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GLIMPSE: A GLobal Ionosphere Modeling Prediction and Specification Environment

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ABSTRACT

We have a collection of separate modeling and data analysis tools that can be integrated together in order to make a working global ionospheric prediction and data assimilation model (which we call GLobal Ionosphere Modeling, Prediction, and Specification Environment or GLIMPSE). GLIMPSE couples together the ionospheric data assimilation algorithm Ionospheric Data Assimilation Four Dimensional (IDA4D), the thermosphere and driver assimilation algorithm Estimating Model Parameters from Ionospheric Reverse Engineering (EMPIRE), and a first principle forecast model for electron density Forward Update Simple IONosphere (FUSION). The resulting coupled algorithm allows for accurate short time (1-3 hour) predictions of the electron density, corrections to the electron density through IDA4D and corrections to the thermospheric state (neutral winds, composition) and driver electric fields through EMPIRE. These corrections are then used to re-initialize FUSION, which then predicts forward to the next assimilative cycle (see Figure 1 below).

IDA4D has been under development since 1996 [1,2], and used in a number of scientific studies [3,4,5]. IDA4D ingests a large number of electron-density related observations including ground and space-based GNSS TEC, GNSS radio occultations, digisonde data, TEC observations from DORIS, in-situ observations from DMSP, 1356 angstrom emissions, and bi-static HF observations. EMPIRE was initiated in 2006, and has validated in several studies [6,7,8]. EMPIRE takes the output of IDA4D, observations of winds, composition and electric fields, and adjust the neutral state and drivers to be consistent with IDA4D estimates of density through the continuity equation. FUSION is a recently developed algorithm at JHUAPL that implements a ionospheric numerical model. Figure 2 below shows a snapshot of a coupled run between FUSION and IDA4D. The time is 12:15 UT, approximately ½ way through the run. In order to more clearly see the effects of data ingestion, no GNSS ground-based TEC was injected.

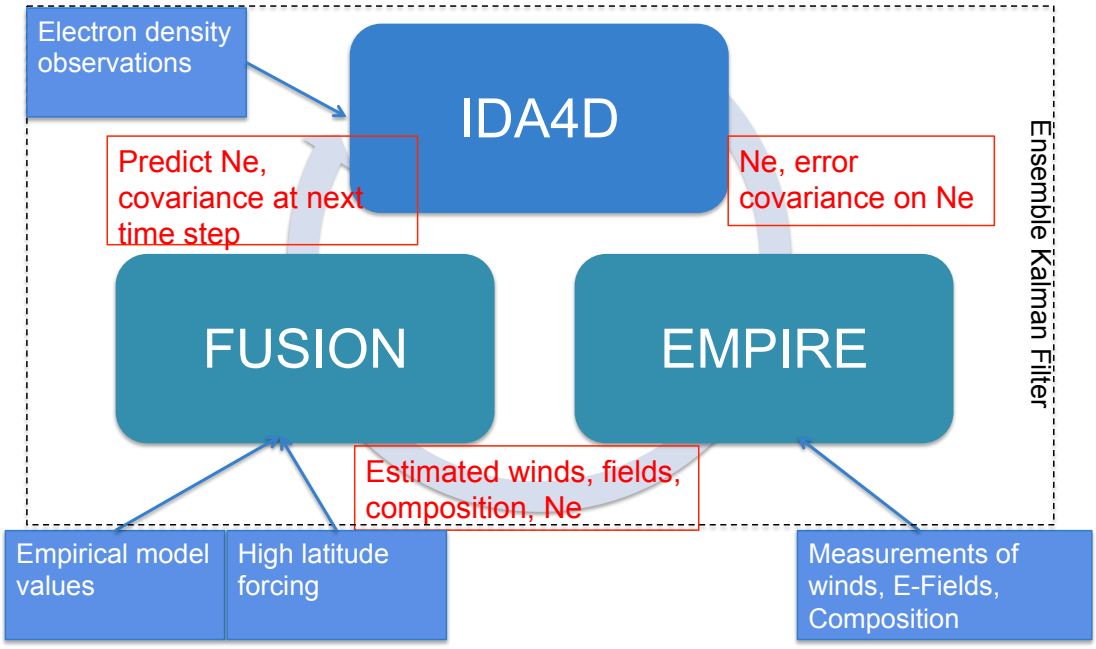

Figure 1. Flow diagram of GLIMPSE. FUSION makes a prediction of electron density. IDA4D ingests observations and corrects the 3D density field. EMPIRE takes the new electron density field, and direct measurements of winds, composition and E-fields and uses constraints to make the drivers to FUSION self consistent.

The primary goal of the GLIMPSE suite of algorithms is to improve the accuracy of ionospheric electron density specification, nowcasts and short forecasts to support various RF applications. Of first importance is accurate specification of the state variables and drivers. Since the forecast model is re-initialized with the current specified state, the accuracy of nowcasts and short forecasts are dependent upon the accuracy of the initialized state.

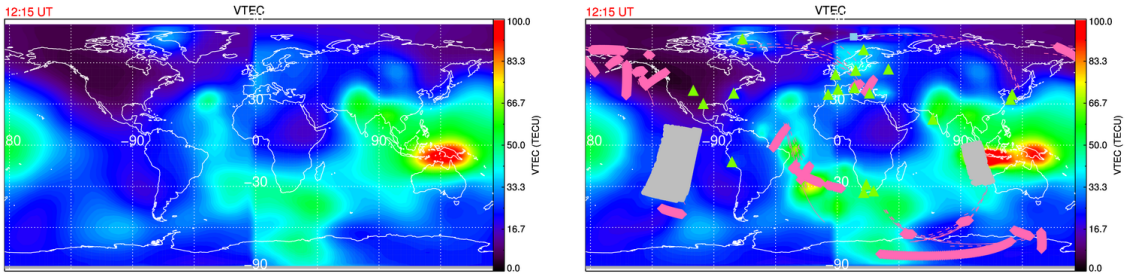

Figure 2. Example of a GLIMPSE run using only FUSION-IDA4D coupling. The above figures represent a vertical TEC snapshot in time approximately ½ the way through a full day run for February 28, 2014. On the left is a FUSION forecast of VTEC at 12:15 UT and the right is the corrections by IDA4D. Also shown are data sources ingested by IDA4D. The green triangles are ionosondes, the pink traces are radio occultations and the grey are SSUSI 1356 emissions. No GNSS was used in this test set.

This presentation will first outline the GLIMPSE development, current status and future plans. We will then discuss the current capability of IDA4D to specify ionospheric electron density. We will then present specification of neutral winds from EMPIRE and compare to wind observations. Finally we will then present initial results demonstrating the ability of GLIMPSE to now-cast and make short forecasts of the electron density for a minor storm period from 2014.

Key words: Data assimilation, Ionosphere, GNSS.

References:

[1] Bust, G. S. and Datta-Barua, S. (2014) Scientific Investigations Using IDA4D and EMPIRE, in Modeling the Ionosphere-Thermosphere System (eds J. Huba, R. Schunk and G. Khazanov), John Wiley & Sons, Ltd, Chichester, UK. doi: 10.1002/9781118704417.ch23

[2] Bust, G.S, T.W. Garner, and T. L. Gaussiran II, Ionospheric Data Assimilation Three Dimensional (IDA3D): A Global, Multi-Sensor, Electron Density Specification

[3] Bust, G.S., and G. Crowley (2008), Mapping the time-varying distribution of high-altitude plasma during storms, in Midlatitude Ionospheric Dynamics and Disturbances, Geophys. Monogr. Ser., vol. 181, edited by P.M. Kintner, A.J. Coster, T. Fuller Rowell, A.J. Mannucci, M. Mendillo and R. Heelis, pp. 91-98, AGU, Washington, D.C.

[4] Bust, G. S., and G. Crowley (2007), Tracking of Polar Cap Ionospheric Patches using Data Assimilation, J. Geophys. Res., 112, A05307, doi:10.1029/2005JA011597.

[5] Bust, G. S., G. Crowley, T. W. Garner, T. L. Gaussiran II, R. W. Meggs, C. N. Mitchell, P. S. J. Spencer, P. Yin, and B. Zapfe (2007) ,Four Dimensional GPS Imaging of Space-Weather Storms, Space Weather, 5, S02003, doi:10.1029/2006SW000237.

[6] Datta-Barua, S., G. S. Bust, and G. Crowley (2013), First storm time plasma velocity estimates from high-resolution ionospheric data assimilation, J. Geophys. Res. Space Physics, 118, 7458–7471, doi:10.1002/2013JA019153.

[7] Datta-Barua, S., G. S. Bust, and G. Crowley (2011), Deducing storm-time F-region ionospheric dynamics from 3-D time-varying imaging, J. Geophys. Res., 116, A05324, doi:10.1029/2010JA016304

[8] Datta-Barua, S., G. S. Bust, G. Crowley, and N. Curtis (2009), Neutral wind estimation from 4-D ionospheric electron density images, J. Geophys. Res., 114, A06317, doi:10.1029/2008JA014004.

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