



UNIVERSITY OF HELSINKI

Three-dimensional Hybrid-Vlasov Simulations of Geomagnetic Storms

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Vlasiator Simulations

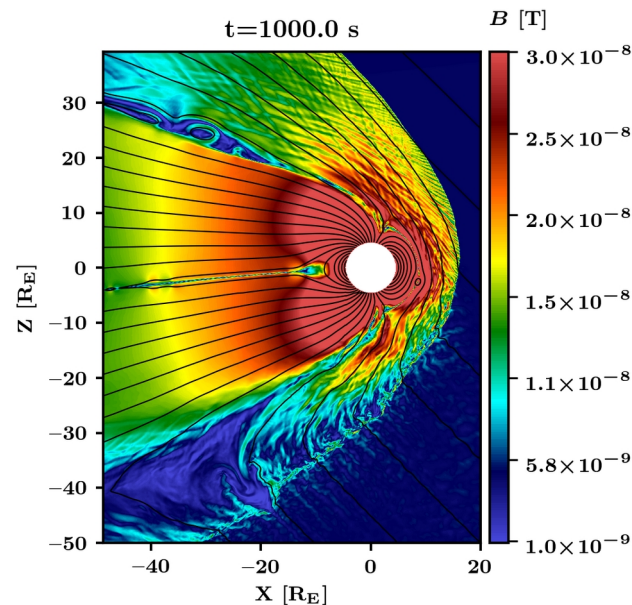
- hybrid-Vlasov (kinetic p+, fluid e-)
- 3D box (side length $\sim 100 R_E$)
- Inner boundary: $r=4 R_E$
- Adaptive mesh

For details:

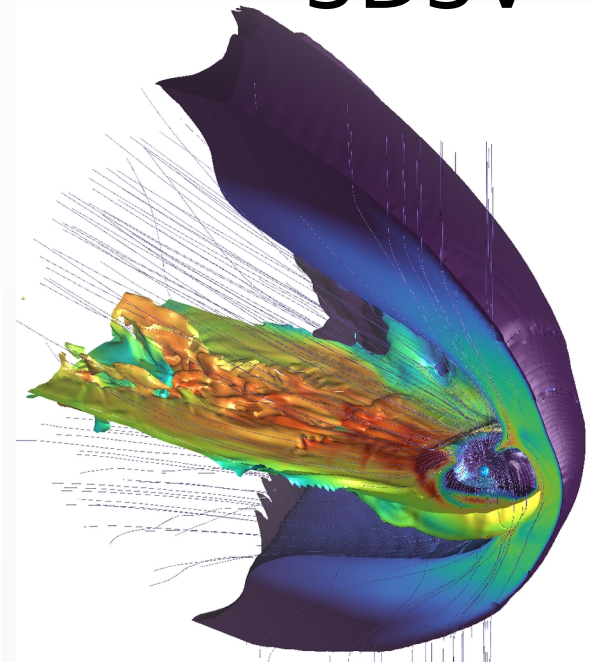
M. Palmroth et al., 2018

“Vlasov methods in space physics and astrophysics”

2D3V



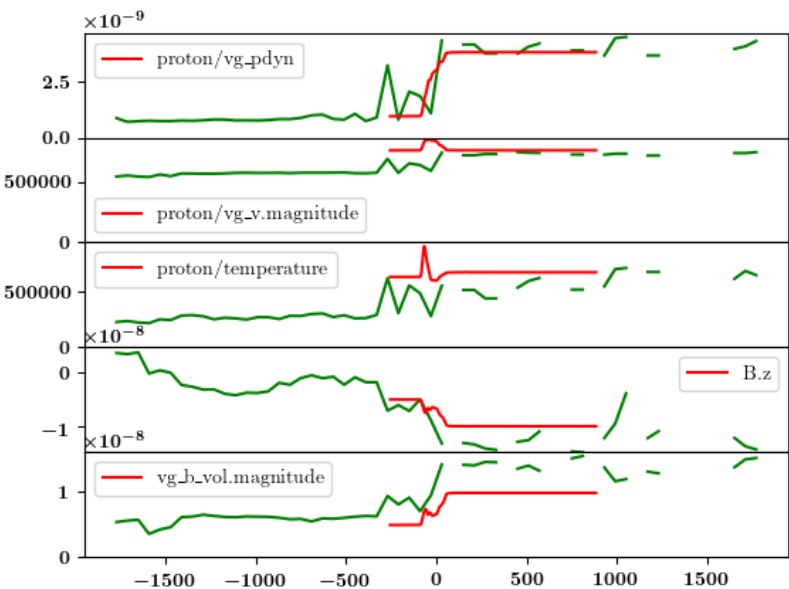
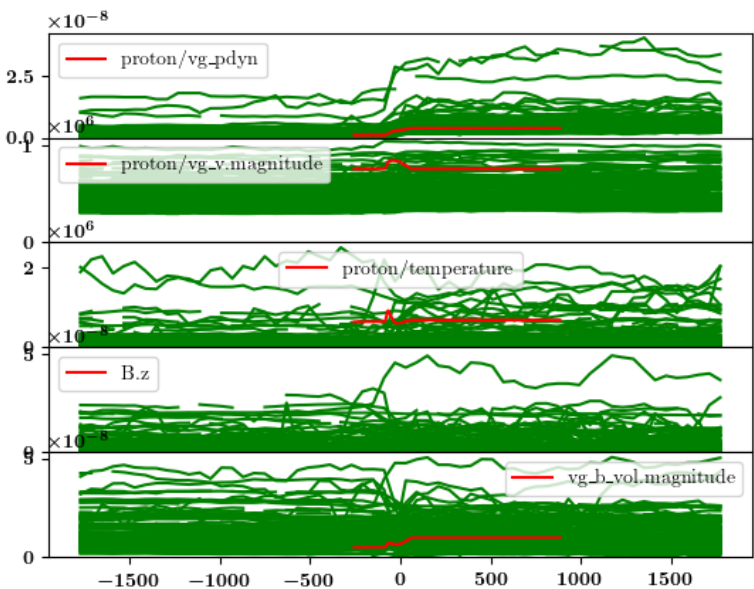
3D3V



Pressure Pulse (normal driving)

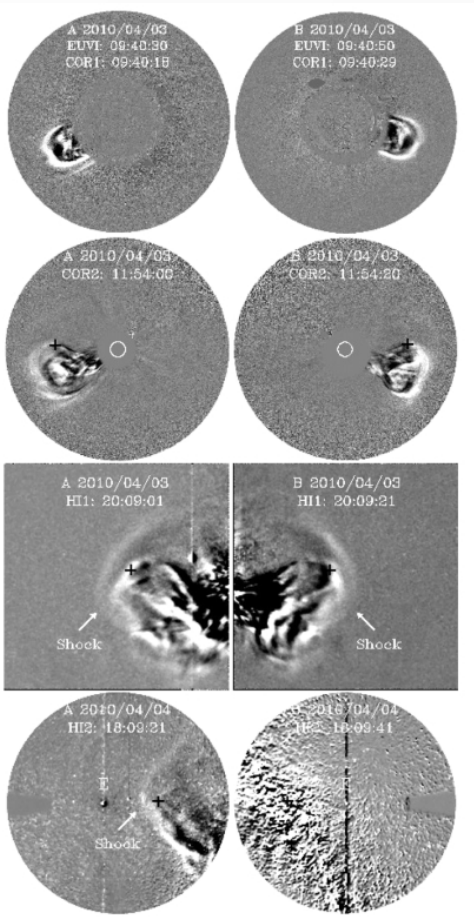
Driving	B [nT]	V _{sw} [km/s]	n [cm ⁻³]
Initial	[0,0,-5]	750	1
Pulse	[0,0,-10]	750	4

Simulation resembles a real CME! 5.4.2010 “Galaxy Anomaly” event



Pressure pulses, *OMNI* data
Pearson correlation >0.95

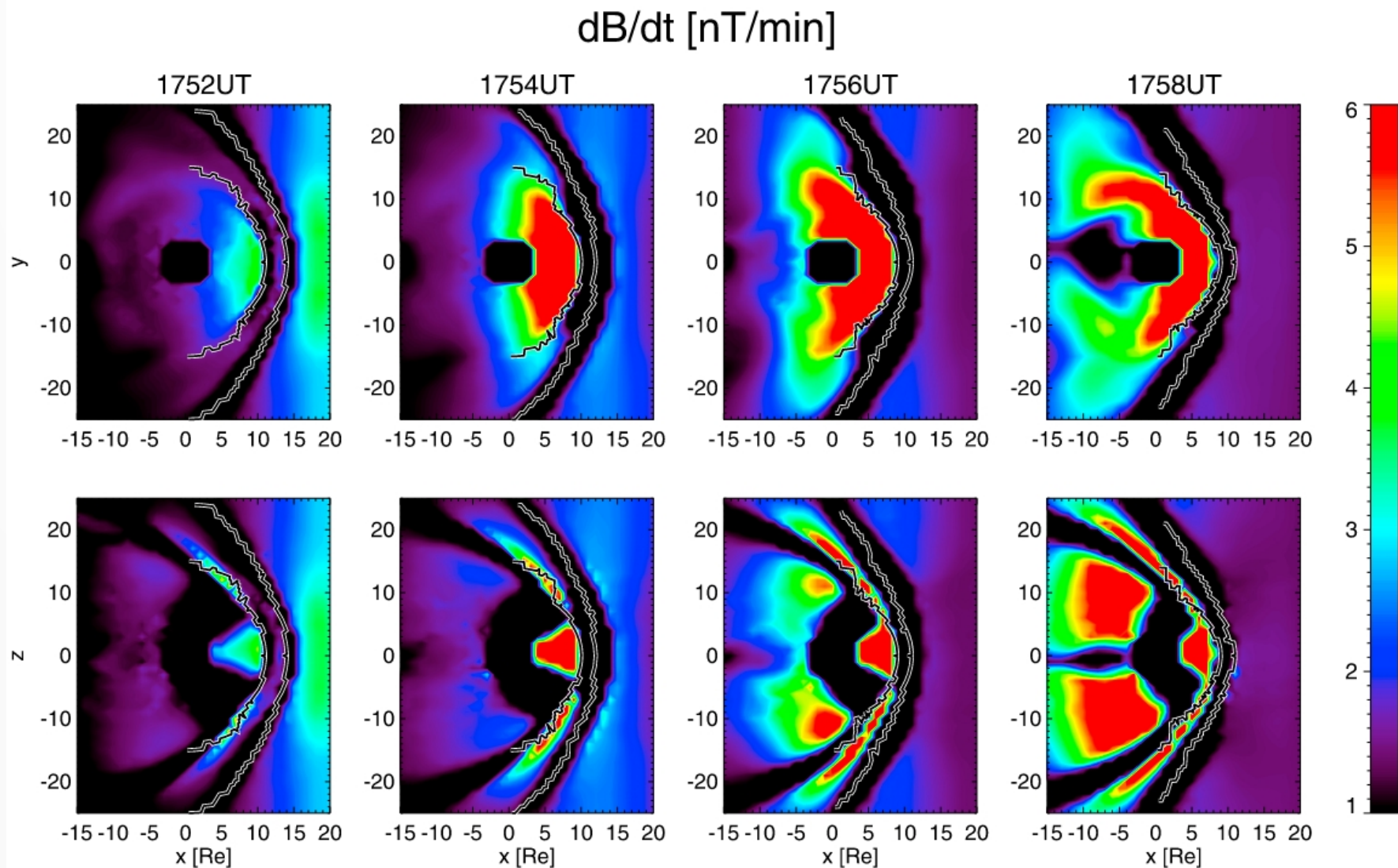
Min. chi-squared



Liu et al. (2011)

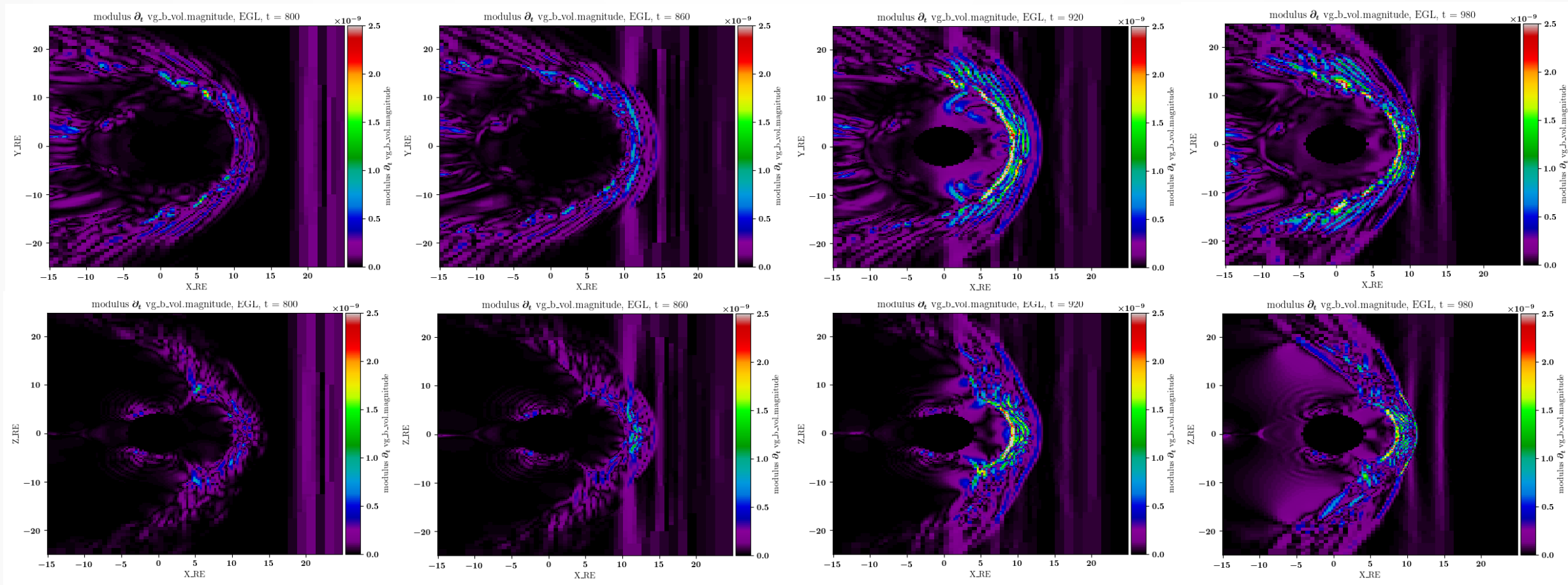
Disturbance Propagation

MHD: GUMICS 4 (Andreeova et al., 2011)



Disturbance Propagation

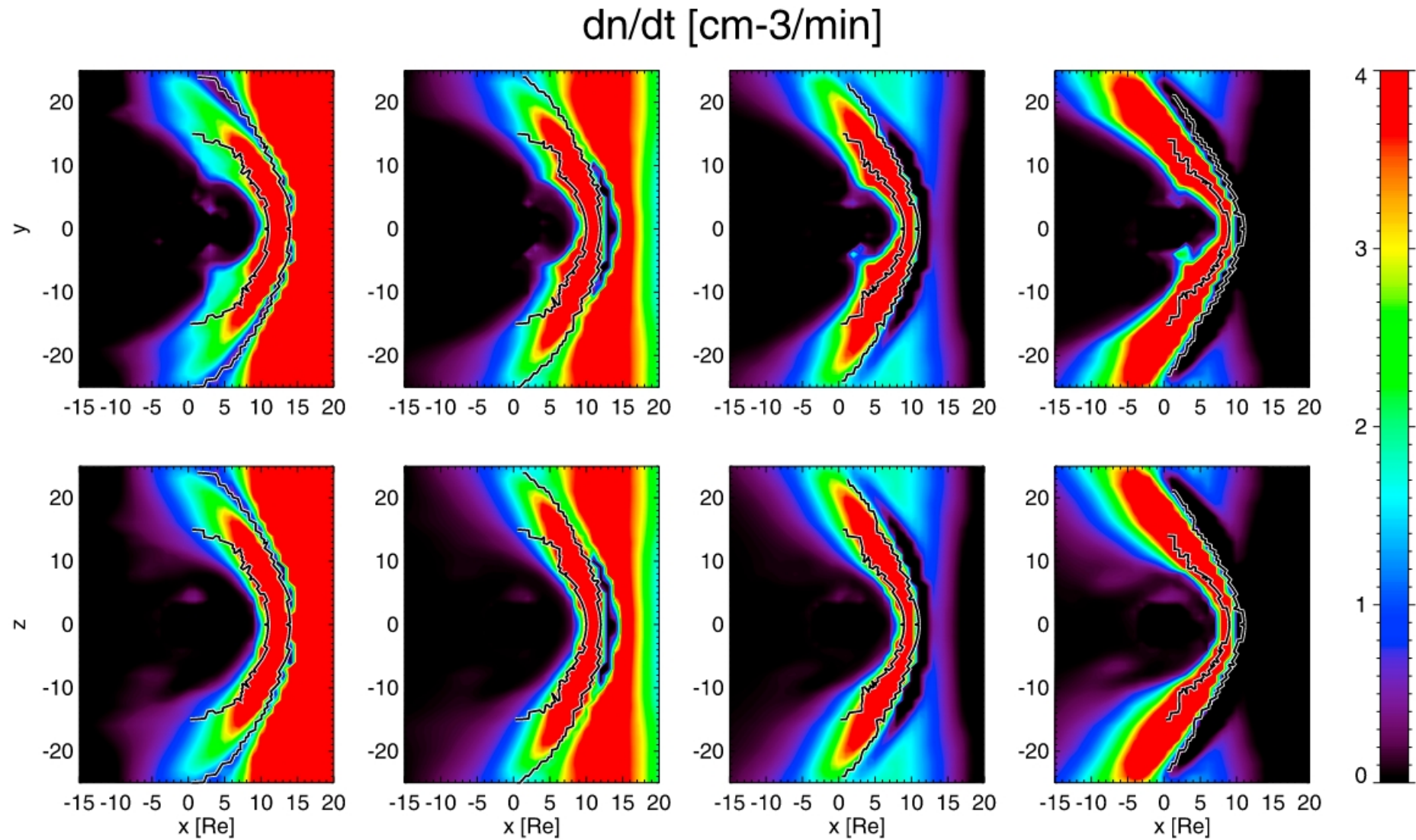
Hybrid-Vlasov: Vlasiator



- Disturbance propagates along magnetopause towards the flanks
- “Sudden Impulse” observed behind magnetopause: large fluctuations in dayside B-field

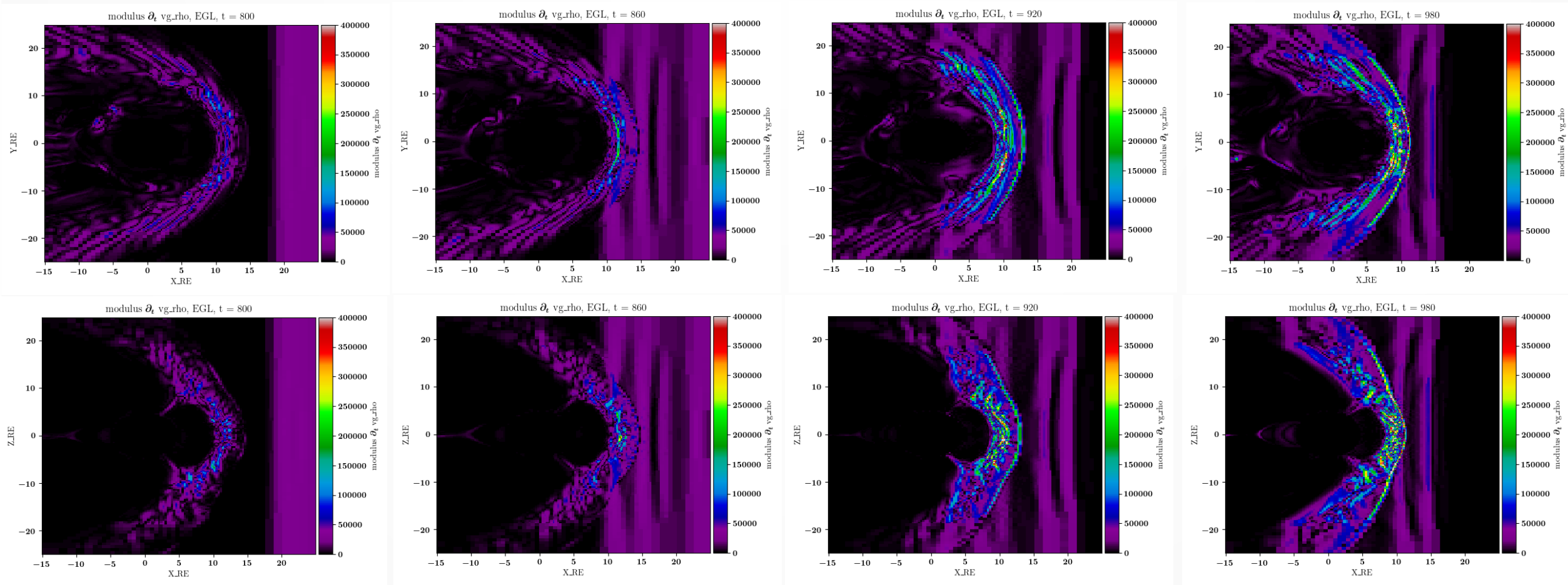
Disturbance Propagation

MHD: GUMICS 4 (Andreeova et al., 2011)



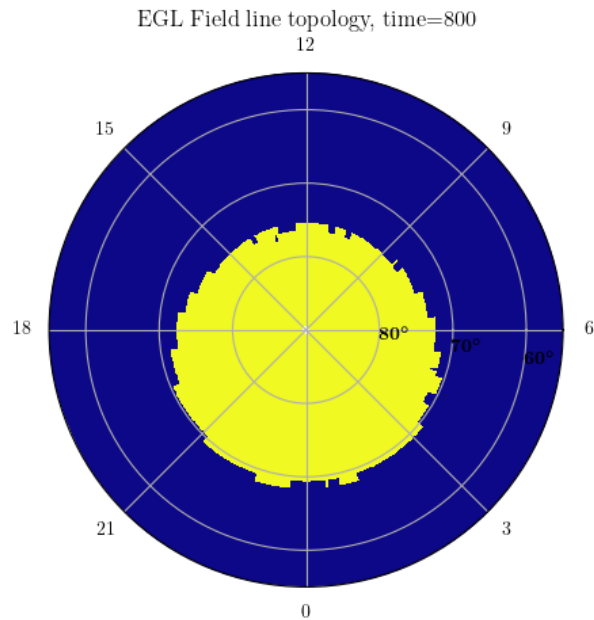
Disturbance Propagation

Hybrid-Vlasov: Vlasiator

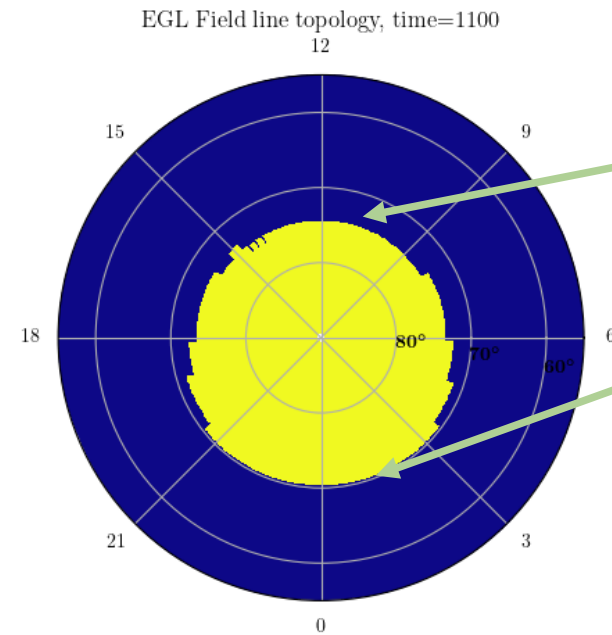


- Vlasov simulations show finer structures at small scales (e.g. mirror modes)

Before Pulse



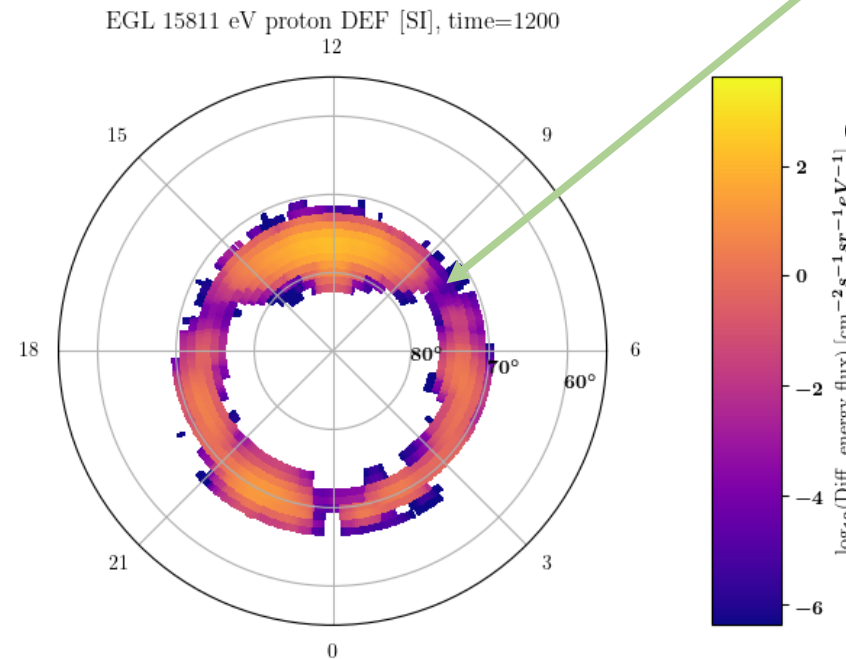
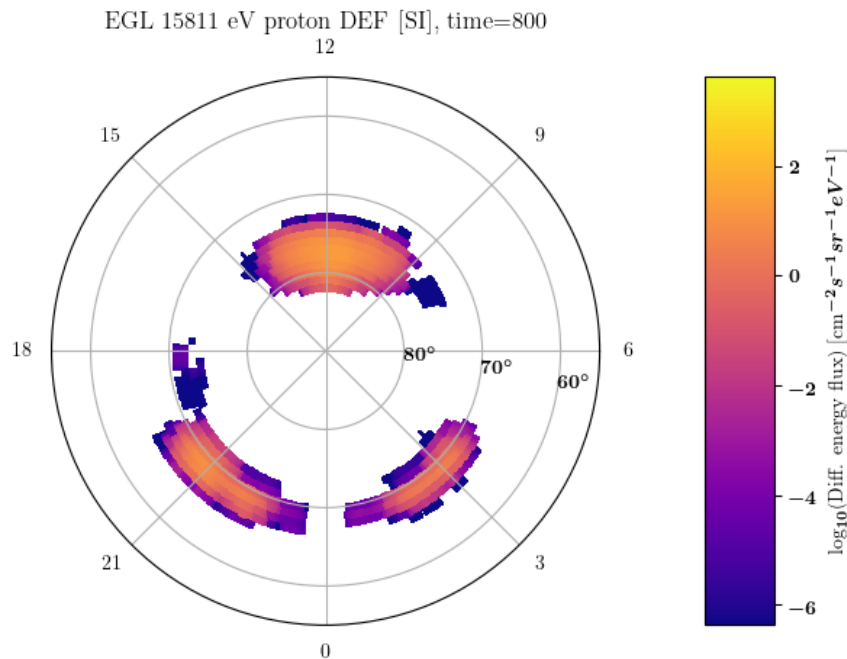
After Pulse



Dayside aurora
expands

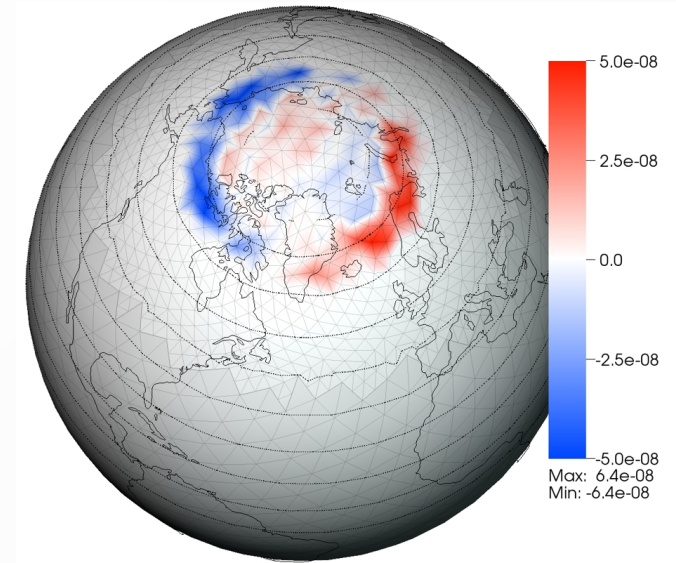
Nightside *contracts*

Increased flux of
precipitating
energetic (15 keV)
protons in
dawn/dusk regions

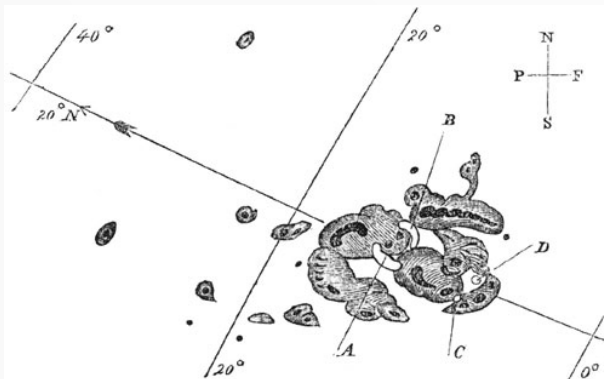


Next Steps

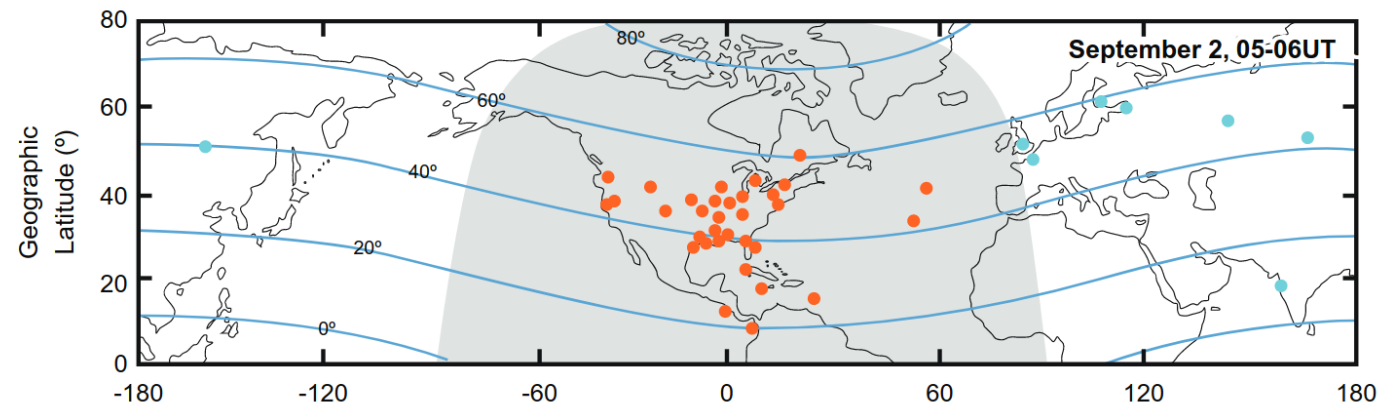
- Model the ionosphere $1 < r < 4 R_E$ (coming soon!)
- Increase the driving parameters to simulate large storms such as the Carrington Event (1859)



Ganse et al. (in progress)



Richard Carrington's sketch of 1859 solar flare



Carrington Event auroral sightings
Cliver & Dietrich (2013)



UNIVERSITY OF HELSINKI

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Carrington
Consortium:

UH & Vlasiator team

Finnish Meteorological
Institute

Change in Momentum
(Roope Siirtola et al.)

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