SHIELD/ARAM-SCB and Opportunities for Partnership with CCMC

Vania Jordanova & the SHIELD/ Team

Project Goals & Scientific Impact:

- Develop a new space weather capability to understand, model, and predict:

  Space Hazards Induced near Earth by Large, Dynamic Storms (SHIELD/)

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23-27 April 2018
Satellite Anomalies

- Some spacecraft are equipped with sensors to:
  - Monitor charged particles in the radiation belts
  - Help determine the cause and conditions under which spacecraft anomalies occur
- Most spacecraft are not equipped with space weather instruments
- LANL MPA data reveals the electron energy range (~5–10 keV) are most closely associated with satellite surface charging

Measurements from the Magnetospheric Plasma Analyzer (MPA) aboard the geosynchronous LANL-02A satellite on Feb 28th, 2003. Spacecraft surface charging is seen in both the electrons (top) and ions (bottom). [Thomsen et al., 2013]

The accurate global specification of the surface charging environment (SCE) fluxes of hot (~10’s keV) electrons is the gap that SHIELDS fills!
Funded by the U. S. Department of Energy through the Los Alamos National Laboratory (LANL) Laboratory Directed Research and Development (LDRD) program, the SHIELDS framework is being developed by world-class experts in the fields of space sciences and computational plasma physics:

- G. L. Delzanno (Co-PI), J. D. Moulton, H. Godinez, C. Meierbachtol, D. Svyatsky, T, LANL
- E. Lawrence, L. Vernon, CCS, LANL
- G. Tóth (Co-PI), D. Welling, Y. Chen, J. Haiducek, University of Michigan

Collaborators:
- M. Thomsen (PSI) and J. Birn, J. Borovsky and M. Denton, SSI
- J. Albert and S. Young, AFRL, Albuquerque, NM
- R. Horne, BAS, Cambridge, UK
- C. Lemon, The Aerospace Corporation, CA
- S. Markidis, I. B. Peng, KTH Stockholm, Sweden
- Y. Yu, Beihang University, Beijing, China
The SHIELDS Framework

Bridging macro- and micro-scale models, combined with data assimilation tools:
- Capture rapid particle injection and acceleration during storms/substorms
- Include plasma wave generation and their feedback on the particles

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RAM-SCB

Ring current - Atmosphere interactions Model with Self-Consistent magnetic (B) field

- Ring current-atmosphere interactions model (RAM) [Jordanova et al., 1994, 2006; 2012]
  - Kinetic equation for H\(^+\), O\(^+\), and He\(^+\) ions and electrons
  - Including all major loss processes
  - Convection and corotation E field
  - Updated to general B field

- 3D equilibrium code [Cheng, 1995; Zaharia et al., 2004; 2010]
  - Force-balanced equation
    \[ \mathbf{J} \times \mathbf{B} - \nabla \cdot \mathbf{P} = 0 \]
  - Euler potentials (flux coordinates)
The model captures the major dynamics of the electron flux:

- Rapid increase after the shock, energy-dispersed injections
- Significant enhancement of electron fluxes during the storm main phase

[Yu et al., GRL, 2014]
Data Assimilation

- Data assimilation fuse observations and model
- Assimilate VA Probe-B data into RAM-SCB, validate with VA Probe-A
- Use Singular Valued Decomposition (SVD) to define a new (better) basis for the state variables
- Significant enhancement is obtained compared to previous conventional method (LETKF)

POC: Humberto Godinez, hgodinez@lanl.gov
Assimilate VA Probe-A data into RAM-SCB, validate with VA Probe-B.

Results showed an order of magnitude improvement and significant error reduction.

**SHIELDS Collaborative Software Development**

Migrate Codes / Developers to Distributed Version control System (DVS)

- Transitioned CVS, Mercurial, etc. into a Git repository
- Work with IC-Project Filesystem & github.com/lanl/

POC: Louis Vernon, vernon@lanl.gov
Compilation, Testing and Deployment of SHIELDS/RAM-SCB
Development of a Real-Time SHIELDSDS-RC capability, a simplified RAM-SCB model driven by solar wind conditions.

Given appropriate upstream solar wind measurements, the model provides a forecast of the SCE with a ~1 hour lead time.

POC: Steve Morley, smorley@lanl.gov
The operational SHIELDS-RC provides output along specific satellite trajectory in the inner magnetosphere, example shown for the Van Allen Probes:

- Drivers (Vsw, Bz) and Kp & Dst indices as a function of time
- Electron energy spectra from ~1 to 350 keV
- Electron flux at 10 keV as an indication of SCE hazard
Real-time DREAM: Assimilating Only GOES Data

- Generate global estimate of radiation belts with DREAM
- With only GOES, there is no radial structure other than provided by the model
- Storm onset near June 5th is clearly visible in DREAM PSD
- Reduction in PSD quickly diffuses away from GEO L-shell

POC: Andrew Walker, awalker@lanl.gov
Real-time DREAM: GOES + Beacon Data

- Van Allen Probe Beacon adds additional radial structure at the cost of discontinuities in PSD
- Structure of low L-shell (3 to 4) is significantly enhanced
- Structure of L-shell from 4 to 6 is also enhanced but diffusion occurs at a faster rate in this region so discontinuities are more noticeable
DREAM: GOES + RBSP Science Data

- Van Allen Probe Science data provides the best assimilated PSD but is not an option for real-time processing.
- Some discontinuities are still visible, but they are significantly diminished compared to the Beacon data.

Real-time DREAM assimilated phase space density based on GOES 13 and Van Allen Probe science local measurements.
Space weather research is rapidly gaining public recognition as the accuracy of space weather forecasts improves.

We developed a space weather model for Space Situational Awareness and forensic analysis of space system failures.

Open source & available at: https://github.com/lanl/ram-scb

SHIELDS won a R&D 100 Award in 2017; these awards honor the latest and best innovations of the past year.

Building strategic partnerships with other agencies (DOD, NOAA, NASA, NSF, FAA), institutions (Aerospace, universities), and commercial customers (satellite operators, etc.)

Website with lists of presentations and publications: http://www.lanl.gov/projects/shields/