Impact of tidal variability on the mean state of the ionosphere and thermosphere during SSWs

Nick Pedatella, Art Richmond, Astrid Maute, and Hanli Liu

High Altitude Observatory, National Center for Atmospheric Research

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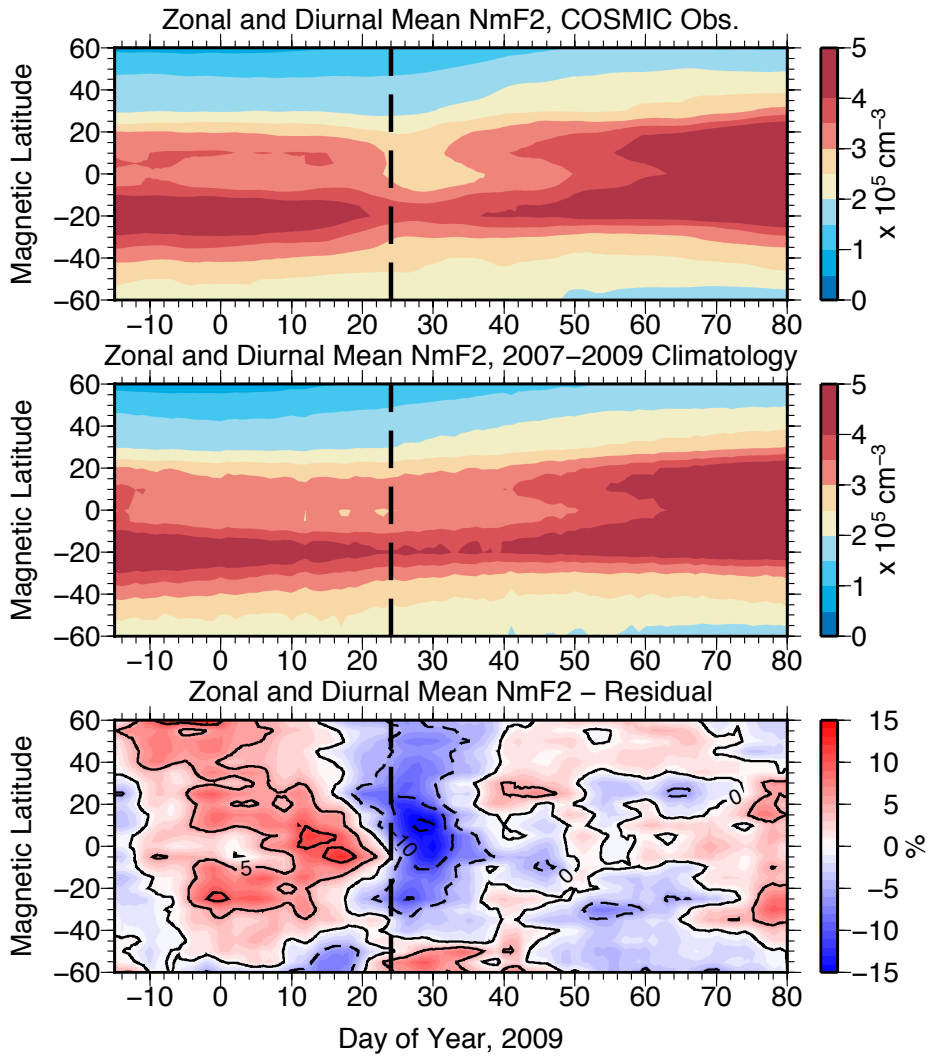
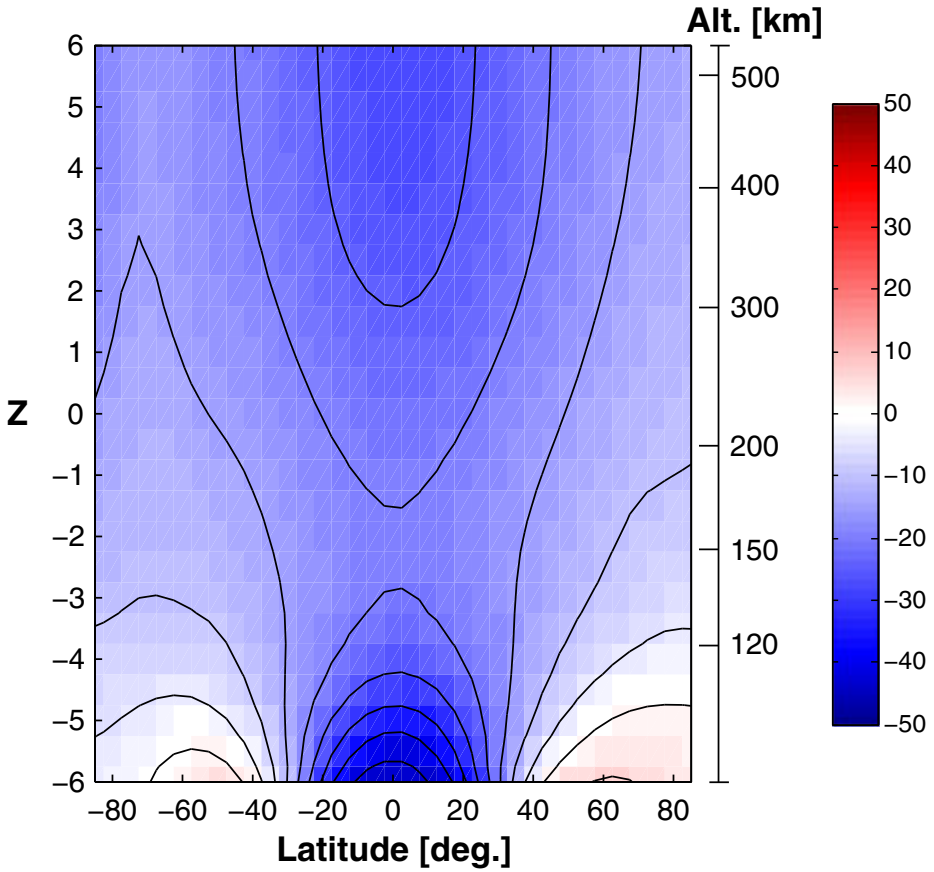
Motivation: Observations reveal a decrease in the zonal and diurnal mean NmF2 during SSWs. The source of this depletion is unknown.



We hypothesize that the decrease in diurnal and zonal mean NmF2 is due to changes in the atmospheric tides during SSWs

The dissipation of atmospheric tides impacts the circulation in the lower thermosphere, leading to global reductions in $[O]/[N_2]$ and electron densities

percentage change in $[O]/[N_2]$ due to migrating diurnal and semidiurnal tides



Previous studies have focused on ionosphere-thermosphere changes due to tides being either included or not included in simulations. We use the NCAR TIE-GCM to investigate the impact of the short-term (~5-10 day) enhancements of tides during SSWs on the ionosphere-thermosphere.

(Yamazaki and Richmond, 2013)

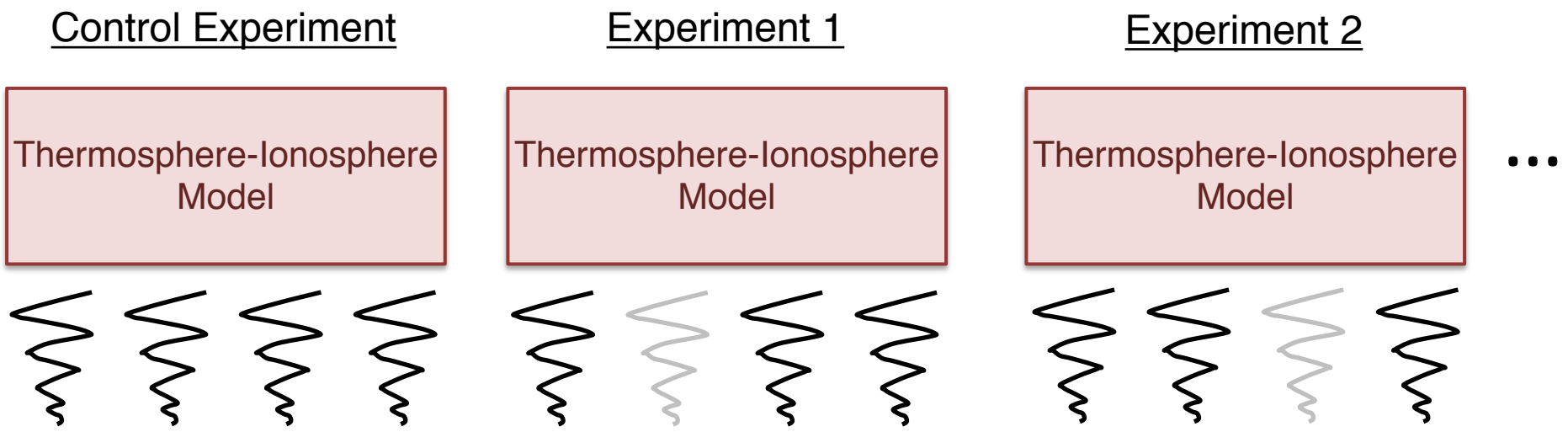
NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM)

TIE-GCM is a first principles global model of the ionosphere and thermosphere, with self-consistent electrodynamics

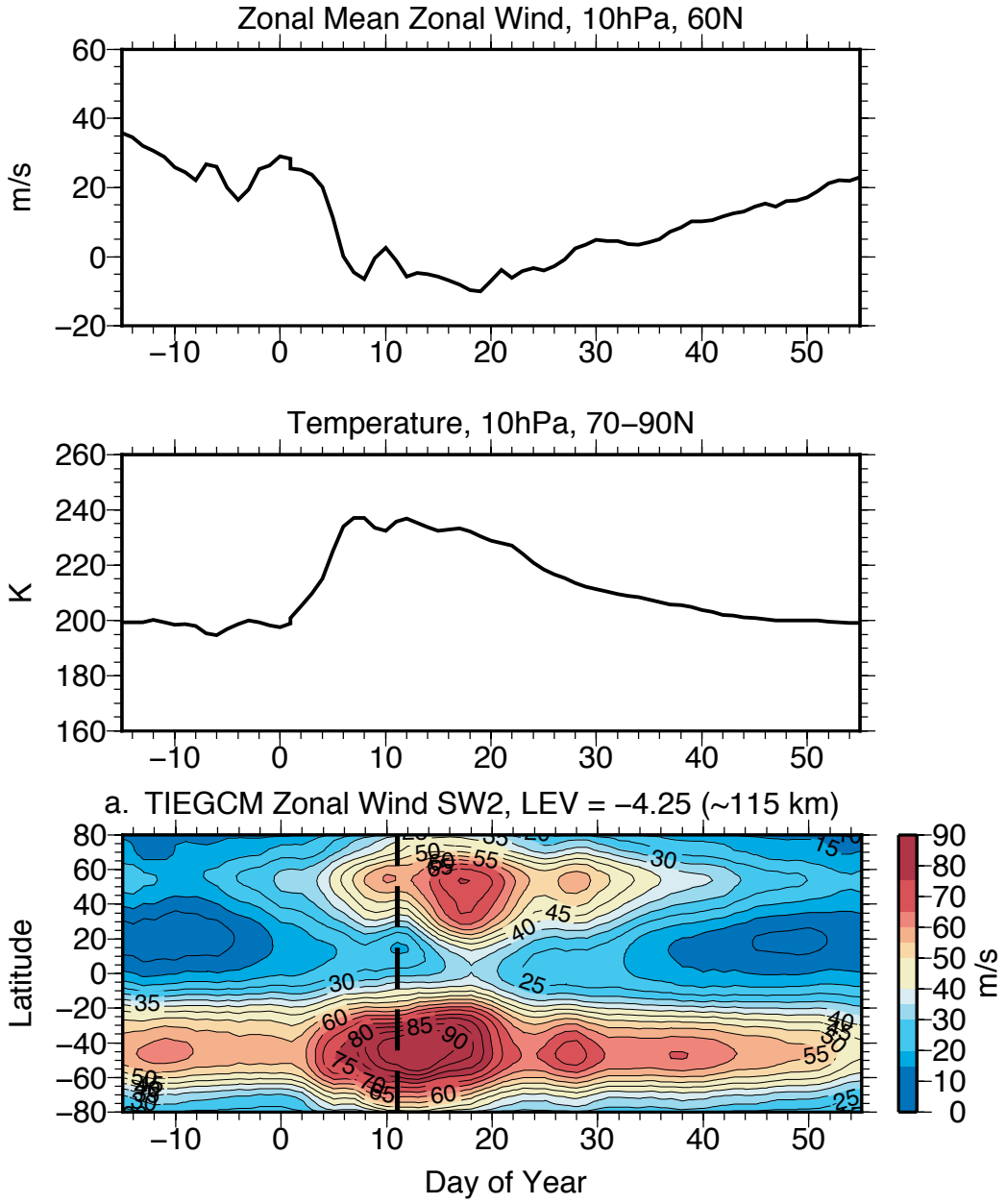
The TIE-GCM altitude domain is ~97 to 500-700 km, and the horizontal resolution is 2.5° in latitude/longitude

We impose lower atmospheric forcing reflective of the 2013 SSW at the TIE-GCM lower boundary using dynamical fields from a TIME-GCM simulation of the 2013 SSW previously performed by *Maute et al.* [2015]

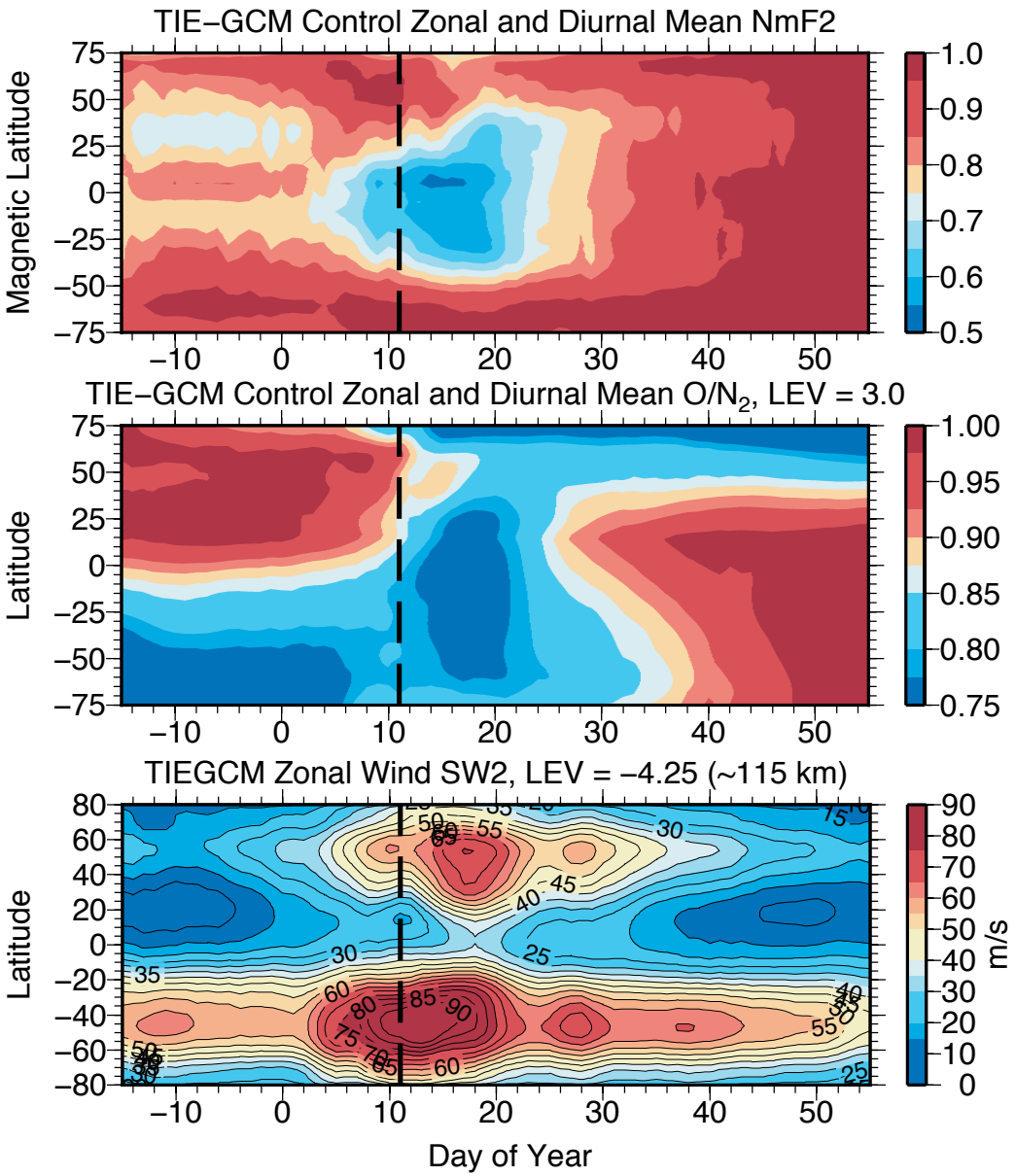
To determine the source of the diurnal and zonal mean variability in the ionosphere, experiments are performed that exclude select tides and/or planetary waves.



2013 Sudden Stratosphere Warming



The control simulation reveals a near global reduction in NmF2 and $[O]/[N_2]$ following the SSW. The depletion is coincident with the increase in the SW2.



O⁺ Production

$O + h\nu \rightarrow O^+ + e^-$

O⁺ Loss

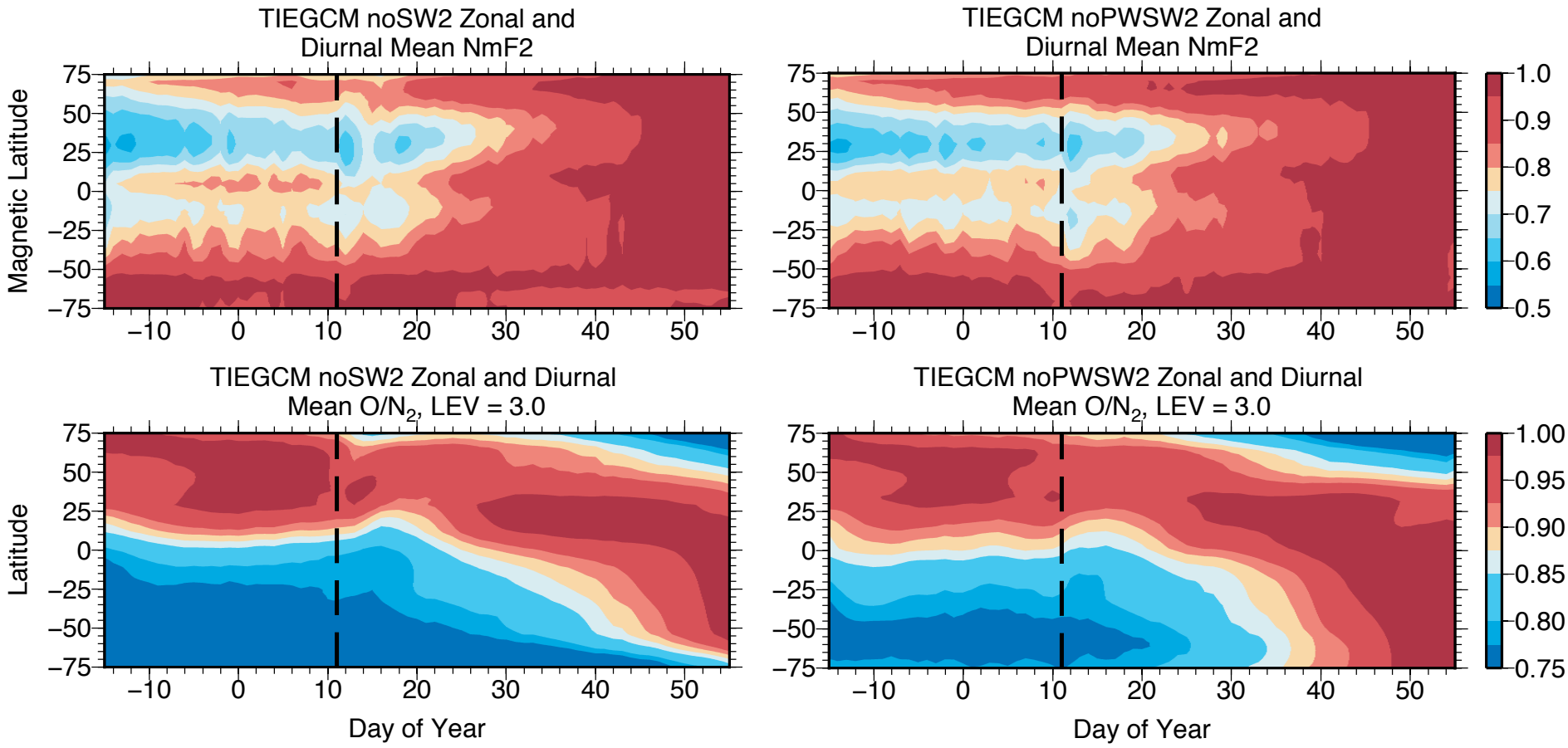
$O^+ + N_2 \rightarrow NO^+ + N$

$O^+ + O_2 \rightarrow O_2^+ + O$

$NO^+ + e^- \rightarrow N + O$

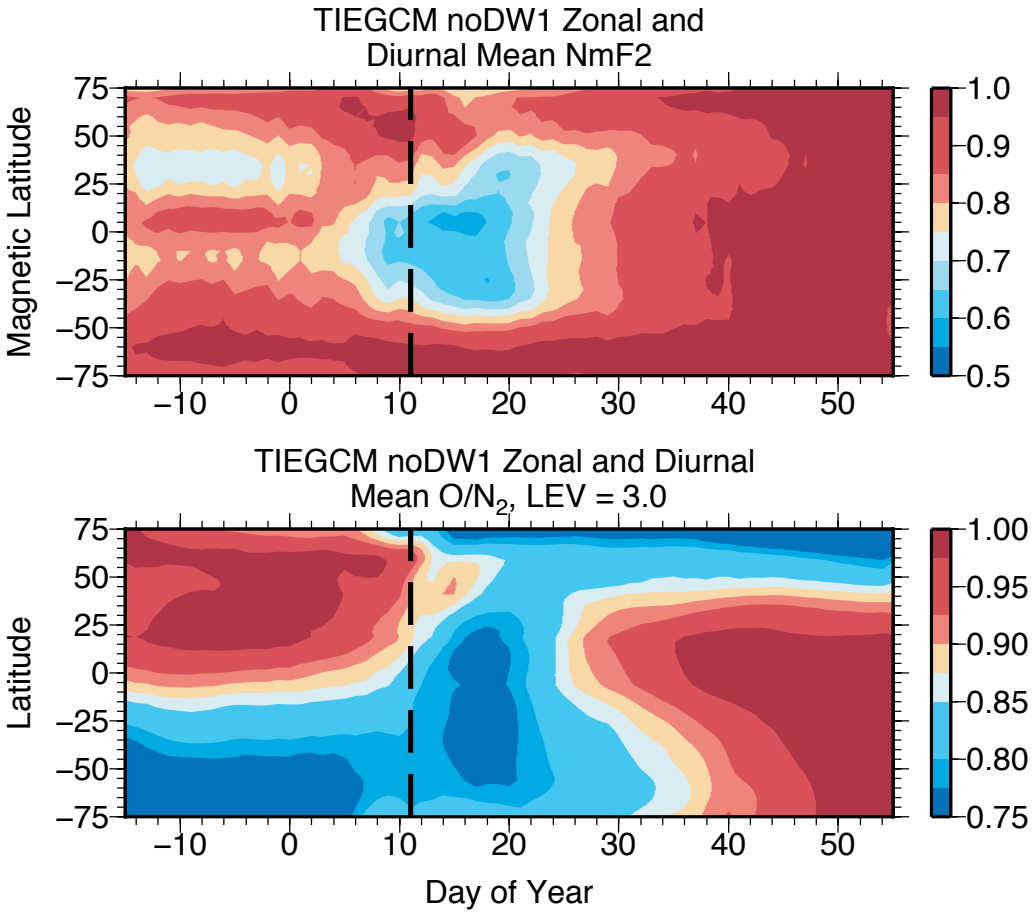
$O_2^+ + e^- \rightarrow O + O$

Removal of the SW2 and planetary waves from the TIE-GCM demonstrates that these waves are the primary source of the NmF2 and [O]/[N_2] variability

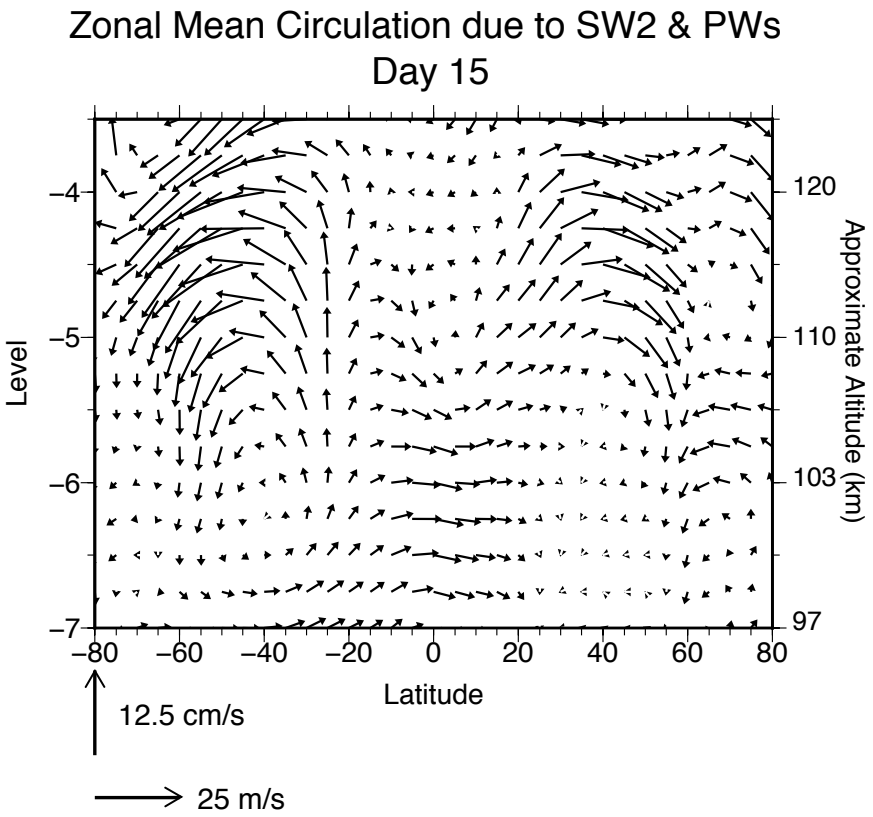


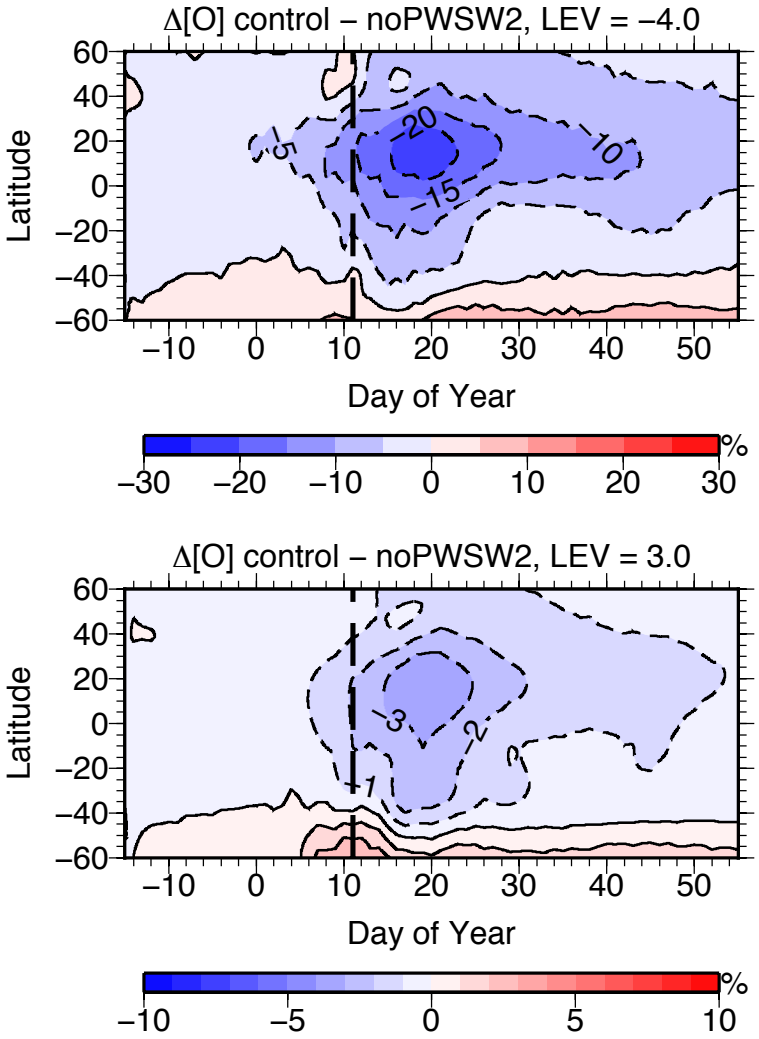
Effect is primarily due to SW2 with secondary contribution from PWs

For comparison, the DW1 does not impact the NmF2 and [O]/[N_2] depletion



SW2 modifies the circulation in the lower thermosphere, directly altering the atomic oxygen distribution below ~120-130 km. Vertical diffusion transfers these changes to higher altitudes.

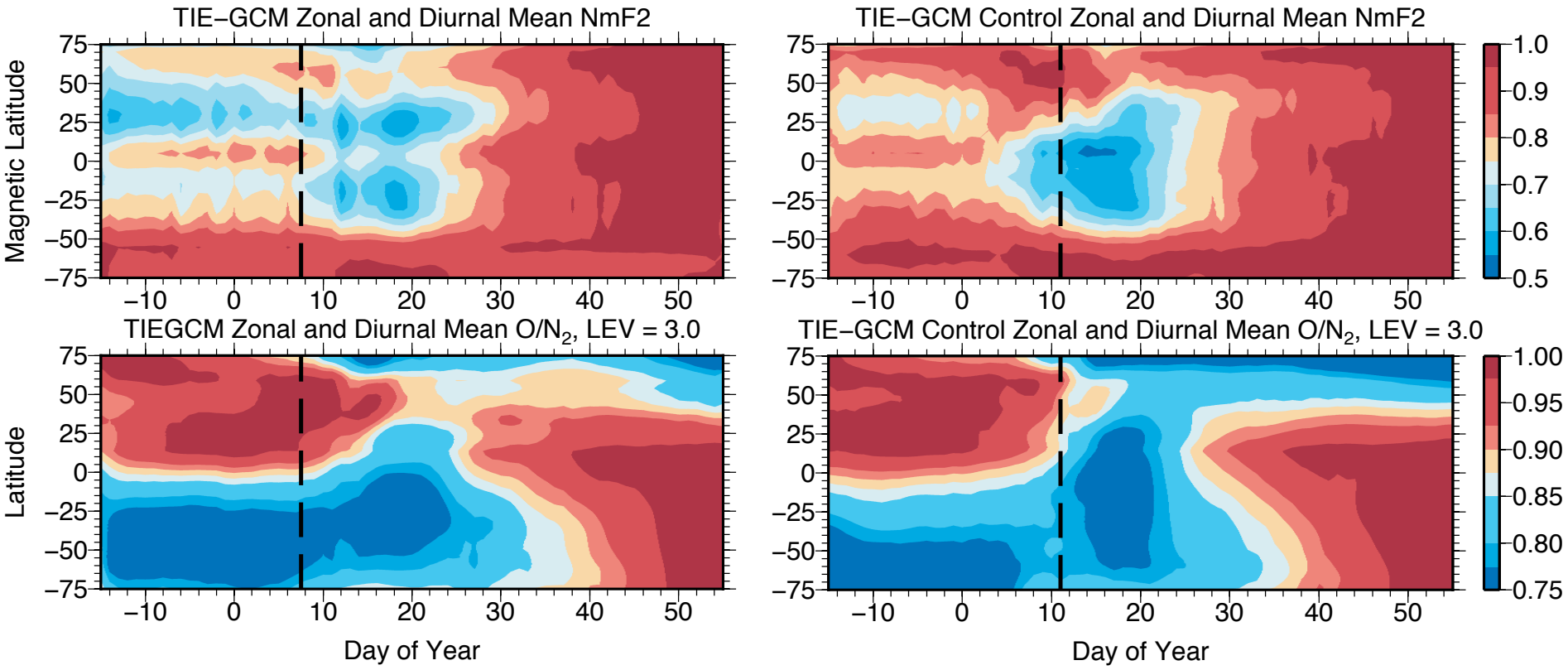




Impact of changes in the mean circulation in the lower thermosphere

Simulation without SW2+PWs, zonal mean $\overline{V}$ and $\overline{\omega}$ below ZP=-3 (~ 130 km) replaced with $\overline{V}$ and $\overline{\omega}$ from simulation with all waves

Simulation with all TIME-GCM PWs and Tides at LB



- The changes in lower thermosphere mean circulation due to the SW2 are the primary source of the NmF2 and [O]/[N_2] reduction at mid latitudes.
- At low-latitudes the ionosphere-thermosphere variability is due to a combination of circulation and electrodynamic changes

Summary and Conclusions

- Observations reveal that a decrease in the zonal and diurnal mean electron density occurs during SSWs.

- The depletion in the zonal and diurnal mean NmF2 is connected to the short-term enhancement in the SW2 during SSW time periods

- The dissipation of the SW2 modifies the lower thermosphere circulation, leading to a decrease in the zonal and diurnal mean $[O]/[N_2]$ and electron density at low-mid latitudes

- The present study neglected the impact of SSW related changes in gravity waves, which may also contribute to changes in the thermosphere composition during SSWs.

- Our results illustrate that in addition to modulating the equatorial electrodynamics, changes in the SW2 during SSWs impact the global ionosphere-thermosphere system.

- Significant short-term enhancements in tides during other time periods may have similar impact on reducing the zonal and diurnal mean NmF2 and $[O]/[N_2]$