NOAA's Space Weather Prediction Center Partnership with NASA's Community Coordinated Modeling Center

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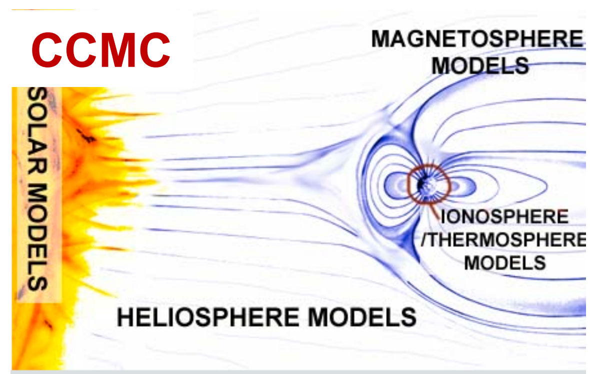
Outline

- Complementary Organization Missions
- Past Accomplishments
- Present Activities
- Future Challenges and Opportunities

Using Models to Support Customers



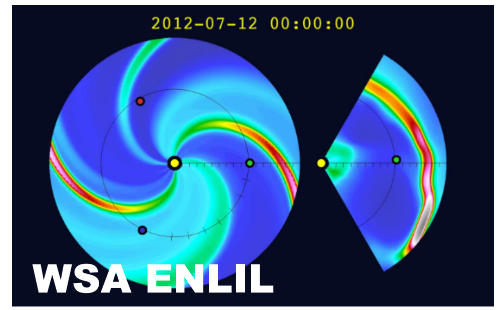
Testing, Evaluating and Transitioning Models of the Solar-Terrestrial System

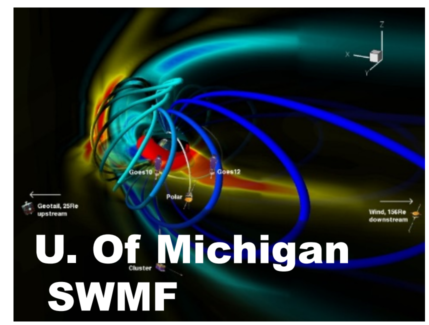
Complementary Agency Missions

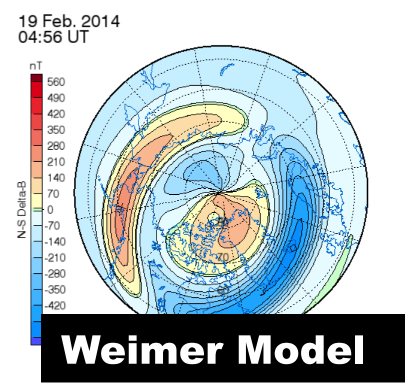
- **Community Coordinated Modeling Center**
  - **Mission:** The CCMC is a multi-agency partnership to enable, support and perform the research and development for next-generation space science and space weather models.
  - **Services include:** test and evaluate models in support of the needs of science users and space weather forecasters; support Space Weather forecasters through transitioning of research models to operations, through model evaluations, and through the provisions of forecasting tools
- **Space Weather Prediction Center**
  - **Mission:** To deliver space weather products and services that meet the evolving needs of the nation.
  - **Services include:** It is the nation's official source of space weather alerts, watches and warnings. SWPC provides real-time monitoring and forecasting of solar and geophysical events which impact satellites, power grids, communications, navigation, and many other technological systems. SWPC also explores and evaluates new models and products and transitions them into operations.

Past Collaborations
(a few examples)

- **WSA-Enlil Improves Geomagnetic Storm Prediction**
  - **Numerous partnerships contribute to the success of this model, including contributions from CCMCs work on the cone model development**
  - **Collaboration on cone model fitting comparisons (ongoing)**
- **Geospace Model Evaluation**
  - **CCMC led evaluation, in collaboration with SWPC and modelers, leading to SWPC selection of the University of Michigan Space Weather Modeling Framework (MHD) and the Weimer Empirical Model**







Lessons Learned: Models Still Need Improvement

It is important to not overrate, even the best of the models. We learn from this evaluation that:

- large dB/dt events are still a challenge for models to capture accurately
- there are differences in model performance from event to event and station to station
- the model rankings in this study cannot be generalized to say that the same model ranking would be found for all applications of these models
- different metrics may show different results for model ranking
- model robustness will need to be evaluated for longer runs than events in this study which were for no more than 48 hours.
- especially for dB/dt, the physics-based models are ranked higher than the empirical models for most events and thresholds
- considering current model limitations, to provide useful guidance to forecasters, products will need to be designed to work within model capabilities

Additional Lessons Learned

- the need for good communication and documentation between the modeler and CCMC (and the modeler and SWPC as we transition to operations)
- the importance of keeping the modeler involved in the entire process
- that verification needs to be considered end-to-end - shortcuts can result in errors
- that the simplest models can't be taken for granted, they still come with complications
- that evaluations for operations (rather than science) provides valuable feedback to science

Present

- SWPC transitioning the U. of Michigan MHD geospace model to operations
  - Developing transition plan and conops (FY14 Q4 test runs and product on NCEP computer and operational end of FY15)
  - Model installed and tested on the NCEP computer with 64 processors (~1.4 x real-time)
  - Working with U. of Michigan (Toth, Lead; Welling, Gombosi…)
  - Evaluating and developing methods for propagating solar wind from L1
  - CCMC assisting with validation
- SWPC transitioning Weimer model to operations (resources permitting)
  - Received model; working with Dan Weimer
  - Model installed and testing initiated

Future Collaborations with CCMC

- CCMC collaborations with SWPC and model developers will contribute the transition of Geospace models at SWPC
  - Periodic telecons underway
  - Version control at SWPC, CCMC, and with modelers-facilitates continuing validation and product development
  - Additional model stability testing
  - Solar wind propagation techniques
  - Expand on model sensitivity studies, including temporal and spatial resolution testing that was initiated during model evaluation period
- Evaluate where there is match between customer needs and research models available at CCMC and in the scientific community
- Invest in those models where there is a significant customer benefit

Prediction

"The overarching goal of the National Space Weather Program is to achieve an active, synergistic, interagency system to provide timely, accurate, and reliable space environment observations, specifications, and forecasts within the next 10 years."

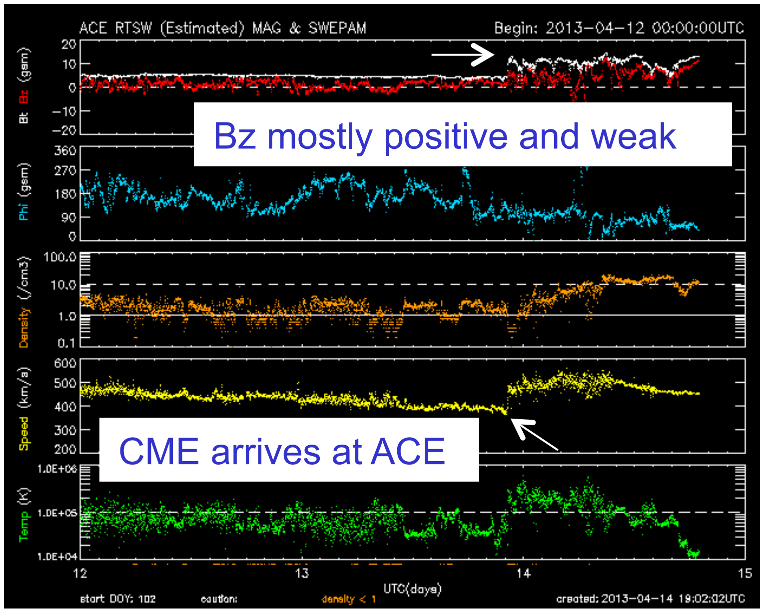
The National Space Weather Program,
The Strategic Plan, August 1995

SCIENCE GOALS FOR THE NEXT DECADE

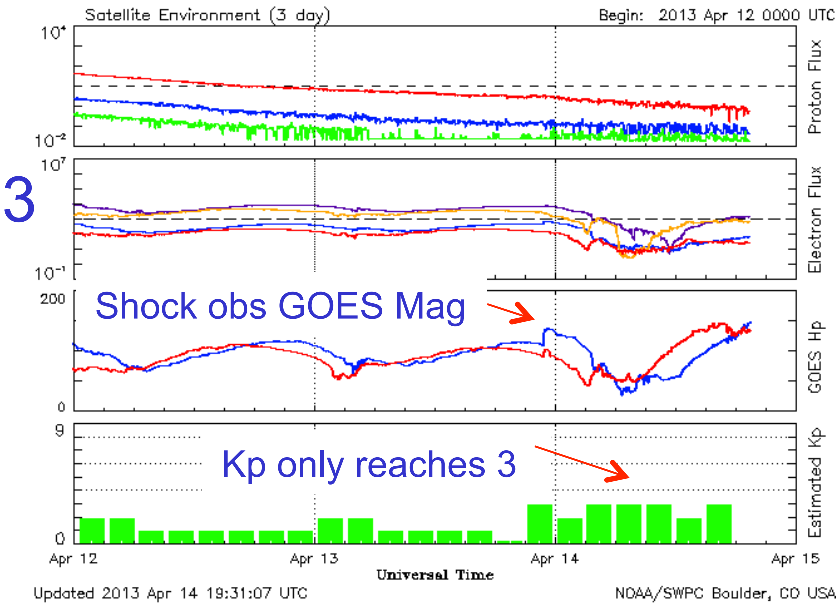
"Goal 1. Determine the origins of the Sun's activity and predict the variations in the space environment."

Solar and Space Physics: A Science for a Technological Society,
Committee on a Decadal Strategy for Solar and Space Physics (Heliophysics)
National Research Council, 2012

The Key to Predicting Storms is the Orientation of the Solar Wind Magnetic Field (Bz)



April 2013 CME



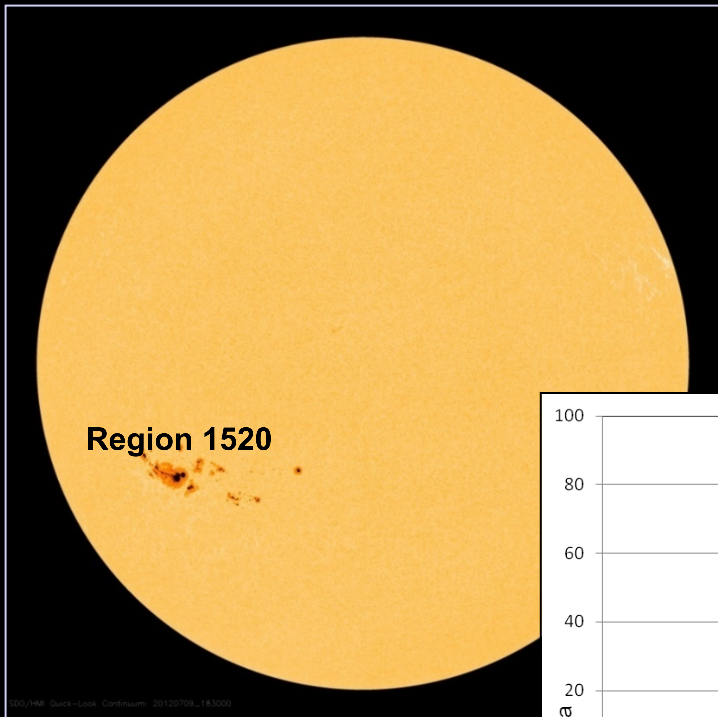
4/12-14/2013

4/12-14/2013

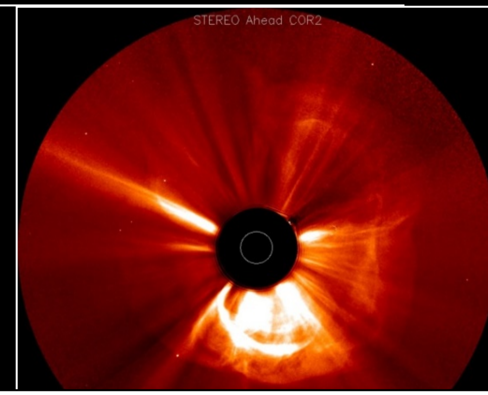
- Solar wind driver: Shock arrived at ACE only 75 min later than predicted by WSA-Enlil - Excellent arrival time prediction provided several days ahead
- Geospace response: Solar wind velocity, density, and By all matter, but Bz southward and the duration of solar wind driver are key to determining storm intensity
- Need to predict the magnetic field in an ICME to provide improved warnings and forecasts of geomagnetic activity

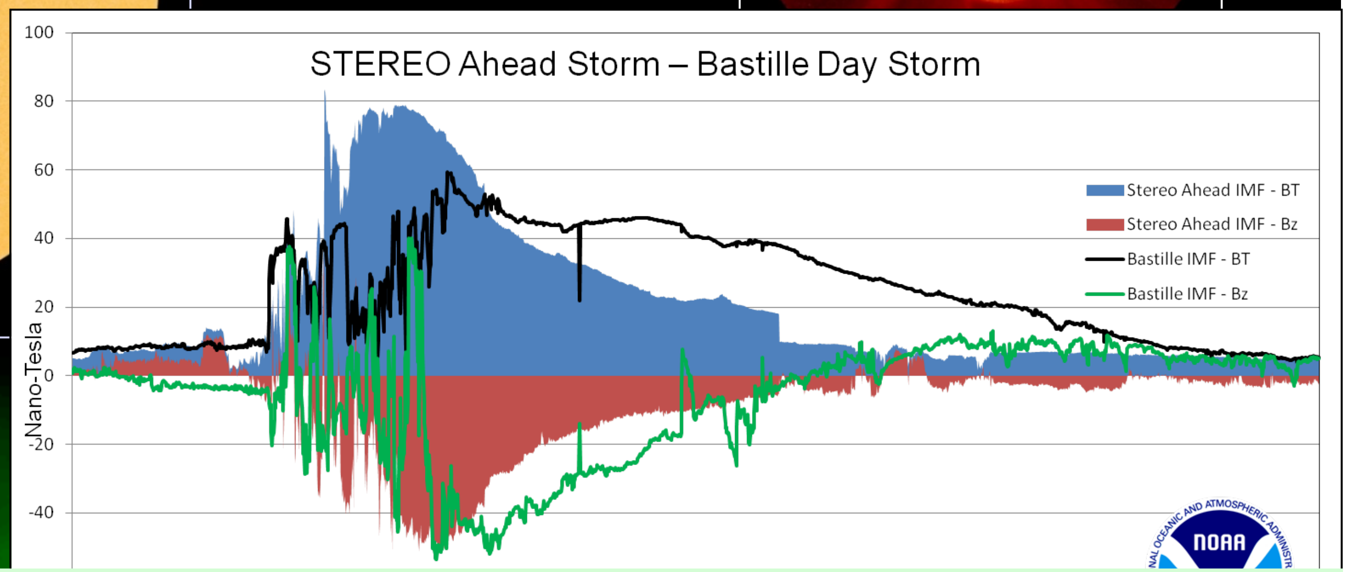
July 2012 Event

The Sun on July 11th



The Sun on July 23rd – STEREO AHEAD





Comparison to July 2000

(figure adapted from R. Rutledge)

- Although not Earth directed, example of a large solar event during a small solar cycle
- Forecasters knew Region 1520 was large and complex, and on 7/10 predicted the potential for further activity, but could we have predicted the timing, intensity and duration of the event that enveloped STEREO Ahead and would have been a record event at Earth?

Evolving Customer Requirements Electric Utilities Examples

User Requirement	Timeliness	Customer	Rationale
Geoelectric Field Vector	6 hr. forecast, updated hourly	Various Power Companies	To know the key ingredient that plays into the GIC at selected points, is a critical parameter for the industry. To do this requires local dB/dt and geologic conductivities.
K-7 Geomagnetic Storm Warnings	Minutes to hours Operators want as much lead time as possible, but any lead time is considered useful	North America Electricity Reliability Corp. Midwest Independent System Operator Electricity Reliability Coordinators	The Midwest Independent System Operator receives the K-index forecast. If the index is K-7 or higher, MISO notifies all NERC reliability coordinators concerning the level and expected duration of the specific event. These forecasts are shared with all power system operating entities throughout North America so that those power systems that are particularly susceptible to this phenomenon can institute preventive procedures
Geomagnetic Storm Warnings/Watches	1-2 days >50% accuracy	Various Power Companies	Allows maintenance procedures that shut down some facilities to be rescheduled, thus maintaining the full reserve for emergency situations.
Geomagnetic Storm Warnings (K-5 through K-9)	2-3 hours >80% accuracy	Various Power Companies	Bring reserve or maintenance generation on line

- **Needs improved solar wind Bz prediction**
- **Needs improved physics-based Geospace models for regional forecasts, intensity, duration**
- **…**

- **In October 2012, the Federal Energy Regulatory Commission (FERC) issued a Notice of Proposed Rulemaking (NOPR) directed to the North American Electric Reliability Corporation (NERC) to submit reliability standards that address the impact of geomagnetic disturbances on the reliable operation of the bulk-power system.**

Reference: SWPC Customer Requirements for Space Weather Services
See: http://www.swpc.noaa.gov/Services/index.html

Evolving Customer Requirements Aviation Industry Examples

User Requirement	Timeliness	Customer	Rationale
Forecasts (text or graphics) of radiation storms (proton events) at energy levels that could create a radiation hazard for aircrew and passengers	6, 12, and 18 hours	Airlines	Forecasts need to be early enough to plan a crew change (for a stop in route) and/or flight-plan. 18 hours is best but a lesser lead time will still aid in the decision making
Graphical forecast product to include intensity, onset and duration, and boundary of degraded communication areas for Polar routes	12 to 24-hours Updated every 6 hours	FAA NavCanada (Air Traffic Control) Airlines	Accurate predictions will help with route selection and management, emergency response, and other critical decision making processes at the control centers
TEC and ionospheric scintillation for GPS applications	TBD in developing NextGen requirements	FAA Airlines	Satellite navigation is a cornerstone of NextGen (i.e., ADS-B). This reliance on GPS/GNSS necessitates space weather products for the conditions that impact the accuracy and availability of GPS.

- **Data and models will be needed to make informed decisions relating to radiation exposure**
- **Need to maintain communications**
- **FAA issues advisories based on space weather**
- **Dec 2012 FAA issued policy for comment on OSHA issue for crew; directed by Congress**
- **Flights: higher alt, lat, longer duration; congestion**

- **Need solar particle event prediction (onset, magnitude, spectrum, duration)**
- **Modeling CME particle acceleration**
- **Modeling radiation exposure at airline and LEO altitudes**
- **Flare predicts (onset…)**
- **…**

Reference: SWPC Customer Requirements for Space Weather Services
See: http://www.swpc.noaa.gov/Services/index.html

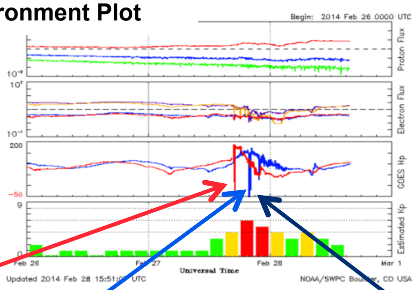
Storm Enhanced Density (SED) Effects, Observations and Prediction

FAA Msg to SWPC

"An Ionospheric Storm began on 2/27/14. The Satellite Operations Specialists were alerted at the WAAS O&M by a Significant Event 757 at 2120 Zulu. So far, LPV and LPV200 service has not been available in Eastern Alaska and Northeastern CONUS. At times, North Central CONUS and all of Alaska have lost LPV and LPV200 Service."

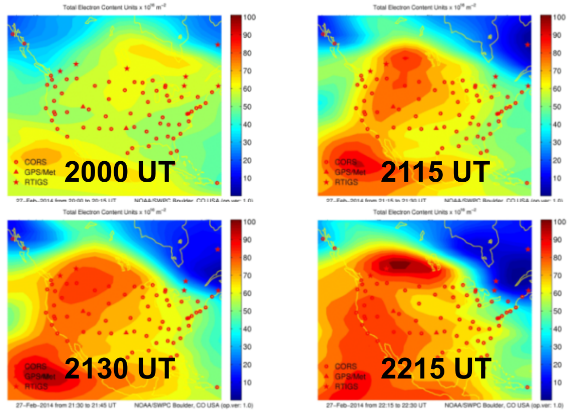
GOES Observes Magnetopause Crossings Prior to FAA Storm Effect

Feb 26-28, 2014 3-day Space Environment Plot



Magnetopause Crossings:
GOES-13 1704 UT, GOES-15 1954 UT

WAAS GPS Outage and US Total Electron Content



- **Strong solar wind – magnetosphere coupling results in:**
  - **GOES magnetometers observing extreme magnetic fields, and in this case the magnetopause moving in over geosynhronous.**
  - **US-TEC increase at mid-latitudes from increase in geomagnetic activity and expanded magnetospheric convection when CONUS is in the sunlit dusk sector. – Tim Fuller-Rowell**
- **GOES magnetic observations and ionospheric electron density variations are both responding to the same solar wind conditions, but it takes more time for the ionosphere to respond.**
- **Therefore, it may be possible to use the GOES signatures to provide a warning/prediction of Storm Enhanced Density in the North American sector that affects GPS signals such as those used by FAA WAAS.**

Howard Singer – NOAA Space Weather Prediction Center

Summary

- Space weather services are provided to support user requirements and to meet national needs for societal and economic benefit and protection of life and property.
- Space weather is receiving increased attention at the highest levels of government and there is a recognized need to predict extreme events and their impacts.
- Meeting user requirements involves space science and space weather understanding, observations, and models; and effectively communicating actionable information for both extreme and routine space weather conditions.
- There are many challenges for space weather prediction: e.g. longer lead time for solar wind Bz, solar particle events, and solar flares. Furthermore, there is a need for developing, evaluating, and validating models for extreme conditions and understanding the intensity of the most extreme events and how often they occur.
- There are also challenges to the operations community. For example, to establish metrics and to select models and observations for transition that can provide the greatest economic and societal benefits and to make these fully operational.
- We require the near-term development and validation of models with sufficient accuracy and lead time to be useful to those impacted by space weather.
- Partnerships and collaborations with NASA, NSF, and other agencies, the national and international science community, and the commercial sector are valued and essential.