Nonmigrating Tidal Impacts on O/N_2 in GUVI Data

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Abstract

TIMED/GUVI O/N_2 column density ratios show large wavenumber-4 (WN4) O/N_2 perturbations on the order of 15% (peak-to-peak) but the propagation direction in the local time frame is inconsistent with the expectation from tidal theory: the GUVI WN4 mainly propagates westward while the theoretical expectation is an eastward propagation caused by the DE3 and SE2 nonmigrating tides. Studies by *Kil and Paxton* [2011] and *Kil et al.* [2013] indicate that a large part of the O/N_2 WN4 signal originates in the ionosphere, that is, from 135.6 nm emissions from WN4-like plasma density variations in the F-region. We assess the relative importance of this ionospheric contamination as a function of local time to determine the "true" impact of nonmigrating tides on the O/N_2 variability in the thermosphere and explain the apparent westward propagation of the GUVI O/N_2 WN4.

Ionospheric Contamination of GUVI WN4 Signals

GUVI on TIMED measures *daytime* O/N_2 column densities by observing OI 135.6 nm and N_2 LBHS bands (140-150 nm) in nadir geometry. In the thermosphere both emissions are produced by photoelectron impact. However, 135.6 nm emissions are also due to O^+ recombination. This ~10% ionospheric contamination is ignored in the GUVI retrieval. *Kil et al.* [2013] showed that the WN4 variation of O^+ in the Equatorial Ionization Anomaly (EIA) due to E-region dynamo action is the primary source of the WN4 in the observed O/N_2.

Objectives

1. Determine the "true" nonmigrating tidal contribution to the WN4 signal in the GUVI O/N_2 ratios from thermospheric tides as opposed to that from ionospheric contamination.
2. Explain why the GUVI O/N_2 WN4 signal propagates westward in contrast to the expectation from tidal theory.

Methodology

1. Fit wavenumbers 0-6 to GUVI O/N2 for each day of the year.
2. WN4 in local time is a superposition of DE3, SE2, DW5, SW5, and SPW4.
3. Use the known phase slopes to diagnose amplitudes and phases within a 60 day TIMED yaw cycle (Figure 1).
4. Estimate the thermospheric tidal signal in O/N_2 using the TIMED-based Climatological Tidal Model of the Thermosphere - CTMT [*Oberheide et al.*, 2011] and MSIS zonal mean O and N_2 (Figures 2 and 3).
5. Identify the ionospheric WN4 contamination by removing the modeled thermospheric tides and interpret the result using COSMIC TEC tidal diagnostics (Figure 4).

References

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WN4 Signal in GUVI Data

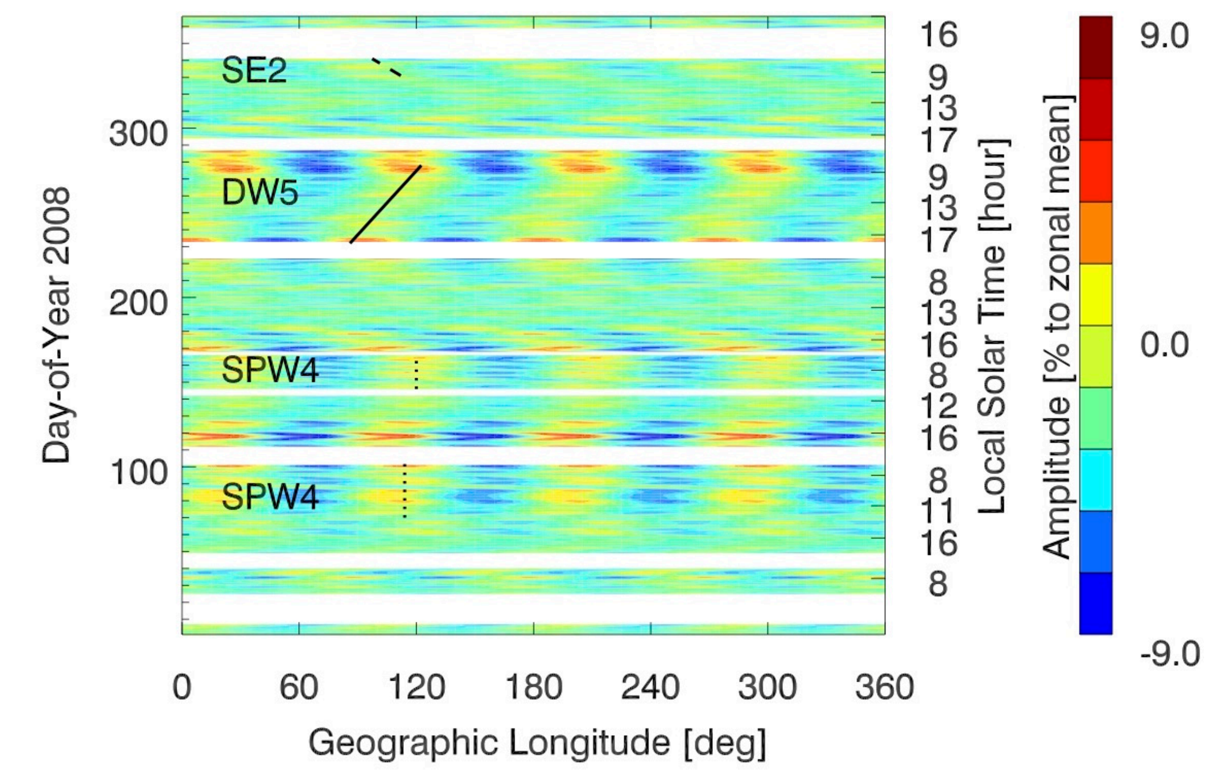


Figure 1. GUVI O/N_2 WN4 signal (relative to the zonal mean) at 20°N geographic latitude in 2008. Note that local time (right axis) is decreasing with increasing day-of-year (left axis). Local time is not continuous because of the daytime restrictions and jumps from morning to evening every 60 days. Overplotted are phase slopes of DW5 (solid), SE2 (dashed), and SPW4 (dotted). The presence of large DW5 and SPW4 is puzzling since both waves should be small in the thermosphere. Even if the GUVI WN4 O/N_2 is caused by an F-region ionosphere signal, we should see the generating DE3 signal as opposed to DW5 or SPW4.

Modeling of Thermospheric O/N_2 Tides

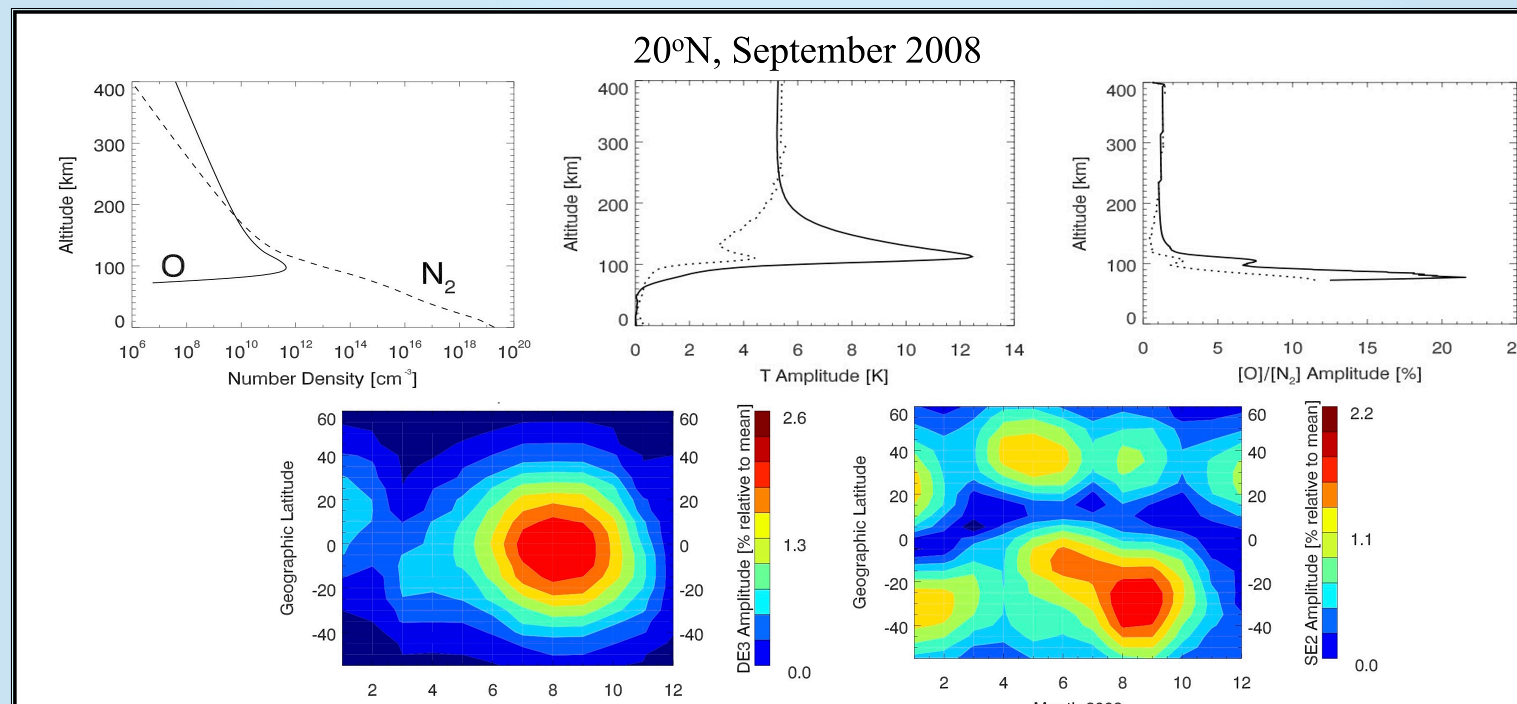


Figure 2. (top, left) MSIS zonal mean number density altitude profile of atomic oxygen (solid) and molecular nitrogen (dashed), **(top center)** CTMT DE3 (solid) and SE2 (dashed) temperature amplitudes, **(top right)** DE3 (solid) and SE2 (dashed) O/N_2 tidal amplitudes computed using a vertical displacement approach. **(bottom)** Modeled O/N_2 column density amplitudes for DE3 **(left)** and SE2 **(right)**.

GUVI Tidal Amplitudes

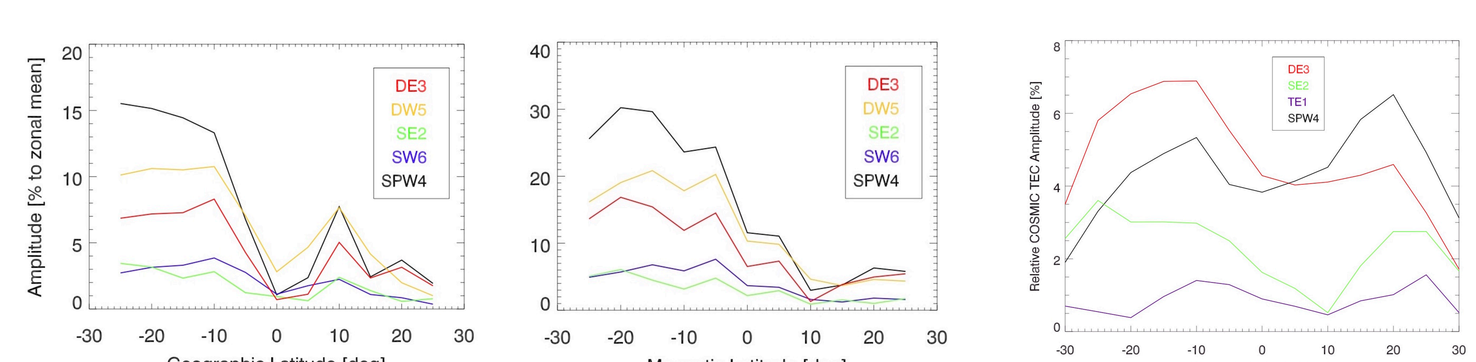
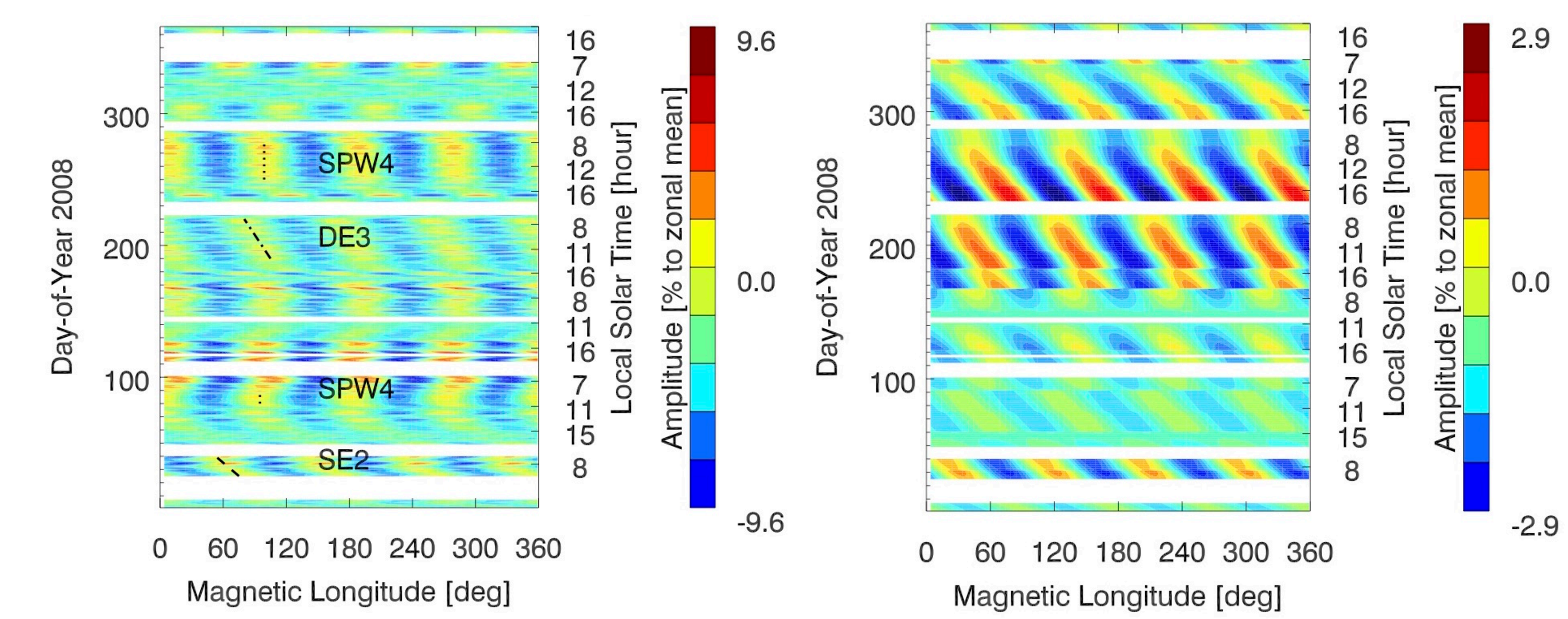


Figure 3. At September equinox in 2008, observed GUVI O/N_2 amplitudes in geographic coordinates **(left)** and in magnetic coordinates **(center)**. The large DW5 and SPW4 contributions are inconsistent with tidal theory and observations from WINDII and CHAMP. **(right)** Relative COSMIC total electron content (TEC) amplitudes in magnetic latitude for September 2008.

The latitudinal structure of the GUVI amplitudes resembles the WN4 amplitudes in the F-region plasma and not the latitudinal structure expected for thermospheric tides (Figure 2).

Thermospheric vs Ionospheric Contributions



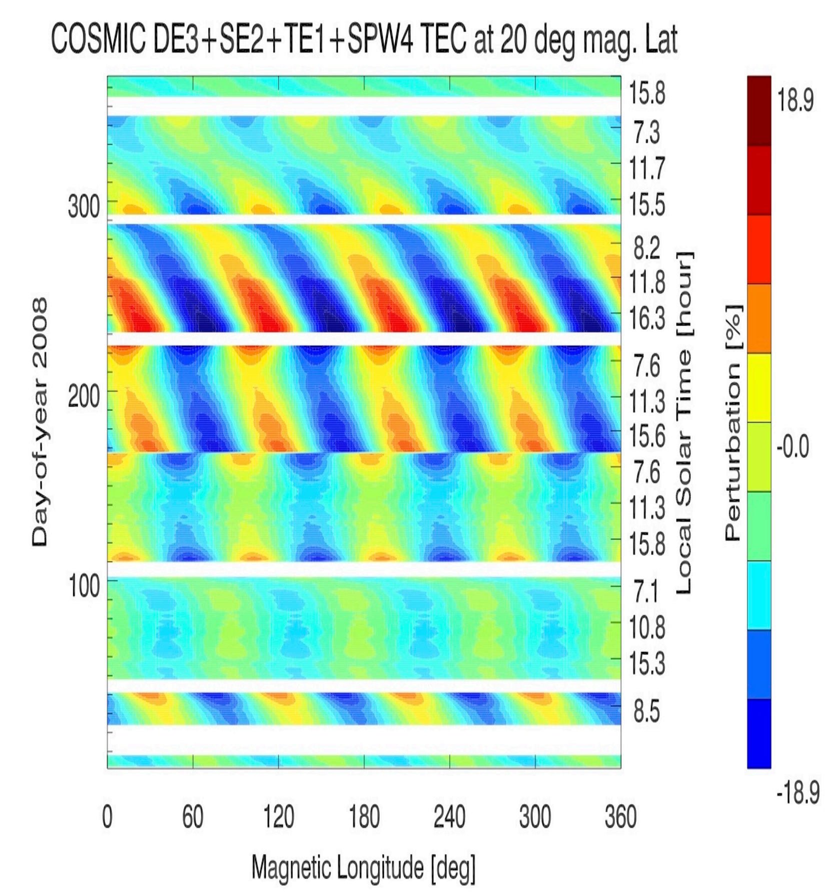


Figure 4. (top left) GUVI O/N_2 WN4 with the modeled thermospheric contribution **(top right)** removed. **(Lower left)** WN4 in TEC from COSMIC diagnostics mapped to GUVI local times [*Chang et al.*, 2013]. Data shown are for 2008, 20°N magnetic latitude and expressed in percent relative to the zonal mean at the indicated local time.

1. The thermospheric "true" tidal contribution to the observed O/N_2 WN4 is on the order of 30%.
2. Removing the thermospheric tides results in an ionospheric O/N_2 WN4 that is either stationary or eastward propagating, as expected from E-region dynamo modulation which is dominated by DE3, SE2 and SPW4. No DW5 pattern remains.
3. COSMIC TEC diagnostics as a proxy for the O^+ density tides is consistent with the interpretation of the top left panel as the O/N_2 WN4 ionospheric contamination. Locations of minima, maxima and phase slopes agree well during most parts of the year. The exception are days 230-290 where COSMIC indicates eastward propagation as opposed to the stationary pattern in GUVI. This is of no concern given the limitations of the modeling approach.
4. The good COSMIC/GUVI agreement indicates that DE3 and SE2 are the most important drivers of the "true" O/N_2 WN4 in the thermosphere.

Conclusions

1. The thermospheric contribution to the observed GUVI O/N_2 WN4 is on the order of ~30% with DE3 and SE2 as the leading drivers.
2. The apparent DW5 signal in GUVI O/N2 is largely caused by the superposition of the "true" nonmigrating tidal signal originating in the thermosphere and the ionospheric WN4 contamination.
3. The ionospheric WN4 contamination is consistent with DE3, SE2 and SPW4 E-region dynamo modulation.