Ionospheric Ensemble- based Data Assimilation System for State and Parameter Estimation.

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Abstract. In this poster, ionospheric data assimilation system is introduced. Physical model outline together with sample results and possible practical applications list are presented. Another topic of current work is estimation of ExB drift velocities, using presented physical- based model and Ensemble Square Root Filter. The scheme of a numerical, experiment and it's sample results are presented in the central frame.

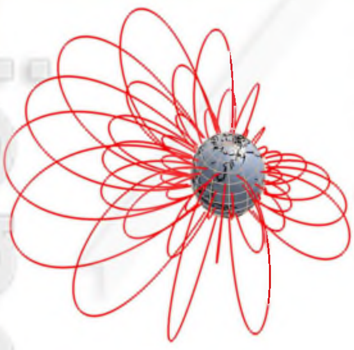
Model Outline

The core of the developed system is a physics- based model of Earth's ionosphere, which consists of three hydrodynamical equations, which are solved along magnetic fiels lines. Diffusion and momentum equations are solved for seven major positive ions: H, O, O_2, N, N_2, NO, He. Temperature equation is solved only for ions of H, He and O. Other speices are assumed to have the same temperature with O. The set of equations, describing plasma behaviour, is given in the frame to the right.

To obtain information about neutral atmosphere and Earth magnetic fied, we use well- developed empirical models, such as NRL MSISE, Horizontal Wind Model and World Magnetic Model.

Utilized data are RINEX files from IGS ground network, containing information about total electron content along the satellite-receiver link. Data assimilation in the presented system can be done with traditional Kalman filter, as well as with Ensemble Square Root filter. The latter is used in parameter estimation scheme.

Model grid covers altitude regions from 80 up to 20 000 km above the surface and from 70N to 70S in latitude.In operational mode, ionospheric nowcasting system's errors lie within 2.5 and 4 TEC Units. It results in 10-30% relative error, which depends highly on time of the day.

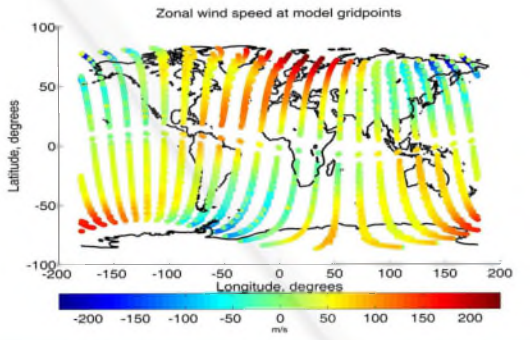


A bunch of magnetic field lines, which are used as a model reference frame. Tilted eccentric dipole approximation is used to represent magnetic field.

$$\frac{\partial N_i}{\partial t} - b_s^2 \frac{\partial \frac{N_i V_i}{b_s}}{\partial s} + N_i \nabla_p V_i + V_i \nabla_p N_i = P_i - L_i N_i$$

$$V_i = \frac{1}{(\sum_{neutrals} \nu_{in} + \sum_{ions} \nu_{ij})}(-g\sin(I) + \frac{b_s k}{m_i}(\frac{T_i}{N_i}\frac{\partial N_i}{\partial s} + \frac{T_e}{N_e}\frac{\partial N_e}{\partial s} + \frac{\partial (T_i + T_e)}{\partial s}) + \sum_{ions} \nu_{ij} V_j)$$

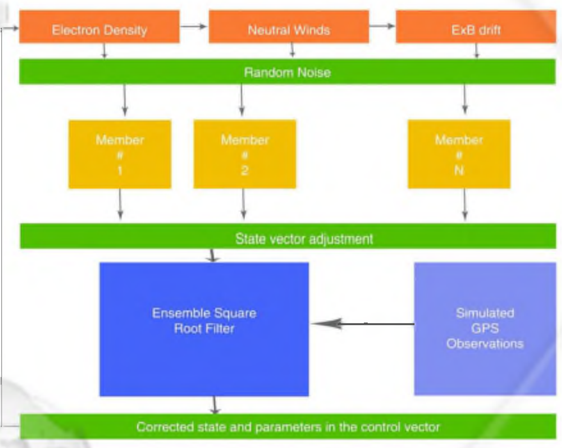
$$\frac{3}{2} k N_i (\frac{\partial T_i}{\partial t} + V_\perp \nabla T_i) = k N_i T_i b_s^2 \frac{\partial}{\partial s}(\frac{V_i}{b_s}) - k N_i T_i \nabla V_\perp + b_s^2 \frac{\partial}{\partial s}(\kappa \frac{\partial T_i}{\partial s}) + \frac{3}{2} k N_i V_i b_s \frac{\partial T_i}{\partial s} + Q + F$$

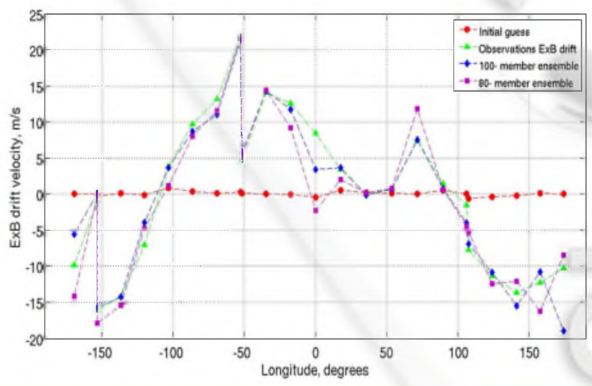


Sample Results Of State And Parameter Estimation System

Ensemble-based assimilation techniques allow one to adjust system state vector with unknown model parameters. These often considered to be parameters of major driving forces, that influence ionospheric behaviour. Thus, given a set of observations, one can restore real values of the most important model parameters.

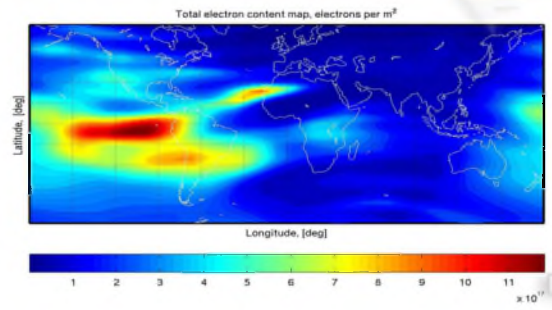
To test model capablities in parameter estimation simulations, we produced a serie of model runs, as it is shown on the scheme to the left. The observations, similar to GPS data were simulated, using realistic **ExB**- drift values. The results of parameter estimation are presented on the plot below.

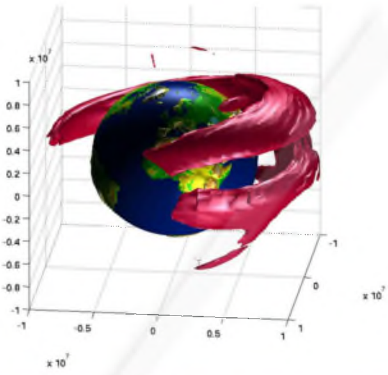


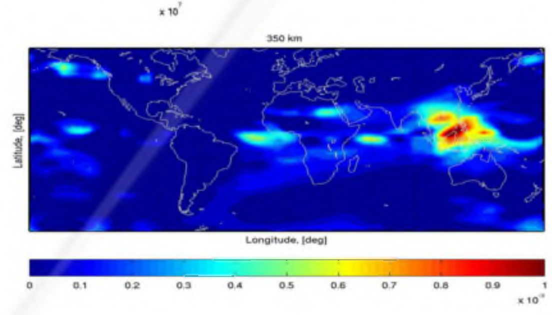


One of the results of the parameter estimation from simulated data is that such approach could be used in real data cases. All the tuning, that is needed by EnSRF algorithm is done, using the simulated observations.

Moreover, results, obtained in parameter estimation experiment show, that usage of ionospheric models together with dense observations network could help in estimation of poorly known factors, that affect plasma conditions.







Practical Applications Of Modeling Results

Sample plots of model results are shown in the frame to the left. They include TEC calculation from a sample model run, isosurface representation of the ionosphere and scintillation map at 350 km.Operational version of the presented model is designed to be used in practical applications, such as:

Ray tracing, radiowave propagation.
High influence of ionospheric conditions on radio wave propagation can be mitigated by prior estimations of crucial aprameters, such as hmF2, f0F2 etc.

GPS/ GLONASS ionospheric corrections.
Single- frequency receivers' solutions can be fixed, given a good estimate of electron density distribution along the satellite- receiver link.

Ionospheric scintillations monitoring.
Scintillations can in some cases prevent radiowave propagation, or cause signal damage. Monitoring of ionospheric disturbancies could increase stability of radiocommunication systems.

Modeling of artificial heating consequencies.
Artificial heaters' effects on ionosphere are widely discussed by the community. Ionospheric model, using real- time observations could describe irregularities' behaviour with global coverage.

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