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On the physical interconnection of Seismic Electric Signals with seismicity: Recent advances

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We review the recent advances on Seismic Electric Signals (SES) which are low frequency ($\leq$ 1Hz) signals that precede earthquakes [1-3]. Since the 1980's Varotsos and Alexopoulos proposed [4] that SES are generated in the future focal area when the stress reaches a *critical* value, thus causing a *cooperative* orientation of the electric dipoles that anyhow exist in the focal area due to lattice imperfections in the ionic constituents of the rocks. A series of such signals within a short time are termed SES activity [5] and usually appear before major earthquakes. The combination of their physical properties enable the determination of the epicentral region and the magnitude well in advance.

Natural time analysis introduced a decade ago [6, 7] may uncover novel dynamic features hidden behind time series in complex systems [8]. By employing this analysis, several advances have been made towards a better understanding of the SES properties. For example, it has been found [6, 8] that the natural time analysis of the seismicity subsequent to the initiation of a SES activity enables the determination of the occurrence time of an impending major mainshock within a time window of around one week. On this basis, predictions -including the magnitude, epicenter and time window of the expected event- have been documented well in advance for all five mainshocks with $M_w \geq 6.4$ in Greece since 2001 [8, 9].

In addition, by applying natural time analysis to the time series of earthquakes, we recently found [10] that the order parameter of seismicity exhibits a unique change approximately at the date at which SES activities have been reported to initiate. This is the first time that before the occurrence of major earthquakes, anomalous changes are found to appear almost simultaneously in two different geophysical observables.

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