2012 Annual Ocean Review

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)

Global SST Anomaly in 2012

- The 2012 SST anomaly (SSTA) was characterized by a transition from La Nina to ENSO-neutral, persistent negative PDO, weak positive Indian Ocean Dipole, a strong warming along the Gulf Stream and in subpolar North Atlantic, and above-normal SST in tropical North Atlantic.

- After a transition from La Nina to ENSO-neutral in spring 2012, NINO3.4 increased to +0.5^{o}C above-normal during Jul-Sep 2012, and then decreased during fall when there were strong intraseasonal activities.

- The warming along the Gulf Stream and its extension exceeded +2 standard deviation during summer 2012. The average SSTA in the maximum warming region (60W-30W, 45N-60N) reached a historical high in summer 2012.

- The strong warming in high-latitude North Atlantic can partially be attributed persistent negative NAO in May-Dec 2012.

- PDO has been in a persistent negative phase from May 2010 to January 2013 that lasted for 33 months so far.

Historical Perspective of 2012 SST Anomaly

- The **tropical Pacific SST** warmed by about 0.3°C, changing from the 2nd coldest year to the 14th warmest year since 1982.

- The **tropical Indian Ocean SST** was at a historical high in 2010, cooled down substantially in 2011, and warmed slightly in 2012, becoming the 5th warmest year since 1982.

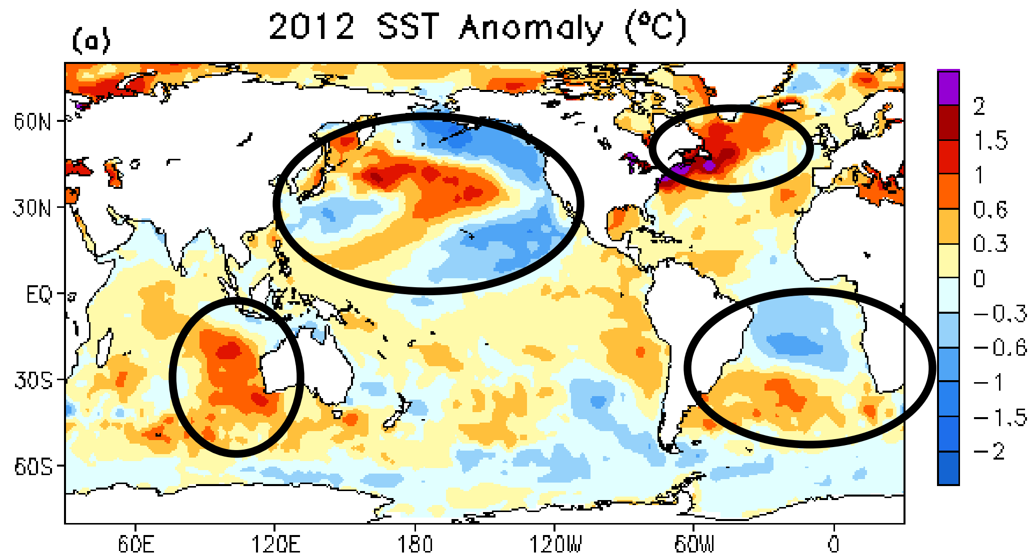
- The **tropical Atlantic SST** was at a historical high in 2010, cooled down substantially in 2011 and further cooled in 2012, becoming the 19th warmest year since 1982.

- The **North Atlantic SST** had a downward trend from 2006 to 2011, and then increased abruptly, **reaching a historical high in 2012**.

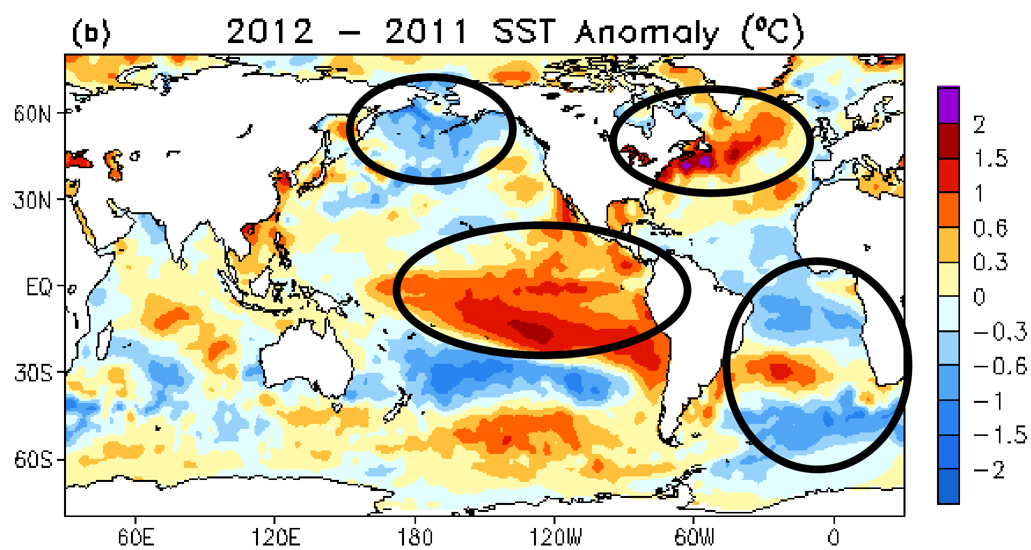
- The **global ocean SST** warmed by about 0.1°C, changing from the 13th to 11th warmest year since 1982.

Xue et al. (2013) to appear in the BAMS State of the Climate in 2012

2012 Yearly Mean SST Anomaly and Tendency

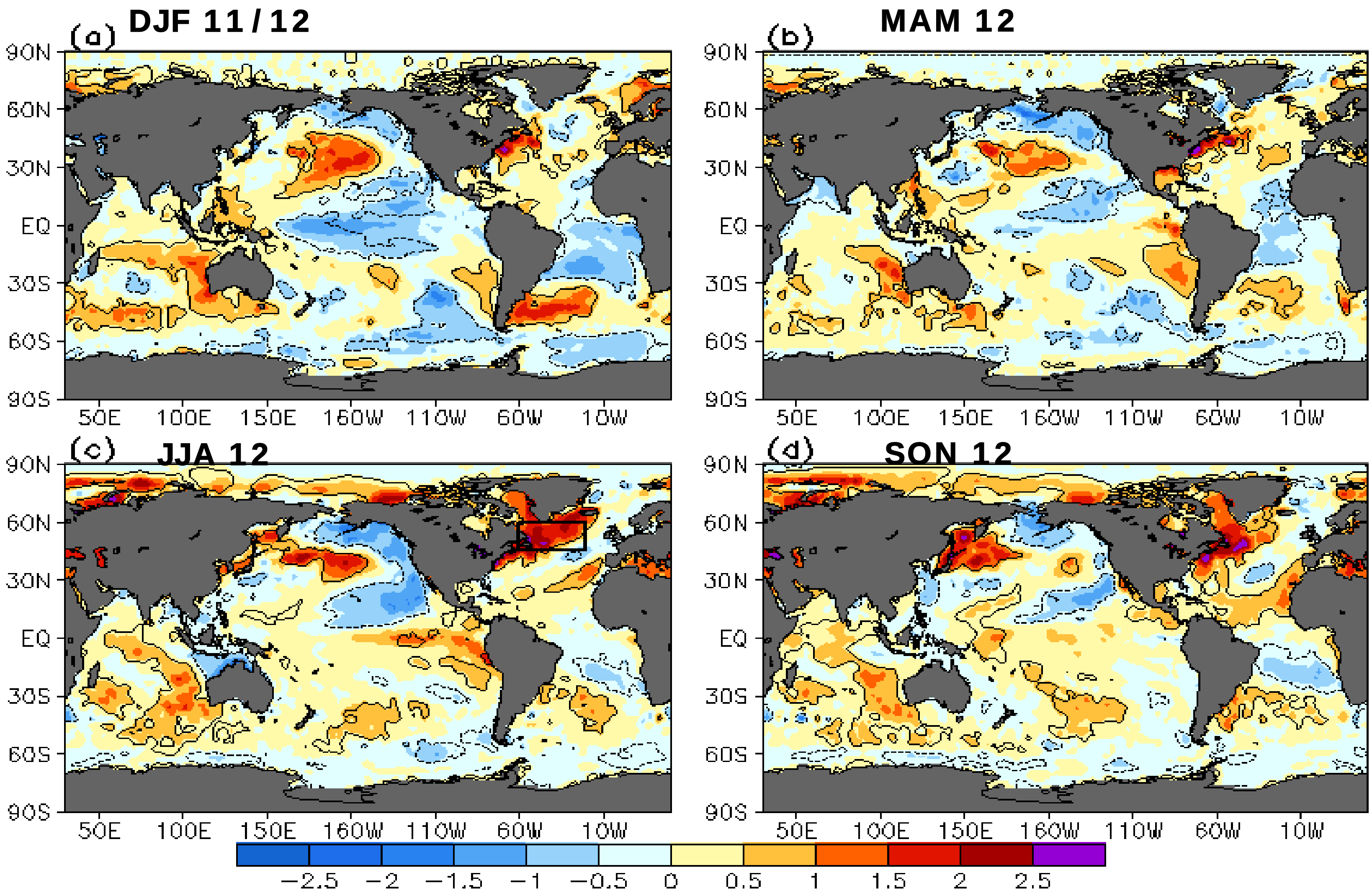


- Negative PDO pattern
- Strong warming along Gulf Stream and in subpolar N. Atlantic
- Subtropical dipole in S. Atlantic
- - Strong warming in southeast Indian Ocean



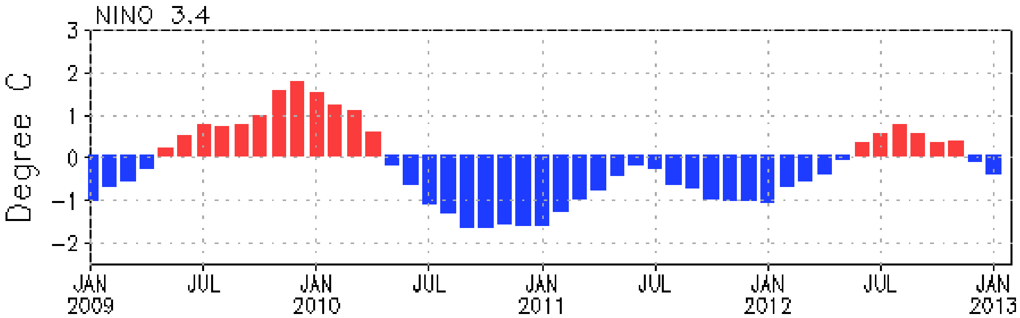
- Strong warming tendency in the tropical Pacific
- Cooling tendency in Bering Sea
- Strong warming tendency along Gulf Stream and in subpolar N. Atlantic
- N-S tripolar pattern in S. Atlantic

Seasonal Mean SST Anomaly in 2012



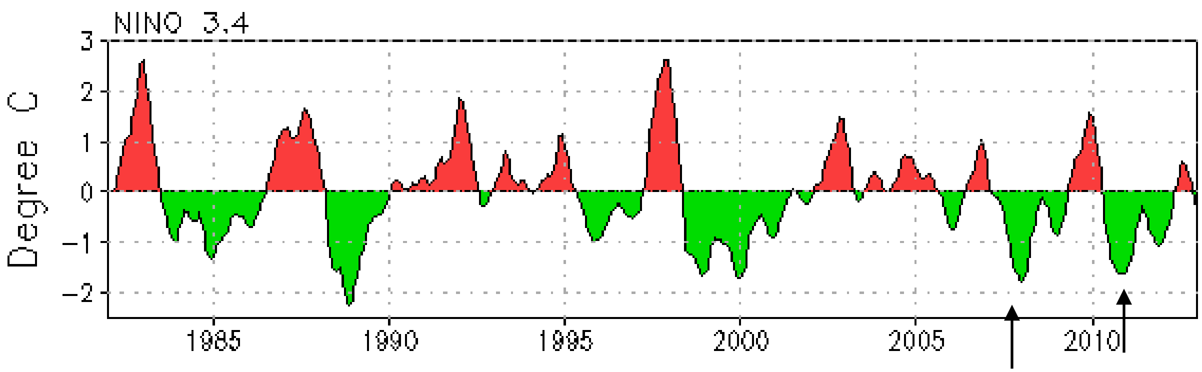
- DJF: La Niña, negative PDO, subtropical dipole in S. Atlantic
- MAM: Positive SSTA in S.E. Pacific and negative PDO
- JJA: Weak warming in eq. Pacific, strong warming in Arctic Ocean and high-latitude N. Atlantic, strong negative PDO
- SON: Strong warming in Arctic Ocean and high-latitude N. Atlantic, weak negative PDO, moderate warming in subtropical N. Atlantic

The Aborted 2012 El Nino and its Prediction



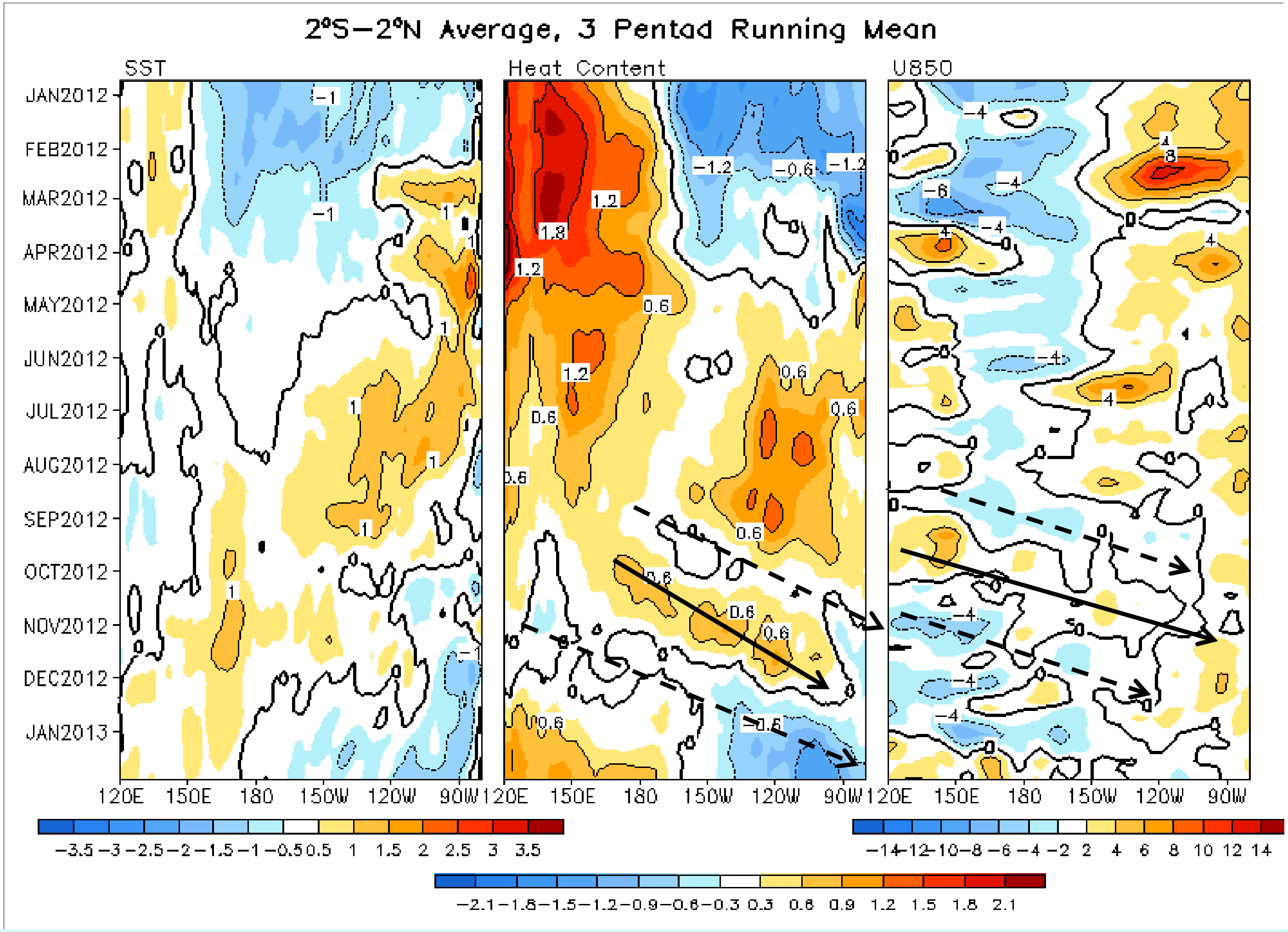
NINO3.4 SST Index

- The definition of ENSO is keyed on the NINO3.4 Index.
- The 2011/12 La Nina dissipated in May 2012.
- NINO3.4 was more than +0.5^{o}C above-normal in Jul-Sep 2012.



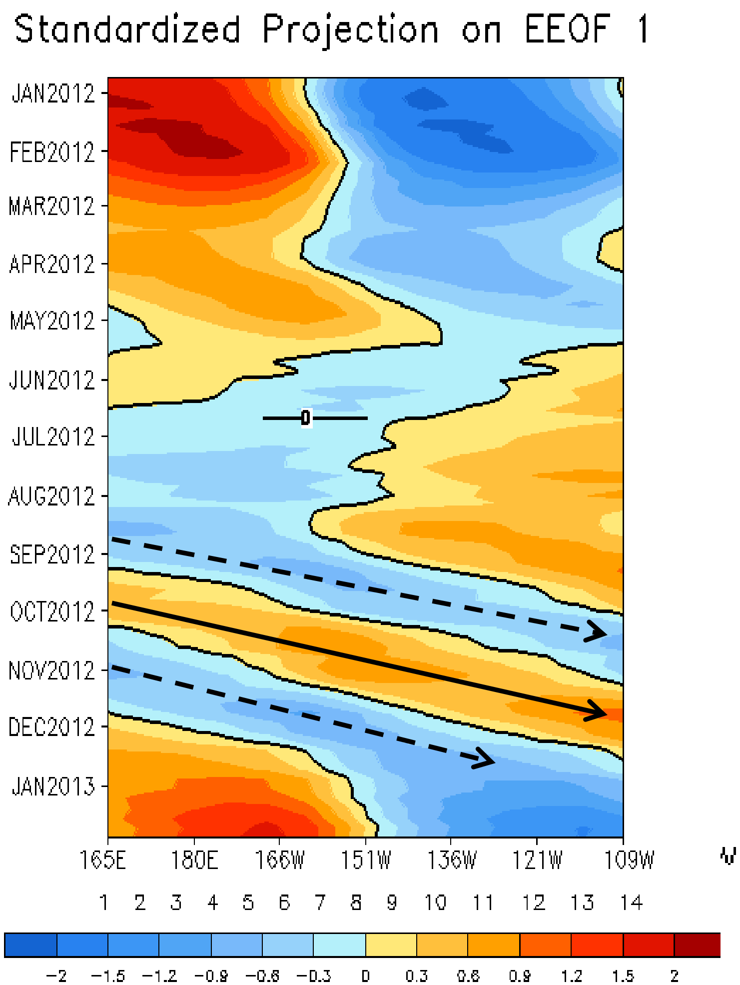
- The 2010-2012 La Nina cycle has a similar strength and duration to the 2007-2009 La Nina cycle.

Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) and OLR(W/m²)Anomalies

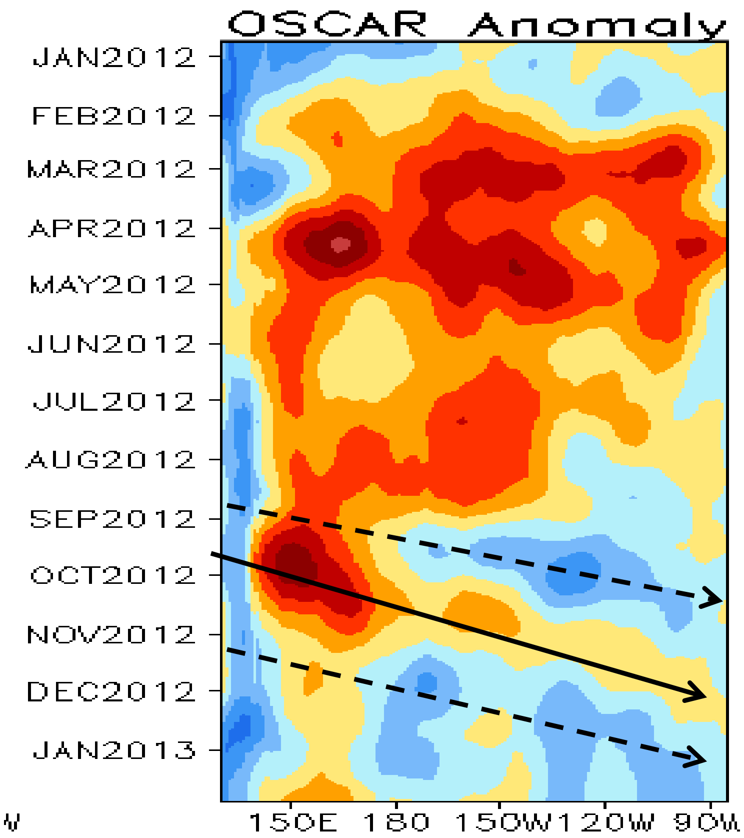


- Positive SSTA more than +1C was accompanied by above-normal heat content in the central-eastern Pacific during Jun-Sep 2012. However, easterly wind anomalies persisted near Dateline during the period.
- MJO activity was enhanced during Sep-Nov 2012, which forced episodes of upwelling and downwelling oceanic Kelvin waves.
- Negative heat content anomaly and SSTA emerged in the central-eastern Pacific in December 2012.

Oceanic Kelvin Wave Indices

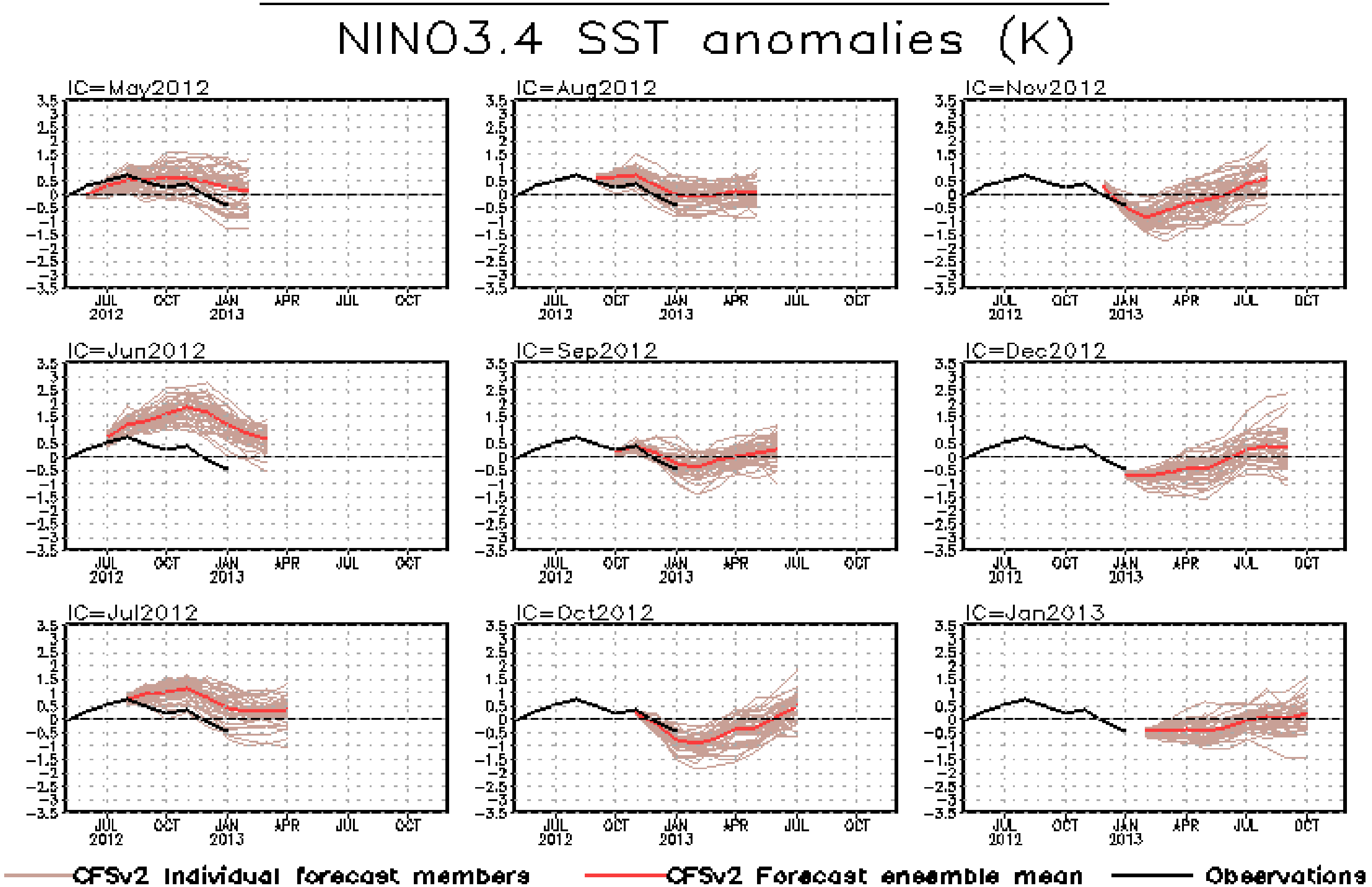


Eq. Surface Zonal Current Anomaly (cm / s)



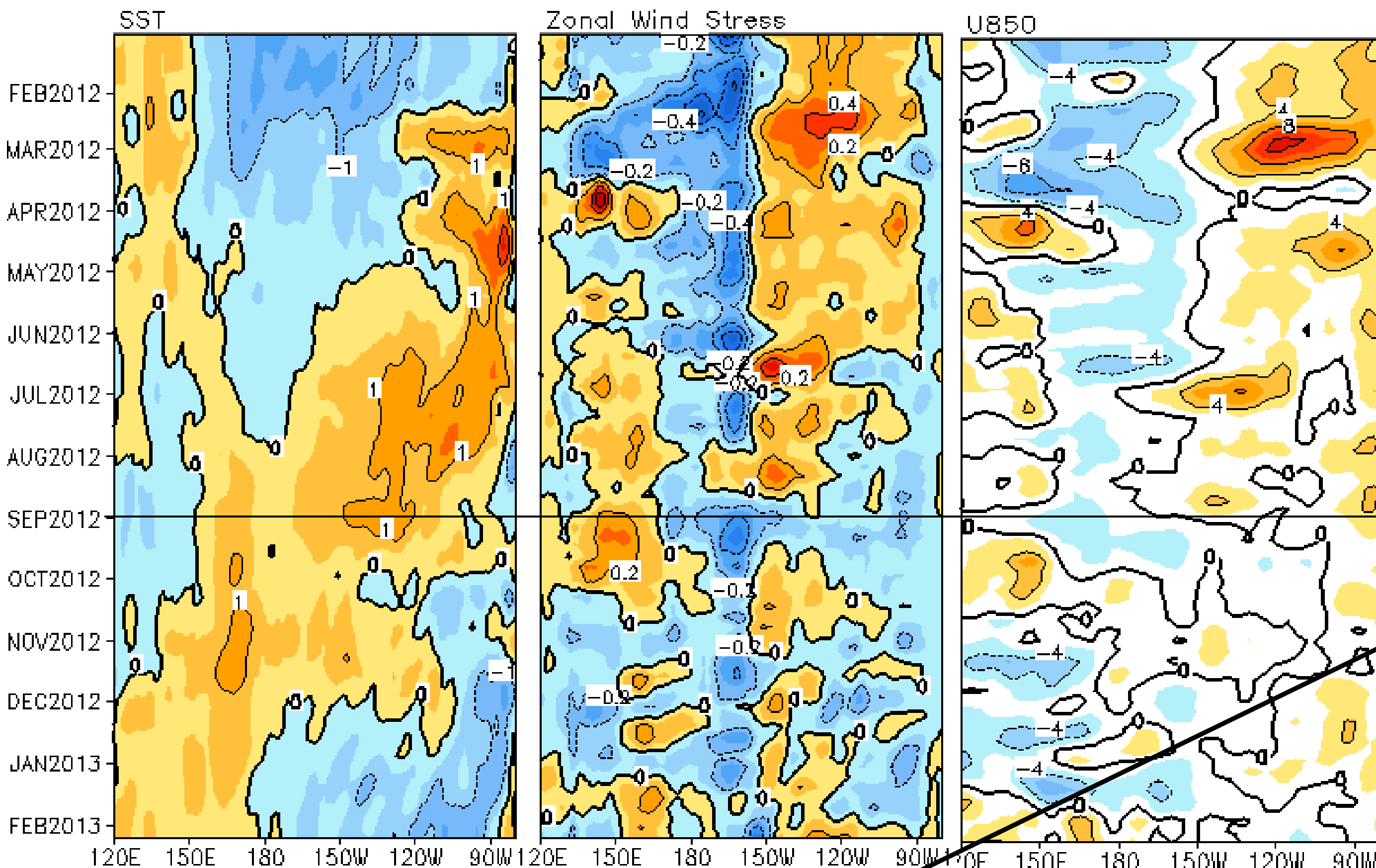
- Episodes of upwelling and downwelling oceanic Kelvin waves presented during Sep-Nov 2012.
- Associated with upwelling (downwelling) oceanic Kelvin waves were westward (eastward) surface zonal current anomaly.

NCEP CFSv2 NINO3.4 Forecast

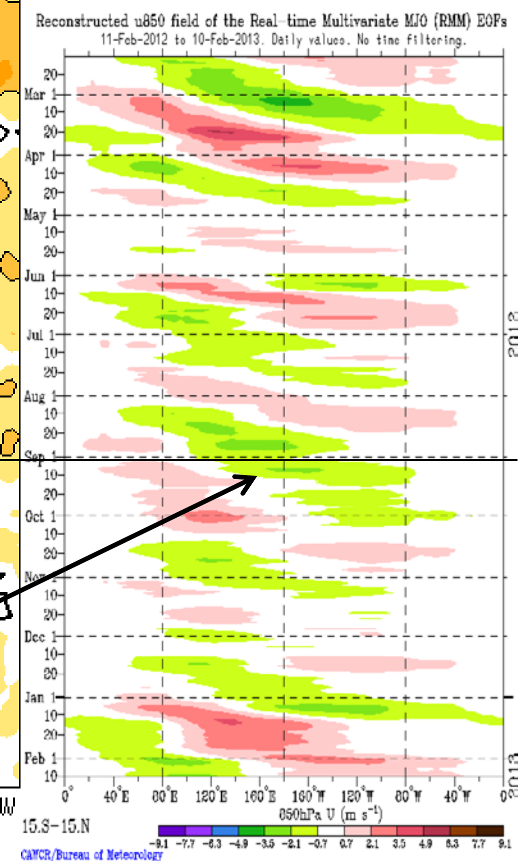


- **CFSv2 forecast had warm biases from Jun-Jul 2012 I.C. (last ten days in Jun and Jul).**
- **From Aug 2012 I.C., CFSv2 successfully forecasted the cooling tendency in NINO3.4, which can be attributed to the easterly wind anomalies that emerged in late Aug.**
- **Latest CFSv2 forecast suggests ENSO-neutral conditions likely persist through spring and summer 2013.**

SST (°C), U850 (m/s) and Zonal Wind Stress Anomalies in 2S-2N



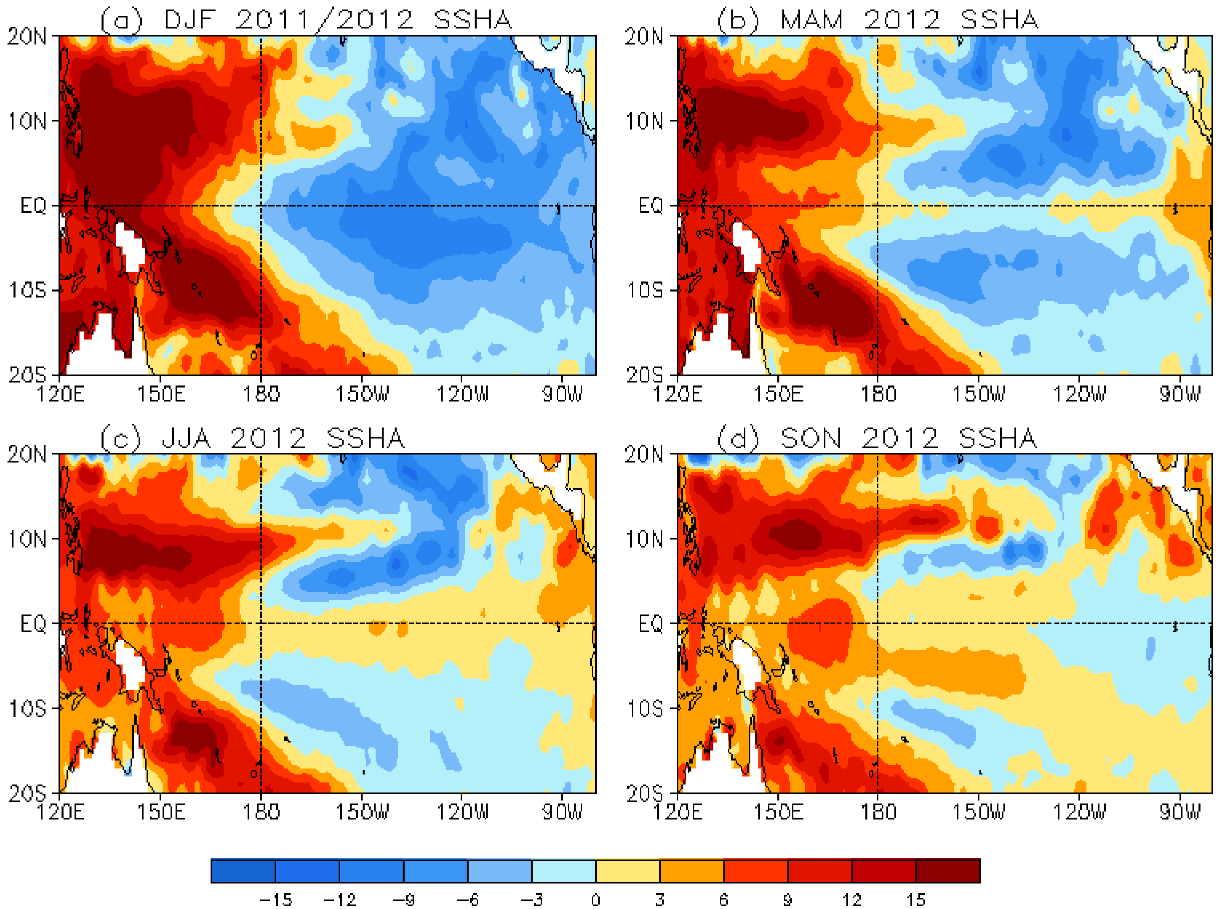
Reconstructed U850 of Wheeler and Hendon MJO



- **The easterly wind anomalies in central equatorial Pacific in late Aug can be attributed to MJO activity.**

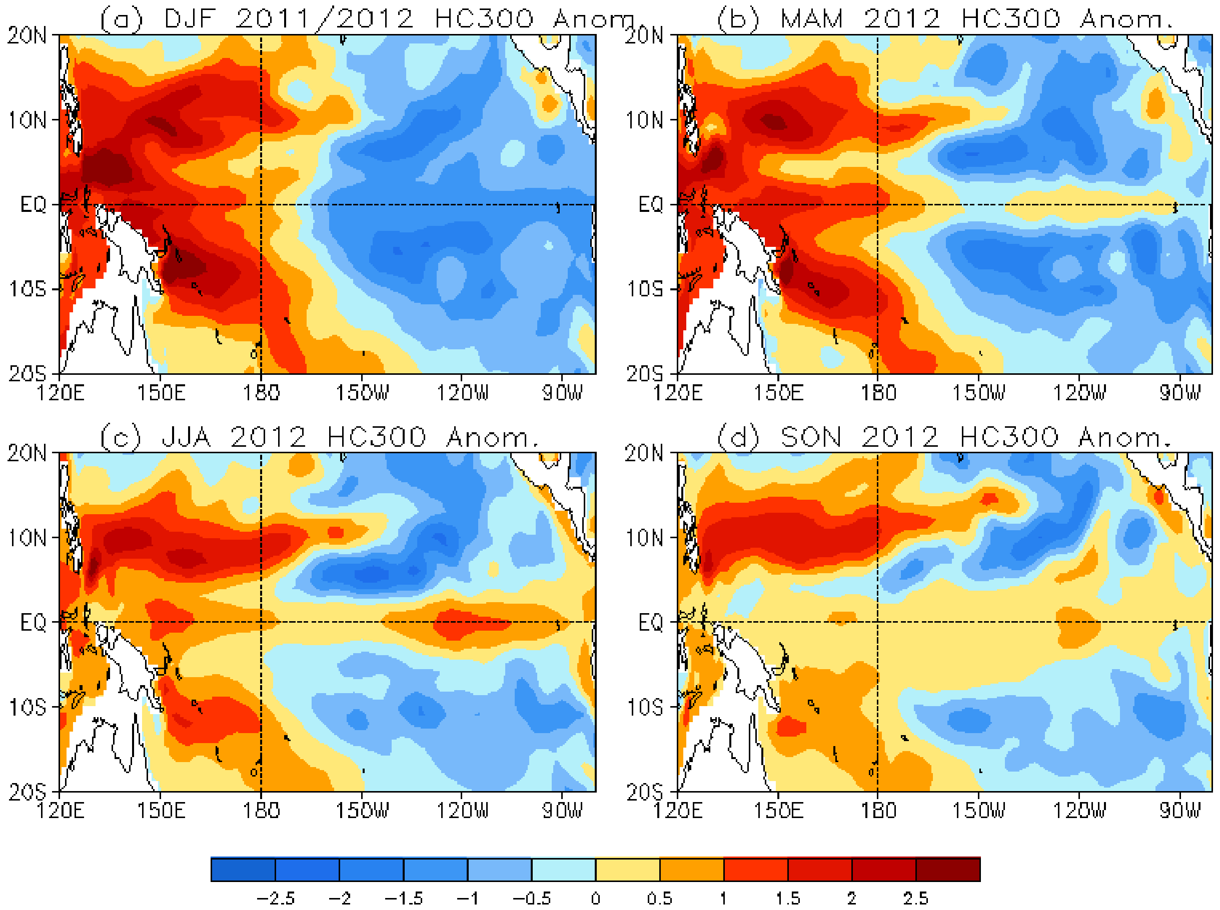
http://cawcr.gov.au/staff/mwheeler/maproom/RMM/index.htm

Seasonal Mean Sea Surface Height Anomaly in 2012

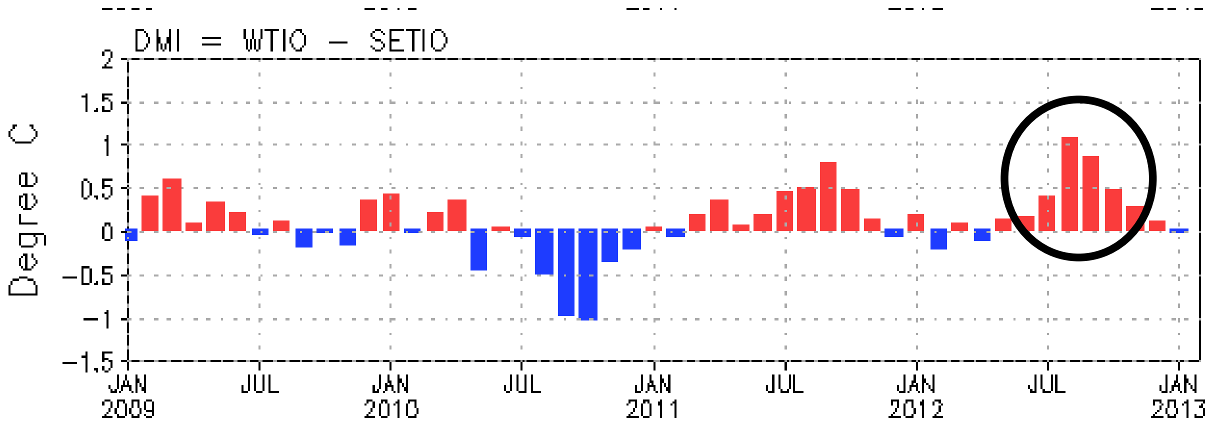


- DJF: Dipole SSHA pattern consistent with La Nina conditions
- MAM: SSH was near-normal (below-normal) along the equator (polarward of 2 degree) in the central and eastern Pacific.
- JJA: SSH was near-normal during summer 2012 when NINO3.4 was +0.5C above-normal, which indicates there was little subsurface support for El Nino development.
- SON: SSH was weakly below-normal east of 120W.

Seasonal Mean HC300 Anomaly (HCA) in 2012



- **DJF: Dipole HCA pattern consistent with La Nina conditions**
- **MAM: HC was near-normal (below-normal) along the equator (polarward of 2 degree) in the central and eastern Pacific.**
- **JJA: HC was above-normal during summer 2012 when NINO3.4 was +0.5C above-normal, which provides some support for El Nino development. This may explain why many dynamical models predicted El Nino to develop in the winter 2012/13.**



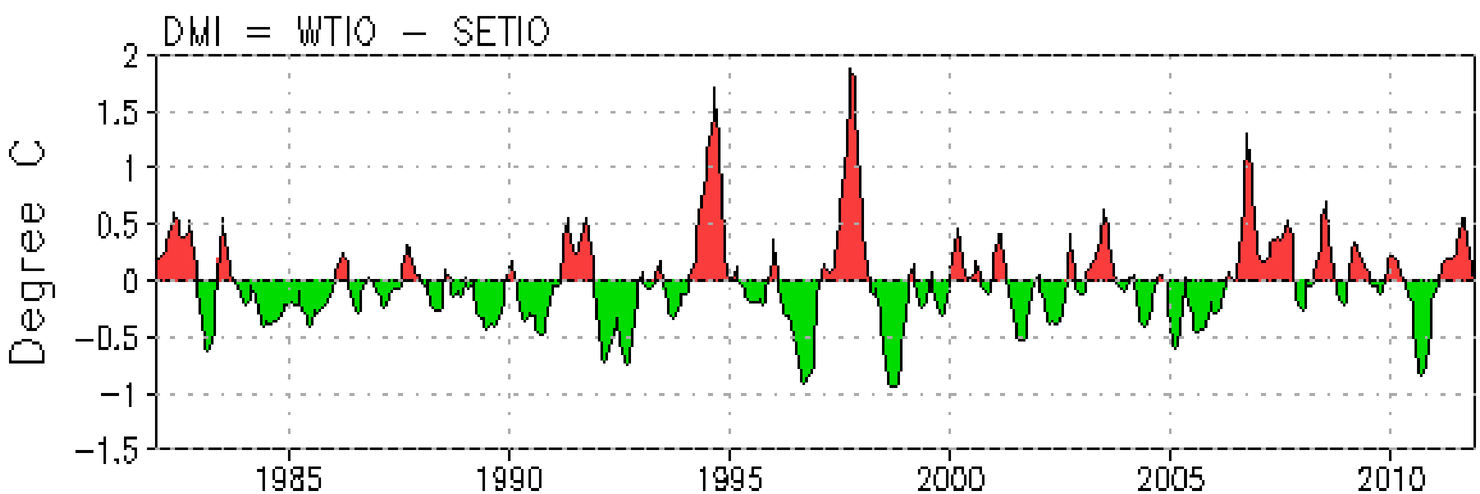
DMI Index

DMI = WTIO- SETIO

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

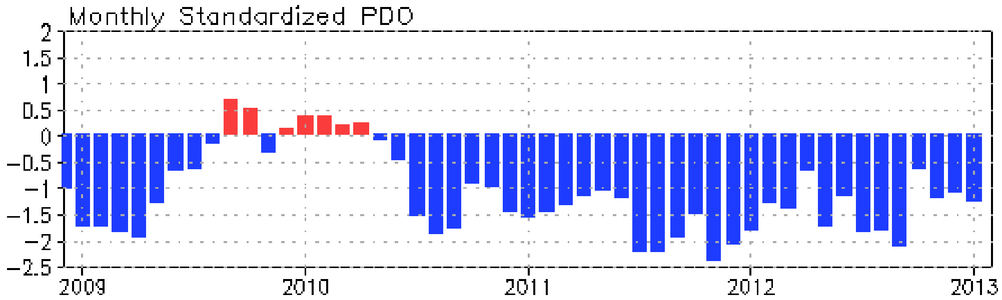
WTIO = SST anomaly in [50ºE-70ºE, 10ºS-10ºN]

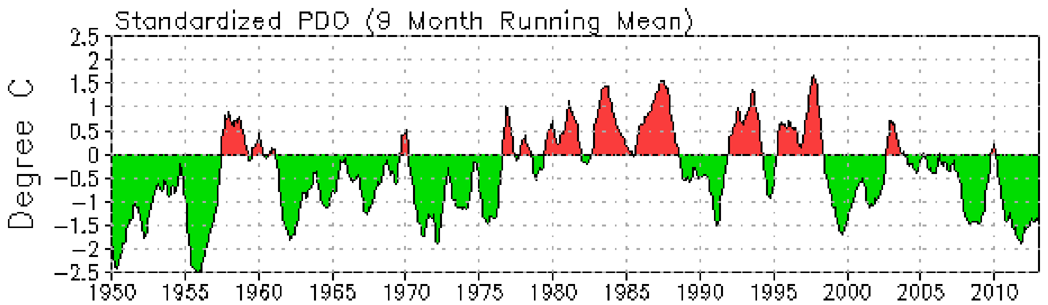
- DMI > +0.5ºC in Aug-Oct 2012, indicating positive IOD conditions.



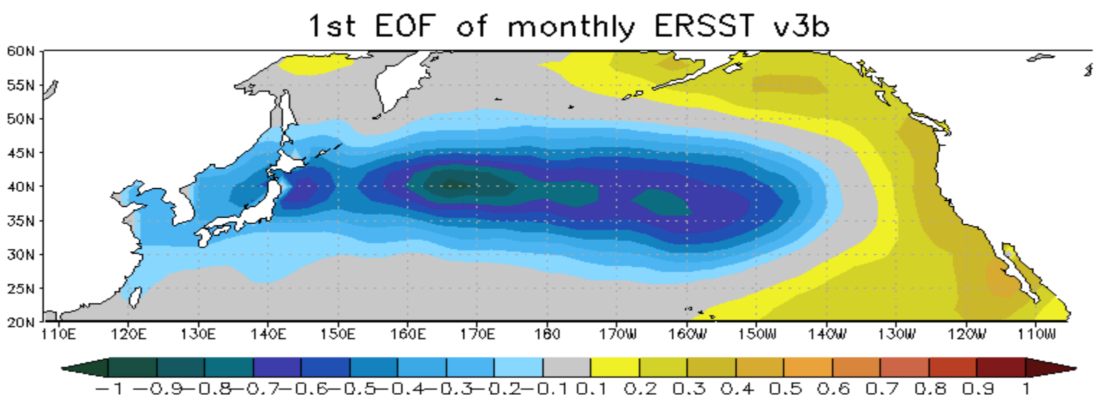
- Positive IOD conditions dominated since 2006.

Pacific Decadal Oscillation



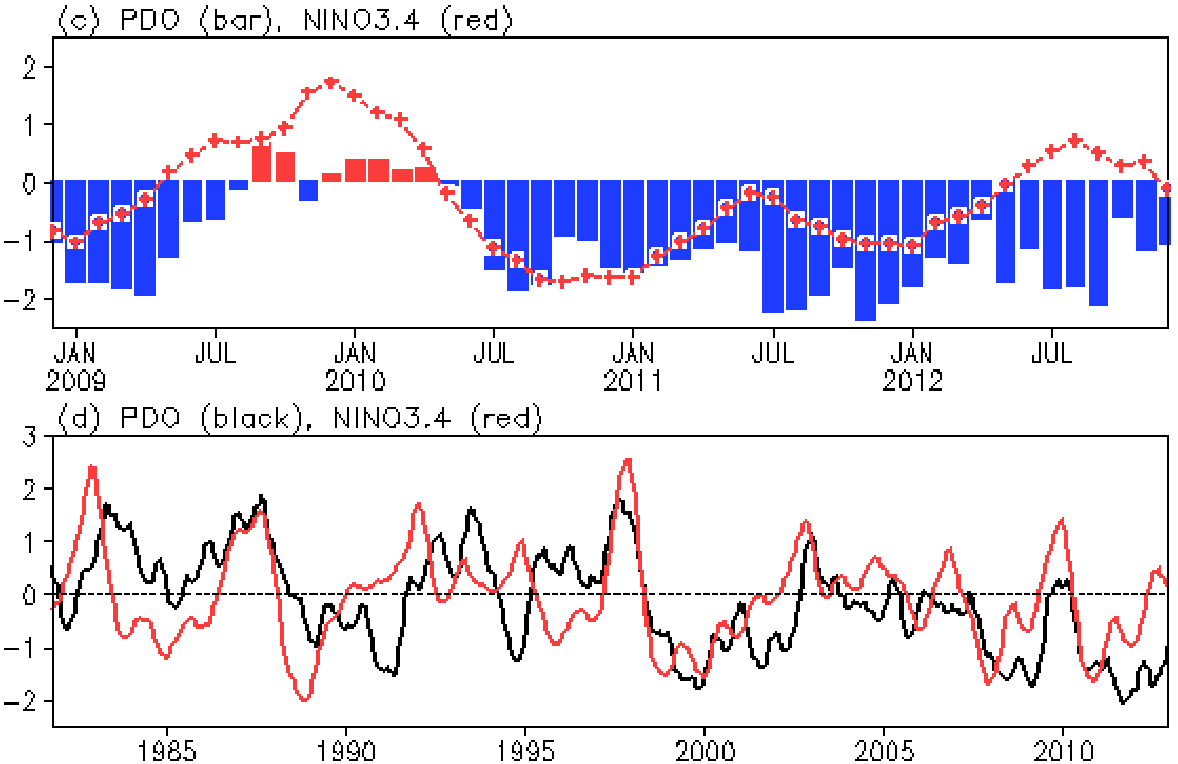


- Negative PDO phase has persisted from May 2010 to Jan 2013, lasting for 33 months now.
- Negative (positive) PDO phase was prevalent during 1950-1975 and 1999-2012 (1976-1998).



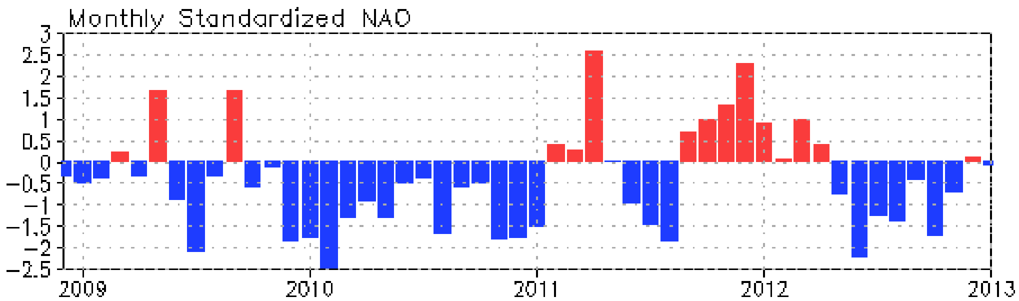
- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

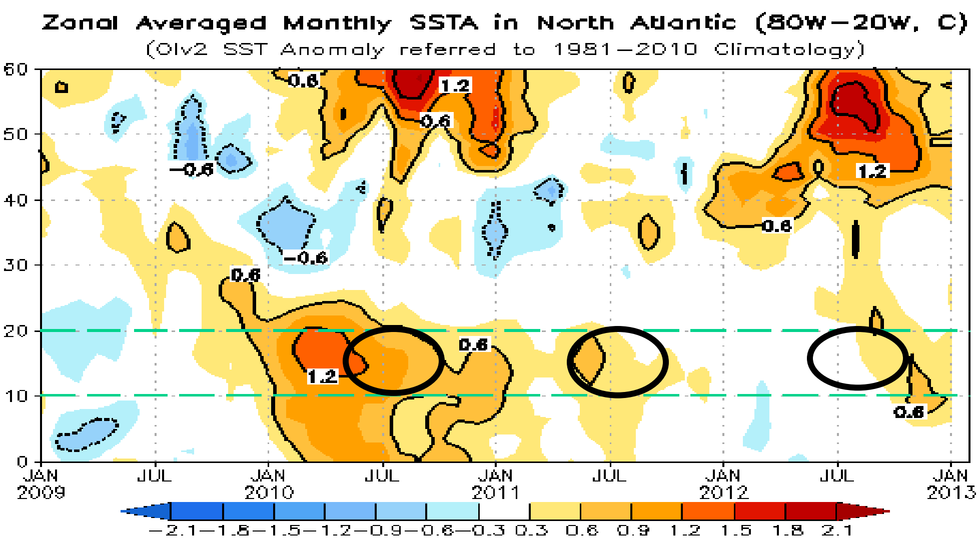
PDO and NINO3.4

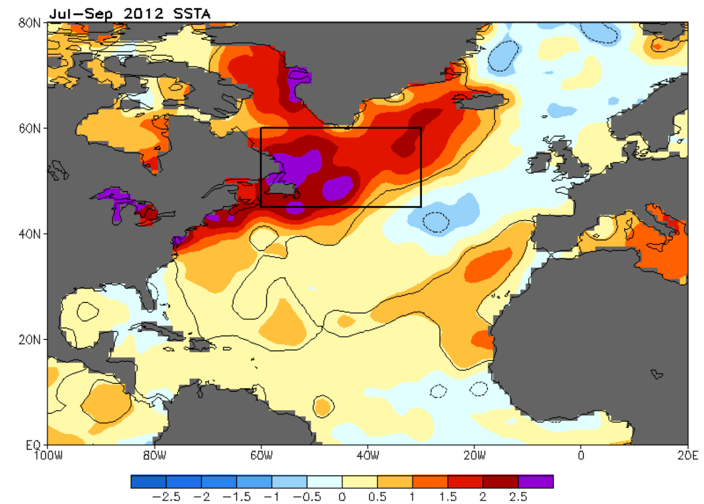


- There was a regime shift of PDO around 1999. After 1999 negative PDO was more frequent than the positive PDO, while before 1999 positive PDO was more frequent. During the positive phase of the PDO, PDO either lagged NINO3.4 (1983-84, 1993-1994) or was in phase with NINO3.4 (1986-87, 1997-98). The correlation between monthly PDO and NINO3.4 at zero lag is 0.3 in 1982-1998 and 0.56 in 1999-2012. This suggests that the relationship between PDO and ENSO may have changed around 1999.

NAO and SST Anomaly in North Atlantic





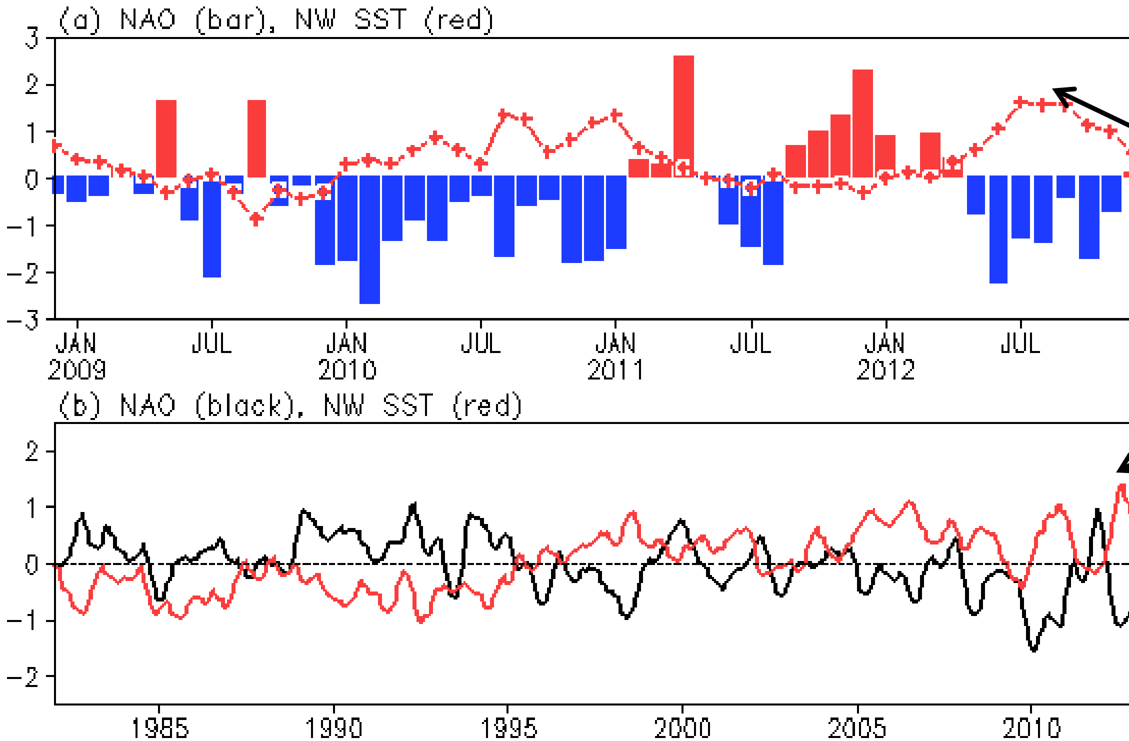


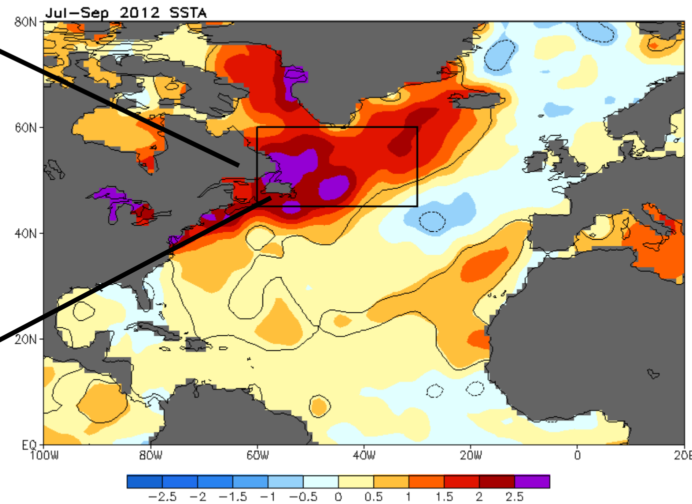
- High-latitude North Atlantic SSTA is generally closely related to NAO index (negative NAO leads to SST warming and positive NAO leads to SST cooling). Negative NAO index has persisted during May-Nov 2012, contributing to persistent positive SSTA in high-latitude N. Atlantic, and also a warming in tropical N. Atlantic in Nov-Dec 2012.

- In the past three hurricane seasons, positive SSTA in Hurricane Main Development Region was strong in 2010, and became weakening in subsequent two years.

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.

NAO and North Atlantic SSTA

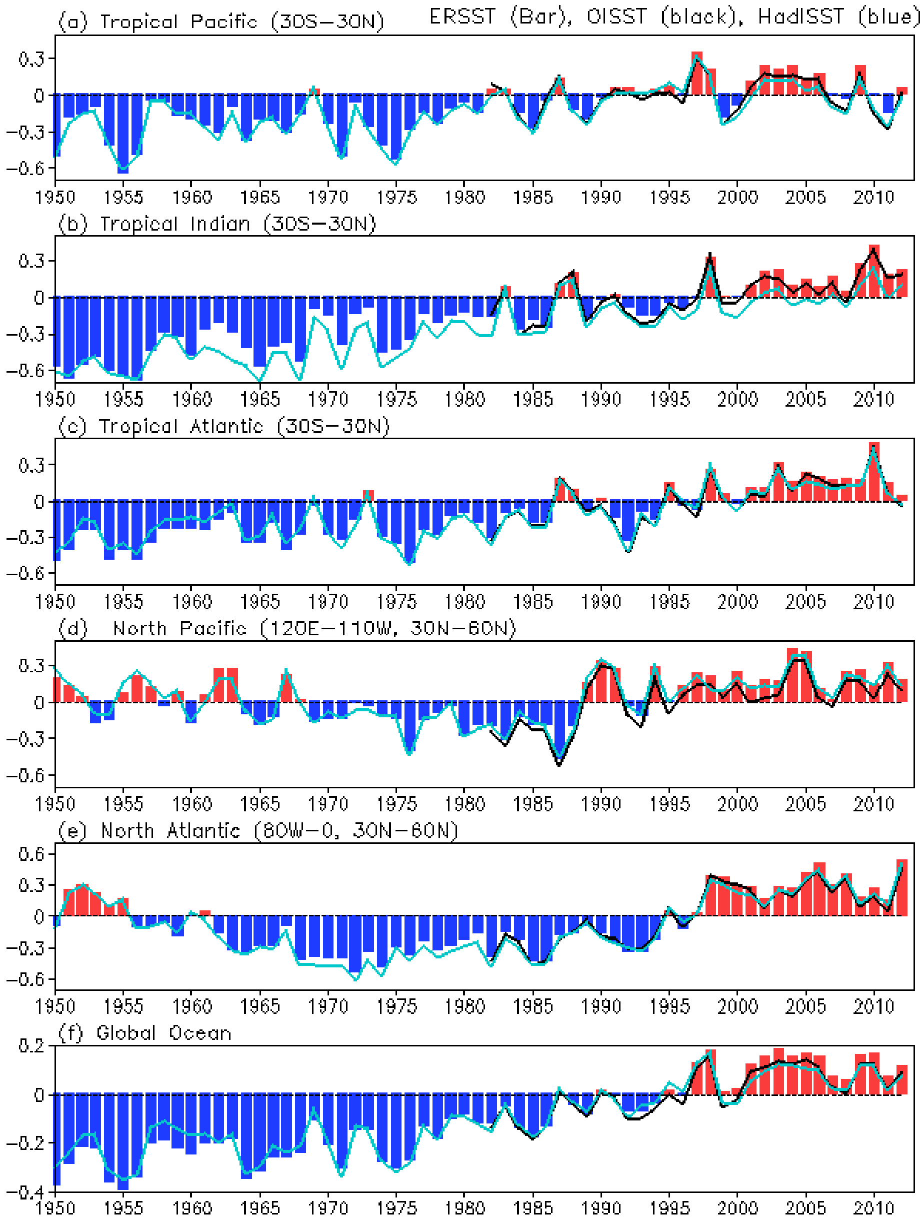




- **SSTA in high-latitude North Atlantic is generally out of phase with NAO, and it had a warming trend with a historical high value in summer 2012.**

- **The correlation between monthly NAO and SSTA is -0.35, which is significant at 99% of level of T-test.**

Yearly Mean SST Anomaly Indices



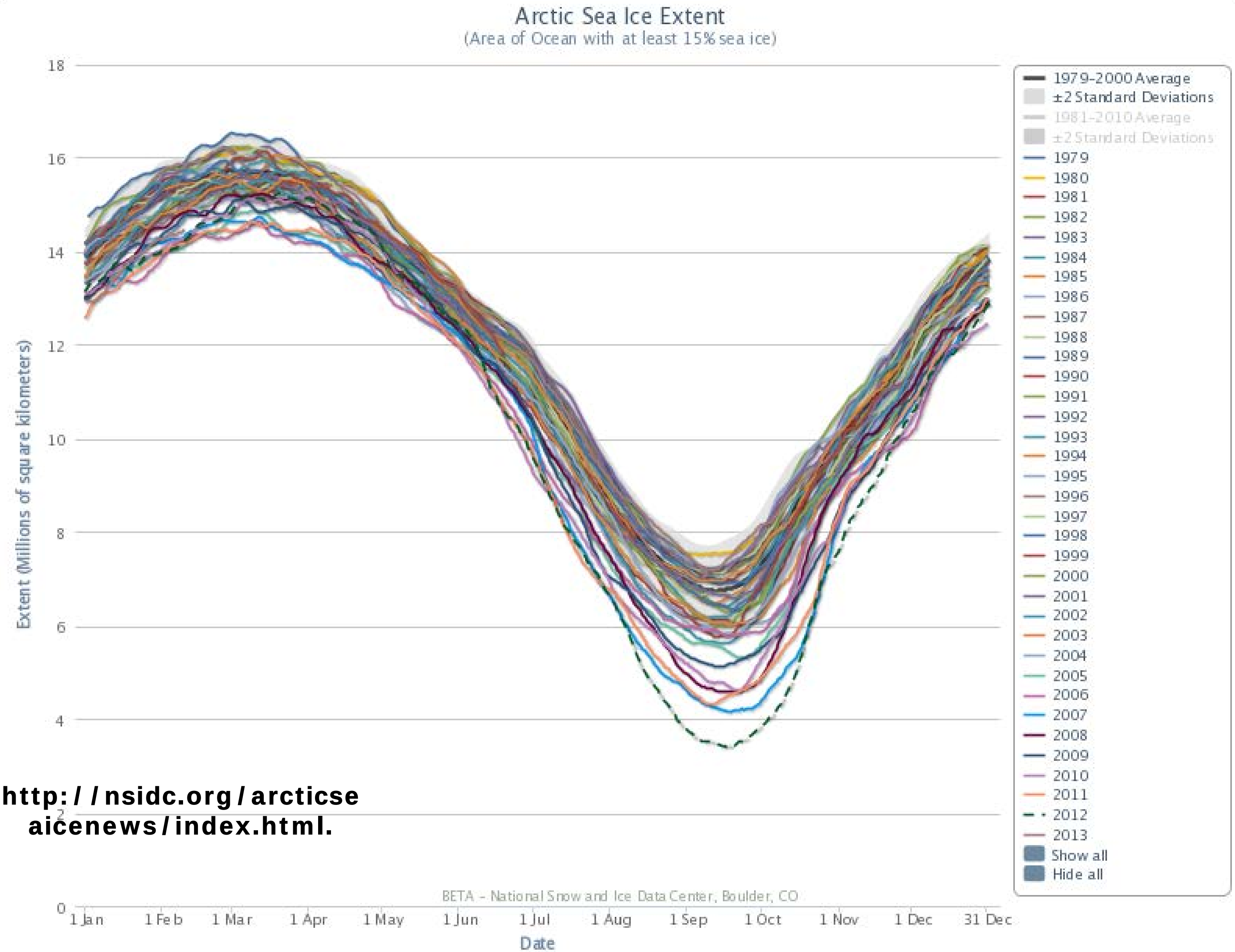
-The tropical Pacific SST warmed by about 0.3°C.

-The tropical Indian Ocean SST was at a historical high in 2010, cooled down substantially in 2011, and warmed slightly in 2012

-The tropical Atlantic SST was at a historical high in 2010, cooled down substantially in 2011 and further cooled in 2012.

-The North Atlantic SST had a downward trend from 2006 to 2011, and then increased abruptly, reaching a historical high in 2012.

-The global ocean SST warmed by about 0.1°C, changing from the 13th to 11th warmest year since 1982.



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

- The Arctic sea ice extent in September 2012 reached the historical low in the satellite record.

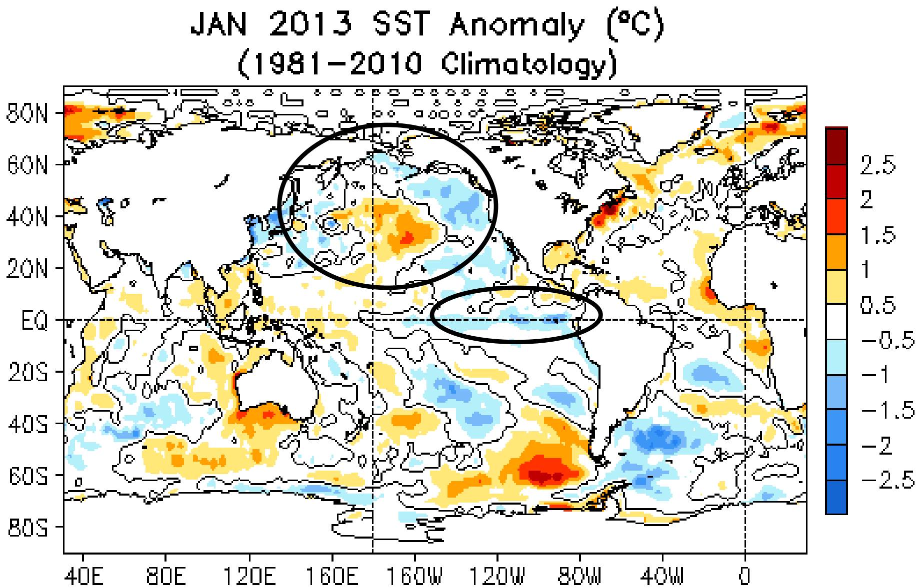
January 2013 Review

- **Pacific and Arctic Oceans**
  - All NINO indices cooled down in the past few months and NINO3.4 became weakly below-normal in Jan 2013.
  - The consensus forecast favors ENSO-neutral conditions to continue into the Northern Hemisphere spring and summer 2013.
  - Negative PDO phase persisted, and NCEP CFSv2 predicted negative PDO phase would continue into the Northern Hemisphere summer.
  - Strong MJO activity dominated atmospheric circulation in the Indo-Pacific region in Jan 2013.

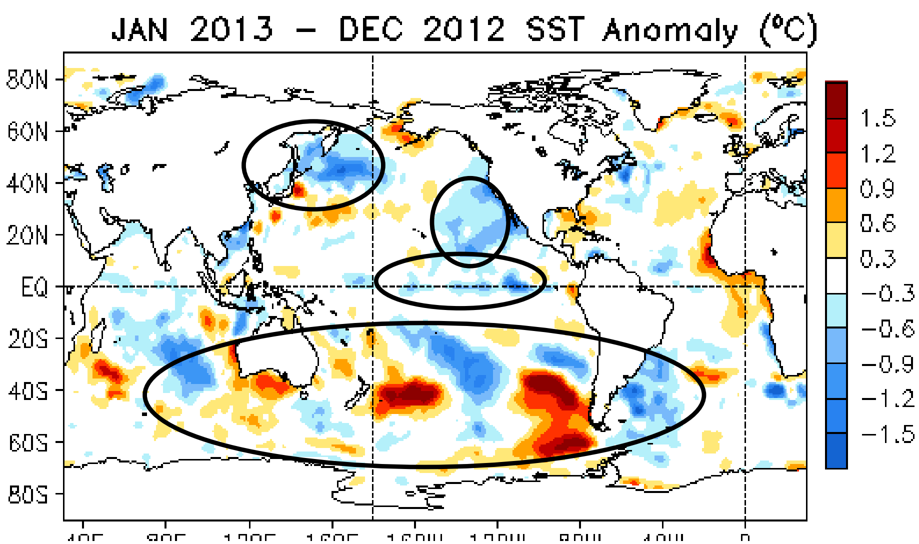
- **Indian Ocean**
  - Indian Ocean Dipole was near-normal in Jan 2013.

- **Atlantic Ocean**
  - NAO was near-normal in the past two months.
  - Tropical North Atlantic SSTA has cooled down continuously since Nov 2012.

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



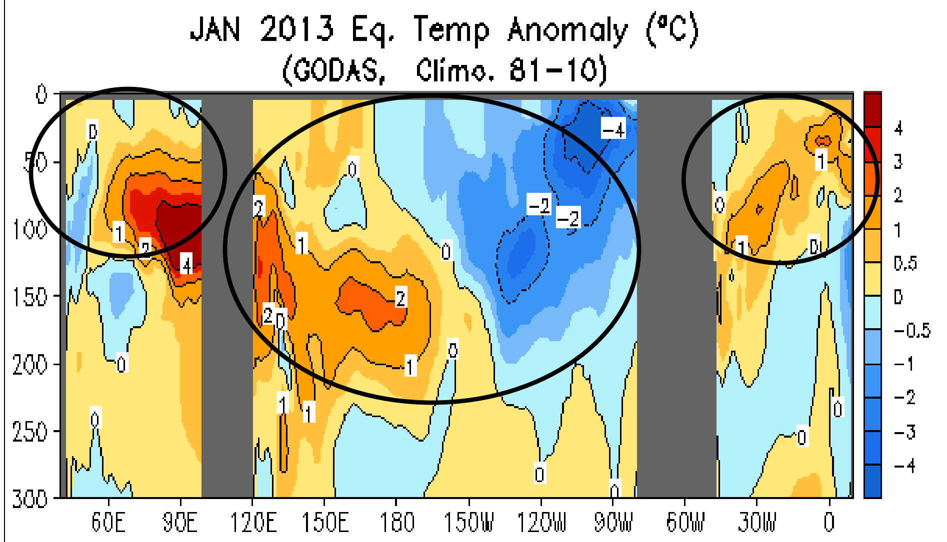
- SST was weakly below-normal in the central-eastern tropical Pacific.
- Negative PDO pattern persisted.



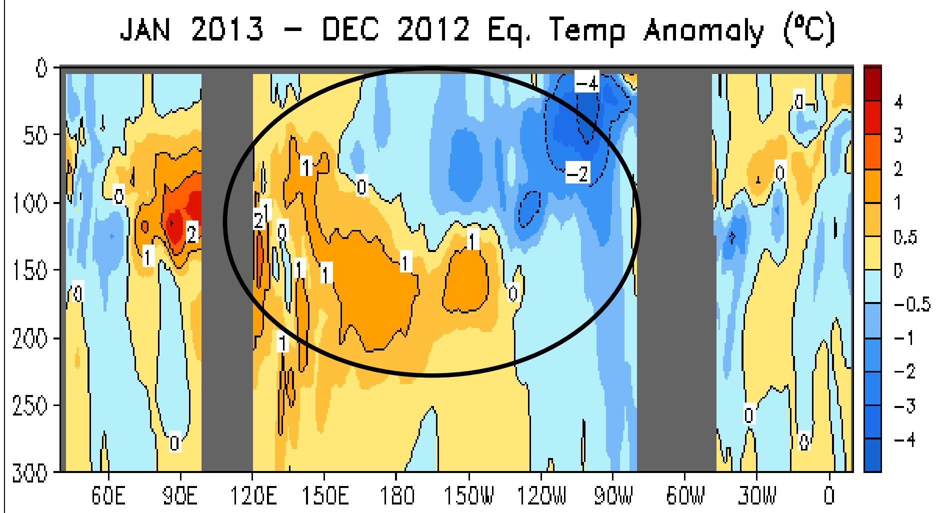
- A cooling tendency presented in the equatorial Pacific, northeast Pacific and north of Japan.
- Strong SST tendency presented in mid-latitude southern oceans.

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



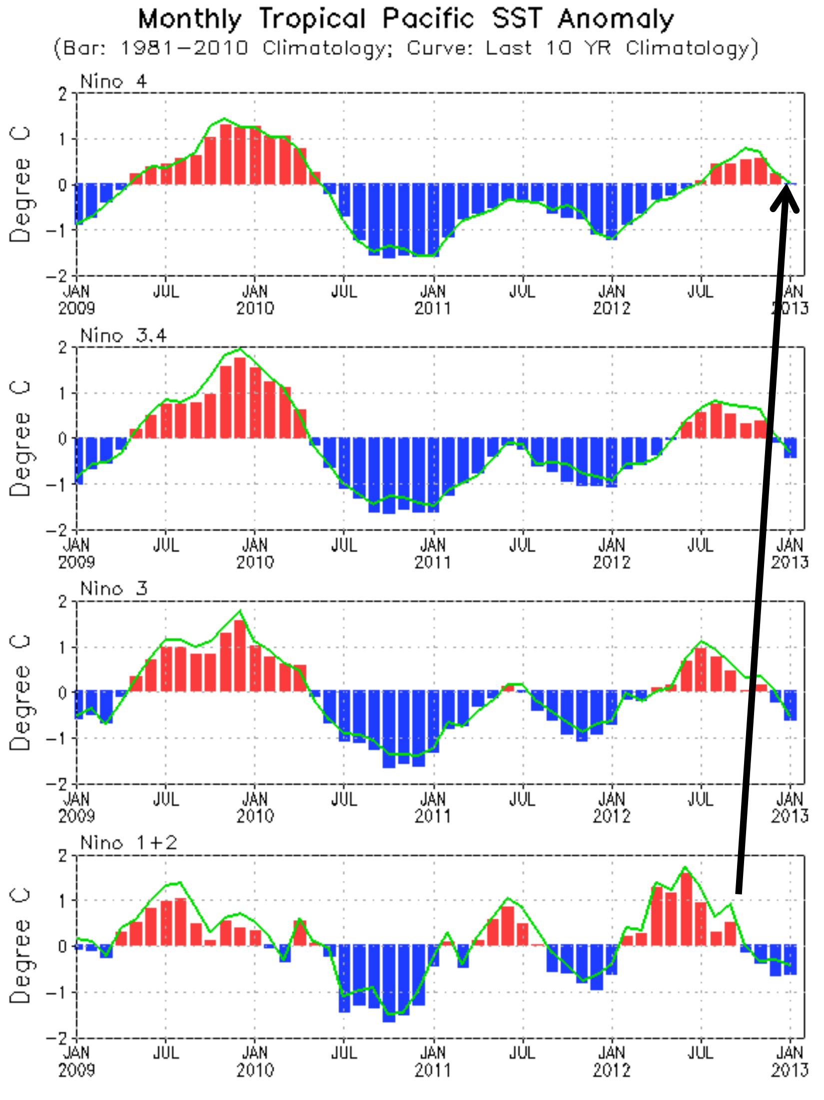
- Positive (negative) temperature anomalies presented near the thermocline in the western (eastern) equatorial Pacific Ocean.
- Positive anomalies dominated at the upper 150m of equatorial Indian and Atlantic Ocean.

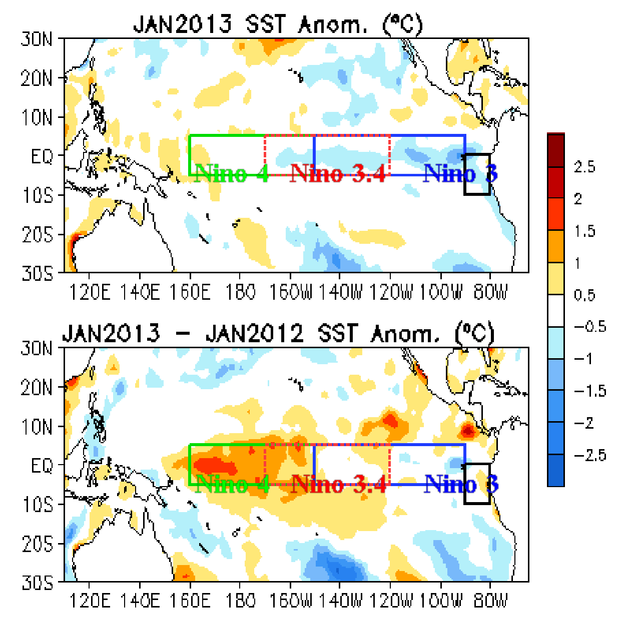


- A cooling (warming) tendency was observed in the eastern (western) equatorial Pacific near the thermocline.

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.

Evolution of Pacific NINO SST Indices

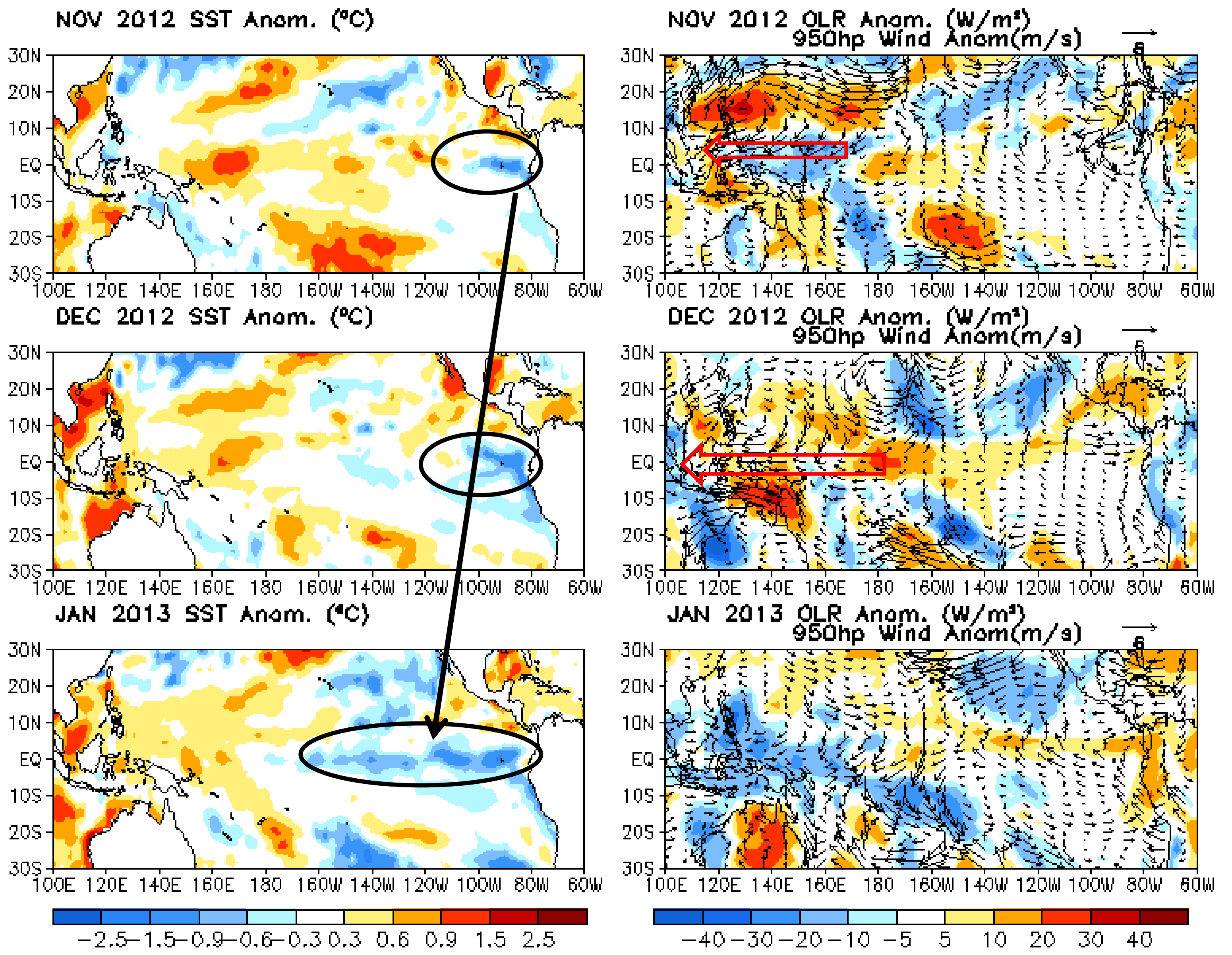




- All NINO indices cooled down in the past few months. NINO3.4 became weakly below-normal in Jan 2013.
- The cooling tendency started from NINO1+2 and then migrated westward to NINO3, NINO3.4 and NINO4.
- The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.

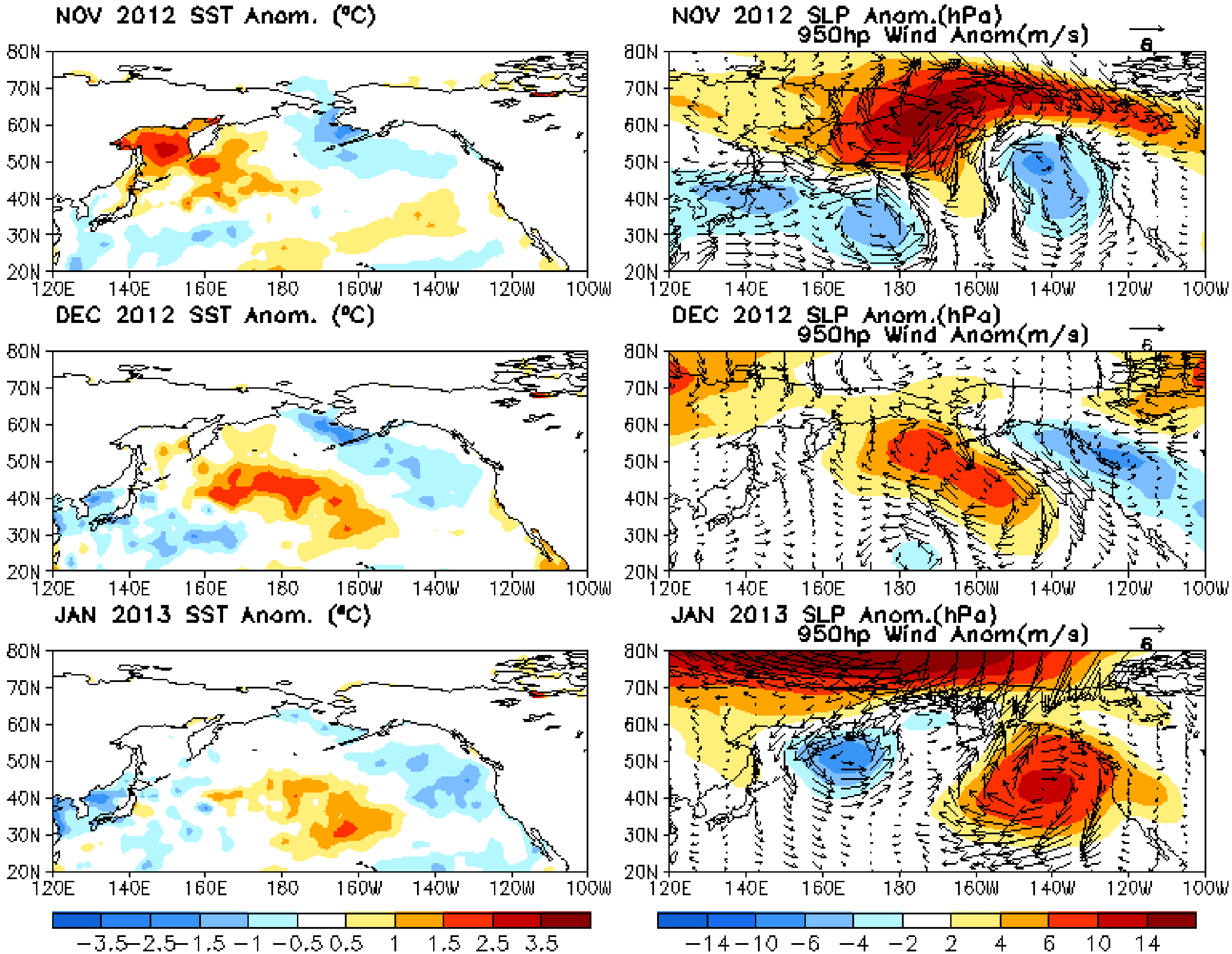
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 (bar) and last ten year (green line) means.

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



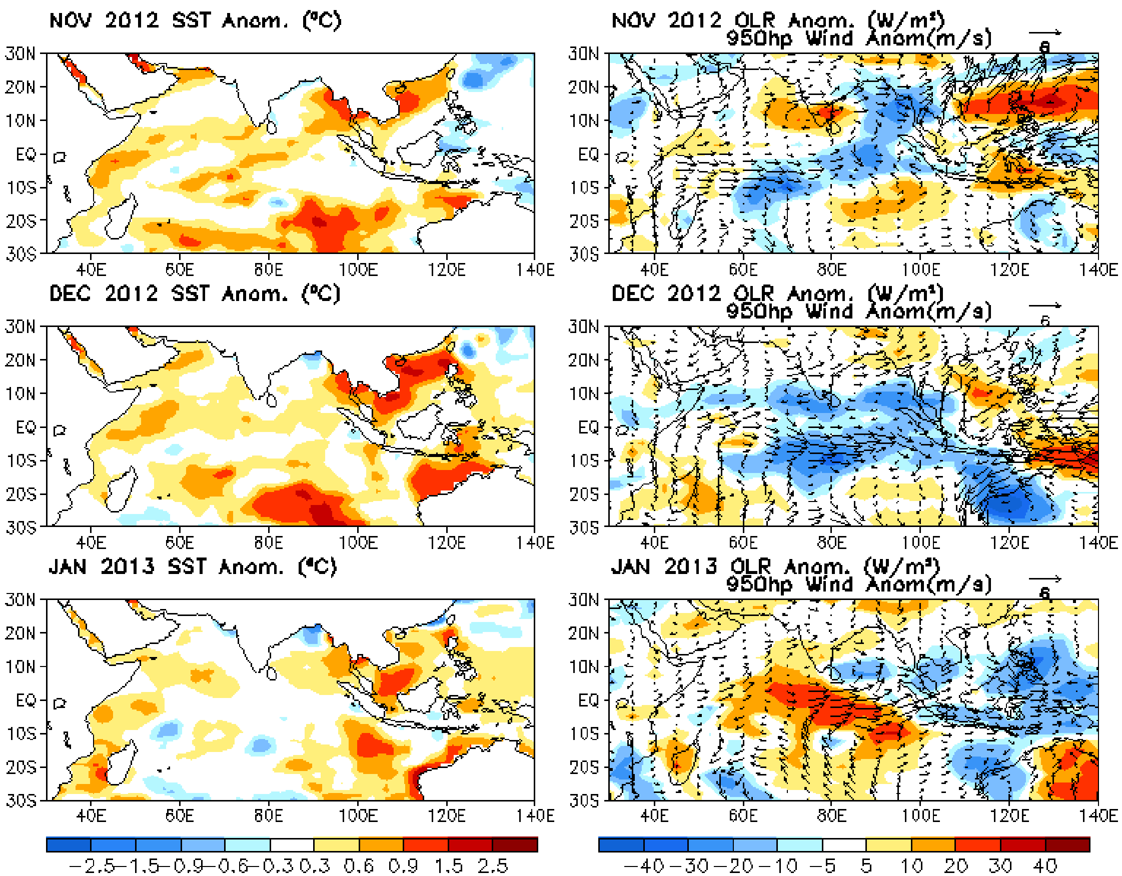
- Cooling initiated from the South America coast and migrated westward and was probably associated with easterly wind anomalies in Nov and Dec 2012 and their forced upwelling oceanic Kelvin waves.

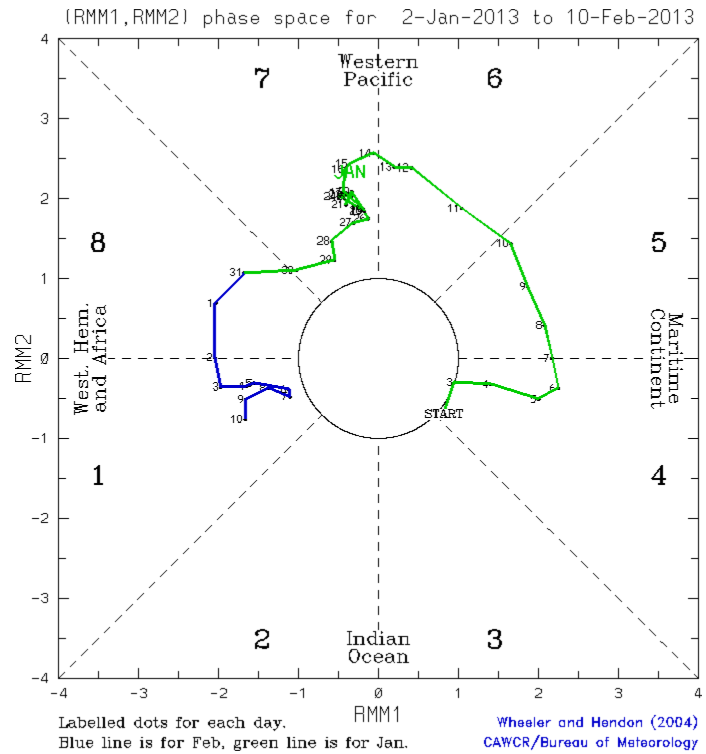
Last Three Month SST, SLP and 925hp Wind Anom.



- Anomalous anticyclone was observed near the coast of Pacific Northwest, favorable for coastal upwelling.

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

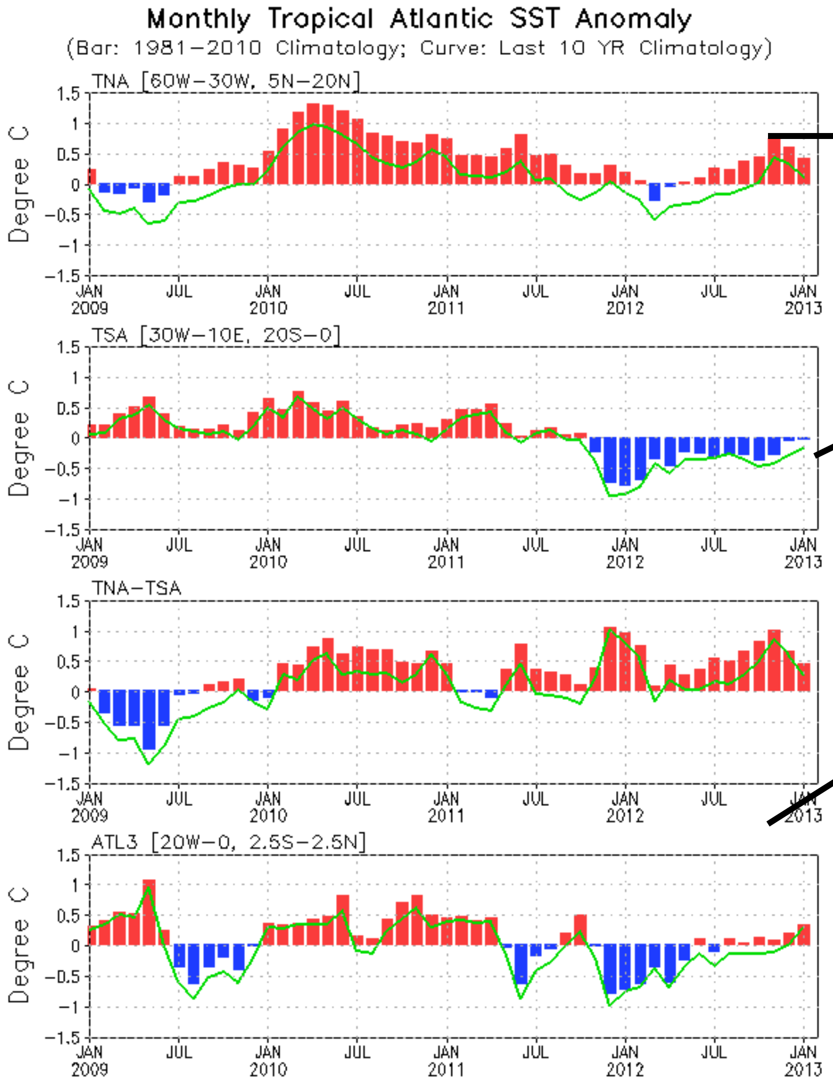


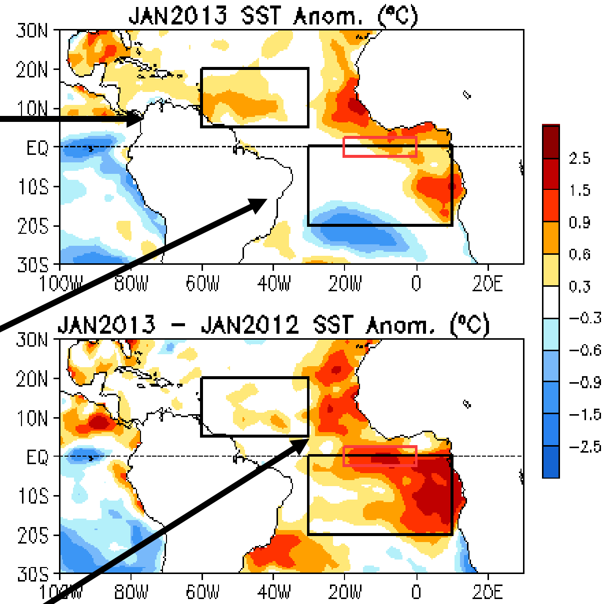


- **Westerly wind anomalies were observed in the central tropical Indian Ocean.**

- **Convection was suppressed (enhanced) in the central tropical Indian Ocean (over Indonesia), which was related to the convective active phase of MJO in the western Pacific in Jan 2013.**

Evolution of Tropical Atlantic SST Indices

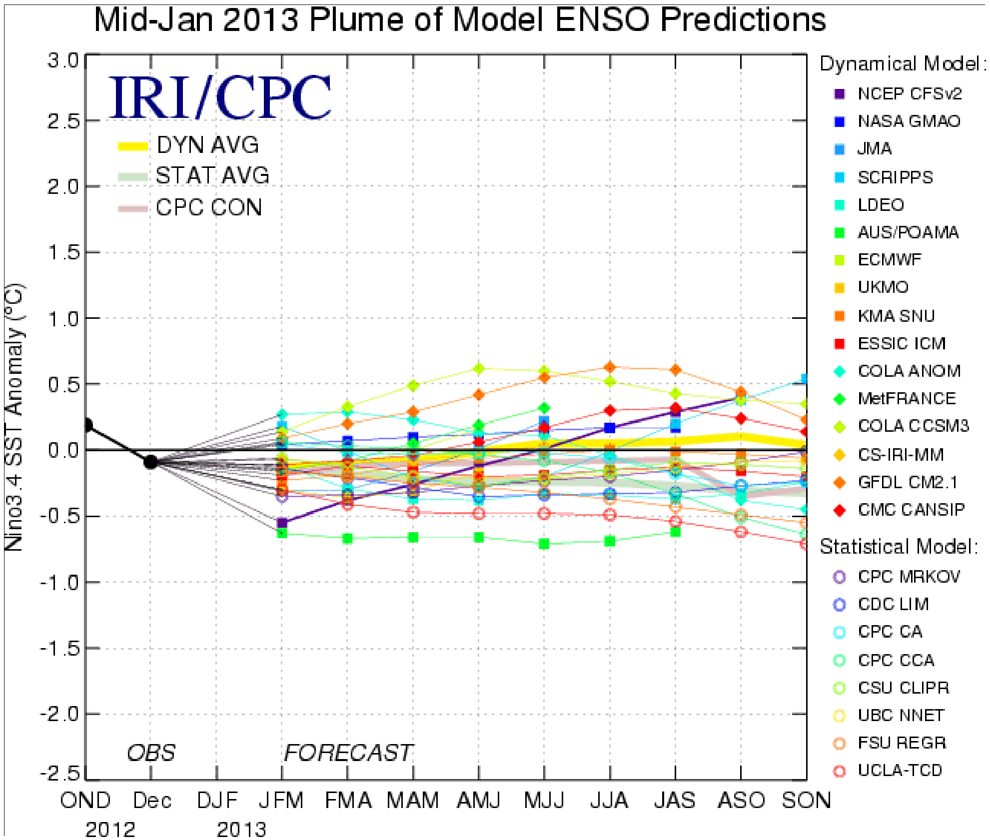


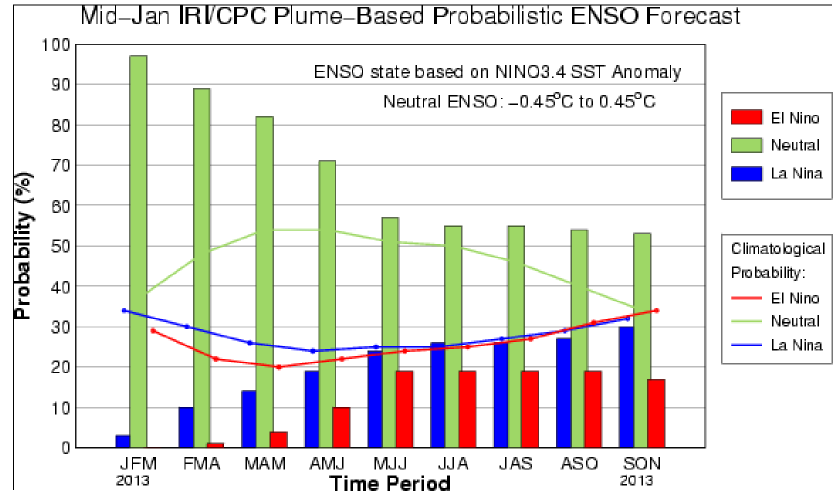


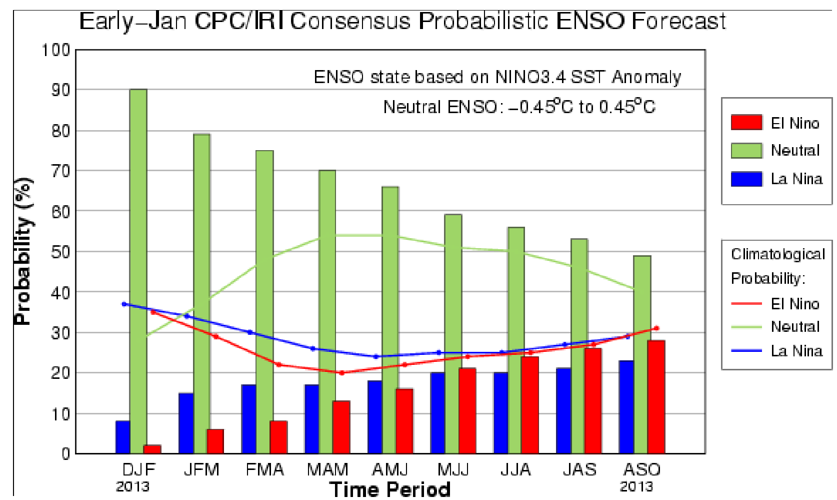
- SSTA in the tropical North Atlantic (TNA) has decreased continuously since Nov 2012.
- Meridional Gradient Mode index (TNA-TSA) also decreased continuously since Nov 2012.
- ATL3 SSTA was near-normal since Jun 2012.

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 departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

IRI / CPC NINO3.4 Forecast Plume

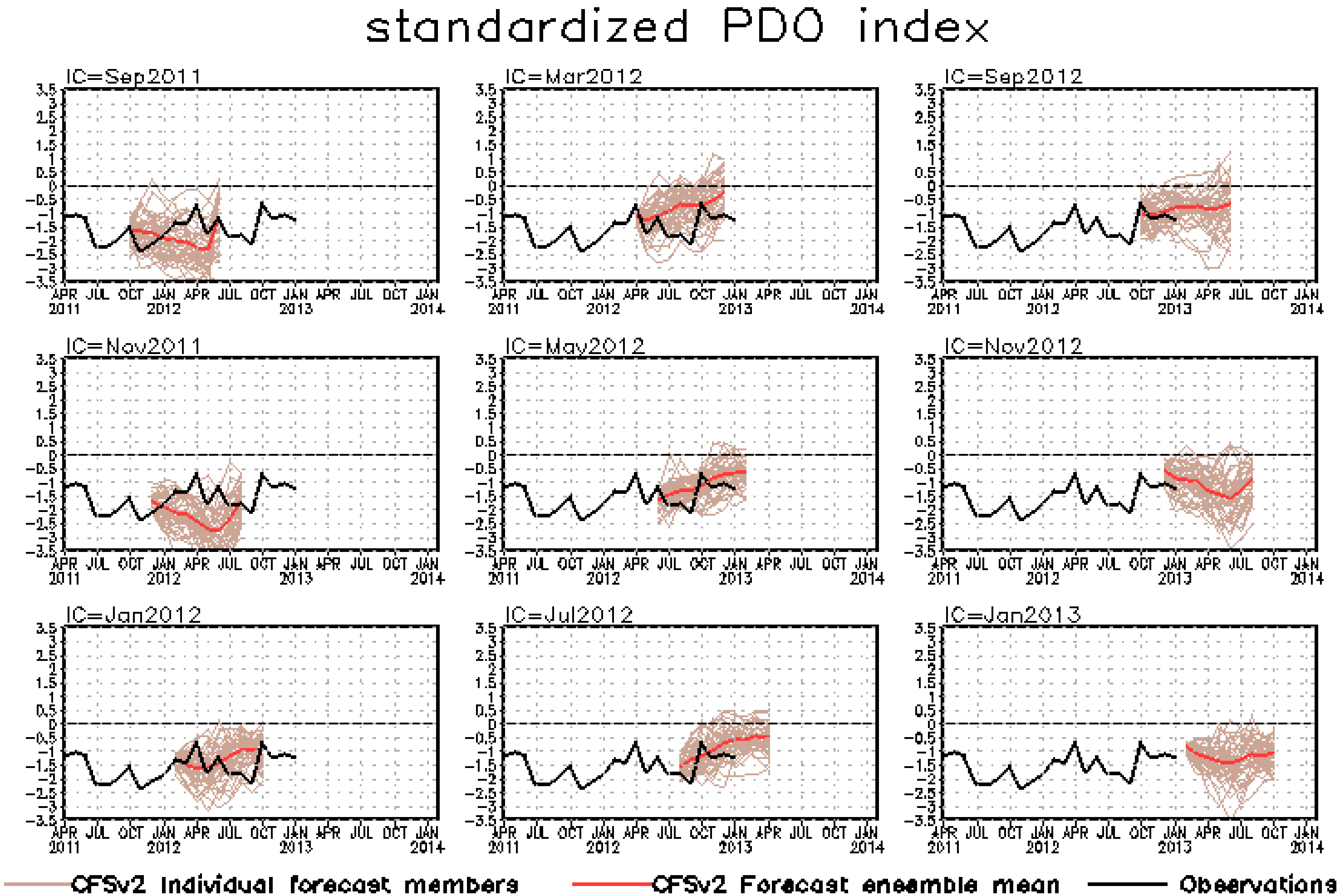






- **The consensus forecast favors ENSO-neutral conditions through the Northern Hemisphere spring and summer.**

NCEP CFSv2 Pacific Decadal Oscillation (PDO) Forecast

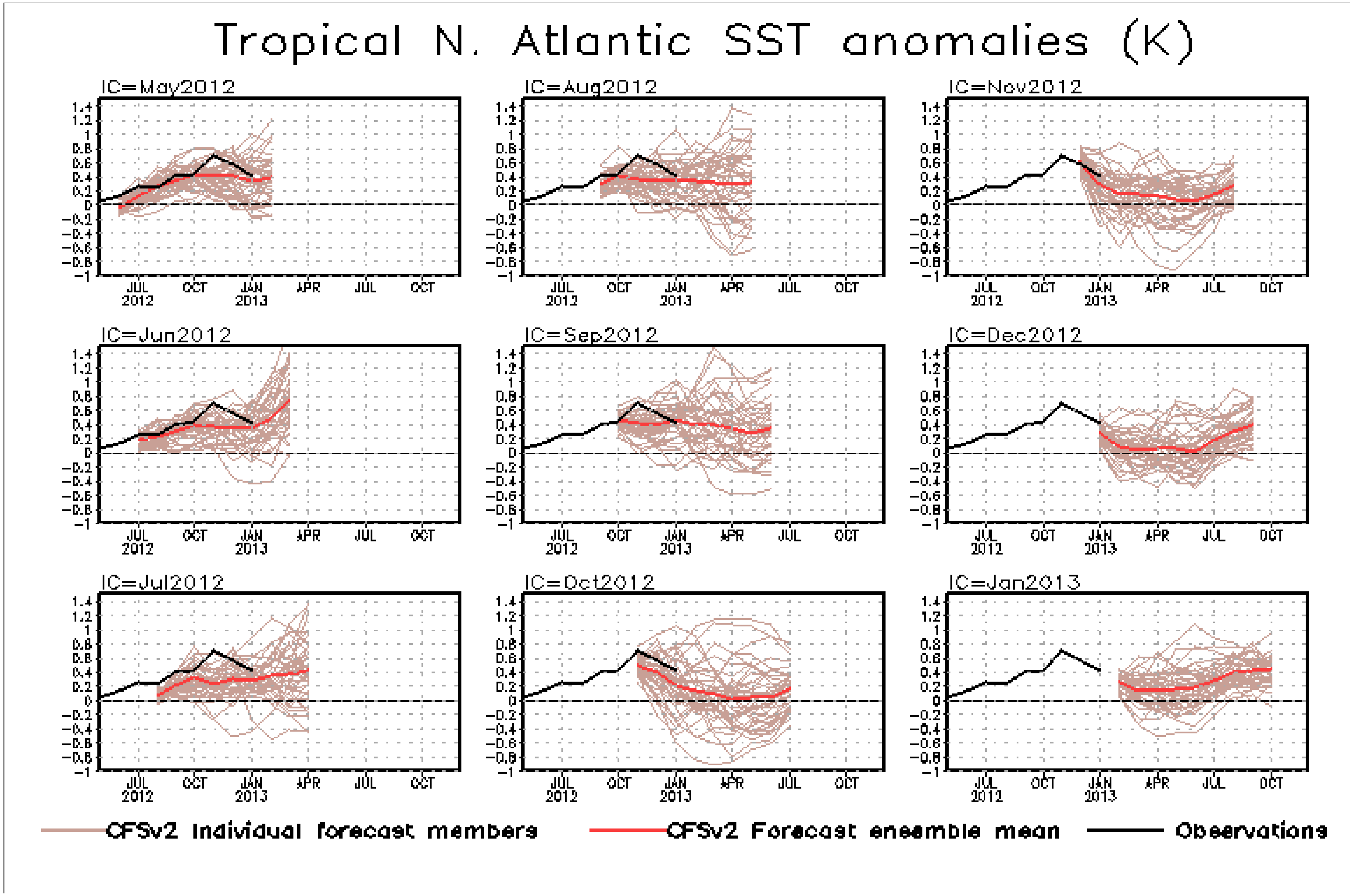


PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

- Latest CFSv2 prediction suggests weak negative PDO phase will persist through the Northern Hemisphere spring and summer.

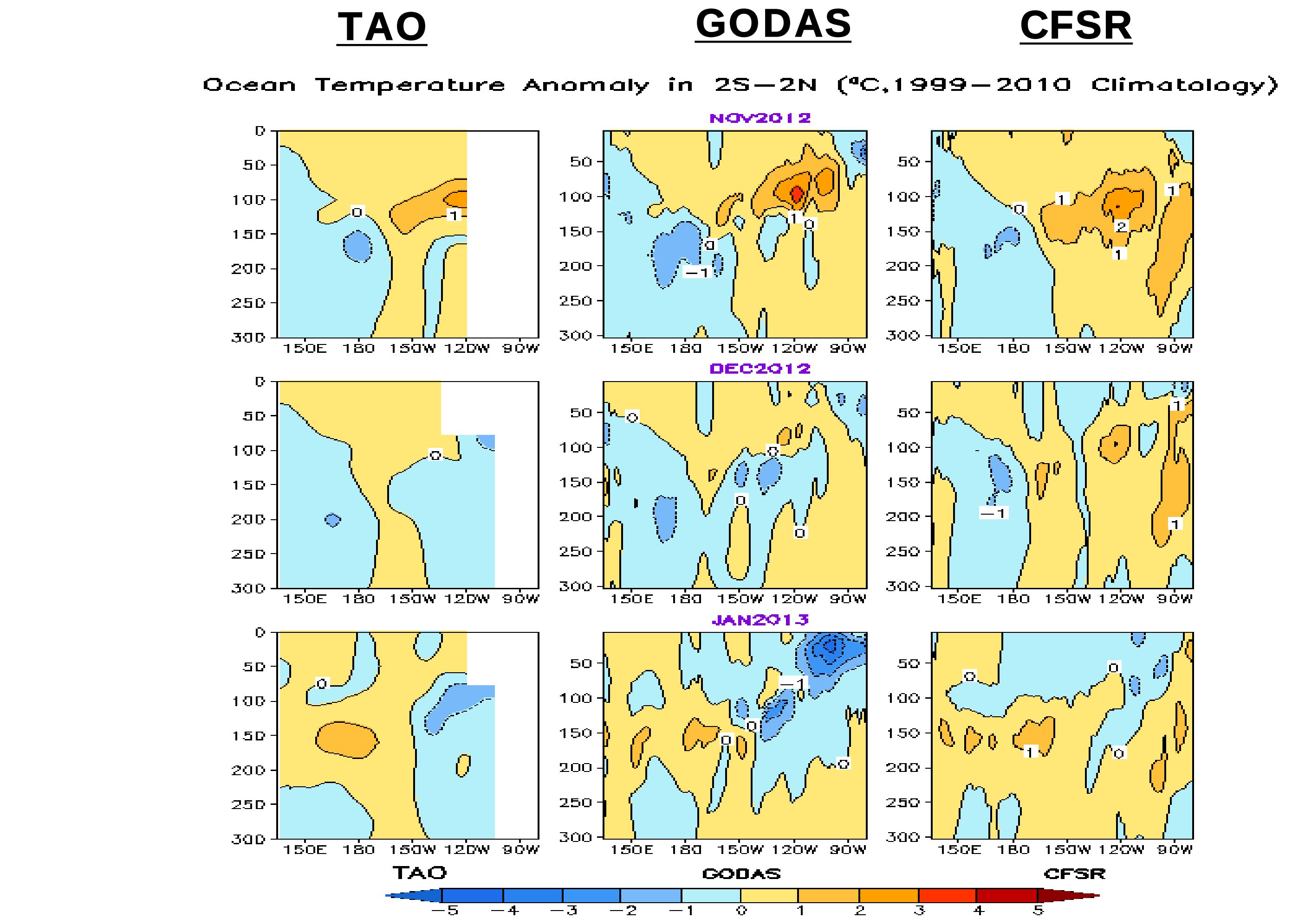
NCEP CFSv2 Tropical North Atlantic SST Forecast



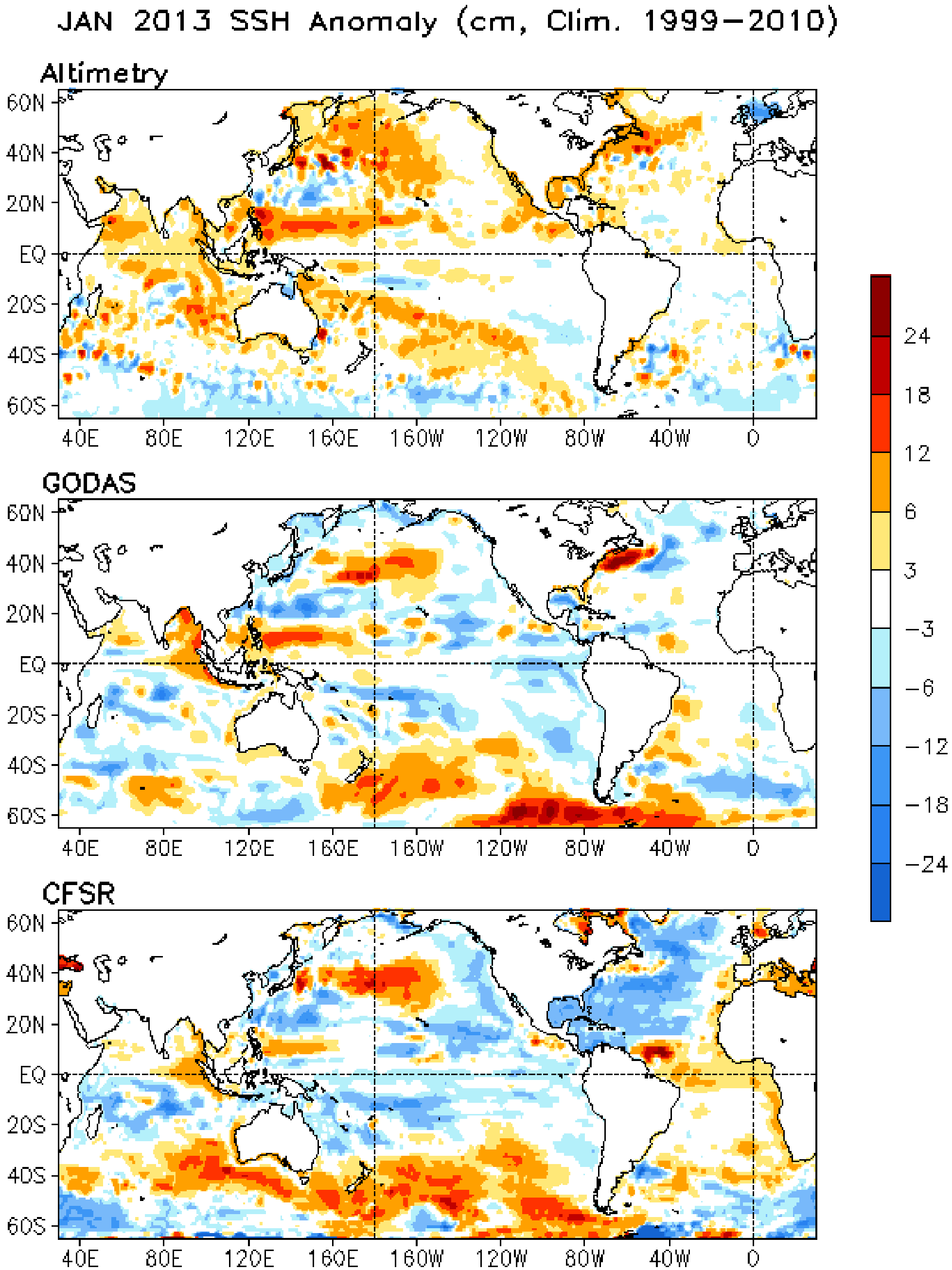
- Latest CFSv2 prediction suggests tropical North Atlantic SST will cool down and return to normal-conditions in spring.
- The CFSv2 predicted the warming tendency quite well from Jan-Mar I.C..

Comparison of CFSR and GODAS

Longitude-Depth Temperature Anomaly in 2^{O}S-2^{O}N



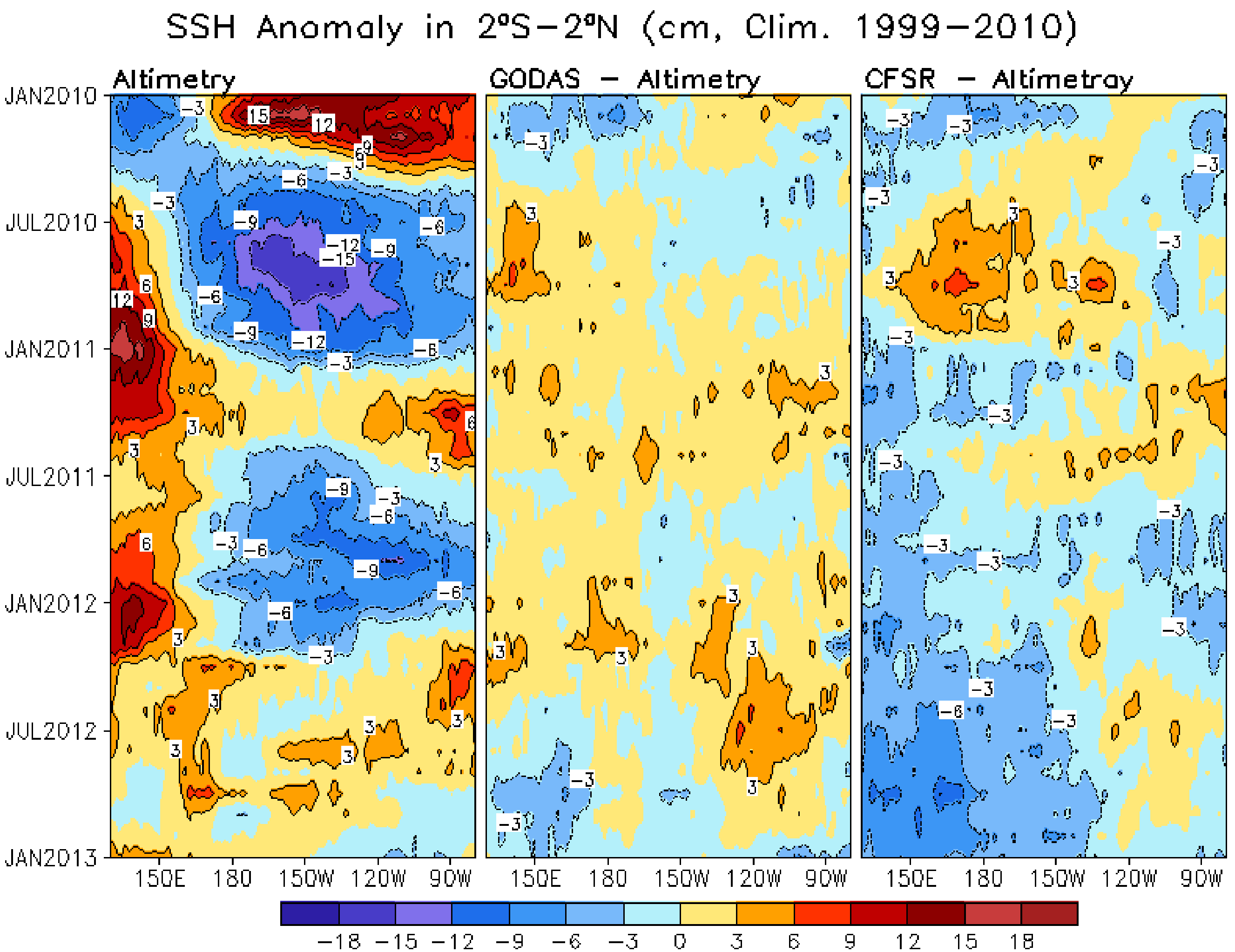
- Anomalies were derived by subtracting the 1999-2010 climatology in each data set separately.
- In Nov-Dec 2012, temperature anomalies in CFSR were similar to those in GODAS except they were warmer near the South America coast. Since TAO data was missing east of 120W, it is hard to know which ocean analysis is better.
- In Jan 2013, GODAS was much colder than CFSR east of 120W, which indicates uncertainties in ocean analysis when TAO data was missing.



SSH Anomaly (SSHA, cm)

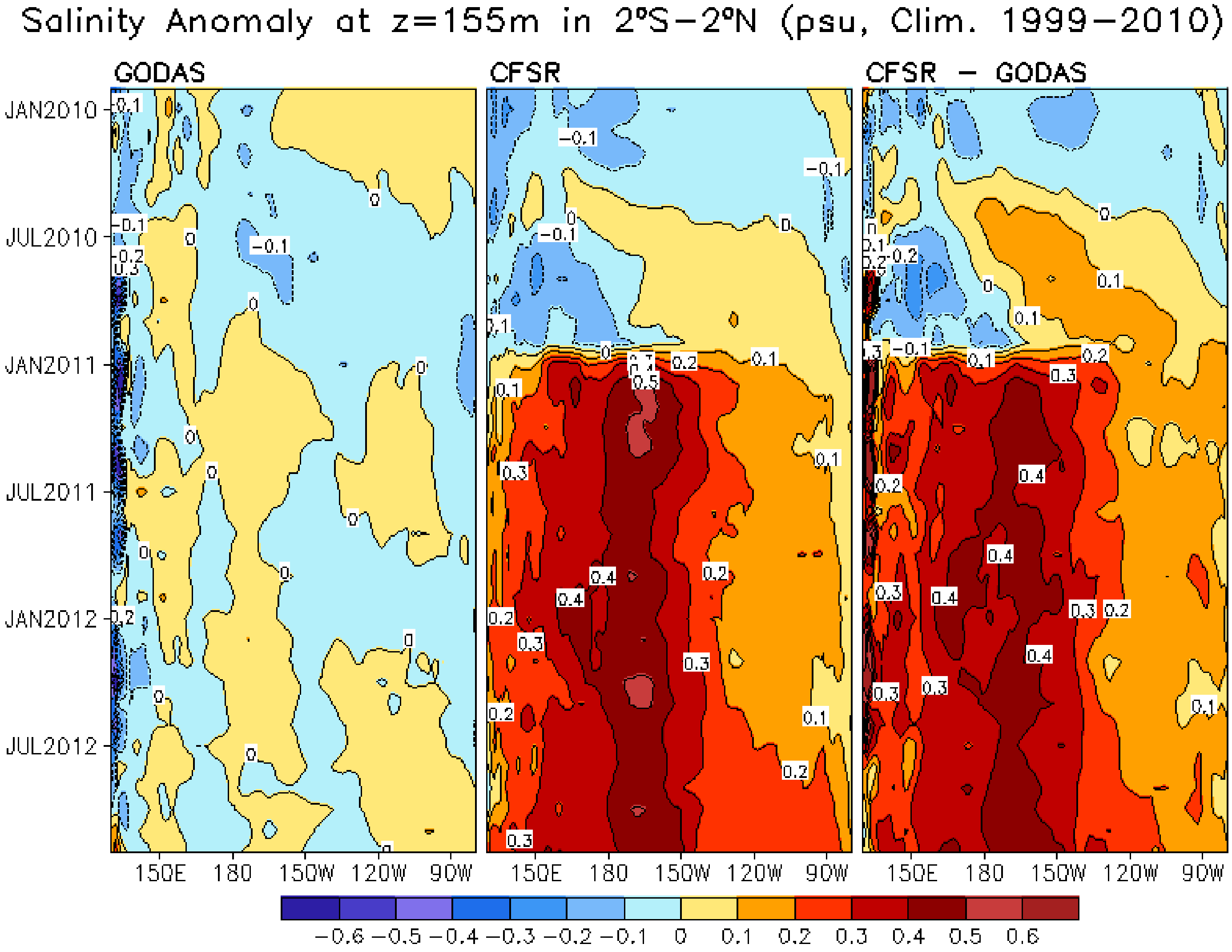
- GODAS SSHA was lower than altimetry SSHA east of 120W in Jan 2013.
- CFSR SSHA was lower than altimetry SSHA along the west coast of North America.
- CFSR SSHA had large discrepancies from altimetry SSHA in the North Atlantic and tropical Atlantic.

Equatorial Pacific SSH Anomaly (cm)



- Differences between GODAS SSHA and altimetry SSHA were less than 3cm.
- However, CFSR SSHA was more than 6cm lower than altimetry SSHA west of 180W since Jul 2012.

Equatorial Pacific Salinity Anomaly (psu)



- There was a sudden increase of salinity at 100-200m depth in CFSR around Jan 2011 when a high resolution atmospheric model was used in CFSR, indicating a sensitivity of ocean analysis to change in atmospheric model.
- It is not clear how the sudden increase in CFSR salinity had impacted CFSv2 ENSO forecast since Jan 2011.

Backup Slides

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

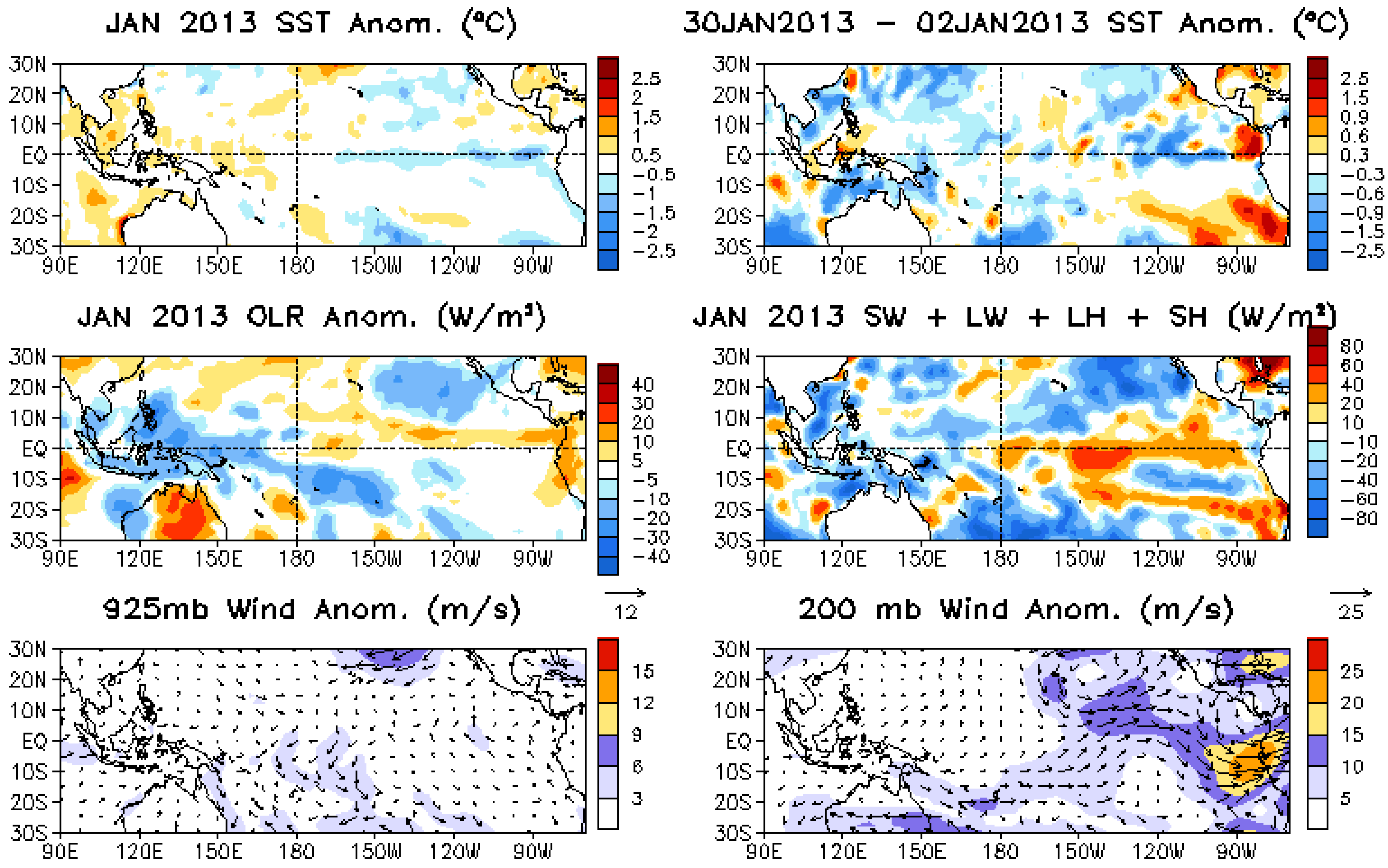


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

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

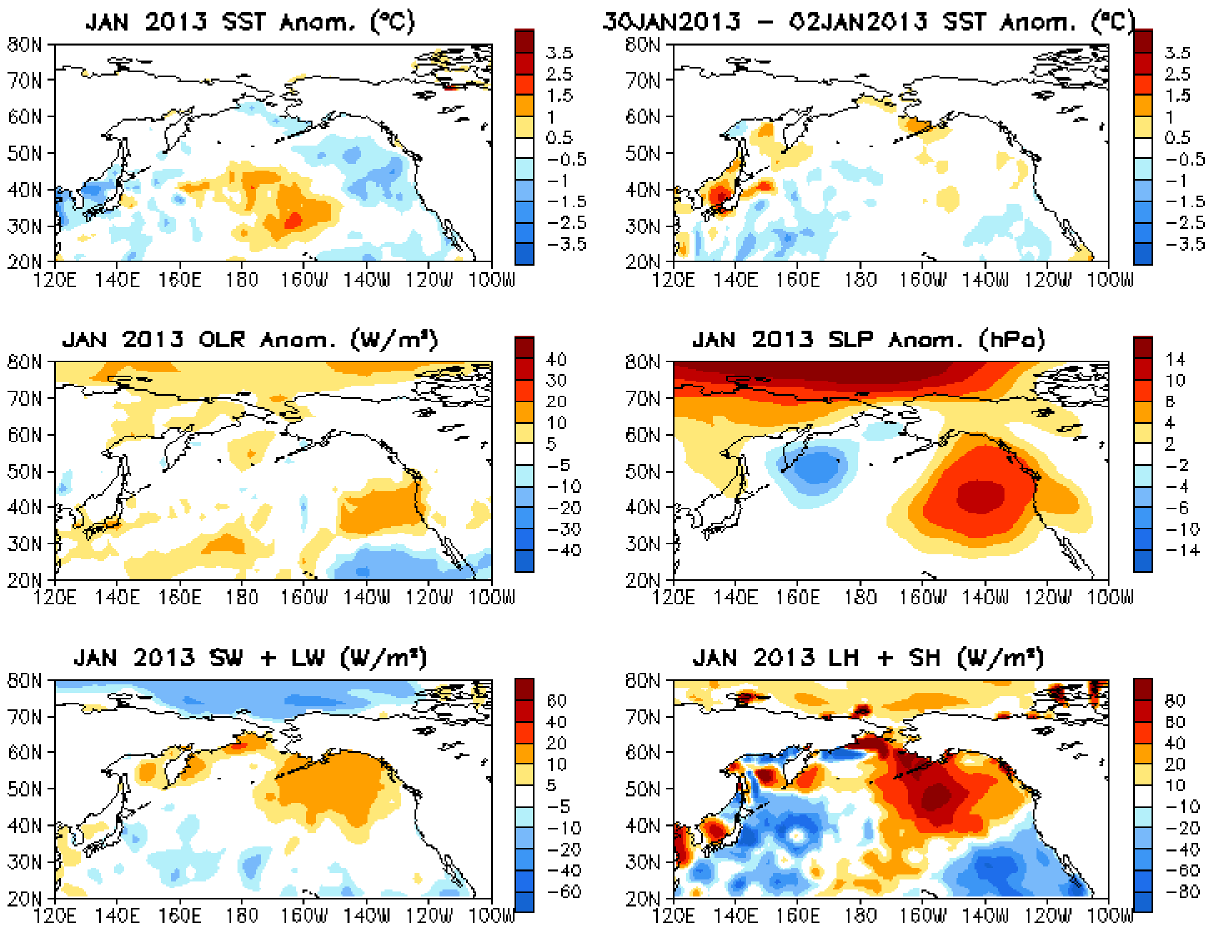


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

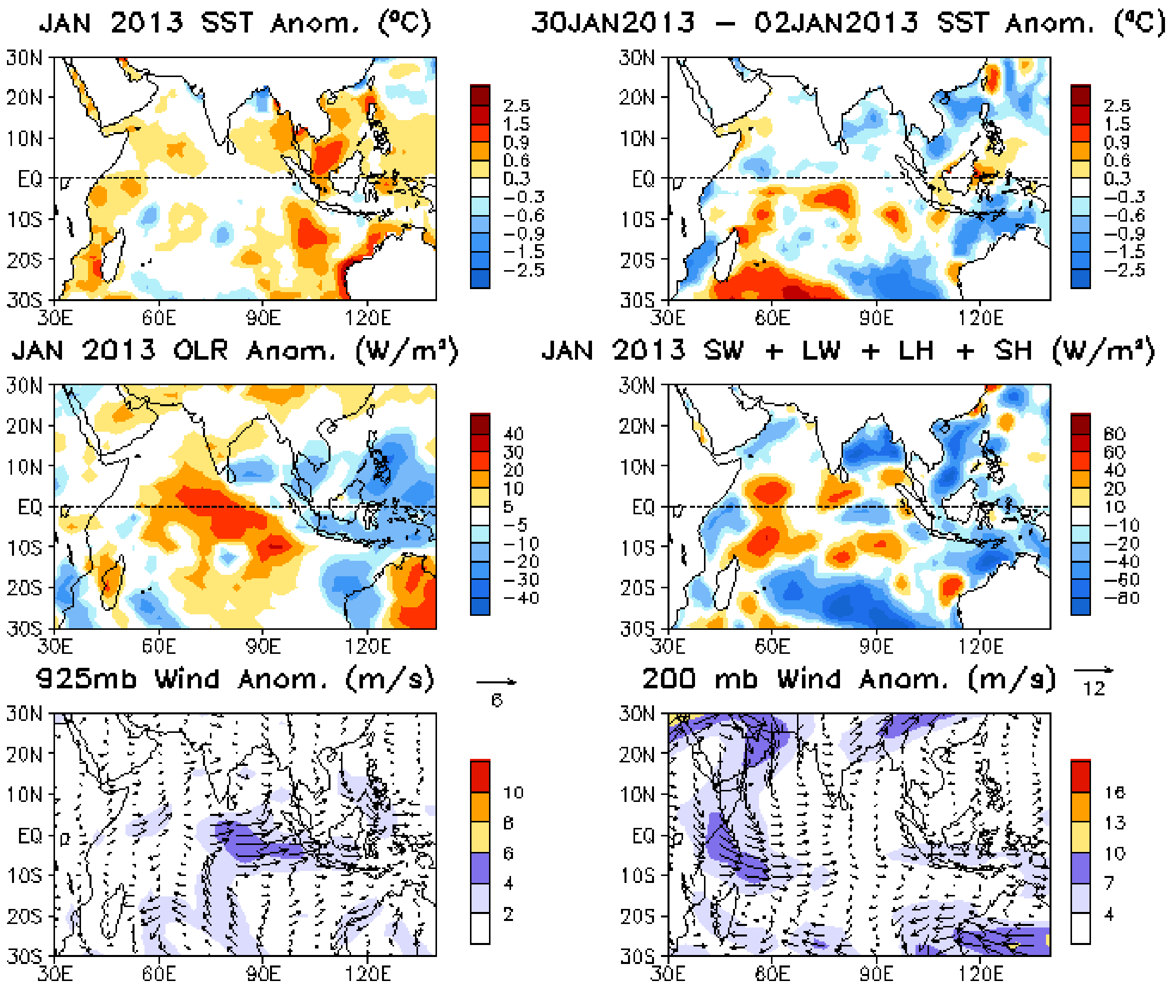


Fig. 12. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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.

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

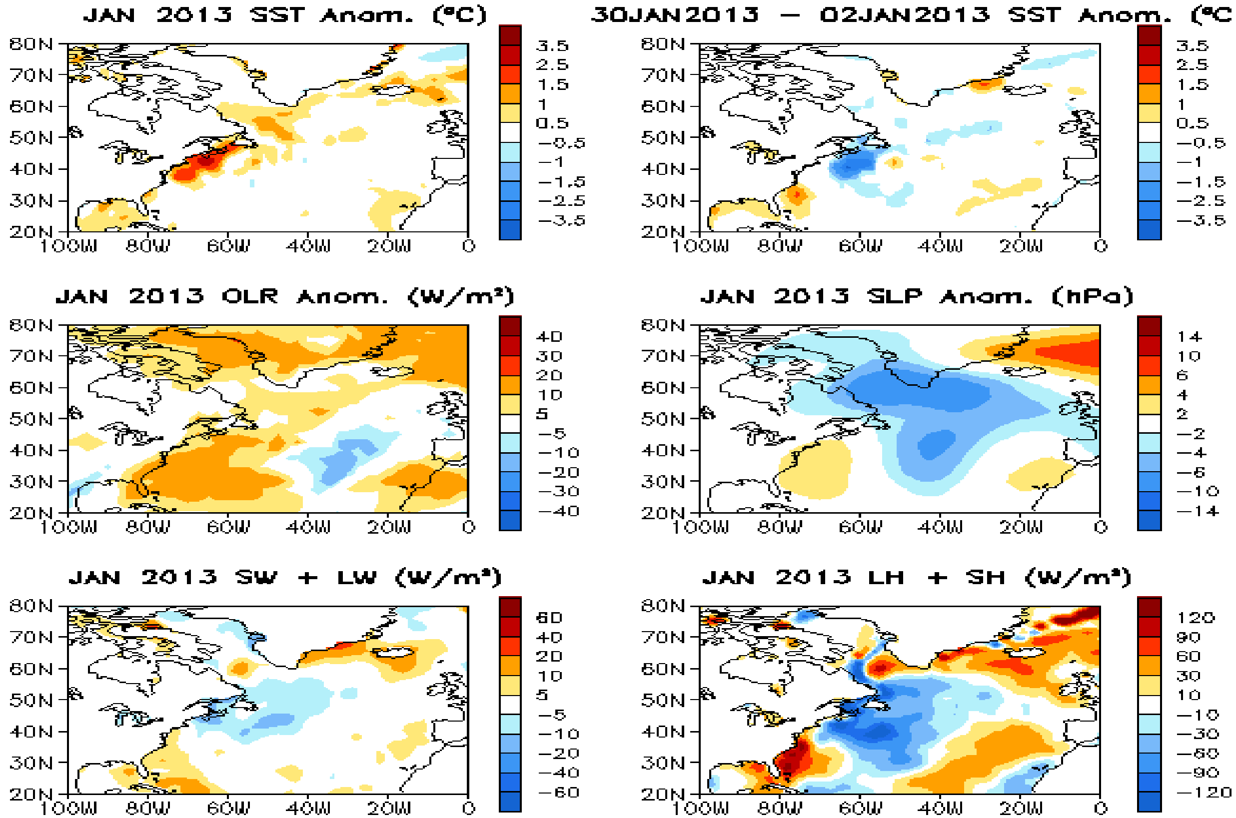
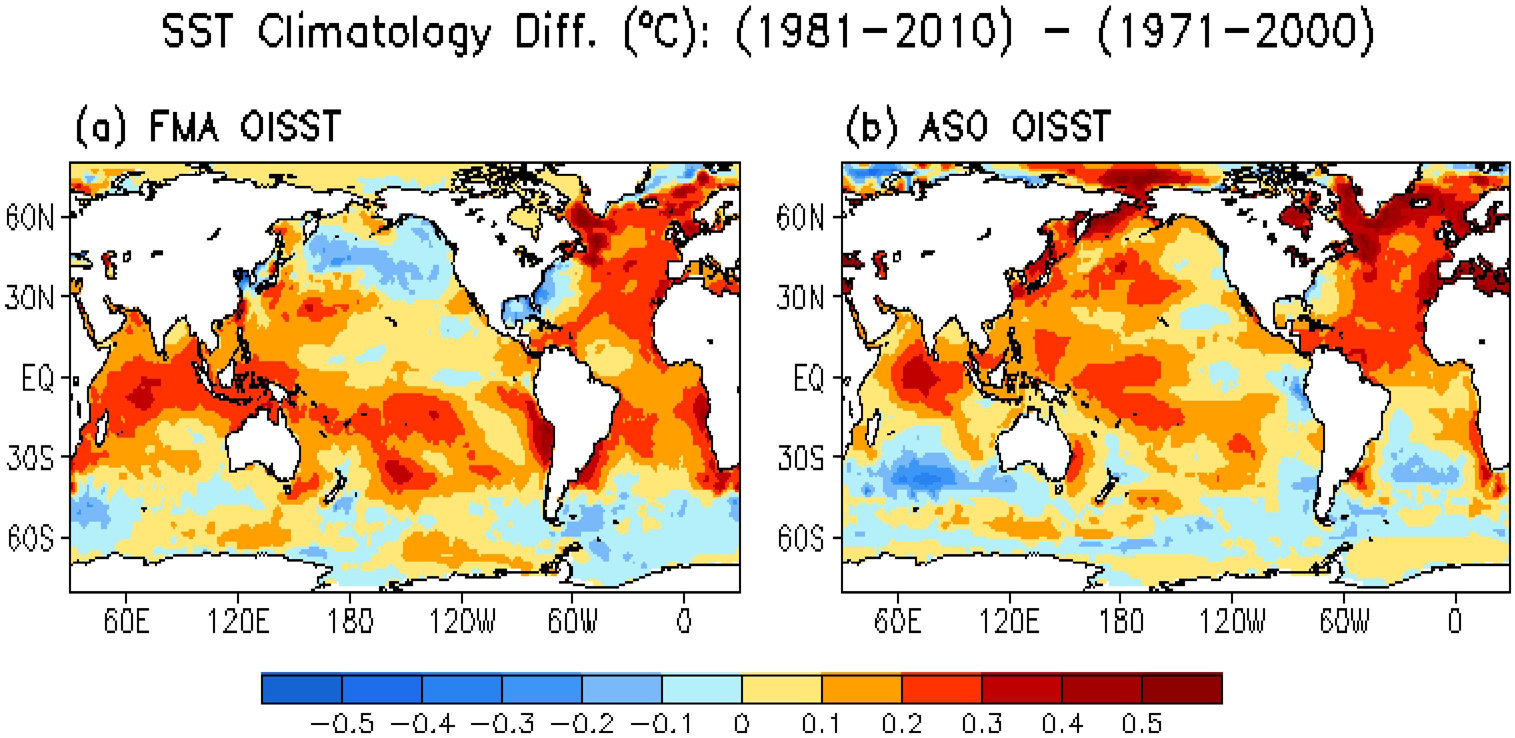


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

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)**

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/

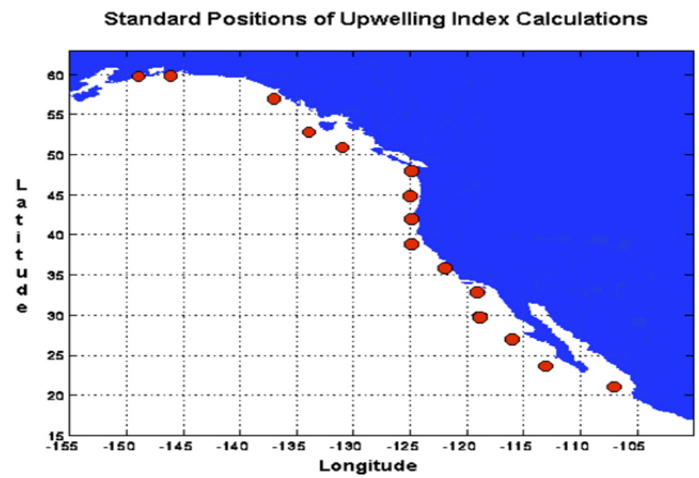
- **The seasonal mean SST in February-April (FMA) increased by more than 0.2°C over much of the Tropical Oceans and N. Atlantic, but decreased by more than 0.2°C in high-latitude N. Pacific, Gulf of Mexico and along the east coast of U.S.**

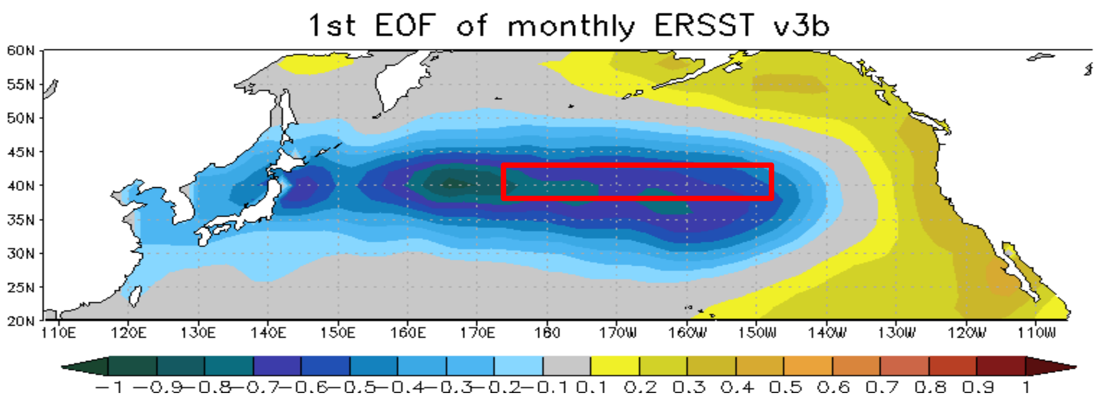
- **Compared to FMA, the seasonal mean SST in August-October (ASO) has a stronger warming in the tropical N. Atlantic, N. Pacific and Arctic Ocean, and a weaker cooling in Gulf of Mexico and along the east coast of U.S.**

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!


Standard Positions of Upwelling Index Calculations
Latitude
Longitude
60
55
50
45
40
35
30
25
20
15
-155
-150
-145
-140
-135
-130
-125
-120
-115
-110
-105


1st EOF of monthly ERSST v3b
60N
55N
50N
45N
40N
35N
30N
25N
20N
110E
120E
130E
140E
150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
−1 −0.9 −0.8 −0.7 −0.6 −0.5 −0.4 −0.3 −0.2 −0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1