2018 Workshop: AO and SAO in the TI

Long title

Annual and Semiannual Variations in the Thermosphere and Ionosphere

Conveners

Mack Jones

Liying Qian

Eric Sutton

Jia Yue

Jeffrey Thayer

Description

Annual and semiannual variations have been observed in the thermosphere and ionosphere since the 1930s. Various mechanisms have been proposed to explain the observed behavior of different local and global average annual and semiannual signals in composition, temperature, and plasma density. The relative importance of the different mechanisms greatly depends on the thermosphere-ionosphere (T-I) model used to reproduce any individual annual or semiannual signature. Thus, we look forward to having a round-table discussion focused on understanding the differences between thermosphere-ionosphere models in the context of reproducing the prominent annual and semiannual oscillations (AO and SAO) in mesospheric, thermospheric, and ionospheric composition, density, and temperature. We ask that participants of this roundtable discussion please be prepared to present 2-4 slides of data/model results in order to motivate the discussion regarding the topics discussed above.

The goal of this roundtable discussion is to survey the AO and SAO of middle and upper atmospheric models and compare with observations; identify the dominant drivers of the AO and SAO in the different models; discuss model limitations; and devise a common set of metrics and model drivers (e.g., solar and terrestrial inputs) for future inter-model comparisons of the AO and SAO.

Agenda

AO/SAO Session Agenda (pdf)

Justification

Accurate representations of thermospheric and ionospheric composition and temperature are critical to satellite operations and radio communications. Although the AO and SAO in the thermospheric and ionospheric composition and temperature have been observed for more than half a century, their origins are still not understood. This workshop addresses CEDAR Strategic Thrust #2 (“Explore Exchange Processes at Interfaces and Boundaries”): Data and model results both show that AO and SAO signals are present in the transition from the fully-mixed region to the diffusively separated region of the atmosphere. This workshop also address the following thrusts in the CEDAR Strategic Plan and Heliophysics Decadal Survey: • CEDAR Strategic Thrust #6 (“Manage, Mine, and Manipulate Geoscience Data and Models”). • Heliophysics Decadal Survey goal to “Determine the dynamics and coupling of Earth’s magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs.” • Atmosphere-Ionosphere-Magnetosphere Interactions (AIMI) Imperative 3 from the Decadal Survey: “Integrate data from a diverse set of observations across a range of scales, coordinated with theory and modeling efforts, to develop a comprehensive understanding of plasma-neutral coupling processes and the theoretical underpinning for space weather prediction.”

Summary

Central Points:

- The long and well observed annual and semiannual oscillations (AO and SAO) in the thermosphere and ionosphere (T-I) are the second largest component of T-I variability, after solar cycle.
- Different T-I models accurately simulating the T-I AO and SAO from first-principles is required to reproduce high fidelity global thermospheric and ionospheric densities.
- The importance of different mechanisms responsible for driving the T-I AO and SAO depends on the T-I model used to reproduce these oscillations. After a number of presentations and group discussion we reached a consensus on the following:
    1. The “thermospheric spoon” mechanism is the dominant driver of the T-I global SAO.
    2. We hypothesize that an AO in eddy diffusivity (Kzz) is the main cause of the T-I global AO.

3. For models whose boundaries are in the upper mesosphere and lower thermosphere, a combination of the intra-annual variations (IAVs) in the neutral major species boundary conditions, as well as Kzz play a dominant role in driving the AO and SAO in the upper T-I.
4. Kzz is the most widely varying parameter amongst the different T-I models, and is a key contributor to model differences.

Finally, the different modeling groups agreed and preliminarily planned an effort to do a benchmark modeling study to compare how the different T-I models including, GITM, TIE-GCM, TIME-GCM, WAM/CTIPe, and WACCM/WACCM-X reproduce the climatological global AO and SAO from first principles.

We had a number of excellent speakers that covered the history of T-I AO and SAO observations, current T-I AO and SAO observations, as well as assessments of the different T-I model capabilities in reproducing the T-I AO and SAO.

First, **John Emmert** offered an historical overview of the AO and SAO from observations and the NRLMSISE00 empirical model. See Presentation

Jia Yue presented thermospheric composition results from the TIMED/GUVI instrument. Specifically, he characterized the intra-annual and interannual variations in O and O/N2 in the lower and upper thermosphere. See Presentation

Dan Weimer spoke about the AO and SAO in thermospheric mass density observed from CHAMP, GRACE A, GOCE, and three Swarm satellites, and compared these density variations with infrared emissions from CO2 and NO using measurements from the TIMED/SABER instrument. See Presentation

Mack Jones showed TIME-GCM results and spoke about the model's capability in reproducing the climatological global AO and SAO in the T-I, as well as the mechanisms responsible for driving these oscillations. See Presentation

Liying Qian presented T-I AO and SAO results from the TIE-GCM and WACCM-X, and described how each model produces these signatures in the upper T-I. See Presentation

Mariangel Fedrizzi presented on modeling results from CTIPe and discussed a number of numerical experiments she performed designed to reproduce the T-I AO and SAO in thermospheric mass density and electron density. See Presentation

Garima Malhotra presented results from GITM focused on delineating the differences between T-I AOs and SAOs simulated by the model using MSIS/HWM vs. WACCM-X fields at the lower boundary. See Presentation

Marcin Pilinski described the effects that changing the peak value or peak altitude of eddy diffusion (Kzz) has in TIME-GCM, in an attempt to reproduce the intra-annual variations in thermospheric density measurements. See Presentation

John Emmert and Mack Jones showed how the eddy diffusion values in WACCM-X are being revisited and altered in order to produce the correct O seasonality at 250 km. They also showed the effects of putting WACCM-X eddy diffusion into the TIME-GCM. See Presentation

Eric Sutton commented on the idea of how the combined continuity and momentum equation is solved and what assumptions are made to get into its final form. He described in detail the forcing terms and highlighted that depending on the phenomenon being considered, horizontal advection could be an important driver of a species seasonal distribution. See Presentation

Finally, **Mack Jones** suggested a coordinated modeling study focused on understanding how each T-I model generates a climatological global AO and SAO in the thermosphere and ionosphere. See Presentation

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