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

Prepared by

Climate Prediction Center, NCEP

**April 7, 2011**

**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**

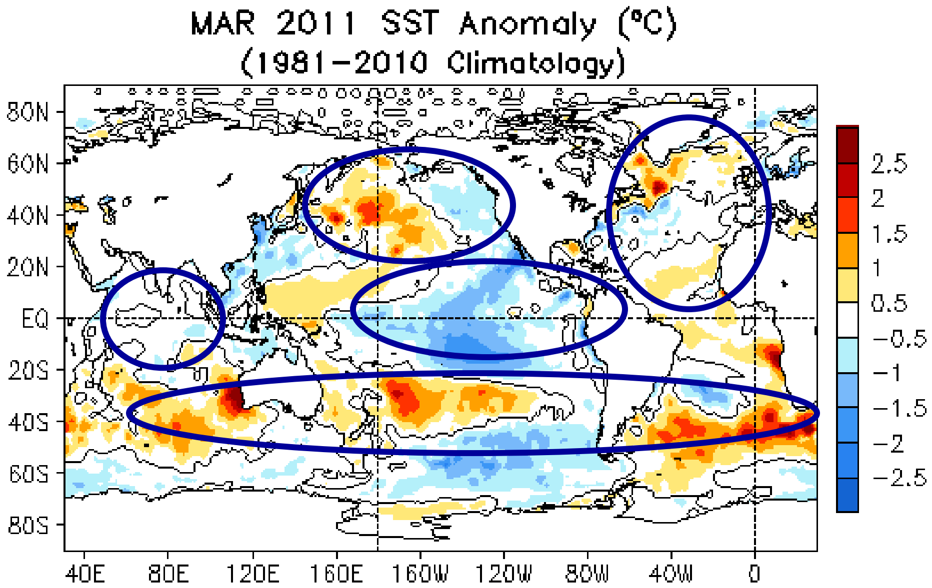
- **Recent highlights**
  - **Pacific/Arctic Ocean**
  - **Indian Ocean**
  - **Atlantic Ocean**

- **CFS SST Predictions**

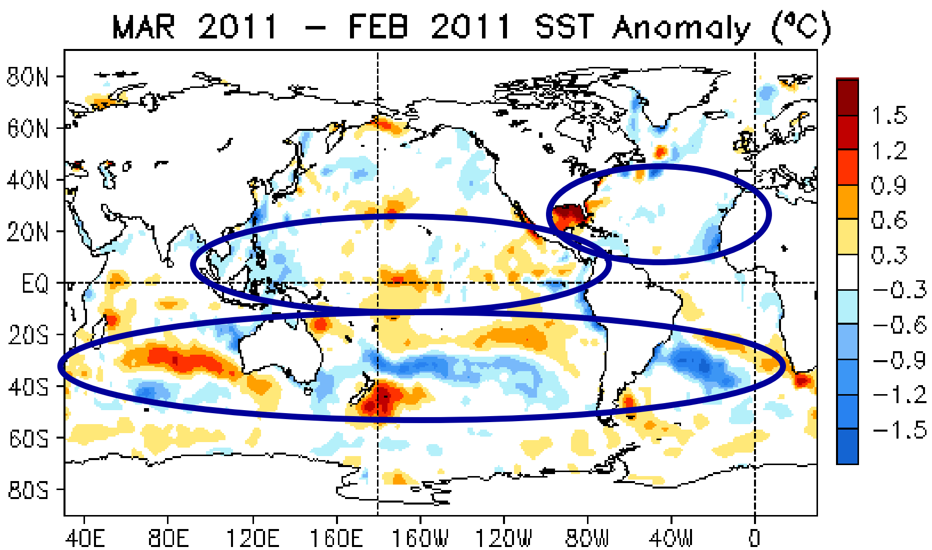
# Overview

- **Pacific and Arctic Oceans**
  - **ENSO cycle: La Niña conditions continuously weakened with OISST NINO3.4=-1.0°C in Mar 2011.**
  - **NOAA/NCEP Climate Forecast System (CFS) suggests that the current La Niña is in a decay phase, and ENSO will be near neutral by summer 2011.**
  - **PDO has been negative since Jun 2010, and weakened slightly since Jan 2011 with PDO index=-1.18 in Mar 2011.**
  - **Seasonal downwelling intensified at 35°N-57°N along the west coast of North America in Mar 2011, leading to below-normal nutrient supply.**
  - **Artic sea ice extent was well below normal in Mar 2011, and it was the second-lowest ice extent for the month in the satellite record, after 2006.**
- **Indian Ocean**
  - **SSTA was small negative.**
- **Atlantic Ocean**
  - **After 16 month persistent negative phase (Oct 2009-Jan2011), NAO has switched to positive phase since Feb 2011 with NAO index = 0.6 in Mar 2011.**
  - **Tripole SSTA pattern has weakened since Feb 2011.**

# Global SST Anomaly ($^0$C) and Anomaly Tendency



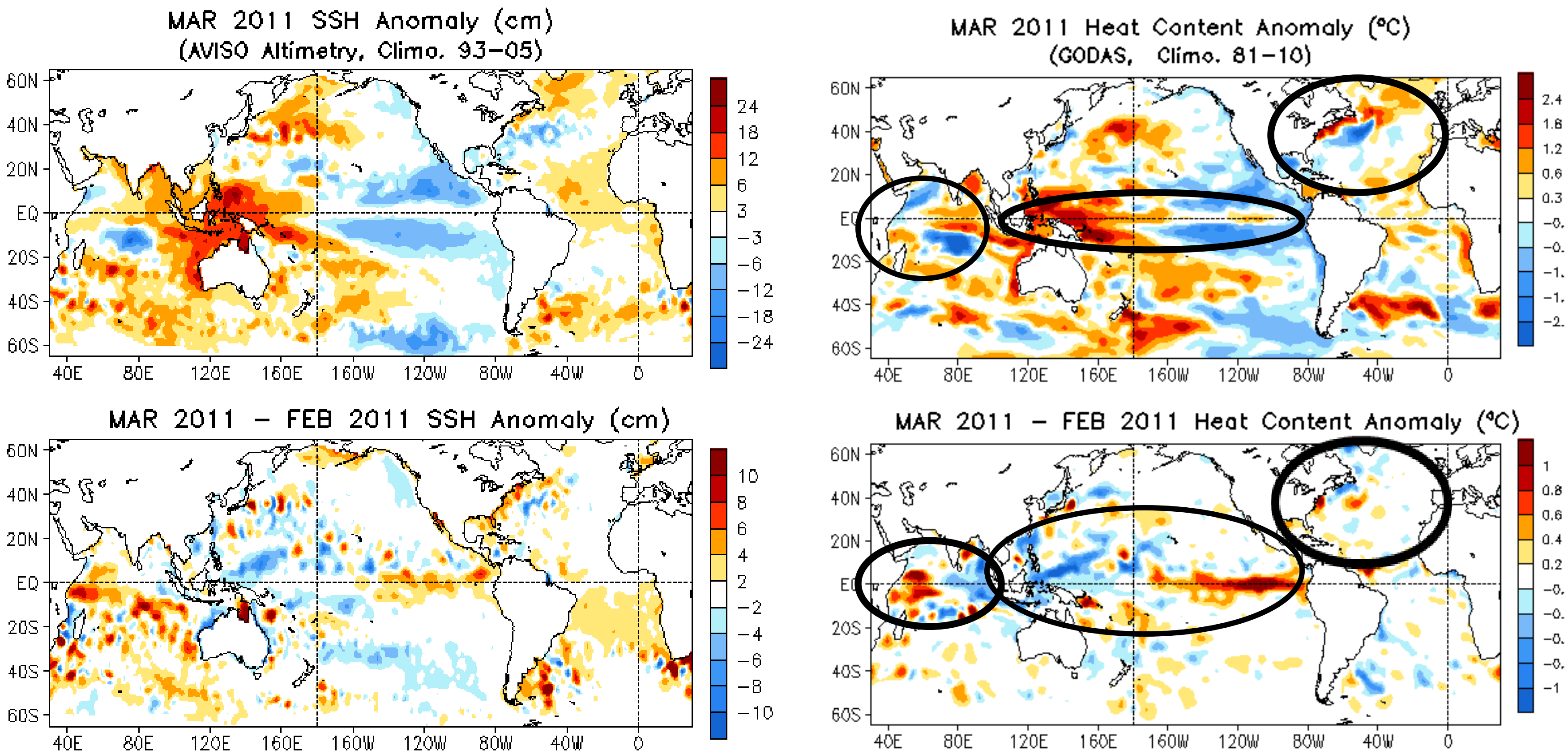

- La Nina conditions presented in the tropical central and eastern Pacific.
- SST anomaly pattern in both N & S Pacific Oceans resembles SST composites of La Nina, suggesting a connection between PDO and ENSO.
- Small negative SSTA was in the Indian Ocean.
- A tripole SSTA pattern existed in North Atlantic.
- Positive SSTA was seen in mid-latitude southern oceans.




- La Nina conditions continue to weaken with positive (negative) SSTA tendency in the central and eastern (NW) tropical Pacific Ocean.
- Strong warming (cooling) tendency in the Gulf of Mexico (North African coast).
- Large SSTA tendency was observed over the 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.

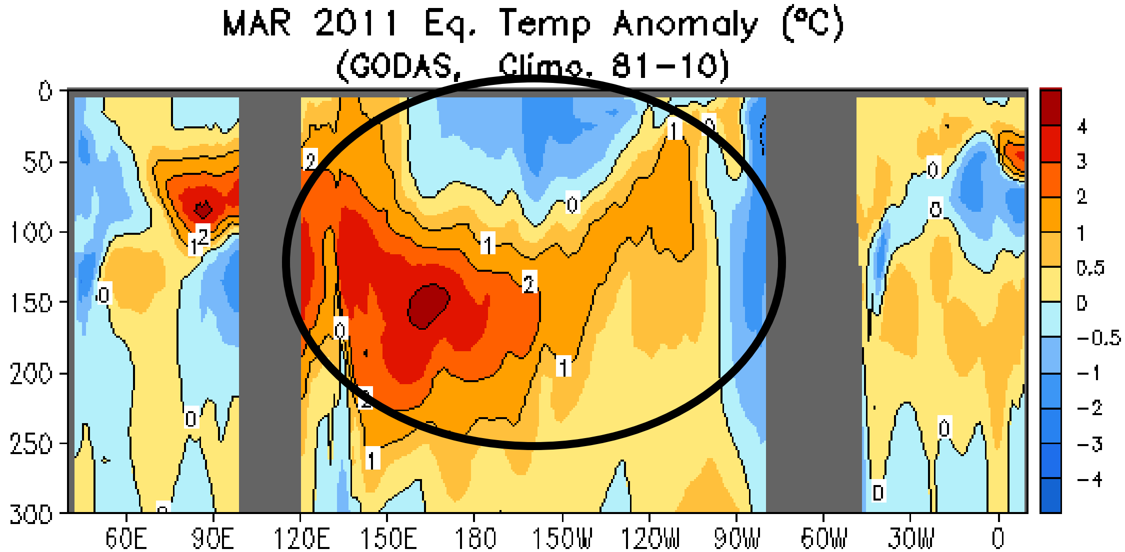
# Global SSH/HC Anomaly (cm/°C ) and Anomaly Tendency



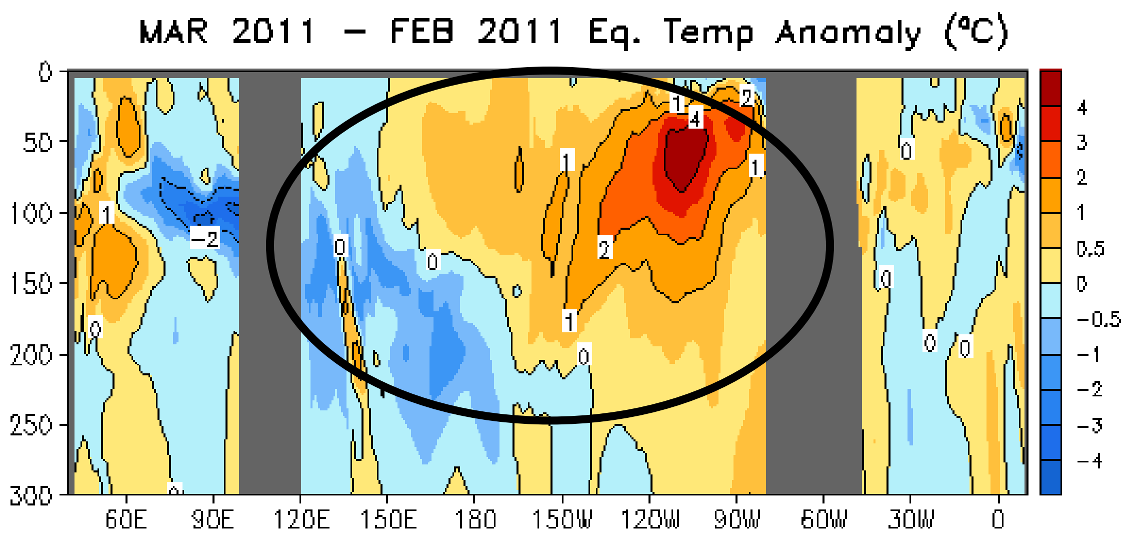

- In the tropical Pacific Ocean, negative (positive) SSHA and HCA presented in the central and eastern (western) basin, but the anomalies along the equatorial central and eastern Pacific weakened significantly, probably reflect the meridional recharge process.
- In the tropical Indian Ocean, positive (negative) SSHA and HCA in the eastern (central) basin weakened, which are probably associated with the weakening of the La Nina conditions.
- In the high latitude of North Atlantic, tripole SSHA and HCA presented.
- SSHA and HCA anomalies as well as their tendencies were largely consistent, except in the Southern Ocean where biases in GODAS climatology are large (not shown).

**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.**

# Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2$^o$S-2$^o$N




- Positive ocean temperature anomalies extent from western to the eastern Pacific along the thermocline layer, which contribute to the weakening of the La Niña conditions.
- Negative (positive) temperature anomalies presented near the thermocline in the equatorial western (eastern) Indian Ocean.
- Both positive and negative temperature anomalies observed cross the equatorial Atlantic Ocean.

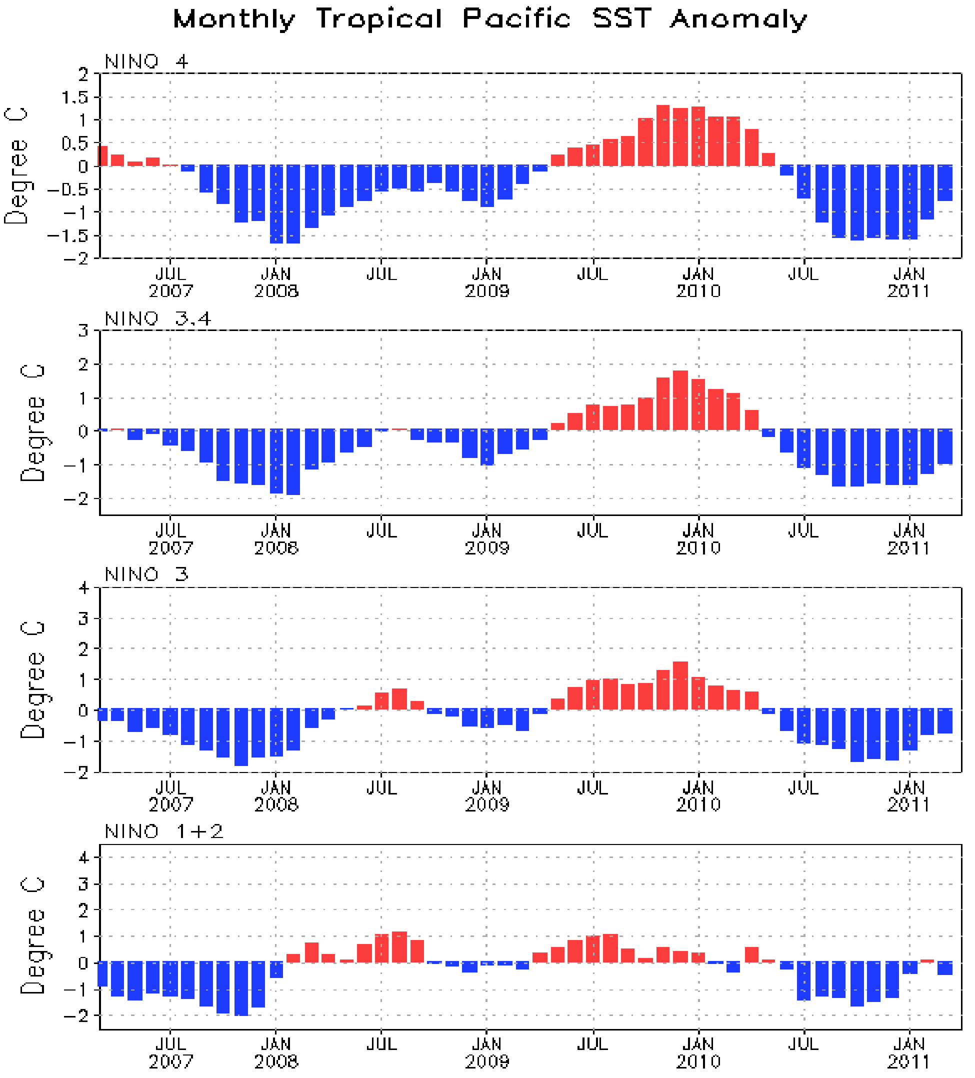


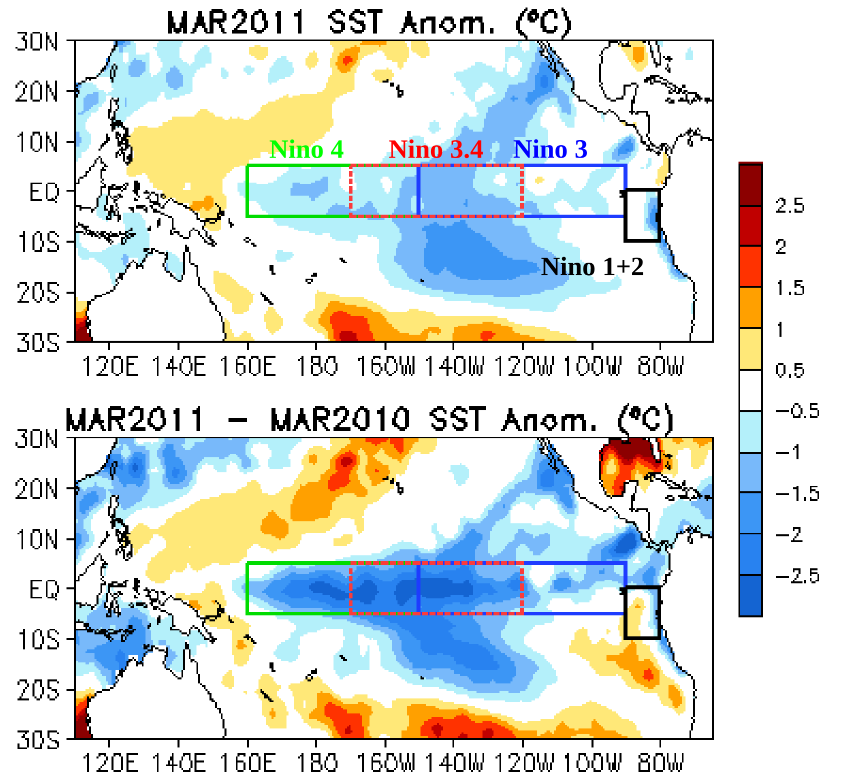

- Temperature increased across much of the equatorial Pacific, particularly between 150$^o$W-90$^o$W, indicating the weakening tendency of the La Nina conditions.
- Both positive and negative temperature anomaly tendencies presented in the equatorial Atlantic and Indian Oceans.

**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 1982-2004 base period means.**

# Tropical Pacific Ocean

# Evolution of Pacific NINO SST Indices



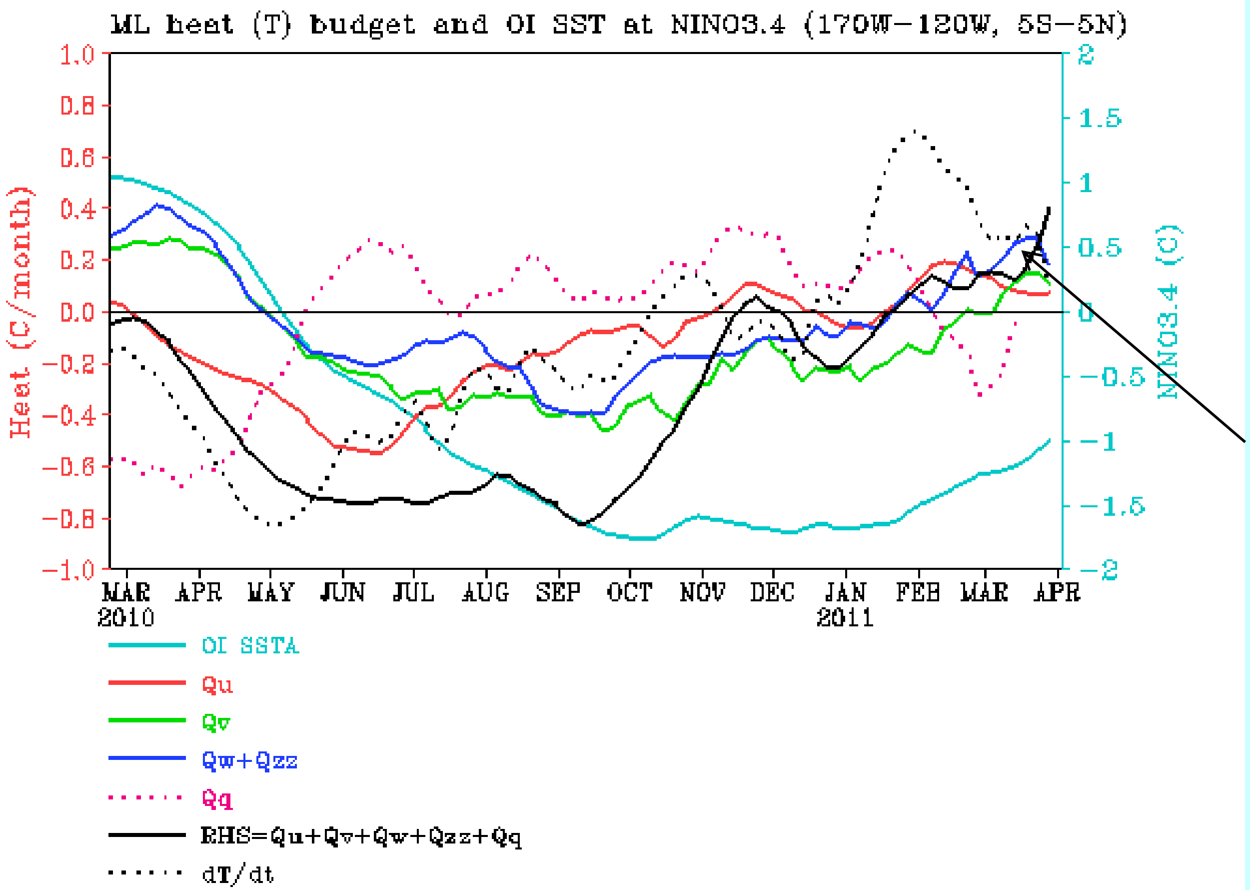




- **All NINO indices weakened, except Nino1+2 which changed from minor positive in Feb 2011 to negative in Mar 2011.**

- **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 (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.**

# NINO3.4 Heat Budget




- **Tendency (dT/dt) in NINO 3.4 (dotted line) has been positive since Jan 2011, indicating the weakening of La Nina.**

- **All dynamical terms (Qu, Qv, Qw+Qzz) were positive in Mar 2011.**

- **The thermodynamic processes (Qq) was positive during Jun 2010-Jan 2011, and negative since Feb 2011.**

- **The total heat budget term (RHS) indicated a warming tendency since Feb 2011, but the overall warming tendency was smaller than dT/dt, particularly in Jan-Feb 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;**

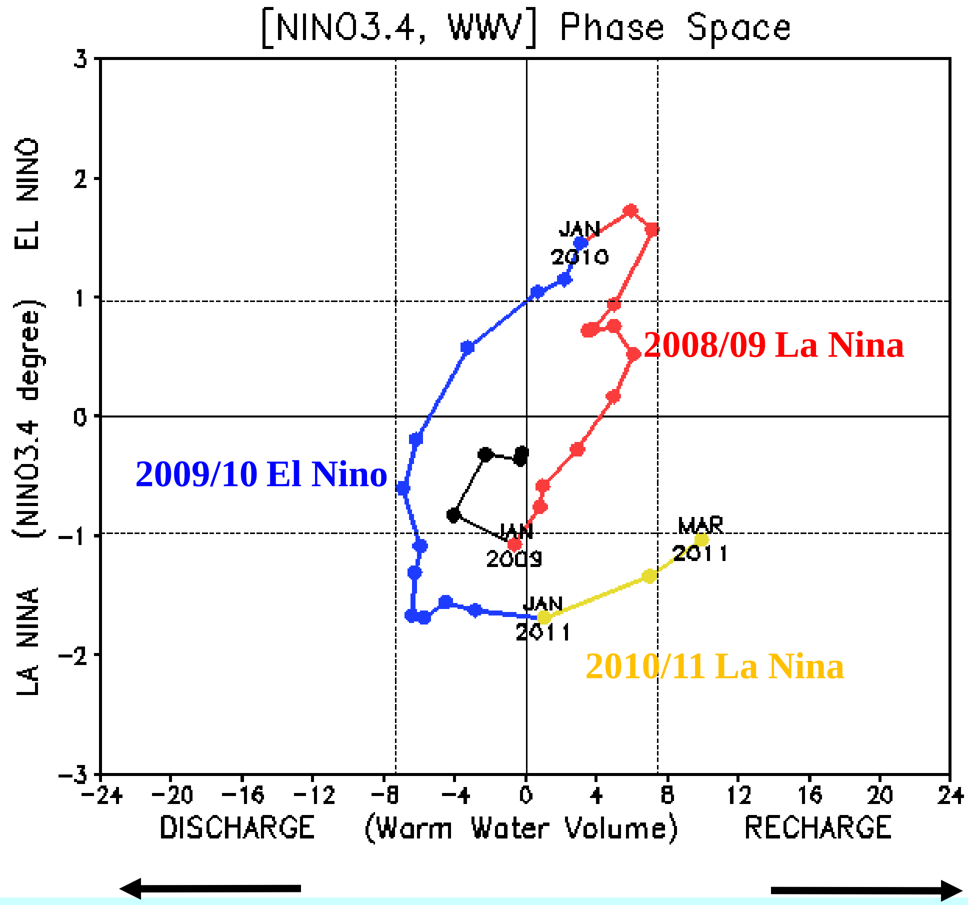
**Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST**

# Warm Water Volume (WWV) and NINO3.4 Anomalies

-WWV is defined as average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] (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.




- Nino3.4 became less than -1ºC since Jul 2010, indicating moderate-strong La Nina conditions.

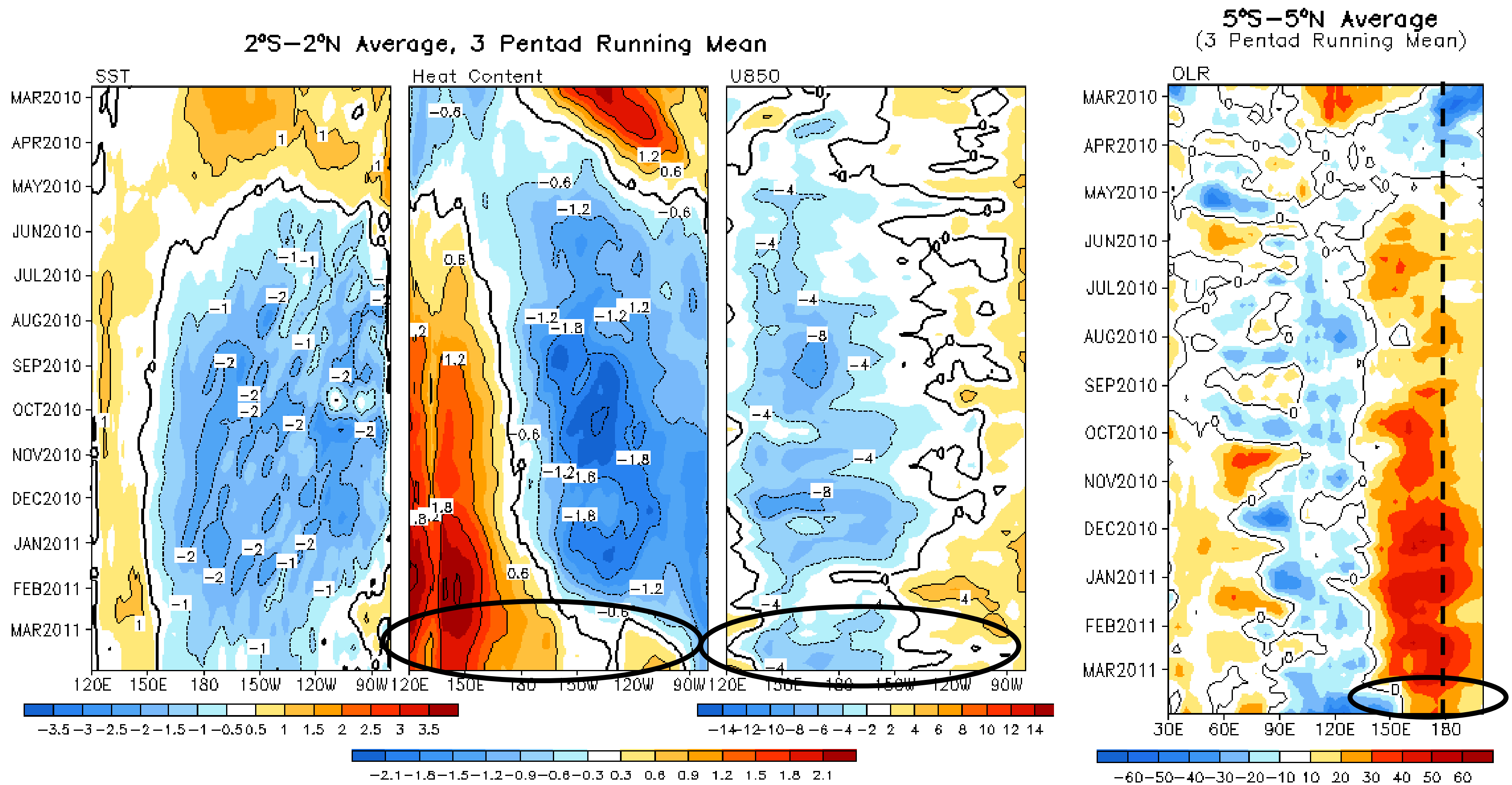
- Nino3.4 has persisted from Sep 2010 to Jan 2011 and weakened since Feb 2011.

- WWV recharge enhanced significantly since Jan2011 due to the recent downwelling Kelvin wave episode and air-sea coupling that links strengthening WWV with increasing NINO3.4.

- Overall consisted with the weakening tendency of La Nina conditions.

Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] calculated with the NCEP's global ocean data assimilation system. Anomalies for WWV (NINO 3.4) are departures from the 1982-2004 (1981-2010) base period means.

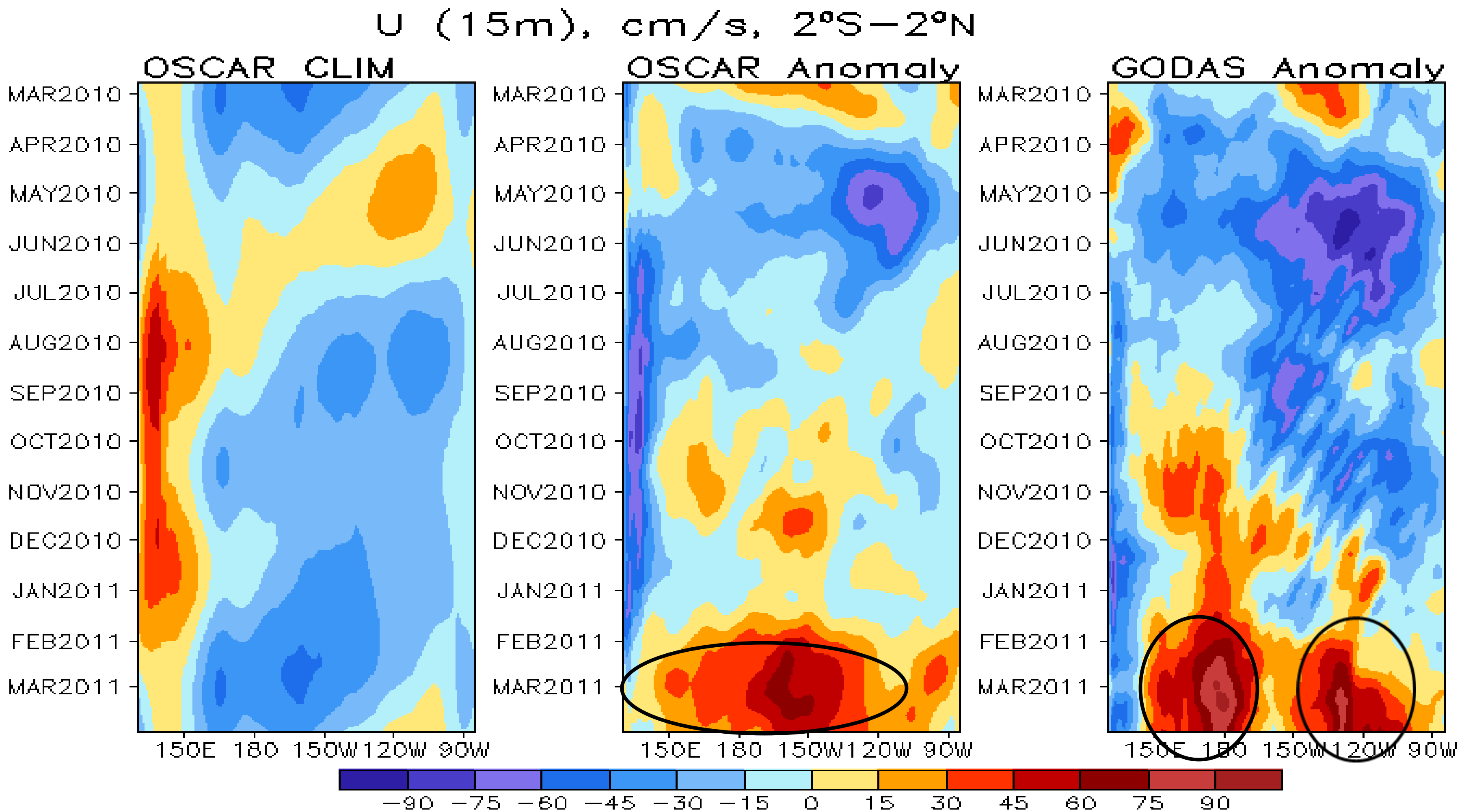
# Evolution of Equatorial Pacific SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s), and OLR (W/m²) Anomaly




- **Positive HC300A in the western and central tropical Pacific presented in response to anomalous easterly winds.**
- **The convection was enhanced (suppressed) over the Maritime Continents (in the central Pacific). Weakening of the suppressed convection was evident in the equatorial central Pacific since mid-Mar 2011.**

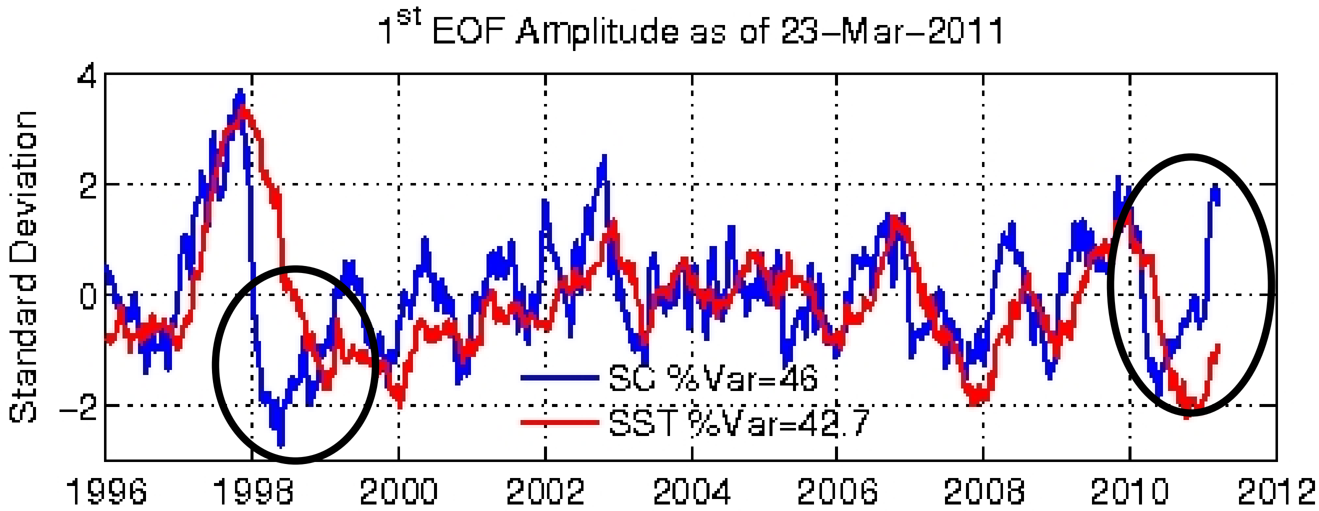
**Fig. P4. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2°S-2°N and Outgoing Long-wave Radiation (OLR, right) averaged in 5°S-5°N. SST is derived from the NCEP 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, 1982-2004, 1979-1995 base period pentad means respectively.**

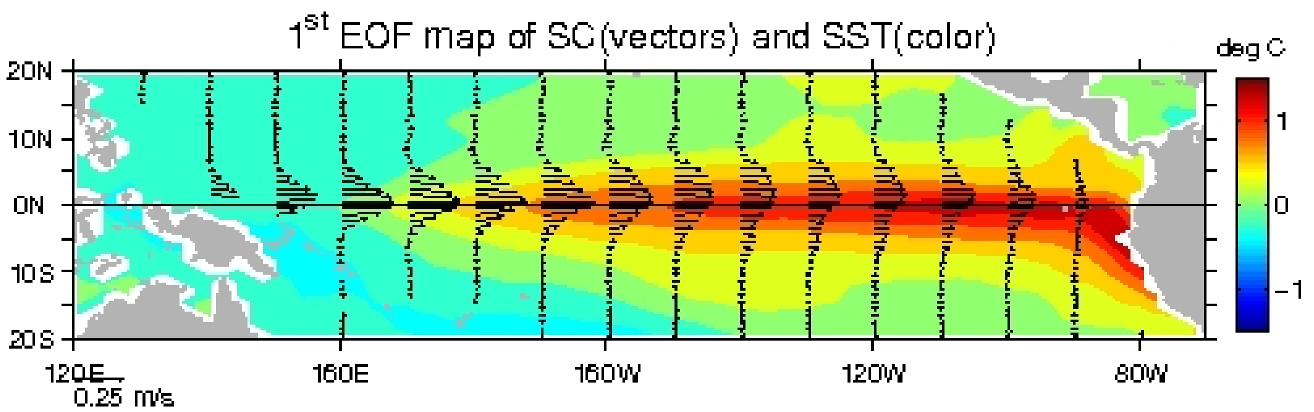
# Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)




- Eastward anomalous current was presented in the central and eastern equatorial Pacific since late Jan 2011, implying reduction of the zonal advection contribution to the cooling associated with the La Niña conditions.
- Anomalous zonal current had one maximum center between 180°-150°W in OSCAR, and two maximum centers around 180° and 130°W, respectively, in the GODAS since Feb 2011.

## ENSO cycle as indicated by 1st EOF of surface current and SST anomalies



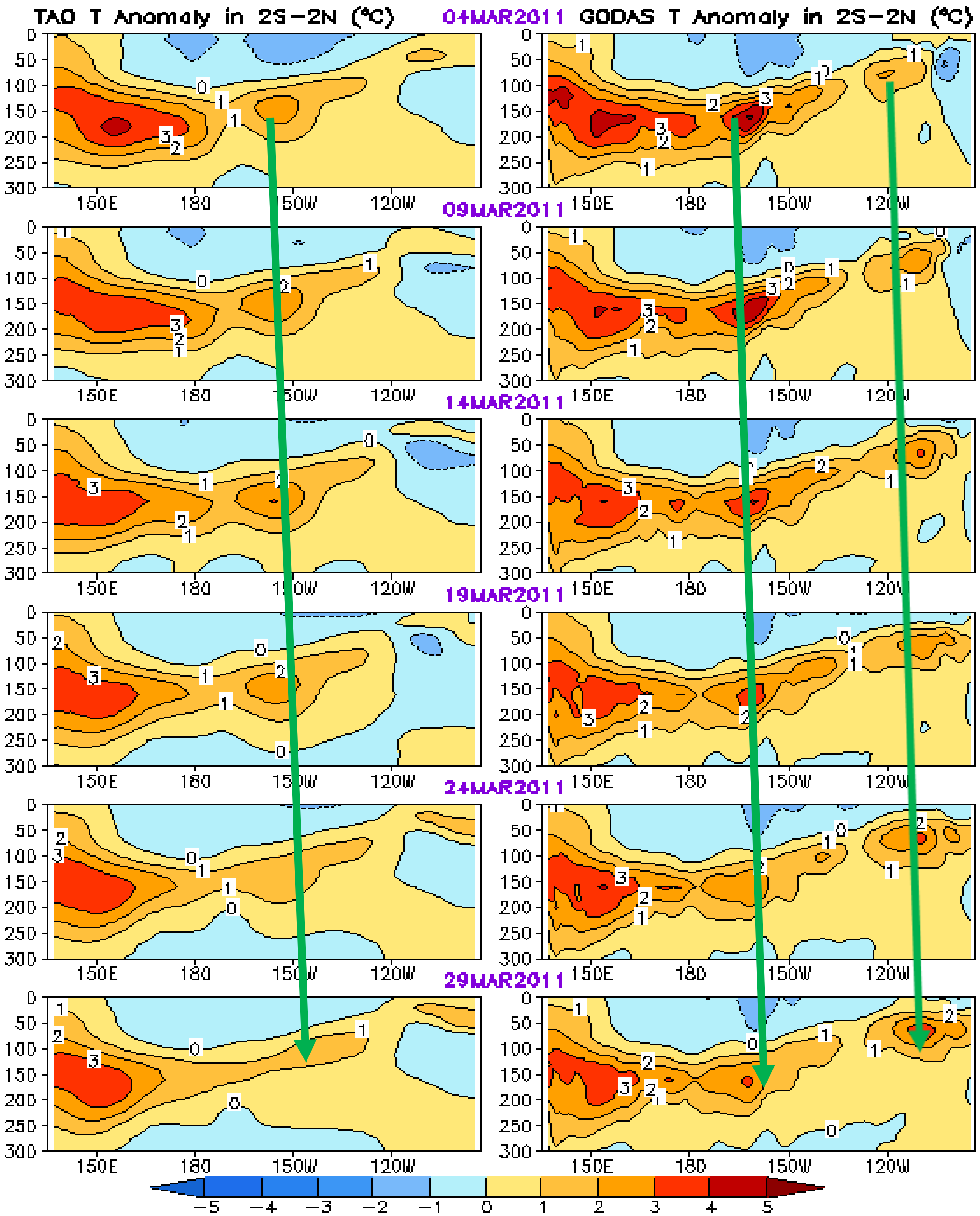

- **Westward surface zonal current anomaly has weakened rapidly since Jul 2010, and the zonal current anomaly has become eastward since Dec 2010.**

- **On average, ocean surface zonal current anomaly leads the SSTA by a few months.**

First EOF mode of ocean surface current (SC) and SST anomalies for the past decade extending through the latest 10-day period. The amplitude time series (top panel) are computed by fitting the data sets to 10-year base period eigenvectors (1993-2002). The amplitudes are then normalized by their respective standard deviations. The bottom panel shows the corresponding EOF maps, scaled accordingly. The El Niño signal can be seen as periods of positive excursions (> 1 Std. Dev.) of the amplitude time series. T the near real-time SC are the output from a diagnostic model.

(supplied by Dr. Kathleen Dohan and see "http://www.esr.org/enso_index.html" for details)

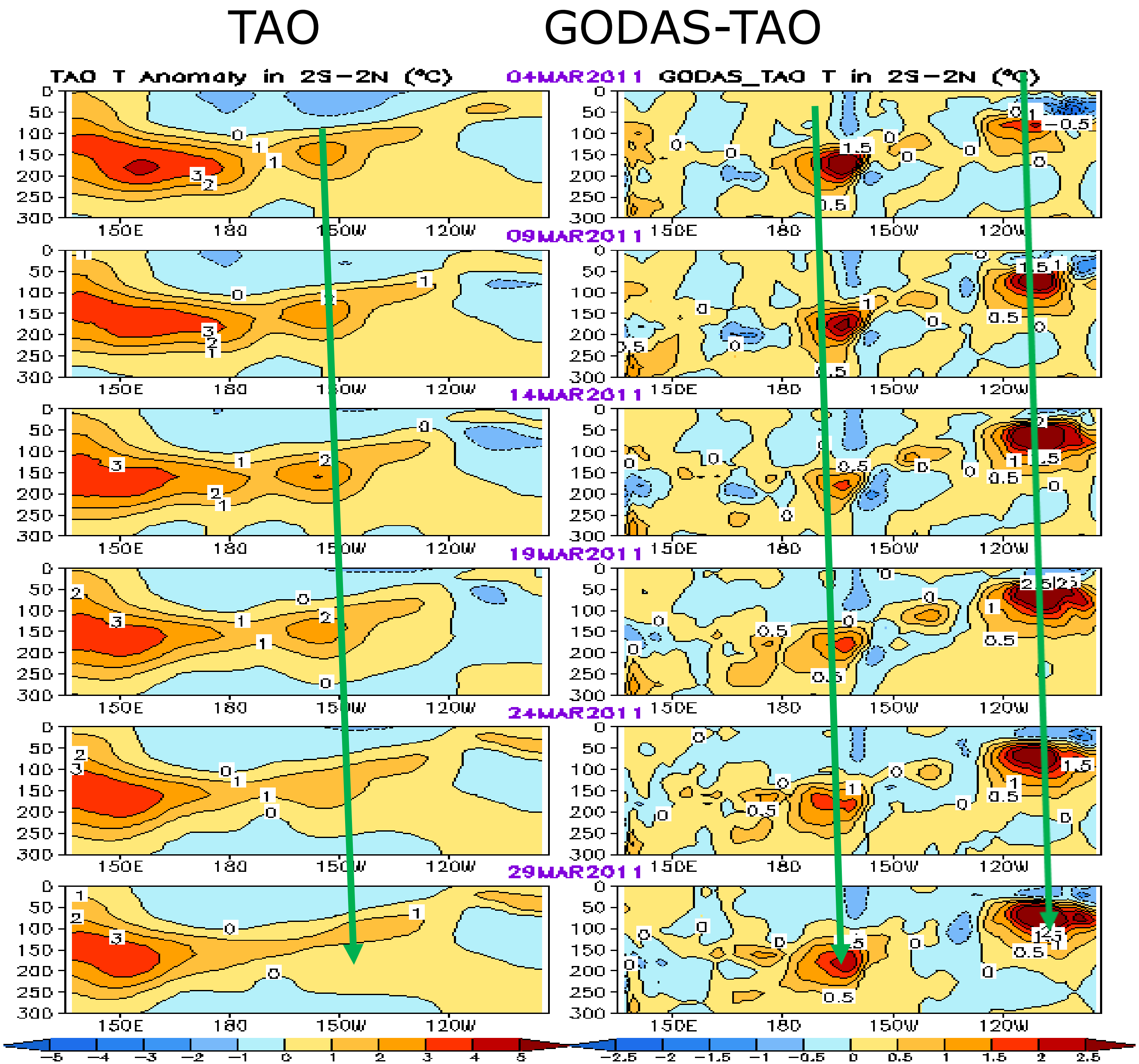
# Equatorial Pacific Temperature Anomaly




**TAO climatology used**

- **Negative temperature anomalies in the equatorial eastern and central Pacific weakened significantly in Mar 2011.**
- **Positive temperature anomalies in the equatorial western Pacific enhanced and propagated eastward in Mar 2011.**
- **Compared to TAO, GODAS has clear warm biases (see next slide).**

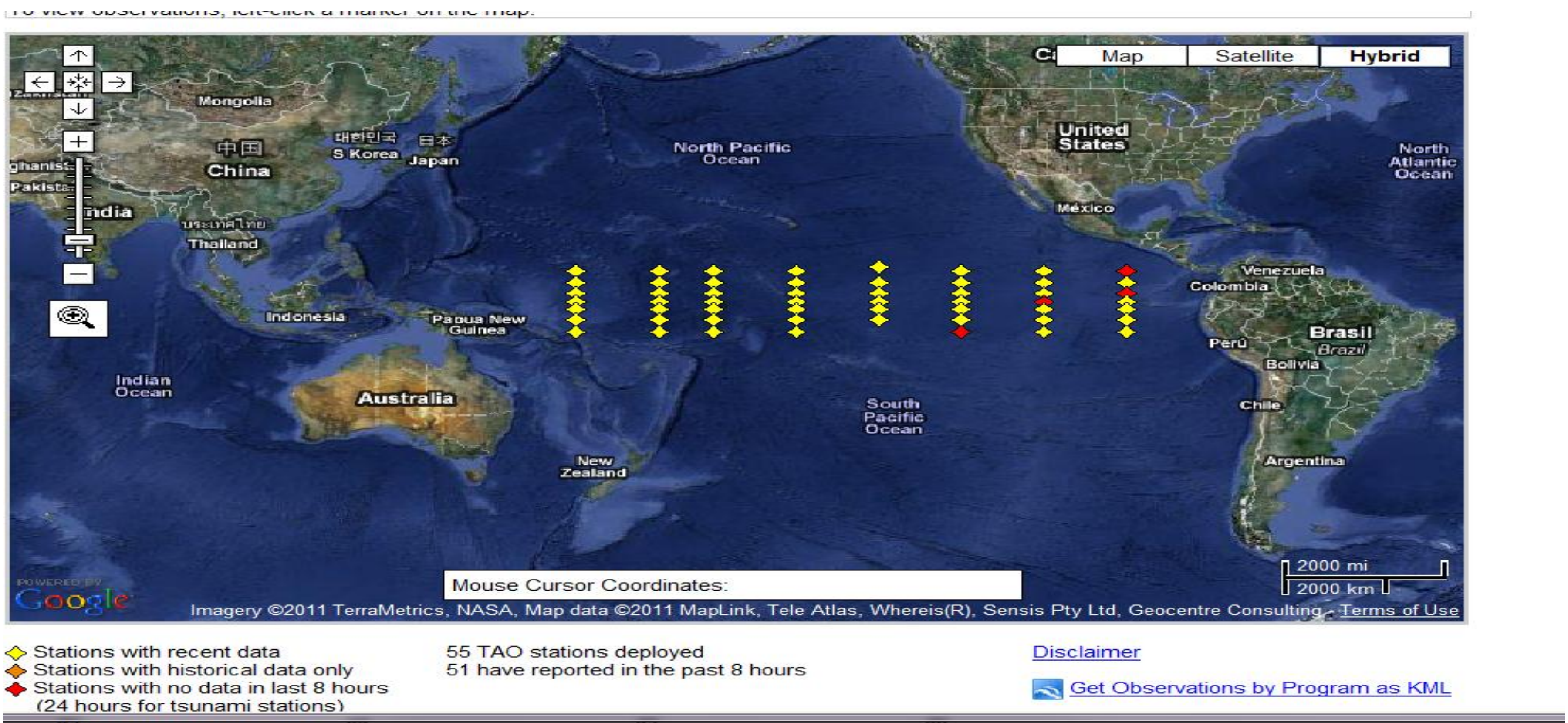
# Equatorial Pacific Temperature Anomaly

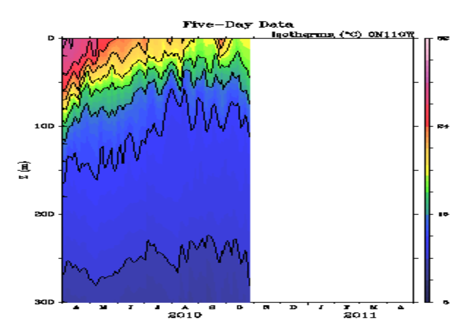



- Compared with TAO, GODAS has clear warm biases with amplitude larger than 2C between 170W-160W and 3C between 120W-90W in the top 75m.

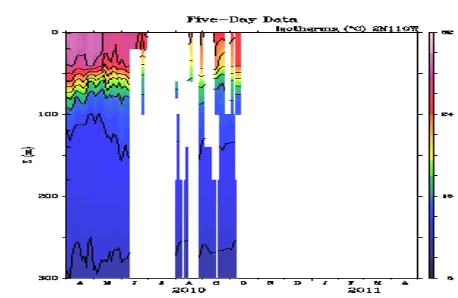
- Some TAO moorings have failed to delivery data in 2010-2011, which might have contributed to the large differences between TAO and GODAS.

# Some TAO moorings have failed to delivery data in 2010 and 2011

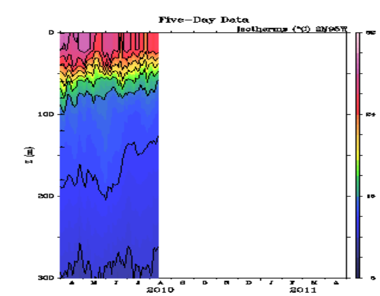


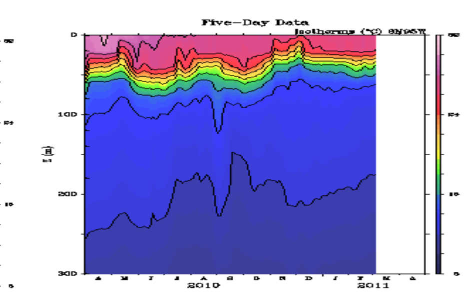

(0°N, 110°W)




(2°N, 110°W)

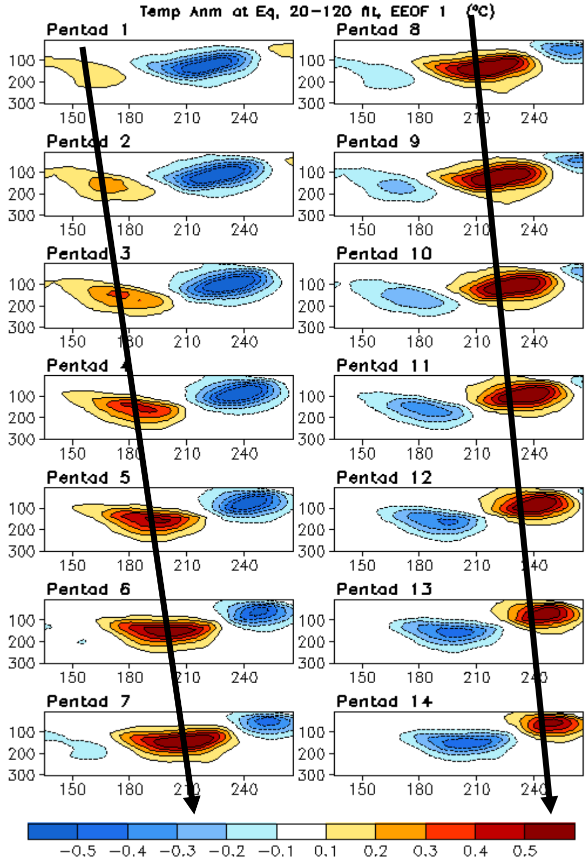


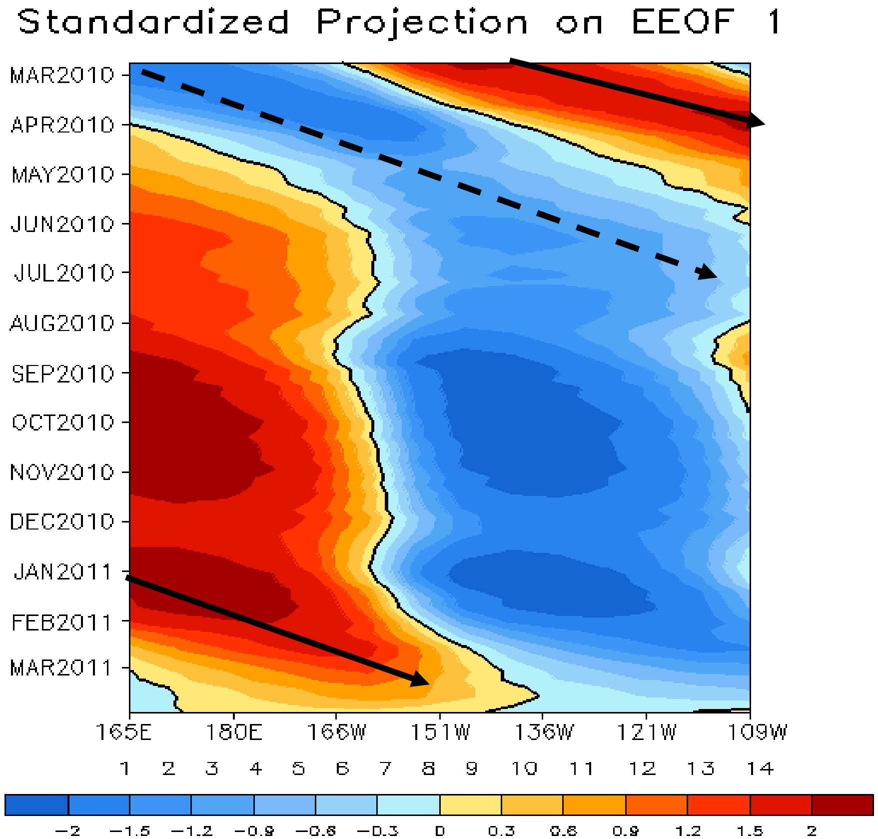

(2°N, 95°W)




(8°N, 95°W)

# Oceanic Kelvin Wave Indices

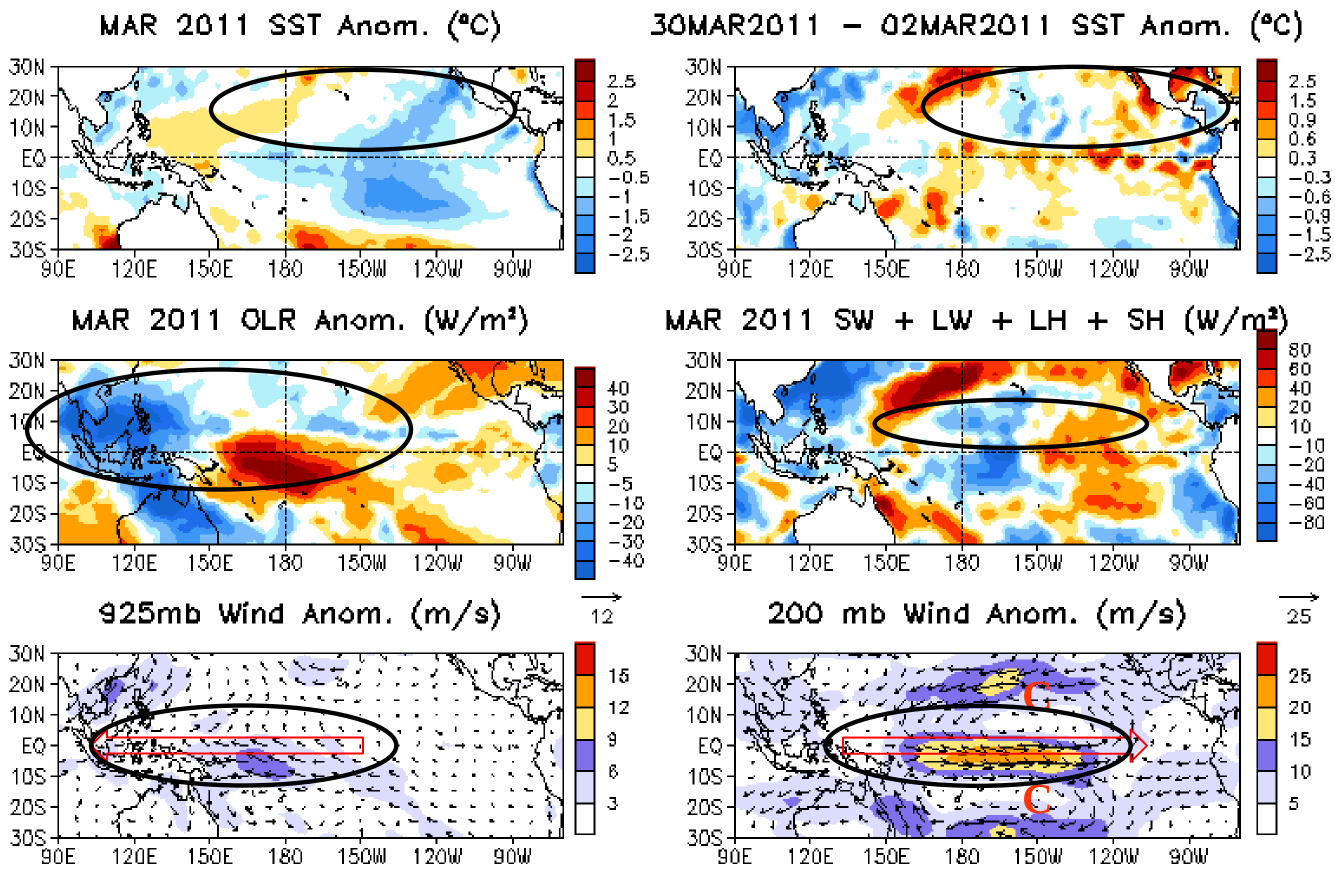



**- Downwelling Kelvin wave observed in late Jan 2011 in the W. Pacific and propagated eastward, which may be a reason causing the weakening tendency of the La Nina event.**

- **Extended EOF (EEOF) analysis is applied to 20-120 day filtered equatorial temperature anomaly in the top 300m using 14 lagged pentads (similar to that in Seo and Xue, GRL, 2005).**
- **EEOF 1 describes eastward propagation of oceanic Kelvin wave cross the equatorial Pacific in about 70 days.**
- **Oceanic Kelvin wave indices are defined as standardized projections of total anomalies onto the 14 patterns of EEOF 1.**

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

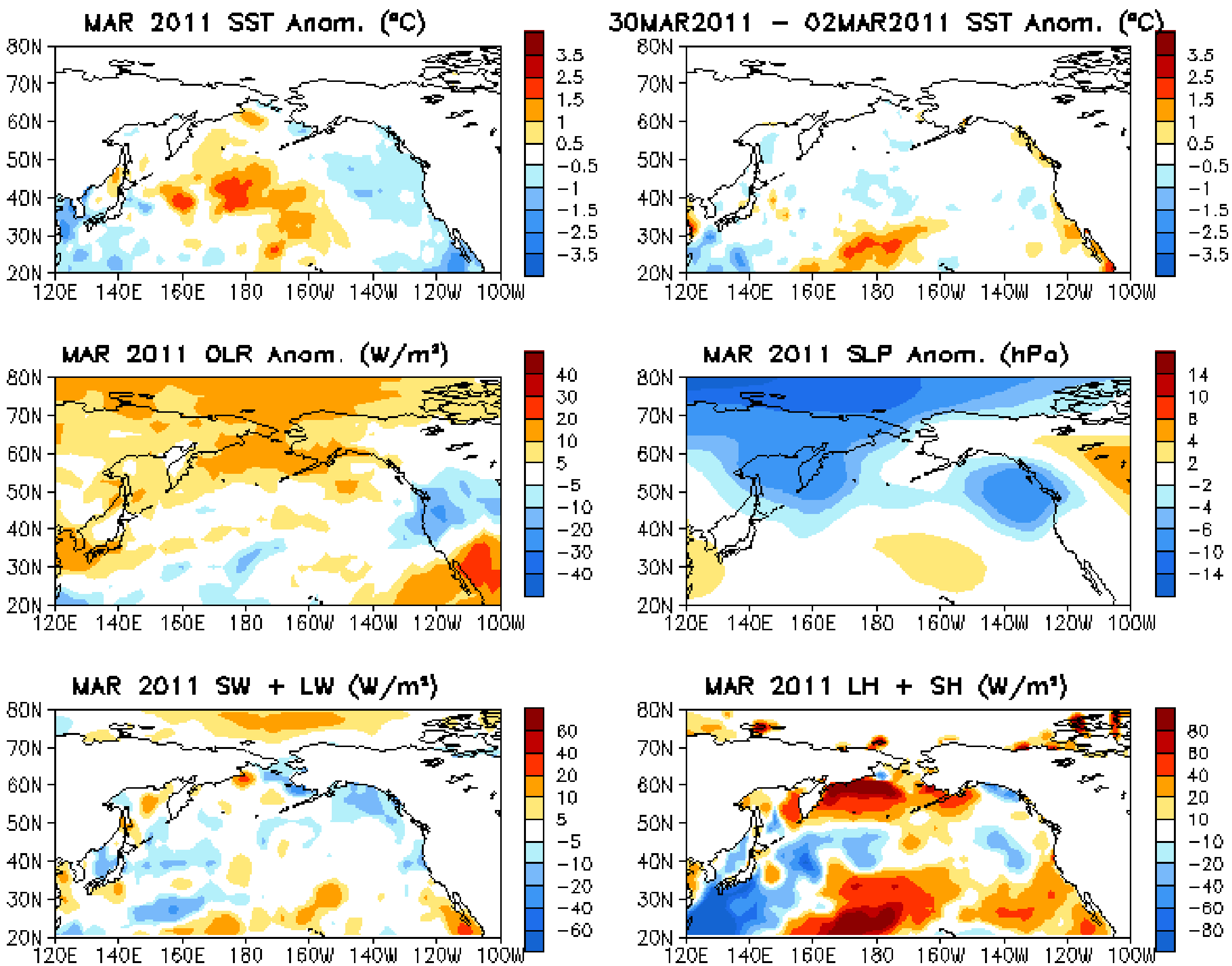



- Negative SSTA weakened in the eastern-central equatorial Pacific in Mar 2011.
- Convection was active (suppressed) over the Maritime Continent (central tropical Pacific).
- Net surface heat flux anomalies damped the negative SSTA between 150°W-90°W.
- Easterly (westerly) wind anomaly in low (high) level in the western and central equatorial Pacific intensified and shifted southward in Mar 2011.

**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 1979-1995 base period means except SST anomalies are computed with respect to the 1981-2010 base period means.**

# North Pacific & Arctic Ocean

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



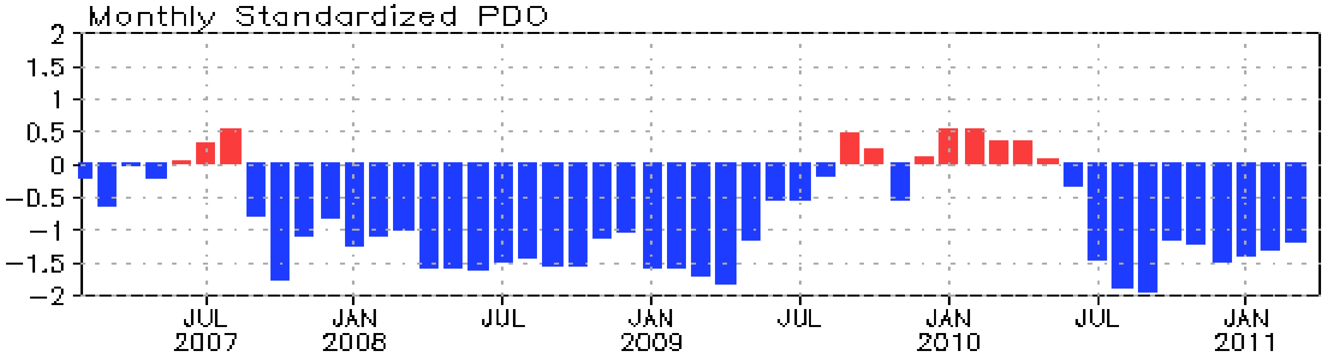

- **Positive (small negative) SSTA was observed in the central (eastern and southwest) N. Pacific in Mar 2011, consistent with the negative PDO index (next slide).**

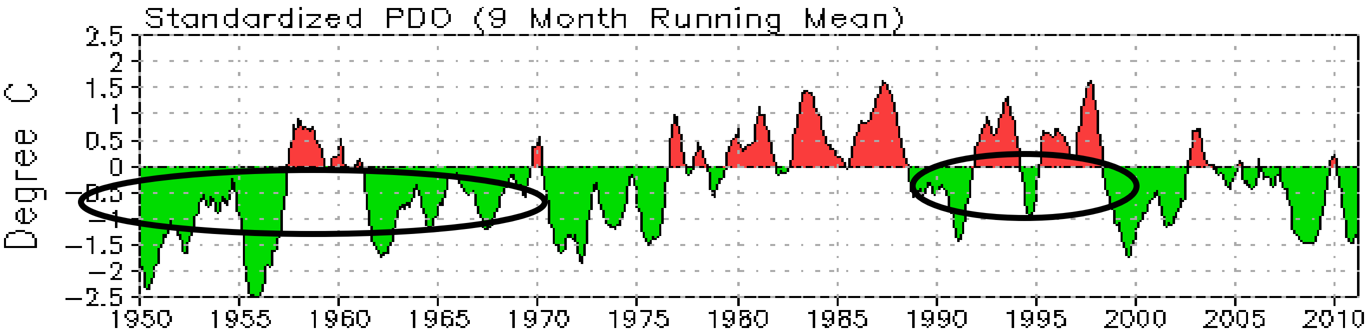
- **SSTA tendency was small and generally consists with total heat flux anomalies (LH+SH+SW+LW).**

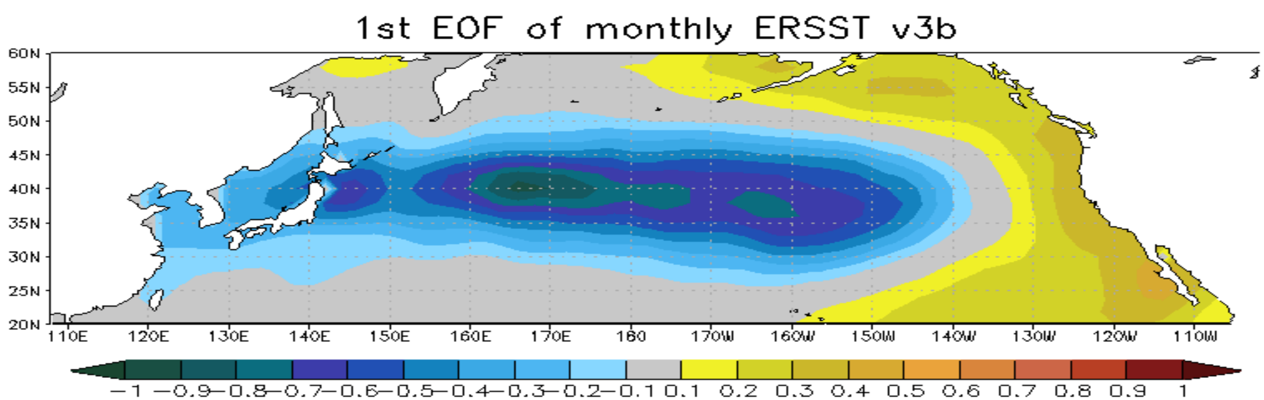
- **Positive (negative) SLP anomaly in the central N. Pacific (the Gulf of Alaska and near the coast of the Pacific Northwest) implies above-normal northerly winds along the coast, which is favorable for downwelling.**

**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 1979-1995 base period means except SST anomalies are computed with respect to the 1981-2010 base period means.**

# PDO index




**- The PDO index was -1.18 in Mar 2011, and weakened slightly.**

**- The PDO index has been below normal since Jun 2010, which was coincident with the La Nina conditions.**

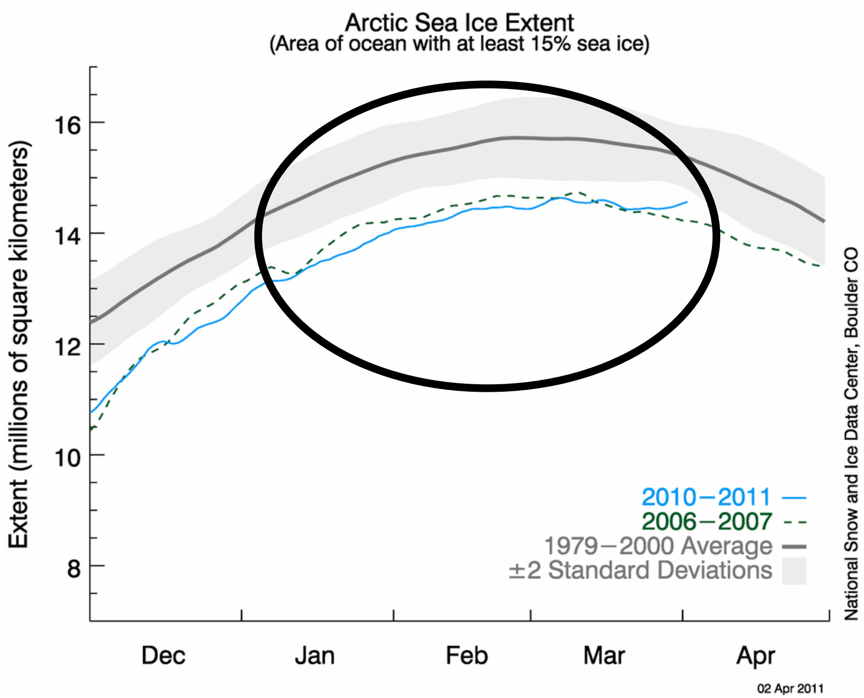
**- Pacific Decadal Oscillation is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.**

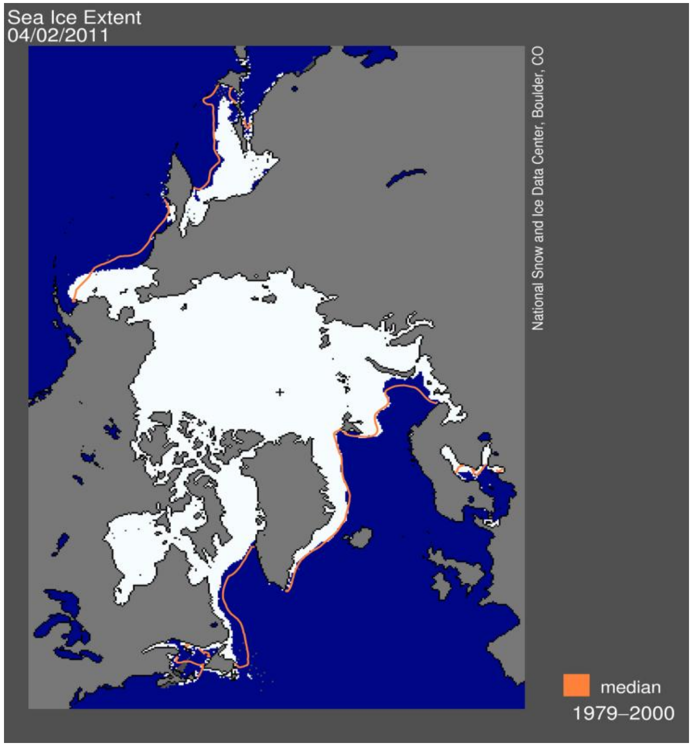
**- The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.**

# Arctic Sea Ice

**National Snow and Ice Data Center**

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



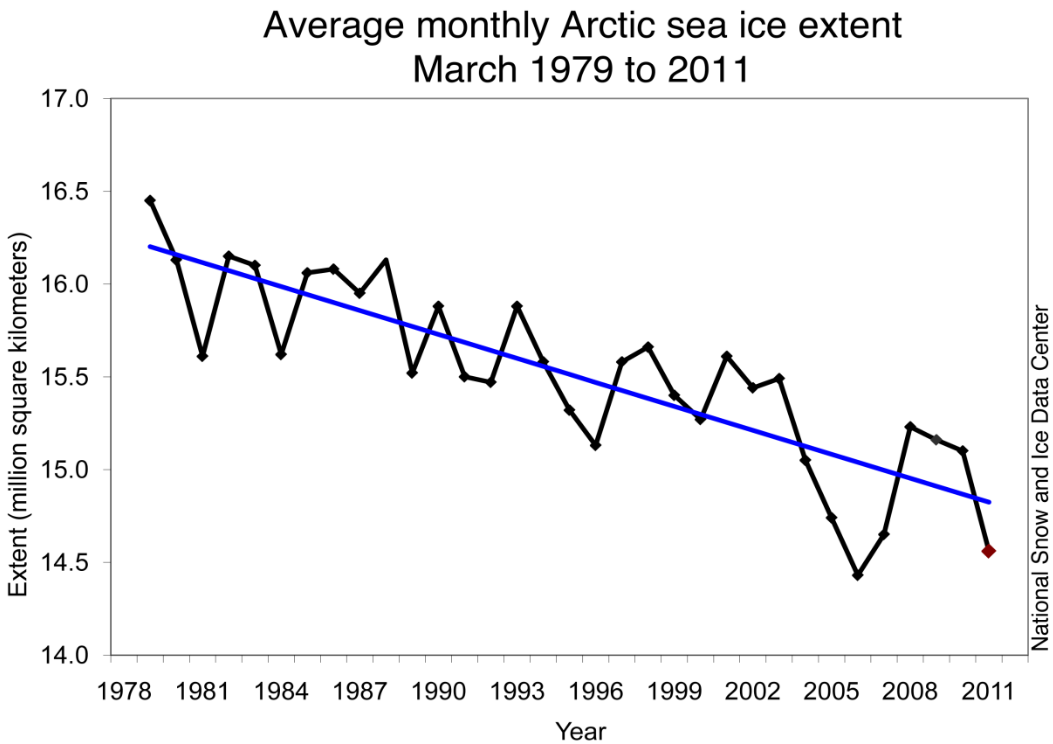



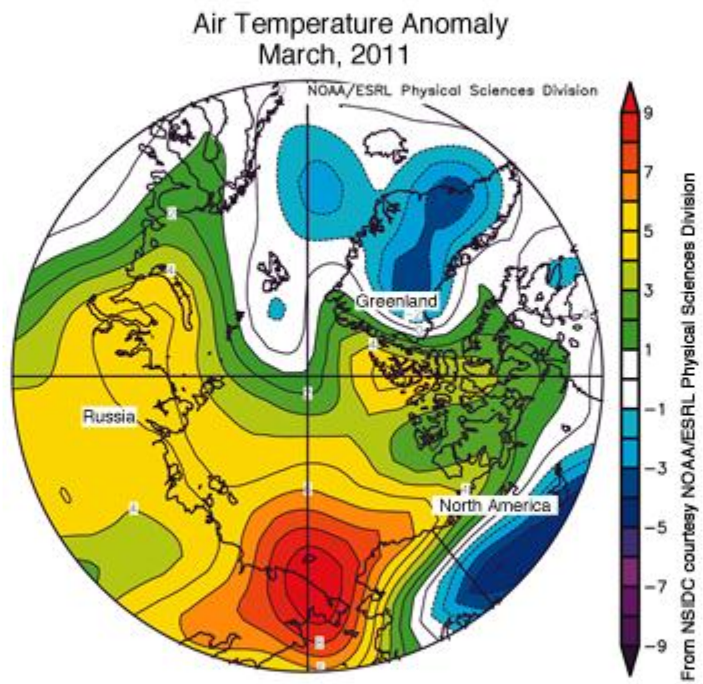

- **The Arctic sea ice extent was well blow normal in Mar 2011.**
- **The sea ice deficit was observed in both the North Atlantic and Pacific sectors.**

# Arctic Sea Ice

**National Snow and Ice Data Center**

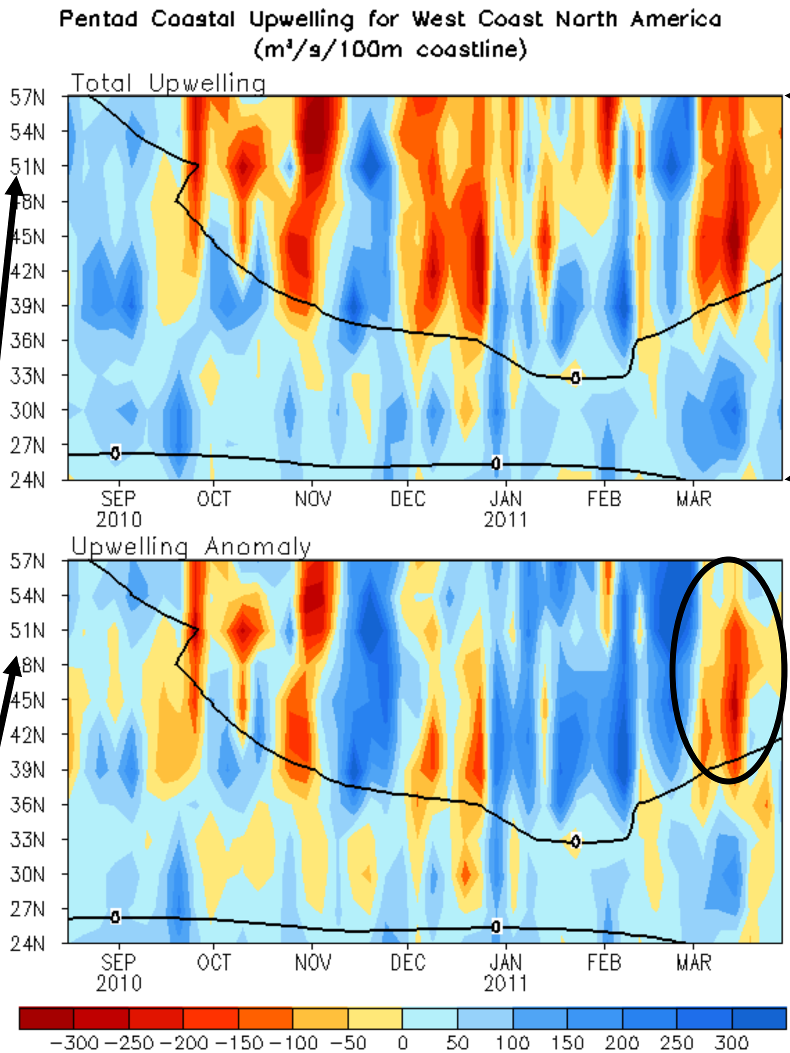
**http://nsidc.org/arcticseaicenews/index.html**

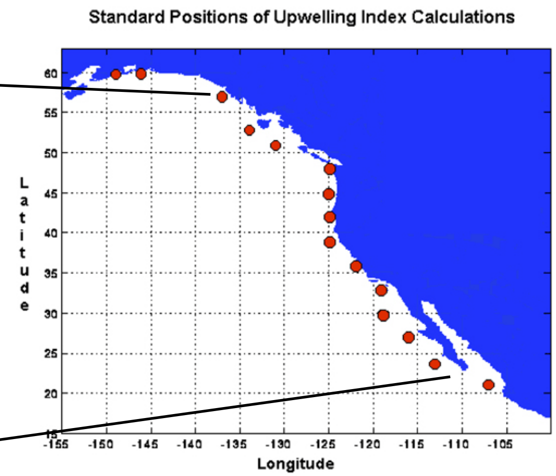



- **March 2011 had the second-lowest ice extent for the month in the satellite record, after 2006.**
- **Including 2011, the Mar trend in sea ice extent is at -2.7% per decade since 1979.**
- **The sea ice deficit may be associated with the warm temperature.**

# North America Western Coastal Upwelling



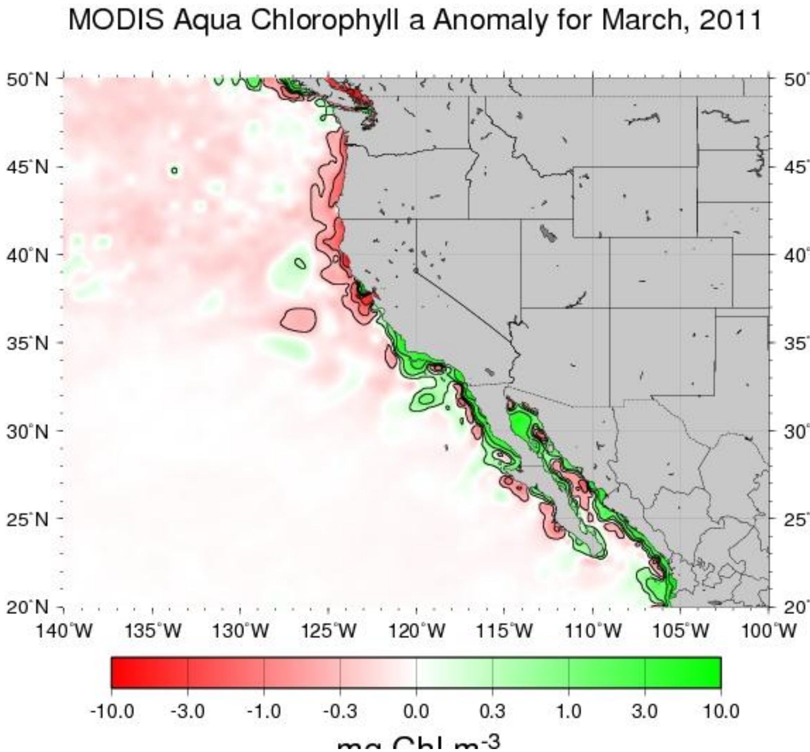




- **Seasonal downwelling intensified at 35ºN-57ºN in Mar 2011.**

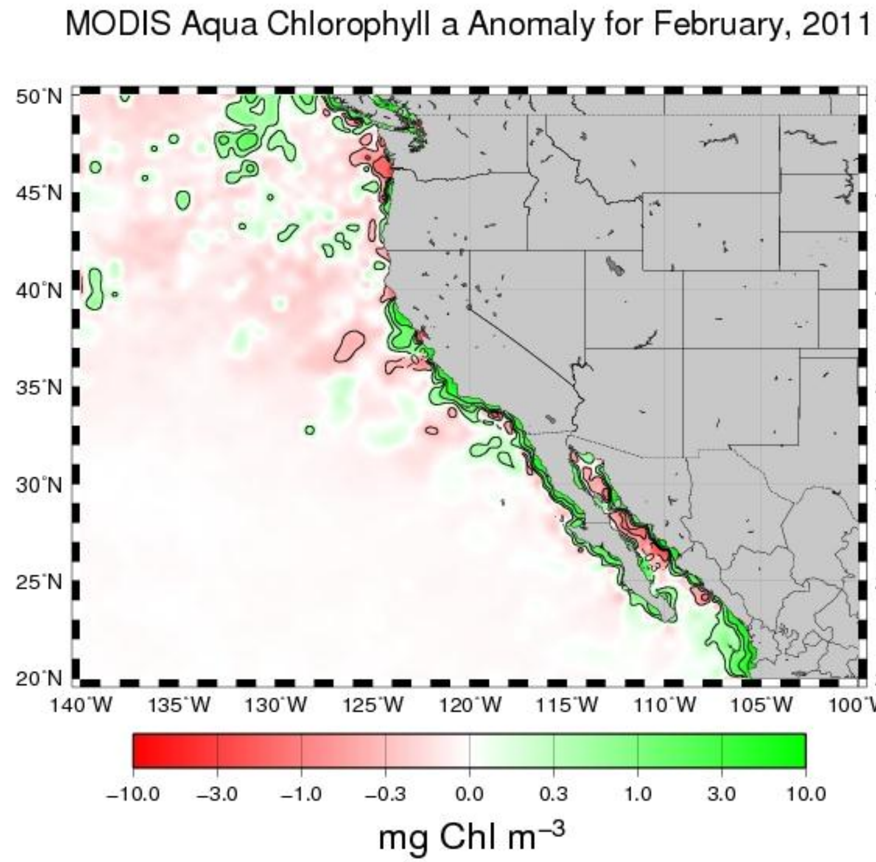
**Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1982-2004 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.**

# Monthly Chlorophyll Anomaly

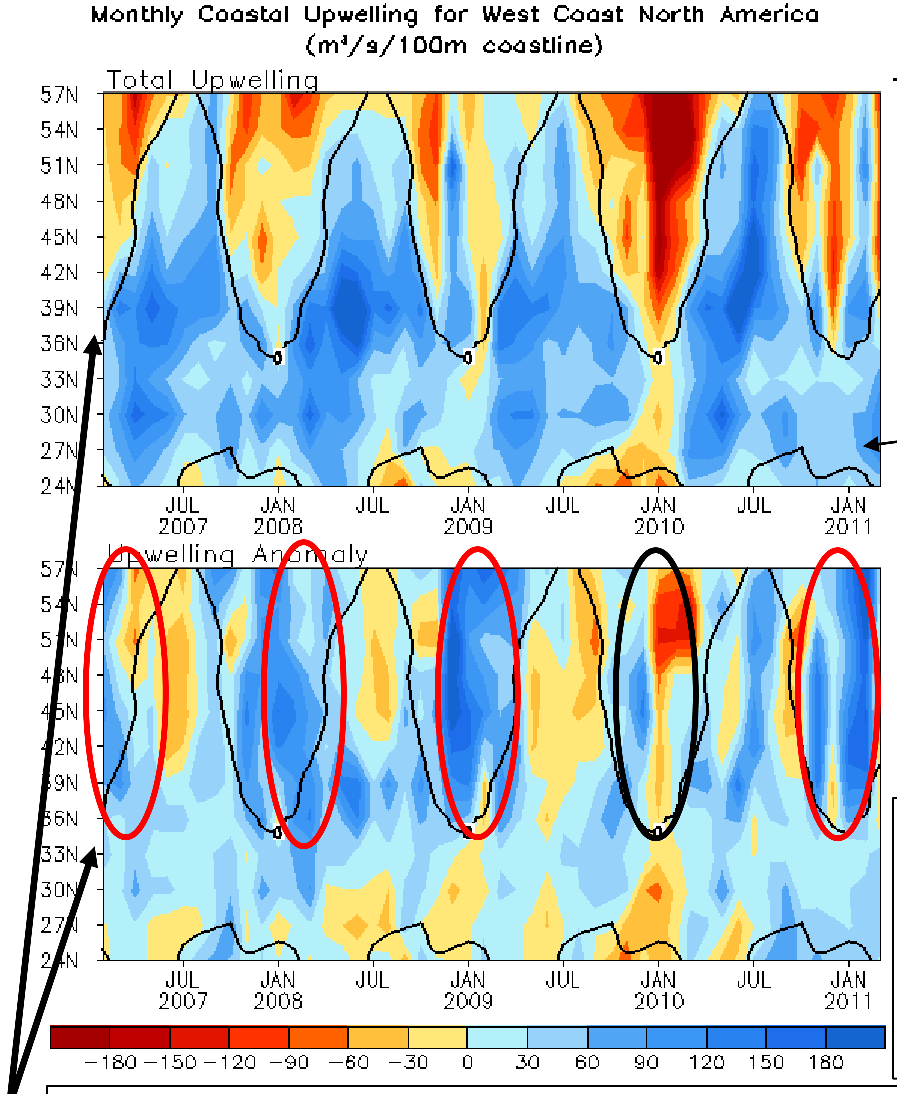


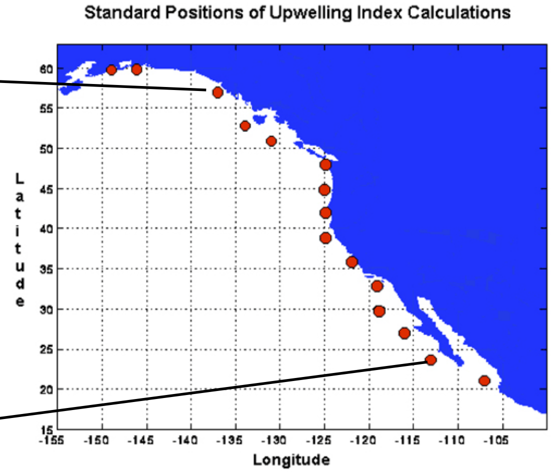

- **Negative chlorophyll anomalies dominated at 35°N-55°N in Mar 2011, consistent with strengthened anomalous downwelling.**




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

# North America Western Coastal Upwelling



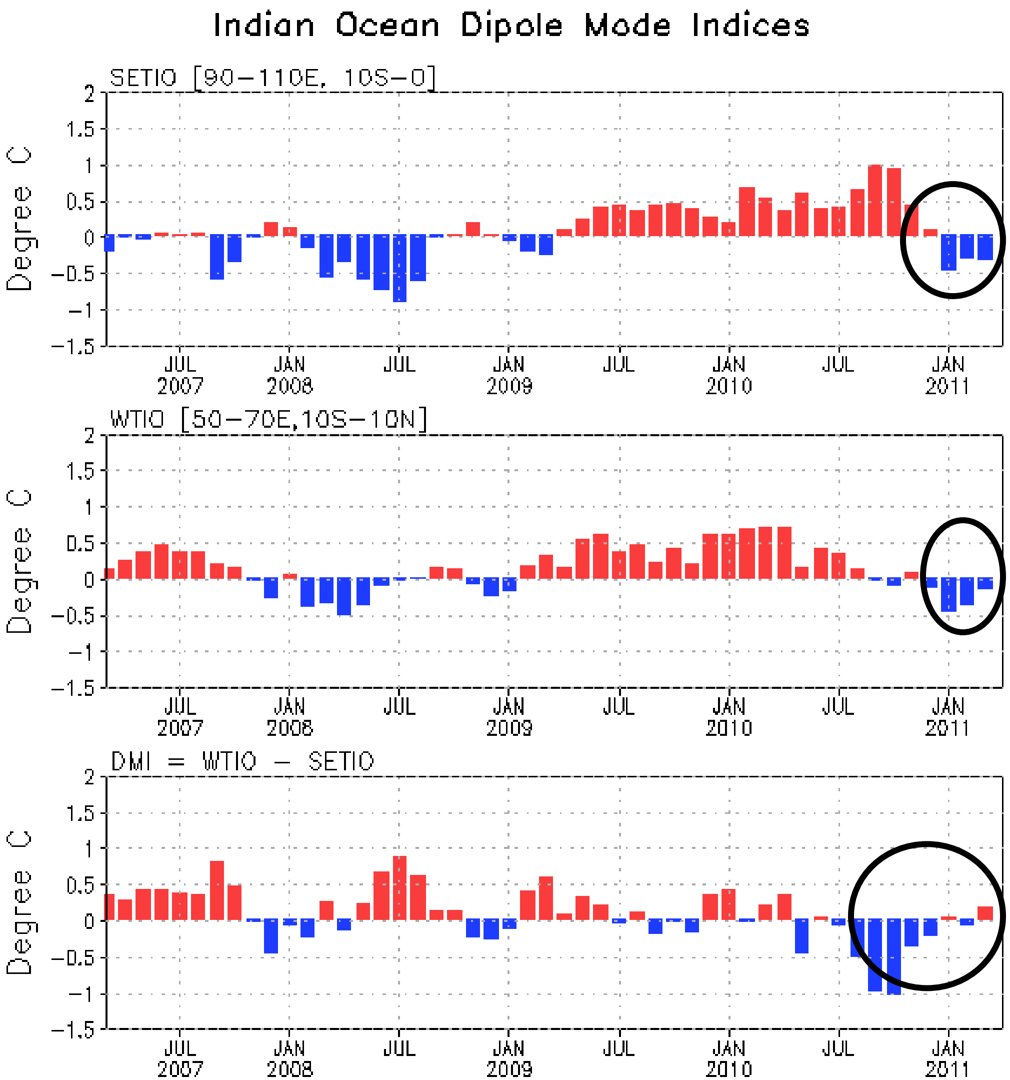

- **Seasonal downwelling was weaker than climatology during the winter of 2006/07, 2007/08, 2008/09, and 2010/11.**
- **But, seasonal downwelling was stronger than climatology during the winter of 2009/10.**

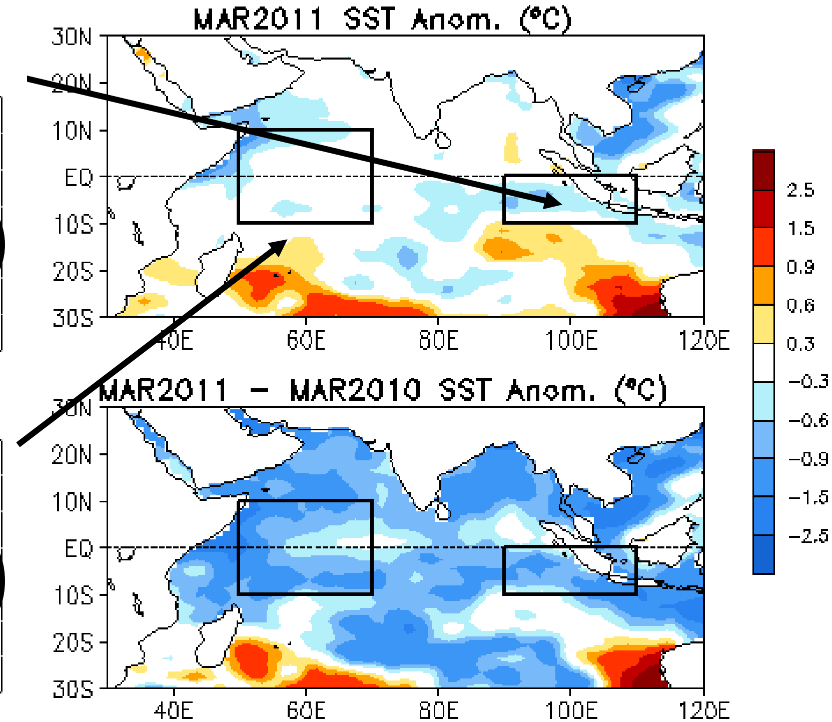
**Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP's global ocean data assimilation system, and are calculated as integrated vertical volume transport at 50 meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1982-2004 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



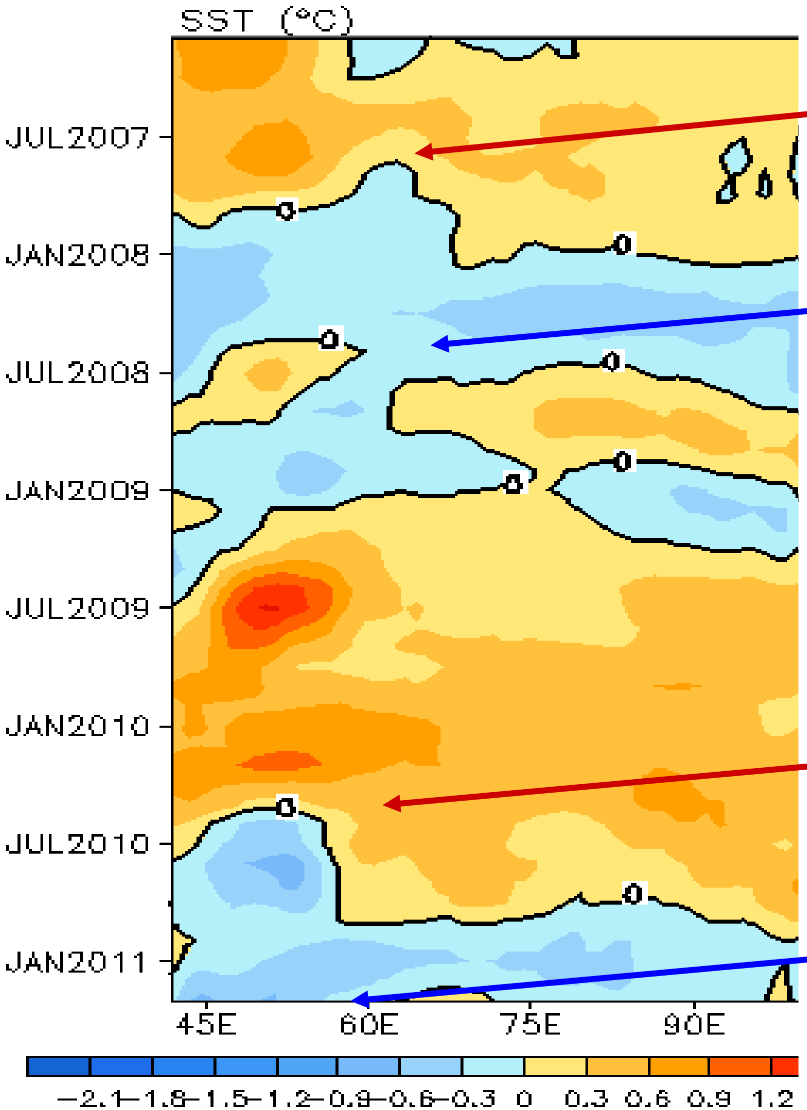

- **Both eastern (SETIO) and western (WTIO) pole SSTA was negative since Jan 2011, consistent with basin wide negative SSTA.**
- **DMI has been below-normal since May 2010, strengthened during Sep-Oct 2010, and near -normal in Jan-Feb 2011 and above normal in Mar 2011.**
- **Compared with Mar 2010, a basin wide cooling of about 2°C was observed in Mar 2011, which is consistent with the contrast impacts of the 2009/10 El Nino and the 2010/2011 La Nina (next slide).**

**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.**

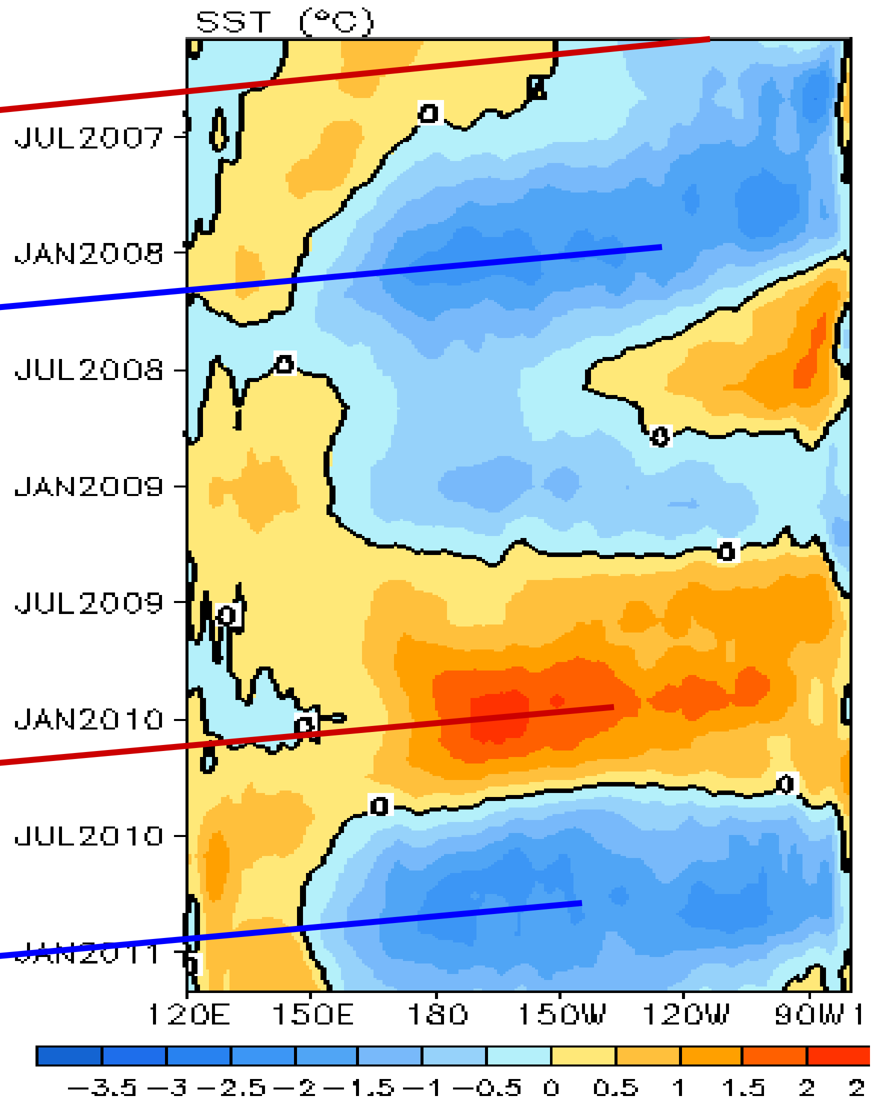
# Connection of Pacific and Indian Oceans:

Central and eastern Pacific SSTA seems to lead Indian Ocean SSTA by a few months

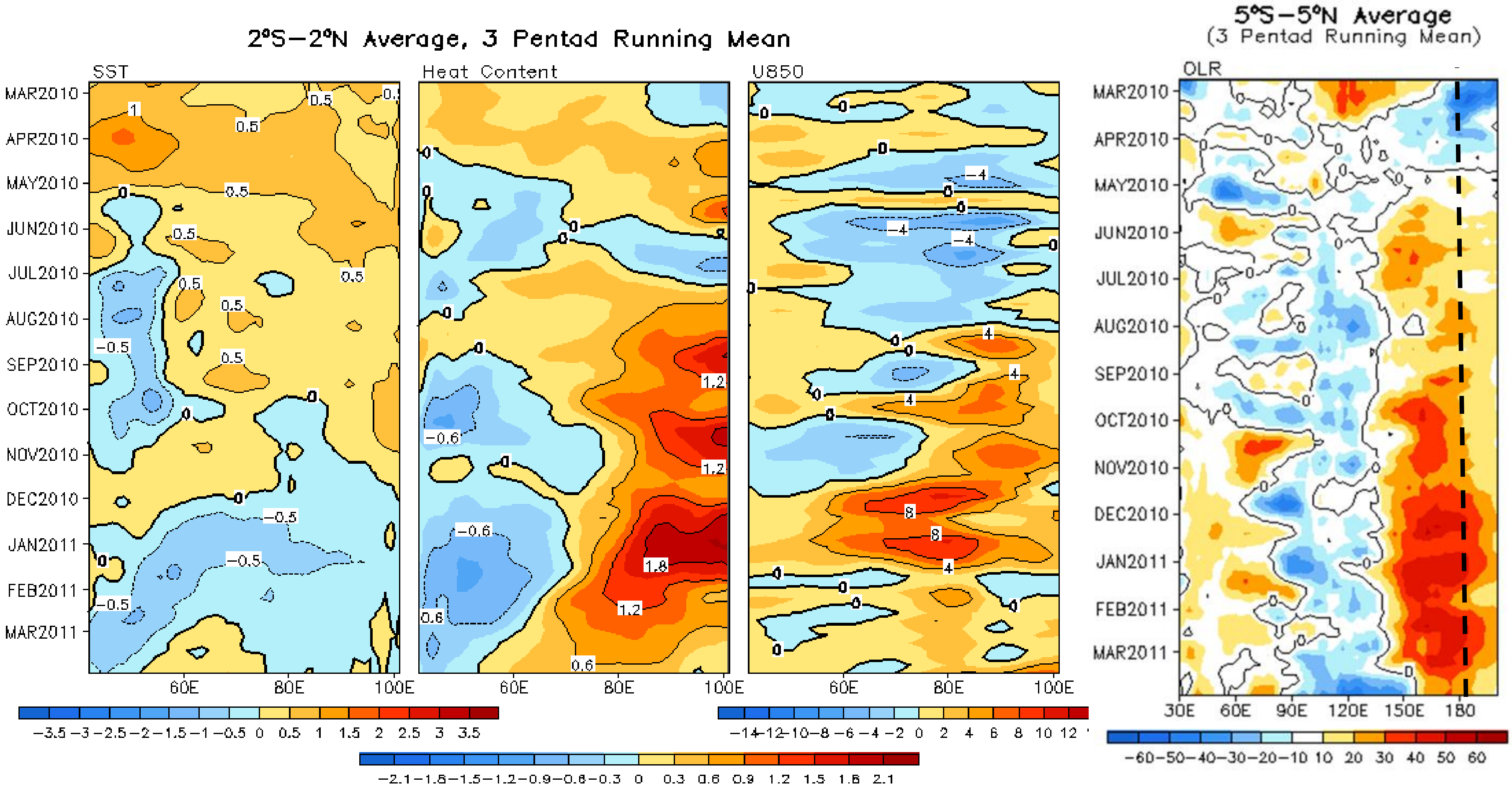
Indian Ocean: 2S-2N




Pacific Ocean: 2S-2N



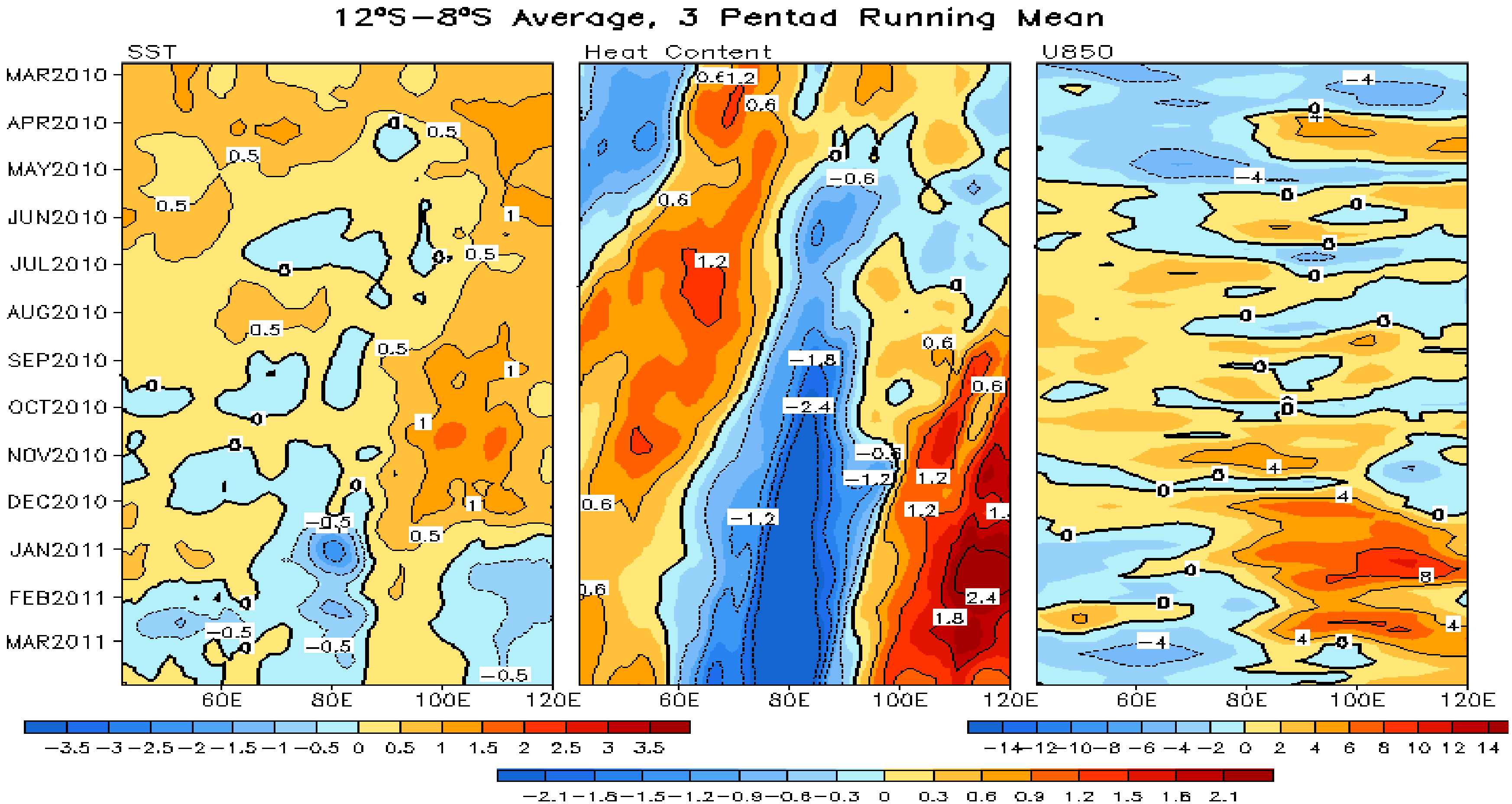
# Recent Evolution of Equatorial Indian SST (ºC), 0-300m Heat Content (ºC), 850-mb Zonal Wind (m/s) and OLR (W/m²) Anomalies




- **SSTA switched to negative for the whole basin since mid-Dec 2010, probably due to the delayed impact of the La Nina. But, positive SSTA presented in central Indian Ocean in Mar 2011.**
- **Positive (negative) heat content anomaly presented in the eastern and central (western) Indian Ocean in response to anomalous westerly wind forcing in the central tropical Indian Ocean.**

**Fig. I3. Time-longitude section of anomalous pentad sea surface temperature (left), upper 300m temperature average (heat content, middle-left), 850-mb zonal wind (U850, middle-right) averaged in 2ºS-2ºN and Outgoing Long-wave Radiation (OLR, right) averaged in 5ºS-5ºN. SST are derived from the NCEP OI SST, heat content from the NCEP's global ocean data assimilation system, and U850 from the NCEP CDAS. Anomalies for SST, heat content and U850/OLR are departures from the 1981-2010, 1982-2004, 1979-1995 base period pentad means respectively.**

# Recent Evolution of 10°S Indian SST (°C), 0-300m Heat Content (°C), 850-mb Zonal Wind (m/s)




- Both negative and positive SSTA weakened in Mar 2011 in the southern Indian Ocean.
- Westerly wind anomalies weakened in the southeastern tropical Indian Ocean, which are probably associated with the La Nina conditions.
- The tripole HC300A, negative near 80°E and positive to its two sides, persisted.

**Fig. I4. 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 12°S-8°S 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 for SST, heat content and U850/OLR are departures from the 1981-2010, 1982-2004, 1979-1995 base period pentad means respectively.**

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

- **Negative SSTA dominated the whole basin.**
- **SSTA tendency generally consisted with the net surface heat flux anomalies.**
- **Convection was enhanced (suppressed) in the eastern (central) tropical Indian Ocean.**

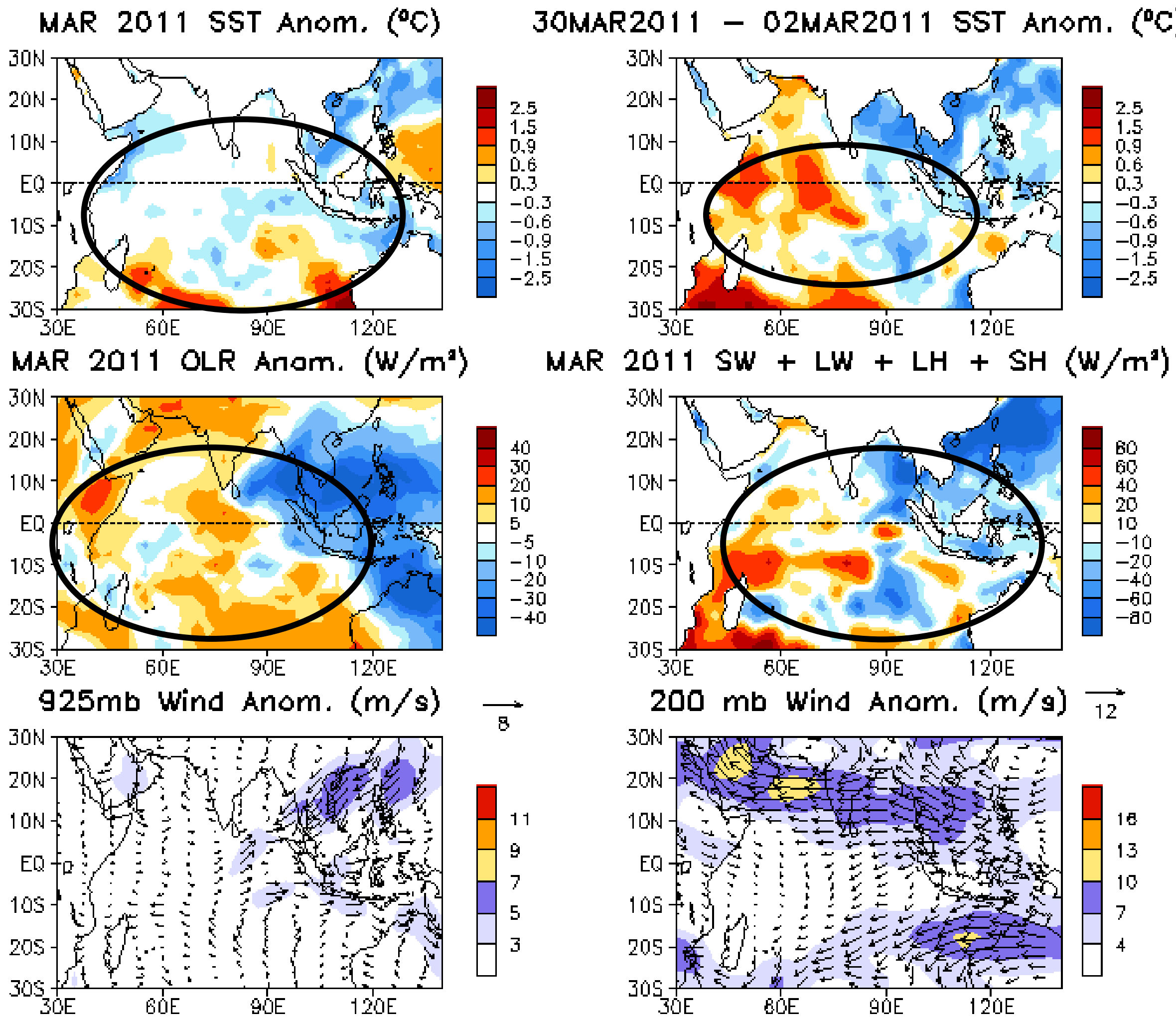
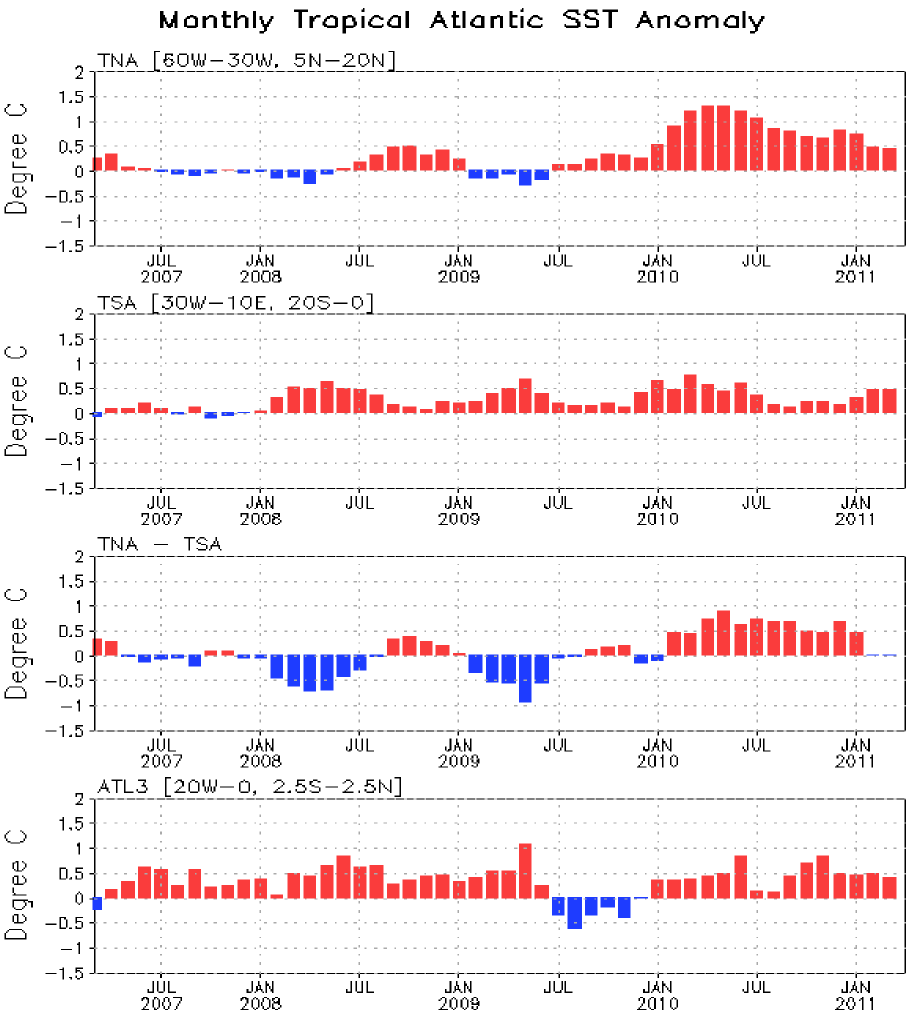
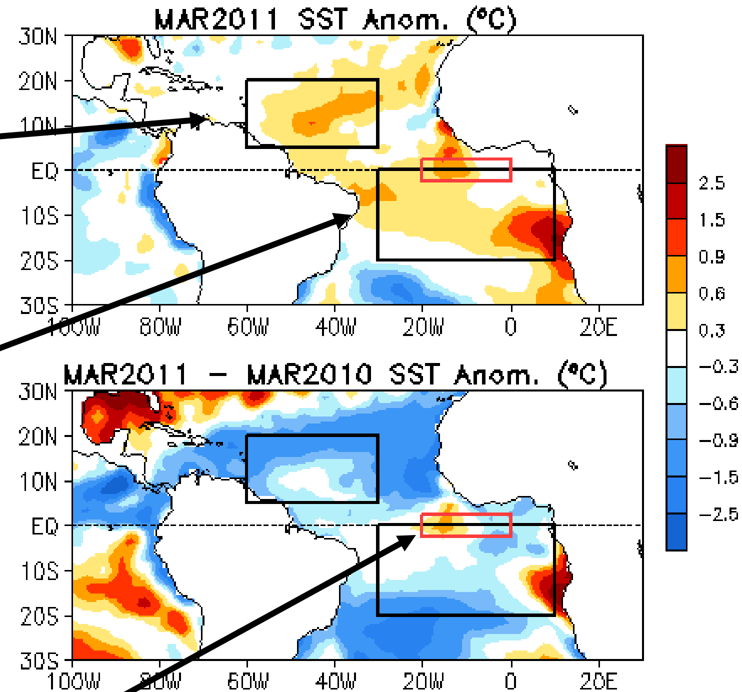



**Fig. I2. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (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 1979-1995 base period means except SST anomalies are computed with respect to the 1981-2010 base period means.**

# Tropical Atlantic Ocean

# Evolution of Tropical Atlantic SST Indices

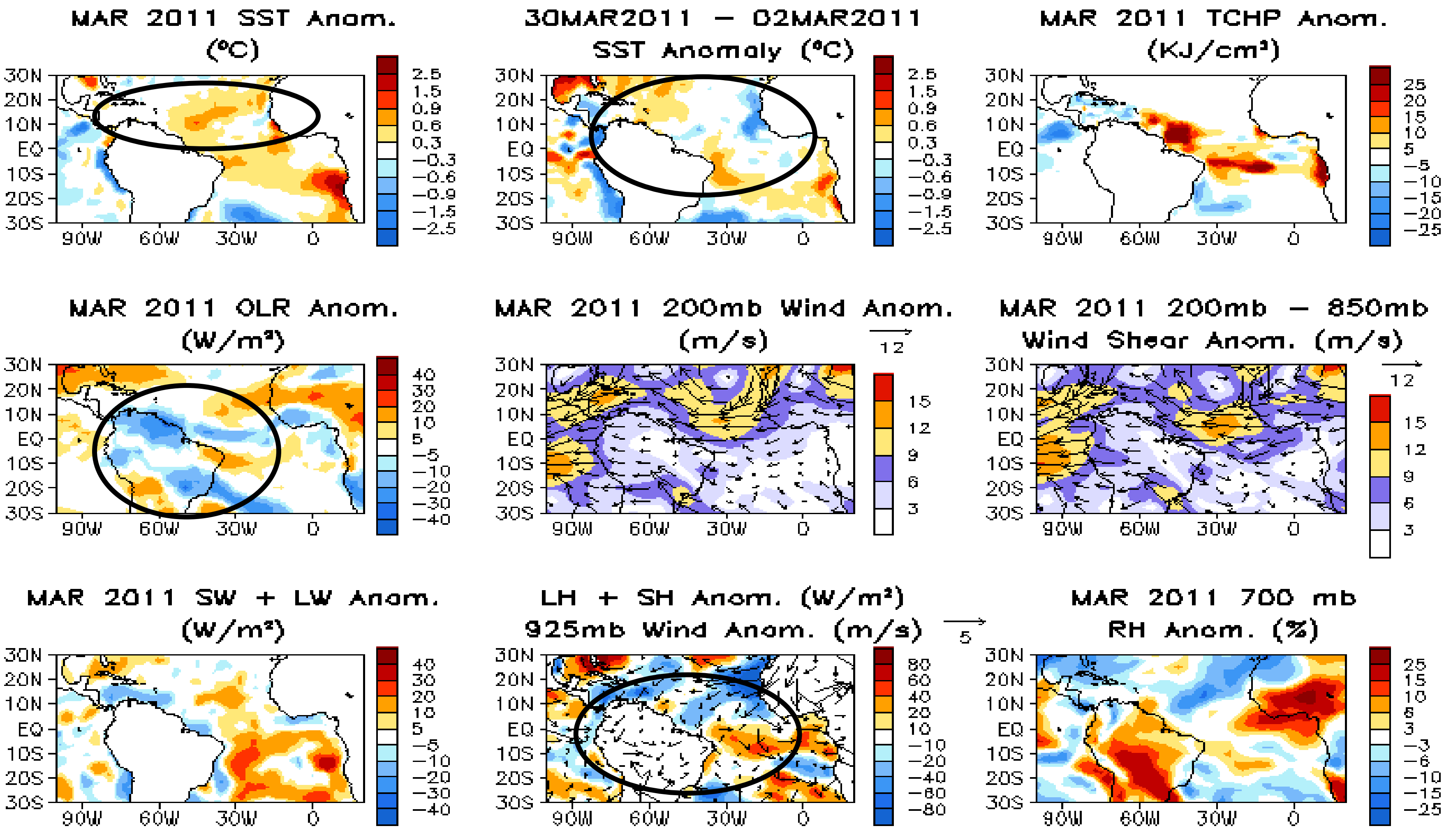



- **Positive SSTA decreased for TNA and increased for TSA since Dec 2010.**
- **Meridional Gradient Mode (TNA-TSA) was near-zero in Mar 2011.**
- **Positive ATL3 SST persistent since Jan 2010.**
- **Compared with Mar 2010, there was a strong cooling in tropical N. Atlantic in Mar 2011.**

**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 anomalies are departures from the 1981-2010 base period means.**

# Tropical Atlantic:




- **Positive SSTA in the tropical N. Atlantic weakened slightly.**
- **Convection was enhanced over the northern S. America, consistent with the La Nina conditions.**
- **SSTA tendency was generally consistent with total heat flux, particularly LH+SH.**

# North Atlantic Ocean

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

- NAO has switched to positive phase since Feb 2011 (next slide), consistent with the SLP anomaly pattern.

- SSTA tendency was relatively small and consistent with total HF (SW+LW+LH+SH).

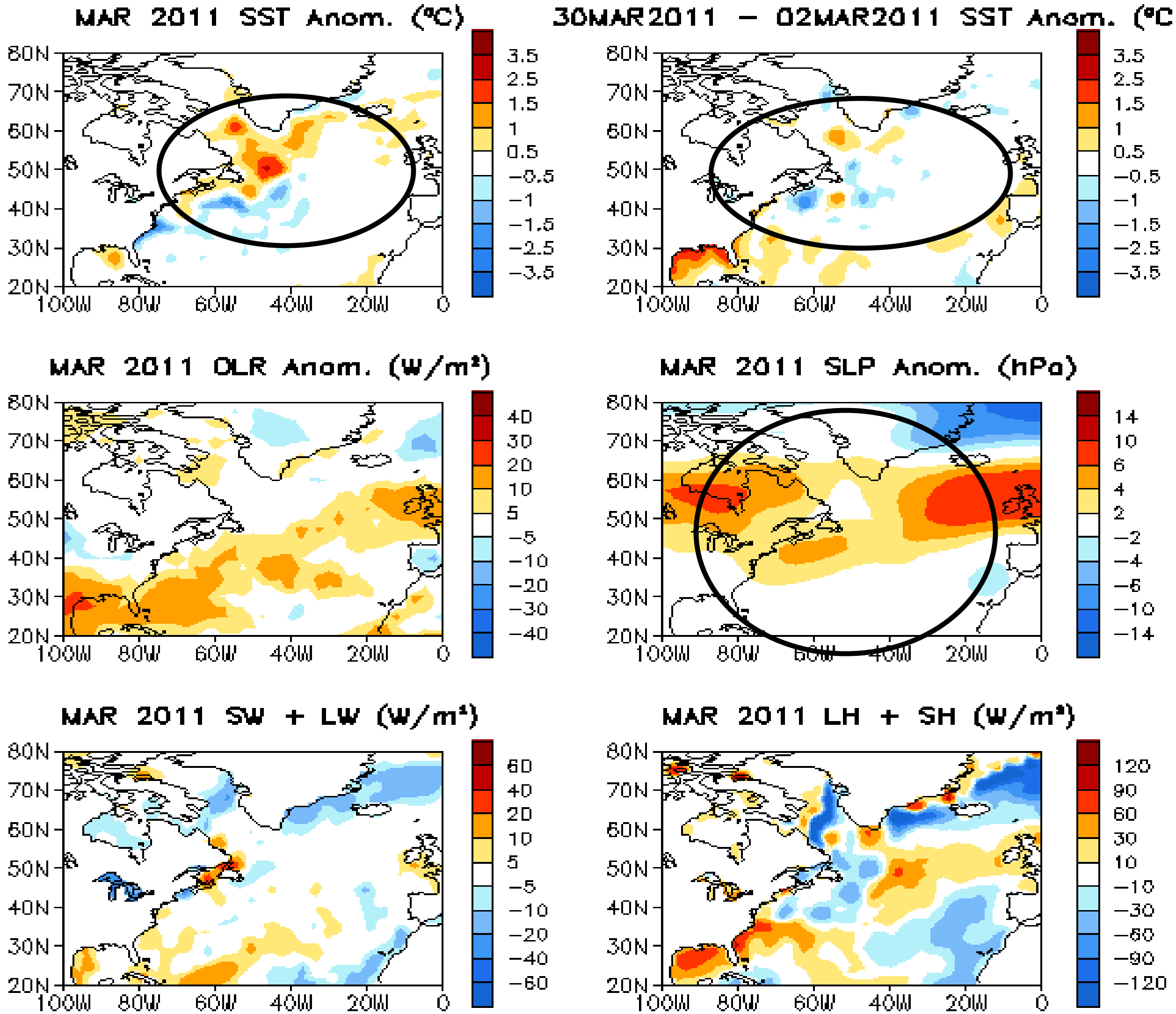
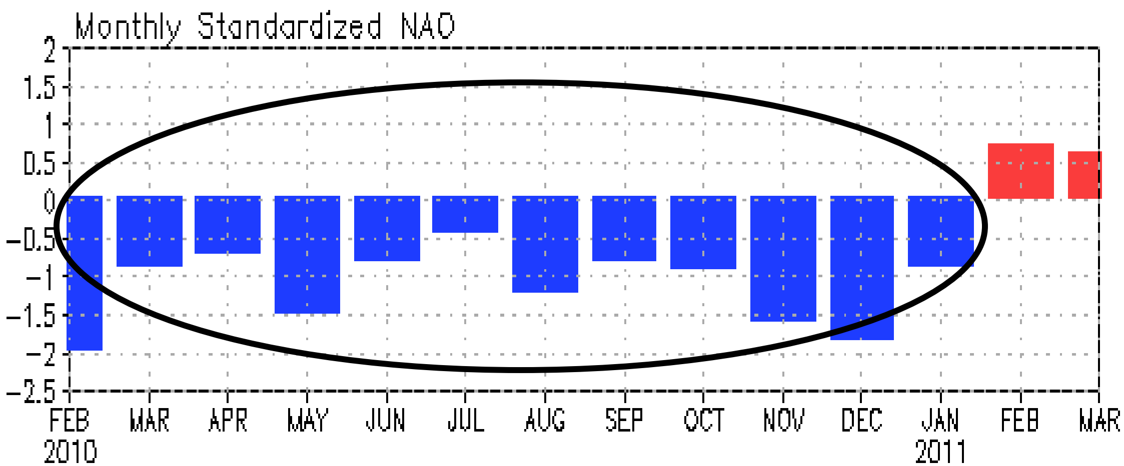
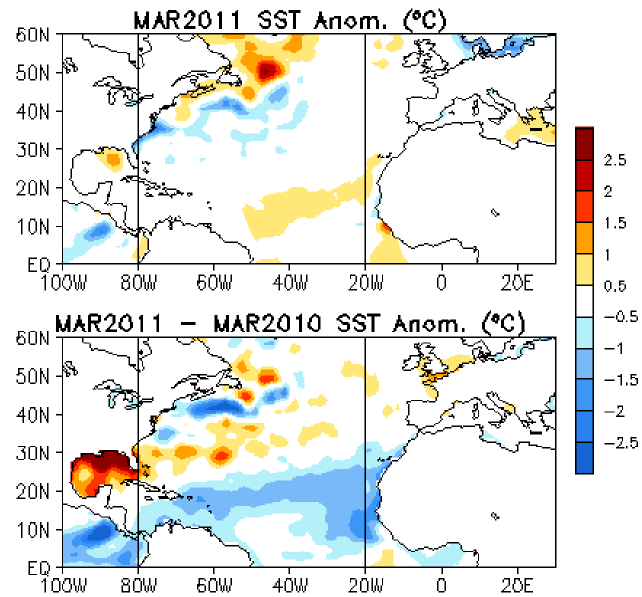
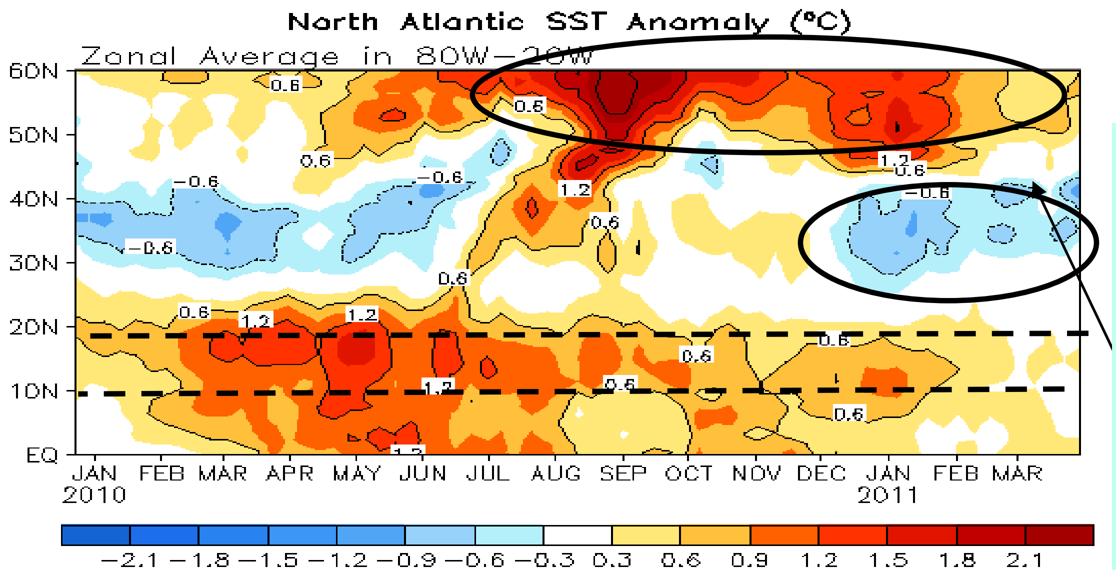



Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible 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 1981-2010 base period means.

# NAO and SST Anomaly in North Atlantic



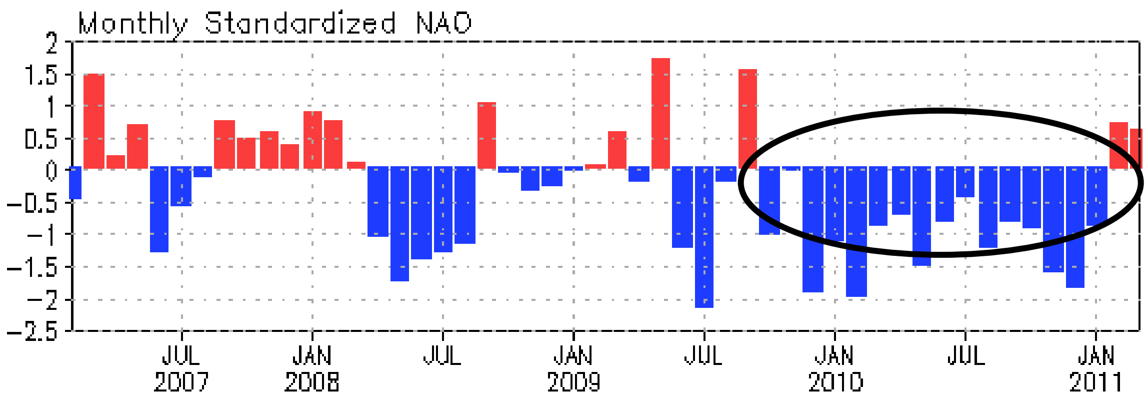

**- NAO has switched from negative to positive phase in Feb 2011 with NAO Index=0.60 In Mar 2011.**

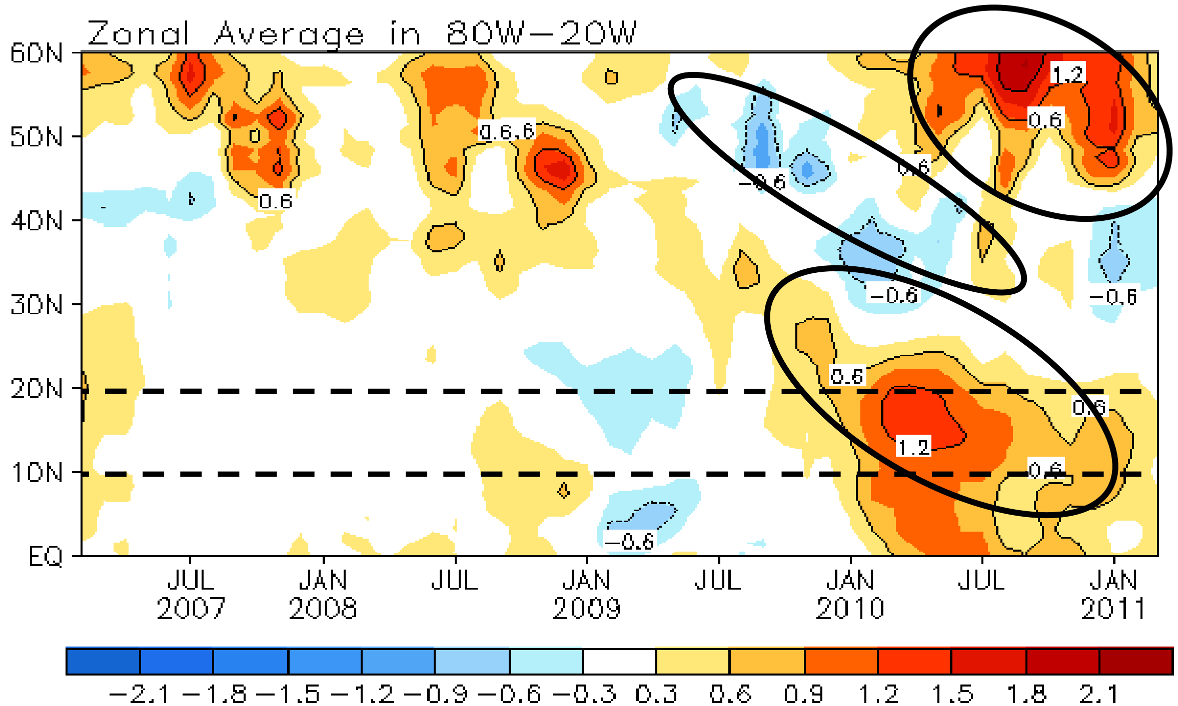
**- Negative SSTA still appeared in mid-latitude, and warming in the low and high latitudes of North Atlantic.**

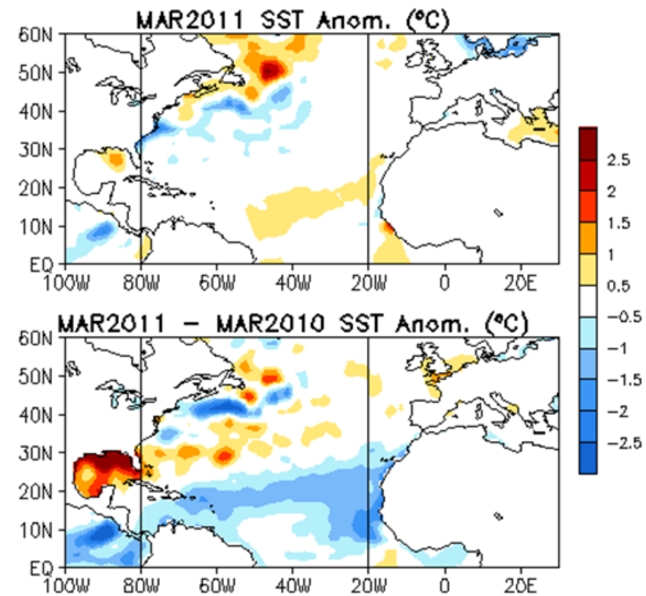
**- Overall amplitudes of the SSTA associated with tripole pattern have weakened since Feb 2011, consistent with the phase switching of the NAO.**

**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.**

# NAO and SST Anomaly in North Atlantic



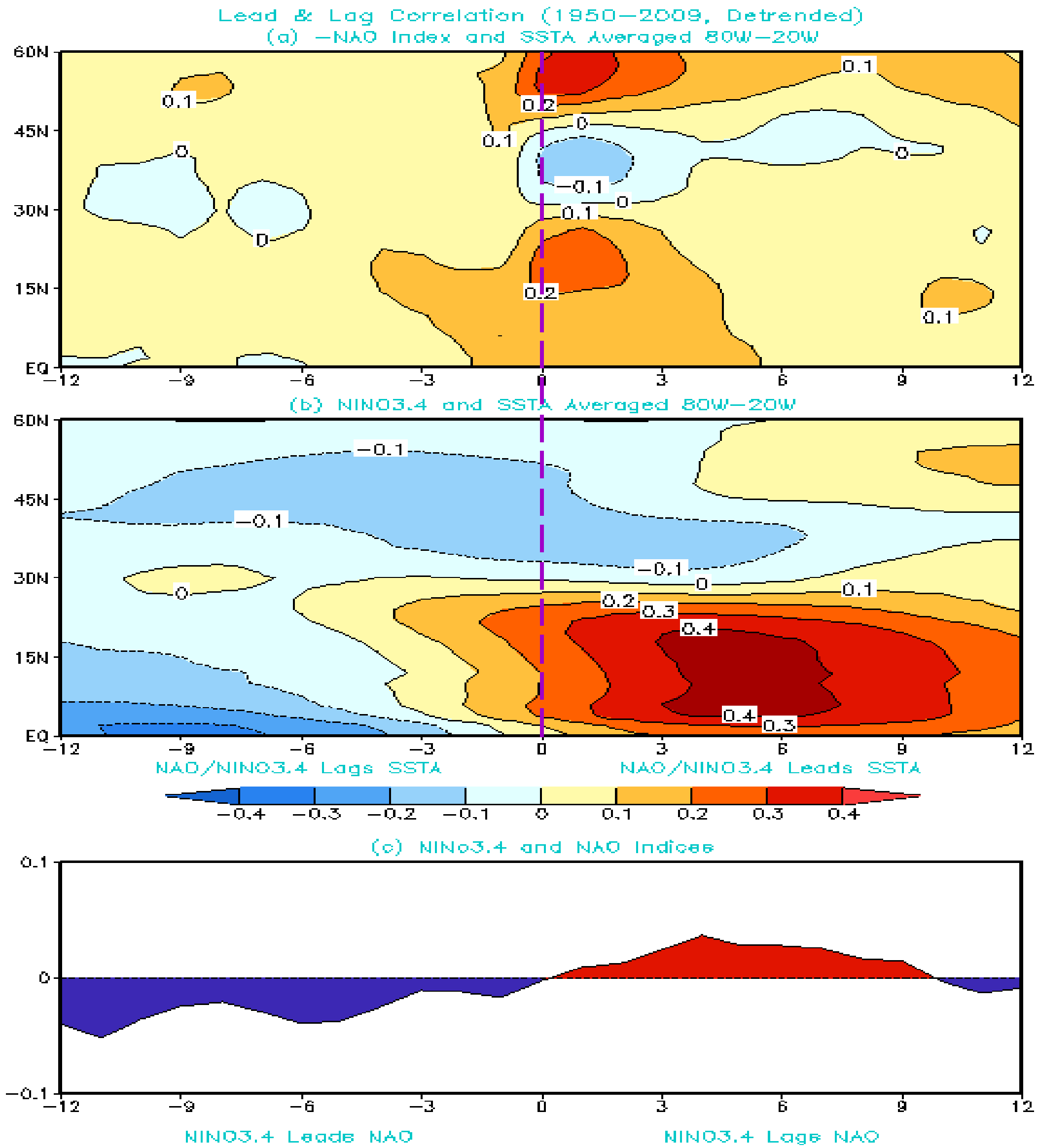




- NAO was persistently below-normal during Oct 2009-Jan 2011, which contributed to the development and maintenance of negative (positive) SSTA in mid-latitude (tropical and high latitude) North Atlantic.
- The tripole or horseshoe pattern of SSTA in 2009-2011 was largely associated with the influence of NAO and ENSO cycle, as well as long-term trend and SST feedback (next slide).

**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.**

# Historical Connection of SST with Nino3.4 & NAO




**NAO's impact on SST is mainly with 0-3 month lag. The NAO correlation is weaker than that of ENSO.**

**The tripole or horseshoe pattern is consisting with the observed SSTA in 2009-2011.**

**ENSO signals propagate into the tropical N. Atlantic in 3-8 months late.**

**ENSO affects the trade wind through atmosphere (PNA), then changes the SST through WES mechanism.**

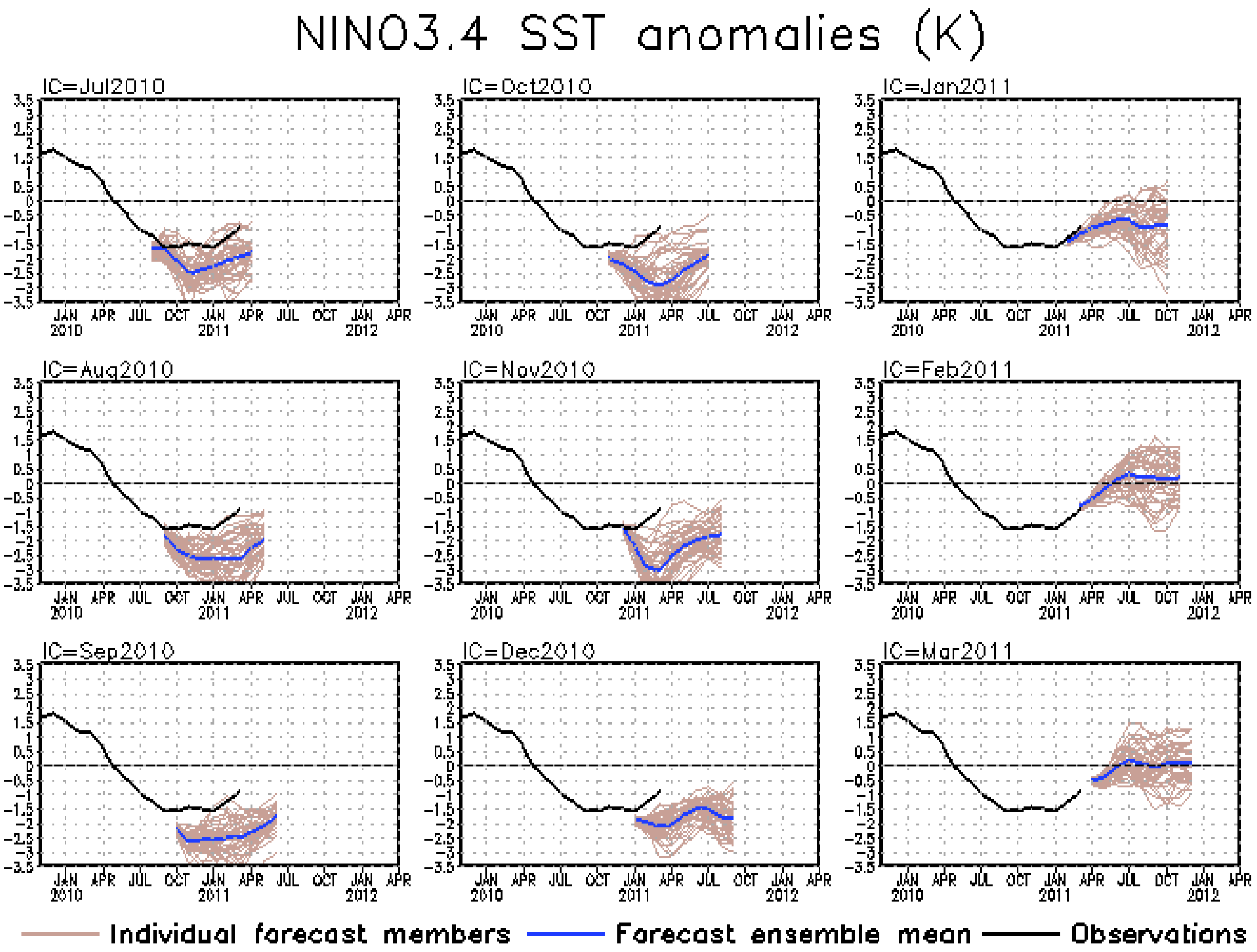
**Preceding El Nino may slightly favor to negative phase of NAO.**

**From:**
*Hu, Z.-Z., A. Kumar, B. Huang, Y. Xue, W. Wang, and B. Jha, 2010: Persistent atmospheric and oceanic anomalies in the North Atlantic from Summer 2009 to Summer 2010. J. Climate (revised).*


40

# CFS SST Predictions and Ocean Initial Conditions

# CFS Niño3.4 SST Predictions from Different Initial Months

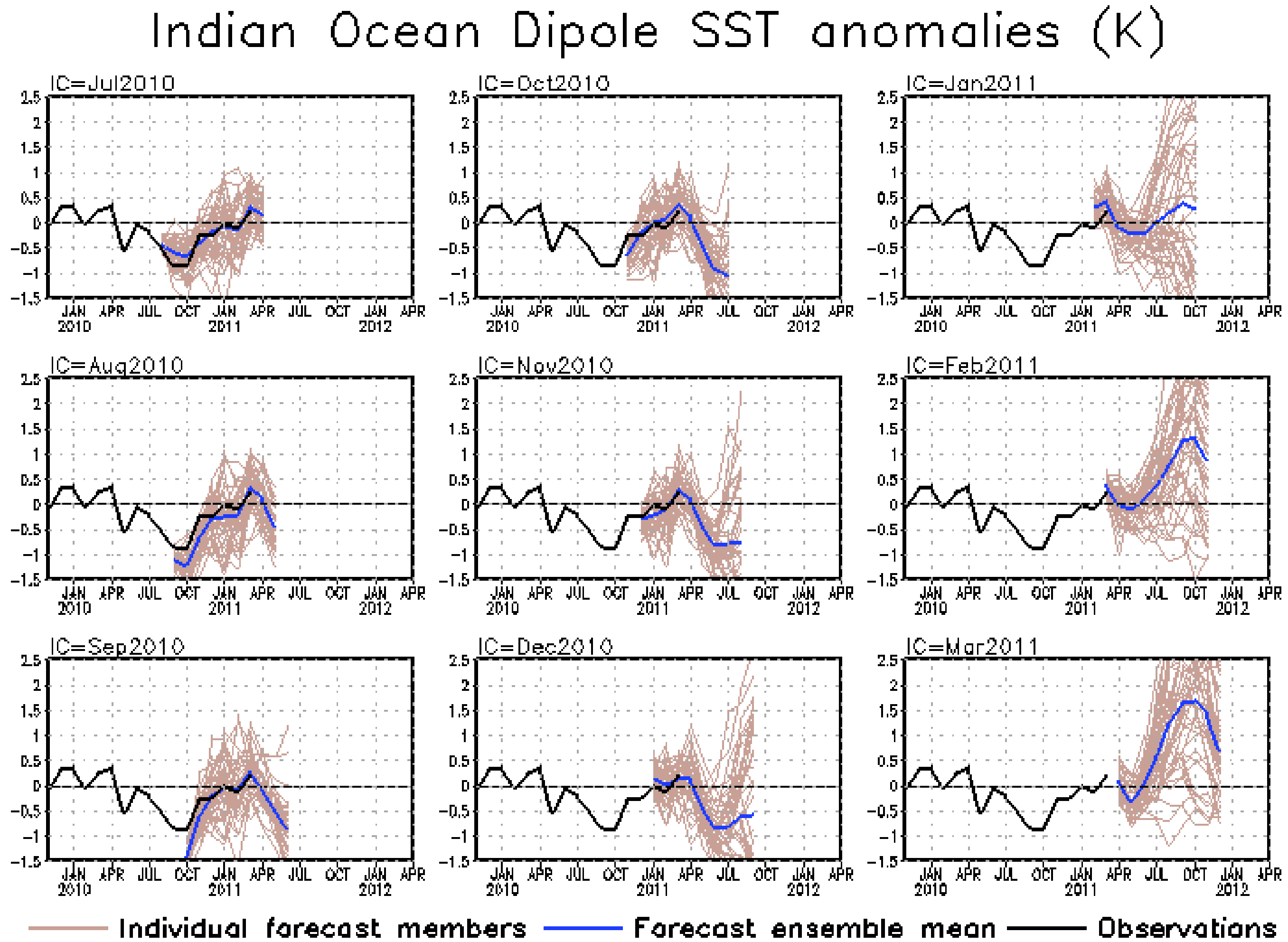



- **Forecasts from Jul-Dec I.C. had cold biases. The recent cold forecast biases can be alleviated through statistical model corrections (*http://www.cpc.ncep.noaa.gov/products/people/wwang/cfs_fcst*).**

- **The latest forecasts from Mar 2011 I.C. suggest that the current La Niña is in decay phase, and ENSO will be near neutral by the summer 2011.**

**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). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1981-2010 base period means.**

# CFS DMI SST Predictions from Different Initial Months




**DMI = WTIO- SETIO**

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

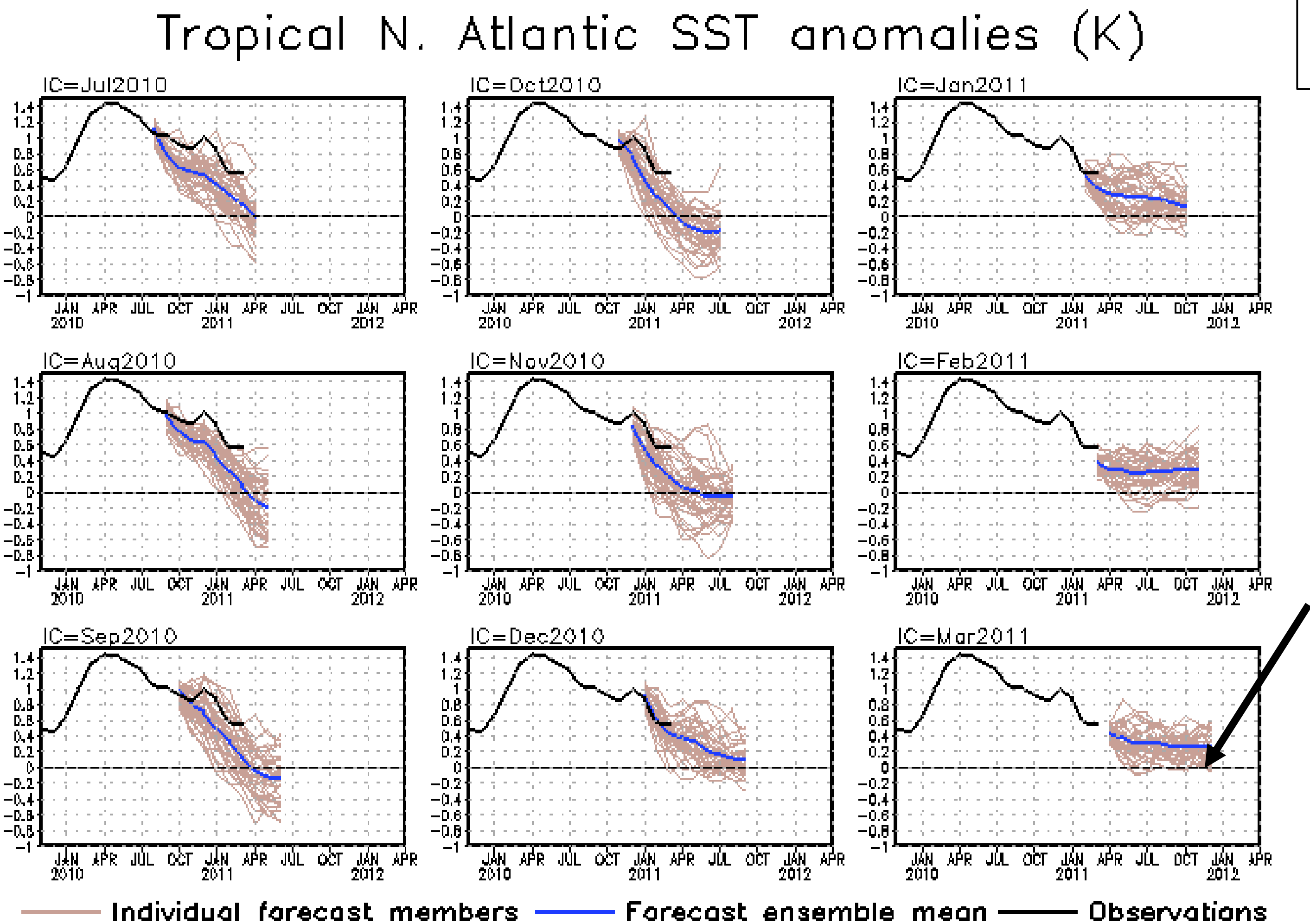
**WTIO = SST anomaly in [50°E-70°E, 10°S-10°N]**

- **The spread between individual members was large, implying the uncertainty of the forecasts.**
- **Forecasts from Mar 2011 I.C. suggest a clear positive phase of IOD will develop in summer-autumn 2011.**

**Fig. M2. CFS Dipole Model Index (DMI) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1981-2010 base period means.**

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

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

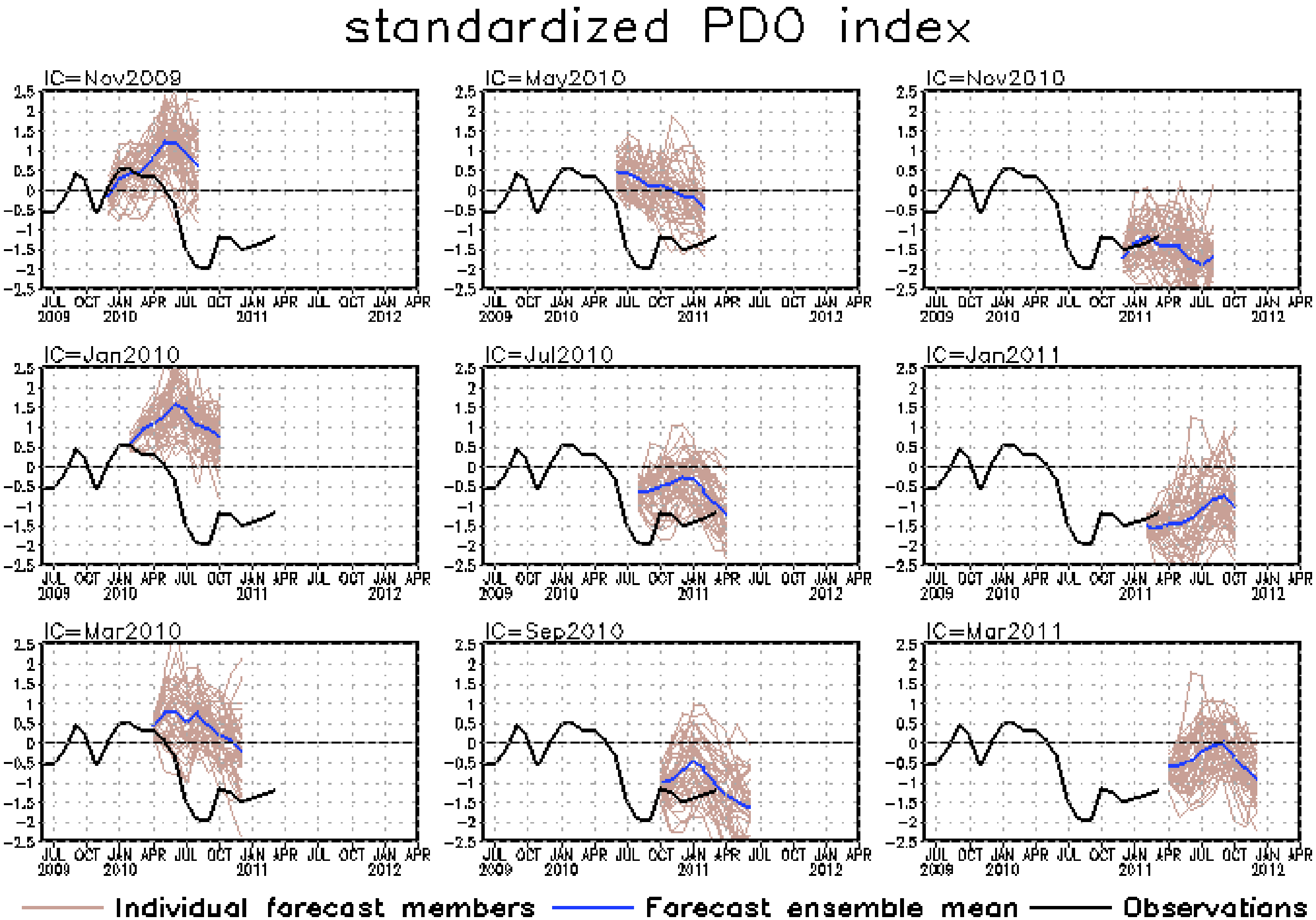



- Cold forecast biases were evident, may due to the fact that the NAO and its impact were poorly predicted.

- Latest forecasts suggest that positive SSTA in the tropical North Atlantic will decay slowly in next few months.

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). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1981-2010 base period means.

# CFS 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.**

**- The onset of the negative phase of the PDO was poorly forecast.**

**- Latest forecasts suggest that the negative phase of the PDO will weaken in next few months and return to near-normal condition in summer/fall 2011.**

**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). 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

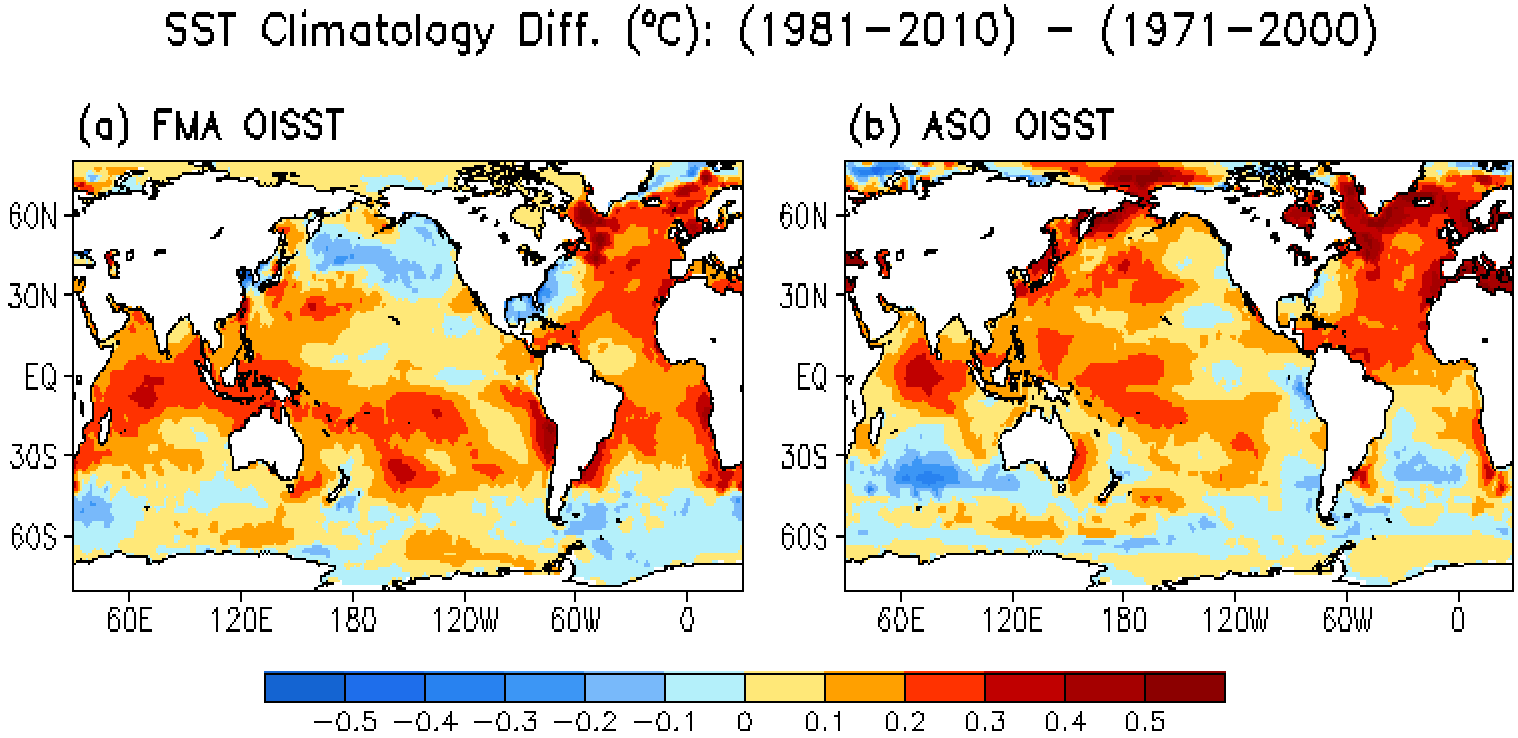
- **Pacific and Arctic Oceans**
  - **ENSO cycle: La Niña conditions continuously weakened with OISST NINO3.4=-1.0°C in Mar 2011.**
  - **NOAA/NCEP Climate Forecast System (CFS) suggests that the current La Niña is in a decay phase, and ENSO will be near neutral by summer 2011.**
  - **PDO has been negative since Jun 2010, and weakened slightly since Jan 2011 with PDO index=-1.18 in Mar 2011.**
  - **Seasonal downwelling intensified at 35°N-57°N along the west coast of North America in Mar 2011, leading to below-normal nutrient supply.**
  - **Artic sea ice extent was well below normal in Mar 2011, and it was the second-lowest ice extent for the month in the satellite record, after 2006.**
- **Indian Ocean**
  - **SSTA was small negative.**
- **Atlantic Ocean**
  - **After 16 month persistent negative phase (Oct 2009-Jan2011), NAO has switched to positive phase since Feb 2011 with NAO index = 0.6 in Mar 2011.**
  - **Tripole SSTA pattern has weakened since Feb 2011.**

# Backup Slides

# 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)**
- **SST 1971-2000 base period means (Xue et al. 2003)**
- **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!**