2021 Workshop: Poynting Flux

Long title
Grand Challenge: Understanding the Electromagnetic Energy Input to Earth’s Atmosphere
Grand Challenge
Conveners
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Description

We plan to bring together observationalists, modelers and data assimilation experts to address a major challenge of the CEDAR community: understanding the electromagnetic energy input to Earth's atmosphere. The idea is to bring these experts together to exchange information, specifically to identify, highlight and ultimately address the current challenges faced by the modeling community in coupling whole-atmosphere models with magnetospheric models. A strong presence from the observational community is required to address the challenges faced by modelers, and to highlight the major deficiencies (in terms of spatio-temporal resolution and overall accuracy). Following the first-year meeting we will mount a coordinated observational campaign focused on determining the Poynting flux as accurately as possible over a specific region (to be chosen in the first-year meeting). In parallel to this, we will work on developing existing approaches to the problem (e.g. AmGEO, MIX) and coupling those specification efforts to models that include the ITM. By the third year, we expect to have validated these specifications and quantified their effects on other model parameters, as well as quantifying the uncertainties and the important covariances between errors at different points and in different variables. This information will be critical in feeding the development of whole-atmosphere-magnetosphere modeling efforts, both through validation of those models and possibly through direct data assimilation.

Agenda

10:00 / Ridley / Energy deposition from a fluid's perspective

10:20 / Pakhotin / Northern preference for terrestrial electromagnetic energy input from space weather

10:40 Weimer Using HASDM neutral densities to validate thermosphere density predictions based on an empirical Poynting flux model

11:00 / Pena / Ionospheric heating due to auroral precipitation: sensor measurements and modeling results

11:10 / Verkhoglyadova / Role of Alfven waves in electromagnetic energy input to Earth's atmosphere

11:20 / Rodriguez-Zuluaga / Equatorial Spread F-related Poynting flux seen at LEO altitudes

11:40 / Plenary / Decadal white paper discussion

10:00 / Deng / Poynting Flux in the Dayside Polar Cap Boundary Regions From DMSP Measurements

10:20 / Zhang / Alfvénic Heating and Thermospheric Upwelling in the Cusp

10:40 / Billett / Statistical Poynting flux patterns from SuperDARN and AMPERE: Is Poynting flux related to thermospheric density enhancements in the cusp?

11:00 / Zesta / Poynting flux in the context of the upcoming GDC mission

11:20 / Knipp / Nine satellite years of DMSP Poynting flux—Insight and Even More Questions form the Data

11:30 / Plenary / Decadal white paper discussion

Justification

At high latitudes, electromagnetic energy from the Solar wind and magnetosphere flows into the upper atmosphere through the ionosphere (e.g. Gary et al., 1994). This is quantified in terms of Poynting flux. During active magnetic periods, this energy source can be larger than Solar radiation (Luhr and Liu, 2006) and is certainly harder to characterize at all times. The Poynting flux is transformed into thermal or kinetic energy through particle acceleration in the magnetosphere and Joule/frictional heating in the upper atmosphere (e.g. Thayer and Semeter, 2004). Despite the obvious importance of this energy source to the coupled Ionosphere-Thermosphere-Mesosphere (ITM) system, an accurate global picture of the Poynting flux at relevant spatio-temporal scales remains elusive. Current models of the ITM typically still rely on empirical models based on historic datasets (e.g. Heelis et al., 1982; Weimer, 2005) to estimate this forcing. Recent major advances in modeling from the ground up to 600-km (e.g. WACCM-X, WAM, GAIA) and, separately, from the Solar wind down to the ionosphere (e.g. GAMERA, BATS-R-US) essentially meet here.

Science Question: What is the electromagnetic energy input into the Earth’s atmosphere? This topic is aligned with the strategic thrusts outlined in the CEDAR strategic vision. It explores an exchange of energy between all of the space-atmosphere-interaction region (SAIR), it merges many geoscience datasets and models, and it synthesizes knowledge from several disciplines of the solar-terrestrial sciences. Therefore, this Grand Challenge is expected to have a major impact on a large segment of the CEDAR research community.

Alignment with Strategic Plan: This Grand Challenge directly addresses the Space-Atmosphere Interaction Region and an energy transfer process that defines its global behavior. The goal is to understand how, and how much, electromagnetic energy from the Solar wind and magnetosphere is transferred into the upper atmosphere and how that affects the dynamics of the region. This addresses GS Plan Goal #3: "[to understand] How mass, energy, and momentum are transported through the heliosphere, magnetosphere, ionosphere, and atmosphere"

Societal Relevance: Geospace system dynamics driven by electromagnetic energy input, including the high-latitude convective and kinetic processes, produce ionospheric and atmospheric phenomena that have major impacts on technology. For example, at high latitudes, the dominant pattern of GPS signal loss observed by Xiong et al. (2018) appears to be directly associated with the convection of plasma into the polar caps from the sub-auroral dayside ionosphere (Chartier et al., 2019). Both the high-latitude plasma convection cycle and particle precipitation are byproducts of the divergence of the Poynting flux in ITM system.

A. D. Richmond (pdf)

Chartier, A. T., Huba, J. D., & Mitchell, C. N. (2019). On the Annual Asymmetry of High-Latitude Sporadic F. Space Weather, 17(11), 1618-1626.

Cosgrove, R. B., Bahcivan, H., Chen, S., Strangeway, R. J., Ortega, J., Alhassan, M., … Cahill, N. (2014). Empirical model of Poynting flux derived from FAST data and a cusp signature. Journal of Geophysical Research: Space Physics, 119(1), 411–430. https://doi.org/10.1002/2013JA019105.

Gary, J. B., Heelis, R. A., Hanson, W. B., & Slavin, J. A. (1994). Field-aligned Poynting flux observations in the high-latitude ionosphere. Journal of Geophysical Research: Space Physics, 99(A6), 11417-11427.

Thayer, J. P., & Semeter, J. (2004). The convergence of magnetospheric energy flux in the polar atmosphere. Journal of atmospheric and solar-terrestrial physics, 66(10), 807-824.

Luhr H. and Liu H. (2006): The thermopheric response to geomagnetic storms. ILWS Workshop. GOA Xiong, C., Stolle, C., & Park, J. (2018, April). Climatology of GPS signal loss observed by Swarm satellites. In Annales Geophysicae (Vol. 36, No. 2, pp. 679-693). Copernicus GmbH.

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