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

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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**
  - **Indian Ocean**
  - **Atlantic Ocean**
- **Global SST Predictions**

Summary

- **Pacific Ocean**

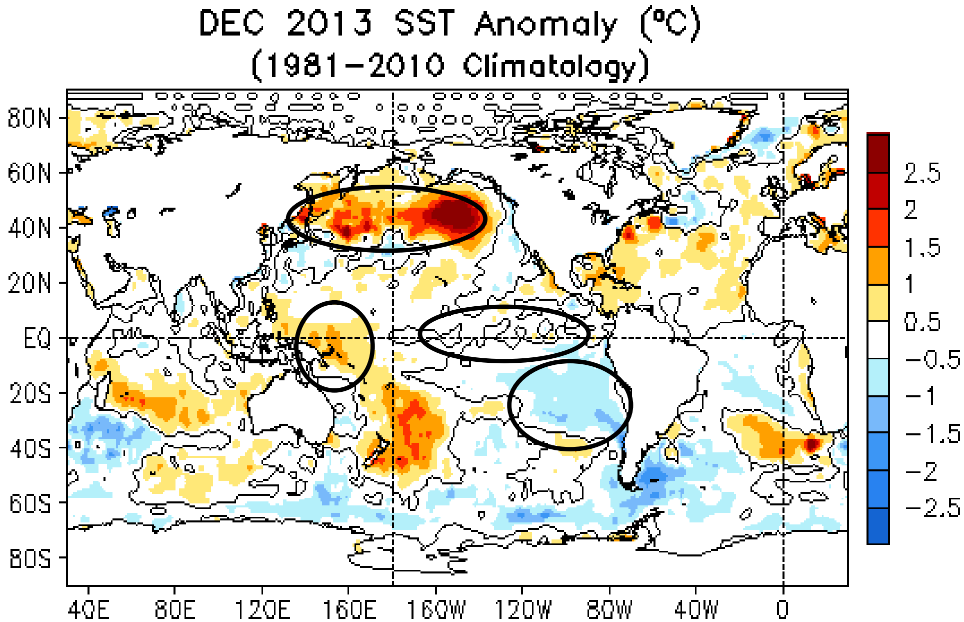
- ENSO-neutral conditions continued during Dec 2013.
- The consensus forecast favors ENSO-neutral conditions to continue into the Northern Hemisphere summer 2014.
- New long-lead ENSO indices were introduced.
- Negative PDO phase has persisted since May 2010, and NCEP CFSv2 has successfully forecast the persistence of negative PDO up to 9 month lead.
- Status of tropical Pacific ocean observing system is updated and most of the TAO moorings east of 155W failed to delivery data.

- **Atlantic Ocean**

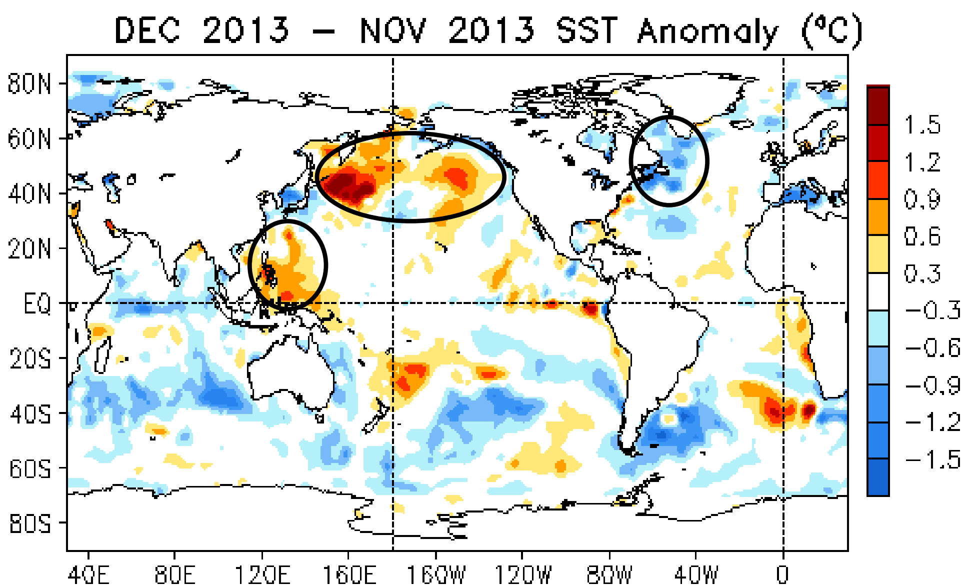
- Positive NAO persisted in Nov-Dec 2013, and NAO= +0.8 in Dec 2013.
- The 2013 Atlantic hurricane season has 13 tropical storms, 2 hurricanes and 0 major hurricanes, and it has the fewest number of hurricanes since 1982. The accumulated cyclone energy (ACE) was about 36% of the 1981-2010 median.
- Possible factors accounting for the very low hurricane activity in 2013 includes near-normal vertical wind shear, below-normal humidity off Africa Continent, strong sinking motion related to un-predictable atmospheric circulation pattern.

Global Oceans

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



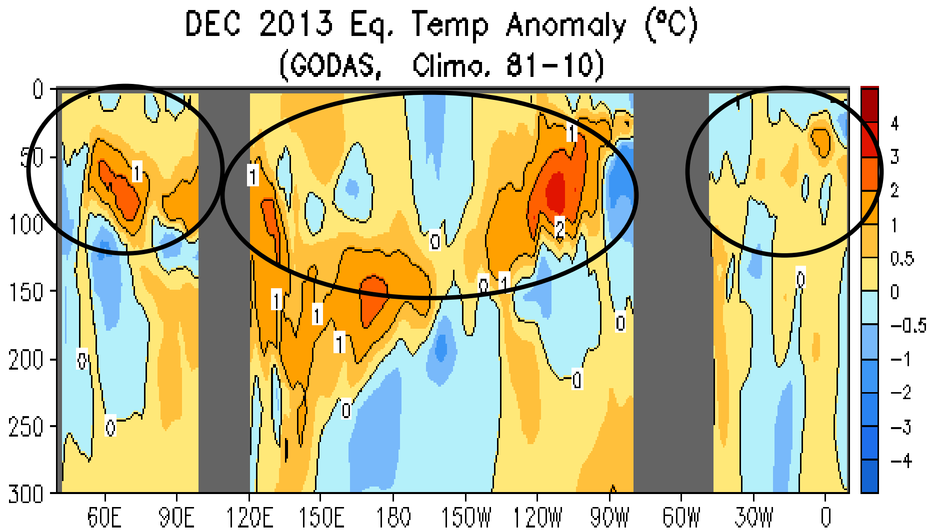
- SST was near-normal in the central-eastern tropical Pacific.
- Positive SST anomalies presented north of Japan, across the N. Pacific, and in the western equatorial Pacific.
- Negative SST anomalies presented in southeast Pacific.



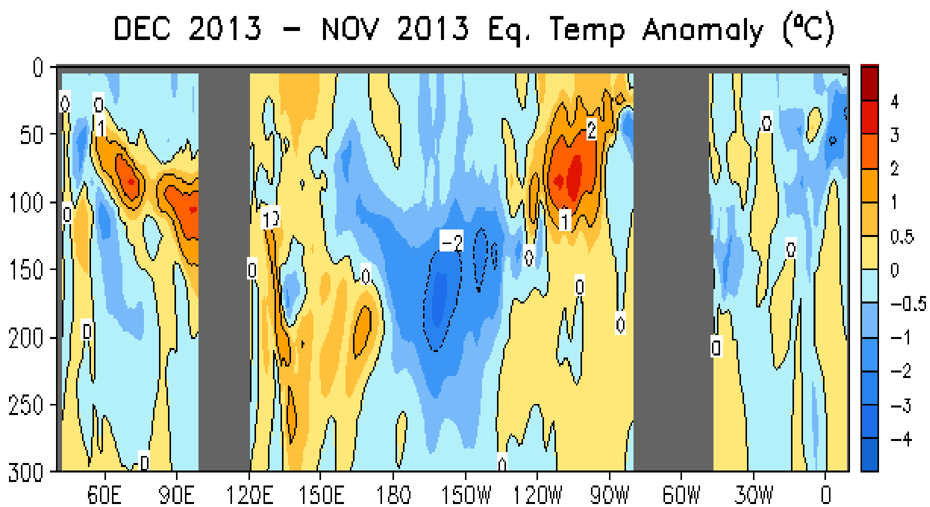
- A warming tendency presented north of Japan and eastern N. Pacific, east of Philippe.
- A cooling tendency was observed along the Gulf Stream and subpolar Arctic.

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 continued to occupy near the thermocline in the equatorial Pacific Ocean.**
- **Positive anomalies dominated at the upper 100m of equatorial Indian and Atlantic Ocean.**

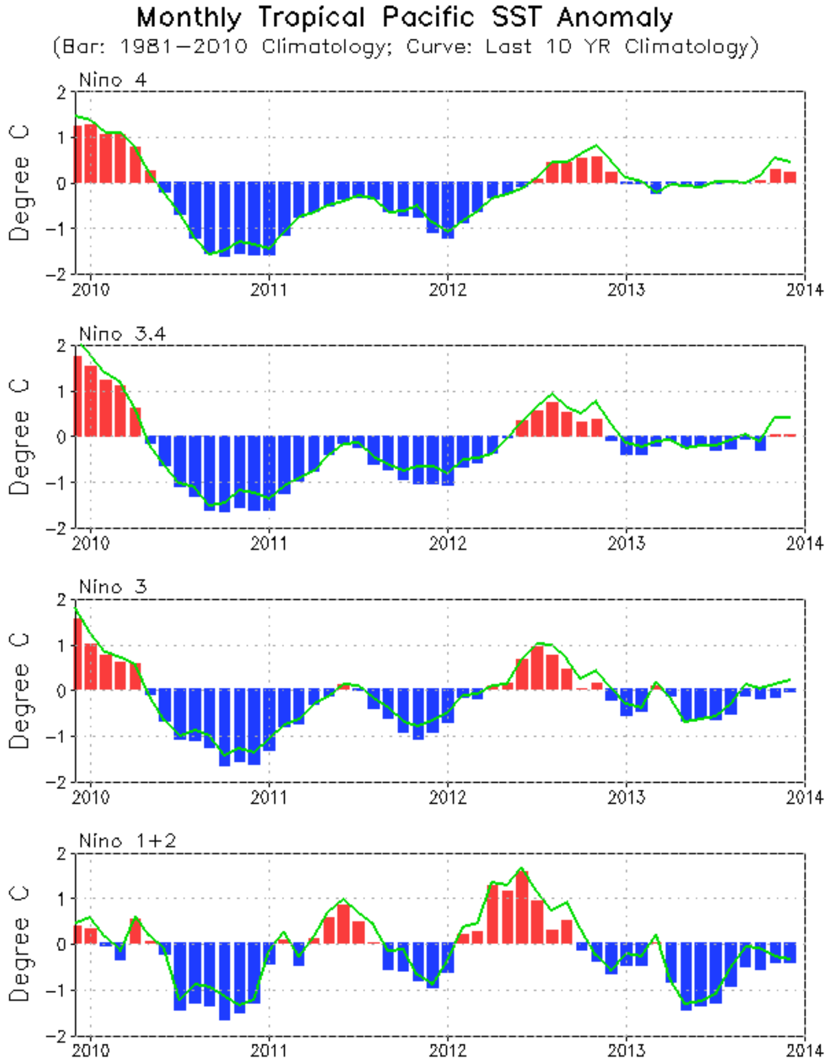


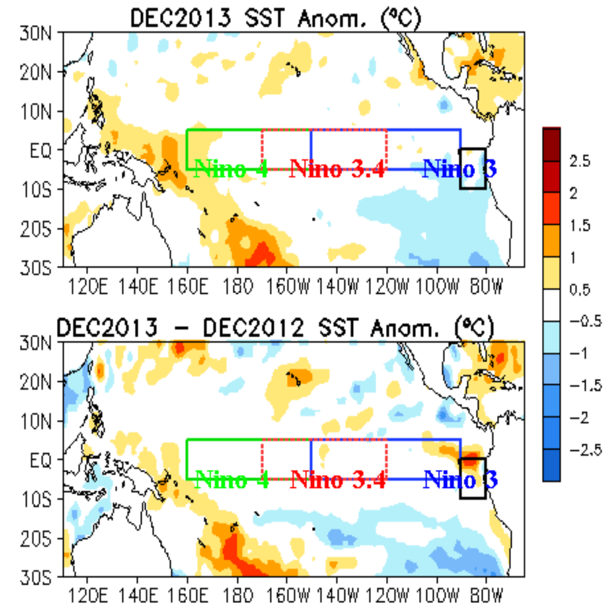
- **A cooling (warming) tendency was observed in the central (eastern/western) Pacific Ocean near the thermocline, largely due to propagation of downwelling and upwelling oceanic Kelvin waves (slide 11).**

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

Evolution of Pacific NINO SST Indices

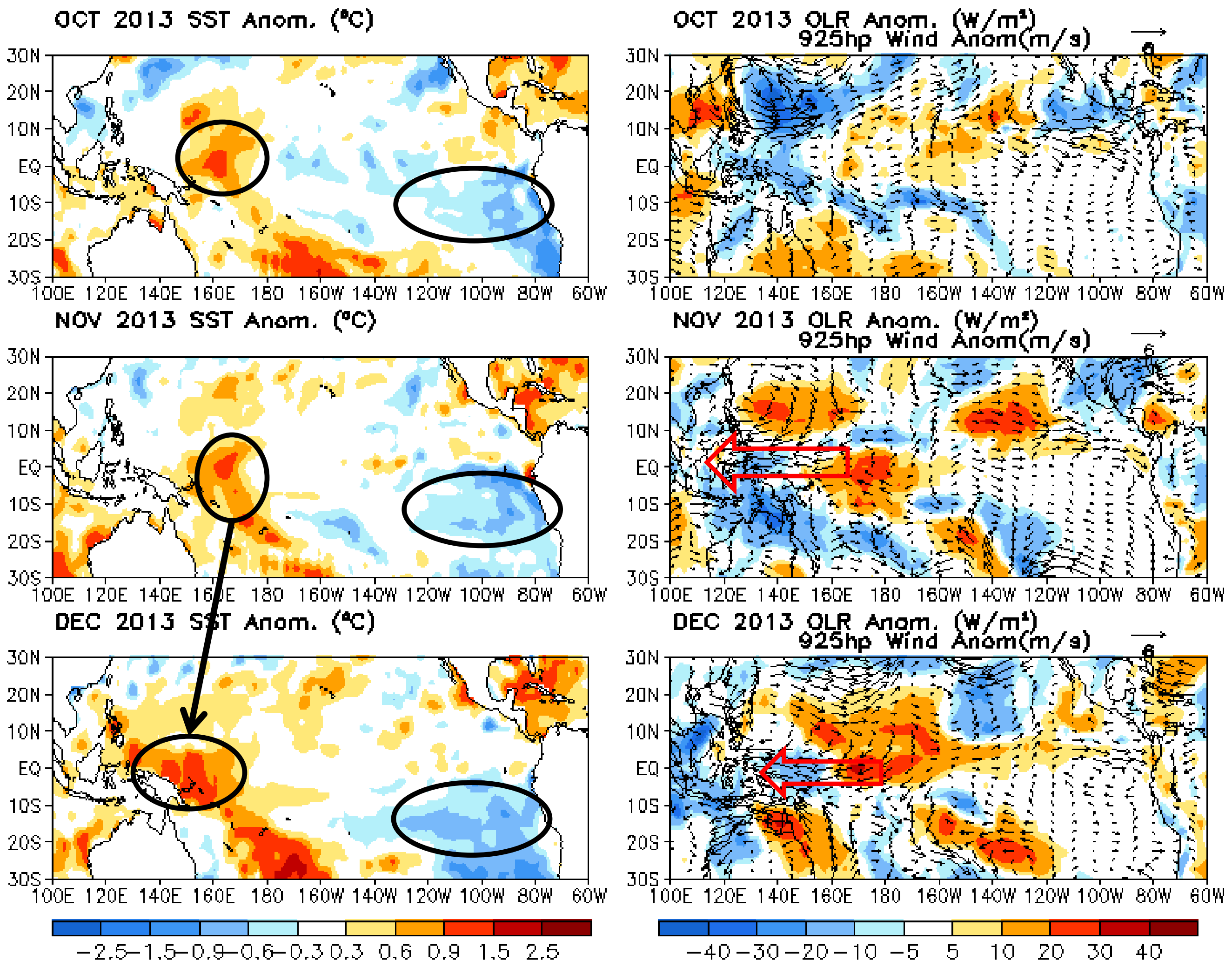




- **All Nino indices were near-normal.**
- **The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v3b.**

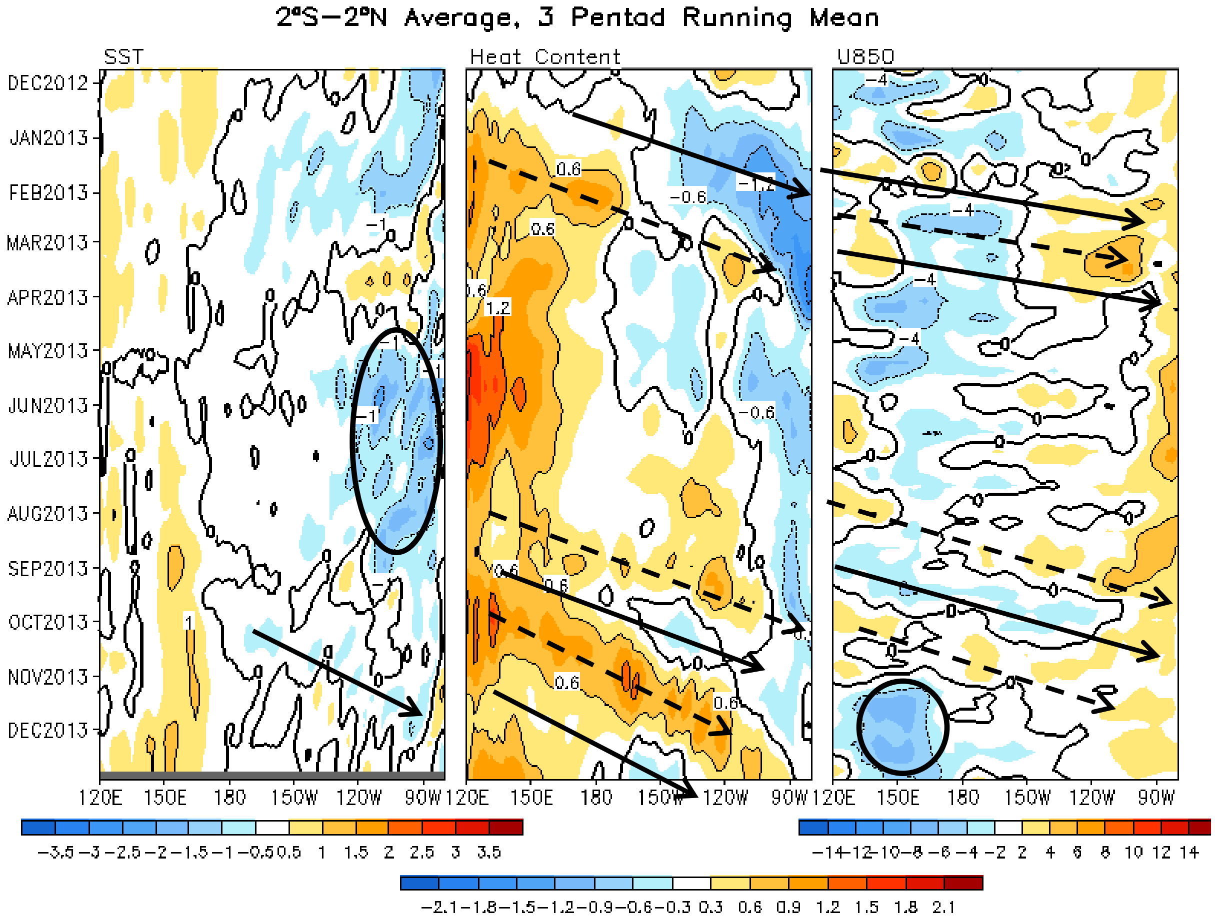
Fig. P1a. Nino region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 (bar) and last ten year (green line) means.

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

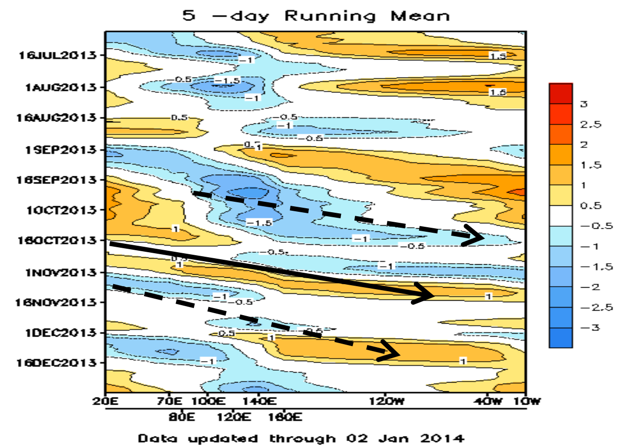


- Positive SSTA persisted west of Dateline, while negative SSTA persisted in the south-eastern Pacific.
- Convection was enhanced (suppressed) over Indonesia (in the central tropical Pacific) in the past two months, and consistently low-level easterly was above-normal in the western tropical Pacific.

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



CPC MJO Indices

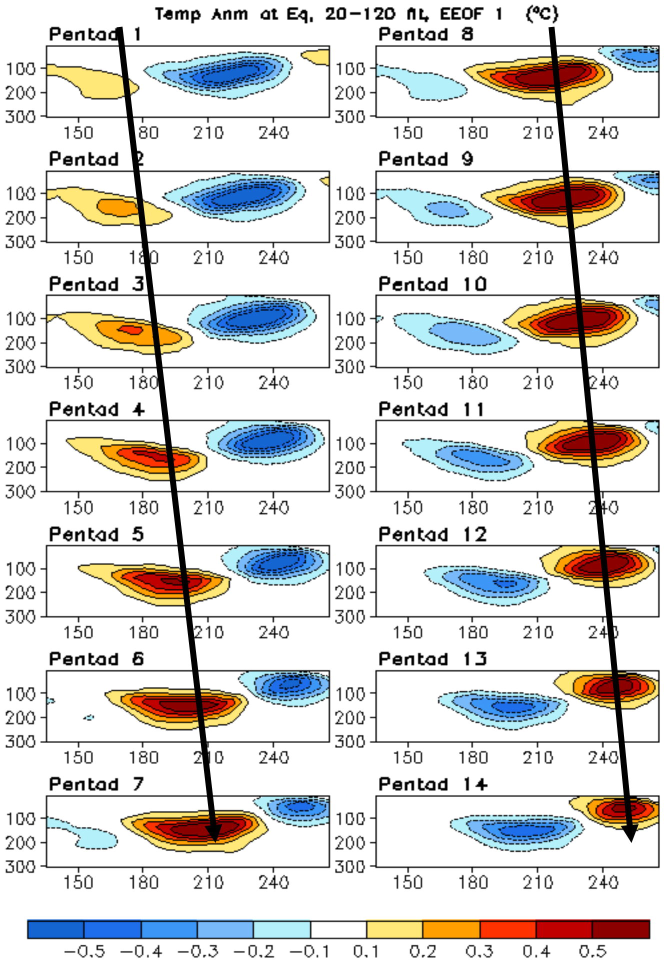


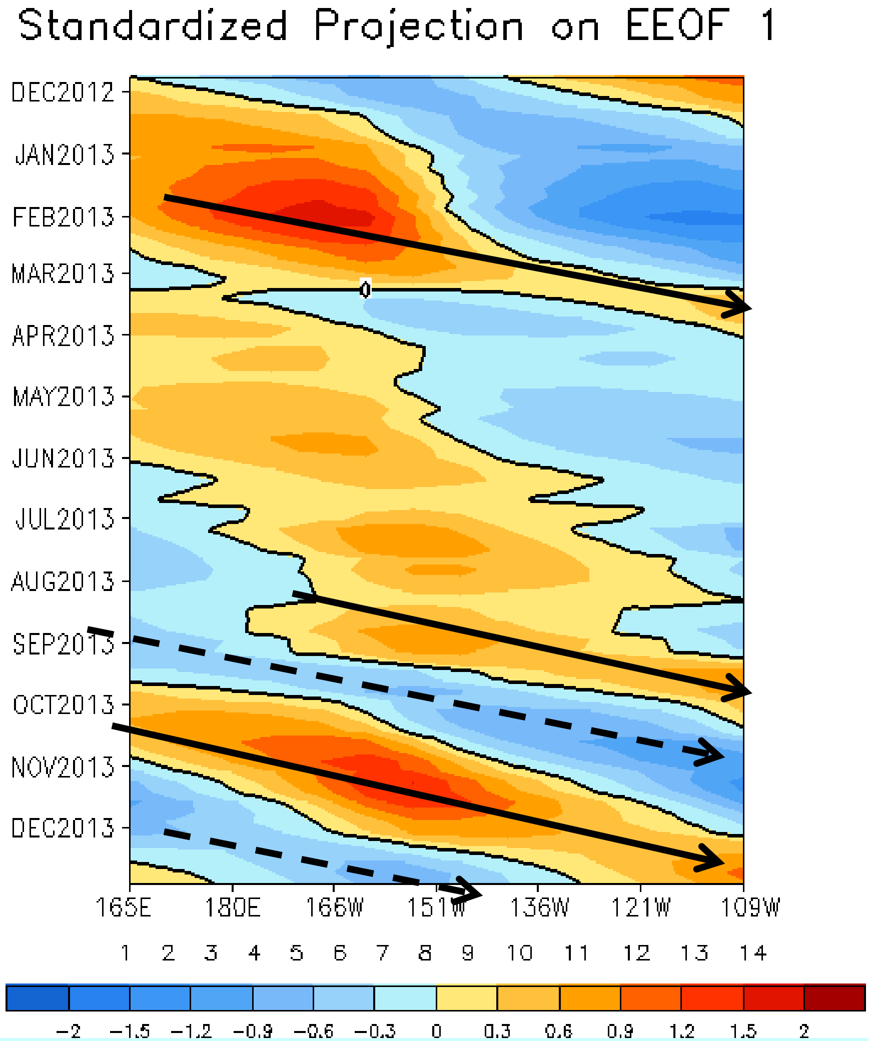
- Ocean heat content anomaly decreased substantially from Nov to Dec following the passage of downwelling oceanic Kelvin waves.

- Easterly wind anomalies dominated in the western equatorial Pacific in the past two months, which would likely cool ocean heat content further in the coming month.

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.

Oceanic Kelvin Wave Indices



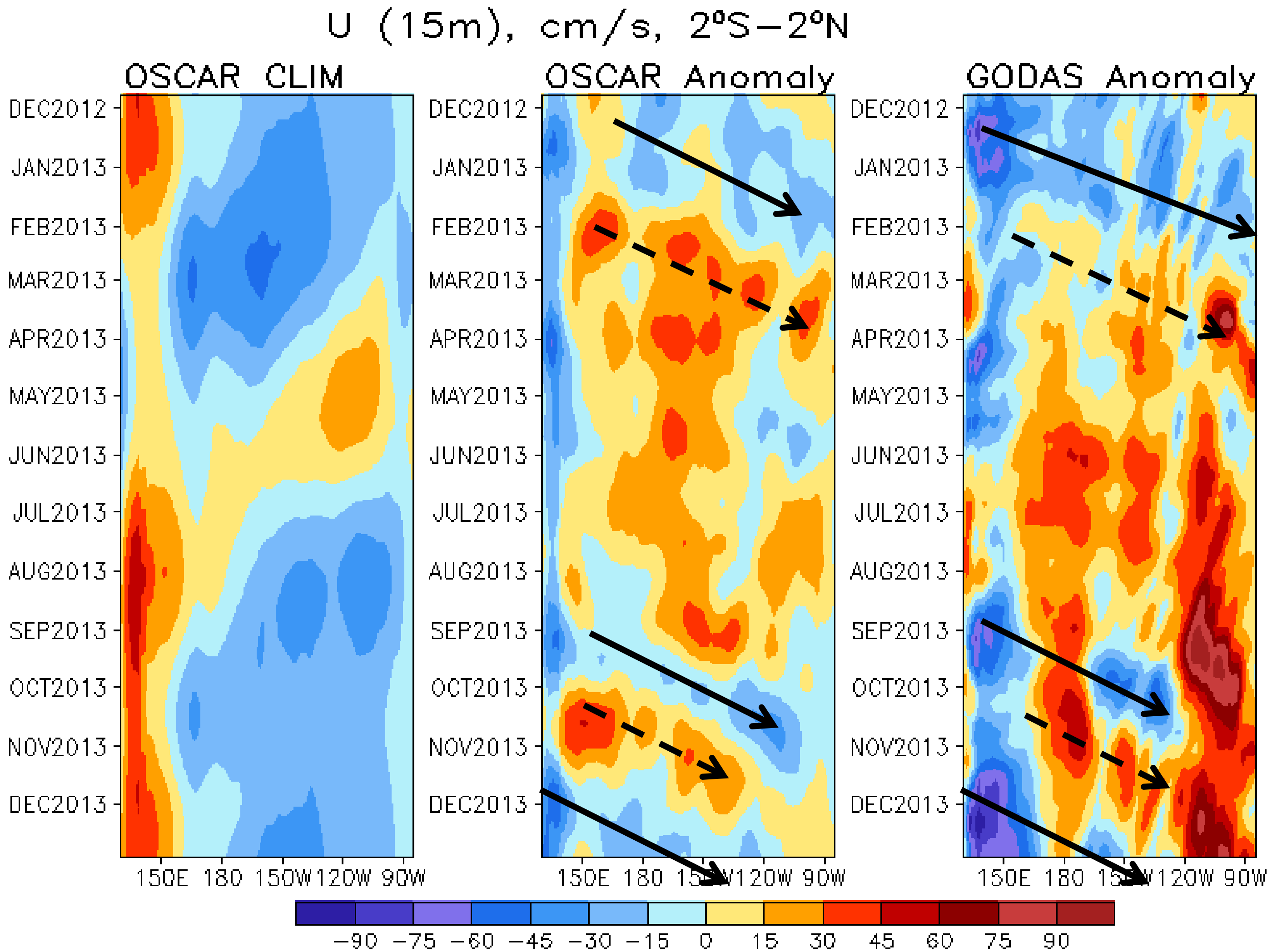


- **Downwelling oceanic Kelvin wave (OKW, solid line) emerged in early Oct in the W. Pacific propagated eastward and reached the coast of S. America in December.**

- **Upwelling OKW (dash line) emerged in mid-Nov in the W. Pacific is expected to propagate eastward and bring cooler subsurface temperature to the central-eastern Pacific in Dec 2013 and Jan 2014.**

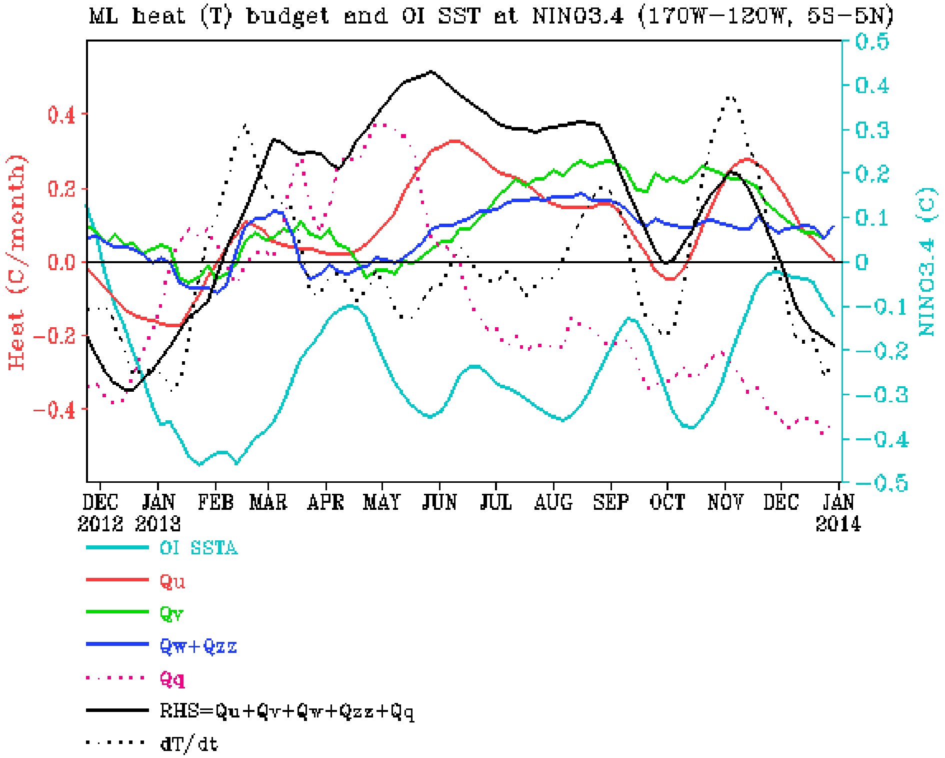
- **Oceanic Kelvin wave indices are defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF 1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).**

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



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

NINO3.4 Heat Budget



- **SSTA tendency (dT/dt) in NINO3.4 region (dotted black line) was negative in Dec 2012, indicating a cooling of NINO3.4.**

- **All of the positive advection terms weakened and the net surface heat flux cooling term strengthened in Dec, contributing to the recent cooling in NINO3.4.**

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

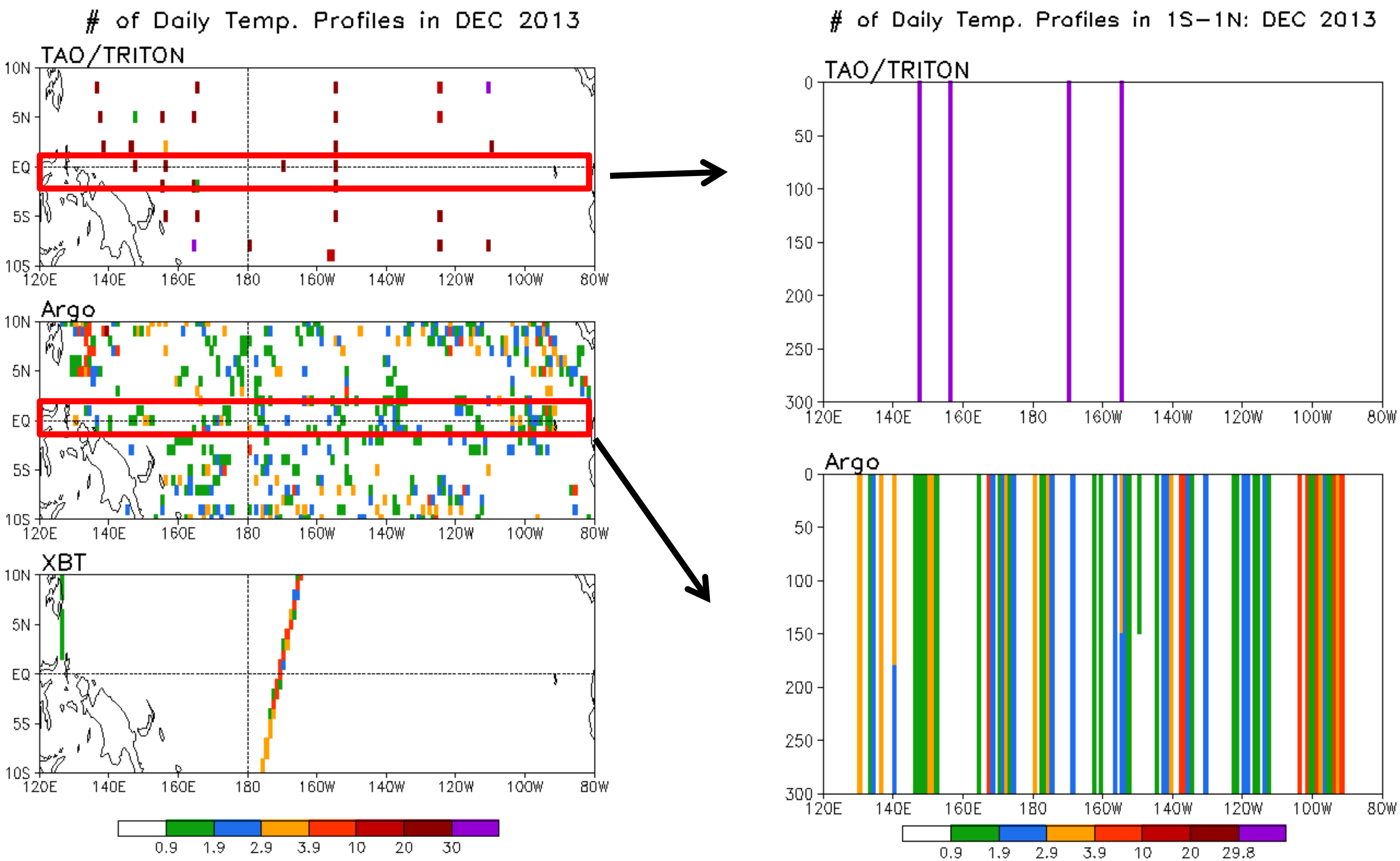
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

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

Tropical Pacific Observing Systems

Real time plots can be accessed at

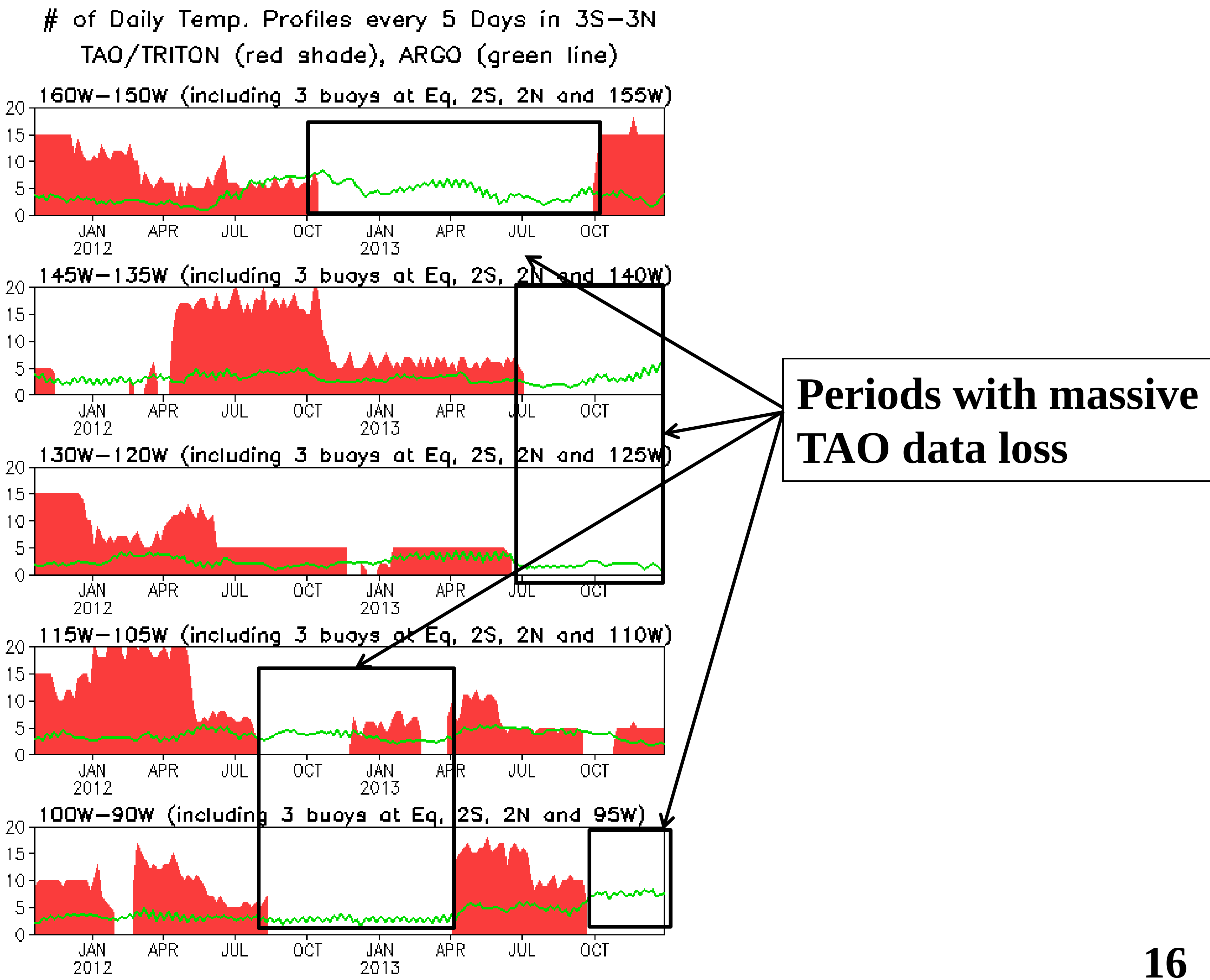
http://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing.shtml



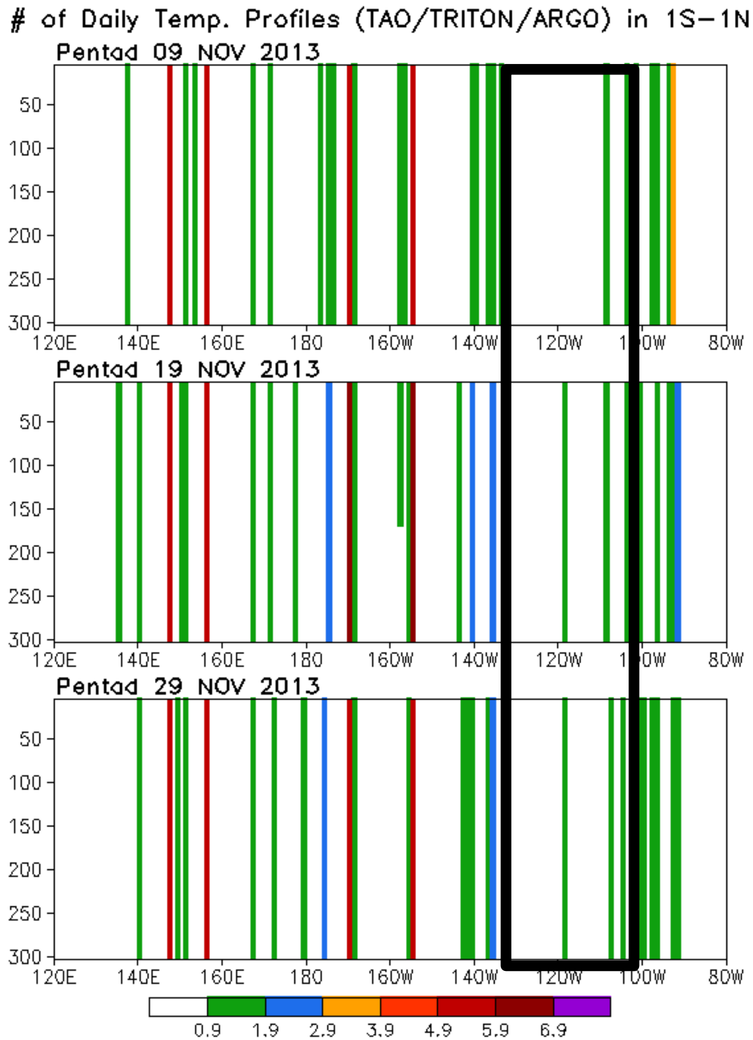
- **The data coverage from the TAO/TRITON array was very poor east of 155W.**

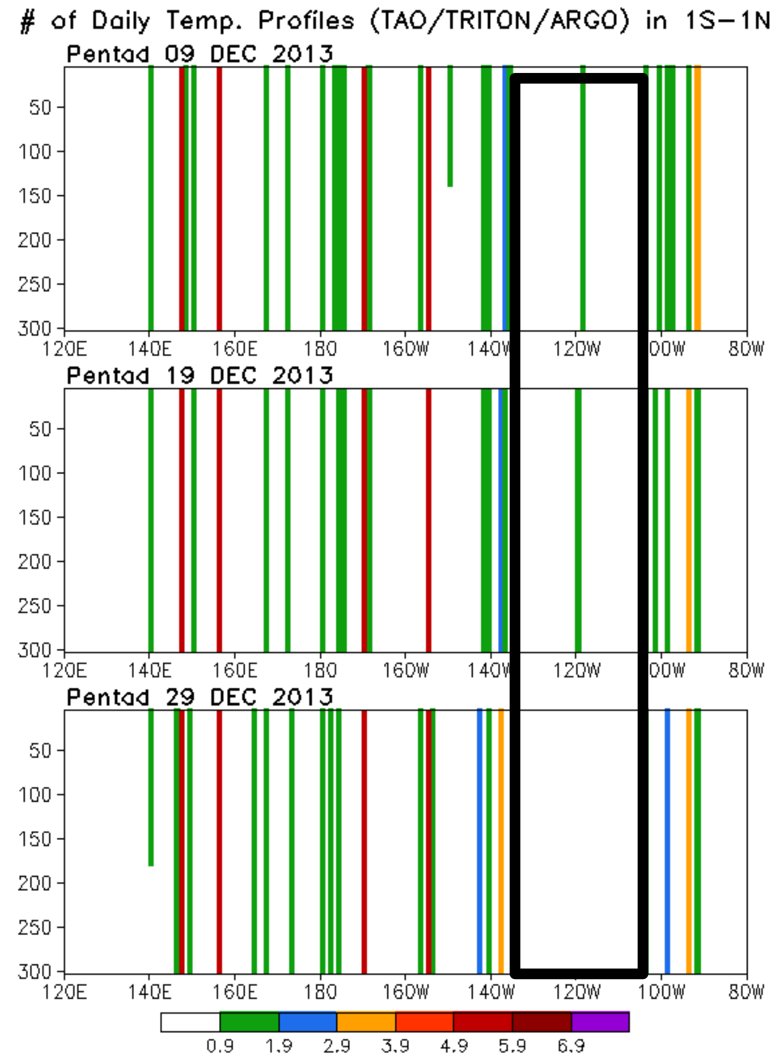
- **The Argo floats provide about 1-2 daily profiles in one degree box, and its coverage in the equatorial Pacific is generally good.**

- **There were little data from XBT.**



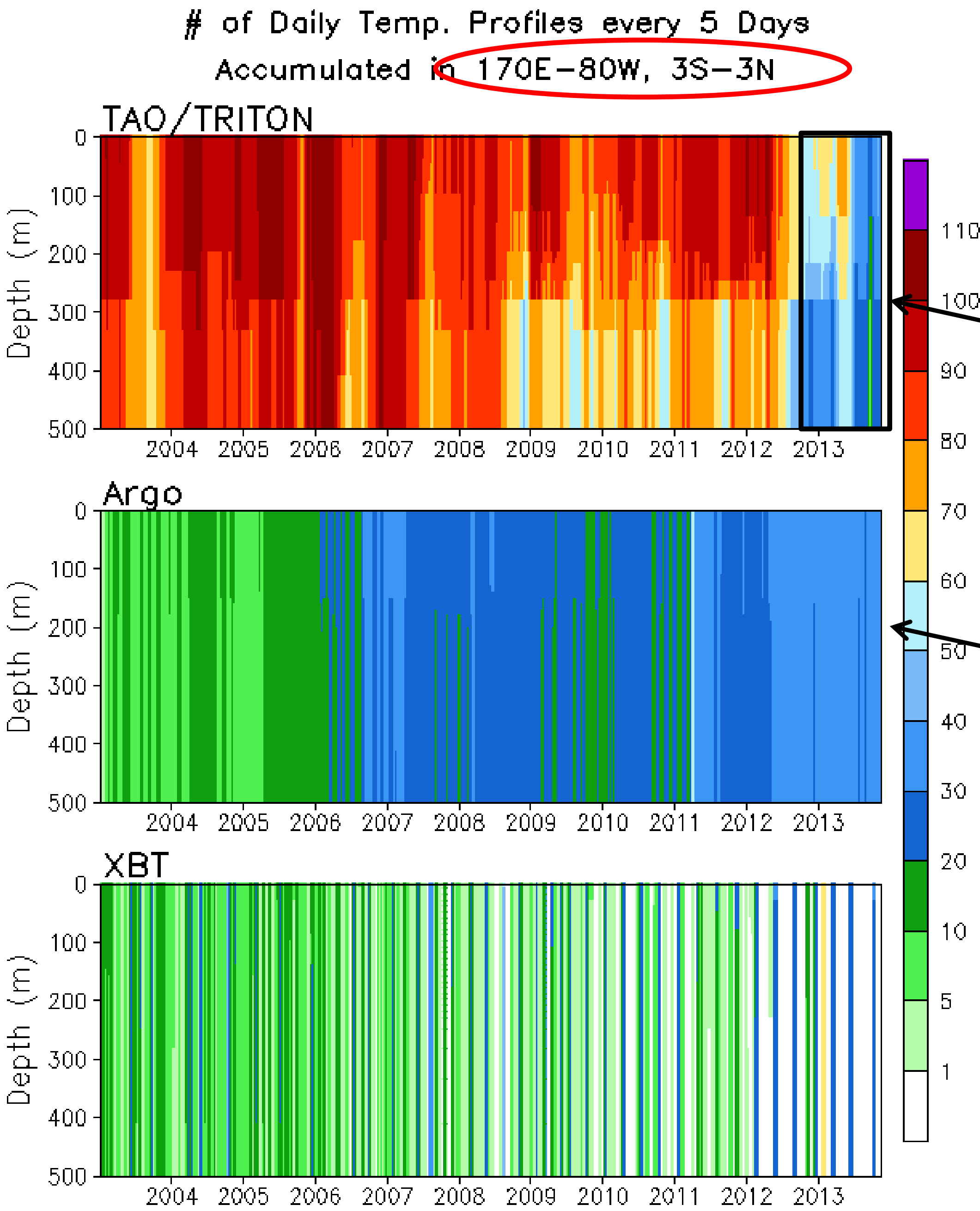
# of Daily Temp. Profiles every 5 Days in 3S-3N
TAO/TRITON (red shade), ARGO (green line)
160W-150W (including 3 buoys at Eq, 2S, 2N and 155W)
145W-135W (including 3 buoys at Eq, 2S, 2N and 140W)
130W-120W (including 3 buoys at Eq, 2S, 2N and 125W)
115W-105W (including 3 buoys at Eq, 2S, 2N and 110W)
100W-90W (including 3 buoys at Eq, 2S, 2N and 95W)
0
5
10
15
20
JAN 2012
APR
JUL
OCT
JAN 2013
APR
JUL
OCT
Periods with massive TAO data loss





- **There were at least one daily profile every 5 day across the equatorial Pacific (1S-1N) except between 140W-100W.**

- **More profiles are needed between 140W-100W to better resolve intraseasonal variability.**

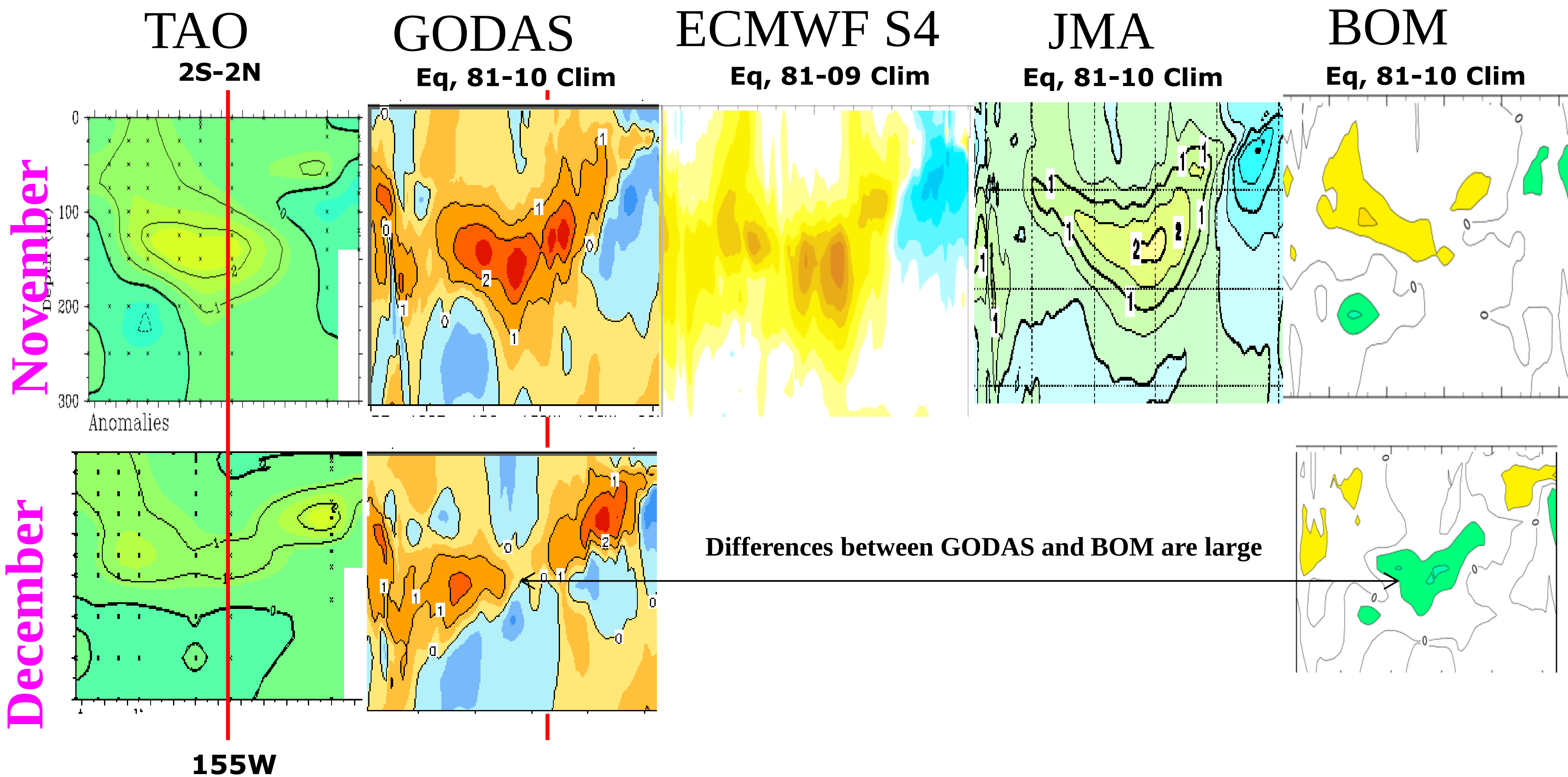


- There is a significant loss of TAO data since summer 2012.

- The total number of Argo profiles in the central-eastern Pacific is increasing and becomes close to the total number of TAO profiles since late 2013.

- There are very few XBT data.

Subsurface Temperature Anomalies along Equator



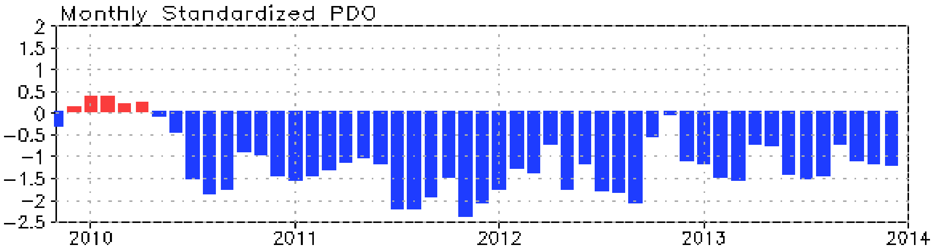
- Subsurface temperature anomalies from different ocean reanalyses exhibited large uncertainties, part of which might be attributed to the loss of TAO data.

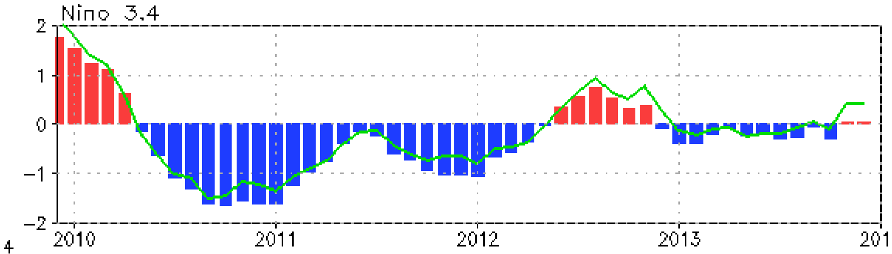
- Ocean reanalysis products are probably more trustful than the TAO temperature subjective analysis, which is basically climatology in places where there were no data.

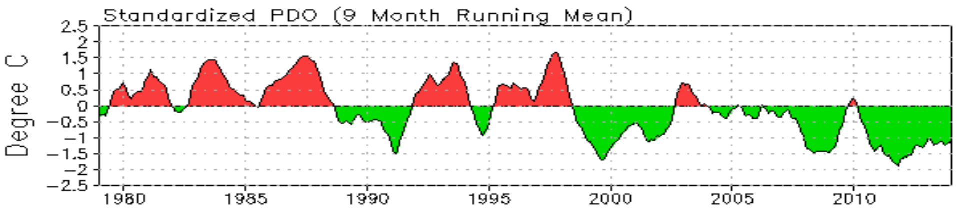
TAO: http://www.pmel.noaa.gov/tao/jsdisplay/
ECMWF S4: http://www.ecmwf.int/products/forecasts/d/charts/oras4/reanalysis/sections/xzmaps/1m!1m!201306!Anomaly!Temperature!/
JMA :http://ds.data.jma.go.jp/tcc/tcc/products/elnino/outlook.html
BOM:http://www.bom.gov.au/climate/enso/

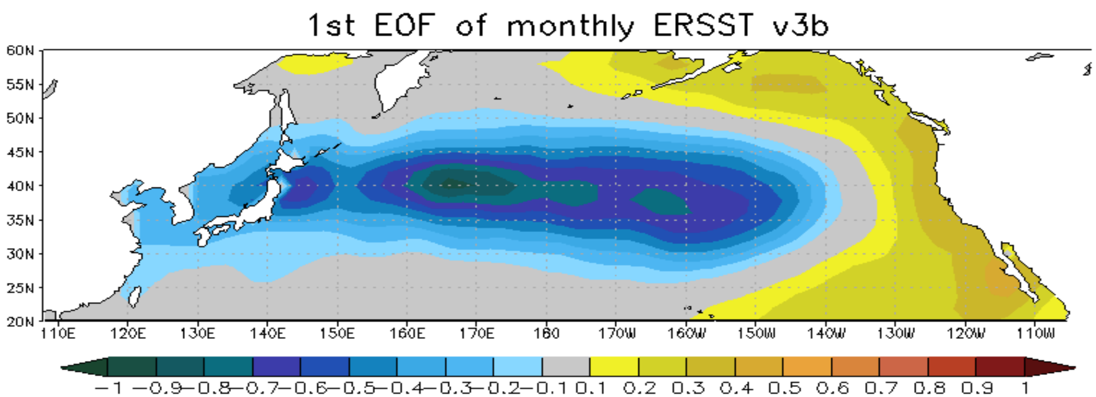
North Pacific & Arctic Oceans

Pacific Decadal Oscillation Index









- **Negative PDO phase since May 2010 has persisted for 43 months now, and the negative PDO index persisted with PDO=-1.2 in Dec 2013.**

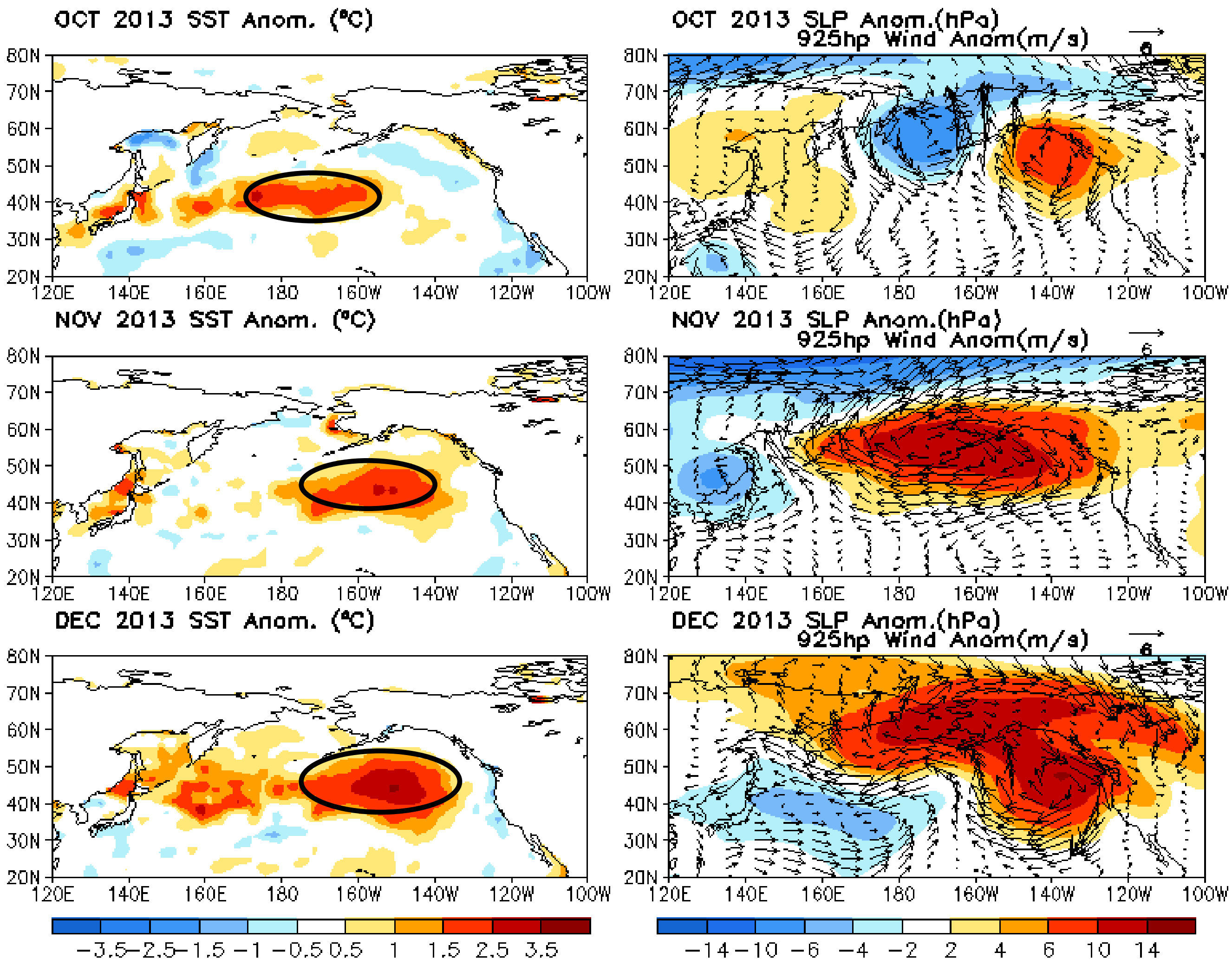
- **-The apparent connection between NINO3.4 and PDO index suggest connections between tropics and extratropics.**

- **However, the negative phase of PDO since Jun 2012 seems not closely connected with the 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.

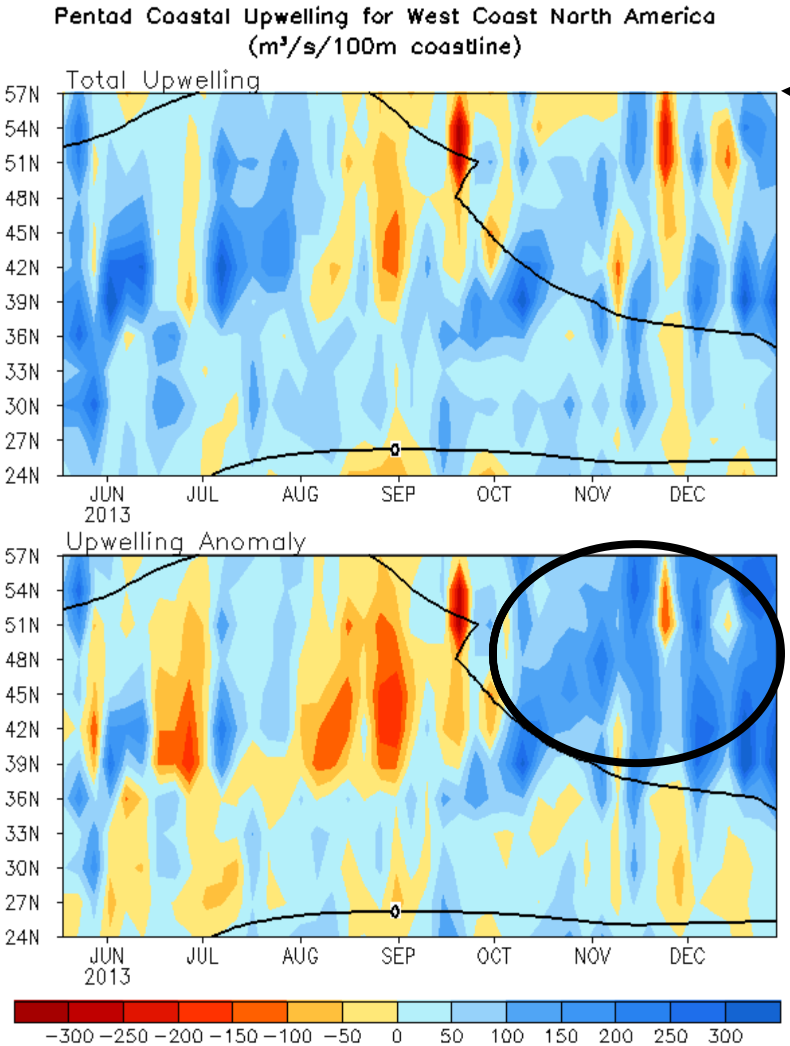
- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

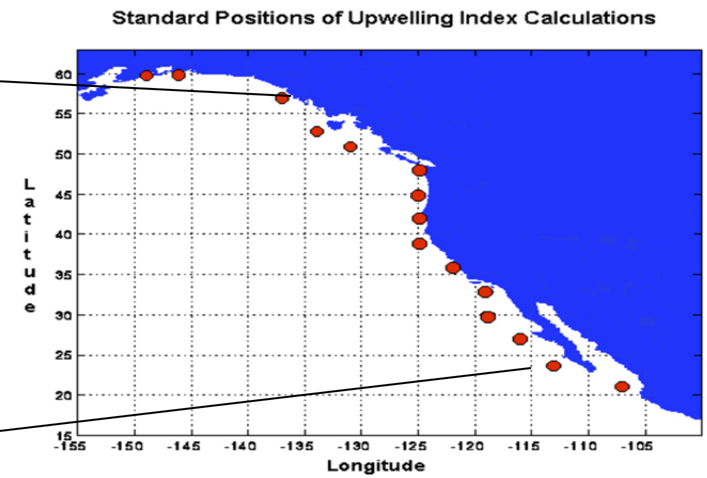
Last Three Month SST, SLP and 925hp Wind Anom.



- **Positive SSTA in the central N. Pacific shifted eastward.**
- **Anomalous anticyclone persisted near the coast of Alaska and Pacific Northwest.**

North America Western Coastal Upwelling





- Downwelling in mid-high latitudes was suppressed in Oct-Dec 2013, consistent with the SLP and surface wind anomalies.

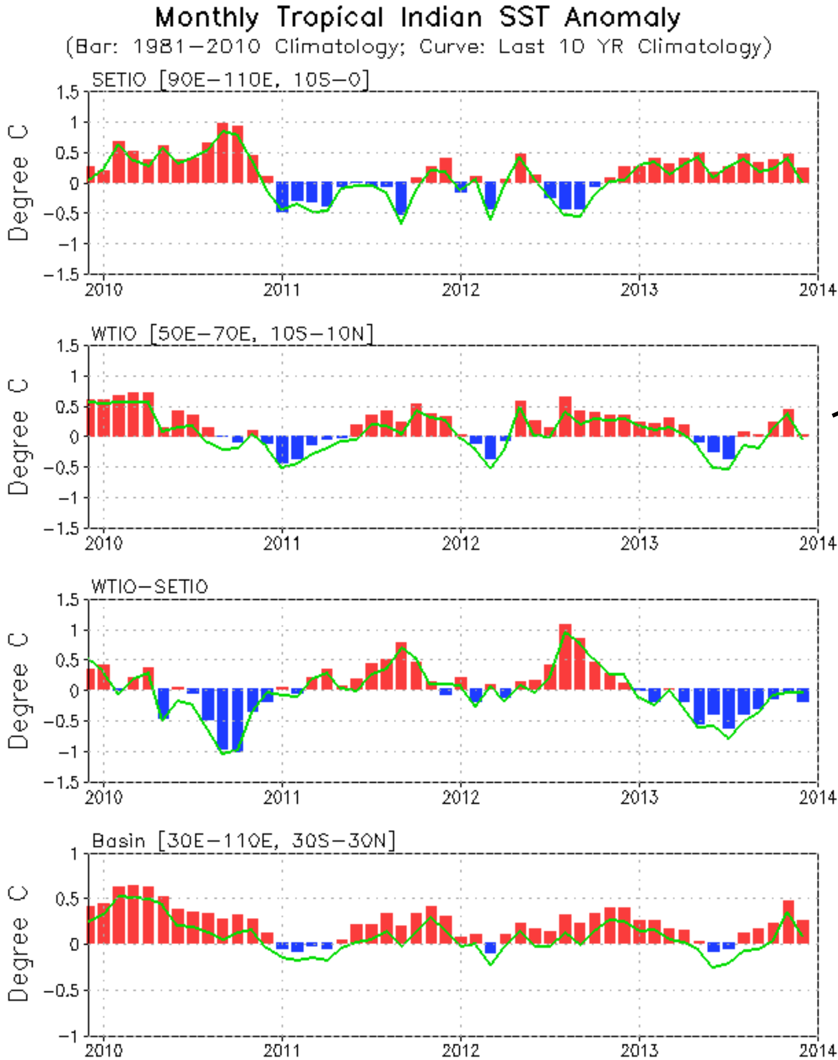
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

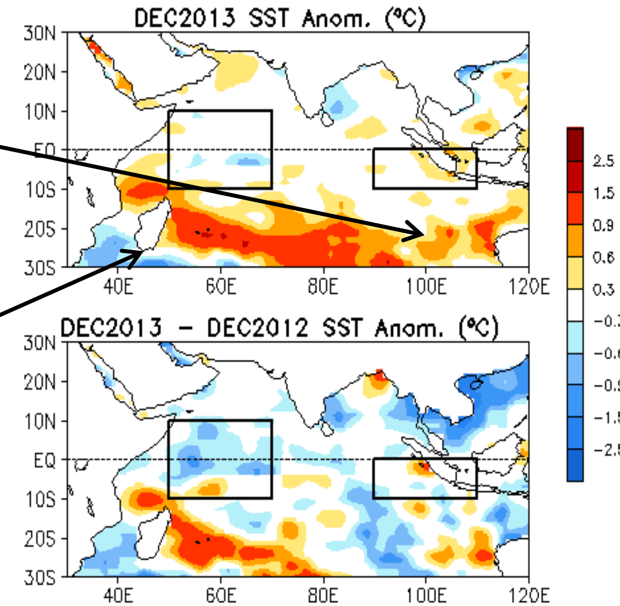
- Area below (above) black line indicates climatological upwelling (downwelling) season.

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

Indian Ocean

Evolution of Indian Ocean SST Indices





- **DMI was near normal in Oct-Dec 2012.**
- **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 (°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 departures from the 1981-2010 base period means and the recent 10 year means are shown in bars and green lines.

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

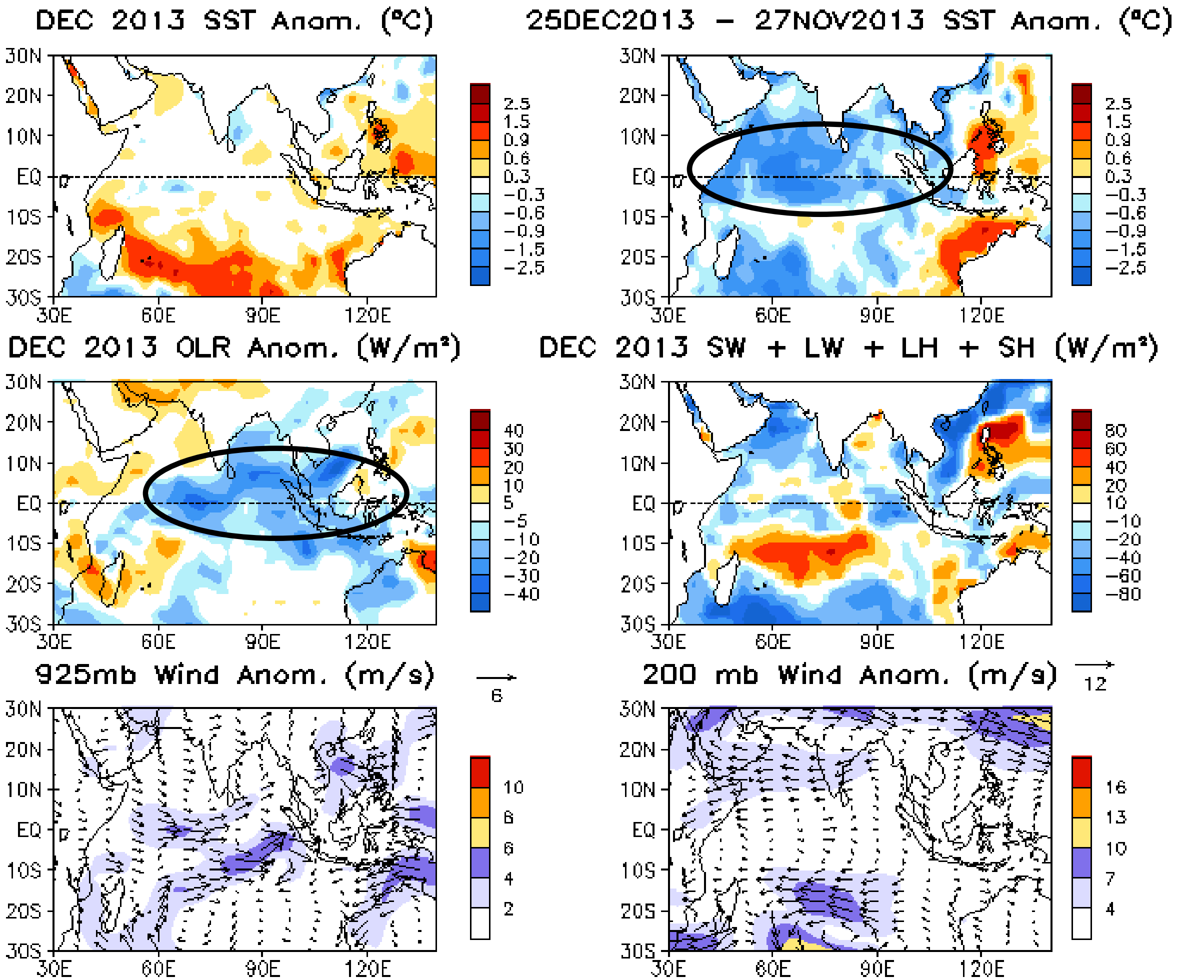
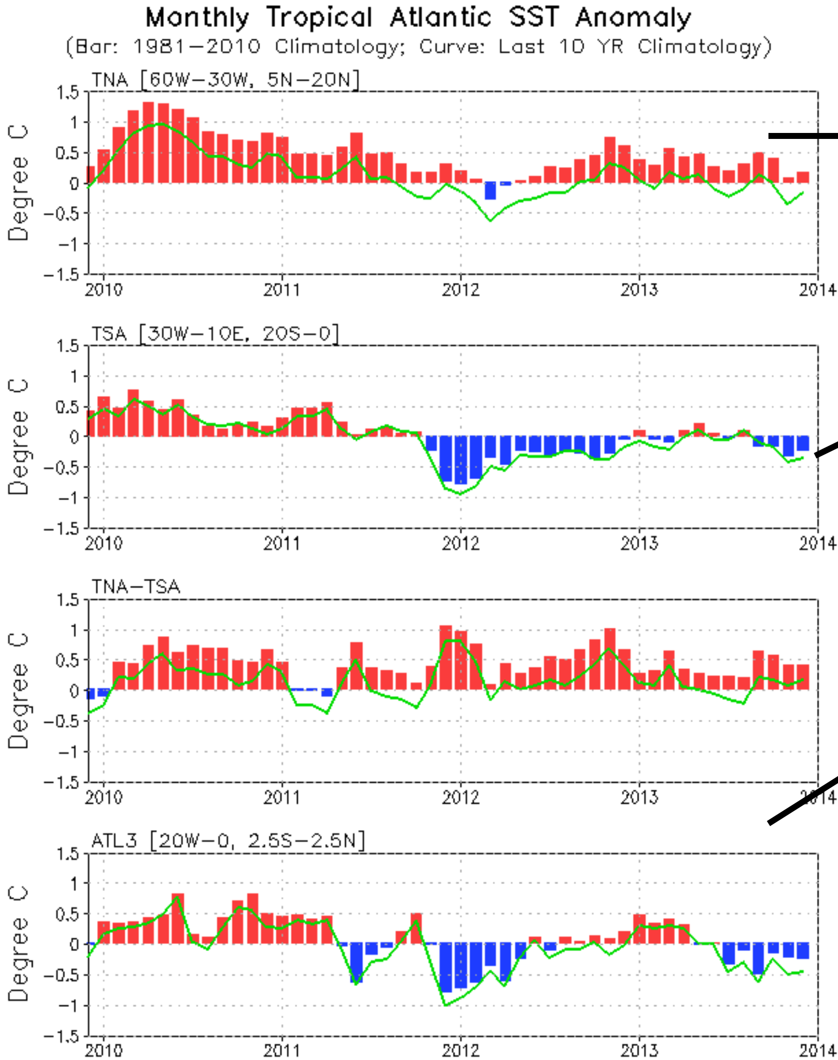
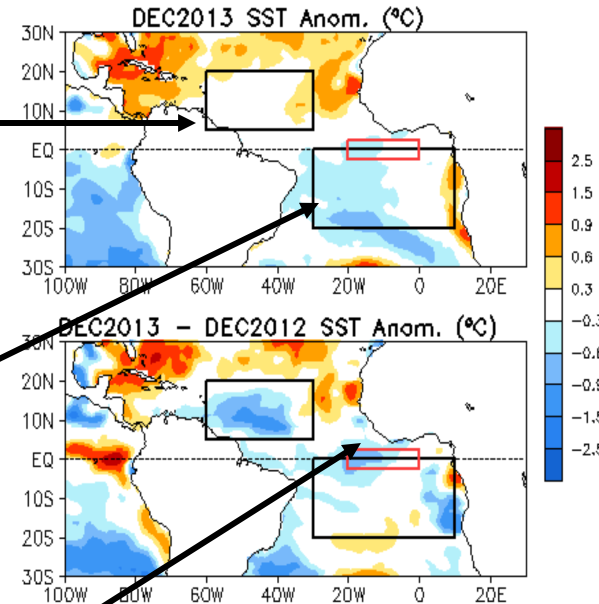


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

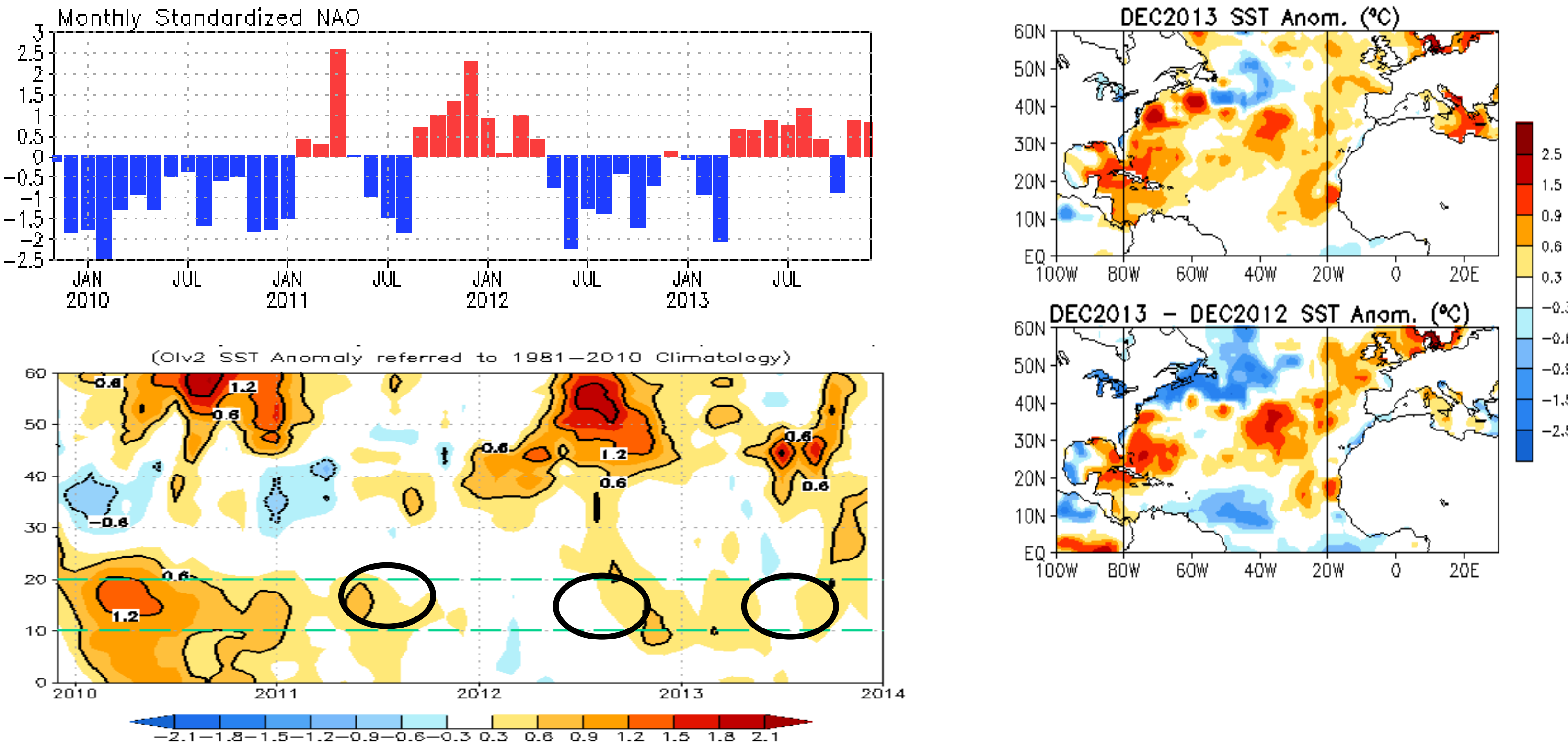




- **SSTA in the tropical North Atlantic (TNA) was near-normal.**
- **Meridional Gradient Mode index (TNA-TSA) was above-normal.**
- **ATL3 SSTA was weakly below-normal.**

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.

NAO and SST Anomaly in North Atlantic



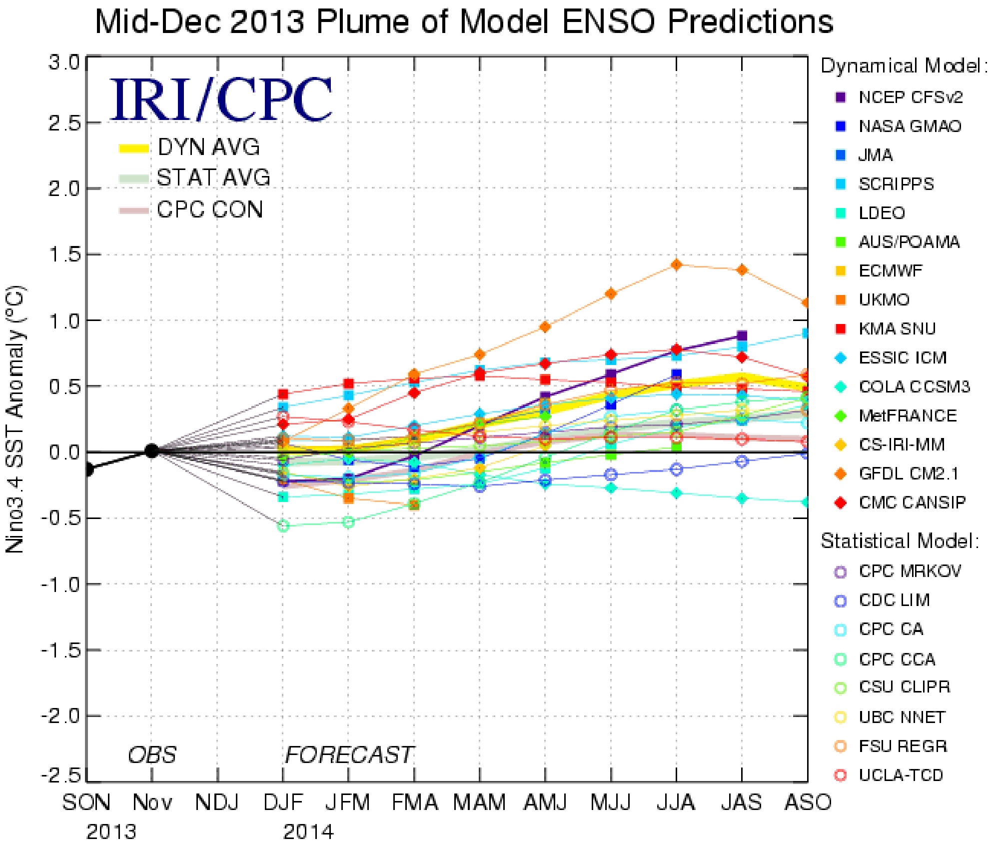
- **High-latitude North Atlantic SSTA is generally closely related to NAO index (negative NAO leads to SST warming and positive NAO leads to SST cooling). Positive NAO index has persisted during Apr-Sep 2013, contributing to persistent positive SSTA in mid-latitude N. Atlantic, and below-normal or near-normal conditions in high-latitude and subtropics.**

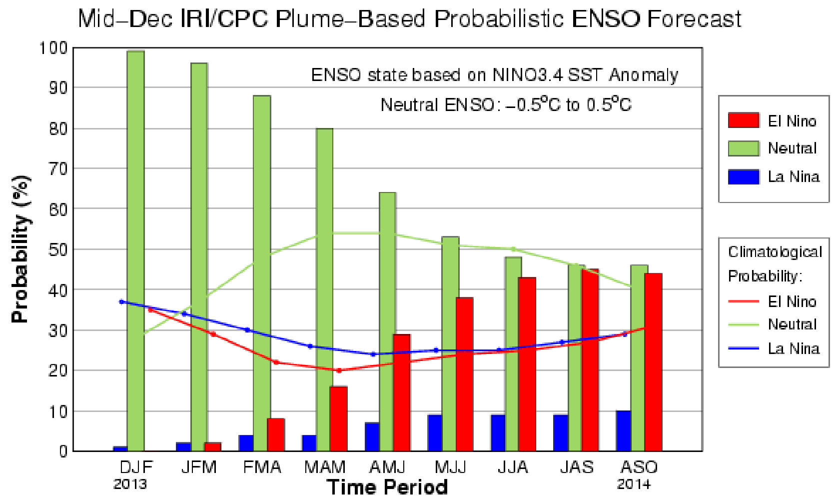
- **Weakly above-normal SST dominated in hurricane main development region (10N-20N) in the past three Atlantic hurricane seasons.**

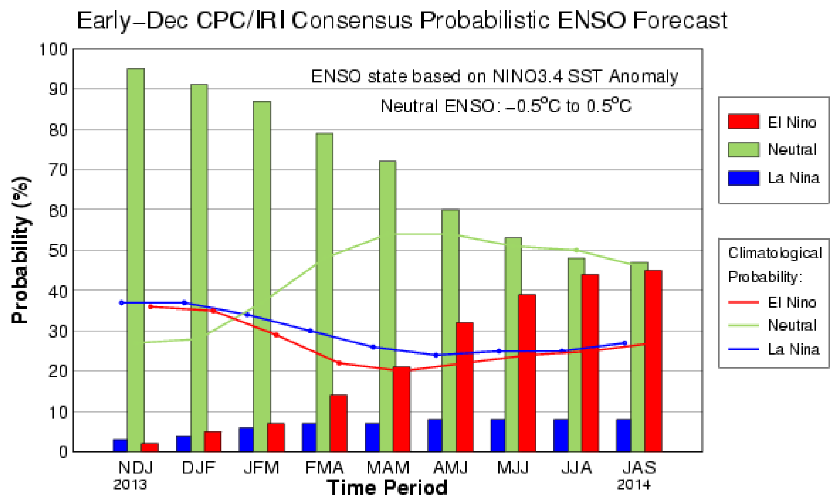
Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (bottom). SST are derived from the NCEP OI SST analysis,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

Global SST Predictions

IRI/CPC NINO3.4 Forecast Plume

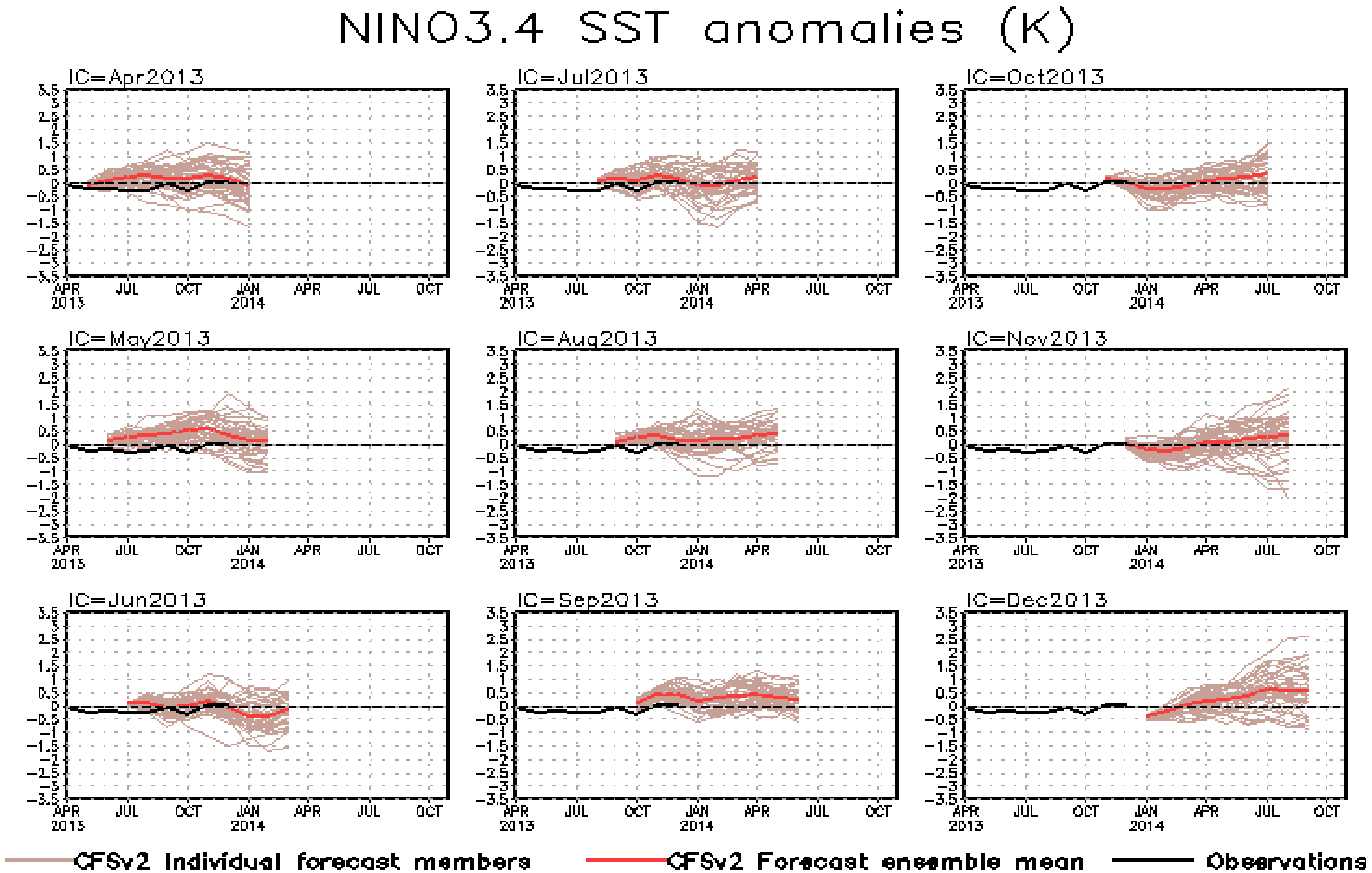






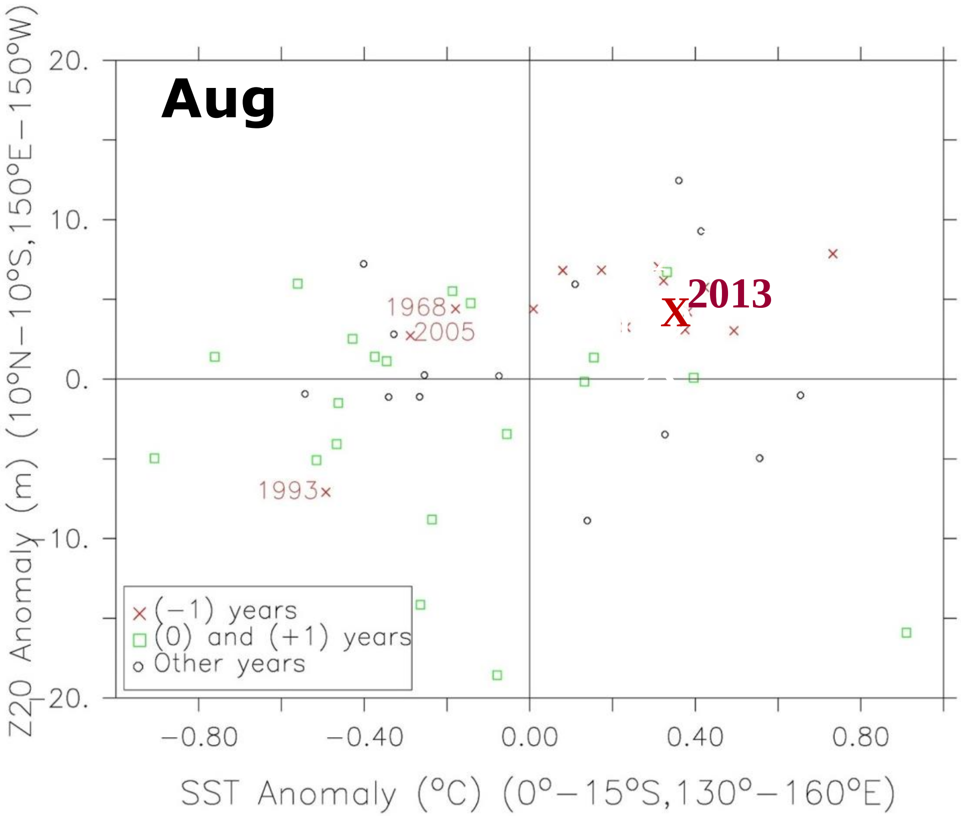
- **Most of the models predicted ENSO-neutral conditions would continue into the Northern Hemisphere summer 2014.**
- **The consensus forecast favors ENSO-neutral conditions in the next spring and summer 2014.**

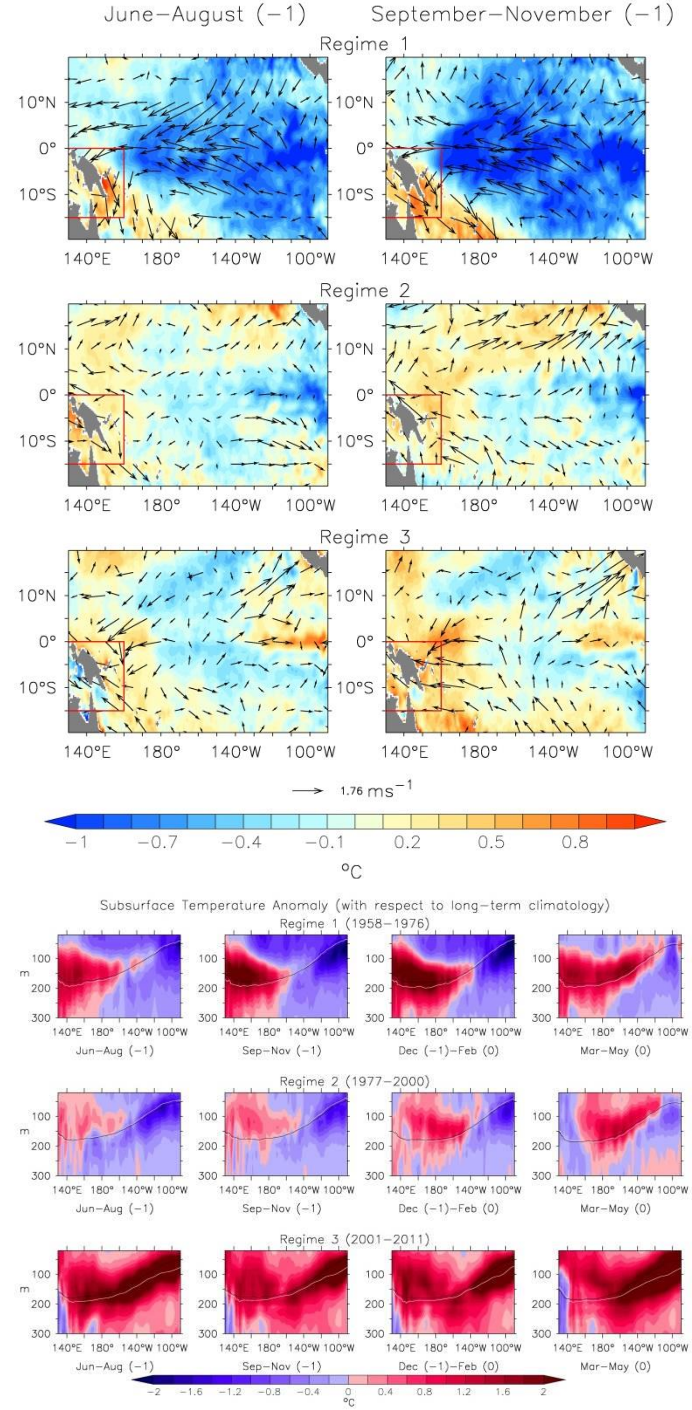
NCEP CFSv2 NINO3.4 Forecast



- **Latest CFSv2 prediction suggests weak El Nino conditions will emerge in summer 2014.**

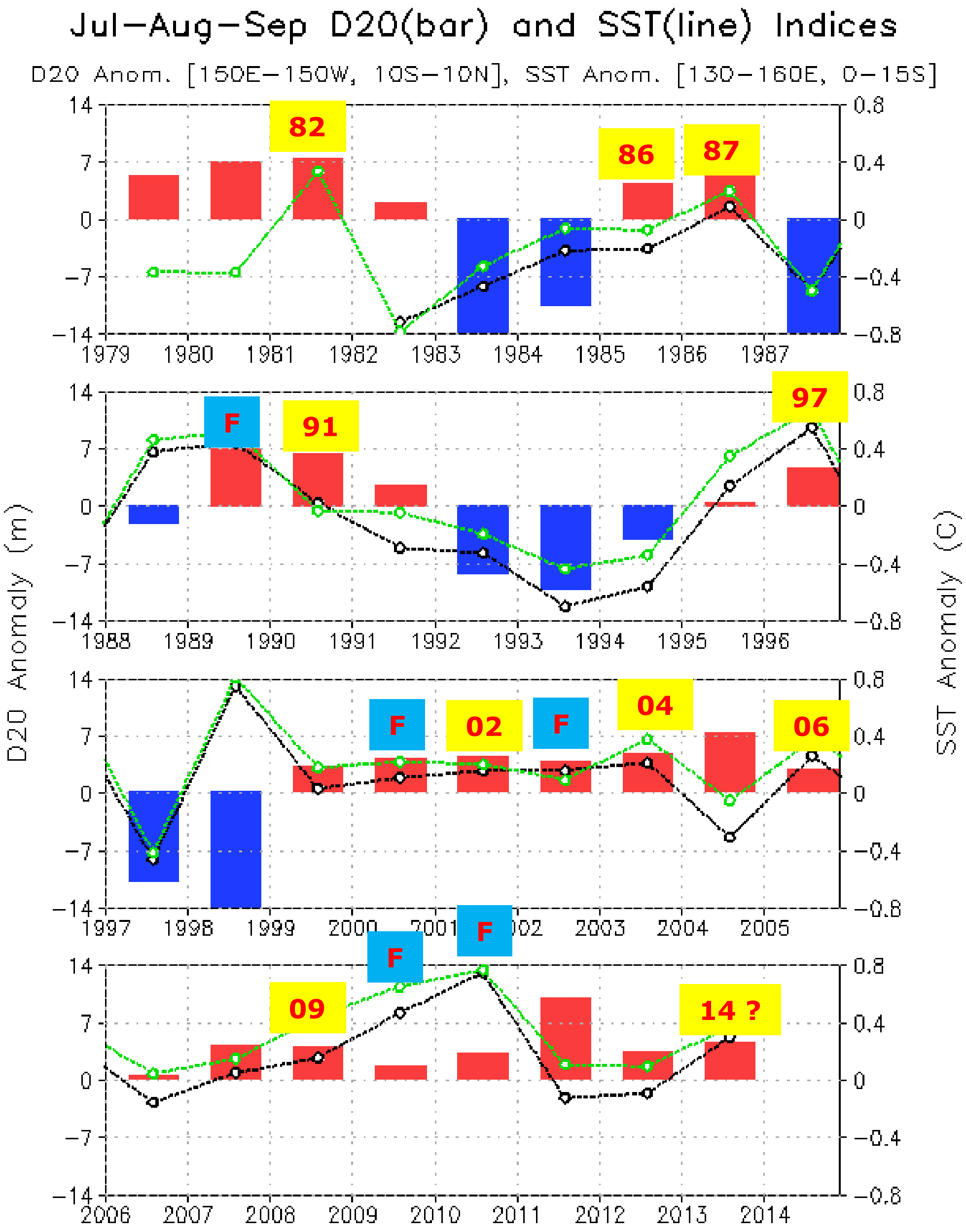
Ramesh-Murtugudde Indices
for Long-Lead El Nino Forecast





The top-right quadrant is an indicator of potential El Nino conditions in the following year

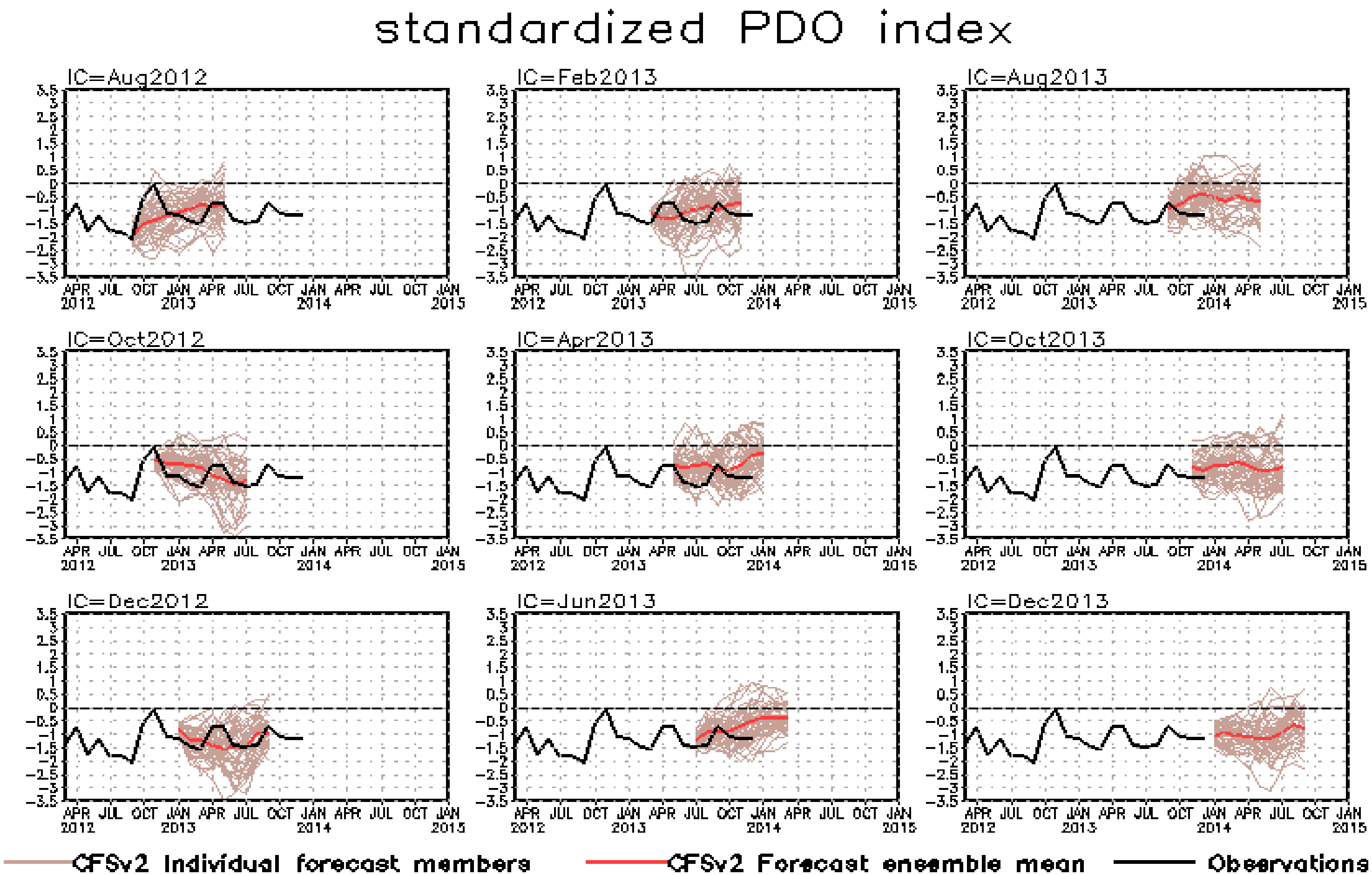
Ramesh and Murtugudde, *Nature Climate Change, 2012*



OISST (black line), ERSST (green line)

- Both D20 and SST indices were above-normal during Jul-Aug-Sep one year before El Nino years (82/83, 87/88, 97/98, 02/03, 04/05, 06/07, 09/10).
- However, the SST (D20) indices were near-normal (above-normal) during Jul-Aug-Sep one year before the 86/87 and 91/92 El Ninos (which might be due to uncertainties in SST).
- There are some false alarm years that can be partially explained. 2002 is a weak El Nino year, which is unlikely followed by a second El Nino year. 1989 and 2000 are both La Nina decay years. 2009 and 2010 are El Nino years.
- Indices in 2011 and 2012 do not indicate El Nino conditions in 2012 and 2013, verified.
- In JAS 2013, both D20 and SST indices were above-normal, indicating possible El Nino conditions in winter 2014.

NCEP CFSv2 Pacific Decadal Oscillation (PDO) Forecast

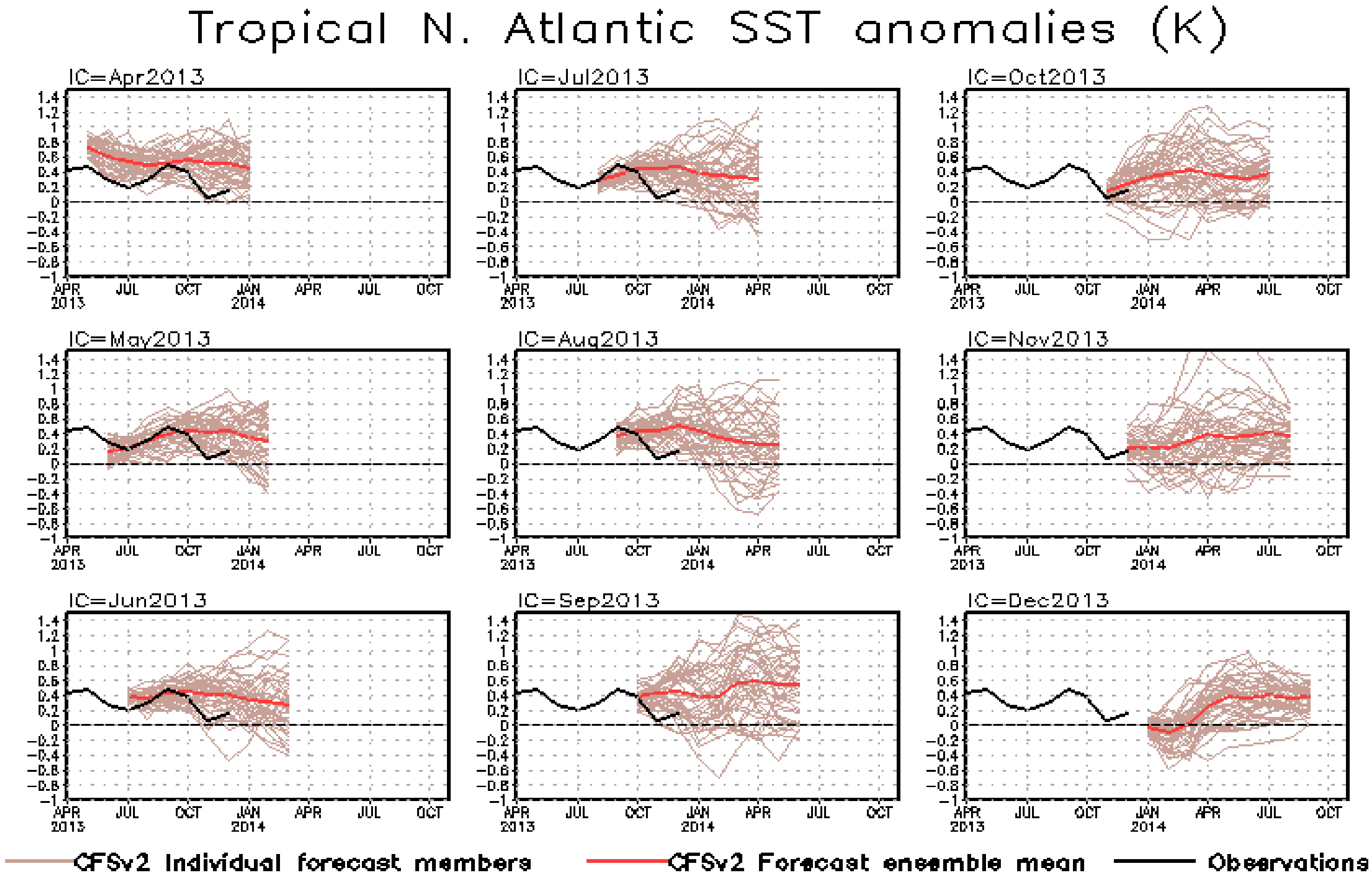


PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N].

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

- Latest CFSv2 prediction suggests negative PDO phase will continue through the next spring and summer.

NCEP CFSv2 Tropical North Atlantic SST Forecast



- Latest CFSv2 prediction suggests tropical North Atlantic SST would be weakly above-normal in late spring and summer 2014.

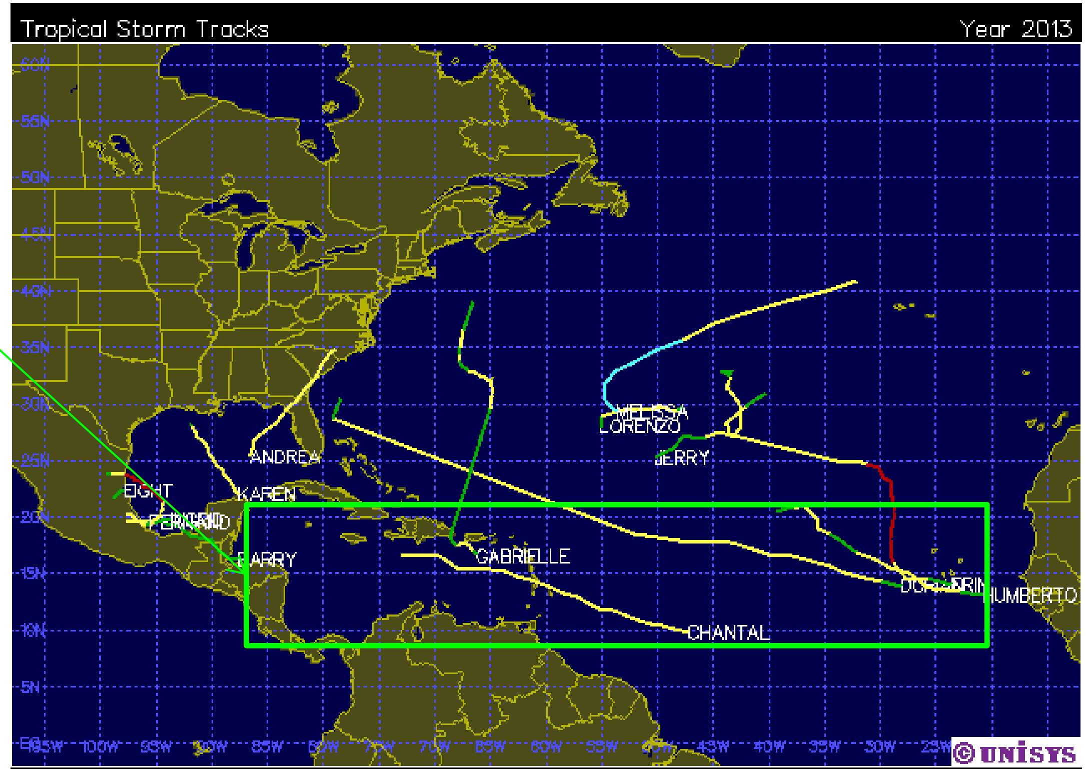
Special Session

<u>Analysis of 2013 North Atlantic Hurricane Season</u>

Gerry Bell

2013 Atlantic Named Storms and Tracks

Main Development Region (MDR):

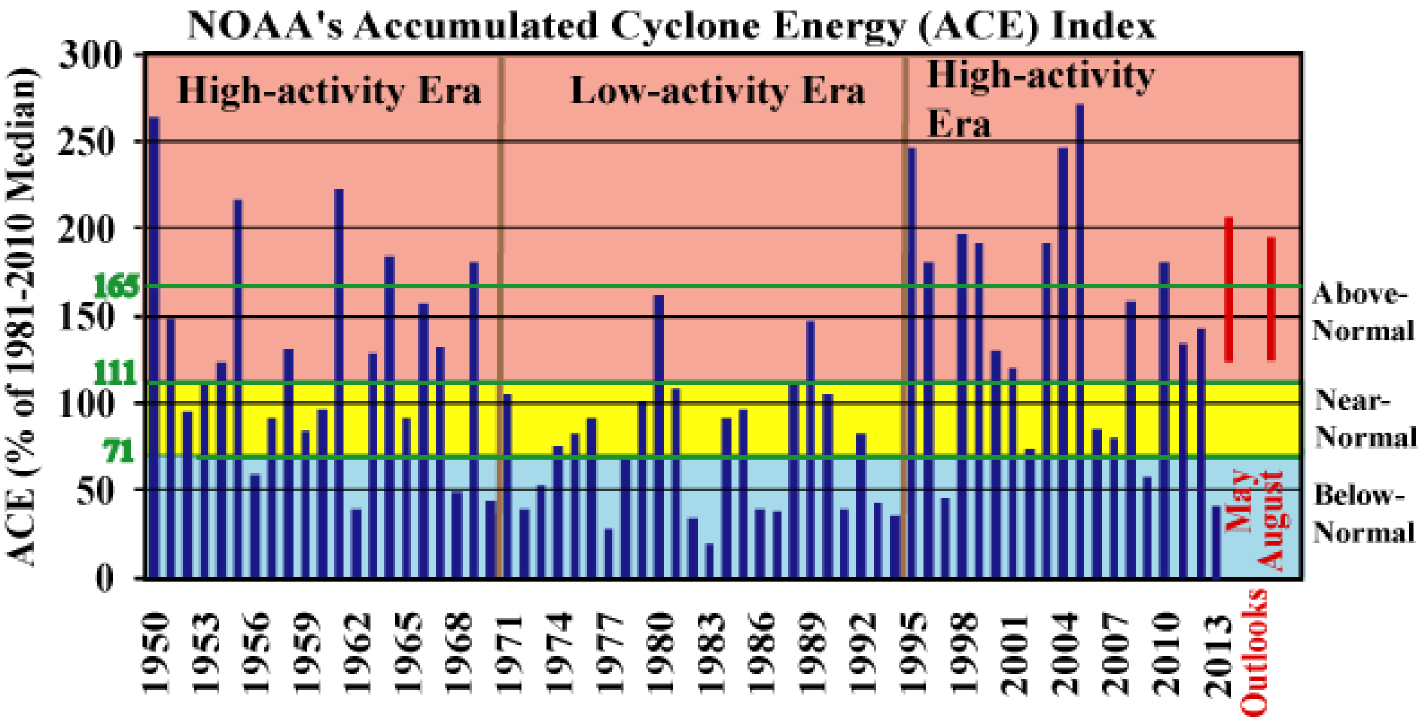


Key:
- Tropical Depression
- Sub-tropical Storm
- Tropical Storm
- Hurricane
- Major Hurricane

<u>2013 Activity: Below normal Season</u>

13 Named Storms (average is 12)
2 Hurricanes (average is 6)
0 Major Hurricanes (average is 2)
Accumulated Cyclone Energy (ACE): 36% of median

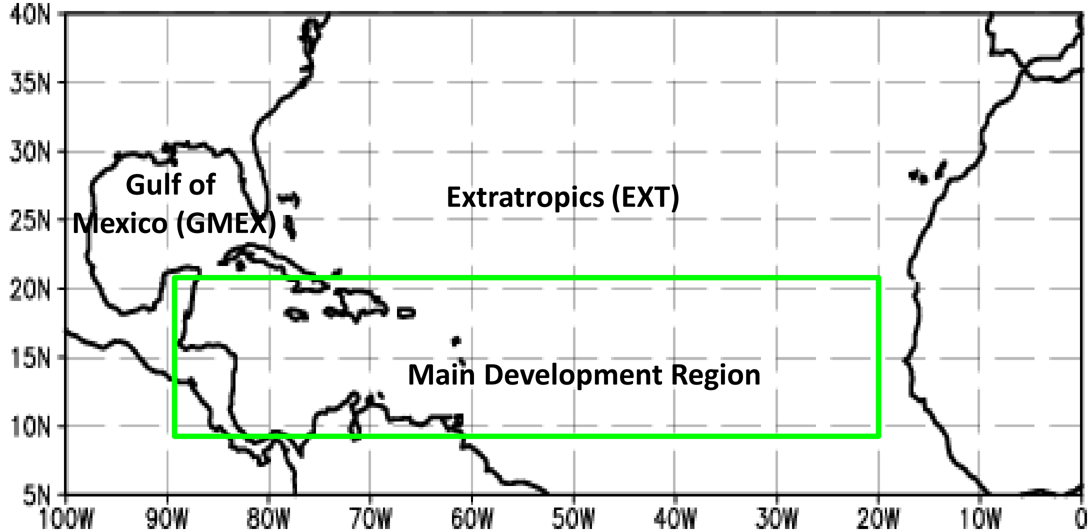
Seasonal ACE values 1950-Present

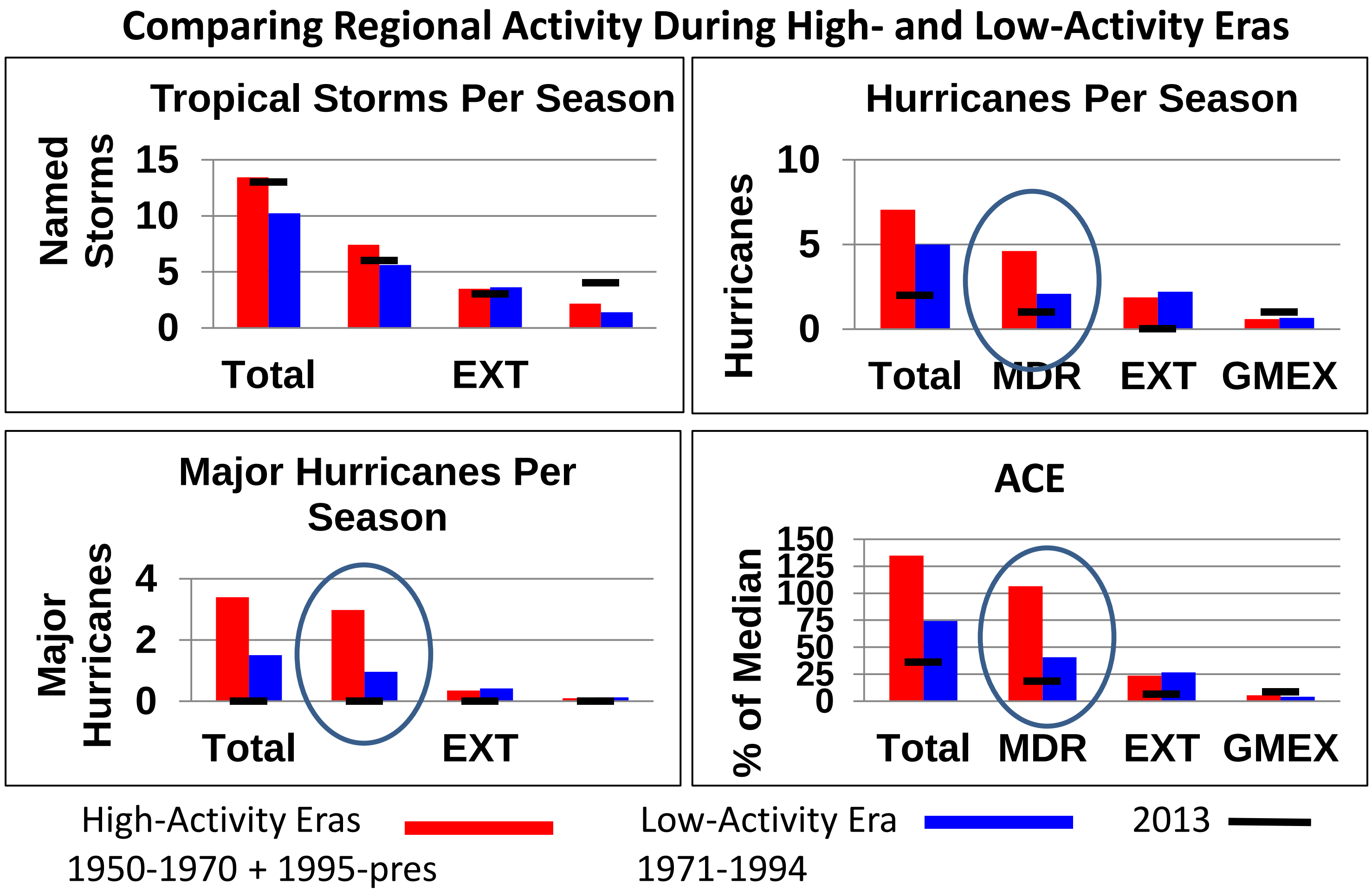


- 2013 is only the 3rd below-normal season since the current high-activity era began in 1995. Since then, 12 of 19 seasons have been above normal.
- 2013 is the only below-normal season (since 1995) to occur in the absence of El Niño. This is one reason why NOAA had predicted only a 5% chance for a below-normal season.

Caption: NOAA's Accumulated Cyclone Energy (ACE) index expressed as percent of the 1981-2010 median value. ACE is calculated by summing the squares of the 6-hourly maximum sustained wind speed (knots) for all periods while the storm is at least tropical storm strength. Red bars show NOAA's predicted ACE ranges from their May and August seasonal hurricane outlooks. Pink, yellow, and blue shadings correspond to NOAA's classifications for above-, near-, and below-normal seasons, respectively. The 165% threshold for a hyperactive season is indicated. Vertical brown lines separate high- and low-activity eras.

Regions examined in next two slides



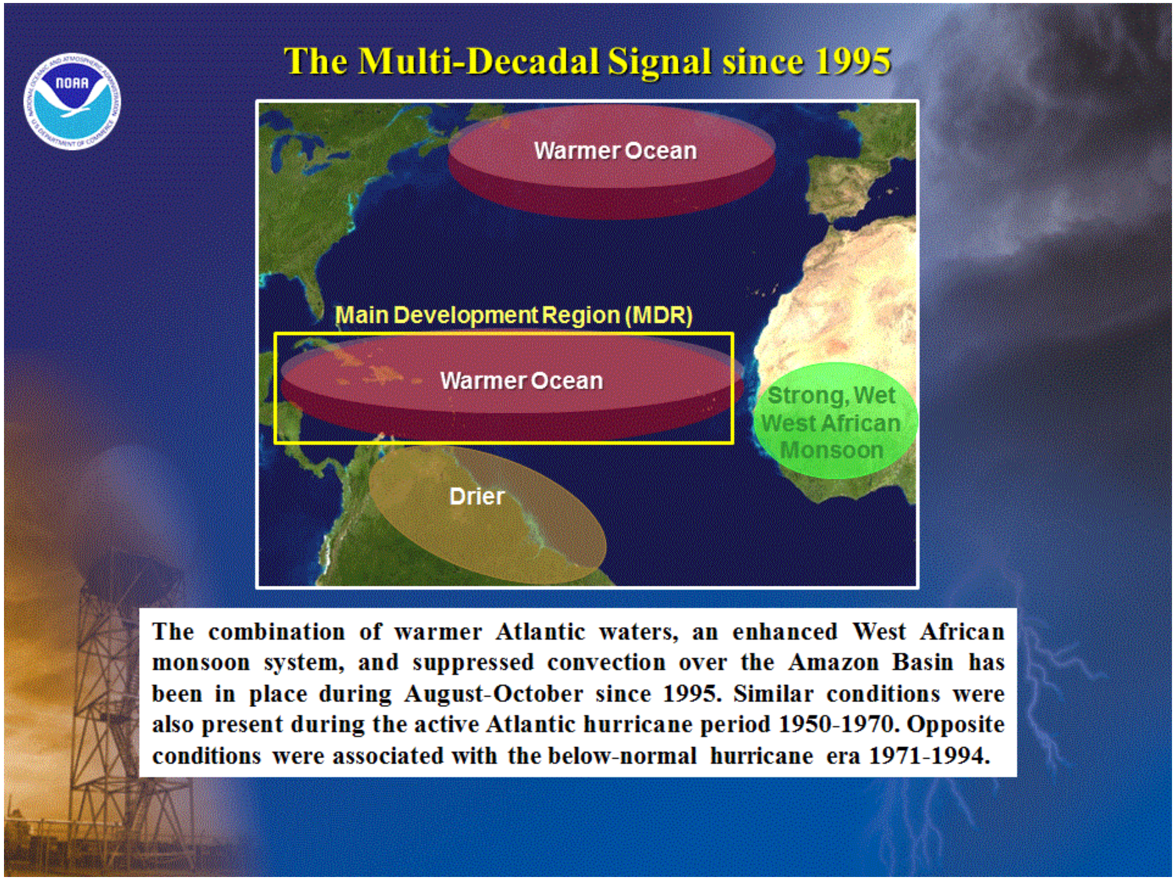


High-activity eras feature

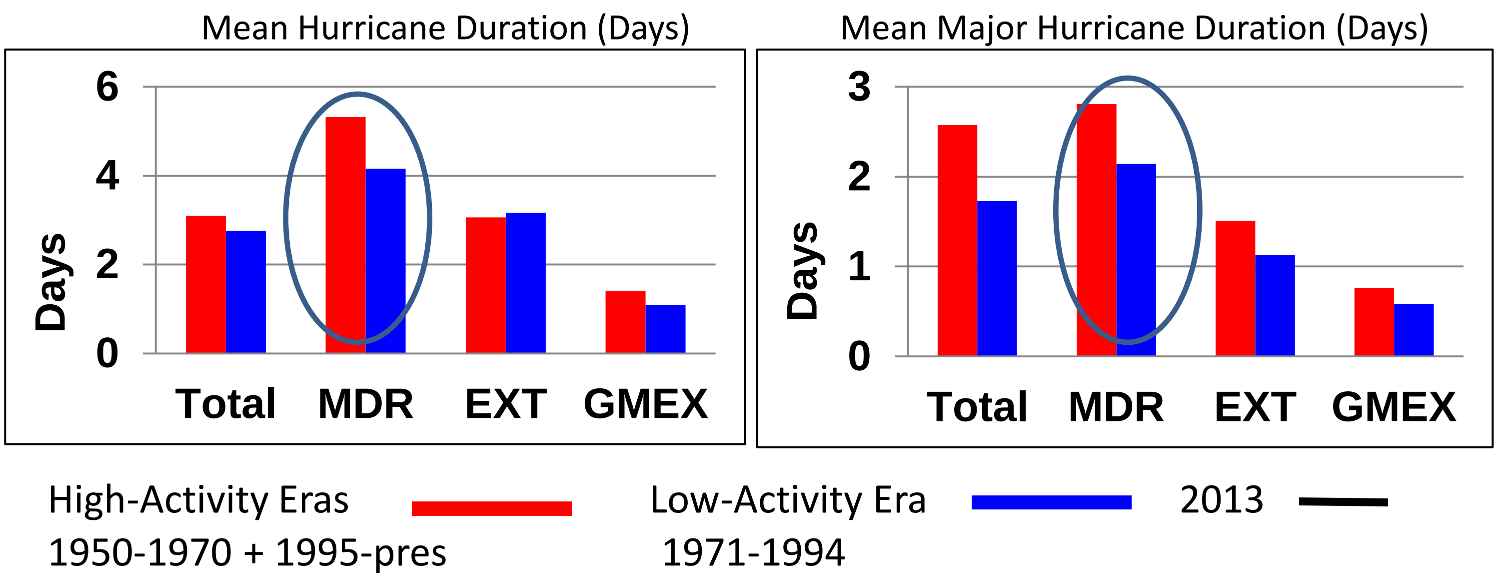
1. Many more hurricanes and major hurricanes that originate as named storms in the MDR, and a much higher percentage (about twice as many) of those storms becoming hurricanes and major hurricanes.
2. A much higher ACE value (nearly triple) produced by MDR-originating storms

This difference in MDR activity accounts for 95% of the difference in ACE between the two eras, and for nearly the entire difference in the numbers of hurricanes and major hurricanes.

Climate Pattern Linked to High-activity eras for Atlantic Hurricanes

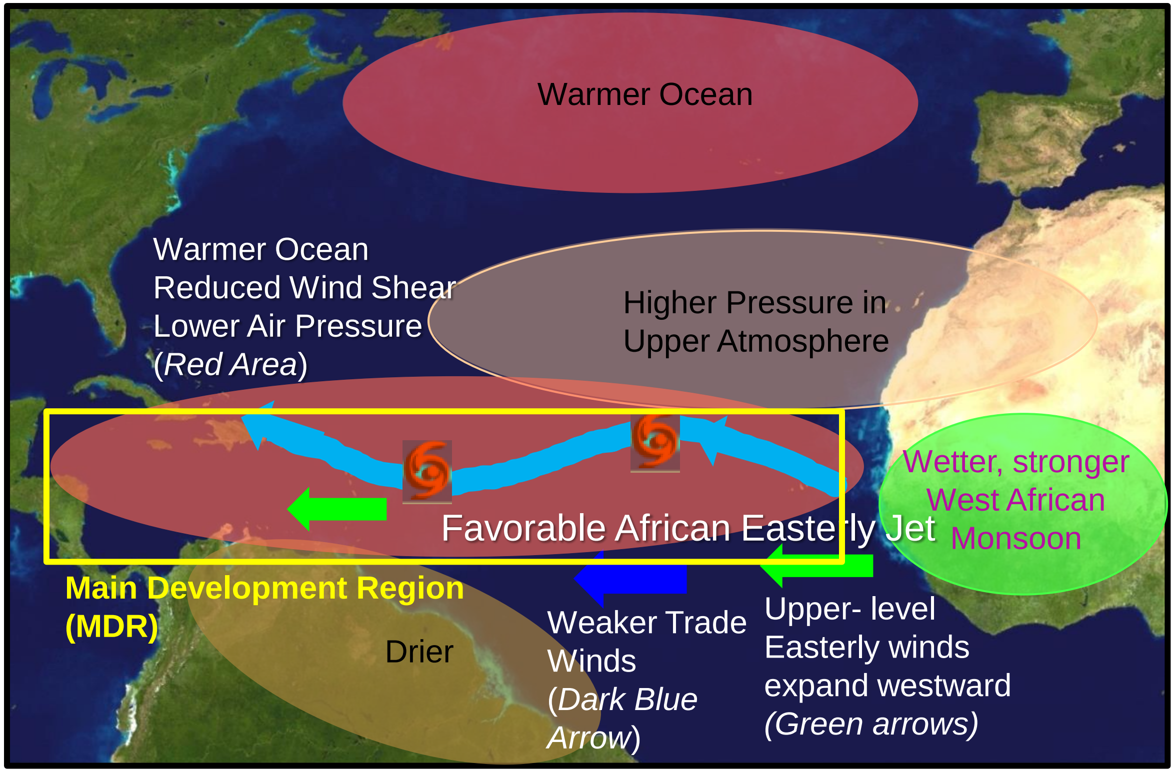


Comparing Regional Activity During High- and Low-Activity Eras



High activity eras also feature a longer duration to the hurricanes and major hurricanes that originate as named storms in the MDR.

Regional Conditions Associated with High-activity era for Atlantic Hurricanes

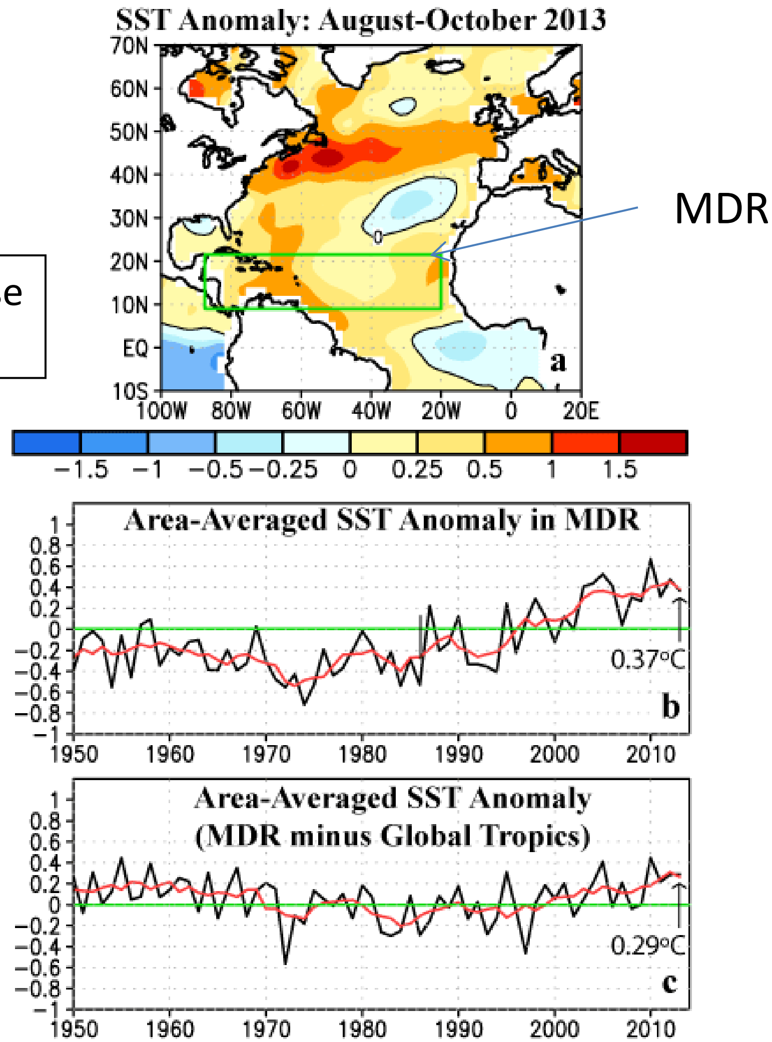


The activity associated storms first named in the MDR represents the primary difference between high- and low-activity eras (and seasons).

The above conditions produce significantly increased Atlantic hurricane activity in the MDR, resulting in high-activity era for Atlantic hurricanes. Bell and Chelliah (2006, J. Clim).

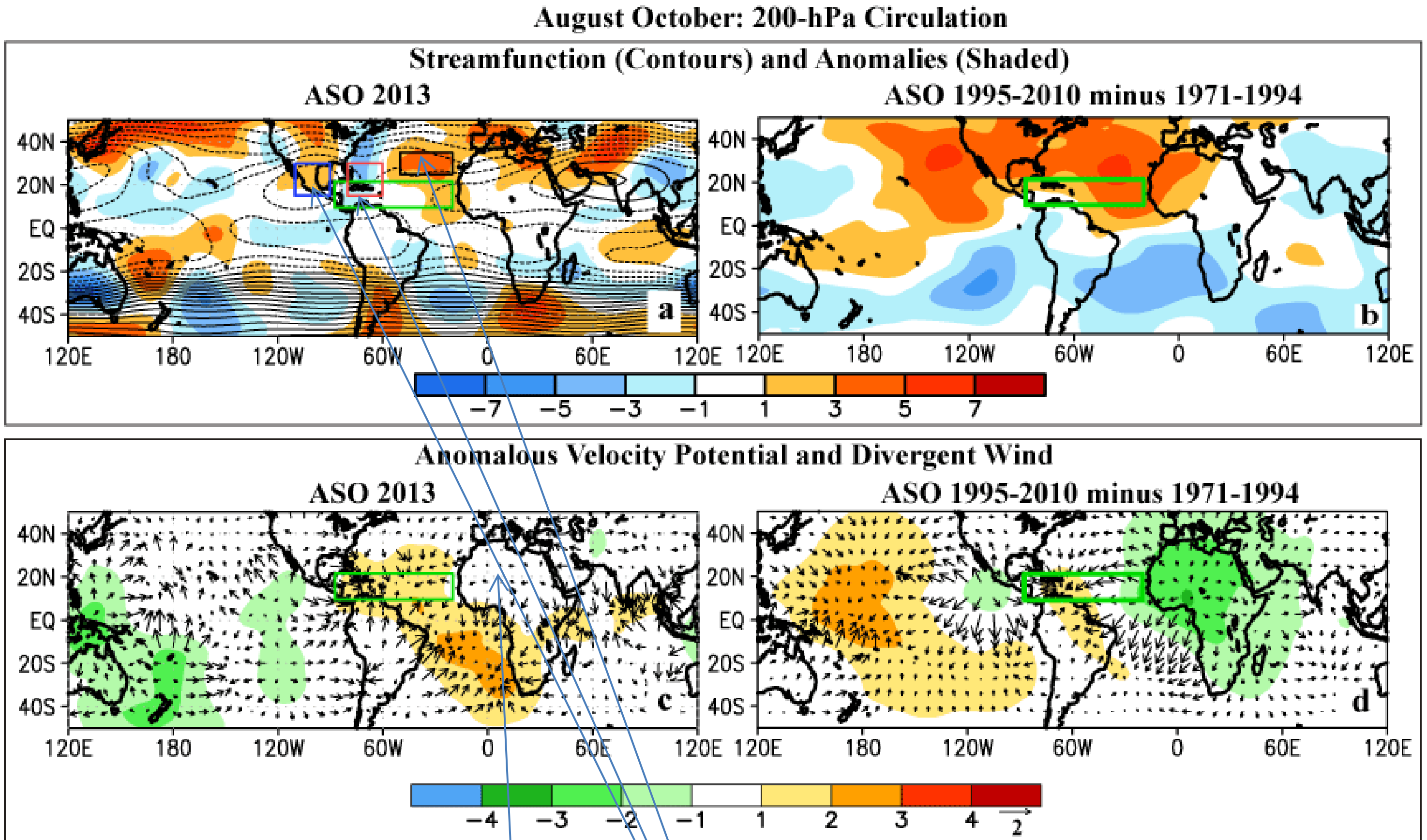
Opposite conditions result in significantly reduced activity in the MDR, resulting in low-activity era for Atlantic hurricanes.

No indication that warm phase of the AMO has ended.



(a) ASO 2013 sea surface temperature (SST) anomalies (°C). (b) Time series during 1950-2013 of ASO area-averaged SST anomalies in the MDR [green box in (a)]. (c) Time series showing the difference between ASO area-averaged SST anomalies in the MDR and those for the entire global tropics (30ºN-30ºS). Anomalies are departures from the ERSST-v3b (Smith et al. 2008) 1981-2010 period monthly means.

August-October 200-hPa Circulation

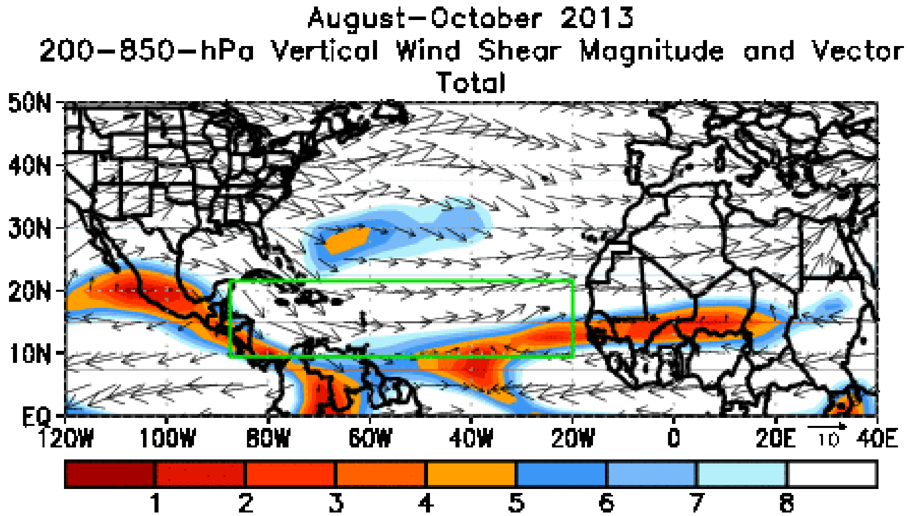


The west African monsoon circulation was not enhanced during ASO 2013.

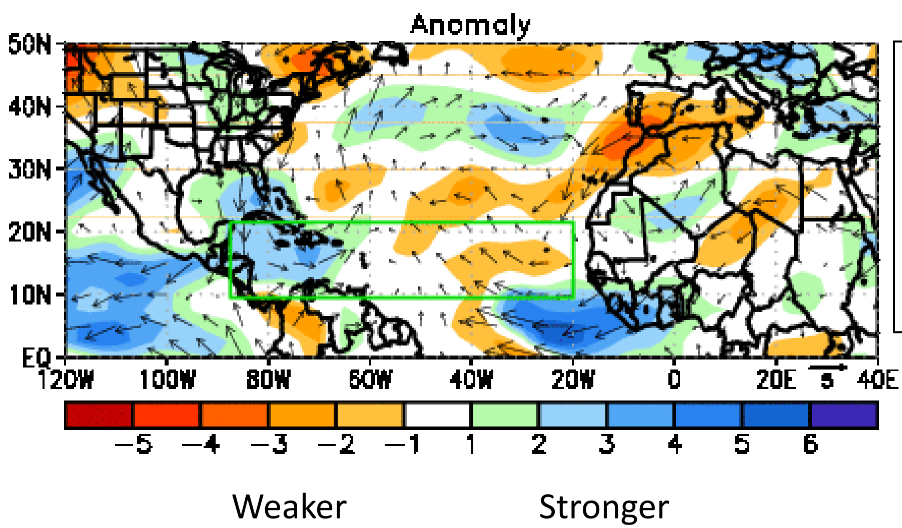
Inter-hemispheric symmetry of streamfunction anomalies across subtropical Atlantic was not well defined.

Strong 3-celled anomaly pattern extending from North America to Europe

August-October 2013 VERTICAL WIND SHEAR

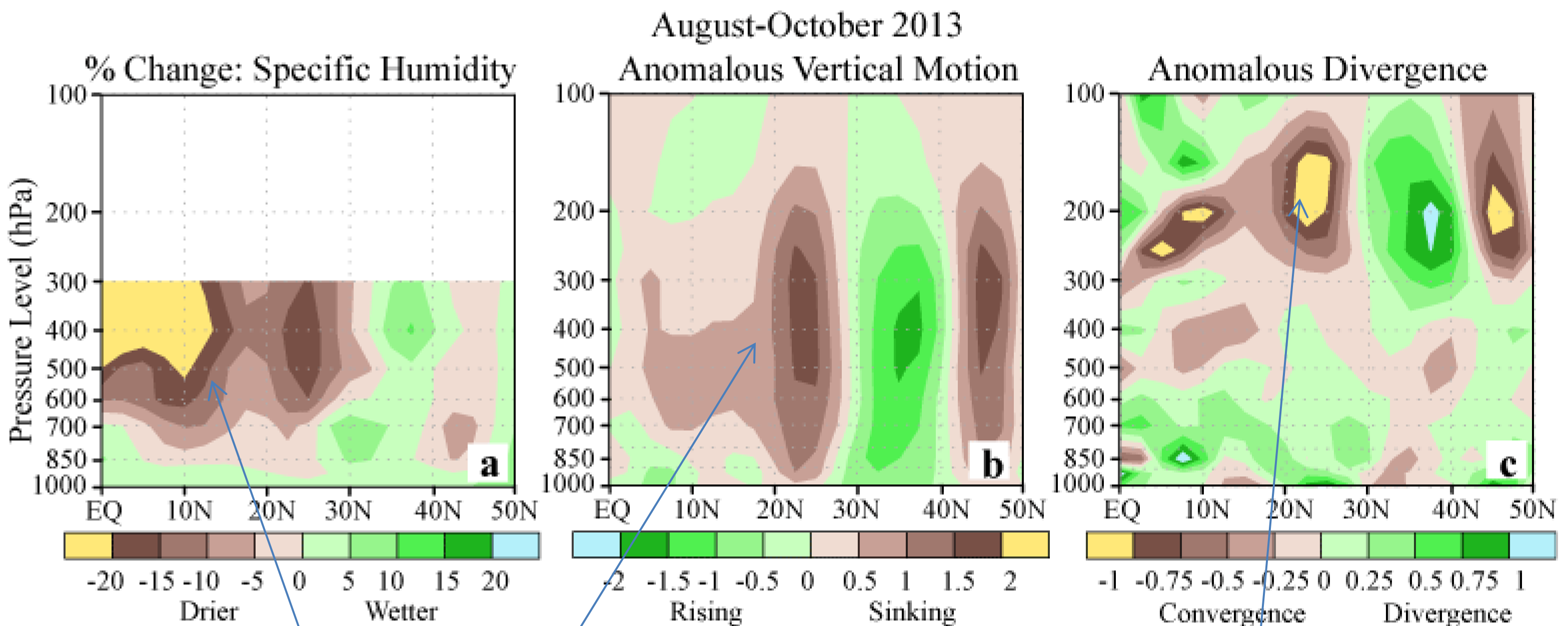


Much of MDR has strong shear (no shading), with weak shear (< 8 m/s) confined to the extreme southern MDR (shading).



Much of MDR had above-average (Blue) or average vertical wind shear. For the MDR as a whole, even average wind shear is too strong to support an active hurricane season.

August-October 2013 Anomalies Averaged 60W-40W

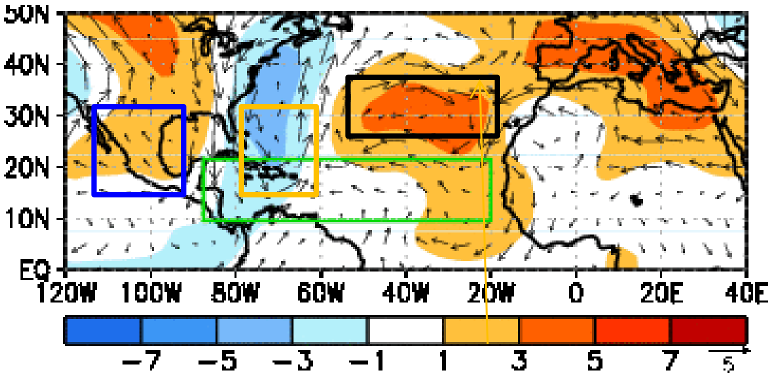


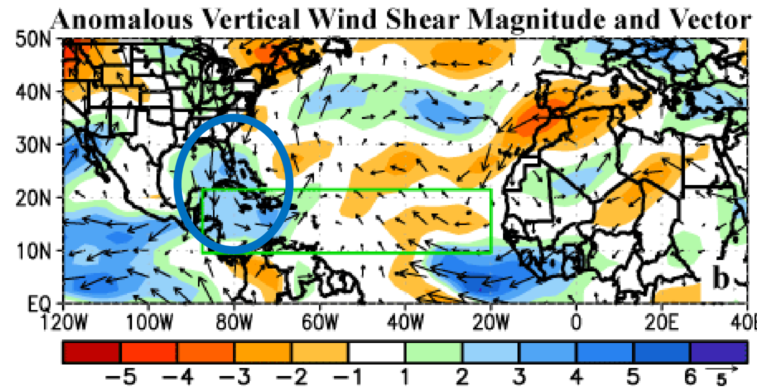
Anomalously dry, sinking air, related to anomalous upper-level convergence and anomalous lower-level divergence, dominated the central MDR and central subtropical North Atlantic in 2013.

Caption: August-October 2013 height-latitude section averaged between 60°W-40°W of (a) percent difference in specific humidity from climatology, (b) anomalous vertical velocity (x 10^{-2} Pa s^{-1}), and (c) anomalous divergence (x 10^{6} s^{-1}). Brown shadings indicates decreased moisture, anomalous sinking motion, and anomalous convergence, respectively. Climatology and anomalies are with respect to the 1981-2010 period monthly means.

Aug-Oct 2013: Links to Persistent Circulation Pattern

Anomalous 200-hPa streamfunction and wind vector

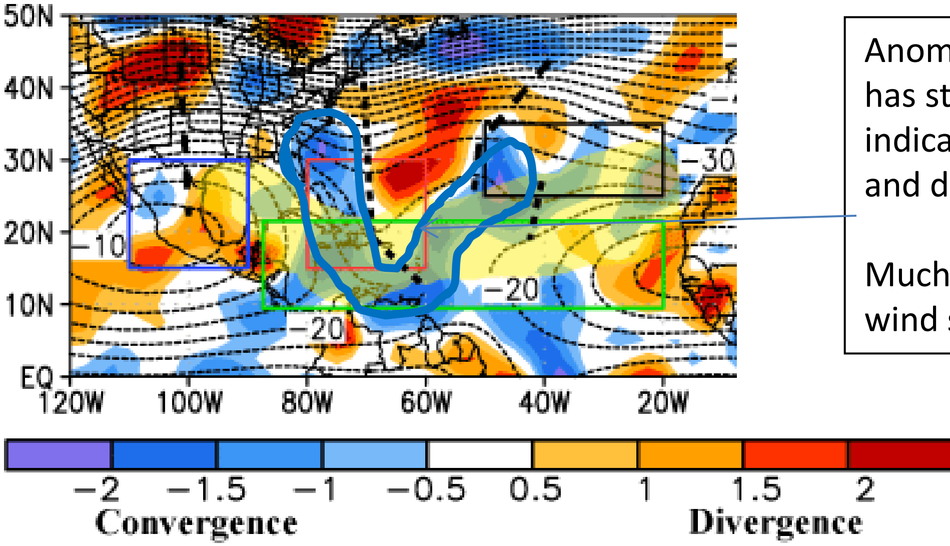




Weaker Stronger

Anomalously strong vertical wind shear in western MDR is linked directly to 3-celled streamfunction anomaly pattern.

200-hPa Total streamfunction and standardized divergence anomaly (shaded). Light yellow shading indicates areas with strong vertical wind shear > 8 m/s

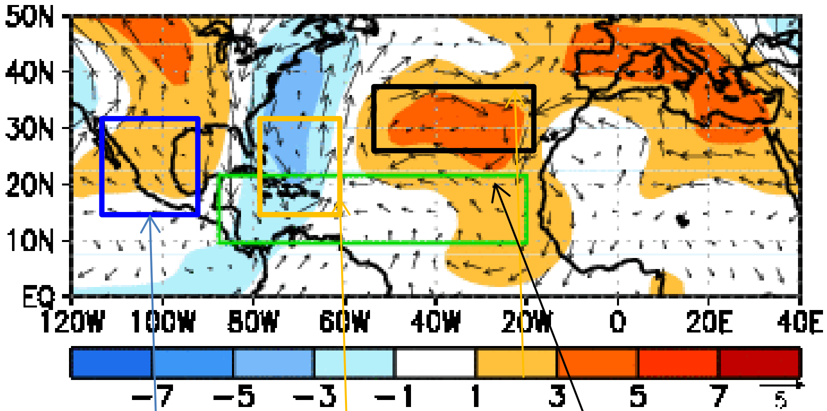


Anomalous upper-level convergence (blue) in MDR also has strong links to the persistent 3-celled wave pattern, as indicated by convergence upstream of mean trough axis and downstream of mean ridge axis.

Much of central and western MDR had strong vertical wind shear and anomalous upper-level convergence.

Strength of the 3-Celled Circulation Anomaly Pattern

Aug-Oct 2013: Anomalous 200-hPa streamfunction and wind vector

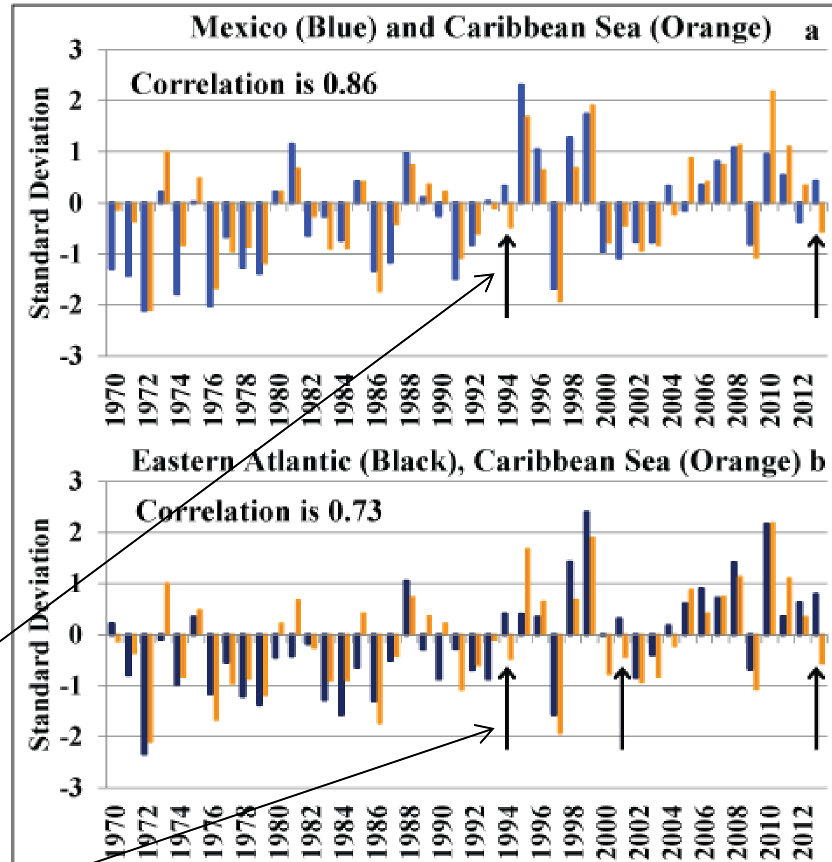


Mexico Averaging Region

Caribbean Sea Averaging Region

Eastern Atlantic Averaging Region

Standardized Streamfunction Indices

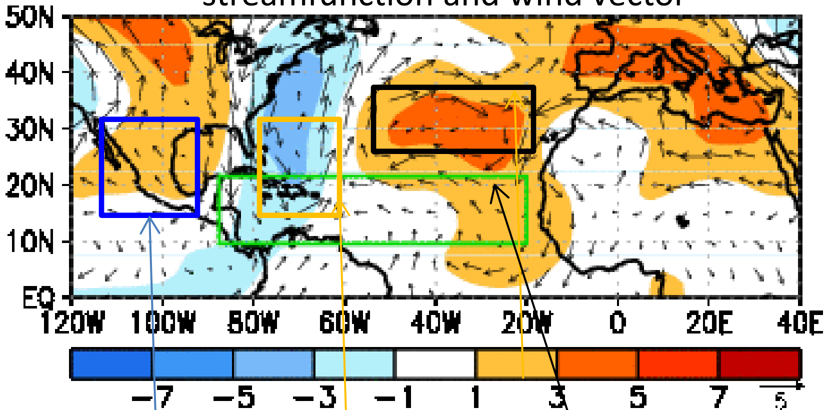


Only two years with Mexico index > 0.25σ and Caribbean Sea index < -0.25σ (1994 and 2013).

Only three years with Eastern Atlantic index > 0.25σ and Caribbean Sea index < -0.25σ (1994, 2001 and 2013).

Strength of the 3-Celled Circulation Anomaly Pattern

Aug-Oct 2013: Anomalous 200-hPa streamfunction and wind vector

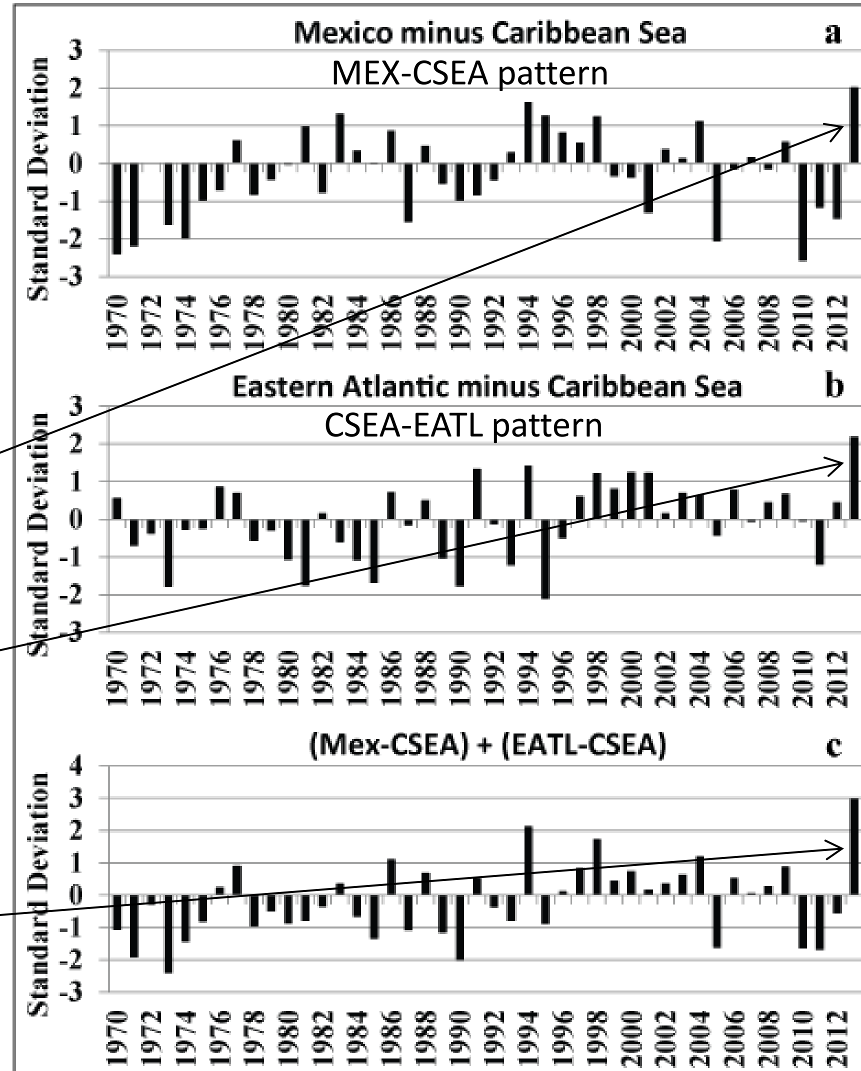


Mexico Region

Caribbean Sea Region

Eastern Atlantic Region

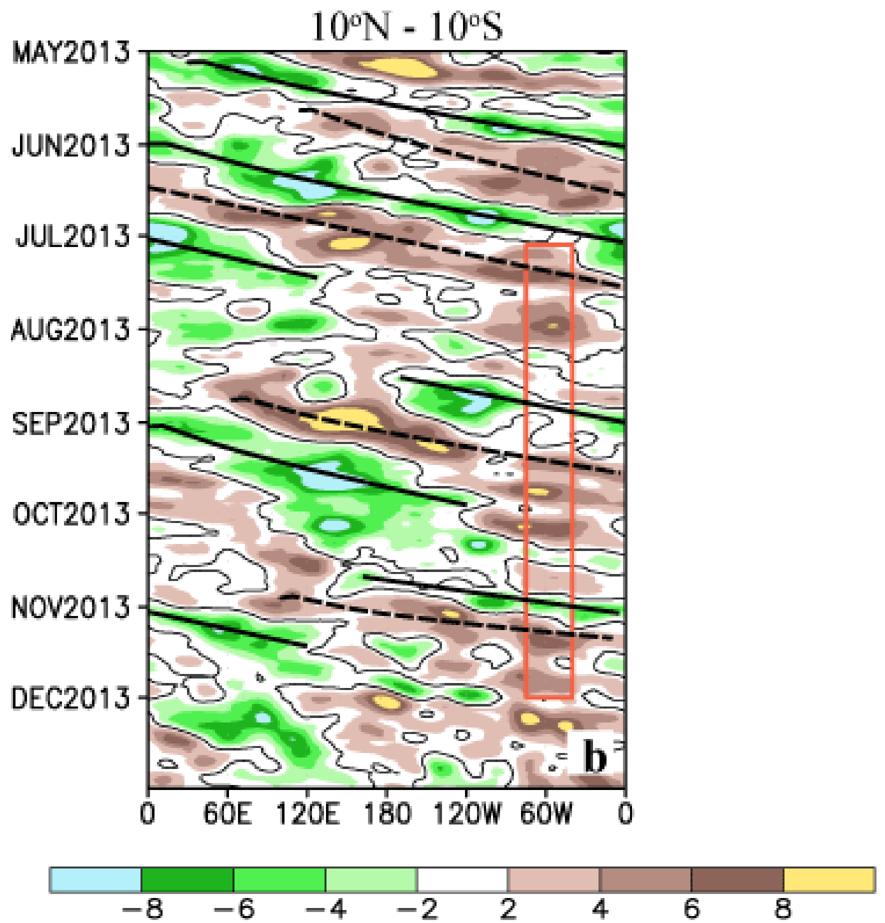
Standardized Streamfunction Indices



The MEX-CSEA pattern and the CSEA-EATL pattern are each the strongest on record, with raw anomaly indices surpassing 1994 by 25% and 82%, respectively.

3-celled streamfunction anomaly pattern was the strongest on record, with raw anomaly index surpassing next largest value (1994) by 40%.

200-hPa Velocity potential anomalies (5-day running means)



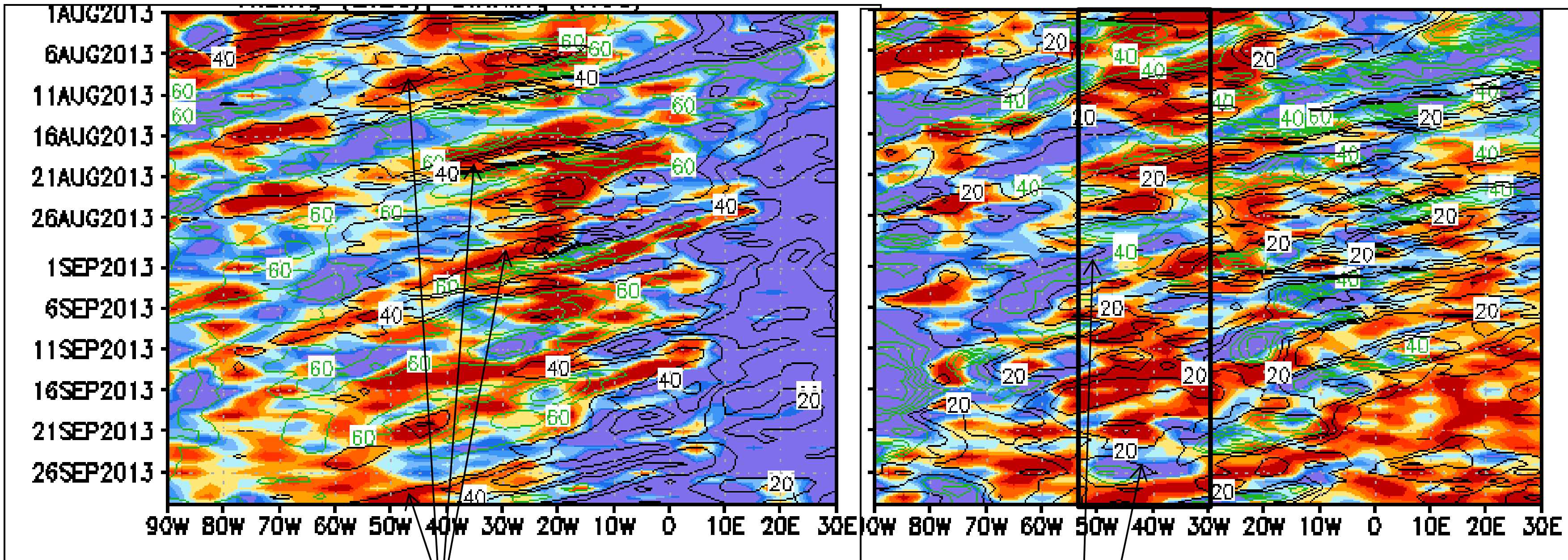
Large-scale upper-level convergence across the MDR is seemingly little affected by the MJO.

Saharan Air Layer (SAL) Analysis: Time-Longitude sections averaged 15N-17.5N

Total VVEL (shading) and Relative Humidity (contours)
Rising motion (blue), Sinking motion (Red)

850-hPa

400-hPa



Aug-Sep 2013 appears to have had 4 significant SAL events with deep descending motion (red) and very dry air (black contours).

SAL events were superimposed upon the more persistent and larger-scale pattern of enhanced mid-level sinking motion.

Only two periods are evident in which easterly waves produced mid-level ascending motion between 30W-50W

Summary

1. The below-normal 2013 Atlantic hurricane season primarily reflected unfavorable conditions in the Main Development Region:
   - strong vertical wind shear,
   - anomalously dry, sinking air,
   - Anomalous upper-level convergence and low-level divergence.

2. These conditions were associated with a persistent and highly anomalous upper-level circulation extending from Northern Hemisphere to Europe.
   - Conclude: A rare, un-predictable circulation pattern of record strength, which does not appear to have climate links, is a main culprit for the reduced Atlantic hurricane activity during 2013.

3. 2013 also featured a suppressed west African monsoon circulation, likely also contributed to anemic easterly wave troughs. Was suppressed west African monsoon system linked to the above pattern?

4. At times, the exceptionally unfavorable conditions were amplified by SAL outbreaks, but these outbreaks affected only a few tropical storms do not appear to be a main factor in suppressing the hurricane season.

Backup Slides

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

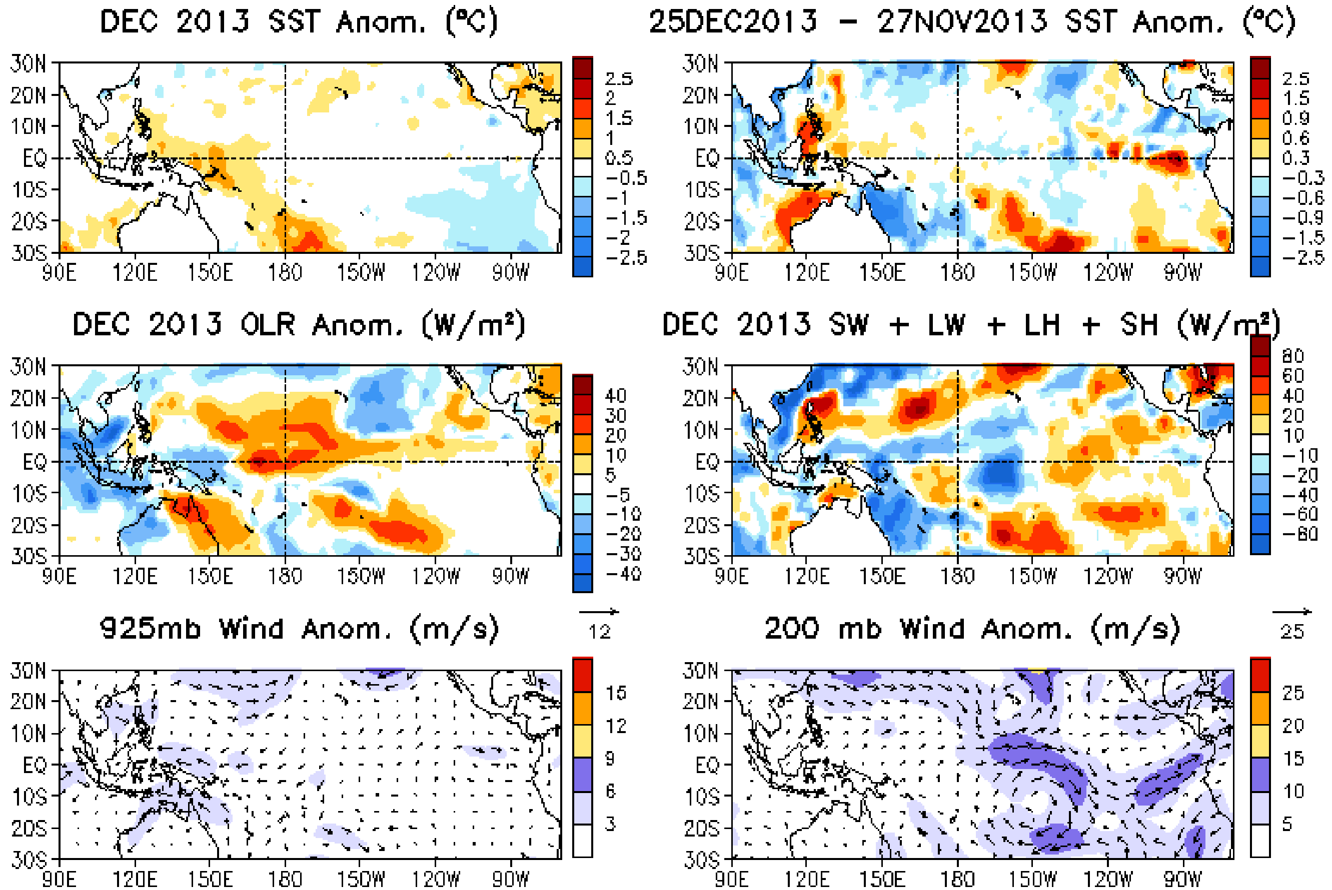


Fig. P2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

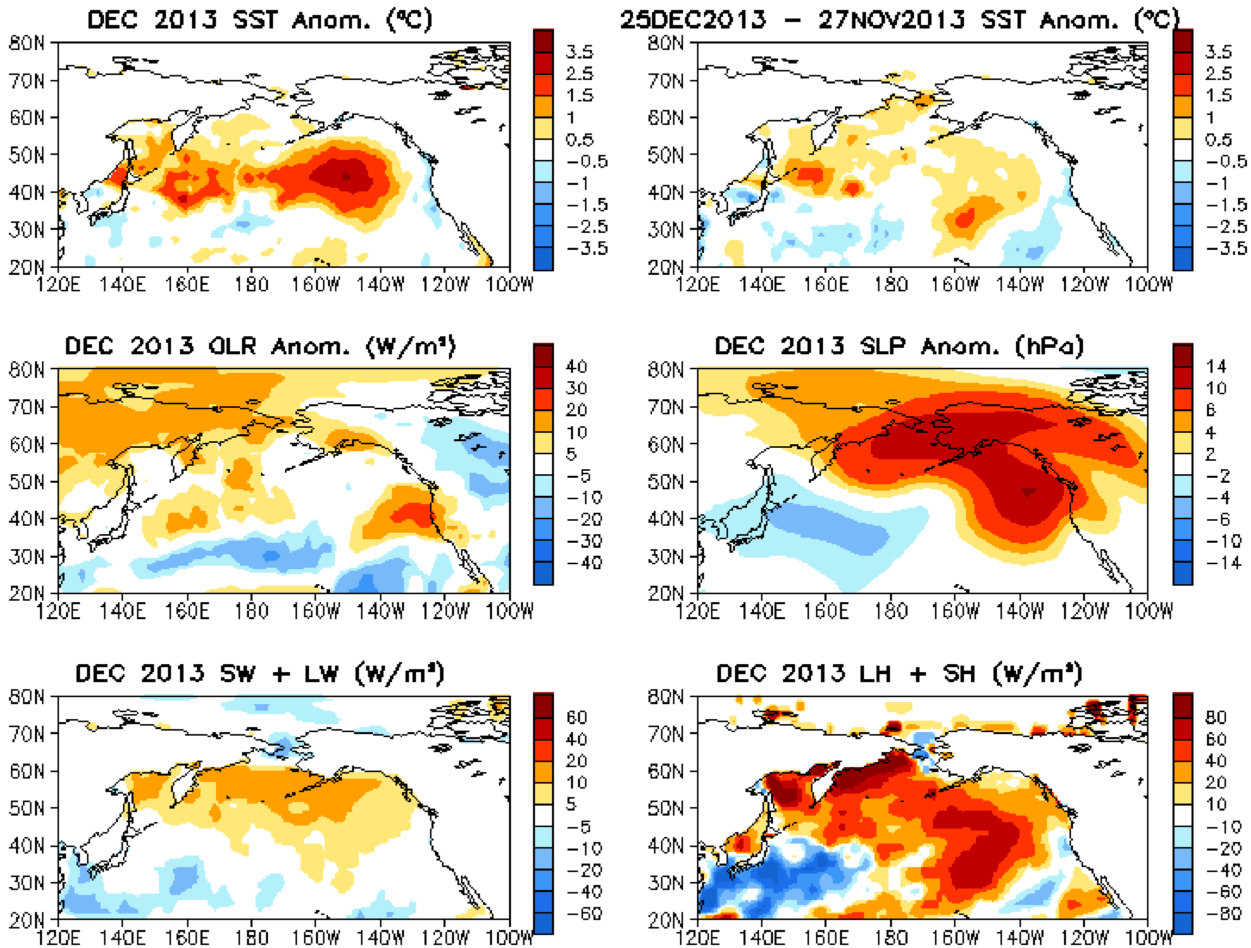
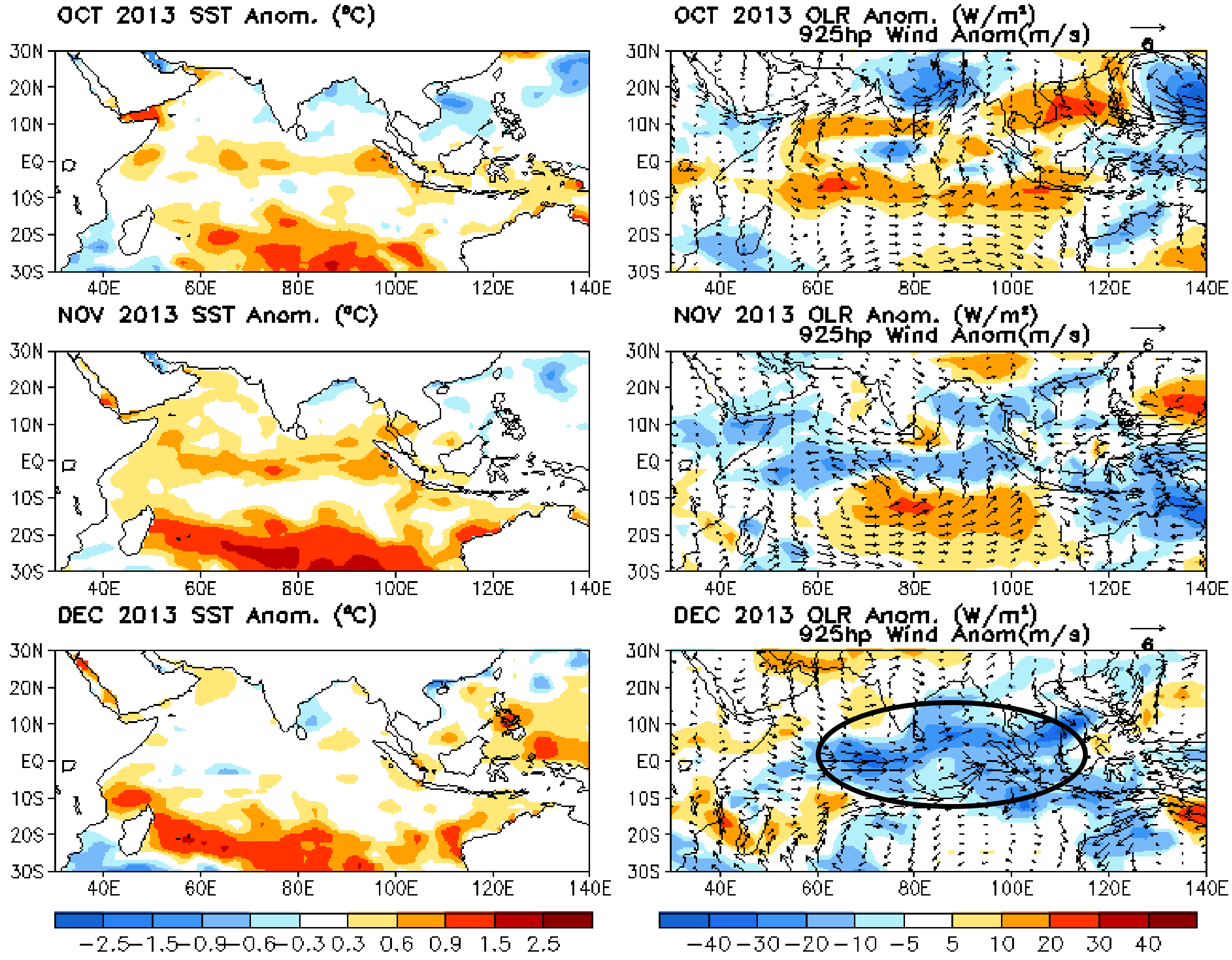


Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

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



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

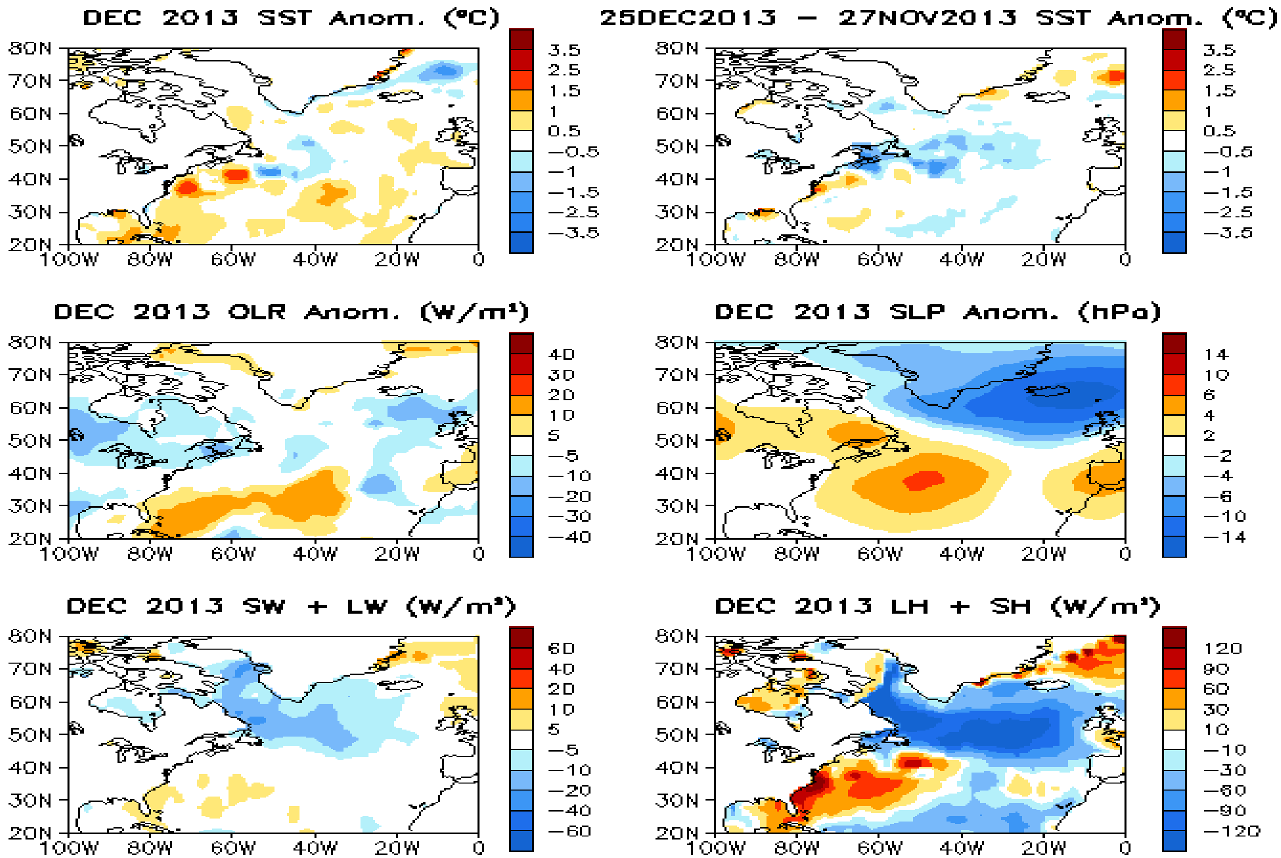


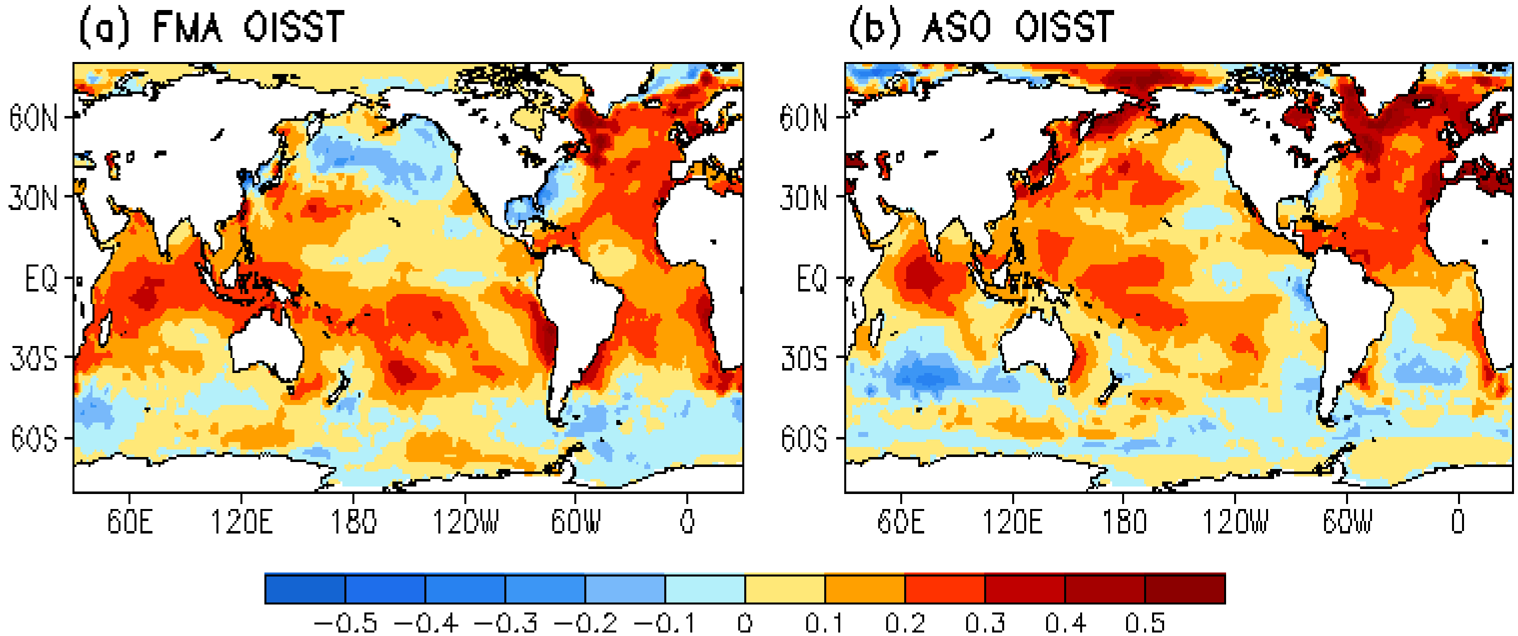
Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

SST Climatology Diff. (°C): (1981−2010) − (1971−2000)



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!