User Feedback (Magnetospheric Models)

Dayside Reconnection and the Solar-Wind Electric Field

Joe Borovsky[1], Joachim Birn[1], Michael Hesse[2], and Masha Kuznetova[2]

1 Los Alamos National Laboratory

2 CCMC NASA/Goddard

FINDING: Contrary to standard wisdom, the solar-wind electric field does not control the rate of dayside reconnection.*

***This finding was made possible by the CCMC.**

Specific Comments about the CCMC

At the time of this project, Los Alamos lacked a global-simulation capability.

Joachim and Joe from Los Alamos teamed up with CCMC to accomplish this science

CCMC is fast and flexible.

As opposed to collaborations with global modelers:

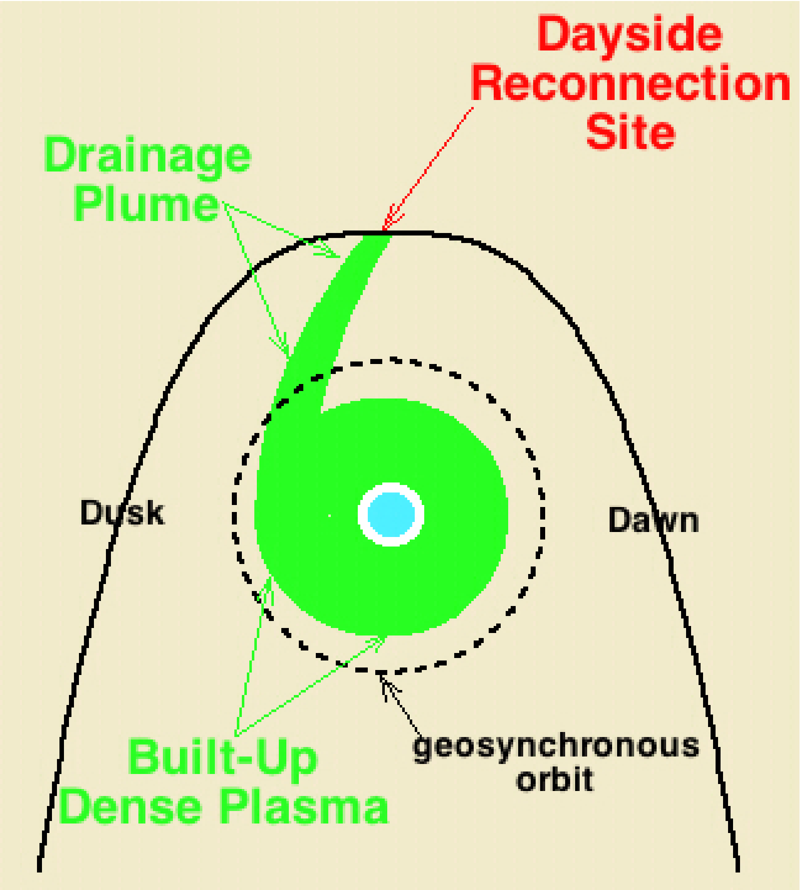
- Suspicious
- Busy
- In need of funding

Without hands-on access to the simulation codes, the computer resources, and the analysis graphics, this project could not have been done by Joe and Joachim.

Motivation for the Project

Develop an understanding and theoretical underpinning for the "plasmasphere effect" seen in satellite data.

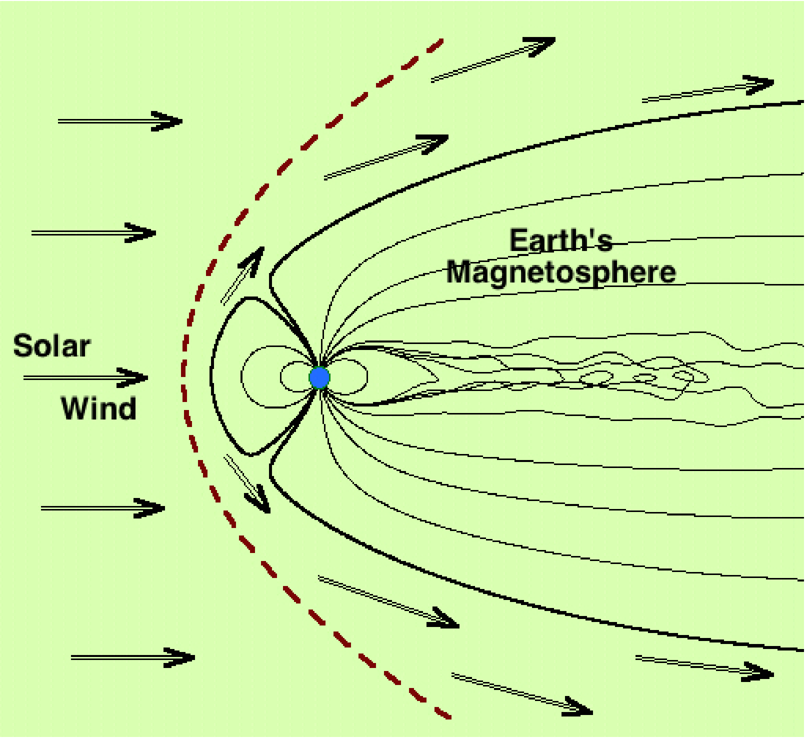
When solar-wind/magnetosphere coupling is examined, the coupling is weaker when plasmaspheric drainage plumes are seen.



The Importance of Dayside Reconnection

(1) Via dayside reconnection, some solar-wind plasma becomes magnetically connected to the magnetosphere-ionosphere system.

(2) Mostly via field-aligned currents, that magnetically connected solar-wind plasma transfers momentum and energy into the magnetosphere-ionosphere system.



(3) The more dayside reconnection, the more coupling.

(4) Whatever controls the dayside reconnection rate, largely controls solar-wind/magnetosphere coupling.

Dayside Reconnection and the Solar-Wind Electric Field

Conventional wisdom has it that the upstream solar-wind electric field $E_y = v_{sw}B_z$ controls the reconnection rate R at the dayside magnetopause.

Examples: solar-wind driver functions are based on vB_z:

vB_z	
vB_s	
$vB_\perp \sin^2(\theta/2)$	
$v^{4/3}B_\perp \sin^2(\theta/2)P^{1/6}$	**Vasyliunas**
$vB^2\sin^4(\theta/2)$	**Akasofu ε**
$v^{4/3}B_\perp^{2/3}\sin^{8/3}(\theta/2)$	**Newell**

In some analyses, a "reconnection efficiency" factor α is specifically added [e.g. *Goertz et al*., 1993], where $R = \alpha\, v_{sw}B_z$.

¿Is the conventional wisdom correct?

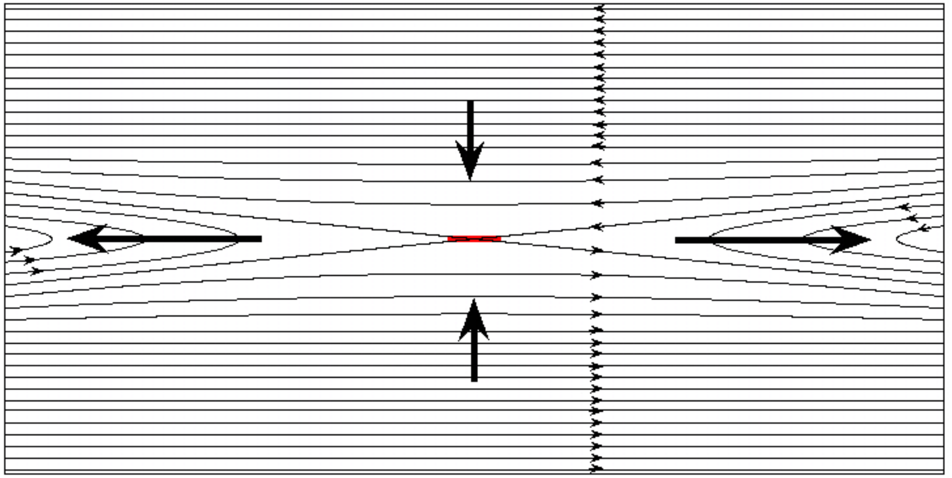
The GEM Reconnection Challenge

A controlled reconnection problem was examined with several computer-simulation techniques:

- **Resistive MHD simulations (Otto, Birn)**
- **Hall MHD simulations (Huba, Shay, Hesse, Birn)**
- **Hybrid simulations (Shay, Kuznetsova)**
- **Particle-in-cell simulations (Hesse, Pritchett)**

This challenge led to a fundamental understanding about what physical processes enable reconnection to proceed.

+The challenge also led to an understanding about how to modify MHD codes to get the correct reconnection rates.

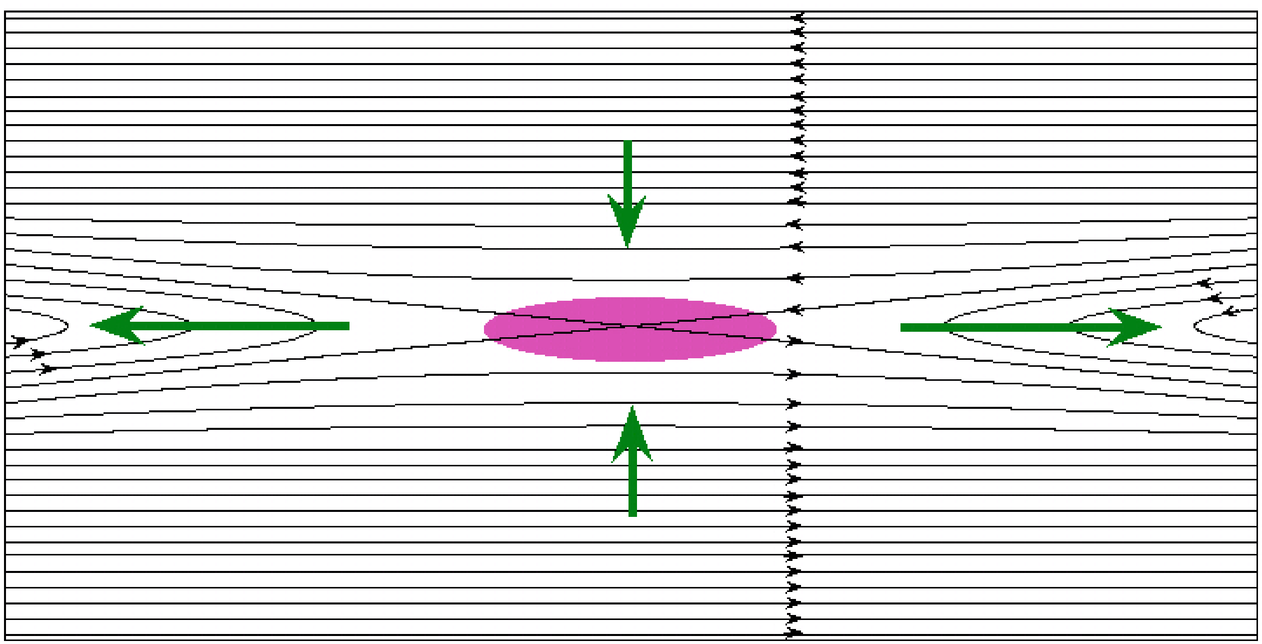


Resistive-Spot MHD

To get the correct reconnection rate in an MHD code you need a localized spot of resistivity at the reconnection site.

The resistivity in the spot must be strong enough (*to fully break the frozen-in condition as plasma flows through the spot*).

The spot must be several gridspacings large (*so the resistivity in the MHD equations controls the reconnection, not numerical errors*).



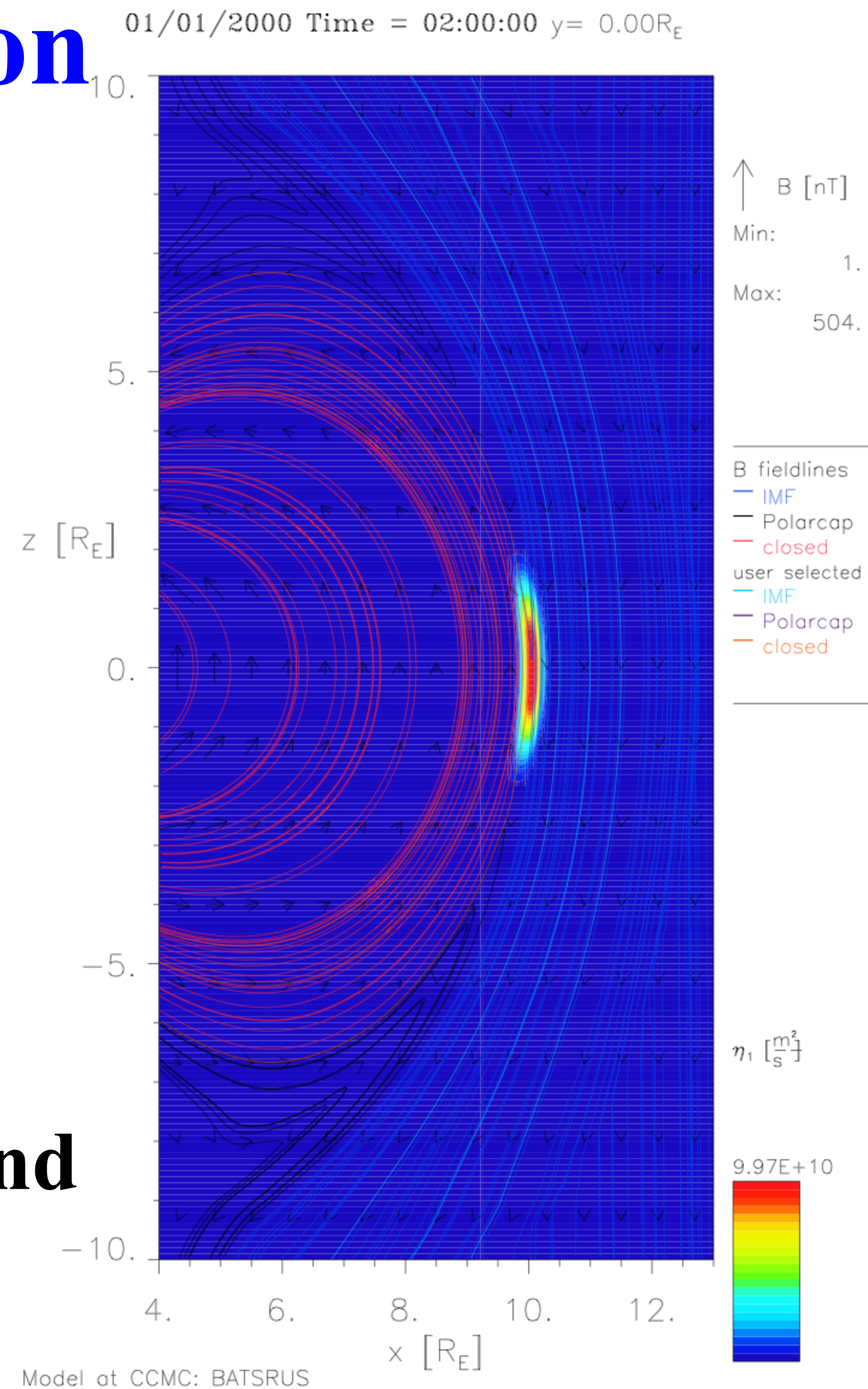
Dayside Reconnection Simulations

BATSRUS code at CCMC

Use high-resolution dayside grid (1/16 R_E).

Using resistive spot across dayside magetopause.

Run large range of solar-wind parameters.



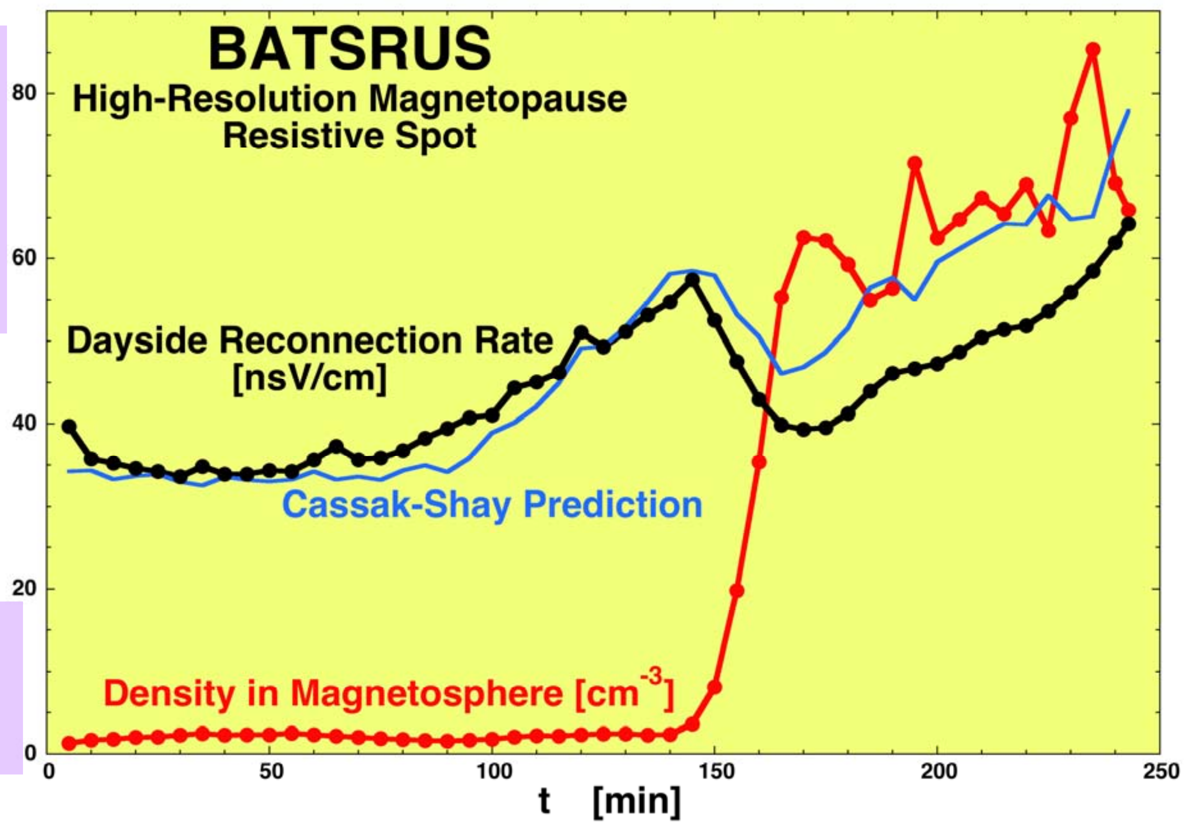
Testing the Global Simulations: The Local Reconnection Rate and the Cassak-Shay Formula

Cassak and Shay [2007] derived this two-plasma reconnection-rate formula:

$$R = 0.1\ \ 2\, B_1^{3/2} B_2^{3/2} \,/\, (B_1 4\pi\rho_2 + B_2 4\pi\rho_2)^{1/2} (B_1 + B_2)^{1/2} \quad \rightarrow \quad 0.1\, v_A B$$

The formula has been well tested in controlled reconnection simulations.

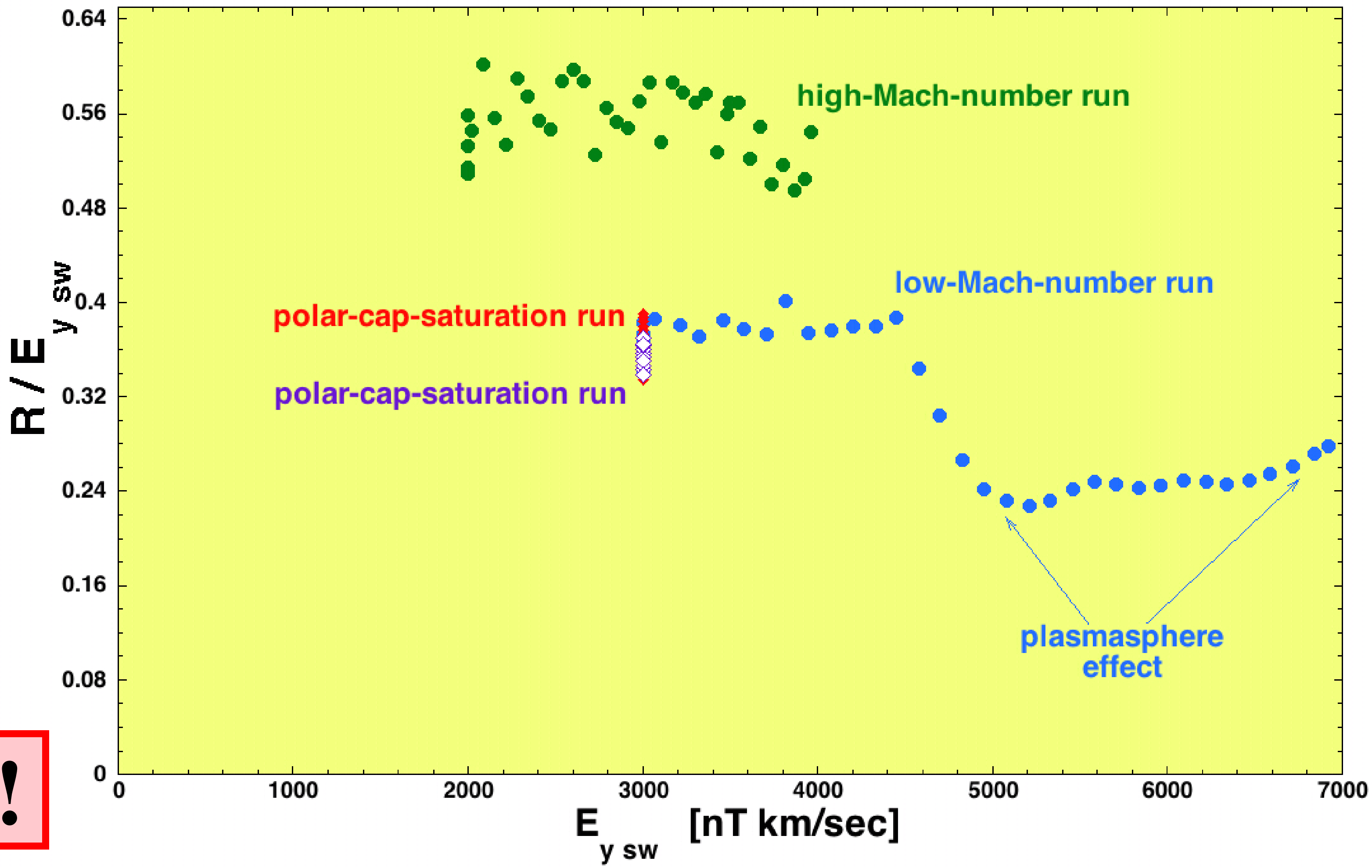
Testing the reconnection rate measured in the CCMC resistive-spot global-simulation against the Cassak-Shay formula.



The reconnection rate in the code is correct!

Testing Whether the Solar-Wind Electric Field Controls the Reconnection Rate

Q: Is $R \propto E_{y\,sw}$?



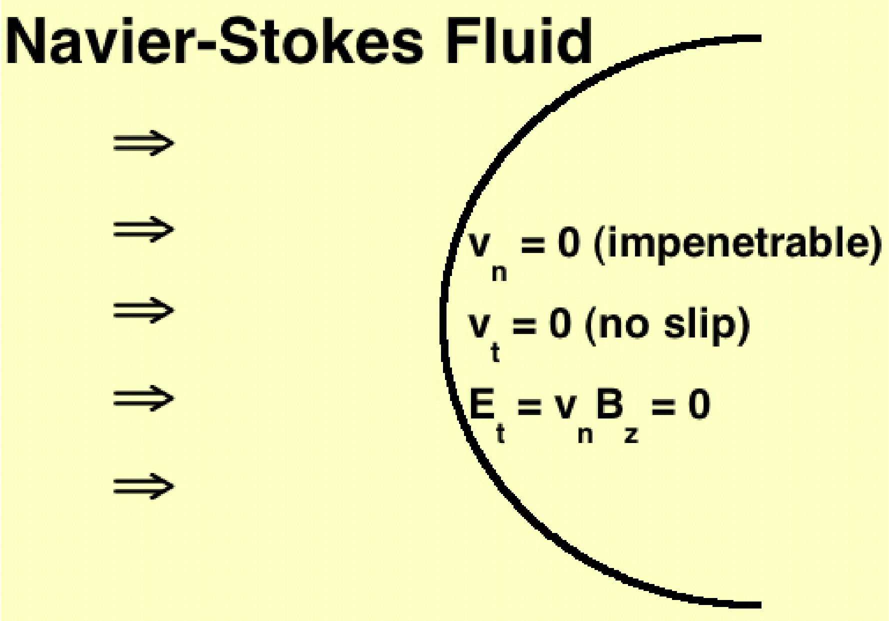
A: No!

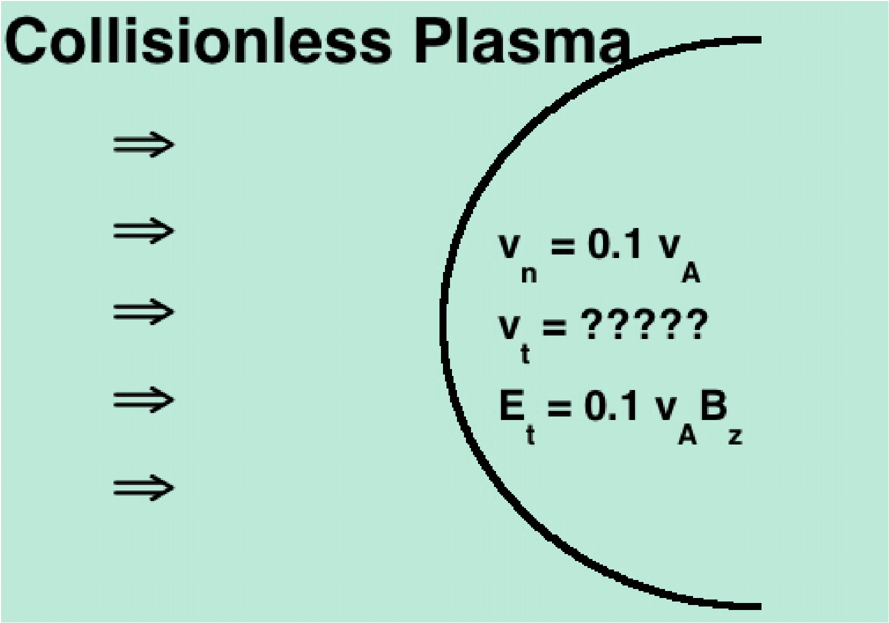
Why Doesn't Solar-Wind Electric Field Control the Reconnection Rate?

The electric field E_y is $v_x B_z$

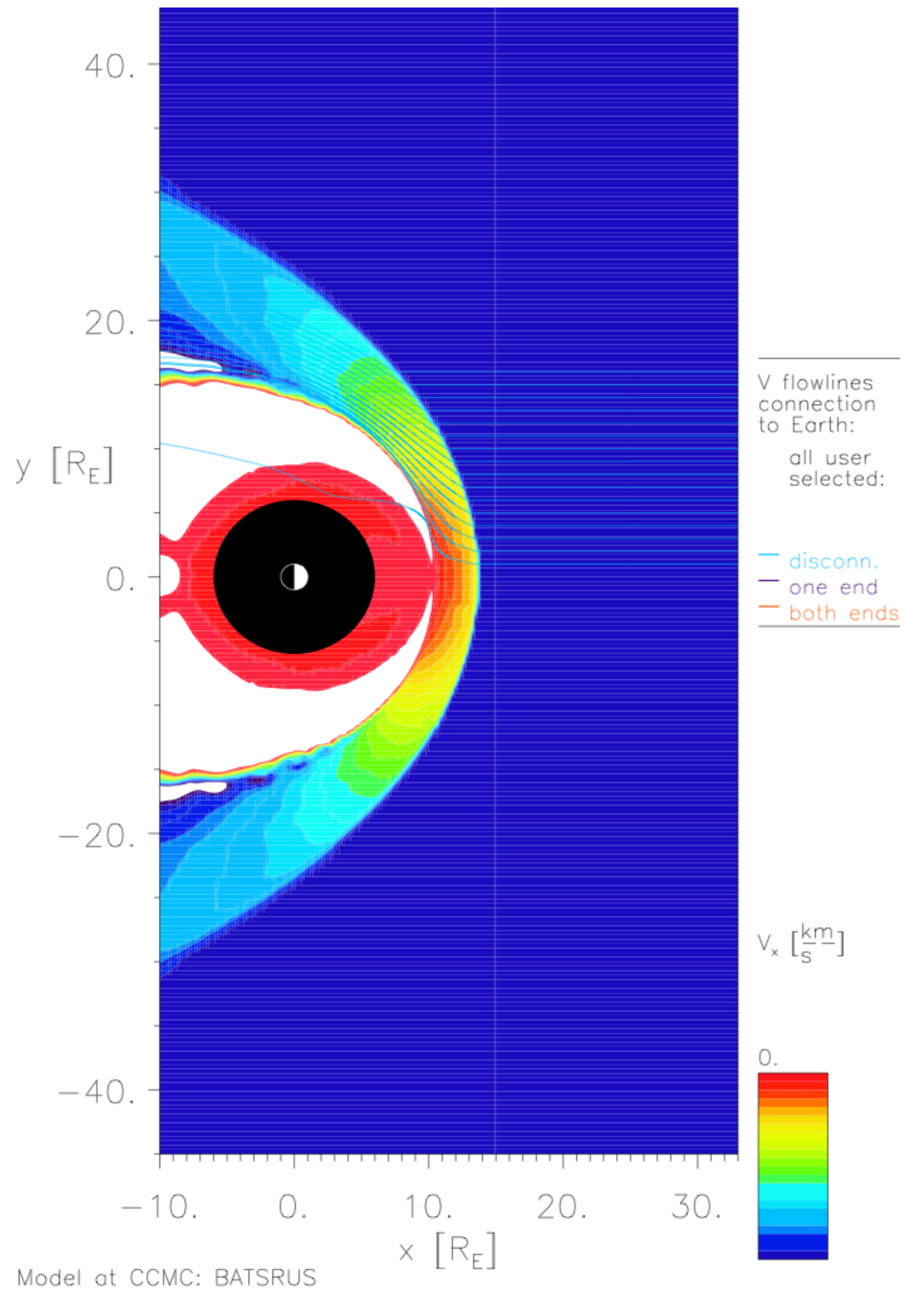
The flow diverges around the magnetosphere, so v and B at the magnetopause both depend of the flow pattern of the wind around the magnetosphere.

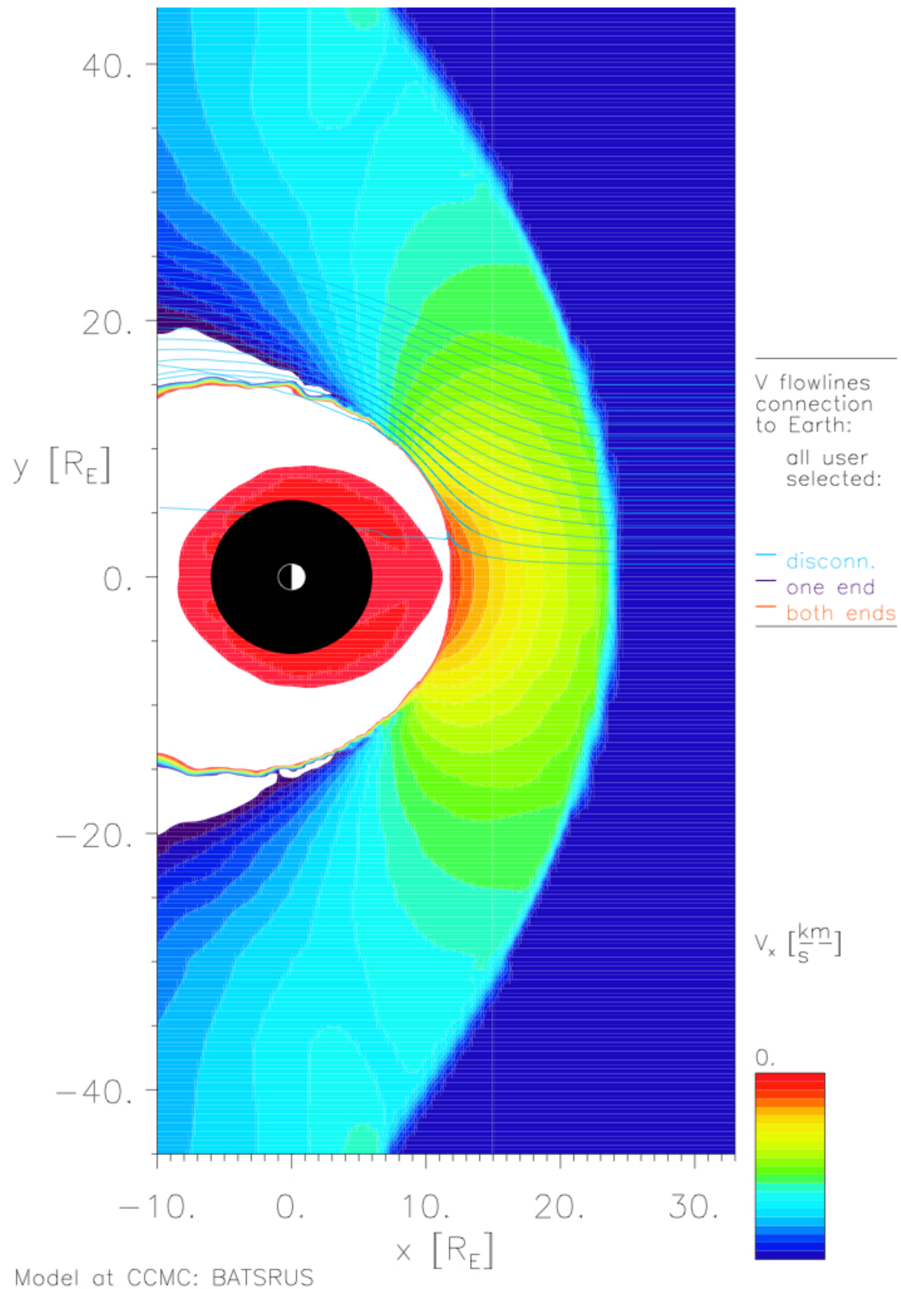
Finding the tangential electric field on the boundary is a flow problem with boundary conditions.





High Versus Low Mach Number Flow





So, What Controls the Dayside Reconnection Rate?

Using help from CCMC simulations, we derived a dayside-reconnection-control function from the Cassak-Shay formula.

$$R = 0.1\,\pi^{-1/2}\sin(\theta/2)\,B_m^{1/2}\,B_s^{3/2} / \{(B_m\rho_s + B_s\rho_m)^{1/2}(B_m + B_s)^{1/2}\}$$

$B_m = (8\pi\rho_{sw})^{1/2}\,v_{sw}$ (from pressure balance)

$B_s = (8\pi\rho_{sw})^{1/2}\,v_{sw}\,(1 + \beta_s)^{-1/2}$ (from pressure balance)

$\rho_s = C\,\rho_{sw}$ (from Rankine-Hugoniot shock jump conditions)

$$R = 0.1\,\pi^{-1/2}\rho_{sw}v_{sw}^2\sin(\theta/2) / \{[C\rho_{sw}+(1+\beta_s)^{-1/2}\rho_m][(1+\beta_s)^{3/2}+(1+\beta_s)]\}^{1/2}$$

$\beta_s = 0.032\,M_A^{1.92}$ (beta of the magnetosheath: CCMC parameterization)

$C = [2.44\text{x}10^{-4} + (1 + 1.63\log_e(M_A))^{-6}]^{-1/6}$ (compression ratio bow shock)

$M_A = v_{sw}(4\pi\rho_{sw})^{1/2}/B_{sw}$ (Alfven Mach number of solar wind)

Note the strong Mach-number dependence in the formula.
Note that vB does not appear anywhere in the formula.

Testing the "Reconnection Control Function"

Correlation coefficients for the 1963-2003 OMNI2 data set (158,000 hours of data).

	AE_1	AU_1	AL_1	PCI_{thule}	MBI_1	Kp
Akasofu ε = $vB^2 \sin^4(\theta/2)$	0.52	0.39	0.52	0.52	0.49	0.47
Electric Field = $-E_y$	0.68	0.51	0.67	0.65	0.61	0.52
$vB_\perp \sin^2(\theta/2)$	0.69	0.56	0.67	0.70	0.66	0.60
Newell Function = $v^{4/3} B_\perp^{2/3} \sin^{8/3}(\theta/2)$	0.76	0.60	0.74	0.75	0.72	0.63
Recon. Control Function	0.75	0.62	0.72	0.73	0.74	0.68

Impact of This

We have learned what controls the dayside reconnection rate: ram pressure, Mach-number effects.

- **This allows us to make better predictions.**

- **This allows us to understand "the plasmasphere effect" wherein the magnetosphere exerts some control of solar-wind/magnetosphere coupling.**

- **This provides a methodology to develop more-advanced physical pictures of solar-wind/magnetosphere coupling.**

What Does This Tell Us?

A) We have learned what controls the reconnection rate.

B) It isn't the solar-wind electric field!

C) But, geomagnetic activity still correlates with E_y.

This tells us that solar-wind/magnetosphere coupling is a two-step process:

1) Reconnection connects the plasmas.

2) The plasmas couple *after* they are connected.

We suspect that the solar-wind electric field plays a role in step (2).

We also have CCMC evidence that polar-cap saturation comes in during step (2).

The Future of this Collaboration

1) Reconnection

- Re-derive reconnection-control-formula
- Base new derivation on the "Birn formula"
- Use CCMC archives to parameterize fluid flow away from nose

2) Post-Reconnection Coupling

- Explore coupling physics with CCMC archives and new runs
- Derive a coupling-physics driver function

Produce "dual" solar-wind driver function:

Reconnection Rate + Strength of Coupling

General Comments about the CCMC

1) Model selection is excellent

2) Turnaround is fast

3) Ease of web-based graphics is surprising

4) Help with the models has been great
- Help with understanding the numerics
- Interfacing with the code authors

5) Response to special requests has been great
- Supplementary graphic capabilities added by Lutz
- Special runs set up by Masha

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