El Niño-Southern Oscillation - What is the outlook for ENSO?

PRESENT | PAST

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Climate variability in the tropical Pacific is dominated by the El Niño/Southern Oscillation (ENSO), which has global impacts, most notably in drought-prone regions such as the southwestern USA and Australia. How will the tropical Pacific fluctuate in the coming decades to century? A first-order answer from both paleoclimate records and climate models is that the Pacific will continue to be characterized by large seasonal and interannual variability during the coming century. Seasonally resolved tropical-Pacific paleoclimate records from periods in the Earth's history that were both warmer and colder than today point to interannual variability (Watanabe et al. 2011; Scroxton et al. 2011; Koutavas and Joanidis 2009; Tudhope et al. 2001). And models too have thus far not been able to rid the tropical Pacific of ENSO variability by either warming (Huber and Caballero 2003; Galeotti et al 2010; von der Heydt et al. 2011) or cooling the climate (Zheng et al. 2008).

This result may seem somewhat surprising given our textbook understanding of ENSO. One might conclude that the positive Bjerknes feedback between the winds, surface temperature gradient and thermocline on the equator would cause the Pacific to run away to one state or another, resulting in what is referred to in the literature as a "permanent El Niño" state. However, a recent analysis by DiNezio et al. (unpublished data) of model simulations of the climate response to doubled CO_2 shows that this does not happen because the winds and thermocline actually have opposing effects on ENSO. A warming climate would, on its own, weaken the Walker circulation and hence reduce ENSO variability. However, weaker trade winds would result in a less tilted but *shallower* thermocline, which would strengthen ENSO variability. These competing effects probably explain some changes in the past too. So it seems that ENSO is here to stay.

There are of course a number of other higher-order and important questions about the tropical Pacific that are still wide open. For example, can ENSO have long periods of quiescence? What causes decadal and multidecadal variability in the tropical Pacific? Are these behaviors of the tropical Pacific predictable on seasonal, interannual and decadal timescales? Are they influenced by greenhouse-gas forcing?

Limitations of the instrumental record do not allow us to fully address the question of decadal variability in the Pacific (Fig. 1). Annually resolved paleoclimate proxies are key to filling in the low-frequency part of the spectrum. Some paleoclimate proxies suggested that the Pacific climate has natural variability on timescales of centuries and even millenia (T. Ault, pers. comm.). We do not yet know of an appropriate mechanism, though feedbacks involving low-level clouds, among others, have been invoked (Clement et al. 2011). Current climate models, being deficient in their representation of low-level clouds (Clement et al. 2009), might not simulate Pacific decadal variability properly. Detection and attribution of anthropogenic change in the tropical Pacific may thus remain an extremely challenging problem for the foreseeable future.

As to predictability, one of the great achievements in the late 20th century was the development of a monitoring and prediction system that can predict ENSO a season in advance. However, despite improving modeling capabilities and increased observations over the past two decades, our predictive skill has not improved significantly. Further, there is now an ongoing international effort coordinated through the Coupled Model Intercomparison Project 5 (CMIP5) to attempt to make decadal or so-called "near-term" climate predictions. But our confidence in these prediction systems is limited by our ability to put them to the test of hindcasting past climate fluctuations. Here again, the instrumental record is simply too short, and the only way around this is to extend the record further back in time with paleoclimate data.

Of course, paleoclimate data are always going to be sparse, but it has been shown that predictions can be made with a relatively few set of the modes (e.g. Kirtman and Schopf 1998). It is encouraging that only a few records from key places in the Pacific over the last several centuries can provide a means to answering the questions about how the tropical Pacific climate will vary during the coming century.

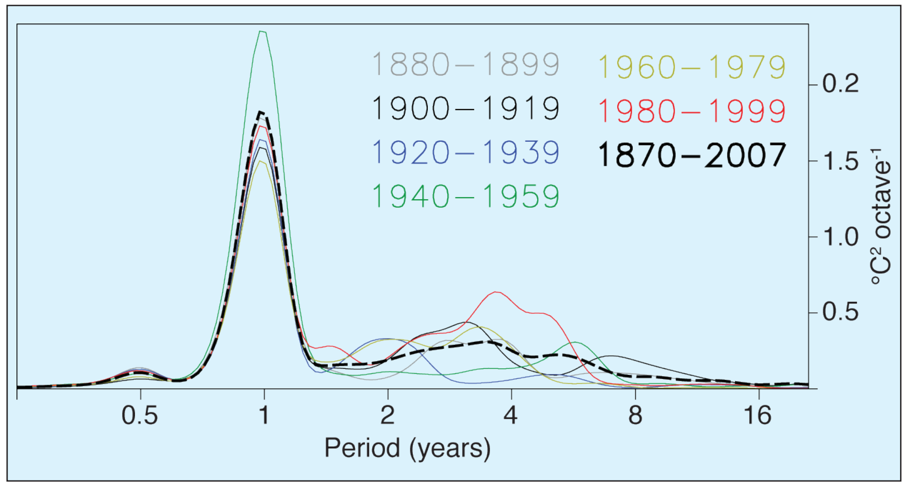

Figure 1: Power spectra of NINO3 SSTs from the ERSST.v3 historical reconstruction (Smith et al 2008), as a function of the period in octaves of the annual cycle. The area to the left of each curve represents the spectral power within a frequency band. Figure after Wittenberg (2009).

Selected references

Full reference list online under:
http://www.pages-igbp.org/products/newsletters/ref2012_1.pdf

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Despite considerable progress in understanding the El Niño-Southern Oscillation (ENSO) over recent decades, several mysteries remain:

- How irregular is ENSO?
- What causes its decadal modulation?
- How does radiative forcing (in particular anthropogenic forcing) influence this system?

The paleoclimate record can shed light onto some of these questions. As recounted by A. Clement (this issue) there is now strong evidence that ENSO has been active since the Pliocene warm epoch and through glacial cycles, suggesting that the phenomenon is rather impervious to external influences. The details are far thornier, for even a small change in the character of ENSO or its teleconnections can have far-reaching societal impacts (e.g. Hsiang et al. 2011). Since very few high-resolution archives take ENSO's pulse from the heart of the tropical Pacific, one must rely on archives from remote sites, which are vulnerable to interferences from local effects or changing teleconnections.

High-resolution sedimentary and coral records have suggested a rise in ENSO activity since the mid-Holocene (Moy et al. 2002; Tudhope et al. 2001). Emerging evidence from longer coral records from this period suggests that this situation is more nuanced (Cobb, McGregor and Tudhope, pers. comm.). This is consistent with a numerical experiment (Wittenberg 2009), which underscores that long observational windows are needed to characterize ENSO's non-stationary behavior.

The wealth of detailed paleoclimate archives spanning the past millennium provides a unique opportunity to test this idea. Li et al. (2011) [L11] took advantage of interannual signals embedded in drought-sensitive tree rings from North America to suggest a link to various indicators of its low-frequency behavior. A recent multiproxy study (Mann et al. 2009 [M09]) argued that the Little Ice Age (~1500-1800 AD) saw enhanced ENSO variability and a warmer eastern equatorial Pacific compared to the "Medieval Climate Anomaly" (~900-1300 AD), consistent with previous studies (Cobb et al. 2003; Mann et al. 2005; Graham et al. 2010). Yet a multiproxy reconstruction based on the latest observations (Emile-Geay et al. 2012 [EG12]) suggests a more granular picture, with no clear dichotomy between the two periods (Fig. 1). This reconstruction and those of Wilson et al. (2010) [W10] and Braganza et al. (2009) [B09] contain considerable decadal and centennial variability - an important benchmark for climate models to reproduce. Nonetheless, the divergence between these estimates exposes considerable uncertainties, due in part to proxy errors and to the short calibration period that the instrumental record condemns us to. Adding to this uncertainty is the divergence between instrumental products over the tropical Pacific (e.g. Deser et al. 2010), which propagates beyond instrumental times [EG12].

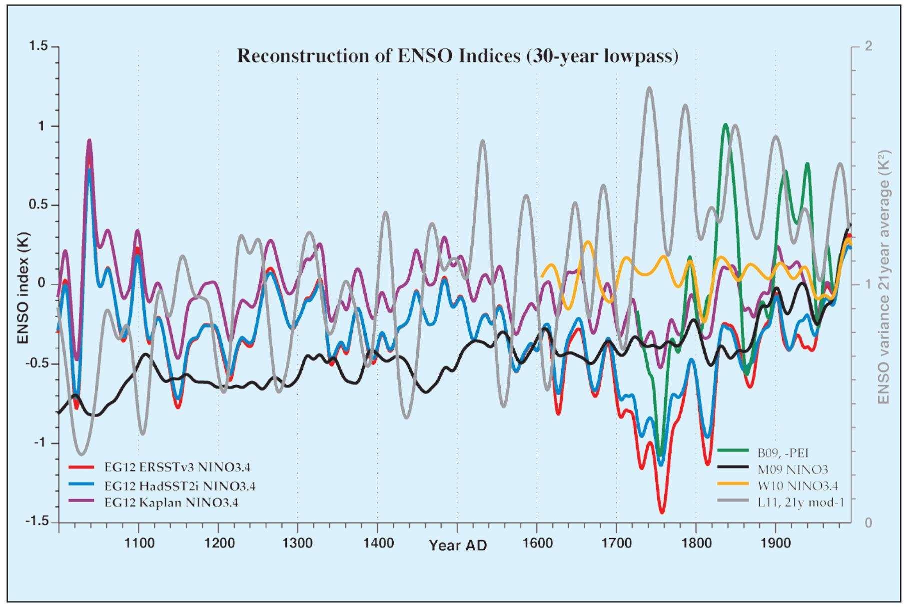

*Figure 1: Comparison of recent ENSO reconstructions. (**left axis**) NINO3.4 from, W10 and EG12, NINO3 from M09, Proxy ENSO index from B09 (inverted scale), (**right axis**) 21-year running ENSO variance from L11 All series have been 30-year lowpass-filtered. See text for details.*

ENSO's response to external forcing over the last millennium is thus poorly constrained. Despite original suggestions of an El Niño-like response to explosive volcanism (Adams et al. 2003), the latest data from Palmyra Island do not appear to support this notion (Cobb 2011). Difficulties in reconstructing low-frequency variability further beset a tie to solar forcing. To establish a clear link between natural radiative forcing and the low-frequency modulation of ENSO, one would need more long and accurately dated tropical Pacific records than are presently available.

Were such a link eventually to be elucidated by new proxy observations, there is no guarantee that ENSO will react similarly to greenhouse forcing as it did to a changing Sun: greenhouse forcing has a very different vertical structure from solar forcing; it is differently impacted by clouds and aerosols, and acts 24 hours a day, unlike the Sun. These differences limit the extent to which natural forcings can serve as analogs for anthropogenic ones. Therefore, one should not view ENSO's past as a set of prophecies, but, rather, as a rich laboratory in which to test the models used to predict its future. The PAGES-sponsored PMIP3 data/model intercomparison effort is expected to bring much insight into this problem.

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