2013 Workshop: Data Assimilation Satellite Simulations

Long title

Planning Observing System Configurations for Answering Geospace System Science by Utilizing Simulation and Data Assimilation

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Description

Space science research is at the dawn of a new era. Many space scientists are learning that future discovery and understanding in space research requires taking a view of the Geospace environment as a complete system. Motivated by this revelation is the growing view that as researchers we cannot tackle many of the open research questions without global coverage of key measurements. Fortunately, many measurements of interest support the deployment of global and dense arrays of instrumentation on both ground and space based platforms. Due to technological advancements in commercial of the shelf (COTS) instrumentation these global measurements are now achievable at a fraction of their historic cost. This cost reduction results from using commercially developed instruments that are repurposed from their original consumer and industrial uses, such as GPS, inertial measurement, and magnetometers, and new low cost access to space via commercially available hosted payloads, sub-orbital flights, and CubeSats. The purpose of the proposed workshop is to explore new frameworks that investigate the scientific value of deploying global networks of these low-cost sensors for space environment applications. This type of Observing System Simulation Experiment (OSSE), as it is more commonly known in Earth sciences, will provide the framework for assessing the potential of future mission scenarios and help to determine the scientific return on investment for a given space science question of interest. This is accomplished by determining the level of measurement fidelity though assimilative modeling and other software tools, which will help to reduce risk and lower costs for both space and ground based sensor deployments.

In order to make progress in understanding the interaction regions, we need global estimates of all or at least most of the IT state variables. Up to now, data assimilation methods have focused on electron density. However, it is clear that we cannot make progress on understanding these interaction regions, without a more complete specification of the state. While incoherent scatter radars (ISRs) have done a great job of measuring multiple state variables in a specific region, further progress requires estimates over a spatially extended region, preferably global.

In the last few years, there have been advances in using data assimilation to estimate other state variables besides electron density. These include 4DVAR methods (JPL/Pi), ensemble Kalman Filters with cross-correlation estimation of neutral densities (NCAR/Matsuo), and estimation of winds and electric fields via minimization of the continuity equation (JHUAPL/Bust and IIT/Datta-Barua).

The hypothesis here is that to advance the state of the science, we will need to have additional ground- and satellite-based measurements of not only observations related to electron densities, but direct observations of other IT state variables such as neutral winds, ion, electron and neutral temperatures, electric fields, and neutral composition such as from O/N2 ratios.

Initially, we intend to meet our objectives by simulating various types of satellite data sources, satellite orbit configurations and constellations of satellites. Since we are trying to understand what would be proper sensors AND configuration of satellites and orbits, we will need to do extensive simulations to investigate this. Simulations will require first principle IT models such as TIEGCM, CTIP and SAMI3. We then will need to simulate satellite orbits and sensor observations, including realistic estimates of errors. Finally the simulated data will be made available to all members of the data assimilation community, who can then use their own algorithms to obtain estimates of the state variables. The estimates will be then compared with the simulated “truth” in order to investigate how different configurations of sensors / satellites perform.

This will truly be a community wide effort. We need the models and modelers, to produce truth simulations; we need the instrument developers to help provide realistic simulation observations and errors for both space and ground instruments; and we need data assimilation researchers to ingest the simulated data. Finally, the entire community will need to help decide what are the most appropriate metrics to assess the performance of various satellite configurations and combinations of data sources. This will be a cooperative effort among a large group of interested parties to attempt to understand and plan for what are the best satellite observations and configurations we should have in the future to support the entire CEDAR community.

We plan for a three year set of workshops. The first year will accomplish the following goals a) Agree on overall plan and approach b) Agree on a simulation plan c) Get agreed action items on developing and running the simulations, with a goal of having the first set of simulations done by AGU, and sent out to the data assimilation people d) Agree upon a set of metrics we will use. e) Then from AGU on, the individual data assimilation efforts can be run using established models, and metrics.

The second year, we will spend ½ of the workshop on results from the previous year and ½ of the workshop planning follow on simulations – based on the results of the first year - for the third year. We will then follow the year 1 approach for the new simulations, and report on results in the third year workshop. The outcome of the three year set of workshops will include a report that summarizes our results for the entire CEDAR community, as well as whatever publications and presentations are made.

Since this is a much bigger problem than we can solve with three CEDAR workshops, we hope this will evolve into a permanent working group, that can extend beyond CEDAR meetings, and perhaps seek some independent funding to allow the investigations to continue.

The main goal of this effort is to assist the entire CEDAR community in realizing the Strategic Vision and research thrusts discussed in “CEDAR : The New Dimension, Strategic Vision” as well as the latest NASA decadal surveys related to ITM science.

Justification

The primary strategic thrust is development of observational and instrumental strategies for geospace system studies related to the exploration of exchange processes at interfaces and boundaries [CEDAR Strategic Thrust #2 and #4]. The workshop is also relevant to the Heliophysics Decadal survey: “Towards a Diversified, Distribued Sensor Deployment Strategy”. The objective of this workshop is to investigate and improve our understanding of: the internal boundaries between the ionosphere and thermosphere (IT) states, the interaction boundaries between IT, magnetosphere and solar wind, and the boundary interactions between the lower mesosphere and the IT system. A secondary objective is enhanced understanding of internal variability of the ITM system. We note that there is a space weather relevance to society that is also part of the CEDAR broader impacts.

The overall approach to these challenges is to develop a significantly improved global data assimilation capability for estimation of all (or at least several) state variables simultaneously. We will accomplish this by investigating how, and to what degree, different satellite and ground sensor networks and configurations (constellations) can improve the accuracy, spatial resolution and temporal resolution of global estimates of ionosphere-thermosphere (IT) state variables through ingestion into IT data assimilation algorithms and models.

The major resources required are first principle models of the ionosphere and thermosphere, the capability to simulate instrument platforms and observations. These resources will allow us to produce comprehensive simulations of data to be ingested by data assimilative models for various configurations of constellations and data sources.

Progress will be measured by metrics that will illustrate how well different configurations and instruments improve the data assimilation of state variables when compared with “truth”.

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