NOAA's Space Weather Prediction Testbed:
Several Paths from Research to Operations

Rodney Viereck, SWPT Director

Presentation to the Test Bed Proving Ground Annual Meeting

14 April, 2015

SWPT Mission

Accelerate and improve the quantitative use of scientific research in space weather specification and prediction to improve forecasts, alerts, watches, warnings and products for customers.

Outline:

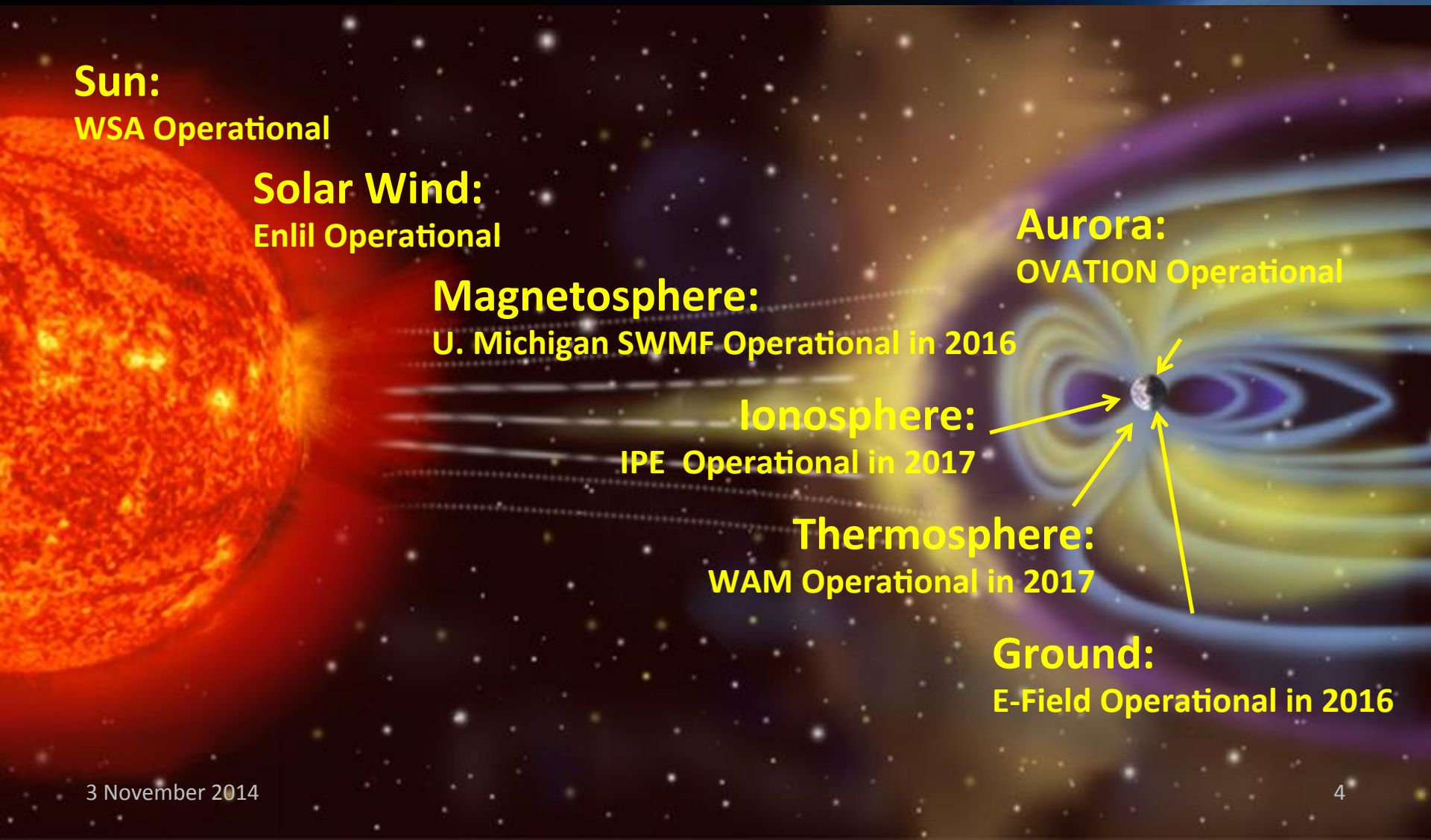
- Science/priorities and service/mission needs
- Brief description of procedures for test project selection and test management
- Most significant accomplishments of FY14
- Top activities in progress/planned for FY15

SWPT Staff and Funding (FY 14)

- 24 PhD scientists (6 Fed, 18 CU/CIRES)
- FY14 Non Fed Funding: ~55% NOAA, ~35% NASA Grants, ~10% NSF/ AFOSR Grants
- DSCOVR Data Collection and Ground Processing System: 3 PhD, 3 Developers
  - Funding 100% NOAA/NESDIS

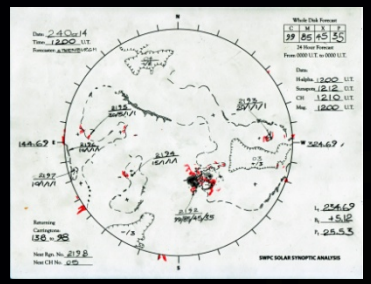
- Now Hiring (FY15)
  - Scientific Programmer: GS 13-14
  - Solar wind scientist programmer (CIRES)
- Hiring soon (FY16)
  - Ionospheric scientist programmer (CIRES)
  - Data assimilation developer (CIRES)

Modeling at NOAA – A Sun to Earth Modeling
Partnerships with the Space Weather Research Community



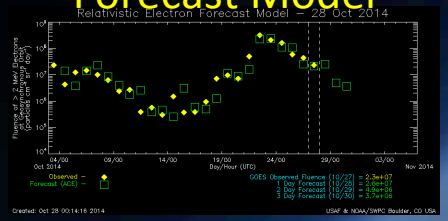
Current SWPC Products

Synoptic Drawings

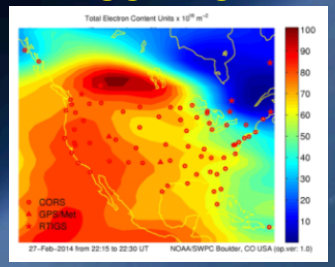


Solar X-ray Flux

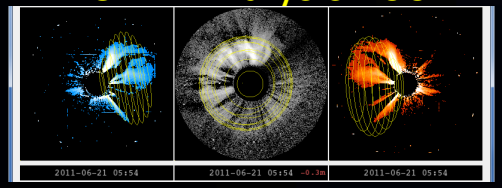
Relativistic Electron Forecast Model



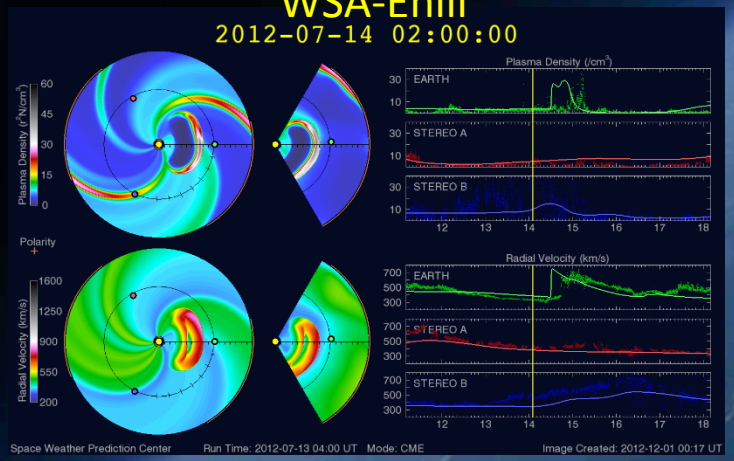
US-TEC



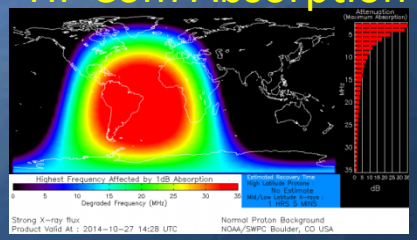
CME Analysis Tool



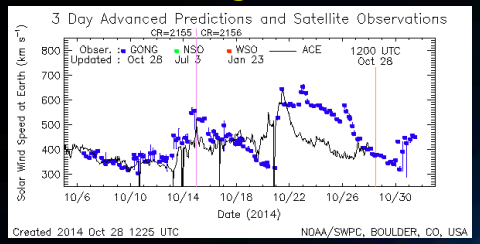
WSA-Enlil



HF Com Absorption

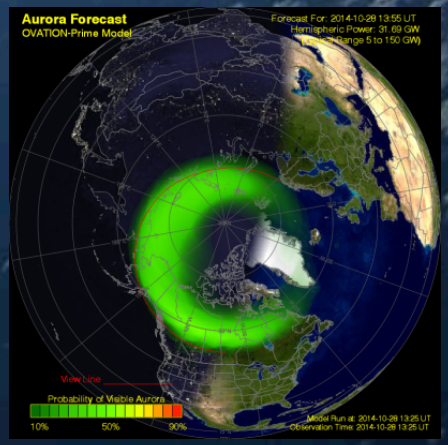


WSA

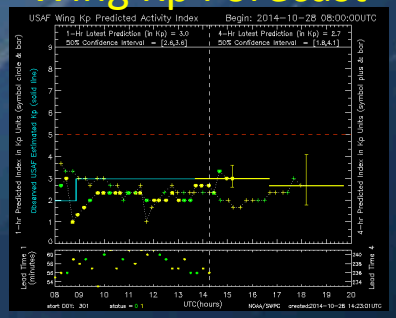


Aurora Forecast Model

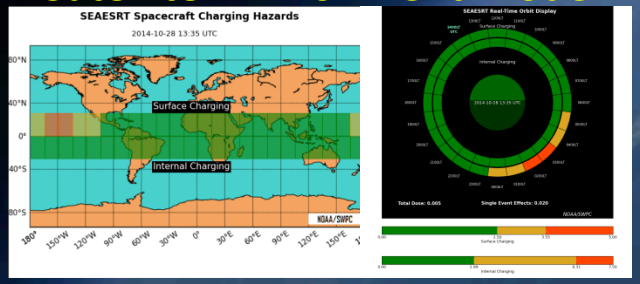
- 30 Minute Forecast



Wing Kp Forecast

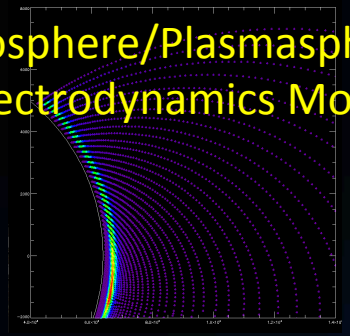


Satellite Environment Model

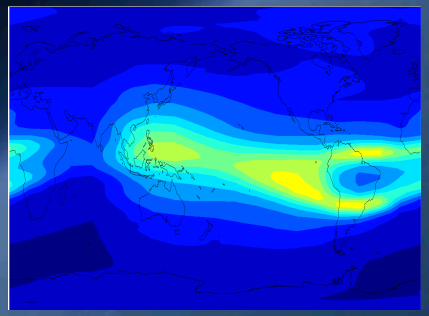


Models Under Development at the Testbed

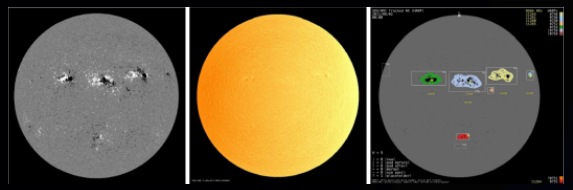
Ionosphere/Plasmasphere/
Electrodynamics Model



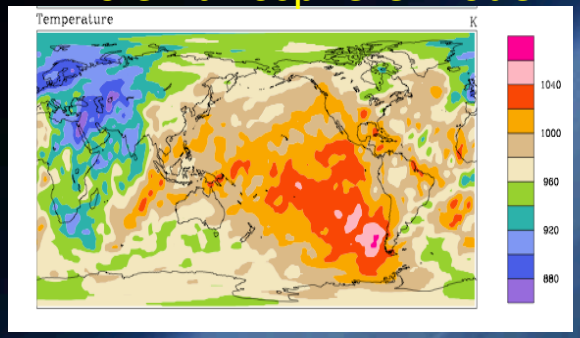
Global TEC
Assimilative Model



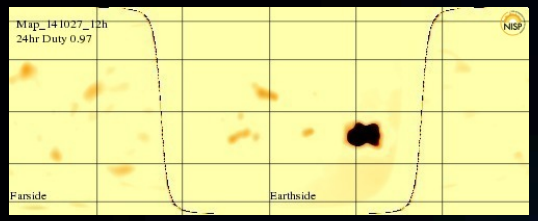
Solar Flare Forecast



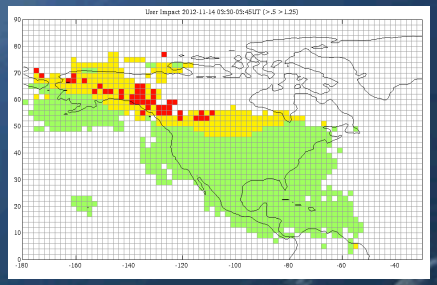
Whole Atmosphere Model



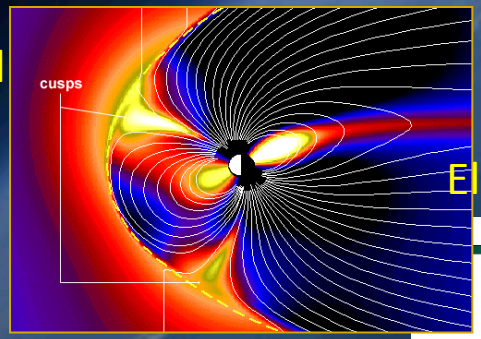
Far-side Analysis



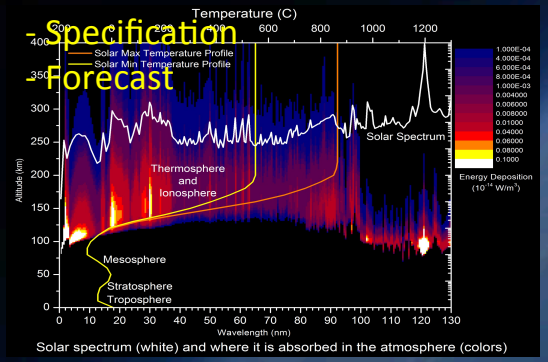
ROTI GPS Product



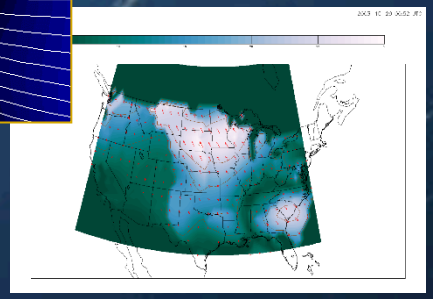
Geospace Model



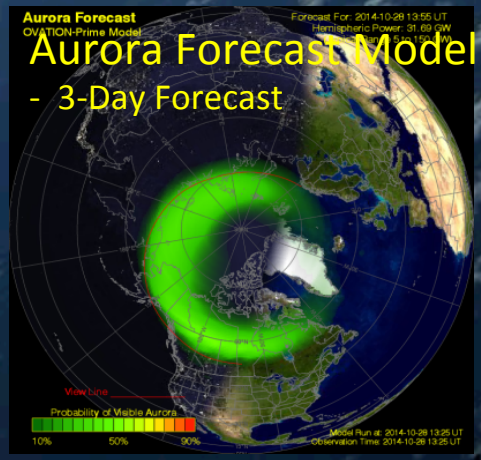
Solar EUV Irradiance Model
- Specification
- Forecast



Electric Field Model



Aurora Forecast Model
- 3-Day Forecast



Science Priorities and Service/Mission Needs

- Forecaster and Customer Needs
  - Improved medium range (1-4 day) forecasts
    - Solar flares: airlines, DOD, DHS/FEMA, etc…)
    - Proton events: satellites, astronauts, airlines, etc…
    - Geomagnetic storms: electric power, GPS, aurora, etc…
    - Ionospheric conditions: GPS, radio communication, etc…
  - Regional specification of storm impacts
    - Regional E-field
      - E.g. electric power industry
    - Regional HF com outages
      - E.g. airline industry, DHS, FEMA
    - Regional ionospheric scintillation
      - E.g. transportation, airlines, mineral/oil exploration, etc…

Science Priorities and Service/Mission Needs

- Forecaster and Customer Needs
  - Improved medium range (1-4 day) forecasts
    - Solar flares: airlines, DOD, DHS/FEMA, etc…)
      - Requires significant new understanding of processes inside the sun*
    - Proton events: satellites, astronauts, airlines, etc…
      - Requires better parameterization of interplanetary shock propagation*
    - Geomagnetic storms: electric power, GPS, aurora, etc…
      - Requires forecasting of the interplanetary magnetic field*
    - Ionospheric conditions: GPS, radio communication, etc…
      - Requires new data assimilation techniques for strongly driven systems*
  - Regional specification of storm impacts
    - Regional E-field
      - E.g. electric power industry
    - Regional HF com outages
      - E.g. airline industry, DHS, FEMA
    - Regional ionospheric scintillation
      - E.g. transportation, airlines, mineral/oil exploration, etc…

*These tasks require basic research support from other agencies (NSF, NASA, DOD)

Procedures for Project Selection and Management

- Direct Approach: Select model from the research community based on published works.

- Democratic Approach: Hold an open competition between modelers, brokered by a neutral third party (NASA).

- Internal Approach: Develop our own model in-house from the ground up.

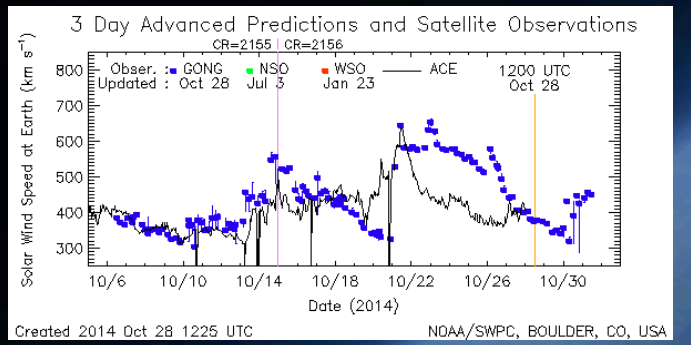
Model Selection and Transition: WSA-Enlil
1. The Direct Approach

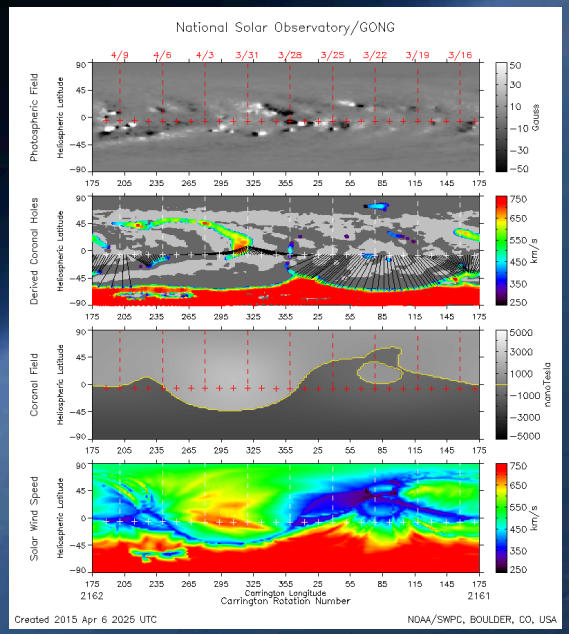
- Specific researchers who had promising models were invited to work at NOAA
  - Researchers learned about NOAA needs and requirements
  - Developed their models accordingly with an eye towards meeting operational needs.
- Issues:
  - SWPC relied heavily on the expertise of the model developers.
  - We did not develop the expertise to maintain and improve the models ourselves
- Solution:
  - SWPC is hiring a solar-heliosphere modeling expert who will take over model O&M.
    - The SWPC version of the model may diverge from the research version maintained by the original developers.

WSA-Enlil Model

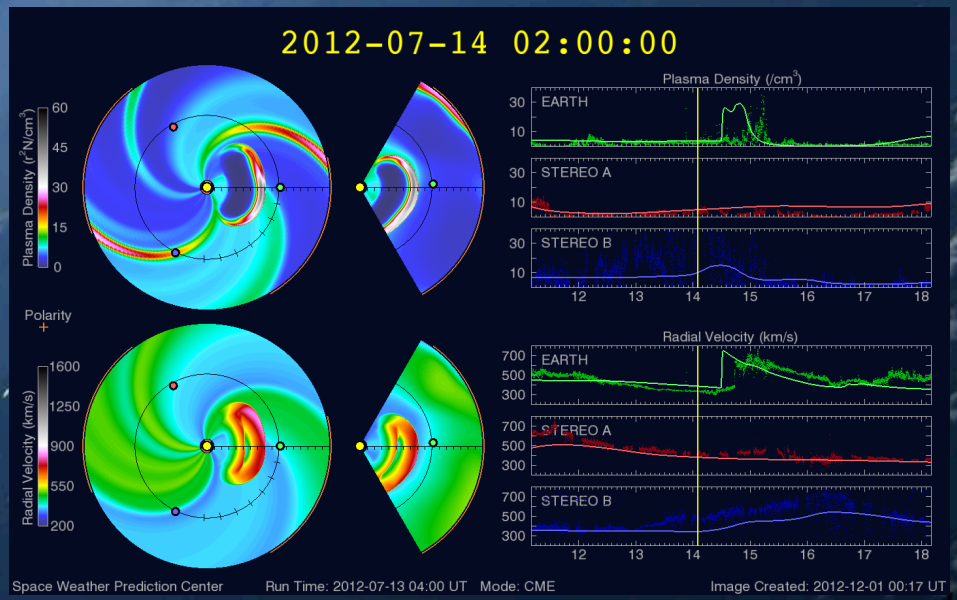
Operational since 2012

- WSA:
  - Surface of the sun to 20 solar radii





- Enlil
  - 20 solar radii to Earth

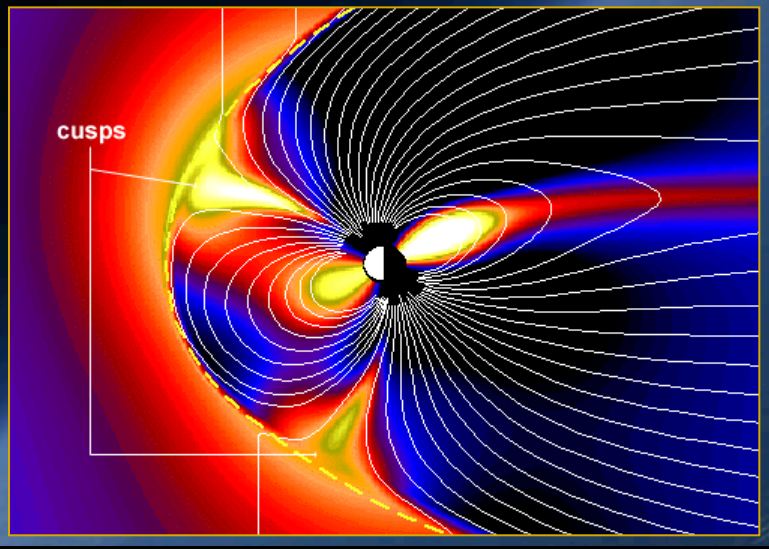


Model Selection and Transition: Geospace
2. The Democratic Approach

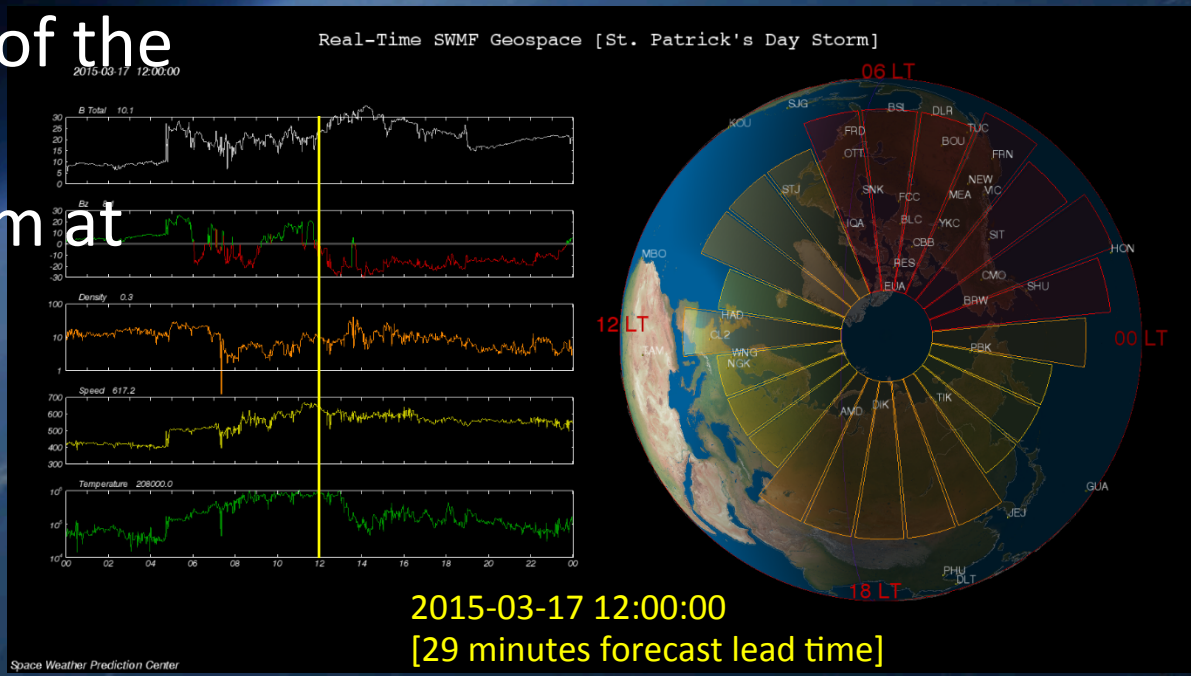
- Researchers were invited to submit their models to the NASA Community Coordinated Modeling Center (CCMC).
  - CCMC ran each of the five models and performed tests.
  - Model performance and comparisons were base on metrics designed to test the model for specific NOAA requirements.
- A model was selected (from the U. Michigan) and is being transitioned to operations.
  - FY15 Milestone: Delivery to NCEP/NCO of a Geospace Model ready for transition to operations.
- Issues:
  - The model was not designed for real-time operations.
    - It would run slower than real-time down during major space weather storms.
  - SWPC must develop the modeling expertise to maintain this model
- Solution:
  - SWPC has contracted with the model developer to help prepare the model to run in real-time.
  - SWPC will hire a magnetosphere modeling expert who is working with the model developer to improve the model, develop products, and prepare it for transition to operations.

Geospace Model

- Geospace model of Earth's magnetosphere



- Regional product of the impact of the geomagnetic storm at Earth



2015-03-17 12:00:00
[29 minutes forecast lead time]

Model Selection and Transition: IDEA = WAM-IPE
3) The Internal Approach

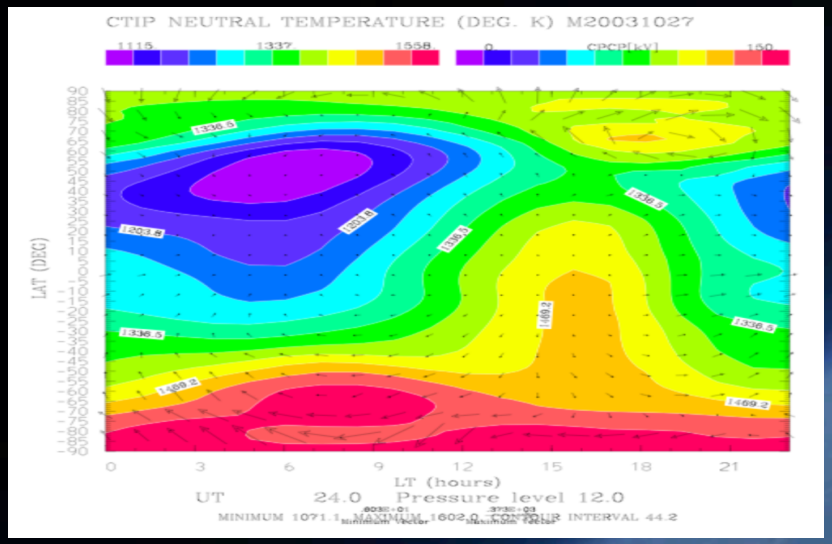
- SWPC researchers recognized an unmet requirement for improved ionospheric forecasting.
  - No one had developed a space weather model coupled to a weather model (there have research efforts using climate models such as NCARs WACCM)
- With funding from NOAA, NSF, NASA, DOD, FAA, etc… SWPT and CIRES scientists developed…
  - The Whole Atmosphere Model (WAM) by extending GFS up to 600 km
  - Ionosphere Plasmasphere, Electrodynamics (IPE) Model.
- Current activities involve…
  - Completing the development of WAM
    - Improving gravity wave parameterization (R2O Grant from NWS)
    - Incorporating geomagnetic storms and solar EUV forcing
    - Improving the stratospheric chemistry (With EMC)
    - Developing scripts to run on a 1-hour cadence (With EMC)
    - Extending GDAS up to 100 km (With EMC)
  - Completing the development of IPE
    - Finishing the electrodynamics
    - Improving the speed (incorporating a more efficient solver)
    - Develop a new DA scheme for the ionosphere/thermosphere system (NASA Grant)
  - Coupling these models and preparing them for transition to operations.
    - Working with GSD and NESII

Model Selection and Transition: IDEA = WAM-IPE
3) The Internal Approach (continued)

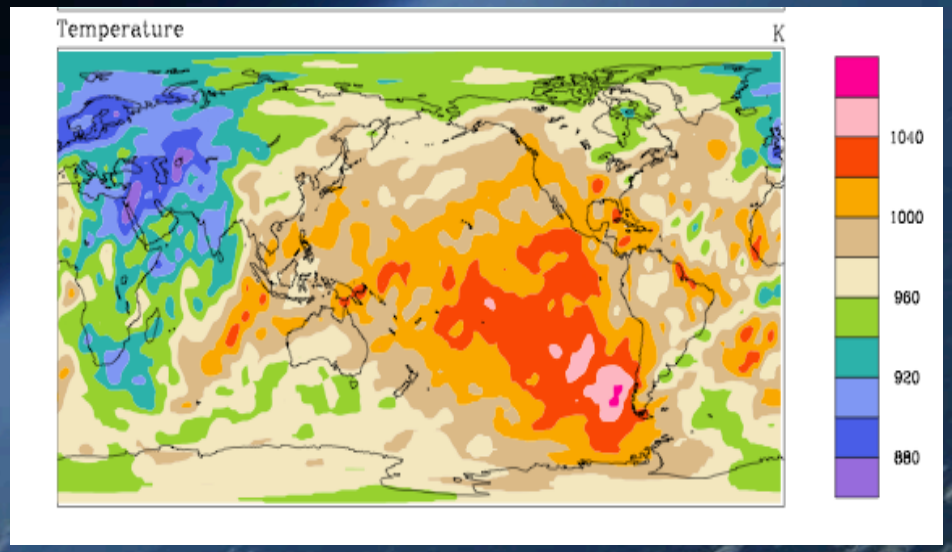
- Delivery schedule
  - FY15 Milestone: WAM running in real-time in parallel mode on WCOSS Dev.
  - FY17 Milestone: WAM-IPE (one way coupling) running in real-time on WCOSS Dev.
  - FY19 Milestone: WAM-IPE (two way coupling) with full data assimilation ready for transition to ops.
- Issues:
  - The Valley of Death is broad
    - Significant amount of basic/applied research still required.
    - Other agency support has dwindled… it is geared to new discovery.
    - NOAA/NCEP funding is aimed at R2O.
- Solution:
  - New money!
    - **<u>$1.5 M for Space Weather R2O in FY16 President's budget!</u>**

Modeling the Upper Atmosphere: With and Without WAM

Typical ionosphere-thermosphere model: Global maps show little fine structure



Ionosphere-thermosphere model coupled to the lower atmosphere: Global maps show structure relevant to GPS accuracy and available



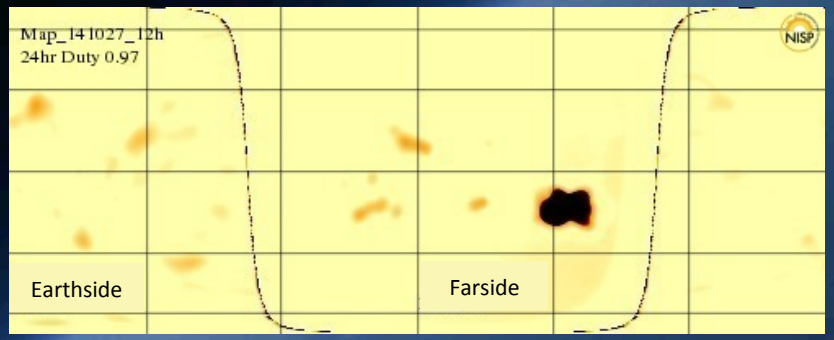
The temperature structure from a stand-alone thermosphere ionosphere plasmasphere model (e.g., CTIPe) is similar to the MSIS empirical model. The Whole Atmosphere Model (WAM) drives variability from the chaotic lower atmosphere which introduces a whole spectrum of variability.

SBIR: Another path from R2O

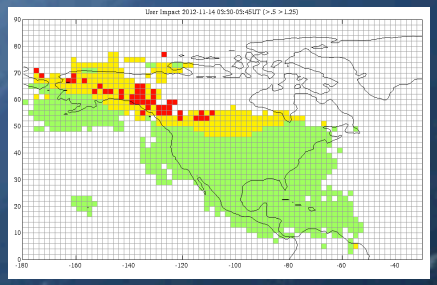
- One Phase I project(in final selection):
  - Imaging the far side of the sun to improve 1-3 day forecasts.

- Two Phase II project:
  - Developing a GPS product to provide a proxy for ionospheric scintillation (for precision GPS users) based on single frequency observations.
  - Developing improved probabilistic flare forecasts based on new high resolution imagery (from NASA and NSF observations).

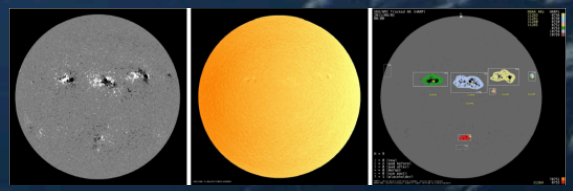
Far-side Analysis
Using Heliosiesmology



ROTI GPS Product



Solar Flare Forecast



FY14 Accomplishments

- Final selection of the Geospace model (U. Mich.)
  - Research grade model ported to NCEP Zeus
  - Contract established with U. Mich to help with transition.
- Initial version of the IPE model ready for test and evaluation. Coupling of IPE to WAM initiated.
- 3-day aurora forecast test product released for public comment (developed with JHU APL)
- North American Total Electron Content (expanded US-TEC) model ready to be implemented as a test product
  - Issue: Competition for internal (SWPC) resources between research and operations has allowed this product to languish.

FY15 SWPT Accomplishments

- Successful launch of DSCOVR, the NOAA satellite mission to the L1 point between Earth and Sun.
  - Ground processing system is performing very well.
- Geospace model ready for transition (handed over to NCO).
- WAM running in parallel mode on WCOSS Dev.
- WSA-Enlil (operational model) upgrades implemented
  - Requires hiring of new person
- Internal SWPC Models:
  - NATEC test product released for public comment
  - 3-Day aurora forecast transitioned to operations.
  - E-Field specification test product released for public comment.

Other SWPT Developments

- SWPC/SWPT will take over the processing of GONG data
  - GONG is an NSF funded National Solar Observatory (NSO) system of 6 ground-based solar telescopes
  - GONG magnetogram data is used operationally to feed several models.
- SWPC/SWPT (with cooperation from AFRL) will develop and transition the new ADAPT model for solar activity forecasting
  - ADAPT will provide continuously updating solar magnetogram forecasts.
    - Improved geomagnetic storm forecasts
    - Improved F10.7 forecasts
    - Improved solar irradiance forecast
- SWPT is working on a CRADA with ASTRA, a company that provides real-time ground-base GPS data from Alaska.
  - These data would greatly improve NA-TEC (GPS specification product).

NOAA/NASA Joint Center

- It has been suggested that a joint center for space weather modeling might help bridge the valley of death.
  - NOAA and NASA senior leadership have been asked to improve relations and define roles and responsibilities.
  - The NOAA SWPT and the NASA CCMC are coordinating activities and developing joint tasks to facilitate the R2O process.
  - CCMC will…
    - Help evaluate models
    - Validate and quantify model performance
    - Test and validate improvements and upgrades to operational models

SWPT Issues

- Competition with Operations for resources
  - Hiring
    - SWPT fed position is on hold based at HR based on NWS priorities. No sign of when HR will start processing this position.
  - IT support
    - Internal SWPC resources are spread too thing. Ops. takes priority over R&D.
- Research Support
  - NWS STI focusses on delivery of new products.
    - It does not take into account that there is no space weather component in OAR.
  - There is a gap between NSF/NASA support and NWS STI supported activities.

Summary

- The SWPT priorities and activities are driven by the needs of the forecasters and customers
- The SWPT works closely with the research community leveraging the best science to improve products and services
- The SWPT continues to make progress in the R2O process moving forward on several major projects and many smaller ones.