# 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
  - Potential New Indices to Monitor Pacific and Atlantic Oceans

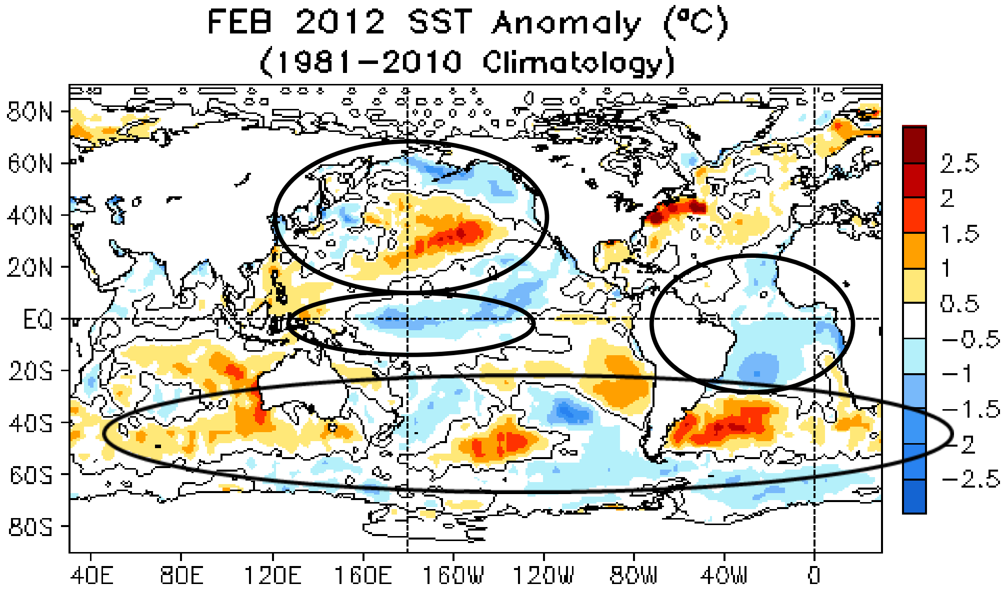
- Global SST Predictions

# Overview

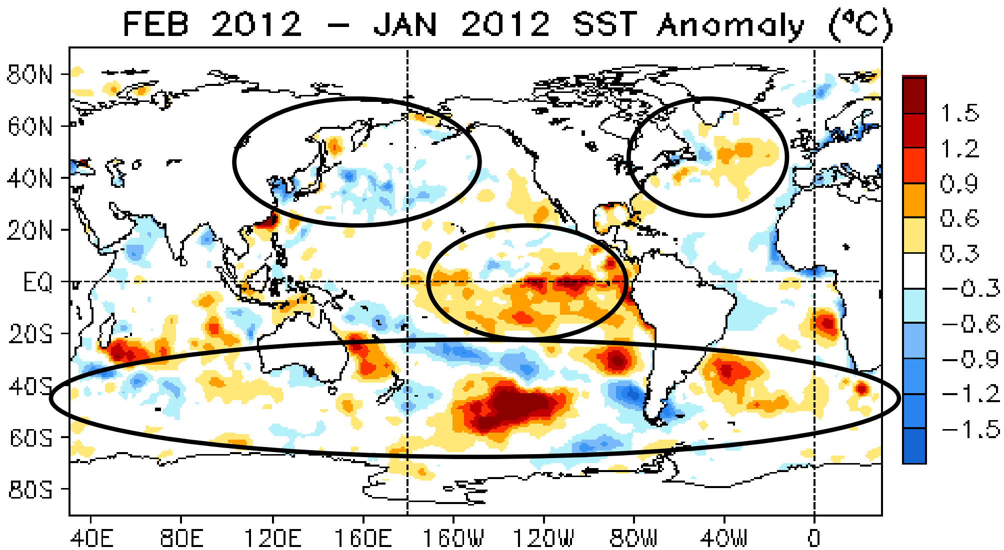
- **Pacific Ocean**
  - La Nina conditions weakened with NINO3.4=-0.7°C in Feb 2012.
  - NOAA "ENSO Diagnostic Discussion" in March suggests La Niña is expected to return to ENSO-neutral conditions by the end of April 2012. A majority of ENSO prediction models predict ENSO-neutral to continue through the NH summer 2012.
  - Some models in the US National Multi-Model Ensemble (NMME) predicts an El Nino since this summer.
  - Negative PDO weakened, with PDOI=-1.3 in Feb 2012. NMME predicts negative PDO pattern to last through the NH spring-autumn 2012.
- **Indian Ocean**
  - Small anomalies.
- **Atlantic Ocean**
  - Positive NAO weakened significantly with NAOI=0.42 in Feb 2012.
  - Tropical South Atlantic has cooled down substantially since Dec 2011, which was the coolest period since 1998. NMME predicts the cooling to last until early autumn 2012.
  - Positive meridional SSTA gradient mode weakened in Feb 2012.

# Global Oceans

# Global SST Anomaly (⁰C) and Anomaly Tendency



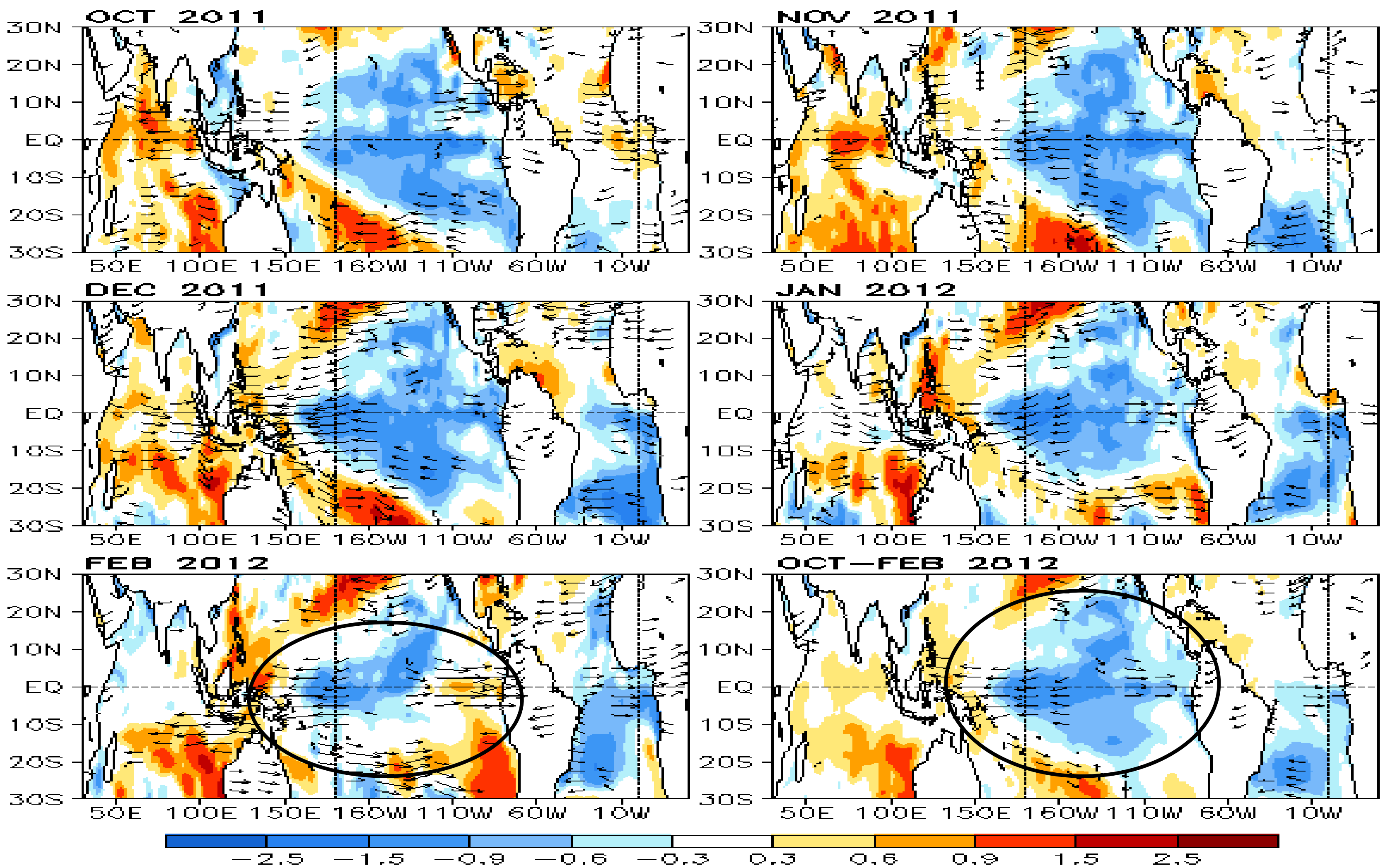

- La Nina associated negative SSTA persisted in the central tropical Pacific, but weakened in the east.
- Negative PDO pattern dominated in the North Pacific.
- Negative SST anomalies presented in the equatorial Atlantic and S. Atlantic.
- Large anomalies in the South Ocean.




- SST increased in the central and eastern tropical Pacific.
- SST decreased in the mid-latitudes of N. Pacific.
- Warming in the high-latitudes of N. Atlantic.
- Large tendencies in the South Ocean.

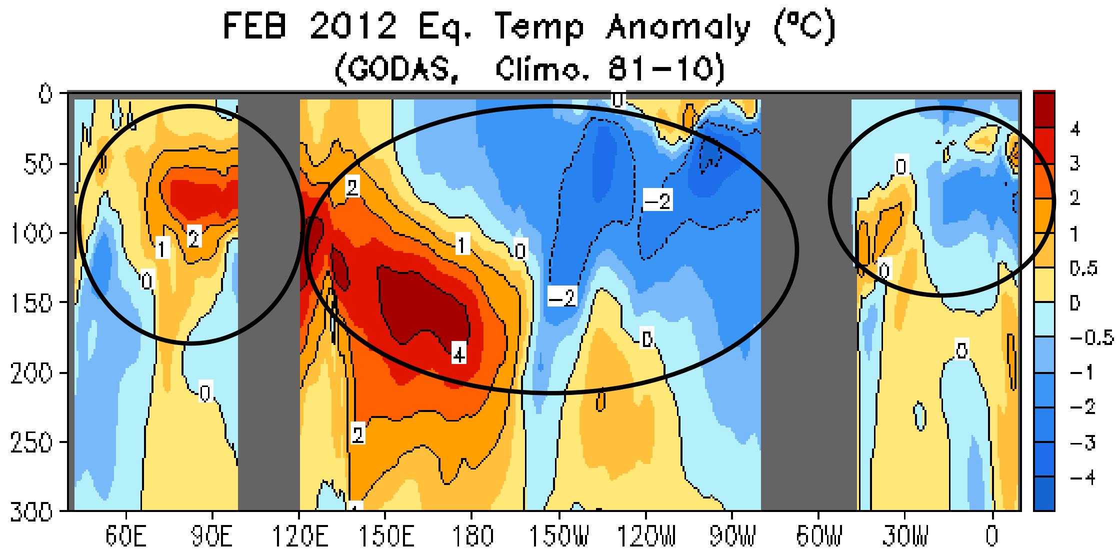
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

# Evolution of SST and 850mb Wind Anomalies

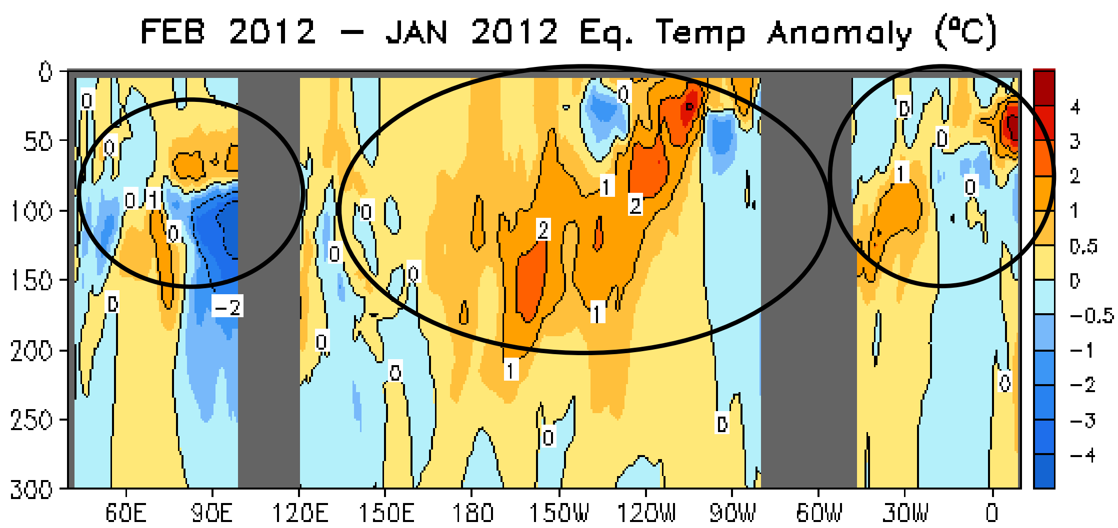



- **Negative SSTA weakened, particularly in the eastern tropical Pacific since Dec 2011.**
- **SSTA pattern in in Feb2012 is similar to the ENSO-Modoki mode.**

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




- Positive (negative) ocean temperature anomalies in the west (central and east) equatorial Pacific are consistent with La Nina conditions.
- Positive ocean temperature anomalies covered most of the top 100m in the equatorial Indian Ocean.
- Both positive and negative ocean temperature anomalies presented at top 100m of the equatorial Atlantic.



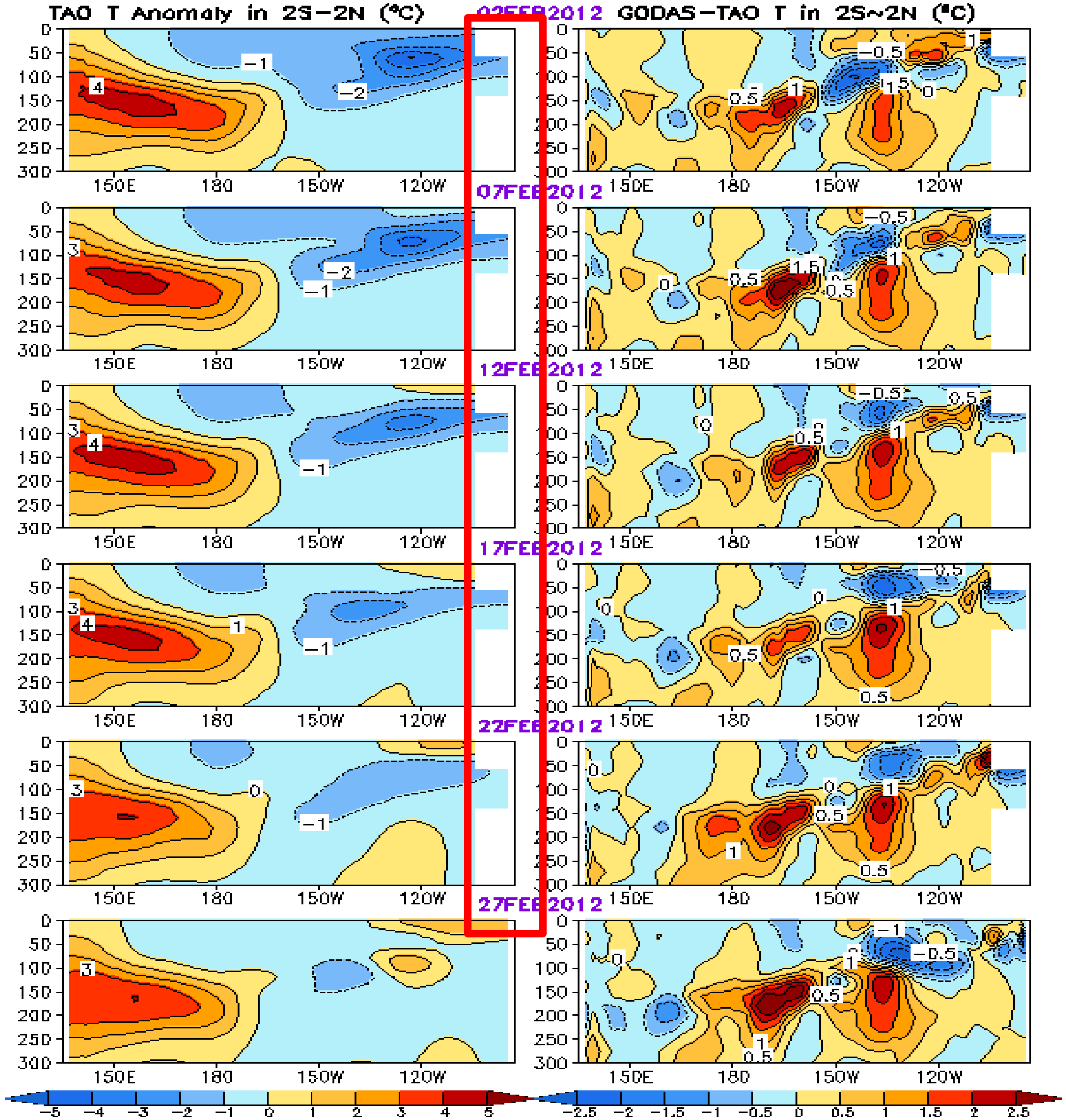

- Ocean temperature increased systematically in almost the whole equatorial Pacific in Feb 2012, consisting with the decay of La Nina.
- Ocean temperature increased (decreased) around 50-70 m (100-200m) in the equatorial Indian Ocean.
- Positive tendency was observed along the thermocline of the equatorial Atlantic.

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.

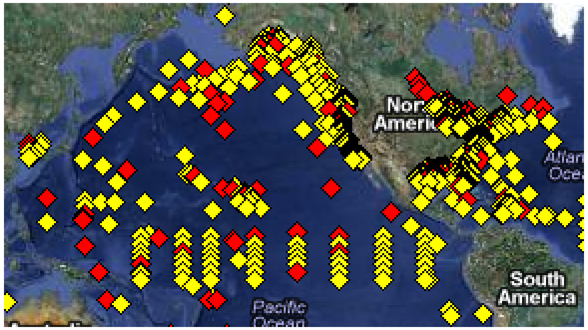
# Tropical Pacific Ocean and ENSO Conditions

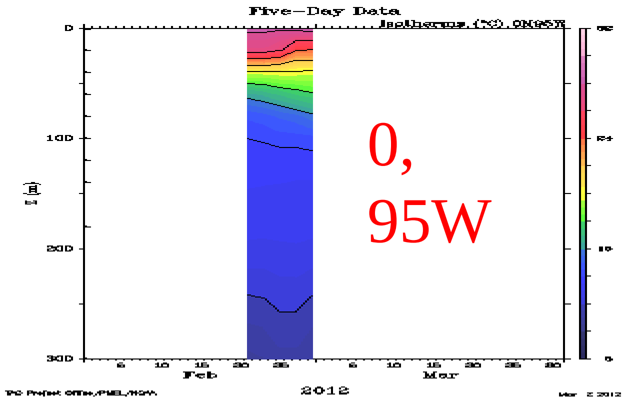
# Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

TAO GODAS-TAO

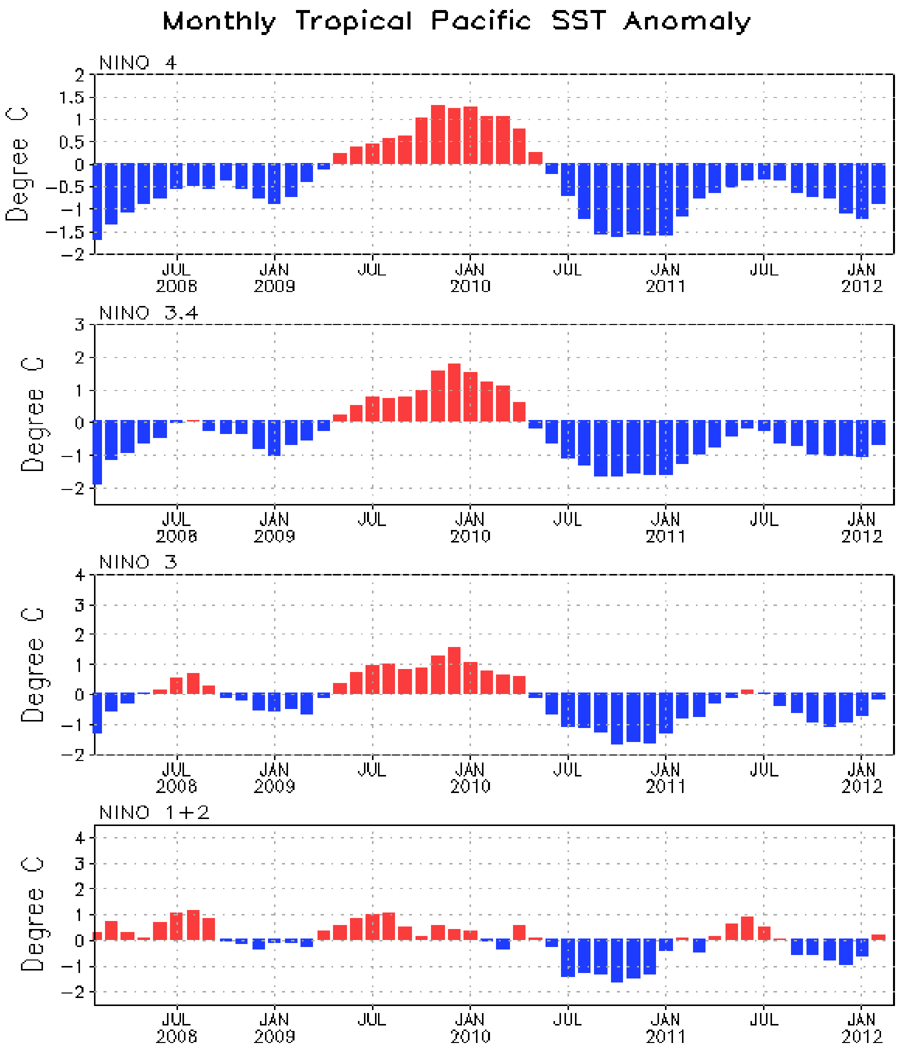


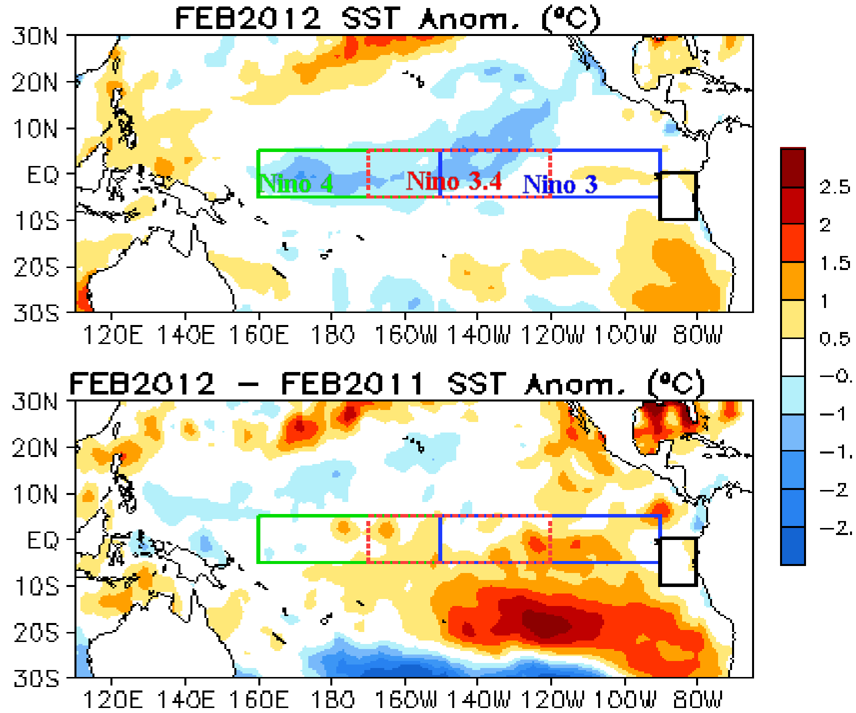

- Both the warming in the west and cooling in the east were weakened , consisting with the decay of La Nina.
- Compared with TAO, GODAS is too warm at 100-250 m depth.
- Some TAO data were missed near the east boundary.



# Evolution of Pacific NINO SST Indices

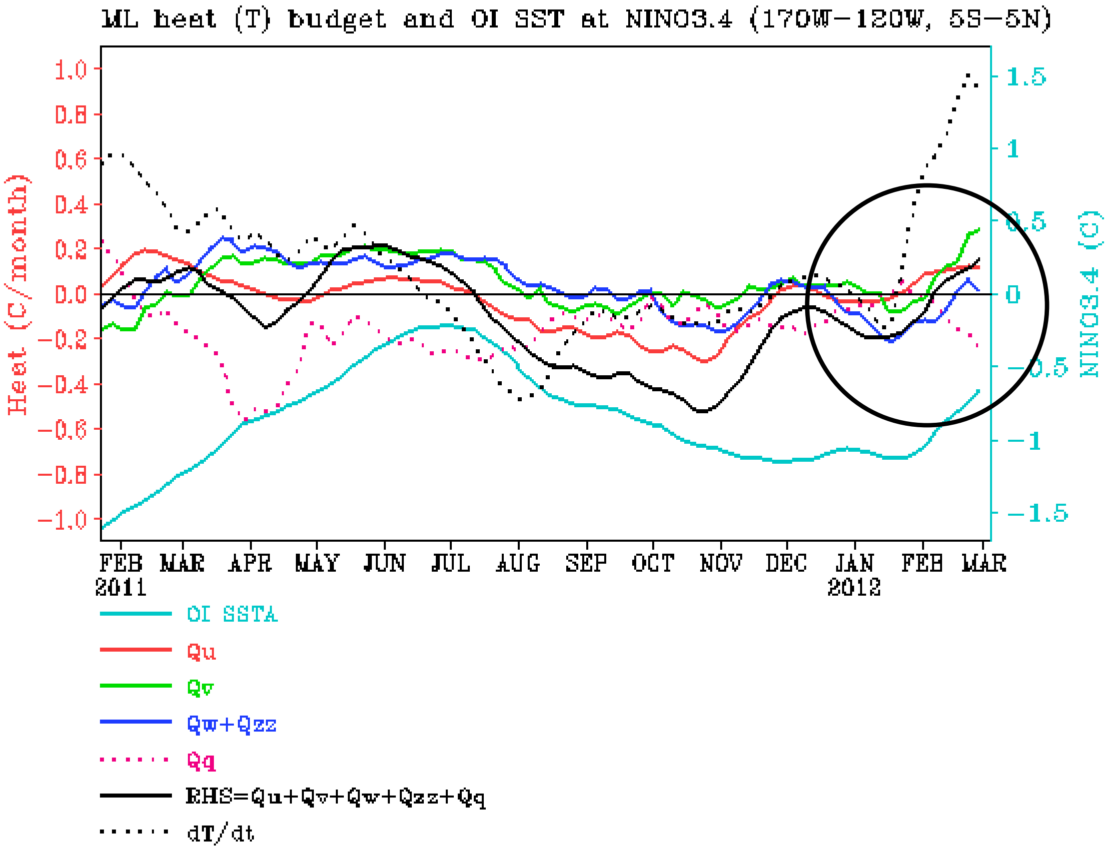



- All NINO indices, except Nino1+2, were still negative, but weakened.
- Nino3.4 = -0.7ºC in Feb2012.
- Compared with last Feb, SST was much warmer in the tropical-subtropical S. Pacific in Feb 2012.
- The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.

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

# NINO3.4 Heat Budget




- SSTA tendency (dT/dt) in NINO3.4 (dotted line) was positive in Jan-Feb 2012, indicating weakening of La Nina conditions.

- Both Qu, Qv and Qw+Qzz were positive in Feb 2012.

- The total heat budget term (RHS) had large cold biases compared with the tendency (dT/dt) in Jan-Feb 2012.

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.

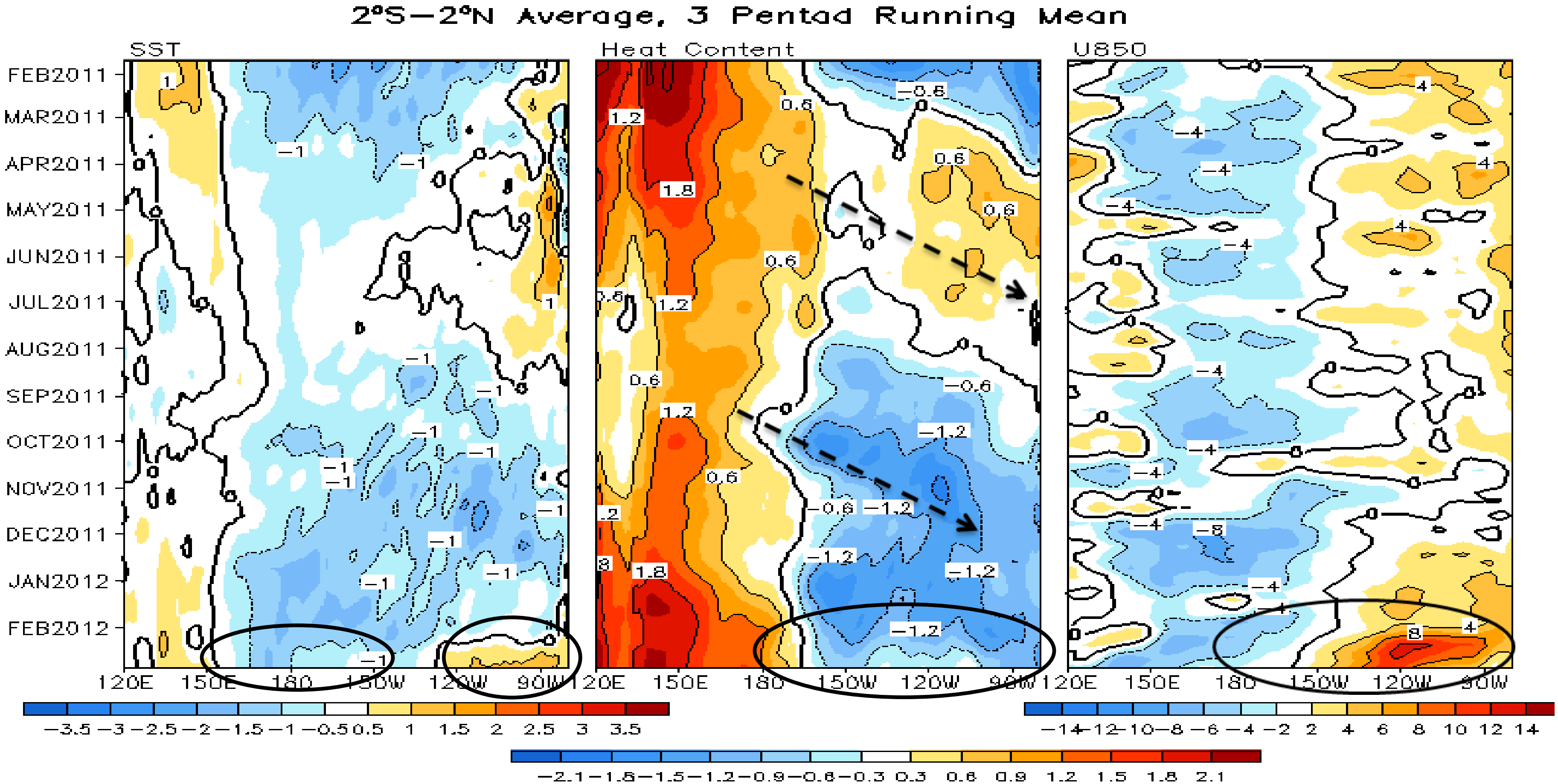
**Qu: Zonal advection; Qv: Meridional advection;**

**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**

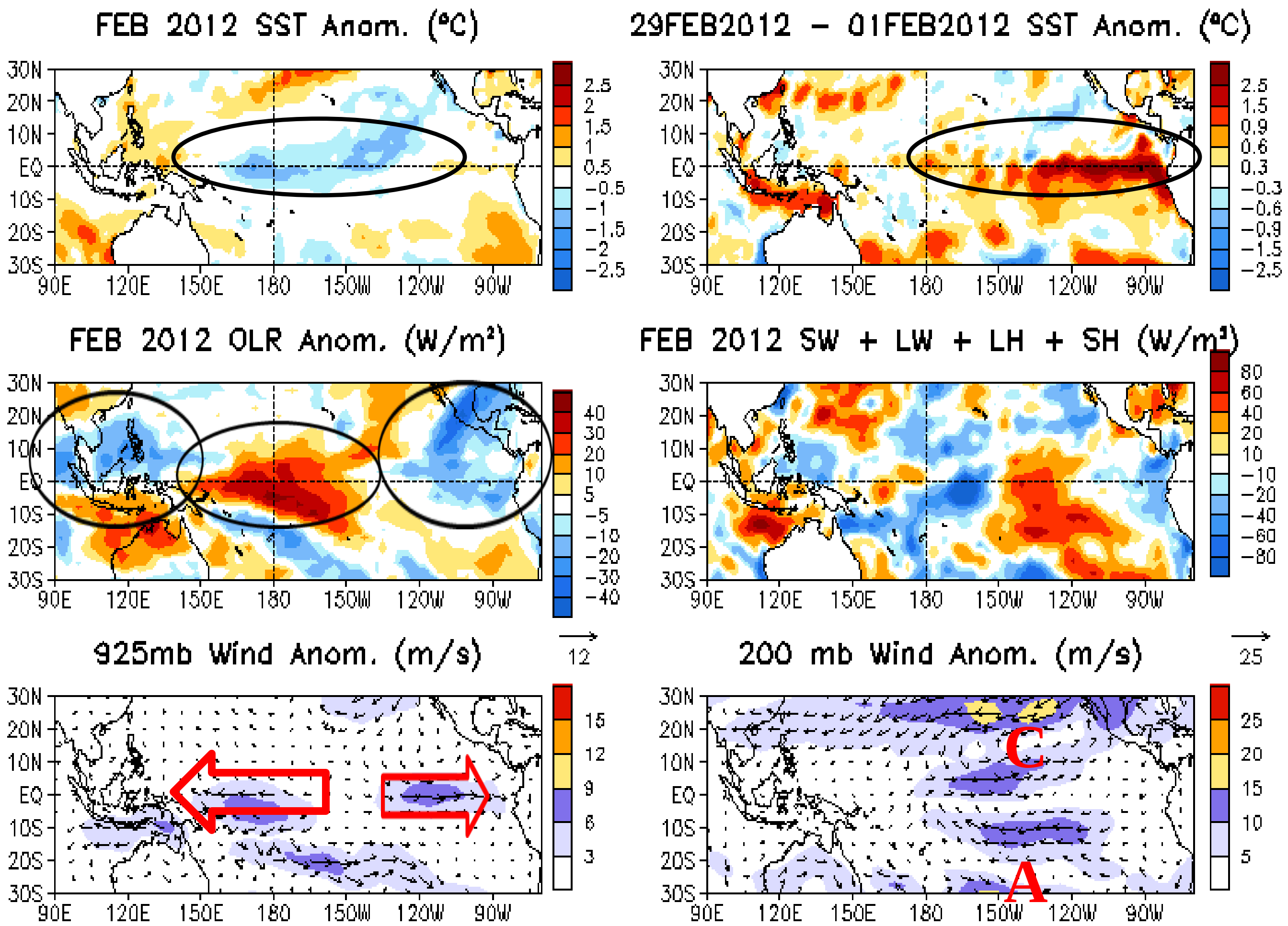
# Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies




- Negative SSTA weakened in the central (eastern) equatorial Pacific since Feb 2012 (Dec 2011), and some positive SSTA developed in the east in Feb 2012.
- HC300 anomalies are consistent with SSTA.
- Westerly wind anomalies enhanced in the E. Pacific in Feb 2012.

Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2°S-2°N and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST is derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1981-2010 base period pentad means respectively.

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

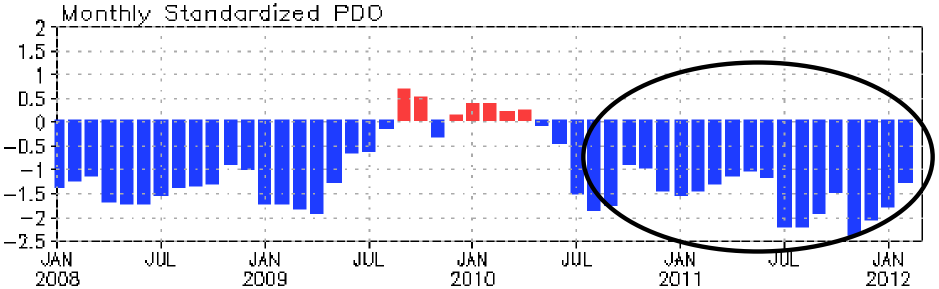


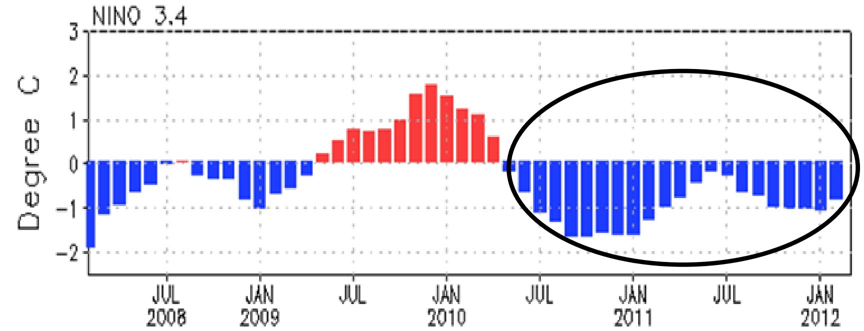

- Negative SSTA presented in the central tropical Pacific in Feb 2012.
- Convection was suppressed (enhanced) near the Dateline (over NW Pacific).
- Divergence observed in the central and eastern Pacific Ocean at low level in Feb 2012.
- Cyclonic (anti-cyclonic) anomalous circulation in 200 hPa in tropical N (S) tropical Pacific, not consistent with typical La Nina conditions.

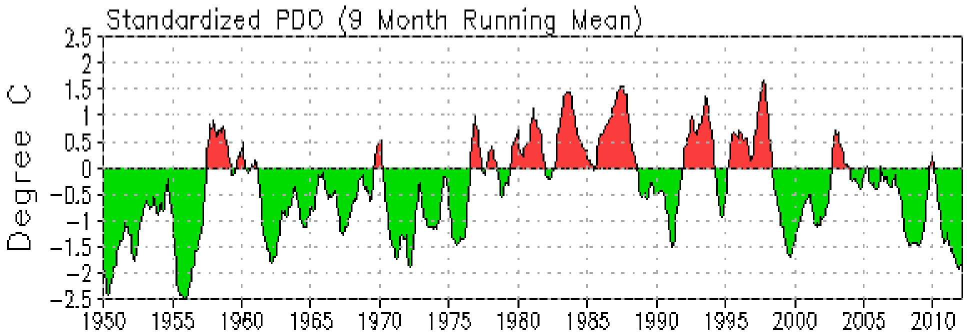
**Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

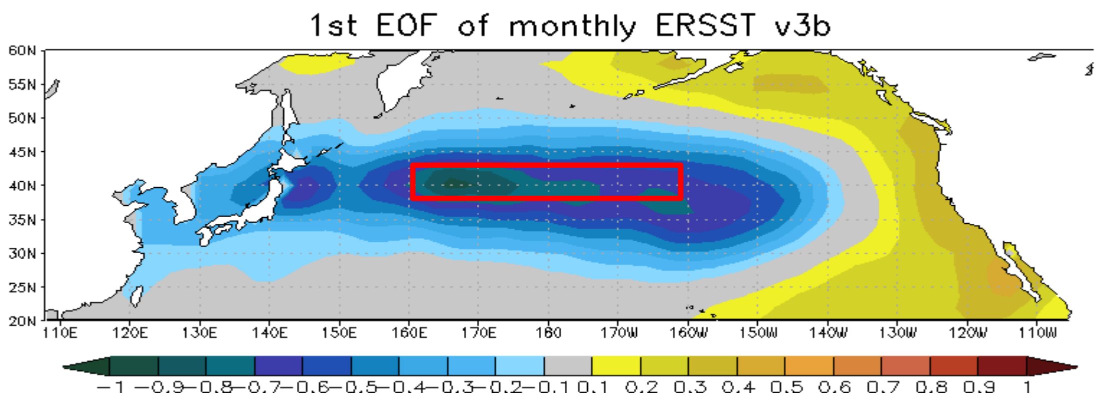


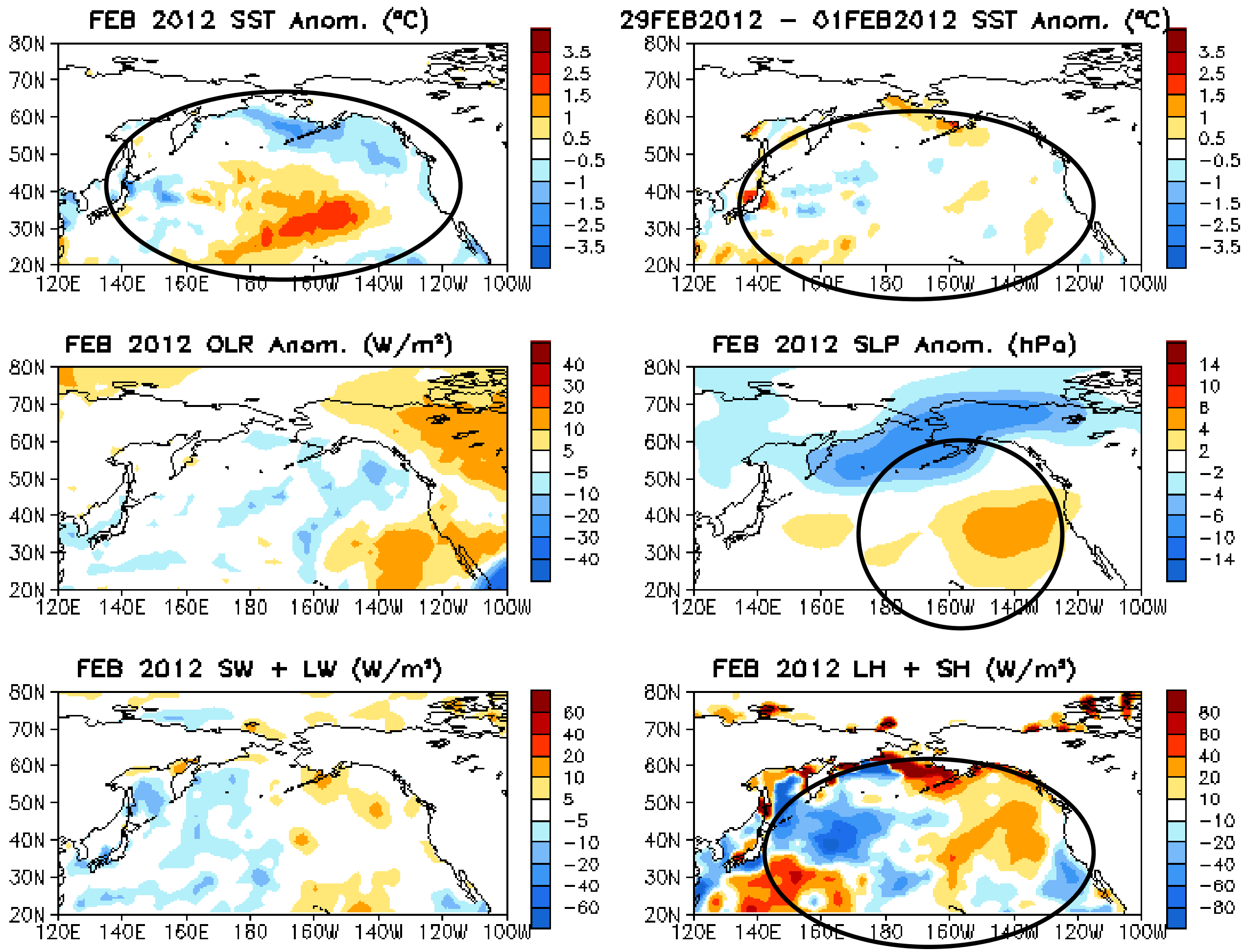

- **The negative PDO index weakened in Feb 2012 with PDO =-1.3.**

- **The apparent connection between NINO3.4 and PDO index may suggest impact of the La Nina on the North Pacific SST variability 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.**

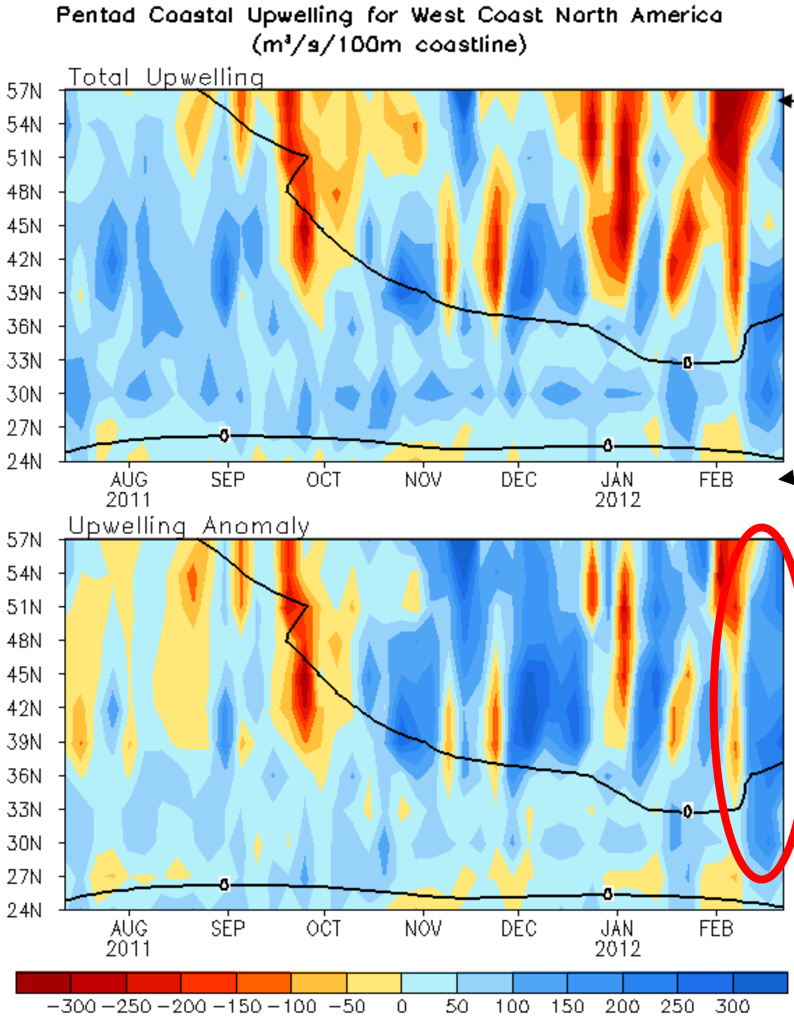
# North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

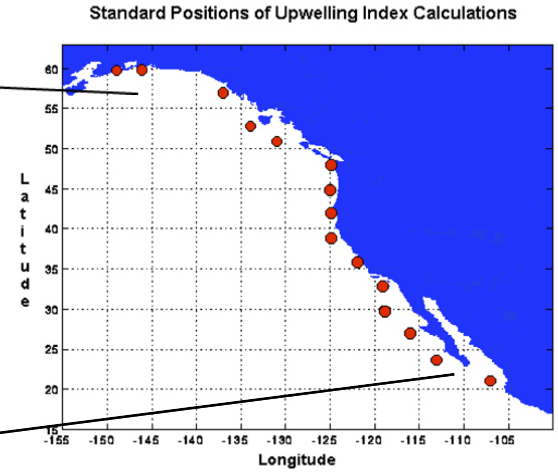



- Positive (negative) SSTA presented in the central (eastern& northern) North Pacific, consistent with the negative PDO index (previous slide).
- Net surface heat flux anomalies contributed to the SST tendency in the North Pacific.
- Above-normal sea level pressure and associated northerly wind anomalies along the coast were favourable for upwelling.

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



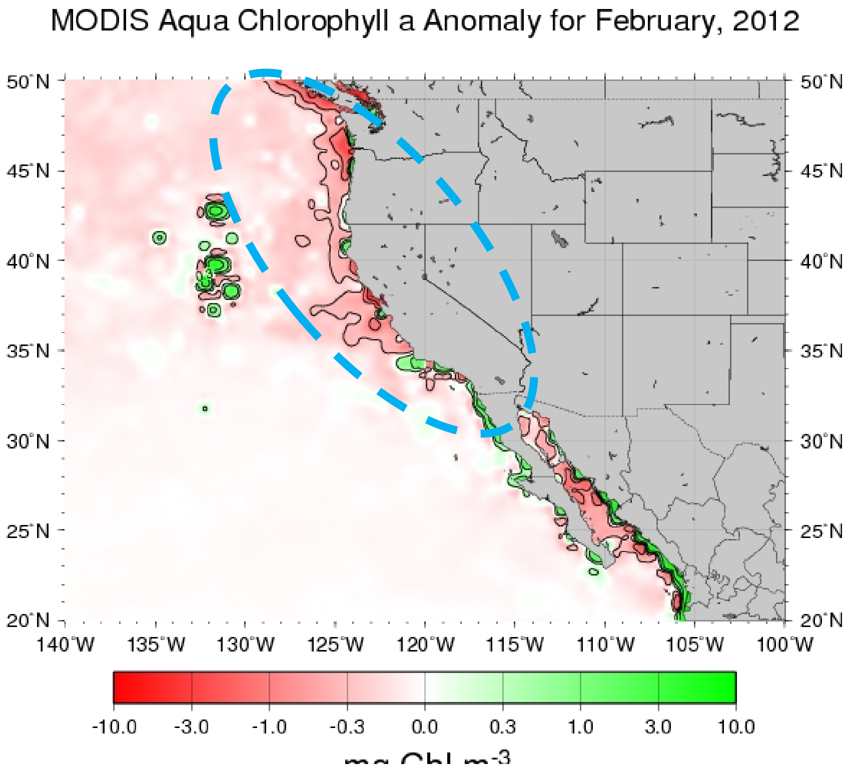




- **Seasonal downwelling between 36N-57N weakened and upwelling enhanced between 24N-36N.**
- **This is due to strong northerly wind anomalies along the coast.**

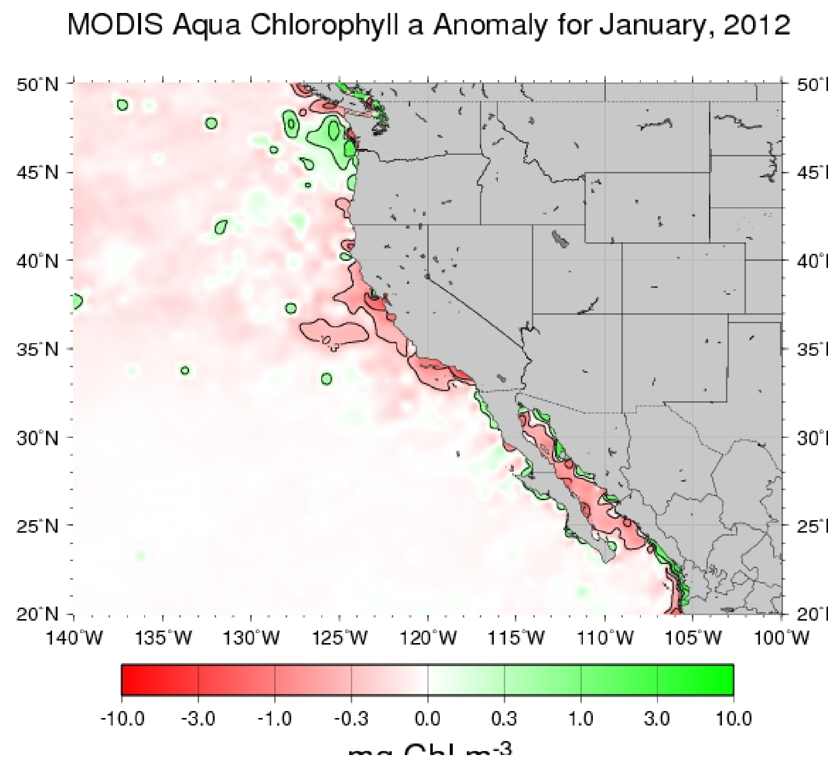
**Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

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

# Monthly Chlorophyll Anomaly




- Chlorophyll anomaly was negative 35N northward.
- It is not consistent with anomalous weakening of downwelling 35N northward along the coast.

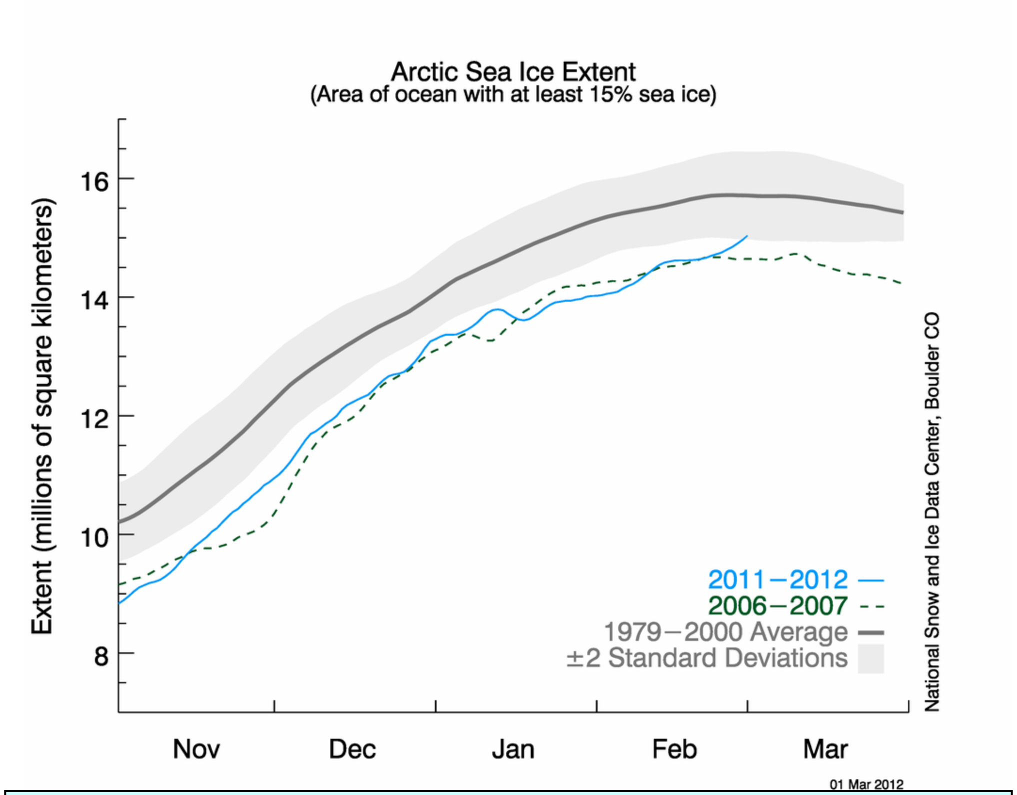


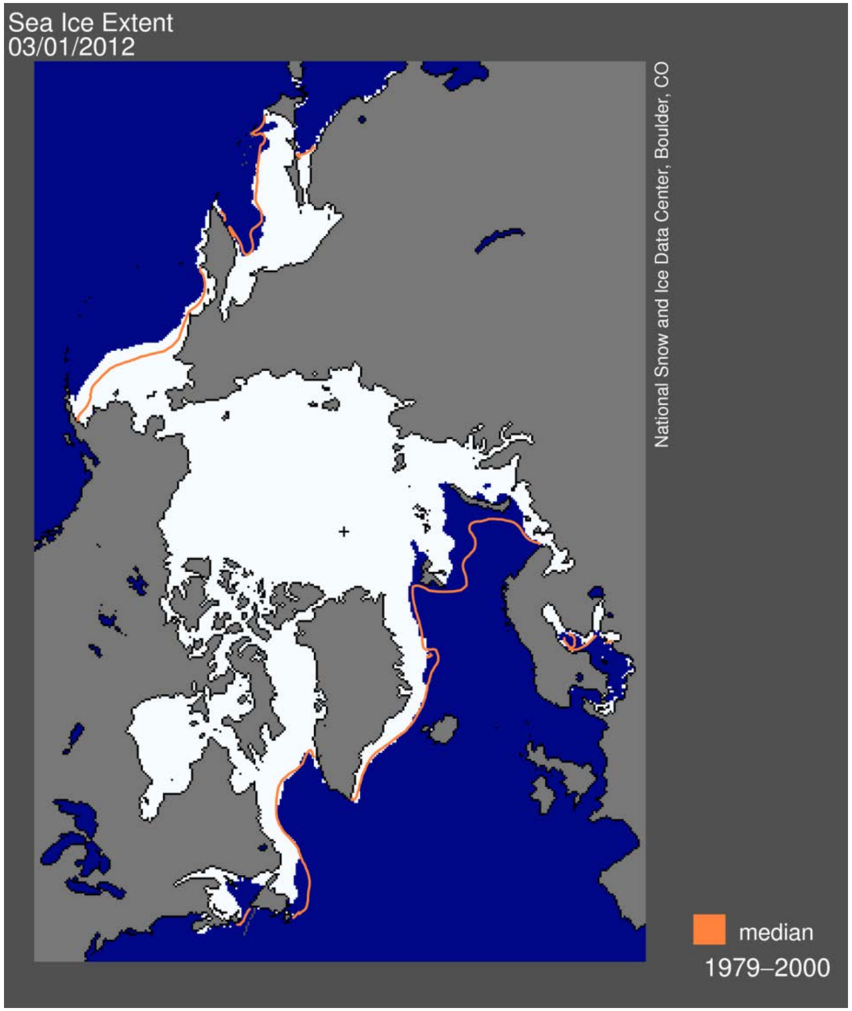

http://coastwatch.pfel.noaa.gov/FAST

# Arctic Sea Ice

National Snow and Ice Data Center

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

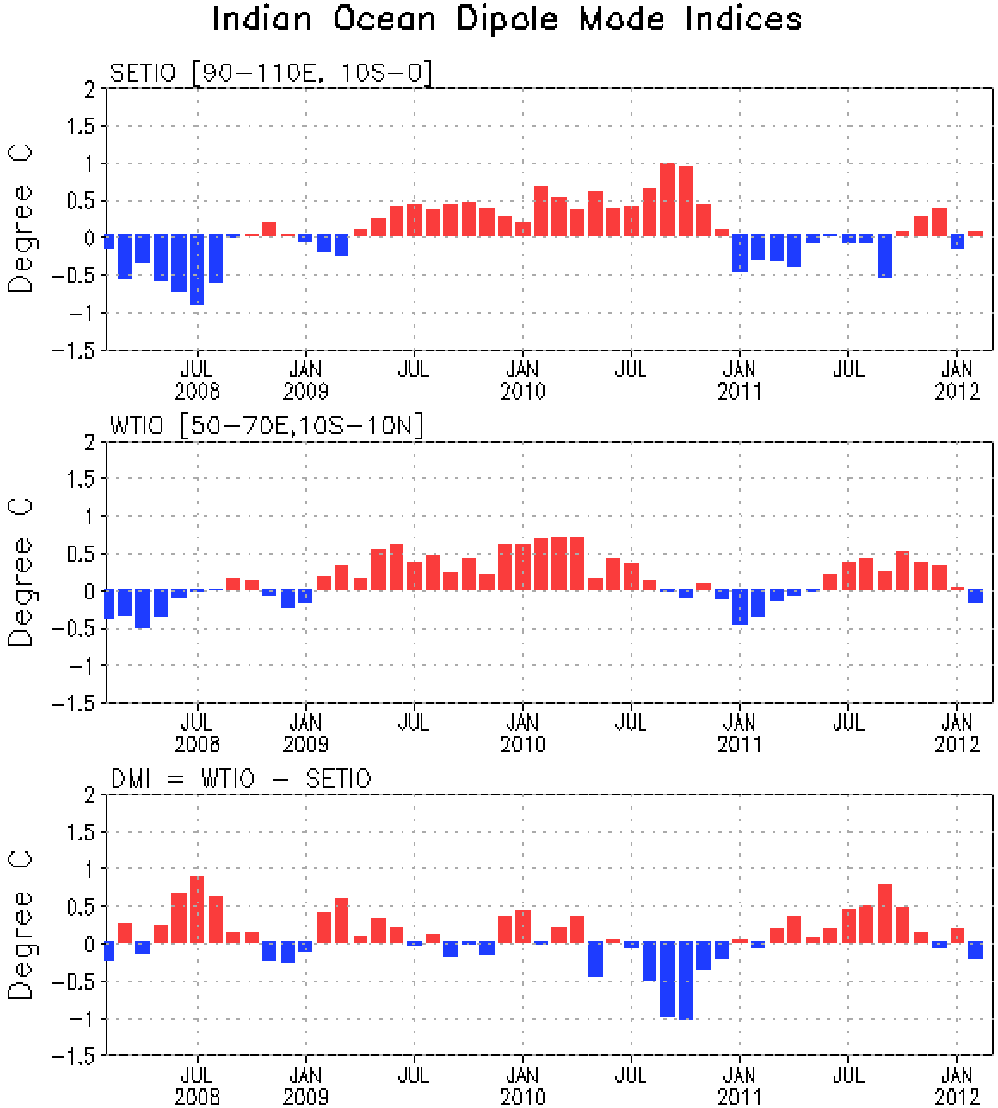


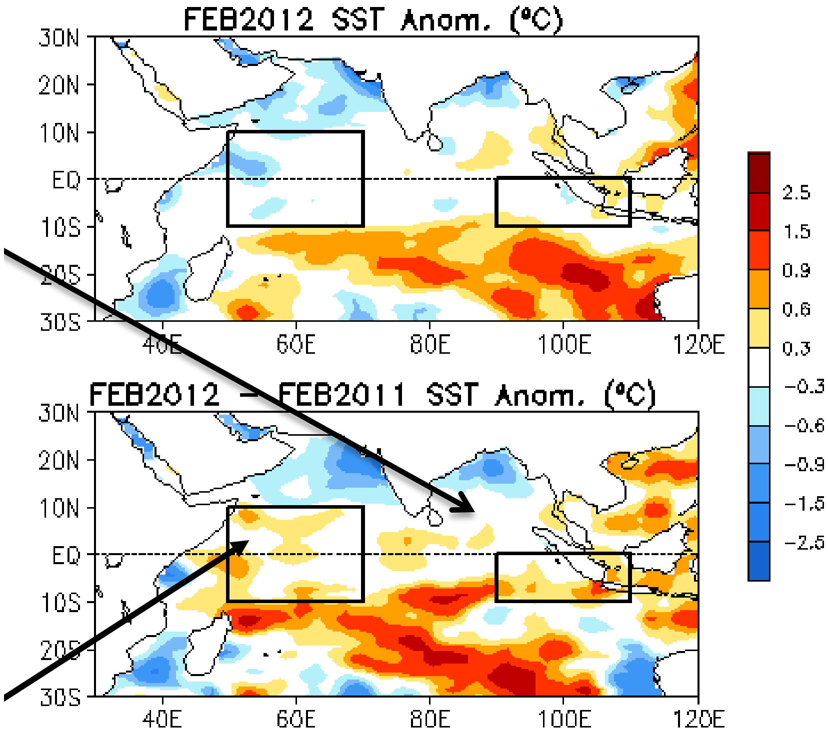




- Arctic sea ice extent in 2011-12 was comparable to the historical low in 2006-07.
- Since the late of Feb 2012, sea ice extent anomaly was slightly larger than the historical low and close to -2 standard deviations.

# Indian Ocean

# Evolution of Indian Ocean SST Indices

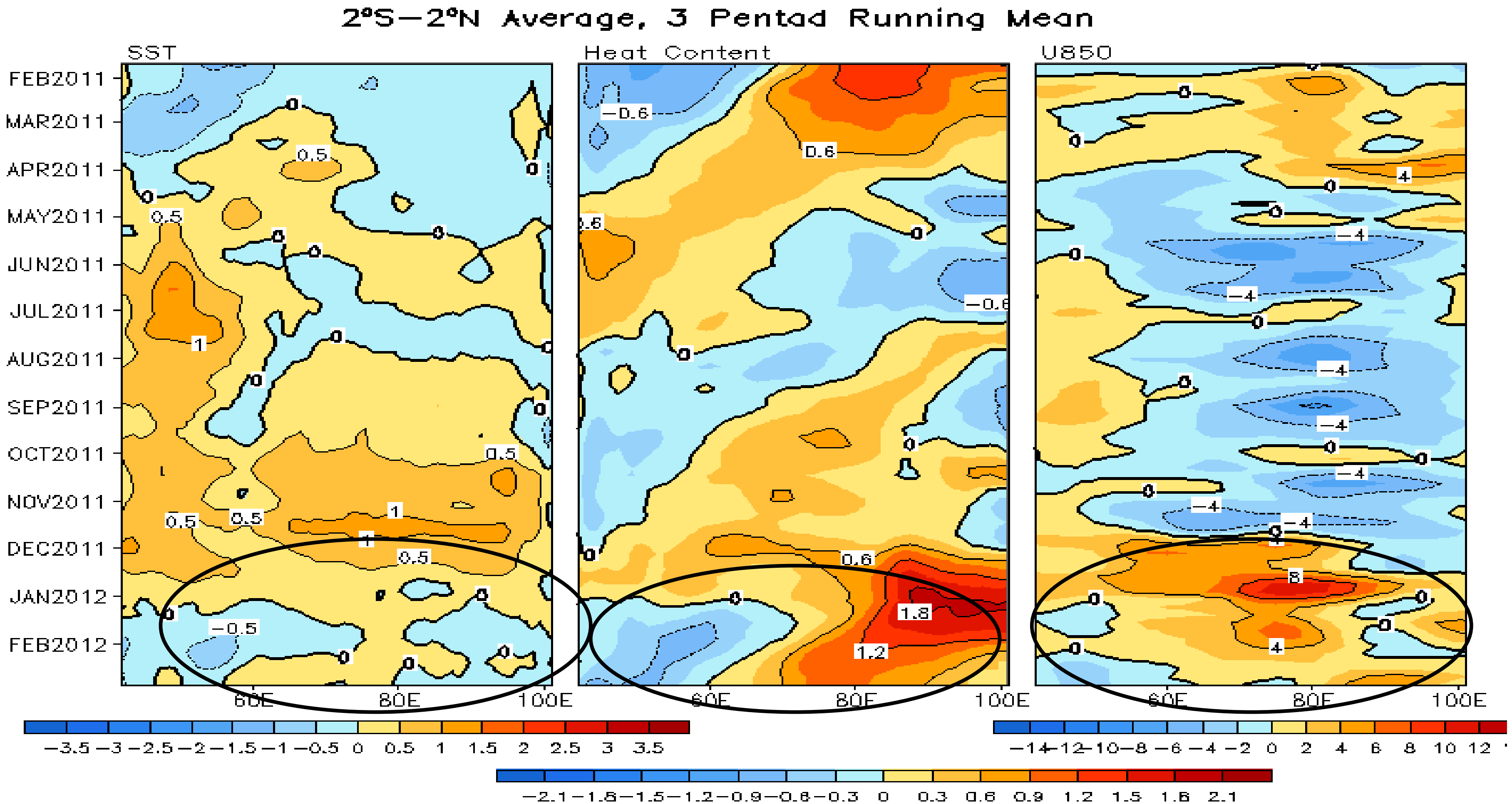



- **SSTA was small.**
- **DMI was close to neutral since Nov 2011.**

**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.**

# Recent Evolution of Equatorial Indian SST (°C), 0-300m Heat Content (°C), and 850-mb Zonal Wind (m/s) Anomalies




- **Positive SSTA has reduced in the tropical Indian Ocean since Dec 2011.**
- **HC300 and westerly wind anomalies have weakened since Jan 2012.**

**Fig. I3. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2°S-2°N and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST are derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, and U850 from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period pentad means.**

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

- SSTA and its tendency were small along the equator.
- Convections were enhanced over Philippines and the equatorial Indian Ocean due to low level convergence.

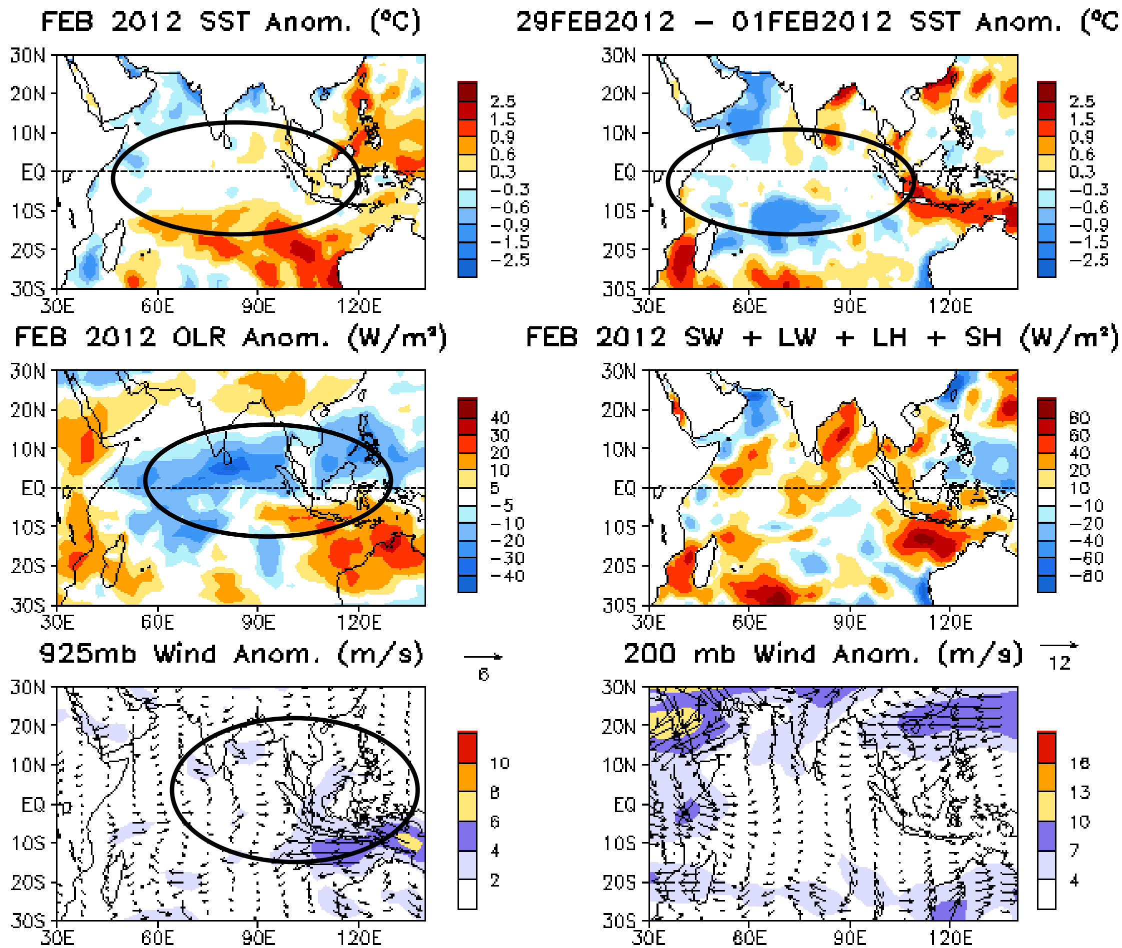
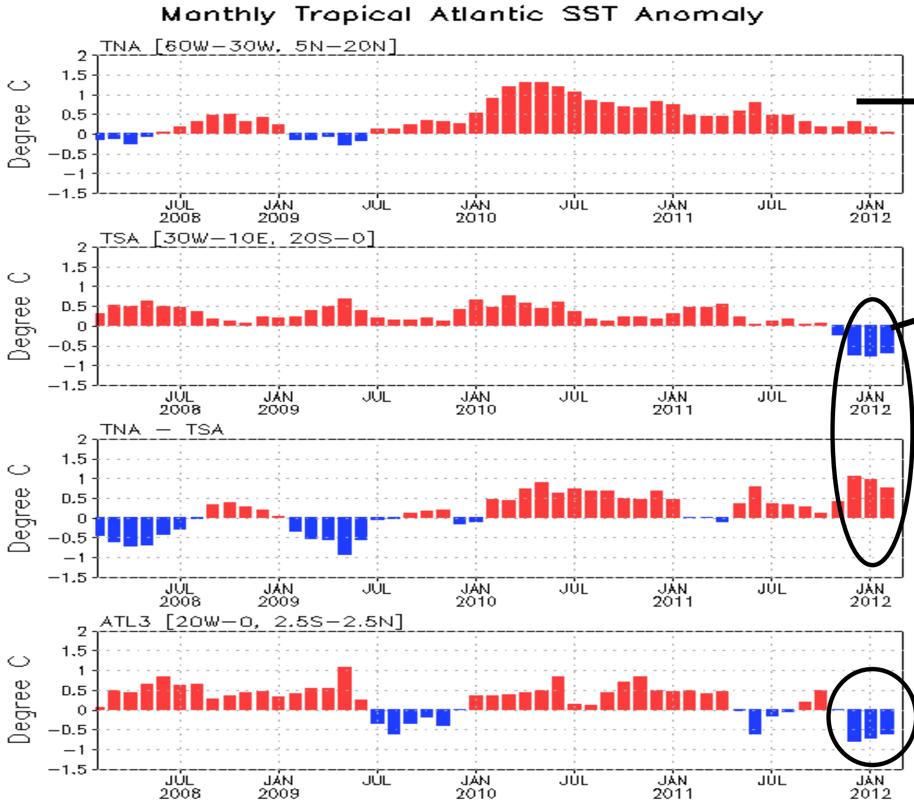
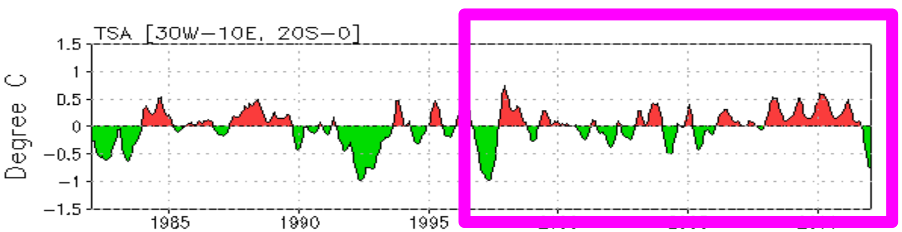


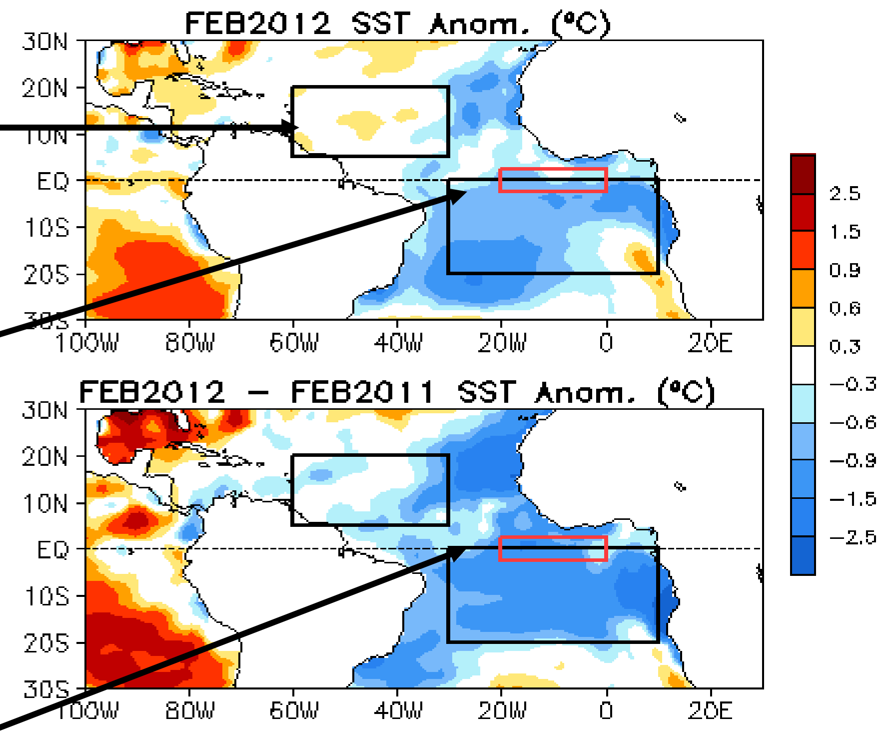

Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

# Tropical and North Atlantic Ocean

# Evolution of Tropical Atlantic SST Indices



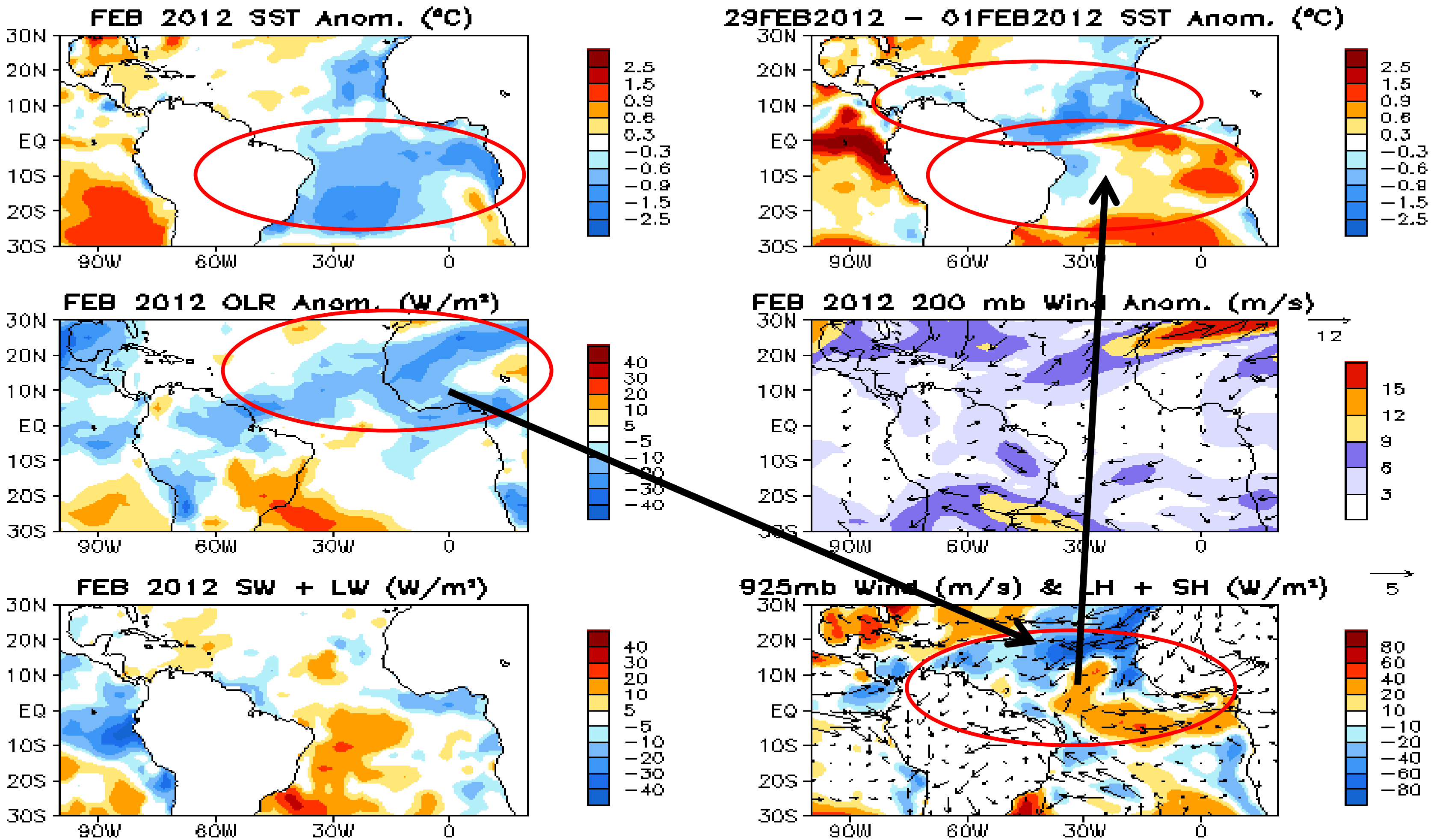




- Tropical North Atlantic (TNA) was small positive.
- Tropical South Atlantic (TSA) has cooled down substantially since Dec 2011, which was the coolest period since 1998.
- Meridional Gradient Mode (TNA-TSA) has increased substantially since Dec 2011.
- ATL3 SSTA has been negative since Dec 2011.
- Tropical Atlantic in Feb was much cooler in 2012 than in 2011.

**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:

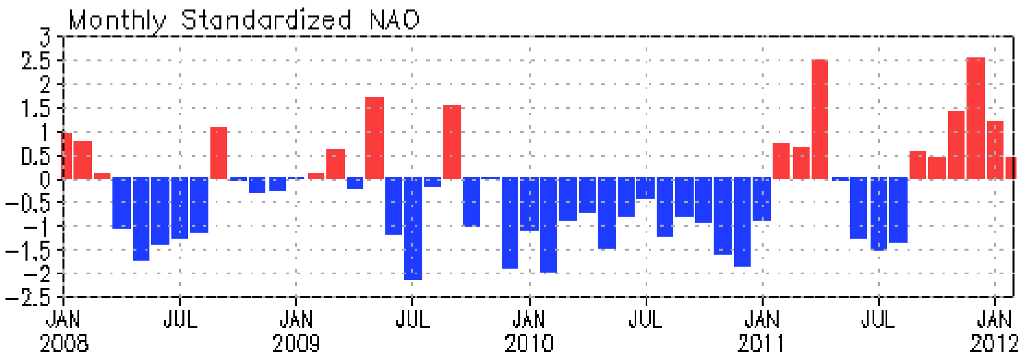


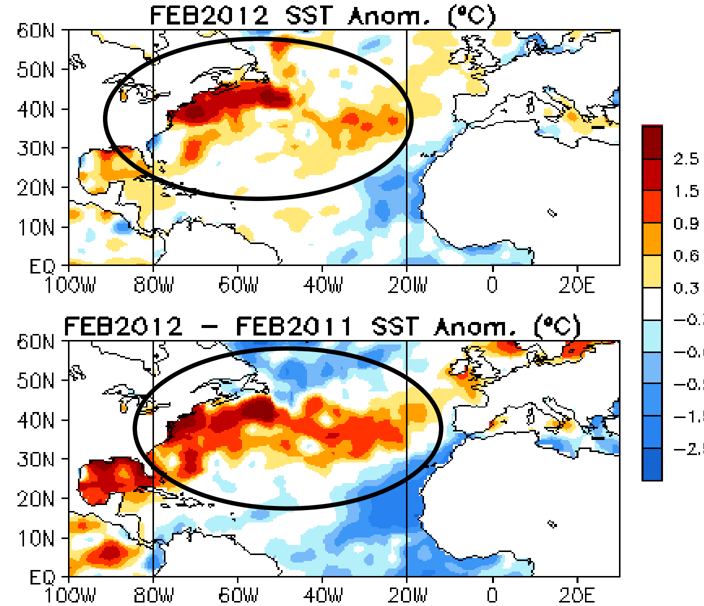

- The low-level wind over the tropical Atlantic (TNA), which may be driven by convections, did not consist with the cooling.

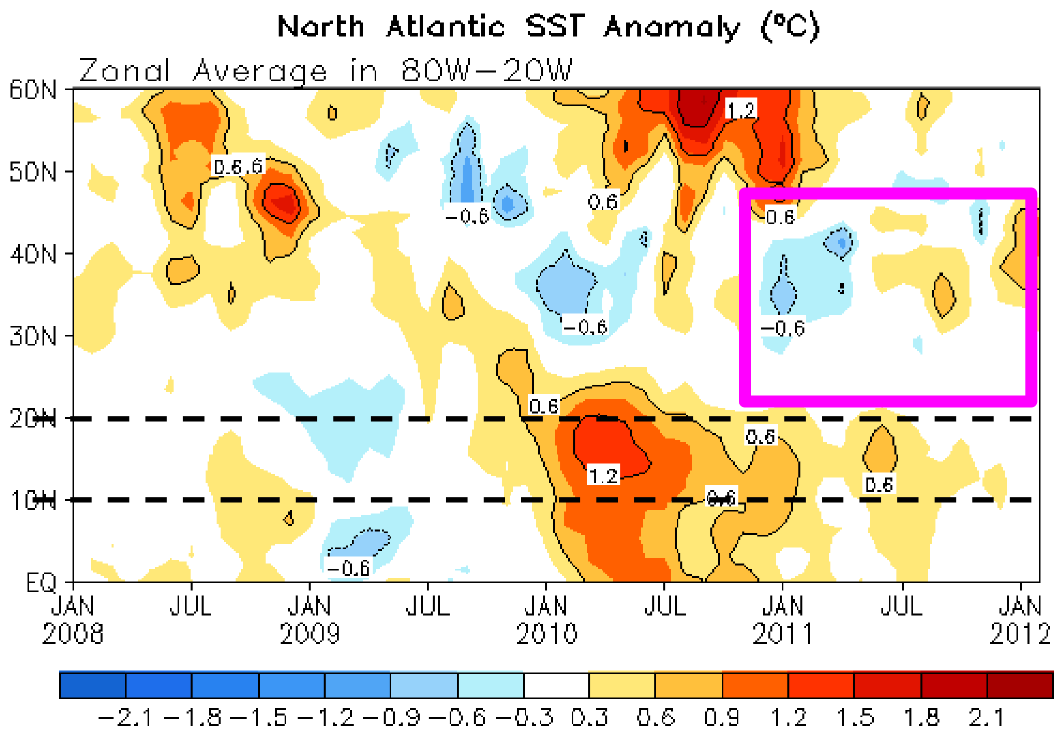
- Compared with Jan 2012, the tropical Atlantic was warmer in the south and cooler in the north in Feb 2012.

- Heat flux (LH+SH) anomalies may contribute to the SST tendency.

# NAO and SST Anomaly in North Atlantic



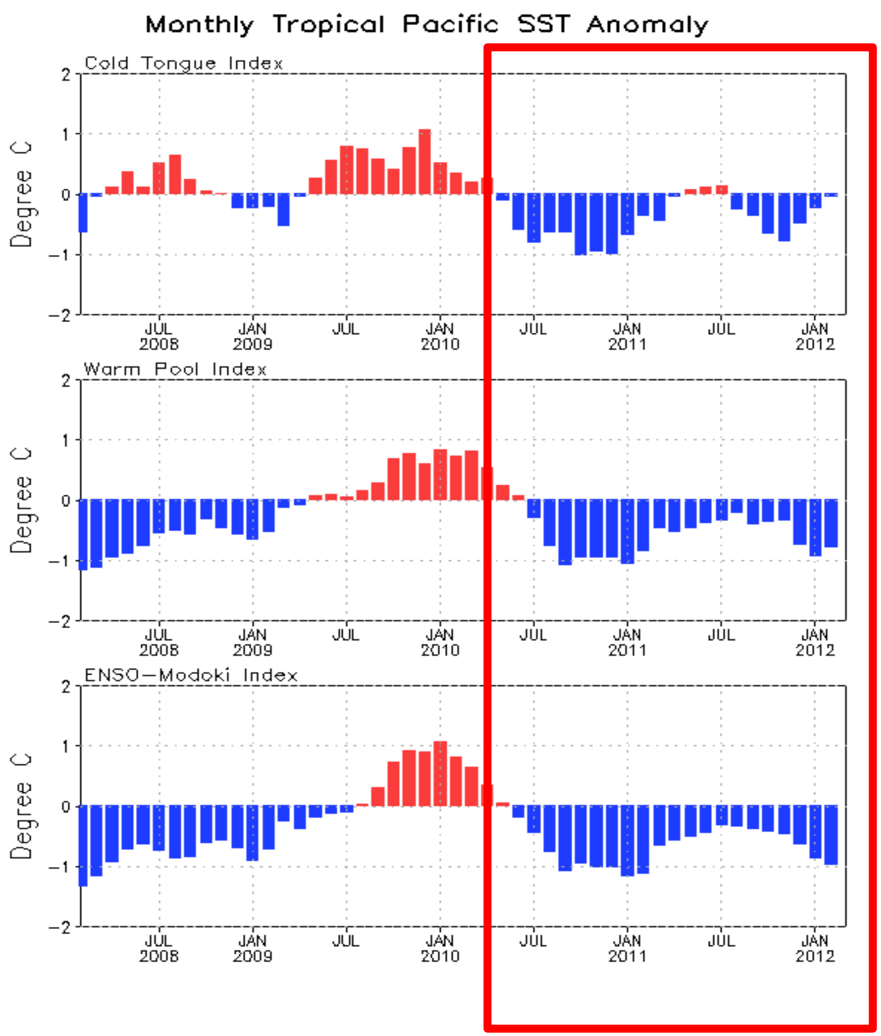

- **Positive NAO weakened significantly with NAOI=0.42 in Feb 2012.**
- **Mid-latitude North Atlantic SSTA are closely related to NAO – negative (positive) NAO leads to SST cooling (warming).**
- **Positive NAO during Sep 2011-Jan20112 may be a reason causing the transition from cool to warm SSTA in mid-latitudes.**
- **Mid-latitude North Atlantic SST was above-normal, warmer than that in last Feb.**

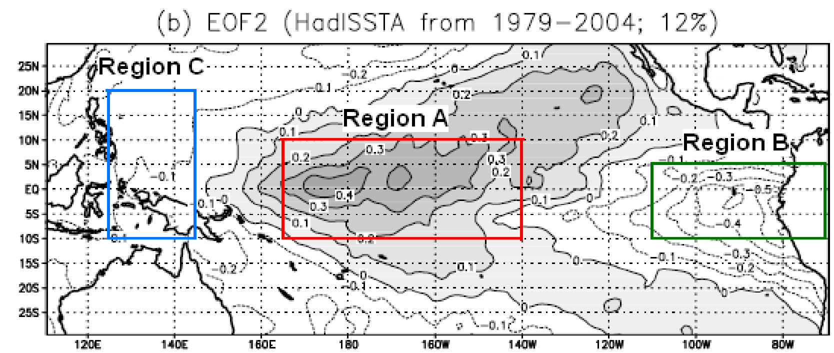
**Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis,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

# Potential New Indices to Monitor Pacific and Atlantic Oceans

# Evolution of Cold Tongue, Warm Pool, and ENSO-Modoki SST Indices

*Modoki Index = A-0.5*(B+C)*
*A (165E-140W, 10S-10N), B (110W-70W, 15S-5N), and C (125E-145E, 10S-20N)*
*(Ashok et al. 2007: J. Geophys. Res.,* ***112****)*




- Since Nov 2011, SSTA have large projection onto Warm Pool and ENSO-Modoki indices than on Cold Tongue index. It was similar for Jan-Feb 2011.

- Cold Tongue index has shorter time scales compared with Warm Pool and ENSO-Modoki indices, consisting with recent work of Kumar and Hu (2012).

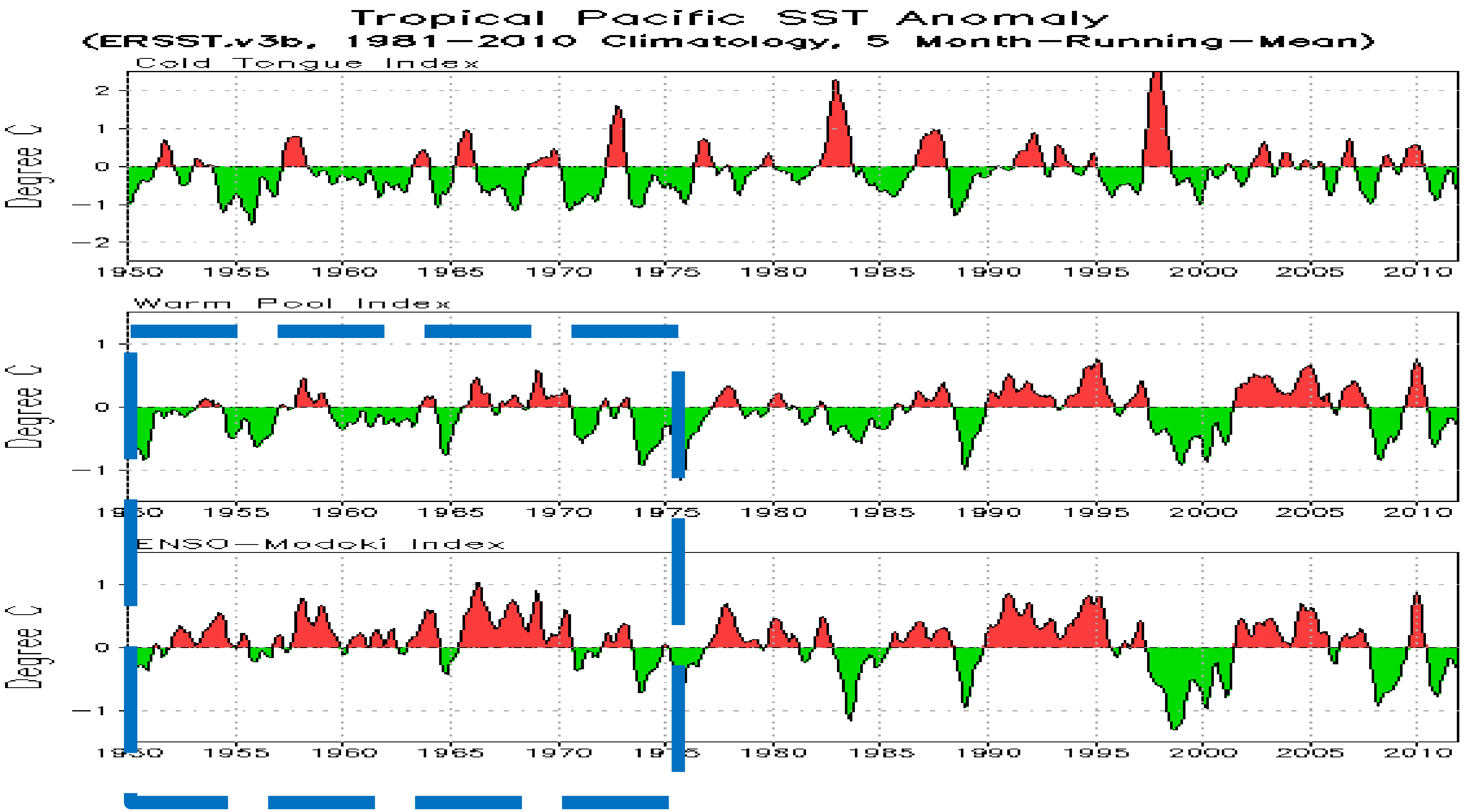
- The evolution of Warm Pool and ENSO-Modoki indices are similar.

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

Cold Tongue Index: Nino3-alpha*Nino4; Warm Pool Index: Nino4-alpha*Nino3; alpha=0.4 when Nino3*Nino4 >0.0 and alpha=0.0 when Nino3*Nino4 ≤ 0.0 (Ren and Jin, 2011: *Geophys. Res. Lett*., **38**)

***Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.***

# Relationship between these indices has decadal variation?



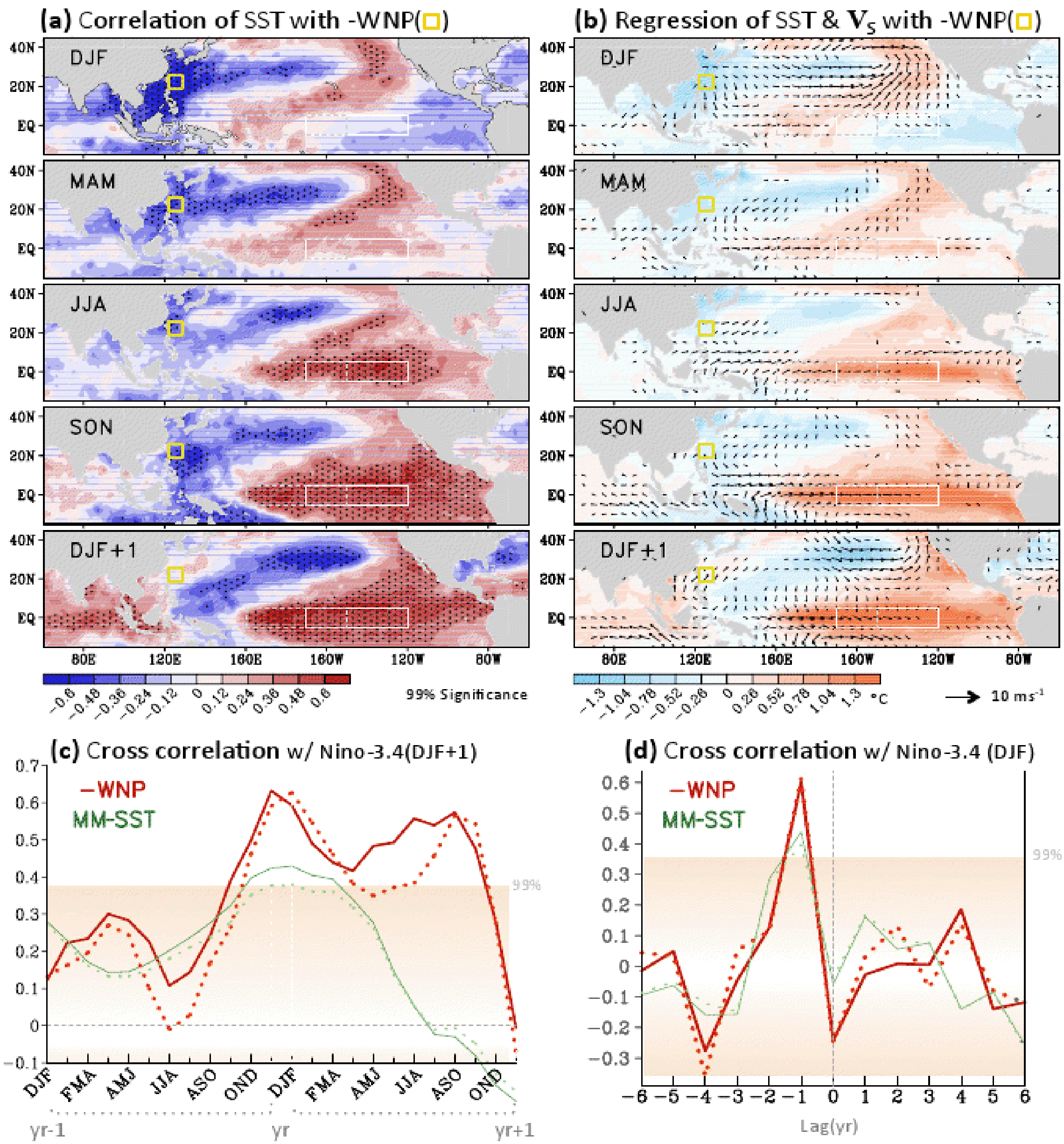

Cold Tongue Index: Nino3-alpha*Nino4; Warm Pool Index: Nino4-alpha*Nino3; alpha=0.4 when Nino3*Nino4 >0.0 and alpha=0.0 when Nino3*Nino4 ≤ 0.0 (Ren, and Jin, 2011: Geophys. Res. Lett., **38**)

Modoki Index = A-0.5*(B+C)

A (165E-140W, 10S-10N), B (110W-70W, 15S-5N), and C (125E-145E, 10S-20N)

(Ashok et al. 2007: J. Geophys. Res., **112**)

# Western North Pacific Variability and ENSO

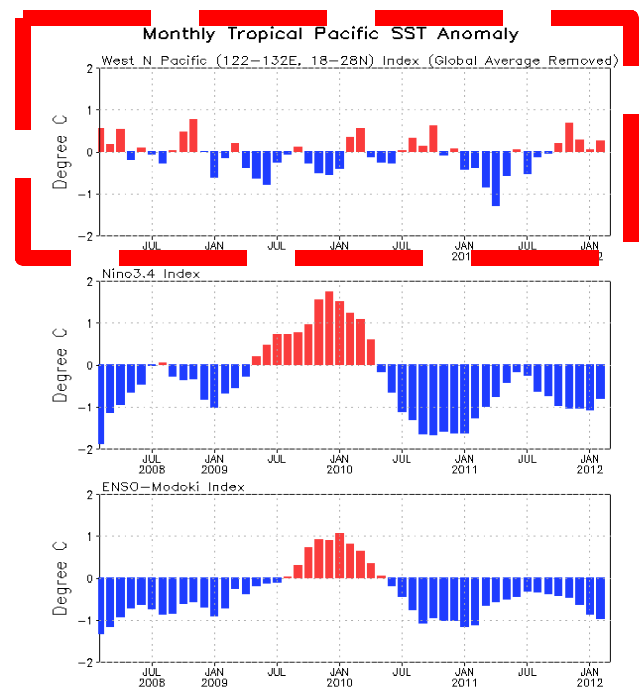



(a) DJF Cooling over the WNP is followed by a warming in the equatorial Pacific in next winter

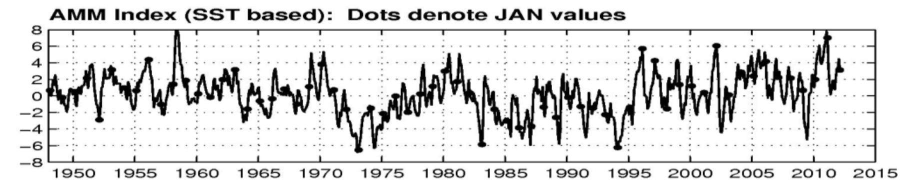
(b) The correlation between WNP and ENSO is higher than that between meridional mode and ENSO.

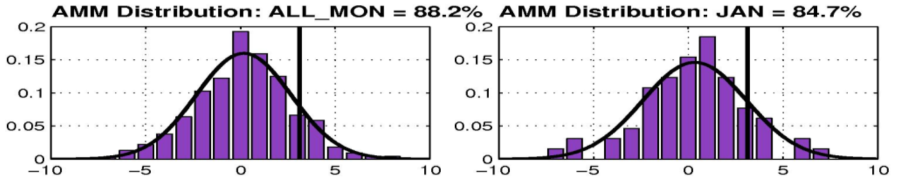
(c) The frequency of WNP variability is higher than ENSO.

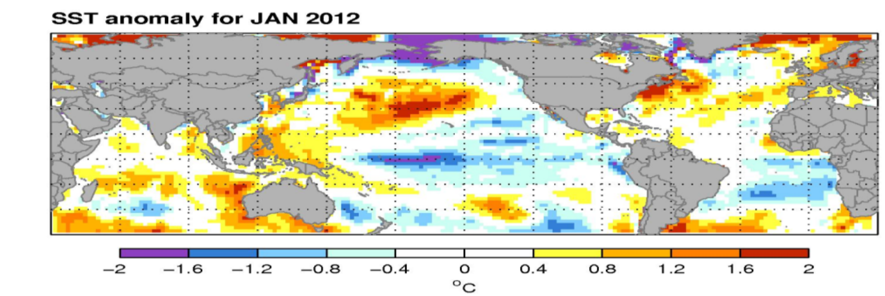
*From Wang, S.-Y., M. L'Heureux, and H.-H. Chia, 2012: ENSO Prediction One Year in Advance Using Western North Pacific Sea Surface Temperatures. GRL (in press)*

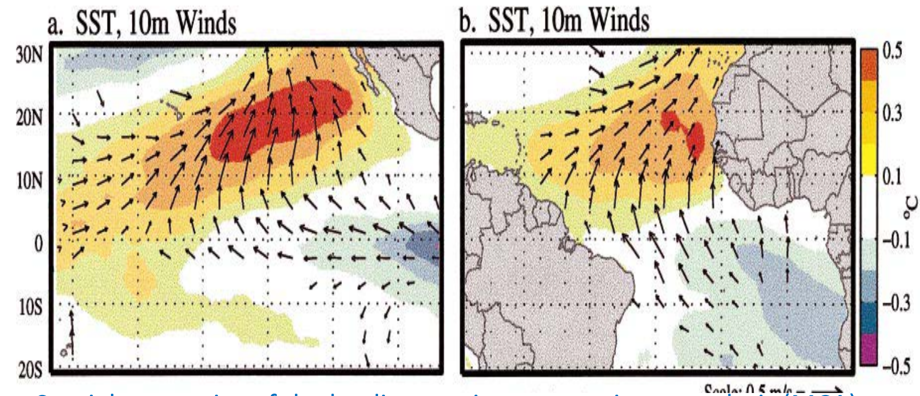


# Pacific and Atlantic Meridional Mode (MM) Indices



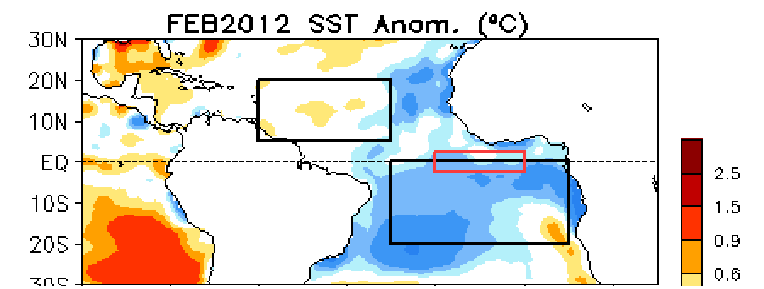



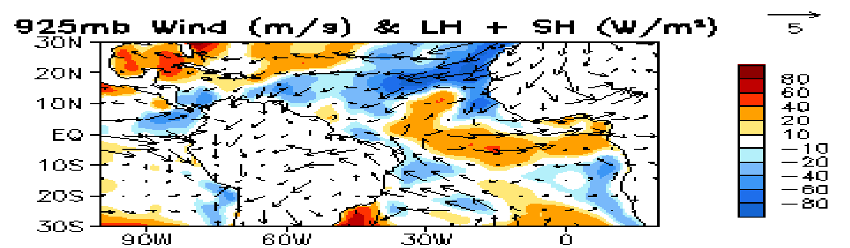

Spatial properties of the leading maximum covariance analysis (MCA) mode 1 in the (left) Pacific, (right) Atlantic. (a), (b) Regression maps of the MCA leading mode SST normalized expansion coefficients on SST and 10-m wind vectors. Wind vectors are plotted where the geometric sum of their correlation coefficients exceeds 0.27 (the 95% confidence level).

*Copy Fig. 1 of Chiang, J. C. H., and D. J. Vimont, 2004: Analagous meridional modes of atmosphere-ocean variability in the tropical Pacific and tropical Atlantic. J. Climate,17(21), 4143–4158.*

The Pacific and Atlantic MMs are characterized by an anomalous SST gradient across the mean latitude of the ITCZ coupled to an anomalous displacement of the ITCZ toward the warmer hemisphere. Both are forced by trade wind variations in their respective northern subtropical oceans. The Pacific meridional mode exists independently of ENSO, although ENSO nonlinearity projects strongly on it during the peak anomaly season of boreal spring. It is suggested that the Pacific and Atlantic modes are analogous, governed by physics intrinsic to the ITCZ/cold tongue complex. (Chiang and Vimont 2004)

## Feb 2012 SSTA is similar to AMM



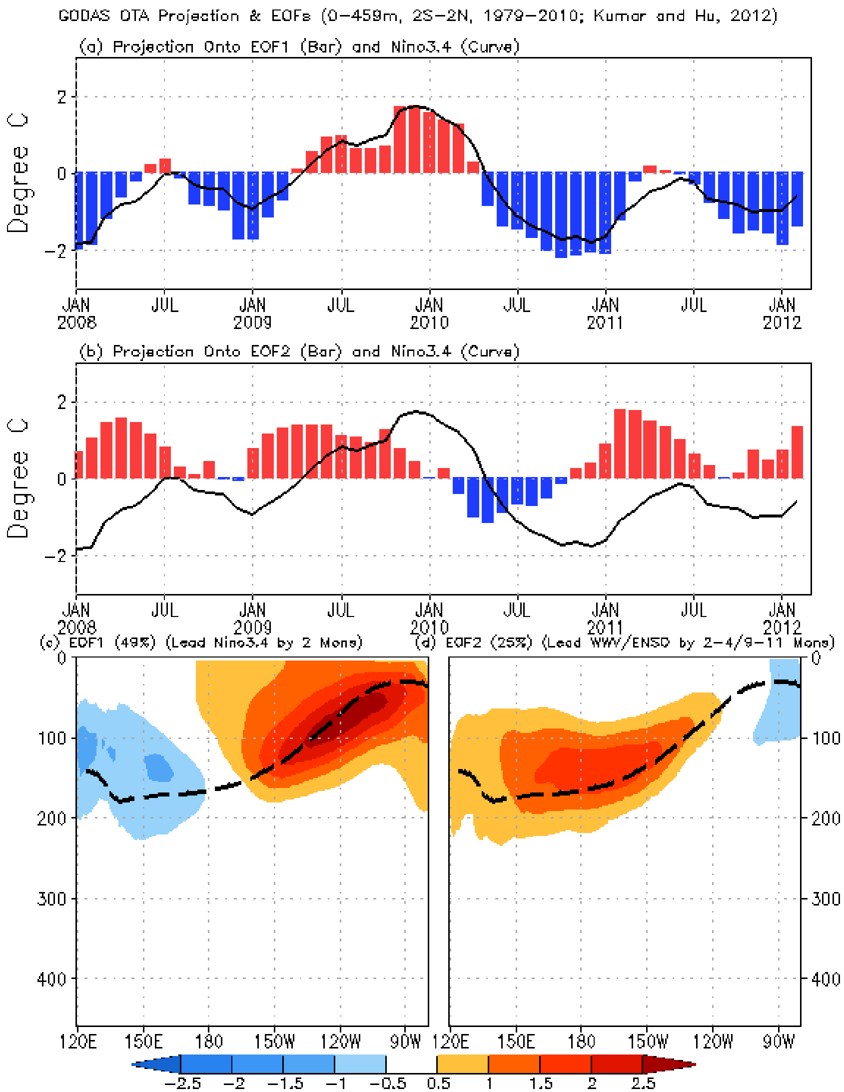

**Copy from "http://sunrise.aos.wisc.edu/~dvimont/MModes/Data/"**

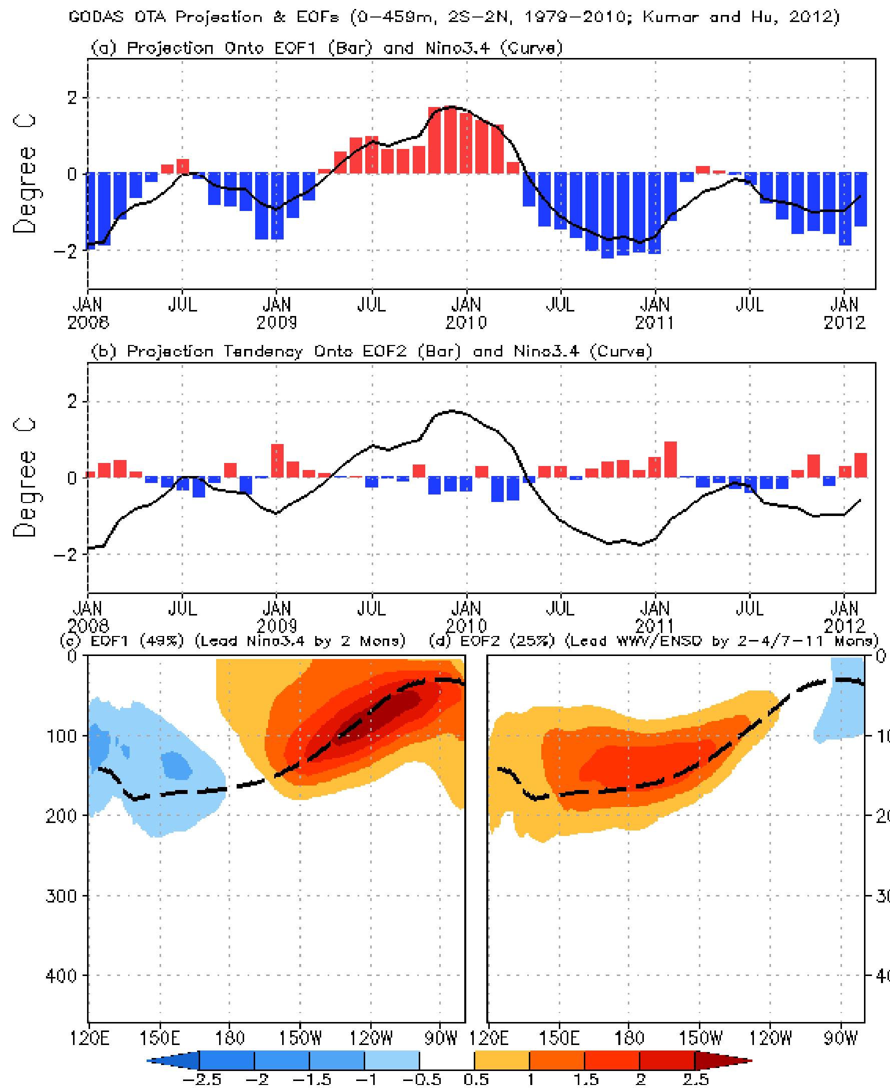
## Projection of OTA onto EOF1 and EOF2 (2S-2N, 0-459m, 1979-2010)

**EOF1: Kelvin wave–like signal**

**EOF2: Recharge and discharge oscillation; its tendency has out-of-phase relation with SSTA**

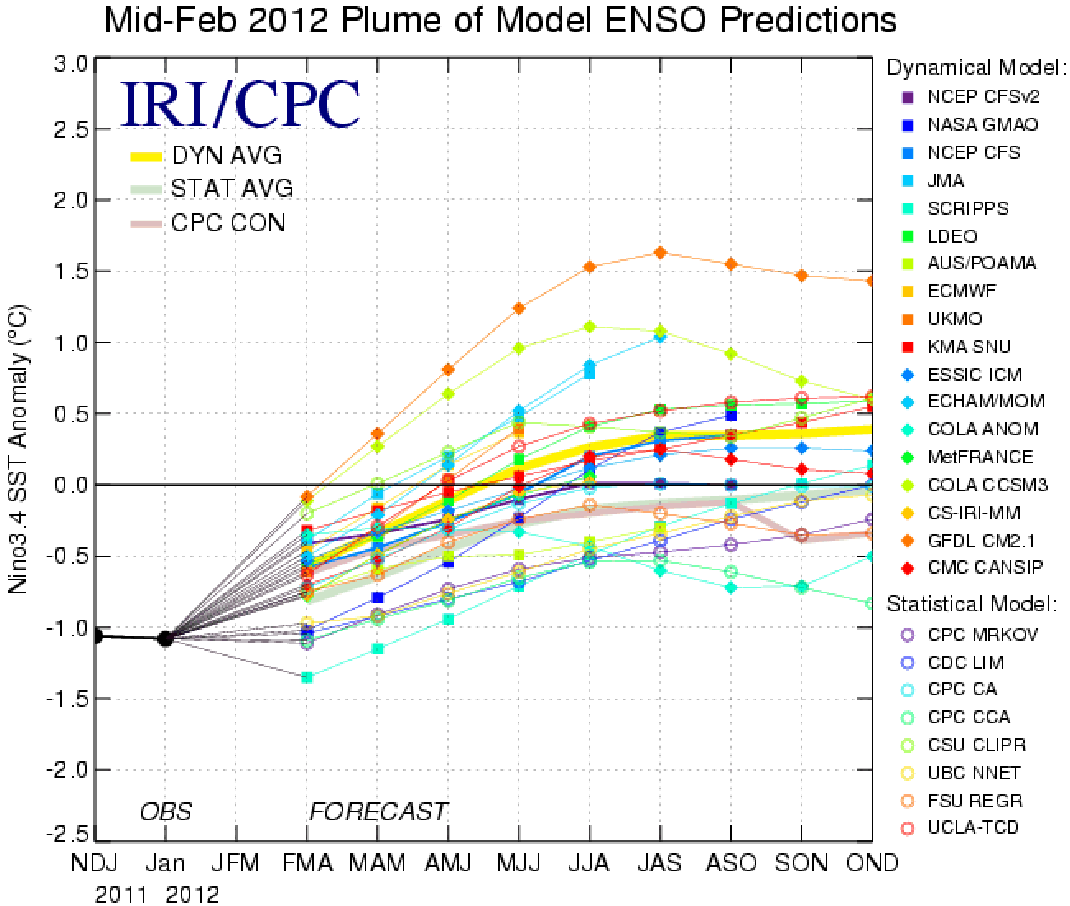
***Right now, it is in recharge phase***

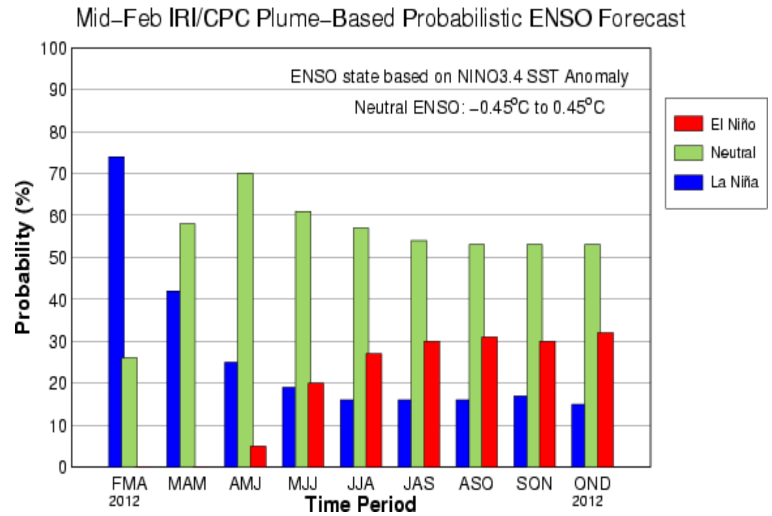


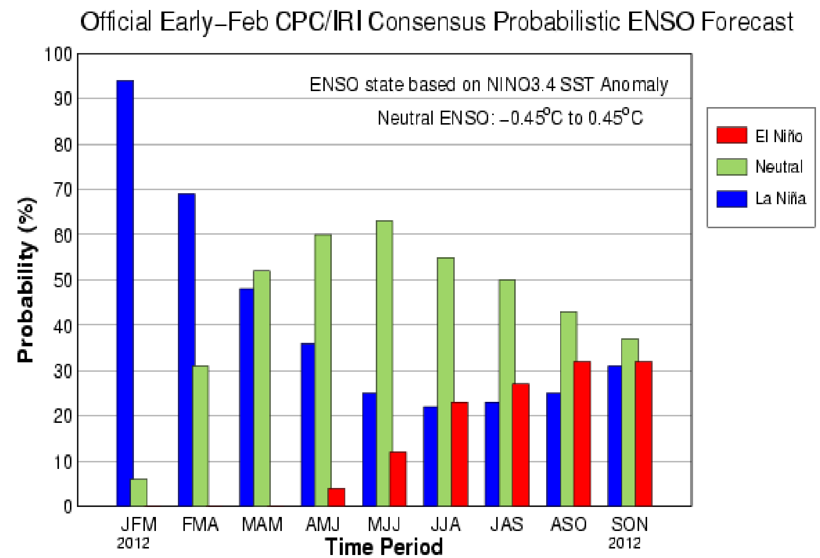



# Global SST Predictions

# IRI NINO3.4 Forecast Plum



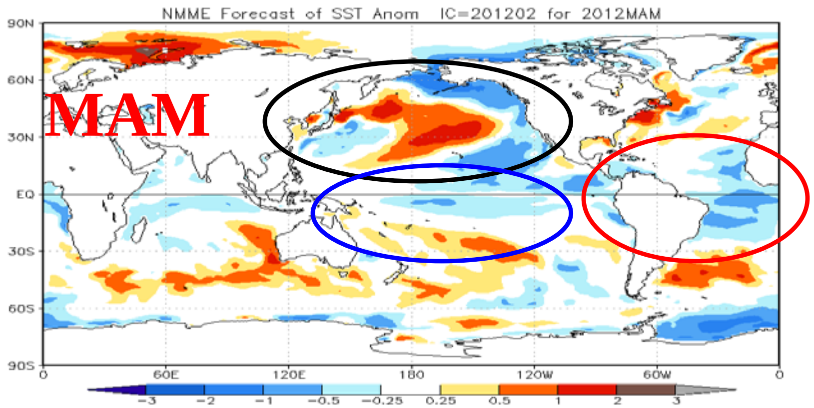

**- A majority of models predicted that ENSO returns to neutral phase in MAM 2012.**

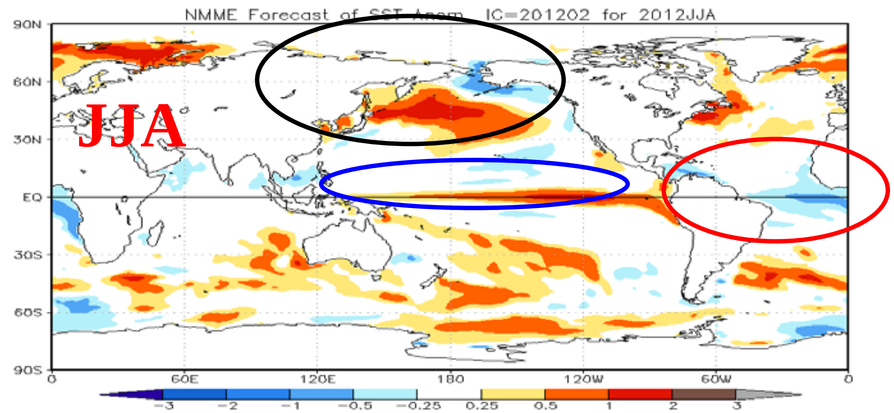
**-After spring 2012, model predictions have large divergence. The predictions cover all three phases of an ENSO cycle.**

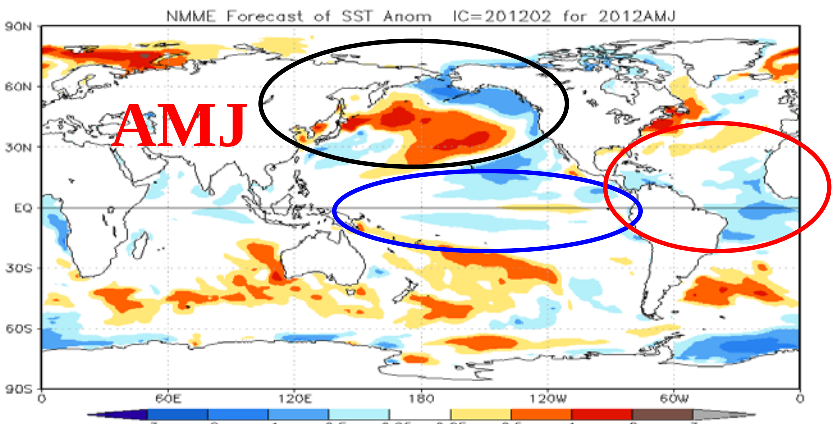
**- Human and no-human probabilistic forecasts favor a neutral phase in 2012.**

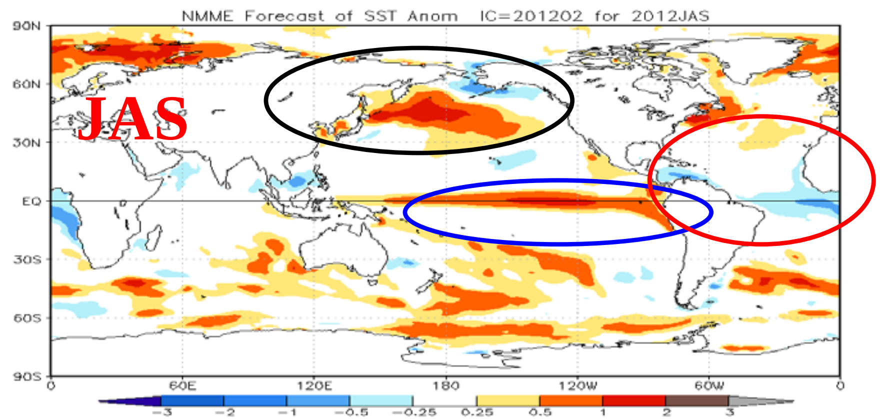
**- NOAA "ENSO Diagnostic Discussion" in March suggests La Niña is expected to return to ENSO-neutral conditions by the end of April 2012.**

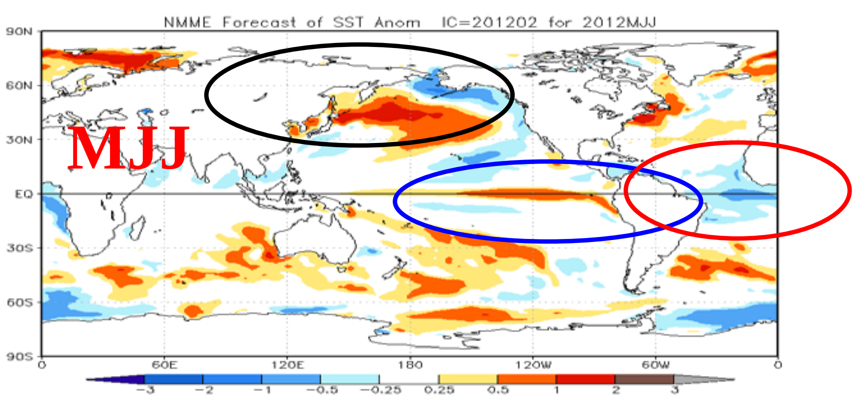
## NMME (CFSv1, CFSv2, ECHAMA, ECHAMF, GFDL, NCAR, NASA) SST Forecast (Feb2012 I.C.)



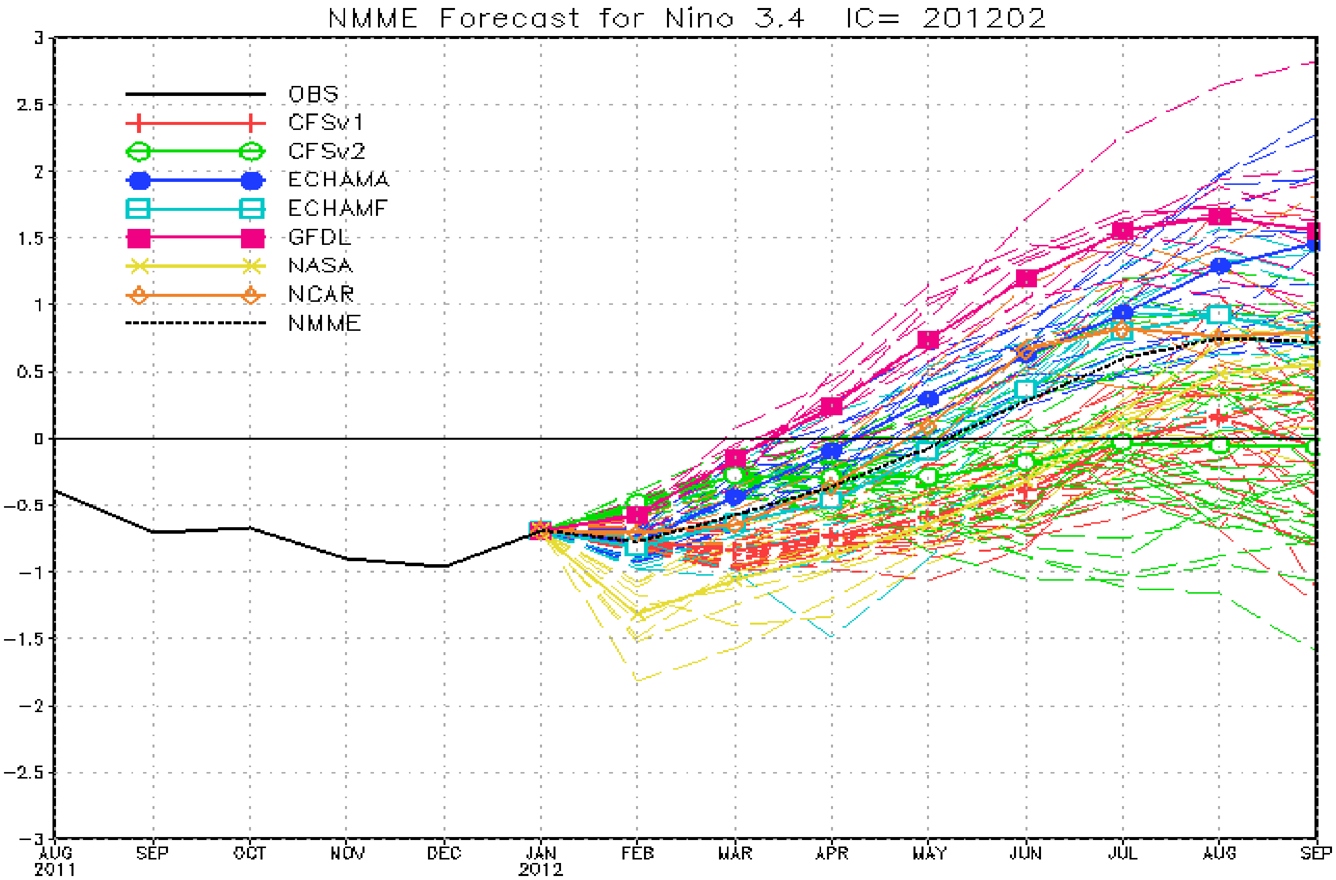




- A warming event is expected since summer 2012.
- The warming in N. Pacific (negative PDO) will be persistent until at least early autumn 2012.
- The cooling along the equatorial Atlantic will last at least until early autumn 2012.

http://www.cpc.ncep.noaa.gov/products/people/wd51yf/NMME
*experimental product*

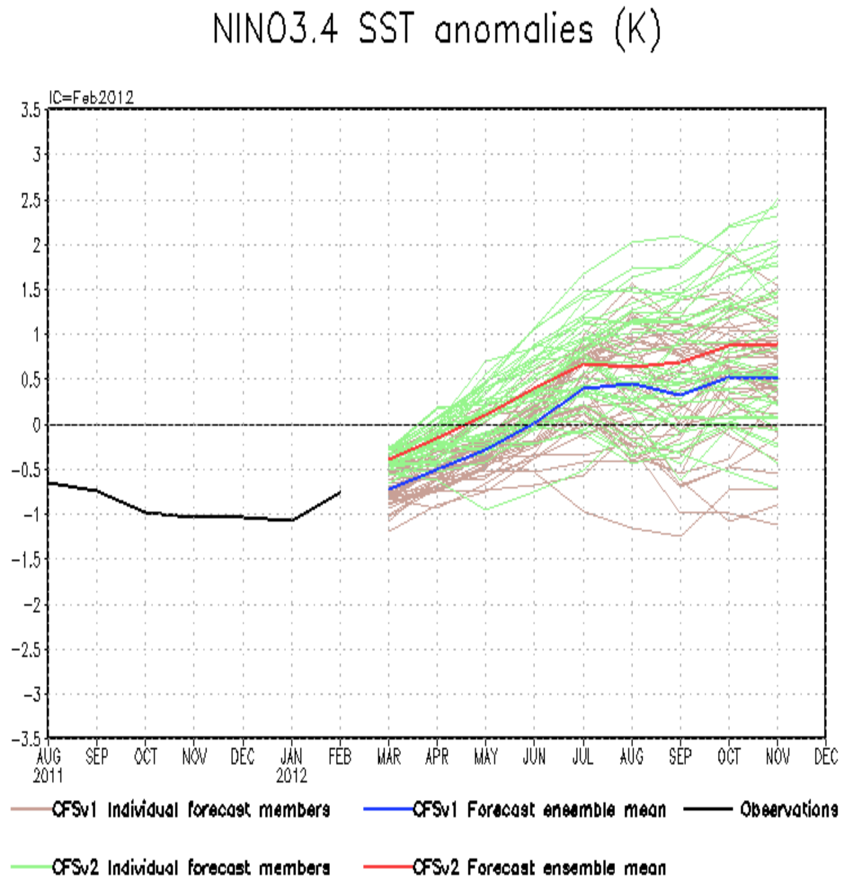
Thanks Qin Zhang, Huug van den Dool, Suru Saha, Malaquias Pena Mendez, Patrick Tripp, Peitao Peng and Emily Becker plus the originators at NASA, NCAR, GFDL, IRI (all coupled models)

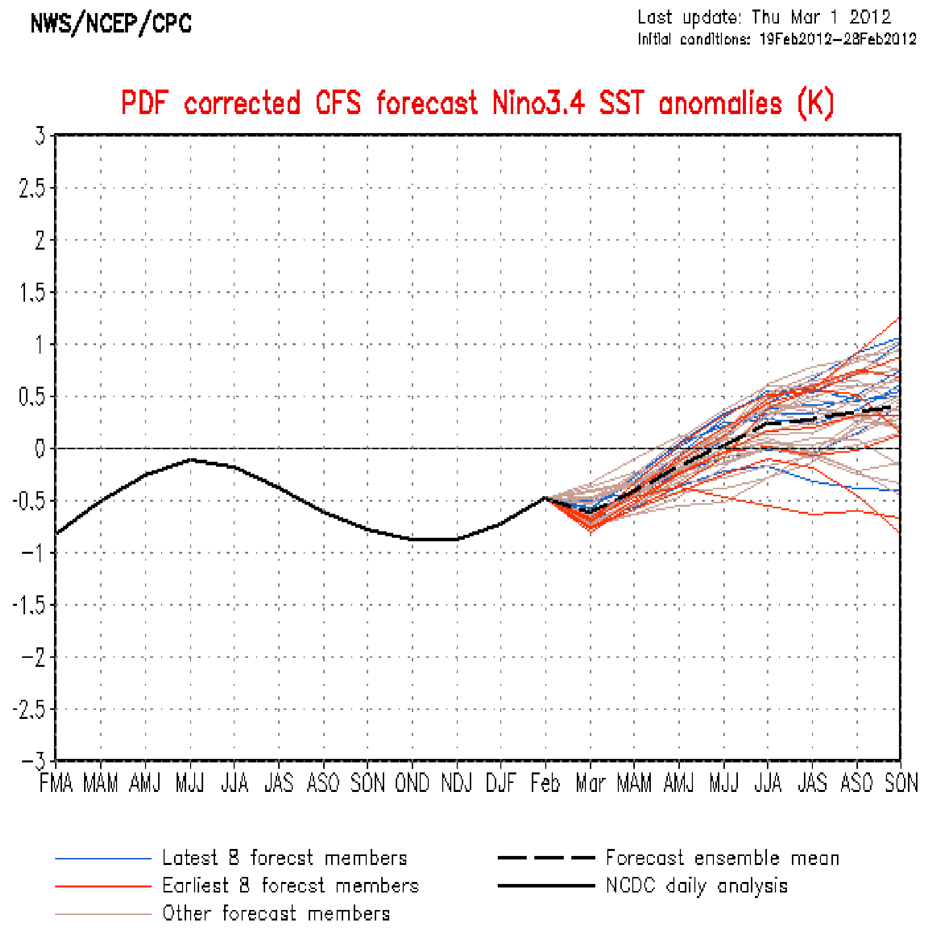
# NMME NINO3.4 Forecast (7-models)




- ***NMME*** **forecasts a warming since summer 2012.**
- **Occurrence of El Nino (Nino3.4 >0.5) is expected since May 2012 for *GFDL*, since Jun 2012 for *NCAR* and *ECHAMA*, since Jul 2012 for *ECHAMF and CFSv2*.**
- ***NASA and CFSv1*** **predict neutral condition until autumn 2012.**

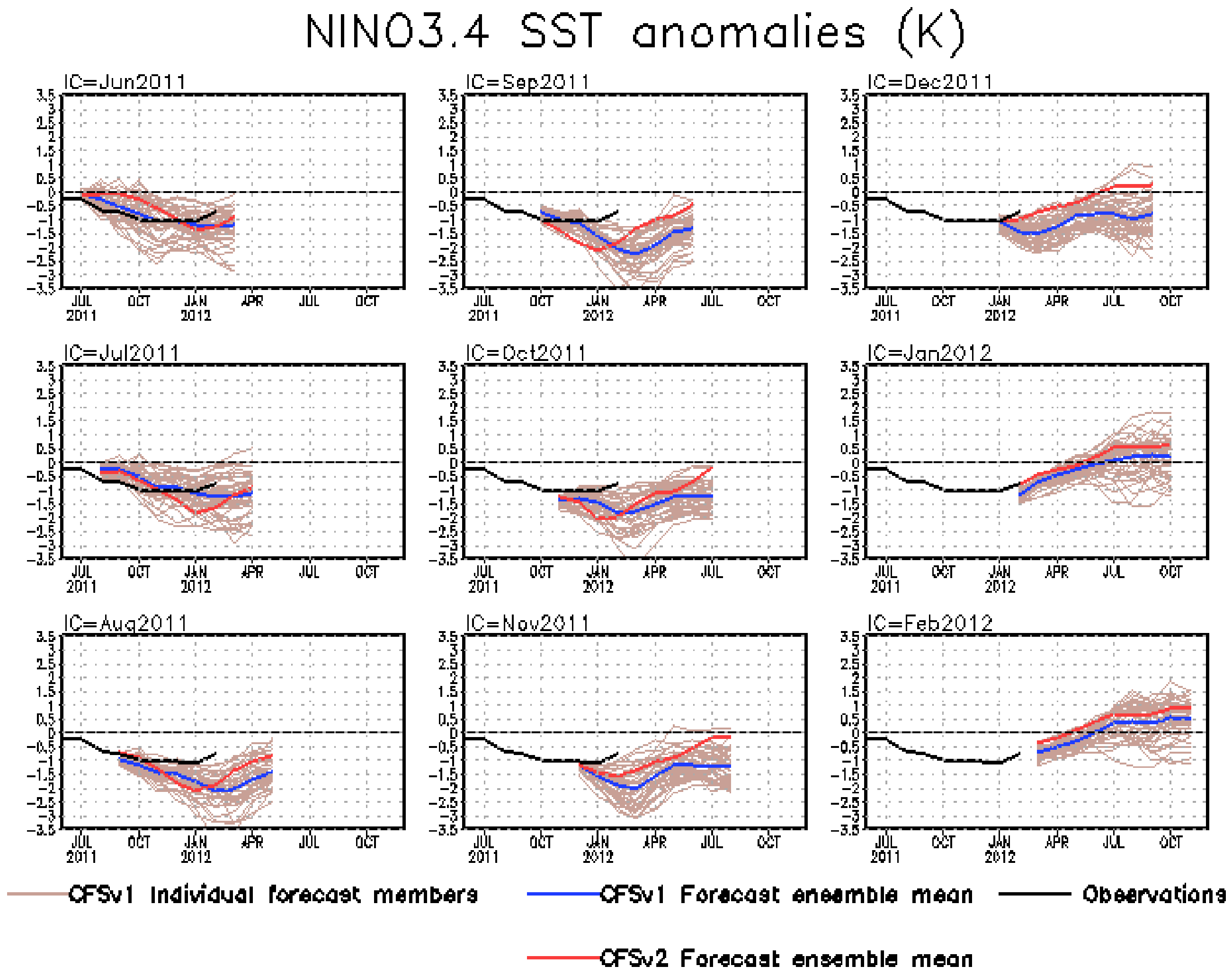
# NCEP CFSv1 and CFSv2 NINO3.4 Forecast




- **Both CFSv1 and CFSv2 predict La Nina would weaken towards neutral-conditions in spring, while CFSv2 predictions are systematically warmer than that of CFSv1.**
- **PDF corrected CFSv1 forecast ENSO neutral conditions in MAM 2012.**

# CFS Niño3.4 SST Predictions from Different Initial Months




- **Both CFSv1 and CFSv2 predict La Nina would weaken towards neutral-conditions in spring.**

- **CFSv2 predictions are systematically warmer than that of CFSv1 with ICs since Nov 2011.**

**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.**

# Overview

- **Pacific Ocean**
  - La Nina conditions weakened with NINO3.4=-0.7°C in Feb 2012.
  - NOAA "ENSO Diagnostic Discussion" in March suggests La Niña is expected to return to ENSO-neutral conditions by the end of April 2012. A majority of ENSO prediction models predict ENSO-neutral to continue through the NH summer 2012.
  - Some models in the US National Multi-Model Ensemble (NMME) predicts an El Nino since this summer.
  - Negative PDO weakened, with PDOI=-1.3 in Feb 2012. NMME predicts negative PDO pattern to last through the NH spring-autumn 2012.
- **Indian Ocean**
  - Small anomalies.
- **Atlantic Ocean**
  - Positive NAO weakened significantly with NAOI=0.42 in Feb 2012.
  - Tropical South Atlantic has cooled down substantially since Dec 2011, which was the coolest period since 1998. NMME predicts the cooling to last until early autumn 2012.
  - Positive meridional SSTA gradient mode weakened in Feb 2012.

# Backup Slides

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

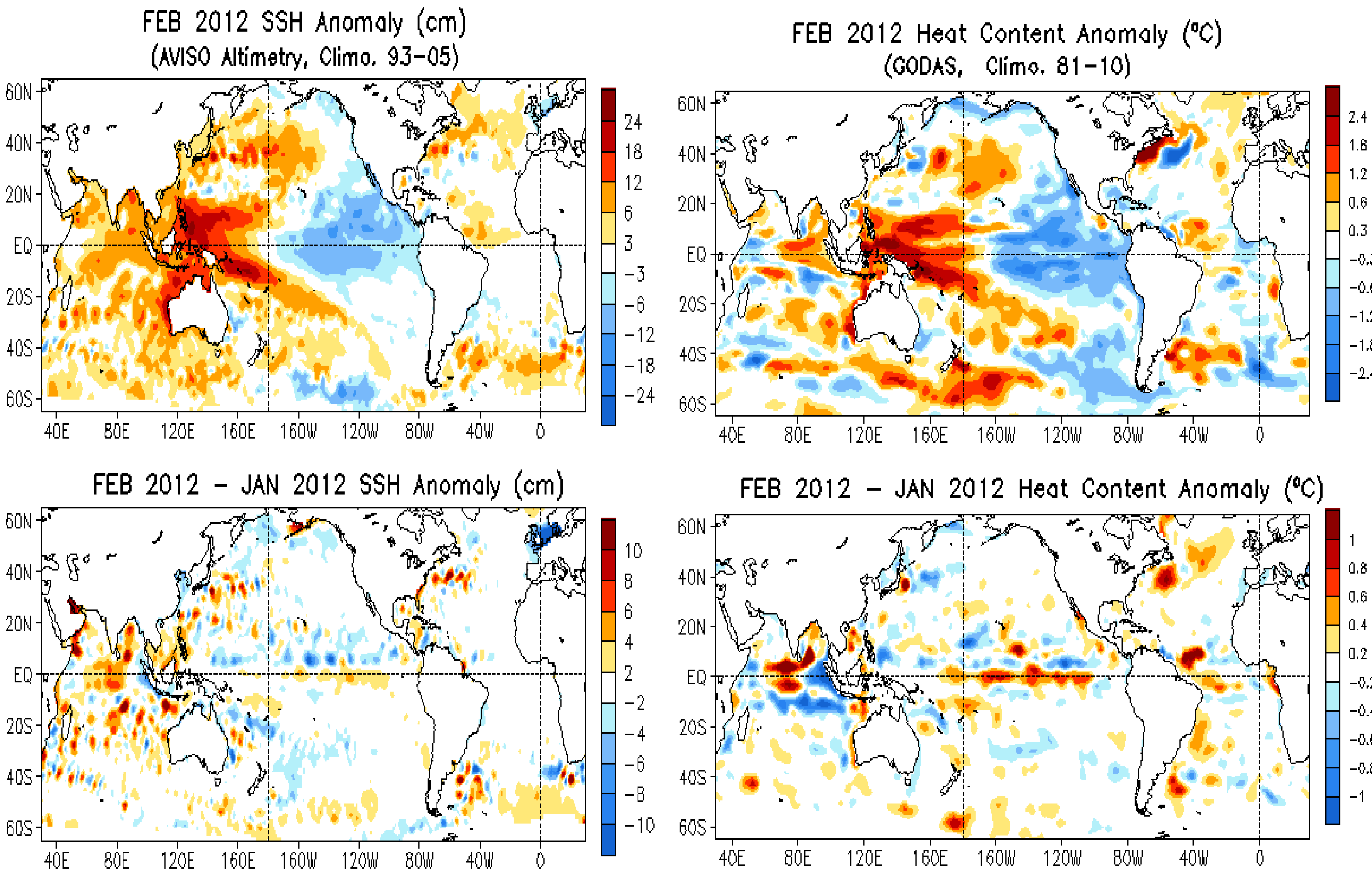
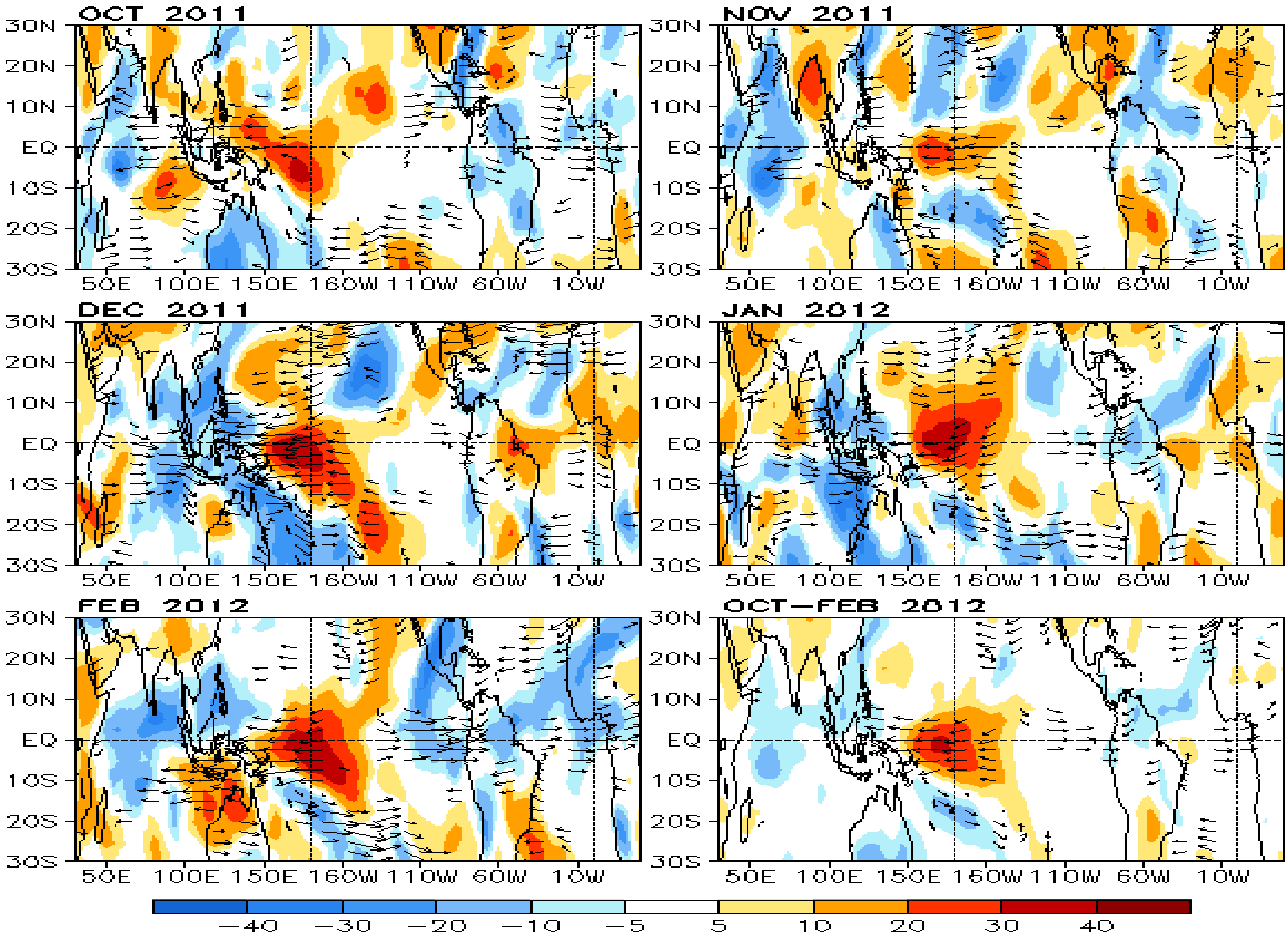



Fig. G2. Sea surface height anomalies (SSHA, top left), SSHA tendency (bottom left), top 300m heat content anomalies (HCA, top right), and HCA tendency (bottom right). SSHA are derived from http://www.aviso.oceanobs.com, and HCA from GODAS.

# Evolution of OLR and 850mb Wind Anom.



# 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.

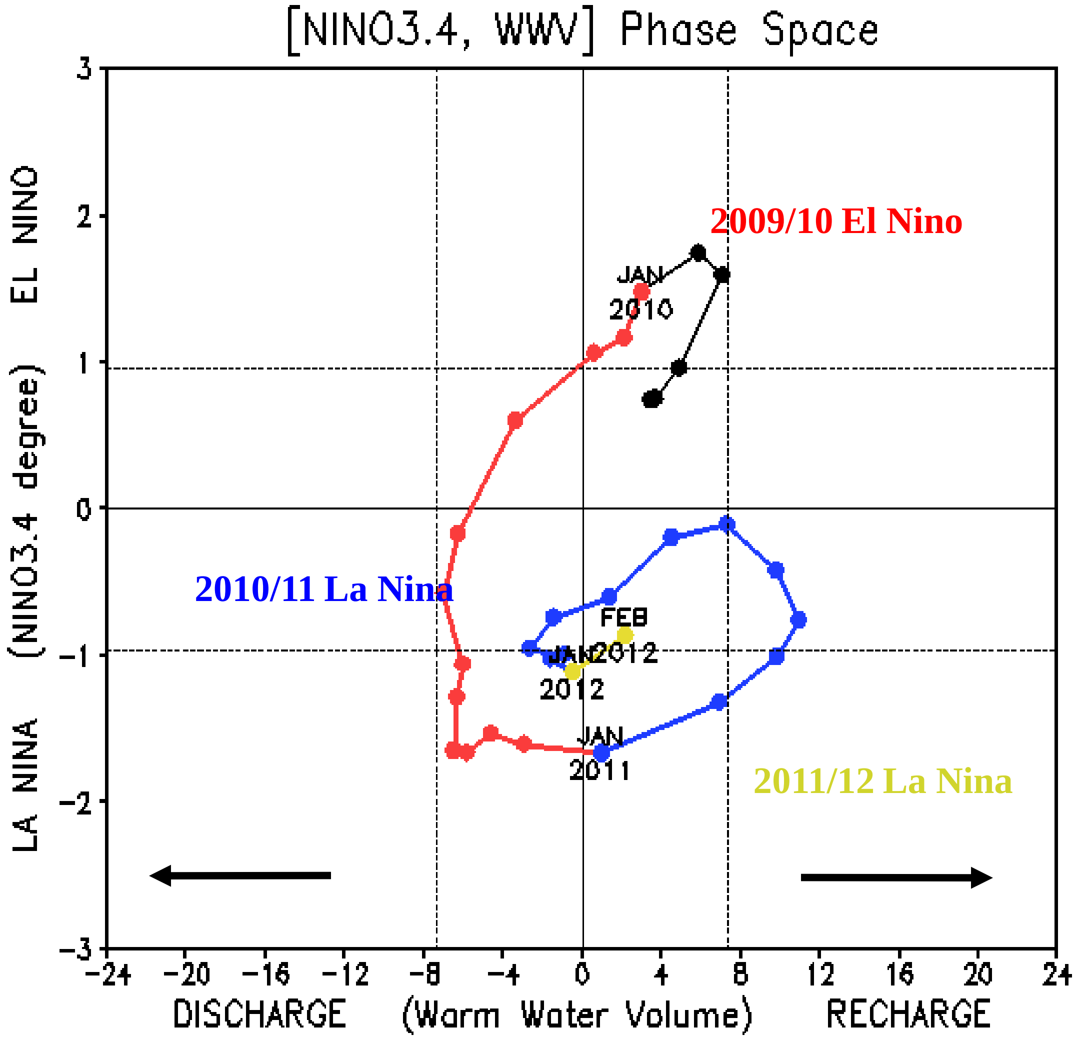
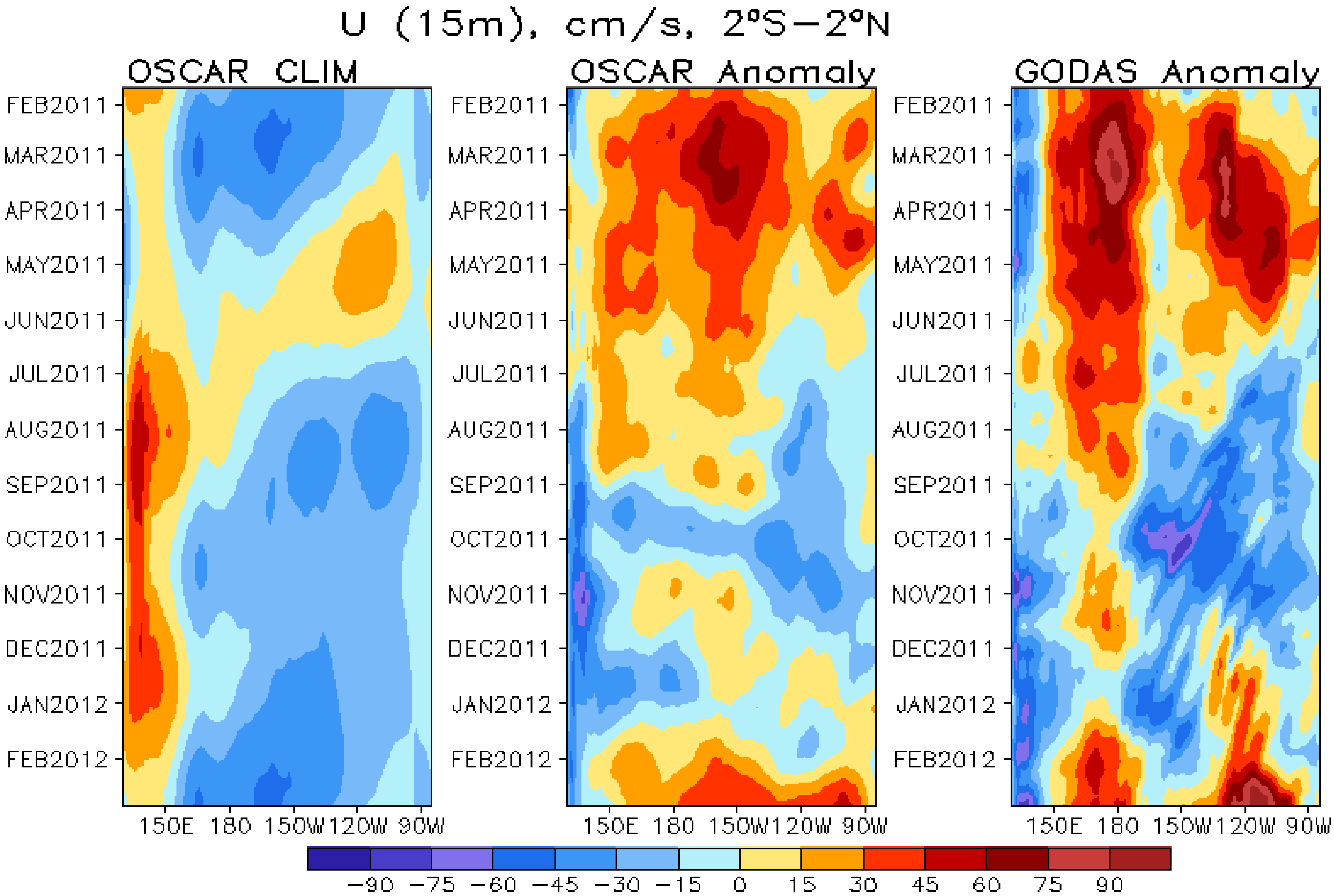



Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

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



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

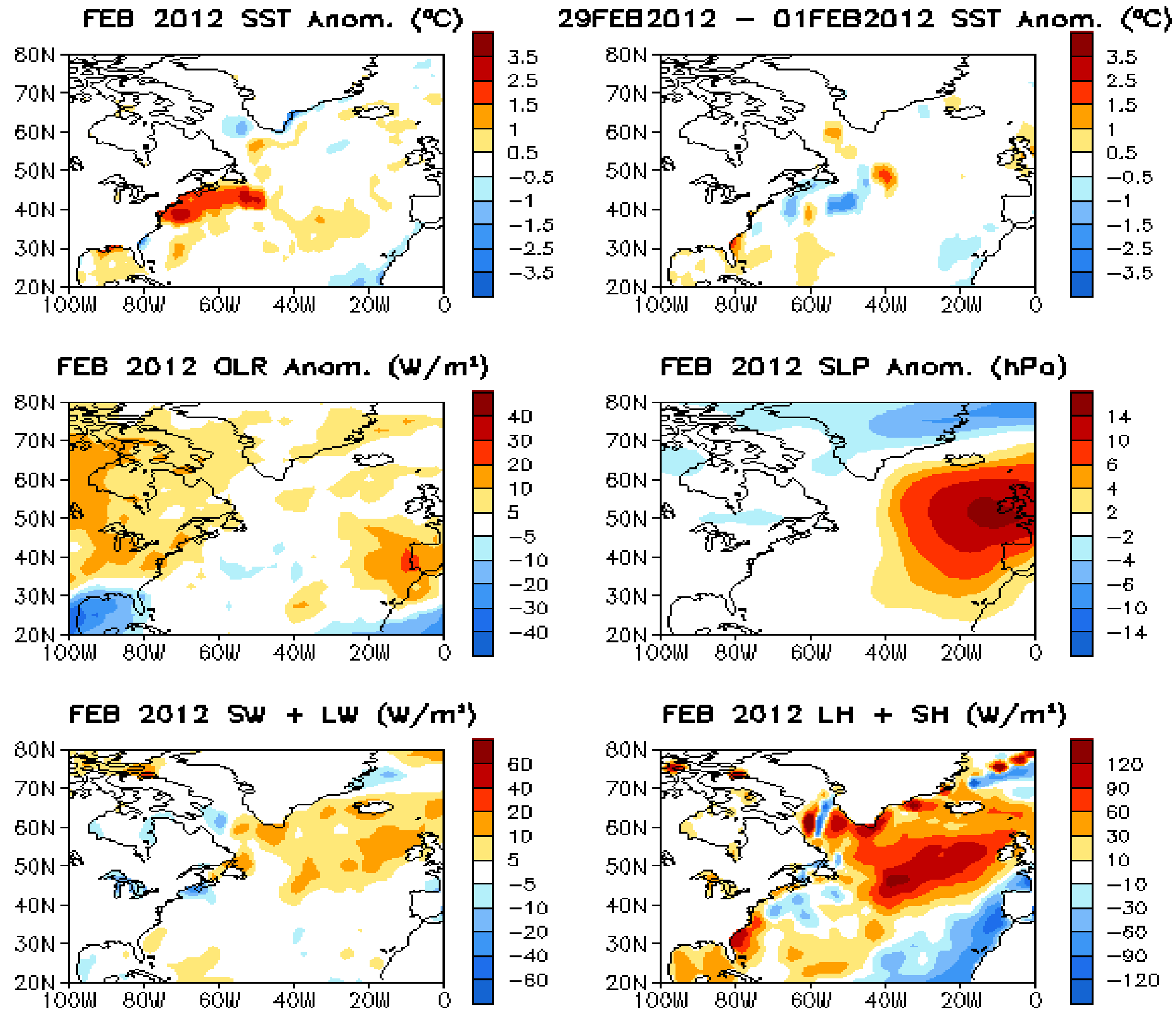
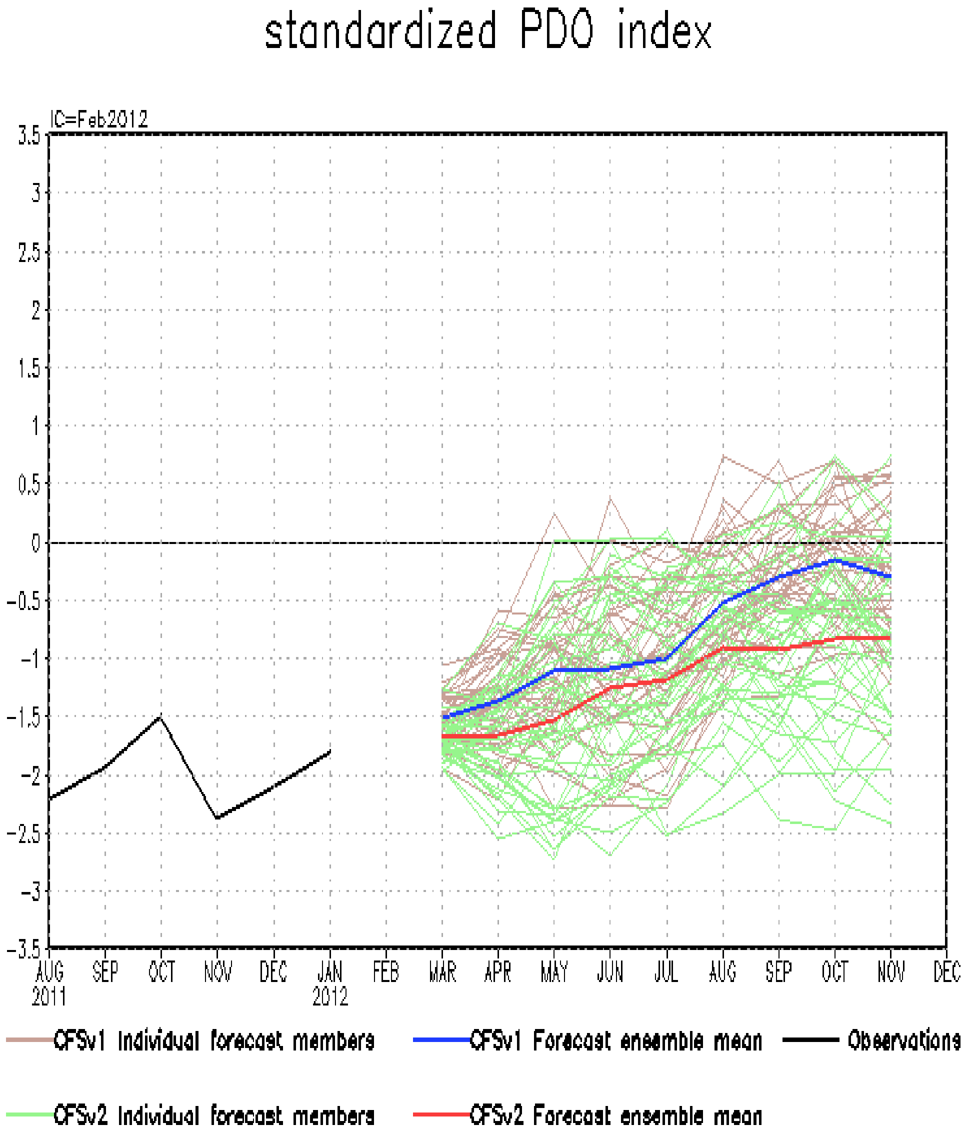
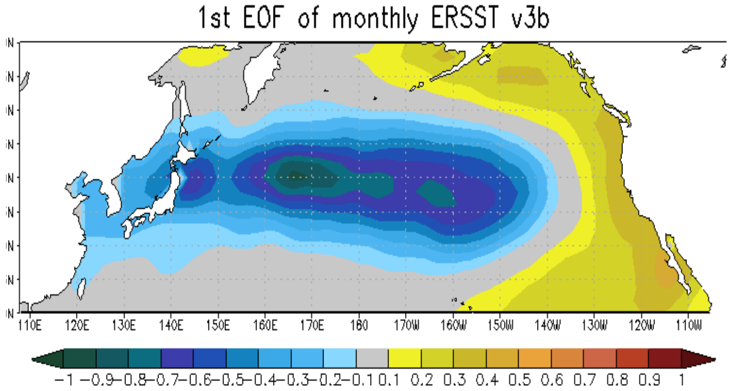



Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

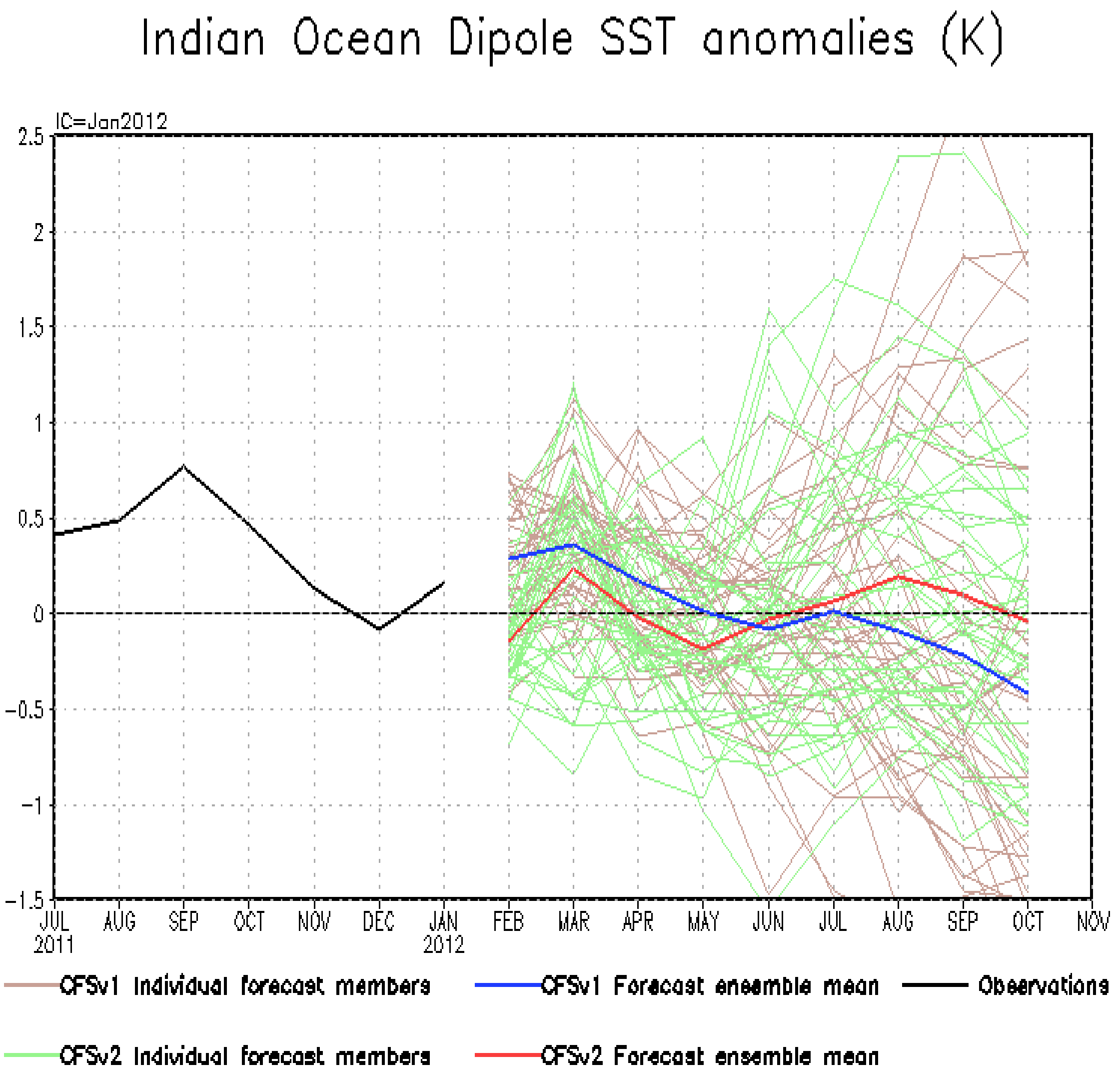
# NCEP CFSv1 and CFSv2 PDO Forecast




- **Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSSTv3b 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.**

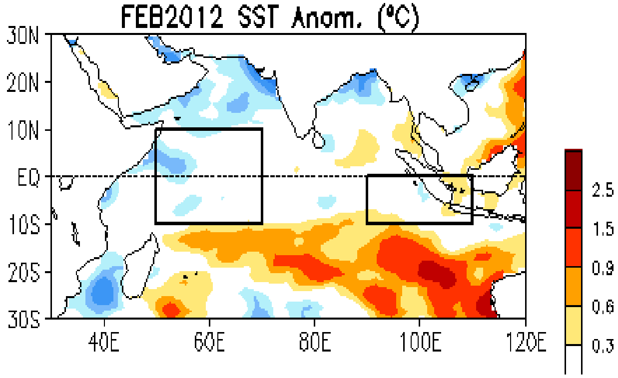
# NCEP CFSv1 and CFSv2 Dipole Model Index Forecast



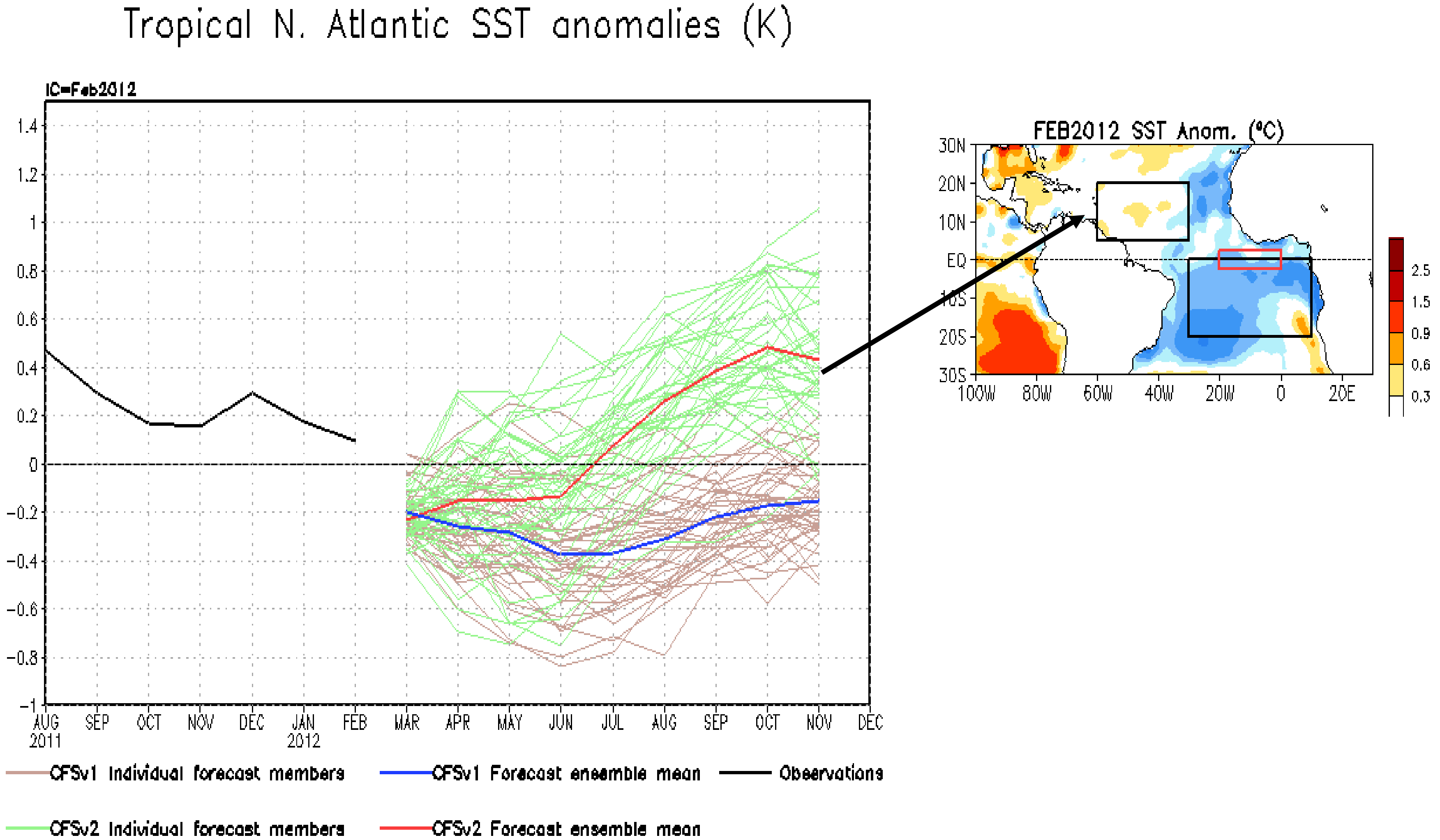

**DMI = WTIO- SETIO**

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

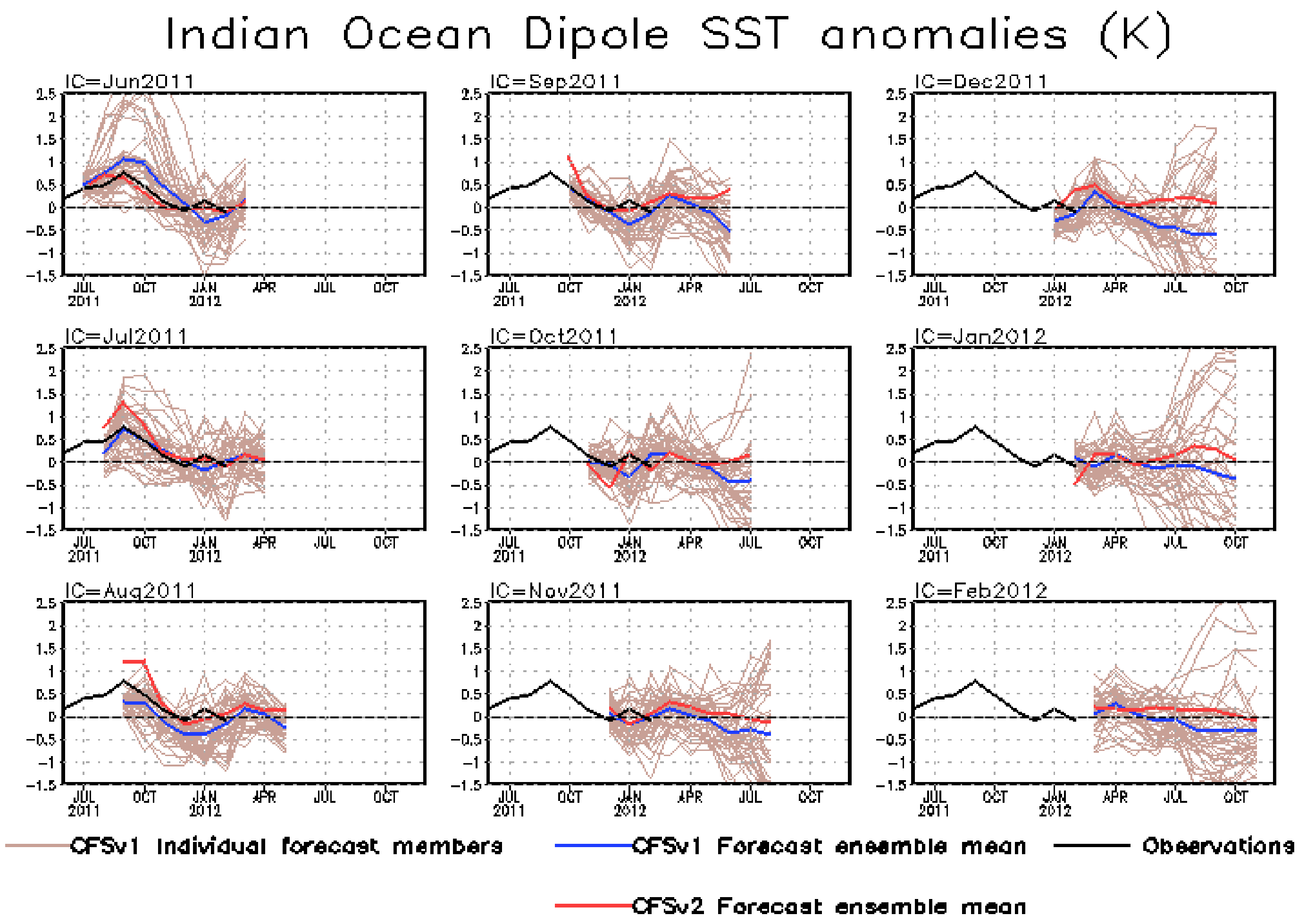
**WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]**



# NCEP CFSv1 and CFSv2 Tropical North Atlantic SST Forecast



# NCEP CFS DMI SST Predictions from Different Initial Months



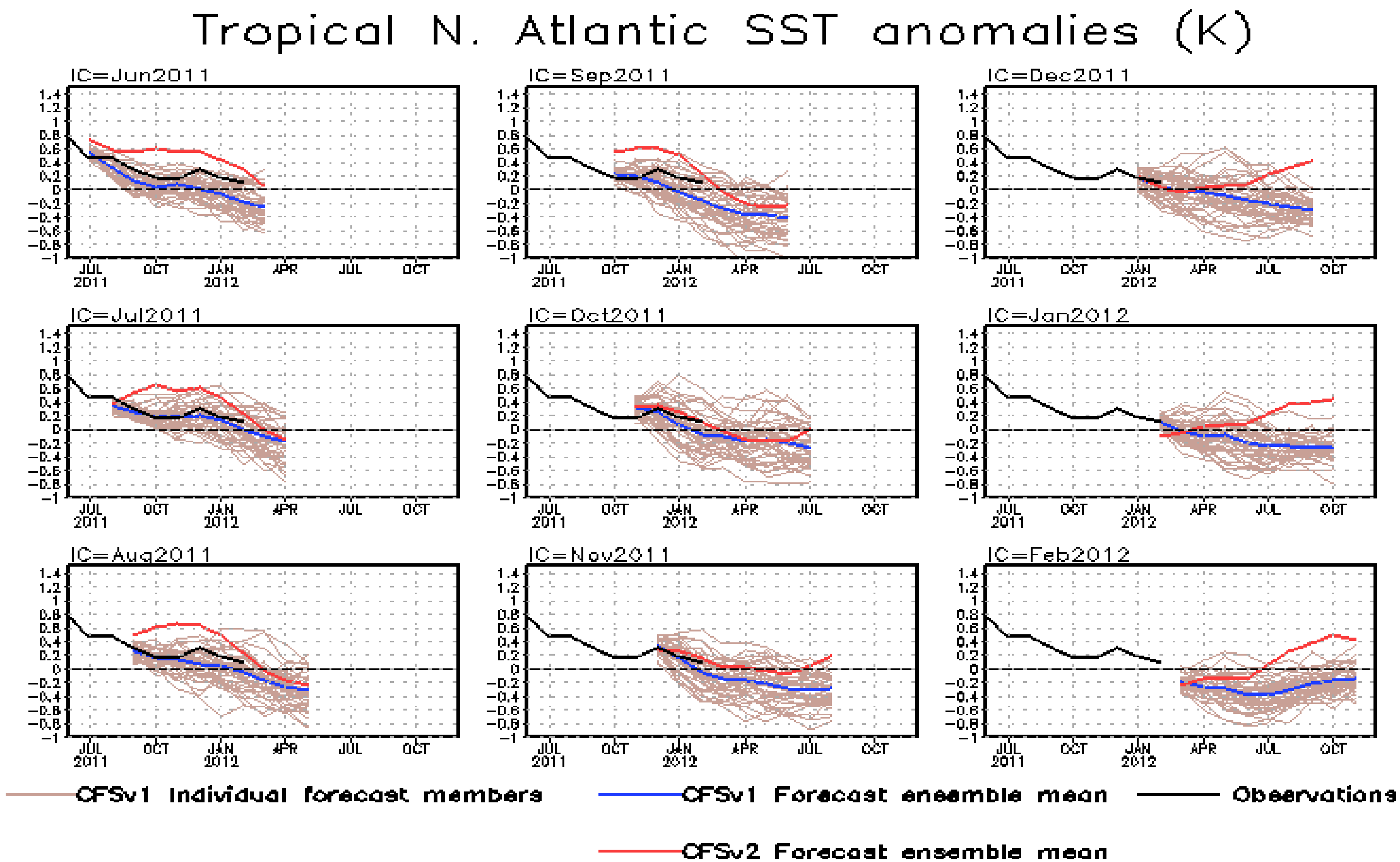

**DMI = WTIO- SETIO**

**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 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].**

**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.**

# 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.

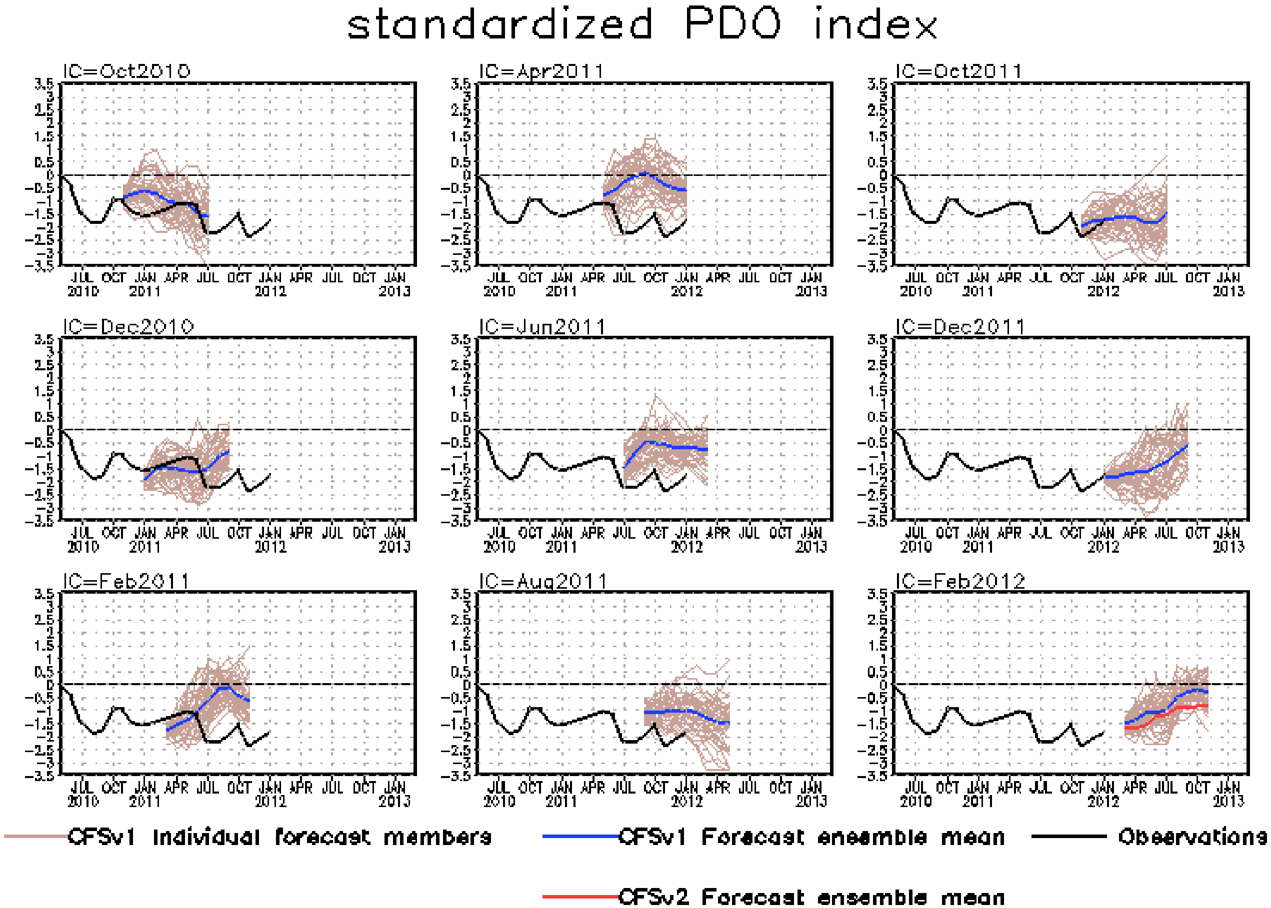
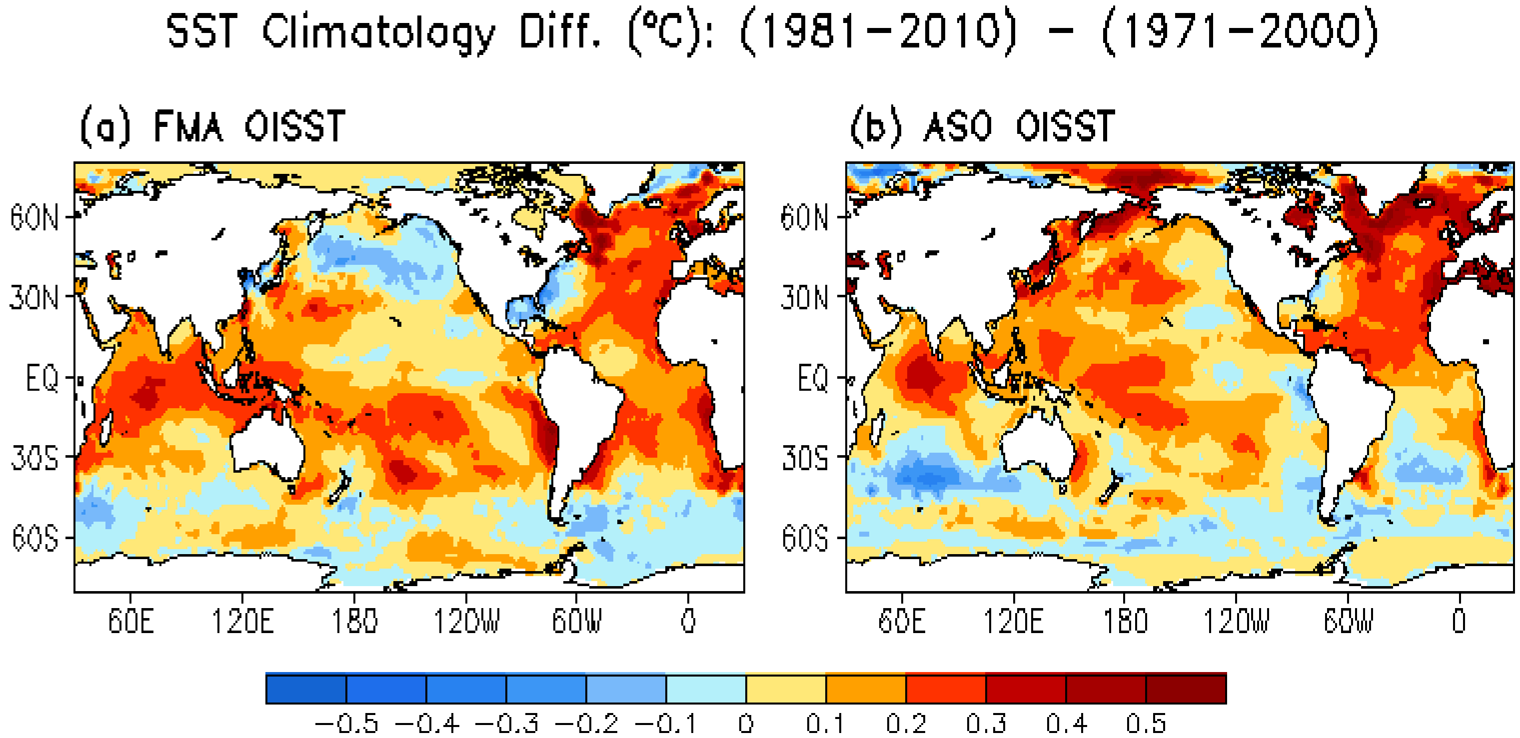



Fig. M4. CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black).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

**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°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!