Ionospheric Outflow and the Magnetosphere: A Poorly Understood, Non-Linear Relationship

D. Welling

University of Michigan

Climate and Space

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The Unsolved Problem:

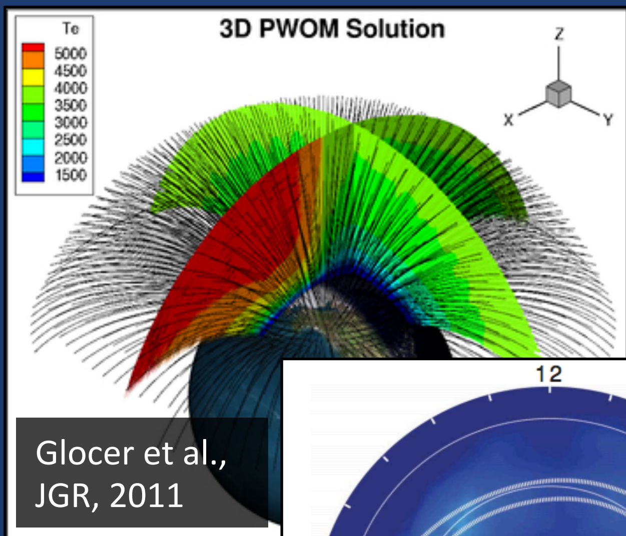
The importance of ionospheric outflow in the magnetosphere is now well established.

Recent numerical studies have demonstrated non-linear feedback loops arising between outflow dynamics and magnetospheric dynamics.

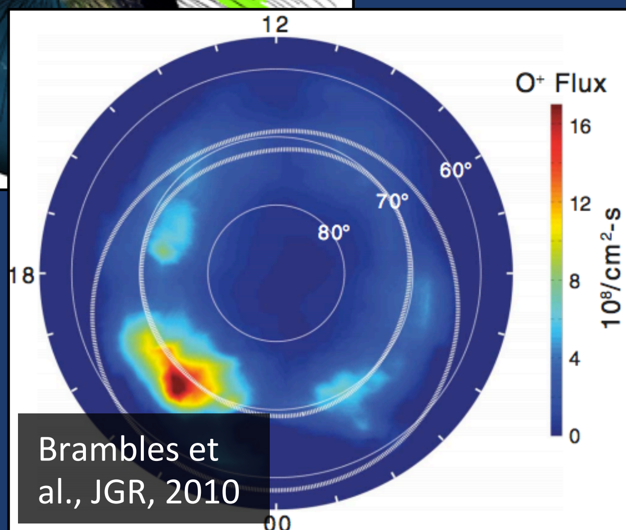
UNSOLVED PROBLEMS:

1. Do these feedback systems manifest in the real magnetosphere?
2. How do we observe them?
3. What other feedback loops exist?

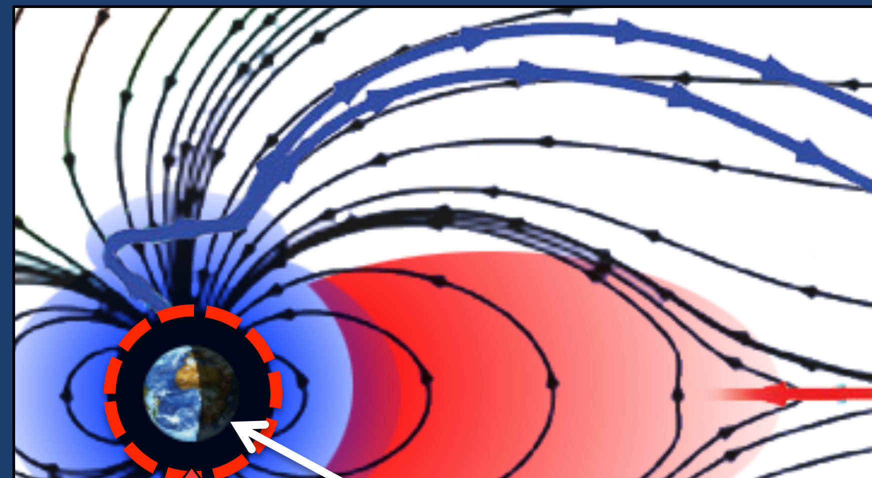
Generic Outflow + MHD Formula



Glocer et al., JGR, 2011



Brambles et al., JGR, 2010



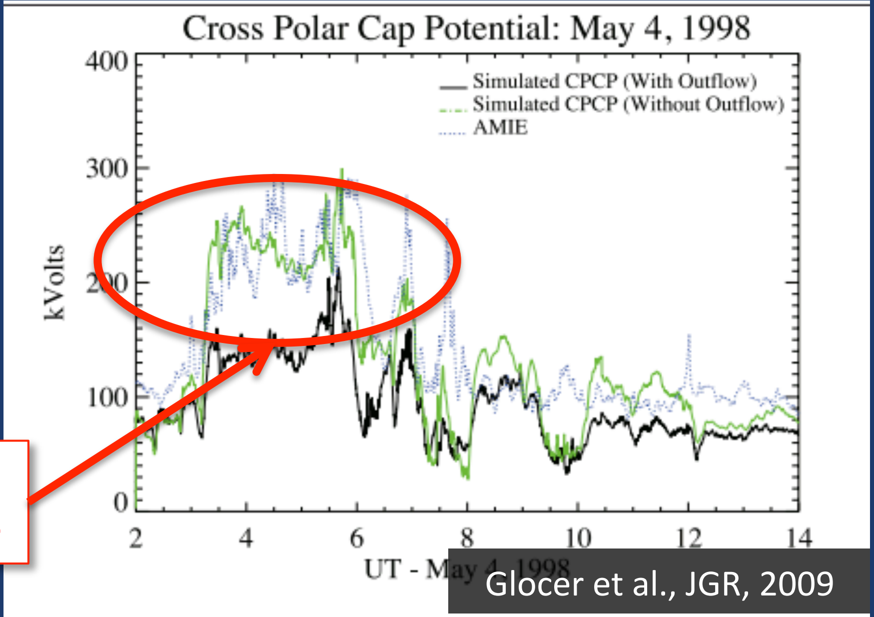
ρ, V_{rad}, t

"Gap Region"
Between ionosphere
and MHD I.B.

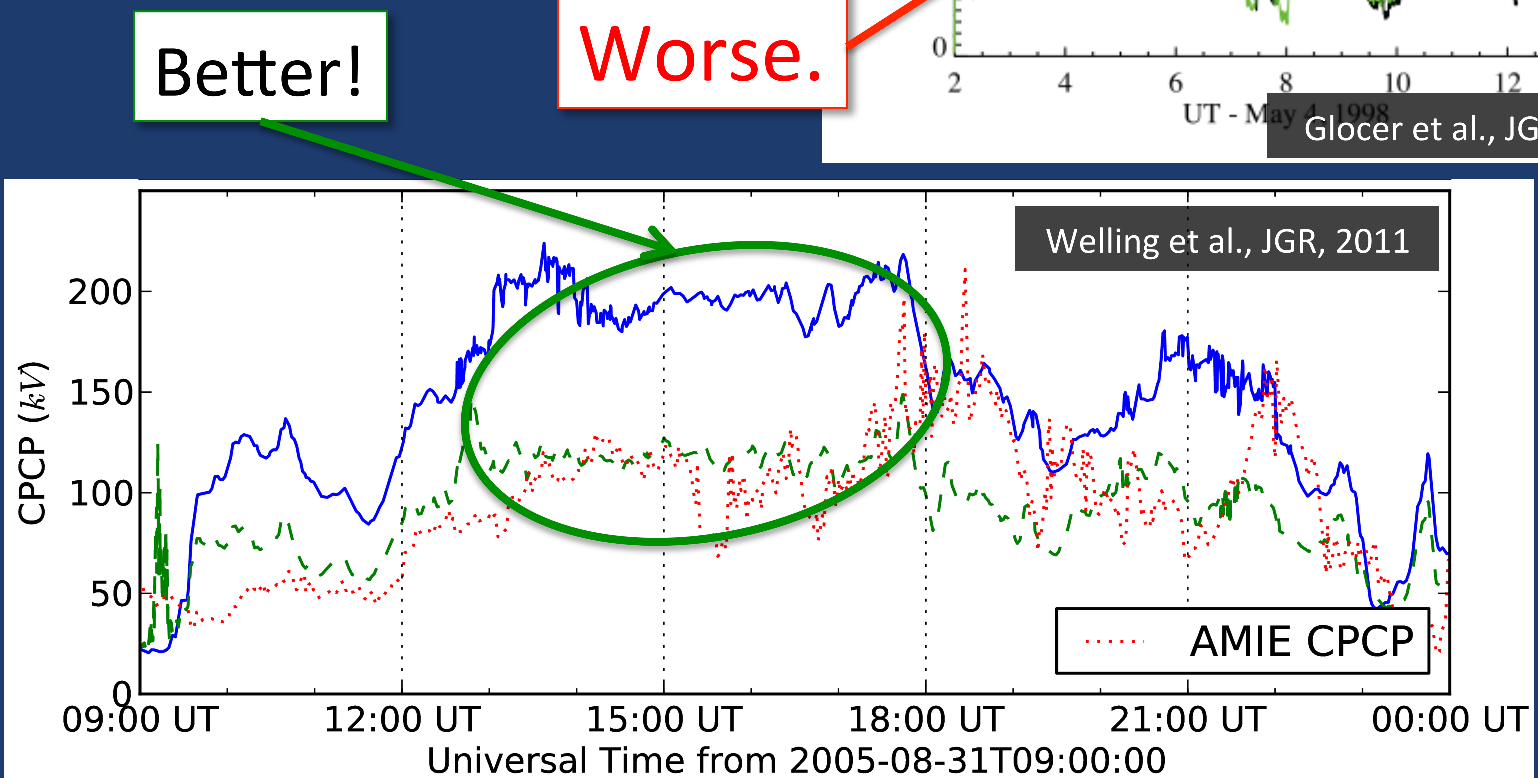
- Outflow calculation ➔ MHD state variables at inner boundary.
- Can be achieved via ad-hoc, empirical, or first-principles models.

Outflow and CPCP

Outflow & MHD studies *repeatedly* find that slow, dense outflow reduces CPCP.

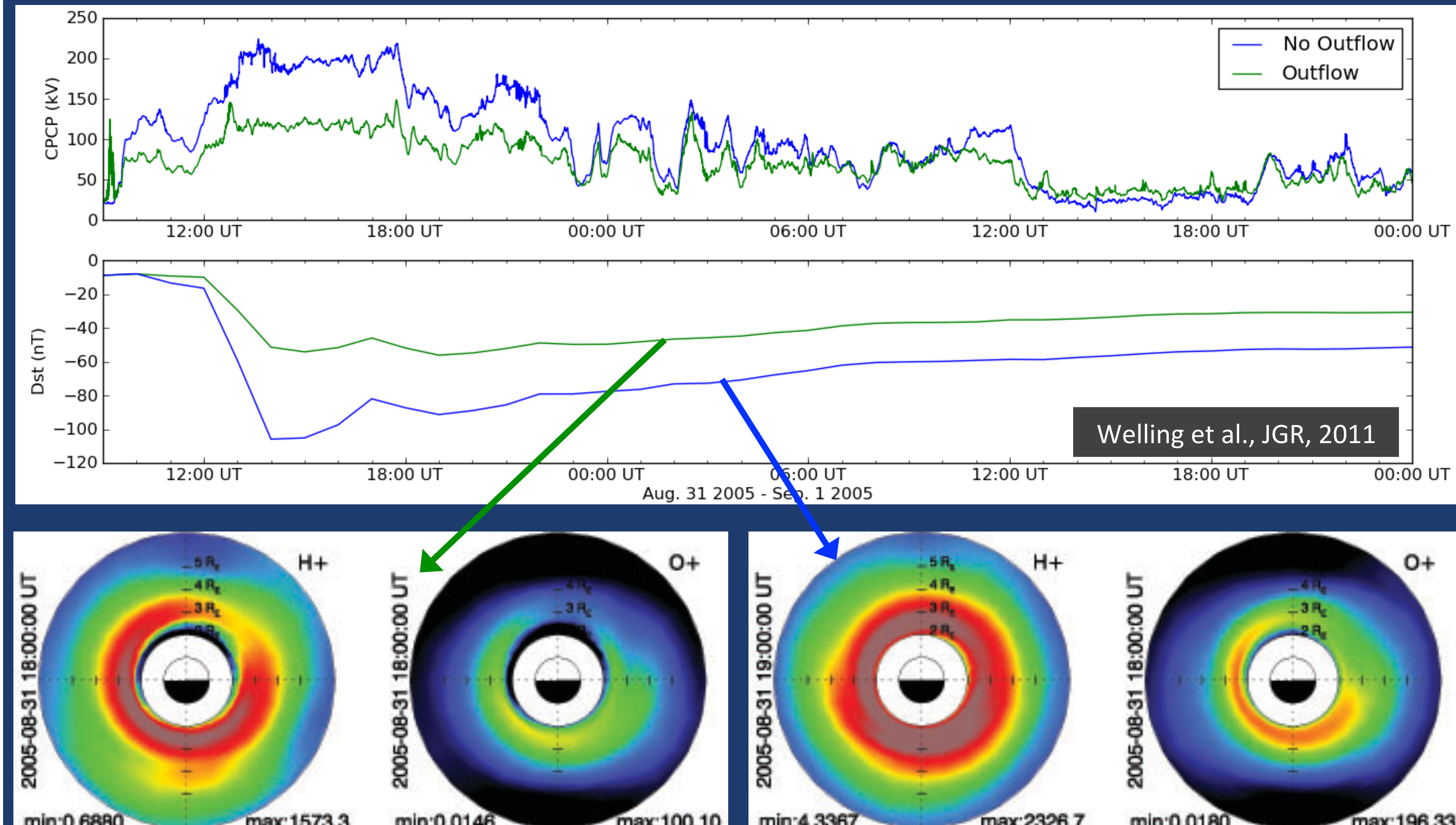


Glocer et al., JGR, 2009



Welling et al., JGR, 2011

Cascading Effects of CPCP Drop



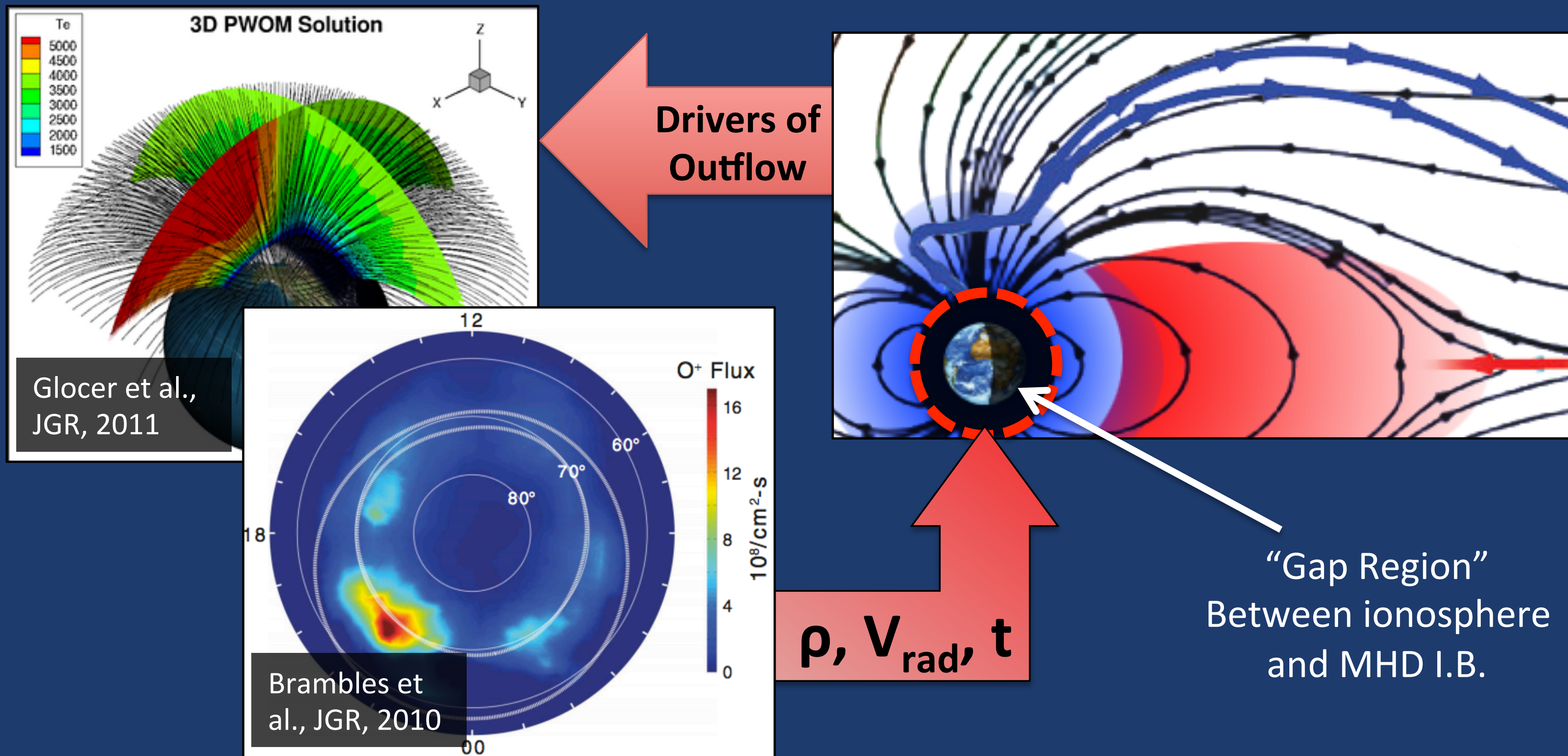
Many Potential Explanations

Publication	Explanation	Verdict
Winglee et al., 2002	Mass loading of field lines.	Perhaps.
Glocer et al., 2009	Increase in I.B. density altering FACs.	Unclear...
Brambles et al. 2010	Blunting of mag'sphere reduces width of upstream geoeffective length.	Occurs, but does not account for total CPCP reduction*.
Wiltberger et al., 2010	Increase in I.B. density altering ionosphere conductance.	Not applicable to BATS, possible for LFM.
Welling & Zaharia, over a beer.	Cold mass reduces Alfven speed, MHD reconnection.	No.

Each line represents one potential explanation from a single model/run-set.

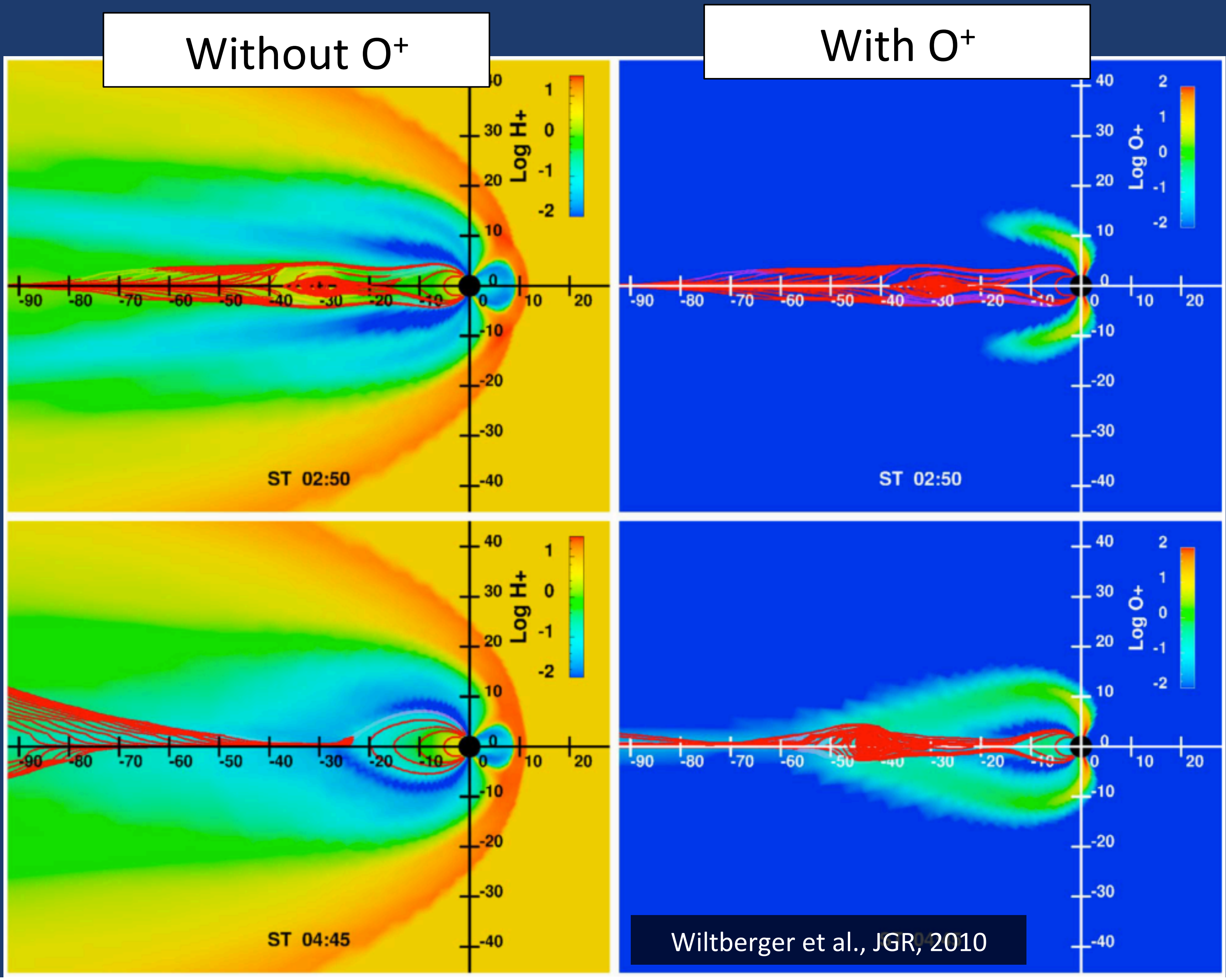
* See Welling & Zaharia , GRL, 2012

Advanced Outflow + MHD Formula



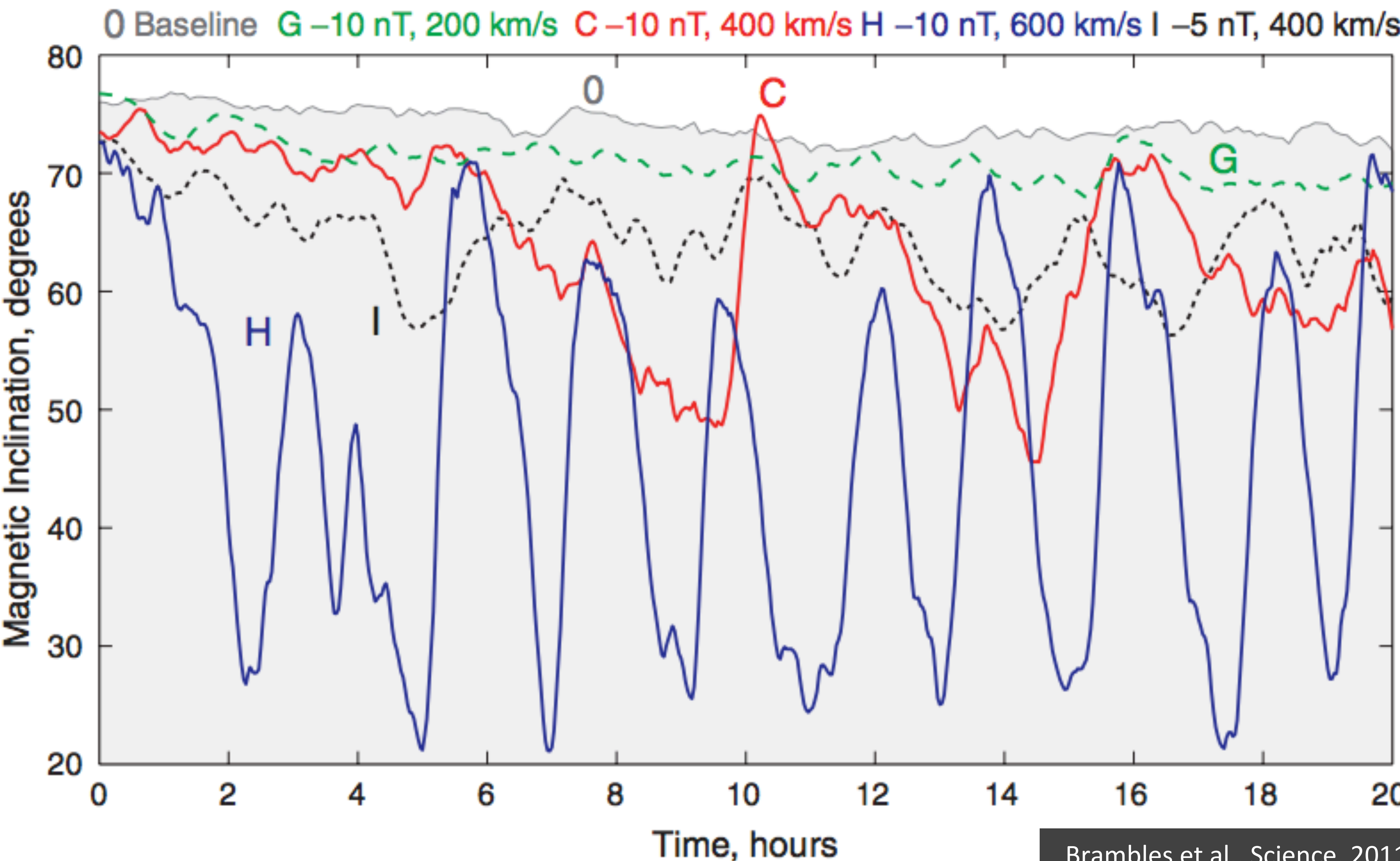
- More complex outflow models need input!
- If MHD provides inputs to outflow model, feedback loops develop.

Outflow and Substorms



Wiltberger et al., JGR, 2010

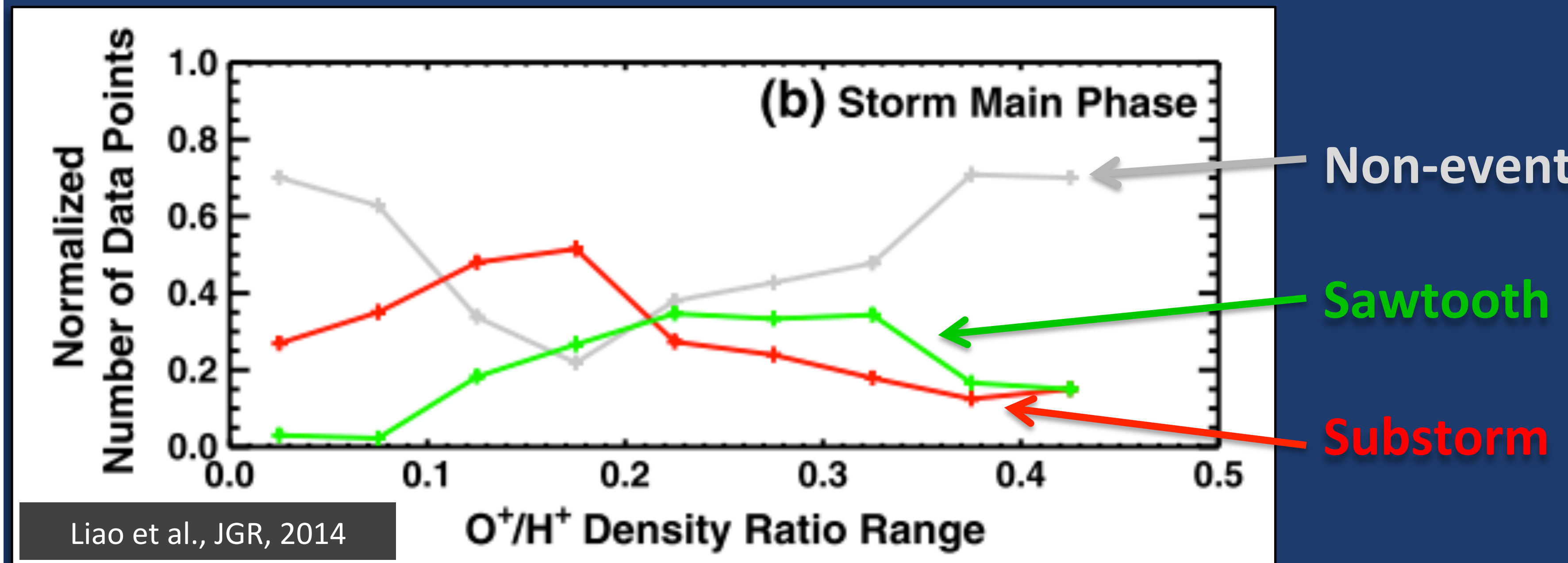
Outflow and Sawteeth



Brambles et al., Science, 2011

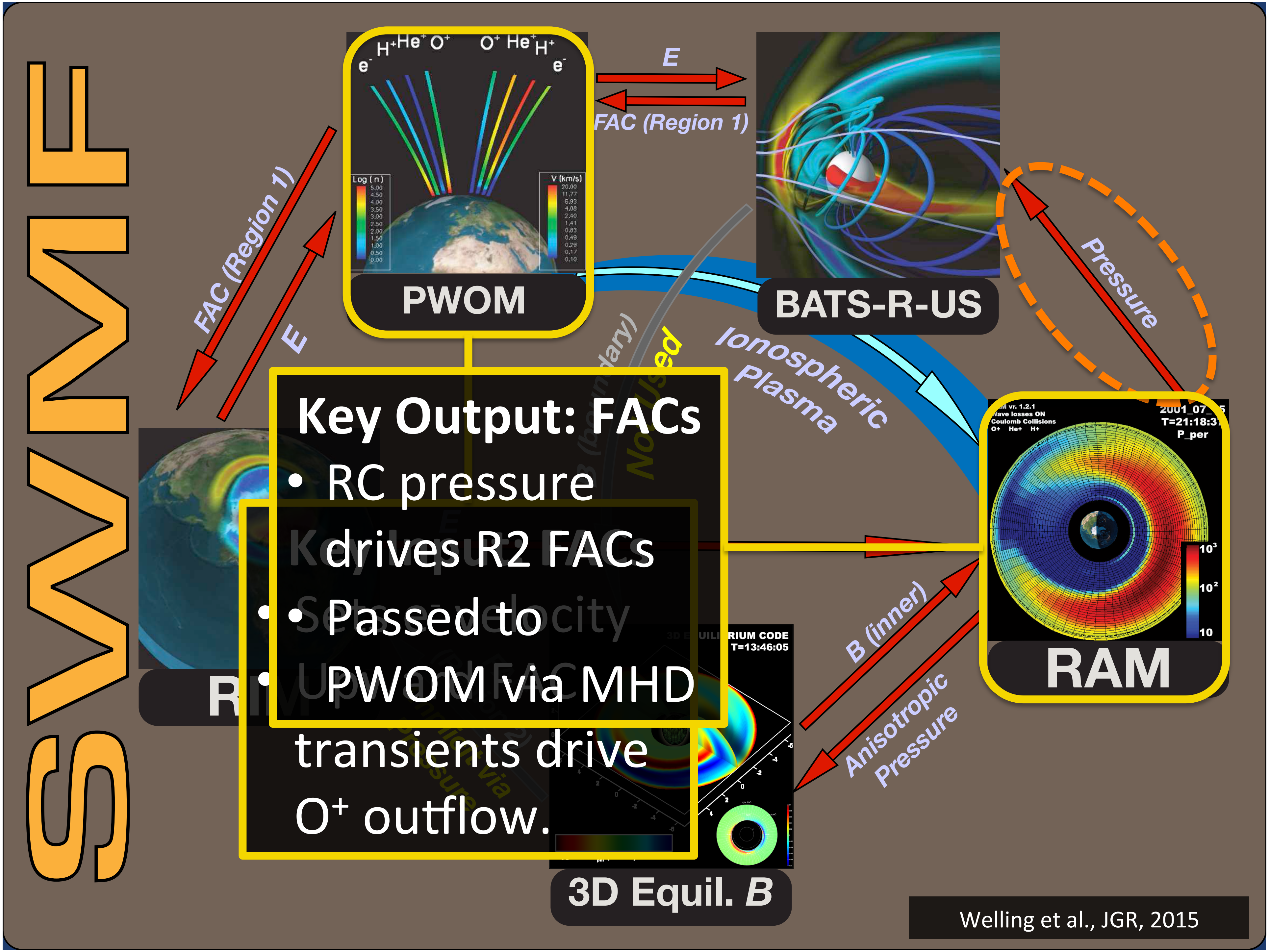
Testing Outflow Sawteeth

Liao et al [2014] investigated plasma sheet conditions during sawteeth & substorms using Cluster

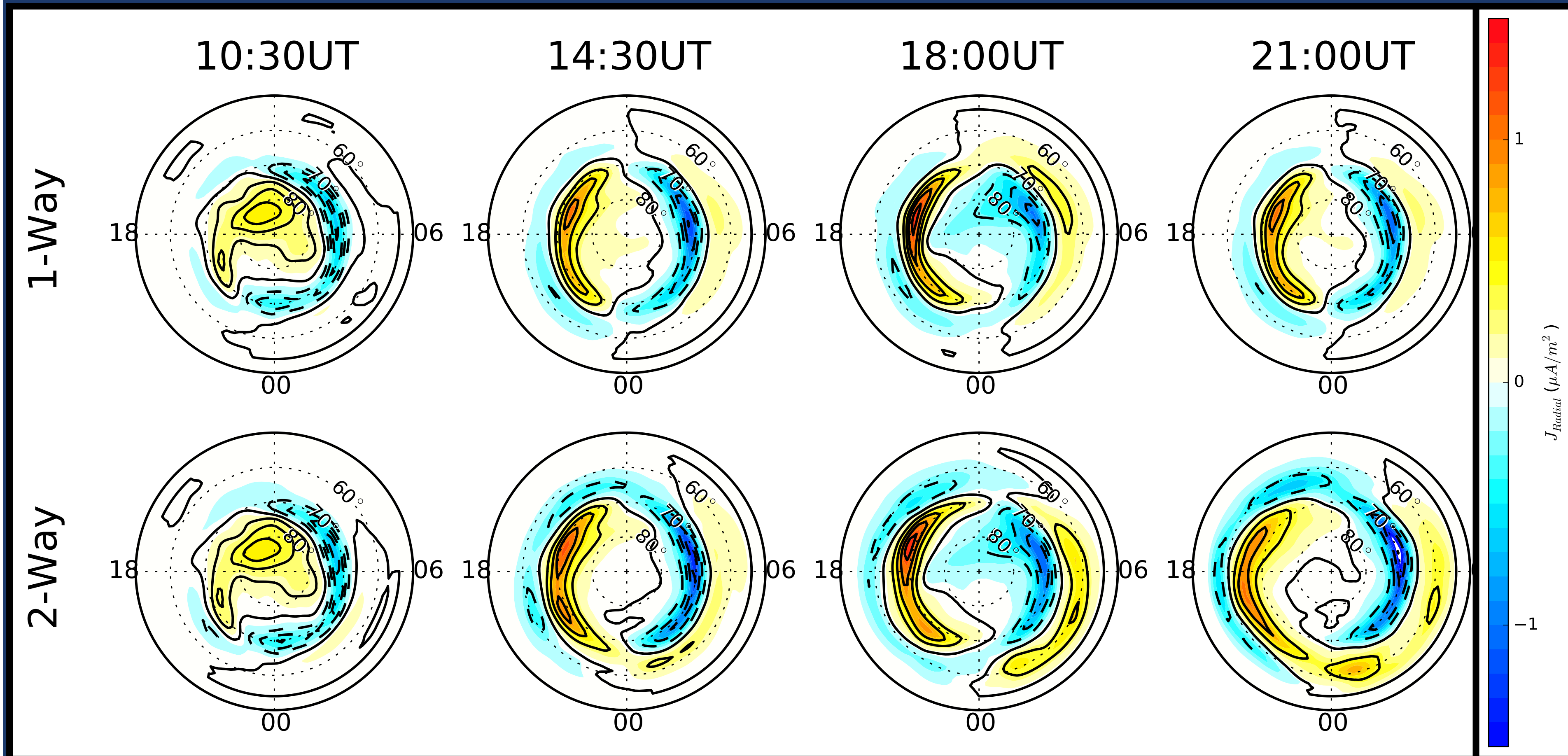


- Sawteeth event density increases with O^+/H^+ ratio
- Strongest O^+/H^+ ratios occur during non-events.

O+ mass loading appears necessary but not sufficient.


SWMF
PWOM
BATS-R-US
RAM
3D Equil. B
E
FAC (Region 1)
FAC (Region 1)
E
Pressure
Ionospheric Plasma
B (inner)
Anisotropic Pressure
Key Output: FACs
• RC pressure drives R2 FACs
• Passed to PWOM via MHD
transients drive
O+ outflow.
Welling et al., JGR, 2015

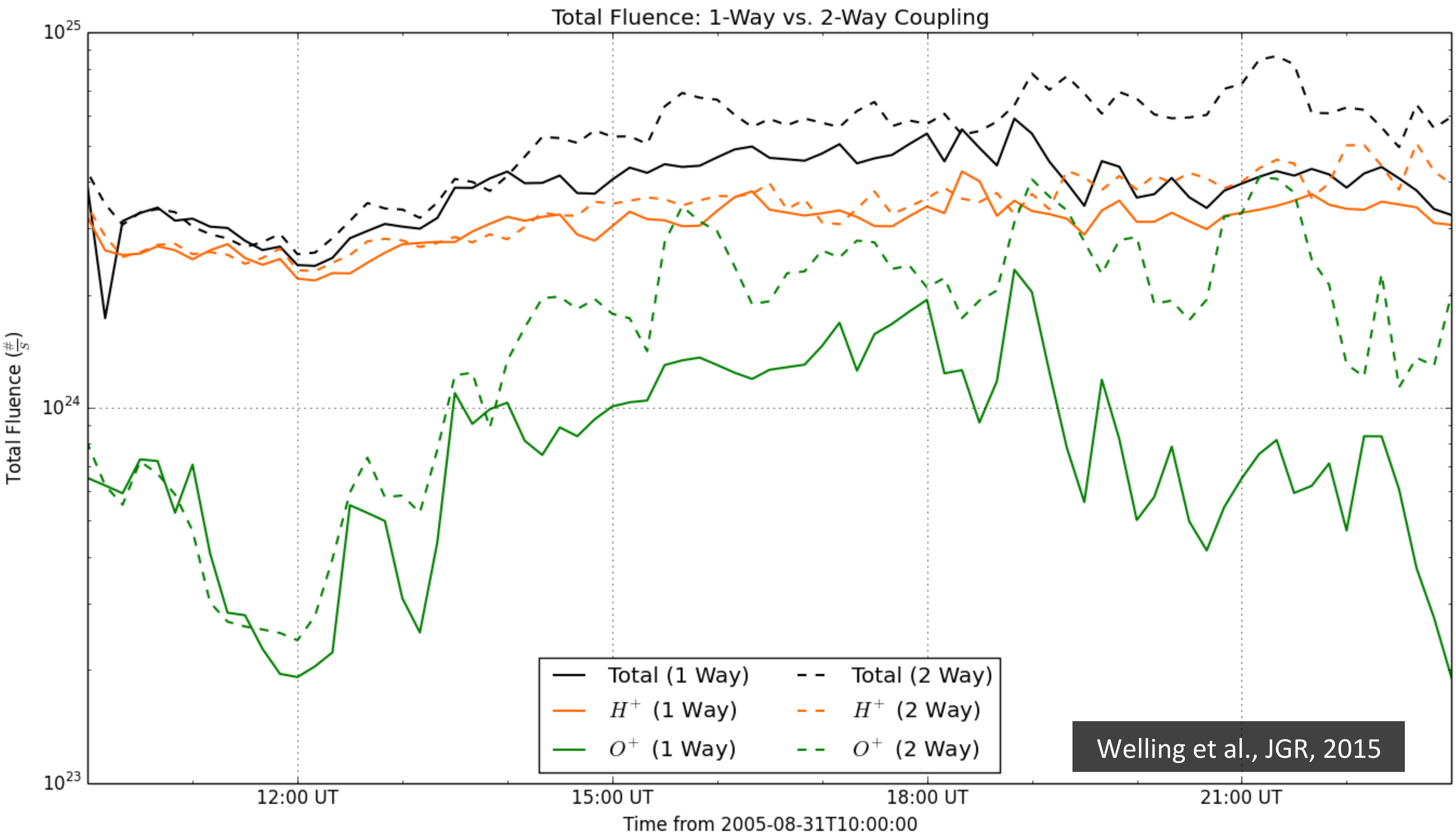
Region 2 FACs



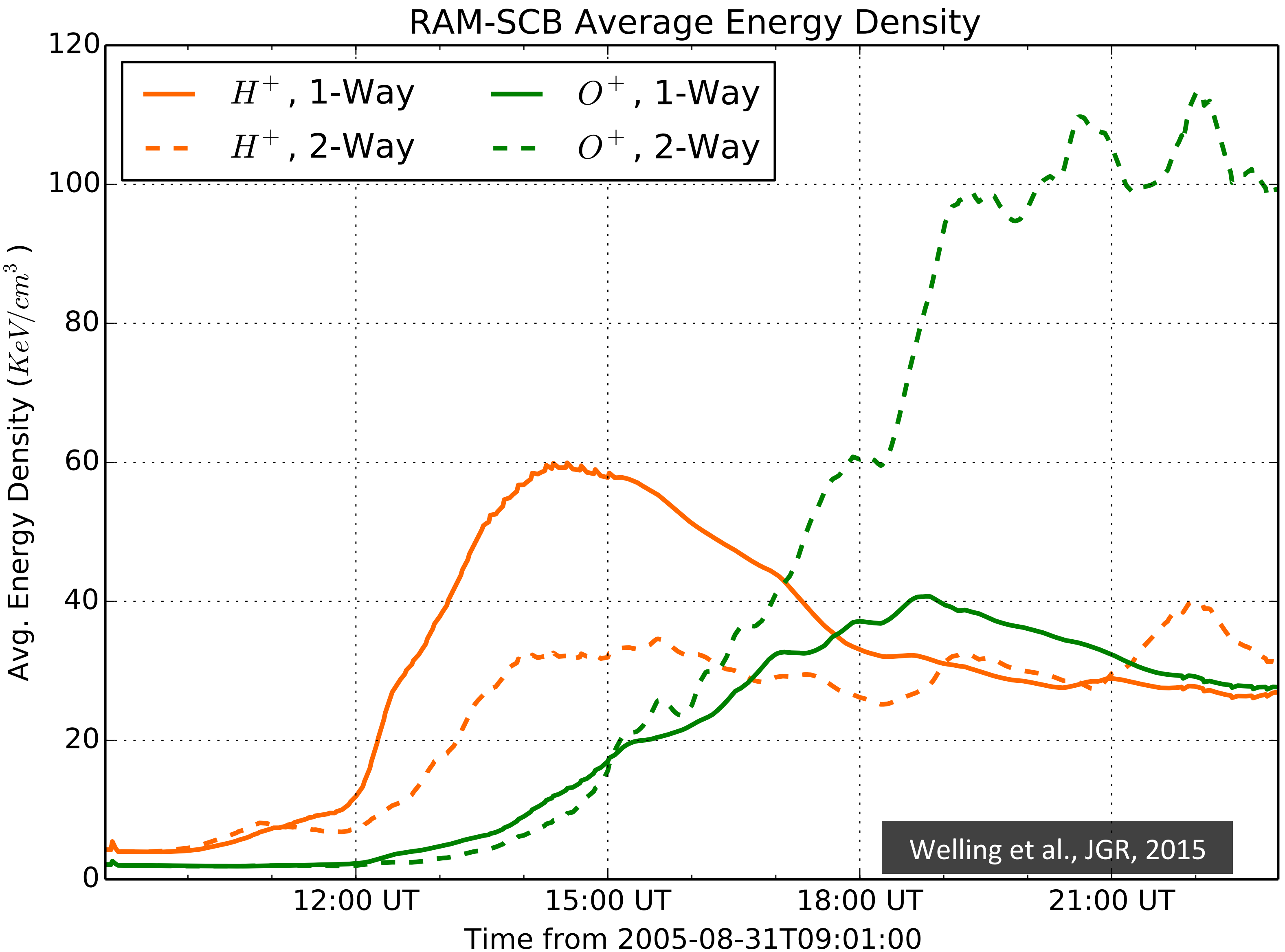
- 2-Way coupling yields stronger region 2 FACs.
- Better agreement with Weimer models.

Welling et al., JGR, 2015

Net Fluence


Total Fluence: 1-Way vs. 2-Way Coupling
10^{25}
10^{24}
10^{23}
Total Fluence ($\frac{\#}{s}$)
12:00 UT
15:00 UT
18:00 UT
21:00 UT
Time from 2005-08-31T10:00:00
Total (1 Way)
Total (2 Way)
H^+ (1 Way)
H^+ (2 Way)
O^+ (1 Way)
O^+ (2 Way)
Welling et al., JGR, 2015

…and back to the Ring Current.



Questions Abound!

MHD results show that outflow must not be thought of as a simple source of plasma, but part of the tightly-coupled, non-linear system.

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References

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