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

Prepared by
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http://www.cpc.ncep.noaa.gov/products/GODAS/

This project to deliver real-time ocean monitoring products is implemented by CPC in cooperation with NOAA's Office of Climate Observation (OCO)

Outline

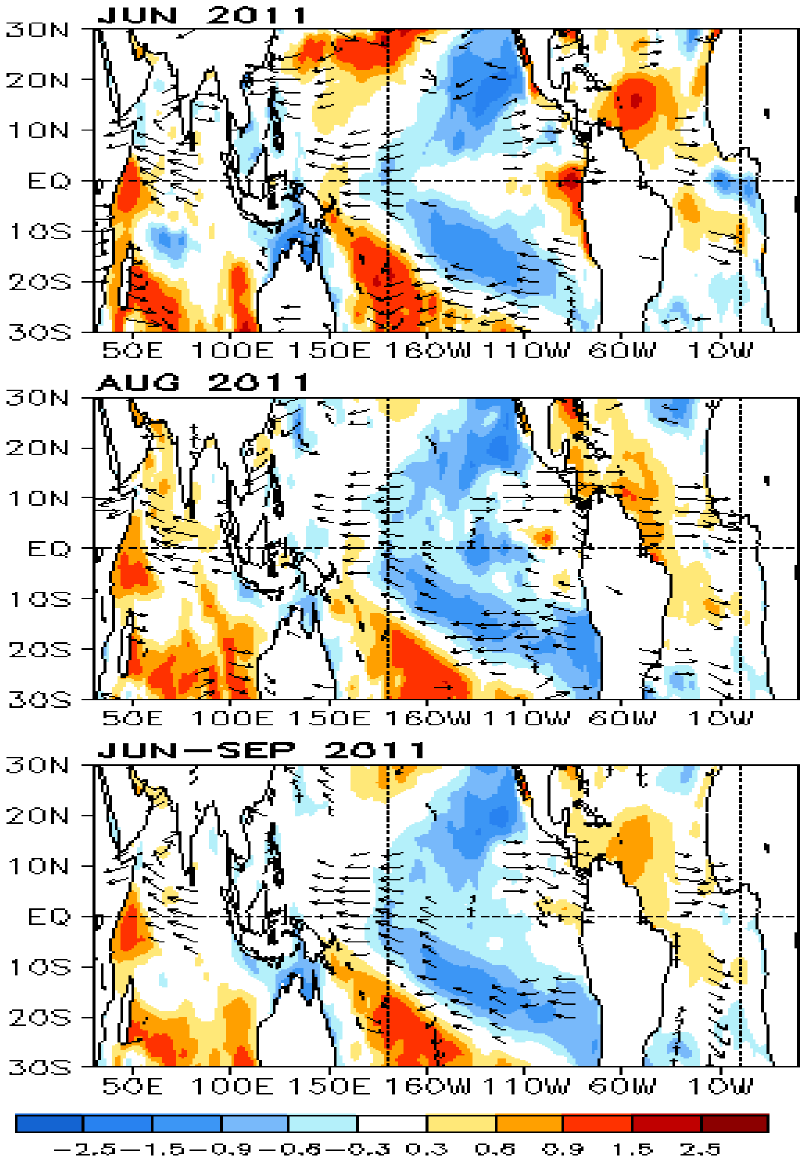
- Overview
- Recent highlights
  - Pacific/Arctic Ocean
  - Indian Ocean
  - Atlantic Ocean
- CFS SST Predictions

Overview

- **Pacific and Arctic Oceans**
  - La Nina conditions persisted with NINO3.4=-0.7°C in Sep 2011.
  - Some models, including CFSv1 and CFSv2 predicted moderate to strong La Nina conditions in the Northern Hemisphere winter.
  - Negative PDO persisted, with PDOI=-1.9 in Sep 2011.
  - Both CFSv1 and CFSv2 predicted the negative phase of PDO would last through the Northern Hemisphere winter and spring.
- **Indian Ocean**
  - Easterly wind anomalies have persisted in the east-central tropical Indian Ocean since May 2011, and positive IOD conditions emerged with DMI=0.75°C in Sep 2011.
- **Atlantic Ocean**
  - Positive SSTA and below-normal vertical wind shear in the Atlantic Hurricane Main Development Region in JJAS 2011 are much weaker than those in JJAS 2010.
  - In JJAS 2011, similar to JJAS 2010, North Atlantic Subtropical High retreated eastward, which helps steer tropical cyclones northward and away from the land (Courtesy of Chunzai Wang and David Enfield).

Global Tropical Ocean

Evolution of SST and 850mb Wind Anom.



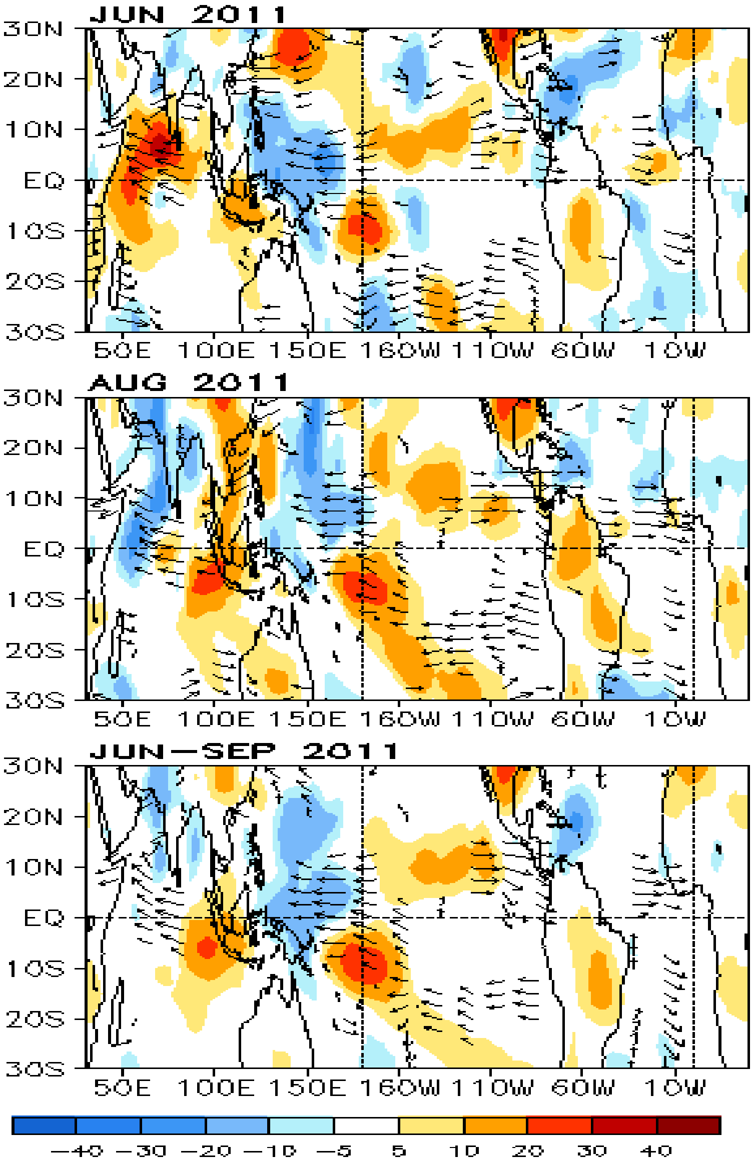
- SSTA was persistent in Jun-Sep 2011: horseshoe negative SSTA pattern in trop. Pacific, positive SSTA in the trop. N. Atlantic, positive (negative) SSTA in W. trop. Indian Ocean (north of Australia).

- Easterly wind anom. have persisted in west-central trop. Pacific, consistent with westward SSTA gradient there.

- Westerly wind anom. have persisted in subtrop. E. Pacific, related to SSTA gradient across Pacific and Atlantic Ocean.

- Easterly wind anom. have persisted in trop. Indian Ocean, related to SSTA gradient across trop. Indian Ocean.

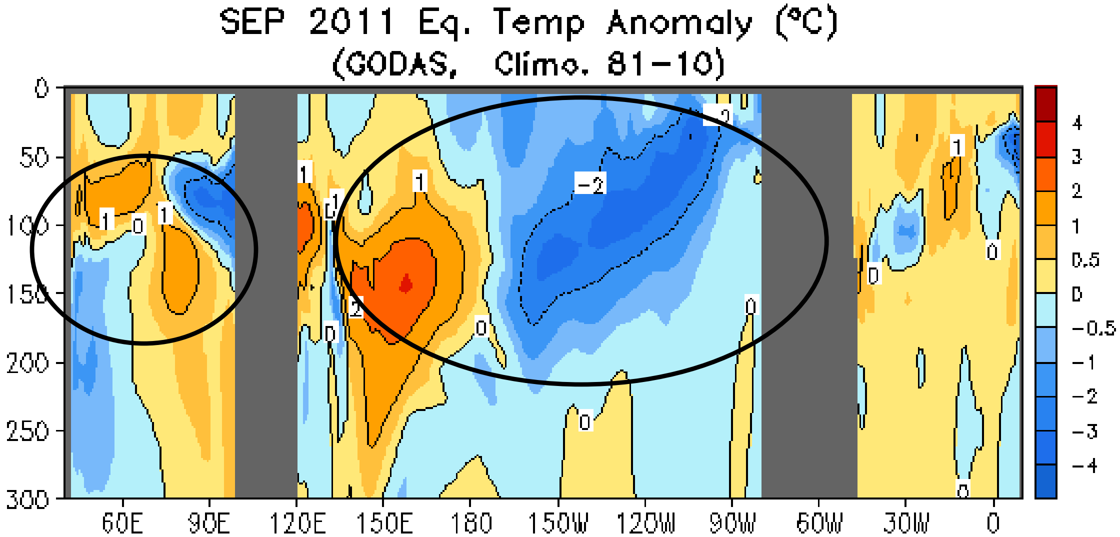
Evolution of OLR and 850mb Wind Anom.



- Persistence was also prominent in OLR anom., a proxy for convection, in Jun-Sep 2011: convection was persistently enhanced in northwest trop. Pacific and Caribbean Sea, suppressed in southeast trop. Indian Ocean, SPCZ, ITCZ.

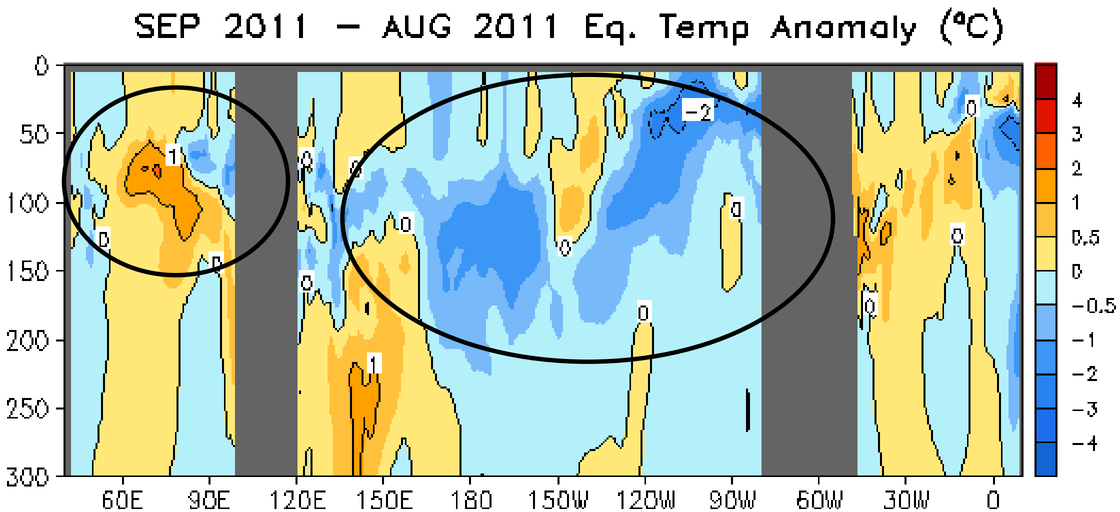
- Wind anomalies converged to (diverged from) the center of enhanced (suppressed) convection.

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



- Dipole temperature anomalies, warm (cold) in the west (east), are consistent with La Nina conditions.

- Dipole temperature anomalies at depths of 50-100m in the equatorial Indian Ocean are associated with positive IOD conditions.



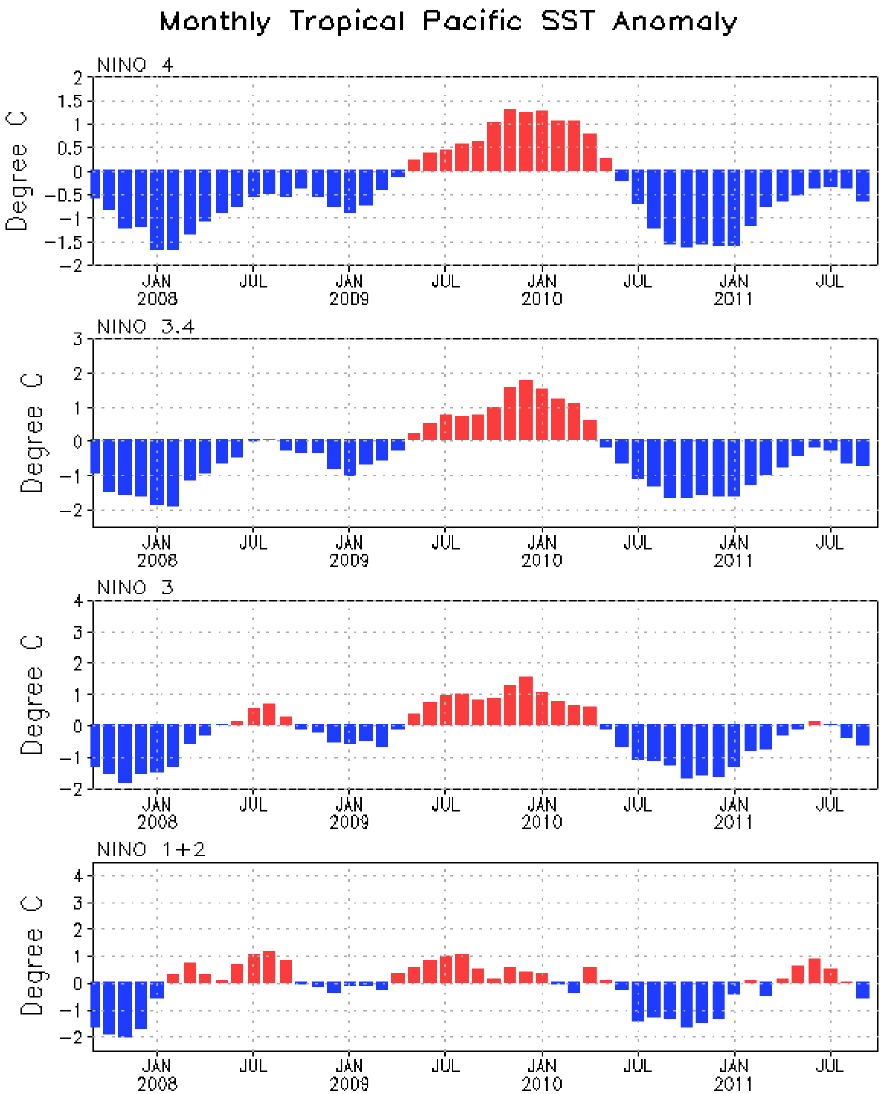
- Temperature in the equatorial Pacific near the thermocline cooled down substantially east of 170E in Sep 2011.

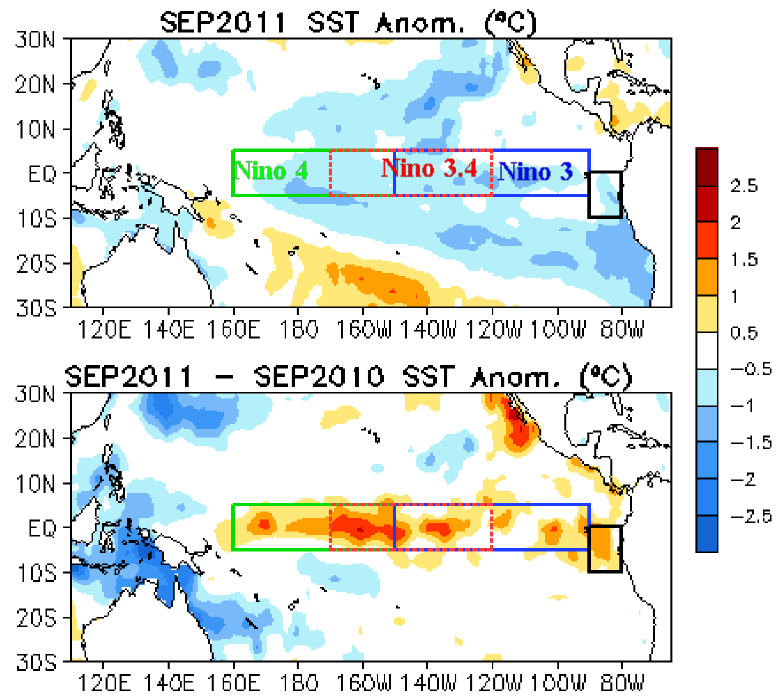
- Dipole temperature anomalies in the tropical Indian Ocean strengthened in Sep 2011.

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.

ENSO Conditions

Evolution of Pacific NINO SST Indices





- NINO4, NINO3, and NINO3.4 indices were negative and slightly strengthened

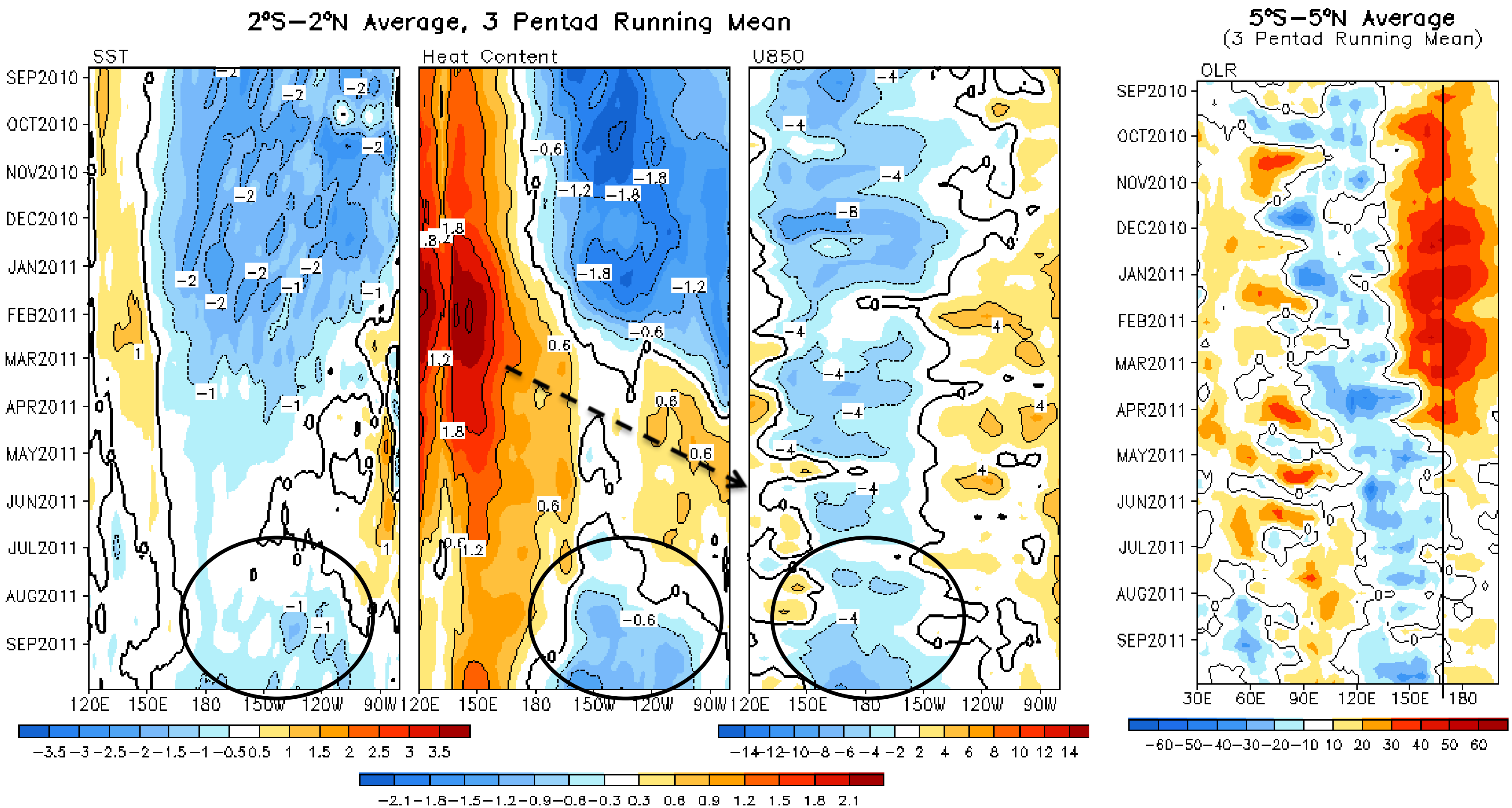
- NINO1+2 index switched to negative.

- Nino3.4 =-0.74ºC in Sep 2011.

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

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

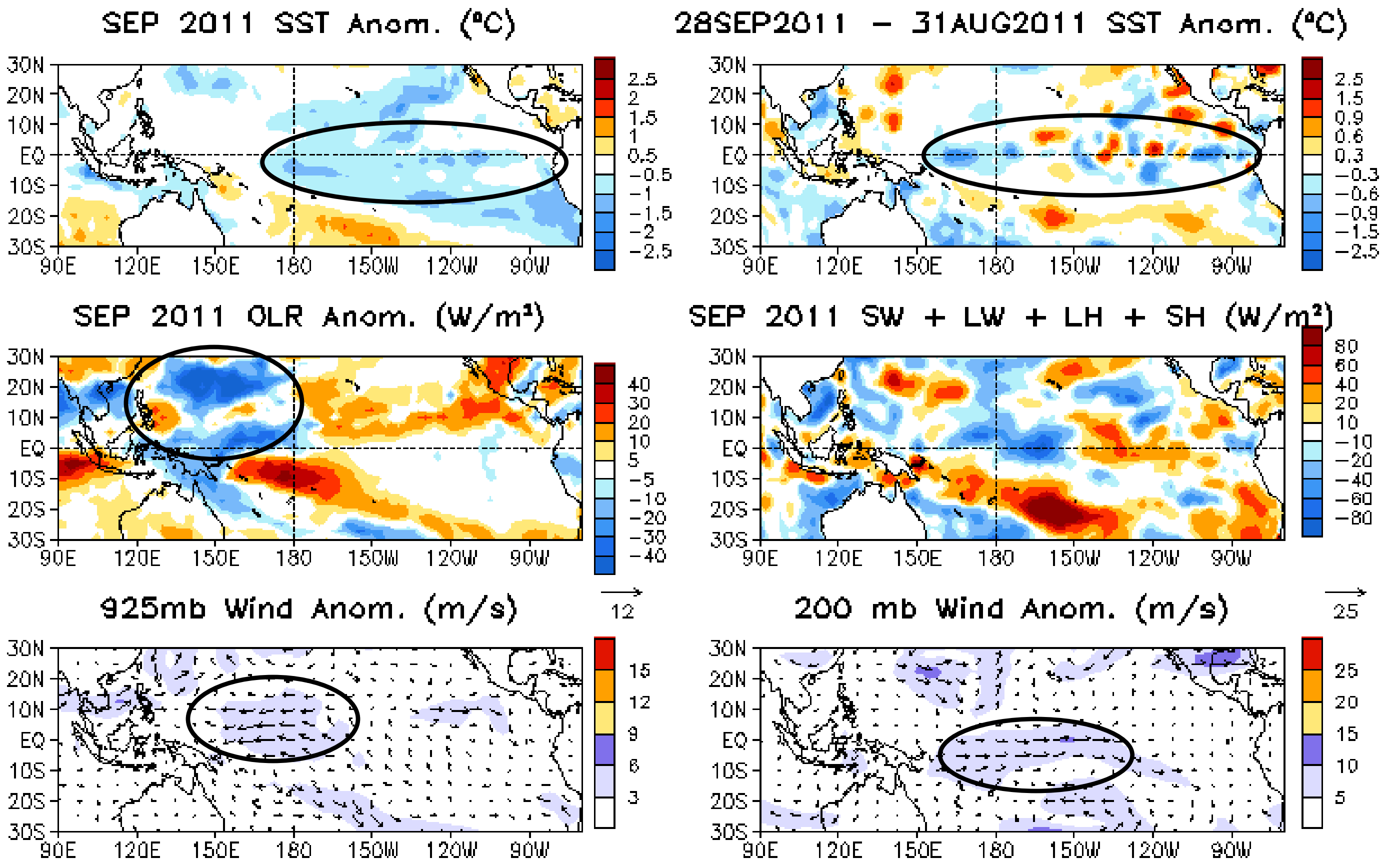
Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m^2) Anomaly



- **Negative HC and SST anomalies rebounded in the central and eastern equatorial Pacific since Jul 2011 and intensified in Aug-Sep 2011.**
- **That is consistent with intensified anomalous easterly wind in the low level in the central Pacific Ocean.**

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

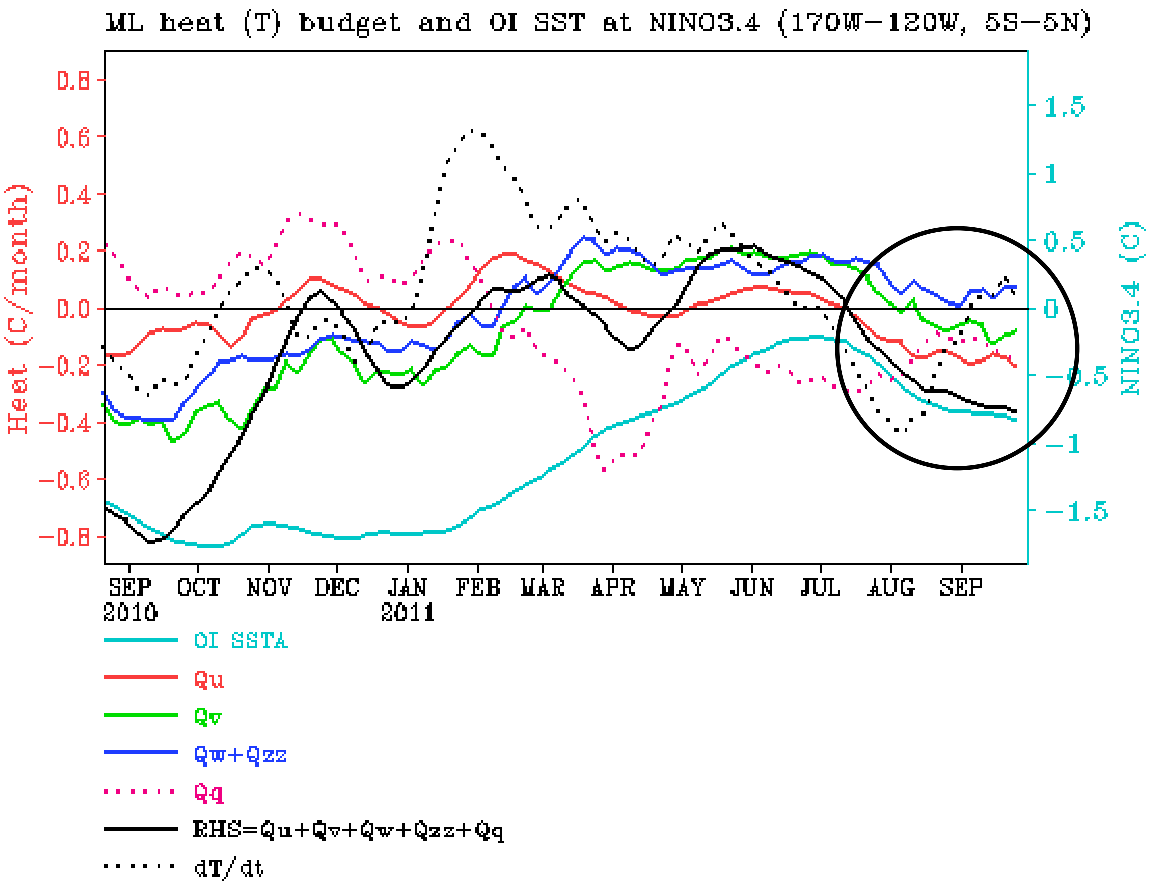
Tropical Pacific: SST Anom., SST Anom. Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds



- Negative SSTA prevailed over much of the equatorial Pacific Ocean and strengthened in Sep.
- Convection was enhanced near the Philippine Sea and western trop. Pacific and suppressed south of the equator near the Dateline.
- Westerly (easterly) wind anomalies in high (low) level presented over the central-eastern (central) Pacific, consisting with the OLR pattern.

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.

NINO3.4 Heat Budget



- The negative SSTA tendency (dT/dt) in NINO 3.4 (dotted line) observed since early Jul reached a minimum in early Aug, and then increased substantially, became slightly positive in Sep 2011, indicating a slowdown of the growth of La Nina conditions.

- Although Qv and Qu were negative, Qw+Qzz, vertical entrainment and vertical diffusion, was near zero in Sep 2011, indicating influence of thermocline variations on growth of La Nina conditions is weakened.

- The total heat budget term (RHS) has large cold biases compared with the tendency (dT/dt) since early Sep 2011.

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;

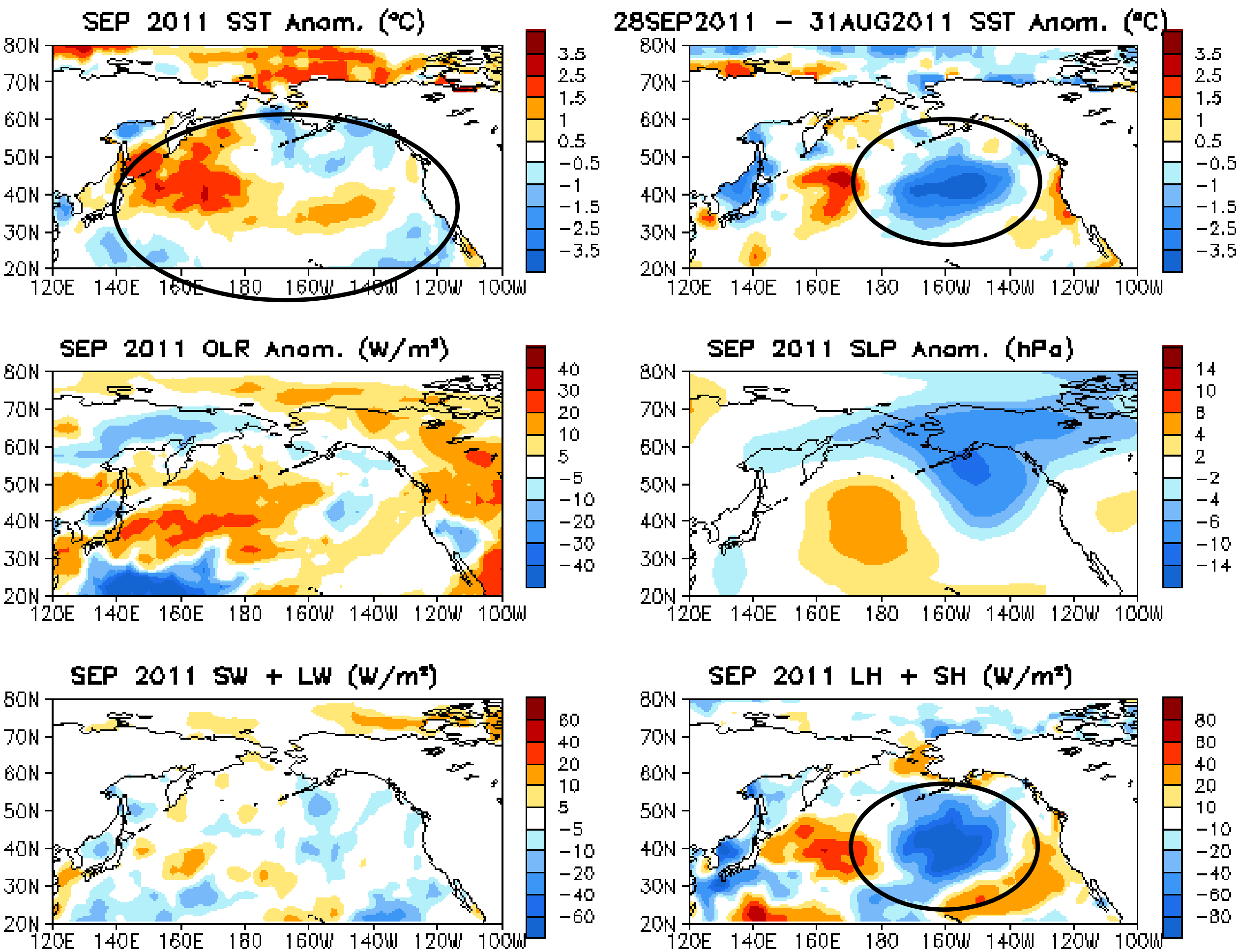
Qw: Vertical entrainment; Qzz: Vertical diffusion

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

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

North Pacific & Arctic Ocean

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



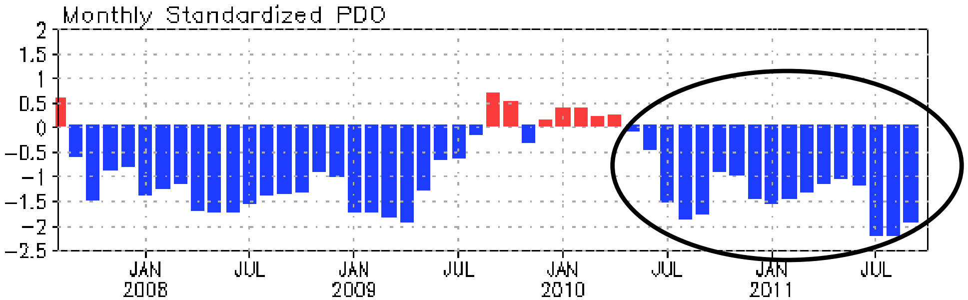
- Positive SSTA was observed in the west-central North Pacific surrounded by negative SSTA near Bering Sea, Gulf of Alaska and southwest and southeast N. Pacific, consistent with the negative PDO index (next slide).

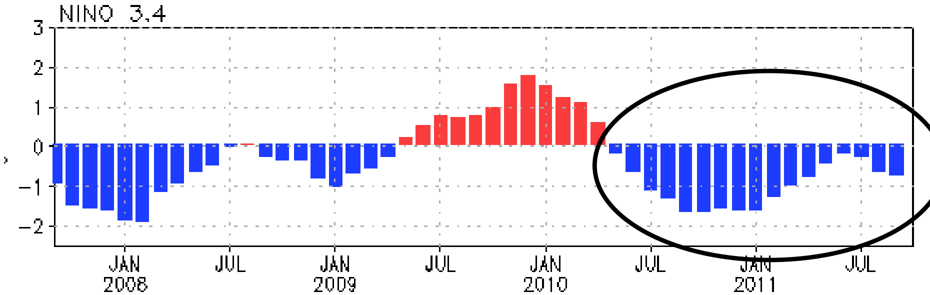
- Negative SSTA tendency was observed over the central North Pacific.

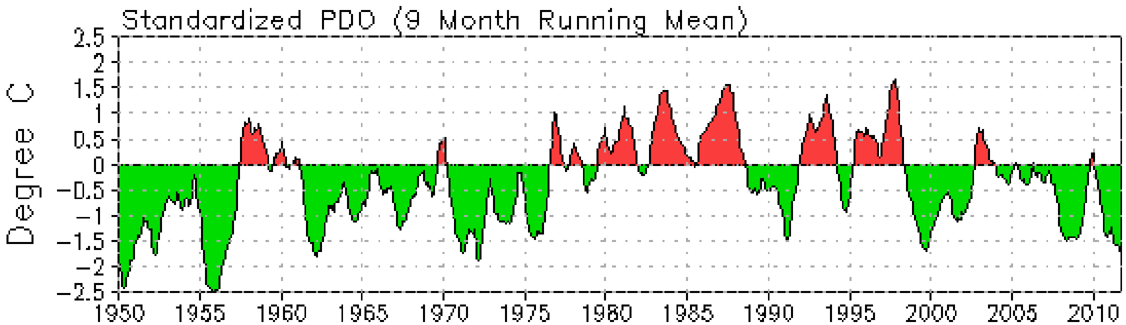
- Net surface heat flux anomalies contributed to the SST tendency in the North Pacific.

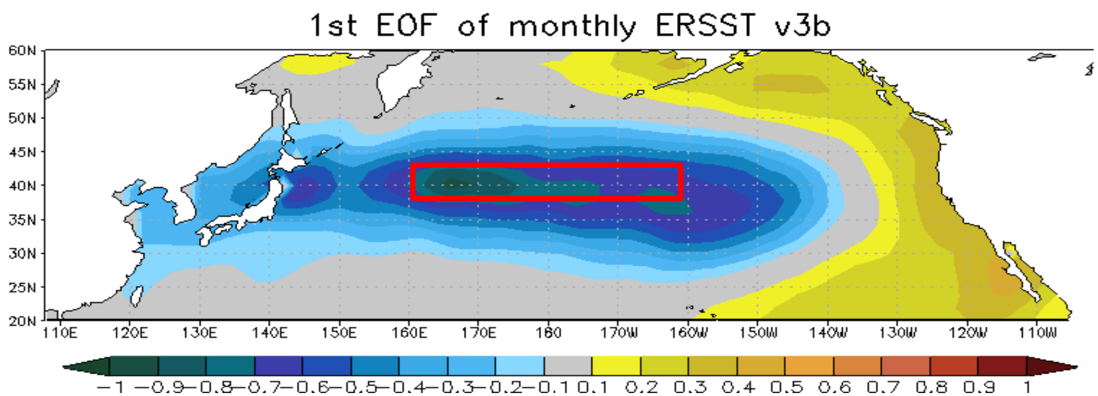
Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible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

PDO index









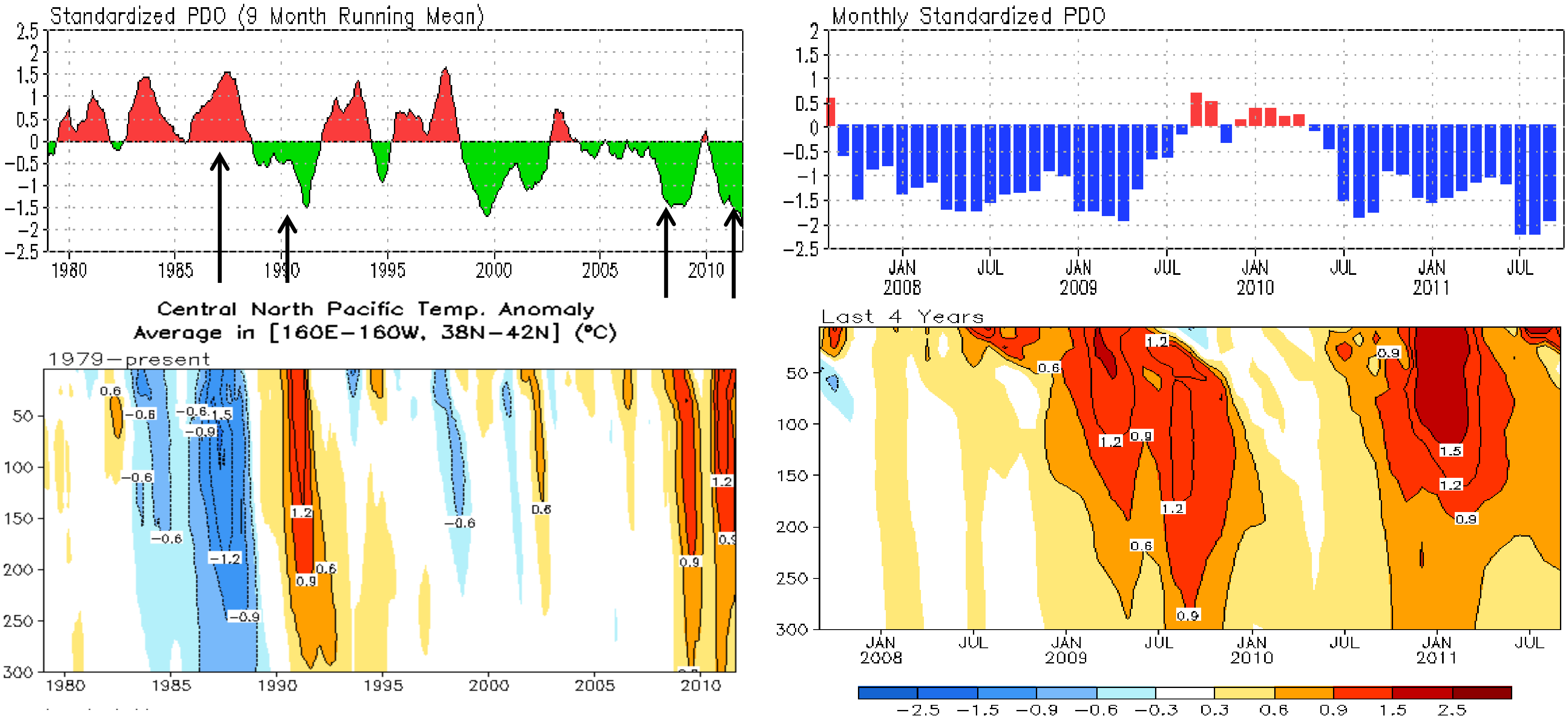
- The negative PDO intensified substantially in Jul, persisted in Aug, and weakened slightly in Sep with PDO index =-1.9.

- The apparent positive correlation between NINO3.4 and PDO index suggests strong influences of the La Nina on the North Pacific SST variability through atmospheric bridge.

- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

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

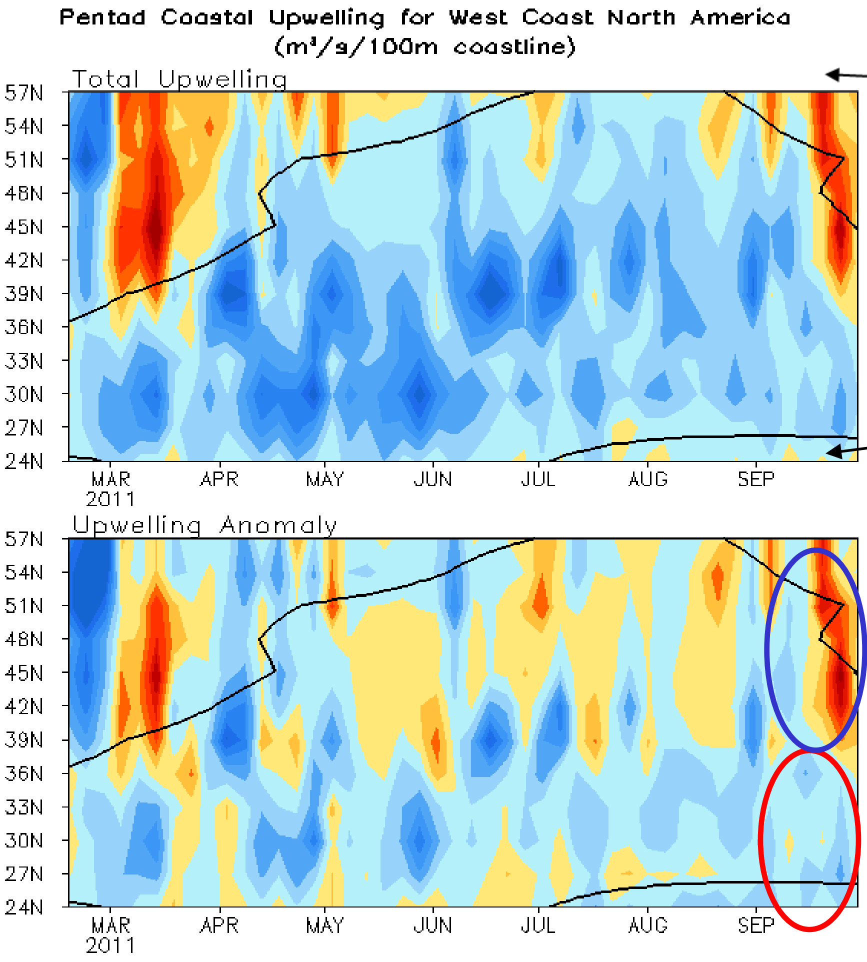
Subsurface Temperature Anom. in Central North Pacific

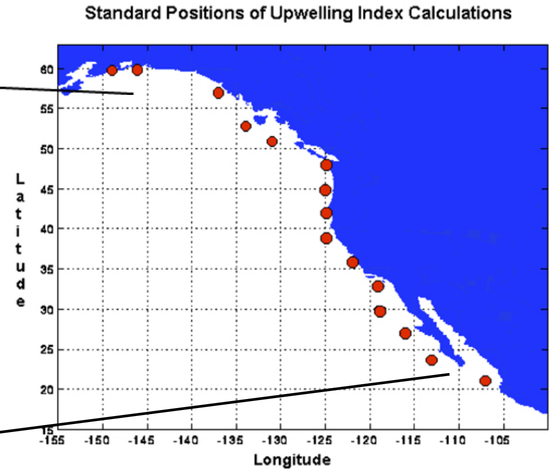


- PDO has strong signature of subsurface temperature anomalies that can penetrate to below 300m.

- Deep ocean warming in the central N. Pacific (160E-160W, 38N-42N) was particularly strong during the negative phases of PDO in 2009 and 2010/11.

North America Western Coastal Upwelling





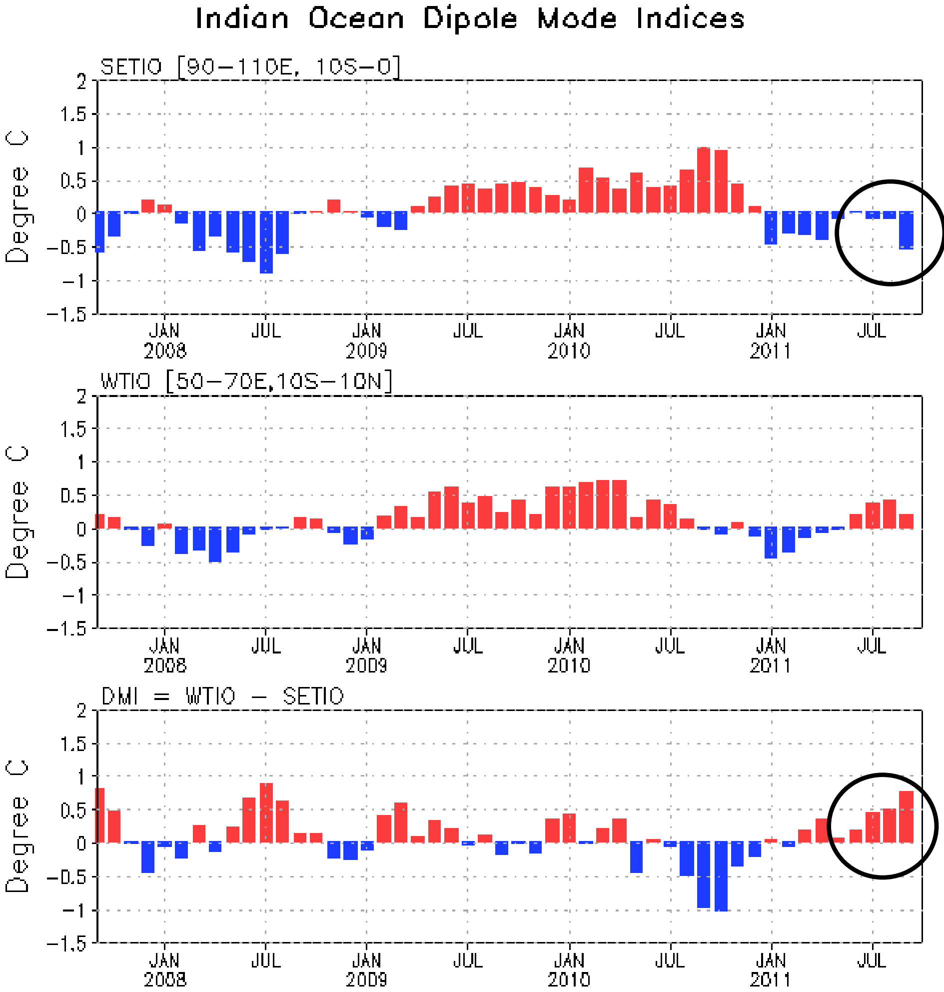
- **Upwelling was suppressed (enhanced) north (south) of 36°N in Sep 2011.**

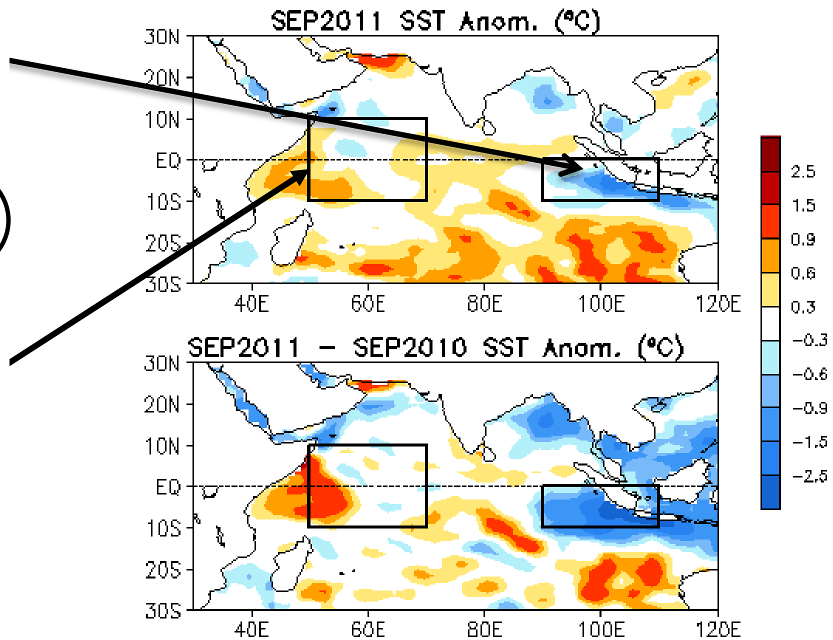
Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport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

Tropical Indian Ocean

Evolution of Indian Ocean SST Indices

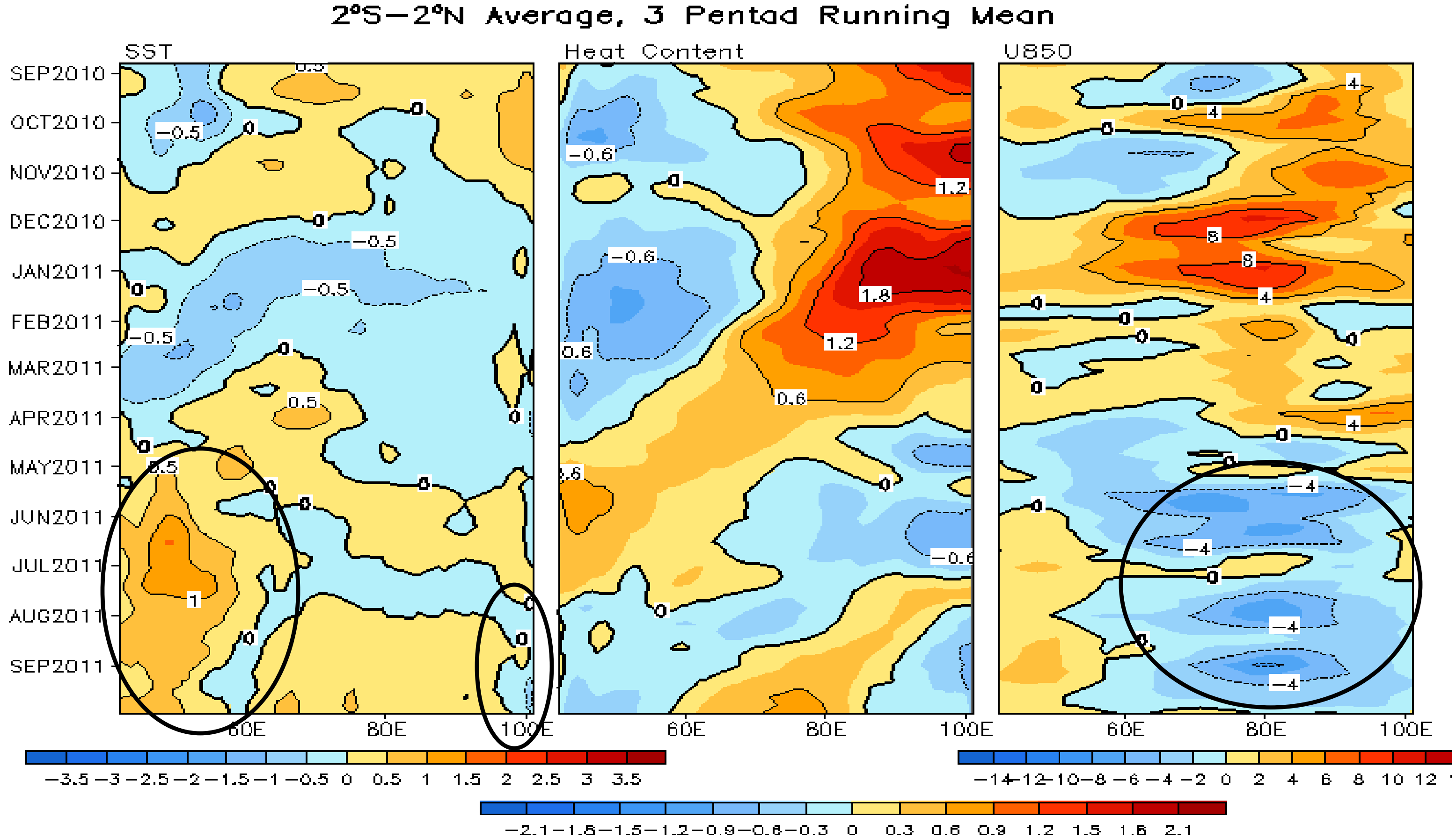




- **SETIO was -0.6°C in Sep 2011.**
- **DMI has been above normal since Mar 2011, and intensified since Jul 2011.**
- **DMI=0.75°C in Sep 2011, indicating onset of positive IOD event.**

Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the SETIO [90°E-110°E, 10°S-0] and WTIO [50°E-70°E, 10°S-10°N] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

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



- Positive SSTA has persisted in the western tropical Indian Ocean since May 2011.
- Negative SSTA emerged in the far eastern tropical Indian Ocean in Sep 2011.
- Easterly wind anomalies have persisted in the central-east tropical Indian Ocean since May 2011, consistent with the westward SSTA gradient.

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

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

- The dipole SSTA pattern, negative (positive) SSTA in the southeast (west-central) tropical Indian Ocean, is consistent with the dipole OLR pattern, featuring enhanced (suppressed) convection in the west-central (southeast) tropical Indian Ocean.

- The dipole SSTA and OLRA, easterly wind anomalies in the central Indian Ocean and the dipole Altimetry SSHA are consistent with positive IOD conditions.

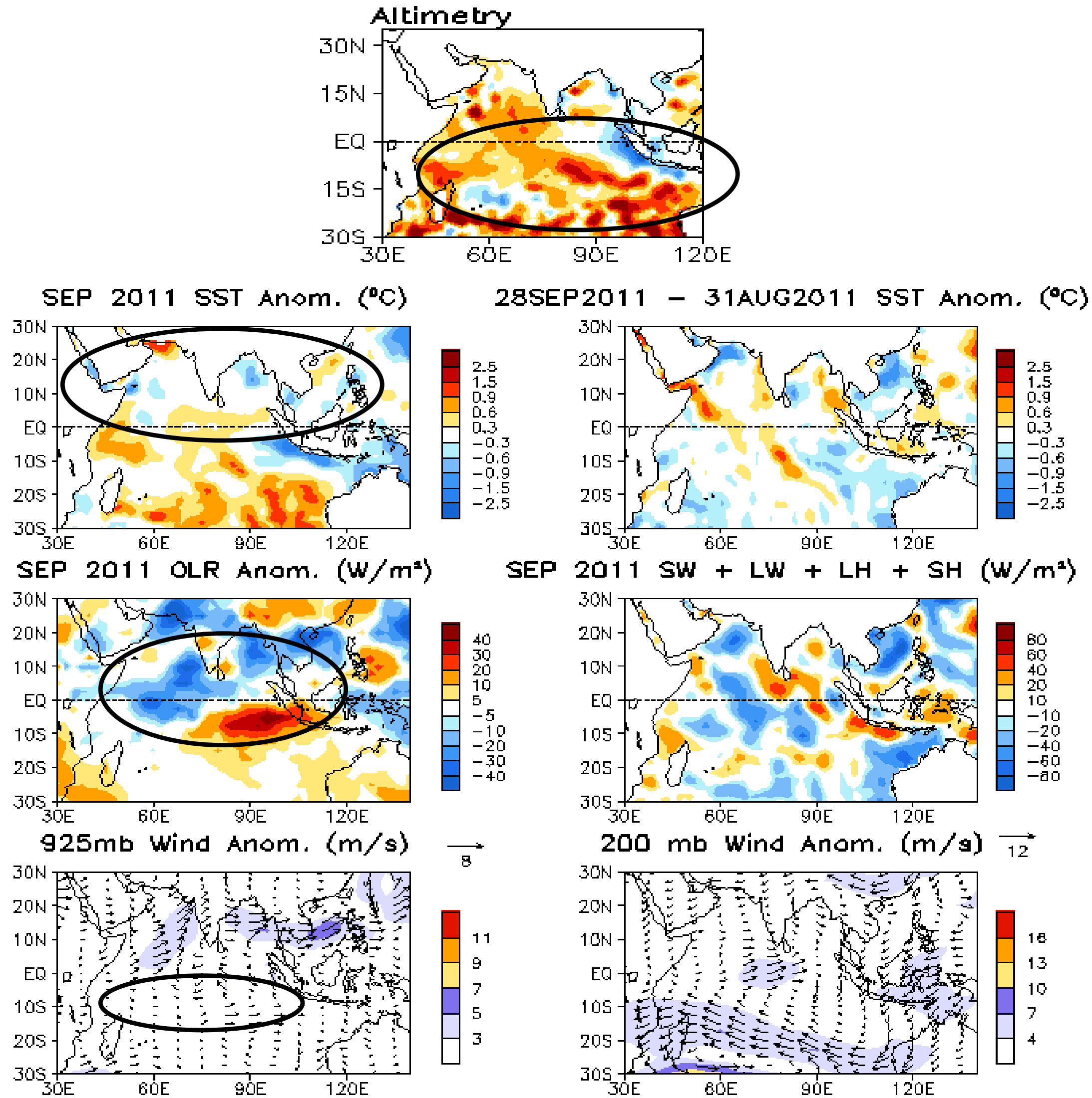
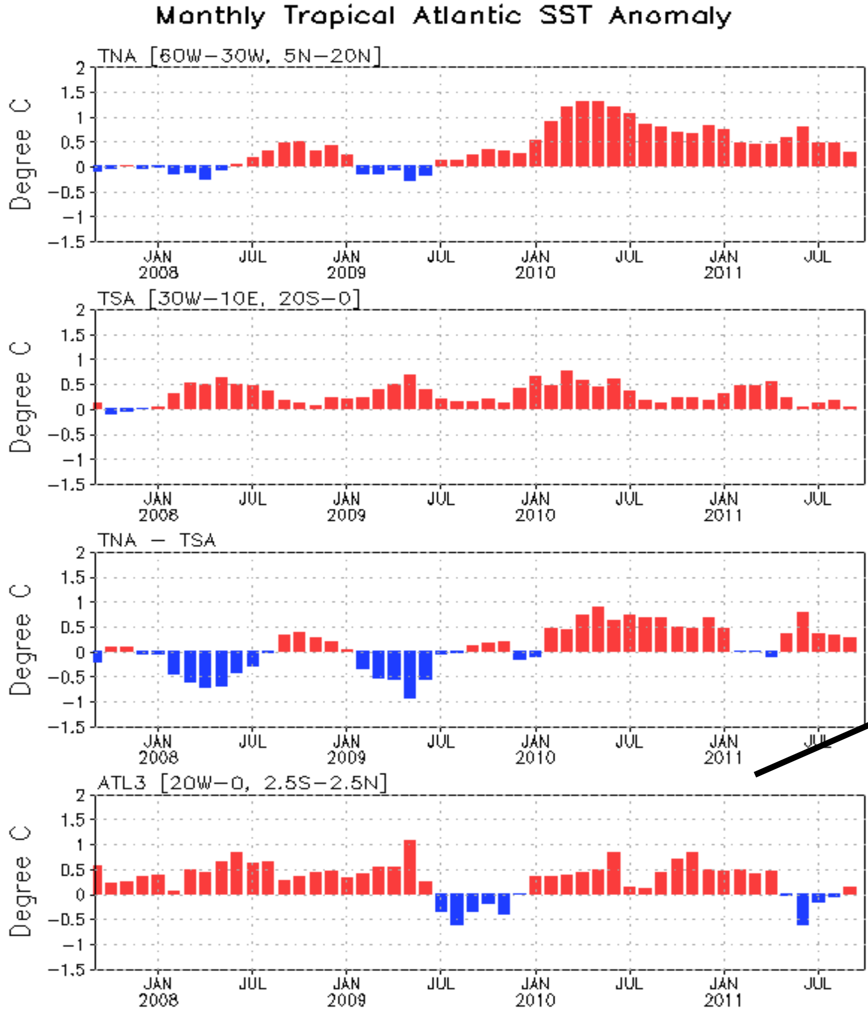
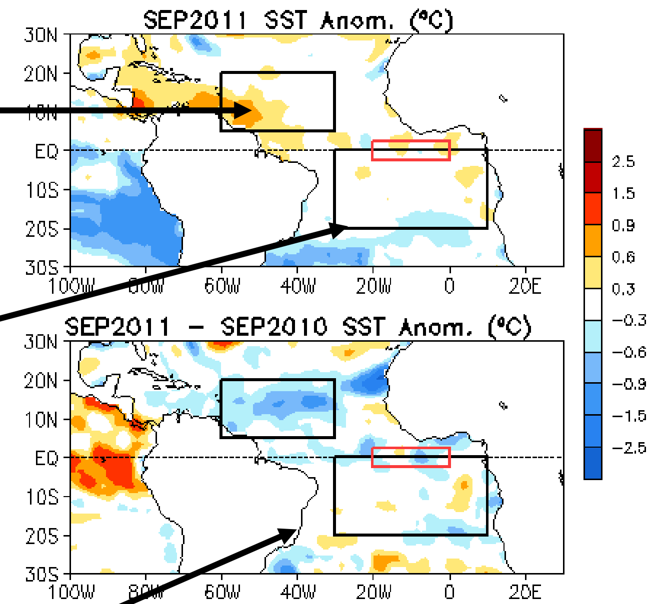


Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude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

Evolution of Tropical Atlantic SST Indices





- **Tropical North Atlantic (TNA) was much cooler in Sep 2011 than in Sep 2010.**

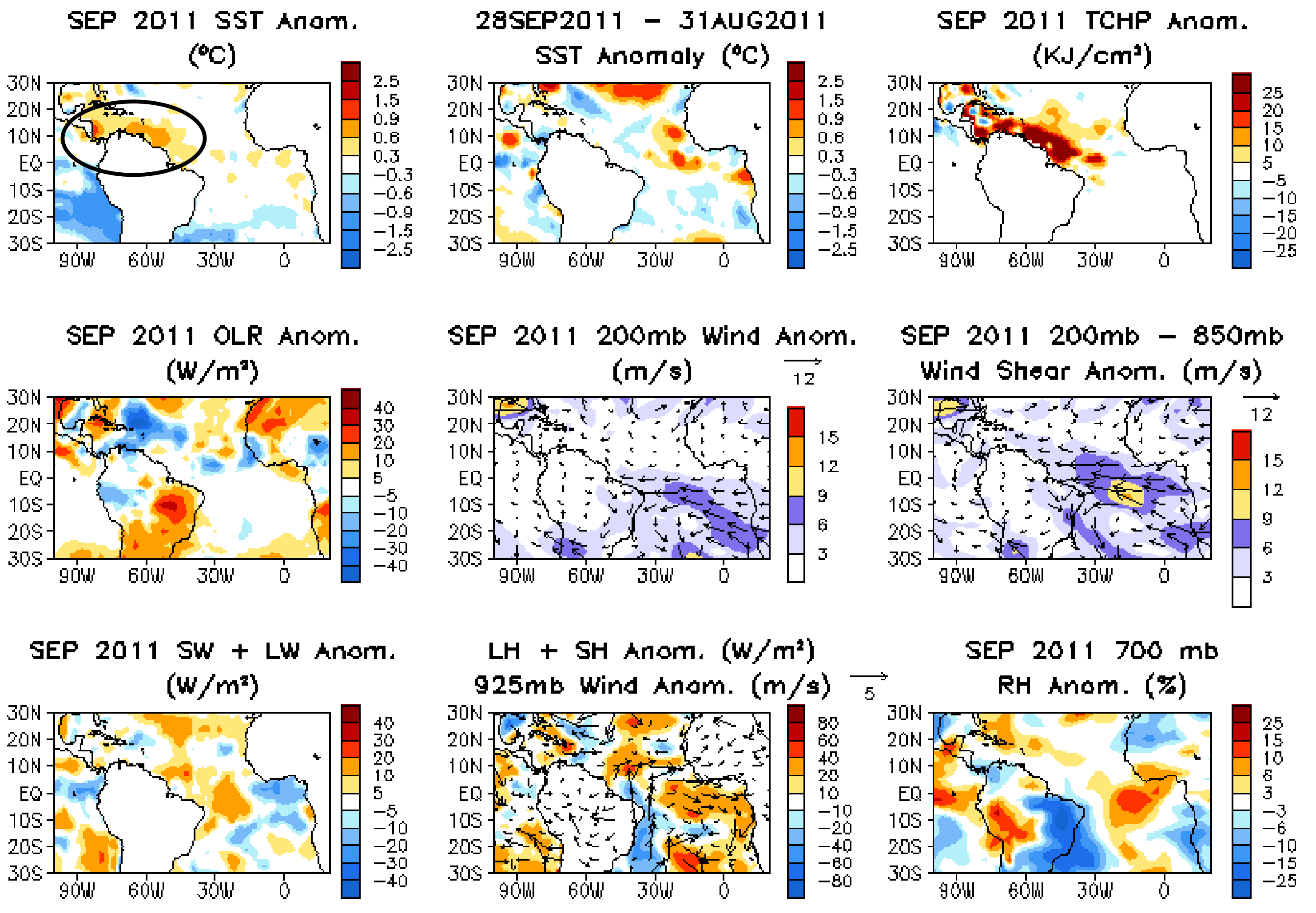
- **Positive TNA SSTA weakened slightly in Sep 2011. TSA SST was near-normal.**

- **Meridional Gradient Mode (TNA-TSA) was weakly positive since May 2011.**

- **ATL3 SST was near-normal in Sep 2011.**

Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

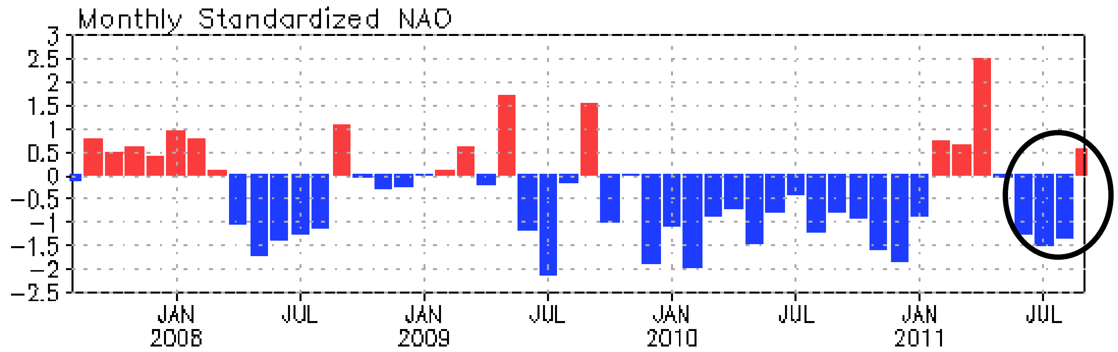
Tropical Atlantic:

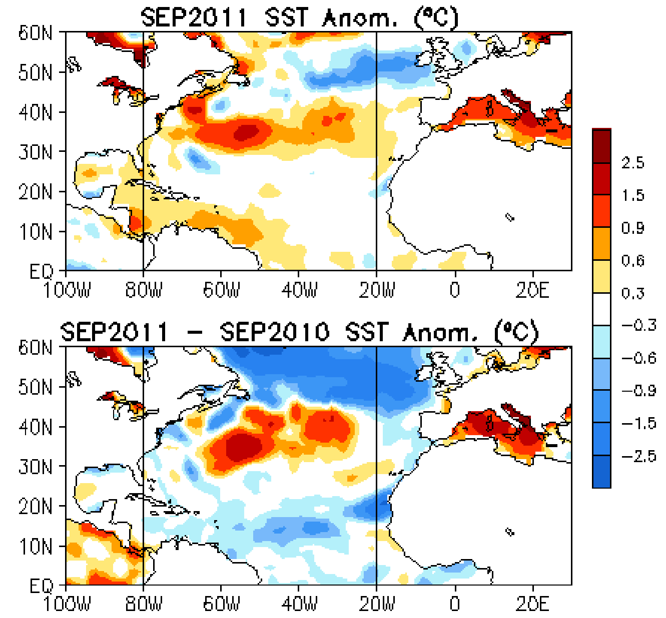


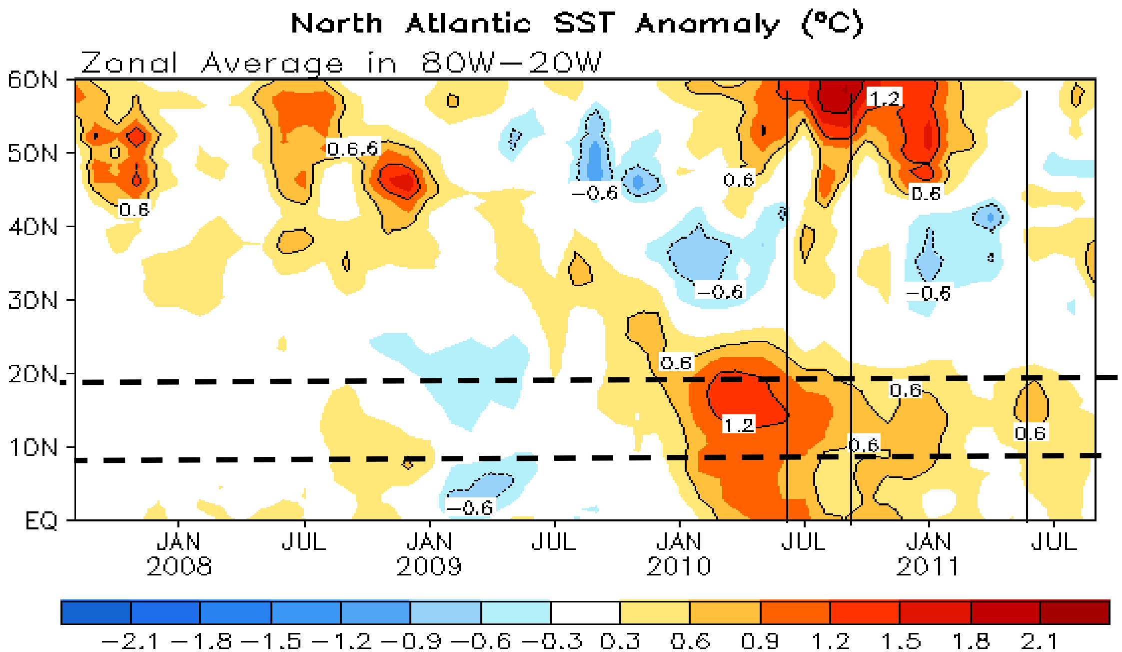
- **Positive SSTA continued in Caribbean Sea and western tropical North Atlantic.**
- **Above-normal SST and TCHP, and below-normal vertical wind shear in hurricane MDR were observed.**

North Atlantic Hurricane Season

NAO and SST Anomaly in North Atlantic



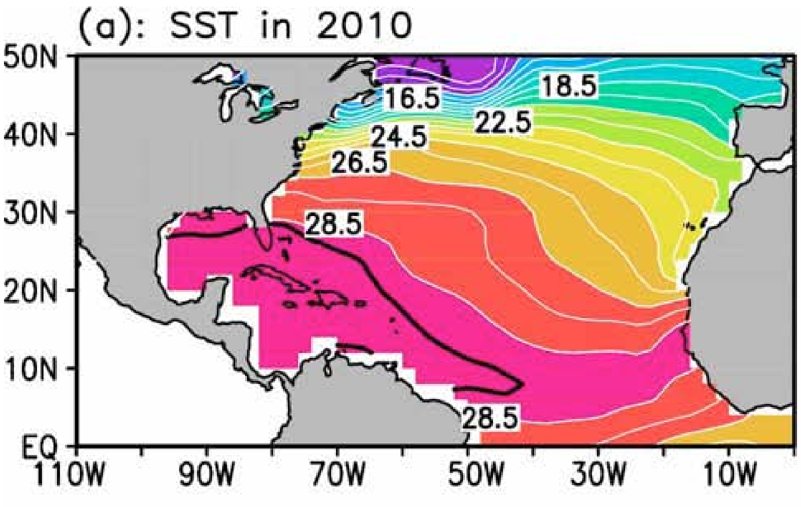




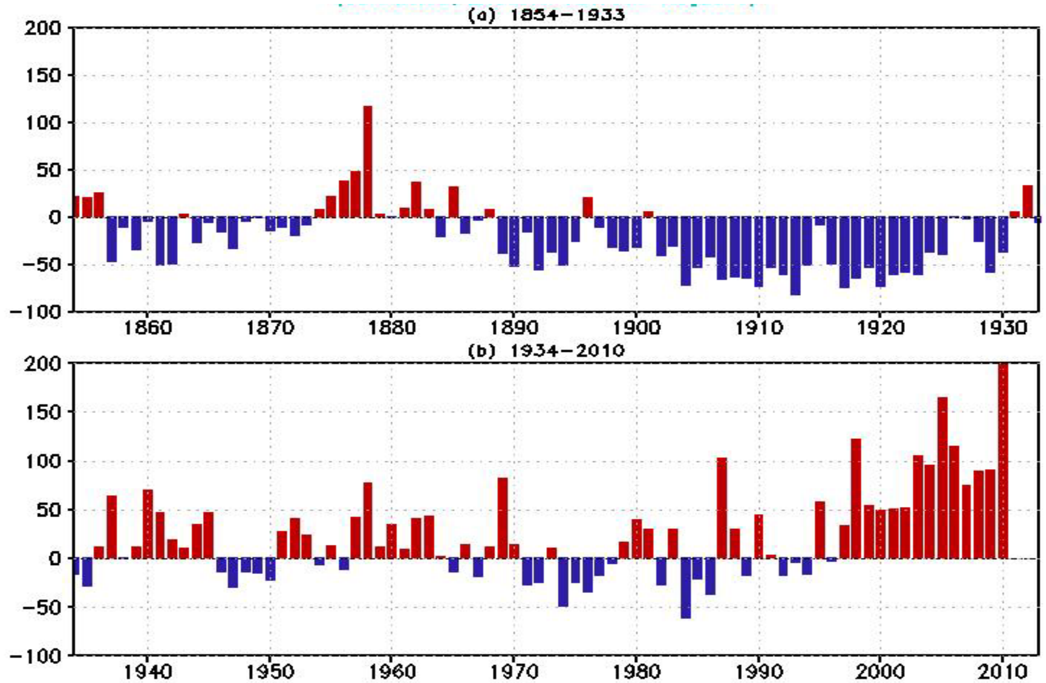
- Negative NAO persisted in Jun-Aug 2011, and switched to positive in Sep 2011.
- SST in high-latitudes was much cooler in summer 2011 than in summer 2010, probably related to opposite phase of NAO in spring 2010 and 2011.
- SST in low-latitudes was also much cooler in summer 2011 than in summer 2010, probably due to the contrary impact of El Nino in spring 2010 and La Nina in spring 2011.

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.

Atlantic Warm Pool (AWP) Index



The black line is the Aug-Oct climatological AWP.

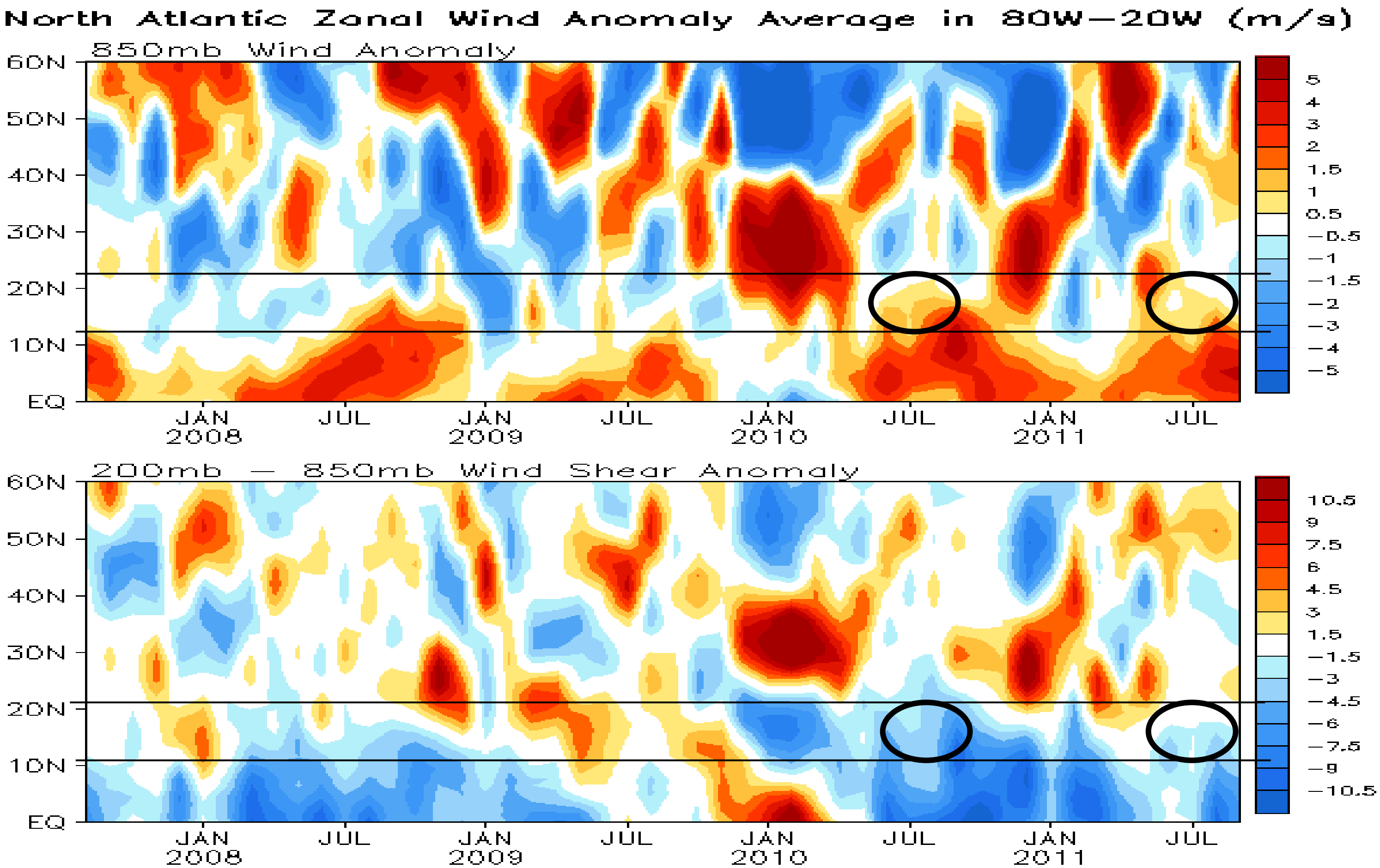


- Atlantic Warm Pool (AWP) index is defined as JJASON anomalies of the area with SST > 28.5ºC in the tropical North Atlantic from 15ºW westward divided by climatology (unit %) (Wang et al. G3 2008). The index was calculated using ERSSTv3.

- A large (small) AWP is unfavorable (favorable) for hurricanes to make landfall in the United States; The mechanisms are due to (1) the shift of tropical cyclone (TC) genesis location & (2) the change of TC steering flow (Wang et al. GRL 2011).

- Both a large AWP and a La Nina increases the number of Atlantic hurricane; however, their influences on the hurricane track are opposite. While a large AWP tends to steer hurricanes away from the United States, a La Niña event tends to enhance the possibility for a hurricane to make landfall in Central America, Caribbean Islands, and the southeastern United States (personal communication, Chunzai Wang, David Enfield).

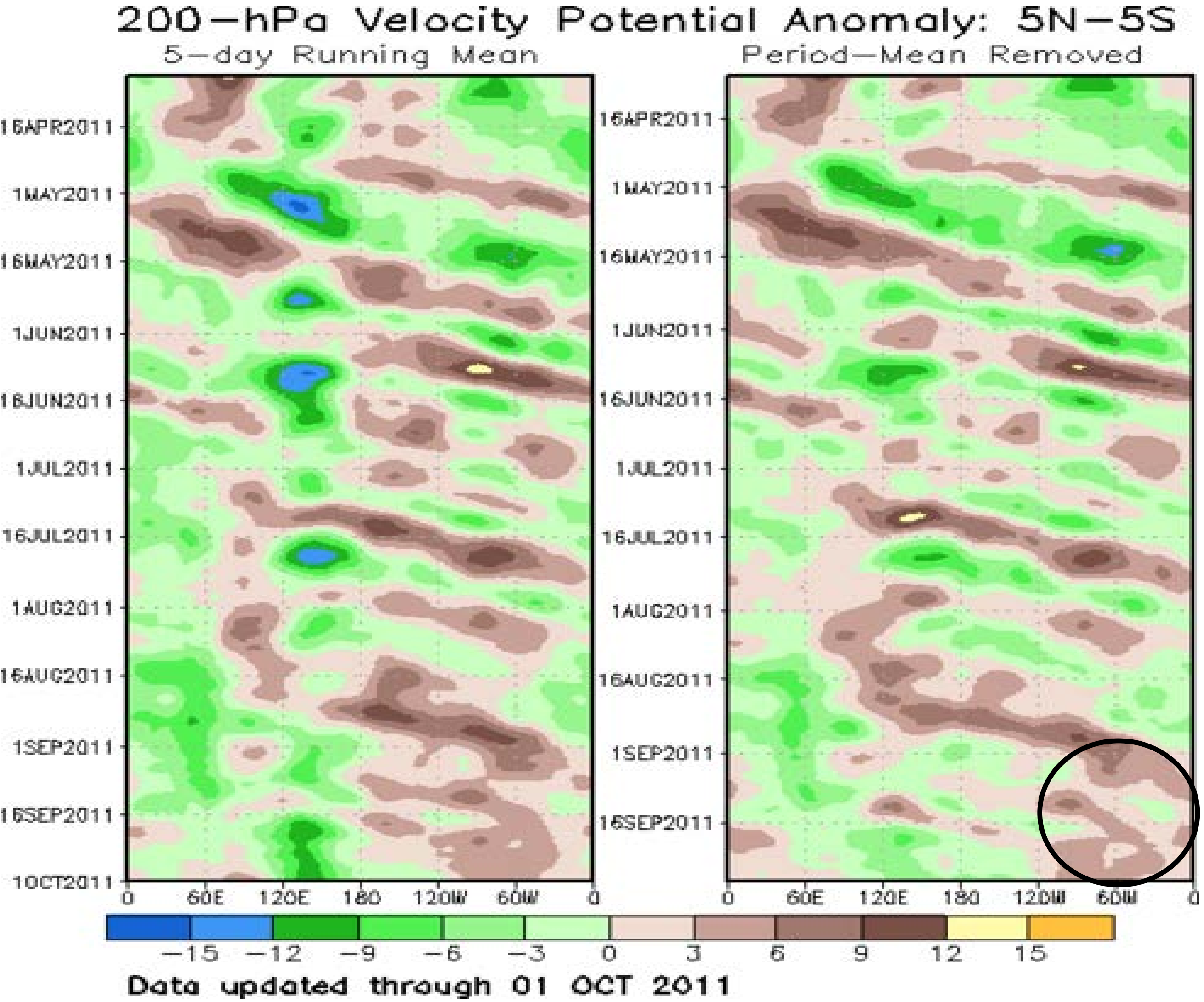
North Atlantic U850 and U200-U850



- In the Hurricane Main Development Region (80W-20W, 10N-20N), westerly wind anomalies near the surface and below-normal vertical wind shear were observed in JJAS 2011, which is favorable for hurricane development.

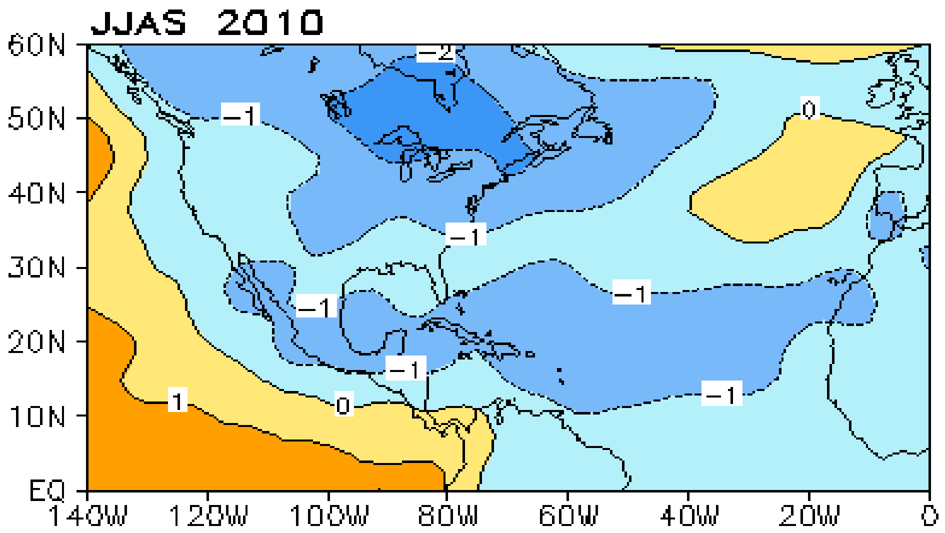
- Those anomalies in JJAS 2011 were weaker than those in JJAS 2010.

MJO or Subseasonal Activity?



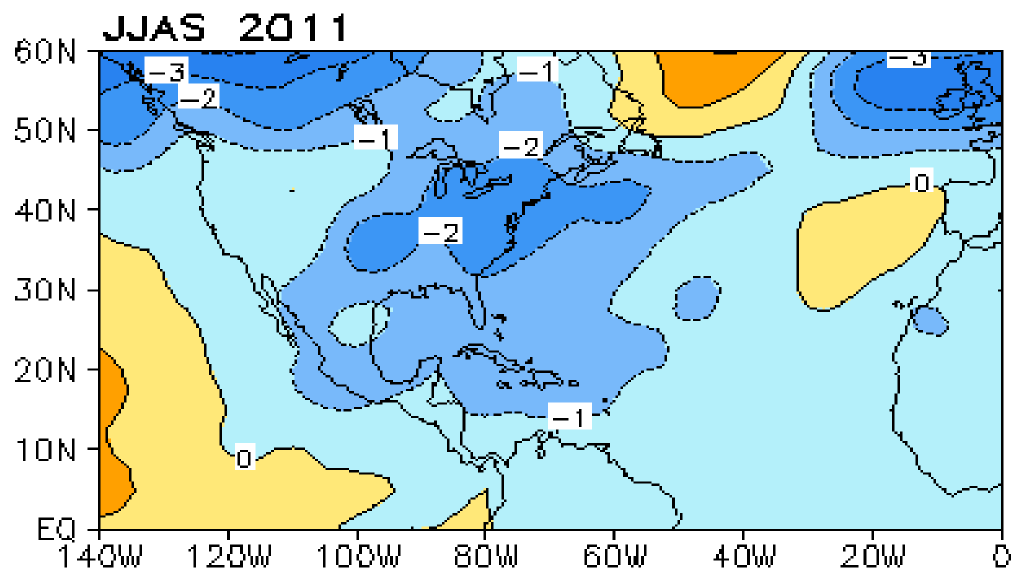
- **Upper-level convergence was observed in the tropical Atlantic in Sep 2011, which is unfavorable for hurricane development.**

North Atlantic Subtropical High (NASH)

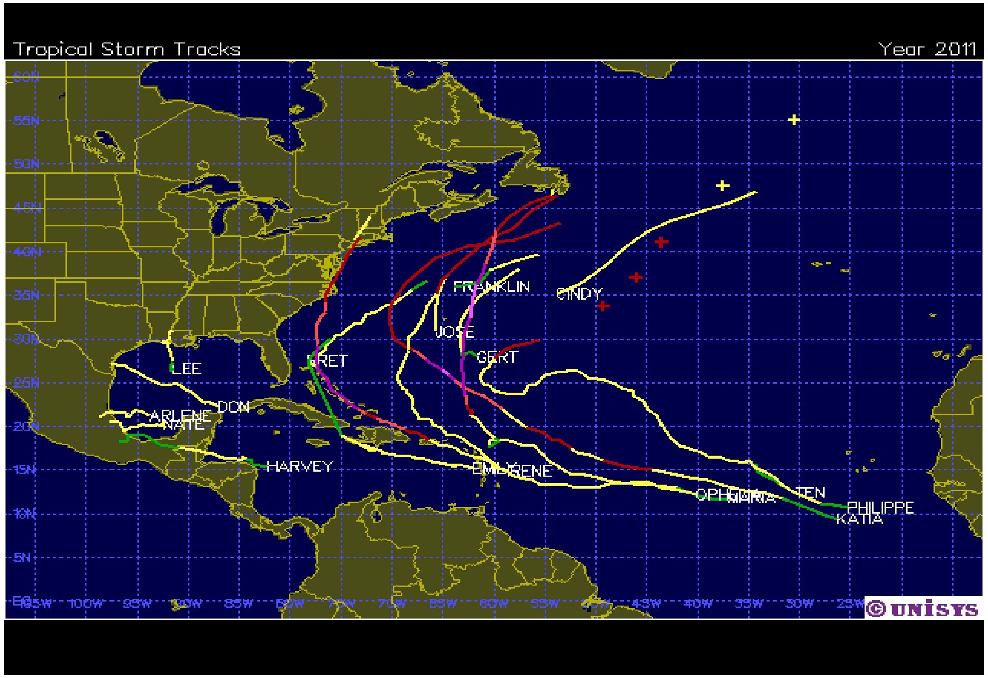


Models & data show that a large AWP is associated with a smaller, weakened North Atlantic subtropical high (NASH) that retreats eastward toward Europe and that SLP weakens off the east coast of the US creating a weakness where tropical cyclones can be steered northward and away from land (Wang et al. 2011). The situation in 2010 (left) is an illustrative case in point.

2011, like 2010, has had a larger than normal warm pool. Once again we find that the high pressure of the NASH has retreated eastward leaving an area of weakness off the east coast where TCs can recurve, as we have observed. The next slide shows how the storm tracks in 2011 have generally avoided making landfall in the US. Even Irene, which narrowly made landfall, was diverted northward by the pressure distribution (personal communication, David Enfield).



NOAA Predicts an Active Atlantic Hurricane Season in 2011

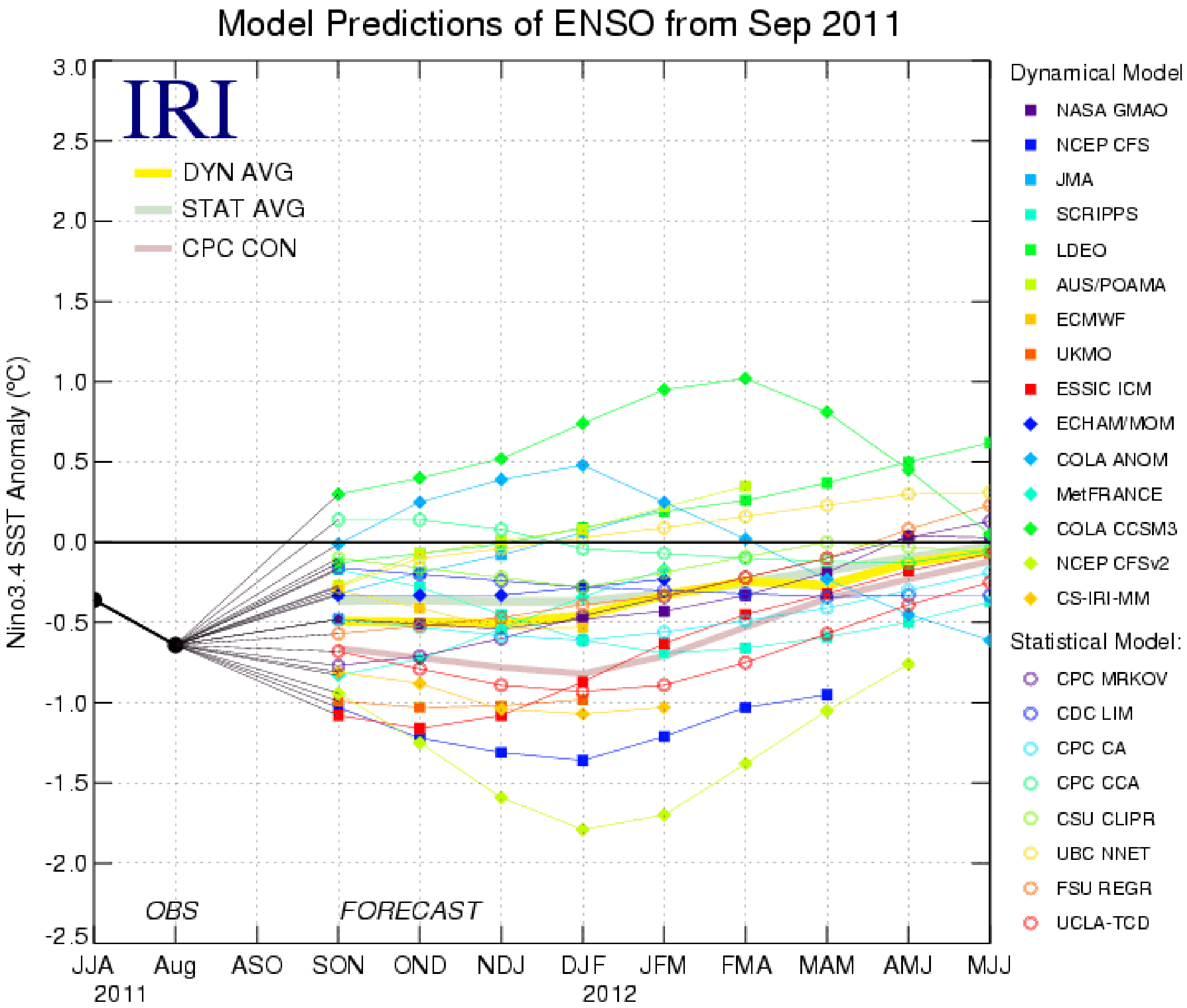


- By Oct. 7, 2011, 16 tropical storms, 5 hurricanes and 3 major hurricanes (category 3, 4) formed in the North Atlantic Ocean.

	Normal	May 19	Aug. 4	*Obs. by Oct. 7*
Named storms	11	12-18	14-19	16
Hurricanes	6	6-10	7-10	5
Major hurricanes	2	3-6	3-5	3
ACE (% median)	100	105-200	135-215	

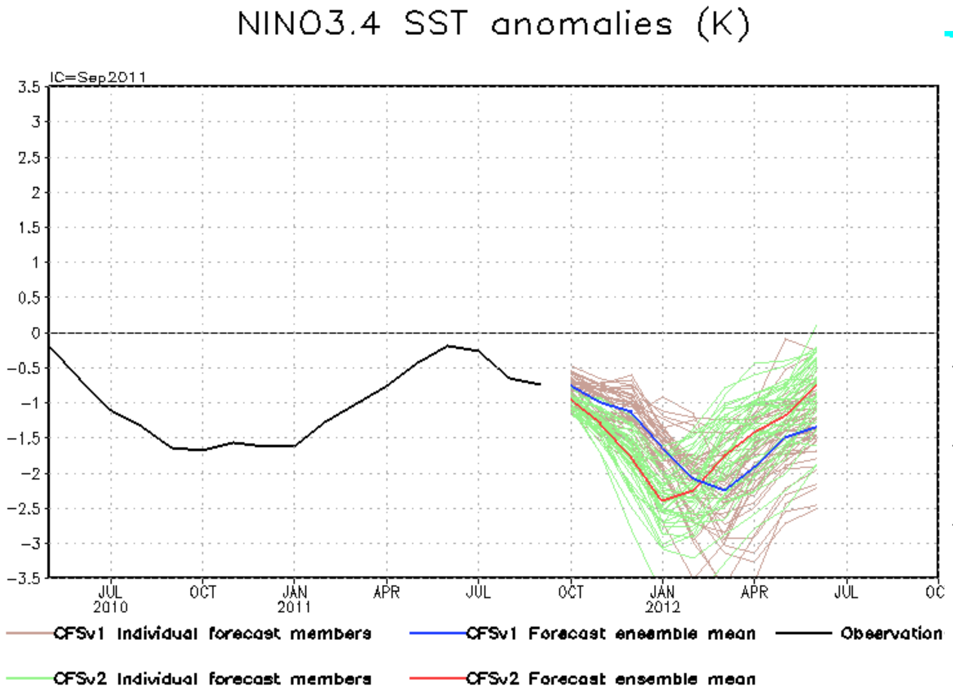
SST Predictions

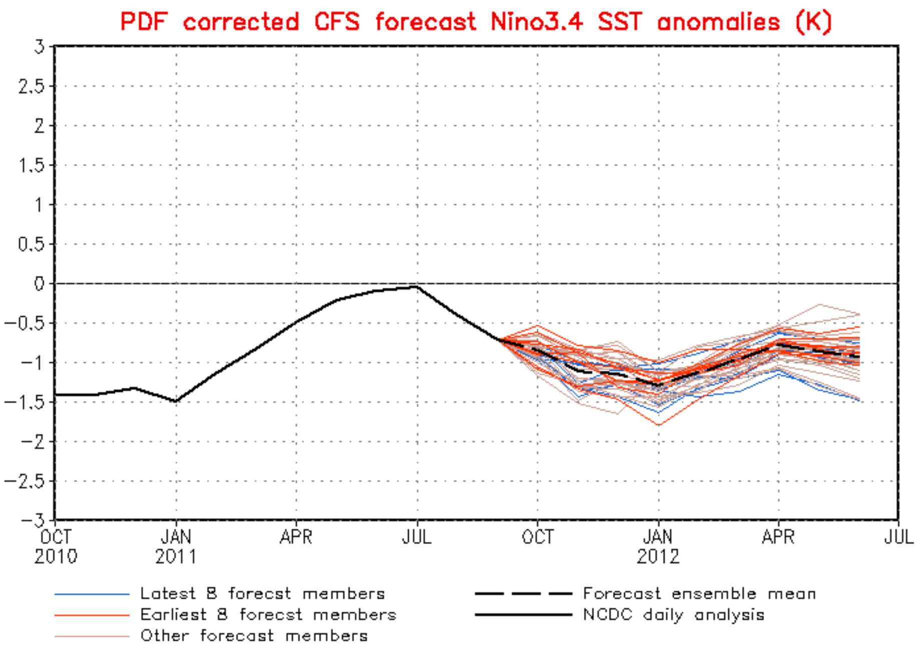
IRI NINO3.4 Forecast Plum



- The majority of models predicted weak to moderate La Nina conditions in the winter 2011/12.

NCEP CFSv1 and CFSv2 NINO3.4 Forecast

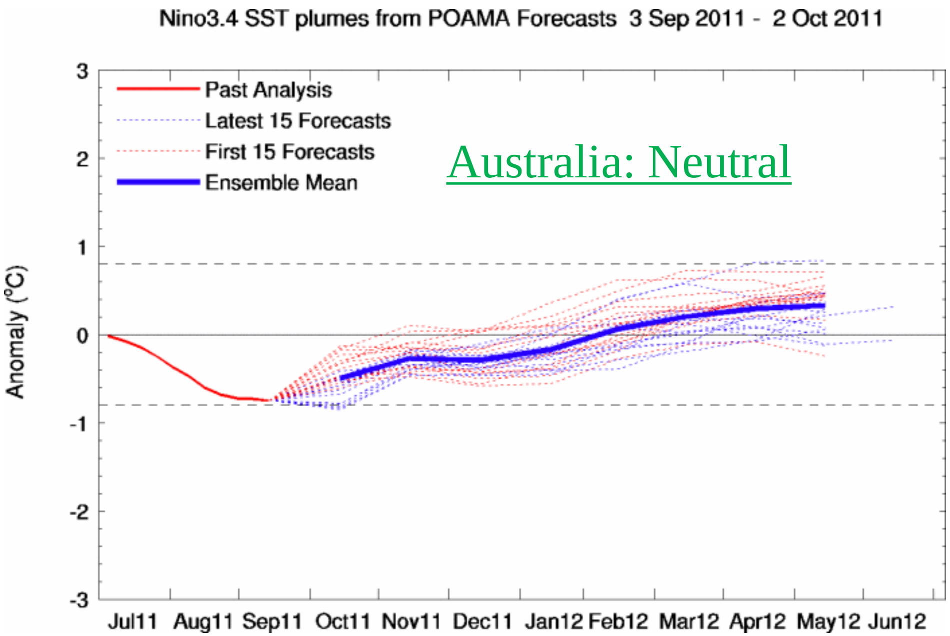




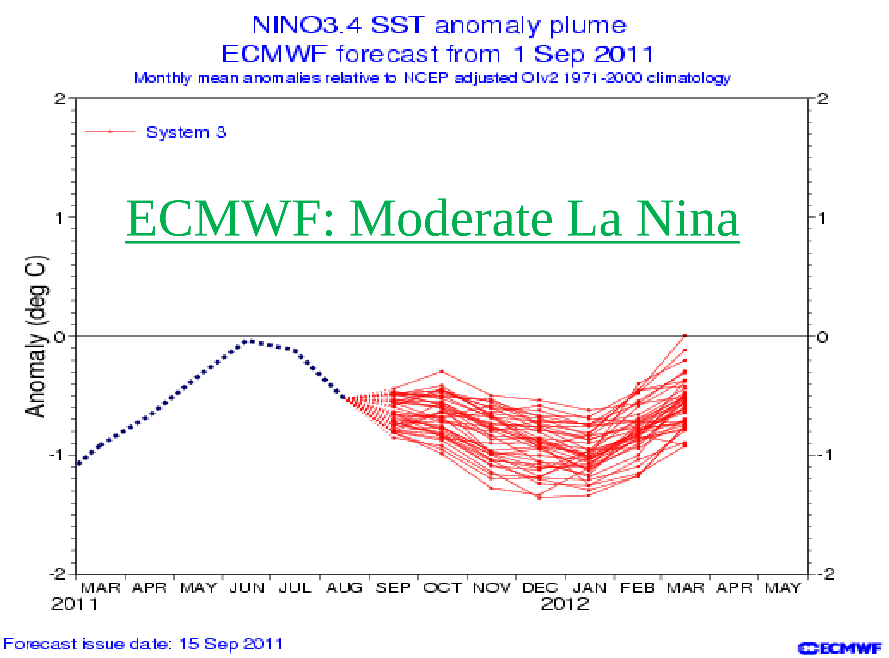
- Both CFSv1 and CFSv2 predicted strong La Nina conditions (NINO3.4 less than -1.5°C) would peak in Mar 2011 and Jan 2011 respectively.

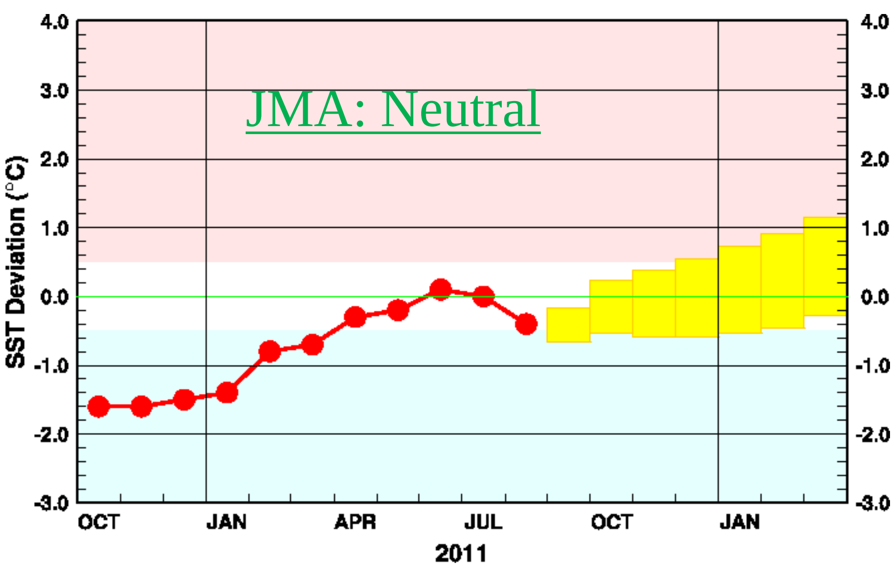
- After a PDF correction, CFSv1 forecast favors moderate La Nina conditions to peak around Jan 2011.

- NOAA "ENSO Diagnostic Discussion" suggests La Niña conditions are expected to gradually strengthen in fall and a weak or moderate strength La Niña is most likely during the Northern Hemisphere winter.

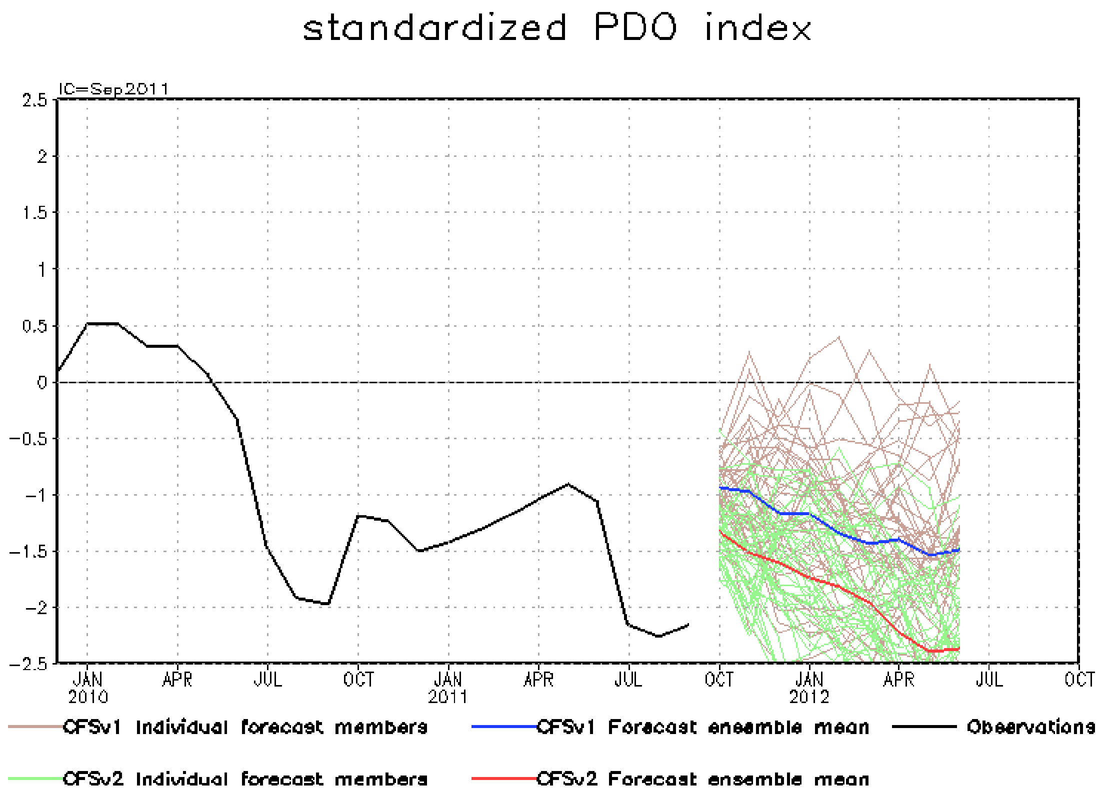


- Large spread in NINO3.4 forecast was evident among models: some examples here.



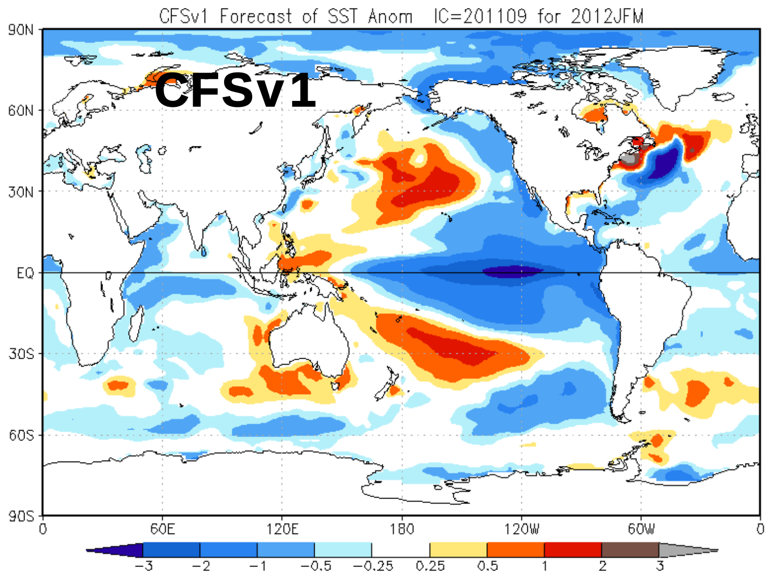


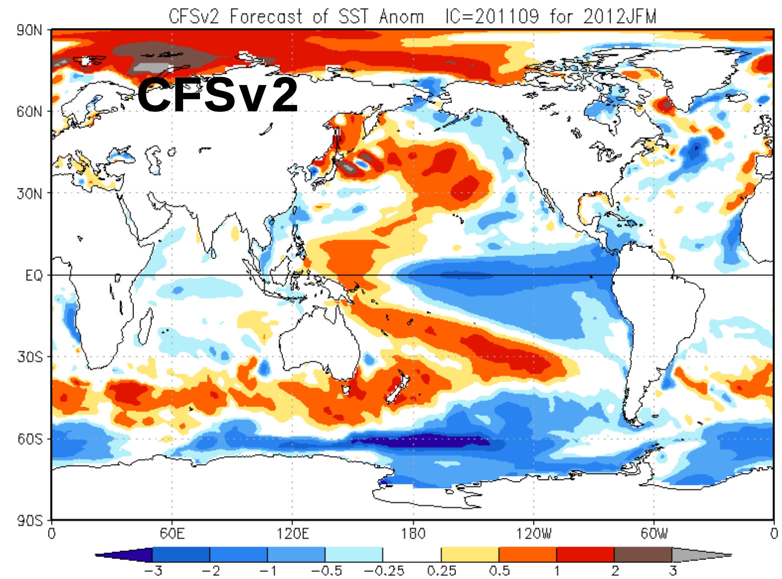
NCEP CFSv1 and CFSv2 PDO Forecast

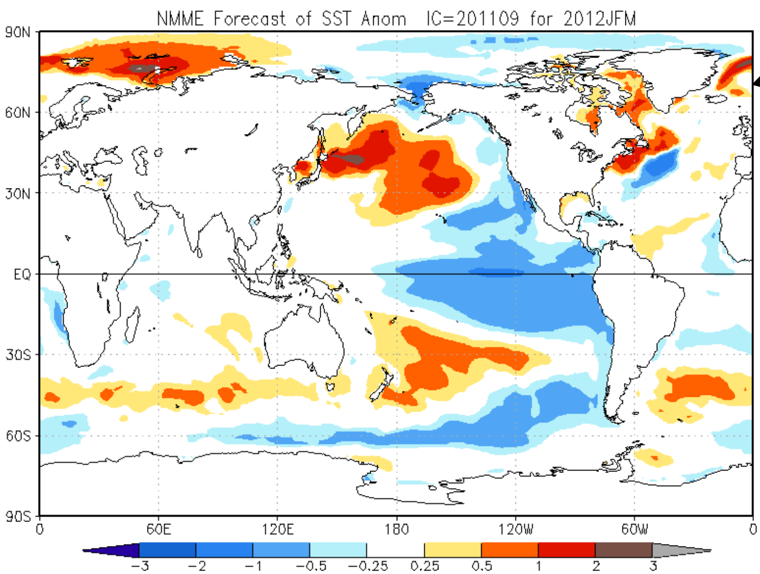


- **Both CFSv1 and CFSv2 predicted that negative PDO phase would last through the Northern Hemisphere winter and next spring.**
- **Both models seems underwent significant initialization shock, but CFSv2 has smaller drift than CFSv1.**

National Multi-Model Ensemble (NMME) SST Forecast for JFM 2011 (Aug 2011 I.C.)







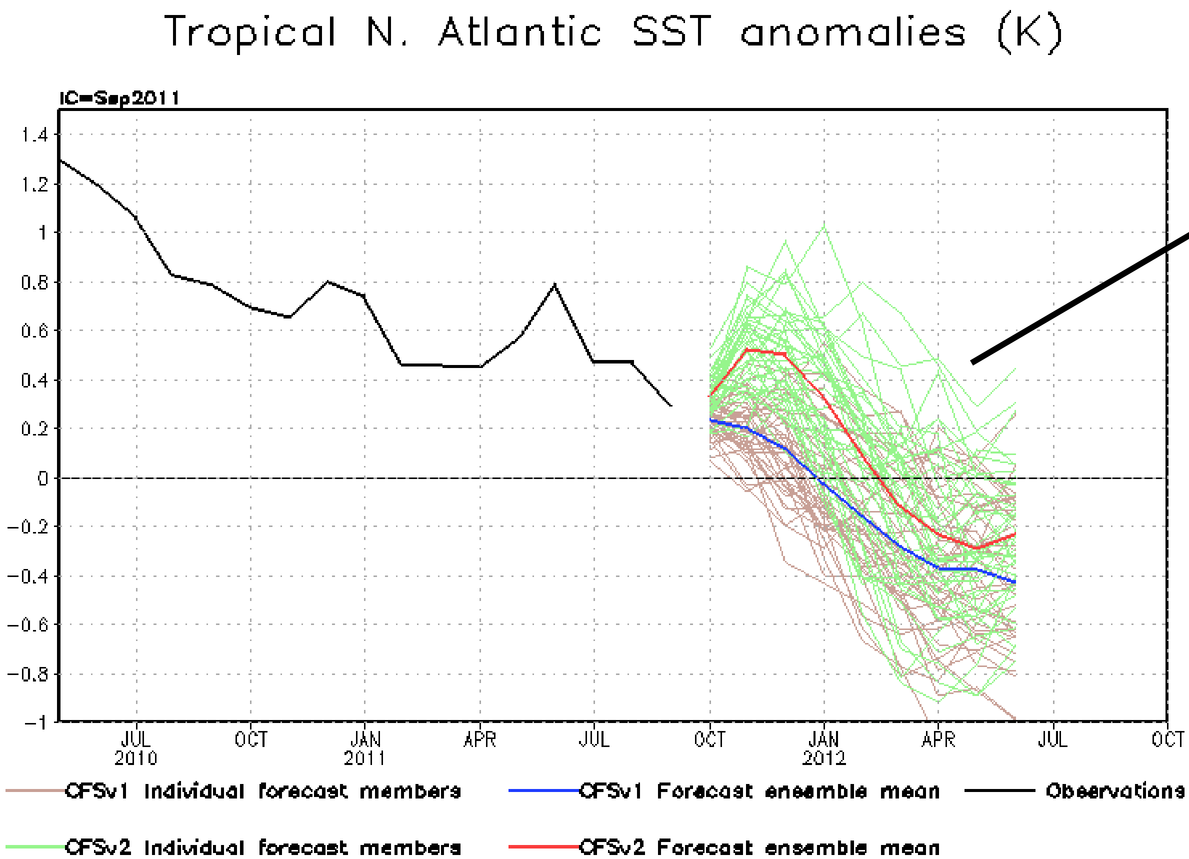
Ensemble Mean of 7 Models
(CFSv1, CFSv2, ECHAMA, ECHAMF, GFDL, NCAR, NASA)

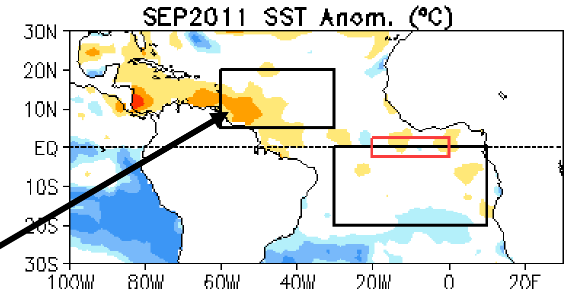
http://origin.cpc.ncep.noaa.gov/products/people/wd51yf/NMME
experimental product

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

- Ensemble mean forecast (EMF) favors La Nina conditions and negative PDO in JFM.
- CFSv2 forecast agrees well with EMF.
- Compared to EMF, CFSv1 forecast is too cold and too broad in the tropical Pacific, too cold near the Kuroshio Extension, tropical Indian and Atlantic Ocean.

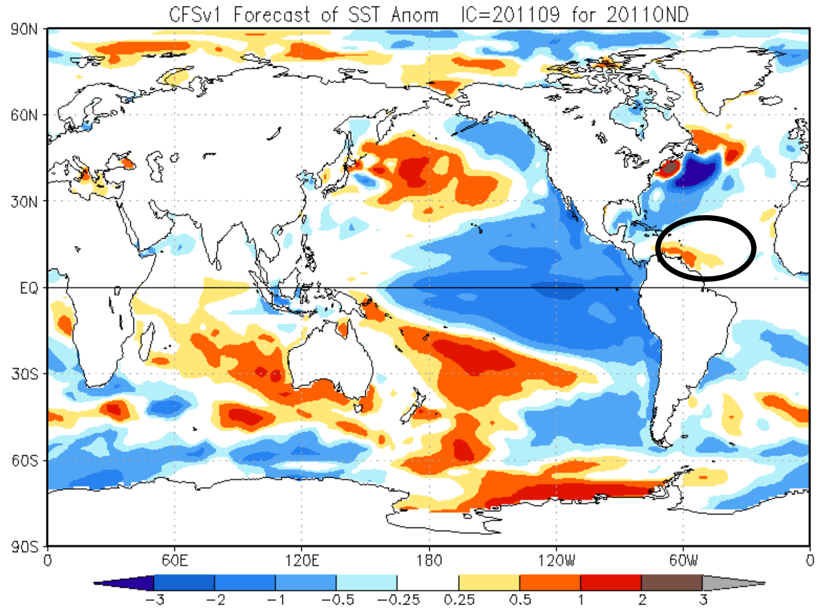
NCEP CFSv1 and CFSv2 Tropical North Atlantic SST Forecast

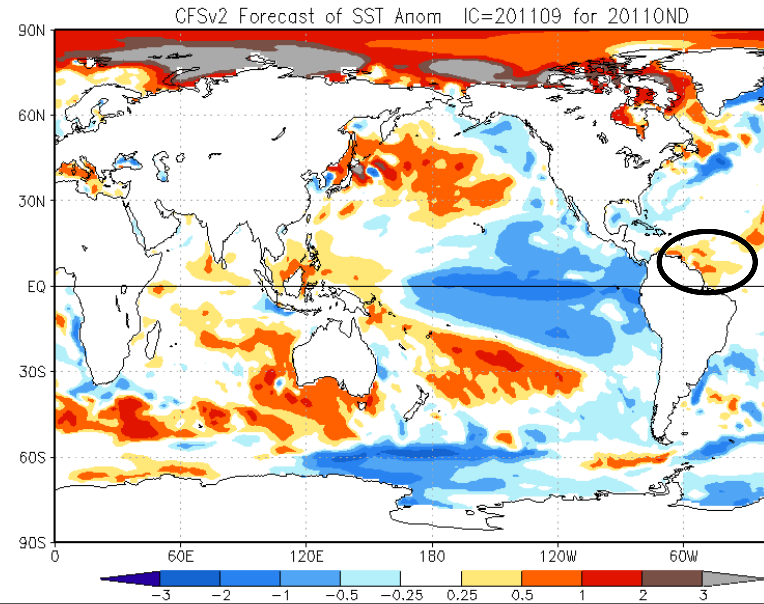


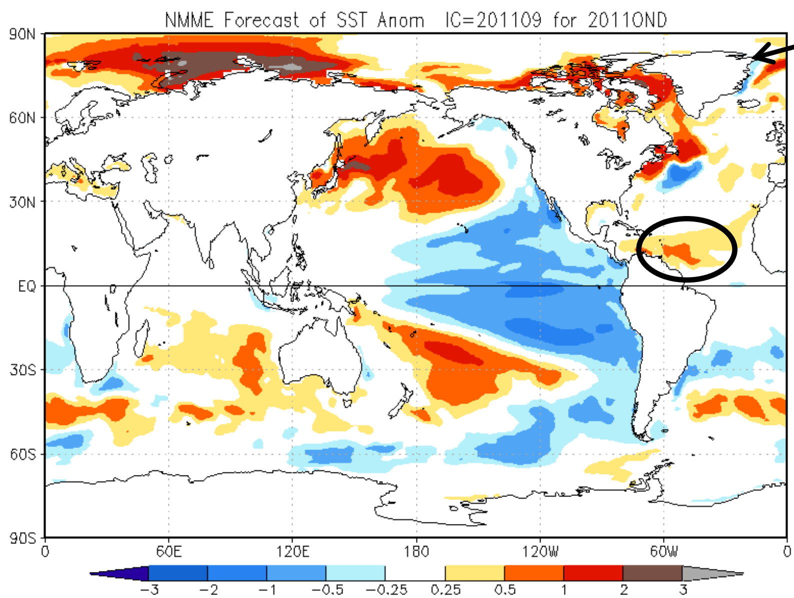


- Both CFSv1 and CFSv2 predicted tropical North Atlantic (TNA) SST would remain above-normal during the remaining hurricane season.
- CFSv1 suggested positive TNA would weaken gradually and switch to negative in mid-winter, continuing to cool in spring 2012.
- However, CFSv2 forecast positive TNA would strengthen in next 2-3 months, and switch to negative in early spring 2012.

National Multi-Model Ensemble (NMME) SST Forecast for OND 2011 (Aug 2011 I.C.)







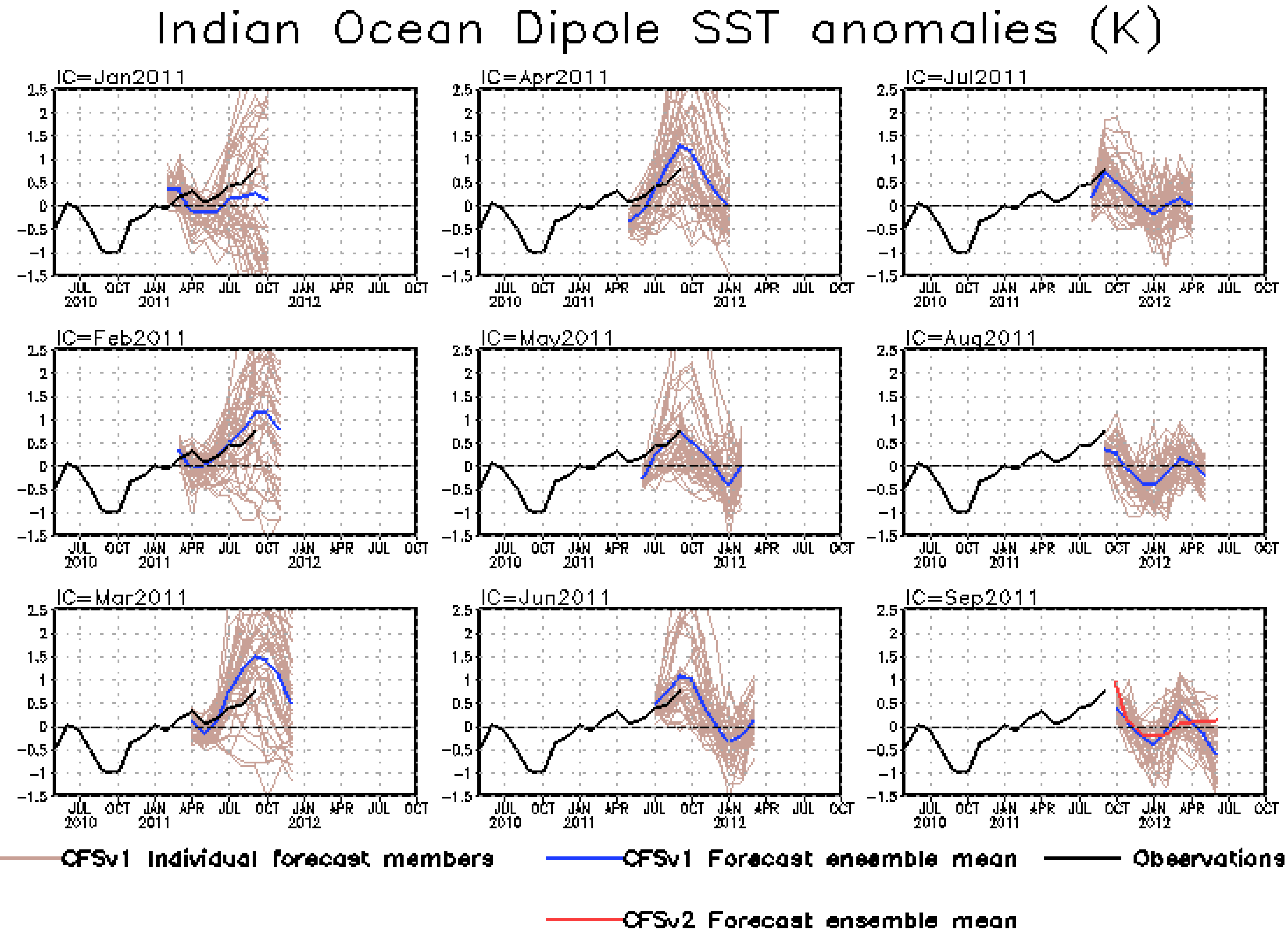
Ensemble Mean of 7 Models
(CFSv1, CFSv2, ECHAMA, ECHAMF, GFDL, NCAR, NASA)

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

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

- **Ensemble mean forecast (EMF) favors above-normal tropical North Atlantic SST in OND.**
- **CFSv2 forecast agrees with EMF better than CFSv1 forecast.**

NCEP CFS DMI SST Predictions from Different Initial Months



DMI = WTIO- SETIO

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

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

- The onset of positive IOD in fall 2011 was forecast well by CFSv1 since Feb 2011.
- However, the spread among ensemble members is quite large.

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.

Overview

- **Pacific and Arctic Oceans**
  - La Nina conditions persisted with NINO3.4=-0.7°C in Sep 2011.
  - Some models, including CFSv1 and CFSv2 predicted moderate to strong La Nina conditions in the Northern Hemisphere winter.
  - Negative PDO persisted, with PDOI=-1.9 in Sep 2011.
  - Both CFSv1 and CFSv2 predicted the negative phase of PDO would last through the Northern Hemisphere winter and spring.
- **Indian Ocean**
  - Easterly wind anomalies have persisted in the east-central tropical Indian Ocean since May 2011, and positive IOD conditions emerged with DMI=0.75°C in Sep 2011.
- **Atlantic Ocean**
  - Positive SSTA and below-normal vertical wind shear in the Atlantic Hurricane Main Development Region in JJAS 2011 are much weaker than those in JJAS 2010.
  - In JJAS 2011, similar to JJAS 2010, North Atlantic Subtropical High retreated eastward, which helps steer tropical cyclones northward and away from the land (Courtesy of Chunzai Wang and David Enfield).

Backup Slides

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

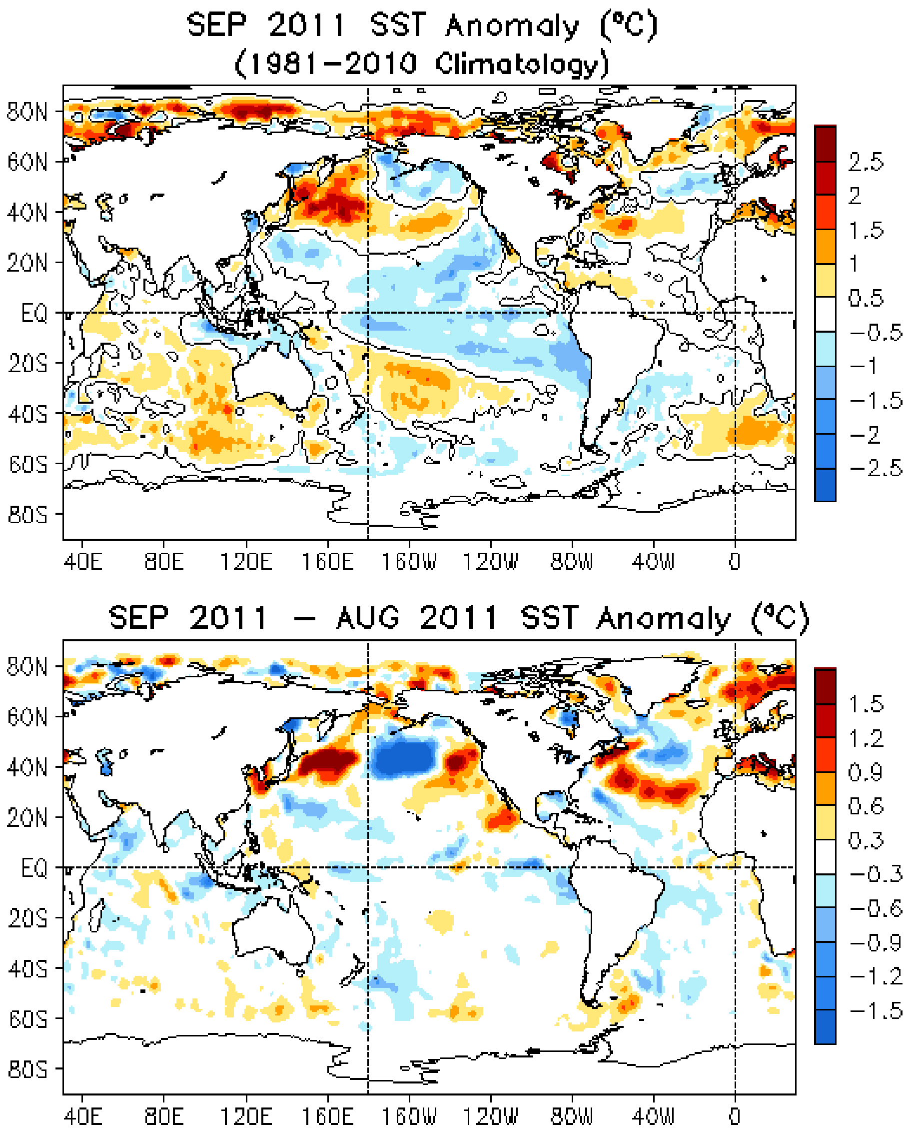


Fig. G1. Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

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

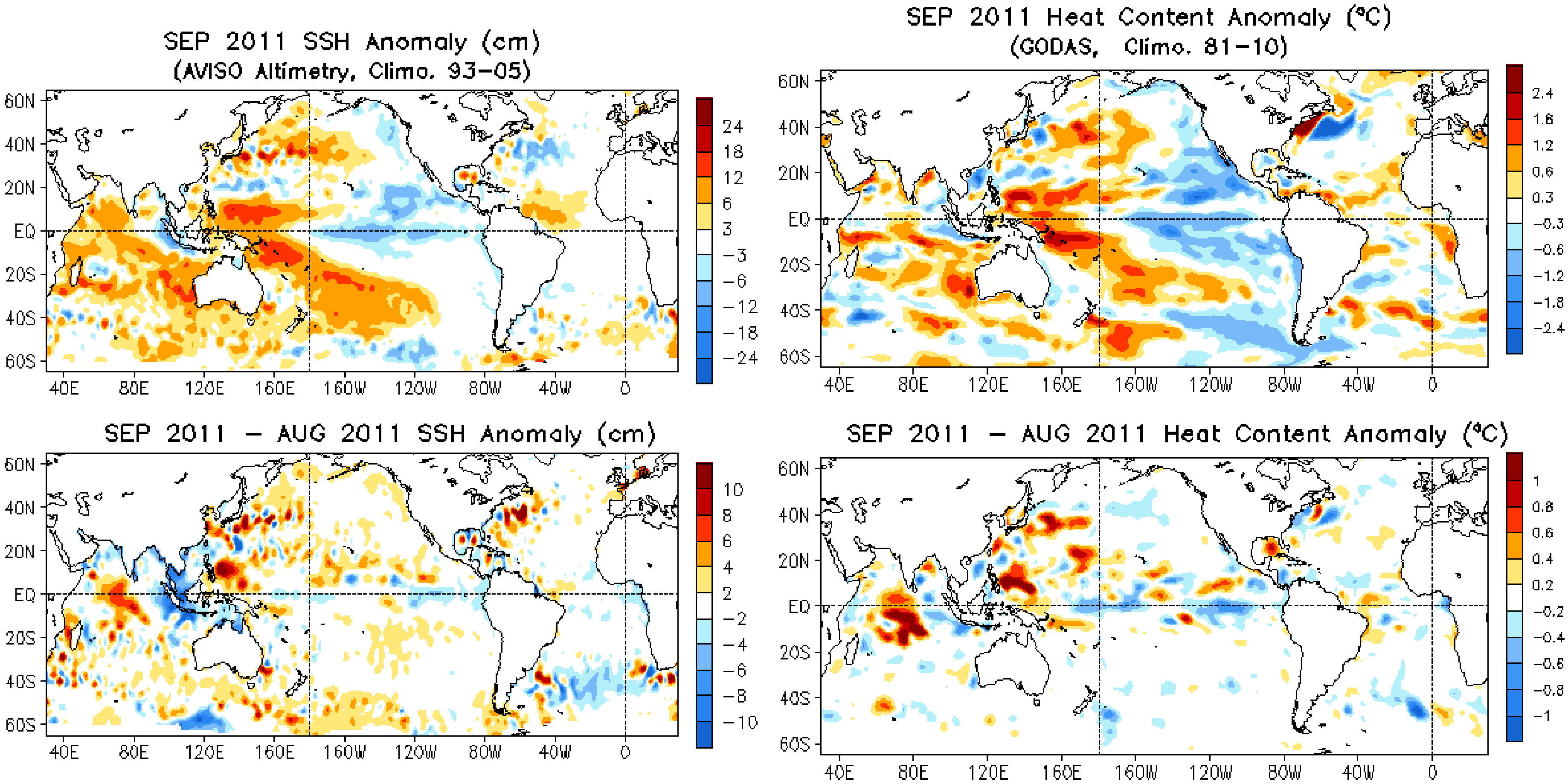
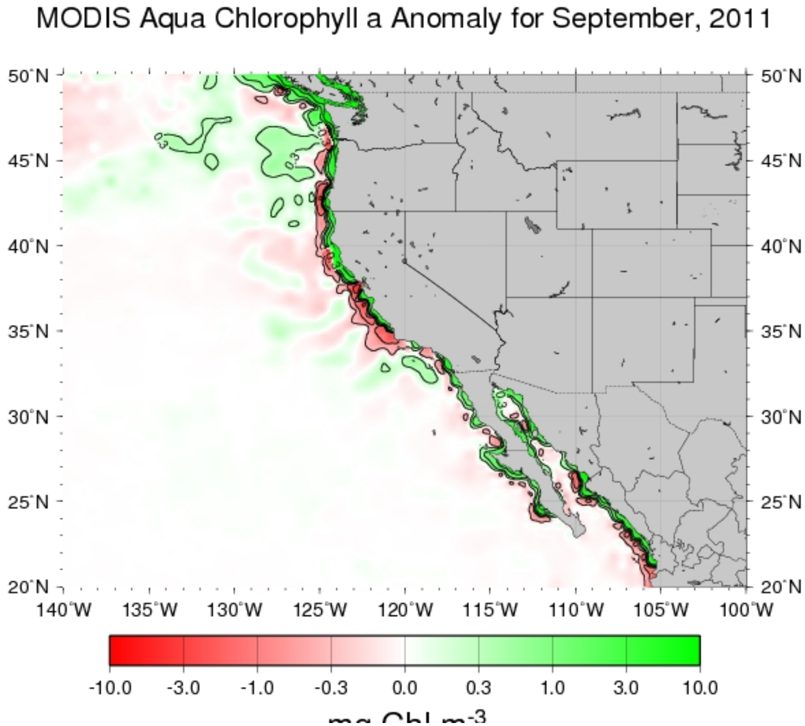
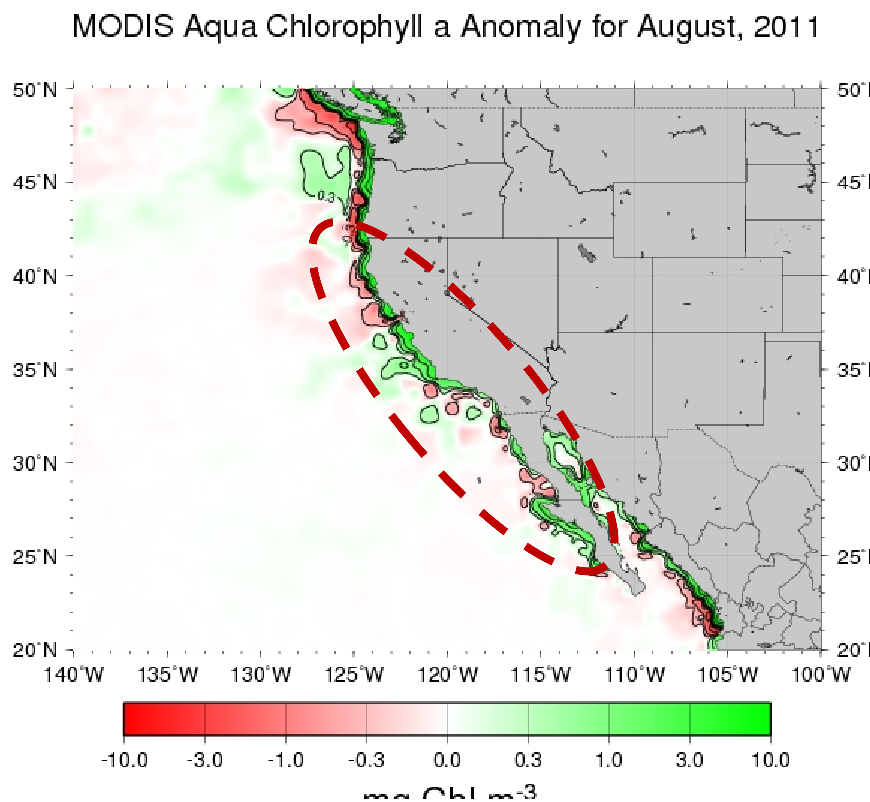


Fig. G2. Sea surface height anomalies (SSHA, top left), SSHA tendency (bottom left), top 300m heat content anomalies (HCA, top right), and HCA tendency (bottom right). SSHA are derived from http://www.aviso.oceanobs.com, and HCA from GODAS.

Monthly Chlorophyll Anomaly



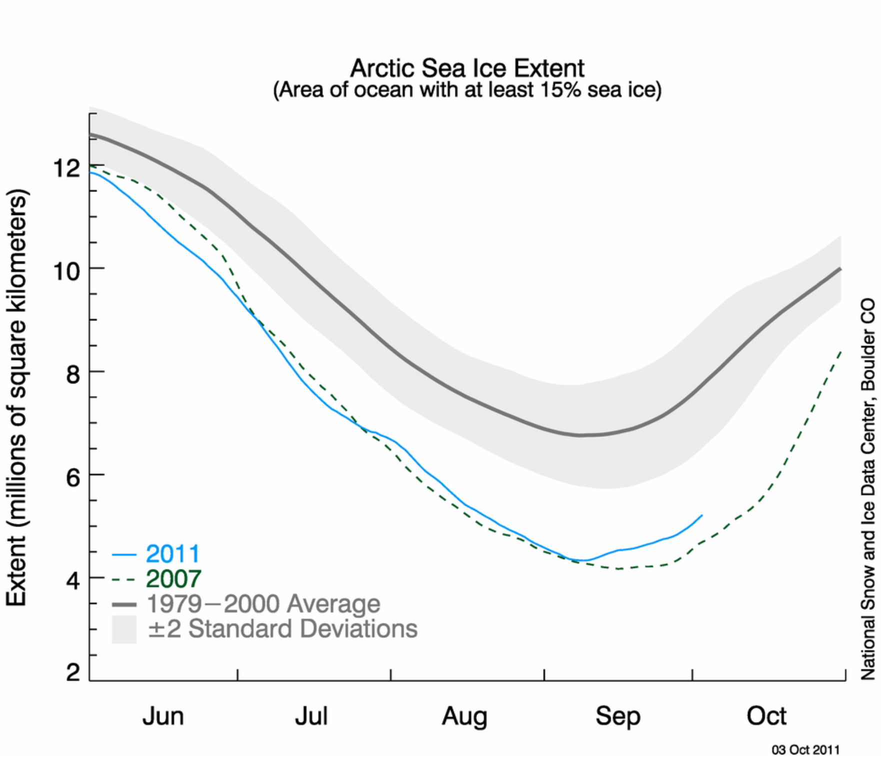


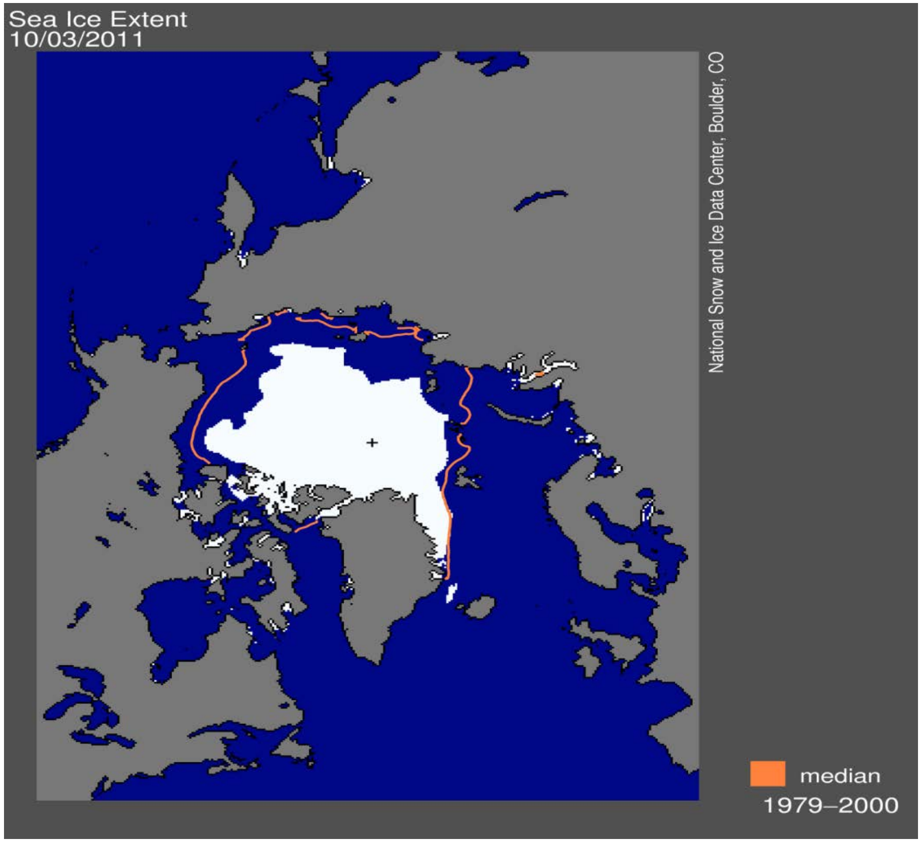
http://coastwatch.pfel.noaa.gov/FAST

Arctic Sea Ice

National Snow and Ice Data Center

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





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.

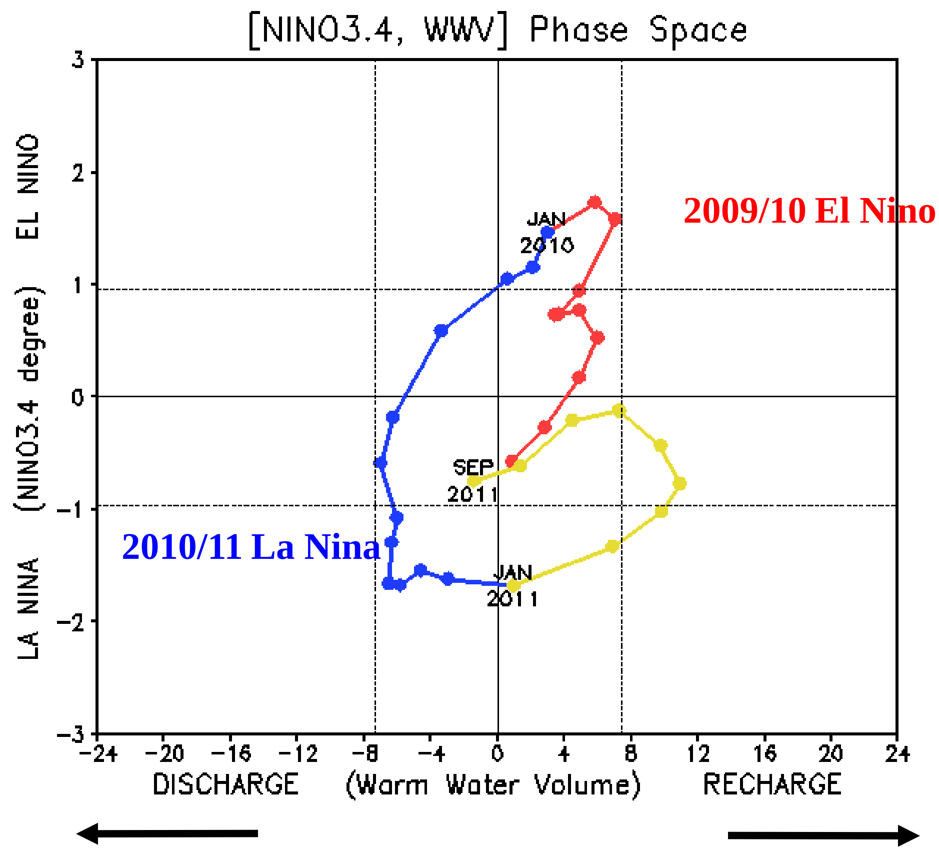


Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

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

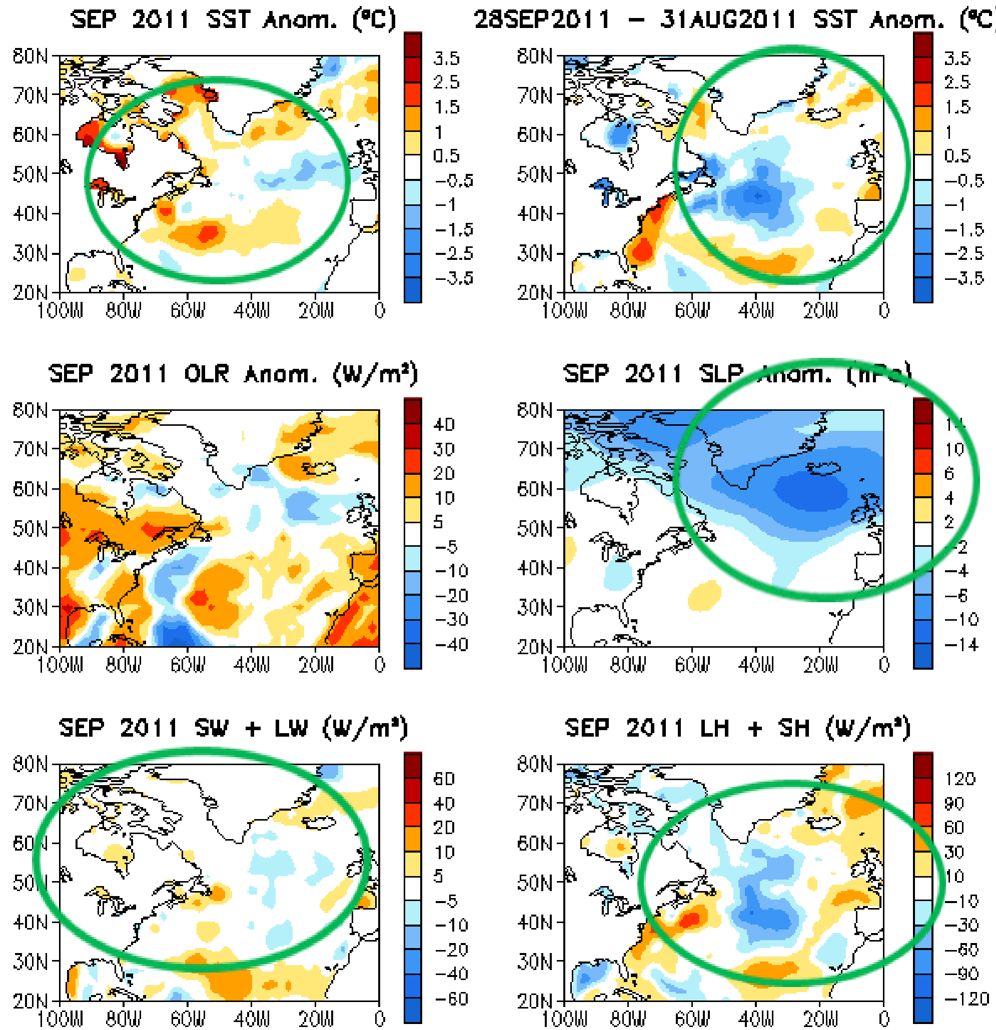


Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

CFS Niño3.4 SST Predictions from Different Initial Months

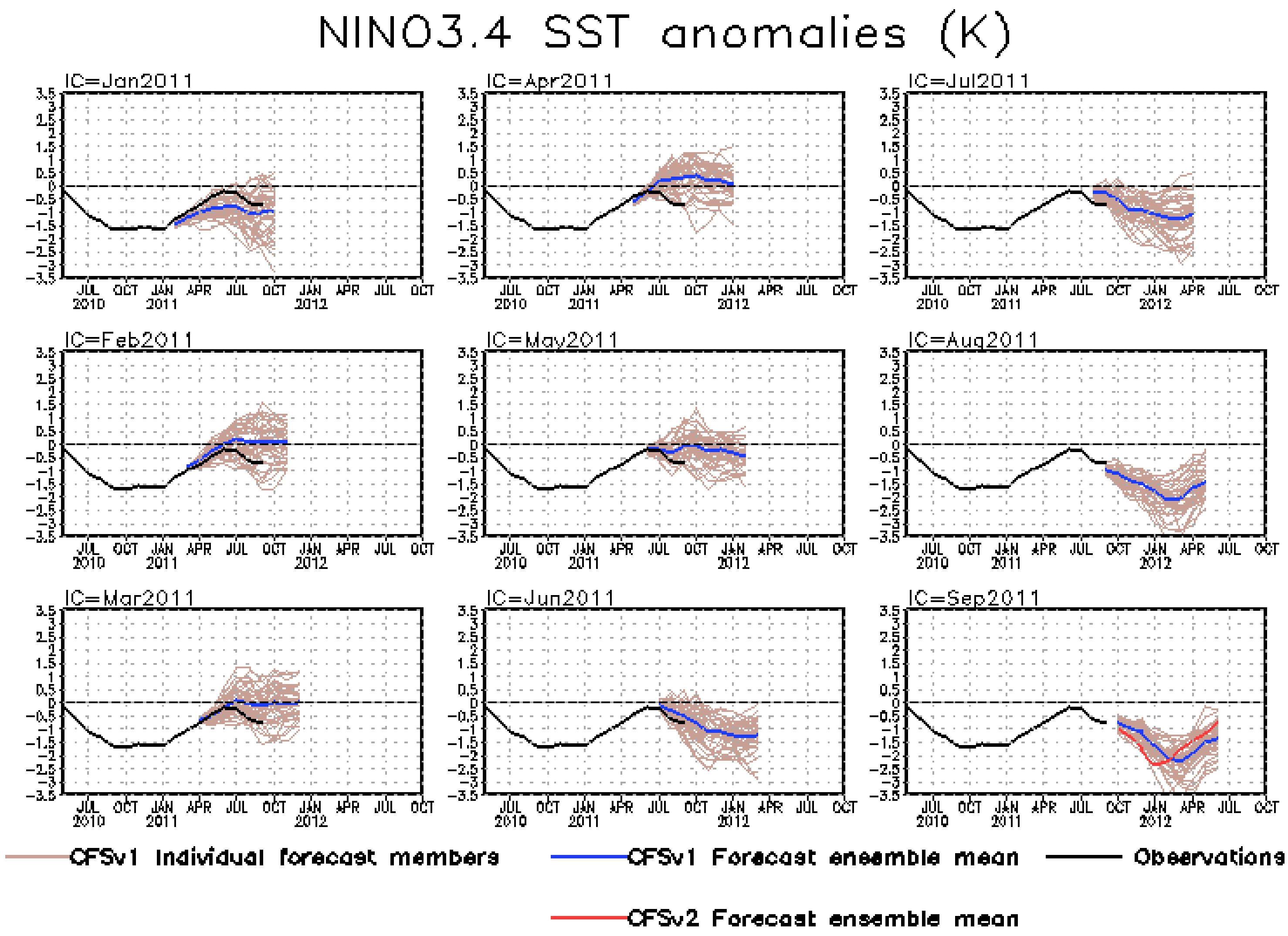


Fig. M1. CFS Nino3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with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

CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months

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

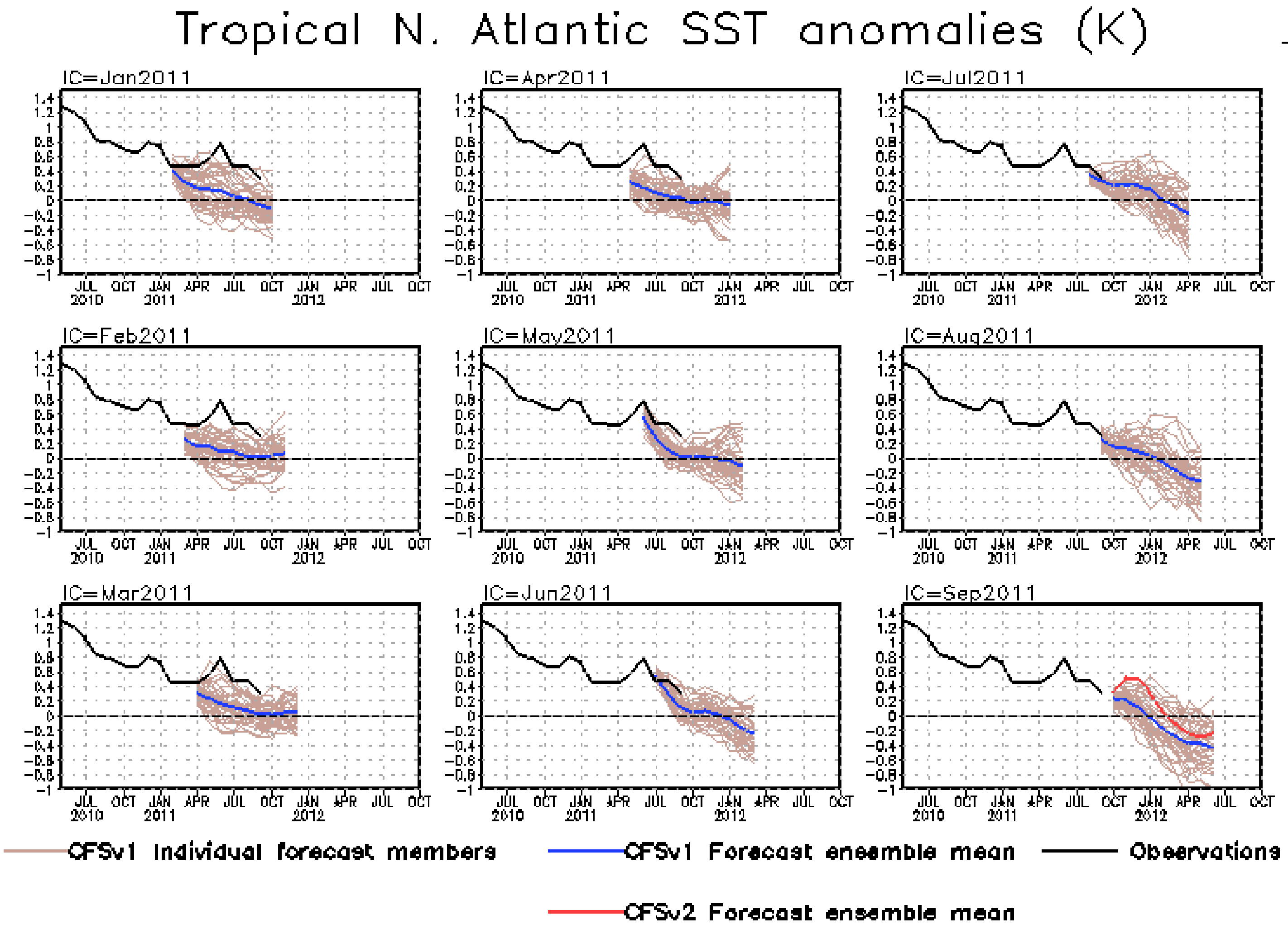


Fig. M3. CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months

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

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

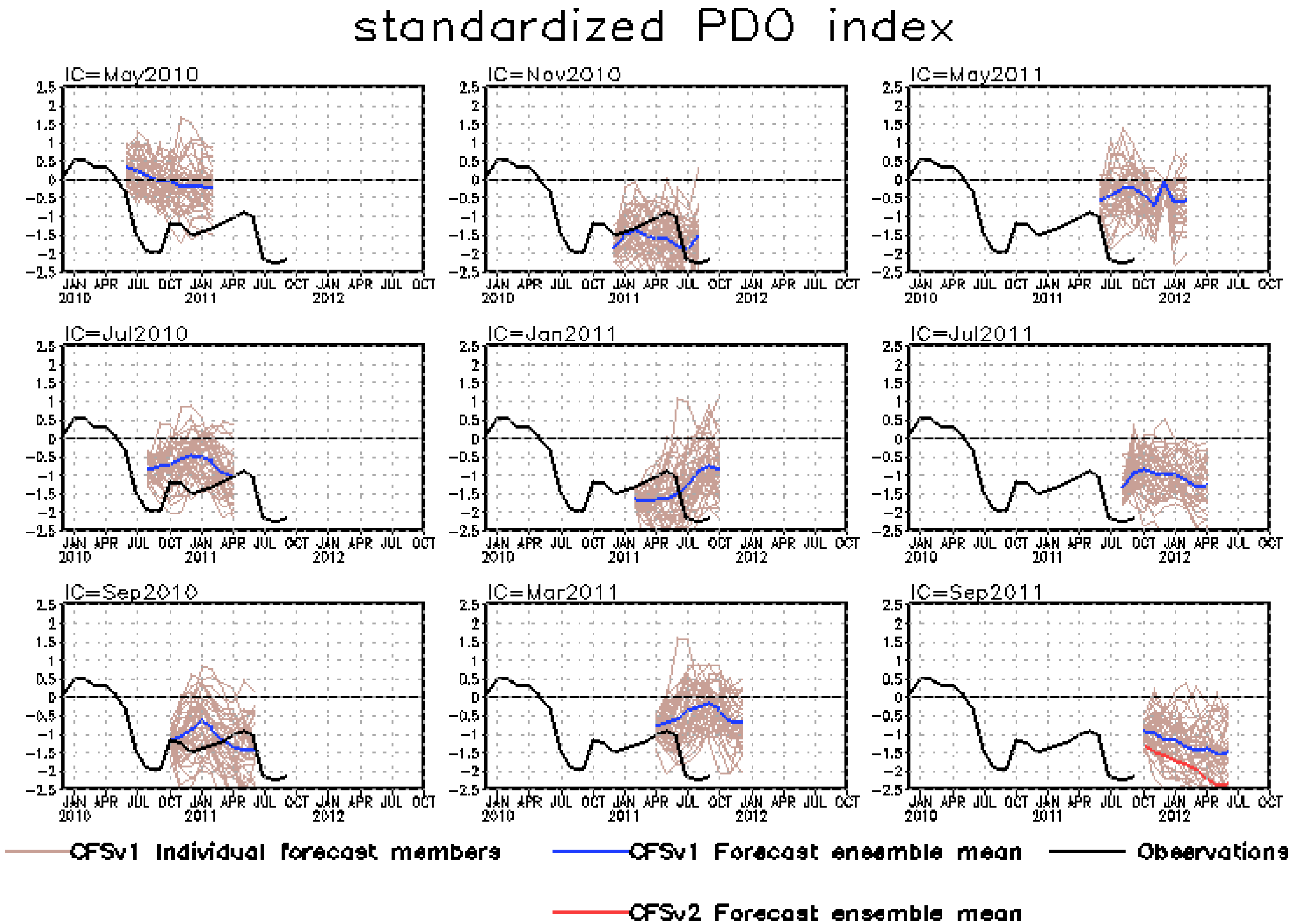
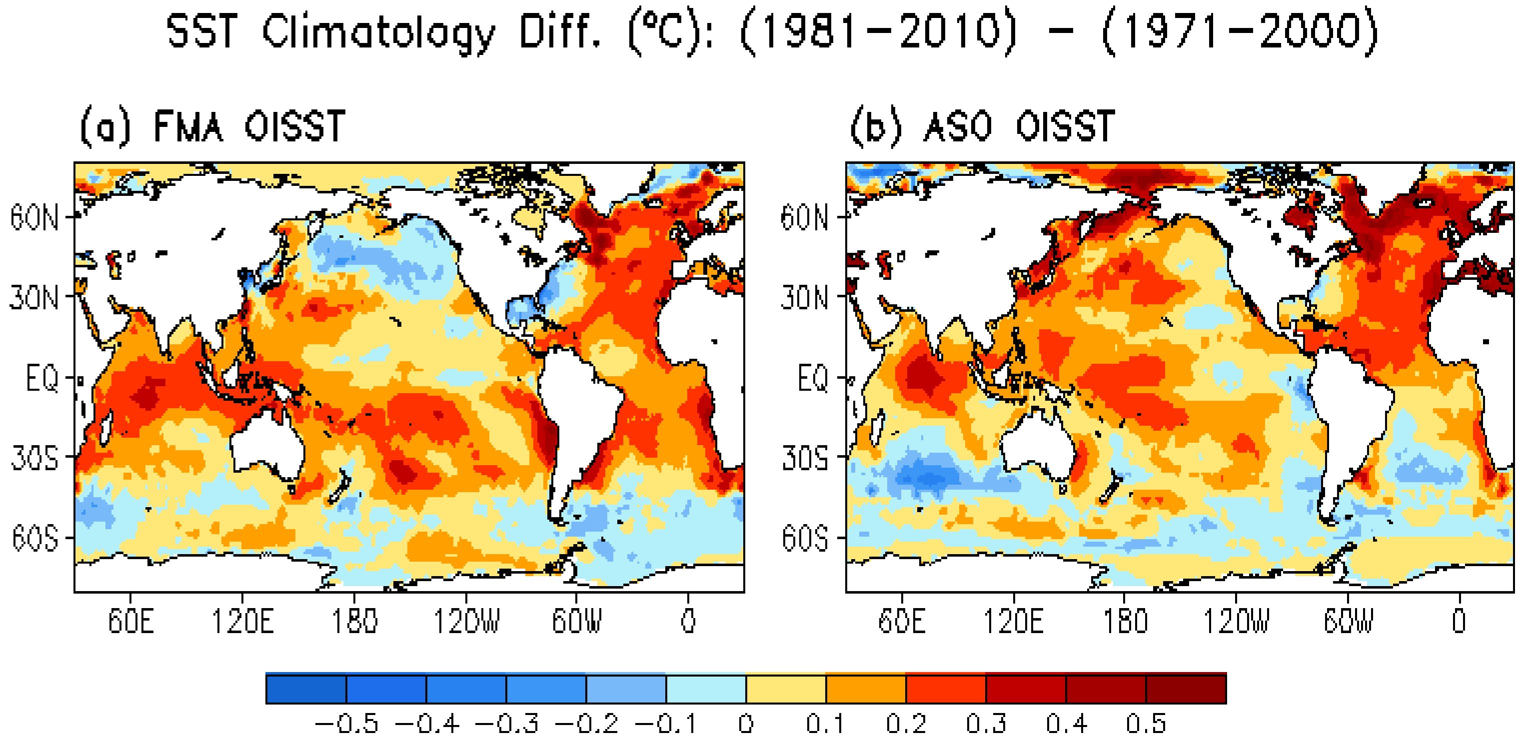


Fig. M4. CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black).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

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!