

Statistical prediction of ENSO (Nino 3) using sub-surface temperature data.

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Abstract

Statistical schemes for predicting the evolution of the El Niño - Southern Oscillation (ENSO) tend to show some skill out to 9 to 12 months from late in the Southern autumn or early winter, but only limited skill for a few months from late summer or early autumn through the so-called "predictability barrier". In contrast, coupled ocean - atmosphere models exhibit some skill through this period. These models are either initialised with, or develop, significant equatorial sub - surface temperature anomalies during the early phases of El Niño (or La Niña) development. Inclusion of sub - surface temperature data can lead to similar improvement of skill through the autumn period in a simple statistical model.

Data and EOF analysis.

The data used in this paper is the BMRC / NMOC operational optimal analysis described by Smith (1995). The subsurface temperatures at 14 levels from the surface to 400 metres are interpolated onto a 1 degree latitude by 2 degree longitude grid covering most of the Pacific ocean. The temporal resolution is one month, and the data set covers 24 complete years from 1980 to 2003, although the data coverage is relatively sparse in the 1980s as the TOGA array was being implemented.

The significant subsurface temperature signal is extracted from this data set using an EOF analysis of a subset of the full data set consisting of the longitude - depth cross sections along the equator. The first two EOFs, shown in Figure 1, account for over 80% of the variance in these cross sections. Both patterns have maximum loadings along the thermocline; EOF1 at a depth of 50 to 100 metres in the eastern Pacific, and EOF2 at about 150 metres in the central and western Pacific. EOF1 represents the mature phase of El Niño events, and its time series (PC1) is strongly correlated with the usual ENSO indices such as Niño3.

Both the spatial patterns and the temporal coefficients appear to be in quadrature, with the maximum amplitude in PC2 leading PC1 (and Niño3) by about 9 to 12 months, corresponding to a 3 to 4 year cycle. Despite the disparity in explained variance (57% vs 24%) of the first two EOFs, it is suggested that together they describe the evolution of ENSO in the subsurface temperatures. This interpretation is supported by a phase plot of PC1 against PC2 which shows clear cyclic or episodic behaviour for at least $\frac{3}{4}$ of a cycle during each of the six ENSO events occurring during the 1980-2003 period.

Regression Forecasts

The simplest possible statistical forecast, and one often used as the benchmark against which more complex schemes are evaluated is that of persistence. As shown in Figure 2, the accuracy of persistence, as measured by the lag correlation of Niño3 drops below 0.6 after 5 months, and to zero at 9 to 10 months. Since PC2 is in quadrature with PC1 and Niño3 (as shown by the dotted curve in Figure 2), a simple improvement on persistence is a series of multiple regression models with Niño3 itself and PC2 at various lags as predictors. The accuracy of this scheme, measured by the correlation between observed and forecast values is shown as the solid curve in Figure 2. These correlations are similar to those achieved by complex coupled ocean - atmosphere models.

The correlations shown in Figure 2 are calculated across the full annual cycle. When stratified by starting month, persistence shows a marked seasonal cycle. Beginning in June, the lag correlation is still 0.6 the following March, *ie* nine months later. In contrast, beginning in March the lag correlation is zero after just six months (*ie* the following September). Although this seasonal variation is still present in the regression forecasts, its amplitude (*ie* the difference between March and June start dates) is much reduced, and overall correlations are much stronger throughout the year.

Examination of individual forecasts during the 1997/98 El Niño event suggests that the regression forecast “predicts” the onset of the event as early as December 1996, but severely underestimates its magnitude. On the other hand the demise of the event is extremely well predicted from its peak around December 1997. This behaviour is probably common to most events, based on the phase space plot of PC1 and PC2 in which the amplitude of both components appears to increase almost simultaneously prior to El Niño onset. The decay of events, and the intensity of the following opposite La Niña phase appears to be more predictable.

Conclusions

This study has shown that statistical models incorporating equatorial subsurface temperatures are capable of skill comparable to that attained by coupled ocean – atmosphere models. However, a number of caveats need to be applied to the results presented here. The estimates of “skill” (actually forecast accuracy) are based on the development data set and therefore may be artificially inflated compared with properly cross-validated forecasts. The length of the data set (24 years, but including only six ENSO events) is still very short for robust statistical forecasts. Recently there have been suggestions that the nature of ENSO has changed since the mid 1970s (eg Fedorov and Philander, 2000) in response to large scale regime changes and/or global warming. The six events covered by this data set all occur in this new or current climate regime, and the different dynamics which governed ENSO evolution in earlier periods may reappear in the future. Finally these results are based on prediction of the Niño3 index. More useful forecasts of Australian seasonal rainfall and temperature anomalies, based on the predicted Niño3 index, or produced directly from the subsurface temperatures, will most likely show lower levels of skill.

References

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 Smith, N.R., 1995: The BMRC ocean thermal analysis system. *Aust. Met. Mag.*, **44**, 93-110.

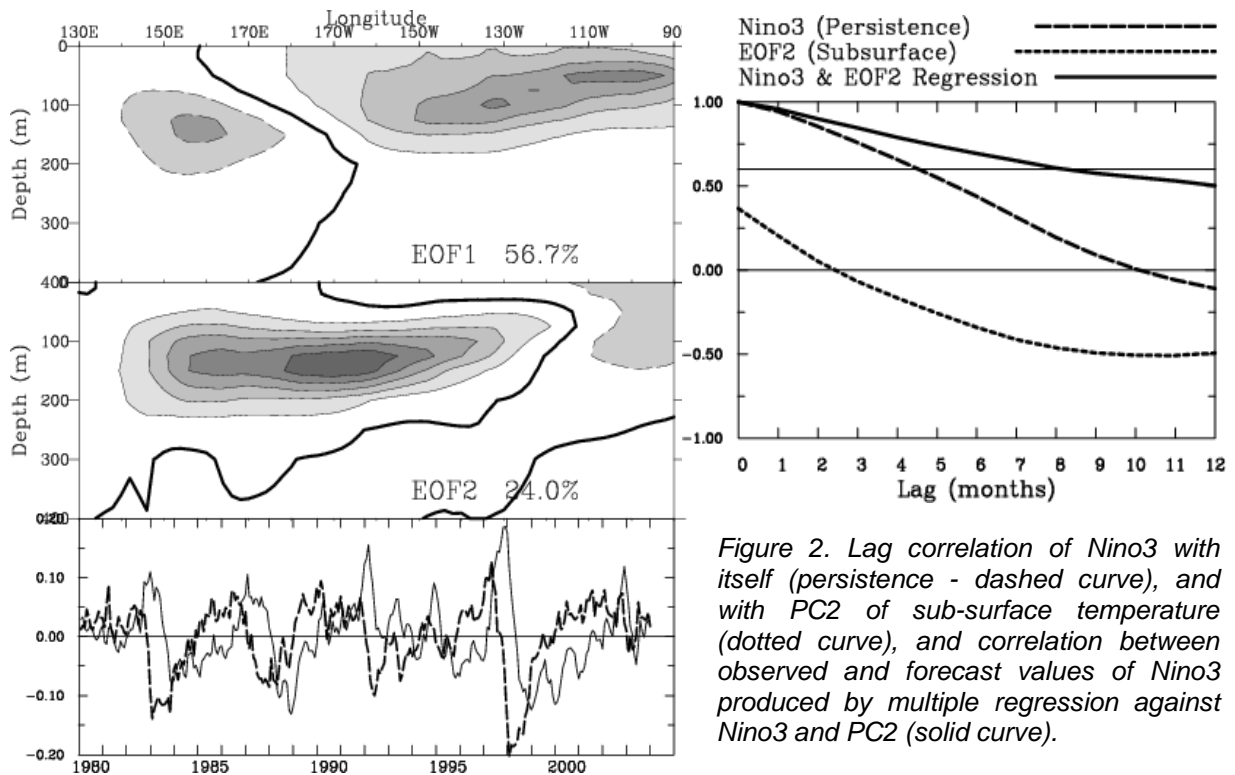


Figure 1. First two EOFs of the equatorial longitude – depth cross section of sub-surface temperature anomalies (zero contour heavy and negative contours dashed), and corresponding PC amplitudes (lower panel), PC1 thin solid curve and PC2 heavy dashed curve.