Quantitative Assessment of the CCMC's Experimental Real-time SWMF-Geospace Results

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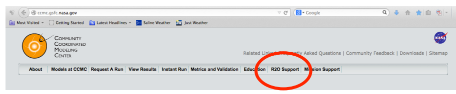
CLASP CLIMATE & SPACE Sciences & Engineering

1. Motivation

- **CCMC has been running a geospace configuration of SWMF in real time since 2007**
  - Just the GM and IE physics modules
    - So, only the BATS-R-US MHD code and the Ridley Ionosphere Model
  - Fairly low grid resolution (<1 M cells) for MHD code (to get faster than real time in 2007)
- **New version running since 2011**
  - Three physics modules: GM, IE, and IM
    - So, now with the Rice Convection Model for near-Earth keV plasma solution
  - Better grid in MHD code and some other improvements
  - Consistently running since July 2015
- Main points of this study:
  - **Raise awareness** about the existence of these simulations, at CCMC and at a new site at U-M
  - **Conduct a quantitative assessment** of these simulations to examine the goodness of the output
    - Error statistics and contingency tables

2. Where to find these results

- A good place to start is the CCMC website, which has a link to "R2O Support" in the header menu:
  - http://ccmc.gsfc.nasa.gov/

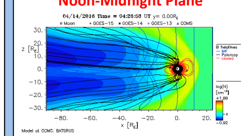


- It gives a link to the page for experimental real-time simulations:
  - http://ccmc.gsfc.nasa.gov/rt_simulations.php
- It gives a link for the SWMF-Geospace real-time simulations:
  - http://ccmc.gsfc.nasa.gov/cgi-bin/SWMFpred.cgi
- Also available through CCMC's Integrated Space Weather Analysis (iSWA) site, many cygnets in "Magnetosphere" and "Ionosphere"
  - http://iswa.ccmc.gsfc.nasa.gov/
- We have created our own site at Michigan to highlight the existence of these simulations and show some qualitative data-model comparisons
- http://csem.engin.umich.edu/realtime/

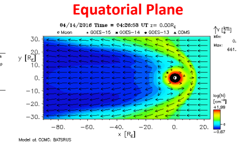
3. What you will find there

- Plots of the magnetosphere and ionosphere are available
- Examples (shown below) include noon-midnight and equatorial plane cuts from the MHD model and ionospheric potential and field-aligned current patterns
- These plots update every minute or so on the websites

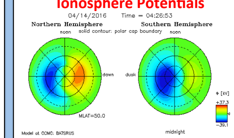
Noon-Midnight Plane



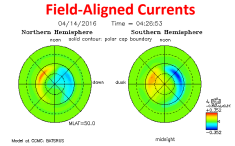
Equatorial Plane



Ionosphere Potentials



Field-Aligned Currents

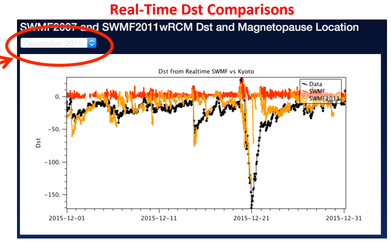


4. Dst Comparison at U-M

- Our addition to the experimental runset is comparison with data
  - In particular, we are focusing on Dst

Real-Time Dst Comparisons

Pick a month

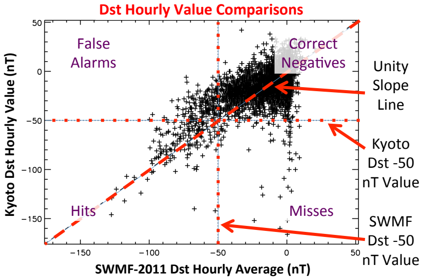


- In the plot above, the black curve is the Kyoto real-time Dst index, the red curve is the SWMF-2007 simulated Dst time series, and the orange curve is the simulated Dst time series from SWMF-2011
- It is clear in this month-long plot for December 2015: the SWMF-2011 run is (qualitatively) very close to the observations

5. Analyzing the Dst time series

- For July-December 2015, we have nearly 4000 hourly values
- Let's calculate some data-model comparison statistics
- Set up a contingency table to quantify how often the code captures the big events

Dst Hourly Value Comparisons



Contingency Table	Dst_M < -50 nT	Dst_M > -50 nT
Dst_K > -50 nT	F = 179	N = 3574
Dst_K < -50 nT	H = 172	M = 66

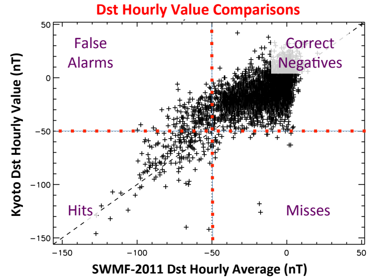
The Statistics

Correlation Coefficient =	0.62
RMS Error =	18.3 nT
Prediction Efficiency =	0.22
Prob. of Detection =	0.72
Prob. False Detection =	0.048
Heidke Skill Score =	0.55

6. Cleaning for Restarts

- As seen in the orange time series in Box 4 above, the SWMF-2011 code suffered from occasional restarts
  - This created a gap and then a "cold restart" from an empty magnetosphere
- The cold restart values were included in Box 5 stats
- Clean results: remove values within 3 h of a restart

Dst Hourly Value Comparisons



Contingency Table	Dst_M < -50 nT	Dst_M > -50 nT
Dst_K > -50 nT	F = 179	N = 3277
Dst_K < -50 nT	H = 172	M = 30

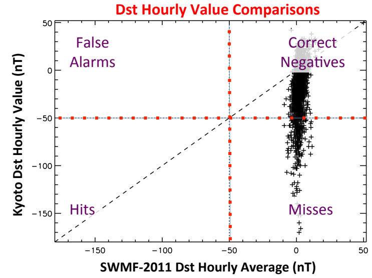
The Statistics

Corr. Coef. =	0.71
RMS Error =	16.0 nT
Pred. Eff. =	0.35
POD =	0.85
POFD =	0.051
HSS =	0.59

7. The SWMF-2007 Output

- We did the same analysis for the SWMF-2007 run
  - Remember: no inner mag model included
- The results are not good
  - Not a single value of hourly Dst below -50 nT
  - This version cannot predict Dst storm intervals

Dst Hourly Value Comparisons



Contingency Table	Dst_M < -50 nT	Dst_M > -50 nT
Dst_K > -50 nT	F = 0	N = 3891
Dst_K < -50 nT	H = 0	M = 266

The Statistics

Corr. Coef. =	0.33
RMS Error =	27.9 nT
Pred. Eff. =	- 0.71
POD =	0.00
POFD =	0.00
HSS =	0.00

8. Conclusions

- **Real-time runs of SWMF-Geospace exist**
  - Available at the main CCMC website, at the CCMC's iSWA site, and at a U-M CSEM website
- **The SWMF-2011 simulation is very good**
  - Especially when the restart intervals are removed
  - High correlation coefficient, prediction efficiency, probability of detection, and Heidke skill score
  - Low probability of false detection
  - This is the NOAA-SWPC operational version, about to go online in 24/7 predictive mode
- **Restart issue has been identified and corrected**
  - Optimization issue for the number of cores assigned to the run
  - It runs without these restarts now
- **SWMF-2007 is not good at predicting Dst**
  - Never predicted Dst below -50 nT in 2015
  - Doesn't have an inner magnetospheric drift physics model included in the setup
- **Inner mag model is critical for Dst prediction**
  - Needed to augment coarse-grid MHD simulation output in this region
- **Additional data-model comparisons are planned and coming soon**
  - Magnetopause location, GOES fields, DMSP potentials, and AMPERE FACs

9. Acknowledgments

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