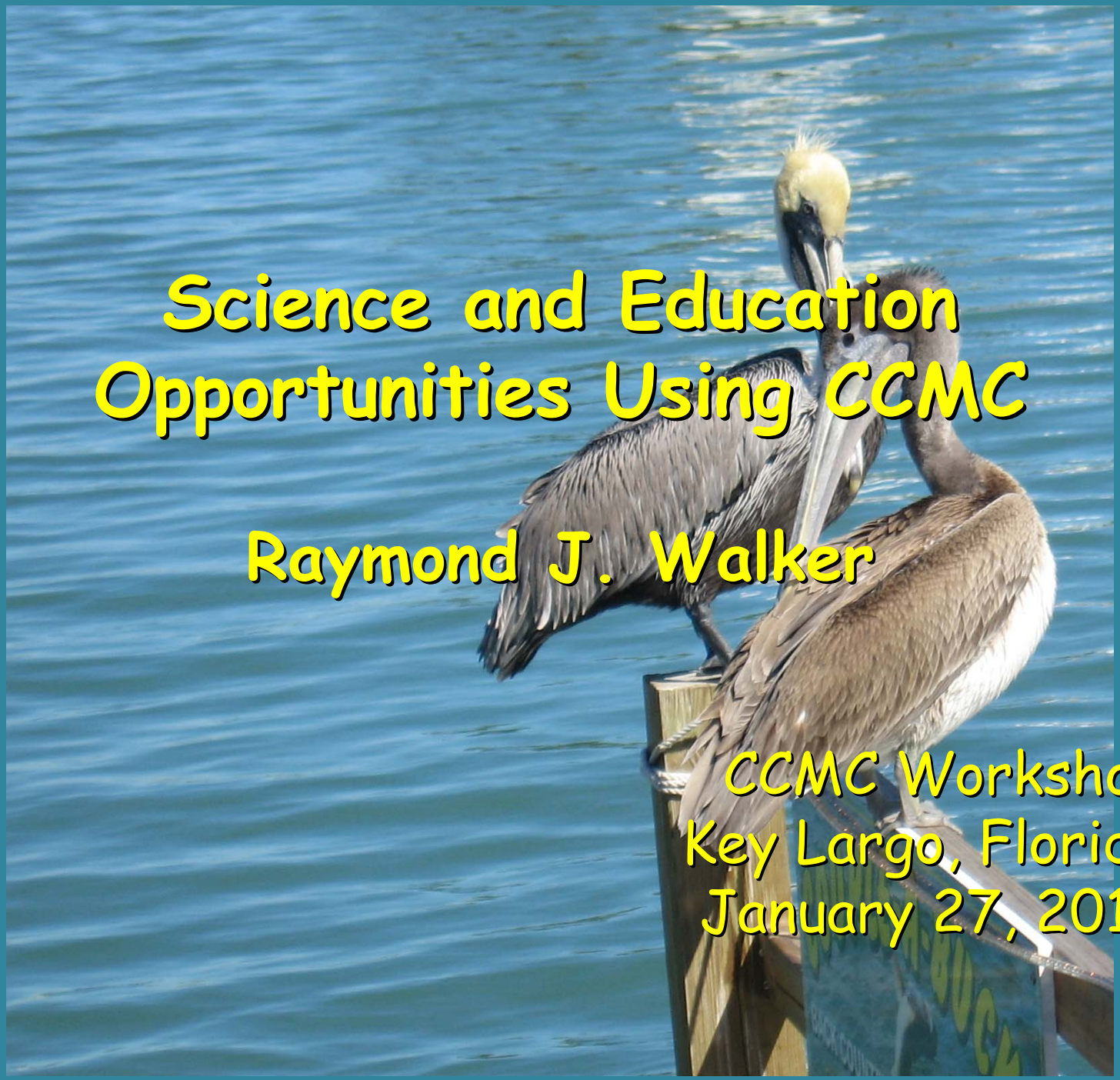


Science and Education Opportunities Using CCMC

Raymond J. Walker

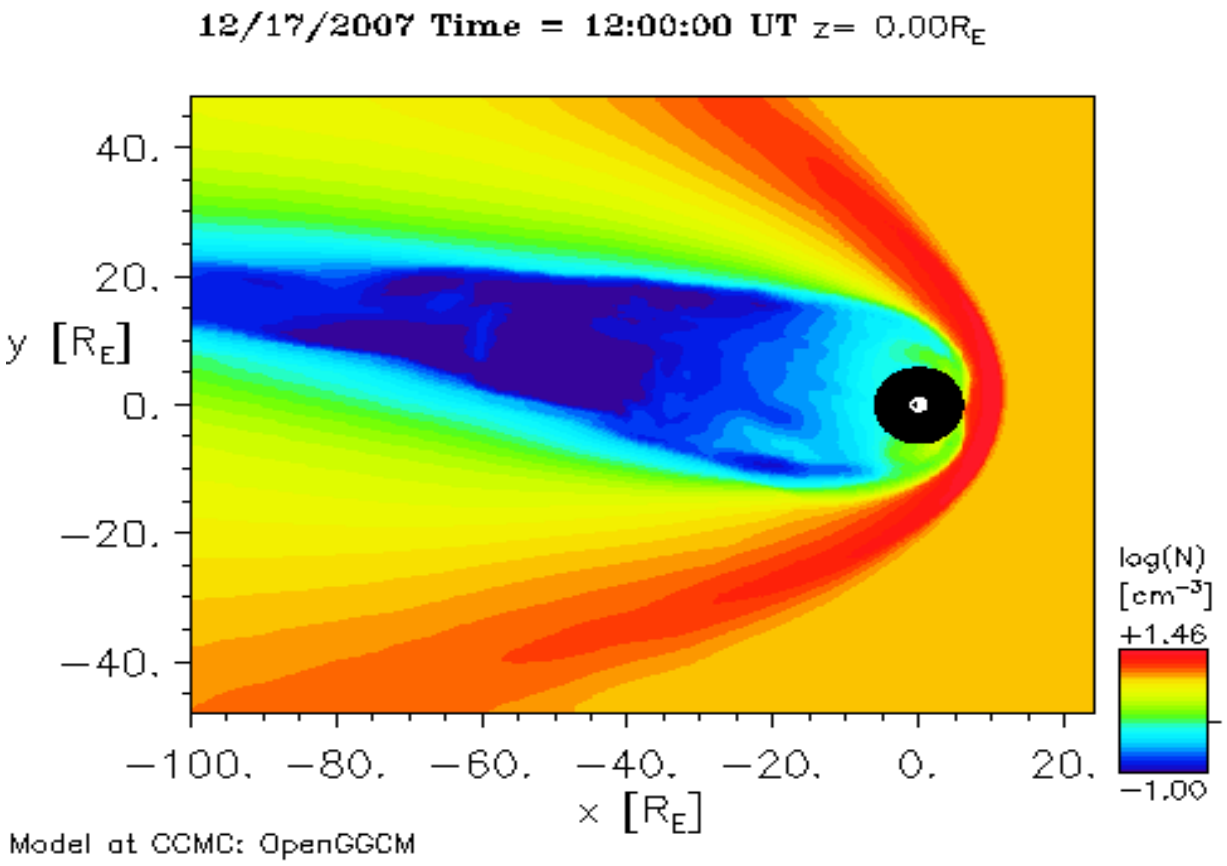
CCMC Workshop
Key Largo, Florida
January 27, 2010

Simulations and Lower Division Education

- Next quarter I will teach a freshman course on the "Perils of Space".
- CCMC now has a large archive of runs which in principle can be useful in education.
- Simulations can be useful for
  - Demonstrating basic ideas
  - Visualizing complex systems
  - Showing time dependencies

Demonstrating a Basic Idea - Courtesy of Martin Connors

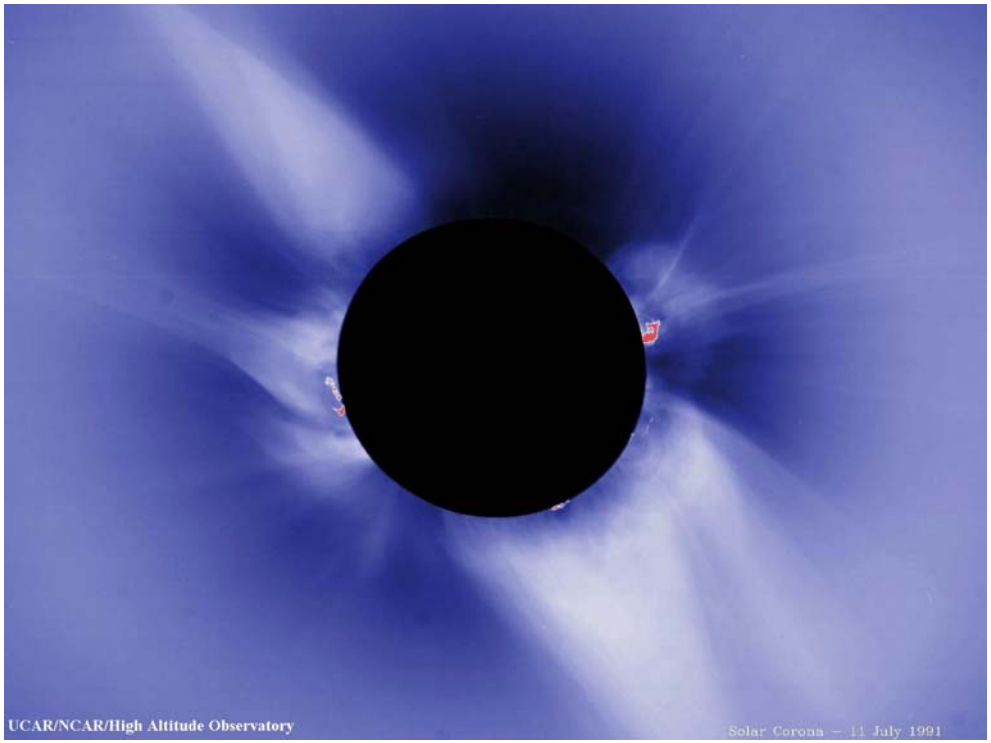
Compression at the Bow Shock

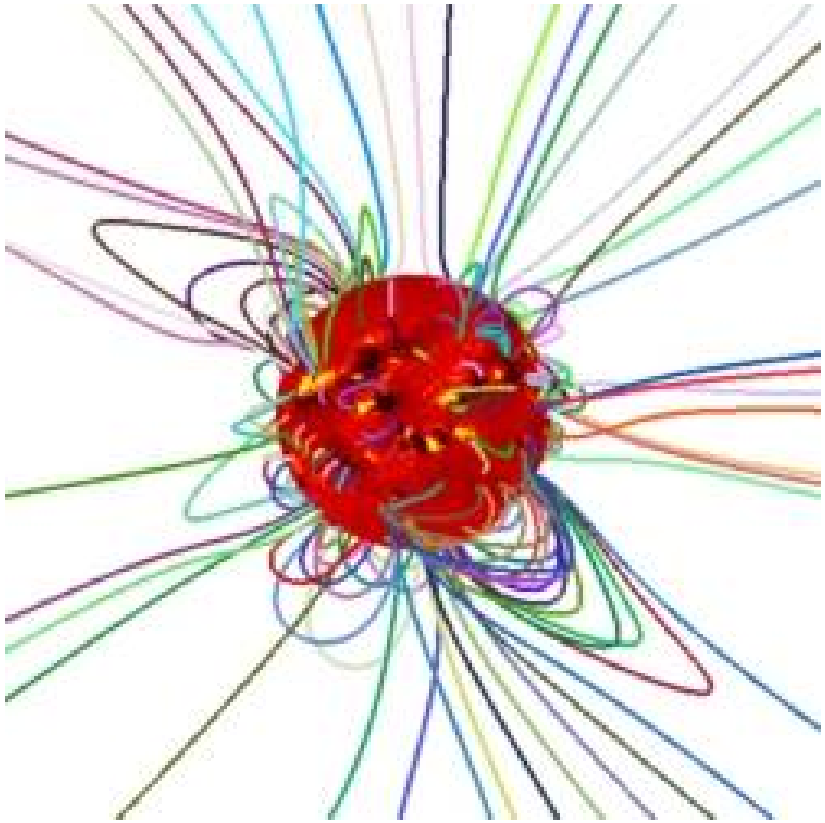


The supersonic solar wind compresses the front side of the magnetosphere and shocked compressed solar wind forms the *magnetosheath*. *Inside* the magnetosphere, the magnetic field dominates and density is low.

Visualize Complex Structures

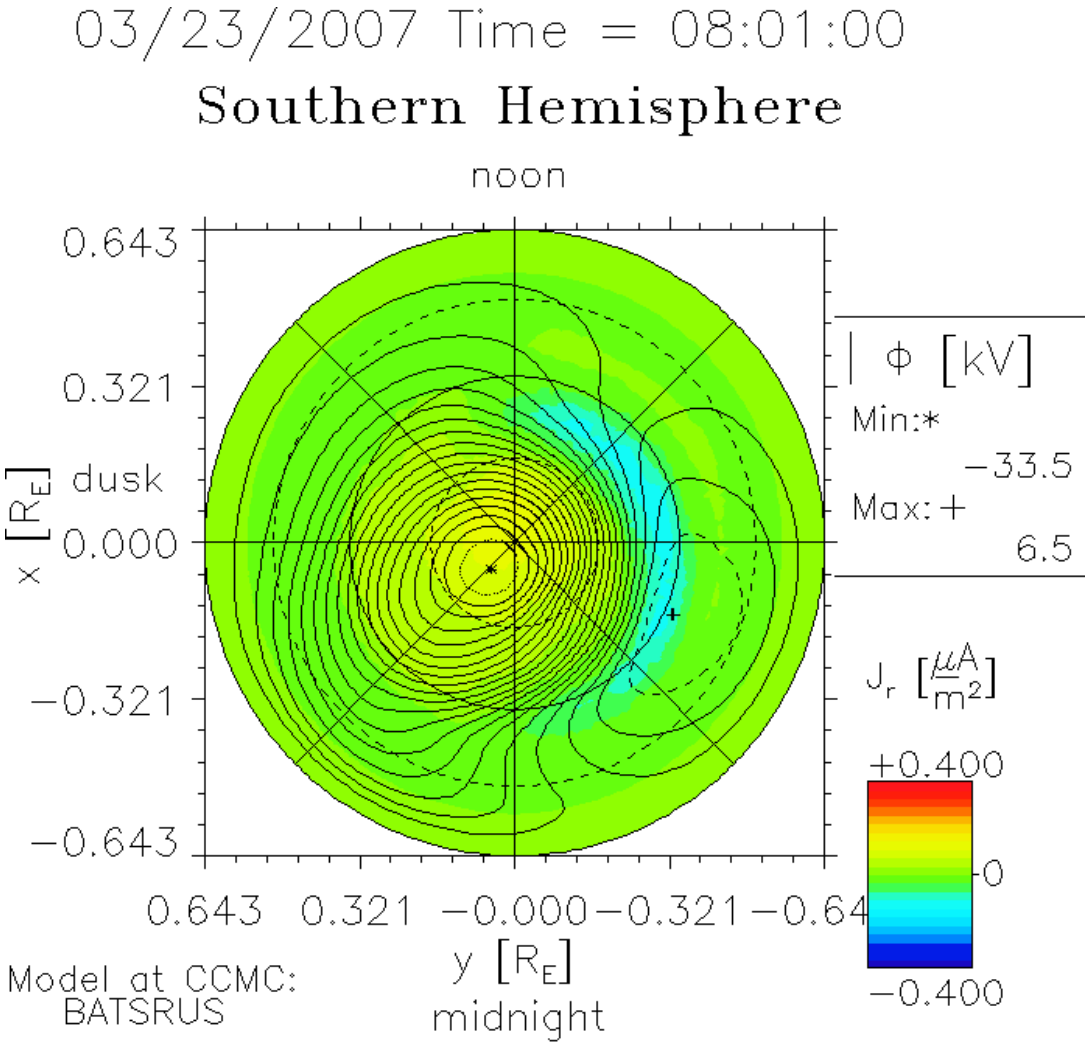
- Space is intrinsically three dimensional.
- Difficult to visualize unless you are a very good artist.





Understand Time Dependencies

- Space physics systems are intrinsically time dependent.



The CCMC Archive

- The CCMC archive of runs is not easy to use if you are looking for good examples for teaching.
- Only the "Global Magnetospheric Models" web page explicitly calls out runs that are useful for education.
- It would be helpful if the web pages for the other disciplines called out useful examples.

The Casual Simulation User

- With the advent of easy to obtain simulations at CCMC a new type of user has been created.
- Data analysts now regularly use simulations to interpret their observations.
- The user frequently knows little about how simulations work.
- Simulations are used as black boxes with little understanding of their strengths or limitations.
- A similar situation occurs with data analysis techniques – with easy to use software (MATLAB, IDL) it is possible to carry out complex analyses without understanding the underlying mathematics.

A Simulation Course for Data Analysts

- **Course goal is to make students into critical simulation users.**
- I am not trying to teach students to become simulators although some simulation students have taken the classes.
- It is not a course in simulation techniques although we discuss them.
- We want students to have a feeling for both the strengths and limitations of simulations.
- Course is based on a current space physics problem that is being addressed by using simulations.
- We study the science problem and the simulations that are being used to address the problem.
- The course covers a lot of material and is fairly intensive.

Syllabus
"Simulating a Space Weather Event"

March 31 Why Study Space Weather?

April 7 Humans and Space Weather

April 9 Basics of Magnetic Storms

April 11 CMEs

April 14 CIRs

April 16 Differences between CME and CIR Storms

April 23 Space Weather Forecast Models (Costello Geomagnetic Activity Index, Relativistic Electron Forecast, Wang Sheeley, Total Electron Content model)

April 28 Space Weather Forecast Models continued

May 2 Introduction to simulation codes

May 5 Introduction to MHD models

May 7 Introduction to CCMC

May 12 The importance of accurate solar wind

May 14 ENLIL (solar wind model)

May 23 Magnetospheric models

May 28 Inner Magnetosphere

May 30 Modeling from the Sun to the Earth

June 2 Modeling a CME

June 4 Modeling a CME at Earth

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The Course

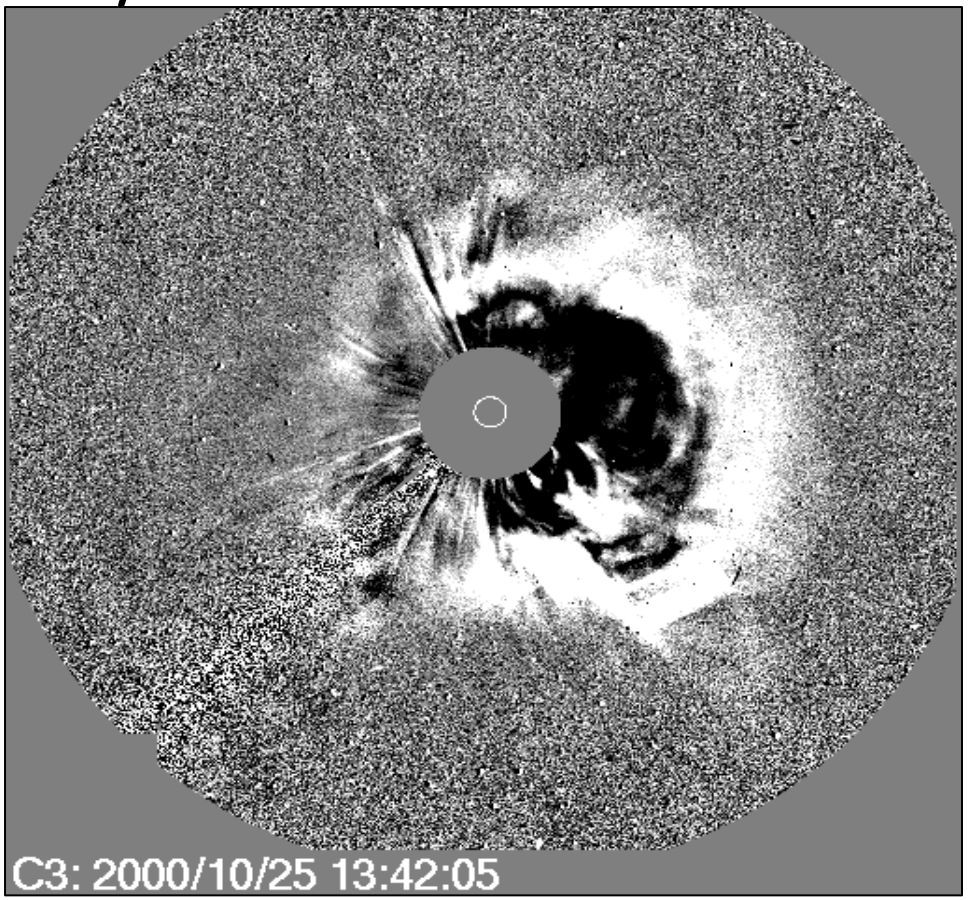
- Four students took the class (Megan Cartwright, Marissa Vogt, Katherine Ramer, Ye Gao).
- Each gave one lecture (2 hours) and the last two classes were group exercises.
- I gave the rest of the lectures.
- Students selected as their goal simulating a CME, propagating it to the Earth and analyzing its effects on the magnetosphere.
- A couple of students had taken a previous class on simulations.
- A tremendous amount of help from people at CCMC (Masha Kuznetsova, Aleksandre Taktakishvili, Peter MacNeice)

What the Students Did

- Studied Halo CME on October 25, 2000
- Used three simulation codes
  - ENLIL with cone model
  - BATS-R-US model using ENLIL with cone model results as input
  - BATS-R-US model using ACE observations as input
  - Ran BATS-R-US with Fok model ring current
  - Ran BATS-R-US with Rice Convection Model

October 25, 2000 Halo CME

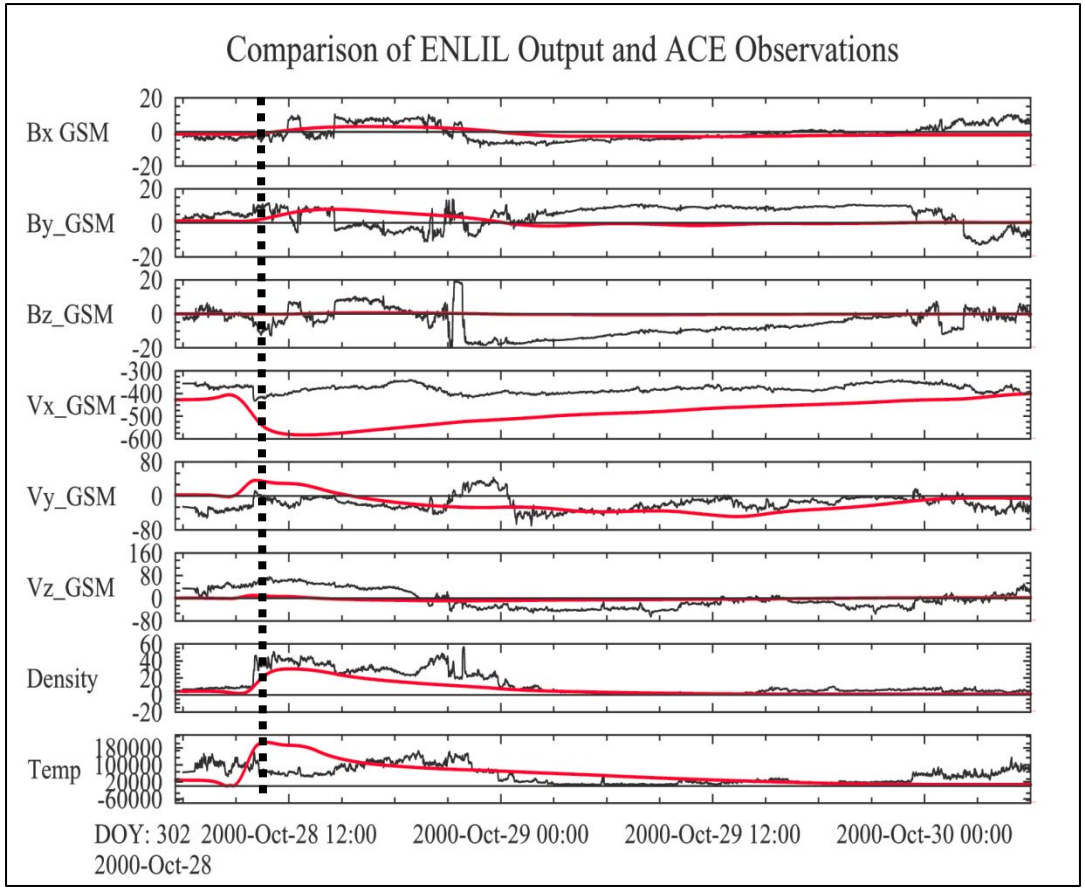
- Good magnetogram coverage
- Associated interplanetary magnetic cloud
- Not previously modeled



LASCO Observations on Oct. 25

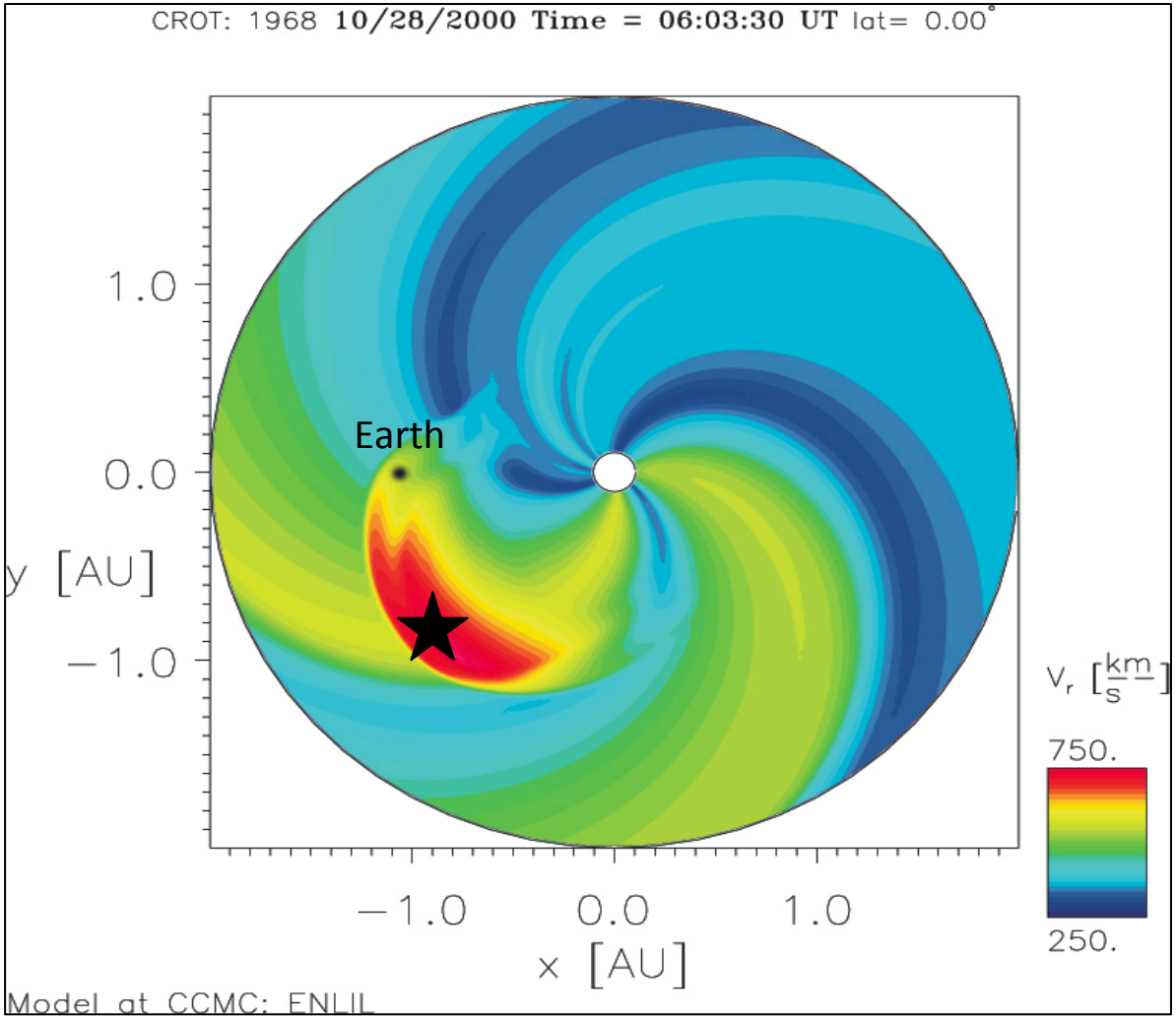
ACE Observations and ENLIL Output

- ENLIL CME arrived 14 h earlier than observed.
- ENLIL results were shifted for comparison with data.
- Shifted results used for input to BATSRUS.
- Output does not reproduce observed shock or magnetic cloud well.



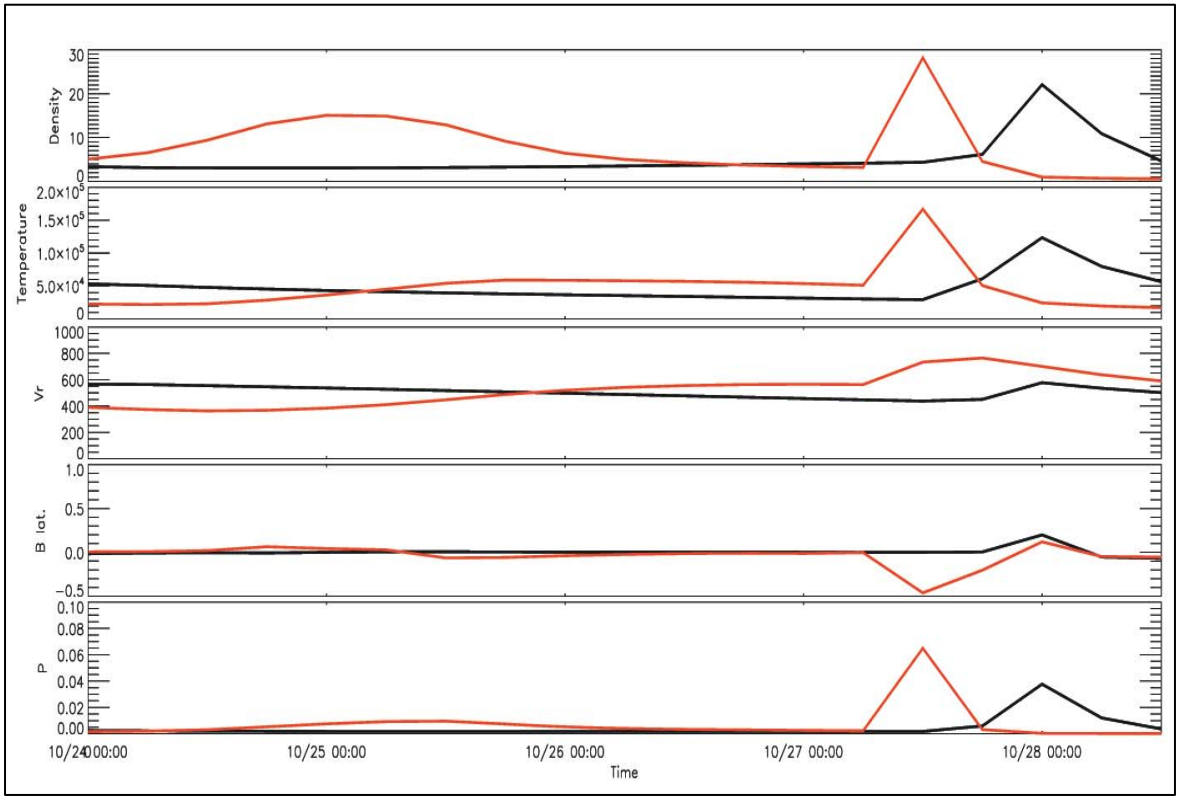
The CME at Earth

- Radial velocity from ENLIL
- Black dot shows location of Earth
- Grazing impact
- Similar results from density and magnetic field
- The star is the "core of the CME"

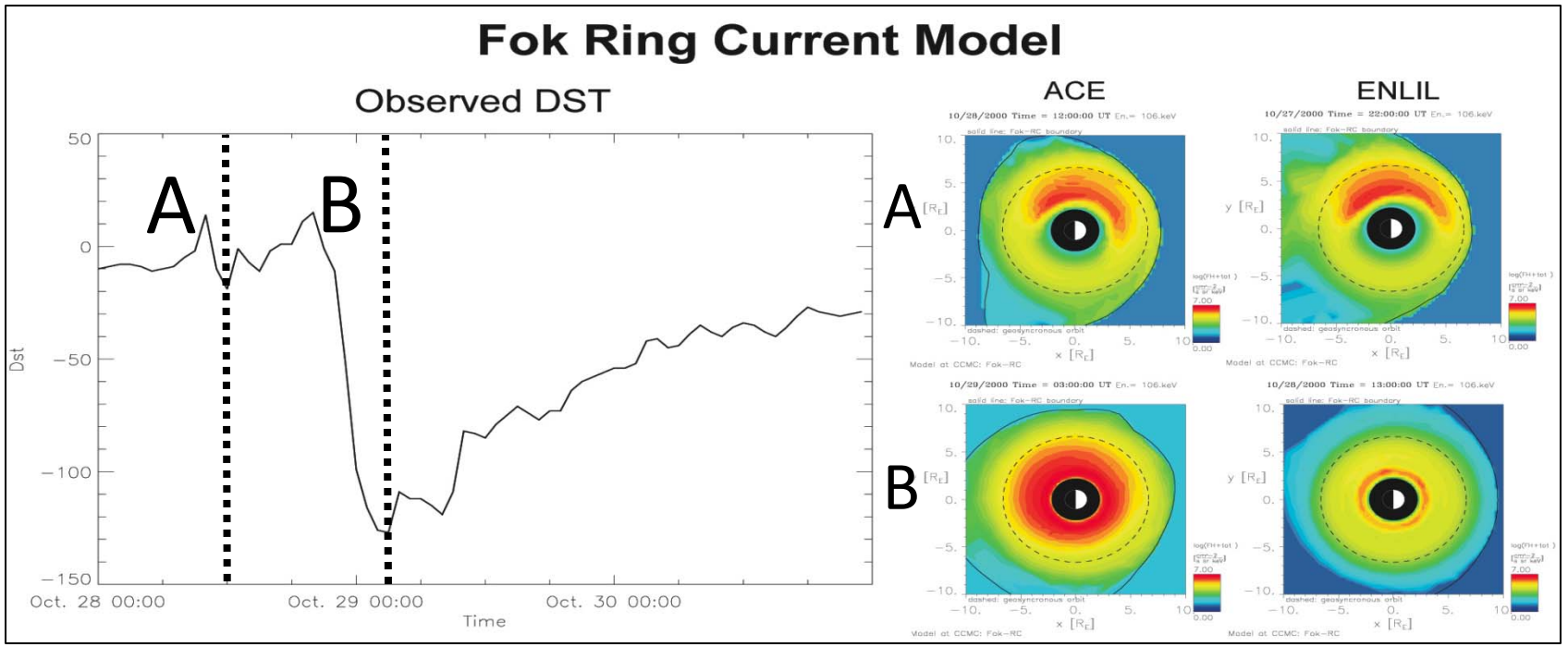


Comparison of ENLIL at 1AU (Earth and Core)

- Parameters at the Earth - black
- Parameters in the core – red
- Temperature and velocity higher in the core.
- B_z<0 in core



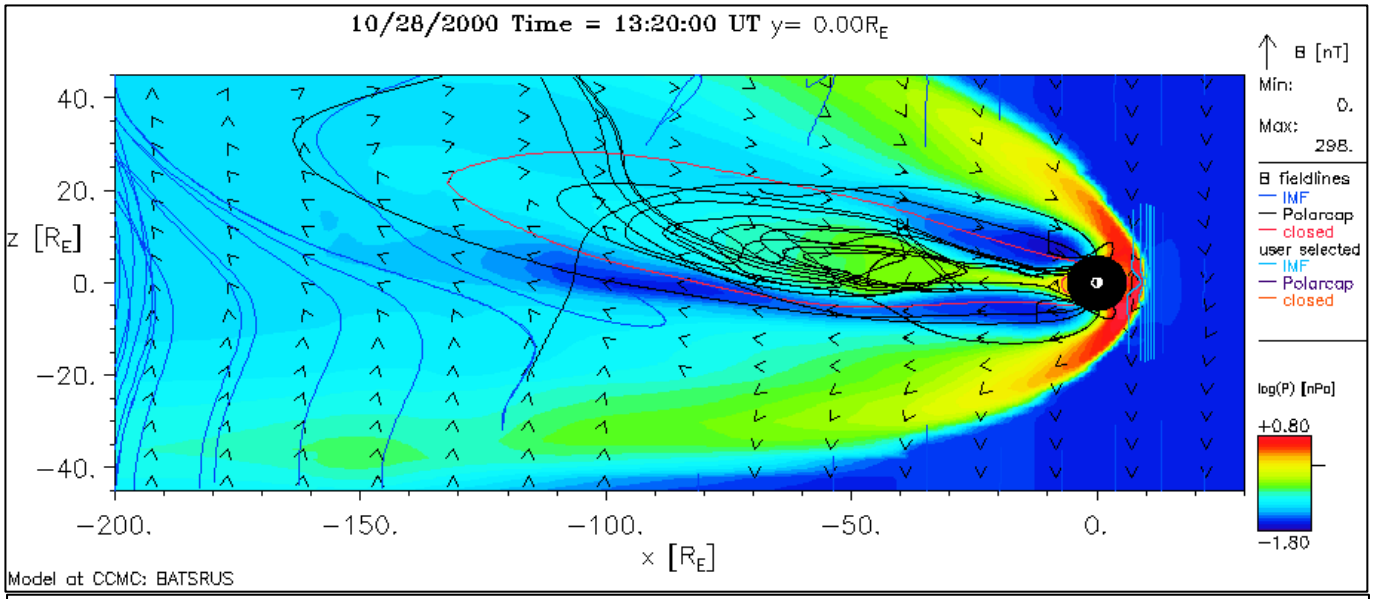
The Magnetosphere – Fok Ring Current



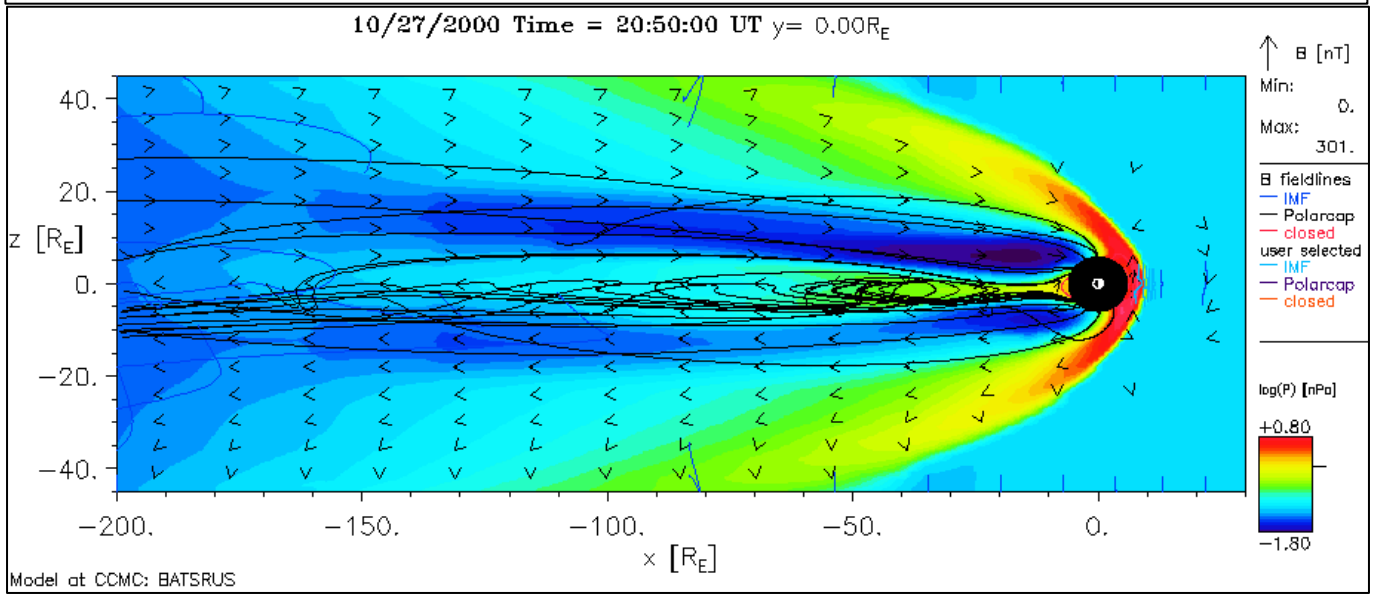
- Differential flux at 106 keV.
- Dashed circle is synchronous orbit
- Solid line is outer limit of Fok model
- Stronger ring current forms when driven by ACE data.

ACE and ENLIL Driven Simulations

ACE



ENLIL



Afterword

- The students ran out of time before they finished the study using the Rice Convection Model.
- The students presented a poster on their simulation at GEM.
- They realized that much more needed to be done and came up with reasonable simulation and analysis plan to further evaluate the models.

Lessons Learned - Students

- Came away with a better feel for how simulations work, their strengths and weaknesses – they became critical users.
- Came away with a better understanding of how hard it is to develop a model from Sun to Earth.
- Wanted more time to work with the simulations.

Lessons Learned - Instructor

- Would reduce the amount of time spent on scientific background – the students were fairly well informed already.
- Would select the event earlier.
- Would spend more time on the principles of simulations – 8 hours was not enough.
- Would spend more time on details of the codes being used – 8 hours was not enough.
- Could have used more than one quarter.
  - It was a lot of work.
  - Both students and instructor would have liked to carry out other numerical experiments.
- Definitely would do it again.


Thank You