# Global Ocean in 2008

Prepared by

Climate Prediction Center, NCEP

**February 6, 2009**

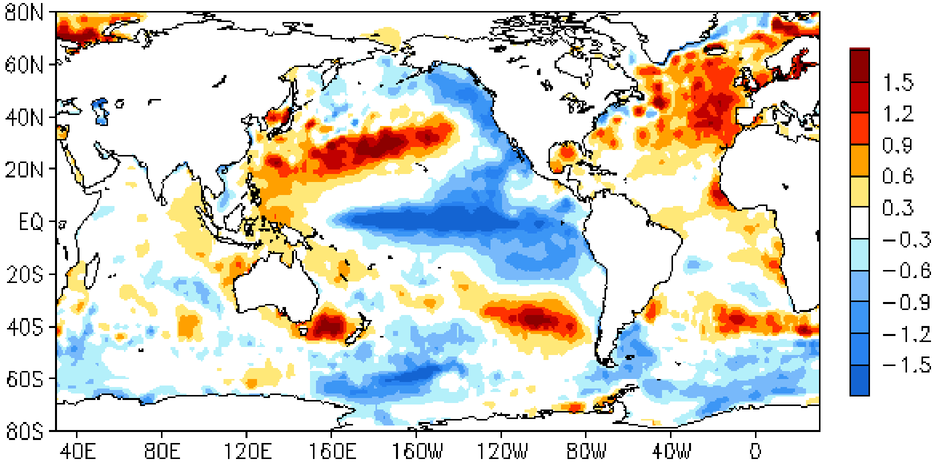
http://www.cpc.ncep.noaa.gov/products/GODAS/

# Overview

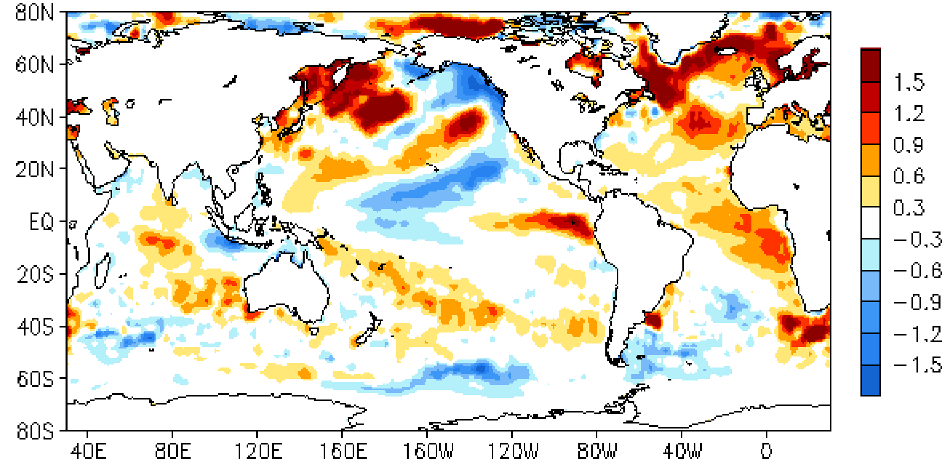
- Ocean 2008 and its comparison with 2007
- Atmospheric responses to SST in 2007 and 2008
- Historical perspective (trend and decadal variability)
- 2008 special feature discussions
  - Arctic Sea Ice and SST
  - Negative PDO phase
  - North America Western Coast Upwelling
  - Atlantic hurricane and non-local SST Anomalies
  - Recent trends and ENSO variability
  - 2007/08 La Nina Cycle Evolution and Prediction

# Seasonal Mean SSTA

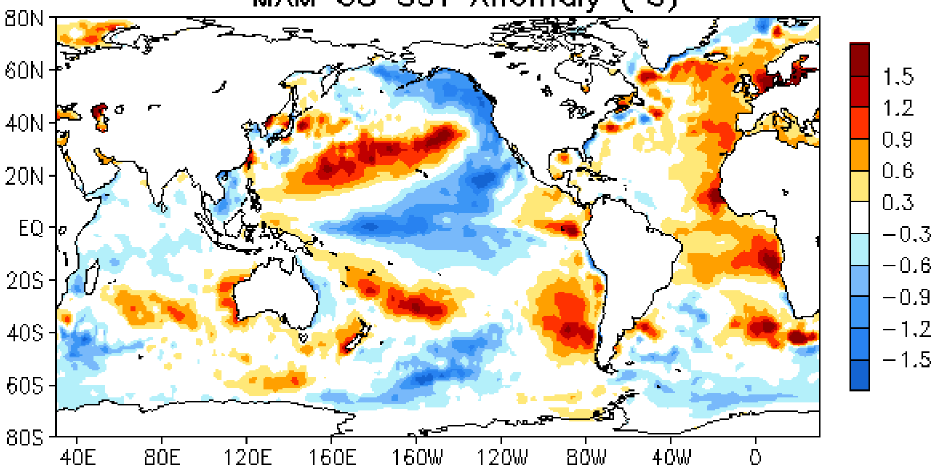
DJF 07/08 SST Anomaly (°C)



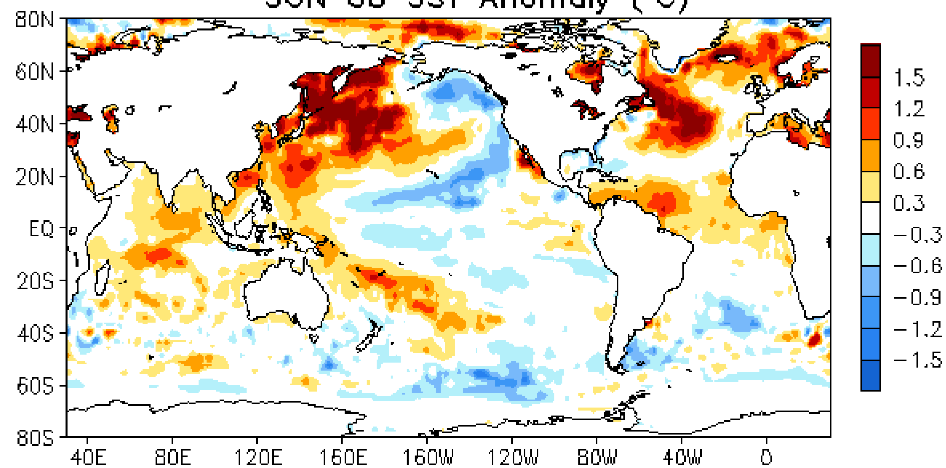

JJA 08 SST Anomaly (°C)




MAM 08 SST Anomaly (°C)

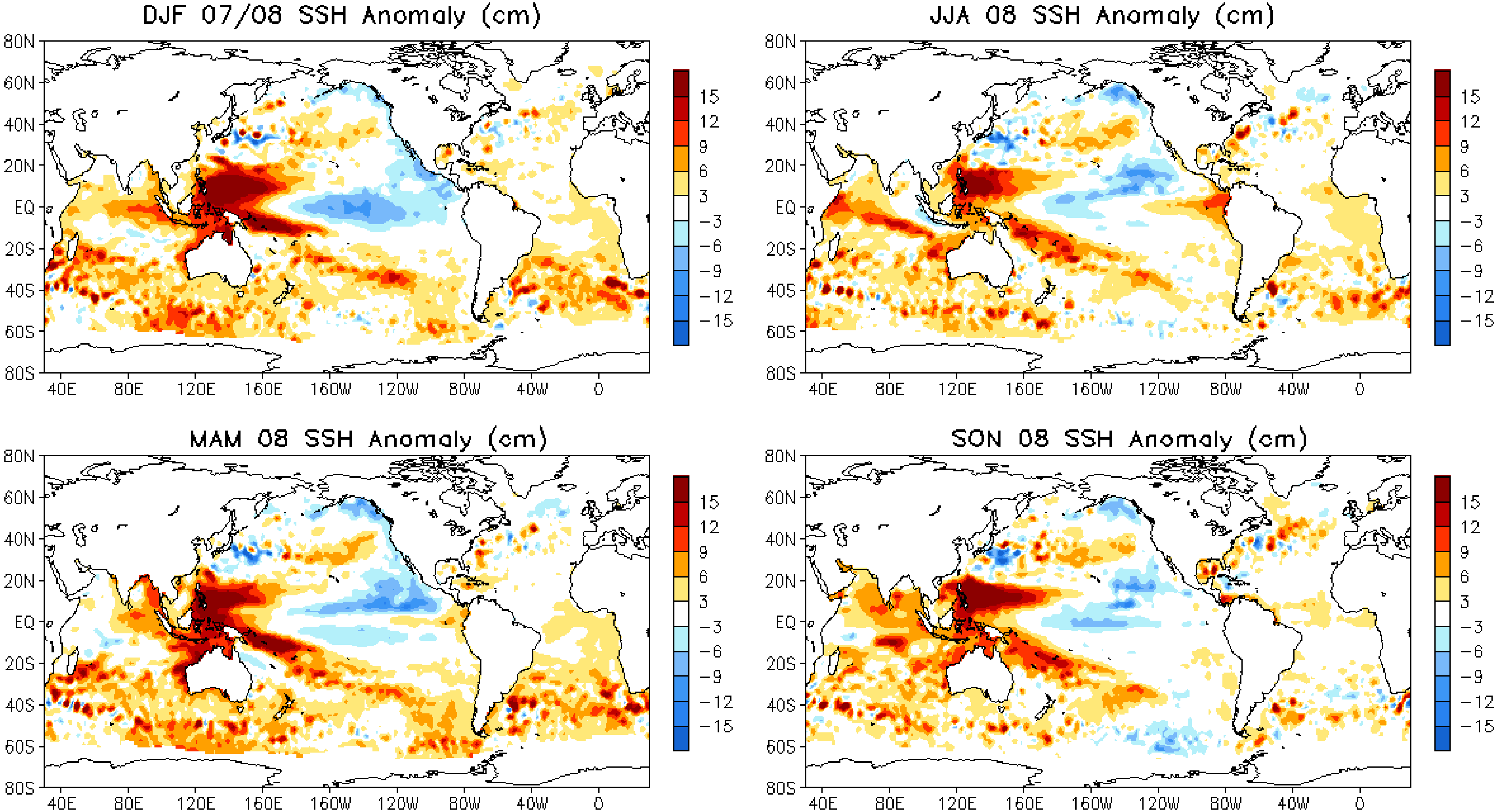



SON 08 SST Anomaly (°C)




- **The 07/08 La Nina matured in DJF, weakened in MAM and diminished in JJA.**
- **The negative PDO initiated in Sep 07 has persisted through out 2008, and it is nearing a historic low (slide 16) .**
- **A tri-pole SSTA pattern presented in the tropical Pacific in JJA.**
- **Above-normal SST presented in most of the Atlantic Ocean in 2008.**

# Seasonal Mean SSHA



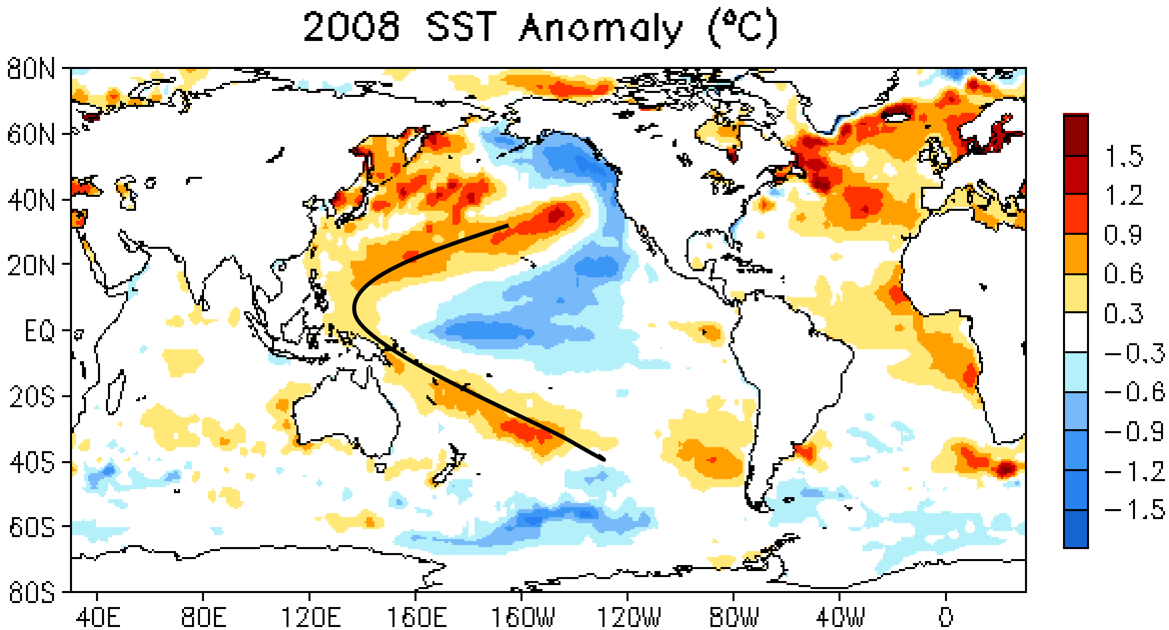

- The 07/08 La Nina contributed to the build up of above-normal (below-normal) SSH in the western (central-eastern) tropical Pacific in DJF.

- Above-normal heat content anomalies along the equator in MAM were associated with oceanic Kelvin waves, contributing to the decay of the 07/08 La Nina.

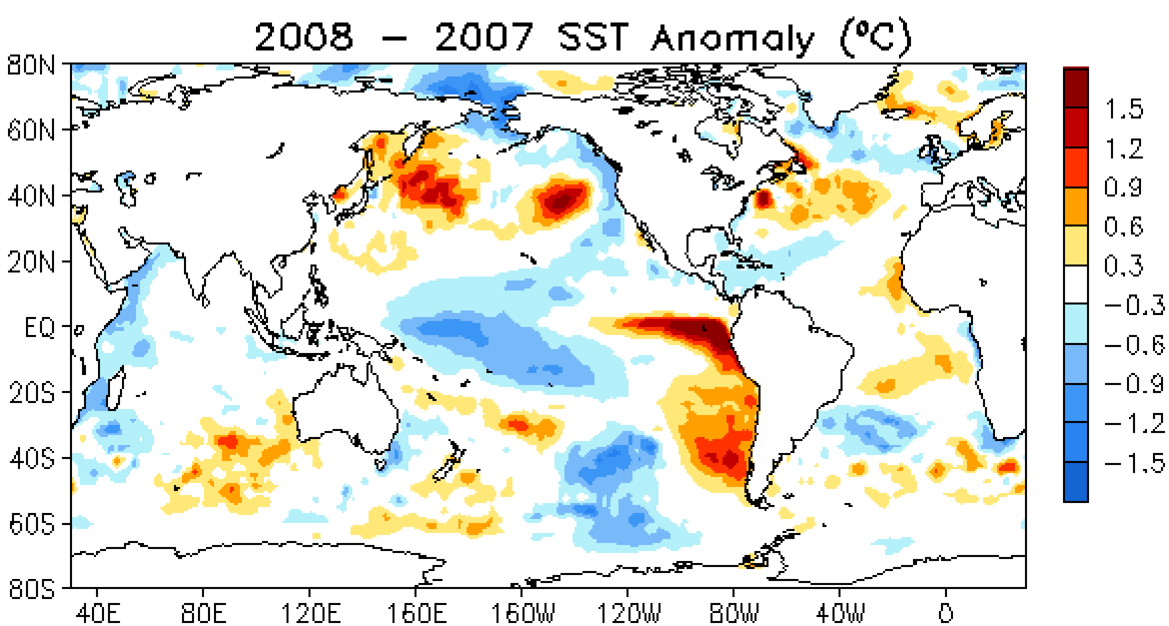
- Below-normal SSH in the Gulf of Alaska and along the western coast of North America were associated with the negative PDO phase.

- Decadal trend has contributed to the above-normal SSH in the western tropical Pacific, tropical Indian Ocean and Southern Oceans.

# Yearly Mean SSTA

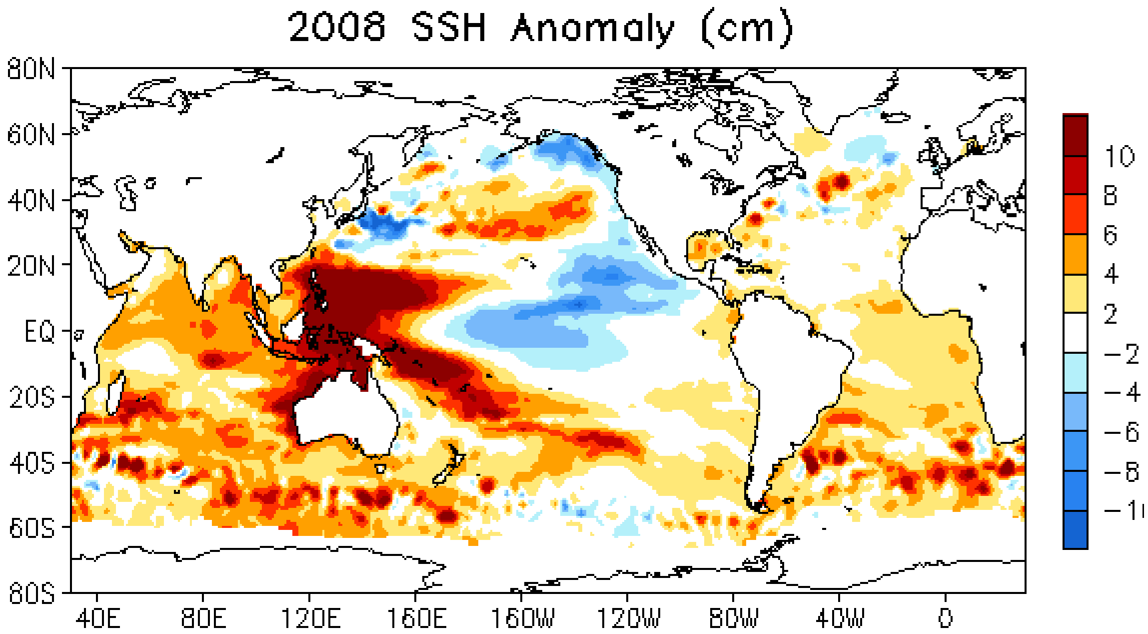


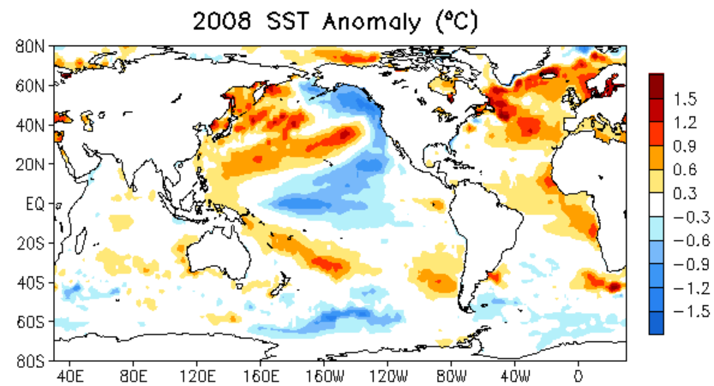

- Negative PDO presented in North Pacific.
- Positive SSTA pattern in the western tropical Pacific extends relative symmetrically into the N and S Pacific, while the eastern Pacific SSTA is asymmetric.
- Positive SSTA presented in North Atlantic and tropical Atlantic.

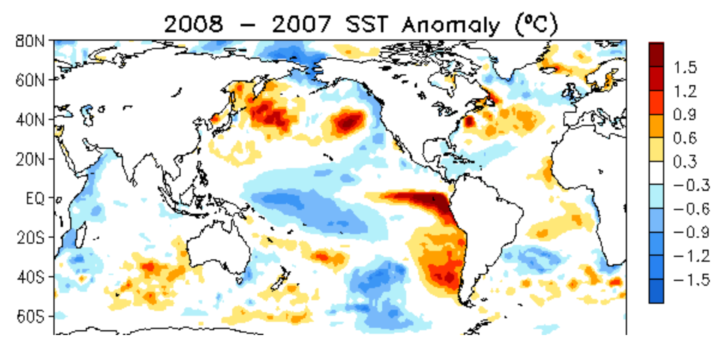



- SST cooled down (warmed up) substantially in the central (eastern) tropical Pacific.
- The Arctic Ocean, Bering Strait, Gulf of Alaska and most of the western coast of North America also cooled down from last year, which might be related to the persistent negative PDO phase.

# Global SSH Anomaly and Anomaly Tendency



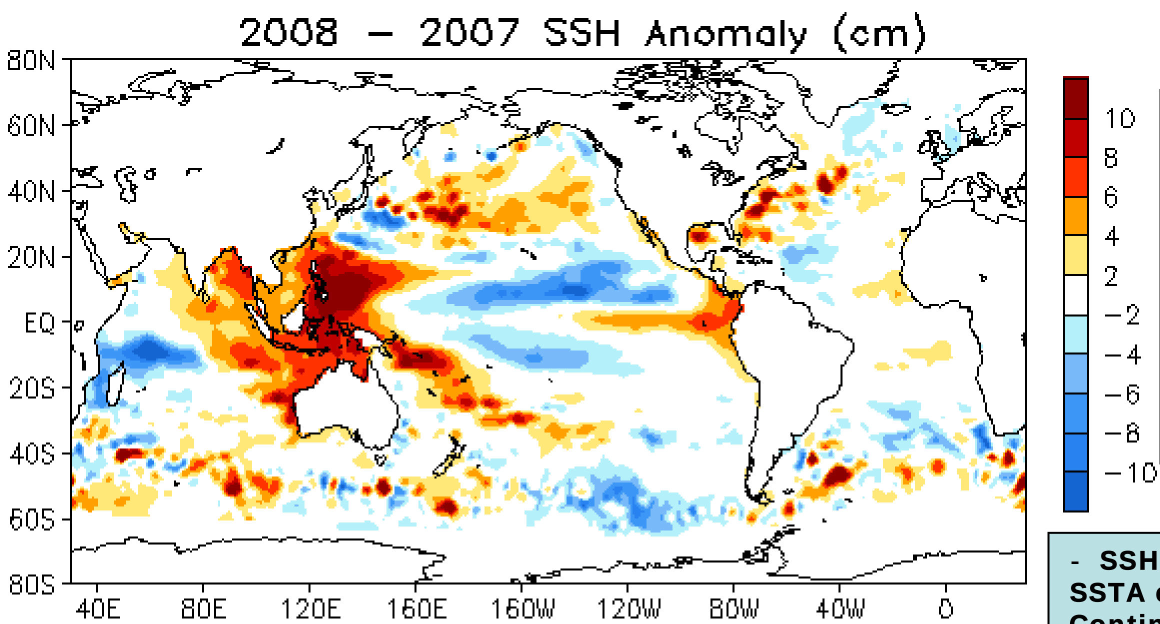




- SSHA pattern corresponds well with SSTA pattern in the Pacific except the amplitude of positive SSHA in the western tropical Pacific is much larger than that of positive SSTA there.

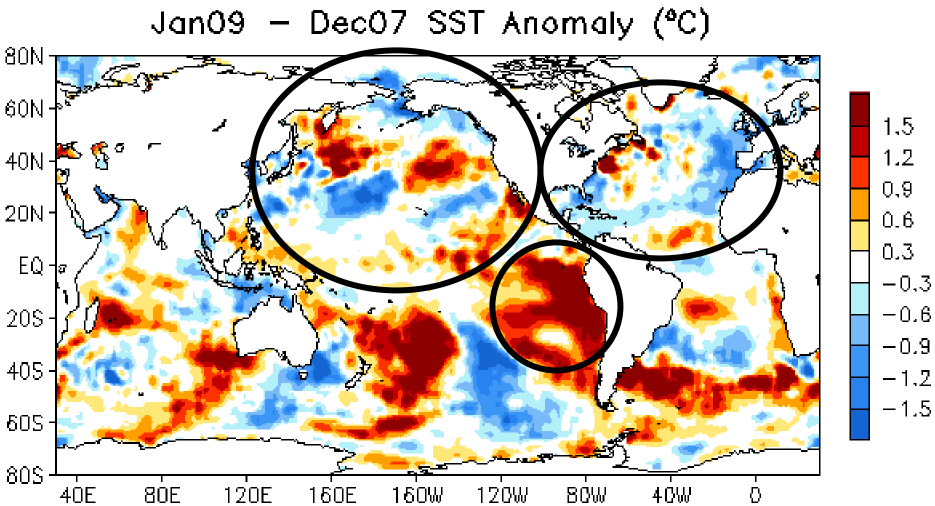
- Near-normal SSH in North Atlantic is associated with above-normal SST there.

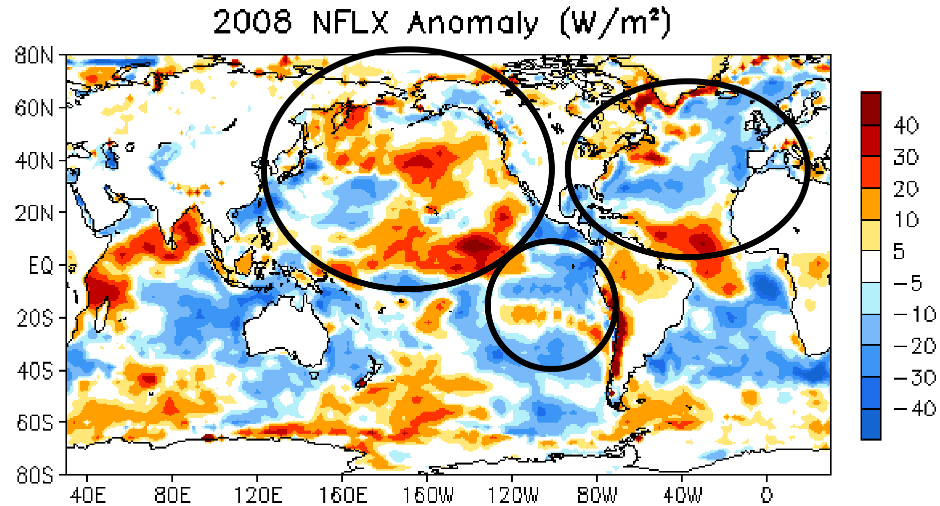
- Above-normal SSH in the tropical Indian Ocean is associated with near-normal SST there.

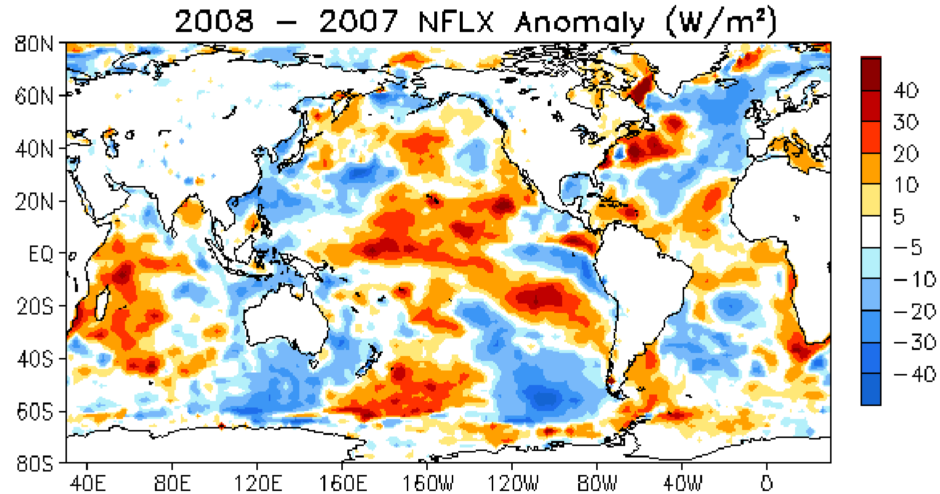



- SSHA change is largely consistent with SSTA change except near the Maritime Continent and North Atlantic.

# SST Tendency and Net Heat Flux Anomaly



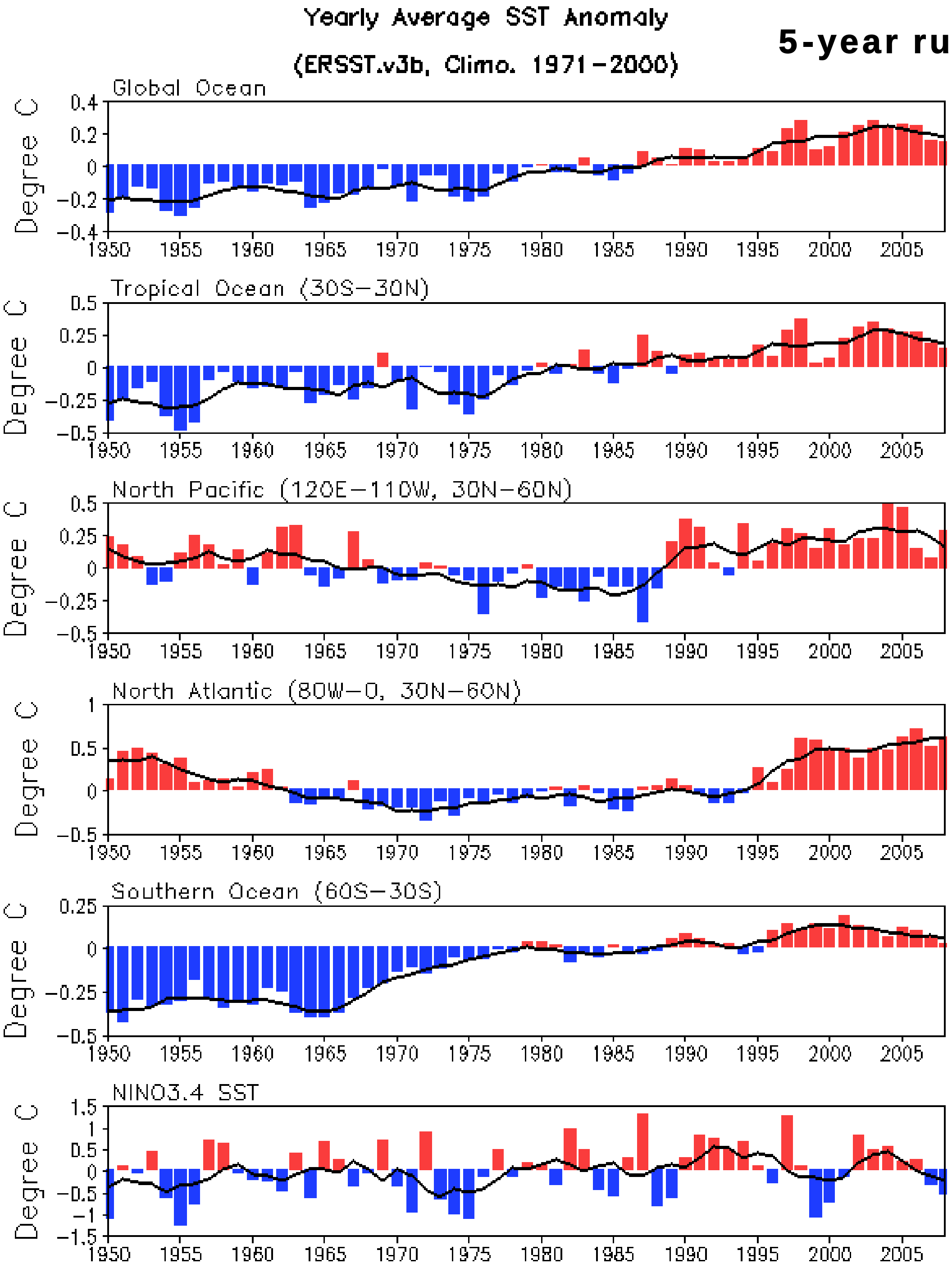




- Surface net heat flux anomalies were dominated by LH+SH (not shown).

- SST tendencies in North Pacific and North Atlantic were largely determined by surface net heat flux anomalies, while SST tendency in the south-eastern Pacific was likely controlled by ocean dynamics.

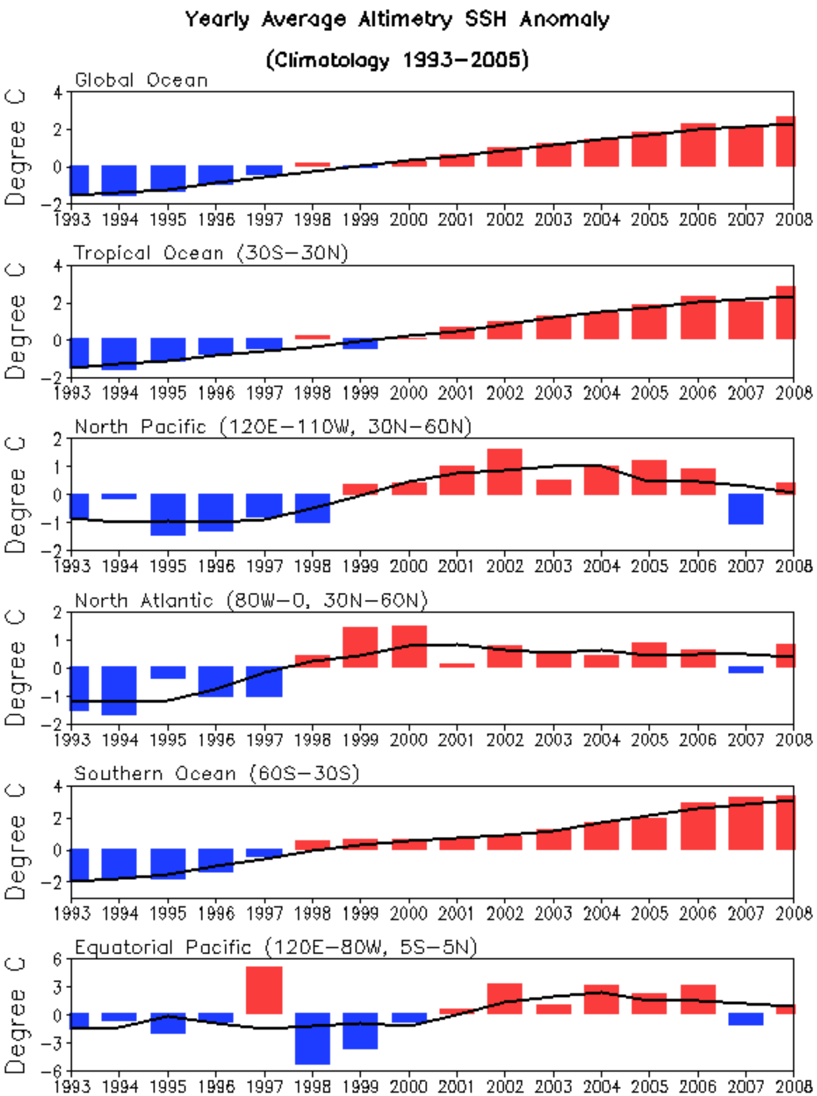
- Compared to 2007, more heat went into the tropical ocean, and lost in the extra-tropical ocean.

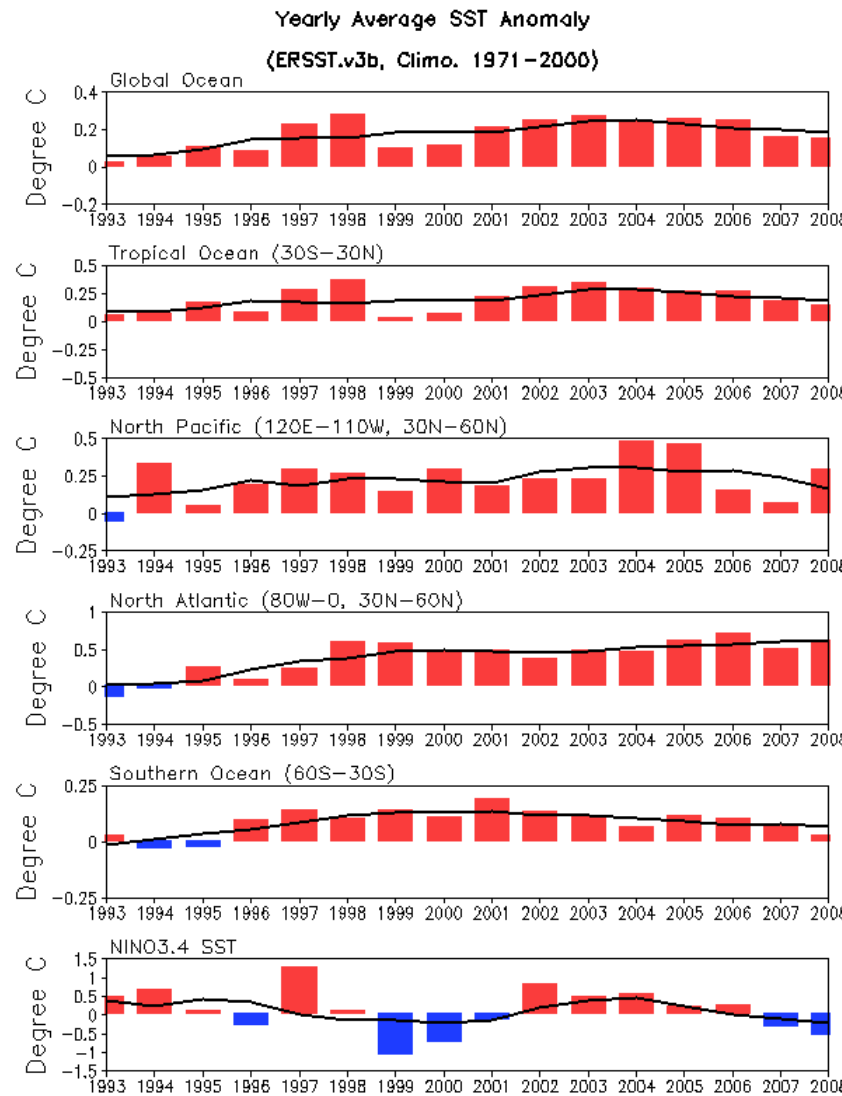
# 5-year running mean (black line)




- Global SST has a downward trend since 2005, consistent with the downward trend in tropical ocean SST.
- North Pacific in 2008 was much warmer than that in 2006/2007.
- North Atlantic SST has been persistently above-normal since 1995.
- Southern Ocean SST has a downward trend since 2001.
- NINO 3.4 SST has a downward trend since 2004.

# 5-year running mean (black line)



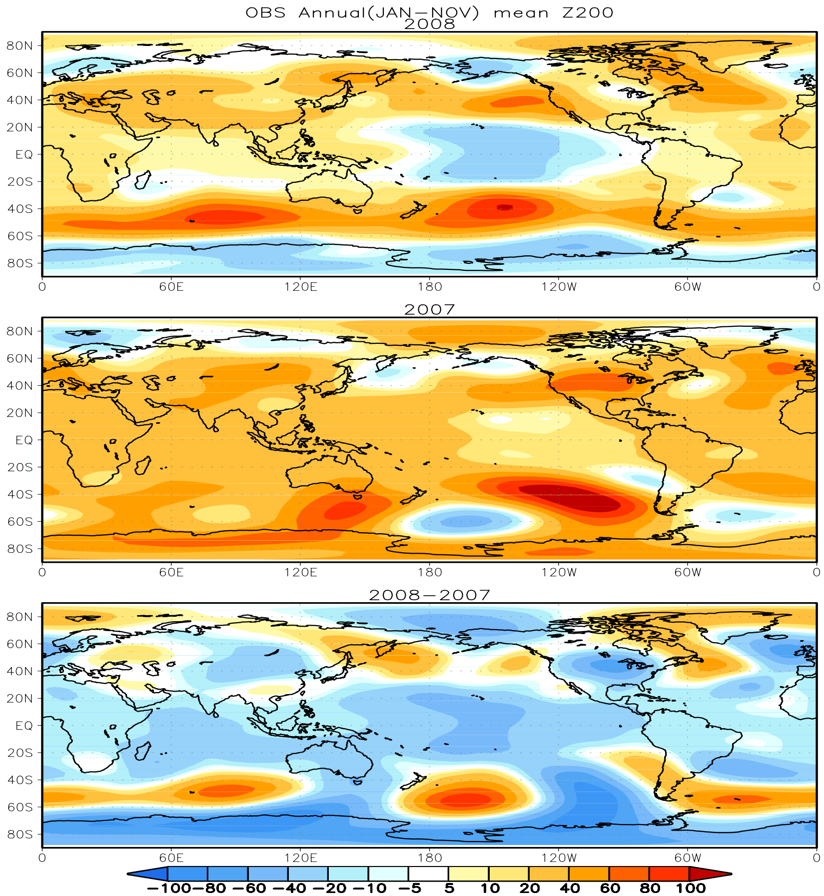

- **SSHA in the global ocean, tropical ocean and Southern Oceans have been trending upward since 1993 when Altimetry SSH observations became available.**
- **SSHA in North Pacific and the equatorial Pacific have been trending downward in the past 5-7 years.**
- **Trends in SSHA do not agree with trends in SSTA in the tropical ocean and Southern Oceans.**

# <u>Atmospheric Responses to SSTA</u>

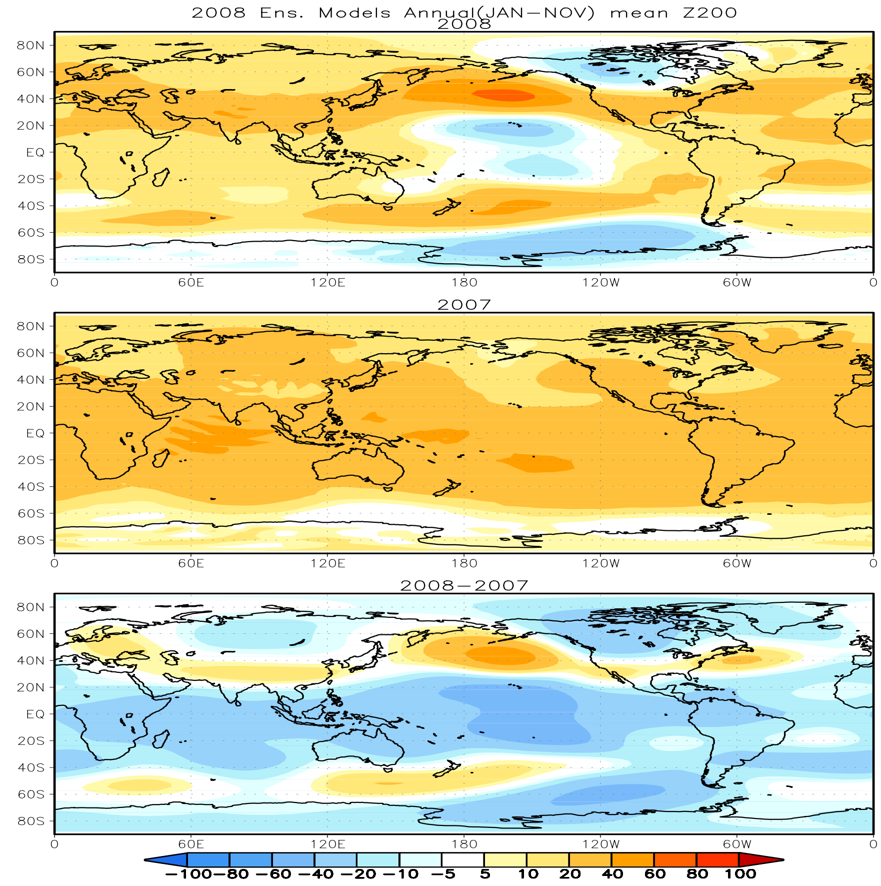
(AMIP Simulations: Averaged Jan-Nov 2008)

# Z200

## OBS



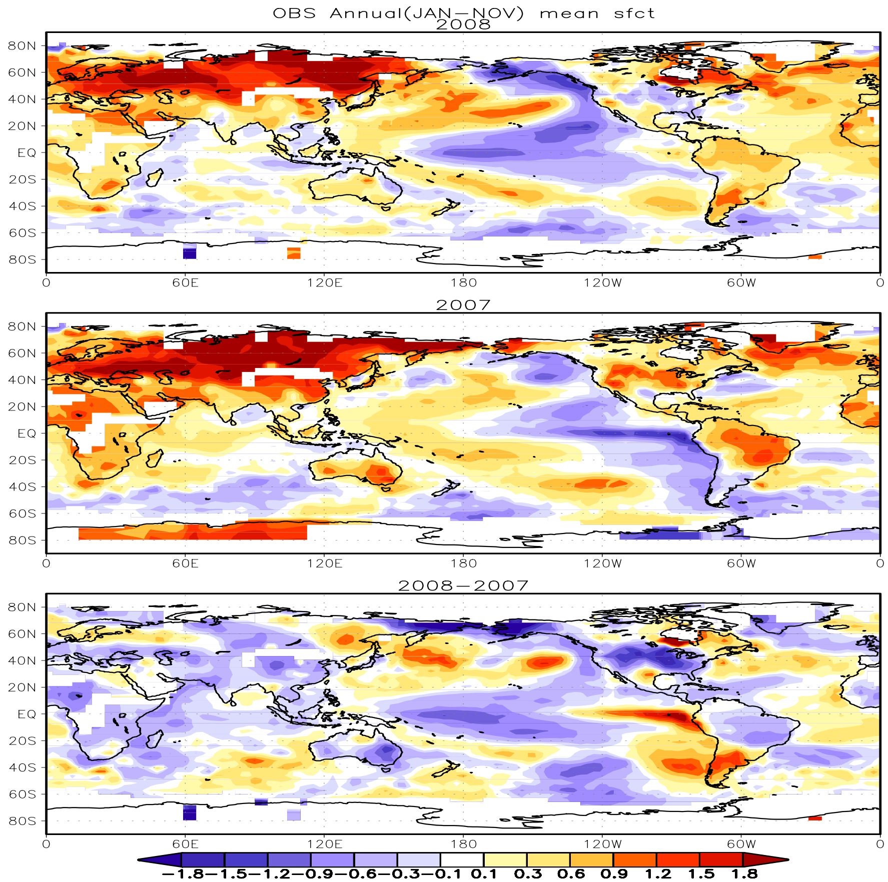

## Models



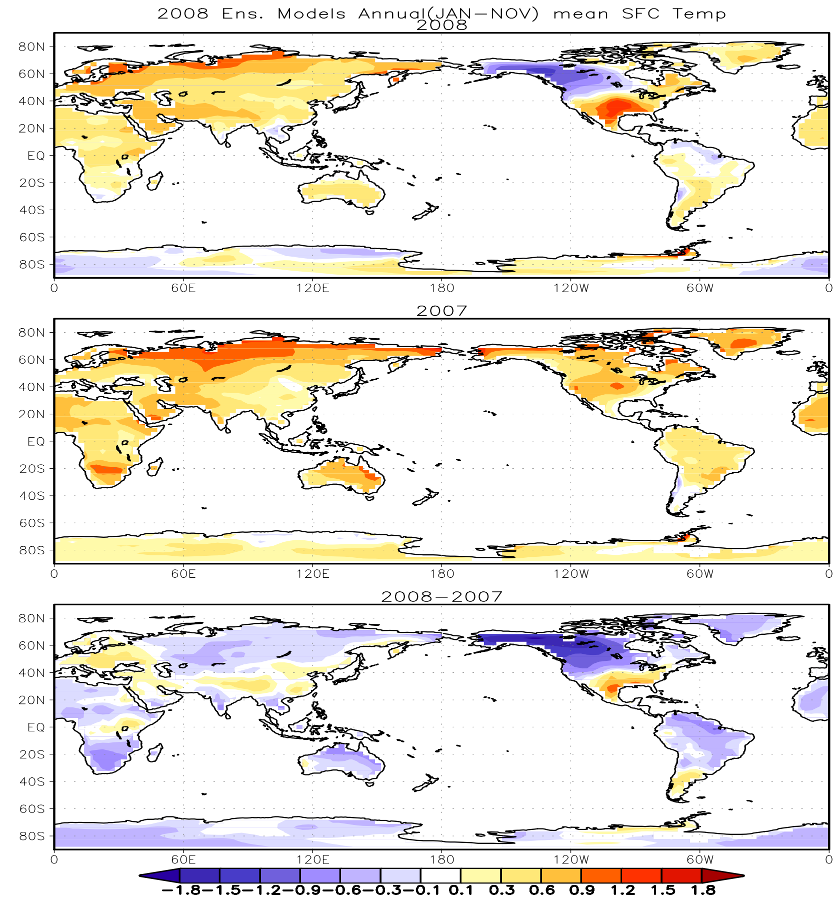

- Consistent with cooler tropical SSTs, 200-mb heights were lower in 2008
- This feature is well simulated in the ensemble of AMIP simulations, confirming the influence of tropical SSTs on heights
- Lower heights in 2008, therefore, could be attributed to changes in SSTs from 2007 to 2008.

# Surface Temp

## OBS

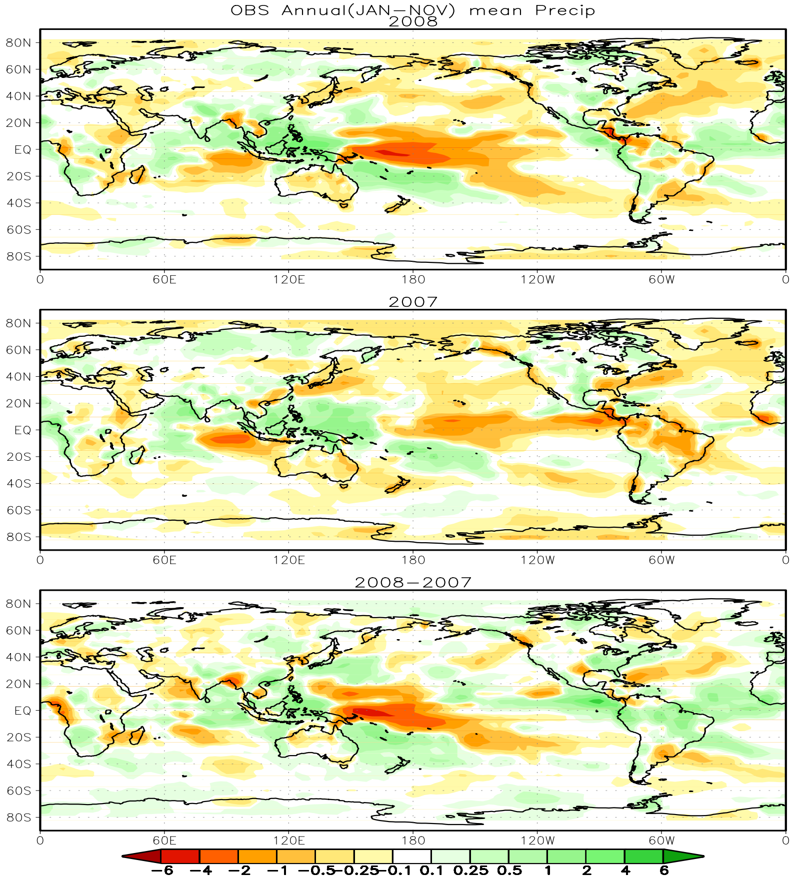


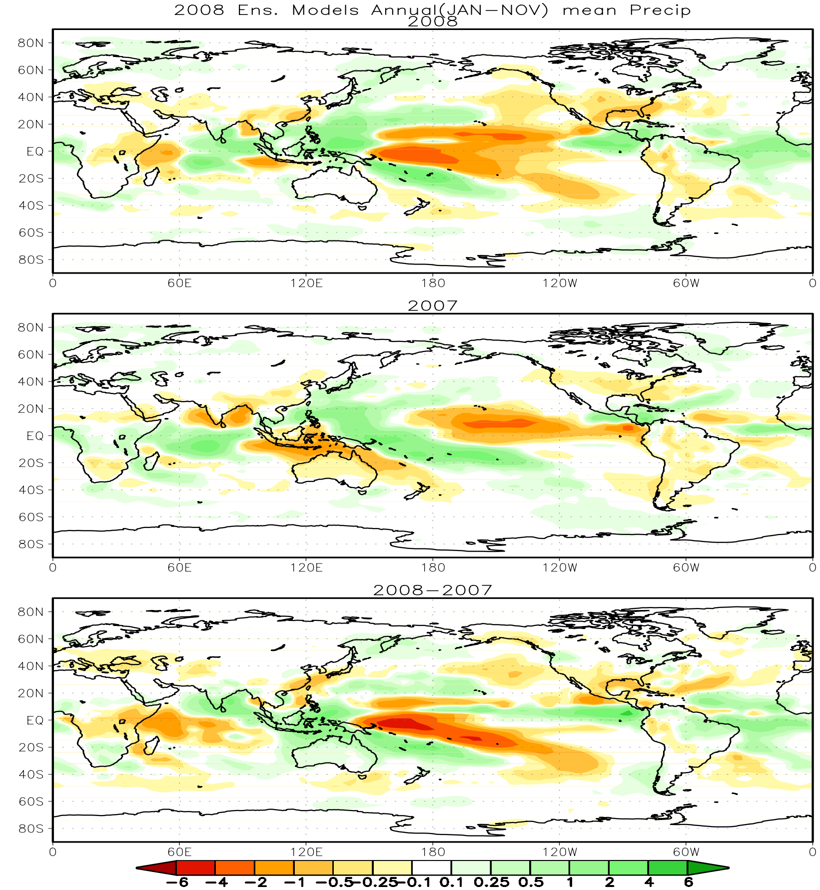

## Models




- **Compared to 2007, land temperatures in 2008 were generally on the cooler side**
- **Once again this feature is well simulated in the ensemble of AMIP simulations, confirming the influence of SSTs**
- **Lower temperatures over the US had an adverse impact on the official CPC seasonal sfc. Temperature forecasts in 2008**

# OBS Prec. Models




- Observed change in the 2008 tropical rainfall, compared to 2007 rainfall, are well replicated in the AMIP simulations (e.g., suppressed rainfall near the Dateline, and the SPCZ; enhanced rainfall over the Maritime Continent; enhanced rainfall in the tropical Atlantic etc.)
- Influencing role of changes in the SSTs is confirmed by the AMIP simulations

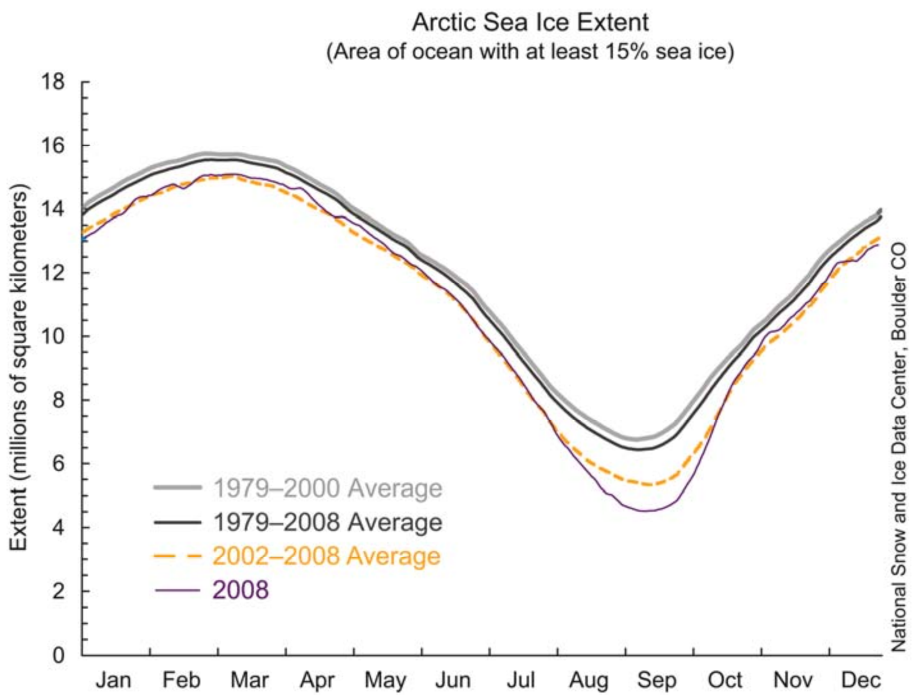
# Special Feature Discussions

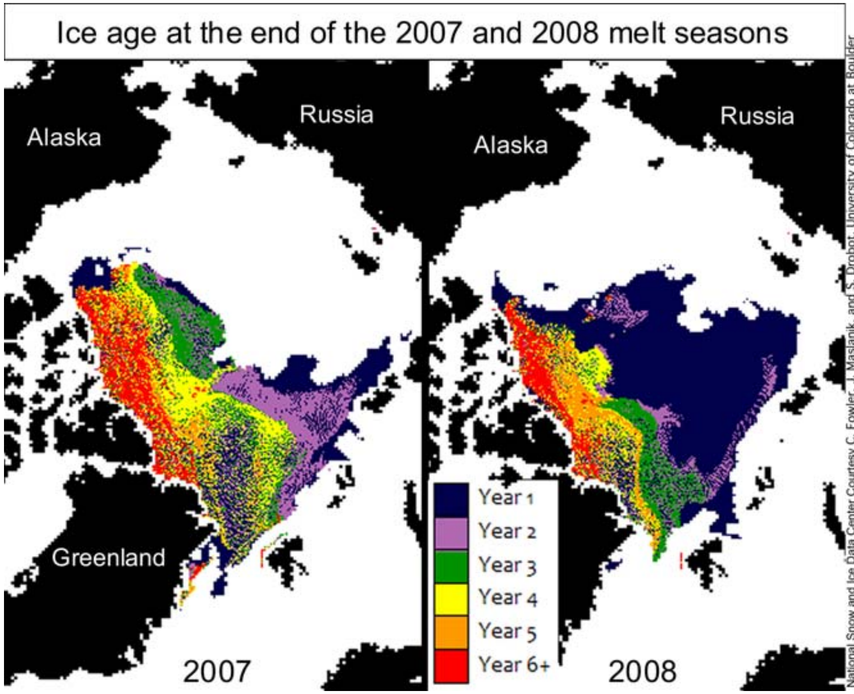
- Arctic Sea Ice and SST
- Negative PDO Phase
- North America Western Coast Upwelling
- Atlantic hurricane and non-local SSTA
- Recent trends and ENSO variability
- 2007/08 La Nina Cycle Evolution and Prediction

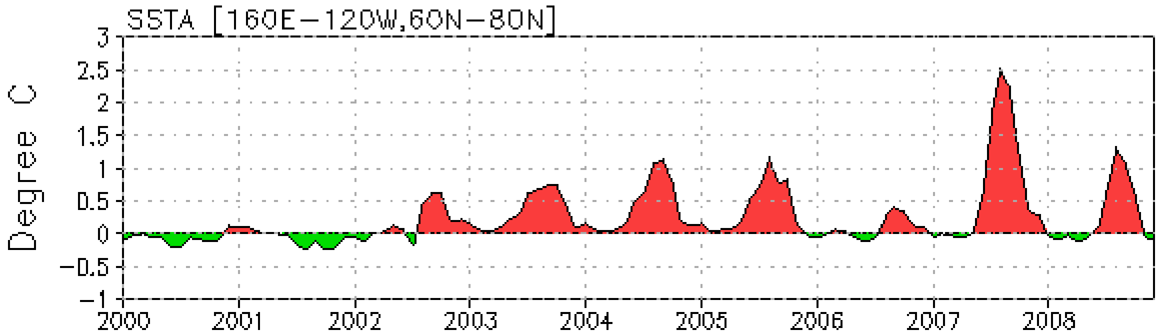
# Arctic Sea Ice & SST

**National Snow and Ice Data Center**

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

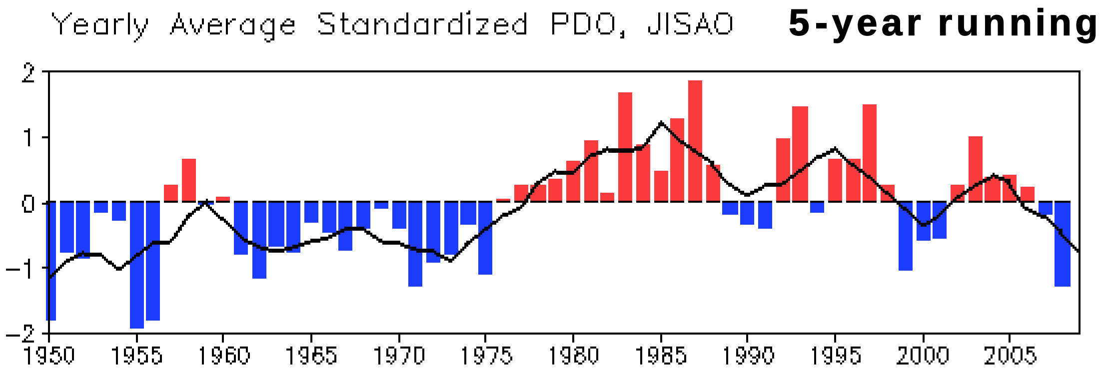


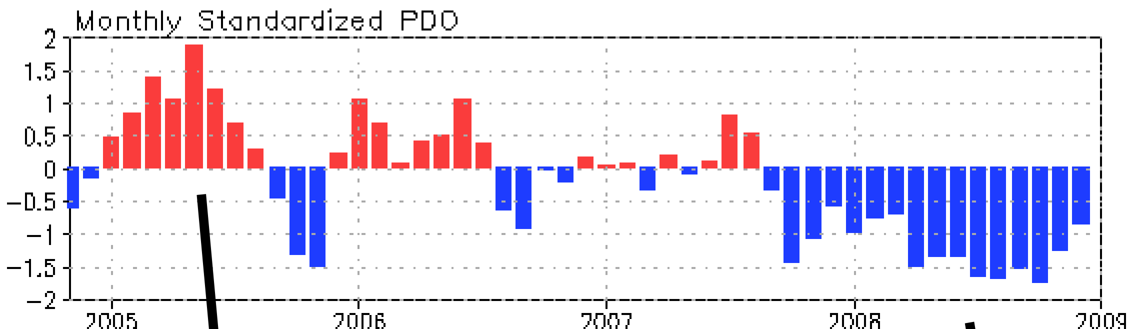

- Arctic sea ice extent in 2008 is the second lowest since 1979, only slightly larger than the 2007 historical low.
- Decreasing of Arctic sea ice extent since 2002 is associated with the above-normal SST during each summer melting season since 2002.

**5-year running mean (black line)**

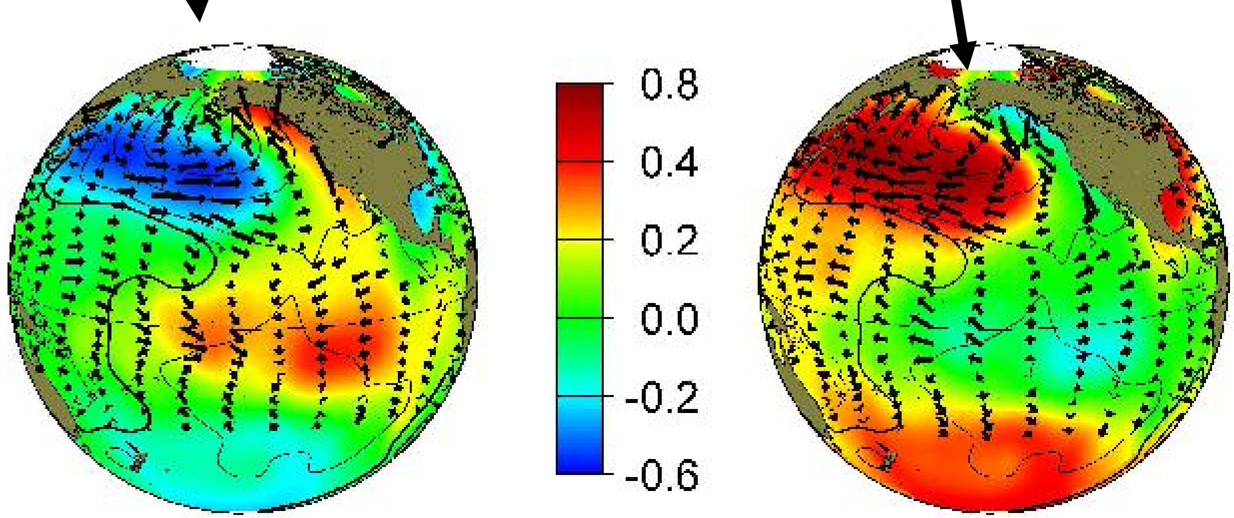



- PDO is the lowest since 1971.

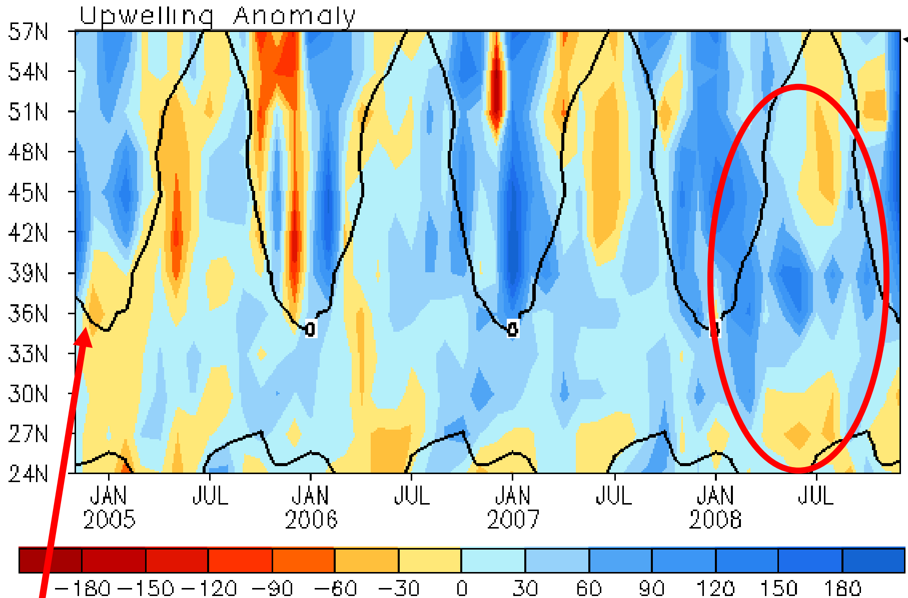
**PDO index downloaded from UW / NOAA JISAO PDO page**



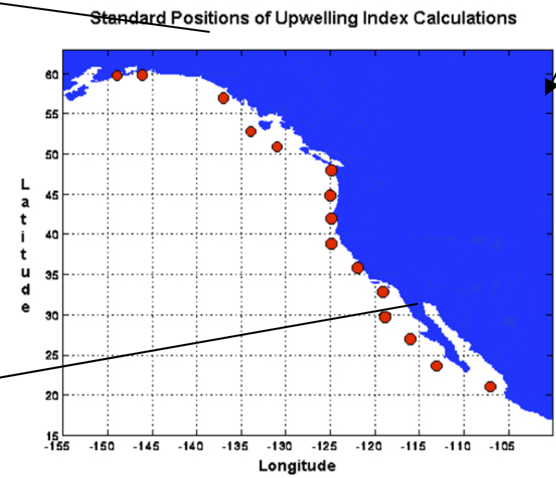

- PDO has been in the negative phase since September 2007, that has lasted 17 months by Jan. 09.



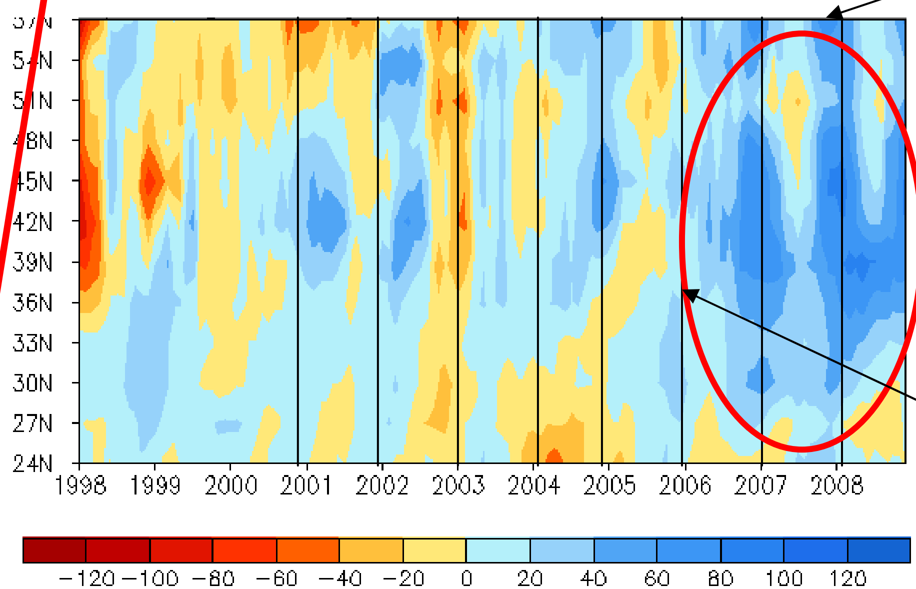
# North America Western Coastal Upwelling from GODAS




SWFSC, NOAA Fisheries Service




7-month running mean

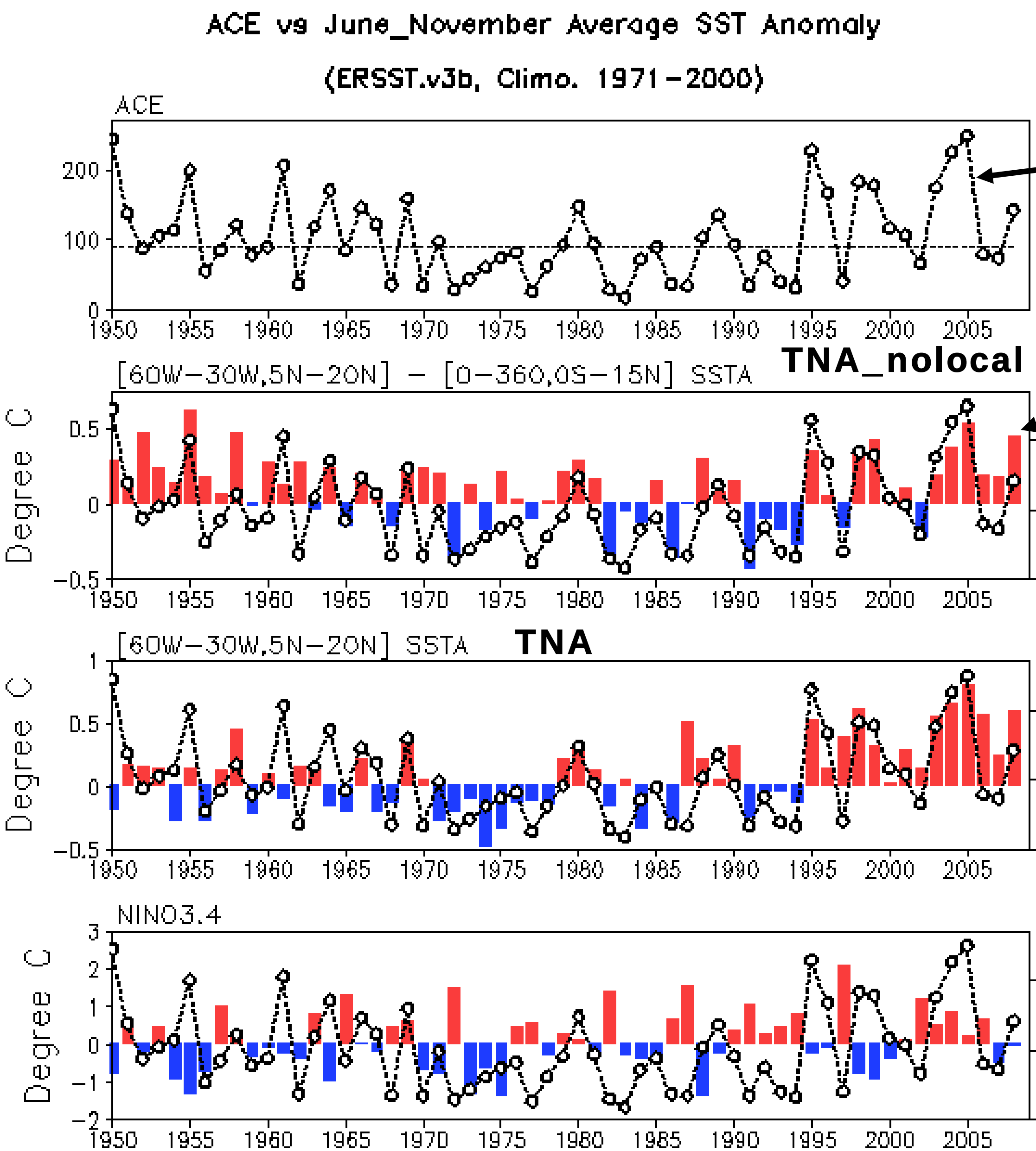



- 2008 upwelling season is above-normal.
- The above-normal upwelling season is associated with the negative PDO phase.
- The early onset of strong upwelling in 2008 (similar to 2007) may be the cause of high biological productivity during 2008 (Bograd et al., 2009, GRL).
- Upwelling has been extremely strong during winters of 2007 and 2008, and likely continue in winter of 2009.
- A shift to a strong upwelling regime may have occurred in late 2005.

• 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.

# Atlantic Hurricane Activity & SST Anomaly




**Accumulated Cyclone Energy (ACE) downloaded from http://en.wikipedia.org**

**Nolocal SST index:**

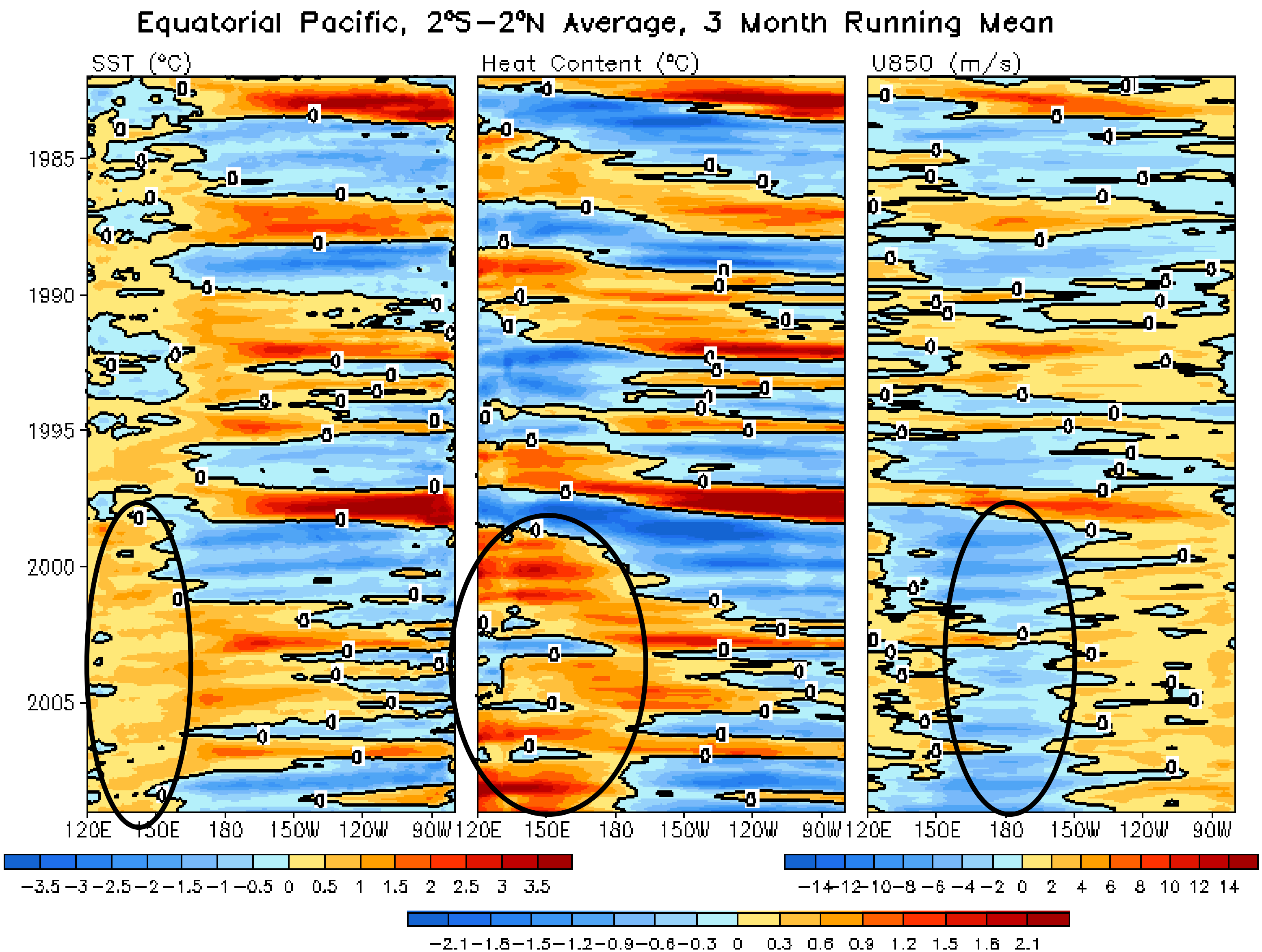
**Swanson (2008);**

**Vecchi & Soden (2007)**

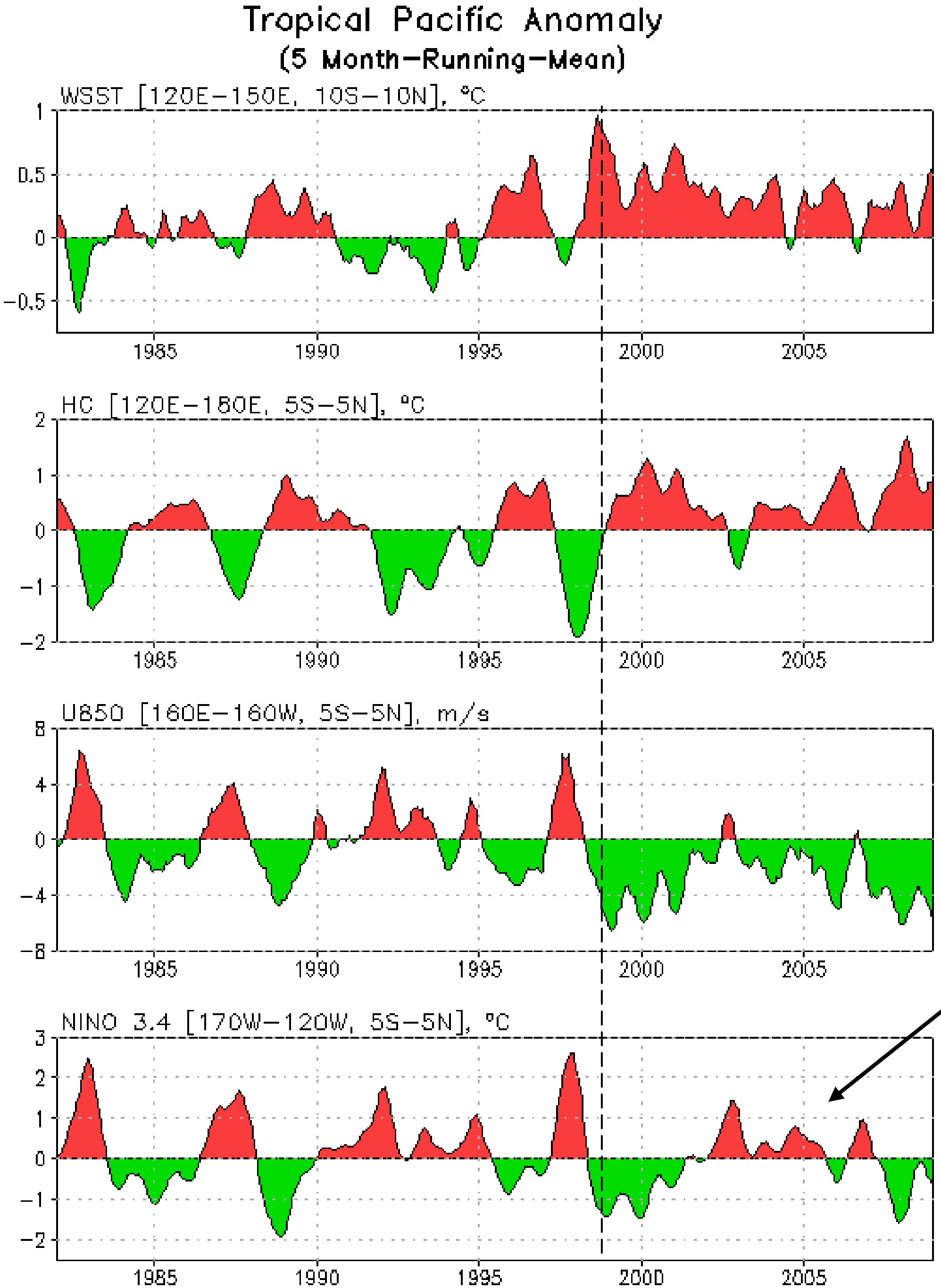
| **Correlation with ACE** | |
|---|---|
| **TNA_nolocal** | **0.64** |
| **TNA** | **0.44** |
| **NINO3.4** | **-0.11** |

- **TNA relative to the global tropical mean SSTA is a better index for explaining Atlantic hurricane activity than either TNA or NINO 3.4 alone.**

# Recent Trends and ENSO Variability



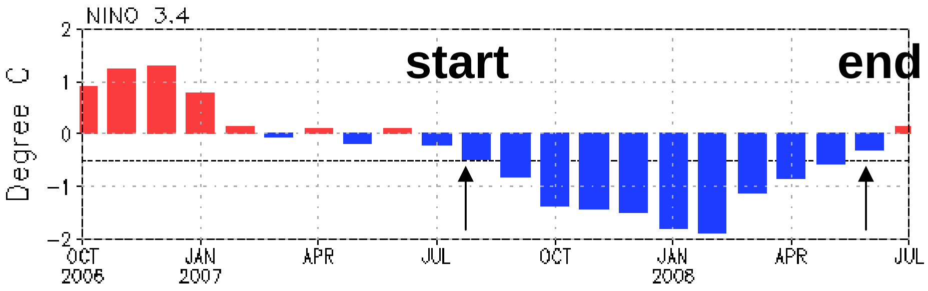

- Above-normal SST has persisted in the far western tropical Pacific since 1999.
- Above-normal heat content has persisted west of the Dateline since 1999.
- Above-normal surface zonal winds have persisted near the Dateline since 1999.




- Above-normal SST has persisted in the far western tropical Pacific since 1999.
- Above-normal heat content has persisted west of the Dateline since 1999.
- Above-normal surface zonal winds have persisted near the Dateline since 1999.

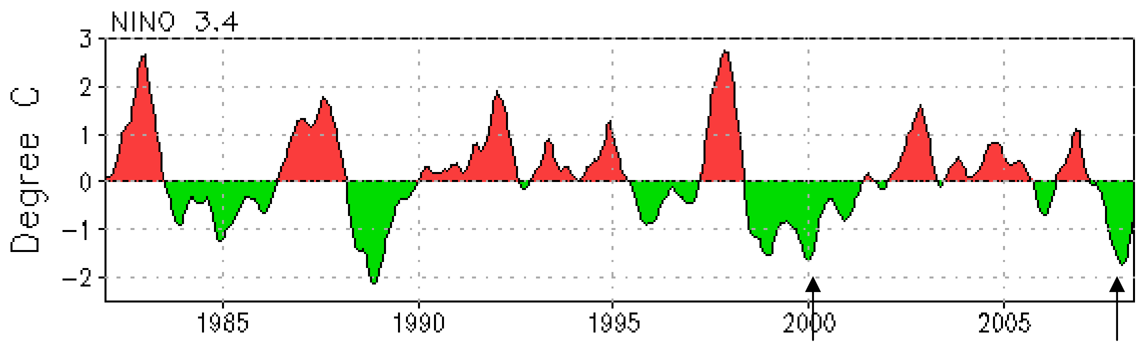
- Based on the NINO 3.4 index, there has been 3 La Nina and 3 El Nino episodes since 1999 (CPC's web site).
- All except the 99/00 La Nina lasted less than 11 months, much shorter than the duration of the major episodes in 1980-1998.
- Persistent surface easterly wind anomalies were La Nina-like.
- The recent trend may have altered ENSO characteristics, making them weaker and less persistent than they were before 1999.
- If the trend continues, we may continue to observe short-lived ENSO events in the near future.

# 2007/08 La Nina Cycle: Evolution and Prediction



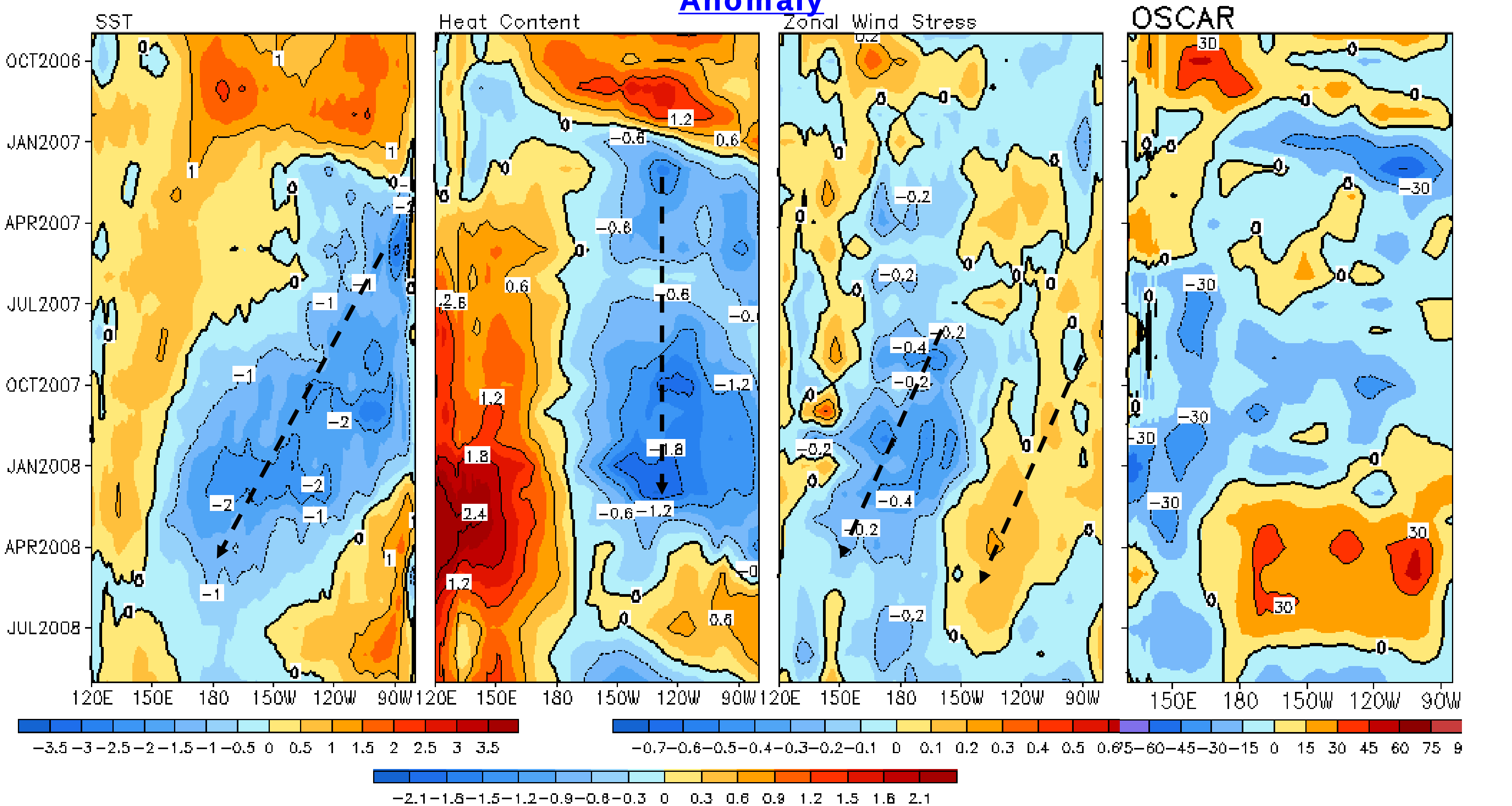

# NINO3.4 SST Index

- The definition of ENSO is keyed on the NINO3.4 Index.
- La Nina is referred to as NINO3.4 =< -0.5ºC.
- The 07/08 La Nina started in August 07 and ended in June 08, with a duration of 10 months.



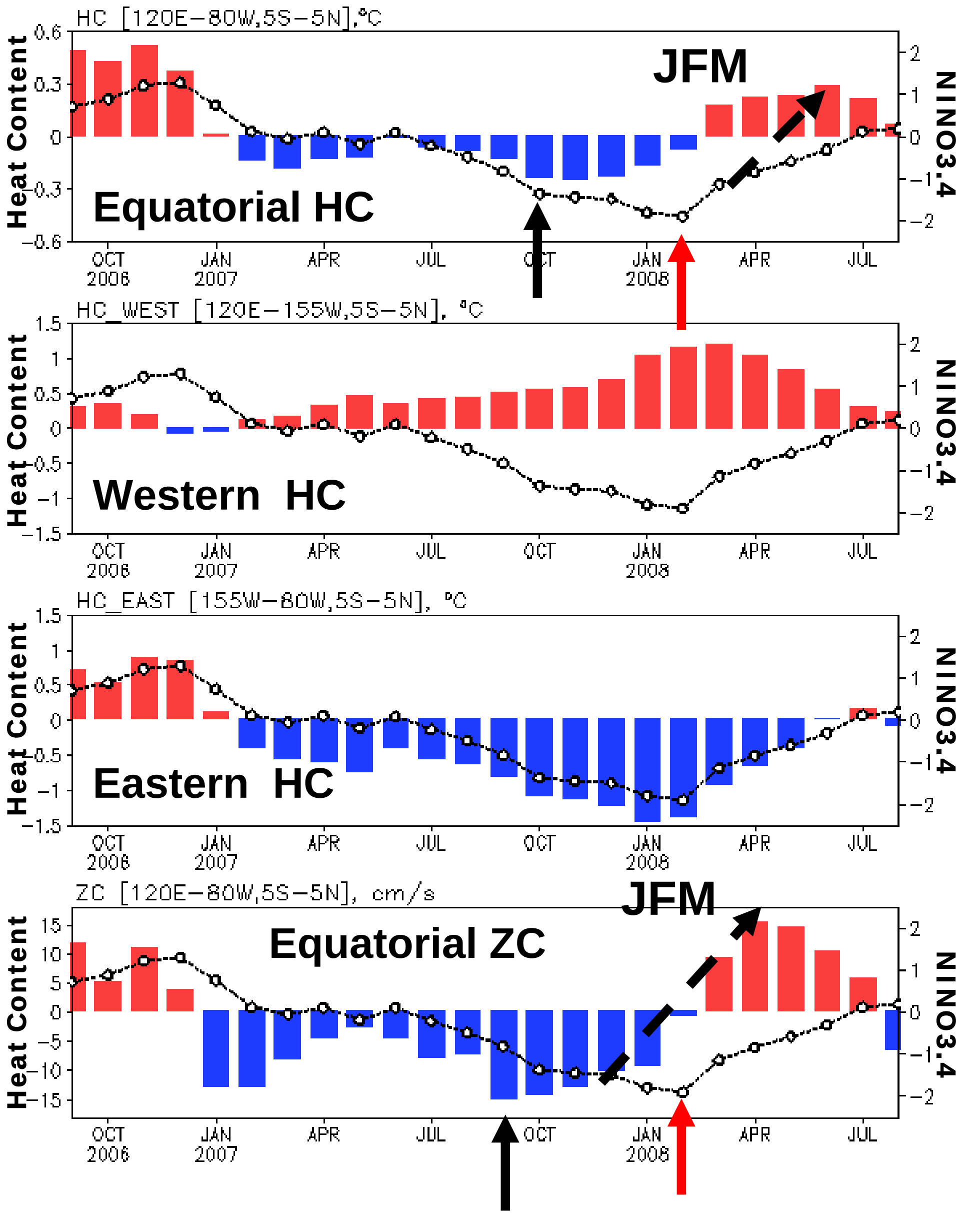

- The 07/08 La Nina has a similar strength as that of the 99/00 La Nina.
- The moderate 07/08 La Nina was noteworthy since ENSO variability has been relatively weak during 01-06.

# Evolution of Equatorial Pacific SST, Heat Content, TAUX, and Surface Zonal Current Anomaly




- **Both SSTA and zonal wind stress anomalies propagated westward.**
- **Heat content (upper 300m temperature average) anomaly was largely stationary.**
- **Warming in the far E. Pac. during early spring 08 accompanied by westerly wind anomalies.**
- **Surface zonal current anomaly (ZCA) switched from westward to eastward in February 08.**

# Equatorial Average of Heat Content (HC) and Zonal Current (ZC) Anomaly



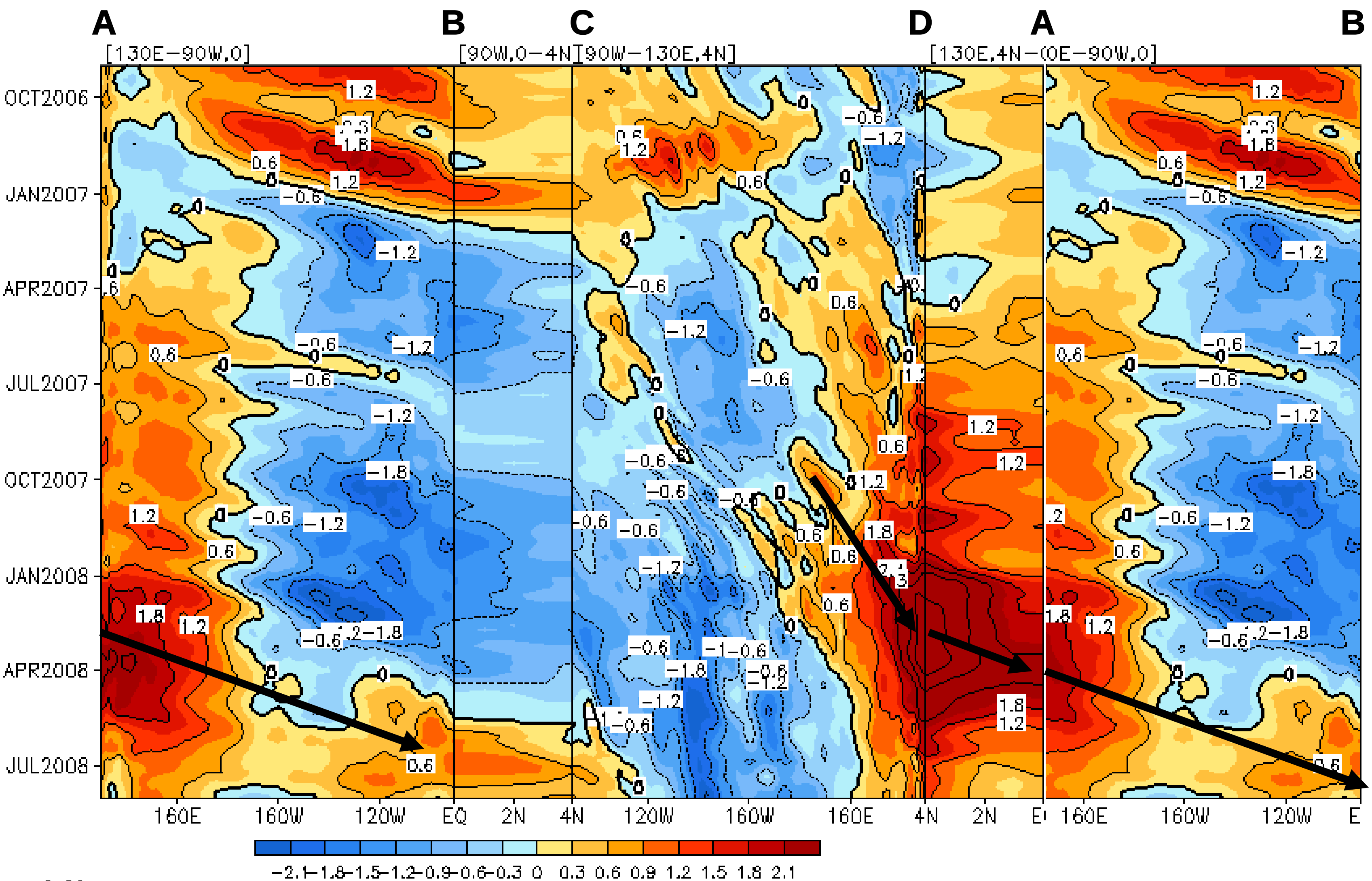

-Eastern HC was in phase with NINO3.4.

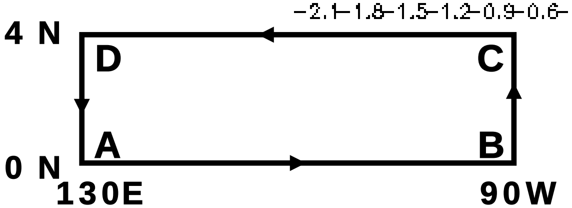
- Equatorial HC and ZC led the peak phase (JFM) of NINO3.4 by 4 months.

- Equatorial HC and ZC underwent transition during the peak phase of NINO3.4.

- The phase lead-lag relationship between equatorial HC/ZC and NINO3.4 indicates that the Recharge Oscillator contributed to the onset and decay of the event.

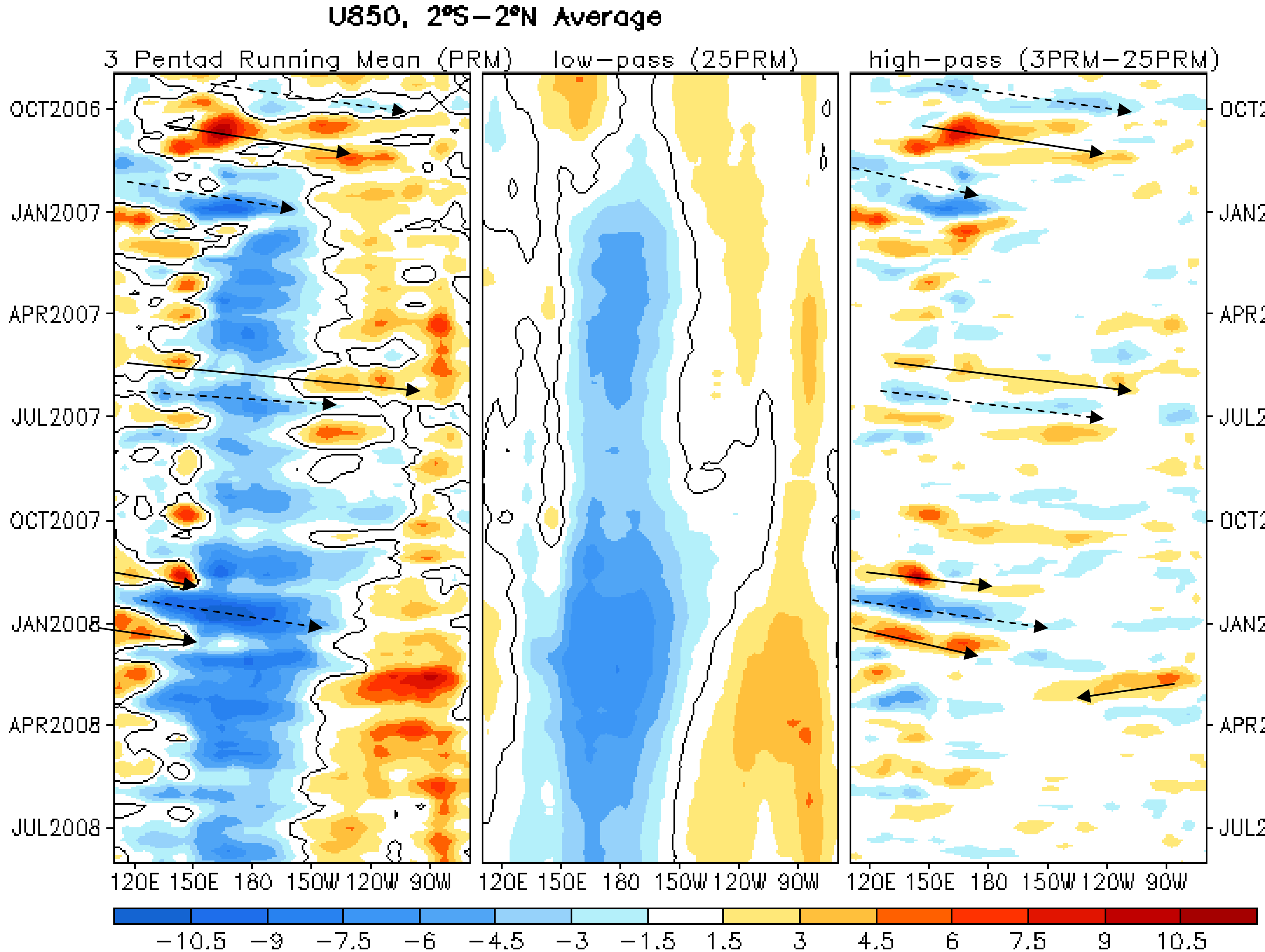
# Circuit Propagation of Heat Content Anomaly




- **Western boundary reflection of downwelling Rossby waves generated downwelling Kelvin waves, and contributed to the decay of the event in spring 08, consistent with the Delayed Oscillator Theory.**

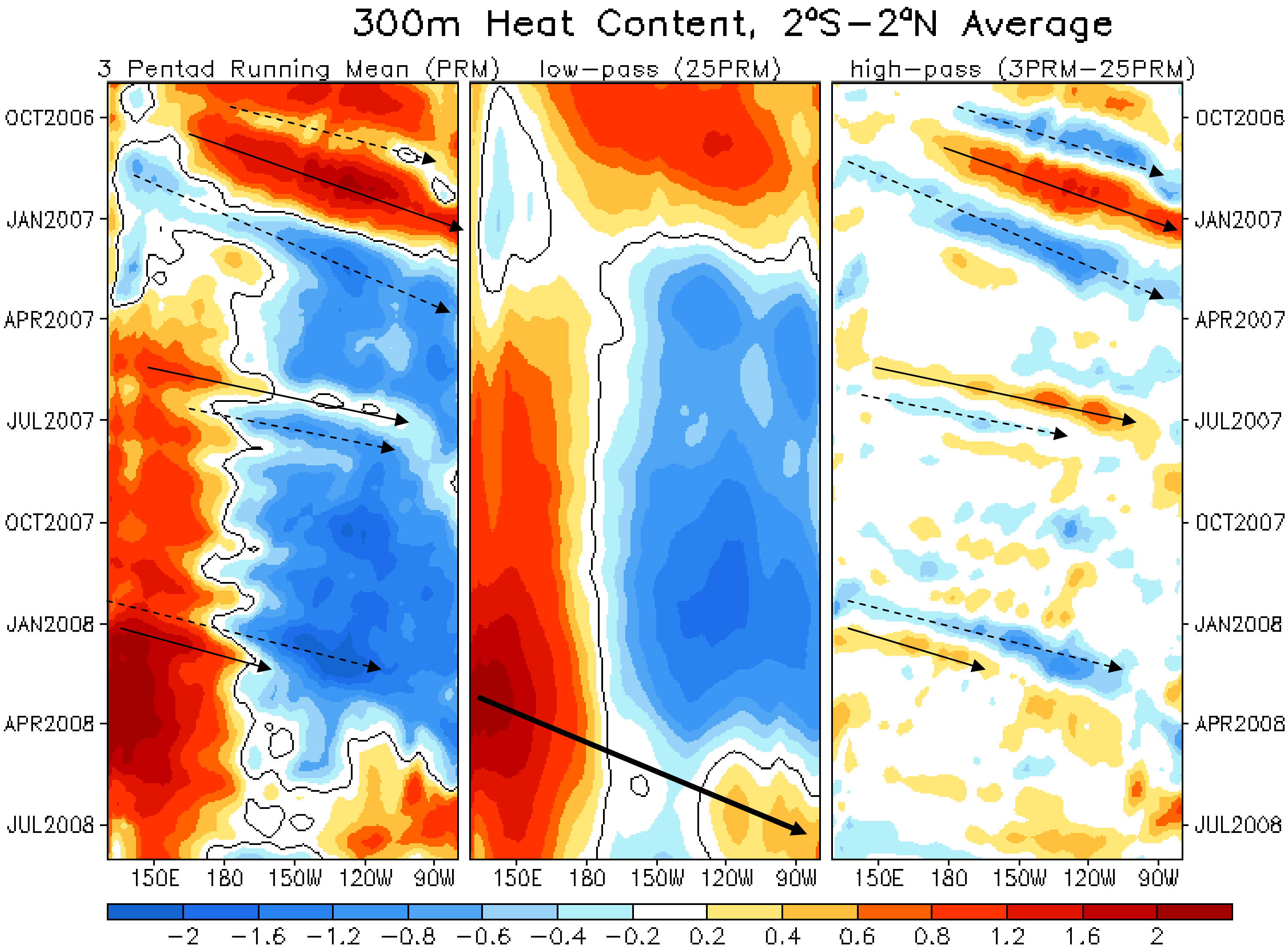
# MJO-related Winds




- Strong MJO-related easterly wind anomalies during Nov-Dec 06 contributed to the sudden demise of the 06/07 El Nino.

- MJO-related westerly and easterly wind anomalies during summer 07 and winter 07/08 had substantial impacts on the evolution of the event (see next slides).

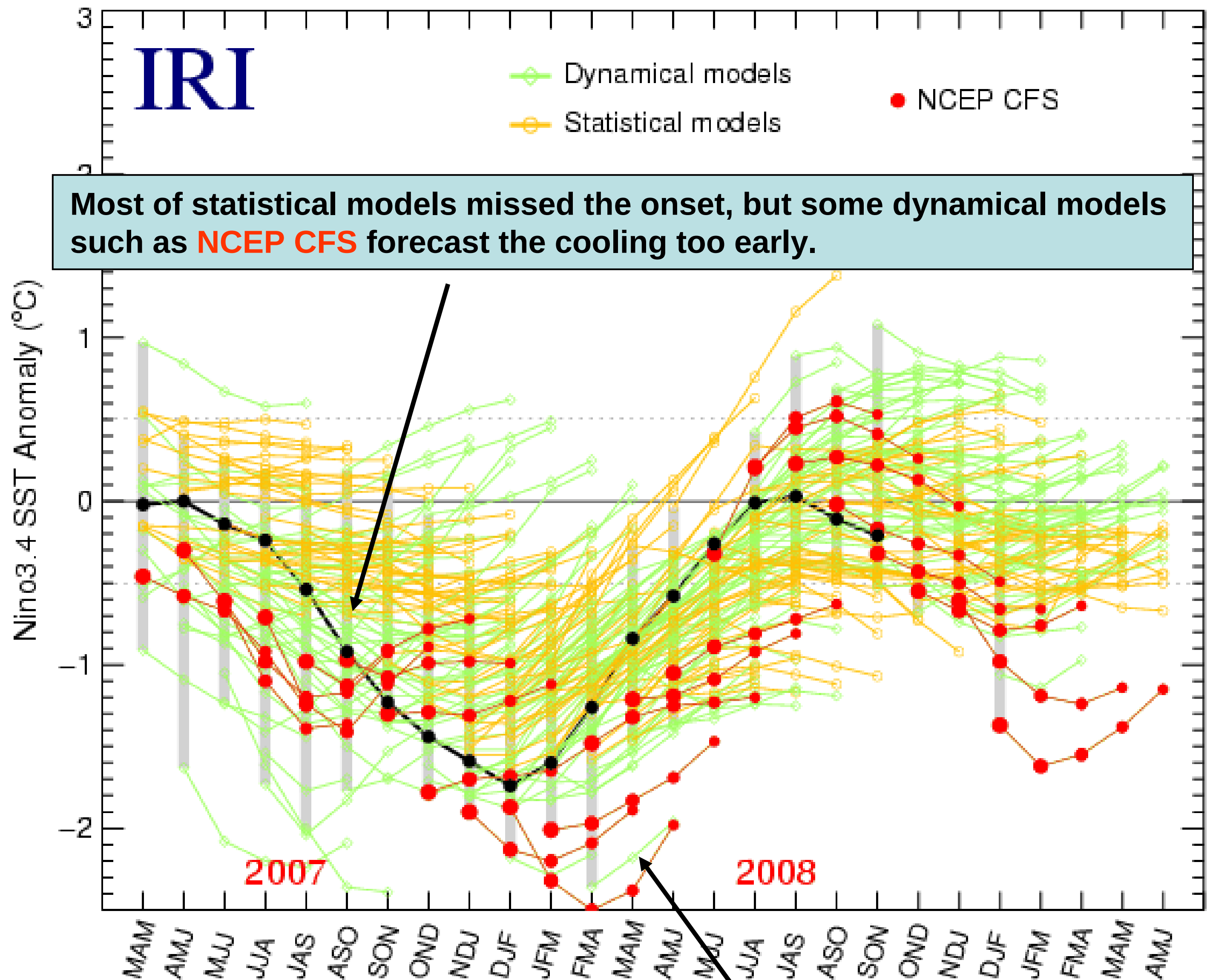
# Oceanic Kelvin Waves: Heat Content Anomaly




- **Upwelling Kelvin waves forced by MJO-related easterly wind anomaly during Nov-Dec 06 contributed to the sudden switch of heat content anomaly from positive to negative in January-February 2007.**

- **Downwelling Kelvin waves forced by MJO-related westerly wind anomalies during Jan 08 contributed to the weakening of negative heat content anomaly in Feb-Mar 08, but were not the cause for the decay.**

## ENSO Forecast from Mar 2007 to Dec 2008

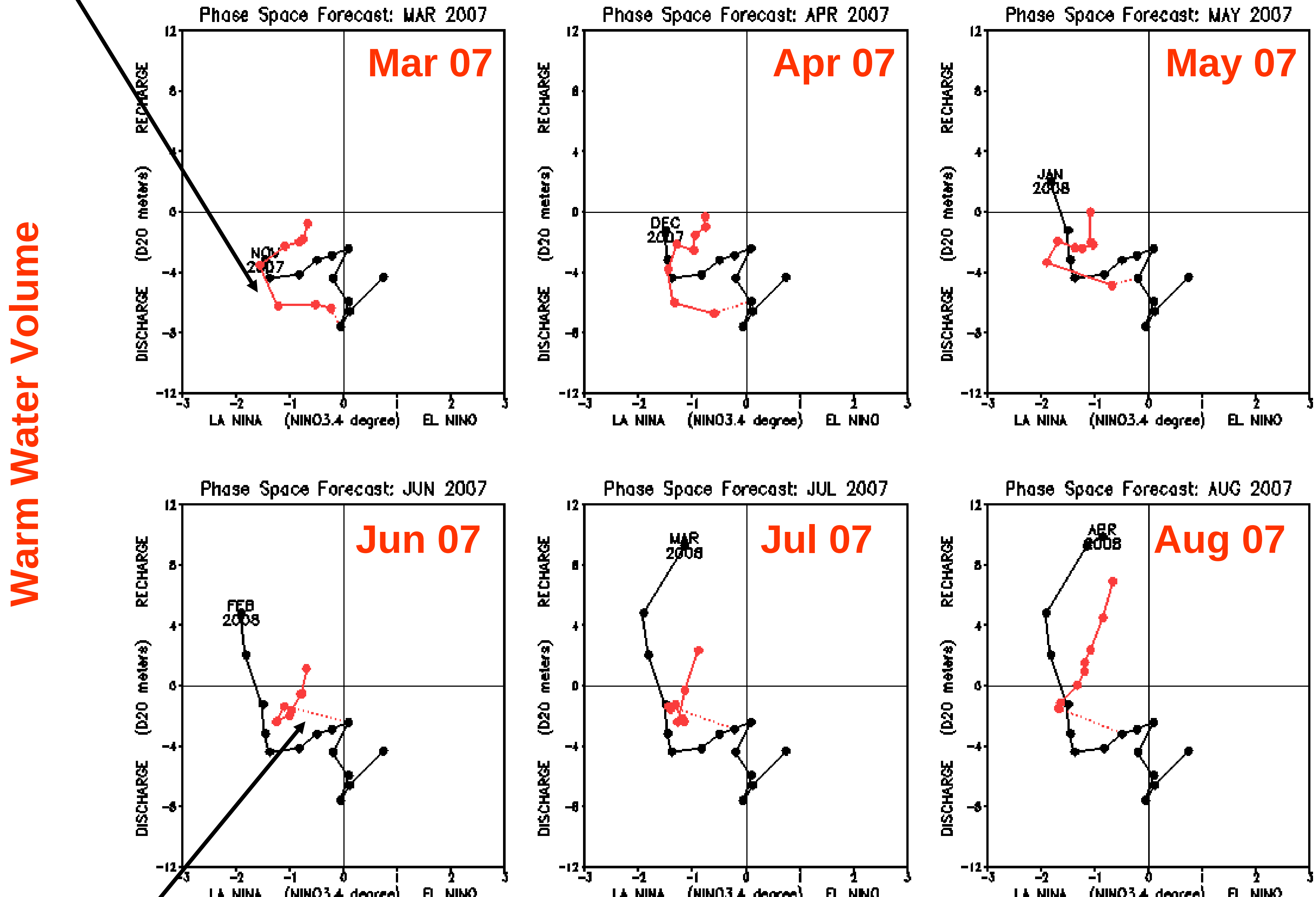



**Most of statistical models missed the onset, but some dynamical models such as NCEP CFS forecast the cooling too early.**

**Most of models forecast the decay phase well, but NCEP CFS extended the cold phase by 2-3 months..**

too early onset in Mar-Apr

# CFS Forecast Phase Diagram

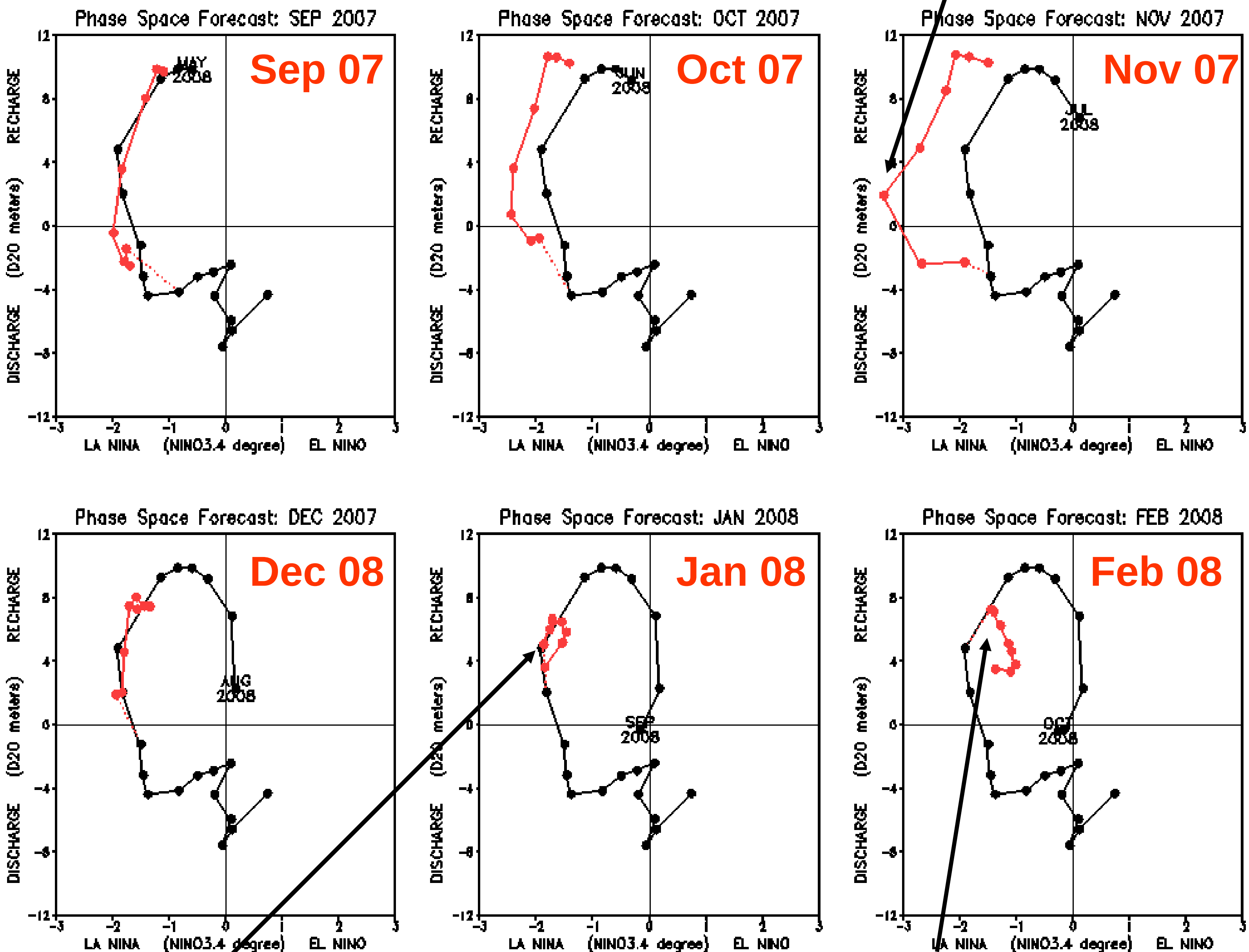



large initialization shock in Jun-Aug 07

# CFS Forecast Phase Diagram

too large amplitude

Warm Water Volume




locked into a steady La Nina phase

NINO3.4

spring difficulty

# Conclusions

- **Features of the 07/08 La Nina**
  - **Negative heat content anomaly in the eastern tropical Pacific preceded the onset phase by 5-6 month.**
  - **Both SSTA and zonal wind stress anomalies propagated westward.**
  - **Zonal advective feedback played a more important role than thermocline feedback during the onset and decay phase of the event despite both contributed about equally to the development phase.**
  - **MJO-related winds had substantial impacts on the evolution of the event.**
  - **Both Recharge Oscillator and Delayed Oscillator contributed to the decay of the event in spring 08.**

- **Prediction of the 07/08 La Nina by NCEP CFS**
  - **NCEP CFS forecasted the onset of the La Nina too early and overshot in the prediction of the mature and decay phases.**
  - **The above forecast errors have been partially corrected by a PDF correction scheme (not shown).**

# Data Sources and References

- Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
- Merged Land-Ocean Surface Temperature Analysis (ERSST v3b, Smith et al. 2008)
- SST 1971-2000 base period means (Xue et al. 2003)
- NCEP/NCAR CDAS winds, surface radiation and heat fluxes
- NESDIS Outgoing Long-wave Radiation
- 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)

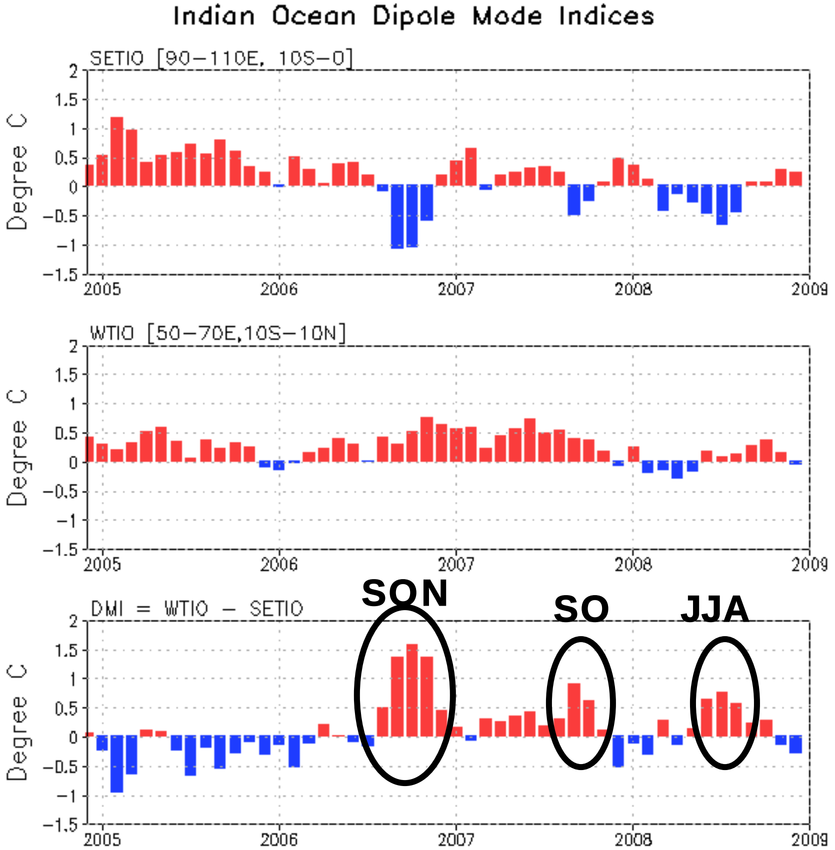
Please send your comments and suggestions to Yan.Xue@noaa.gov. Thanks!

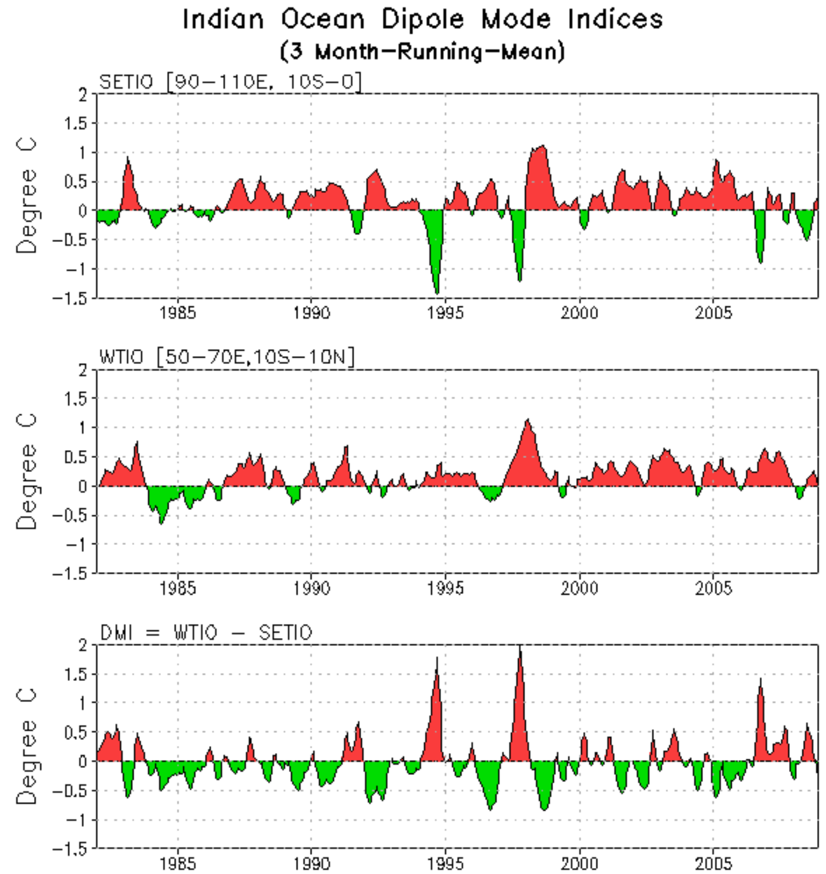
# <u>Backup Slides</u>

(monthly Indices)

# Early or Aborted IOD

# Indian Ocean Dipole Indices

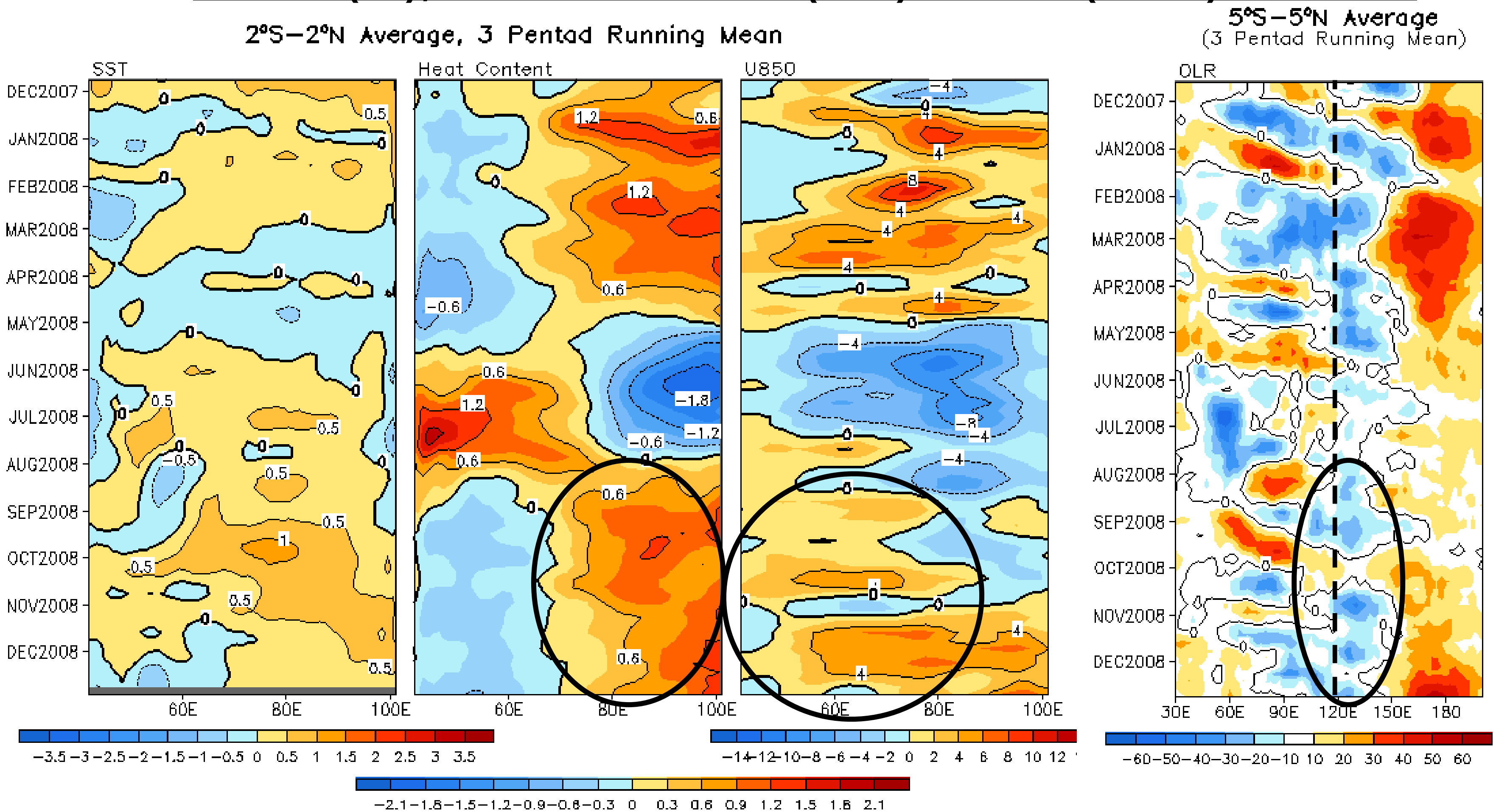



- Positive IOD events in SON 2006 and SO 2007.
- Aborted IOD event in JJA 2008, that occurred three months earlier than typical IOD events do.

- Three consecutive IOD events in the past three years.

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

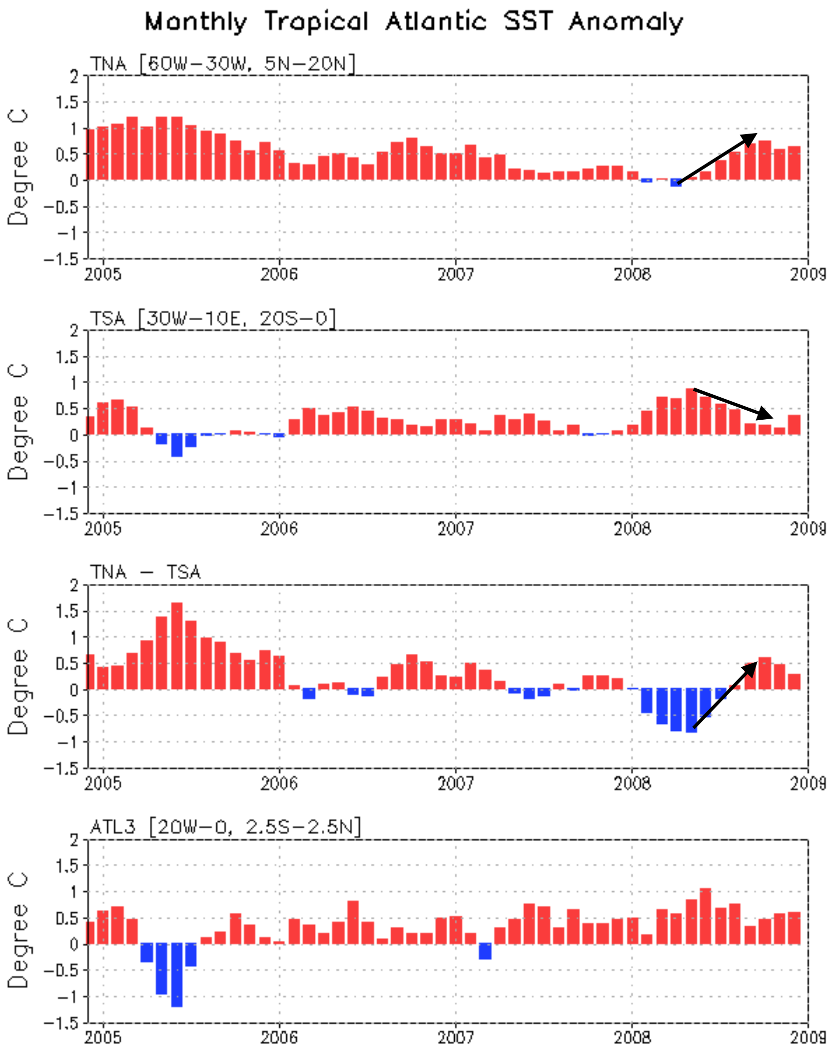


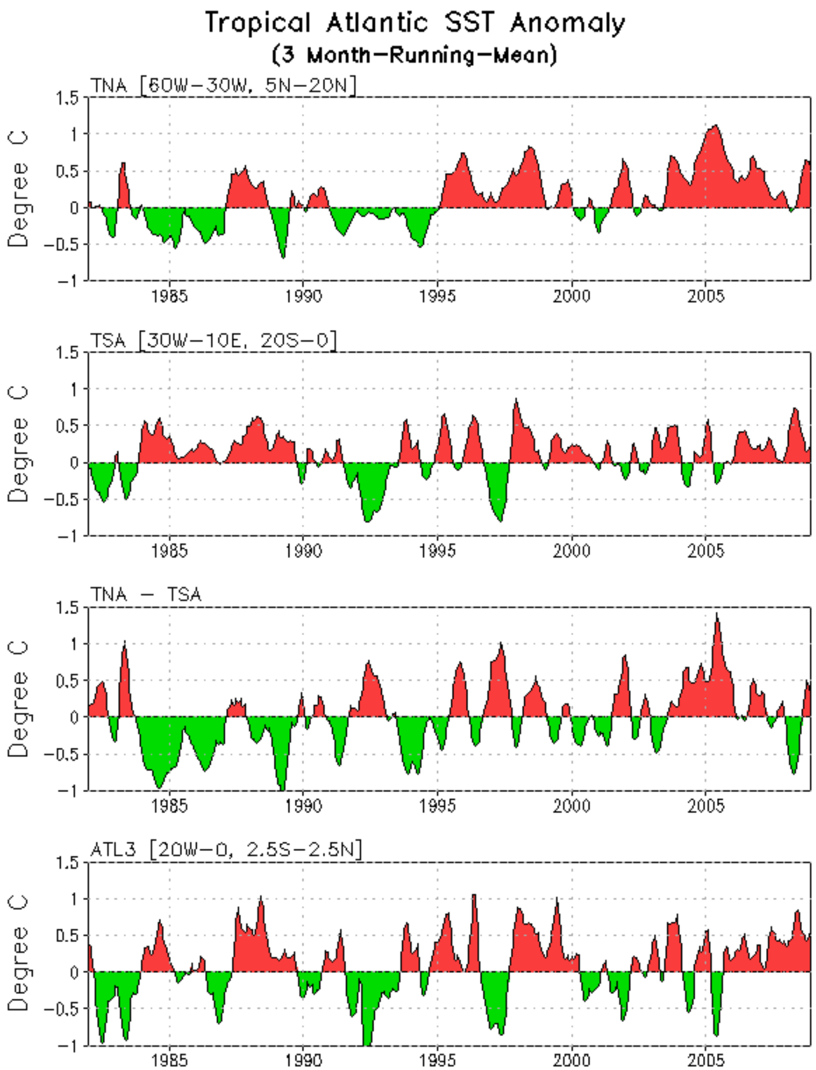

- Westerly wind anomalies since August are associated with the persistent enhanced-convection over the Maritime Continent, which killed the positive IOD event formed in summer.

Fig. 13. 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 for SST, heat content and U850/OLR are departures from the 1971-2000, 1982-2004, 1979-1995 base period pentad means respectively.

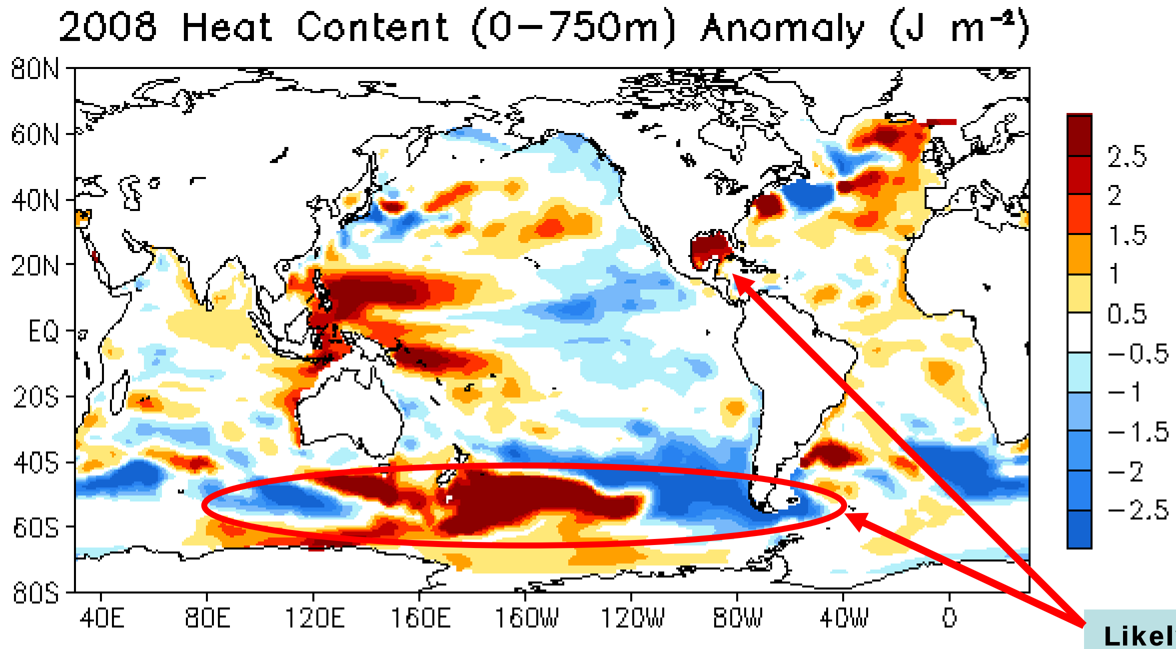
# Summer Development of Positive Meridional SST Gradient Mode in Tropical Atlantic

# Tropical Atlantic SST Indices



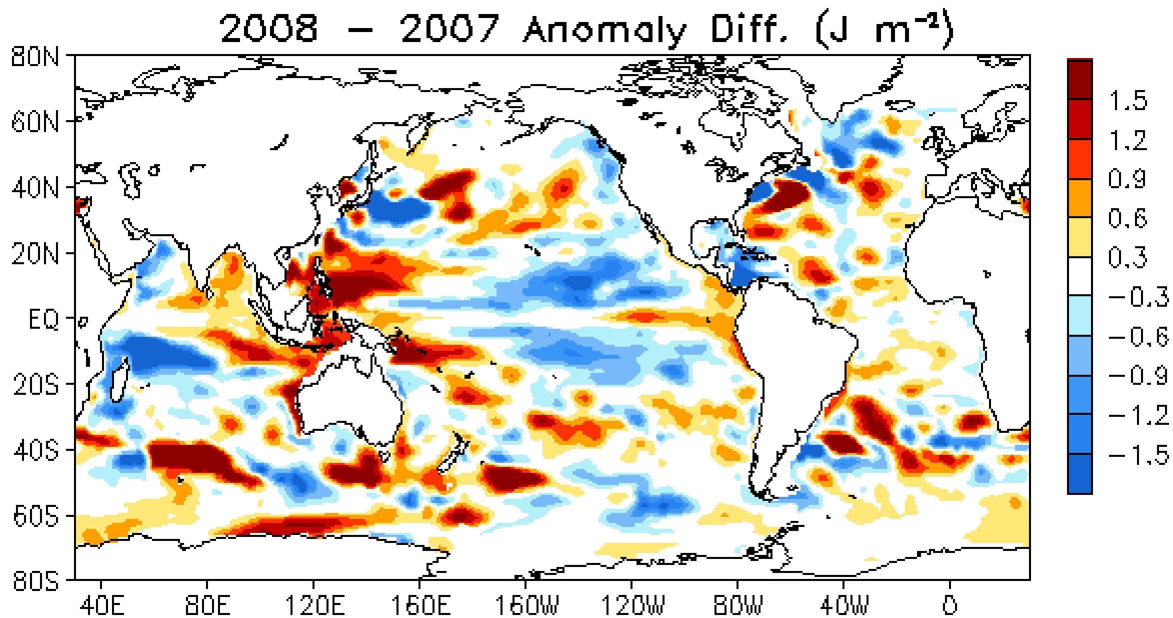



# Global Heat Content (0-750m) Anomaly




- East-west HC dipole in tropical Pacific due to 2007/08 La Nina
- Below-normal HC in Gulf of Alaska

Likely problematic due to lack of observations




- HC increased (decreased) in western (central) tropical Pacific.
- HC increased (decrease) in eastern (western) tropical Indian Ocean.
- The global mean difference is