The GEMstone

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Focus Group Final Report

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Metrics and Validation Focus Group 2010-2015 : Final Report

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The Metrics and Validation Focus Group (M&V FG) was formed to address GEM needs for systematic and quantitative evaluation of general geospace circulation models (GGCM) with a goal of testing current space weather modeling capabilities and identifying areas in need of future scientific development.

The activities of the M&V FG in 2010-2012 were focused on building upon successes of the series of GGCM Modeling Challenges initiated by the M&V FG in 2008-2010. The goals of the Challenges were:

- To evaluate the current state of geospace models, to demonstrate model capabilities, and to track model improvements over time by testing model predictions against observations;
- To gather information on model validation efforts and to define observables and numerical methods to compare models with measurements;
- To facilitate interactions between research communities and users of space weather products in developing metrics for model evaluations tailored for specific space weather applications;
- To facilitate collaborations among modelers and data providers, to address challenges of model-data comparisons;
- To facilitate further model improvement and to advance GEM science.

In 2010 the GEM M&V FG supported the CEDAR community in setting up a CEDAR Electrodynamics Thermosphere Ionosphere (CEDAR ETI) Challenge based on the set of events selected by the GEM M&V FG and focused on global ionosphere physical parameters including neutral and electron densities, NmF2, HmF2, drift velocities, and Total Electron Content [Shim et al, 2012, 2014]. The partnership between the GEM M&V FG and the CEDAR community was further expanded during the 2011 Joint GEM-CEDAR Summer Workshop, when a series of GEM-CEDAR Modeling Challenges were initiated. The GEM-CEDAR Challenges were focused on physical parameters, spatial domains and aspects of model validation of interest to both communities, such as the role of high altitude drivers in storm-driven ionospheric and thermospheric disturbances, changes in regional TEC, and neutral densities, processes and boundaries in the auroral region. The GEM-CEDAR Challenges also addressed issues related to observational data quality and availability, sensitivity of model outputs to input parameters, boundary conditions, modeling assumptions, adjustable parameters.

In support of the Challenges the Community Coordinated Modeling Center (CCMC, http://ccmc.gsfc.nasa.gov) developed a suite of interactive on-line metrics tools for simulation results submissions and analysis. The CCMC continues maintaining the web site with interactive access to model output archive and observational data used for Challenge projects.

The Modeling Challenge projects initiated by the Metrics and Validation Focus Group in 2008-2012 are listed in the Table 1. The table includes status, deliverables, GEM Focus Group Co-Sponsors, relevant missions and space weather applications.

The results of the Ground magnetic perturbation and Regional-K Challenges were

Table 1. The Modeling Challenge projects initiated by the Metrics and Validation Focus Group in 2008-2012

Phys. Parameter/ Challenge Project	Status (1st round)	Deliverables (Publications, Reports)	Relevant GEM research topics, Space weather applications, Missions
Magnetic field at geosyn. orbit.	completed	Rastaetter et al., 2011; Pulkkinen et al., 2010	Inner Magnetosphere FG, VA Probes
Magnetopause location	on-going	Rastaetter et al, 2013, 2015; Collado-Vega and Sibeck, 2015; Analysis based on MMS data is expected in Dec 2016	Dayside Research Area, Reconnection, MMS
Regional K*	completed	Glocer et al, 2016 A report (Phase II) to NOAA/SWPC on operational geospace model selection	Geomagnetically Induced Currents (GICs)
Ground magnetic perturbations*	completed	Pulkkinen et al., 2009, 2011, 2013 Rastaetter et al., 2014 A report (Phase I) to NOAA/SWPC on operational geospace model selection	
Dst Index	completed	Rastaetter et al., 2012	Inner Magnetosphere, Storm impact
Heat flux into ionosphere**	completed	Rastaetter et al, 2016	Dayside FACs and Energy Deposition FG, Satellite Drag
Auroral boundaries *, **	on-going	Zheng et al, 2015, Lane et al, 2015	Inner Magnetosphere, Surface charging
CEDAR ETI (NmF2, hmF2, drift velocities, TEC) **	completed	Shim et al, 2012, 2014	Ionosphere Disturbances, GPS, Communications, Satellite Drag
Role of High-Latitude Drivers on Ionosphere/ Thermosphere **	on-going	M-I Coupling Patch-Panel Driver Swapping Tool, Library of drivers for selected events	M-I Coupling

(*) Metric studies of primary interest to operational community (NOAA/SWPC, AFWA).
(**) Joint GEM-CEDAR Challenge

utilized as a basis for the Operational Geospace model selection by NOAA/SWPC and will be used as a benchmark for an upcoming 2nd round of Challenges to trace model improvements. In addition, carrying out these challenges resulted in model developers providing new and improved versions of their models for use by the research community for runs-on-request. Efforts to define and model auroral boundaries were started in 2011 as well as determining and comparing the magnetopause position and standoff distance using geosynchronous satellites. Both studies are still ongoing and are being taken up by the GEM GSM Modeling Methods and Validation Focus Group (MMV, 2016-2020). The MMS data opened new opportunities for these Challenges that are now also of interest to the GEM Magnetic Reconnection FG. Since 2013 the Heat Flux into Ionosphere, and the Role of Driver Challenges are carried on by the GEM-CEDAR Challenge Working Group hosted by CEDAR. The GEM-CEDAR Challenge discussion sessions are continuously organized at CEDAR Summer Workshops and at GEM Fall mini-Workshops (GEM-CEDAR Challenge special sessions).

In 2013-2015 under new leadership the M&V FG continued to define and pursue modeling challenges encompassing different regions of the Earth magnetosphere-ionosphere coupled system. The efforts were expanded into new analysis methods (including climatological techniques), model uncertainty and extreme event simulations such as Carrington-style events (that are beyond the range of events ob-

served during the space age). In 2013-2014 presentations by various modelers addressed sensitivity of models to variations in input data and approaches to validate simulations of extreme events by using different types of historic records related to storm impacts and by extrapolation of well-observed storm events. To understand significant differences in model outputs demonstrated by some metrics studies, a series of baseline model comparisons were initiated. The researchers agreed to run different MHD codes for various solar wind and IMF conditions and compare the results. The sensitivity of models to boundary conditions and internal (numerical) parameters were explored to uncover reasons for the differences among the major global magnetosphere MHD models.

Consistent with the goal of being the glue that binds GEM together, the M&V FG reached out to other GEM FGs to facilitate relevant modeling challenges for the state of the art models in their groups. In 2013, modelers explored ways to validate and improve models through comparisons with observational maps of electric currents (from AMPERE). New sources of data were introduced (TIMED/GUVI) that can aid model development in magnetosphere-ionosphere coupling. The focus group also started a study to model ULF wave fields in global magnetosphere MHD models for eventual comparison with in-situ (Van Allen Probes) and ground-based observations (PC-4 magnetic perturbations). In 2015, there was more discussion on the assessment of real-time model runs. After the completion of the Metrics and Validation Focus Group, the ULF modeling study is now being continued by the new UMEA and MMV focus groups (2016-2020).

Resources:

Web pages (workshop agendas and modeling challenges):

- http://ccmc.gsfc.nasa.gov/support/GEMMetrics_and_Validation/
- http://ccmc.gsfc.nasa.gov/challenges/GEM_Metrics_Challenge
- http://ccmc.gsfc.nasa.gov/challenges/GEM-CEDAR
- http://ccmc.gsfc.nasa.gov/challenges/ULF/
- http://ccmc.gsfc.nasa.gov/challenges/Magnetopause/

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