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

Prepared by
Climate Prediction Center, NCEP/NOAA

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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)

Outline

- **Overview**
- **Recent highlights**
  - **Pacific/Arctic Ocean**
  - **Indian Ocean**
  - **Atlantic Ocean**
- **Global SST Predictions**
- **Comparison of the 2015/16 El Niño with the 1982/83 and 1997/98 El Niños and their transitions to cold phase**

Overview

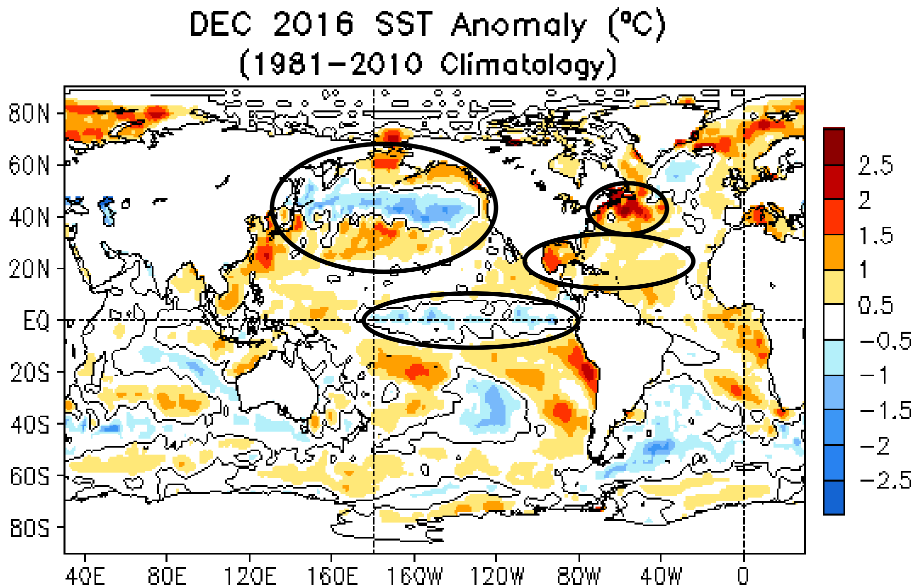
- **Pacific Ocean**
  - La Niña conditions weakened in Dec 2016
  - Negative temperature anomalies weakened substantially due to the eastward propagation of a downwelling Kelvin wave
  - CPC/IRI consensus favors the continuation of weak La Niña conditions through December-February (DJF) 2016-17
  - Positive PDO phase continued with PDO = +0.9 in Dec 2016
  - Arctic sea ice extent in Dec 2016 was slightly higher than the record low in Dec 2010

- **Indian Ocean**
  - The basin wide warming since spring 2015 dissipated in summer 2016 coincided with the onset of La Niña conditions
  - Westerly wind anomalies prevailed since summer 2016, consistent with enhanced convection over the Maritime Continents

- **Atlantic Ocean**
  - NAO was near-normal in Dec 2016
  - Strong positive SSTA continued along the eastern coast of North America and Gulf of Mexico

Global Oceans

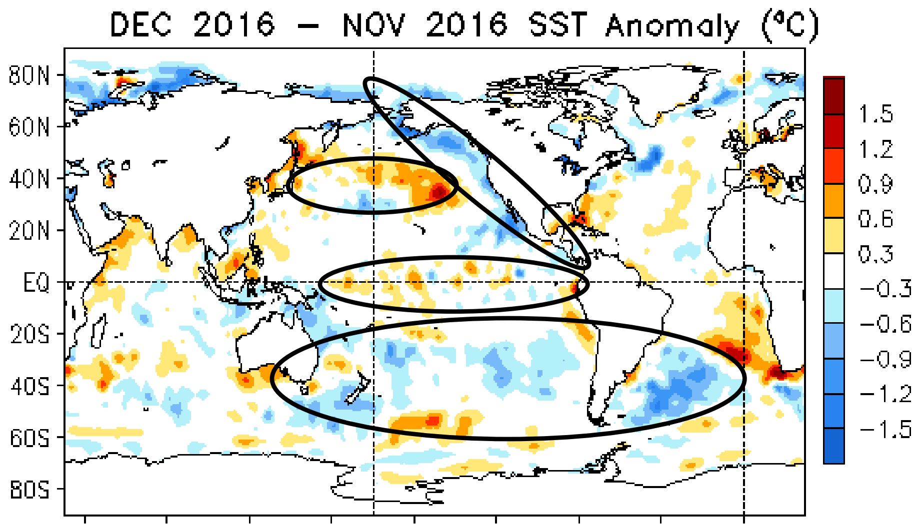
Global SST Anomaly (⁰C) and Anomaly Tendency



- Negative SSTA continued in a narrow band along the C.-E. equatorial Pacific, and surrounded by positive SSTA in off-equatorial regions and the W.-C. Pacific.

- Positive PDO-like pattern in N. Pacific.

- Positive SSTA presented along the E. coast of N. America, in Gulf of Mexico and subtropical N. Atlantic.



- Both negative and positive SSTA tendencies were small and presented in the C.-E. tropical Pacific

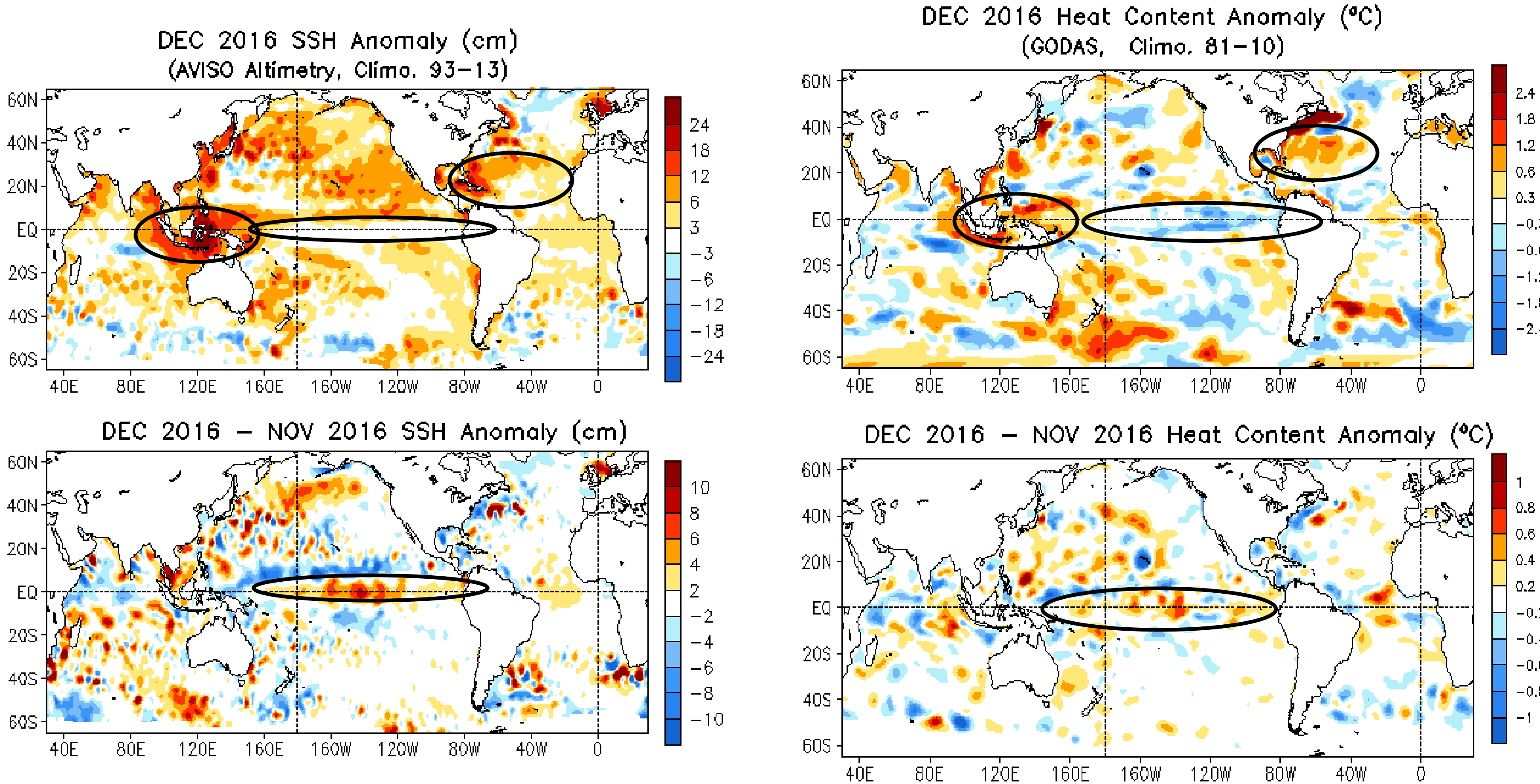
- Negative SSTA tendency presented along the W. coast of N. America and Gulf of Alaska.

- Positive SSTA tendency was observed in the central N. Pacific.

- Negative SSTA tendencies dominated in high-latitude Southern Oceans.

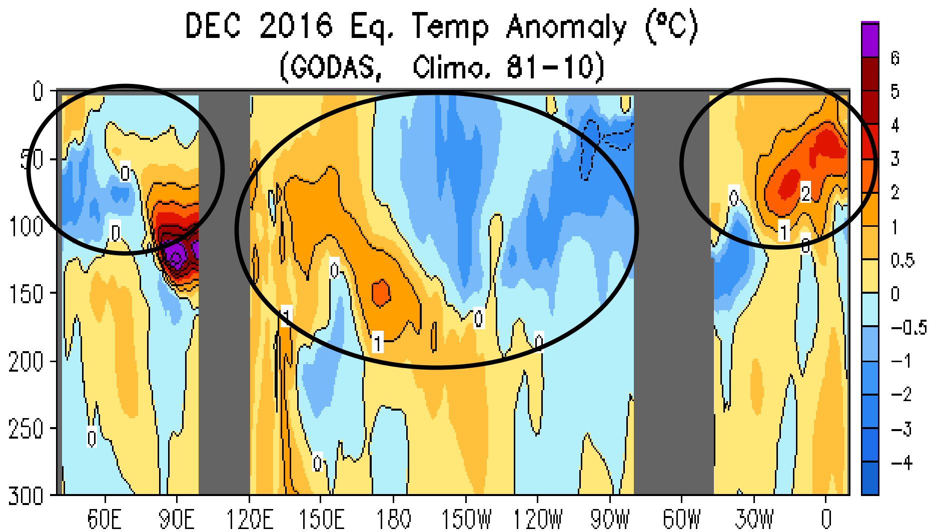
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

Global SSH and HC300 Anomaly & Anomaly Tendency



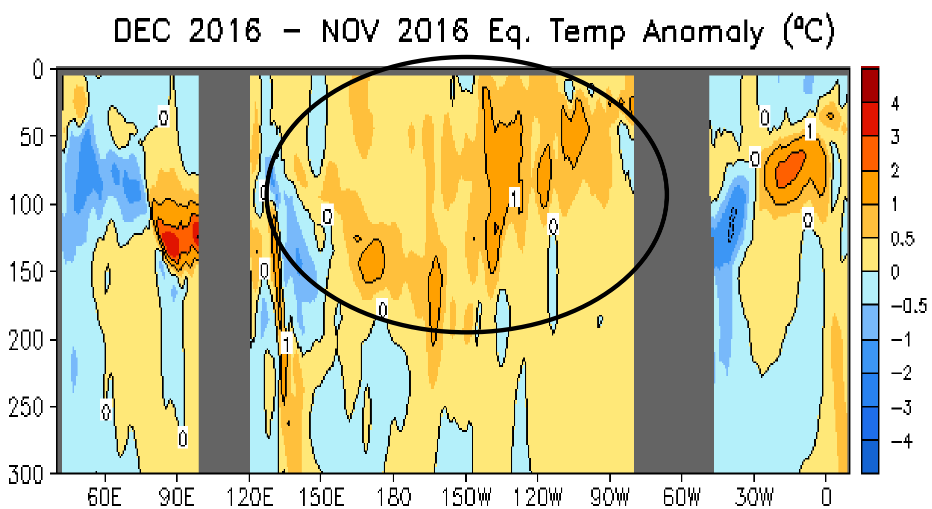
- **SSH was near-normal, but HC300 was below-normal in the central-eastern equatorial Pacific.**
- **SSH and HC300 were both above-normal over the Maritime Continents and near the E. coast of N. America.**
- **Positive SSHA and H300A tendency dominated in the central-eastern equatorial Pacific.**

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



- Negative (positive) temperature anomalies presented in the C-E. Pacific (W. Pacific) Ocean.

- Dipole temperature anomaly pattern presented in the equatorial Indian and Atlantic Ocean.

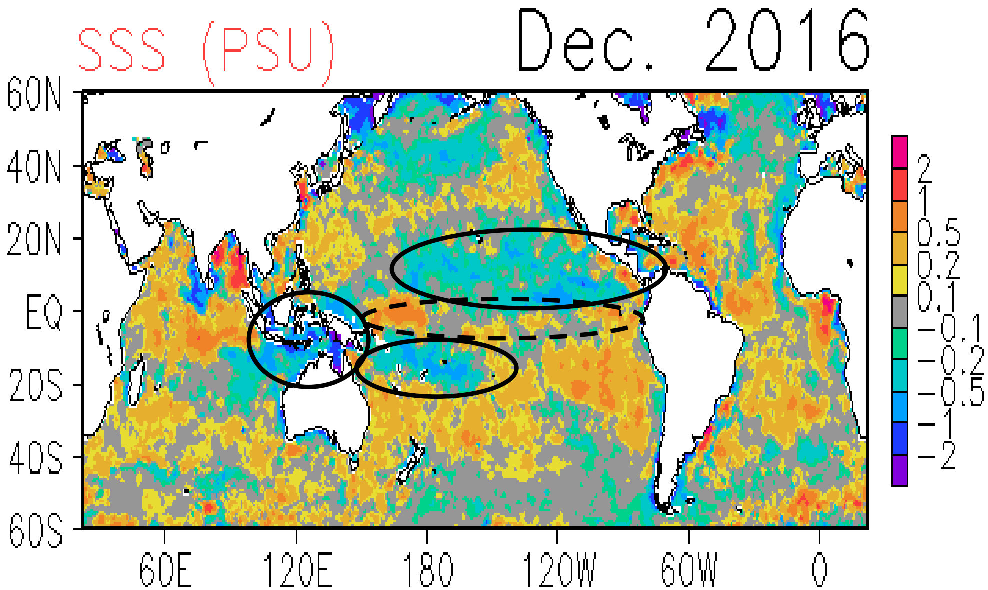


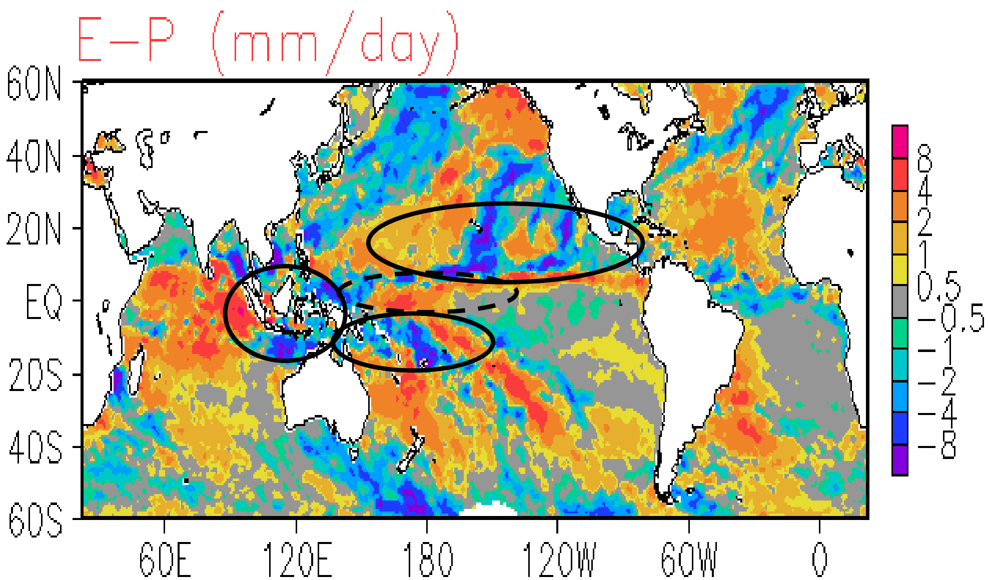
- Positive temperature anomaly tendency covered most of the equatorial Pacific.

- Dipole temperature anomaly pattern enhanced in the equatorial Indian and 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.

Sea Surface Salinity and Freshwater Flux (E-P) Anomaly





SSS: Blended Analysis of Surface Salinity (BASS) based on in situ and satellite observations (Xie et al. 2014) ftp.cpc.ncep.noaa.gov/precip/BASS

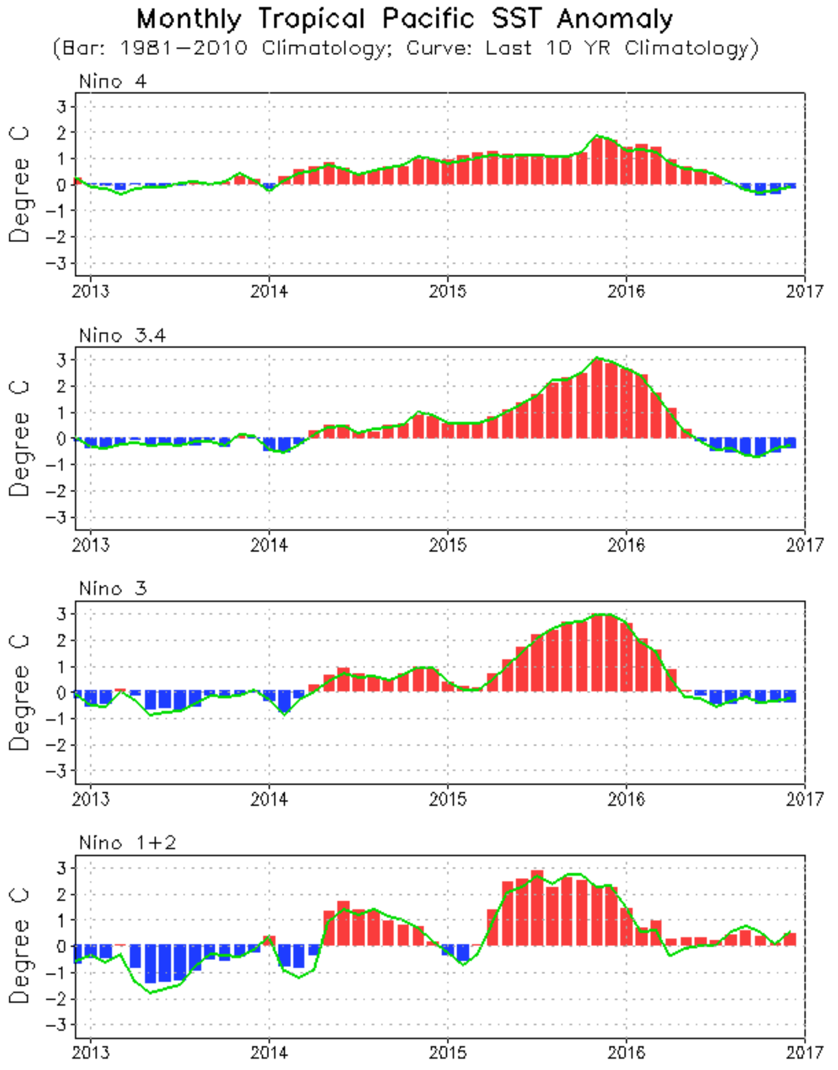
Precipitation: CMORPH adjusted satellite precipitation estimates

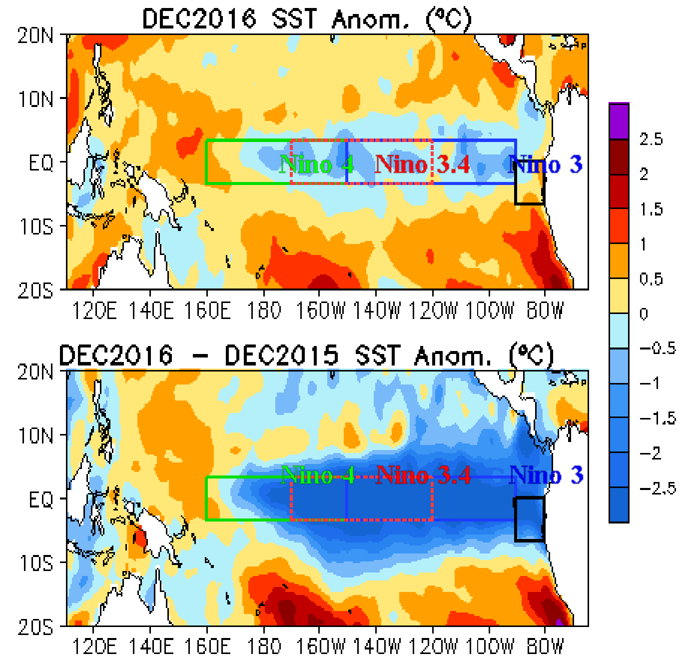
Evaporation: CFSR

- **Positive (negative) SSS anomaly is generally tided up with positive (negative) E-P anomaly, indicating the dominant role of E-P forcing on SSS variability.**
- **Fresher than normal SSS presented over the Maritime Continents and ITCZ and SPCZ.**
- **Saltier than normal SSS presented in the equatorial Pacific, consistent with the La Niña conditions.**

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific NINO SST Indices





- Negative Nino4 and Nino3.4 weakened slightly, with Nino3.4 = -0.4°C in Dec 2016.

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

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

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

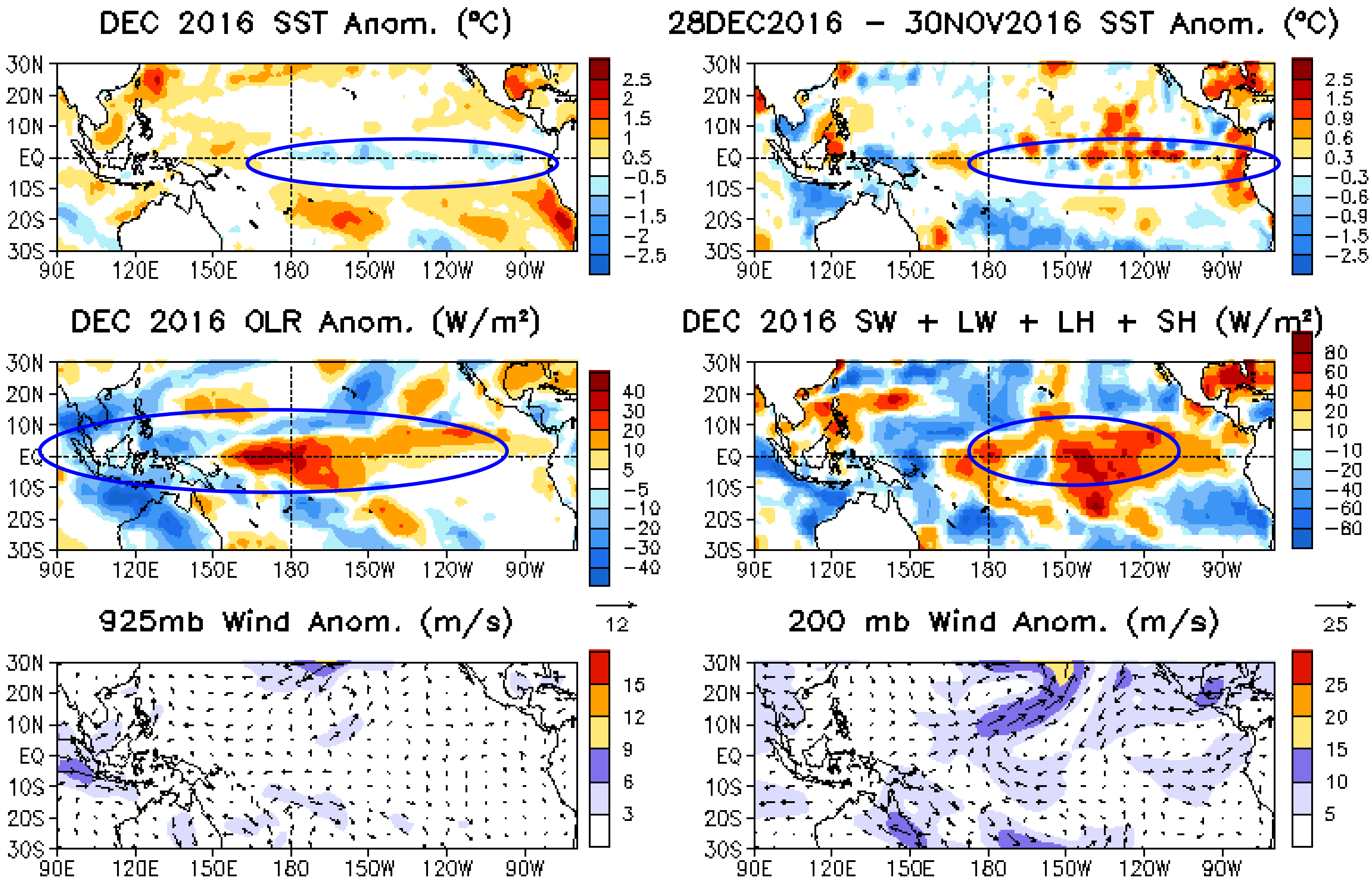
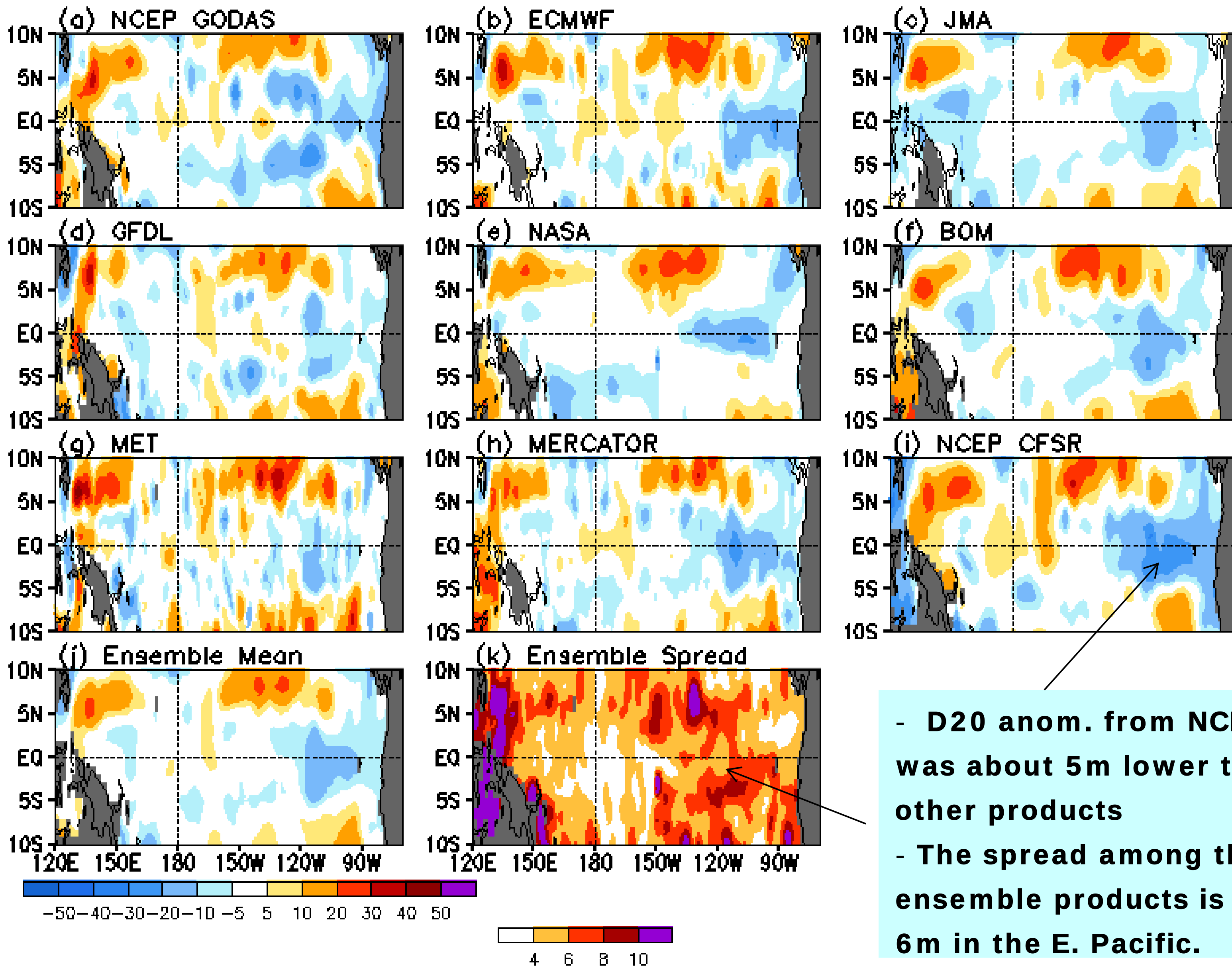


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

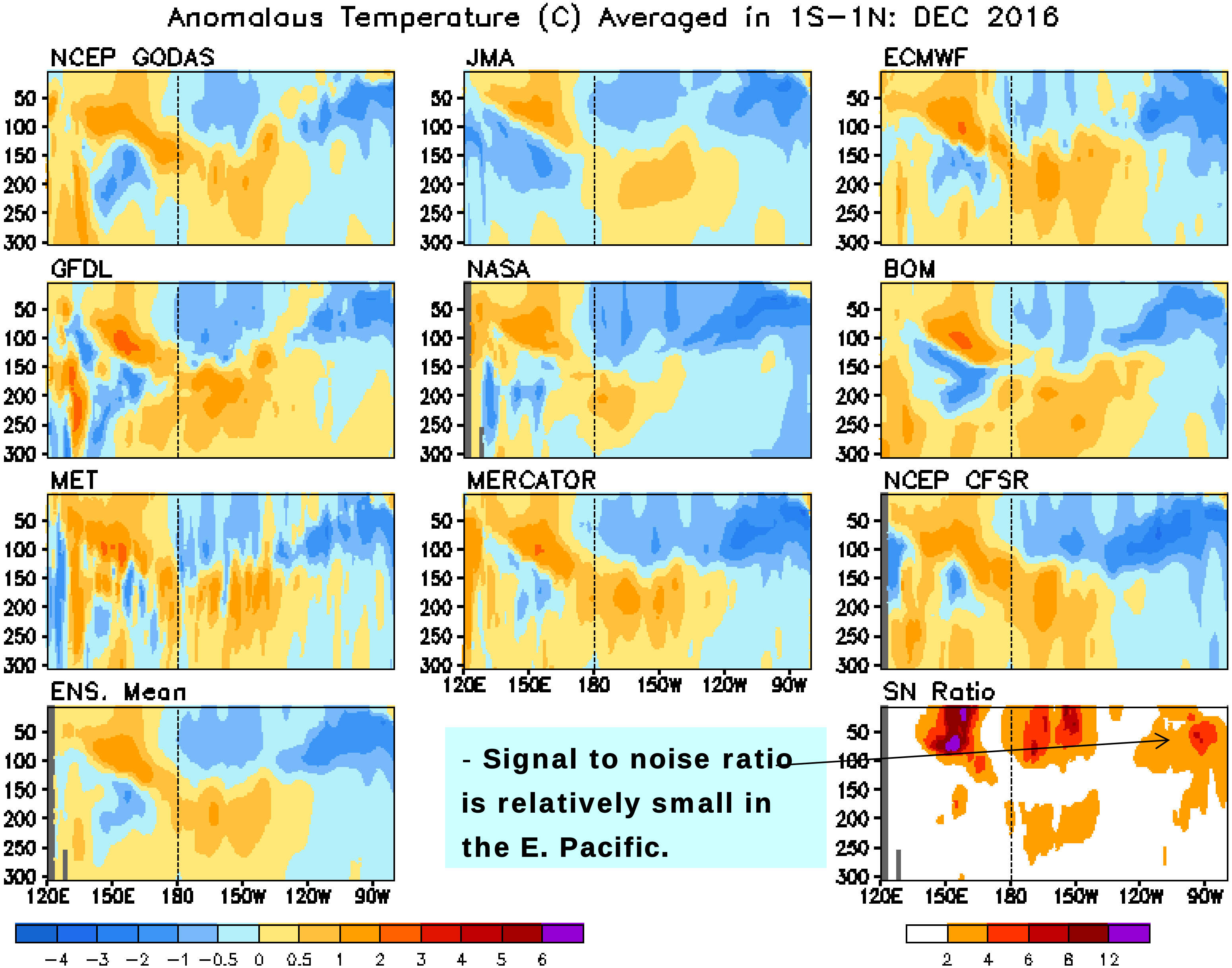
Real-Time Ocean Reanalysis Intercomparison: D20 Anom. in Dec 2016

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



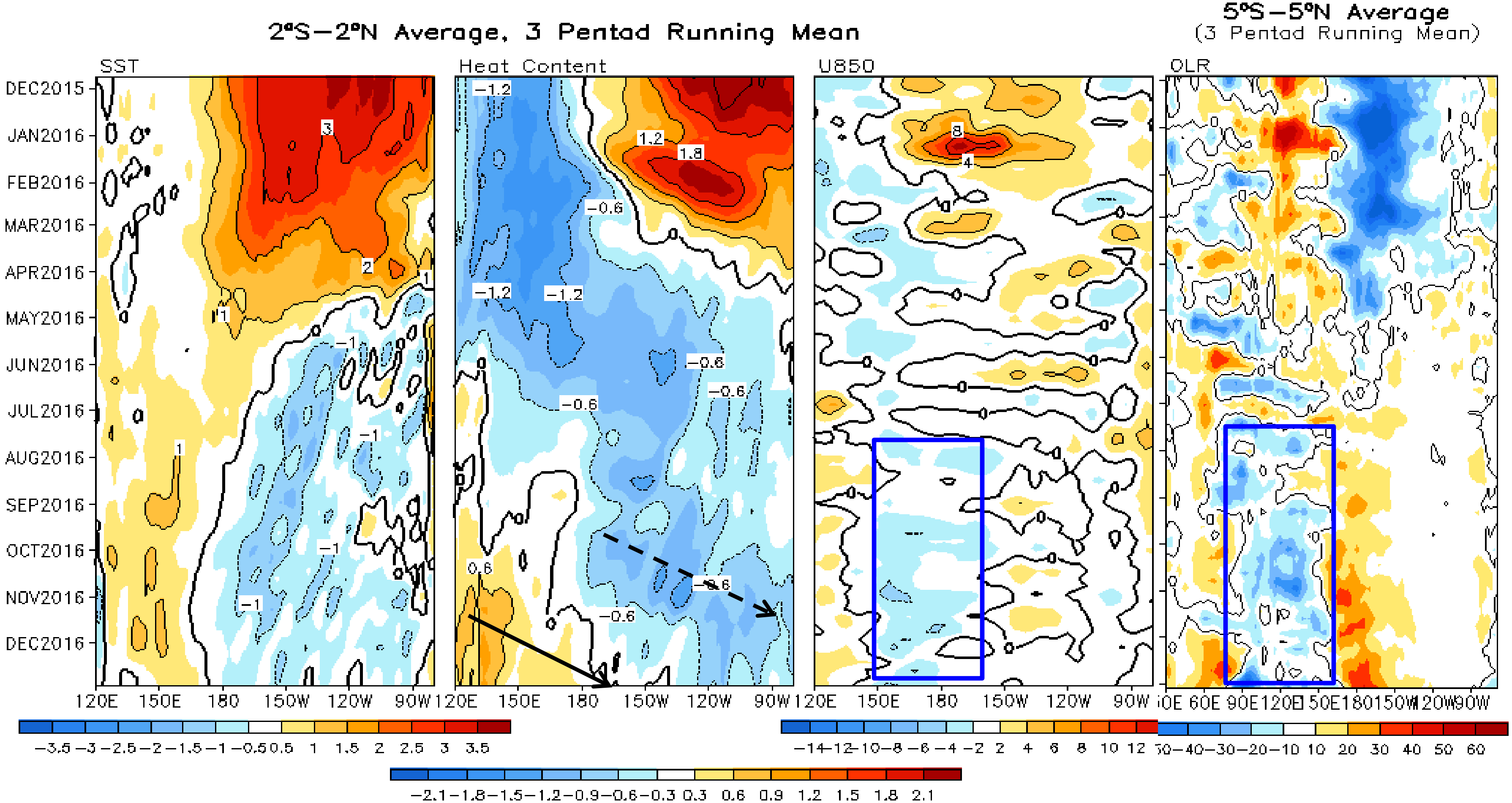
- D20 anom. from NCEP CFSR was about 5m lower than other products
- The spread among the ensemble products is about 6m in the E. Pacific.

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



- Signal to noise ratio is relatively small in the E. Pacific.

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



- Negative SSTA weakened in the C-E. Pacific in Dec 2016.
- Negative HC300 anomalies weakened due to the eastward propagation of downwelling Kelvin wave.
- Easterly wind anomalies presented in the western and central equatorial Pacific, and convection enhanced (suppressed) over the Maritime Continents (near the Dateline), reflecting the weak La Nina conditions.

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 2°S-2°N and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. 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.

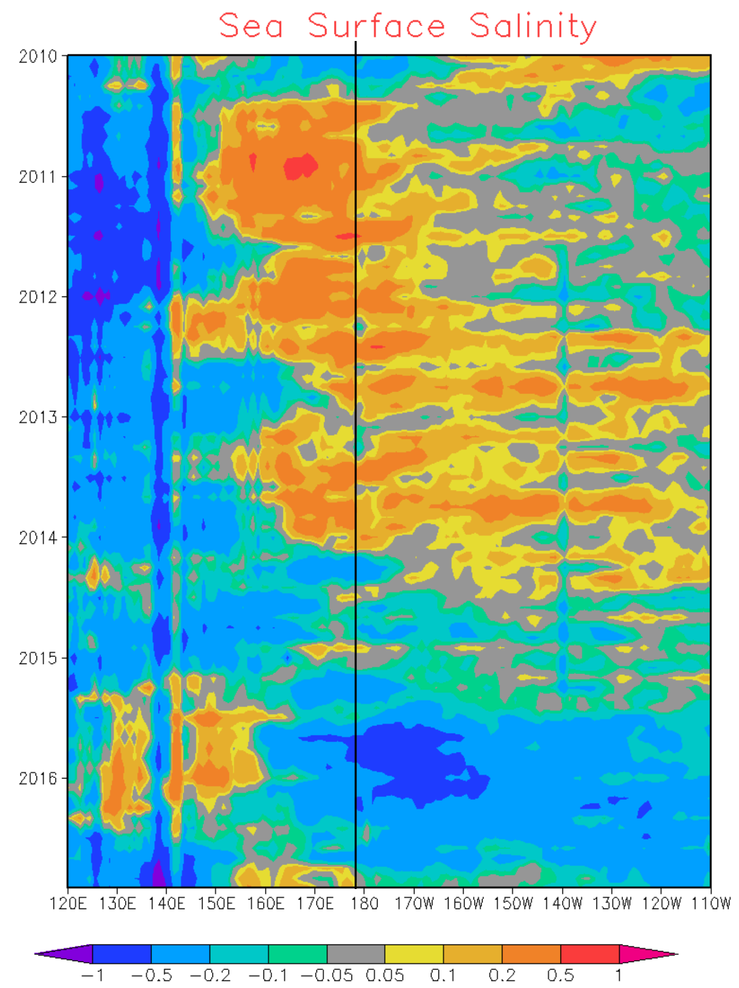
Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific

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

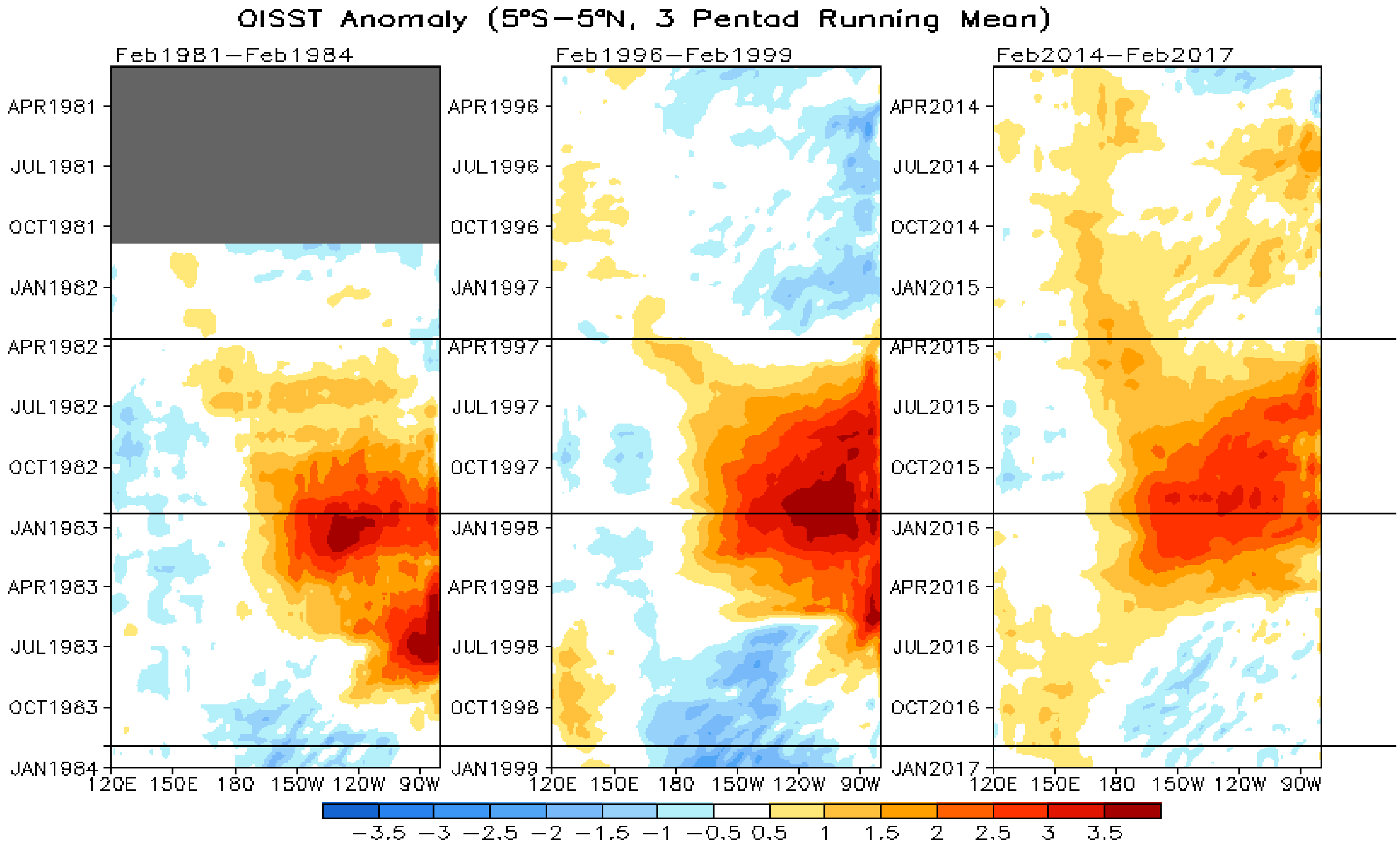
- Negative (positive) SSS anomalies presented over the Maritime Continents (the western equatorial Pacific) since fall 2016, which is consistent with the La Niña conditions

- However, the positive SSS anomalies associated with the 2016 La Niña did not extend to the east of the Dateline, indicating smaller eastward extension compared to those during the 2010/11 and 2011/12 La Niña and the neutral year 2013.



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

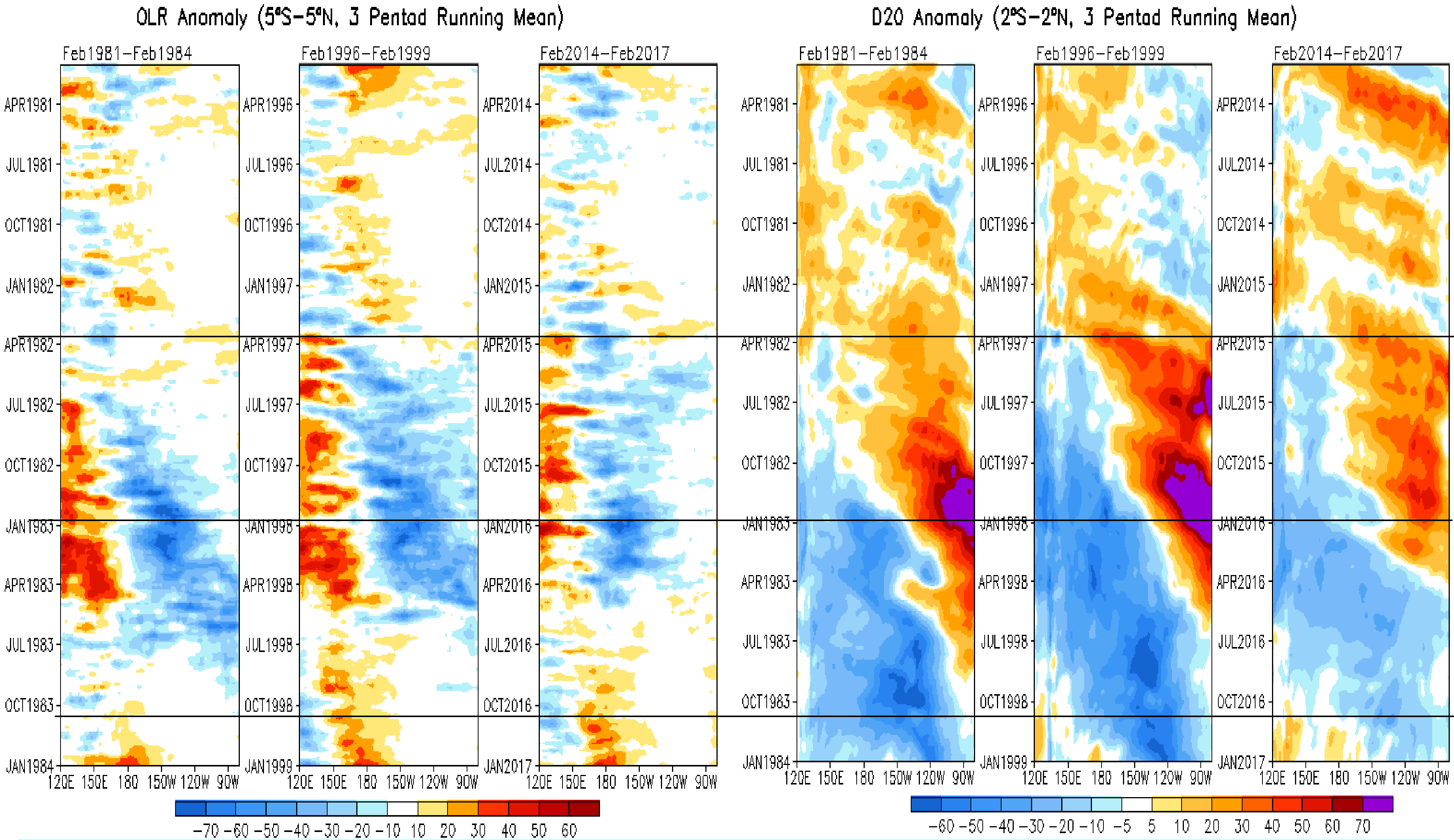
Comparison of Time Evolution of the 1982/83, 1997/98 and 2015/16 El Nino



- **NINO4 reached a historical high (1.7ºC) during winter 2015/16, which was +1ºC (+0.8ºC) higher than that during winter 1982/83 (1997/98).**
- **Although NINO3 was comparable, NINO1+2 was much weaker in the 2015/16 El Niño compared to other two El Ninos.**
- **The cold phase following the 2015/16 El Nino was also much weaker than that of other two El Ninos.**

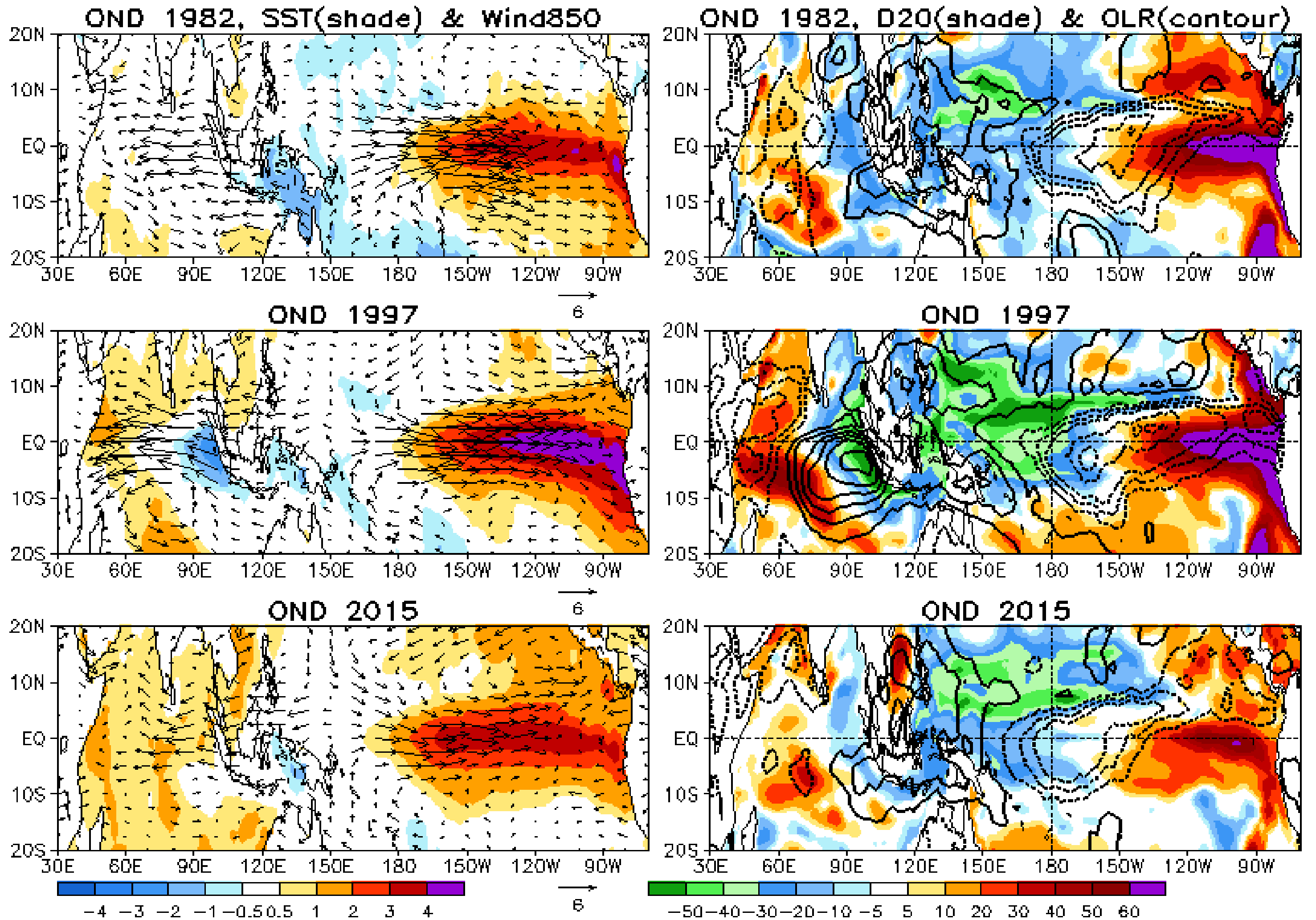
Xue, Y. and A. Kumar , 2016: Evolution of the 2015/16 El Niño and Historical Perspective since 1979. *Science China Earth Sciences,* doi: 10.1007/s11430-016-0106-9 . See paper in **http://rdcu.be/n6CB**

Huang, B., M. L'Heureux, Z.-Z. Hu, and H.-M. Zhang, 2016: Ranking the strongest ENSOs while incorporating SST uncertainty. *Geophys. Res. Lett.*, **43 (17)**, 9165-9172, DOI: 10.1002/2016GL070888



- **Compared to other two El Ninos, the enhanced convection in the 2015/16 El Nino was much weaker and displaced westward.**
- **The maximum D20 anomaly in winter 2015/16 was about 1/3-1/2 of that during winter 1997/98 and 1982/83 near the west coast of South America.**
- **The cold phase of D20 anomalies following the 2015/16 El Nino was also much weaker.**

Xue, Y. and A. Kumar , 2016: Evolution of the 2015/16 El Niño and Historical Perspective since 1979. *Science China Earth Sciences*

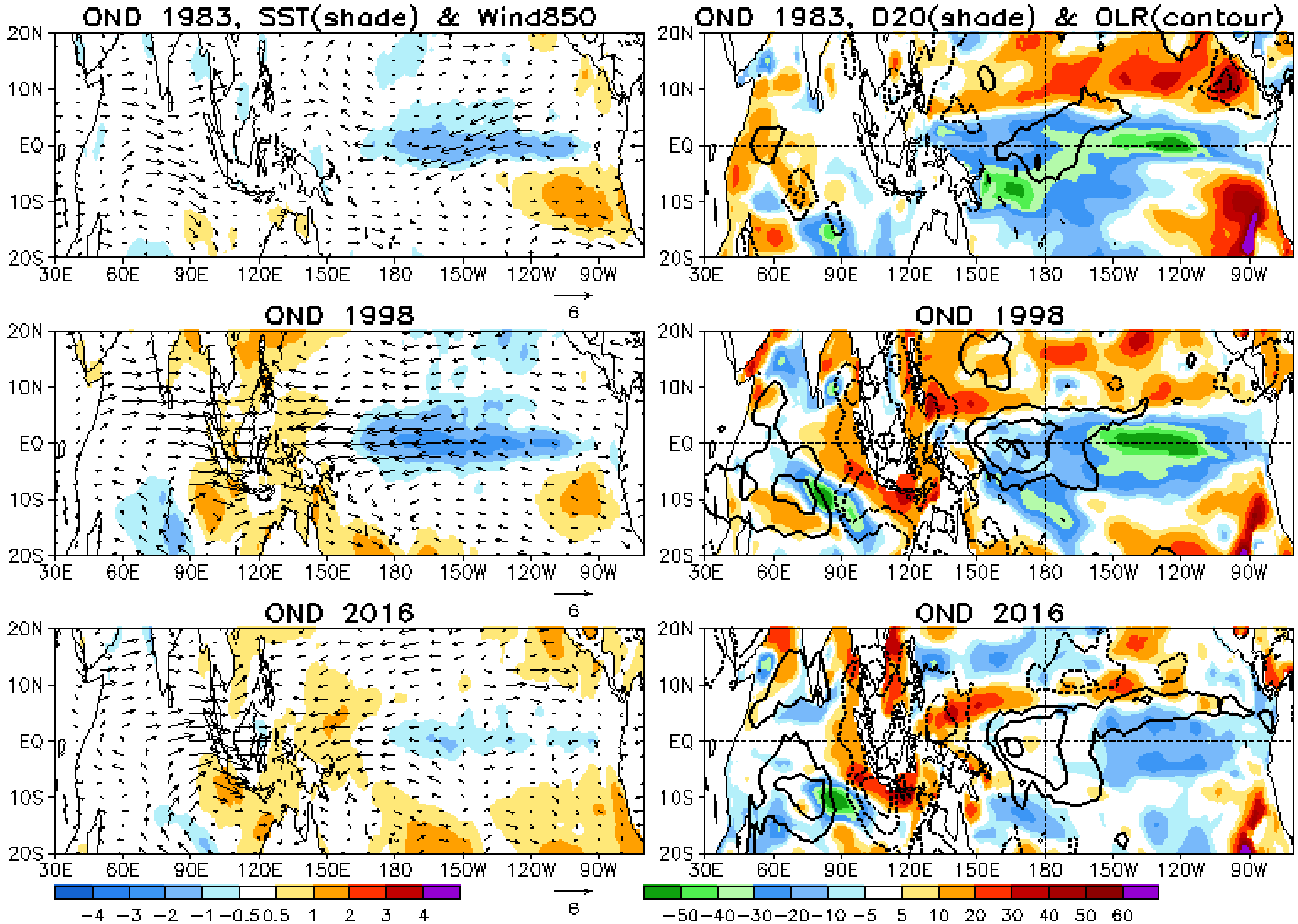


- **Compared to 1982 and 1998, the enhanced convection in OND 2015 was much weaker and displaced westward.**

- **The maximum D20 anomaly in OND 2015 was about 1/3-1/2 of that in OND of 1982 and 1998 in the far eastern Pacific.**

- **Westerly wind anomalies were also weaker in 2016 than in 1982 and 1998.**

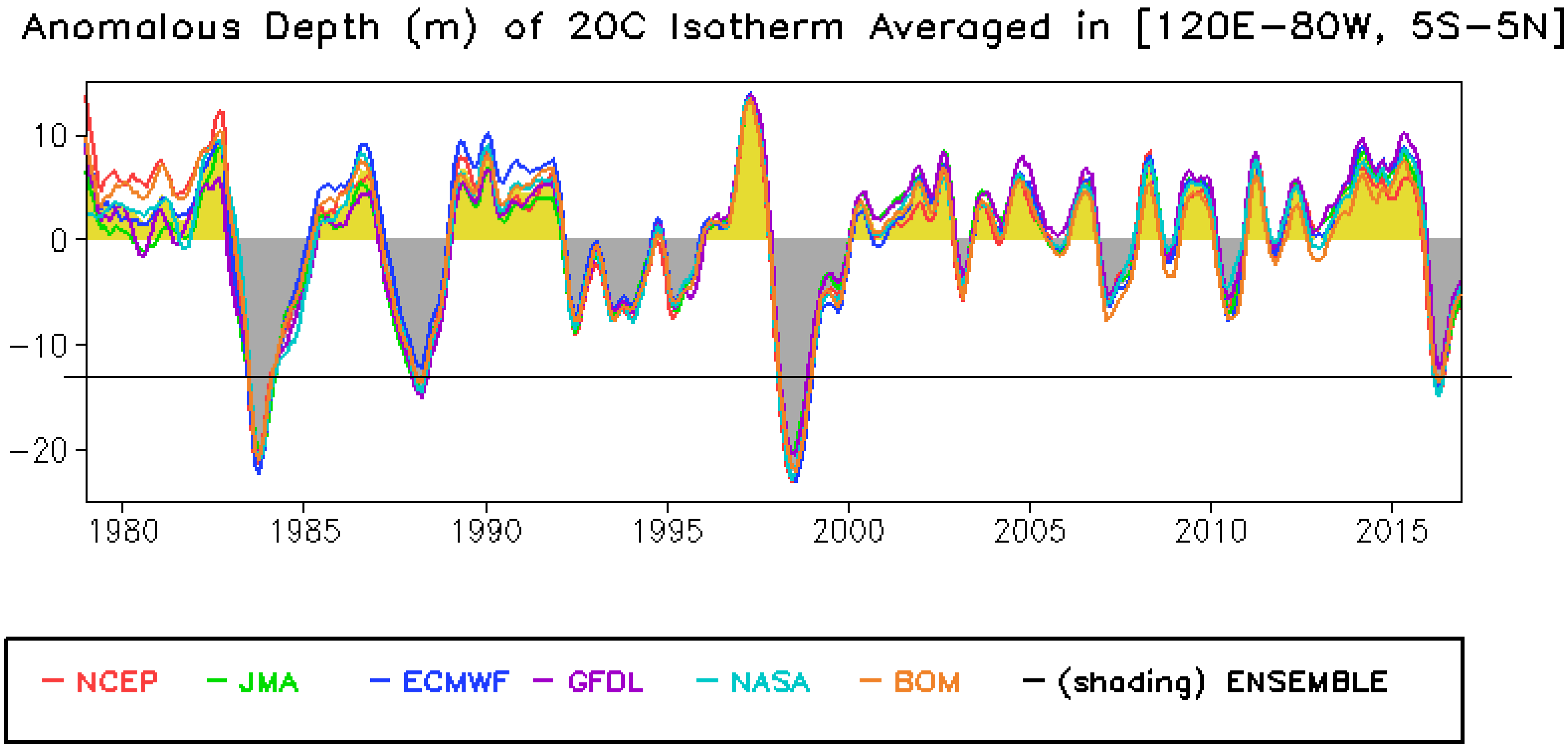
- **Positive IOD existed in OND 1997, while the basin-wide warming presented in OND 2015.**



- In the cold phase, OLR anomalies in OND 2016 were similar to those in OND 1998.
- But the negative D20 anomaly in OND 2016 was much weaker compared to 1983 and 1998.
- Negative SSTA and easterly wind anomalies were also weaker in 2016 than in 1983 and 1998.

Real-Time Ocean Reanalysis Intercomparison: WWV Index

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



- **WWV is defined as average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN]. Statistically, peak correlation of Nino3 with WWV occurs at 7 month lag (Meinen and McPhaden, 2000).**

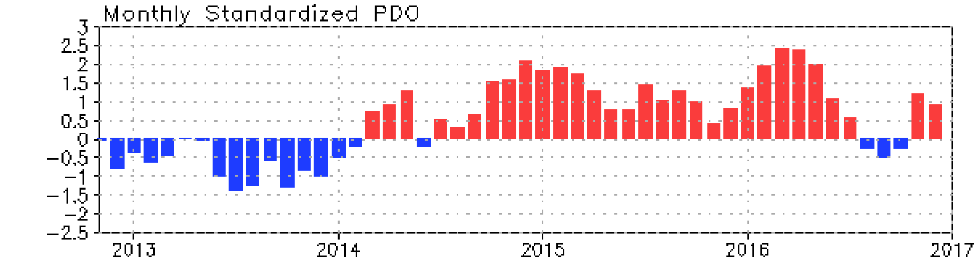
- **Since WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and NINO3.4 (Kessler 2002).**

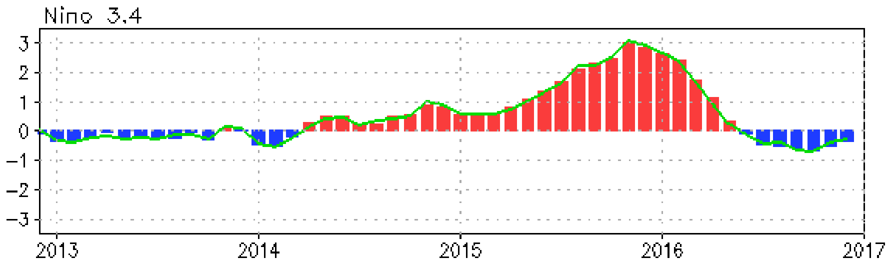
- **Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.**

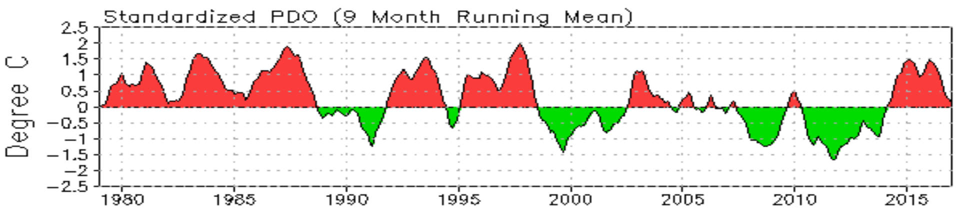
- **The discharge of the equatorial ocean heat content following the 2015/16 El Nino was much weaker than that following the 1982/83 and 1997/98 El Nino.**

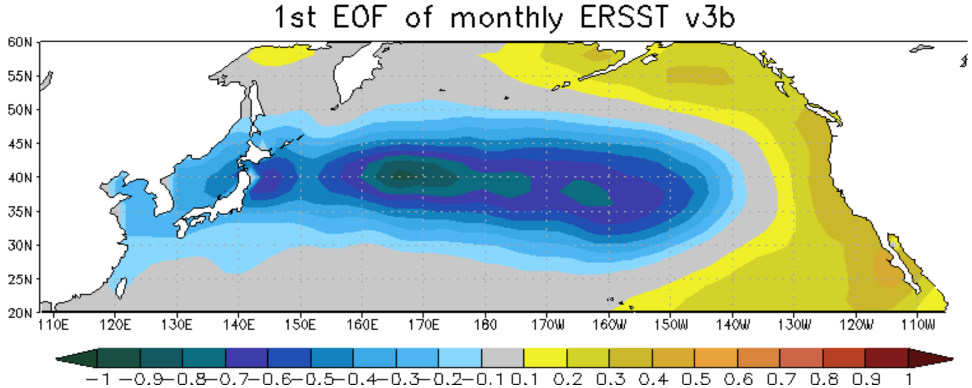
North Pacific & Arctic Oceans

Pacific Decadal Oscillation Index









- Previous CPC PDO index based on ERSST.v3b discontinued in Oct. 2016.

- Current CPC PDO index is based on ERSST.v4.

- For uncertainty in PDO indices, choices of EOF vector and SST data set are important sources of uncertainty on seasonal to decadal time scales, while choice of climatology base period only contributes to uncertainty on seasonal time scale (Wen et al. 2014).

-To reduce uncertainty, EOF vector and climatology base period are the same between current PDO index and previous PDO index.

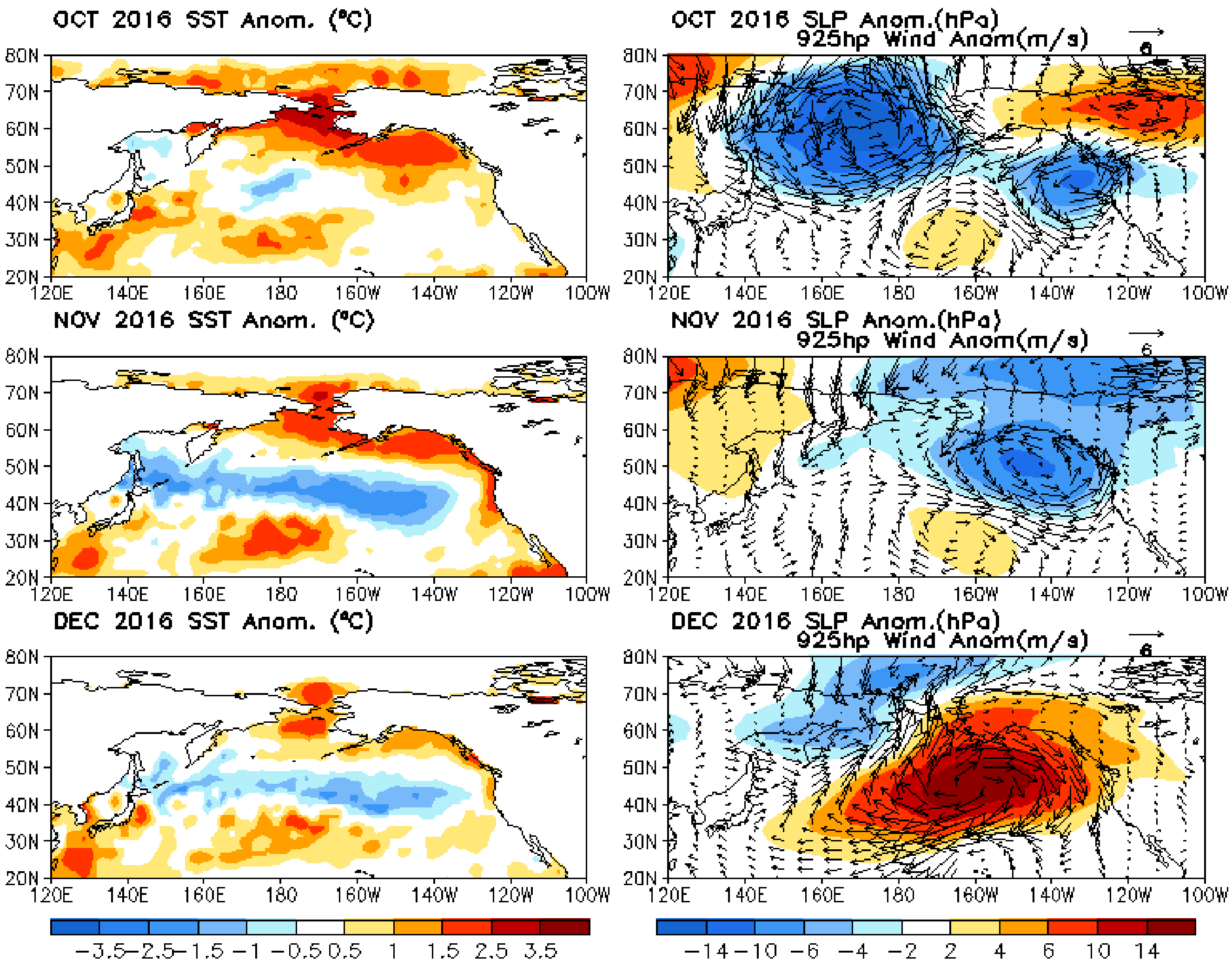
- Positive PDO weakened slightly, with PDO index = 0.9.

Wen, C., A. Kumar, and Y. Xue (2014), Factors contributing to uncertainty in Pacific Decadal Oscillation index, Geophys. Res. Lett., 41, 7980–7986, doi:10.1002/2014GL061992.

- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST.v4 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.

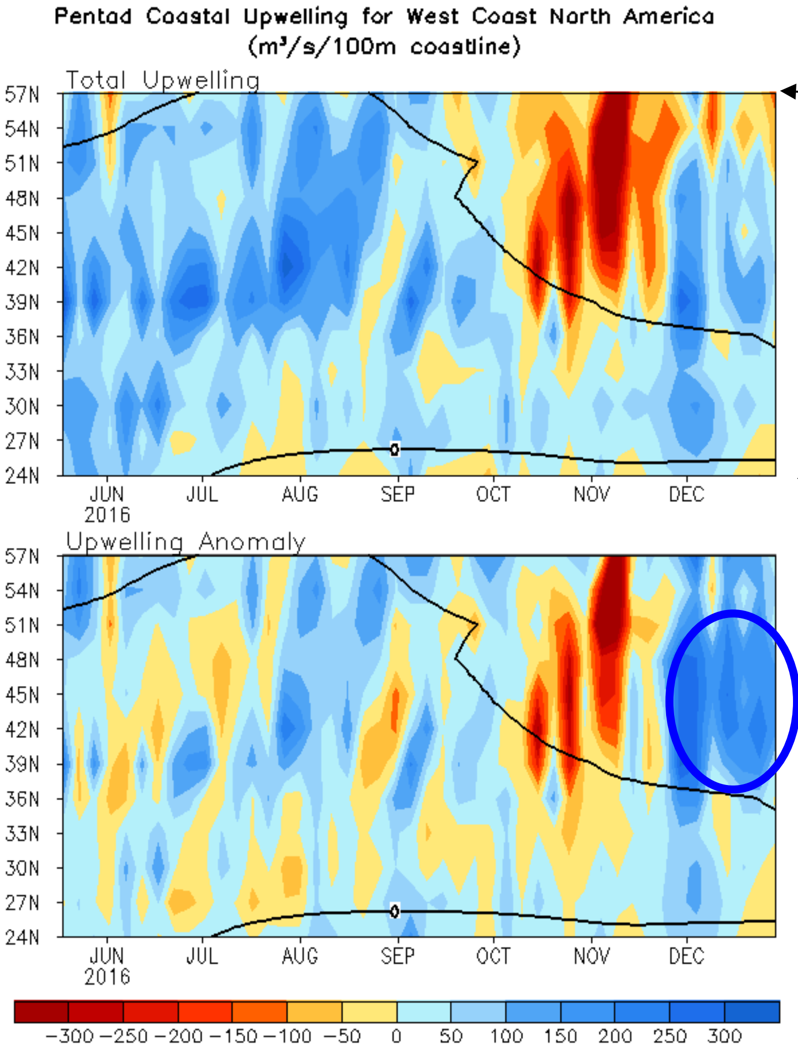
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

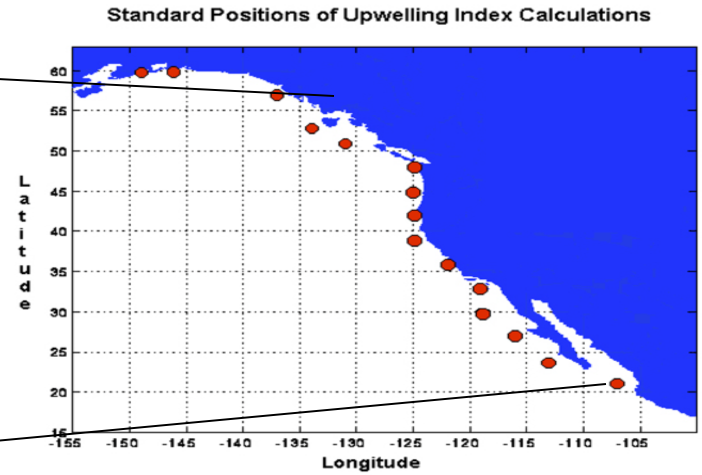
Last Three Month SST, SLP and 925hp Wind Anom.



- Both positive and negative SSTA weakened in N. Pacific in Dec 2016.
- Anomalous anticyclone SLP dominated in N. Pacific in Dec 2016 and northerly wind anomalies along the W. Coast favor anomalous upwelling.

North America Western Coastal Upwelling





- Seasonal downwelling north of 36N suppressed, consistent with the northerly wind anomalies long the coast.

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

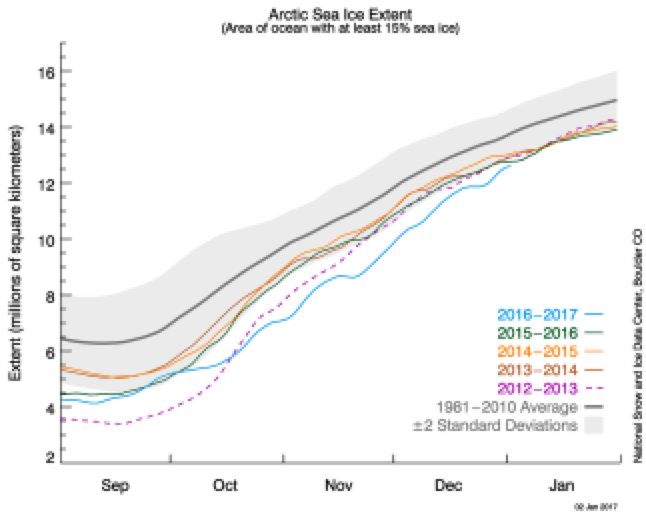
- Area below (above) black line indicates climatological upwelling (downwelling) season.

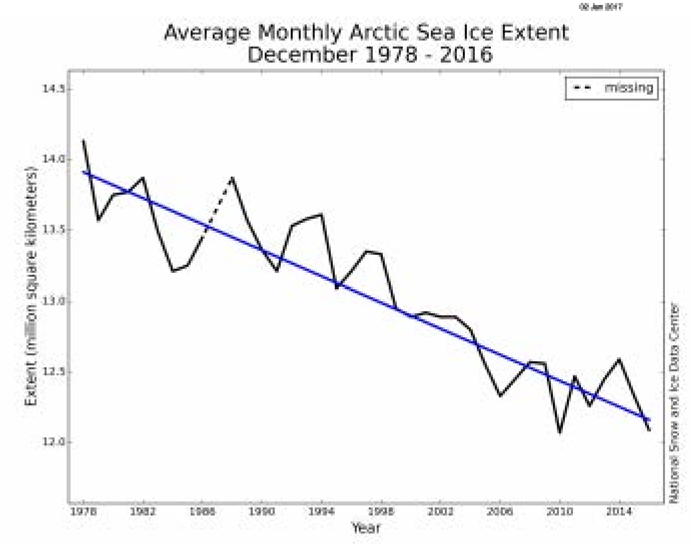
- Climatologically upwelling season progresses from March to July along the west coast of North America from 36°N to 57°N.

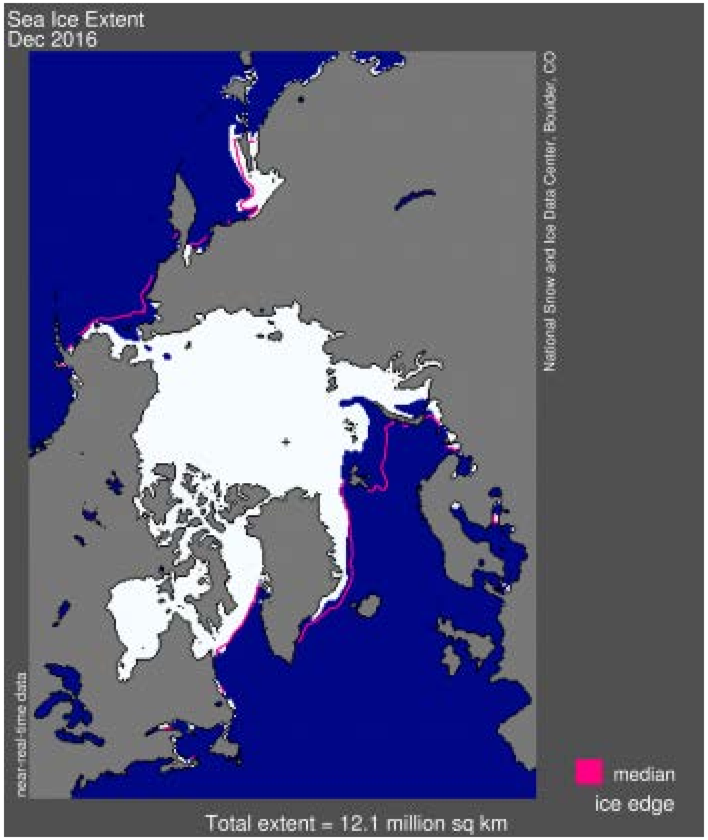
Arctic Sea Ice

National Snow and Ice Data Center

http://nsidc.org/arcticseaicenews/index.html



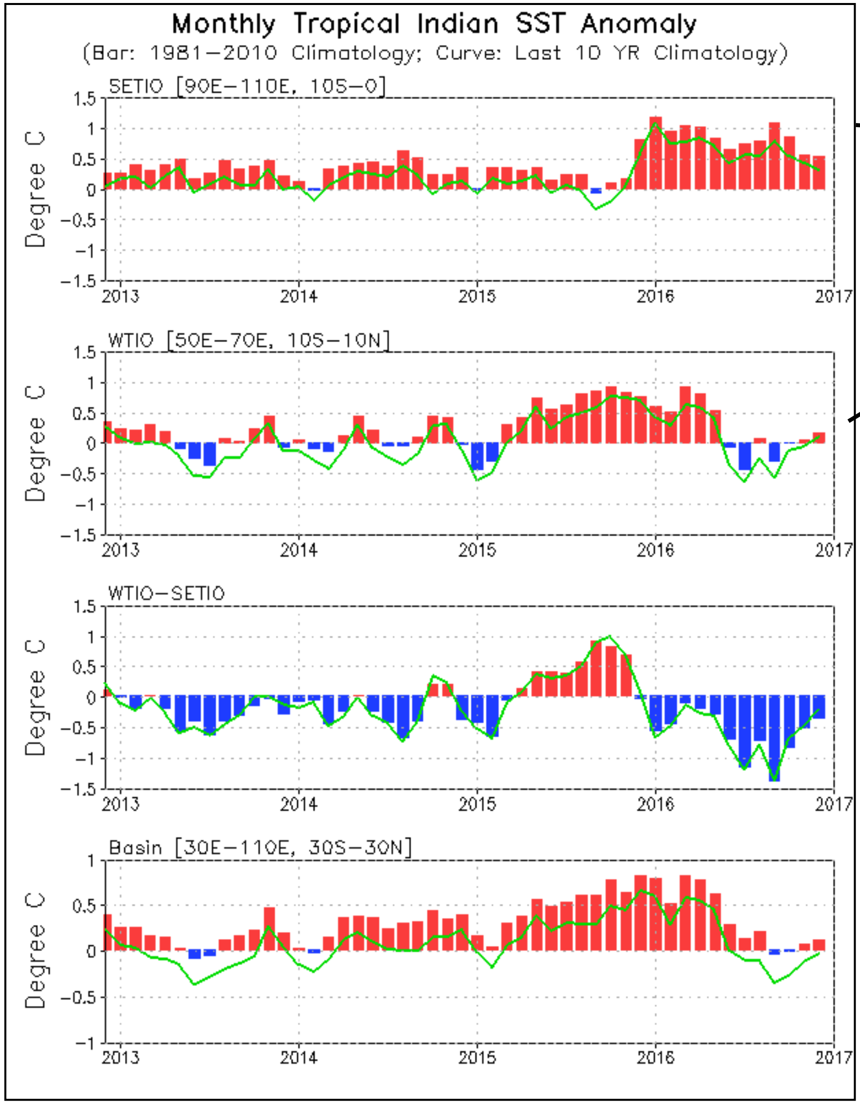


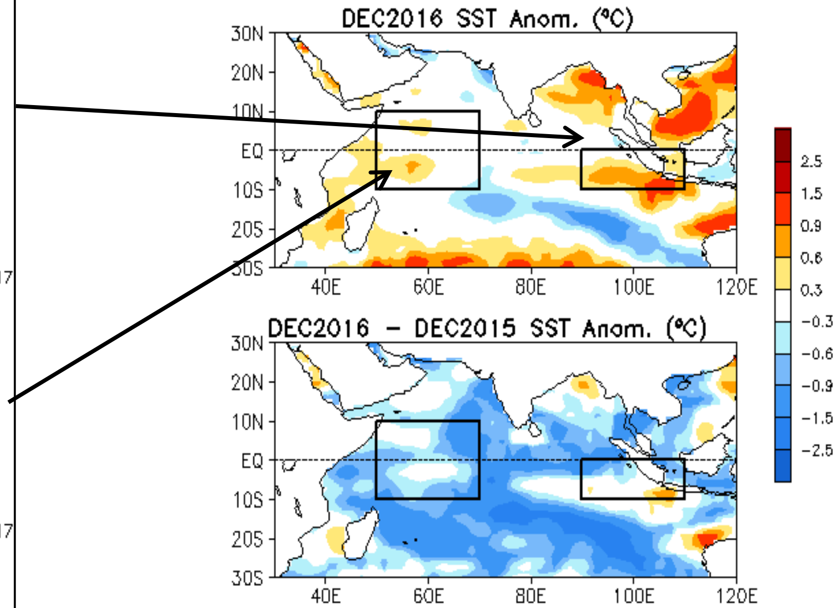


- The monthly average sea ice extent for Dec 2016 was slightly higher than the record low in Dec 2010.

Indian Ocean

Evolution of Indian Ocean SST Indices





- SETIO has been strongly positive (> +0.7°C) since Dec 2015, WTIO has been near-normal since Jun 2016.
- Negative DMI weakened in Dec 2016.
- Basin index were 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.

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

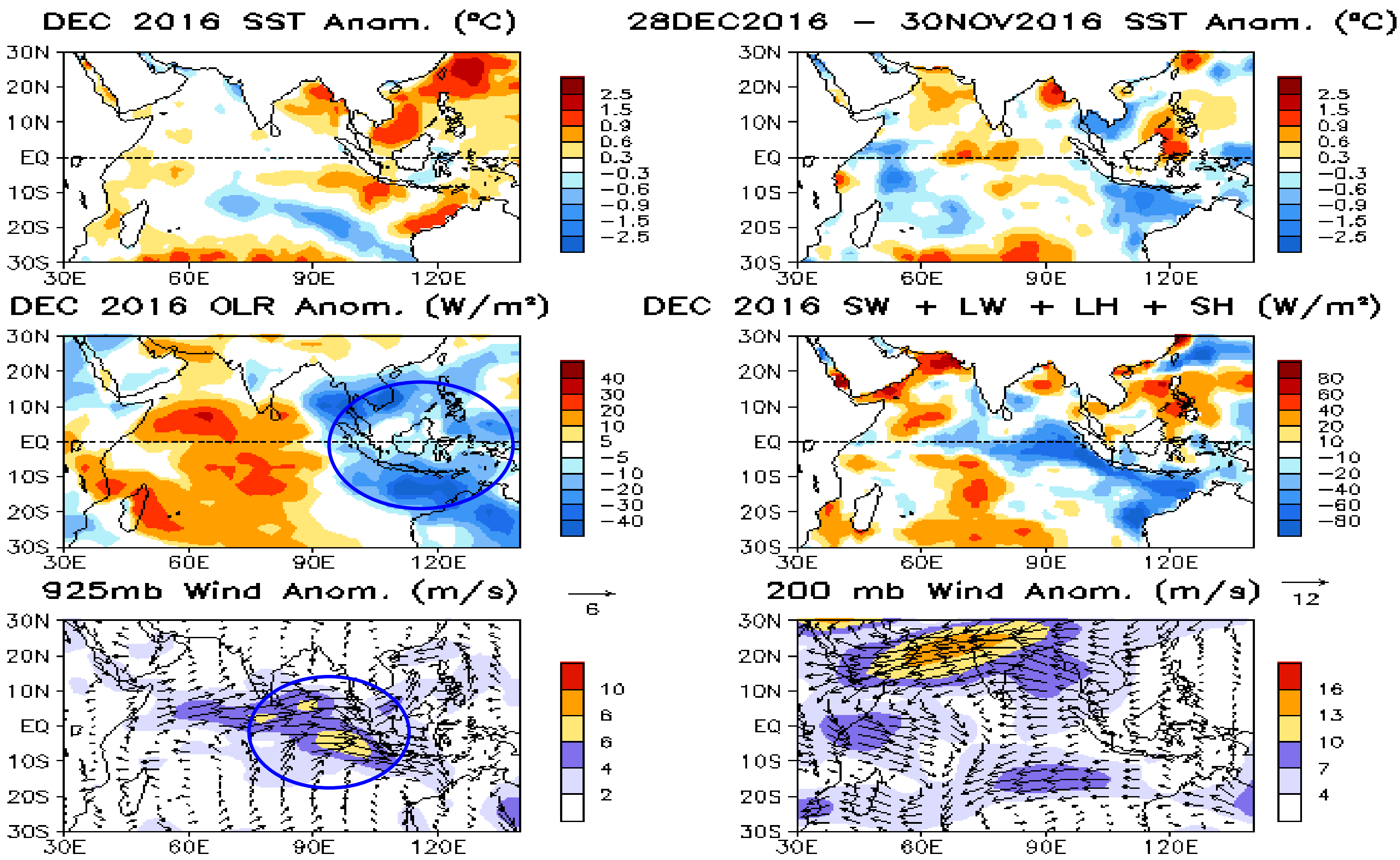
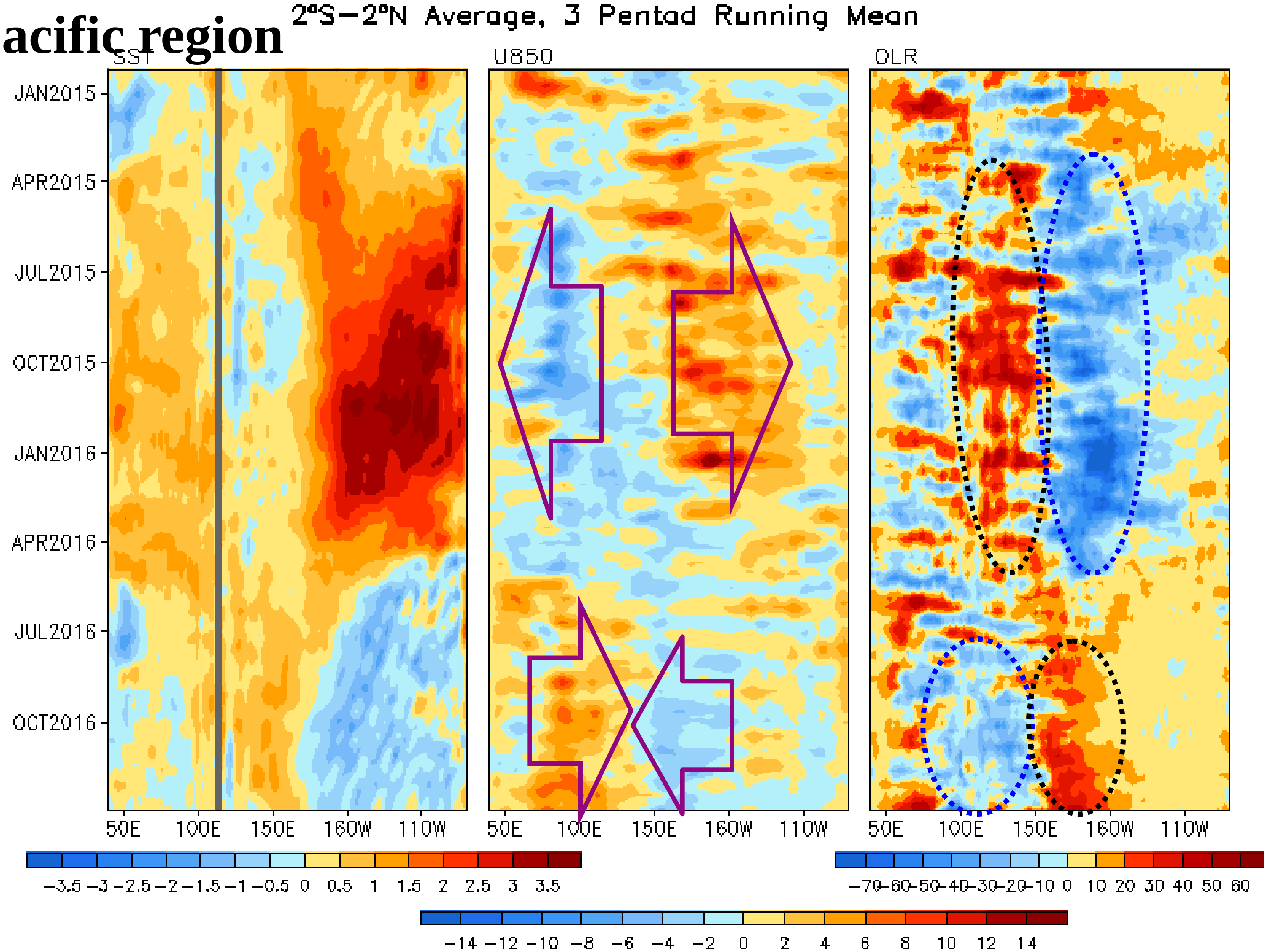


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

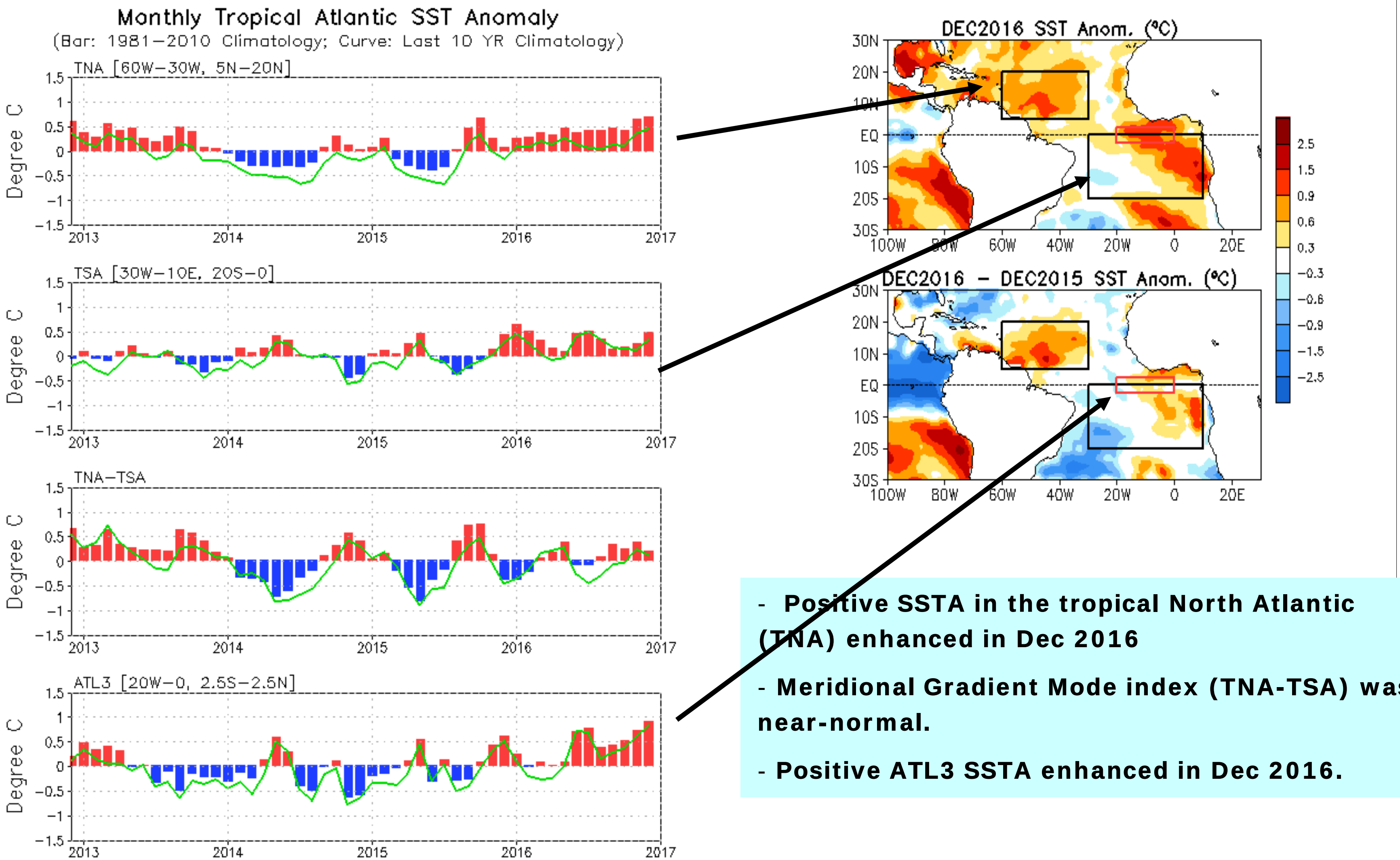
Indo-Pacific region



- 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.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices



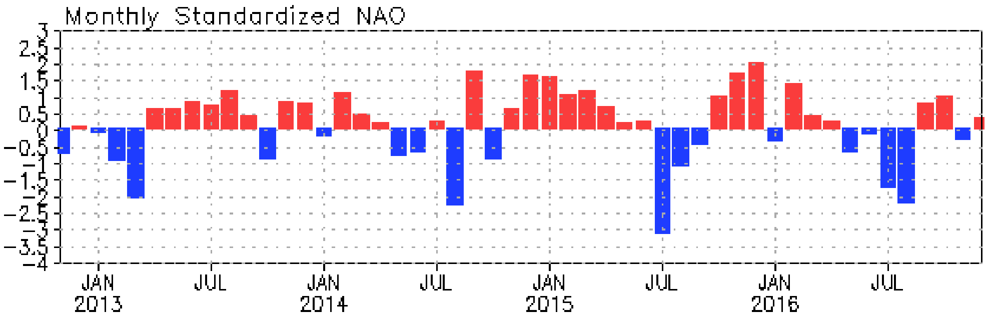
- Positive SSTA in the tropical North Atlantic (TNA) enhanced in Dec 2016

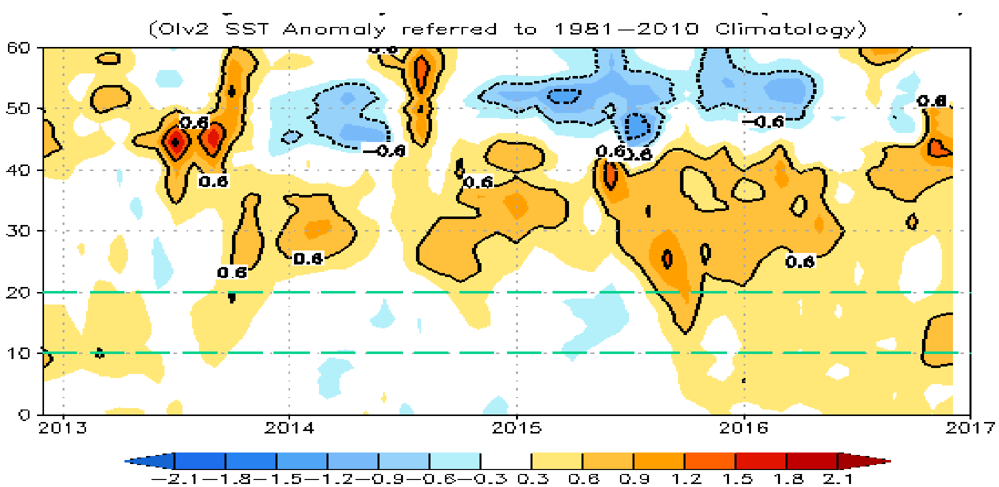
- Meridional Gradient Mode index (TNA-TSA) was near-normal.

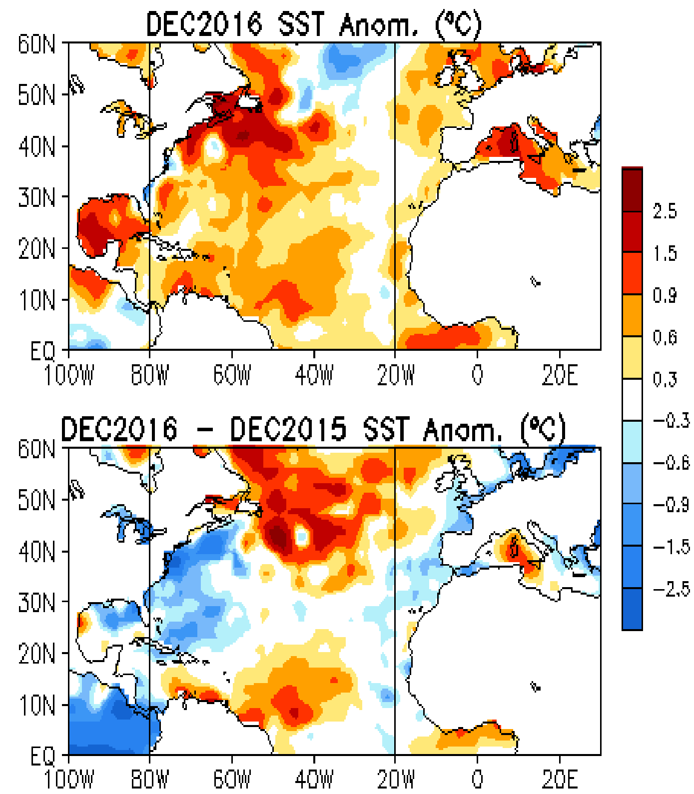
- Positive ATL3 SSTA enhanced in Dec 2016.

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.

NAO and SST Anomaly in North Atlantic





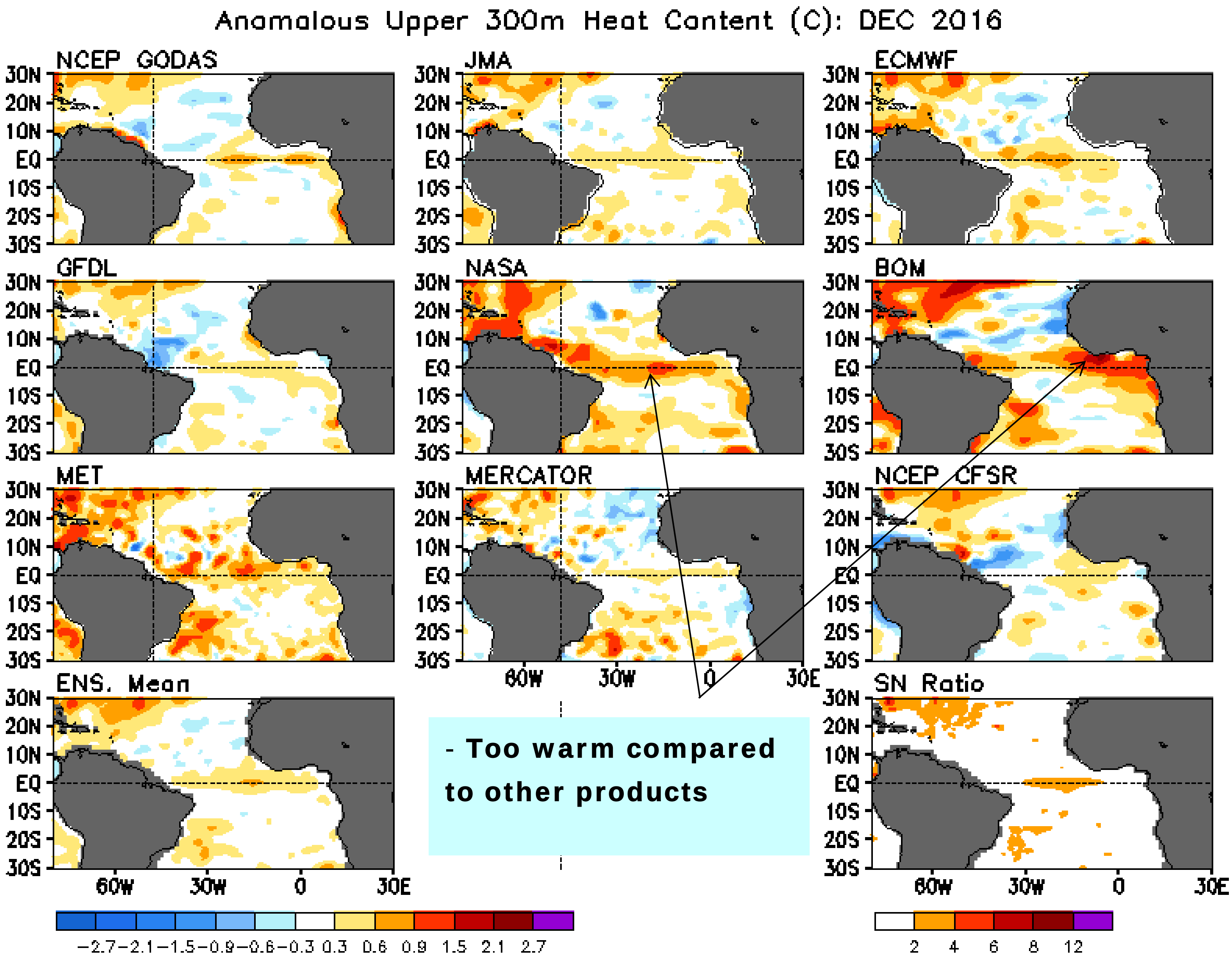


- NAO was near-normal in Dec 2016.
- Strong positive SSTA persisted along the Gulf of Mexico and E. coast of North America.

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.

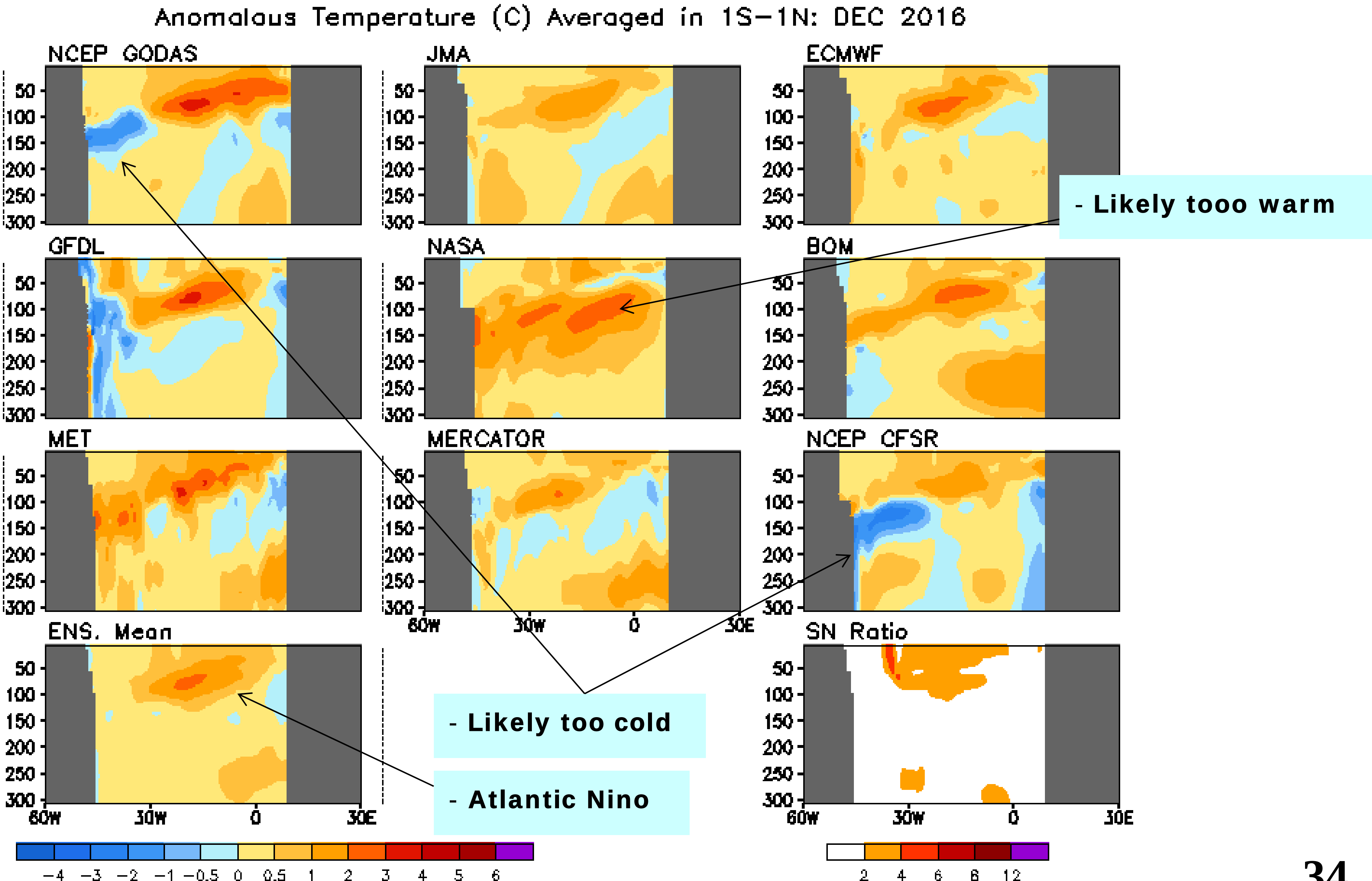
Real-Time Ocean Reanalysis Intercomparison: HC300 Anom. in Dec 2016

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



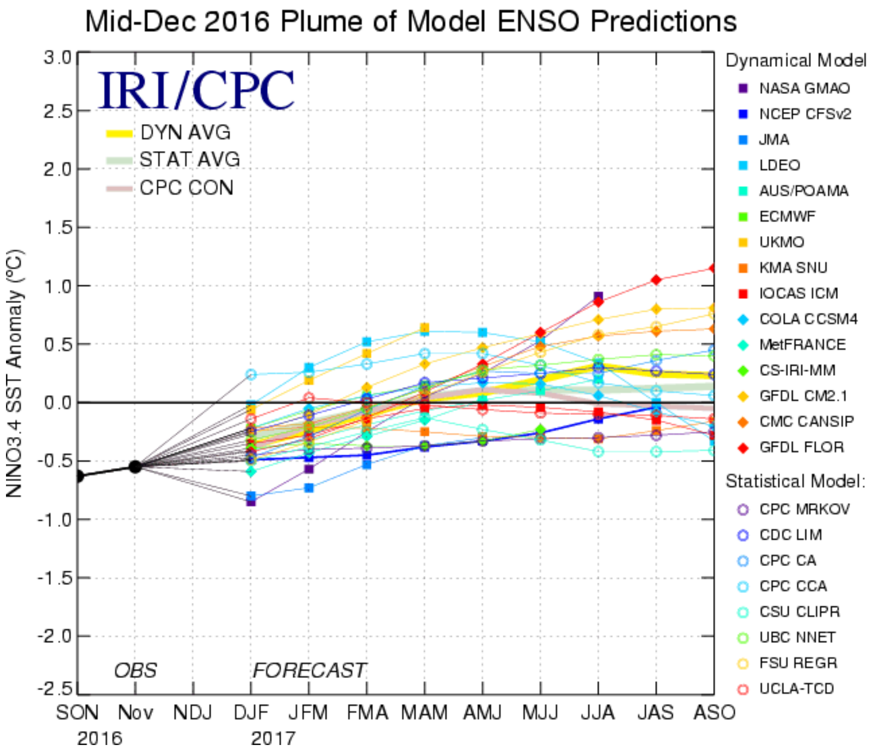
Real-Time Ocean Reanalysis Intercomparison: Eq. Temp. Anom. in Dec 2016

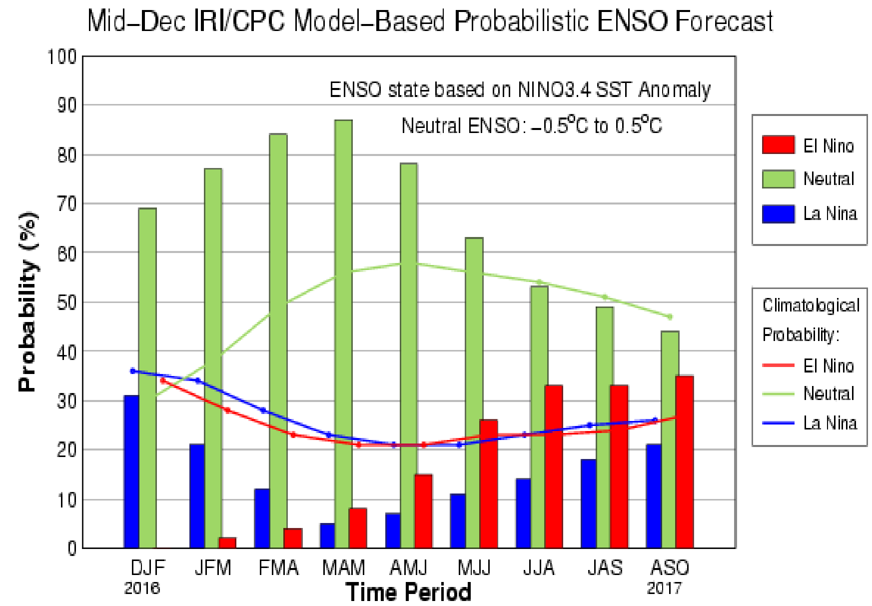
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)



Global SST Predictions

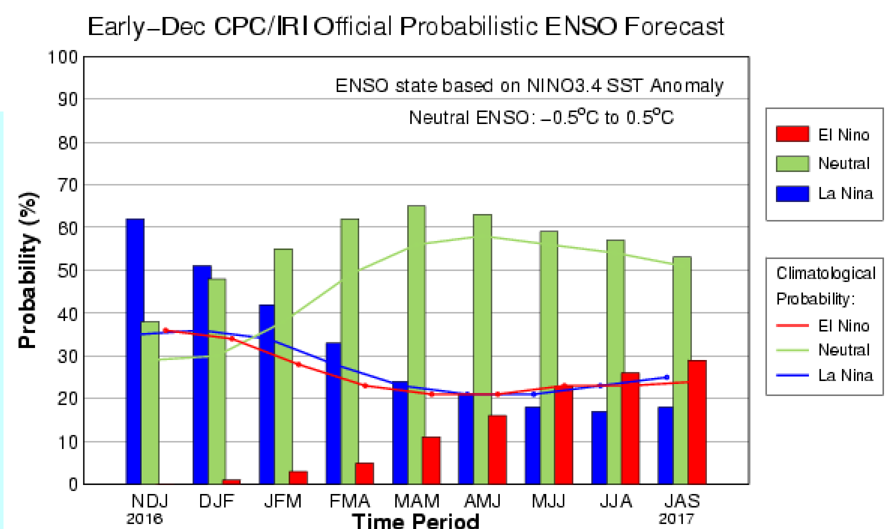
IRI NINO3.4 Forecast Plume



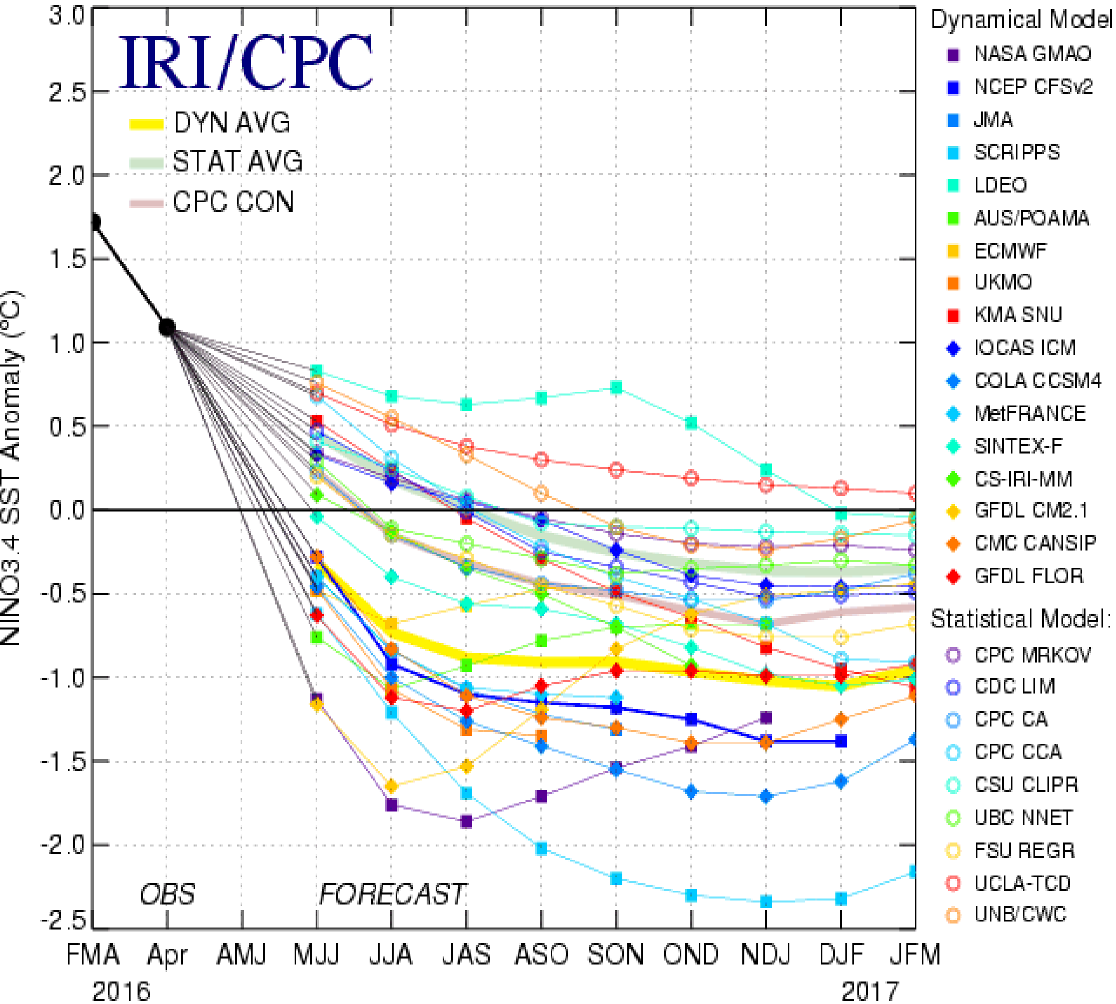


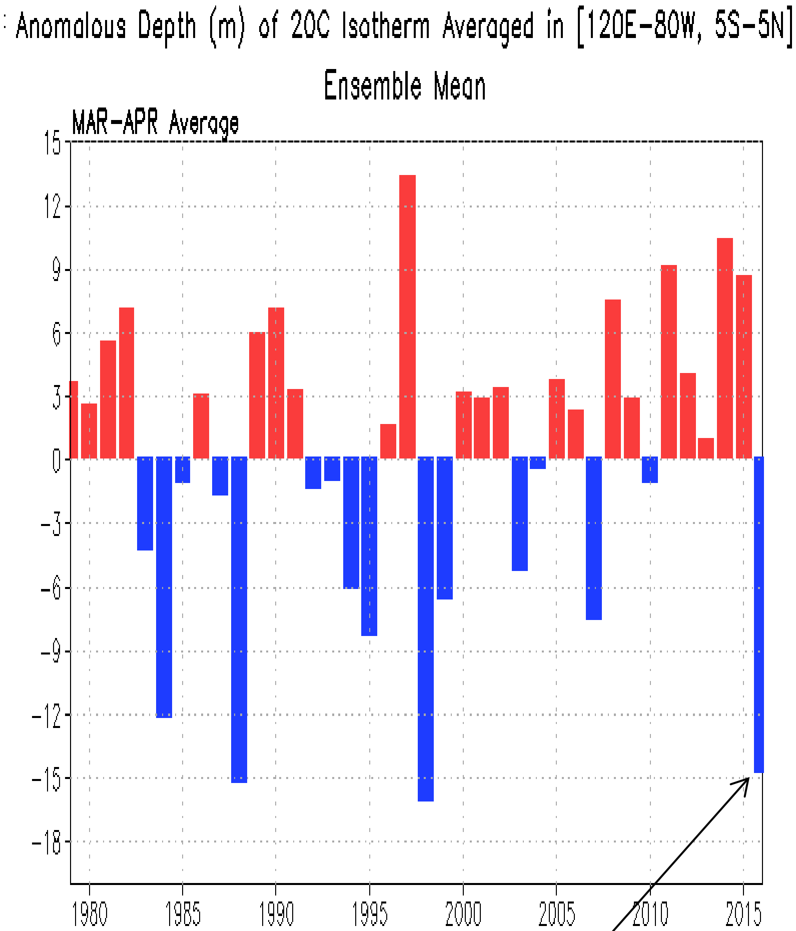
- **Multi-model ensemble forecasts suggest that La Niña conditions will weaken and likely transition into ENSO-neutral in early spring 2017.**

- **NOAA "ENSO Diagnostic Discussion" on 8 Dec 2016 suggested that "La Niña conditions are present, with a transition to ENSO-neutral favored during January-March 2017".**



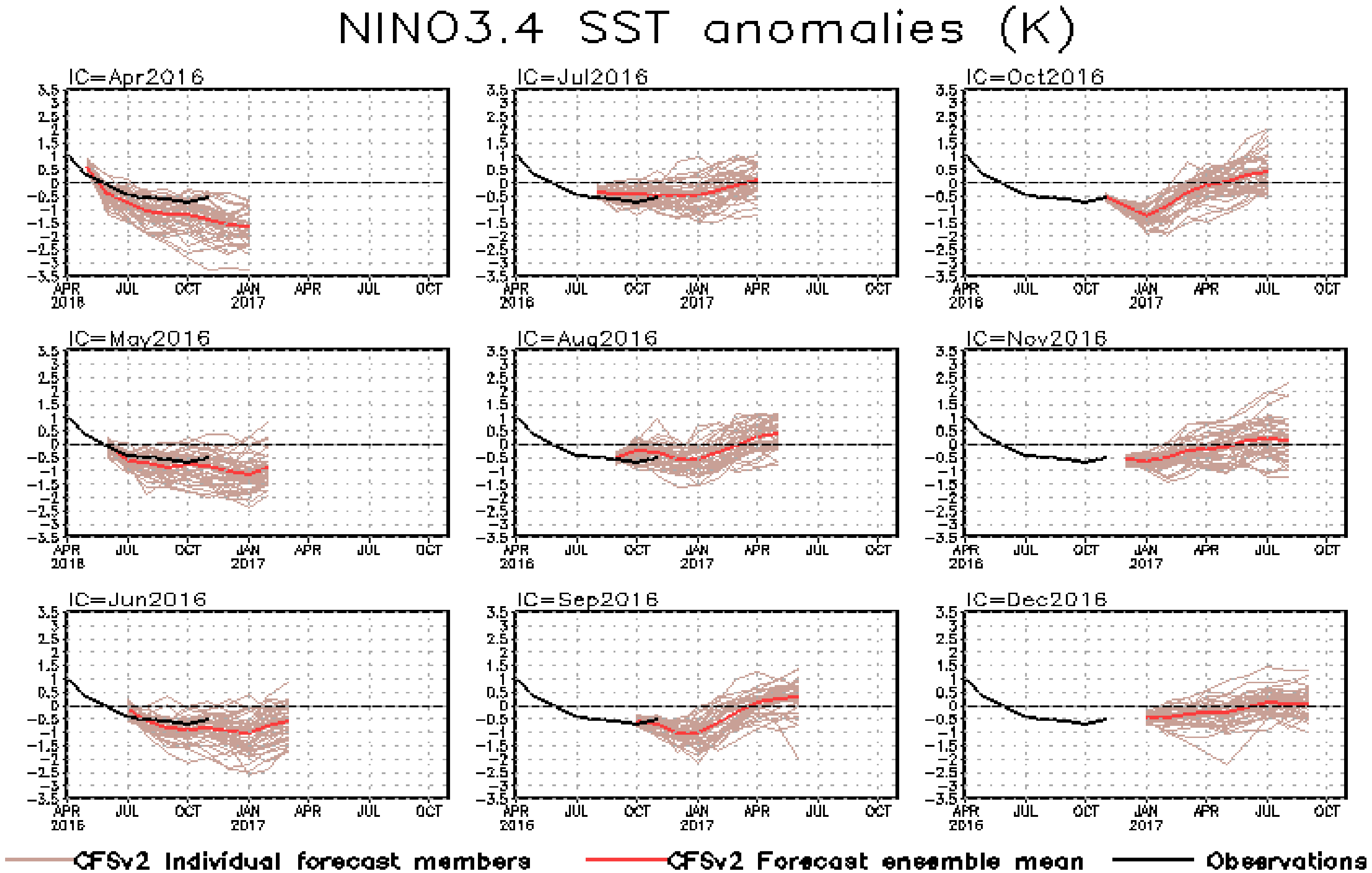
Mid-May 2016 Plume of Model ENSO Predictions





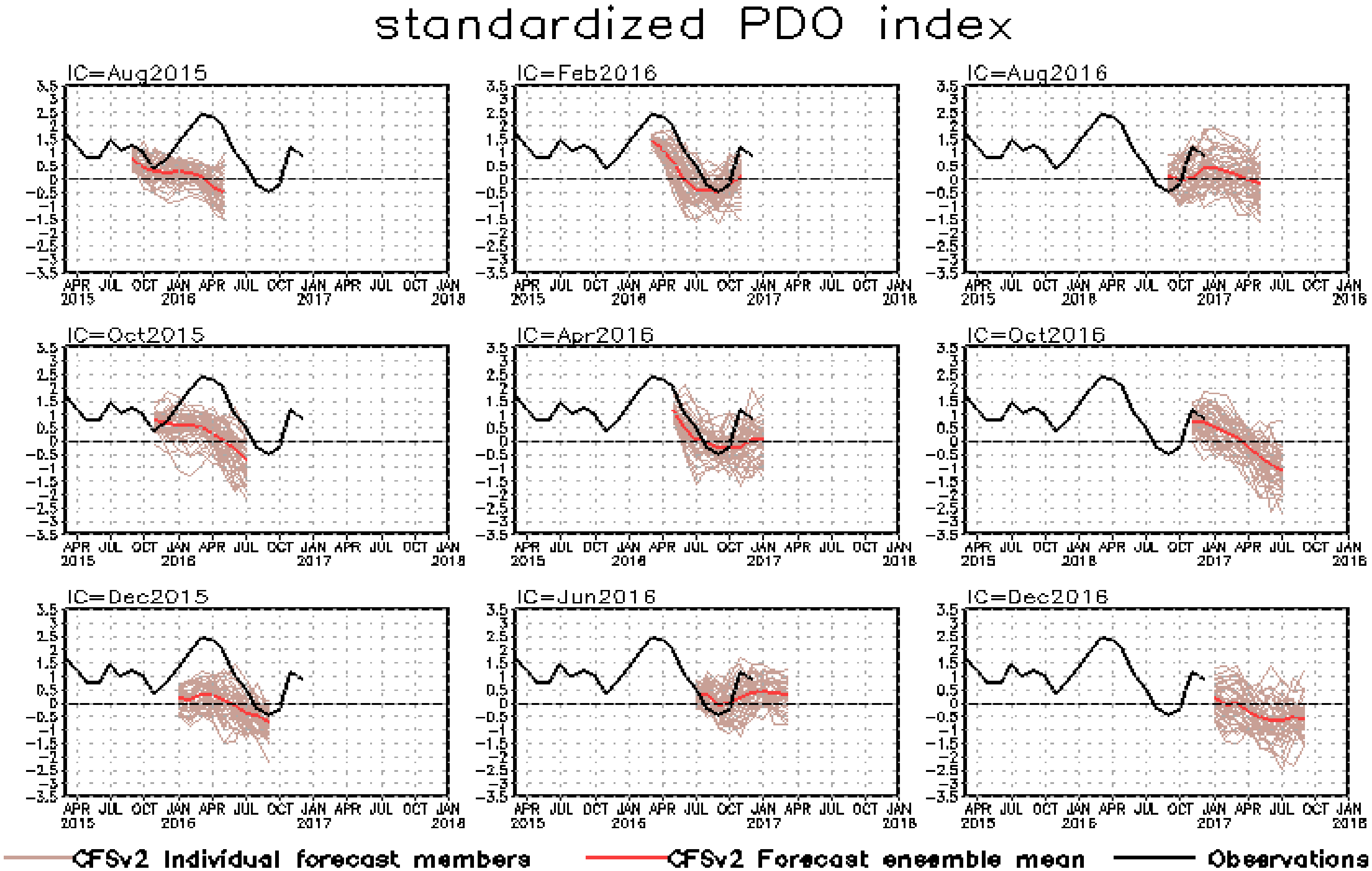
- **The ensemble mean of dynamical model forecasts issued in Mid-May 2016 overestimated the La Niña conditions, indicating the models were too sensitive to the subsurface cold anomalies in Apr 2016.**
- **However, the ensemble mean of statistical model forecasts captured the amplitude of the cold phase more realistically.**

NCEP CFSv2 NINO3.4 Forecast



- Latest CFSv2 predictions suggest weak La Nina conditions will weaken and transition into ENSO-neutral in spring 2017.

NCEP CFSv2 Pacific Decadal Oscillation (PDO) Forecast

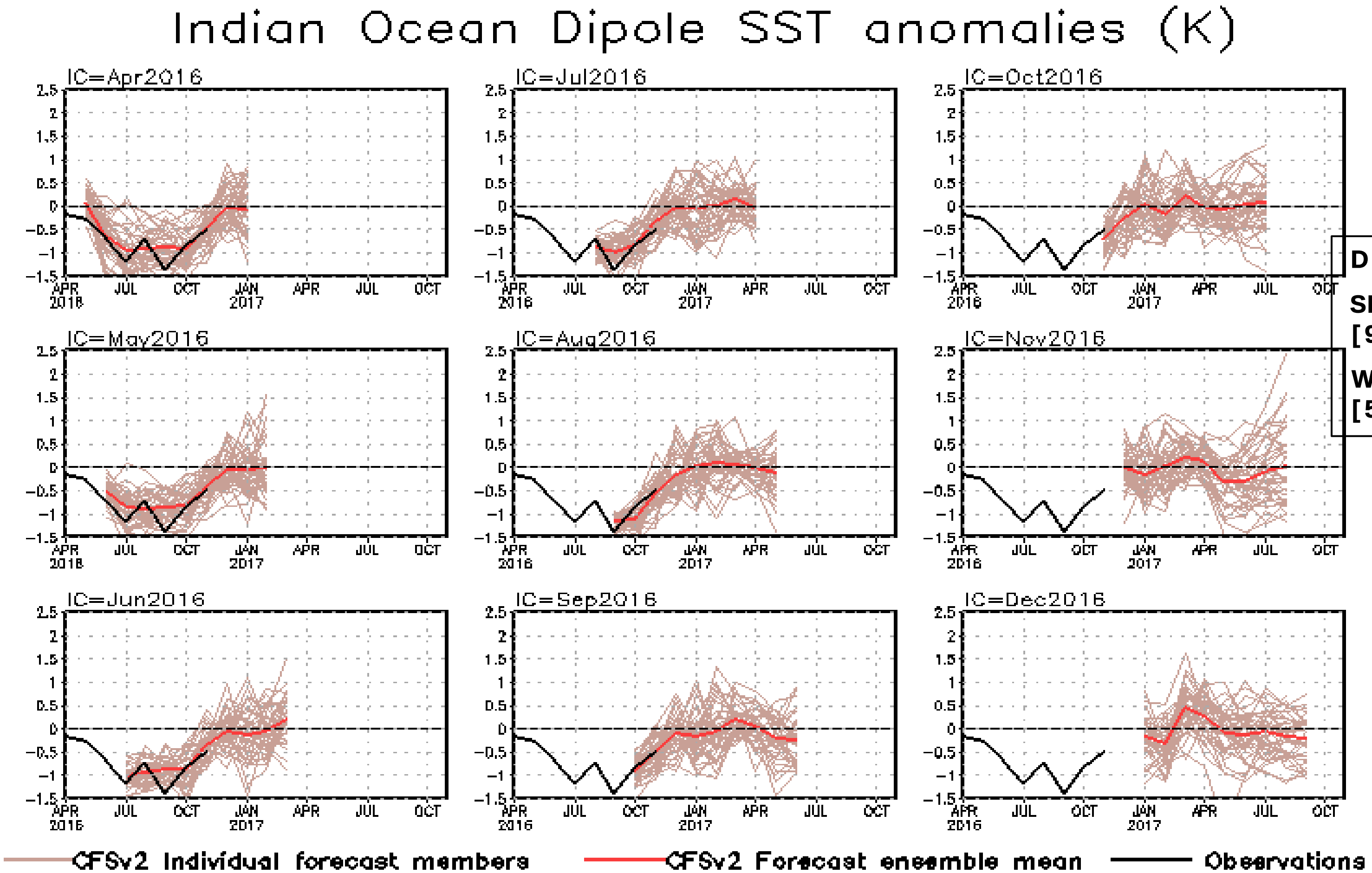


PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

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

NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

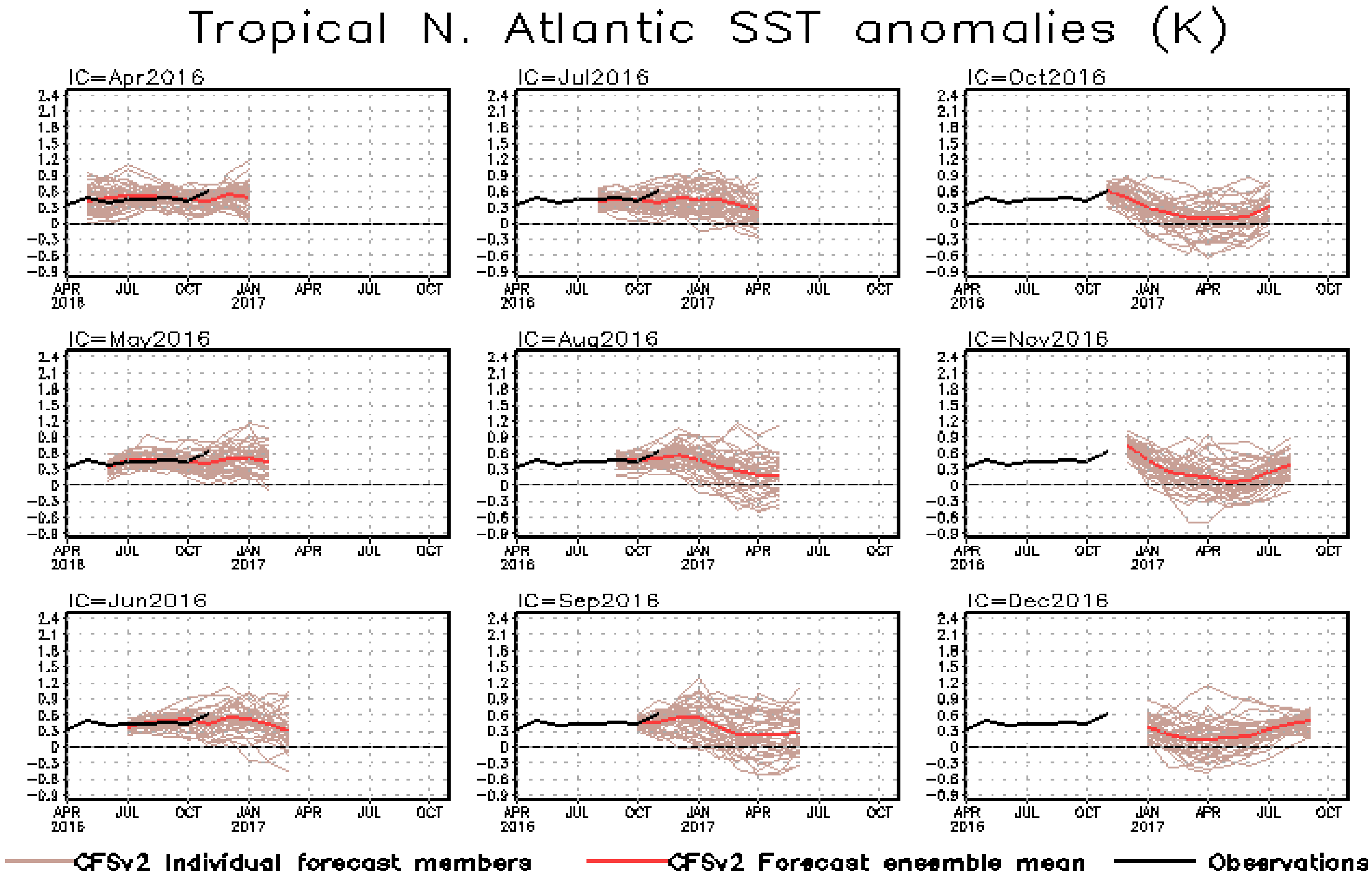
SETIO = SST anomaly in [90ºE-110ºE, 10ºS-0]

WTIO = SST anomaly in [50ºE-70ºE, 10ºS-10ºN]

- Latest CFSv2 prediction suggests neutral IOD in next spring and summer.

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.

NCEP CFSv2 Tropical North Atlantic SST Forecast



- Latest CFSv2 prediction suggests tropical North Atlantic SST will cool down and return to normal-conditions in next spring and summer.

Overview

- **Pacific Ocean**
  - La Niña conditions weakened in Dec 2016
  - Negative temperature anomalies weakened substantially due to the eastward propagation of a downwelling Kelvin wave
  - CPC/IRI consensus favors the continuation of weak La Niña conditions through December-February (DJF) 2016-17
  - Positive PDO phase continued with PDO = +0.9 in Dec 2016
  - Arctic sea ice extent in Dec 2016 was slightly higher than the record low in Dec 2010

- **Indian Ocean**
  - The basin wide warming since spring 2015 dissipated in summer 2016 coincided with the onset of La Niña conditions
  - Westerly wind anomalies prevailed since summer 2016, consistent with enhanced convection over the Maritime Continents

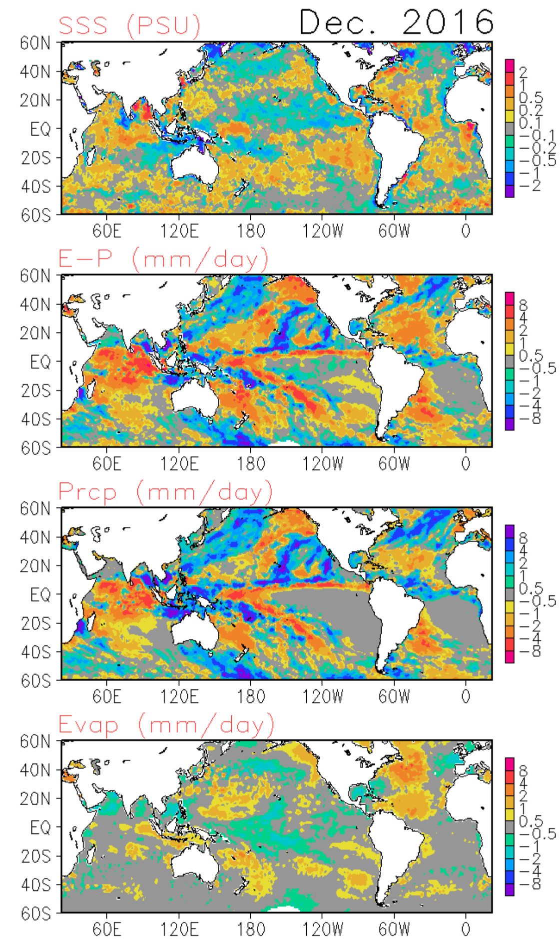
- **Atlantic Ocean**
  - NAO was near-normal in Dec 2016
  - Strong positive SSTA continued along the eastern coast of North America and Gulf of Mexico

Backup Slides

Global Sea Surface Salinity (SSS)

Anomaly for December 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 positive SSS anomaly in the Pacific Ocean along the Equator indicates the La Nina condition continues this month. Off the equator, similar as last month, large scale of SSS decreasing appears in the east basin of 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 still exit, con-incident with increasing of precipitation. In this month, the SSS in the Bay of Bengal significantly increased, while both the evaporation and precipitation decreased leading to a strong E-P decrease. Therefore, the winter ocean circulation must control the salinity change in this region.



- **Data used**

  SSS :

  Blended Analysis of Surface Salinity (BASS) V0.Y

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

  (Xie et al. 2014)

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

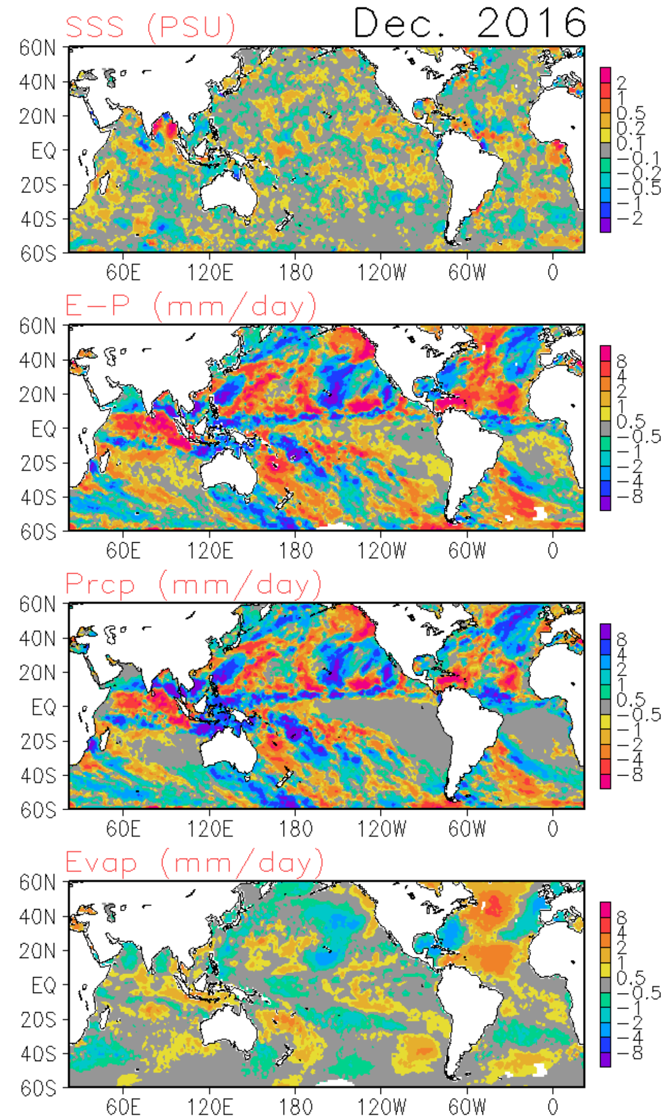
  Precipitation: CMORPH adjusted satellite precipitation estimates

  Evaporation: CFS Reanalysis

Global Sea Surface Salinity (SSS)

Tendency for December 2016

Compared with last month, the salinity in the Pacific Ocean at the equatorial region was continuing increasing, particularly east of 150° E, which suggests that the La Nina condition is continuing or slightly strengthening this month. The SSS significantly increased in the Bay of Bengal with decreasing precipitation/evaporation, which is primarily due to the oceanic advection and/or entrainment which brings salty water to this region.



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

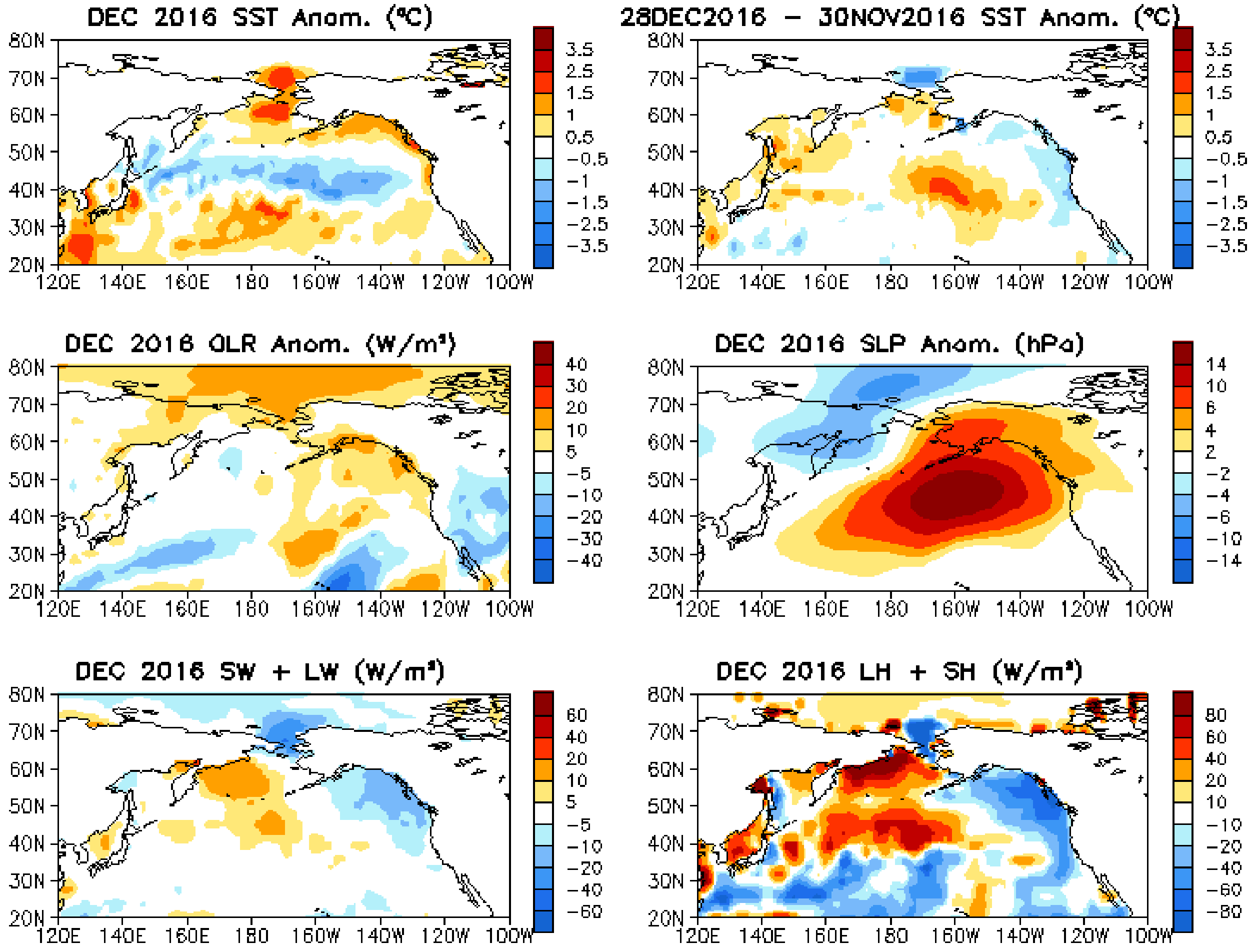


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

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

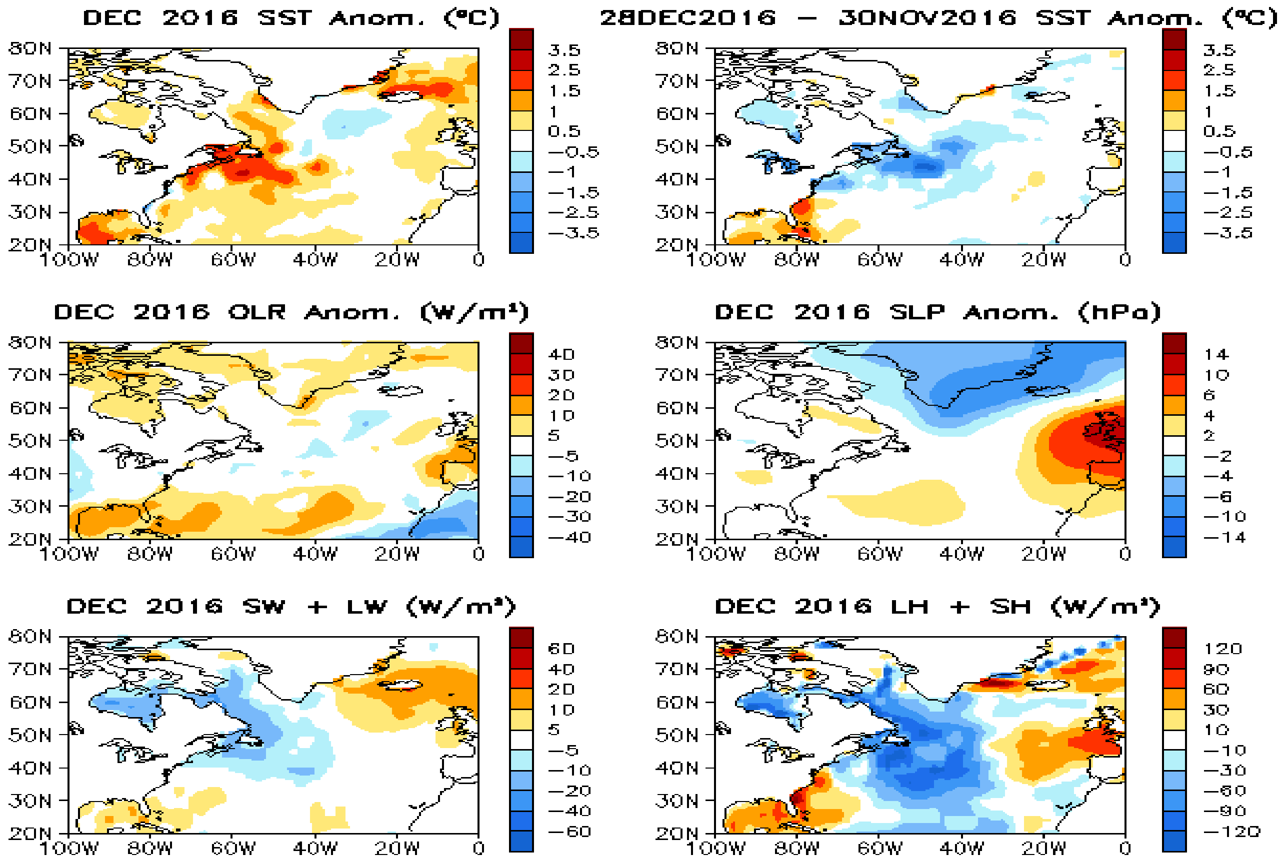
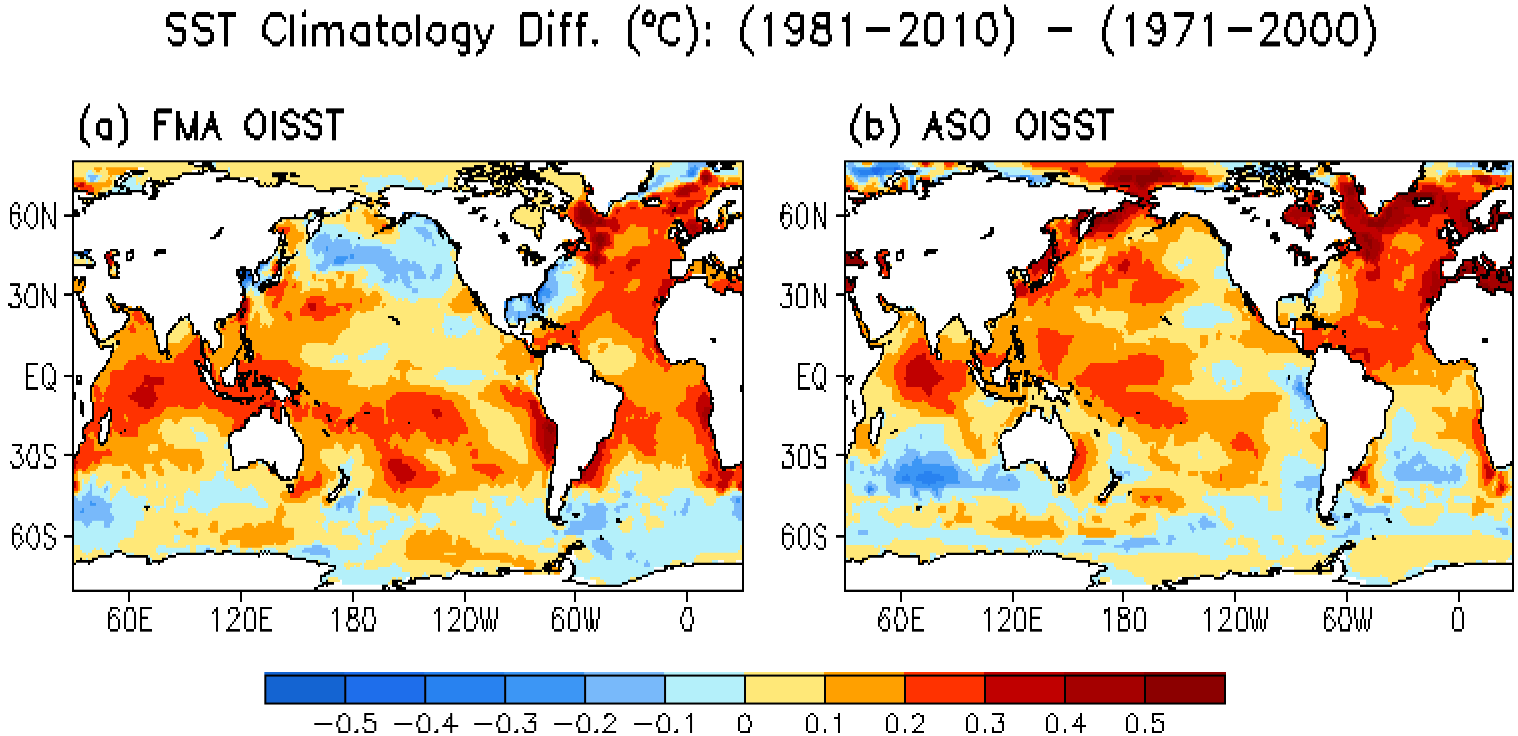


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

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^{o}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!