Space Weather

Research-to-Operations Operations-to-Research R2O2R2O…

(The Many Paths Across the Valley of Death)

Rodney Viereck

Head of Research and Director of the Space Weather Prediction Testbed

NOAA Space Weather Prediction Center

Presentation to the
National Academies, Committee on Solar and Space Physics
6 October, 2016

Space Weather Prediction Center

established 1949

R & D –
Space Weather Prediction Testbed

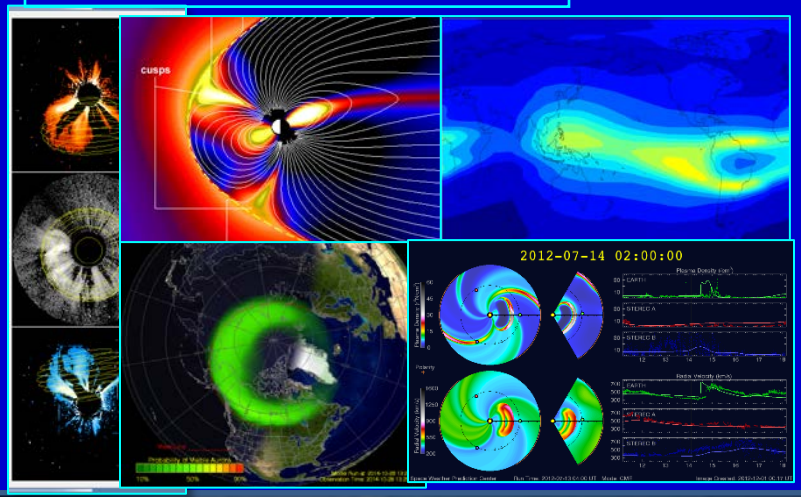
Transitioning models into operations

R2O

Research-to-Operations
- Applied Research
- Model Development
- Model Test/Evaluation
- Model Transition
- Operations Support

Operations-to-Research
- Customer Requirements
- Observation Requirements
- Research Requirements

O2R



Operations –
Space Weather Forecast Office

Putting out daily forecast since 1965.

Specifications; Current conditions
Forecast; Conditions tomorrow
Watches; Conditions are favorable for storm
Warnings; Storm is imminent with high probability
Alerts; observed conditions meeting or exceeding storm thresholds

SWPC Research Staff and Activities

Applied Research Section (Space Weather Prediction Testbed)

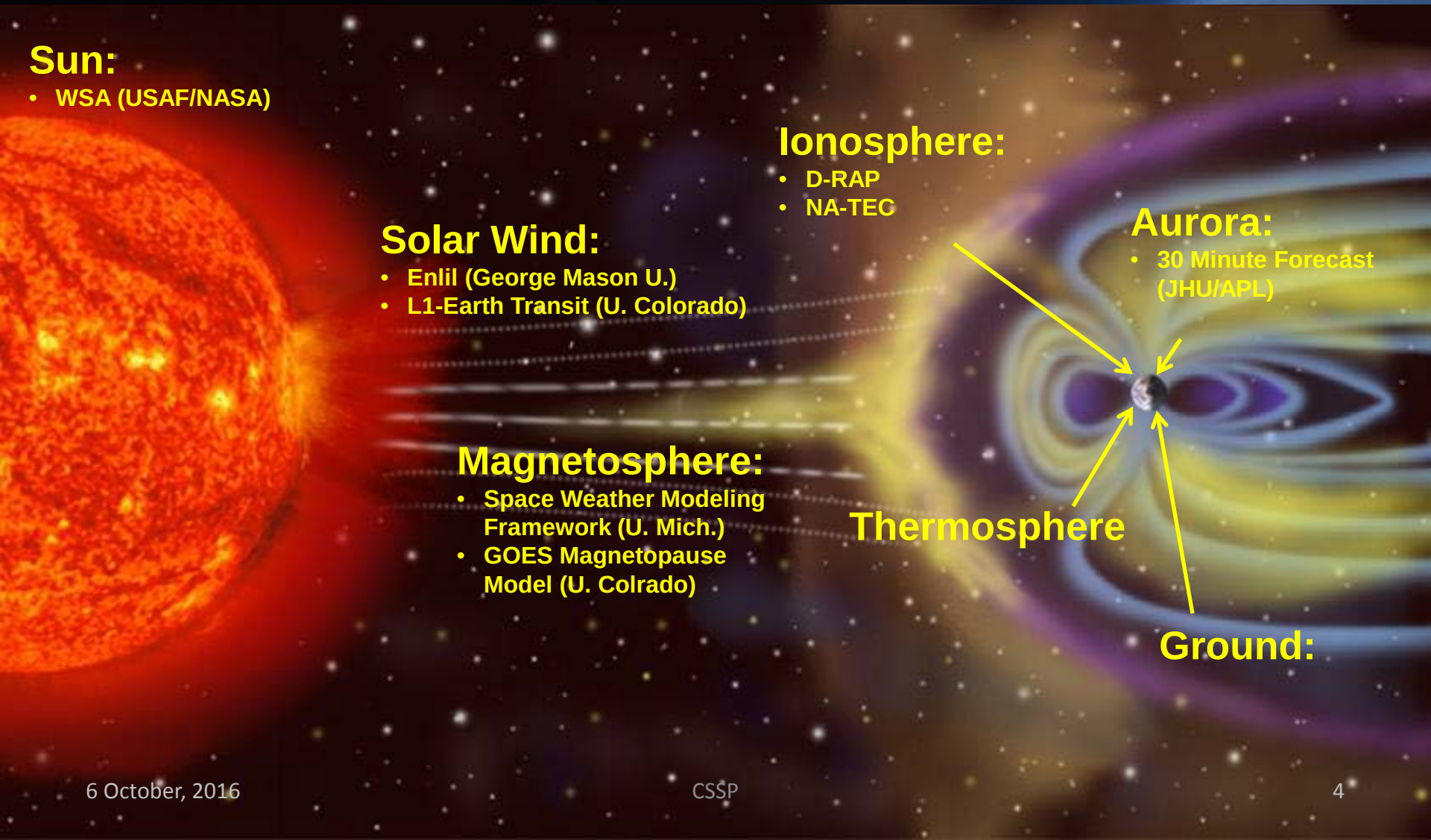
- 18 PhD scientists (7 Fed, 11 CU/CIRES)
- PhD student (COSMIC II)
- Feds are fully funded
- CU/CIRES Researchers are funded…
  - ~50% NOAA,
  - ~50% NASA/NSF/AFOSR Grants

Activities:

- Basic and Applied Research
- Model and Product Development
- Operations, Maintenance, and Upgrades
- Data Processing
- Satellite Ground Systems and Data Processing
- SWAP/SWORM Actions (SWPC leads on 31 of the 99 actions)

SWPC Models

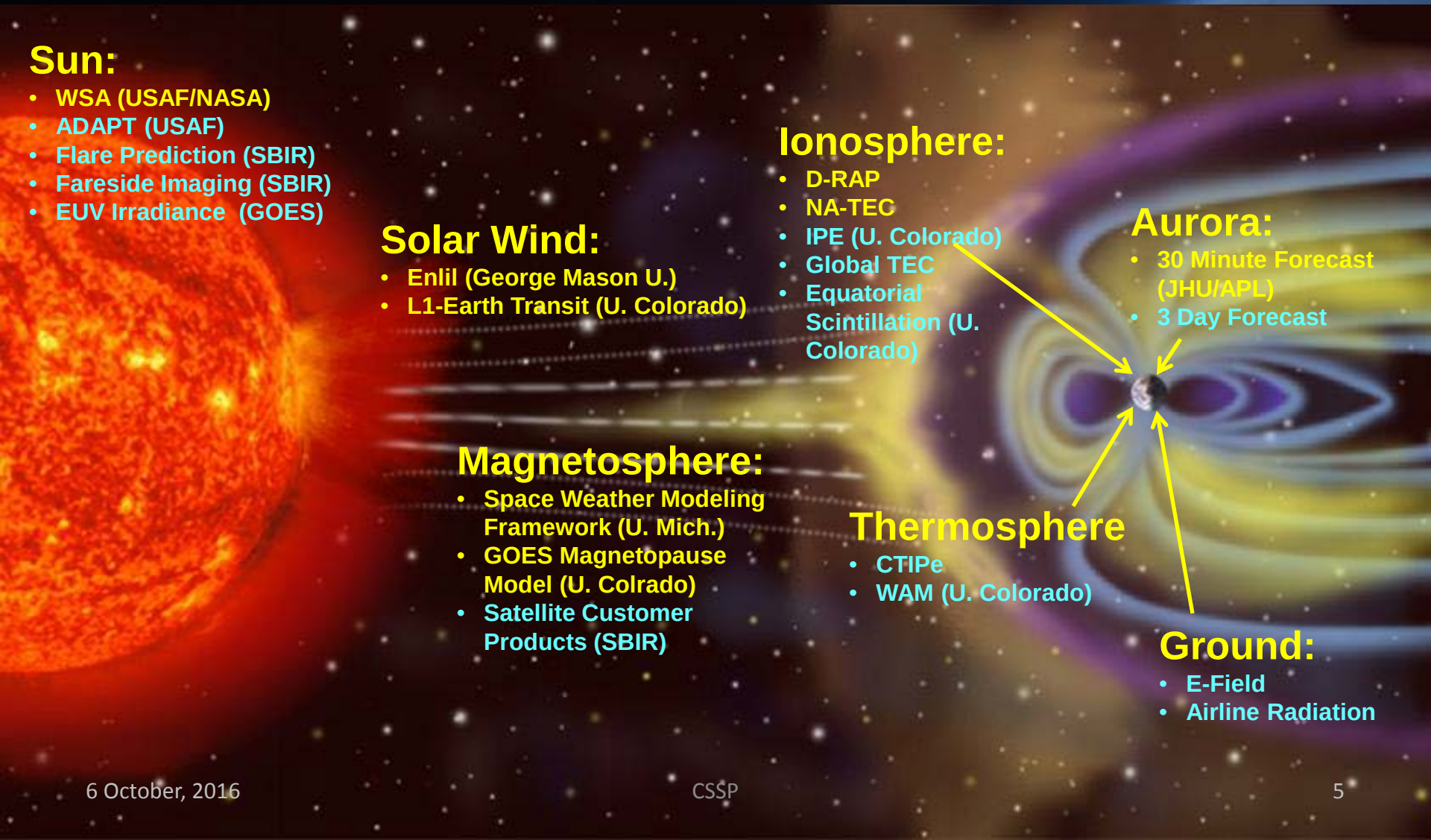
Operational



SWPC Models

Operational

Under Development



Sun:

- WSA (USAF/NASA)
- ADAPT (USAF)
- Flare Prediction (SBIR)
- Fareside Imaging (SBIR)
- EUV Irradiance (GOES)

Solar Wind:

- Enlil (George Mason U.)
- L1-Earth Transit (U. Colorado)

Ionosphere:

- D-RAP
- NA-TEC
- IPE (U. Colorado)
- Global TEC
- Equatorial Scintillation (U. Colorado)

Aurora:

- 30 Minute Forecast (JHU/APL)
- 3 Day Forecast

Magnetosphere:

- Space Weather Modeling Framework (U. Mich.)
- GOES Magnetopause Model (U. Colrado)
- Satellite Customer Products (SBIR)

Thermosphere

- CTIPe
- WAM (U. Colorado)

Ground:

- E-Field
- Airline Radiation

Different Ways to Transition Models into Operations

- 1. Direct Approach: Select model from the research community and work directly with that modeler to develop what we need.
  - Examples: WSA, Enlil, OVATION
- 2. Competitive Approach: Hold an open competition between modelers, brokered by a third party (NASA CCMC).
  - Example: Geospace
- 3. Internal Approach: Develop our own model in-house from the ground up (often with collaborations).
  - Examples: WAM, IPE, USTEC, GloTEC, D-RAP, E-Field, Magnetopause, Aurora Forecast,

Model Selection and Transition

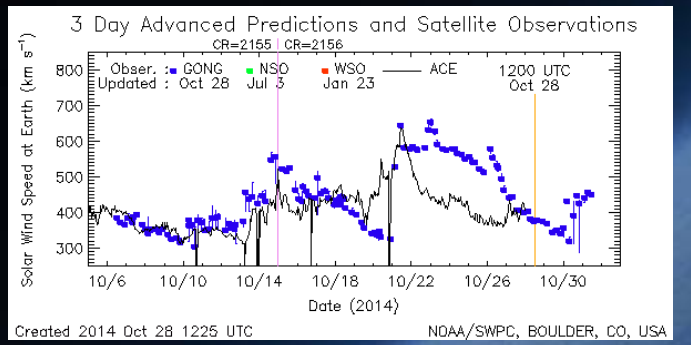
1. WSA-Enlil: The Direct Approach

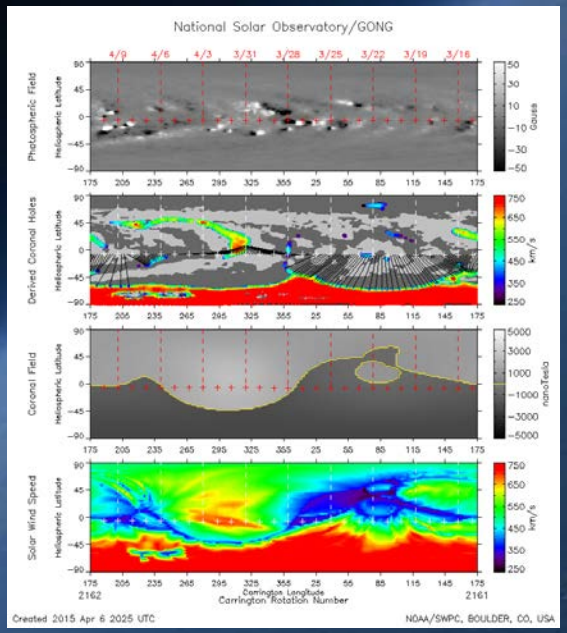
- Model developers were invited to work at NOAA (Arge, Odstrcil)
  - Learned about NOAA needs and requirements.
  - Developed their models accordingly with the intention of meeting operational needs.
- Issues:
  - May not get the best model.
  - Rely heavily on the expertise of the model developers.
    - SWPC did not develop the expertise to maintain and improve the models.
  - SWPC does not obtain intellectual property rights.
    - Improvements and upgrades can only be made with collaboration with the model developer.
    - Sharing the models with other forecast centers requires approval and coordination with the model developer.

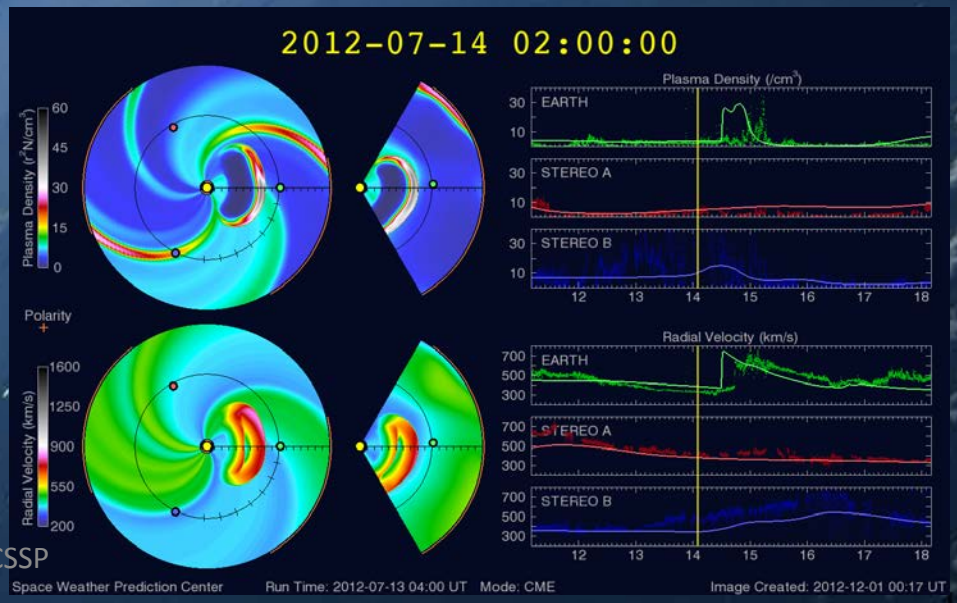
WSA-Enlil Model

Operational since 2012

- WSA:
  - Surface of the sun to 20 solar radii
- Enlil
  - 20 solar radii to Earth
- Improves the forecast of geomagnetic storms







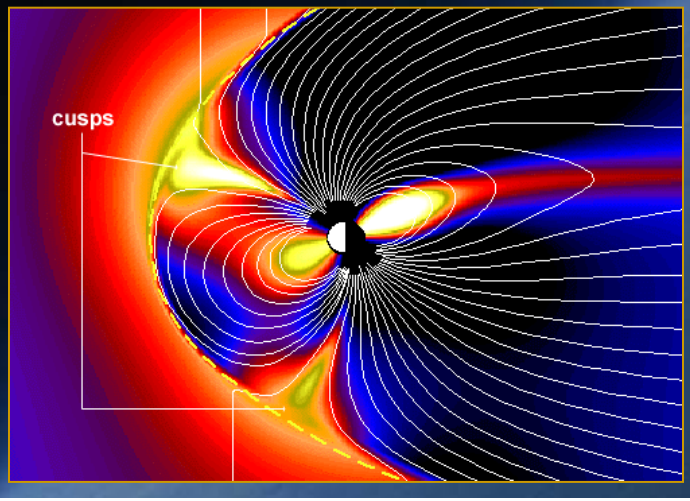
Model Selection and Transition
2. Geospace Model: the Competitive Approach

- Requirements for improved geomagnetic storm forecasts and regional information come from customer (power grid operators)
- Researchers 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.
- The U. Michigan Space Weather Modeling Framework was selected and has been transition to operations (it took 2 years).
- Issues:
  - The model was not designed to run in real-time
  - SWPC relies heavily on the expertise of the model developers.
    - We have not develop the expertise to maintain and improve the models ourselves
  - SWPC does not have intellectual property rights.
    - Improvements and upgrades can only be made with collaboration with the model developer

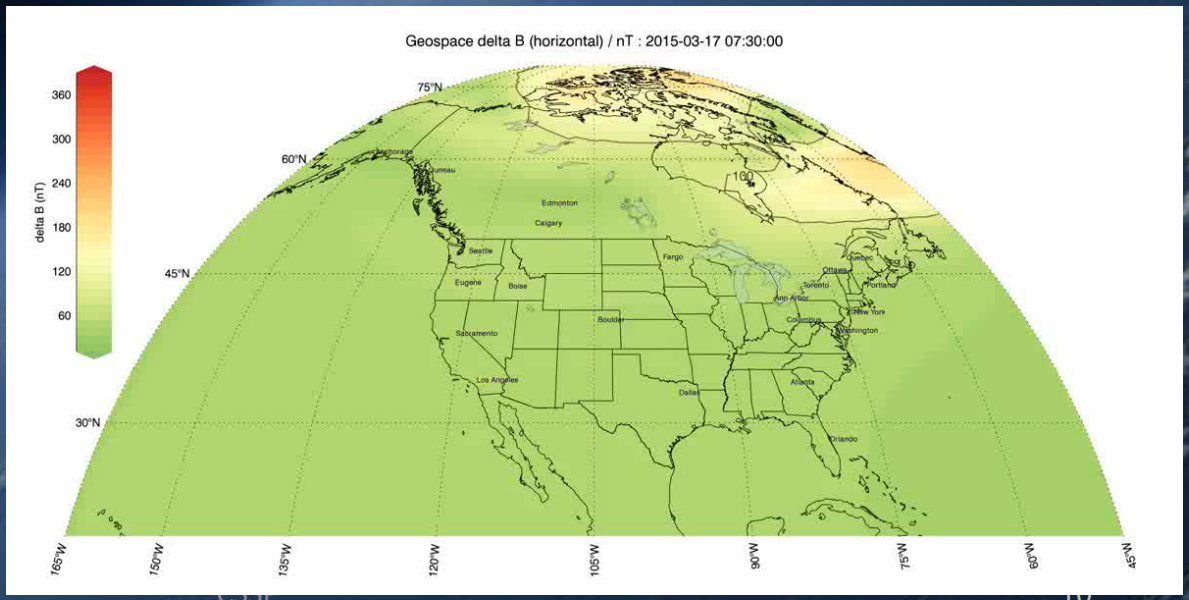
Geospace Model

Operational as of Tuesday (10/4)

- Geospace model of Earth's magnetosphere



- Regional Delta-B product: The impact of the geomagnetic storm



Model Selection and Transition

3. IDEA = WAM+IPE+WDAS: The Internal Approach

A coupled atmosphere, thermosphere, ionosphere modeling system with data assimilation

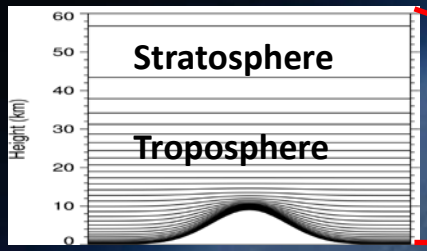
- Requirements for ionosphere-thermosphere forecasts for GPS/GNSS, Communication, Satellite Operations
  - No alternative existed.
- With funding from NOAA, NSF, NASA, DOD, FAA, etc… NOAA and CIRES scientists developed two models from the ground up (~10 years);
  - The Whole Atmosphere Model (WAM) is an extension of GFS up to 600 km
  - Ionosphere Plasmasphere, Electrodynamics (IPE) model is a 3-D version of FLIP.
- Development and Delivery Schedule
  - FY16: WAM with space weather inputs running in real-time in parallel mode on WCOSS Dev.
  - FY17: WAM-IPE (one way coupling) running in real-time on WCOSS Dev.
  - FY18: WAM-IPE (two way coupling) with middle atmosphere data assimilation ready for transition to ops.
  - FY19: Ionosphere-Thermosphere data assimilation scheme ready for testing and implementation.

Modeling the Structure in the Ionosphere

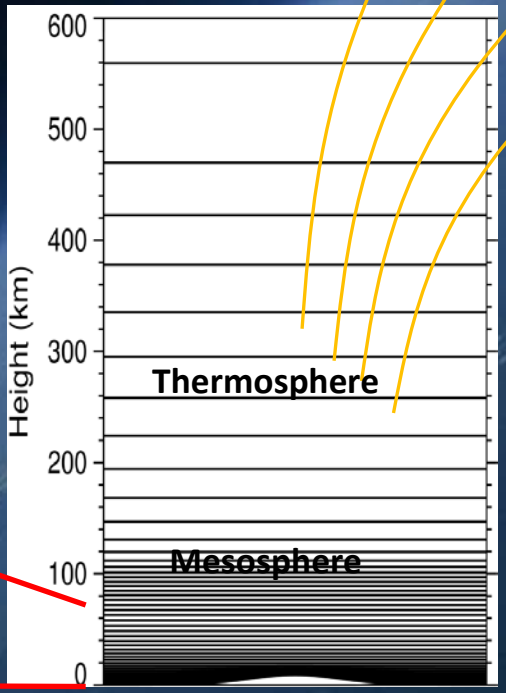
Integrated Dynamics in Earth's Atmosphere (IDEA)

Whole Atmosphere Model (WAM = Extended GFS)
Ionosphere Plasmasphere Electrodynamics (IPE)
WAM Data Assimilation System (WDAS)
Integrated Dynamics in Earth's Atmosphere (IDEA = WAM + WDAS + IPE)

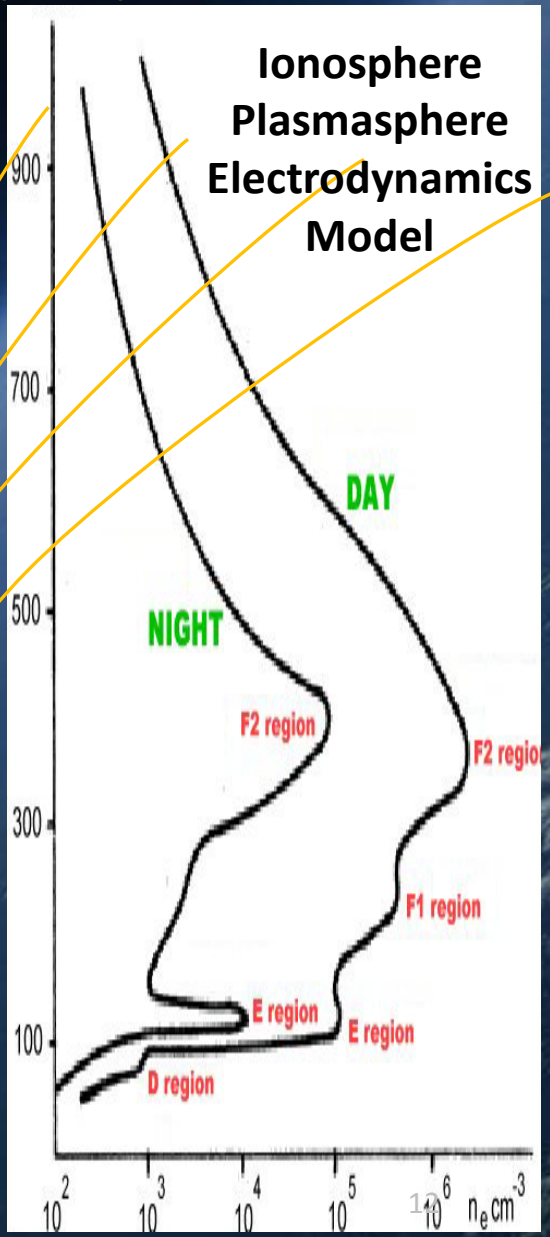
Global Forecast System Model
Weather Forecast Model
0 – 60 km



Whole Atmosphere Model
Neutral Atmosphere 0 – 600 km



Ionosphere Plasmasphere Electrodynamics Model



Ionospheric Structure

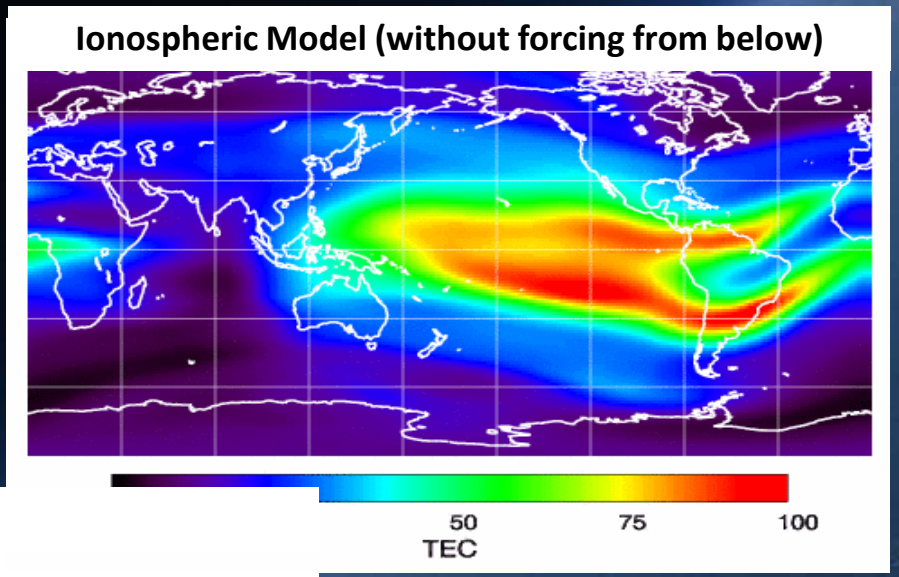
Motivation for IDEA

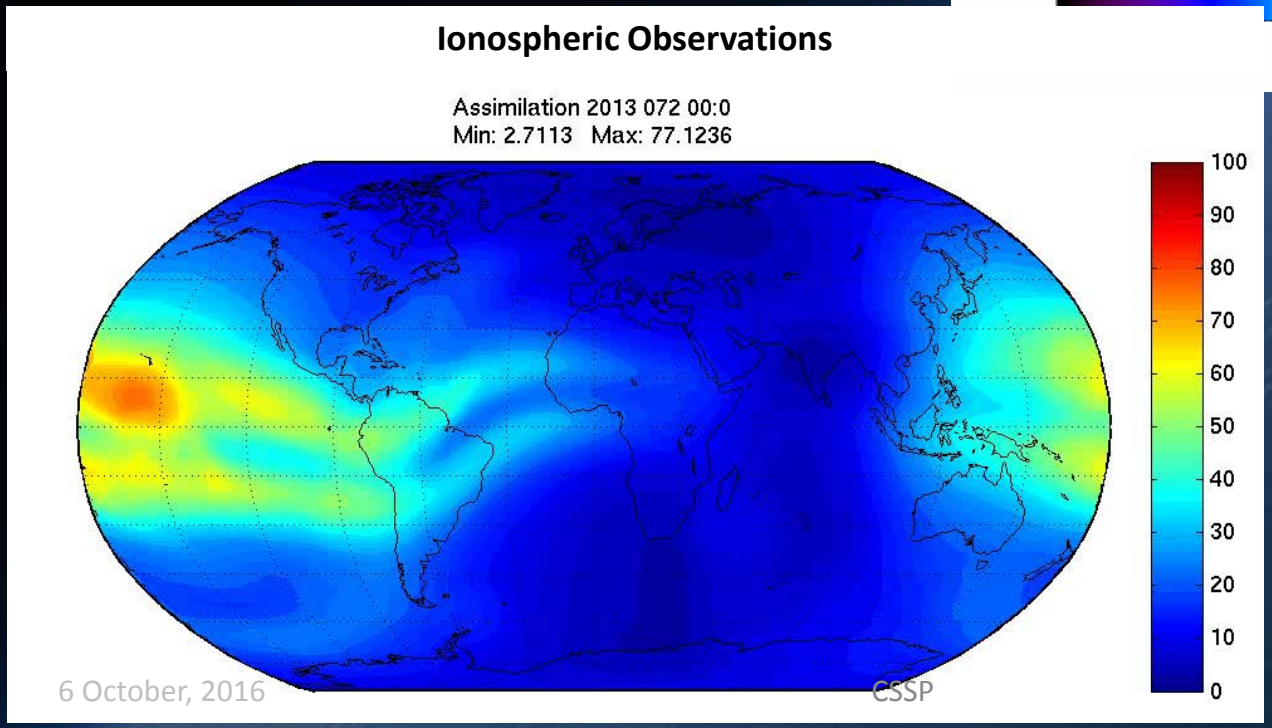
Typical ionospheric models do not capture the full variability of the ionosphere.

WAM will drive IPE from below and generate the atmospheric structures that are observed.

IPE (Model)

Input: Solar EUV, Solar Wind, IMF





GloTEC (Observations)

Input: Space-based GPS radio occultation data (COSMIC 2) and ground based GPS line-of-site TEC

Output: TEC on a 2.5 deg lat x 5 deg lon by 10 km ht

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

- Pros:
  - We get what we want
  - We own the models
- Issues:
  - Takes a Lot of NOAA Resources
    - Significant amount of basic/applied research required
    - Applied research for space weather is not well supported
    - Current development activities (some fundamental science)
      - Incorporating geomagnetic storms and solar EUV forcing into WAM
      - Improving gravity wave parameterization (R2O Grant from NWS)
      - Developing scripts to run WAM on a 1-hour cadence
      - Extending Data Assimilation up to 100 km (R2O Grant from NWS)
      - Improving IPE 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.

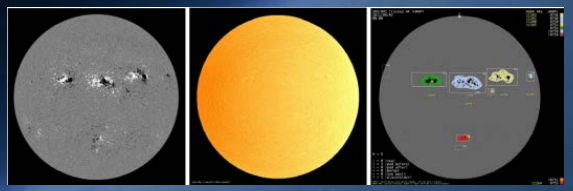
Model Development:
Small Business Innovative Research (SBIR)

- Current SBIR Phase I projects:
  - Developing new products for satellite customers
  - Evaluating options for tracking L1 satellites

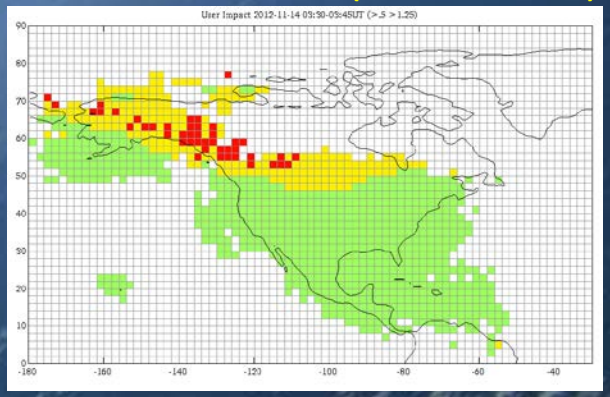
- Current SBIR Phase II projects:
  - Improving probabilistic flare forecasts based on high resolution imagery (from NASA and NSF observations).
  - Identifying solar active regions on the far side of the sun (helioseismology)

- Pros: We get what we want
- Cons: We may not own the results

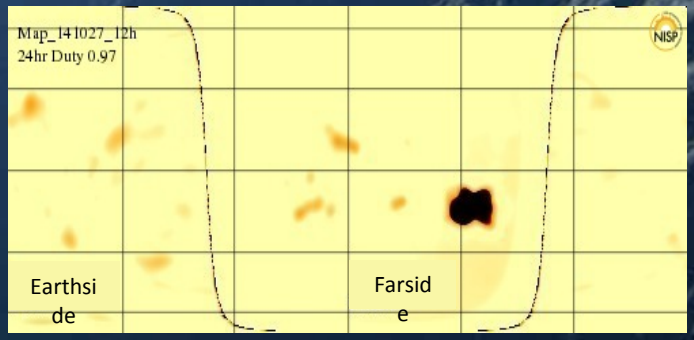
Solar Flare Forecast



ROTI GPS Product (earlier SBIR)



Far Side Analysis (Helioseismology)



Other Development Activities

- GONG Solar Magnetograms
  - GONG is an NSF funded National Solar Observatory (NSO) system of 6 ground-based solar telescopes
  - GONG magnetogram data are used operationally to feed several models.
  - NOAA is $supporting NSF to keep real-time GONG data flowing
  - NOAA is taking on the real-time processing of GONG data

- ADAPT model for solar activity forecasting (with USAF support)
  - ADAPT will provide continuously updating solar magnetogram forecasts.
    - Improved geomagnetic storm forecasts
    - Improved F10.7 forecasts
    - Improved solar irradiance forecast

SWAP Action 5.6.2: Improve R2O2R…

- Improve the transition of models from research to operations.

- Develop better ways to maintain and improve existing operational models.

SWAP Action 5.6.2: Improve R2O2R…

- Improve the transition of models from research to operations.
  - Much of the space environment research does not addresses problems that are critical to forecasters and customers
  - Research models are not ready for transition
- Develop better ways to maintain and improve existing operational models.
  - Intellectual property rights prevent NOAA from using the full intellect of the space research community.
  - There is little support for upgrades and improvements to Operational models.

SWAP Actions: Improve R2O2R…
One Option: A Joint Center for Space Weather Modeling
Terrestrial Weather Example: Joint Center for Satellite Data Assimilation

- A place for testing, evaluating, and transitioning new models into operations.
- A platform for improving, upgrading, and adding capabilities to existing operational models
- Provide funding opportunities
  - For researchers to improve operational models
  - For researchers to use operational models to do research
- A multi-agency supported center for applied space weather research

Summary of Gaps

- Support for applied research to transition models to operations and to improve existing operational models is not well established.
  - There is little support for making models ready for transition.
  - There is little support for improving operational models.

- Models in operations at SWPC have impediments to improvements and upgrades.
  - Space weather models are largely developed outside of federal labs and are not open source or community models.
    - Only the original model developer is involved.
    - This limits the intellectual pool for improvements.
  - Other researchers do not have access to the operational models and real-time data streams.

Questions