Understanding the Effects of Lower Thermospheric Atomic Oxygen on Upper Ionosphere-Thermosphere system

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ABSTRACT

The exchange of energy between lower atmosphere with the ionosphere thermosphere (IT) system is not well understood. A number of studies have observed day-to-day and seasonal variabilities in the exchange between data and model output of various IT parameters. It is widely speculated that the forcing from the lower atmosphere may be responsible for these spatial and temporal variations in the IT region, but their exact nature is unknown. One of the parameters that is important at the lower boundary of thermosphere is Atomic Oxygen. In recent years, it has been observed that the distribution of atomic oxygen reverses between the two hemispheres at the upper mesospheric heights from higher in the winter hemisphere at around 80 km to higher in the summer hemisphere at around 95 km. In this study, we investigate the sensitivity of the thermospheric parameters such as O/N₂ to these different atomic oxygen distributions using Global Ionosphere-Thermosphere Model (GITM). We use Whole Atmosphere Community Climate Model with thermosphere and ionosphere extension (WACCM-X) to drive the lower atmospheric boundary in GITM at ~97 km, and compare the results with the current Mass Spectrometer Incoherent Scatter (MSIS) driven version of GITM. These two boundary conditions are different because MSIS has higher atomic oxygen in the winter hemisphere while WACCM-X has higher atomic oxygen in the summer hemisphere consistent with SABER data. The reversal of atomic oxygen affects the pressure distribution between 100-120 km which changes the wind magnitudes, temperatures, scale heights and O/N₂ composition in the upper thermosphere. It also modifies the interhemispheric summer to winter circulation. All these differences between the two simulations in the lower thermosphere map to higher altitudes due to diffusive equilibrium. Thus, the lower boundary drives a significant role in the IT system and should be defined using a model which is closer to observations.

RESULTS AND DISCUSSION

- **OPEN QUESTIONS**
  - How does the lower and upper thermosphere respond to different atomic oxygen distribution between 95-100 km ?
  - Why does atomic oxygen distribution reverse between upper mesospheric and lower thermospheric heights ?

- **METHODOLOGY**
  - The hourly concentrations for O from WACCM-X at 96 km, 97.5 km, 100 km are used to replace the lower boundary of GITM.
  - O₂, NO, N₂, T, U, V are given a constant value at the lower boundary.
  - Runs : Simulation of Smith et al. (2010) with Jan with MSIS and WACCM-X (hereof referred to as GITM-MSIS and GITM-WACCM).
  - GITM Model Resolution : 2° x 4°. WACCM-X model resolution : 1.9° x 0°25°.
  - It takes around 10 days for the model to get stable. We plot the results only for the last 10 days of each simulation.

CONCLUSIONS AND FUTURE WORK

- **EFFECT ON WINDS IN 100-130 KM**
  - Zonal Mean winds in both the simulations are equatorial.
  - Higher O densities in a hemisphere lead to larger equatorward winds due to pressure gradients.
  - In the summer hemisphere, GITM-WACCM has larger equatorward winds.
  - In the winter hemisphere, GITM-MSIS has larger equatorward winds.

- **EFFECT ON TEMPERATURE in 100-130 KM**
  - Equatorward winds lead to divergence and cooling in the polar regions.
  - Similarly, in the winter hemisphere, GITM-WACCM has lower temperatures.
  - The temperature differences between two simulations leads to corresponding effects on thermal heights in the two hemispheres and affects species densities such as N₂.

- **EFFECT ON OXYGEN**
  - Approximate diffusive equilibrium, the effect of temperature on scale height of N₂ leads to larger difference in O/N₂ between the two simulations.

- **EFFECT ON INTERHISPHERIC SUMMER-WINTER WINDS (ABOVE 150 KM)**
  - The equatorward winds in the 100-130 km lead to larger O/N₂ in the equatorial region in GITM-WACCM which also leads to larger electron density.
  - Larger equatorward O in GITM-WACCM runs changes the summer to winter winds in the upper thermosphere by modifying the summer to winter pressure gradients.
  - For GITM-WACCM runs, the winds slow down in the summer hemisphere while they speed up in the winter hemisphere as compared to GITM-MSIS runs.

- **COMPARISON WITH GUVI**
  - In the summer hemisphere, GITM-WACCM-X O/N₂ matches better with GUVI data.
  - In the winter hemisphere, GITM-MSIS O/N₂ matches better with GUVI data.

REFERENCES