Project Details

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Topic: Atmosphere-Ionosphere Coupling During Stratospheric Sudden Warmings

Project Title:
Coupling of the Atmosphere and Ionosphere During Stratospheric Sudden Warming Events: Signals, Processes and Their Sensitivities

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Summary:
Stratospheric Sudden Warming (SSW) events give us the opportunity to study how strong disturbances in the stratosphere propagate upwards, change mesospheric and thermospheric dynamics, and affect the ionosphere. Although during the recent solar minimum clear ionospheric signals due to SSW events could be observed, it is still unclear what the major coupling processes of the atmosphere-ionosphere are.

The main science objective of this proposal is to understand what are the major processes which influence the ionosphere during SSW periods, and to elucidate their sensitivity with respect to geospace conditions. The NCAR-Thermosphere-Ionosphere-Mesopshere-Electrodynamic General Circulation Model (TIME-GCM) will be used to self-consistently simulate different SSW events. The Ionosphere-Plasmasphere-Electrodynamics (IPE) model will be driven by the TIME-GCM results to examine the importance of the major coupling mechanisms. We will focus on two mechanisms that have been proposed to explain effects observed in the F-region ionosphere: electrodynamic coupling via electric fields modulated by waves and tides mainly in the E region during the day and in the F region at night, and direct penetration of tidal disturbances to the upper thermosphere. We will quantify their relative importance during the evolution of SSW events with respect to latitude for both day and night time.

For space weather applications it is important to understand the influence of the solar cycle on the ionosphere during SSW events. Using realistic SSW events we will study the ionospheric SSW effects for different levels of solar activity, and examine if the major atmosphere-ionosphere coupling mechanisms are changing. Modeling results have shown that the geomagnetic disturbance signals in the ionosphere are stronger when planetary wave forcing is included at the lower boundary. Using numerical simulations we will investigate if there are positive feedback mechanisms between meteorological and geospace forcing. SSW events originate in the polar winter stratosphere due to strong planetary wave activity. The ionosphere at low and middle latitudes exhibits decreases in zonal mean NmF2 and hmF2 as seen by, e.g., COSMIC, with a 2-4 day delay from the stratospheric temperature maximum. We will quantify the simulated ionospheric SSW effects at all latitudes, compare with observations, and investigate possible mechanisms.

Ground magnetic perturbation observations have a long historical record and a wide-spread spatial distribution. Signatures of SSW are seen in the ground magnetic perturbations. At low latitude the magnetic perturbations can be used to quantify the strength of the equatorial electrojet. In the afternoon a counter-electrojet has been reported during SSW events. We will use the TIME-GCM to calculate ground magnetic perturbations and the current system. We will examine the effects of SSW events on the magnetic perturbations, and determine how ground magnetic perturbations can be used to study ionospheric SSW signals and the atmosphere-ionosphere coupling.

The proposal addresses NASA strategic goal 2 Expand scientific understanding of the Earth and the universe in which we live , specifically the objective Improve understanding of the fundamental physical processes of the space environment from the Sun to Earth& . Understanding the causes of ionospheric variability is important since these can lead to ionospheric irregularities and scintillations of communication and navigation systems. The outcome of this study will help guide improvements to space weather models by elucidating the importance of different coupling mechanisms. Model simulations and processed model data will be made available to the scientific community through this investigation, further extending its impact.

Publication References:

Summary: no summary

Reference: Pedatella, N. M.; Liu, H.-L.; Richmond, A. D.; Maute, A.; Fang, T.-W.; (2012), Simulations of solar and lunar tidal variability in the mesosphere and lower thermosphere during sudden stratosphere warmings and their influence on the low-latitude ionosphere, Journal of Geophysical Research: Space Physics, Volume 117, Issue A8, CiteID A08326, doi: 10.1029/2012JA017858

Summary: no summary

Reference: Maute, A.; Hagan, M. E.; Richmond, A. D.; Roble, R. G.; (2014), TIME-GCM study of the ionospheric equatorial vertical drift changes during the 2006 stratospheric sudden warming, Journal of Geophysical Research: Space Physics, Volume 119, Issue 2, pp. 1287-1305, doi: 10.1002/2013JA019490

Summary: no summary

Reference: Maute, A.; Hagan, M. E.; Yudin, V.; Liu, H.-L.; Yizengaw, E.; (2015), Causes of the longitudinal differences in the equatorial vertical E × B drift during the 2013 SSW period as simulated by the TIME-GCM, Journal of Geophysical Research: Space Physics, Volume 120, Issue 6, pp. 5117-5136, doi: 10.1002/2015JA021126

Summary: no summary

Reference: Pedatella, N. M.; Maute, A.; (2015), Impact of the semidiurnal lunar tide on the midlatitude thermospheric wind and ionosphere during sudden stratosphere warmings, Journal of Geophysical Research: Space Physics, Volume 120, Issue 12, pp. 10,740-10,753, doi: 10.1002/2015JA021986

Summary: no summary

Reference: Pedatella, N. M.; Richmond, A. D.; Maute, A.; Liu, H.-L.; (2016), Impact of semidiurnal tidal variability during SSWs on the mean state of the ionosphere and thermosphere, Journal of Geophysical Research: Space Physics, Volume 121, Issue 8, pp. 8077-8088, doi: 10.1002/2016JA022910

Summary: no summary

Reference: Wu, Qian; Maute, A.; Yudin, V.; Goncharenko, L.; Noto, J.; Kerr, R.; Jacobi, Christoph; (2016), Observations and simulations of midlatitude ionospheric and thermospheric response to the January 2013 stratospheric sudden warming event,