SEE YOU ON THE OTHER SIDE: The impact of N^+/O^+ composition on heavy ion transport and magnetosphere dynamics in multifluid modeling

Hsinju Chen (*hsinjuc2@illinois.edu*) and Raluca Ilie Heliophysics Research and Applications (HeRA), Department of Electrical & Computer Engineering, University of Illinois at Urbana-Champaign

view animations at hsinjuchen.web.illinois.edu/AGU22.html

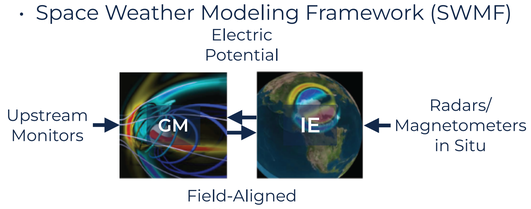
HeRA HELIOPHYSICS RESEARCH & APPLICATIONS

MOTIVATION

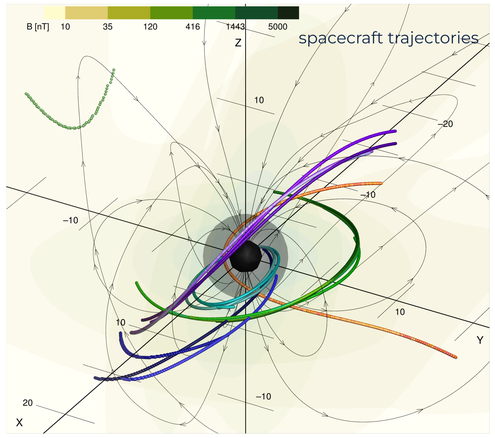
- Ion composition regulates many magnetospheric processes.
- N^+ density in the inner magnetosphere rivals that of O^+ during moderate geomagnetic activity.
- What is the effect of variations in ionospheric heavy ion composition on the magnetosphere dynamics?

METHODOLOGY

- Space Weather Modeling Framework (SWMF)



- Multifluid Magnetohydrodynamics (MHD)
- Sept 2017 Storm: DISCOVR measurements as driver (12h)
- Inner Boundary Ion Density Setup ($\Sigma_i \rho_i$ = 28 cm^{-3} @ 2.5 R_E):
  $[n_{O^+} = n_{N^+}]$ 80% H^+, 10% N^+, 10% O^+
  vs. **$[n_{O^+} = 3n_{N^+}]$** 80% H^+, 5% N^+, 15% O^+
- Domain: 292 R_E × 256 R_E × 256 R_E (~2.6M cells)
- Model Validation: 20 spacecraft data



THEMISA THEMISB THEMISC THEMISD THEMISE
MMS1 MMS2 MMS3 MMS4
CLUSTER1 CLUSTER2 CLUSTER3 CLUSTER4
GOES13 GOES14 GOES15 GOES16
GEOTAIL RBSPA RBSPB

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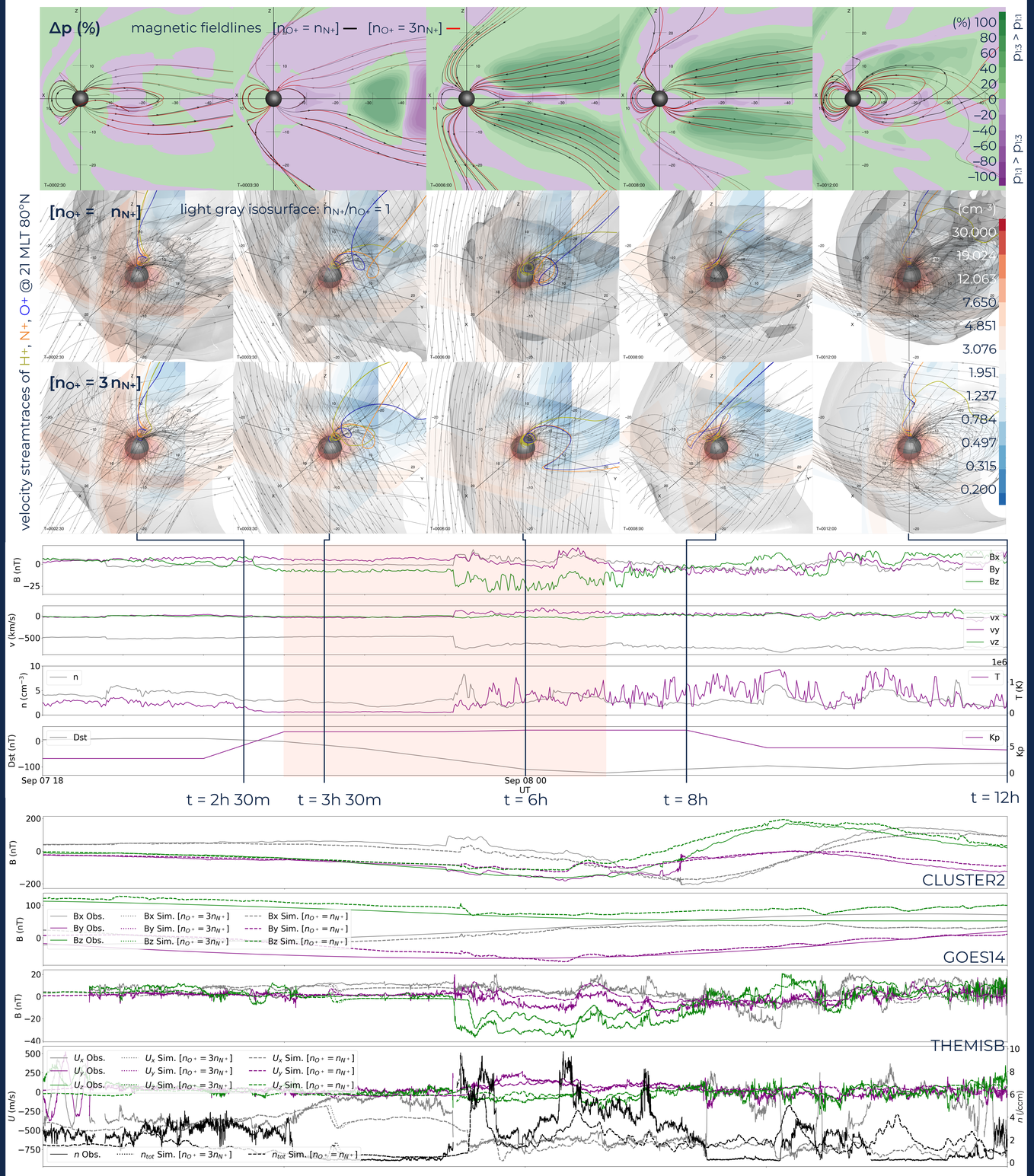
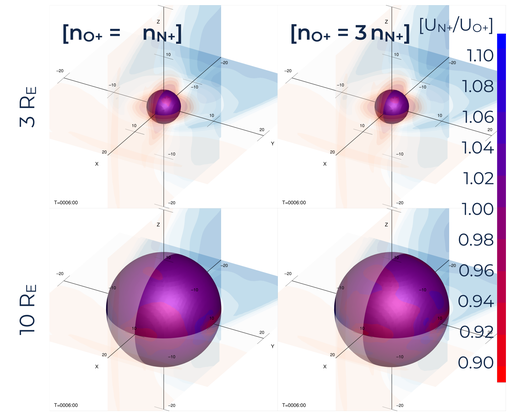
MAGNETOSPHERE VARIATION UNDER DIFFERENT N^+/O^+ COMPOSITION RATIOS



HEAVY ION VELOCITIES @ t = 6h



CONCLUSIONS

- **Effects of $n_{O^+} > n_{N^+}$ on the inner boundary:**
  - Shorter magnetotail (closer X-line).
  - Larger pressure at x ≈ –25 ~ –40 R_E and smaller pressure at x < –40 R_E during early–main phase.
  - Larger pressure in the lobes during late–main phase and early–recovery phase.
  - Returns to normal (comparable pressure) in late–recovery phase.
- **Small variations in heavy ion composition on the inner boundary lead to sizable differences in X-line location.**
  - Largest differences are observed during the main phase.

time	$[n_{O^+} = n_{N^+}]$	$[n_{O^+} = 3n_{N^+}]$	Δx (R_E)	Δx (%)
2h 30m	-48.8	-48.4	-0.4	0.823%
3h 30m	-15.1	-14.2	-0.9	6.143%
6h	-12.4	-10.9	-1.5	12.876%
8h	-15.6	-14.8	-0.8	5.263%
12h	-27.7	-25.9	-1.8	6.716%

- While $U_{N^+}/U_{O^+} = 1$ when $n_{O^+} = n_{N^+}$ on the inner boundary, the N^+ and O^+ transport diverges as they are convected throughout the magnetosphere.
  - The change in the density ratio on the inner boundary leads to different N^+ and O^+ pathways.
- **Multi-fluid simulation captures key features seen in spacecraft data.**

ACKNOWLEDGMENTS

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