

# OpenGGCM New Developments

W. Douglas Cramer

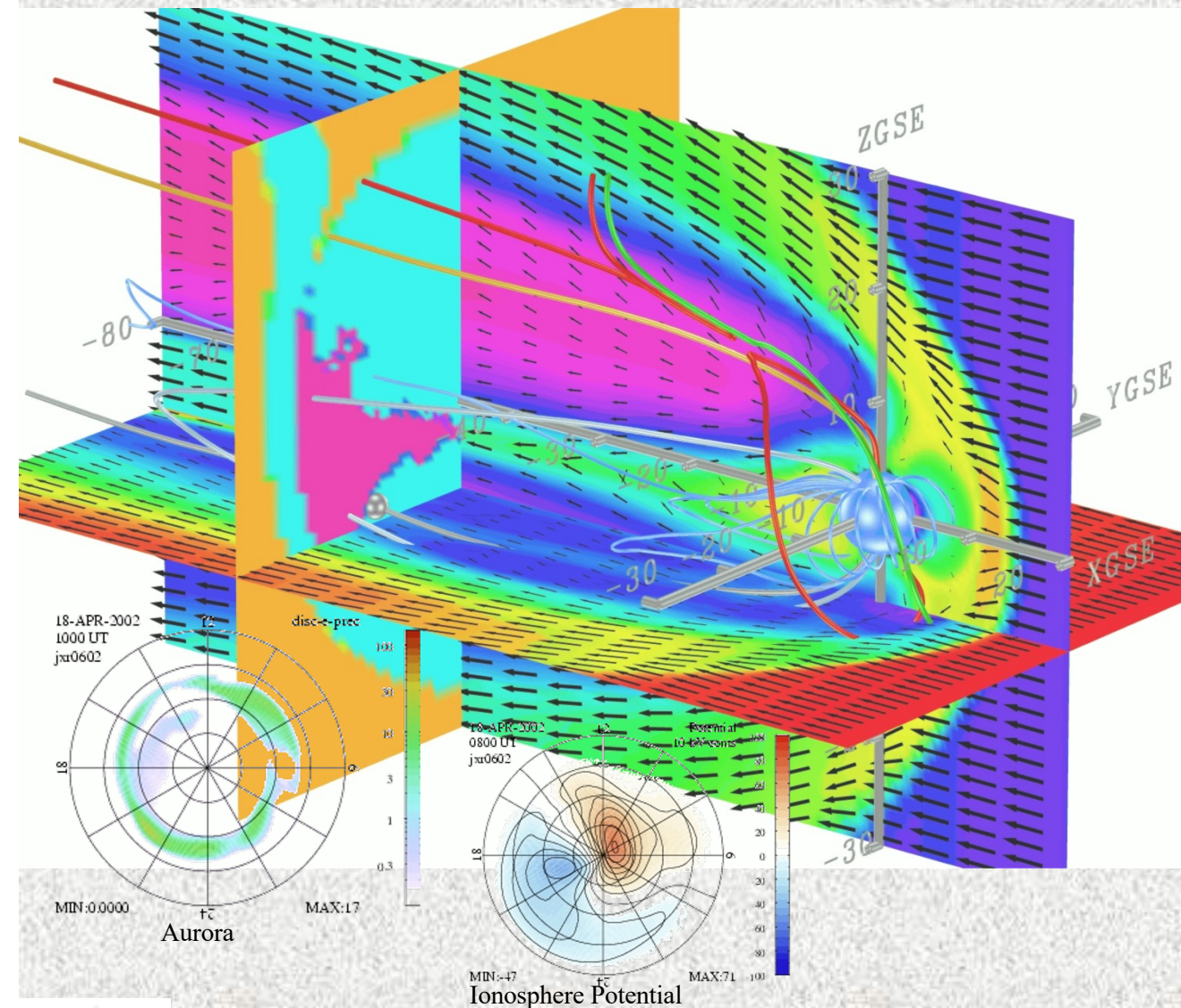
Space Science Center, University of New Hampshire

CCMC Workshop, June 8, 2022

# OpenGGCM: Global Magnetosphere Modeling

## The Open Geospace General Circulation Model:

- Coupled global magnetosphere - ionosphere - thermosphere model.
- 3d Magnetohydrodynamic magnetosphere model.
- Coupled with NOAA/SEC 3d dynamic/chemistry ionosphere - thermosphere model (CTIM).
- Coupled with inner magnetosphere / ring current models: Rice U. RCM, NASA/GSFC CRCM/CIMI (under development).
- Model runs on demand provided at the Community Coordinated Modeling Center (CCMC at NASA/GSFC).  
<http://ccmc.gsfc.nasa.gov/>
- Fully parallelized code, real-time capable. Runs on IBM/datastar, IA32/I64 based clusters, PS3 clusters, and other hardware.
- Used for basic research, numerical experiments, hypothesis testing, data analysis support, NASA/THEMIS mission support, mission planning, space weather studies, and Numerical Space Weather Forecasting in the future.
- Funding from NASA/LWS, NASA/TR&T, NSF/GEM, NSF/ITR, NSF/PetaApps, AFOSR programs.



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# Development Team

## University Of New Hampshire

- Jimmy Raeder – main contact, general development
- Doug Cramer – RCM, CRCM/CIMI, general development
- Kai Germaschewski - general development
- Bashi Ferdousi – IPE

## Non-UNH Collaborators

- Tim Fuller-Rowell – CTIM
- Naomi Maruyama – IPE
- Frank Toffoletto – RCM
- Mei-Ching Fok – CRCM/CIMI

# MHD models

	BATS-R-US	GUMICS-4	LFM (GAMERA)	OpenGGCM
MHD equations	ideal, conservative, $B_0 + B_1$	ideal, conservative, $B_0 + B_1$	ideal, semi-conservative, $B_0 + B_1$	semi-conservative with resistivity
Solver notes	eight-wave approximate Riemann	mostly Roe, subcycling, $\nabla \cdot B$ cleaning	total variation diminishing (TVD), constrained transport (CT)	TVD, CT
Order of MHD discretization: spatial / temporal	2 / 2	1 / 1	8 / 2	4 / 2
MHD grid	Cartesian, static, block-refined	Cartesian, dynamic, cell-refined	distorted spherical, static, not refined	stretched Cartesian, static, not refined
Dipole tilt updated with time	yes	no	yes <sup>a</sup>	no
Coordinate system of magnetosphere	GSM	GSE	SM	GSE

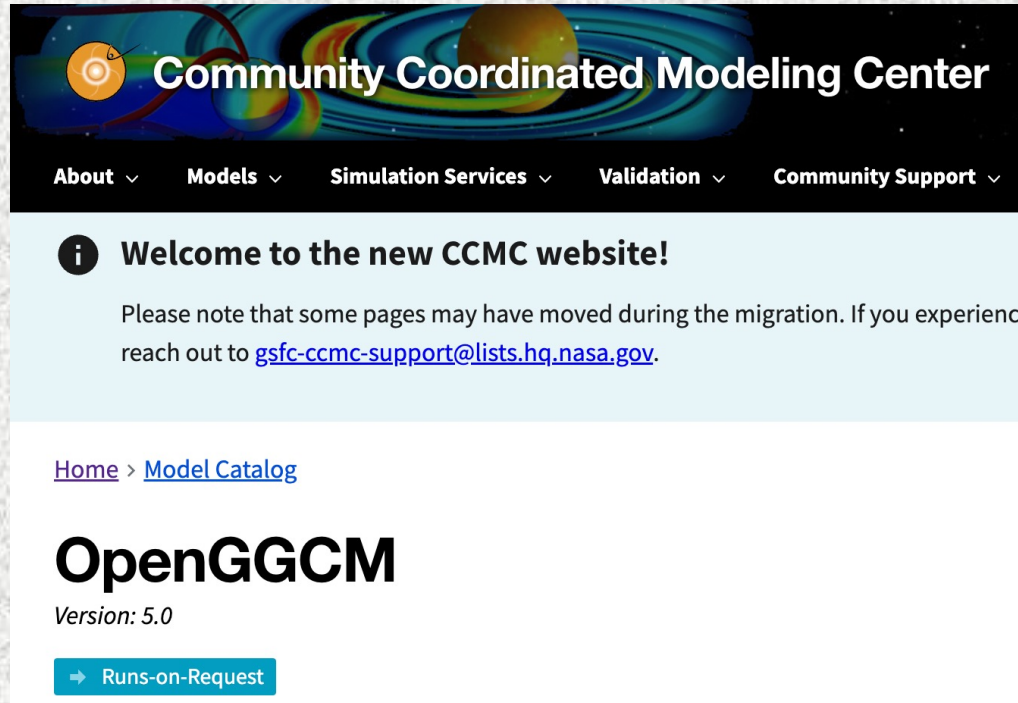
<sup>a</sup>The dipole orientation is fixed in SM coordinates, but solar wind and solar EUV conditions are adjusted with time.

(from Honkonen, 2013)

- Different methodologies, grid
- Comparison can identify relative importance of guiding assumptions, handling of different phenomena
  - Honkonen et al., 2013 – Cross Polar Cap Potential (CPCP)
  - Gordeev et al., 2016 – Substorm flux transport
  - Ridley et al., 2016 – Magnetic field model-data comparison
  - Mukopadhyay et al., 2021 – Magnetopause standoff distance

# Version 5.0 now @ CCMC!

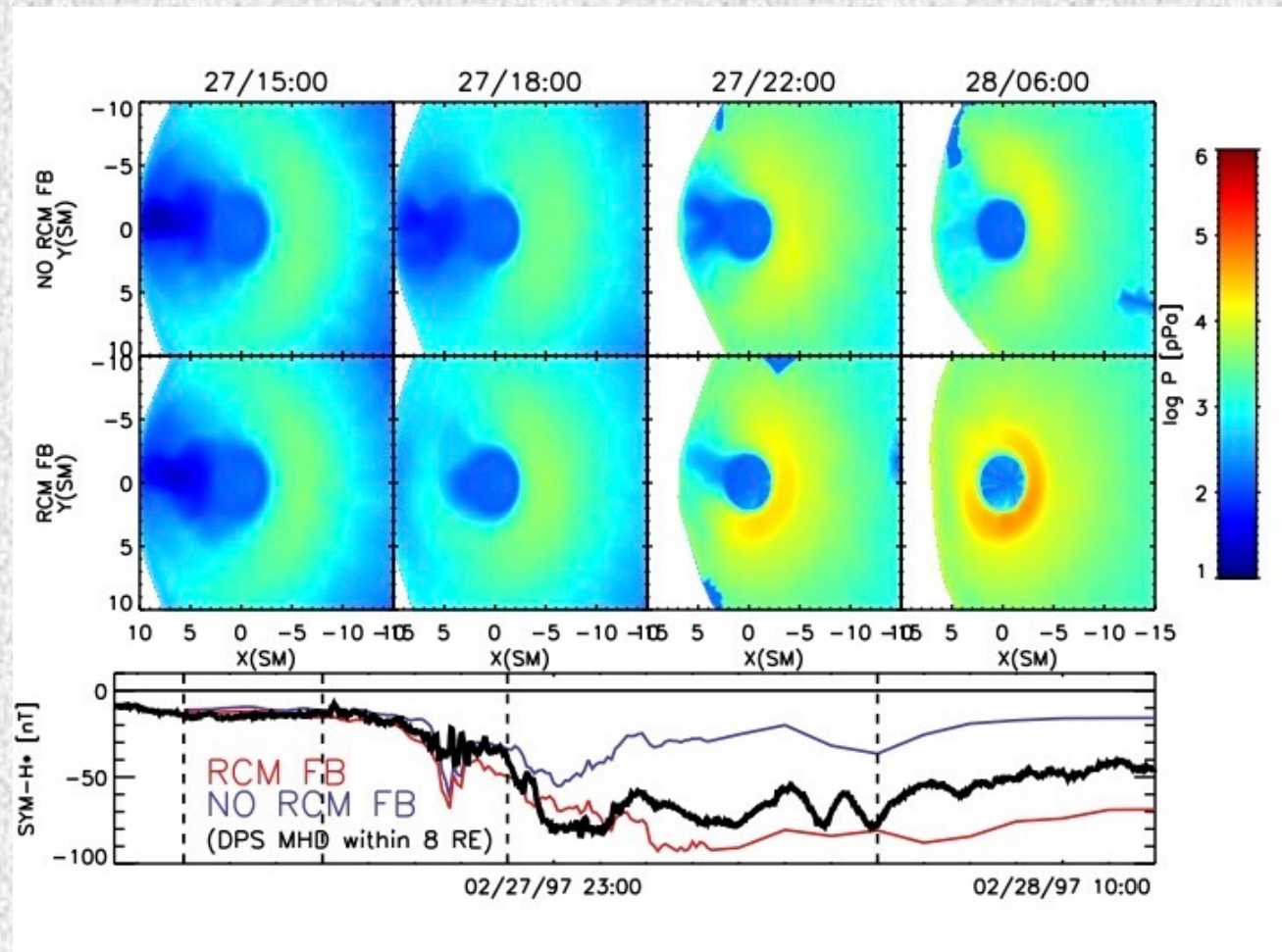
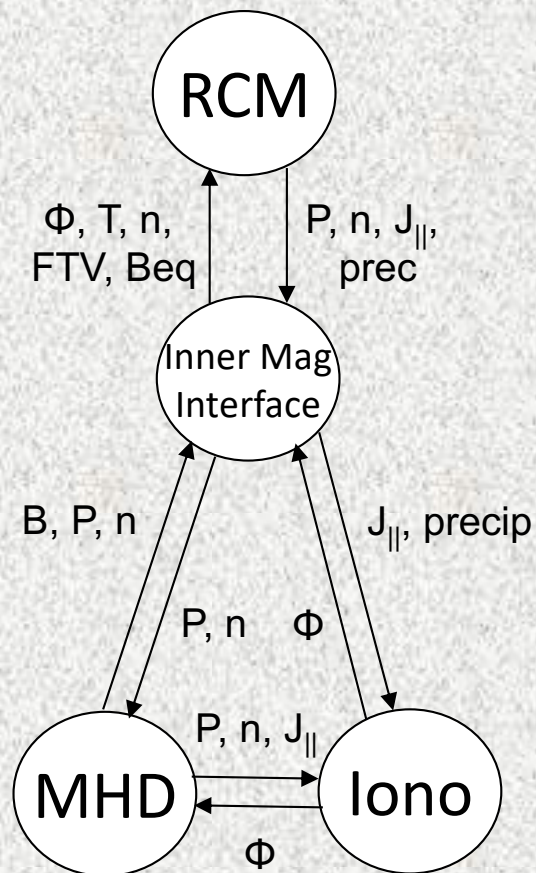
- Version 4 has been hosted at CCMC since 2011
- Version 5.0 recently made available
  - RCM two-way coupling
  - More mature (behind-the-scenes fixes)
  - Modularized OpenGGCM based on LIBMRC



The screenshot shows the top portion of the CCMC website. At the top is a dark banner with the CCMC logo (an orange circle with a white dot) and the text "Community Coordinated Modeling Center" in white. Below the banner is a navigation menu with five items: "About", "Models", "Simulation Services", "Validation", and "Community Support", each followed by a downward-pointing chevron. Below the navigation menu is a light blue informational box with a dark blue circle containing a white "i" icon, followed by the text "Welcome to the new CCMC website!". Below this is a paragraph of text: "Please note that some pages may have moved during the migration. If you experience reach out to [gsfc-ccmc-support@lists.hq.nasa.gov](mailto:gsfc-ccmc-support@lists.hq.nasa.gov)." Below the informational box is a breadcrumb trail: "Home > [Model Catalog](#)". Below the breadcrumb trail is the text "OpenGGCM" in a large, bold, black font, followed by "Version: 5.0" in a smaller font. At the bottom of the page is a blue button with a white right-pointing arrow and the text "Runs-on-Request".

# RCM two-way coupling

Improved representation of pressure, magnetic field, region 2 currents

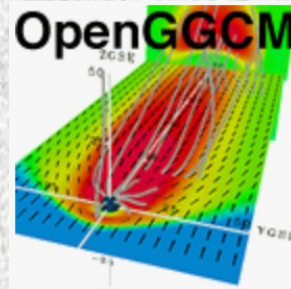


# Research in last 24 years

- Kelvin-Helmholtz
  - Kavosi, S., Spence, H. E., Fennell, J. F., Turner, D. L., Connor, H. K., & Raeder, J. (2018). **MMS/FEEPS observations of electron microinjections due to Kelvin-Helmholtz waves and flux transfer events: A case study**. JGR, 123, 5364– 5378. doi:10.1029/2018JA025244
- Ionosphere
  - Ferdousi, B., J. Raeder, E. Zesta, W. Cramer, and K. Murphy (2021), **Association of Auroral Streamers and Bursty Bulk Flows During Different States of the Magnetotail: A Case Study**. JGR, 126(9), doi:10.1029/2021JA029329.
- Reconnection
  - Boudouridis, A., Connor, H. K., Lummerzheim, D., Ridley, A. J., & Zesta, E. (2021). **Changes in the magnetic field topology and the dayside/nightside reconnection rates in response to a solar wind dynamic pressure front: A case study**. JGR, 126, e2020JA028768. doi:10.1029/2020JA028768
- Geomagnetic Storms
  - Maharana, A., Scolini, C., Raeder, J., and Poedts, S.: **Predicting geo-effectiveness of CMEs with EUHFORIA coupled to OpenGGCM**, EGU General Assembly 2021, doi:10.5194/egusphere-egu21-9854, 2021.
  - Tulegenov, B., Raeder, J., Cramer, W., Ferdousi, B., Fuller-Rowell, T., Maruyama, N. (2020), **Storm time polar cap expansion: IMF clock angle dependence**, Ann. Geo.
- Other magnetospheres / Multi-fluid
  - Wang, L., Germaschewski, K., Hakim, A., Dong, C., Raeder, J., & Bhattacharjee, A. (2018). **Electron physics in 3-D two-fluid 10-moment modeling of Ganymede's magnetosphere**. JGR, 123, 2815– 2830. doi:10.1002/2017JA024761
- Data assimilation with NCAR/DART

# Model Info/ Access

- CCMC
- GitHub repository  
([github.com/unh-hpc/openggcm](https://github.com/unh-hpc/openggcm))
- Wiki ([openggcm.sr.unh.edu](http://openggcm.sr.unh.edu))



## OpenGGCM

- Home Page
- Model Information
- Using the Model
- Publications
- Development
- Old Wiki

## Collaboration

- SAPS
- Extreme Space Weather
- Bubble Injections

## PmWiki

- Initial Setup
- Tasks
- Basic Editing
- Documentation
- Index
- PmWiki FAQ
- PmWikiPhilosophy
- Release Notes
- ChangeLog

[Main](#) /

## Using the Model

The OpenGGCM can either be run at the source code.

Requesting a model run

- [Run on demand](#) at the CCMC (Corr

Running a local copy of the model

- [Basic rules](#)
- [Installing the model](#)
- [Preparing the model](#)
- [Preparing model inputs](#)
- [Starting a run](#)

Tools and information

- [Output file specifications](#)
- [Various scripts for input data prepar](#)

Model Info/Use

Collaborative Projects



# Under Development

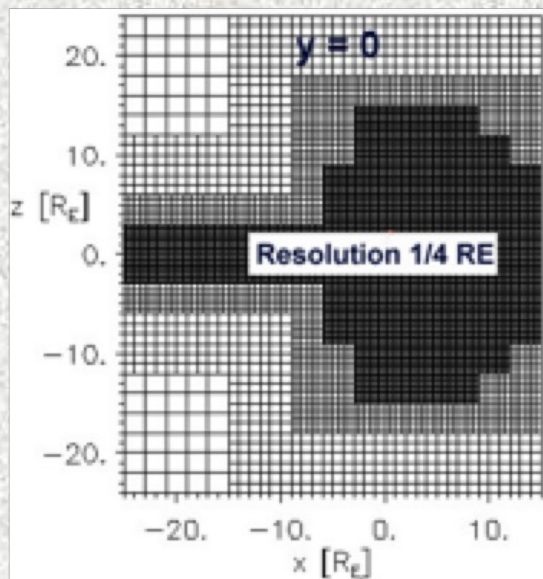
- CRCM/CIMI coupling
- IPE integration
- Dipole rotation
- New visualization tools
- Static mesh refinement
- New MHD / Hall-MHD solvers
- Coupling with gkeyll to provide multi-fluid capabilities
- Flexibility to simulate systems other than Earth

*Possible incremental updates to CCMC to provide access to other control parameters or output formats, if demand exists*

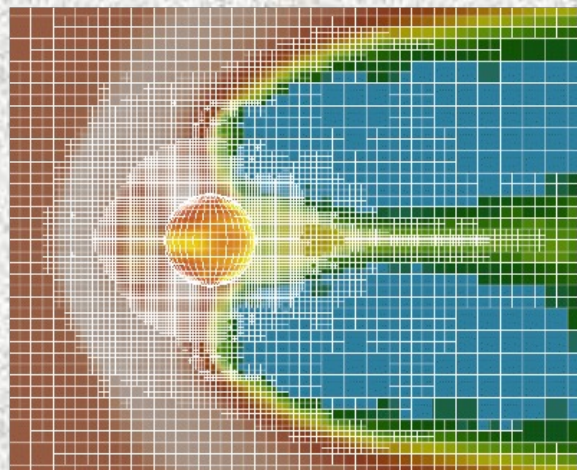
# Extra Slides

# MHD Model Grids

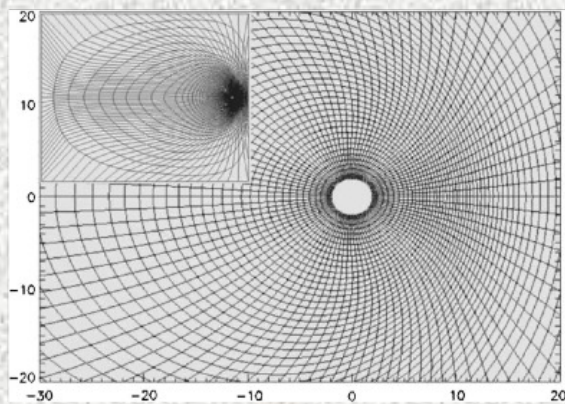
BATS-R-US



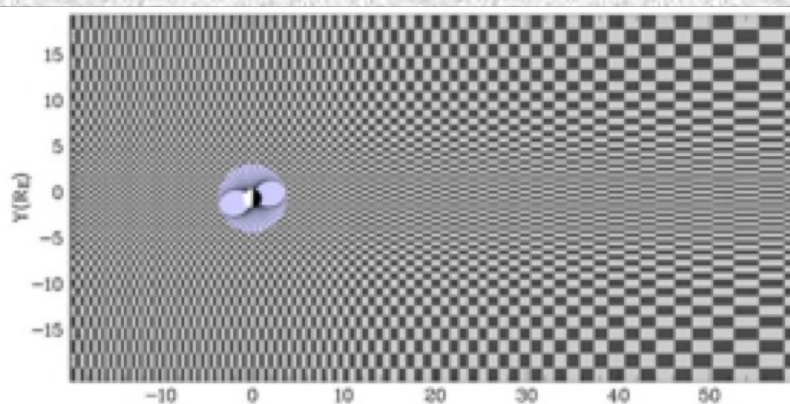
GUMICS



LFM



OpenGGCM



(from Komar, 2011)