COUP-5

On the Response of the Thermospheric Column O/N_2 Ratio to Non-Migrating Tides as Seen by the Ionospheric Connection Explorer

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Introduction

- **Non-migrating tides** introduce large longitudinal/ local time perturbations in the temperature and winds of the mesosphere/lower thermosphere.
- It has been hypothesized that non-migrating tides substantially impact the column number density ratio of atomic oxygen to molecular nitrogen (**column O/N_2 ratio**), a diagnostic of thermospheric composition inferred from the intensity ratio of emissions at 135.6 nm and the Lyman-Birge-Hopfield bands.
- However, the tidal variability in the column O/N_2 ratio is not properly understood owing primarily to the impacts of **ionospheric contamination** of 135.6 nm emissions at afternoon local times around the equatorial ionization anomaly (Kil et al., 2013).
- Observations of the column O/N_2 ratio from the **Far UltraViolet (FUV) imager** onboard the **Ionospheric Connection Explorer (ICON)** provide the opportunity to study non-migrating tides, but the effects of ionospheric contamination need to be removed.

Objectives

A. Delineate the response of the thermospheric column O/N_2 ratio to upward propagating non-migrating tides as a function of local time at low-latitudes as seen by the FUV imager onboard the ICON observatory in low Earth orbit.
B. Derive an ICON column O/N_2 data product where the ionospheric contamination has been removed.
C. Calculate the ionospheric contribution to the ICON/FUV shortwave channel observations along the line of sight of the column O/N_2 ratio retrieval.

ICON FUV Observations

Shortwave column brightness (SW)	OI 135.6 nm, day and night Version 3 used
Longwave column brightness (LW)	Portion of LBH bands centered at 157 nm, day only, Version 3 used
Disk atomic oxygen to molecular nitrogen column density ratio (O/N2)	Inferred from ratio of SW to LW, daytime only, Version 4 used (Meier, 2021; England et al, 2021)
O+ profile	Retrieved from SW profile, night only

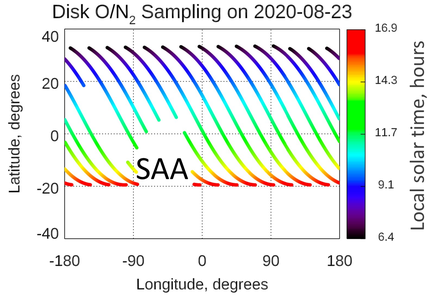
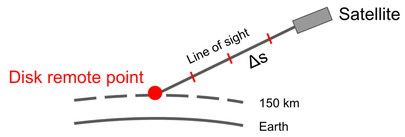


Figure 1. Global distribution and local times of one day of disk column O/N_2 samples by the far ultraviolet imager onboard ICON. SAA indicates the South Atlantic Anomaly.

Methodology

A. Calculate path integrals for the ionospheric contribution (radiative recombination + mutual neutralization), see Figure 2 and Equation 1.
   i. Test three data sets as the source for electron density: Global Ionospheric Specification (**GIS**), International Reference Ionosphere (**IRI**), and the Extreme Ultraviolet (**EUV**) spectrometer onboard ICON.
   ii. Scale factors are needed to properly treat ionosphere. Factors for GIS are determined by comparing GIS calculated brightness at night to observed ICON/FUV SW (Figure 3). EUV scale factor is determined by first comparing to GIS.
B. Run the **operational ICON/FUV O/N_2 algorithm** with modified SW radiances from which the ionosphere contribution has been subtracted.
C. Perform **longitudinal wavenumber decomposition** as a function of latitude and day (local time) during different seasons: March-April 2020 and August-September 2020. Do so on original dataset and "clean" datasets.

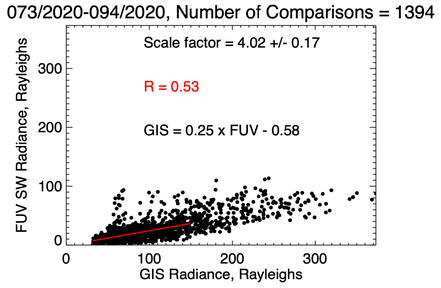
Figure 2



Equation 1

$$I_{RR} = \frac{1}{10^6}\int \alpha_{1356}(T_e)N_e[O^+]ds + \frac{\beta_{1356}k_1k_2}{10^6}\int \frac{N_e[O][O^+]}{k_2[O^+]+k_3[O]}ds.$$

Figure 3



March-April 2020 Results

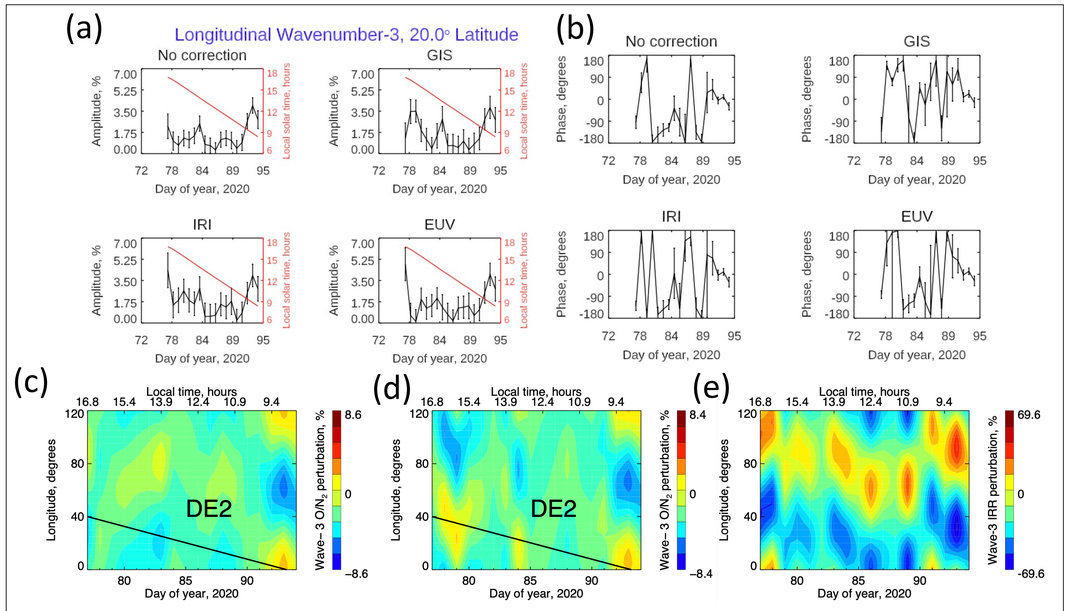


Figure 4. Longitudinal wavenumber-3 decomposition of ICON O/N_2 observations during March-April 2020 at 20° latitude. **(a)** Amplitude in units of percent relative to the zonal mean as a function of day of year (local time) for four cases (i) original dataset = no correction, (ii) GIS-based corrected dataset, (iii) IRI-based corrected dataset, (iv) EUV-based corrected dataset. **(b)** Same as 4a but phases. Error bars show 1-sigma uncertainty estimates of the amplitudes and phases. **(c)** Longitudinal wave-3 reconstruction as a function of longitude and day of year (local time) in the original dataset. The DE2 phase slope is shown for reference. **(d)** Same as 4c but for the GIS-based corrected dataset. (e) Longitudinal wavenumber-3 reconstruction of the GIS-based estimated ionospheric contribution to the SW radiances used in the O/N_2 retrieval.

Discussion of Results

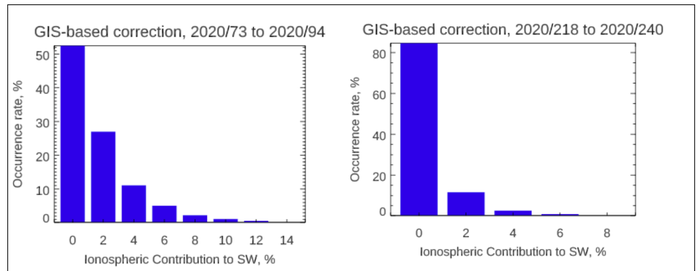


Figure 5. Histogram for the ionospheric contribution to SW during the March-April 2020 time period.

Figure 6. Histogram for the ionospheric contribution to SW during the August-September 2020 time period.

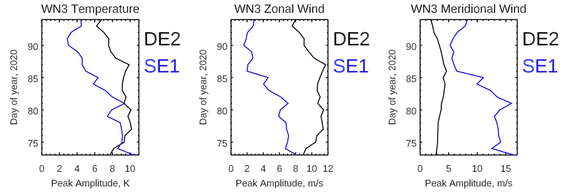


Figure 7. ICON Hough Mode Extension wavenumber-3 tide peak amplitudes around 20° latitude as a function of day of year.

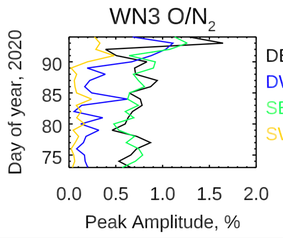


Figure 8. Wavenumber-3 tidal amplitudes around 20° latitude as a function of day of year modeled by ICON-TIEGCM Note DE2 is the diurnal eastward propagating wavenumber 2 tide and appears as wave-3 at a fixed local time.

Conclusions

One of the science objective of the ICON Mission is to determine how atmospheric tides control the low-latitude ionosphere. Quantifying tidal perturbations in column O/N_2 contributes to this objective as and this work provides the framework for further modeling/theoretical analyses.

1. Scale factors for GIS/IRI/EUV based calculations of IRR are needed to properly remove ionospheric contribution from version 3 SW radiances (Fig 3).
2. In the clean O/N_2 dataset, a DE2-like pattern is present in wavenumber-3 during March-April 2020 (Fig 4d). HME tides and ICON-TIEGCM confirm that DE2 should be present (Figs 7 and 8). The original dataset had no such pattern (Fig 4c).
3. Observed amplitudes (Figs 4a) are higher than those modeled by ICON-TIEGCM (Fig 8).
4. No change in WN4 structures in clean O/N_2 is observed in August-September 2020 compared to the original O/N_2 (not shown).
5. There is greater ionospheric contribution to SW in March-April which explains the apparent seasonal dependence on the difference between original and clean results (Figs 5 and 6).