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Co-volcanic ionospheric perturbations: observations and modeling

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Abstract

It is known that natural hazard events such as earthquakes, tsunamis, volcano eruptions and explosions, can generate perturbations in the atmospheric and ionospheric parameters. The development of the global and regional networks of ground-based GPS/GNSS receivers has opened a new era in the ionospheric detection of natural hazard events. However, while co-seismic and co-tsunamic ionospheric perturbations have been sufficiently well investigated, the features of co-volcanic ionospheric perturbations are not well understood yet. It is known that eruptions with the volcanic explosivity index (VEI) of more than 2 can be detected in the ionosphere, especially in regions with dense GPS/GNSS-receiver coverage.

In this work, we study the ionospheric total electron content (TEC) response to the two VEI 4-5 eruptions of the Calbuco volcano in South Chile. The first eruption began at 21:04UT on 22 April 2015, preceded by only an hour-long period of volcano-tectonic activity. This first eruption lasted 90 minutes and generated a sub-Plinian (i.e. medium to large explosive event), gray ash plume that rose 15 km above the main crater. A larger second event on 23 April began at 04:00UT (01:00LT), it lasted six hours, and also generated a sub-Plinian ash plume that rose higher than 15 km.

We first use ground-based GNSS receivers located around the volcano area to analyze the characteristics of the eruption-generated ionospheric perturbations. We find that in both cases the TEC response manifested itself as quasi-periodic signals with several consecutive wave trains. The averaged amplitude of the observed co-volcanic TEC perturbations reached 0.45 TECU for the first eruption and 0.16 TECU for the second one. The perturbations propagated at 900-1200 m/s away from the volcano. At the second step, we use parameters of the ionospheric GNSS-detection to calculate the location of the volcanic source as well as the onset time of the volcano eruption. This was done by using the approximation of a spherical wave propagating at a constant velocity from a point source. We show that even from 30 s ionospheric GPS data it is possible to "localize" the eruptive source thin several degrees of latitude/longitude.

Finally, we use the normal mode summation technique to model the ionospheric TEC response to the Calbuco volcano eruptions, in both acoustic and gravity domain. It should be noted that gravity waves are rare to observe after eruptions. We analyze the power spectrum of the observed TEC response and we find small-amplitude low-frequency component.