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# The influence of the description of the neutral atmosphere on the results of modeling the effects of the February 2022 magnetic storm

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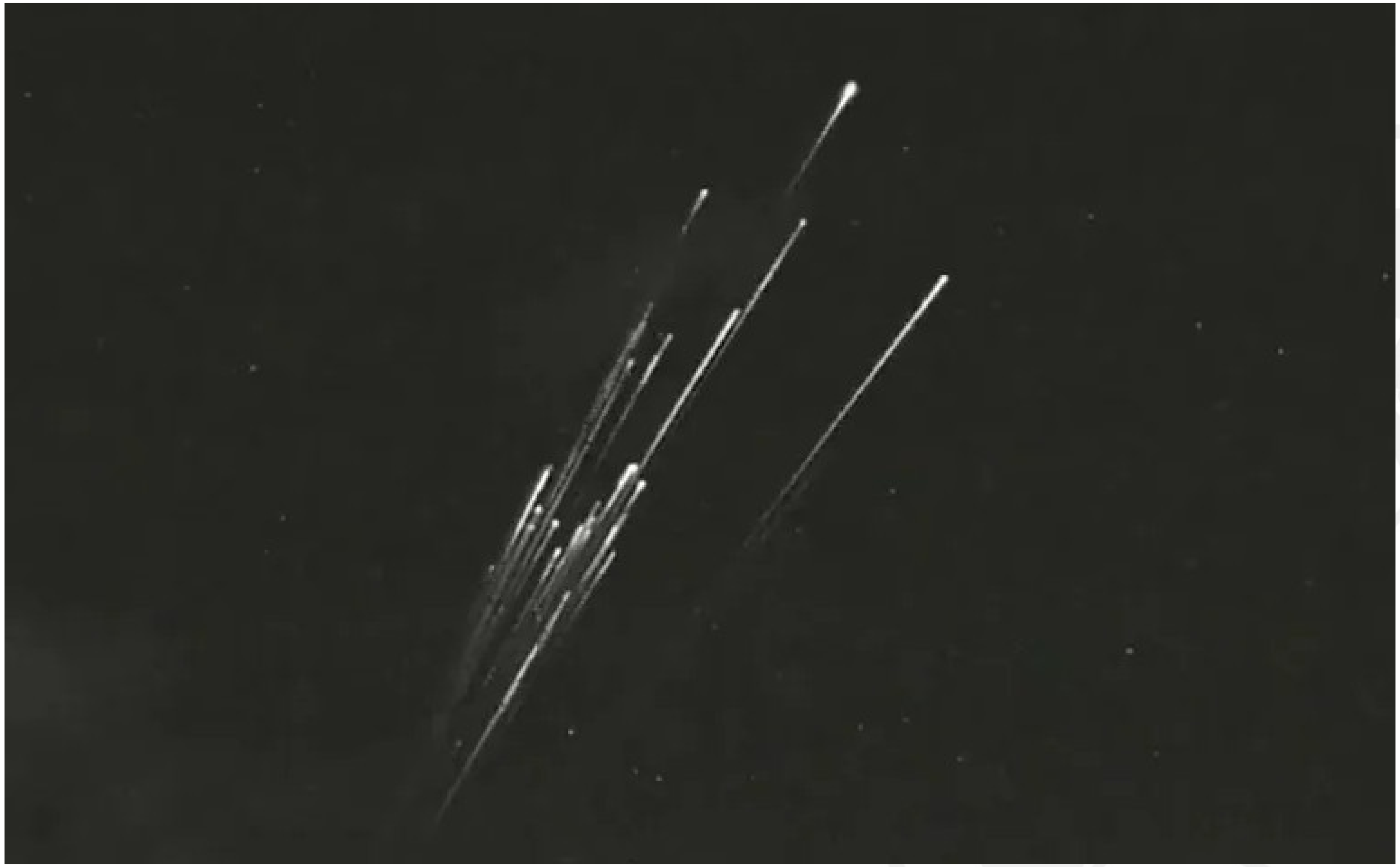
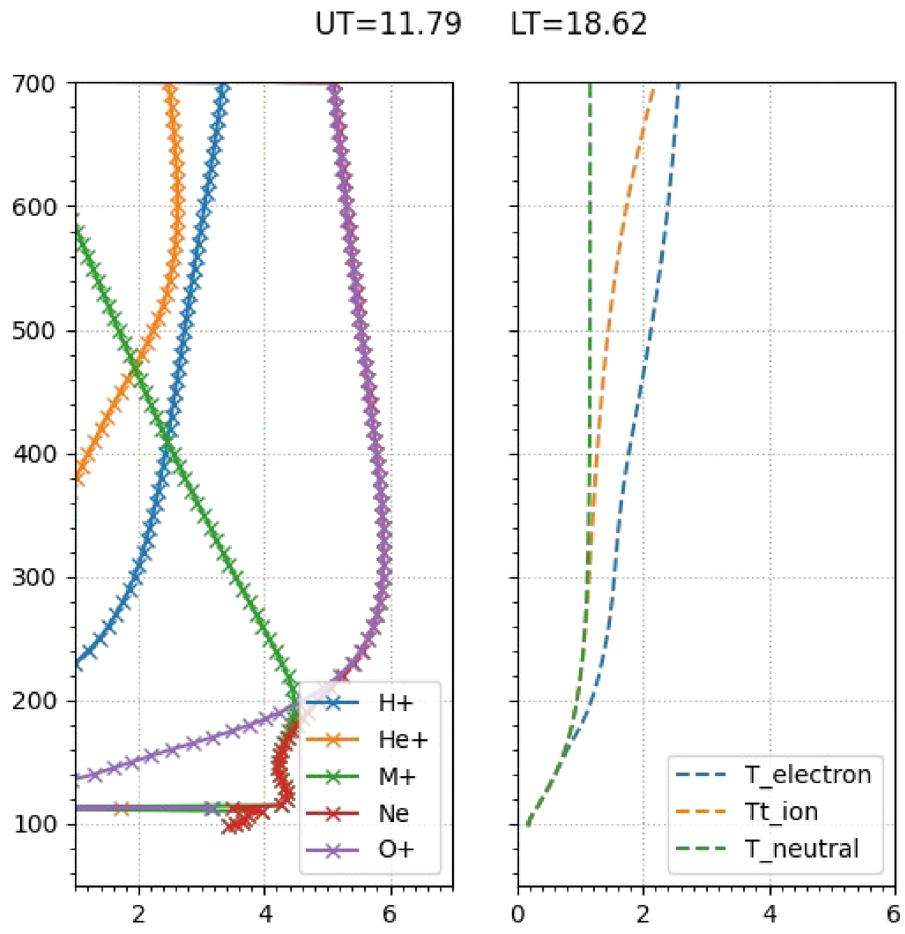
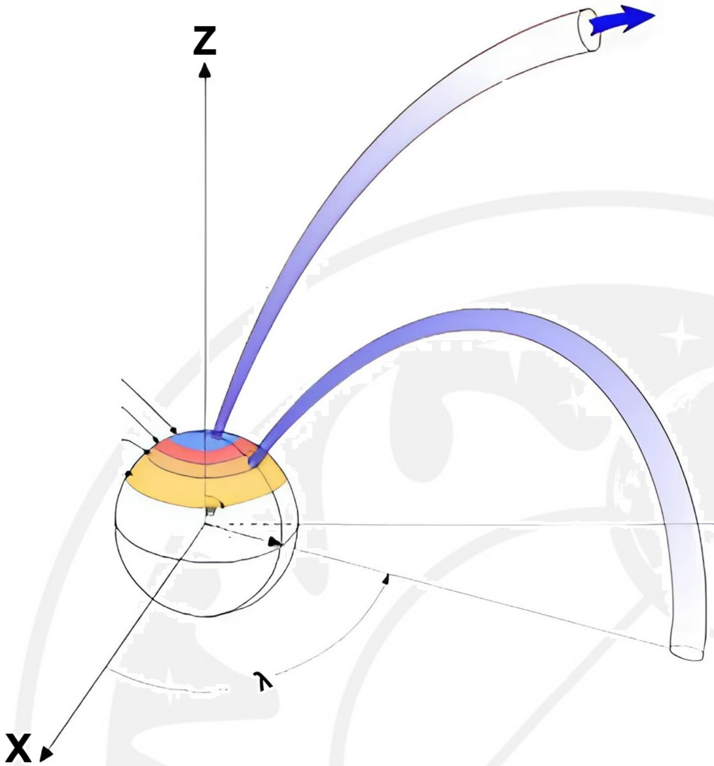
# «Satellite killer» storm of 3-4 Feb 2022



# Global ionosphere-plasmasphere coupling (GIPC) model




- electrons — $e^-$
- atomic ions — $O^+$, $H^+$, $N^+$, $He^+$
- molecule ions — $O_2^+$, $N_2^+$, $NO^+$

# GIPC model

## Continuity equation

$$\frac{dn_i}{dt}+\frac{1}{A}\frac{\partial}{\partial s}\left(A n_i V_i\right)=-n\vec{\nabla}\cdot\vec{w}-\frac{n_i}{\tau_i}+P_i$$

concentration

field tube crossection

total flux

transversal velocity

lifetime

ionization/
recombination
rate for i type of ions

## Transport equation for thermal ions

$$-\frac{\partial}{\partial s}\left(n_i T_i\right)-\frac{n_i}{n_e}\frac{\partial}{\partial s}\left(n_e T_e\right)+m_i n_i g_{\parallel}=\left(V_i-U_{\parallel}\right)m_i n_i\sum_n \nu_{in}+m_i n_i\sum_j \nu_{ij}\left(V_i-V_j\right)$$

pressure

electric field

gravity

neutral-forced drift

ion collisions

field-aligned neutral wind

collision rate

# Heat balance equations

defines $T_e/T_i$ distribution alog drifting field lines

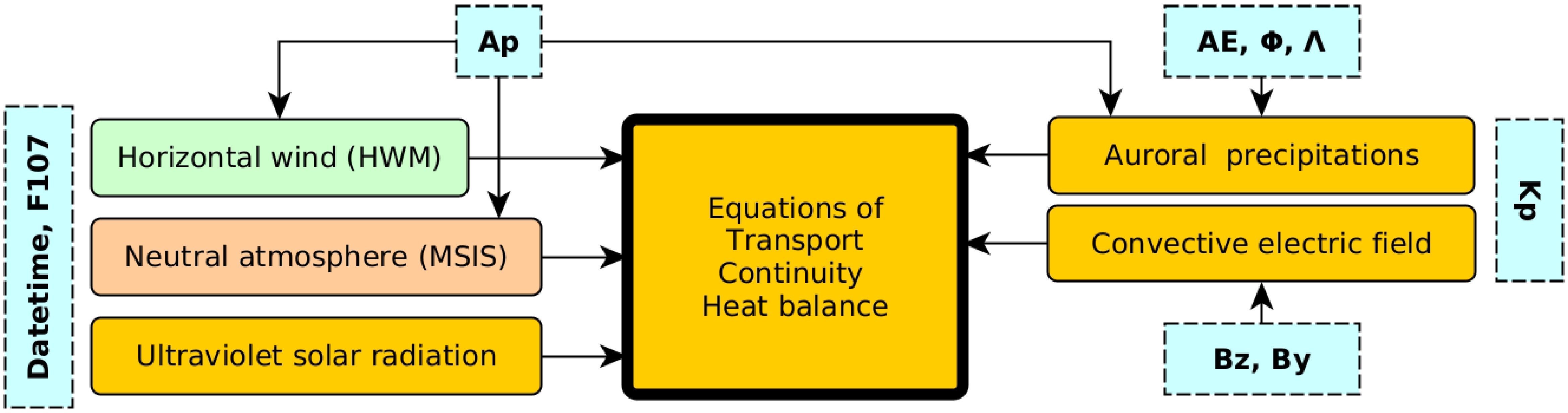
$$\frac{3}{2}\frac{d}{dt}\left(n_e T_e\right)=\frac{1}{A}\frac{\partial}{\partial s}\left(Ak_i\frac{\partial T_e}{\partial s}\right)+Q_e+\sum_i\frac{3m_e}{m_i}n_e\nu_{ei}\left(T_i-T_e\right)-\sum_n L_{en}$$

$$\frac{3}{2}\frac{d}{dt}\left(n_e T_i\right)=\frac{1}{A}\frac{\partial}{\partial s}\left(Ak_i\frac{\partial T_i}{\partial s}\right)+$$

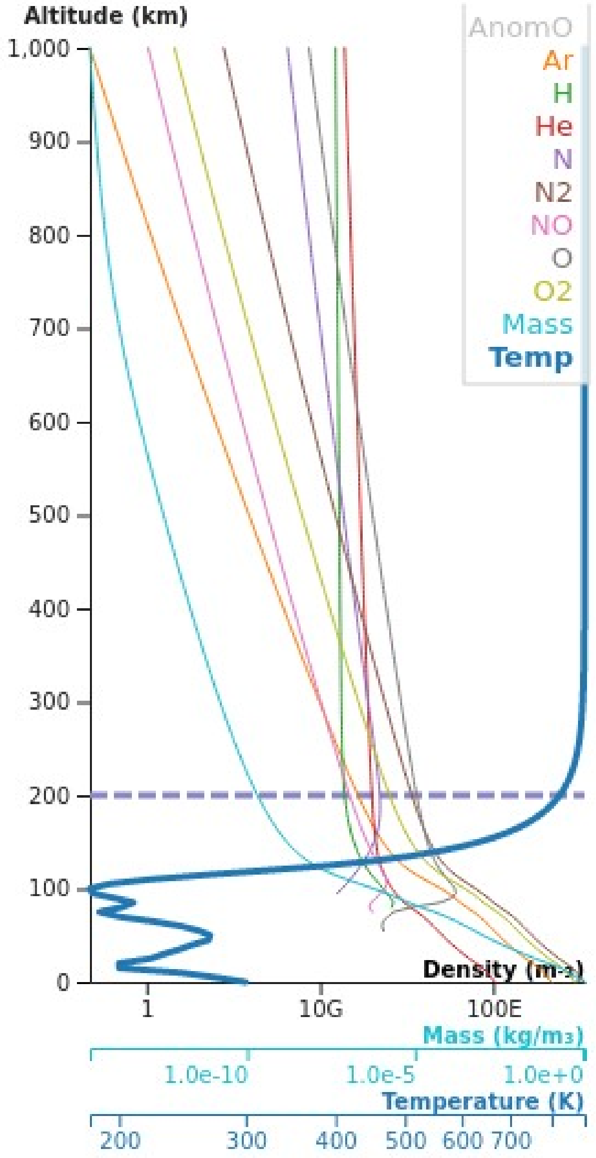
$$+\sum_{i,n}\frac{\mu_{in}m_n}{m_i+m_n}n_i\nu_{in}\left(\vec{w}-\vec{U}\right)^2+\sum_{n,i}\frac{3m_e}{m_i+m_n}n_i\nu_{in}\left(T_n-T_i\right)-\sum 3n_i\nu_{ie}\left(T_e-T_i\right)$$

$Q_e=Q_T^{ph}+Q_T^{e}$ total heating rate by photo-electrons and secondary electrons, produced by high-energy electrons precipitated from magnetosphere

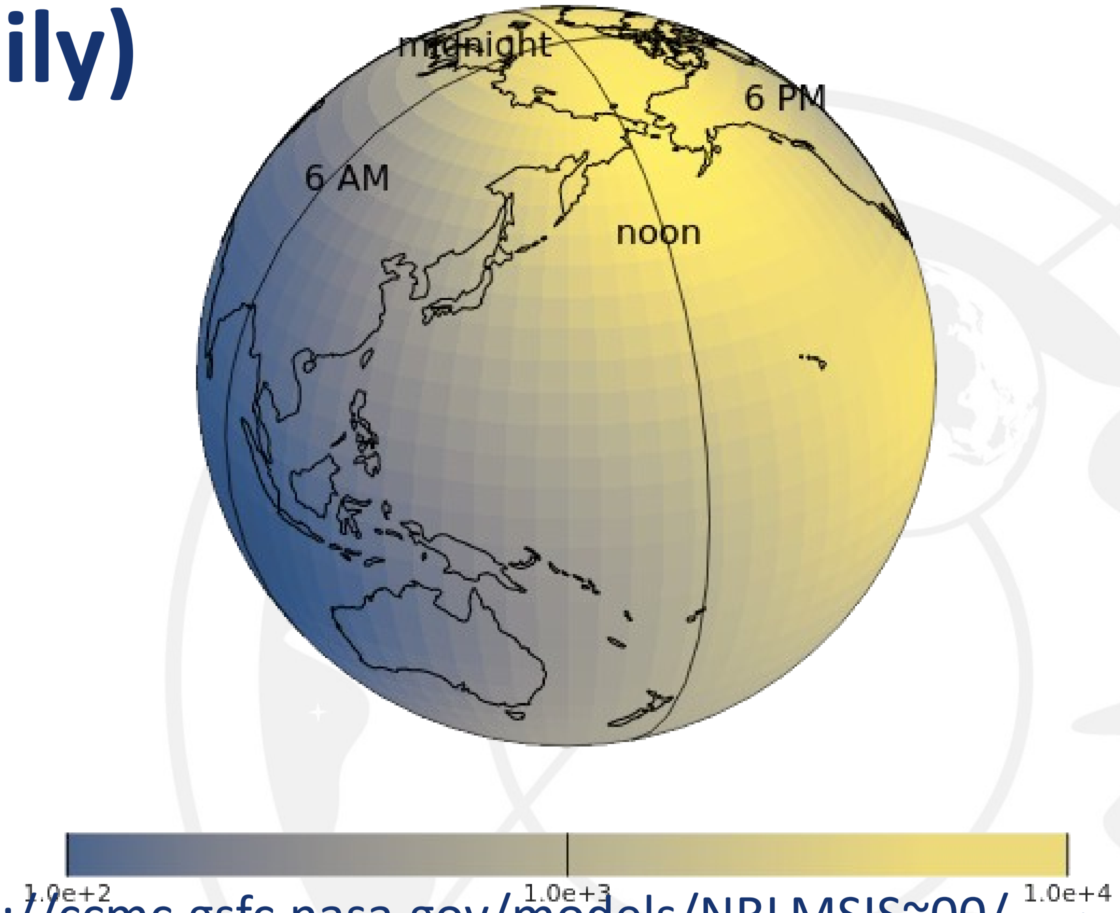
# GIPC dependence on space weather indices



# MSIS model




## Ap (3h)
## F10.7 (daily)




https://ccmc.gsfc.nasa.gov/models/NRLMSIS~00/

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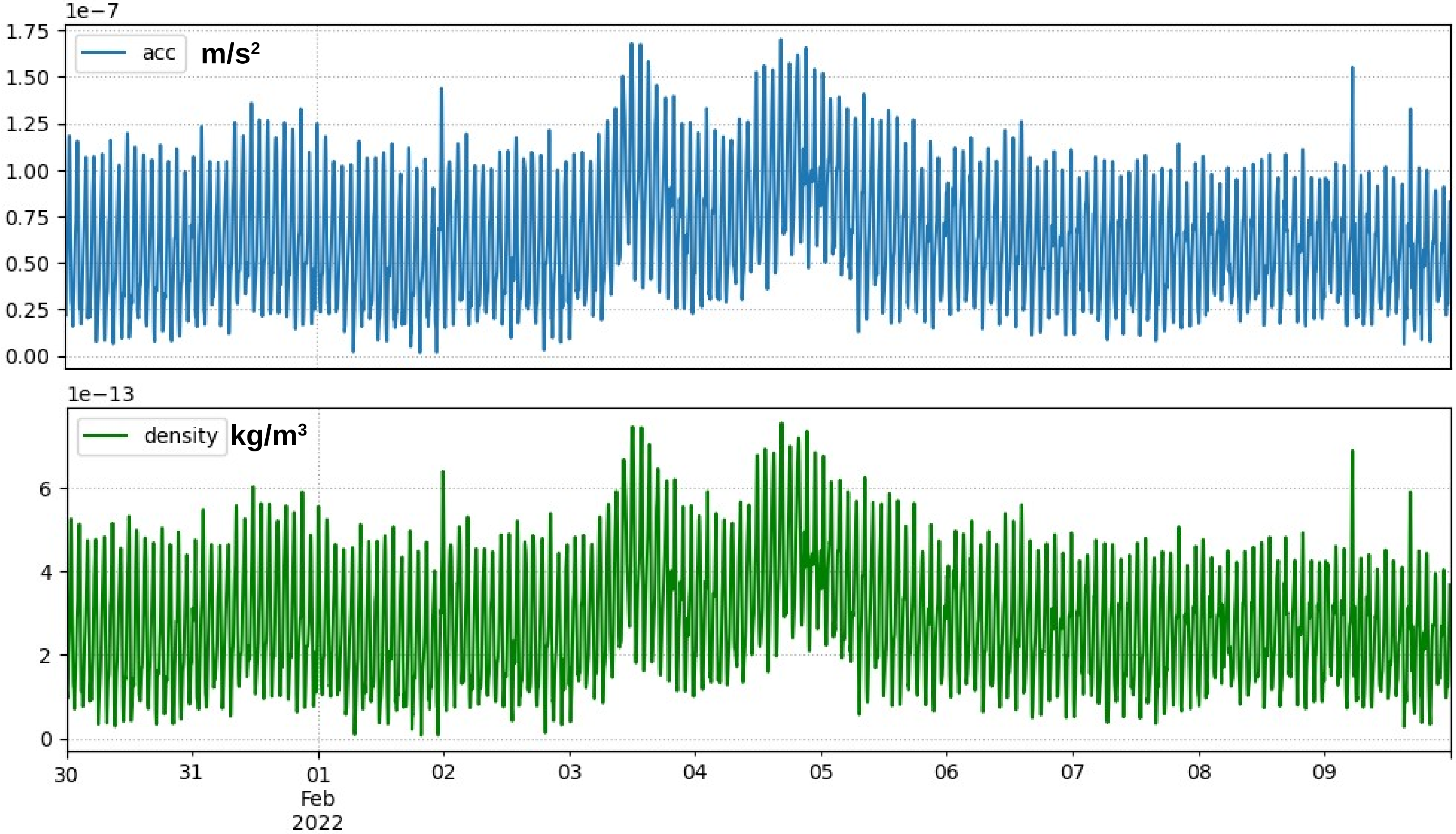
# SWARM satellite non-gravitational acceleration

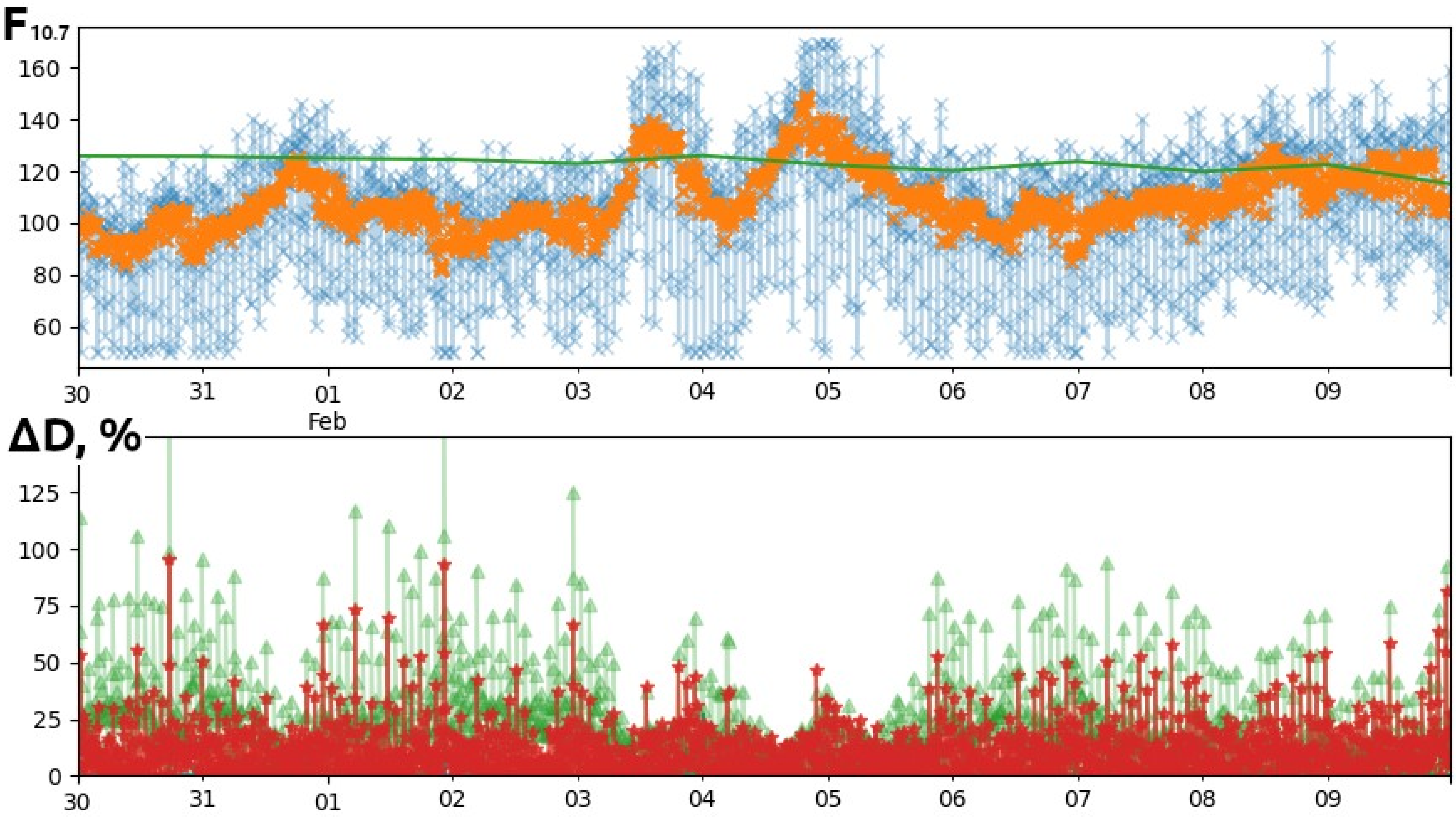
$$\mathbf{a}_{\mathbf{aero}} = \mathbf{C}_{\mathbf{a}} \frac{A_{ref}}{m} \frac{1}{2} \rho v_r^2$$



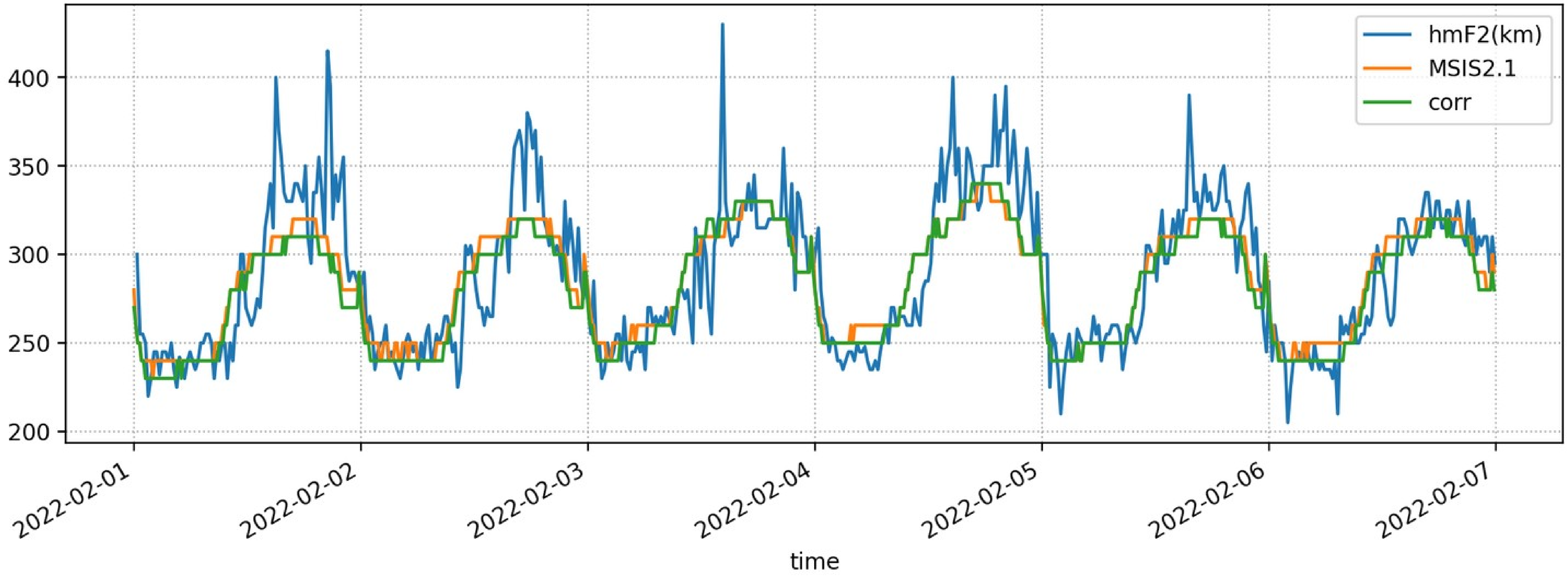

**IJssel J. et al.,**
**ASR, 2020**
**10.1016/j.asr.2020.01.004**

**He J., Astafyeva E. et al.,**
**2023, SW,**
**10.1029/2023SW003521**

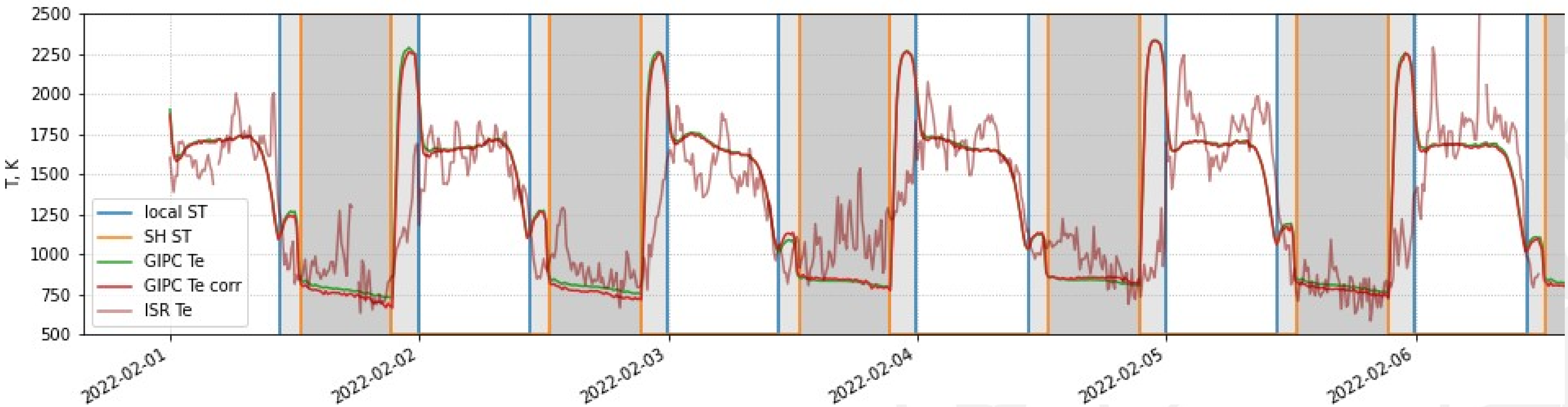
# F10.7-driven minimization of density deviation



# Comparison with IS radar hmF2 data



# Electron temperature variations



# Conclusion

- F10.7 correction allows MSIS to reflect neutral atmosphere density during a magnetic storm pretty fine ($\Delta D < 25\%$)
- ionospheric parameters (hmF2, Te) by GIPC generally in a correspondence with values measured on IS radar
- neutral atmosphere correction is not enough to restore small scale structures in GIPC

# Thank you for your attention!