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AGU FALL MEETING
New Orleans, LA & Online Everywhere
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Can we detect traveling ionospheric disturbances using ICON FUV and EUV ultraviolet limb scans?

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ICON Ionospheric Connection Explorer

LIÈGE université

Background

Traveling ionospheric disturbances (TIDs) are common ionospheric irregularities observed in both mid and low-latitude regions. They are known to play an important role in energy and momentum transfer from the lower to the upper atmosphere. While large-scale TIDs are generally associated with global processes such as geomagnetic storms, medium and short-scale TIDs are mainly related to mesoscale processes such as wind jets, hurricanes, etc. Whether they are due to the propagation of atmospheric gravity waves originating from the lower atmosphere or related to sporadic E layers, their harmonic signature in the temperature or density remains the key feature allowing to easily identify them.

TIDs have been extensively studied and characterized during the last two decades, mainly based on GNSS measurements, ground-based all-sky imagers, radars and ionosondes. However, only few studies aimed at describing their vertical structure using remote sensing observations from space, which is helpful to understand their propagation and their dissipation processes.

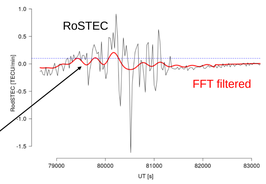
Since the launch of the NASA-ICON mission in 2019, the ionospheric airglow over equatorial and low latitude regions has been scanned every 12s by two instruments operating in the far (FUV) and extreme (EUV) ultraviolet domains. The FUV imager provides six simultaneous brightness limb profiles in two wavelengths: the oxygen 135.6 nm emission line and the N_2 Lyman-Birge-Hopfield (LBH) bands during both nighttime and daytime. Ionospheric 83.4 nm and 61.7 nm limb profiles of the oxygen ion are obtained at daytime from the EUV instrument measurements.

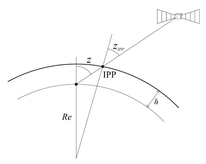
1. Data processing: GNSS and ICON

GNSS processing

1. Geometry-Free (GF) phase computation → « biaised » slant Total Electron Content (STEC)
2. Epoch-to-epoch differencing → dSTEC
3. Low-cut polynomial fitting to remove orbital and gradients trends → RoSTEC (rate of STEC)
4. Fourier filtering for frequency range 5 – 60min (tuned for small and medium-scale TIDs)
5. 15-min Standard-Deviation of the Fourier-filtered RoSTEC time series → $\sigma_{RoSTEC\_FFT\_filtered}$
6. TID/irregularity detection by applying a detection threshold in $\sigma_{RoSTEC\_FFT\_filtered}$

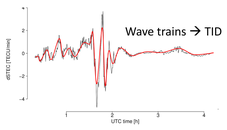
Mapping of Ionospheric Pierce Points (IPP) at 300 km (single layer model) → geolocation of the TID

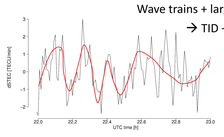




Examples of TIDs or similar wave-like fluctuations

Example of GNSS-detected TIDs but also other features (depending on geomagnetic latitude and / or geomagnetic conditions)





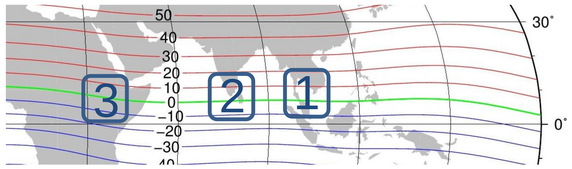
ICON data

- Search for ICON nearly simultaneous and co-located observations (called « matches ») with TID detected by GNSS : distance < 500 km and time difference < 15 min
- Time period: 2019 – 2021 under quiet geomagnetic conditions (international quiet days)
- Latest level-1 file version/revision available at mid-December 2021
- Data plotted : time series of limb level-1 calibrated brightness (airglow expressed in Rayleighs), centered on a given TID event

	FUV	EUV
Number of vertical pixels in limb region for altitudes between 100 and 550 km	approx. 137 → ~ 3km vertical resolution	approx. 92 → ~ 5 km vertical resolution
Wavelengths [nm]	135.6, LBH band (157 nm)	61.7, 83.4 (used for O^+ profile retrieval)… and many more !
Time resolution	12s	12s
Horizontal « resolution »	6 stripes (3° apart), merged into 2 stripes to enhance SNR during nighttime	Single profile per epoch

2. ICON FUV : first results

- Equatorial region
- DOY 071/2020 (March, 11)
- 3 matches
- Nighttime
- FUV 135.6 nm



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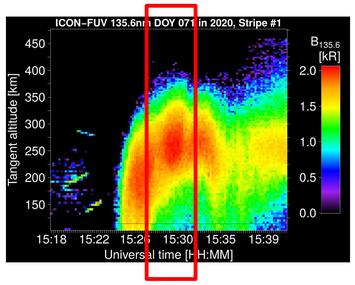

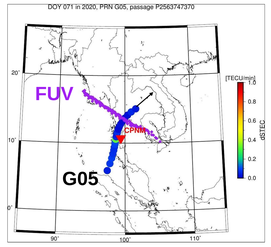

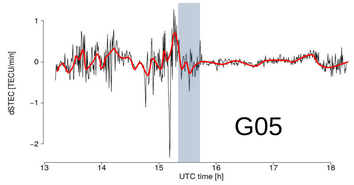

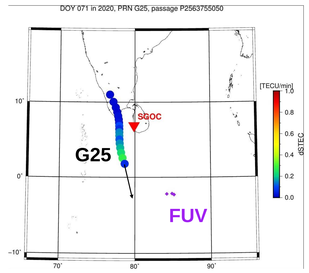

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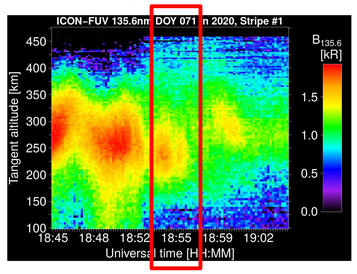

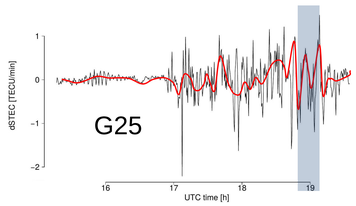

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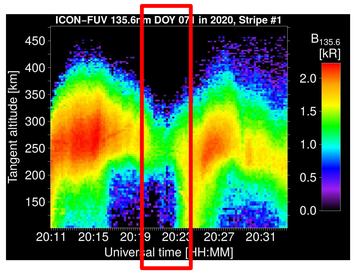

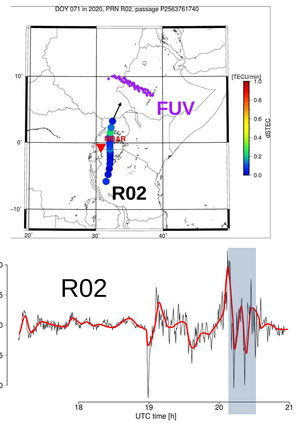

3. ICON EUV : first results

- Equatorial region (Ascension Island)
- DOY 107/2020
- Daytime
- EUV 61.7 nm and 83.4 nm

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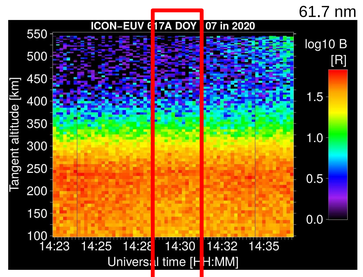

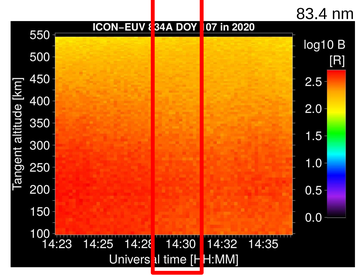

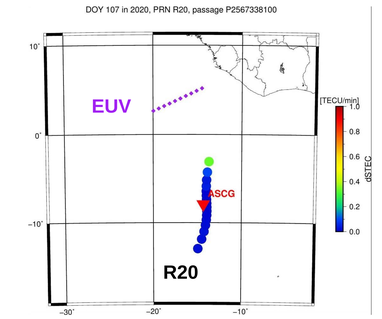

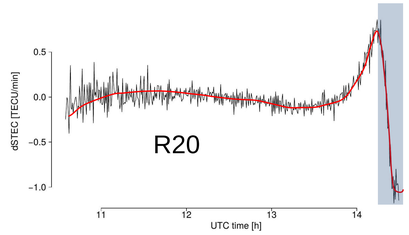

No distinguishable brightness variation in these EUV lines during GNSS related TEC variations.

Summary and future work

- Very first attempt to detect simultaneous and co-located ionospheric features (including TIDs) using both ICON and GNSS measurements
- Period of solar minimum (years 2019-2021), over the equatorial region during quiet geomagnetic conditions
- For FUV: analysis of oxygen line 135.6 nm (nighttime)
- For EUV: analysis of oxygen lines 61.7 nm and 83.4 nm (daytime)

- Very preliminary results show:
  - that FUV 135.6 nighttime brightness profiles can clearly detect ionospheric irregularities that were previously detected by GNSS
  - these irregularities present wave-like patterns that could be associated to traveling ionospheric disturbances (TIDs), but also to a more general typical nighttime ionospheric feature: the equatorial plasma bubbles
  - EUV 61.7 and 83.4 nm lines do not show significant brightness fluctuations during the TEC variations observed with GNSS

Future work and investigation:

- Extract ionospheric features from GNSS using cross-correlation technique with several ground stations: TID wavelength, period, amplitude
- Develop an algorithm to extract TID/bubble information from FUV brightness time series and compare the results with GNSS-related ones
- Apply the methodology to ionization crests and mid-latitudes and consider disturbed geomagnetic conditions
- Compare the bubbles/TIDs detected by FUV-limb with disk views provided by GOLD in the 135.6 nm line

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