2023 Workshop: Dynamic ITM coupling during geomagnetic storms

Long title
Dynamic coupling of the thermosphere-ionosphere system during geomagnetically active periods
Grand Challenge
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Description

Earth’s coupled ionosphere-thermosphere (I-T) system is controlled by complicated chemical and physical processes that vary greatly with external driving conditions and internal dynamics. These variabilities become much stronger during storm times, when the interaction between the solar wind and geospace produces significant energy and momentum inputs to the I-T system through enhanced high-latitude convective electric fields, particle precipitation, and thus Joule heating and ion drag, changing high latitude composition, winds, and temperature. These storm-time, high-latitude perturbations are then transmitted to middle and low latitudes, as well as to different heights, through non-linear dynamics and electrodynamics, such as penetration electric fields, disturbance dynamo and traveling atmosphere/ionosphere disturbances (TADs/TIDs), changing global neutral and plasma densities, and producing structures of different spatial and temporal scales. Recent development of first principles models of the coupled geospace system and new observations from space missions such as TIMED, GOLD, ICON and COSMIC II and various ground-based observations provide new opportunity to explore the fundamental coupling physics in the I-T system during geomagnetically active periods and its feedback on the magnetospheric dynamics. Variations in the storm response are thought to be partially controlled by preconditioning, including the state of lower atmospheric forcing, requiring the use of whole atmosphere models such as WACCM-X and GAIA. This session welcomes presentations of both observations and modeling on the dynamic changes of the I-T system during storms.

Agenda

13:30

Immel, Thomas

E- and F- region disturbance winds in daytime

13:40

Detrich, Nick

Investigating the I-T storm response using Data Assimilation Reanalysis

13:48

Gan, Quan

Thermospheric responses to the 3rd November 2021 geomagnetic storm observed by NASA GOLD and ICON

13:56

Laskar, Fazlul

Thermospheric temperature and composition variability during and after and geomagnetic storm

14:04

Cai, Xuguang

Thermosohere composition and temperature response to the first severe storm in solar cycle 25 observed by GOLD

14:12

Zhu, Qingyu

Investigating storm-timeionospheric and thermospheric responses using FAC-driven GITM simulations: Advantages and challenges

14:20

Lyons, Larry

Mesoscale polar cap flow channels: Long Duration Azimuthal Propagation and Driving of Space Weather Disturbances

14:28

Hecht, Jim

First Results from DAILI, a 6U CubeSat Designed to Study O2 Density from 140 to 200 km at Low and Mid Latitudes

14:38

Cosgrove, Russell

An electromagnetic calculation of electric field mapping that finds very unexpected results

14:46

Selvaraj, D.

Effects of Geomagnetic Storms on the Ionosphere over Arecibo

14:54

Zhang, Yongliang

Storm-time O density increase in the upper thermosphere: TIMED/GUVI observation

15:02

Sivadas, Nithin

Uncertainty in solar wind propagation leads to biased estimates of the ionospheric response

15:10

Zhang, Jiarong

The dynamical influence of the October-November 2003 solar proton events on the lower thermosphere

15:18

Suresh, Sunanda

Ionospheric Electron Temperature and Density during Extreme Geomagnetic Storm Events

Justification

Geomagnetic storms are an important driver of variability in geospace. Geomagnetic storms can cause dramatic fluctuations in the ionosphere and thermosphere's density, composition, and temperature. Increased high latitude energy input and precipitation causes heating and increased ionization, significantly altering dynamics. These effects can also propagate down into the lower atmosphere. The effects of geomagnetic storms are of particular interest because extreme events can affect spacecrafts, or electric transmission grids on earth. Changes in thermospheric density can dramatically change spacecraft drag. Ionospheric irregularities produced by geomagnetic activity can affect radio communication and GPS. Understanding the effects of geomagnetic storms on geospace dynamics and structure is important for understanding geospace conditions and coupling as a whole.
Coupling in the I-T system during geomagnetic storms is a broad and important topic. All regions of geospace are involved and affected by geomagnetic storms, making this topic well suited for a grand challenge session at CEDAR. Individual, isolated studies are not likely to make significant advances, so a forum for community collaboration is essential. A multi-year effort will allow focus on each relevant region. This session will encourage collaboration between experts in each region, enabling progress on coupling. This session will also create the opportunity for collaboration between modeling and observations, both within the CEDAR community and between the GEM and CEDAR communities. The modeling advances at the Center for Geospace Storms, a NASA DRIVE center focused on geomagnetic storms in all regions of geospace, are particularly relevant. With new missions on the

horizon and recent developments in coupled geospace models, there are many opportunities for advancing the understanding of geomagnetic storms. Solar cycle 25 is currently ramping up and is expected to peak in July 2025, making this session particularly relevant now. So far, solar cycle 25 has exceeded predicted solar activity levels. This grand challenge session will help to coordinate efforts during this vital period for studying geomagnetic activity. In the next three years, there will only be more opportunities for new observations and discoveries, and the proposed workshop will help synergize efforts (e.g., by identifying observational and modeling campaigns).

The upper atmosphere is a complex system influenced by the deposited energy and momentum from below (tides, gravity waves, etc.) and from above (solar and magnetosphere forcing). Although the behavior of the system during geomagnetically disturbed periods has been studied for many decades, significant knowledge gaps still exist. For example, What is the fundamental physics governing the coupling in the I-T system during geomagnetic disturbances? How do high latitude energy input and momentum transfer alter the mass circulation in the I-T system at different spatial and temporal scales? How do changes in the I-T system affect the coupling to the magnetosphere? How do magnetospheric forcing and atmospheric forcing contribute to the formation of ionospheric irregularities? What is the interplay of mechanical, chemical, and electrodynamic forcing in causing low-latitude storm effects?

How the science question will be addressed: The science questions will be addressed with modeling and observational studies.

Resources that exist, are planned, or needed: Space missions are important existing resources along with ground-based observatories such as ISRs, airglow imagers, GNSS, SuperDARN, ionosondes, magnetometers . Upcoming GDC and DYNAMIC missions are extremely relevant to these science questions. Coupled ITM models, such as MAGE, are also important resources.

How to measure progress: Progress can be measured through improved ability of models to capture observed storm-time phenomenon/irregularities and improved understanding of storm-time dynamics.

Related to CEDAR Science Thrusts:

Encourage and undertake a systems perspective of geospace

Explore exchange processes at boundaries and transitions in geospace

Workshop format

Short Presentations

Keywords

ion-neutral coupling, high latitude energy input, ionospheric irregularities,

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