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Synthetic study of internal atmospheric variability using TIE-GCM

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Abstract

In this study, we use the general circulation model TIE-GCM as well as synthetic lower boundary forcing to investigate the behavior of the lower Thermosphere Ionosphere (TI) system.
The lower boundary forcing is synthetically generated, by atmospheric measurement data or corresponding model data to artificially mimic different atmospheric conditions, like sudden stratospheric warmings (SSW) or elevated stratopause (ES) and then used as input for TIE-GCM. The influence of these conditions on the TI system will be analyzed for different external forcing conditions, like high/low solar activity or geomagnetic quiet or active times. The goal of this study is to improve the understanding of the importance of the different (internal vs. external) driving mechanisms in the TI system.

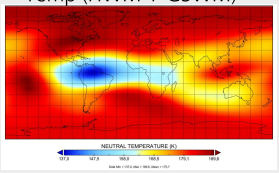
Model Setup

High resolution run (2.5x2.5)
Heelis convection model
OMNIweb solar forcing

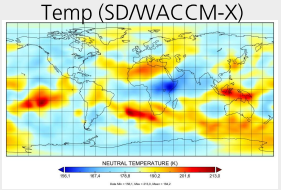
Synthetic lower boundary conditions (BC)
(Using TIDI/SABER input):

- Climatology:
  - HWM + NRLMSIS
  - No input
- Wave input
  - GSWM
  - No waves
- SD/WACCM-X

Temp (HWM + GSWM)



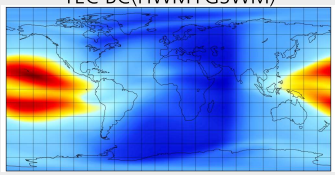
Temp (SD/WACCM-X)



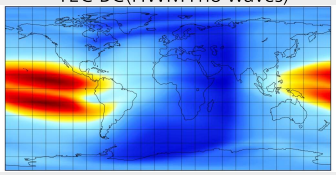
Model Results

Total electron content (TEC) maps

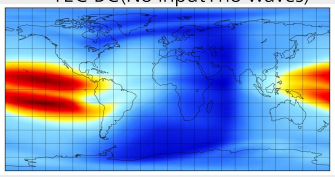
TEC BC(HWM+GSWM)



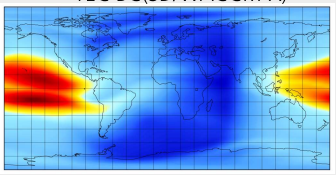
TEC BC(HWM+no waves)



TEC BC(No input+no waves)



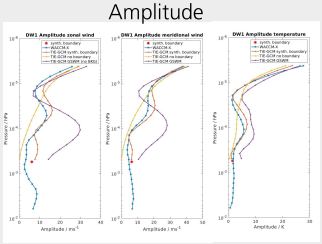
TEC BC(SD/WACCM-X)



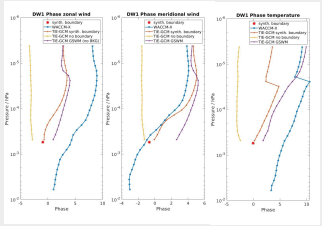
The resulting TEC maps for the different lower boundary forcing are very similar and difference are only visibly in the difference or ratio maps

Adaptive Spectral filtering

Amplitude



Phase



Amplitude and phase show that the lower boundary imprint survives up to 10^{-5} hPa (~150km)

References:

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Pedatella, N.M. Impact of the lower atmosphere on the ionosphere response to a geomagnetic superstorm. Geophys. Res. Lett. 2016, 43, 9383–9389

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Goncharenko, L. P., Harvey, V. L., Liu, H., & Pedatella, N. M. (2021). Sudden stratospheric warming impacts on the ionosphere–thermosphere system: A review of recent progress. Ionosphere dynamics and applications, 369-400.

Conclusion

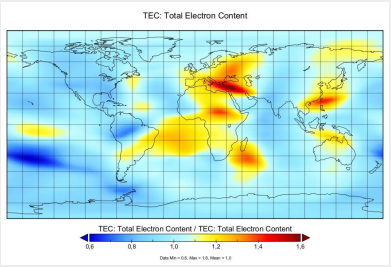
BC(SD/WACCM-X)
BC(HWM+GSWM)

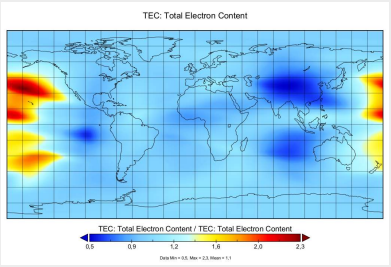
Ratio of TEC in range
0.5 – 2.3

Structures similar to
DW1 wave structure

Same structures are
visible in the difference
maps

Lower boundary condition influences TEC map result





Outlook

Simulation of lower boundary condition of 2013 SSW:
- Standard solar forcing (control run)
- Halloween 2003 Storm

Simulation of a grid of solar forcing conditions and lower boundary forcing:
- Solar max/min conditions
- Multiple strong storm events
- Multiple SSW events

The main goal is the understanding of the influence of lower boundary forcing on the output of TIE-GCM simulation runs.

Acknowledgments:

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