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Time series of GNSS-derived ionospheric maps to detect anomalies as possible precursors of high magnitude earthquakes

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The modification of some atmospheric physical properties prior to a high magnitude earthquake has been recently debated within the Lithosphere-Atmosphere-Ionosphere (LAI) Coupling model. Among this variety of phenomena the ionization of air at the higher level of the atmosphere, called ionosphere, is investigated in this work. Such a ionization occurrences could be caused by possible leaking of gases from earth crust and their presence was detected around the time of high magnitude earthquakes by several authors. However, the spatial scale and temporal domain over which such a disturbances come into evidence is still a controversial item. Even thought the ionospheric activity could be investigated by different methodologies (satellite or terrestrial measurements), we selected the production of ionospheric maps by the analysis of GNSS (Global Navigation Satellite Data) data as possible way to detect anomalies prior of a seismic event over a wide area around the epicentre.
It is well known that, in the GNSS sciences, the ionospheric activity could be probed by the analysis of refraction phenomena occurred on the dual frequency signals along the satellite to receiver path.
The analysis of refraction phenomena affecting data acquired by the GNSS permanent trackers is able to produce daily to hourly maps representing the spatial distribution of the ionospheric Total Electron Content (TEC) as an index of the ionization degree in the upper atmosphere.
The presence of large ionospheric anomalies could be therefore interpreted in the LAI Coupling model like a precursor signal of a strong earthquake, especially when the appearance of other different precursors (thermal anomalies and/or gas fluxes) could be detected.
In this work, a six-month long series of ionospheric maps produced from GNSS data collected by a network of 49 GPS permanent stations distributed within an area around the city of L'Aquila (Abruzzi, Italy), where an earthquake (M = 6.3) occurred on April 6, 2009, were investigated.
Basically, the proposed methodology is able to perform a time series analysis of the TEC maps and, eventually, define the spatial and temporal domains of ionospheric disturbances.
This goal was achieved by a time series analysis of the spatial dataset able to compare a local pattern of ionospheric activity with its historical mean value and detect areas where the TEC content exhibits anomalous values. This data processing shows some 1 to 2 days long anomalies about 20 days before of the seismic event (confirming also results provided in recent studies by means of ionospheric soundings).