Space Weather Forecasting Advancements at the University of Michigan

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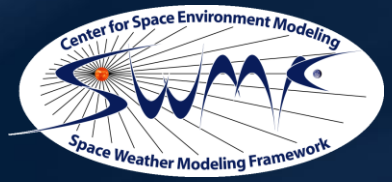
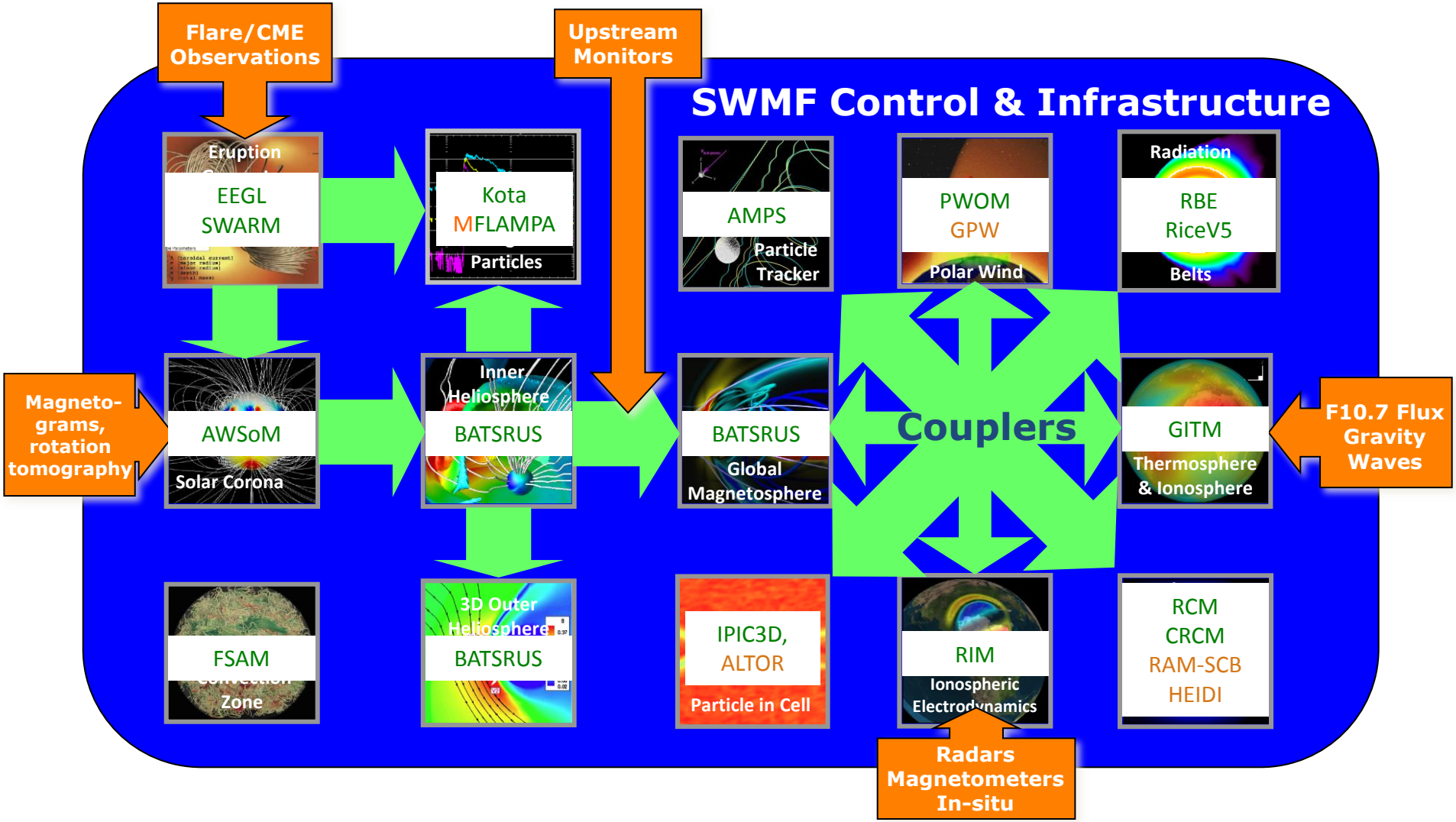
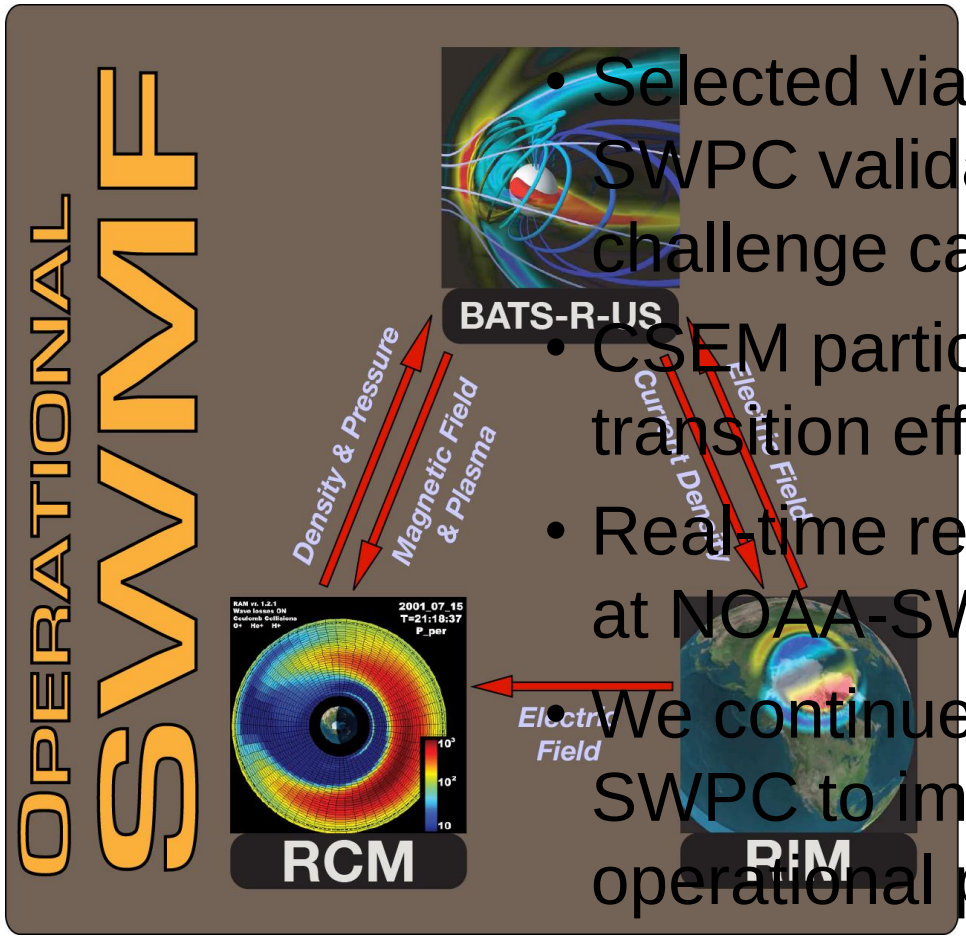


Center for Space Environment Modeling

- We **develop** & **maintain** research-grade numerical models for community use.
- We **distribute** our models & source code openly.
- We **collaborate** with SWPC, CCMC, and other institutions to expand the community's capabilities.
- We **facilitate** transition to operations via our software engineering approach to code development.

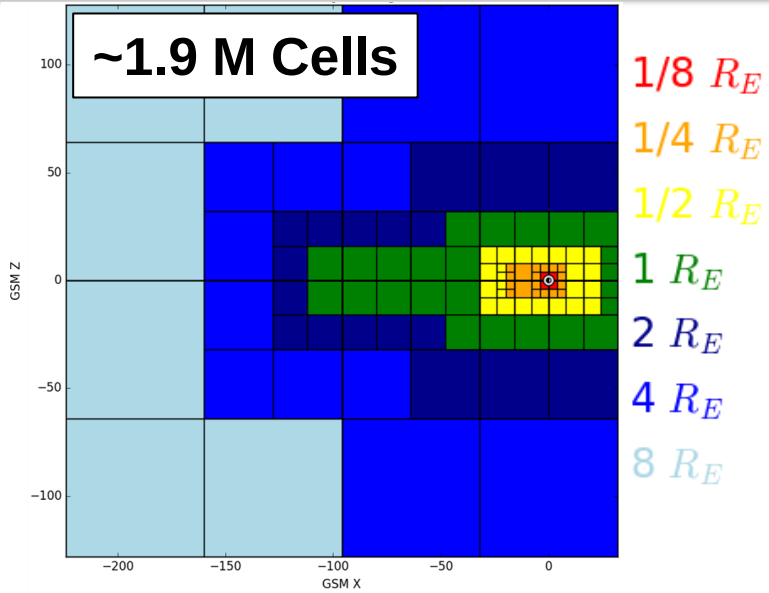

Flare/CME Observations
Upstream Monitors
SWMF Control & Infrastructure
Eruption
EEGL
SWARM
Kota
MFLAMPA
Particles
AMPS
Particle Tracker
PWOM
GPW
Polar Wind
Radiation
RBE
RiceV5
Belts
Magneto-grams, rotation tomography
AWSoM
Solar Corona
Inner Heliosphere
BATSRUS
BATSRUS
Global Magnetosphere
Couplers
GITM
Thermosphere & Ionosphere
F10.7 Flux Gravity Waves
FSAM
Zone
3D Outer Heliosphere
BATSRUS
IPIC3D,
ALTOR
Particle in Cell
RIM
Ionospheric Electrodynamics
RCM
CRCM
RAM-SCB
HEIDI
Radars Magnetometers In-situ

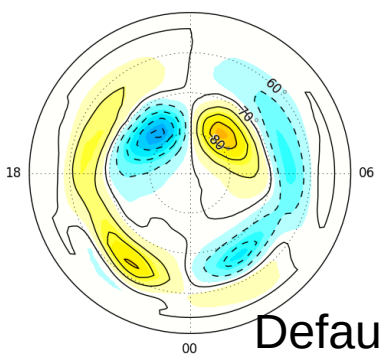
Operational SWMF for Geospace



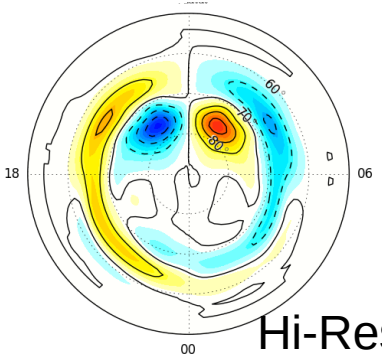
- Selected via CCMC-SWPC validation challenge ca. 2013
- CSEM participates in transition effort
- Real-time results are live at NOAA-SWPC
- We continue to work with SWPC to improve operational product.

SWMF Geospace Improvements





Default



Hi-Res

Geospace Vers. 2.0:

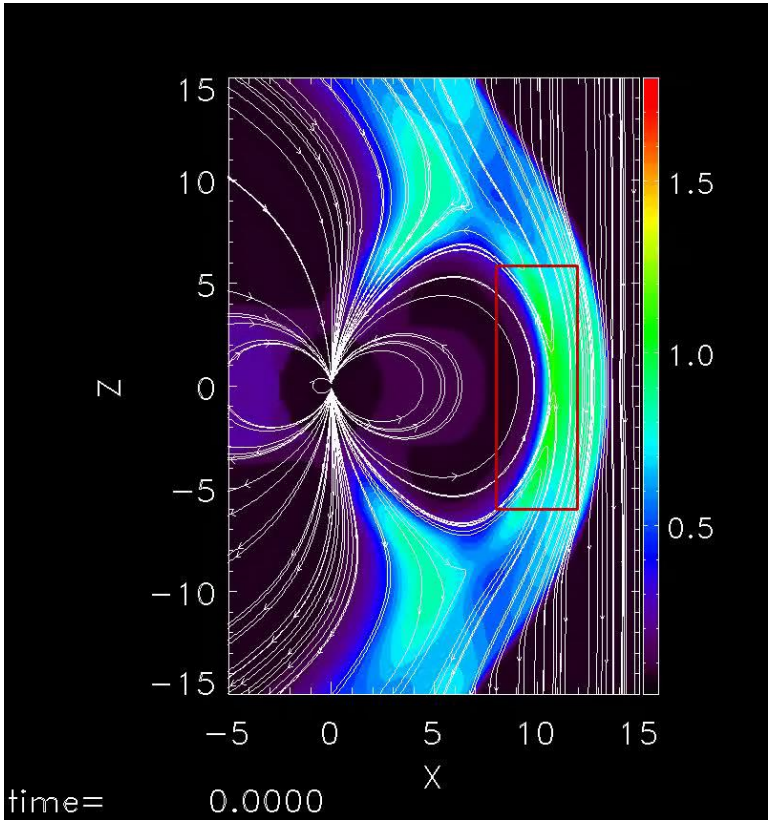
- Higher MHD resolution
- Improved auroral conductance application
- Expanded output products

Ongoing improvements:

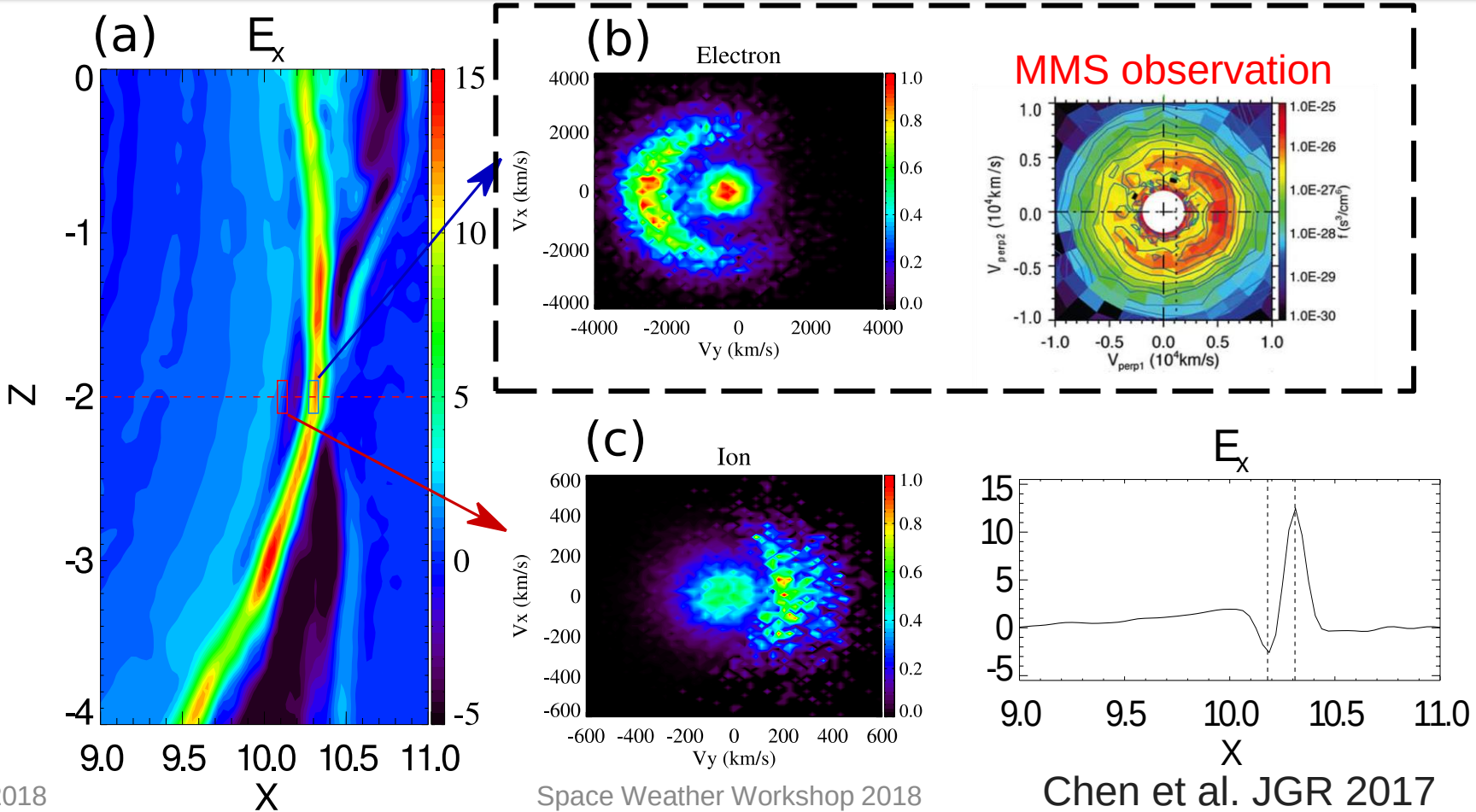
- Anisotropic MHD + CIMI
- Multi-species/fluid MHD

MHD with Embedded PIC (EPIC)

- MHD does not capture the kinetic physics inside of the reconnection region.
- Particle-in-cell models are comprehensive but prohibitively expensive.
- “Why not both?” MHD-EPIC combines the efficiency of global MHD with the kinetic physics of local PIC code!

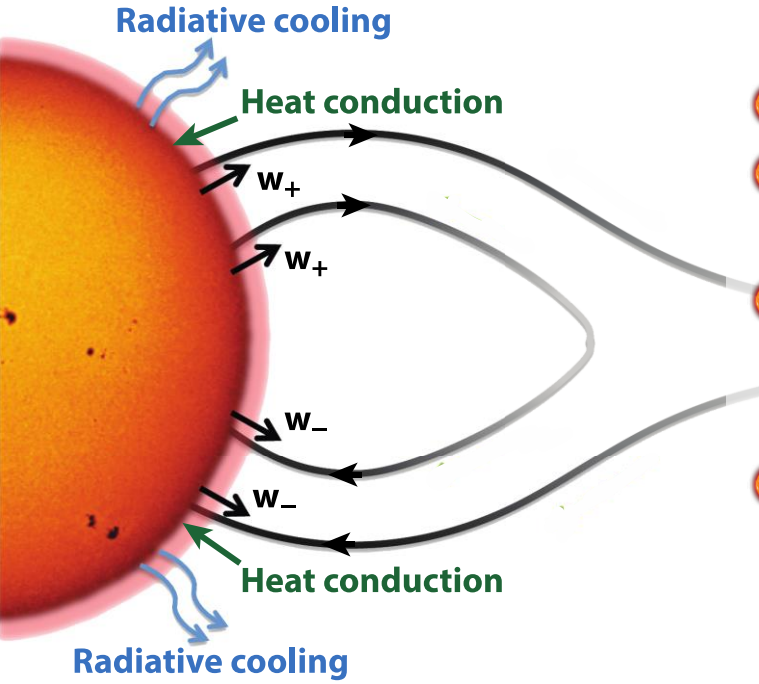


Comparisons to MMS



Chen et al. JGR 2017

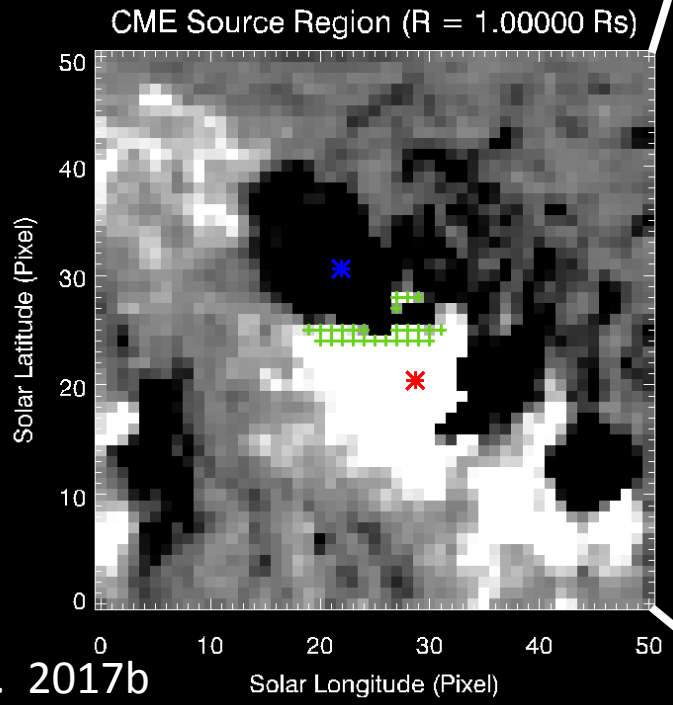
SWMF Heliosphere with AWS☀M-R



- Between $1R_s$ and $1.15\ R_s$ **u || B** and $u \ll V_{slow}, V_A, V_{fast}$
- Inner boundary of AWS☀M-R is at $1.15\ R_s$
- Each boundary cell center is connected to the upper chromosphere by a magnetic field line
- Quasi-steady-state mass, momentum and energy transport is solved along the connecting field line (1D equations)
- The many small cells in the lower corona of the AWS☀M model are avoided ⇒ AWS☀M-R is ~100 times faster ⇒ enables faster than real-time Sun to-Earth space weather prediction
- **AWS☀M and AWS☀M-R are running at CCMC**

Eruptive Event Generator with Gibson-Low Configuration (EEGGL)

Blue Weighted Center of Negative Polarity
Red Weighted Center of Positive Polarity
Green Polarity Inversion Line



M. Jin et al. 2017b

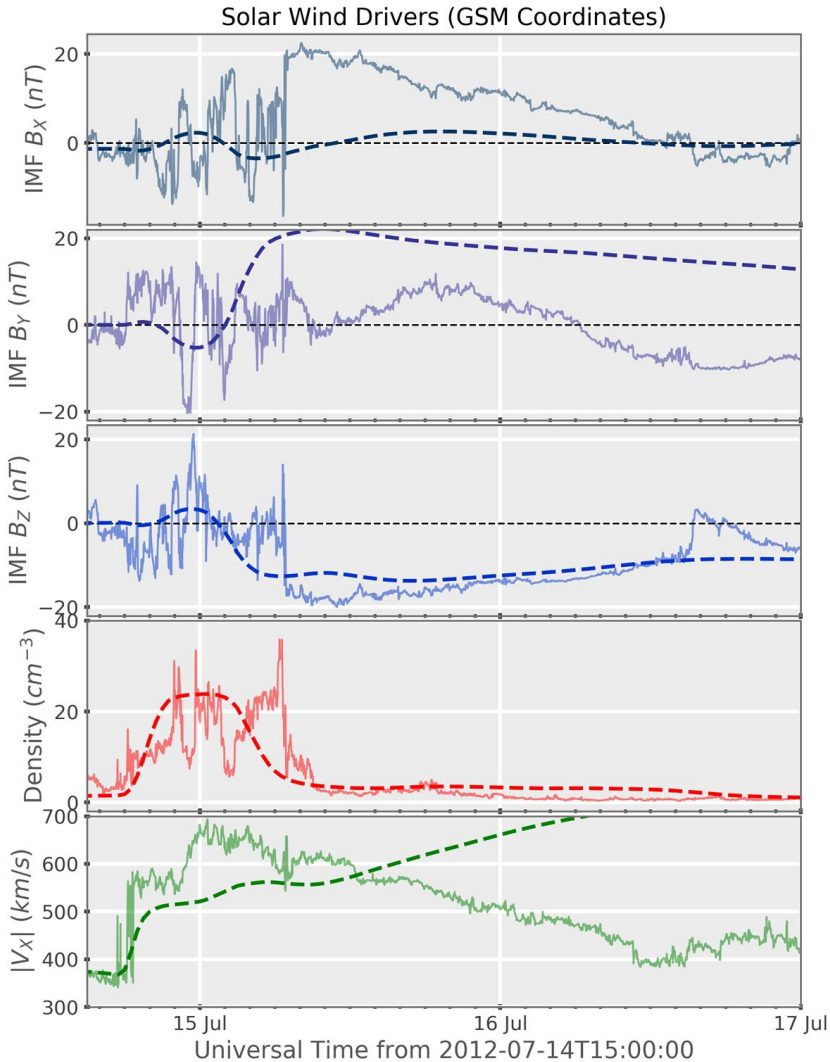
Next Goal: Automate initialization of CMEs

- Leverage image processing & machine learning to automatically locate source active region.
- Validate forecasts made with automated CME initialization.
- Apply deep learning techniques to determine probability of solar eruptions.

Extending Lead Time

AWSoM-EEGL L1 Forecast

- Arrival time is shifted by 13 hours (compare to ~50-hour transit time)
- Initial velocity and density are about right
- Jump across shock is about right
- IMF B_Z is good
- Overall too smooth



Extending Forecast Lead Time

	ΔB_H (100 nT Threshold)		
	PoD	**PoF**	**Heidke**
L1 Obs. + Geospace	0.5760	0.0211	0.5871
EEGL-AWSOM + Geospace	0.5732	0.0564	0.5431

Time from 2012-07-14 15:00UT

AWSoM-EEGL prediction of Dst, ΔB_H

- Good amplitudes
- Too smooth variation
- **Metrics still good!**
- Further validation underway

Building Research-to-operations Infrastructure in Diverse Geospace Environments (BRIDGE)

In order to **BRIDGE** the R2O-O2R “valley of death”, we propose a testbed center that will…

1. Carry out cutting edge research in new areas
   Leverage machine learning, ensemble forecasting, new physics.
2. Maintain a community software framework
   Work with developers, operational community, & NASA CCMC to support & develop standardized versions of the software framework.
3. Support testing, validation, and operational use
   Partner with NSEP/SWPC to transition framework to operations.
   Work with CCMC & research community to expand framework to meet operational requirements & feedback.

CSEM at Michigan

- We continue to perform cutting-edge science using our suite of numerical models.
- New model developments coming to the operational SWMF Geospace
- Our long-term goal is the BRIDGE testbed center to support community-wide R2O-O2R efforts.