Three-axial Fiber Bragg Grating Strain Sensor for Volcano Monitoring

Umberto Giacomelli[1](umberto.giacomelli@df.unipi.it), Nicolò Beverini[1], Daniele Carbone[2], Giorgio Carelli[1,3], Francesco Francesconi[1,3], Salvatore Gambino[2], Enrico Maccioni[1], Mauro Morganti[4,5], Massimo Orazi[6], Rosario Peluso[6], Fiodor Sorrentino[3,7]

(1) Dipartimento di Fisica, Università di Pisa, Pisa, Italy, (2) INGV - Osservatorio Etneo, Sezione di Catania, Catania, Italy, (3) Marwan Technology Srl, Pisa, Italy, (4) Istituto Nazionale di Fisica Nucleare, Sezione di Pisa, Pisa, Italy, (5) Accademia Navale di Livorno, Livorno, Italy, (6) INGV - Osservatorio Vesuviano, Napoli, Italy, (7) Istituto Nazionale di Fisica Nucleare, Sezione di Genova, Genova, Italy

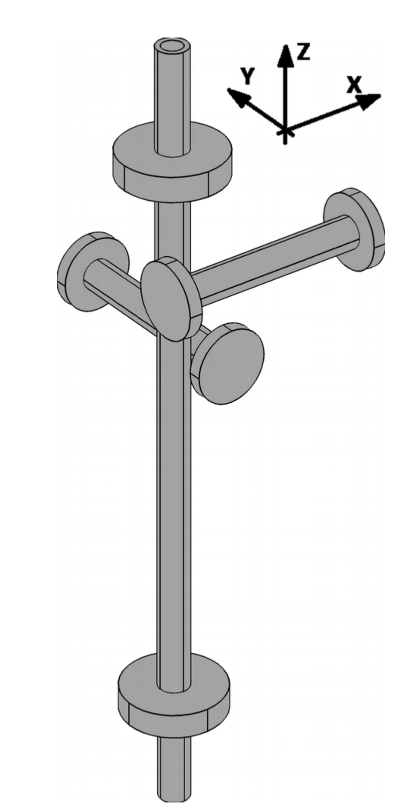
ABSTRACT

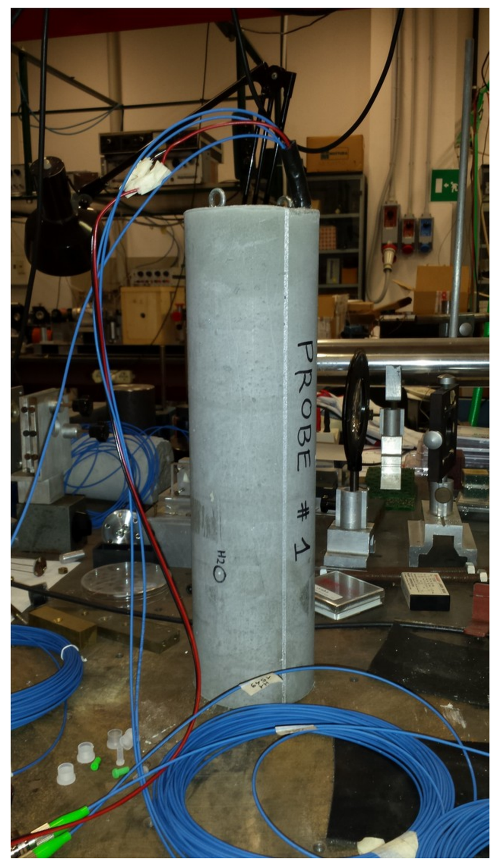
Stress and strain behavior is among the best indicators of changes in the activity of volcanoes. Deep bore-hole dilatometers and strainmeters have been employed for volcano monitoring. These devices are very sensitive and reliable, but are not cost-effective and their installation requires a large effort. Fiber optic based devices offer low cost, small size, wide frequency band, easier deployment and even the possibility of creating a local network with several sensors linked in an array. In the framework of the MEDSUV[1] project we present the realization, installation and first results of a shallow-borehole (8,5 meters depth) three-axial Fiber Bragg Grating (FBG) strain sensor prototype.

Sensor Design

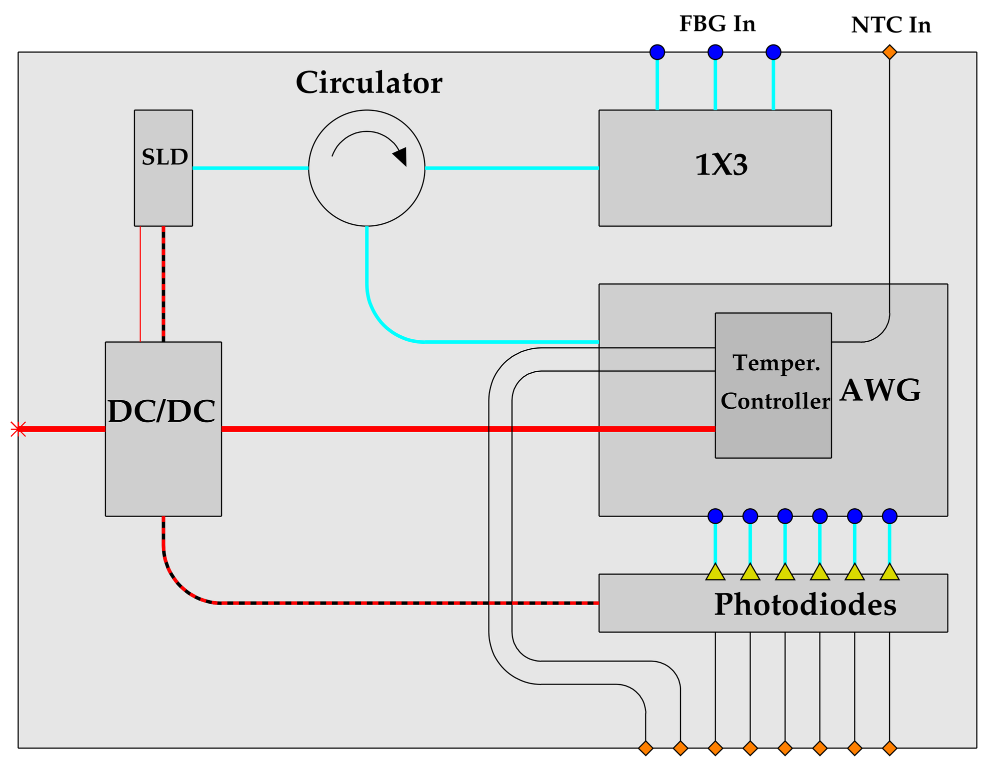
The instrument is composed by three different FBG sensors, placed along three orthogonal axes. Thanks to the bragg grating peculiarities it is easy to link the characteristic bragg grating wavelength variations ($\Delta\lambda_b$) to the grating strain (ε) and temperature (ΔT) variations[2]:

$$\Delta\lambda_b = A\varepsilon + B\Delta T$$



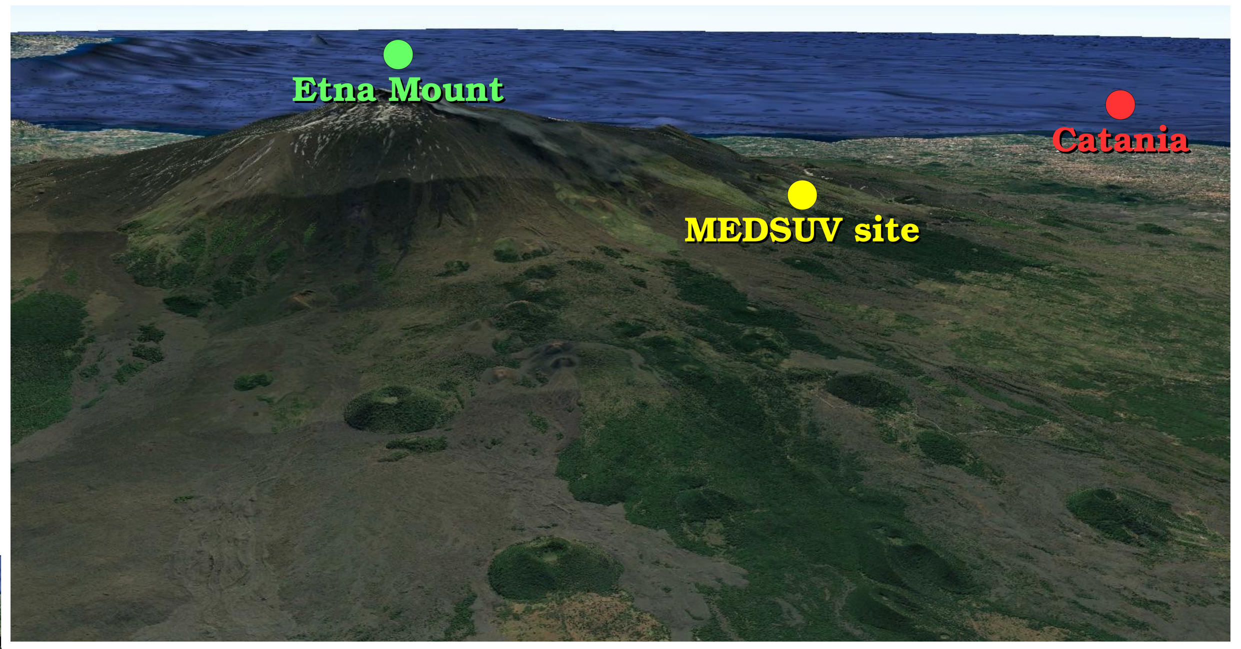


The final sensor set up consists in a concrete cylinder containing the three FBG and a NTC probe. The three fiber containing the FBG are encapsulated in three metallic tube, in order to maximize the sensitivity to the longitudinal stress and to protect the gratings. These three tubes are walled up in the concrete cylinder with the temperature probe.



The data acquisition system is based on an electro-optic system that converts the FBG optical variations into voltage signals and a dedicated acquisition system: Geophysical Instruments for Low power Data Acquisition (GILDA)[3]

Installation



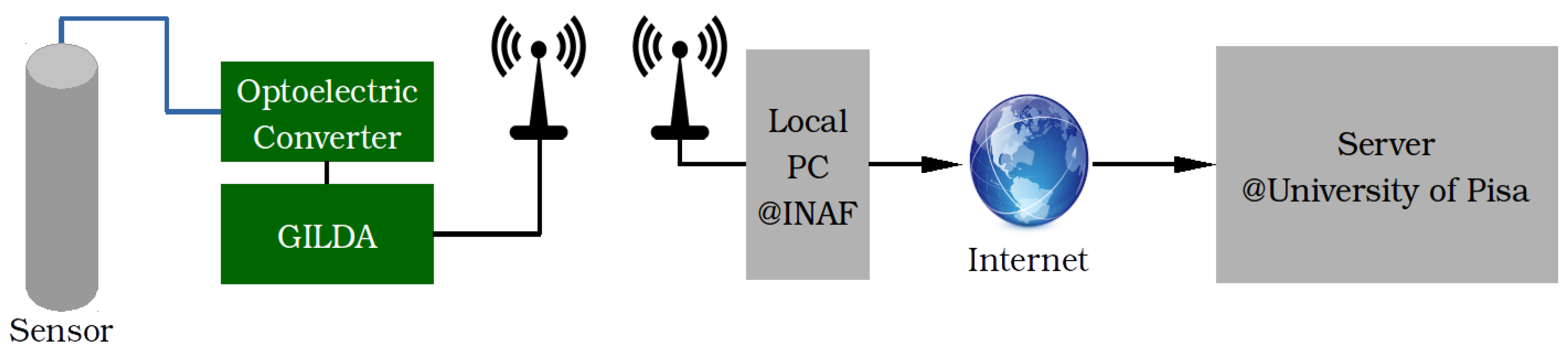
The installation site is near the INAF observatory Serra la Nave (37°41'35.1"N 14°58'28.3"E) at about 1725 meters above sea level

We have installed the sensor in a borehole 8.5 meters deep. Once it has reached the bottom, we have cemented it filling one meter of borehole with concrete. The control system has been located few meters from the borehole in a waterproof box.

At the end of the installation procedure we have measured the orientation angle with respect to the North with a precision of 1 degree

Special thanks to the INAF (Istituto Nazionale di AstroFisica) that provided us with the installation facilities

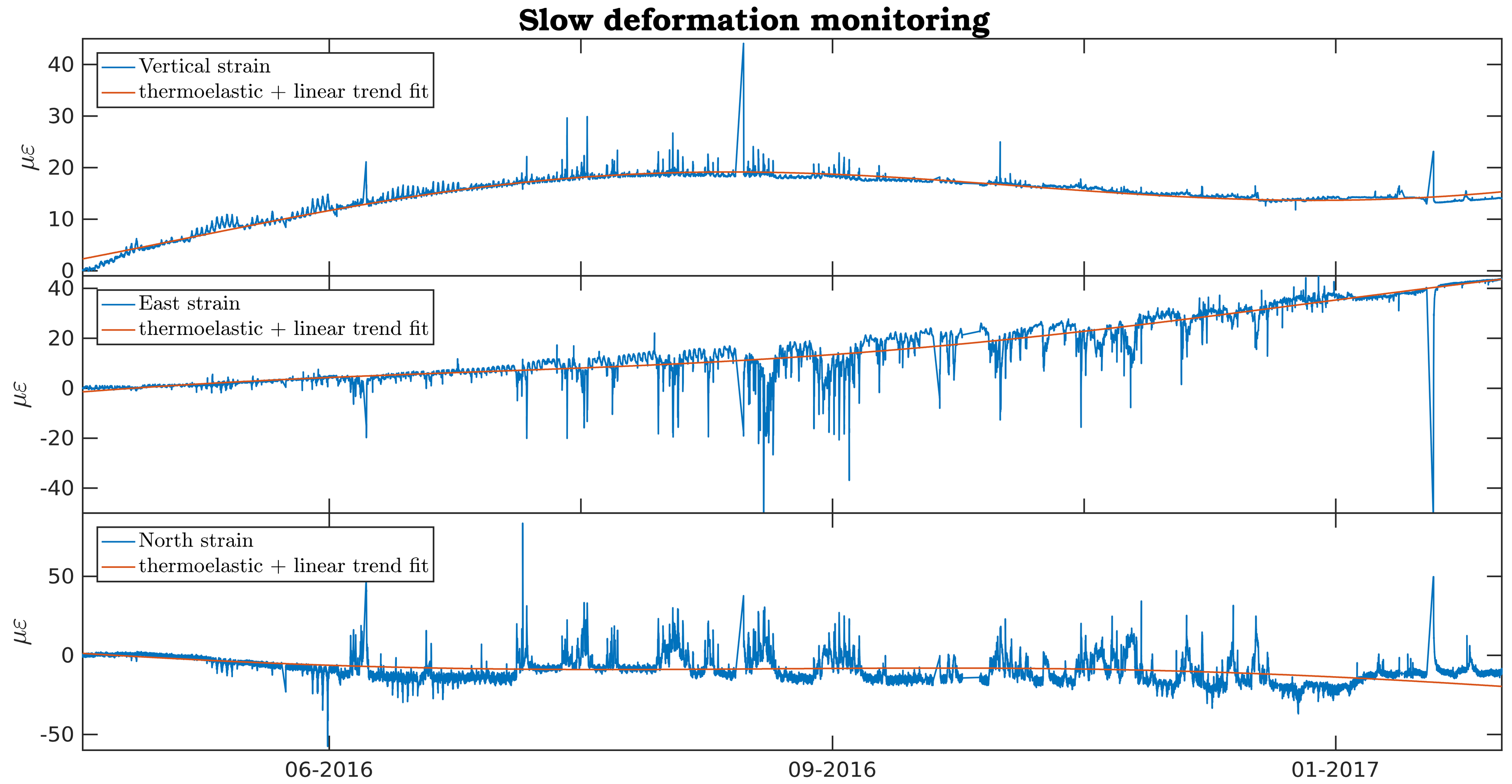
Data Acquisition & Transfer



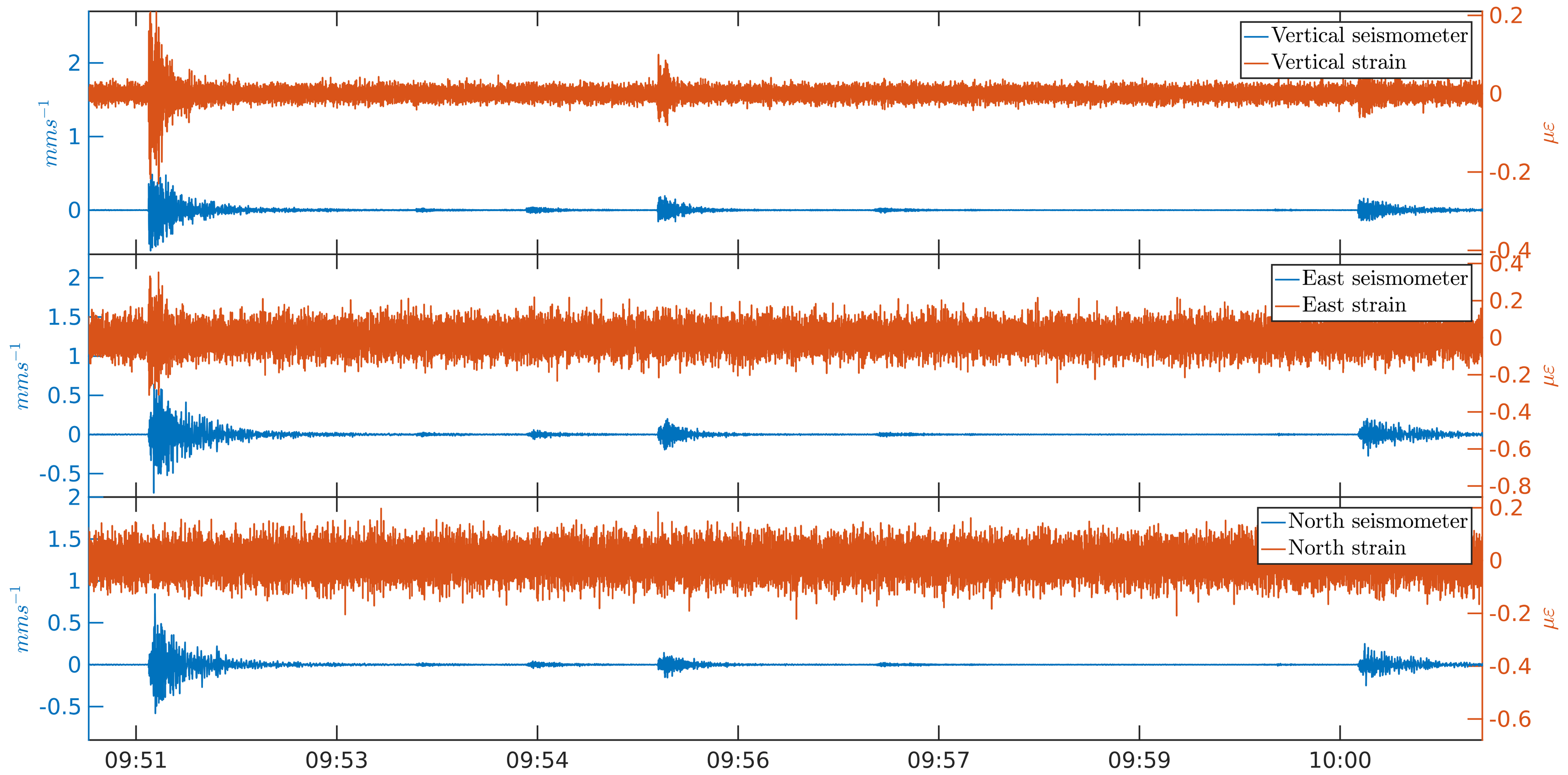
The optoelectronic converter is realized in order to exploit the S-Ratio algorithm[4] that allows to evaluate the bragg wavelength variation with a resolution higher than 0.5 pm (1 pm ≈).
The GILDA converts the electric signals into binary files every half an hour. These files are temporary stored in a pc located inside the INAF building. From here the data are sent to the University of Pisa server. Here we process and store the data in real time.

Results

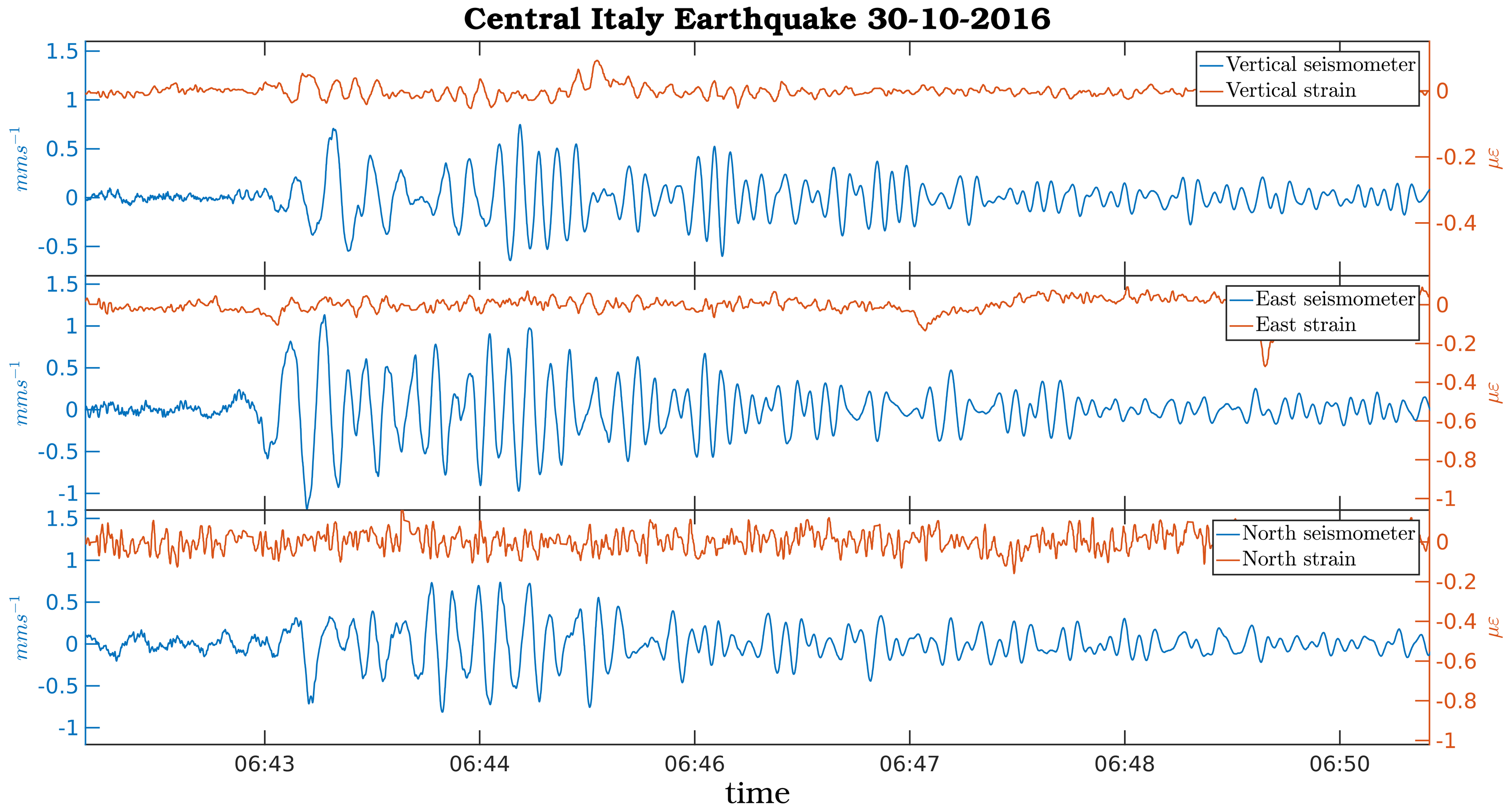
Slow deformation monitoring



Local seismic event 30-01-2017



Central Italy Earthquake 30-10-2016



References

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[2] Z. Zhou, X. Zhao, W. Li Hong, and J. Ou. "*Embedded Fbg Strain Sensors and Their Applications in Bridge Health Monitoring*"
[3] M. Orazi, R. Peluso, M. Martini, C. Buonocunto, M. Capello, and A. Caputo. "*L'acquisitore a basso consumo GILDA*". In *I Work. Tec. Monit. Sism.* DEL Territ. Naz., pages 86–88, Roma, 2010.
[4] S. Hui and G. H. Xu. *"A novel fiber Bragg grating interrogating sensor system based on AWG demultiplexing"*. Opt. Commun. , 275(1):196–200, jul 2007.