2018 Workshop: Multi scale IT system System Dynamics

Long title

Grand Challenge: Multi-scale I-T System Dynamics

Grand Challenge

Conveners

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Description

It has been recognized that there are various scales in the thermosphere and ionosphere system, and that a variety of processes interact across these scales, depositing energy and momentum at different levels. Until recently, researchers who study larger- scale processes and researchers who study smaller-scale processes have not interacted much at all, since there was little ability to apply lessons learned on meso/small scales to the large scales and vice-versa. With the advent of more global scale networks of sensors (all sky imagers, GPS receivers, SuperDARN, Iridium, etc.), and large-scale models that can be run at fine resolution (less than 100 km) and local-scale models that can be run over fairly large scales, it has become possible to explore the coupling between scales.

Agenda

Session 1 Monday 13:30-15:30

Discussion on multi-scale M-I-T processes

- **Aaron Ridley and Toshi Nishimura** Introduction to the theme/problem
- **Kristina Lynch** Observations of small scale arcs in larger systems, and how to combine measurements on different scales
- **Erdal Yigit** Processes among large/meso/small scales, including the role of small-scale gravity waves on the I-T system
- **Open discussion on Grand Challenge questions**

Session 2 Tuesday 10:00-12:00

Meso-scale processes

- **Brent Parham/Josh Semeter** Cubesat FAC observation
- **Eric Donovan** A statistical survey of the 630.0 nm optical signature
- **Shasha Zou** IT response to solar wind dynamic pressure changes
- **Evgeny Mishin** Plasma turbulence in the plasmasphere boundary layer during intrusion of MPFs and ionospheric heating
- **Bea Gallardo-Lacourt** STEVE
- **Shasha Zou** Global IT response during geomagnetic storms focusing on storm enhanced density
- **Kshitija Deshpande** Two different models (plasma and spectral) covering different scales in ionospheric irregularities
- **Discussion continued from Session 1**

Session 3 Wednesday 10:00-12:00

Small-scale processes

- **Katrina Bossert** Effects of small-scale driving on the I-T system from below: Observational
- **Hanli Liu** Effects of small-scale driving on the I-T system from below: Modeling
- **Don Hampton** Effects of small-scale driving on the I-T system from above: Observational
- **Yue Deng** Effects of small-scale driving on the I-T system from above: Modeling

- **Tomoko Matsuo** Stochastic modeling/parameterization of non-Gaussian high-latitude small-scale electric fieldS
- **Meers Oppenheim, Matt Zettergren, Aaron Ridley, Vania Jordanova** Panel discussion

Justification

(1) Introduction

Owing to recent advances in global simulations and a rapidly increasing amount and coverage of observations, the community has gained an appreciable level of understanding of large-scale and dynamics in the and . On the other hand, high-resolution network observations by distributed sensors have revealed the existence of strong localized and transient structures between a few 10s and a few 100s km size and several minute duration. Those are referred to as meso-scale structures and have indicated to have potential substantial impacts on the - system. Small size (<~10 km) dynamics including turbulence are also recognized as a critical component for Global Navigation Satellite System (GNSS) signal scintillation, conductance, and energy dissipation. The multi-scale (large, meso, small) nature is ubiquitous in the global including the , polar cap, auroral oval, mid latitudes, and equatorial regions. For example at high latitudes, flows and precipitation imposed by the tend to be more intense at meso-scale than at large-scale, and has been shown to have strong responses to such meso-scale energy input. Localized fast flows and density structures travel across regions as flow channels and waves, giving rise to coupling across latitude and longitudes. Meso-scale structures are also important sources of energy that cascades down to small-scale structures and forms density irregularities.

Despite the now-known importance and ubiquity of multi-scale dynamics in the global , their properties have not been thoroughly examined or documented. The lack of multi-scale input to models has prevented simulations from testing their impact on the global I-T system. Also simulation capabilities for handling multi-scale I-T processes are significantly limited. Thus nonlinear processes of the cross scale coupling are not clearly understood. Furthermore, impacts of multi-scale coupling processes have not been quantified or reproduced.

(2) Proposed challenge questions

While we will welcome any investigations that explore coupling across scales, we will specifically focus on:

- How much can we improve physics understanding and reproducibility of multi-scale coupling processes?
- What are quantitative properties of meso/small-scale structures in the I-T system? How are they driven by the magnetosphere and atmosphere?
- What are the roles of meso/small-scale I-T structures and dynamics? How much do they impact on the global state?
- What are physical processes that result in multiscale density structuring? e.g., polar cap patch generation, auroral and subauroral density structures, and associated instabilities (e.g., gradient-drift and Kelvin-Helmholtz) in the presence of density structures.
- What are the roles of energy cascading processes (e.g., by Farley-Buneman Instabilities) in creating increased conductance and the effect of this increase on structures, Joule heating and momentum forcing at global scales?
- What are the roles of small-scale gravity waves in momentum and energy forcing in the lower and how this drives ionospheric structuring?

(3) How the questions will be addressed

We will have three sessions each year, each being discussion-oriented and not filled with AGU-style presentations. The three sessions will be focused on: (1) the general topic of cross-scale coupling; (2) specific data analysis results; and (3) specific model analysis results. Invited speakers will give updates that will drive discussion through the rest of the workshop time.

(4) What resources exist, are planned, or are needed

Growing networks of ground and satellite instruments will be heavily utilized for this activity. We will discuss the use of the available data for building science knowledge of multi-scale coupling processes, quantifying control parameters and test ability of forecasting by machine learning and data assimilation, and combine those with numerical simulations for physics understanding. The proposed activities will be coordinated with GEM (M-I-T coupling FG, Substorm FG, and ULF FG) by bringing their knowledge and holding joint campaigns.

(5) How progress should be measured

(a) Identify science goals that have high impacts on I-T research, and scientific and technical gaps to reach these goals; (b) Identify pathways to address these through discussions and collaborations; (c) Plan and conduct data analysis and modeling campaigns; (d) Enable improved and newly developed models and data technologies to feedback for community-wide benefit; and (e) Report updates and discuss strategies to fill gaps to reach the goals.

Community-wide discussions and collaborations among observers and modelers across regions and scales are required to address the challenge of understanding geospace across scales (i.e., multi-scale). At previous CEDAR meetings, multi-scale discussions have taken place in a rather ad hoc, uncoordinated, and disjointed manner. Multi-scale coupling is a Grand Challenge because the science understanding and technologies for bridging the different scales do not exist in our community, either on the observational or the modeling side. Despite understanding of potential and auroral patterns on global scales, existing models do not specify meso-scale (a few 10s and a few 100s km) and small-scale (<~10 km) in the context of the large-scale system. On the modeling side, we have large-scale and meso/small-scale models that have never been compared, since the systems have been operated independently. This subject is timely, since both observation and modeling systems are increasingly sophisticated and capable to explore a variety of scales and the CEDAR community needs to develop the tools to bridge this knowledge gap. We propose a workshop-style format that consists of a coherent discussion of activities, identification of science questions and diversified solution methodologies, implementation and evaluation amongst relevant experts who otherwise are not usually deliberately aligned in a single session.

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