



UNIVERSITY OF HELSINKI

Three-dimensional Hybrid-Vlasov Simulations of Geomagnetic Storms

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Vlasiator Simulations

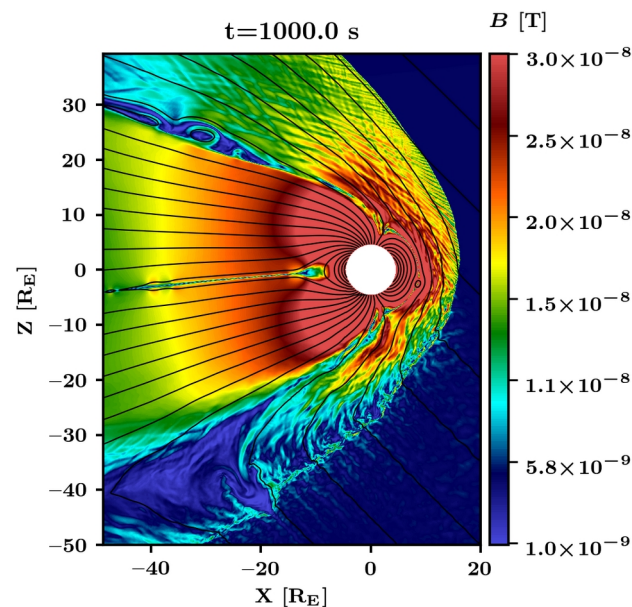
- hybrid-Vlasov (kinetic p+, fluid e-)
- 3D box (side length $\sim 100 R_E$)
- Inner boundary: $r=4 R_E$
- Adaptive mesh

For details:

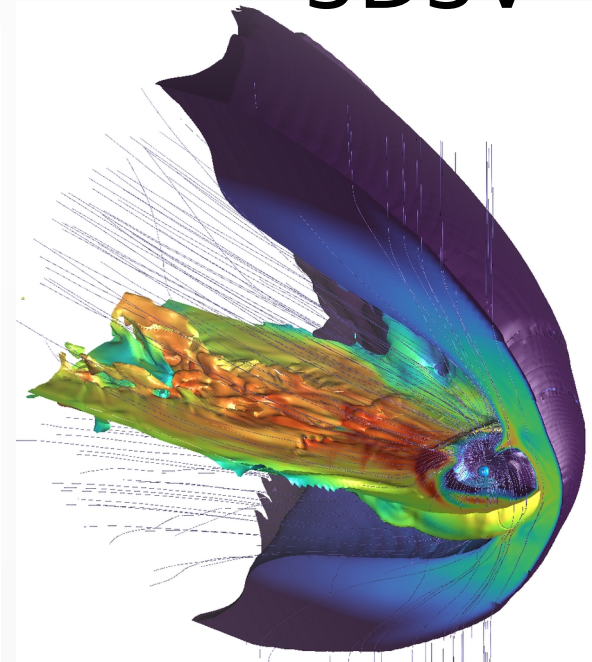
M. Palmroth et al., 2018

“Vlasov methods in space physics and astrophysics”

2D3V



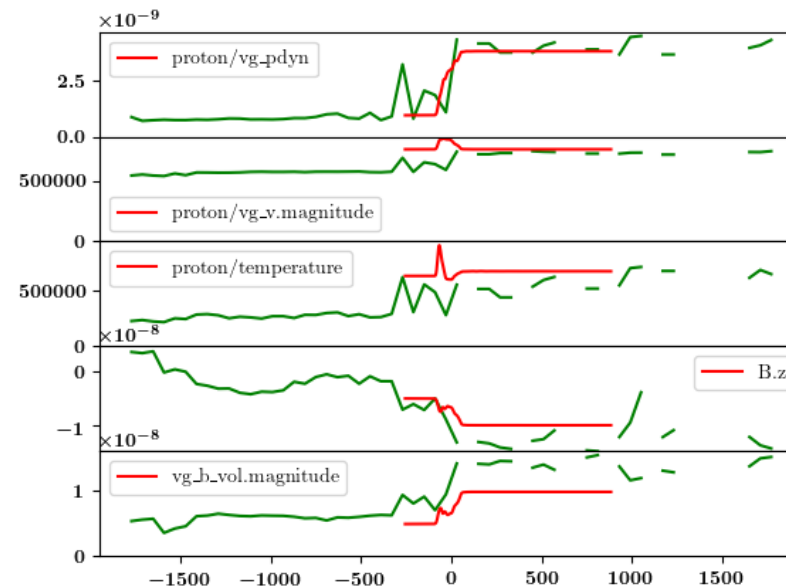
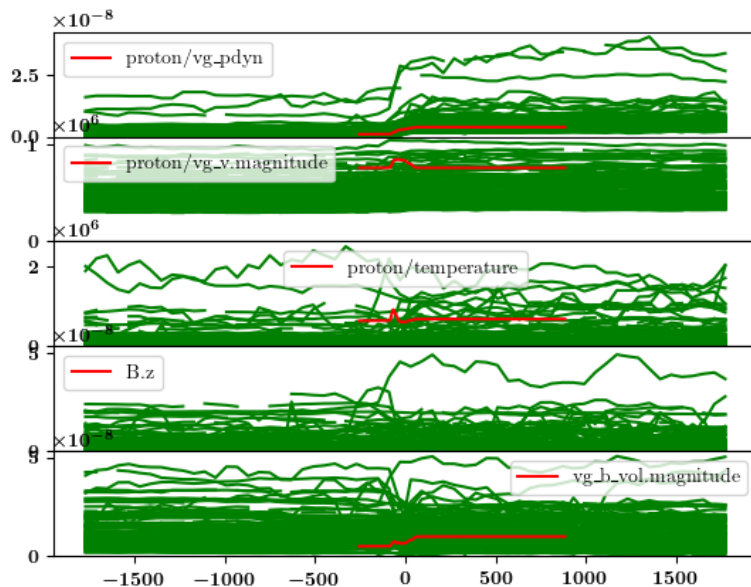
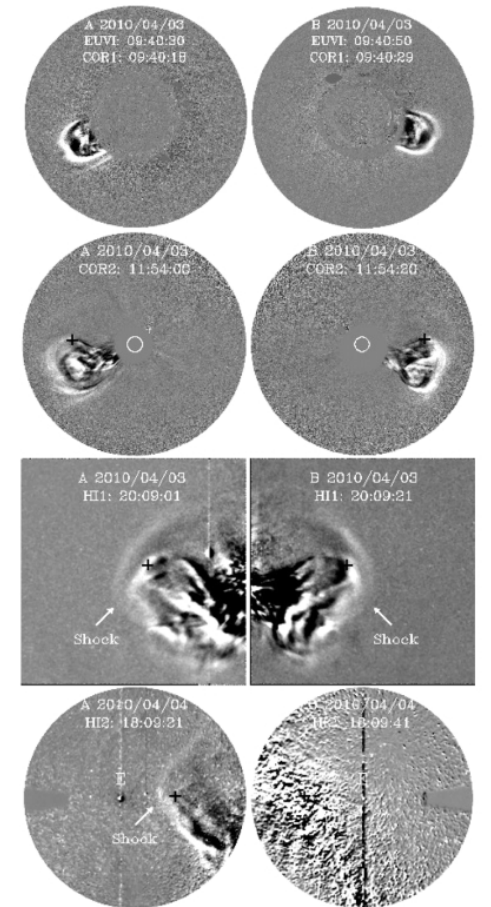
3D3V



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



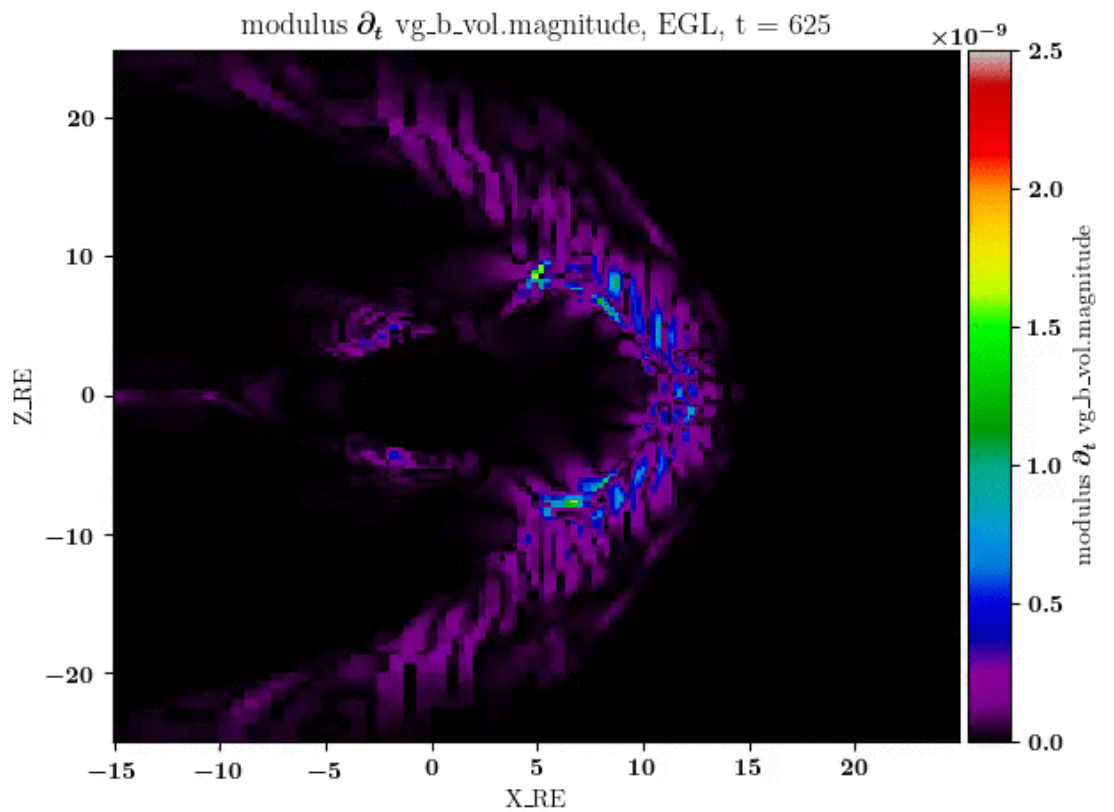
Pressure pulses, *OMNI* data

Min. Pearson Correlation

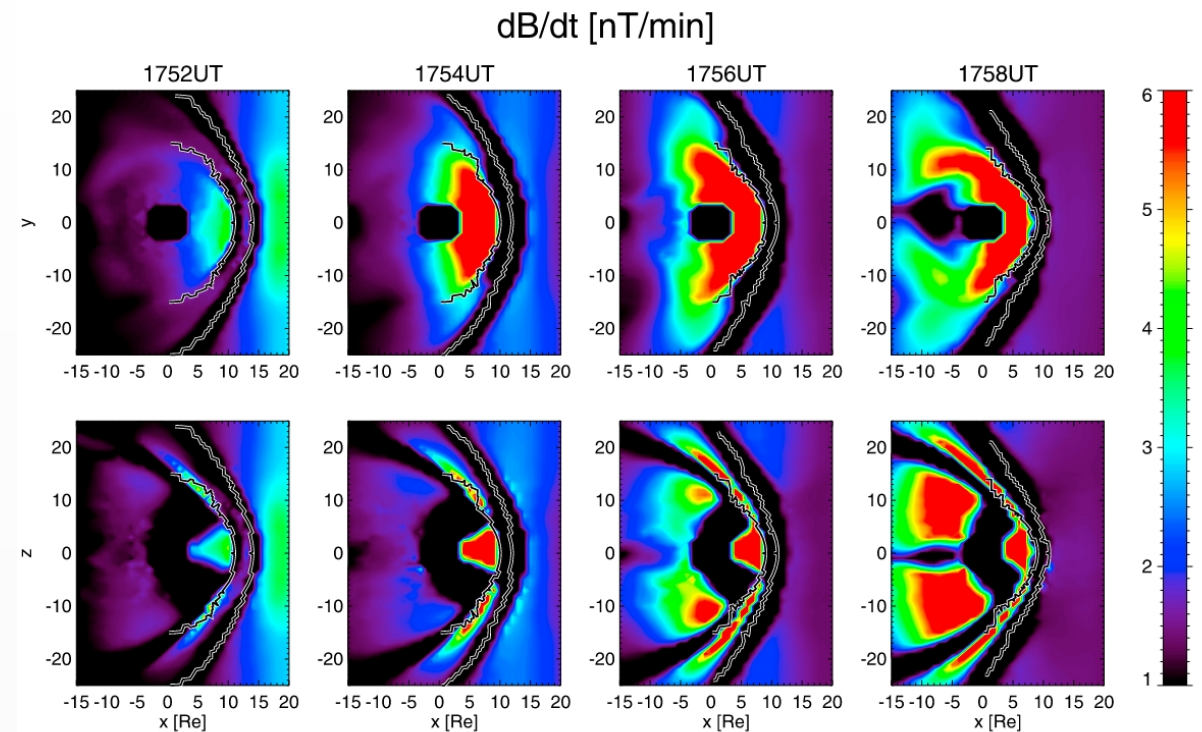
Liu et al. (2011)

Disturbance Propagation

Hybrid-Vlasov: Vlasiator



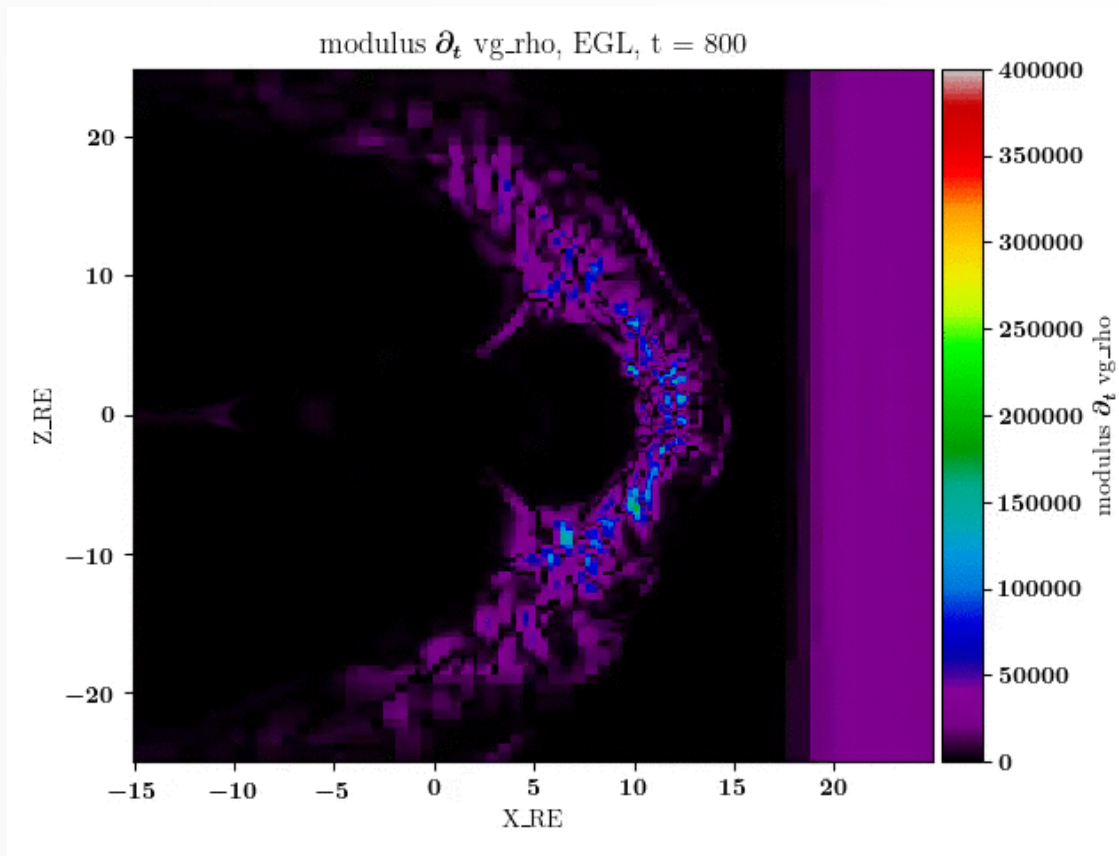
MHD: GUMICS 4
(Andreeova et al., 2011)



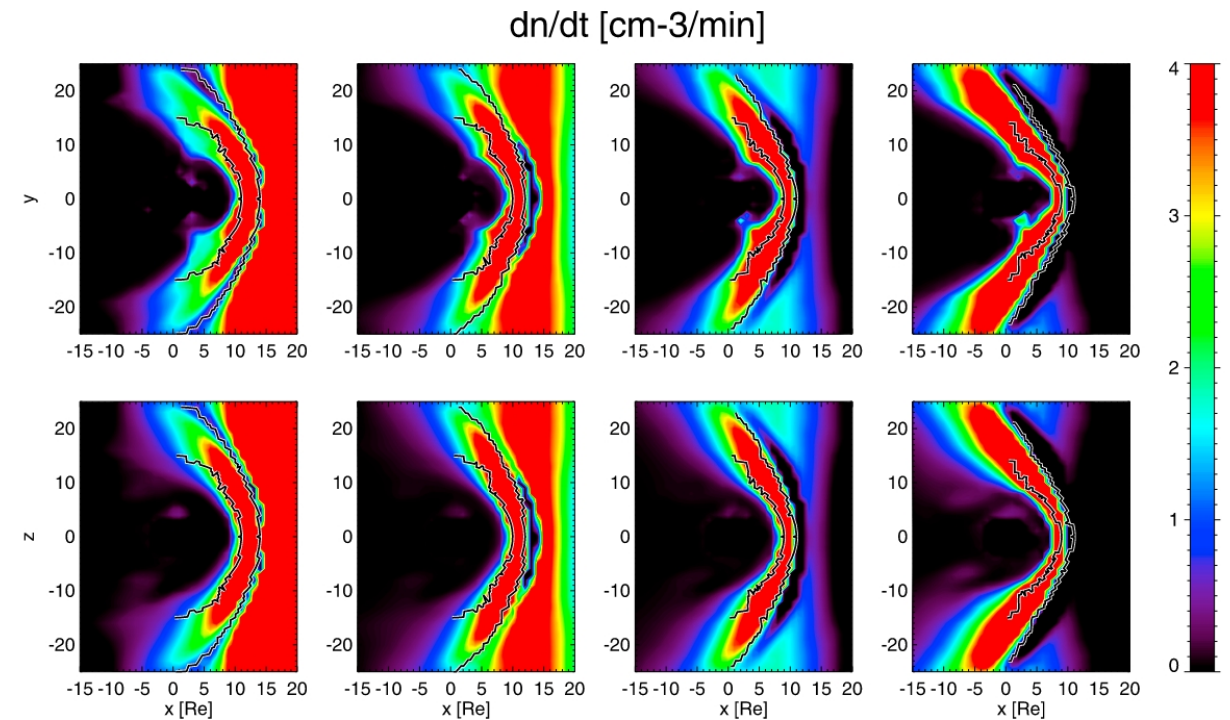
- Disturbance propagates along magnetopause towards the flanks
- “Sudden Impulse” observed behind magnetopause: large fluctuations in dayside B-field

Disturbance Propagation

Hybrid-Vlasov: Vlasiator



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

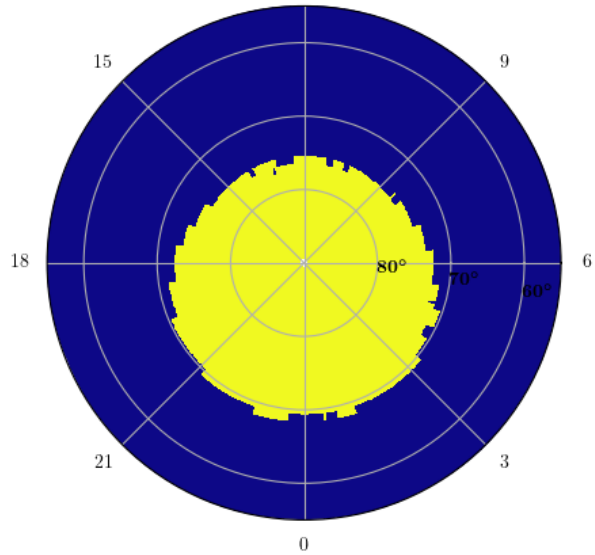


- Vlasov simulations show finer structures at small scales (e.g. mirror modes)

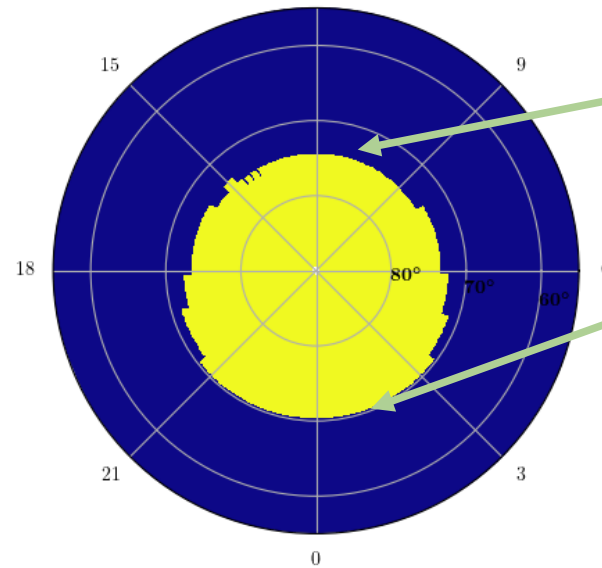
Before Pulse

After Pulse

EGL Field line topology, time=800



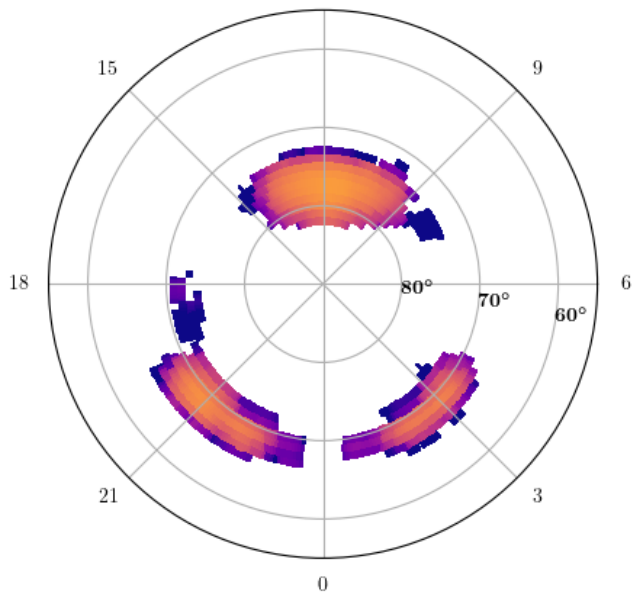
EGL Field line topology, time=1100



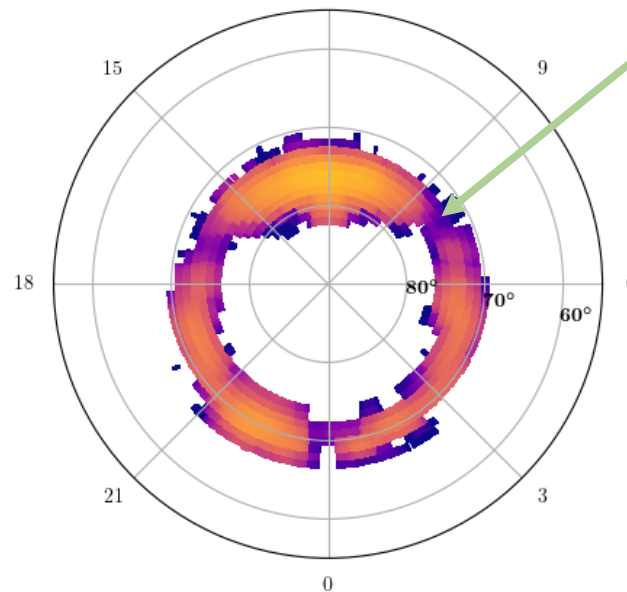
Dayside aurora expands

Nightside contracts

EGL 15811 eV proton DEF [SI], time=800



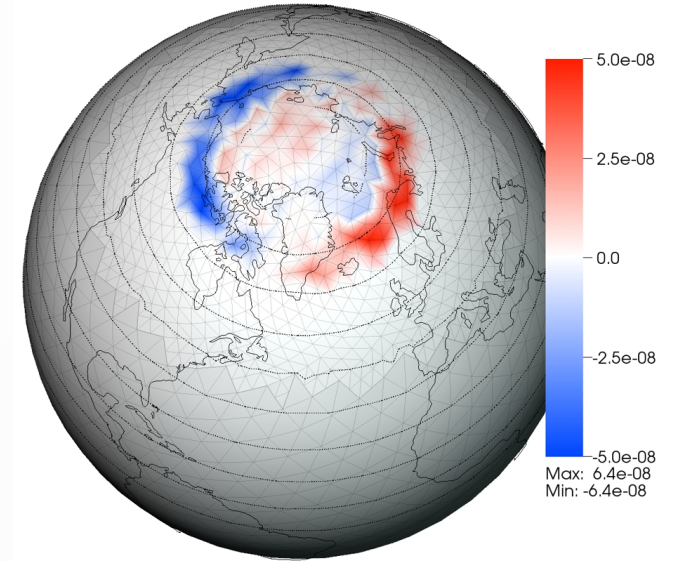
EGL 15811 eV proton DEF [SI], time=1200



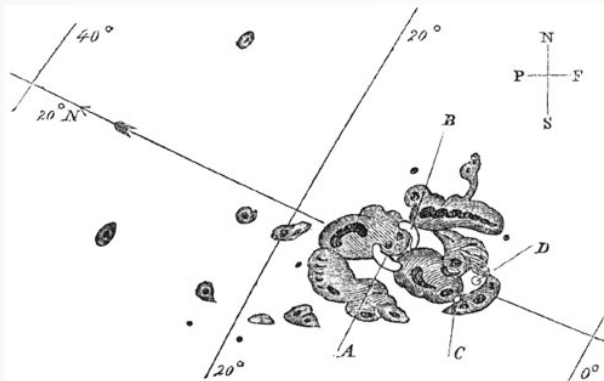
Increased flux of precipitating energetic (15 keV) protons in dawn/dusk regions

Next Steps

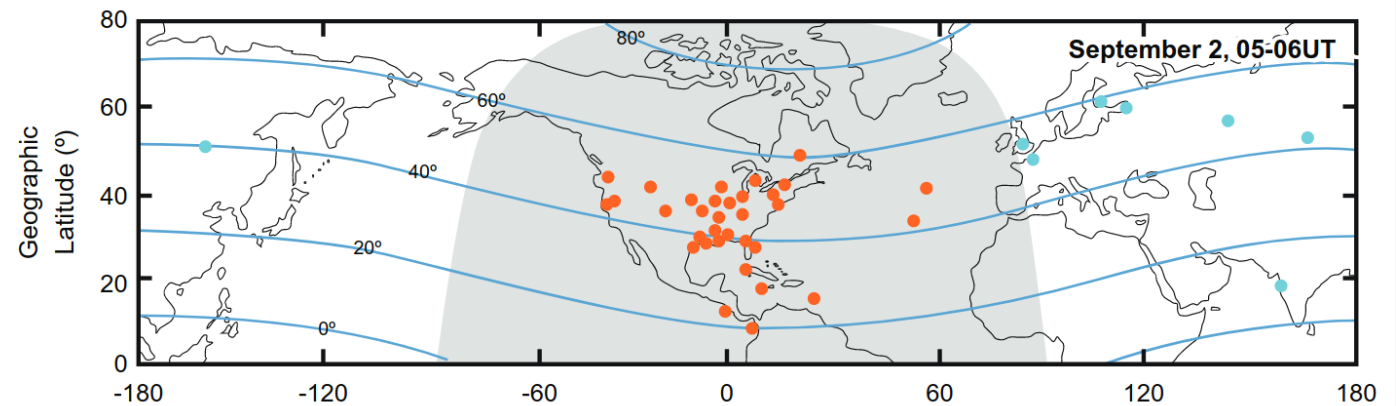
- Model the ionosphere $1 < r < 4 R_E$ (coming soon!)
- Increase the driving parameters to simulate large storms such as the Carrington Event (1859)



Ganse et al. (in progress)



Richard Carrington's sketch of 1859 solar flare



Carrington Event auroral sightings
Cliver & Dietrich (2013)



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Carrington
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Change in Momentum
(Roope Siirtola et al.)

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