



## Identification of the Earth's Free Oscillation Modes from VTEC Time Series

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Ionosphere is an ionized layer of the upper atmosphere. This layer plays an important role in HF and satellite communications as well as in the understanding of the earth's magnetism. Total electron content (TEC) is a measure of ionization level in the ionosphere. Currently, reliable TEC estimates can be calculated via GNSS signals without resorting to expensive sounding experiments. In this study, GPS-based VTEC (Vertical Electron Content) time series are investigated. We are able to identify the earth's free oscillations from VTEC time series via a system identification approach based on canonical correlation analysis. We take VTEC time series as the response of the ionospheric dynamics to solar radiation. By taking a simple solar intensity model reaching its peak at the local-noon time as an input signal, and by considering the VTEC time series associated with the same location as an output signal, we define an empirical input-output model. In order to identify this input-output model as a high-dimensional linear difference equation, we make use of the canonical correlation analysis (CCA). By exploiting CCA in an innovative manner, we identify a linear model for the ionospheric dynamics excited by the solar radiation. The obtained ionospheric model is studied in the frequency domain. We identify the resonance modes of the ionospheric model (technically, the poles of the transfer function of the linear model) as the earth's free oscillation modes. Earth's free oscillations, with specific periods ranging from 5- 60 minutes, are the natural oscillation modes of the earth crust as an elastic medium. Hitherto, the free oscillation modes of the earth have been observed only via seismic measurements taken after large earthquakes. This is the first observation of free oscillations of the earth via ionospheric phenomena. We are able to produce these results from VTEC time series estimated from different times and different stations. In all models we derived from VTEC time series, we identify resonance frequencies of the ionospheric model as the free oscillation frequencies of the earth with surprisingly good accuracy. In some of the modes, the discrepancy (relative error) is less than 0.1 percent.