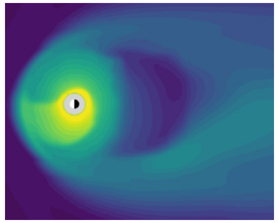

Understanding the Sources, Recirculation, and Impacts of Cold Plasma with Self-Consistent Modeling

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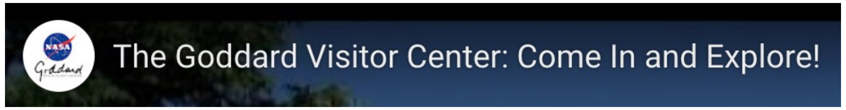
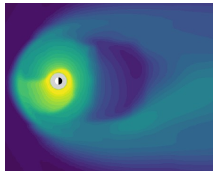
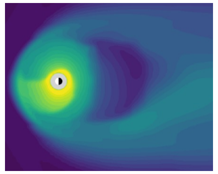
LWS Cold Plasma Team Meeting
March 23 - 24, 2023





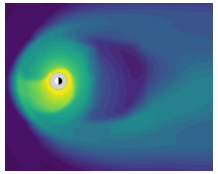
Science Objectives

1. Understanding the factors controlling the **refilling rate** of the plasmasphere.
2. Follow the **pathways** of cold plasma from its source to the drainage plume, to the magnetotail and back to the plasmasphere region.
3. Determine the **impacts** of cold plasma on reconnection rates and mass loading in the magnetospheric system.



Methodology

- Simulation study with Multifluid BATSRUS-CIMI-SAMI3 Model
- Model-data comparison with data from RBSP, LANL, MMS, THEMIS



Early Work by Moore et al, 2008

Plasma plume circulation and impact in an MHD substorm

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[1] We investigate the fate of a plasmaspheric plume generated by a discrete period of southward interplanetary magnetic field (IMF) to assess its contribution to plasma sheet and ring current pressure and compare with that for other sources. We use test particle motions in Lyon-Fedder-Mobarry (LFM) global circulation model fields. The inner magnetosphere is simulated with the Comprehensive Ring Current Model (CRCM) model of Fok and Wolf, driven by the transpolar potential developed by the LFM magnetosphere. A variant of the Ober plasmasphere model is embedded within the models and driven by them. Global circulation is stimulated by a period of southward IMF embedded within a long interval of northward IMF. This leads to the production of a well-defined plasmaspheric plume, enhancing the plasma density sunward of the plasmasphere. Test particles are launched with the properties of plasmaspheric ions on the $L = 6.6\ R_E$ shell and weighted with densities as specified by the Ober model, as it responds to convection imposed by CRCM. Particles are tracked until they are lost from the system downstream or into the atmosphere, using the Delcourt full equations of motion, implemented for finite element fields. Results are compared with earlier computations of polar and auroral wind outflows. The plume produces an enhanced flow of plasma ~10 times the normal polar wind global fluence. However, we find that most of the "plasmaspheric wind" is lost from the magnetosphere such that its contribution to the ring current energy density is comparable to that of the normal polar wind for this type of event.

Early Work by Moore et al, 2008

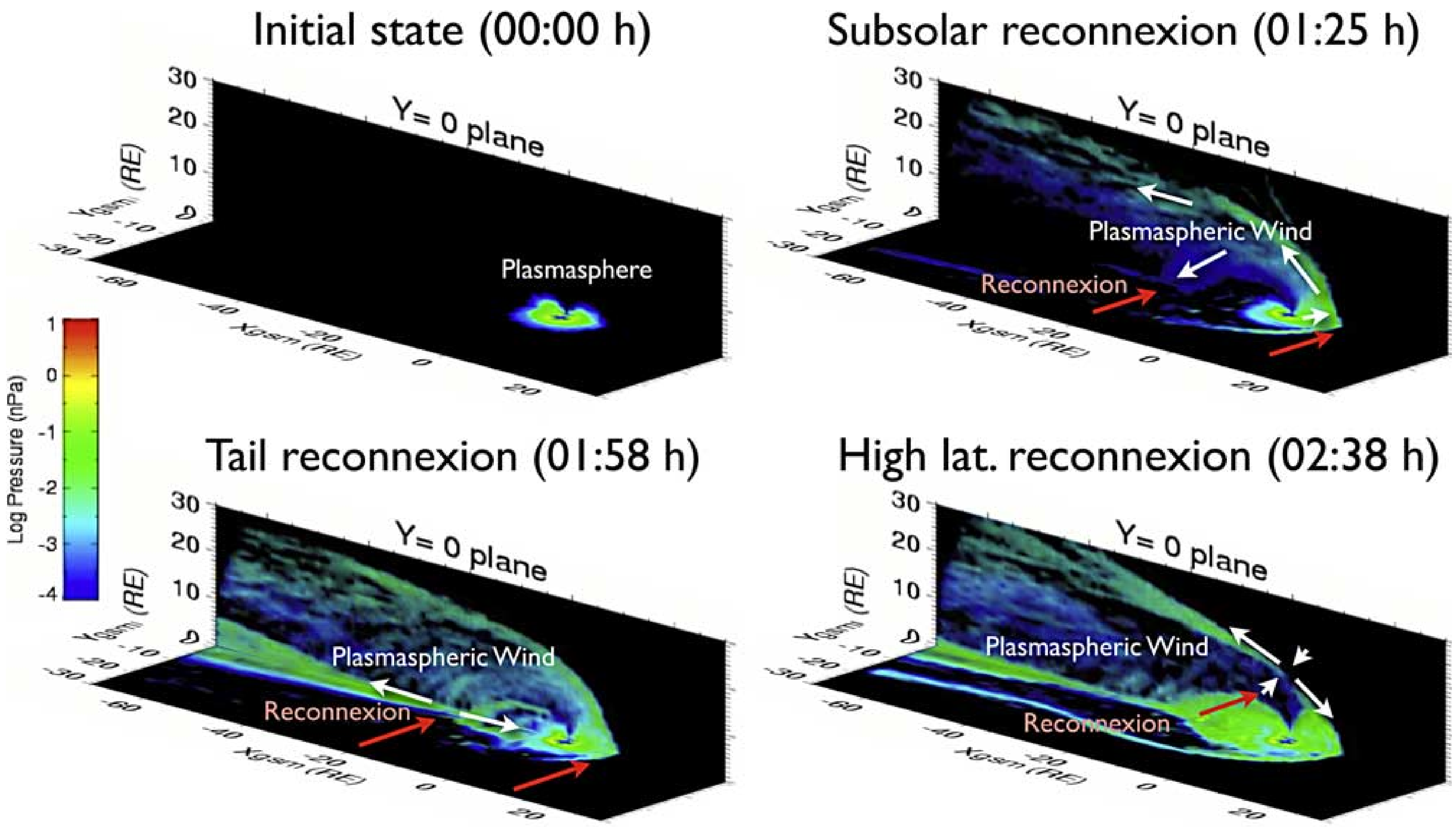
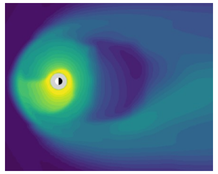


Figure 8. A comparison of plasmaspheric pressure distributions, as indicated by the color bar at the right, in two orthogonal slices through the simulation space at four times during the simulation, as indicated.

Multifluid BATSRUS-CIMI-SAMI3 Model



- **BATSRUS** MHD Model (**B**lock-**A**daptive-**T**ree-**S**olarwind-**R**oe-**U**pwind **S**cheme)
- **CIMI** Model (**C**omprehensive **I**nner **M**agnetosphere-**I**onosphere)
- **SAMI**3 Model (**S**ami3 is **A**lso a **M**odel of the **I**onosphere/Plasmasphere)

Multifluid BATSRUS with a Plasmasphere Fluid

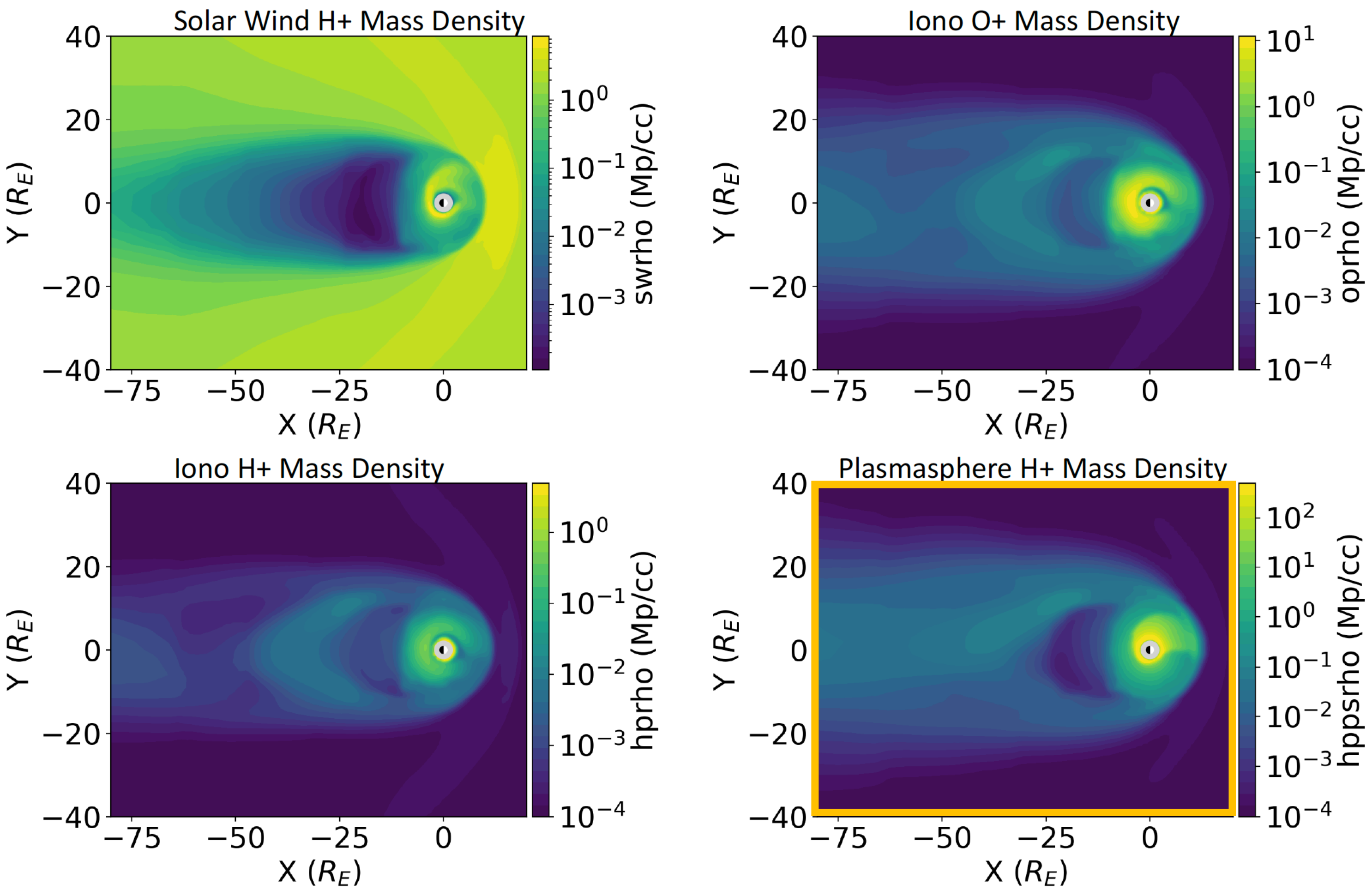
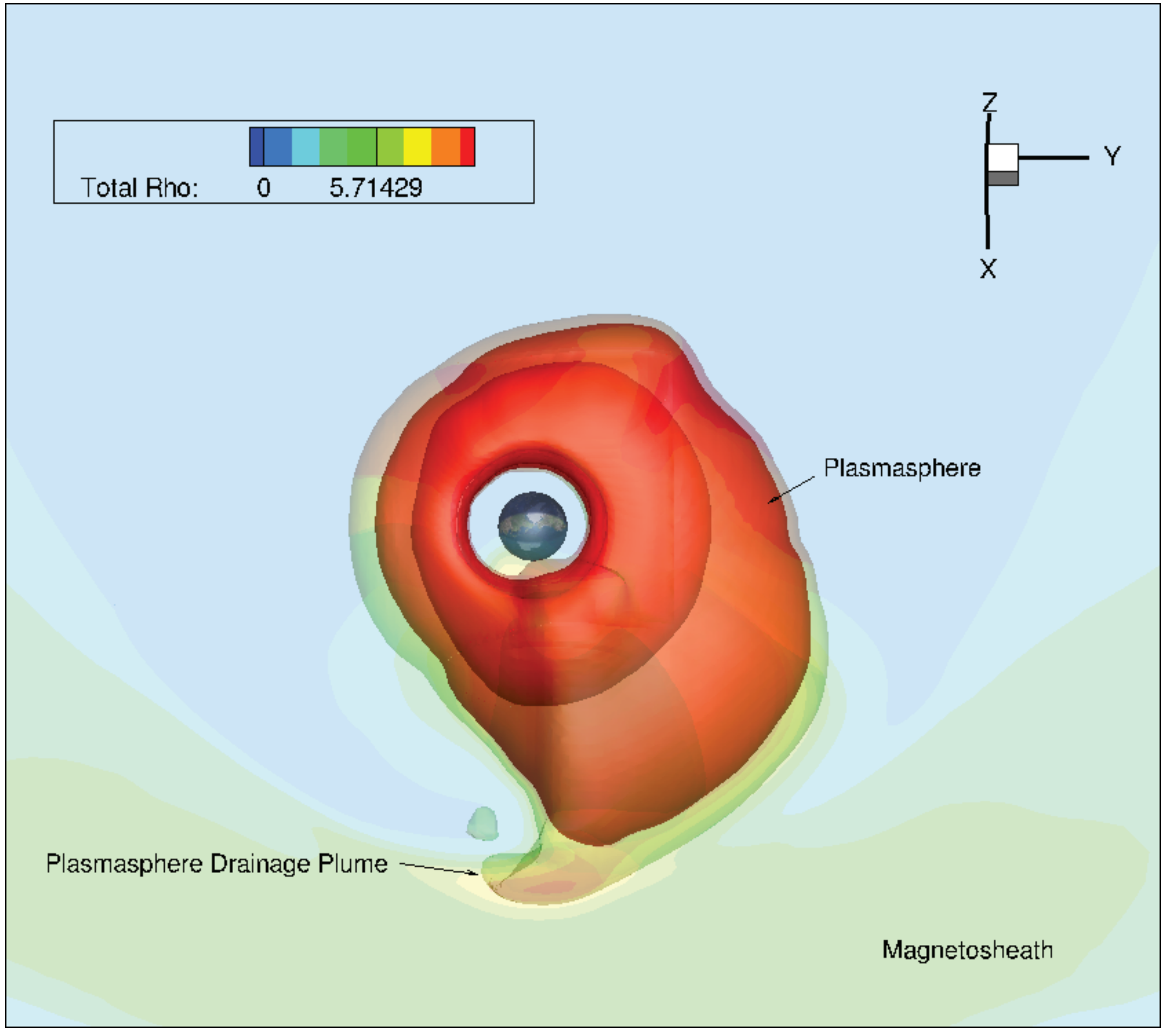
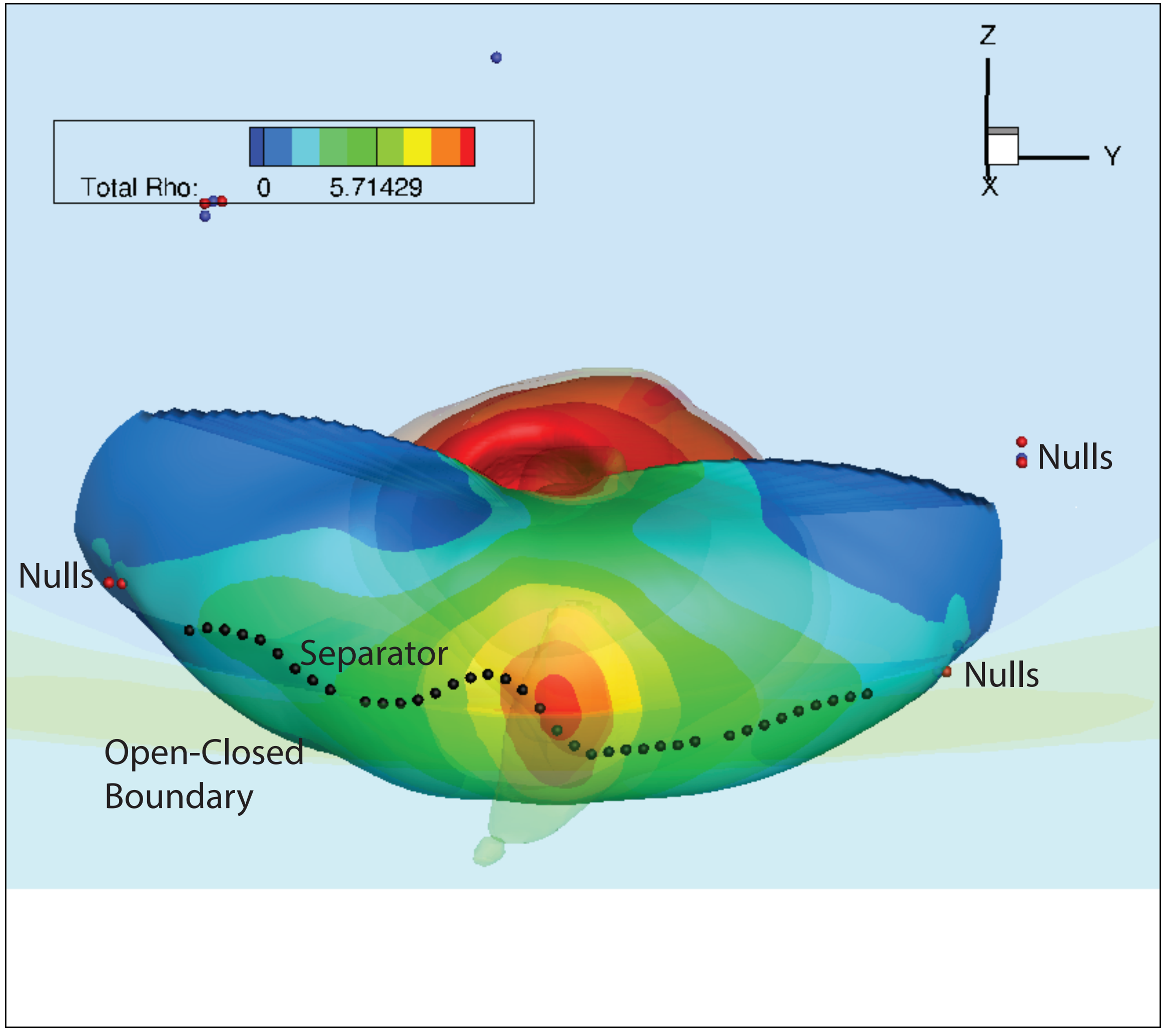


Figure 2. An image showing the mass density of four different ion species from the coupled model in the equatorial plane (adapted from results of (Glocer et al., 2020)). Mp/cc = proton mass per cm^{-3}

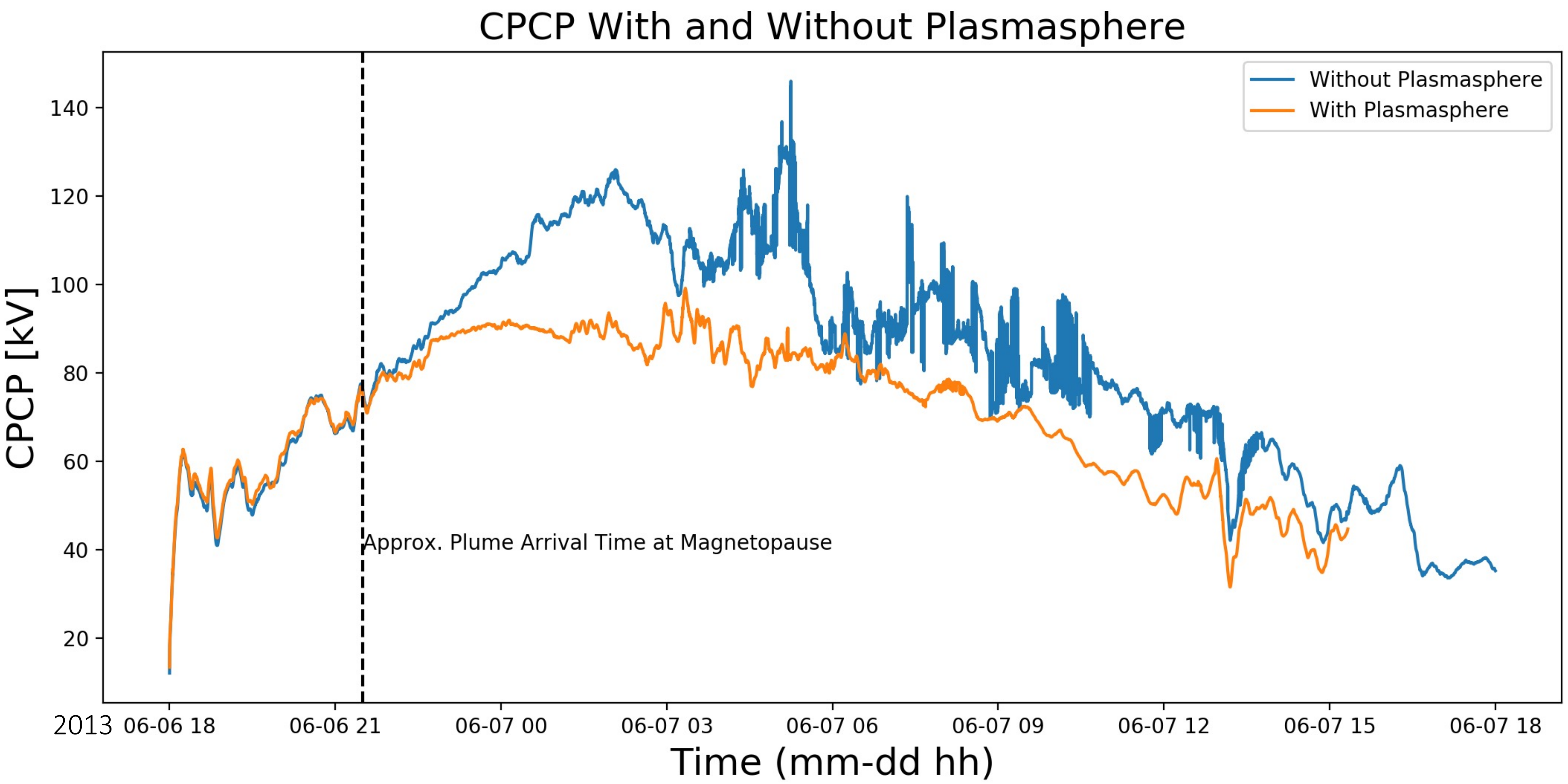
Plasmasphere at Dayside Magnetopause





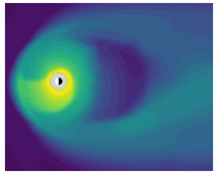
Glocer et al., [2020]

Plasmasphere Plume Reduces Global Reconnection Rate



Glocer et al., [2020]

Coupling Between BATSRUS-CIMI-SAMI3



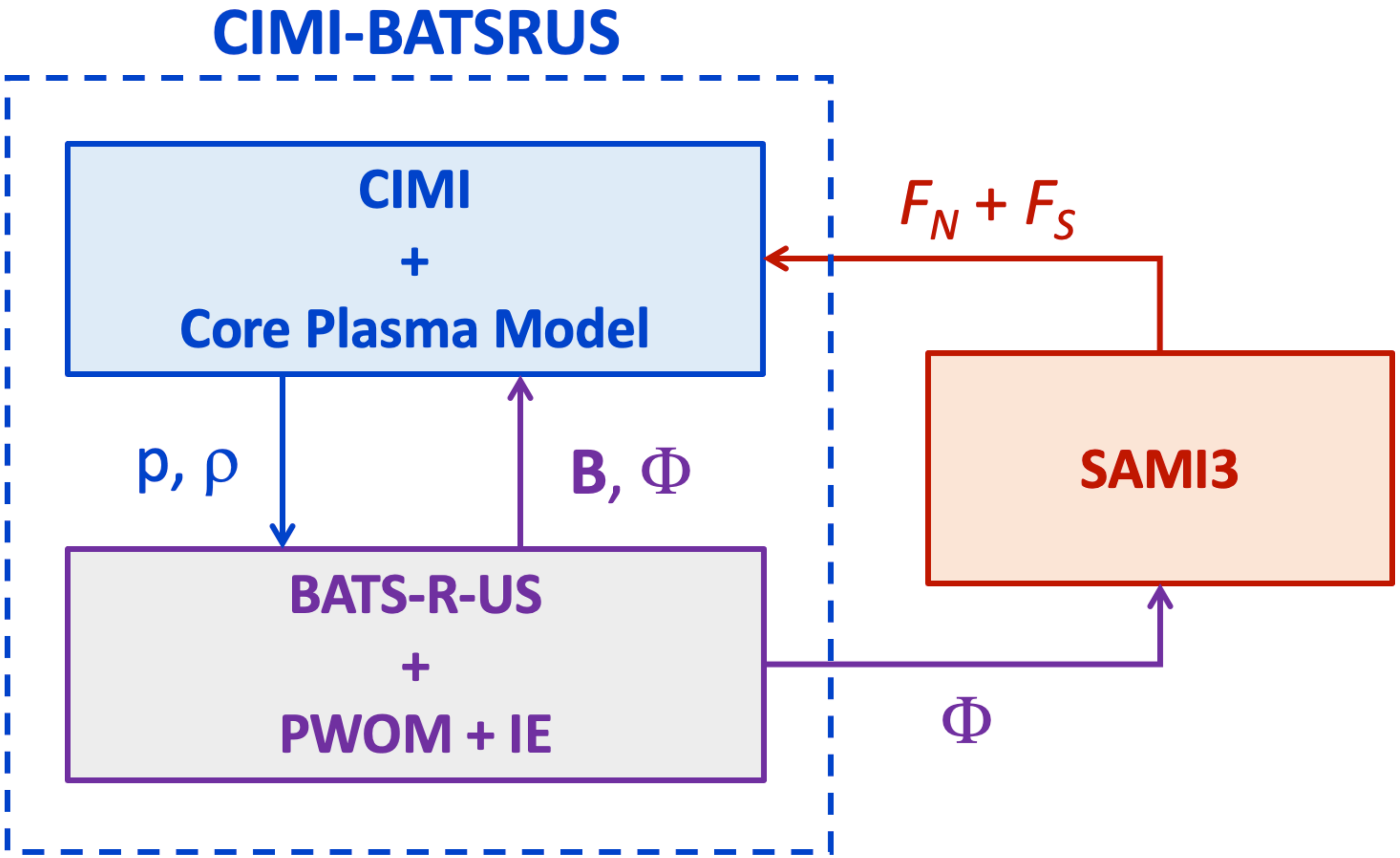
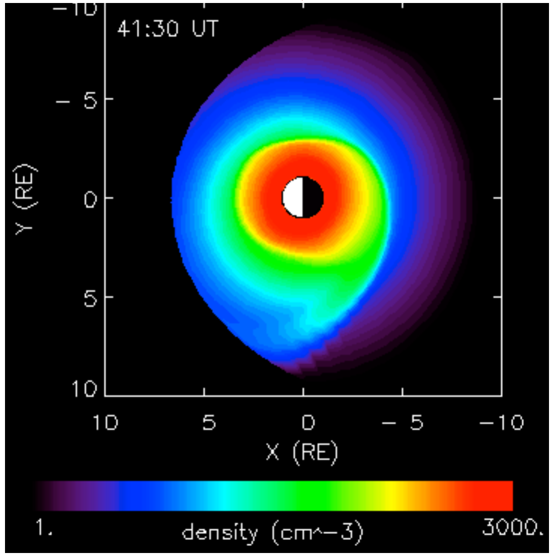


Figure 4. The coupling between the CIMI-BATSRUS and SAMI3. Φ is the convection potential; F_N and F_S are ionospheric fluxes at northern and southern ionosphere, respectively.

The Core Plasma Model in CIMI

N: plasma content

$$\frac{\partial N}{\partial t} + \mathbf{u_E} \cdot \nabla N = \frac{F_N + F_S}{B_i}$$



$$F_{day} = \frac{n_{sat} - n}{n_{sat}} F_{max}$$

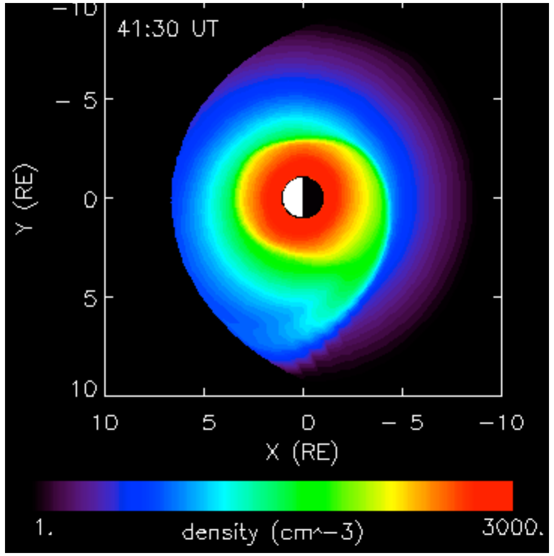
$$F_{night} = -\frac{N B_i}{\tau_{diff}}$$

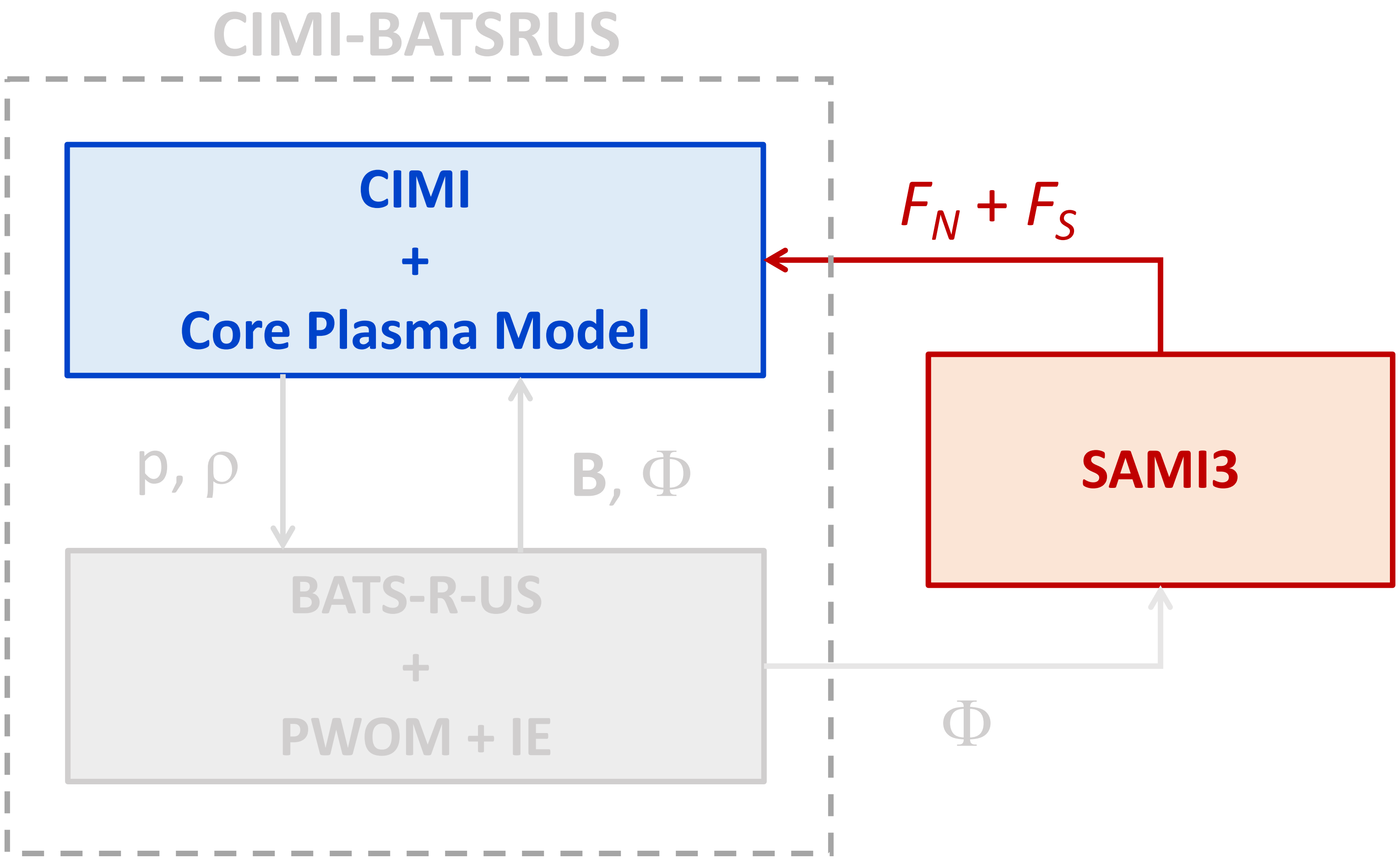
(Fok et al., 2014)

Core Plasma Model with Refilling Rates from SAMI3

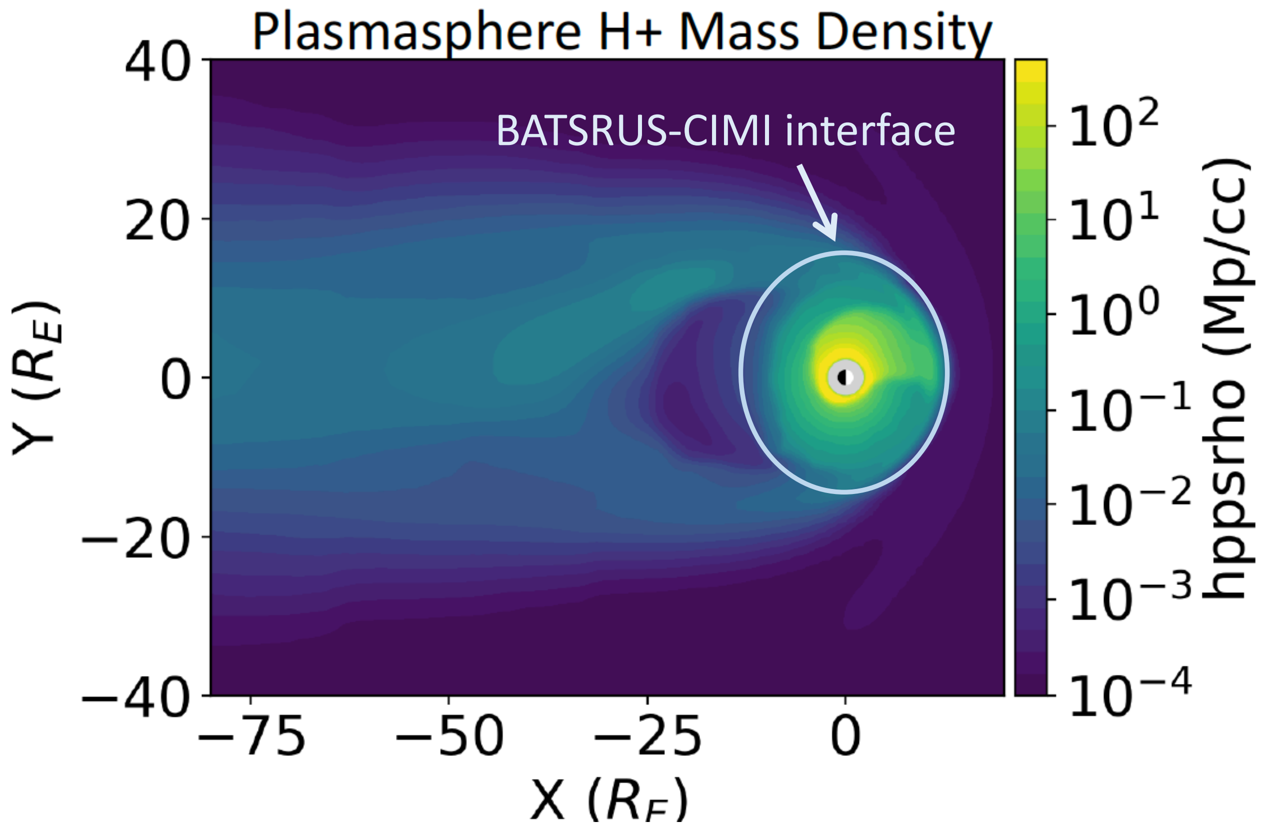
N: plasma content

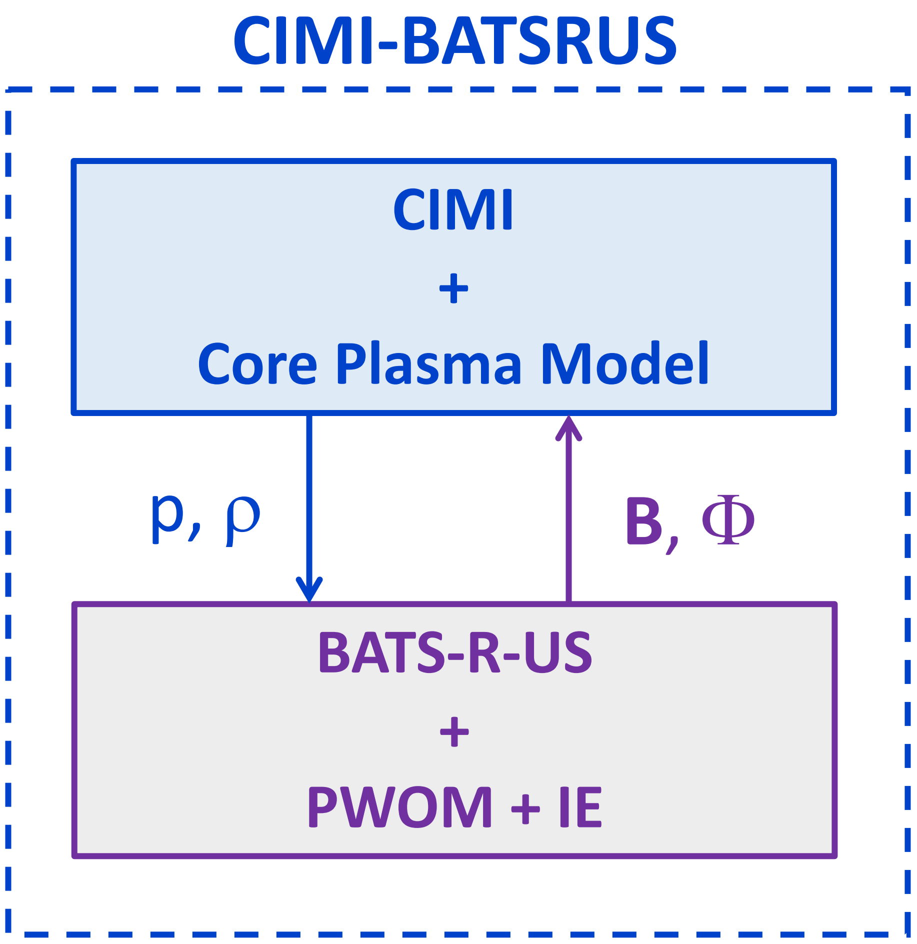
$$\frac{\partial N}{\partial t} + \mathbf{u_E} \cdot \nabla N = \frac{F_N + F_S}{B_i}$$





BATSRUS with a Plasmasphere Fluid



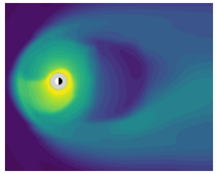


Plasmasphere parameters are solved by

- Core plasmasphere model inside CIMI domain
- MHD equations outside CIMI domain

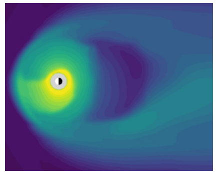
(Glocer et al., 2020)

Science Objectives and Proxies in Simulations



Science Objective	Proxies
1. Sources (refilling rate)	F_N or $F_S = \int n/B \, ds$
2. Pathways	pressure and temperature maps, fractional loss
3. Mass Loading	R_{local}, CPCP

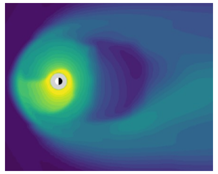
Table 1. Science Objectives and physical parameters that can serve as proxies to address the corresponding objective.



Simulations of Idealized Events

Run	F107	[H], [O]	IMF (nT)	Clock Ang	Vsw (km/s)	plasmasphere	SO
1	70	NRLMSIS	8	180°	300	yes	
2	180	NRLMSIS	8	180°	300	yes	1
3	70	2×NRLMSIS	8	180°	300	yes	1
4	70	NRLMSIS	4	180°	300	yes	1, 2
5	70	NRLMSIS	16	180°	300	yes	1, 2
6	70	NRLMSIS	8	90°	300	yes	2
7	70	NRLMSIS	8	0°	300	yes	2
8	70	NRLMSIS	8	180°	600	yes	2
9	70	NRLMSIS	8	180°	300	no	3
10	70	NRLMSIS	8	0°	300	no	3
11	70	NRLMSIS	16	180°	300	no	3

Table 2. Runs of idealized events will be performed to address the 3 Science Objectives (SO). Run 1 is the base run. The parameters which are different from the base run are highlighted.



Data Analysis Plan

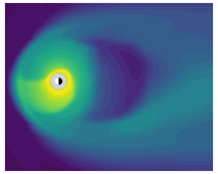
- **Task 1:** a statistical analysis of plasmaspheric plume presence

  Maps of plume event in (L, MLT, MLAT) binned by IMF, clock angle and Vsw

  Data: MMS, geosyn s/c

- **Task 2:** case studies of the recirculation of the plasmaspheric material

  Study of 3 plume events identified by Task 1



Key Milestones

Project Year 1

- Establish the coupling between CIMI-BATSRUS and SAMI3
- Perform idealized event runs 1-2.
- Identify plume events from satellite data.

Project Year 2

- Perform idealized event runs 3-5.
- Establish [L, MLT, MLAT] maps of plume event.
- Select the first plume event for simulation and data analysis study.
- Publish paper on the factors controlling the plasmasphere refilling rate.

Project Year 3

- Perform idealized event runs 6-8.
- Select the second plume event for simulation and data analysis study.
- Publish paper on the factors controlling the pathways of plasmasphere particles.
- Publish paper on real event study and data-model comparison.

Project Year 4

- Perform idealized event runs 9-11.
- Select the third plume event for simulation and data analysis study
- Publish paper regarding the impacts of plasmasphere mass loading on the magnetosphere system.
- Publish paper on real event study and data-model comparison.