

NOTES AND CORRESPONDENCE

Comments on “The Connection between the Boreal Spring Southern Oscillation Persistence Barrier and Biennial Variability”

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Clarke and Van Gorder (1999, hereafter CV99) state that the boreal spring persistence barrier in the Southern Oscillation index (SOI) is due to a purely biennial oscillation $B(t)$. The lack of a biennial peak in the SOI spectrum is explained as result of the modulation of $B(t)$ on interannual and decadal timescales.

The purpose of this comment is to note that the biennial oscillation is but one of many equally plausible models that can explain the persistence barrier in the SOI. The persistence barrier is found in numerous El Niño–Southern Oscillation (ENSO) indexes (Walker and Bliss 1932; Wright 1985; Webster and Yang 1992). Webster and Yang (1992) suggest that the barrier occurs because the Walker circulation is weak during the boreal spring and is therefore more easily influenced by random variability. The barrier is also found in the forecast skill of Pacific basin coupled ocean–atmosphere models (Barnston et al. 1994). In models the barrier is attributed to the low ENSO variance during spring, which fosters the growth of initialization errors and “weather” noise (Blumenthal 1991; Moore and Kleeman 1996).

Torrence and Webster (1998, hereafter TW98), of which CV99 seem to be unaware, found that the persistence barrier is a result of the phase locking of ENSO to the annual cycle, which tends to cause transitions in ENSO indices to occur during boreal spring. It is the spring transition through zero anomaly that is the root cause of the persistence barrier. Any model that contains

such a phase-locked transition will exhibit a dropoff in persistence during the spring season.

The persistence barrier for the SOI is shown in Fig. 1 (cf. TW98, Fig. 2b, and CV99, Fig. 1). The SOI index is the same as that used by CV99 and is given by the standardized anomalous Tahiti sea level pressure (SLP) minus the standardized anomalous Darwin SLP (available monthly 1876–1997; courtesy R. Allan, CSIRO). The fixed-phase persistence, $P_m(k)$, is defined as the correlation of the values for one month m (all years) with a future month $m + k$ [the persistence is denoted by $r(i, i + \tau)$ in CV99]. For most months the SOI persistence remains significantly high (the 1% significance level is 0.21 assuming 119 degrees of freedom), except for April–May, when $P_m(k)$ drops off precipitously.

To examine the connection between the spring transition and the persistence barrier, one can consider the two models of TW98: (i) An autoregressive (AR) model with an annual cycle of AR coefficients, and (ii) an “ENSO event” model with phase-locked warm and cold events. As shown below, each of these models explains a significant fraction of the SOI variance and both contain a persistence barrier.

Autoregressive model. The AR model is given by

$$X_t = \alpha_m X_{t-1} + R_t, \quad m = 1, \dots, 12, \quad (1)$$

where X_t is the modeled SOI at time index t (in months), α_m is the AR coefficient for month m , and R_t is a residual noise. Following TW98 the persistence for (1) is

$$P_m(k) = \frac{\sigma_m}{\sigma_{m+k}} \prod_{j=1}^k \alpha_{m+j}, \quad (2)$$

where σ_m is the standard deviation of month m (all years). The persistence depends on the ratio of the standard deviations and the product of all AR coefficients between months m and $m + k$. The variance of each

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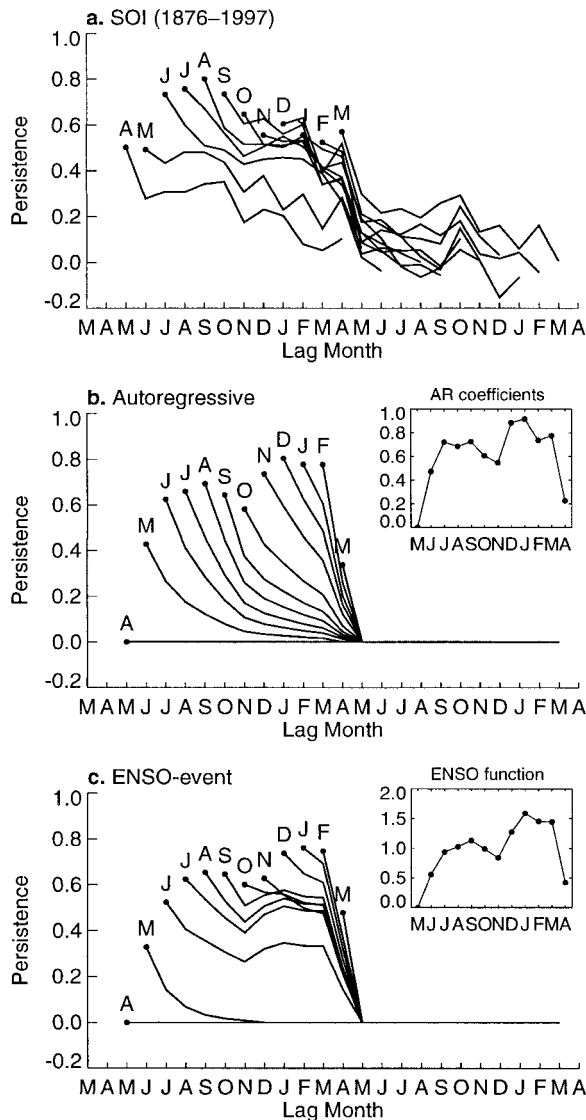


FIG. 1. (a) The persistence for the Southern Oscillation index. Each curve has been shifted to line up the starting month (letters at top) with the lagged month (x axis). (b) The persistence for the AR model (1). The inset plot shows the AR coefficients. (c) The persistence for the ENSO event model (3). The inset plot shows the values of the ENSO function.

month is given by the recursive relation, $\sigma_m^2 = \alpha_m^2 \alpha_{m-1}^2 + \sigma_R^2$, where σ_R^2 is the variance of the residual noise. To simulate the SOI persistence barrier we assume that $\alpha_5 = 0$ (i.e., there is no persistence from April to May). The noise variance is then given by the true May SOI variance, $\sigma_R^2 = \sigma_5^2$. Given the SOI monthly variances one can use the recursive relationship to determine the remaining 11 AR coefficients (see inset plot in Fig. 1b). The persistence barrier for the AR model (Fig. 1b) is very sharp, although the persistence is too small for most months. As noted in TW98, the persistence structure for the AR model comes from a somewhat arbitrary set of AR coefficients rather than from any inherent

phase locking of ENSO events. Nevertheless, the AR model correlates at 0.60 with the SOI (assuming $X_t = \alpha_m S_{t-1}$, where S_{t-1} is from the true SOI) and also contains a strong persistence barrier.

ENSO event model. The second model is similar to that of CV99 in that the SOI is given by the slowly varying modulation of a prototypical event. In this case, however, the event is just a single ENSO peak, with a zero in May and a maximum in January. The model equation is

$$Y_{mn} = f_m A_n + R_{mn}, \quad (3)$$

where Y_{mn} is the modeled SOI for month m and year n , f_m is a 12-month cycle representing the typical ENSO event, A_n is the amplitude of the ENSO event for a given year n , and R_{mn} is a residual noise. The persistence of (3) is given by

$$P_m(k) = \frac{f_m f_{m+k} \delta_{m'}}{(f_m^2 + \sigma_r^2)^{1/2} (f_{m+k}^2 + \sigma_r^2)^{1/2}}, \quad (4)$$

where $\rho(k)$ and σ_r^2 are the autocorrelation and variance of R_{mn} , respectively; and $\delta_{m'}$ is zero unless m and $m+k$ are in the same May–April year. The ENSO event is defined using the SOI variance for each month minus the May variance, $f_m = (\sigma_m^2 - \sigma_5^2)^{1/2}$, and is therefore zero in May (see inset plot in Fig. 1c). The noise is assumed to have variance $\sigma_r^2 = \sigma_5^2$ and autocorrelation $\rho(k) = \alpha^k$ where α is arbitrarily chosen to be 0.5 (the results are insensitive to this choice). The persistence for the ENSO event model (Fig. 1c) is similar to the SOI, with a slow decay during most of the year followed by a rapid spring decline. A least squares fit to the SOI for each May–April year ($A_n = C^{-1} \sum_m f_m S_{mn}$; $C = \sum_m f_m^2$) yields a time series that is correlated at 0.73 with the true SOI.

Both the autoregressive and ENSO event model capture the SOI persistence structure. The SOI correlations are lower than in CV99 (their biennial model correlated at 0.78), yet neither model contains the residual noise term. In CV99 the residual component $M(t)$ was essentially a low-pass version of the SOI. One can approximate this residual by subtracting the model-fitted SOI from the true SOI and smoothing twice with a 13-month running average. Reintroducing this smoothed residual increases the correlations with the SOI for the AR and ENSO-event models to 0.69 and 0.76, respectively. The above results suggest that all three models (AR, ENSO event, and biennial) are viable as explanations of the SOI persistence barrier.

In CV99 the biennial oscillation is unstable in the sense that it is fit to the SOI each month and can therefore vary (or even change sign) during the course of the year. This monthly modulation suggests that the biennial oscillation could be viewed as a convenient filter rather than as a robust feature of the SOI. In addition, any model that shows preferred spring transitions will inherently exhibit biennial behavior simply by chance. The biennial model can therefore be viewed as a special

case of the ENSO event model. For example, during 1986–96 the CV99 biennial component is rather weak and most of the variance is explained by the residual term, yet several El Niño events and one La Niña event occurred. The ENSO event model is better able to capture this variability.

There is little doubt that the tropical Indo–Pacific basin does indeed have a biennial component (Meehl 1997) and that this component varies on decadal time-scales (Torrence and Webster 1999). Nevertheless, by admitting the possibility of other explanations for the SOI persistence barrier, the following questions can be asked. (i) Is the biennial variability more than would be expected by chance for phase-locked events? (ii) Why do some decades show little biennial variability yet large ENSO variance? Both of these questions seem easier to answer using a phase-locked ENSO event model rather than forcing the behavior into a modulated biennial mode. In short, while it may seem logical and aesthetically pleasing to decompose the SOI into a modulated biennial oscillation, it is certainly not necessary to use such a model to explain the persistence barrier.

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