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The stress-field variation on the Italian active volcanic areas: the shear wave splitting monitoring

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Shear wave splitting is the elastic-equivalent of the well-known phenomenon of optical birefringence. A shear wave propagating through an anisotropic volume splits into two S-waves (qS1 and qS2) that travel with different velocities and different polarization directions. This process generates two observables: Td is the time delay between the two split S-waves, and phi is the polarization direction of the faster one, qS1. Seismic anisotropy is widely observed in the upper crust, regardless of the tectonic setting. This phenomenon has been interpreted as occurring in zones of fluid-filled cracks, microcracks or preferentially oriented pore spaces. The time evolution of anisotropic distribution of microcracks due to a differential stress, according to the nonlinear anisotropic poroelasticity (APE) model, is explained by fluid migration along pressure gradients between neighbouring microcracks and pores. Stress intensity variations cause modifications of the fluid mobility and consequently of the anisotropic characteristics of the medium. In this framework the shear wave splitting parameters, Td and phi, are indicators of the stress field in the upper crust. Time delay variations are related to changes in microcrack densityand aspect ratio, while the polarization directions of the two S-waves interchange (90°-flip of phi) when the system reaches the overpressurized regime (Crampin et al., 2004 and references therein).

The main goals of our analysis are:
1) to improve the splitting parameter estimation for monitoring purposes;
2) to define Td and phi background values (i.e. out of eruptive periods);
3) to look for temporal variation of the two observables and its relationship with volcanic activity.

Regarding the first point, we set up a semi-automatic procedure for measuring the splitting parameters in quasi-real time. Regarding points 2) and 3), we performed shear wave splitting measurements on local earthquakes, recorded in the following Italian active volcanoes: Vesuvius, Campi Flegrei and Etna.

Mt. Vesuvius experienced various regimes of eruptive activity, from effusive to Plinian. Its last eruption occurred in March, 1944, and was a mild effusive event that concluded a period of almost continuous activity dating back to 1631. Since the 1944 eruption ended, the volcano has started a period of quiescence that seems to indicate a closure of its conduit. Up to the time of writing, Vesuvius activity consists of low seismicity and a little degassing at the crater top. We found splitting parameter variations from the background values during two seismic swarms, in 1996 and 1999, in which the largest earthquakes were M 3.4 and M 3.6 respectively. At Campi Flegrei the most recent activity in 1538 has been the formation of a 200 m height spatter cone, preceded by a ground uplift of several meters. After this event, the caldera floor started sinking continuously and aseismically. This general trend is occasionally interrupted by faster resurgence episodes, accompanied by earthquake swarms. We measured the splitting parameters during the last 3 uplifts: 1982-1984 (180 cm of deformation); 2000 (6 cm of deformation); and 2005-2006 (3 cm of deformation). We found a complex pattern for both splitting parameters in both spatial and temporal domains.

Mt. Etna has experienced many eruptions and its almost persistent seismicity makes it a natural laboratory for volcano-seismic studies. We calculated the splitting parameters searching for their variations related to the 1988, 1989, 2001 and 2002 eruptions. The background value of phi is parallel to the direction of the compressive stress field acting on the area, but it shows some variation especially before or during the eruptions. Also the time delays changed, depending on the periods considered and on the eruptive activity.

It has been possible to test the validity of this new semi-automatic method through the comparison of our results with those obtained in previous works for the same datasets (see Bianco et al., 1996,1998a, 1998b, 1999, 2004, 2006; Del Pezzo et al., 2004; Zaccarelli et al., 2009). We interpret the observed time variations of the splitting parameters as indicators of complex stress changes, discussing their role as precursors of critical events such as major earthquakes or eruptions in the investigated areas.

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