Atmos. Chem. Phys. Discuss., 15, 35787–35797, 2015
www.atmos-chem-phys-discuss.net/15/35787/2015/
doi:10.5194/acpd-15-35787-2015


Atmospheric Chemistry and Physics Discussions
Open Access



# Technical note: On the progress of the 2015–2016 El Niño event

**C. A. Varotsos[1], C. G. Tzanis[1], and N. V. Sarlis[2]**

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

Received: 13 November 2015 – Accepted: 4 December 2015 – Published: 18 December 2015

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

Published by Copernicus Publications on behalf of the European Geosciences Union.







Technical note: On the progress of the 2015–2016 El Niño event

C. A. Varotsos et al.

## 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 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 well-known impacts on climate and weather not only in the tropical Pacific, but in many regions all over the world (Kondratyev and Varotsos, 1995; Klein et al., 1999; Xue et al., 2000; Eccles and Tziperman, 2004; Lin, 2007; Chattopadhyay and Chattopadhyay, 2011; Efstathiou et al., 2011; Varotsos et al., 2009, 2014). The disastrous effects of the strong ENSO events necessitate their reliable short-term 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 change of the entropy in "natural time" (a new time domain, Varotsos et al., 2002) under time reversal. The analysis of the Southern Oscillation Index (SOI) time series by performing this modern method provided significant precursory signals of two of the strongest El Niño events (1982–1983 and 1997–1998).

Very recently, Klein (2015) reported that the running 2015–2016 El Niño could become "one of the strongest on record". Furthermore, the Australian Government Bu-





ACPD
15, 35787–35797, 2015

reau of Meteorology (BOM) in their report of 1 September 2015 stated that "The 2015 El Niño is now the strongest El Niño since 1997–98" (http://www.bom.gov.au/climate/enso/archive/ensowrap_20150901.pdf) and moreover on 29 September 2015 they reported that most international climate models indicate current El Niño "is likely to peak towards the end of 2015" (http://www.bom.gov.au/climate/enso/archive/ensowrap_20150929.pdf) as also reported on 8 October 2015 by the Climate Prediction Center, National Centers for Environmental Prediction, National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_oct2015/ensodisc.pdf). In this study, we further explore these claims, by employing the new aforementioned analysis (Varotsos et al., 2015) to the SOI time series.

## 2 Results and discussion

As mentioned in the previous section, we apply the method described in detail in Varotsos et al. (2015) to the SOI time series (Troup, 1965; Power and Kociuba, 2011) for the period January 1876–October 2015. We analyze the SOI monthly values from the dataset, entitled "Monthly SOIPhase 1887–1989 Base", derived from the Long Paddock site (https://www.longpaddock.qld.gov.au/seasonalclimateoutlook/southernoscillationindex/soidatafiles/index.php). We use the monthly values of SOI instead of daily ones, as the latter can vary significantly due to daily weather patterns and therefore should not be used for climate studies. It should be reminded here that El Niño and La Niña episodes are associated with negative and positive values of the SOI, respectively.

The method used by Varotsos et al. (2015) is based on the change of the entropy in natural time under time reversal $\Delta S_i$ (e.g., see Varotsos et al., 2005, 2007; Sarlis et al., 2011) calculated for a window size of $i$ events. $\Delta S_i$ 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.,



Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper |

ACPD
15, 35787–35797, 2015

Technical note: On the progress of the 2015–2016 El Niño event

C. A. 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 Fawcett, 2006). When $\Delta S_{20} \geq \Delta S_{\text{thres}}$, one issues an alarm that the value of SOI for the next month will be smaller than or equal to $T$ (see the black broken line in Fig. 2). If this turns out to be true, then we have a true positive prediction. If $\Delta S_{20} < \Delta S_{\text{thres}}$ and the next month's SOI is larger than $T$ then we have a true negative prediction. All other combinations lead to errors (which are inevitable in stochastic prediction) which can be either false positive or false negative predictions. Figure 2 depicts the ROC curve obtained when using $\Delta S_{20}$ as a predictor for the SOI value of the next month with $T = -14$ (which is the upper limit of the yellow area in Figs. 1 and 3 discussed below). This is a diagram of the hit rate (or True Positive rate, i.e., the number of true positive predictions over all cases with $\text{SOI} \leq T = -14$) vs. the false alarm rate (or False Positive rate, i.e., the number of false positive predictions over all cases with $\text{SOI} > -14$) as we vary $\Delta S_{\text{thres}}$. One method to estimate an appropriate value of $\Delta S_{\text{thres}}$ is that of iso-performance lines suggested by 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





ACPD
15, 35787–35797, 2015

$T = -15$). 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 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 1$\sigma$ 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 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" (cf. from the beginning of our study $\Delta S_{20}$ exceeded the value of 0.0205, which is well above the currently observed values, only in three strong El Niño events, namely those of 1905–1906, 1982–1983 and 1997–1998).

## 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





ACPD
15, 35787–35797, 2015

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".

*Acknowledgements.* This study was partly funded by Greek General Secretariat for Research and Technology (GSRT) through the project 12CHN350.

## References

Barnston, A. G., Tippett, M. K., L'Heureux, M. L., Li, S. H., and DeWitt, D. G.: Skill of real-time seasonal ENSO model predictions during 2002–11: is our capability increasing?, B. Am. Meteorol. Soc., 93, 631–651, 2012.

Chattopadhyay, S. and Chattopadhyay, G.: The possible association between summer monsoon rainfall in India and sunspot numbers, Int. J. Remote Sens., 32, 891–907, 2011.

Cheng, Y. J., Tang, Y. M., and Chen, D. K.: Relationship between predictability and forecast skill of ENSO on various time scales, J. Geophys. Res., 116, C12006, doi:10.1029/2011JC007249, 2011.

Eccles, F. and Tziperman, E.: Nonlinear effects on ENSO's period, J. Atmos. Sci., 61, 474–482, 2004.

Efstathiou, M. N., Tzanis, C., Cracknell, A. P., and Varotsos, C. A.: New features of land and sea surface temperature anomalies, Int. J. Remote Sens., 32, 3231–3238, 2011.

Fawcett, T.: An introduction to ROC analysis, Pattern Recogn. Lett., 27, 861–874, 2006.

Hsiang, S. M., Meng, K. C., and Cane, M. A.: Civil conflicts are associated with the global climate, Nature, 476, 438–441, 2011.

Klein, K.: NOAA predicts strong El Niño, Eos, 96, doi:10.1029/2015EO035535, 2015.

Klein, S. A., Soden, B. J., and Lau, N. C.: Remote sea surface temperature variations during ENSO: evidence for a tropical atmospheric bridge, J. Climate, 12, 917–932, 1999.

Kondratyev, K. Y. and Varotsos, C.: Atmospheric greenhouse effect in the context of global climate change, Il Nuovo Cimento C, 18, 123–151, 1995.

Krapivin, V. F. and Shutko, A. M.: Information Technologies For Remote Monitoring of the Environment, Springer/Praxis, Chichester, UK, 2012.

Latif, M., Anderson, D., Barnett, T., Cane, M., Kleeman, R., Leetmaa, A., O'Brien, J., Rosati, A., and Schneider, E.: A review of the predictability and prediction of ENSO, J. Geophys. Res., 103, 14375–14393, 1998.

Lin, J.-L.: Interdecadal variability of ENSO in 21 IPCC AR4 coupled GCMs, Geophys. Res. Lett., 34, L12702, doi:10.1029/2006GL028937, 2007.

Monks, P. S., Granier, C., Fuzzi, S., Stohl, A., Williams, M. L., Akimoto, H., Amann, M., Baklanov, A., Baltensperger, U., Bey, I., Blake, N., Blake, R. S., Carslaw, K., Cooper, O. R., Dentener, F., Fowler, D., Fragkou, E., Frost, G. J., Generoso, S., Ginoux, P., Grewe, V., Guenther, A., Hansson, H. C., Henne, S., Hjorth, J., Hofzumahaus, A., Huntrieser, H., Isaksen, I. S. A., Jenkin, M. E., Kaiser, J., Kanakidou, M., Klimont, Z., Kulmala, M., Laj, P., Lawrence, M. G., Lee, J. D., Liousse, C., Maione, M., McFiggans, G., Metzger, A., Mieville, A., Moussiopoulos, N., Orlando, J. J., O'Dowd, C. D., Palmer, P. I., Parrish, D. D., Petzold, A., Platt, U., Pöschl, U., Prévôt, A. S. H., Reeves, C. E., Reimann, S., Rudich, Y., Sellegri, K., Steinbrecher, R., Simpson, D., ten Brink, H., Theloke, J., van der Werf, G. R., Vautard, R., Vestreng, V., Vlachokostas, C., and von Glasow, R.: Atmospheric composition change – global and regional air quality, Atmos. Environ., 43, 5268–5350, 2009.

Power, S. B. and Kociuba, G.: The impact of global warming on the Southern Oscillation Index, Clim. Dynam., 37, 1745–1754, 2011.

Provost, F. and Fawcett, T.: Robust classification systems for imprecise environments, in: Proceedings of the AAAI-98, Menlo Park, CA, 706–713, 1998.

Provost, F. and Fawcett, T.: Robust classification for imprecise environments, Mach. Learn., 42, 203–231, 2001.

Sarlis, N. V., Skordas, E. S., and Varotsos, P. A.: The change of the entropy in natural time under time-reversal in the Olami–Feder–Christensen earthquake model, Tectonophysics, 513, 49–53, 2011.

Stenseth, N. C., Ottersen, G., Hurrell, J. W., Mysterud, A., Lima, M., Chan, K. S., Yoccoz, N. G., and Adlandsvik, B.: Studying climate effects on ecology through the use of climate indices: the North Atlantic Oscillation, El Niño Southern Oscillation and beyond, P. Roy. Soc. Lond. B Bio., 270, 2087–2096, 2003.

Tippett, M. K., Barnston, A. G., and Li, S. H.: Performance of recent multimodel ENSO forecasts, J. Appl. Meteorol. Clim., 51, 637–654, 2012.

Troup, A. J.: The Southern Oscillation, Q. J. Roy. Meteor. Soc., 91, 490–506, 1965.





ACPD

15, 35787–35797, 2015

Technical note: On the progress of the 2015–2016 El Niño event

C. A. Varotsos et al.

Varotsos, C., Efstathiou, M., and Tzanis, C.: Scaling behaviour of the global tropopause, Atmos. Chem. Phys., 9, 677–683, doi:10.5194/acp-9-677-2009, 2009.
Varotsos, C., Christodoulakis, J., Tzanis, C., and Cracknell, A. P.: Signature of tropospheric ozone and nitrogen dioxide from space: A case study for Athens, Greece, Atmos. Environ., 89, 721–730, 2014.
Varotsos, C. A. and Tzanis, C.: A new tool for the study of the ozone hole dynamics over Antarctica, Atmos. Environ., 47, 428–434, 2012.
Varotsos, C. A., Tzanis, C., and Cracknell, A. P.: Precursory signals of the major El Niño Southern Oscillation events, Theor. Appl. Climatol., doi:10.1007/s00704-015-1464-4, online first, 2015.
Varotsos, P. A., Sarlis, N. V., and Skordas, E. S.: Long-range correlations in the electric signals that precede rupture, Phys. Rev. E, 66, 011902, doi:10.1103/PhysRevE.66.011902, 2002.
Varotsos, P. A., Sarlis, N. V., Tanaka, H. K., and Skordas, E. S.: Some properties of the entropy in the natural time, Phys. Rev. E, 71, 032102, doi:10.1103/PhysRevE.71.032102, 2005.
Varotsos, P. A., Sarlis, N. V., Skordas, E. S., and Lazaridou, M. S.: Identifying sudden cardiac death risk and specifying its occurrence time by analyzing electrocardiograms in natural time, Appl. Phys. Lett., 91, 064106, doi:10.1063/1.2768928, 2007.
Varotsos, P. A., Sarlis, N. V., and Skordas, E. S.: Natural Time Analysis: The new view of time, Precursory Seismic Electric Signals, Earthquakes and other Complex Time-Series, Springer-Verlag, Berlin Heidelberg, 2011.
Xue, Y., Llewellyn-Jones, D. T., Lawrence, S. P., and Mutlow, C. T.: On the Earth's surface energy exchange determination from ERS satellite ATSR data: Part 3. Turbulent heat flux on open sea, Int. J. Remote Sens., 21, 3427–3444, 2000.





ACPD
15, 35787–35797, 2015

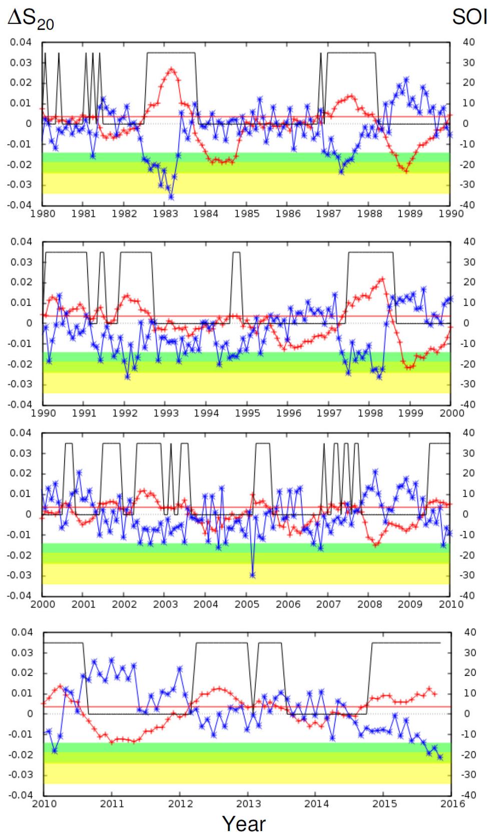


**Figure 1.** The entropy change $\Delta S_{20}$ in natural time for the window length $i = 20$ months (red line, left scale) along with SOI monthly values (blue line, right scale) for the period January 1980–October 2015. The alarm is set on (black line) when $\Delta S_{20}$ exceeds the threshold value $\Delta S_{\text{thres}} = 0.0035$.





ACPD
15, 35787–35797, 2015

Technical note: On the progress of the 2015–2016 El Niño event

C. A. Varotsos et al.

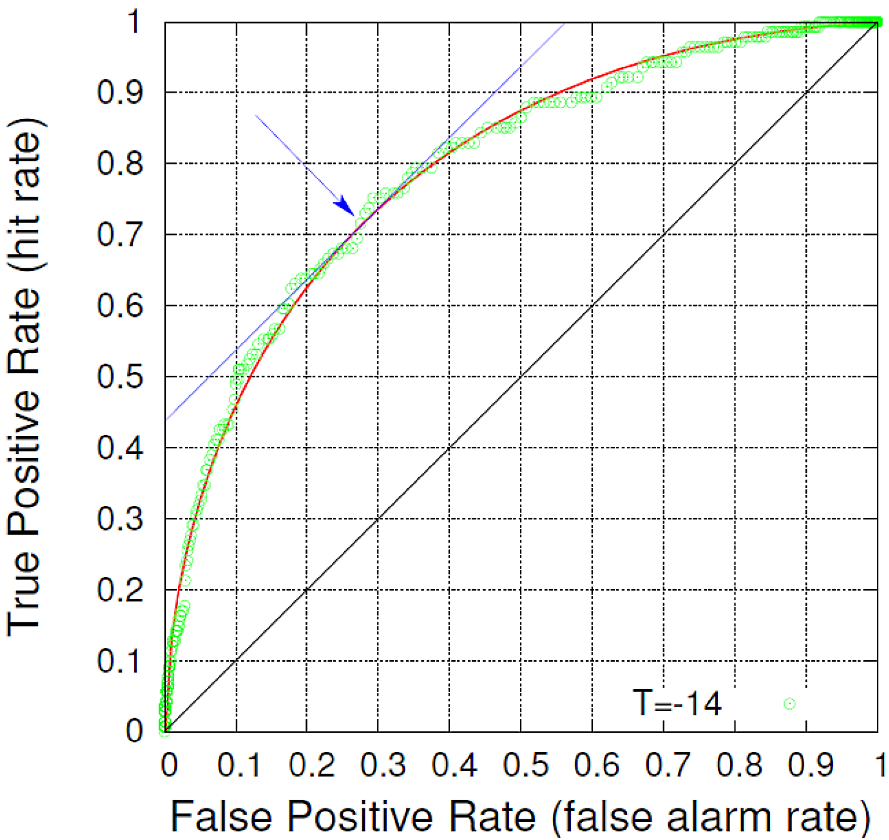


**Figure 2.** The hit rate vs. false alarm rate when using $\Delta S_{20}$ as a predictor for the SOI value of the next month. The ROC point indicated by the arrow has been selected so that the slope of the tangent of the analytical fitting of the ROC points indicated by the red curve has unit slope 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).





ACPD
15, 35787–35797, 2015

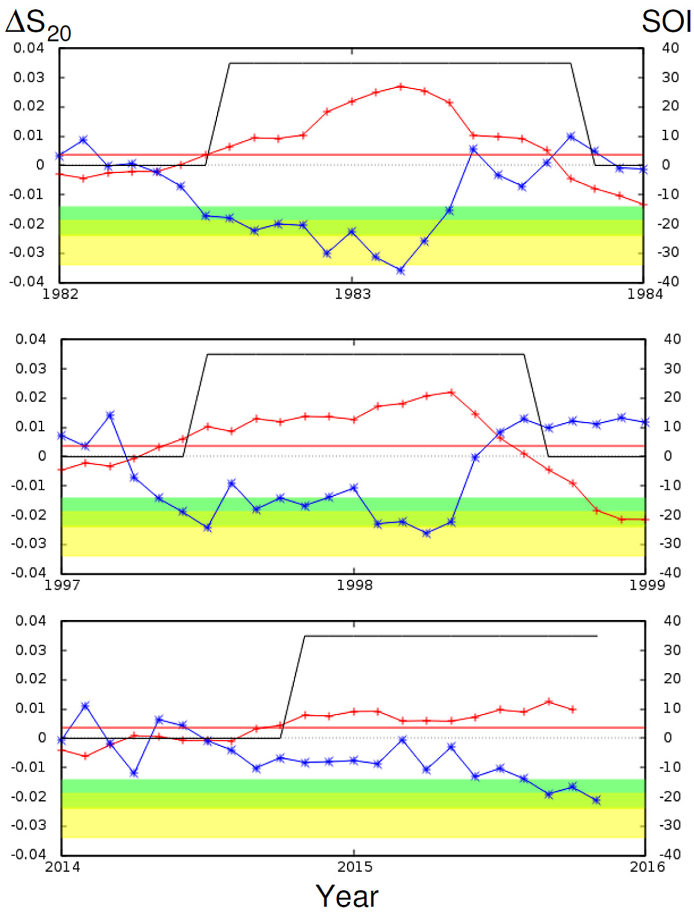


**Figure 3.** As in Fig. 1, but only for the 1982–1983, 1997–1998 (the two strongest in the last century) and the current 2015–2016 El Niño events.





ACPD
15, 35787–35797, 2015

Technical note: On the progress of the 2015–2016 El Niño event

C. A. Varotsos et al.

Title Page
Abstract Introduction
Conclusions References
Tables Figures
◄ ►
◄ ►
Back Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion