Transitioning the SWMF Geospace Model into Operations at the National Weather Service

George Millward [CU/CIRES – NOAA/SWPC]

Howard Singer, Chris Balch [SWPC]
Gabor Toth, Dan Welling [UMICH]
...and the Geospace evaluation team at CCMC
The National Centers for Environmental Prediction (NCEP) a part of the National Weather Service:
“..the starting point for nearly all weather forecasts in the US”

- Global Observations
- Operational computer modeling / Data Assimilation
- Post-Processing / Reforecasts
WSA-Enlil

- Transitioned by SWPC: 2010 - 2011
- Operational since 2012

2012-01-24 15:00:00

Plasma Density (\(\text{cm}^{-3}\))
- Earth
- Stereo A
- Stereo B

Radial Velocity (km/s)
- Earth
- Stereo A
- Stereo B

Space Weather Prediction Center
Run Time: 2012-01-23 06:00 UT
Mode: CME
Image Created: 2012-04-24 22:14 UT
CME Analysis Tool (CAT)

Stereo B Coronagraph

SOHO Coronagraph

Stereo A Coronagraph

CME Direction and Velocity
WSA-Enlil: invaluable forecasting tool at the 1 to 3 days level (18 hours) – but it can only get us so far:

- Inaccuracies in measured CME parameters (direction, velocity)
- No information about Geomagnetic storm severity – just possibility and CME time of arrival
In situ measurements, 92,000,000 miles further downstream..

\[ \text{ACE(1997)} \rightarrow \text{DSCOVR(2015)} \quad :: \quad \text{Operational Sentinels at L1} \]

Fast incoming CMEs (say, >1000 km/s), Forecast lead time is less than 30 minutes
Satellite measurements of Solar Wind

Forecast of Geomagnetic activity: single value for the whole planet

Simple empirical relationships / neural networks etc.

Global Forecast:
“In 18 minutes time the lights could go out – somewhere on planet Earth (probably at higher latitudes)”
PROPOSED SYSTEM

Satellite measurements of Solar Wind

Sophisticated 3D model of Solar Wind-Magnetosphere running on WCOSS

Forecast of Geomagnetic activity as a global map

Regional Forecast:
“In 18 minutes time the lights could go out in New York, but not in Seattle, Tokyo, etc”
- focused, latitude, longitude, time.
Timeline to Operations......

- 2013: SWPC and NASA-CCMC - evaluation of suitable Magnetospheric models [in coordination with the modelers themselves]. Metrics: model skill scores for predicting dB/dt, regional K value, compared to 3 chains of magnetometers (east/West US and Europe). 6 magnetic storms evaluated.

- 2 reports prepared by CCMC (dB/dt | regional K)

- 2014: Space Weather Modeling Framework (SWMF), University of Michigan, chosen by SWPC as best performing – mature enough to provide significant advance in Geomagnetic forecasting.

- 2014/2015: SWPC now working closely and extensively with model developers at UMICH to facilitate model changes needed for real-time operations.

- Transition timeframe: Basic test-system running under DEV by Oct 1 2014 [done]....Full test system (v1.0) handed to NCO by October 1, 2015 for DEVONPROD.

- 2016: Operational (system v1.0)
Space Weather Modeling Framework

SWMF:

- Developed at the University of Michigan, Ann Arbor
- Comprehensive, 3D, time-dependent, physics-based, first principles model(s)
- Components can be combined together within the common “framework” (examples: Solar Corona, Inner Heliosphere)

(essentially like the Enlil model)
The components we are using for Geospace modeling........
GM: Global Magnetosphere
IE: Ionospheric Electrodynamics
Several contributing current systems: Magnetopause, field-aligned, Ring Current, Ionospheric Pederson and Hall Currents:

Spatial and time-varying dB on the ground calculated via Biot-Savart integration.
Running a Geospace model as an operational forecast model:

Essential Points:

- The magnetosphere is fundamentally a system driven by the Solar Wind.
- The model does not “run into the future” (in a traditional weather model sense) – it just steps along in time with it’s Solar Wind input.
- Forecasting ability comes because the SW is measured 1 million miles upstream, at L1 – propagated forwards in time to the position of Earth.
- Forecast lead time is dependent upon incoming SW speed.
- Geospace model needs to run in Real-time (a paradigm shift for the NWS ops computer) – any computing delays will seriously eat into our 18 minutes.
- Sharp jump upwards in SW speed (ie, incoming CME) – model has to STOP and RESTART from a previous point consistent with the new SW data.
SW Transit Time: Validation (Michele Cash, SWPC)

ACE data propagated to the location of the Wind spacecraft using two different methods, flat plane propagation and tilted phase planes.

MVAB-0/CP method shows improved agreement.
The **STOP and RESTART** part

Solar Wind Speed

- **RT SW speed (ACE)**
- **SW propagated to Earth**
- **Calculated Model Restarts:**
  - RESTART (14:29:00)
  - Model Restart (13:46:00)
  - Model Restart (13:53:00)
  - Model Restart (14:57:00)
  - Model Restart (14:52:00)

**Wallclock:** 14:39:00
**Propagated:** 15:07:21
**SWMF:** NORMAL (SOLARWIND DECREASING)
**Model Run:** from 15:06:01 to 15:07:21 (Timestep: 79 s)
**SW speed** (t-1) -> (t): 892.08 -> 881.82
The **STOP** and **RESTART** part

**Lead Time**: 45 mins

Wallclock : 12:50:00
Propagated : 13:35:27
SWMF : NORMAL (SOLARWIND INCREASING)
Model Run from to 13:35:27 (Timestep : 0 s)
SW speed (t-1) -> (t) : 0.00 -> 549.94
Schematic for SWMF running in real-time on WCOSS: basic time stepping

1. **V[t] < V[t-1]** (solar wind decreasing)
2. **V[t] > V[t-1]** (solar wind increasing)
3. **V[t] >> V[t-1]** (sharp increase - shock)

**WCOSS stores last 45 files before removing**

**SWMF checks and waits for new input data**

**SWMF saves restart file always saved on the minute**
Forecast Products

• Initial products: Local Time regional K and dB/dt calculations at a few select locations

• More complete products and product displays to be developed in 2016

• Meanwhile - a suggestion from UMICH (Dan Welling) of a Local Time Regional K product shows interesting results (St Patrick’s Day Storm)
Real-Time SWMF Geospace [St. Patrick's Day Storm]

2015-03-17 00:00:00

B Total 7.6
Bz 3.1
Density 11.5
Speed 421.4
SWMF predicted Kp 3.0

Space Weather Prediction Center
Initial Test Product: Local Time regional K prediction
Initial Test Product: Local Time regional K prediction

Real-Time SWMF Geospace [St. Patrick's Day Storm]

predicted
Kp = 7

Space Weather Prediction Center
Summary

• Transition team at SWPC working in solid collaboration with model developers at UMICH to build a real-time operational Geospace model

• Real-time run environment in place on the DEV environment at NCEP: SWMF running in real-time with propagated SW data

• Initial forecast products show interesting, and very encouraging, results (St Patrick’s day storm) – obviously lots more work to be done

• Handover to NCO techs slated for 1 October 2015 – V1.0 operational 2016

USERS: We will have [x,y,z,t] – 30 minutes ahead of time – what do you want ??? (global picture, local time series etc. etc.)

Get in the loop…. We have ideas – but we want yours…..

george.millward@noaa.gov