

# **Modeling: New Challenges and Approaches**

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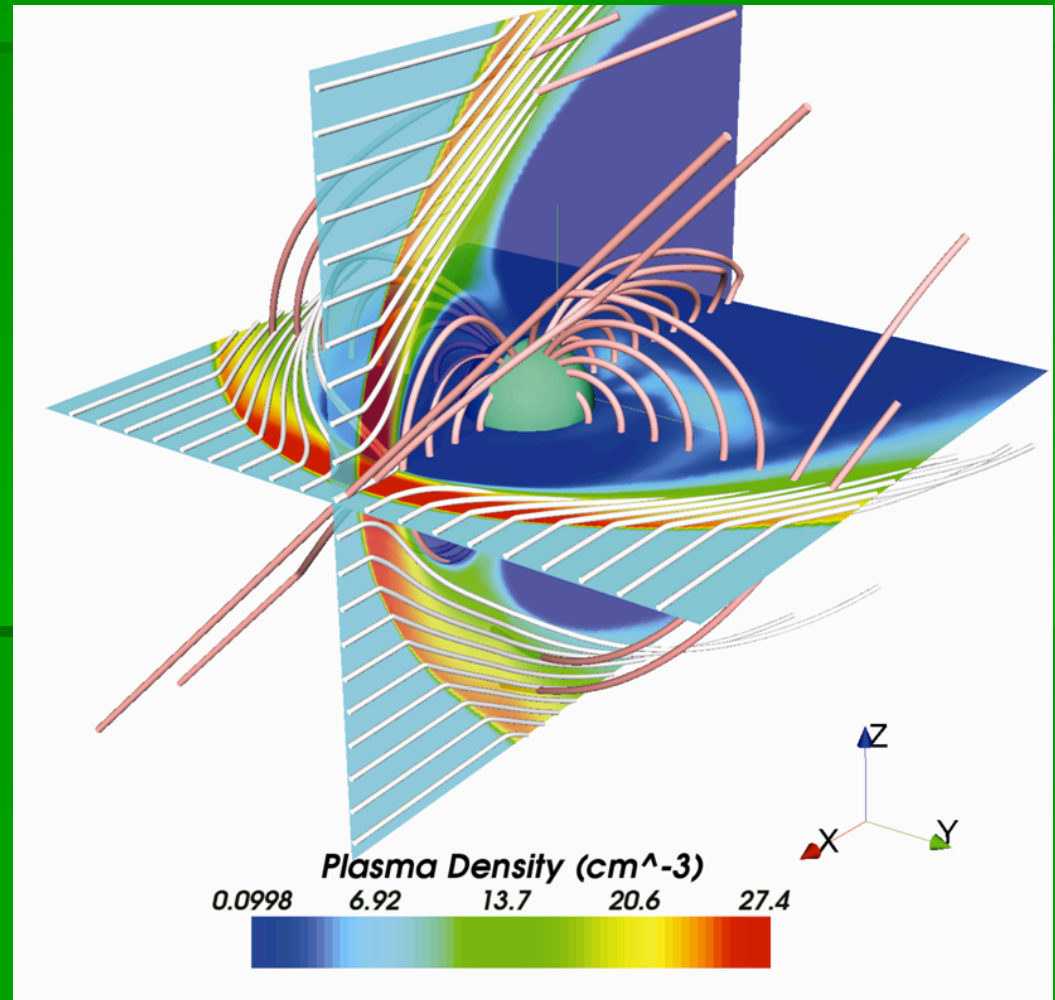
Advisor: W. Jeffrey Hughes

# In a nutshell

- The new challenge is the old challenge: Make a representation of the geospace environment that balances
  - Accuracy (should we model the Lorentz trajectory of every single particle in the system?) and
  - Speed (hmm... that may not be computationally feasible)

# Zoom Out: MHD

- Plasma = fluid
- No minimum spatial resolution
- Fluid equations invalid at scales  $<$  ion scale lengths ( $\sim 10$  km at  $3 R_E$ )



Dorelli et al. [2007]

# Zoom In: PIC codes

High maintenance



A PROFESSIONAL  
PARTICLE MODEL

by Andrew Jordan

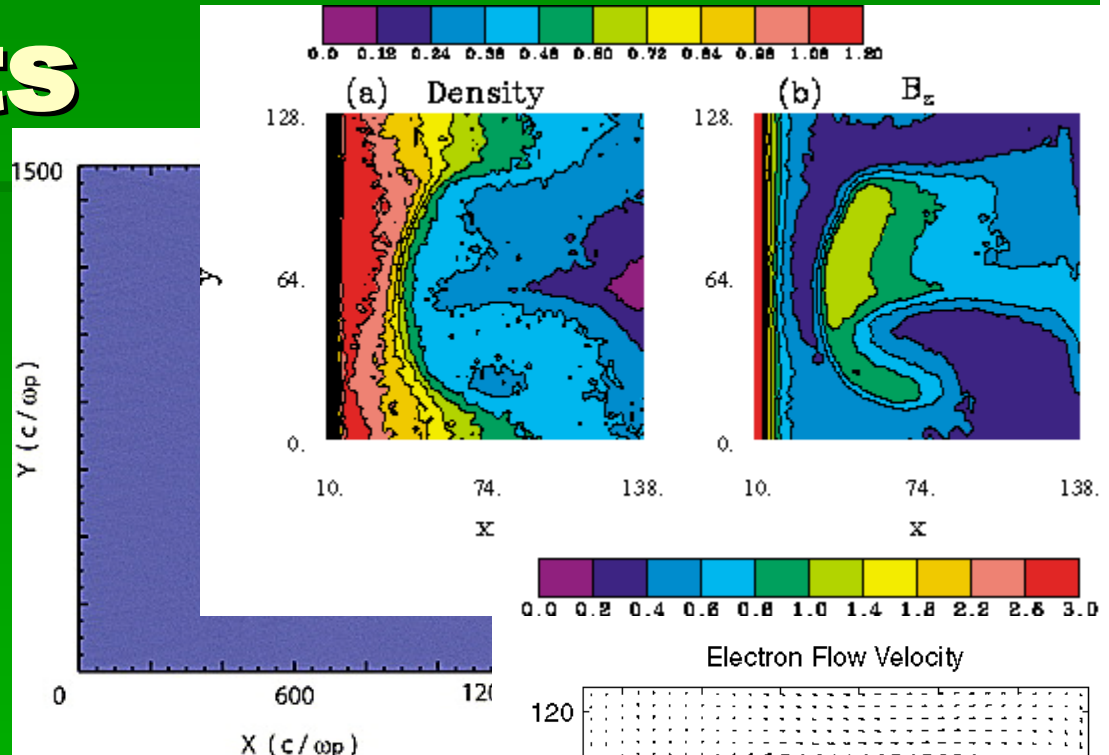
- Look at complicated processes on very small scales
  - Waves & instabilities
  - Reconnection
  - And more...

# Approaches:

- Pushing old methods to new heights
- Coupling of models in different regions
- Inclusion of improved physics
- Moving beyond model development to improve analysis and availability of model results

# Pushing old methods to new heights

- 2-D and even 3-D global hybrid simulations
  - Shock (FG-3)
  - Future: ring current? Or ion outflow?



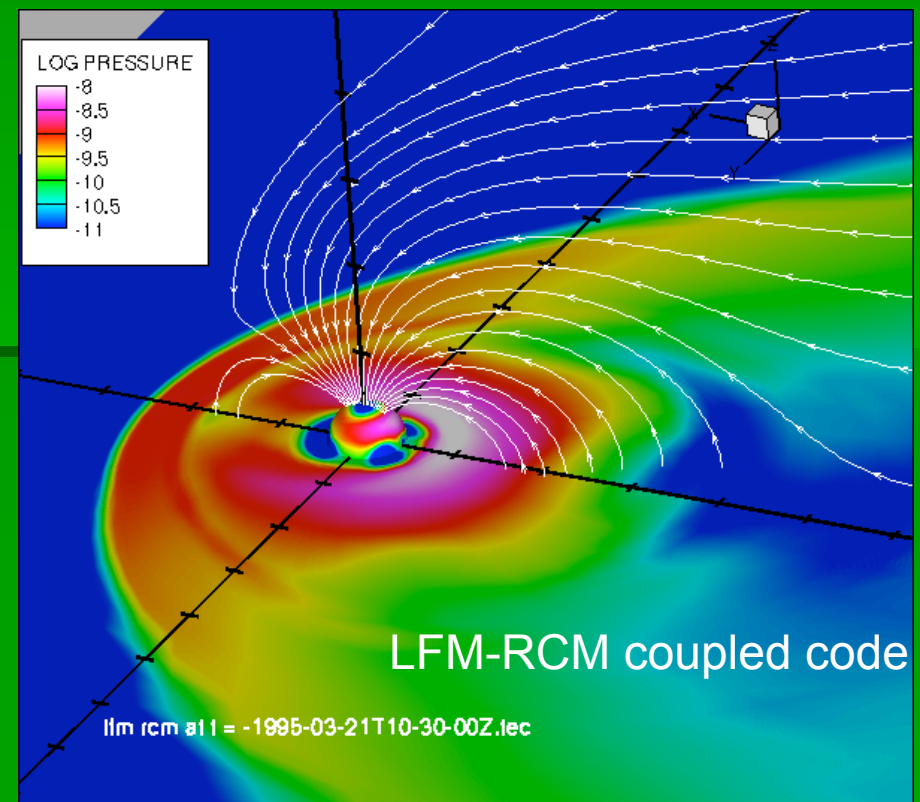
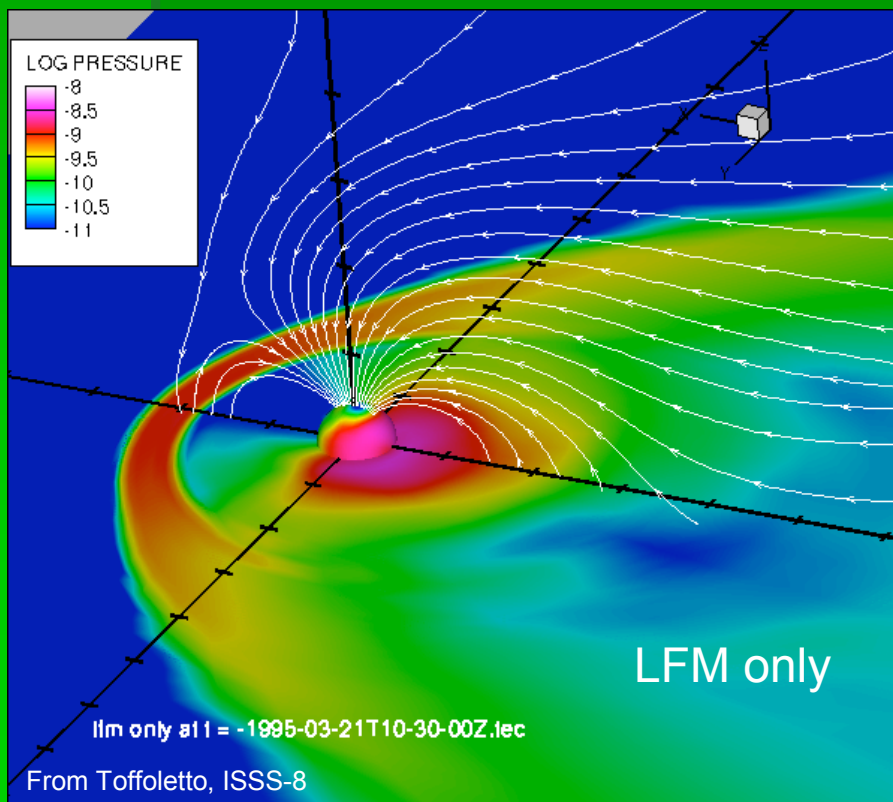
From Omidi, Blanco

- PIC simulations of the magnetotail

From Pritchett and Coroniti [2000]

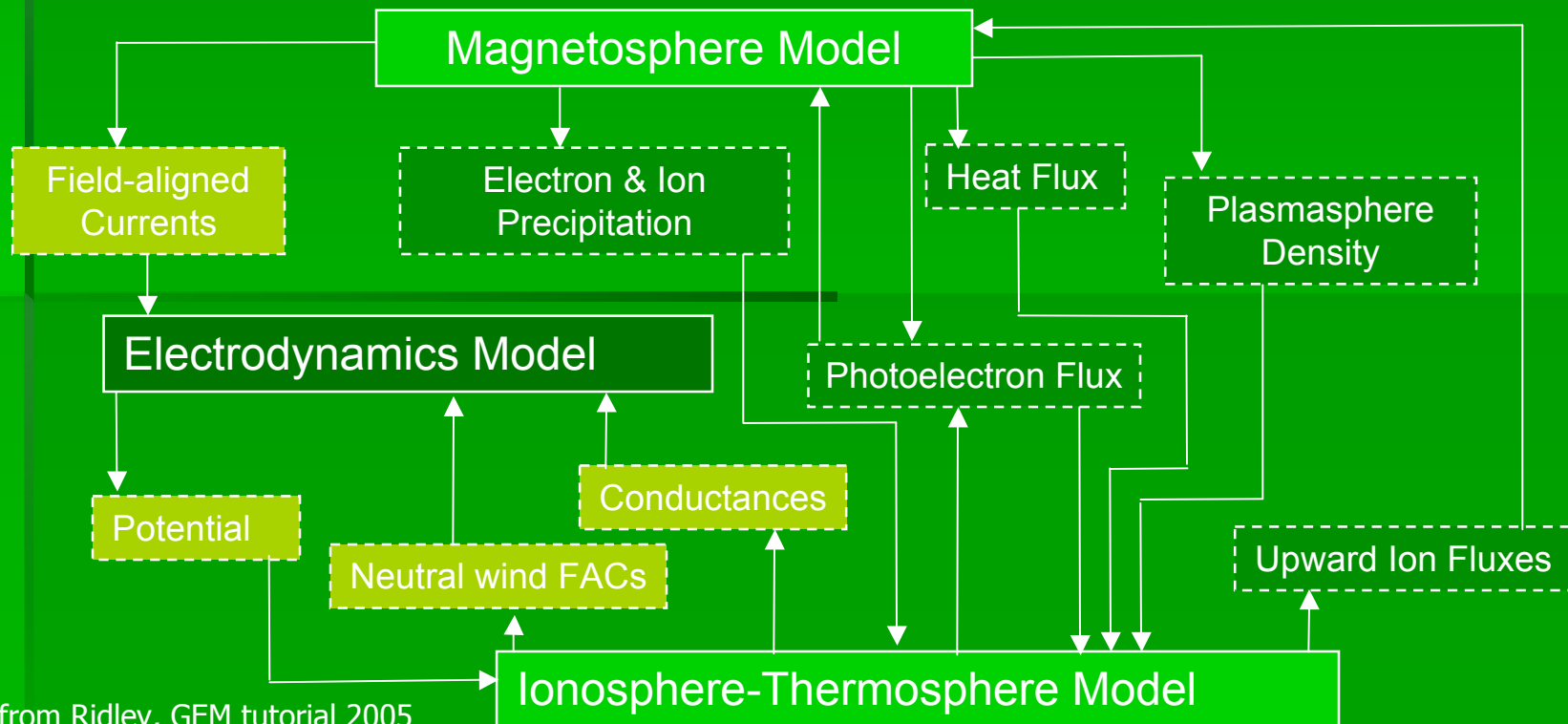
# Coupling of models in different regions

- MHD-Ring Current Physics: Focus Group-8



# Coupling of models in different regions

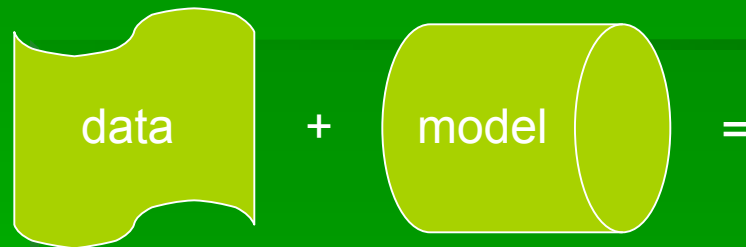
- MHD-Ring Current: Focus Group-8
- M-I coupling: Focus Group-7



Modified from Ridley, GEM tutorial 2005



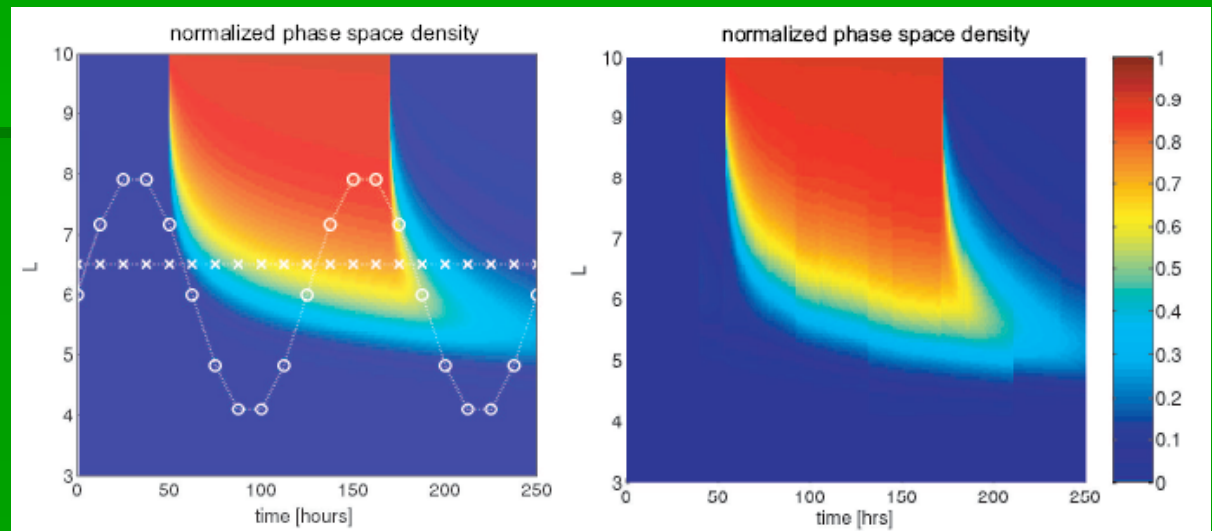
# Data assimilation



a perfect description  
of life in the  
magnetosphere!

## ■ How do you incorporate data self-consistently into a model?

- ▣ Mass conservation
- ▣ Energy conservation
- ▣ Introduction of noise



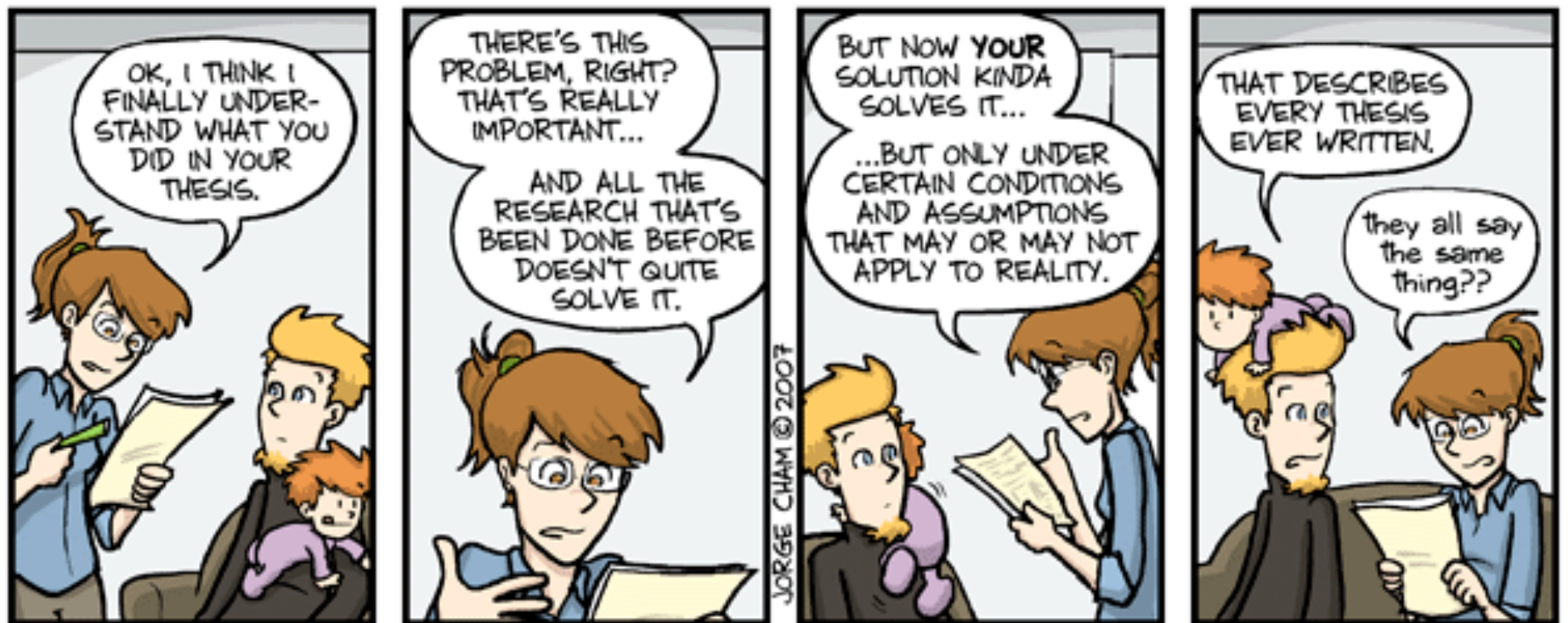
from Koller, Friedel, and Reeves

# Inclusion of improved physics

- Ideal or resistive MHD
  - Single fluid
  - Isotropic pressure
  - $\vec{E} = -\vec{v} \times \vec{B} (+\eta \vec{j})$
- Improvements:
  - anisotropic pressure:  $\bar{P} \neq P$
  - Hall MHD:  $\vec{E} = -\vec{v} \times \vec{B} + \eta \vec{j} + \frac{1}{en} \vec{j} \times \vec{B} - \frac{1}{en} \nabla P_e$ 
    - e.g. for improved modeling of reconnection Focus Group-2
  - Multi-fluid MHD

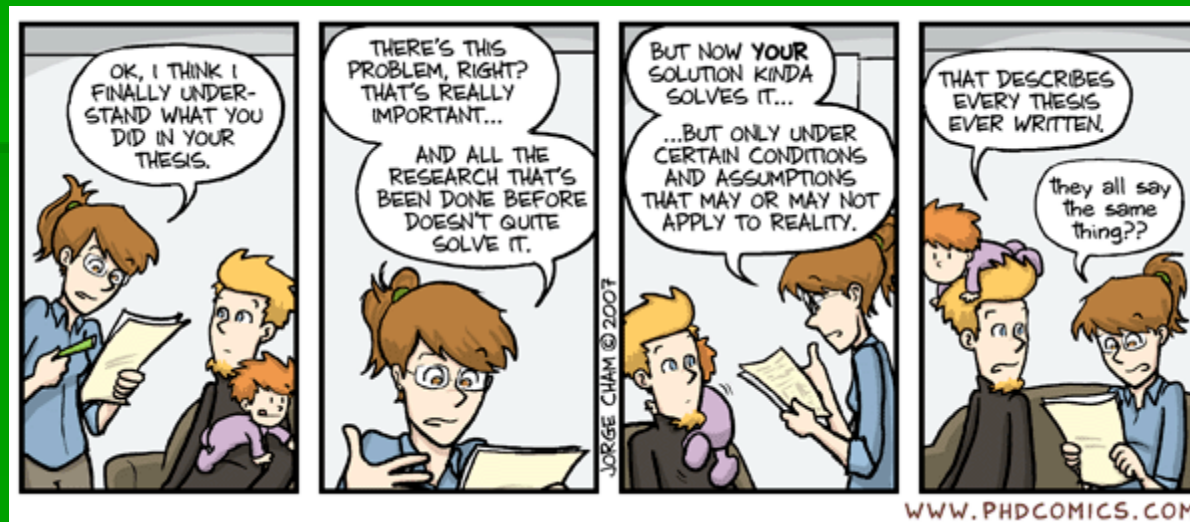
# Beyond model development

- Validation & Metrics: Focus Group-1



# Beyond model development

- Validation & Metrics: Focus Group-1
- Accessibility, e.g. CCMC
- Analyzing model results

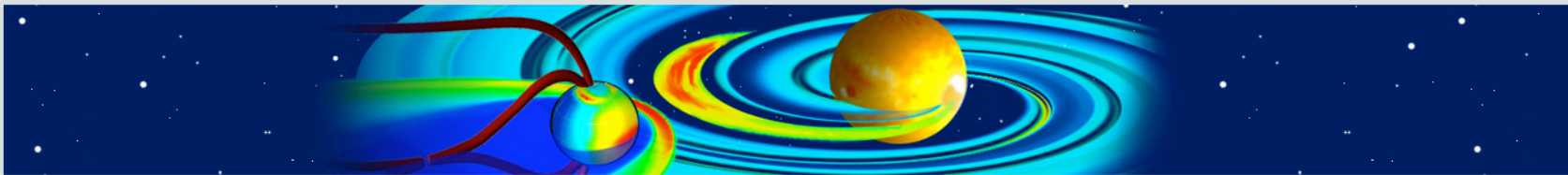


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CCMC now has additional 3D visualization options available for BATSRUS/SWMPF and UCLA-GGCM/OpenGGCM runs. The new visualizations, created using Space Weather Explorer (an OpenDX-based application) can all be exported as VRML. New plot modes include 3D flowlines as tubes, slices and surface plots both with and without contour lines (shown in 3D), and combinations of flowlines and slice/surface plots.

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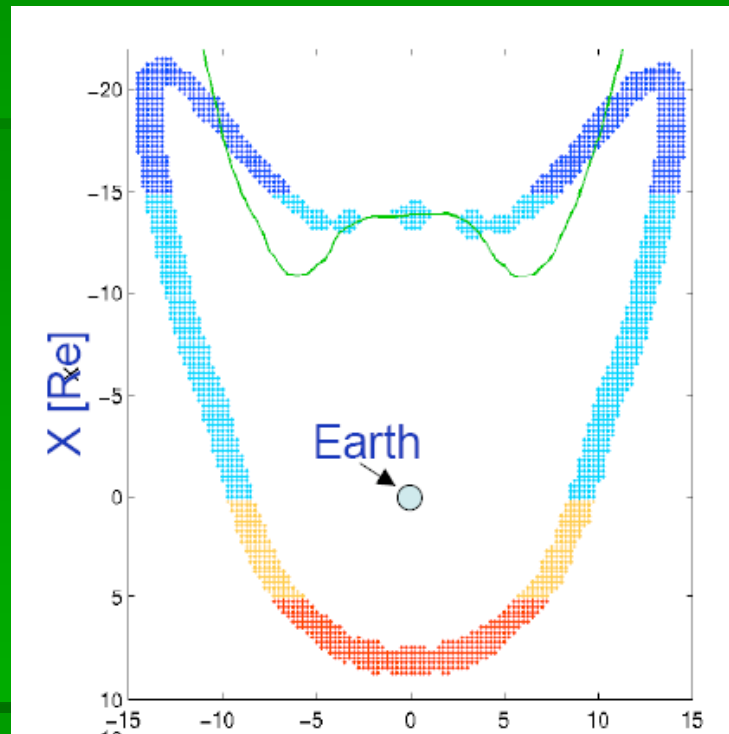


Curator: Ms. Anna Chulaki | NASA Official: Dr. Michael Hesse | [Privacy, Security Notices](#)

<http://ccmc.gsfc.nasa.gov/>

# Analysis beyond the “big picture”

- Where is reconnection occurring? →
- Energy budgeting
- Polar cap potential saturation



From Pulkkinen, GEM tutorial 2006

- Go beyond examining the numbers that come directly out of the codes

# Conclusion

- Old: Individual model development
- New: A synthesis of models or models and data
- Old: Taking the code output at face value
- New: Creativity in validation and extracting science from codes
- Tuesday 8:15 - GGCM Tutorial:  
Jimmy Raeder, UNH: "Quo Vadis, GGCM?"

# Acknowledgements

- Many thanks to:
  - Michael Hesse, George Siscoe, Mike Liemohn, Nick Omid, Jimmy Raeder