Seasonal Transition of the Southeast Pacific Anticyclone

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1. Introduction

Southerly flow along the coast of Chile (v) is driven by the southeast Pacific (SEP) anticyclone and the wind stress forces upwelling along the coast. Marked seasonal variation occurs especially near Punta Lavapié and Punta Lengua de Vaca as the SEP shifts meridionally (Fig. 1). Year-to-year variability can be large and impact the timing, duration, and nature of the transition. Detection of the transition is often clear at Punta Lavapié, but unclear at Punta Lengua de Vaca. Thus, an objective method must be employed to detect these changes.

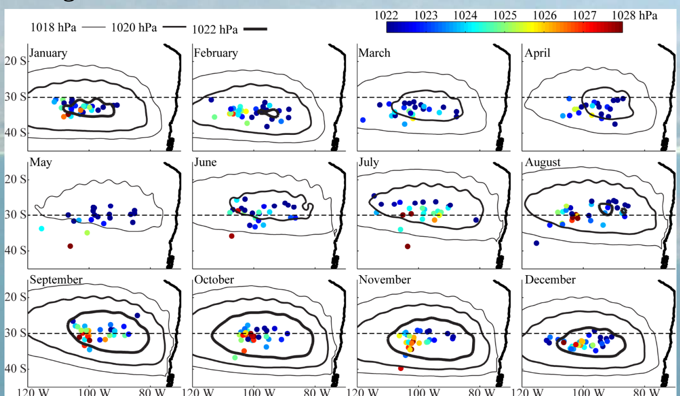

Fig. 1: Monthly mean isobars (contours, key in upper left) and the mean anticyclone center (circle) and strength (color, key in upper right) for each individual year (1979-2012), following criteria in Schroeder et al. (2013). When locating the anticyclone center, the maximum pressure must be above 1022 hPa or the center is undefined, leading to fewer points in May, for example. Data from Climate System Forecast Reanalysis (Saha et al. 2010).

2. Method

Pseudo-wind stress (v*|v|) is used to calculate a cumulative upwelling index (CUI). Near Punta Lavapié the transition is usually unambiguous since CUI often shifts from a negative to positive slope at the beginning of the season. Examples in Fig. 2 and 3 are for 1989-1990 (ENSO-neutral) and 2008-2009 (weak La Niña). To objectively distinguish more subtle changes in slope at Punta Lengua de Vaca, we employ a two-phase regression model:

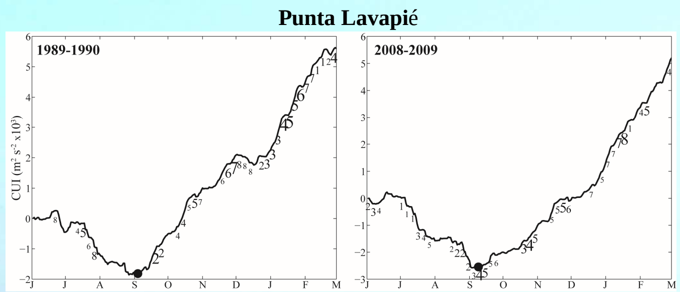

Fig. 2: CUI at Punta Lavapié with a black circle indicating the start of the upwelling season (negative to positive slope). MJO phase and amplitude is from Wheeler and Hendon (2004), where the number is the phase and its size is the relative amplitude (amplitudes < 1 not shown).

$$X_t = \begin{cases} a_1 + b_1 t + e_t & 1 \le t \le c \\ a_2 + b_2 t + e_t & c < t \le n \end{cases} \qquad (1)$$

The abscissa of the intersection of the two regression lines is:

$$c = \frac{a_1 - a_2}{b_1 - b_2} \qquad (2)$$

Equation (1) can be rewritten as:

$$X_t = a_1 + b_1 t + (b_2 - b_1)(t - c) IND_c(t) + e_t \qquad (3)$$

$$IND_c = \begin{cases} 0 \; if \; t \le c \\ 1 \; if \; t > c \end{cases}$$

To detect changes, the likelihood ratio statistic is used:

$$F = \frac{S_o - S}{3} \Big/ \frac{S}{n-4} \qquad (4)$$

Where S_o is the residual sum of squares from fitting the null model ($X_t = a_1 + b_1 t + e_t, 1 \le t \le n$) and S is the residual sum of squares from the alternative model (3).

Since this technique is sensitive to the time period used, it was repeated in a 90-day moving window over the period 1 June-1 March. The distribution of F for all time windows is shown in Fig. 3 as thin gray lines, and the maximum F of all windows on each day is the bold black line. Peaks correspond to the beginning or end of the upwelling season at Punta Lengua de Vaca.

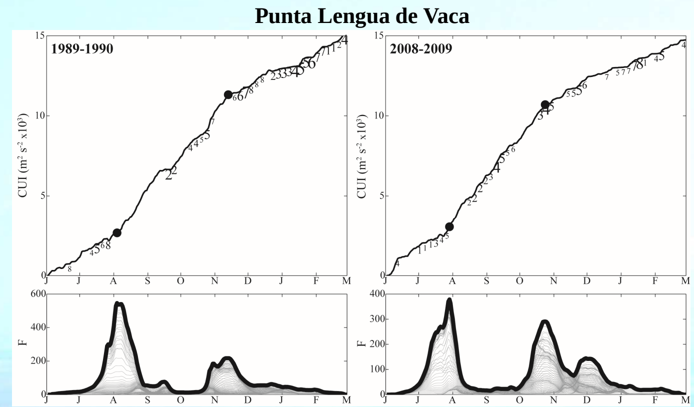

Fig. 3: (top) CUI at Punta Lengua de Vaca with black circles indicating the beginning and end of the upwelling season based on the local maximum of F. MJO phase and amplitude are from Wheeler and Hendon (2004), where the number is the phase and its size is the relative amplitude (amplitudes < 1 not shown). (bottom) The likelihood ratio statistic (F) for each 90-day window (thin gray) and maximum value for all windows (bold black).

3. Results

This method can objectively determine the beginning and end of the upwelling season at Punta Lengua de Vaca, which is more subtle than at Punta Lavapié. Smaller windows can give more detail of sub-seasonal shifts, but the 90-day window works well to detect the upwelling season.

Long-term composites indicate phases 4, 5, and 6 (7, 8, and 1) of the Madden Julian Oscillation (MJO) tend to have stronger (weaker) northerly alongshore wind. Many years indicate some relationship with the onset of the upwelling season by delaying or expediting the transition, but it is not the case every year and many other factors can be involved.

4. References

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