Preliminary results of long term correlation analysis among earthquakes (M>4) occurrence and anomalous transients in Radon emission and Earth's emitted TIR radiation in Northeastern Italy

Anna Riggio[1], Stefano Capobianco[2], Nicola Genzano[2,4], Mariano Lisi [2,5], Alberto Tamaro[6], Marco Santulin[7], Giancanio Sileo[2], Valerio Tramutoli[2,3,5]

[1] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – OGS, Trieste, Italy , [2] School of Engineering, University of Basilicata, Potenza, Italy , [3] Institute of Methodologies for Environmental Analysis of the National Research Council, Tito Scalo (PZ), Italy, [4] Graduate School of Science, Chiba University, Chiba, Japan, [5] International Space Science Institute, Bejiing, China, [6,1] Università degli studi di Udine, [7] Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Milano

I. INTRODUCTION

The idea that earthquakes have no precursors at all has been often used to support purely statistical studies only based on the analysis of historical seismic records discouraging for long time investments in multi-parametric observation networks and related research activities. A renewed interest on the study of preparatory phases of earthquakes has been solicited in recent years by the, everyday more evident, weakness of traditional approaches to seismic hazard assessment as well as from the significant consequences of their failures in terms of human and economic losses (e.g., Wyss et al., 2012; Kossobokov and Nekrasova, 2012; Geller, 2011).

Also for these reasons, an everyday increasing interest of scientific community, has been addressed to alternative observational techniques and data analysis methods suitable for improving our present capability to assess seismic hazard in the short– medium term. In this context a renewed role could be played by the research on earthquake precursors if it is addressed to develop/improve systems for time- Dependent Assessment of Seismic Hazard (t-DASH, Tramutoli et al., 2014) instead to the deterministic earthquake predictions.

Looking toward the assessment of a multi-parametric system for dynamically updating seismic hazard estimates and earthquake short term (from days to weeks) forecast, a preliminary step is to identify those parameters (chemical, physical, biological, etc.) whose anomalous variations can be, to some extent, associated to the complex process of earthquake preparation. Among the other parameters claimed as possible indicators of an impending seismic activity, the anomalous variations of radon (Rn) emissions and of Earth's thermally emitted infrared radiation (TIR), have been proposed, since long time, as potential earthquake precursors. In this paper the added value of a multi-parametric approach is evaluated by applying a similar statistical analysis (based on the general RST approach) to long-term time series of Radon and TIR data collected in Northern Italy. Preliminary results of the correlation analysis performed with earthquakes (M>4) clearly show a strong reduction of false positive as soon as the number of considered parameter pass from one (just Radon) to two (Radon & TIR anomalies) (contemporary) considered parameters.

II. METHODS: RST AND RETIRA

Among the other parameters claimed as possible indicators of an impending seismic activity, the anomalous variations of Rn emission and the Earth's TIR emitted radiation, have been proposed, since long time, as potential earthquake precursors. However, very refined data analysis techniques are required in order to isolate residual variations, potentially associated with earthquake occurrences, from the normal variability of signal due to other causes (see for instance Tramutoli et al., 2015a; Tramutoli et al., 2005). To define/identify anomalous measured signals, since 2001 the general Robust Satellite Techniques (RST) methodology, have shown the ability of this approach to discriminate anomalous signals from the normal fluctuations of parameter related to other causes (e.g. meteorological) independent from the earthquakes occurrences

RETIRA
Robust Estimator of TIR anomalies
Tramutoli et al., 2005

$$\otimes_{\Delta T}(\mathbf{r},t) = \frac{\Delta T(\mathbf{r},t) - \mu_{\Delta T}(\mathbf{r})}{\sigma_{\Delta T}(\mathbf{r})}$$

* Cloud-detection is performed by using the One-channel Cloud-detection Approach (OCA) described in Cuomo et al., 2004

ALICE Rn

$$\otimes_{Rn}(\mathbf{r},t) = \frac{Rn(\mathbf{r},t) - \mu_{Rn}(\mathbf{r})}{\sigma_{Rn}(\mathbf{r})}$$

r≡(x,y) represent the coordinates of the center of the ground resolution cell corresponding to the pixel under consideration on a satellite image;

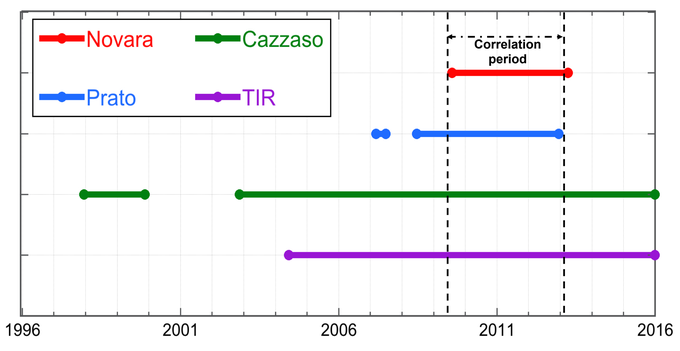
- t is the time of the measurement acquisition with $t \in \tau$, where τ defines the homogeneous domain of multi-annual satellite imagery collected in the same time slot of the day and period (month) of the year;
- $\Delta T(\mathbf{r},t)=T(\mathbf{r},t)-T(t)$ is the value of the difference between the punctual value of TIR brightness temperature $T(\mathbf{r},t)$ measured at the location x,y acquisition time t, and its spatial average $T(t)$ computed on the investigated area considering only cloud-free locations, all belonging to the same, land or sea, class
- $\mu_{\Delta T}(\mathbf{r})$ time average value of $\Delta T(\mathbf{r},t)$ at the location x,y computed on cloud-free records belonging to the selected data set ($t \in \tau$);
- $\sigma_{\Delta T}(\mathbf{r})$ standard deviation value of $\Delta T(\mathbf{r},t)$ at the location x,y computed on cloud-free records belonging to the selected data set ($t \in \tau$).
- $Rn(\mathbf{r},t)$ punctual value of Radon content measured at the station x,y acquisition time t;
- $\mu_{Rn}(\mathbf{r})$ time average value of $Rn(\mathbf{r},t)$ at the station x,y computed records belonging to the selected data set ($t \in \tau$);
- $\sigma_{\Delta T}(\mathbf{r})$ standard deviation value of $Rn(\mathbf{r},t)$ at the station x,y computed records belonging to the selected data set ($t \in \tau$).
- τ is the collection of homogeneous observational time slot in the daily (time of the day) and annual (month) solar cycle

VALIDATION analysis (1st - March 2009 – 30rd - September 2012)

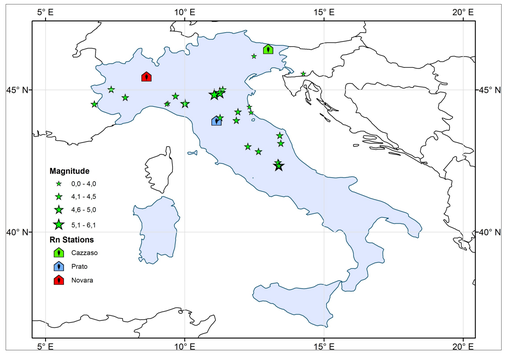
As discussed in previous papers (e.g. Tramutoli et al., 2015b) to identify Significant TIR Anomalies (STA) possibly related to an impending earthquake, the following requirements have to be preliminarily satisfied by candidate pixels:

- Relative intensity: $\otimes_{\Delta T}(r,t) \geq 3.5$
- Images affected by particular meteorological conditions (e.g. wide cloudy coverage), navigation errors (Filizzola et al., 2004), and/or know spurious effects (e.g. cold spatial average effect, Aliano et al., 2008, Genzano et al. 2009) have to be discarded
- Spatial persistence: it is not isolated being part of a group of TIR anomalies covering at least 150km^2 within an area of 1×1°
- Temporal persistence: previous conditions (i.e. the existence of a group of TIR anomalies covering at least 150km^2 within an area of 1×1° around x,y) are satisfied at least one more time in the 7 days preceding/following t.

In order to identify Significant Sequences of Rn Anomalies (SSRA) possibly related to an impending earthquake a relative intensity of $\otimes_{Rn}(\mathbf{r},t) \geq 2$ requested together with at least one repetition in the 7 days preceding/following t.

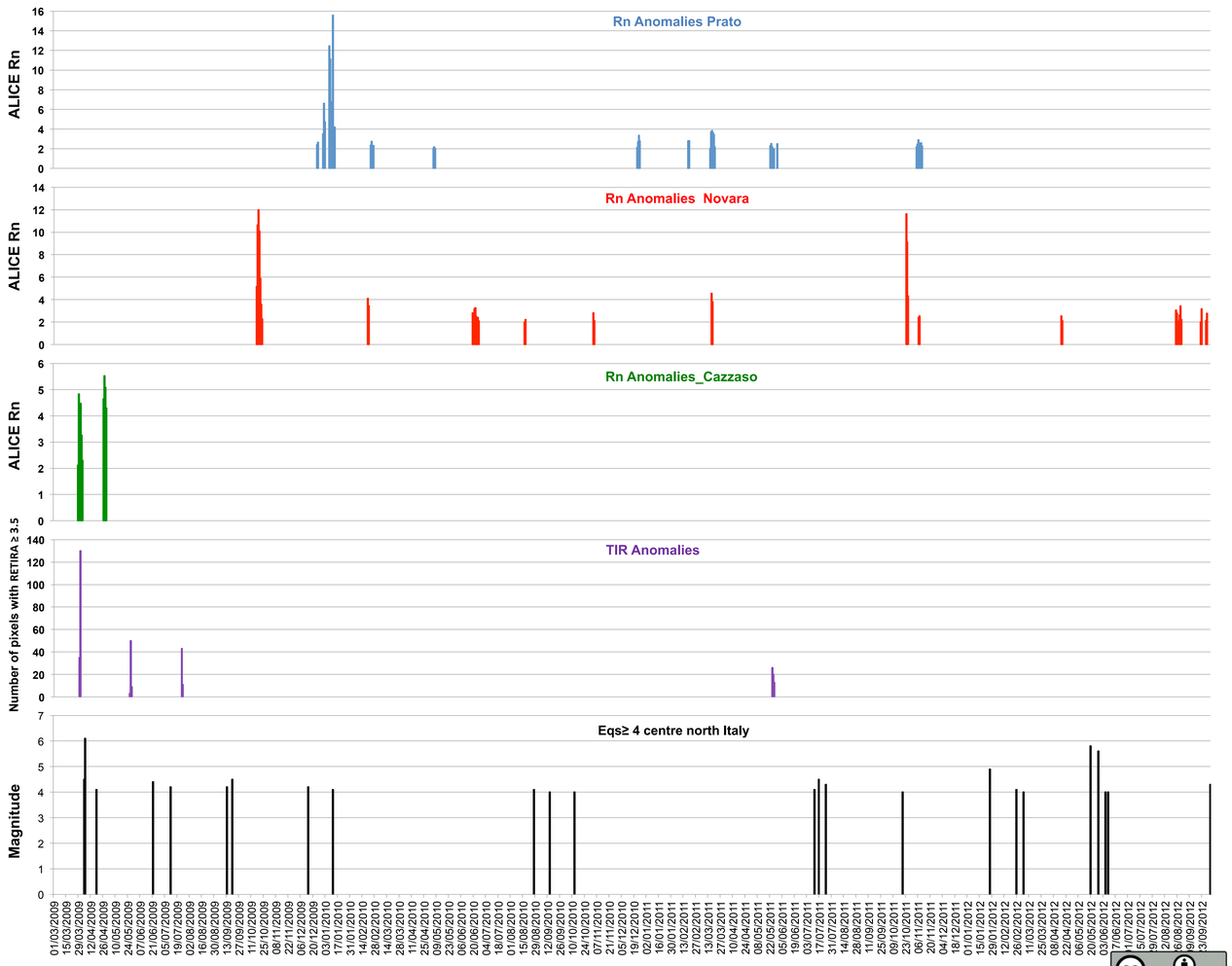


Data set at hand. Acquisition periods at radon stations operating continuous monitoring in soil and by MSG/SEVIRI sensor measuring TIR signal from space. All data used for the analysis are referring to the time slot 00:00 - 00:15



Seismic events (M≥4.0) occurred in Italy in between March 1st, 2009 and September 30rd, 2012 as reported by ISIDe Working Group.

CORRELATION ANALYSIS



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