N^+: A Possible Gatekeeper for Surface Water

Shiru Shong(shirus2@illinois.edu), Raluca Ilie, Mei-Yun Lin, Huizi Hu

Department of Electrical and Computer Engineering

University of Illinois at Urbana-Champaign

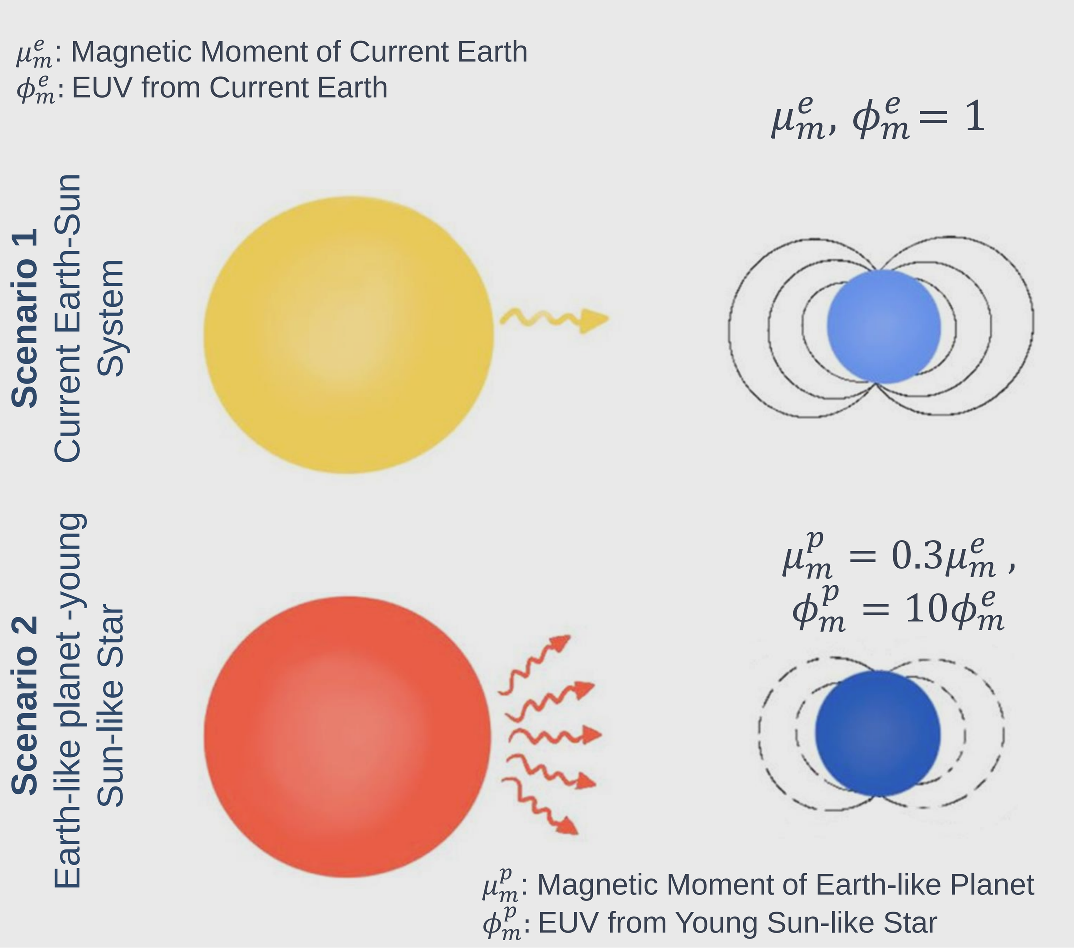
ABSTRACT

Magnetic fields of rocky planets have been suggested to play an important role in planetary habitability by regulating the interaction between a planet and the stellar wind, while the absence of an intrinsic magnetic field may make a planet prone to atmospheric ablation through direct interaction between the stellar wind and the neutral atmosphere. At present-day Earth, the geomagnetic field acts to prevent direct contact between the solar wind and the atmosphere, while it facilitates the loss of the ionized component of the atmosphere (the ionosphere) into outer space. In addition, the stellar wind condition determined by the star activity is considered as one important factor to control the atmosphere sustained by the planet itself. Here, we test the extent to which the strength of planetary magnetic field and the solar EUV control the loss or retention of the heavy ions (N^+ and O^+) in the terrestrial atmosphere.

MOTIVATION

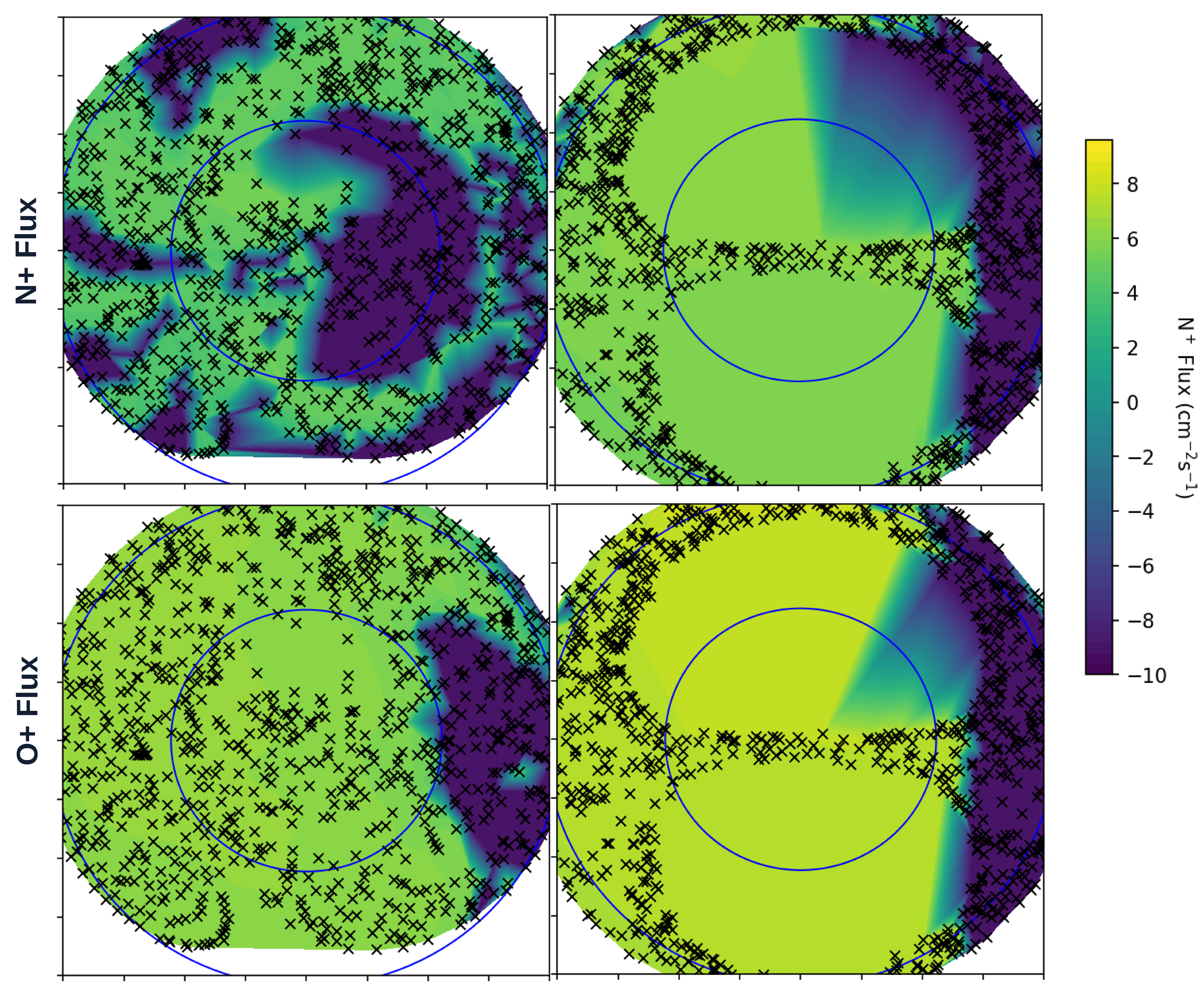
- *Magnetospheres facilitate the loss of the ionized component of the atmosphere (the ionosphere) into outer space. The extent to which a large magnetosphere controls the loss or retention of the atmosphere depends on how it allows for energy and momentum transfer into the atmosphere, and how it inhibits the plasma escape.*
- *Clement climate conditions on the Earth's surface are facilitated by its nitrogen-dominated atmosphere. Therefore, **tracking the loss of N^+**, in addition to that of O^+, could provide clues regarding a planet's ability to sustain life.*

How does the strength of a planet's dipole field and stellar illumination impact atmospheric escape?

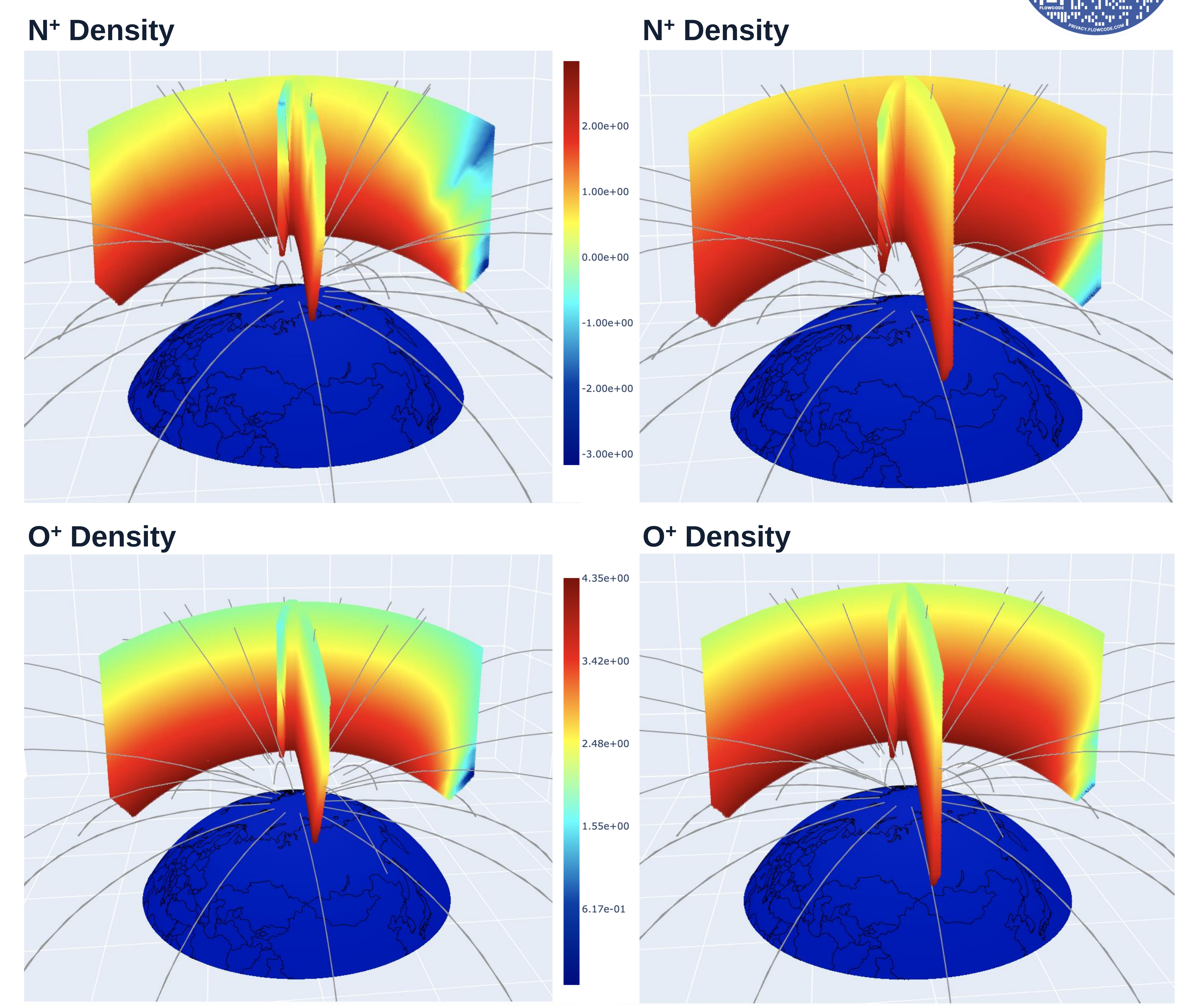


RESULTS

3D PWOM Visualization: https://hera.ece.illinois.edu
Flux and Field Line Convection Animation: https://yilerat19.github.io/posts/V-GEM2021_SS



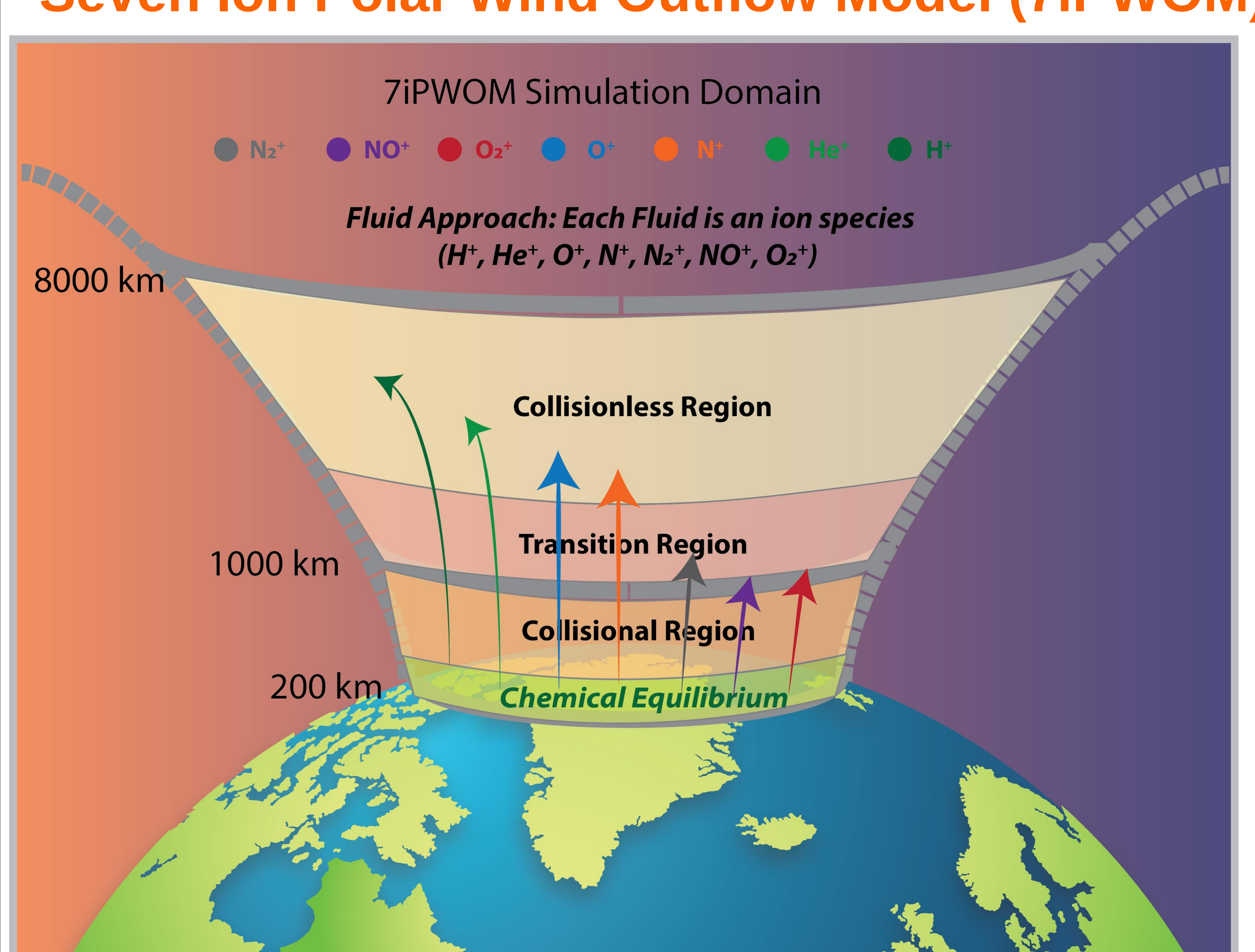
Log10 of O^+ and N^+ Flux derived from 7iPWOM at 4000km (2D Slice)

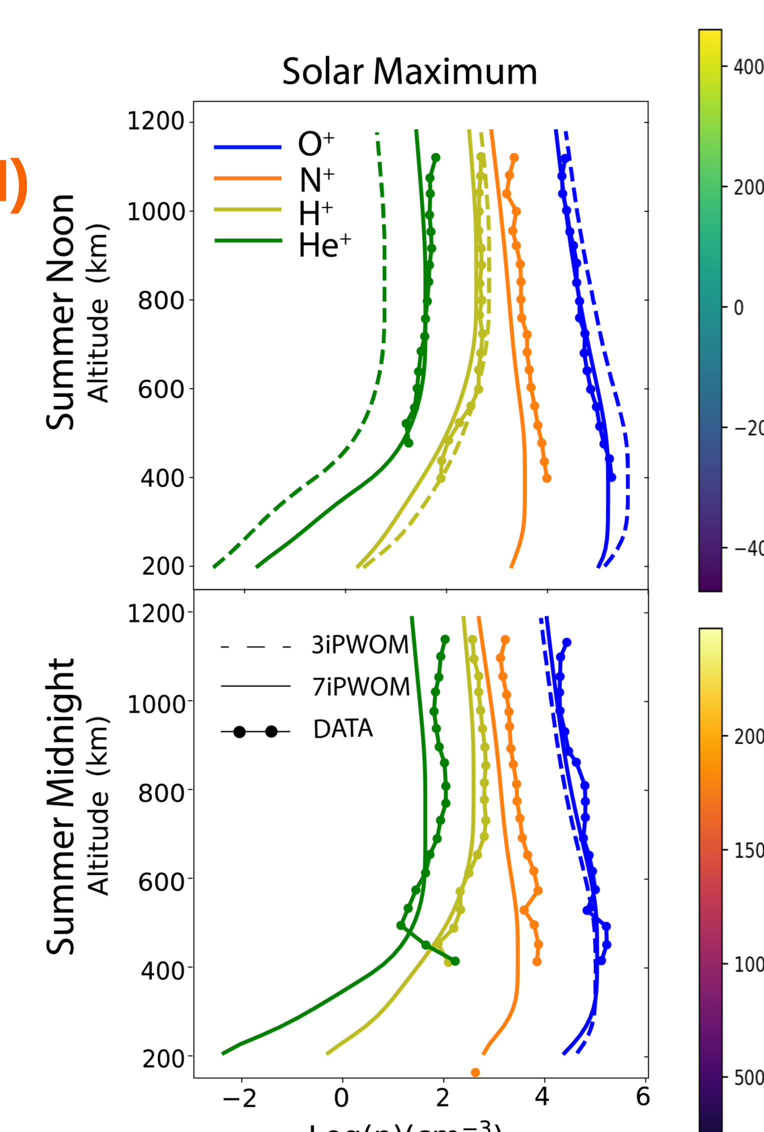


3D Slice of N^+ and O^+ Density derived from 7iPWOM from 200-7000km.

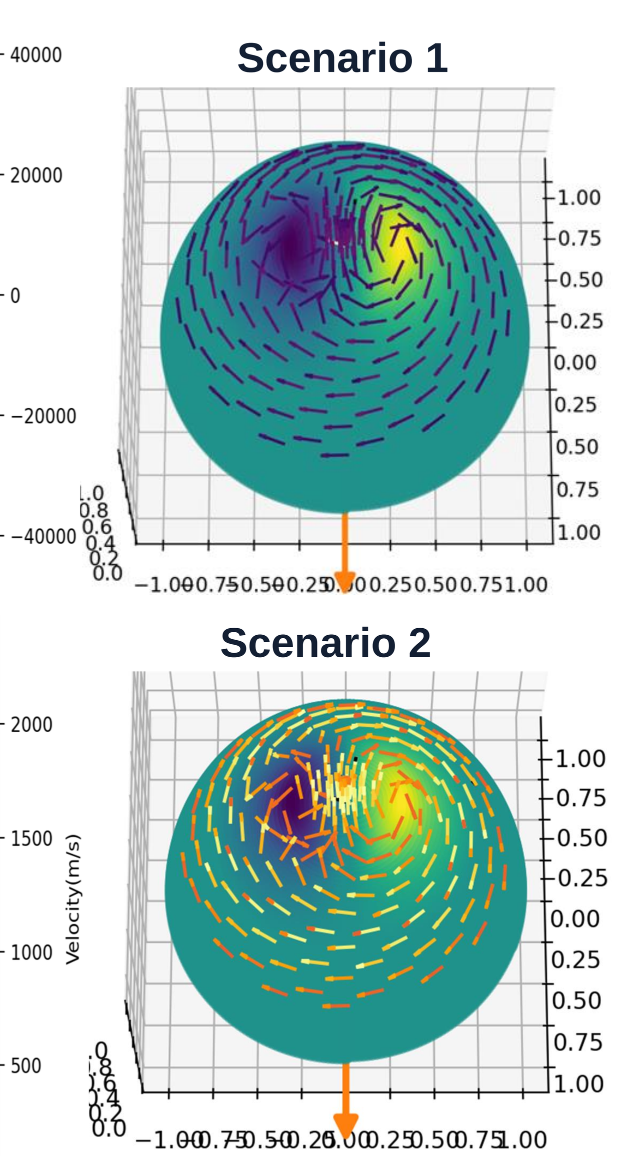
Nitrogen Ion Escape @

Seven Ion Polar Wind Outflow Model (7iPWOM)



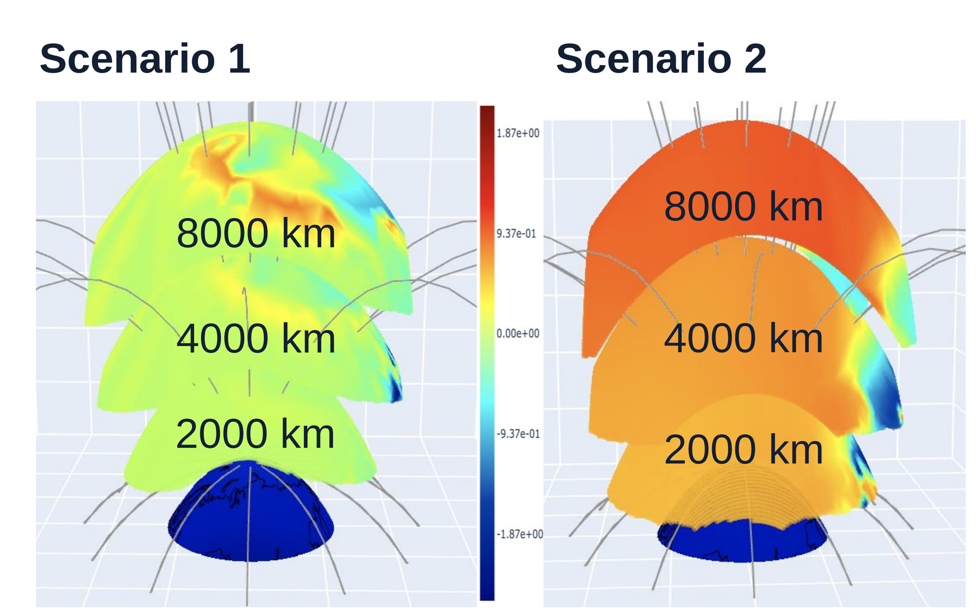


H^+, He^+, O^+ and N^+ densities from 7iPWOM (solid line) and 3iPWOM (dashed line) under solar maximum summer (Lin et al. [2020], GRL).

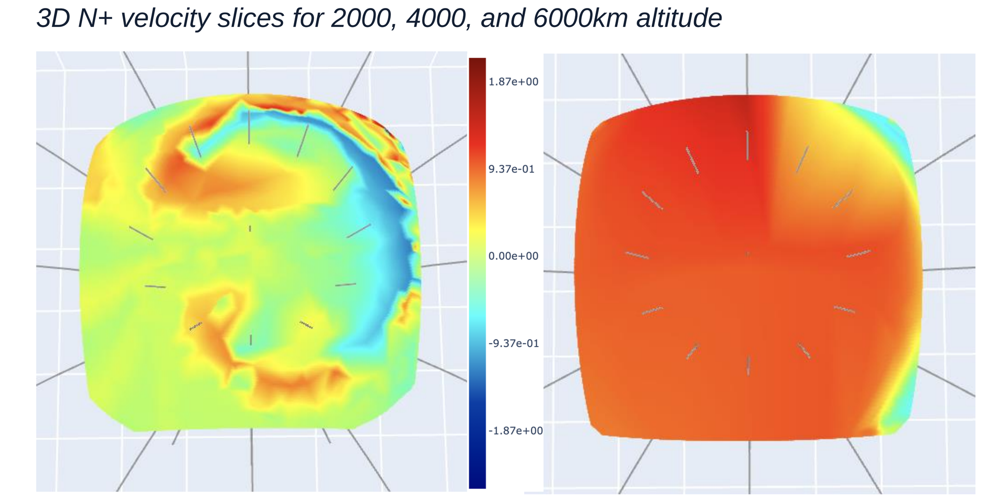


3D CPCP showing velocity vectors for Earth Velocity is calculated by $\vec{v} = -\vec{E} \times \vec{B}/B^2$

Nitrogen Velocity Profile



3D N+ velocity slices for 2000, 4000, and 6000km altitude



3D N+ velocity slice for 6000km

CONCLUSIONS

- The question of how planets develop and retain a habitable atmosphere carries deep and far-reaching implications and is of high societal relevance as it may shape exploration goals, the search for life, and the future of humanity's relationship with space.
- The effect of a weaker magnetic field is to increase the convection across the polar cap, leading to faster circulation of plasma from dayside to night side, and exposure to ionization at different rates than under nominal conditions (Scenario 1). This will likely accelerate the ion production and loss for cases similar to Scenario 2.
- N^+ ions are most sensitive in the changes of EUV flux.

ACKNOWLEDGEMENTS

I gratefully thank my mentors Mei-Yun Lin, Professor Ilie Raluca, and all the members of the UIUC HeRA Research for supporting this research project.