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Application of Modified Particle Swarm Optimization Method for Parameter Extraction of 2-D TEC Mapping

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Ionosphere is a very important part of Space Weather. Modeling and monitoring of ionospheric variability is a major part of satellite communication, navigation and positioning systems. Total Electron Content (TEC), which is defined as the line integral of the electron density along a ray path, is one of the parameters to investigate the ionospheric variability. Dual-frequency GPS receivers, with their world wide availability and efficiency in TEC estimation, have become a major source of global and regional TEC modeling. When Global Ionospheric Maps (GIM) of International GPS Service (IGS) centers (http://iono.jpl.nasa.gov/gim.html) are investigated, it can be observed that regional ionosphere along the midlatitude regions can be modeled as a constant, linear or a quadratic surface. Globally, especially around the magnetic equator, the TEC surfaces resemble twisted and dispersed single centered or double centered Gaussian functions.

Particle Swarm Optimization (PSO) proved itself as a fast converging and an effective optimization tool in various diverse fields. Yet, in order to apply this optimization technique into TEC modeling, the method has to be modified for higher efficiency and accuracy in extraction of geophysical parameters such as model parameters of TEC surfaces.

In this study, a modified PSO (mPSO) method is applied to regional and global synthetic TEC surfaces. The synthetic surfaces that represent the trend and small scale variability of various ionospheric states are necessary to compare the performance of mPSO over number of iterations, accuracy in parameter estimation and overall surface reconstruction. The Cramer-Rao bounds for each surface type and model are also investigated and performance of mPSO are tested with respect to these bounds. For global models, the sample points that are used in optimization are obtained using IGS receiver network. For regional TEC models, regional networks such as Turkish National Permanent GPS Network (TNPGN-Active) receiver sites are used.

The regional TEC models are grouped into constant (one parameter), linear (two parameters), and quadratic (six parameters) surfaces which are functions of latitude and longitude. Global models require seven parameters for single centered Gaussian and 13 parameters for double centered Gaussian function. The error criterion is the normalized percentage error for both the surface and the parameters. It is observed that mPSO is very successful in parameter extraction of various regional and global models. The normalized reconstruction error varies from 10^{-4} for constant surfaces to 10^{-3} for quadratic surfaces in regional models, sampled with regional networks. Even for the cases of a severe geomagnetic storm that affects measurements globally, with IGS network, the reconstruction error is on the order of 10^{-1} even though individual parameters have higher normalized errors. The modified PSO technique proved itself to be a useful tool for parameter extraction of more complicated TEC models.

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