Modeling of volcanomagnetic dynamics by recurrent orthogonal least-squares learning systems

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We present a new model of volcanomagnetic dynamics created by means of recurrent orthogonal least squares. The advantages of our approach are: low complexity algorithm as compared to recurrent kernel machines and parsimonious representation of observed dynamical system that enables physical interpretation. The observations of the geomagnetic time series from the magnetic network on Etna volcano are analyzed to investigate the dynamical behavior of magnetic anomalies. The predictability of the geomagnetic time series was evaluated to establish a possible low-dimensional deterministic dynamics. The analysis of the 10-minutes differences at PDN station with respect to the reference station located far away from the volcano edifice shows prominent peaks centered around diurnal components at the period of 8, 12 and 24 h. After having removed the dominant periodic components, the filtered differences appear to be aperiodic and broadband. We attempt to explain the mechanism generating the time dependent variations by constructing the recurrent learning system. The data from PDN station was normalized to the range [-1,1]. We used a learning data set from 7th to 13th January 2008. The testing data set spans from 15th to 21st January 2008. The idea of recurrent model of nonlinear dynamical system is based on the general NARMAX form. The idea is to find the mapping rule between the past values of the observed process and its prediction. Hence, the learning algorithm consists of 2 phases. In the phase 1 the model state inputs are delayed measured output values of the process for the input-output representation. In the learning phase 2 the measured output values are replaced by the estimated output values of the predictor before performing the new learning phase. The performed model has the form of linear combination of RBF functions selected by Gram-Schmidt orthogonalisation from the hierarchical basis function system. The result of embedding analysis shows that the geomagnetic time series is 3rd order dynamical system. The recurrent orthogonal least squares system was first used as model of the Chua circuit dynamics and applied to predict the Etna geomagnetic time series. The obtained models are accurate enough to explain the chaotic mechanism of observed processes and to distinguish various modes of behavior. As compared to the recurrent least-squares support vector machines tested on the same data sets, the orthogonal least squares systems require 10 times less number of regressors at higher accuracy due to the ability to explore RBF basis functions with flexible width parameters.