Global Air-Sea Coupled Modes: Recent Evolution, Current Status and Prediction

Update prepared by
Climate Prediction Center / NCEP
July 9, 2007

Outline

- Overview
- Recent Evolution and Current Conditions
  - ✓ Pacific Ocean
  - ✓ Indian Ocean
  - ✓ Atlantic Ocean
- Uncertainties in NCEP's Global Ocean Data Assimilation System (GODAS)
- SST Predictions by NCEP's Climate Forecast System

Overview

• In mid-May 2007, a Kelvin wave episode, forced by relaxation of easterly wind anomalies, moved positive heat content anomalies eastward and pushed negative heat content anomalies back to east of 100°W in the tropical Pacific.

• Negative SST and SSH anomalies over the Gulf of Alaska increased from May to June 2007 due to Ekman pumping forced by cyclonic surface wind anomalies in the region.

• Upwelling along the west coast of North America has been close to normal conditions during the spring-summer 2007 upwelling season.

• Easterly wind anomalies in the tropical Indian Ocean, probably associated with Asian Monsoon forcing, generated negative (positive) sea surface height anomalies in the eastern (central) equatorial Indian Ocean.

• Positive SST anomalies in the eastern equatorial Atlantic persisted, probably supported by westerly wind anomalies in the central Atlantic and positive heat content anomalies in the eastern Atlantic.

• The triple-pole SST pattern in North Atlantic has been persistent since February 2007.

Data Sources

- Optimal Interpolation SST version 2
- NCEP/NCAR Reanalysis-1 850 mb and 200 mb winds
- Outgoing Long Wave Radiation (NOAA 18 AVHRR IR by NESDIS/ORA)
- NCEP's Global Ocean Data Assimilation System (GODAS)
- Aviso Altimetry Sea Surface Height
- Ocean Surface Current Analyses – Realtime (OSCAR)

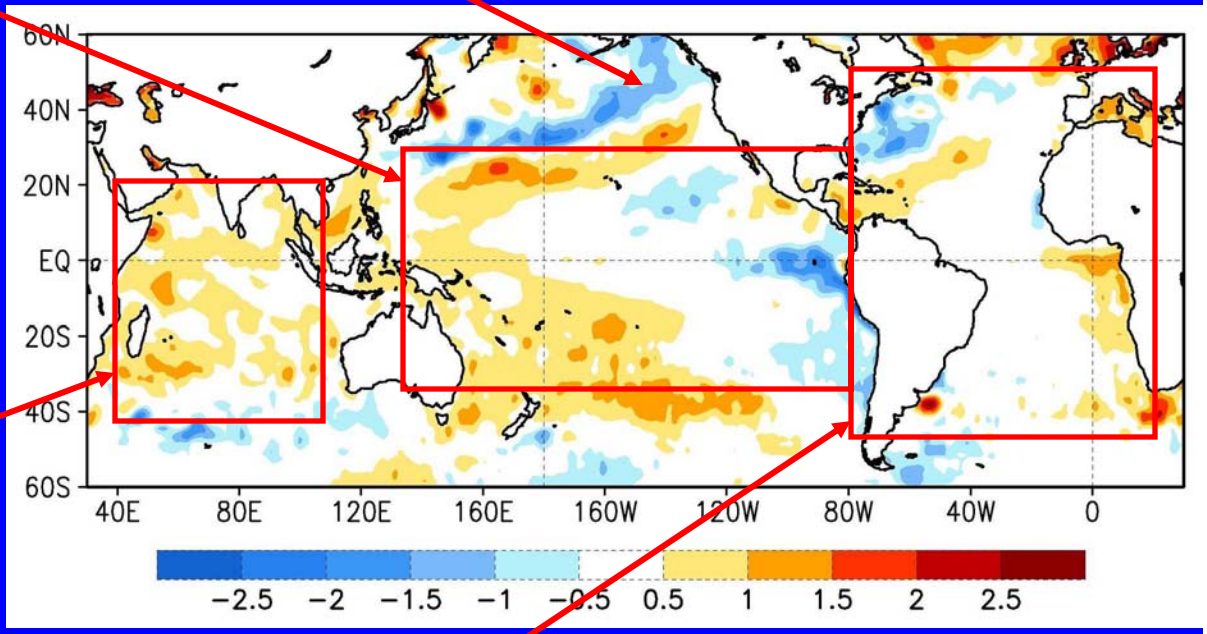
Global Ocean SST Departures (°C)

(Climatology 1971-2000)

June 2007

Negative SST departures were present over the Gulf of Alaska.

Positive SST departures were present in the western equatorial Pacific, western-central subtropical Pacific, and negative SST departures were present in the eastern equatorial Pacific.



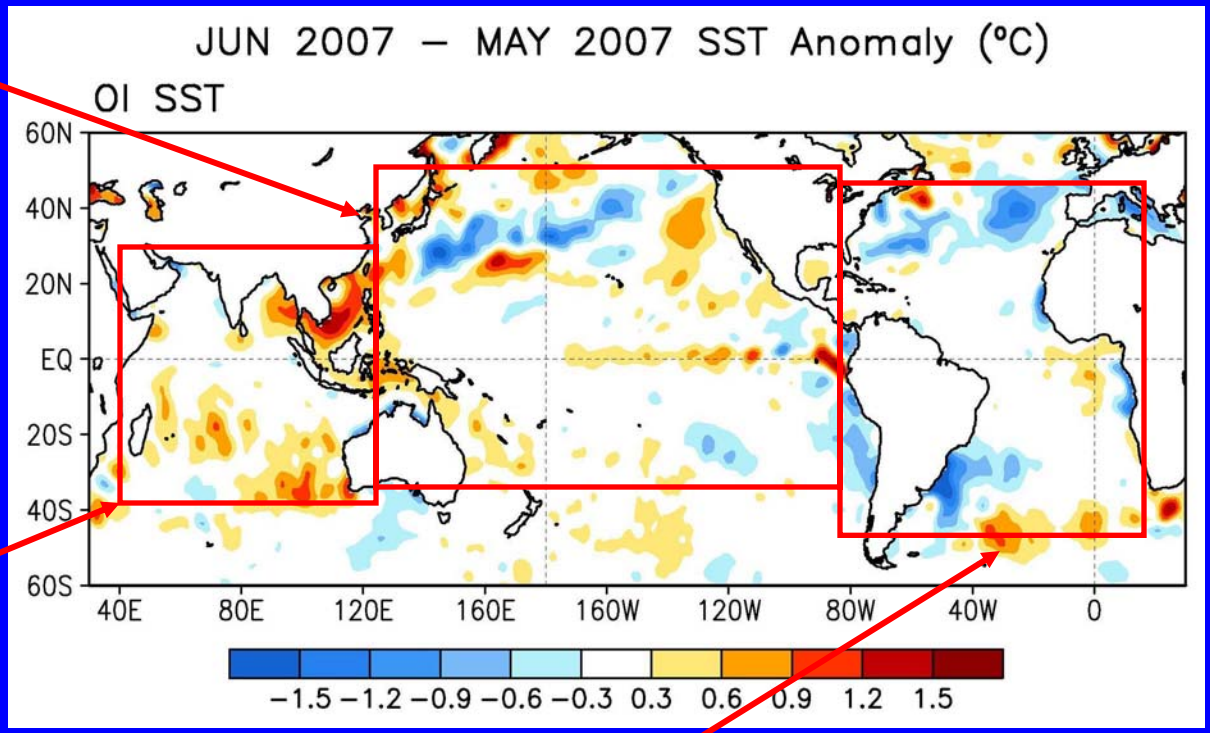
Positive SST departures were present in the tropical Indian Ocean, southeast of Madagascar, and near the coasts of Somalia and Arabia.

Positive SST departures were present in the Caribbean Sea, the western coast of Africa and eastern equatorial Atlantic. Negative SST departures were present along the eastern coast of North America.

Global Ocean SST Departure Tendency (°C)

(Climatology 1971-2000)

SST anomalies increased in the eastern equatorial Pacific and northeast Pacific, but decreased along the Kuroshio Extension.



SST anomalies increased substantially in South China Sea and the eastern Bay of Bengal.

SST anomalies decreased substantially in the southwest Atlantic, the western coast of Africa and midlatitude North Atlantic. SST anomalies increased slightly in the central-eastern equatorial Atlantic.

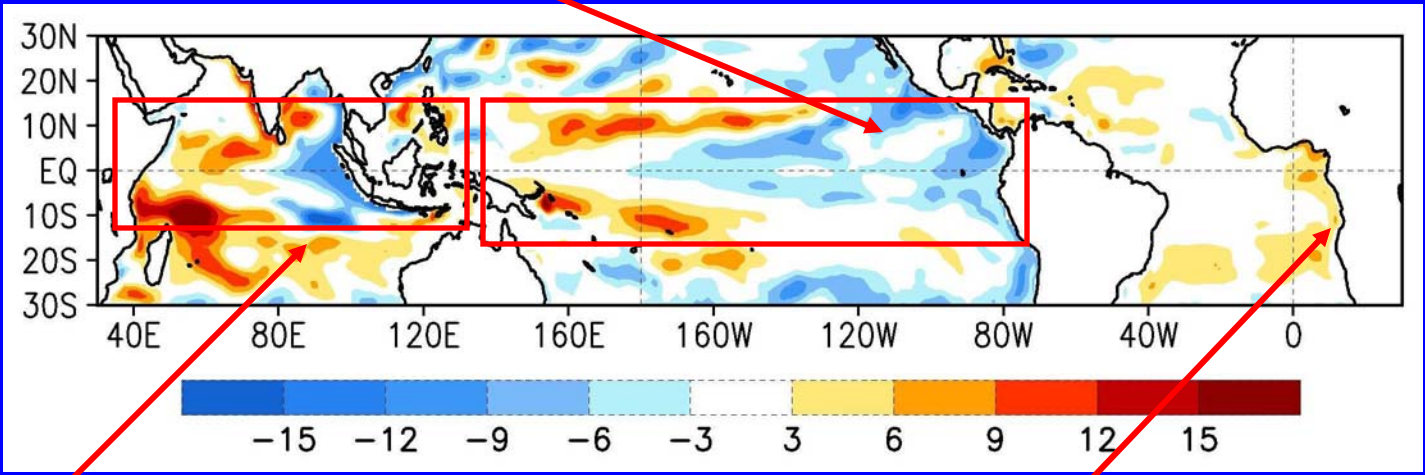
Tropical Sea Surface Height Departures (cm)

(Climatology 1982-2004)

June 2007

SSH is from the Global Ocean Data Assimilation System (GODAS) (http://www.cpc.ncep.noaa.gov/products/GODAS)

Negative SSH departures were present in the eastern-central equatorial Pacific, and positive SSH departures in the western-central subtropical Pacific.



Negative SSH departures were present in the far eastern equatorial Indian Ocean and along its eastern boundary. Positive SSH departures were present in the western tropical Indian Ocean.

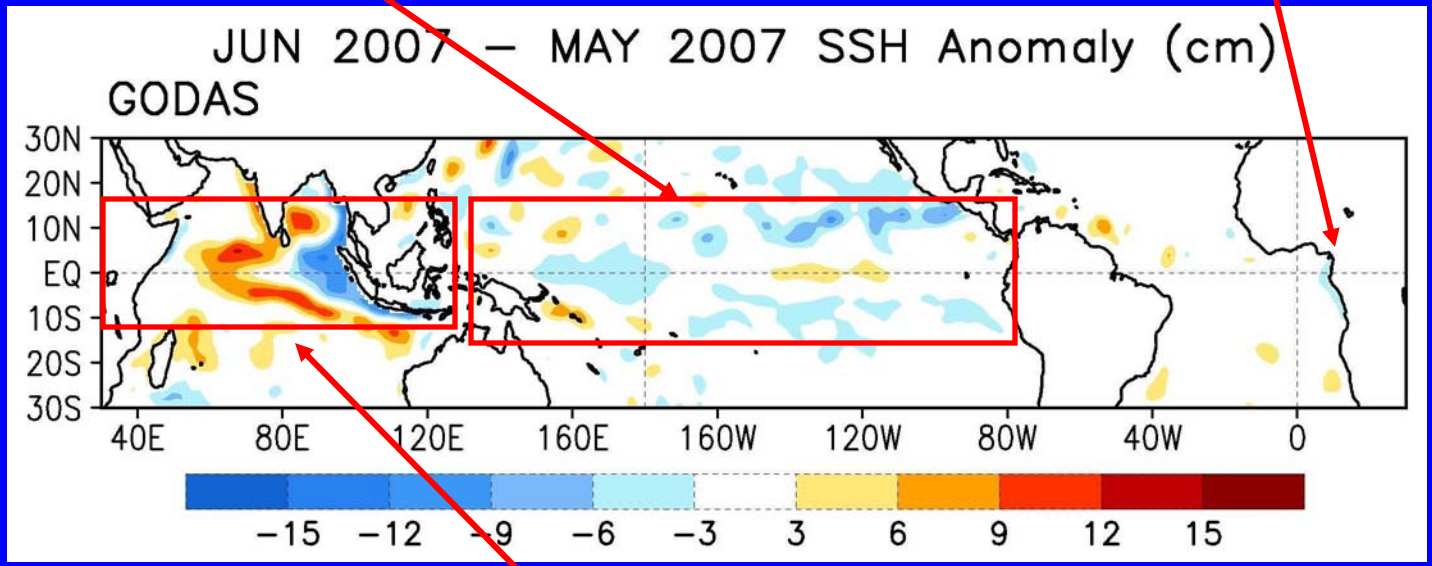
Positive SSH departures were present in the far eastern equatorial Atlantic Ocean.

Sea Surface Height Departure Tendency (cm)

(Climatology 1982-2004)

SSH decreased in the western equatorial Pacific and northeast subtropical Pacific, but increased in the eastern equatorial Pacific between 150°W and 110°W.

SSH decreased in the far eastern equatorial Atlantic Ocean.

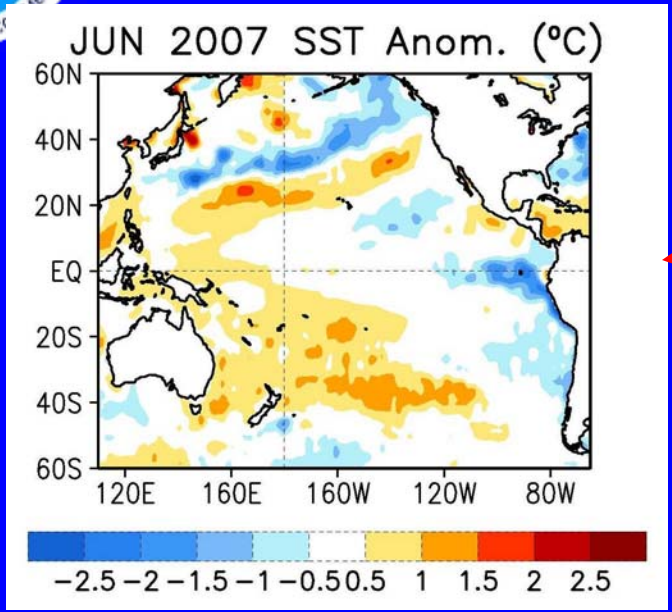


SSH decreased (increased) substantially in the far eastern (central) equatorial Indian Ocean.

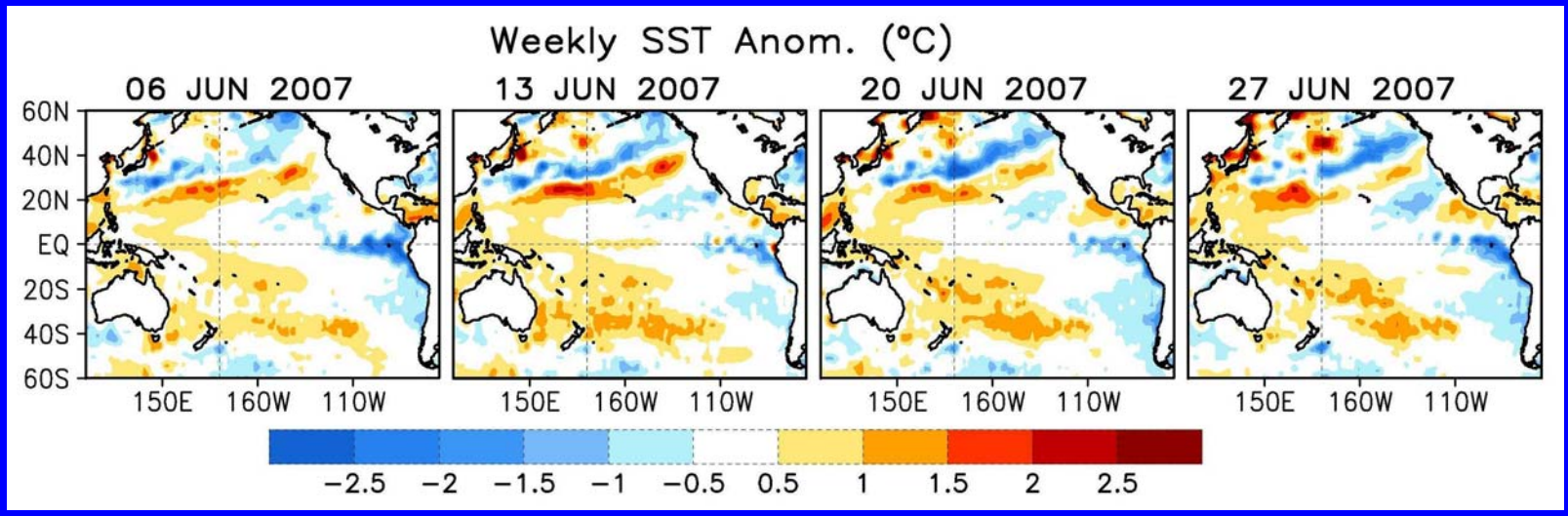
Pacific Ocean

Pacific Ocean SST Departures (ºC)

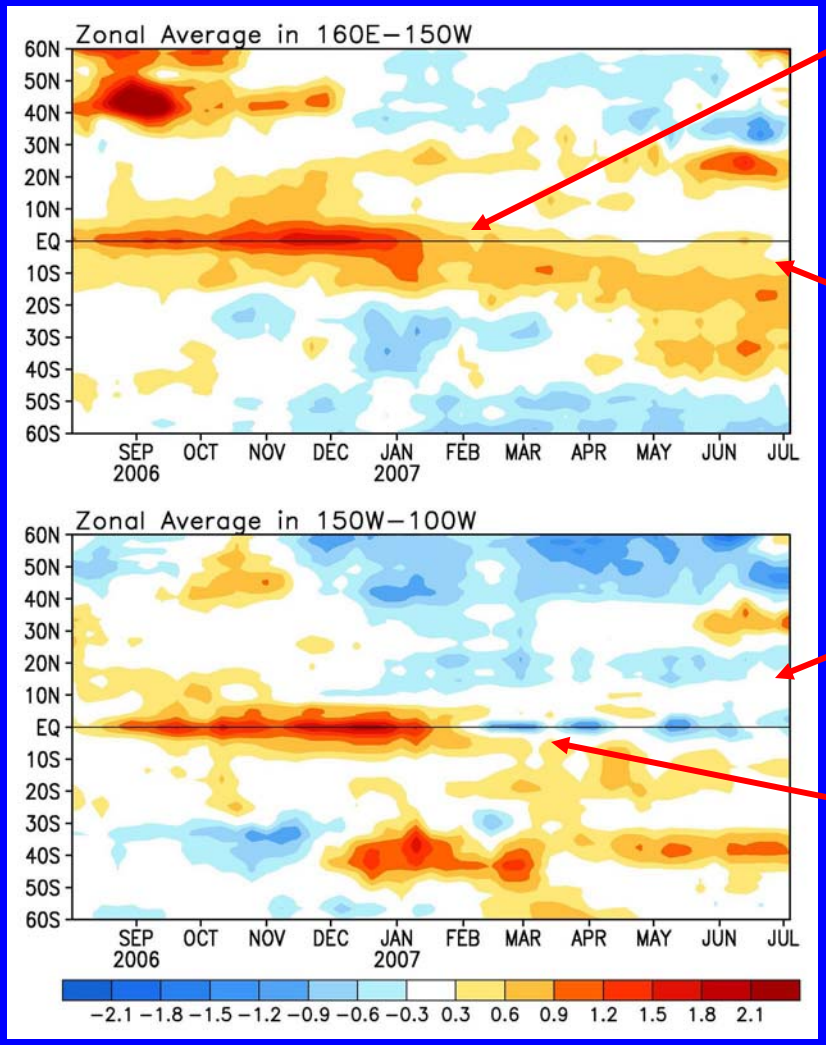
(Climatology 1971-2000)



Positive SST departures were present in the western equatorial Pacific, the western-central subtropical Pacific, and negative SST departures were present in the eastern equatorial Pacific and from the Gulf of Alaska to the Kuroshio Extension.



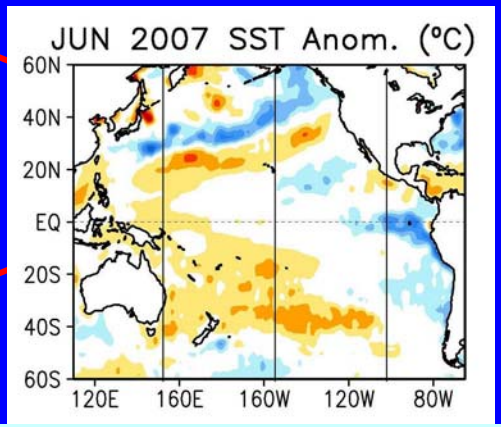
Recent Evolution of SST Departures (ºC) in the Central and Eastern Pacific



Latitude

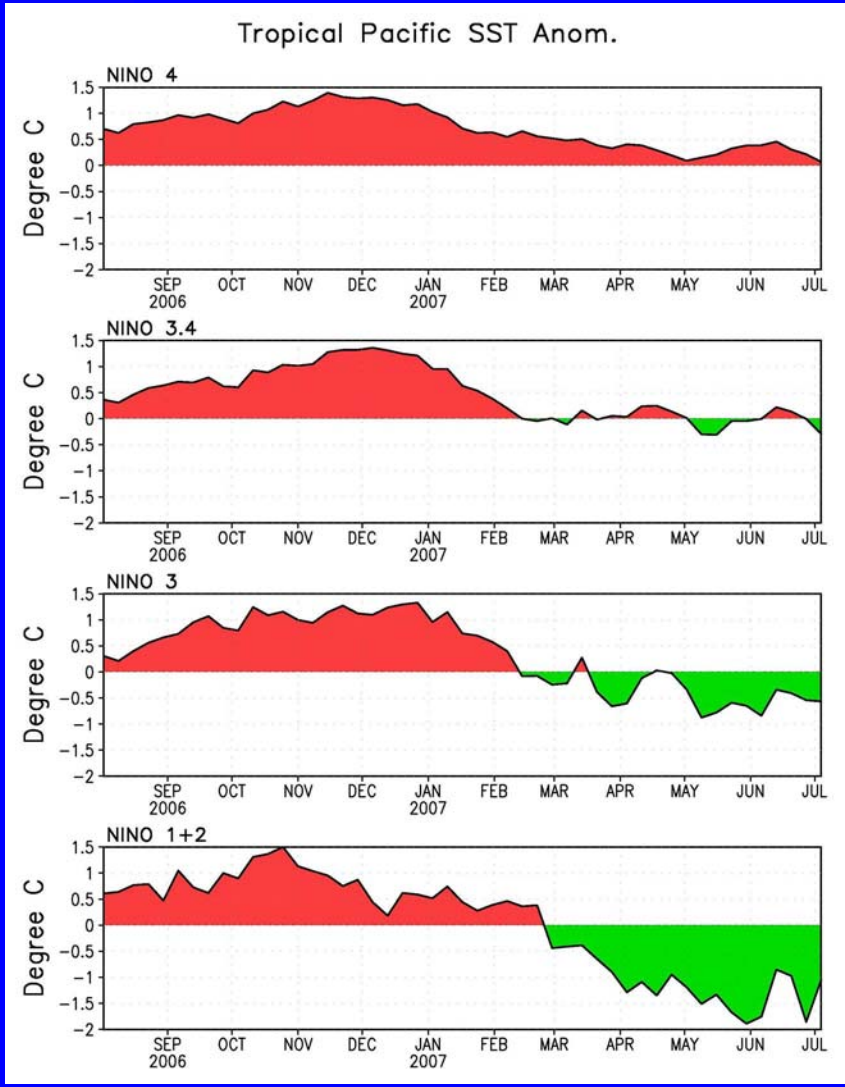
Time

During the past 12 months, the zonal average SSTs in 160ºE-150ºW have been above-average between 20ºS and 5ºN with anomalies > +1º during September to December 2006. The center of anomalies shifted from the equator to about 10ºS and persisted since January 2007.



During the past 12 months, the zonal average SSTs in 150ºW-100ºW have been above-average between 10ºS and 5ºN during September 2006 to January 2007, and below-average afterwards. The negative SST anomalies between 40ºN and 60ºN over the Gulf of Alaska and positive SST anomalies in South Pacific have persisted since December 2006.

Recent Evolution of Pacific NINO SST Indices



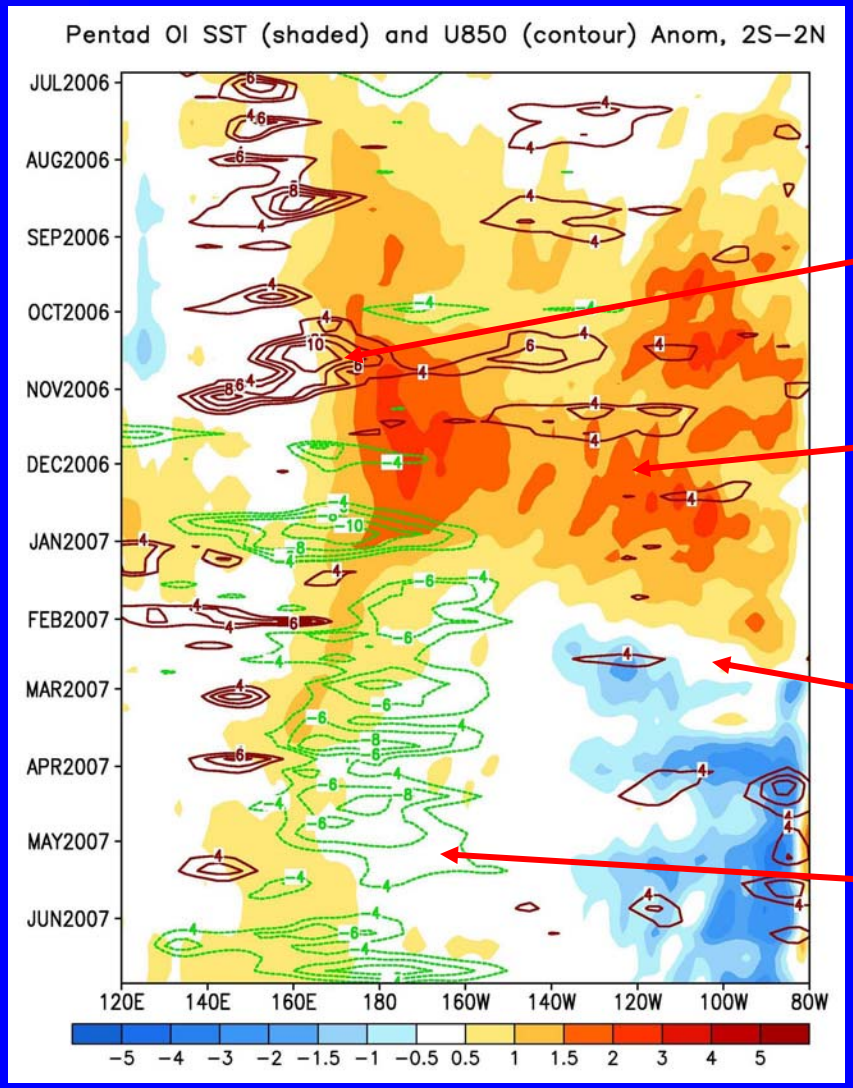
- **NINO 4 SSTs increased gradually from 0.5ºC in August to 1.4ºC in November-December, decreased rapidly in January 2007 to about 0.5ºC. It has been near neutral since then.**

- **NINO 3.4 increased from near neutral in July to about 1.3ºC in November-December, and then decreased rapidly to near neutral in February 2007, and remained neutral since then.**

- **NINO 3 increased from near neutral in July to ~ 1.1ºC in November-December, and then decreased rapidly to below-average in March 2007. It was ~ -0.4ºC in June 2007.**

- **NINO 1+2 increased from near neutral conditions in June to ~ 1.4ºC in October, and then decreased gradually. It became below-average since March 2007.**

Recent Evolution of Equatorial Pacific SST (shaded, ºC) and Surface Zonal Wind (contour, cm/s) Departures



Time

Longitude

Climatology: SST 1971-2000

850 mb winds 1979-1995

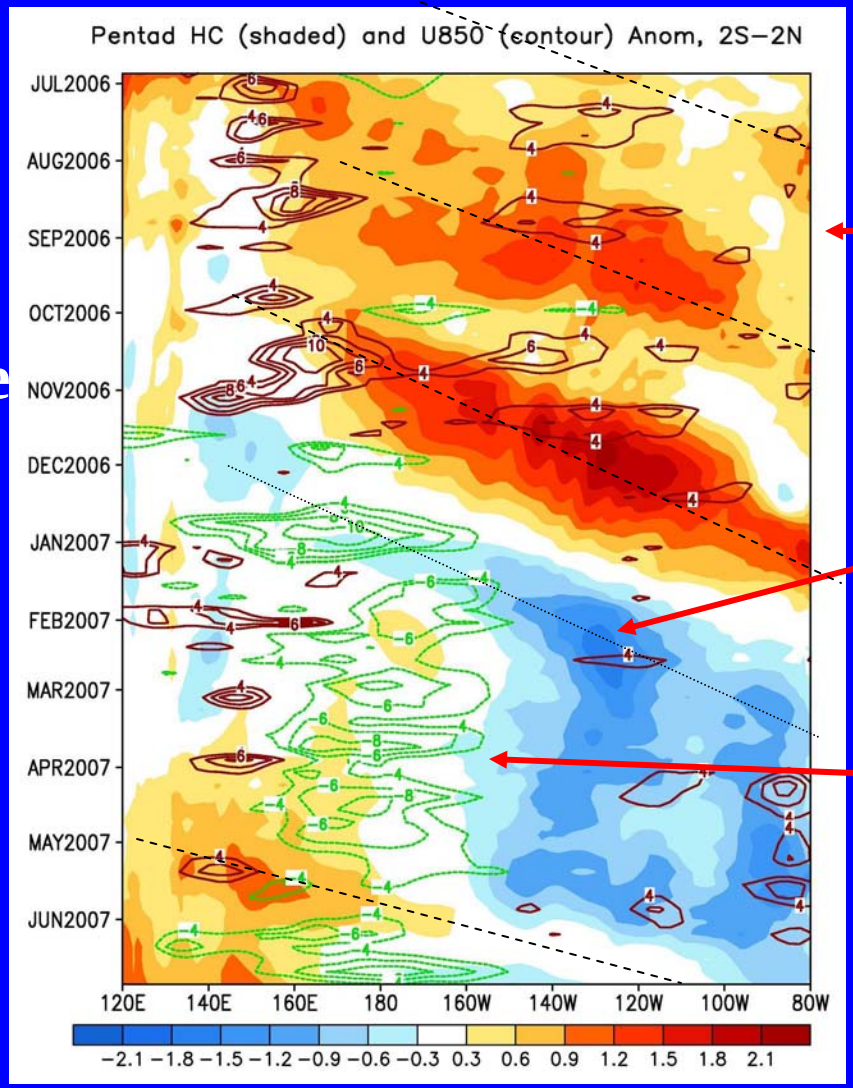
Above-average SST departures were accompanied by westerly wind anomalies to the west of SST anomalies.

Between July 2006 and December 2006, positive SST anomalies increased across the equatorial Pacific between 160ºE and the South American coast.

During January-February 2007, SST anomalies decreased everywhere east of the Date Line.

Easterly wind anomalies have been persistent since December 2006 while they were interrupted by intraseasonal variability in May-June 2007.

Recent Evolution of Equatorial Pacific Upper Ocean (0-300m) Heat Content and Surface Zonal Wind Departures



Time

Longitude

Climatology: GODAS Heat Content 1982-2004
850 mb wind 1979-1995

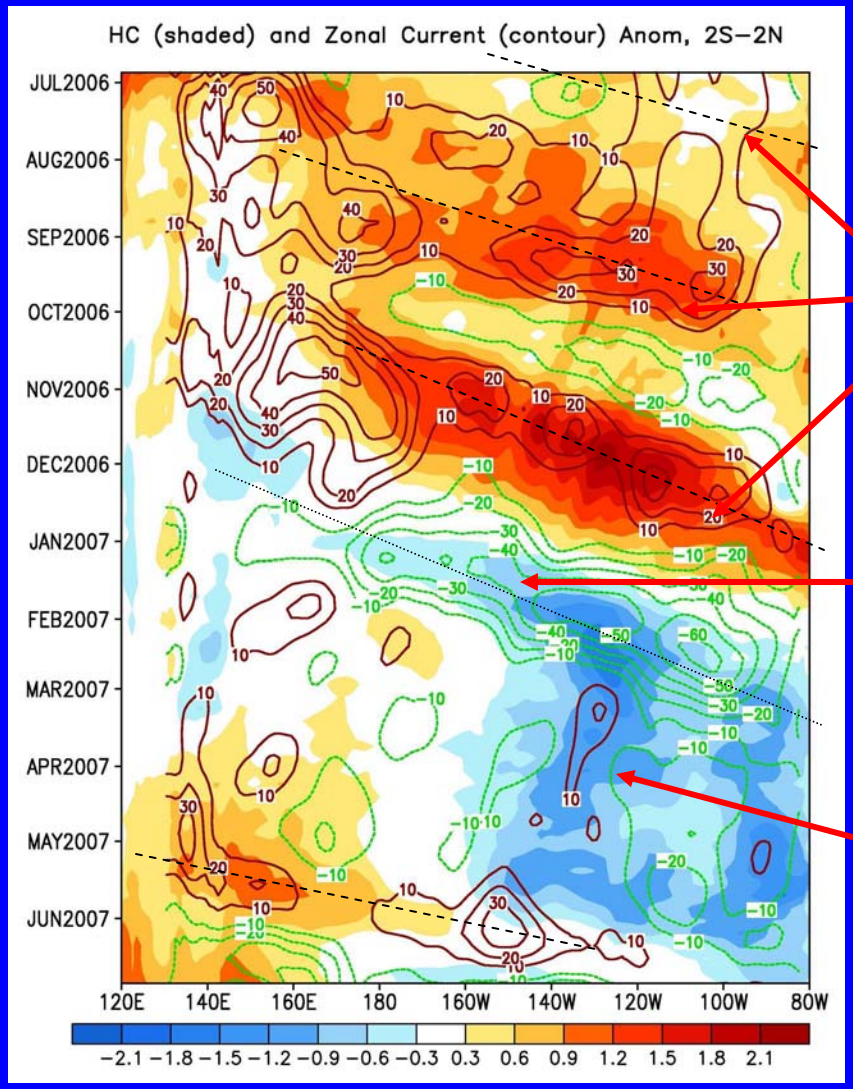
Three episodes of Kelvin waves, the warm phases of which are indicated by the dashed lines, were evident in heat content (HC) departures during May to December 2006. They were forced by westerly wind anomalies (contour) in the western-central Pacific.

One Kevin wave episode, the negative phase of which is indicated by the dotted line, was initiated in late December 2006 by strong easterly wind anomalies (EWA).

During January-May 2007, EWA were present between 160ºE-160ºW, consistent with the negative HC anomalies in the eastern Pacific.

During mid-May 2007, a Kevin wave episode, forced by relaxation of EWA, has largely removed negative HC anomalies in the eastern Pacific.

Recent Evolution of Equatorial Pacific Upper Ocean (0-300m) Heat Content and Surface Zonal Current Departures



Time

Longitude

Climatology: GODAS Heat Content 1982-2004
OSCAR Surface Zonal Current 1979-1995

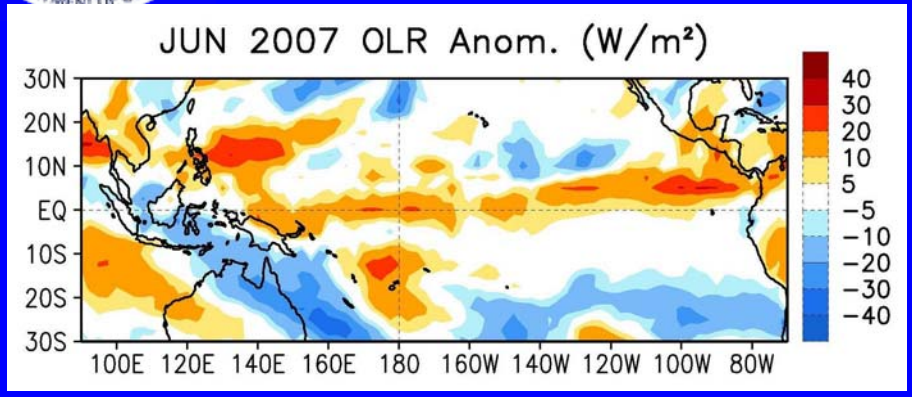
Three episodes of Kelvin waves, the warm phases of which are indicated by the dashed lines, were evident in not only heat content (HC) (shaded) but also surface zonal current (SZC) (contour) departures during May to December 2006.

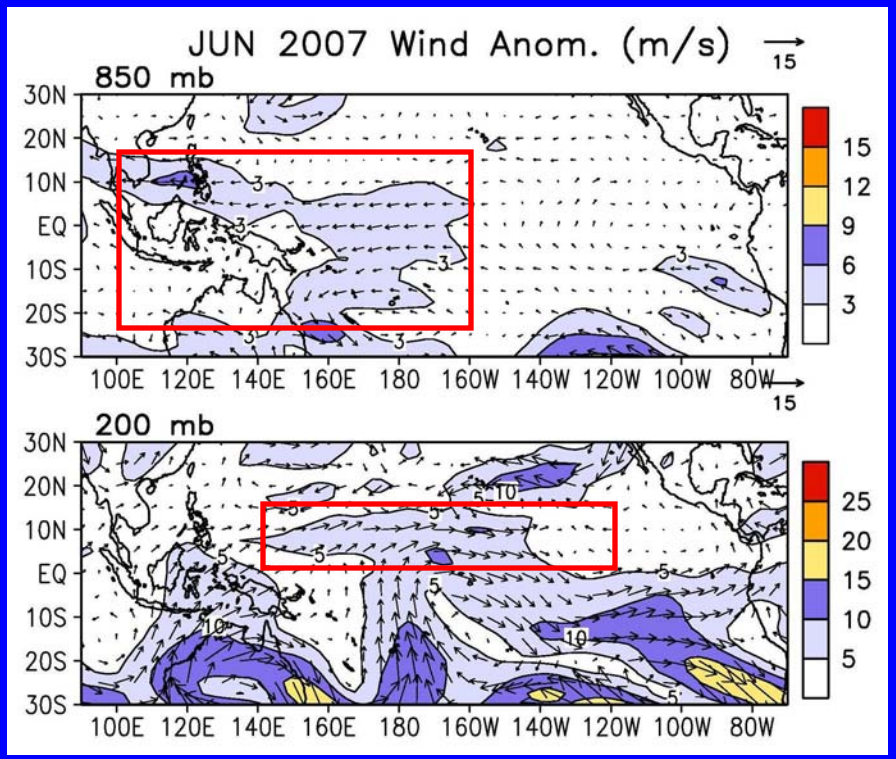
One Kevin wave episode, the negative phase of which is indicated by the dotted line, was initiated in late December 2006 and had signatures in both HC and SZC anomalies.

During January-May 2007, negative HC anomalies were persistent in the eastern Pacific, while negative SZC anomalies decreased substantially in early March.

During mid-May 2007, a Kevin wave episode, forced by relaxation of EWA, was evident in both HC and SZC.

Tropical Pacific: OLR and Wind Anomalies





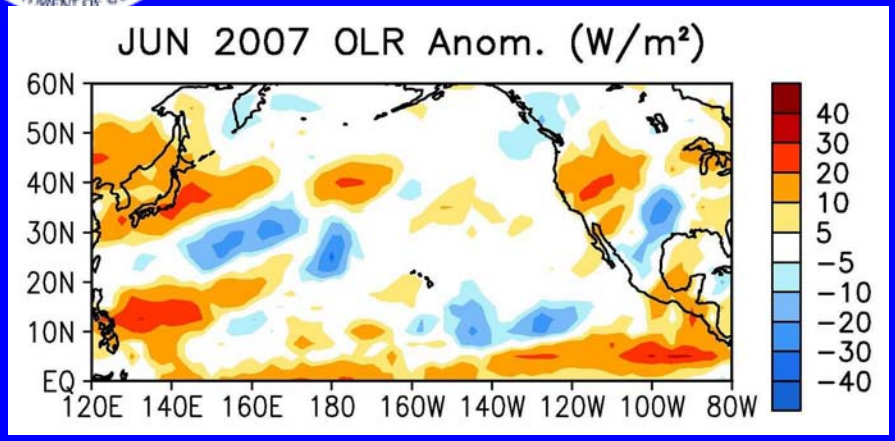
Climatology: OLR 1979-1995
Winds 1979-1995

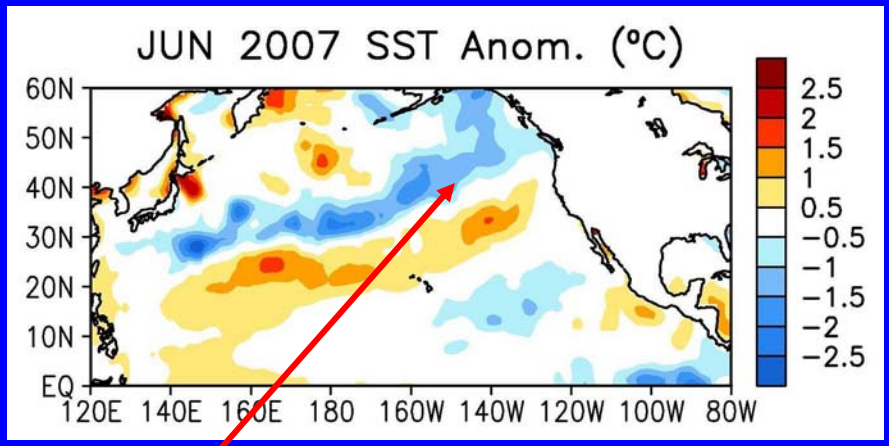
Negative OLR anomalies (enhanced convection and precipitation, blue shading) were observed over parts of the Maritime Continent and the northeast Australia, while positive OLR anomalies (suppressed convection, orange shading) were observed in the tropical Pacific.

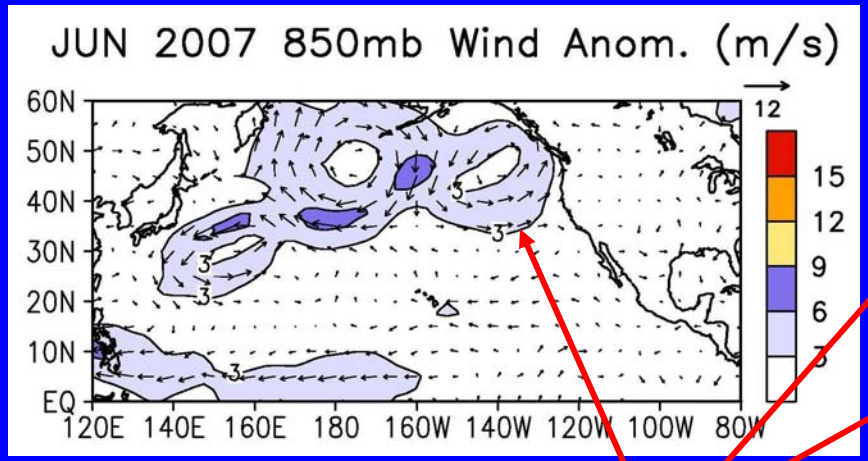
Low-level (850-hPa) easterly wind anomalies were observed in the western-central tropical Pacific and South China Sea.

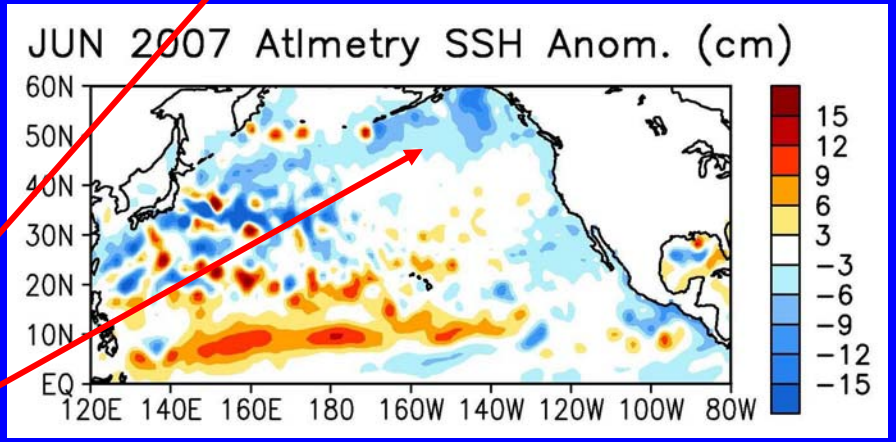
Upper-level (200-hPa) westerly wind anomalies were observed in the central tropical Pacific north of the equator.

North Pacific OLR, 850mb Wind, SST and SSH Anom.



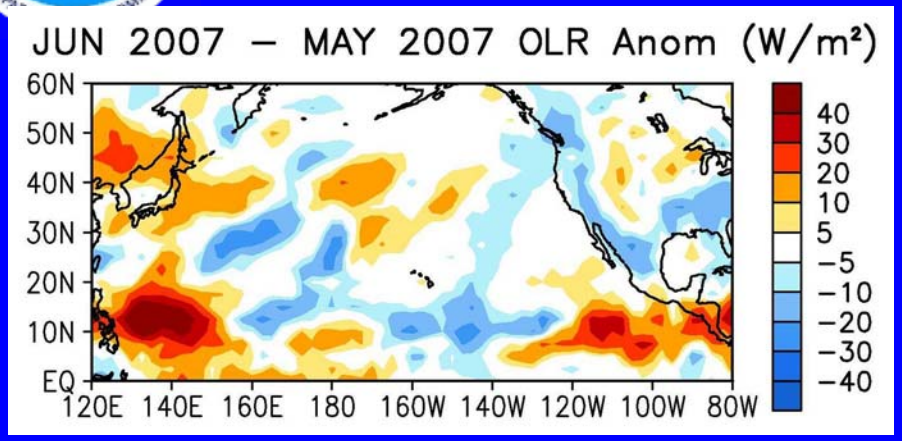


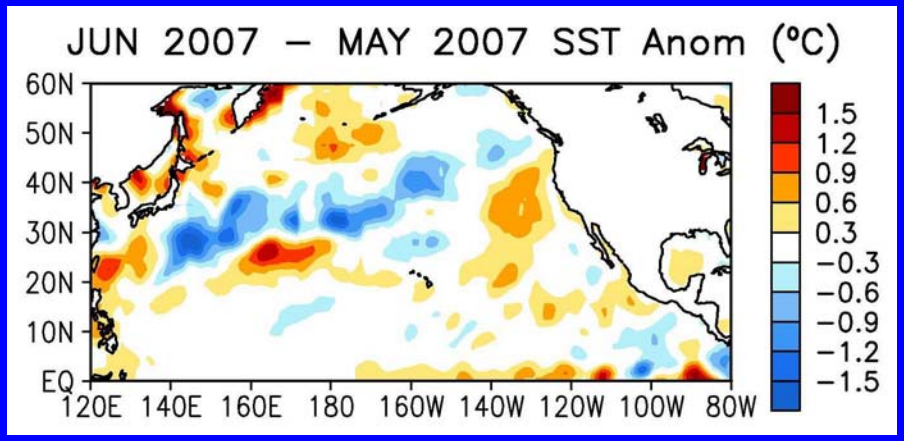


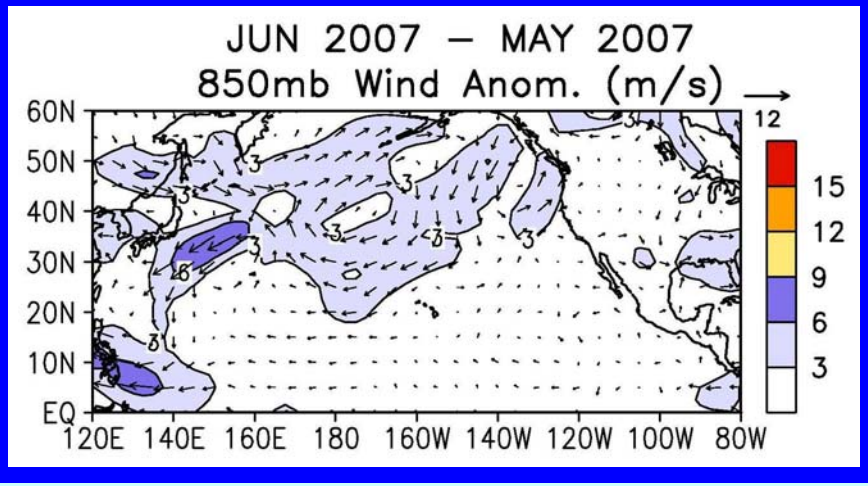


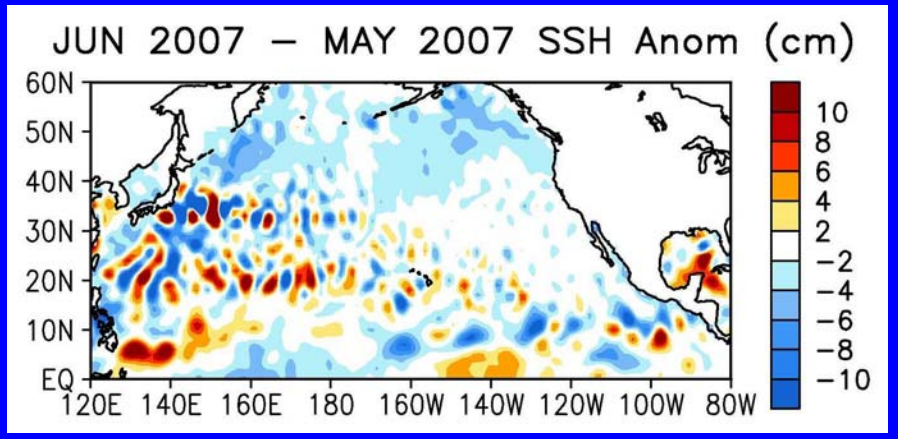
The below-average SST and Sea Surface Height (SSH) in the Gulf of Alaska were associated with the cyclonic surface wind anomalies, which lowered SST and SSH by Ekman pumping.

Tendency of North Pacific OLR, 850mb Wind, SST and SSH Anom.





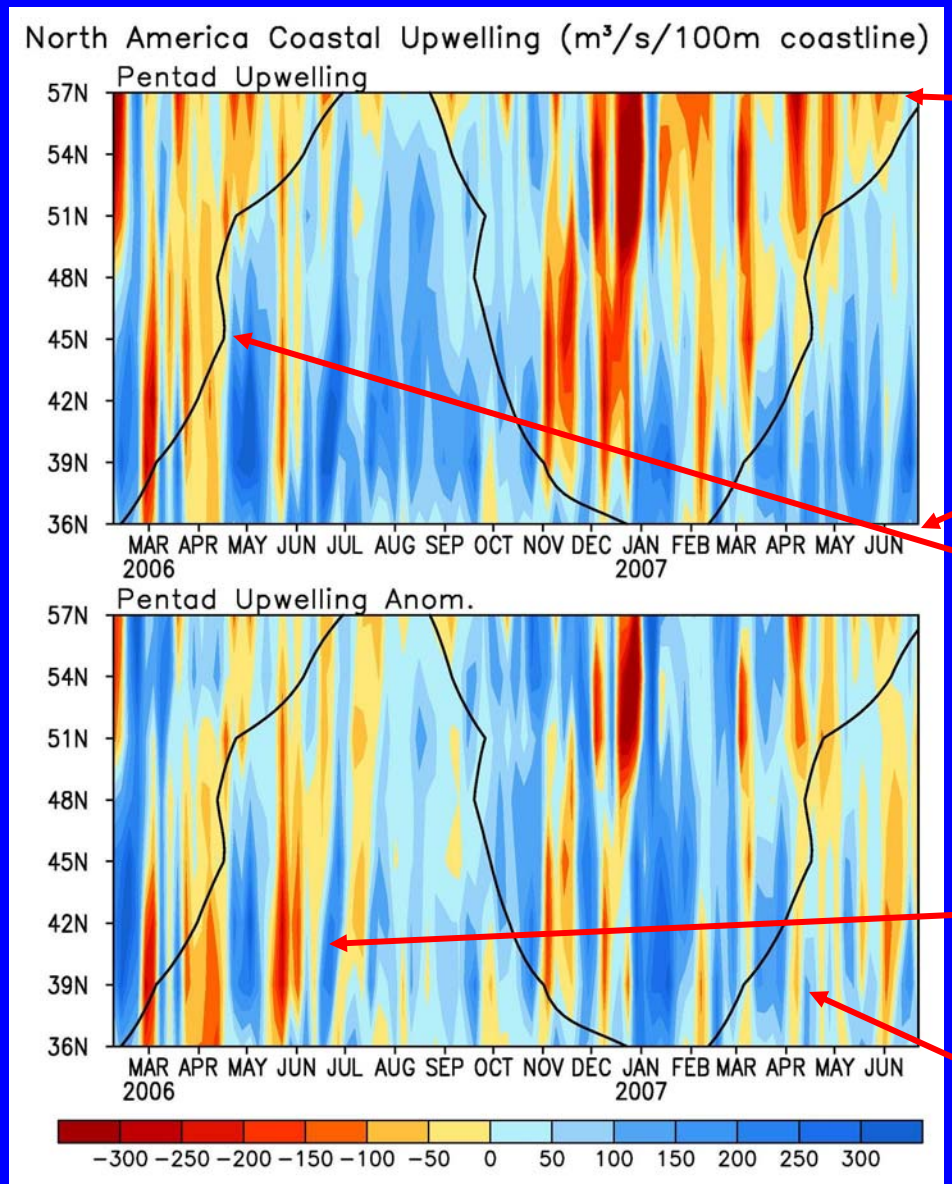


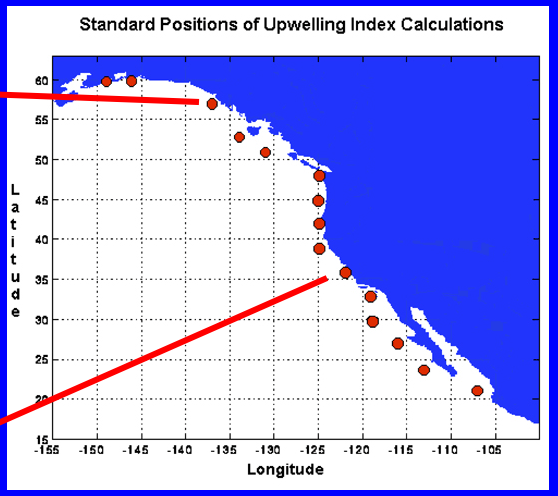


The southwesterly surface wind tendency near the west coast of North America was associated with enhanced precipitation (negative OLR tendency) in Pacific Northwest by transporting moisture inland. The cyclonic surface wind tendency over the Gulf of Alaska was associated with negative SSH and SST tendency by Ekman pumping. The easterly surface wind tendency near the Kuroshio Extension was associated with the negative SST tendency in the region by enhancing evaporation.

Recent Evolution of Coastal Upwelling at 8 West Coast Sites of North America

PFEL, NOAA Fisheries Service



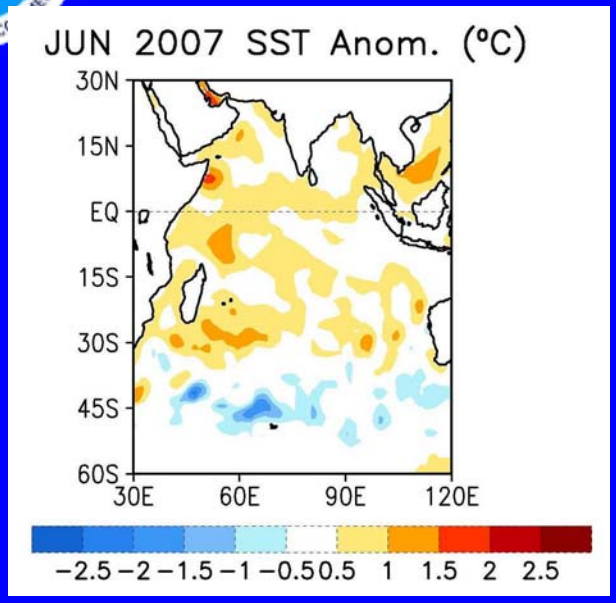


- **The climatological zero upwelling, represented by the black line, indicates that the climatological upwelling seasons progress from March to July along the west coast of North America from 36ºN to 57ºN.**
- **The upwelling in the spring-summer of 2006 had large intraseasonal variability, but the cumulative upwelling for the upwelling season is probably near average.**
- **The upwelling in 2007 is near average.**

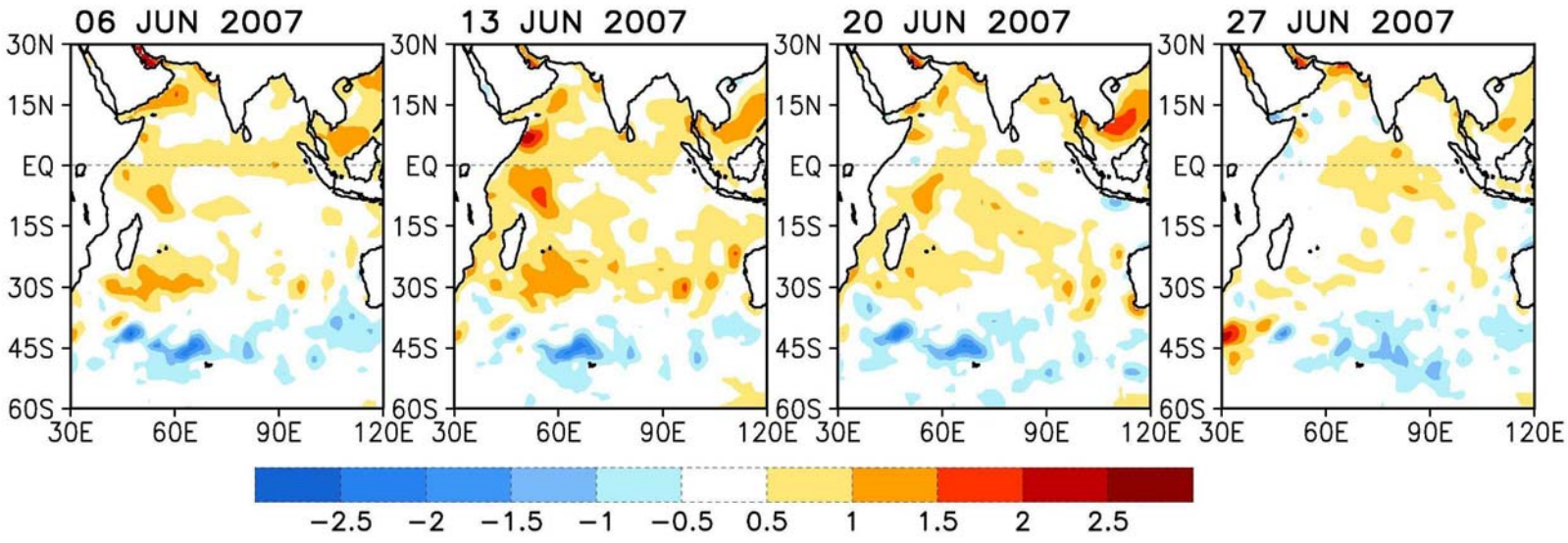
Indian Ocean

Indian Ocean SST Departures (°C)

(Climatology 1971-2000)

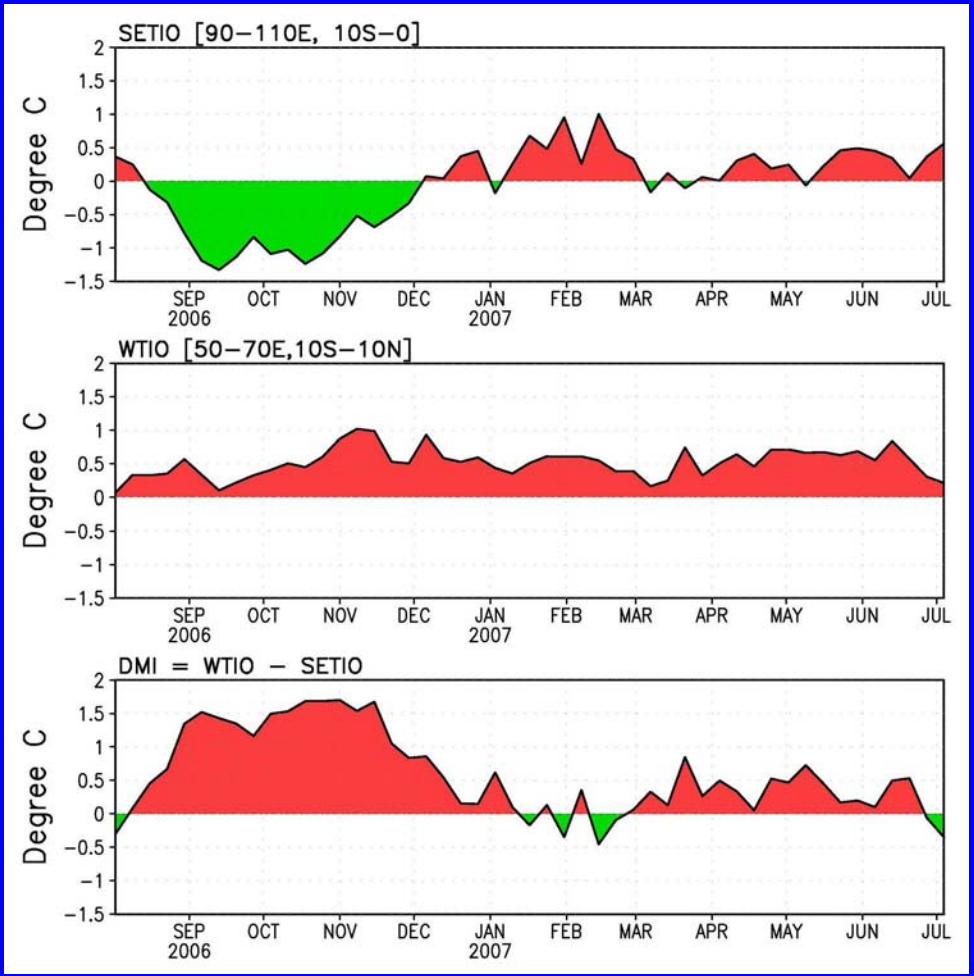


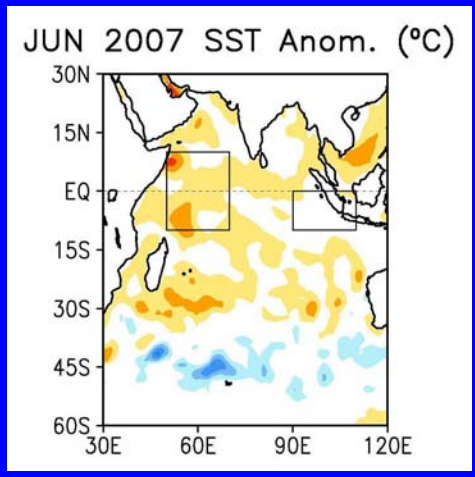
Positive SST departures were present in the tropical Indian Ocean, southeast of Madagascar, and near the coasts of Somalia and Arabia.



Recent Evolution of Indian Ocean Dipole Indices

SETIO: SST anomaly in 90ºE-110ºE, 10ºS-0.
WTIO: SST anomaly in 50ºE-70ºE, 10ºS-10ºN.
DMI = WTIO - SETIO

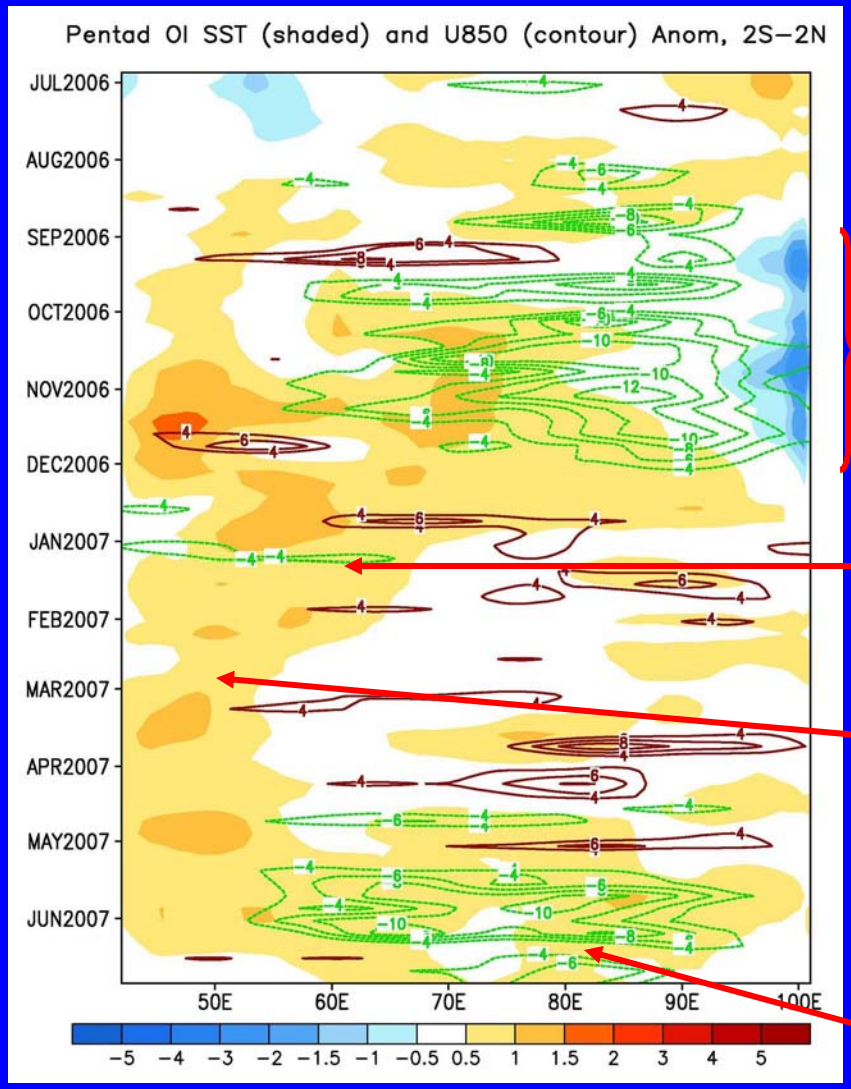




- **Negative SETIO was observed in September-November-December 2006. It has been weakly positive (< 0.5ºC) since December 2006.**
- **WTIO has been about 0.5ºC above-average since November 2006.**
- **DMI increased rapidly from neutral to +1.5ºC in August 2006, persisted during September-October, and then decreased rapidly in November-December 2006. It has been close to neutral since January 2007.**

Recent Evolution of Equatorial Indian SST (shaded, ºC) and Surface Zonal Wind (contour, cm/s) Departures

Climatology: SST 1971-2000
850 mb winds 1979-1995



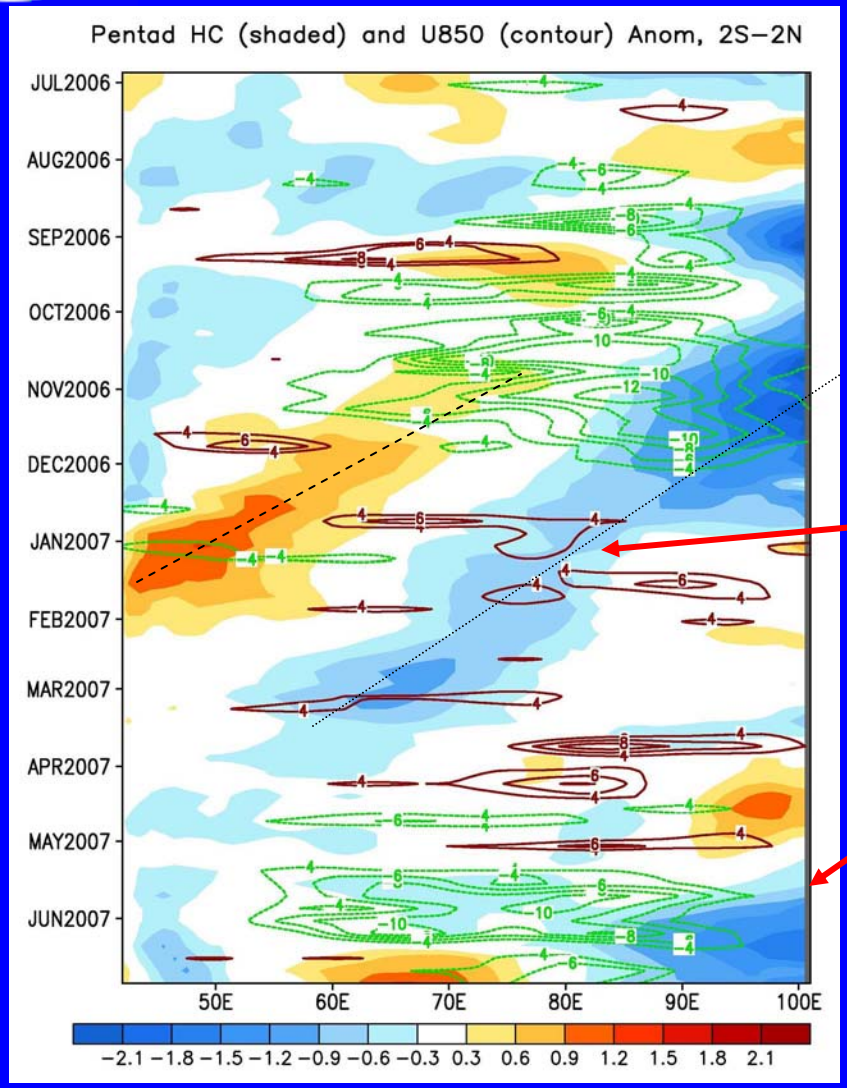
Between September and November 2006, negative SST anomalies developed in the far eastern equatorial Indian Ocean, accompanied by easterly wind anomalies in the central-eastern Indian Ocean.

During June-December 2006, SSTs in the central Indian Ocean were mostly above-average, and warm anomalies extended to the western Indian Ocean during September-December 2006.

Since January 2007, SSTs were above-average in the western Indian Ocean, accompanied by weak westerly wind anomalies in the central-eastern Indian Ocean.

Positive SST anomalies extended into the central Indian Ocean accompanied by easterly wind anomalies in May 2007.

Recent Evolution of Equatorial Indian Upper Ocean (0-300m) Heat Content and Surface Zonal Wind Departures



Time

Longitude

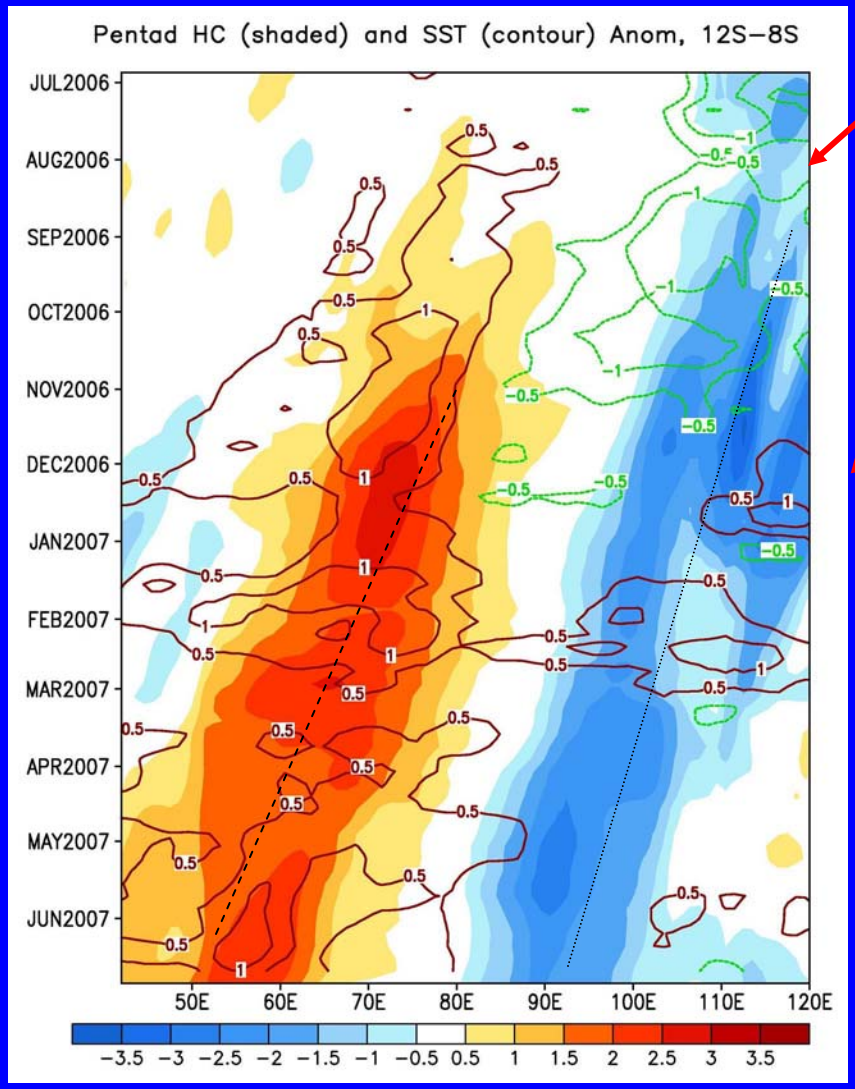
Climatology: GODAS Heat Content 1982-2004
850 mb wind 1979-1995

Negative heat content (HC) anomalies in the eastern Indian Ocean were accompanied by easterly wind anomalies in the central Indian Ocean in June 2006, and during August to December 2006.

Westward propagating Rossby waves, indicated by dashed and dotted lines for positive and negative phases, were observed between November 2006 and March 2007.

In response to the easterly wind anomalies since mid-May 2007, negative (positive) HC anomalies developed in the eastern (central) Indian Ocean in June 2007.

Recent Evolution of Heat Content (shaded, °C) and SST (contour, °C) Departures along 10°S in the Indian Ocean



Time

Longitude

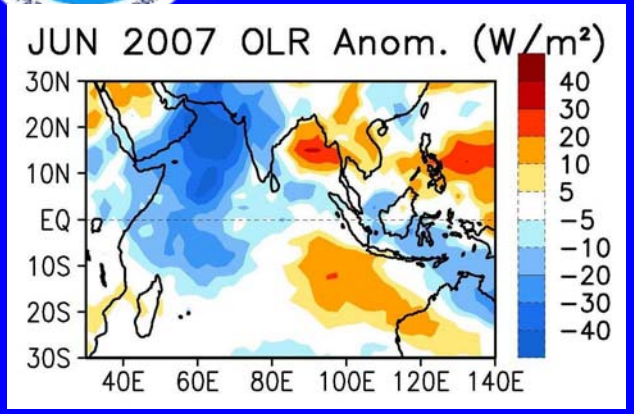
Negative SST anomalies less than -1°C collocated with negative heat content anomalies near the coast of Java during June-July 2006.

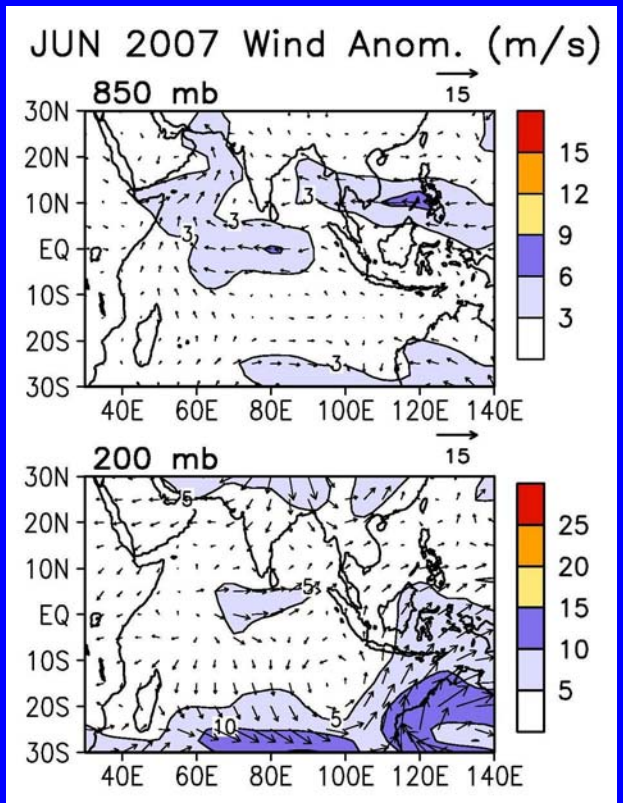
Pronounced westward propagating Rossby waves, indicated by dashed and dotted lines for positive and negative phases, were observed during August 2006 to June 2007.

Positive SST anomalies in the central Indian Ocean and negative SST anomalies in the eastern Indian Ocean propagated westward along with westward propagating heat content anomalies during August – October 2006.

SST departures in the eastern Indian Ocean transitioned from negative to positive in mid-November, while positive SST departures in the central Indian Ocean persisted since November 2006.

Tropical Indian OLR and Wind Anomalies





Climatology: OLR 1979-1995
Winds 1979-1995

Negative OLR anomalies (enhanced convection and precipitation, blue shading) were observed in the western tropical Indian Ocean, the Arabian Sea and its surrounding coastal regions. Positive OLR anomalies (suppressed convection, orange shading) were observed in the Bay of Bengal.

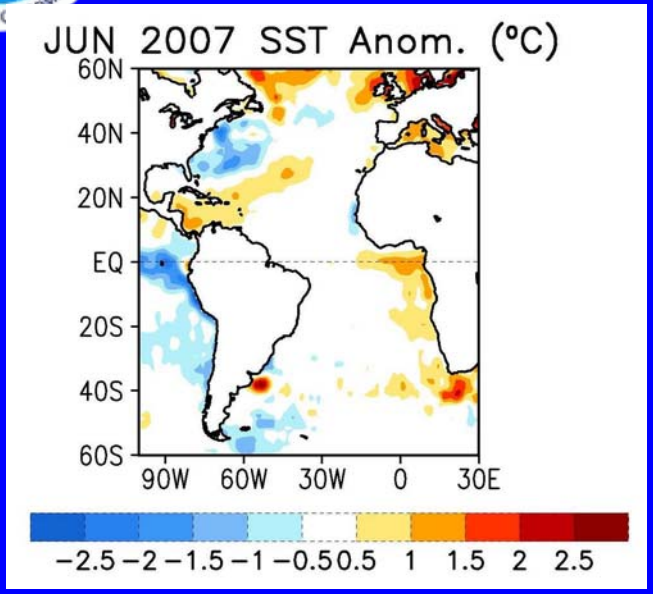
Lower-level (850-hPa) easterly wind anomalies were observed in the central equatorial Indian Ocean, southwesterly wind anomalies along the Somalia coast line and easterly wind anomalies in South China Sea.

Upper-level (200-hPa) westerly wind anomalies were observed in the central equatorial Indian Ocean.

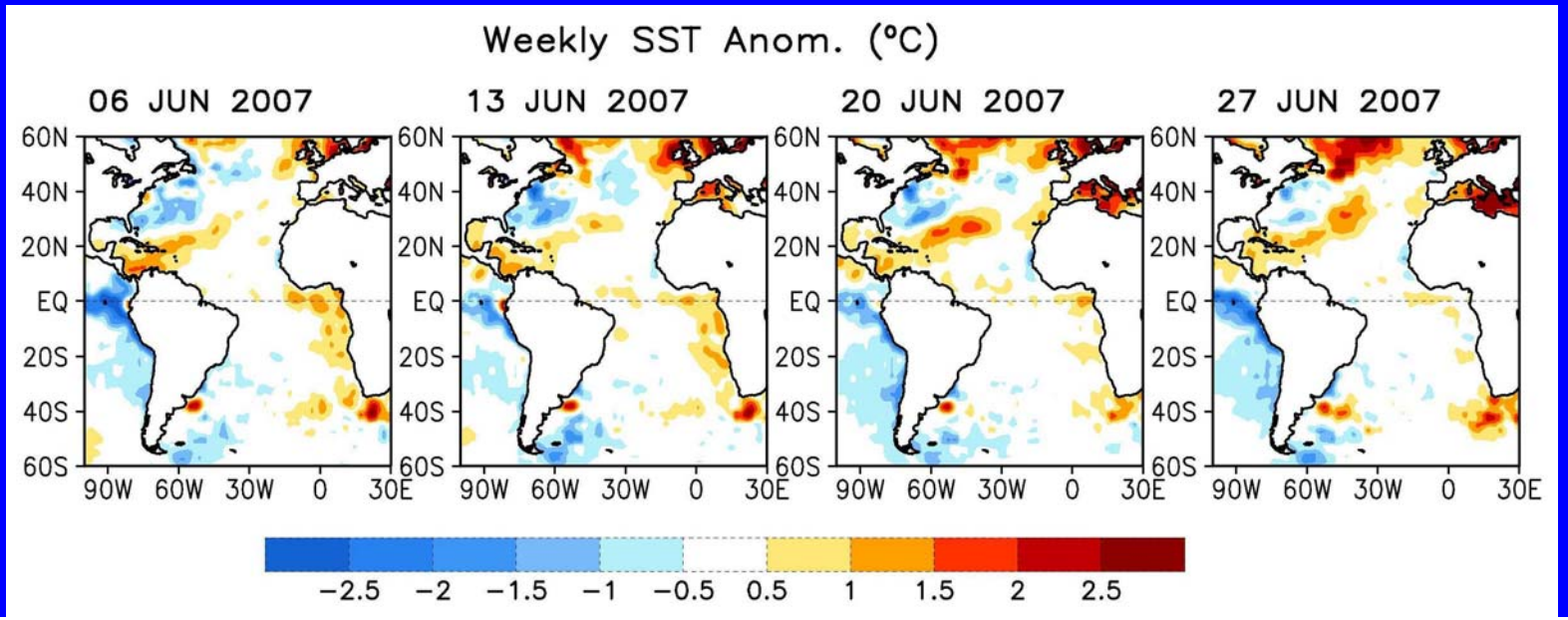
Atlantic Ocean

Atlantic Ocean SST Departures (ºC)

(Climatology 1971-2000)

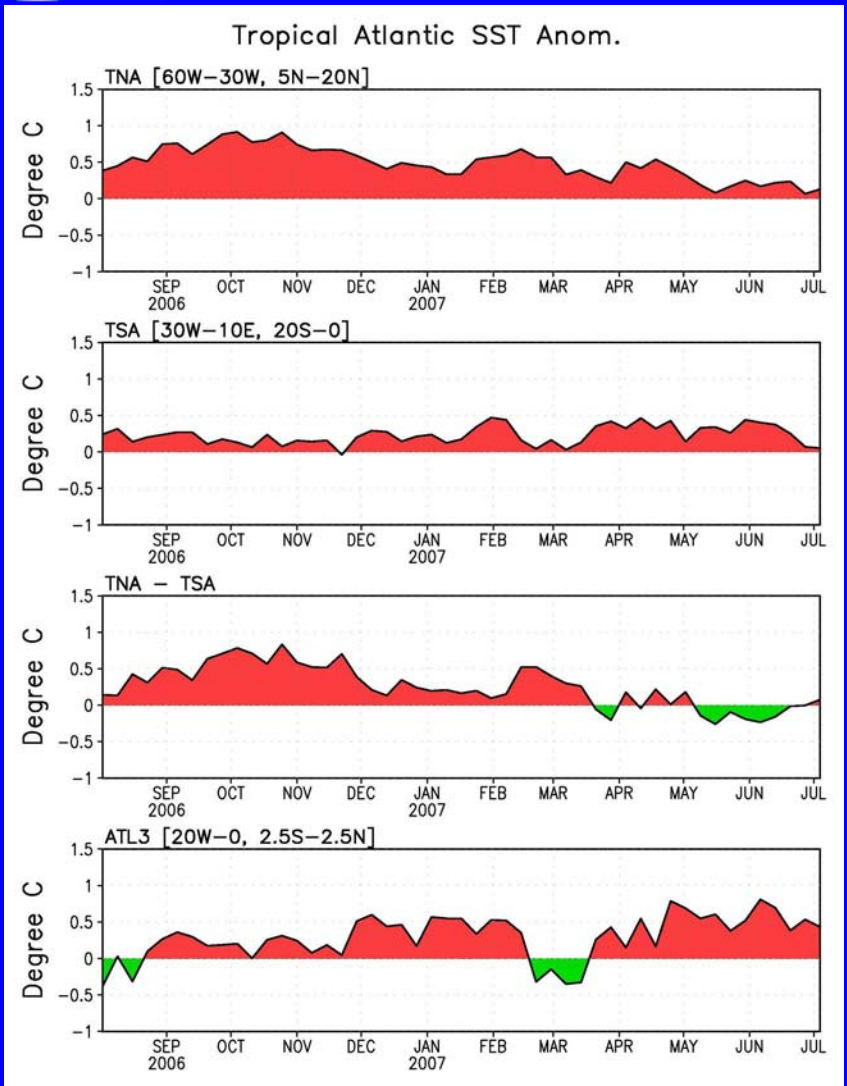


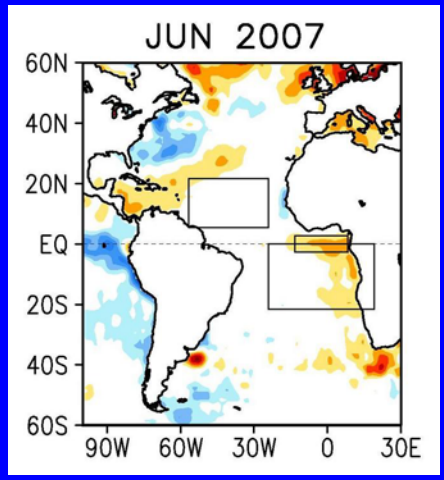
Positive SST departures were present in the Caribbean Sea, the western coast of Africa and eastern equatorial Atlantic Ocean. Negative SST departures were present along the eastern coast of North America.



Recent Evolution of Tropical Atlantic SST Indices

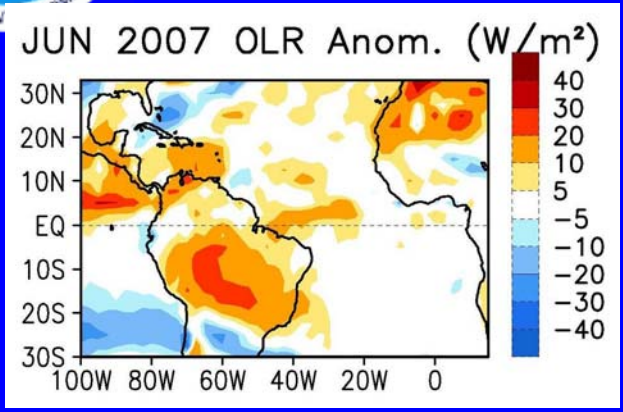
(Climatology 1971-2000)

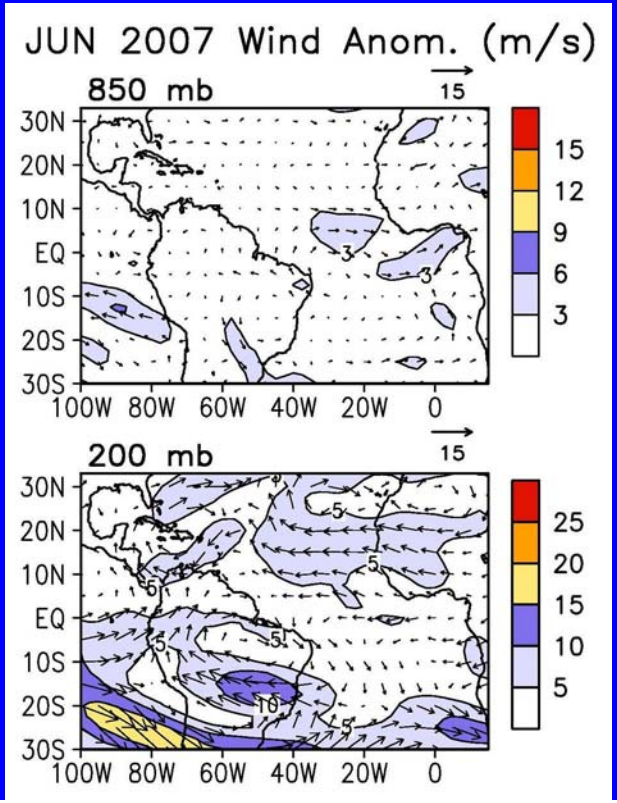




- **During the past 12 months, TNA has been above-average. TNA decreased to near neutral in May 2007**
- **TSA has been weakly above-average during the past 12 months.**
- **The north-south gradient mode has been near neutral since April 2007.**
- **Atlantic NINO has been 0.5ºC above-average in May-June 2007.**

Tropical Atlantic OLR and Wind Anomalies





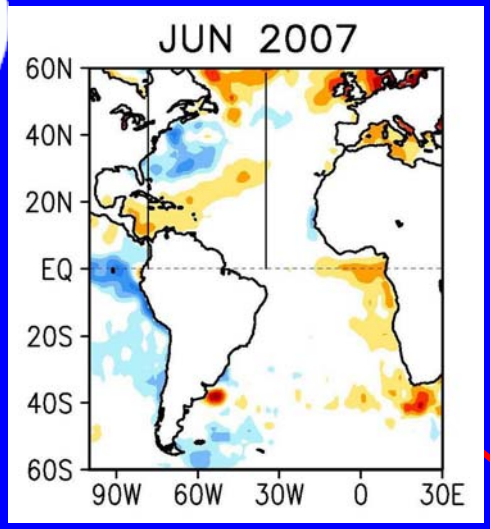
Climatology: OLR 1979-1995
Winds 1979-1995

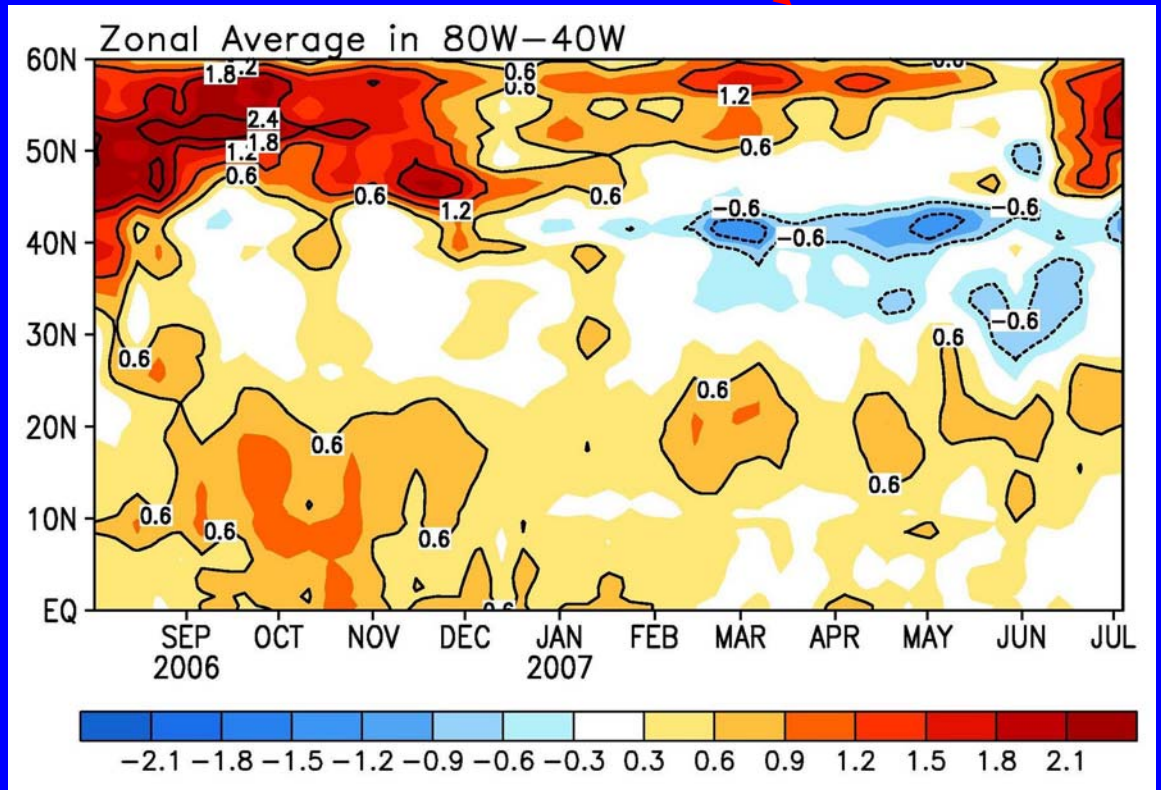
Positive OLR anomalies (suppressed convection and precipitation, red shading) were observed in the Caribbean Sea, the central South America and North Africa.

Lower-level (850-hPa) westerly wind anomalies were observed in the central-eastern equatorial Atlantic.

Upper-level (200-hPa) easterly wind anomalies were observed in the northeast Atlantic and northwest Africa.

Recent Evolution of SST Departures (ºC) in the Northwest Atlantic





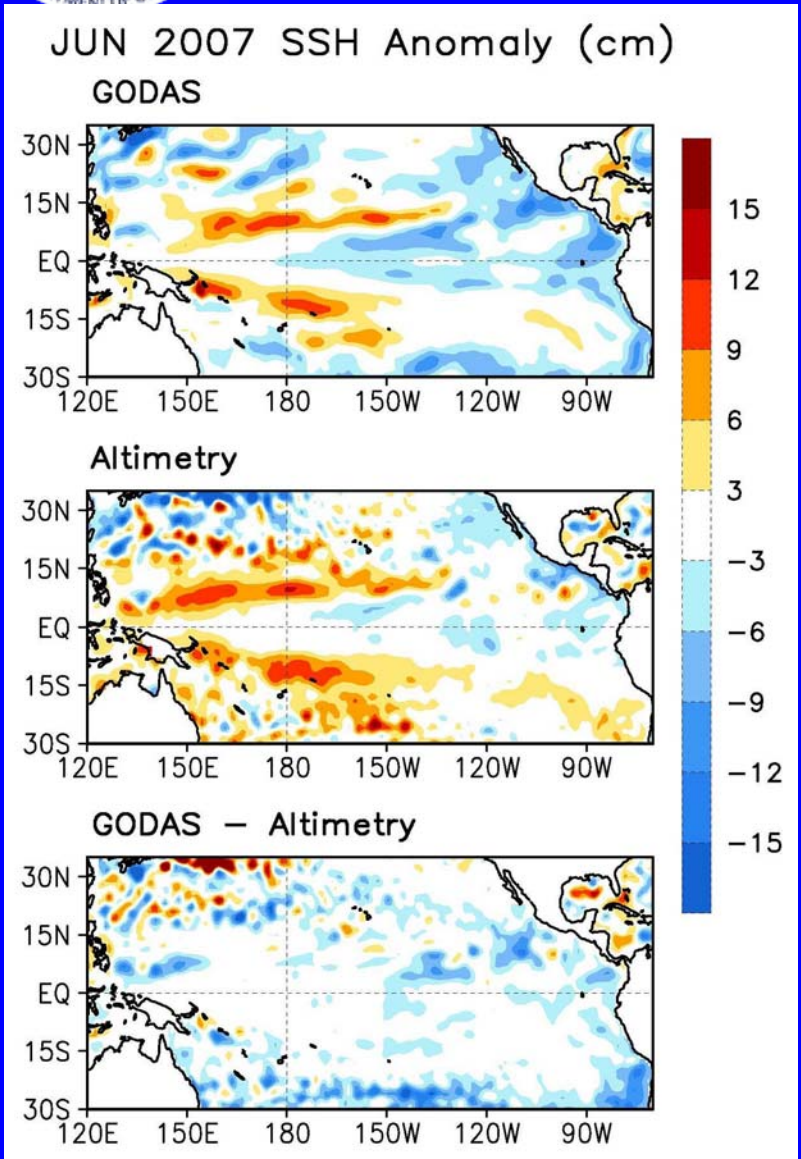
During the past 12 months, the zonal average SSTs in 80ºW-40ºW between 10ºN and 25ºN have been above-average.

Above-average SSTs greater than +2ºC were observed between 40ºN and 60ºN during May to November 2006. Starting December 2006, the anomalies decreased to ~ +1ºC in 50ºN-60ºN, but switched to negative anomalies near 40ºN.

The triple-pole SST pattern persisted since February 2007.

Uncertainties in NCEP's Global Ocean Data Assimilation System

Tropical Pacific Sea Surface Height Anomalies
GODAS vs. Altimetry



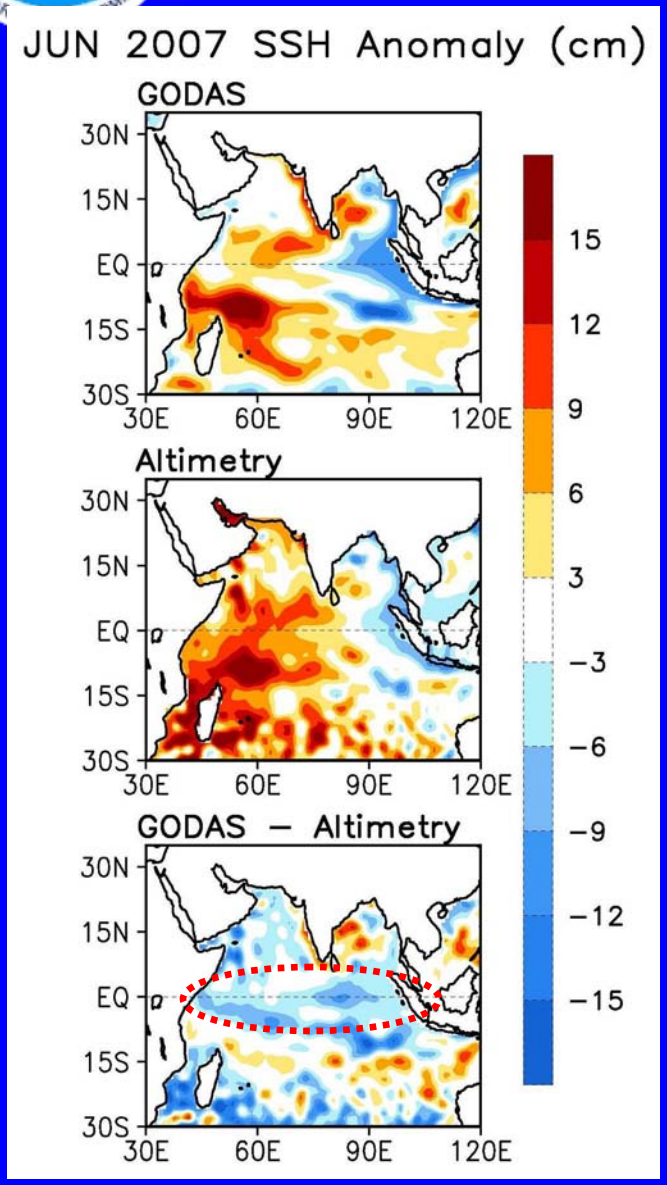
Climatology: 1993-2005

GODAS SSH was more than 6 cm below-average in the central-eastern equatorial Pacific, and above-average in the western-central subtropical Pacific.

Compared to GODAS, the negative SSH anomalies of Altimetry in the eastern equatorial Pacific were weaker.

Differences between SSH anomalies of GODAS and Altimetry were generally less than 3 cm within 10 degree of the equator, but larger than 3 cm in the subtropics.

Tropical Indian Sea Surface Height Anomalies
GODAS vs. Altimetry



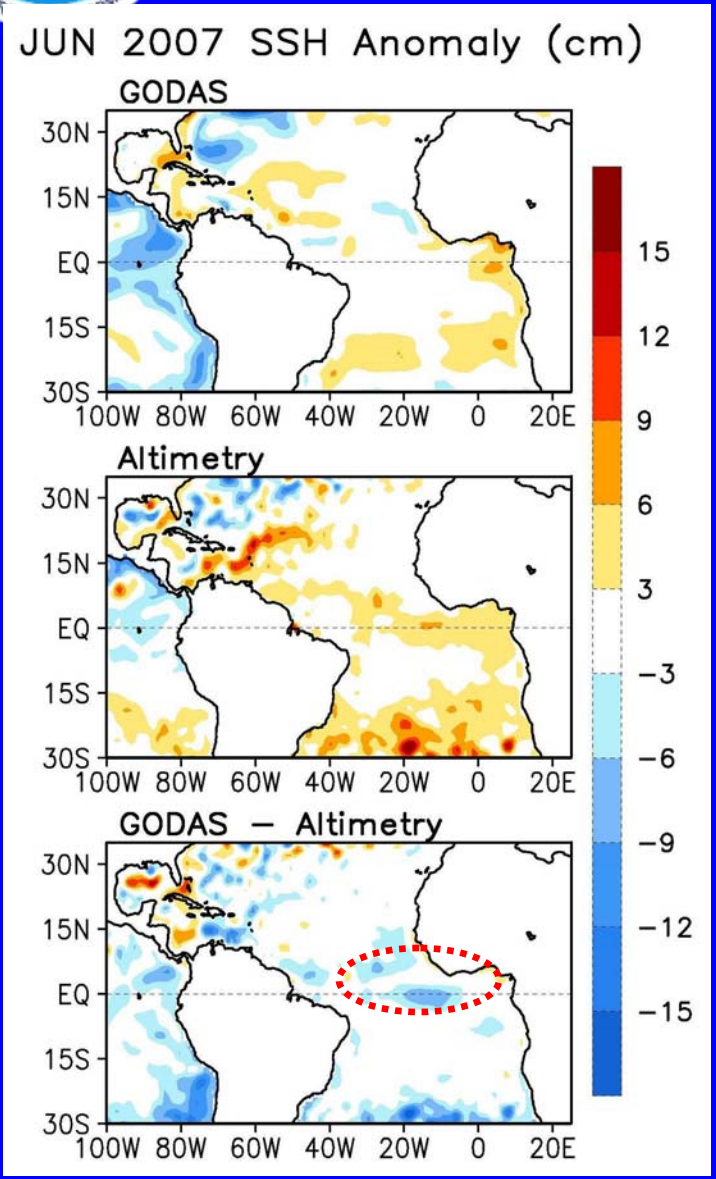
Climatology: 1993-2005

GODAS SSH anomalies were negative in the far eastern equatorial Indian Ocean and along its eastern boundary, and positive in the western tropical and southwest Indian Ocean.

Compared to GODAS, amplitude of Altimetry SSH anomalies were smaller in the eastern equatorial Indian Ocean but larger in the western Indian Ocean.

Differences between SSH anomalies of GODAS and Altimetry were more than 3cm in the tropical Indian Ocean.

Tropical Atlantic Sea Surface Height Anomalies
GODAS vs. Altimetry

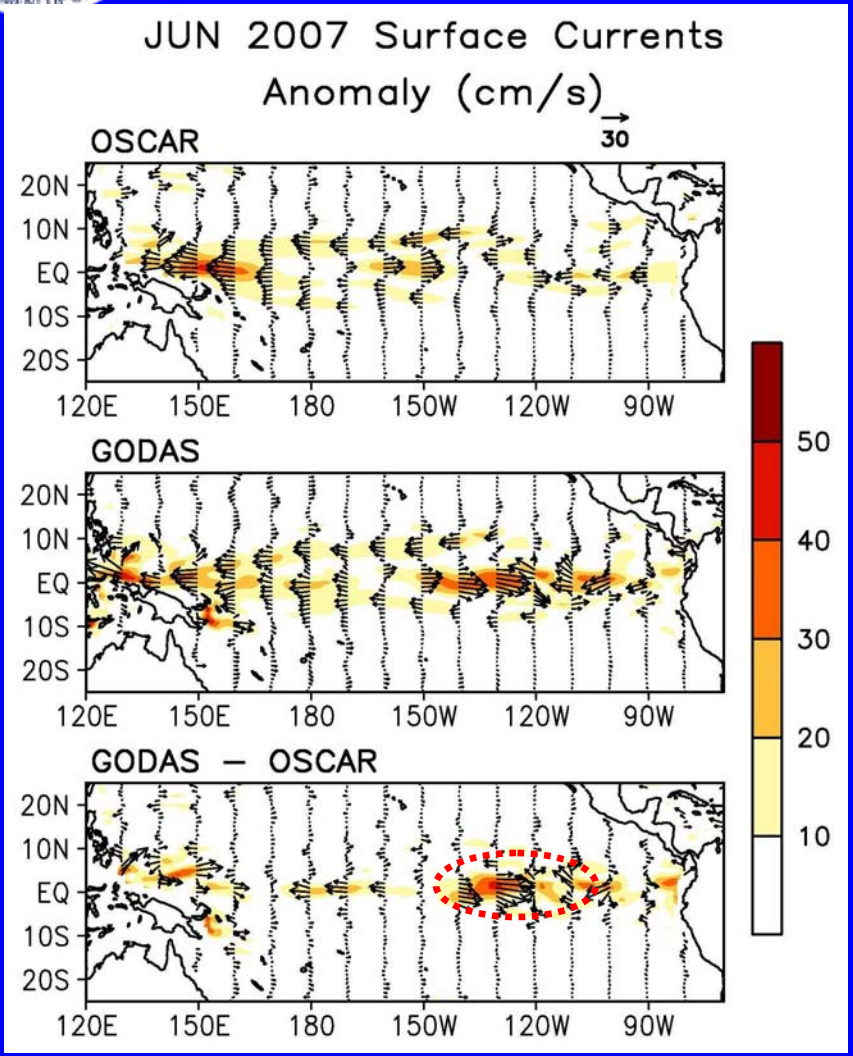


Climatology: 1993-2005

GODAS SSH were above-average in the far eastern equatorial Atlantic Ocean.

Compared to the Altimetry SSH anomalies, the GODAS SSH anomalies were about 6 cm too low in the central equatorial Atlantic Ocean.

Tropical Pacific Surface Current Anomaly
GODAS vs. OSCAR

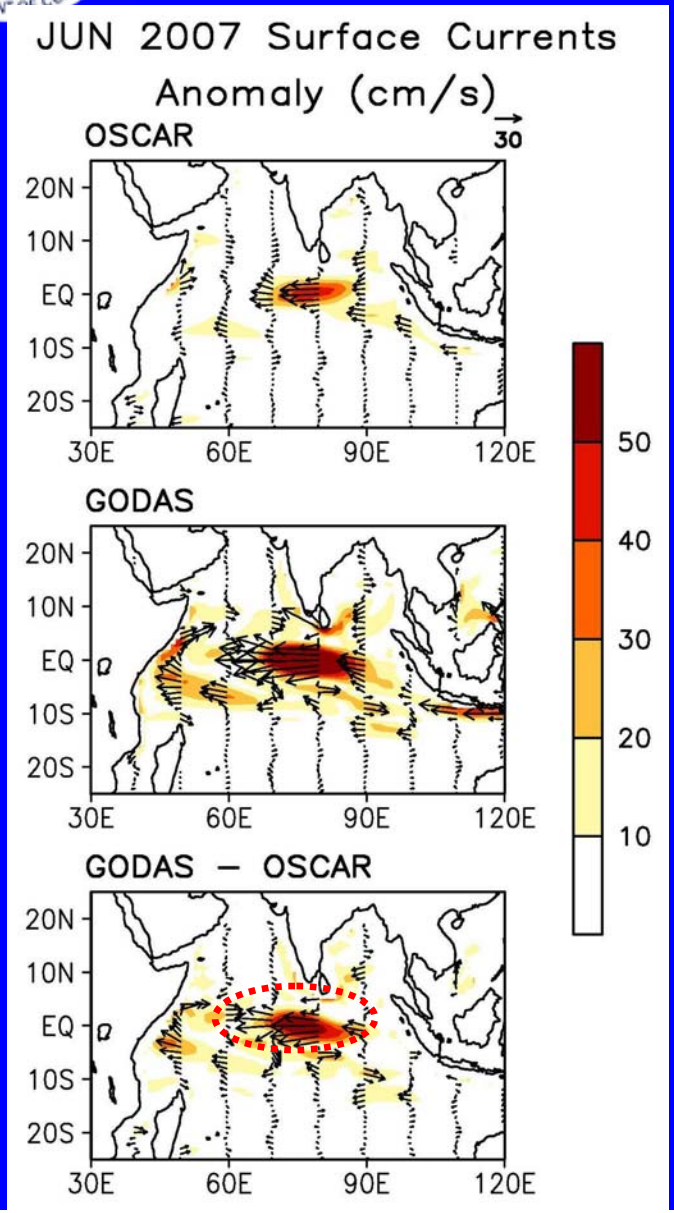


Climatology: 1993-2005

The surface zonal current anomalies at 15 meters from OSCAR were westward in the far western and eastern equatorial Pacific, but eastward in the central equatorial Pacific.

Compared to the OSCAR currents, the surface zonal currents of GODAS had eastward biases larger than 30 cm/s near 130°W.

Tropical Indian Surface Current Anomaly
GODAS vs. OSCAR

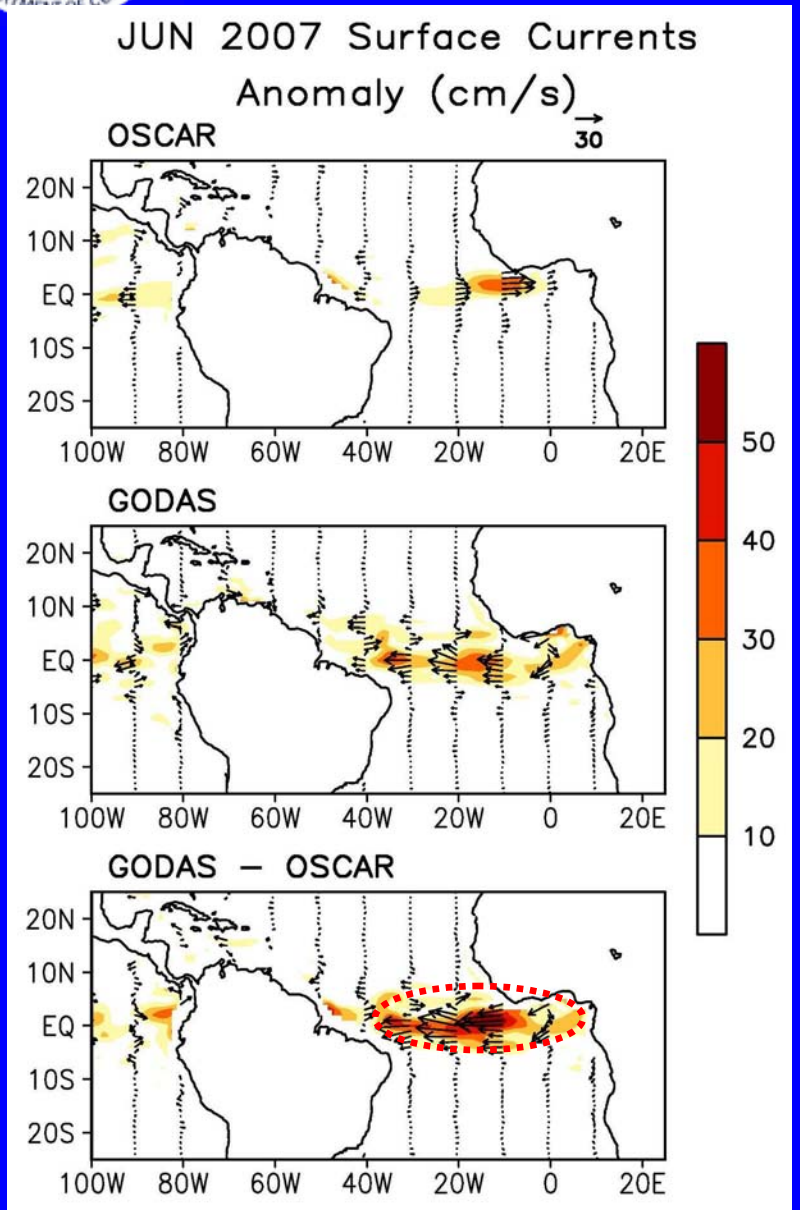


Climatology: 1993-2005

The surface zonal current anomalies from OSCAR were westward in the central equatorial Indian Ocean.

Compared to OSCAR, the GODAS surface zonal current anomalies had westward biases larger than 30 cm/s in the central equatorial Indian Ocean.

Tropical Atlantic Surface Current Anomalies
GODAS vs. OSCAR



Climatology: 1993-2005

The surface zonal current anomalies from OSCAR were weakly eastward in the central-eastern equatorial Atlantic Ocean.

Compared to OSCAR, the GODAS surface zonal current anomalies had westward biases larger than 30cm/s in the western-central equatorial Atlantic Ocean, probably due to biases in NCEP Reanalysis-2 winds which had easterly wind anomalies.

SST Predictions by NCEP Climate Forecast System

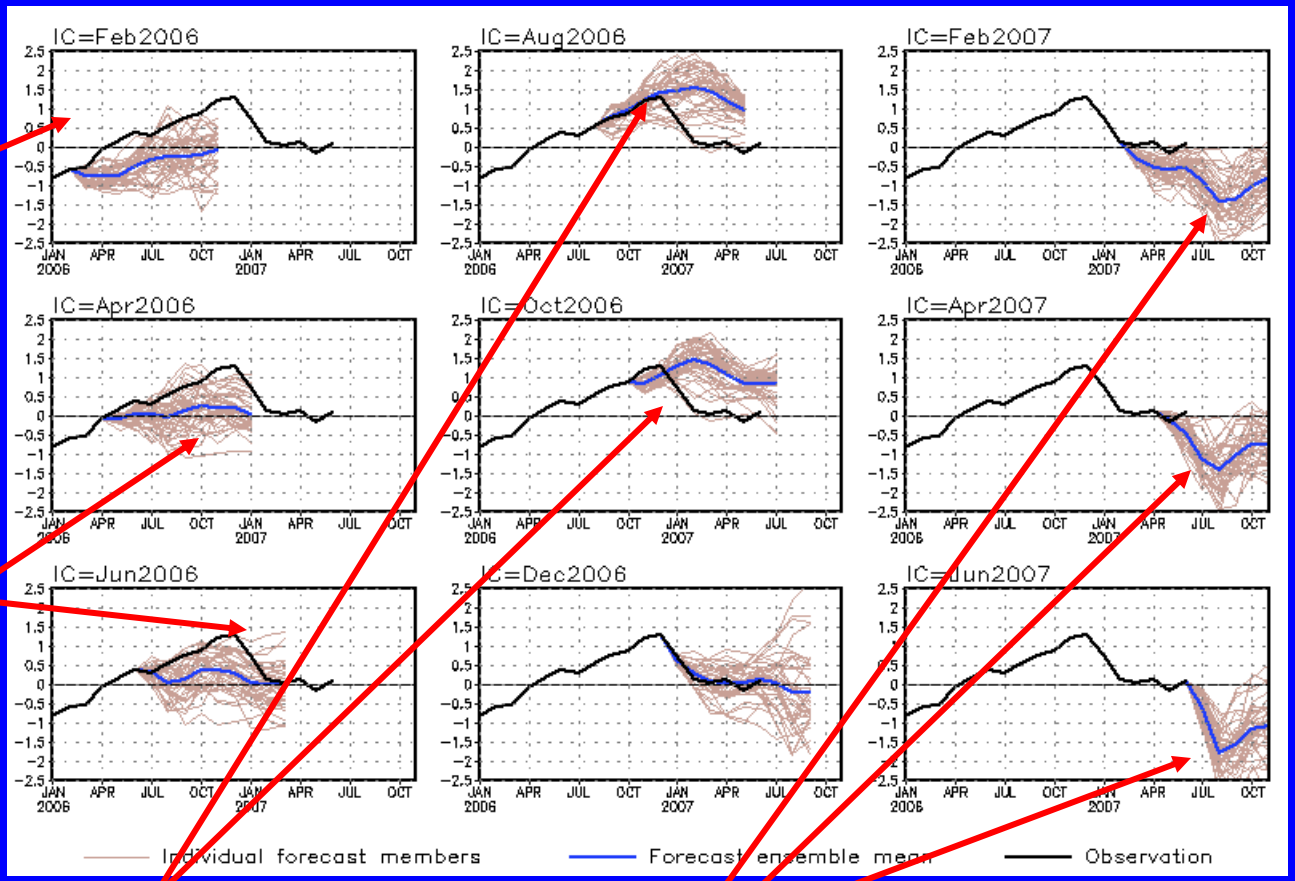
CFS Nino3.4 Forecasts from Different Initial Months

Missed the onset of the 2006/07 El Nino from January-March 2006 I.C.

Underestimated the amplitude of the 2006/07 El Nino from April-July 2006 I.C.

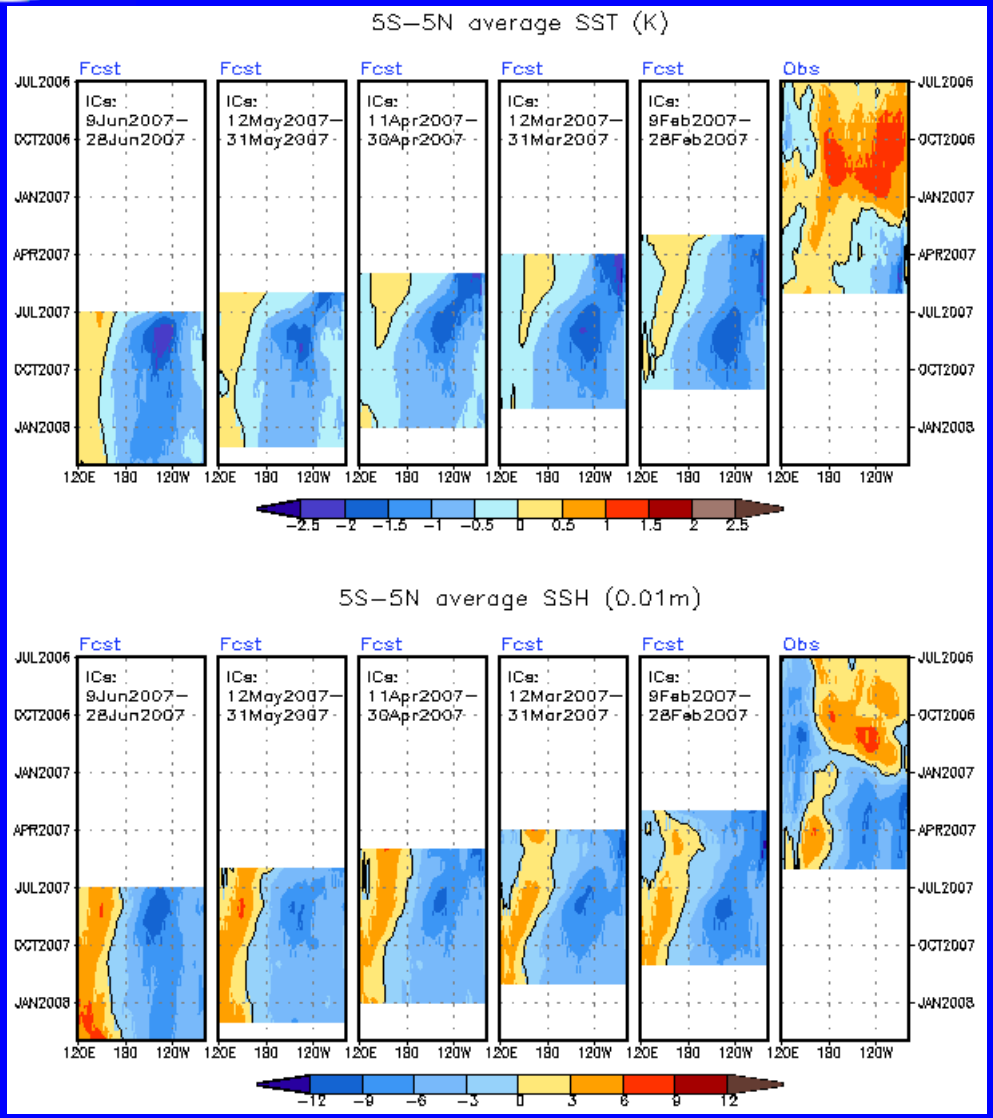
Missed the fast termination of the 2006/07 El Nino from August-November 2006 I.C.

Forecast La Nina to be developed during summer of 2007 from February-June 2007 I.C.



Evolution of CFS SST and SSH vs. OBS in 5ºS-5ºN

JUN MAY APR MAR FEB



Time

Longitude

From February-June 2007 I.C., CFS consistently predicted that the negative SST anomalies in the far eastern equatorial Pacific would grow and spread to the western Pacific, and peak during summer 2007. Compared to observations, the forecast negative SST anomalies are too large and extend too westward.

From February-June 2007 I.C., CFS consistently predicted that the negative heat content (represented by SSH) anomalies in the eastern equatorial Pacific would persist in amplitude but move slowly westward. The forecast SSH anomalies agrees with observations well.

Summary

- In mid-May 2007, a Kelvin wave episode, forced by relaxation of easterly wind anomalies, moved positive heat content anomalies eastward and pushed negative heat content anomalies back to east of 100°W in the tropical Pacific.
- Negative SST and SSH anomalies over the Gulf of Alaska increased from May to June 2007 due to Ekman pumping forced by cyclonic surface wind anomalies in the region.
- Upwelling along the west coast of North America has been close to normal conditions during the spring-summer 2007 upwelling season.
- Easterly wind anomalies in the tropical Indian Ocean, probably associated with Asian Monsoon forcing, generated negative (positive) sea surface height anomalies in the eastern (central) equatorial Indian Ocean.
- Positive SST anomalies in the eastern equatorial Atlantic persisted, probably supported by westerly wind anomalies in the central Atlantic and positive heat content anomalies in the eastern Atlantic.
- The triple-pole SST pattern in North Atlantic has been persistent since February 2007.