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

Prepared by

Climate Prediction Center, NCEP/NOAA

May 8, 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 2014/2015

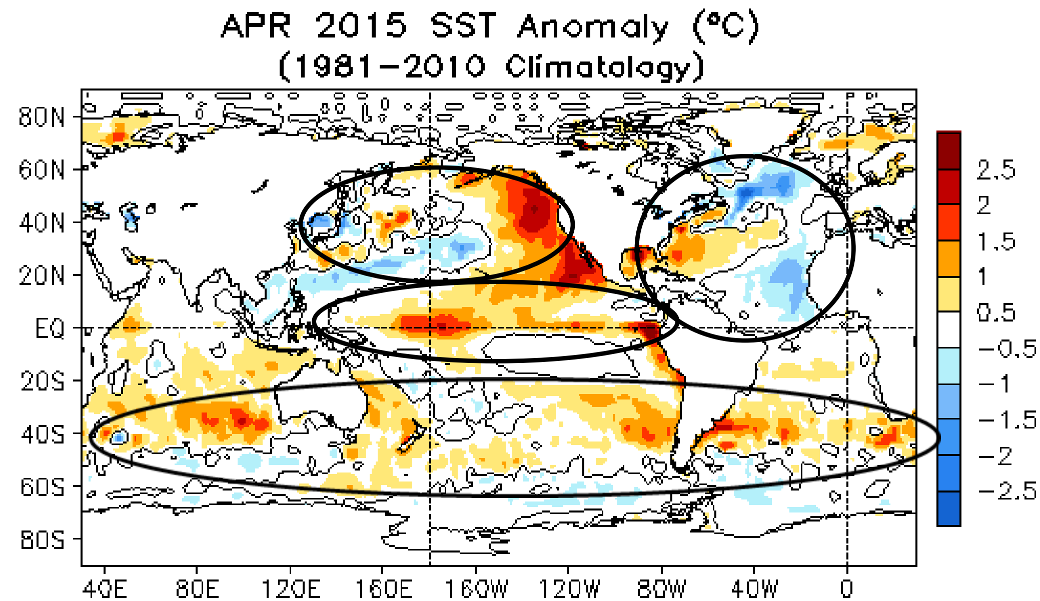
*Sea surface salinity (SSS) monitoring and possible role of ocean salinity on ENSO prediction

Overview

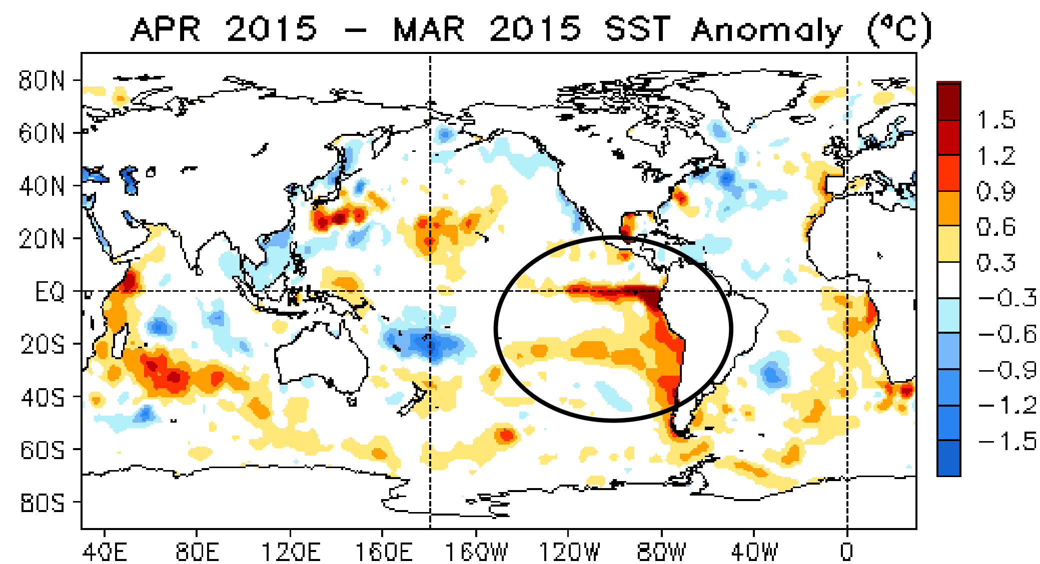
- **Pacific Ocean**
  - **NOAA "ENSO Diagnostic Discussion" on 09 Apr 2015 suggested "There is an approximately 70% chance that El Niño will continue through Northern Hemisphere summer 2015, and a greater than 60% chance it will last through autumn."**
  - **Positive SSTAs were observed in the central and eastern tropical Pacific with NINO3.4=0.8^{o}C in Apr 2015.**
  - **Positive anomalies of subsurface ocean temperature along the equator persisted and propagated eastward slowly in Apr 2015.**
  - **Majority of dynamical models predicted a warming tendency (El Nino) in 2015, but some of statistical models favor ENSO neutral conditions in 2015.**
  - **Positive phase of PDO has persisted for 10 months, with PDOI=1.3 in Apr 2015.**
- **Indian Ocean**
  - **Positive SSTAs were mainly in the southern Indian Ocean.**
- **Atlantic Ocean**
  - **Positive phase of NAO has persisted for 6 months with NAOI=0.6 in Apr 2015, causing a horseshoe-like pattern of SSTA in N. Atlantic.**

Global Oceans

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



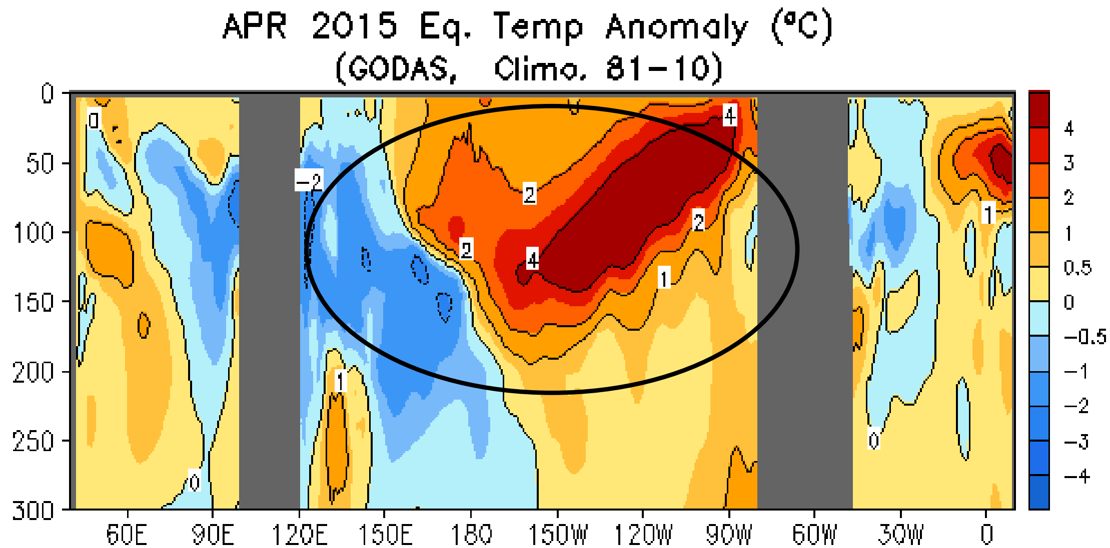
- **Positive SSTA was observed in the central and eastern tropical Pacific, and it was strong in the central Pacific and along the Central American coast.**
- **Strong positive SSTA presented in the NE Pacific and was associated with positive phase of PDO.**
- **Horseshoe-like SSTA persisted in the North Atlantic.**
- **Positive SSTA existed in the Southern Ocean.**



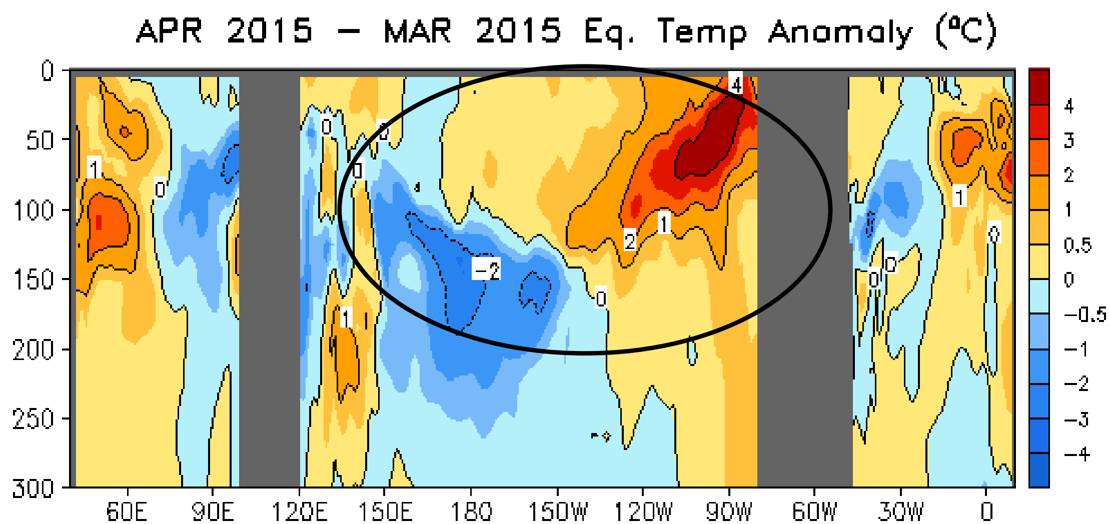
- **SSTA tendencies were large in the eastern equatorial Pacific and along the southern and central American coast.**

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

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



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



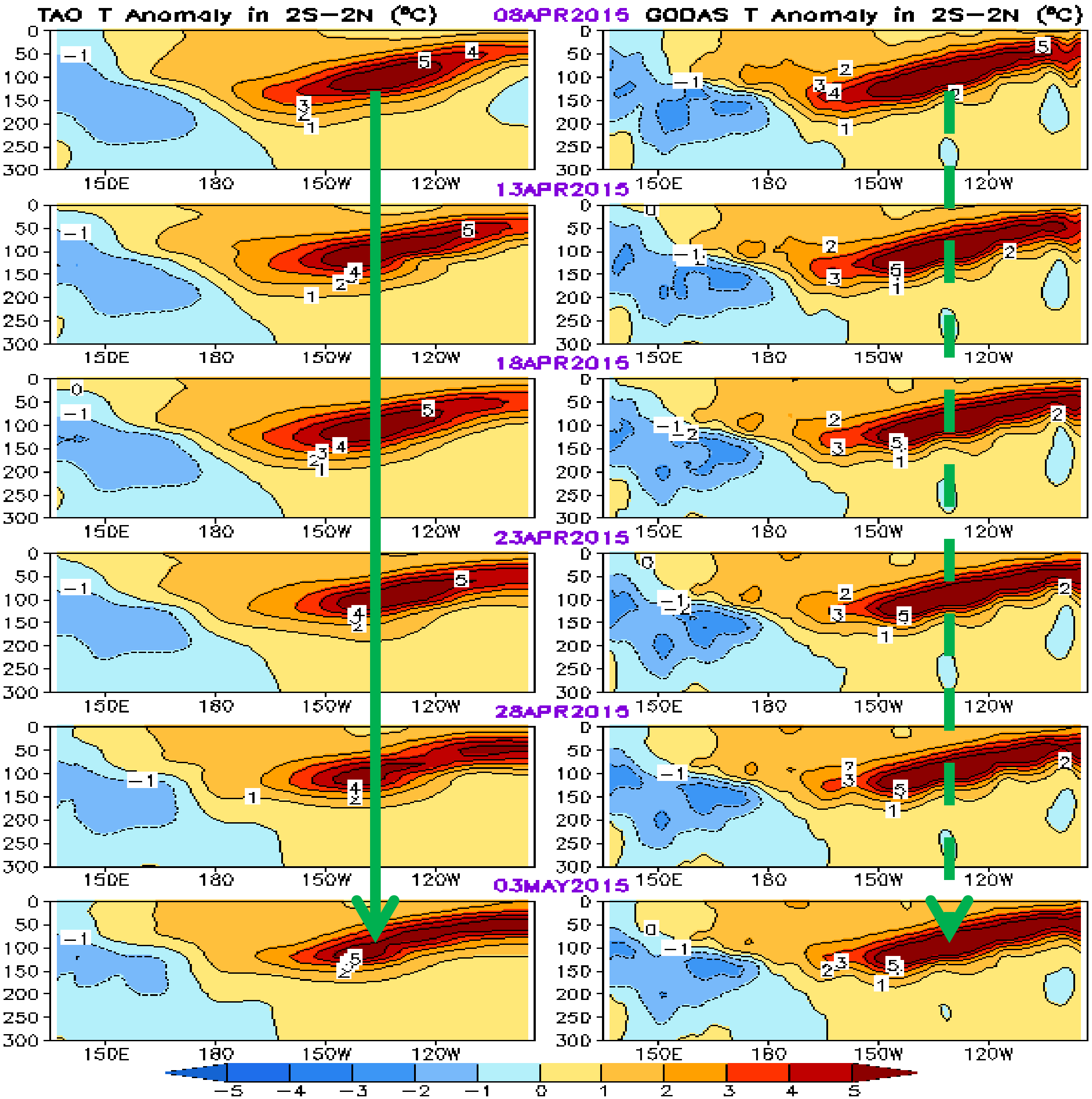
- Ocean temperature tendencies were positive in the central-eastern Pacific and negative in the west.

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.

Tropical Pacific Ocean and ENSO Conditions

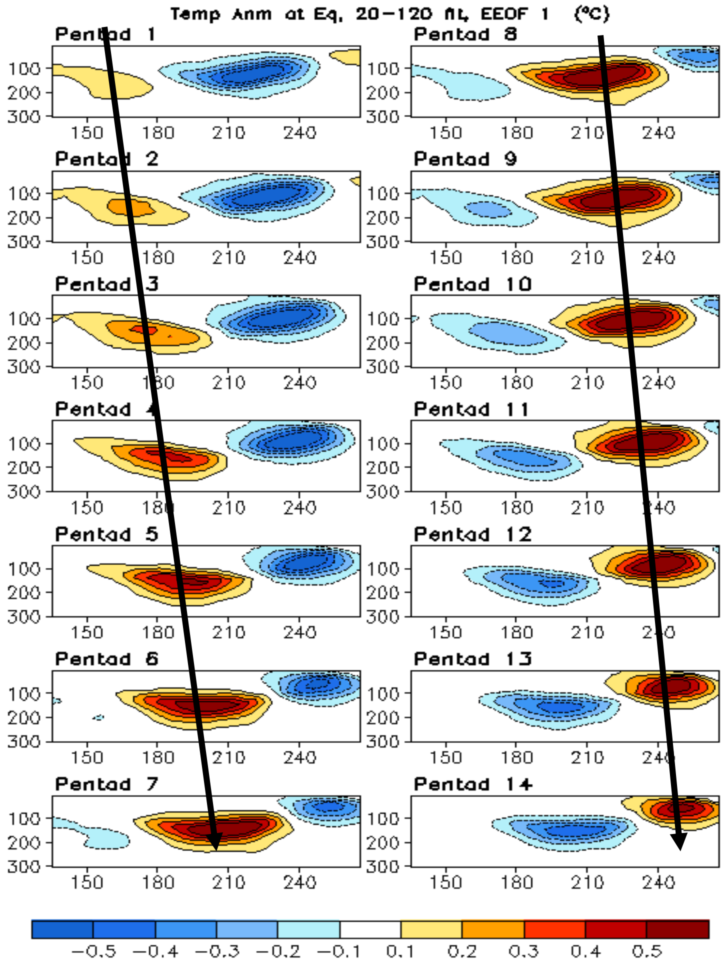
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

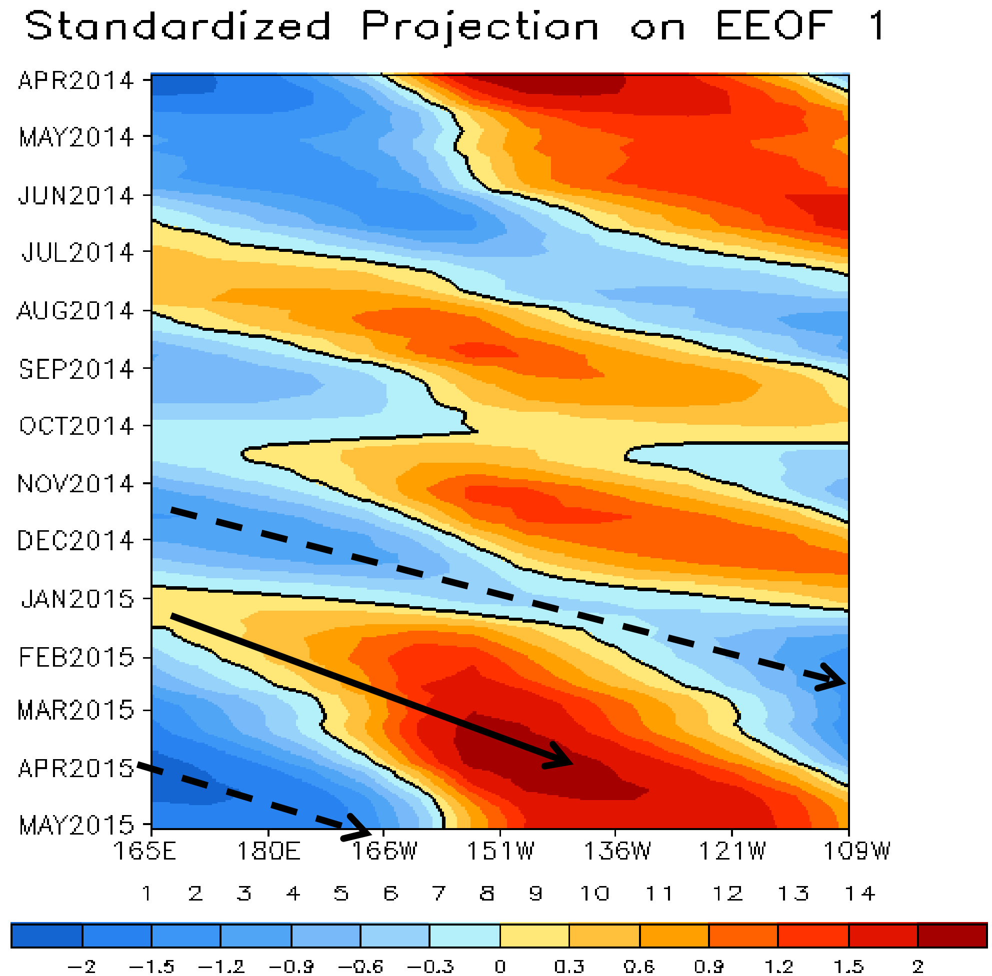
TAO GODAS



- Strong positive ocean temperature anomalies persisted and propagated eastward slowly.
- Both the intensity and propagation are comparable in recent months between GODAS and TAO.

Oceanic Kelvin Wave (OKW) Index

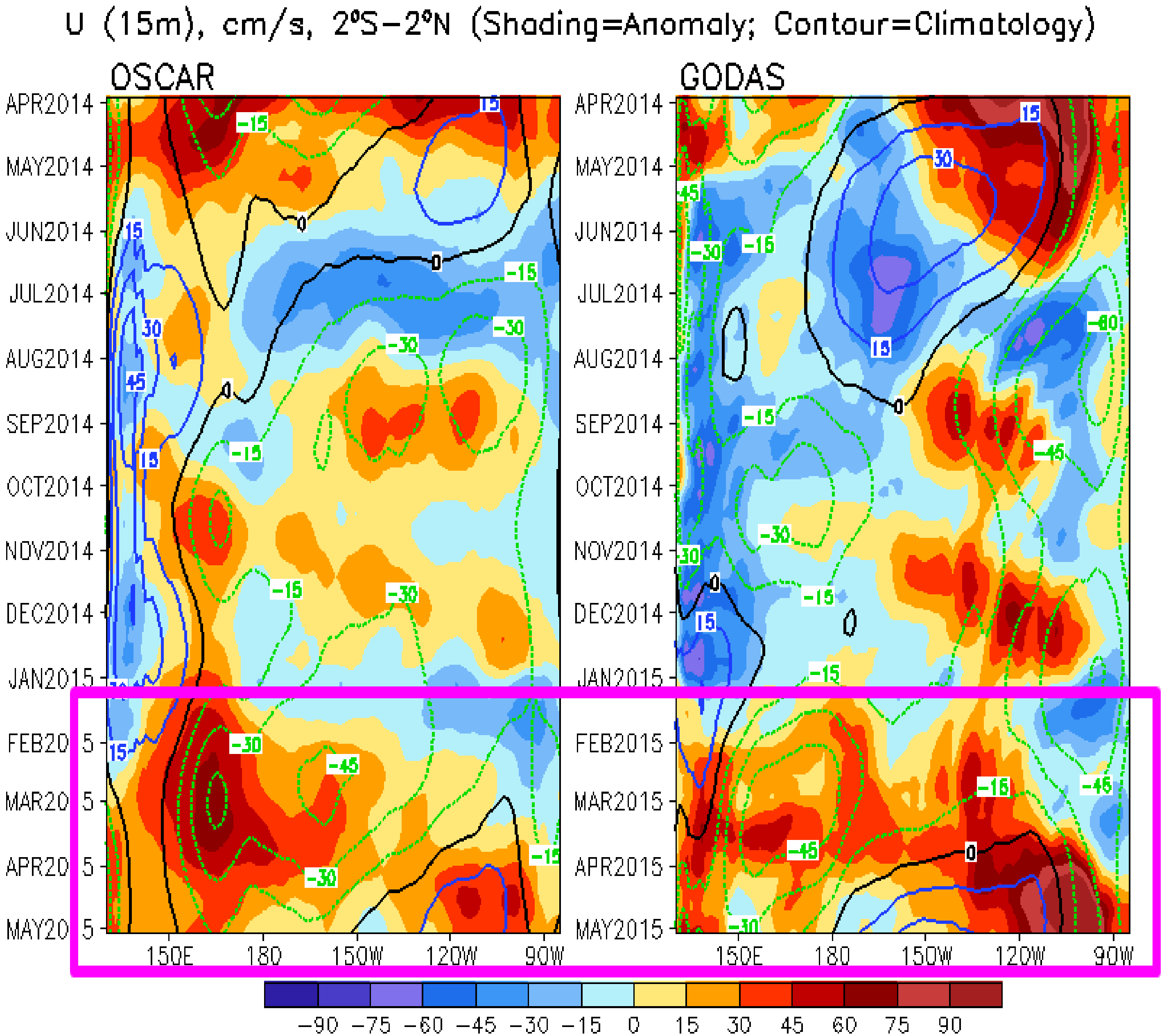




- **Downwelling OKW (solid line) emerged since Jan 2015 in the C. Pacific, while upwelling OKW initiated in mid-Jan in the W. Pacific. The downwelling may be associated with the observed subsurface ocean warming.**

(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, may leading to positive zonal advective feedback.

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

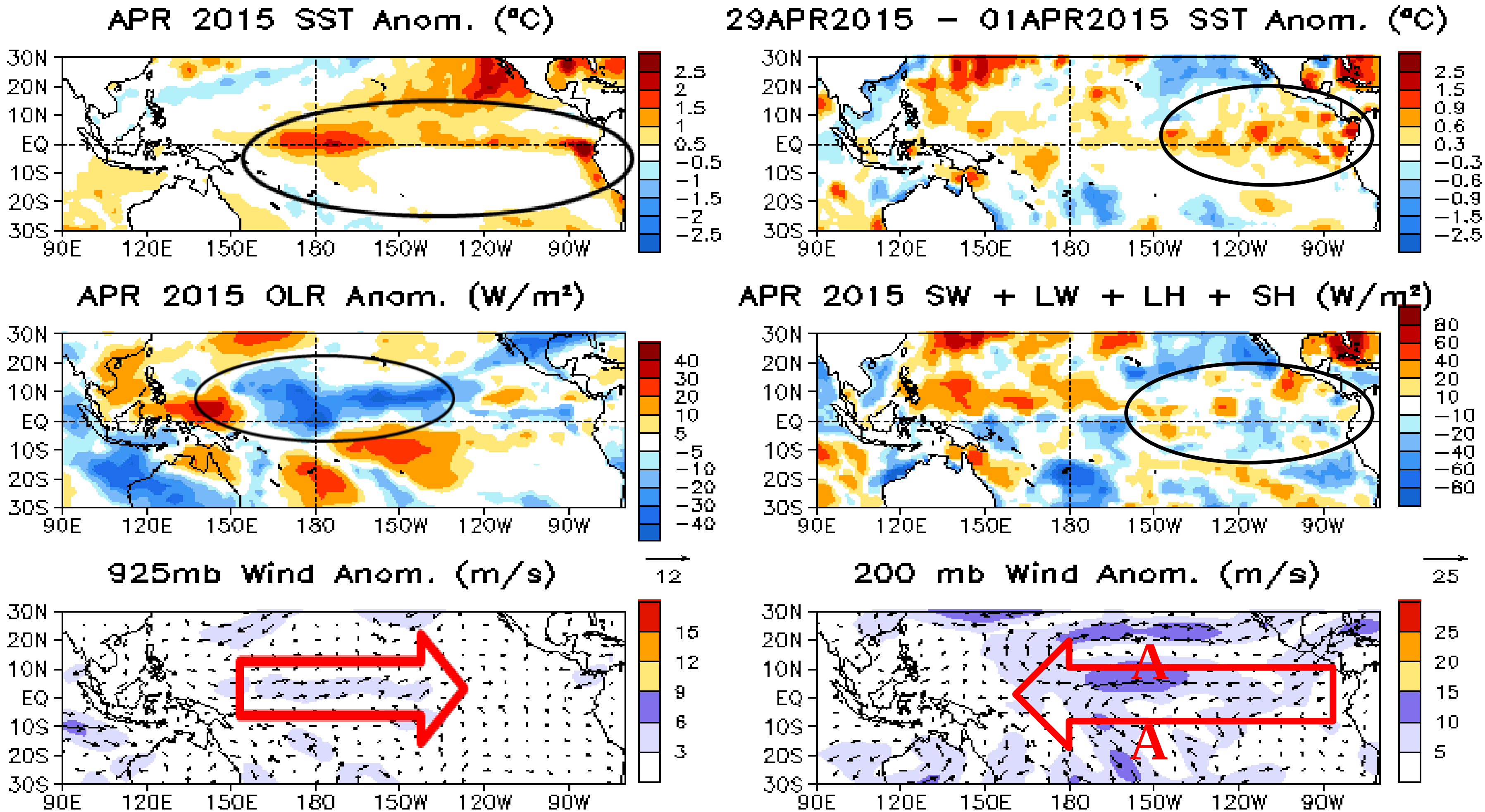
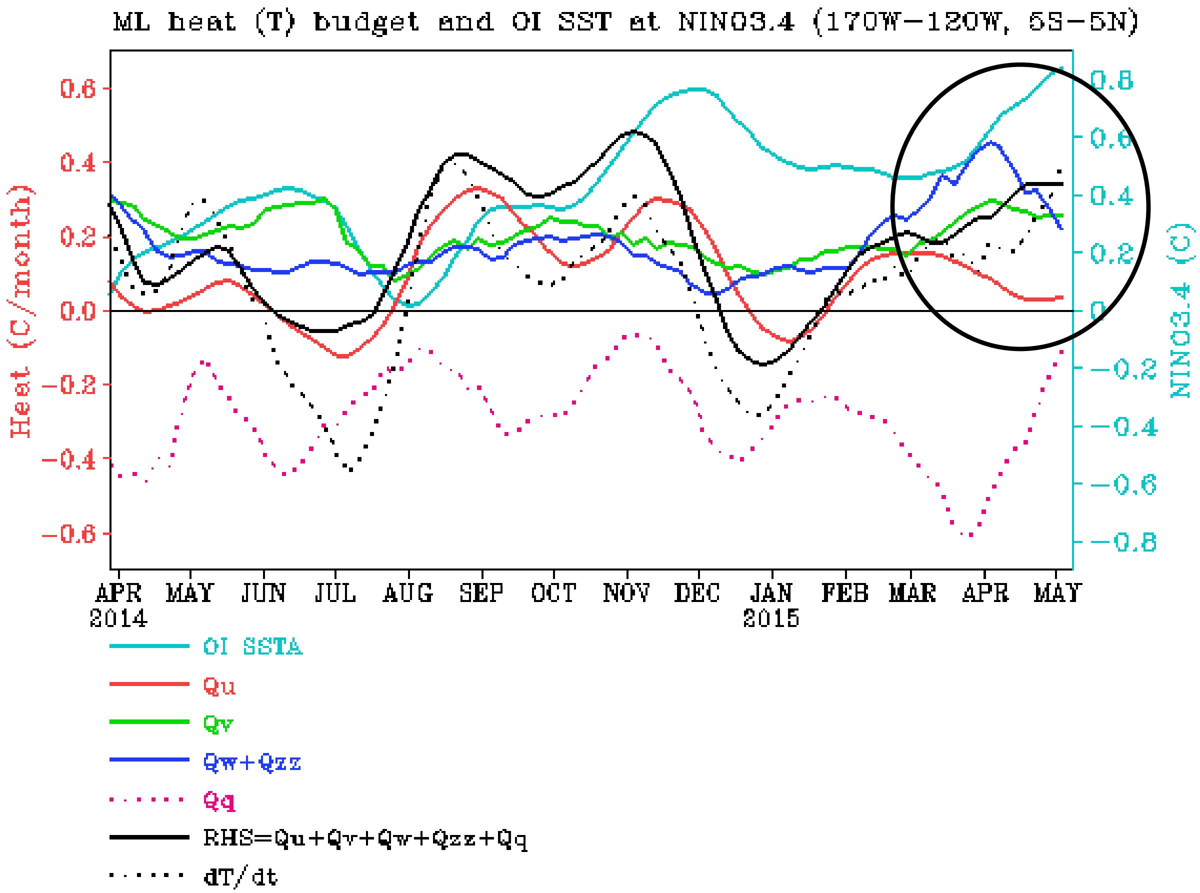


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

NINO3.4 Heat Budget



- **Observed SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) was positive since mid-Jan 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.

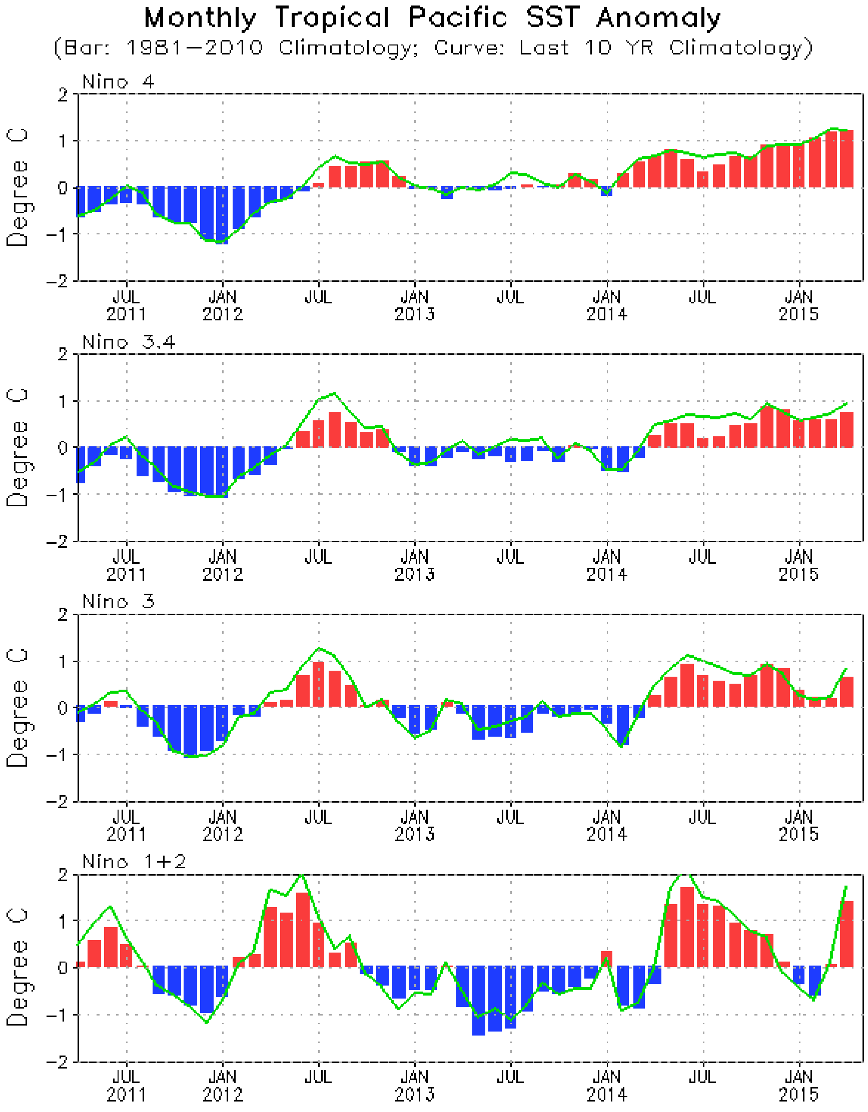
Qu: Zonal advection; Qv: Meridional advection;

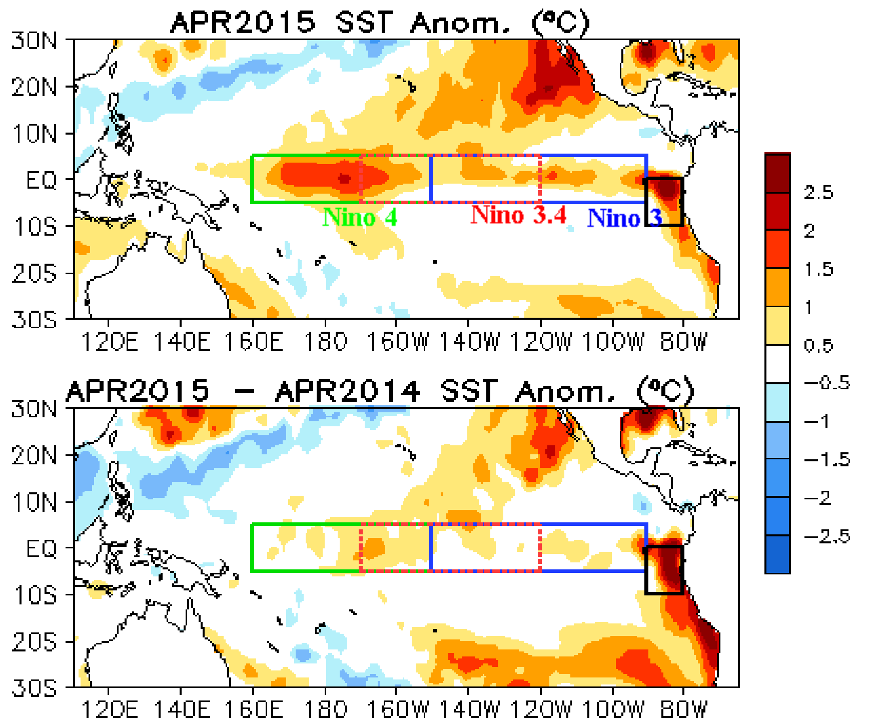
Qw: Vertical entrainment; Qzz: Vertical diffusion

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 were positive and strengthened (or persisted for Nino4) in Apr 2015.**

- **Nino3.4 slightly strengthened and = 0.8°C in Apr 2015.**

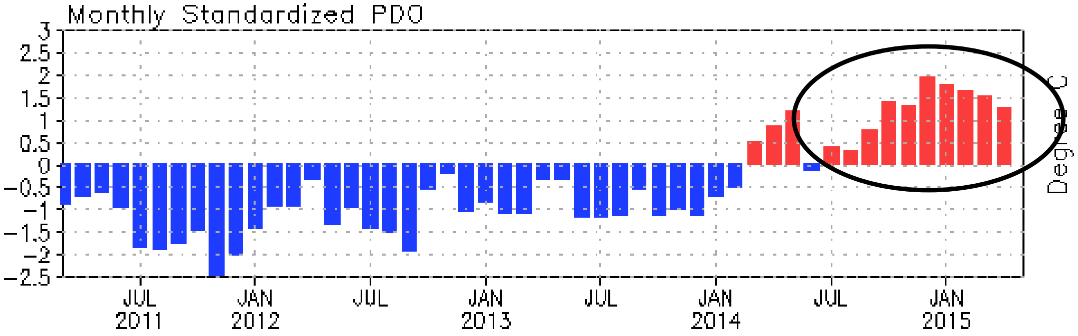
- **Compared with last Apr, the central and eastern equatorial Pacific as well as American coast was warmer in Apr 2015.**

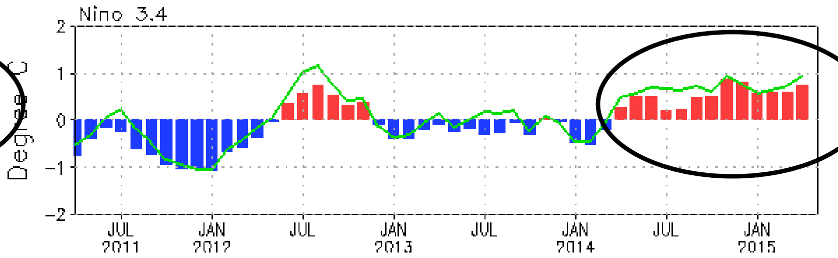
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.**

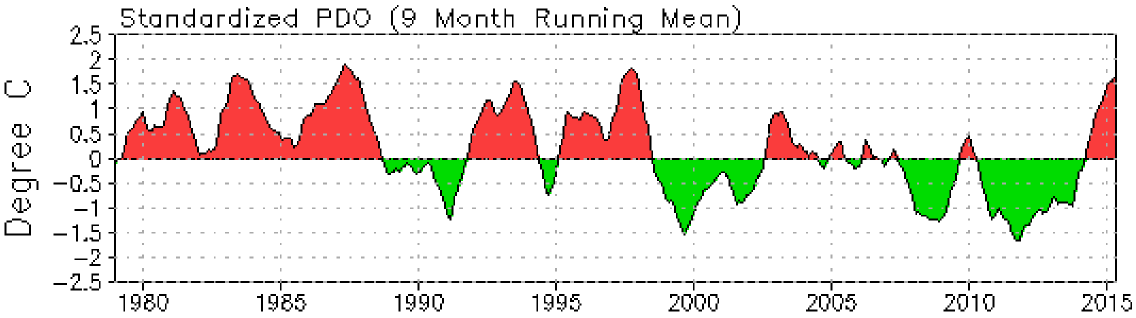
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

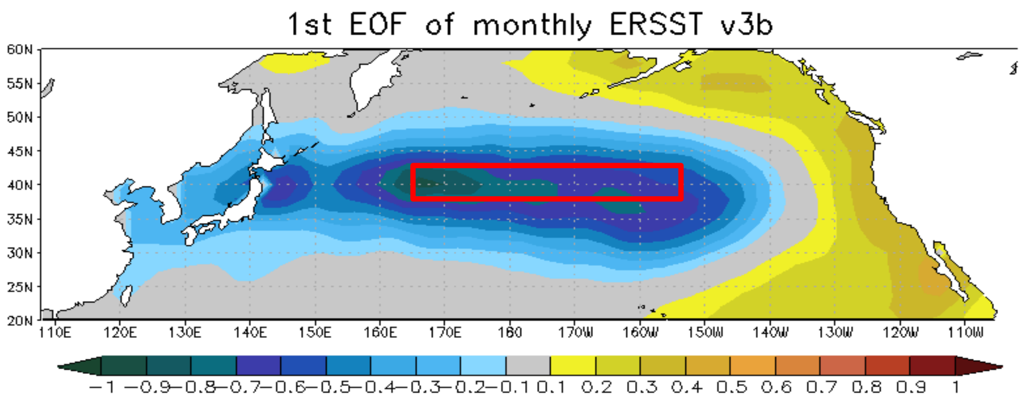
North Pacific & Arctic Oceans

PDO index









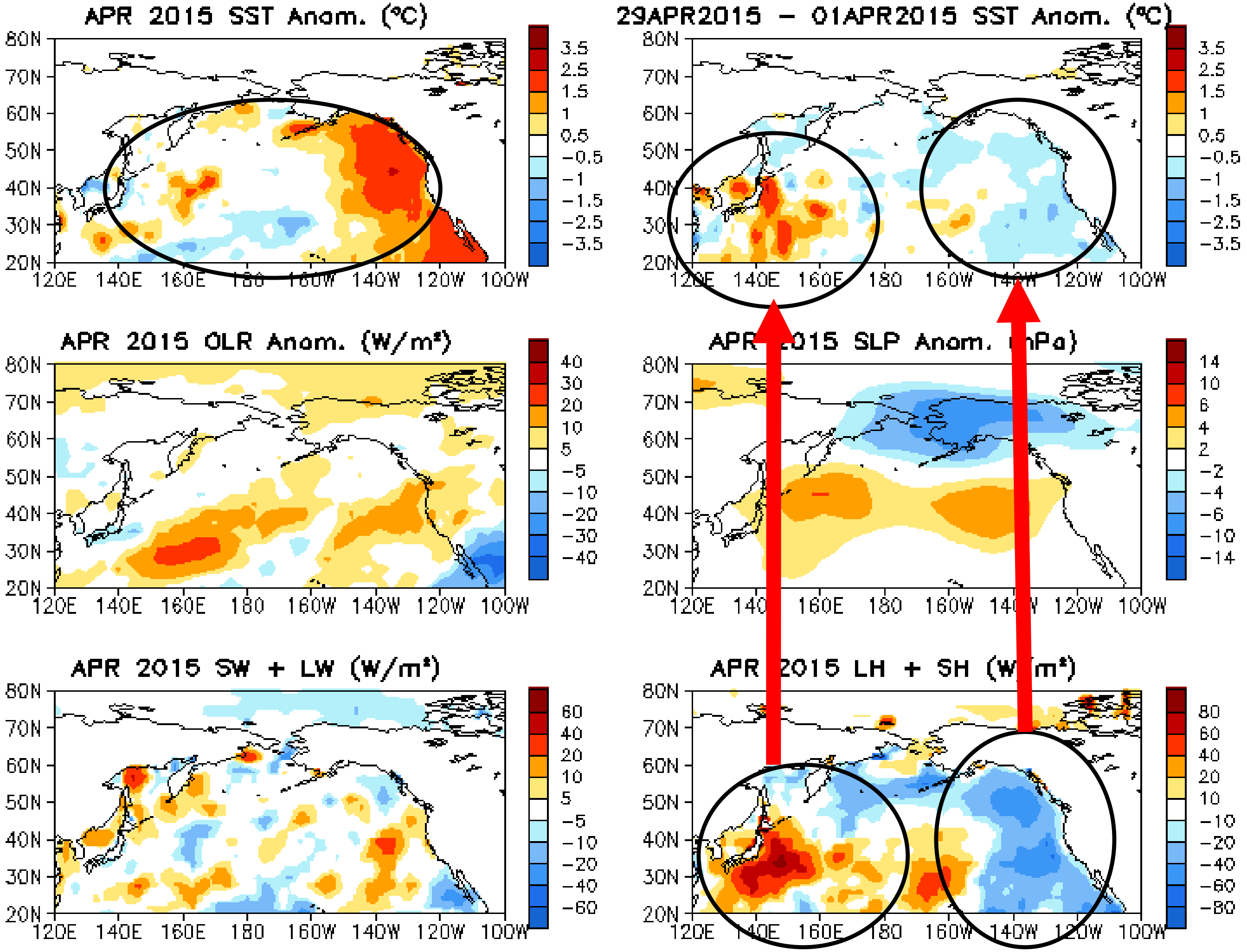
- The positive phase of PDO index has persisted 10 months since Jul 2014 with PDO index =1.3 in Apr 2015.

- 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.

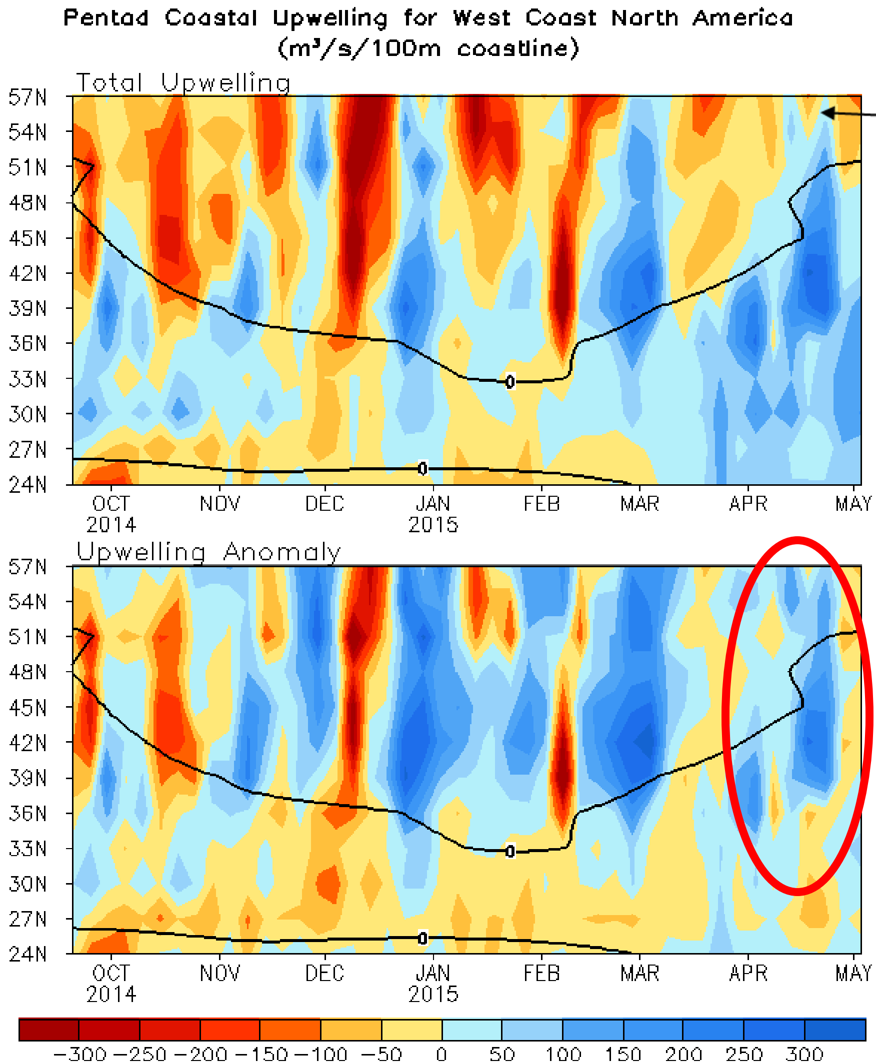
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

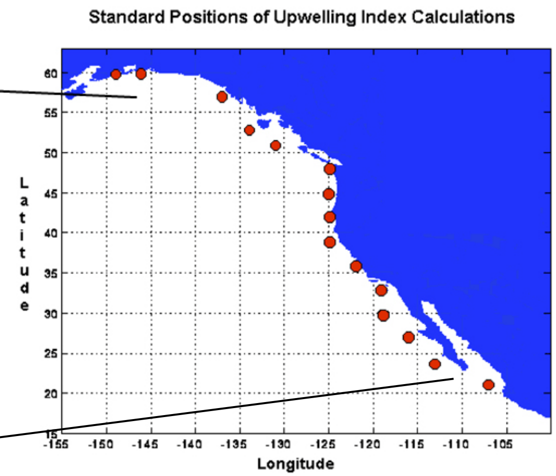


- **Positive SSTA presented in the NE Pacific, consistent with the positive phase of PDO index (previous slide).**
- **The SSTA tendency was positive in the east and negative in the west, which was mainly driven by LH+SH.**

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 was observed in mid-latitudes in Apr 2015.**

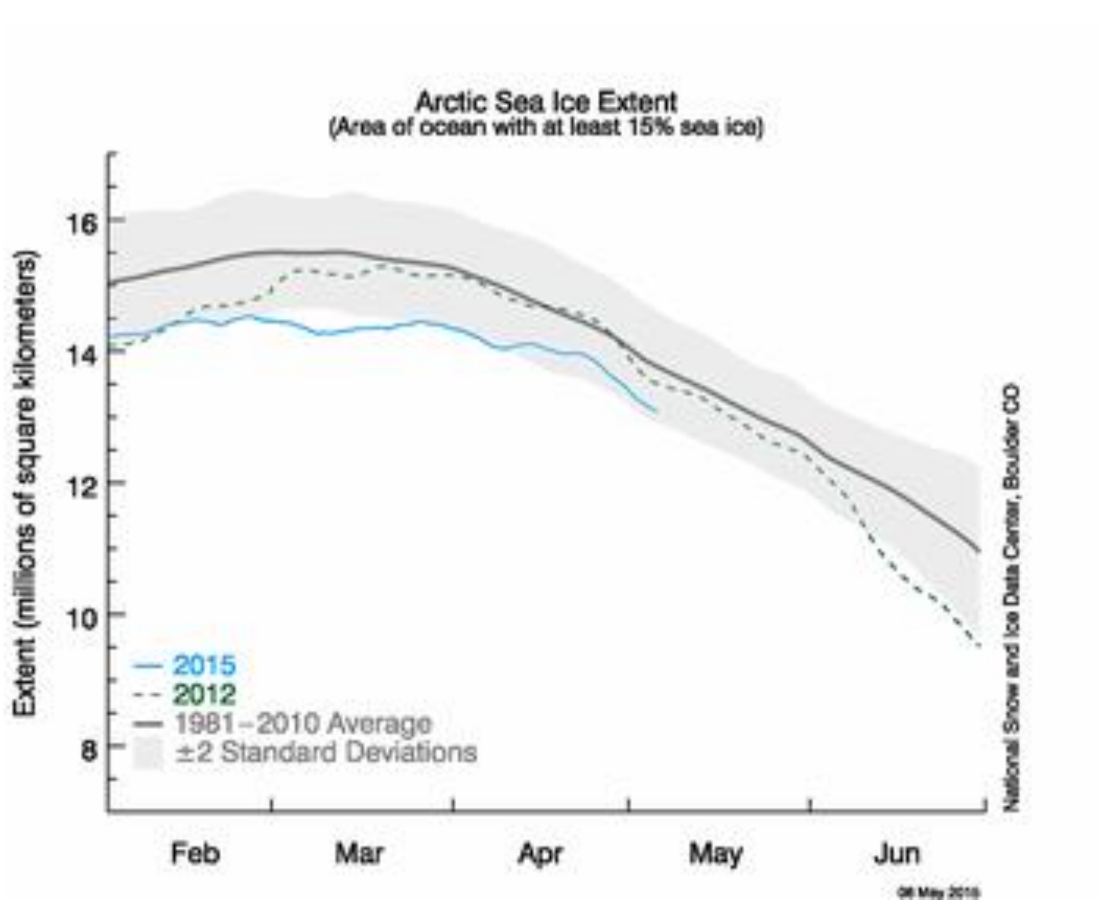
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

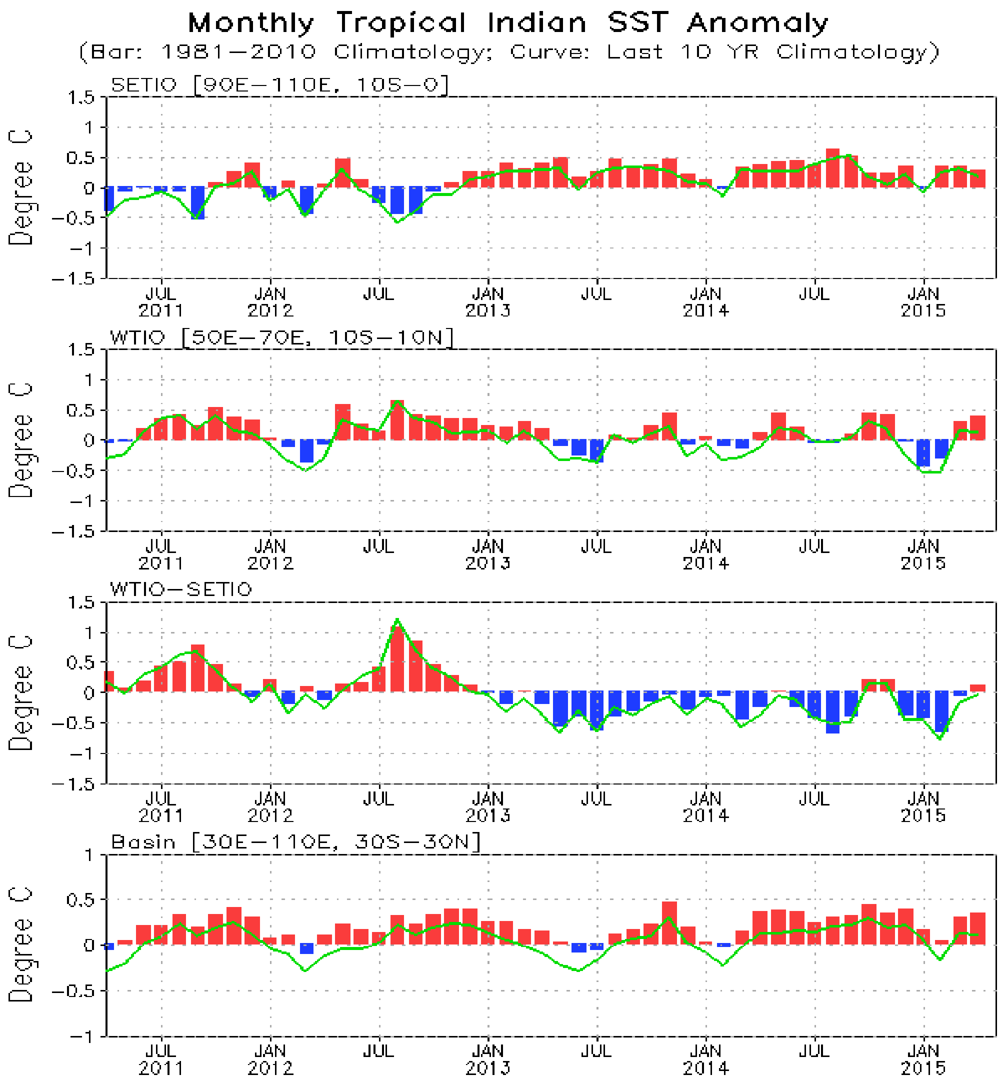
http://nsidc.org/arcticseaicenews/index.html

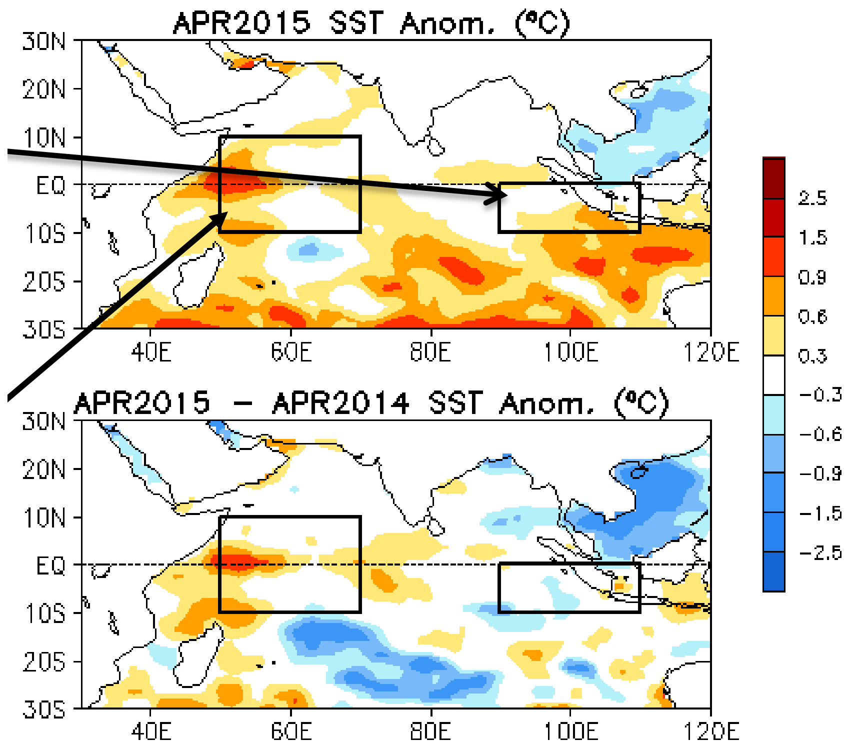


- **Arctic sea ice extent was below normal in April 2015.**

Indian Ocean

Evolution of Indian Ocean SST Indices



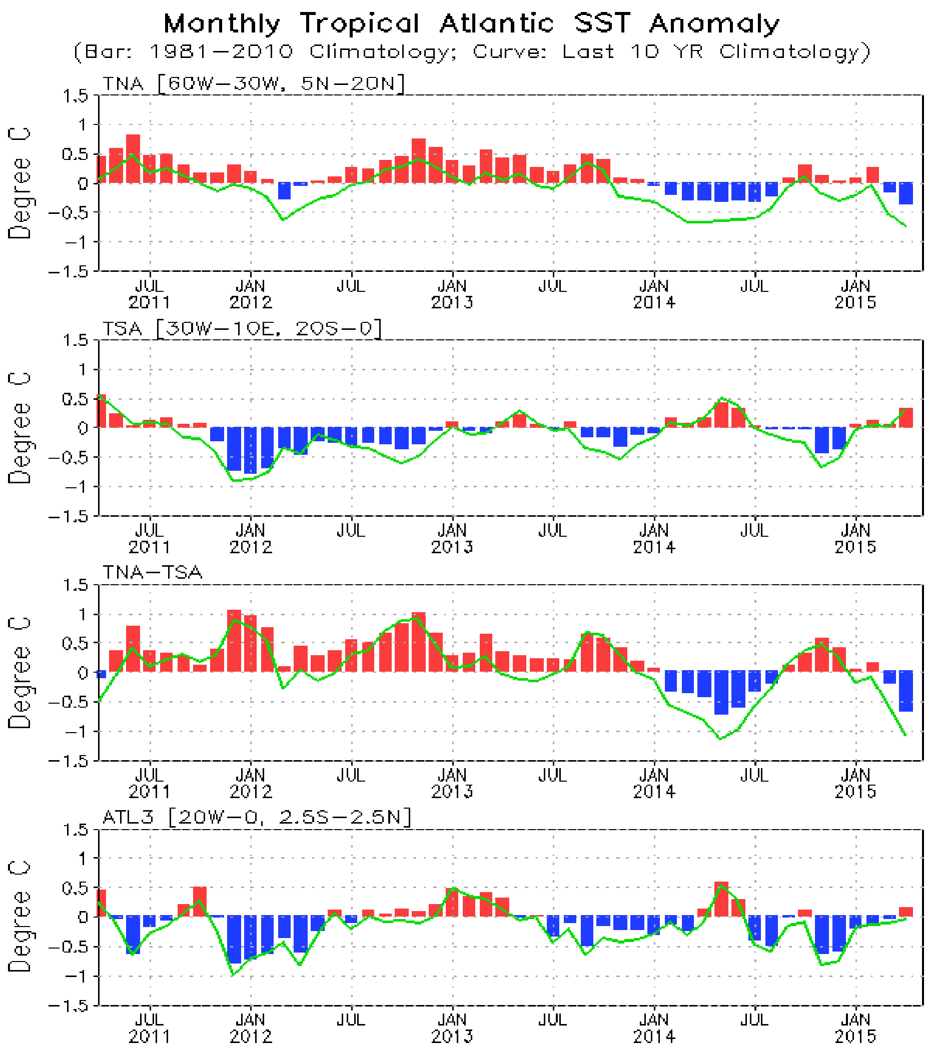


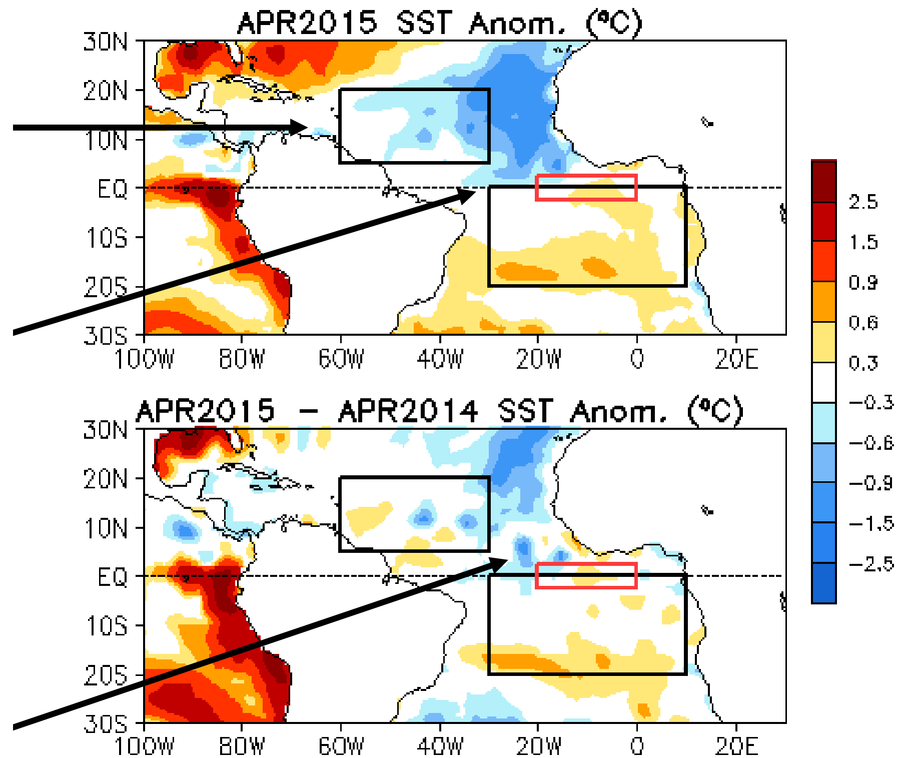
- **Positive SSTA was mainly in the southern Indian Ocean.**
- **DMI was small in Mar-Apr 2015.**

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 and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

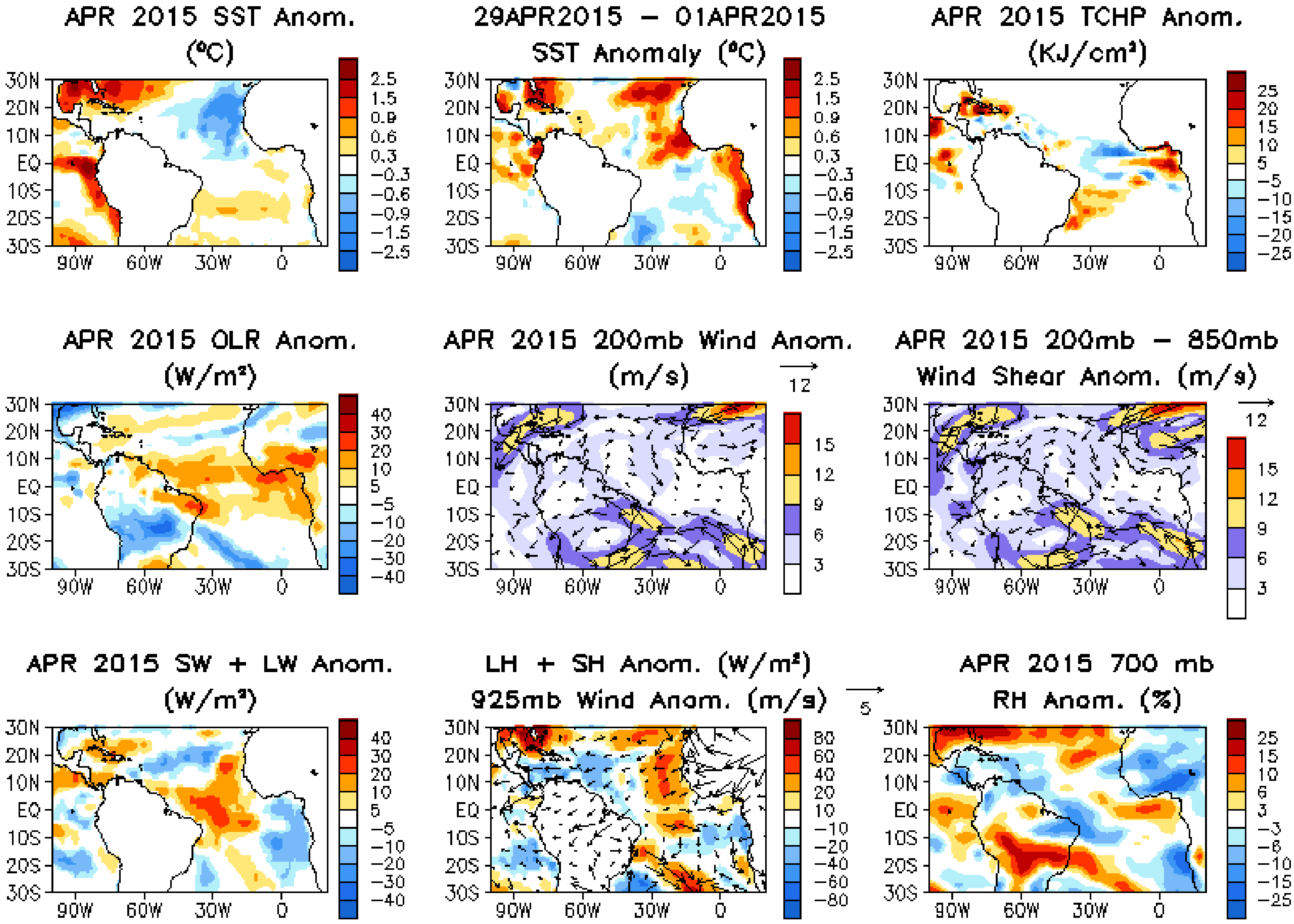




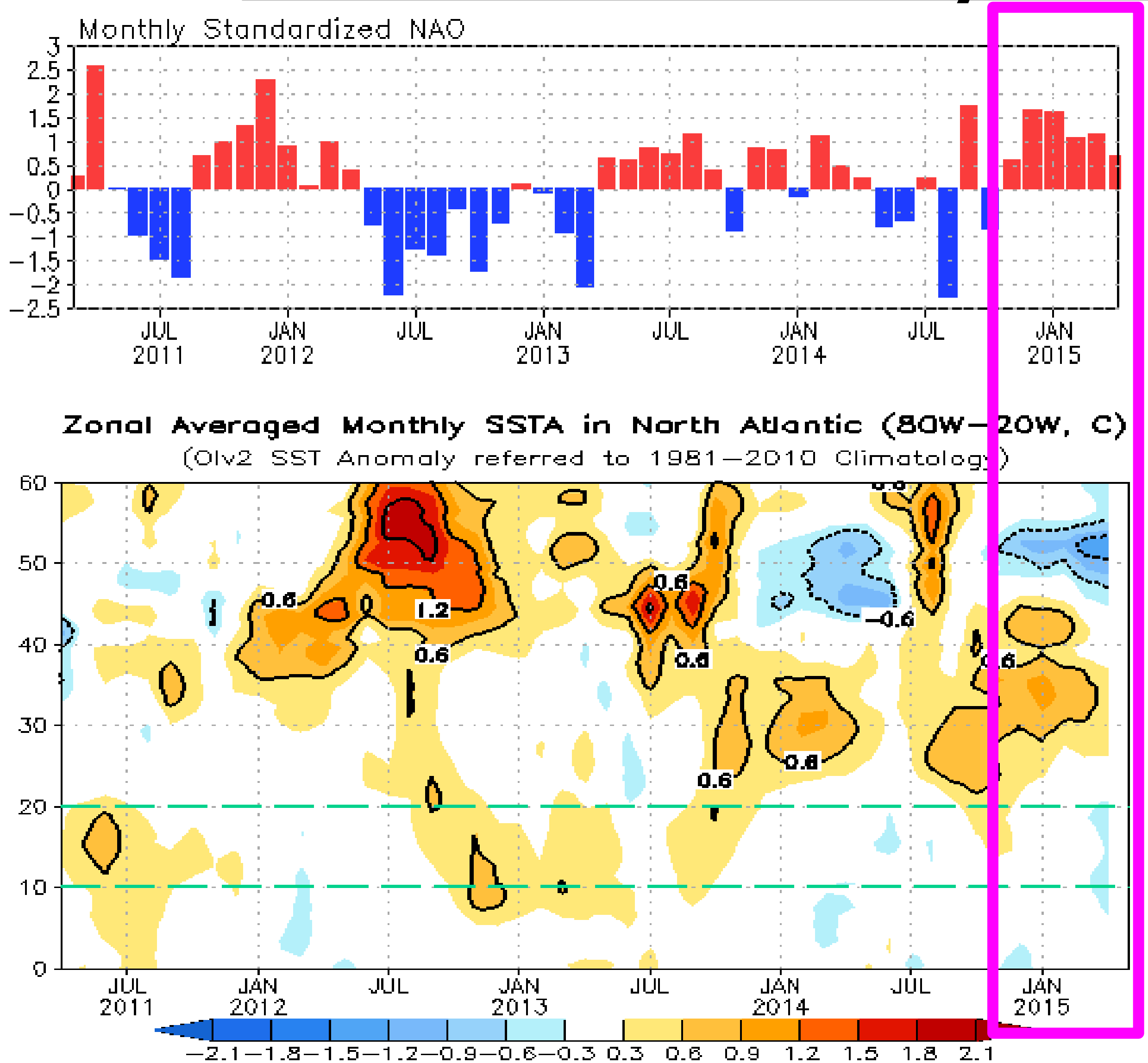
- **Cooling persisted in the NE Atlantic.**
- **ATL3 was small and dipole index was negative.**

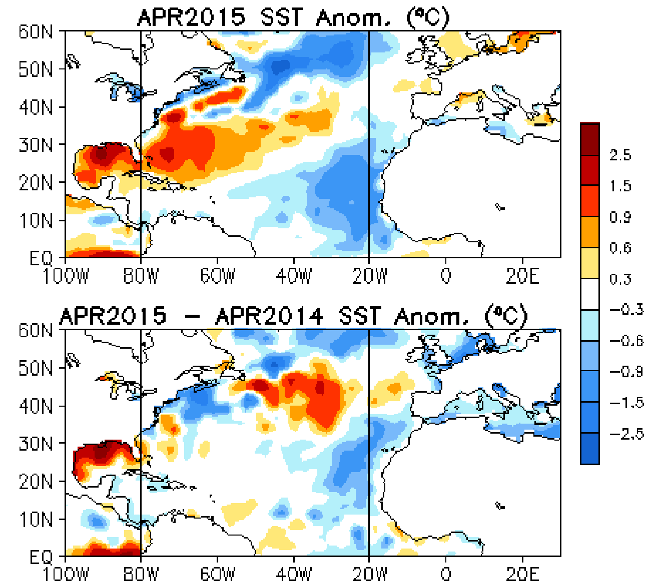
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) for the TNA [60ºW-30ºW, 5ºN-20ºN], TSA [30ºW-10ºE, 20ºS-0] and ATL3 [20ºW-0, 2.5ºS-2.5ºN] regions, and Meridional Gradient Index, defined as differences between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

Tropical Atlantic:



NAO and SST Anomaly in North Atlantic





- Positive phase of NAO has persisted 6 months with NAOI=0.6 in Apr 2015.
- SSTA was a horseshoe-like pattern, which was due to the 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.

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

- SSTA tendency showed a horseshoe-like pattern, which was driven by heat flux due to the persistent positive phase of NAO (Hu et al. 2011: *J. Climate*, 24 (22)).

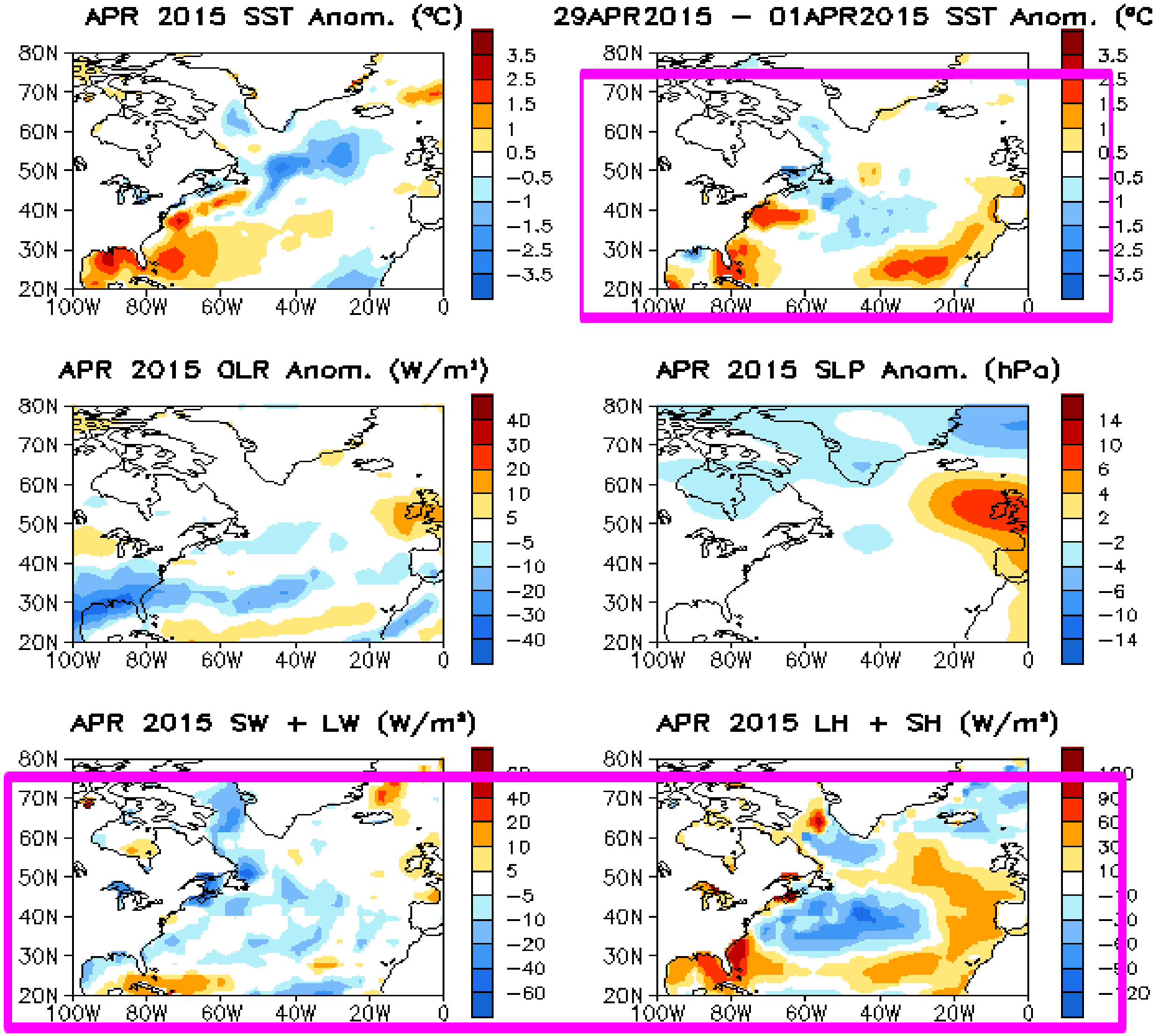
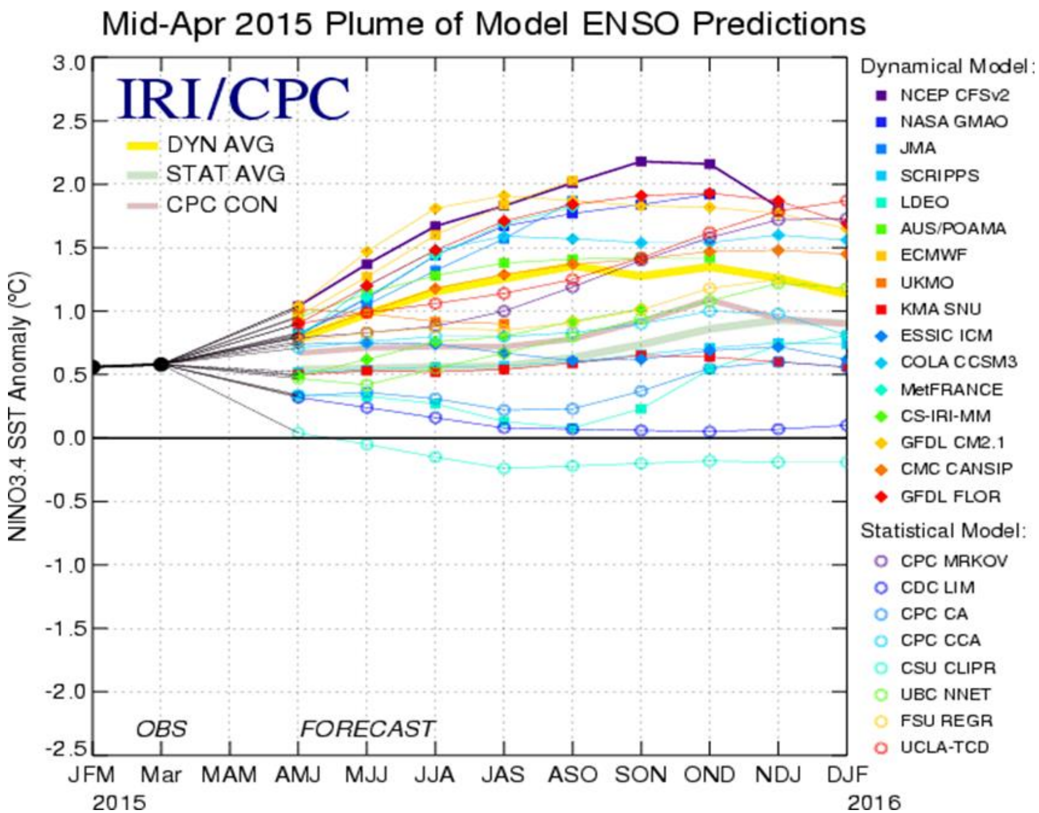
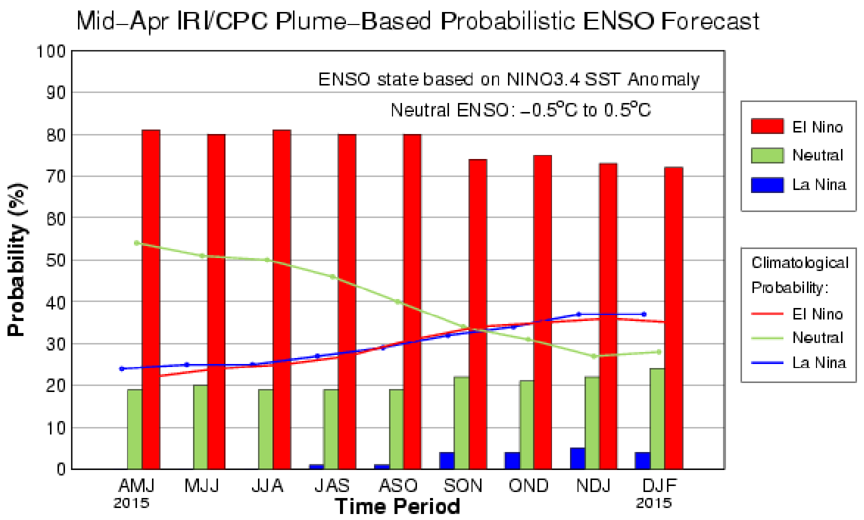


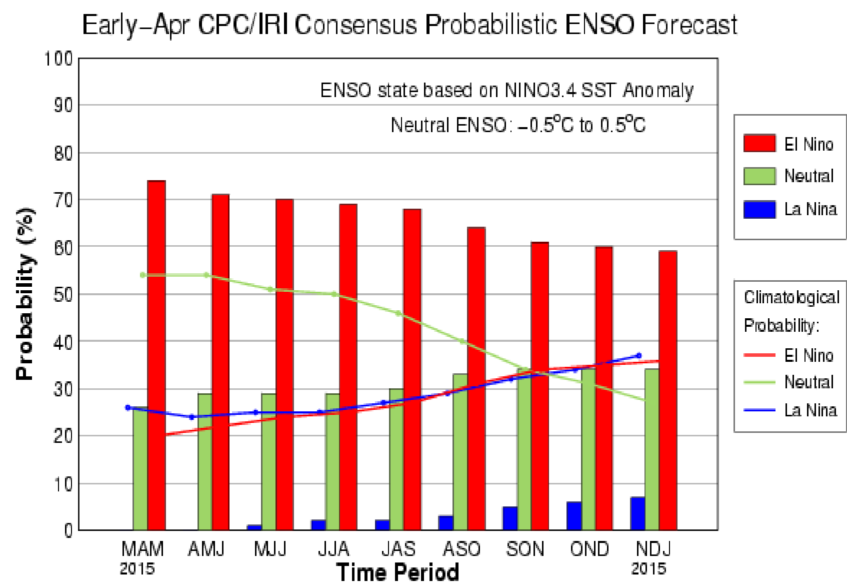
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

ENSO and Global SST Predictions

IRI NINO3.4 Forecast Plum

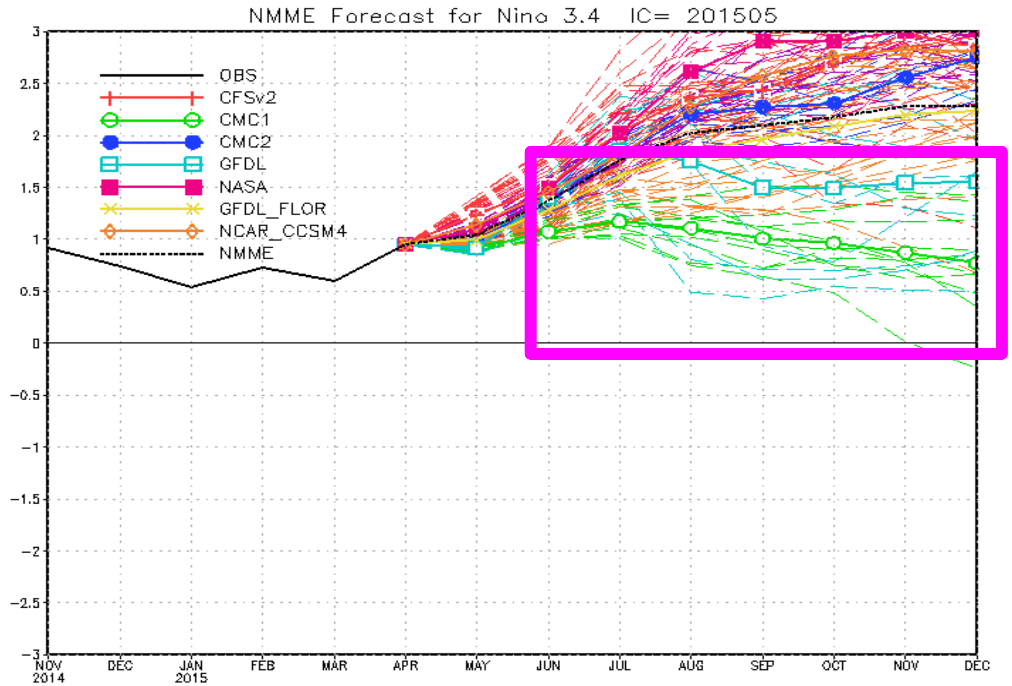


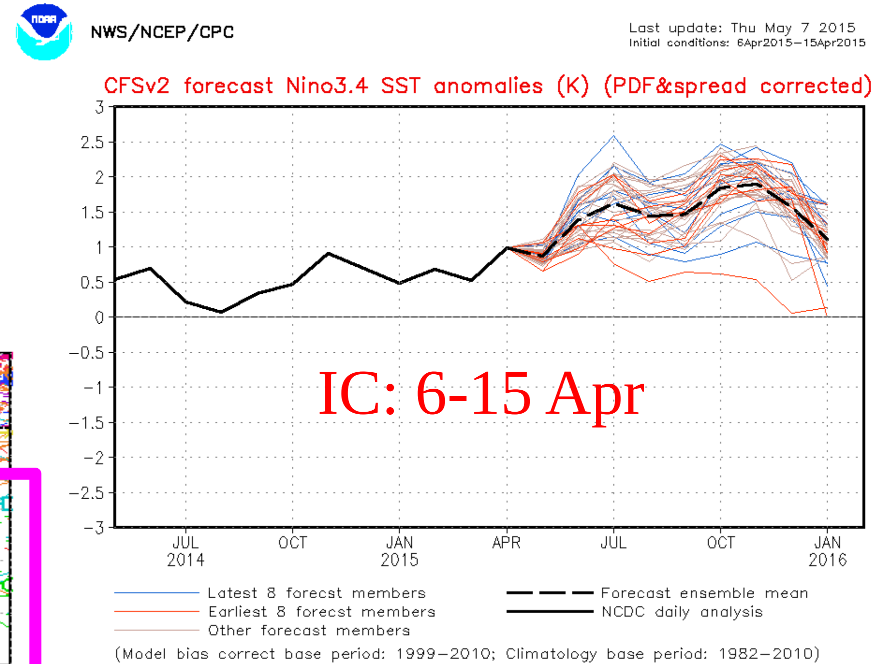


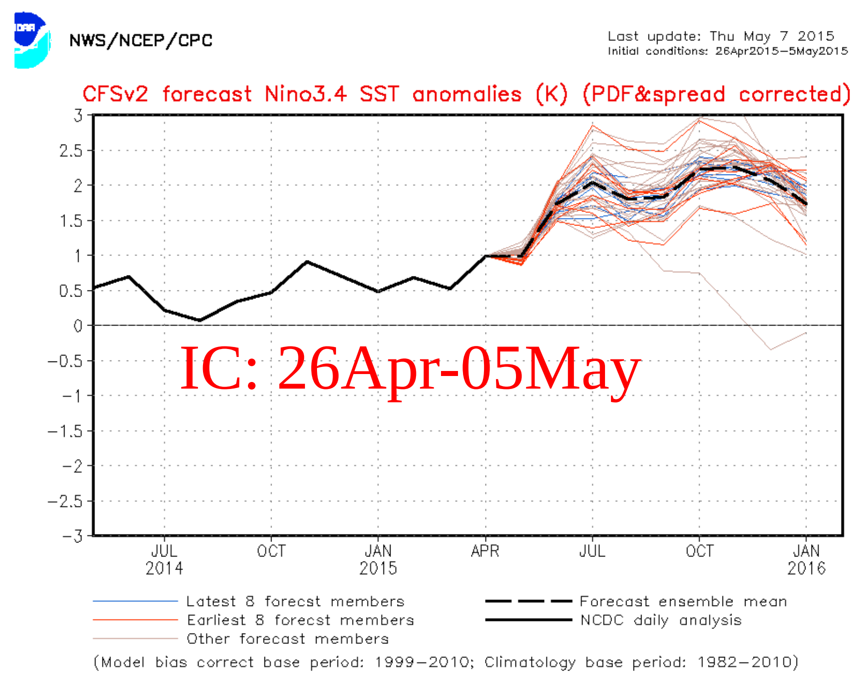


- **Majority of dynamical models predicted a warming tendency (El Nino) in 2015, but some of statistical models favor ENSO neutral in 2015.**
- **NOAA "ENSO Diagnostic Discussion" on 09 Apr 2015 suggested that "*There is an approximately 70% chance that El Niño will continue through Northern Hemisphere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

NMME & CFSv2

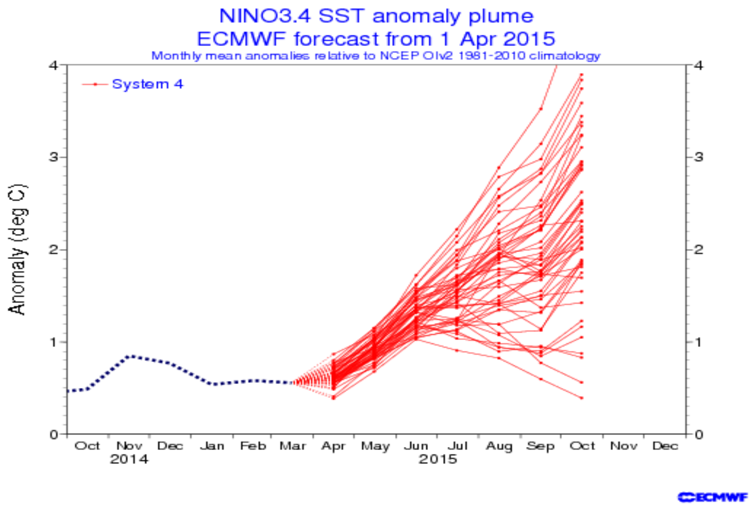

NMME Forecast for Nino 3.4 IC= 201505
OBS
CFSv2
CMC1
CMC2
GFDL
NASA
GFDL_FLOR
NCAR_CCSM4
NMME
NOV 2014
DEC
JAN 2015
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


NWS/NCEP/CPC
Last update: Thu May 7 2015
Initial conditions: 6Apr2015–15Apr2015
CFSv2 forecast Nino3.4 SST anomalies (K) (PDF&spread corrected)
IC: 6-15 Apr
JUL 2014
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)

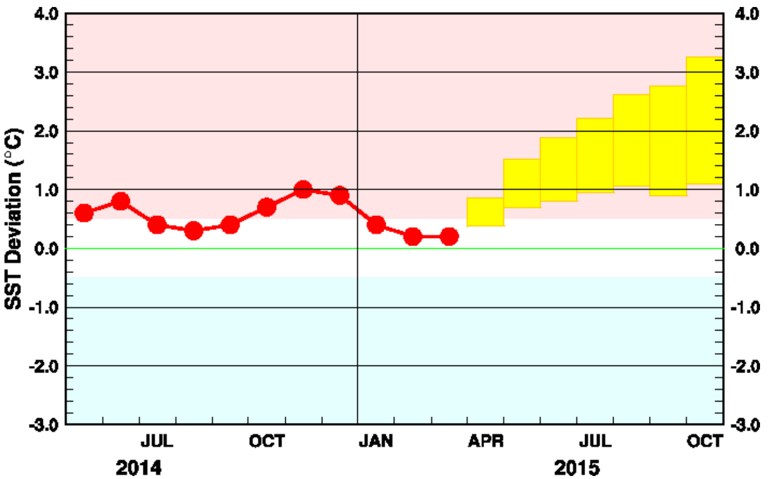

NWS/NCEP/CPC
Last update: Thu May 7 2015
Initial conditions: 26Apr2015–5May2015
CFSv2 forecast Nino3.4 SST anomalies (K) (PDF&spread corrected)
IC: 26Apr-05May
JUL 2014
OCT
JAN 2015
APR
JUL
OCT
JAN 2016
Latest 8 forecst members
Earliest 8 forecst members
Other forecast members
Forecast ensemble mean
NCDC daily analysis
(Model bias correct base period: 1999–2010; Climatology base period: 1982–2010)

Individual Model Forecasts: warming or little tendency

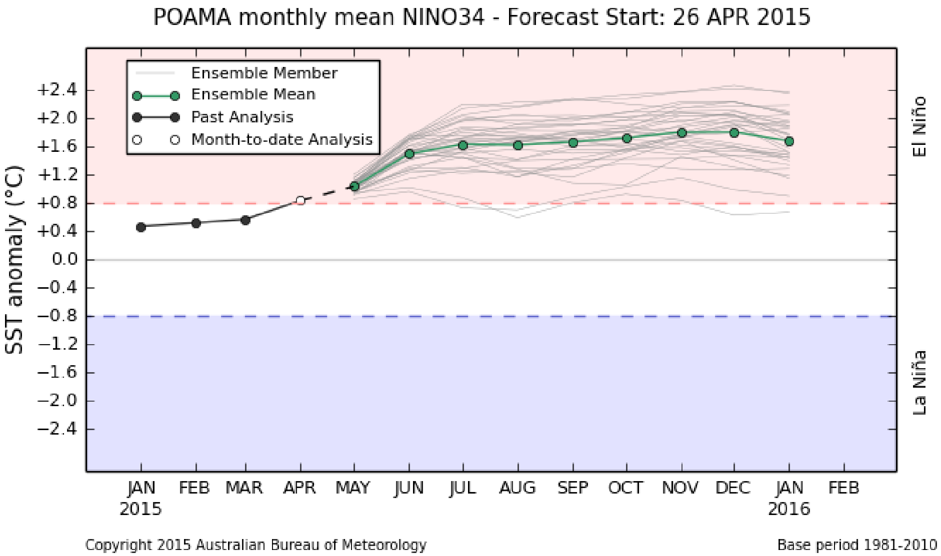
EC: Nino3.4, IC=01 Apr 2015



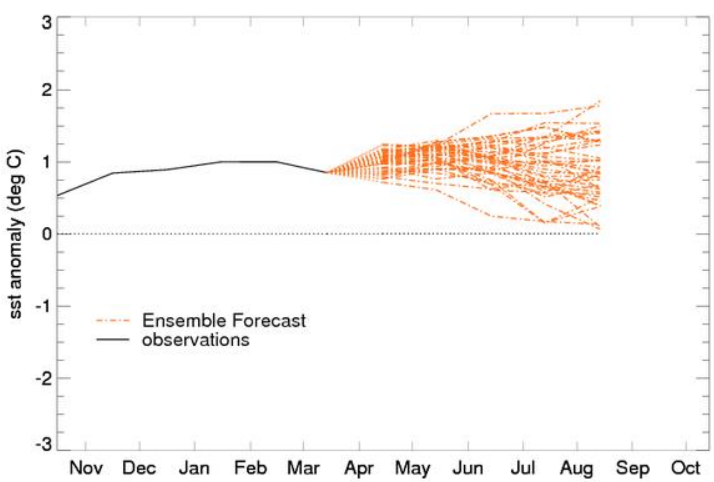
JMA: Nino3, IC=Apr2015



Australia: Nino3.4, IC=26Apr 2015



UKMO: Nino3.4, IC=Apr 2015



CPC Markov Model ENSO Forecast

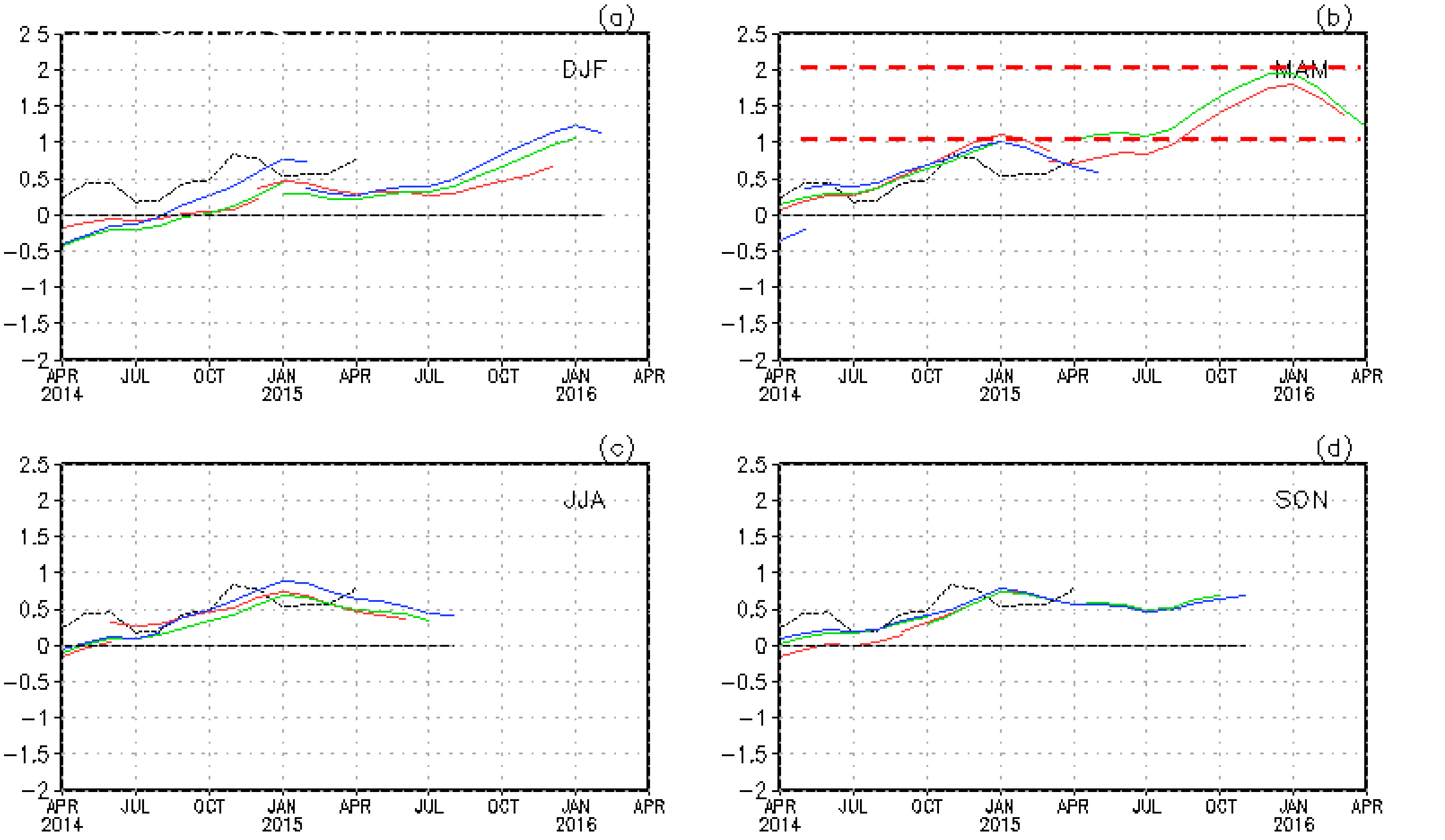
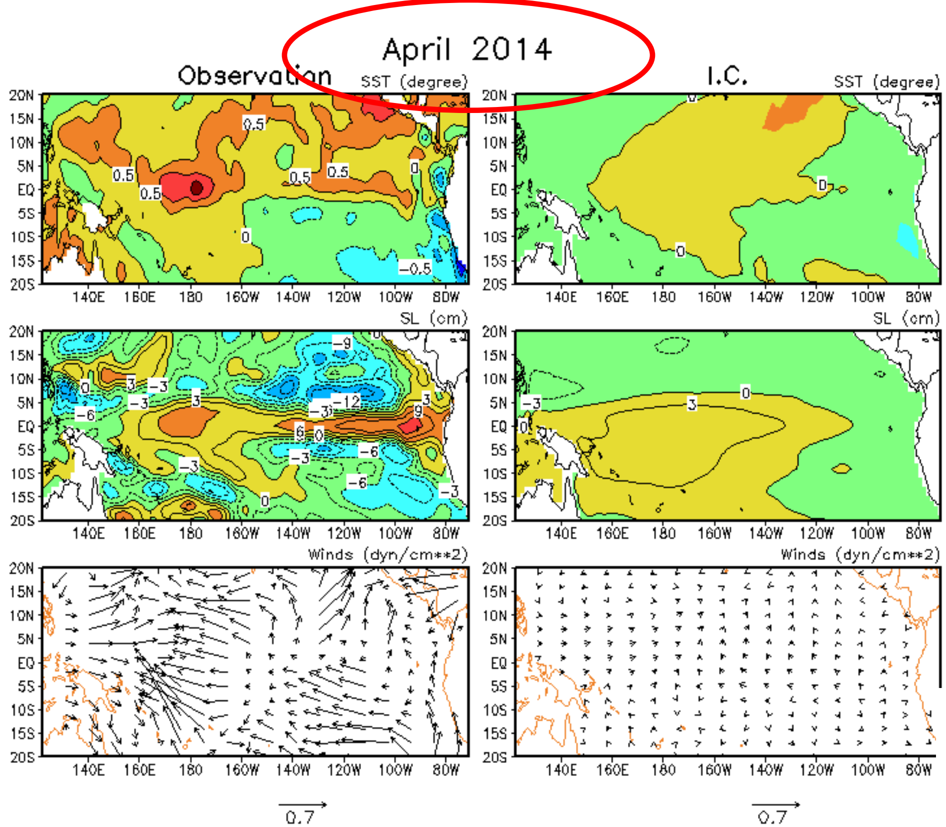
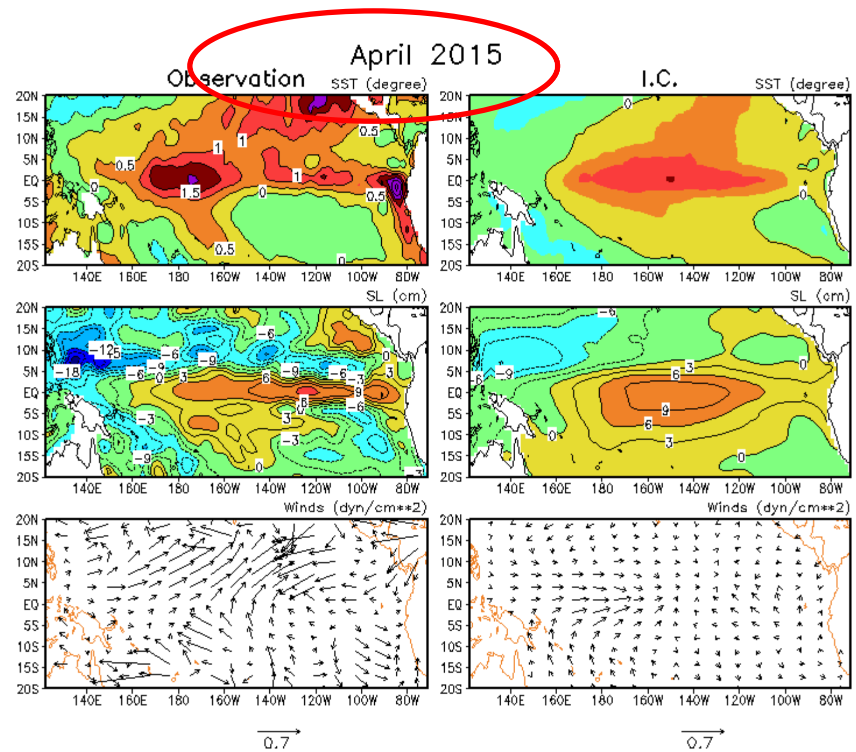
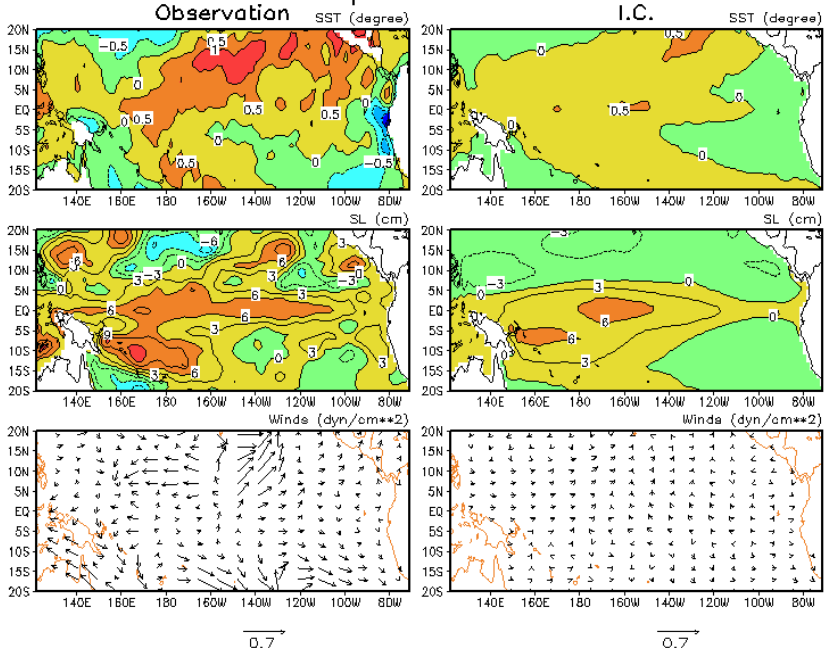


Fig. 4. Time evolution of NINO3.4 forecasts up to 12 lead months by the Markov model initiated monthly up to April 2015 . Shown in each panel are the forecasts grouped by three consecutive starting months: (a) is for December, January and February, (b) is for March, April and May, (c) is for June, July and August and (d) is for September, October and November. The observed NINO3.4 SST anomalies are shown in the heavy-dashed lines.

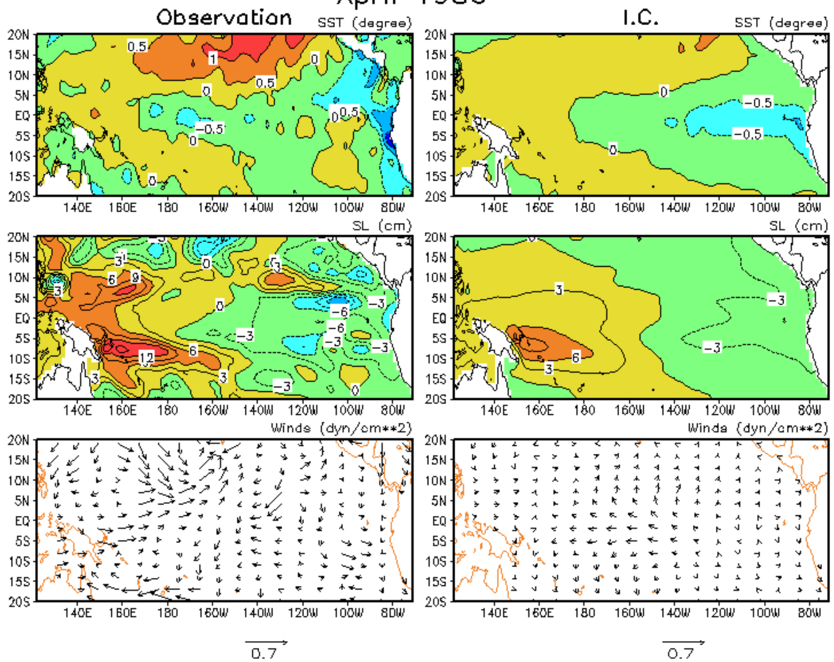

April 2014
Observation
I.C.
SST (degree)
SL (cm)
Winds (dyn/cm**2)
20N
15N
10N
5N
EQ
5S
10S
15S
20S
140E
160E
180
160W
140W
120W
100W
80W
0.7


April 2015
Observation
I.C.
SST (degree)
SL (cm)
Winds (dyn/cm**2)
20N
15N
10N
5N
EQ
5S
10S
15S
20S
140E
160E
180
160W
140W
120W
100W
80W
0.7

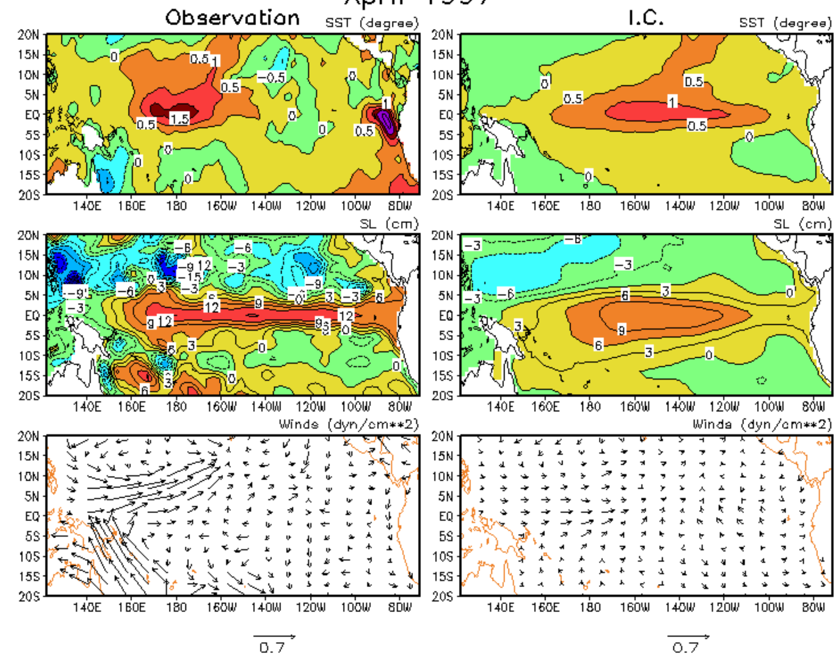
April 1982



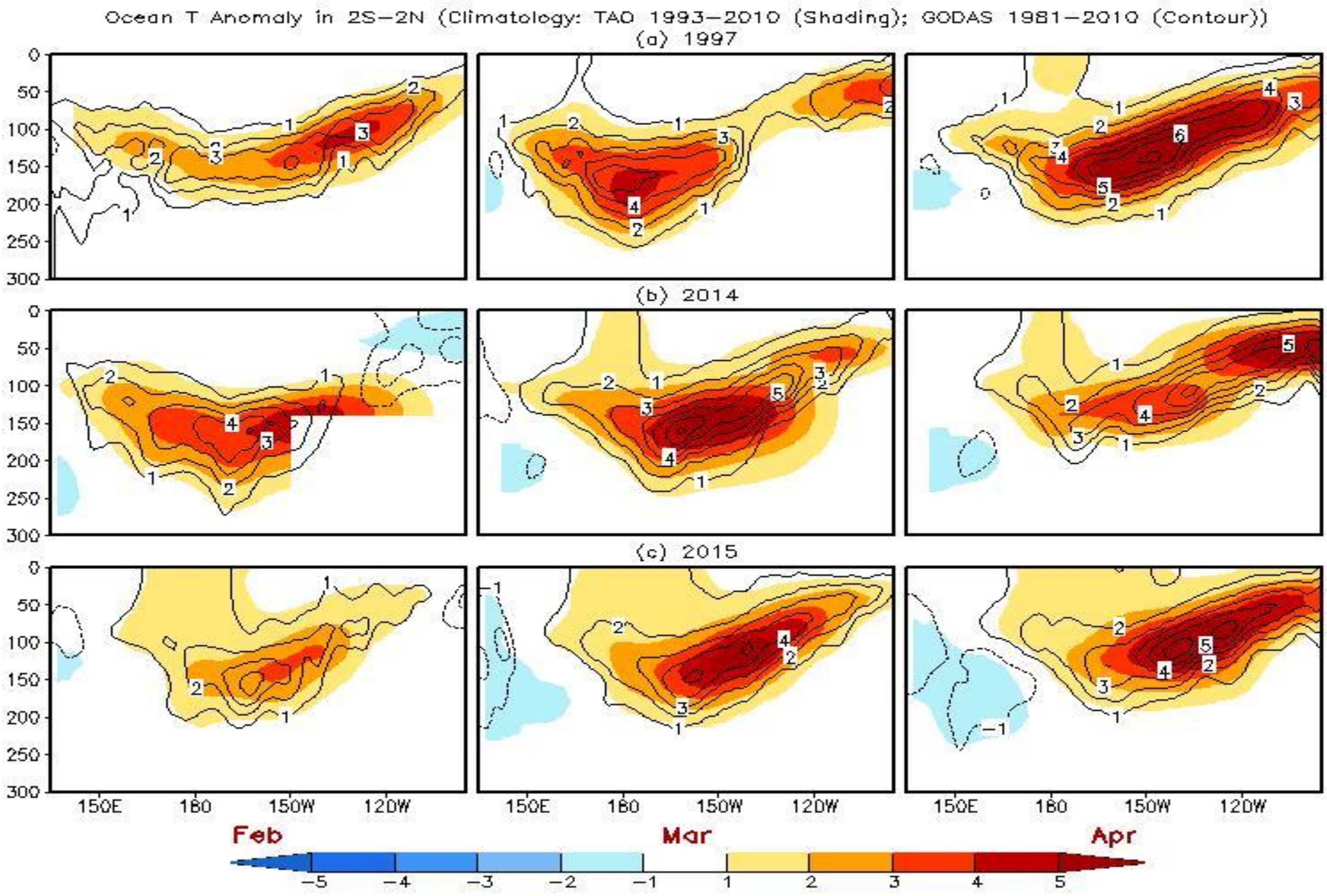
April 1986

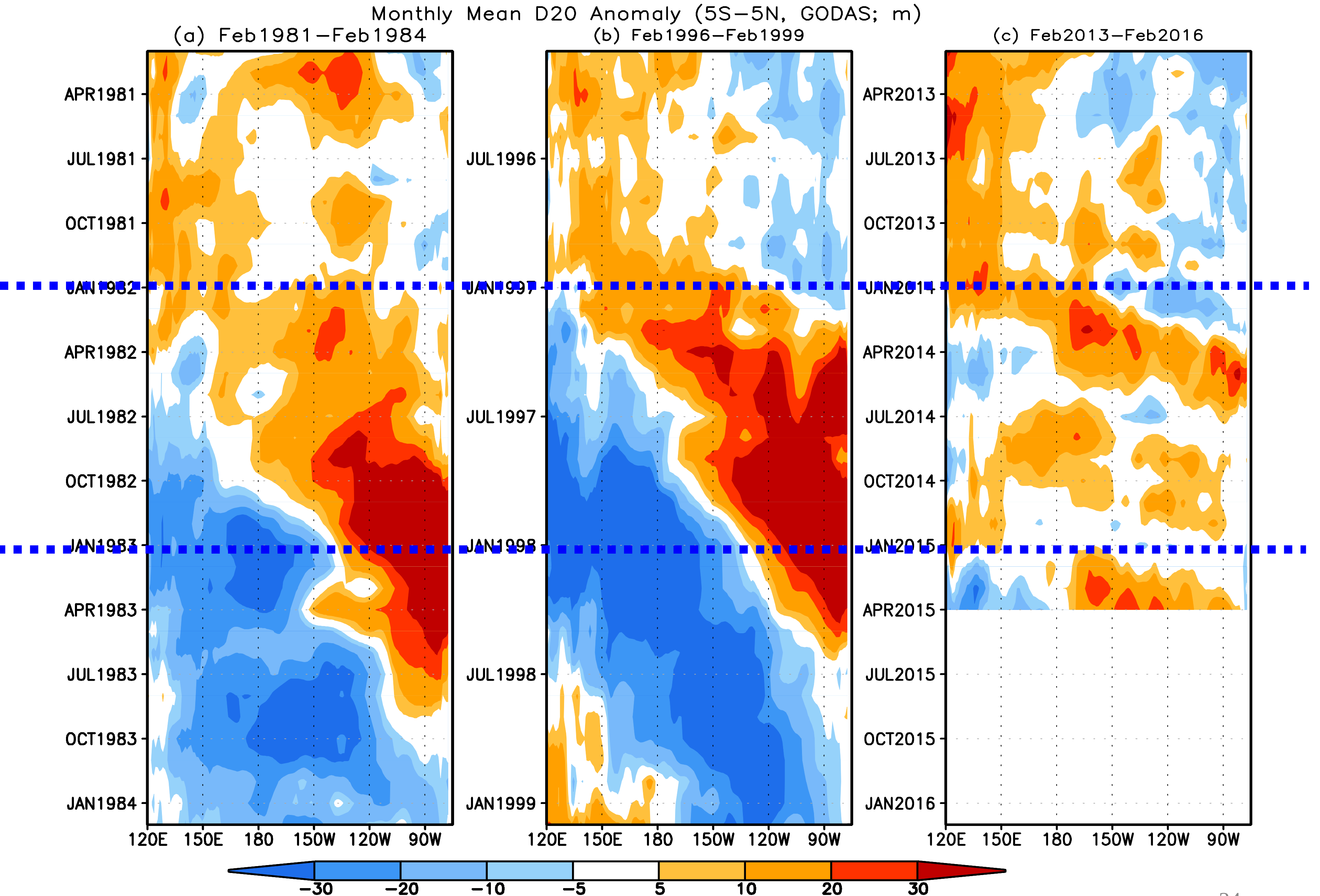


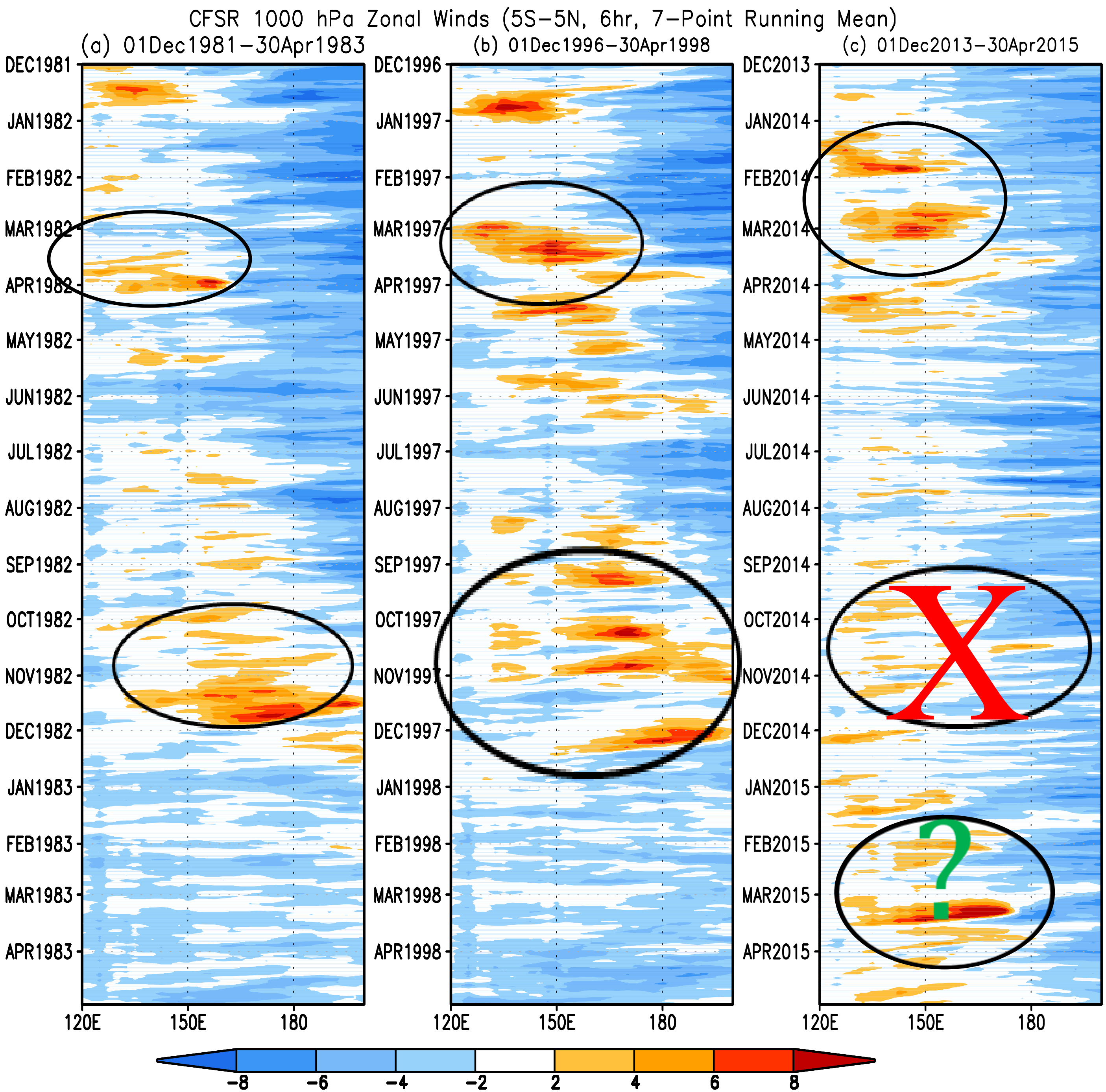
April 1997



Subsurface Ocean T Anomaly in Feb, Mar and Apr 1997, 2014, 2015




Monthly Mean D20 Anomaly (5S-5N, GODAS; m)
(a) Feb1981-Feb1984
(b) Feb1996-Feb1999
(c) Feb2013-Feb2016
APR1981
JUL1981
OCT1981
JAN1982
APR1982
JUL1982
OCT1982
JAN1983
APR1983
JUL1983
OCT1983
JAN1984
JUL1996
JAN1997
JUL1997
JAN1998
JUL1998
JAN1999
APR2013
JUL2013
OCT2013
JAN2014
APR2014
JUL2014
OCT2014
JAN2015
APR2015
JUL2015
OCT2015
JAN2016
120E
150E
180
150W
120W
90W
-30
-20
-10
-5
5
10
20
30



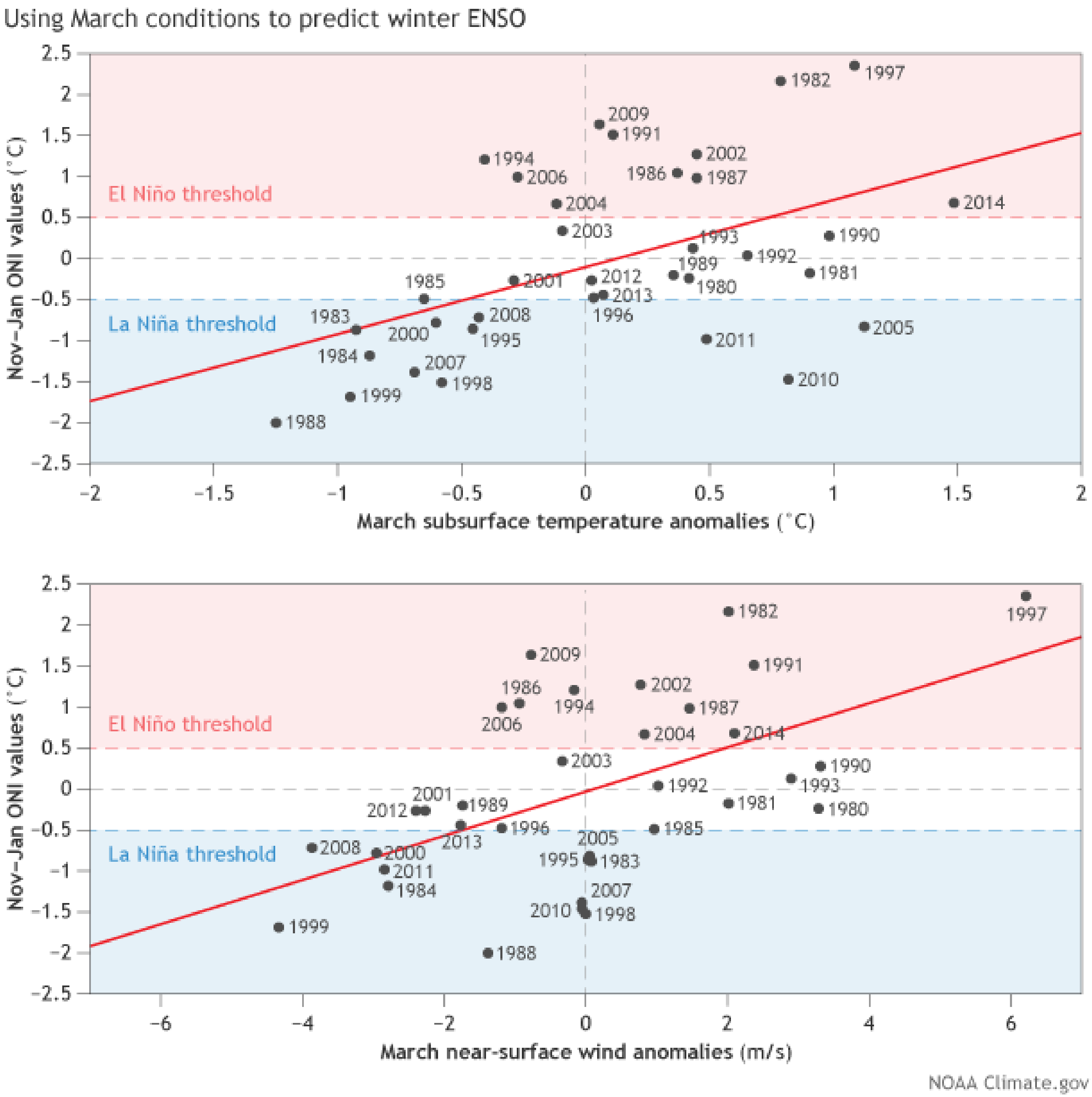
U1000

Anomaly in

1982-83,

1997-98,

2014-15



<u>Prediction skill with IC in Mar:</u>

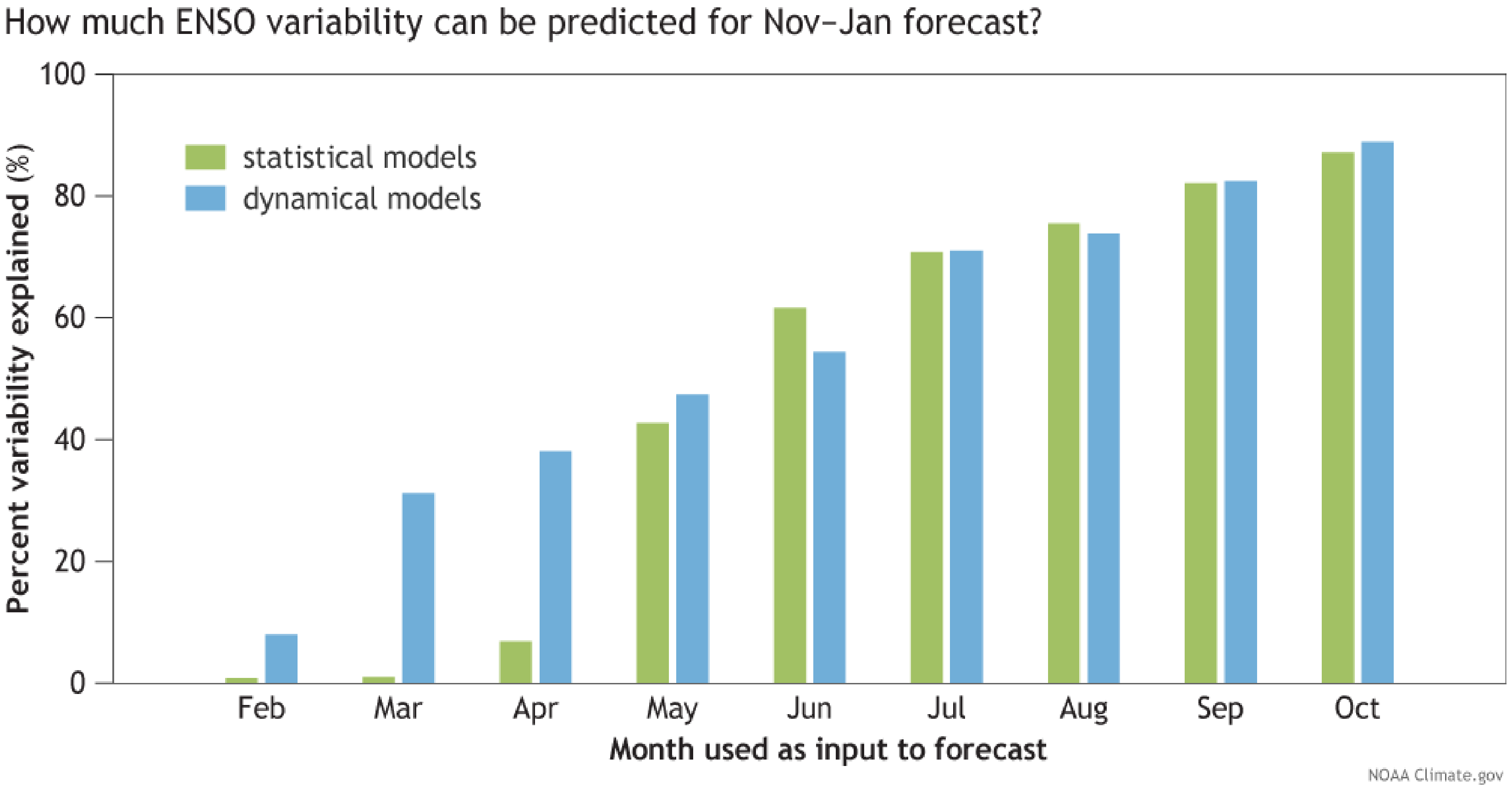
The western Pacific winds and subsurface temperatures in the eastern half of the tropical Pacific Ocean for Mar – explain only about a quarter to a third (~25-33%) of the coming winter ENSO state.

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

The Spring Predictability Barrier: we'd rather be on Spring Break

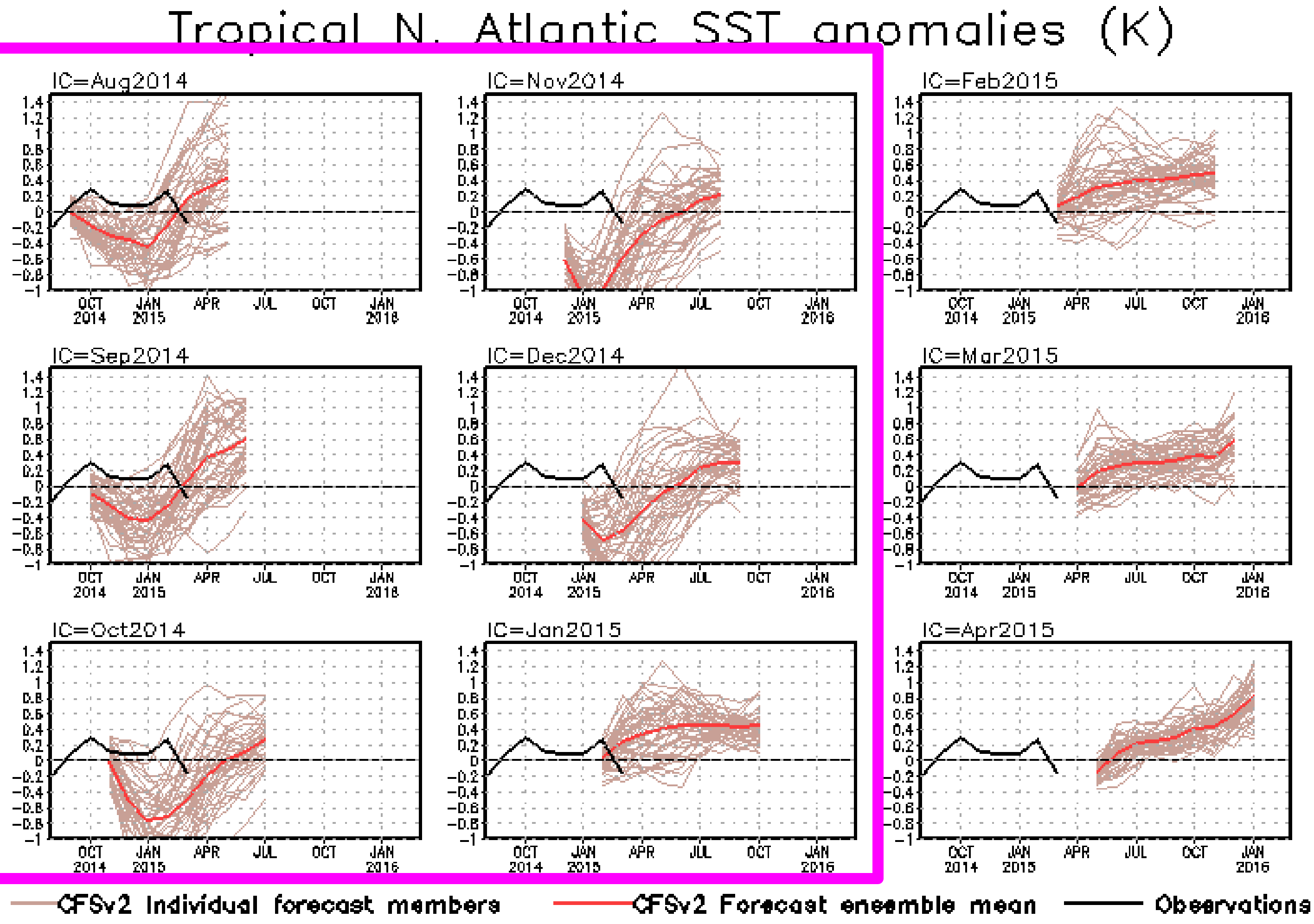
Author: Michelle L'Heureux

(http://www.climate.gov/news-features/blogs/enso/spring-predictability-barrier-we%E2%80%99d-rather-be-spring-break)



The skill (or forecasting ability) of model runs based on February-October observations to predict the November-January (NDJ) average value in the Niño-3.4 SST region (ENSO). Results shown here are an average correlation coefficient from each of the 20 models between 2002-2011 (data used from Barnston et al, 2012). Percent Explained Variance (%) is calculated by squaring the correlation coefficient and multiplying by 100 (see footnote #1). Models that explain all ENSO variability would equal 100%, while explaining none of the ENSO variance would equal 0%. Graphic by Fiona Martin based on data from NOAA CPC and IRI.

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



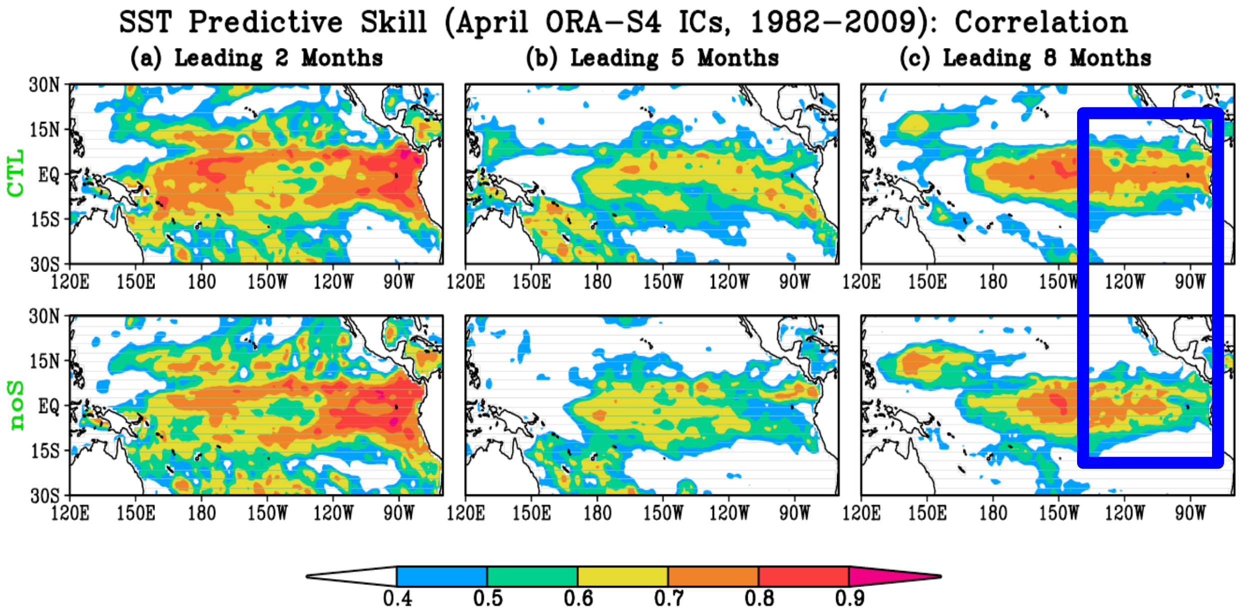
TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

- Predictions initiated in Oct-Dec 2004 may be biased by errors in the Atlantic in CFSR.
- Latest CFS2 prediction calls above normal SST in North Atlantic in summer-winter 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.

Why we monitor sea surface salinity (SSS) ?

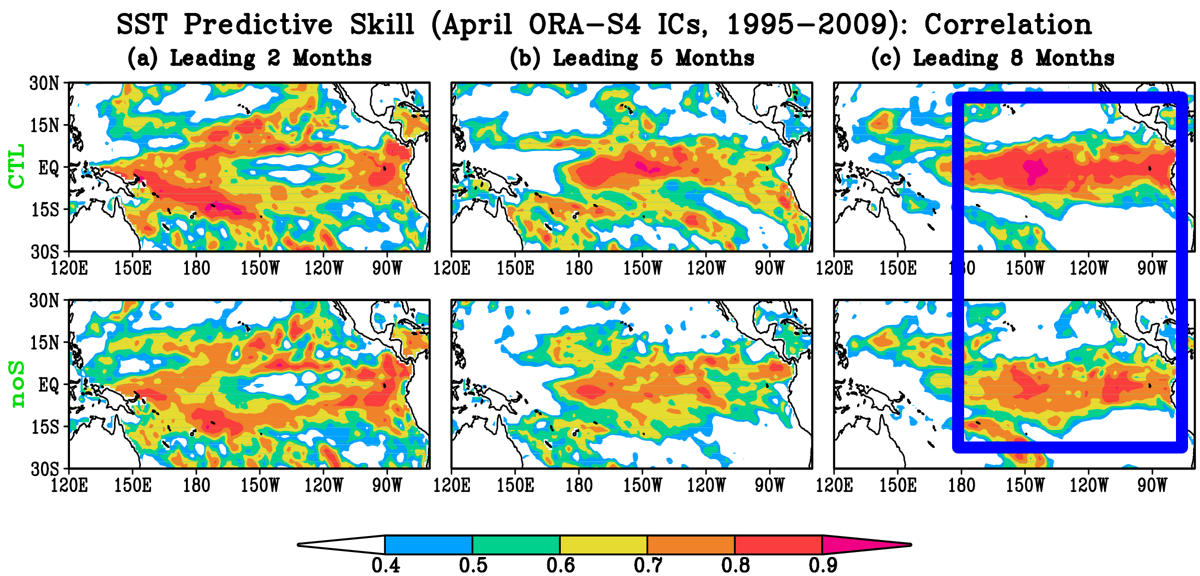
(possible role of SSS on ENSO prediction)



1982-2009

1) 1982-2009: Exp. noS degrades SSTA prediction in the eastern Pacific.

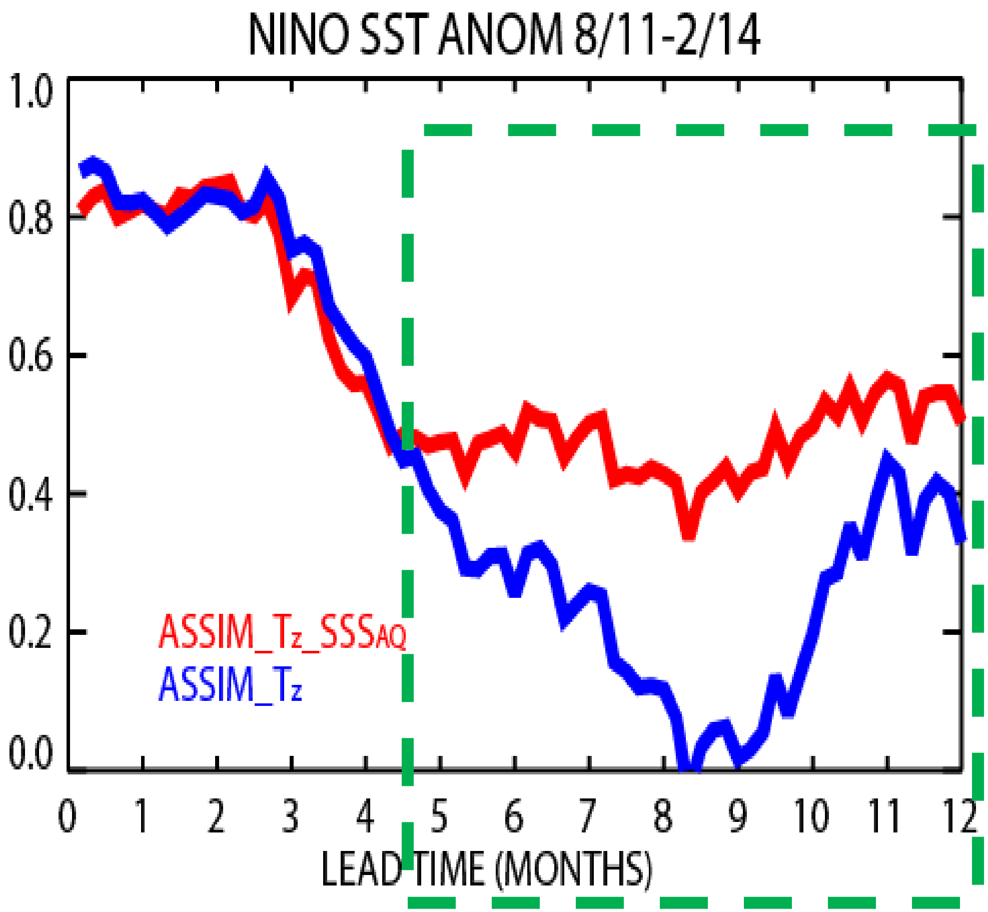
(2) 1995-2009: Exp. noS clearly degrades SSTA prediction in the whole tropical Pacific.



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.

Aquarius SSS assimilation significantly improves coupled forecasts due to enhanced mixing, entrainment of cool subsurface water into the mixed layer, and subsequent Bjerknes feedback in the eastern Pacific.



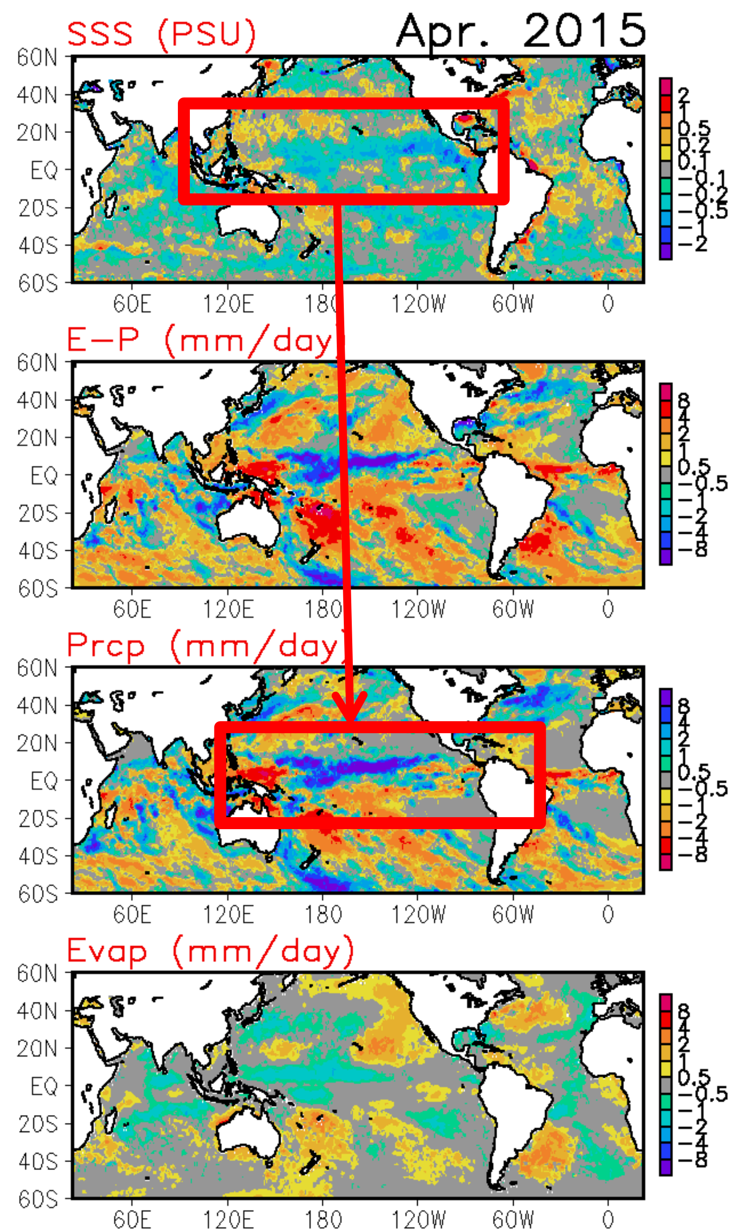
Correlation of our Indo-Pacific statistical atmospheric Hybrid coupled model results for August 2011 to February 2014 versus observed NINO3 SST anomaly. The solid blue curve is the baseline - initialized using assimilation of subsurface temperature. The red curve adds assimilation of Aquarius SSS at initialization. Note that Aquarius SSS assimilation significantly outperforms no-SSS assimilation after 5 month forecasts due to enhanced density-induced upwelling, mixing of cooler subsurface waters to the surface and subsequent Bjerknes feedback in the Pacific.

Hackert, E., J. Ballabrera-Poy, A. Hackert, E., A. Busalacchi, and J. Ballabrera-Poy (2014), Impact of Aquarius sea surface salinity observations on coupled forecasts for the tropical Indo-Pacific Ocean, Journal of Geophysical Research, Oceans, 119. (DOI: 10.1002/2013JC009697)

Global Sea Surface Salinity (SSS)

Anomaly for April 2015

- Global SSS pattern was characterized by negative anomalies over equatorial Pacific, and by positive anomalies over the SW Pacific east of Australia and over the NW Atlantic offshore of the eastern North America;
- SSS anomalies over the Tropical pacific and SW Pacific were clearly associated with the E-P over the respective regions, while that over the NW Atlantic seems a result of multiple processes.



Data used

SSS :

Blended Analysis of Surface Salinity (BASS) V0.Y

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

(Xie et al. 2014)

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

Precipitation:

CMORPH adjusted satellite precipitation estimates

Evaporation:

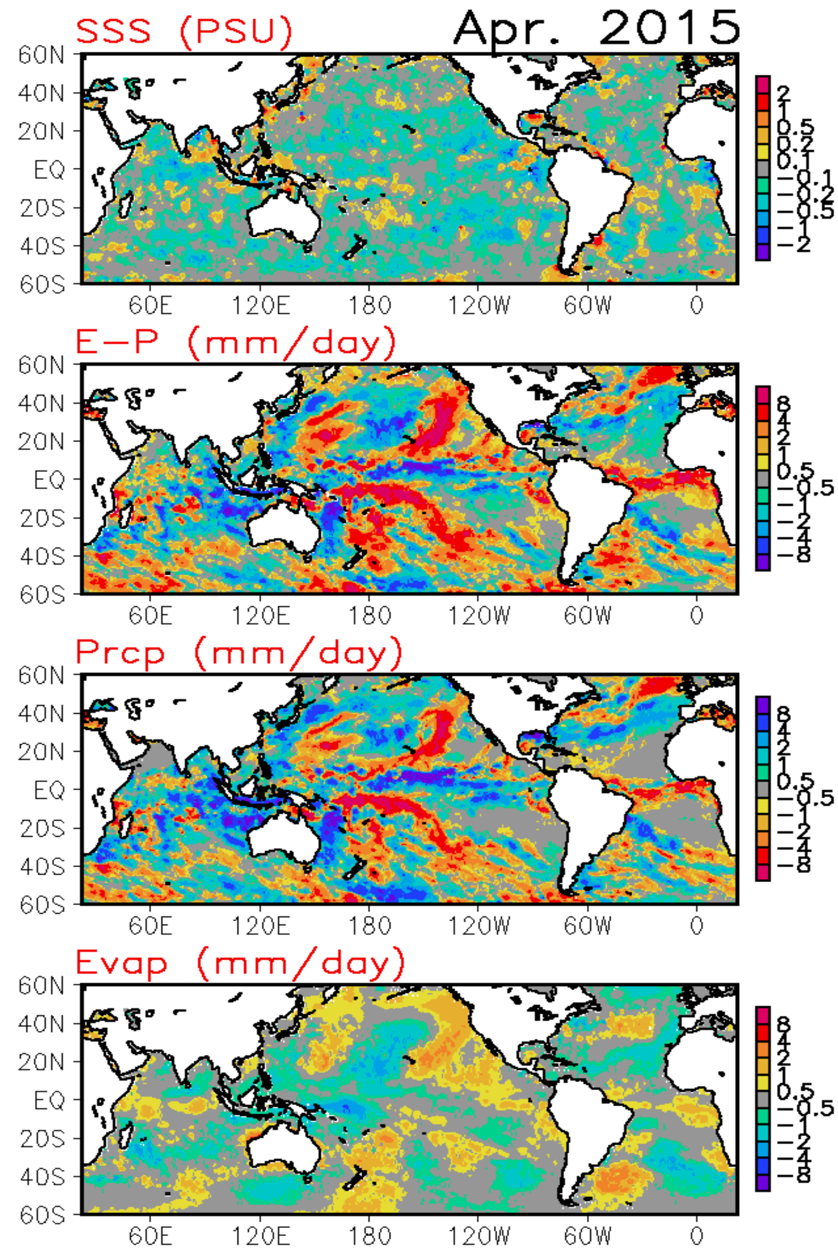
CFS Reanalysis

Global Sea Surface Salinity (SSS)

Tendency for April 2015

- SSS anomaly becomes fresher over most regions of the tropical Pacific;

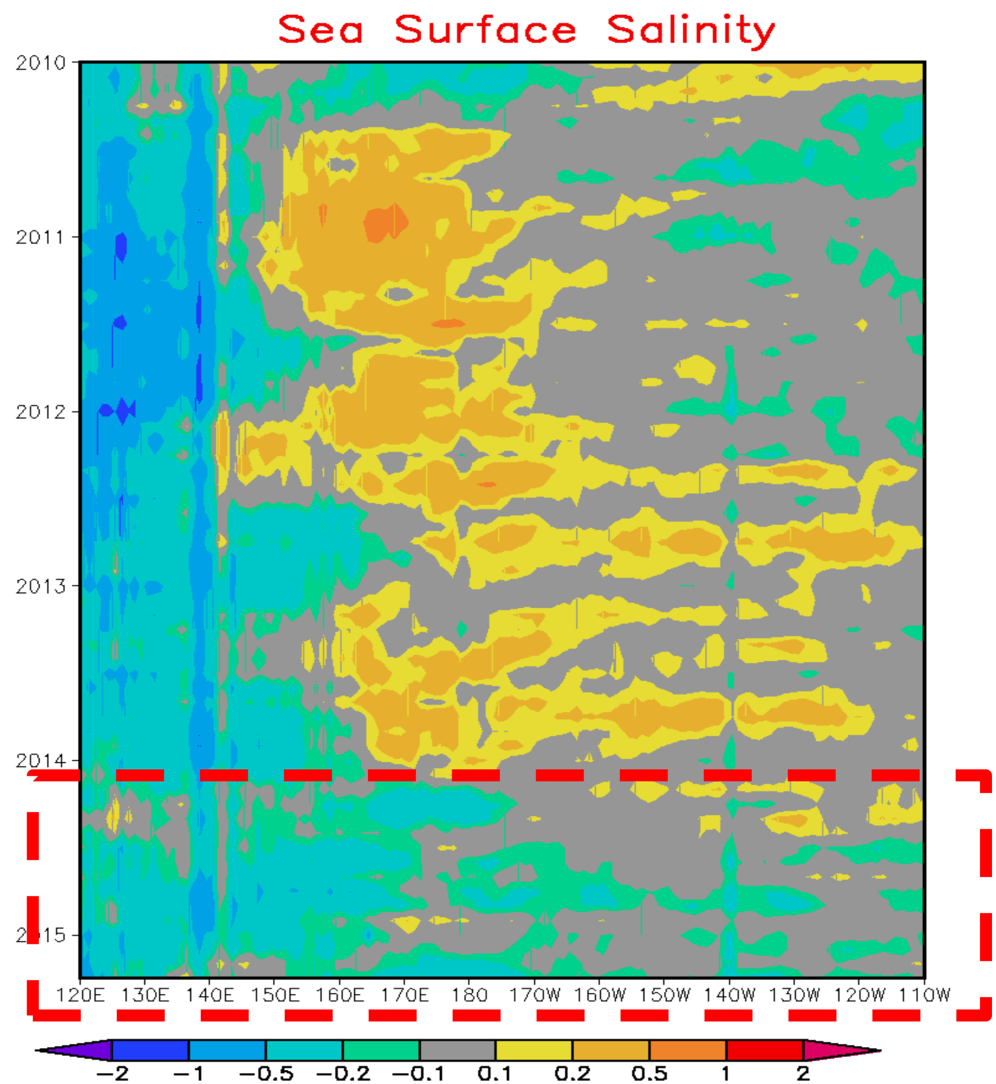
- Positive SSS anomalies are also noticed over several coastal regions off the NE and SE coasts of the South America and parts of maritime continent, possibly attributable to the changes in the river runoffs there.



Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific

- Hovemoller diagram for equatorial anomaly **(10ºS-10ºN);**
- Negative SSS anomaly enhanced in recent months over the equatorial western and central Pacific;
- In April 2015, the negative anomaly averaged over the equatorial belt reached east of the date line, to ~150ºW;

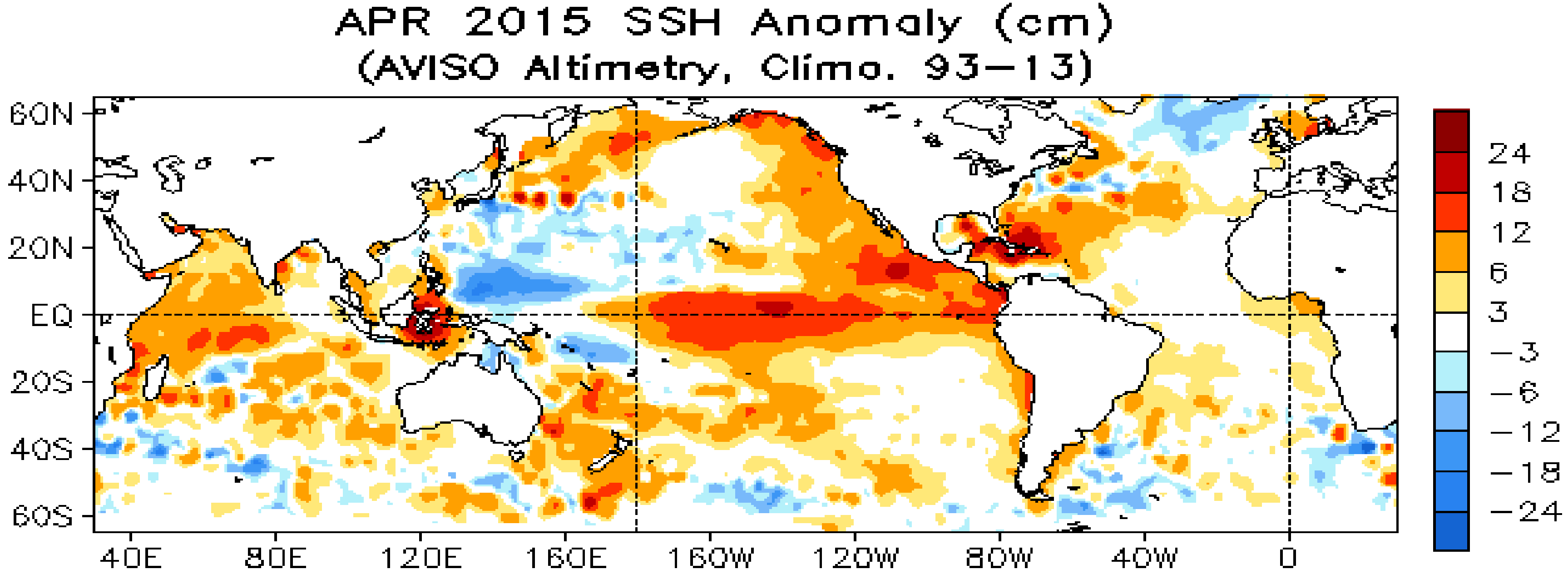


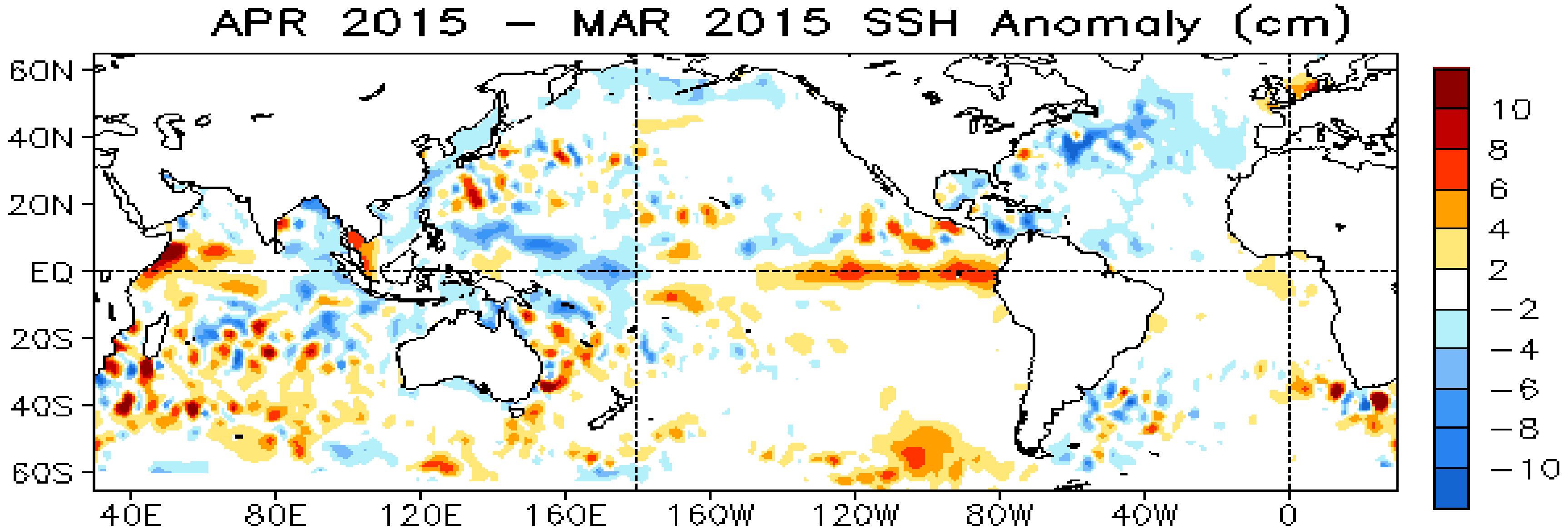
Overview

- **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 and eastern tropical Pacific with NINO3.4=0.8^{o}C in Apr 2015.**
  - **Positive anomalies of subsurface ocean temperature along the equator persisted and propagated eastward slowly in Apr 2015.**
  - **Majority of dynamical models predicted a warming tendency (El Nino) in 2015, but some of statistical models favor ENSO neutral in 2015.**
  - **Positive phase of PDO has persisted for 10 months, with PDOI=1.3 in Apr 2015.**
- **Indian Ocean**
  - **Positive SSTAs were mainly in the southern Indian Ocean.**
- **Atlantic Ocean**
  - **Positive phase of NAO has persisted for 6 months with NAOI=0.6 in Apr 2015, causing a horseshoe-like pattern of SSTA in N. Atlantic.**

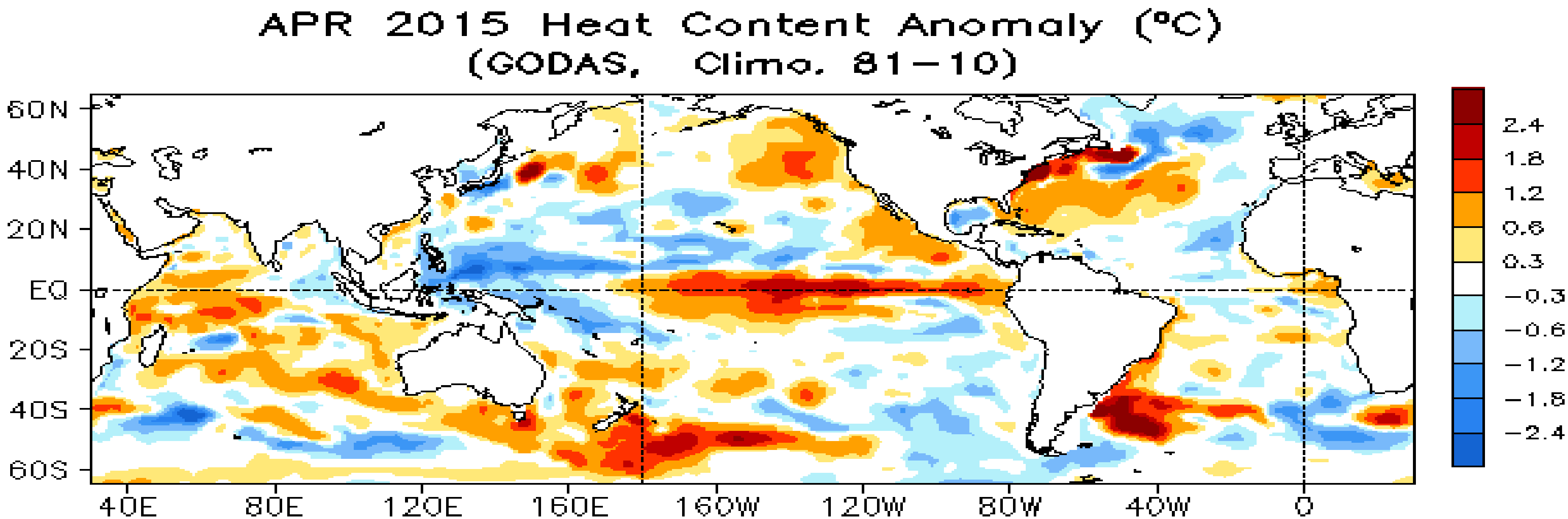
Backup Slides

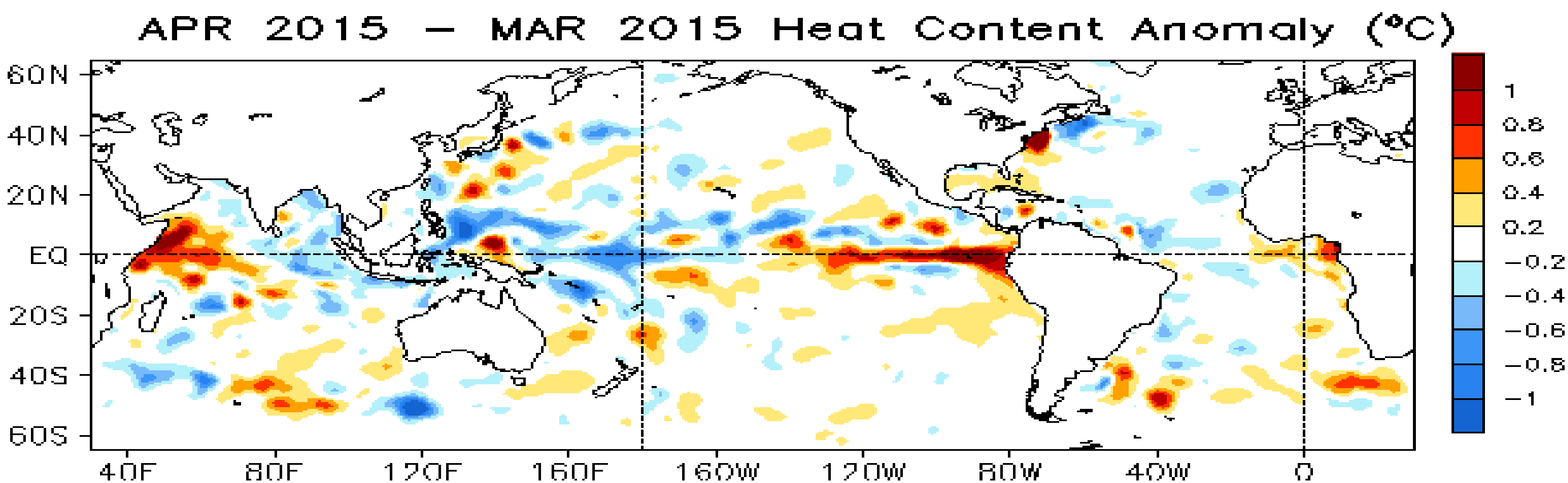
Global SSH Anomaly (cm) and Anomaly Tendency





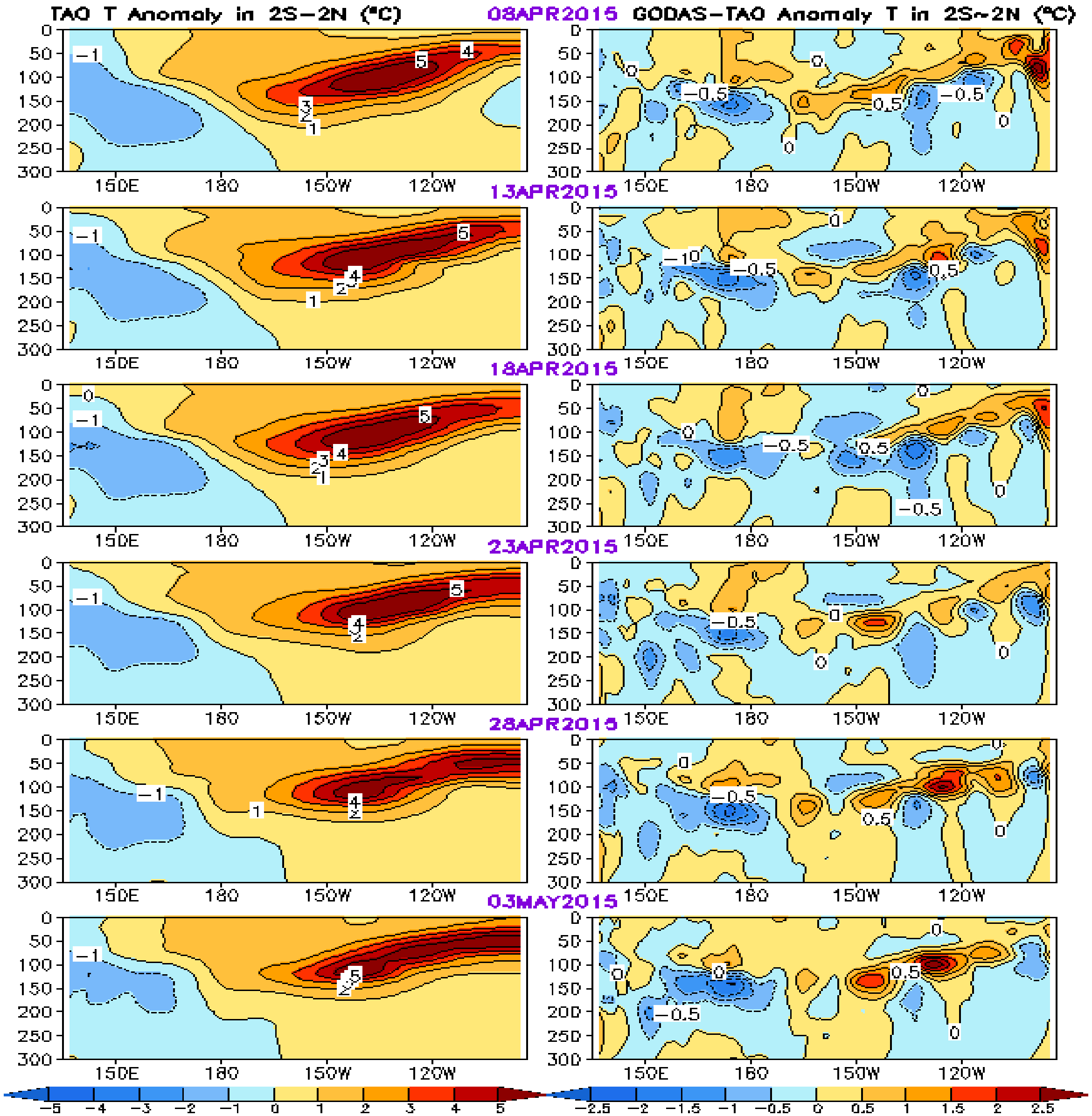
Global HC Anomaly (cm/^{o}C) and Anomaly Tendency





Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

TAO Anomaly GODAS-TAO T Anomaly



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.**

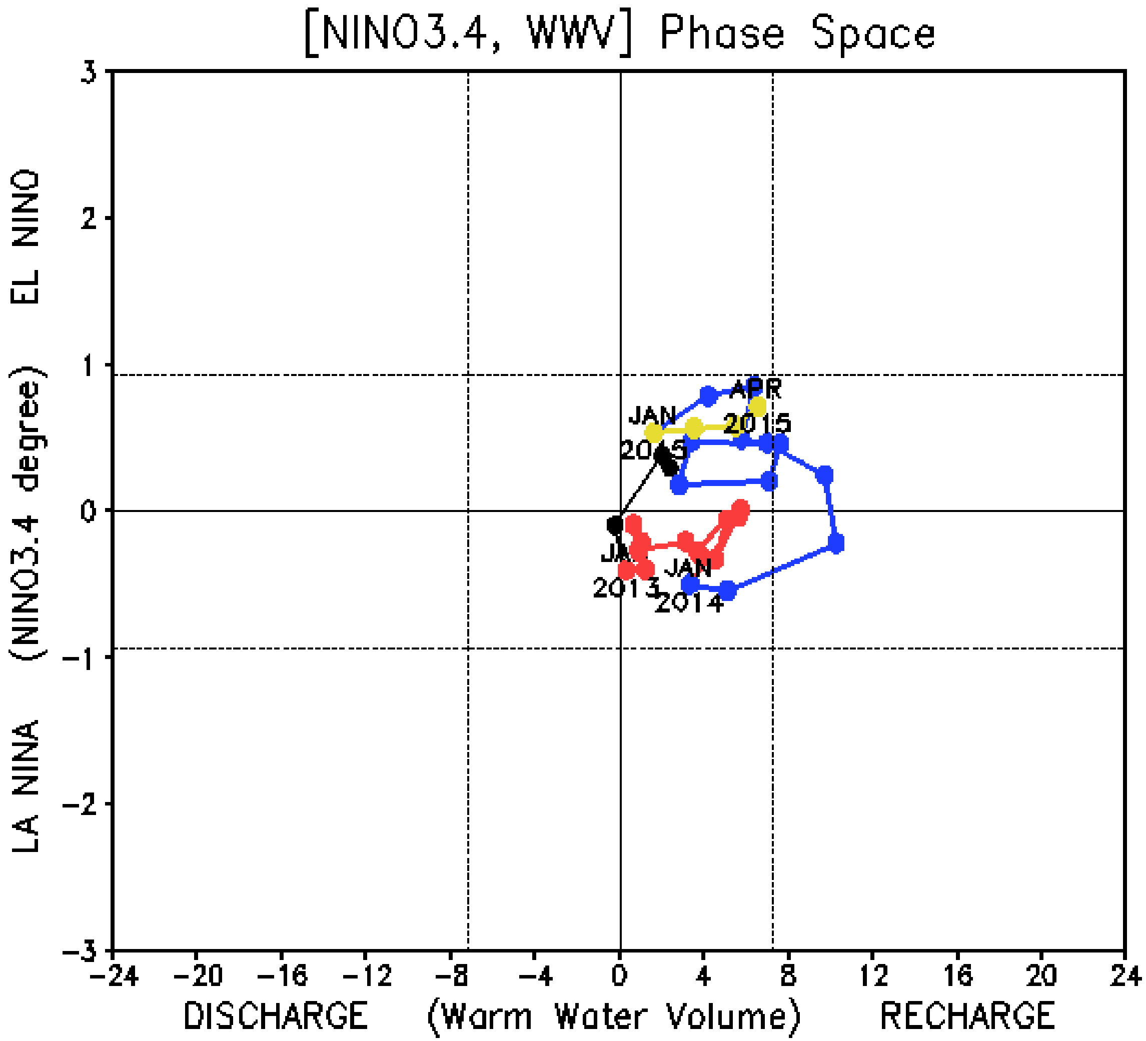
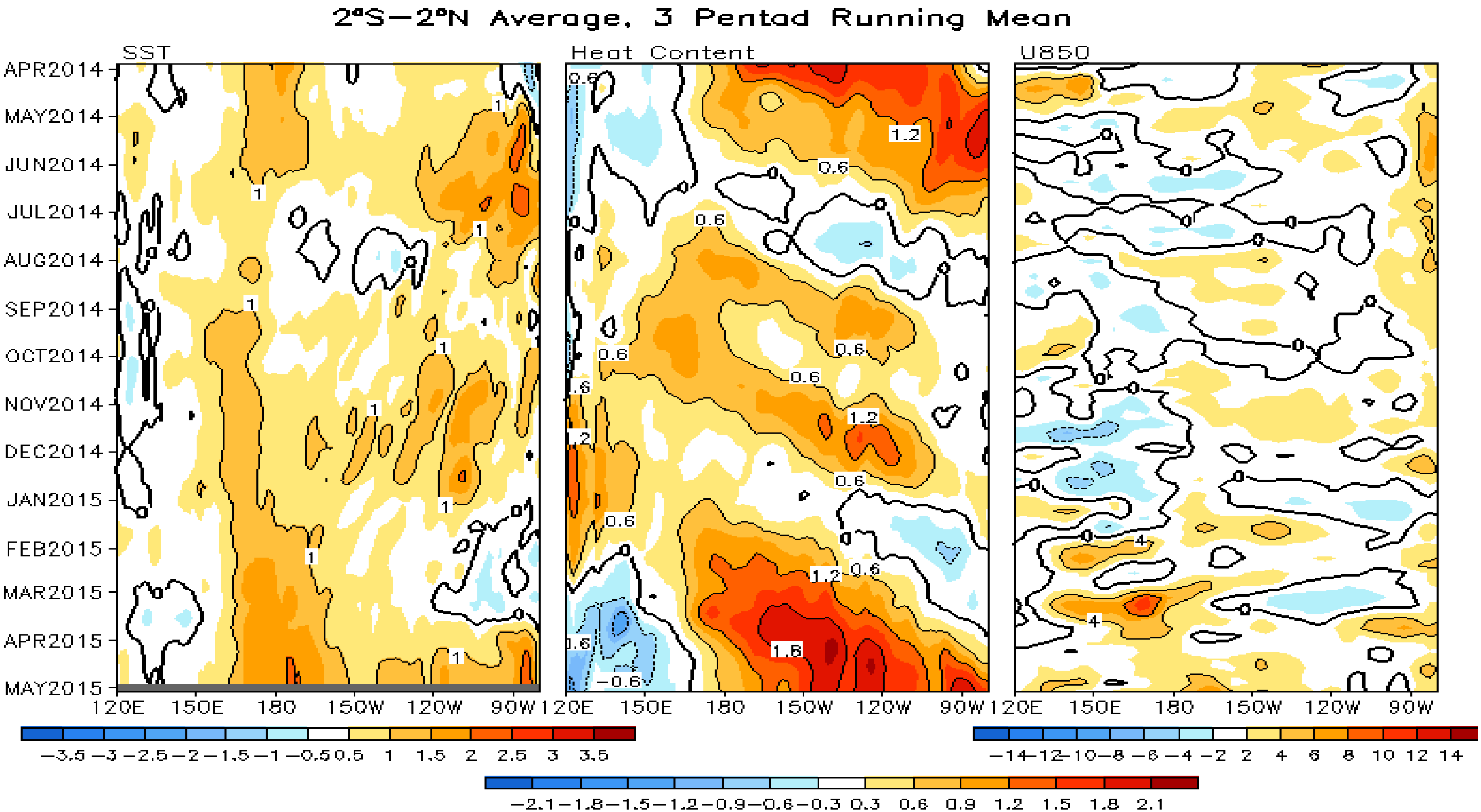
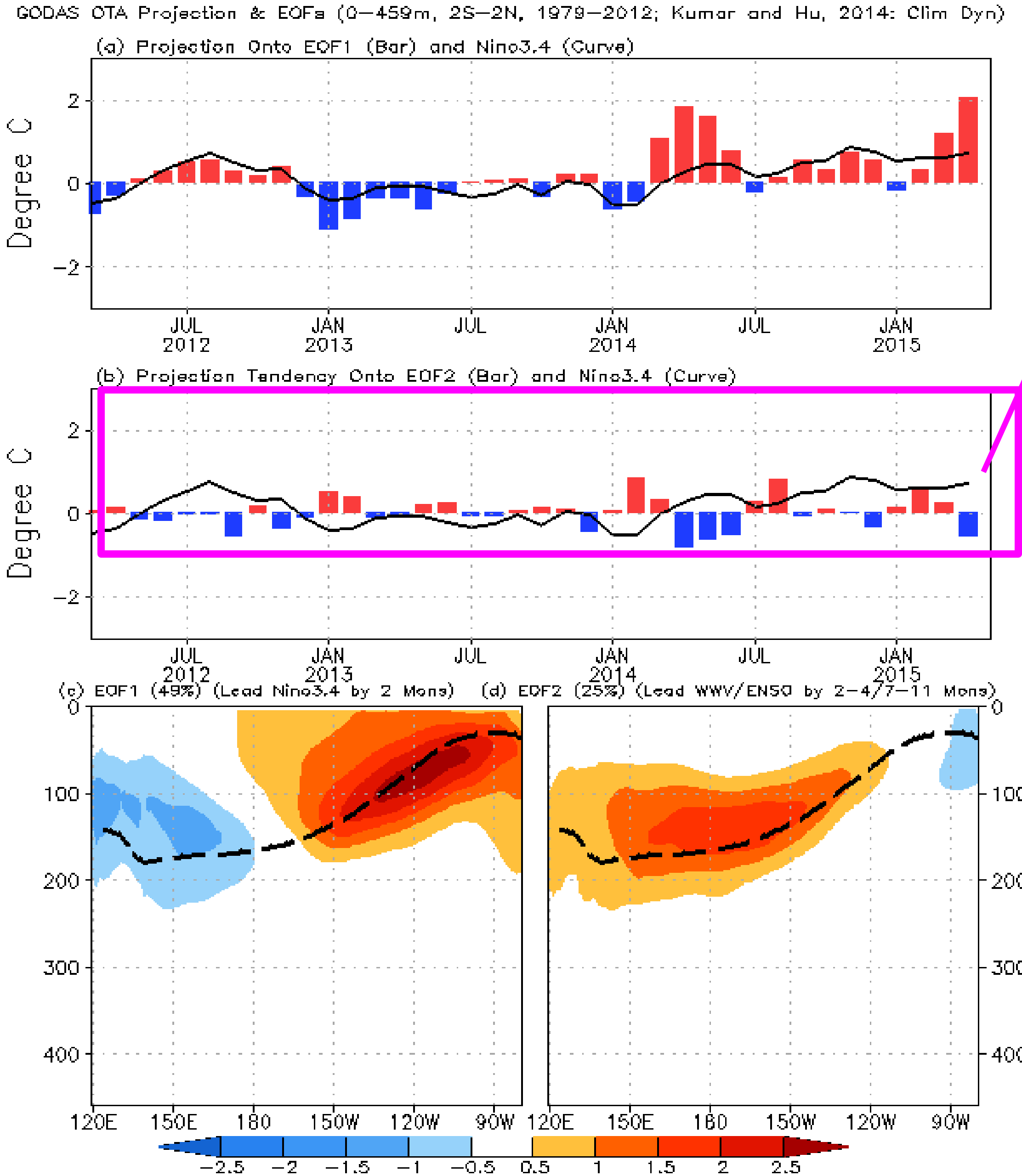


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

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



- **Positive SSTA presented in the central-eastern equatorial Pacific in Apr 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.**
- **Low-level westerly wind anomalies were more frequent in the past 3-4 months.**



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

<u>Projection of OTA onto EOF1 and EOF2 (2S-2N, 0-459m, 1979-2010)</u>

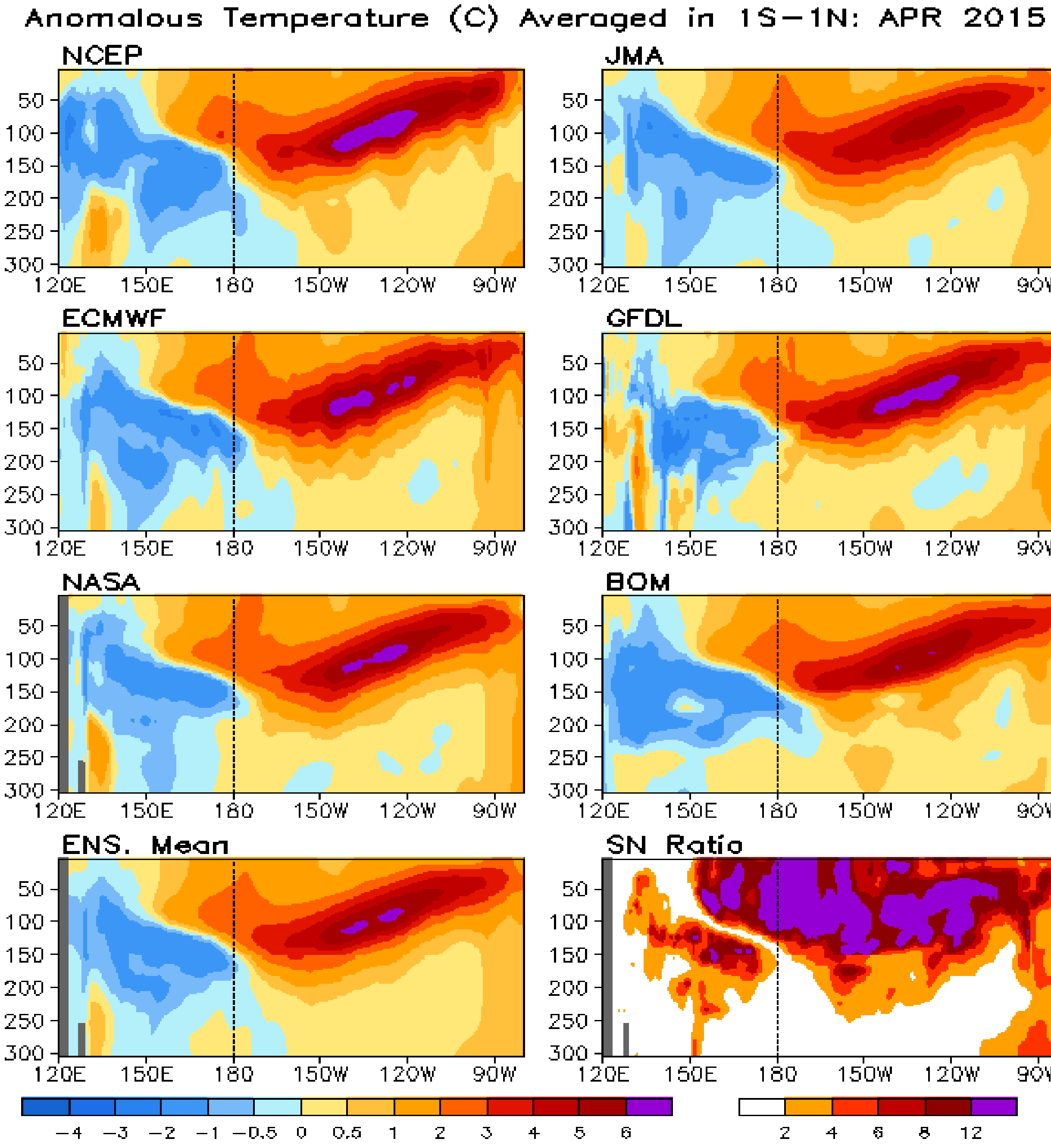
EOF1: Tilt mode (ENSO peak phase);

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

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

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

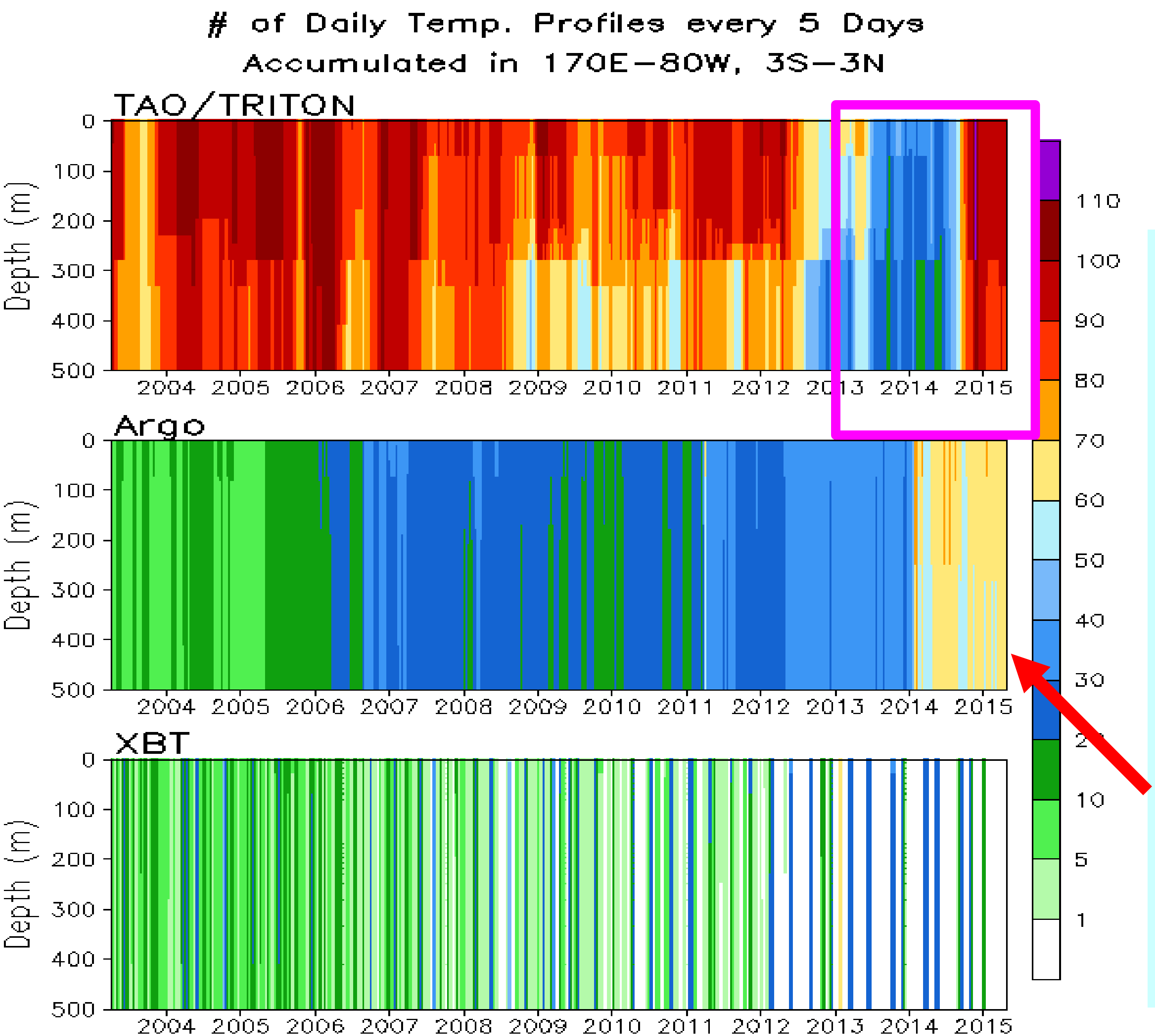
<u>For details, see:</u>
Kumar A, Z-Z Hu (2014) Interannual and interdecadal variability of ocean temperature along the equatorial Pacific in conjunction with ENSO. Clim. Dyn., 42 (5-6)**, 1243-1258.** *DOI: 10.1007/s00382-013-1721-0*.



Multiple Ocean Reanalyses: Ocean Temperature along the equator

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

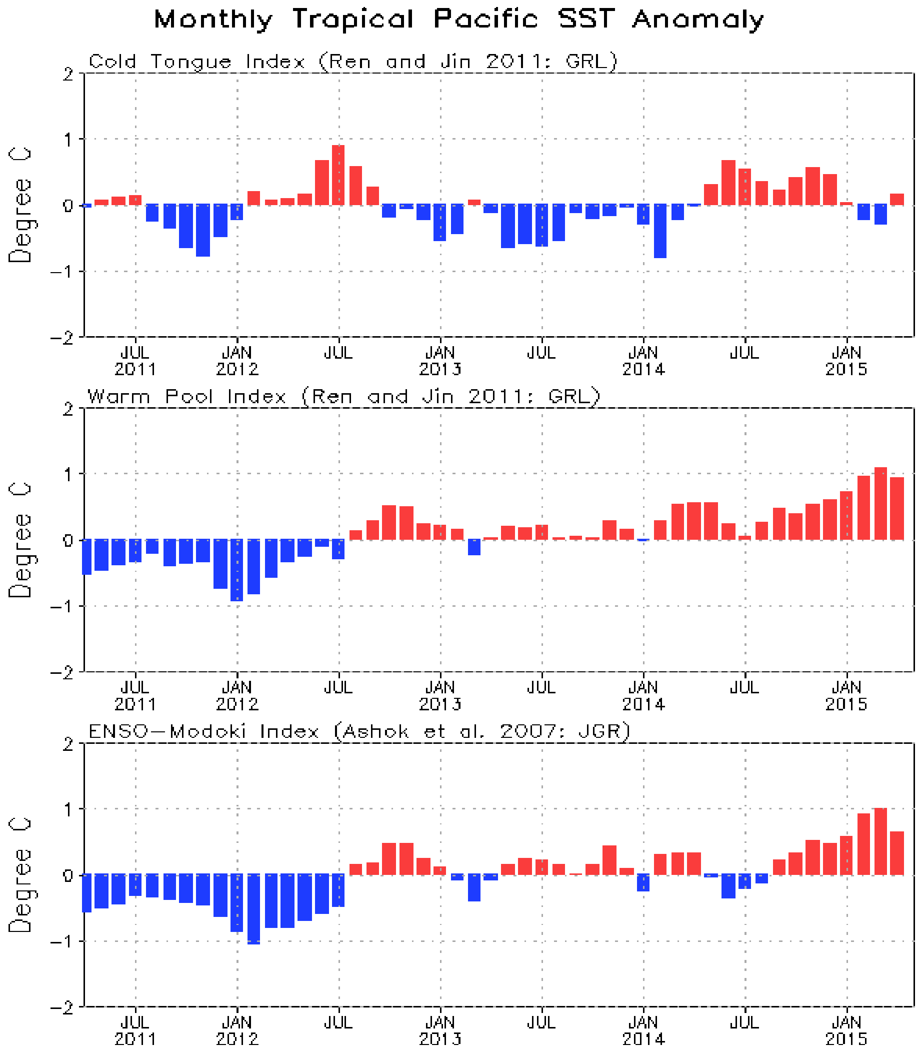
-(http://origin.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)



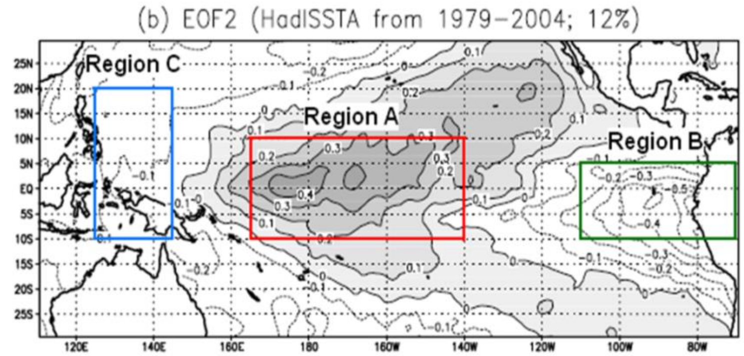
- TAO data delivery rate decreased significantly during late 2012 to mid-2014, and largely recovered since late 2014.

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

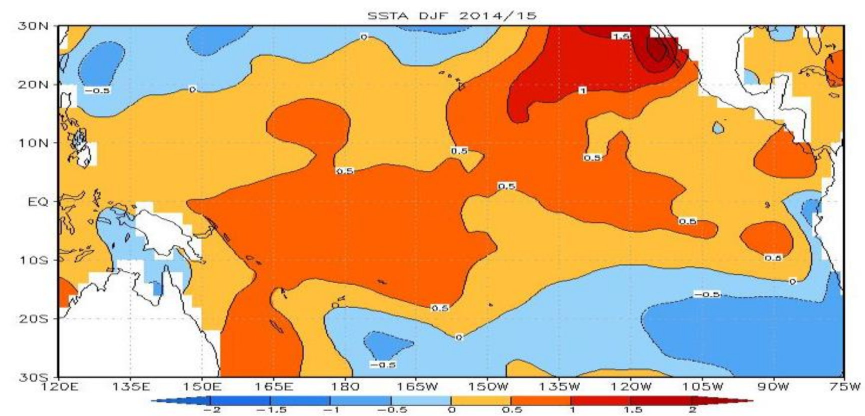
Evolution of Pacific NINO SST Indices

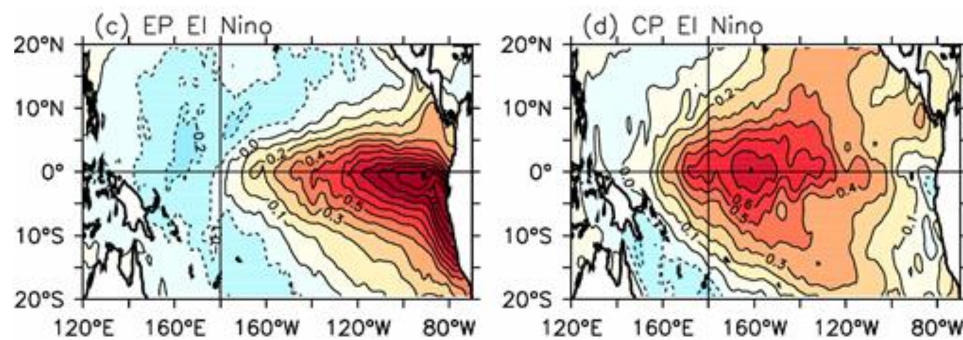


- **The SSTA evolution in 2014/15 was more similar to the pattern associated with central Pacific (warm pool) El Nino, or ENSO-Modoki.**



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





Kao and Yu (2009)

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

- **Positive SSTA was in the whole basin.**

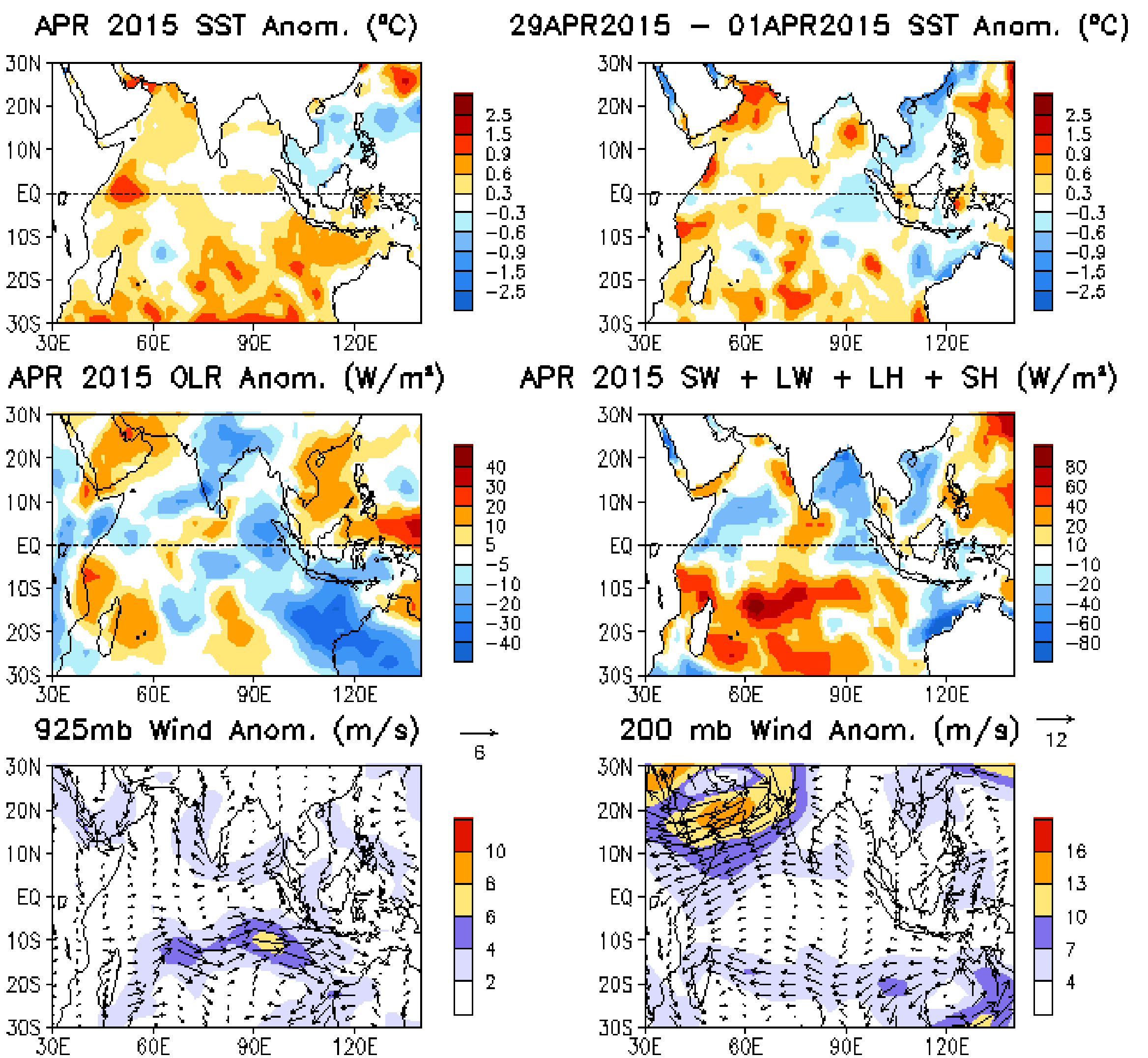
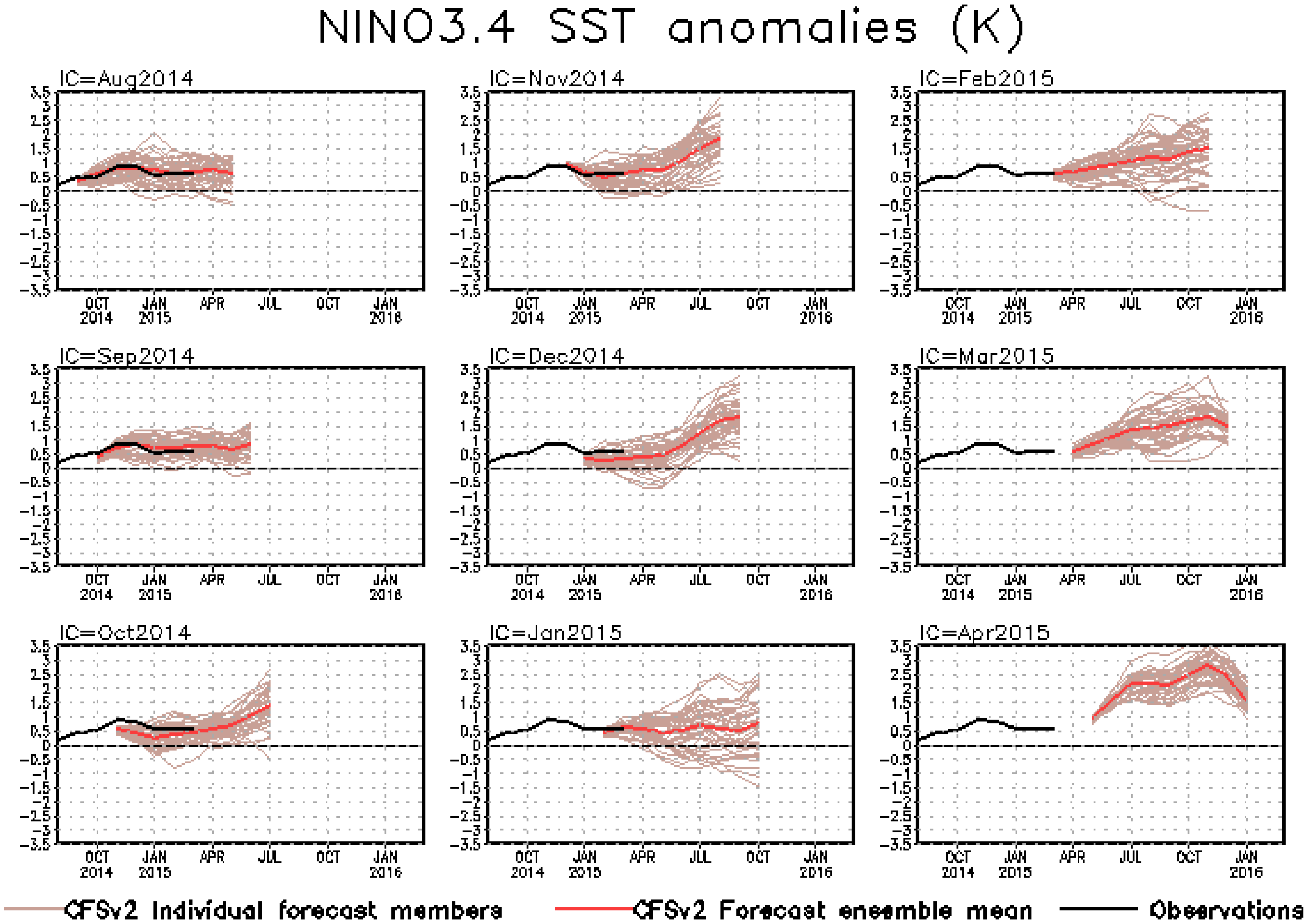


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

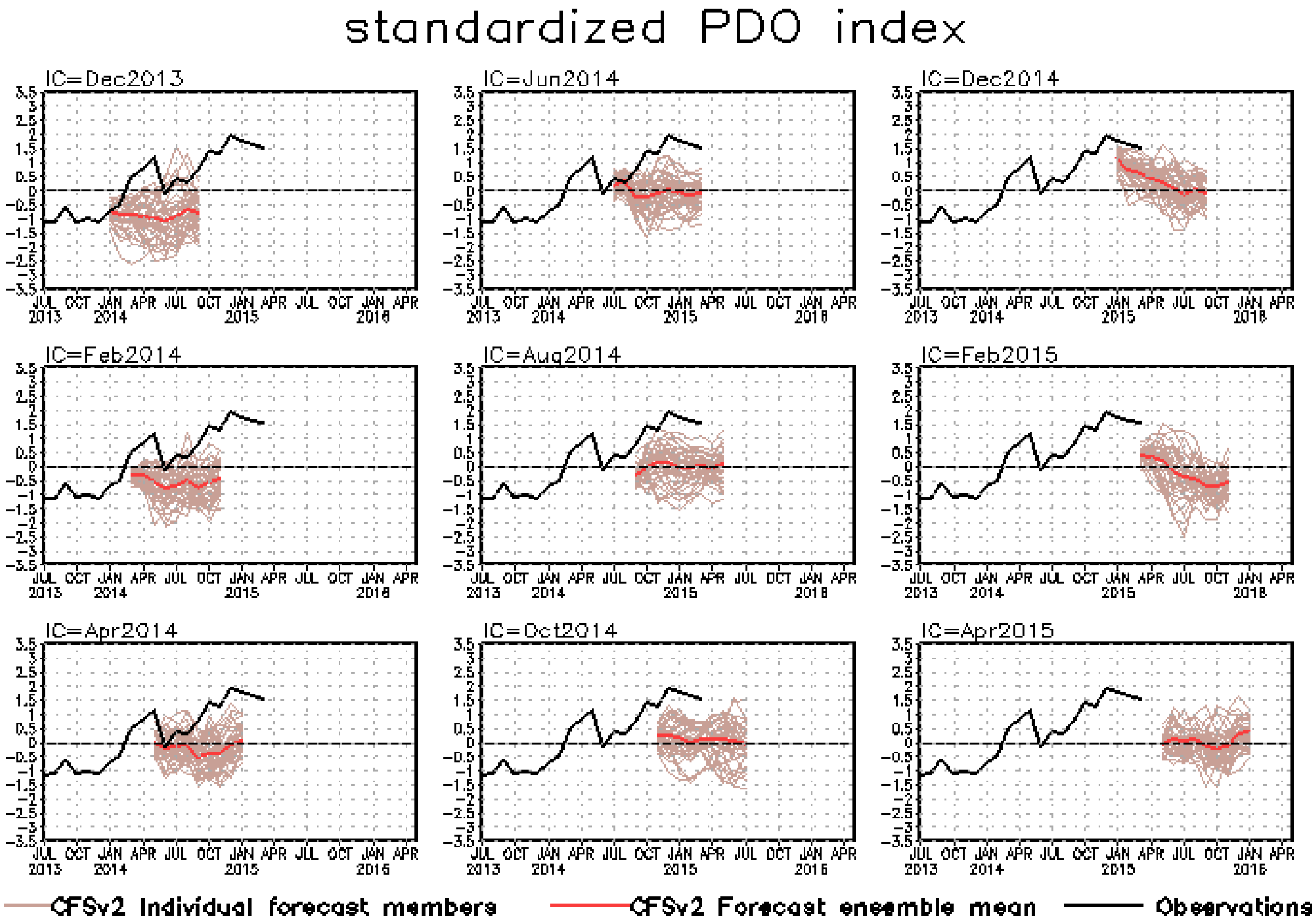
CFS Niño3.4 SST Predictions from Different Initial Months



- 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.

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



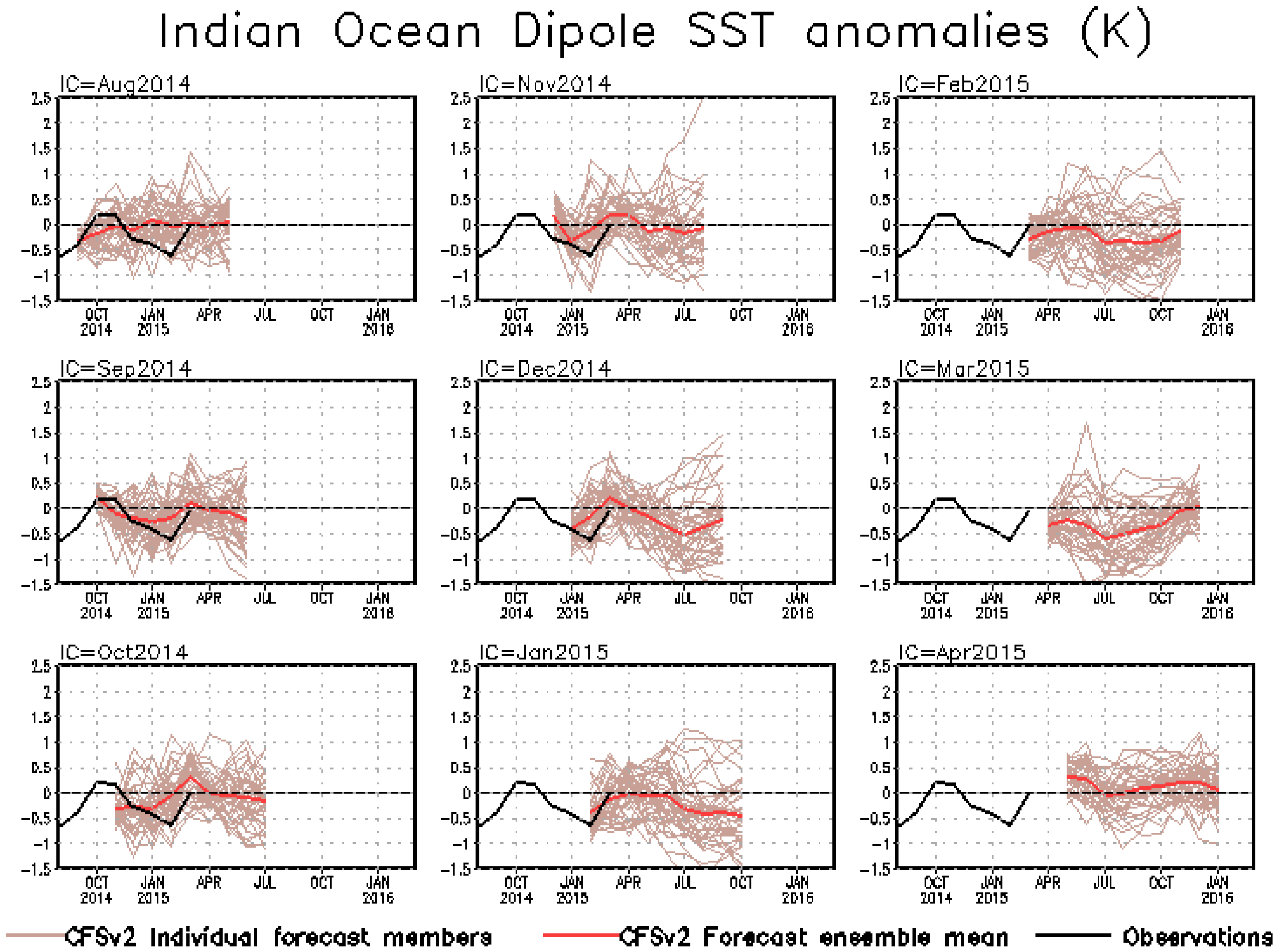
PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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 neutral 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.

NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

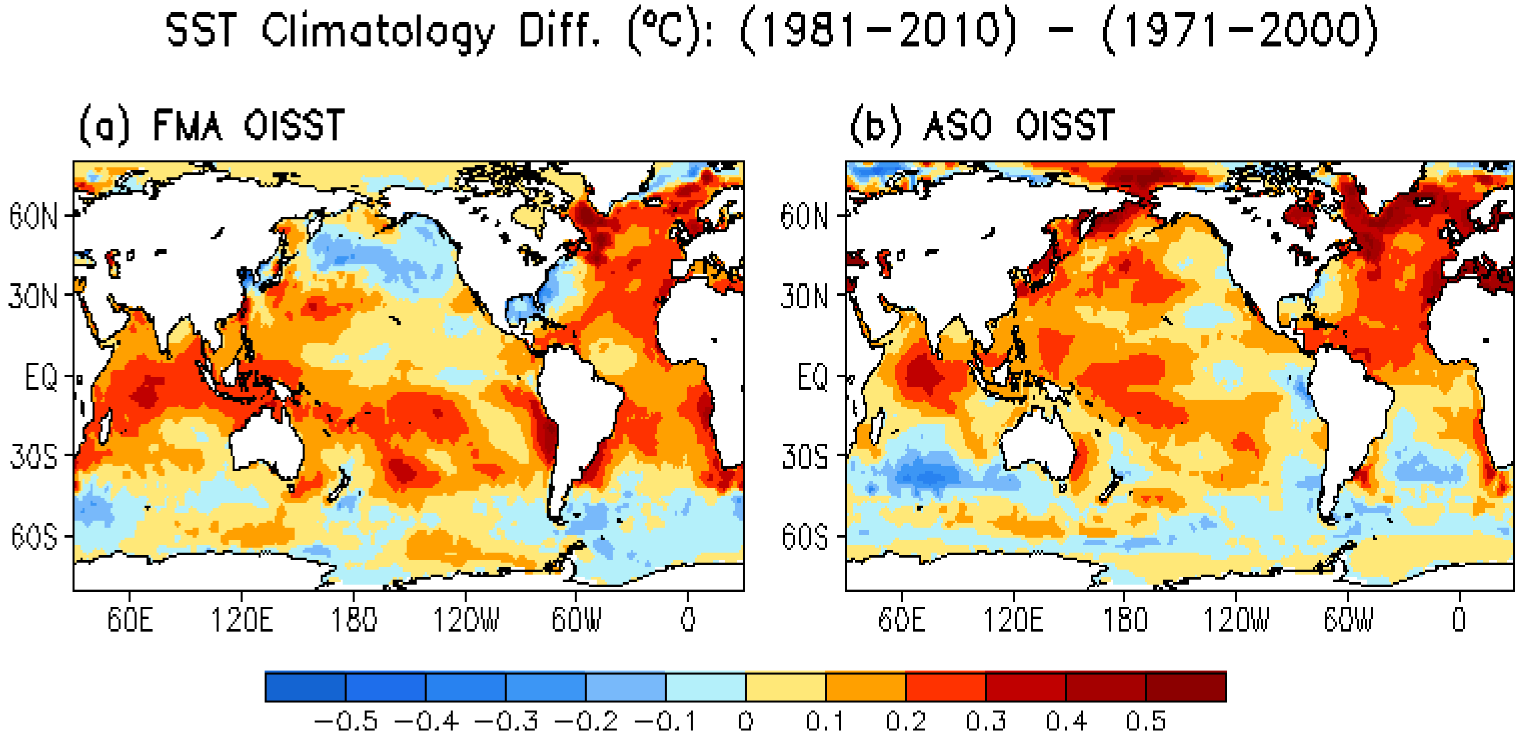
SETIO = SST anomaly in [90°E-110°E, 10°S-0]

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

- **CFSv2 predicts neutral phase of IOD since summer 2015.**

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!