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

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

This project to deliver real-time ocean monitoring products is implemented by CPC in cooperation with NOAA 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 Dec 2014 (NINO3.4=+0.8C, but the tropical Pacific atmosphere circulation remained ENSO-neutral.)

➢ The consensus forecast suggests about 50-60% chance of El Niño conditions in Jan-Feb 2015, with ENSO-neutral favored thereafter.

➢ Positive subsurface temperature anomalies weakened substantially due to eastward propagation of upwelling oceanic Kelvin waves.

➢ Surface easterly wind anomalies persisted in western Pacific and emerged in eastern Pacific in Dec 2014, unfavorable for El Nino development.

➢ Precipitation was enhanced (suppressed) in W. Pacific and SPCZ (near Dateline).

➢ Correspondingly, sea surface salinity was below-normal (above-normal) in W. Pacific and SPCZ (near Dateline).

➢ Positive PDO phase enhanced with PDO=+1.9 in Dec 2014.

- **Indian Ocean**

➢ Precipitation was enhanced in E. tropical Indian Ocean.

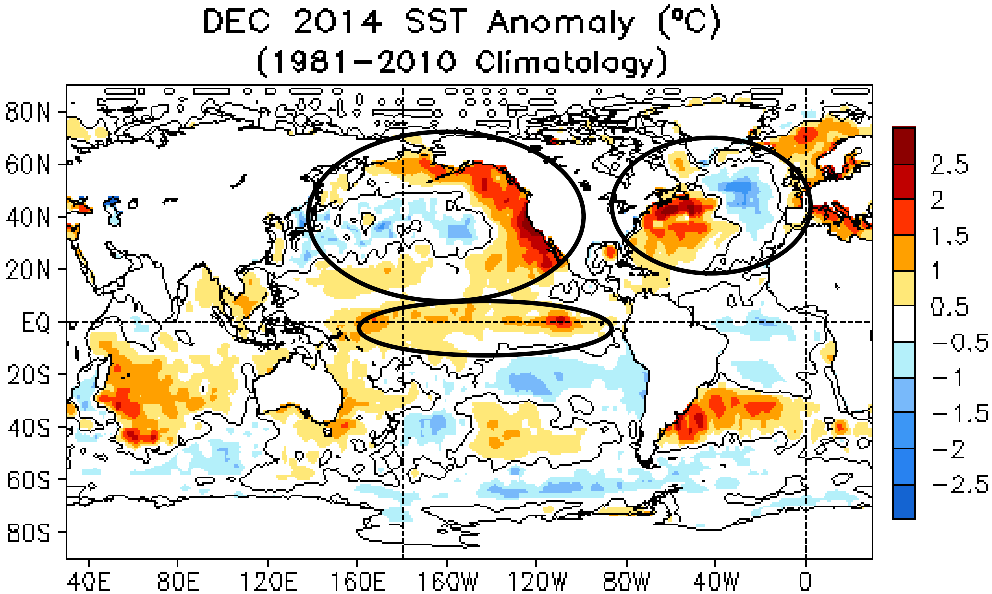
➢ Strong westerly wind anomalies presented in tropical Indian Ocean.

- **Atlantic Ocean**

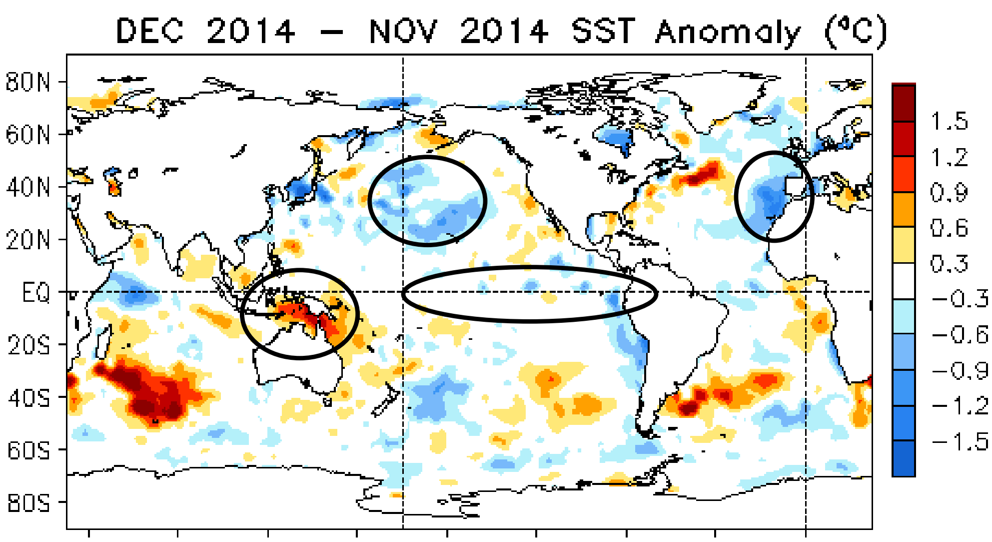
➢ Positive NAO phase enhanced with NAO index = +1.6 in Dec 2014.

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.



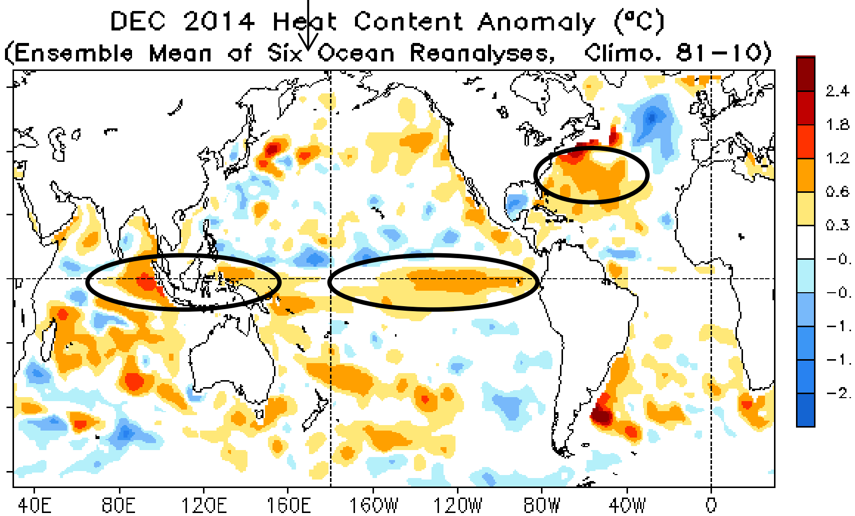
- A cooling tendency presented in central N. Pacific, equatorial Pacific and coast of N. Africa.
- A warming tendency was observed over Maritime Continents.

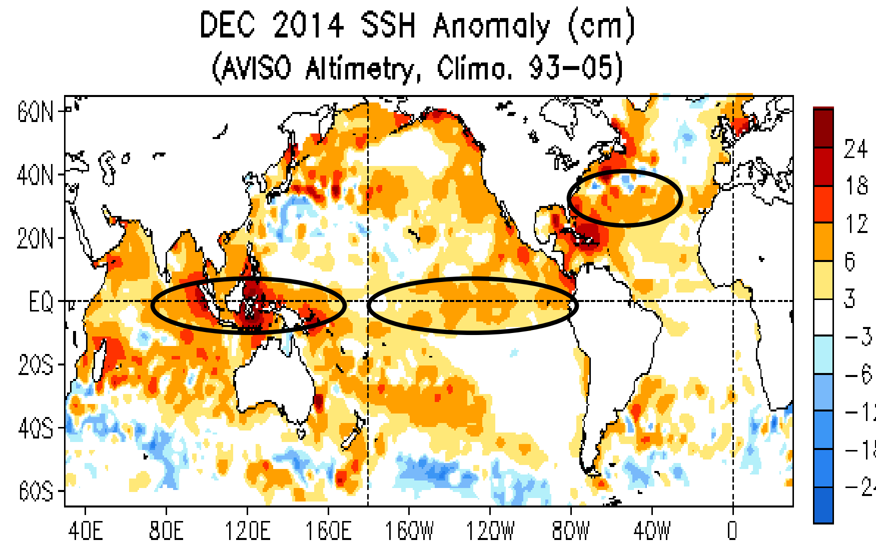
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

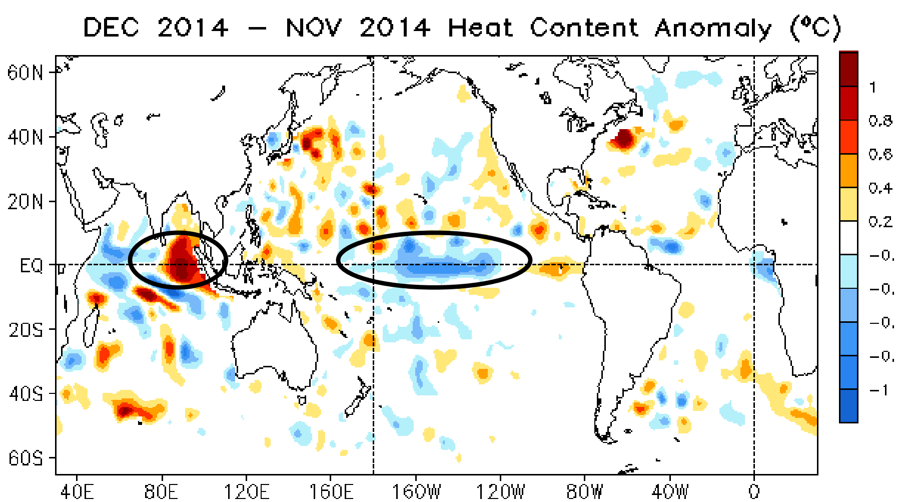
Upper 300m Heat Content Anomaly

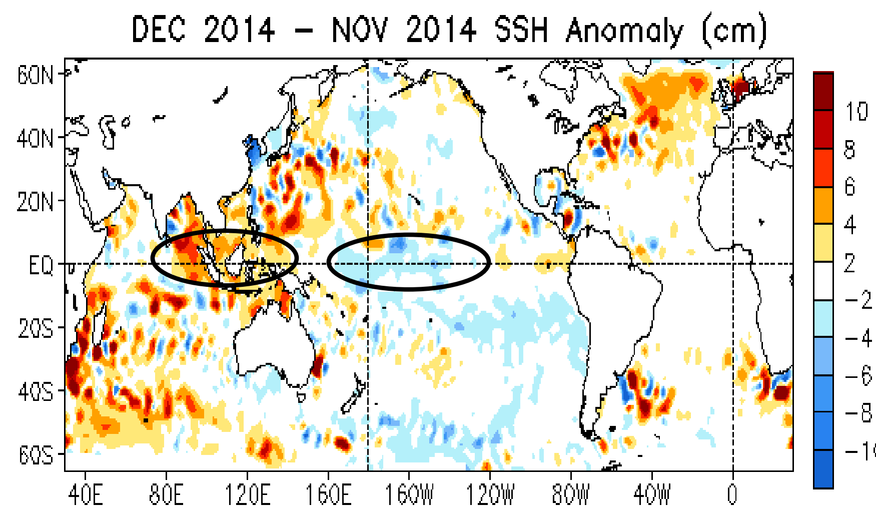
http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

Sea Surface Height Anomaly





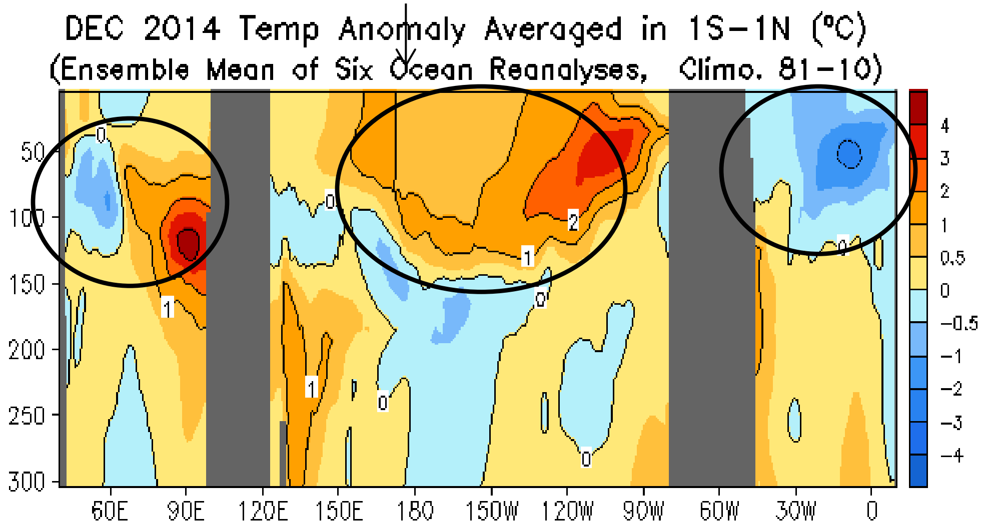




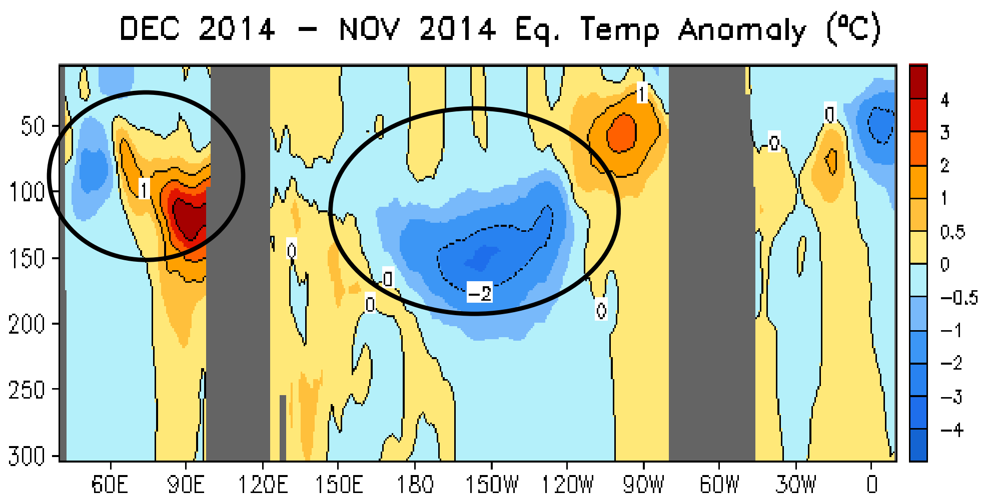
- There are good correspondences between upper 300m heat content and sea surface height anomalies in tropical Indian Ocean, tropical Pacific and middle-latitude North Atlantic.

Longitude-Depth Temperature Anomaly and Anomaly Tendency in 1ºS-1ºN

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



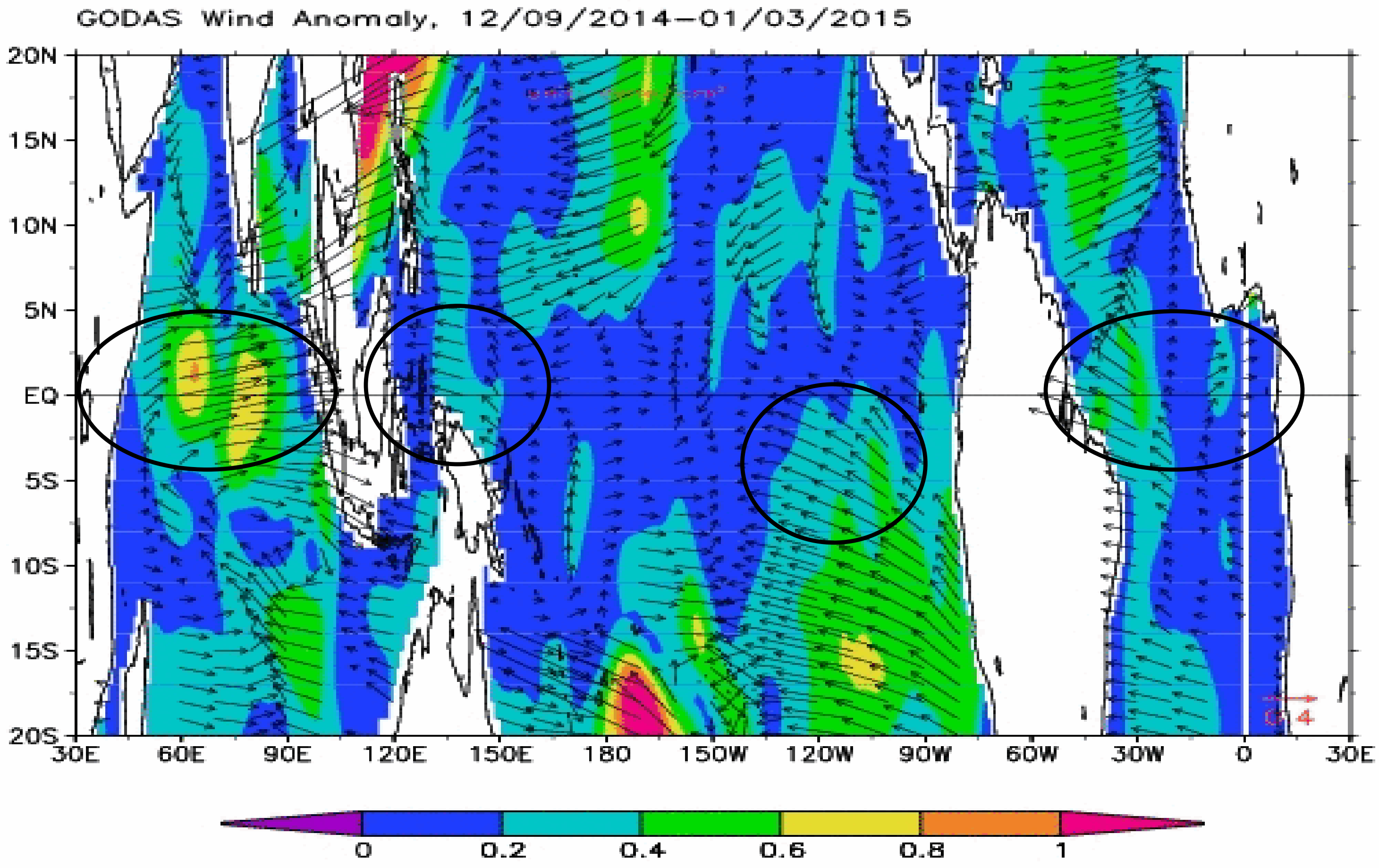
- **Positive temperature anomalies occupied most of equatorial Pacific and Indian Ocean.**
- **Negative anomalies dominated the upper equatorial Atlantic Ocean.**



- **A cooling (warming) tendency was observed in the central (eastern) Pacific Ocean near the thermocline, largely due to propagation of oceanic Kelvin waves.**
- **A strong warming tendency was observed in the eastern tropical Indian Ocean.**

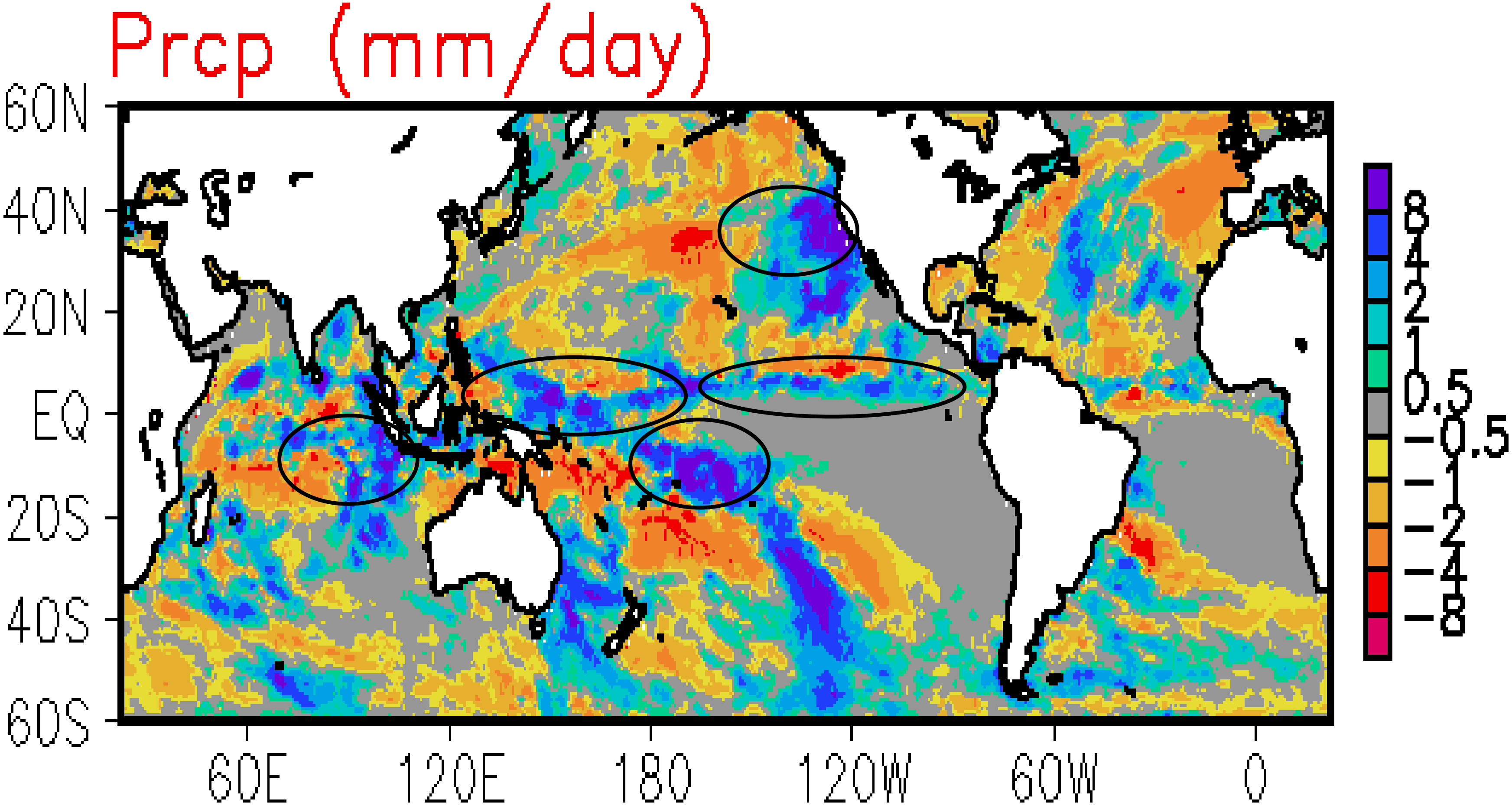
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1981-2010 base period means.

Wind Stress Anomaly from NCEP Reanalysis 2



- The strong warming tendency in the eastern tropical Indian Ocean (previous slide) was associated with strong westerly wind anomalies.
- The cooling tendency in the equatorial Atlantic (previous slide) was associated with divergent wind anomalies in that region.

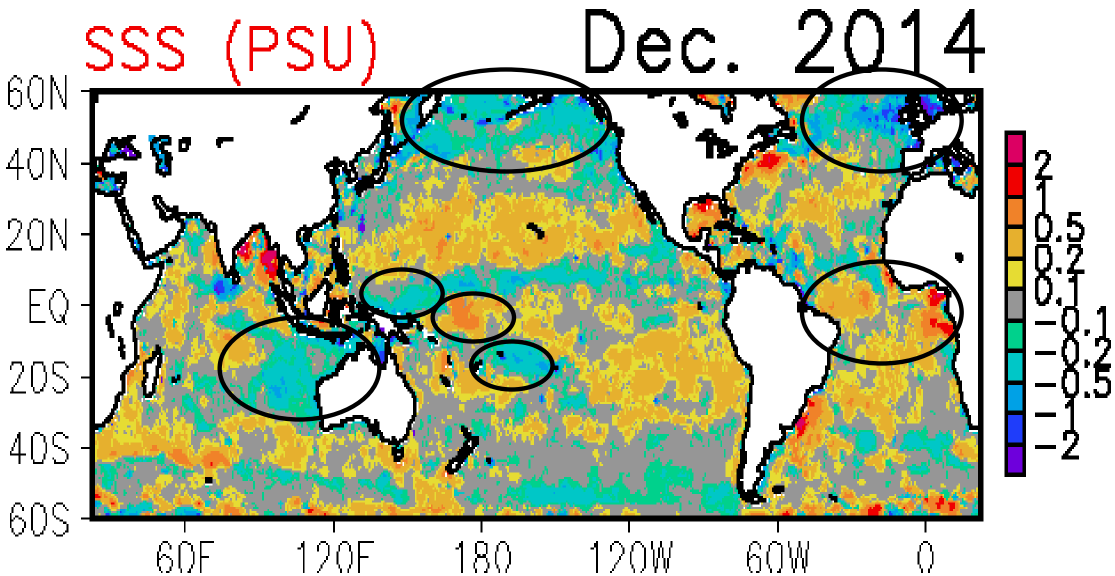
Precipitation Anomaly



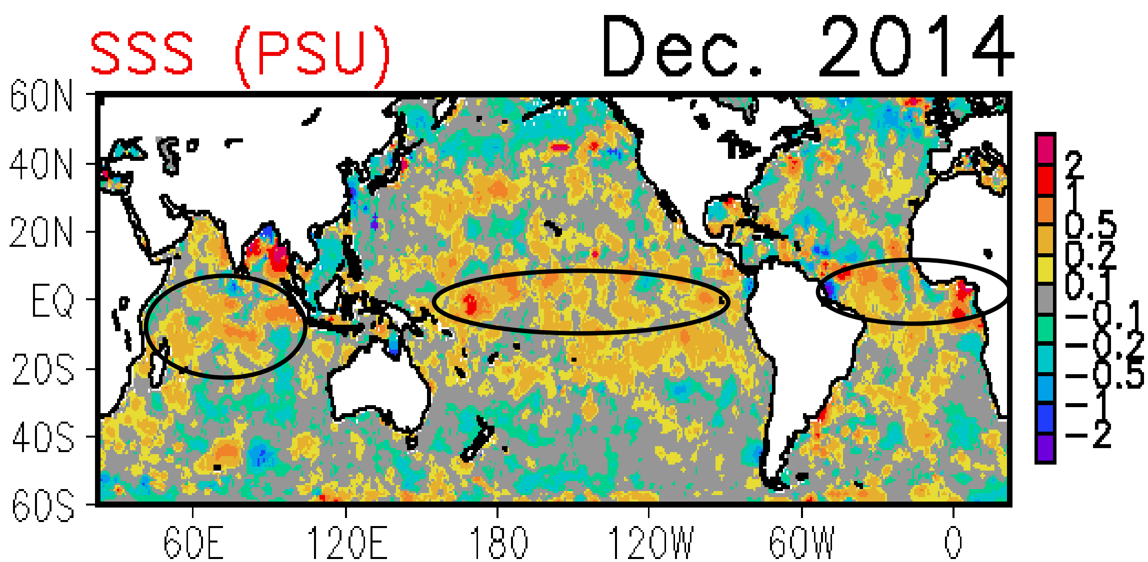
- Above-normal precipitation was observed in the western tropical Pacific, SPCZ, ITCZ, eastern tropical Indian Ocean and eastern North Pacific in Dec 2014.

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

Sea Surface Salinity (SSS) Anomaly and Anomaly Tendency



- SSS was below-normal (fresher than normal) in E. Indian Ocean, far W. Pacific, high-latitude North Pacific and North Atlantic.
- SSS was above-normal near Dateline and tropical Atlantic.

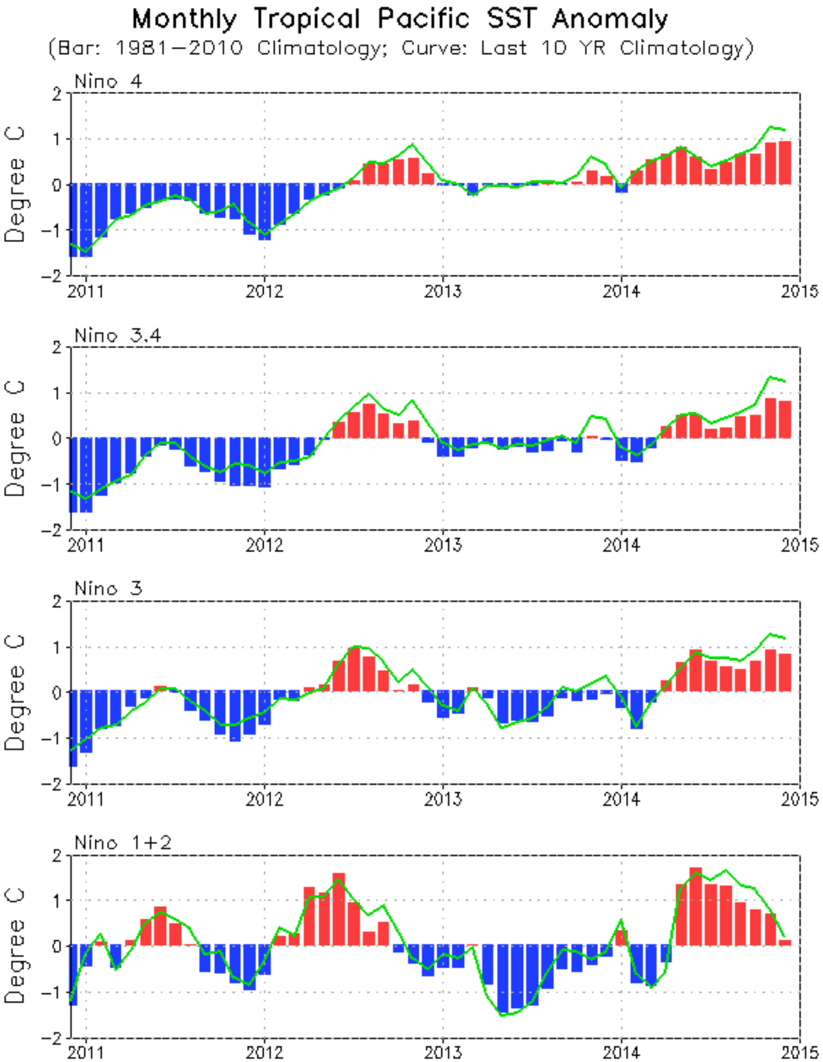


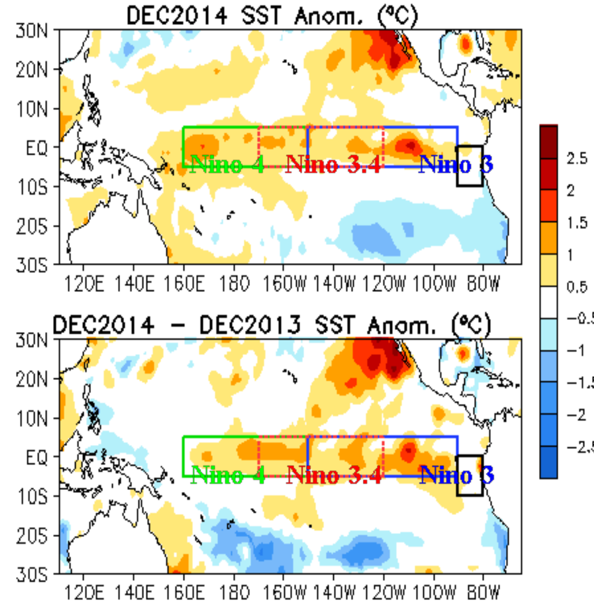
- Positive anomaly tendency was observed in all tropical Oceans in Dec 2014.

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

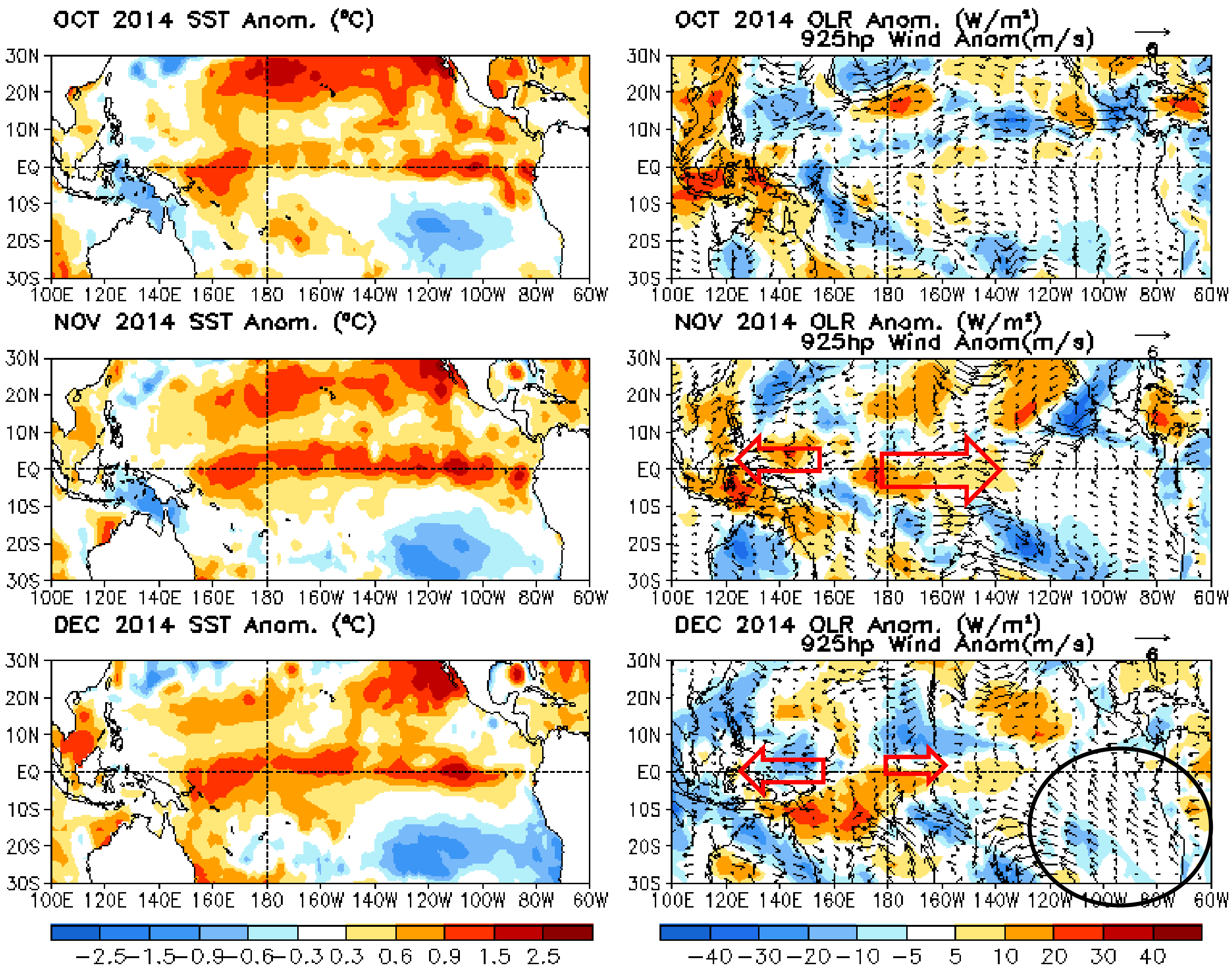




- **All Nino indices were above-normal: NINO1+2=+0.1, NINO3=+0.8, NINO3.4=+0.8, NINO4=+0.9**
- **NINO3.4 >= +0.5 in May-Jun and Sep-Dec.**
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.**

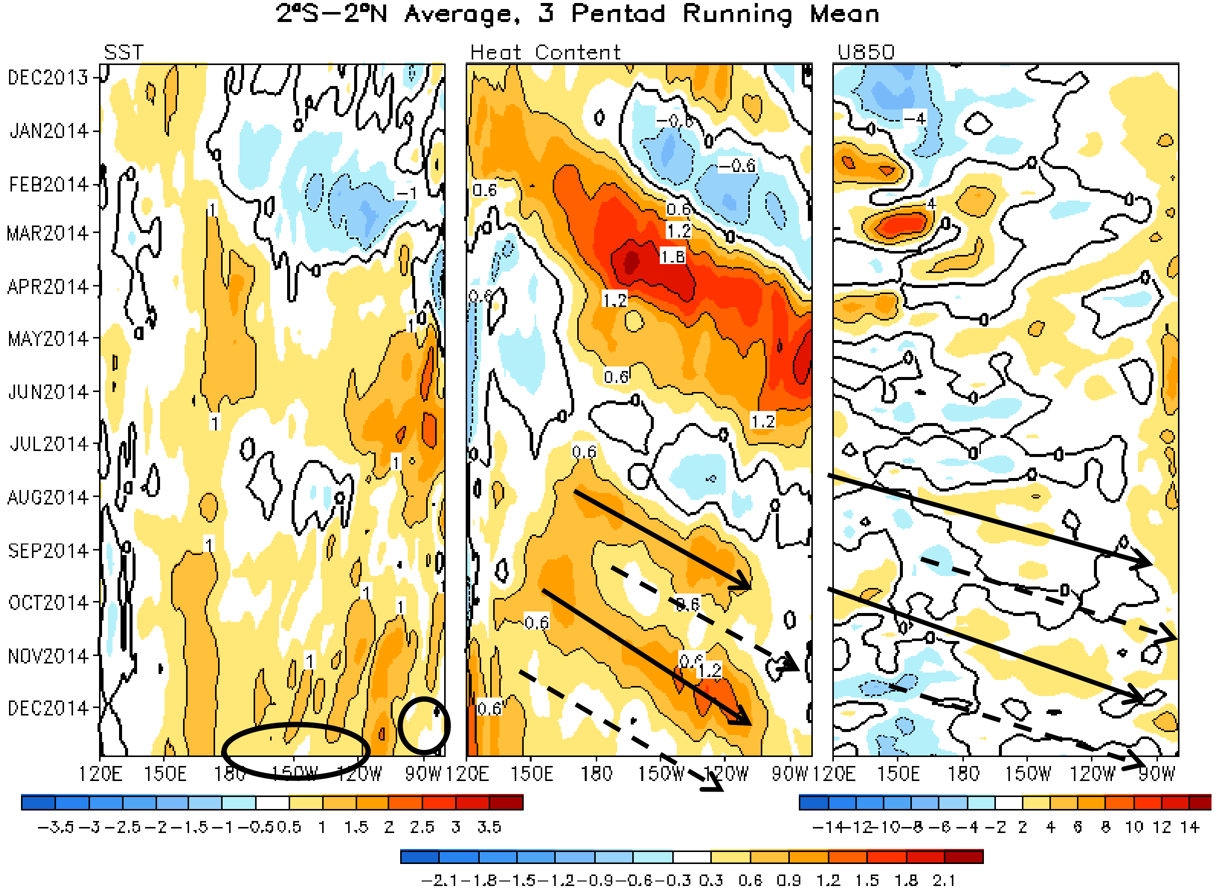
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 (bar) and last ten year (green line) means.

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

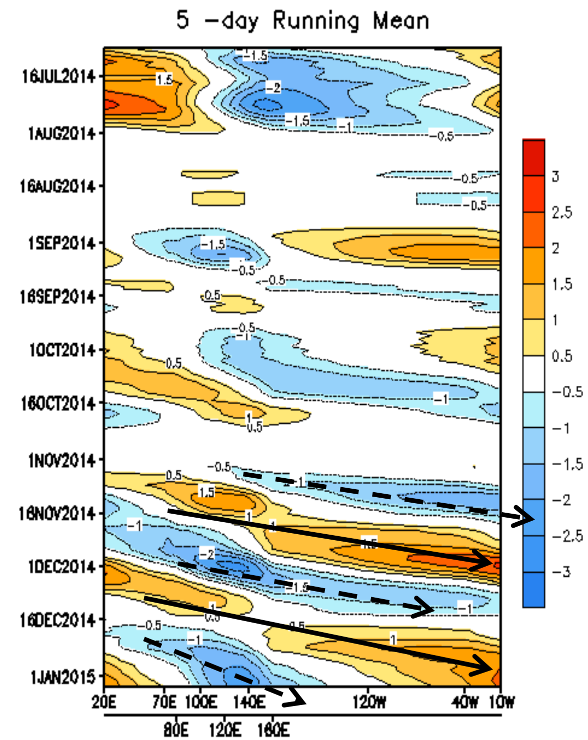


- Convection was suppressed near the Dateline in the last two months, absence of El Nino-like convection.
- Easterly wind anomalies persisted in W. Pacific, while westerly anomalies weakened in central Pacific.
- South-easterly and cross-equatorial wind anomalies enhanced in the eastern Pacific in Dec 2014.

Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) and OLR(W/m^2) Anomalies



CPC MJO Indices

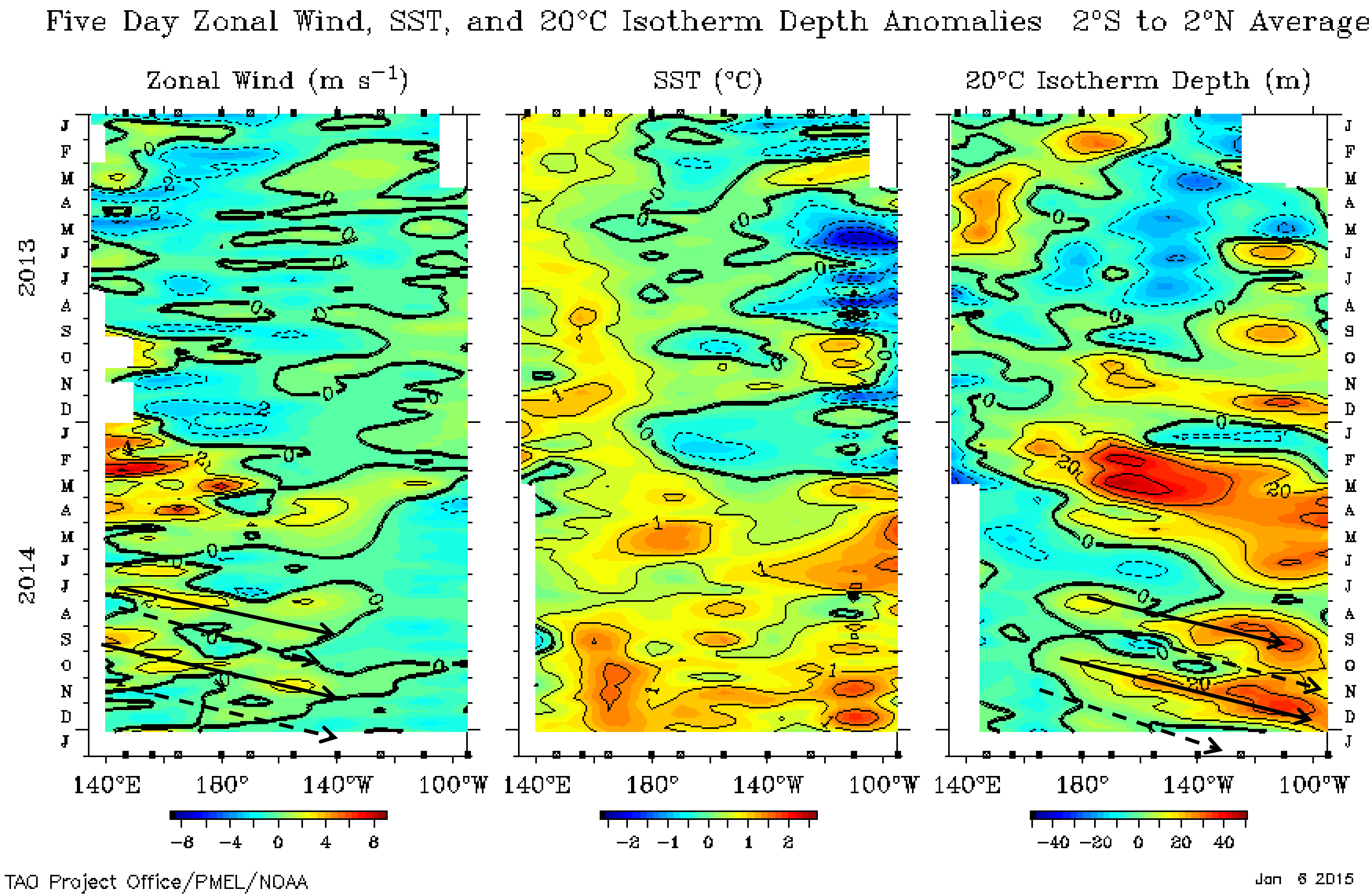


http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/mjo_index.shtml

- **Positive SSTA weakened in the central-eastern Pacific and far eastern Pacific.**
- **Positive HC300 anomalies propagated eastward and reached 100W, due to downwelling oceanic Kelvin waves.**
- **Intraseasonal variability has been strong in surface winds and heat content anomaly since Aug., indicating weak low frequency variability.**

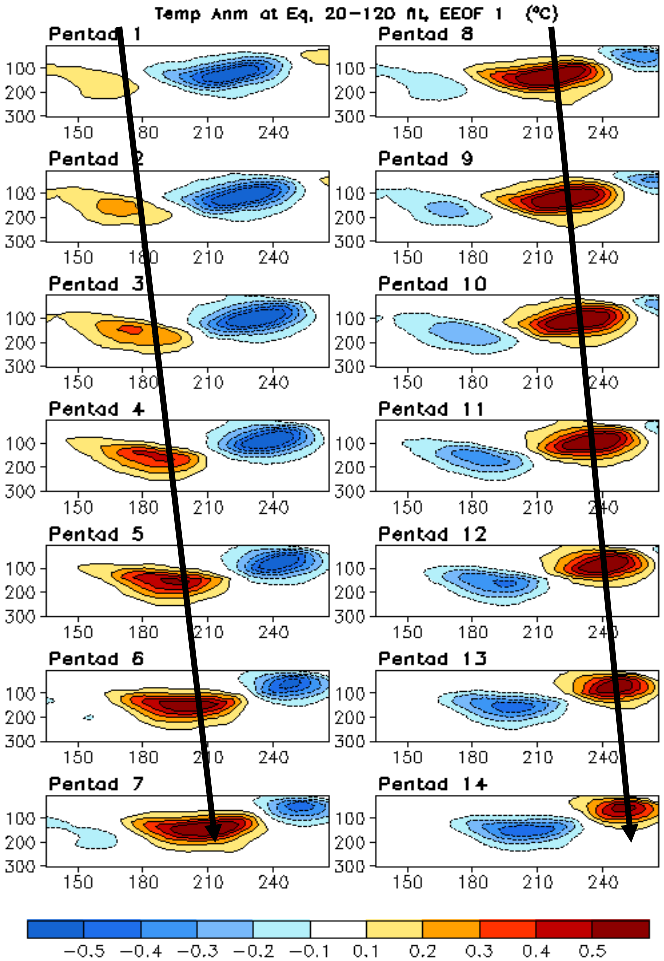
Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2°S-2°N and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST is derived from the NCEP OI 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.

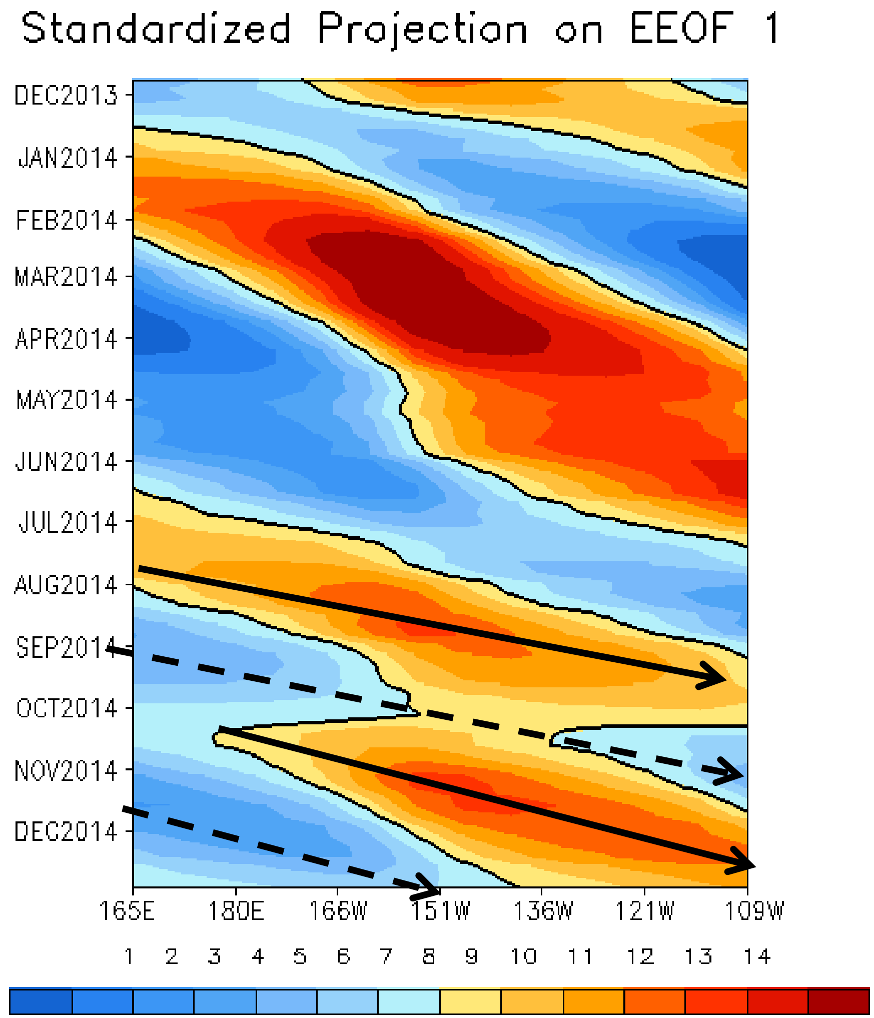
TAO Data



Five Day Zonal Wind, SST, and 20°C Isotherm Depth Anomalies 2°S to 2°N Average
Zonal Wind (m s⁻¹)
SST (°C)
20°C Isotherm Depth (m)
2013
2014
J F M A M J J A S O N D J F M A M J J A S O N D J
140°E 180° 140°W 100°W
−8 −4 0 4 8
−2 −1 0 1 2
−40 −20 0 20 40
TAO Project Office/PMEL/NOAA
Jan 6 2015

Oceanic Kelvin Wave Indices



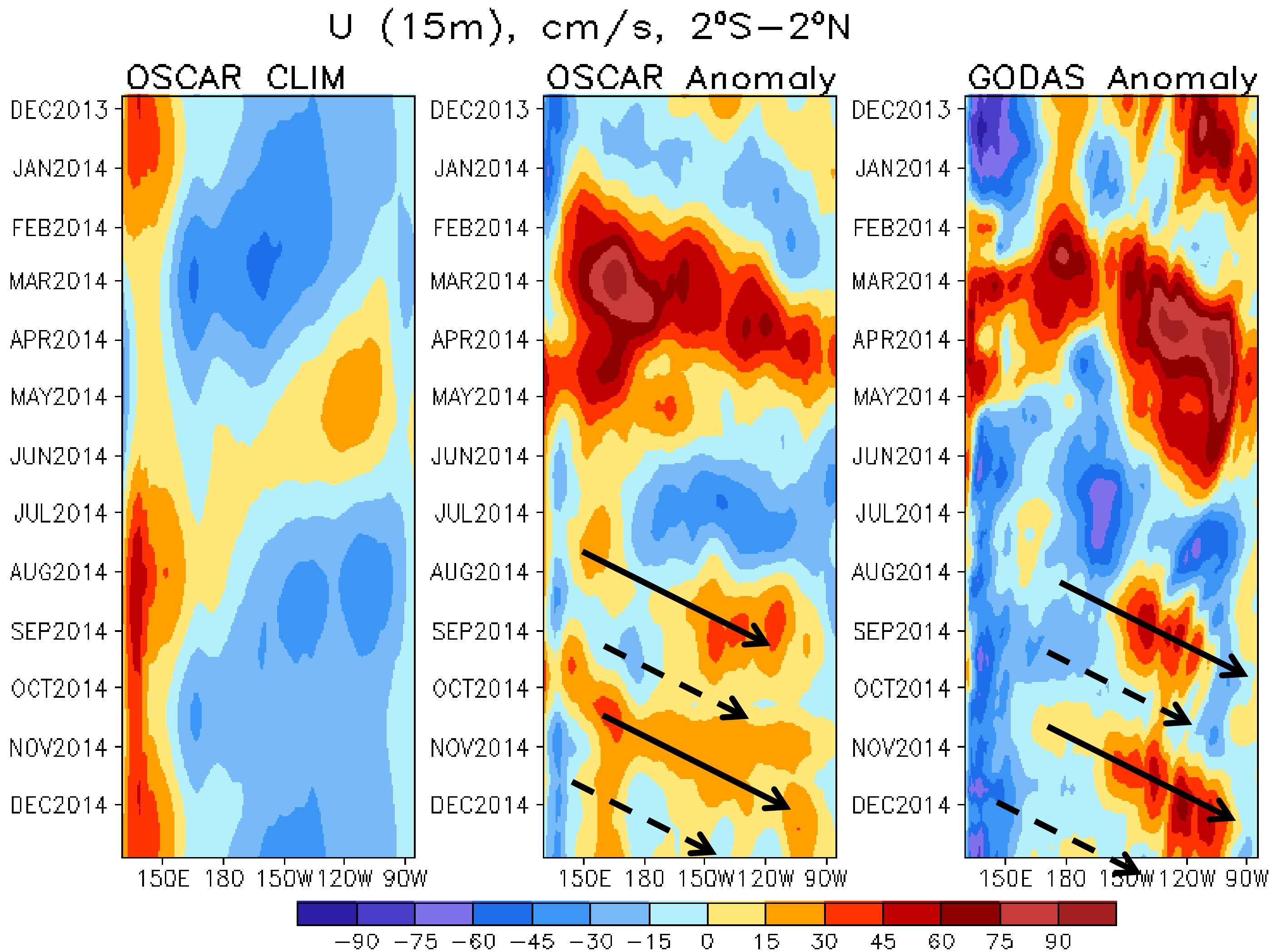


- Upwelling oceanic Kelvin wave (OKW, dash line) emerged in mid-Aug in the W. Pacific and propagated eastward associated with the negative phase of MJO.

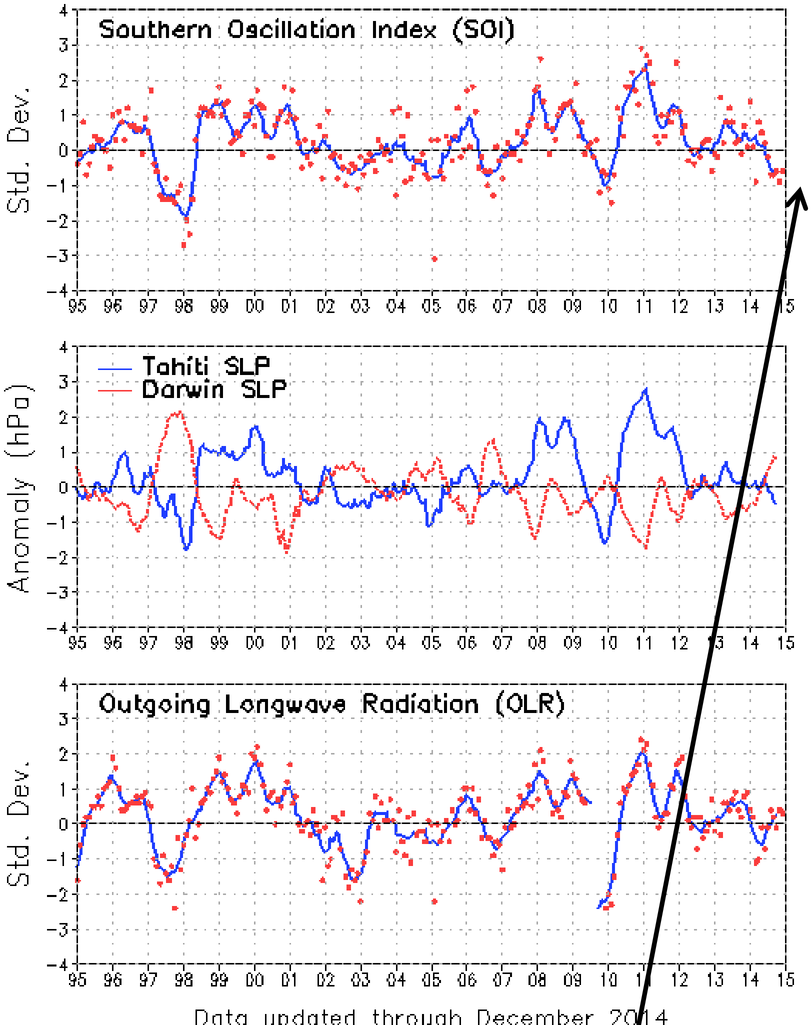
- Downwelling OKW (solid line) emerged in mid-Sep in the W. Pacific was associated with the positive phase of MJO, while upwelling OKW initiated in early-Nov in the W. Pacific was associated with the negative phase of MJO.

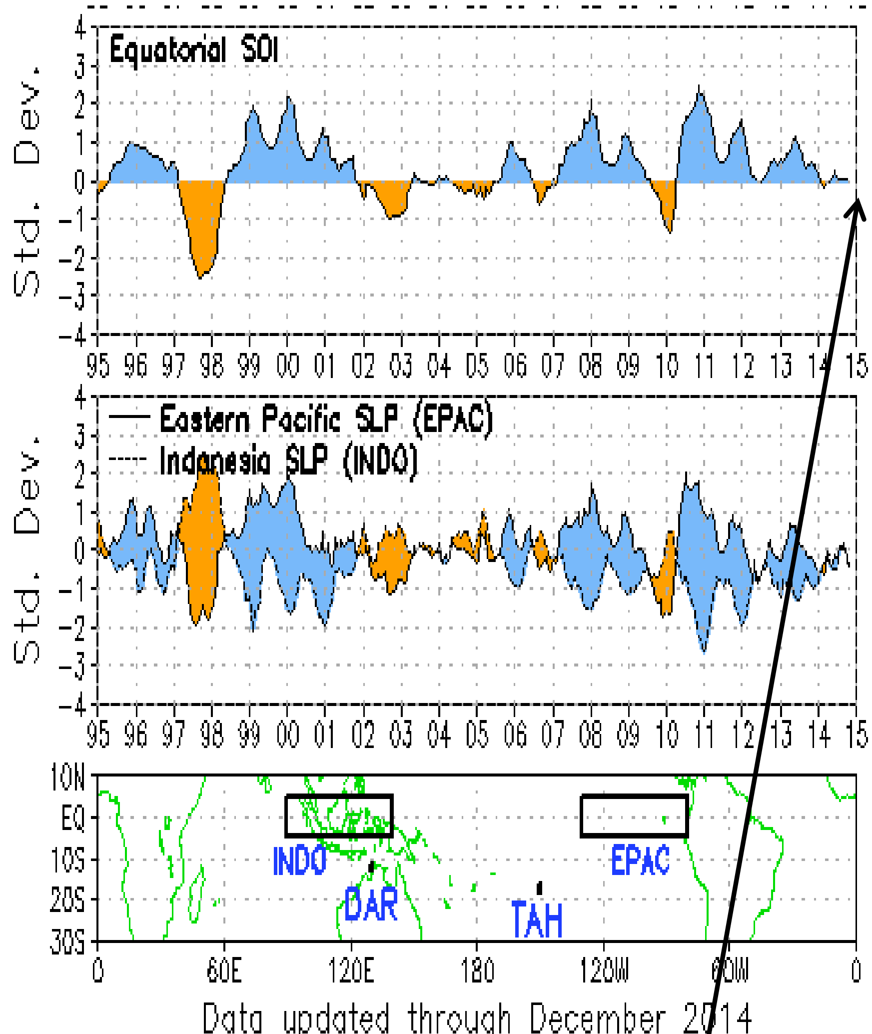
- Oceanic Kelvin wave indices are defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF 1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).

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



- **Positive (negative) zonal current anomalies were associated with downwelling (upwelling) oceanic Kelvin waves, but the eastward propagation signal was not as clear as that in heat content.**

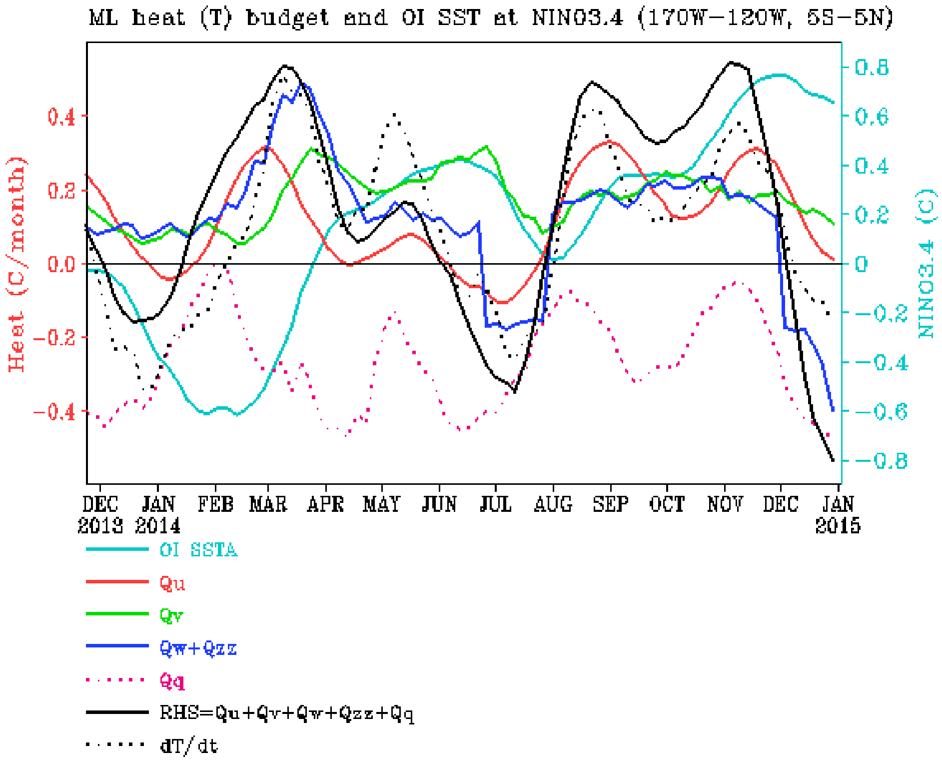




- **Southern Oscillation Index (SOI) was below-normal since Jul 2014, but Equatorial SOI was near-normal.**

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

NINO3.4 Heat Budget



- **SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) was negative in Dec 2014, indicating a cooling tendency in NINO3.4.**

- **The vertical entrainment and diffusion term (Qw+Qzz, blue line) and thermodynamical term (Qq) were negative, contributing to the cooling tendency.**

Huang, B., Y. Xue, X. Zhang, A. Kumar, and M. J. McPhaden, 2010 : The NCEP GODAS ocean analysis of the tropical Pacific mixed layer heat budget on seasonal to interannual time scales, J. Climate., 23, 4901-4925.

Qu: Zonal advection; Qv: Meridional advection;

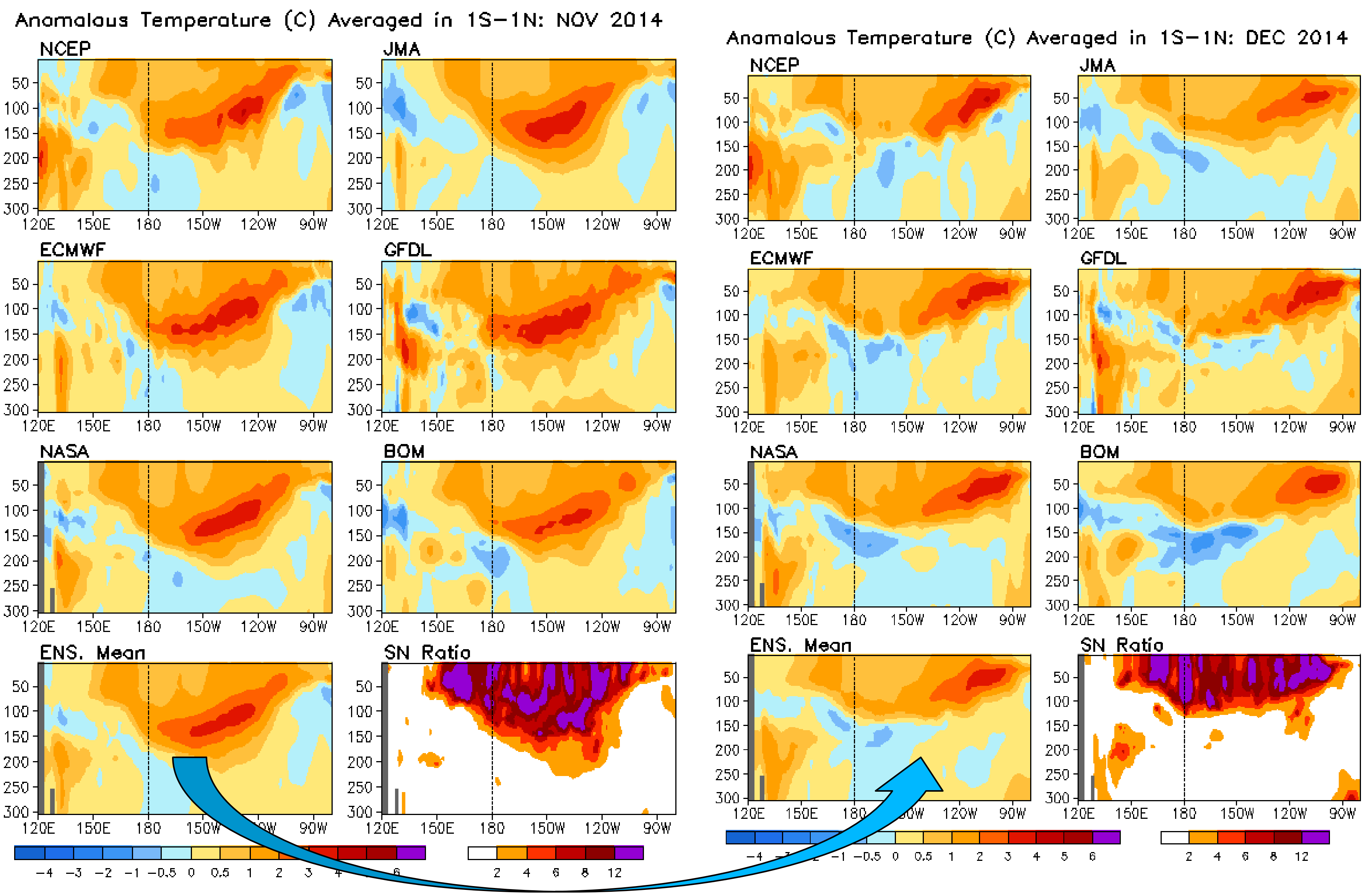
Qw: Vertical entrainment; Qzz: Vertical diffusion

Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

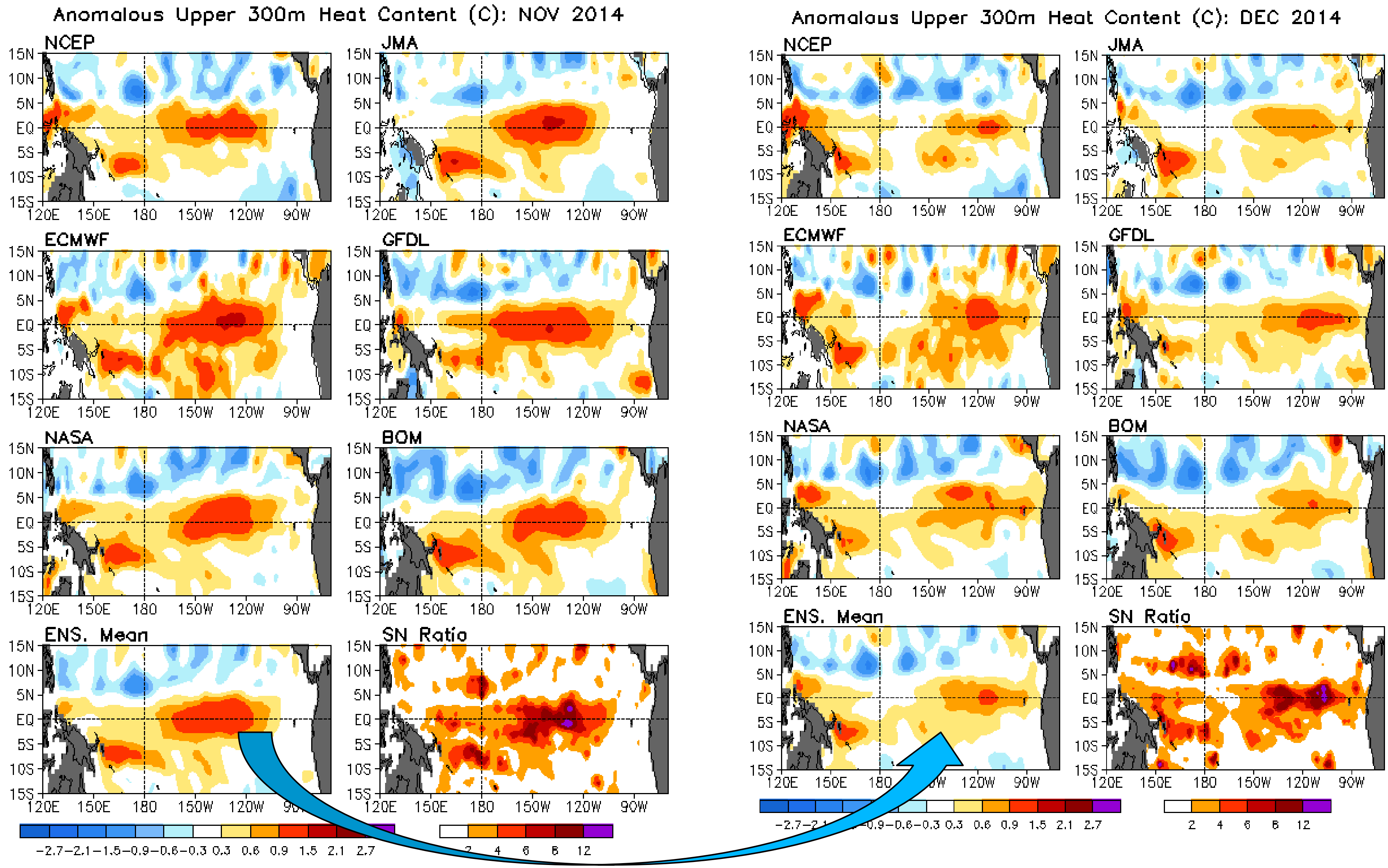
Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

Real-Time Ocean Reanalyses Intercomparison

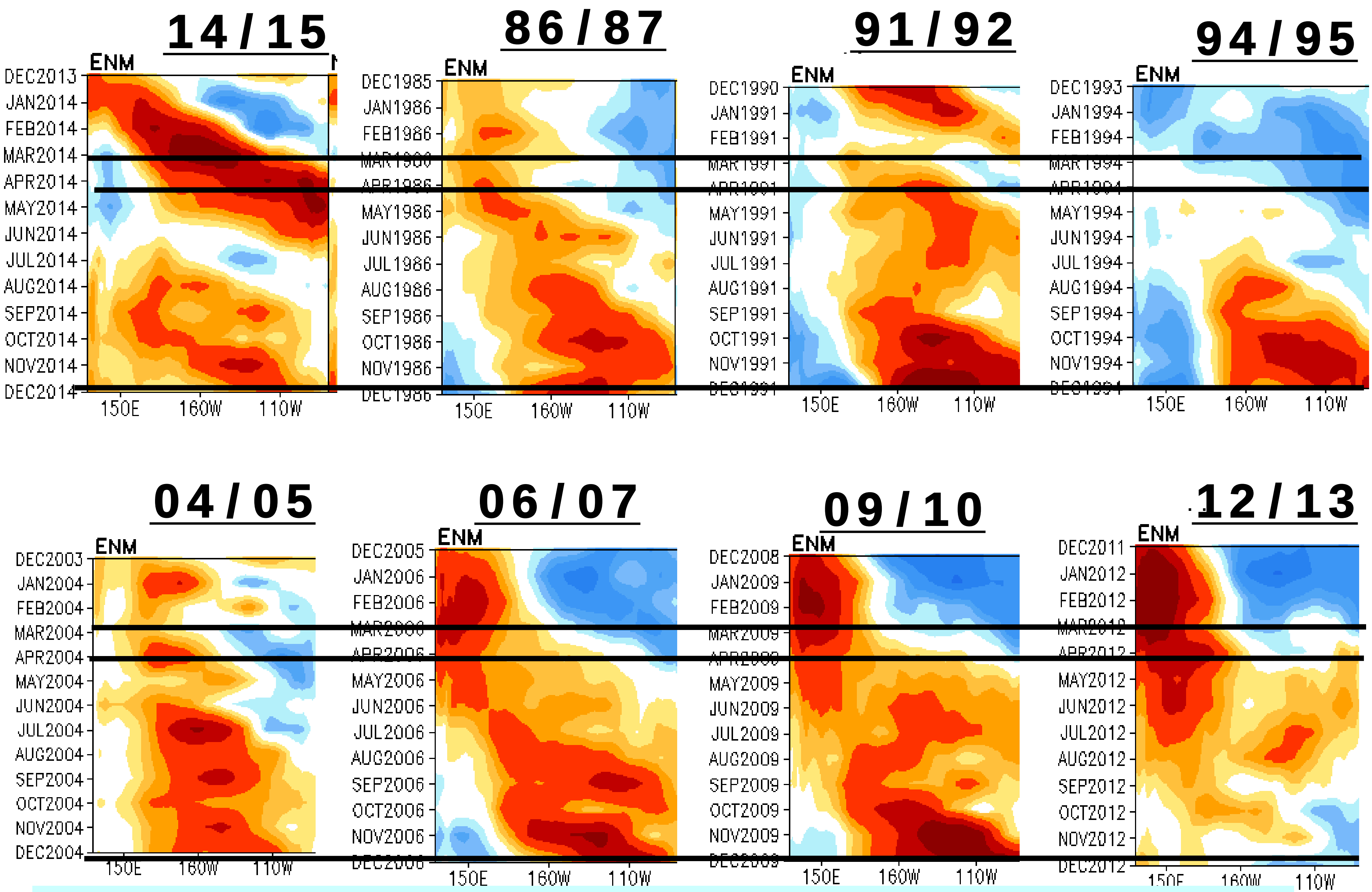
(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)



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



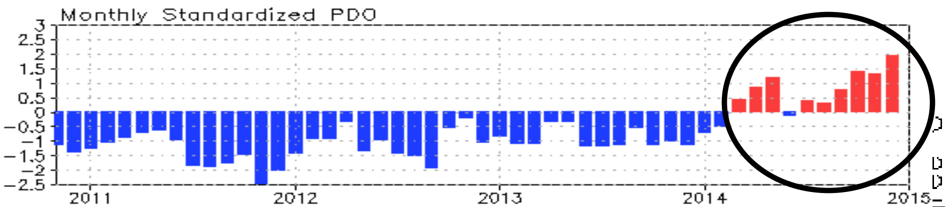
Upper 300m Heat Content Anomaly Averaged in 1S-1N

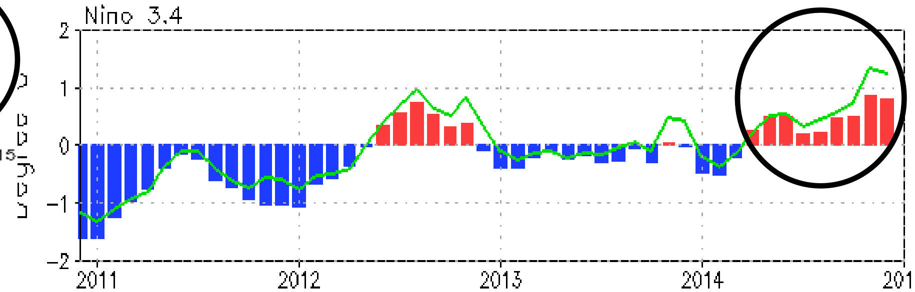


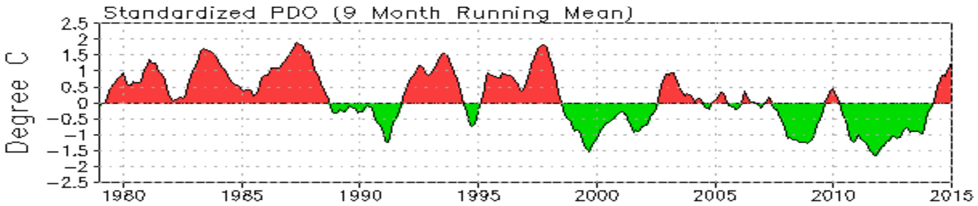
- **Positive heat content anomalies in Dec 2014 were weaker and centered further eastward than other El Nino events.**

North Pacific & Arctic Oceans

Pacific Decadal Oscillation Index

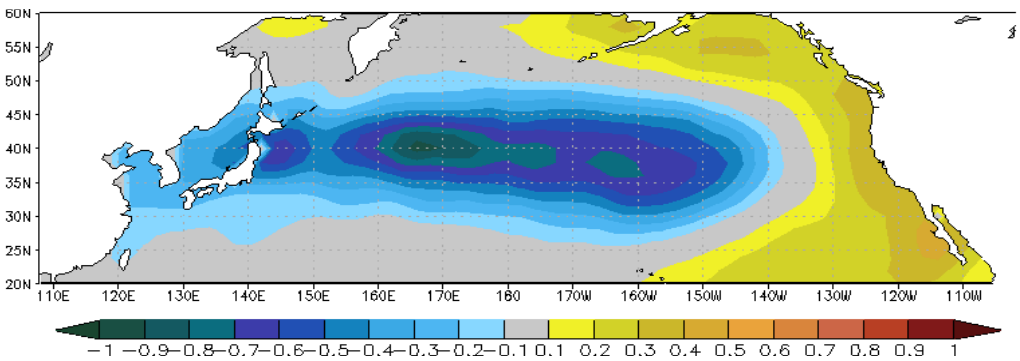






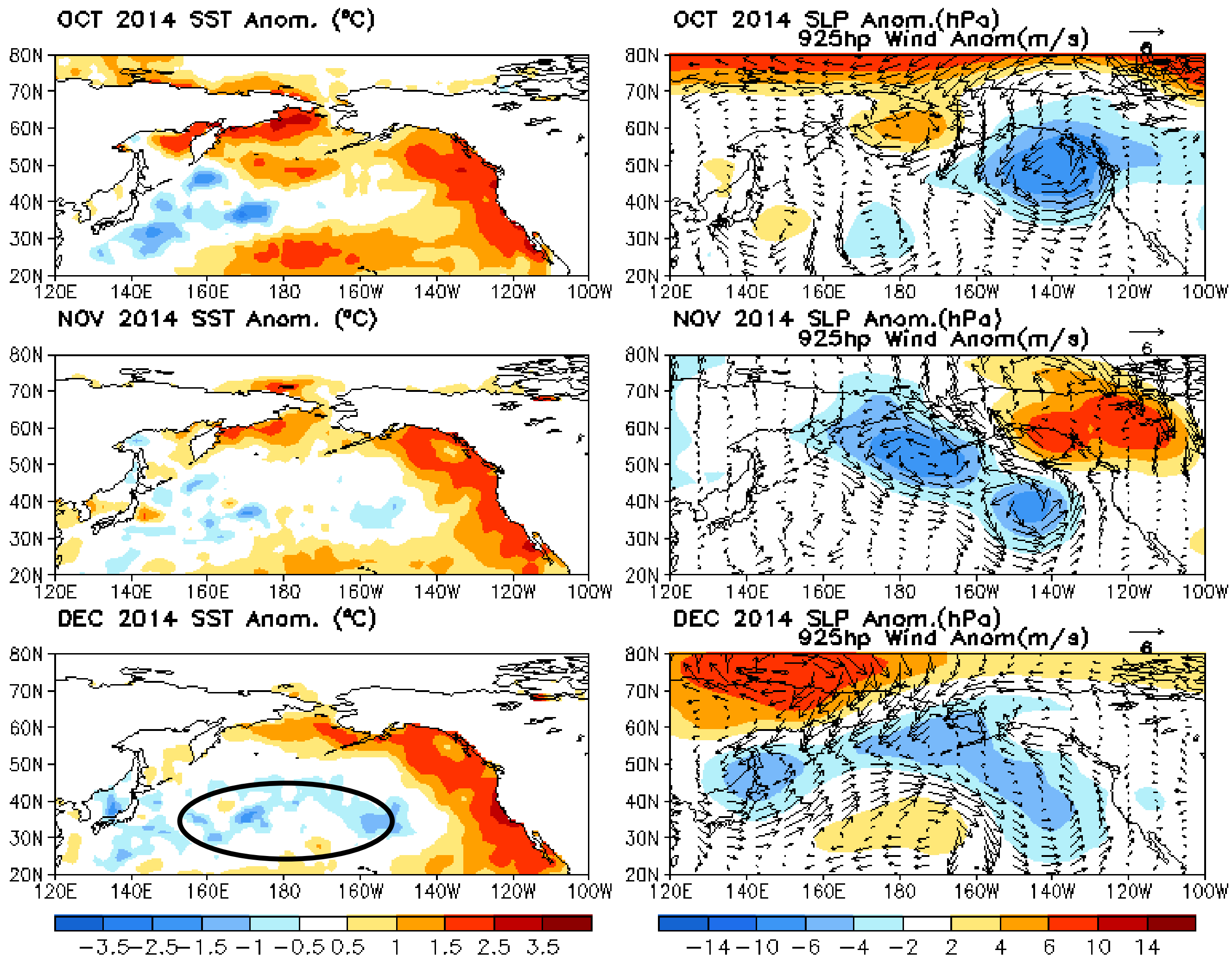
- **Positive PDO phase has persisted since Mar 2014, and enhanced substantially in Dec 2014 with PDO=+1.9.**

- **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.**

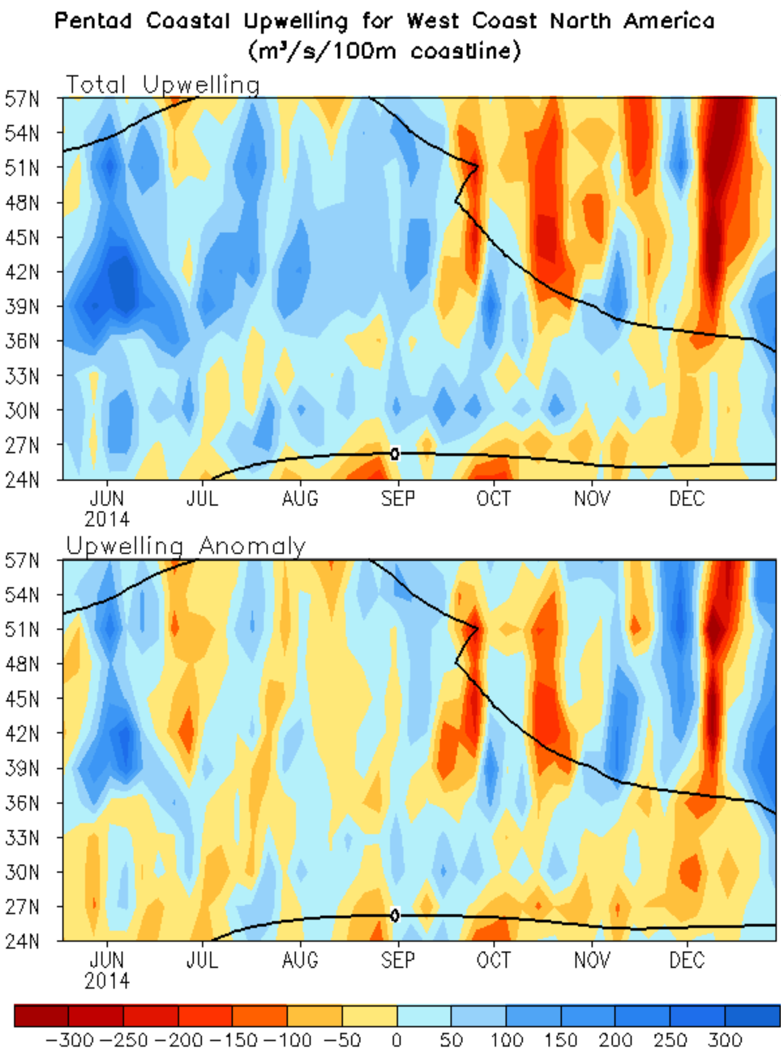
Last Three Month SST, SLP and 925hp Wind Anom.

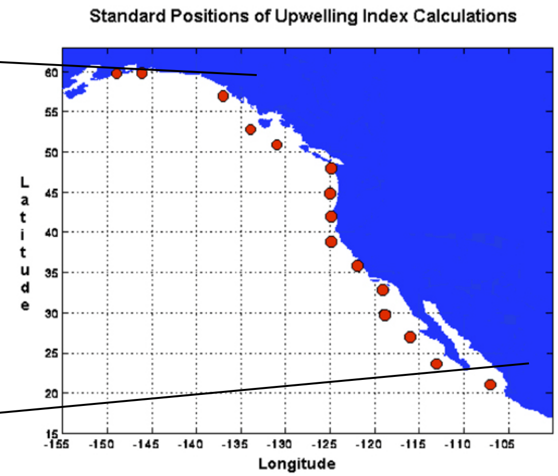


- **Negative SSTA enhanced in the central N. Pacific, leading to strengthening of positive PDO.**

- **Westerly wind anomalies in the central N. Pacific were associated with cyclonic (anti-cyclonic) anomaly circulation to the north (south).**

North America Western Coastal Upwelling





- Upwelling anomalies north of 33N were dominated by intraseasonal variability since Sep 2014.

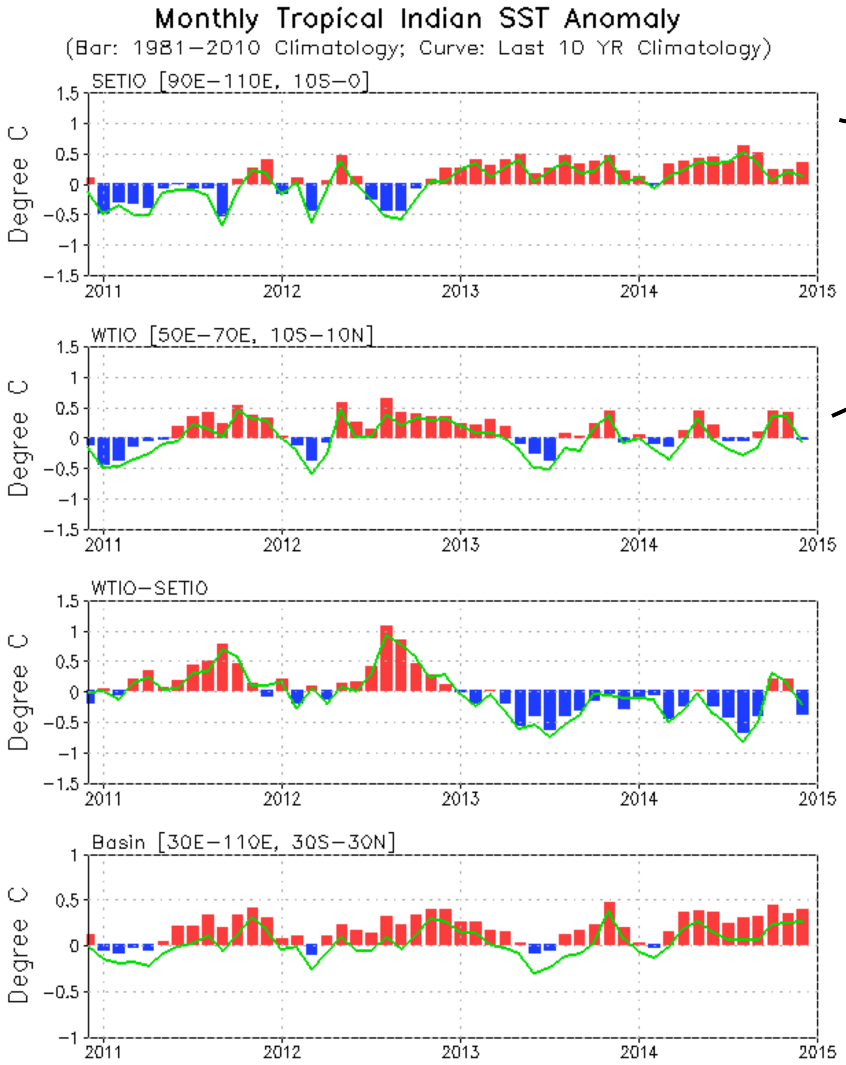
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

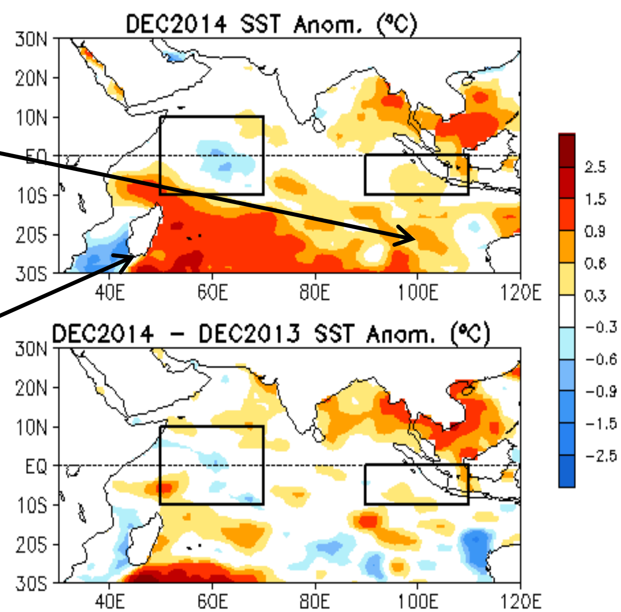
- Area below (above) black line indicates climatological upwelling (downwelling) season.

- 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



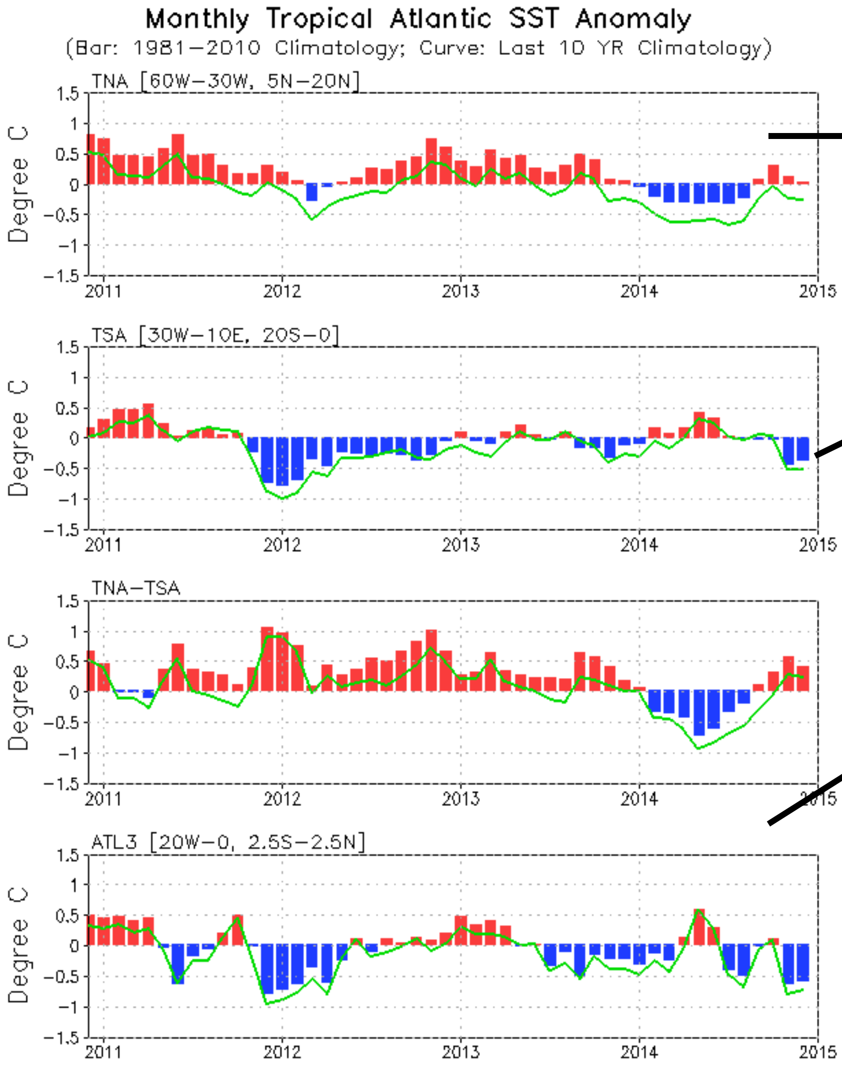


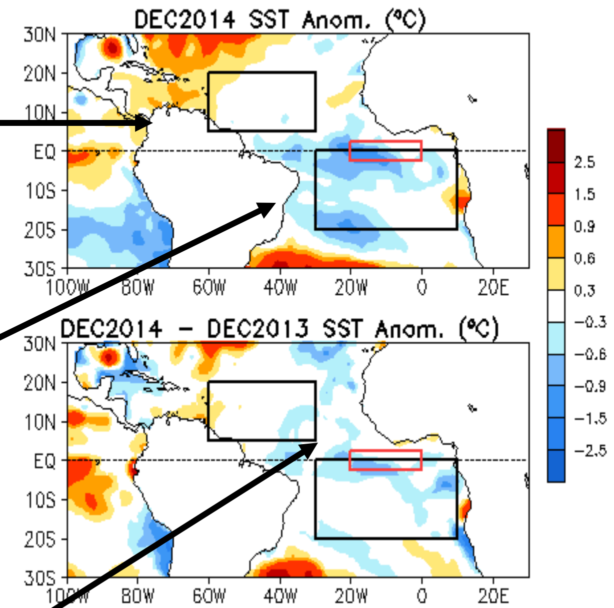
- **DMI was below-normal in Dec 2014.**
- **The basin mean SSTA was above-normal.**

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



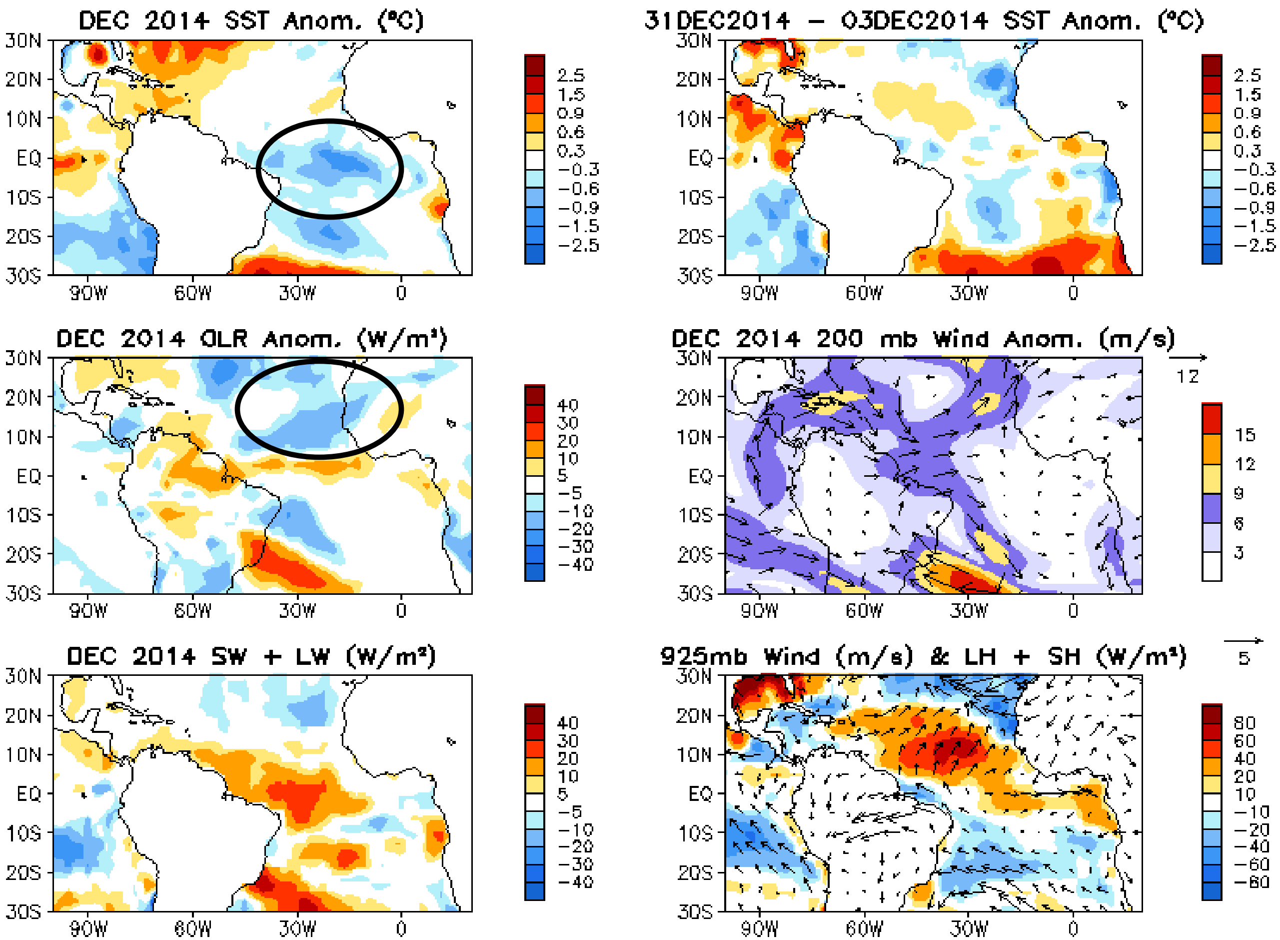


- TNA was near-normal in Dec.
- TSA was below-normal in Nov-Dec 2014.
- Meridional Gradient Mode index (TNA-TSA) has been increasing steadily since May 2014, and was above-normal since Oct 2014.
- Negative ATL3 SSTA persisted in Dec 2014.

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:

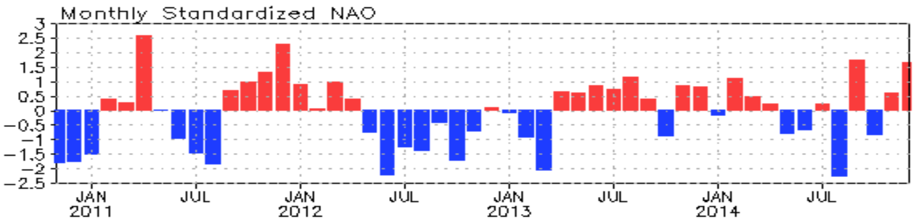
SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb / 200-mb Winds

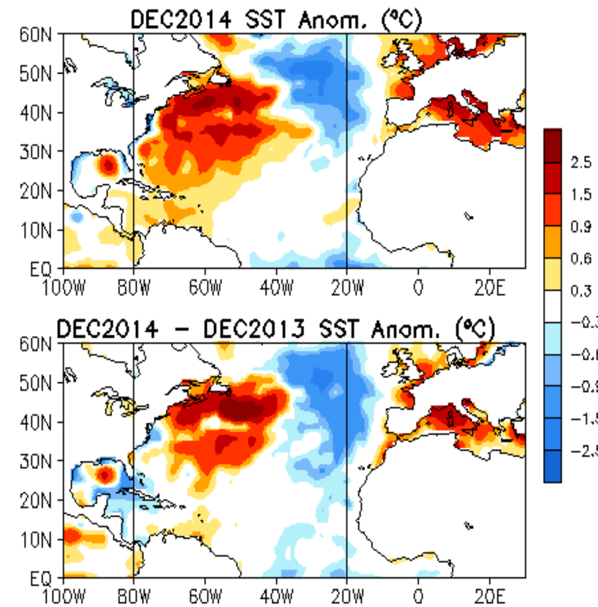


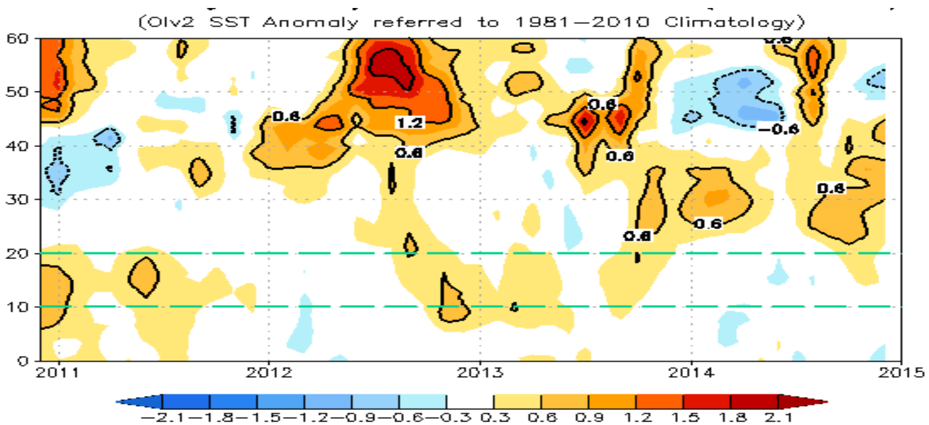
- Negative SSTA persisted in the tropical Atlantic associated with negative subsurface temperature anomalies.

- Convection was enhanced in tropical North Atlantic.

NAO and SST Anomaly in North Atlantic





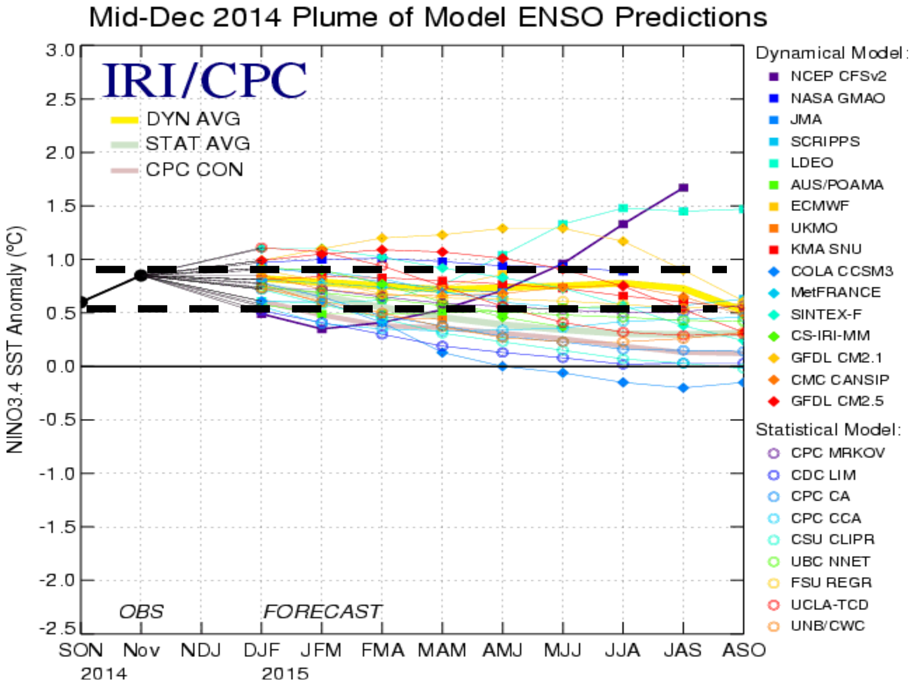


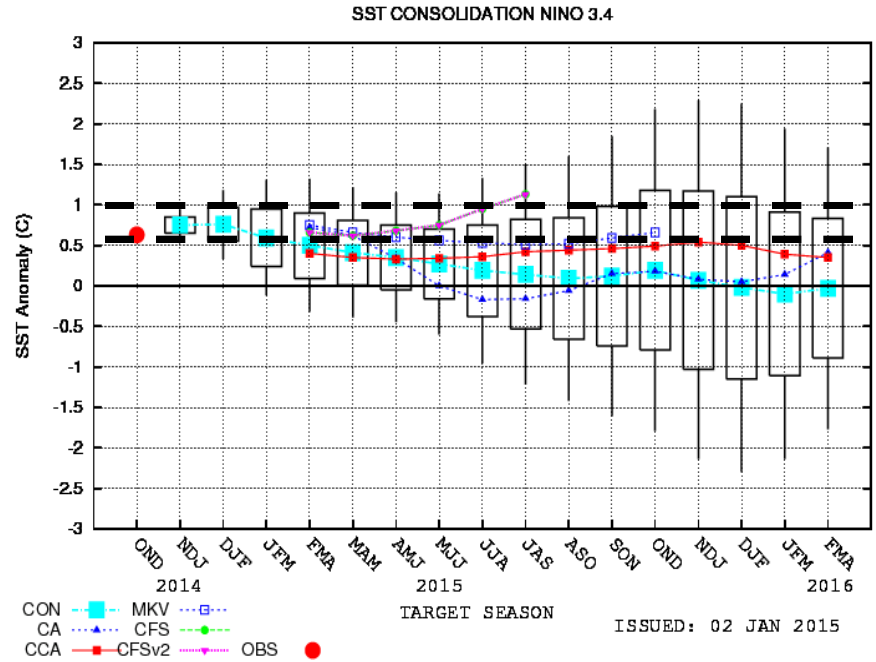
- High-latitude North Atlantic SSTA is generally closely related to NAO index (negative NAO leads to SST warming and positive NAO leads to SST cooling).
- NAO index enhanced in Dec 2014 with NAO index =+1.6.
- SST in MDR was near-normal.

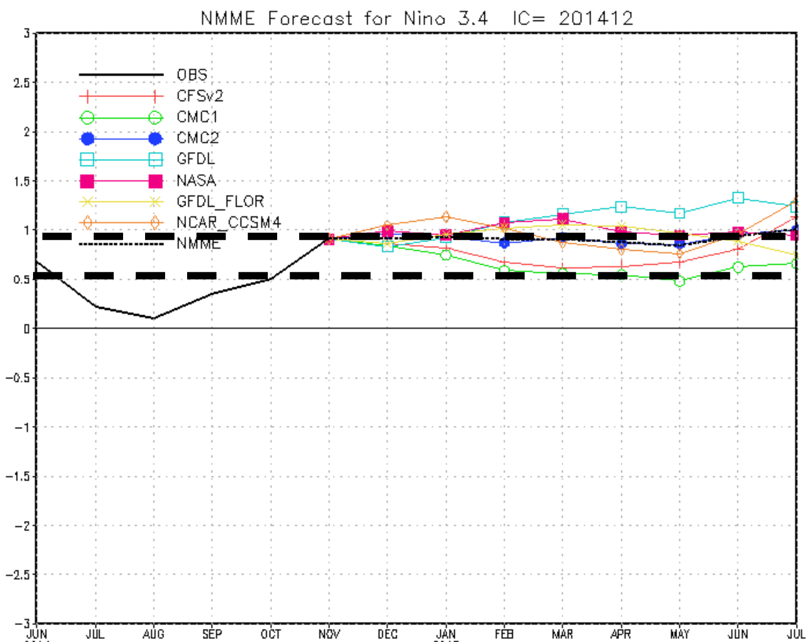
Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis,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

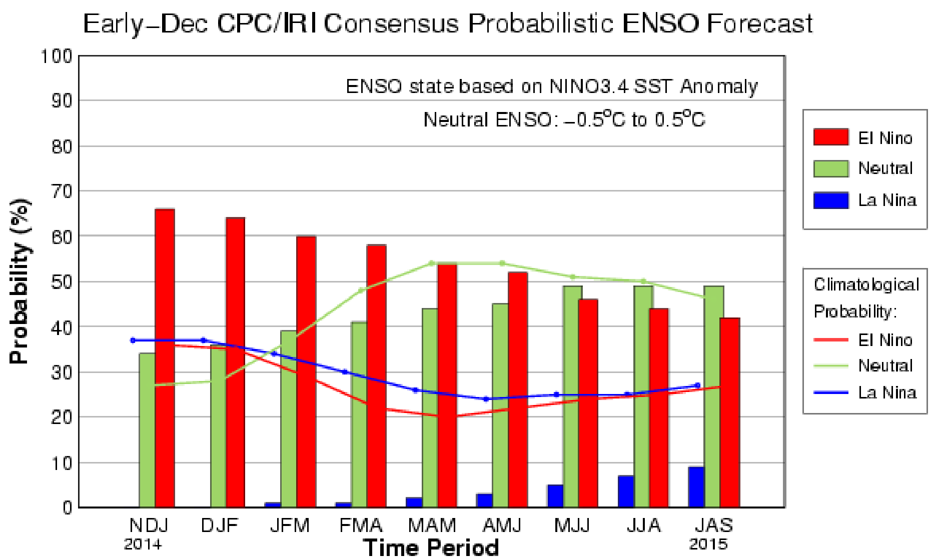
Global SST Predictions

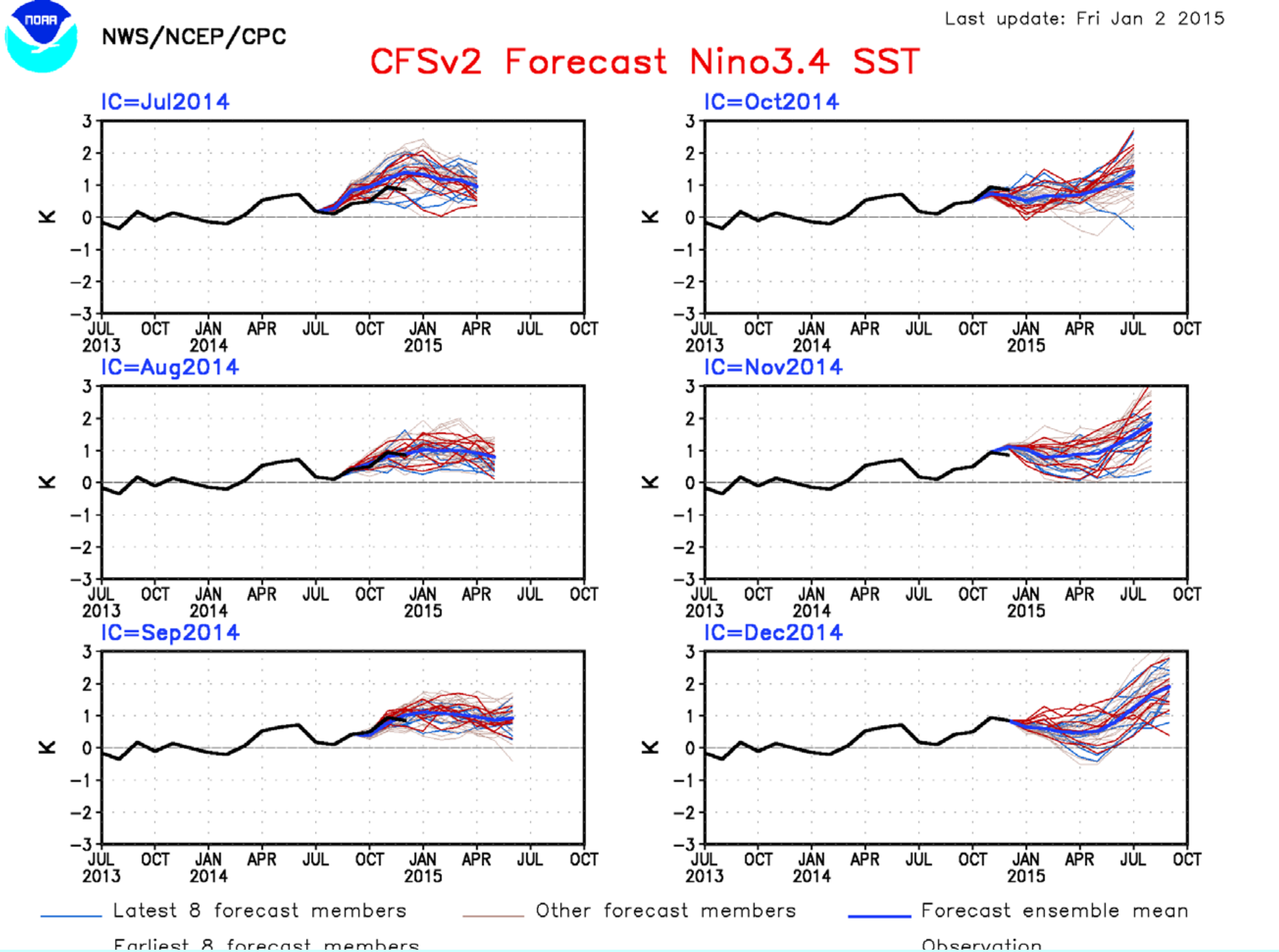
NINO3.4 Forecast Plume





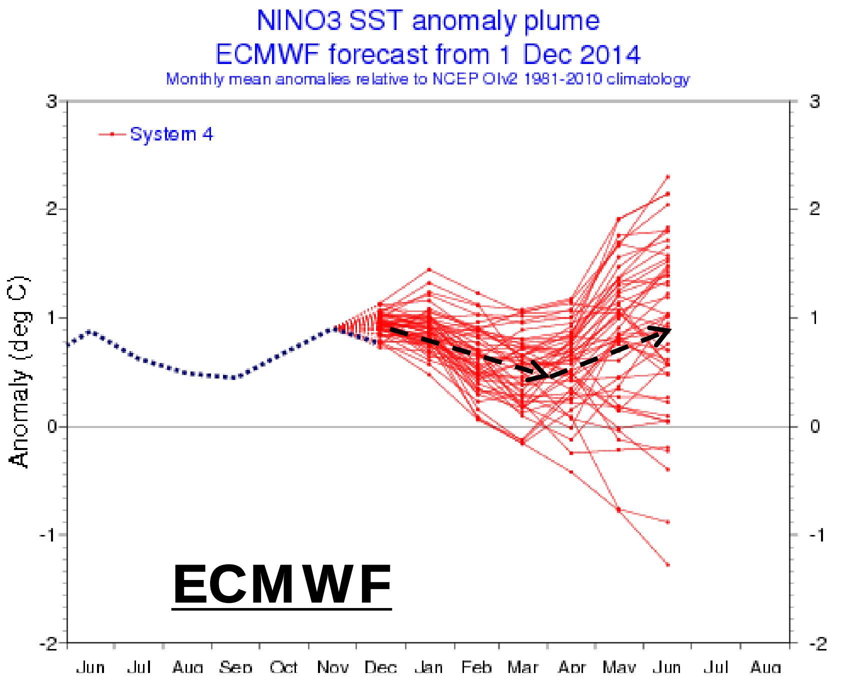


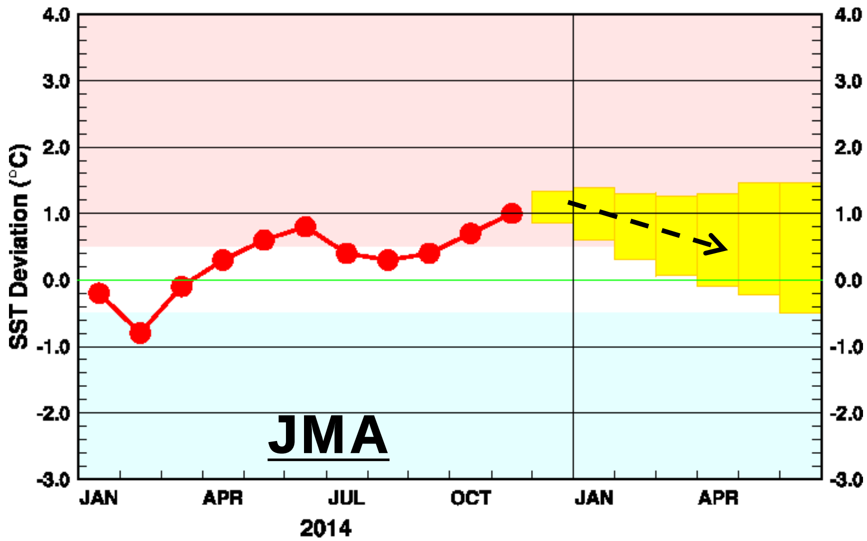


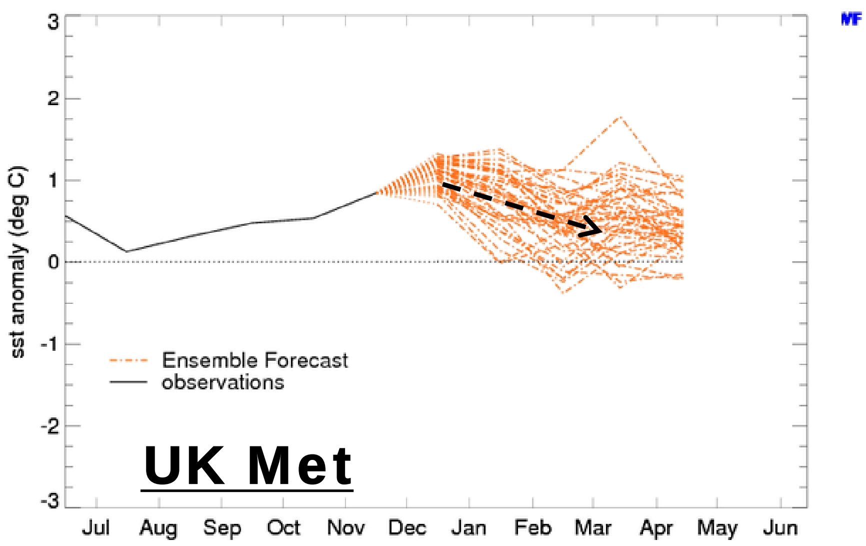


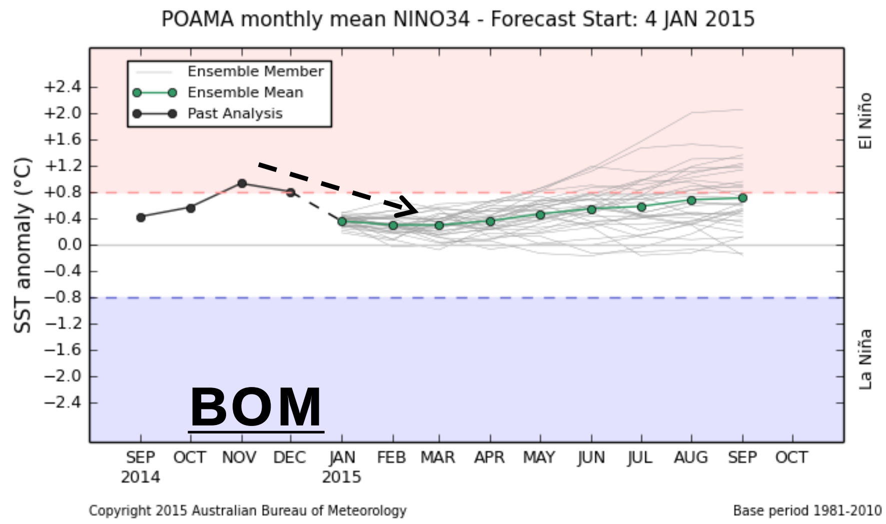
- **CFSv2 forecasts captured the recent warming tendency since Jul, and suggested the warming will peak in Jan-Feb.**
- **The latest forecast from Dec I.C. suggested that the warming has peaked in Nov, and favored to return to ENSO-neutral conditions in late winter, and rebound to El Nino conditions in summer 2015.**

Selected NINO3.4 Forecast Plume

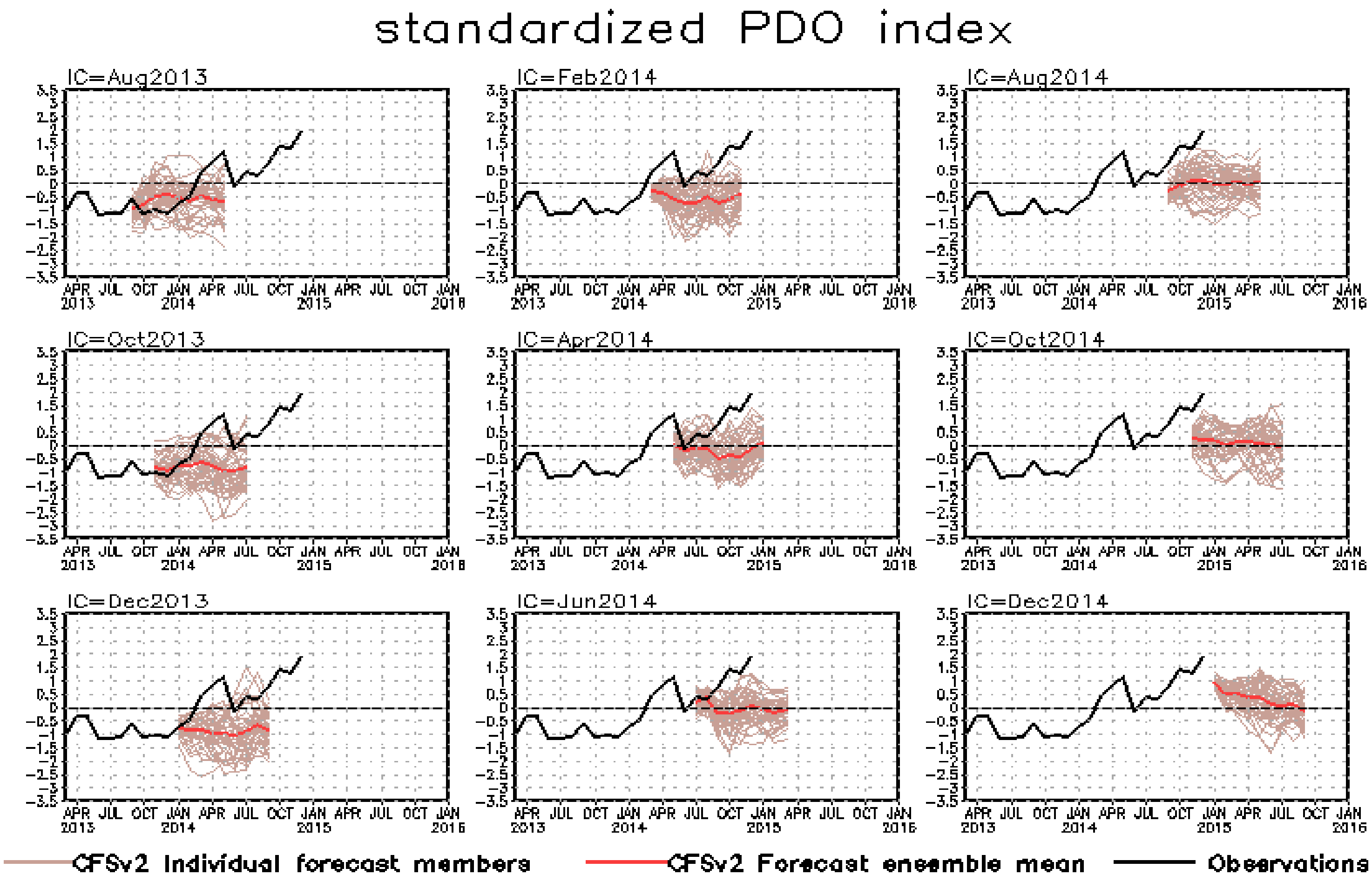








NCEP CFSv2 Pacific Decadal Oscillation (PDO) Forecast

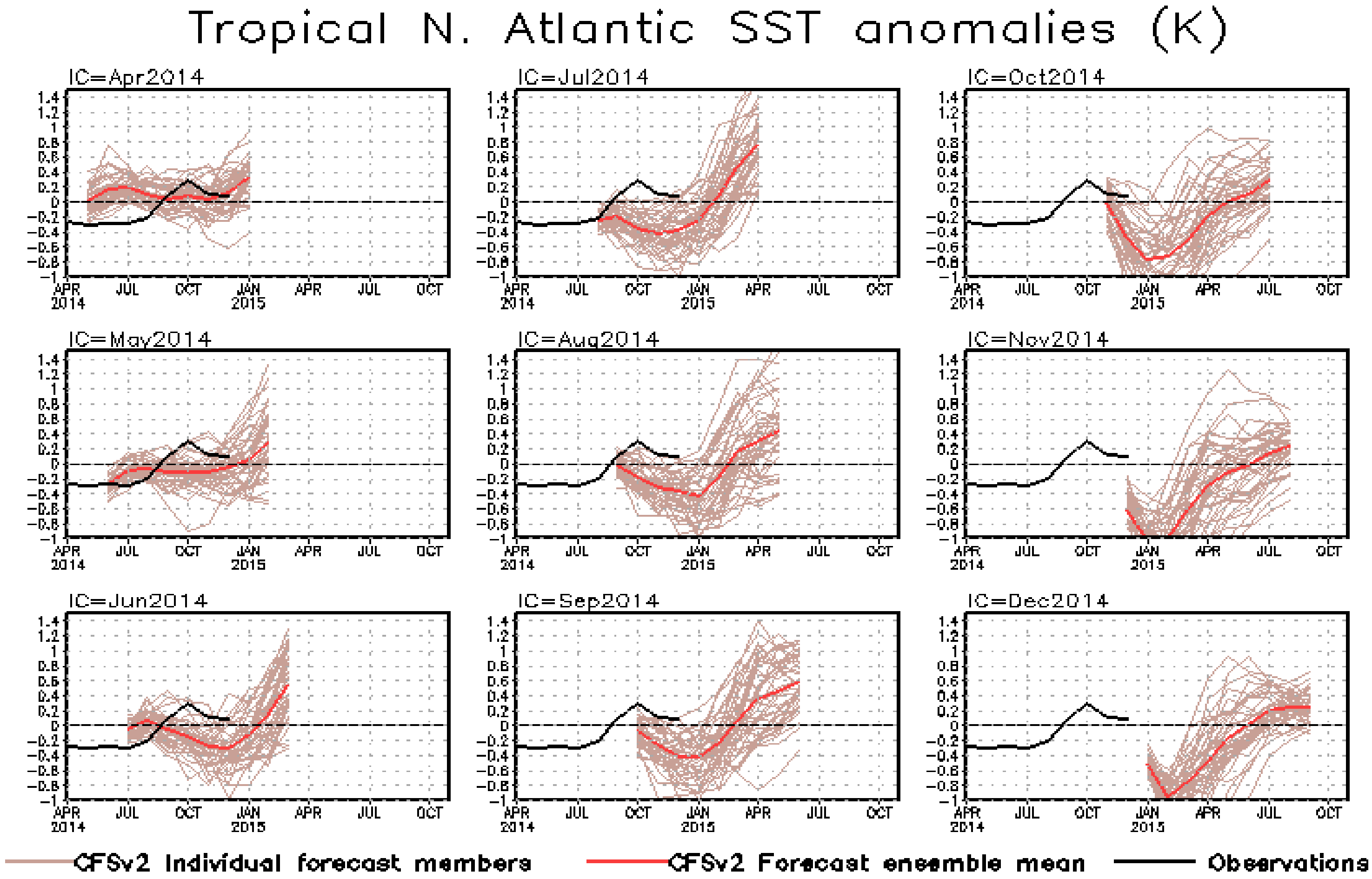


PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

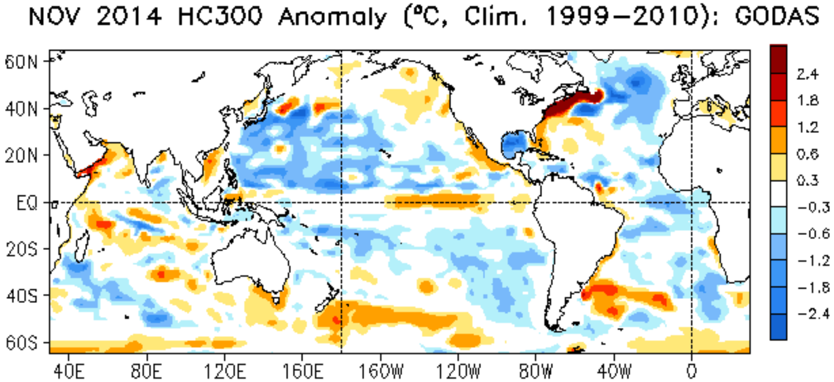
- CFSv2 had a poor skill in capturing the phase transition from negative to positive PDO in early spring 2014 as well as the strengthening of positive PDO since Jul.

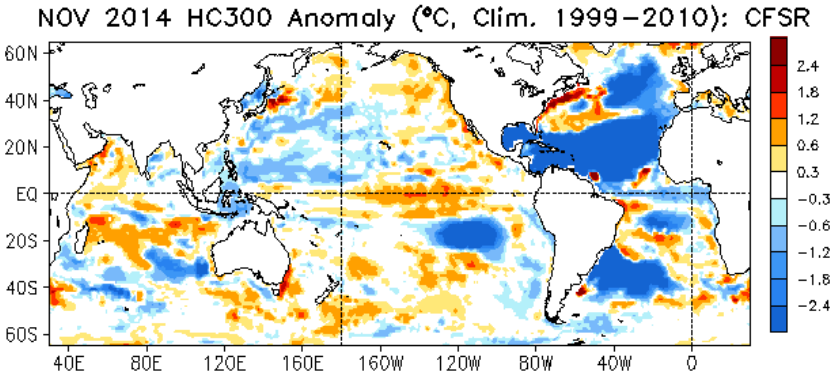
NCEP CFSv2 Tropical North Atlantic SST Forecast

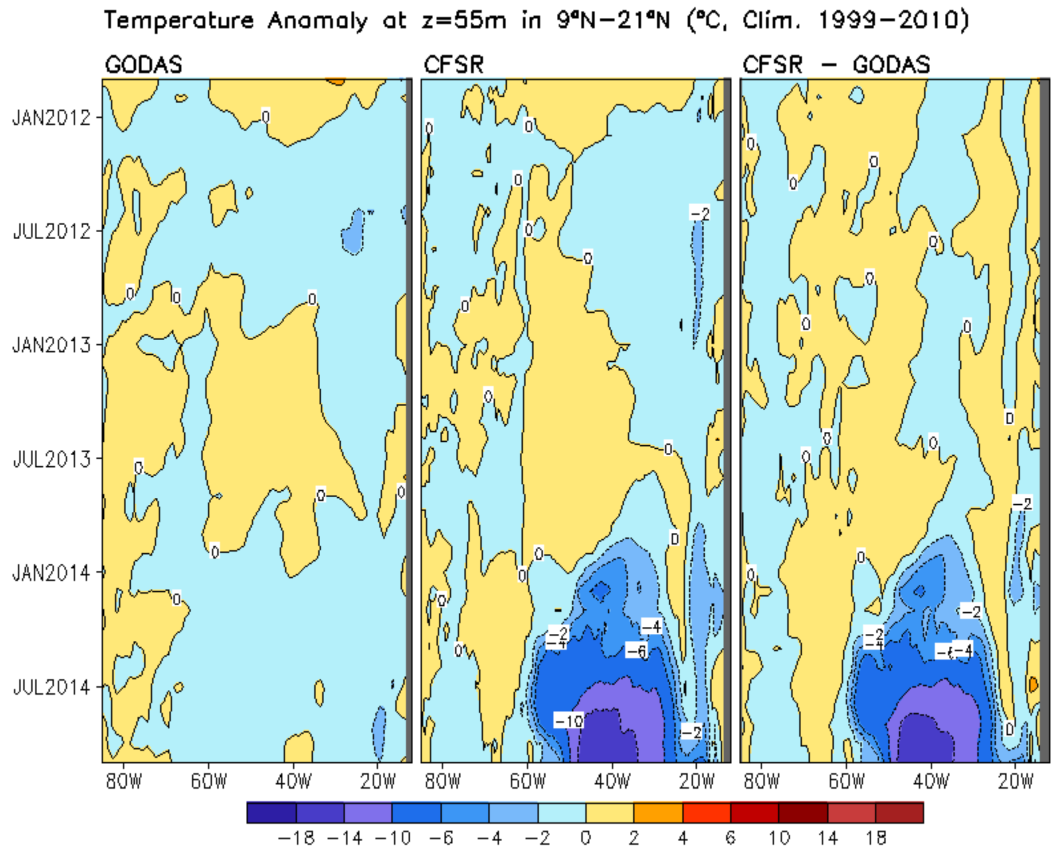


- CFSv2 had a poor skill in forecasting the phase transition from negative to positive tropical North Atlantic SSTA in late summer.
- The forecast became increasing colder starting from Jun to Nov I.C., which reaches the coolest value in winter 2014/2015 and then warms up rapidly afterwards.

Impacts of CFSR on Tropical N. Atlantic SSTA Forecast

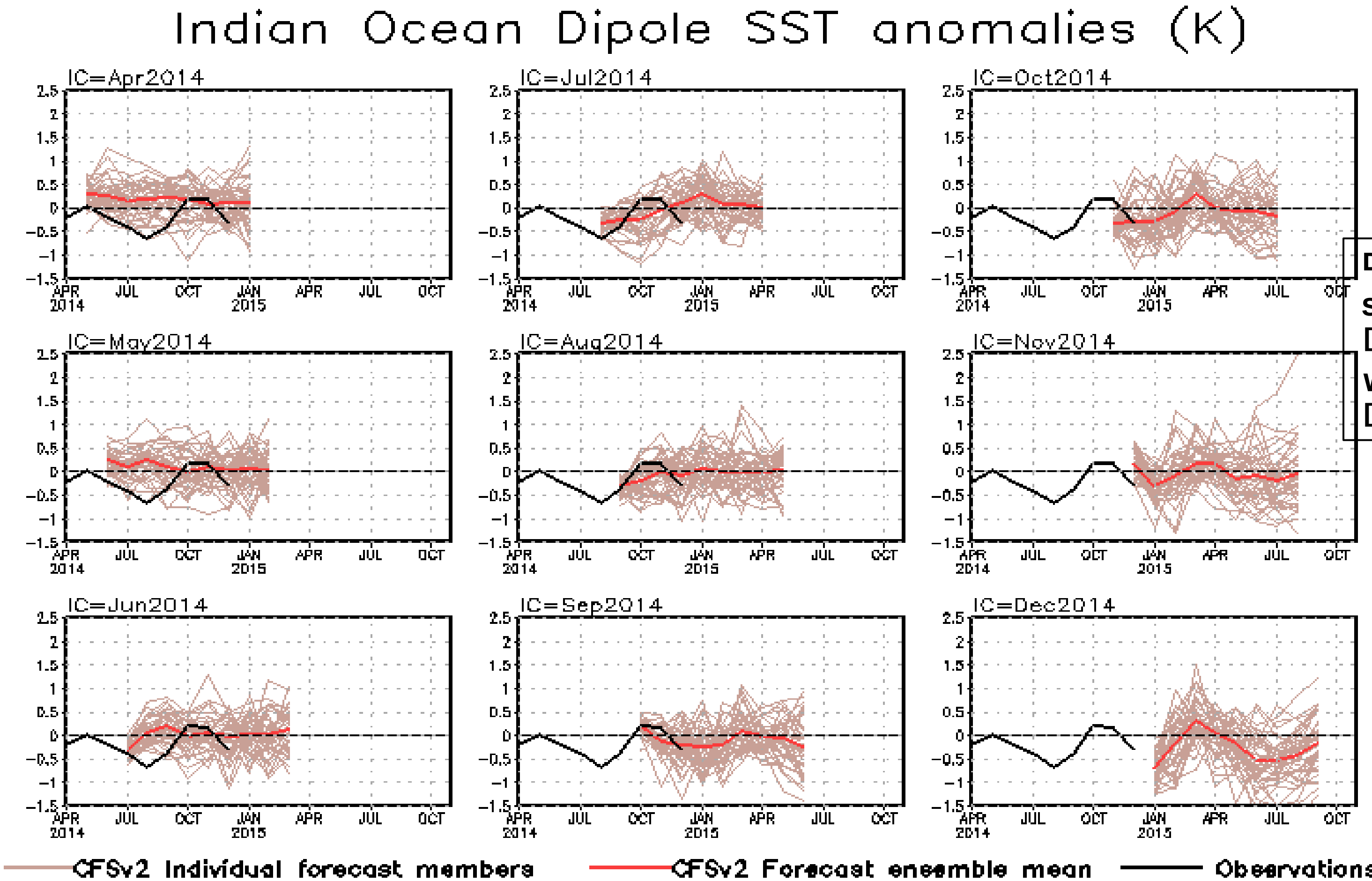






- Compared to GODAS, CFSR - initial conditions for CFSv2 - had large cold biases in North Atlantic, middle-latitude South Atlantic and some parts of South Pacific.
- The cold biases in the Atlantic Hurricane Main Development Region (MDR) emerged around October 2013 (reasons unknown) and enhanced quickly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

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]

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.

Overview

Pacific Ocean

- ENSO-neutral conditions continued during Dec 2014 (NINO3.4=+0.8C, but the tropical Pacific atmosphere circulation remained ENSO-neutral.)
- The consensus forecast suggests about 50-60% chance of El Niño conditions in Jan-Feb 2015, with ENSO-neutral favored thereafter.
- Positive subsurface temperature anomalies weakened substantially due to eastward propagation of upwelling oceanic Kelvin waves.
- Surface easterly wind anomalies persisted in western Pacific and emerged in eastern Pacific in Dec 2014, unfavorable for El Nino development.
- Precipitation was enhanced (suppressed) in W. Pacific and SPCZ (near Dateline).
- Correspondingly, sea surface salinity was below-normal (above-normal) in W. Pacific and SPCZ (near Dateline).
- Positive PDO phase enhanced with PDO=+1.9 in Dec 2014.

Indian Ocean

- Precipitation was enhanced in E. tropical Indian Ocean.
- Strong westerly wind anomalies presented in tropical Indian Ocean.

Atlantic Ocean

- Positive NAO phase enhanced with NAO index = +1.6 in Dec 2014.

Backup Slides

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

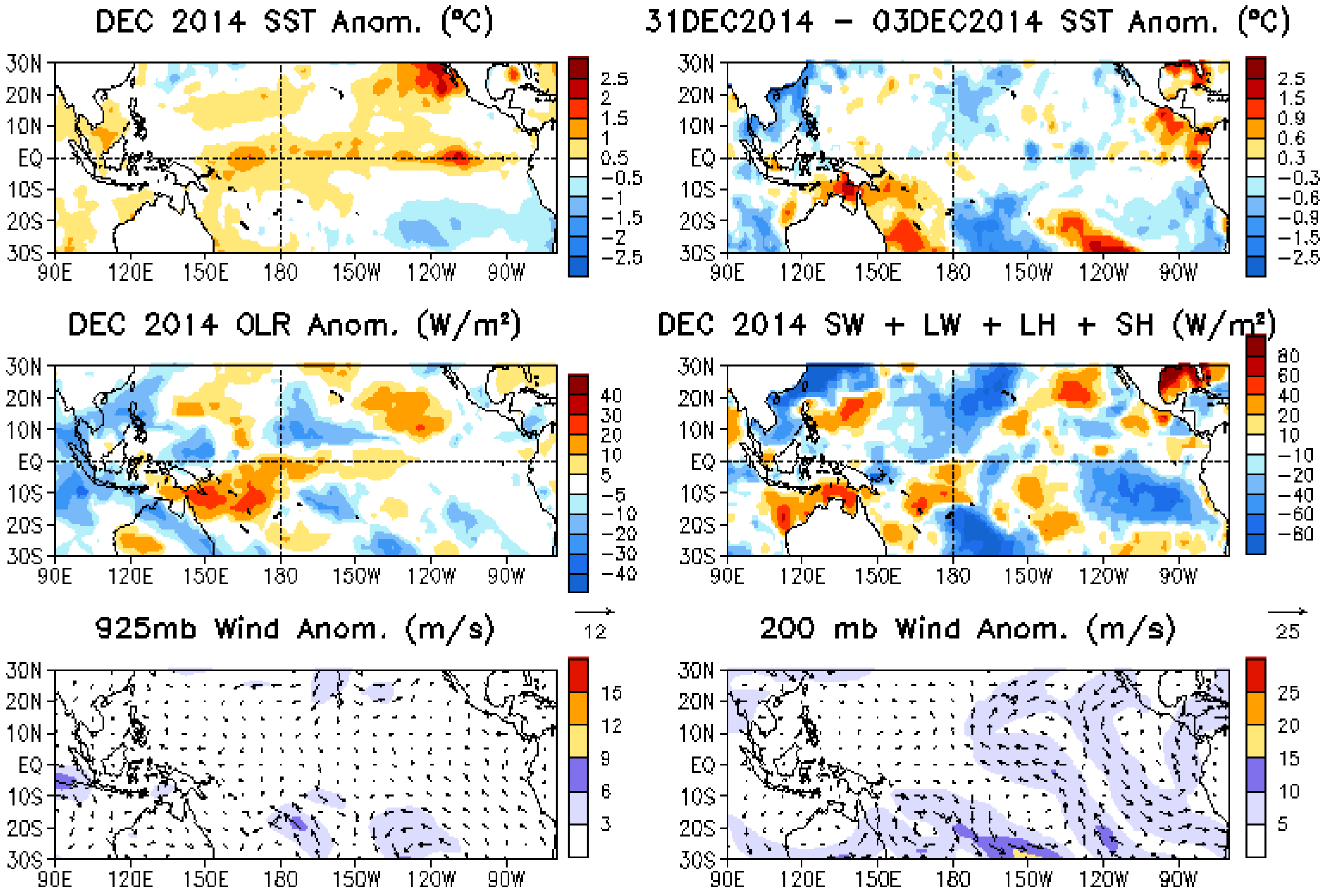


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

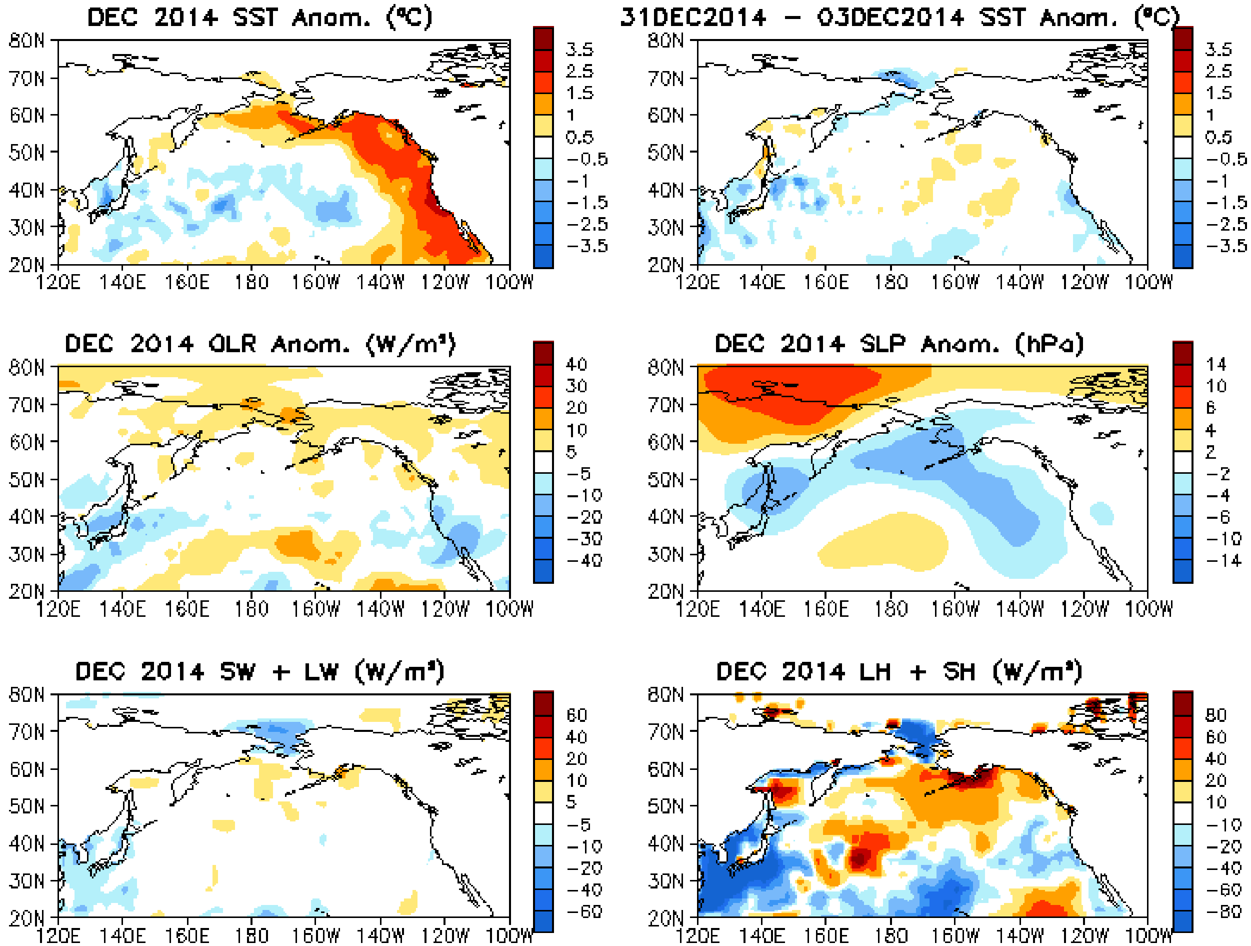


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

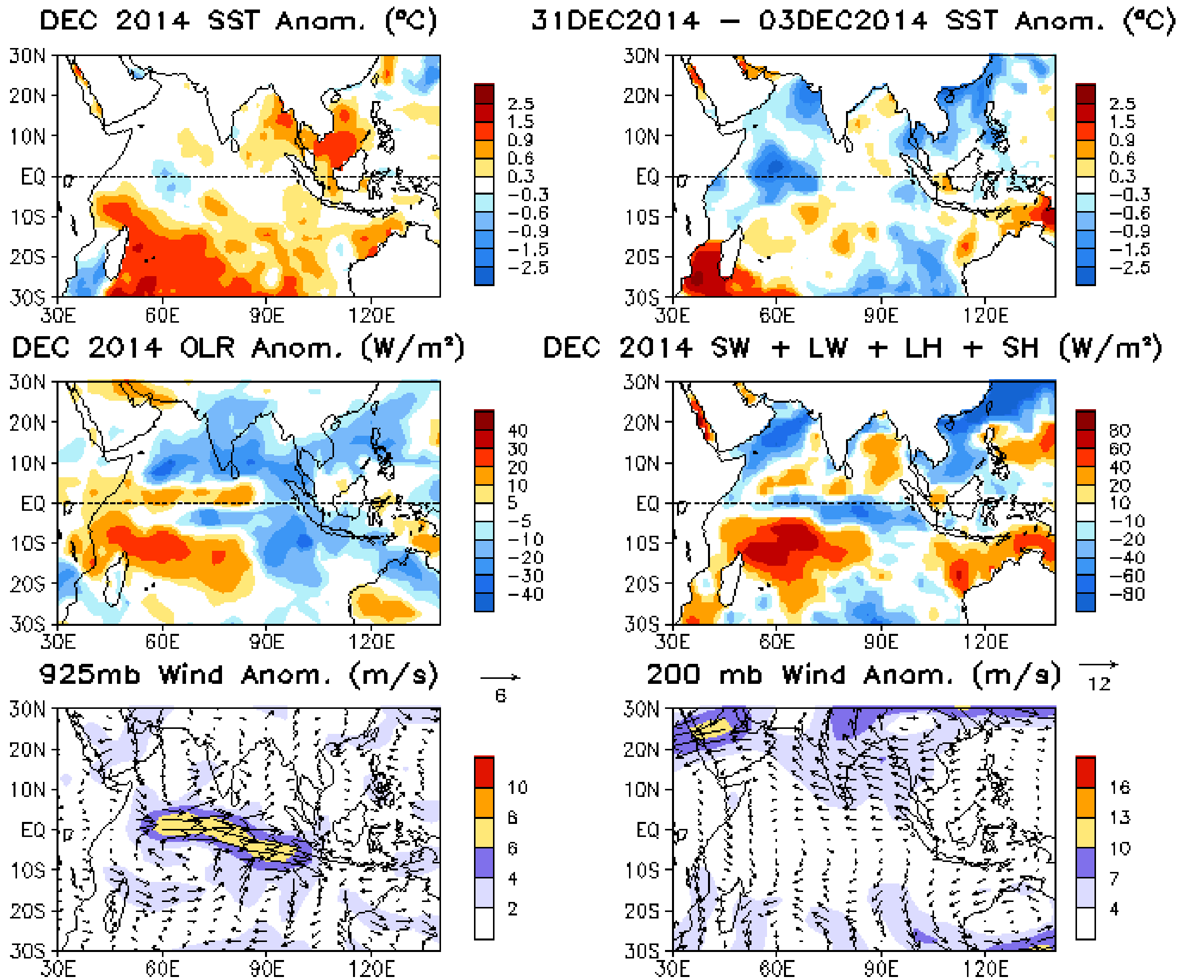


Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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

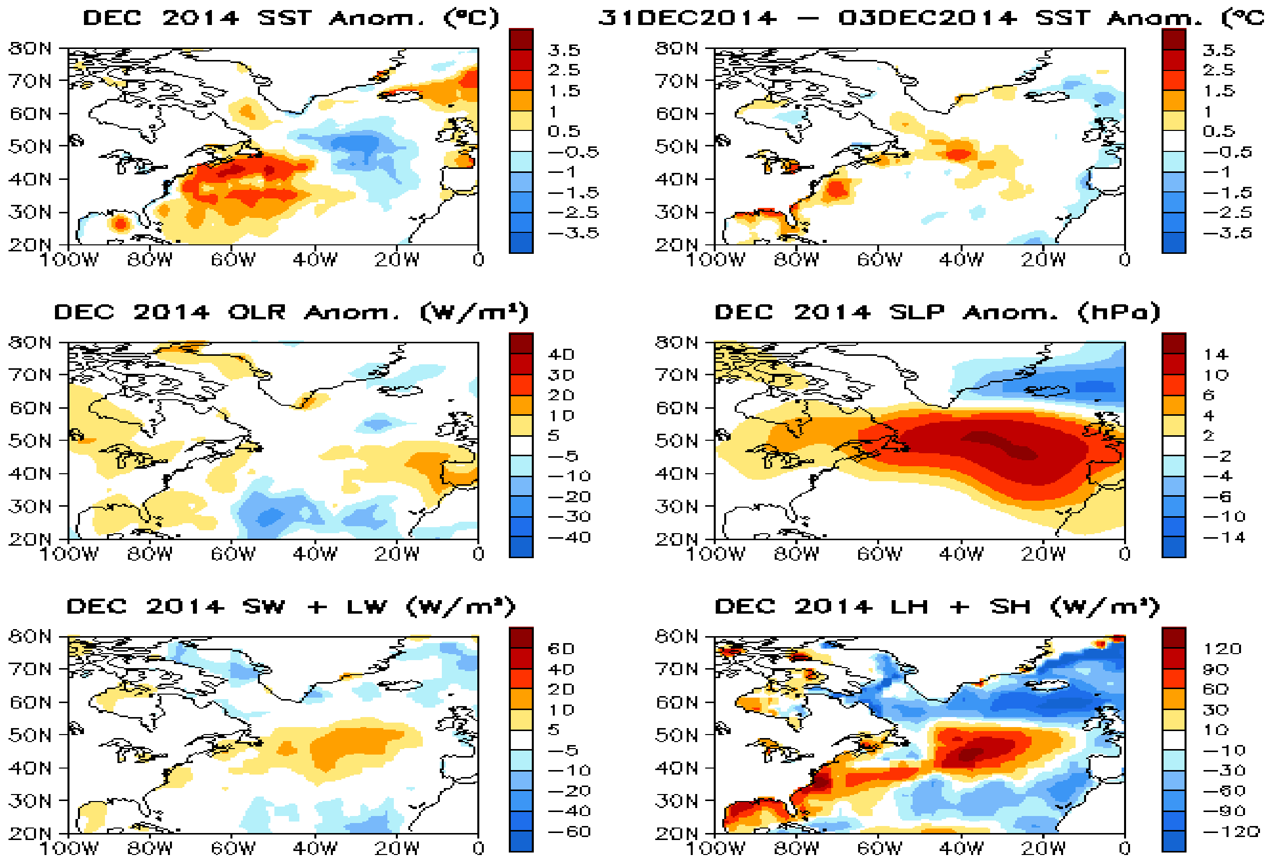
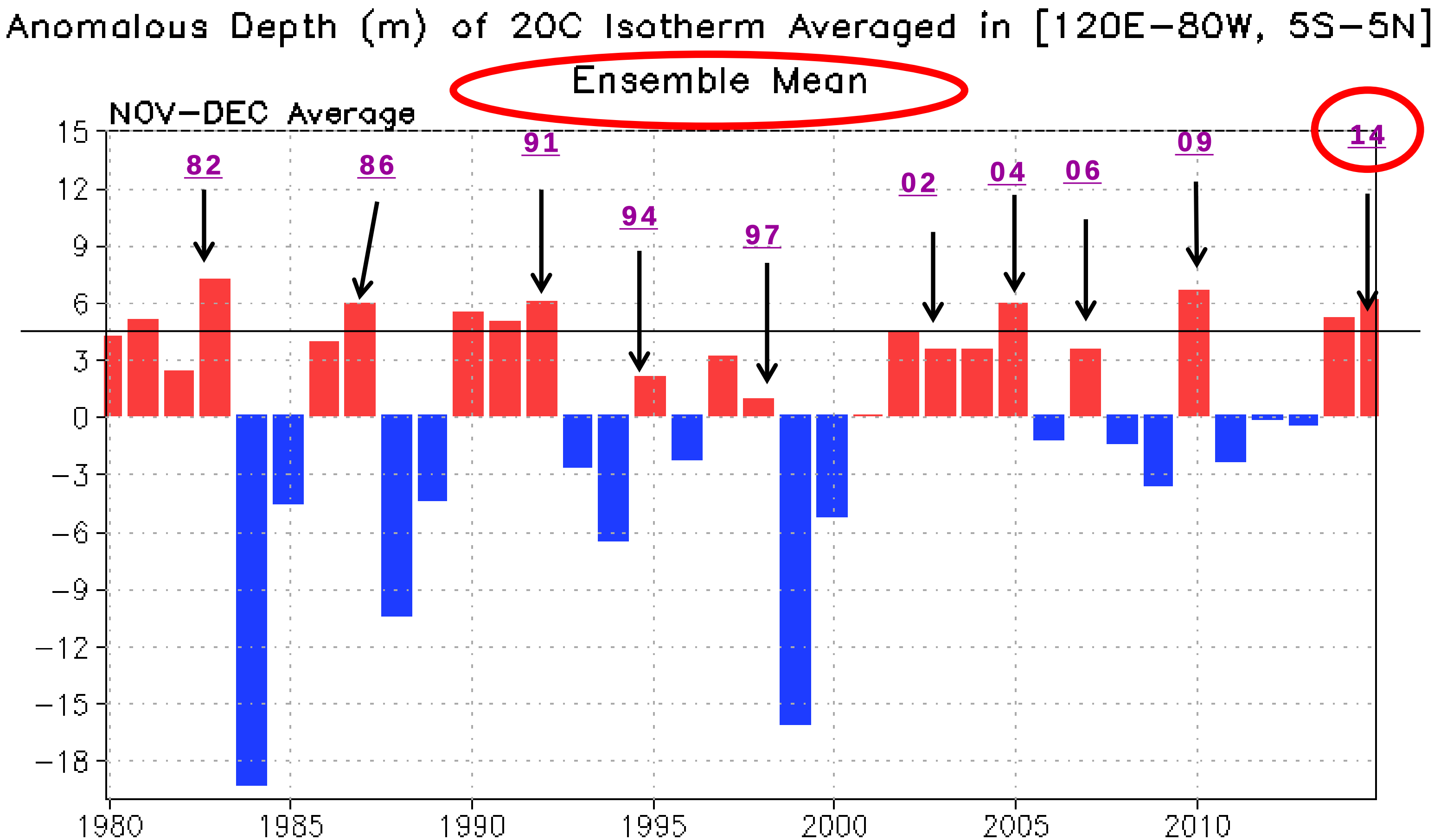


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

Warm Water Volume Index Derived From Ensemble Mean of Ocean Reanalyses

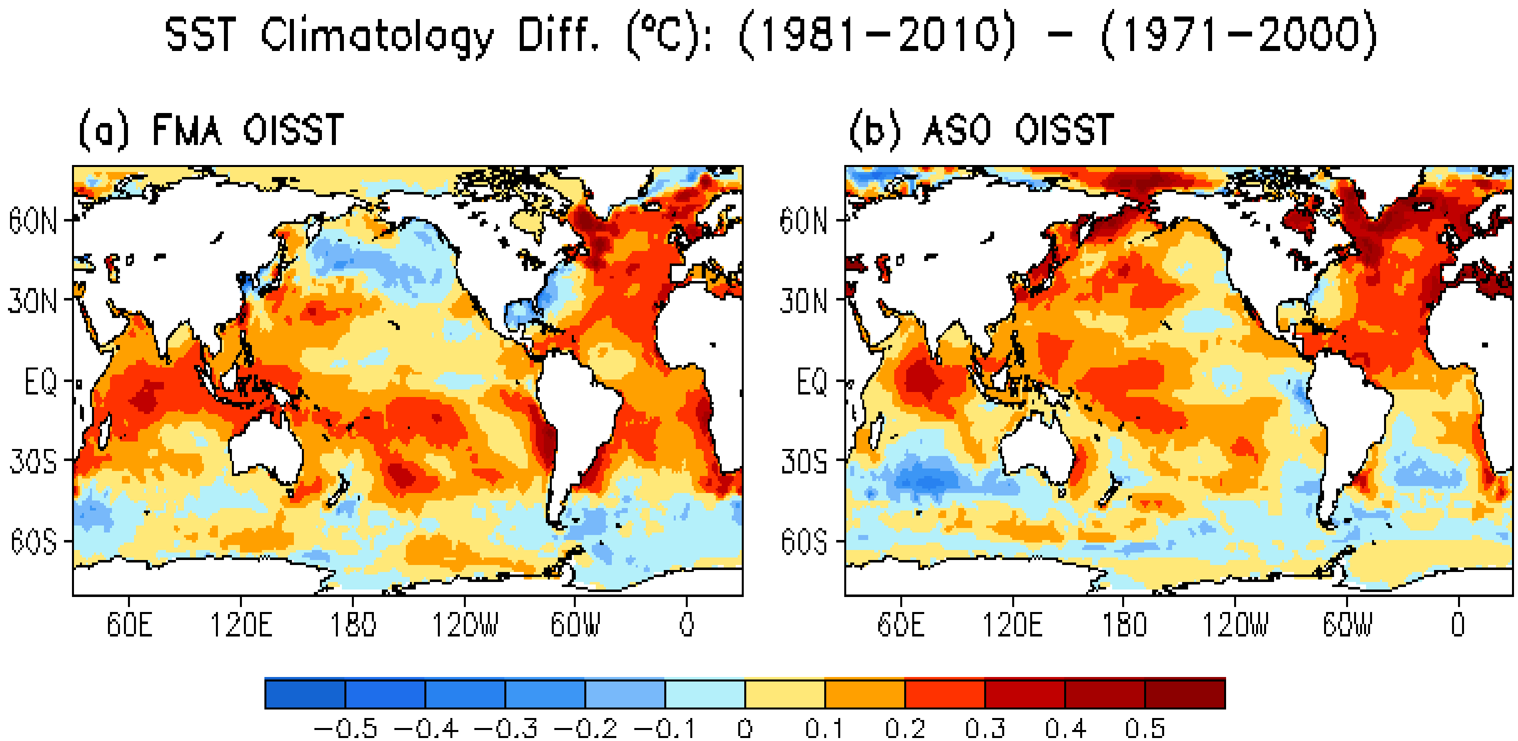


- Warm Water Volume averaged in Nov-Dec 2014 was similar to that in other El Nino years.

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!