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S3-Projetc: Short term earthquake prediction and preparation

This research has partially benefited from funding provided by the Italian Presidenza del Consiglio dei Ministri - Dipartimento della Protezione Civile (DPC). Scientific papers funded by DPC do not represent its official opinion and policies.

The Pollino seismic sequence: Can shear wave anisotropy monitoring help earthquake forecast?

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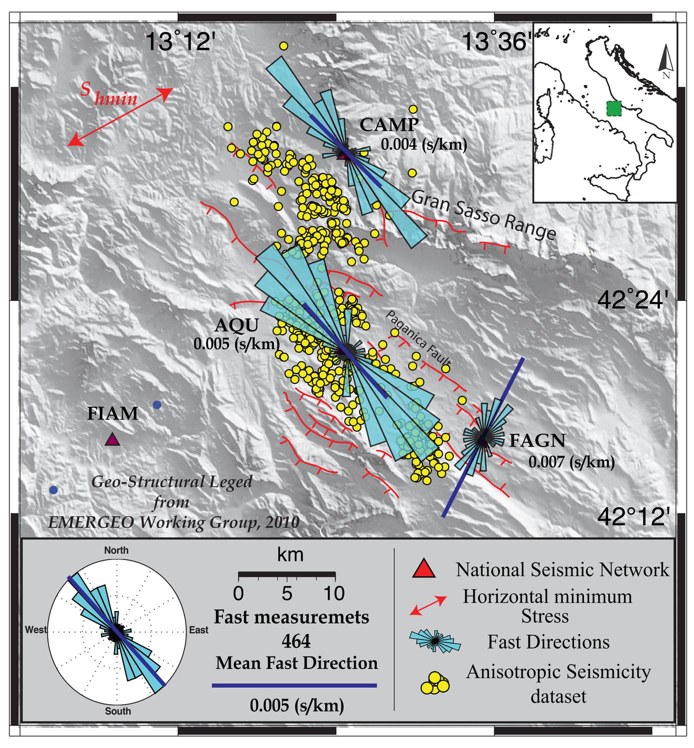
Abstract

Since the late the late '60s-early '70s era seismologists started developed theories that included variations of the elastic property of the Earth crust and the state of stress and its evolution crust prior to the occurrence of a large earthquake. Among the others the theory of the dilatancy (Scholz et al., 1973): when a rock is subject to stress, the rock grains are shifted generating micro-cracks, thus the rock itself increases its volume. Inside the fractured rock, fluid saturation and pore pressure play an important role in earthquake nucleation, by modulating the effective stress. Thus measuring the variations of wave speed and of anisotropic parameter in time can be highly informative on how the stress leading to a major fault failure builds up.

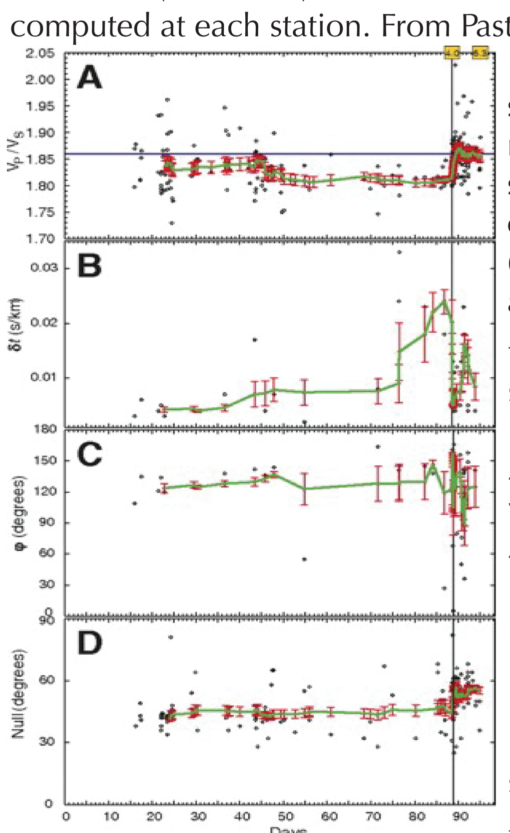
In 80s and 90s such kind of research on earthquake precursor slowed down and the priority was given to seismic hazard and ground motions studies, which are very important since these are the basis for the building codes in many countries. Today we have dense and sophisticated seismic networks to measure wave-fields characteristics: we archive continuous waveform data recorded at three components broad-band seismometers, we almost routinely obtain high resolution earthquake locations. Therefore we are ready to start to systematically look at seismic-wave propagation properties to possibly reveal short-term variations in the elastic properties of the Earth crust. In active fault areas and volcanoes, tectonic stress variation influences fracture field orientation and fluid migration processes, whose evolution with time can be monitored through the measurement of the anisotropic pa- rameters (Piccinini et al., 2006). Through the study of S waves anisotropy it is therefore potentially possible to measure the presence, migration and state of the fluid in the rock traveled by seismic waves, thus providing a valuable route to understanding the seismogenic phenomena and their precursors (Crampin & Gao, 2010).

Variations of anisotropic parameter and of the ratio between the compressional (P-wave) and the shear (S-wave) seismic velocities, the Vp/Vs (Nur, 1972)have been recently observed and measured during the preparatory phase of a major earthquake (Lucente et al. 2010). Here we show the anisotropic parameters at station MMN during the Pollinoseismic sequence 2010-2013

L'Aquila 2009

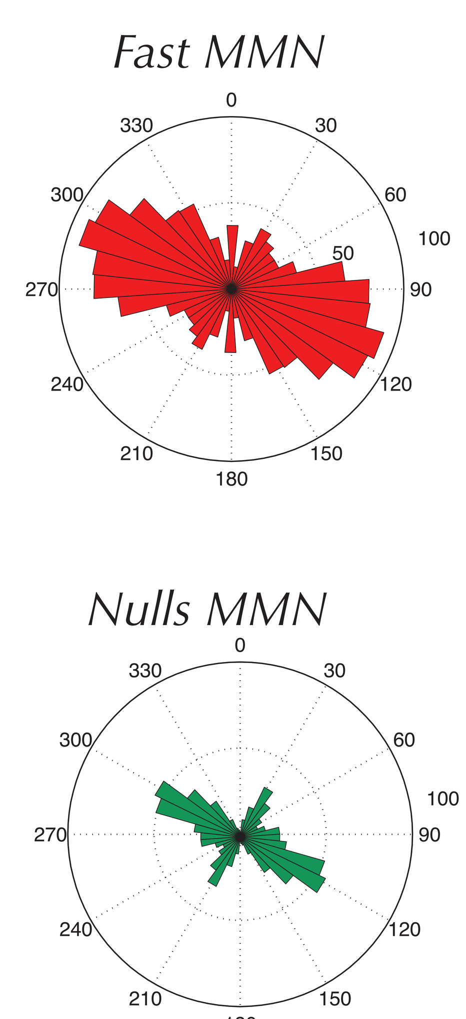


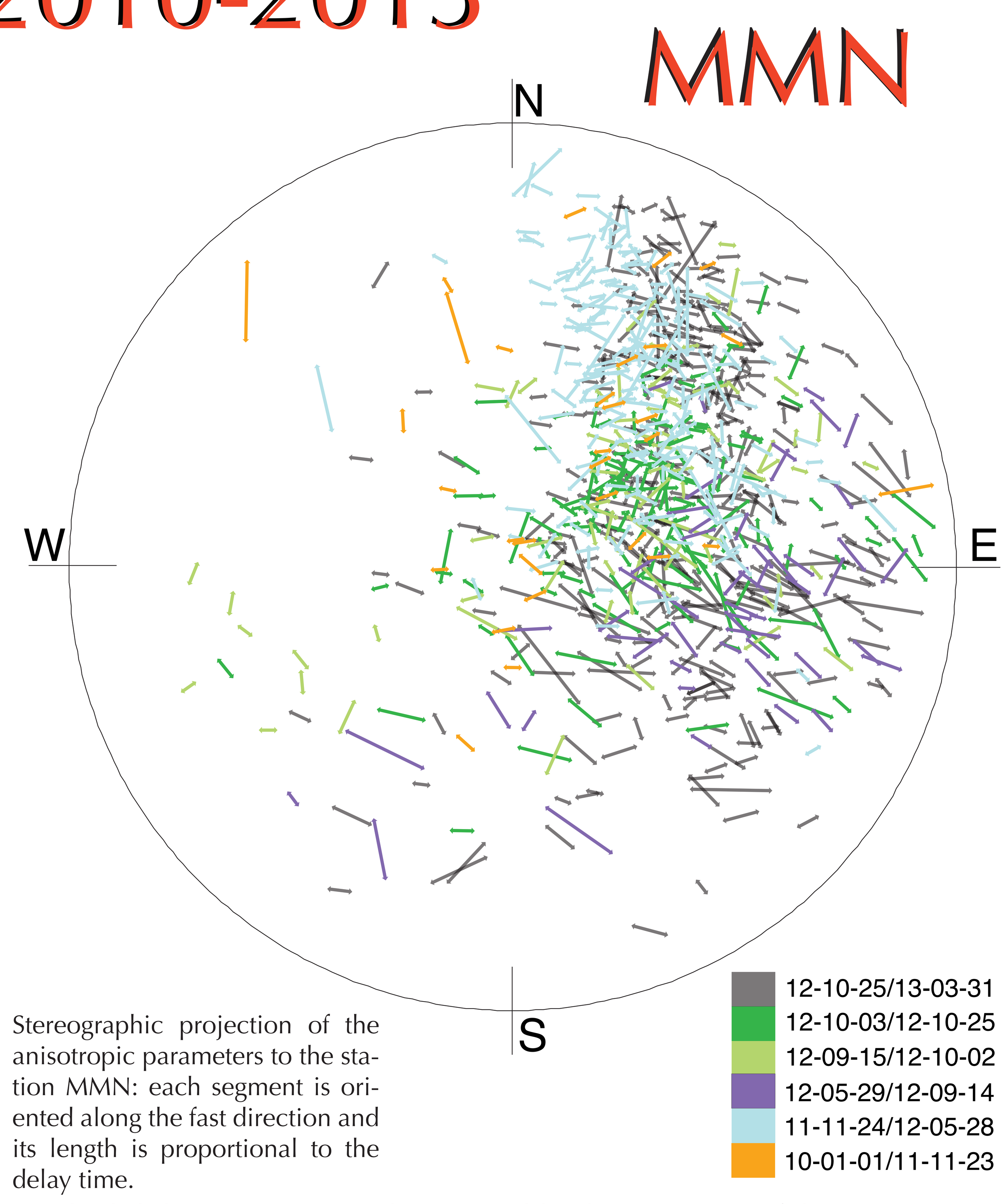
Two different representations of the obtained anisotropic results for the L'Aquila area: 1) fast direction rose diagrams, with petal size proportional to the number of the measurements, along with earthquake epicentres (yellow dots) and main structural features [red lineaments modified from EMERGEO Working group (2010)]; 2) mean fast directions (blue lines) scaled to the normalised delay time computed at each station. From Pastori et al., BGTA 2012.



Exception made for station FAGN, the directions at the other stations and the total of the measurements (lower inset) are almost perpendicular to the Shmin, which strikes about NE-SW. Comparison between time series of VP /VS (ratio between compressional-wave and shear-wave velocity) and anisotropy param- eters at AQU. A: VP /VS values at stations AQU. B: Normalized delay time dt (delay time divided by length of S-wave path). C: Azimuth f of fast shear-wave polarization direction. D: Azimuth of shear waves linearly polarized: null directions. On each panel, vertical line represents time occurrence of ML = 4 foreshock; black circles are individual measurements; red circles are mean values; red vertical bars indicate stan- dard deviation of mean; green lines are mean values interpolating functions. Mean values are calculated on running windows of 20 samples with 1 sample step in A and D, and of 5 samples with 1 sample step in B and C. From Lucente et al., Geology 2010.

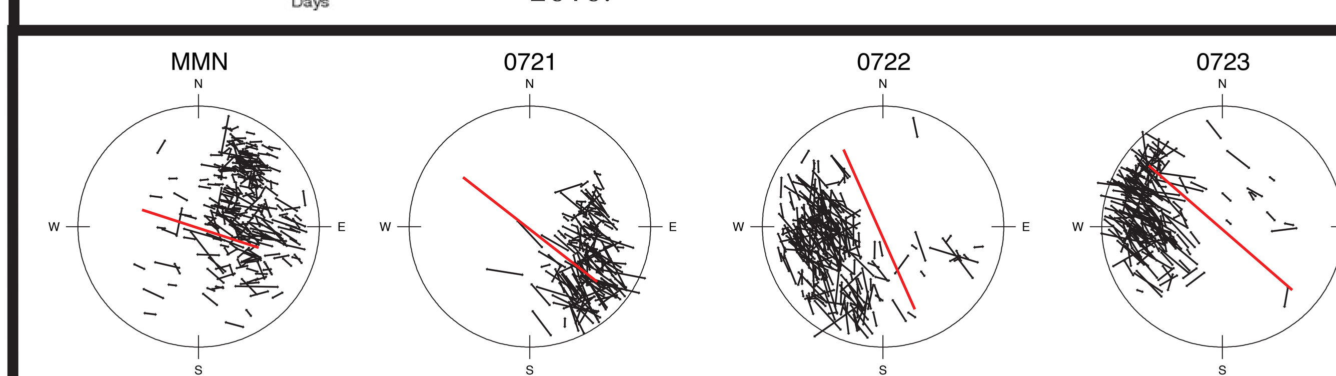
Pollino 2010-2013





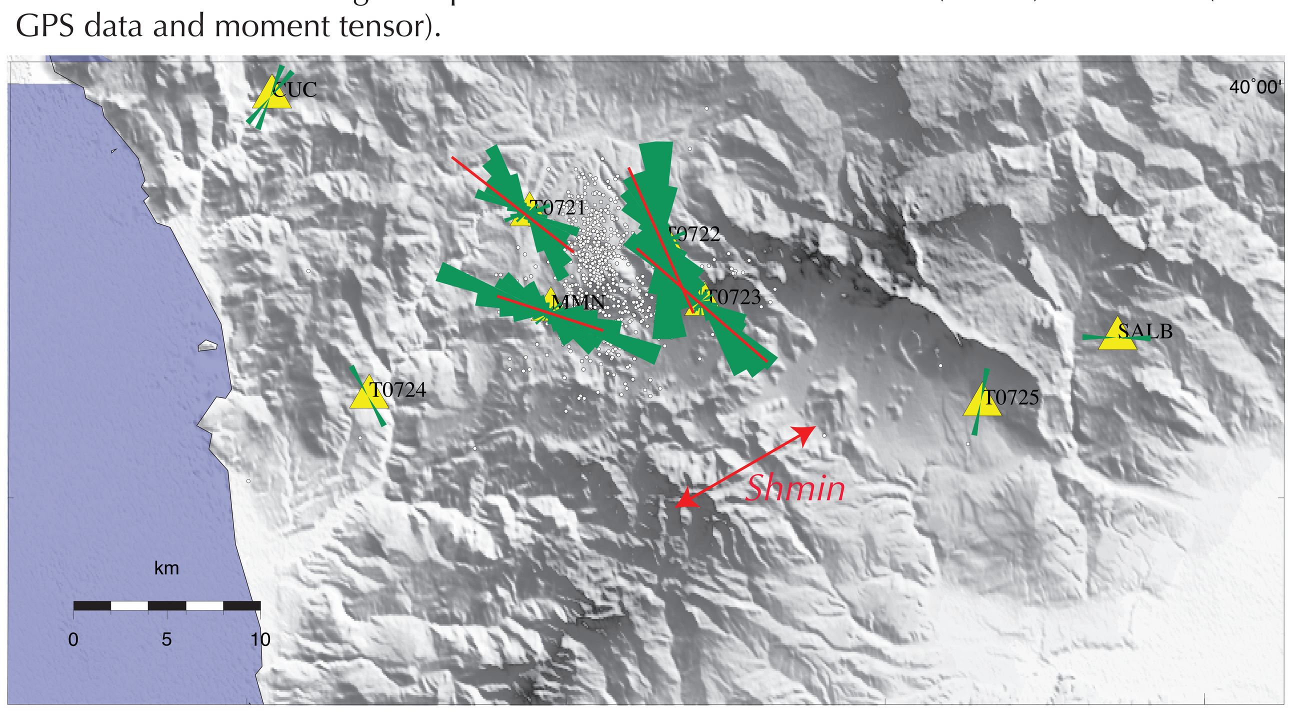
Stereographic projection of the anisotropic parameters to the station MMN: each segment is oriented along the fast direction and its length is proportional to the delay time.

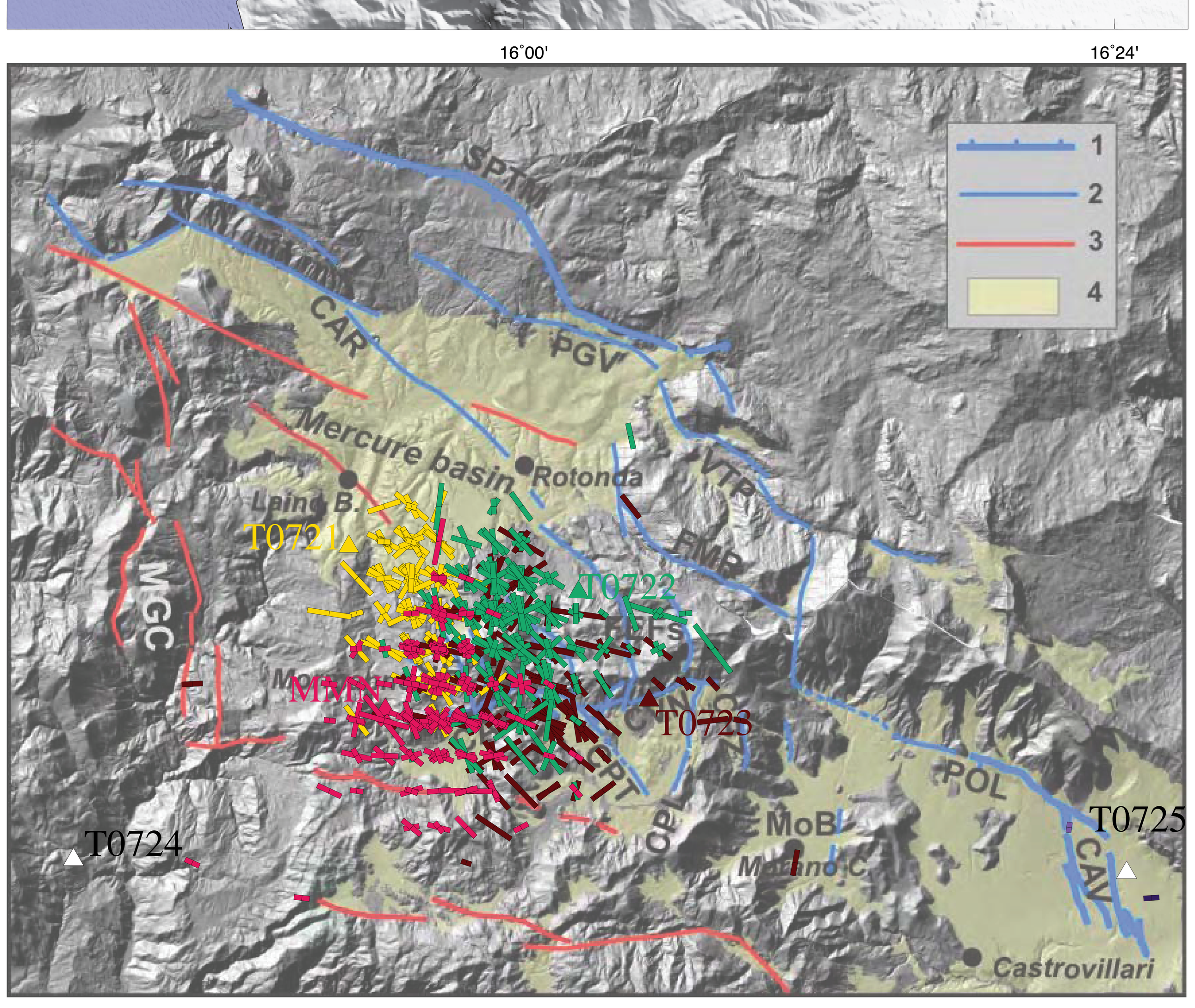
We divided dataset into 5 periods, separated by the occurrence of the 2012 strongest events (24/11/2011, 28/05/2012 M=4.3, 14/09/2012 M=3.7, 01/10/2012 M=3.6, 25/10/2012 M=5.0). the anisotropic parameters are shown using stereographic projection: The center of stereographic projection represents the station MMN while the position of the bar represents the backazimuth of the event and the distance from the center is a function of the angle of incidence geometry (the outer circle represent 45 degrees).



To understand how the anisotropic parameters vary spatially we analyzed waveforms recorded at stations installed after the occurrence of the earthquake of 25 October 2012. The red bars in the center of the stereographic projection represent the average direction of the fast measurements at the stations. The average values of Δt range from 0.05 seconds at MMN to 0.08 seconds at T0723 station. Fast directions range from 108°N at MMN to 156°N at T0722.

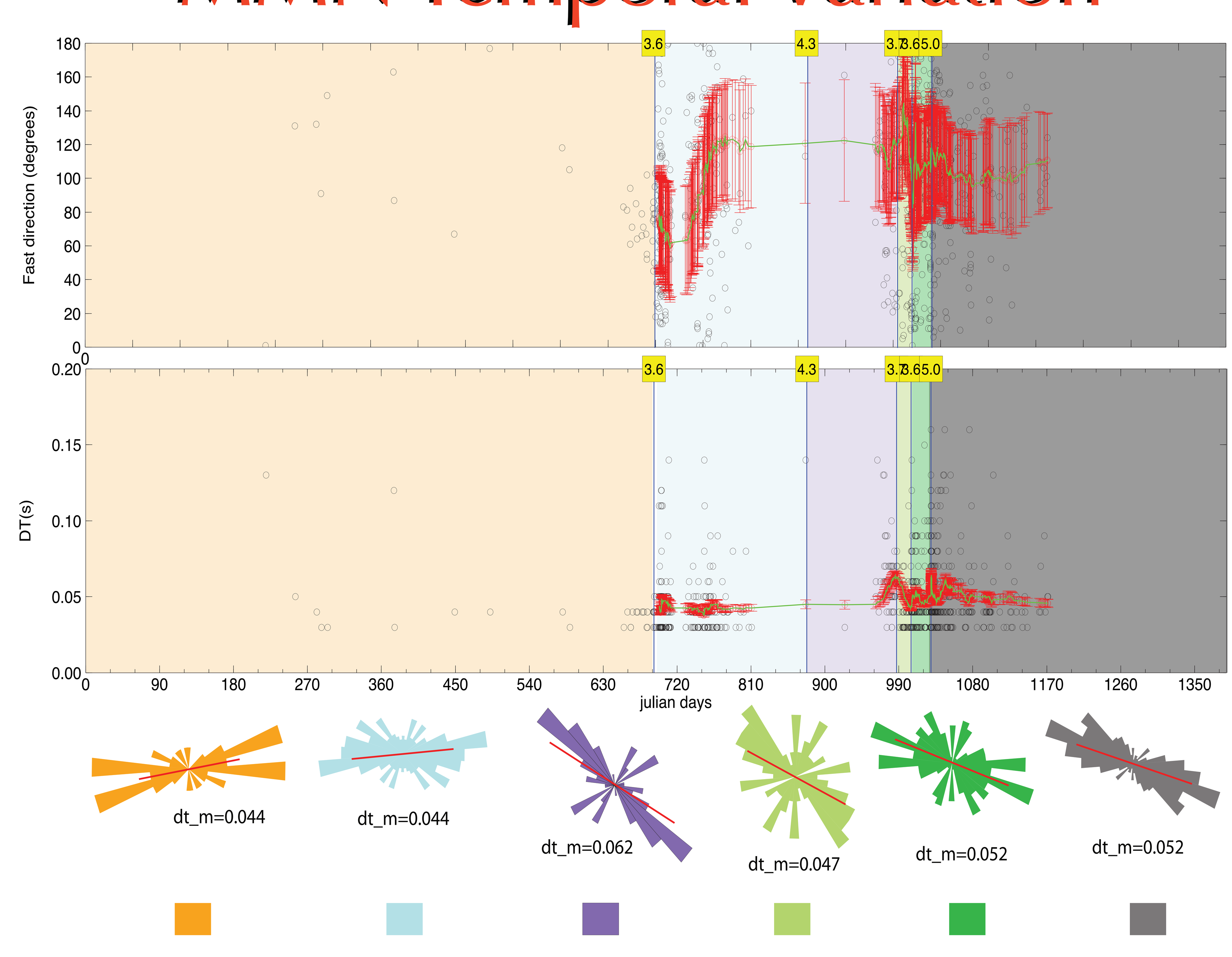
The Green rose diagrams on the map below are frequency plots representing how fast directions trending NW-SE are prevalent at all stations with a significant number of measures. The black arrow in the figure represents the direction of extension (Shmin) in the area (from GPS data and moment tensor).





Anisotropic parameters for the aftershoks of th M=5 earthquake at the stations in the area over the map of Middle-Late Quaternary extensional fault, (Preliminary version of Brozzetti et al S1). 1 – blue lines with barbs: normal faults whose present activity is suggested by seismological and paleoseimological data; 2 - Light blue: W-SW and S-SEdipping normal faults; Red: E –NEdipping normal faults. 4: outcrop of Quaternary continental successions. Parameters are projected at the piecing point of the S ray at half the hypocentral depth.

MMN Temporal Variation



Temporal trend of fast directions and delay time at MMN, averaged over time for the period 2010 - 2010. The vertical bars and color changesrepresent 6 events with magnitude greater than 3.5 (24/11/2011; 28/05/2012 M = 4.3; 19/08/2012 M = 3.7; 14/09/2012 M = 3.7; 01/10/2012 M = 3.6; 25/10/2012 M = 5.0). The gray circles are the individual measurements, the green lines represent averaged values over 50 measurements. We considered allparameters with cc greater than 0.7 and delay time greater than 0.02s. The averaged trends are obtained using the running average algorithm and an overlap length of SM-1 points. Frequency plots of fast direction for each period are shown in different colors, the red bar is the average for the period. The colors are the same used in the stereographic projection on MMN on the top.

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Ringraziamenti: Le stazioni temporanee sono state installate dai gruppi rete mobile INGV di Roma e Grottaminarda in collaborazione con L'Università della Calabria (Margheriti et al 2013) e il German Research Centre for Geoscience (GFZ) (Govoni et al 2013). Per i dati delle stazioni temporanee si ringraziano Aladino Govoni e Milena Moretti, per le letture dei tempi di arrivo delle onde P ed S e per le localizzaioni si ringrazia il gruppo INGV surfanelpick ed in particolare Pasquale De Gori e Francesco Pio Lucente.