2023 Workshop: Uncertainty in the ionosphere-thermosphere models and measurements

Long title

Uncertainty in the ionosphere-thermosphere models and measurements: sources, impacts, quantification, mitigation, and challenges

Conveners

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Description

“A critical element to enhance our current understanding and predicting capabilities is the determination of whether the model releases or data products being developed are accurate and reliable”. In the joint NSF-NASA program Space Weather with Quantified Uncertainty, we focus on uncertainty quantification. Every time we conduct numerical simulations, develop empirical models or estimate geophysical parameters from observing instruments, uncertainty arises due to limitations of the observing techniques, assumptions to derive parameters from measurements, simplified physics, and discretization in models.

The workshop will focus on several aspects of uncertainty in models and observations. Specific questions are like:

1. What causes models and measurements to be uncertain?
2. How does uncertainty impact the analysis and interpretation of data and model results?
3. What techniques can be applied to quantify uncertainties in models and measurements and their impact on our results?
4. What are the challenges and corresponding measures to better reduce or mitigate the impact of uncertainty?

Agenda

10:00AM–12:00PM, June 30, 2023 (2 hours)

Join Zoom Meeting

https://cuboulder.zoom.us/j/91740984013

Meeting ID: 917 4098 4013

Passcode: 157812

10:00–10:02 Introduction

10:02–10:22 Christoph R. Englert (Naval Research Laboratory)

Title: Michelson Interferometer for Global High-Resolution Thermospheric Imaging (MIGHTI): On-Orbit Instrument Performance.

10:22–10:34 Patrick Alken (NOAA/CIRES)

Title: A tutorial on modeling data with an application to ionospheric magnetic fields

10:34–10:46 Joshua Daniell (West Virginia University)

Title: Probabilistic Space Weather Modeling for Orbital Drag.

10:46–10:58 Sai Gowtam Valluri (UAF)

Title: Machine Learning based Ionospheric electrodynamics model: Present State and Challenges

Auroral electrodynamics models play a crucial role in determining the magnetospheric influences within the GCMs. However, the current models still rely on the old empirical models for potential specification in GCMs highlighting the need for substantial improvements. As part of the MAGICIAN project, we developed a novel ML-based model framework called ML-AIM, which utilizes the ML-based FAC model and statistical conductance models to calculate high-latitude ionospheric electrodynamics. By solving the current continuity equation, important ionospheric electrodynamic parameters such as electrostatic potential, Joule heating rate, Pedersen, and Hall currents are computed. The CNN-FAC model developed by Kunduri et al. (2020) is utilized to compute FACs, while conductance is determined using the methods established by Moen and Brekke (1993) and Robinson et al. (2020). ML-AIM takes various inputs, including the 60-minute time history of interplanetary magnetic field (IMF) components (Bx, By, and Bz), solar wind velocity (Vx), proton number density (Np), geomagnetic indices (Sym-H, Asym-H, SuperMAG AL, and AU indices), F10.7 solar flux, and the month number. The outputs of ML-AIM consist of the electrostatic potential, electric field, Joule heating rate, and horizontal ionospheric currents. This presentation discusses the advantages, limitations, and challenges of ML-AIM.

11:58–11:10 Marcin Pilinski (Laboratory for Atmospheric and Space Physics, University of Colorado)

Title: Uncertainties Associated with Satellite Drag Datasets for Atmospheric Model Construction and Assimilation

11:10–11:22 Simin Zhang (1.National Space Science Center, Chinese Academy of Sciences, Beijing, China; 2. High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA)

Title: Ionospheric Vertical Correlation Distance Calculation Based on COSMIC Electron Density Profile Data

11:22–11:34 Chih-Ting Hsu (UCAR)

Title: Effects of forcing uncertainties on the thermosphere and ionospheric states during geomagnetic storm and quiet period in the WACCM-X

Upper-atmospheric weather prediction is subject to various types of forcing uncertainties. Understanding the sensitivity of the thermosphere and ionosphere to forcing uncertainties under different geomagnetic conditions is critical for space weather predictions. Ensemble simulations of a whole atmospheric model, the National Center for Atmospheric Research Whole Atmosphere Community Climate Model with thermosphere and ionosphere eXtension (WACCM-X), with various kinds of forcing perturbation is used to evaluate the upper atmosphere's response to the uncertainties of different forcings. Two kinds of forcing uncertainties are addressed: the lower atmospheric wave and tide forcing uncertainties and high-latitude electric potential uncertainty. These uncertainties are estimated in different ways and applied to generate forcing perturbations in the WACCM-X. WACCM-X can simulate the upper atmosphere's response to the uncertainties of the lower atmospheric wave and tide forcings related to different lower atmospheric conditions. High-latitude electric potential uncertainty is estimated based on the SuperMag and SuperDARN data through the Assimilative Mapping of Geospace Observations, which is applied to generate the forcing perturbation of high-latitude electric potential in the WACCM-X. The results show that the impact of high-latitude electric potential uncertainty is significant globally during the 2013 St. Patrick's Day storm. The lower atmospheric wave and tide forcing uncertainties result in a global impact on the upper atmosphere in the model. The sensitivity of the upper atmosphere to both uncertainties is approximately the combination of the two individually, though the combined effects are not a linear sum, indicating non-linearities in the ionosphere and thermosphere response to forcing uncertainties.

11:34–11:46 Weijia Zhan (CU Boulder)

Title: Uncertainty quantification and its application to ionosphere-thermosphere model.

11:46–12:00 Discussion

Justification

A critical element to enhance the understanding and developing predictive capabilities is the determination of whether the model or data products being developed, and any associated simulations, are accurate and reliable. This session will convene experienced researchers in the community to share their achievements on uncertainty quantification and mitigation in models and measurements, and thoughts on the challenges and needs. The session will cover tutorials on uncertainty and achievements of the innovative research areas to reach the young attendees at CEDAR. This session will be a specific platform for the community to share the newest techniques for reducing the impacts of uncertainty in data processing and model development, and thoughts on strengths and weaknesses in current techniques. This session will respond to the CEDAR Strategic Thrust #5 Fuse the Knowledge Base across Disciplines in the Geosciences to promote collaborations in related but distinct disciplines of geosciences, mathematics, engineering, and physics to attract a greater variety of researchers and students spawning new ideas and methodologies that will more rapidly advance geospace studies.

Related to CEDAR Science Thrusts:

Fuse the knowledge base across disciplines in the geosciences

Manage, mine, and manipulate geoscience/geospace data and models

Keywords

Uncertainty, Data science, Model development

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