On the progress of the 2015–2016 El Niño event

Costas A. Varotsos1, Chris G. Tzanis1, and Nicholas V. Sarlis2

1Climate Research Group, Division of Environmental Physics and Meteorology, Faculty of Physics, University of Athens, University Campus Bldg. Phys. V, Athens, 157 84, Greece
2Department of Solid State Physics, Faculty of Physics, School of Science, National and Kapodistrian University of Athens, Panepistimiopolis Zografos, 157 84 Athens, Greece

Correspondence to: Costas A. Varotsos (covar@phys.uoa.gr)

Received: 13 November 2015 – Published in Atmos. Chem. Phys. Discuss.: 18 December 2015
Revised: 13 February 2016 – Accepted: 15 February 2016 – Published: 23 February 2016

Abstract. It has been recently reported that the current 2015–2016 El Niño could become “one of the strongest on record”. To further explore this claim, we performed the new analysis described in detail in Varotsos et al. (2015) that allows the detection of precursory signals of the strong El Niño events by using a recently developed non-linear dynamics tool. In this context, the analysis of the Southern Oscillation Index (SOI) time series for the period 1876–2015 shows that the running 2015–2016 El Niño would be rather a “moderate to strong” or even a “strong” event and not “one of the strongest on record”, as that of 1997–1998.

1 Introduction

El Niño/La Niña Southern Oscillation (ENSO) is an oceanic-atmospheric quasi-periodic phenomenon with several impacts on climate and weather not only in the tropical Pacific, but in many regions all over the world (Varotsos and Deligiorgi, 1991; Kondratyev and Varotsos, 1995a, b; Klein et al., 1999; Xue et al., 2000; Eccles and Tziperman, 2004; Cracknell and Varotsos, 2007, 2011; Lin, 2007; Chattopadhyay and Chattopadhyay, 2011; Efstathiou et al., 1998, 2011; Varotsos, 2013; C. Varotsos et al., 2009, 2012, 2014a, b). The disastrous effects of the strong ENSO events necessitate their reliable short- and long-term prediction (Latif et al., 1998; Stenseth et al., 2003; Monks et al., 2009; Hsiang et al., 2011; Cheng et al., 2011; Barnston et al., 2012; Krapivin and Shutko, 2012; Tippett et al., 2012). In this context, Varotsos et al. (2015) presented a new method (see also Varotsos and Tzanis, 2012) for the detection of precursory signals of the strong El Niño events by using the entropy change in “natural time” (a new time domain, see Varotsos et al., 2002) under time reversal. The analysis of the Southern Oscillation Index (SOI) time series by using this modern method provided significant precursory signals of two of the strongest El Niño events (1982–1983 and 1997–1998).


In this study, we further explore these claims, by applying to the SOI time series the recently proposed analysis by Varotsos et al. (2015). The ability of accurate predictions of such severe natural events, like El Niño, is of crucial importance especially nowadays, where the global annual average temperature in 2015 reached the warmest on record values, which might be associated with the 2015 El Niño event (WMO, 2016).
As mentioned in the previous section, we analyze the SOI time series (Troup, 1965; Power and Kociuba, 2011) for the period January 1876–October 2015 by employing the method described in detail in Varotsos et al. (2015). More specifically, we conduct the analysis of the SOI monthly values by using the data set, entitled “Monthly SOIPhase 1887–1989 Base”, (https://www.longpaddock.qld.gov.au/seasonalclimateoutlook/southernoscillationindex/soidatafiles/index.php) derived from the Long Paddock site. It should be clarified that we use the monthly values of SOI, instead of the daily ones, as the latter introduce significant noise due to daily weather patterns variability. It should be noted here that El Niño and La Niña episodes are associated with negative and positive values of the SOI, respectively, and

SOI = 10 × [PA(Tahiti) − PA(Darwin)]/SDD, where the Pressure Anomaly (PA) is the monthly mean minus long-term mean (1887–1989 base period) and SDD is the standard deviation of the difference (1887–1989 base period) of mean sea level pressure between Tahiti and Darwin.

The method suggested by Varotsos et al. (2015) is based on the entropy change in natural time under time reversal ΔS (e.g., see P. A. Varotsos et al., 2005, 2007, 2009; Sarlis et al., 2010, 2011) calculated for a window size of i events (SOI monthly values). To this end, Varotsos et al. (2015) converted the original SOI time series to a new one Qk = (SOIk + [min(SOI)])/, where min(SOI) is the minimum value of SOI during the whole study period, keeping the temporal sequence of the events and not considering their time of occurrence. Hence, for each Qk value we calculate the ratio (χk) of the order of its occurrence (k) and the total number (i) of events within the window, i.e. χk = k/i. The latter quantity, which replaces the conventional time (t), is natural time χk characterizing the kth event (Varotsos et al., 2002). This way, Varotsos et al. (2015) introduced a new series the members of which are the pairs (χk, Qk) where Qk > 0. Thus, one can define the quantity pk = Qk/ΣQn which can be considered as a probability, since it is positive and satisfies the condition Σpk = 1 (Varotsos et al., 2011). Under these assumptions, the average values of quantities, which are functions of natural time χ, can be evaluated by ⟨f(χ)⟩ = Σni=1 f(χn)pn, and the entropy in natural time can be defined by S = ⟨χlnχ⟩ − ⟨χ⟩ln⟨χ⟩ (Varotsos et al., 2005, 2011). The latter quantity changes to a value S− if, instead of the true sequence of events, one uses the time-reversed process that is described by p′k = ˆtpk = pi−k+1, where ˆt denotes the time reversal operator in the window.

Figure 2. The hit rate vs. false alarm rate when using ΔS20 as a predictor for the SOI value of the next month. The ROC point indicated by the arrow has been selected so that the slope of the tangent of the ROC points indicated by the red curve has unit slope and hence it corresponds to the m = 1 iso-performance line of the ROC space (e.g., see Fawcett, 2006; Provost and Fawcett, 1998, 2001).
of $i$ events. The quantity $\Delta S_i (= S - S_{-})$ reveals the breaking of time symmetry by capturing the difference in the dynamics as the system evolves from present to future and vice versa. In short, it has been shown (e.g., see Varotsos et al., 2007, 2011) that positive values of $\Delta S_i$ correspond to a decreasing time series in natural time, and hence when $\Delta S_i$ exceeds a certain threshold this reveals that SOI is approaching small values indicating El Niño (Varotsos et al., 2015). Varotsos et al. (2015) have also shown (see their Fig. 4) that the most useful window size for this purpose is $i = 20$ events (months). In their prediction scheme, the monthly SOI values for the past 20 months are used for the calculation of $\Delta S_{20}$ (see the red crosses in Figs. 1 and 3) and compared with a threshold $\Delta S_{\text{thres}}$, which can be determined on the basis of Receiver Operating Characteristics (ROC, see Provost and Fawcett, 1998, 2001). In this scheme, a line of constant slope $m$ (see the blue line in Fig. 2) is selected on the basis of the relative cost of false positive predictions over the cost of false negative predictions multiplied by the relative frequency of negatives over positives, i.e., see Eq. (1) of Fawcett (2006). As a typical selection we chose $m = 1$. We fitted ROC points with the red curve (having a simple analytical form $a + b \sqrt{x} + cx^d$) and determined the point at which the slope was unity. This leads to the ROC point indicated by an arrow in Fig. 2 and corresponds to $\Delta S_{\text{thres}} = 0.0035$ (i.e., a value very close to that 0.00326 presented in Table 1 of Varotsos et al. (2015) for $T = -15$). Thus, in Figs. 1 and 3 when $\Delta S_{20} \geq 0.0035$ the alarm is set on for the SOI value of the next month.

The time progress of the SOI monthly values as well as the entropy change in natural time under time reversal (for the window length $i = 20$ months) $\Delta S_{20}$ are depicted in Fig. 1 (as well as in Fig. 3). Beyond the information gained from the exploration of the $\Delta S_{20}$ dynamics and in order to further identify if 2015–2016 El Niño could be characterized as a “very strong” one or even more as “one of the strongest on record”, we followed the classification and characterization

Figure 4. The PDF of $\Delta S_{20}$ (black curve, left scale) together with the corresponding histogram (red bars, left scale) obtained from the time series of $\Delta S_{20}$, which is also plotted vs. time (blue crosses, right scale) along the vertical axis. The arrows indicate when $\Delta S_{20}$ exceeds 0.0205 and are labeled by the corresponding ongoing strong El Niño events.
of the past El Niño events given by BOM (http://www.bom.gov.au/climate/enso/enlist/). The colored areas in Figs. 1 and 3 represent the mean minimum negative values of SOI along with the 1σ standard deviation bands for the two cases of “weak, weak to moderate, moderate, moderate to strong” (green band) and “strong, very strong” (yellow band) El Niño events.

As can be clearly seen in Fig. 3, the SOI values during the last three months remain in the green band and in the limits of the yellow one, indicating that 2015 El Niño should be rather characterized as a “moderate to strong” or even “strong” event and not “one of the strongest on record”, as also shown by comparing with the El Niño events of 1982–1983 and 1997–1998. Furthermore, the variation of $\Delta S_{20}$ during the 2015 El Niño in comparison with 1982–1983 and 1997–1998 El Niño events is not as sharp, confirming that the undergoing El Niño event is not “one of the strongest on record”. In order to estimate the extent of this variation, we plot with the black curve in Fig. 4 the probability density function (PDF) of $\Delta S_{20}$ obtained from the estimator $f_N(\Delta S_{20}) = \frac{1}{N} \sum_{i=1}^{N} \frac{1}{b_N} K \left( \frac{\Delta S_{20} - O_i}{b_N} \right)$, where $O_i$ are the observed values of $\Delta S_{20}$ since the beginning of our study, $N$ is the total number of these observations, the kernel $K(x) = \frac{3}{4} (1 - x^2)$ and $b_N$ is related with the standard deviation $\sigma$ of the observed $\Delta S_{20}$ values by $b_N = 10.25 \sigma / N^{0.34}$ as suggested by Mercik et al. (1999). We observe in Fig. 4 that only rarely $\Delta S_{20}$ exceeds the value of 0.02, which can be also verified by the red histogram obtained for $\Delta S_{20}$ using the TISEAN package (Hegger et al., 1999) (also plotted in Fig. 4). In the latter histogram, the minimum non-zero height is observed in the bar that includes the value $\Delta S_{20} = 0.02$ covering the range up to approximately 0.0205. To detect when $\Delta S_{20}$ exceeds the latter value, we plot with blue crosses the time series of $\Delta S_{20}$ vs. time, which can be read in the right axis of Fig. 4. We see (blue arrows in Fig. 4) that $\Delta S_{20} > 0.0205$ is observed only in the three strong El Niño events of 1905–1906, 1982–1983 and 1997–1998. This inequality, however, is not fulfilled in the current case (2015–2016 El Niño), since the currently observed values are close to 0.01, i.e., markedly smaller than the value of 0.0205.

3 Conclusions

Recent reports indicate that 2015–2016 El Niño event could become “one of the strongest on record” or could be already characterized as “the strongest El Niño since 1997–98”. In order to investigate these assertions, we analyzed the SOI time series for the period January 1876–October 2015 by using the method described in Varotsos et al. (2015) based on the entropy change in natural time under time reversal. The results obtained indicate that the undergoing 2015–2016 El Niño event should be rather characterized as a “moderate to strong” or even “strong” event and not “one of the strongest on record”.

Edited by: A. Hofzumahaus

References


