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** **(ENSO evolution and prediction)**
  - **Indian Ocean**
  - **Atlantic Ocean**
- **Global SST Predictions**

Overview

Pacific Ocean

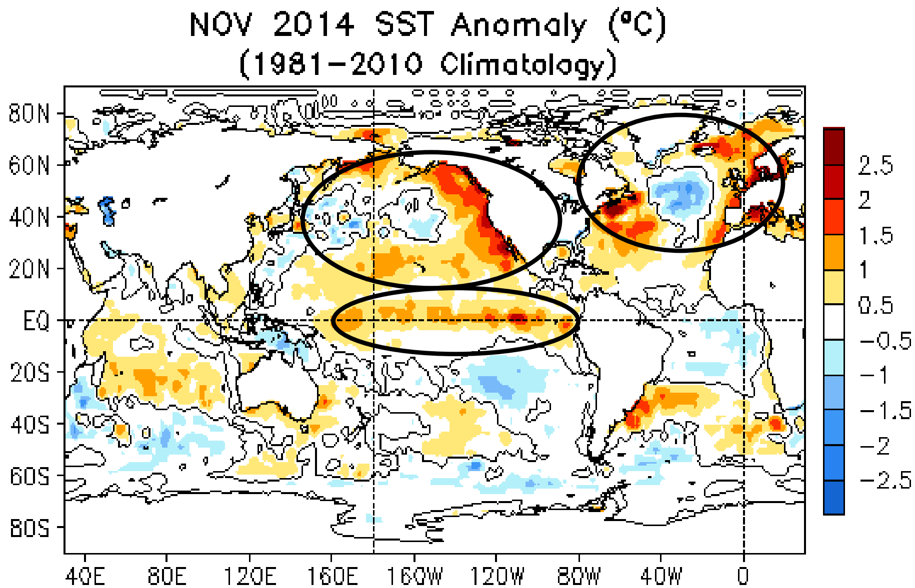
- ENSO-neutral conditions continued during Nov 2014 (NINO3.4=+0.9C, but the tropical Pacific atmosphere was not fully in El Nino conditions yet).
- The consensus forecast suggests 65% chance of El Niño conditions during the Northern Hemisphere winter, which is favored to last into the Northern Hemisphere spring 2015.
- Intraseasonal variability in equatorial subsurface temperature was associated with oceanic Kelvin wave episodes.
- Recent low-level easterly wind anomalies in the western tropical Pacific were probably associated with Madden Julian Oscillation (MJO) activity.
- Positive PDO phase persisted with PDO=+1.3 in Nov 2014.

Atlantic Ocean

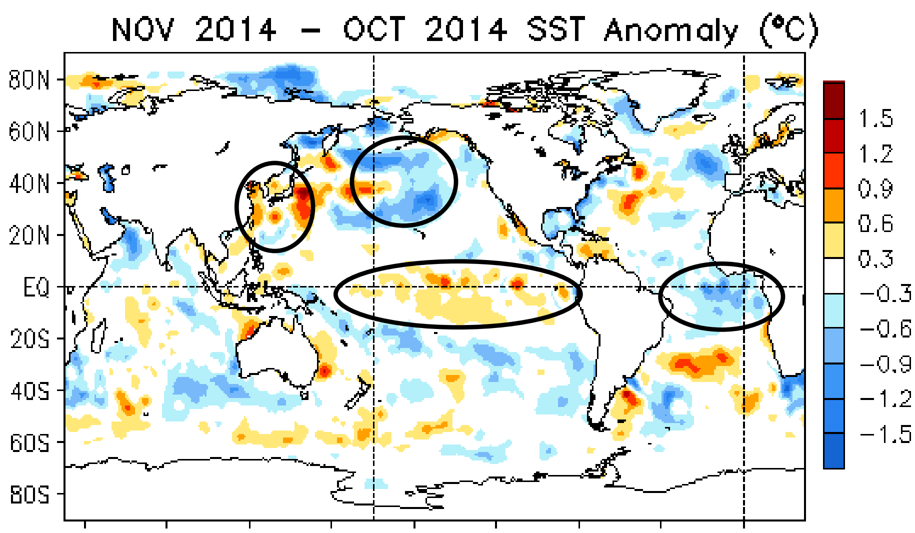
- NAO phase switched to positive with NAO index = +0.58 in Nov 2014.
- 2014 Atlantic hurricane season had 8 tropical storms (TSs), 6 hurricanes (Hs) and 2 major hurricanes (MHs), which is below the average (12 TSs, 6 Hs, 3 MHs). The ACE is 64% of normal.
- 2014 Eastern Pacific hurricane season had 22 TSs, 16 Hs and 9 MHs, which is well above the average (15 TSs, 8 Hs, 4 MHs). The ACE is 198% of normal.

Global Oceans

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



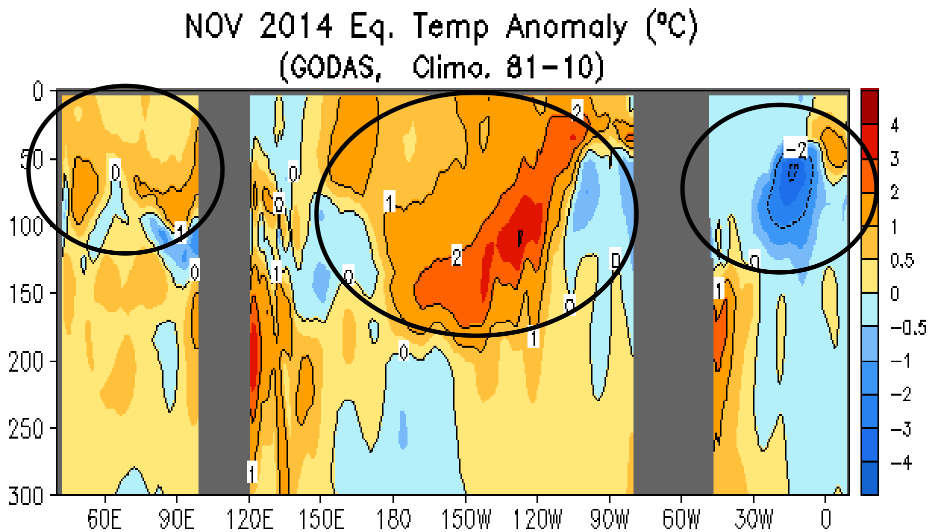
- SST was above-normal cross the central-eastern equatorial Pacific.
- A positive PDO pattern presented in N. Pacific.
- Positive SST anomalies were observed near the coast of Northeast US and Northwest Europe.



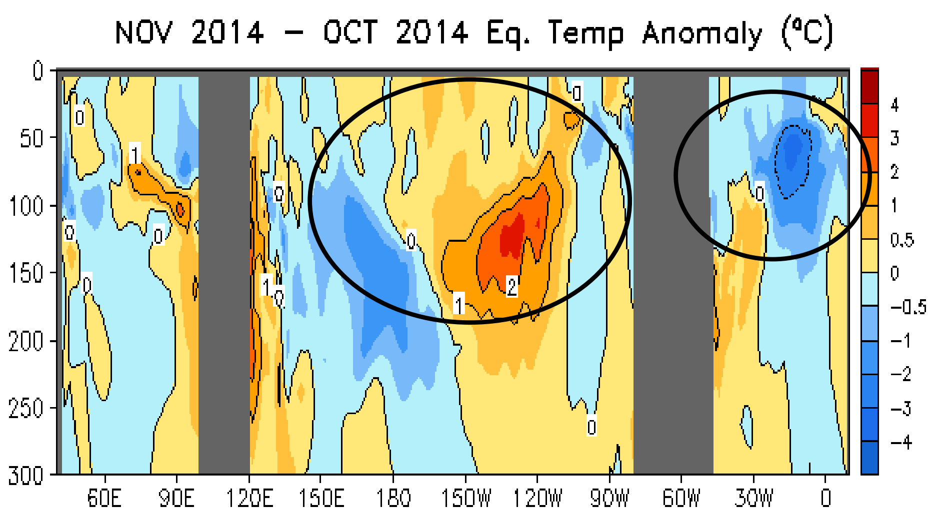
- A cooling tendency presented in central N. Pacific and tropical Atlantic.
- A warming tendency was observed near Japan and equatorial Pacific.

Fig. 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^{O}S-2^{O}N



- Positive temperature anomalies occupied most of the equatorial Pacific and Indian Ocean.
- Negative anomalies dominated the upper equatorial Atlantic Ocean.

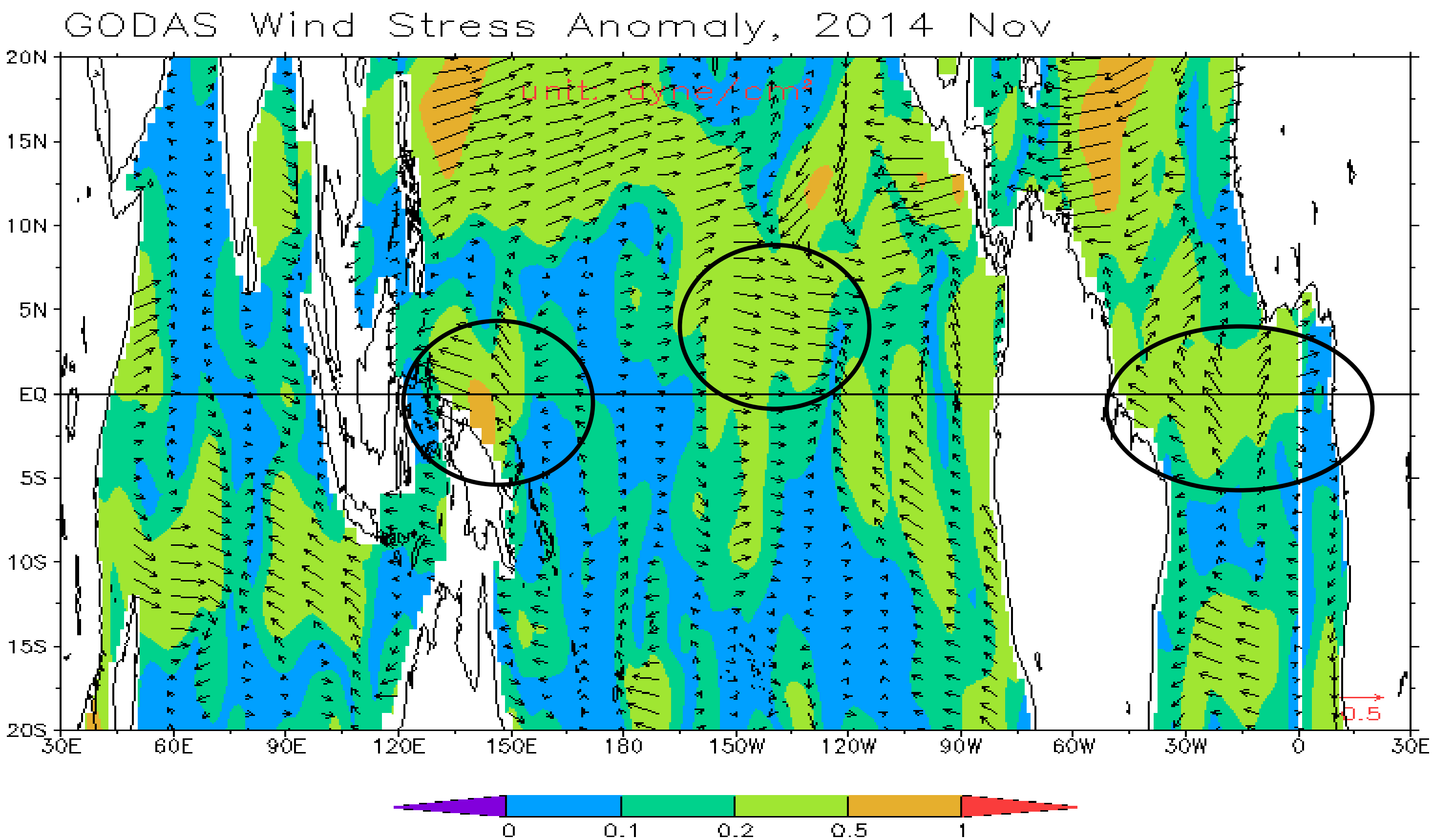


- A cooling (warming) tendency was observed in the western (eastern) Pacific Ocean near the thermocline, largely due to propagation of downwelling and upwelling oceanic Kelvin waves.

- A strong cooling tendency was observed in the upper equatorial Atlantic Ocean.

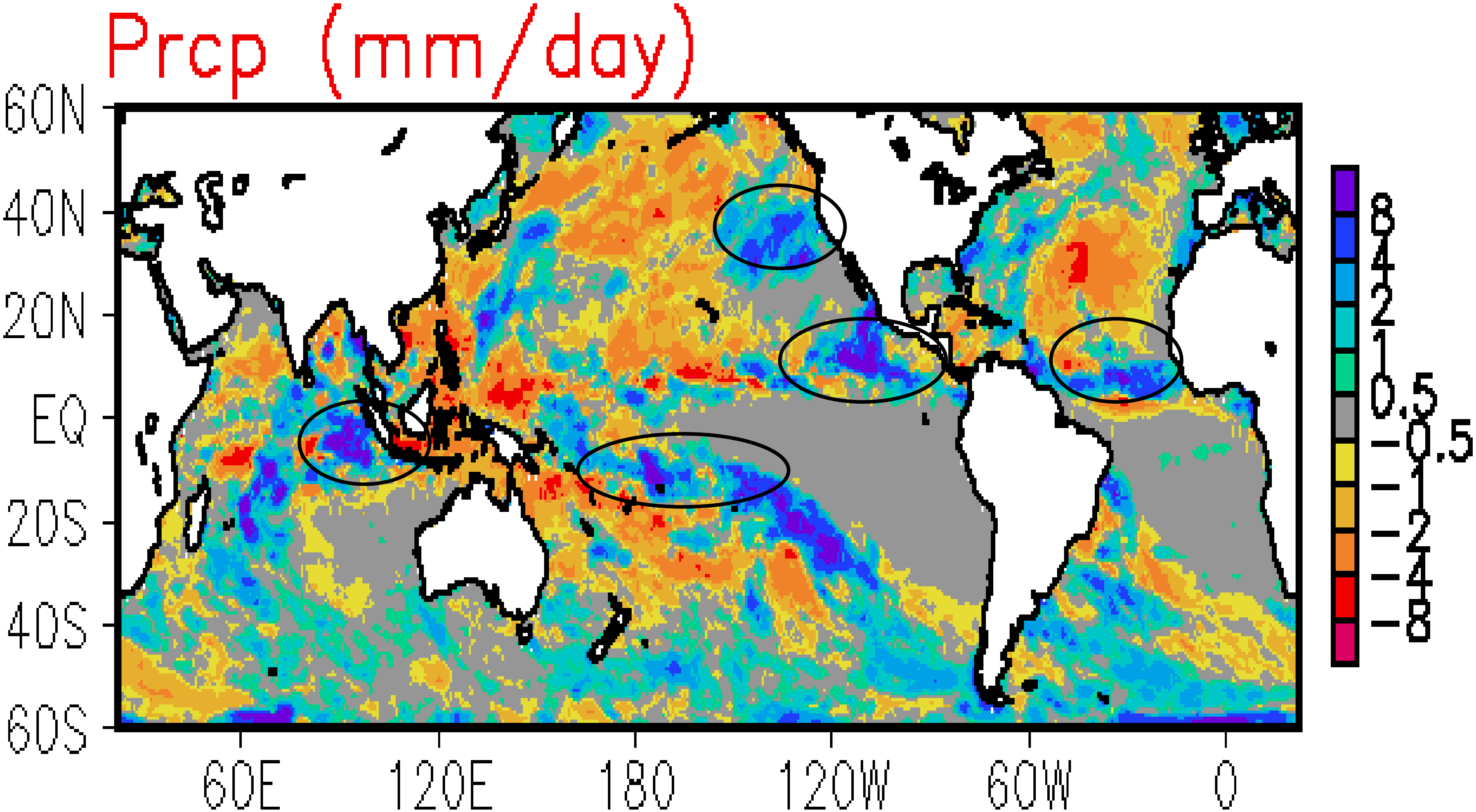
Fig. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1981-2010 base period means.

Wind Stress Anomaly from NCEP Reanalysis 2



- The cooling tendency in the equatorial Atlantic (slide 6) was associated with divergent wind anomalies in that region.
- Easterly wind anomalies in the western tropical Pacific were probably associated with MJO-related convection in the eastern tropical Indian Ocean (see next slide and discussions later).
- Westerly wind anomalies located between 160W-120W north of the equator were probably associated with enhanced convection in northeast tropical Pacific.

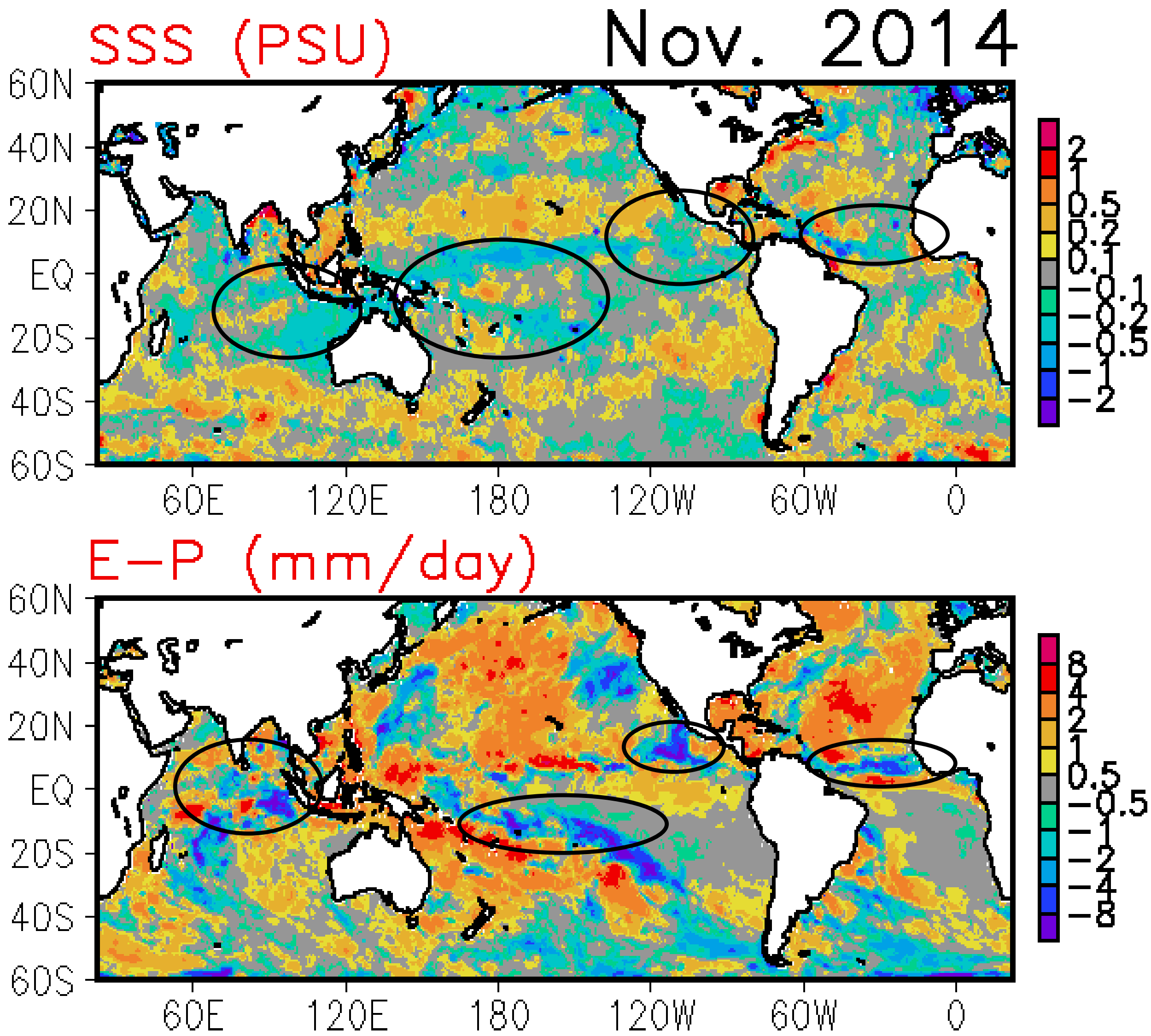
Precipitation Anomaly



- Above-normal precipitation was observed in eastern tropical Indian Ocean, SPCZ, northeast tropical Pacific, near the west coast of U.S. and equatorial Atlantic Ocean in Nov 2014.

CMORPH adjusted satellite precipitation estimates ftp.cpc.ncep.noaa.gov/precip/BASS

Sea Surface Salinity (SSS) and E-P Anomaly



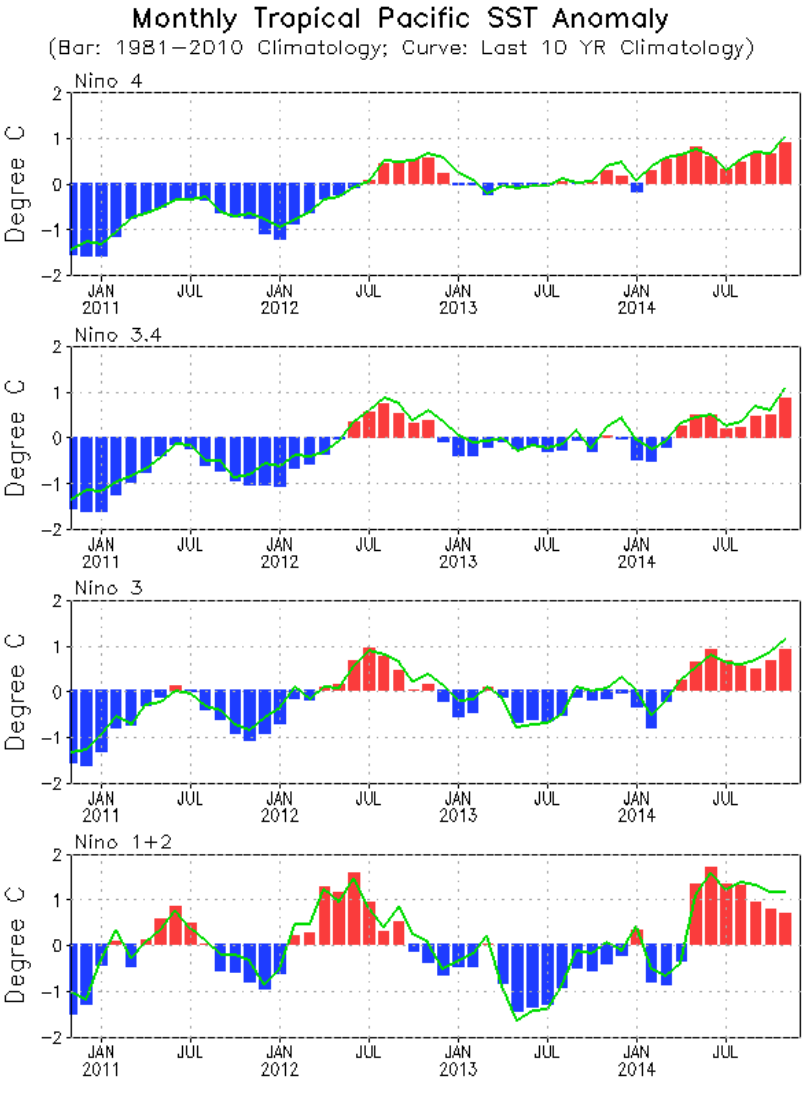
- SSS was below-normal (fresher than normal) in E. Indian Ocean, W. Pacific, northeast Pacific and tropical Atlantic Ocean.

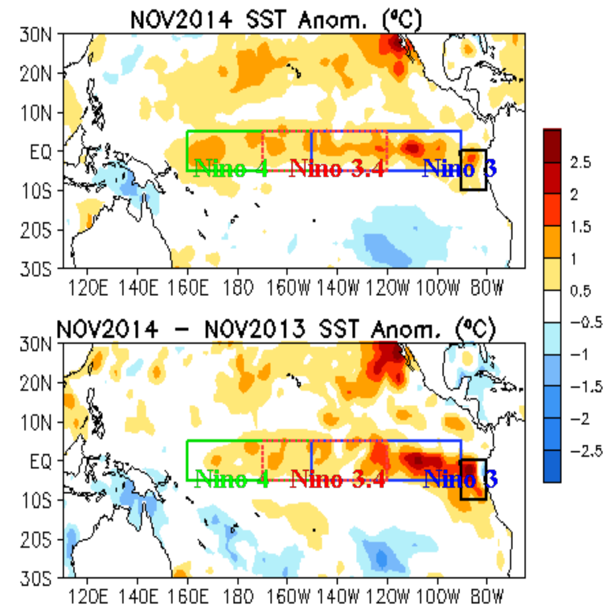
- The negative SSS anomaly was associated with negative E-P resulted from above-normal precipitation in E. Indian Ocean, southwest Pacific, northeast Pacific and tropical Atlantic.

Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014) ftp.cpc.ncep.noaa.gov/precip/BASS

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific NINO SST Indices

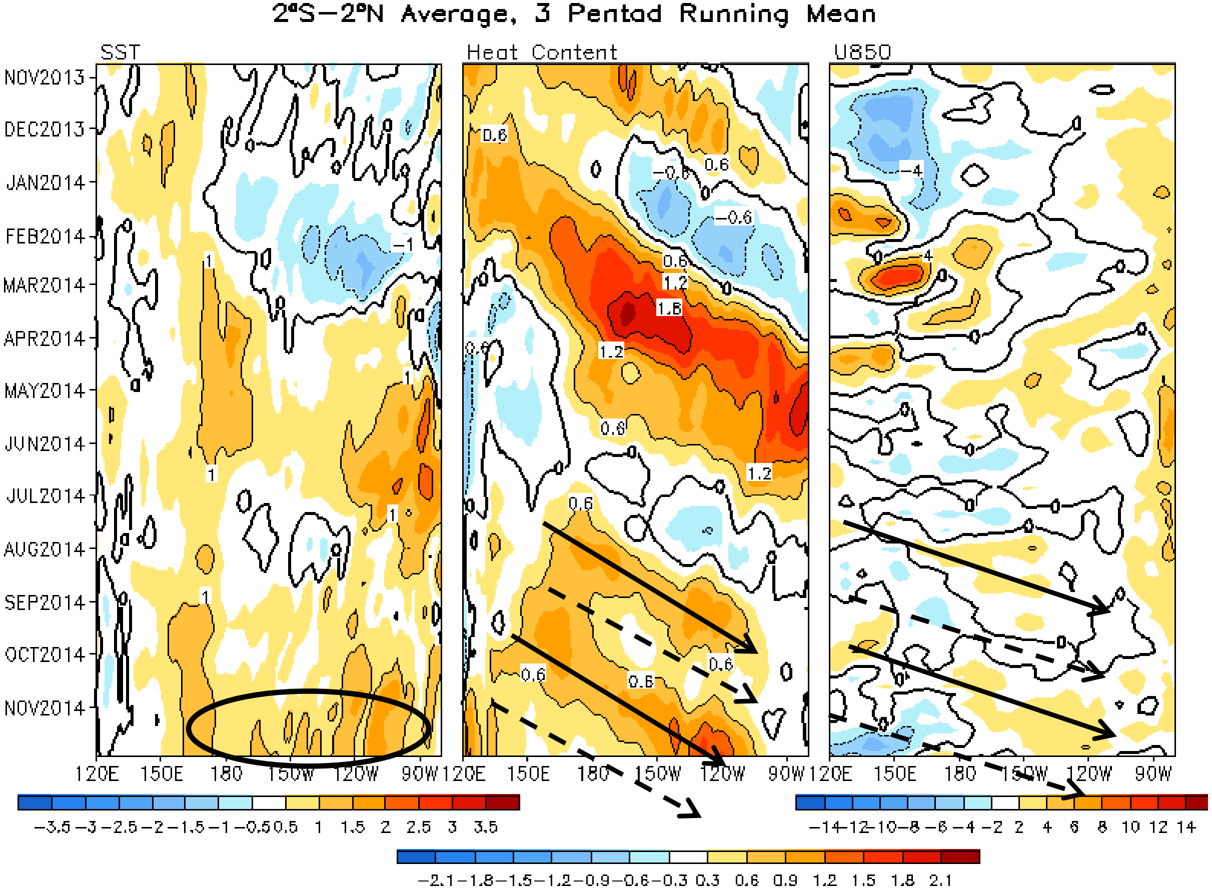




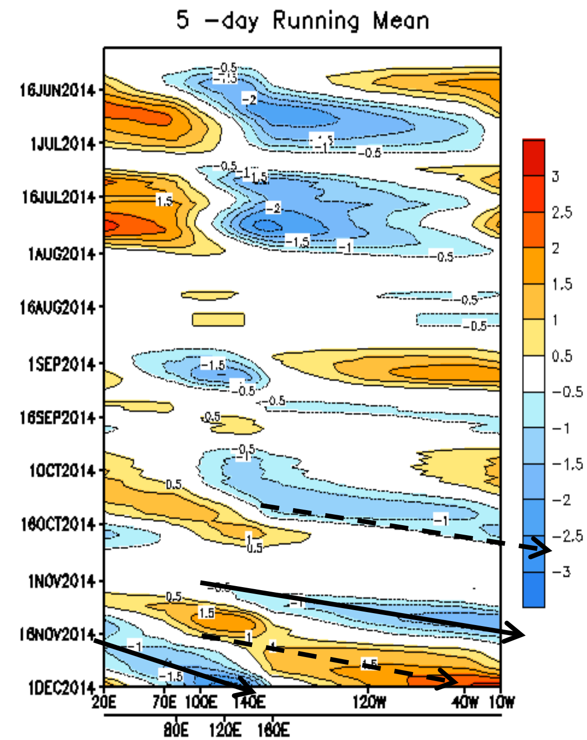
- **All Nino indices were above-normal: NINO1+2=+0.7, NINO3=+0.9, NINO3.4=+0.9, NINO4=+0.9**
- **NINO3.4 >= +0.5 in May-Jun and Sep-Nov.**
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.**

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

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



CPC MJO Indices

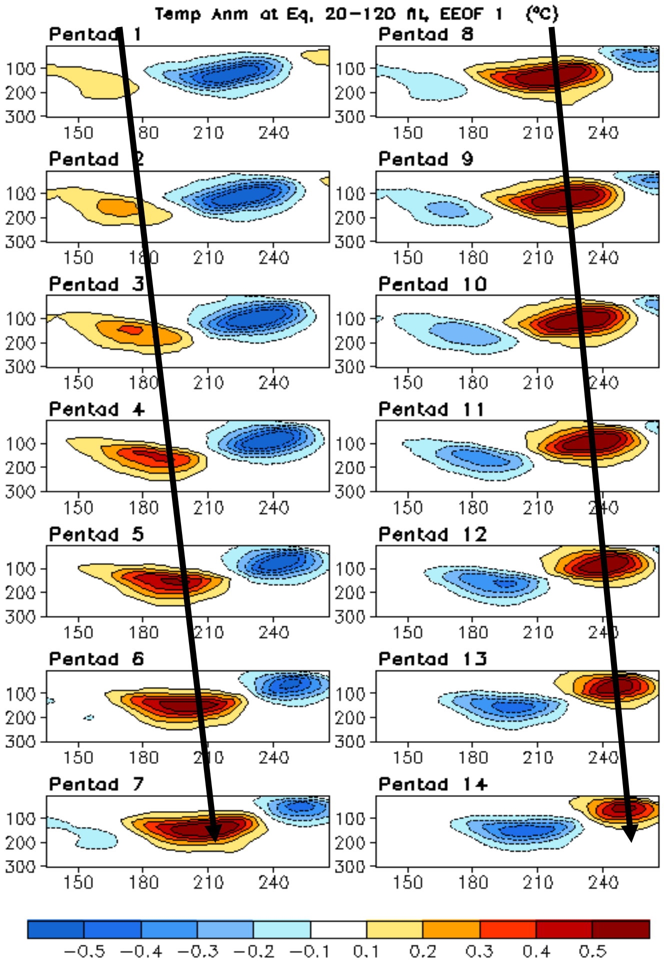


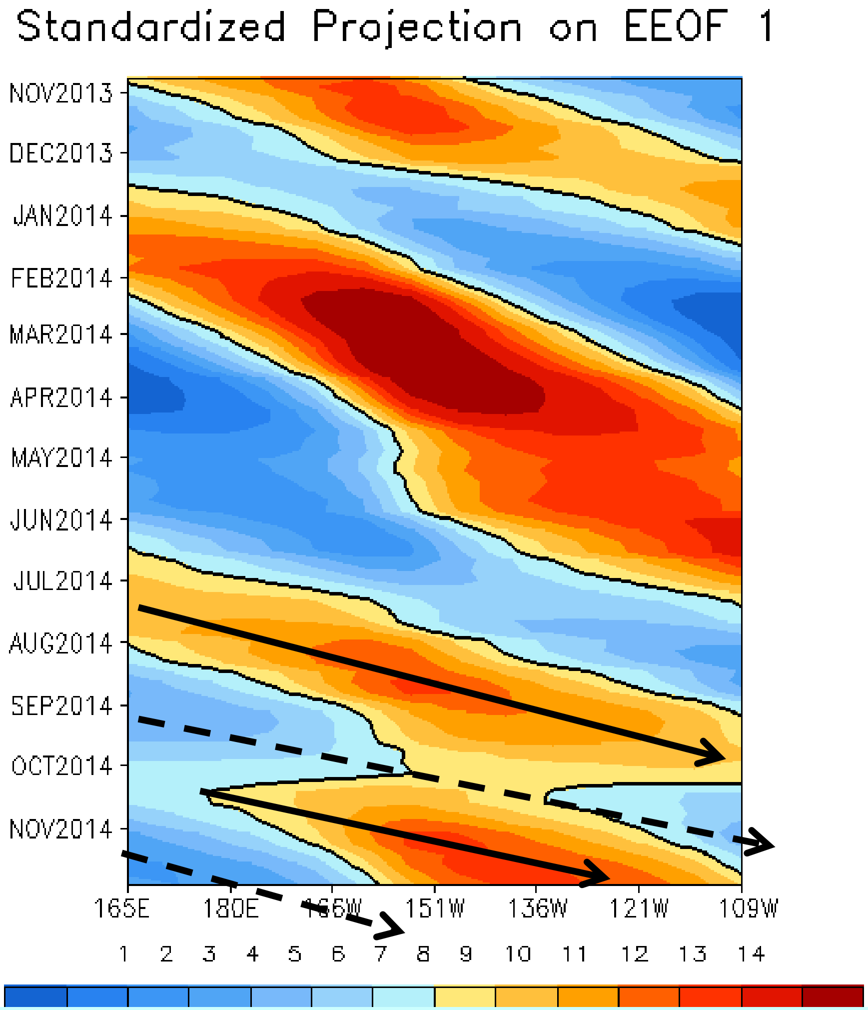
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/mjo_index.shtml

- Positive SSTA more than +1°C covered most of the equatorial Pacific.
- Positive HC300 anomalies propagated eastward and reached 120W due to downwelling oceanic Kelvin waves. An upwelling oceanic Kelvin followed and appears associated with easterly wind anomalies in the western Pacific, which were associated with the convective phase of MJO in the Indian Ocean (blue color in CPC MJO indices).

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.

Oceanic Kelvin Wave Indices

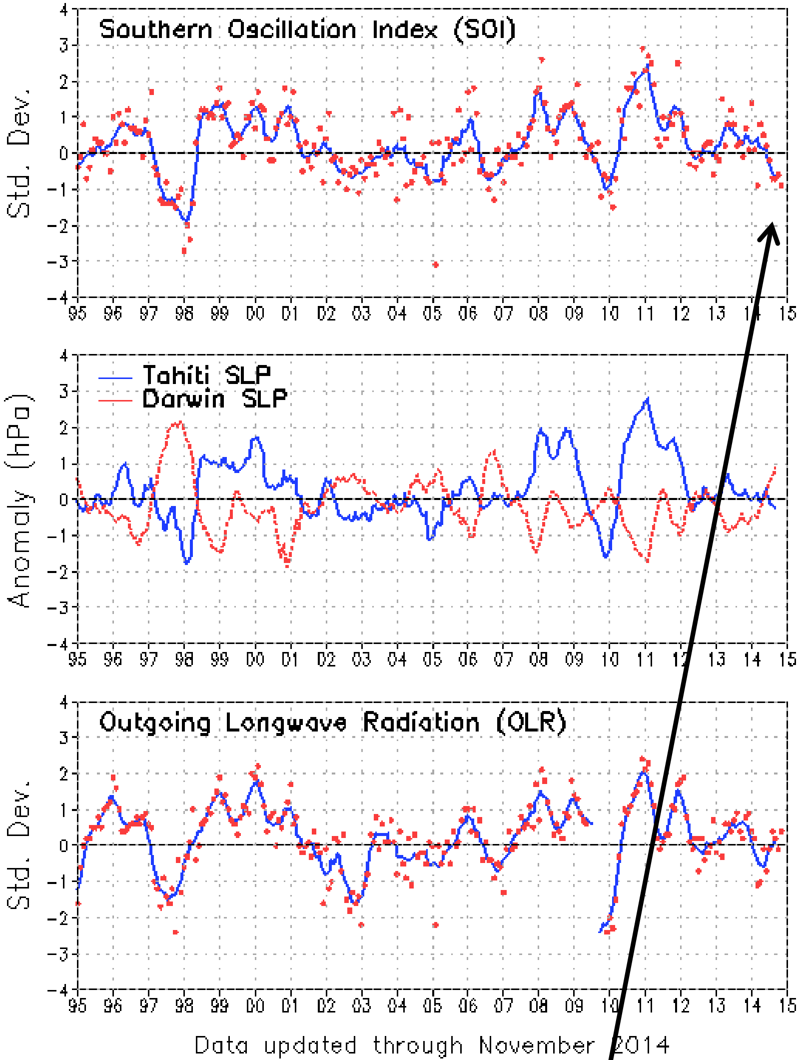


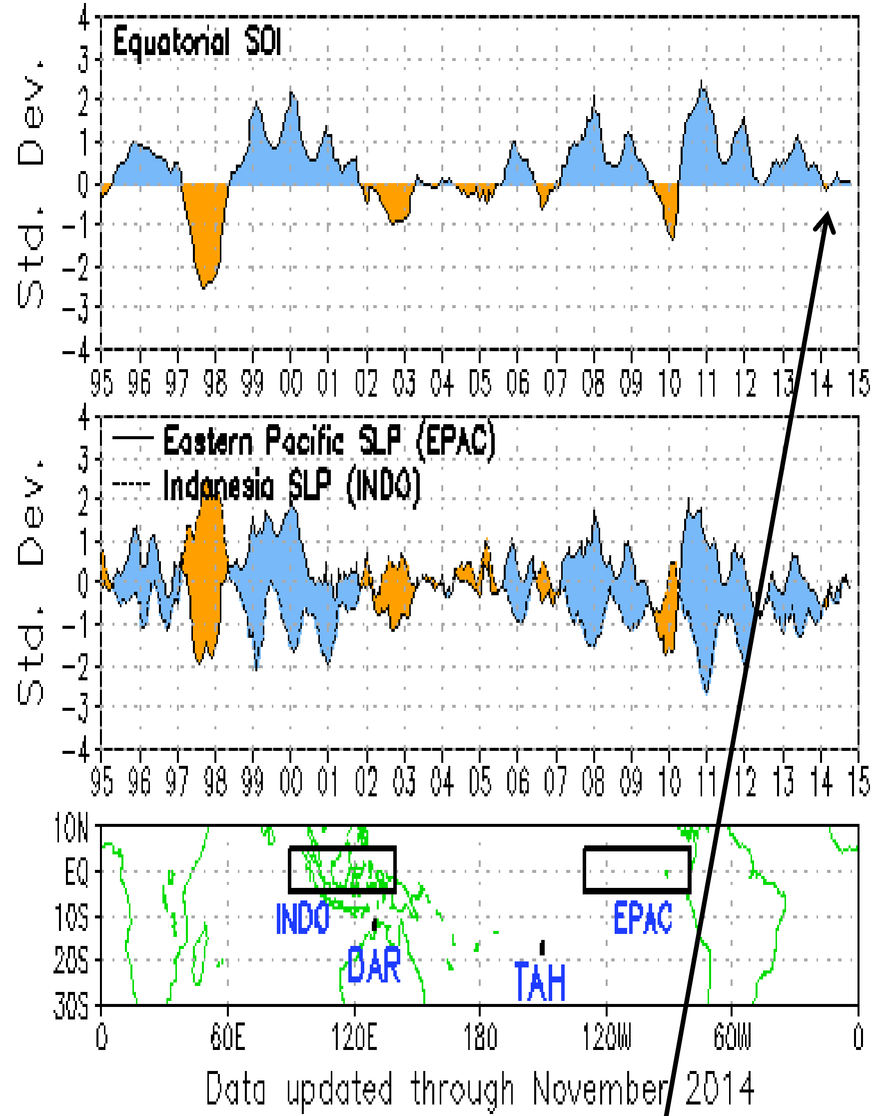


- **Downwelling oceanic Kelvin wave (OKW, solid line) emerged in mid-Jul in the W. Pacific and propagated eastward.**

- **Another downwelling OKW (solid line) emerged in mid-Oct in the C. Pacific and propagated eastward and followed by an upwelling OKW generated in early Nov.**

- **Oceanic Kelvin wave indices are defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF 1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).**

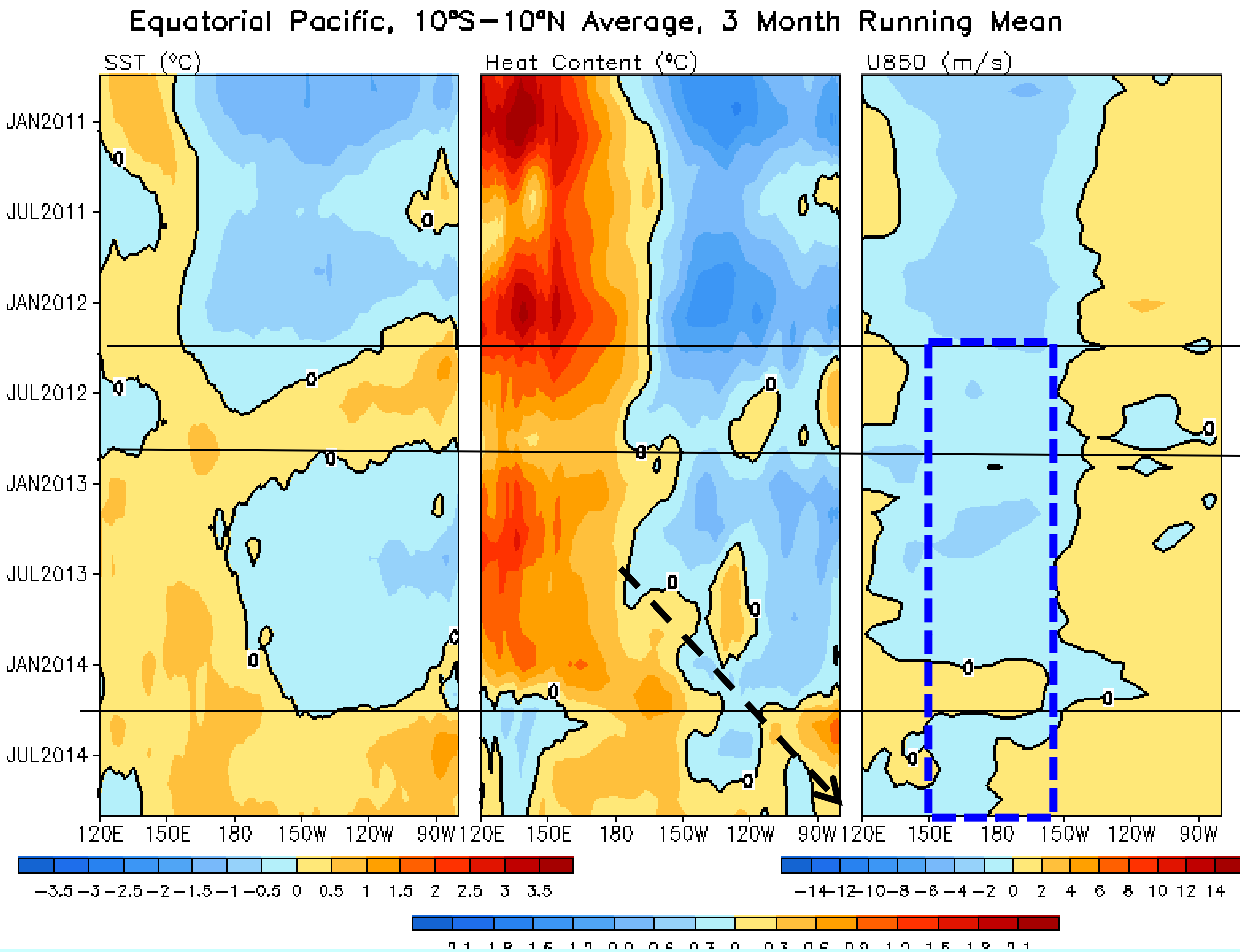




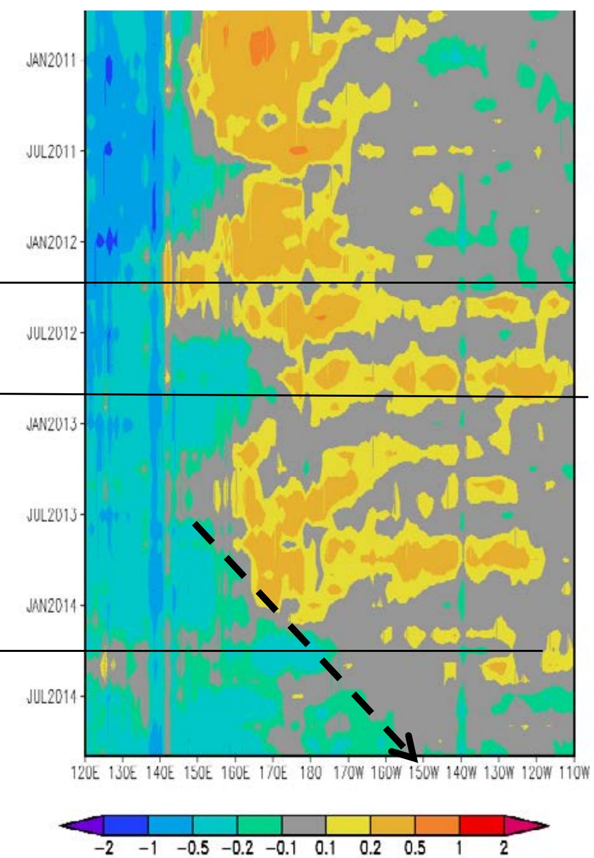
- Southern Oscillation Index (SOI) was below-normal since Jul 2014, but Equatorial SOI was near-normal.

- Convection near Dateline (160E-160W, 5S-5N) was near-normal, indicating that atmospheric circulations are not quite in El Nino conditions yet.

SST, HC300, U850 Anomaly (10S-10N)

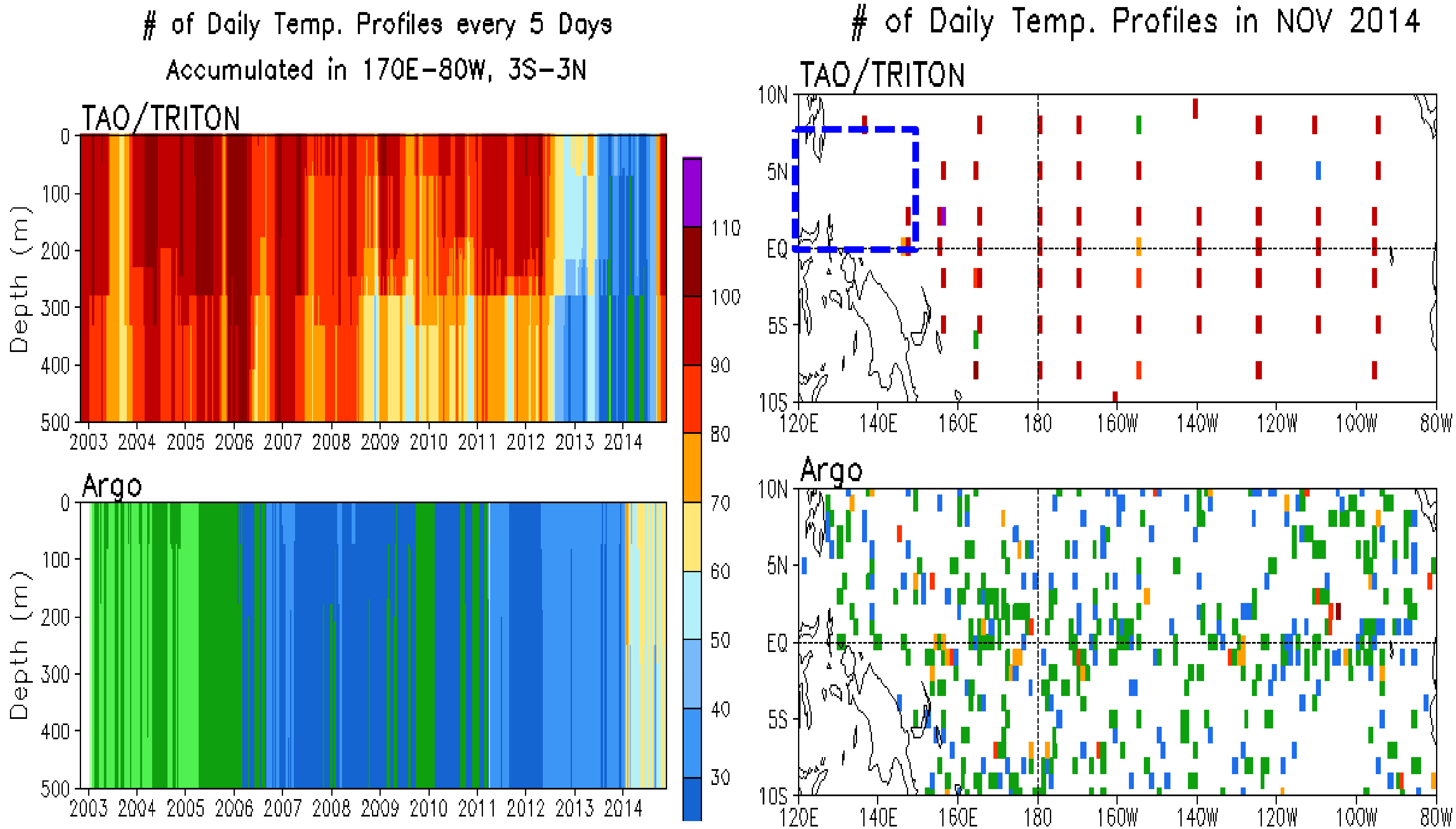


Sea Surface Salinity Anomaly (10S-10N)



- **Negative SSS anomaly extended to near Dateline in summer 2012, probably in response to enhanced convection forced by positive SST anomaly, but it retreated westward in following months.**
- **In 2014, negative SSS anomaly extended to Dateline in spring, and continued to migrate eastward in summer and fall, consistent with eastward migration of positive heat content anomalies.**
- **In contrast to dominated easterly wind anomalies in 2012, westerly wind anomalies dominated in 150E-150W in 2014.**

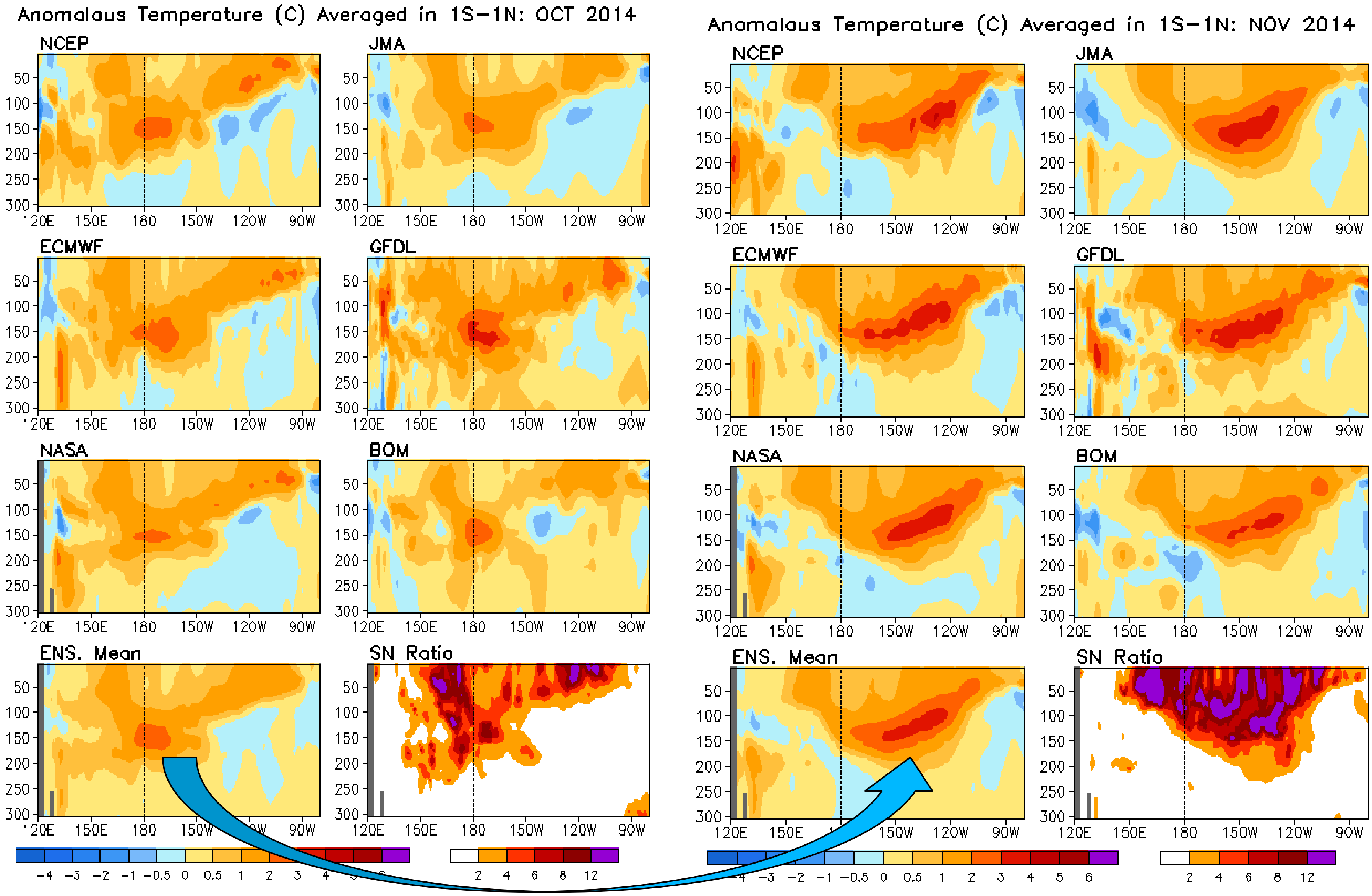
Tropical Pacific Observing System



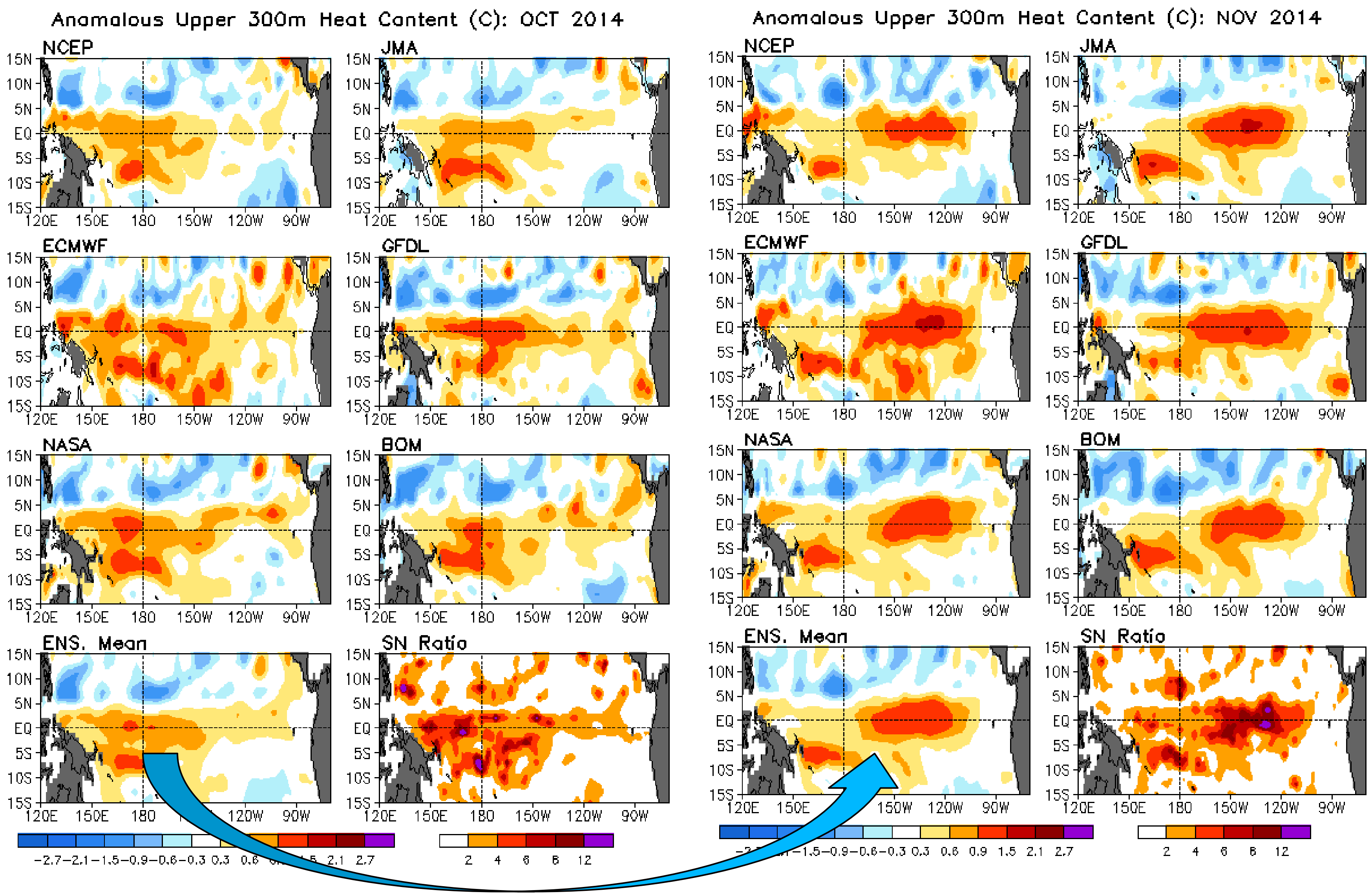
- Data availability from the TAO array has improved dramatically to 83% from 28% in March
- From April 2014 through October, 45 TAO buoys have been replaced on 7 TAO longitude lines (personal communication with Kathleen C. Oneil, NDBC)
- However, most of TRITON moorings west of 156E failed to delivery data.

Real-Time Ocean Reanalyses Intercomparison

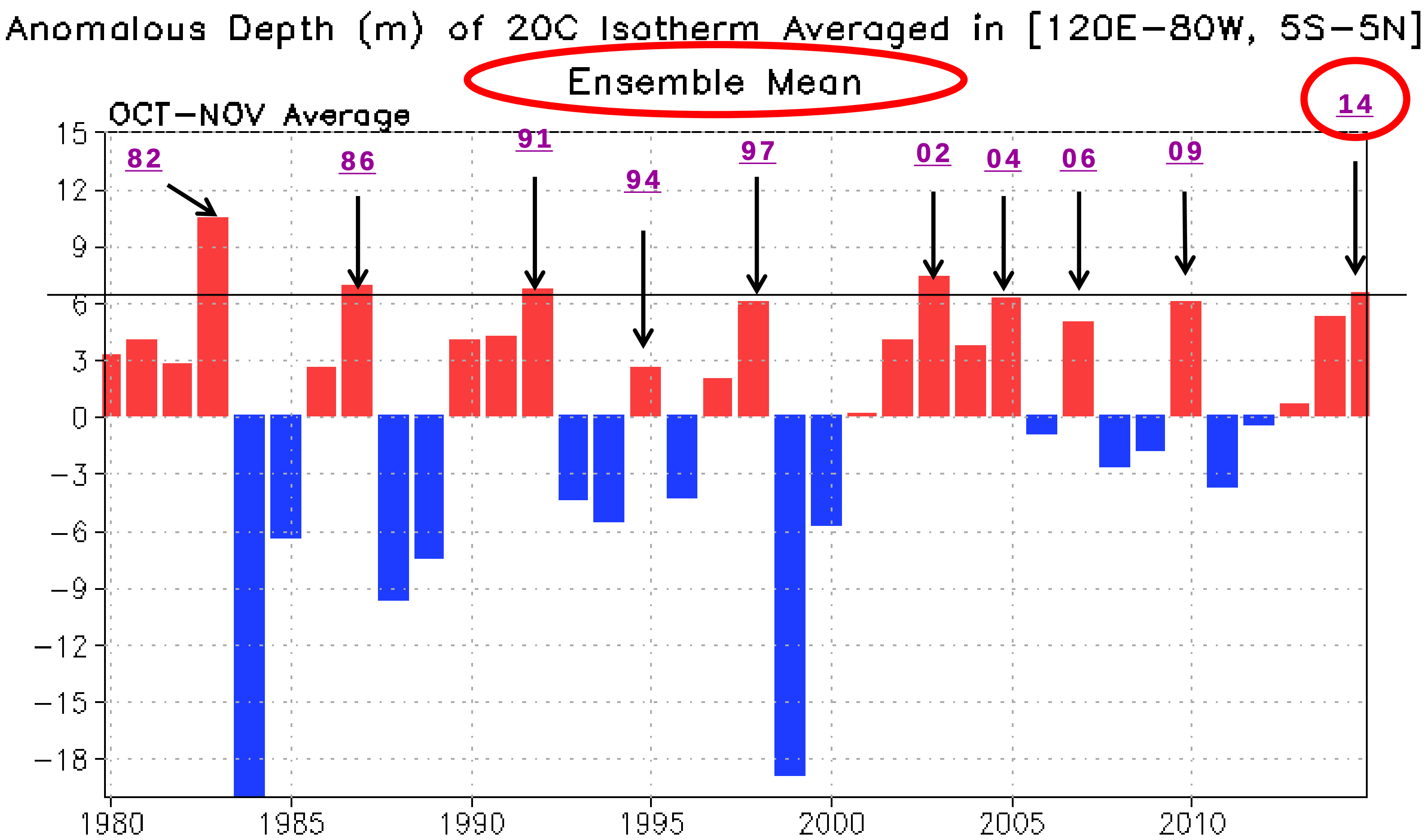
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)



Upper 300m Heat Content Anomaly (1981-2010 Clim.)

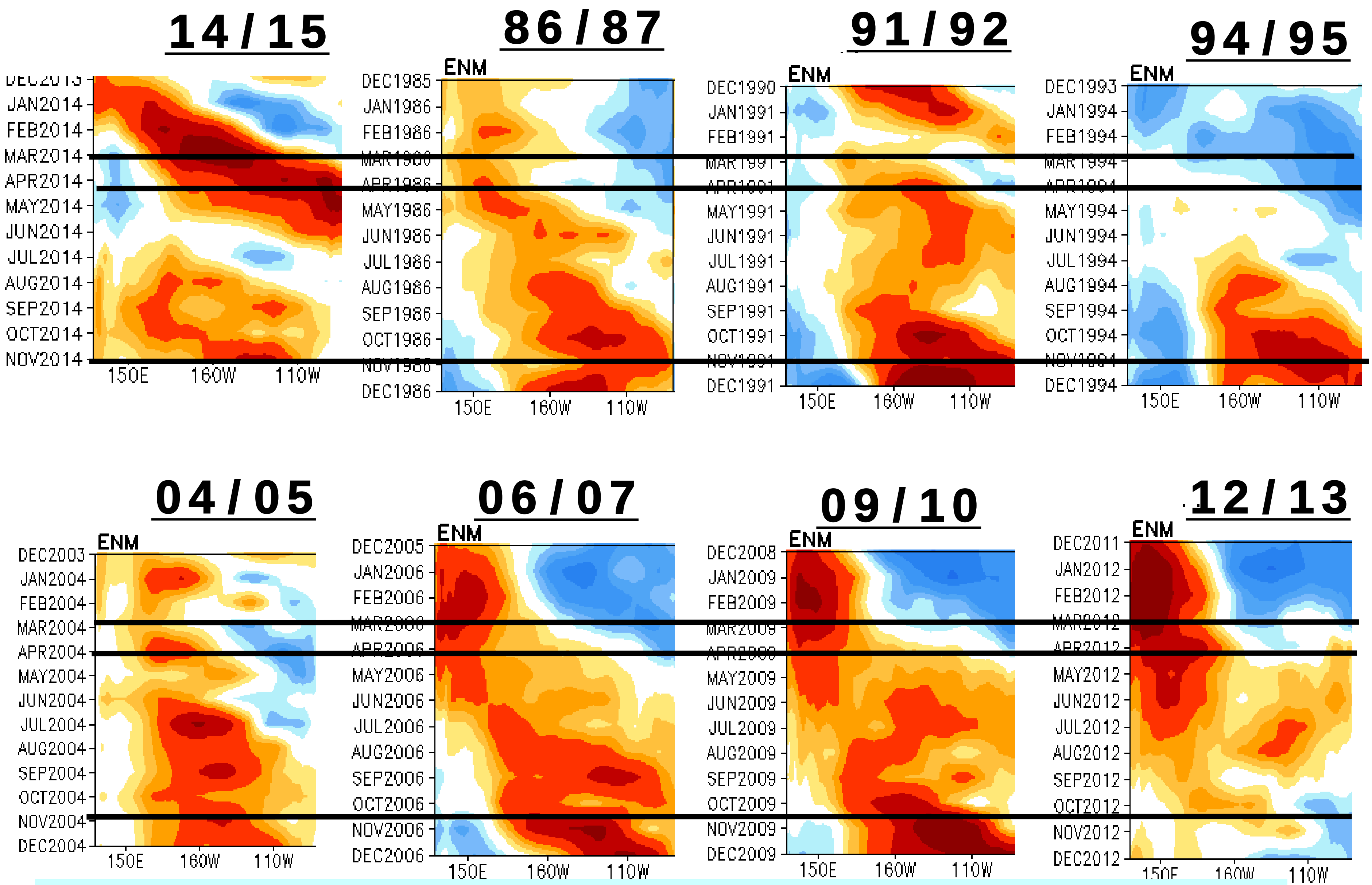


Warm Water Volume Index Derived From Ensemble Mean of Ocean Reanalyses



- Warm Water Volume averaged in Oct-Nov 2014 was similar to that in Oct-Nov of 1986, 1991, 2004, 2006, 2009, and in those years NINO3.4 exceeded +0.5C in Aug, May, Jul, Sep, Jul respectively.

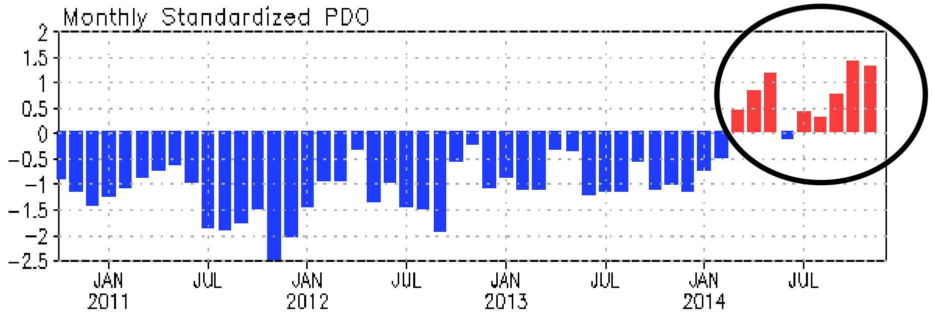
Upper 300m Heat Content Anomaly Averaged in 1S-1N

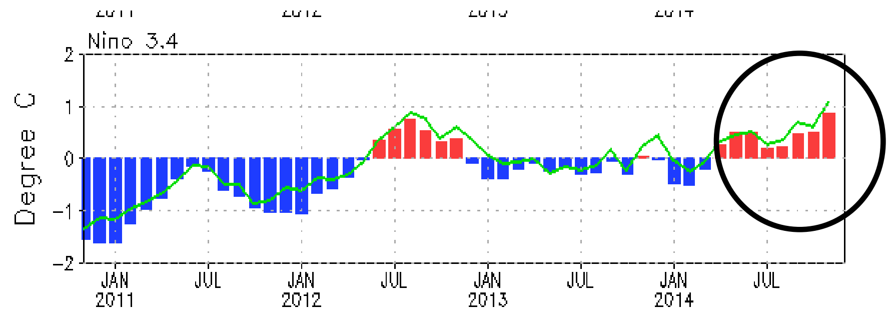


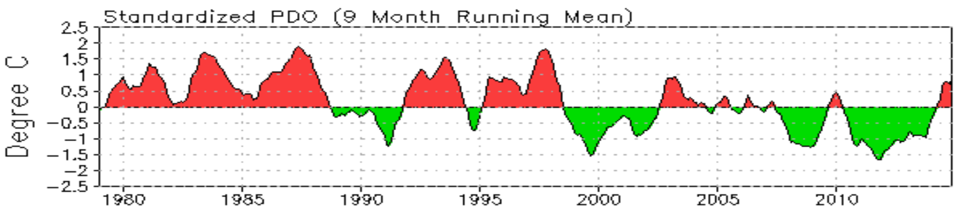
- **Positive heat content anomalies in Nov 2014 were centered near 160W-120W, which was similar to other El Nino events.**

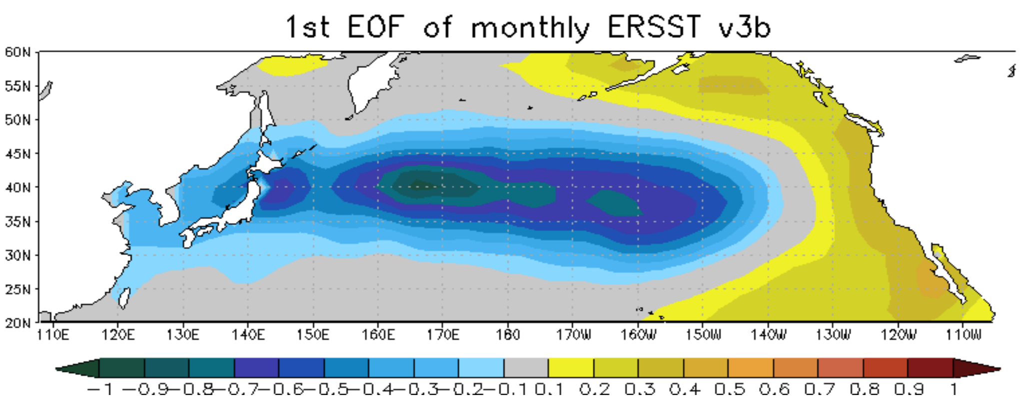
North Pacific & Arctic Oceans

Pacific Decadal Oscillation Index









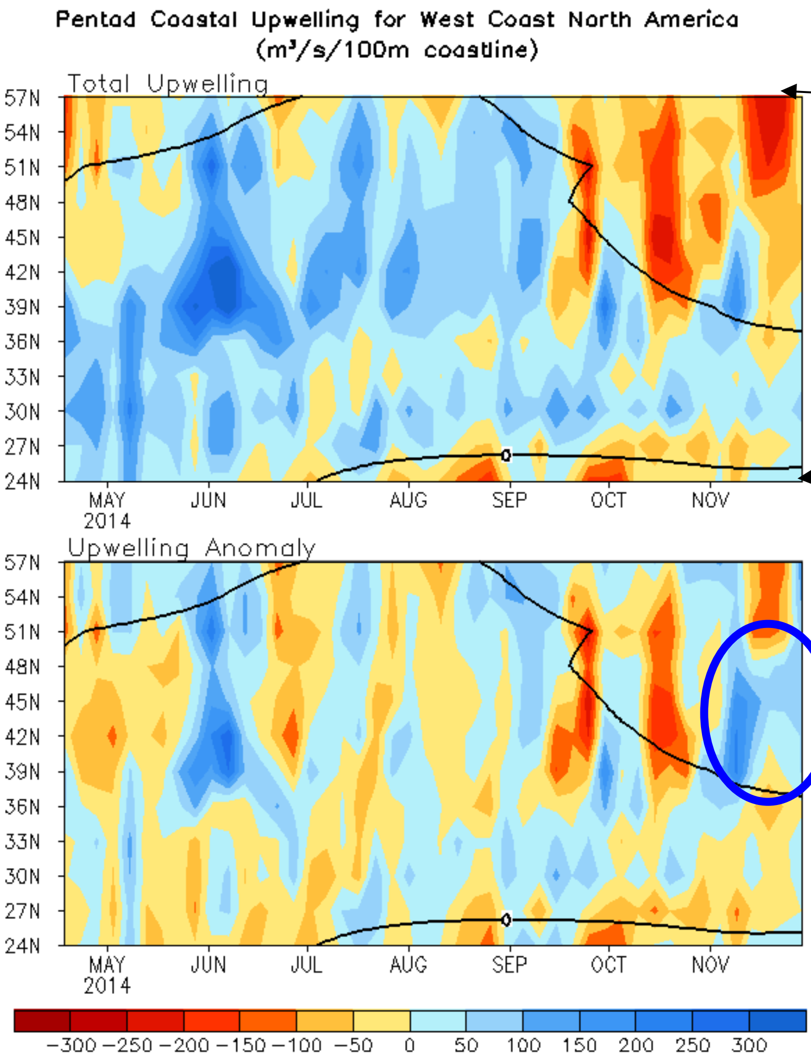
- Positive PDO phase has persisted since Mar 2014, and increased substantially in Oct and persisted in Nov 2014 with PDO=+1.3

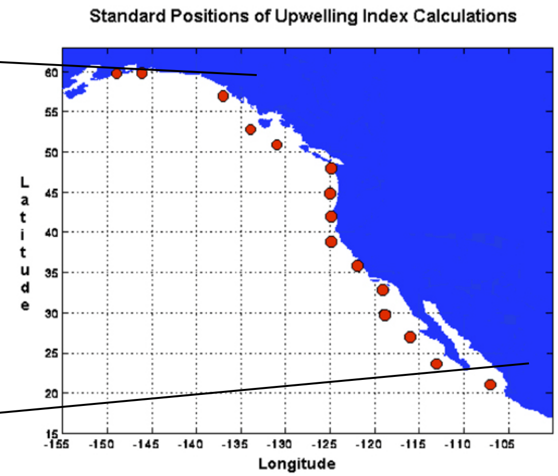
- The apparent connection between NINO3.4 and PDO index suggest connections between tropics and extratropics.

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

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

North America Western Coastal Upwelling





- Downwelling north of 36N was weakened.

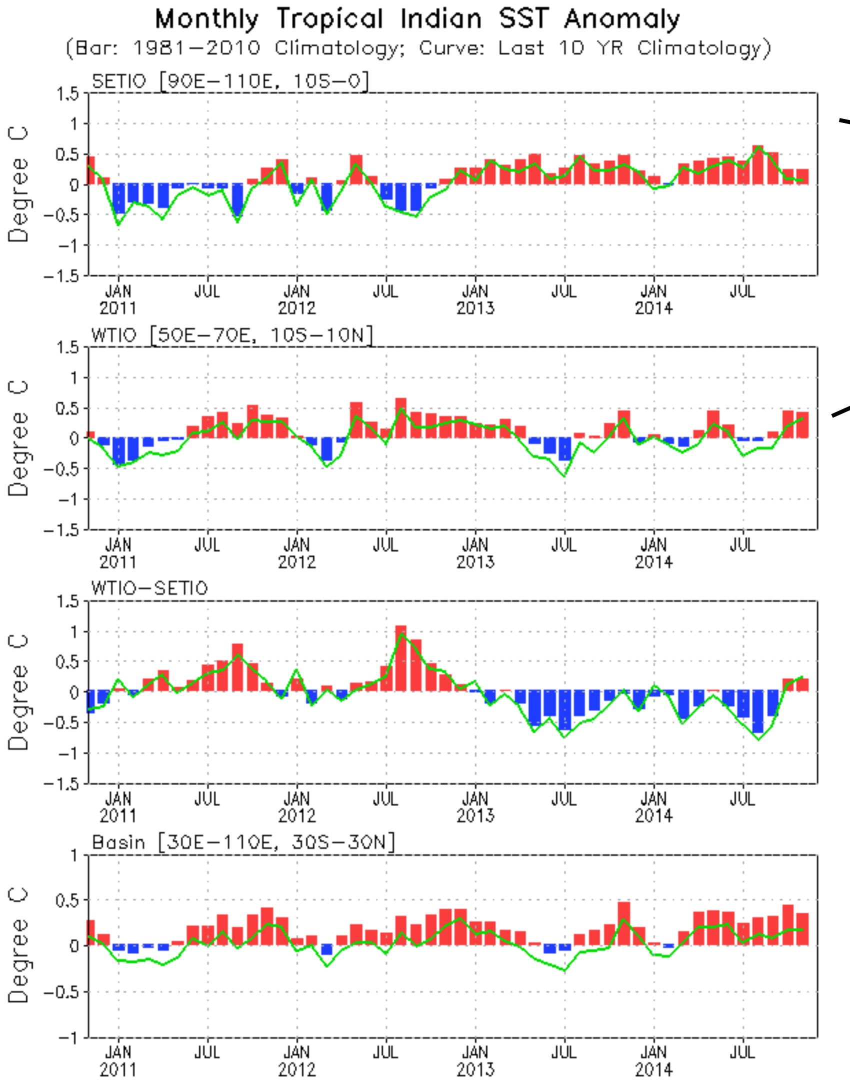
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport 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.

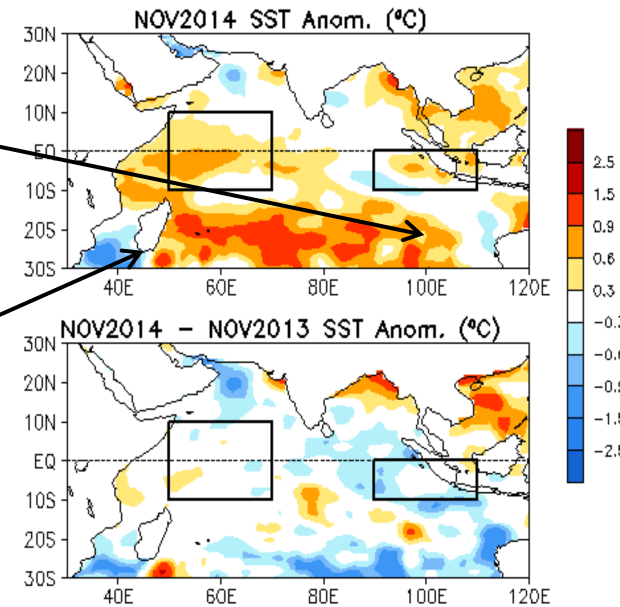
- Area below (above) black line indicates climatological upwelling (downwelling) season.

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

Indian Ocean

Evolution of Indian Ocean SST Indices



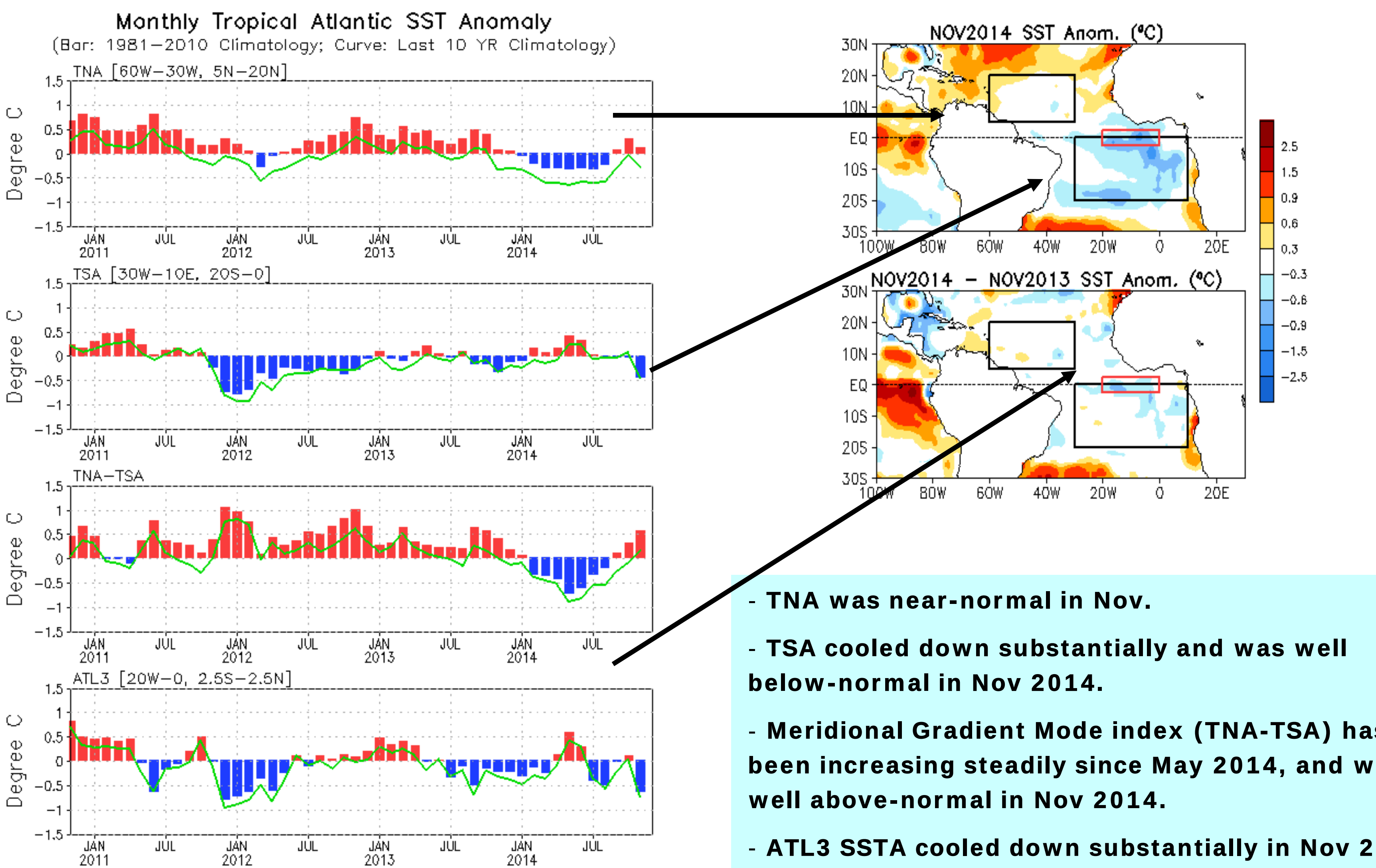


- DMI was weakly above-normal in Nov 2014.
- The basin mean SSTA was above-normal.

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 and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

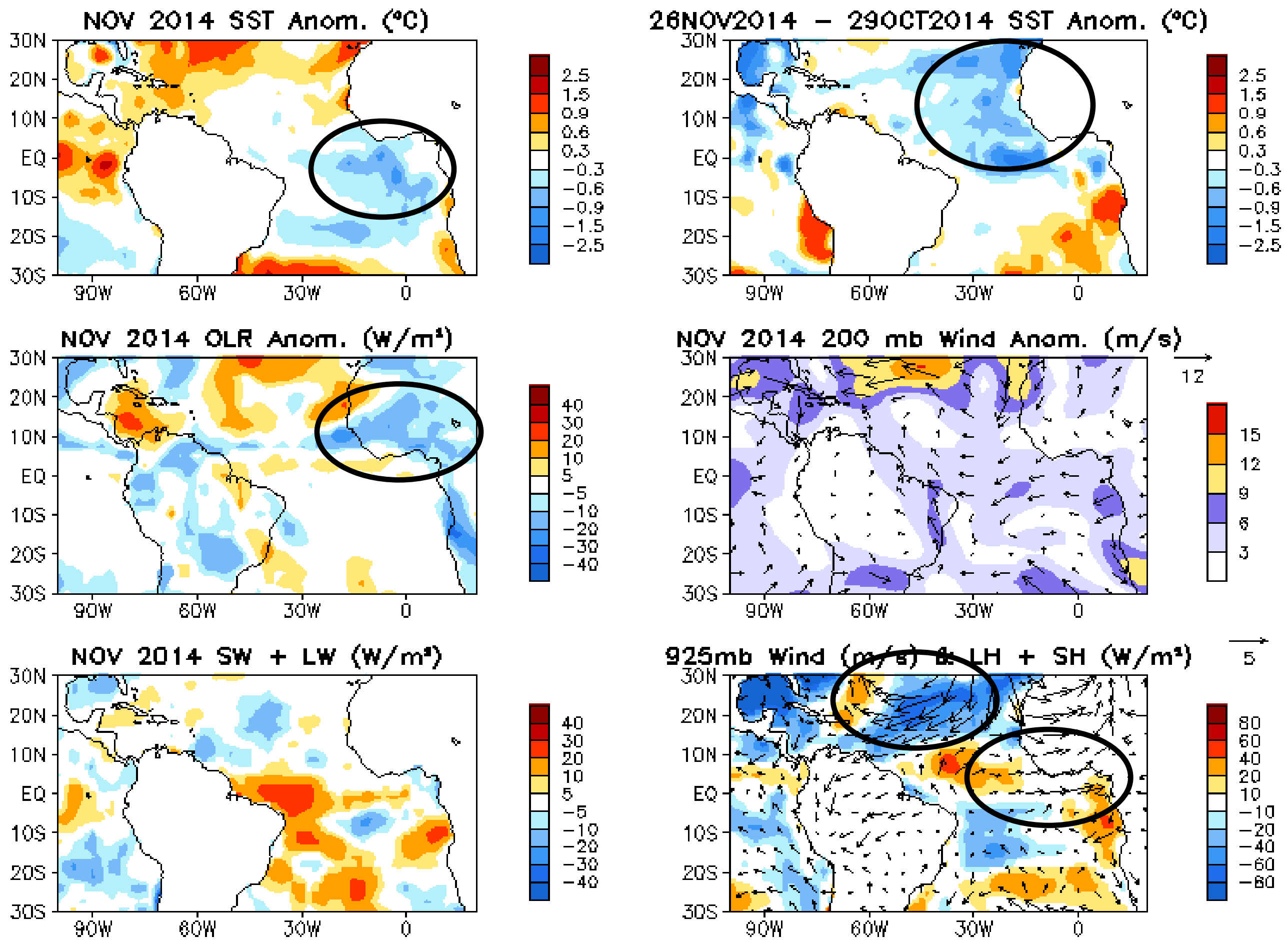


- TNA was near-normal in Nov.
- TSA cooled down substantially and was well below-normal in Nov 2014.
- Meridional Gradient Mode index (TNA-TSA) has been increasing steadily since May 2014, and was well above-normal in Nov 2014.
- ATL3 SSTA cooled down substantially in Nov 2014.

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.

Tropical Atlantic:

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

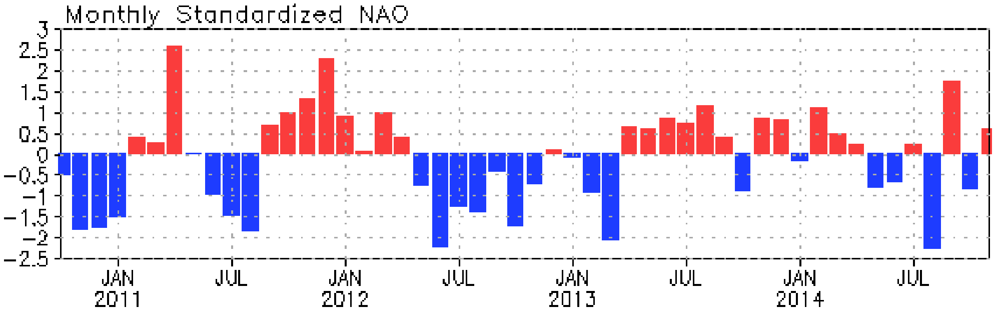


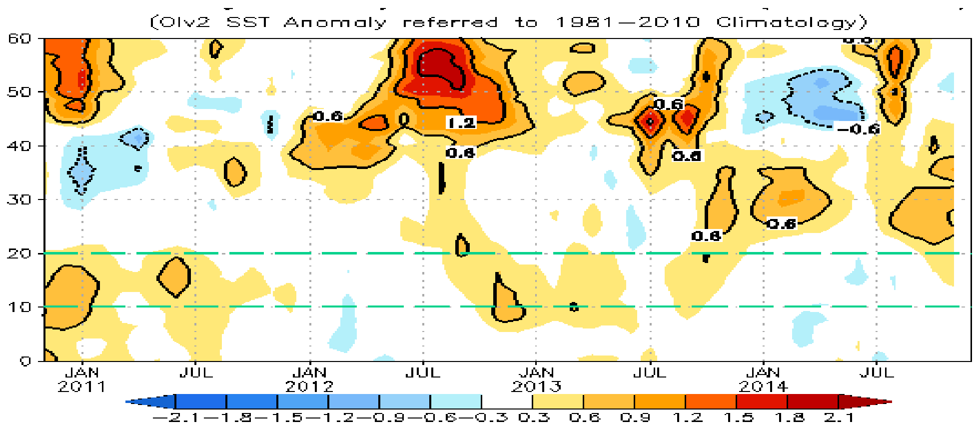
- Negative SSTA emerged in the tropical Atlantic associated with cooling subsurface temperature.

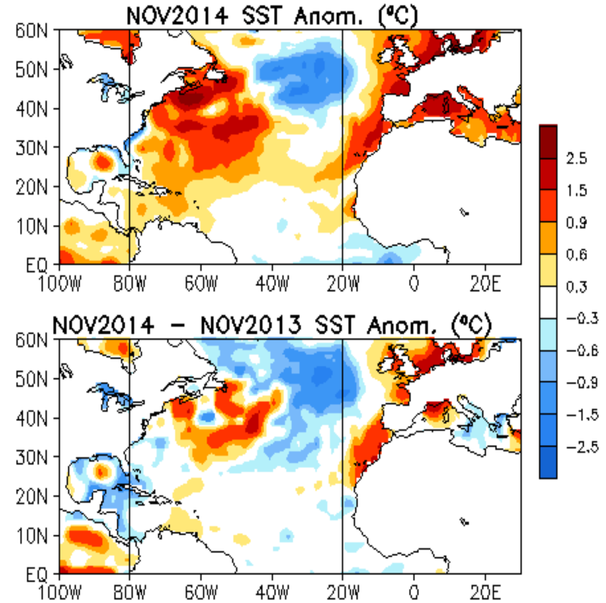
- The cooling tendency off the west cost of North Africa was associated with anomalous anti-cyclone in that region.

- Convection was enhanced in North Africa, which was consistent with low-level westerly wind anomalies.

NAO and SST Anomaly in North Atlantic





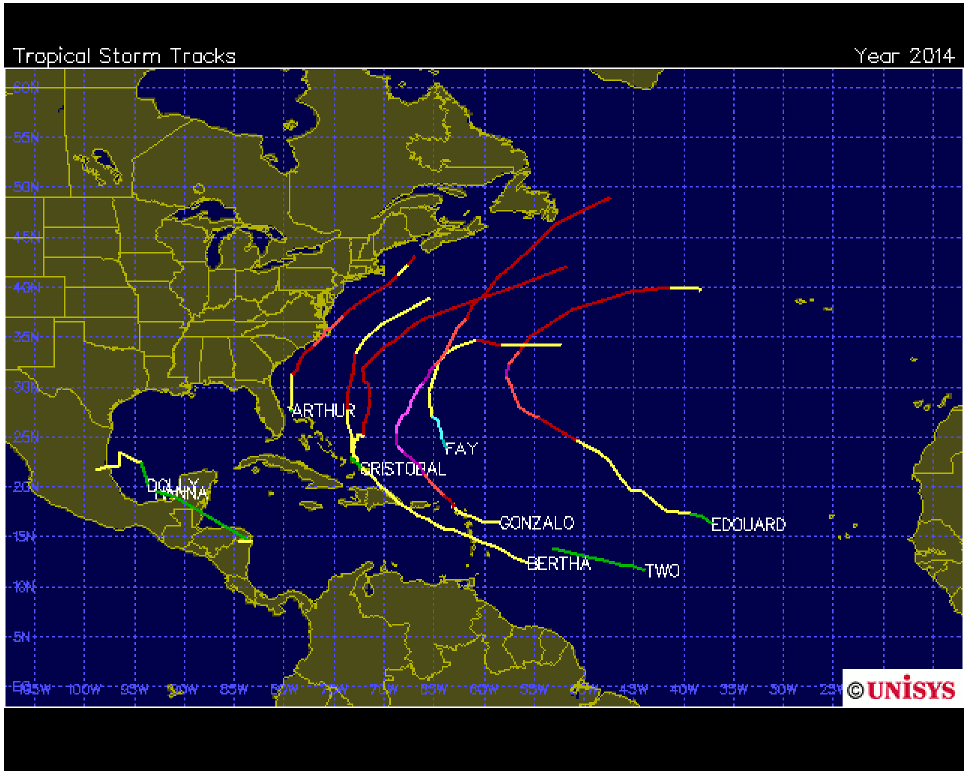


- High-latitude North Atlantic SSTA is generally closely related to NAO index (negative NAO leads to SST warming and positive NAO leads to SST cooling).
- NAO index switched to positive with NAO index =+0.58.
- SST in MDR in this hurricane season was the coolest during the past four years.

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.

2014 Atlantic Hurricane Counts

(http://weather.unisys.com/hurricane)



- Only three seasons since 1995 were below-normal (1997, 2009, and 2013).
- If the current outlook verifies, 2014 will become the fourth below-normal season since 1995.
- It would mark the first time since 1995 that two consecutive seasons were below-normal.

- **Atlantic Outlook (Aug update, 70% below-normal):**

  7-12 Named Storms (12 average)

  3-6 Hurricanes (6 average)

  0-2 Major Hurricanes (3 average)

  40%-90% ACE

- **Atlantic Counts by Nov 30:**

  8 Named Storms

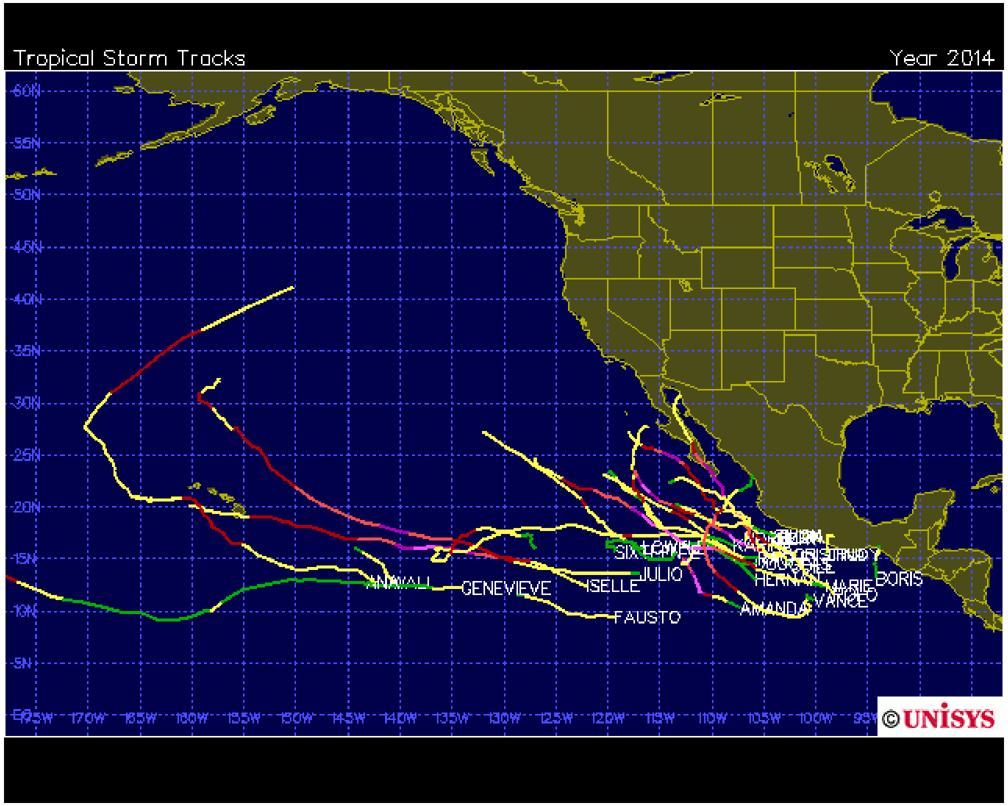
  6 Hurricanes

  2 Major Hurricanes

  64% ACE

2014 E. Pacific Hurricane Counts

(http://weather.unisys.com/hurricane)



- The ACE for 2014 E. Pacific hurricane season is the 6th highest since 1971.

- **E. Pacific Outlook (50% above-normal):**

  14-20 Named Storms (16 average)

  7-11 Hurricanes (9 average)

  3-6 Major Hurricanes (4 average)

  95%-160% ACE

- **E. Pacific Counts by Nov 30:**

  22 Named Storms

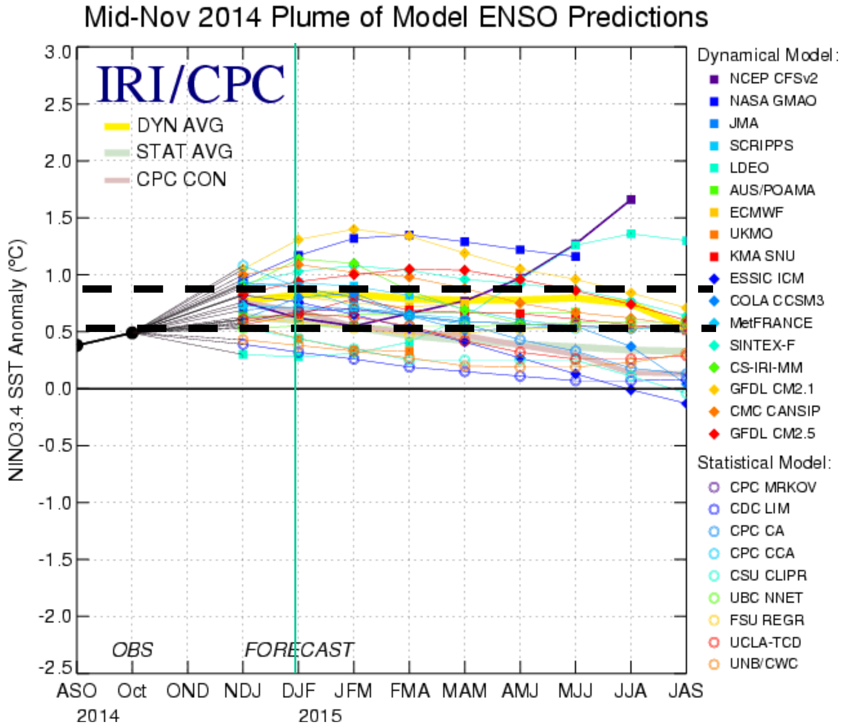
  16 Hurricanes

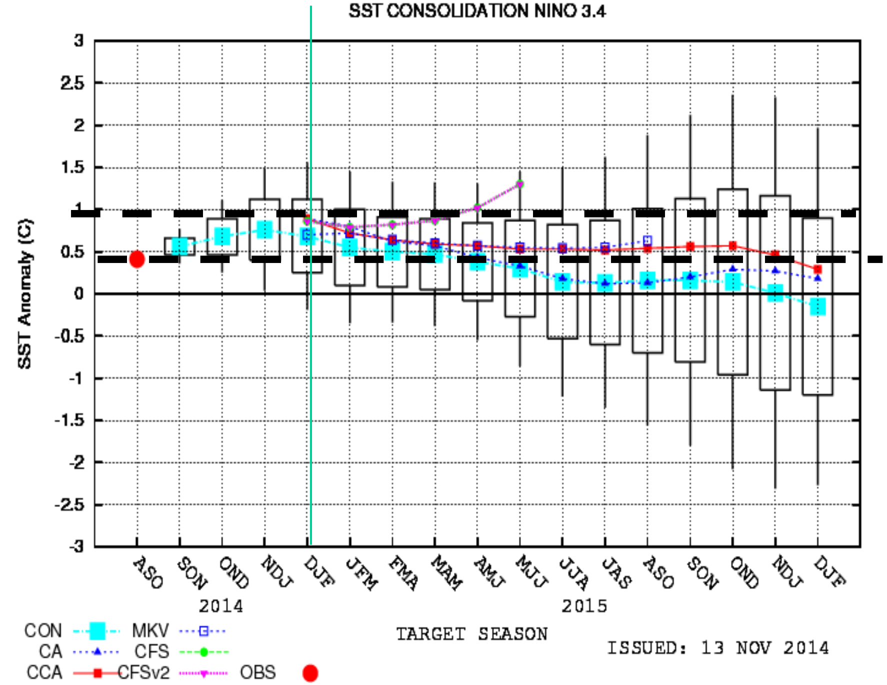
  9 Major Hurricanes

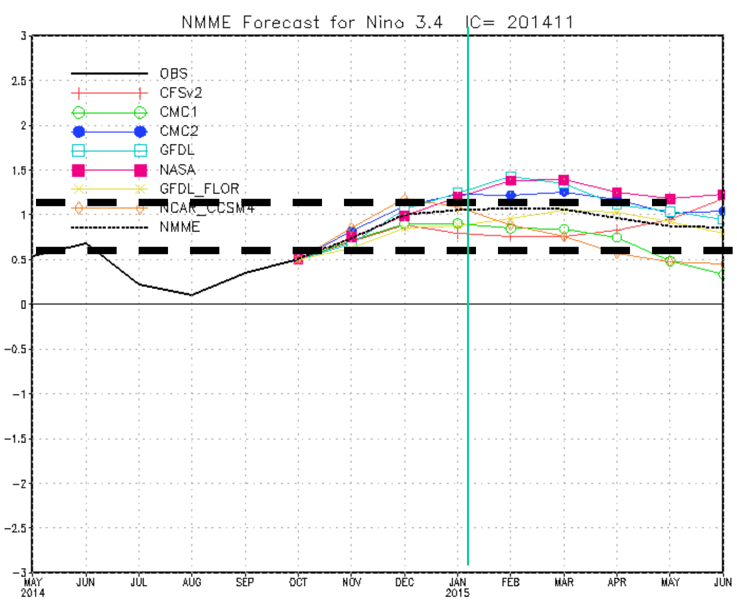
  198% ACE

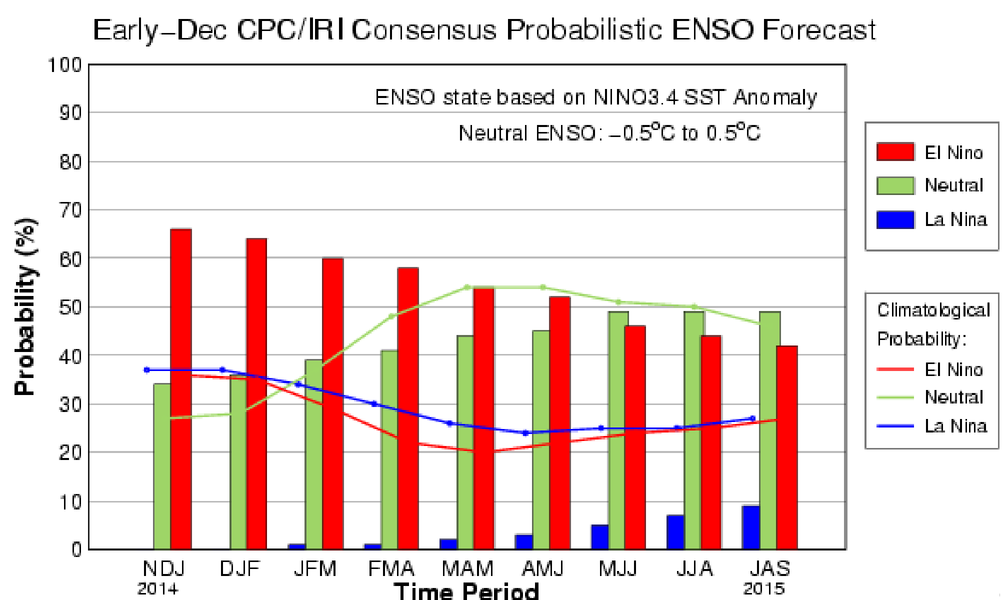
Global SST Predictions

NINO3.4 Forecast Plums





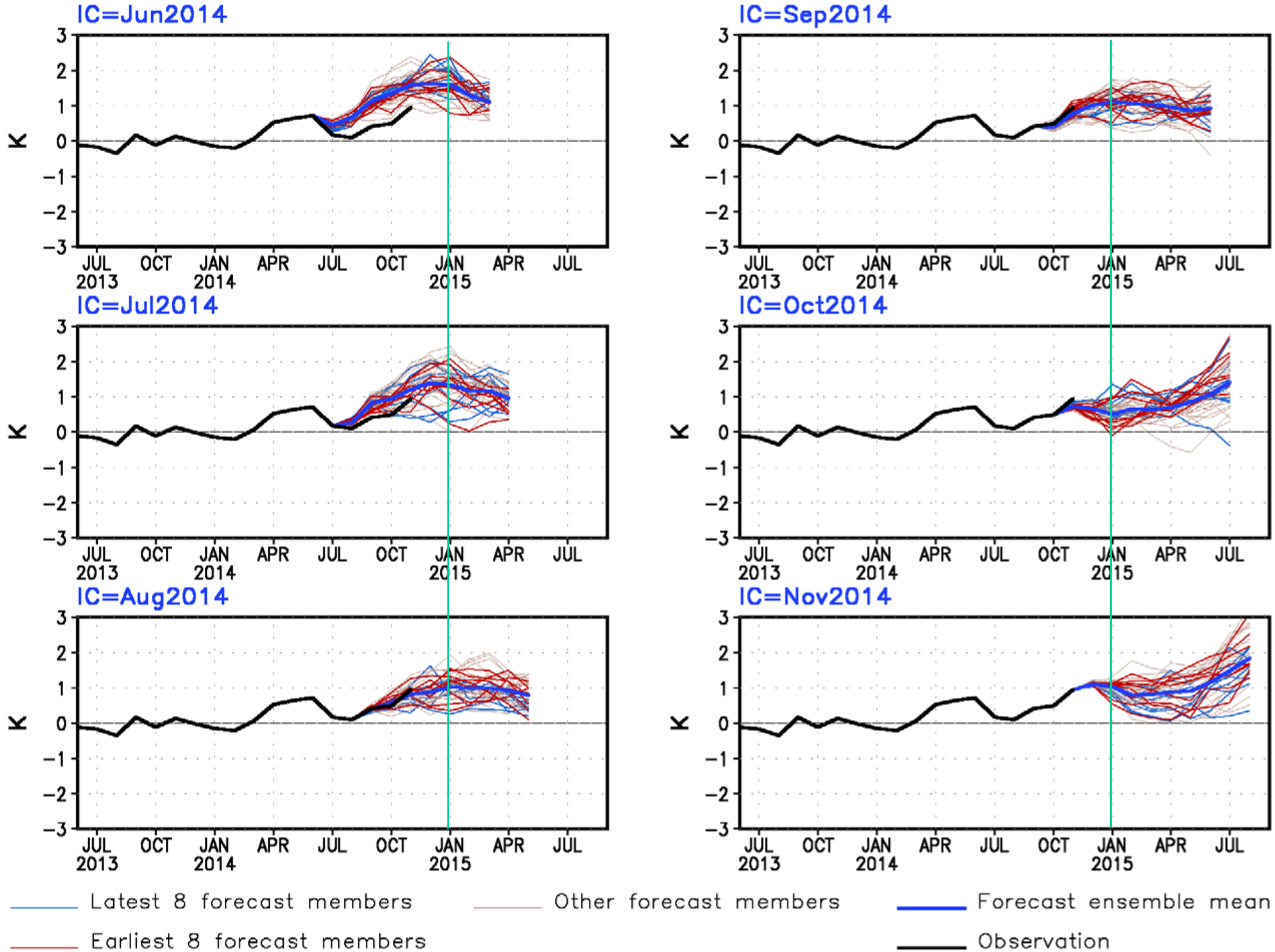


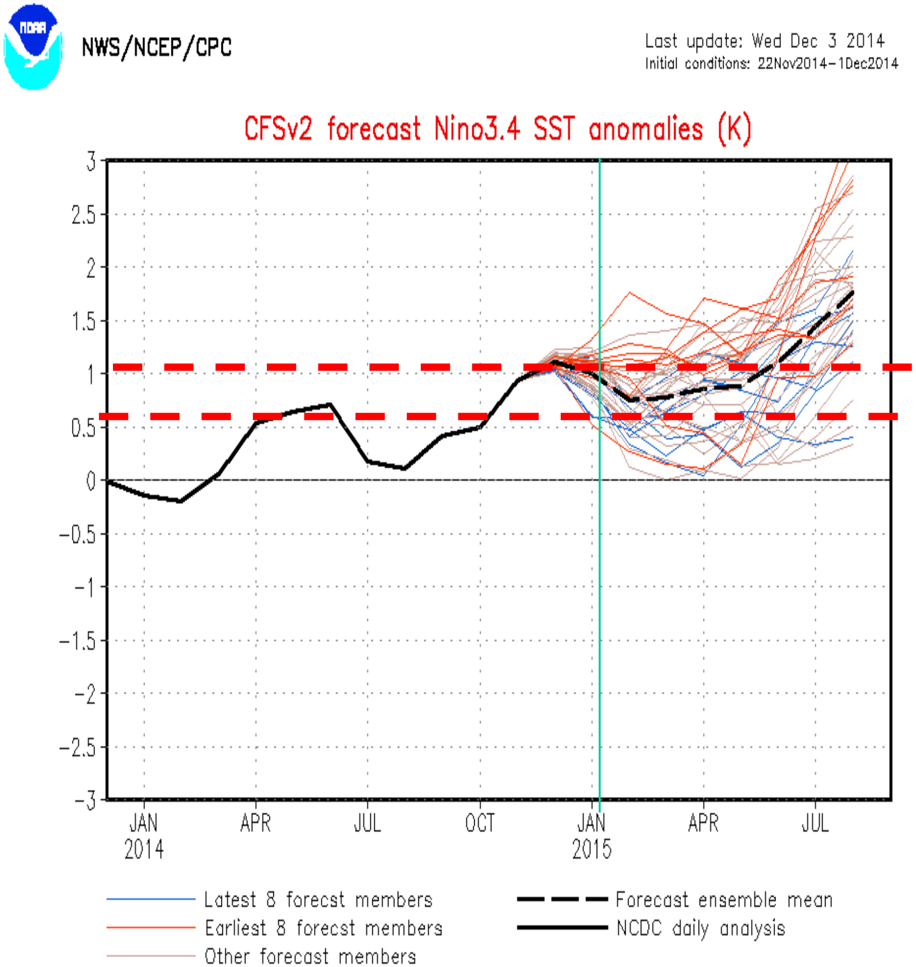


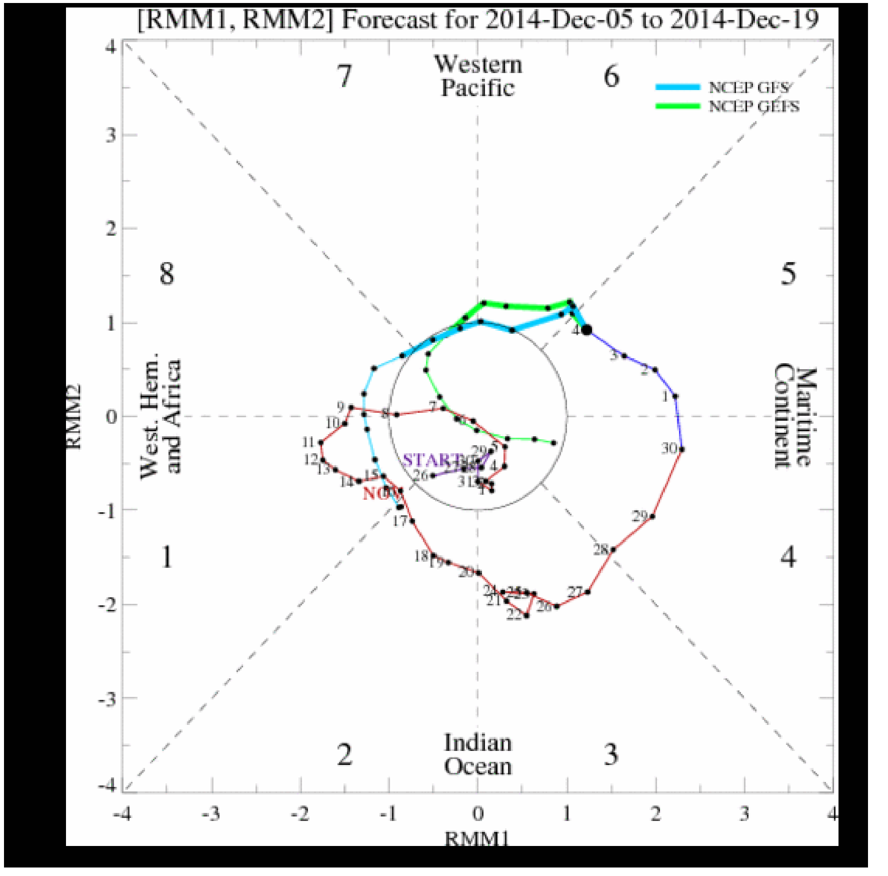
NWS/NCEP/CPC

Last update: Tue Dec 2 2014

CFSv2 Forecast Nino3.4 SST

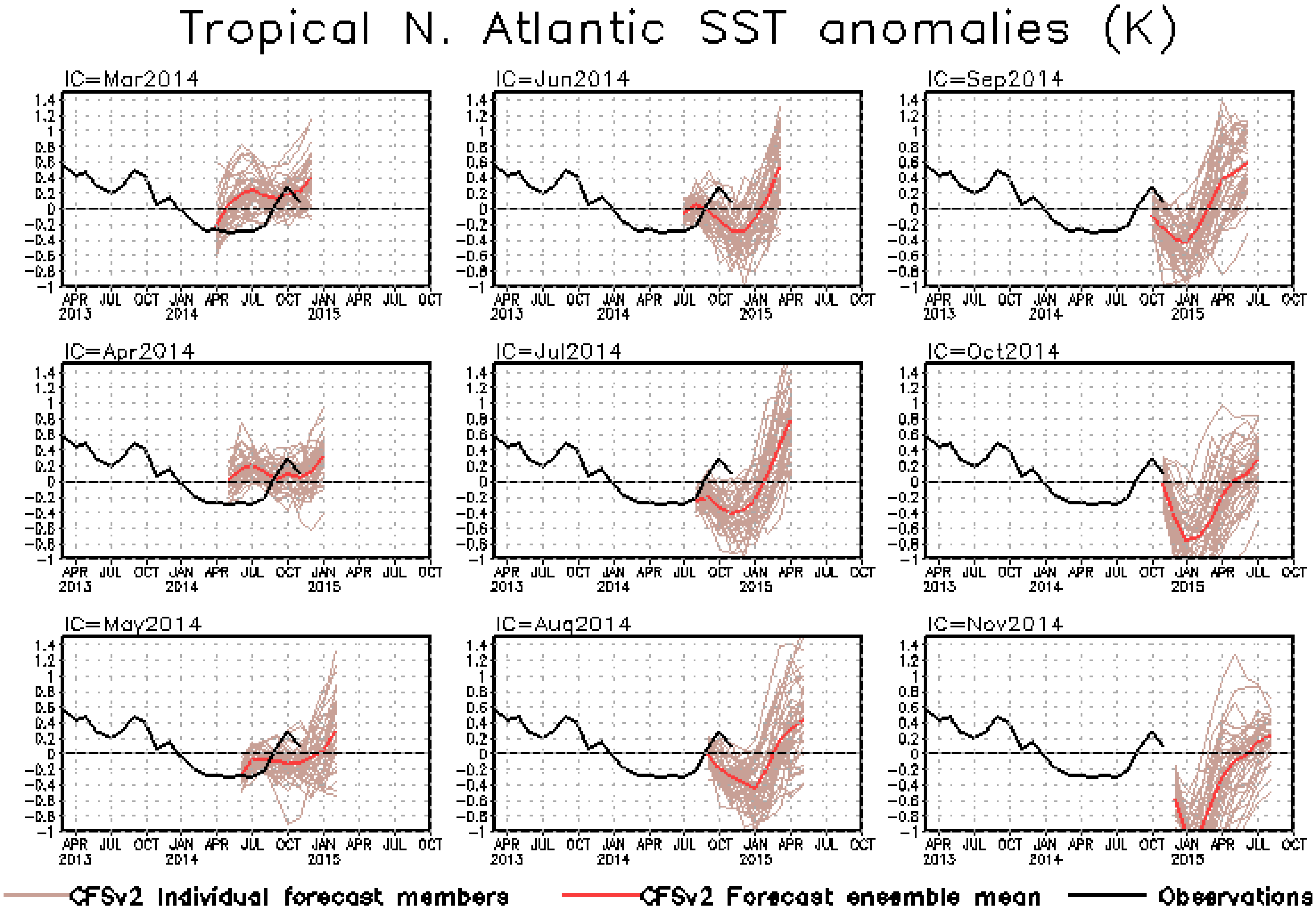






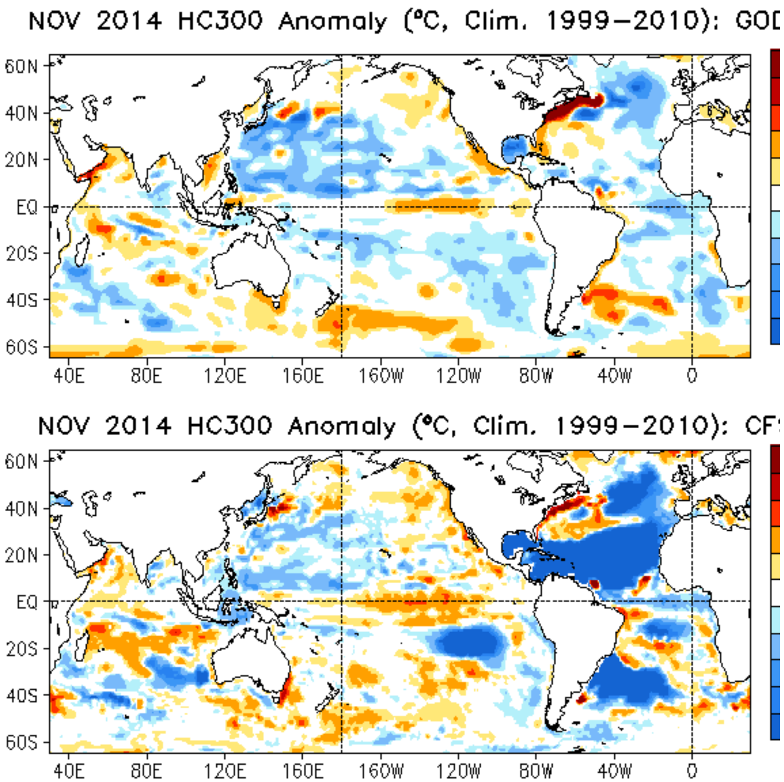
- **The CFSv2 forecasts initiated from the latest initial conditions (Dec 2-3) are cooler than those from older initial conditions, which seems related to the recent MJO phase that favors easterly wind anomalies in the western Pacific.**
- **MJO is expected to evolve into phase 6-8 in 1-2 weeks that will favor westerly wind anomalies in the western Pacific (see right panel).**
- **The CFSv2 forecast is highly sensitive to intraseasonal variability in initial conditions (**Wang, W, M. Chen, A. Kumar, and Y. Xue, 2011: How important is intraseasonal surface wind variability to real-time ENSO prediction? Geophys.Res. Lett., 37 DOI:10.1029/2011GL047684.).

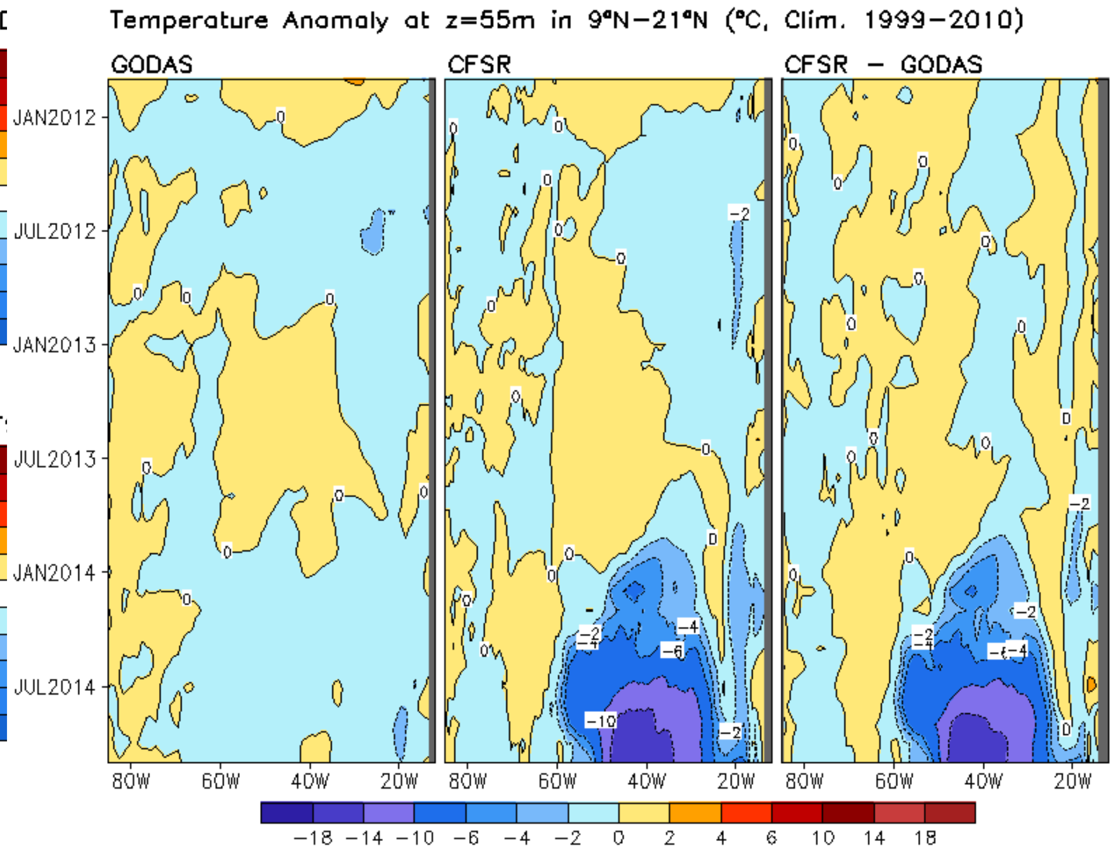
NCEP CFSv2 Tropical North Atlantic SST Forecast



- CFSv2 had a poor skill in forecasting the recent variations in tropical North Atlantic SST.
- The forecast becomes increasing colder starting from Jun to Nov I.C., that reaches the lowest value in winter 2014/2015 and then warms up afterwards.

Impacts of CFSR on Tropical N. Atlantic SSTA Forecast





- Compared to GODAS, CFSR, initial conditions for CFSv2, had large cold biases in North Atlantic, middle-latitude South Atlantic and some parts of South Pacific.
- The cold biases in the Atlantic Hurricane Main Development Region (MDR) emerged around October 2013 (reasons unknown) and enhanced quickly with time. For example, the departure of temperature in MDR at 55m depth from GODAS grew to be -10 degree by Jul 2014.
- The growing cold biases seem have contributed to the growing negative TNA forecast starting from Jul to Nov 2014 initial conditions (previous slide).

Overview

- **Pacific Ocean**

➢ ENSO-neutral conditions continued during Nov 2014 (NINO3.4=+0.9C, but the tropical Pacific atmosphere was not fully in El Nino conditions yet).

➢ The consensus forecast suggests 65% chance of El Niño conditions during the Northern Hemisphere winter, which is favored to last into the Northern Hemisphere spring 2015.

➢ Intraseasonal variability in equatorial subsurface temperature was associated with oceanic Kelvin wave episodes.

➢ Recent low-level easterly wind anomalies in the western tropical Pacific were probably associated with Madden Julian Oscillation (MJO) activity.

➢ Positive PDO phase persisted with PDO=+1.3 in Nov 2014.

- **Atlantic Ocean**

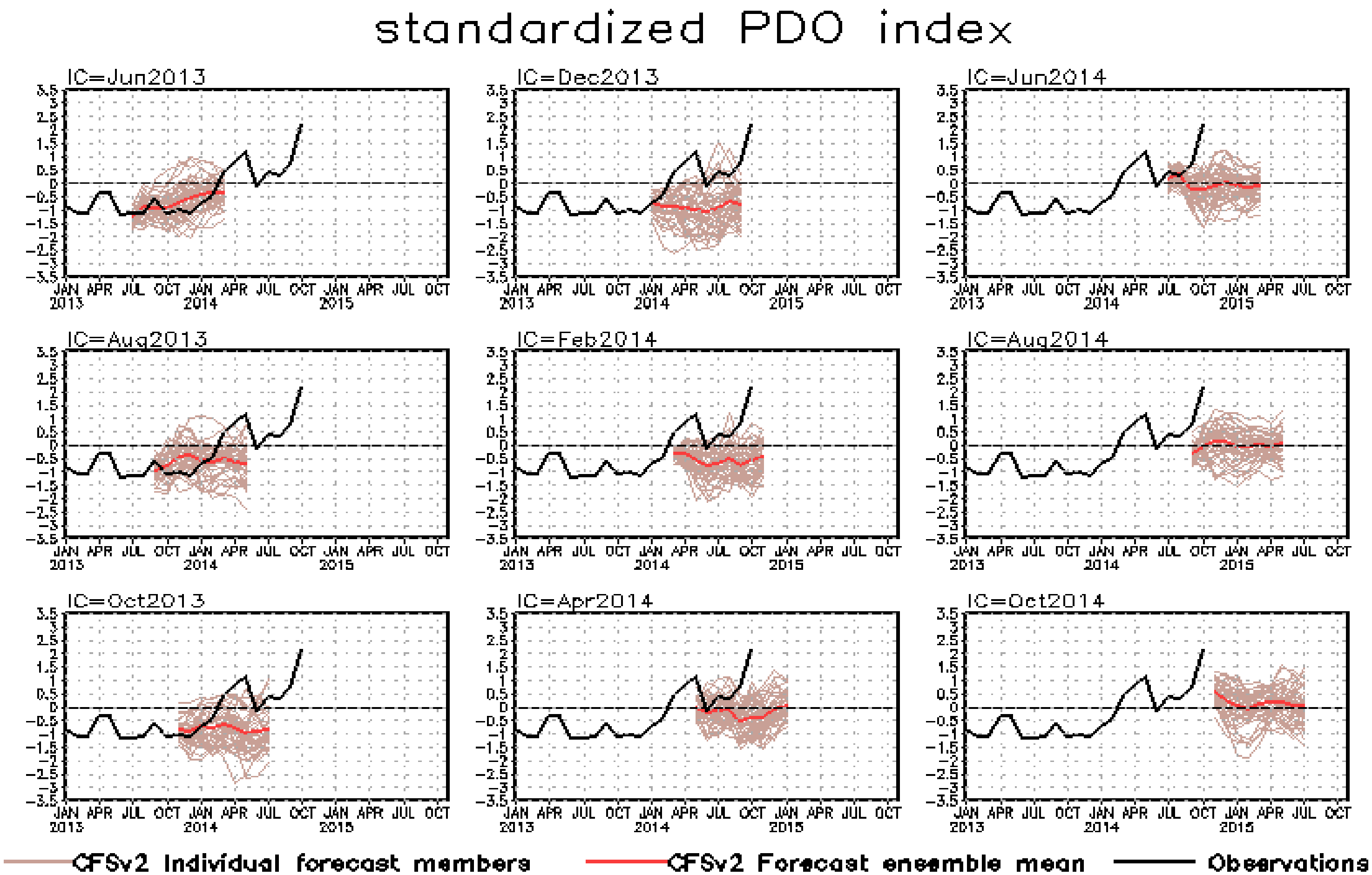
➢ NAO phase switched to positive with NAO index = +0.58 in Nov 2014.

➢ 2014 Atlantic hurricane season had 8 tropical storms (TSs), 6 hurricanes (Hs) and 2 major hurricanes (MHs), which is below the average (12 TSs, 6 Hs, 3 MHs). The ACE is 64% of normal.

➢ 2014 Eastern Pacific hurricane season had 22 TSs, 16 Hs and 9 MHs, which is well above the average (15 TSs, 8 Hs, 4 MHs). The ACE is 198% of normal.

Backup Slides

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.

- CFSv2 had a poor skill in forecasting the switch from negative to positive PDO phase.

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

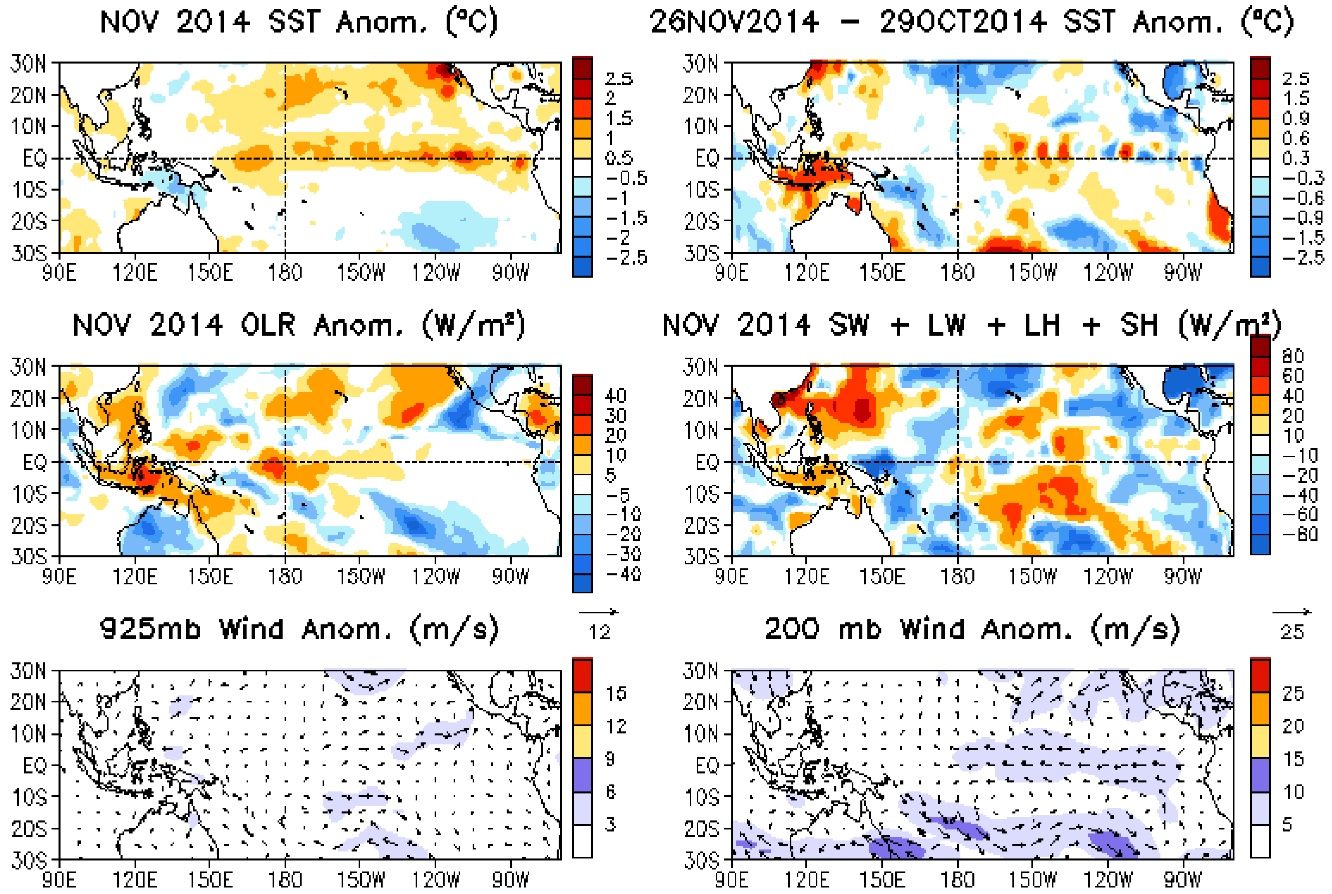


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

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

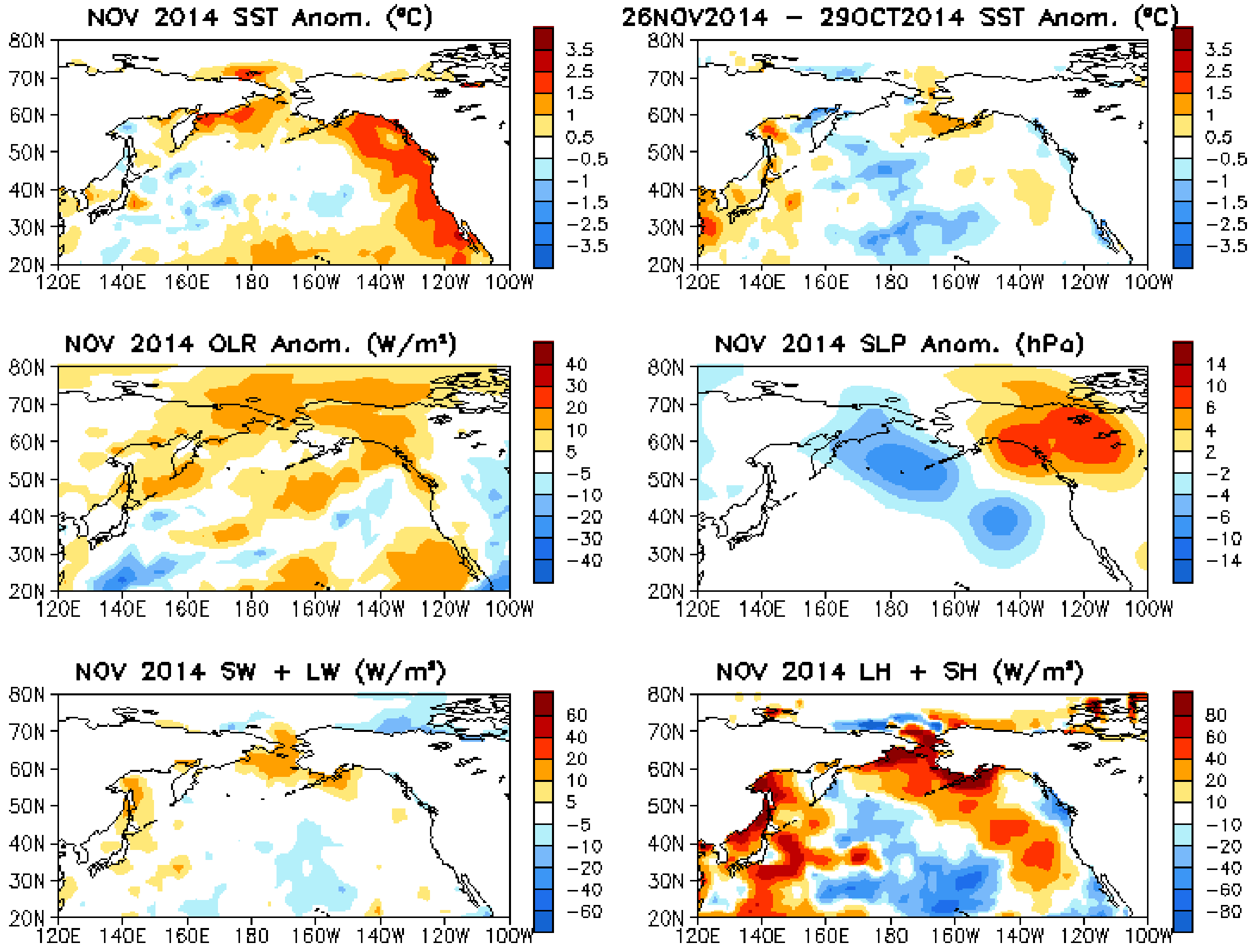


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

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

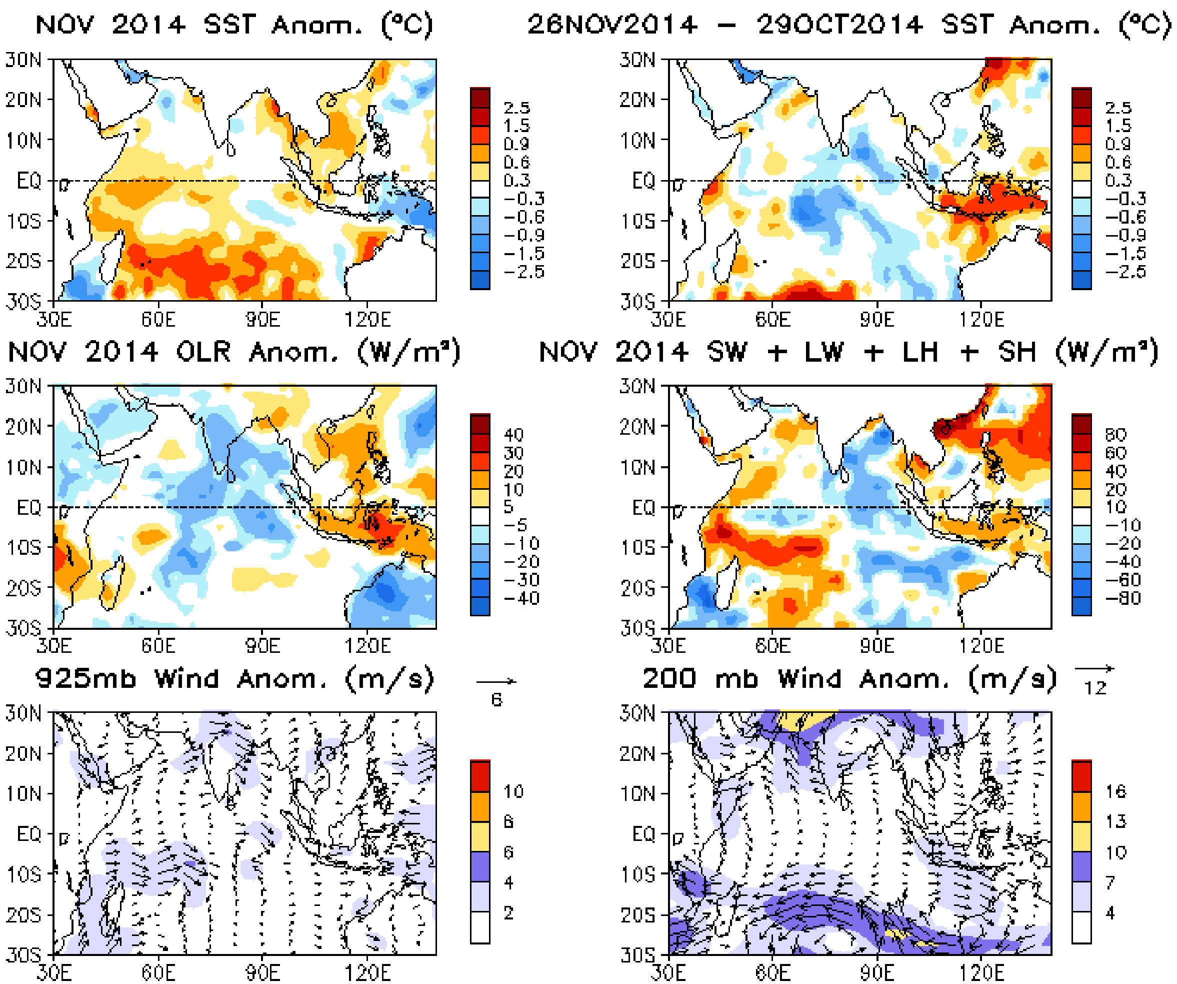


Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

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

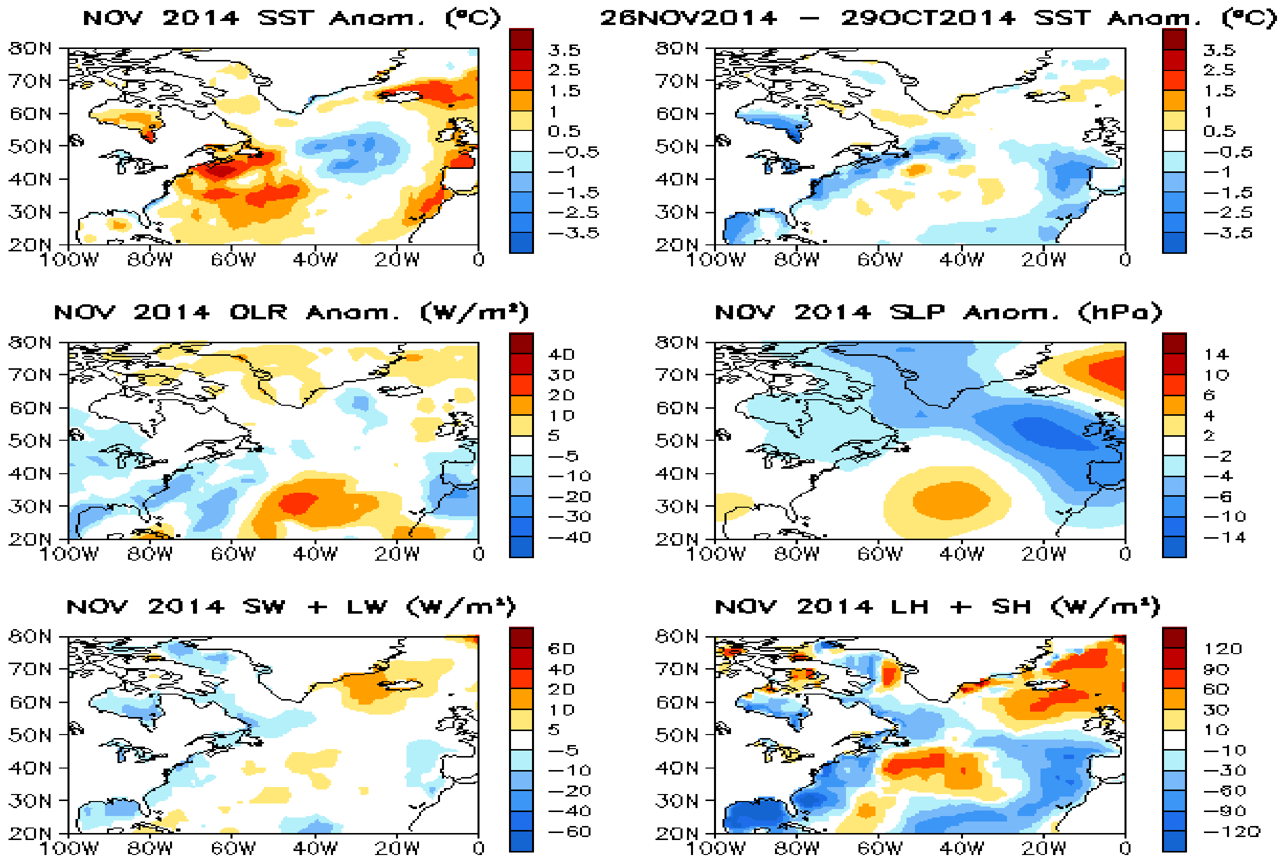
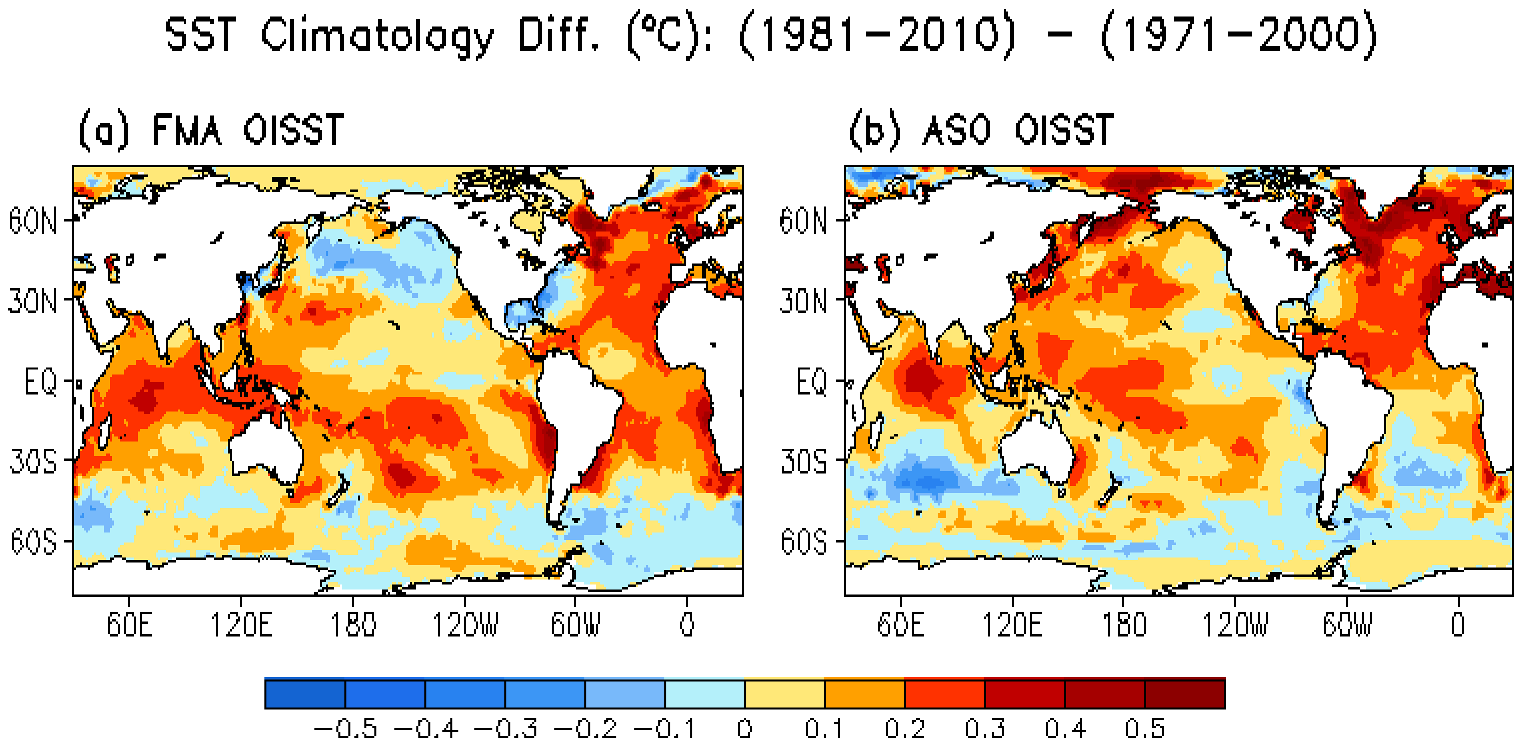


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

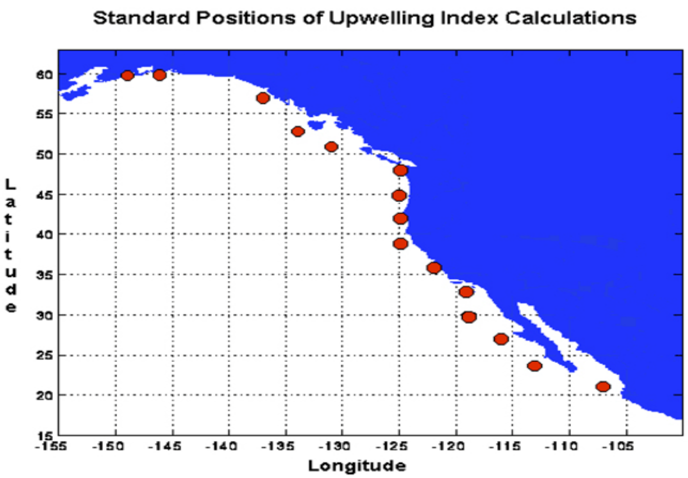
1981-2010 SST Climatology: http://origin.cpc.ncep.noaa.gov/products/people/yxue/sstclim/

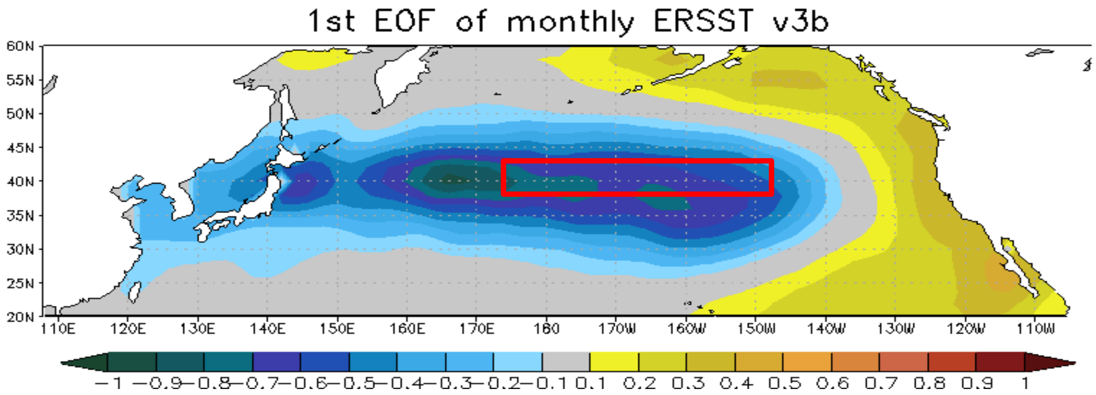
- **The seasonal mean SST in February-April (FMA) increased by more than 0.2°C over much of the Tropical Oceans and N. Atlantic, but decreased by more than 0.2°C in high-latitude N. Pacific, Gulf of Mexico and along the east coast of U.S.**
- **Compared to FMA, the seasonal mean SST in August-October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


Standard Positions of Upwelling Index Calculations
Latitude
Longitude


1st EOF of monthly ERSST v3b