2023 Workshop: Coupling between the Stratospheric Polar Vortex and the Ionosphere-Thermosphere-Mesosphere

Long title
Whole-Atmosphere Interconnections between the Stratospheric Polar Vortex and the Ionosphere-Thermosphere-Mesosphere: New Insights from Recent Modeling and Observational Studies
Conveners
Federico Gasperini
Larisa Goncharenko
McArthur Jones Jr
Nicholas Pedatella
Katelynn Greer
Tarique Siddiqui
Zishun Qiao
Katrina Bossert
federico.gasperini@orionspace.com
Description

The coupling of different atmospheric layers is one of the central topics of the annual CEDAR workshop. Processes generated by terrestrial weather in the lower atmosphere (i.e., below ~50 km altitude) are increasingly recognized as sources of variability in both the structure and composition of the ionosphere-thermosphere-mesosphere (ITM) region over a broad range of time scales. An exemplary case of such coupling are Sudden Stratospheric Warming (SSW) events. SSWs are large-scale phenomena characterized by dramatic dynamic disruptions in the stratospheric winter polar regions associated with a weakened polar vortex. SSWs lead to significant disturbances in the whole atmosphere, producing remarkable changes in composition, dynamics, and electrodynamics of the whole ITM system, pole-to-pole. Modeling and observational evidence also indicate that SSW impacts can extend into the summer mesosphere, mesopause, and ionosphere-thermosphere region via inter-hemispheric coupling. Meanwhile, recent evidence suggests that the connection between the stratospheric polar vortex and ITM is not limited to SSWs, and variability in the stratospheric polar vortex is a constant source

of ITM variability, especially during Northern Hemisphere wintertime. This session aims to promote discussions and collaborations among scientists working on different aspects of whole atmosphere coupling. Modeling and observational studies focused on stratospheric polar vortex variability, including but not limited to SSWs, and that examine atmospheric coupling in more general terms, including studies of connections via tides, planetary waves, Kelvin waves, and gravity waves, are invited.

Agenda

Join Zoom Meeting: https://cuboulder.zoom.us/j/91020398399
Meeting ID: 910 2039 8399, Passcode: 093122

13:30 – 13:35 Introductory Remarks (*Federico Gasperini*)

13:35 – 13:50 Tutorial: Stratospheric Polar Vortex (*Lynn Harvey, invited*)

13:50 – 14:02 New Results: Gravity Waves and Traveling Ionospheric Disturbances from the Polar Vortex (*Sharon Vadas*)

14:02 – 14:14 Tidal Contribution to Quiet-time Thermosphere Zonal Wind Variations over Alaska During the December 2018 SSW (*Komal Kumari, invited*)

14:14 – 14:26 Impact of the 2020/2021 SSW on the Thermospheric Circulation and Temperature as Observed by ICON and GOLD (*Erdal Yiğit*)

14:26 – 14:38 Response of the F-region Ionosphere to Variations in the Polar Stratospheric Vortex (*Deepali Aggarwal*)

14:38 – 14:50 Multi-Instrument Observations and Modeling of MSTIDs, LSTIDs, and the SPV: 2018-19 Case Study and 2010-2022 Climatology *(Nathaniel Frissell*)

14:50 – 15:02 Connections Between Stratospheric and Mesospheric Gravity Waves, Winds and Traveling Ionospheric Disturbances *(Sevag Derghazarian*)

15:02 – 15:14 Quantifying the Impact of the Stratospheric Vortex on Short-Term O/N_2 Variability in the IT from GOLD and WACCM-X (*Ben Martinez*)

15:14 – 15:30 Discussion

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Justification

It is well established that dynamical disturbances of lower atmospheric origin have a significant impact on the variability of the ionosphere-thermosphere-mesosphere (ITM) system. While until the past two decades or so terrestrial influences on ITM variability were generally thought to be limited to narrow geographic regions and short time scales, progress in the field has now unequivocally demonstrated that the effects can be broad both spatially and temporally, particularly during times characterized by prominent weakening in the winter stratospheric polar vortex known as Sudden Stratospheric Warmings (SSWs).

SSWs are large-scale phenomena characterized by dramatic dynamic disruptions in the stratospheric winter polar regions associated with a weakened stratospheric polar vortex (SPV). SSWs cause global variations in temperature, wind, and ozone density in the Arctic wintertime stratosphere (60°N-90°N). SSWs lead to considerable impacts throughout the middle and upper atmosphere, pole-to-pole, including changes in mesosphere composition, temperature, and winds; ionosphere electron densities, electrodynamics, and irregularities; and thermosphere composition, density, and temperature. Modeling and observational evidence indicate that SSW impacts can extend into the summer ITM regions through inter-hemispheric coupling. The SSW-induced effects on the ITM are primarily driven by changes in migrating and nonmigrating solar and lunar tides. The tidal variability occurs due to a combination of changes in tidal forcing and background winds which impact tidal propagation and resonance conditions. Recent evidence suggests that significant ITM variability can also occur following anomalously strong SPV conditions with significant consequences for the whole ITM system on different spatial and temporal scales. However, relatively little is known about ITM variability induced by strong polar vortex conditions.

More comprehensive knowledge of ITM variability during times of altered SPV has been hindered by observational limitations, especially given the relatively short time scales involved. Ground-based observations are suitable to examine SPV-driven day-to-day variations in the ITM that occur due to SPV variability, however, they are limited in their longitudinal coverage. Satellite observations can potentially address this issue, yet they lack sufficient sampling to observe the ITM variability on short-time scales. Moreover, the cross-scale and multi-scale nature of these whole atmosphere interconnections is ubiquitous and these effects are not well quantified or reproduced by whole atmosphere models. Additionally, only limited knowledge exists on the impacts of solar and geomagnetic preconditioning in this coupling.

Understanding how terrestrial weather impacts space weather of the ITM system across different spatial and temporal scales, especially during times of altered SPV, and delineating the underlying physical processes responsible for this coupling is a domain of compelling scientific inquiry. Such a domain can only now be studied by synergistically taking advantage of new capabilities from recent space missions (including ICON, GOLD, COSMIC-2, and CubeSats), ground-based observations, and sophisticated models. Modeling and observational studies focused on SPV variability and that examine atmospheric coupling in more general terms across different spatiotemporal scales, including studies of whole-atmosphere interconnections via tides, planetary waves, Kelvin waves, and gravity waves, are invited.

Summary

The overarching objective of this session is to advance the community’s understanding of whole atmosphere interconnections between terrestrial weather and ITM variability, particularly during times of altered stratospheric polar vortex (SPV), through discussion of combined modeling and observational studies across different spatial and temporal scales. This session will welcome any investigations that explore the coupling between terrestrial weather and the Ionosphere-Thermosphere-Mesosphere (ITM) system across scales, with a particular focus on the following challenge questions:

SQ1: What are the impacts on the ITM system from terrestrial weather associated with altered SPV conditions? How do they depend on the strength of the polar vortex? How do they vary with altitude and geographic region?

SQ2: What are the primary physical mechanisms that connect SPV variability with ITM variability? What are the temporal and spatial scales most relevant for this coupling? What are the comparative roles of tides, gravity waves, planetary waves, and ultra-fast Kelvin waves in this forcing? What are the effects of solar and geomagnetic preconditioning in the coupling?

SQ3: How well do state-of-the-art models perform across different spatio-temporal scales and what is the impact of data assimilation on model performance?

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Keywords
Stratospheric Polar Vortex, ITM Coupling, Waves, Global ITM System Responses
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