Project Details

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Topic: Impact of Terrestrial Weather on the Ionosphere-Thermosphere

Project Title:
Imprint of stratospheric QBO on the thermosphere and ionosphere

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Summary:
Science goals and objectives
During the past decade or so, it has been established that the troposphere-stratosphere region drives ionosphere-thermosphere-mesosphere (ITM) variability through generation of a spectrum of vertically propagating waves, including planetary waves, tides, and gravity waves. It was also revealed that the stratospheric Quasi-Biennial Oscillation (QBO) is one of the significant sources of variability in the mesosphere and lower thermosphere (MLT). However, studies of the QBO signature in the ITM are challenging due to the complex nature of the sun-atmosphere ionosphere system. In particular, earlier studies of links between the stratospheric QBO and the ionosphere remain inconclusive due to similar oscillations in solar flux.
This project strives to identify and quantify the imprint of stratospheric QBO on the ITM. It is well known that changes in the middle atmosphere wind are associated with tidal amplification and larger ionospheric variability during transient events such as sudden stratospheric warming. We hypothesize that stratospheric wind changes associated with the QBO produce tidal variability on QBO time scales and, consequently, are imprinted on ionospheric electron density. Moreover, the QBO-related variation in non-migrating diurnal tides in the MLT can modulate the equatorial ionospheric anomaly wave-4 longitudinal structure. Confirmation of this hypothesis will provide a basis for improved physical understanding of additional terrestrial sources of ionospheric variability, and it will have implications for the prediction of ionospheric conditions on short-term, sub-seasonal and interannual time scales.

Methodology
We will use a combination of space-based and ground-based data to identify anomalies in the ITM that are associated with the westerly and easterly stratospheric QBO phases, and study impact of different QBO phases on the ITM variability. TIMED SABER and TIDI data will be used to determine impact of QBO on tidal amplitudes. Observations of O/N2 from TIMED GUVI will be used to isolate QBO signatures in the ITM. We will develop localized empirical models of total electron content (TEC) and peak electron density at several latitude/longitude locations to form a broad grid, using 20+ years of data of GNSS TEC observations and multiple ionosondes. These models will be used to separate TEC/NmF2 variations attributed to solar flux, season, latitude, longitude, and local time from variability induced by the stratospheric QBO. We will use NASA MERRA2 data products to examine the importance of several tropospheric and stratospheric parameters as independent drivers for empirical ionospheric models for multiple distinct low-latitude locations. In addition to standard linear regression models, we will use machine learning tools and investigate the use of nonparametric regression (e.g. Gaussian processes and neural networks) to formulate our empirical models and select the most appropriate set of terrestrial drivers for the final models. Simulations with WACCM-X constrained with MERRA-2 will be employed to interpret variability of tidal dynamics in the MLT region for different phases of QBO and their subsequent impact on the thermosphere and ionosphere.

Relevance and Proposed Contributions to the FST Effort
This project is directly relevant to the scientific objectives of the FST, as it will identify and quantify the relative role of stratospheric QBO in the ITM variability on sub-seasonal and longer time scales. Our team will contribute unique capabilities to the FST effort: (1) Observations-based characterization of QBO in ITM parameters at low and middle latitudes; (2) Model-based understanding of driving mechanisms that cause QBO in ITM; (3) Numerous data sets, numerical simulations, and empirical models developed during the project will be provided to the FST team to enhance other studies.

Publication References:

no references