Evaluating the impact of RST-TIR Satellite Observations on a multi-parametric system for time –Dependent Assessment of Seismic Hazard (t-DASH): a long term Correlation Analysis over California, Greece, Italy, Japan, Taiwan and Turkey.

Valerio Tramutoli[1,2,3], Alexander Eleftheriou[4,1], Carolina Filizzola[2], Nicola Genzano[1,5], Katsumi Hattori[3,5], Mariano Lisi[1], Rossana Paciello[2], Fillippos Vallianatos[3,1], Nicola Pergola[2,1].

[1]University of Basilicata, School of Engineering (Potenza), Italy (Valerio.tramutoli@unibas.it)
[2] IMAA-CNR Institute of Methodologies for Environmental Analysis, National Research Council, Tito Scalo, Italy
[3]International Space Science Institute, Beijing, China
[4]Technological Educational Institute of Crete - School of Applied Sciences, Department of Environmental and Natural Resources Engineering (Chania) – Greece
[5]Graduate School of Science, Chiba University, Chiba, Japan

Abstract

Several authors reported the weakness of traditional approaches to seismic hazard assessment as well as the significant consequences of their failures in terms of human and economic losses (e.g. Kossobokov and Nekrasova, 2012, Wyss et al. 2012). For instance Geller (2011) reports that "…since 1979, earthquakes that caused 10 or more fatalities in Japan actually occurred in places assigned a relatively low probability". No better results were achieved in other regions where seismic hazard assessment is based mostly (if not exclusively) on the study of earthquakes catalogues. This is for instance the case of Italy where, on the base of PSHA (Probabilistic Seismic Hazard Analysis) methods (e.g. Cornell 1968), all the events that caused 10 or more fatalities in the past 20 years were largely unexpected and/or underestimated in terms of magnitude or Peak Ground Acceleration (PGA). For instance the San Giuliano earthquake (31 October 2002, M_L=5.4) that killed 27 kids in a school, occurred in an area that was previously considered of minor concern. Particularly enlightening is the explanation given by Chiarabba et al. (2005): "…Seismic hazard for the region had not been previously retained high and the earthquake was mostly unexpected by seismologists. The reason was that neither historical or instrumental events had been previously reported in seismic catalogues for that area". In the case of Emilia earthquake (20 May 2012, M_W=5.8) the observed PGA (>0,25 g) in the epicentral zone (Panza et al 2014) was significantly higher than the one (< 0.175 g) predicted by the PSHA map assumed as reference by the Italian Ministry of Infrastructures (see Zuccolo et al, 2011 and reference herein) in defining the new rules for build in seismic areas. Even more weak are the results until now achieved by the so called Operational Earthquakes Forecast (OEF) methods which still suffer from strong limitations in terms of their actual (too low absolute value of estimated probabilities) and general (forecast is substantially limited to earthquakes which are preceded by foreshocks) operational applicability (e.g. Wang and Rogers, 2014; Panza et al., 2014). Mostly for these limitations they have been scarcely used until now justifying the renewed interest of the scientific community for the study of the preparatory phases of earthquakes and for those, not just seismological, geophysical properties whose anomalous transients could be considered and monitored as earthquake precursors. Although many of them (chemical, physical, biological, etc.) have been since long time proposed in literature (see for instance Tronin 2006 and reference herein; Cicerone et al 2009) and several physical models (e.g. Scholz et al 1973, Tronin 1996, Freund 2007, Pulinets and Ouzounov 2011, Huang 2011, Tramutoli et al. 2013, etc.) exist that explain why those parameters could exhibit significant variations in relation with the preparation phases of an earthquake, until now no one single measurable parameter, no one observational methodology, has demonstrated to be sufficiently reliable and effective for the implementation of an operational earthquake prediction system. However, moving from deterministic prediction to a probabilistic forecast goal, a multi-parametric approach can be today considered the most promising one, both in terms of reliability (forecast probabilities could be orders of magnitude higher than the ones offered by traditional OEF approaches) and precision (strongly reducing the "alerted" space-time windows).

To this aim a very preliminary step is to identify (and to characterize them for their actual informative content) those parameters (chemical, physical, biological, etc.) whose anomalous variations can be actually associated to the earthquake preparation phases.

In this paper the fluctuations of Earth's thermally emitted radiation (see Tramutoli et al. 2015 for a review) - observed by satellite sensors operating in the Thermal InfraRed (TIR) spectral range – will be considered.

More than 10.000 TIR images collected by sensors operating on different satellite platforms (MSG, GOES, MTSAT, GMS, etc.) over European (Italy, Greece and Turkey), American (California) and Asian (Taiwan and Japan) regions were analyzed. The general RST (Robust Satellite Technique, Tramutoli 1998, 2007) data analysis approach and the specific RETIRA (Robust Estimator of TIR Anomalies) index were used to isolate Significant TIR Anomalies (STAs) possibly associated to seismic activity, from the normal variations of TIR signal due to other causes (e.g. meteorological) in quite long (from 5 to 12 years) continuous periods of observations. Prescriptions on STA's relative intensity and space-time persistence, were used to identify Significant Sequences of TIR Anomalies (SSTAs). Significance of the correlation existing among SSTAs and earthquakes (with M≥4) occurrence was then investigated in order to evaluate the possible contribute of RST-TIR observations in the framework of a multi-parametric system for time-Dependent Assessment of Seismic Hazard (t-DASH).

A long-term retrospective correlation analysis was performed among the appearance of SSTAs and time, location and magnitude of earthquakes occurred within predefined space-time windows. Preliminary results highlight that, depending on the considered geographic region, the occurrence of SSTAs falling out of the pre-fixed space-time correlation window range between 7% (Greece) and 39% (Italy). Molchan error diagram analysis gave a clear indication of non-casualty of such a result with a probability gain (compared with the random guess) ranging from 1,5 up to 3,5. Such a result confirm the positive informative contribution that the use of RST-TIR analysis could give in the framework of a multi-parametric t-DASH system.

References

Chiarabba C, De Gori P, Chiaraluce L, Bordoni P, Cattaneo M, De Martin M, Frepoli A, Michelini A, Monachesi A, Moretti M, Augliera GP, D'Alema E, Frapiccini M, Gassi A, Marzorati S, Bartolomeo P Di, Gentile S, Govoni A, Lovisa L, Romanelli M, Ferretti G, Pasta M, Spallarossa D, Zunino E (2005) Mainshocks and aftershocks of the 2002 molise seismic sequence, southern Italy. J Seismol 9:487–494.

Cicerone RD, Ebel JE, Britton J (2009) A systematic compilation of earthquake precursors. Tectonophysics 476:371–396.

Cornell CA (1968) Engineering seismic risk analysis. Bull Seismol Soc Am 58:1583–1606.

Freund FT (2007) Pre-earthquake signals – Part I: Deviatoric stresses turn rocks into a source of electric currents. Nat. Hazards Earth Syst. Sci., 7, 535–541.

Huang QH (2011) Rethinking earthquake-related DC-ULF electromagnetic phenomena: towards a physics-based approach. Nat Hazards Earth Syst Sci, 11(11): 2941–2949.

Geller RJ (2011) Shake-up time for Japanese seismology. Nature 472:407–409. doi: 10.1038/nature10105

Kossobokov V, Nekrasova A (2012) Global seismic hazard assessment program (GSHAP) maps are Erroneous. Seismic Instruments 48(2):162-170.

Panza G, Kossobokov VG, Peresan A, Nekrasova A (2014) Why are the Standard Probabilistic Methods of Estimating Seismic Hazard and Risks Too Often Wrong, in Earthquake Hazard, Risk and Disasters. Max Wyss ed., Academic Press. 309–357.

Pulinets SA, Ouzounov D (2011) Lithosphere–Atmosphere–Ionosphere Coupling (LAIC) model - An unified concept for earthquake precursors validation. Journal of Asian Earth Sciences 41, 371-382

Scholz CH, Sykes LR, Aggarwal YP (1973) Earthquake prediction: a physical basis. Science 181(4102):803–810.

Tramutoli V (1998) Robust AVHRR Techniques (RAT) for Environmental Monitoring: theory and applications. In: Zilioli E (ed) Proc. SPIE. pp 101–113

Tramutoli V (2007) Robust Satellite Techniques (RST) for Natural and Environmental Hazards Monitoring and Mitigation: Theory and Applications. 2007 Int. Work. Anal. Multi-temporal Remote Sens. Images. IEEE, pp 1–6

Tronin AA (1996) Satellite thermal survey—a new tool for the study of seismoactive regions. Int J Remote Sens 17:1439–1455.

Tronin AA (2006) Remote sensing and earthquakes: A review. Phys Chem Earth 31:138–142.

Wyss M, Nekrasova A, Kossobokov V (2012) Errors in expected human losses due to incorrect seismic hazard estimates. Nat Hazards 62:927–935. doi: 10.1007/s11069-012-0125-5

Zuccolo E, Vaccari F, Peresan A, Panza GF (2011) Neo-Deterministic and Probabilistic Seismic Hazard Assessments: a Comparison over the Italian Territory. Pure Appl Geophys 168:69–83.

Wang, K., Rogers G., C., Earthquake Preparedness Should Not Fluctuate on a Daily or Weekly Basis Seismological Research Letters (2014) 85 (3): 569-571.