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

Prepared by

Climate Prediction Center, NCEP/NOAA

**April 9, 2015**

**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's Climate Observation Division (COD)**

# Outline

- **Overview**

- **Recent highlights**
  - **Pacific/Arctic Ocean**
  - **Indian Ocean**
  - **Atlantic Ocean**
  - **Global SST Predictions**

  * ENSO evolution in 2014/15 and different influences of two types of El Nino on US climate

  *Sea surface salinity (SSS) monitoring and possible role of SSS on ENSO prediction

# Overview

## Pacific Ocean

- NOAA "ENSO Diagnostic Discussion" on 09 Apr 2015 suggested "There is an approximately 70% chance that El Niño will continue through Northern Hemisphere summer 2015, and a greater than 60% chance it will last through autumn."
- Positive SSTAs were observed in the central tropical Pacific with NINO3.4=0.6°C in Mar 2015.
- Positive anomalies of subsurface ocean temperature along the equator strengthened and had little propagation in Mar 2015.
- Majority of dynamical models predicted a warming tendency (El Nino) in 2015, but majority of statistical models favor ENSO neutral in 2015.
- Positive phase of PDO has persisted for 9 months, with PDOI=1.5 in Mar 2015.

## Indian Ocean

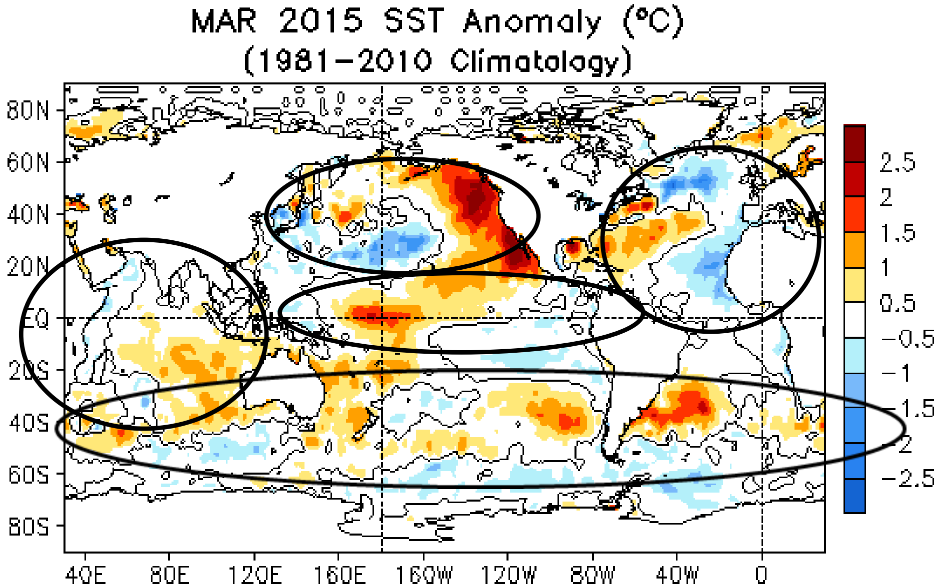
- Positive SSTAs were in the southeast Indian Ocean.

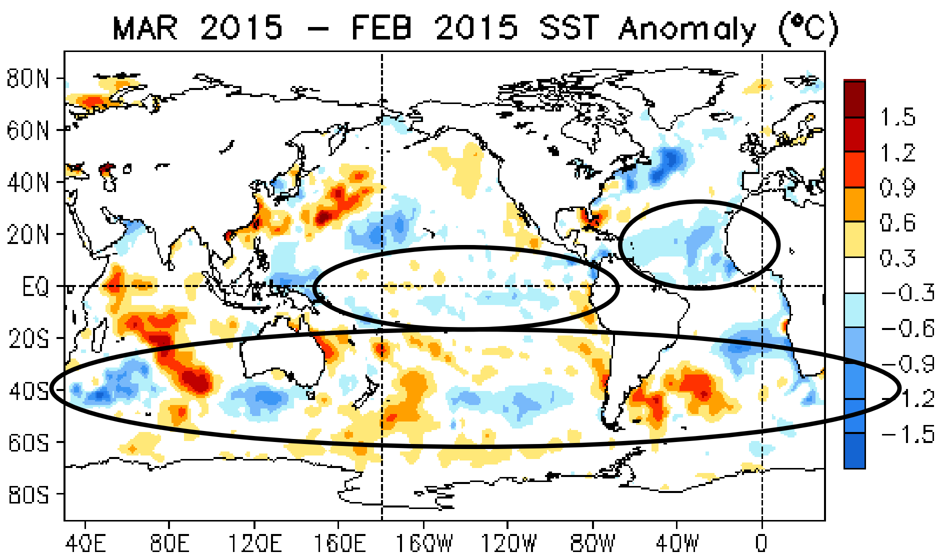
## Atlantic Ocean

- Positive phase of NAO has persisted for 5 months with NAOI=1.1 in Mar 2015, causing a horseshoe-like pattern of SSTA in N. Atlantic.

# Global Oceans

# Global SST Anomaly ($^0$C) and Anomaly Tendency



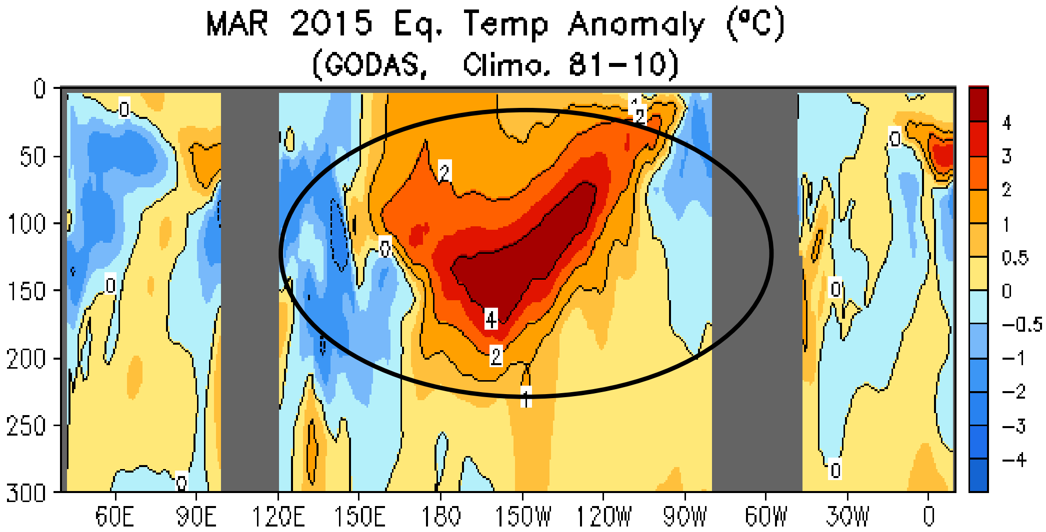




- Strong positive (weak negative) SSTA was observed in the central (eastern) tropical Pacific.
- Strong positive SSTA presented in the NE Pacific and was associated with positive phase of PDO.
- Horseshoe-like SSTA occurred in the North Atlantic.
- Positive SSTA existed in the southeast Indian Ocean.

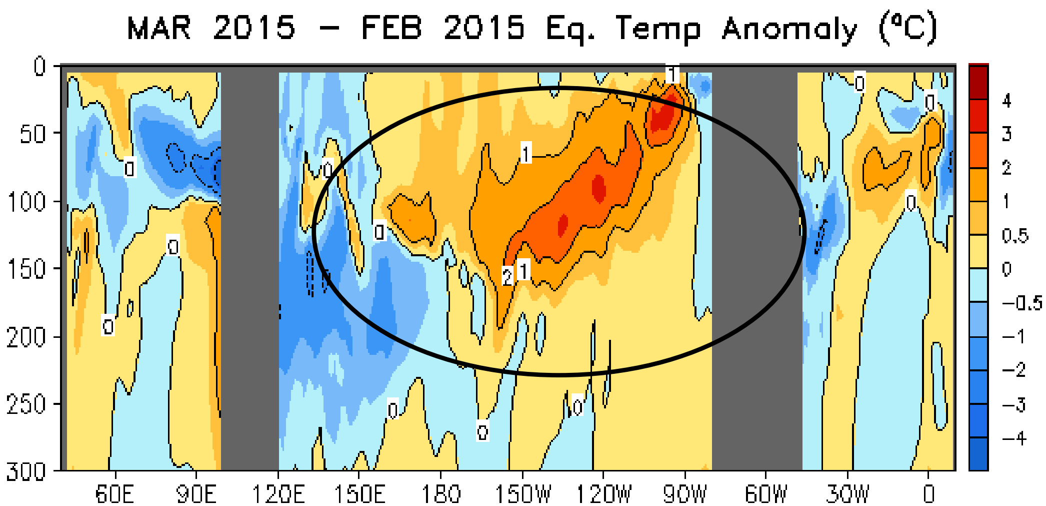
- SSTA tendencies were small in the equatorial Pacific.
- Negative SSTA tendencies were seen in the tropical North Atlantic.

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

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

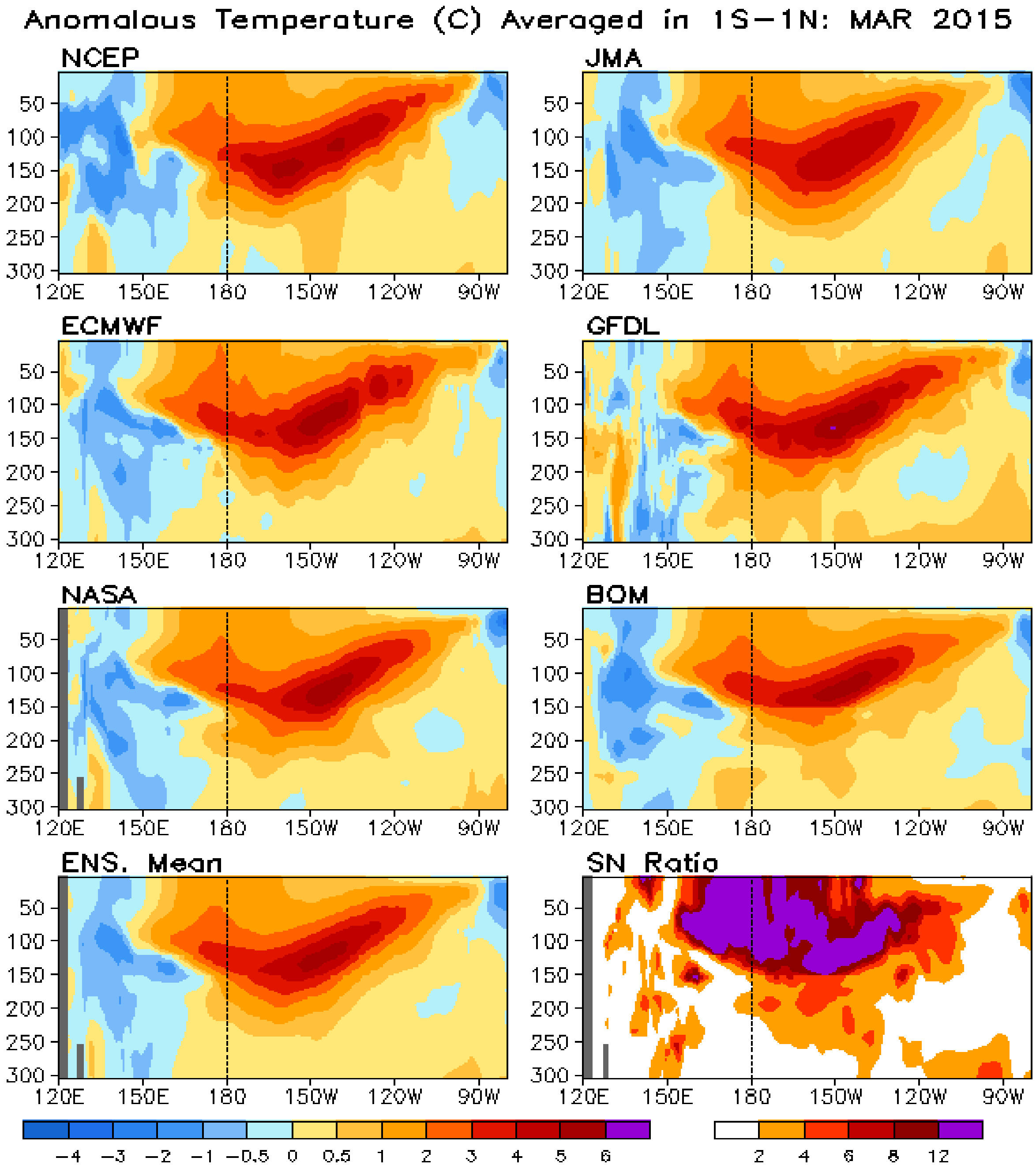



- Strong positive (weak negative) ocean temperature anomalies presented in the central (eastern and western) equatorial Pacific.
- Both positive and negative ocean temperature anomalies were observed in the Indian and Atlantic Oceans.




- Ocean temperature tendencies were positive in the central-eastern Pacific and negative in the west.
- There was little eastward propagation of the positive ocean temperature anomalies along the equatorial Pacific.

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



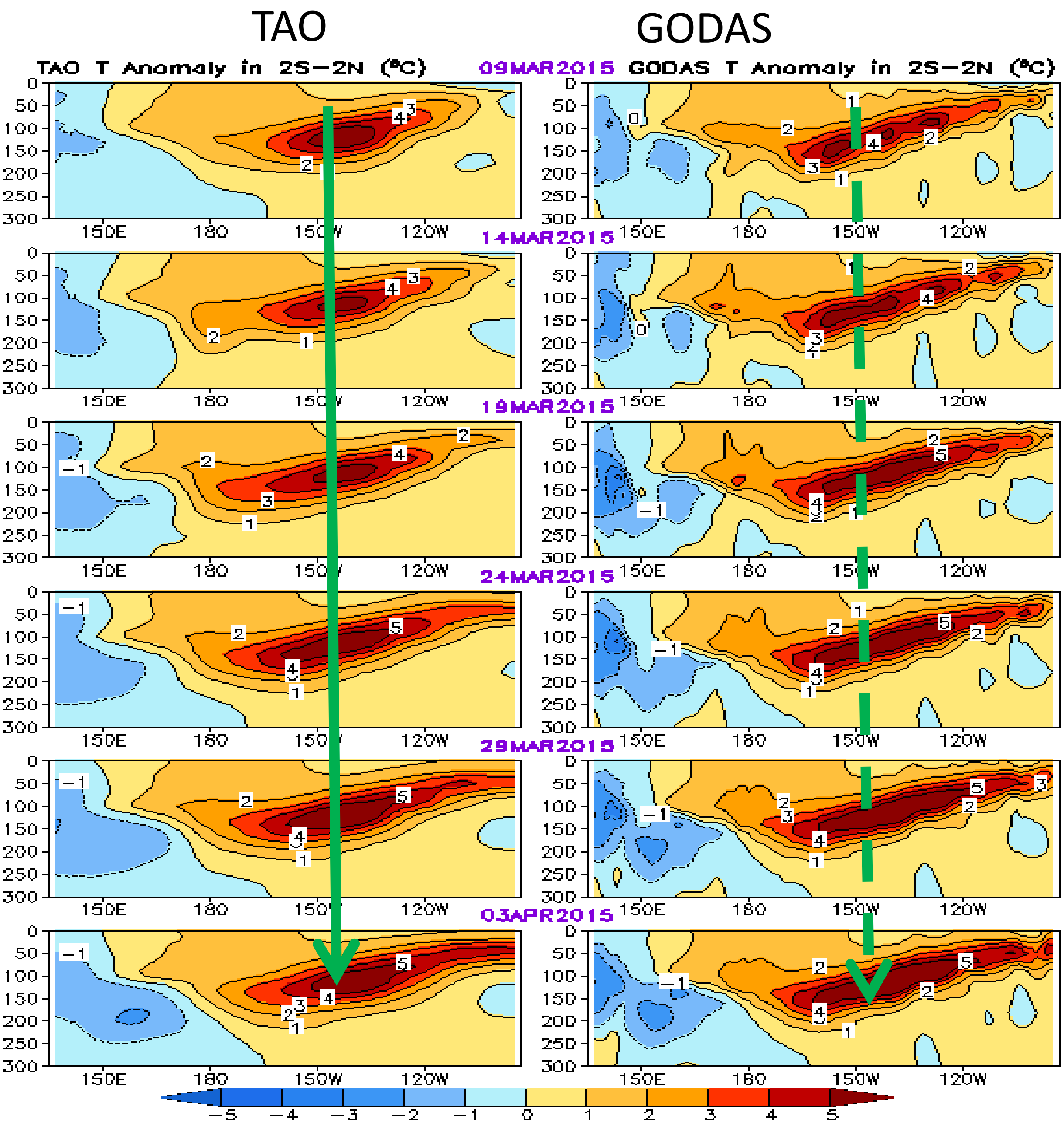

# Multiple Ocean Reanalyses: Ocean Temperature along the equator

**- Overall, the anomalous pattern is similar for 6 re-analyses.**

**-(http://origin.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)**

# **Tropical Pacific Ocean and ENSO Conditions**

# Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

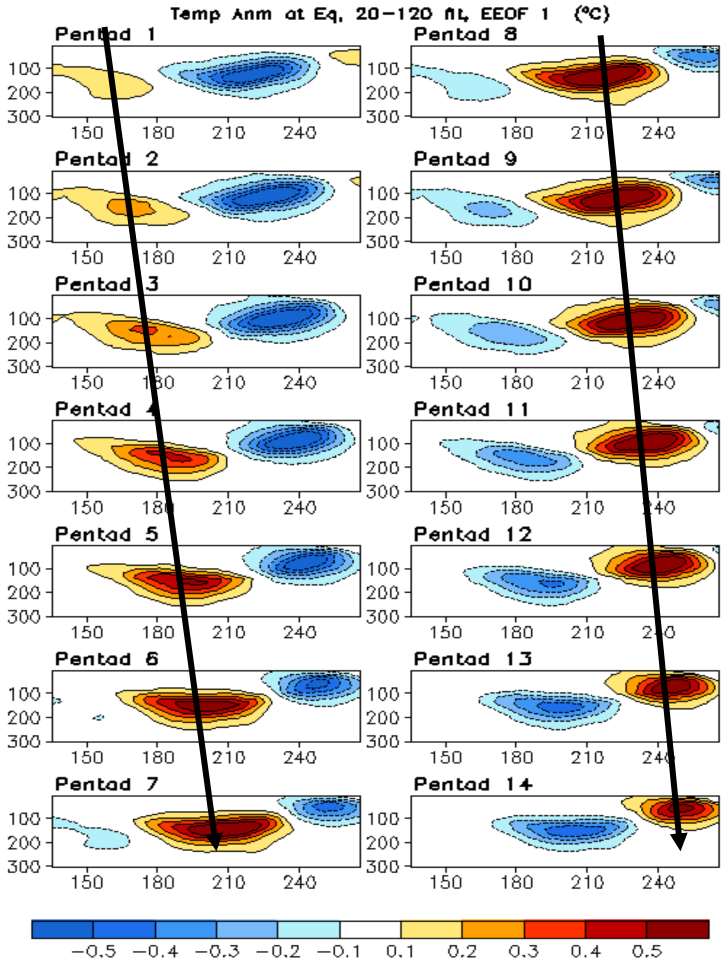


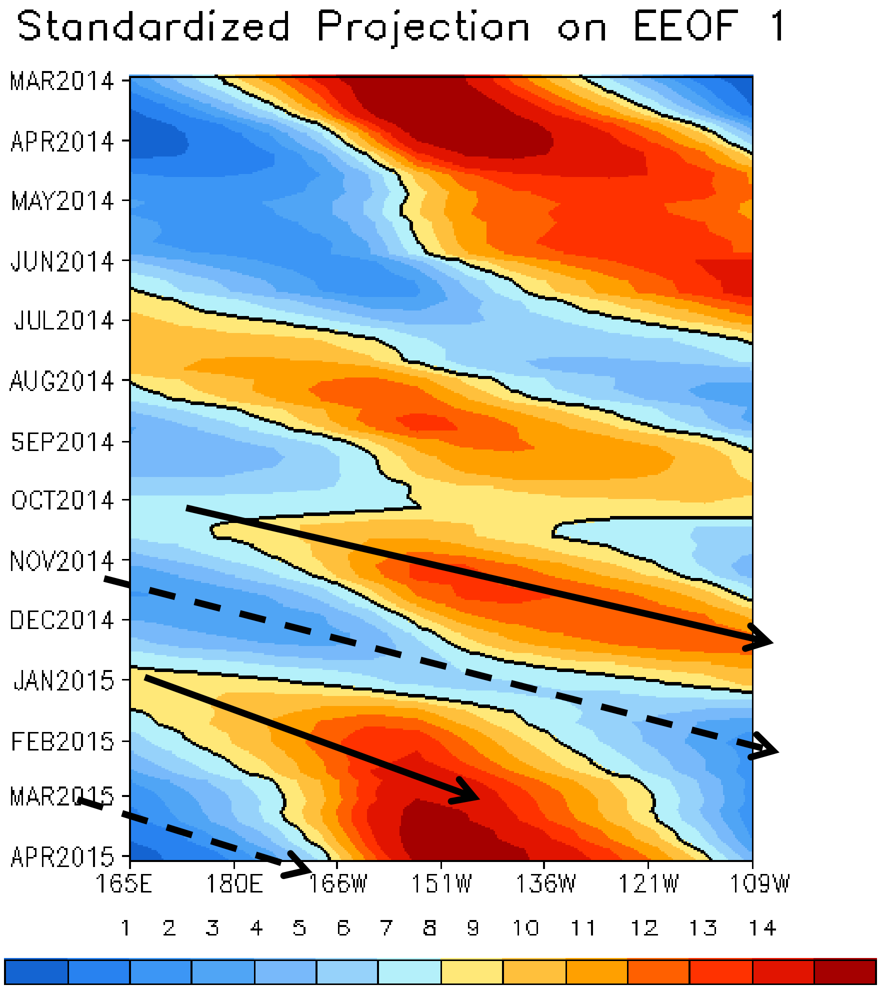

- Strong positive ocean temperature anomalies strengthened and showed little eastward propagation.

- Both the intensity and propagation are comparable in recent months between GODAS and TAO.

- That may be due to the recovery of TAO data delivery rate.

# Oceanic Kelvin Wave (OKW) Index

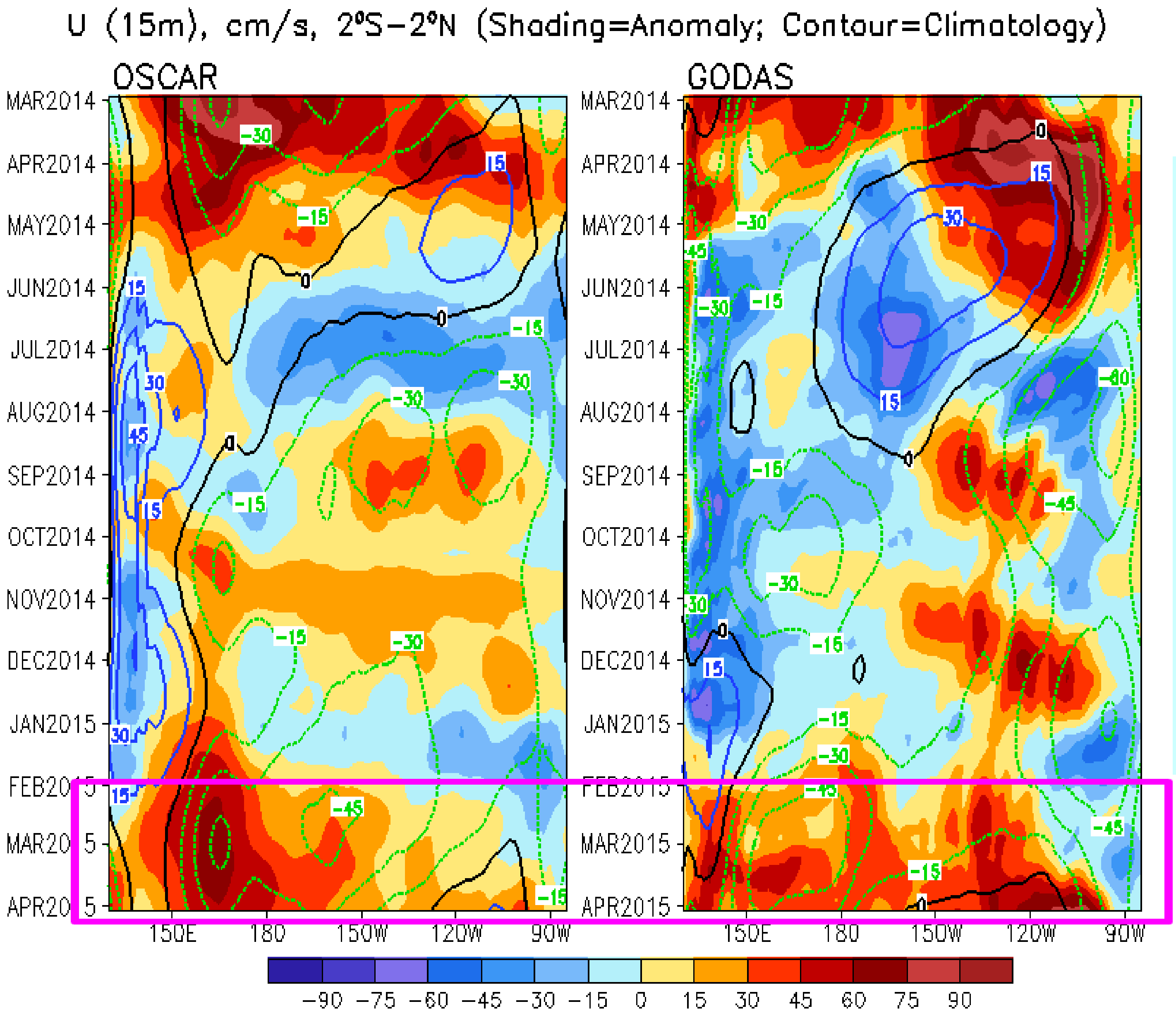



- **Downwelling OKW (solid line) emerged since Jan 2015 in the C. Pacific, while upwelling OKW initiated in mid-Jan in the W. Pacific. The downwelling may be associated with the observed subsurface ocean warming.**

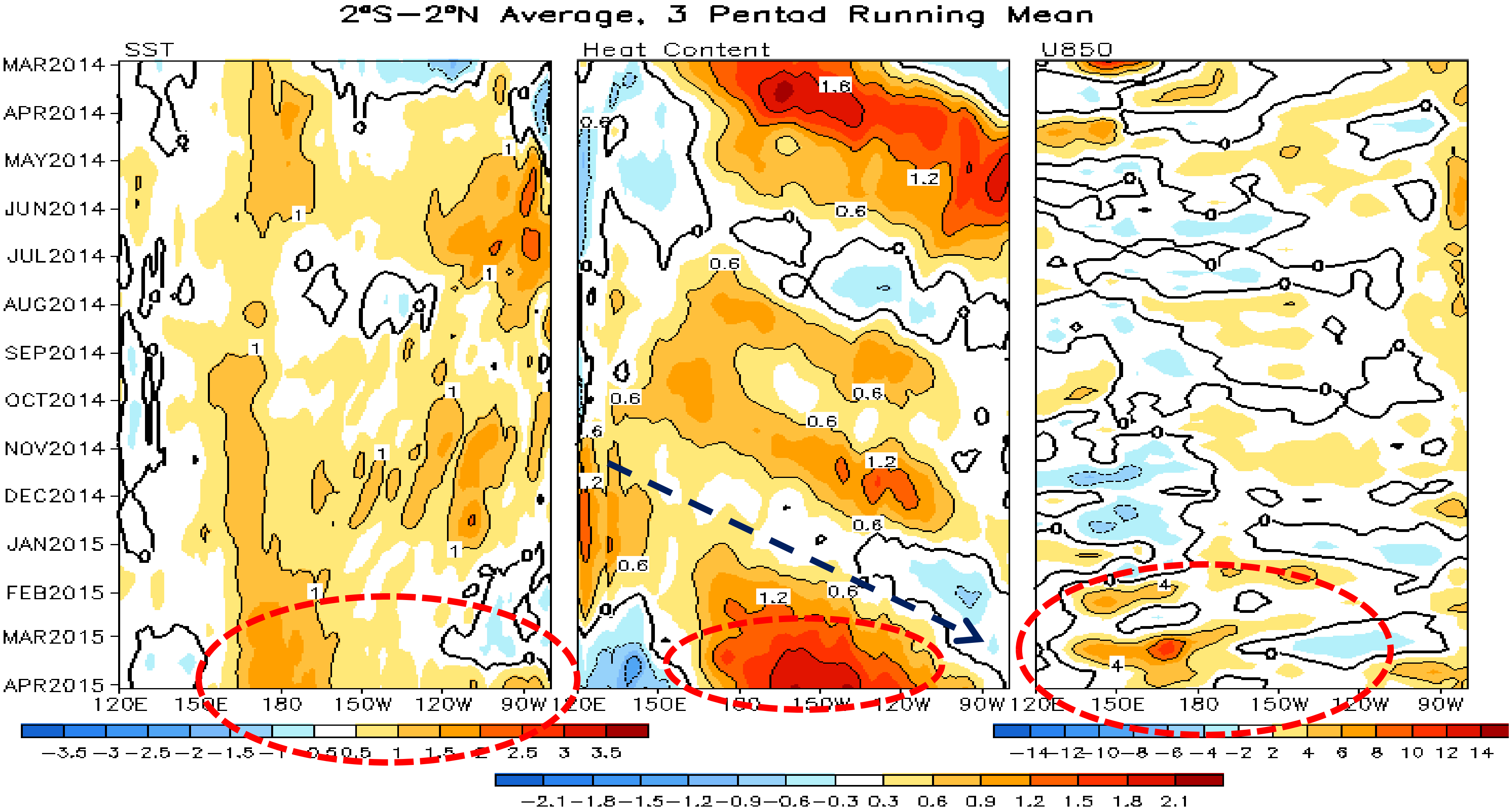
*(OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)*

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



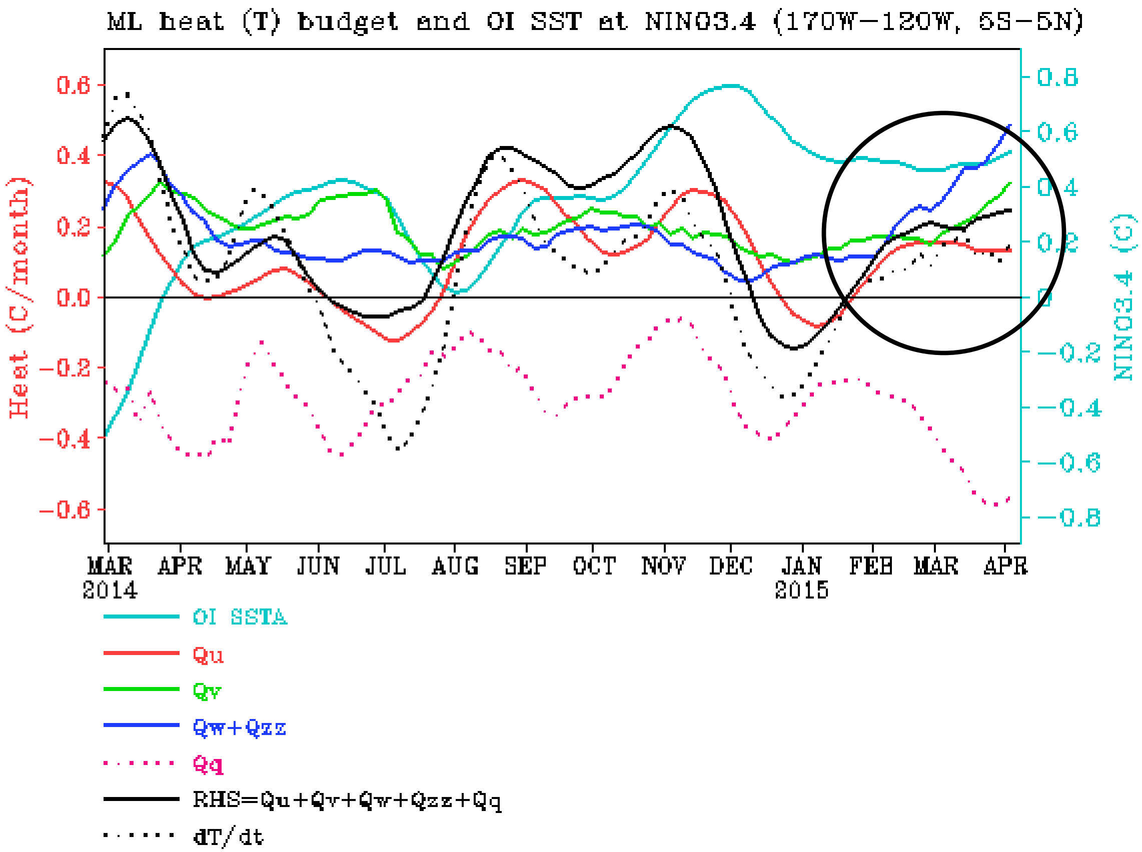

- **The anomalous current patterns were similar between OSCAR and GODAS.**
- **Anomalous eastward current initiated in Jan 2015 and slightly strengthened in Feb-Mar 2015.**

# Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies




- **Positive (negative) SSTA presented in the central-eastern (western) equatorial Pacific in Mar 2015.**
- **Positive HC300 anomalies initiated in Dec. 2014, and propagated eastward then largely became stationary since Feb 2015, consistent with ocean surface current and subsurface ocean temperature anomalies.**
- **A WWB event was observed in Mar, and low-level westerly wind anomalies were more frequent in the past 2-3 months.**

# NINO3.4 Heat Budget




- **Observed SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) was small positive in Mar 2015.**

- **All dynamical terms (Qu, Qv, Qw+Qzz) were positive and heat flux term (Qq) was strong negative since Feb 2015.**


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.

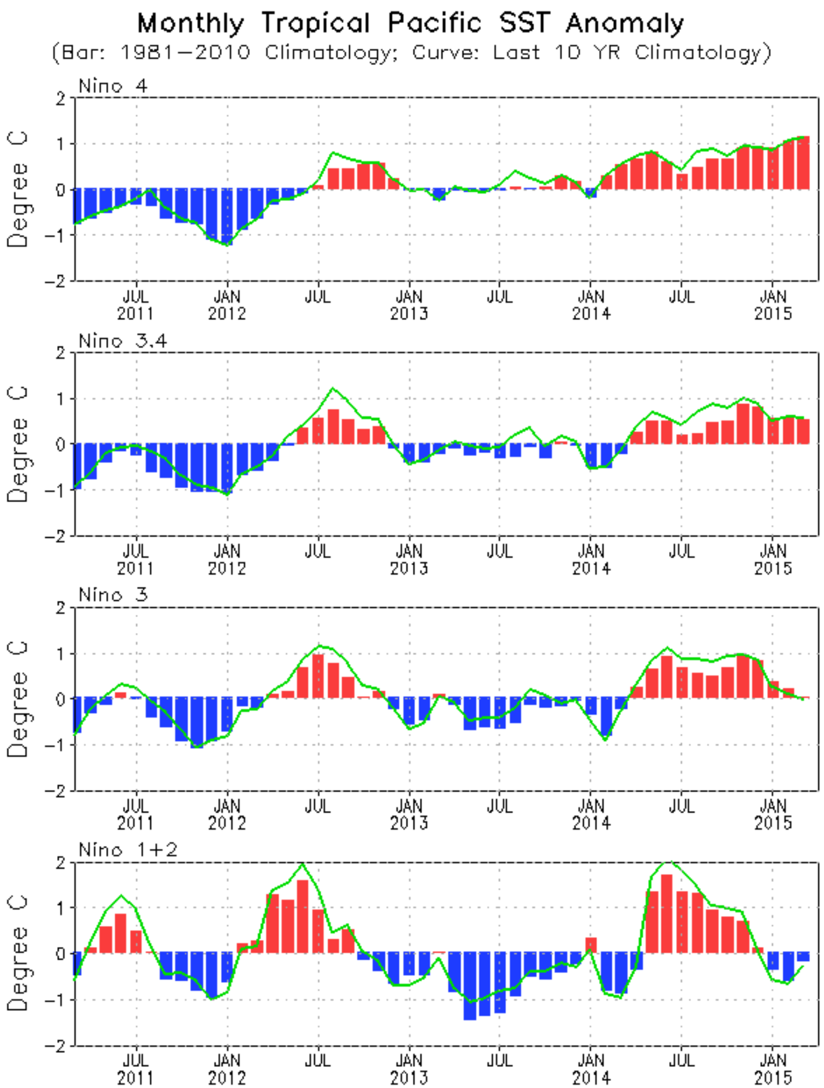

**Qu: Zonal advection; Qv: Meridional advection;**

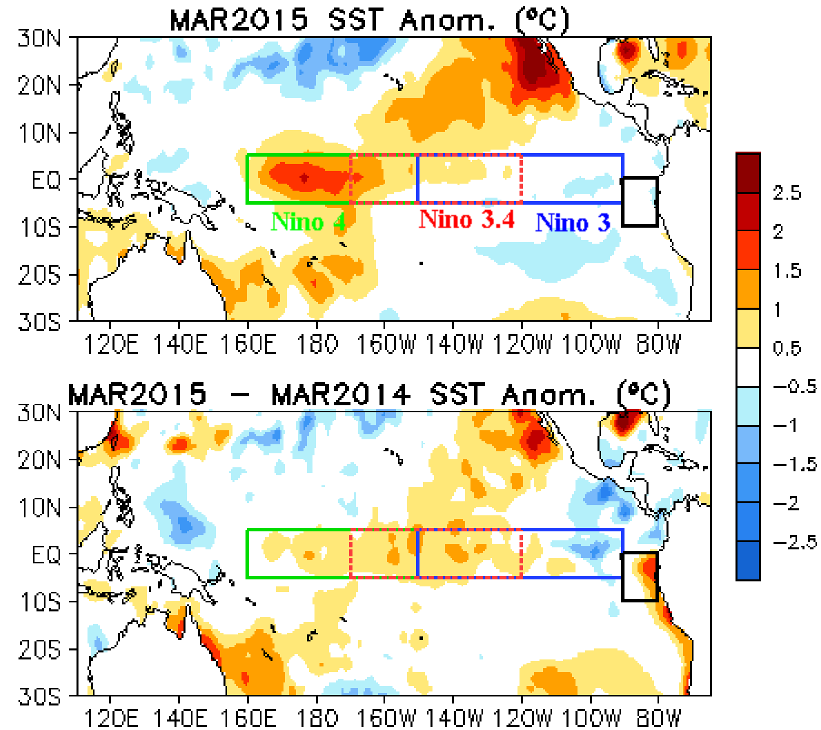
**Qw: Vertical entrainment; Qzz: Vertical diffusion**

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

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

# Evolution of Pacific NINO SST Indices




- All NINO indices, except Nino1+2, were positive; Nino4 strengthened and Nino3 weakened in Mar 2015.

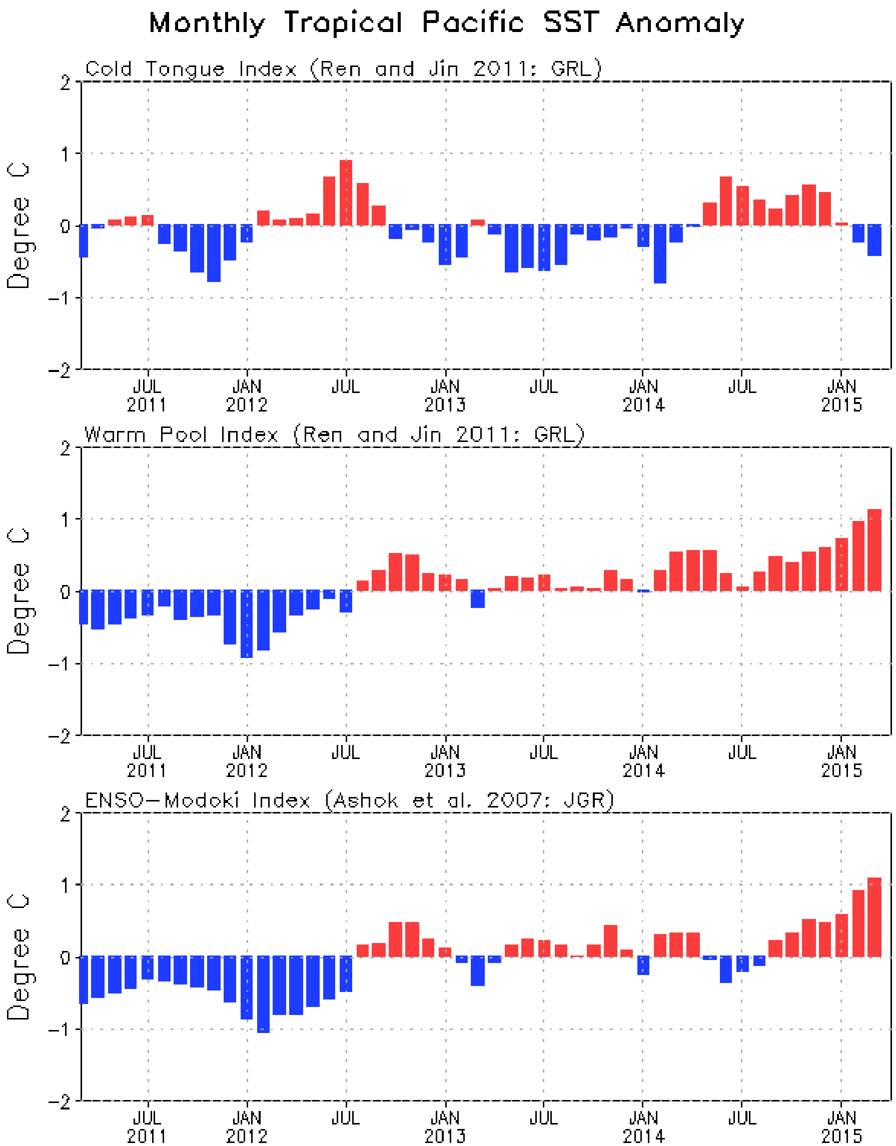
- Nino3.4 persisted and = 0.6°C in Mar 2015.

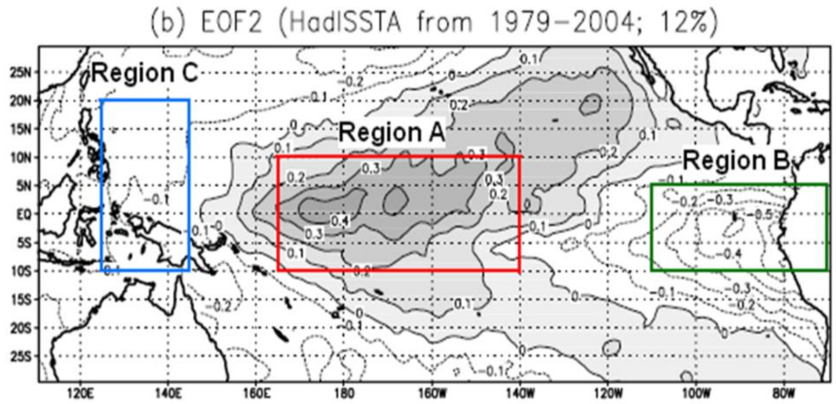
- Compared with last Mar, the central and eastern equatorial Pacific was warmer in Mar 2015.

- The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.

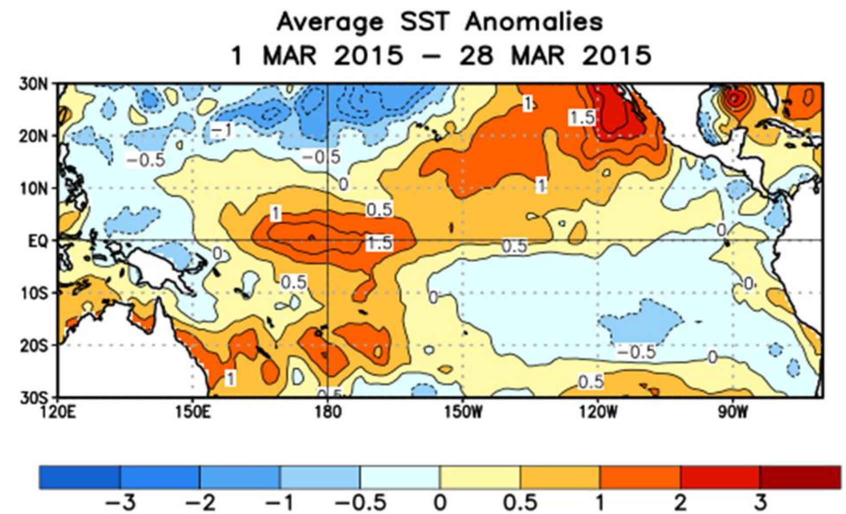
**Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.**

# Evolution of Pacific NINO SST Indices




From: http://bobtisdale.blogspot.com/2009/07/comparison-of-el-nino-modoki-index-and.html




**- The SSTA evolution in 2014/15 is more similar to the pattern associated with Central Pacific (warm pool) El Nino, or ENSO-Modoki.**

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

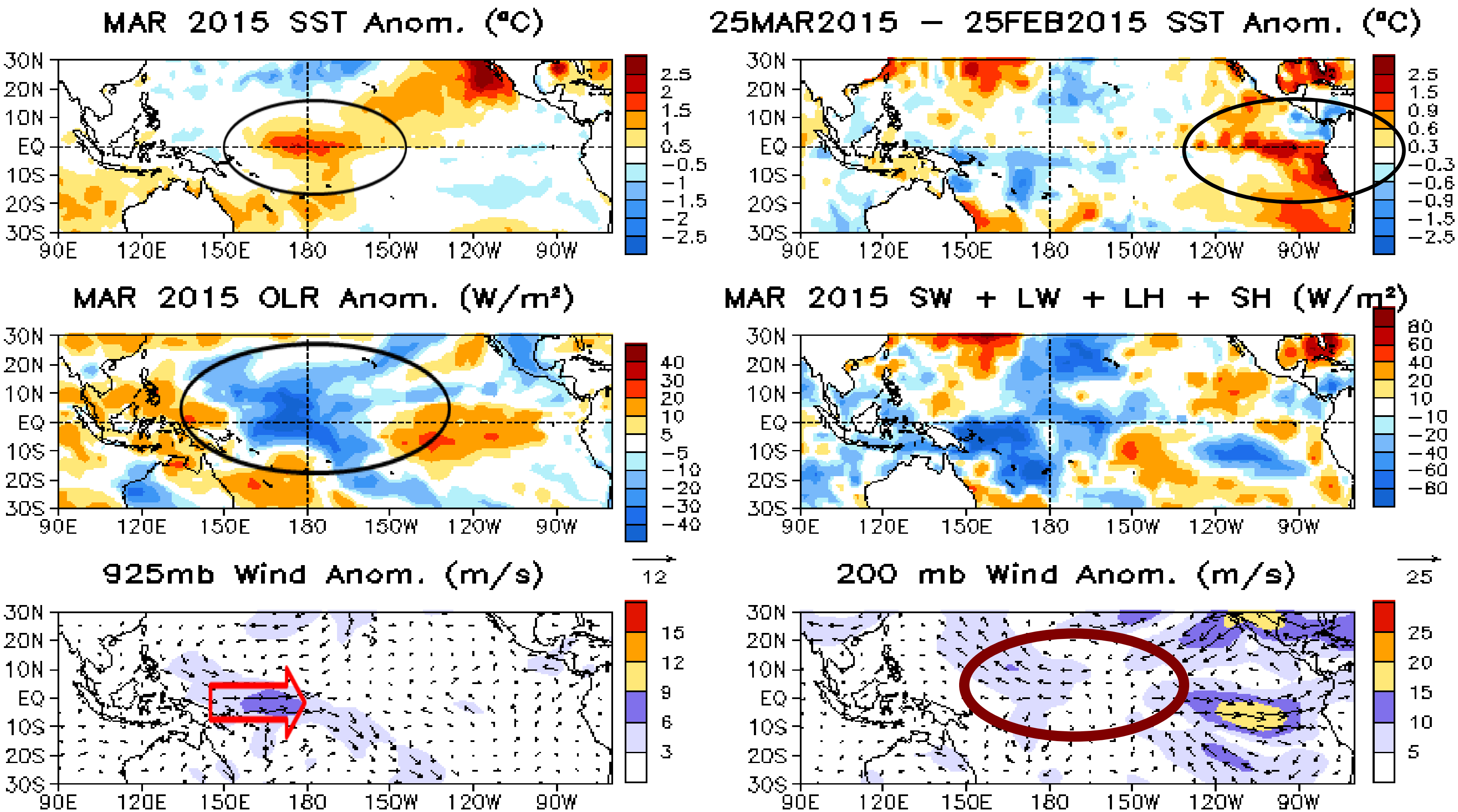
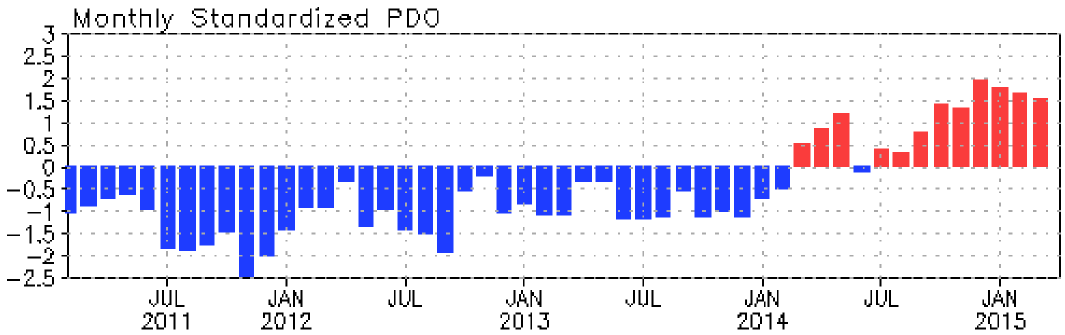
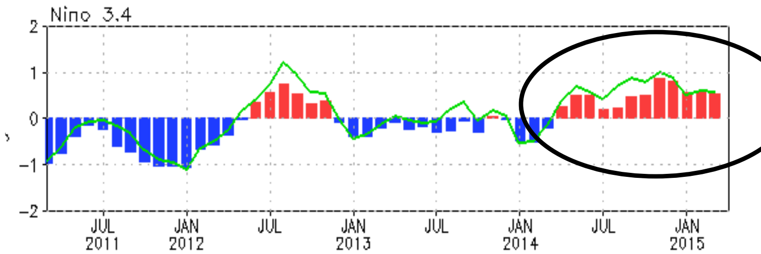


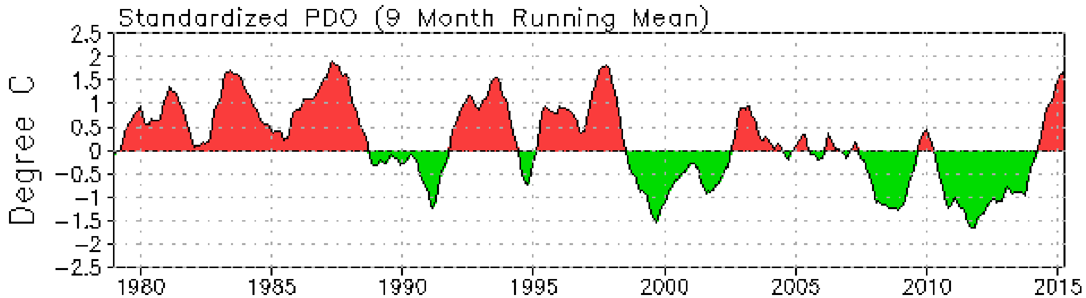

**Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

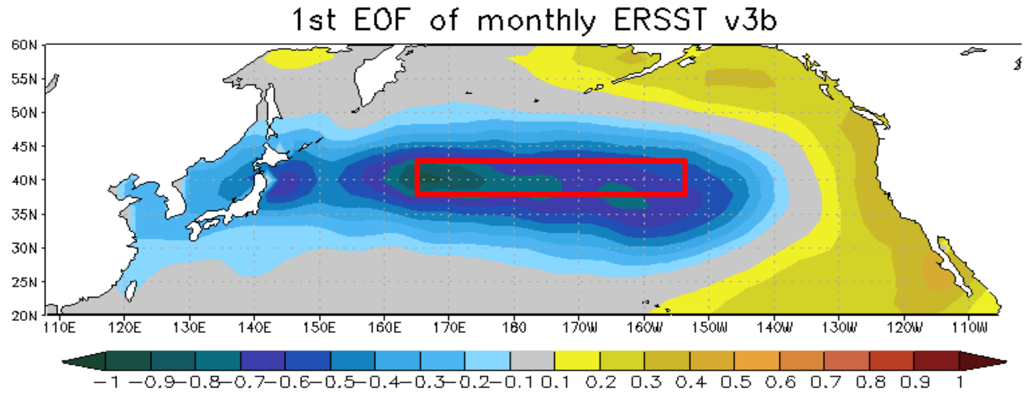
# North Pacific & Arctic Oceans

# PDO index



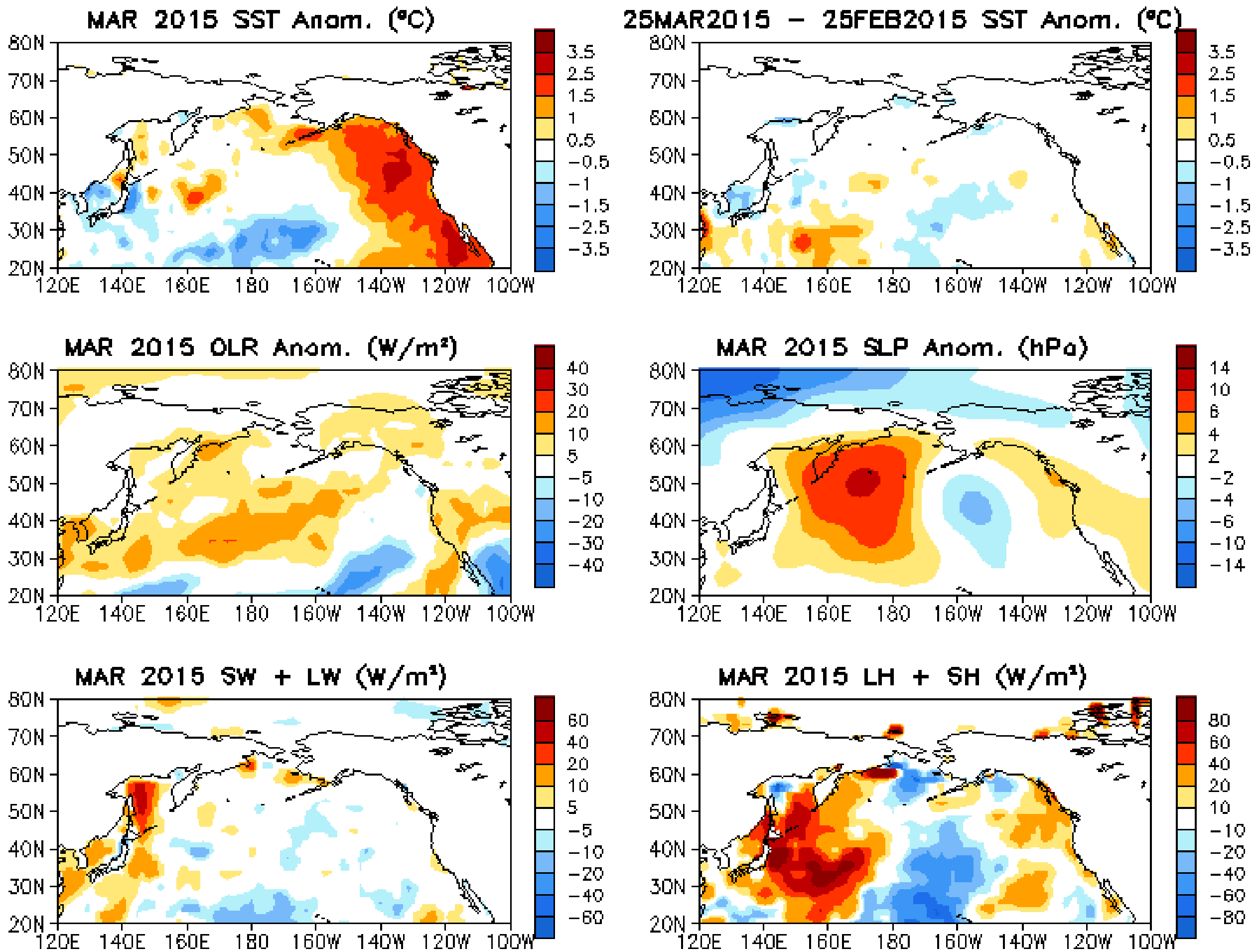

**- The positive phase of PDO index has persisted 9 months since Jul 2014 with PDO index =1.5 in Mar 2015.**

**- Statistically, ENSO leads PDO by 3-4 months, may through atmospheric bridge.**

**- 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 Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

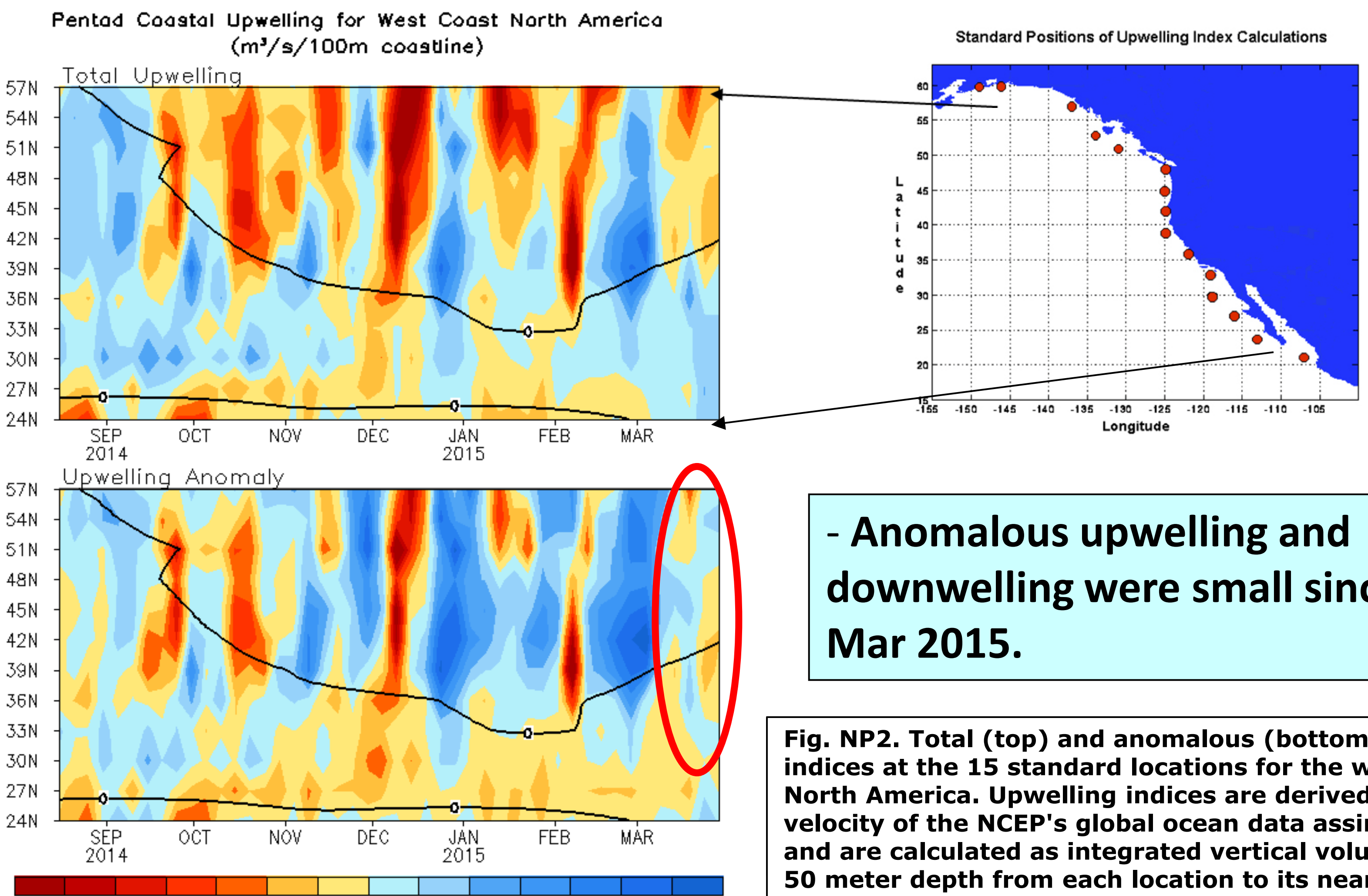



**- Positive SSTA presented in the NE Pacific, consistent with the positive phase of PDO index (previous slide).**

**- The SST tendency was small in North Pacific and may be associated with LH+SH.**

**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 America Western Coastal Upwelling




- Anomalous upwelling and downwelling were small since mid Mar 2015.

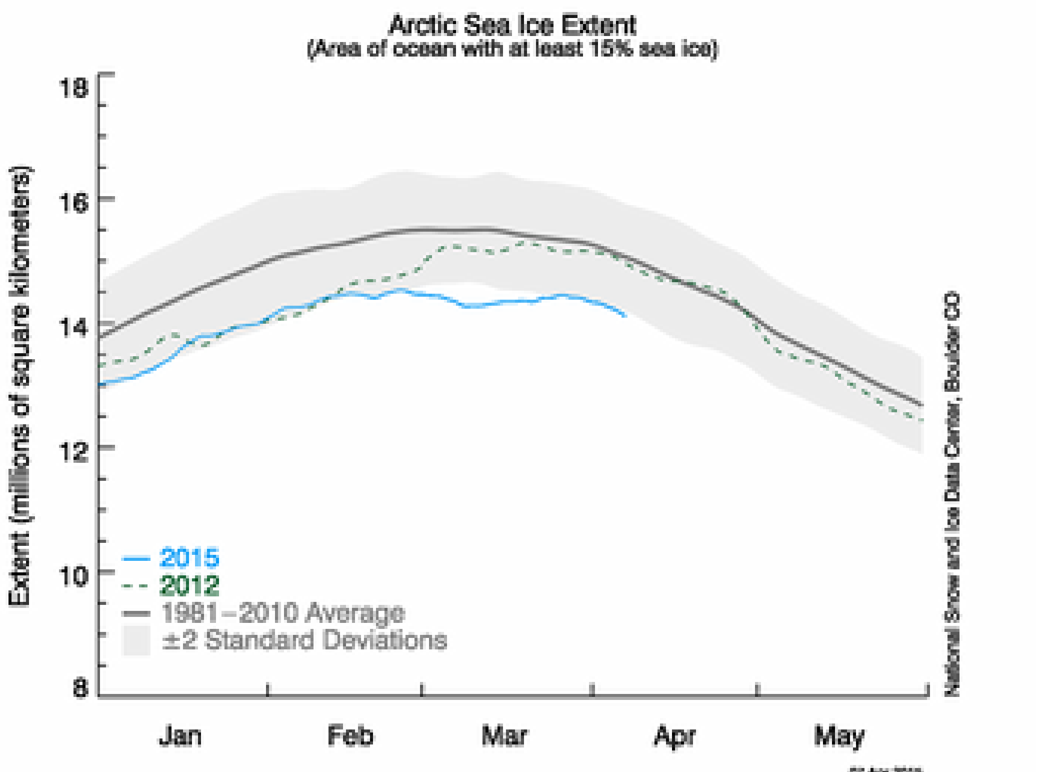
**Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

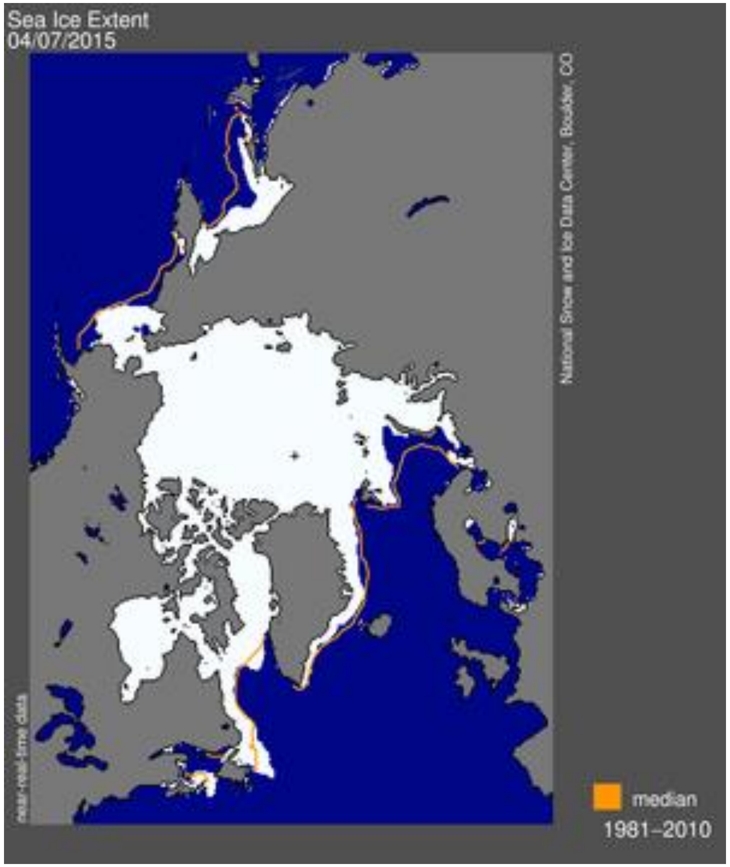
- **Area below (above) black line indicates climatological upwelling (downwelling) season.**
- **Climatologically upwelling season progresses from Mar to Jul along the west coast of North America from 36ºN to 57ºN.**

# Arctic Sea Ice

**National Snow and Ice Data Center**

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

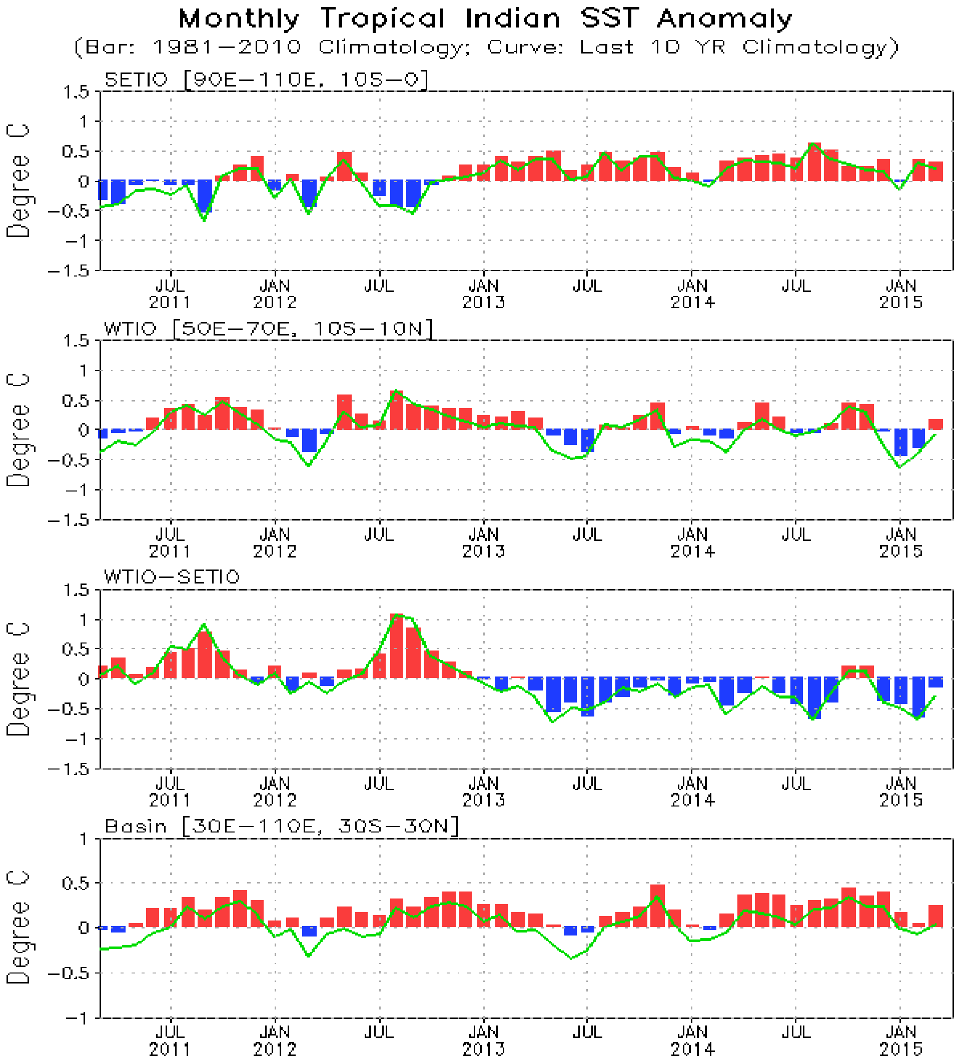


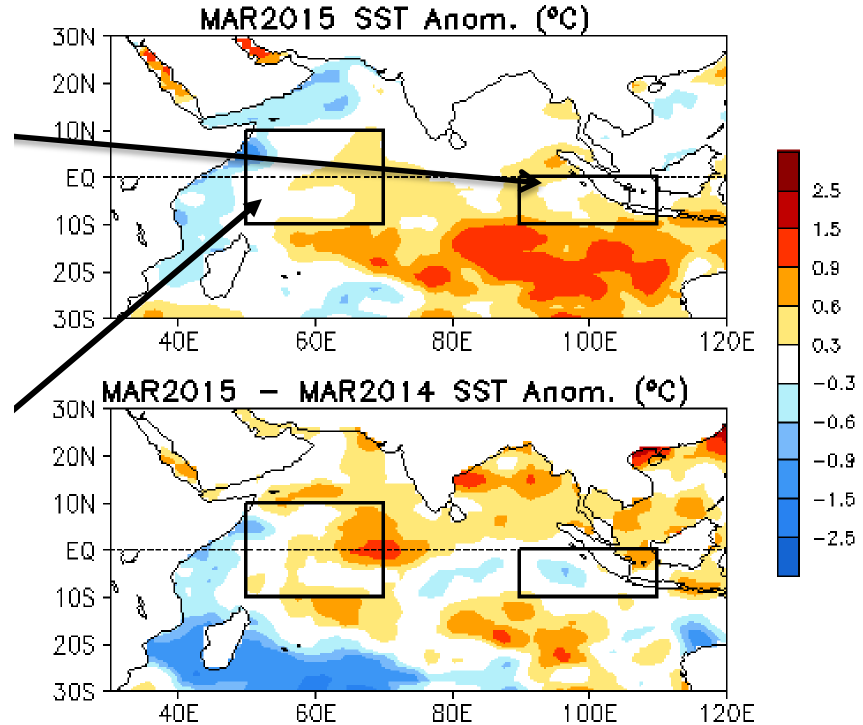




**- "On February 25, 2015, Arctic sea ice extent appeared to have reached its annual maximum extent, marking the beginning of the sea ice melt season. This year's maximum extent not only occurred early; it is also the lowest in the satellite record."**

# **Indian Ocean**

# Evolution of Indian Ocean SST Indices




- **Positive SSTA was in the southeast Indian Ocean.**
- **DMI was small in Mar 2015.**

**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 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.

- **Positive (negative) SSTA was in the central and east (west).**
- **SSTA tendency was largely determined by heat flux.**
- **Convections were suppressed over the central basin.**

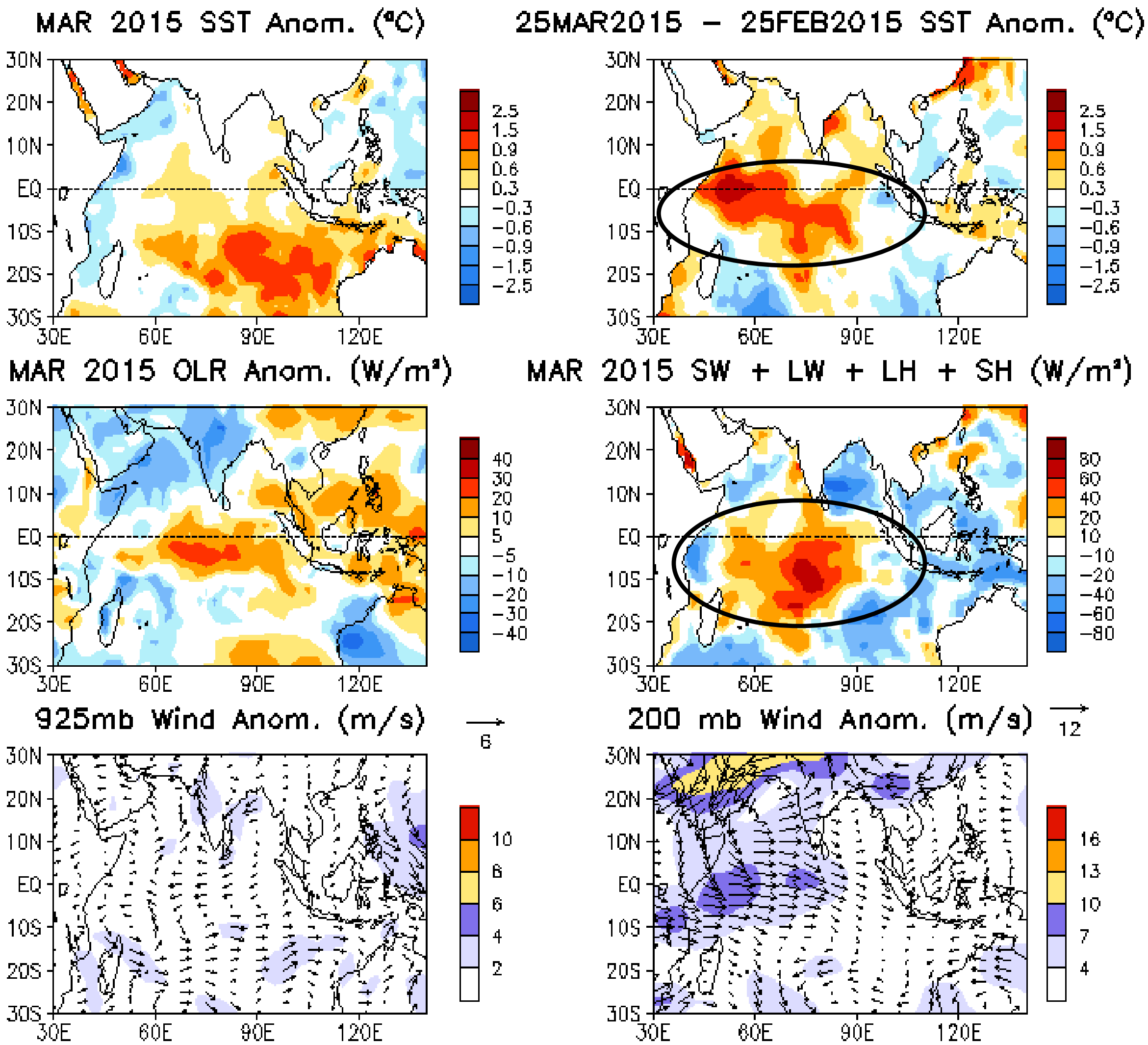
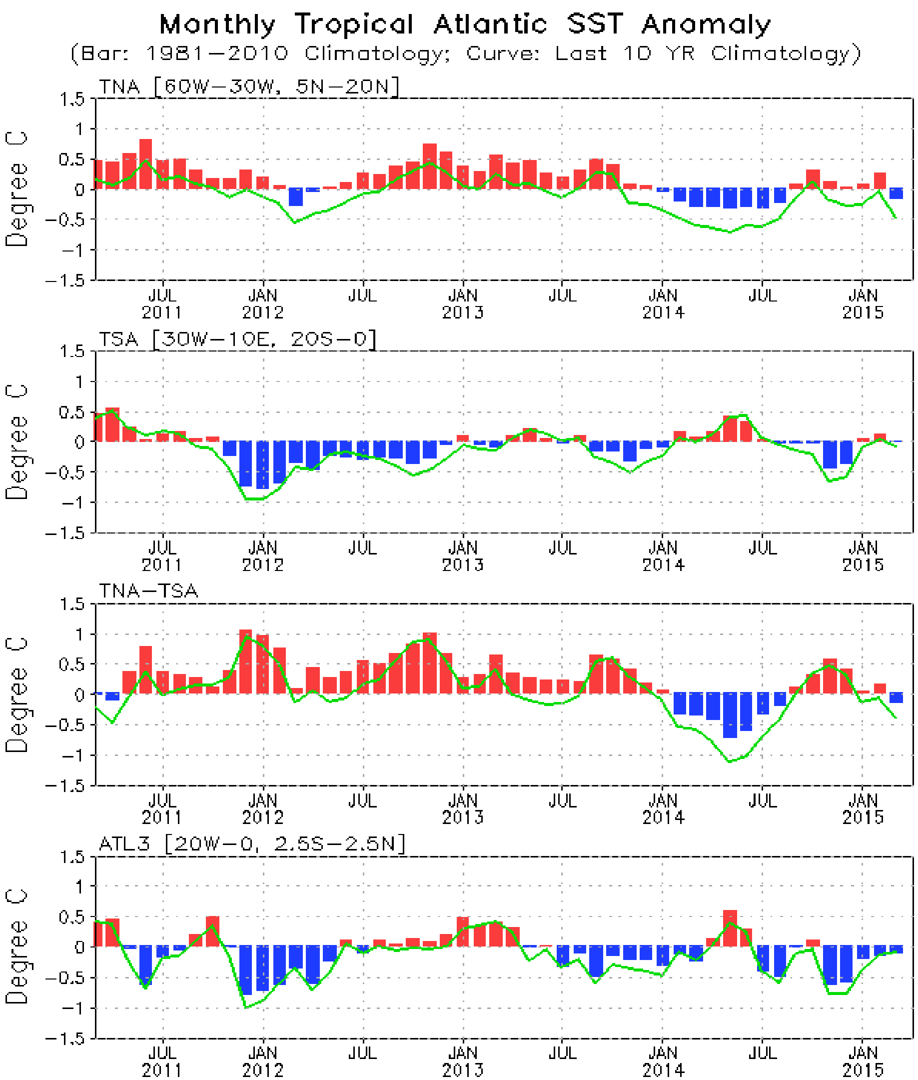
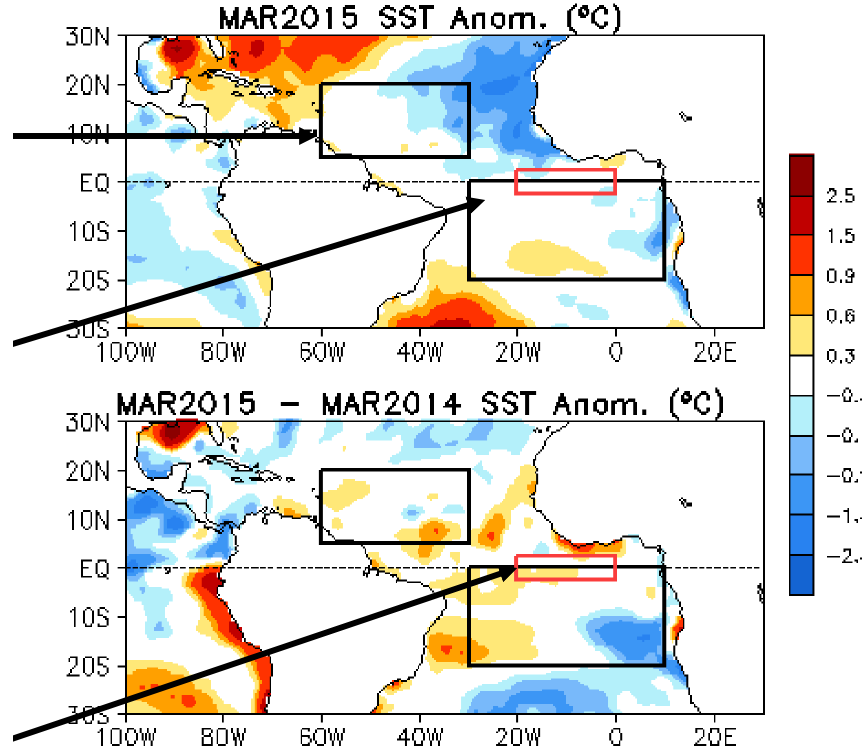



**Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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.**

# Tropical and North Atlantic Ocean

# Evolution of Tropical Atlantic SST Indices

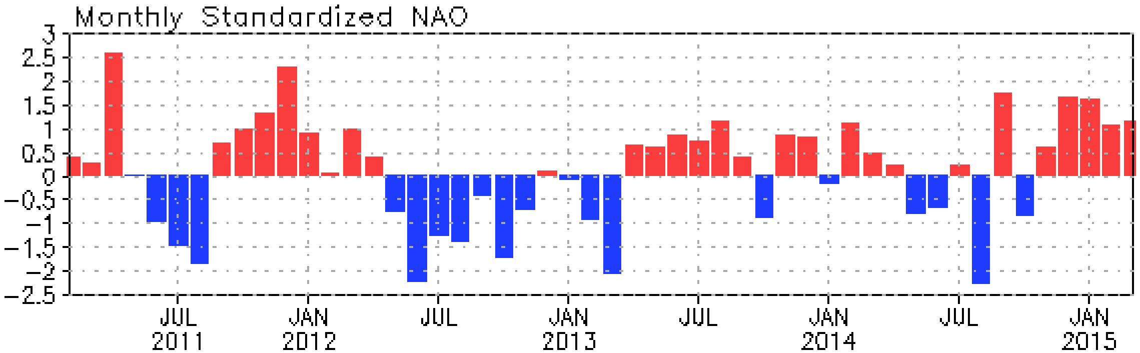


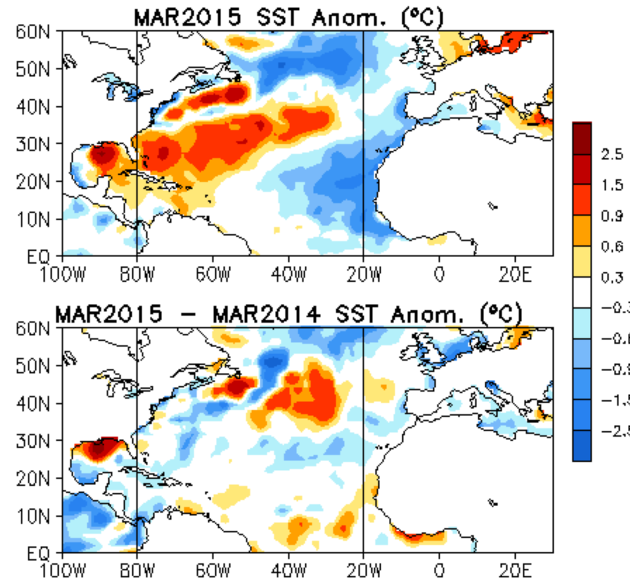



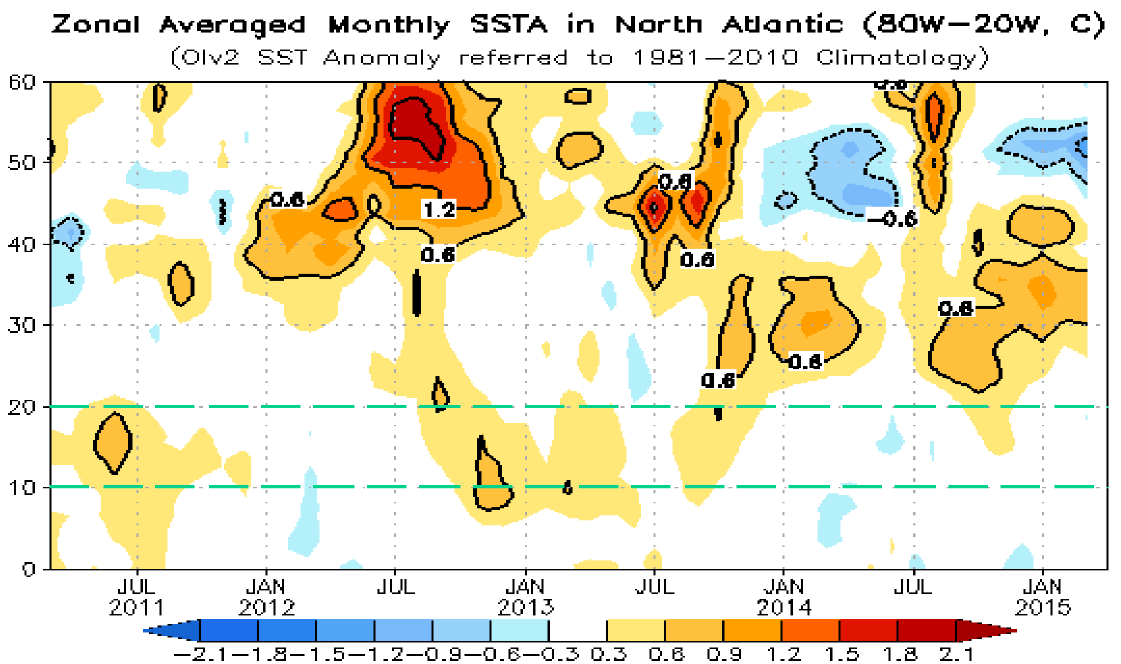

- **Cooling was observed in the NE Atlantic.**
- **All indices had small values in recent months.**

**Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) for the TNA [60ºW-30ºW, 5ºN-20ºN], TSA [30ºW-10ºE, 20ºS-0] and ATL3 [20ºW-0, 2.5ºS-2.5ºN] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.**

# NAO and SST Anomaly in North Atlantic



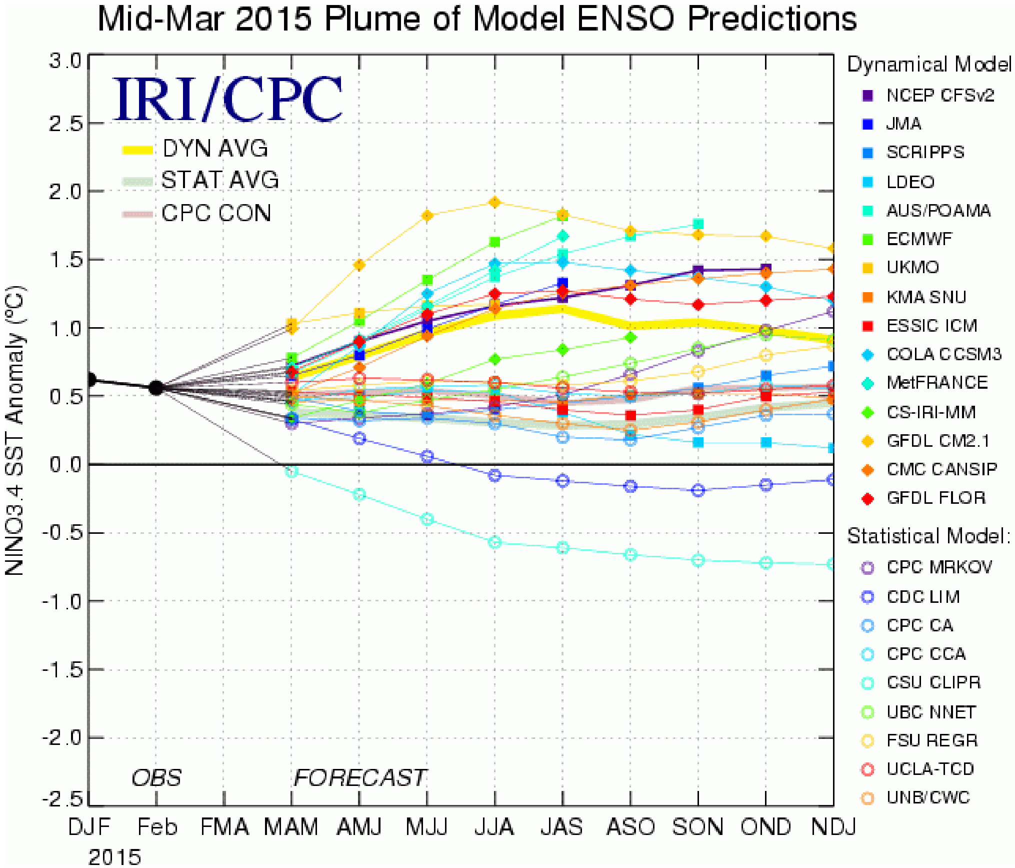

**- Positive phase of NAO has persisted 5 months with NAOI=1.1 in Mar 2015.**

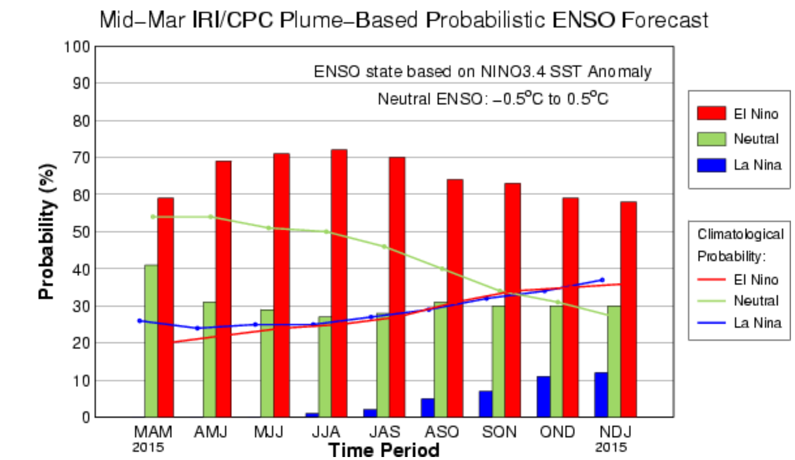
**- SSTA showed a horseshoe-like pattern, which may be due to the influence of persistent positive phase of NAO.**

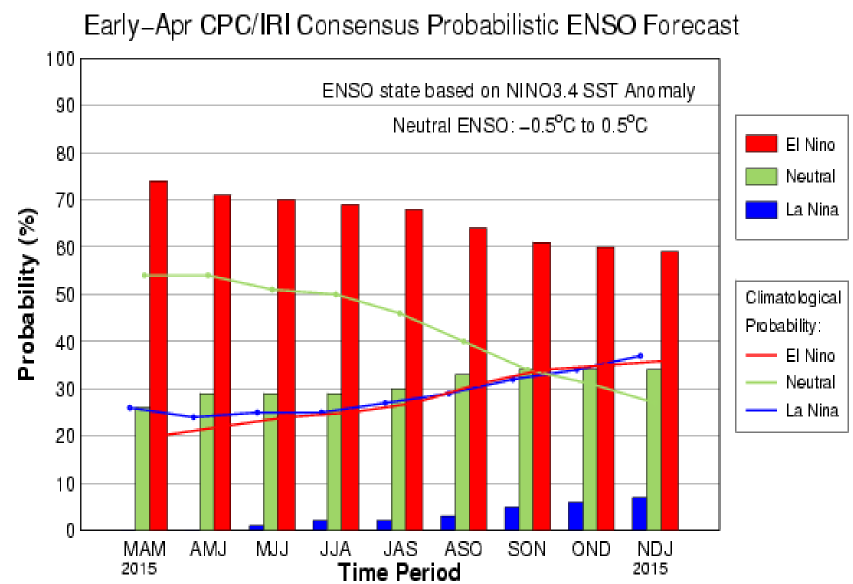
**Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (bottom). SST are derived from the NCEP OI SST analysis,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

# ENSO and Global SST Predictions

# IRI NINO3.4 Forecast Plum

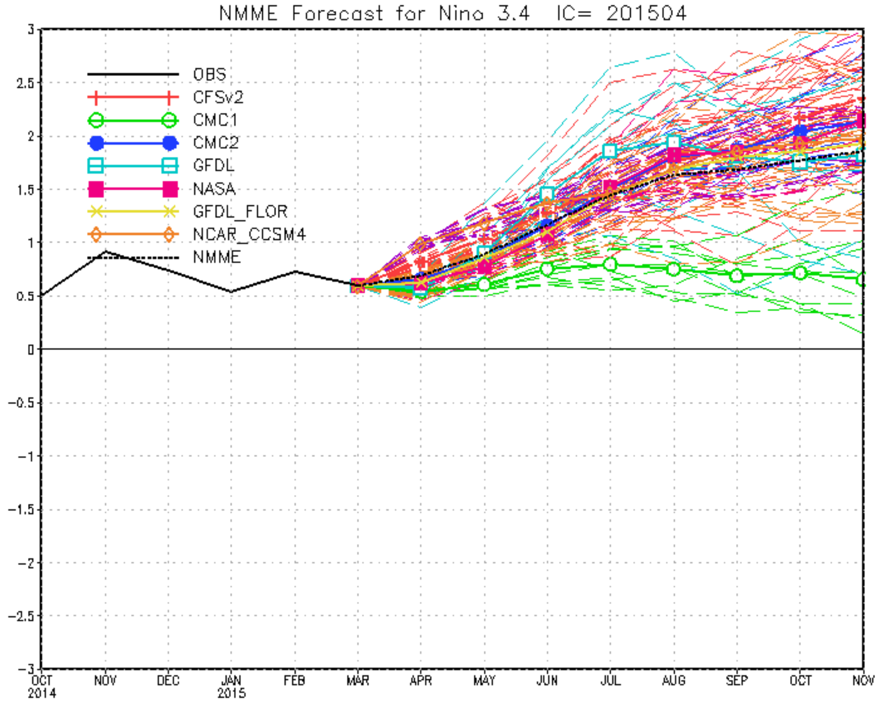


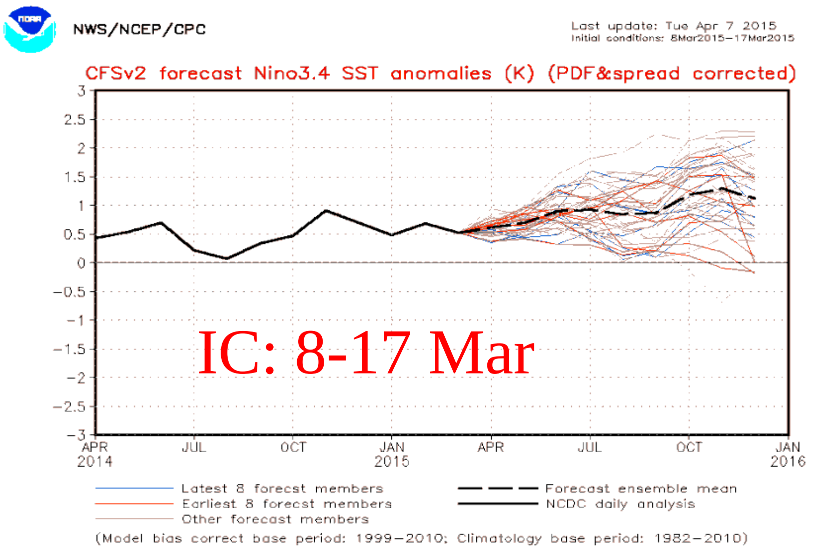




- **Majority of dynamical models predicted a warming tendency (El Nino) in 2015, but majority of statistical models favor ENSO neutral in 2015.**
- **NOAA "ENSO Diagnostic Discussion" on 09 Apr 2015 suggested that "*There is an approximately 70% chance that El Niño will continue through Northern Hemisphere summer 2015, and a greater than 60% chance it will last through autumn.*"**

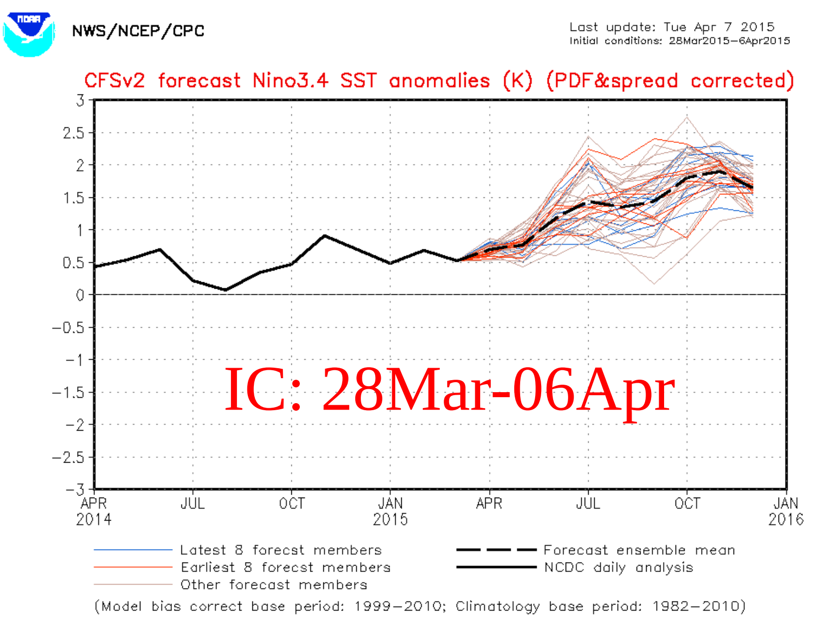
# NMME & CFSv2



NMME Forecast for Nino 3.4 IC= 201504
OBS
CFSv2
CMC1
CMC2
GFDL
NASA
GFDL_FLOR
NCAR_CCSM4
NMME
OCT 2014
NOV
DEC
JAN 2015
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV

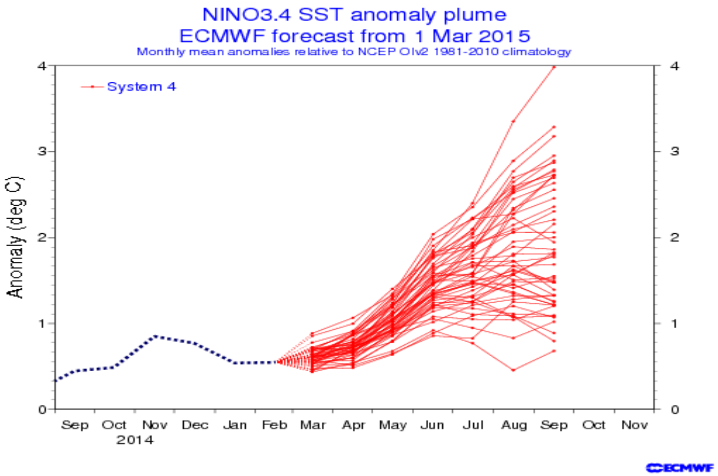
NWS/NCEP/CPC
Last update: Tue Apr 7 2015
Initial conditions: 8Mar2015–17Mar2015
CFSv2 forecast Nino3.4 SST anomalies (K) (PDF&spread corrected)
IC: 8-17 Mar
APR 2014
JUL
OCT
JAN 2015
APR
JUL
OCT
JAN 2016
Latest 8 forecst members
Earliest 8 forecst members
Other forecast members
Forecast ensemble mean
NCDC daily analysis
(Model bias correct base period: 1999–2010; Climatology base period: 1982–2010)

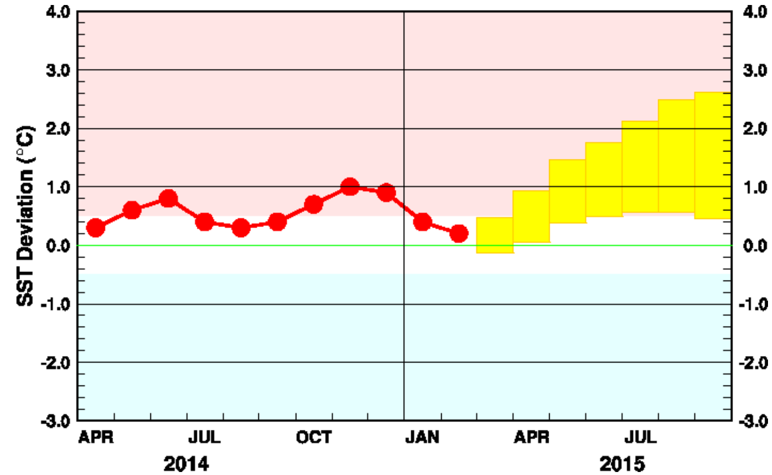
NWS/NCEP/CPC
Last update: Tue Apr 7 2015
Initial conditions: 28Mar2015–6Apr2015
CFSv2 forecast Nino3.4 SST anomalies (K) (PDF&spread corrected)
IC: 28Mar-06Apr
APR 2014
JUL
OCT
JAN 2015
APR
JUL
OCT
JAN 2016
Latest 8 forecst members
Earliest 8 forecst members
Other forecast members
Forecast ensemble mean
NCDC daily analysis
(Model bias correct base period: 1999–2010; Climatology base period: 1982–2010)

# Individual Model Forecasts: warming or little tendency

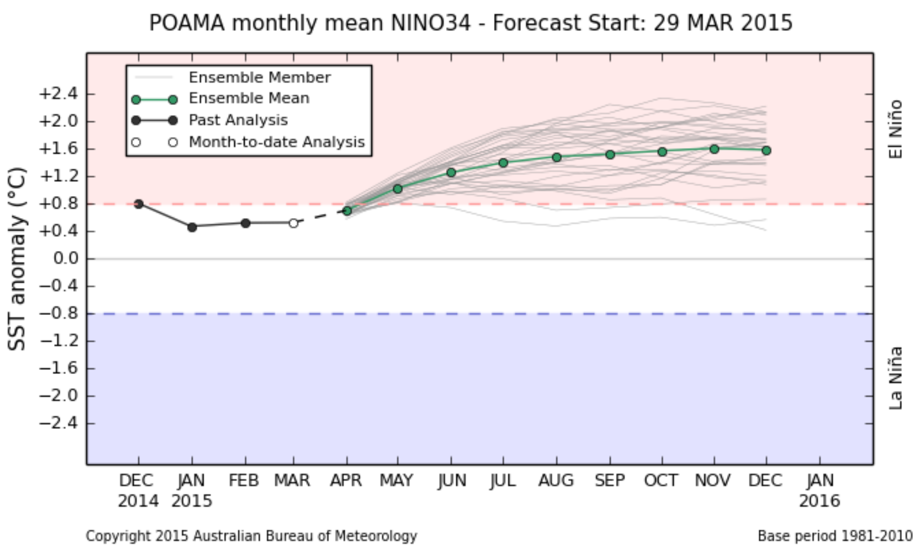
## EC: Nino3.4, IC=01Mar 2015



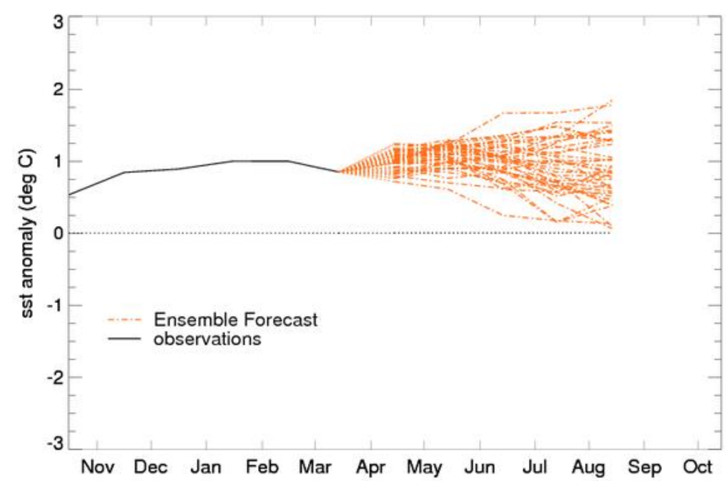

## JMA: Nino3, IC=Mar 2015



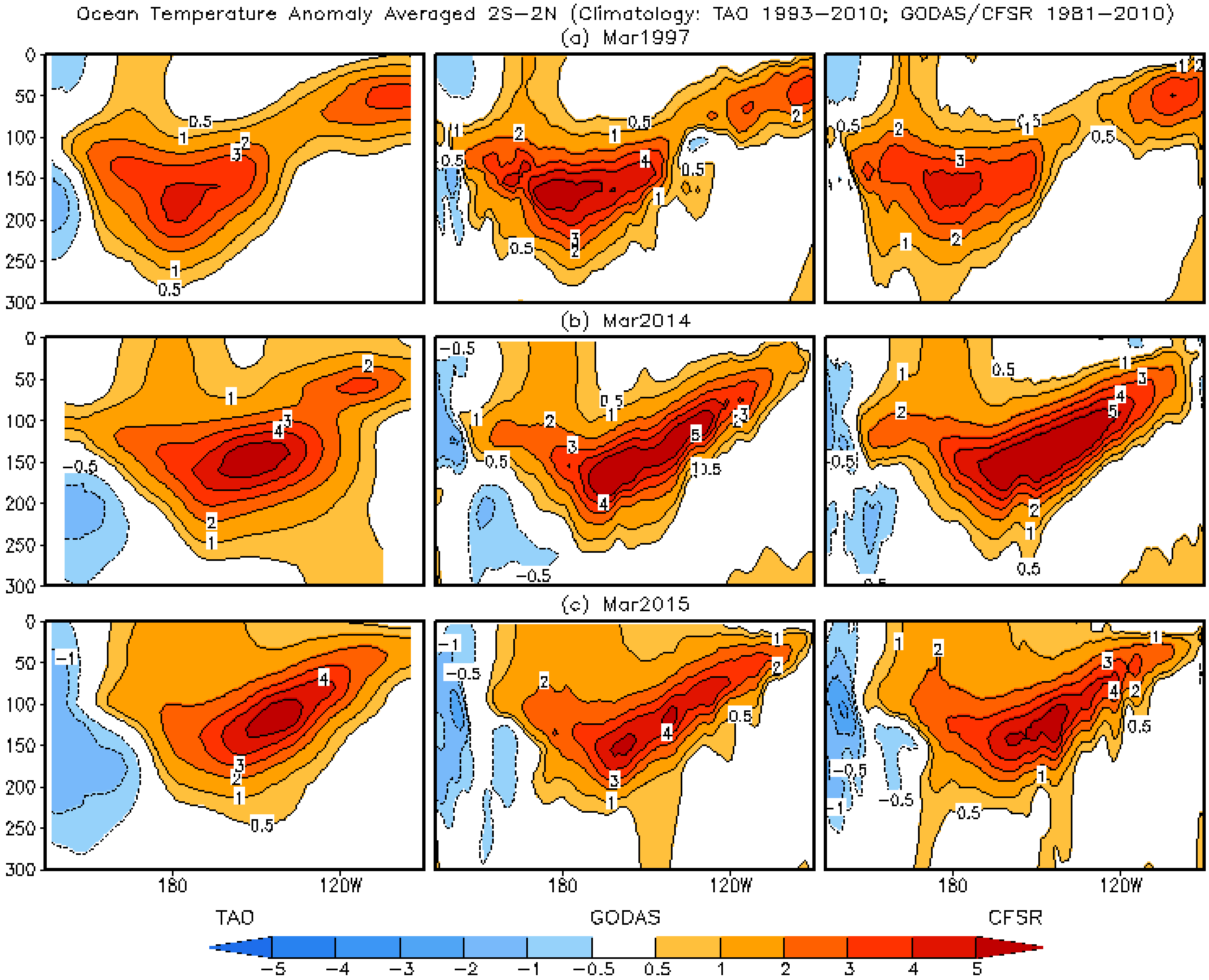

## Australia: Nino3.4, IC=29Mar 2015

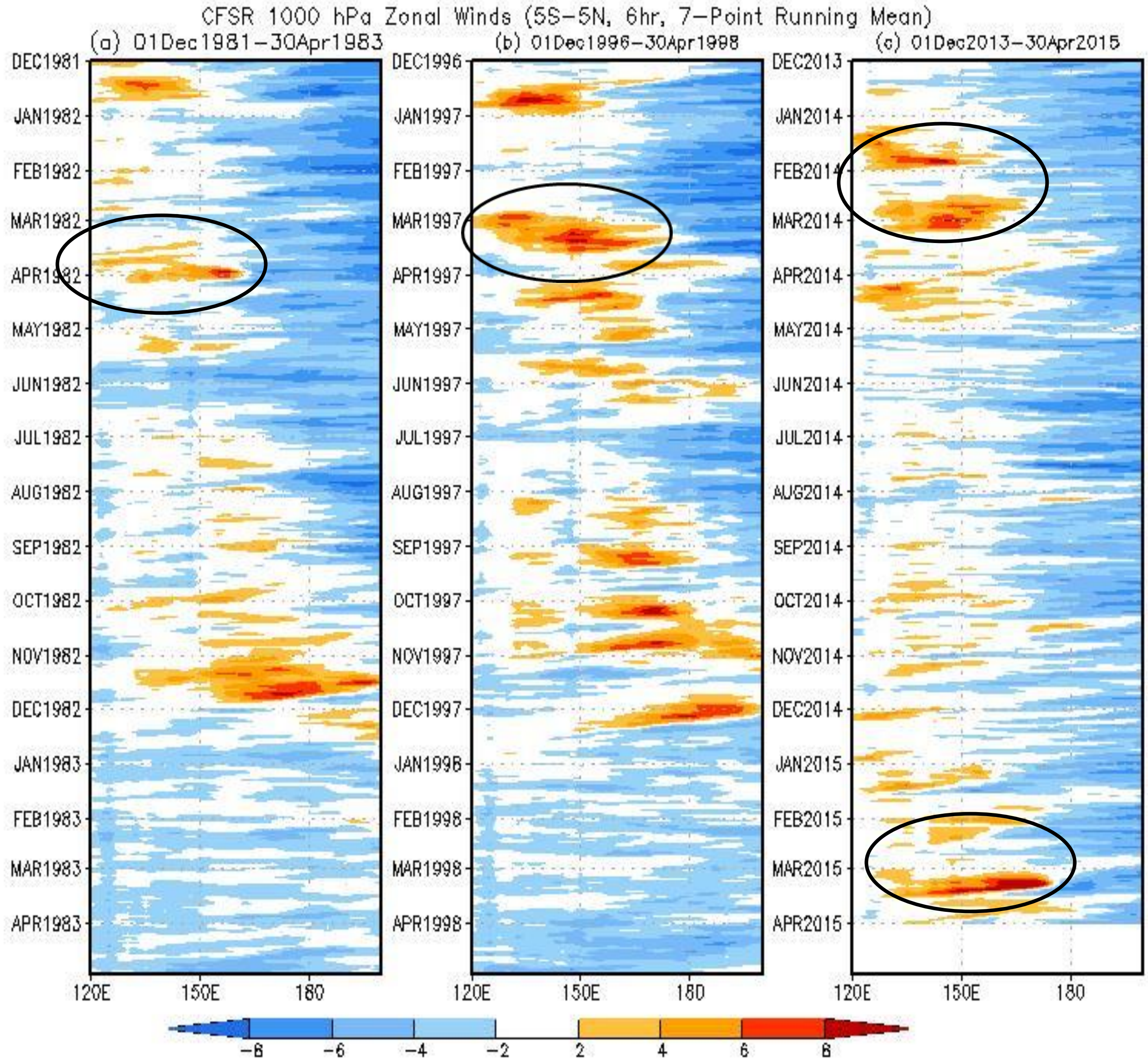



## UKMO: Nino3.4, IC=Apr 2015



# Subsurface Ocean T Anomaly in Mar 1997, 2014, 2015





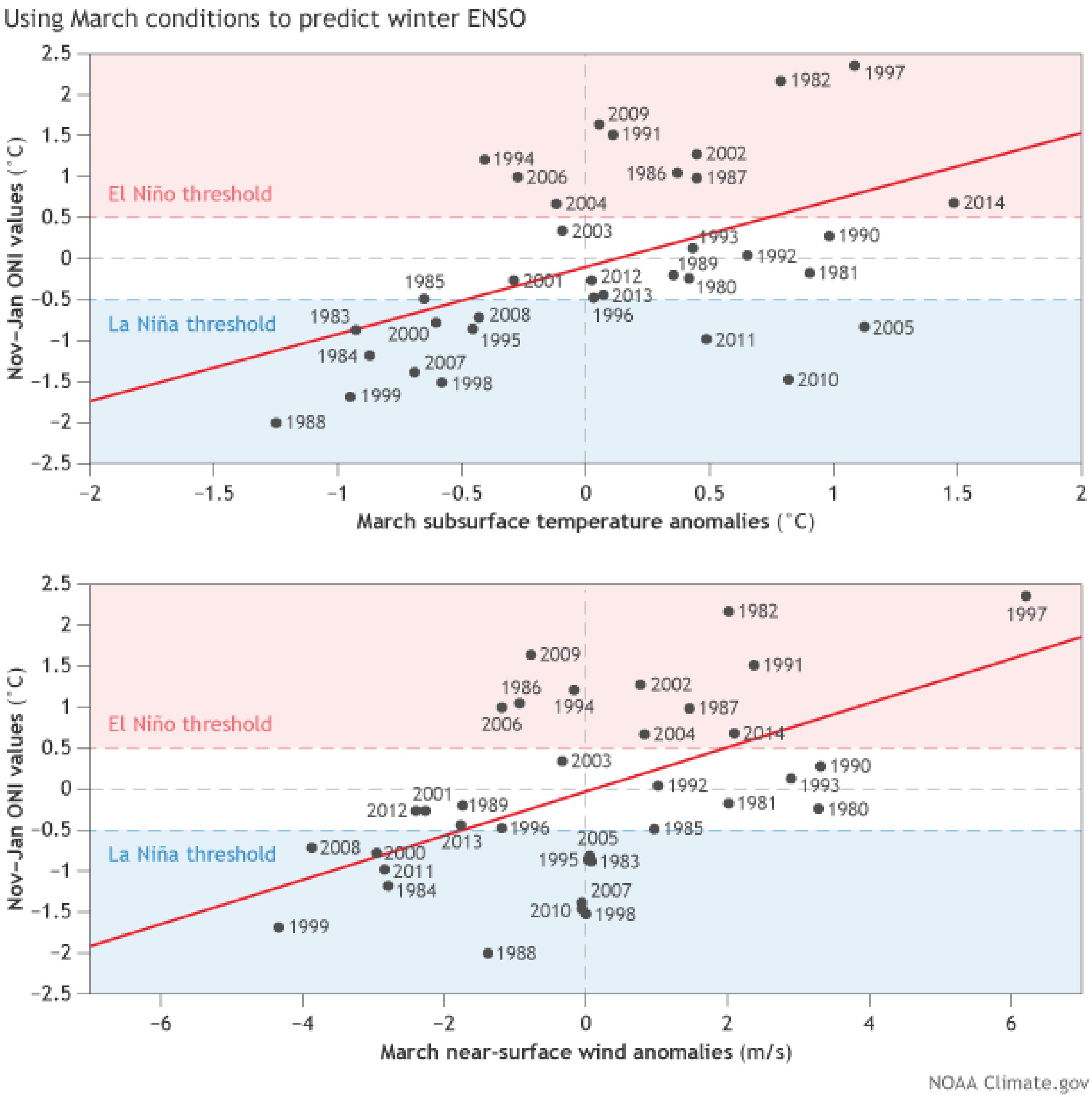

**<u>U850</u>**

**<u>Anomaly in</u>**

**<u>1982-83,</u>**

**<u>1997-98,</u>**

**<u>2014-15</u>**




**Prediction skill with IC in Mar:** The western Pacific winds and subsurface temperatures in the eastern half of the tropical Pacific Ocean for Mar – explain only about a quarter to a third (~25-33%) of the coming winter ENSO state.

[Michelle L'Heureux](): **Déjà Vu: El Niño Take Two.**
http://www.climate.gov/news-features/blogs/enso/d%C3%A9j%C3%A0-vu-el-ni%C3%B1o-take-two

# * ENSO evolution in 2014/15 and different influences of two types of El Nino on US climate

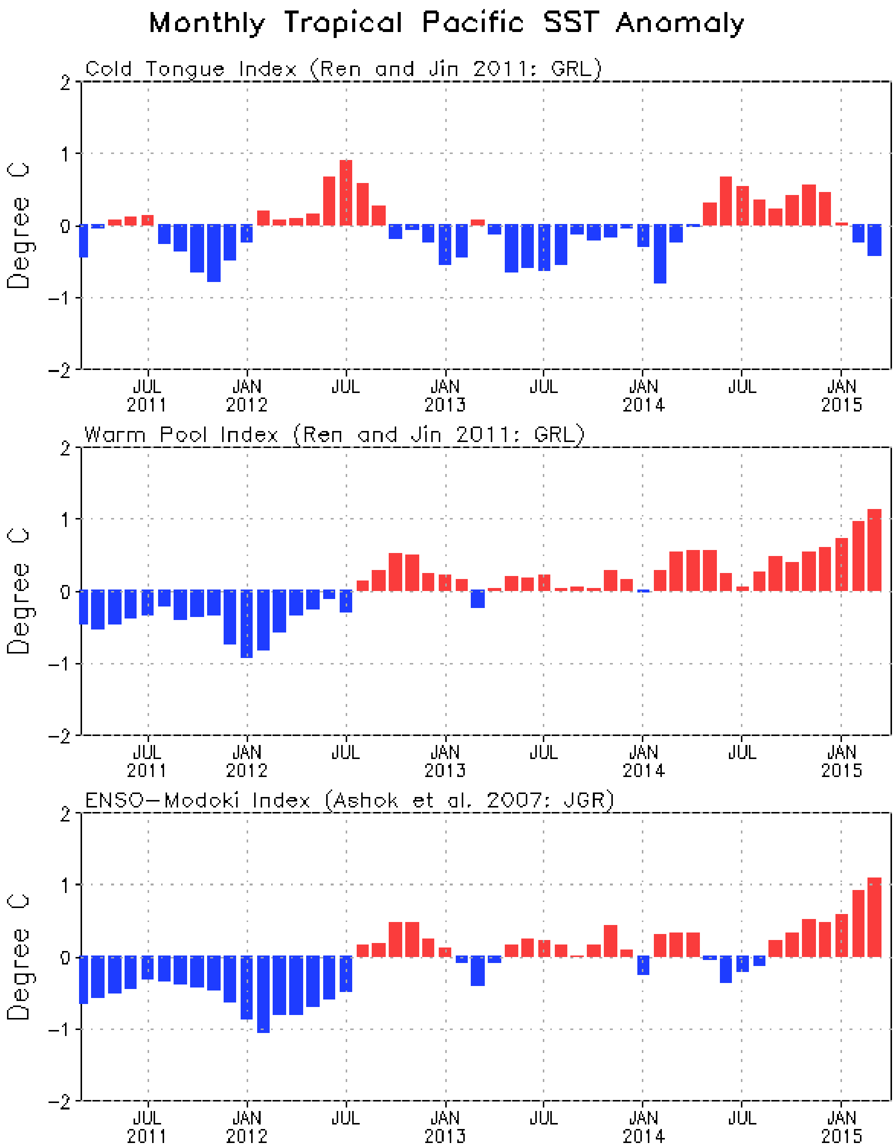
# CPC issued El Niño Advisory in March and April 2015: El Nino conditions were observed and expected to continue.

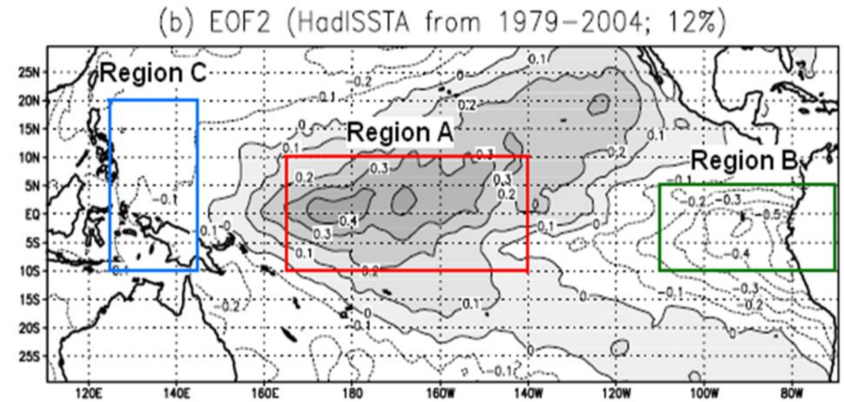
**Oceanic Nino Index (ONI): 3 month running mean of ERSST.v3b SSTAs in the Nino 3.4 region.**
**For historical purposes El Niño and La Niña episodes are defined when the threshold is met for a minimum of 5 consecutive over-lapping seasons.**

| Time | ONI |
|---|---|
| **2014 ASO** | **0.2** |
| *2014 SON* | *0.49* |
| **2014 OND** | **0.65** |
| **2014/2015 NDJ** | **0.67** |
| **2014/2015 DJF** | **0.55** |
| *2015 JFM* | *0.46* |

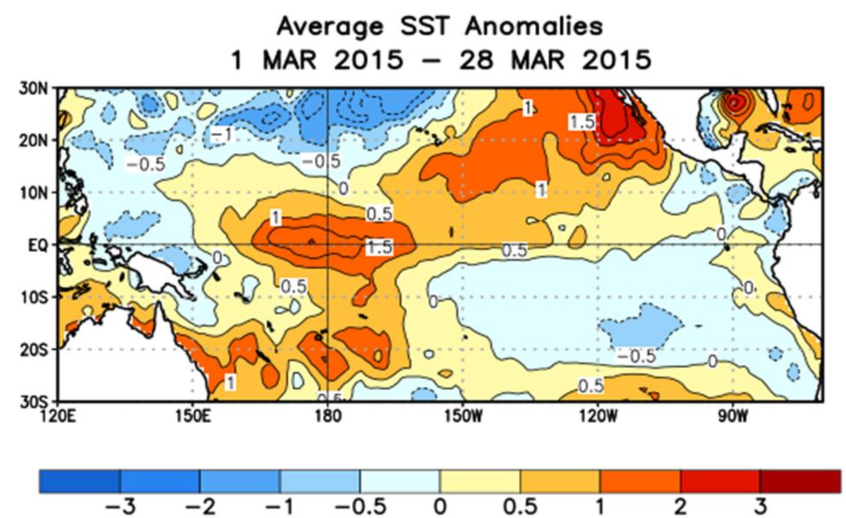
**El Niño conditions: one-month positive SST anomaly of +0.5 (not 0.50) or greater in the Niño-3.4 region and an expectation that the 3-month ONI threshold will be met.**
**La Niña conditions: one-month negative SST anomaly of −0.5 (not -0.50) or less in the Niño-3.4 region and an expectation that the 3-month ONI threshold will be met.**
**AND**
***An atmospheric response* typically associated with El Niño/ La Niña over the equatorial Pacific Ocean.**

# Evolution of Pacific NINO SST Indices



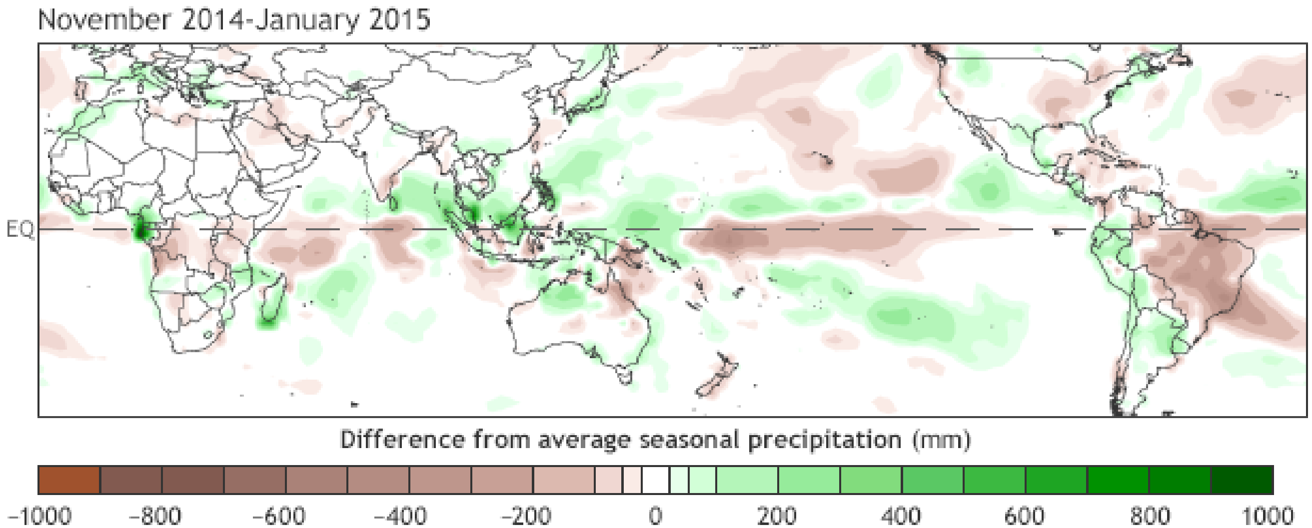



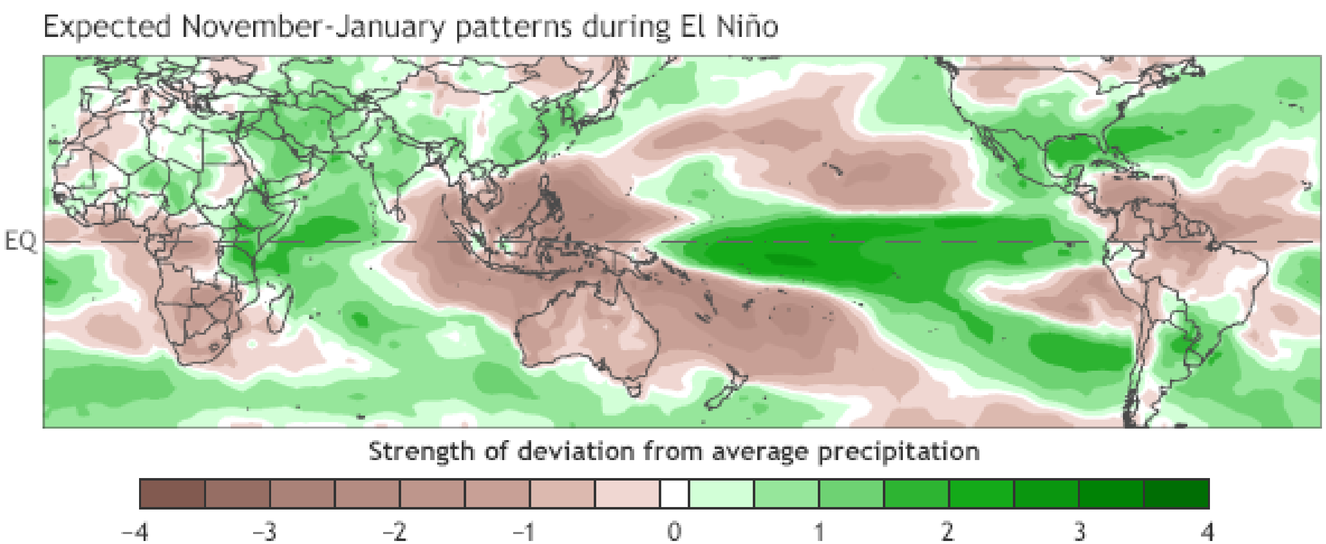

From: http://bobtisdale.blogspot.com/2009/07/comparison-of-el-nino-modoki-index-and.html




- **The SSTA evolution in 2014/15 is more similar to the pattern associated with central Pacific (warm pool) El Nino, or ENSO-Modoki.**

# Do recent global precipitation anomalies resemble those of El Niño (by Anthony Barnston)?



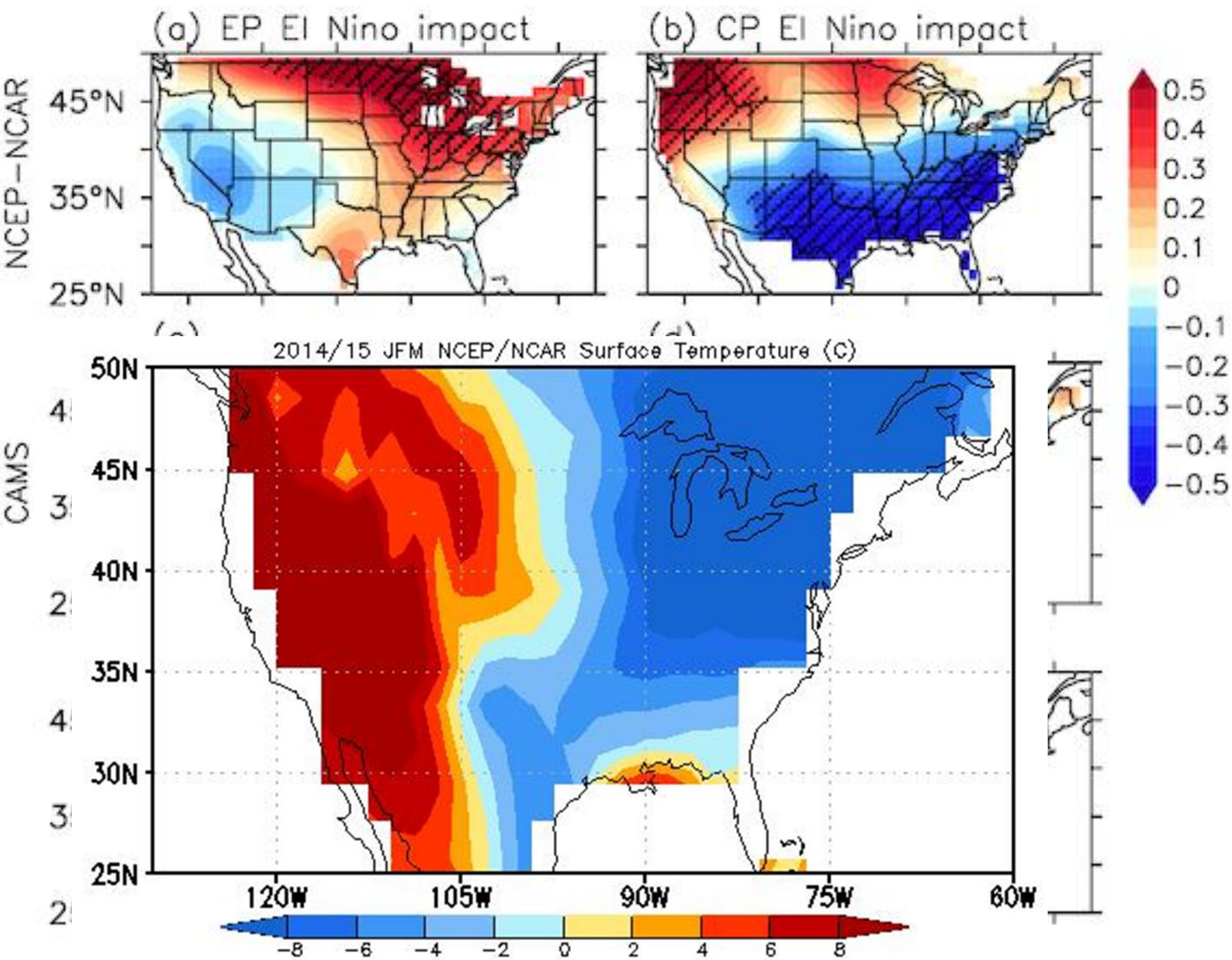

***Barnston said:***

"Bottom Line: So far in 2014-15, we have not seen large-scale precipitation anomalies over the globe (including the United States) that clearly resemble those expected during El Niño."

http://www.climate.gov/news-features/blogs/enso/do-recent-global-precipitation-anomalies-resemble-those-el-ni%C3%B1o

# EP/CP El Niño on US winter temperatures: 1950-2010

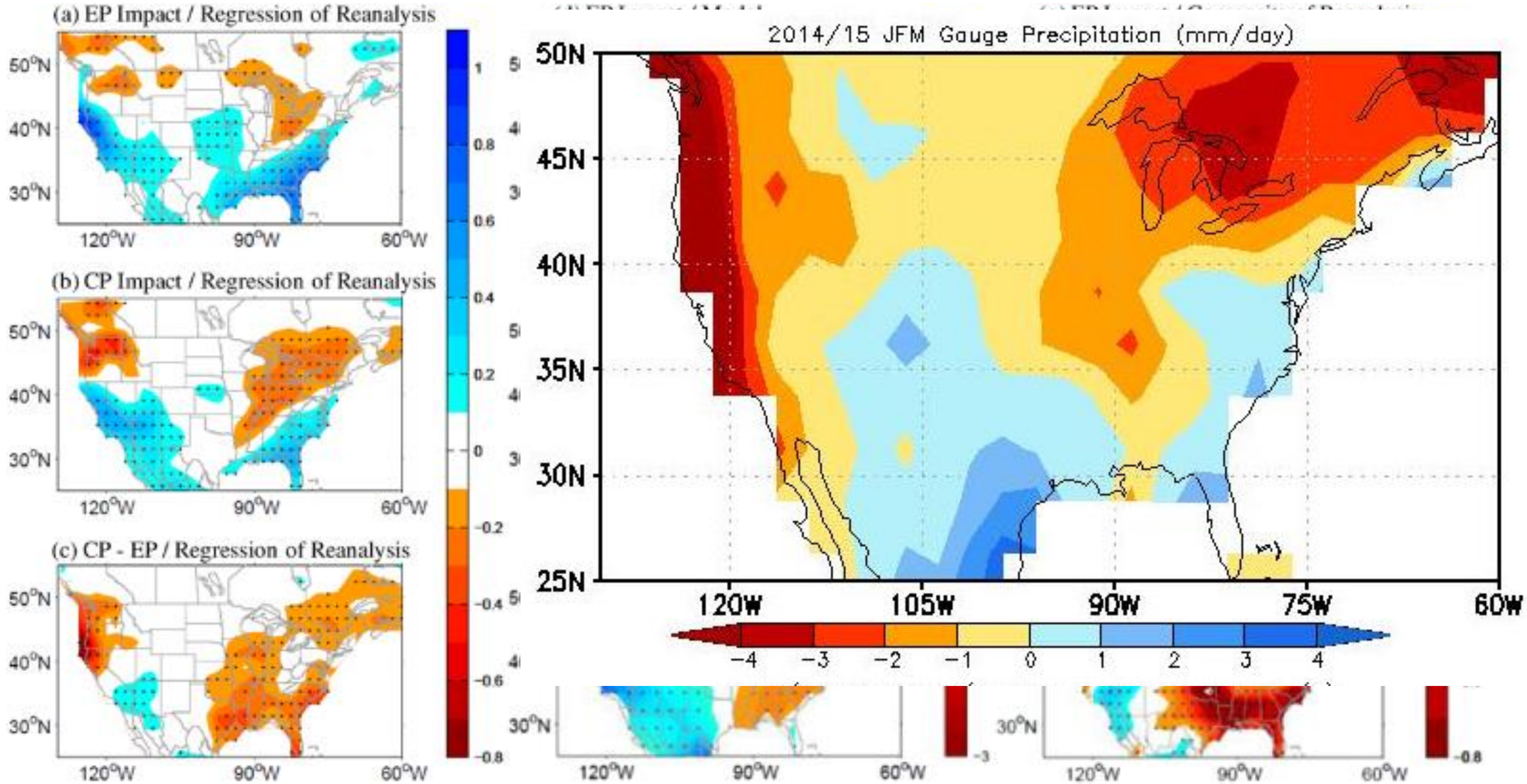
**(Yu, J.-Y., et al. 2012: The changing impact of El Nino on US winter temperatures. GRL 39, L15702)**




Observed US winter (JFM) surface air temperature anomalies regressed onto the (left) EP and (right) CP El Niño indices. Observations correspond to (a, b) the NCEP-NCAR reanalysis and (c, d) the CAMS air temperature data set. Regression coefficients significant at the 90% confidence level based on the student-t test are shaded. (e, f) Schematic diagrams of the EP and CP El Niño impacts on US winter surface air temperatures are also shown.

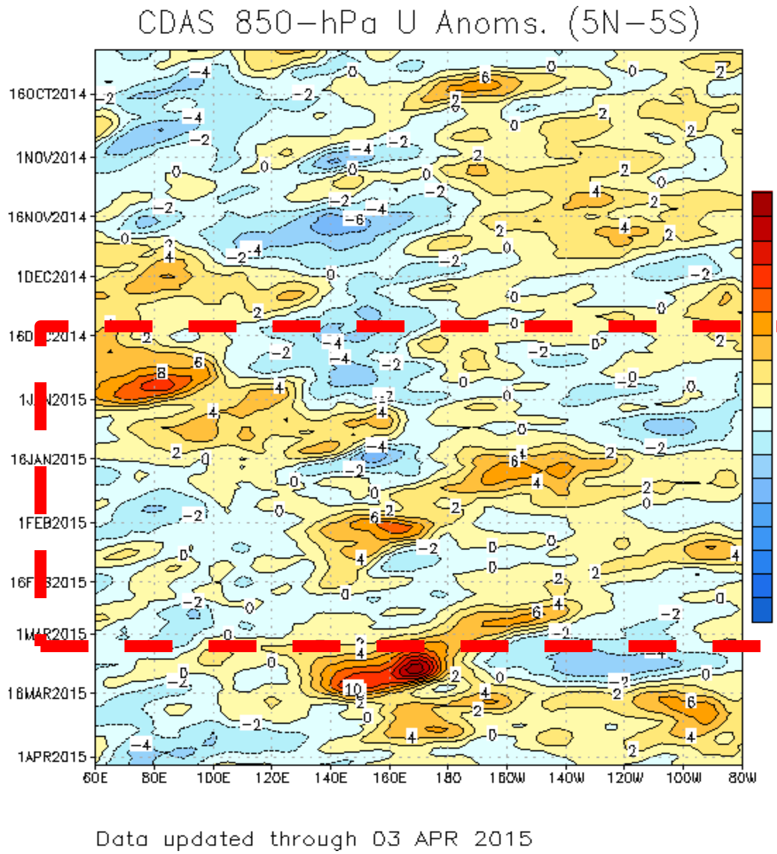
# The enhanced drying effect of CP El Niño on US winter: 1948-2010

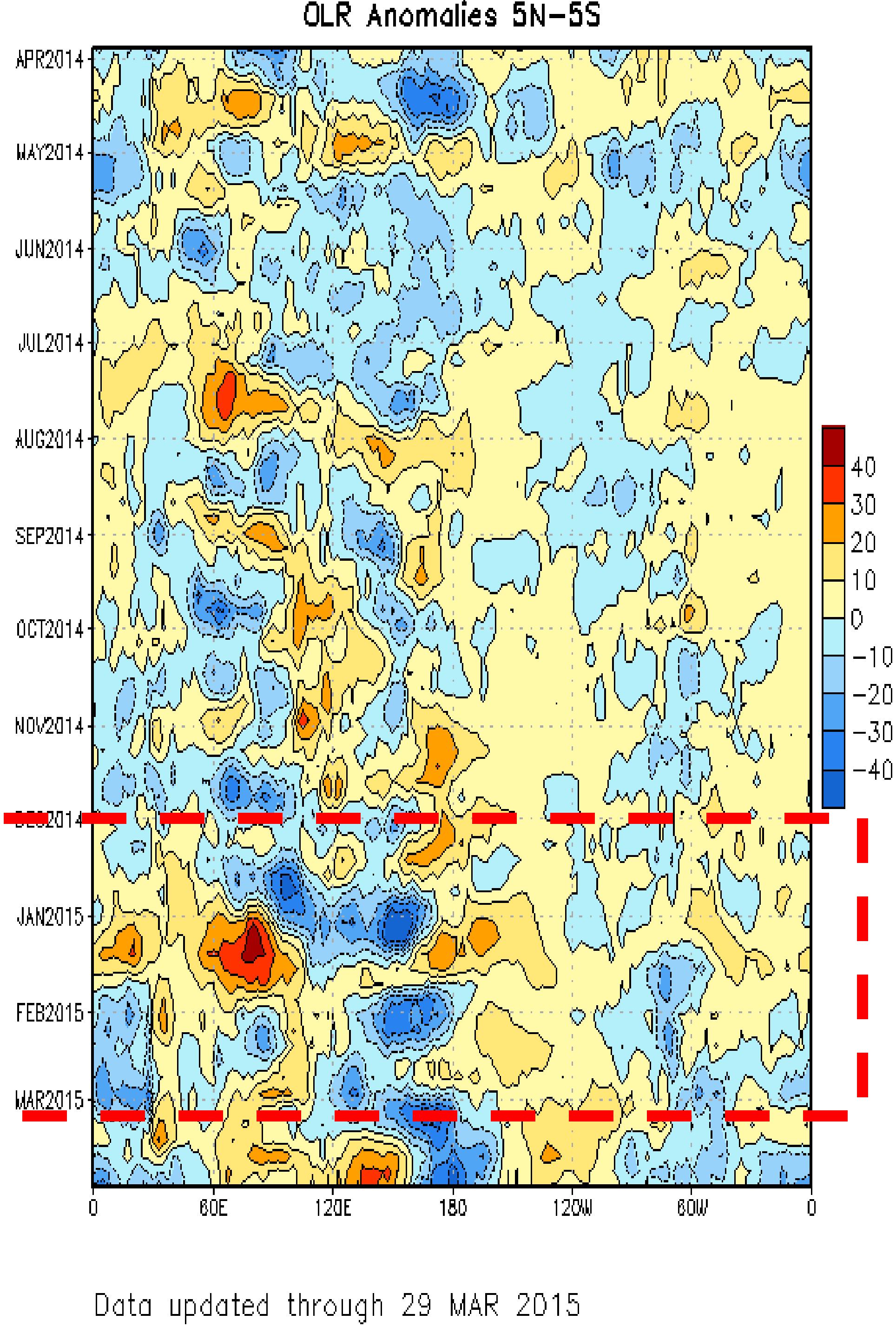
**(Yu, J-Y, Y. Zou 2013: The enhanced drying effect of Central-Pacific El Niño on US winter. *Environ. Res. Lett.* 8)**




US winter (JFM) precipitation anomalies associated with the El Niño are shown in the top panels for the EP El Niño, in the middle panels for the CP El Niño, and in the bottom panels for the difference between the two types of El Niño (i.e., CP impact minus EP impact). The values shown in the left column (a)–(c) are obtained by regressing US winter precipitation anomalies to the EP and El Niño index. The values shown in the second column (d)–(f) are calculated by subtracting the ensemble-mean winter precipitation of the forced AGCM experiments from the ensemble means of the EP and CP runs. The values shown in the right column (g)–(i) are obtained by compositing major EP and CP El Niño events that have occurred since 1950. Values shown are in units of mm/day, and areas passed 90% significance test using a student-t test are hatched.

# No large-scale air-sea coupling happened in the tropical Pacific in winter 2014/15.



# 2014-15 ENSO Evolution

(a) Main warming was in the central Pacific, similar to CP/WP El Nino or ENSO-Modoki;
(b) No significant westerly wind anomaly in the surface was observed in the tropical central Pacific;
(c) Tropical deep convection was more analogue to the composite of La Nina instead of El Nino;
(d) Precipitation and surface temperature in N. America had little similarities between JFM 2015 and El Nino composite.

**Therefore, 2014/15 is at least not a canonical El Nino, *even might not be an El Nino from large-scale air-sea coupling view.***

Why we monitor sea surface salinity (SSS) ?

(possible role of SSS on ENSO prediction)

# Global Sea Surface Salinity (SSS)

## Anomaly for March 2015

Anomaly of fresh water flux, dominated by that of precipitation, is characterized by intensified precipitation over equatorial western Pacific and north eastern Pacific, northward / southward shift of the ITCZ over eastern Pacific / Atlantic and depressed convection over the Indian ocean;

Responding to the fresh water variations, SSS presents negative anomaly over the equatorial western and northeastern Pacific. Zonally lined parallel bands of positive and negative SSS anomalies are observe over the equatorial Atlantic

- Data used

  SSS :

  Blended Analysis of Surface Salinity (BASS) V0.Y

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

  (Xie et al. 2014)

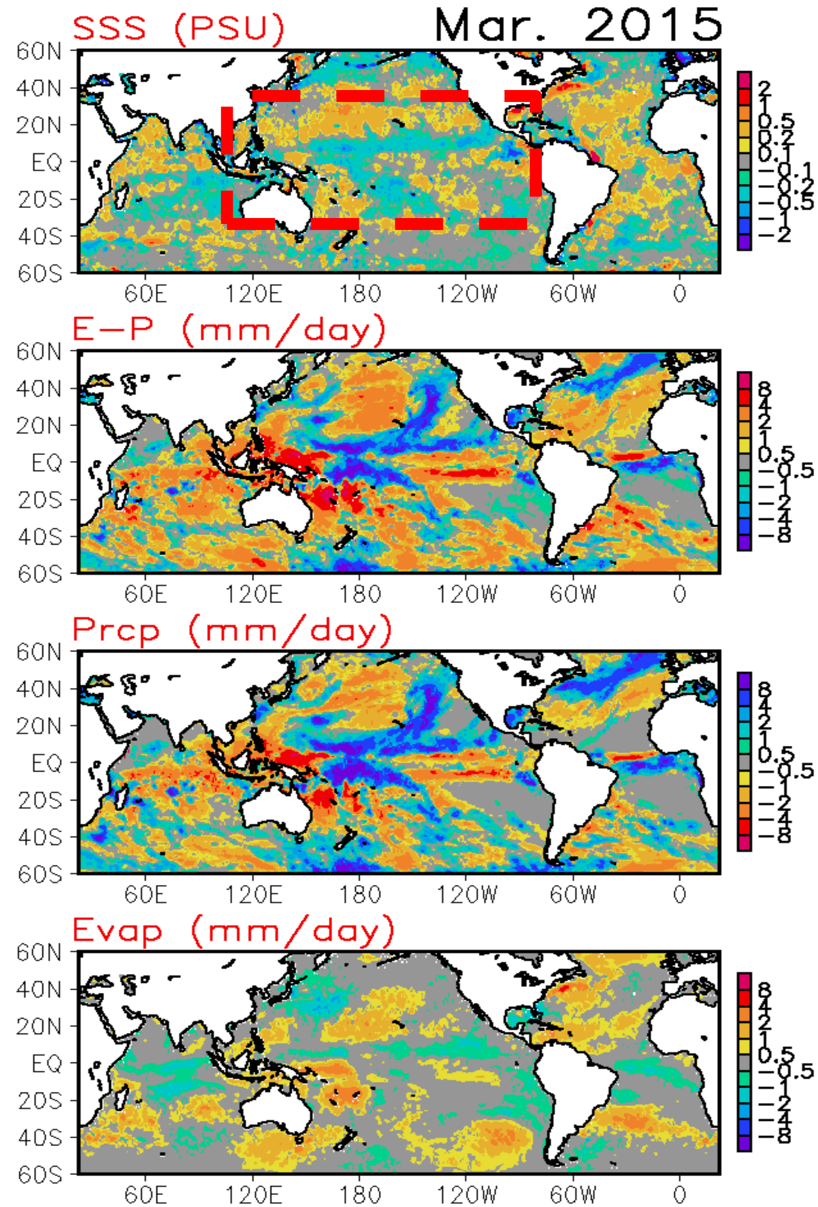
  [ftp.cpc.ncep.noaa.gov/precip/BASS](ftp.cpc.ncep.noaa.gov/precip/BASS)

  Precipitation:

  CMORPH adjusted satellite precipitation estimates

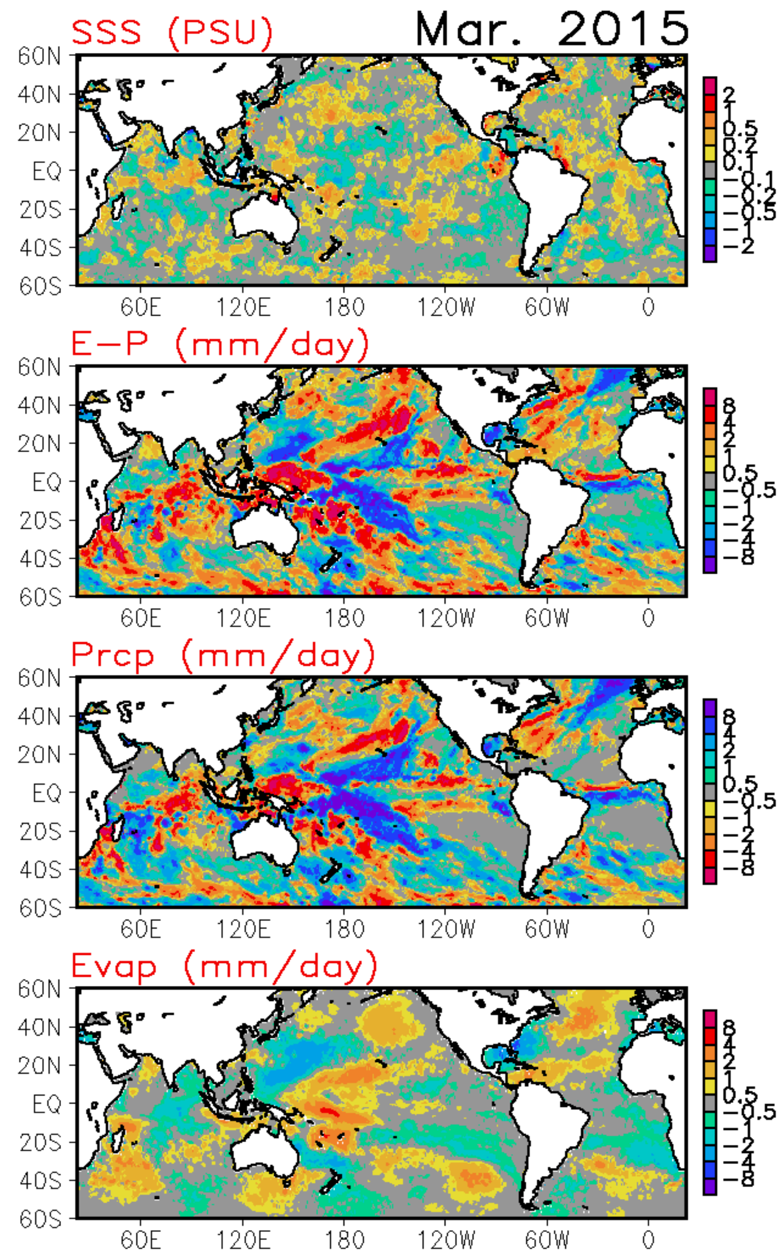
  Evaporation:

  CFS Reanalysis



# Global Sea Surface Salinity (SSS)

## Tendency for March 2015



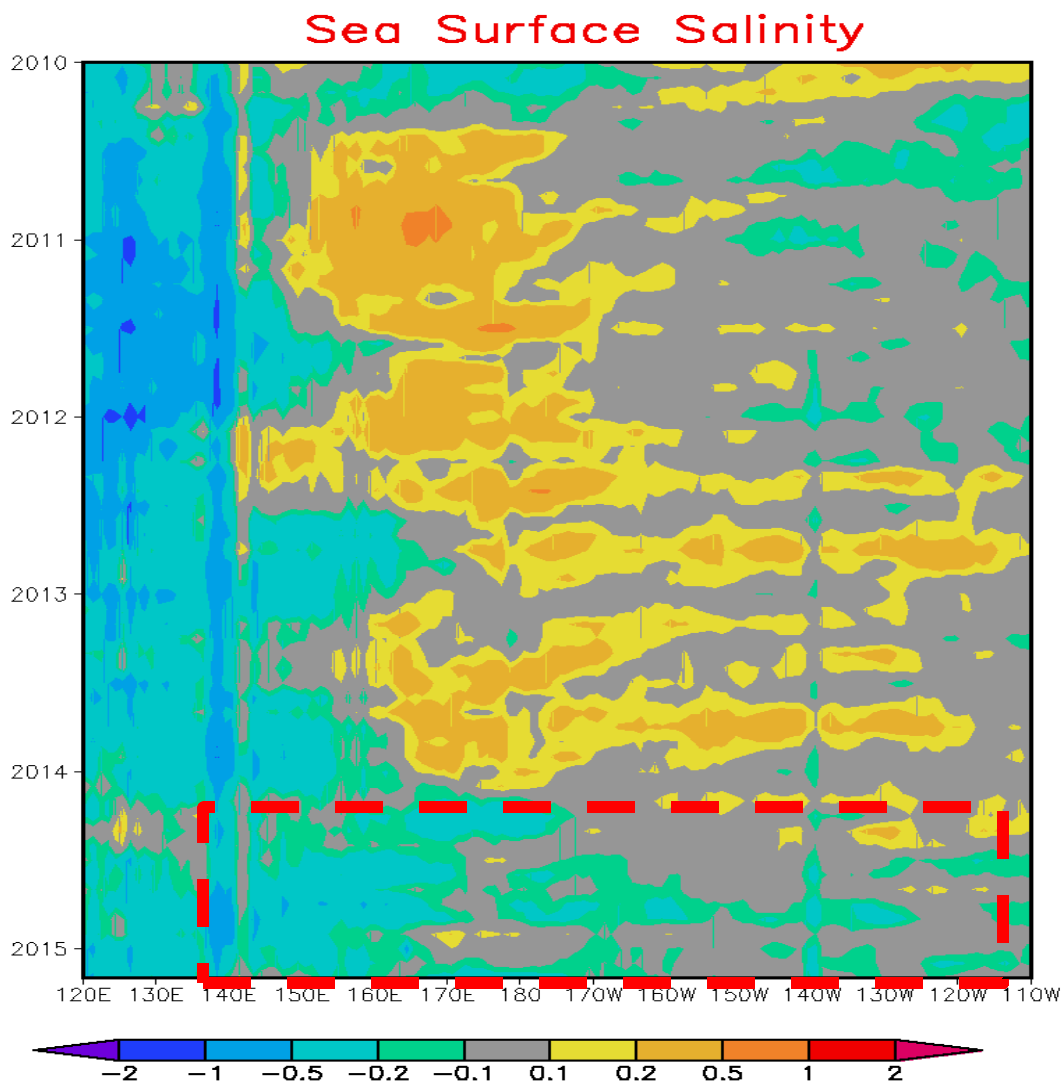

- SSS anomaly becomes fresher over the equatorial western Pacific where enhanced convection generated above-than-normal;

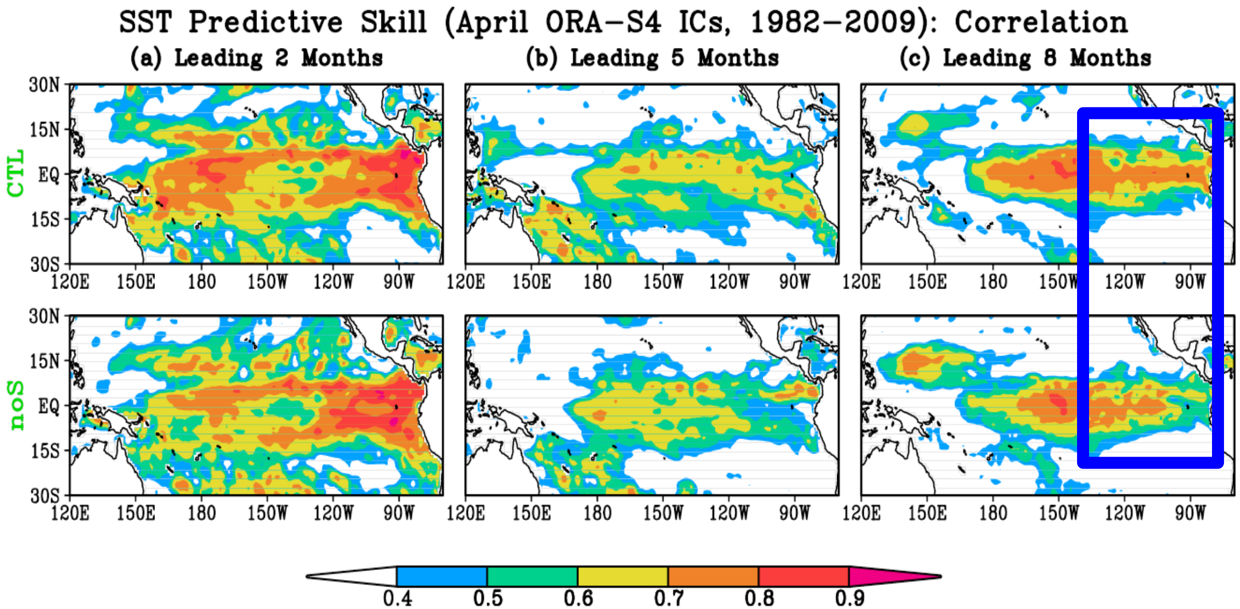
- Positive SSS anomalies are also noticed over the coastal regions off the northern coast of the South America, possibly attributable to the changes in the river runoffs there;

# Global Sea Surface Salinity (SSS)

## Anomaly Evolution over Equatorial Pacific

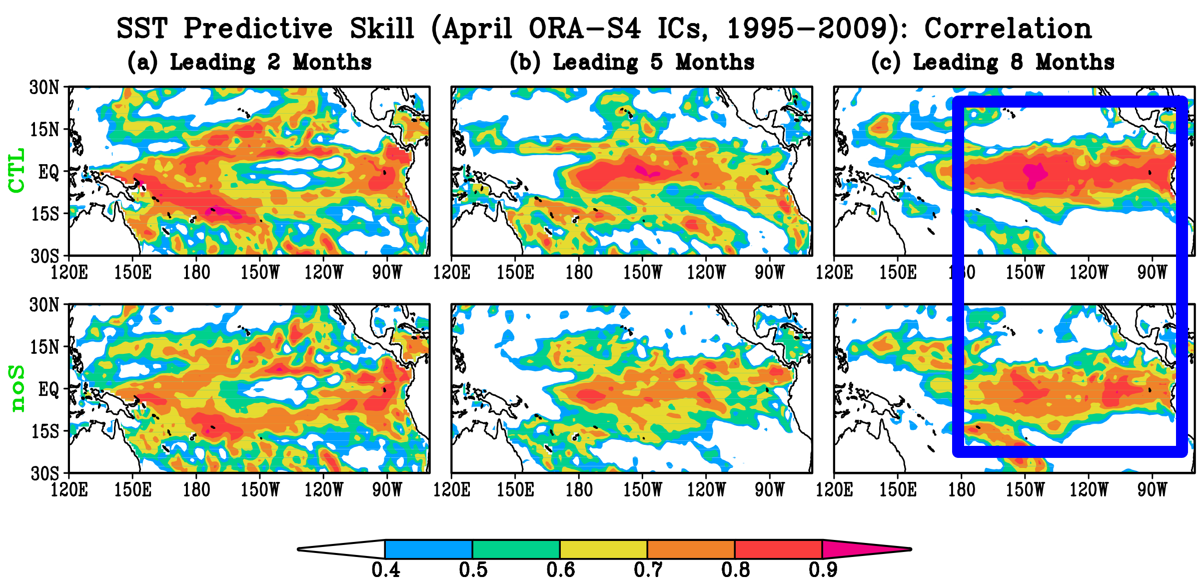
- Hovemoller diagram for equatorial SSS anomaly **(10ºS-10ºN);**
- Negative SSS anomaly enhanced in recent months over the equatorial western and central Pacific;
- In March 2015, the negative anomaly averaged over the equatorial belt reached east the date line, to ~160ºW;





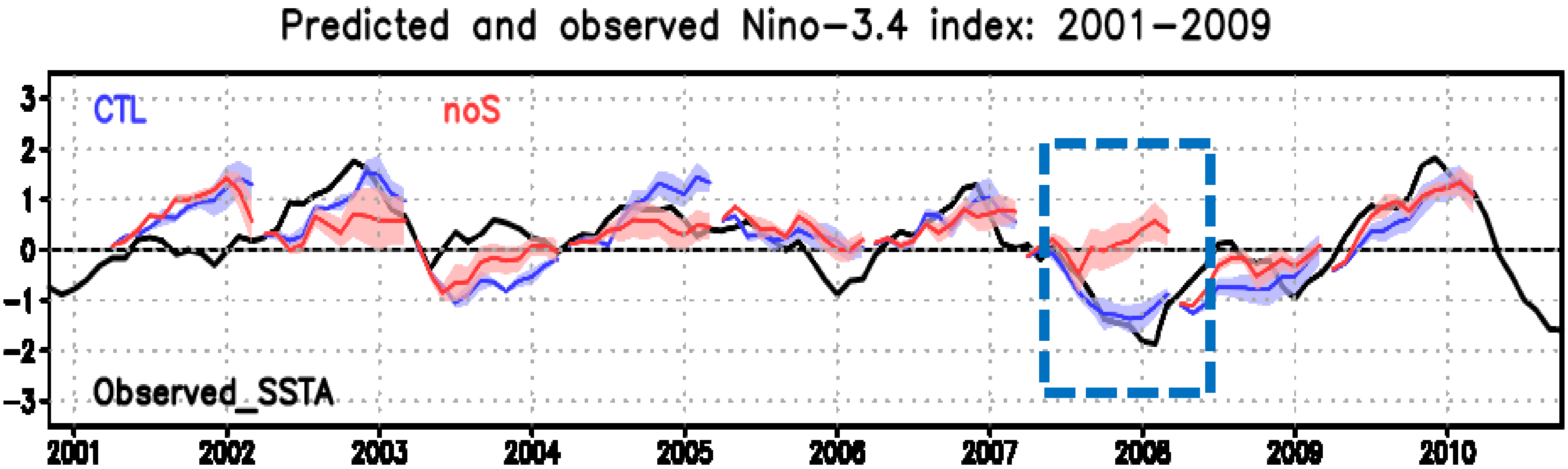

# 1982-2009

1) 1982-2009: Exp. noS degrades SSTA prediction in the eastern Pacific.
(2) 1995-2009: Exp. noS clearly degrades SSTA prediction in the whole tropical Pacific.




# 1995-2009

*Zhu, J., B. Huang, R.-H. Zhang, Z.-Z. Hu, A. Kumar, M. A. Balmaseda, and J. L. Kinter III, 2014: Salinity anomaly as a trigger for ENSO events. Scientific Reports* , 4. doi: 10.1038/srep06821.

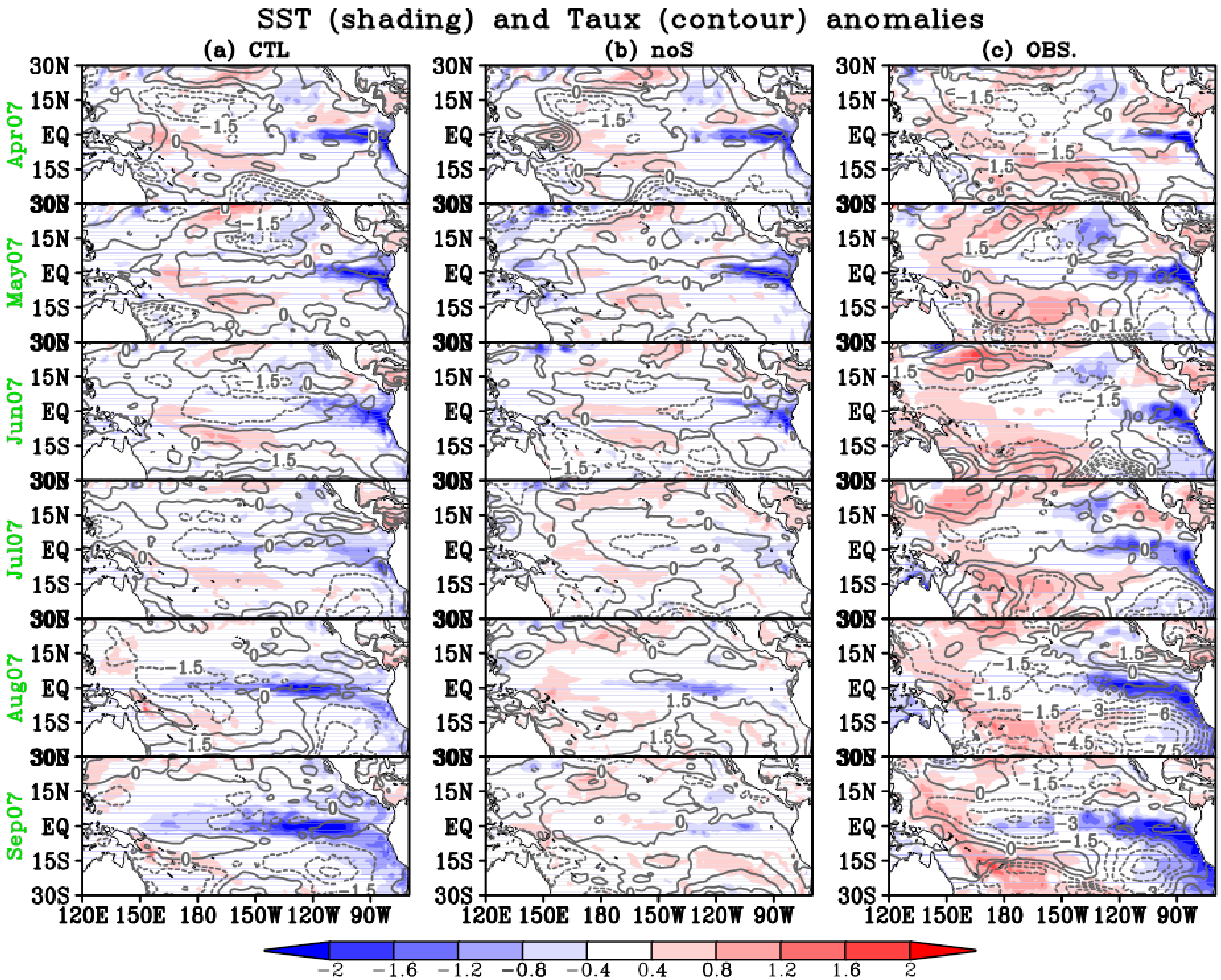



**Niño-3.4 SSTAs (C) for the period 2001-2010 .** SSTAs are shown in black, blue, and red curves for observations, CTL and noS, respectively. For forecasts, solid curves (shaded areas) represent the ensemble mean (ensemble spread).

**Observed salinity anomaly included in IC better predicts 2007 La Nina; but the effect is small for other ENSO years.**

With realistic salinity ICs, the tendency to decay of the subsurface cold condition during the spring and early summer 2007 was interrupted by the positive salinity anomalies in the upper central Pacific, which works together with the Bjerknes positive feedback and contributes to the development of the La Niña event.

***Zhu, J., B. Huang, R.-H. Zhang, Z.-Z. Hu, A. Kumar, M. A. Balmaseda, and J. L. Kinter III, 2014: Salinity anomaly as a trigger for ENSO events. Scientific Reports*** **, 4. doi: 10.1038/srep06821.**

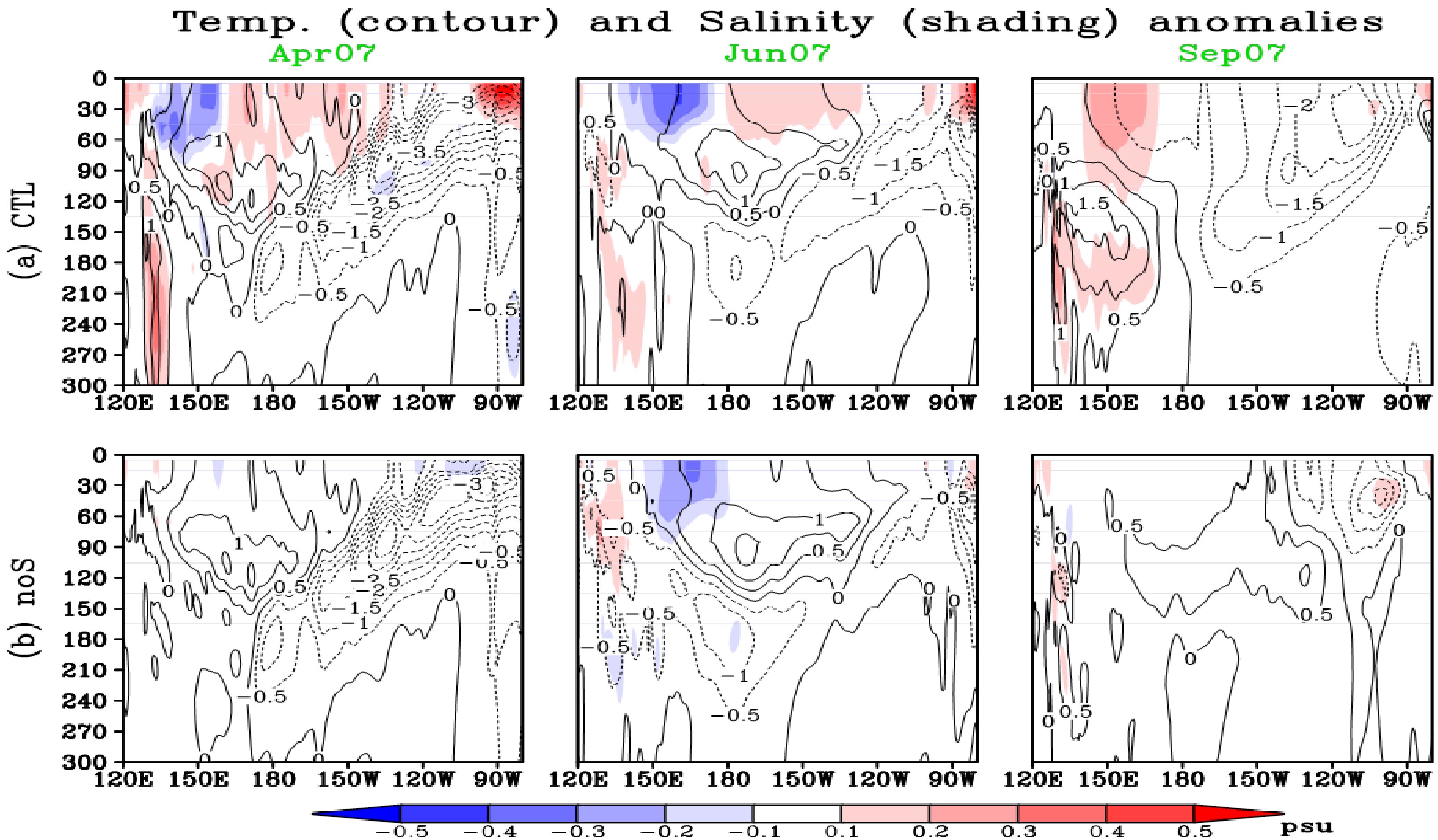



**Observed salinity anomaly included in IC better predicts 2007 La Nina:**

SST (shading, C) and zonal wind stress (contour, dyn cm-2) anomalies in (a) CTL, (b) noS, and (c) observations, with Apr-Sep 2007 shown from the most upper to the lowest row.

*Zhu, J., B. Huang, R.-H. Zhang, Z.-Z. Hu, A. Kumar, M. A. Balmaseda, and J. L. Kinter III, 2014: Salinity anomaly as a trigger for ENSO events. Scientific Reports* **, 4. doi: 10.1038/srep06821.**

# Salinity anomalies in the central-eastern Pacific are important, which destabilize the upper layer and increase the vertical mixing, cooling the upper layer




**Longitude-depth sections of anomaly fields.** Ocean temperature anomalies (contour, $^{o}$C) and salinity anomalies (shading, psu) along the equator (averaging over 2$^{o}$S-2$^{o}$N) in **(a)** CTL and **(b)** noS during Apr, Jun, &Sep b2007.

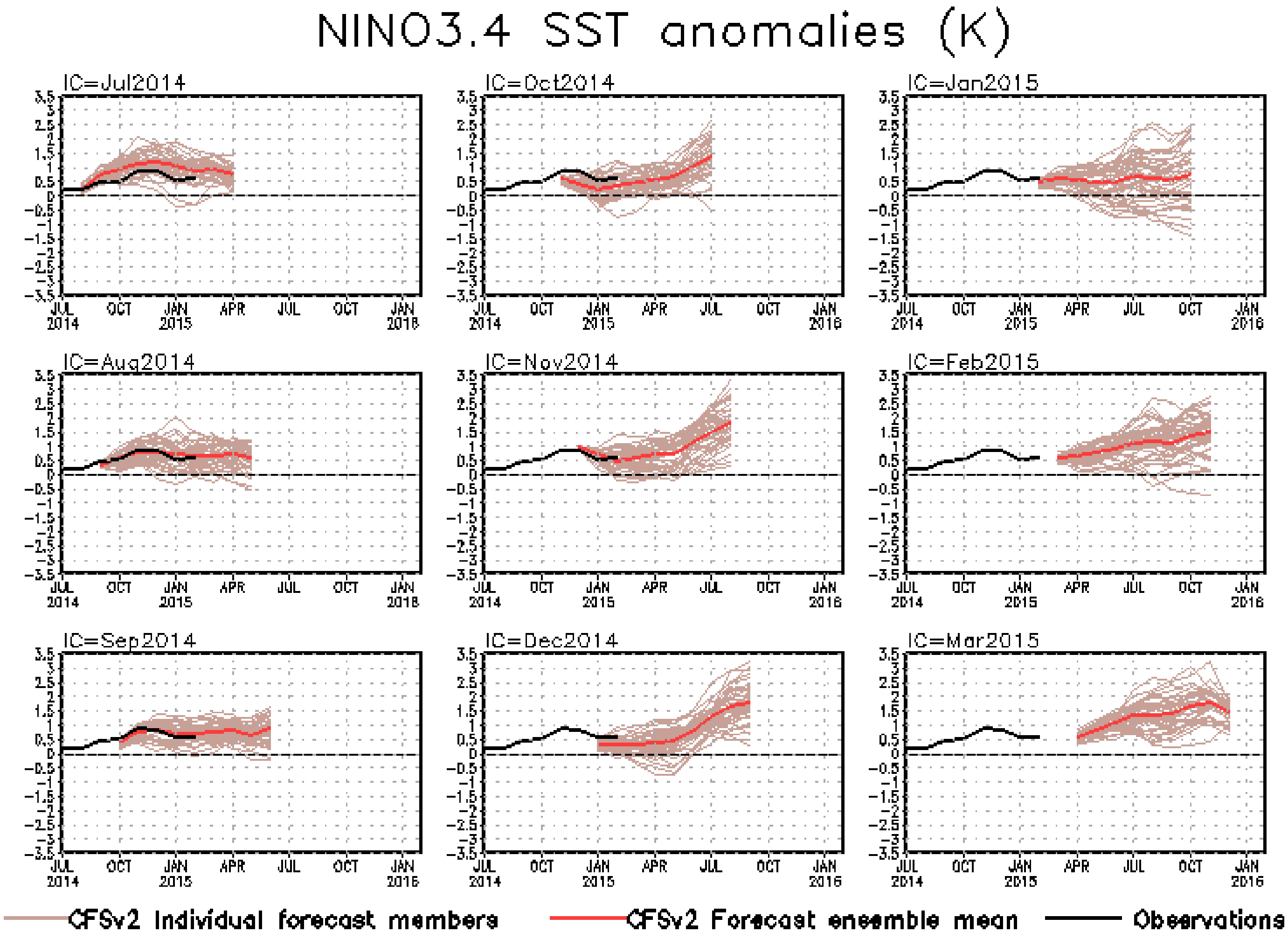
***Zhu, J., B. Huang, R.-H. Zhang, Z.-Z. Hu, A. Kumar, M. A. Balmaseda, and J. L. Kinter III, 2014: Salinity anomaly as a trigger for ENSO events. Scientific Reports*** **, 4. doi: 10.1038/srep06821.**

# Overview

- **Pacific Ocean**
  - NOAA "ENSO Diagnostic Discussion" on 09 Apr 2015 suggested "There is an approximately 70% chance that El Niño will continue through Northern Hemisphere summer 2015, and a greater than 60% chance it will last through autumn."
  - Positive SSTAs were observed in the central tropical Pacific with NINO3.4=0.6$^{o}$C in Mar 2015.
  - Positive anomalies of subsurface ocean temperature along the equator strengthened and had little propagation in Mar 2015.
  - Majority of dynamical models predicted a warming tendency (El Nino) in 2015, but majority of statistical models favor ENSO neutral in 2015.
  - Positive phase of PDO has persisted for 9 months, with PDOI=1.5 in Mar 2015.
- **Indian Ocean**
  - Positive SSTAs were in the southeast Indian Ocean.
- **Atlantic Ocean**
  - Positive phase of NAO has persisted for 5 months with NAOI=1.1 in Mar 2015, causing a horseshoe-like pattern of SSTA in N. Atlantic.

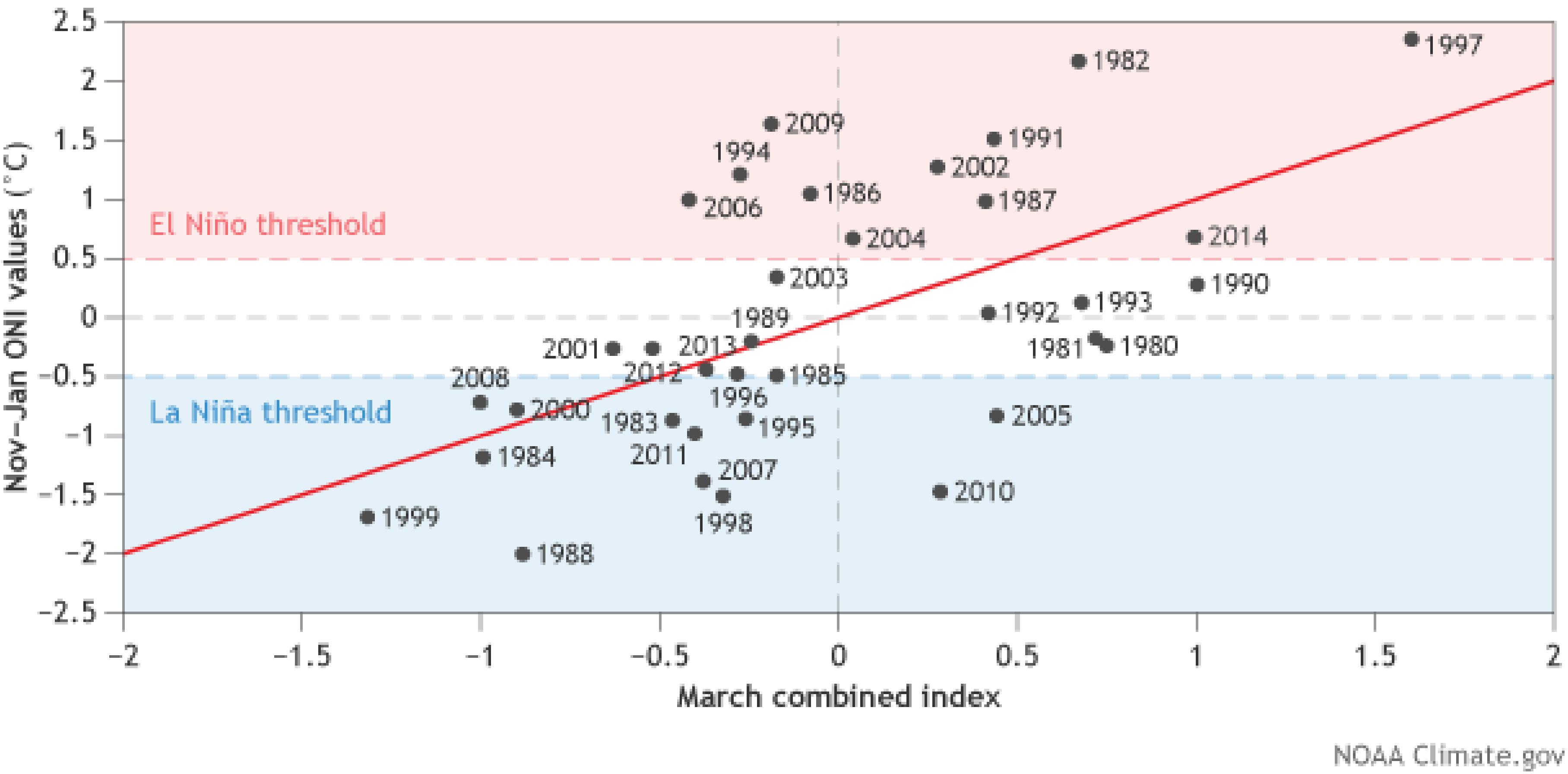
# Backup Slides

## CFS Niño3.4 SST Predictions from Different Initial Months




**- CFSv2 predicts a warming tendency, and suggests development of a El Nino in 2015.**

**Fig. M1. CFS Nino3.4 SST prediction 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). Anomalies were computed with respect to the 1981-2010 base period means.**




## Prediction skill with IC in Mar:

The western Pacific winds and subsurface temperatures in the eastern half of the tropical Pacific Ocean for Mar – explain only about a quarter to a third (~25-33%) of the coming winter ENSO state.

Michelle L'Heureux: **Déjà Vu: El Niño Take Two.**
http://www.climate.gov/news-features/blogs/enso/d%C3%A9j%C3%A0-vu-el-ni%C3%B1o-take-two

# Warm Water Volume (WWV) and NINO3.4 Anomalies

- **WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N].** **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.**

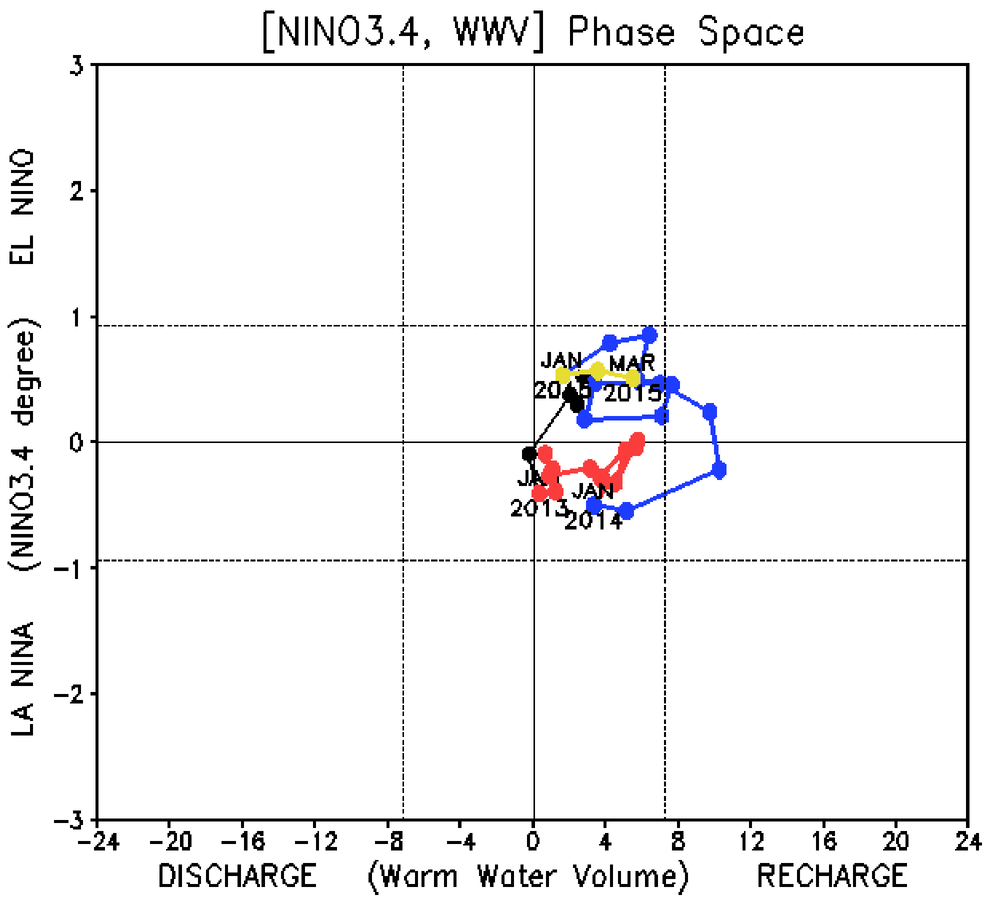
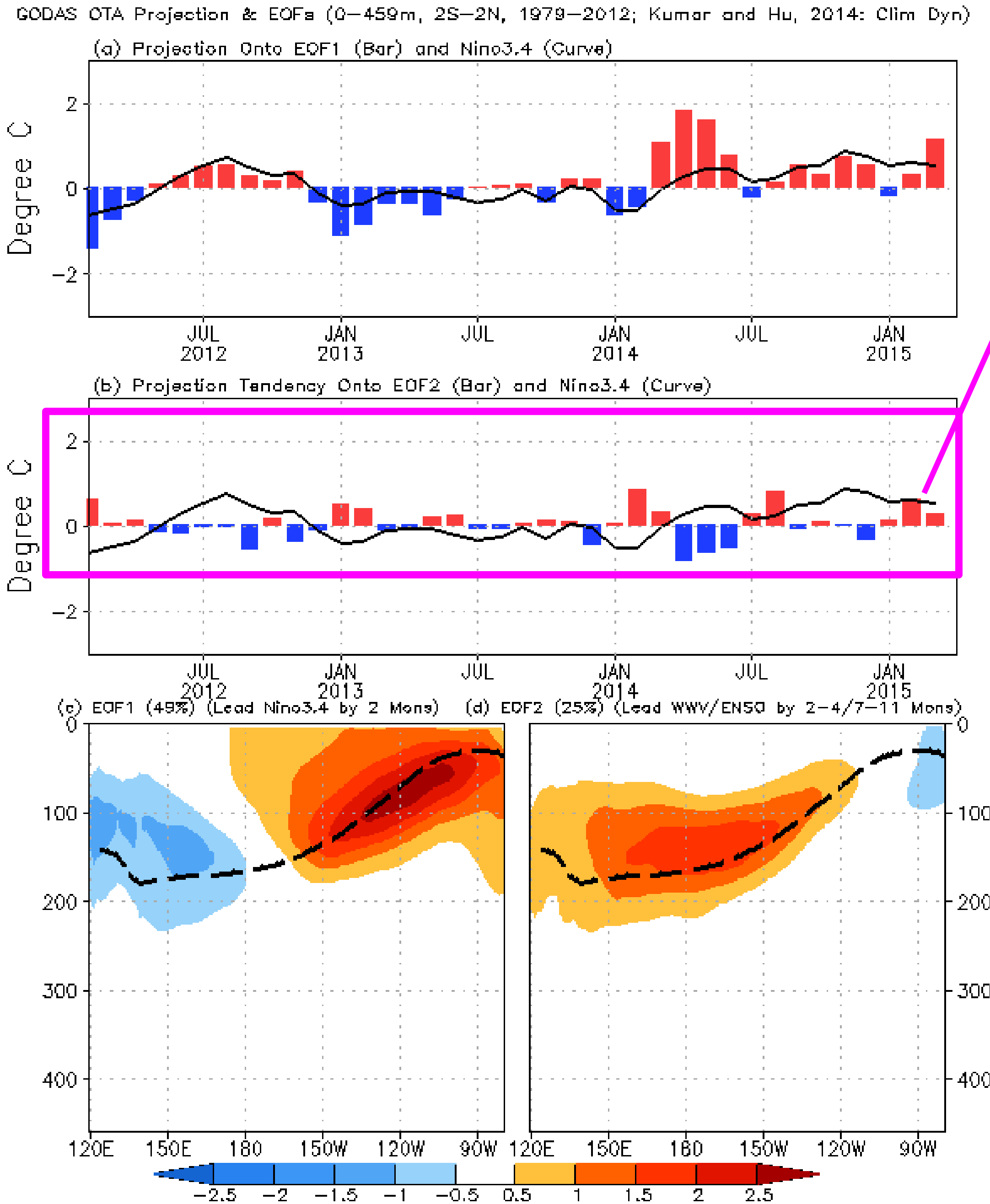



**Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.**




**Equatorial subsurface ocean temperature monitoring: Right now, it was in recharge phase; Overall recharge/discharge were weak in last 2-3 years.**

**Projection of OTA onto EOF1 and EOF2 (2S-2N, 0-459m, 1979-2010)**

**EOF1: Tilt mode (ENSO peak phase);**

**EOF2: WWV mode, Recharge/discharge oscillation (ENSO transition phase).**

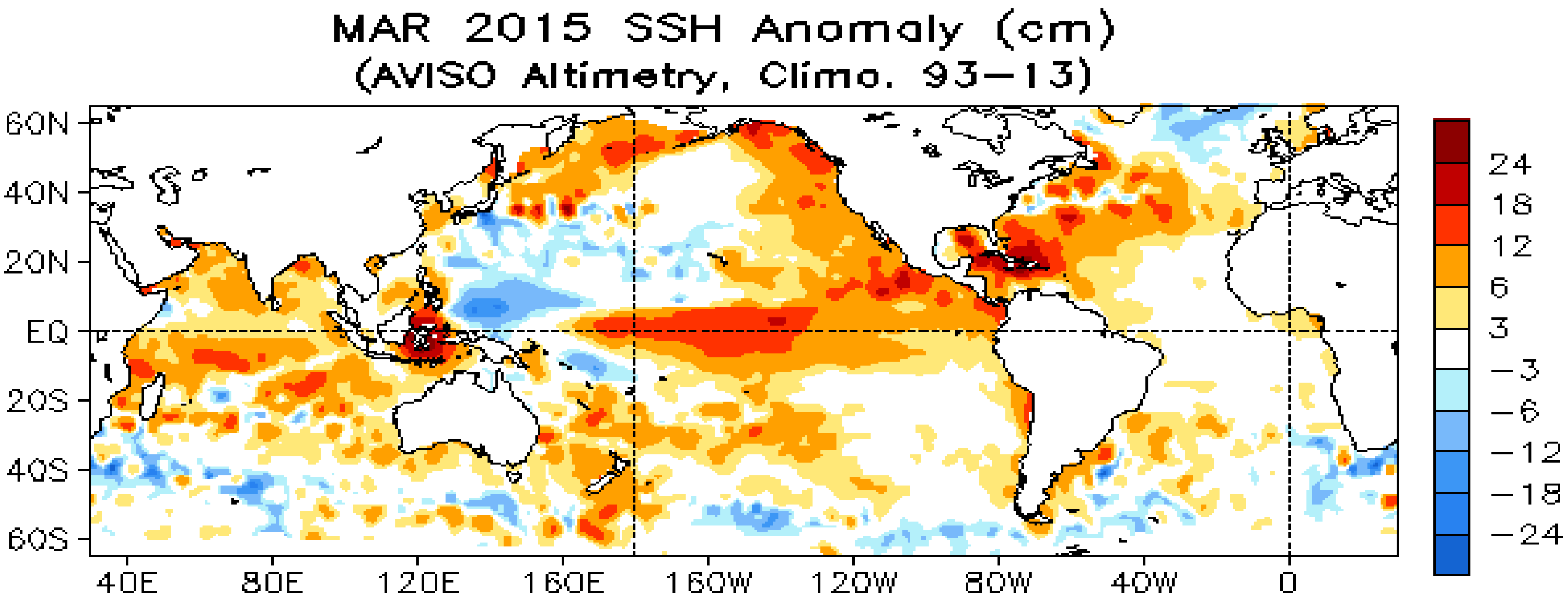
**Recharge process: heat transport from outside of equator to equator : Negative -> positive phase of ENSO**

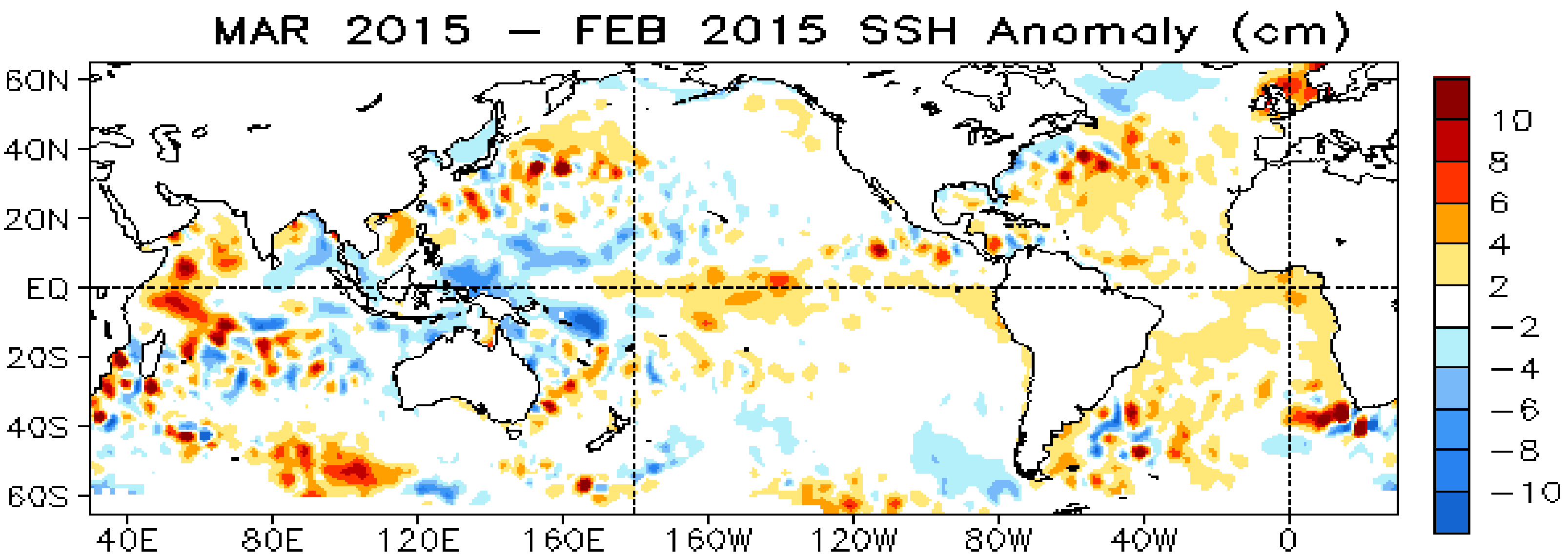
**Discharge process: heat transport from equator to outside of equator: Positive -> Negative phase of ENSO**

For details, see:

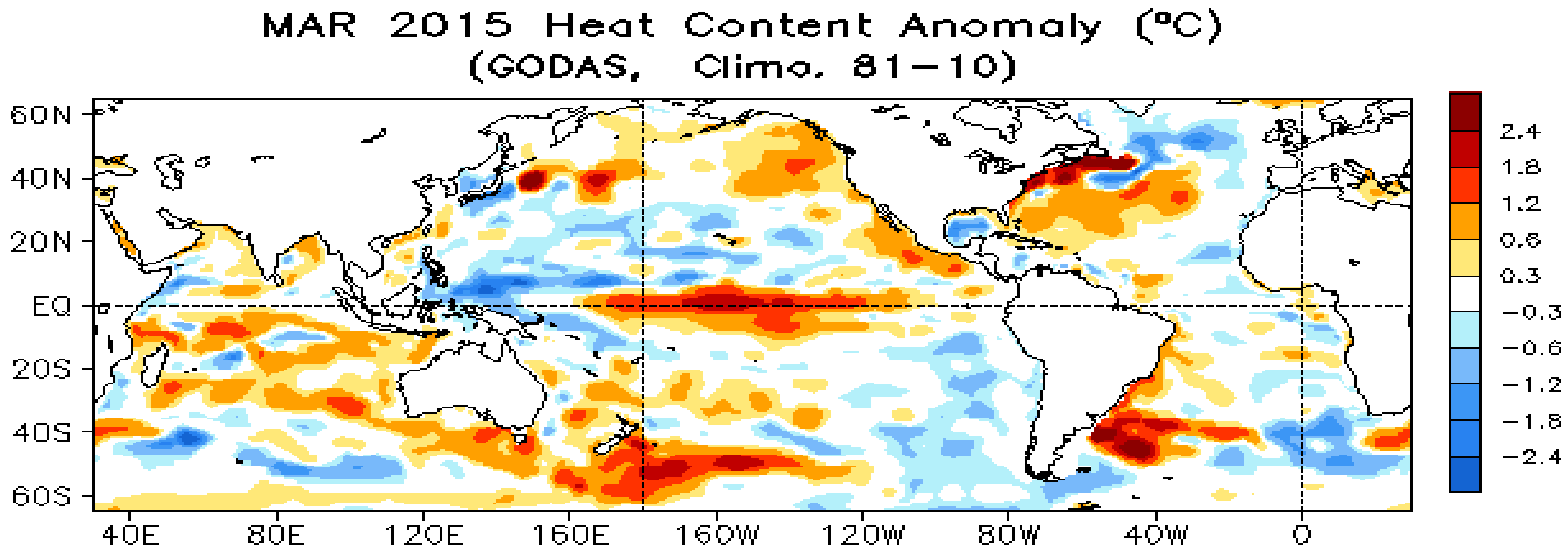
*Kumar A, Z-Z Hu (2014) Interannual and interdecadal variability of ocean temperature along the equatorial Pacific in conjunction with ENSO. Clim. Dyn.,* 42 (5-6), **1243-1258.** *DOI: 10.1007/s00382-013-1721-0*.

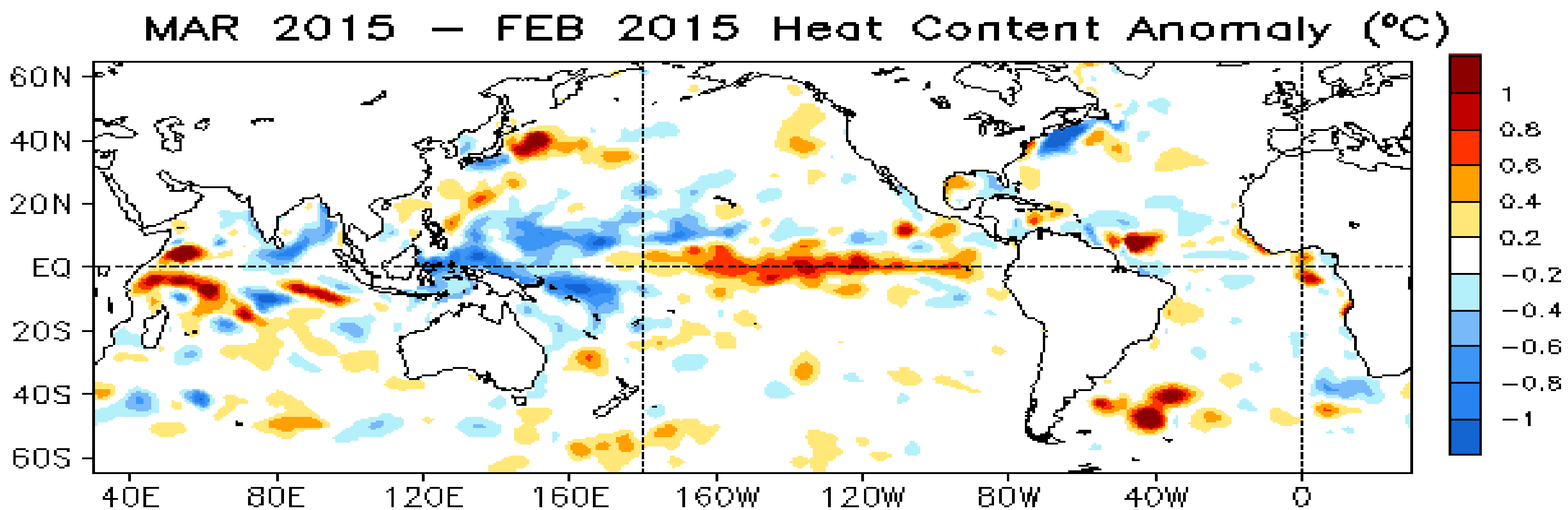
# Global SSH Anomaly (cm) and Anomaly Tendency

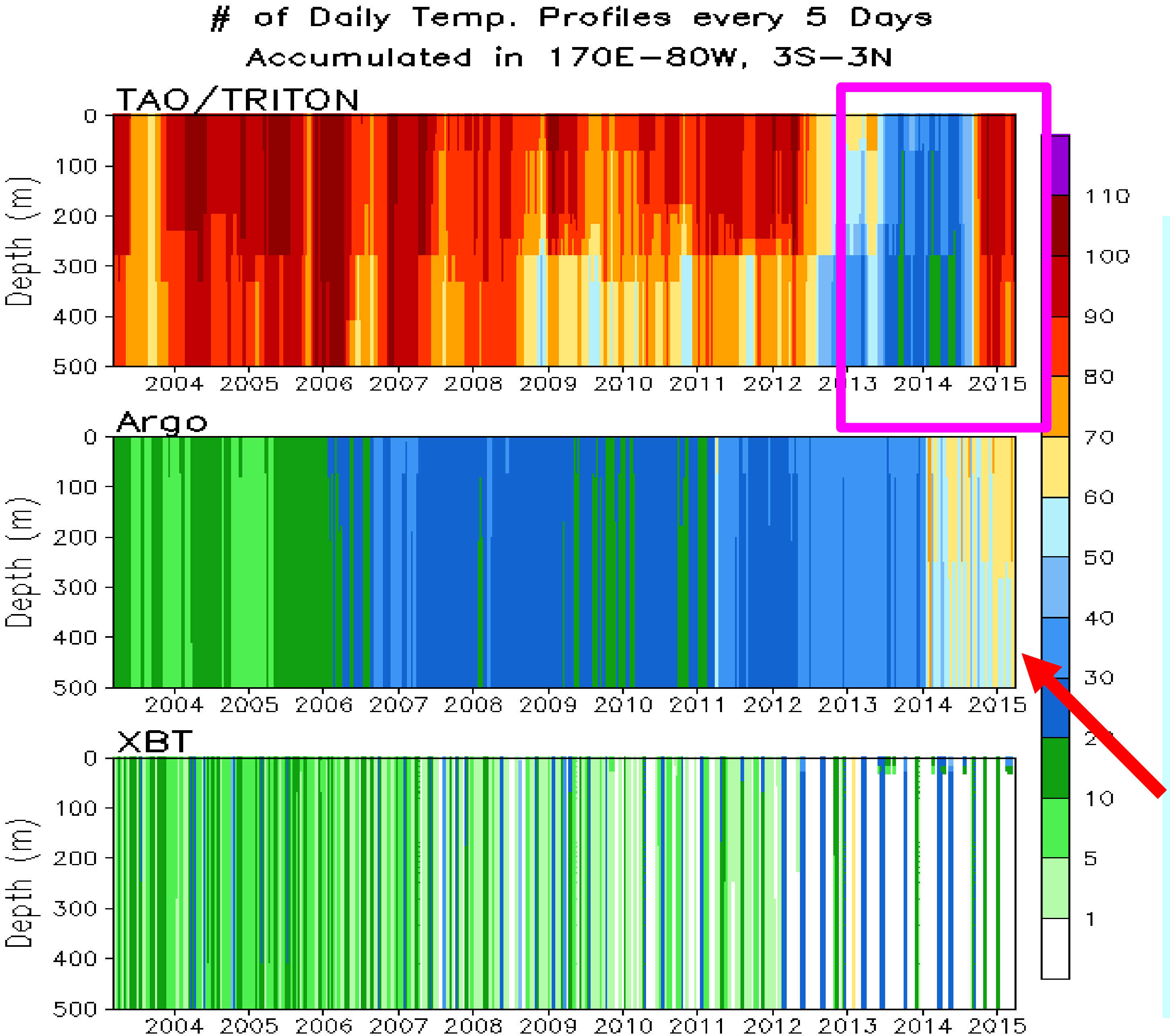


# Global HC Anomaly (cm/°C ) and Anomaly Tendency



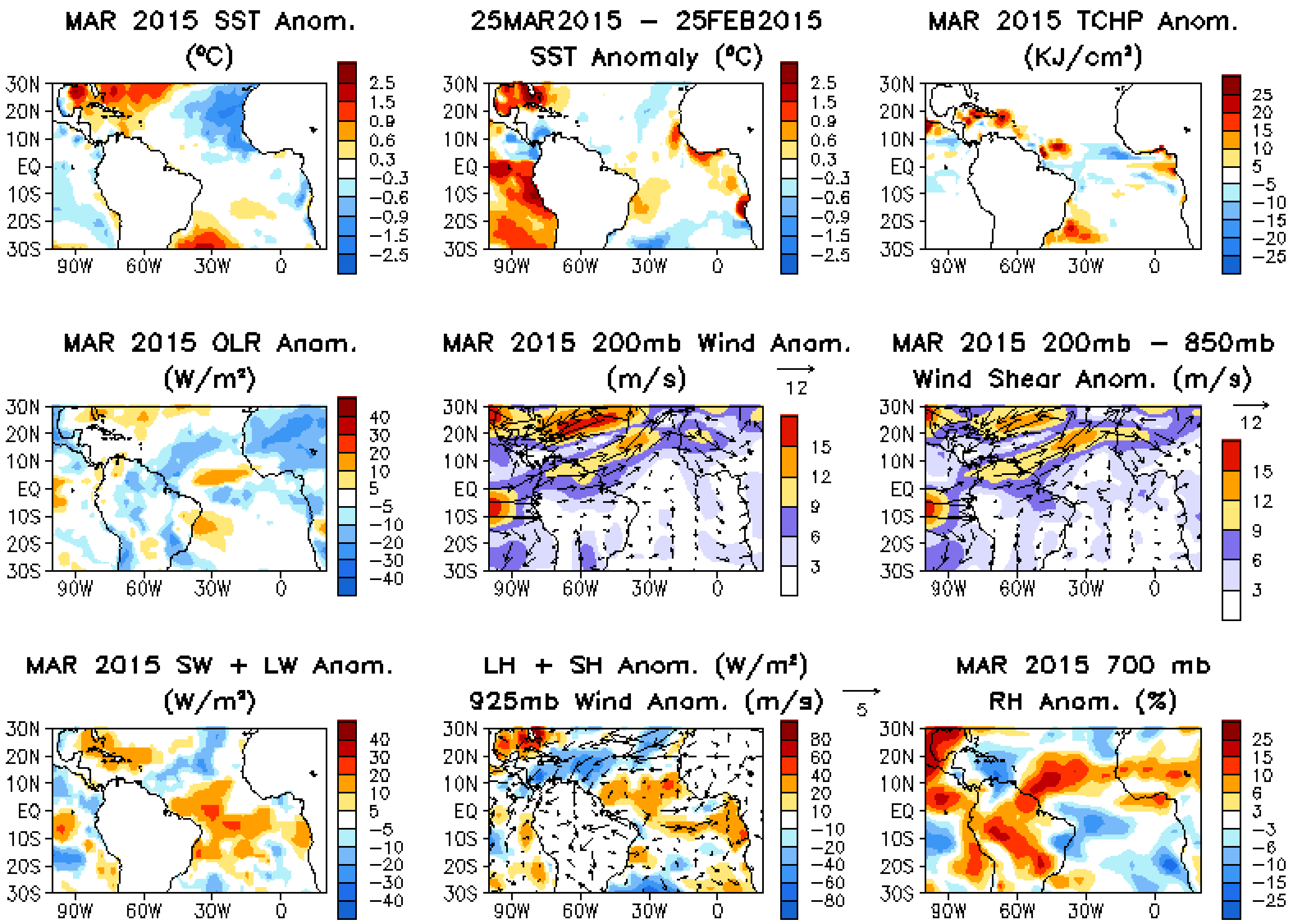





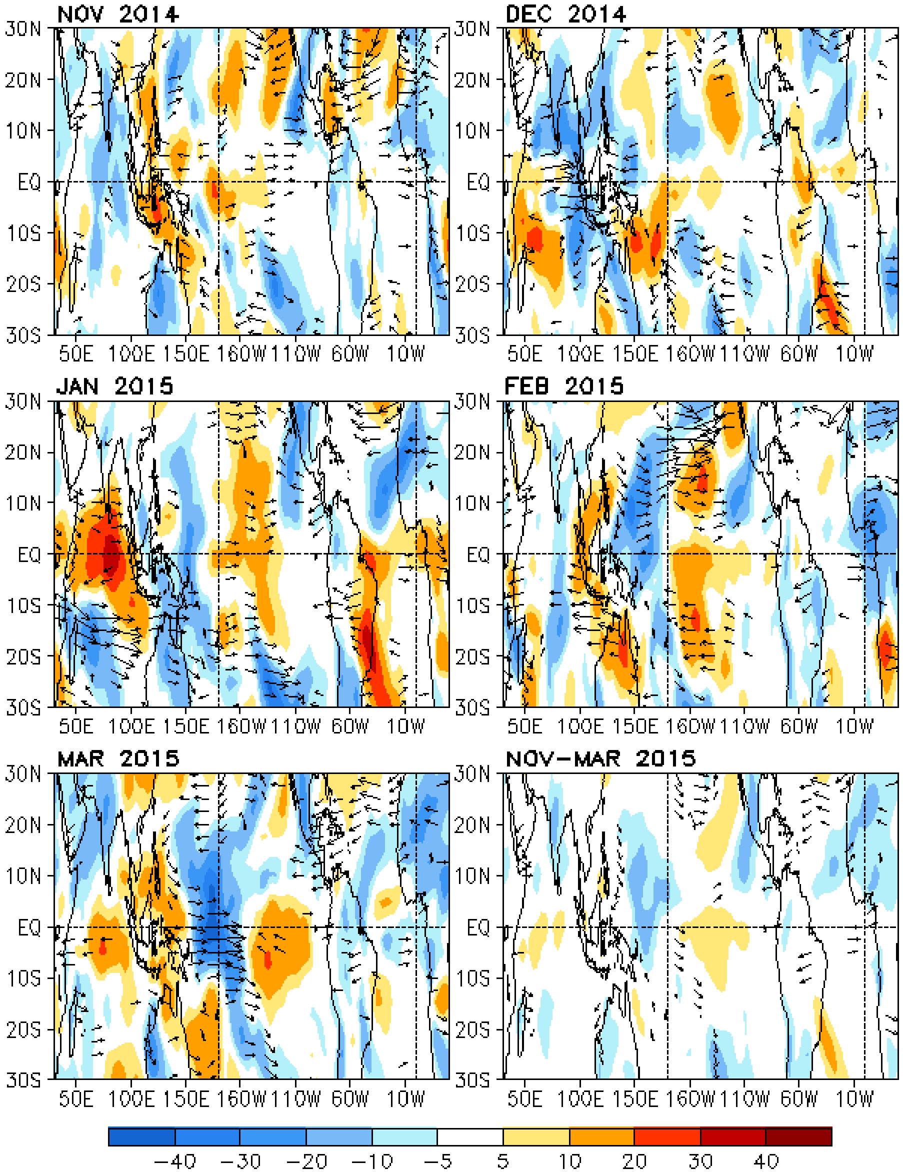

**- TAO data delivery rate decreased significantly during late 2012 to mid-2014, and largely recovered since late 2014.**

**- There was a sharp increase of Argo data since late Jan 2014.**

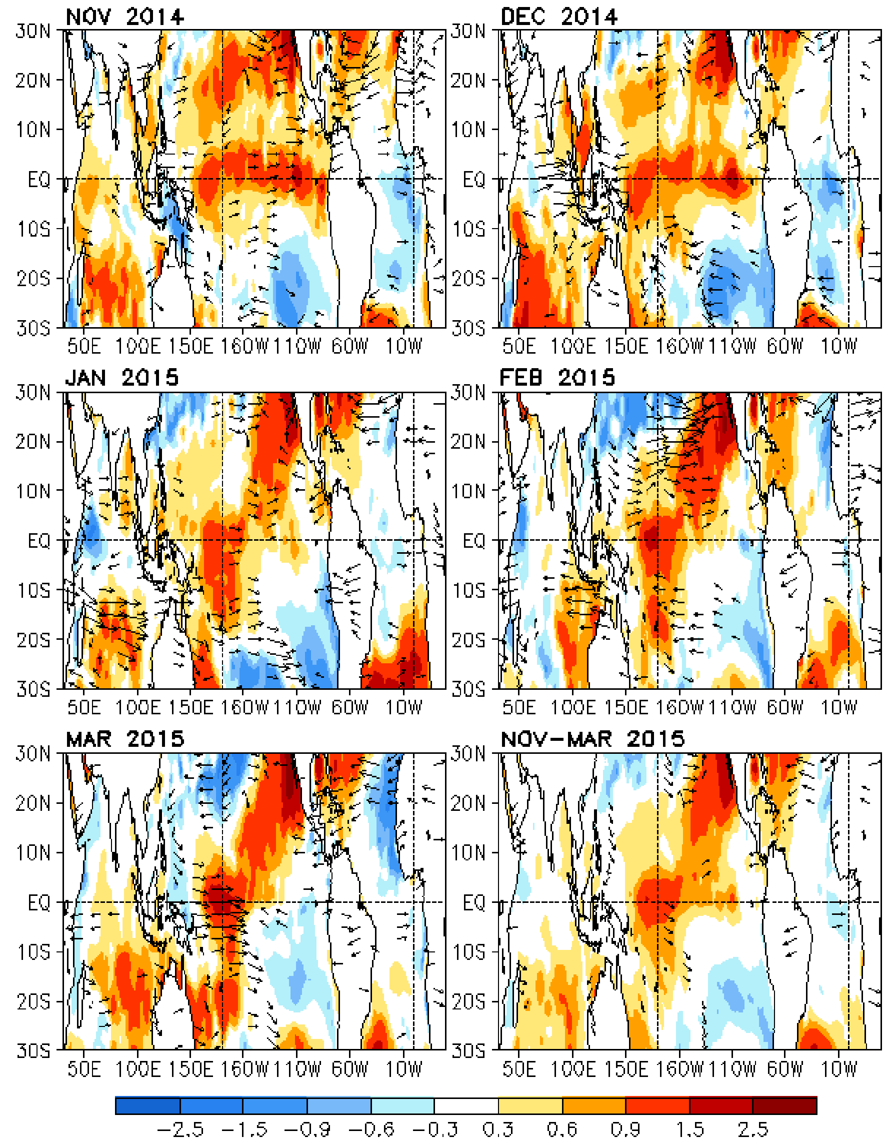
# Tropical Atlantic:



# OLR and UV850




# SSTA and UV850



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

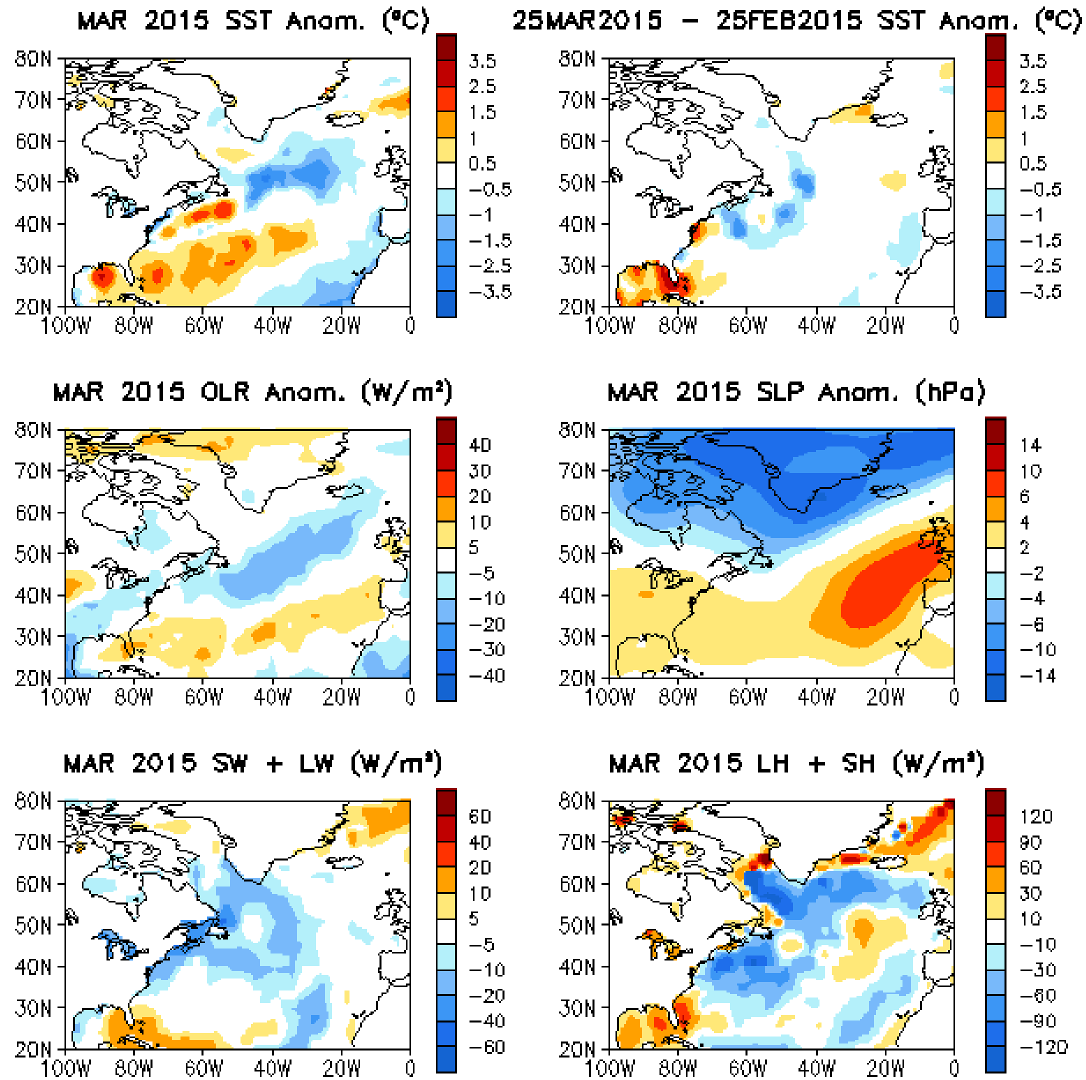
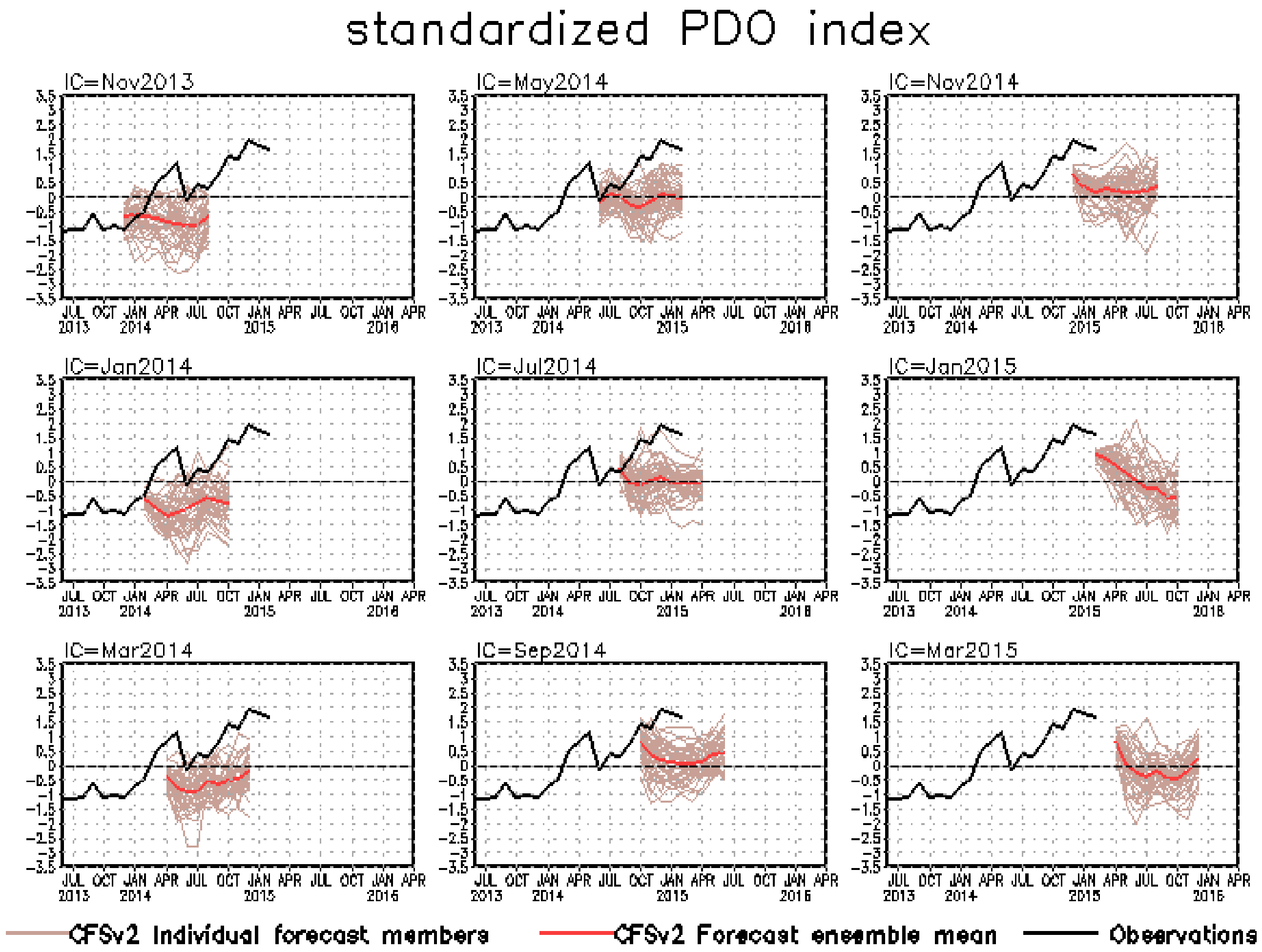



Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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 1981-2010 base period means.

# CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



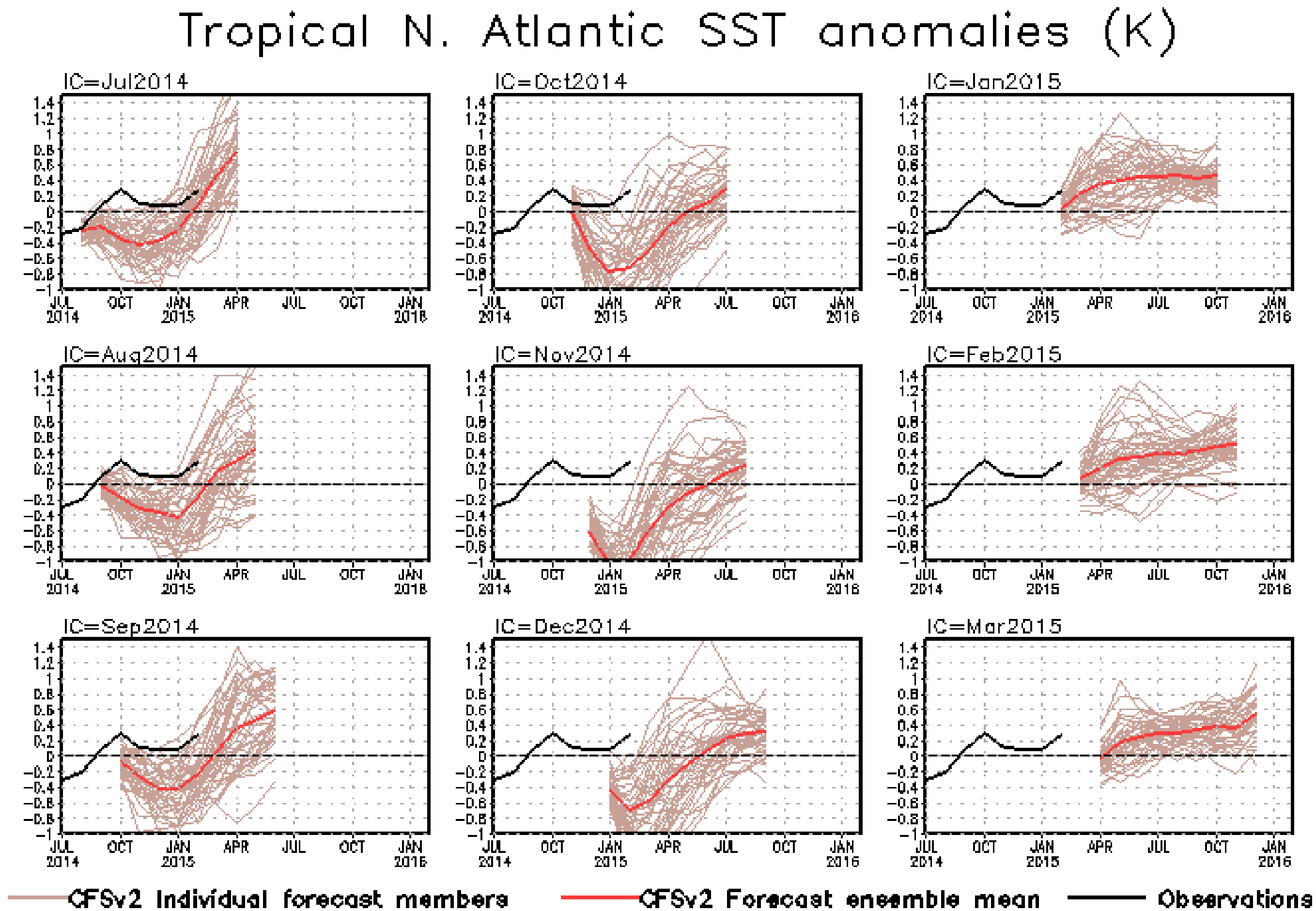

PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

- CFSv2 predicts a downward tendency of PDO, and negative phase since summer 2015.

**Fig. M4. CFS Pacific Decadal Oscillation (PDO) index 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). Anomalies were computed with respect to the 1981-2010 base period means.**

# CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months

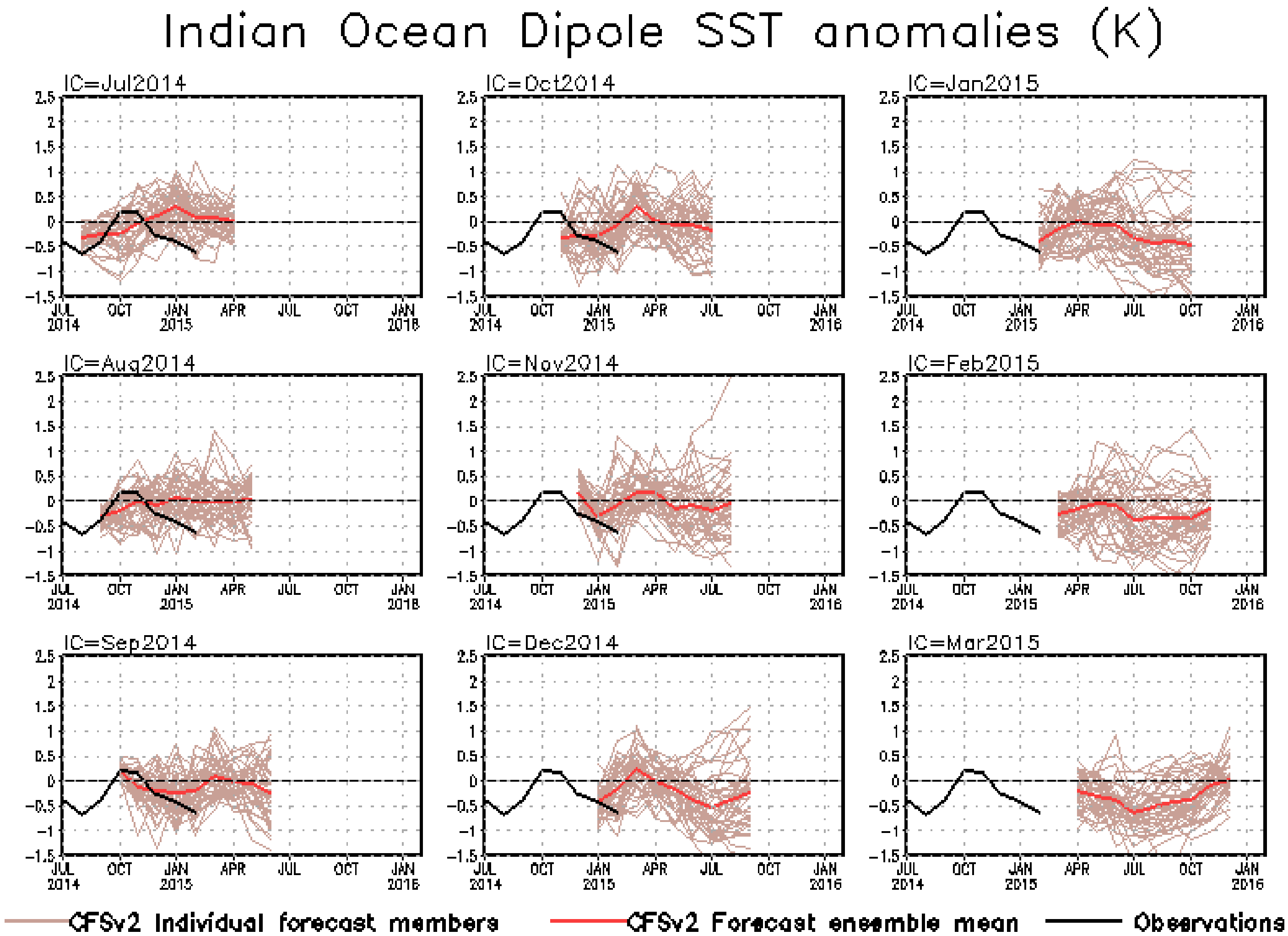



TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- Predictions initiated in Oct-Dec 2004 may be biased by errors in the Atlantic in CFSR.
- CFS2 predicts above normal SST in North Atlantic in 2015.

Fig. M3. CFS Tropical North Atlantic (TNA) 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). Anomalies were computed with respect to the 1981-2010 base period means.

# NCEP CFS DMI SST Predictions from Different Initial Months



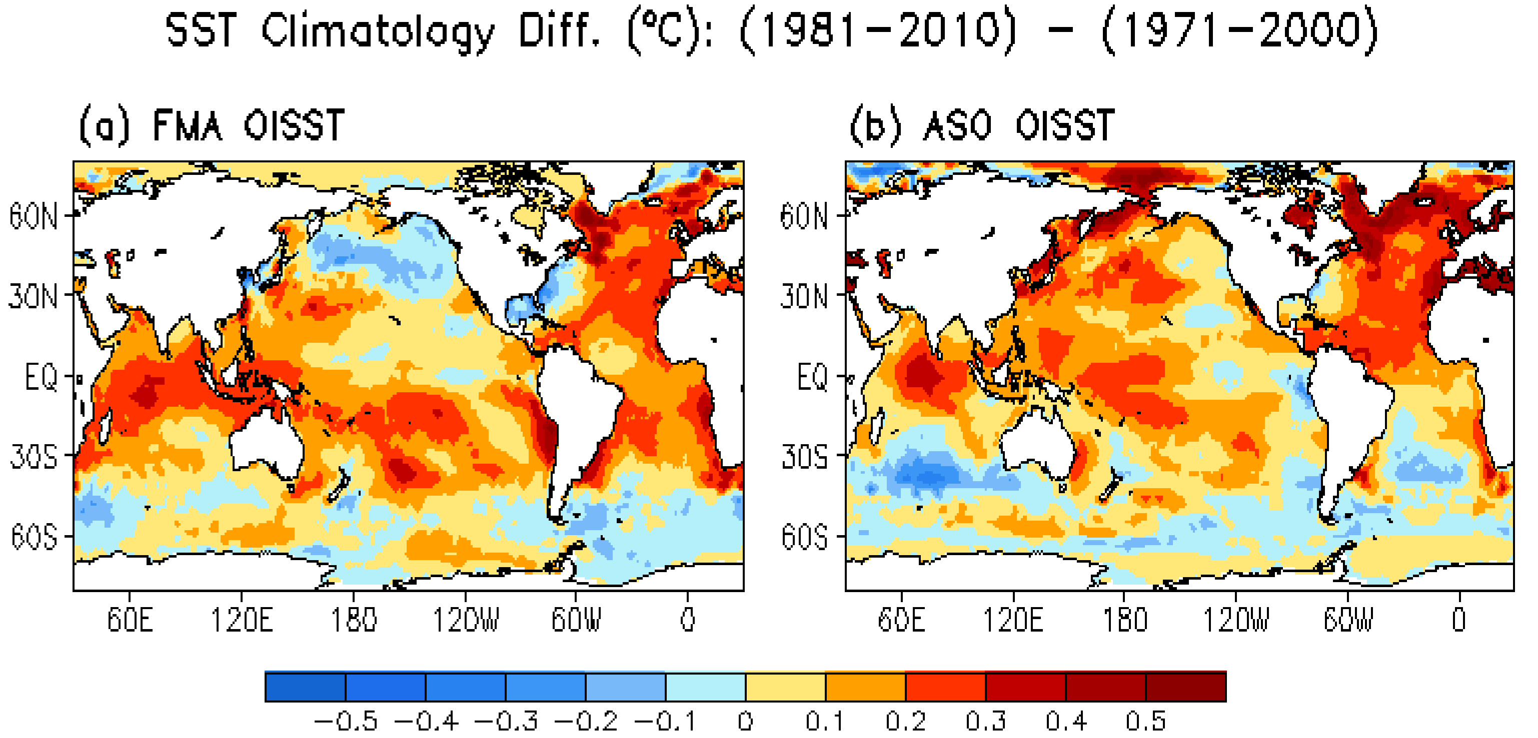

**DMI = WTIO- SETIO**

**SETIO = SST anomaly in [90°E-110°E, 10°S-0]**

**WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]**

**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.**

**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.**

# 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)**

# 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!**

# NOAA Operational Definitions for El Niño and La Niña

**El Niño: characterized by a positive ONI greater than or equal to +0.5ºC.**

**La Niña: characterized by a negative ONI less than or equal to -0.5ºC.**

**By historical standards, to be classified as a full-fledged El Niño or La Niña *episode*, these thresholds must be exceeded for a period of at least 5 consecutive overlapping 3-month seasons.**

**CPC considers El Niño or La Niña *conditions* to occur when the monthly Niño3.4 OISST departures meet or exceed +/- 0.5°C along with consistent atmospheric features. These anomalies must also be forecasted to persist for 3 consecutive months.**

# Creation of the NOAA ENSO Outlook

**(from Michelle L'Heureux and Mike Halpert)**

***ENSO Alert System:***

**El Niño or La Niña Watch:**
**Favorable for development of ENSO within the next six (6) months.**

**El Niño or La Niña Advisory: conditions are observed and expected to continue.**

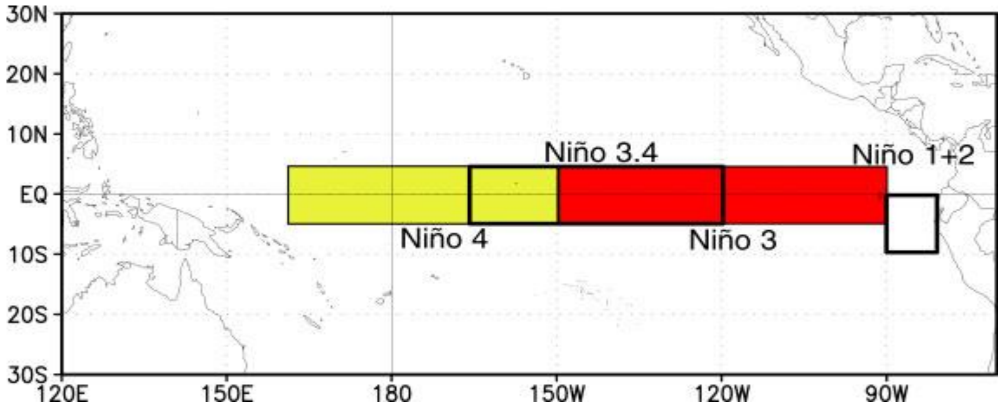
**Final El Niño or La Niña Advisory: conditions have ended.**

**NA: El Niño or La Niña conditions are not observed or expected to develop in the equatorial Pacific basin.**

# What is the criteria for an ENSO Advisory? (from Michelle L'Heureux)

**The ENSO Alert System is based on El Niño and La Niña "conditions" that allows the NOAA to be able to issue watches/ advisories in real-time.**

**The value of the ONI is to define episodes retrospectively.**



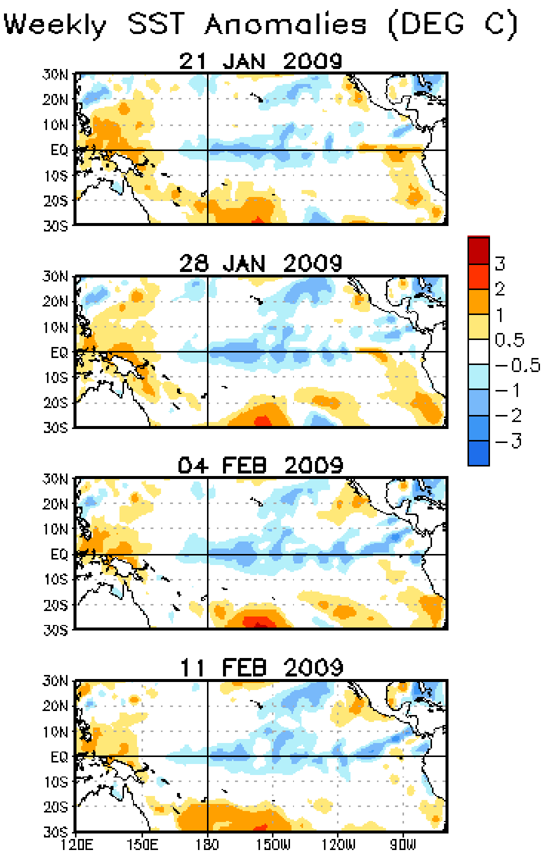

**El Niño conditions: one-month positive SST anomaly of +0.5 or greater in the Niño-3.4 region and an expectation that the 3-month ONI threshold will be met.**

**La Niña conditions: one-month negative SST anomaly of −0.5 or less in the Niña-3.4 region and an expectation that the 3-month ONI threshold will be met.**

**AND**

***An atmospheric response* typically associated with El Niño/ La Niña over the equatorial Pacific Ocean.**

# What products do we use to monitor ENSO (From Mike Halpert)?




Weekly and monthly graphics of the tropical Pacific:

* sea surface temperature (SST)
* subsurface temperature
* sea level pressure (i.e. SOI)
* outgoing longwave radiation (OLR)
* Various levels of winds (850/200-hPa)
* velocity potential + streamfunction