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Analysis of low frequency seismic signals recorded at Stromboli Volcano

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During September-October 1997, the seismic activity of Stromboli Volcano (Aeolian Islands, Italy) has been monitored by broad-band seismometers. The recorded seismic signals show the typical strombolian activity, characterised by discrete explosions superimposed on the background of tremor. In present work, we study long series of tremor in the frequency range 0.02-0.5 Hz, starting from preliminary results obtained by De Martino et al. (2004).

Spectral analysis of tremor series shows the existence of low frequencies (period around to 30-40s - long period tremor). Moreover this analysis shows that the spectrum of Strombolian tremor is approximately divided in three frequency bands: 1-10 Hz, 0.1-1 Hz, 0.02-0.1 Hz. Lowest frequencies usually have low amplitude compared with highest frequencies and approximately equal to amplitude of frequencies of the central band. Therefore, long period oscillations have never been observed in the raw seismograms. We have analysed the time evolution (spectrogram) of amplitude of long period. These frequencies are not continuous along the series. Only during a period of recording they appear intense and practically continuous and they are visible also in the raw seismograms. In order to investigate the properties of long period tremor we have used techniques typically applied in seismology together with analysis not common in this matter. The Independent Component Analysis (ICA) is a statistical technique never used in seismology before some years ago. The basic idea of ICA is that a signal can be considered as a linear superimposition of some mutually statistically independent source functions. The independent components are extracted maximizing their non-gaussianity. We have applied this analysis on low frequency tremor ($<$0.5 Hz). Two components are extracted with different spectral properties: one has 30-40 s period (long period tremor), the other one has about 3 s period. The second component appears as a beat. The polarization analysis has been carried out

on the tremor filtered under 0.5 Hz. We have used the eigen-decomposition of the covariance matrix (Kanasawich, 1981). This analysis shows two different directions of polarization corresponding to different filters: band-pass between 0.02 and 0.1 Hz and 0.1 and 0.5 Hz. The projections of vectors of polarization on E-O N-S plane, calculated using tremors filtered between 0.1 and 0.5 Hz, are directed towards a region at N-O of the vents. In this zone it has been localized also the source of explosions [Chouet et al., 2003]. Instead, when the polarization vectors, calculated using tremors filtered in the range [0.02 - 0.1]Hz, to isolate long period tremor, are projected on E-O N-S plane they seem very different from the vectors of polarization calculated using the previous frequency filter, even though they do not characterize one source region. Horizontal particle velocities observed on the network confirm the results on polarization analysis, for both frequency band filters. Moreover, they show that some stations of middle ring have recorded long period tremor with very high rectilinearity (next to one), while at some other stations the direction of polarization of these waves does not appear with this evidence, also being nearly always identifiable. In order to gain information about the dynamical system that governs long period tremor we used the technique introduced by Takens (1981), by which we have reconstructed the time evolution in the phase space. We have found that such dynamics may be explained by a trajectory whose dimension is approximately 1.05 - calculated by Grassberger and Procaccia method (1983). The dynamical system generating long period tremor is very simple and the asymptotic dynamics evolves in a zone of the phase space similar to limit cycle. Moreover, it turns out that long period tremors are generated by only one dynamical system. In fact, through the procedure described by Paladin and Vulpiani (1987) we have proved that 180 trajectories corresponding to different tremor series are on an unique attractor.

References

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