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 Ocean Climate Observation Program (OCO)

Outline

- **Overview**

- **Recent highlights**
  - **Pacific/Arctic Ocean**

    (Show the impact of TAO missing on NCEP data assimilation)
  - **Indian Ocean**
  - **Atlantic Ocean**

- **Global SST Predictions**

  (Introduce a new strategy to improve ENSO prediction)

Overview

- **Pacific and Arctic Oceans**

➢ ENSO-neutral condition continued during Mar 2013 with Nino3.4=-0.2C.

➢ NOAA officially forecast ENSO-neutral condition to continue in the Northern Hemisphere spring-summer 2013.

➢ Negative PDO phase slightly strengthened with PDO index =-1.6 in Mar 2013, and NCEP CFSv2 predicted negative phase of PDO would continue.

➢ Arctic sea ice extent in Mar 2013 was well below-normal and was beginning its seasonal decline.

- **Indian Ocean**

➢ SSTs in Indian Ocean were above or near-normal in Mar 2013.

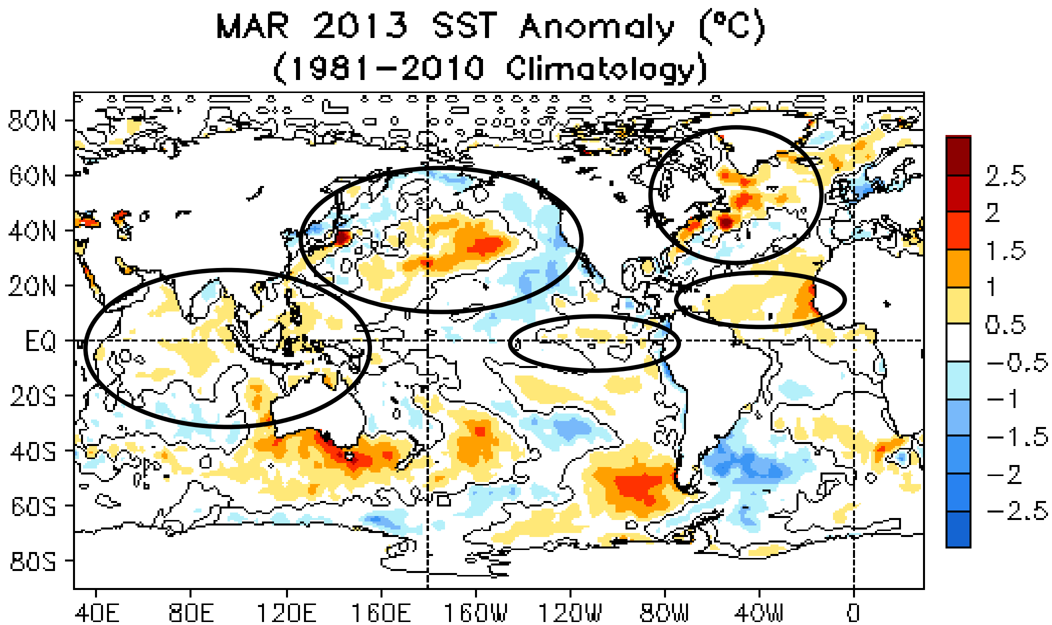
- **Atlantic Ocean**

➢ Negative phase of NAO strengthened significantly with NAO index =-2.1 in Mar 2013.

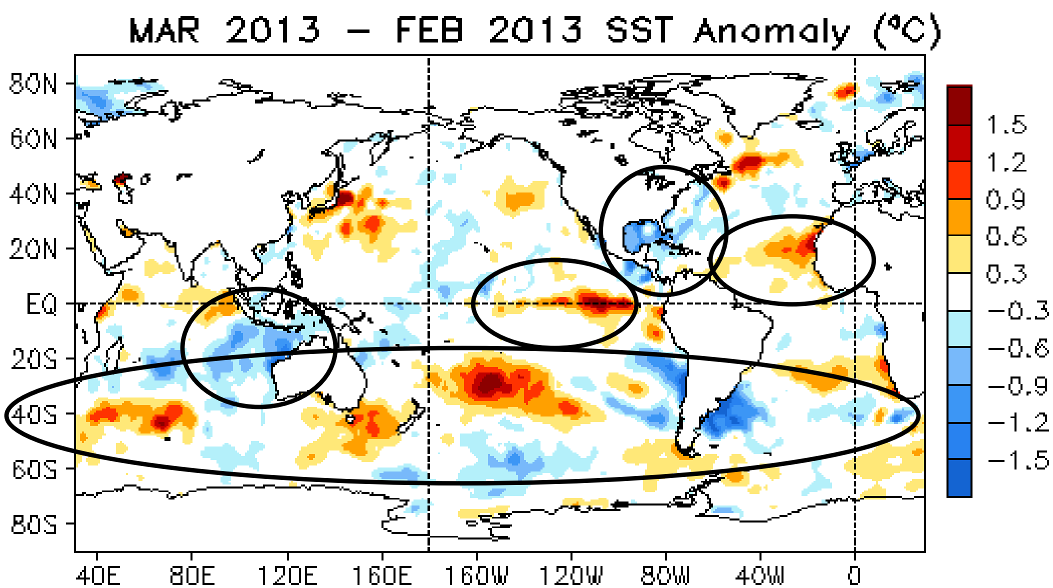
➢ Positive SSTA in high-latitude and tropical N. Atlantic enhanced in Mar 2013.

Global Oceans

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



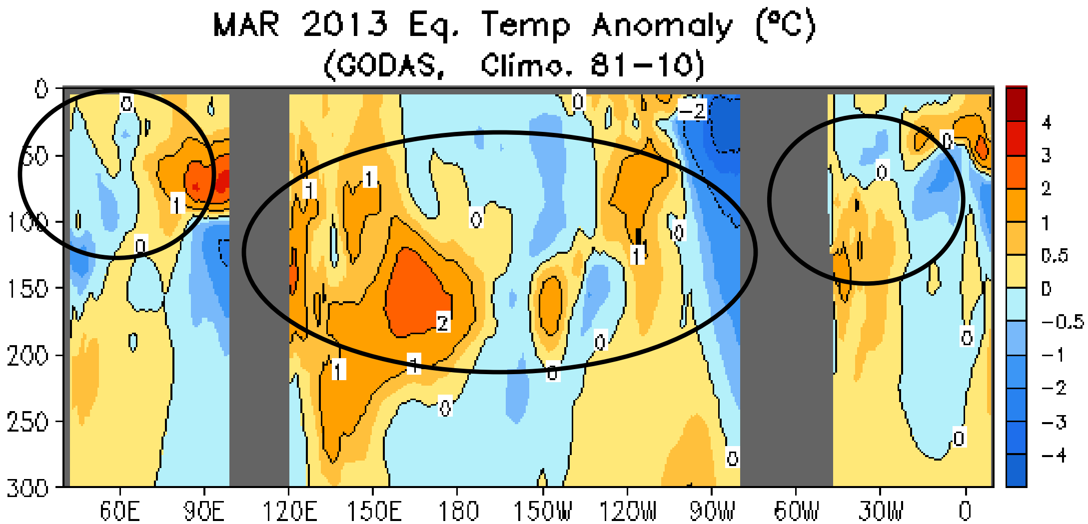
- SST was slightly above (below) normal in the eastern (central) equatorial Pacific.
- Negative phase PDO associated SSTA presented in North Pacific.
- Positive SSTA was observed in the Indian Ocean and western Pacific.
- Above-normal SST occurred in high and low latitudes of North Atlantic.
- Large SST anomalies were observed in the South Ocean.



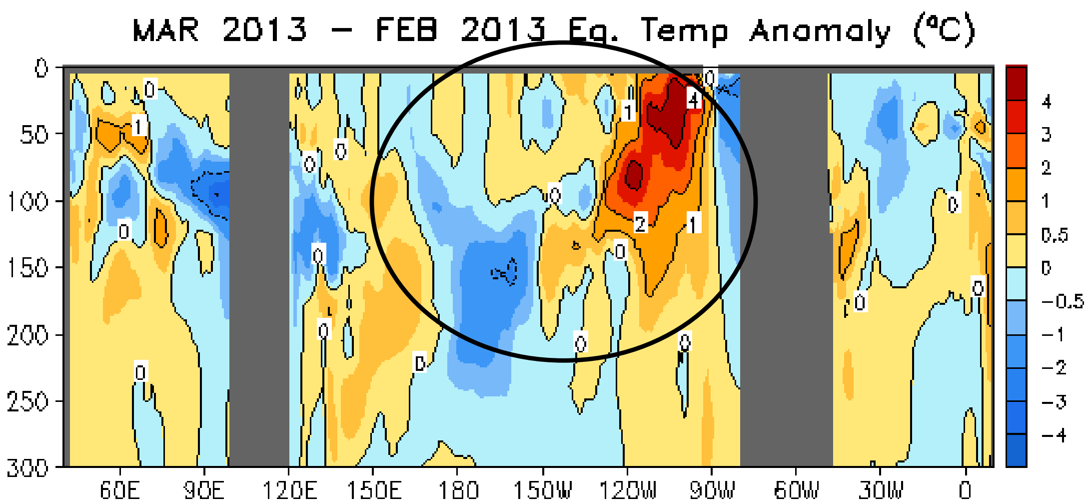
- A warming tendency presented in the equatorial eastern Pacific, and tropical North Atlantic.
- A cooling tendency was observed in Gulf of Mexico, and SE Indian Ocean.
- Large tendencies were observed in the mid-latitudes of the Southern Hemisphere.

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

Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2^{o}S-2^{o}N



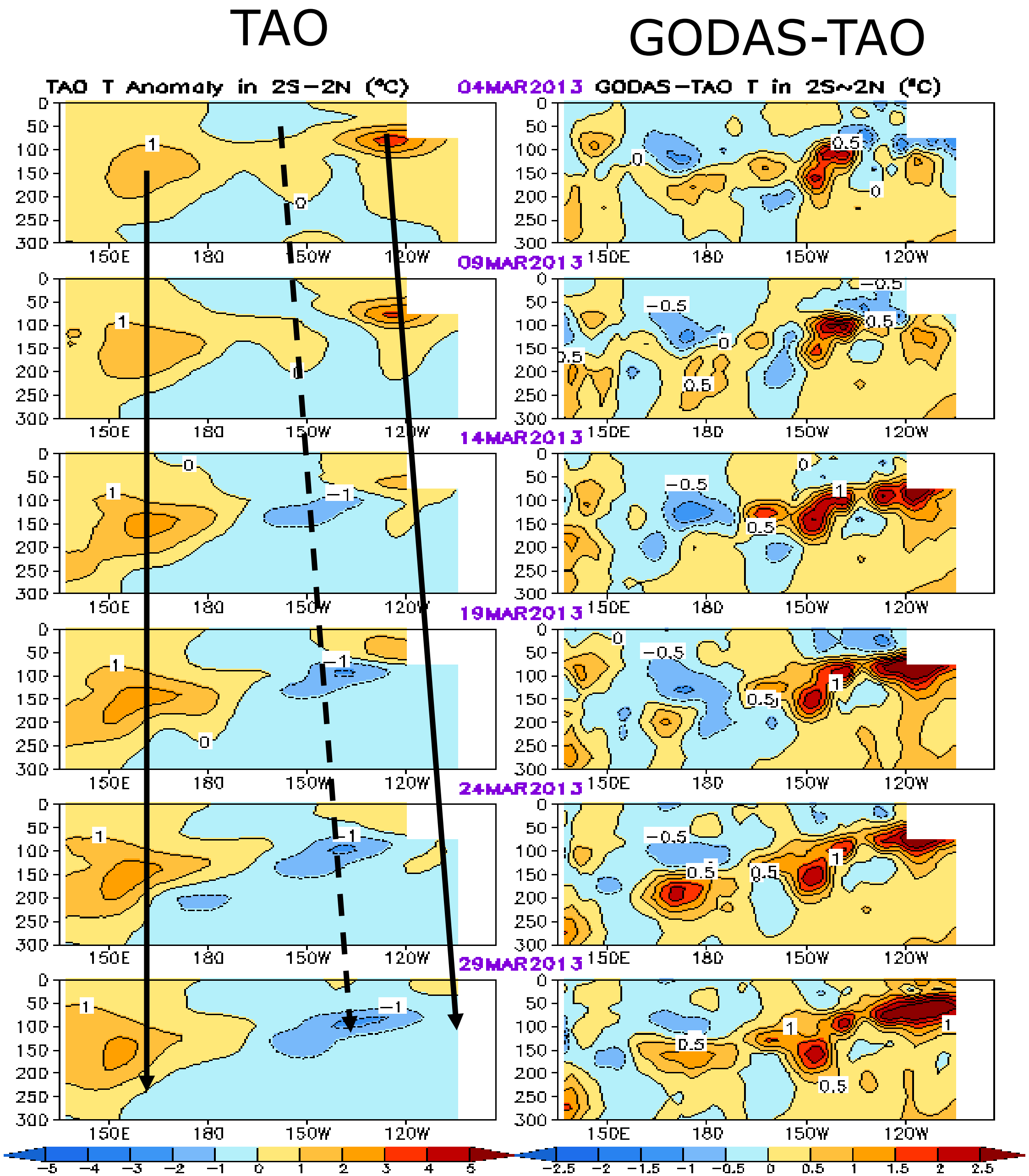
- **Positive temperature anomalies occupy near the thermocline in the equatorial Pacific Ocean, except near the American coast and in the central Pacific.**
- **Positive anomalies dominated at the upper 100m of equatorial eastern Indian Ocean.**



- **A warming (cooling) tendency was observed in the eastern (central) Pacific Ocean near the thermocline, may largely due to propagation of downwelling and upwelling oceanic Kelvin waves.**

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



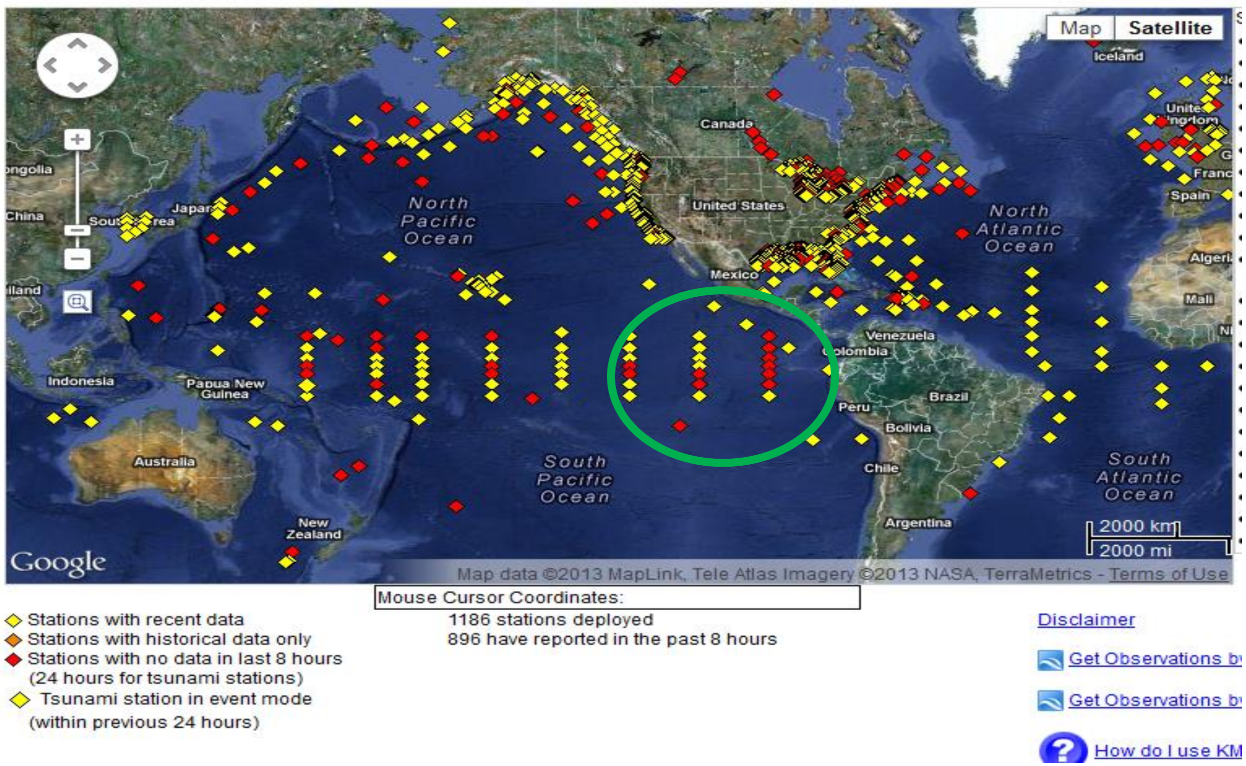
Pentad Mean Equatorial Pacific Temperature Anomaly

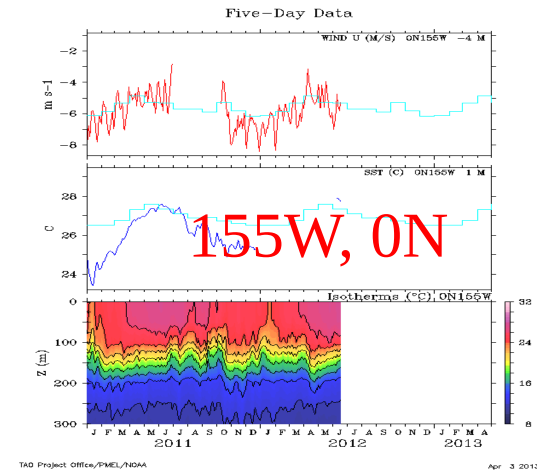
- Positive and negative temperature anomalies along the thermocline in the central and eastern Pacific propagated eastward, associated with ocean Kelvin waves.
- Positive temperature anomalies along the thermocline in the western Pacific were intensified and with little propagation.
- However, the differences between TAO and GODAS were large in the central and eastern Pacific. **What causes the differences?**

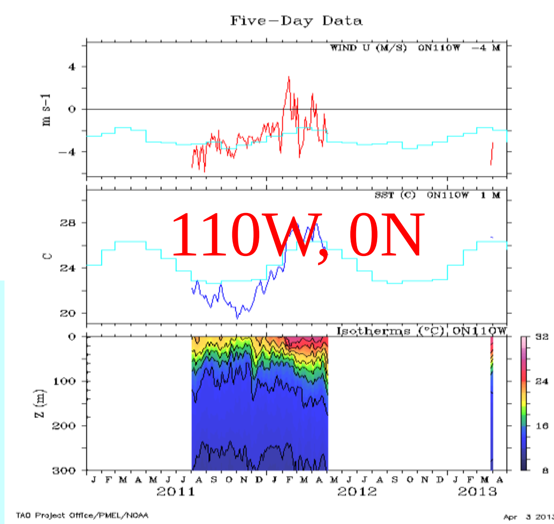
Status of TAO/TRITON Data Delivery

http://www.ndbc.noaa.gov

http://www.pmel.noaa.gov/tao/jsdisplay/

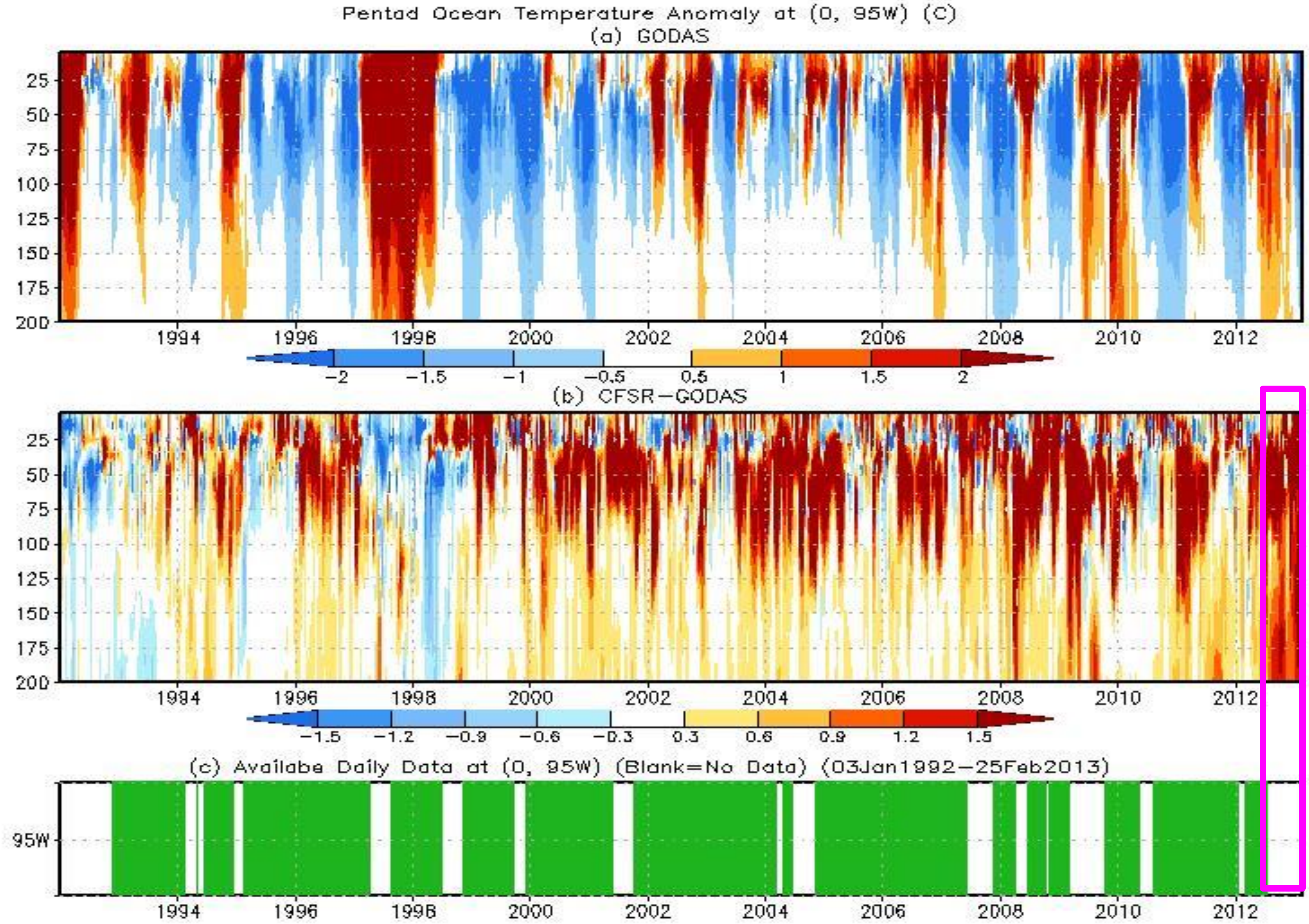




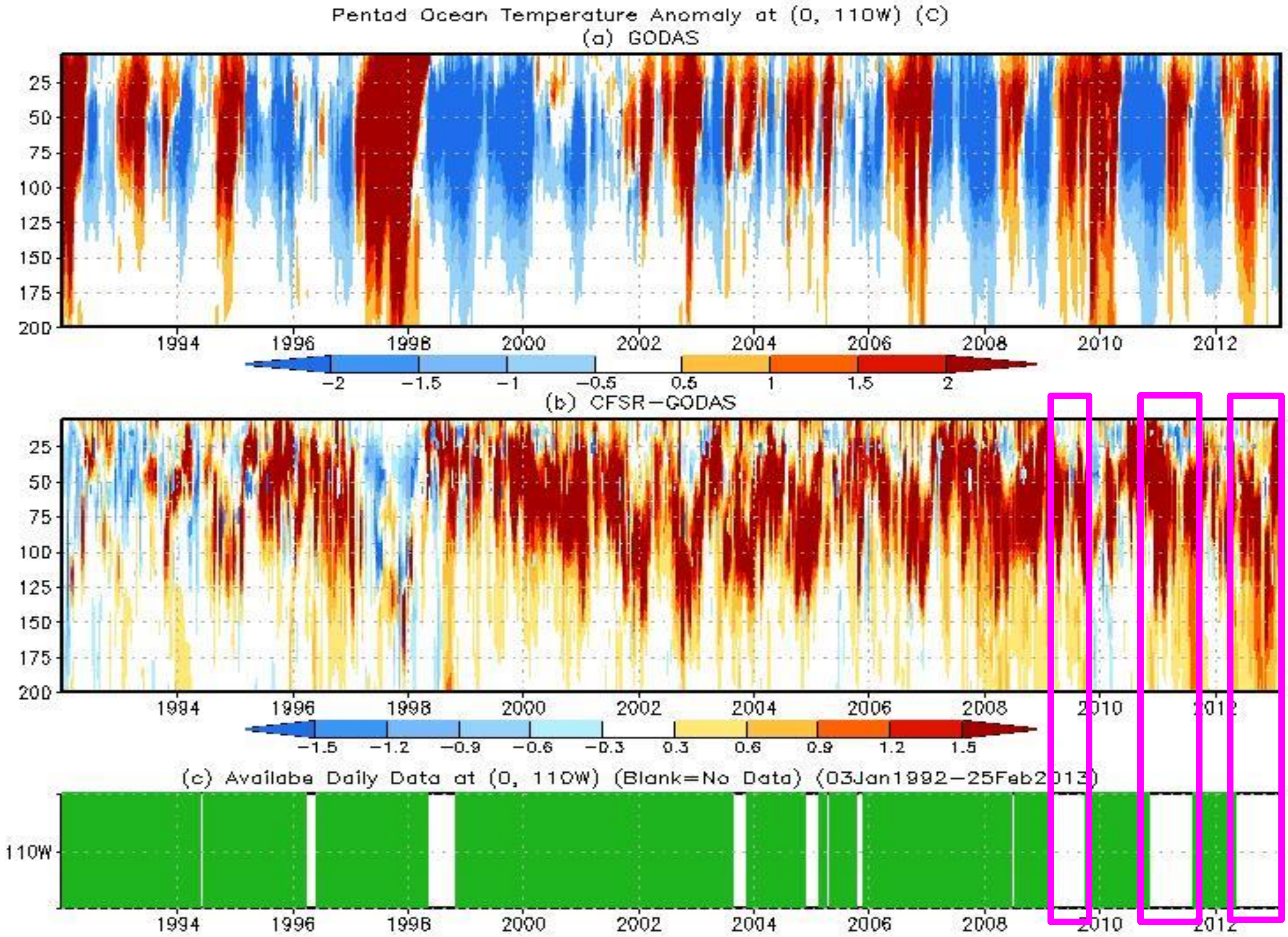


- **The TAO/TRITON array has encountered significant outages, particularly in the eastern part of the array.**
- **For example, the mooring at (155W, 0N) has been down since July 2012, and the mooring at (110W, 0N) went down since May 2012.**

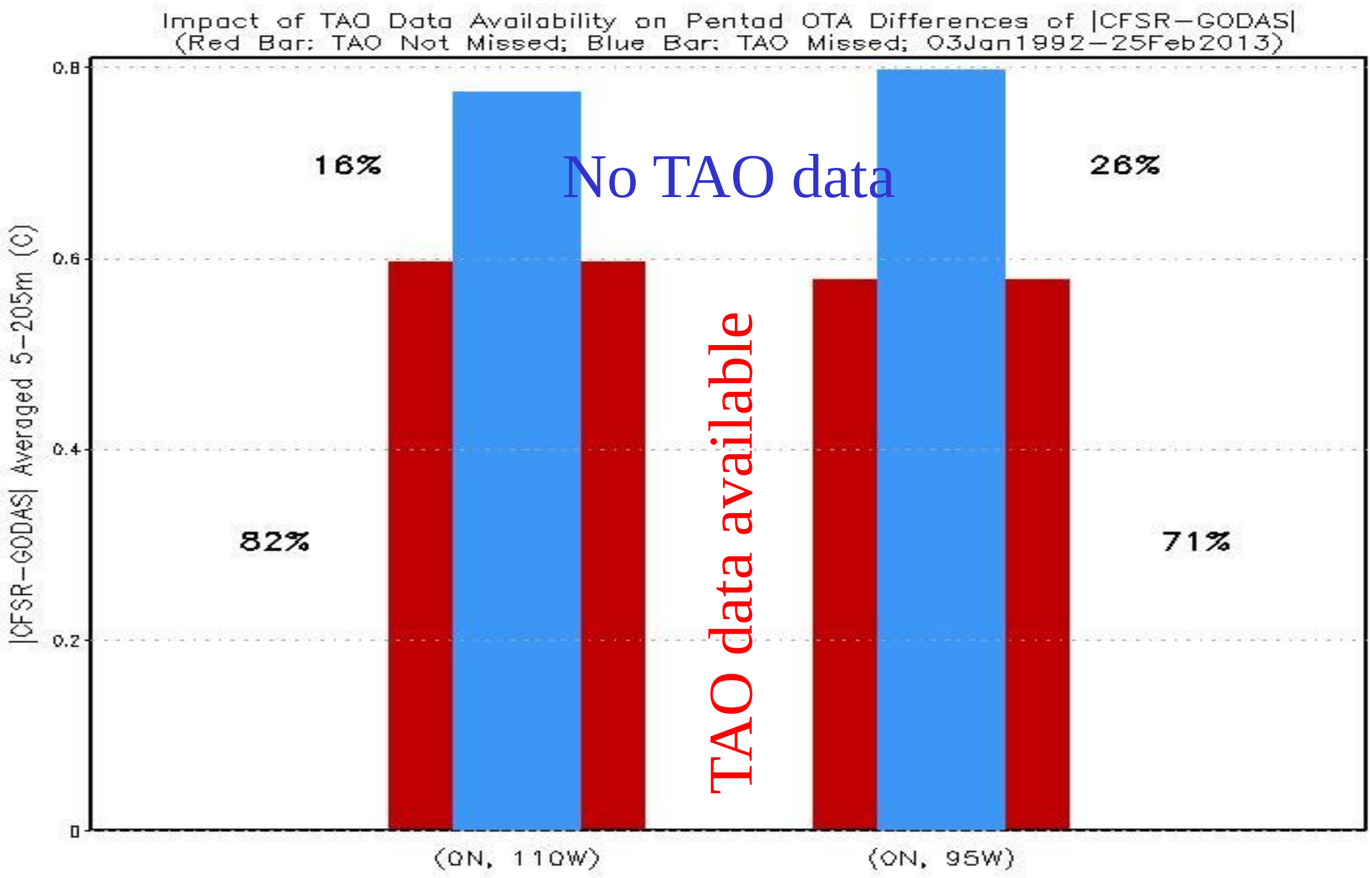
Possible Impact of TAO Data Missing on NCEP Data Assimilations (CFSR and GODAS; 1981-2010 Climatology) at (0, 95W)



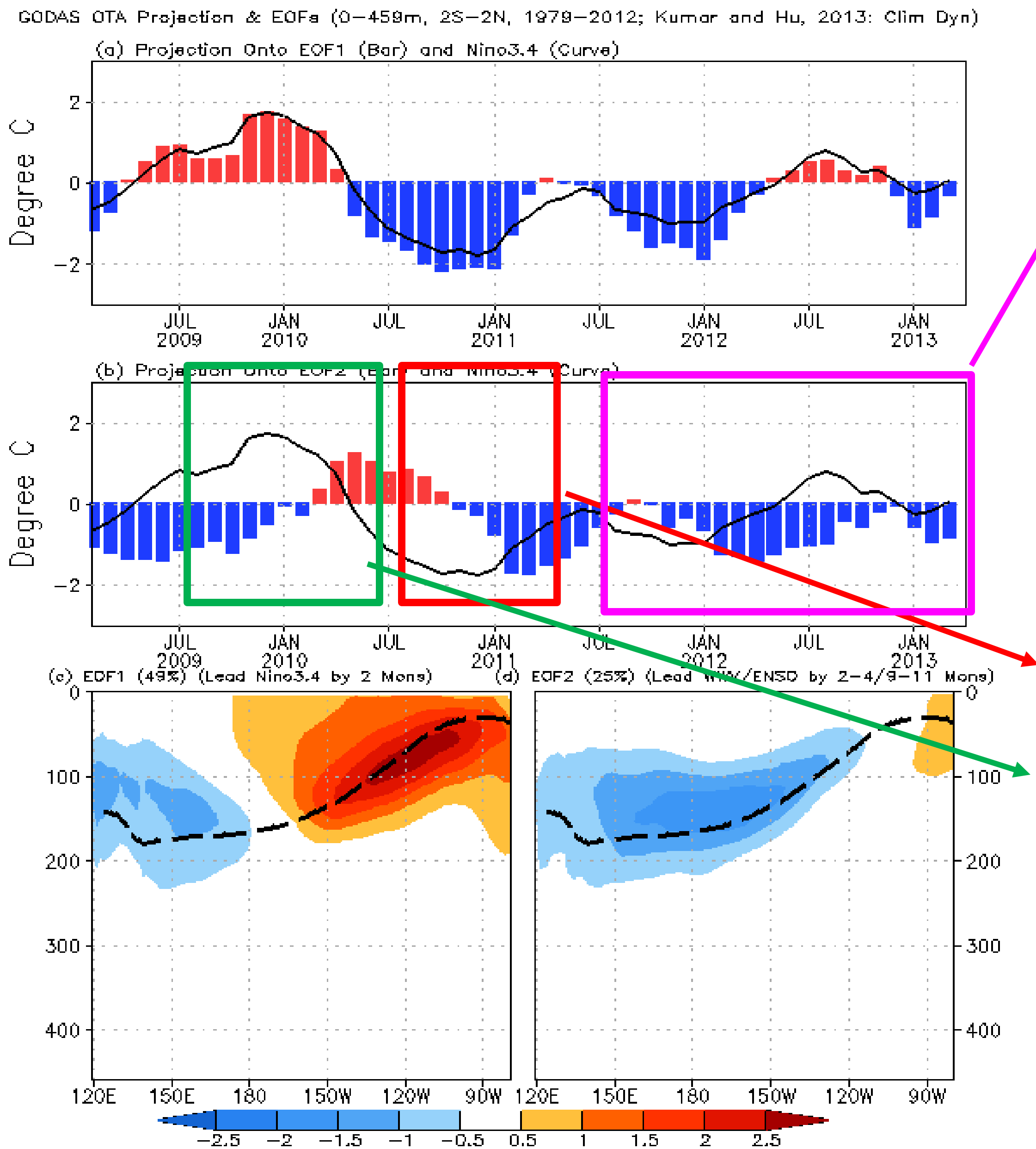
Possible Impact of TAO Data Missing on NCEP Data Assimilations (CFSR and GODAS; 1981-2010 Climatology) (0, 110W)



Possible Impact of TAO Data Missing on NCEP Data Assimilations ($\sum_{5m}^{205m}$|CFSR-GODAS|)



- **The ocean temperature anomaly differences between CFSR and GODAS are larger when TAO data are missed compared with that they are not missed.**
- **Statistically, it seems to suggest that without constraint of TAO data, the differences become larger between GODAS and CFSR.**



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

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

EOF1: Tilt mode (ENSO peak phase);

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

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

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

<u>For details, see:</u>

Kumar, A. and Z.-Z. Hu, 2013: Interannual and interdecadal variability of ocean temperature along the equatorial Pacific in conjunction with ENSO. Clim. Dyn. DOI: 10.1007/s00382-013-1721-0 (published online).

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.

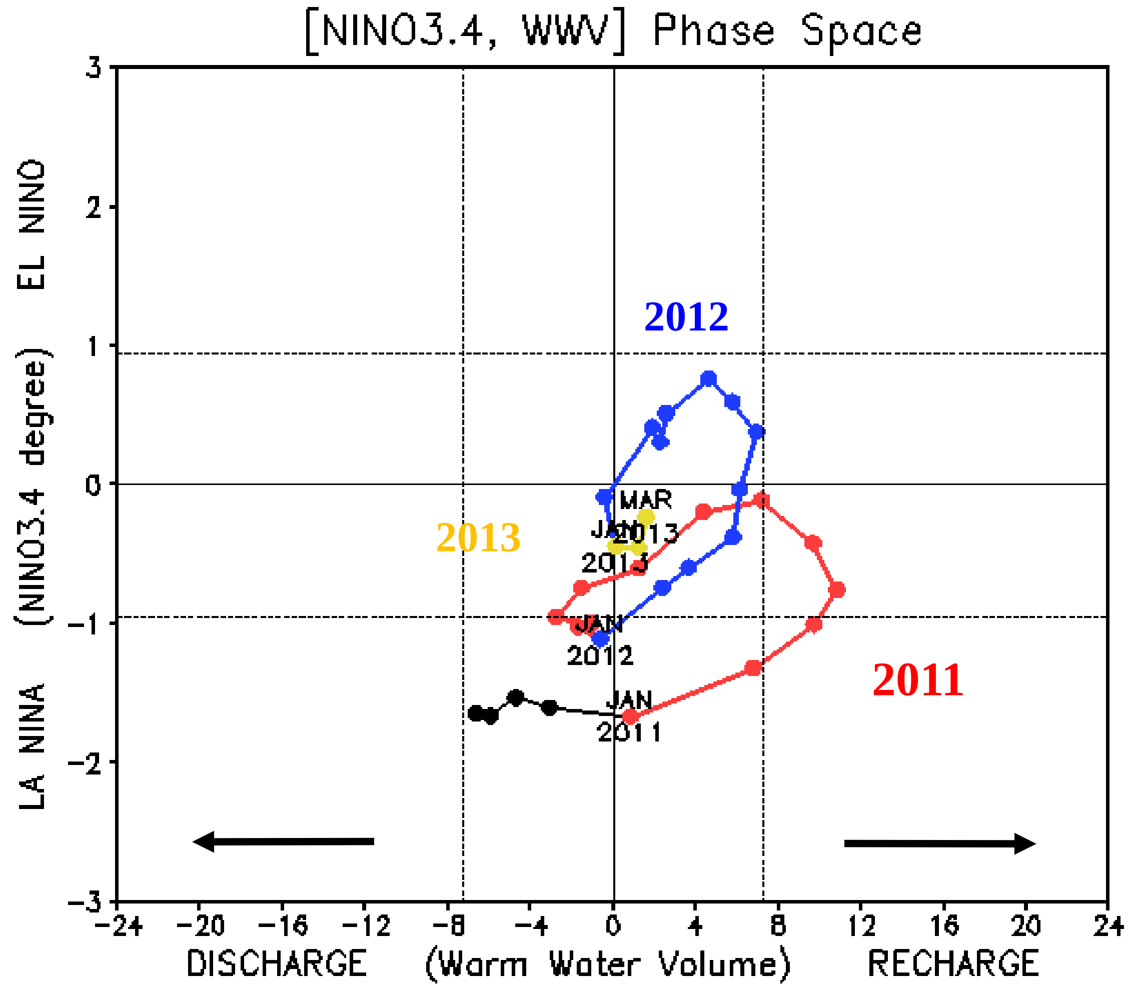
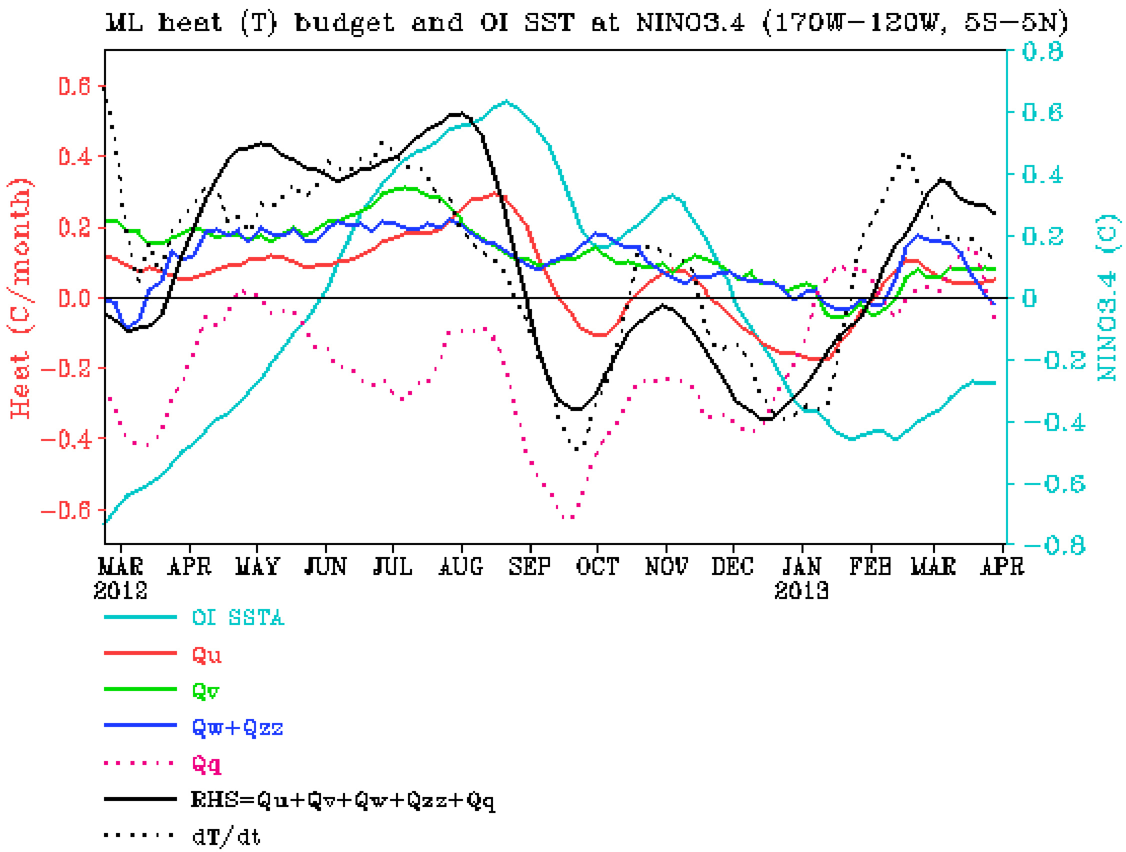


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

NINO3.4 Heat Budget



- **SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) was positive, but decreased in Mar 2013.**

- **All the advection terms, as well as thermodynamical term (Qq) were positive, consistent with weakening of negative SSTA**

Huang, B., Y. Xue, X. Zhang, A. Kumar, and M. J. McPhaden, 2010 : The NCEP GODAS ocean analysis of the tropical Pacific mixed layer heat budget on seasonal to interannual time scales, J. Climate., 23, 4901-4925.

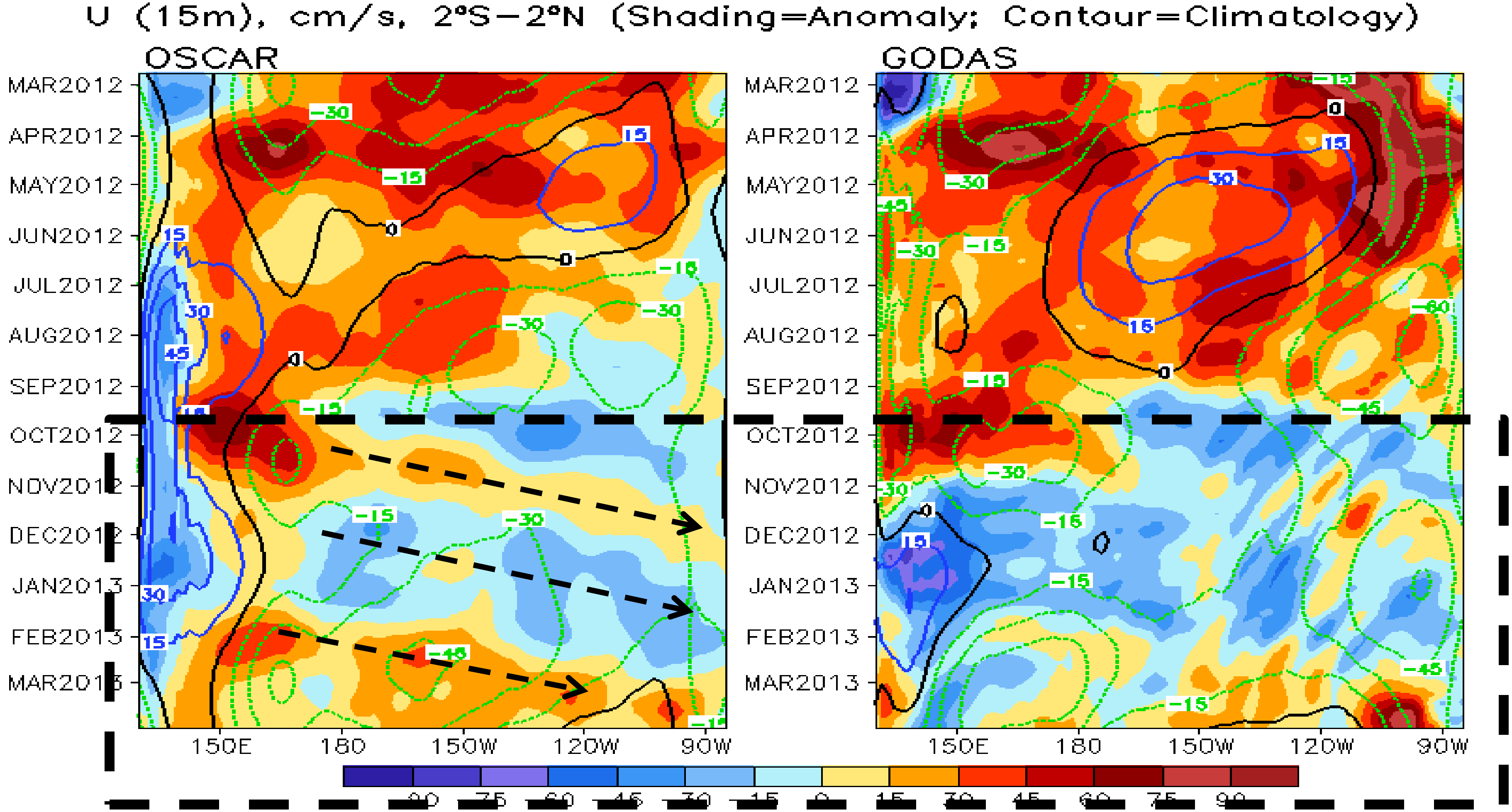
Qu: Zonal advection; Qv: Meridional advection;

Qw: Vertical entrainment; Qzz: Vertical diffusion

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

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

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

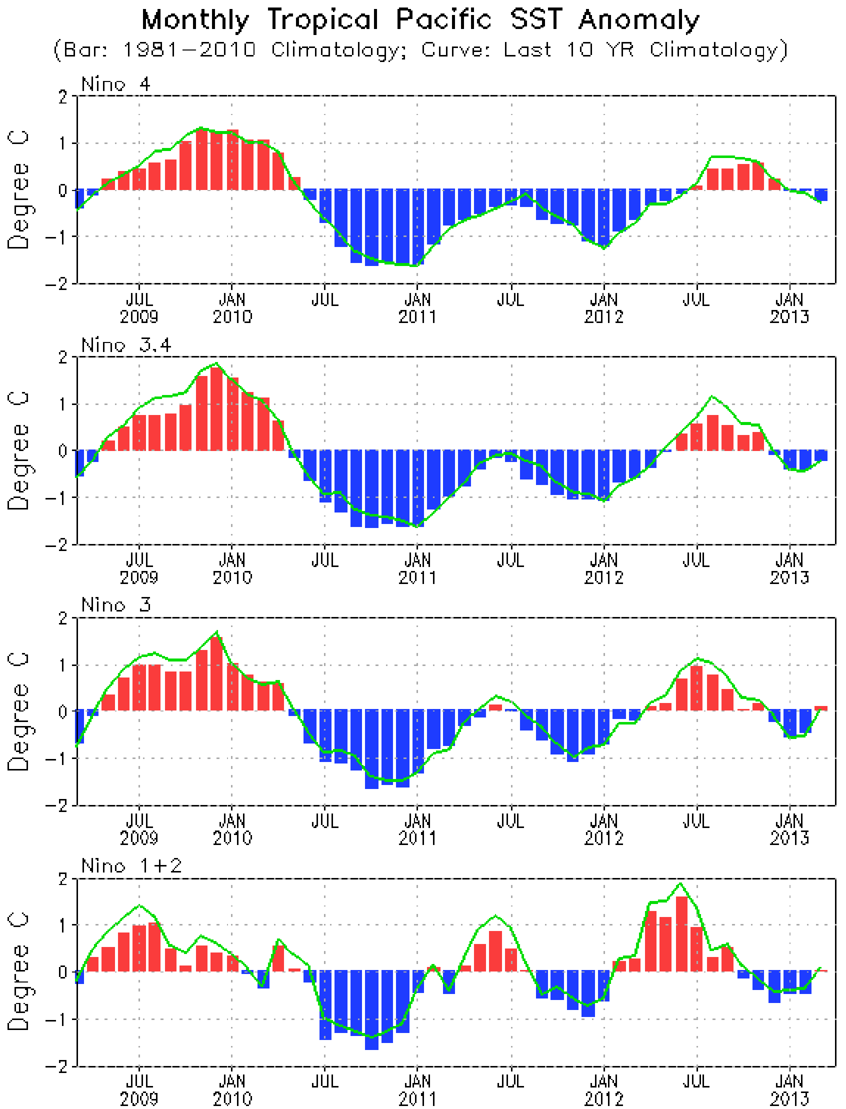


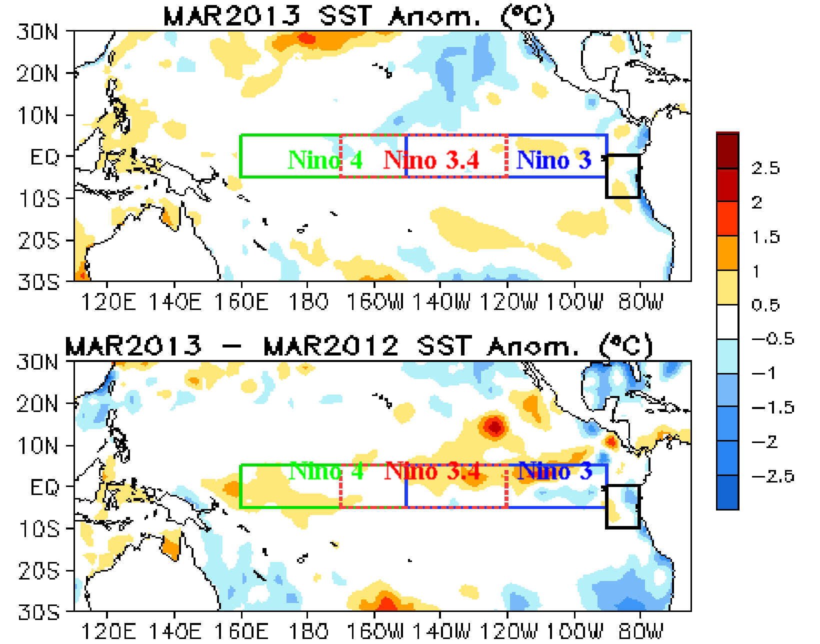
- In the last two months, eastward anomaly current was observed, consistent with warming tendency in the eastern Pacific Ocean.

- Positive (negative) zonal current anomalies were associated with downwelling (upwelling) oceanic Kelvin waves.

- Profound differences noted for both anomaly and climatology between OSCAR and GODAS.

Evolution of Pacific NINO SST Indices



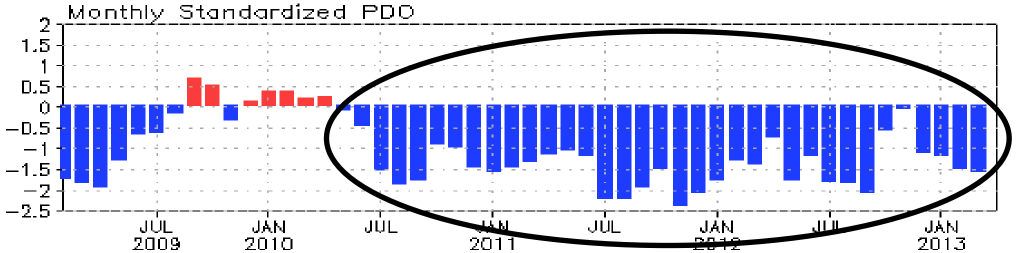


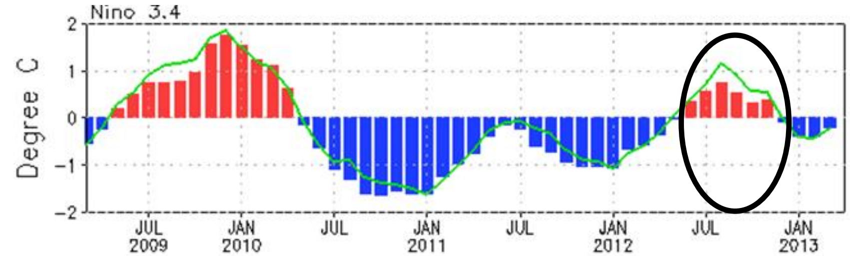
- **All Nino indices were near-normal and NINO 3.4 = -0.2°C.**
- **NINO 3.4 was above 0.5°C in Jul-Sep 2012, but the duration was too short to meet El Nino definition.**
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.**

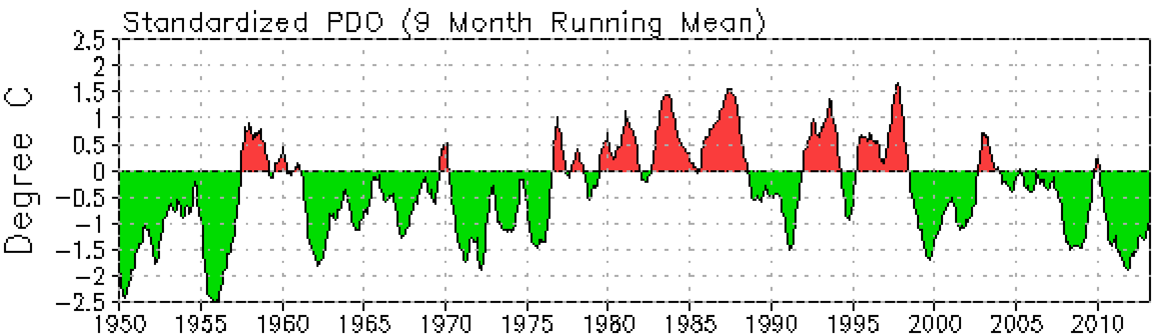
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 (bar) and last ten year (green line) means.

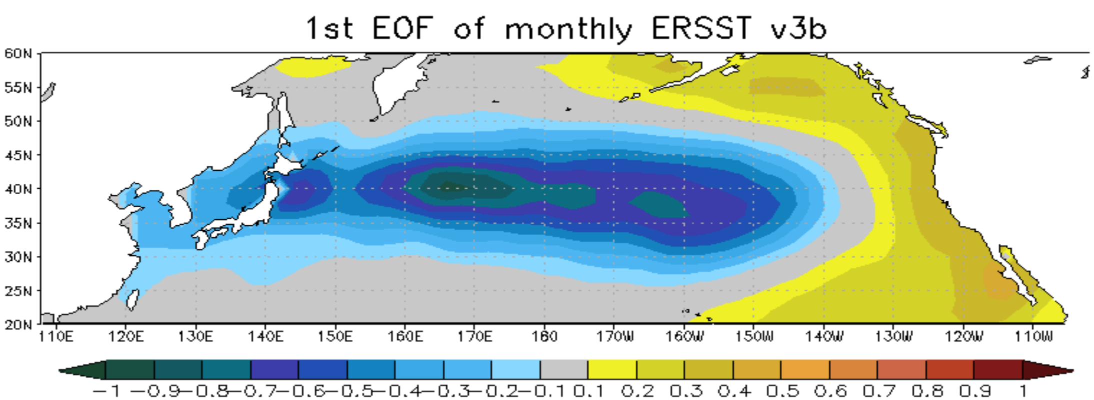
North Pacific & Arctic Oceans

Pacific Decadal Oscillation Index









- Negative PDO phase since May 2010 has persisted for almost 3 years (35 months) now, and the PDO index strengthened slightly in Mar 2013 with PDO index=-1.6.

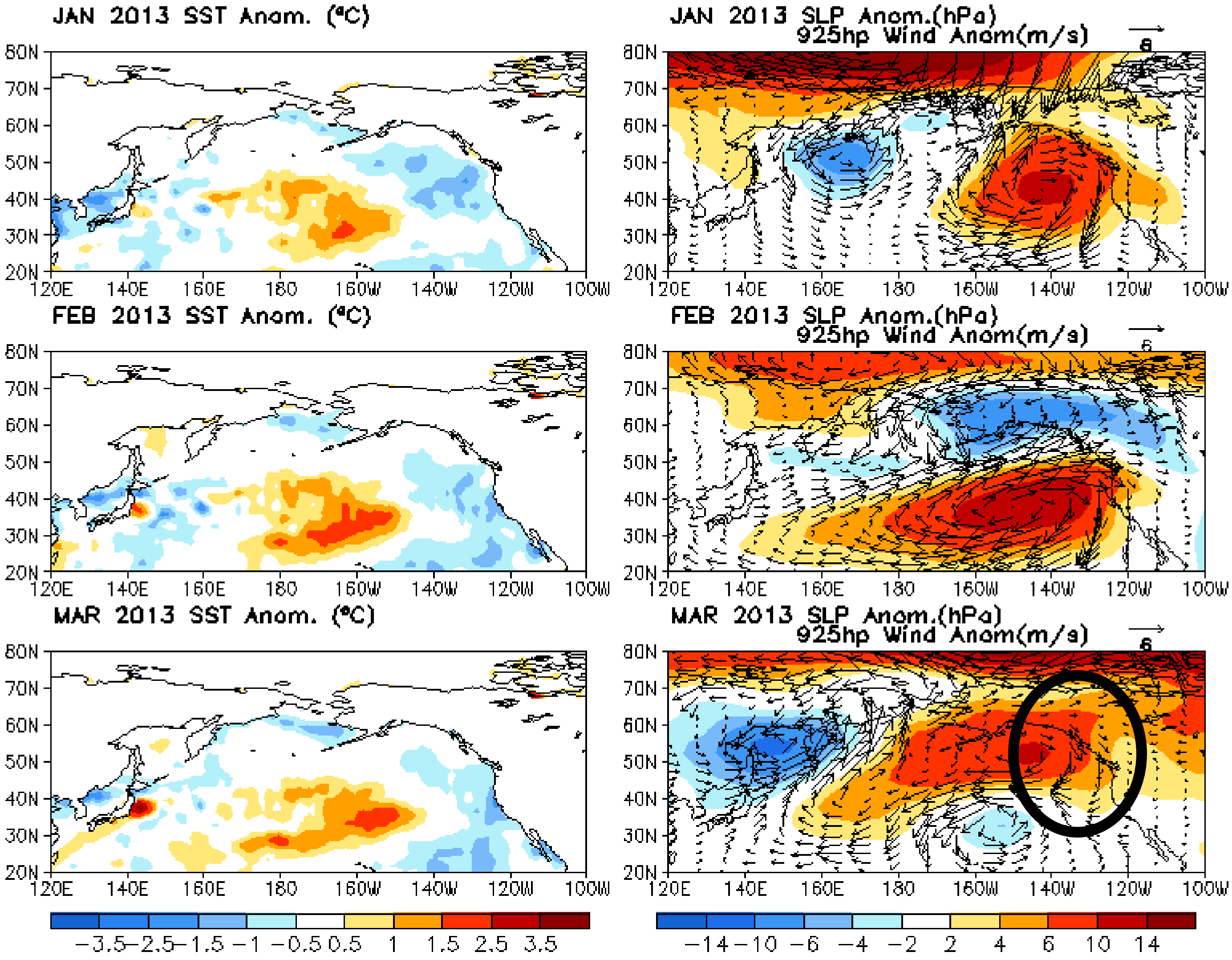
- The apparent connection between Nino3.4 and PDO indices suggest connections between tropics and extra-tropics.

- However, the negative phase of PDO during Jun-Nov 2012 seems not connected with the positive Nino3.4 SSTA.

- 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.

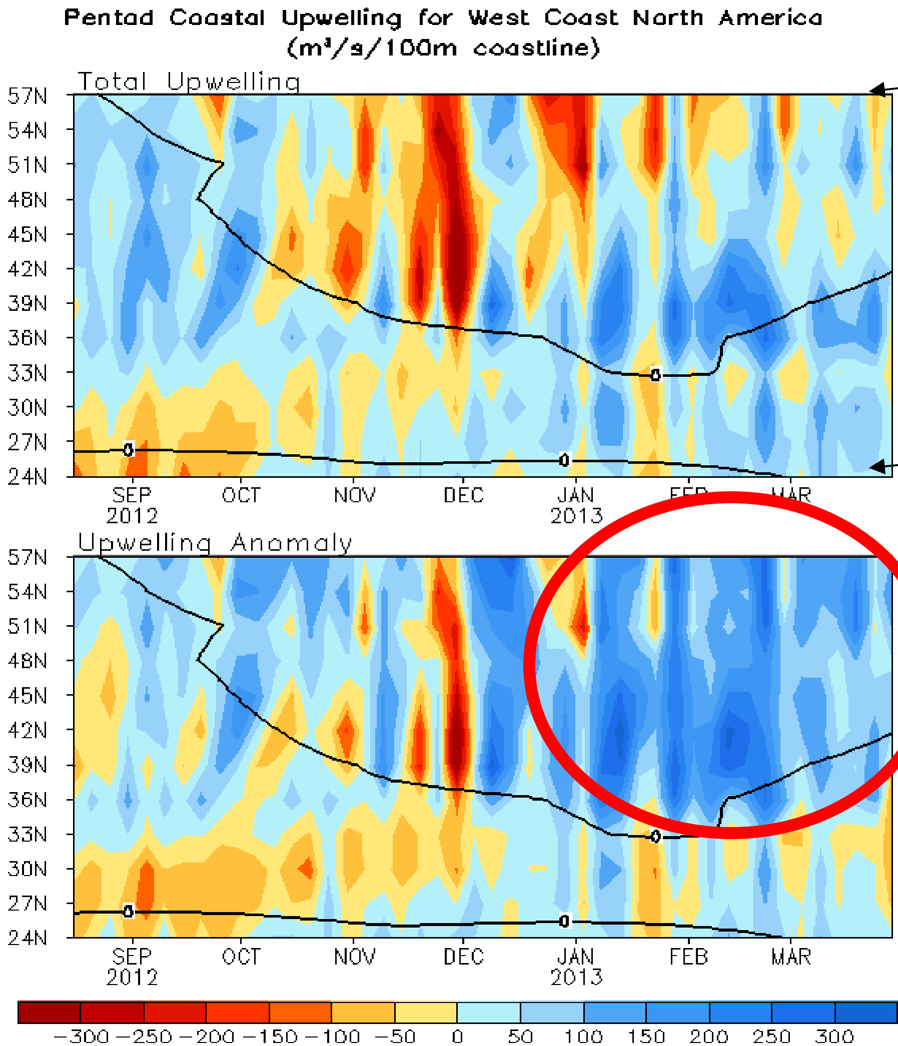
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

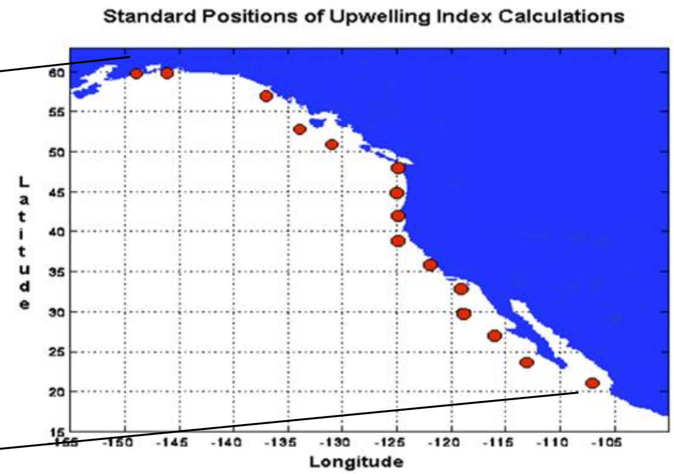
Last Three Month SST, SLP and 925hp Wind Anom.



- **Negative phase of PDO associated SSTA persisted.**
- **Anomalous anti-cyclone was observed near the coast of Alaska and Pacific Northwest in Mar 2013.**

North America Western Coastal Upwelling





- Consisted with the anomalous northerly wind, downwelling in 36-57N was suppressed.

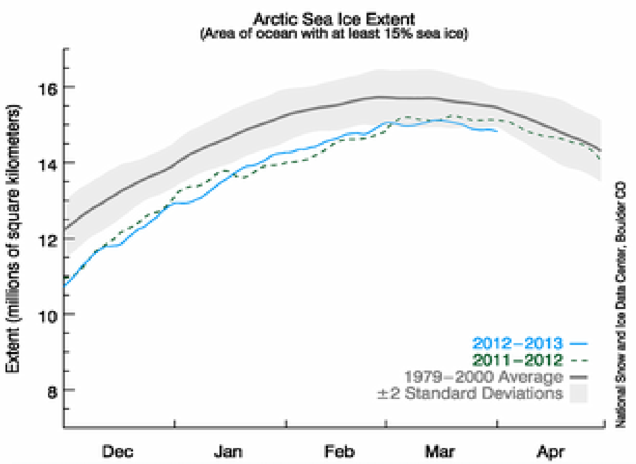
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

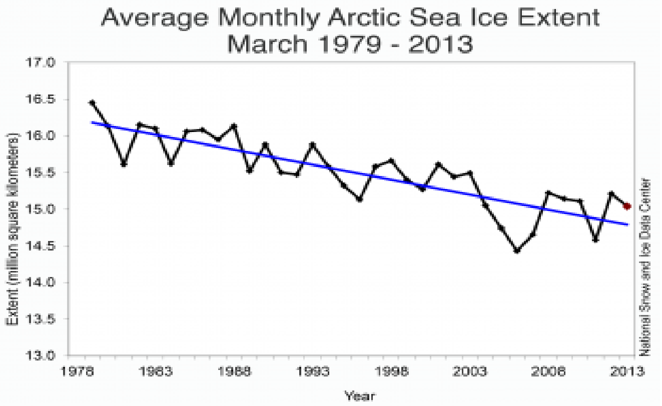
- Area below (above) black line indicates climatological upwelling (downwelling) season.

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

Arctic Sea Ice

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





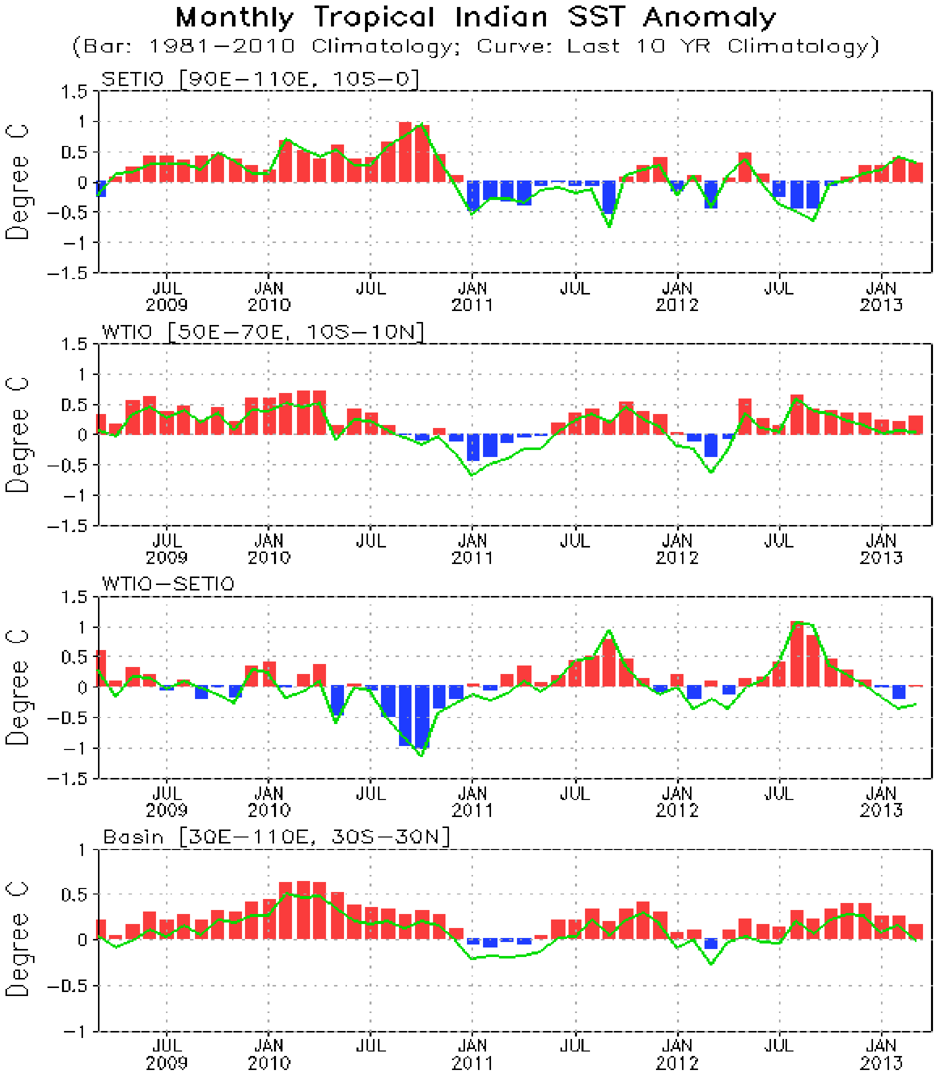
- **Average sea ice extent for Mar 2013 was well below-normal (-2 standard deviations).**

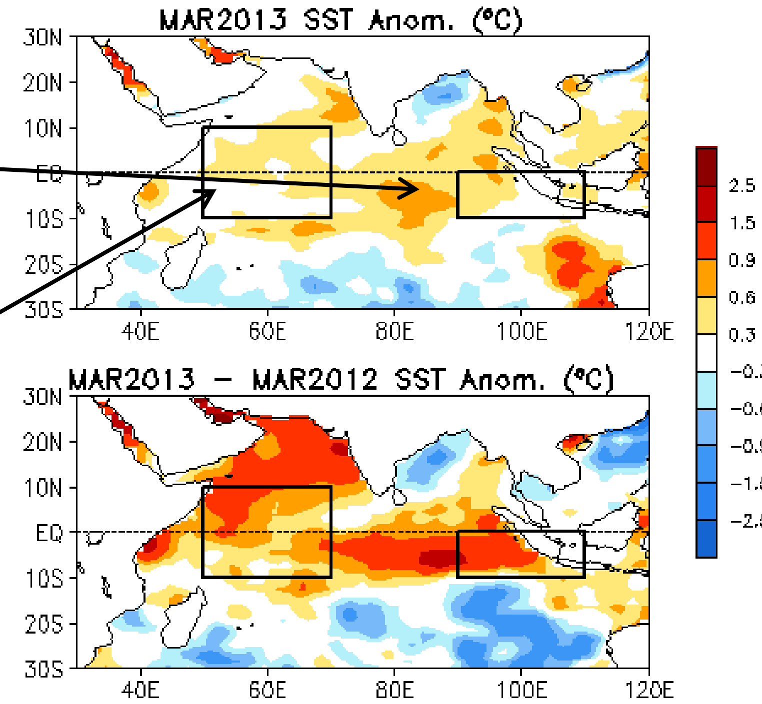
- **Arctic sea ice has passed its annual maximum extent and was beginning its seasonal decline through the spring and summer.**

- **This year's maximum ice extent was the sixth lowest in the satellite record. The lowest maximum extent occurred in 2011. The ten lowest maximums in the satellite record have occurred in the last ten years, 2004 to 2013. (From Follow Rachael)**

Indian Ocean

Evolution of Indian Ocean SST Indices



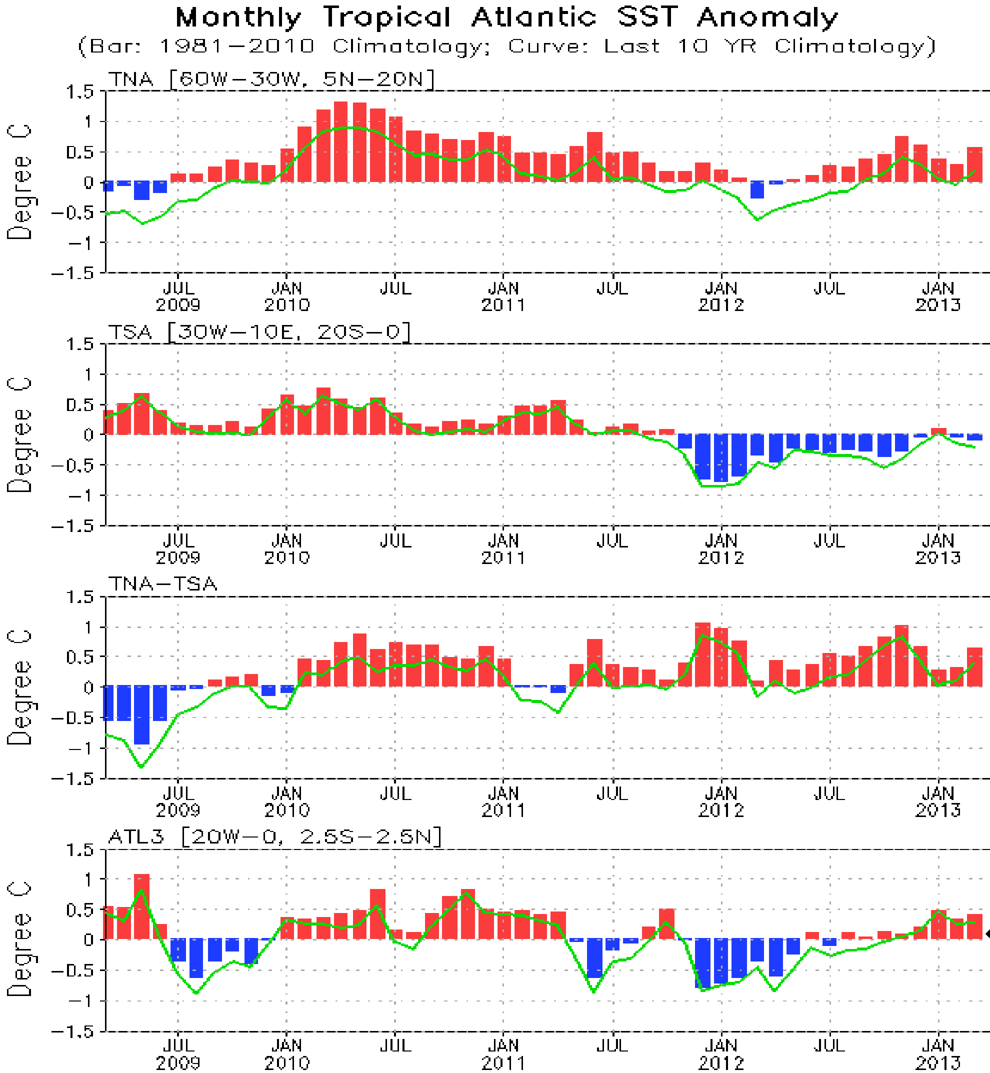


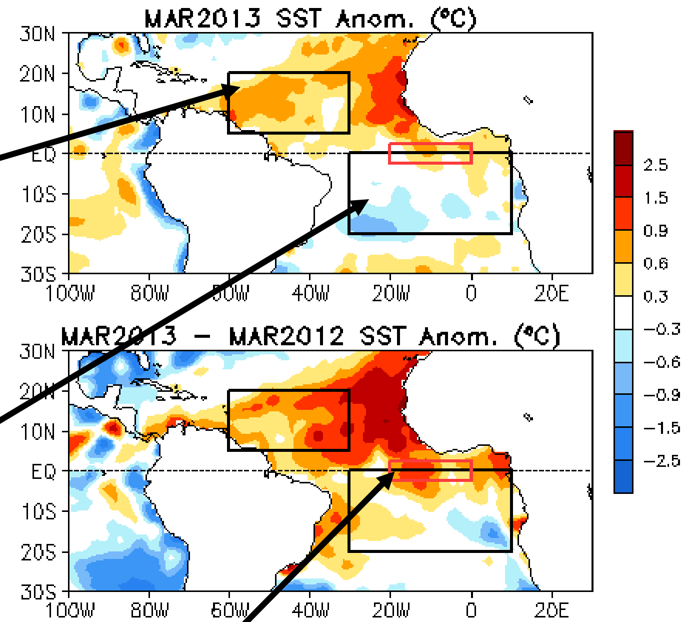
- **DMI was near normal in Mar 2013.**
- **The basin mean SSTA was above-normal.**

Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (ºC) for the SETIO [90ºE-110ºE, 10ºS-0] and WTIO [50ºE-70ºE, 10ºS-10ºN] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices



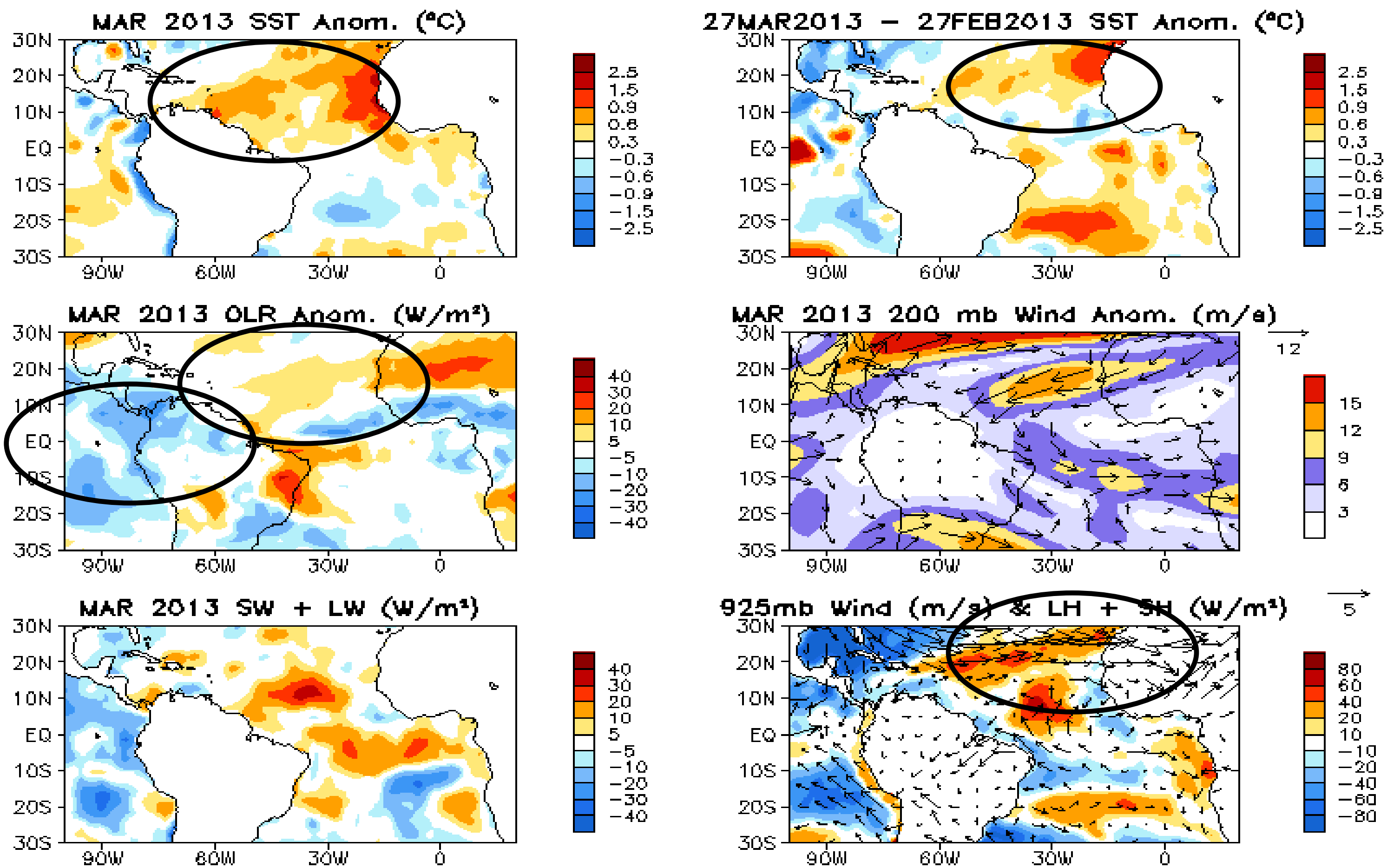


- **SSTA in the tropical North Atlantic (TNA) was positive since May 2012.**
- **Meridional Gradient Mode index (TNA-TSA) was positive since May 2011.**
- **ATL3 SSTA was positive since Aug 2012.**

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

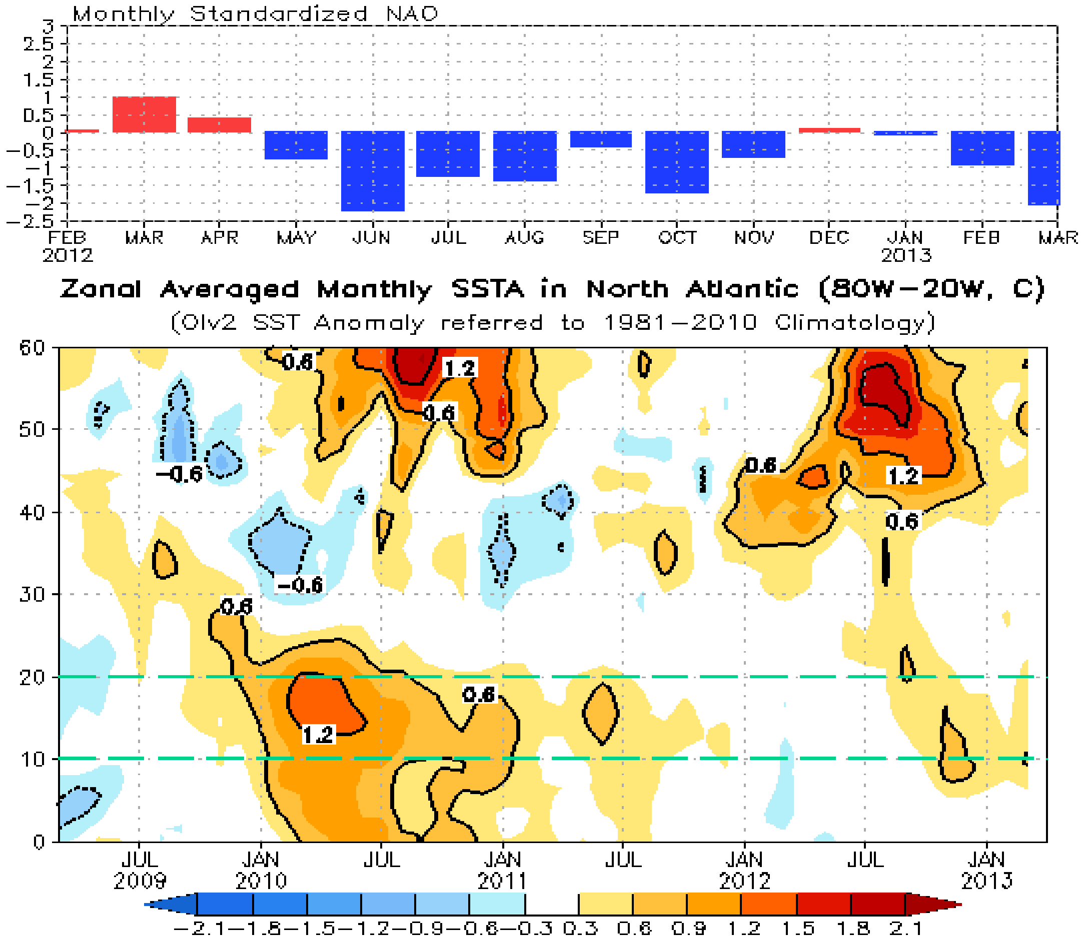
Tropical Atlantic:

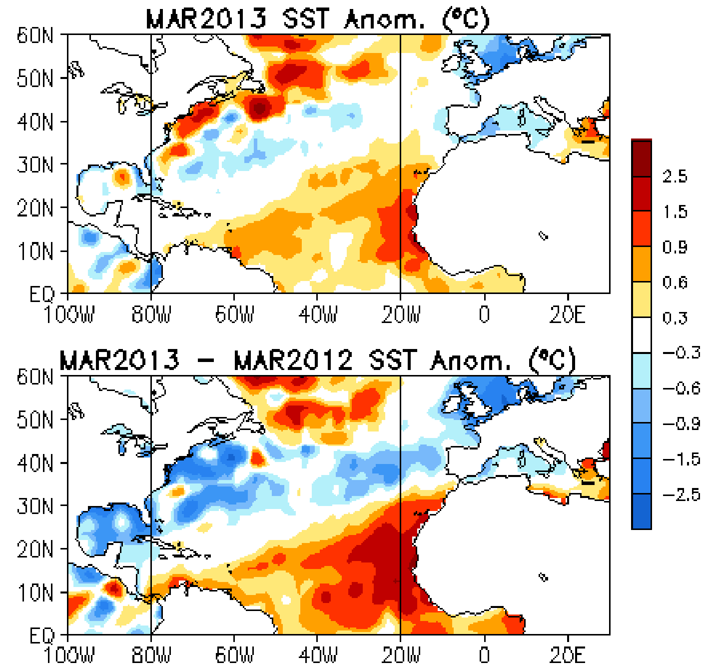
SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb/200-mb Winds



- Above-normal SSTA enhanced in the hurricane Main Development Region (MDR).
- Convection was enhanced in Central America and suppressed in the tropical North Atlantic.
- Westerly low-level wind blew towards the western Africa.

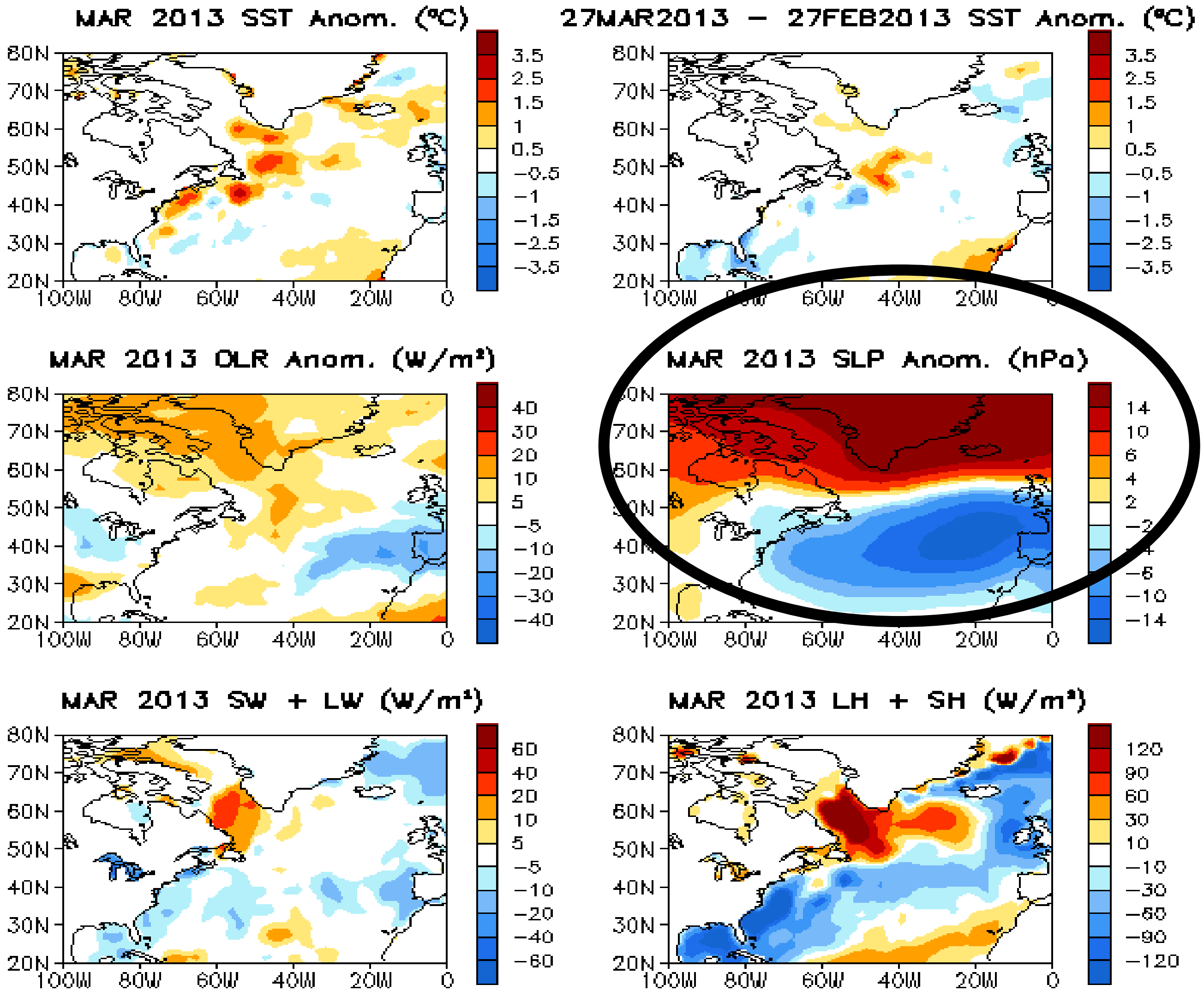
NAO and SST Anomaly in North Atlantic





- **Negative NAO strengthened significantly in Mar 2013, with NAO index = -2.1.**
- **High-latitude North Atlantic SSTA is generally related to NAO index (negative NAO results in SST warming and positive NAO leads to SST cooling) (Hu et al. 2011: *J. Climate*, 24(22)).**

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

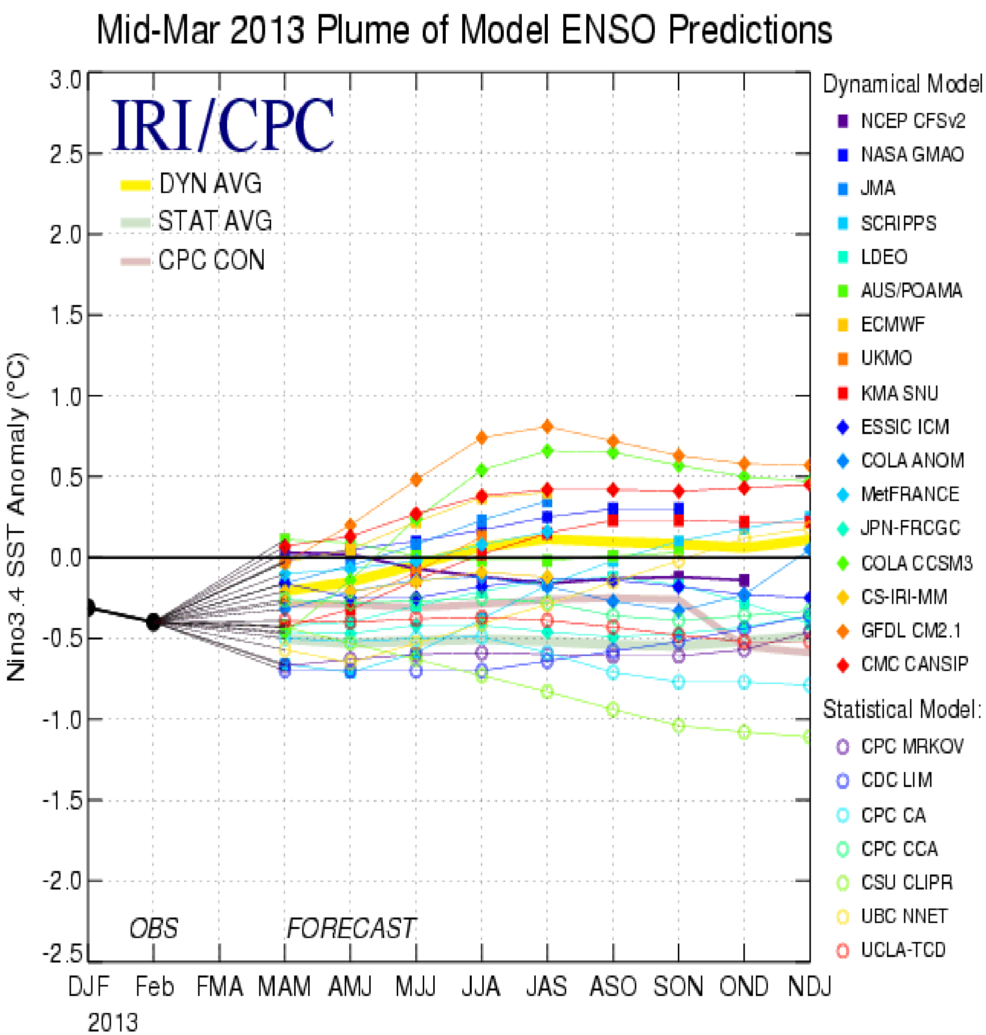


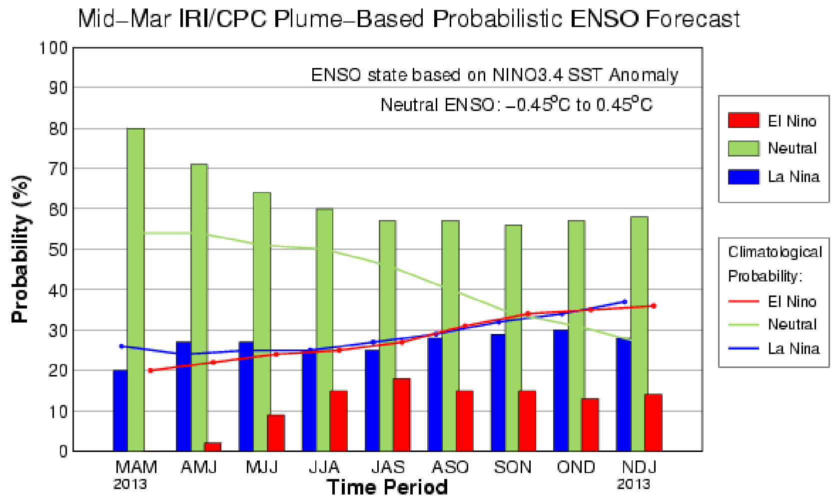
North Atlantic: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

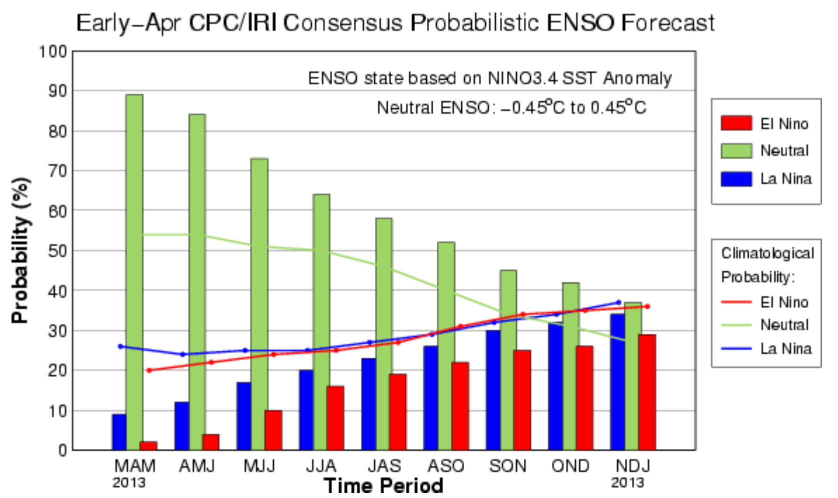
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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 1979-1995 base period means except SST anomalies are computed with respect to the 1971-2000 base period means.

Global SST Predictions

IRI/CPC NINO3.4 Forecast Plume

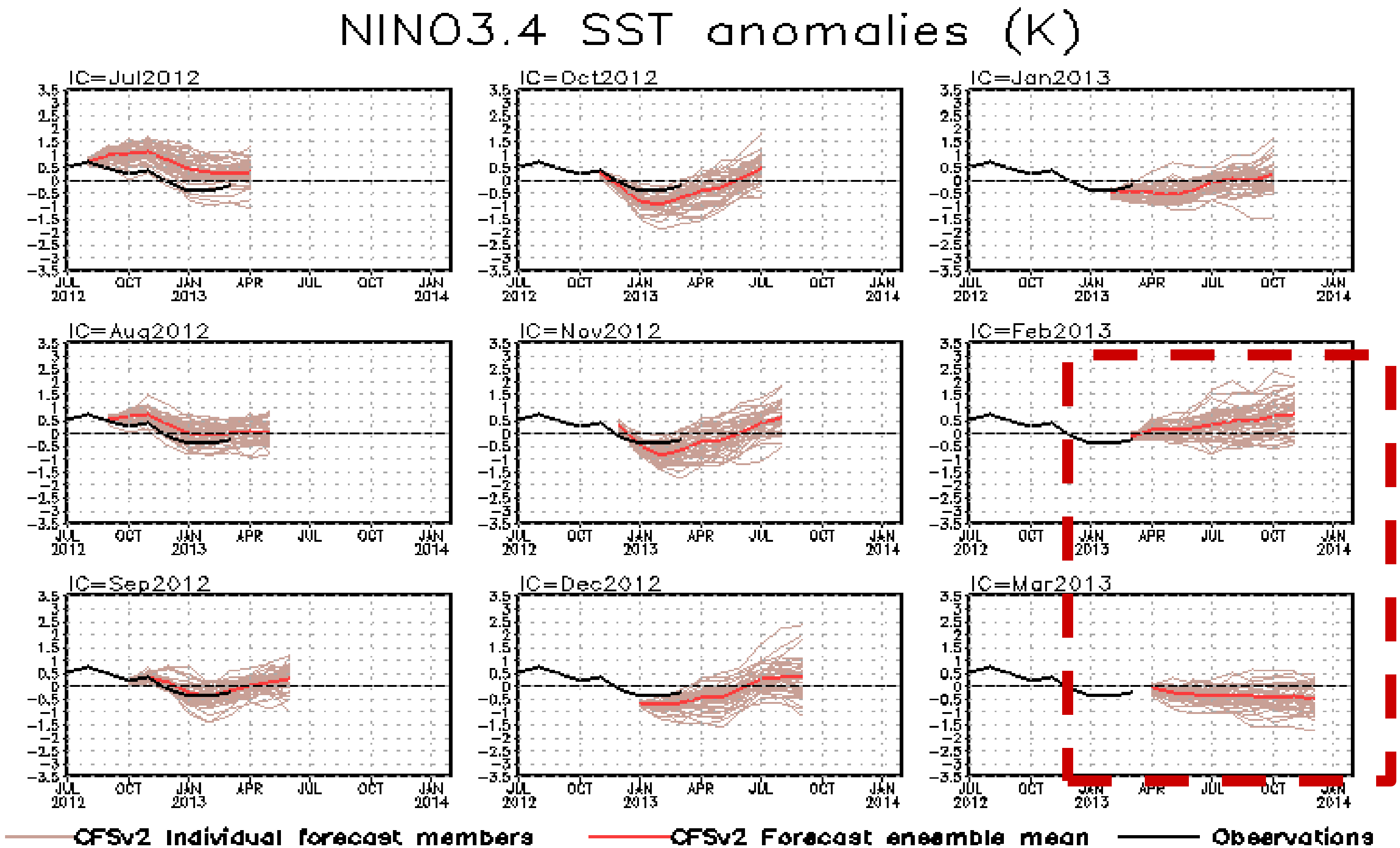






- **Majority of the models predicted ENSO-neutral in the Northern Hemisphere spring-summer.**
- **The consensus forecast favors ENSO-neutral conditions in the spring and summer.**

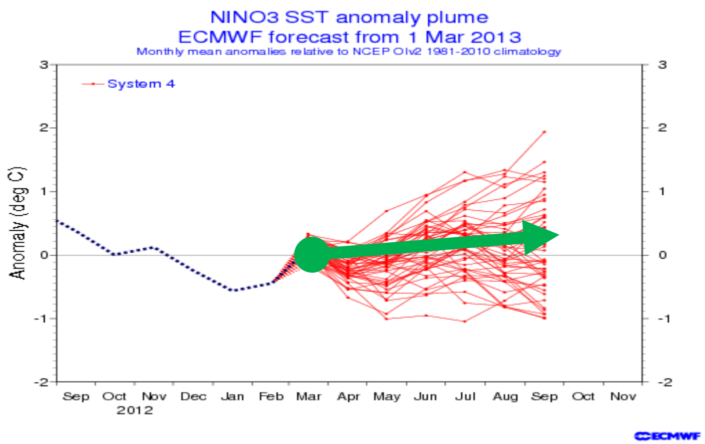
NCEP CFSv2 NINO3.4 Forecast



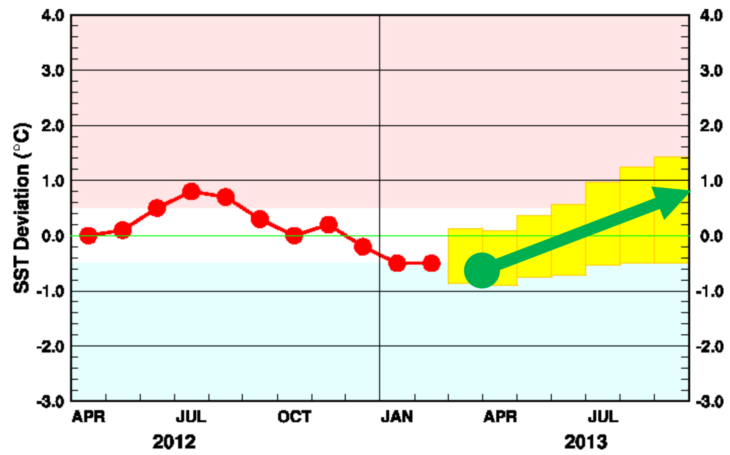
- **The predictions of CFSv2 shifted from positive SSTA in summer-autumn with IC in Feb 2013 to negative with IC in Mar 2013, may imply the uncertainty and challenge of ENSO prediction with IC in spring.**

Individual Models: Slightly warming tendency in some models

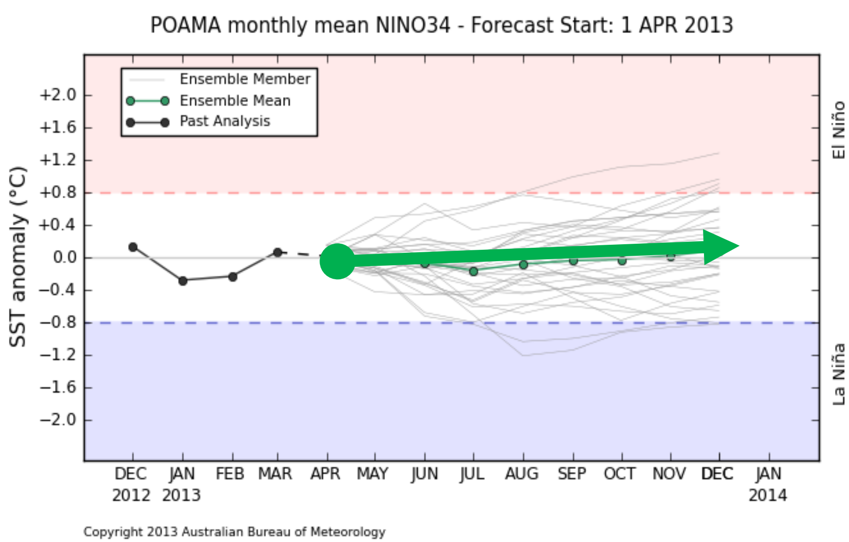
ECMWF: Nino3, IC=01Mar2013



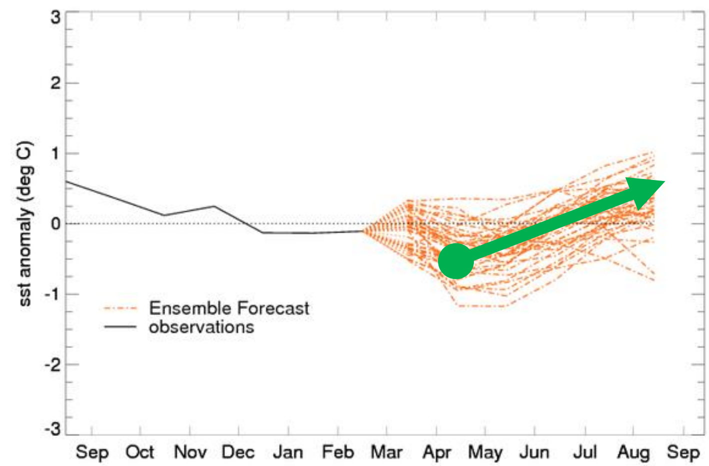
JMA: Nino3, IC=Mar2013



Australia: Nino3.4, IC=01Apr2013



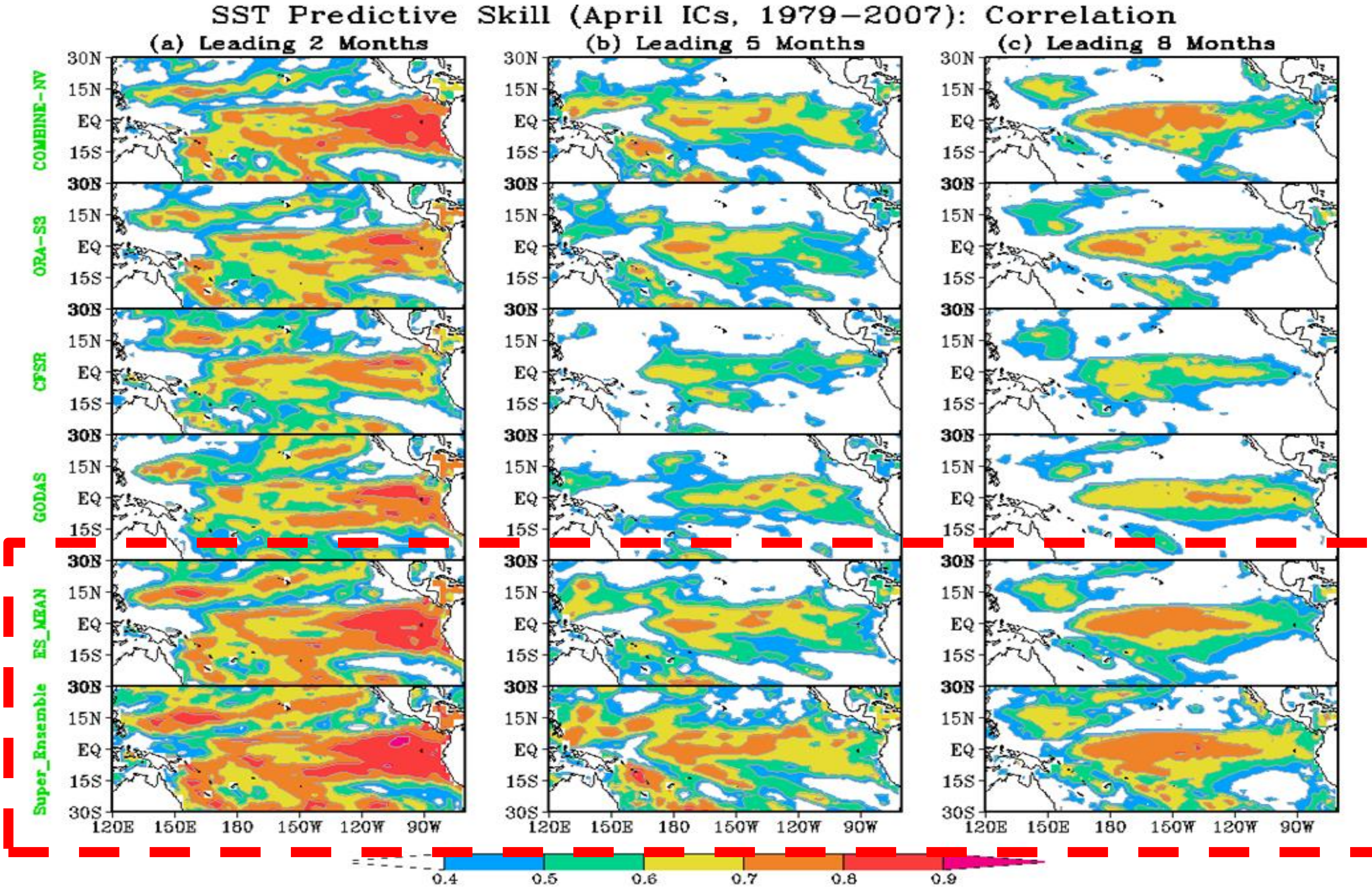
UKMO: Nino3.4, IC=Mar2013



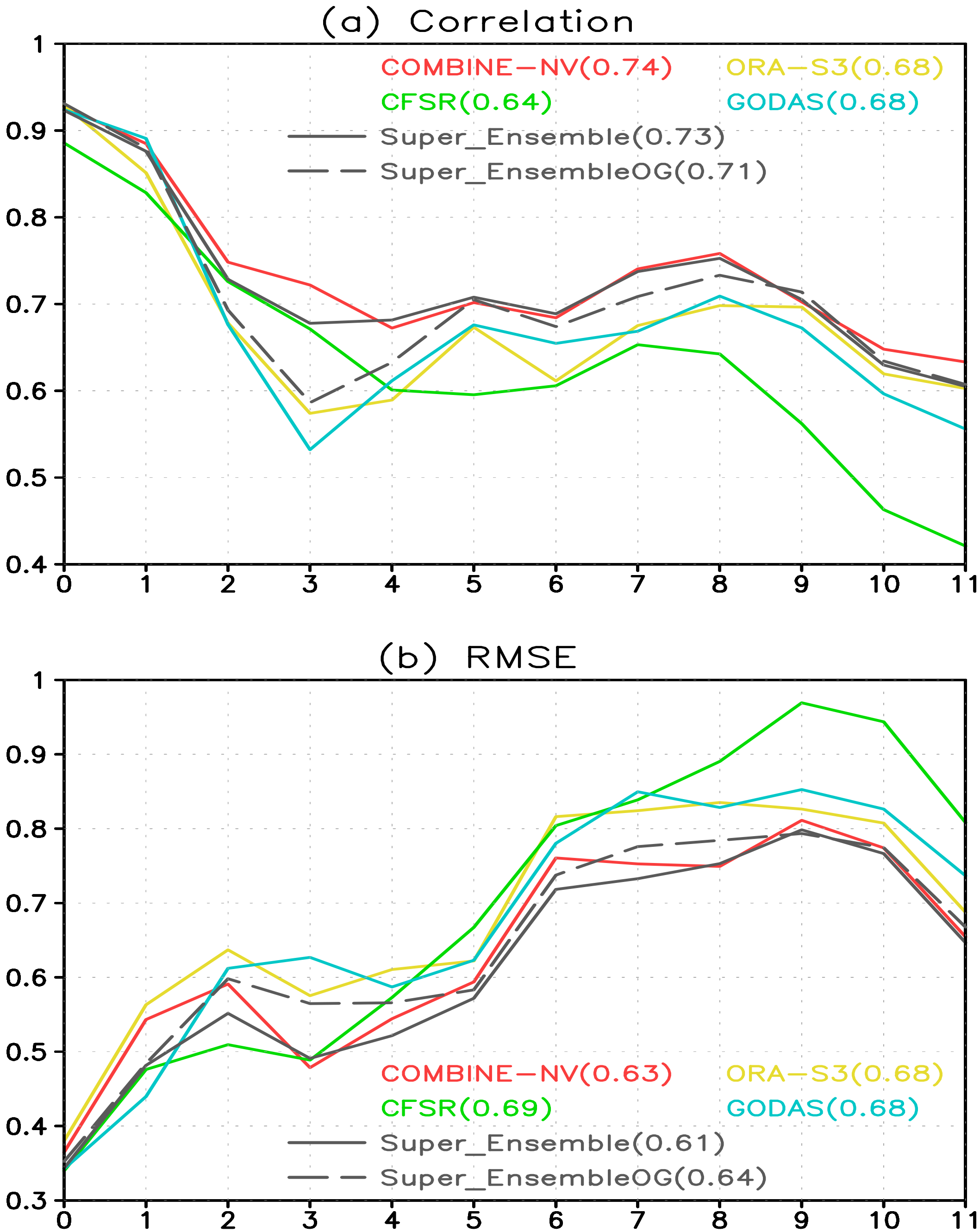
A New Strategy to Improve ENSO/Climate Prediction:

Individual Model Forecasts: Multi-Ocean IC Ensemble

(From: Zhu et al., 2012: Ensemble ENSO hindcasts initialized from multiple ocean analyses. *Geophys. Res. Lett*., **39,** L09602)



Distribution of anomaly correlations between observed and predicted SST anomalies at 2-, 5-, and 8-month lead times with being shown in the 1st, 2nd and 3rd column, respectively. The results for COMBINE-NV, ORA-S3, CFSR, GODAS, ES_MEAN, and Super-Ensemble are shown from the most upper row to the lowest row.



A New Strategy to Improve ENSO/Climate Prediction:

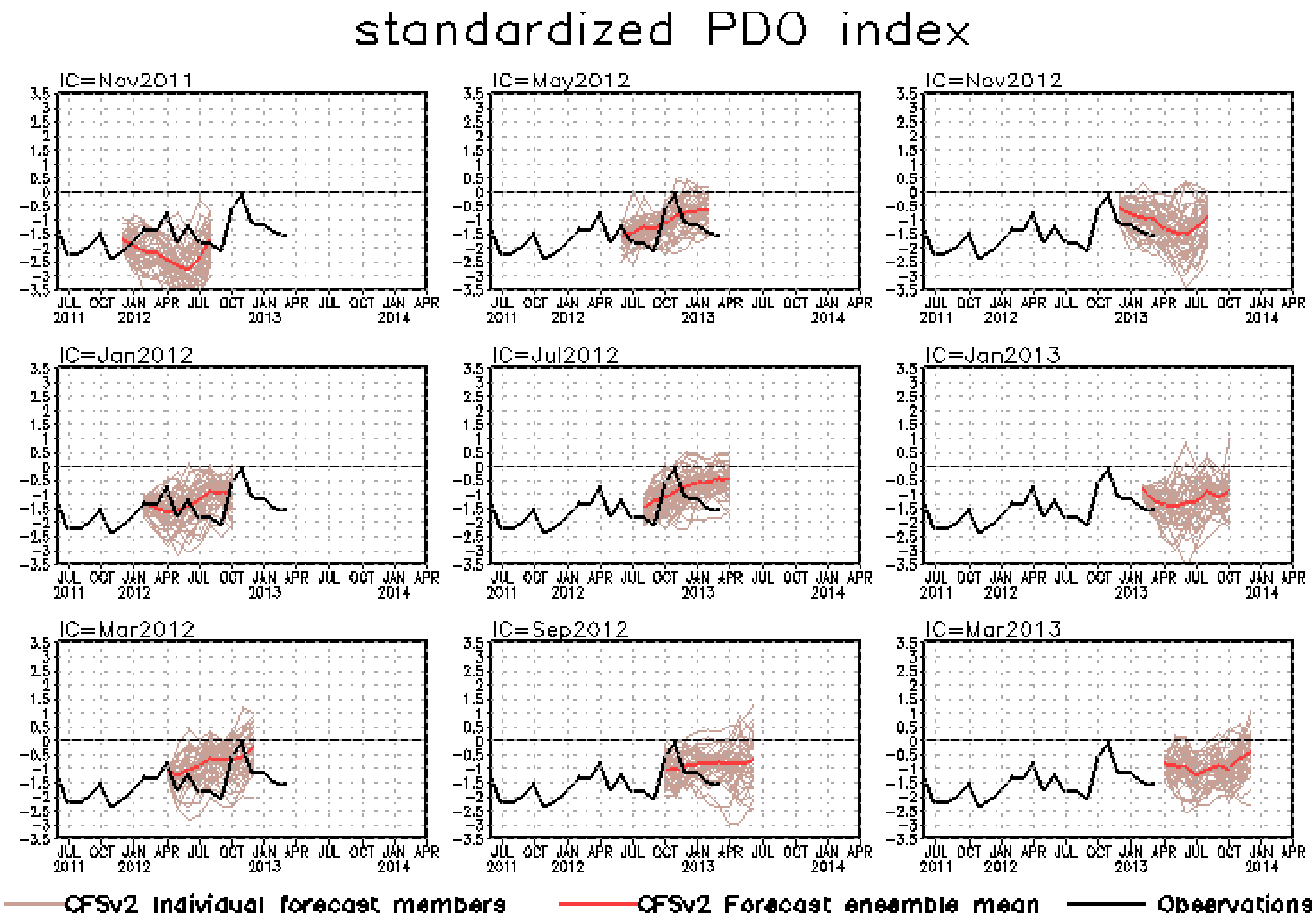
Individual Model Forecasts:
Multi-Ocean IC Ensemble:

Similar to multi-atmospheric IC ensemble, multi-oceanic IC ensemble also has the potential to improve climate prediction skill.

(From: Zhu et al., 2012: Ensemble ENSO hindcasts initialized from multiple ocean analyses. *Geophys. Res. Lett*., **39,** L09602)

(a) Anomaly correlation coefficients and (b) RMS errors (ºC) of NINO3.4 index during 1979–2007 with respect to lead months after removing the mean bias. Colored curves are for forecasts with four different ocean analyses. The solid grey curve is for the super ensemble based on all four sets of forecasts. The dashed grey curve is for the super ensemble based on forecasts from ORA-S3 and GODAS analyses.

NCEP CFSv2 Pacific Decadal Oscillation (PDO) Forecast

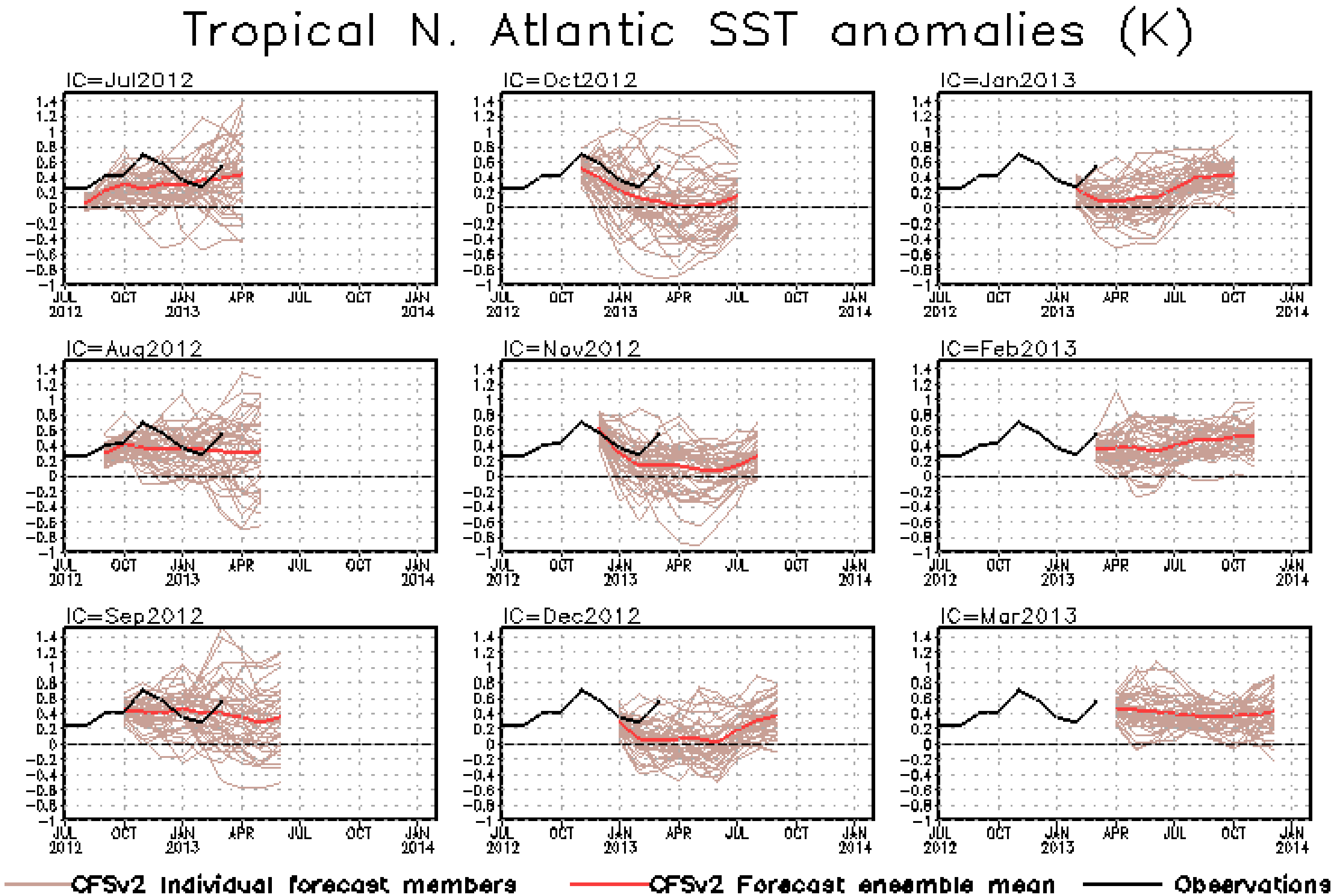


PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

- Latest CFSv2 prediction suggests negative phase of PDO will persist through the coming summer and autumn.

NCEP CFSv2 Tropical North Atlantic SST Forecast



- Latest CFSv2 prediction suggests that above-normal SST in the tropical North Atlantic will continue in spring-autumn 2013 (hurricane season).

Overview

- **Pacific and Arctic Oceans**

➢ ENSO-neutral condition continued during Mar 2013 with Nino3.4=-0.2C.

➢ NOAA officially forecast ENSO-neutral condition to continue in the Northern Hemisphere spring-summer 2013.

➢ Negative PDO phase slightly strengthened with PDO index =-1.6 in Mar 2013, and NCEP CFSv2 predicted negative phase of PDO would continue.

➢ Arctic sea ice extent in Mar 2013 was well below-normal and was beginning its seasonal decline.

- **Indian Ocean**

➢ SSTs in Indian Ocean were above or near-normal in Mar 2013.

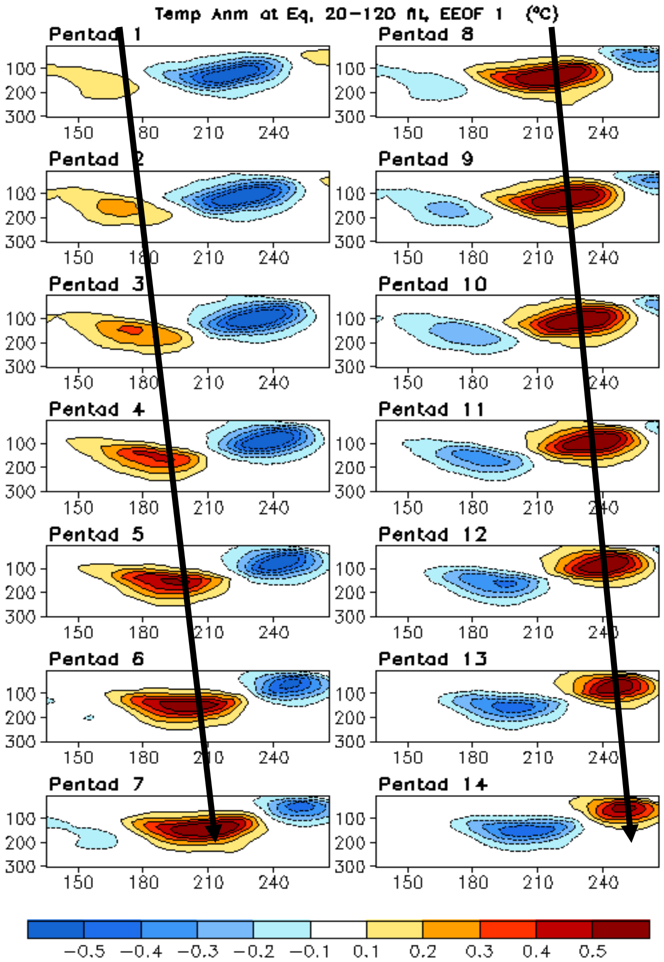
- **Atlantic Ocean**

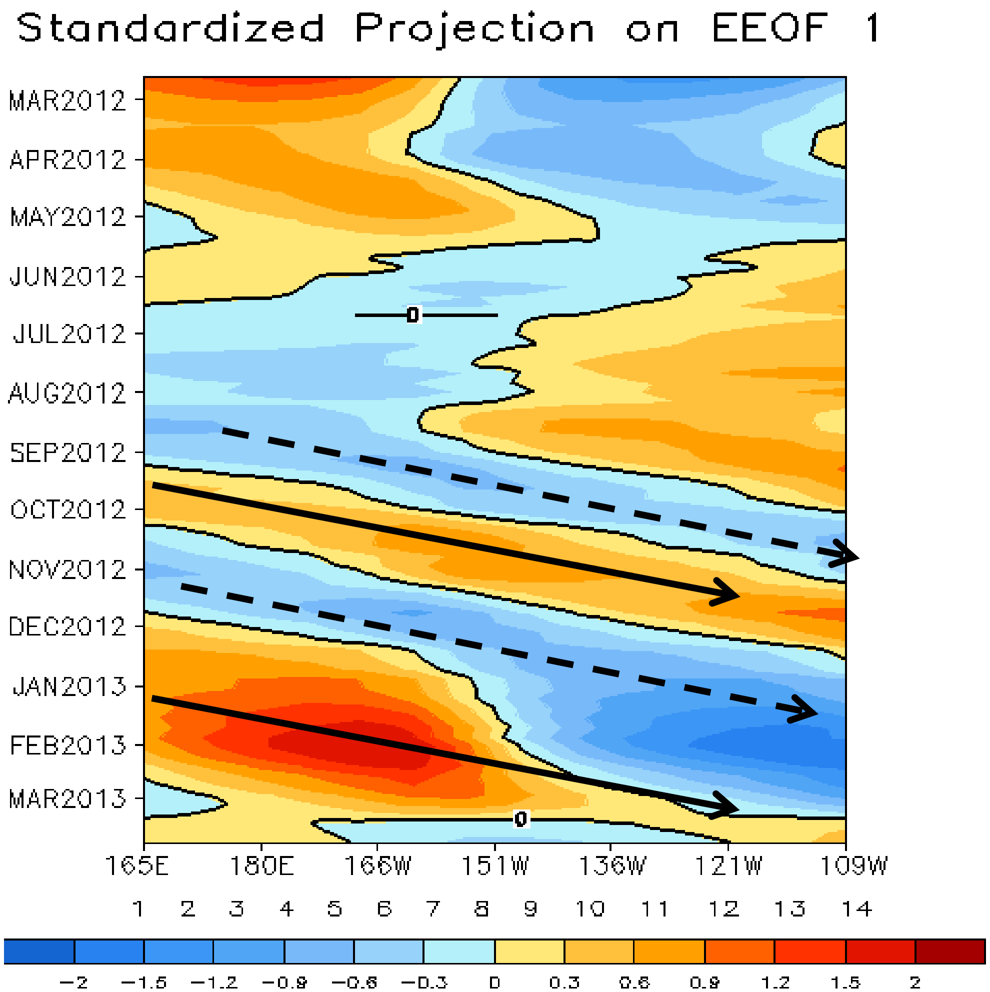
➢ Negative phase of NAO strengthened significantly with NAO index =-2.1 in Mar 2013.

➢ Positive SSTA in high-latitude and tropical N. Atlantic enhanced in Mar 2013.

Backup Slides

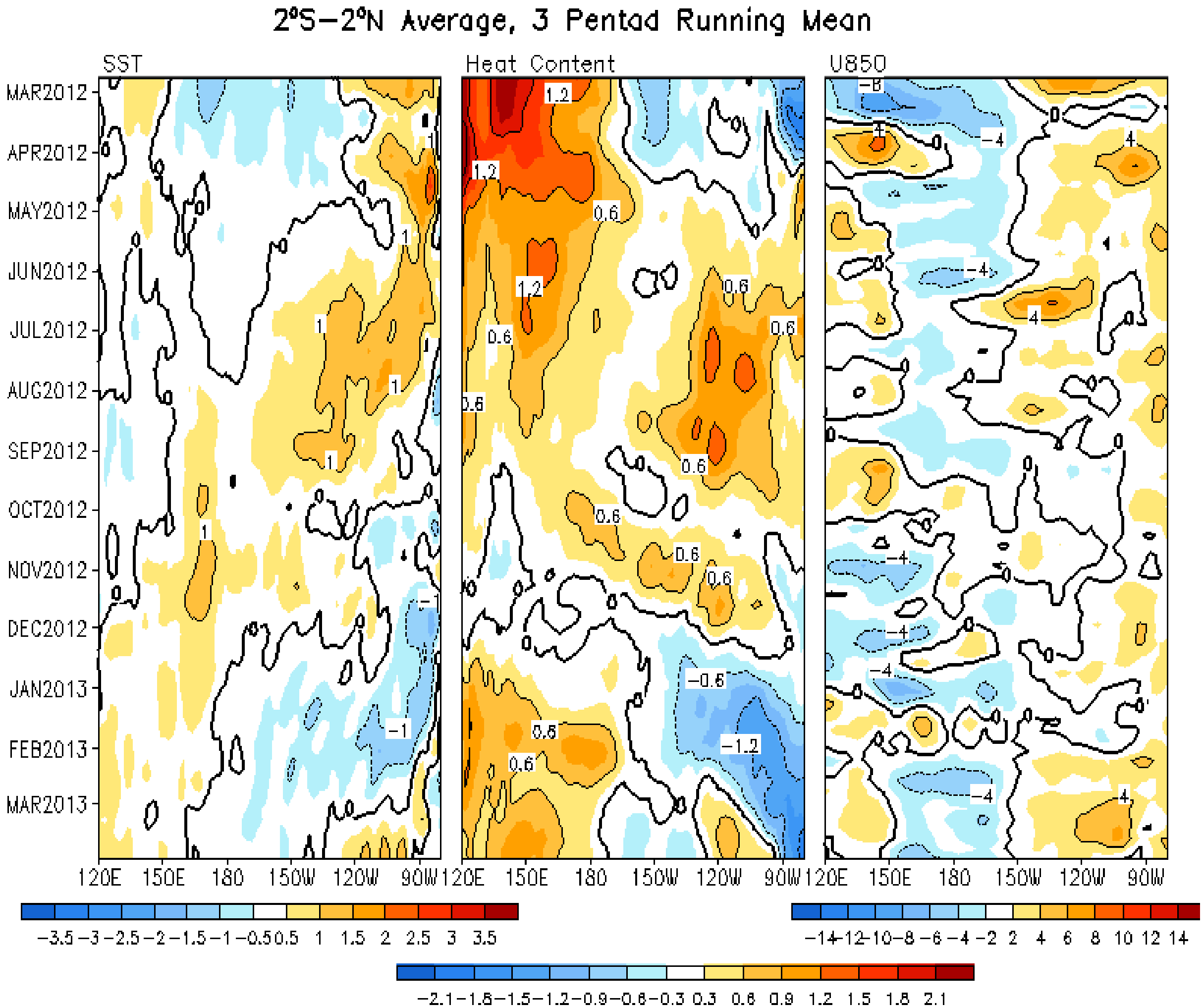
Oceanic Kelvin Wave Indices





- Oceanic Kelvin wave indices are defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF 1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).

Equatorial Pacific SST (ºC), HC300 (ºC), u850 (m/s) and OLR(W/m^2)Anomalies



CPC MJO Indices

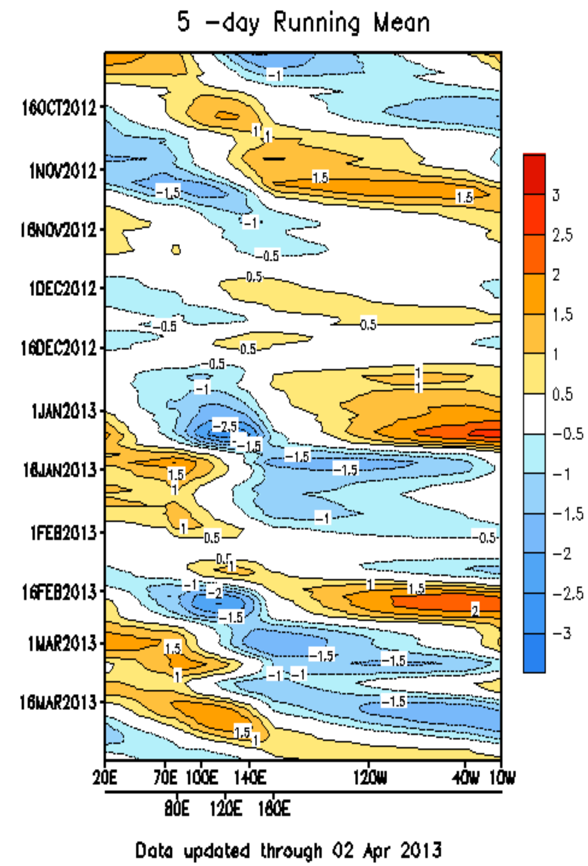


Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2ºS-2ºN and Outgoing Long-wave Radiation (OLR, right) averaged in 5ºS-5ºN. SST is derived from the NCEP OI 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

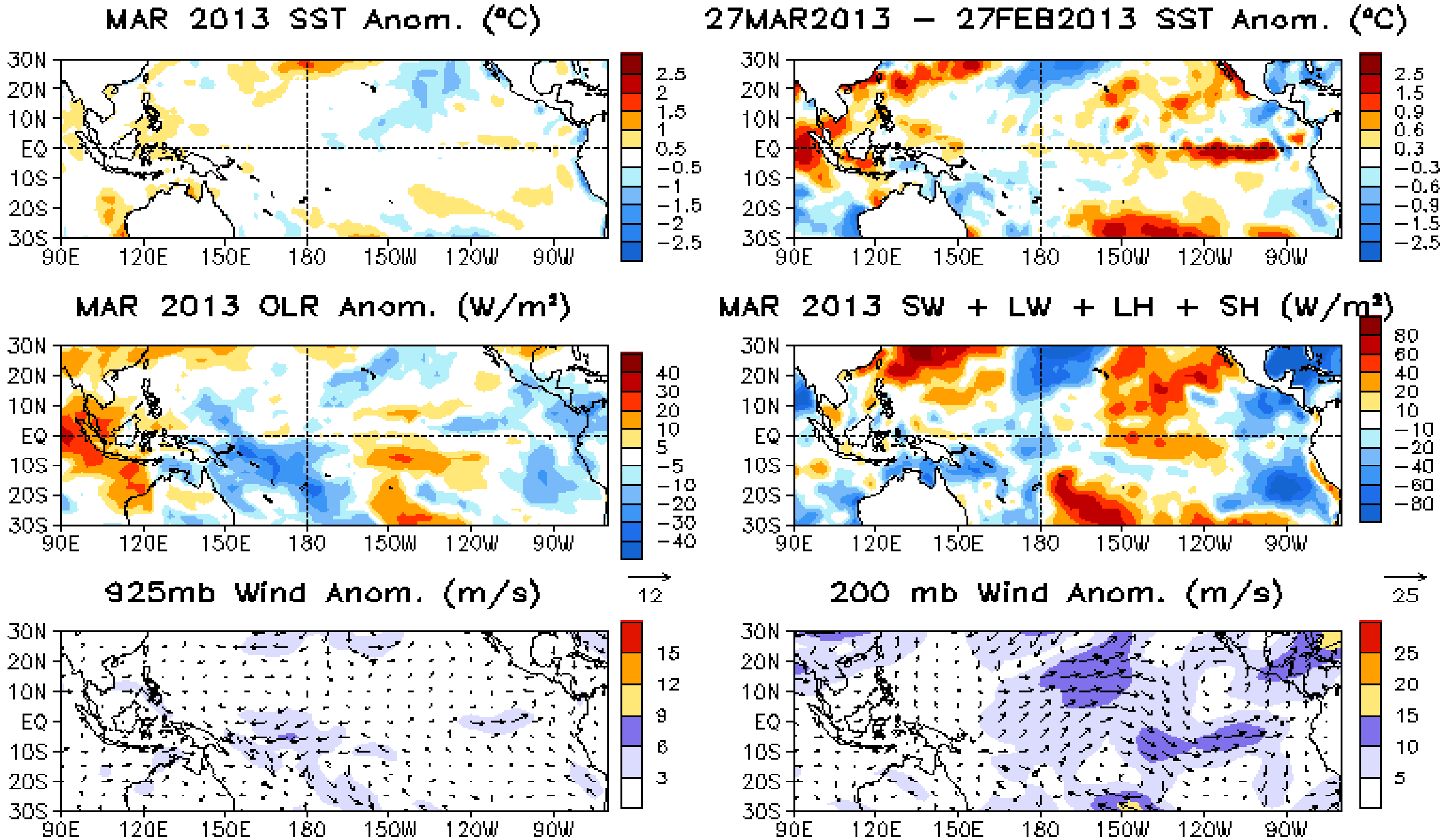
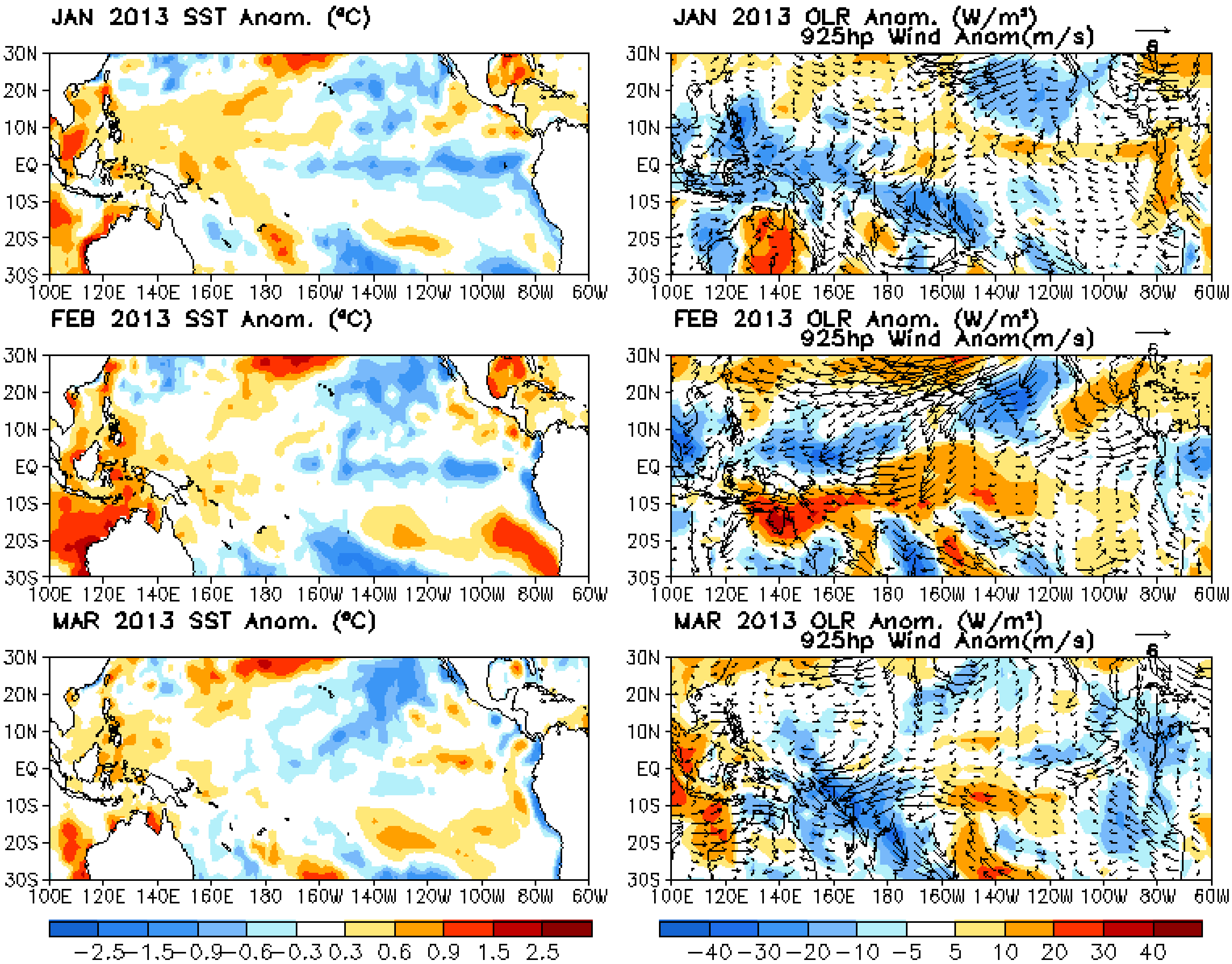


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Last Three Month SST, OLR and 925hp Wind Anom.



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

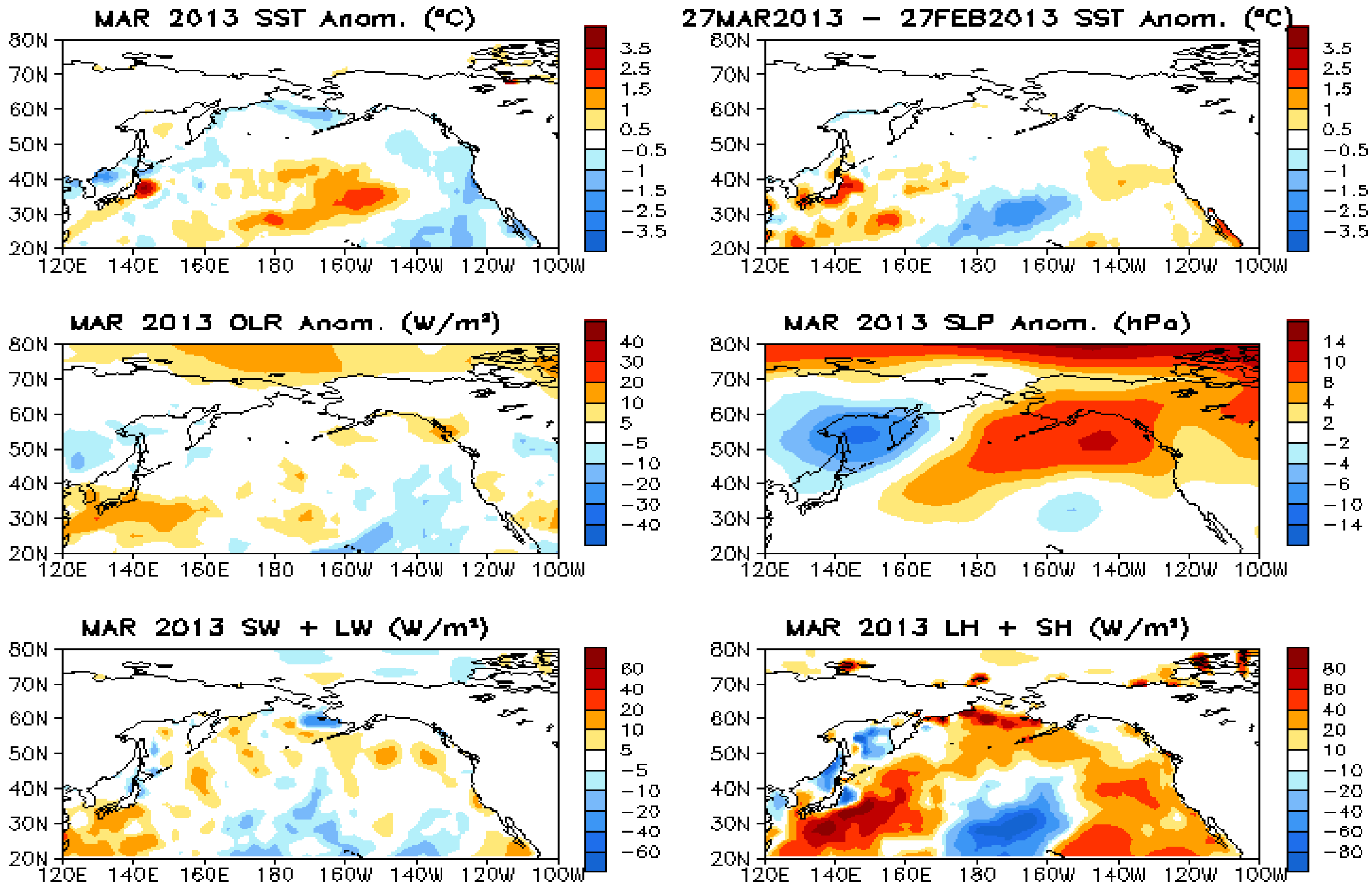
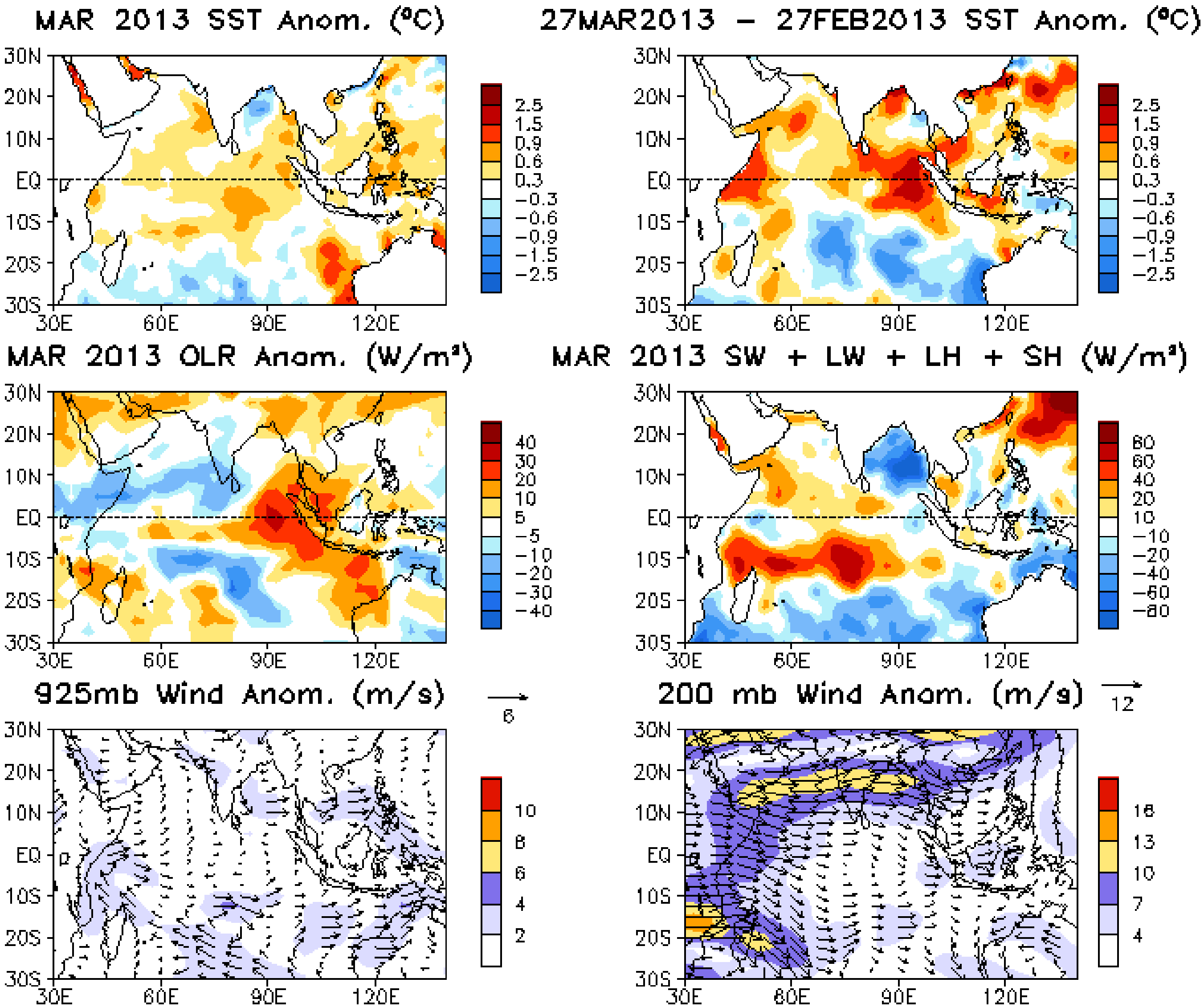
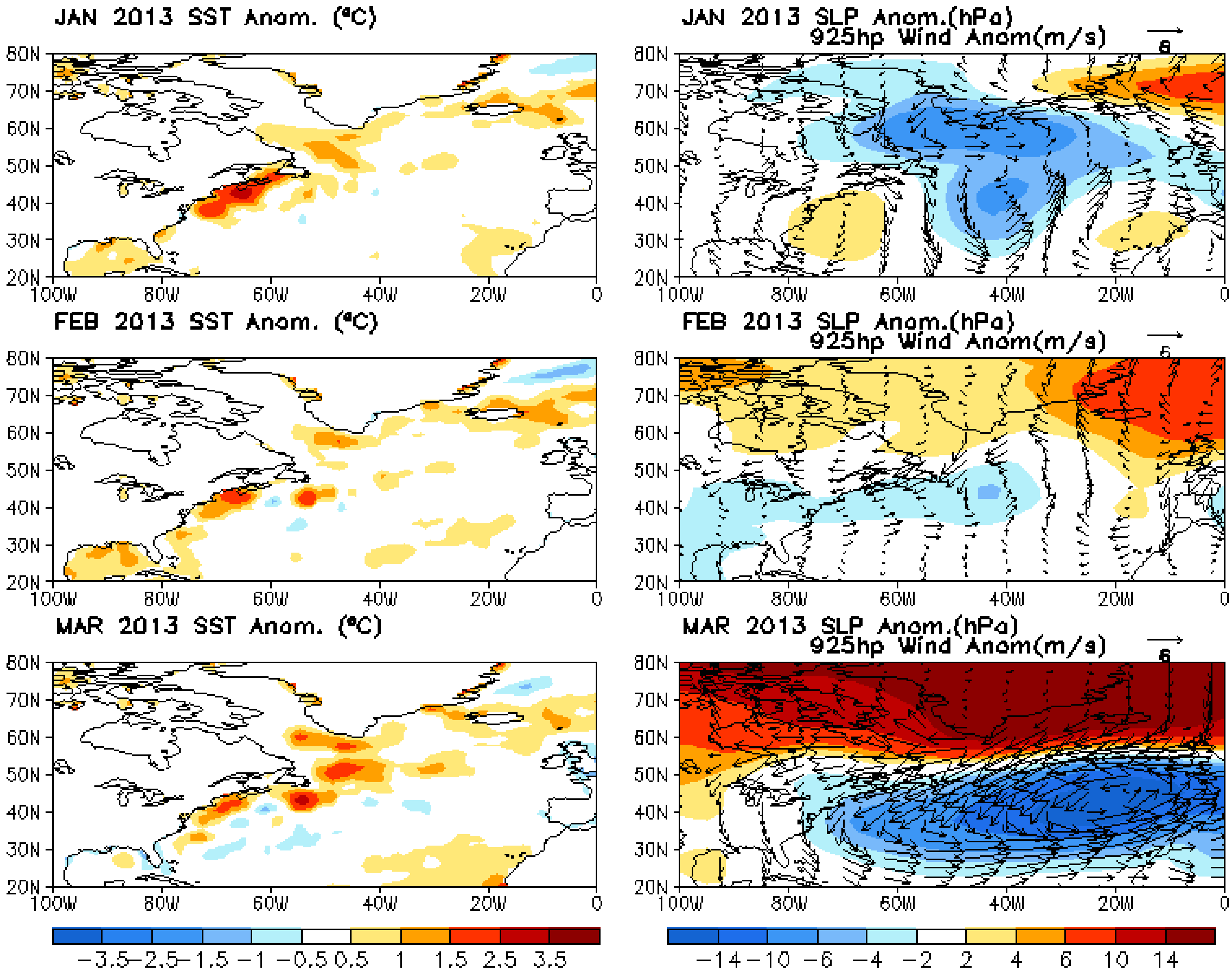


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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.

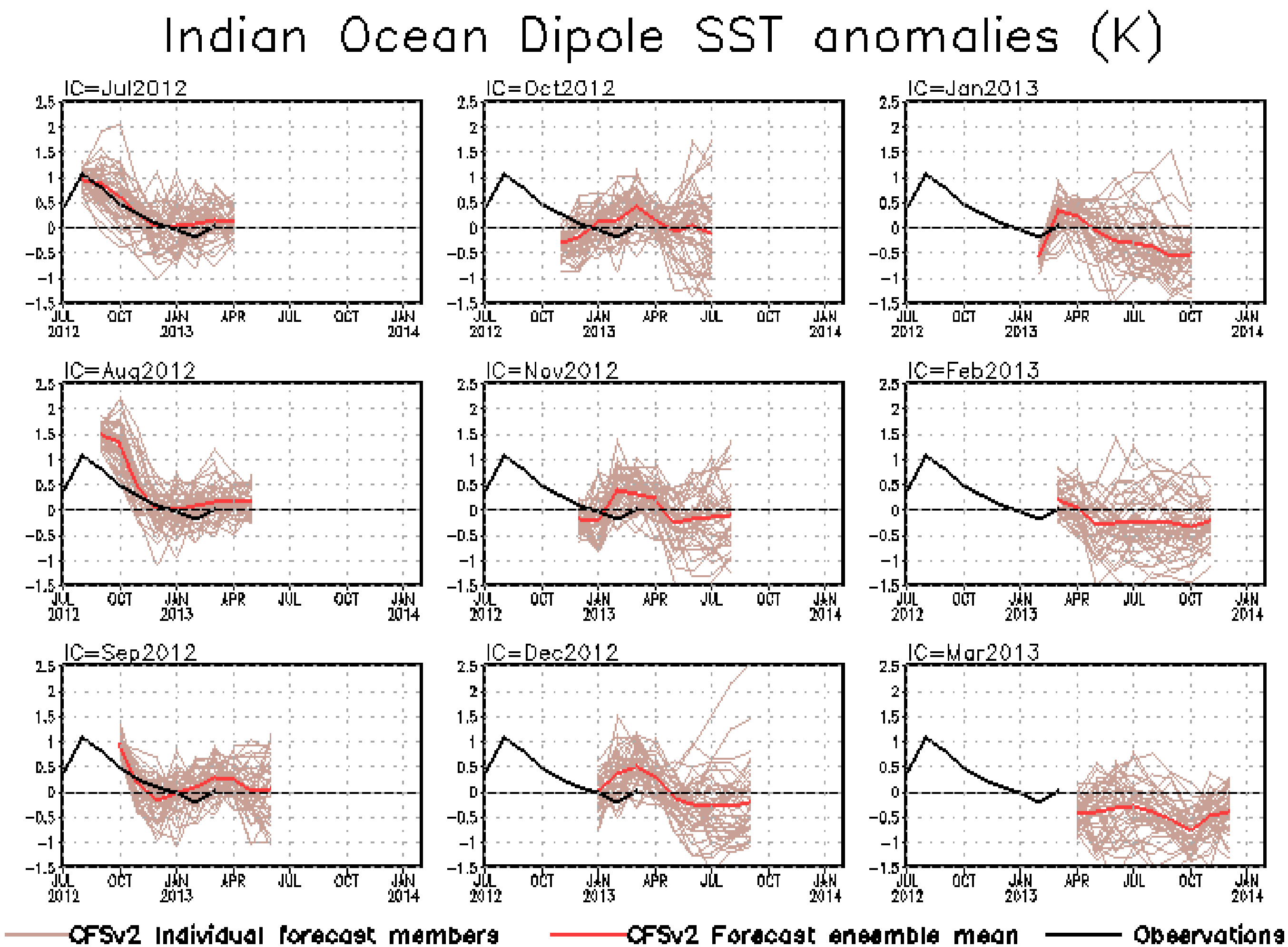


Tropical Indian: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.

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.


JAN 2013 SST Anom. (°C)
JAN 2013 SLP Anom.(hPa)
925hp Wind Anom(m/s)
FEB 2013 SST Anom. (°C)
FEB 2013 SLP Anom.(hPa)
925hp Wind Anom(m/s)
MAR 2013 SST Anom. (°C)
MAR 2013 SLP Anom.(hPa)
925hp Wind Anom(m/s)
80N 70N 60N 50N 40N 30N 20N
100W 80W 60W 40W 20W 0
−3.5 −2.5 −1.5 −1 −0.5 0.5 1 1.5 2.5 3.5
−14 −10 −6 −4 −2 2 4 6 10 14

NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

SETIO = SST anomaly in [90ºE-110ºE, 10ºS-0]

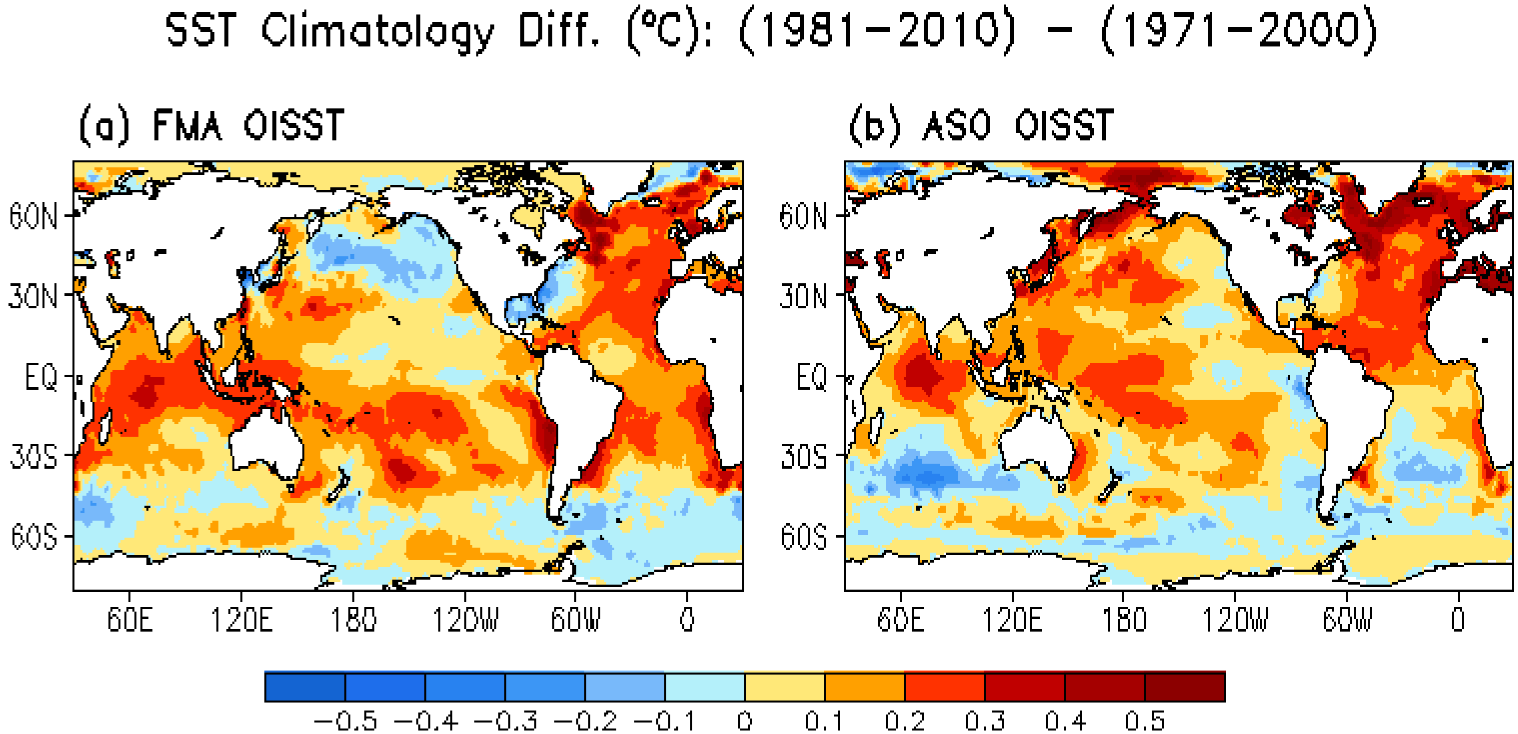
WTIO = SST anomaly in [50ºE-70ºE, 10ºS-10ºN]

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.

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!