A 21st Century Shift in ENSO Properties

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Recent Decrease in ENSO Forecast Skill

SKILL OF REAL-TIME SEASONAL ENSO MODEL PREDICTIONS DURING 2002–11

Is Our Capability Increasing?

BY ANTHONY G. BARNSTON, MICHAEL K. TIPPETT, MICHELLE L. L'HEUREUX, SHUHUA LI, AND DAVID G. DEWITT

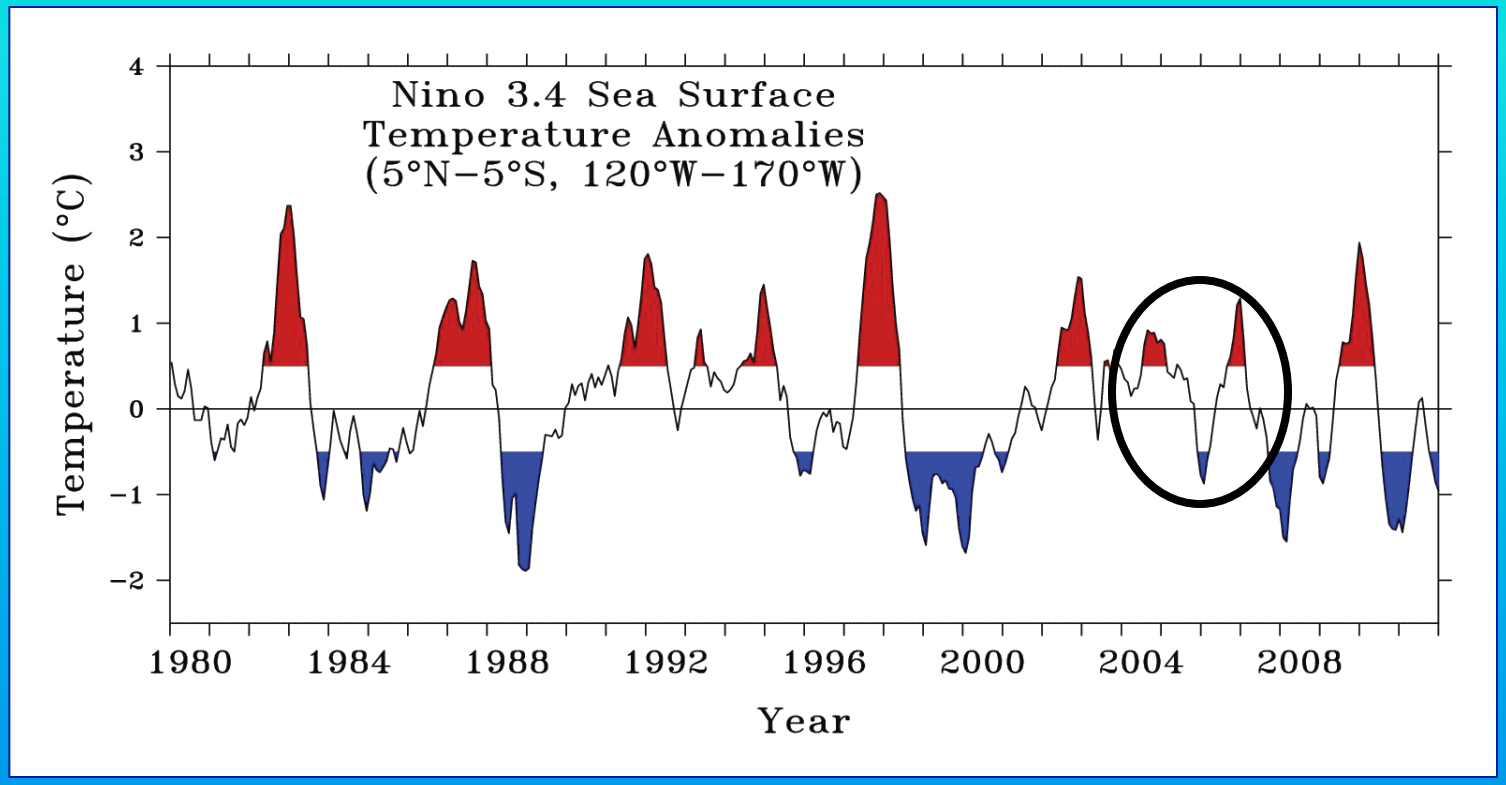
The low predictability of the past decade masked a gradual improvement of ENSO predictions, with skill of dynamical models now exceeding that of statistical models.

Barnston et al, Bull. Am. Meteor. Soc., May 2012

Dynamical models, assimilation systems and data availability have improved, but ENSO forecast skill has not

Weaker amplitude ENSO cycle leads to lower predictability

Recent Decrease in ENSO Forecast Skill (especially at longer lead times)



"For the tropical eastern Pacific… <u>the forecast skill for 2005-08 at lead times longer than 2 months is less</u> than the average for 1981-2004 in the NOAA Coupled Forecast System (CFS) forecasts….due to the relatively weaker ENSO variability"

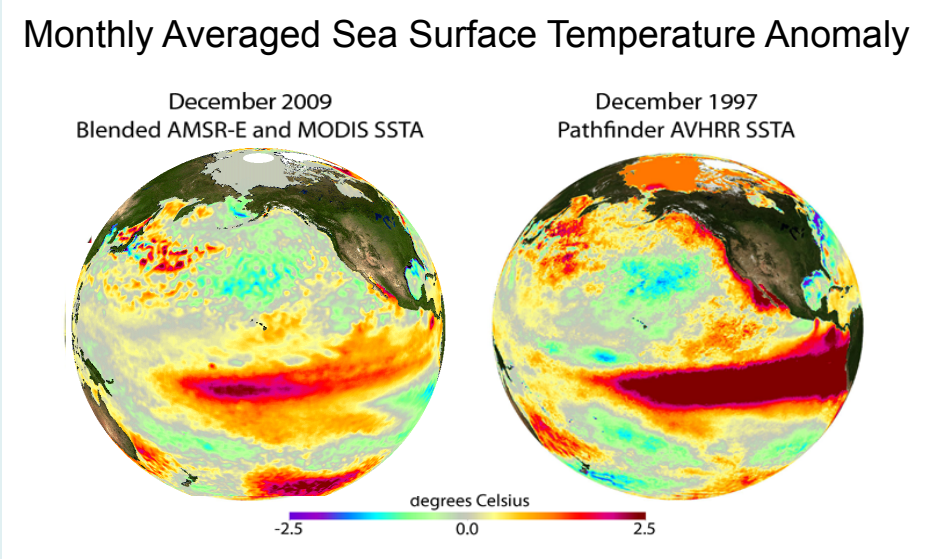
Wang et al (2010, Weather Forecasting)

A new (?) type of El Nino: maximum warming in the central-equatorial Pacific (CP)

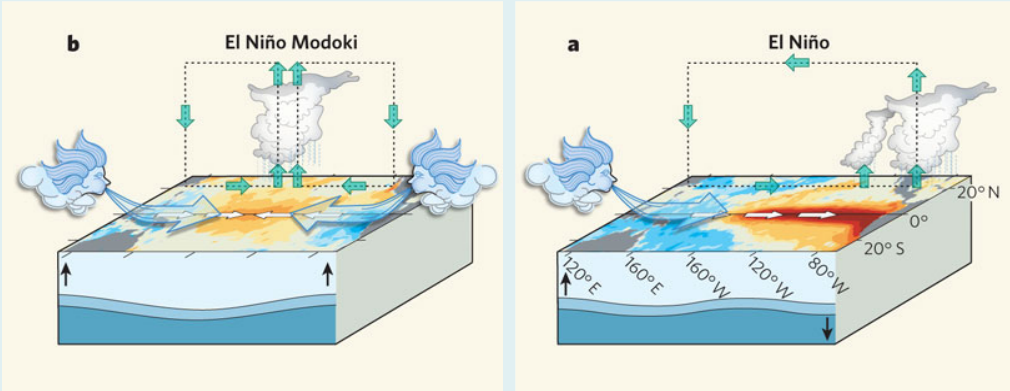
Classical El Nino: maximum warming in the eastern-equatorial Pacific (EP)

The strongest CP-El Nino in the past 3 decades

Image Credit: NASA JPL

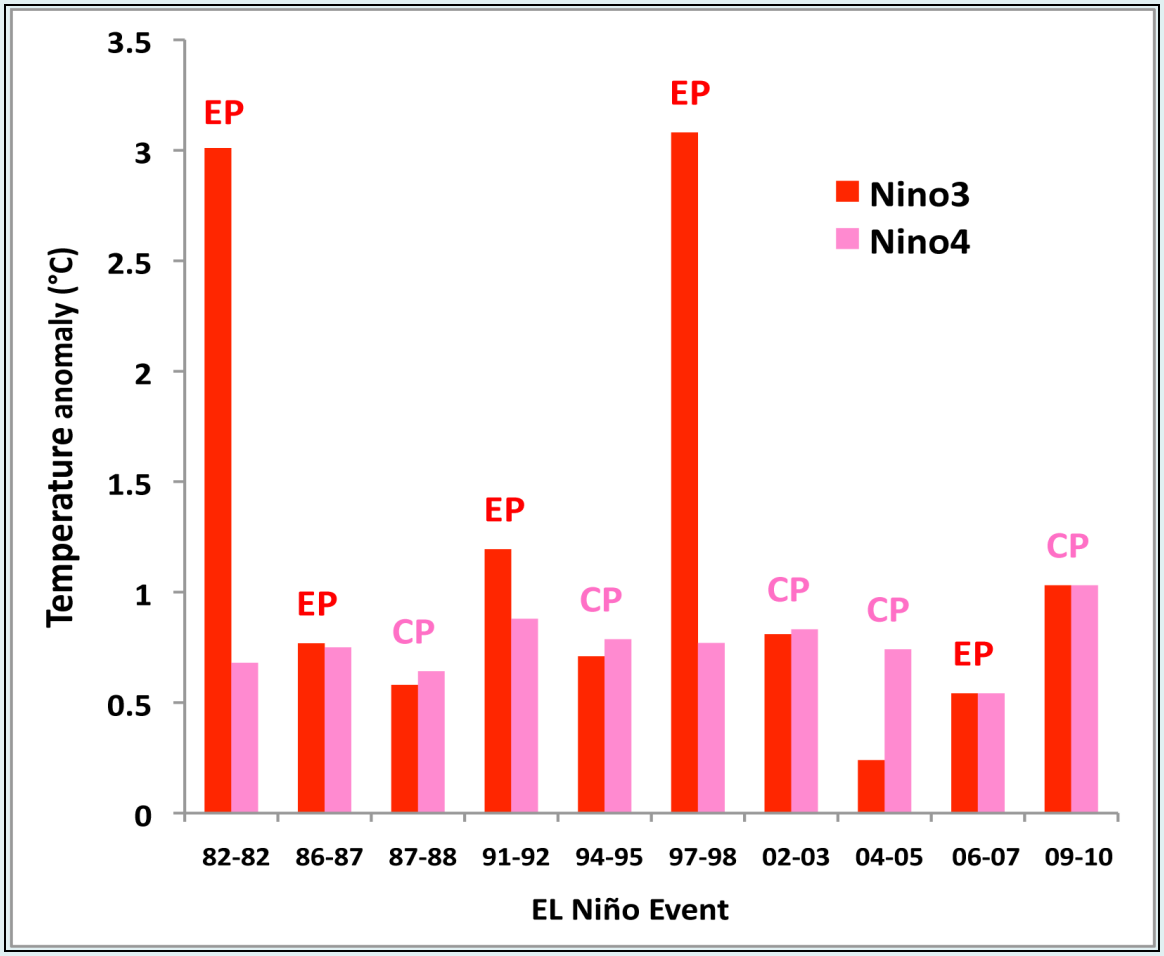


The strongest EP-El Nino in the past 3 decades



Ashok, 2009

CP vs EP El Niño
Based on DJF SST Anomalies



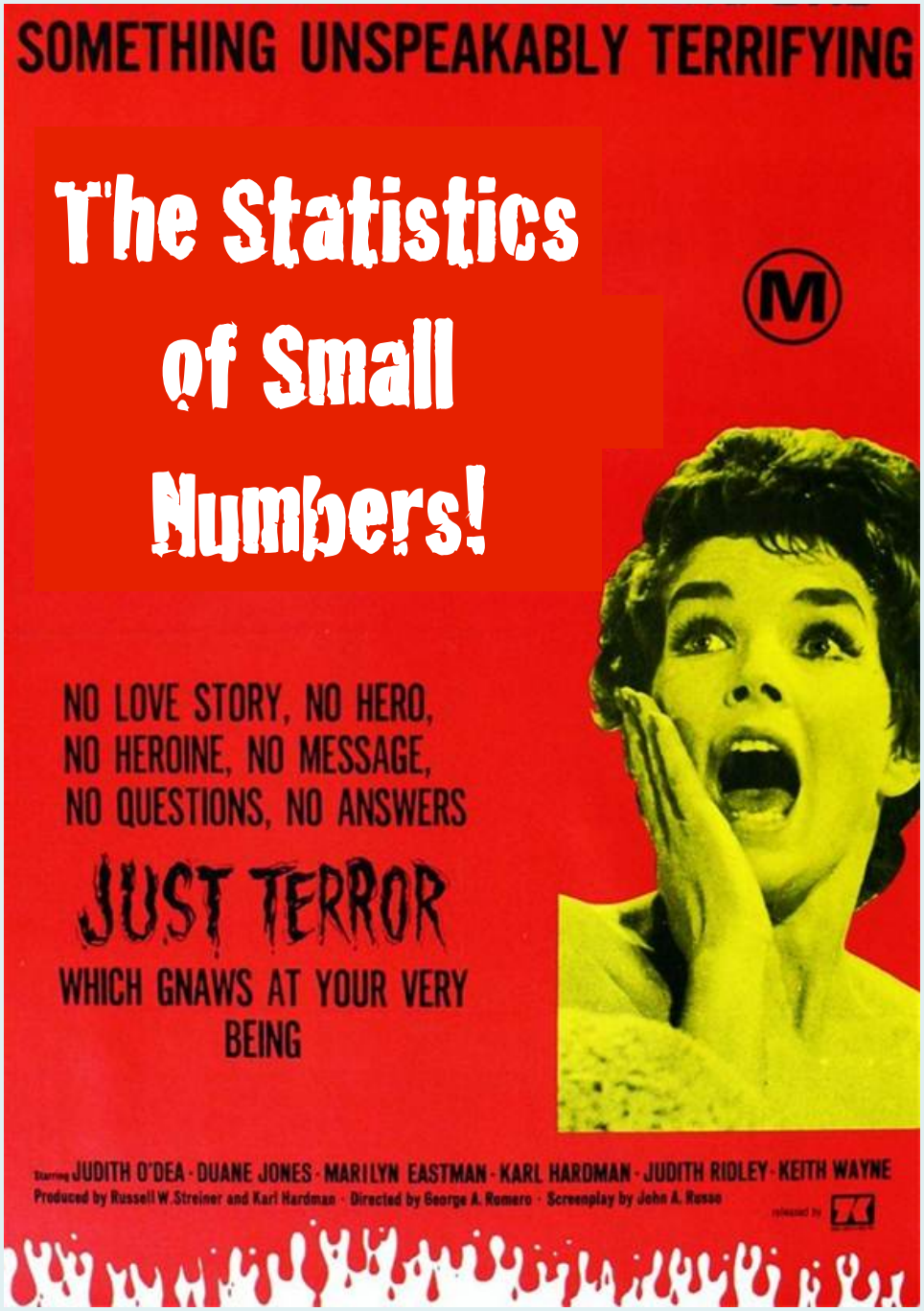
1980-1999:
4 EP+2 CP

2000-2010:
3 CP+1 EP

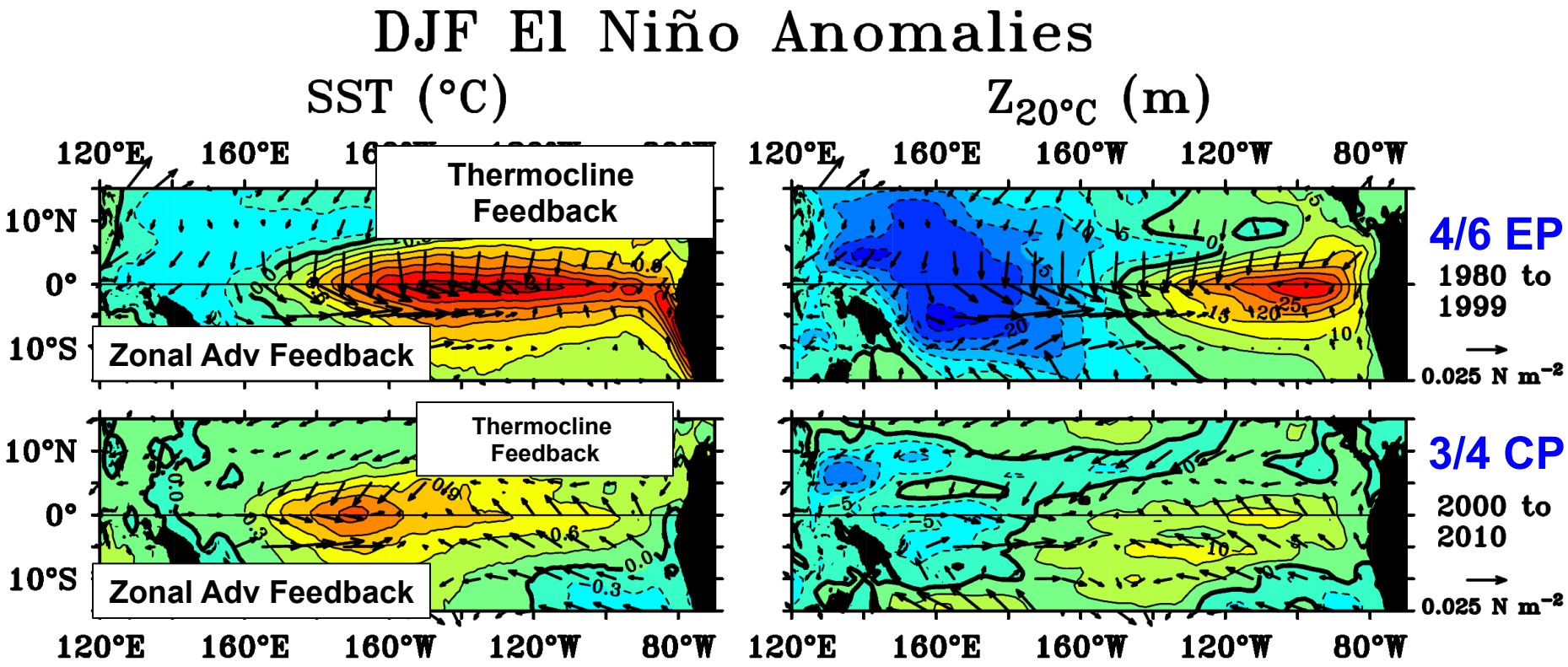
<u>CP El Niño</u>:

- Niño4 > Niño3 by 0.2°C in DJF (Yeh et al, 2009)
- Niño4 > 0.4 x Niño3 if Nino3 > 0 in DJF (Ren & Jin, 2011)

The Statistics of Small Numbers!



EP vs CP El Niños

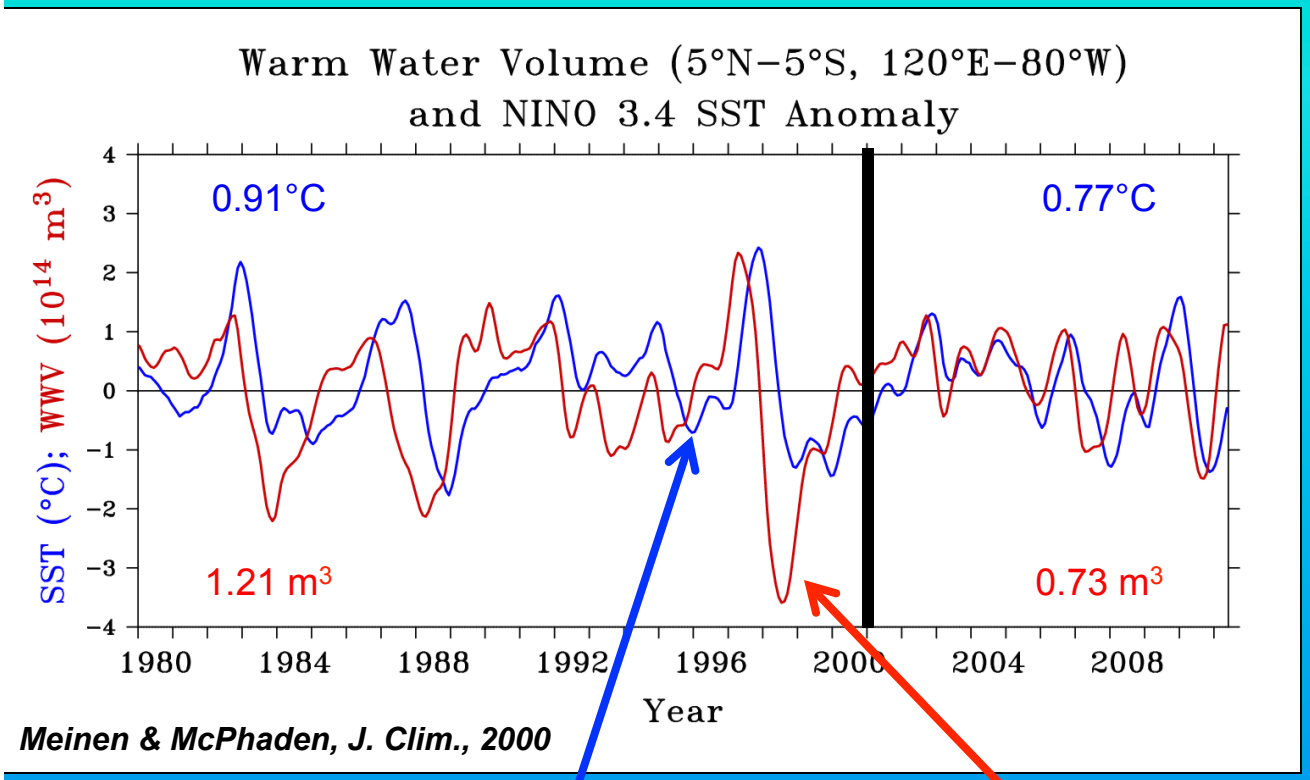


ERSST, ECMWF winds, BMRC 20°C

McPhaden, Lee & Mclurg, 2011

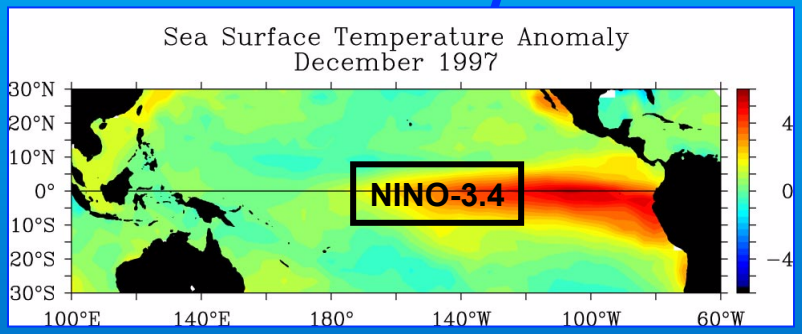
Upper Ocean Heat Content as a Predictor

Based on Recharge Oscillator Theory (Jin, 1997)

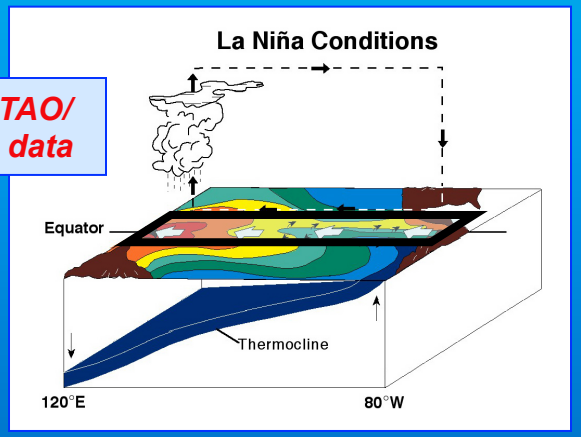


Meinen & McPhaden, J. Clim., 2000

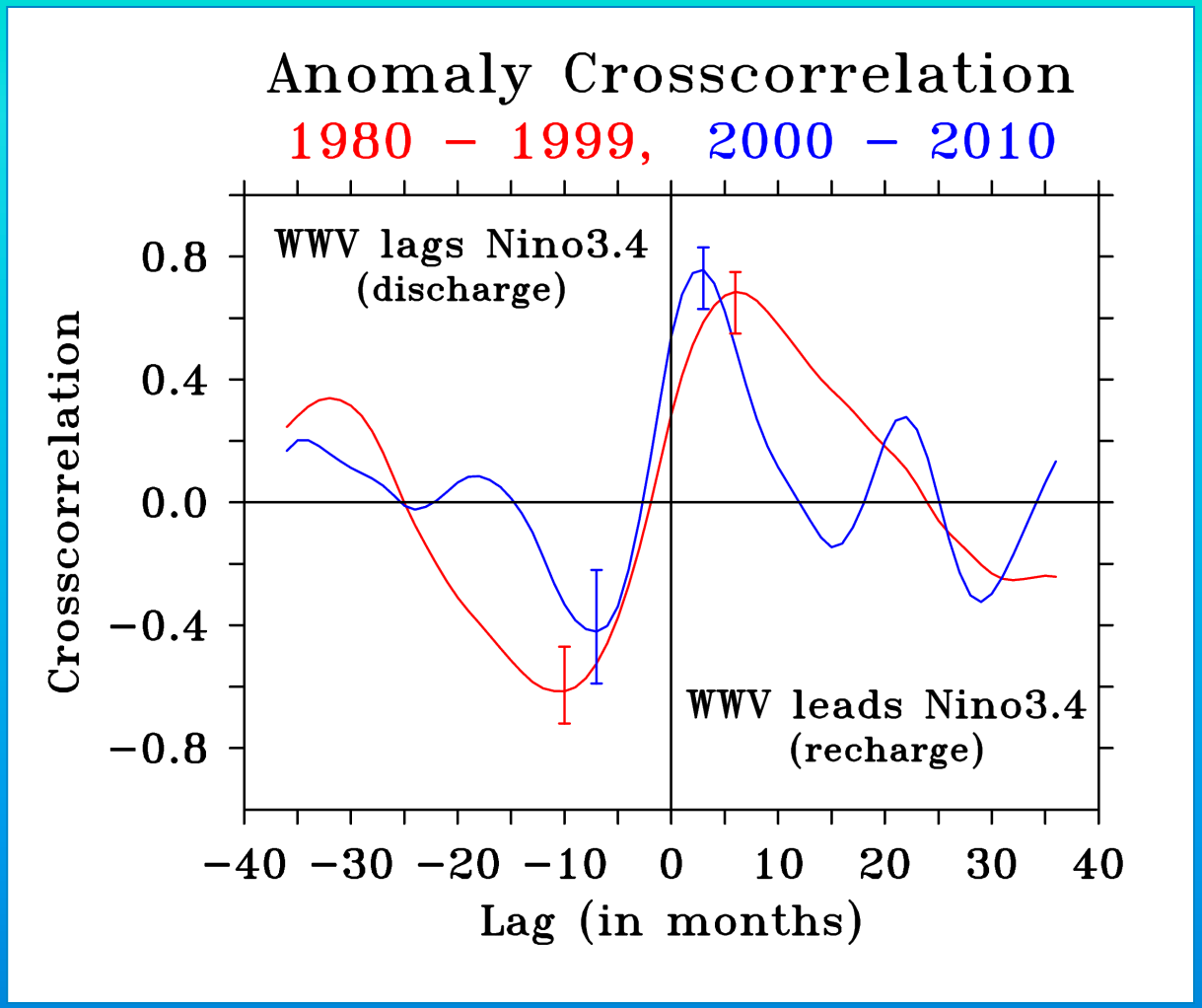
- **Build up of excess heat content along equator is a necessary precondition for El Niño to occur.**
- **El Niño purges excess heat to higher latitudes, which terminates the event.**
- **The time between El Niños is determined by the time to recharge.**



Heat content based on TAO/ TRITON, XBT, and Argo data



WWV and Nino3.4 Lag Correlation



Peak WWV lead has decreased from ~2-3 seasons in 1980-99 to only ~1 season during 2000-2010

Bjerknes (BJ) Index

- BJ Index defined by Jin et al. (2006) as a measure for the stability of the coupled ENSO mode
- Based on recharge oscillator theory for ENSO
- Evaluate using SODA 2.0.2-4 ocean reanalysis separately for 1980-1999 and 2000-2007

with Joke Luebbecke

Bjerknes Stability Index

Growth Rate for Coupled ENSO Anomalies

$$2I_{BJ} = -\left(\frac{\langle \bar{u} \rangle_E}{L_x} + \frac{\langle -2y\bar{v} \rangle_E}{L_y^2} + \frac{\langle \bar{w} \rangle_E}{H_m}\right) - \alpha + \mu_a \beta_u \langle -\frac{\delta \bar{T}}{\delta x} \rangle_E + \mu_a \beta_w \langle -\frac{\delta \bar{T}}{\delta z} \rangle_E + \mu_a \beta_h \langle \frac{H(\bar{w})\bar{w}}{H_m} a_h \rangle_E$$

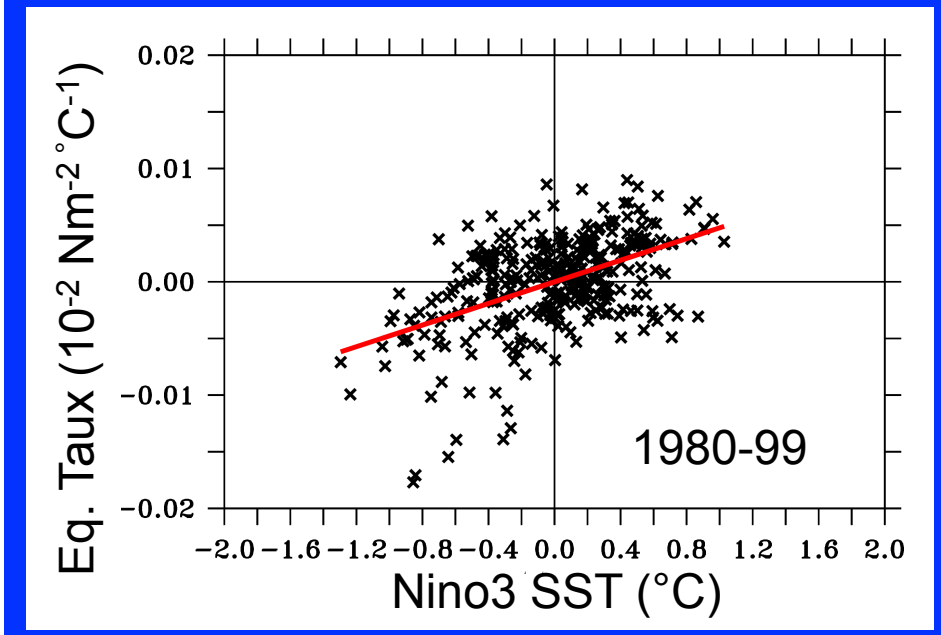
(1) Dynamical damping
(2) Thermal damping
} Negative Feedbacks

(3) Zonal advective feedback
(4) Ekman feedback
(5) **<u>Thermocline feedback</u>**
} Positive Feedbacks

BJ Index: Positive feedbacks

$$+\mu_a\beta_u\langle-\frac{\delta\bar{T}}{\delta x}\rangle_E + \mu_a\beta_w\langle-\frac{\delta\bar{T}}{\delta z}\rangle_E + \mu_a\beta_h\langle\frac{H(\bar{w})\bar{w}}{H_m}a_h\rangle_E$$

$$[\tau_x] = \mu_a\langle T\rangle_E$$



μ_a : Wind response to SST forcing estimated from linear regression between equatorial zonal wind stress anomalies and Nino3 SSTA

$\mu_a = 0.63 \times 10^{-2}$ Nm^{-2} °C^{-1} (1980-99)

$\mu_a = 0.33 \times 10^{-2}$ Nm^{-2} °C^{-1} (2000-07)

BJ Index: Thermocline feedback

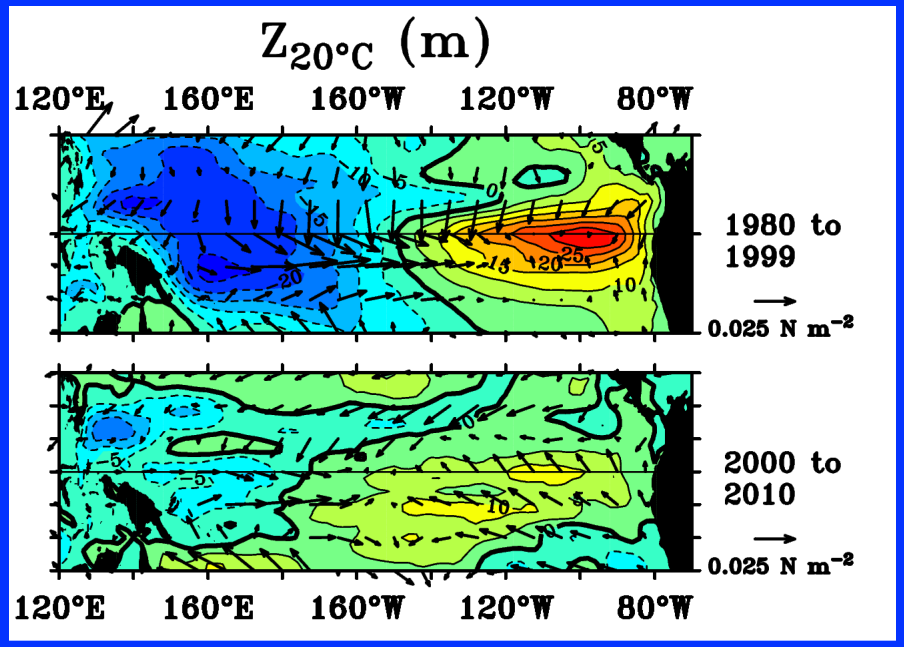
a_h effect of thermocline depth changes on subsurface temperature (no change between 1980-99 and 2000-07)

$$\mu_a \beta_h \langle \frac{H(\bar{w})\bar{w}}{H_m} a_h \rangle_E$$

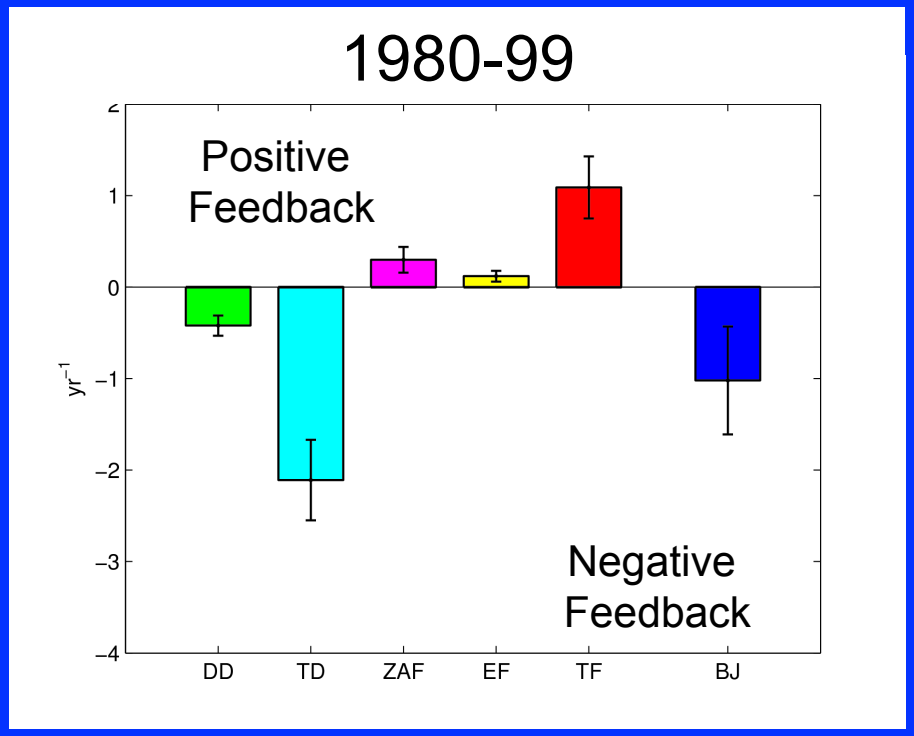
β_h thermocline slope response to wind forcing

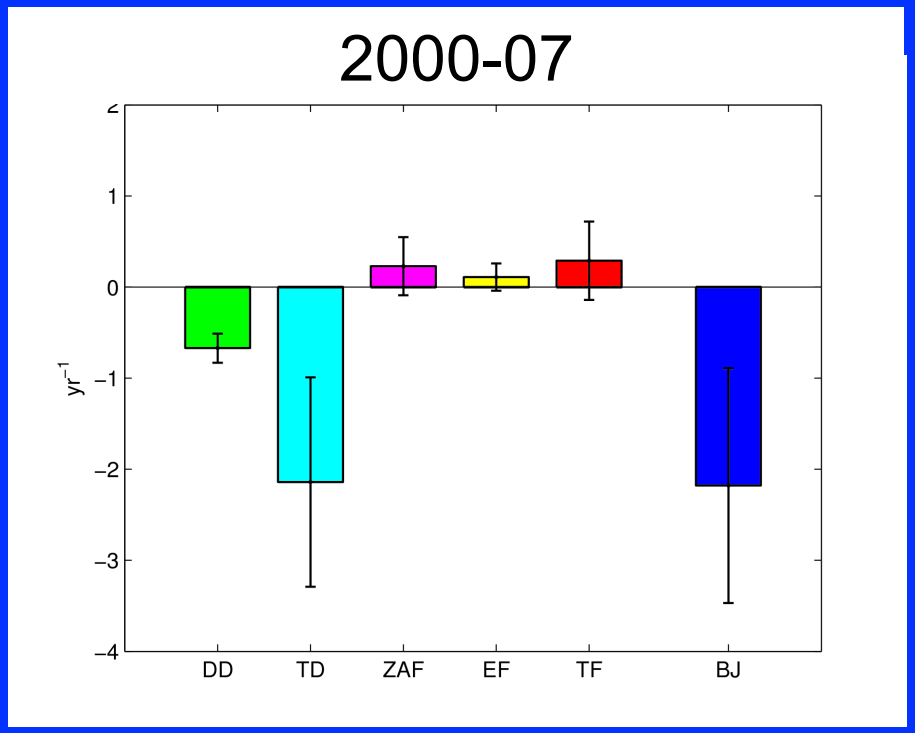
β_h = 24 m per 10^{-2} N m^{-2} (1980-99)

β_h = 12 m per 10^{-2} N m^{-2} (2000-07)



BJ Index Comparsion





Biggest change is in thermocline feedback:
4 x weaker in 2000-07; ENSO more damped

Summary

- Central Pacific (CP) El Niños have occurred more frequently in recent decades and dominated 2000-2010 at a time when ENSO forecast skill decreased;

- CP El Niños during 2000-2010 occurred quasi-biennially and were associated with weaker cold tongue SST anomalies, weaker upper ocean heat content variations, and weaker thermocline depth variations compared to 1980-1999.

- Upper ocean heat content less effective as a predictor at 2-3 season leads during 2000-2010, consistent with reduced ENSO forecast skill at long lead times.

- BJ Index suggests thermocline feedbacks 4 times weaker in the first decade of the 21st century and that ENSO is more damped compared to last two decades of the 20th century, consistent with weaker, less predictable El Niños.