

## “Do Seismic Electric Signals (VAN method) really exist?”

Panayiotis A. Varotsos, Nicholas V. Sarlis, Efthimios S. Skordas, and Mary S.  
Lazaridou

*Solid State Section and Solid Earth Physics Institute, Physics Department, University of Athens,  
Panepistimiopolis, Zografos 157 84, Athens, GREECE*

Natural time analysis introduced a decade ago [1-4], has been shown [5] to be optimal for enhancing the signals in time-frequency space when employing the Wigner function and measuring its localization property. This analysis has found applications in a variety of fields compiled in a recent monograph [6], including Cardiology, e.g., the identification of the sudden cardiac death risk [7-9] and Geophysics, e.g., the distinction of Seismic Electric Signals (SES) activities -which are series of low frequency electric signals that precede earthquakes [10-13] - from signals due to man made sources [3,4]. Almost 30 years ago, it has been suggested [12-14] that SES activities presumably arise from a cooperative orientation of electric dipoles formed due to defects when the stress in the focal area reaches a *critical* value. A multitude of alternative SES generation models have been suggested to date.

Here, upon employing natural time analysis we demonstrate that:

First, the SES generation model is fully supported when analyzing properly the experimental data of SES activities.

Second, based on the data of the SES activities and on the natural time analysis of subsequent seismicity, predictions (concerning the magnitude, epicenter and time-window) have been publicized well in advance, see Chapter 7 of Ref.[6], for all five major earthquakes with  $M_w \geq 6.4$  (related to four mainshocks) in Greece.

Third, the SES activities that preceded the aforementioned major earthquakes are shown to be accompanied by independent geophysical data.

As a conclusion: It is known that long ago a debate arose in the international community on whether SES are true precursory signals. This debate we feel should end here in view of the aforementioned three facts.

### References

- [1.] P. Varotsos, N. Sarlis, and E. Skordas, Spatiotemporal complexity aspects on the interrelation

- between Seismic Electric Signals and seismicity, *Practica of Athens Academy*, 76, 294-321, 2001.
- [2.] P.A. Varotsos, N.V. Sarlis, and E.S. Skordas, Long-range correlations in the electric signals that precede rupture, *Phys. Rev. E*, 66, 011902 (7), 2002.
- [3.] P.A. Varotsos, N.V. Sarlis, and E.S. Skordas, Long-range correlations in the electric signals that precede rupture: Further investigations, *Phys. Rev. E*, 67, 021109 (13), 2003.
- [4.] P.A. Varotsos, N.V. Sarlis, and E.S. Skordas, Attempt to distinguish electric signals of a dichotomous nature, *Phys. Rev. E*, 68, 031106 (7), 2003.
- [5.] S. Abe, N.V. Sarlis, E.S. Skordas, H.K. Tanaka and P.A. Varotsos, Origin of the usefulness of the natural time representation of complex time series, *Phys. Rev. Lett.* 94, 170601(4), 2005.
- [6.] 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.
- [7.] P.A. Varotsos, N.V. Sarlis, E.S. Skordas, and M.S. Lazaridou, Entropy in the natural time-domain, *Phys. Rev. E*, 70, 011106(10), 2004.
- [8.] P.A. Varotsos, N.V. Sarlis, E.S. Skordas, and M.S. Lazaridou, Natural entropy fluctuations discriminate similar looking electric signals emitted from systems of different dynamics, *Phys. Rev. E* 71, 011110(11), 2005a.
- [9.] P.A. Varotsos, N.V. Sarlis, E.S. Skordas, and M.S. Lazaridou, Identifying sudden cardiac death risk and specifying its occurrence time by analyzing electrocardiograms in natural time, *Appl. Phys. Lett.* 91, 064106(3), 2007.
- [10.] P. Varotsos and M. Lazaridou, Latest aspects of earthquake Prediction in Greece based on Seismic Electric Signals, I, *Tectonophysics* 188, 321-347, 1991.
- [11.] P.A. Varotsos, N.V. Sarlis, and E.S. Skordas, Electric fields that “arrive” before the time-derivative of the magnetic field prior to major earthquakes, *Phys. Rev. Lett.*, 91, 148501 (4), 2003c.
- [12.] P. Varotsos and K. Alexopoulos, Physical properties of the variations of the electric field of the earth preceding earthquakes, I, *Tectonophysics* 110, 73-98, 1984a.
- [13.] P. Varotsos and K. Alexopoulos, Physical properties of the variations of the electric field of the earth preceding earthquakes, II. Determination of epicenter and magnitude, *Tectonophysics* 110, 99-125, 1984b.
- [14.] P. Varotsos and K. Alexopoulos, *Thermodynamics of Point Defects and their relation with the bulk properties*, Eds. S. Amelinckx, R. Gevers, and J. Nihoul, North Holland (1986) 474 pages.