GROUND TILT OBSERVATIONS IN AN ACTIVE GEODYNAMIC AREA OF SOUTHERN ITALY: THE CALABRIA ARC SYSTEM

A. Albano[1], A. Gervasi[2,3], I.Guerra[3], G. Corrado[3]
[1] *Istituto Statale di Istruzione Superiore, Baronissi (SA), Italy*
[2] *Istituto Nazionale di Geofisica e Vulcanologia, CNT, Sede di Rende (CS), Italy*
[3] *Università della Calabria, Dip. di Biologia, Ecologia e Scienze della Terra, Arcavacata (CS), Italy*

In the past years we presented at the GNGST meetings the results obtained progressively by elaborating the continuous recordings of gravity and ground tilt at the *ad hoc* station activated in 2011 inside the Calabria University settlements (ϕ = 39°.359005 N; λ = 16°.226858 E; h = 221 m asl), limiting ourself to the time variations of g (e.g. Albano *et al*., 2011, 2013). A quite detailed description of the station and the models of the gravity tide and of the tidal field in northern Calabria were reported and discussed by Albano *et al*. (2015). Long term aim of these activities is the improved knowledge of the overall geophysical frame that will be the scenery of possible medium and high energy earthquakes expectable in the region on the basis of its past history and geodynamical features. With this in mind, the Geophysics and Seismology Laboratory of the Calabria University developed in the last decades a multidisciplinary system of scientific monitoring devices.

We report here the results obtained by the analysis of four years (May 2011 - May 2015) of continuous tilt observations at the Calabria University site.The Earth's surface is feeling changes of the atmospheric temperature and pressure spanning a wide spectrum both in space and time. The diurnal rotation and the orbital motion of the Earth are sources of fluctuations of the air temperature and pressure at the surface with main daily and annual periods. Moreover random fluctuations (weather continuum) are superimposed to these fundamental frequencies, associated with the changes of the weather patterns. Owing to the propagation of the thermal wave through the Earth's surface, stresses and ground tilts are induced in the rocks of the upper crust by thermo-elastic effect. A model of the temperature induced tilt and strain at the Earth's surface was provided by Berger (1975). Changes of the atmospheric pressure also induce deformations in the Earth's crust. The size of such effects are considerably influenced by the physical parameters of the surface rocks (e.g. the water content) and depends also on both the space and time patterns of the thermal and baric fields. Strain and tilt of thermo-baric origin at the Earth's surface can be considered as a noise masking or distorting the effects of other

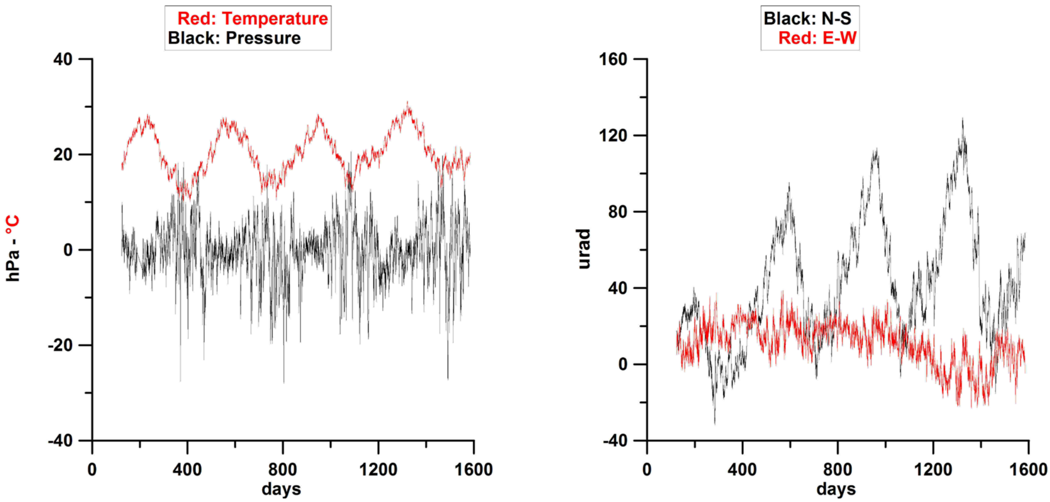

Fig. 1 - Changes versus time of the air temperature and atmospheric pressure (left) and of the tilt components (right) at the Calabria University station.

geophysical sources. (i.e. slow earthquakes) and therefore they must be filtered out from tilt signals. We show in Fig. 1 the time behaviour of the hourly values of the atmospheric pressure and temperature and of the E-W and N-S components of the ground tilt at the station.

The analysis of the tilt records points out a clear influence of the fluctuations of the air temperature on ground deformation, mainly at annual and diurnal periods. We observe a significant correlation between the seasonal trends of the temperature T and N-S component (r = 0.8) while a weak inverse correlation affects the E-W component.The spectral analysis of the cross-correlation function between the deviations of T and tilt components from the seasonal trends, highlights the presence, in both E - W and N - S components, of significant energy in the band of the diurnal frequencies. Being $T(t)$ and $p(t)$ mutually correlated (Fig, 2), it is hard, and practically impossible, to build the functions $f_p[p(t)]$ and $f_T[T(t)]$ accounting for the influence of $p(t)$ and $T(t)$ on the tilt signal $s(t)$. The Ocean Tide Load contribution to the tilt at the station is here neglected as it results of the order of magnitude of 10^{-3} μrad for the main tidal waves.

We propose here a statistical numerical procedure aimed at removing from the ground tilt measurements the joint effects of the atmospheric temperature and pressure changes. Let $s(t)$ be the signal and $c(t)$ the joint contribution to $s(t)$ of both the atmospheric pressure $p(t)$ and temperature $T(t)$; then $s(t)$ could be expressed by the general relationship:

$$s(t) = c(t) + r(t) = f_p[p(t)] + f_T[T(t)] + r(t) \tag{1}$$

where $r(t)$ is the residual part of the signal not affected by $p(t)$ and $T(t)$. The most general relationship correlating the signal s(t) with p(t) and T(t) is a time convolution relation:

$$s(t) = \int_{-\infty}^{\infty} a(t')\, p(t-t')\, dt' + \int_{-\infty}^{\infty} b(t')\, T(t-t')\, dt' + r(t) \tag{2}$$

The admittance functions $a(t)$ and $b(t)$ in eq. (2) are the solutions of the multiple regression simultaneous equations (Hannan, 1970):

$$\begin{aligned} \Phi_{pp}(\omega)\, A(\omega) + \Phi_{pT}(\omega)\, B(\omega) &= \Phi_{sp}(\omega) \\ \Phi_{Tp}(\omega)\, A(\omega) + \Phi_{TT}(\omega)\, B(\omega) &= \Phi_{sT}(\omega) \end{aligned} \tag{3}$$

where $A(\omega)$ and $B(\omega)$ are the Fourier Transform (FT) of $a(t)$ and $b(t)$ and Φ_{ij} denotes the cross power (FT of the cross correlation function) between any couple of the variables $p(t)$, $T(t)$ and $s(t)$; ω is the angular frequency. Once $A(\omega)$ and $B(\omega)$ have been computed they can be back

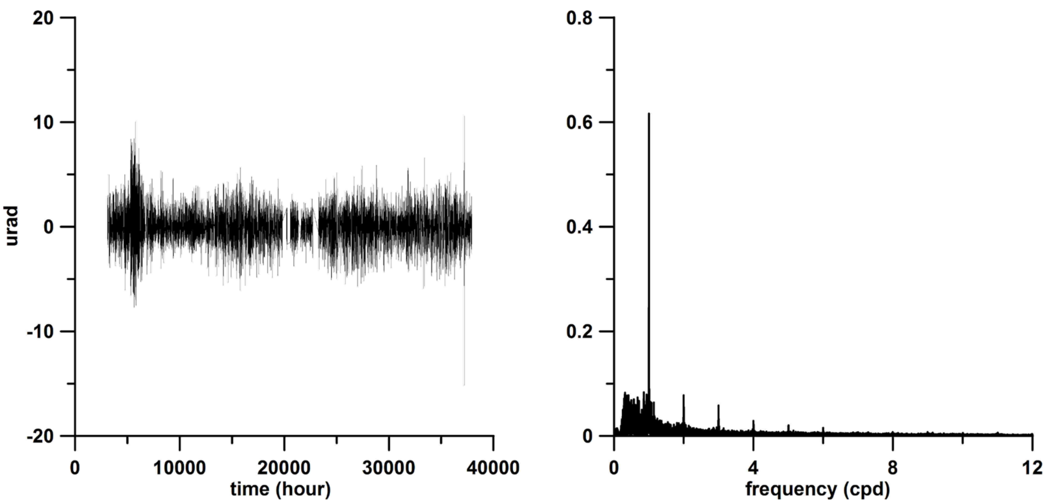

Fig. 2 - Contribution to the tilt of the temperature (left) and the pertinent spectral content (starting time of the plot is 2011, May 9 at 4h 00m 00s GMT).

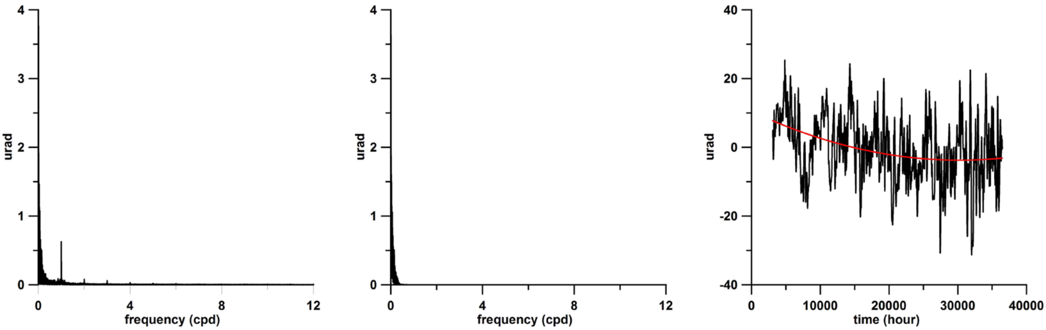

Fig. 3 - Spectra of the tilt, before (left) and after (centre) the application of the procedure and the residual tilt (right) (starting time of the plot is 2011, May 9 at $4^h\ 00^m\ 00^s$ GMT). The red line represents the average trend.

transformed to obtain $a(t)$ and $b(t)$. This allows, via Eq. (2), the computation of the residual signal $r(t)$.

We have applied the described procedure to the tilt signal resulting from the vectorial sum of the E-W and N-S components of the ground tilt. In the Fig. 2 (left) the total contribution to the tilt of the temperature and pressure changes is shown together its spectral content (right).

In the Fig. 3 the spectra of the signal, before and after the application of the procedure, are represented. In the right plot of the same figure, the residual tilt depurated of the contribution given by the temperature and pressure is shown. Here the red line represents the average trend of the tilt, mainly in the north-south direction (immersion southward), on which fluctuations of variable amplitude are superimposed. An average decrease of the tilt is observable till the end of 2013, reaching a total of 11 μrad; later the observed trend remains constant. The fluctuations around the average trend result randomly distributed with an average amplitude of 9 μrad.

Two points of conclusion. The proposed algorithm seems efficiently able at the removal from the ground tilt records of the combined influence of the atmospheric temperature and pressure. A slow significant ground tilt affects the site where the station is located. Attempts of understanding the geophysical meaning of the observed trend require analogous observations to be carried at sites near that being monitored.

References

Albano A., Corrado G., Gervasi A., Guerra I., 2011. *La stazione gravimetrica registratrice dell'Università della Calabria*. 30° Conv. Ann. GNGTS, Trieste.

Albano A., Corrado G., Gervasi G., Guerra I., 2013. *Continuous gravity and tilt observations in Calabria*. 32° Conv. Ann. GNGTS, Trieste.

Albano A., Corrado G., Gervasi A., Guerra I. ;2015. *Continuous gravity and tilt observations in an active geodynamic area of Southern Italy: the Calabria Arc System*. Boll. Geofis. Teor. Appl., 56, 1-18.

Berger J.; 1975. *A note on thermoelastic strains and tilts*. J. Geophys. Res., 88, 2.

Hannan E. J., 1970. *Multiple Time Series*. J. Wiley & Sons, .536 pag.