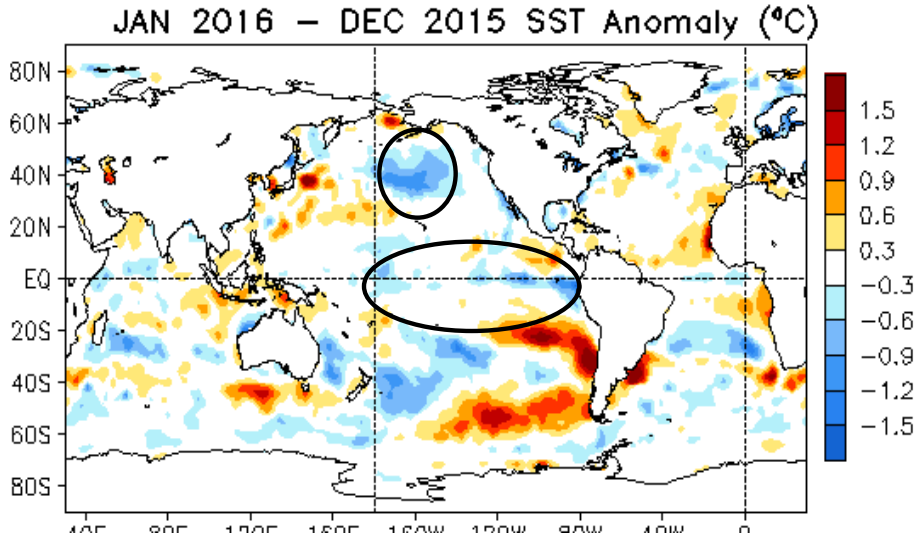




Highlights in January 2016

Global SST Anomaly (°C) and Anomaly Tendency



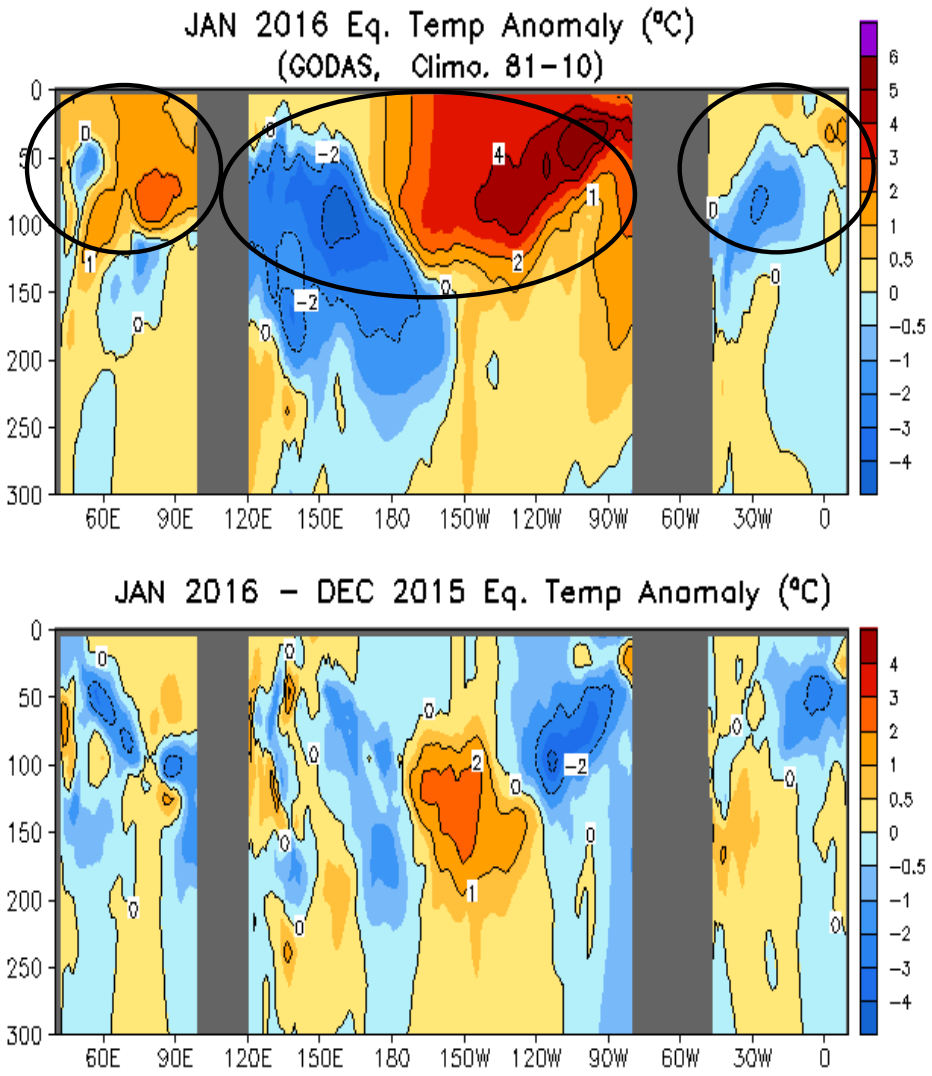


- **SSTA exceeded +2.5°C across the central-eastern equatorial Pacific.**
- **Positive (negative) SSTA presented near the eastern coasts of North America (subpolar North Atlantic).**
- **Positive SSTA dominated in the tropical Indian Ocean.**

- **Negative SSTA tendency was observed along the equatorial Pacific and mid-latitude North Pacific.**

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

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

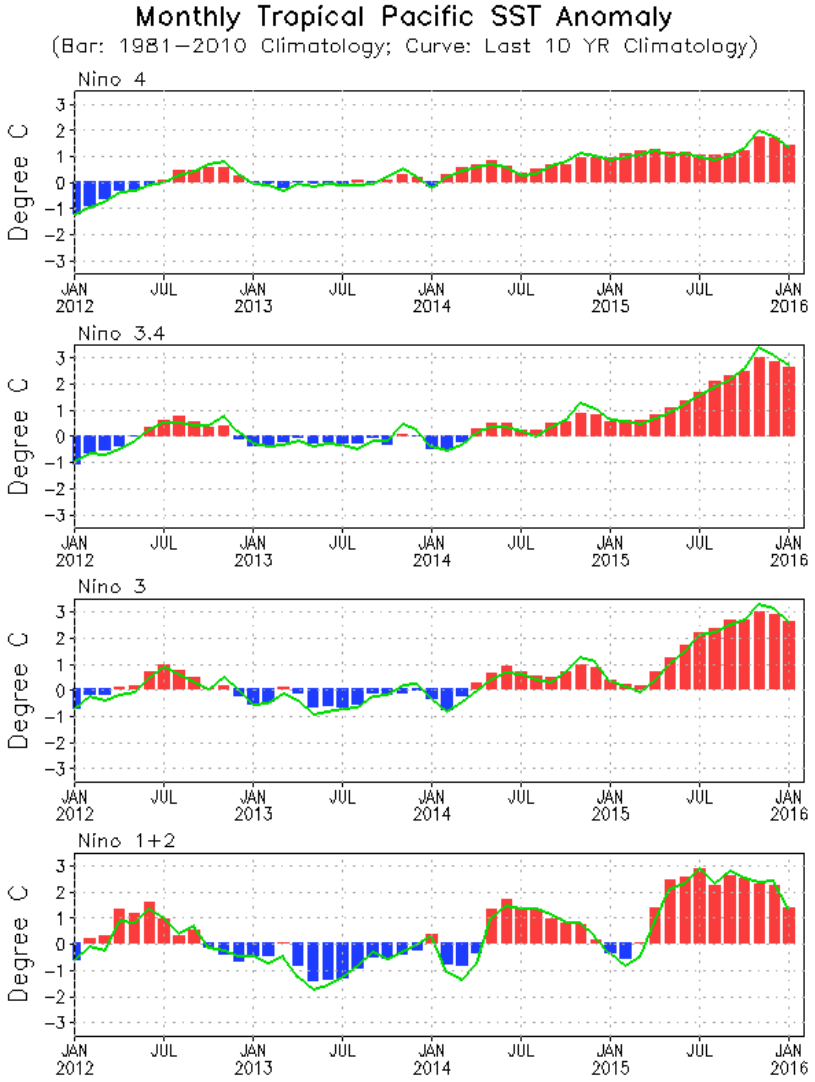


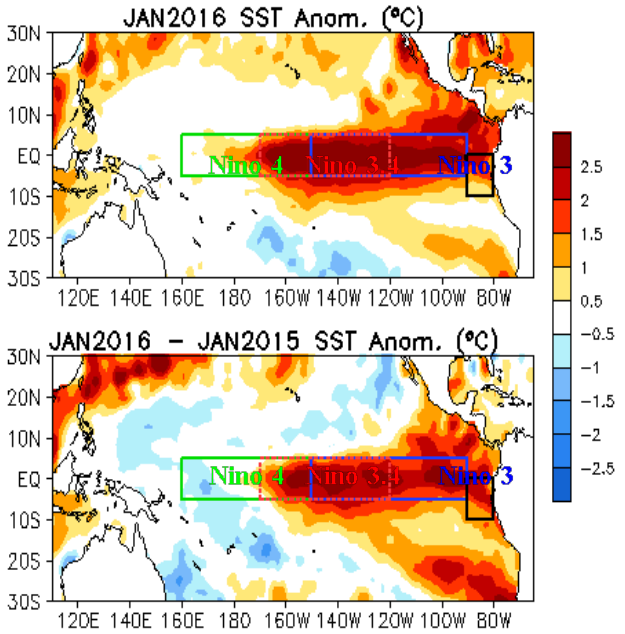
- Positive (negative) temperature anomalies presented in the central-eastern (western) equatorial Pacific.
- Positive temperature anomalies dominated in the upper equatorial Indian Ocean.

- Anomaly tendency was most prominent near the thermocline in the central and eastern equatorial Pacific.
- Negative anomaly tendency was observed in the equatorial Atlantic.

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





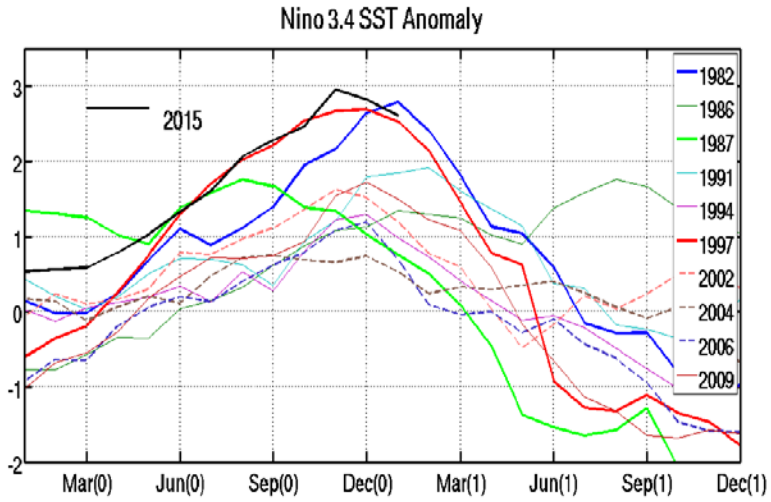
- **All NINO indices decreased in Jan 2016.**

- **Nino3.4 = +2.6°C in Jan 2016, which is based on weekly OI SST.**

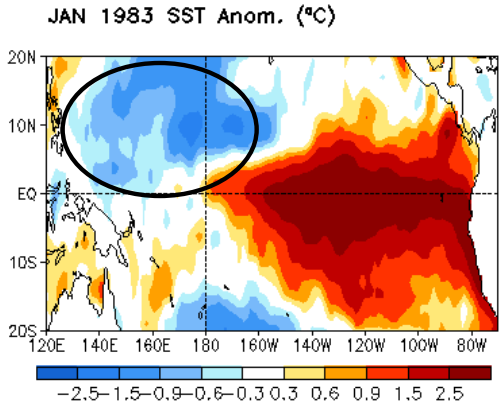
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 (bar) and last ten year (green line) means.

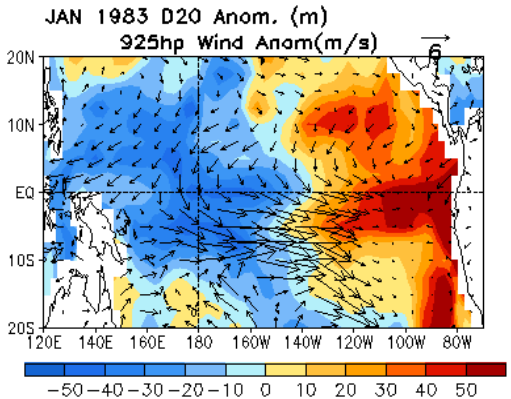
SST, D20 and 925hPa

Wind Anomalies

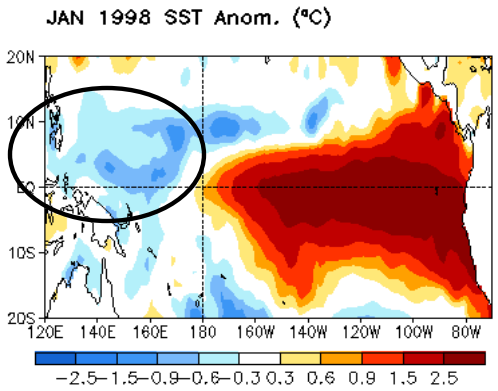


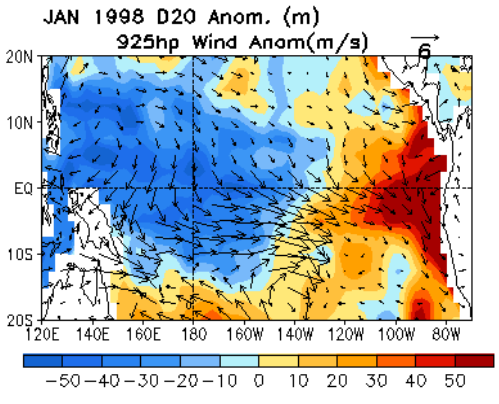
1983



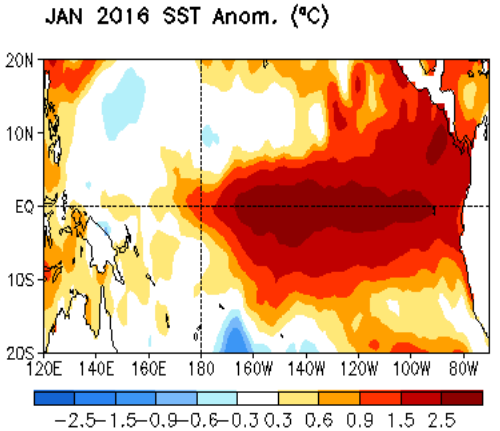


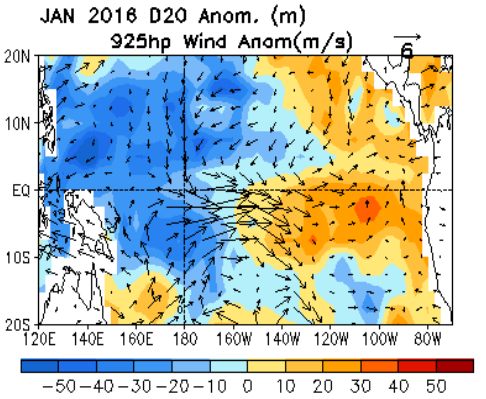
1998





2016

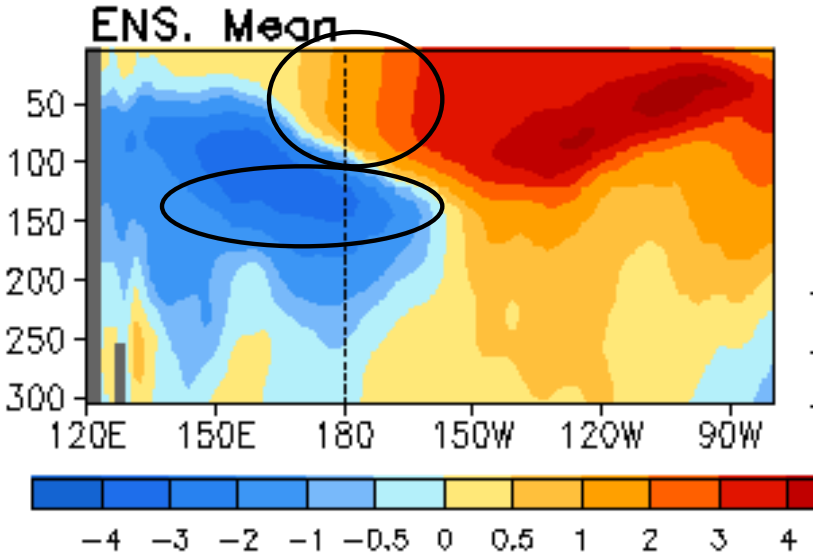




Real-time Ocean Reanalysis Intercomparison Project

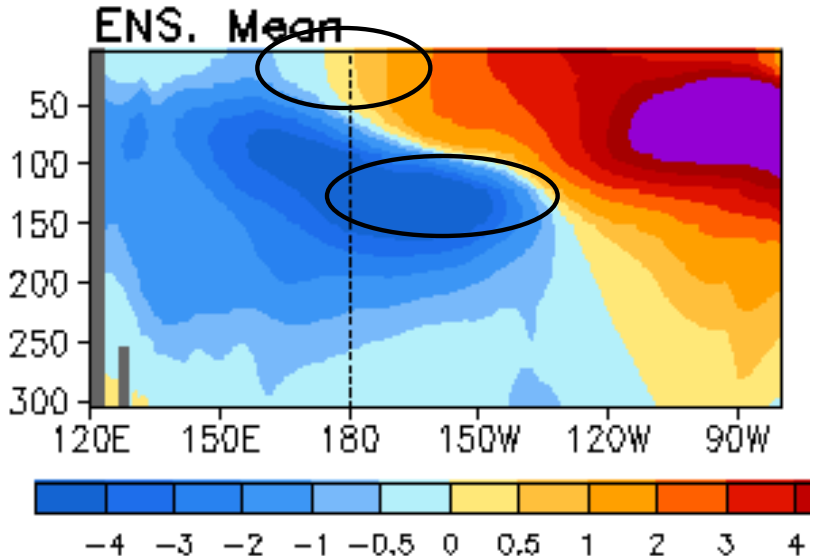
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)

Jan 2016

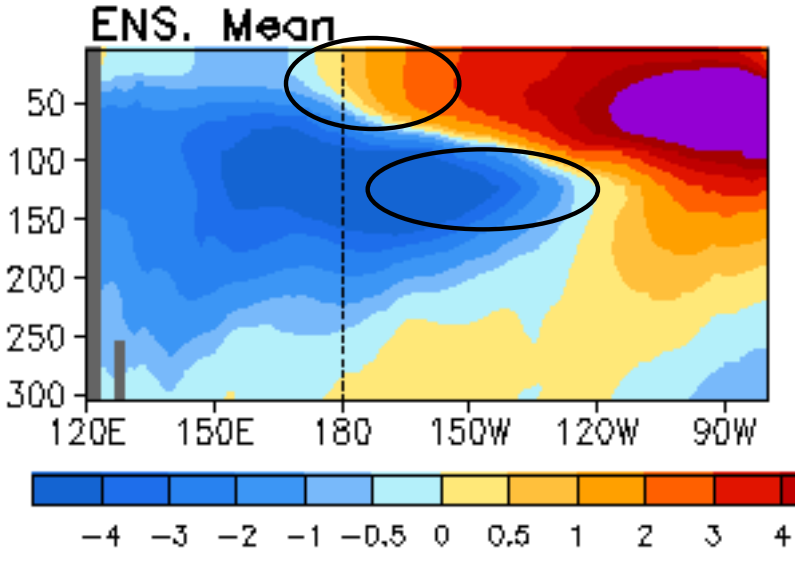


- **The equatorial subsurface temperature anomalies in Jan 2016 were much weaker than those in Jan 1983 and 1998. In addition, there was a westward shift of warm anomaly near the surface and cold anomaly near the thermocline in 2016 relative to 1983 and 1998.**

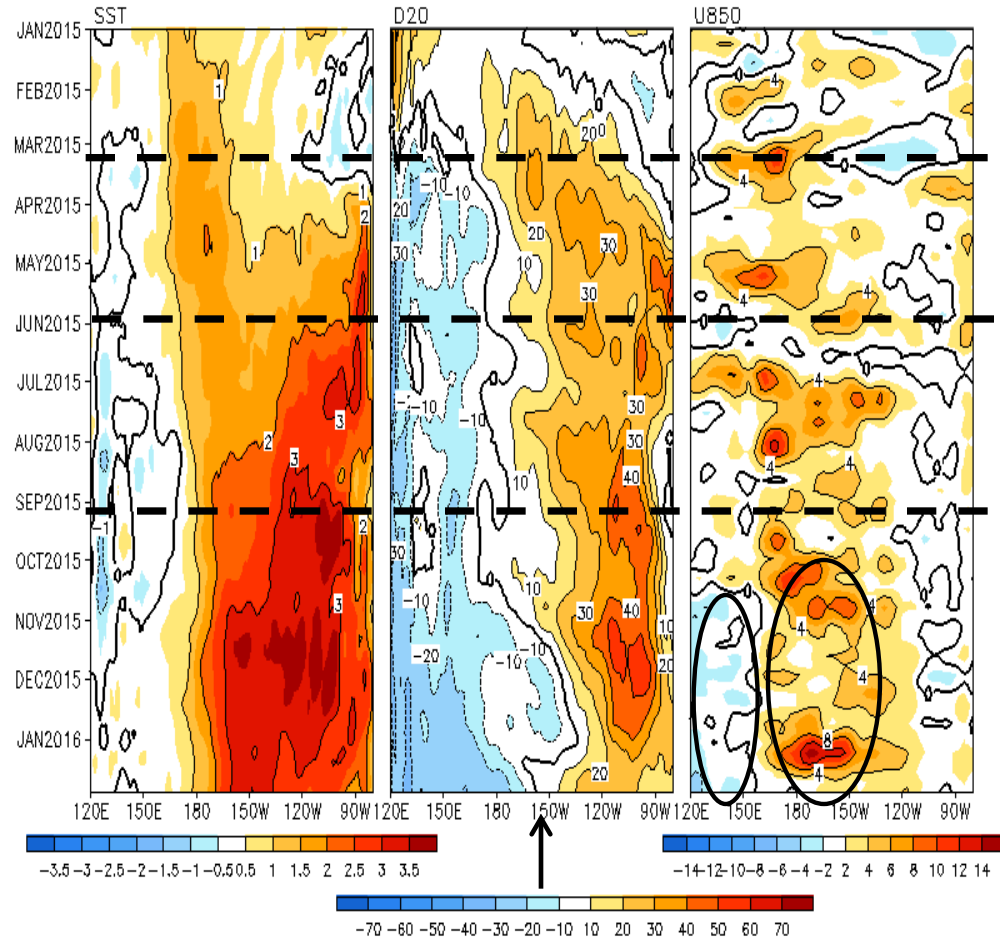
Jan 1983



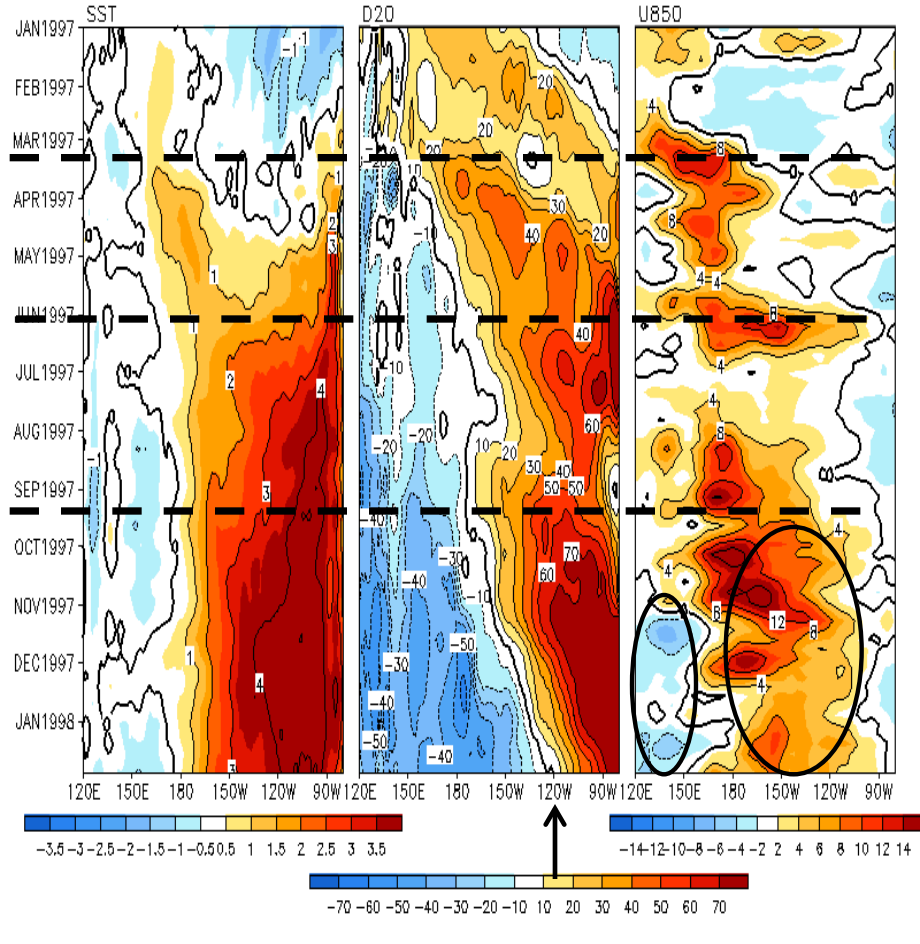
Jan 1998



2015

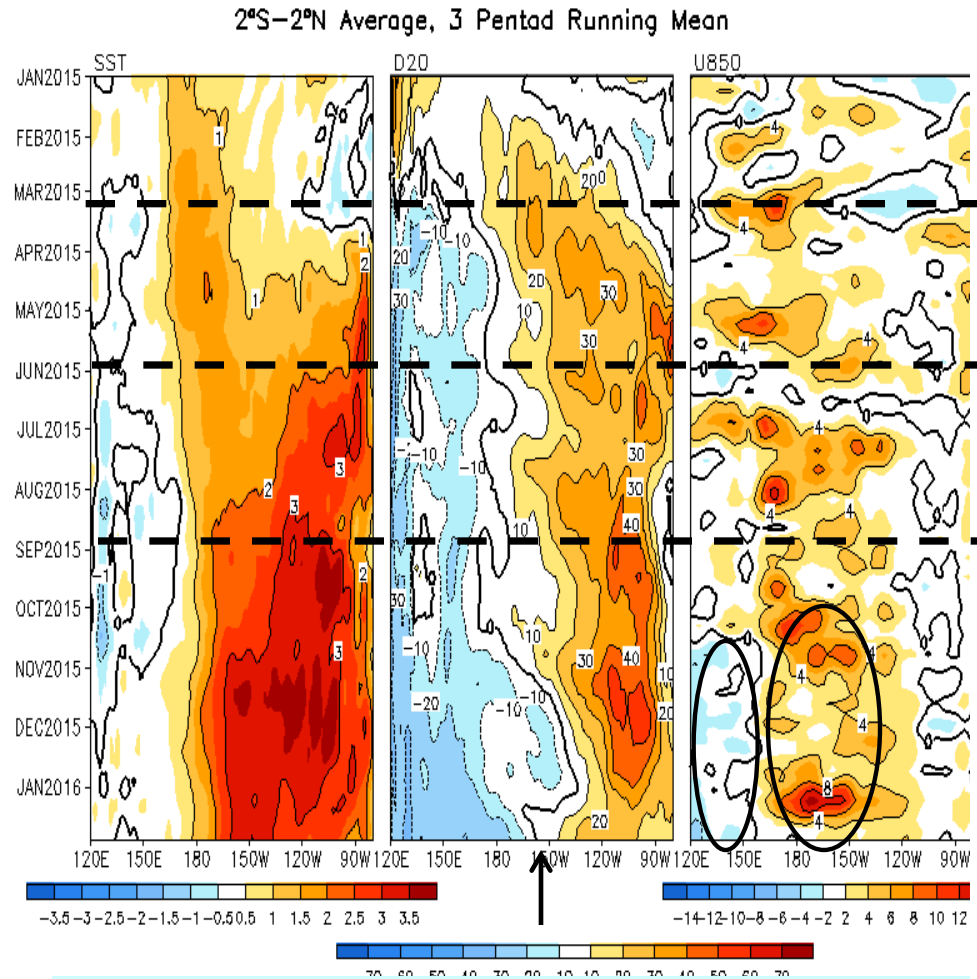


1997

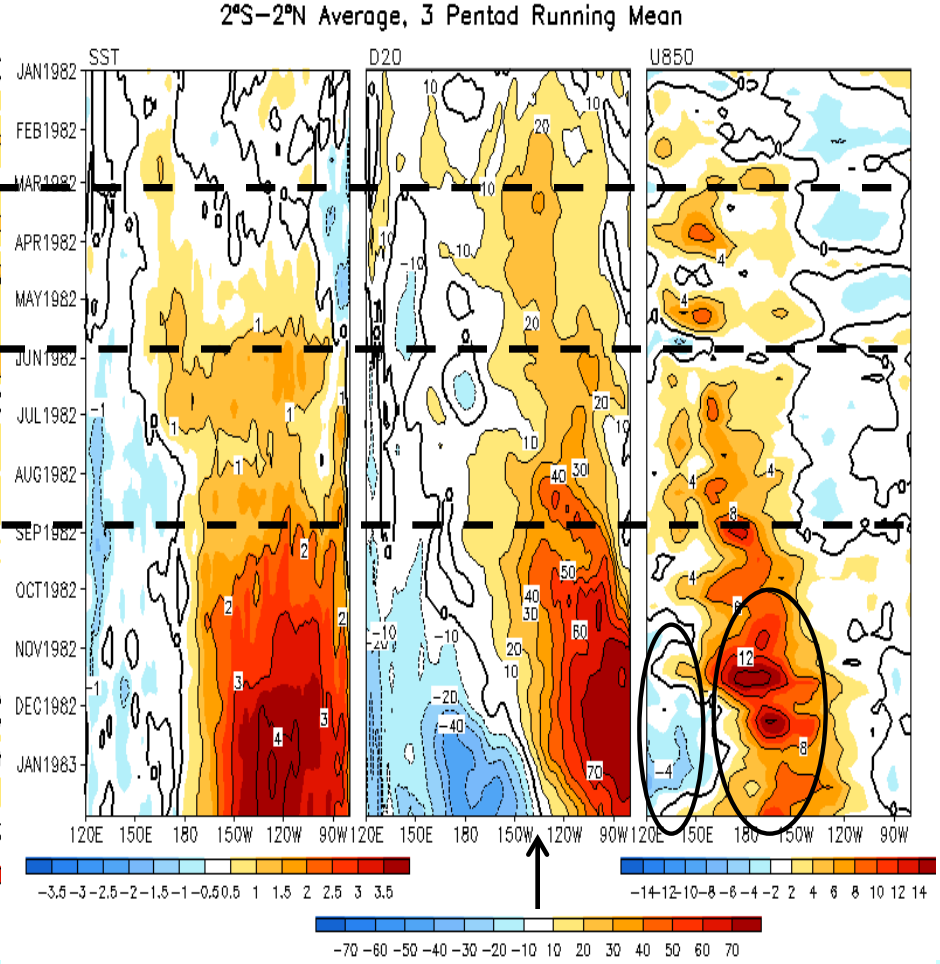


- **Compared to the 1997 El Nino, westerly wind anomalies in the 2015 El Nino were much weaker.**
- **Consistent with weaker westerly wind anomalies, the 20°C depth anomaly dipole, positive in the east and negative in the west, was much weaker.**
- **Negative D20 anomalies extended further eastward in Jan 1998 than in Jan 2016.**

2015

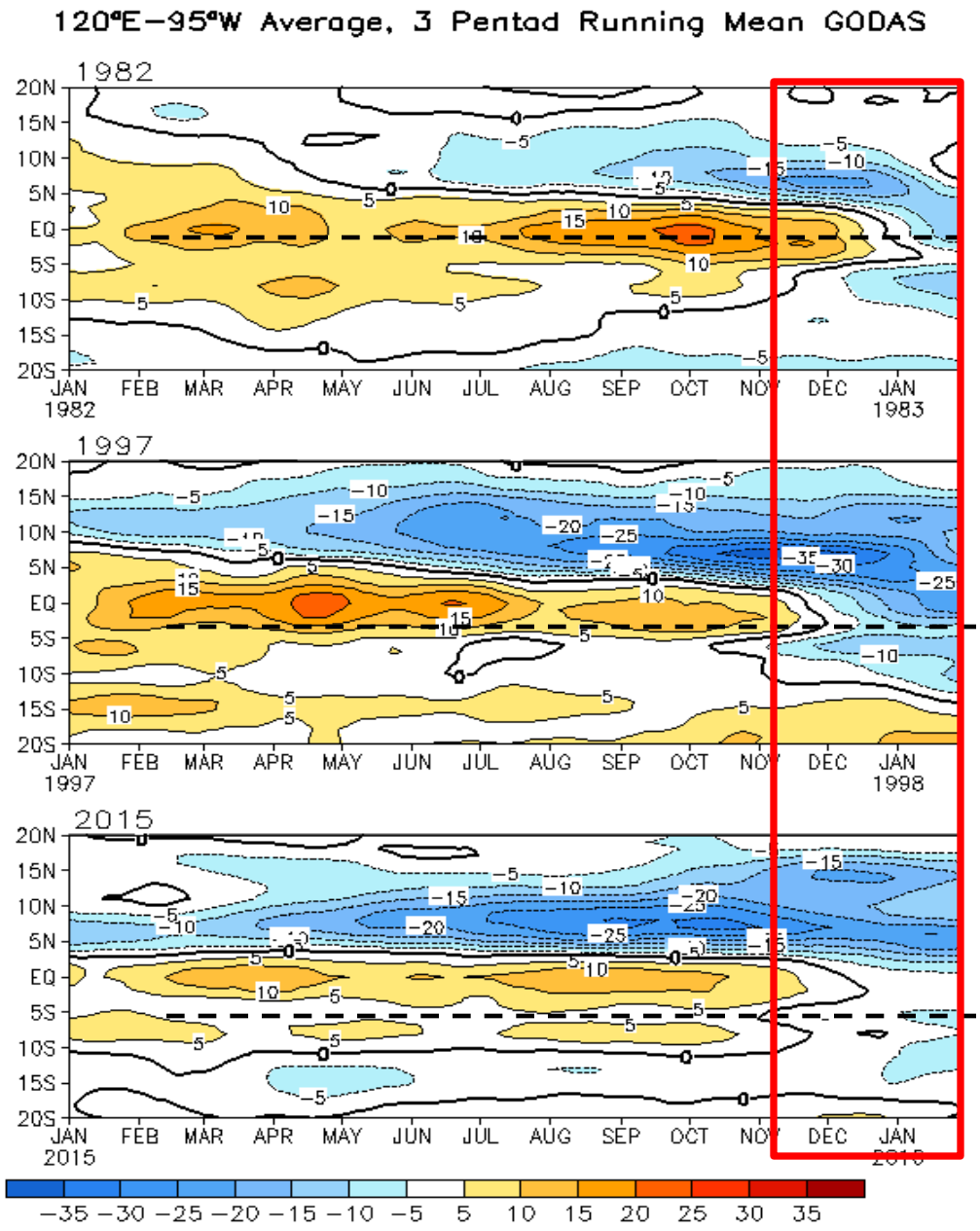


1982

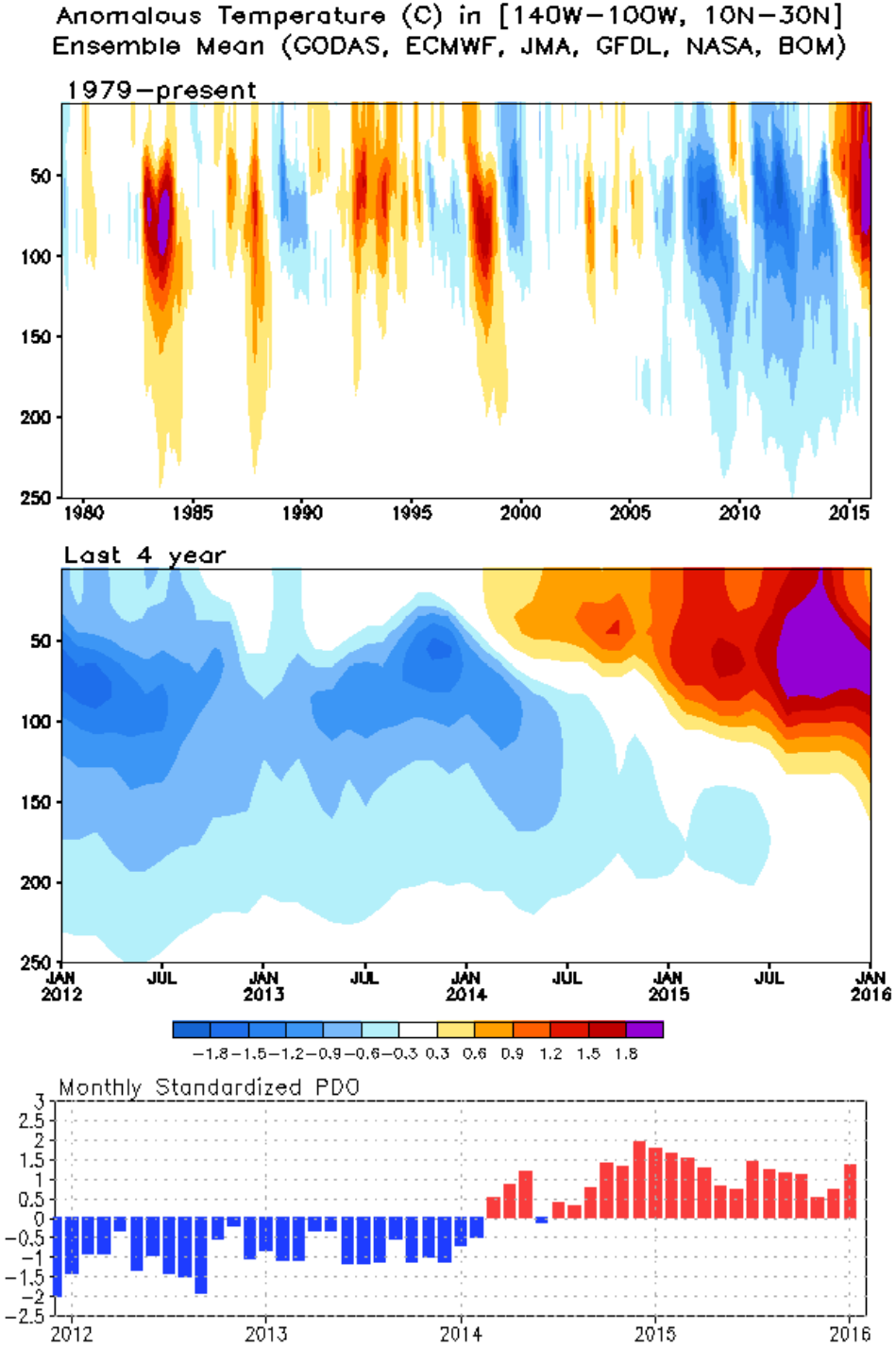


- **The SST and 20°C depth anomalies were stronger in 2015 than those in 1982 before September.**
- **However, associated with strong westerly wind anomalies since September 1982, the amplitude of 20°C depth anomaly grew rapidly and became stronger than that in 2015 since then.**
- **Negative D20 anomalies extended further eastward in Jan 1983 than in Jan 2016.**

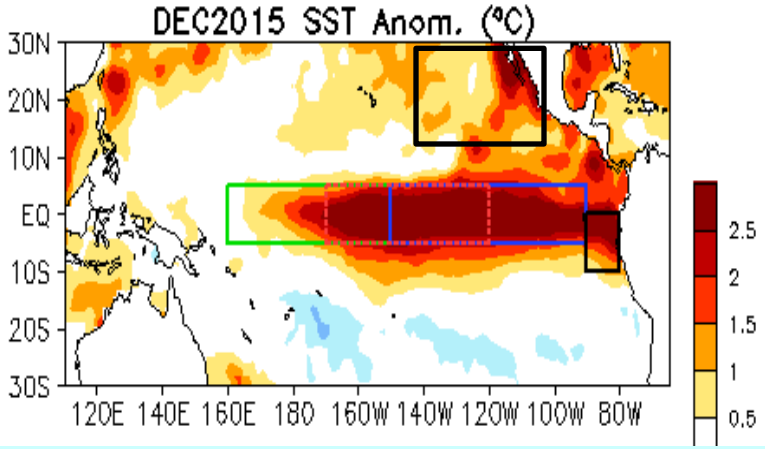
Zonal Average of 20°C Depth anomaly



- There was warm (cold) water built up in 3S-3N (5N-10N) in spring 2015, which was similar to that in spring 1997 except the anomalies were weaker and more confined near the equator.
- For both the 1997 and 2015 El Nino, there was a rapid enhancement of the cold anomaly around 5N-15N in spring and summer.
- During Oct-Dec, there was a rapid discharge of warm anomaly in 5S-5N in 1982 and 1997. Comparatively, the equatorial warm water discharge was much weaker in 2015.

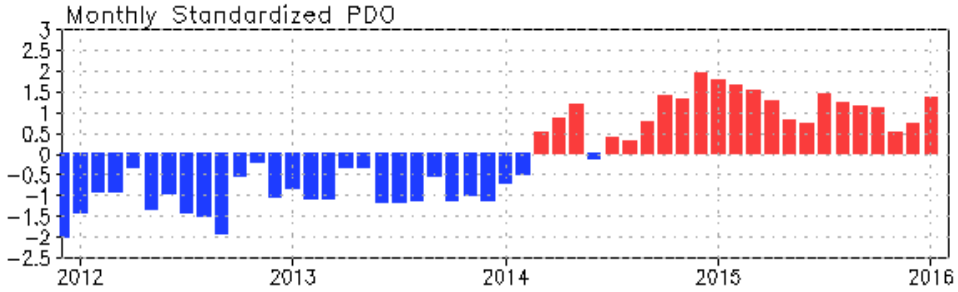


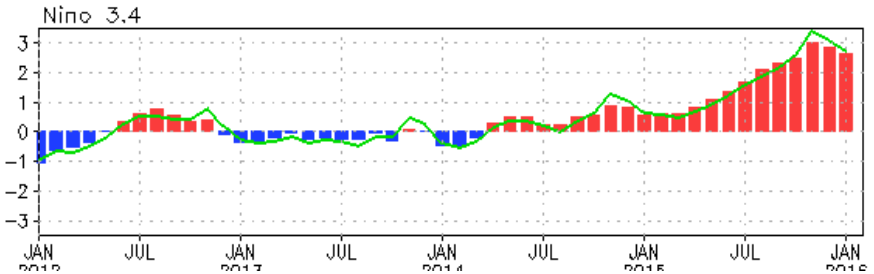
NE Subtropical Pacific Warming

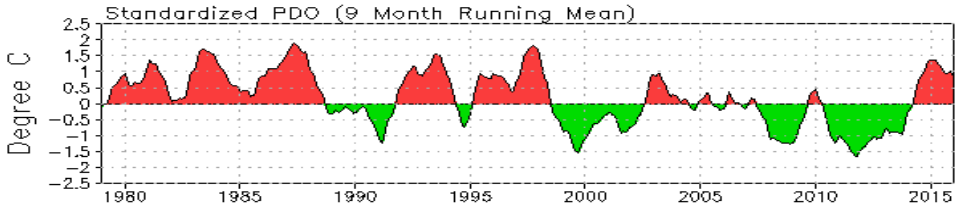


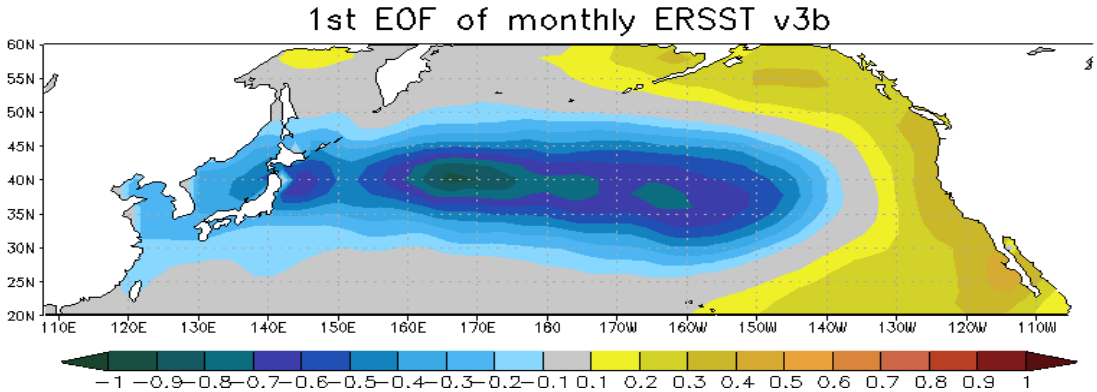
- **The strong positive SSTA in the NE subtropical Pacific [140°W-100°W, 10°N-30°N] emerged in early 2014, and the warming enhanced and migrated to the depth since then.**
- **The development of positive SSTA in the region coincided with the switch to positive PDO phase.**
- **The warming in upper 50m depth dissipated rapidly in last two months, while the warming in the depth of 50-150m persisted.**

Pacific Decadal Oscillation Index







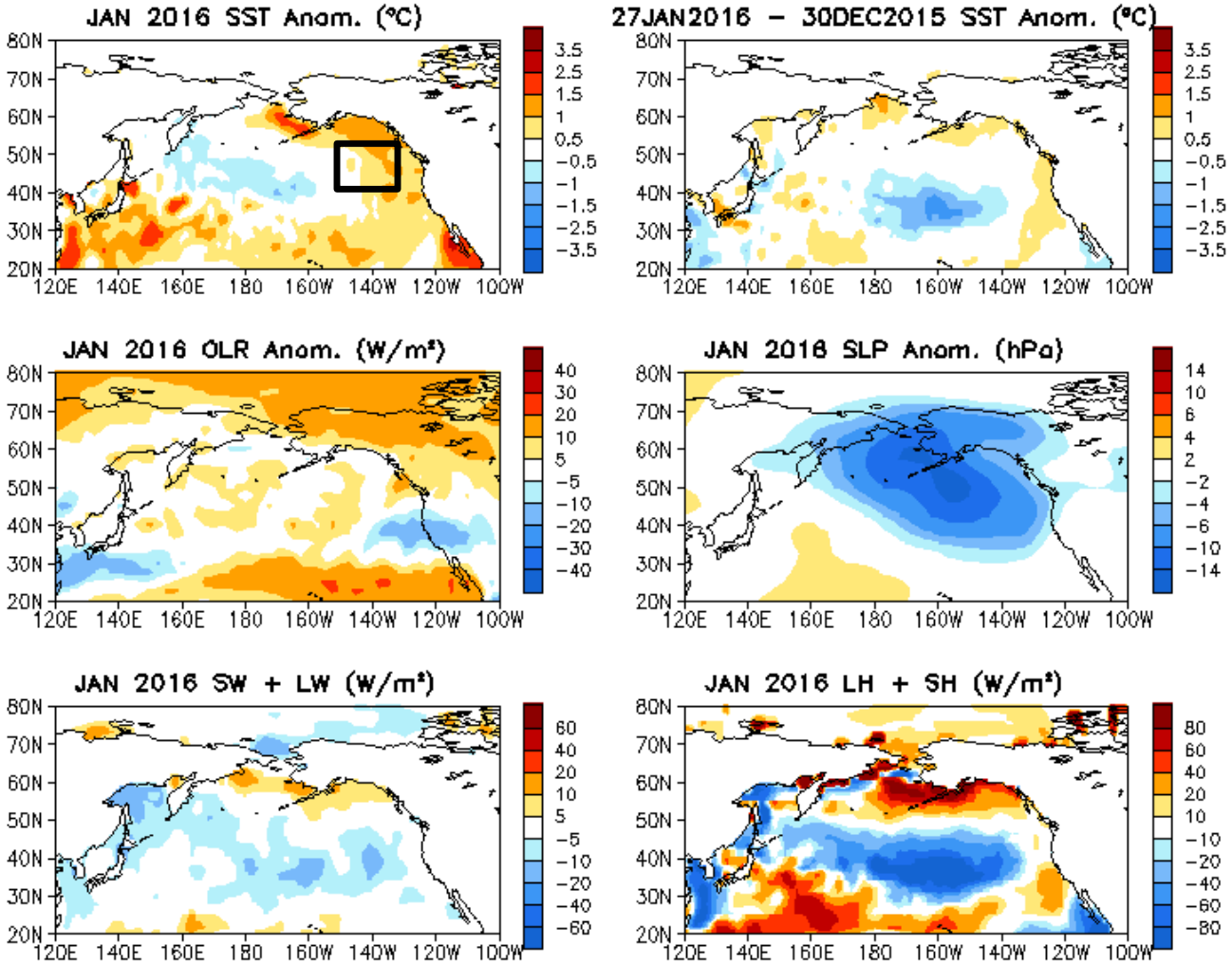


- Positive PDO has persisted for 19 months since July 2014 and positive PDO increased with PDO = +1.3 in Jan 2016.

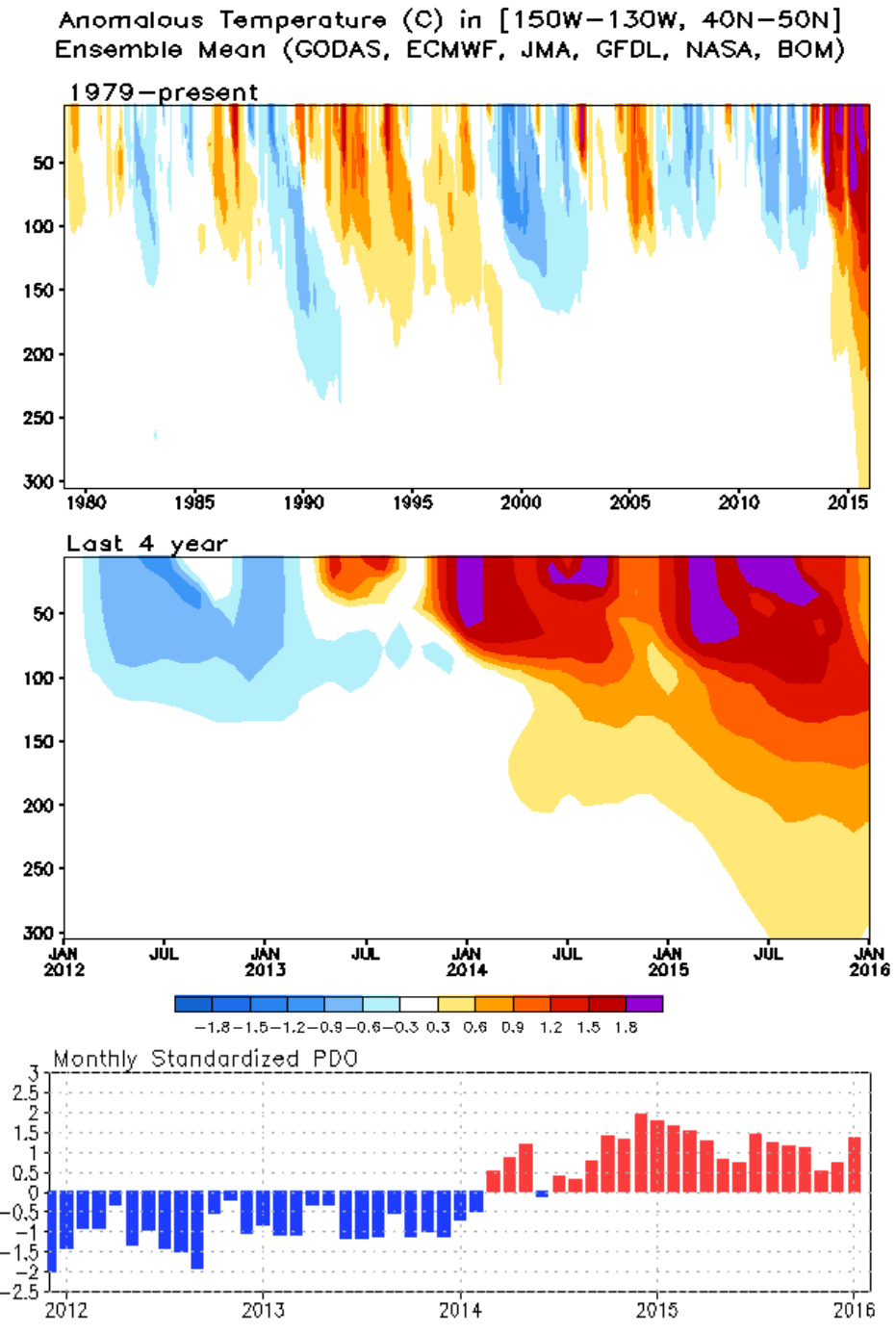
- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

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

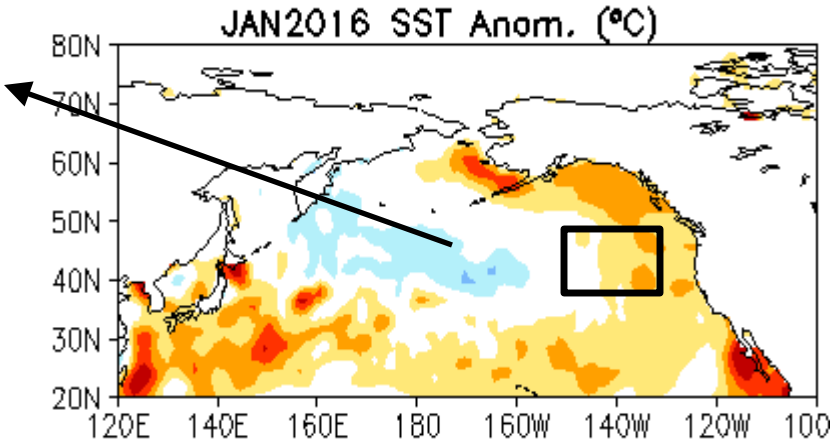
Last Three Month SST, SLP and 925hp Wind Anom.



- **Positive SSTA in the NE Pacific (“Blob”) weakened.**
- **Anomalous low SLP were observed in the North Pacific, consistent with the impacts of El Nino.**



"Blob" in North Pacific

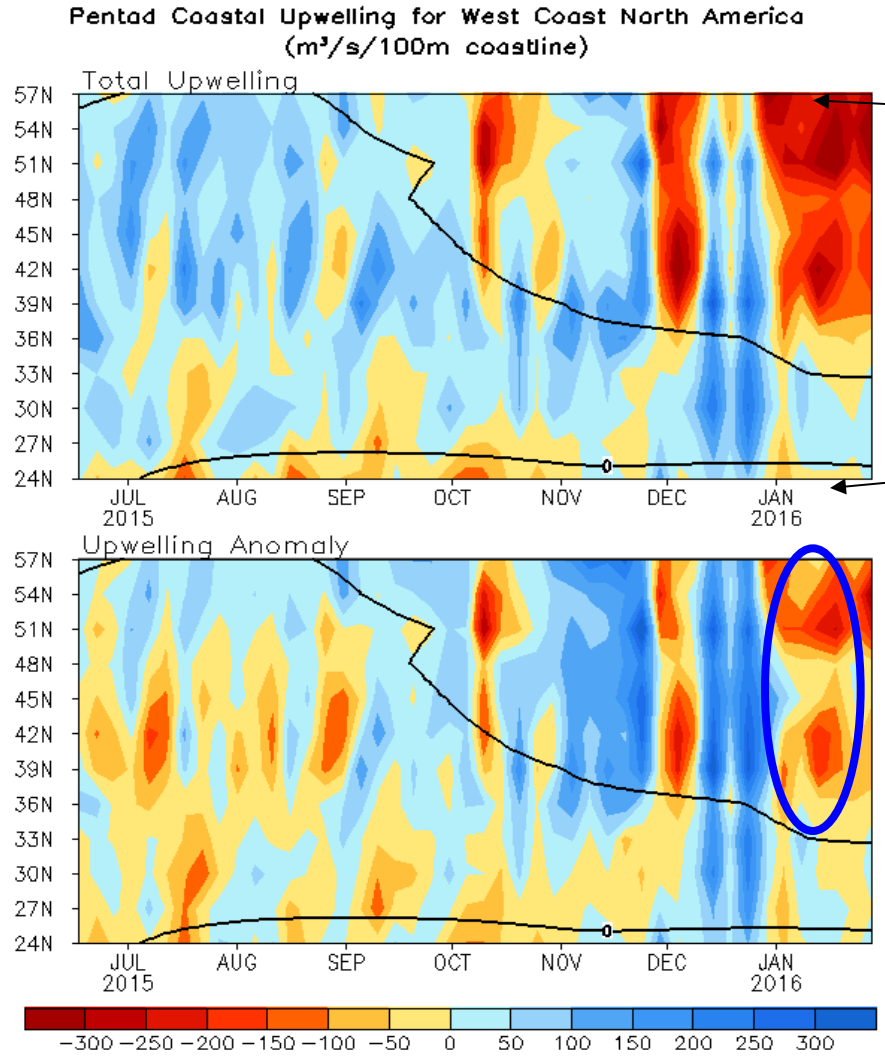


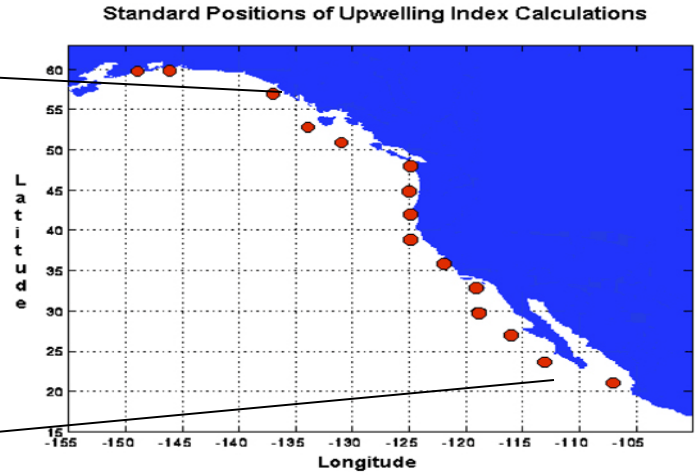
- **Record SST warming appeared off shore near the west coast of North America in late 2013, referred to as "Blob" by Bond et al. (2015).**

- **The warming in the NE Pacific box [150°W-130°W, 40°N-50°N] started near the surface in late 2013 and seems associated with the switch to positive PDO phase.**

- **The warming in upper 100m depth dissipated rapidly in last two months, while the warming in the depth of 100-300m persisted.**

North America Western Coastal Upwelling



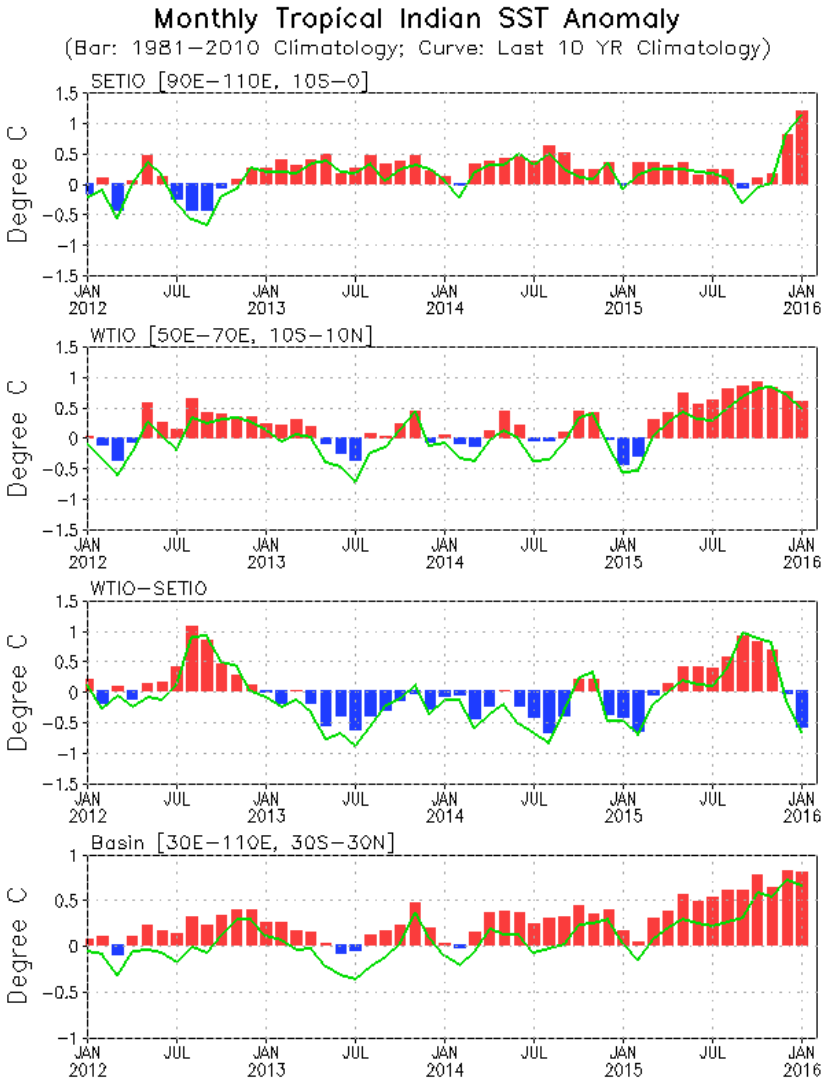


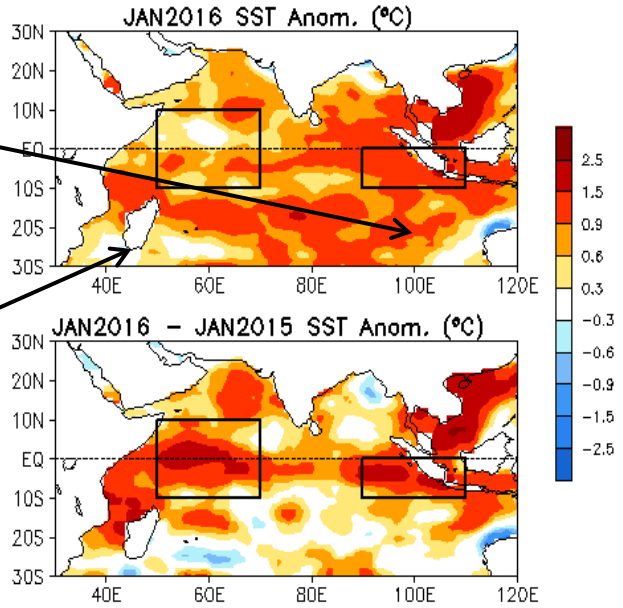
- Downwelling north of 36N was enhanced in Jan 2016, consistent with southerly wind anomalies near the shore.

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 (m³/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 36°N to 57°N.**

Evolution of Indian Ocean SST Indices





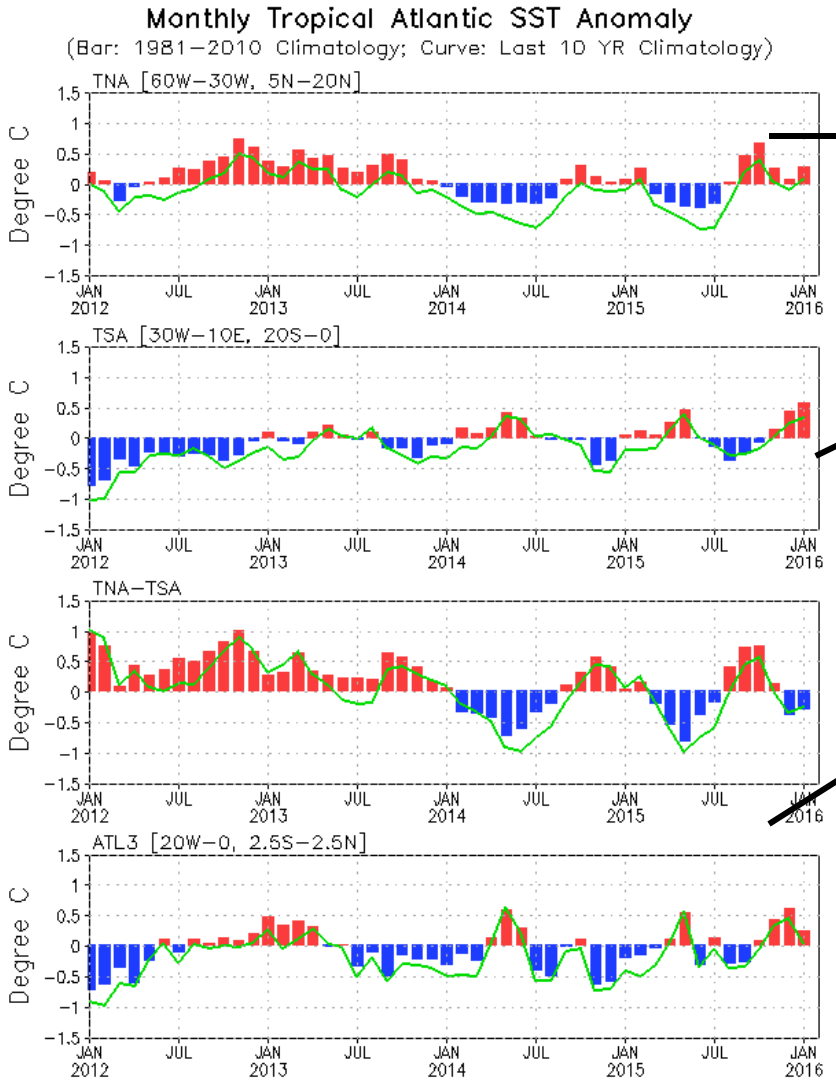
- The southeastern tropical Indian Ocean (SETIO) warmed up to 1.2C above-normal.

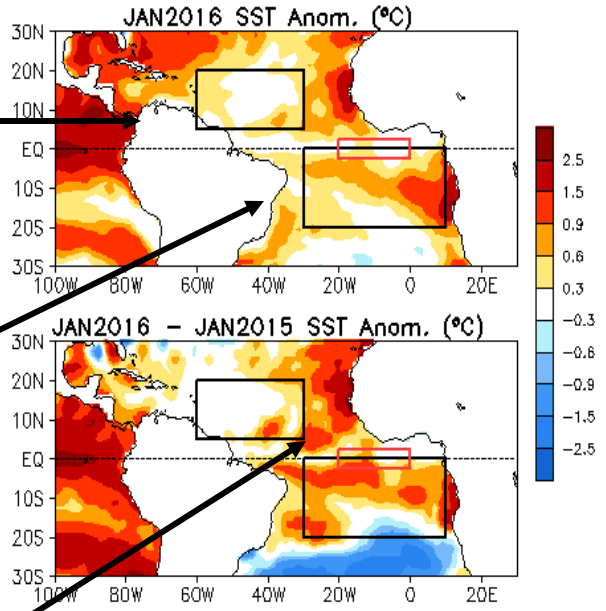
- The warming in the western tropical Indian Ocean (WTIO) weakened.

- The warming in the basin average SSTA persisted.

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.

Evolution of Tropical Atlantic SST Indices



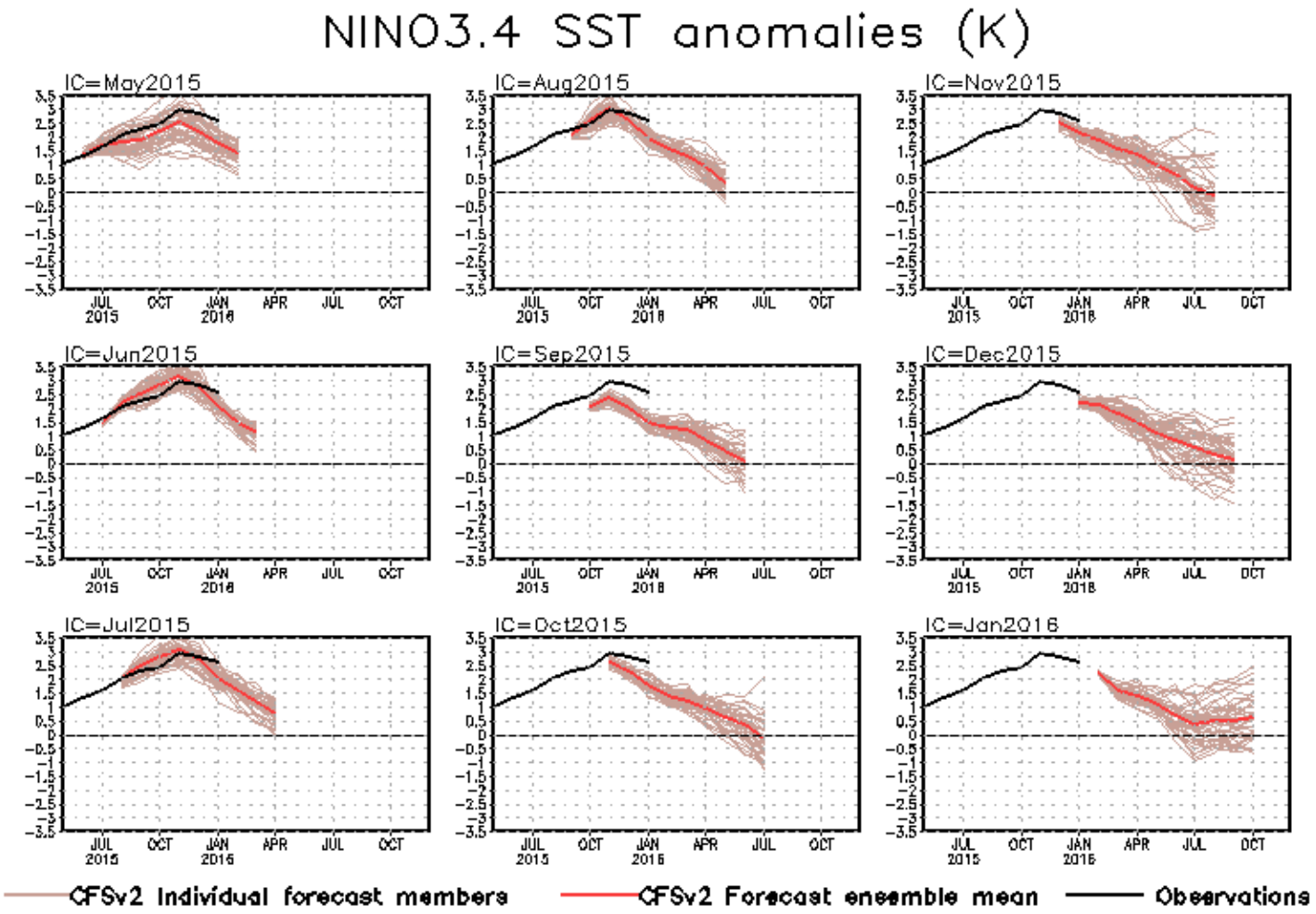


- **Positive SSTA in the tropical South Atlantic (TSA) enhanced in Jan 2016.**
- **Negative Meridional Gradient Mode Index (TNA-TSA) persisted in Jan 2016.**

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

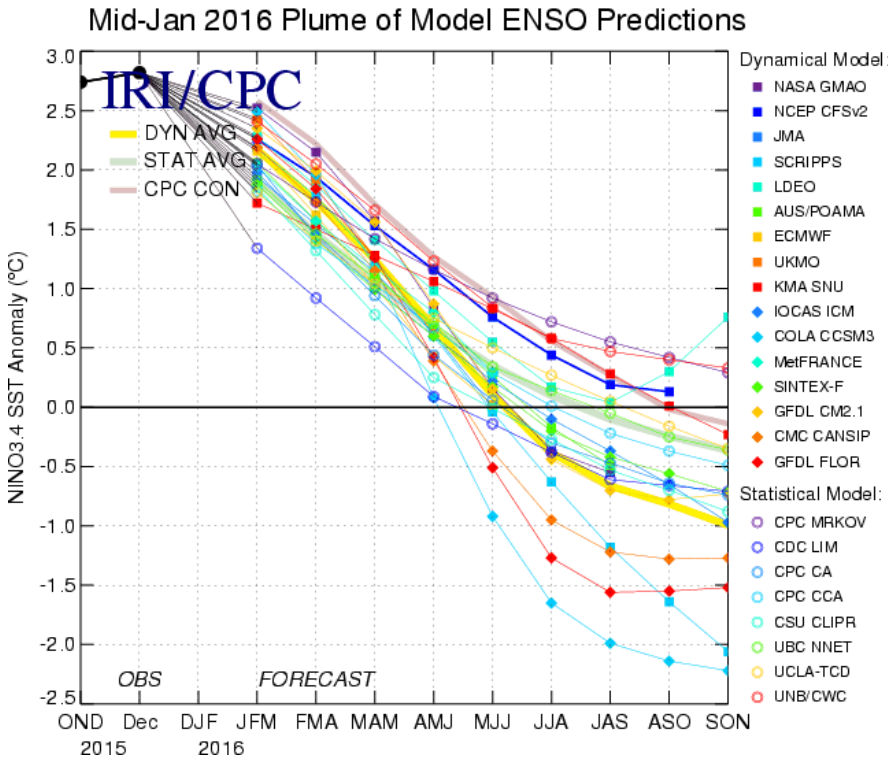
Global SST Predictions

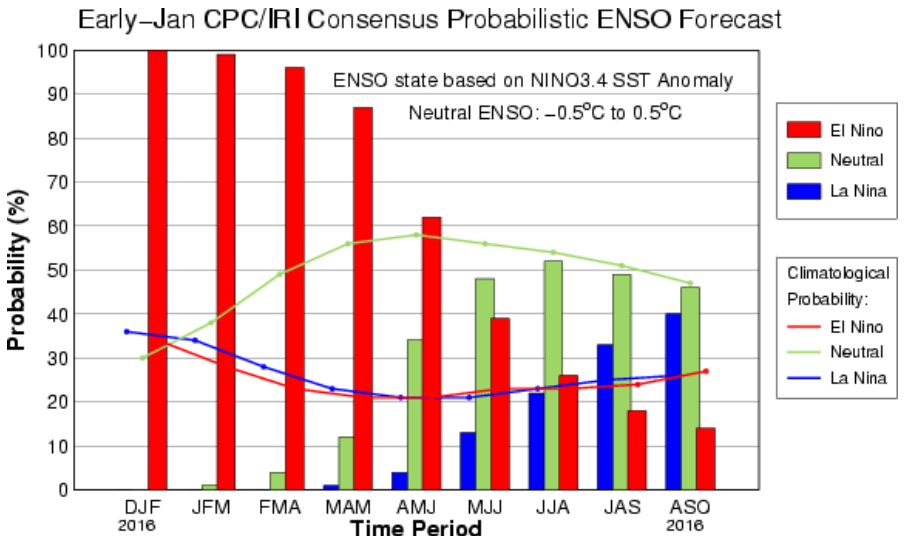
NCEP CFSv2 NINO3.4 Forecast

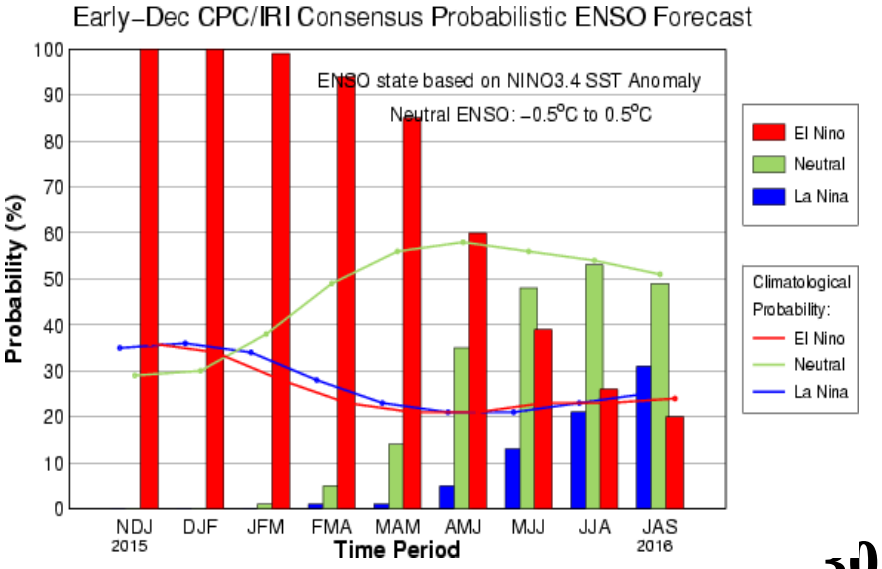


- **CFSv2 predicted Nino3.4 will gradually dissipate through northern hemisphere winter/spring with a transition into neutral conditions by summer 2016.**
- **The ensemble spread in the CFSv2 forecasts is noticeably large during summer/fall 2016, indicating uncertainties in forecasting the transition phase.**

IRI NINO3.4 Forecast Plum





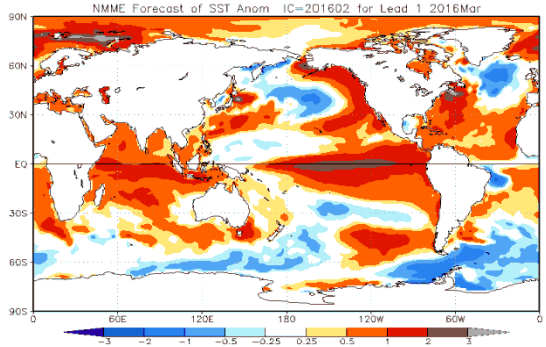


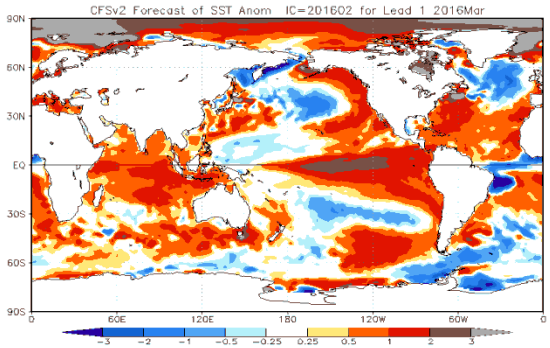
- **NOAA "ENSO Diagnostic Discussion" on Jan 14 2015 states that "A strong El Niño is expected to gradually weaken through spring 2016, and to transition to ENSO-neutral during late spring or early summer."**

North American Multi-Model (NMME) SST Prediction

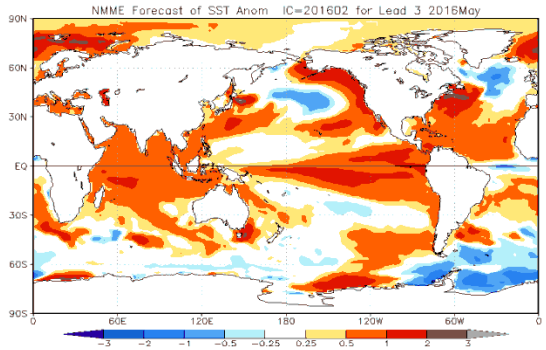
http://www.cpc.ncep.noaa.gov/products/NMME

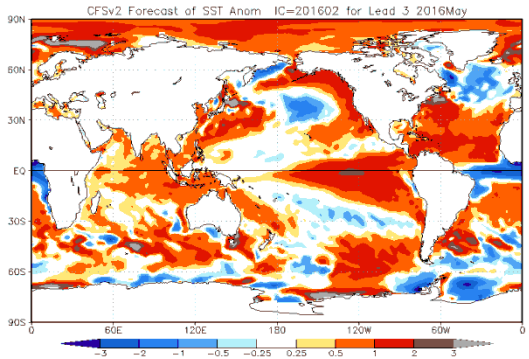
Ensemble Mean **Mar2016** **CFSv2**



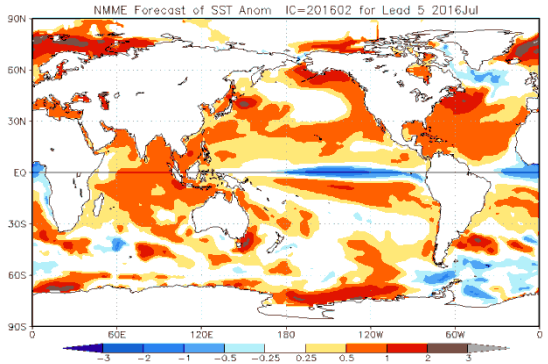


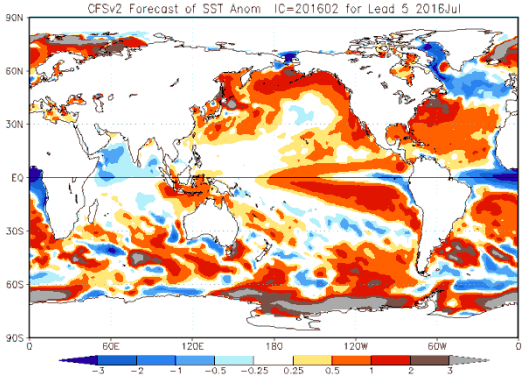
Ensemble Mean **May2016** **CFSv2**

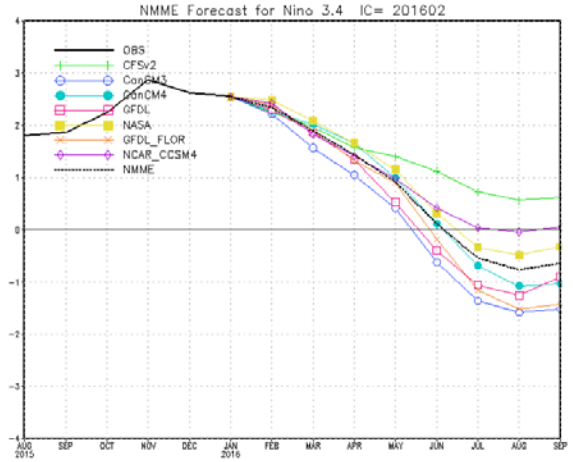




Ensemble Mean **Jul2016** **CFSv2**



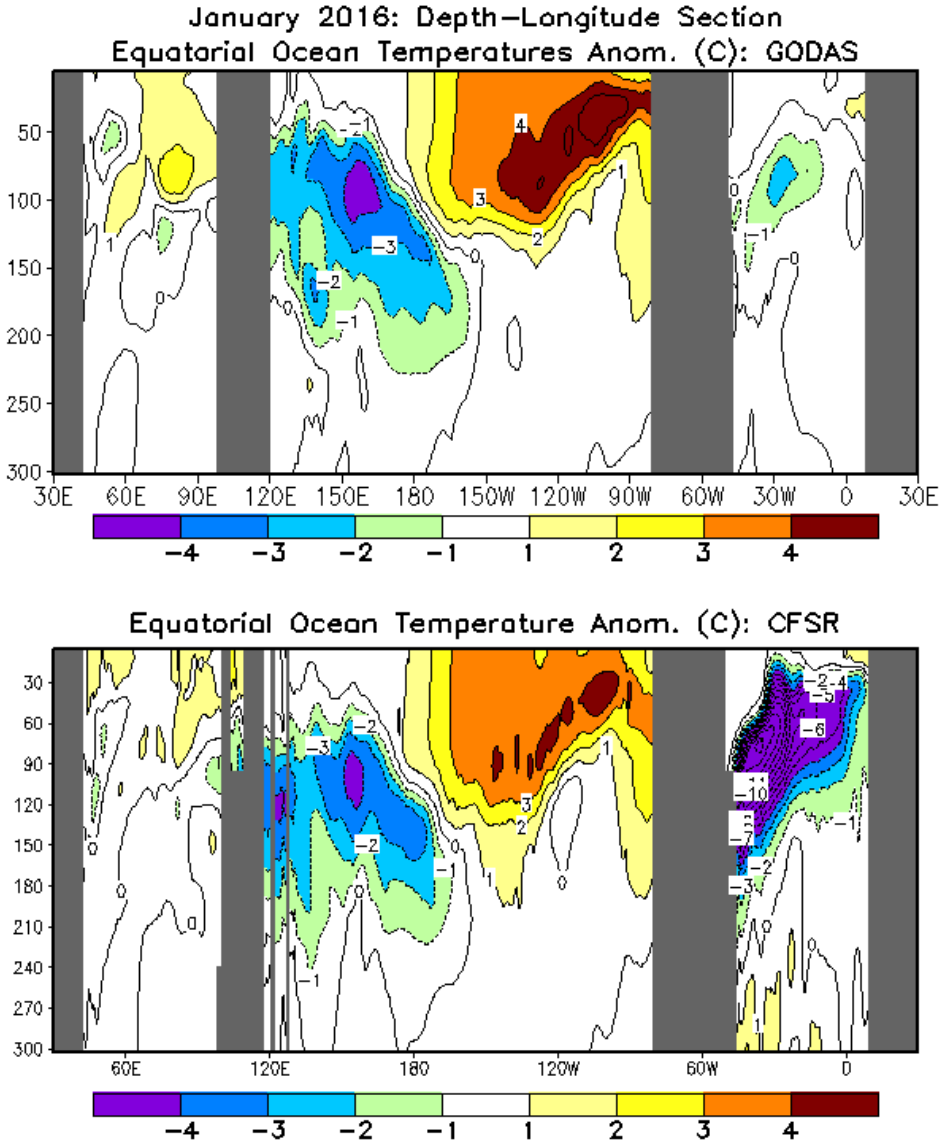




There are some noticeable differences between CFSv2 and the ensemble mean forecast that is the average of seven seasonal forecast models including CFSv2.

- **CFSv2 has a slower dissipation of warm anomalies in the central Pacific;**
- **but a faster dissipation of warm anomalies in the tropical Indian Ocean**

31



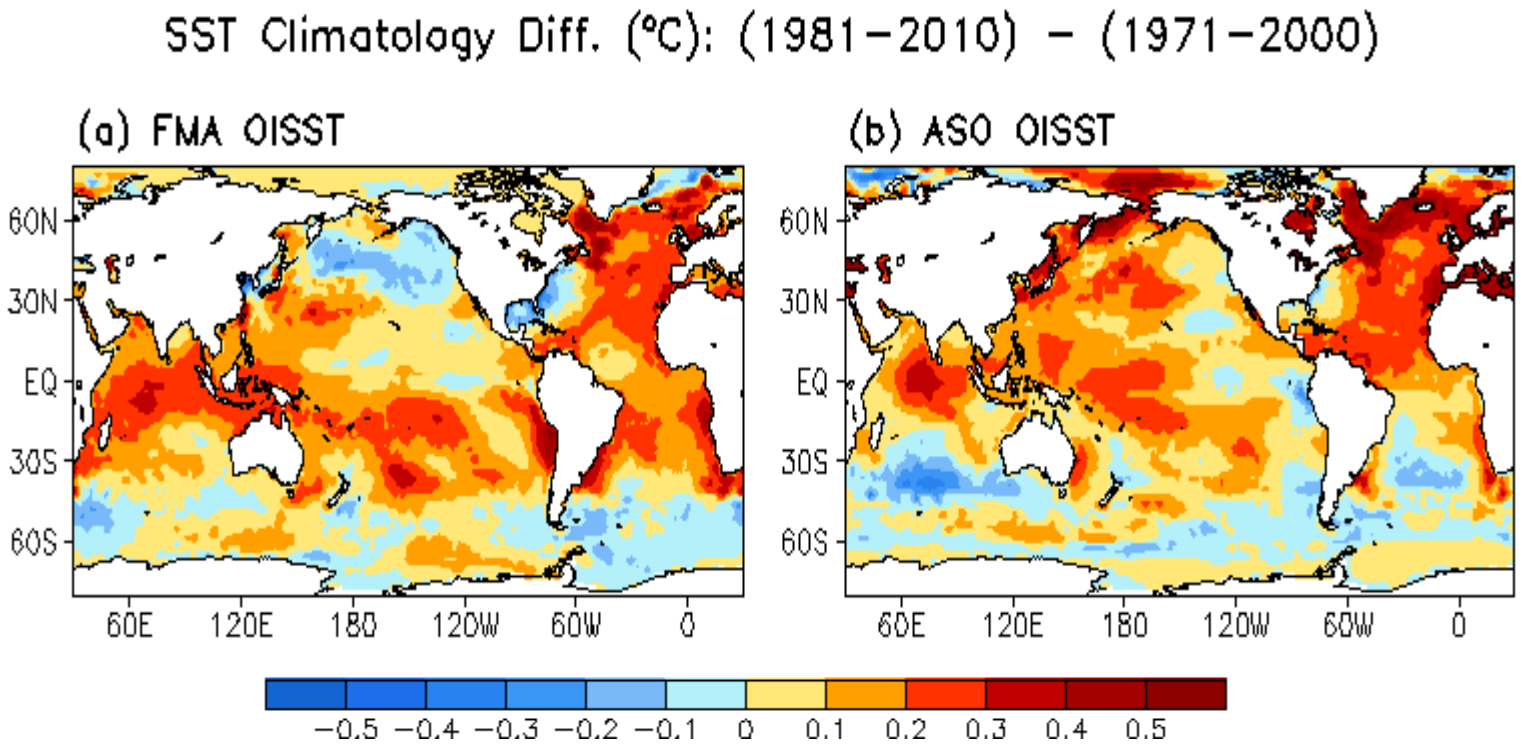
There are some noticeable differences between the GODAS and CFSR, which provides initial conditions for CFSv2.

- **In the equatorial Atlantic, the subsurface temperature is about 10 degree colder in CFSR than in GODAS;**
- **In the equatorial Pacific, the cold (warm) anomalies in the western (eastern) Pacific are weaker in CFSR than in GODAS.**

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!

Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific

- Hovemoller diagram for equatorial SSS anomaly **(10°S-10°N);**

- Strong negative SSS anomaly continues over the central and eastern Pacific, with the maximum SSS anomaly observed around 170°W. The maximum negative SSS anomaly likely started to propagate to the east. At the meantime, a stretch of positive SSS anomaly remains and widened slightly over the western Pacific and eastern Indian Ocean from 130°E – 160°E;