A 21st Century Shift in ENSO Properties

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Recent Decrease in ENSO Forecast Skill

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

Weaker amplitude ENSO cycle leads to lower predictability.

**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.

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

“For the tropical eastern Pacific… the forecast skill for 2005-08 at lead times longer than 2 months is less 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

The strongest EP-El Nino in the past 3 decades

Image Credit: NASA JPL

Ashok, 2009
CP vs EP El Niño
Based on DJF SST Anomalies

1980-1999:
4 EP+2 CP

2000-2010:
3 CP+1 EP

CP El Niño:
- 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!

NO LOVE STORY, NO HERO, NO HEROINE, NO MESSAGE, NO QUESTIONS, NO ANSWERS

JUST TERROR WHICH GNAWS AT YOUR VERY BEING

Produced by Russell W. Streiner and Karl Hardman - Directed by George A. Romero - Screenplay by John A. Romano
**EP vs CP El Niños**

**DJF El Niño Anomalies**

- **SST (°C)**
- **Z$_{20°C}$ (m)**

**ERSST, ECMWF winds, BMRC 20°C**

*McPhaden, Lee & McIurg, 2011*
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.

Upper Ocean Heat Content as a Predictor Based on Recharge Oscillator Theory (Jin, 1997)

- Warm Water Volume (5°N–5°S, 120°E–80°W)
- NINO 3.4 SST Anomaly


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

La Niña Conditions

NINO-3.4
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

with Joke Luebbecke
Bjerknes Stability Index
Growth Rate for Coupled ENSO Anomalies

\[ 2I_{BJ} = -\left( \frac{\langle \bar{u} \rangle_E}{L_x} + \frac{\langle -2y\bar{v} \rangle_E}{L^2_u} + \frac{\langle \bar{w} \rangle_E}{H_m} \right) - \alpha \]

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

(1) Dynamical damping
(2) Thermal damping
(3) Zonal advective feedback
(4) Ekman feedback
(5) **Thermocline feedback**

\{ \text{Negative Feedbacks} \}
\{ \text{Positive Feedbacks} \}
**BJ Index: Positive feedbacks**

\[ \tau_{xx} = \mu_a \left\langle T \right\rangle E \]

\[ + \mu_a \beta_a \left\langle -\frac{\delta T}{\delta x} \right\rangle E + \mu_a \beta_w \left\langle -\frac{\delta T}{\delta z} \right\rangle E + \mu_a \beta_h \left( \frac{H(\bar{w}) \bar{w}}{H_m} \right) a_h E \]

\[ \mu_a : \text{Wind response to SST forcing estimated from linear regression between equatorial zonal wind stress anomalies and Nino3 SSTA} \]

\[ \mu_a = 0.63 \times 10^{-2} \text{ Nm}^{-2} \text{ °C}^{-1} \quad (1980-99) \]

\[ \mu_a = 0.33 \times 10^{-2} \text{ Nm}^{-2} \text{ °C}^{-1} \quad (2000-07) \]
BJ Index: Thermocline feedback

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

$\beta_h$ thermocline slope response to wind forcing

$\beta_h = 24 \text{ m per } 10^{-2} \text{ N m}^{-2}$ (1980-99)

$\beta_h = 12 \text{ m per } 10^{-2} \text{ N m}^{-2}$ (2000-07)
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.