Assimilation of the GNSS data into the ionospheric model using the Ensemble Kalman Filter

Dmitry Solomentsev[1], Anton Titov[1], Boris Khattatov[2], Vyacheslav Khattatov[1], and Ruslan Mazakirov[1]

[1]Central Aerological Observatory, Dolgoprudny, Russian Federation

mail: d.solomentsev@gmail.com

[2]Fusion Numerics LLC, Boulder, CO, USA

mail: boris@fusionumerics. com

***Abstract* – The developed ensemble- based assimilative ionospheric model is outlined. Within the system, the physical model calculations are adjusted with the results of global GNSS- based ionospheric observations. The main purpose of the current research is building a reliable ionosphere nowcasting system for technological and scientific purposes. The sample model results are presented in the current paper and a short outline of possible model application is given.**

BIOGRAPHIES

Dmitry Solomentsev is employed as a leading engineer in the ionospheric model development project at Central Aerological Observatory (CAO). He has implemented data assimilation algorithms for the ionospheric nowcasting system, outlined in the current paper. His research interests are the data assimilation techniques and numerical analysis application to the geophysical systems.

Anton Titov is a leading engineer at CAO. His research interests concern GNSS data usage for geophysical applications, including ionosphere and troposphere. He also works on the physical ionosphere model improvements.

Boris Khattatov is a CEO at the FusionNumerics LLC. He has implemented the first version of the ionosphere model and is now providing the scientific governance for the further model development. His research interests now concern numerical analysis application to the complex systems.

Vyacheslav Khattatov is the department head at the Central Aerological Observatory. He is also the ionosphere model development project supervisor. His research interests are atmosphere and ionosphere sounding and modelling.

Ruslan Mazakirov is a leading engineer at the CAO. Hy is responsible for the ionosphere state databases formation and the case- study analysis.

I. INTRODUCTION

Nowadays, the space weather in general and the ionosphere in particular are the growing concern for the scientific and technological community. The behaviour of the space plasma in near- Earth vicinity provides a lot of questions to the geophysicists to resolve. So far, plenty of the ionosphere- atmosphere and Sun- Earth interactions are explained only on a quantitative basis. On the other hand, the satellites, responsible for the vital surveys operations (e.g. GNSS, satellite communications etc.), suffer from space weather events, such as Coronal Mass Ejections (CMEs) and geomagnetic storms. These events and their impact on the near- Earth medium is hard to predict.

Several approaches are currently implemented to estimate the current ionosphere state and a mere of it's variability during the solar and geomagnetic storm events. These include empirical modelling (e.g. International Reference Ionosphere model), physics-based modelling and instrumental monitoring. Along with the well- known advantages, the traditional approaches have several serious drawbacks, which constrain their usage within the high- precision applications. The empirical models are based on the limited datasets, and, as a result, are inaccurate in the low- data regions. The physics- based models, while covering the whole globe, are based on the approximate empirical parameterizations of the crucial processes, which makes their results diverge from the real ionosphere state with time.

The recent decades advance in the numerical weather prediction is highly related to the modern approach, combining the physical model results with the operational system observations. The so- called data assimilation technique allows to update the initial conditions for the physical model, maintaining thus the desired level of precision and stability. The current paper focuses on the data assimilation ionosphere model, adjusting the first- principle model results with the ionosphere slant Total Electron Content (TEC)