Air Force Institute of Technology / CCMC
Educational Activities

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AFIT Programs

• Resident Graduate Education
  –Graduate School of Engineering and Management
    • Physics
    • Electrical & Computer Engineering
    • Aeronautics & Astronautics
    • Systems & Engineering Management
    • Mathematics & Statistics
    • Operational Sciences

• Resident Graduate Education
  –Graduate School of Engineering and Management

• Professional Continuing Education
AFIT Programs

• Resident Graduate Education
  – Graduate School of Engineering and Management

• Professional Continuing Education
  – Civil Engineer and Services School
  – School of Systems and Logistics

• Civilian Institution Programs
  – Graduate and Continuing Education
  – Health Care Education
• Primary mission to educate future space wx officers
  – Breadth of coverage
  – Ops focus to courses & research
  – Faculty field experience

• Also serve cross-over students and civilians


**Space Physics Curriculum**

- **PHYS 792** Space Weather Lab
- **PHYS 791** Operational Assessments

**Thesis**

- **PHYS 777** Solar Atmosphere
- **PHYS 776** Magnetospheric Physics
- **PHYS 775** Ionospheric Electrodynamics
- **CHEM 675** Upper Atmospheric Chemistry

**Lab exercises**

- **PHYS 519** Intro to Space Environment
- **PHYS 655** Quantum Physics
- **MATH 511** Methods of Applied Math
- **PHYS 650** Plasma Physics

**Opportunities for CCMC interaction**

- **Demonstrations**

- **Research Collaboration**

- **Lab exercises**

- **Opportunities for CCMC interaction**

*Space physics tracks also available to other programs (e.g. aero, astro, and electrical engineering)*
Overview

• Three areas of “interaction”
  – Research
  – Laboratory exercises
  – Classroom demonstrations

• Research
  – Best fit within current paradigm

• Laboratory exercises
  – Lessons learned

• Demos vs. eye-candy
  – Most room for improvement
• Small program; leverage external resources

• Most research performed in collaboration with AFRL

• Traditional research areas
  • Validate computer models (e.g. PRISM, MSM)
  • Exploitation of new data sources (e.g. CEASE, SCINDA)
  • New modeling/forecasting techniques for
    – HF communication
    – Spacecraft hazards
    – Scintillation effects
Recent Thesis Topics

- “Ionospheric response to solar x-ray flares”
- “GPS scintillation climatology measured by the SCINDA network”
- “Assessment of HF ray-tracing through assimilative ionospheric models”
- “Anisotropy in the South Atlantic Anomaly”
- “Characterization of the solar wind using DMSP ion drift data”
- “Flight-level radiation hazards due to solar energetic protons”
- “A correlation of GEO and LEO energetic electron events using data from the CEASE instrument”
- “Derivation of the Dst index from the SSM magnetometer on DMSP”
- “Estimating equatorial, F-region vertical E×B drift velocities from ground-based magnetometers”
• Performance metrics for models of interest to DoD
  – e.g. GAIM, WSA, radiation belt
  – Compare empirical, assimilative, physical models
  – Fits comfortably within current CCMC paradigm

• Leverage CCMC infrastructure for research
  – The promise of CCMC
  – Reality: resources vs flexibility
  – Access to numerical output critical
  – Examples: ray-tracing using GAIM; ionospheric response to solar flares
HF Geo-location Example

• Joshua Werner, M.S. 2007
• Improve geo-location of HF emitters
  – Requires accurate 3-D ionospheric specification
  – Current approach employs “active” ionospheric measurements versus “passive”
• Technique: combine assimilative ionospheric models with ray-tracing code; test capability vs ground-truth
HF Geo-location Example

- Do assimilative ionospheric models improve HF ray-tracing capabilities?
- Initial work used GPS Ionospheric Inversion (GPSII) model [Fridman et al., 2006]
- Extend study to include GAIM – Ideal use of CCMC capabilities
- Issues:
  - Resolution: ran GPSII at 0.5°, CCMC GAIM nominally 5°×15°
  - Ability to select data sources

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Propagation of a 7 MHz signal transmitted from Dayton, OH toward Norfolk, VA at local noon on 9 Jan 06
• Evelyn Schumer, Ph.D. student
• Validate and improve current models of HF radio absorption during solar flares
• Technique: Generate empirical model from HF signal database; cross-validate with physical D-region models; improve understanding of D-region processes
• ABBYNormal computes absorption due to single pass through ionosphere
  – CCMC: Global maps by request, single location on demand

• Not suited for comparison to data (multi-pass)
  – Couple ABBYNormal ionosphere with ray-tracing code
Research Summary

• Collaboration with CCMC when it makes sense
  – Leverage infrastructure to overcome computational requirements, data inputs, model idiosyncrasies
  – Ideal for GAIM, WSA, magnetosphere codes
  – Validation and verification easiest within current framework

• Downside is a lack of flexibility
  – Grid resolution, input variables
  – Altering model physics
  – e.g. ABBYNormal, SAMI2
Laboratory Exercises

• Space Weather Lab course
  – Goal: Familiarize students with available space weather models

• Method
  – Lecture: describe model, provide context/background
  – Guided tour: step-by-step instructions to familiarize student with required inputs, plotting output, interpretation
  – Open-ended exercises
  – Student write-up

• Currently taught using both AF-GEOSpace and CCMC models
  – Each has strengths and weaknesses
AF-GEOSpace v2.1

- Windows based GUI interface to numerous space weather models
- Stand-alone application

- **Strengths**
  - Simple standard plotting routines; 1-, 2-, 3-D
  - Easy to overlay output from multiple models
  - Excellent documentation

- **Weaknesses**
  - Nearly all empirical models
  - *Simple* plotting routines
  - Difficult to access numerical output
Laboratory Exercises

CCMC

- Internet based GUI interface
- Strengths
  - Most advanced models
  - Common interface for input/plotting
- Weaknesses
  - Uneven documentation
  - *Simple* plotting routines
  - Difficult to access numerical output
Laboratory Summary

- CCMC provides excellent resource for lab course
  - Greatest strength is diversity and quality of models
- But…students find it daunting
- Lessons learned (i.e. requested improvements)
  - Improve/standardize documentation
  - Ability to overlay/compare model output
  - More advanced visualization features
  - Better extraction of numerical output
Demos vs. “eye-candy”

- Without explanation, the best model output is just “eye-candy”
- Should be a CCMC strength
- Few movies available, small figures
- Intimidating to all but experts – missed opportunity
Public Outreach/Education

- CCMC needs Public Outreach/Education link
  - All models create *highlights* page with movie or figures
  - Require detailed description geared to educators/public

**CCMC Mission Statement**

The CCMC is a multi-agency partnership to enable, support and perform the research and development for next-generation space science and space weather models.

**Space Weather Explorer (SWX) Now Available at CCMC**

CCMC now has additional 3D visualization options available for BATSRS/SWMF 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.

**CCMC Services**

- We provide, to the scientific community, access to modern space research models
- We test and evaluate models
- We support Space Weather forecasters
- We support space science education

The CCMC website has undergone extensive redesign, with some of the pages renamed in the process. If you are unable to locate a previously bookmarked page or have difficulties navigating the redesigned website, please contact the CCMC staff.
Summary

- Many opportunities for research interaction
- Laboratory projects have been successful
- Work remains in packaging product for wider use

“the CCMC will strive to make all output beneficial to educational institutions, and amenable to broad distribution to the general public”

“Graphics and visualization techniques will be exploited for displaying CCMC output in appealing formats that can be used in classrooms or for public dissemination”

CCMC CONOPS