



Ionospheric Connection Explorer



ICON Level 2.5 Data Product: Nighttime O^+ Density Retrievals

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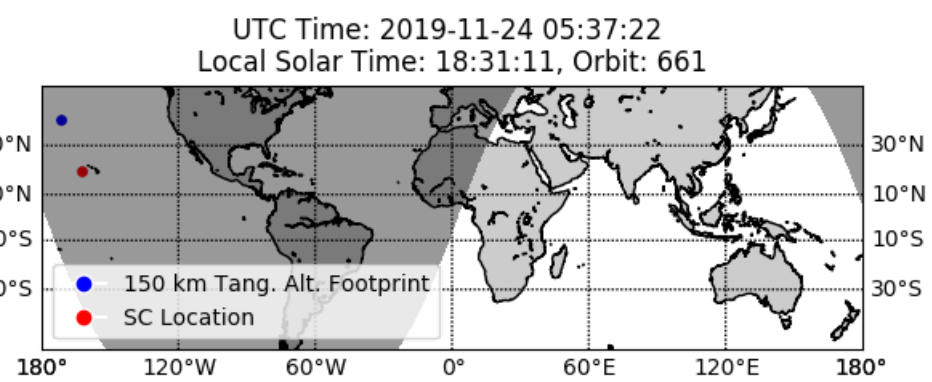
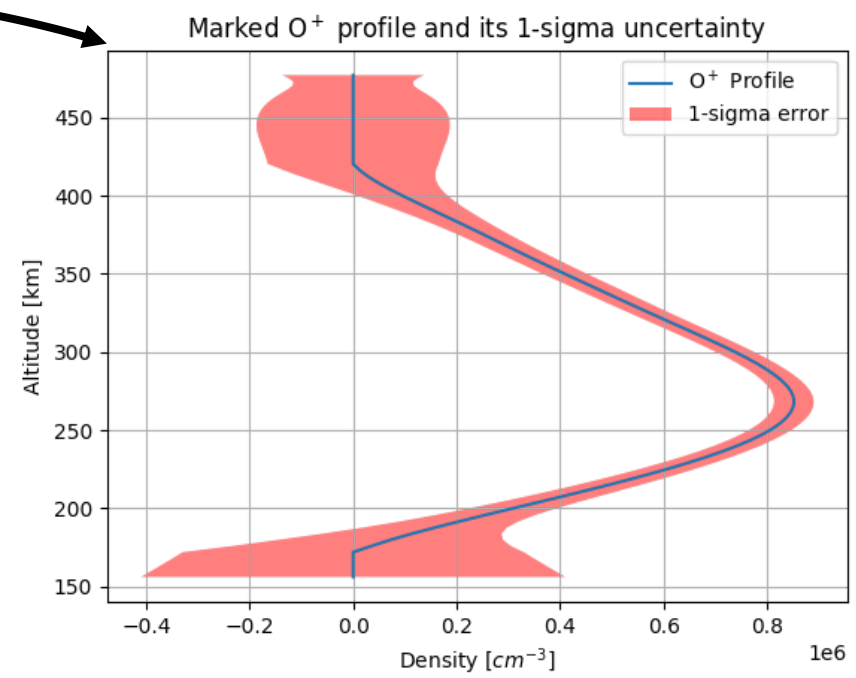
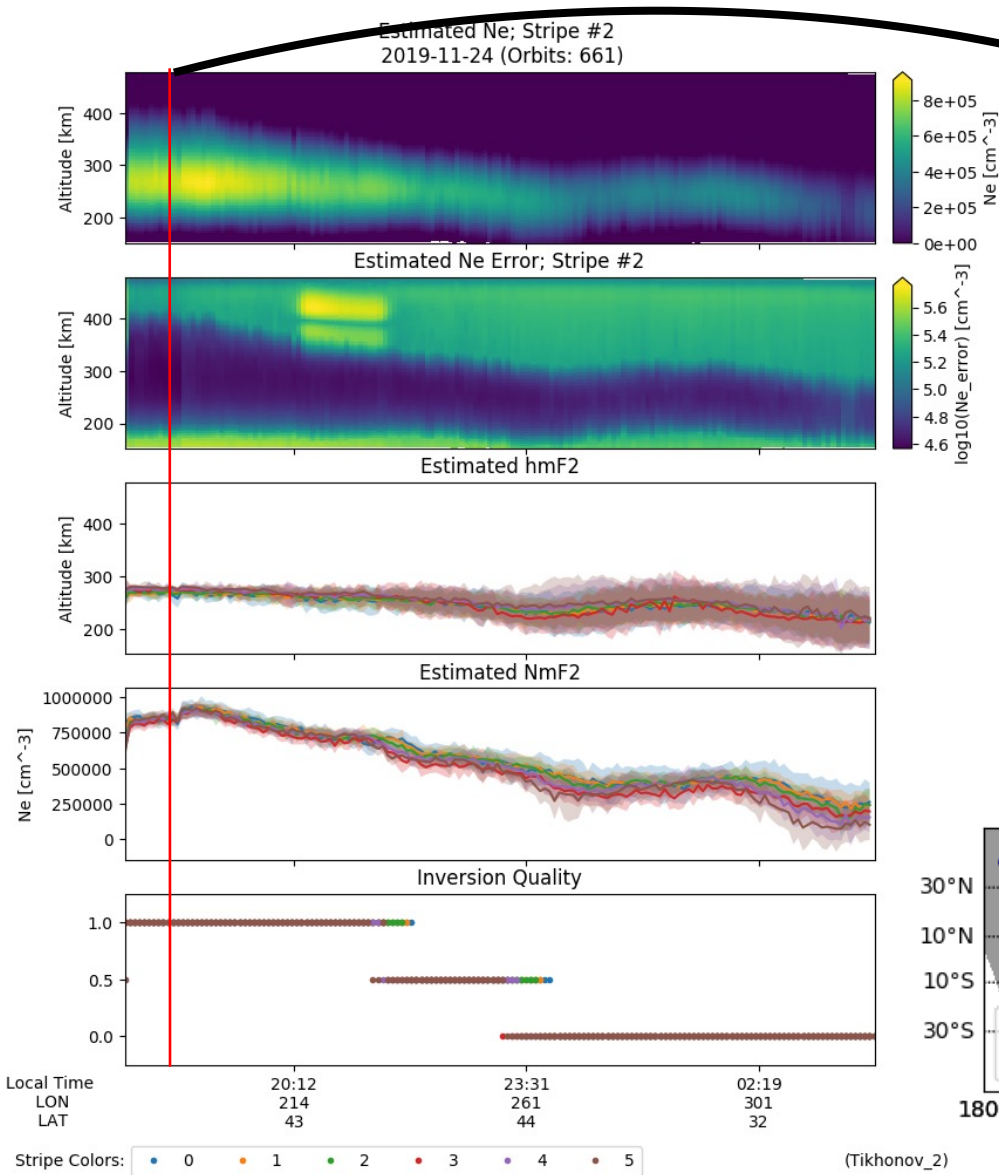
University of Illinois at Urbana-Champaign

And the ICON FUV Team

24 June, 2020

CEDAR Workshop

Example Retrieval: Nighttime Plasma Density Altitude Profiles and Uncertainties

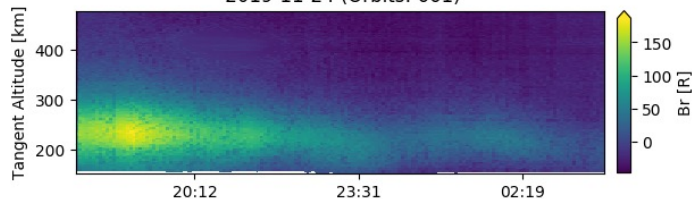


(Tikhonov_2)

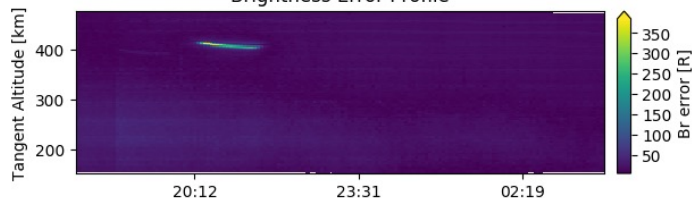
Retrieval Input/Output: Data Product Summary Plots

I
N
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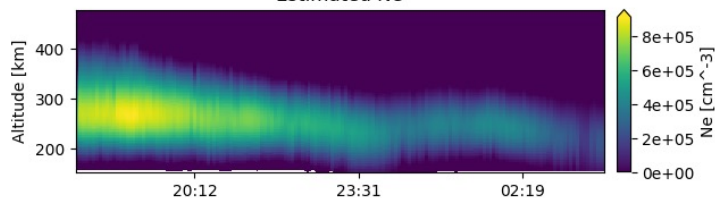
Brightness Profile; Stripe #2
2019-11-24 (Orbits: 661)



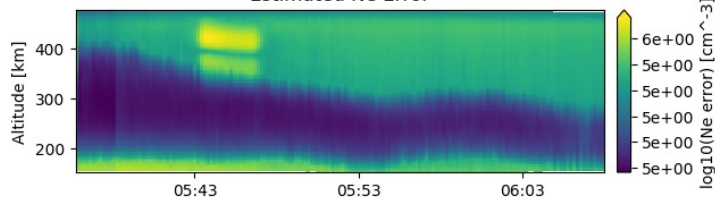
Brightness Error Profile



Estimated Ne

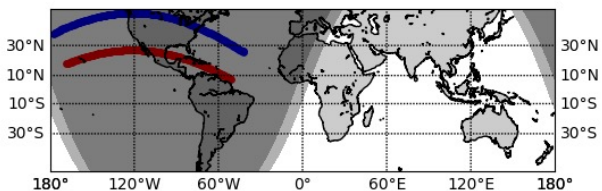


Estimated Ne Error



O
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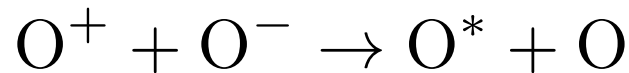
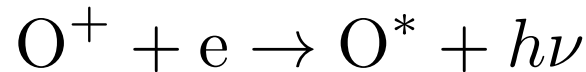
- OI 135.6-nm radiance (R)
- OI 135.6-nm radiance 1-sigma error (R)
- Retrieved electron density profiles (cm⁻³)
- Retrieved electron density 1-sigma error profiles (cm⁻³) (log scale)
- : 150 km tangent point footprints
- : Satellite location footprints



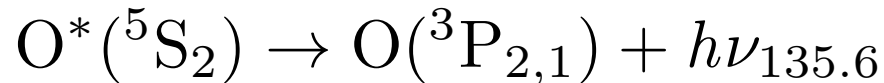
OI 135.6-nm Production Mechanisms Included in the Forward Model



- Production of excited oxygen atoms via radiative recombination and mutual neutralization:



- Production of the 135.6-nm emissions from electric dipole transitions:



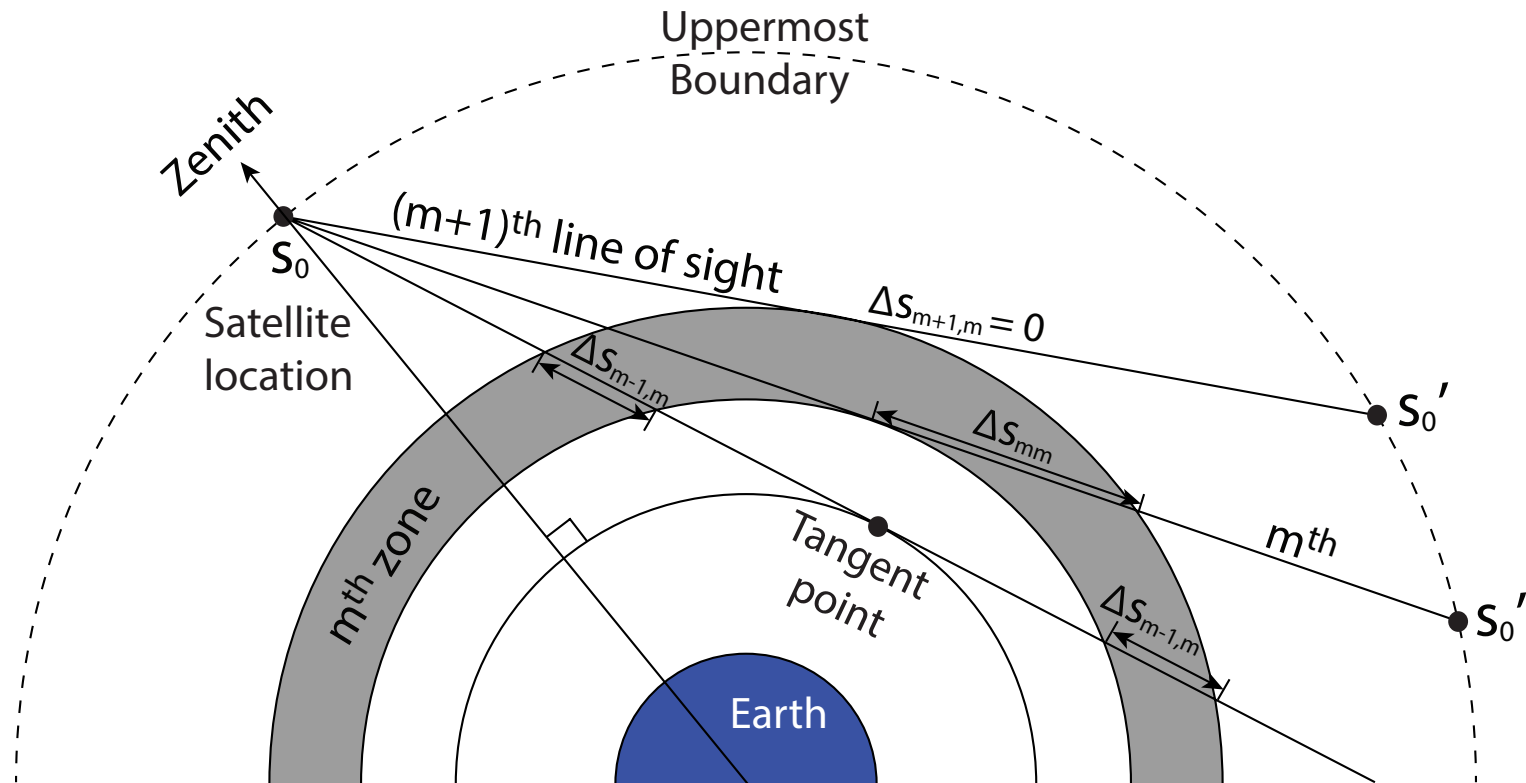
- Volume emission rate (VER) of the sources is calculated as:

$$4\pi\varepsilon_0 = \alpha_{135.6} N_e [\text{O}^+] + \beta_{135.6} k_1 k_2 \frac{N_e [\text{O}] [\text{O}^+]}{k_2 [\text{O}^+] + k_3 [\text{O}]}$$

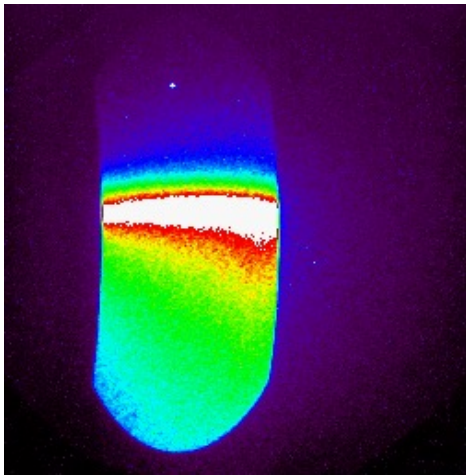
with coefficients obtained from [Melendez-Alvira *et al.*, JGR, 1999], see [Qin *et al.*, JGR, 2015] for the full description.

Observational Geometry Used in the Forward Model

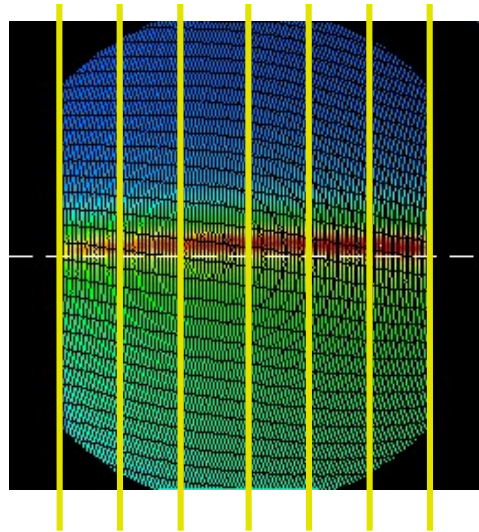
- The brightness observed by the ICON FUV is modeled as projections through circularly symmetric ionosphere:



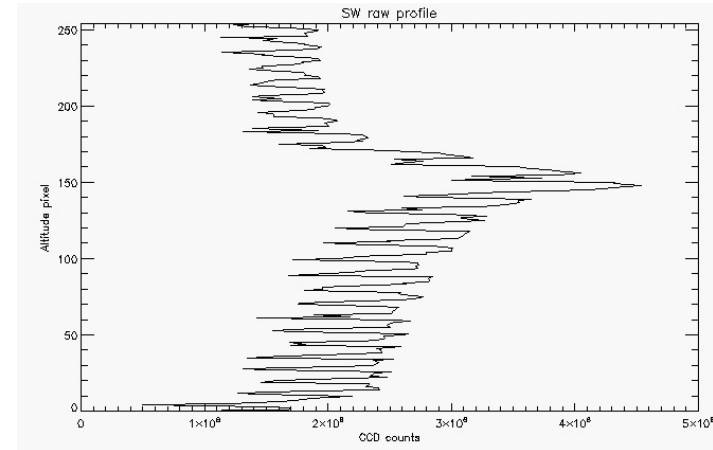
FUV 135.6-nm Measurements



Optical system creates a distorted image on the detector with 120 ms exposure time.

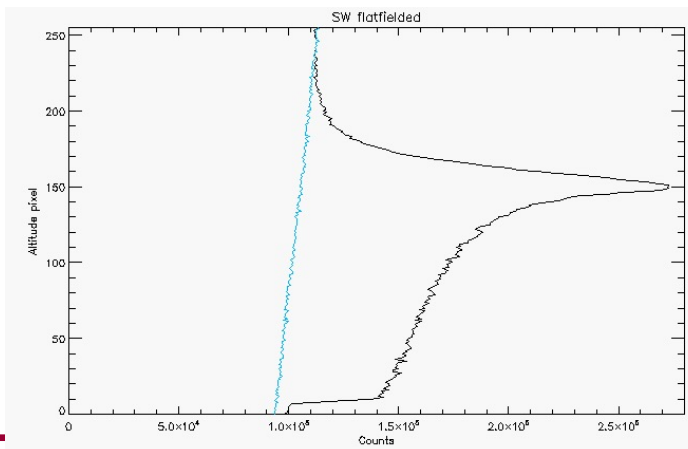


Distortion correction is performed and 6 stripes are generated by combining pixels.

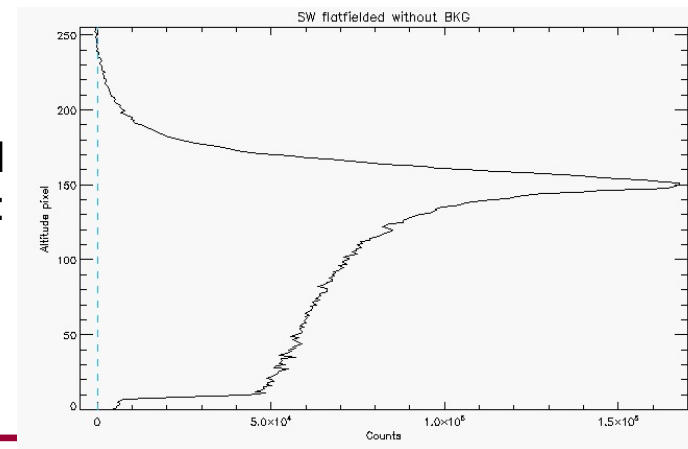


Each stripe profile is generated from 100 frames (12 second exposure time)

Flatfield Correction:



Background Subtraction:



Inverse Model – Estimating the Source Volume Emissivity

- Source volume emissivity is retrieved by minimizing the following cost:

$$\phi(\mathbf{x}) = \underbrace{\|\mathbf{y} - \mathbf{A}\mathbf{x}\|_2^2}_{\text{Data Fidelity}} + \lambda \underbrace{\|\mathbf{L}\mathbf{x}\|_2^2}_{\text{Regularization (prevents fitting noisy measurements)}}$$

where

\mathbf{y} : 135.6-nm measurement vector

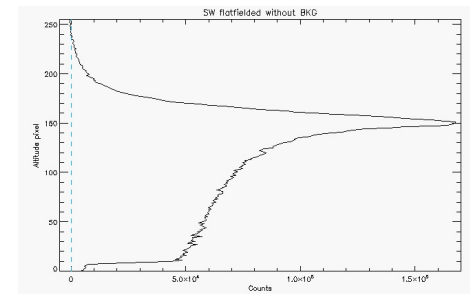
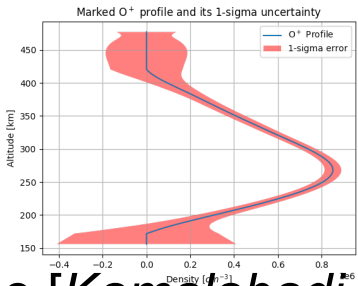
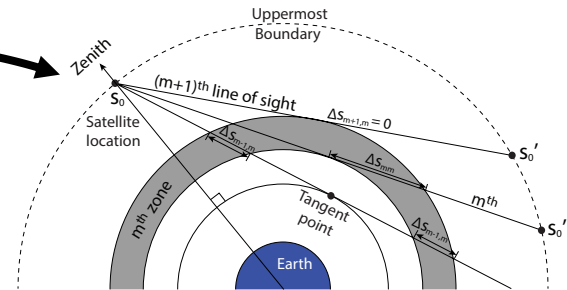
\mathbf{A} : forward model matrix

\mathbf{x} : source volume emissivity vector

\mathbf{L} : regularization matrix – derivative operator ; λ : regularization parameter

which has a closed form solution:

$$\hat{\mathbf{x}} = (\mathbf{A}^T \mathbf{A} + \lambda \mathbf{L}^T \mathbf{L})^{-1} \mathbf{A}^T \mathbf{y}$$



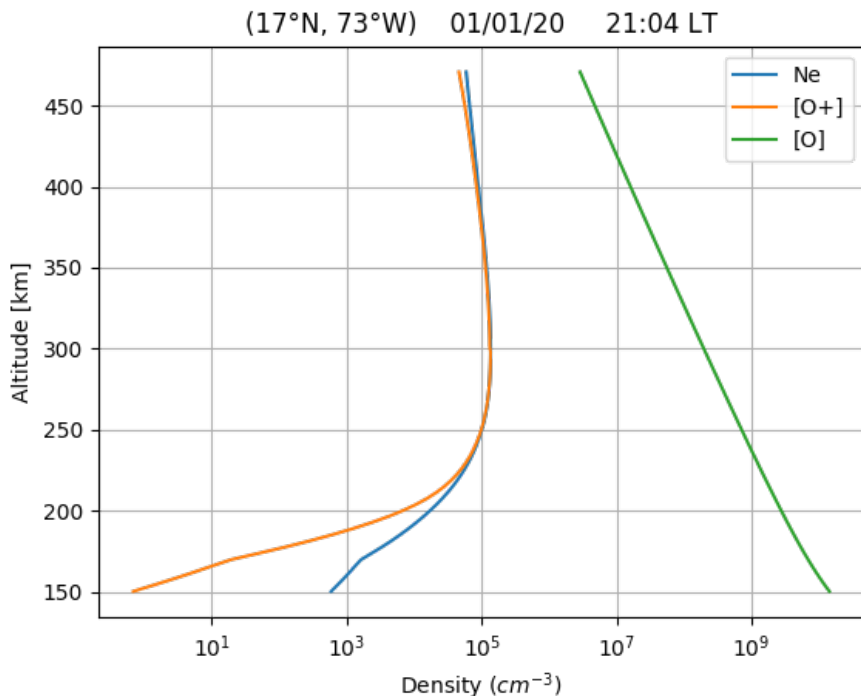
see [Kamalabadi et al., Space Sci Rev, 2018] for the full description.

Inverse Model – Estimating the Electron Density

- Electron density is retrieved by solving the following equation:

$$N_e^3 + \left(\frac{k_3}{k_2} + \frac{\beta_{135.6}}{\alpha_{135.6}} \right) [\text{O}] N_e^2 - \frac{4\pi\epsilon_0}{\alpha_{135.6}} N_e = \frac{4\pi\epsilon_0 k_3 [\text{O}]}{\alpha_{135.6} k_2}$$

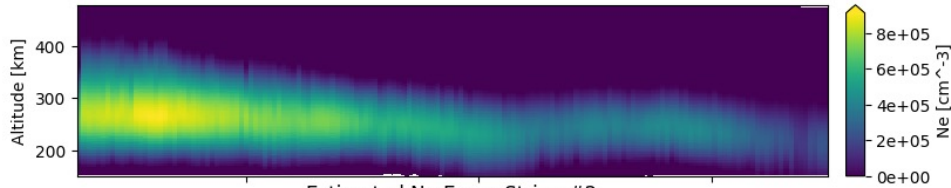
- Assumption: $N_e = [\text{O}^+]$ in the F-region ionosphere.



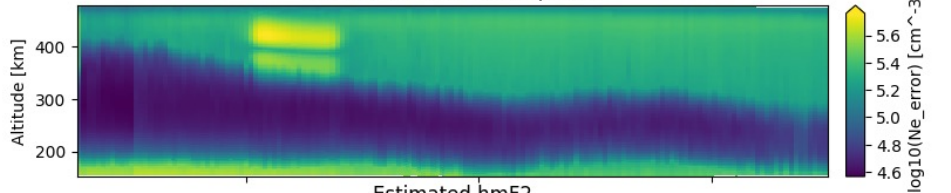
- [O] densities required for the retrieval are obtained from the MSIS00 model.

Data Product Summary Plots

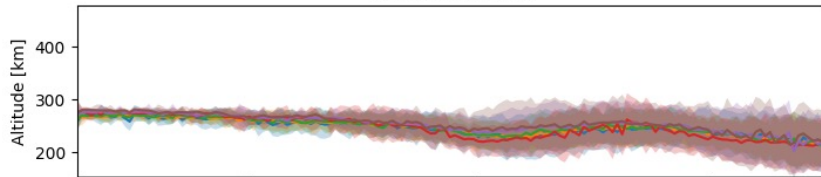
Estimated Ne; Stripe #2
2019-11-24 (Orbits: 661)



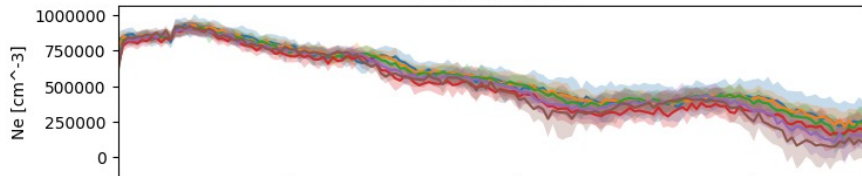
Estimated Ne Error; Stripe #2



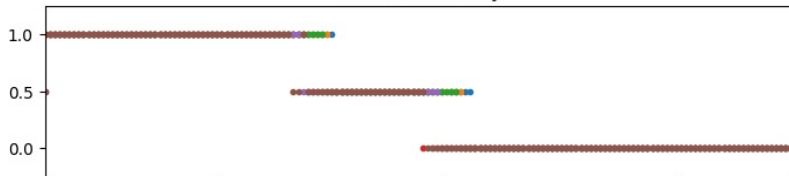
Estimated hmF2



Estimated NmF2



Inversion Quality



Local Time
LON LAT
20:12 214 43
23:31 261 44
02:19 301 32

Stripe Colors: 0 1 2 3 4 5

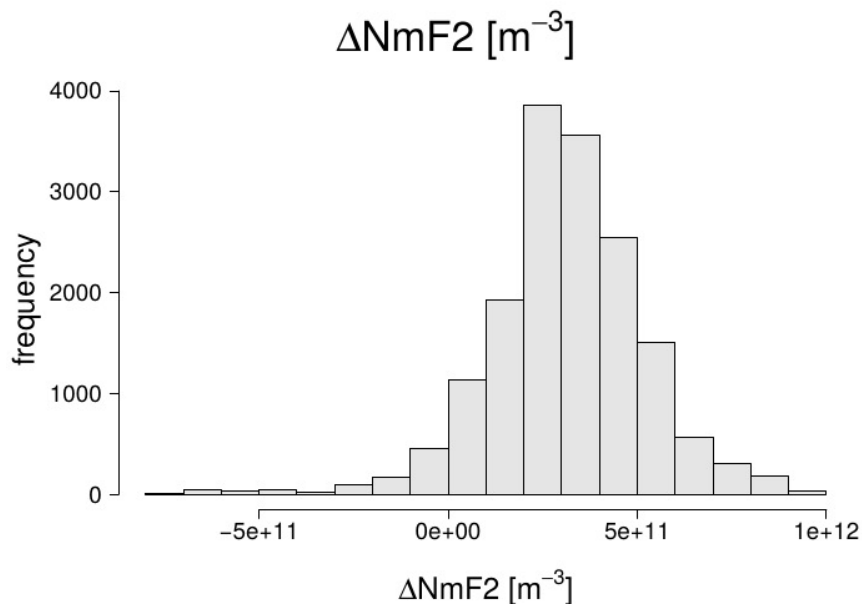
(Tikhonov_2)

- Retrieved electron density profiles (cm^{-3})
- Retrieved electron density 1-sigma error profiles (cm^{-3}) (log scale)
- HmF2 for all the stripes (km)
- NmF2 for all the stripes (cm^{-3})
- Quality for all the stripes:
1: Good quality
0.5: Be cautious
0: Bad quality

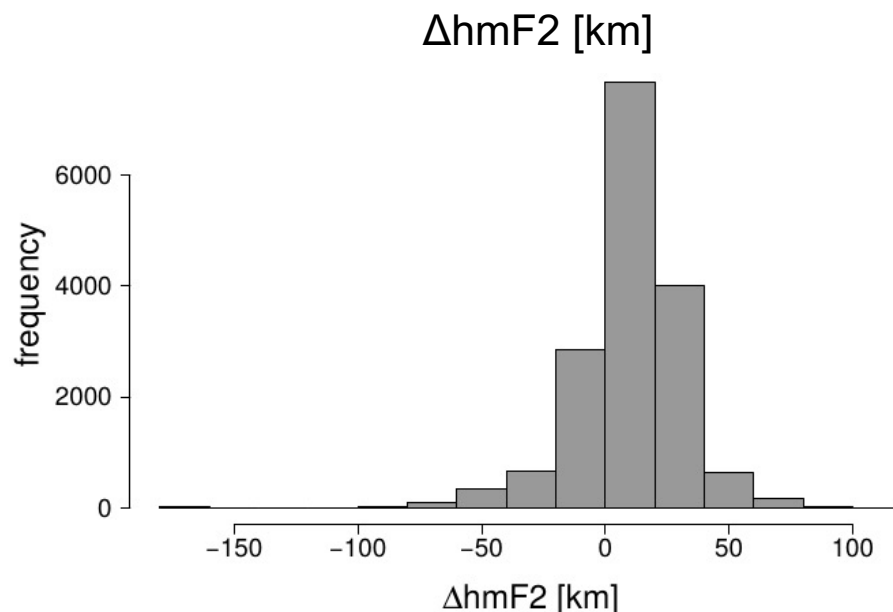
FUV vs Cosmic-2 [Statistics over 18166 comparisons*]



- $\Delta NmF2$ and $\Delta hmF2$ histograms for FUV vs Cosmic-2:



Mean/std.dev = $3.1E+11 m^{-3} \pm 2.1E+11 m^{-3}$



Mean/std.dev = $10.3 km \pm 22 km$

*: comparison by [Gilles WAUTELET, B. HUBERT, J-C GÉRARD
STAR Institute, University of Liège (Belgium)]

Caveats

- Retrievals are volumetric average quantities corresponding to 12 seconds of spacecraft motion (~ 85 km) and a volume spanned by $18^\circ \times 24^\circ$ FOV (3×24 for each stripe) and integrated along the LOS.
- Therefore, single-point comparisons should be interpreted with caution.
- Caution needed near morning terminators.
- Additional validations ongoing.
- Data after mid May has higher sensitivity (increased FUV voltage) and dynamic background correction.

