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An Ionospheric Multimodel Ensemble Prediction System

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ABSTRACT

Under the U.S. NASA and NSF collaborative space weather modeling initiative, a Multimodel Ensemble Prediction System (MEPS) is being developed by a joint team from Utah State University (USU), the Jet Propulsion Laboratory (JPL), and the University of Southern California (USC) [1][2][3][4][5][6]. The MEPS incorporates a suite of state-of-the-art first-principle-based data assimilation models for the purpose of specifying global weather conditions in the thermosphere and the ionosphere, as well as their electrodynamics. This presentation highlights the ionospheric MEPS (MEPS), as part of the overall effort, that is composed of the Global Assimilation of Ionospheric Measurements models (or USU-GAIM) and Global Assimilative Ionospheric Models (or JPL-USC-GAIM). To reproduce real-world ionospheric state, these GAIMs assimilate a variety of ionospheric data, including total electron content (TEC) obtained from ground-based and spaceborne GPS measurements, ground-based digisonde and satellite in-situ density data, satellite UV observations, etc. The MEPS has been applied to studies of ionospheric response to space weather storms [2][3][4][7]. Examples of such storm studies will be presented, to demonstrate MEPS's capability of assimilative modeling of ionospheric disturbances under perturbed space weather conditions.

Key words: Ionospheric modeling, data assimilation, space weather.

MEPS is an ensemble approach that incorporates outcomes of multiple-models. Such an approach has been practiced in weather prediction to help reduce model-dependent uncertainties. The approach has often proven to be more robust than relying on a single model. For assimilative ionospheric modeling, our MEPS is composed of several versions of GAIMs, namely GAIM-GM (Gauss Markov), GAIM-BL (Band-Limited), GAIM-FP (Full Physics), and GAIM-4DVAR

(4 Dimensional VARiational approach).

These models are all physics-based multiple-ion models. However, their incorporation of different data assimilation techniques necessitates emphasis on different modeling aspects so as to optimize each model's performance in the context of different specific requirements. For example, by assimilating a variety of ionospheric observations, GAIM-GM and GAIM-BL adjust the model state (electron densities and total electron content – TEC) to model ionospheric weather conditions, while GAIM-4DVAR and GAIM-FP attempt to also estimate weather variations of model drivers. The non-driver-estimation models require less in the way of computational resources and thus tend to be more attractive for operations requiring short latency. On the other hand, the driver-estimation models, although much more complex in their modeling techniques, offer potentials to provide self-consistent predictions.

These models and MEPS have been applied to studies of ionospheric responses to space weather storms. The investigated storm events include primarily two types of storms, namely high speed stream and coronal mass ejection storms. Figure 1 shows examples of modeled nominal conditions and ionospheric perturbations under space weather storm conditions, respectively. For this event, the assimilative modeling reproduces enhanced TEC and ionospheric densities as well as hemispherically asymmetric ionospheric disturbances under the equinox conditions during the storm main phase.

In this presentation, we will describe the development status of MEPS, discuss different model techniques for assimilating various data types, and show examples of modeling ionospheric storms.

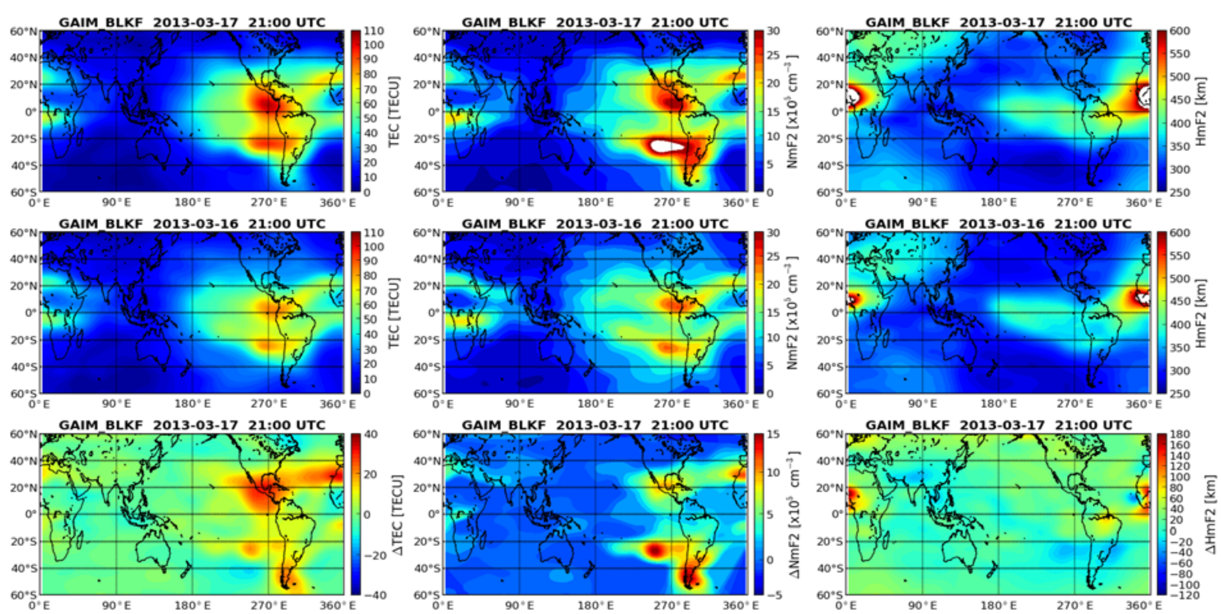

Figure 1. Ionospheric TEC (left), NmF2 (central), and HmF2 (right) reproduced from of the MEPS models for quiet (2013-03-16) and perturbed (2013-03-17) space weather conditions. The bottom panel shows differences of three parameters, respectively, between the perturbation and quiet state.

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References

[1] R. W. Schunk, L. Scherliess, V. Eccles, L. C. Gardner, J. J. Sojka, L. Zhu, X. Pi, A. J. Mannucci, B. D. Wilson, A. Komjathy, C. Wang, G. Rosen, K. Tobiska, R. K. Schaefer and L. Paxton (2013), Ensemble Modeling with Data Assimilation Models: A New Strategy for Space Weather Science, Specifications and Forecasts, *American Geophysical Union 2013 Fall Meeting,* San Francisco, December 2013.

[2] X. Pi, A. J. Mannucci, Mark Butala, B. D. Wilson, A. Komjathy, Vardan Akopian, Olga Verkholgydova, C. Wang, G. Rosen, R. W. Schunk, L. Scherliess, V. Eccles, L. C. Gardner, J. J. Sojka, L. Zhu (2013), A Multimodel Ensemble Prediction System to Specify Ionospheric Storms, *American Geophysical Union 2013 Fall Meeting,* San Francisco, December 2013.

[3] L. Scherliess, R.W. Schunk, L. Gardner, L. Zhu, V. Eccles, J.J. Sojka, X. Pi, M. D Butala, A. J Mannucci, B. D Wilson, A. Komjathy, C. Wang, and G. Rosen (2014), A Multimodel Ensemble Data Assimilation Approach to Specify Ionospheric Weather, *American Geophysical Union 2014 Fall Meeting, San Francisco*, December 2014.

[4] X. Pi, Mark Butala, A. J. Mannucci, B. D. Wilson, A. Komjathy, C. Wang, G. Rosen, R. W. Schunk, L. Scherliess, V. Eccles, L. C. Gardner, J. J. Sojka, L. Zhu (2014), Study of Ionospheric Storms Using Global Assimilative Ionospheric Models, *American Geophysical Union 2014 Fall Meeting, San Francisco*, December 2014.

[5] R. W. Schunk, L. Scherliess, V. Eccles, L. C. Gardner, J. J. Sojka and L. Zhu, X. Pi, A. J. Mannucci, M. Butala, B. D. Wilson, and A. Komjathy, C. Wang and G. Rosen (2014), Multimodel Ensemble Prediction System (MEPS) for the Ionosphere-Thermosphere-Electrodynamics System, *American Geophysical Union 2014 Fall Meeting, San Francisco*, December 2014.

[6] R. W. Schunk, L. Scherliess, V. Eccles, L. C. Gardner, J. J. Sojka and L. Zhu, X. Pi, A. J. Mannucci, M. Butala, B. D. Wilson, and A. Komjathy, C. Wang and G. Rosen (2015), Modeling the Ionosphere-Thermosphere-Electrodynamics System for Space Weather Specifications, Forecasts and Applications, *American Geophysical Union 2015 Fall Meeting*, San Francisco, December 2015.

[7] X. Pi, M. Butala, P. Vergados, A. J. Mannucci, and A. Komjathy, C. Wang and G. Rosen, R. W. Schunk, L. Scherliess, V. Eccles, L. C. Gardner, J. J. Sojka, and L. Zhu, Multi-Scale Ionospheric Responses to the St. Patrick’s Day Storm (2015) Studied Using a Multimodel Ensemble Prediction System and GPS Data, *American Geophysical Union 2014 Fall Meeting,* San Francisco, December 2015.