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Using CCMC Space Weather Modeling Resources in a Classroom

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AOSS 477: Space Weather Modeling

- U-M offers a senior-level course in space weather modeling
  - Taken by all Space Weather concentration students in our ESSE BSE degree program
  - Also taken by a fraction of the space physics PhD students
  - Also taken by a few M-Eng in Space Engineering students
- We've taught it 5 times now
  - Elevated to an every-year offering
  - Enrollment varies from 7 to 14
  - Seems reasonable but I would like it be higher

What is it about?

- ***Using*** state-of-the-art space weather models
  - Not really a programming course
  - We have a different one for that
- Synthesis, capstone course for the undergraduates
  - Applying knowledge learned in previous courses
  - They have taken several others up to this point:
  - AOSS 323: Earth System Analysis
  - AOSS 370: Solar-Terrestrial Relations
  - AOSS 410: Earth System Modeling
  - AOSS 462: Atmospheric and Space Instrumentation
  - PHYS 405: Electricity and Magnetism
  - NERS 471: Plasma Physics

Sidenote on AOSS 370

- First-time-exposure to space physics
  - Emphasize the conceptual level first, then equations
  - Highly data oriented with a mixture of theory
  - Spend a class session each week in a computer lab
  - No modeling, just some model-result graphics
  - Designed for junior-level undergrads, not MS/PhD students
  - End-of-term project: analyze a space weather event
- CCMC is introduced in this class
  - Only used a little to visualize space physics concepts
  - Individual and small-group work exploring CCMC
- Most who take 477 have taken 370 (or AOSS 574)

AOSS 477 is a report-based course

- Students use models and conduct their own space weather numerical investigation
  - Several projects on using codes and writing/presenting reports based on their numerical experiments
  - Data used as model input and for model result comparison
- Variety of student assessment criteria
  - Many oral presentations and written reports
  - Peer grading of the oral presentations
  - In-class discussion participation

Peer grading?

- Yes, every oral presentation is assessed by the rest of the class
  - The form is nearly identical to what I am using for that presentation
- Two ways this counts towards their grade
  - The score that their peers gave them
    - Small percentage of the project grade
  - The depth of their assessments of their peers
    - A slightly larger percentage of the project grade
- Learning how to watch for good and bad science in both methodology and communication

Course Content

- Class content is a mixture of modeling nuts-and-bolts, code usage and visualization, and research techniques
- Students learn about the guts of numerical models used for space physics
  - Lots of details on equations being solved and numerical methods used to convert equations to code
  - Examples across the entire spectrum of space physics
- But also, they will:
  - Hone your technical report writing skills
  - Improve your public presentation skills
  - Read/discuss a few journal articles and decide what is good/bad about them

Journal articles?

- Final report is essentially a journal article
  - Pose a space physics question and use model to address it
  - Literature search, model description, sensitivity study, data-model comparison, interpretation of their findings, and summary
- I teach this by having them critique other modeling papers
  - Five in-class paper discussions of modeling studies
  - Two of their presentations/reports are paper critiques
  - I spend time going over good and bad presentation and paper writing techniques
  - "Journal club" is a significant part of the course

"Under the Hood" with CCMC Models

- Details of CCMC models
  - One model per class session, sometimes combined
- Many aspects to this:
  - What region/phenomenon is being modeled by a code?
  - What equations are being solved by the code?
  - What numerical approach was used in the code?
  - What typical grids are used in the code?
  - What inputs does the code require?
  - What outputs does the code produce?
  - What are the ranges of I/O validity for the code?
  - What other codes are similar in region, equation, or numerics?

Models Covered This Year

- MHD Models
  - Started with a general discussion of MHD equations, MHD extensions, and typical CFD techniques
  - BATS-R-US, LFM, OpenGGCM, Winglee code, ENLIL
- Inner Mag Models
  - HEIDI, RCM, RAM-SCB, CRCM/RBE/CIMI, VERB, DGCPM, IMPTAM, STET
- Ionosphere-Thermosphere Codes
  - GITM, SAMI, CTIP, TIEGCM
- Kinetic Codes
  - General discussion of test particle and hybrid modeling
- Empirical Models
  - Weimer codes, Tsygnanenko family, IRI, MSIS, WINDMI, formulaic models for m'pause, CPCP, Dst
- Coupled code suites
  - SWMF, CISM, other examples from coupled codes at CCMC

Intro to CCMC and VMR

- Spend a day going over what's at CCMC website
  - What's there, how it's structured, examples of runs/plots
- Spend a day playing with the plotting tools
  - Playing around with visualization pages
  - Lots of small group work
  - At first: assign them a specific task
  - Later on: give them a question to explore
- Spend a day going over the VMR (Darren came in)
  - Virtual Model Repository, a NASA-sponsored VxO
  - In case you don't have it: http://vmr.engin.umich.edu/
  - Linked to CCMC output files
- Spend a day with iSWA/SWE
  - Explore the real-time Sun-to-Earth space weather connection

Modeling Study #1

- Students will use CCMC to explore a region of space
  - Data only as input, just model results as output
  - Pick one model and get to know it
  - Read papers on the model to understand what others have done with it
  - Explore the range of input parameters
    - See what this does to the output
    - Could just use archival run results, but also instant/RoR jobs
  - Write a report and give a presentation on your findings
- Students can choose what code to use for this
  - But, they have to change for modeling studies #2 and #3

Modeling Study #2

- Write your own numerical model
  - Any formulaic "model" is acceptable
    - I will go over a bunch in class before assigning this project
  - Dst, CPCP, magnetopause, RB e- fluxes, etc.
  - Must write the code from scratch yourself
  - Must use a month of data to drive the model
  - Must use other data for output comparison
    - Dst predictor: Kyoto Dst or SYM-H
    - CPCP: AMIE values from VMR repository
    - Magnetopause predictor: GOES/LANL crossings
  - Write a report and give a presentation on your findings
- No direct CCMC involvement here

Modeling Study #3

- The biggy: putting it all together
  - Conduct a study that leads to a journal-style report
  - Data as input and output comparisons
  - Lots of literature review and interpretative discussion
  - Bigger report and longer presentation
- CCMC is heavily used by most in the class
  - Undergrads: almost certainly using a CCMC model
  - M-Eng students: definitely using a CCMC code
  - PhD students: maybe using their research project code
    - But maybe not, especially for non-numerical-oriented students

CCMC Student Research Contest

- Modeling Study #1 and #3 are perfect for this
  - I have specific requirements for the projects, but in general they fit nicely with the requirements of this contest
- AOSS 477 student prize winners:
  - Ava Dupre, a junior undergrad, won second place in 2012!
- This year's CCMC Student Research Contest
  - Submissions are due May 1
  - Model Study #3 is due April 21 in my class
  - I hope that several students will refine their reports and submit them to your contest

Summary on my class experience

- AOSS 477 is a fun class to teach
  - Students already know the relevant physics...apply it here
  - Focus on good-v-bad approaches to both conducting and communicating science
- Pedagogical balance is appreciated
  - Even split between "assessing" other people's studies and "doing" their own modeling studies
  - Students really enjoy the hands-on approach and discussion-based class environment
- Please hire our students!
  - AOSS undergrads and M-Eng students are highly qualified to run space weather models and explore the space environment

Summary: "classroom CCMC" is fantastic

- CCMC staff are very responsive to student requests
  - They understand that I impose deadlines for projects!
  - Having past run output available is very useful
  - Visualization tools and model selection is expanding
- I am here to learn
  - I would love to tweak the course based on what others do with the CCMC in their classes
  - I am very receptive to suggestions and comments
- I am willing to share
  - Developing a course is a lot of work, let's help each other
  - Find me at the break or email me and we can talk