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

Prepared by

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

This project to deliver real-time ocean monitoring products is implemented by CPC in cooperation with NOAA's Climate Observation Division (COD)

Outline

- **Overview**

- **Recent highlights**

  – **Pacific/Arctic Ocean**

  – **Indian Ocean**

  – **Atlantic Ocean**

  – **Global SST Predictions**

  *** Will a La Nina emerge in 2016-17?**

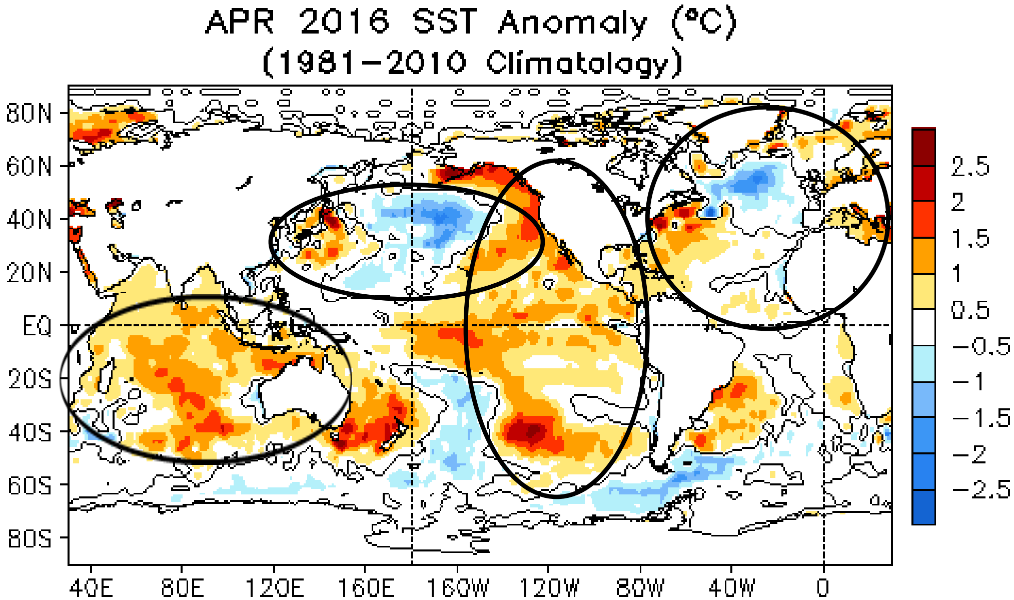
  *** Introduce a new analogue method for global SST and ENSO prediction.**

Overview

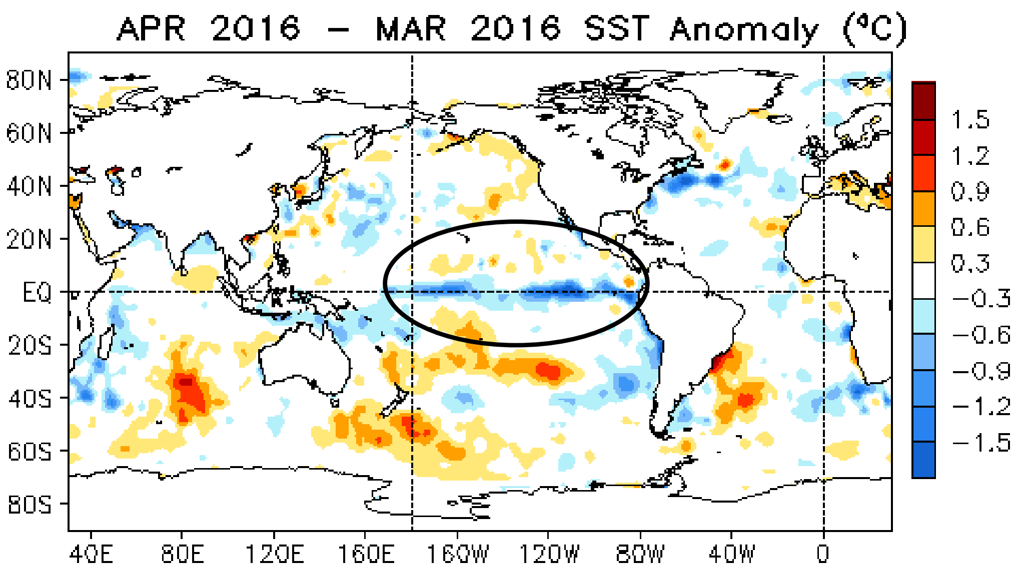
- **Pacific Ocean**
  - **NOAA "ENSO Diagnostic Discussion" on 14 Apr 2016 issued "El Nino Advisory/La Niña Watch" and suggested that *"A transition to ENSO-neutral is likely during late Northern Hemisphere spring or early summer 2016, with an increasing chance of La Niña during the second half of the year."***
  - **Positive SSTAs weakened in the central and eastern tropical Pacific with NINO3.4=1.1^{o}C in Apr 2016.**
  - **Strong negative ocean temperature anomalies along the thermocline strengthened in the western and central Pacific and propagated eastward.**
  - **Positive phase of PDO has persisted for 22 months, and strengthened with PDOI=2.4 in Apr 2016.**
- **Indian Ocean**
  - **Positive SSTA was larger in the east than in the west.**
- **Atlantic Ocean**
  - **NAO was in positive phase with NAOI=0.26 in Apr 2016, causing a horseshoe-like pattern of SSTA in North Atlantic.**

<u>Global Oceans</u>

Global SST Anomaly (^0C) and Anomaly Tendency



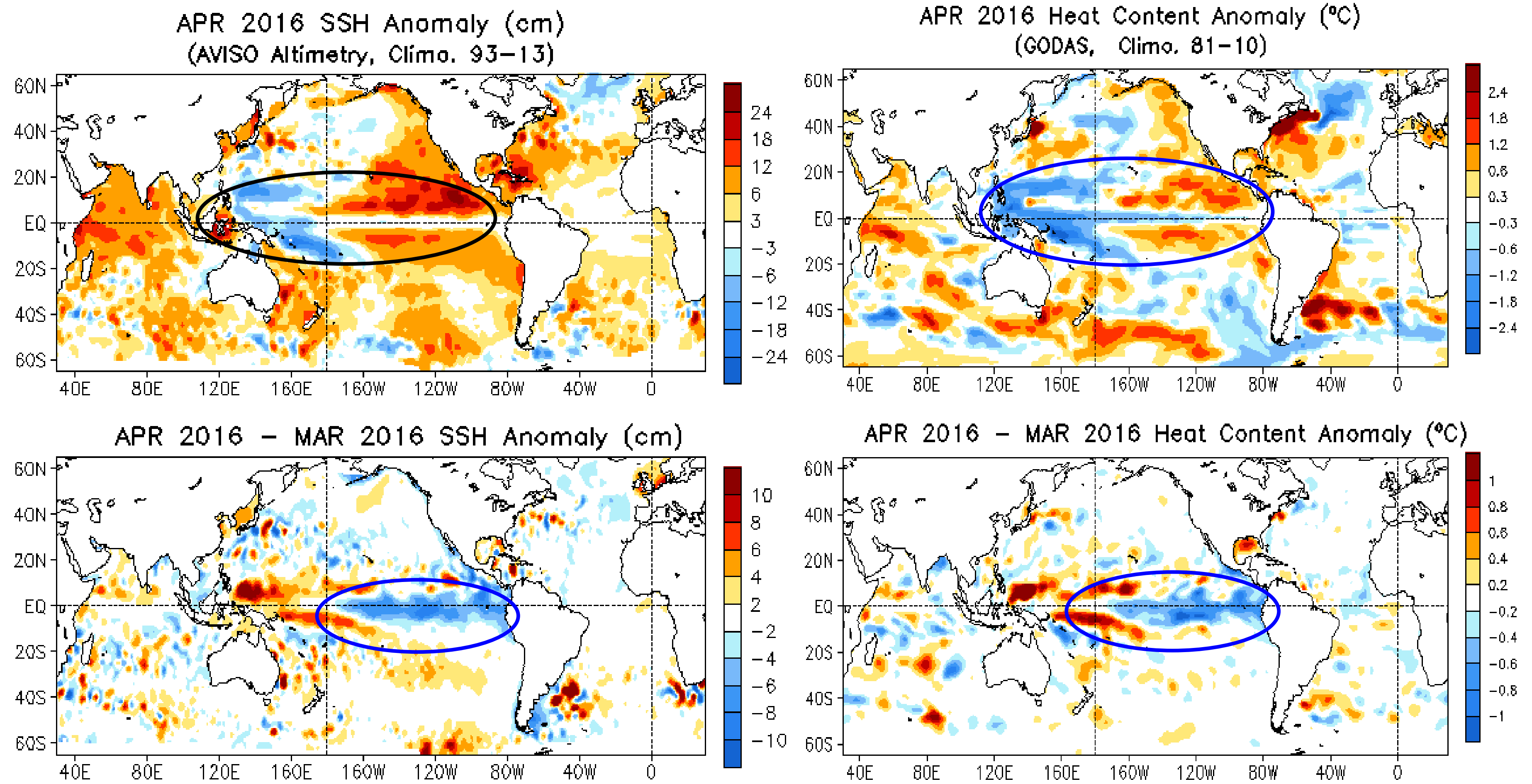
- Positive SSTA presented in the eastern Pacific.
- SSTA pattern in N. Pacific was associated with positive phase of PDO.
- Horseshoe-like SSTA presented in N. Atlantic.
- SSTA was positive in the whole Indian Ocean.



- Remarkable negative SSTA tendency in the central and eastern equatorial Pacific was associated with the decay of El Nino.

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

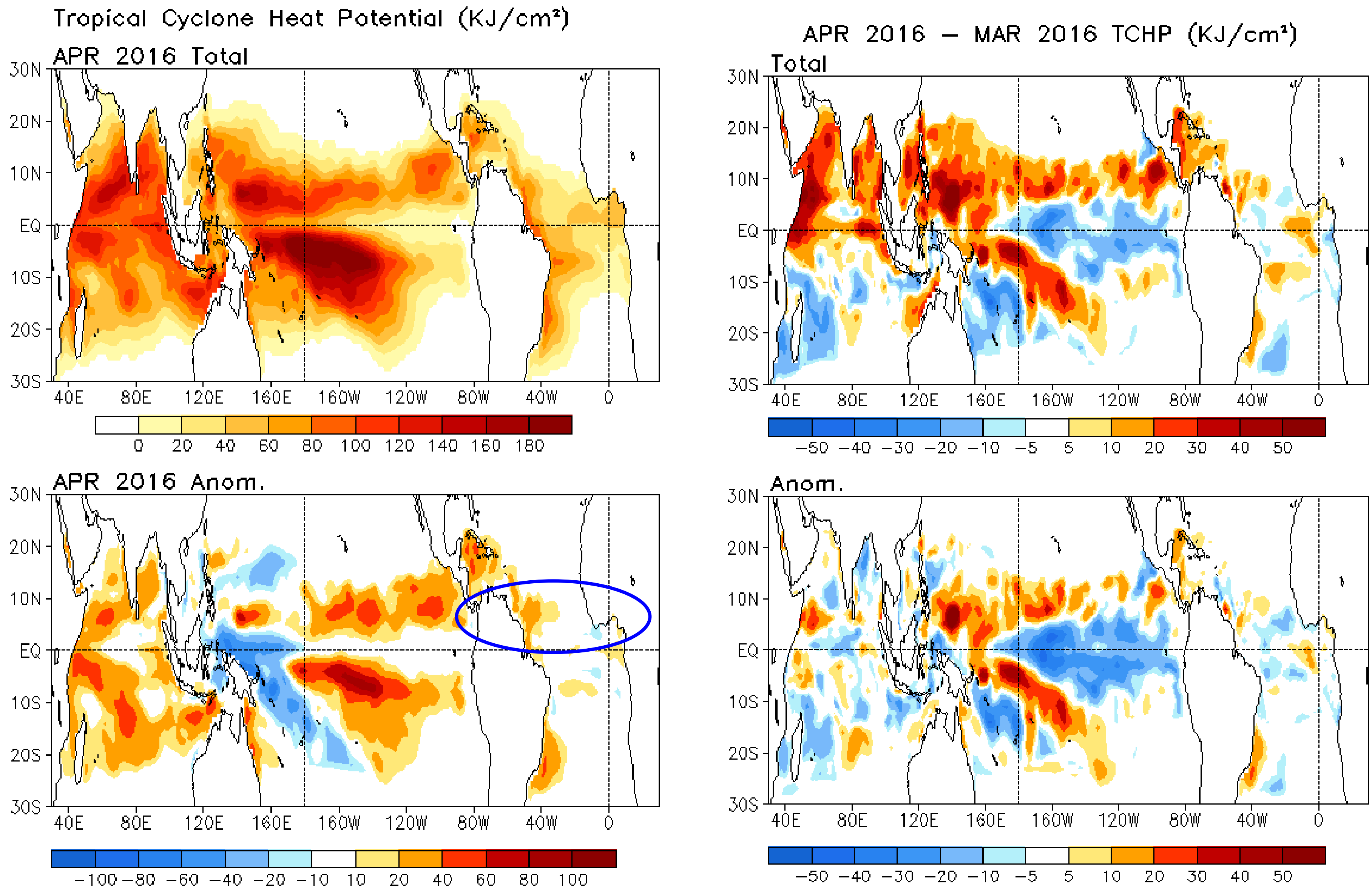
Global SSH and HC300 Anomaly & Anomaly Tendency



- The SSHA was overall consistent with HC300A: Positive (negative) HC300A is tied up with positive (negative) SSHA.

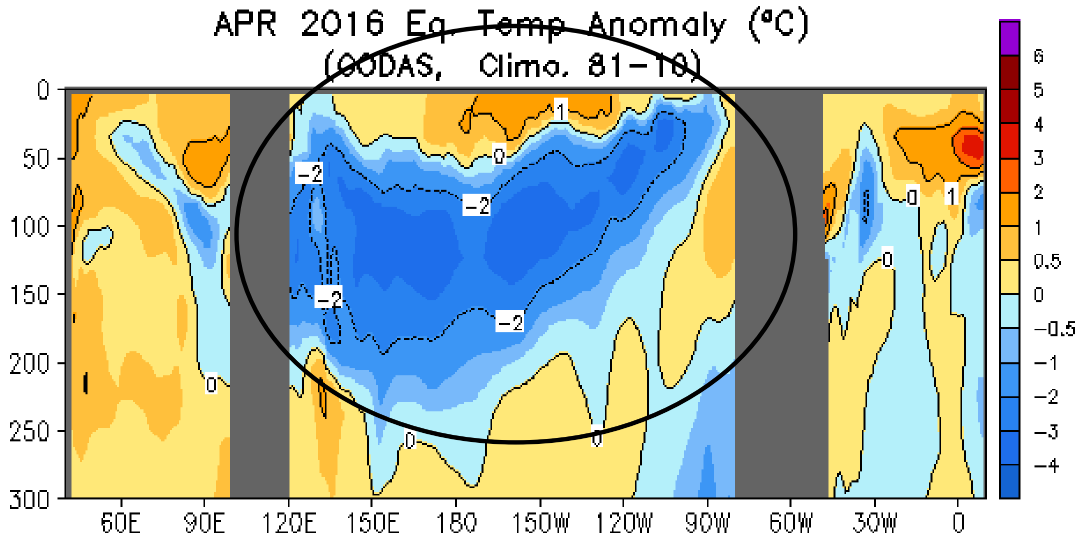
- Both SSHA and HC300A showed a dipole pattern off the equatorial Pacific with negative in the west and positive in the east, consisting with the feature in decay phase of El Nino.

- Negative tendencies of SSHA and HC300A were observed in the central and eastern equatorial Pacific, indicating an eastward propagation of cold subsurface anomaly and a decay tendency of El Nino.

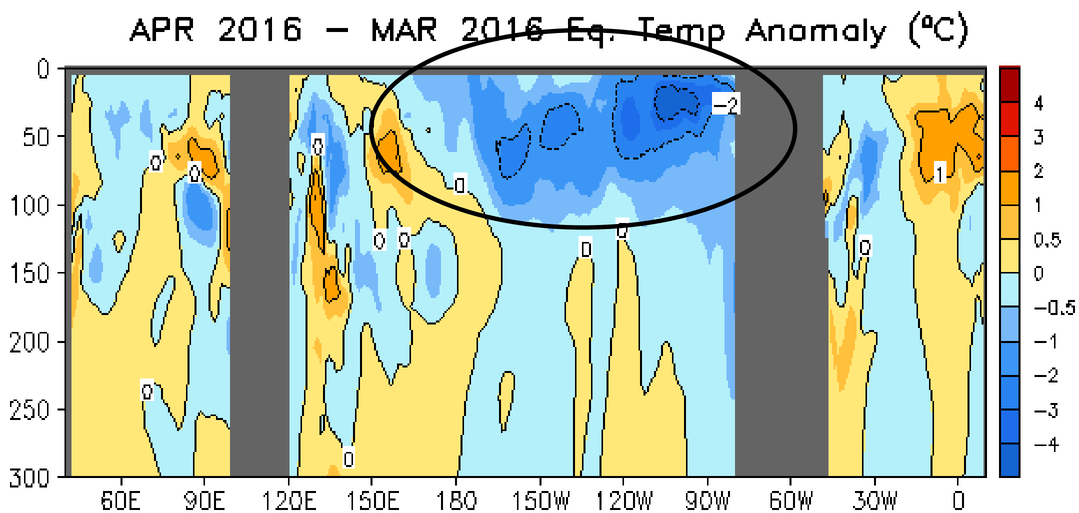


Tropical Cyclone Heat Potential (KJ/cm²)
APR 2016 Total
APR 2016 – MAR 2016 TCHP (KJ/cm²)
Total
APR 2016 Anom.
Anom.
30N 20N 10N EQ 10S 20S 30S
40E 80E 120E 160E 160W 120W 80W 40W 0
0 20 40 60 80 100 120 140 160 180
-100 -80 -60 -40 -20 -10 10 20 40 60 80 100
-50 -40 -30 -20 -10 -5 5 10 20 30 40 50

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

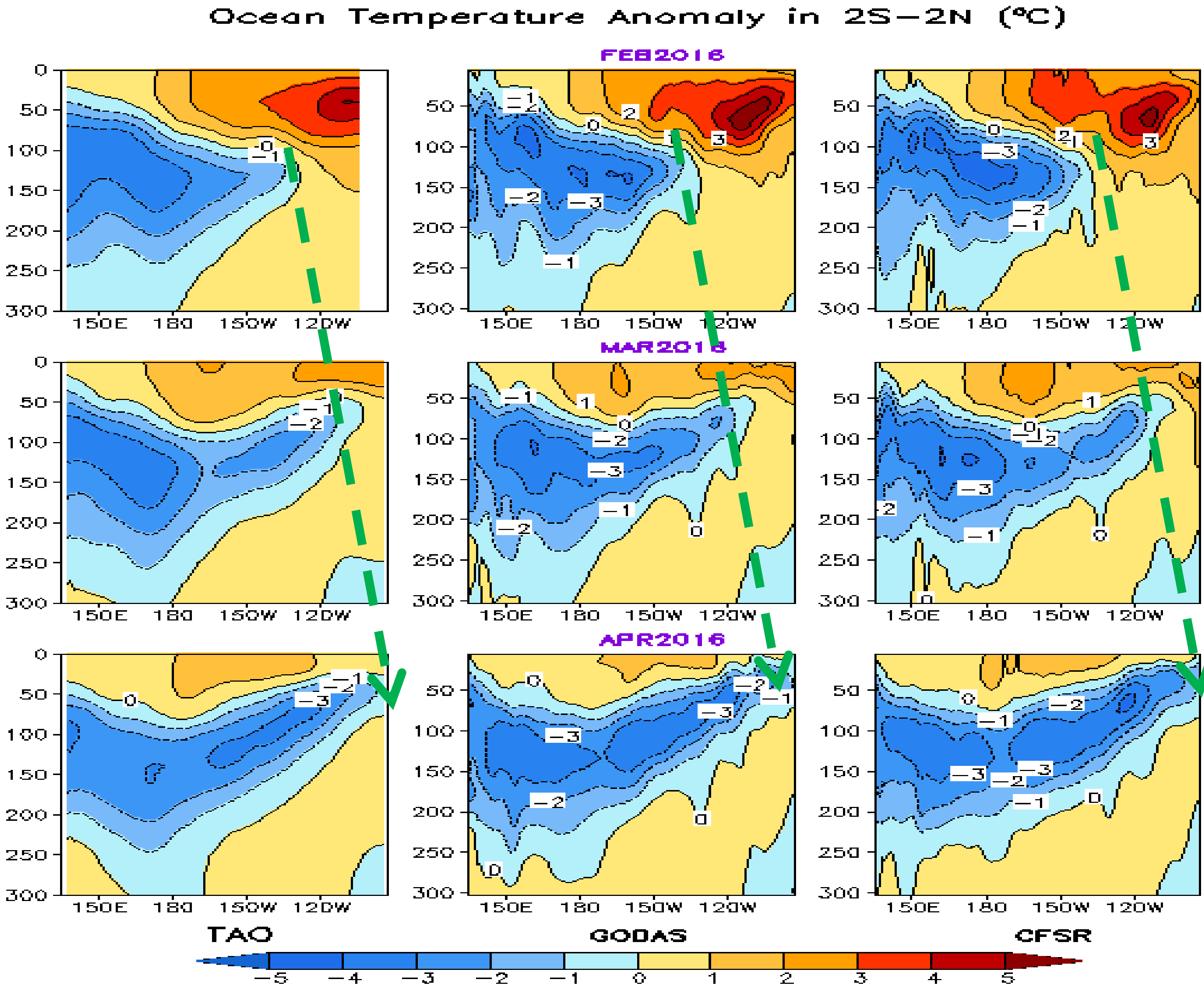


- **Strong negative ocean temperature anomalies presented along the thermocline in the whole Pacific.**
- **Positive ocean temperature anomalies were confined near the surface in the Pacific.**



- **Remarkable negative tendencies of ocean temperature anomalies were observed in the central and eastern Pacific, suggesting an eastern propagation of the negative anomalies.**

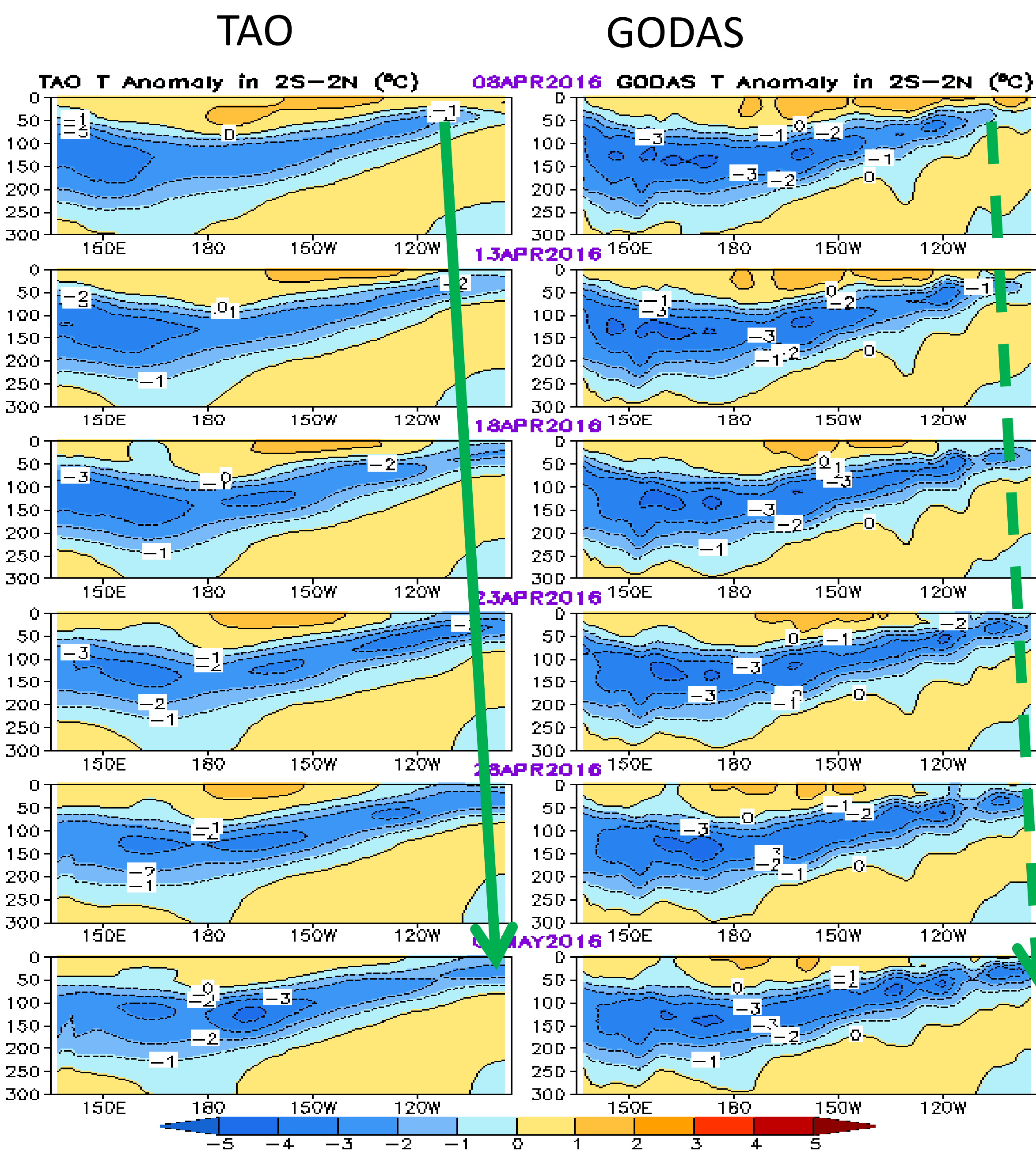
Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP's global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1981-2010 base period means.



Ocean Temperature Anomaly in 2S-2N (°C)
FEB2016
MAR2016
APR2016
TAO
GODAS
CFSR
150E 180 150W 120W
-5 -4 -3 -2 -1 0 1 2 3 4 5

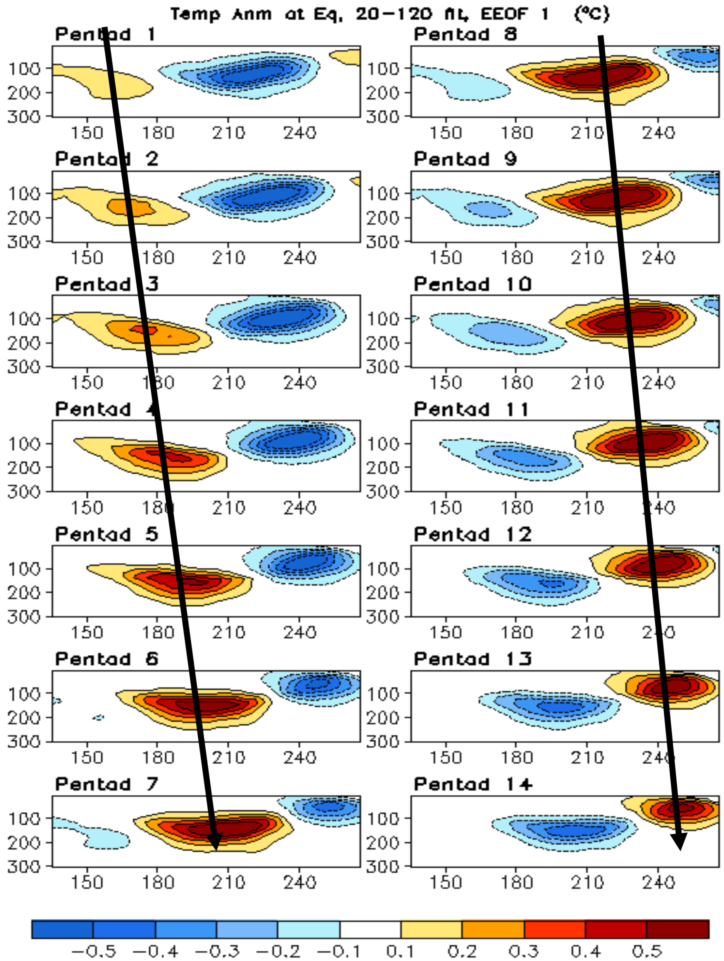
Tropical Pacific Ocean and ENSO Conditions

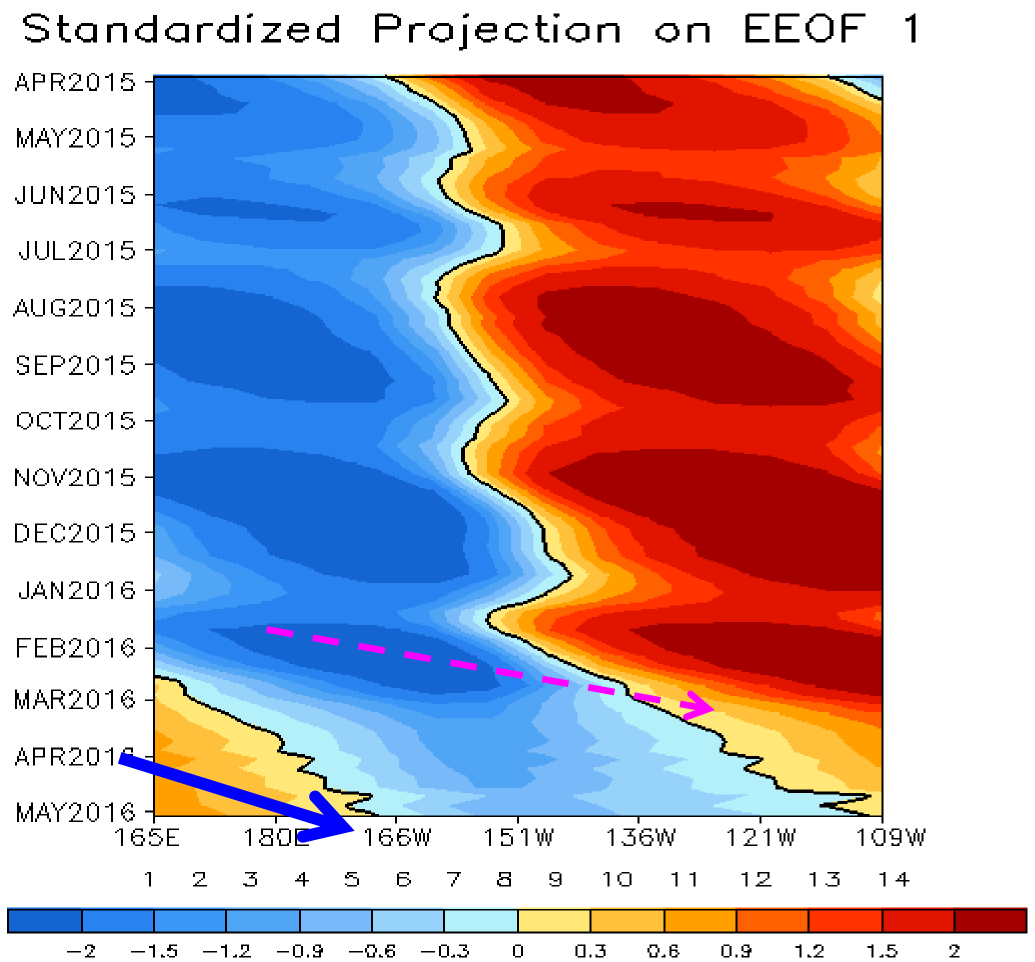
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



- **Ocean temperature anomalies were negative along the thermocline, and positive near the surface.**
- **The negative anomalies propagated eastward.**
- **Both the anomalous pattern and propagation are comparable between TAO and GODAS.**

Oceanic Kelvin Wave (OKW) Index

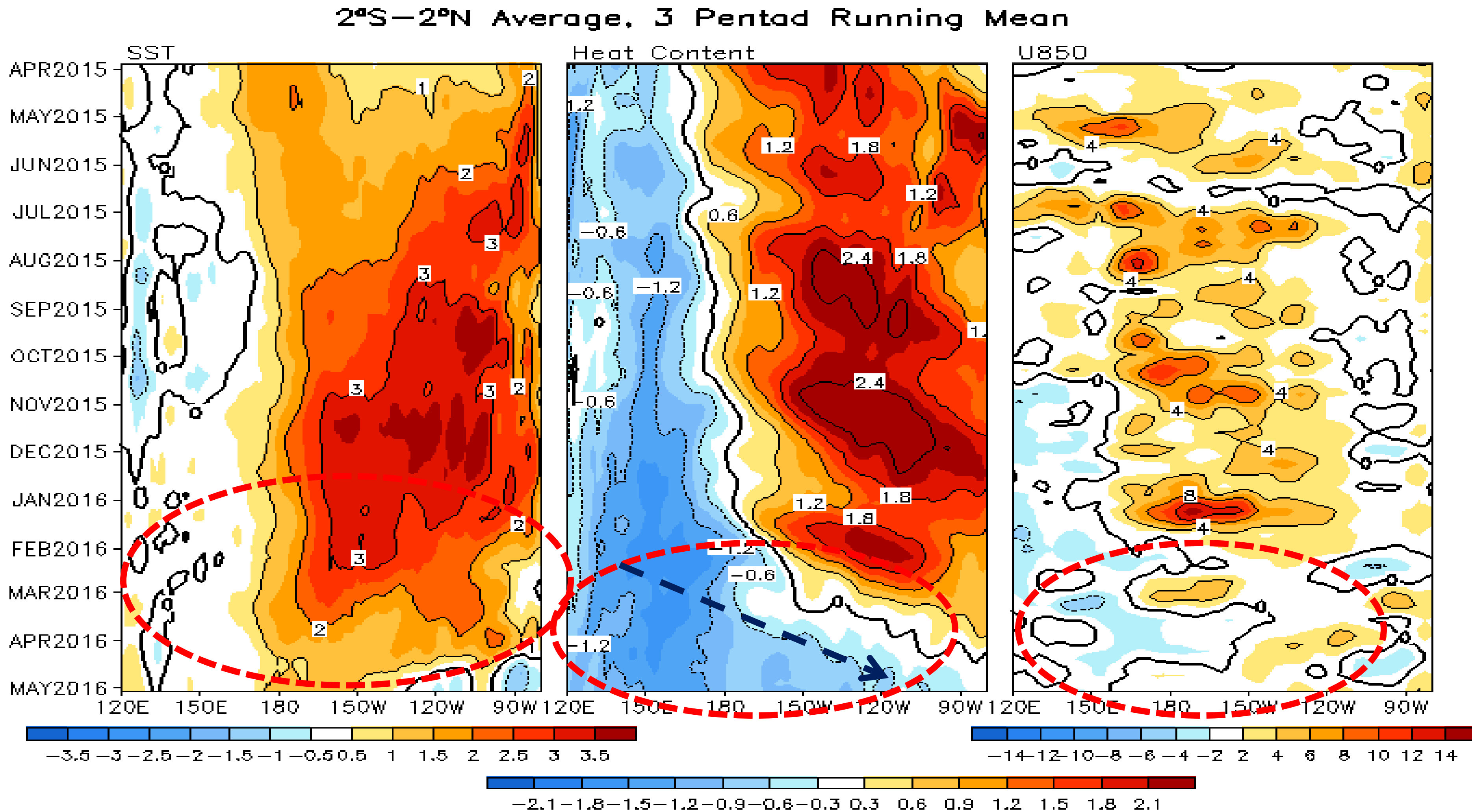




- Upwelling OKW (dashed line) emerged since Jan 2016 in the western Pacific. The upwelling may be associated with the observed strengthening of subsurface ocean cooling in the western and central Pacific and the eastward propagation.

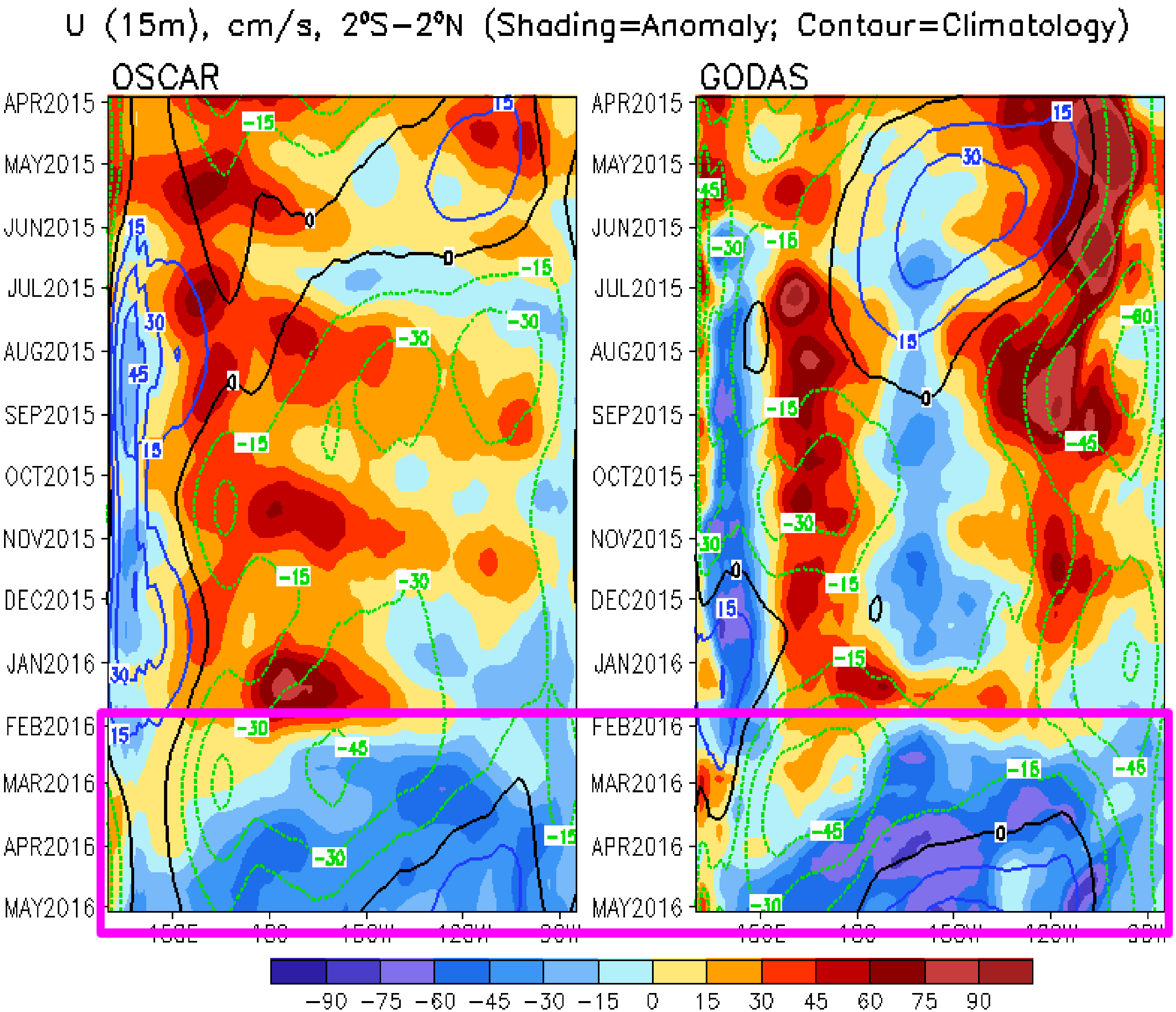
- (OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EEOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)

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



- **Positive SSTA in the central and eastern equatorial Pacific weakened since Dec 2015.**
- **Positive HC300A disappeared, and negative ones strengthened and propagated eastward.**
- **Low-level westerly wind anomalies weakened since Feb 2016.**

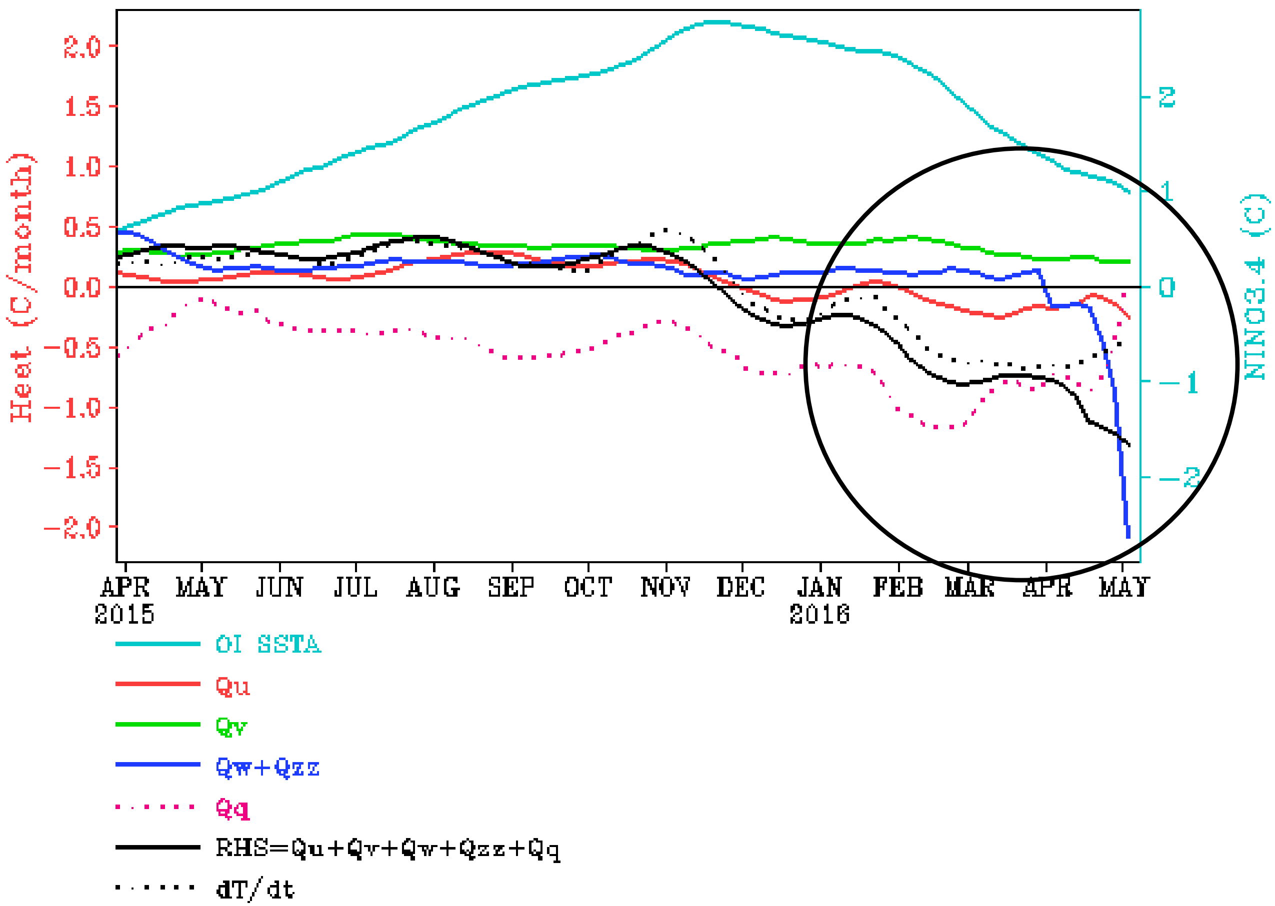
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- The anomalous current patterns were similar between OSCAR and GODAS.

- Anomalous westward current initiated in Feb 2016 and strengthened in Mar-Apr 2016. That was favorable for a cooling tendency in the central-eastern Pacific SSTA

NINO3.4 Heat Budget



- **Observed SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) became negative since Dec 2015.**

- **Except Qv, all other dynamical terms (Qu, Qw+Qzz) as well as heat flux term (Qq) were mainly negative in Apr 2016, consistent with the decay of El Nino.**

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;

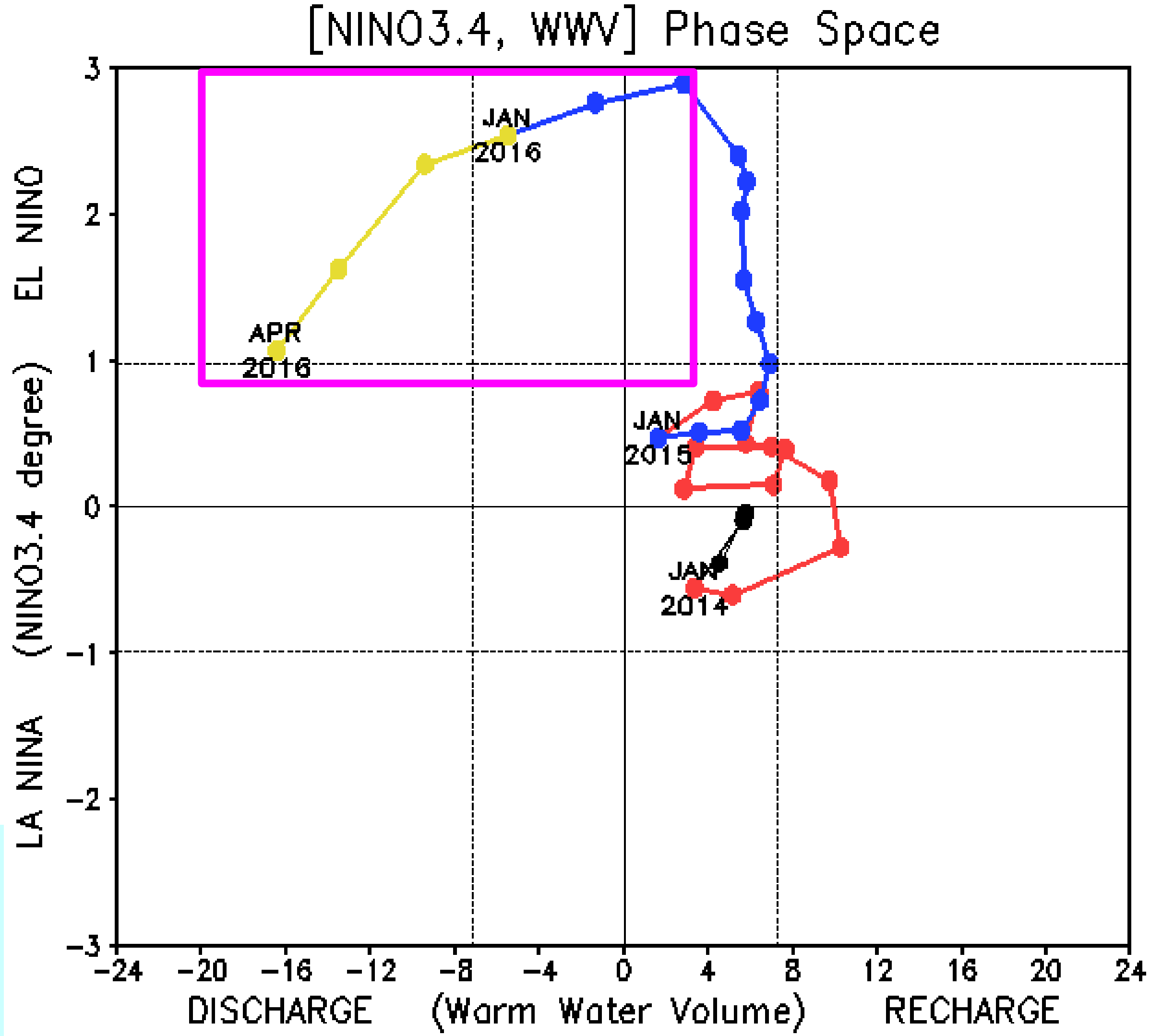
Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

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).

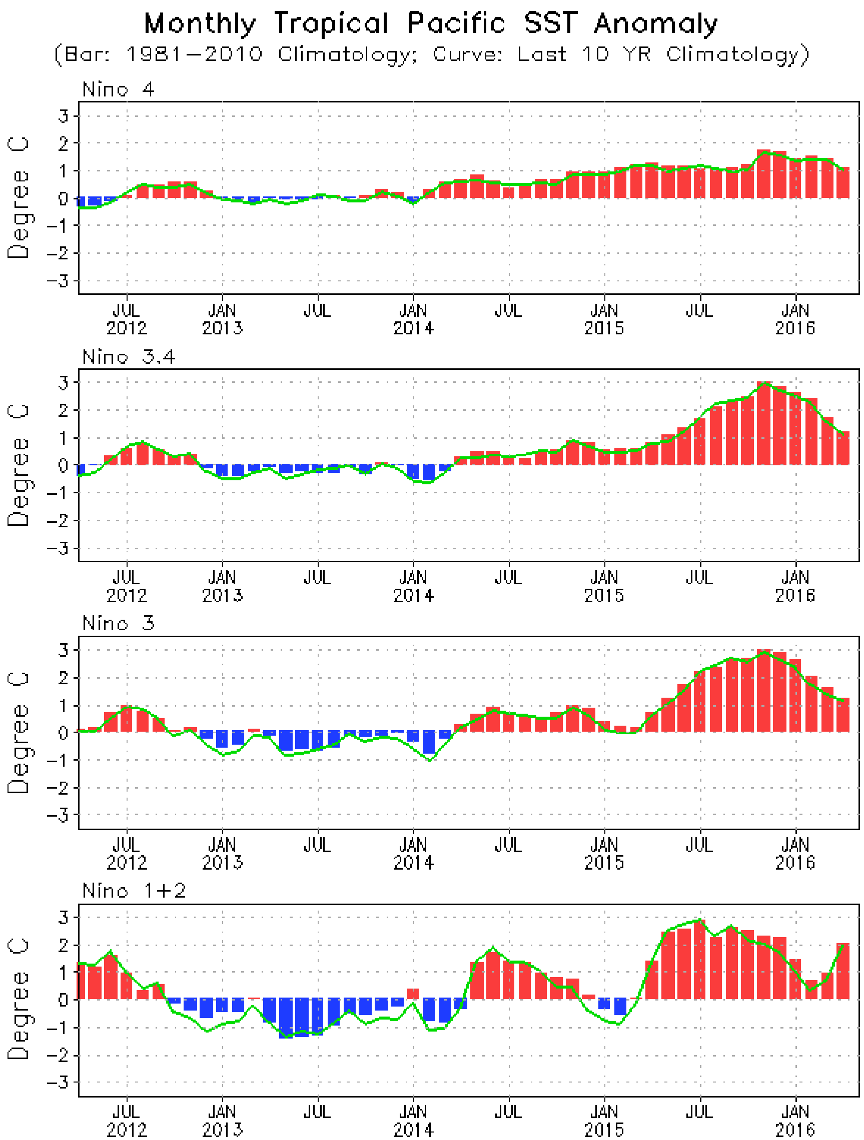
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.

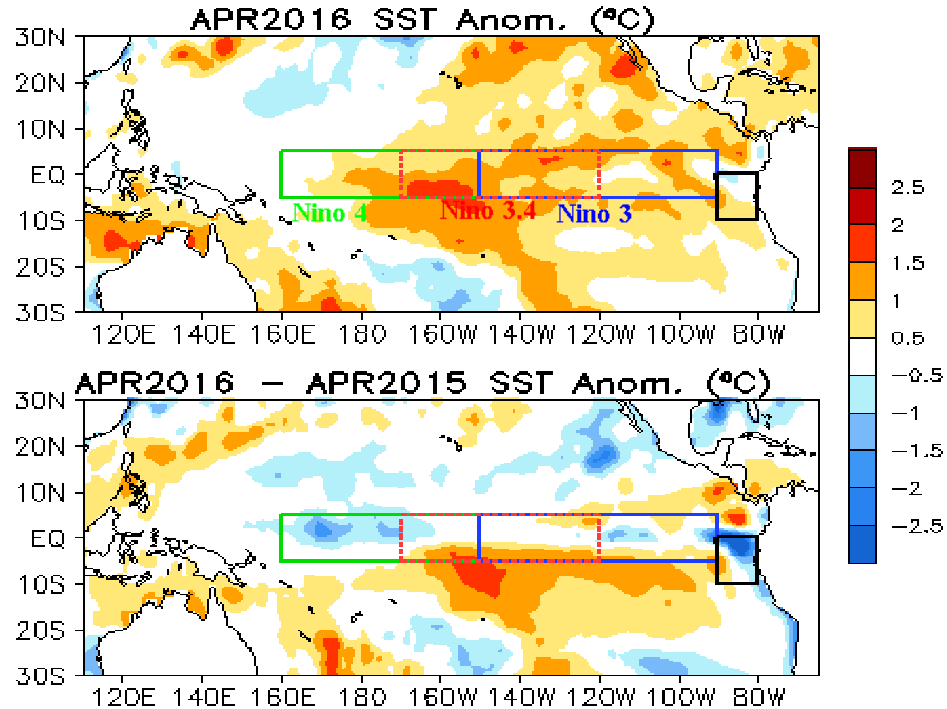


- Equatorial Warm Water Volume (WWV) has been rapidly discharging since Nov 2015.

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

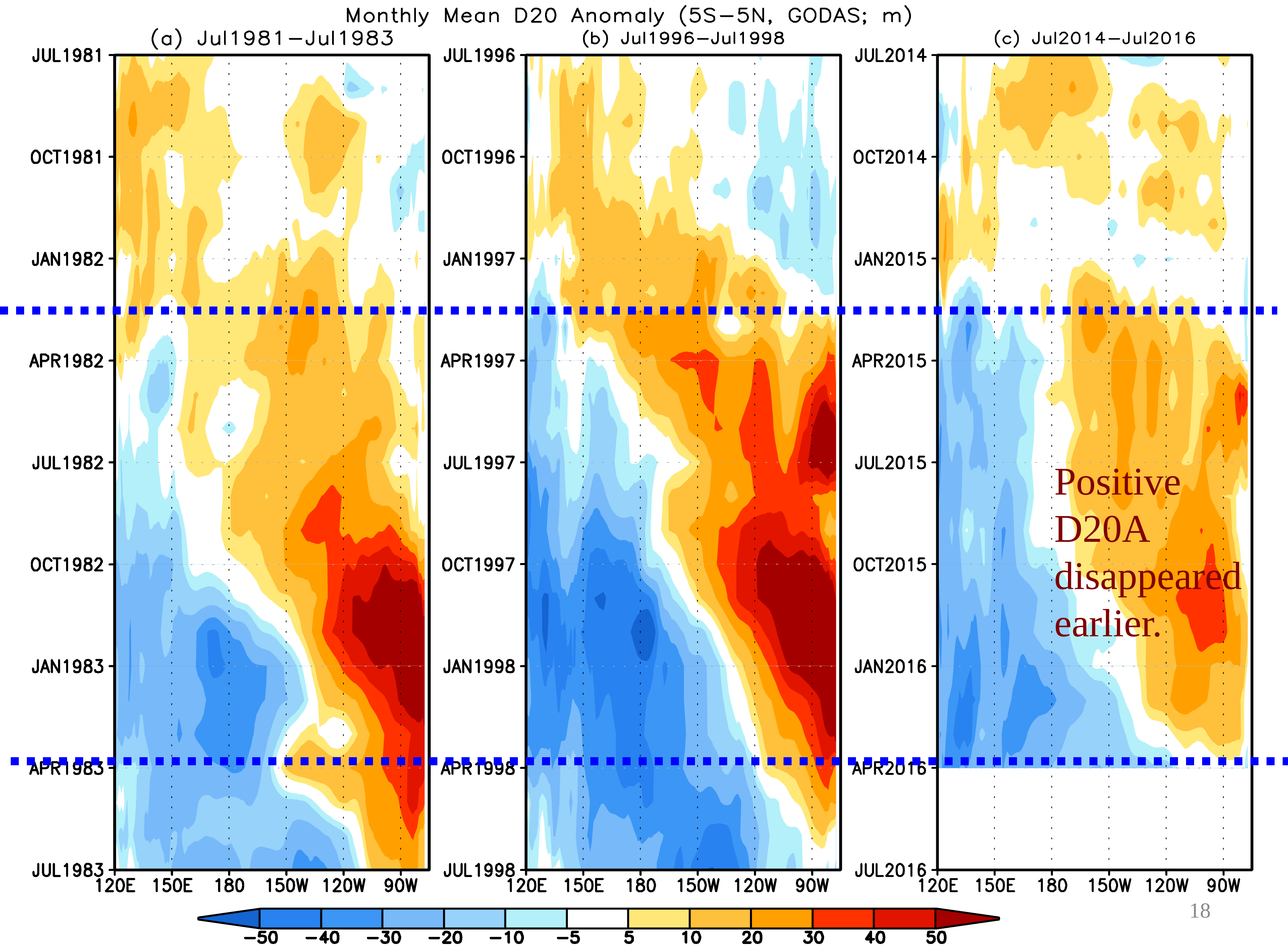
Evolution of Pacific NINO SST Indices



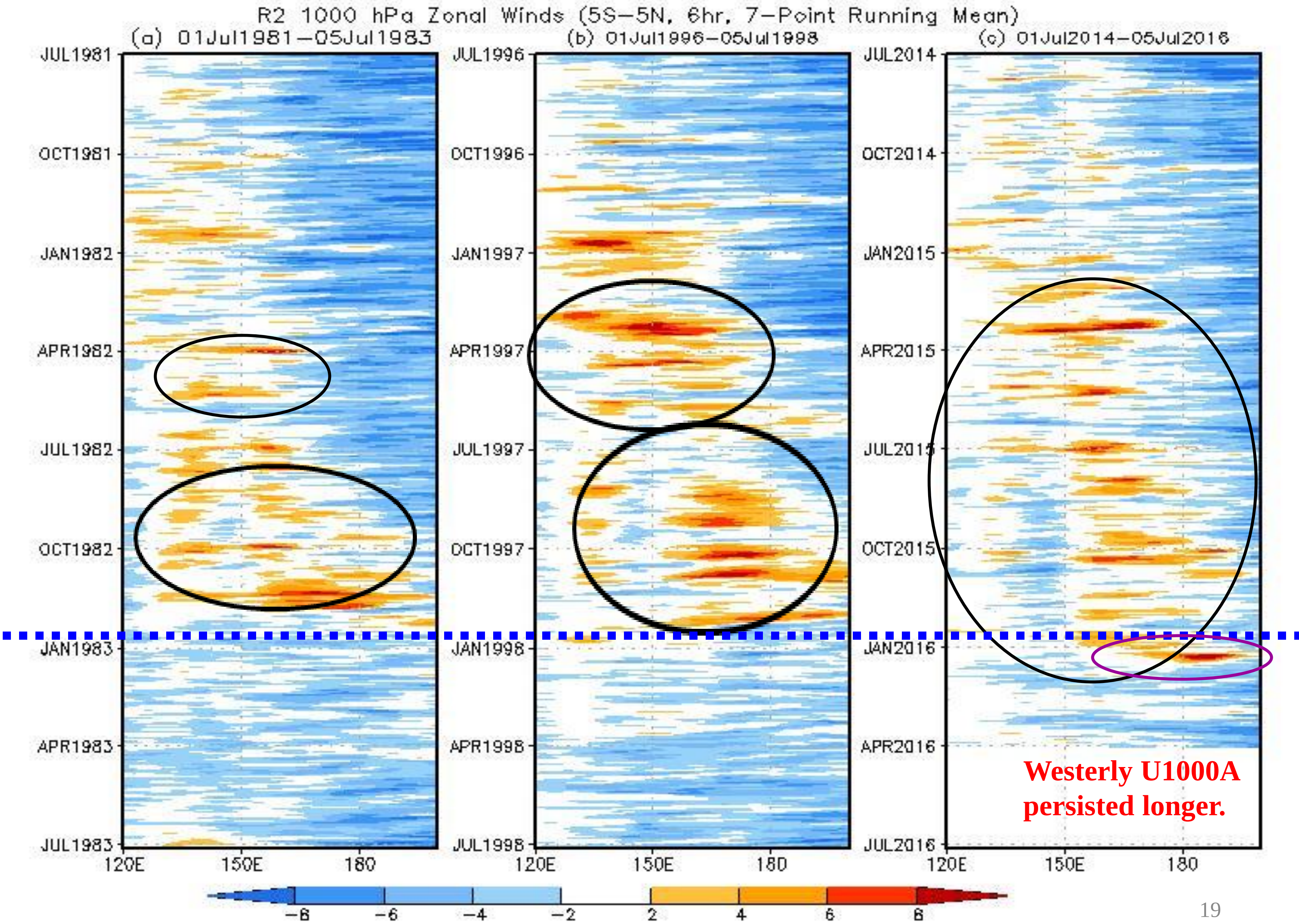


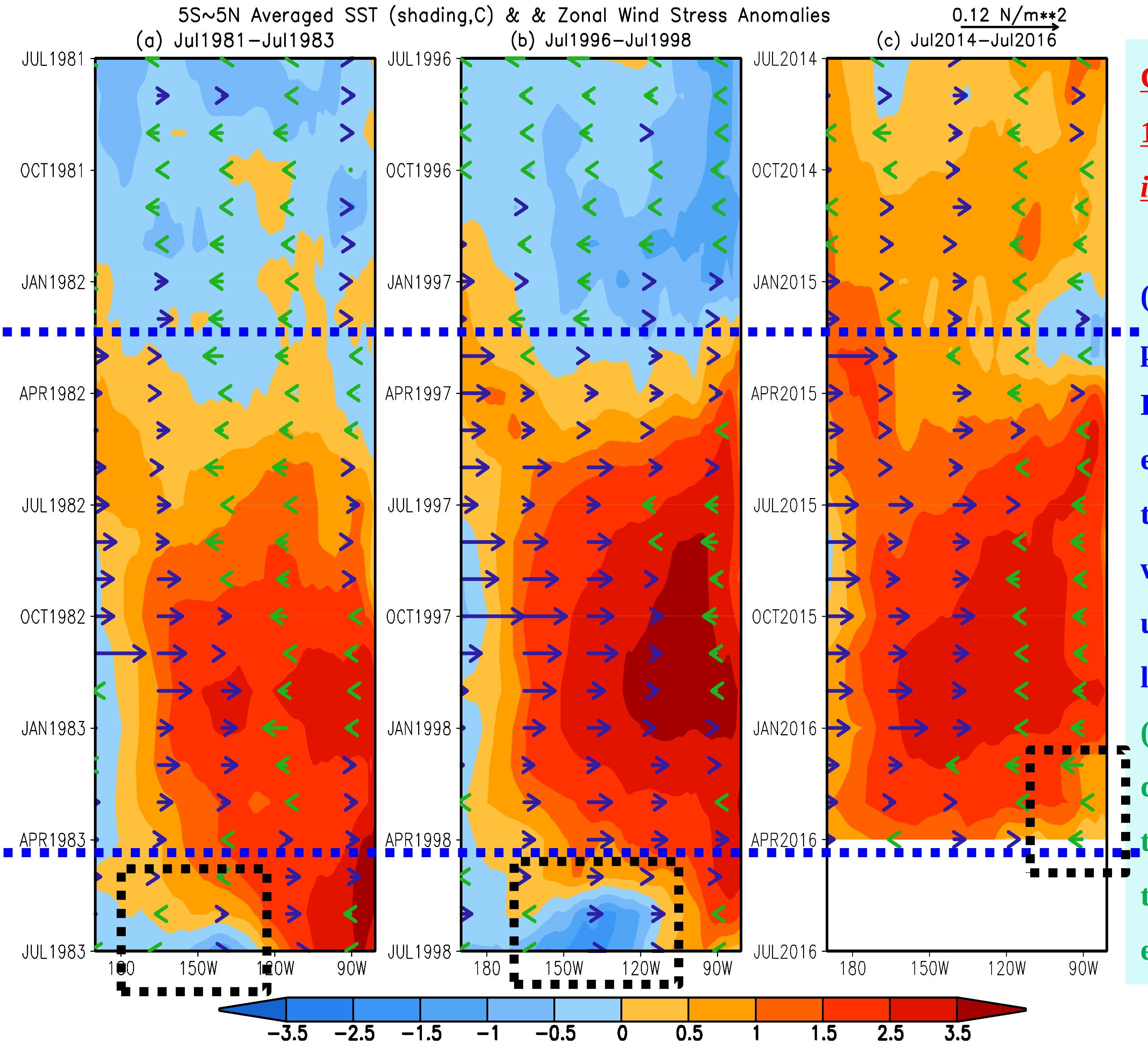
- All Nino indices were still positive, but weakened, except for Nino1+2 in Apr 2016.
- Nino3.4 = 1.1°C in Apr 2016.
- Compared with last Apr, the central and eastern equatorial South Pacific was still warmer in Apr 2016.
- The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v4.

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



Monthly Mean D20 Anomaly (5S–5N, GODAS; m)
(a) Jul1981–Jul1983
(b) Jul1996–Jul1998
(c) Jul2014–Jul2016
JUL1981
OCT1981
JAN1982
APR1982
JUL1982
OCT1982
JAN1983
APR1983
JUL1983
JUL1996
OCT1996
JAN1997
APR1997
JUL1997
OCT1997
JAN1998
APR1998
JUL1998
JUL2014
OCT2014
JAN2015
APR2015
JUL2015
OCT2015
JAN2016
APR2016
JUL2016
120E 150E 180 150W 120W 90W
Positive D20A disappeared earlier.
−50 −40 −30 −20 −10 −5 5 10 20 30 40 50


R2 1000 hPa Zonal Winds (5S-5N, 6hr, 7-Point Running Mean)
(a) 01Jul1981-05Jul1983
(b) 01Jul1996-05Jul1998
(c) 01Jul2014-05Jul2016
JUL1981
OCT1981
JAN1982
APR1982
JUL1982
OCT1982
JAN1983
APR1983
JUL1983
JUL1996
OCT1996
JAN1997
APR1997
JUL1997
OCT1997
JAN1998
APR1998
JUL1998
JUL2014
OCT2014
JAN2015
APR2015
JUL2015
OCT2015
JAN2016
APR2016
JUL2016
120E
150E
180
-8
-6
-4
-2
2
4
6
8
Westerly U1000A
persisted longer.



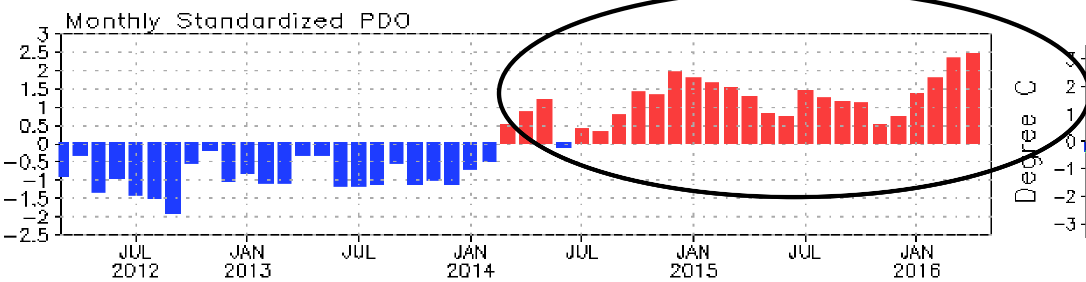
Compared with 1982-83 and 1997-98, *in 2015-16,*

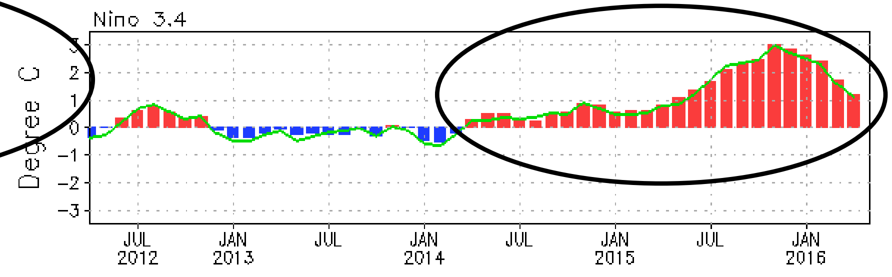
(a) Transition from positive to negative D20A occurred earlier, but the transition of westerly to easterly u1000 anomaly was later;

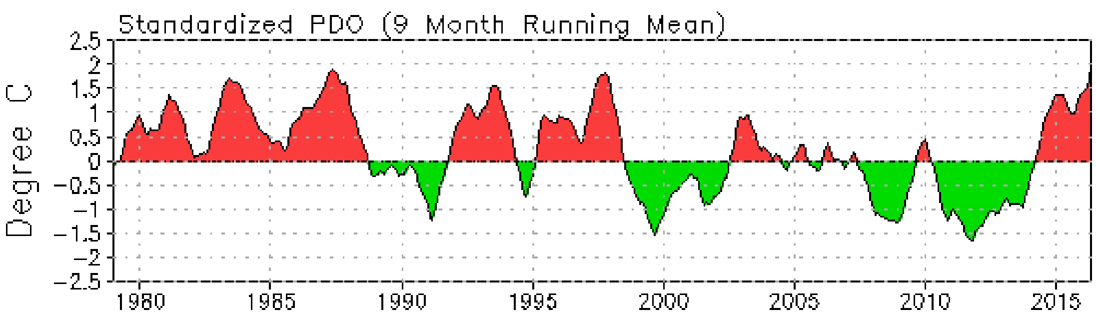
(b) Positive SSTA decline started from the coast instead of the central and eastern open ocean.

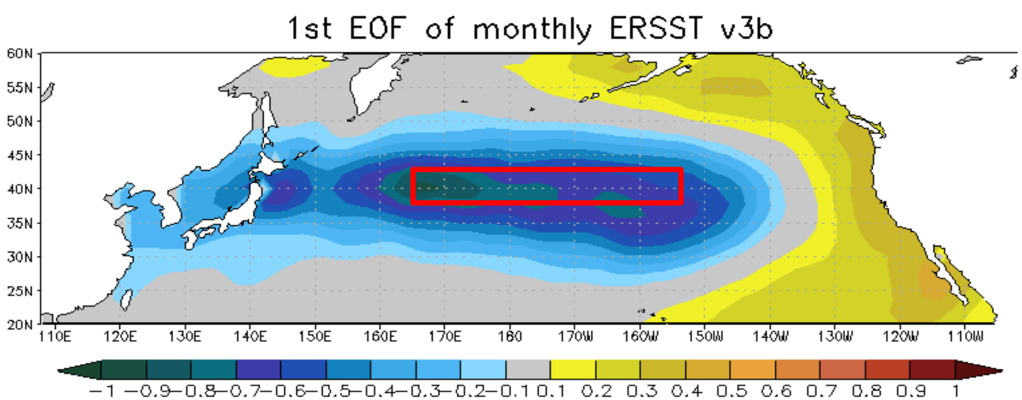
North Pacific & Arctic Oceans

PDO index









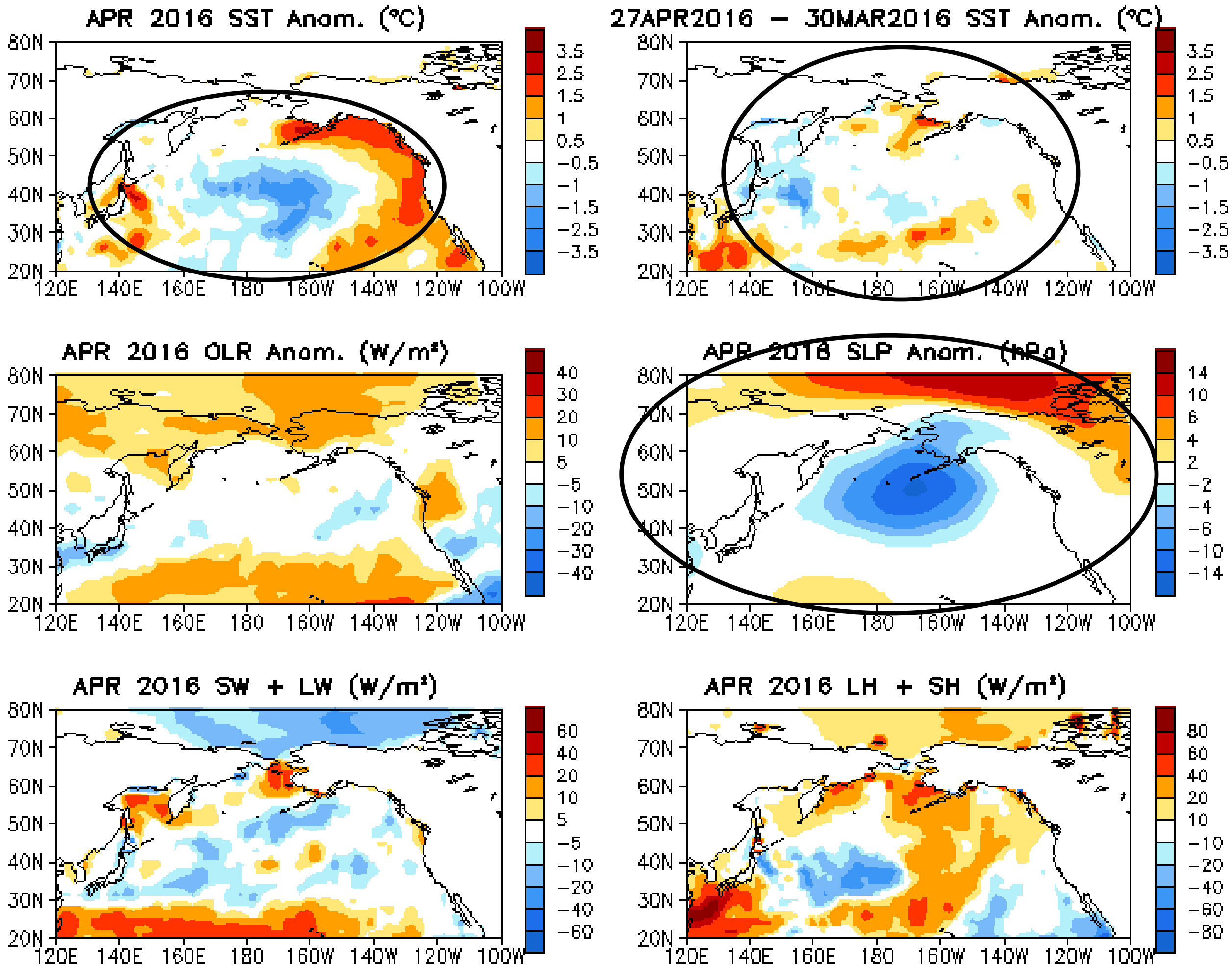
- The positive phase of PDO index has persisted 22 months since Jul 2014, and strengthened with PDO index =2.4 in Apr 2016.

- 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.

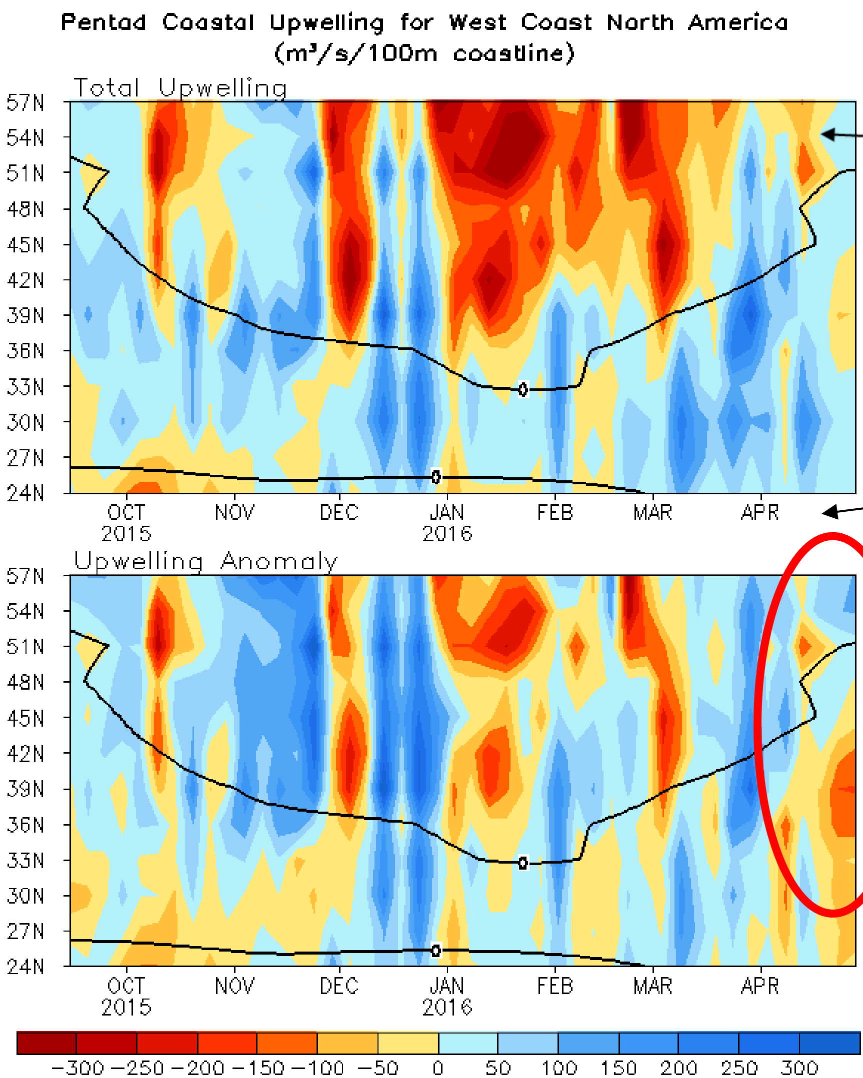
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

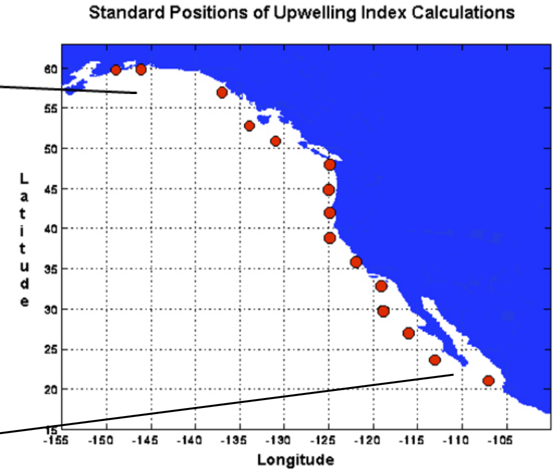


- **Positive SSTA presented in the NE. Pacific, consistent with the positive phase of PDO index (previous slide).**
- **The SST tendency was small in N. Pacific.**
- **Below-normal SLP presented in the mid-high latitudes, and above-normal one was observed in the polar region of N. Pacific.**

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





- **Both anomalous upwelling and downwelling presented in Apr 2016.**

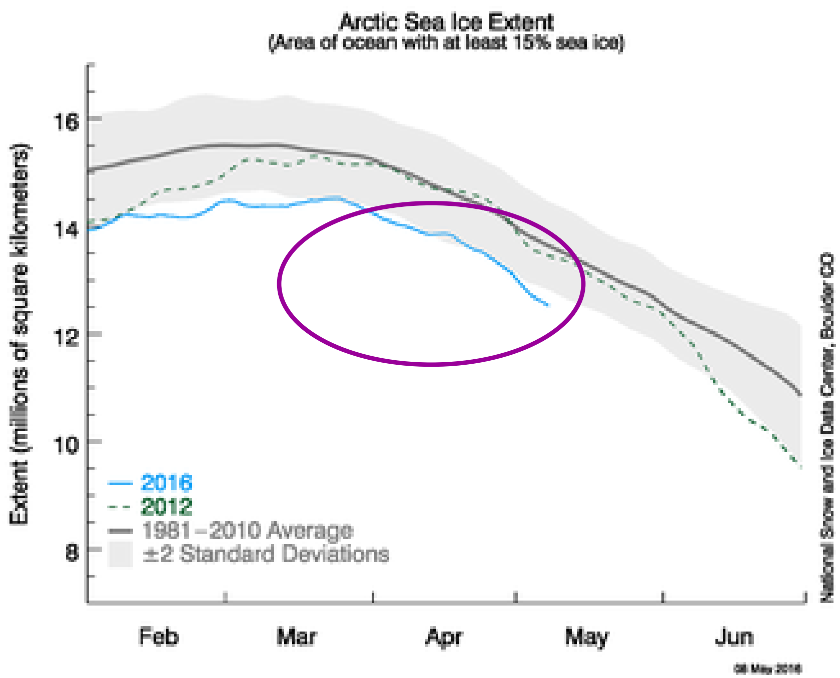
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

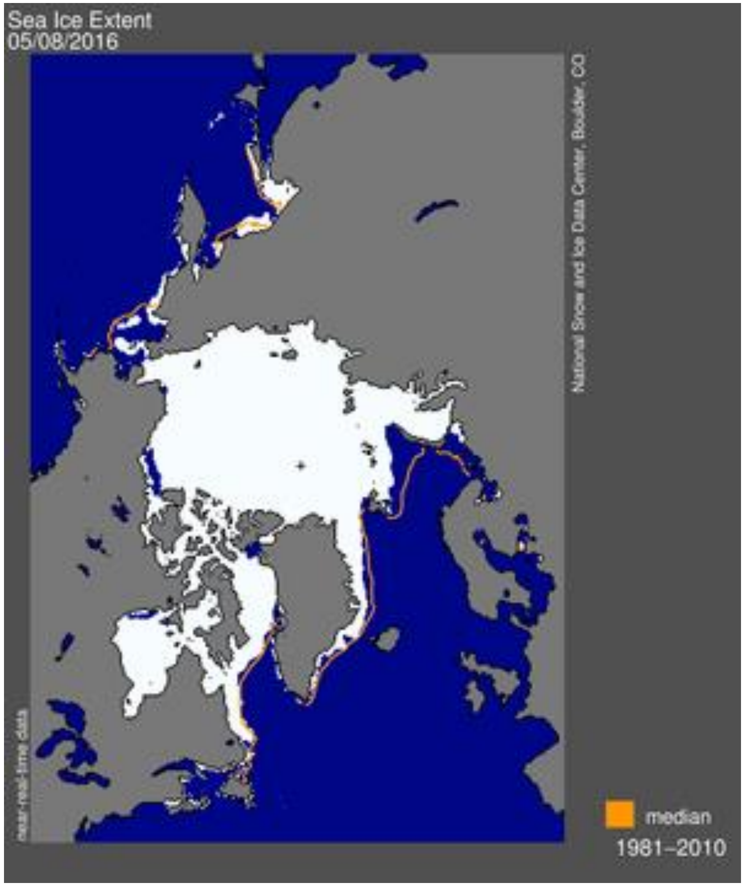
- **Area below (above) black line indicates climatological upwelling (downwelling) season.**
- **Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.**

Arctic Sea Ice

National Snow and Ice Data Center

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

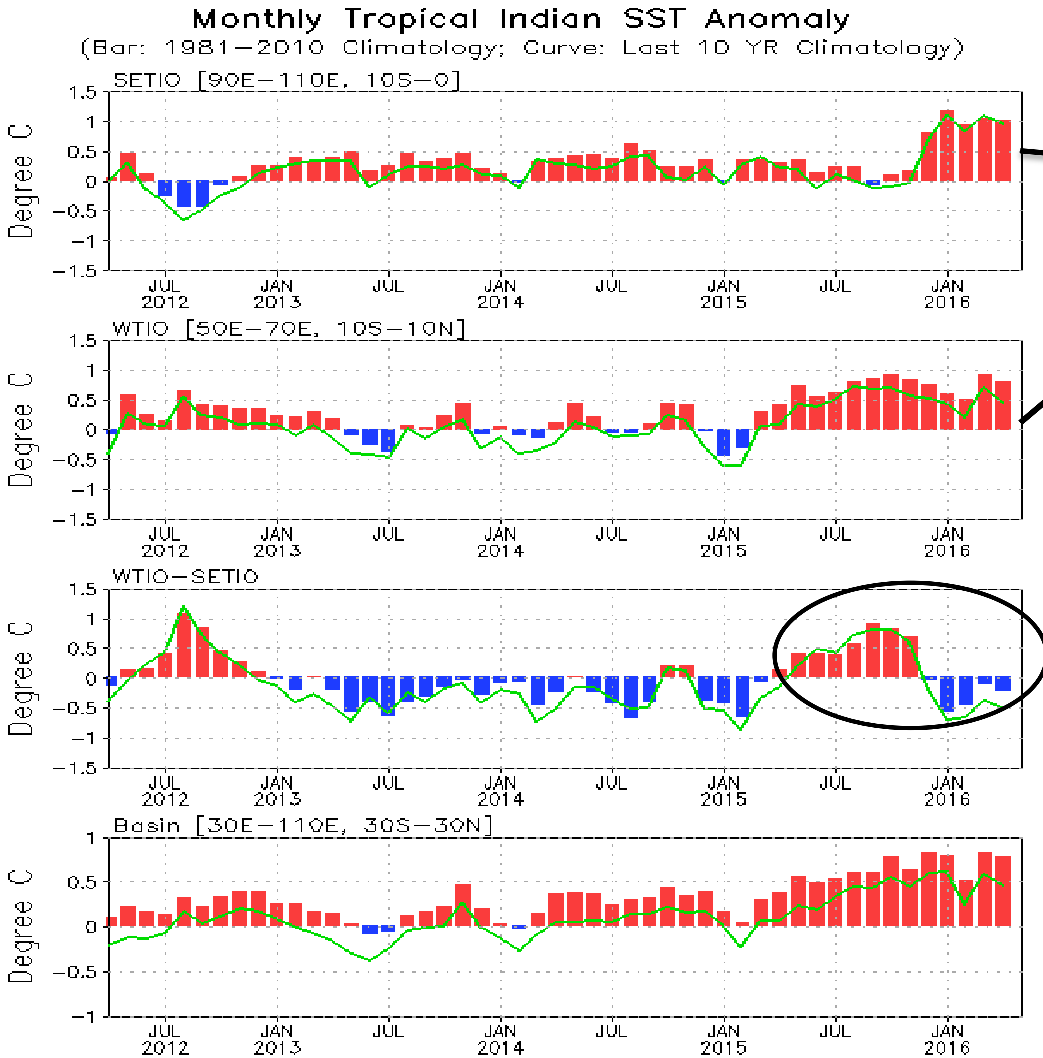


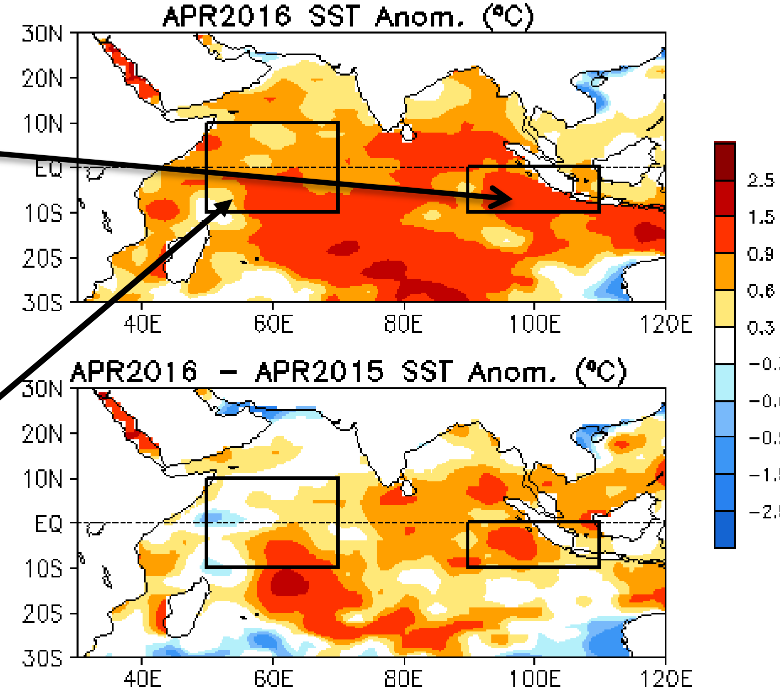


- **Arctic sea ice extent in Apr 2016 was smaller than -2 standard deviations and less than that in 2012.**

Indian Ocean

Evolution of Indian Ocean SST Indices





- **Positive SSTA was larger in the east than in the west.**
- **DMI was below normal since Dec 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 SSTA was larger in the east than in the west.**
- **SSTA tendency was largely determined by heat flux.**
- **Convections were suppressed over the NE. basin.**

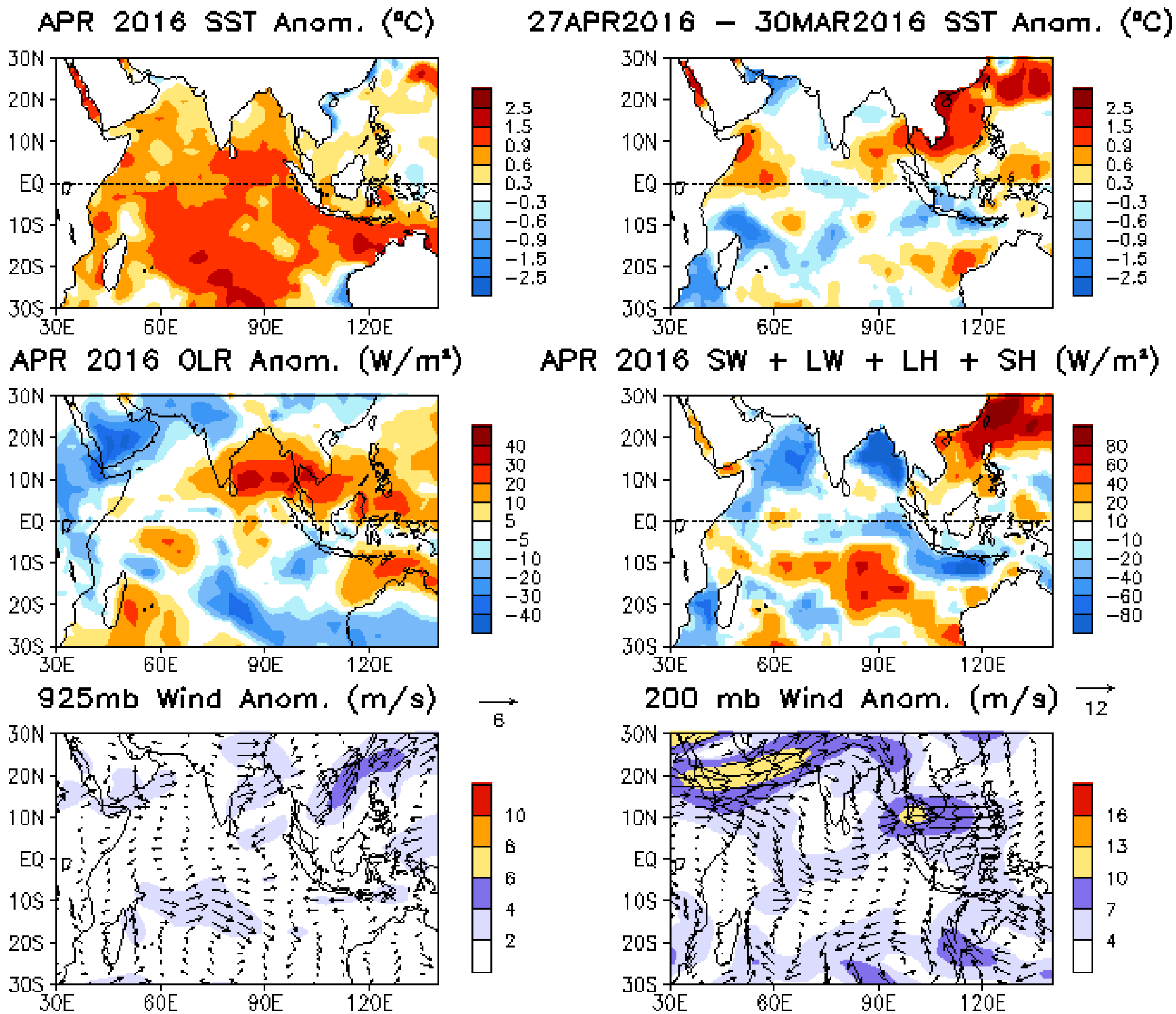
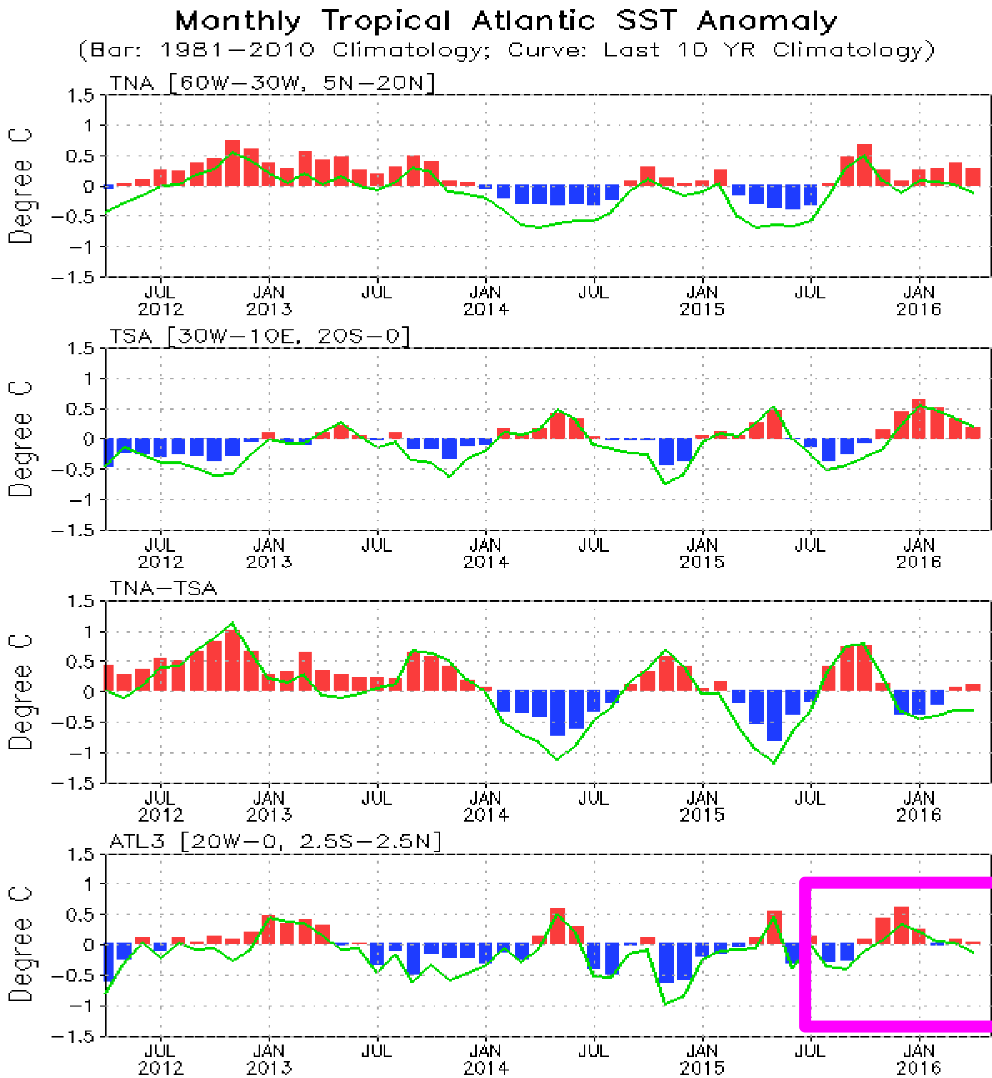
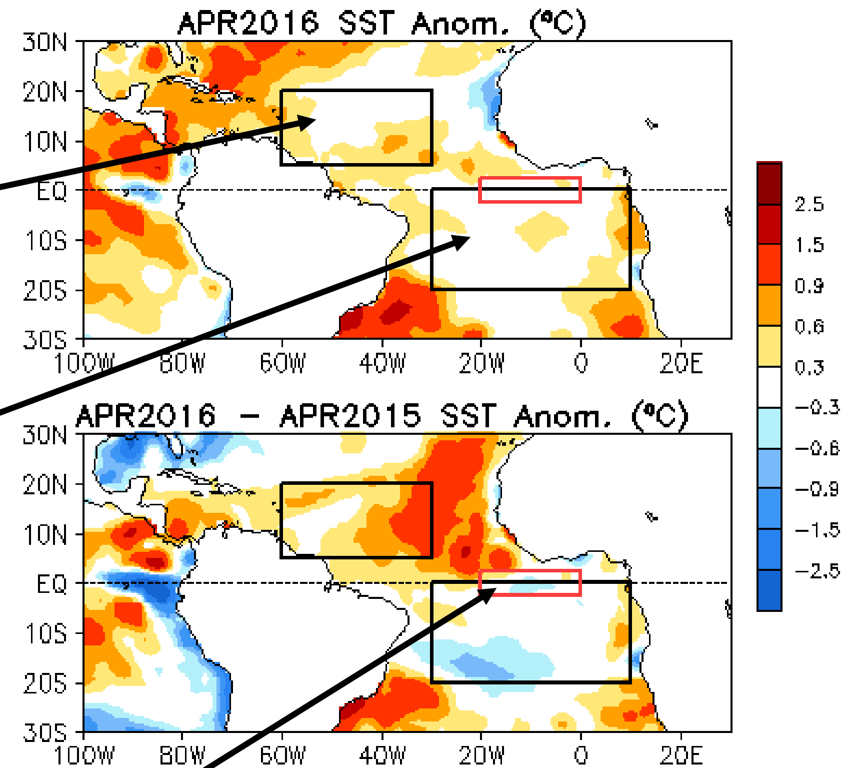


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

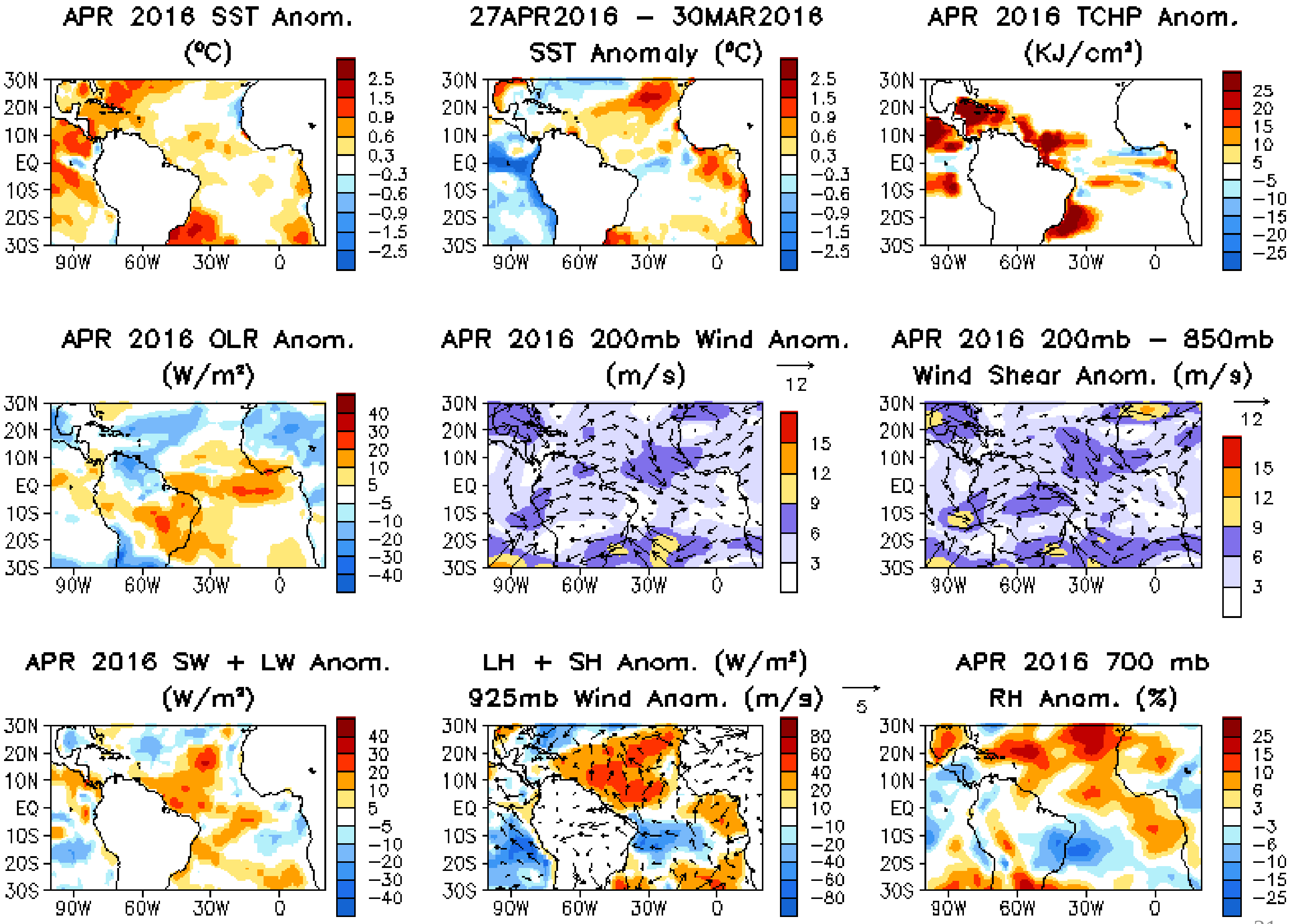




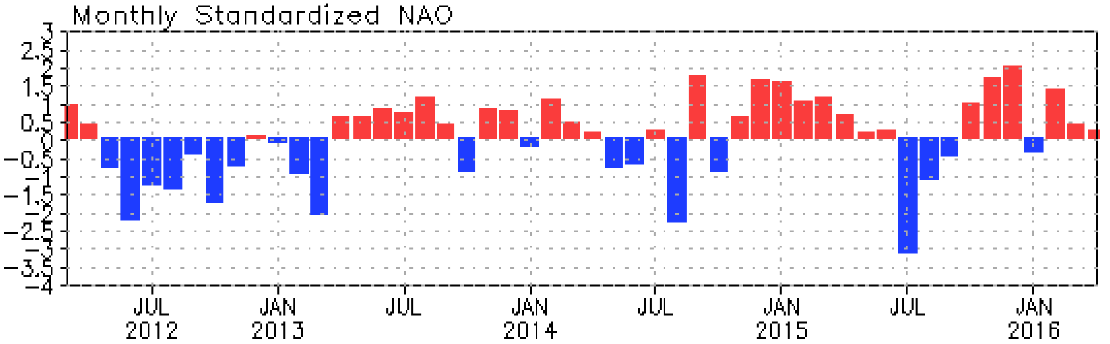
- **ATL3 index had small value since Feb 2016.**

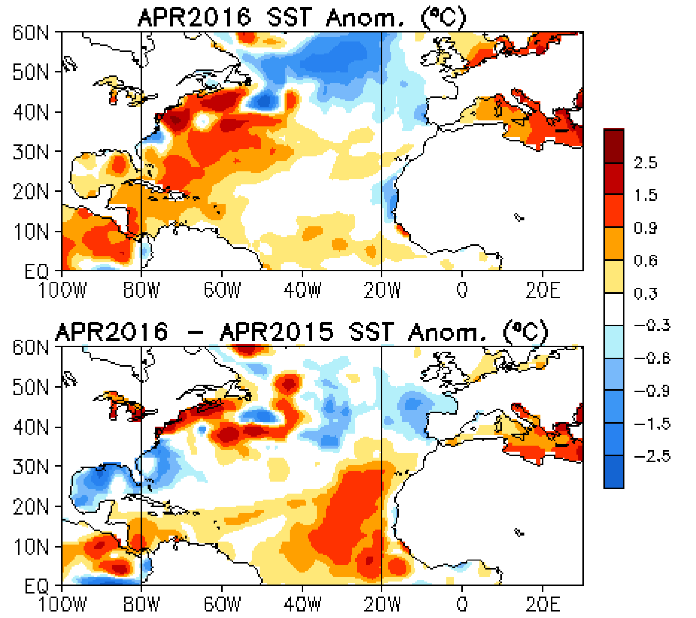
Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between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

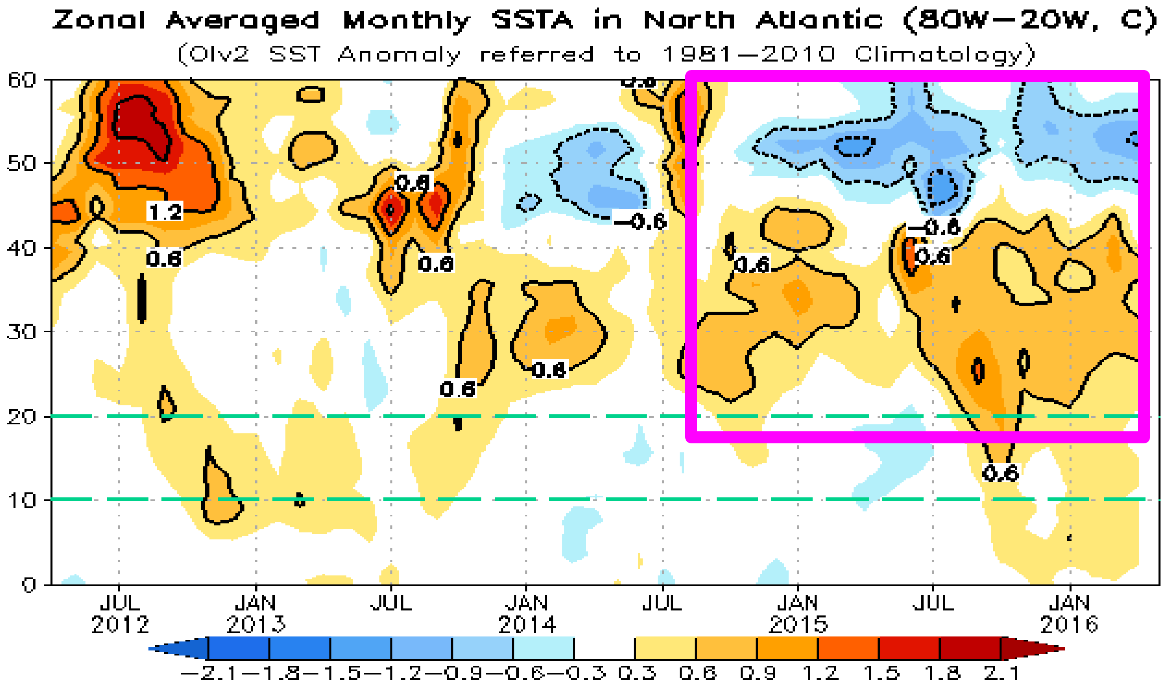
Tropical Atlantic:



NAO and SST Anomaly in North Atlantic





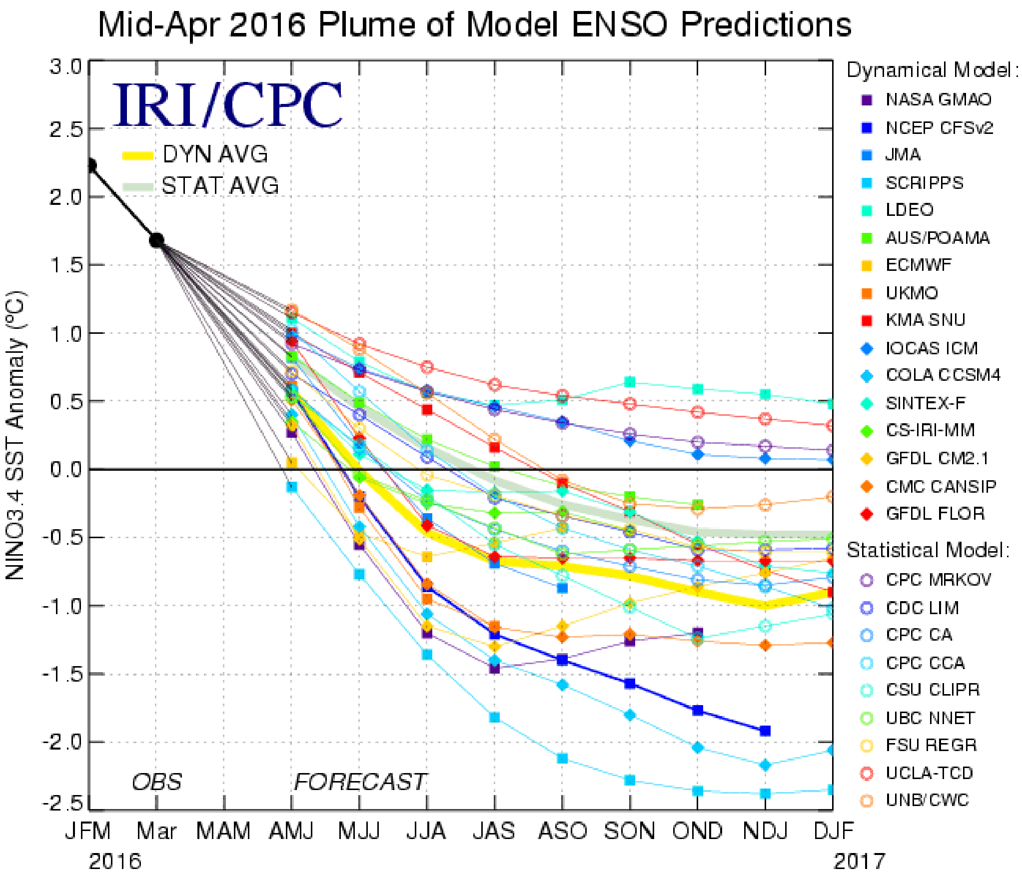


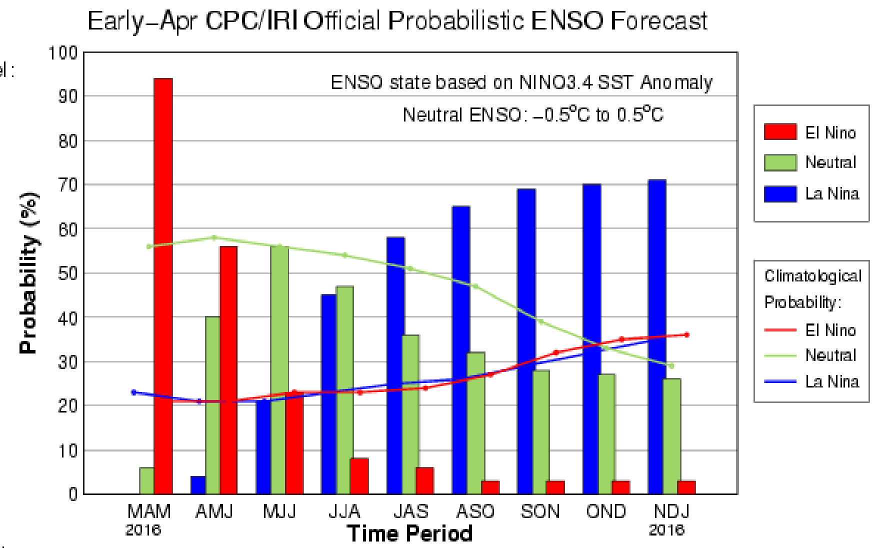
- NAO was in positive phase with NAOI=0.26 in Apr 2016.
- SSTA was positive in the middle latitudes and negative in the high latitudes since autumn 2015, may be due to the influence of positive phase of NAO.

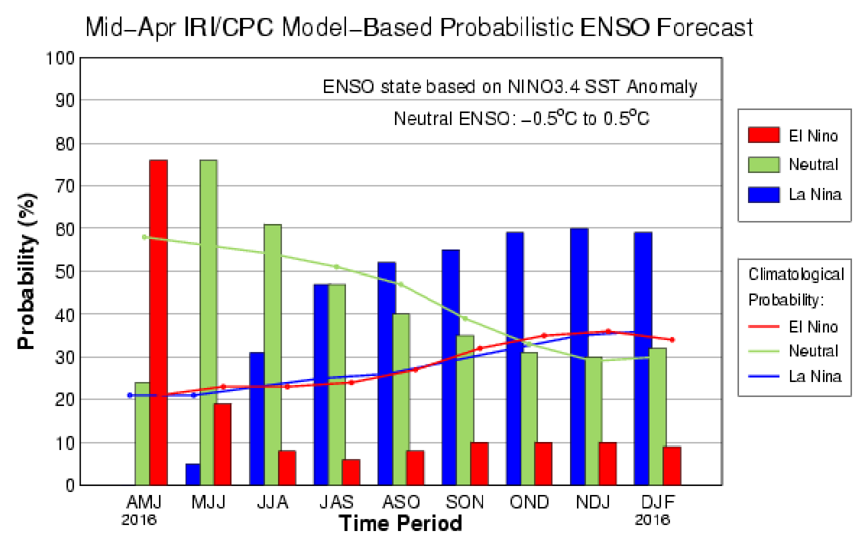
Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (bottom). SST are derived from the NCEP OI SST analysis,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

ENSO and Global SST Predictions

IRI NINO3.4 Forecast Plum



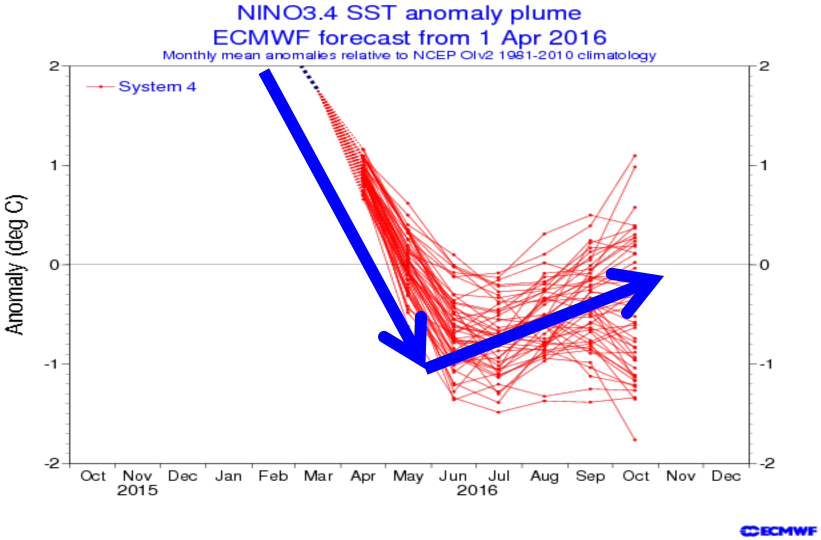




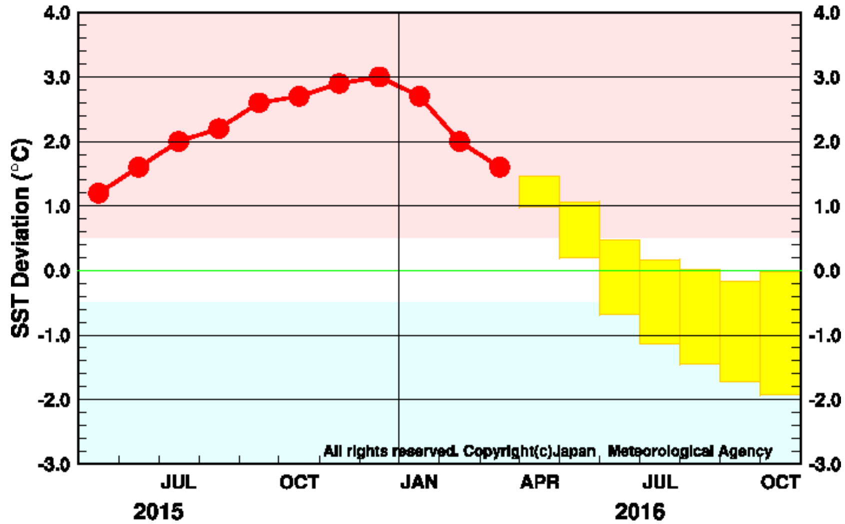
- **Majority of models predicted a La Nina, and some models predicted neutral started since the second half of 2016.**
- **NOAA "ENSO Diagnostic Discussion" on 14 Apr 2016 issued "El Nino Advisory/La Niña Watch" and suggested that** ***"A transition to ENSO-neutral is likely during late Northern Hemisphere spring or early summer 2016, with an increasing chance of La Niña during the second half of the year."***

Individual Model Forecasts: neutral or La Nina

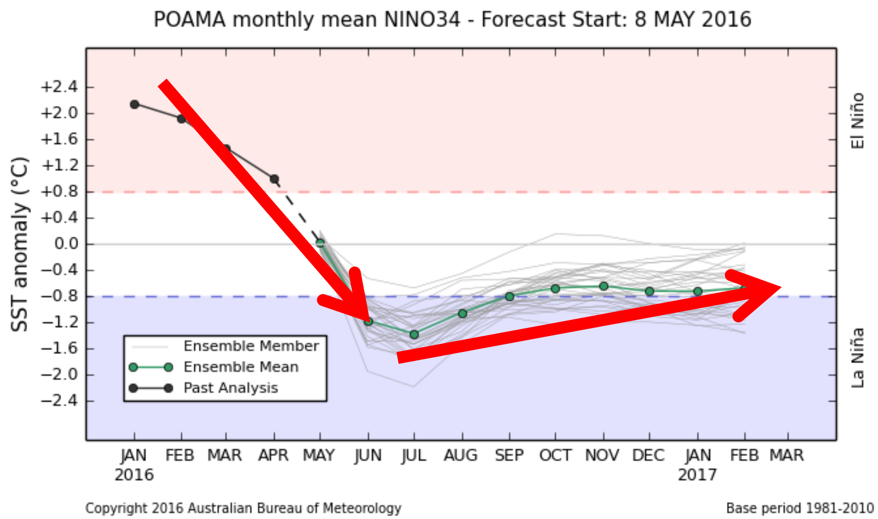
EC: Nino3.4, IC=01Apr 2016



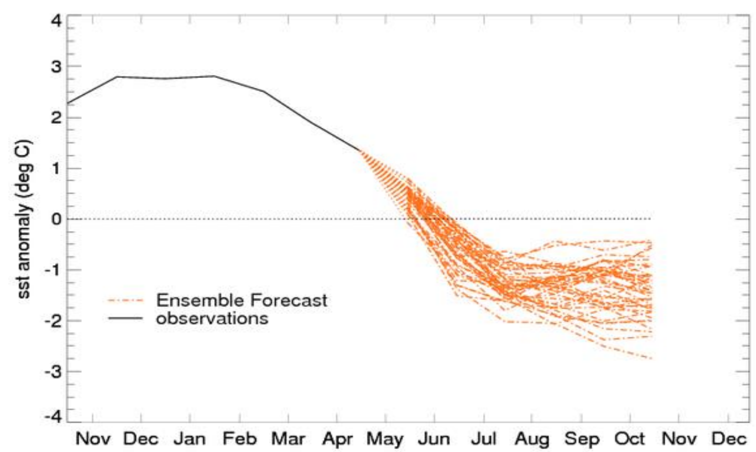
JMA: Nino3, IC= Apr 2016

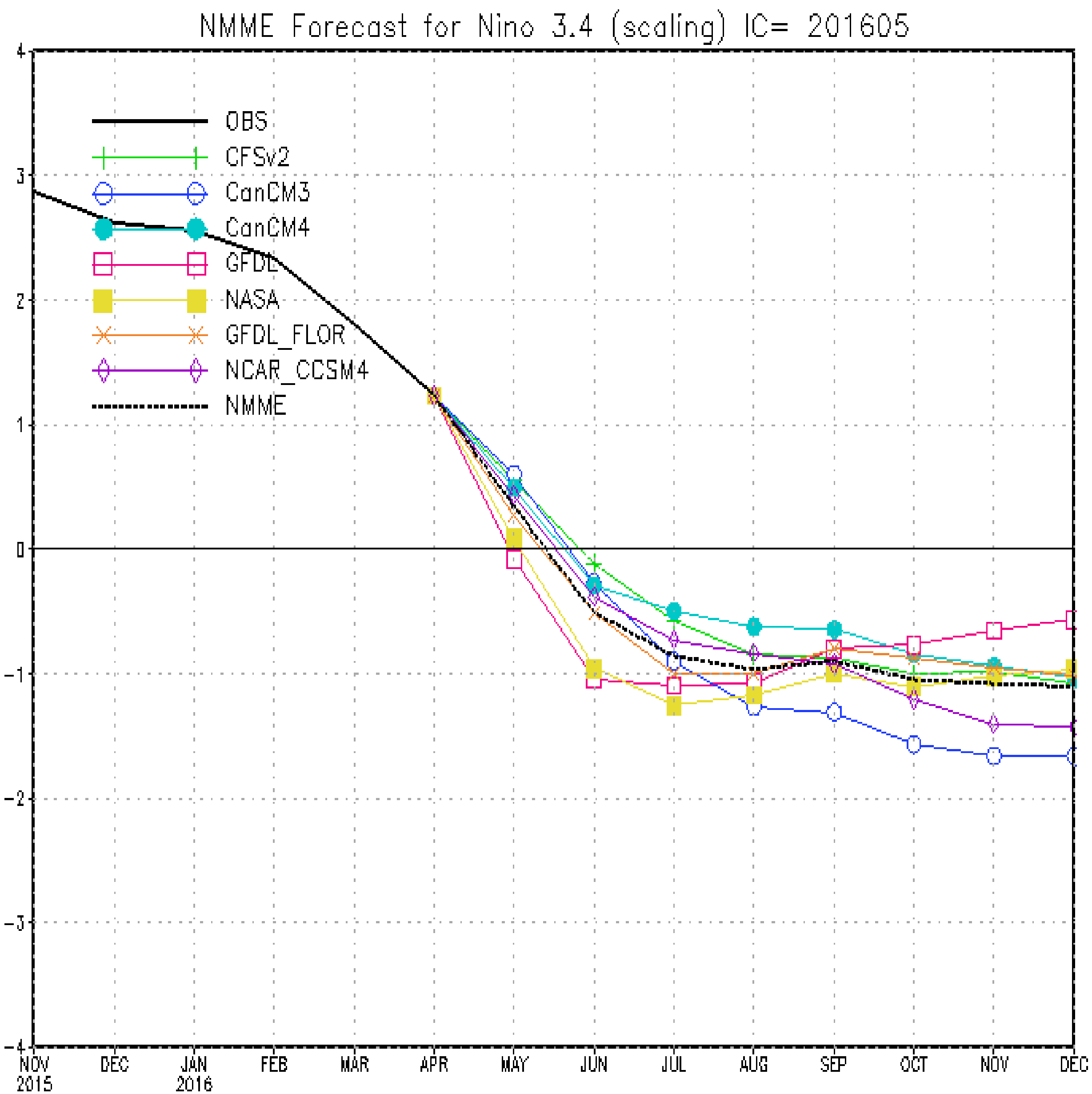


Australia: Nino3.4, IC=8 May 2016



UKMO: Nino3.4, IC=May 2016





- NMME models suggest a transition to La Nina conditions in later summer and fall.

- The impact of the biases in CFSR ocean ICs in the tropical Atlantic during past a few months seems eliminated in both the CFSv2 and CCSM4.

An analogue method to predict tropical SST and ENSO

(From Dr. Peitao Peng: Peitao.Peng@noaa.gov)

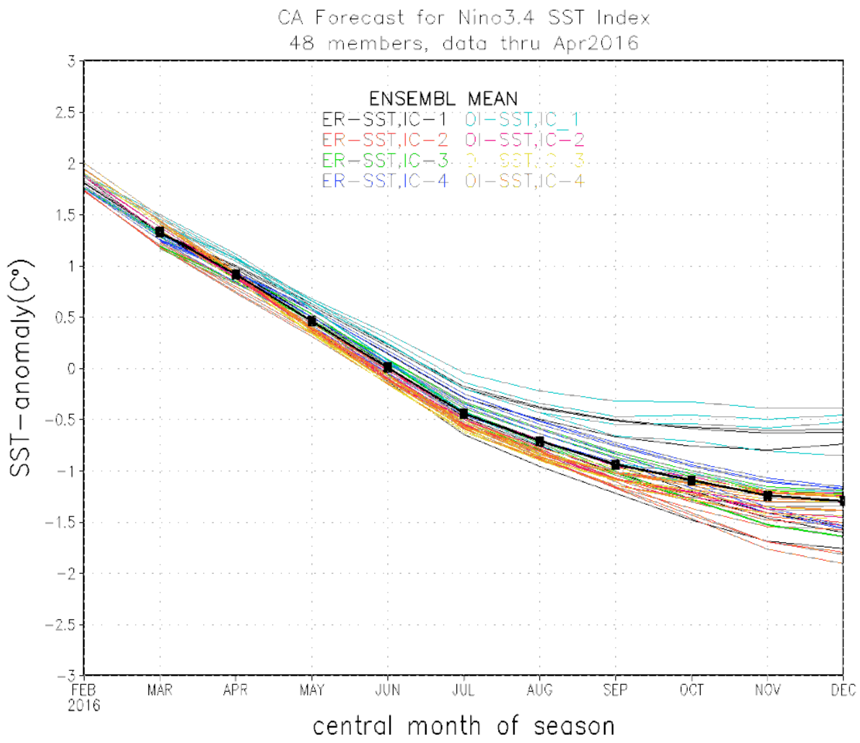
- Use weighted average of historical data to approximate current data (IC);
- The weights are obtained by minimizing the RMS error;
- Construct forecast by applying the weights to the lagged data in history

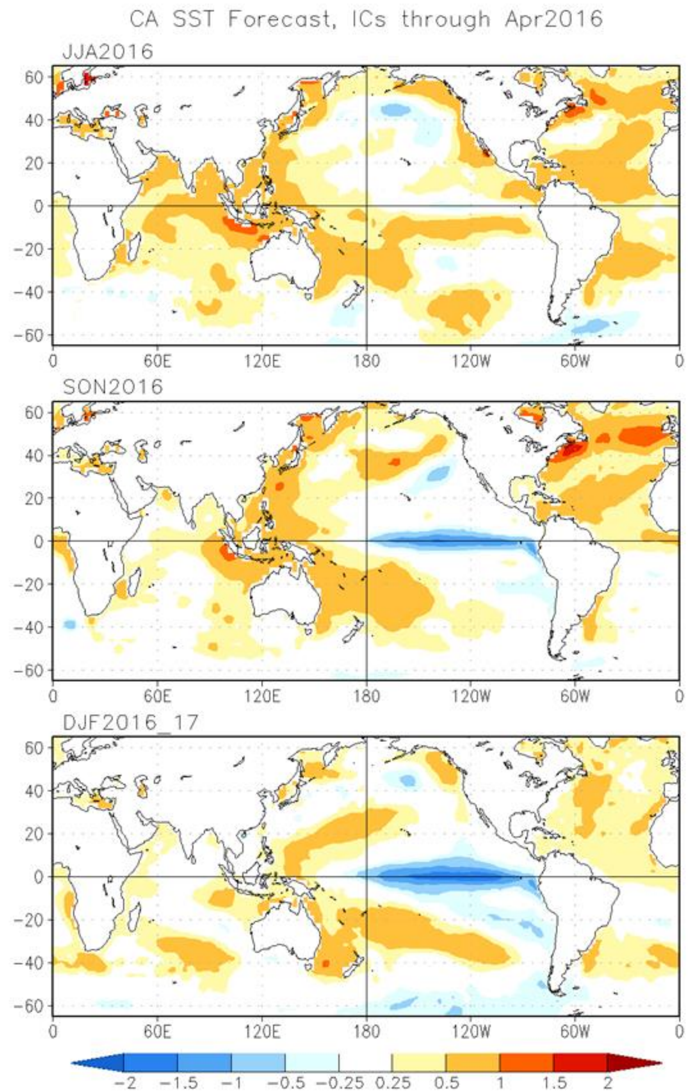
1. Use both HAD-OI SST and ERSST since 1948;
2. Choose EOF truncations at 20, 25, 30, 40, 50, 60;
3. Have season number 1 to 4 in ICs;

Combine 1-3 above to have a 48-member ensemble

CA 48-member Ensemble Forecast for SST

(From Peitao.peng@noaa.gov)



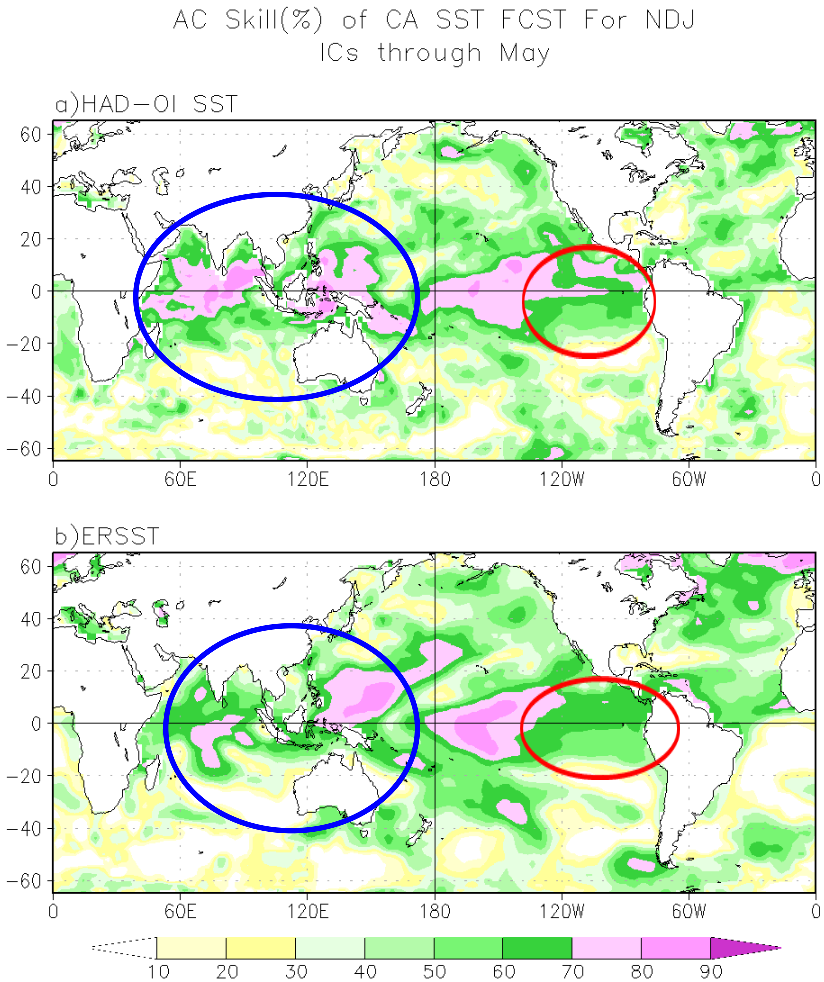


Moderate La Nina is expected for 2016/17 winter

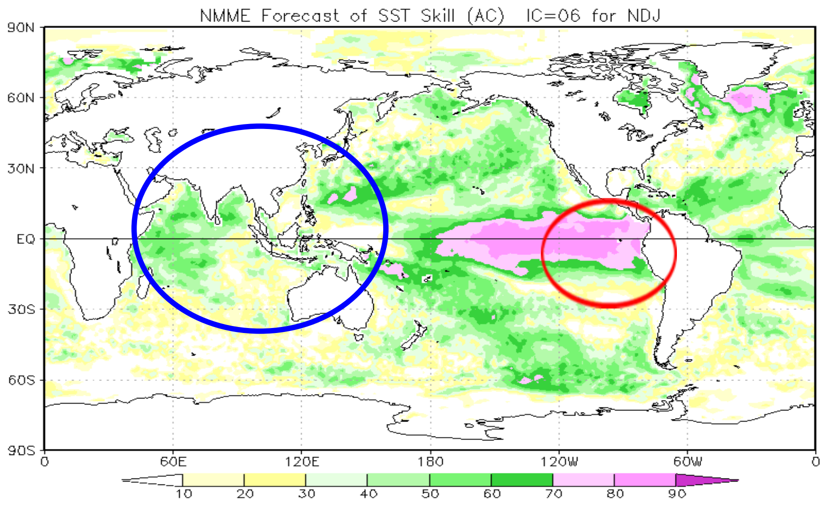
ICs through MAM, Lead-5 for NDJ

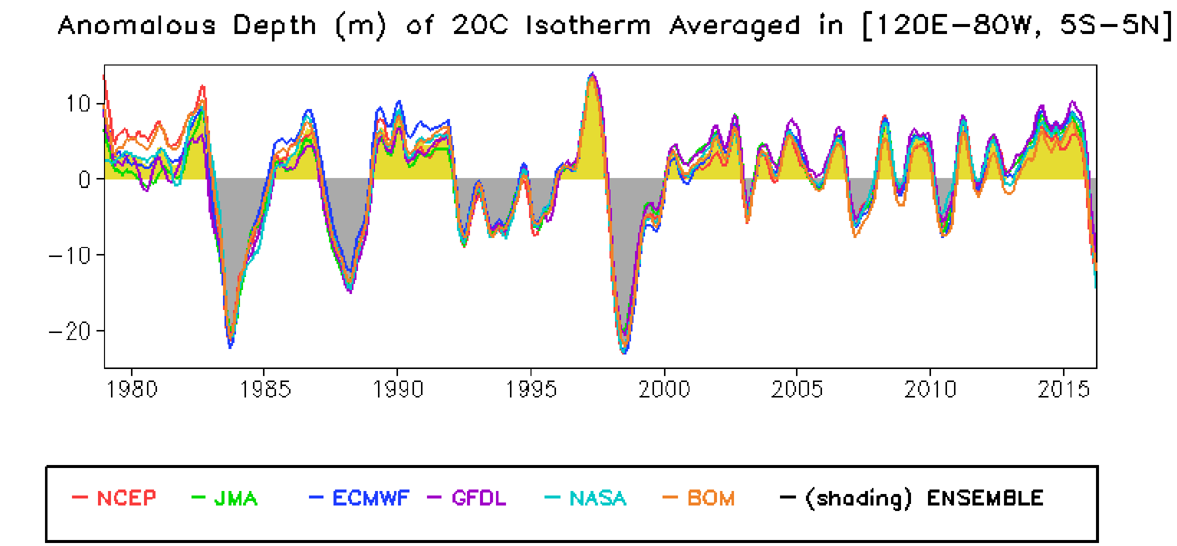
(From Peitao.peng@noaa.gov)

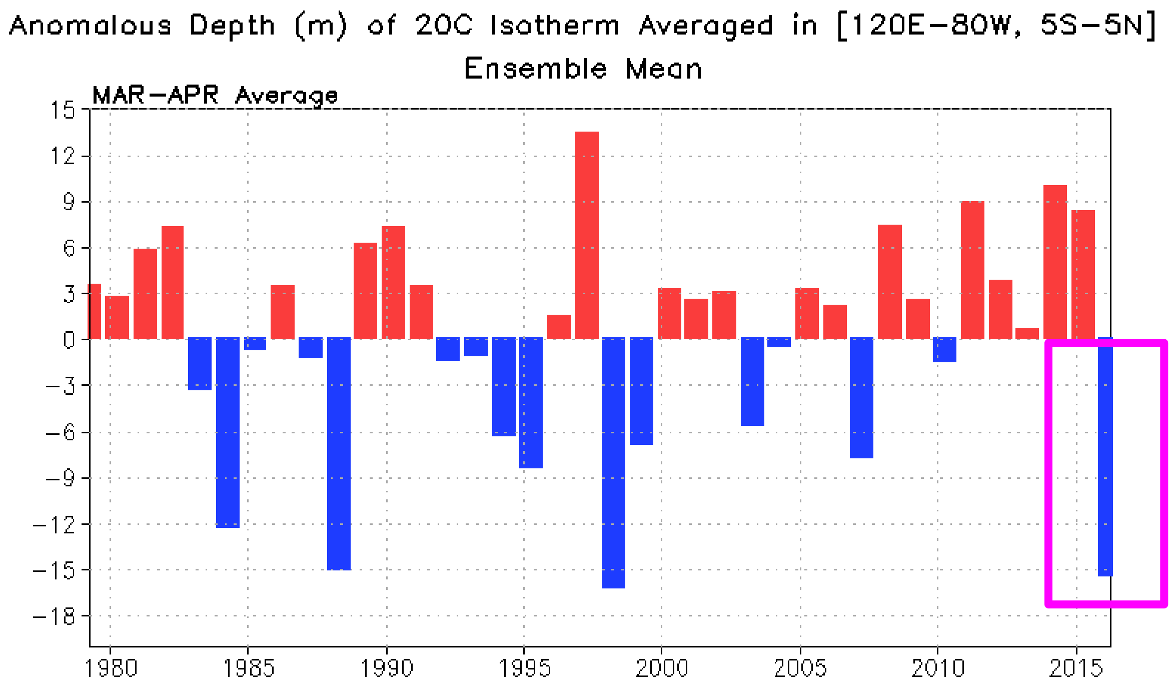
CA



NMME







1: Now the WWV for Mar-Apr 2016 is the second lowest since 1979.

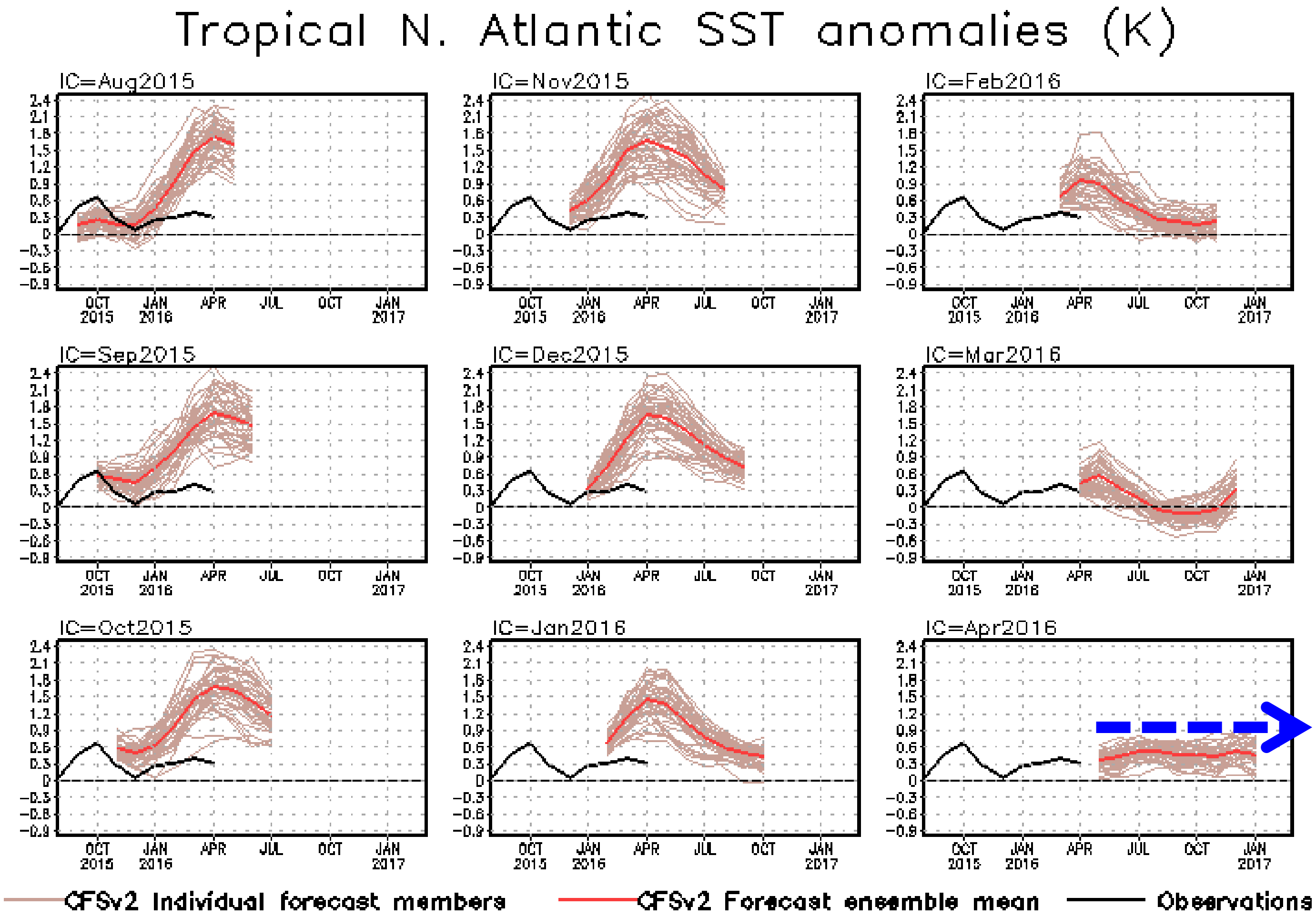
2: Corresponding NDJ ONI of the top six lowest WWVs in Mar-Apr are

	NDJ ONI
1998	-1.4
2016	???
1988	-1.8
1984	-1.1
1995	-0.9
2007	-1.3

(Yan.Xue@noaa.gov)

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

TNA is the SST anomaly averaged in the region of [60ºW-30ºW, 5ºN-20ºN].



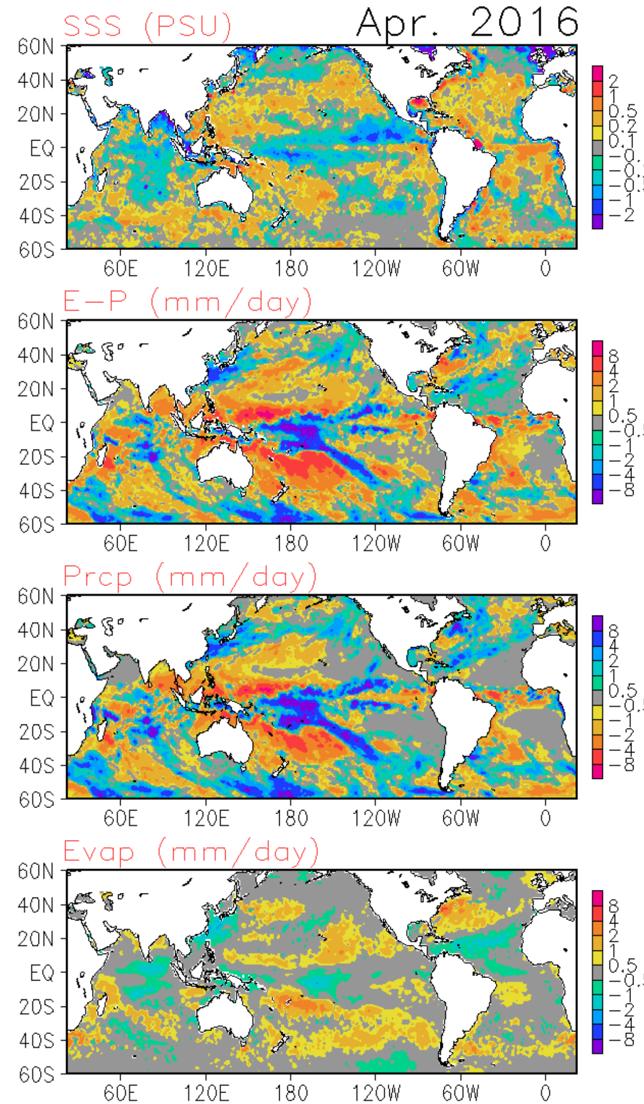
- Latest CFSv2 predictions call slightly above normal SSTA in tropical N. Atlantic in summer and autumn 2016.

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.

Global Sea Surface Salinity (SSS)

Anomaly for Apr. 2016

- NOTE: Since Aquarius terminated operations, the blended SSS analysis is from in situ and SMOS only from June 2015. Please report to us any suspicious data issues!
- The El Nino condition continues in this month producing positive precipitation anomaly over the eastern and central tropical Pacific Ocean and negative anomaly in the western tropical Pacific Ocean. The enhanced flux water flux maintains the fresh SSS anomaly across most of the tropical Pacific. Increased precipitation in the SPCZ region was observed in this month. Positive precipitation anomaly in the central South Indian Ocean along with the negative evaporation anomaly likely decrease the SSS in the region.



- **Data used**

  SSS :

  Blended Analysis of Surface Salinity (BASS) V0.Y

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

  (Xie et al. 2014)

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

  Precipitation:

  CMORPH adjusted satellite precipitation estimates

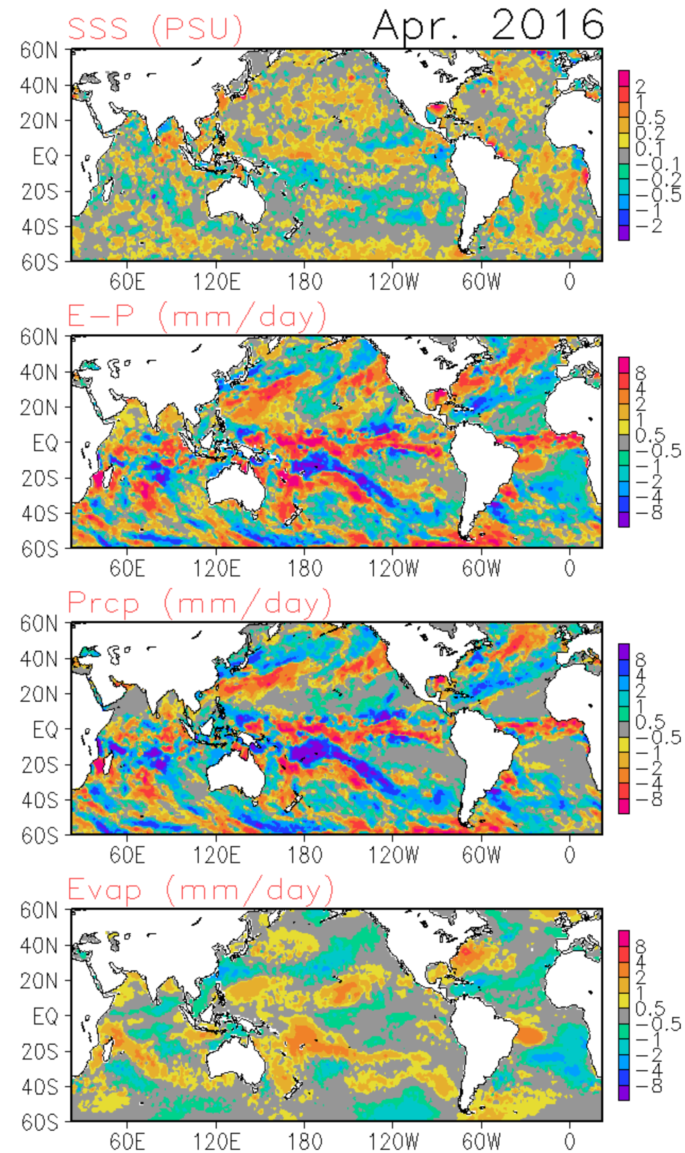
  Evaporation:

  CFS Reanalysis

Global Sea Surface Salinity (SSS)

Tendency for Apr. 2016

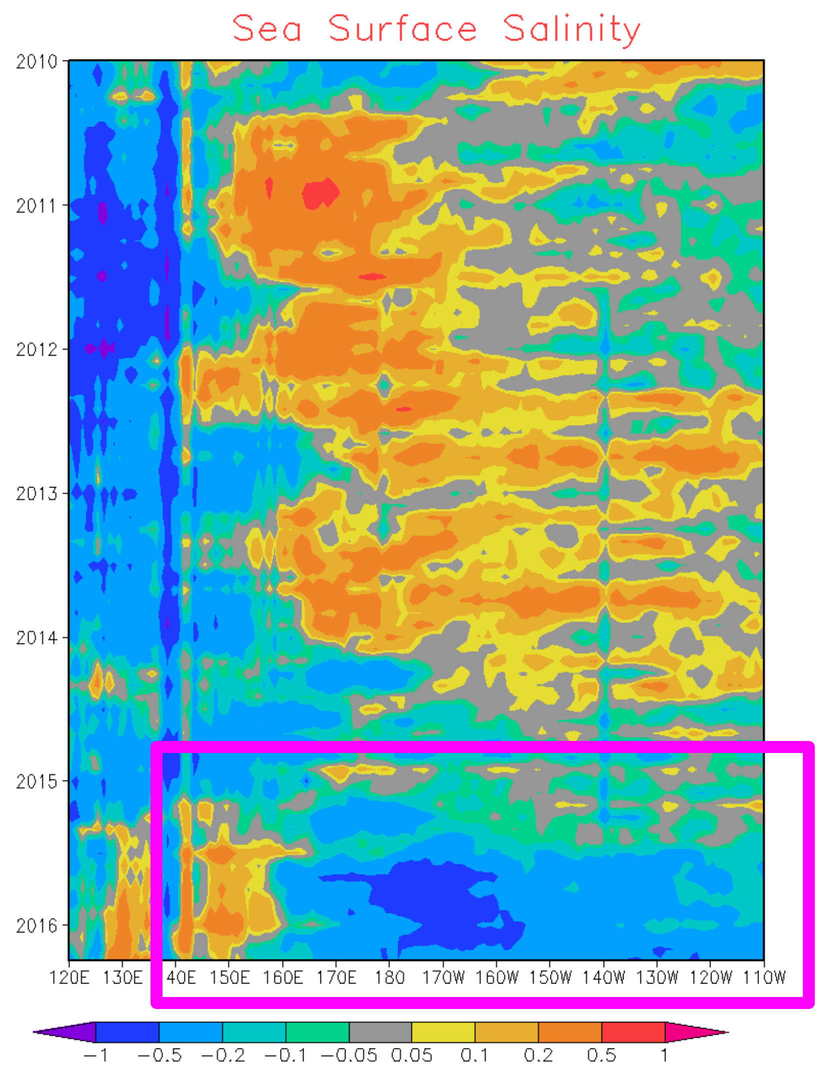
- Compared with last month, negative SSS anomalies appear in the SPCZ region due to enhanced precipitation. Positive SSS anomalies continue in the central and eastern equatorial Pacific Ocean due to less enhanced precipitation, which likely indicates the weakening of the El Nino. Negative SSS anomalies appear in the Eastern Equatorial Pacific region north of Equator where positive precipitation anomalies were found. SSS continues becoming fresher in the central South Indian Ocean (20ºS to 40ºS), which is likely caused by positive precipitation anomalies and negative evaporation anomalies in this region.



Global Sea Surface Salinity (SSS)
Anomaly Evolution over Equatorial Pacific

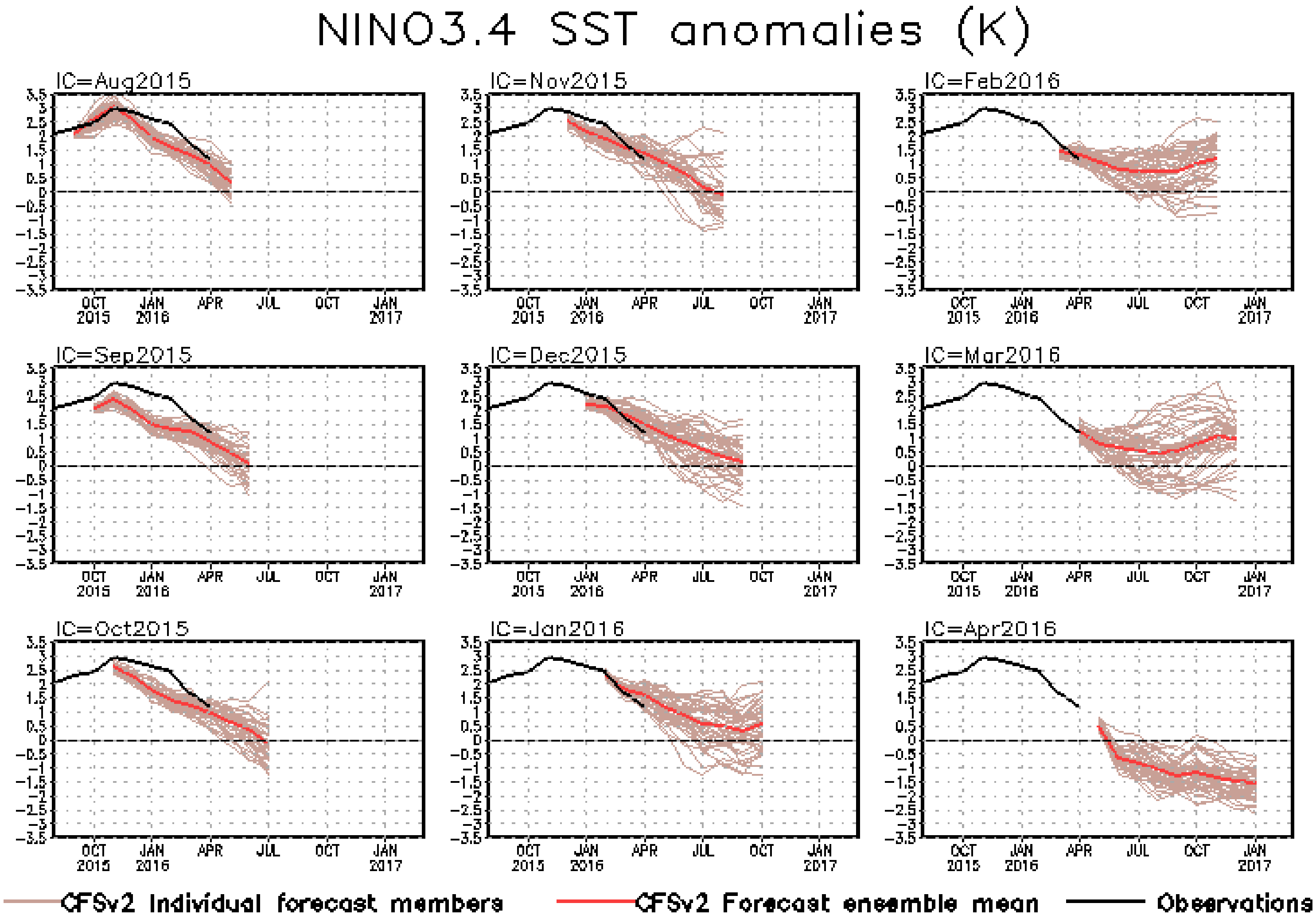
- Hovemoller diagram for equatorial SSS anomaly **(10ºS-10ºN);**

- Negative SSS in the Eastern Equatorial Pacific from 160ºE to 110ºW has been persistent for a year, but its maximum anomalies centered from 180ºE to 160ºW was reduced in this month. At the meantime, a stretch of positive SSS anomaly remains over the western Pacific and eastern Indian Ocean from 130ºE – 160ºE;



Backup Slides

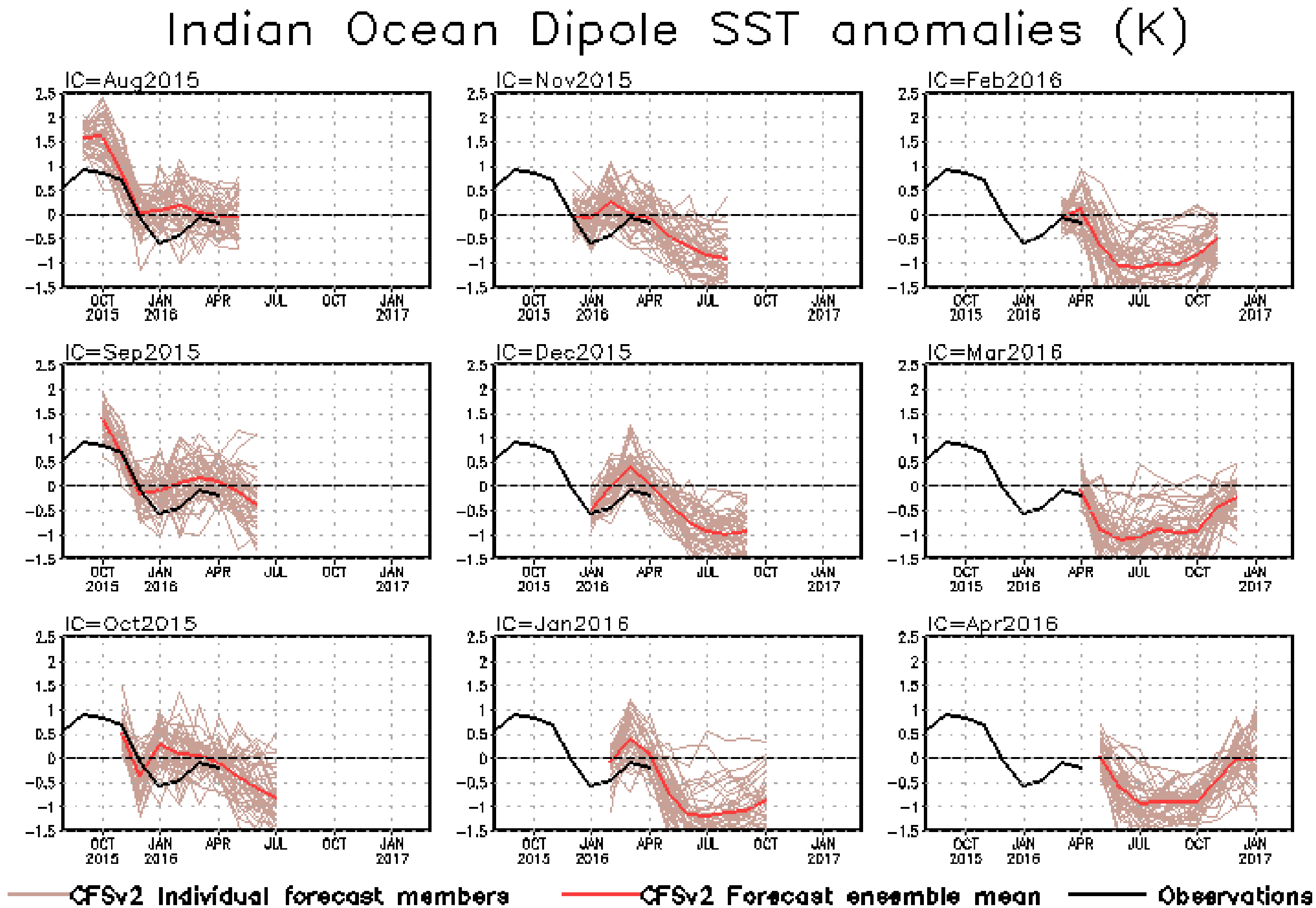
CFS Niño3.4 SST Predictions from Different Initial Months



- **CFSv2 predicted a La Nina started from second half of 2016.**

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.

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.

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

PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110ºE-100ºW, 20ºN-60ºN].

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

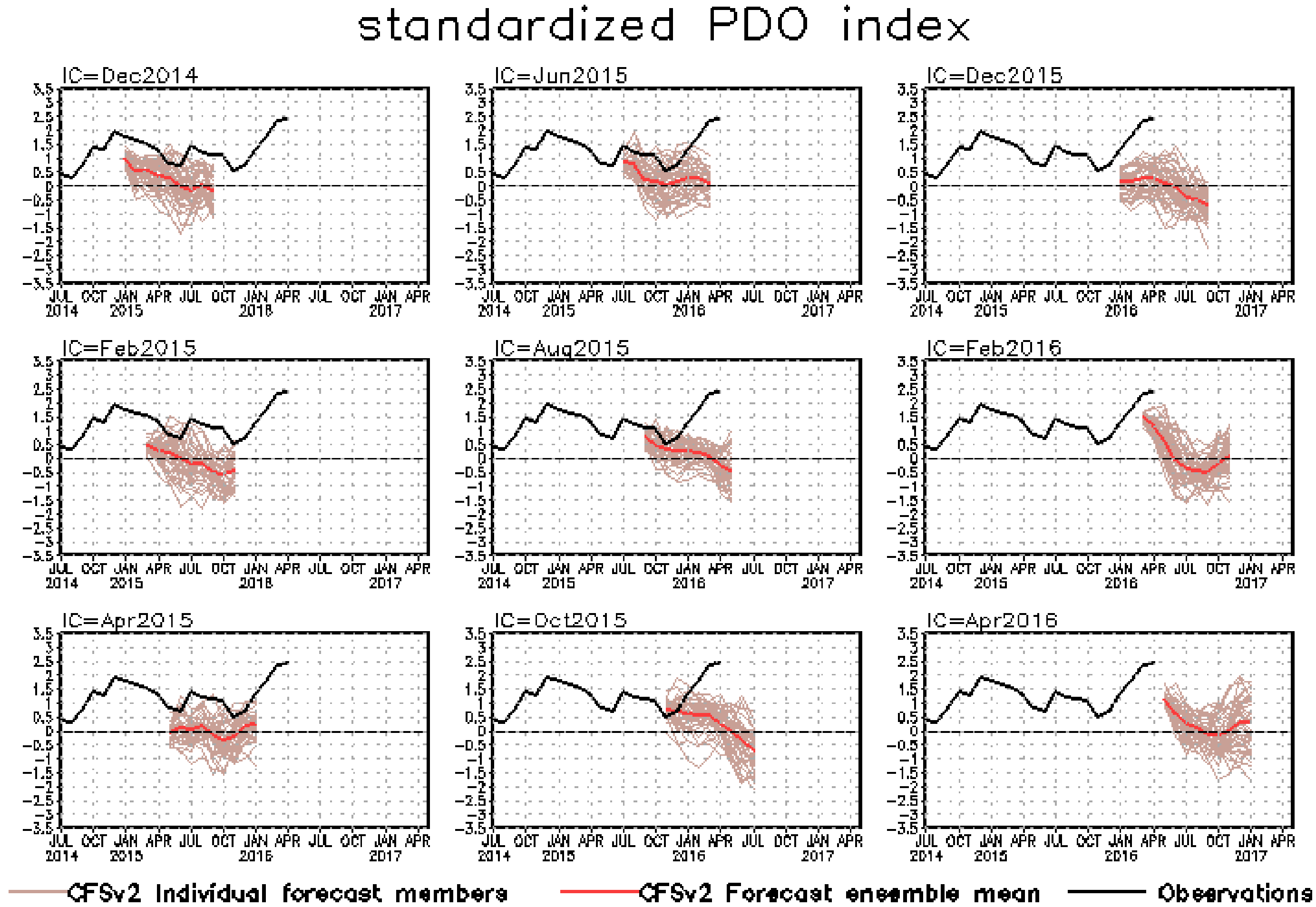


Fig. M4. CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

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

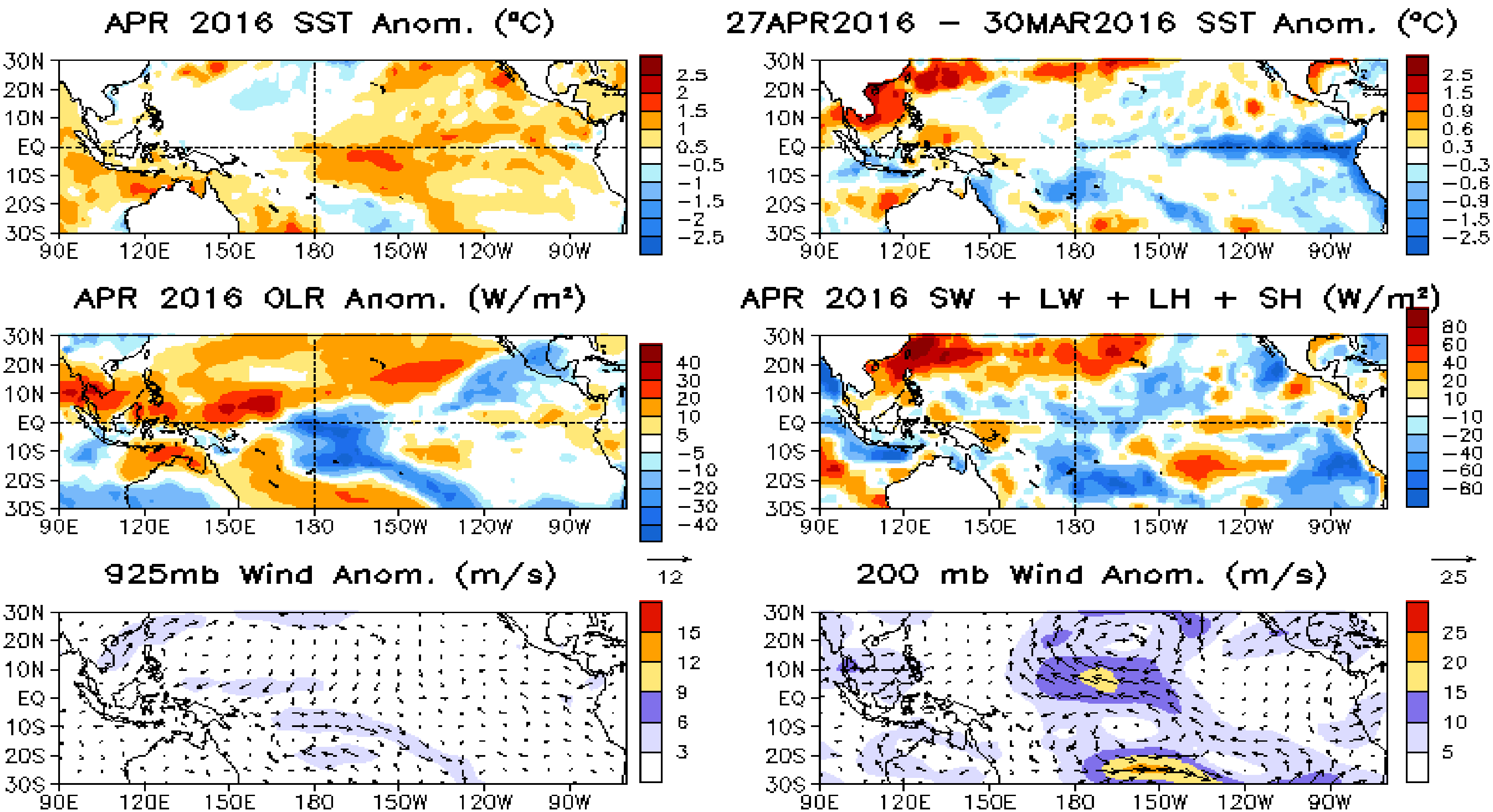


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

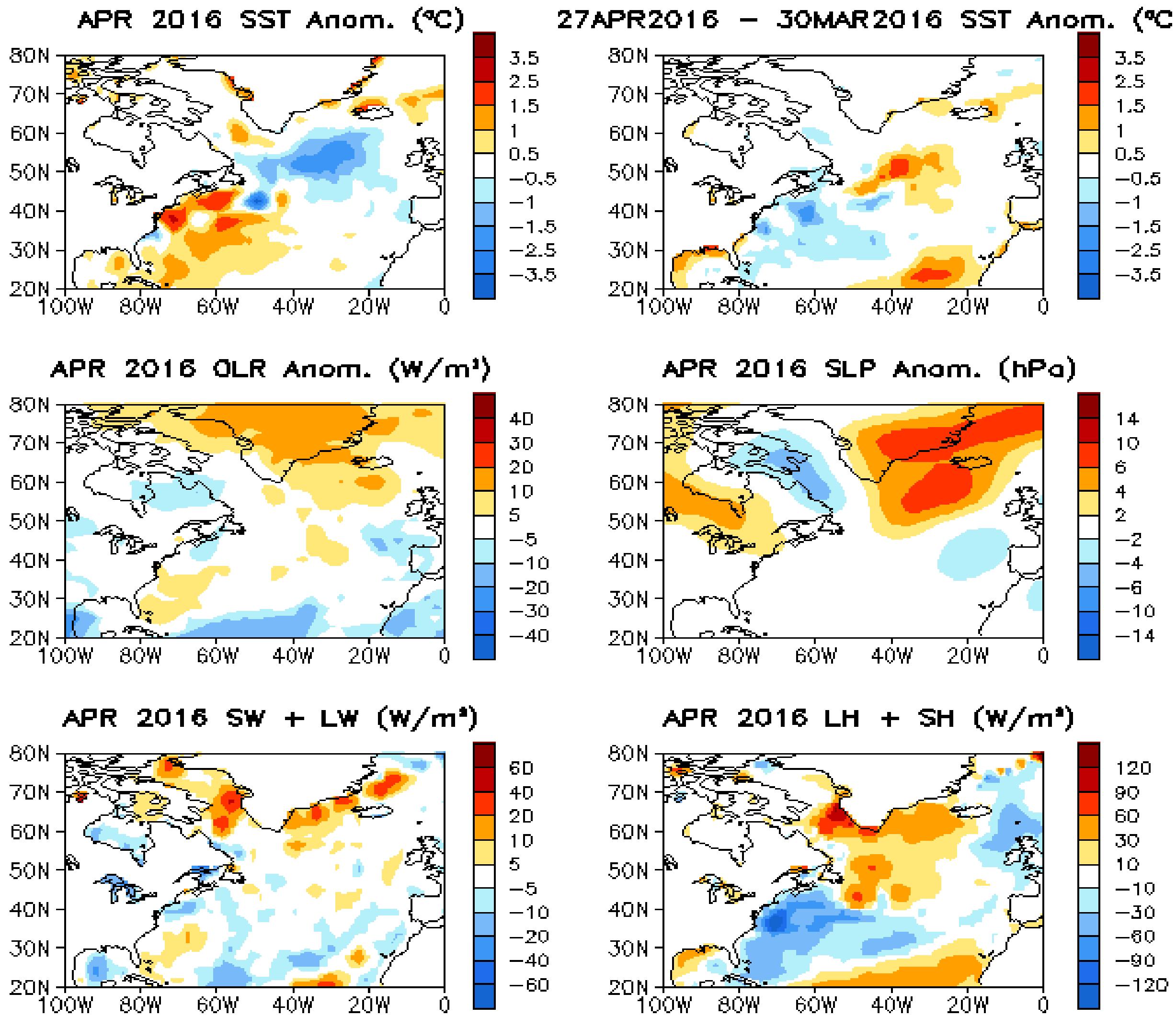


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

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.ndbc.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!