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 Influence of Low Frequency Variations on ENSO and Ocean Monitoring**

- **Global SST Predictions**

Overview

- **Pacific Ocean**

- ENSO has returned to neutral phase with NINO3.4=-0.4^{o}C in Apr 2012.
- NOAA "ENSO Diagnostic Discussion" in May suggests that ENSO-neutral conditions to continue through north summer 2012. A majority of ENSO models predict ENSO-neutral to continue through the NH summer 2012. Some models predict an El Nino beginning in summer 2012.
- Negative phase of PDO weakened, with PDOI=-0.66 in Apr 2012.

- **Indian Ocean**

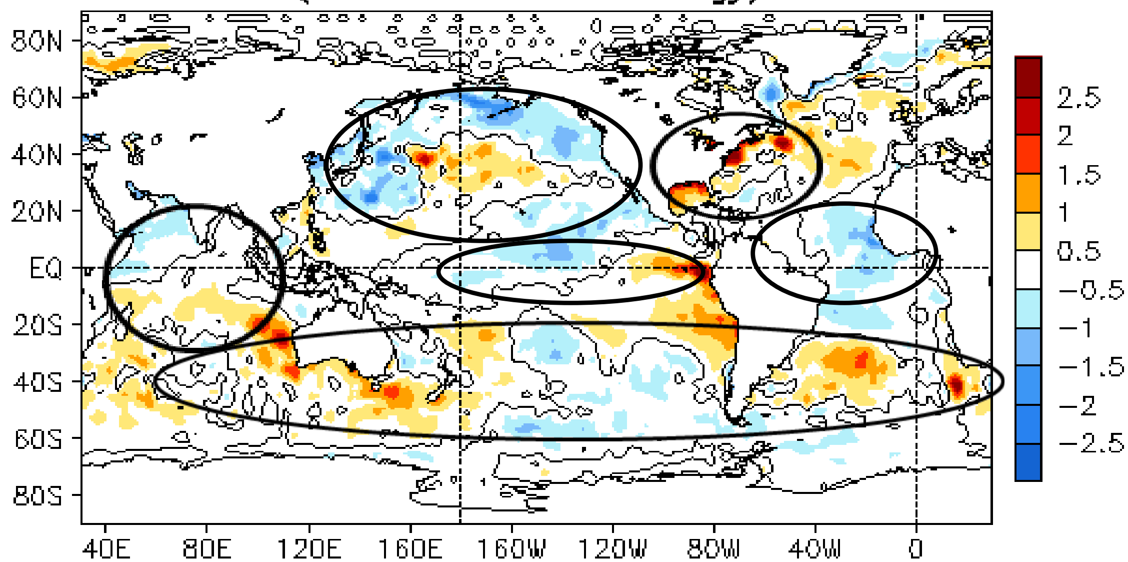
- Positive (negative) SSTA was observed in the tropical southern (NW) Indian Ocean.

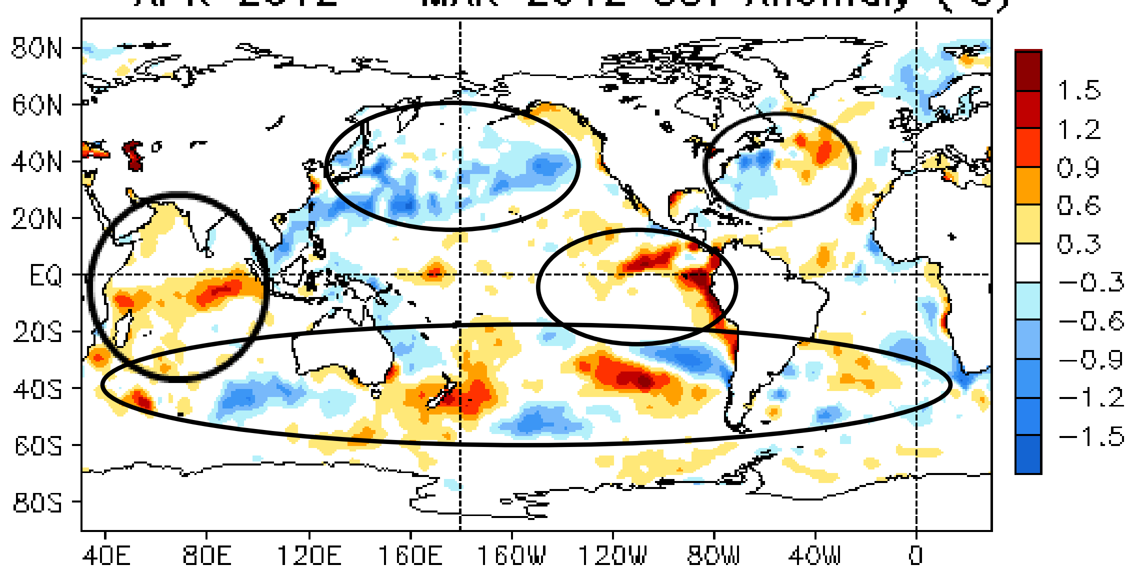
- **Atlantic Ocean**

- Positive NAO weakened with NAOI=0.47 in Apr 2012.
- SST cooled down (warmed up) over the tropical (mid-latitude of) North Atlantic, probably due to the impact of La Nina and positive phase of NAO.
- The cooling along the equatorial Atlantic persisted in Apr 2012.

Global Oceans

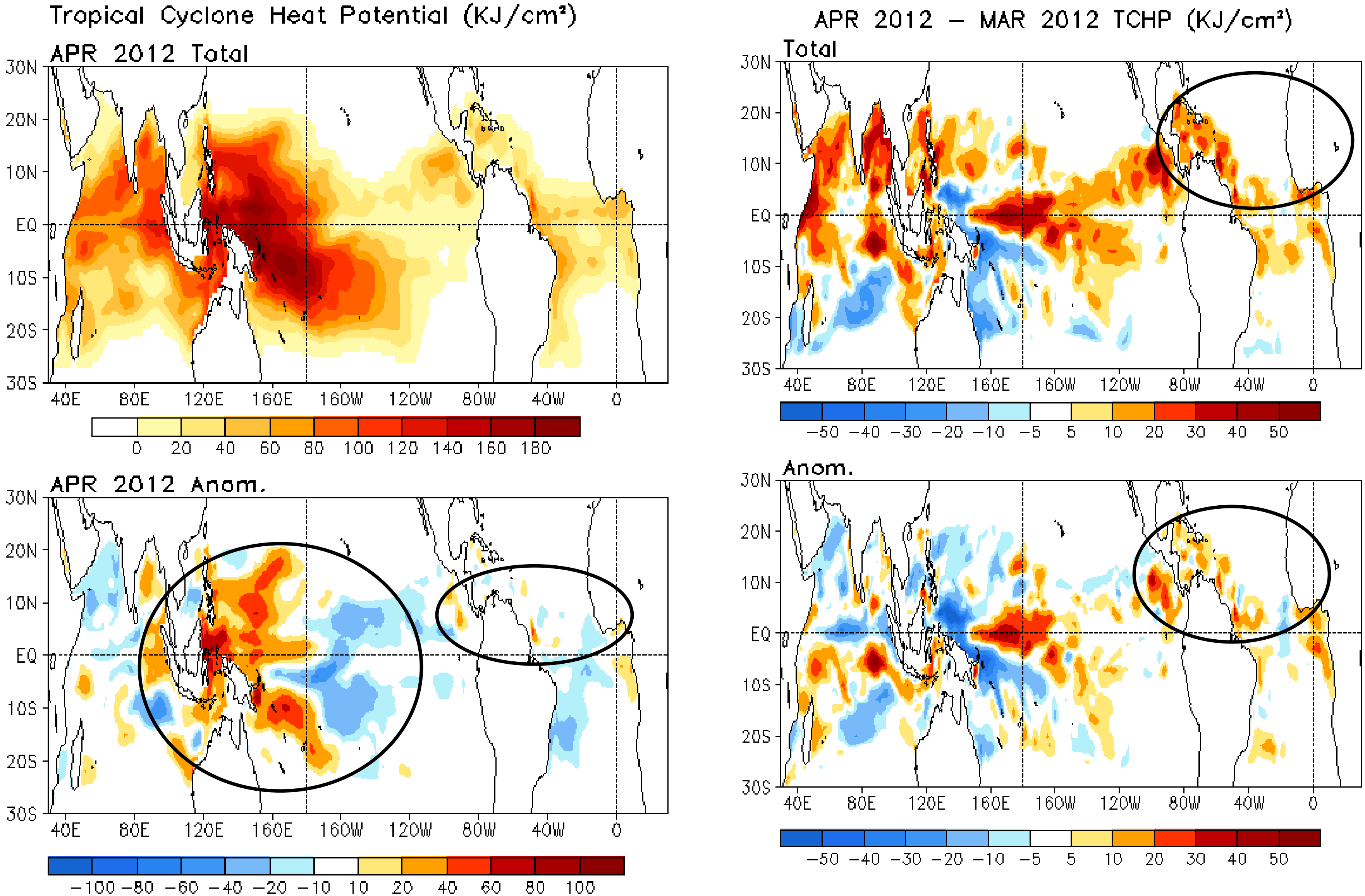
Global SST Anomaly (^{0}C) and Anomaly Tendency





- **The warming tendency continued in the eastern equatorial Pacific.**
- **Negative phase PDO associated SSTA weakened.**
- **Positive SSTA developed in tropical southern Indian Ocean.**
- **Negative SSTA persisted along the equatorial Atlantic and weakened in the tropical North Atlantic. Warming along American Atlantic coast was observed.**
- **Large anomalies and tendencies emerged in the South Ocean.**

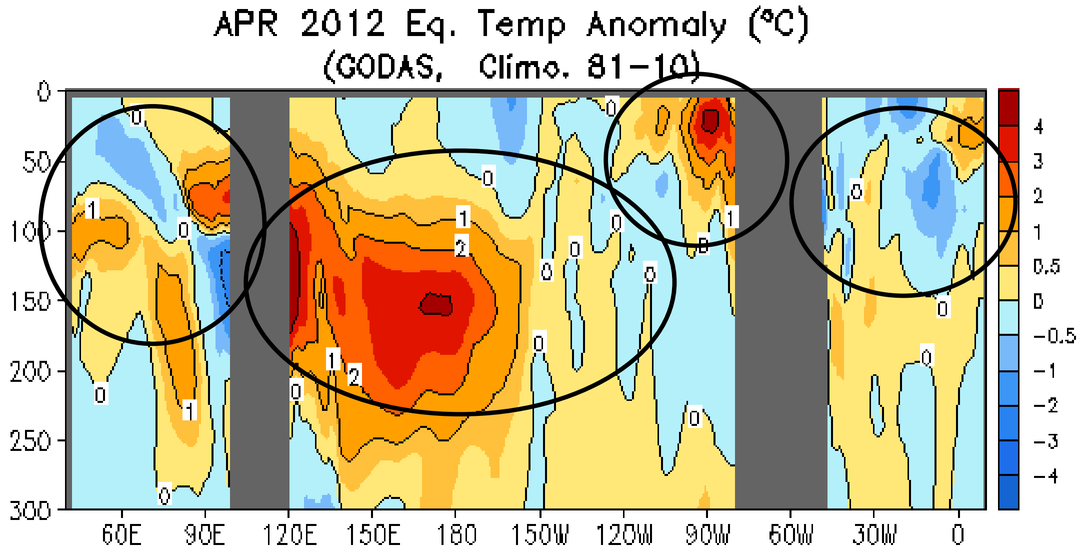
Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.



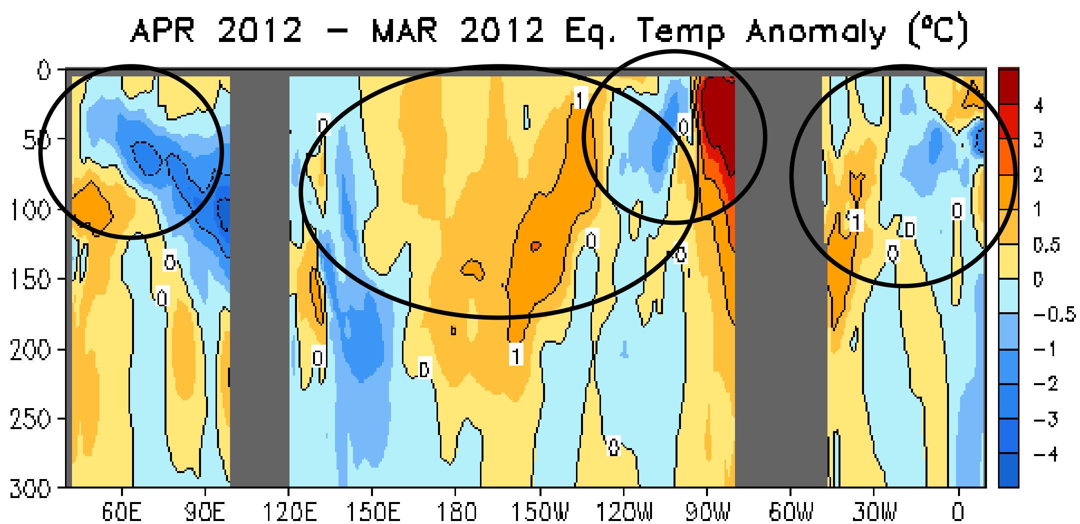
- **Positive TCHP anomalies presented in the western Pacific and negative ones in the central and eastern Pacific.**
- **Anomalies over the Atlantic Ocean were small.**

TCHP field is the anomalous heat storage associated with temperatures larger than 26 ℃.

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



- Large positive anomalies along the thermocline in the west and American Pacific coast and small anomalies in the central and eastern equatorial Pacific were observed.
- Both positive and negative ocean temperature anomalies presented in the equatorial Indian Ocean.
- Both positive and negative ocean temperature anomalies were weak and presented at top 150m of the equatorial Atlantic.

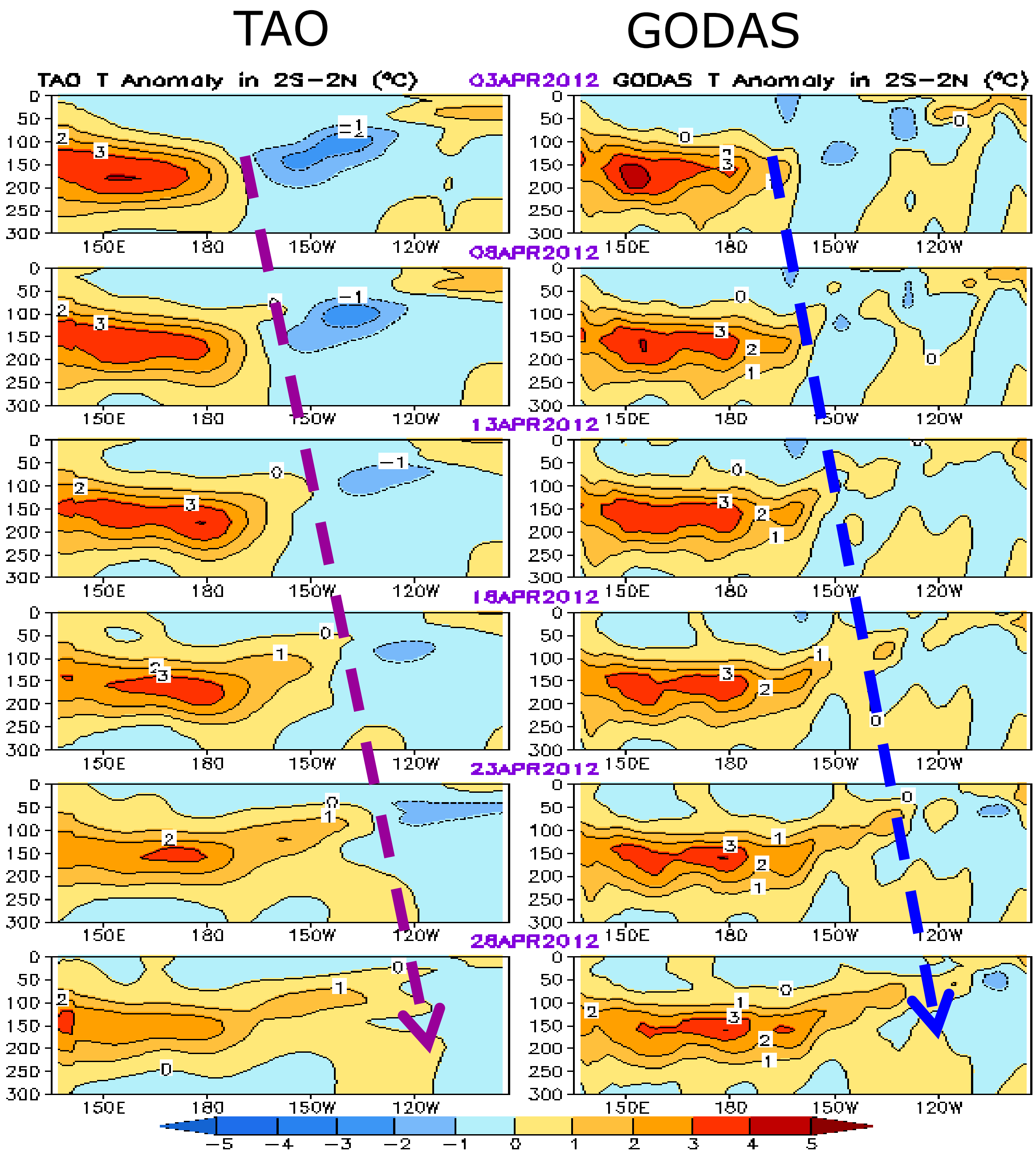


- Ocean temperature warmed up in the central and eastern equatorial Pacific, particularly along the Pacific coast.
- Ocean temperature decreased around 50-150 m in the equatorial Indian Ocean.
- Both positive and negative tendencies were observed in the equatorial Atlantic.

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.

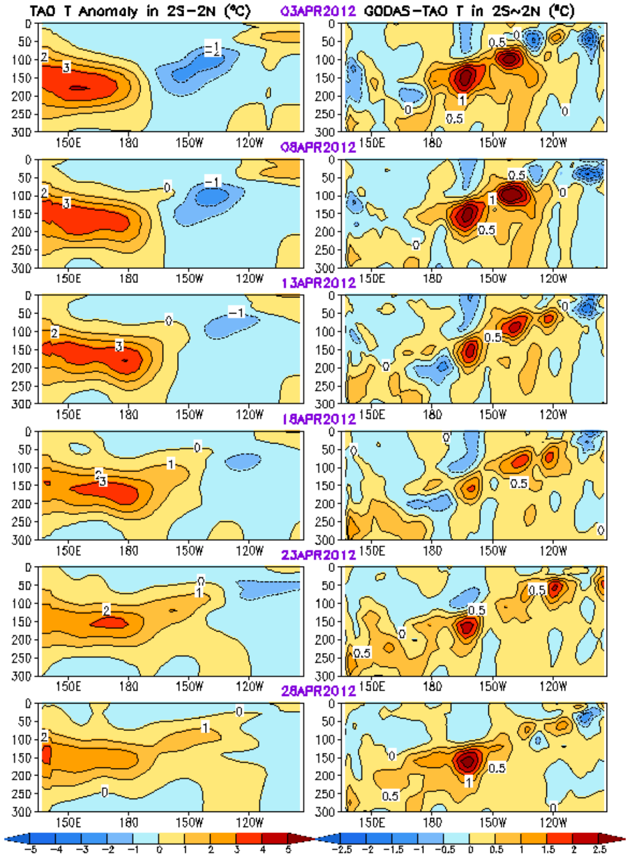
Tropical Pacific Ocean and ENSO Conditions

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

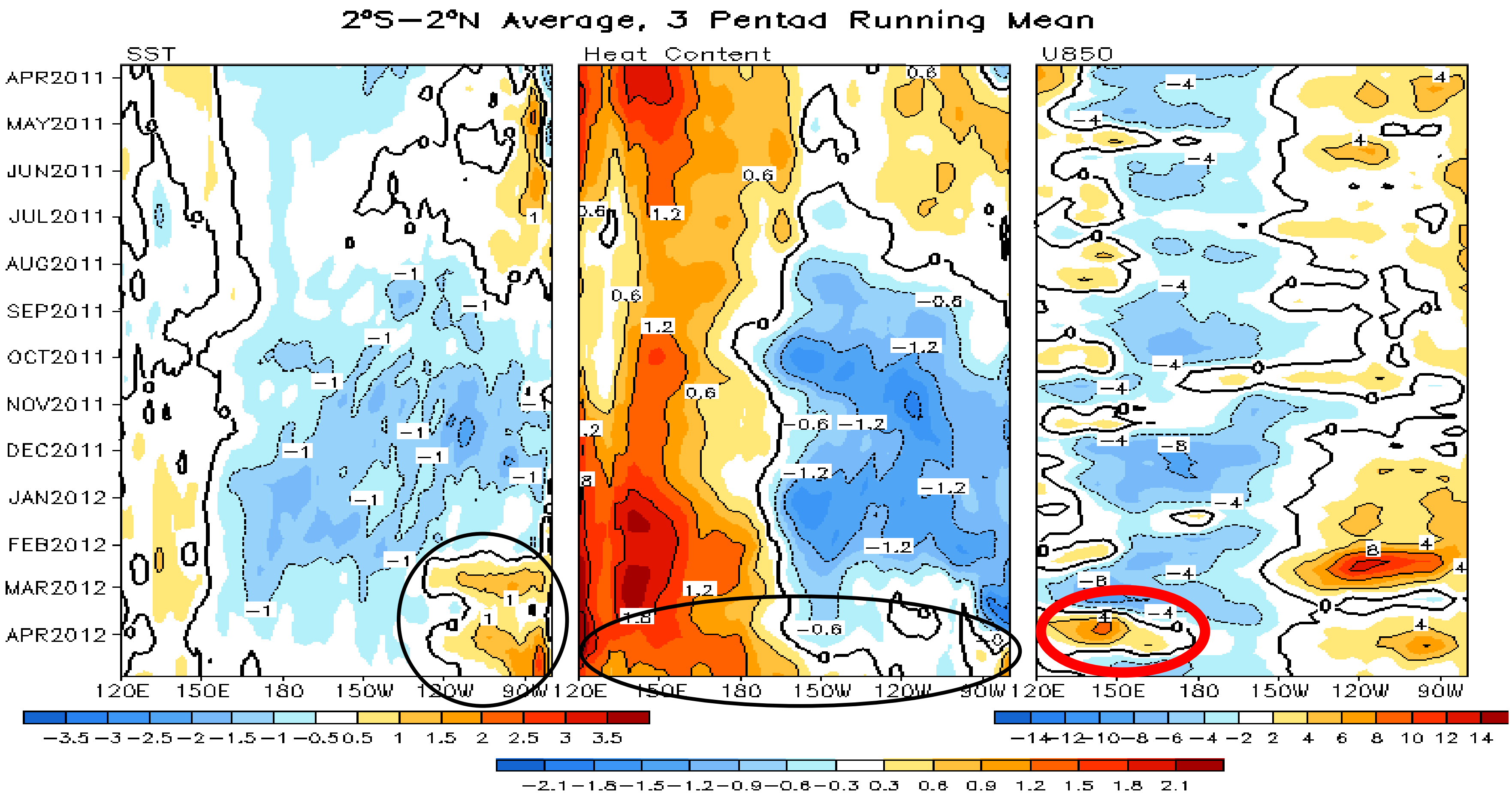


- In both TAO and GODAS, large positive anomaly in west weakened and propagated eastward.

- Compared with TAO, GODAS is too warm at 100-250 m depth.



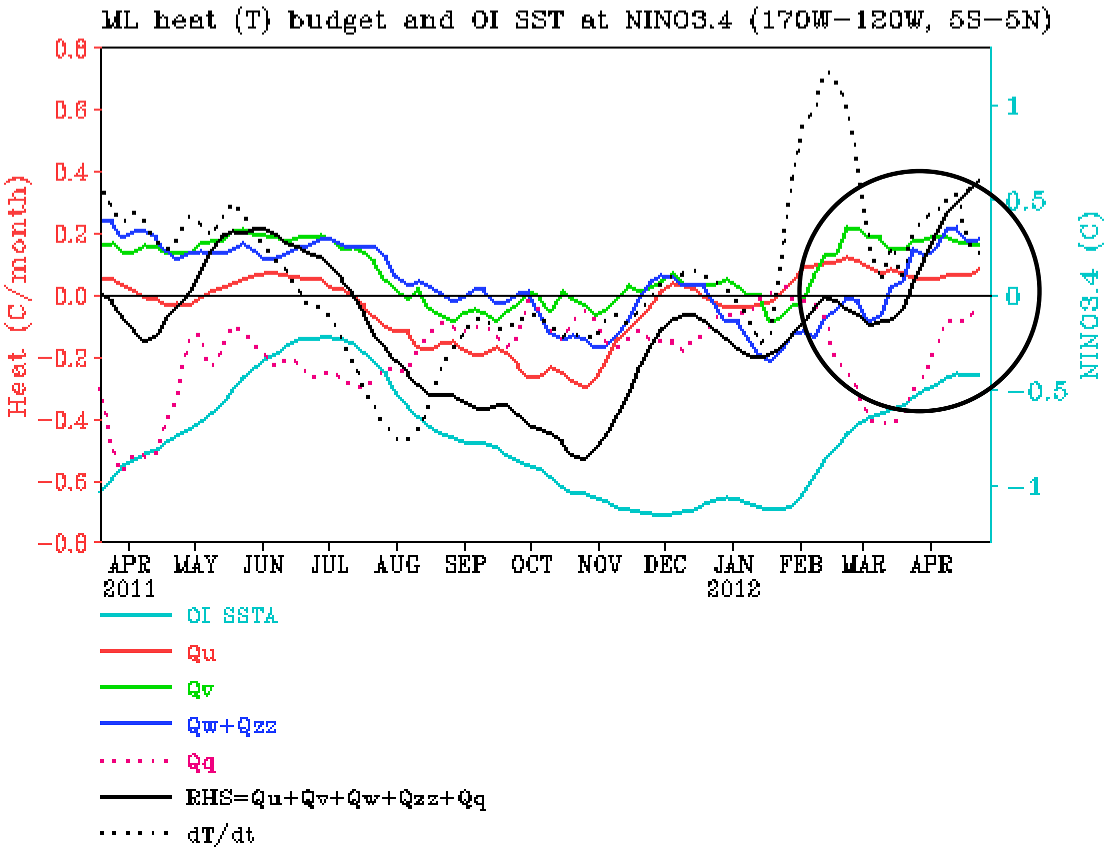
Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies



- **Negative SSTA weakened in the central (eastern) equatorial Pacific since Feb 2012 (Dec 2011), and positive SSTA developed in the east since Feb 2012.**
- **The recent eastward propagation of HC300, characteristic of downwelling oceanic Kelvin wave, is probably forced by the MJO-related westerly wind anomalies in later March.**
- **Westerly wind anomalies presented in the W. Pacific during mid-Mar to mid-Apr 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.

NINO3.4 Heat Budget



- **SSTA tendency (dT/dt) in NINO3.4 (dotted line) was positive during mid-Jan-Apr 2012, indicating the warming tendency in the eastern and central Pacific.**

- **All dynamical terms (Qu, Qv, Qw+Qzz) were positive and heat flux (Qq) negative in Apr 2012.**

- **The total heat budget term (RHS) was consistent with the observed tendency (dT/dt) since mid-Mar 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.

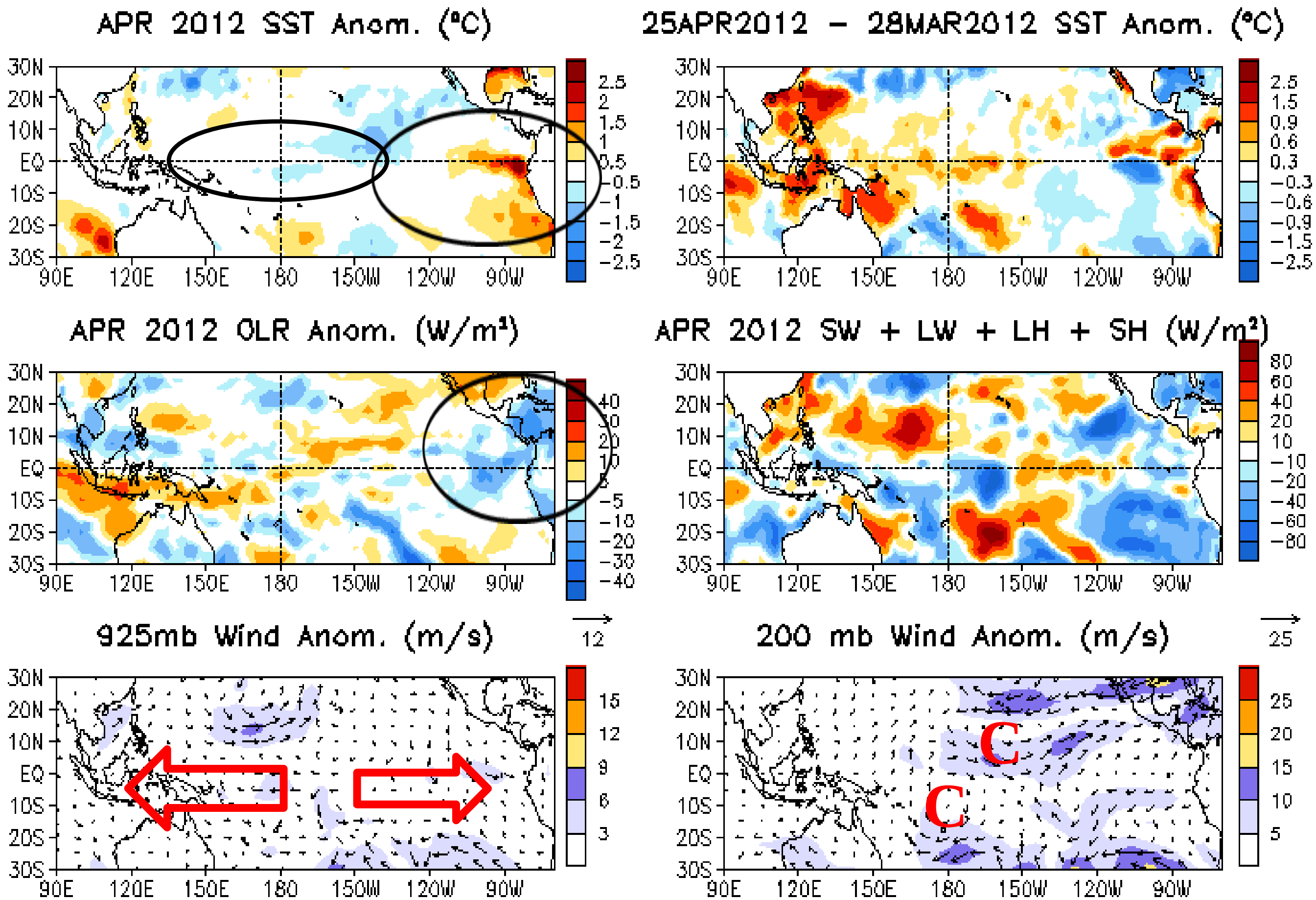
Qu: Zonal advection; Qv: Meridional advection;

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

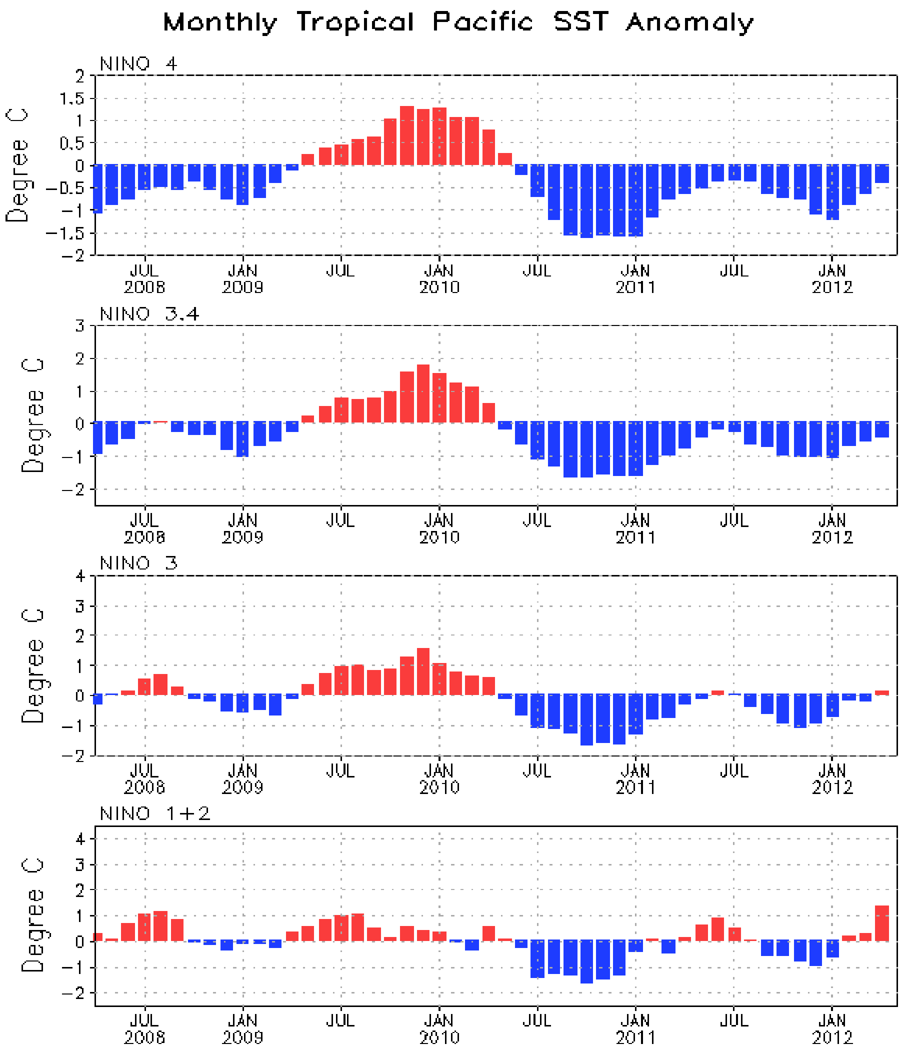
Tropical Pacific: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds

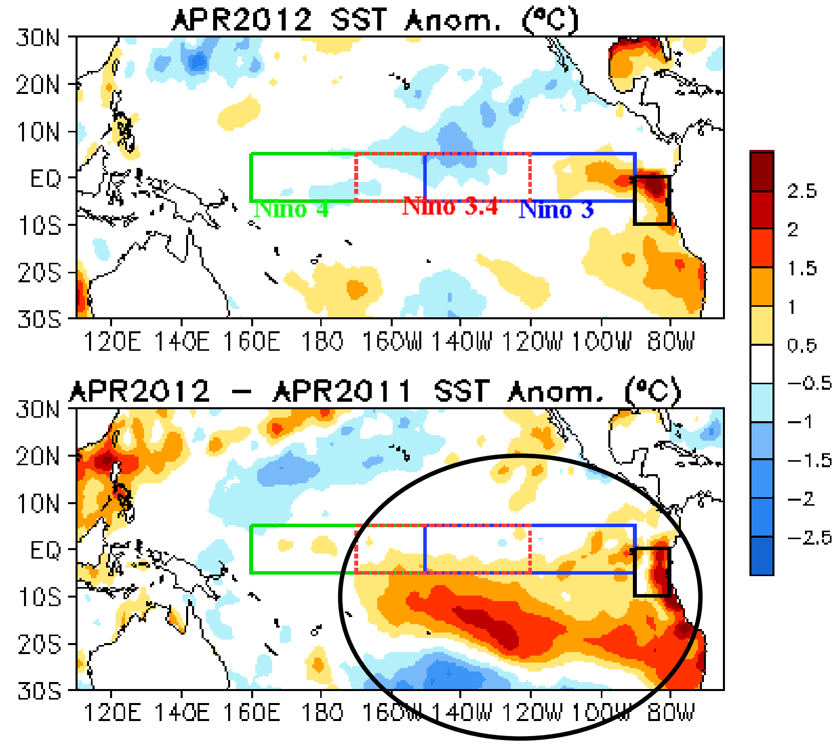


- **Negative SSTA in the central tropical Pacific weakened, and warming in the eastern equatorial and SE Pacific observed.**
- **Tropical convection was enhanced in the eastern Pacific and western Atlantic.**
- **Easterly (westerly) anomaly observed over the western and central (eastern) equatorial Pacific at low level.**
- **Cyclonic anomalous circulation at 200 hPa in tropical N.&S. Pacific in Apr 2012 weakened compared with Mar 2012.**

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.

Evolution of Pacific NINO SST Indices





- **Nino4 and Nino3.4 remained negative, but weakened, Nino1+2 and Nino3 were positive.**

- **Nino3.4 = -0.4°C in Apr 2012.**

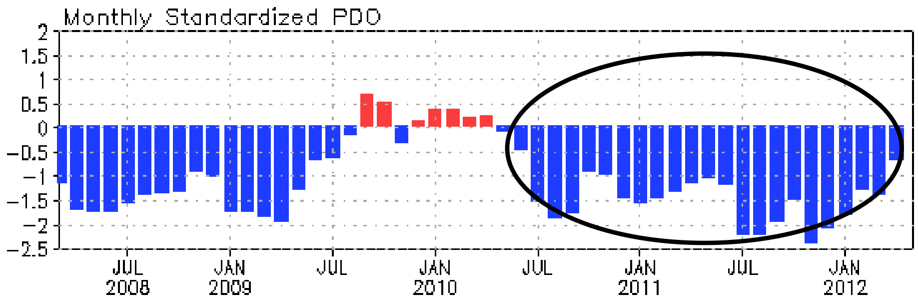
- **The distribution of SSTA was asymmetric between the north and south Pacific. Compared with last Apr, SST was much warmer in the tropical-subtropical S. Pacific in Apr 2012.**

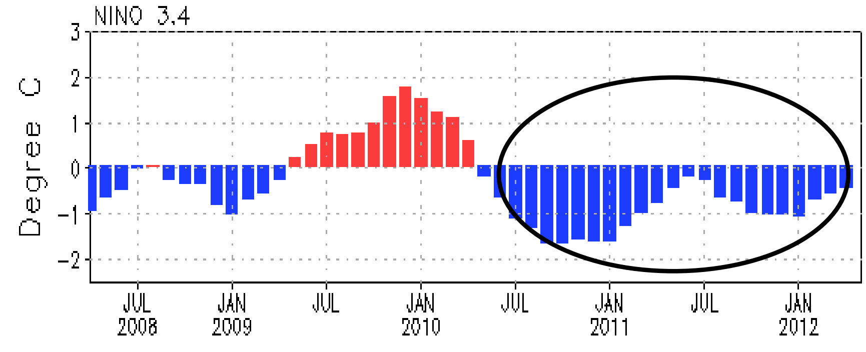
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.**

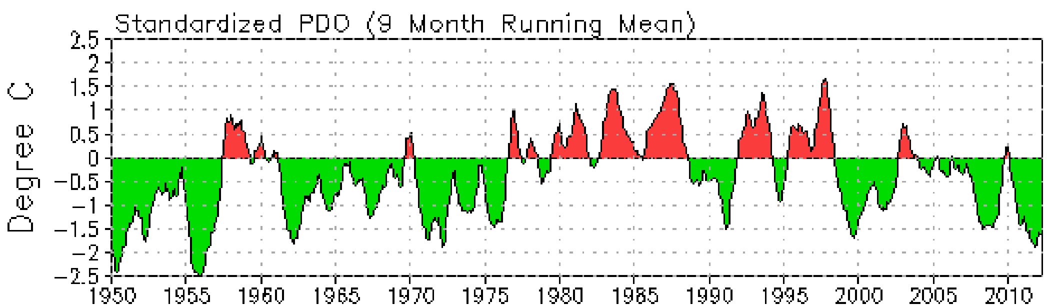
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

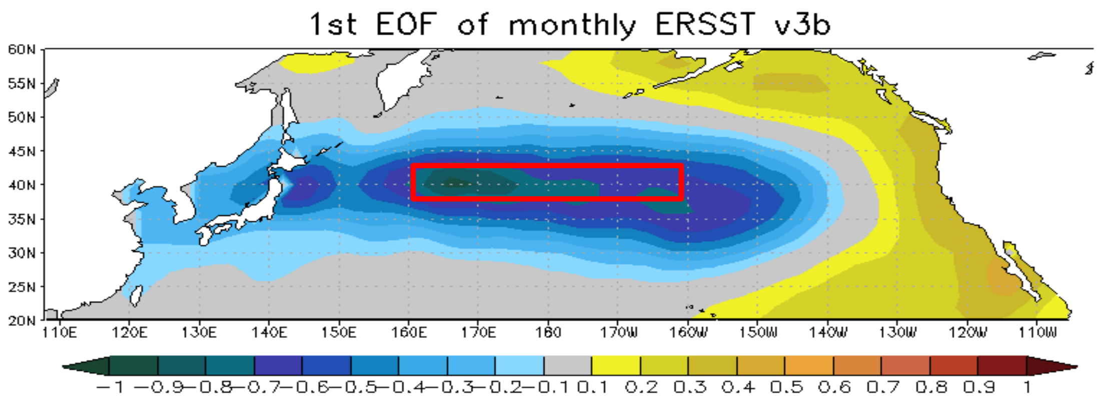
North Pacific & Arctic Oceans

PDO index









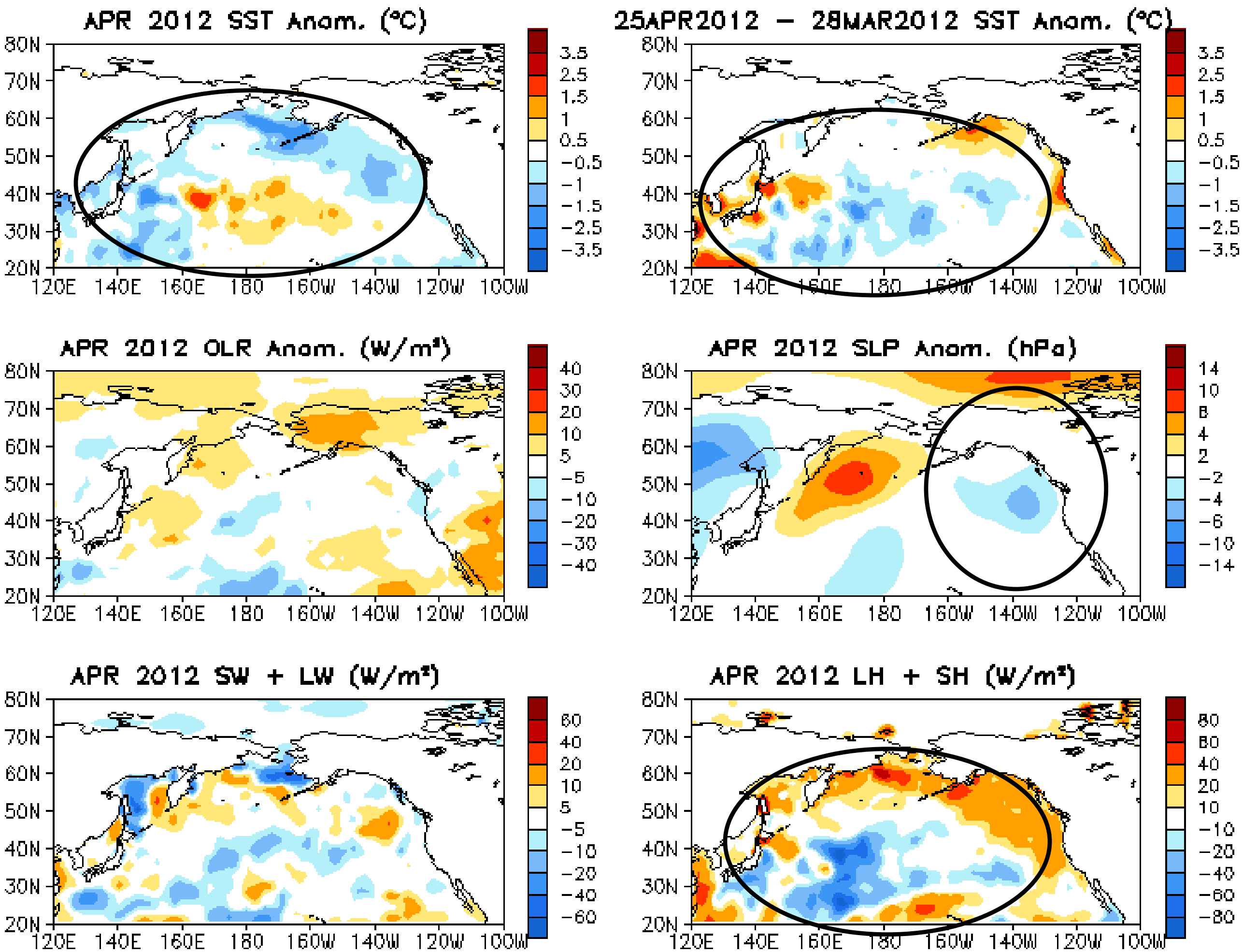
- The negative PDO index weakened in Apr 2012 with PDO index =-0.66.

- 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.

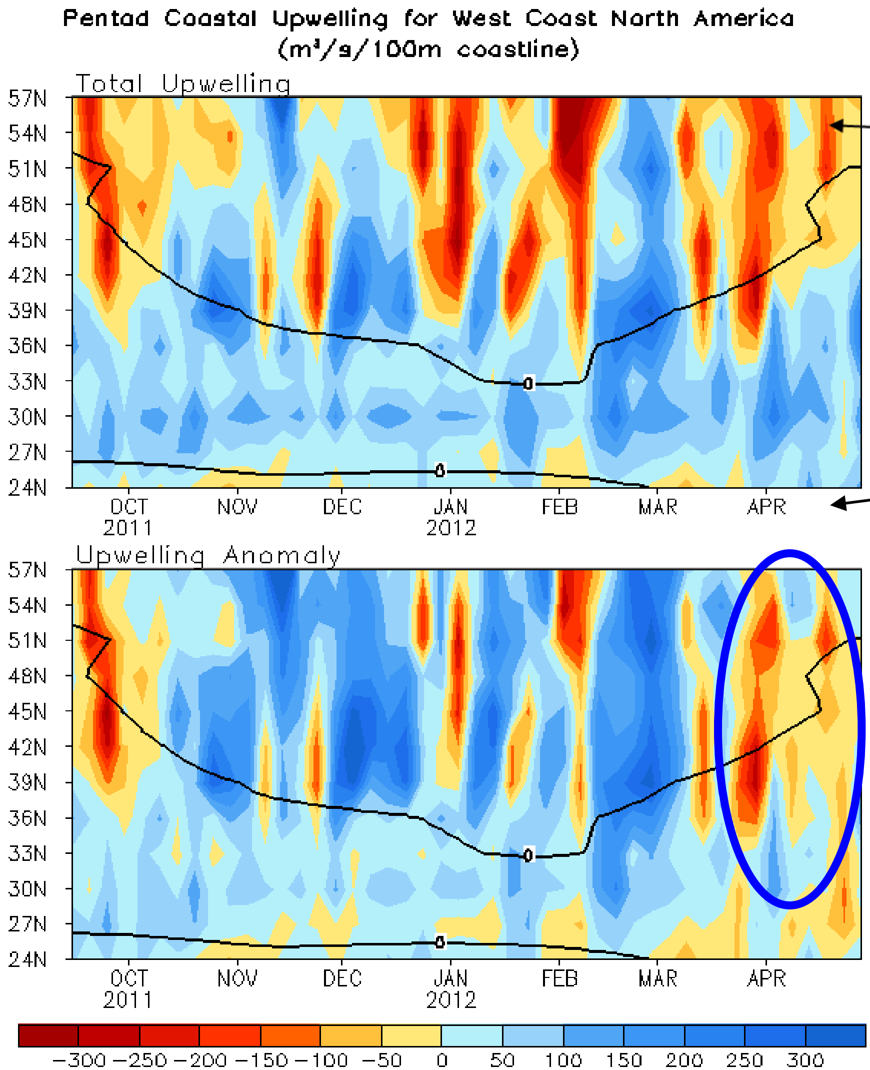
North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

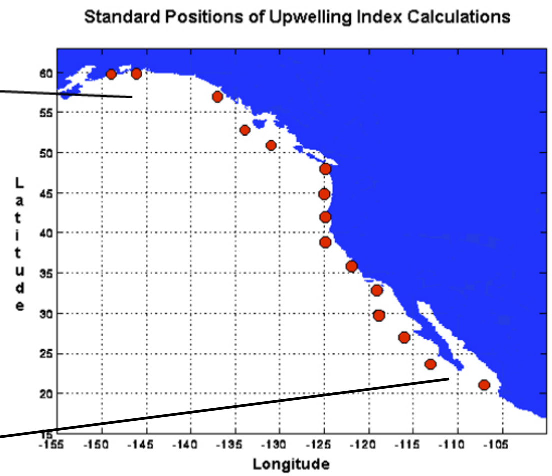


- **Positive (negative) SSTA presented in the central (western& northern) N. Pacific, consistent with the negative PDO index (previous slide).**
- **PDO associated SSTA weakened, largely due to net surface heat flux anomalies.**
- **The sea level pressure gradient between the land and ocean may cause southerly wind anomalies along the coast.**

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 downwelling dominated since late Mar 2012.

- This is consistent with anomalous southerly wind along the coast.

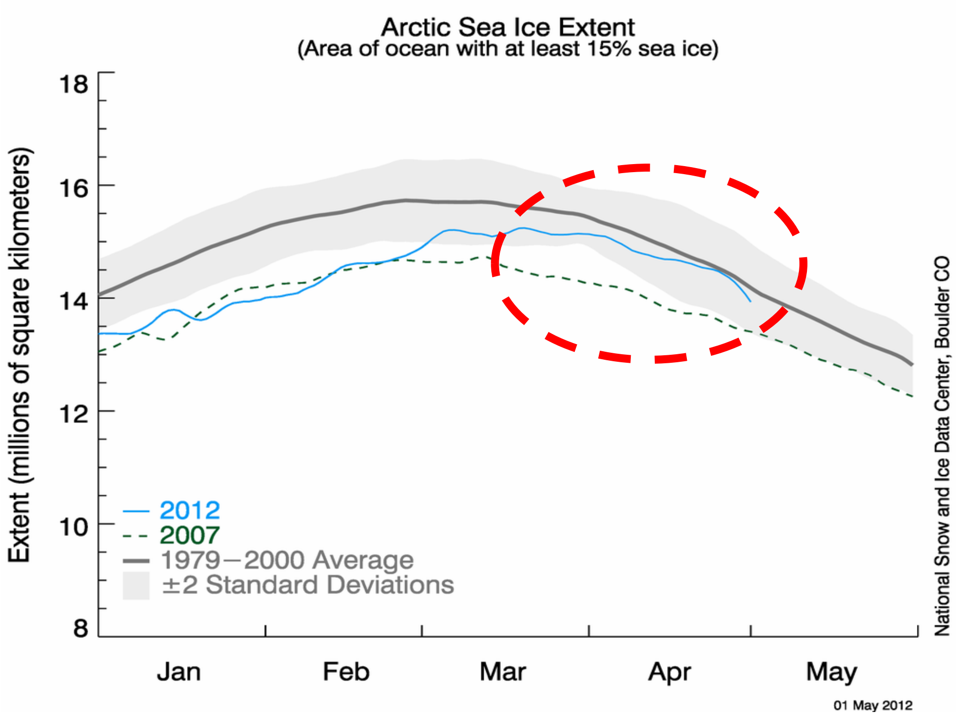
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

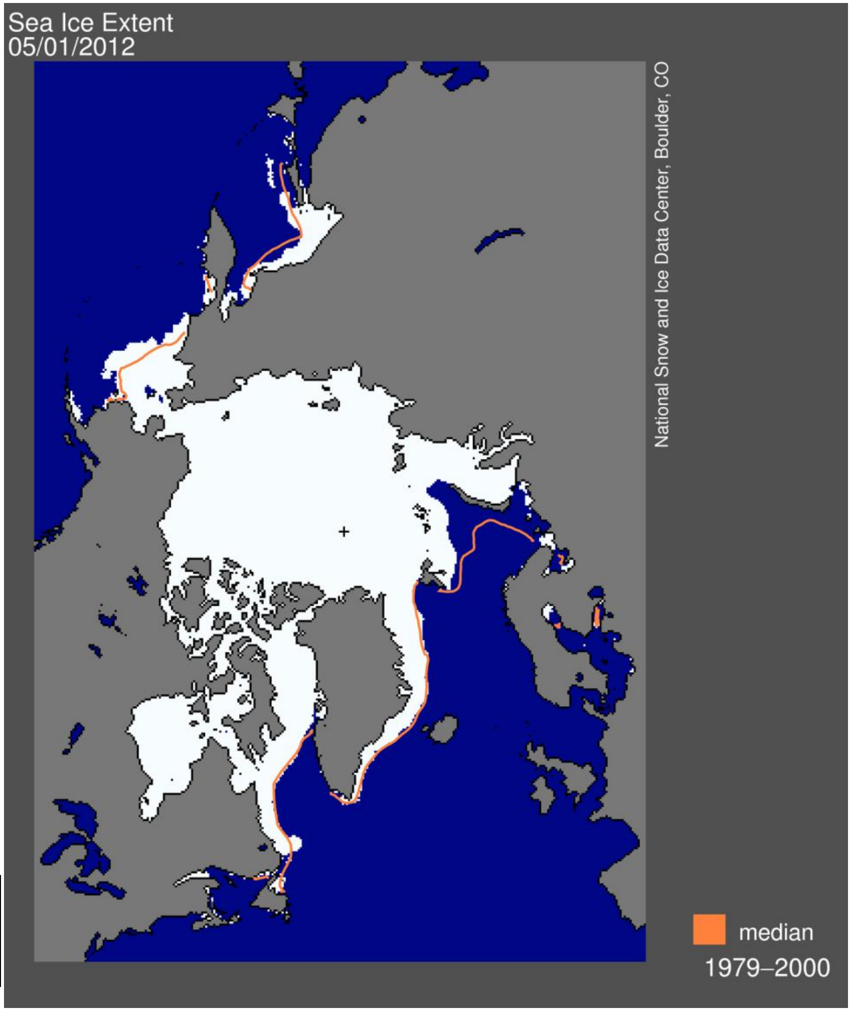
- Area below (above) black line indicates climatological upwelling (downwelling) season.

- Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.

Arctic Sea Ice

National Snow and Ice Data Center
http://nsidc.org/arcticseaicenews/index.html

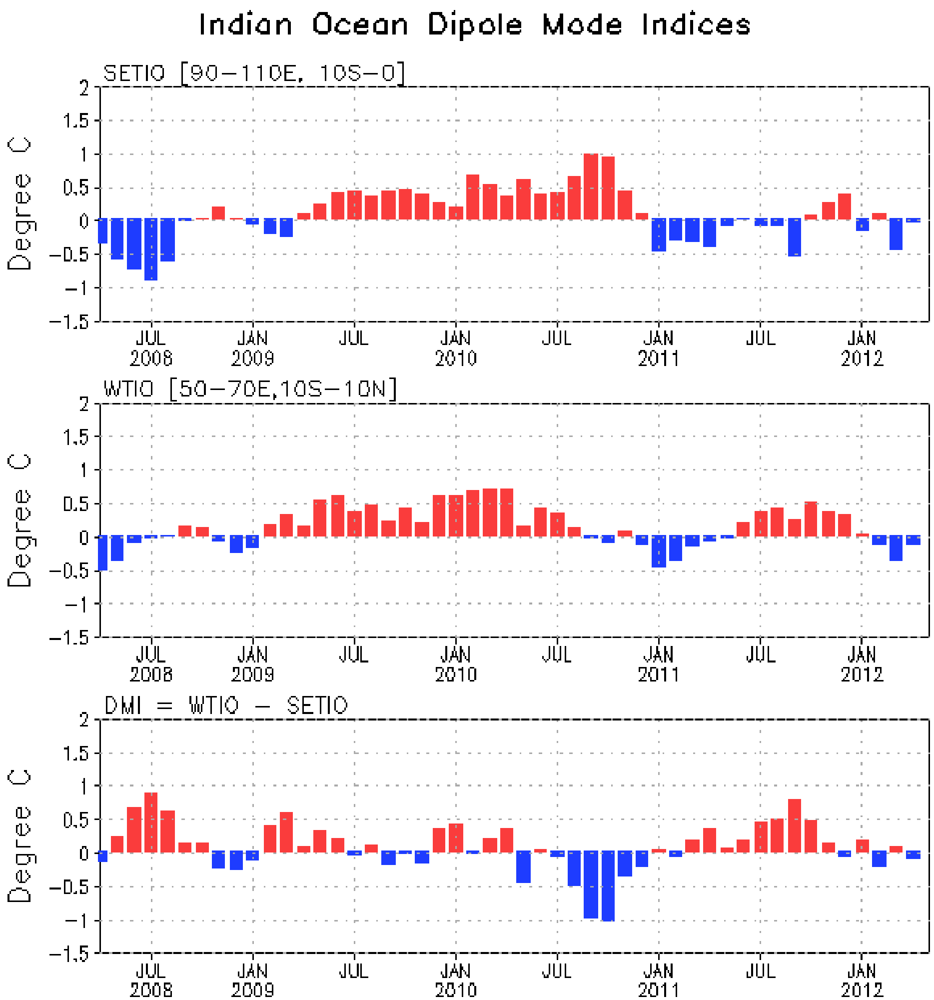


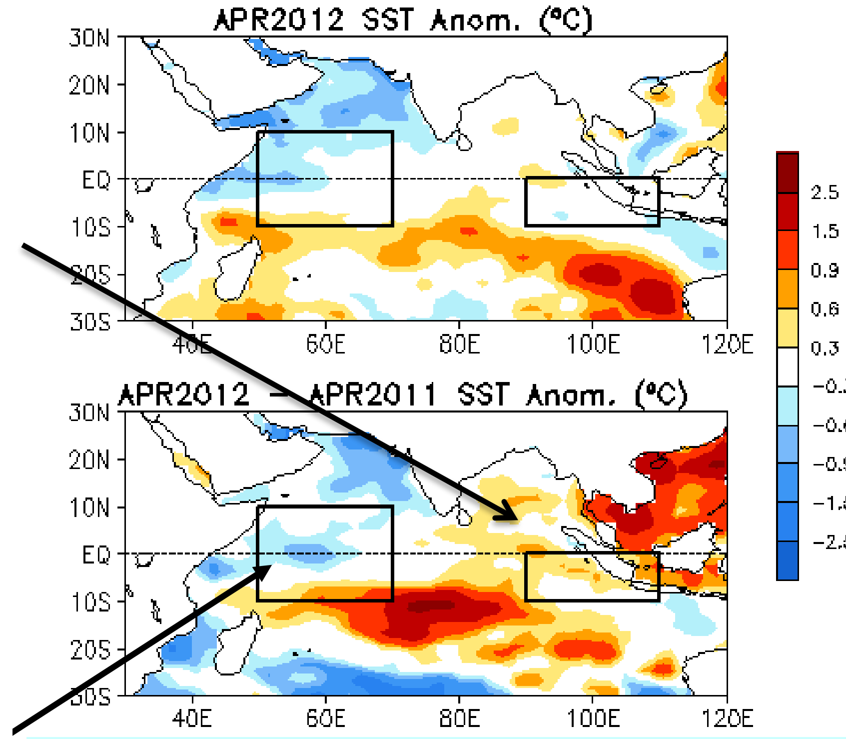


- In Apr 2012, Arctic sea ice extent was slightly below the long-term climatology.

Indian Ocean

Evolution of Indian Ocean SST Indices





- **Negative SSTA presented in the NW and along the equator W. Indian Ocean.**
- **Compared with 2011, NW Indian Ocean was cooler and tropical S. Indian Ocean was warmer.**
- **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.

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

- Negative (positive) SSTA presented in the NW (SE).
- Convections were enhanced (suppressed) over the extra-equator (along the equator).

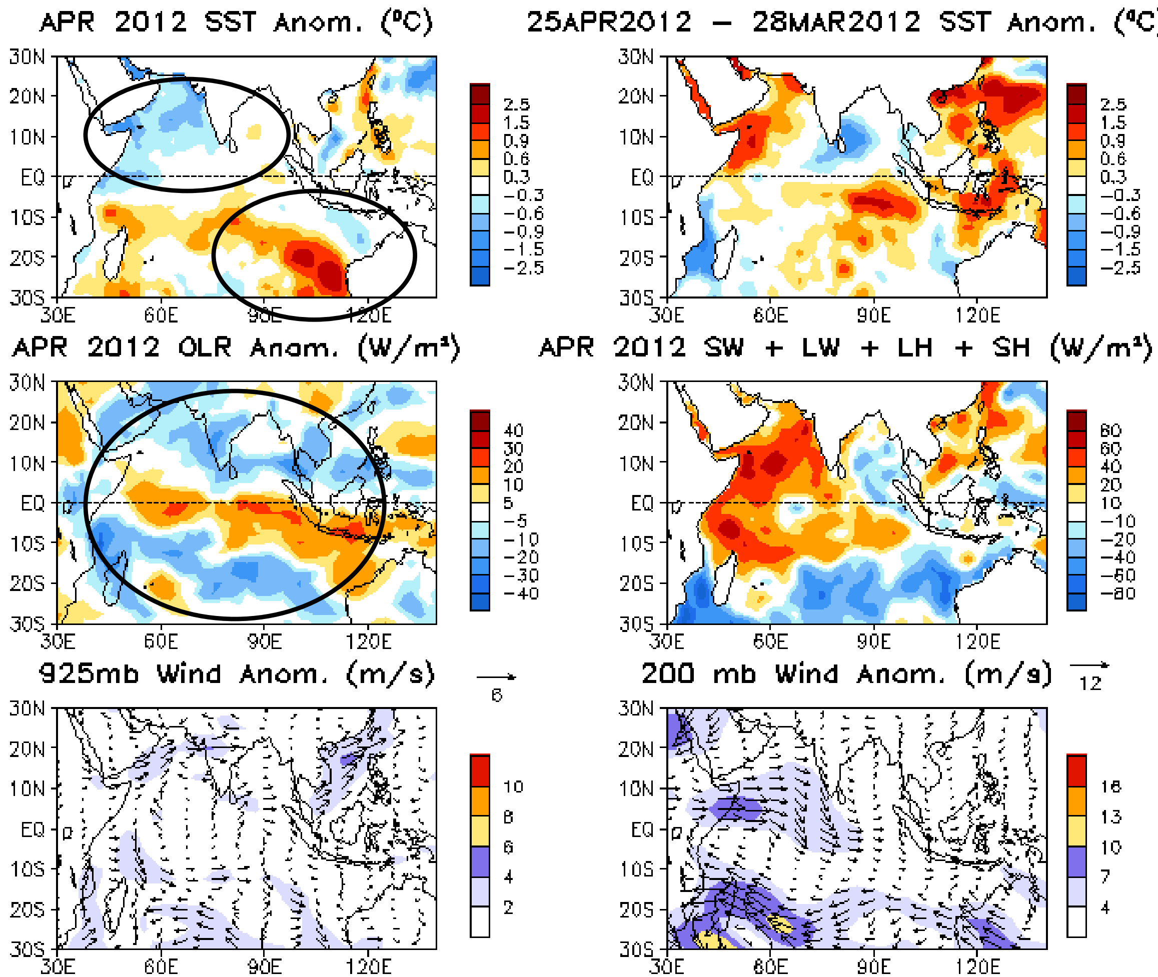
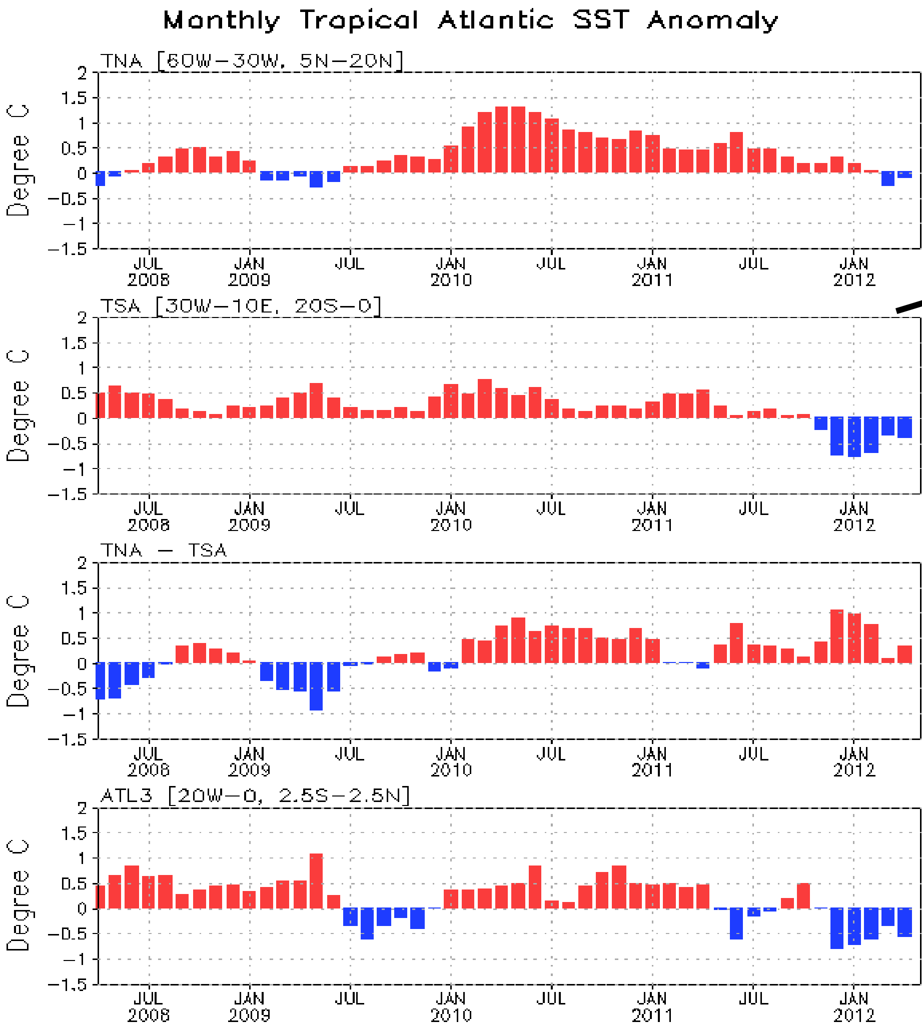
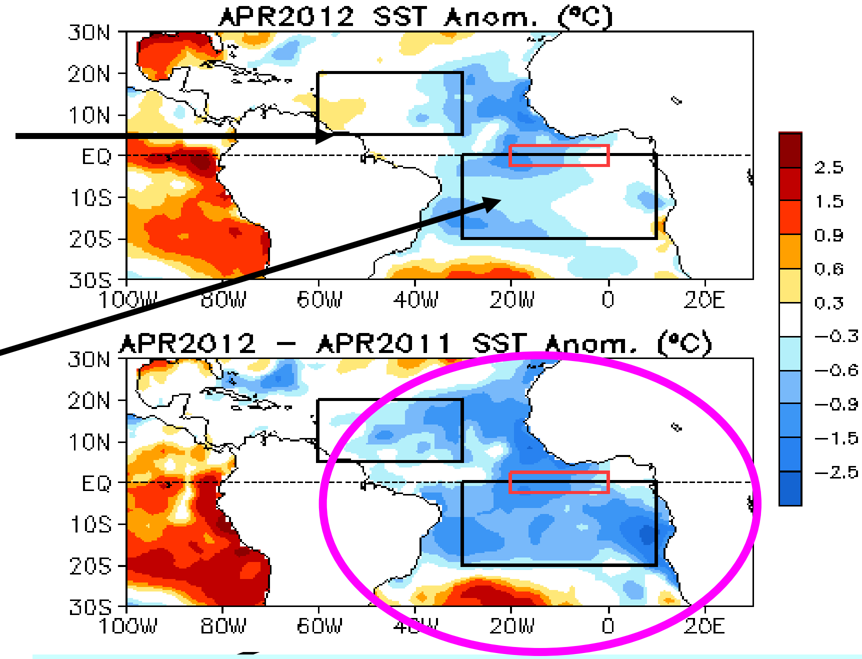


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

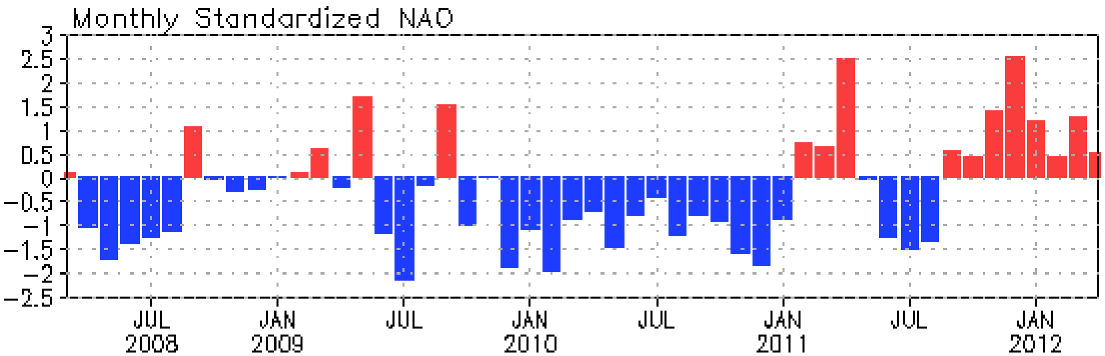


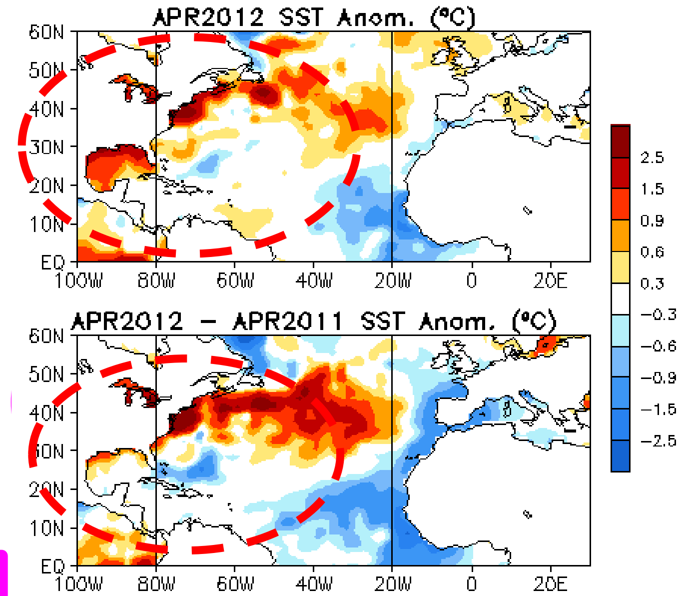


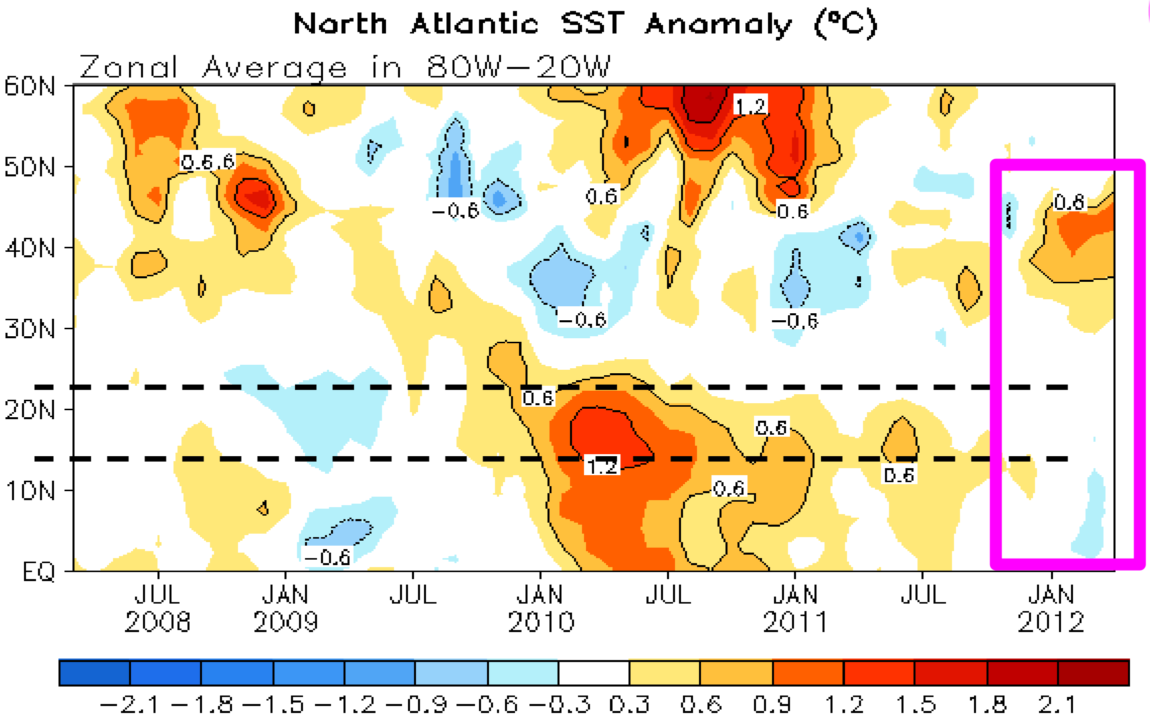
- **SSTA in the tropical North Atlantic (TNA) was minor positive in the west and negative in the east.**
- **Tropical South Atlantic (TSA) has cooled down substantially since Dec 2011, and the cooling persisted in Apr 2012.**
- **Meridional Gradient Mode index (TNA-TSA) was positive in Apr 2012.**
- **ATL3 SSTA has been negative since Dec 2011 and persisted in Apr 2012.**
- **Tropical Atlantic in Apr 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.

NAO and SST Anomaly in North Atlantic



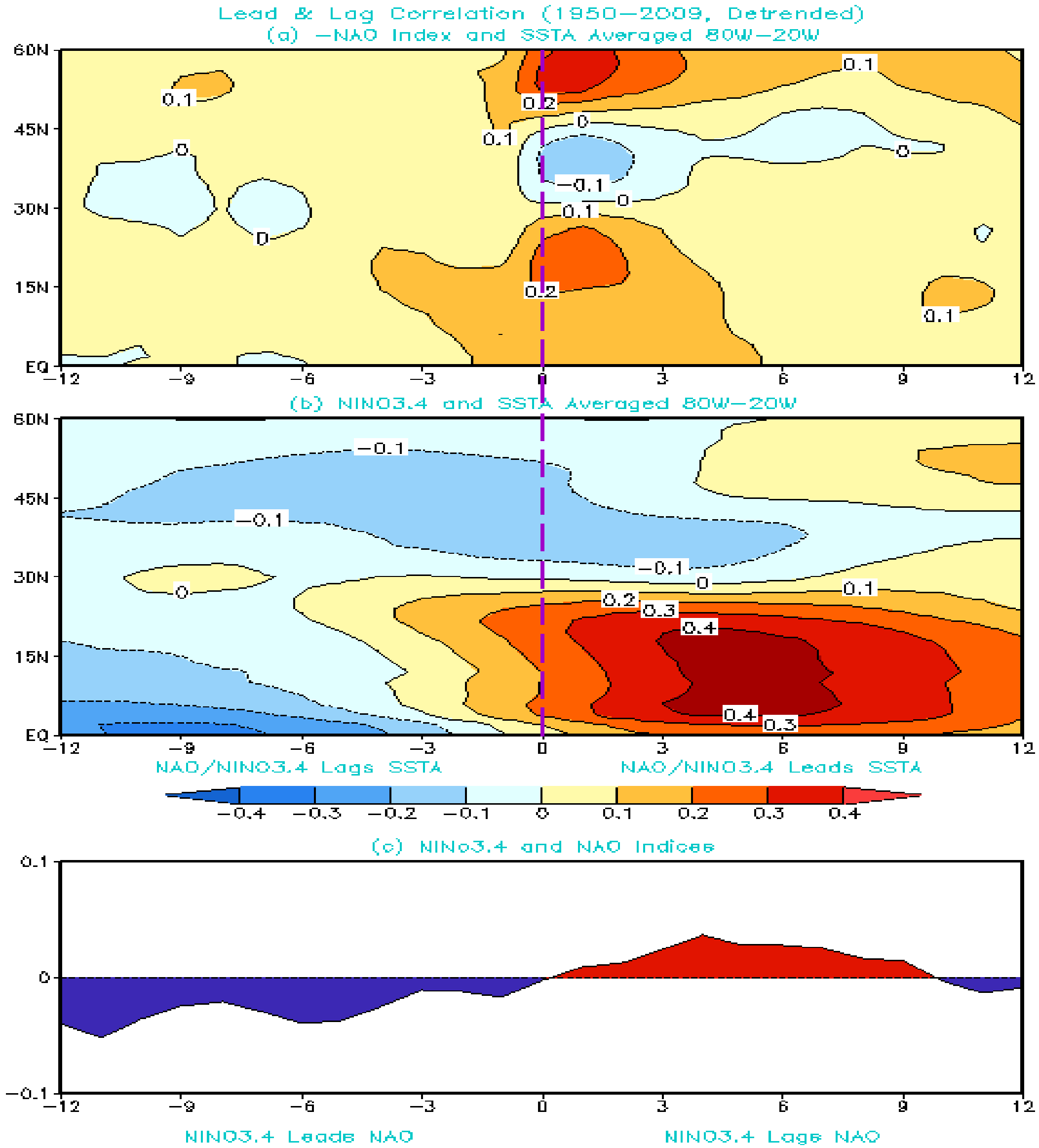




- **Positive phase of NAO weakened in Apr 2012, with NAOI=0.47.**
- **Since Jan 2012, positive (negative) SSTA developed in the mid-latitude (tropical) North Atlantic SSTA , probably due to the impact of La Nina and positive phase of NAO.**
- **Positive SSTA along the American Atlantic coast persisted in Apr 2012.**

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.

Historical Connection of SST with Nino3.4 & NAO



NAO's impact on SST is mainly with 0-3 month lag. The NAO correlation is weaker than that of ENSO.
The tripole or horseshoe pattern is consisted with the observed SSTA in previous slide.

ENSO signals propagate into the tropical N. Atlantic in 3-8 months late.
ENSO affects the trade wind through atmosphere (PNA), then changes the SST through WES mechanism.

Preceding El Nino may slightly favor to negative phase of NAO.

Based on the statistical relations and current observed evidences (La Nina decay phase and positive NAO), it might suggest a unfavorable environment for the hurricane generation in the coming summer and fall.

From:
Hu, Z.-Z., A. Kumar, B. Huang, Y. Xue, W. Wang, and B. Jha, 2011: Persistent atmospheric and oceanic anomalies in the North Atlantic from Summer 2009 to Summer 2010. J. Climate, **24(22)**, 5812-5830, DOI: 10.1175/2011JCLI4213.1

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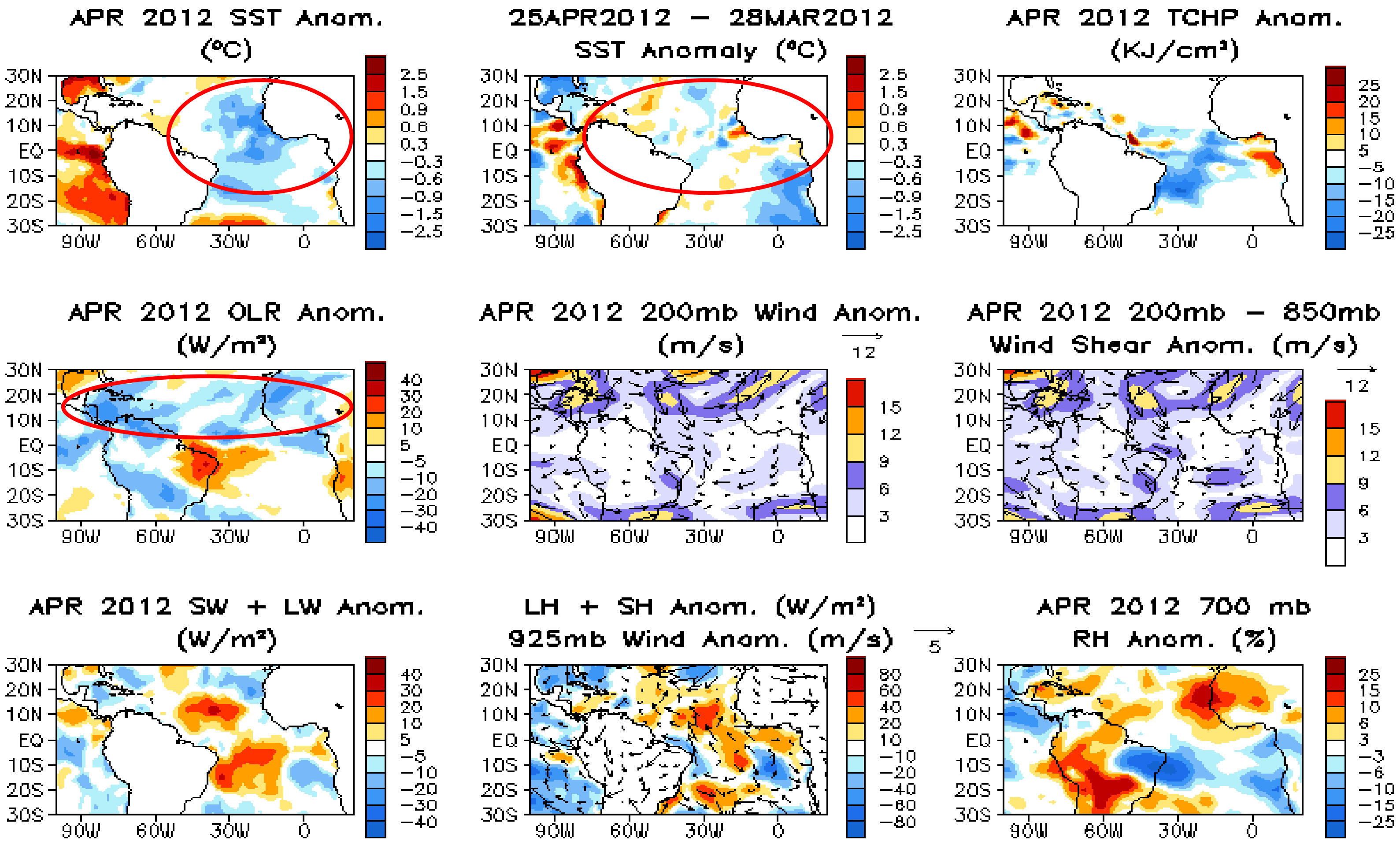
Tropical Atlantic:



- Negative SSTA presented in the tropical Atlantic, probably due to the lagged impact of La Nina as well as the impact of positive phase of NAO.

- Both positive and negative SSTA tendencies presented with small amplitudes in the tropical N. Atlantic.

- Gulf of Mexico was cooling down, largely due to LH+SH heat flux.

- Convections enhanced over the tropical N. Atlantic.

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

- Positive SSTA presented in the mid-latitudes of N. Atlantic and along the American coast.

- SSTA tendency showed a horseshoe-like pattern in the N. Atlantic.

- Gulf of Mexico and US coast regions were cooling down, largely due to LH+SH heat flux.

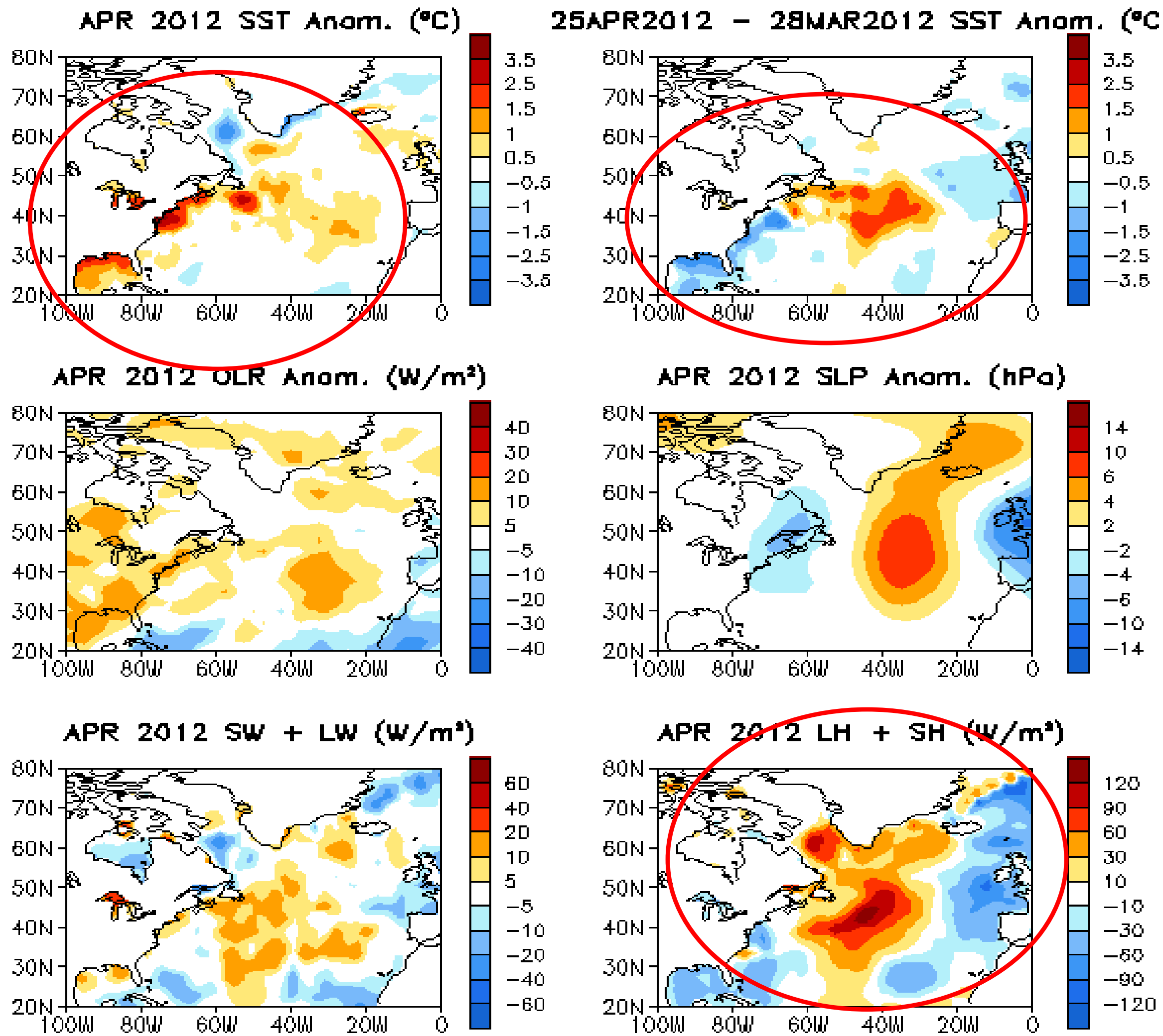


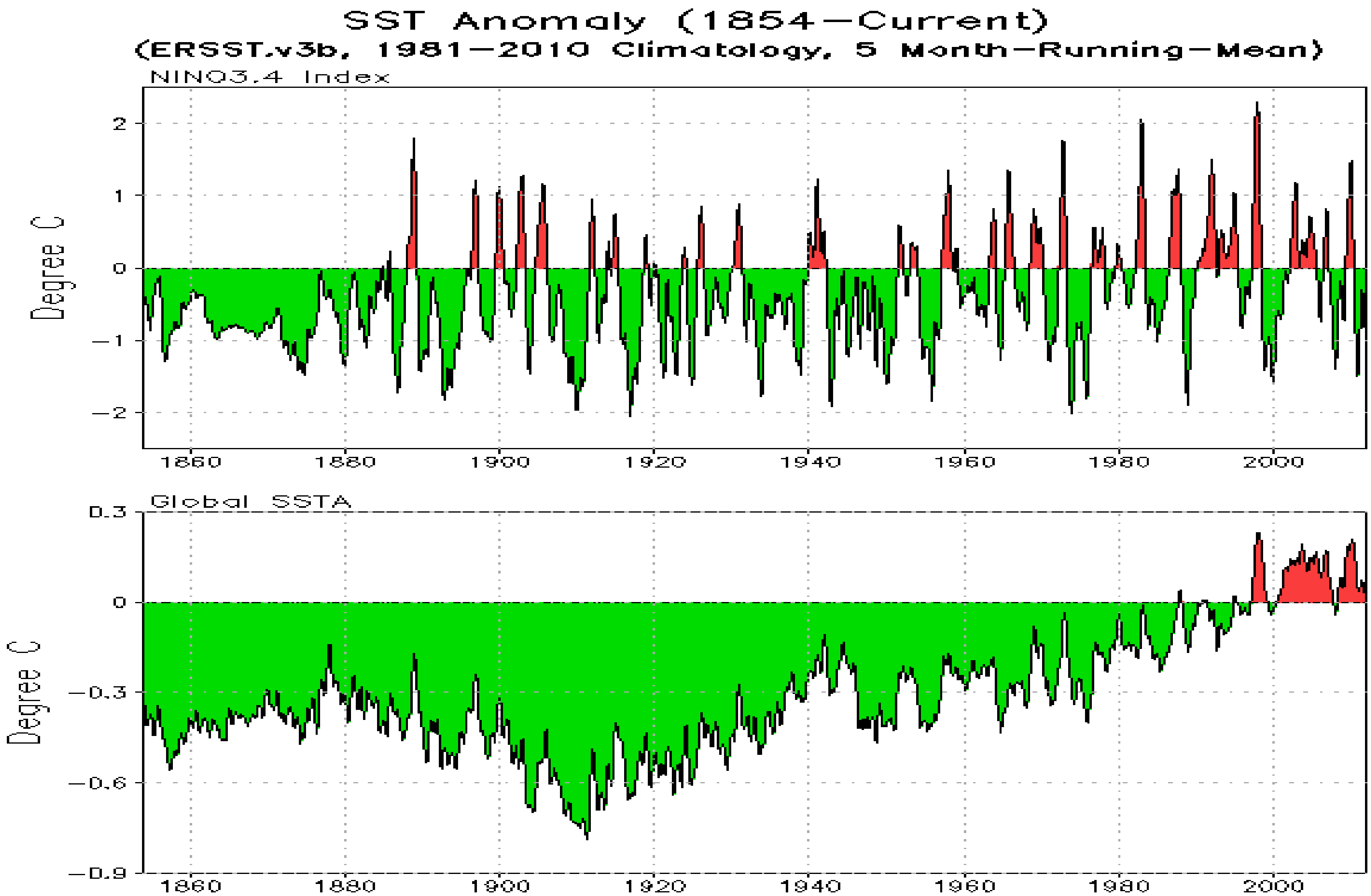
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

Potential Influence of Low Frequency Variations on ENSO and Ocean Monitoring

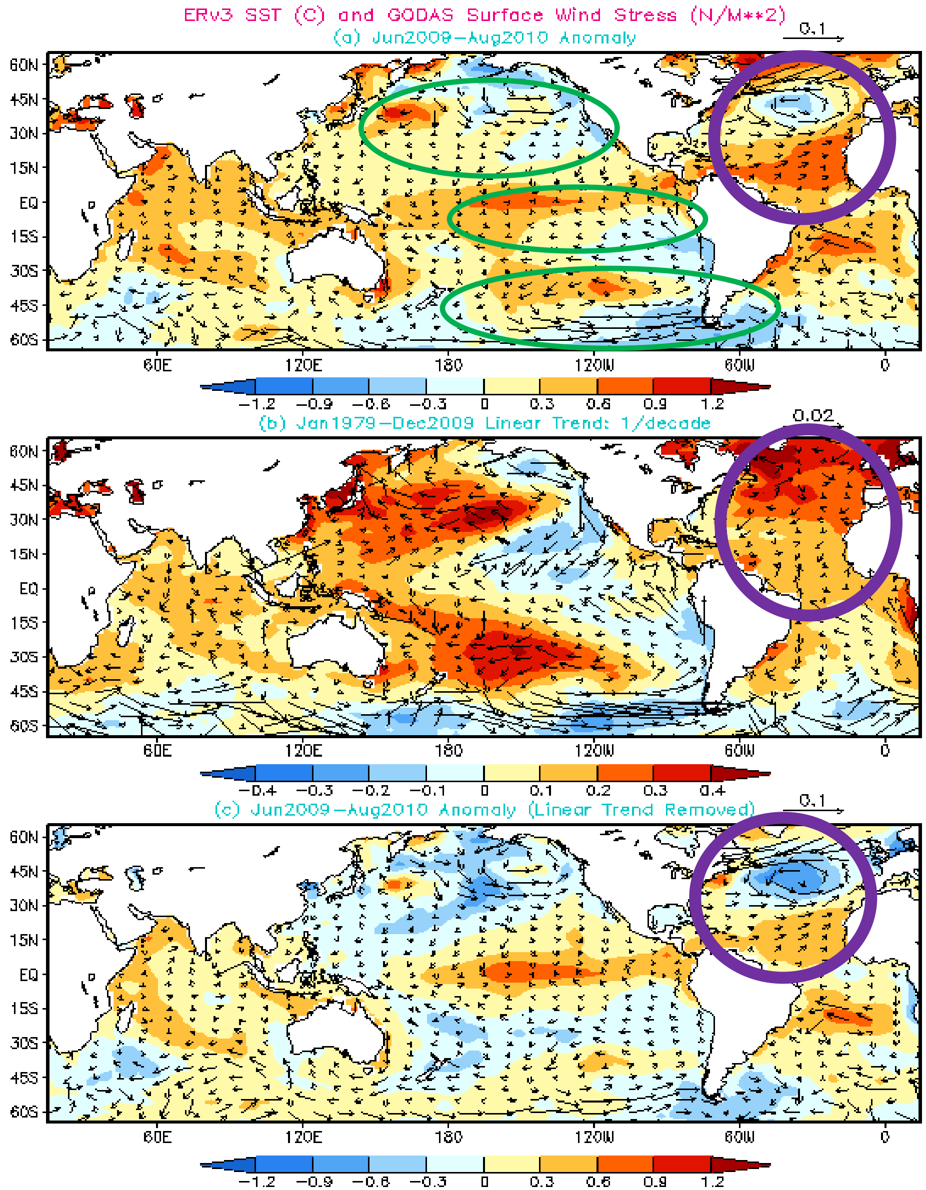
How to separate seasonal-interannual variability signal from long-term trend?

Ocean is warming!

Warming trend was less significant in NINO34 region than the global average



Global Anomalies of SST and Wind Stress and their Linear Trends



Mean SSTA in Jun2009-Aug2010:

Warming in tropics and high latitudes and cooling in mid-latitudes of N. Atlantic

Linear Trend of SSTA in Jan1979-Dec2009:

Warming in North Atlantic, Western Pacific, Indian Ocean

Cooling in eastern Pacific and high latitudes of SH

Is this a global warming pattern?

Central value of averaged SSTA is between -0.6 and -0.9 ^{o}C for the negative SSTA in the mid-latitudes, and 0.6 and 0.9 ^{o}C for the positive SSTA in the low latitudes. The corresponding values are between -0.9 and -1.2 ^{o}C, and between 0.3 and 0.6 ^{o}C after the linear trend removed.

Thus, the long-term trend may account for about 1/3 of the warming in the tropical Atlantic and weakens the cooling in the middle latitudes of the North Atlantic by about 1/3.

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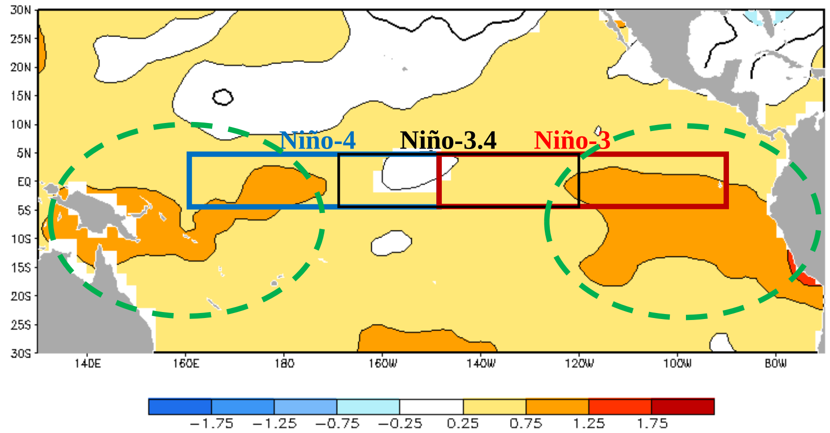
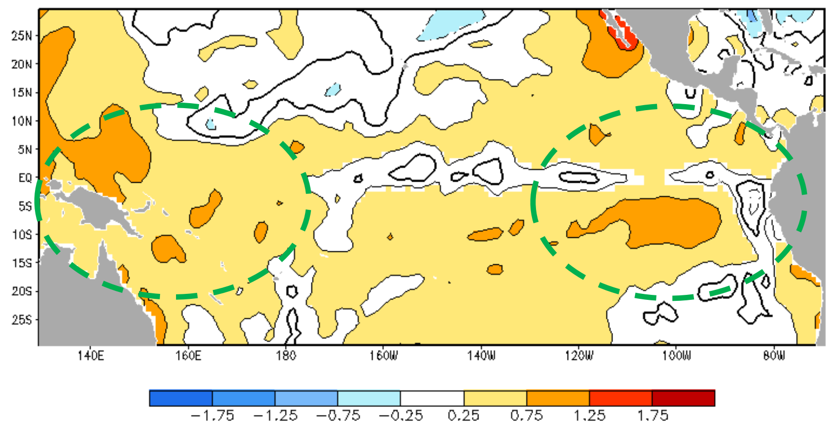
Linear SST Trends from 1950-2010 (all months)

ERSSTv3b monthly data (2° x2°)
- Smith et al. (2008)
- no satellite data



From L'Heureux et al. (2012, on-line at *Climate Dynamics*)

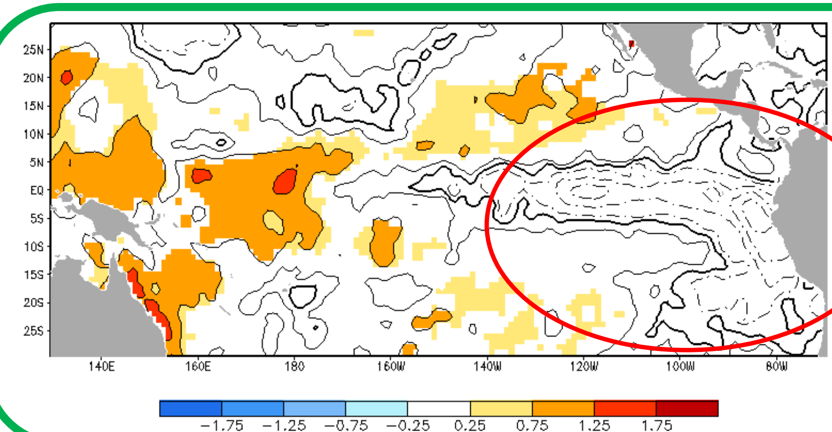
HadISST monthly data (1° x1°)
- Rayner et al. (2003)



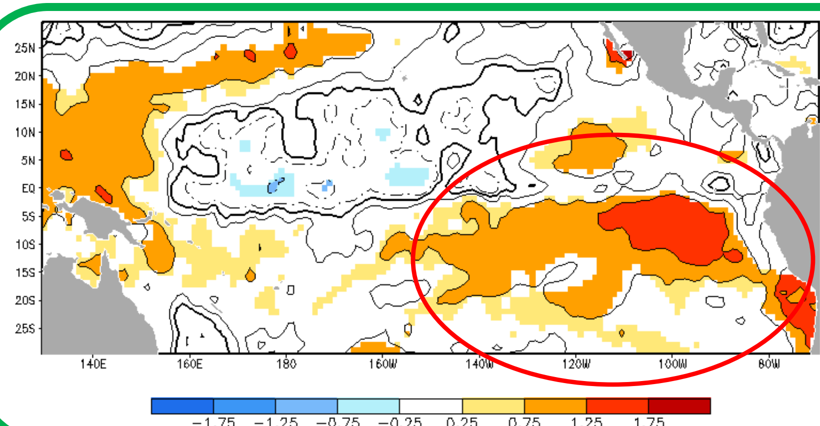
- Warming trends are dominated.
- General consistency between datasets with <u>greatest warming in the western and eastern Pacific</u> with <u>insignificant or small trends over the central Pacific</u>.

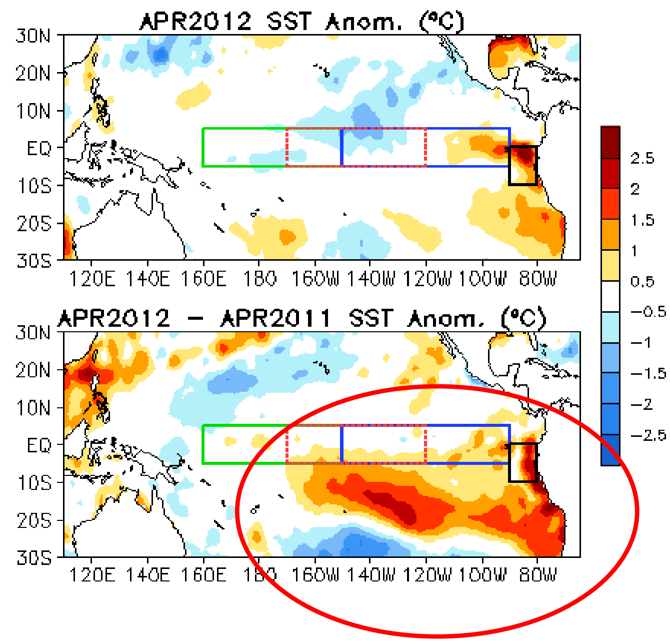
The longer-term trends depend on season and ENSO phase

SST trends during July-September (El Niño only)

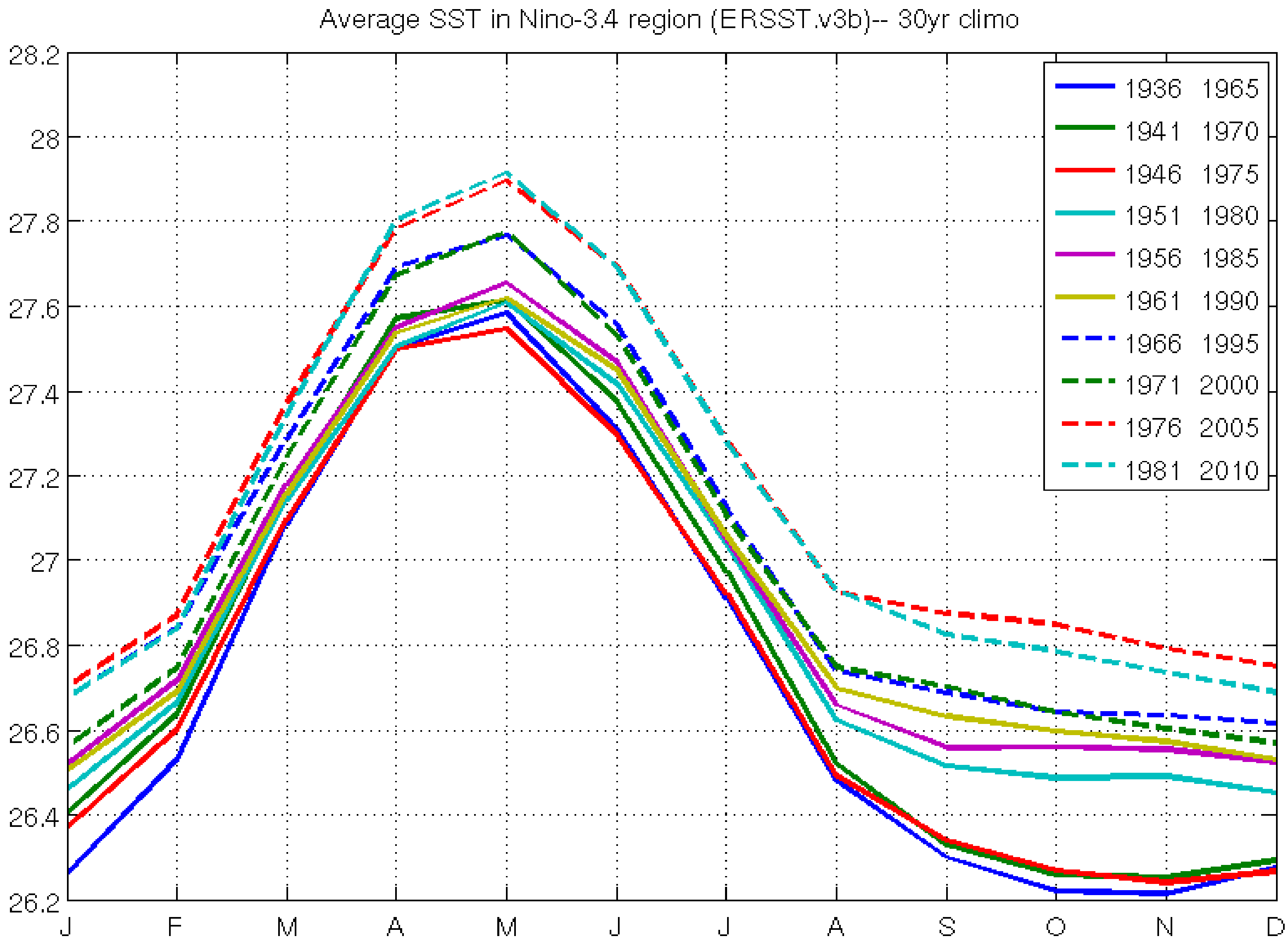


SST trends during March-May (La Niña only)

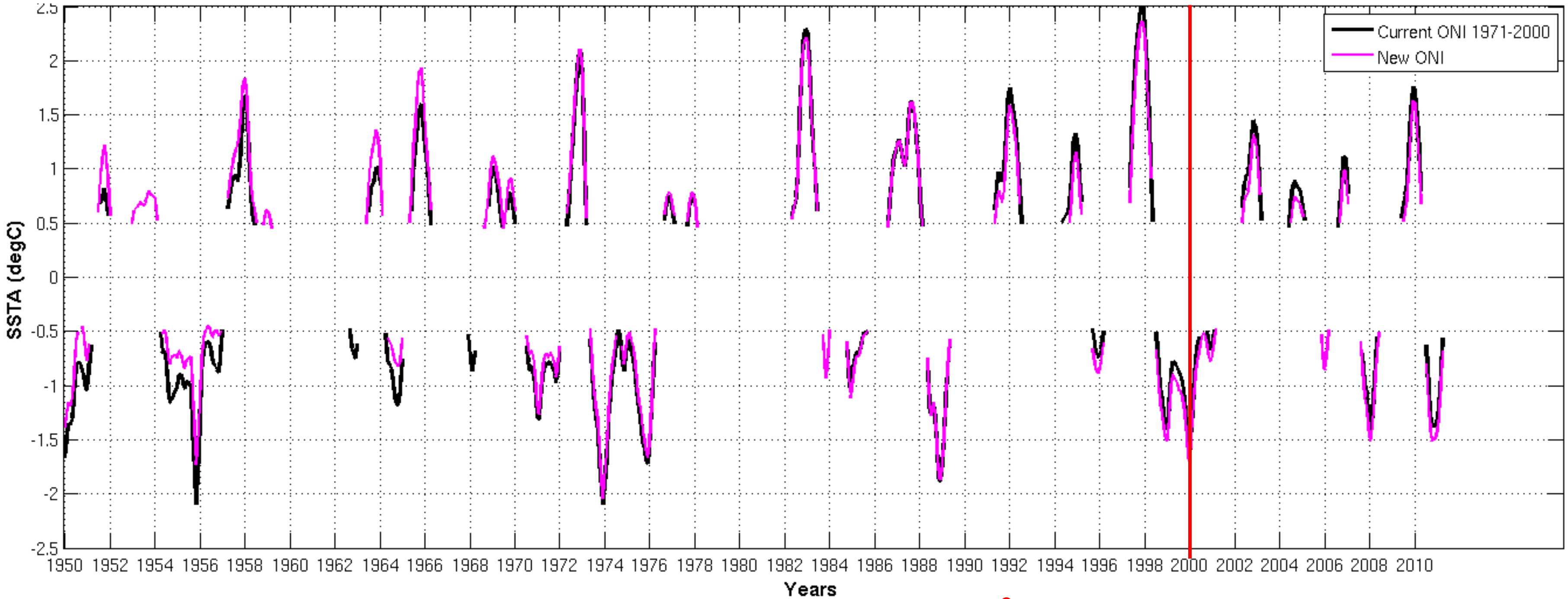




Change of 30-year climatology in NINo34 region



ENSO Episodes using the "New ONI" (pink) or the "Current ONI" (black)



Via this new method, the ENSO episode classifications prior to 2000 will remain <u>unchanged</u> in future base period updates.

<u>The switch to the "New ONI" results in:</u>

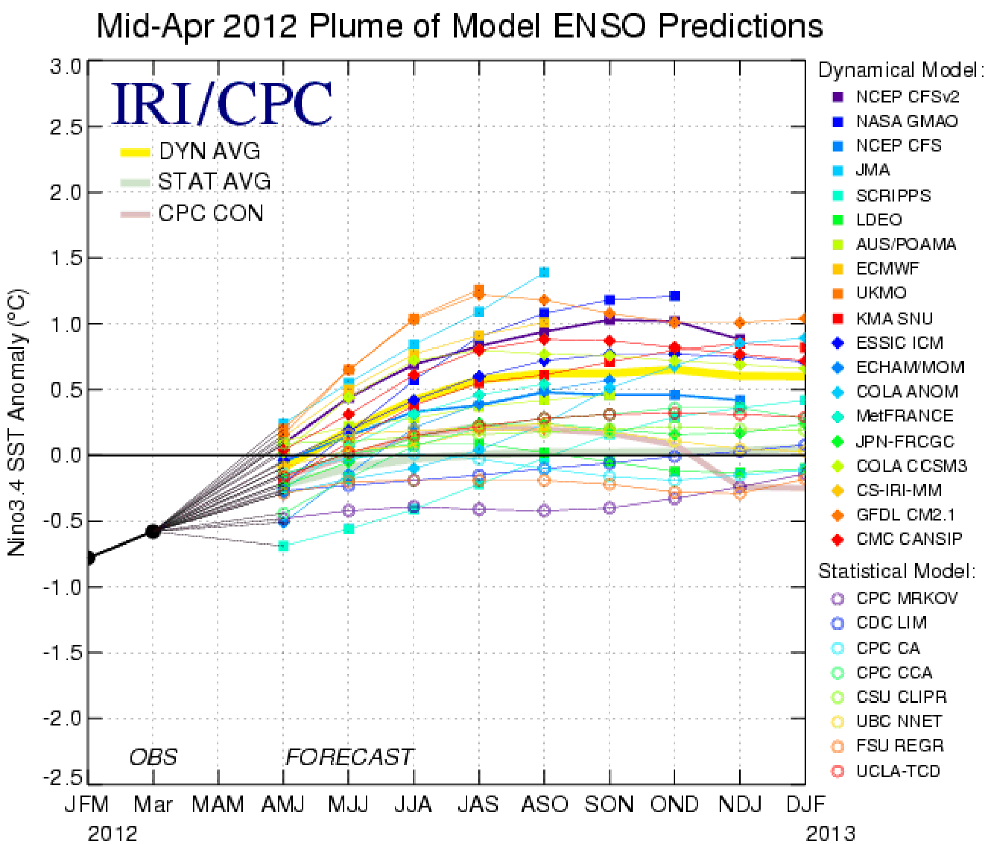
Gain of 2 El Nino Episodes: 1953-54 / 1958-59
Loss of 0 El Nino Episodes

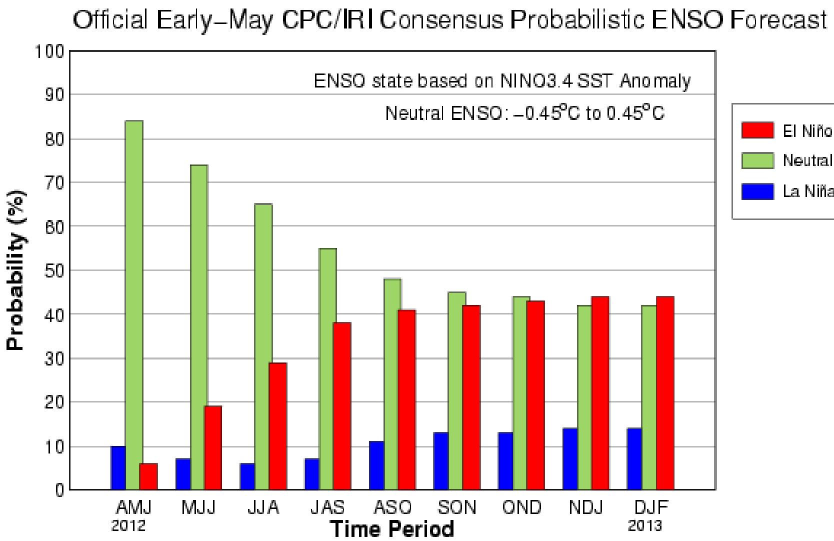
Gain of 2 La Nina Episodes: 1983-84 / 2005-06
Loss of 2 La Nina Episodes: 1962-63 / 1967-68

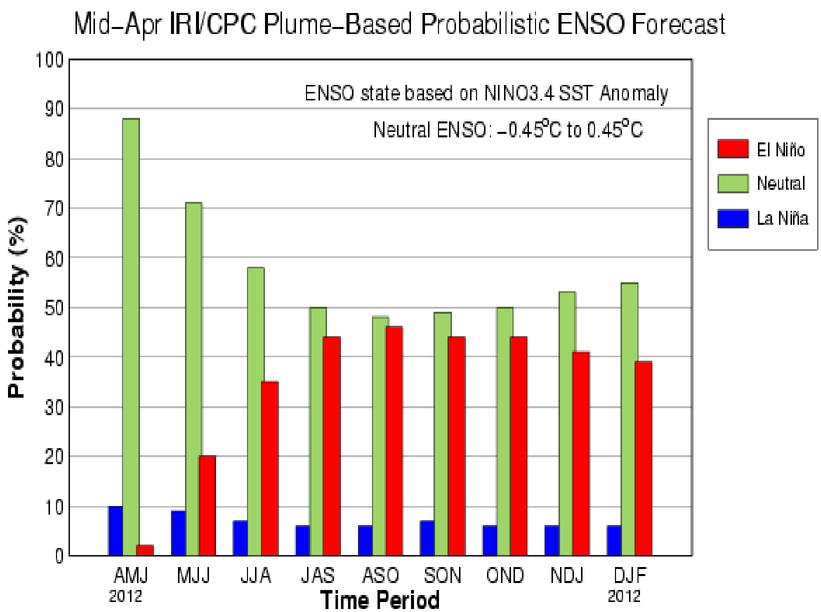
- Also, in the early part of the record (mostly pre-1966), the amplitude of La Ninas have weakened, while the amplitude of El Ninos has strengthened.
- In later part of the record (mostly post-1991), there is a slight strengthening of La Ninas, while the amplitude of El Ninos have weakened.

Global SST Predictions

IRI NINO3.4 Forecast Plum

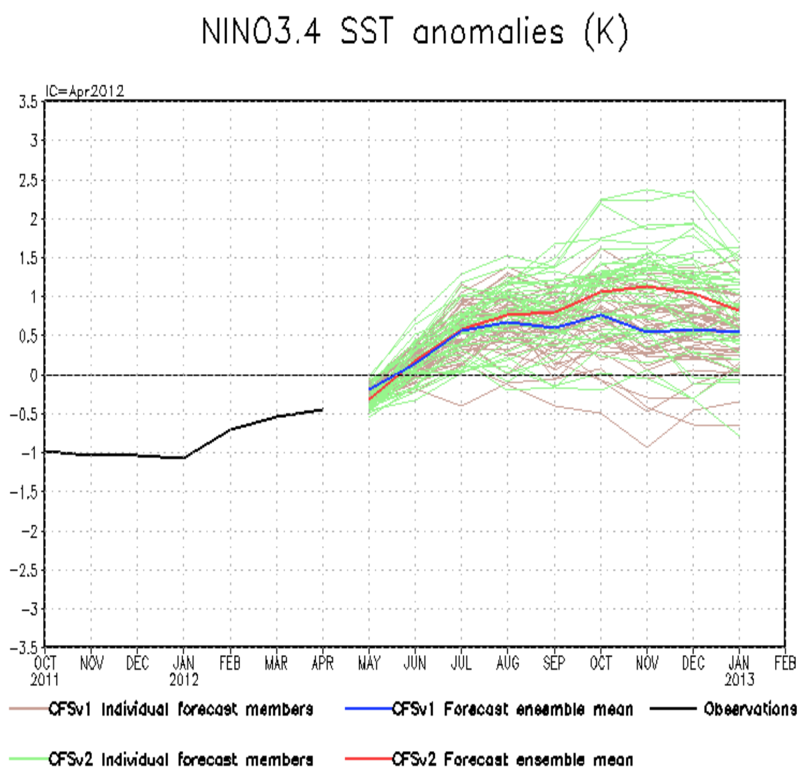


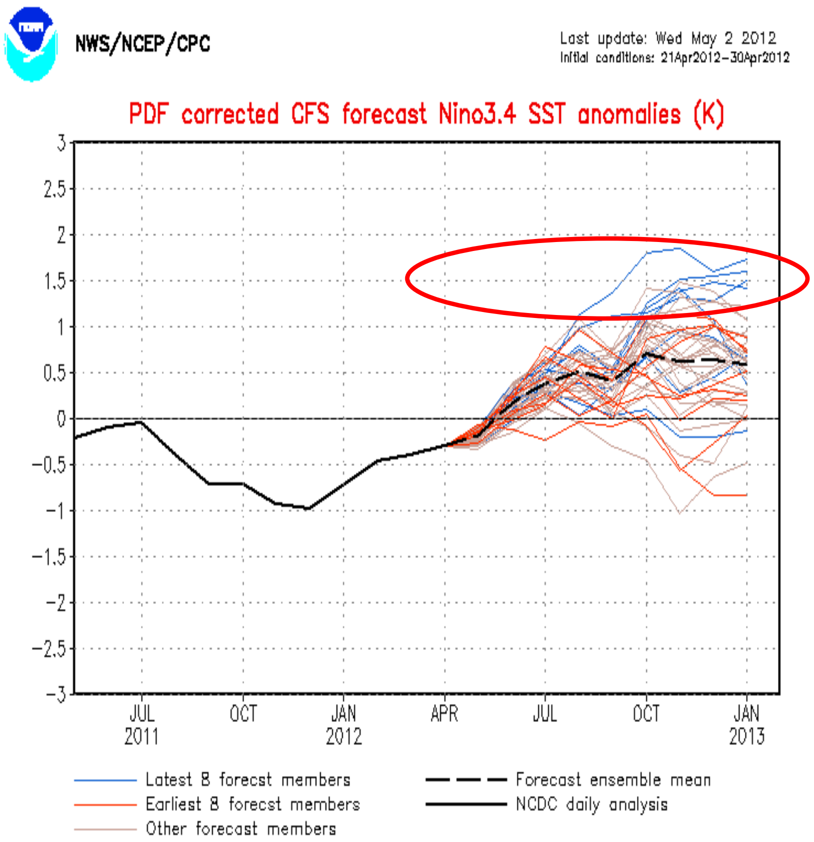




- **A majority of models predicted that ENSO is in neutral phase before summer 2012.**
- **After spring 2012, model predictions have large spread. Some models predicted an El Nino since this summer.**
- **Official probabilistic forecast slightly favors an El Nino in winter 2012/2013.**
- **NOAA "ENSO Diagnostic Discussion" in May suggests that ENSO-neutral conditions continue through north summer 2012.**

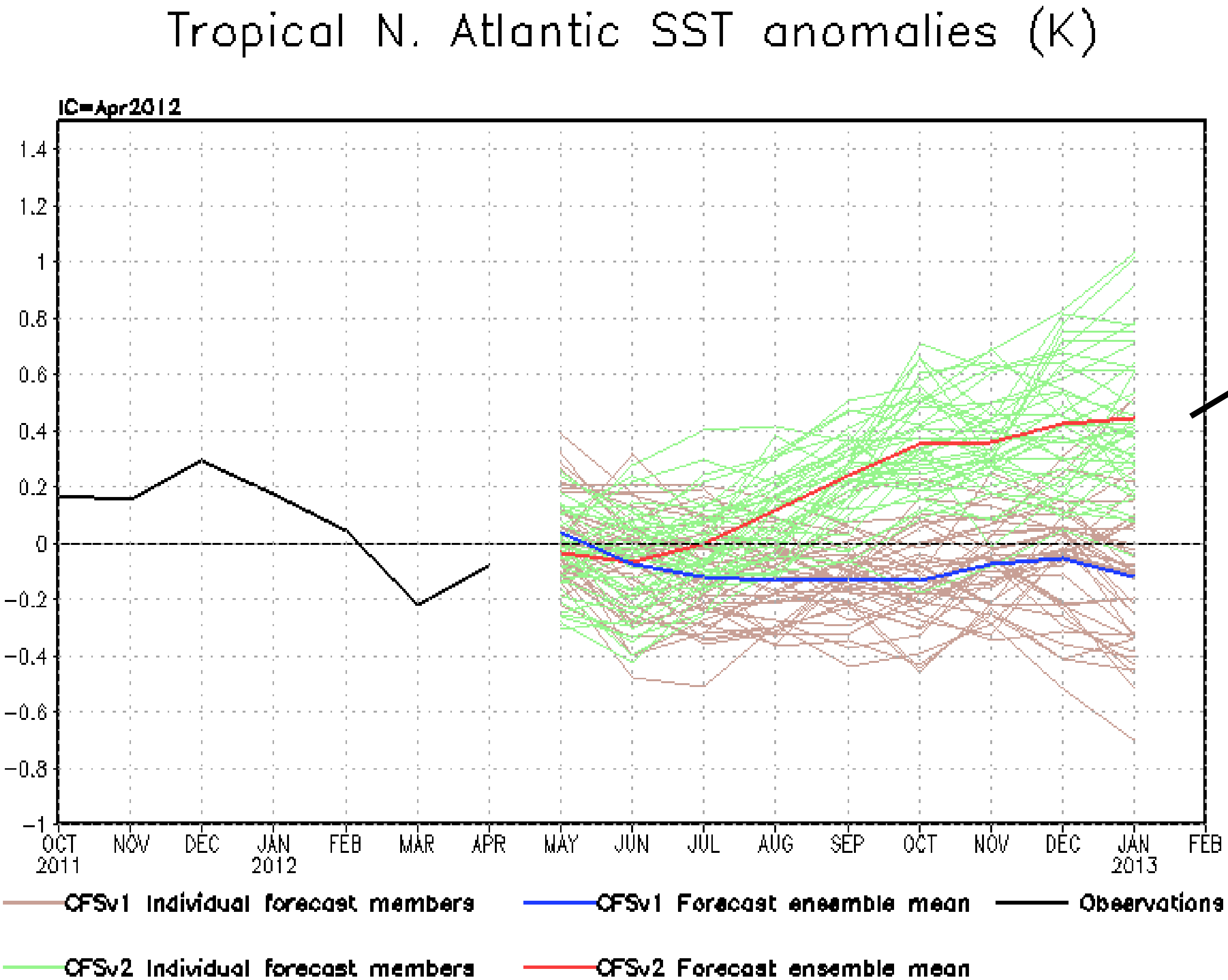
NCEP CFSv1 and CFSv2 NINO3.4 Forecast (IC=*201205*)

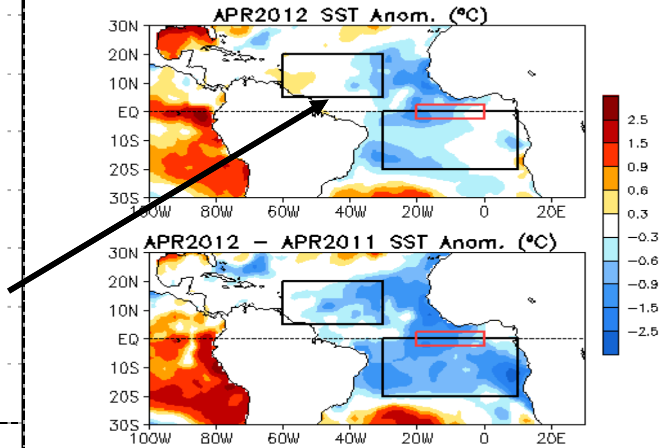




- Both CFSv1, CFSv2, and PDF corrected CFSv1 predicted ENSO neutral-conditions in spring and early summer, while CFSv2 prediction is warmer than that of CFSv1 after summer 2012.
- CFSv2 and latest 8 forecasts of CFSv1 predicted an El Nino since summer 2012.

NCEP CFSv1 and CFSv2 Tropical North Atlantic SST Forecast





- **CFSv1 predicted below normal SST and CFSv2 predicted above normal in 2012.**

Overview

- **Pacific Ocean**

➢ **ENSO has returned to neutral phase with NINO3.4=-0.4^{o}C in Apr 2012.**

➢ **NOAA "ENSO Diagnostic Discussion" in May suggests that ENSO-neutral conditions to continue through north summer 2012. A majority of ENSO models predict ENSO-neutral to continue through the NH summer 2012. Some models predict an El Nino beginning in summer 2012.**

➢ **Negative phase of PDO weakened, with PDOI=-0.66 in Apr 2012.**

- **Indian Ocean**

➢ **Positive (negative) SSTA was observed in the tropical southern (NW) Indian Ocean.**

- **Atlantic Ocean**

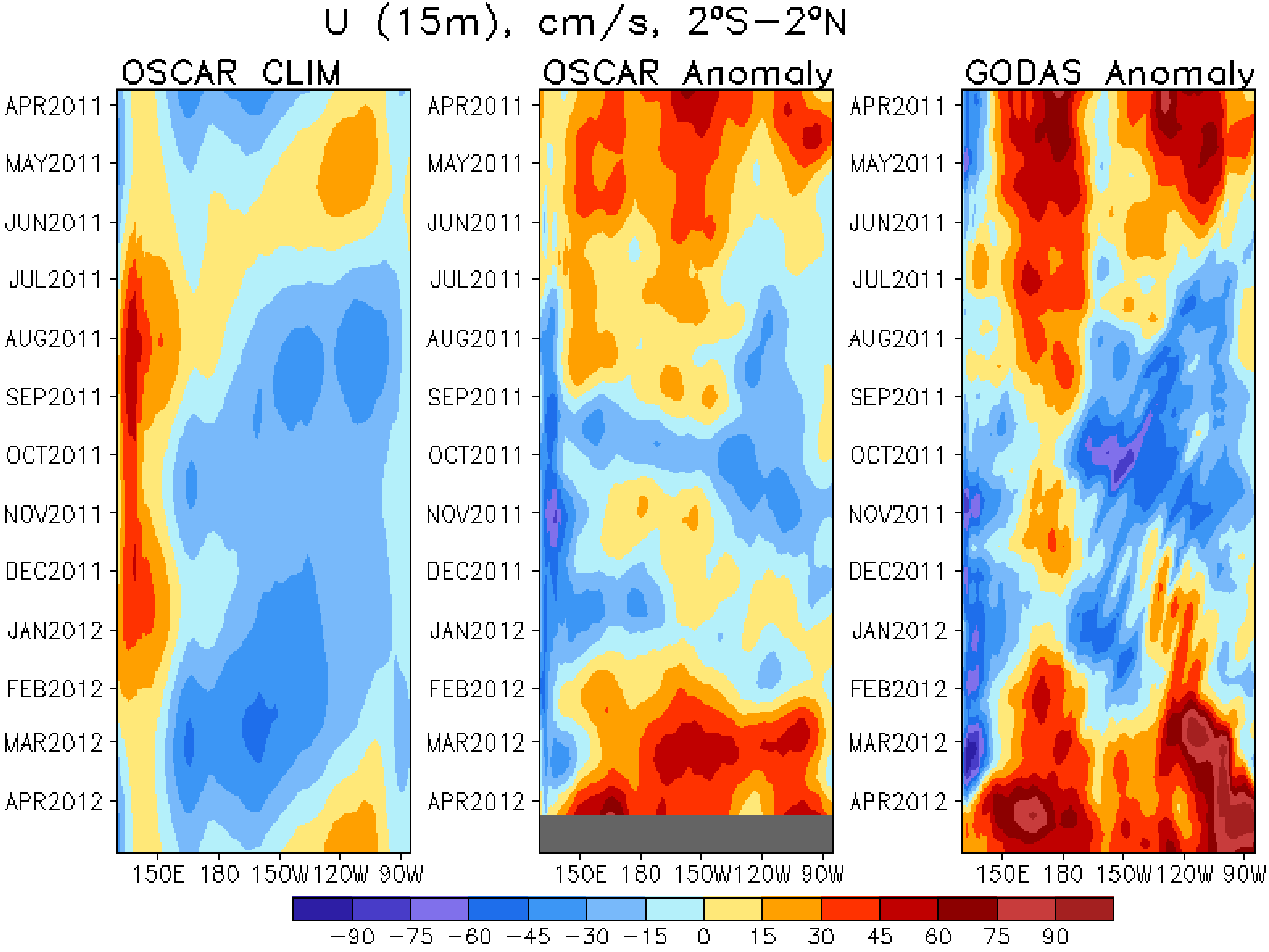
➢ **Positive NAO weakened with NAOI=0.47 in Apr 2012.**

➢ **SST cooled down (warmed up) over the tropical (mid-latitude of) North Atlantic, probably due to the impact of La Nina and positive phase of NAO.**

➢ **The cooling along the equatorial Atlantic persisted in Apr 2012.**

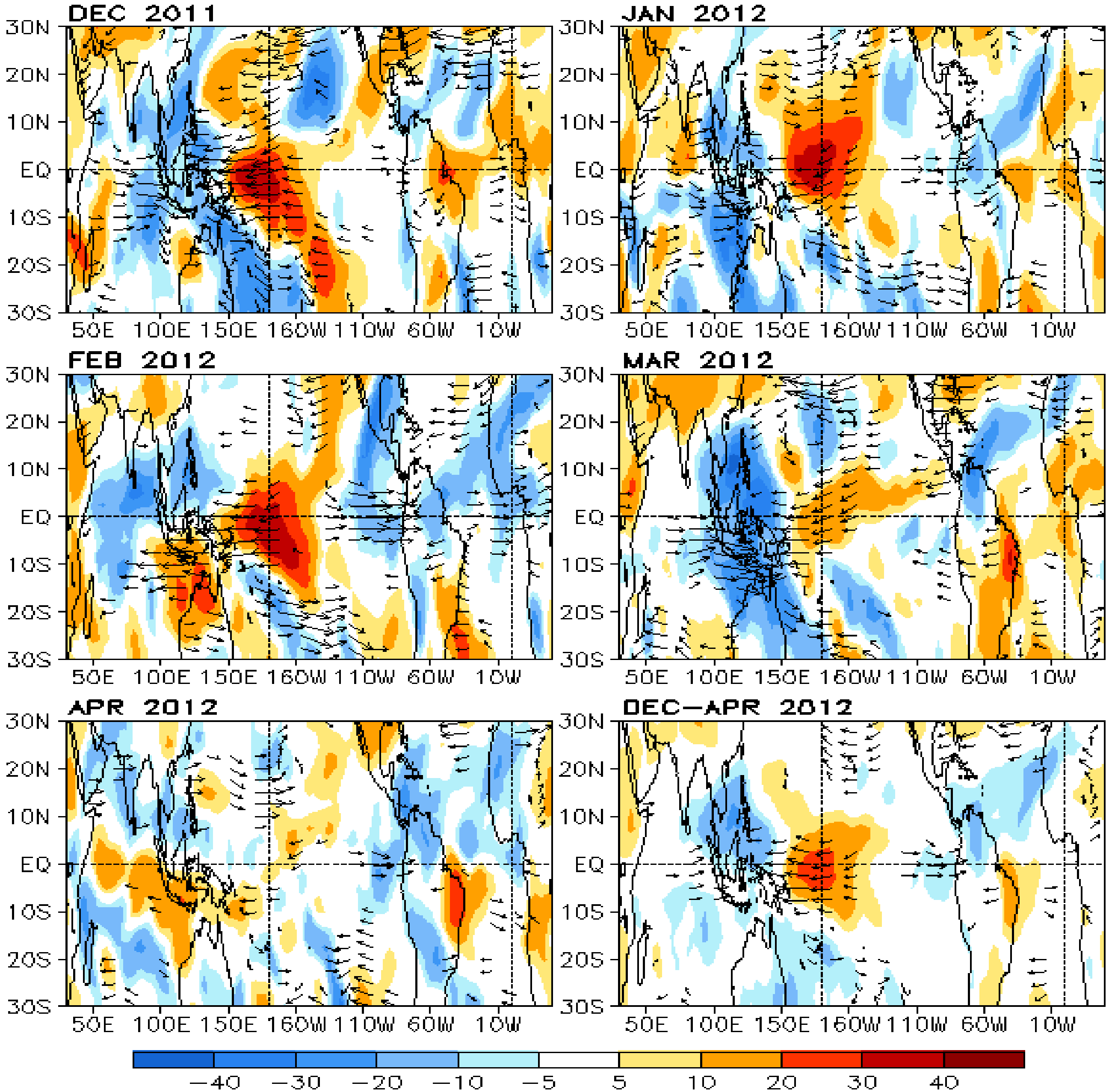
Backup Slides

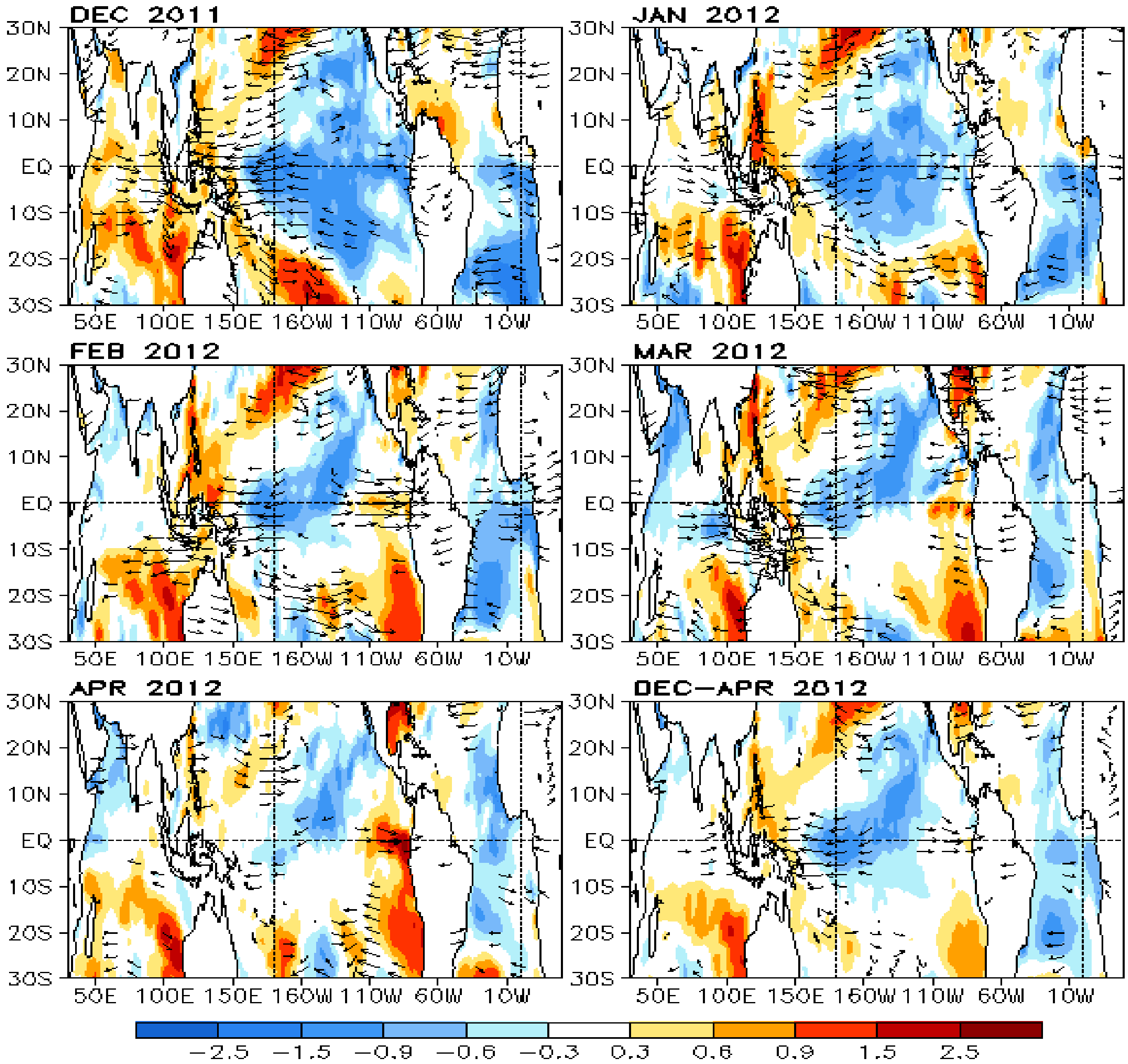
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



Original OSCAR data are unavailable since Apr 7, 2012

Evolution of OLR and 850mb Wind Anomalies





Evolution of SST and 850mb Wind Anomalies

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

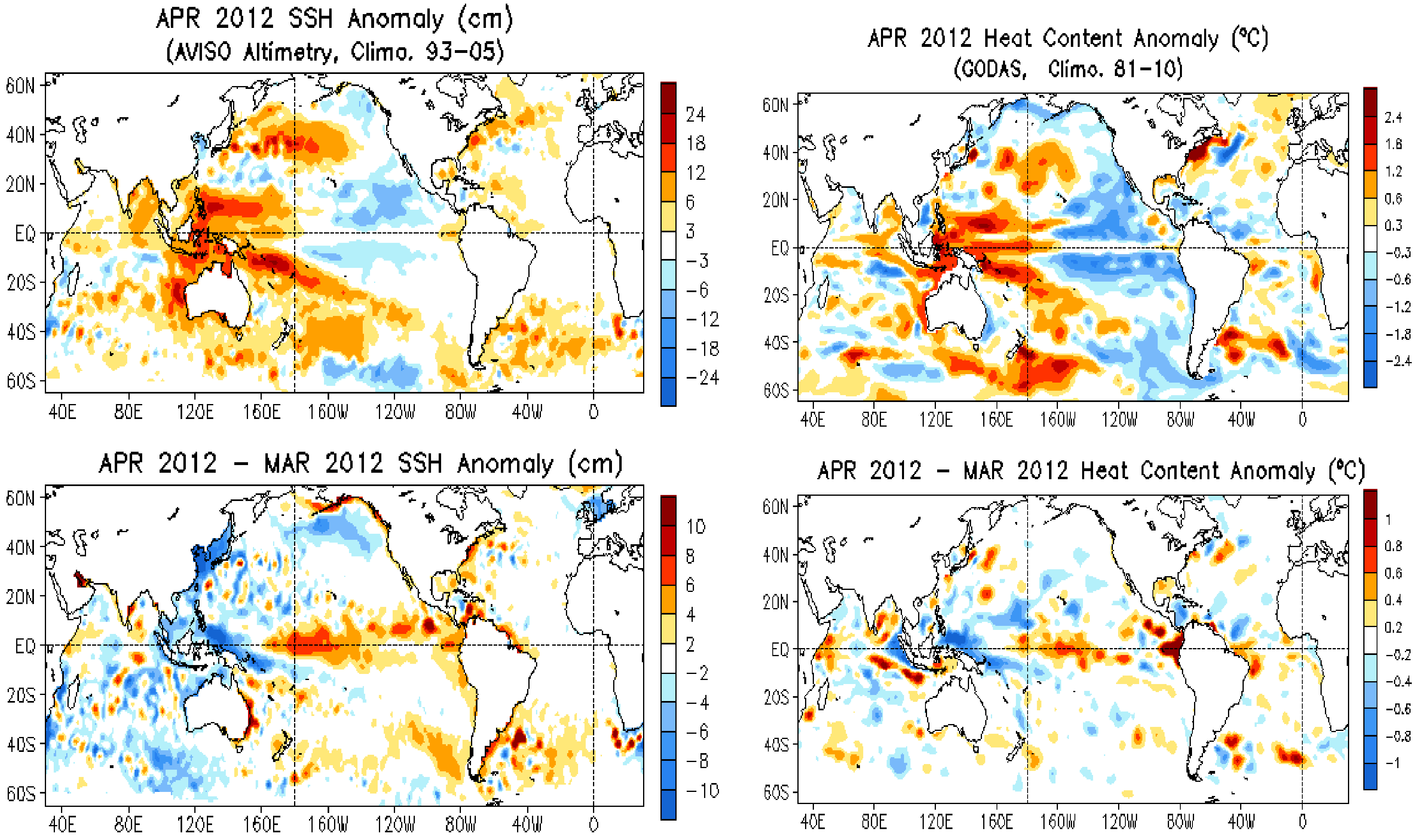


Fig. G2. Sea surface height anomalies (SSHA, top left), SSHA tendency (bottom left), top 300m heat content anomalies (HCA, top right), and HCA tendency (bottom right). SSHA are derived from http://www.aviso.oceanobs.com, and HCA from GODAS.

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.

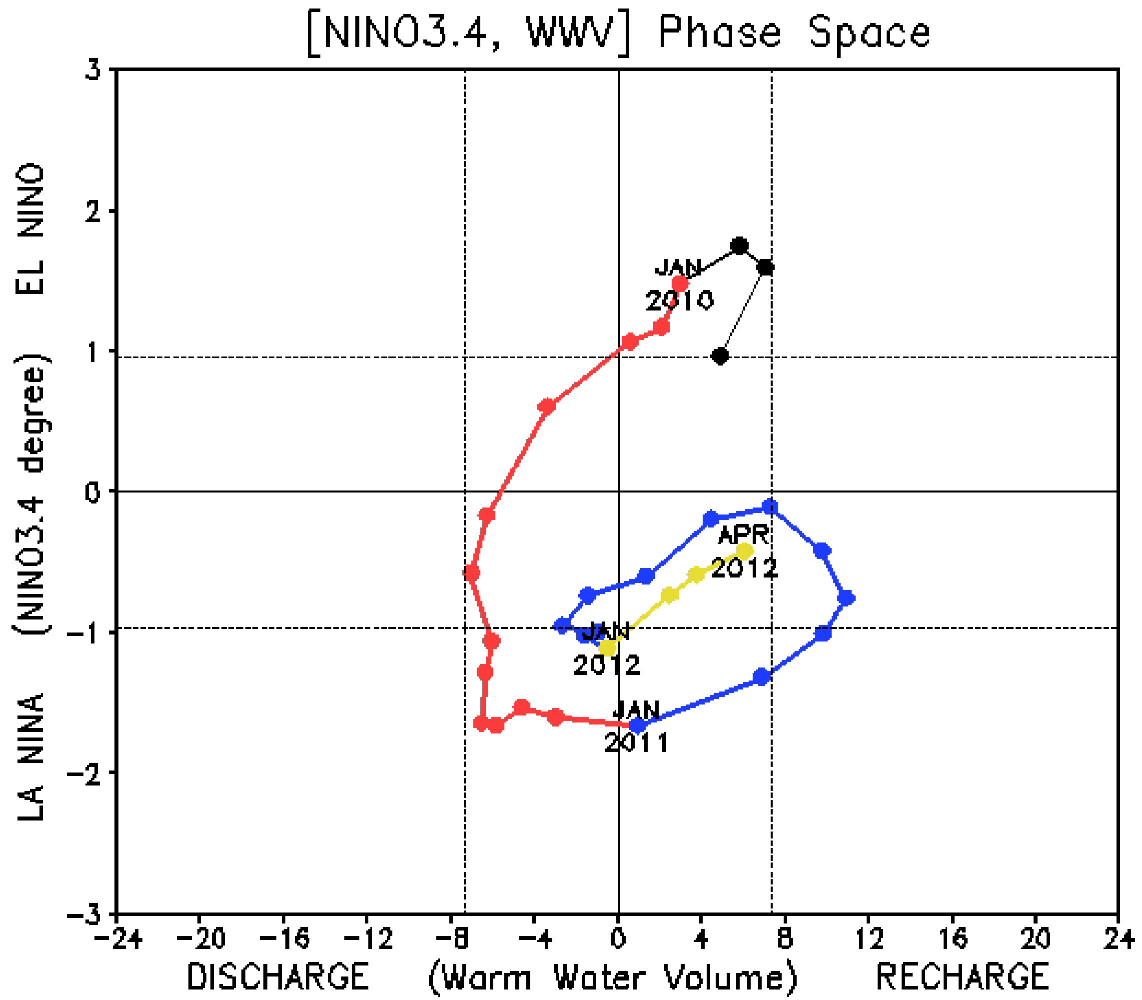


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

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

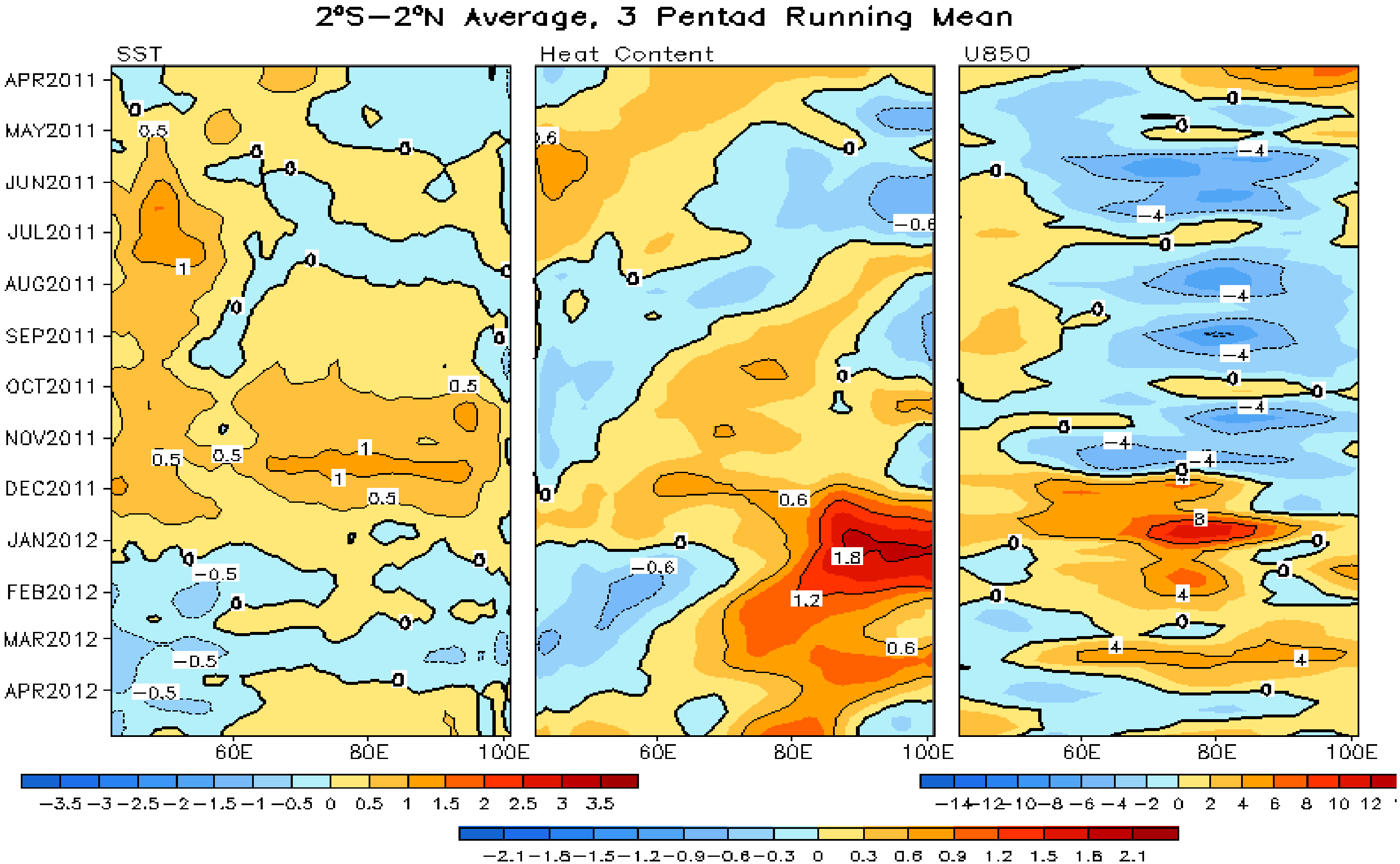


Fig. I3. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2ºS-2ºN and Outgoing Long-wave Radiation (OLR, right) averaged in 5ºS-5ºN. SST are derived from the NCEP OI 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.

CFS Niño3.4 SST Predictions from Different Initial Months

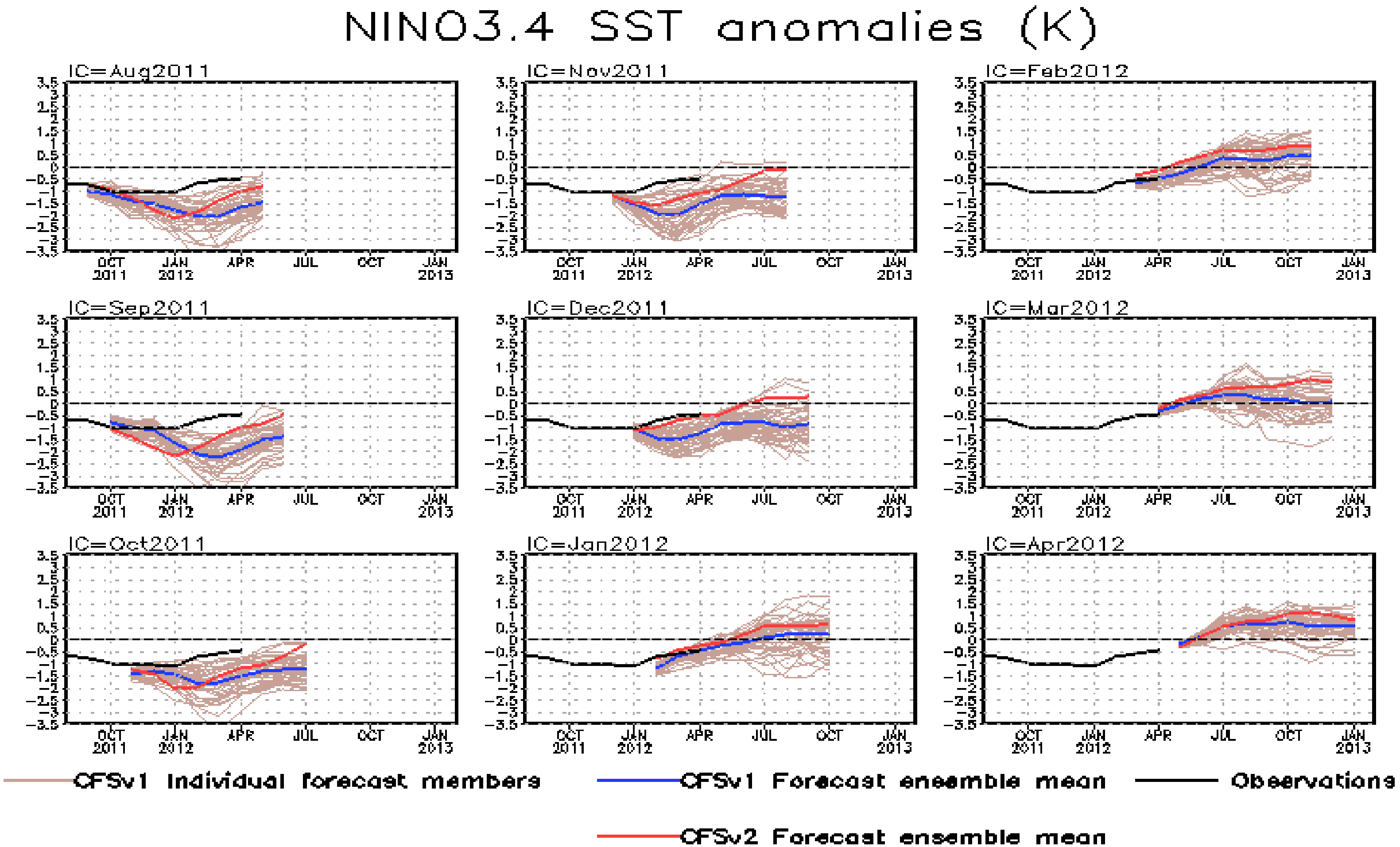
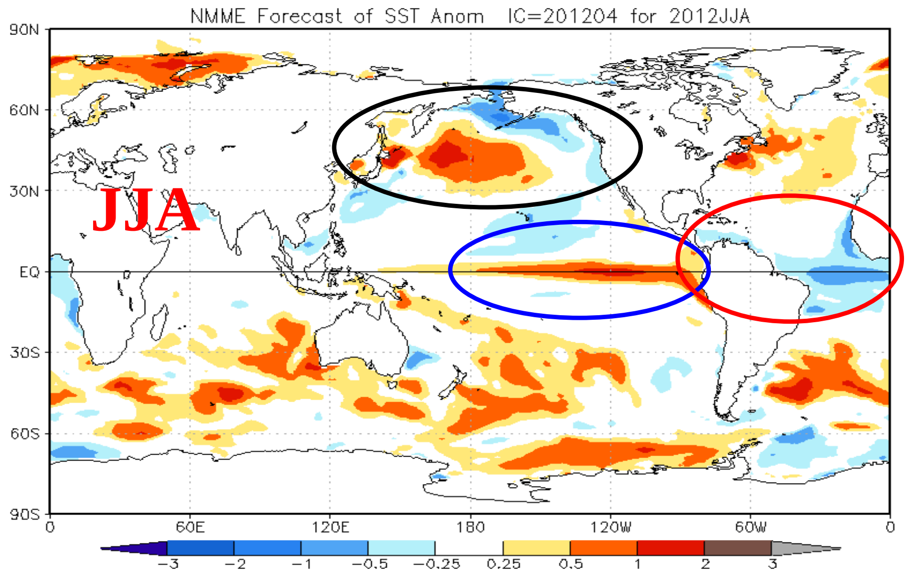
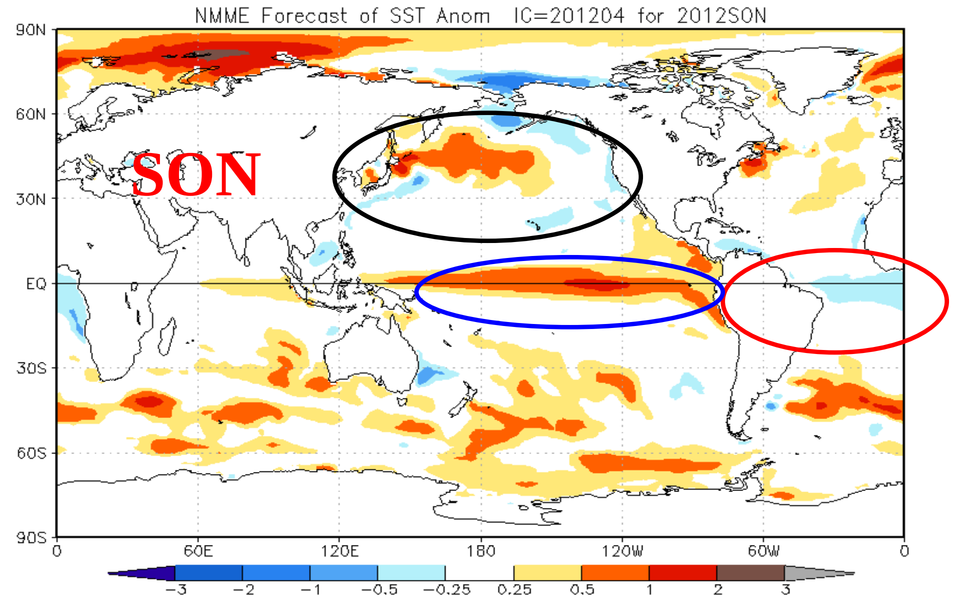
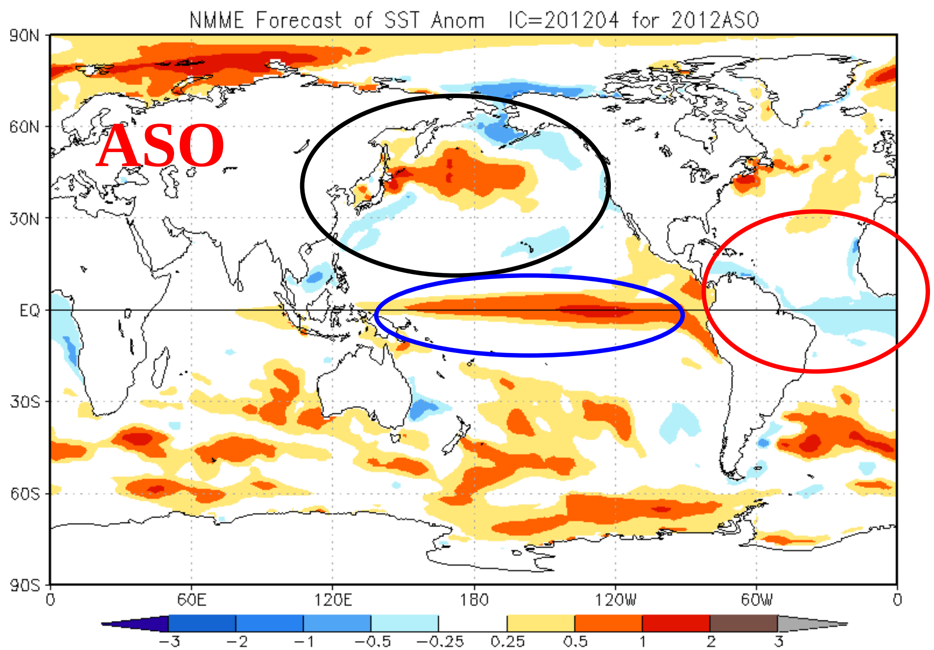


Fig. M1. CFS Nino3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

NMME (CFSv1, CFSv2, ECHAMA, ECHAMF, GFDL, NCAR, NASA) SST Forecast (IC=201204)

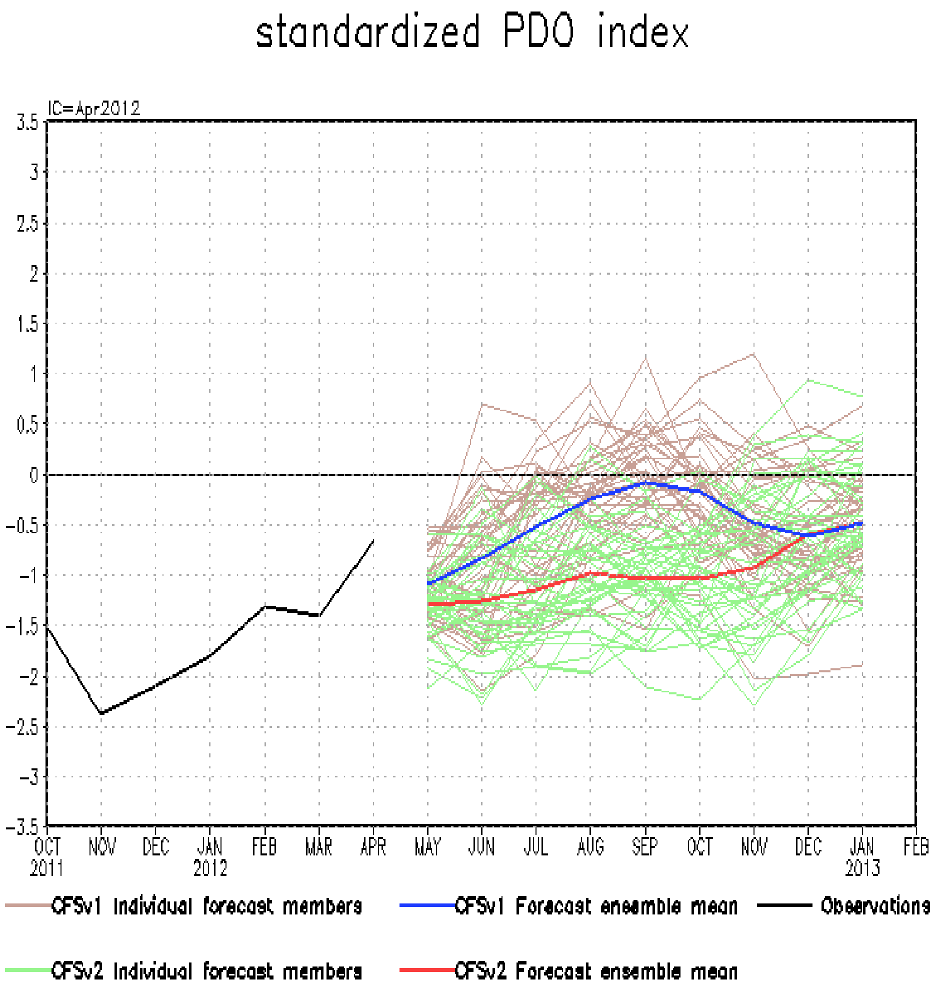


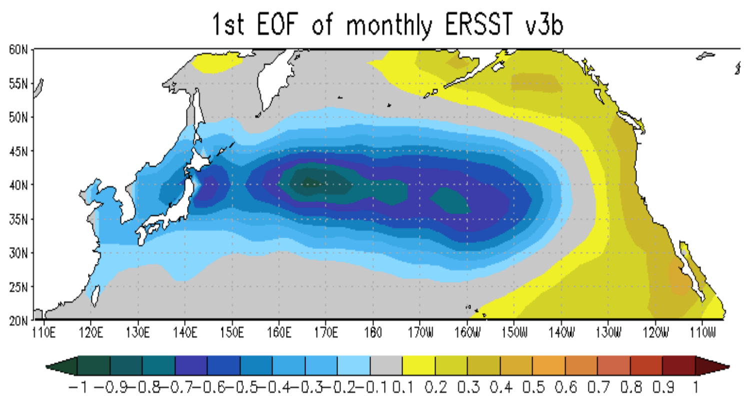




http://www.cpc.ncep.noaa.gov/products/people/wd51yf/NMME
experimental product
Thanks Qin Zhang, Huug van den Dool, Suru Saha, Malaquias Pena Mendez, Patrick Tripp, Peitao Peng and Emily Becker plus the originators at NASA, NCAR, GFDL, IRI (all coupled models)

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.

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.

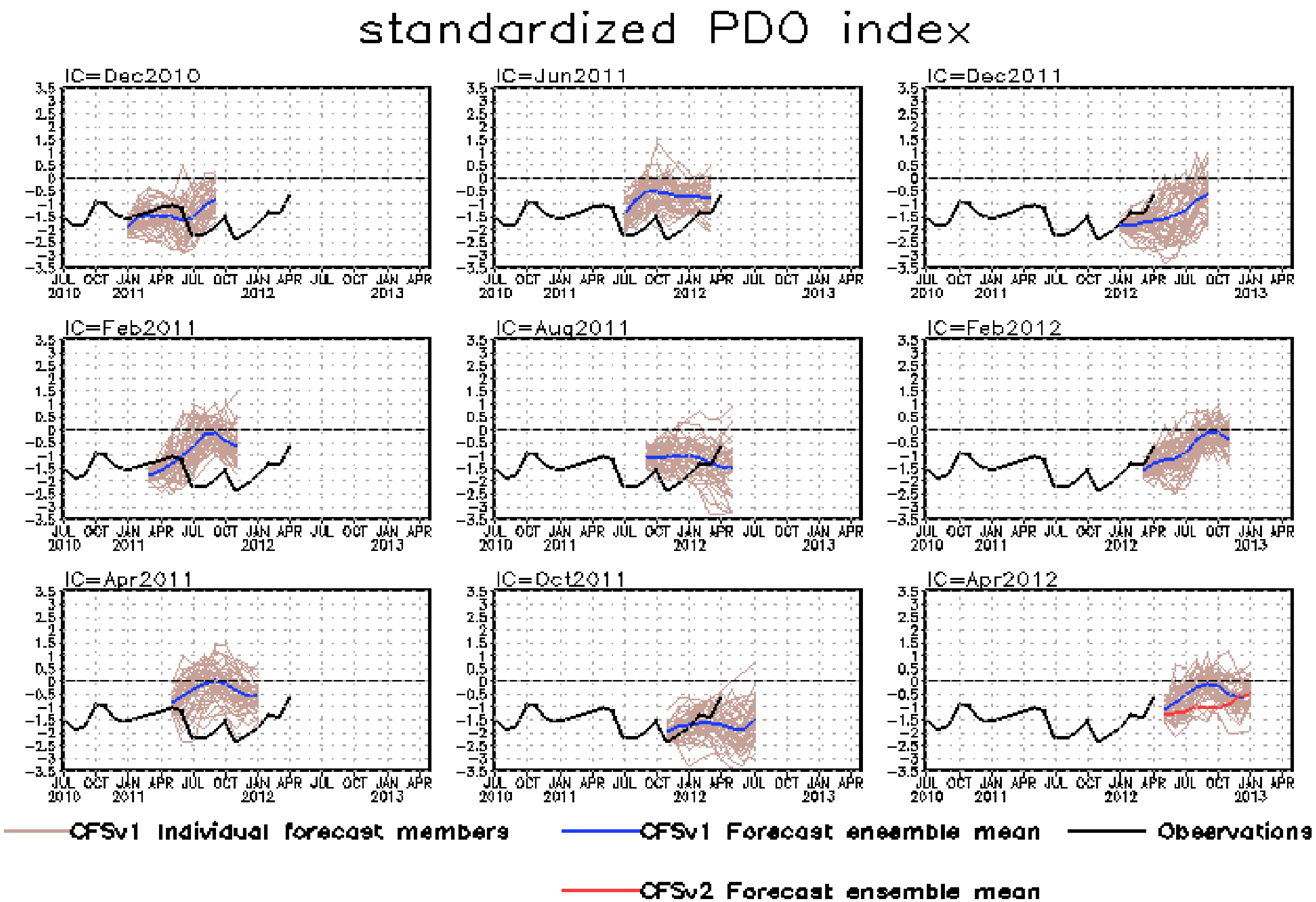


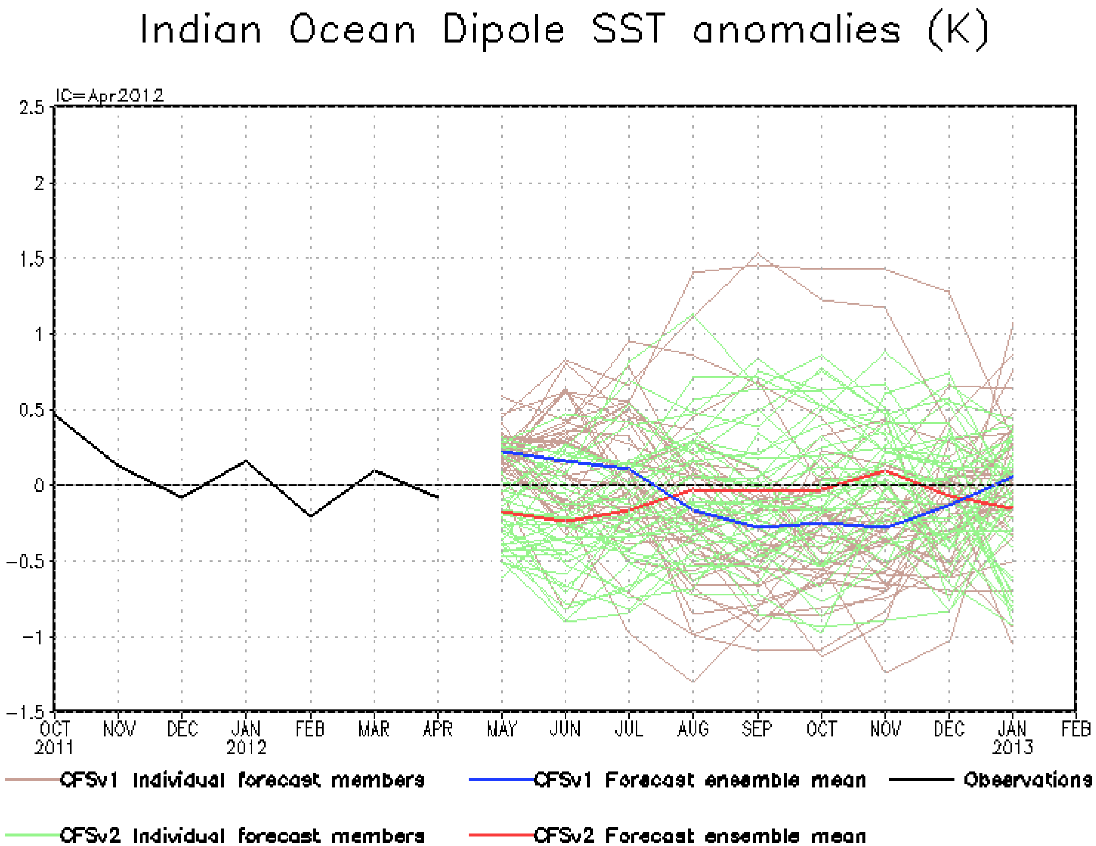
Fig. M4. CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black).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

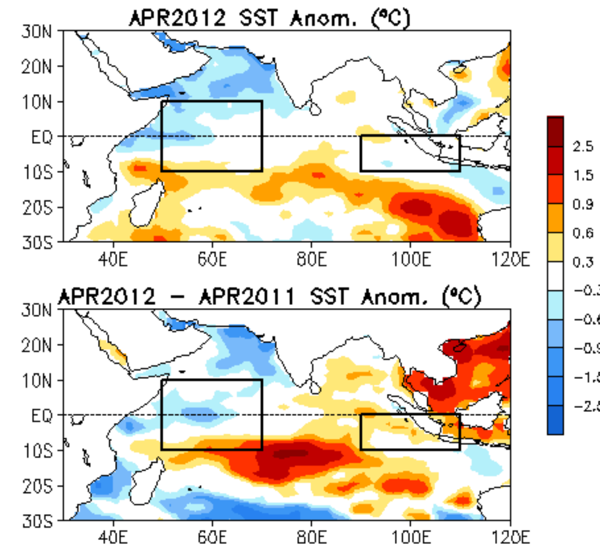
NCEP CFSv1 and CFSv2 Indian Ocean Dipole Model Index Forecast

DMI = WTIO- SETIO

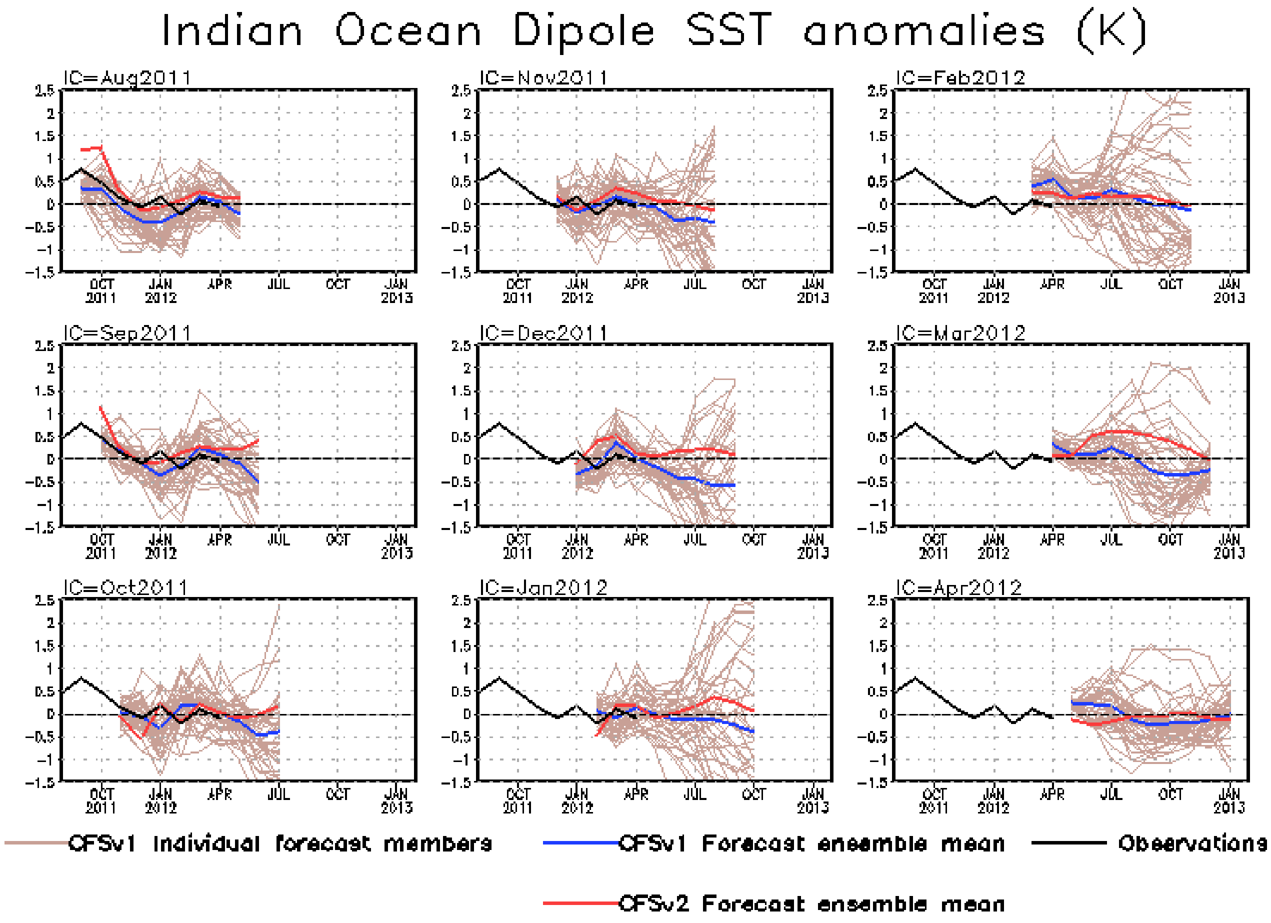
SETIO = SST anomaly in [90°E-110°E, 10°S-0]

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





NCEP CFS DMI SST Predictions from Different Initial Months



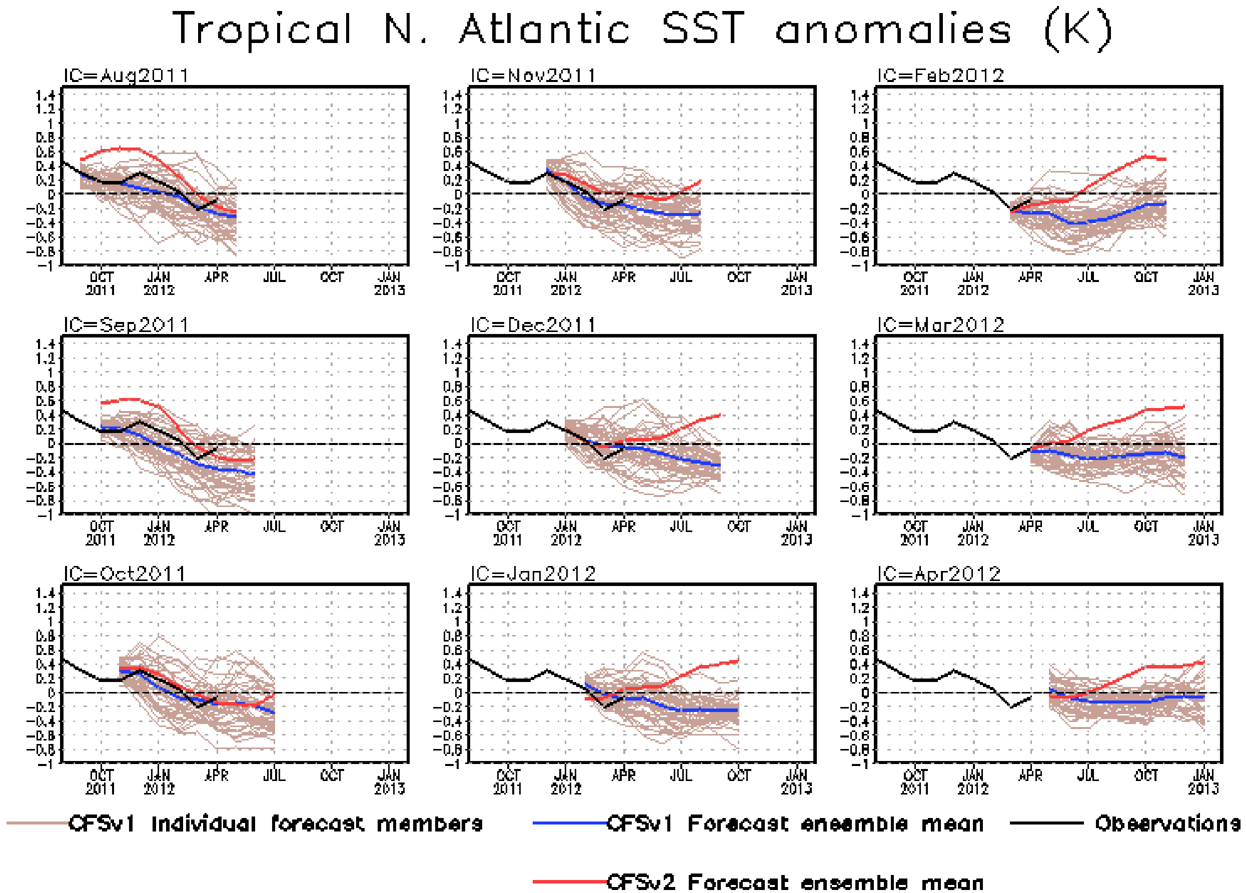
DMI = WTIO- SETIO

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



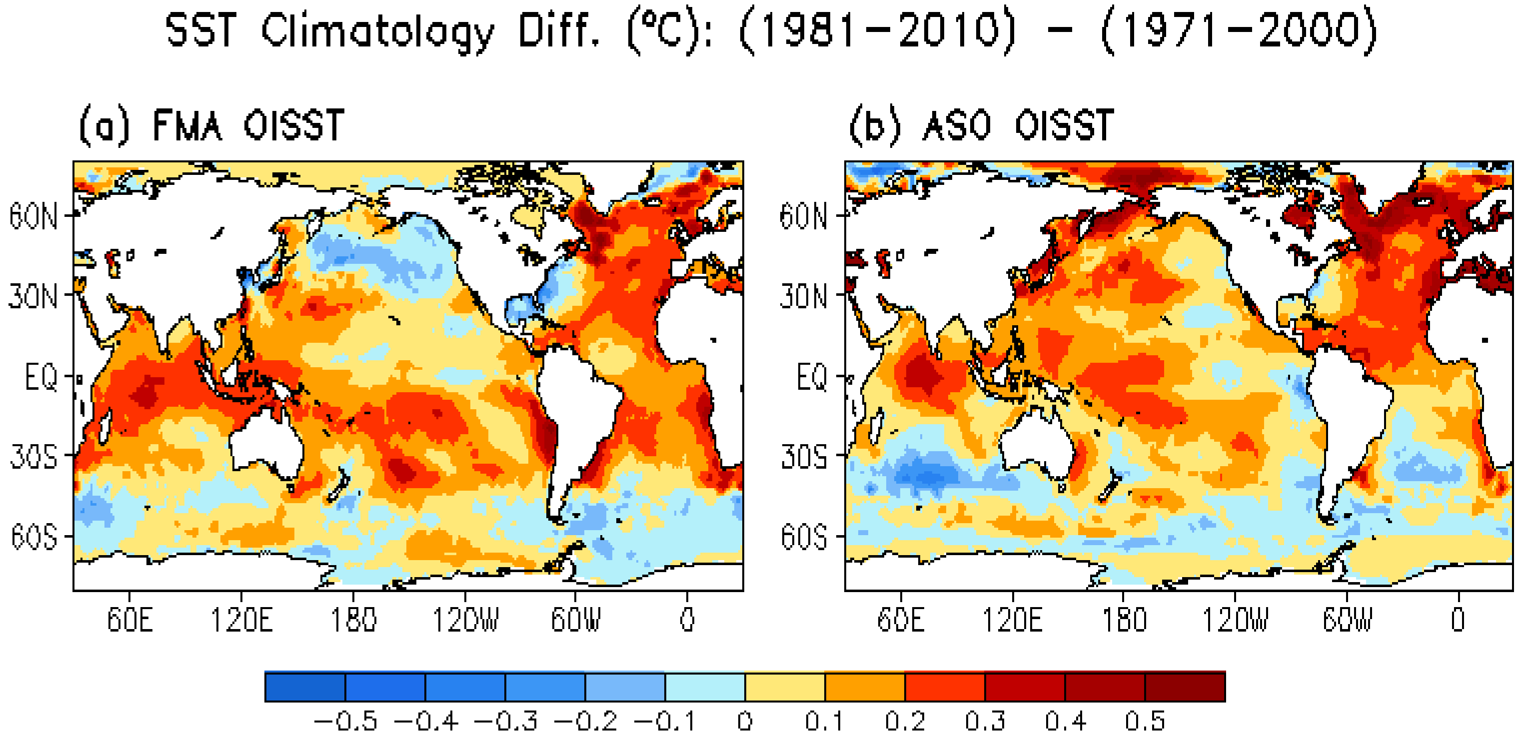
TNA is the SST anomaly averaged in the region of [60°W-30°W, 5°N-20°N].

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.

Switch to 1981-2010 Climatology

- **SST from 1971-2000 to 1981-2010**
  - **Weekly OISST.v2, monthly ERSST.3b**
- **Atmospheric fields from 1979-1995 to 1981-2010**
  - **NCEP CDAS winds, sea level pressure, 200mb velocity potential, surface shortwave and longwave radiation, surface latent and sensible fluxes, relative humidity**
  - **Outgoing Long-wave Radiation**
- **Oceanic fields from 1982-2004 to 1981-2010**
  - **GODAS temperature, heat content, depth of 20^{o}C, sea surface height, mixed layer depth, tropical cyclone heat potential, surface currents, upwelling**
- **Satellite data climatology 1993-2005 unchanged**
  - **Aviso Altimetry Sea Surface Height**
  - **Ocean Surface Current Analyses – Realtime (OSCAR)**

Be aware that new climatology (1981-2010) was applied since Jan 2011



1971-2000 SST Climatology (Xue et al. 2003):
http://www.cpc.ncep.noaa.gov/products/predictions/30day/SSTs/sst_clim.htm

1981-2010 SST Climatology: http://origin.cpc.ncep.noaa.gov/products/people/yxue/sstclim/

- The seasonal mean SST in February-April (FMA) increased by more than 0.2°C over much of the Tropical Oceans and N. Atlantic, but decreased by more than 0.2°C in high-latitude N. Pacific, Gulf of Mexico and along the east coast of U.S.

- Compared to FMA, the seasonal mean SST in August-October (ASO) has a stronger warming in the tropical N. Atlantic, N. Pacific and Arctic Ocean, and a weaker cooling in Gulf of Mexico and along the east coast of U.S.

Data Sources and References

- Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
- NCEP CDAS winds, surface radiation and heat fluxes
- NESDIS Outgoing Long-wave Radiation
- NDBC TAO data (http://tao.noaa.gov)
- PMEL TAO equatorial temperature analysis
- NCEP's Global Ocean Data Assimilation System temperature, heat content, currents (Behringer and Xue 2004)
- Aviso Altimetry Sea Surface Height
- Ocean Surface Current Analyses – Realtime (OSCAR)

Please send your comments and suggestions to Yan.Xue@noaa.gov. Thanks!