Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

MGI032-P01 Room:Convention Hall Time:May 23 13:45-16:15

Development of Ionospheric Tomography Using Neural Network

Shinji Hirooka[1*], Katsumi Hattori[1], Tatsuoki Takeda[2]

[1]Chiba Univ., [2]Univ. of Electro-Communications

In order to investigate the dynamics of ionospheric phenomena, an estimation of three-dimensional ionospheric electron density distribution is effective. Recently, GPS occultation observations by satellites can provide a global profile of ionosphere. However, satellite observations have an essential difficulty in discrimination in time and space. Therefore, in addition to the occultation observation, continuous ground-based GPS observation will be required to investigate ionospheric physics. In the past, various algorithms for ionospheric tomography have been proposed. In this paper, the Residual Minimization Training Neural Network (RMTNN) tomographic approach is selected (Ma et al., 2005). TEC data with location and altitude derived by ground based GPS receivers and ionosonde are used for the developed method. This approach has an advantage in reconstruction with sparse data.

However, Ma et al., (2005) have demonstrated few results in specific conditions and they did not provide the general performance. Therefore, we validate the performance of reconstruction in the case of disturbed period and sparse data by the simulation and/or real data in this paper.

At first, in order to examine the effectiveness of the method for disturbed conditions, a simple plasma bubble model is investigated. The reconstructed image agrees well with plasma bubble model, and it suggests the high capability of RMTNN method for the disturbed ionosphere.

Then, we checked the RMTNN method for the Sumatra region, Indonesia as a sparse data case. It is found that the reconstruction indicates a good agreement with the model data except below 250 km altitudes. In order to improve these difficulties, information on electron density at the lower ionosphere (100 km altitude) by NeQuick model for restriction is used. As a result, the proposed method shows a great improvement in estimation of densities at lower altitudes below 250 km.

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A model of the plasmaspheric density profile combined with the GCPM and its error-correction model using GPS-TEC

Yoshitaka Goto[1*], Yoshiya Kasahara[1]

[1]Kanazawa University

The earth's plasmasphere is filled with relatively dense core plasmas which are predominantly provided from the ionosphere. A realistic plasmaspheric density model is useful for applications not only in plasma physics but also in engineering. The plasmasphere is, however, too vast to be probed by a single spacecraft. In order to construct the realistic model, an integration of observational knowledge is indispensable. Formerly, diffusive equilibrium models were generally used to represent plasmaspheric density profiles but the models were insufficient to deal with a variety of solar and geomagnetic activities. In recent years, several new density models, such as the global core plasma model (GCPM), the global plasmasphere ionosphere density (GPID) and the standard plasmasphere ionosphere model (SIM), were developed theoretically, semi-empirically or fully-empirically. These models are more reliable than the traditional diffusive equilibrium model but each model still has weaknesses. Among these models, the GCPM has an advantage in supporting continued improvements.

The final purpose of our study is to develop a realistic plasmaspheric density model by incorporating large data sets of VLF whistler dispersions obtained by the Akebono satellite and GPS-derived TECs provided by the International GNSS Service (IGS) into the GCPM. In the present study, we adopt a new representation for the density profile. That is, the profile is constructed by a combination of the GCPM and an additional model which represents GCPM errors. The combination model makes it possible to reflect the characteristics of the long-term observations to the profile without varying the parameters in the physical base model and it always provides spatially and temporally continuous distribution. By assuming smoothness prior to the errors in multi-dimensional parameter space of the GCPM, we first estimated equatorial error distribution in order that model-derived TECs agree with the observed ones. The equatorial density is the most important factor to reconstruct the whole plasmaspheric density profile in the GCPM. By using the GPS-TECs obtained from LEO (low earth orbit) satellites, we confirmed that the developed error-reduced GCPM accurately reconstructs plasmaspheric density profiles. The model profiles show larger seasonal variations and local-time dependences than the original GCPM.

Keywords: electron density model, GCPM, GPS-TEC

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Mixed linear-nonlinear inversion of crustal deformation data: Bayesian inference of model and hyperparameters

Jun'ichi Fukuda[1*], Kaj M. Johnson[2]

[1]ERI, University of Tokyo, [2]Indiana University

We present a unified theoretical framework and solution method for probabilistic, Bayesian inversions of crustal deformation data. The inversions involve multiple data sets with unknown relative weights, model parameters that are related linearly or non-linearly through theoretic models to observations, prior information on model parameters, and regularization priors to stabilize underdetermined problems. To efficiently handle nonlinear inversions in which some of the model parameters are linearly related to the observations, this method combines both analytical least-squares solutions and a Markov chain Monte Carlo (MCMC) sampling technique. In this method, model parameters that are linearly and nonlinearly related to observations, relative weights of multiple data sets, and relative weights of prior information and regularization priors are determined in a unified Bayesian framework.

In this presentation, we define the mixed linear-nonlinear inverse problem, outline the theoretical basis for the method, provide a step-by-step algorithm for the inversion, validate the inversion method using synthetic data, and apply the method to real data sets. Our method can potentially be applied to high dimensional mixed linear-nonlinear inverse problems to which it is difficult to apply the MCMC methods to sample full posterior probability distributions due to high computational costs.

Keywords: inversion, Markov chain Monte Carlo, crustal deformation

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Analysis of accuracy and effectiveness in ensemble-type data assimilation considering continuity and nonlinearity

Kazuyuki Nakamura[1]*

[1]Meiji University

In the data assimilation, variables in a numerical simulation model are modified through observed data. This procedure makes it possible to give more accurate estimation of uncertain initial and boundary conditions, unobservable state variables and parameters, and predictions. We analyzed the property of the ensemble type data assimilation such as ensemble Kalman filter and smoother, ensemble 4DVAR, particle filter and smoother, and merging particle filter, which can give direct approximation of probability density. We compare their similarity and differences through mathematical analysis, and show pros and cons among them. We also show the numerical results of several assimilated models including Lorenz 96 model. Those results imply that spatially continuous property and nonlinearity of physical systems play an important role for the estimation effectiveness and accuracy in the ensemble type data assimilation.

Keywords: data assimilation, ensemble approximation, ensemble Kalman filter, particle filter