NOAA Space Weather Services

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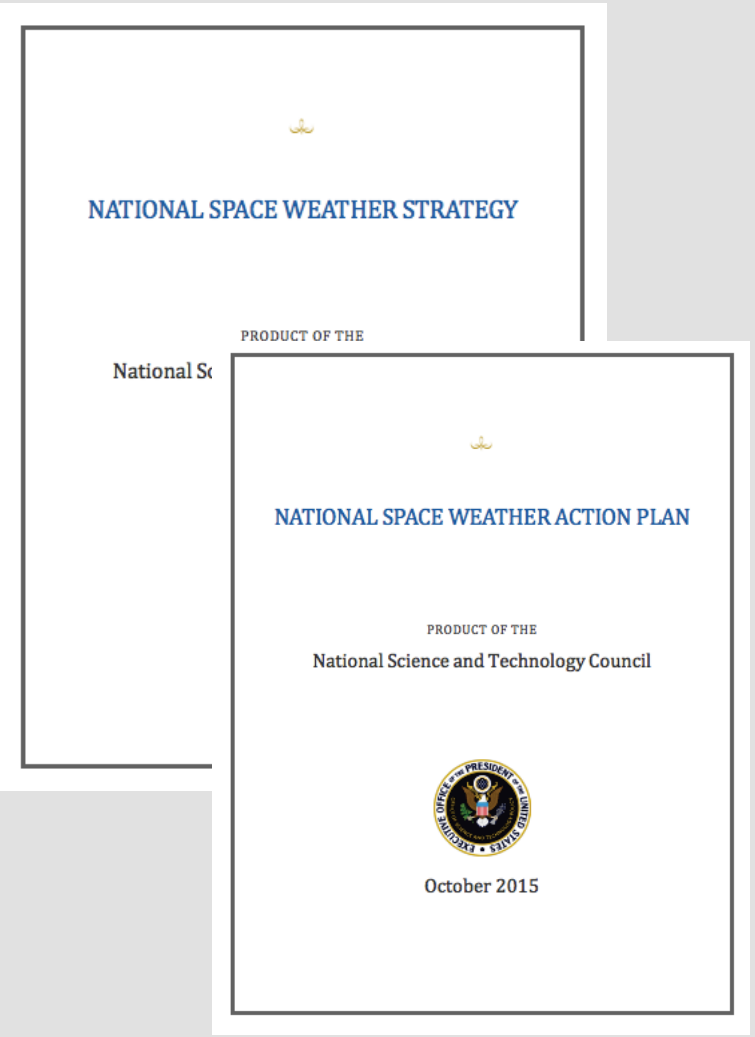
Space Weather Enterprise Forum
27 June 2017

Outline

- Space Weather Operations, Research, and Mitigation (SWORM) and Space Weather Action Plan update
- Drivers for NOAA space weather services
- Sustaining Critical Space Weather Observations
- NOAA/NWS perspective – Capitalize on the Nation's research investment; implementing the SWPC operational model suite

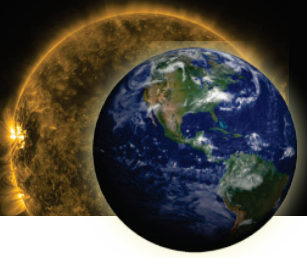
Space Weather Action Plan - Highlights in Observations, Data and Research



- Chartered under White House Office of Science & Technology Policy (OSTP)
  - Co-Chaired by OSTP, National Weather Service, and Dept. of Homeland Security.
  - OSTP: policy lead
  - NWS: operational forecasting
  - DHS: mitigation and response
- Released 29-October-2015
- Outlines goals for operations, research, mitigation, and response in preparation for extreme events.

Goals

- **Goal 1: Establish Benchmarks for Space-Weather Events**
- **Goal 2: Enhance Response and Recovery Capabilities**
- **Goal 3: Improve Protection and Mitigation Efforts**
- **Goal 4: Improve Assessment, Modeling, and Prediction of Impacts on Critical Infrastructure**
- **Goal 5: Improve Space-Weather Services through Advancing Understanding and Forecasting**
- **Goal 6: Increase International Cooperation**



National Space Weather Strategy and Action Plan
Operations to Research and Research to Operations

National Space Weather Action Plan: "Federal and non-Federal partners must ensure that research is effectively transitioned to operational forecasting centers"

EO 13744, 5(d): "The Secretaries of Defense and Commerce, the Administrator of NASA, and the Director of NSF, in collaboration with other agencies as appropriate, shall identify mechanisms for advancing space weather observations, models, and predictions, and for sustaining and transitioning appropriate capabilities from research to operations and operations to research, collaborating with industry and academia to the extent possible"

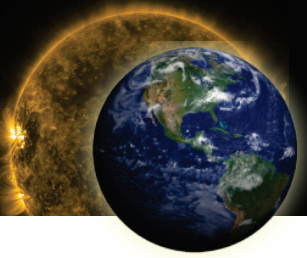
National Space Weather Strategy and Action Plan Operations to Research and Research to Operations

DOC and DOD in collaboration with NASA and NSF developing a plan for the improvement, testing, and maintenance of operational forecasting models

First Space Weather O2R Workshop 16-17 August 2016, Boulder CO another public meeting held 1 May 2017

- O2R Plan that was open for public comment, emphasizes Coupling between R20 and O2R
- Open source and community models
- Communication and collaborations, between government agencies and academia, private enterprise, space weather customers, and international
- Connections between fundamental research and the needs and requirements of the operational space weather community

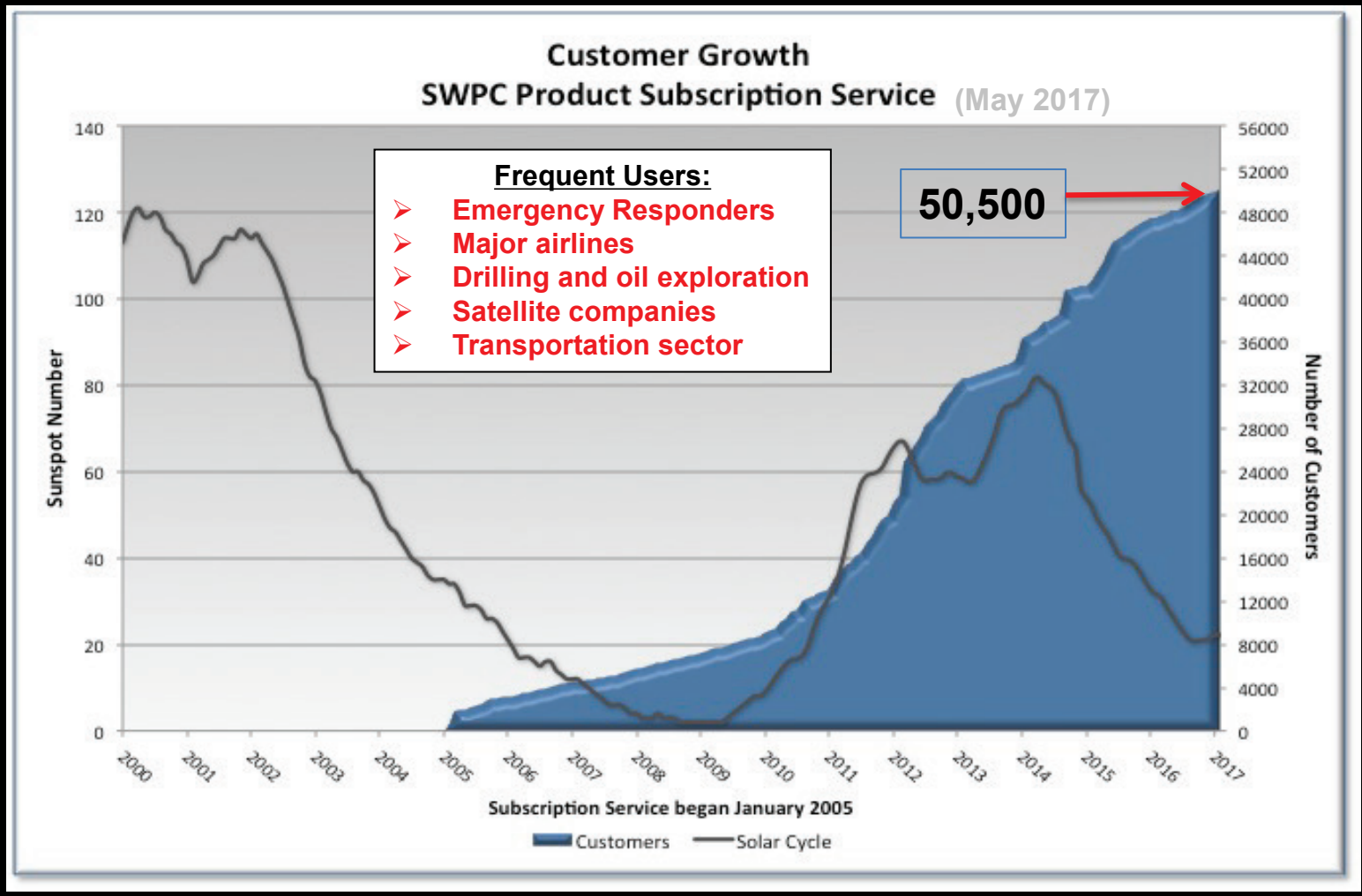
Next steps: Publish revision and determine next steps to implement opportunities presented in O2R Plan. Implement the signed MOU between NOAA and NASA (signed May 2017).



Evolving Drivers for NOAA Space Weather Services

- National Space Weather Strategy and Action Plan (Oct 2015)
- Executive Order 13744 – *Coordinating Efforts To Prepare the Nation for Space Weather Events* (Oct 2016)
- FERC Reliability Standard TPL-007-1: T*ransmission System Planned Performance for Geomagnetic Storms* (Sep 2016)
- Senate bill 141 - Space Weather Research and Forecasting Act, (Passed Senate May 2017)
- International – United Nations: World Meteorological Organization Inter-Programme Coordination Team on Space Weather; UN International Civil Aviation Organization; Office for Outer Space Affairs

Growth in SWPC Customer Subscriptions



- Averaging 200 new subscribers monthly…even through solar minimum
  - Increased awareness across all sectors
  - Space weather disturbances can occur at any time

NWS Strategic Outcome: A Weather- and Water-Ready Nation

"Ready, Responsive, Resilient"

Becoming a Weather-Ready Nation is about **building community resiliency in the face of increasing vulnerability** to extreme weather, water and climate events

Better forecasts and warnings

Consistent products and services

Actionable environmental intelligence

Connecting forecasts to decisions

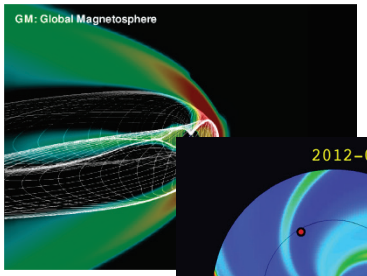
Involves the entire US Weather, Water and Climate Enterprise WORKING TOGETHER

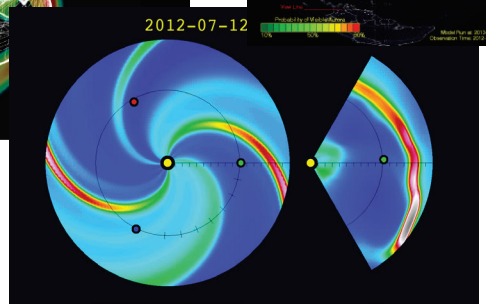
We have 5800+ WRN Ambassadors

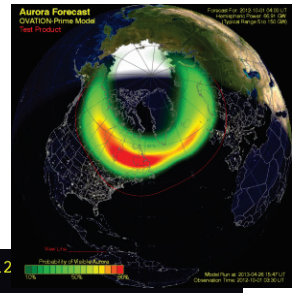
A Space Weather-Ready Nation: Building our Nation's resilience to space weather

Critical observations

New modeling capability







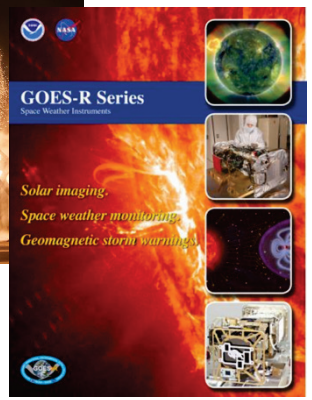
Partnerships

Involves the entire US Space Weather, Enterprise working together

Better information connected to key stakeholders for better decisions

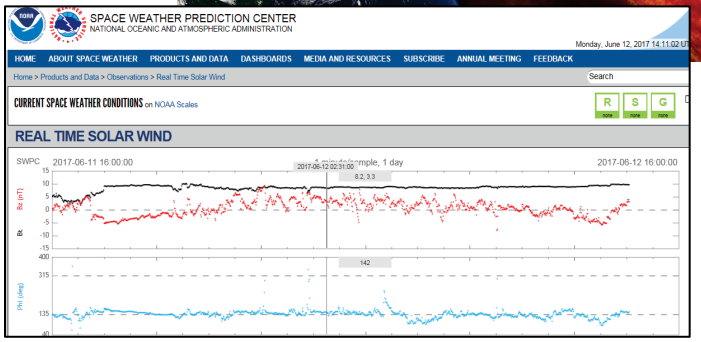
Better forecasts and warnings	*Actionable environmental intelligence*
Consistent products and services	*Connecting forecasts to decisions*

Sustaining Critical Space Weather Observations



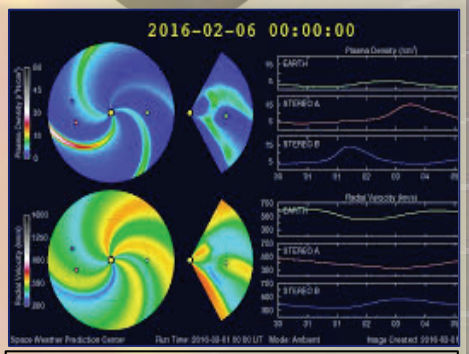
- DSCOVR – operational July 2016
- GOES-16 – launched Nov 2016
- GONG network – provides operational support - sustaining ground-based solar imaging (including solar magnetic field) for operational forecasting)

- Future L1: planned for 2022 and 2027
- COSMIC-2: planned 2018



SWPC Operational Model Suite

Tracking solar storms from "Sun to Mud"



GMU/AFRL WSA/Enlil

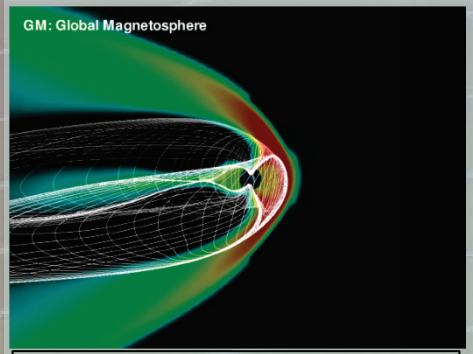
Inputs:

1. GONG solar magnetic field data
2. SOHO/LASCO coronagraph CME images from L1

Validation:

1. DSCOVR solar wind character at L1
2. GOES magnetometer shock arrival

Operational since 2011



U. Michigan Geospace

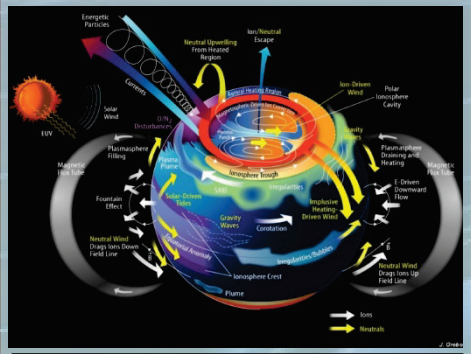
Inputs:

1. DSCOVR solar wind density, temp, speed, mag field at L1
2. Solar F10.7 radio flux measurements

Validation:

1. GOES vector magnetic field
2. USGS magnetometer network

Upgrades Sept 2017



NOAA/CIRES WAM-IPE

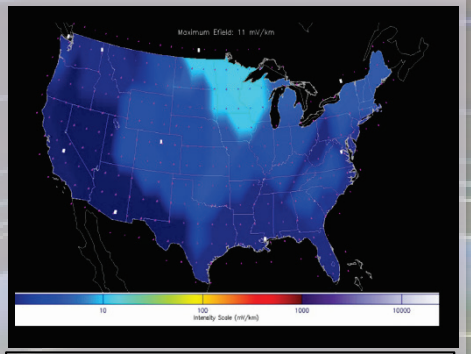
Inputs:

1. GFS Tropospheric weather model inputs
2. GOES Solar Extreme Ultraviolet flux
3. COSMIC-2 RO electron density
4. Geomagnetic storm data from Geospace Model

Validation:

1. GPS receiver network TEC measurements

Operational FY17-19



NOAA/USGS E-field

Inputs:

1. 1D earth conductivity model (3D coming soon)
2. USGS magnetometer network

Validation:

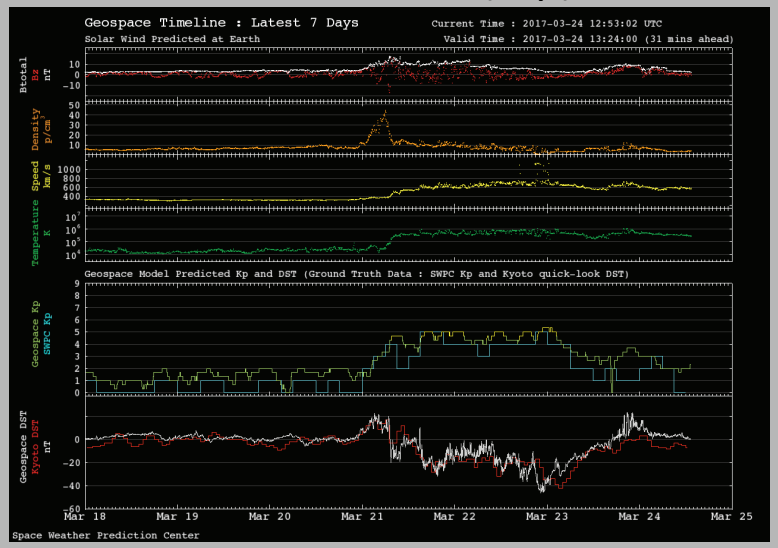
1. Geoelectric field measurements.

Operational FY18

Note: all models developed with NASA and/or NSF funding at some level.

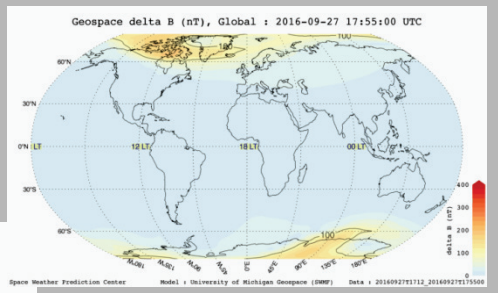
Initial Geospace Products

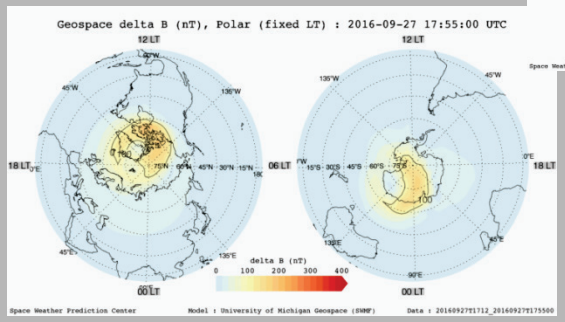
Solar Wind Data (top)



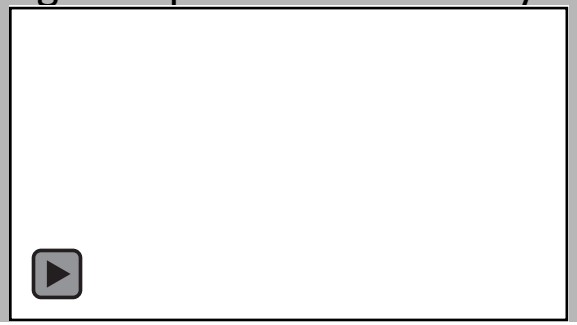
Obs and Forecast Indices - Verification (bottom)

Predicted Magnetic Disturbances





Views of Earth's Magnetosphere Predicted by Geospace Model



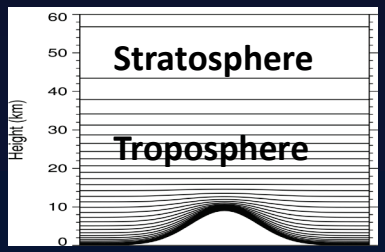
WAM + IPE
Model Development in the Thermosphere-Ionosphere

Whole Atmosphere Model (WAM = Extended GFS) + Ionosphere Plasmasphere Electrodynamics (IPE)

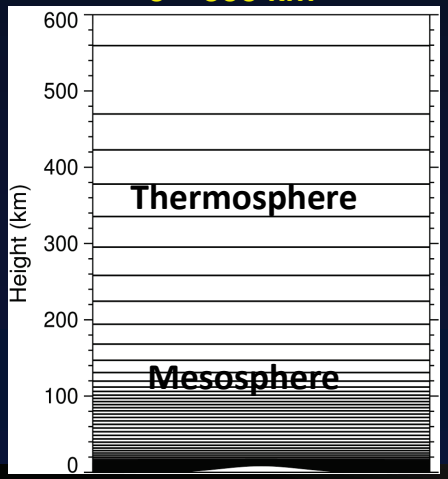
- **Multi-day forecasts for GPS/GNSS and radio communication customers**
- **FY17 Deliverable: Execute Real-time run of one-way coupled WAM->IPE on NOAA WCOSS**

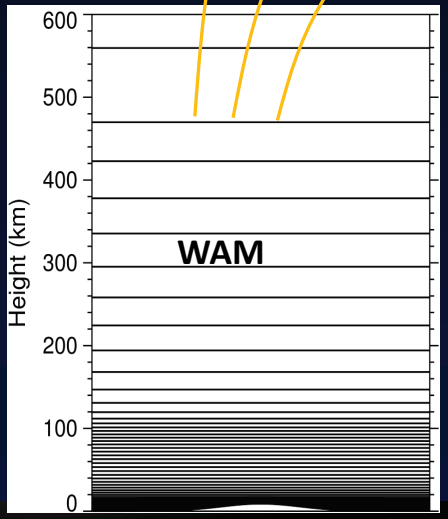
Ionosphere Model

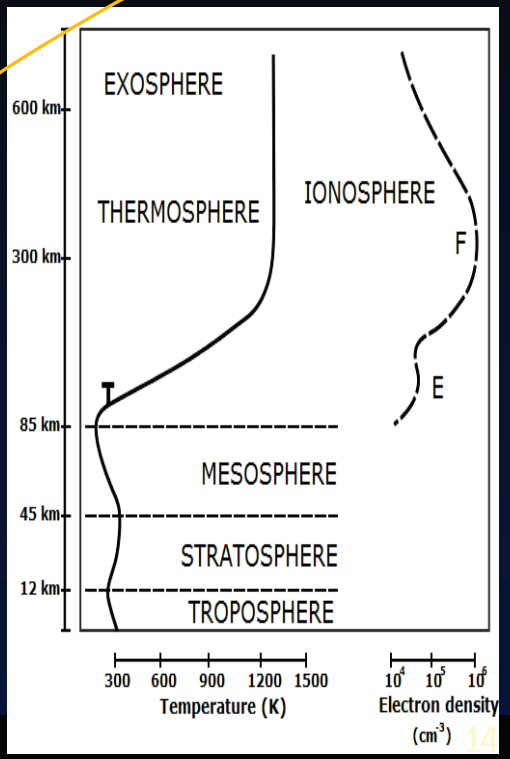
GFS
0 – 60 km



WAM
Neutral Atmosphere
0 – 600 km







E-field Model Update

Nowcast and Forecast Capabilities

Nowcast and eventually Forecast of the local geoelectric field (V/km)

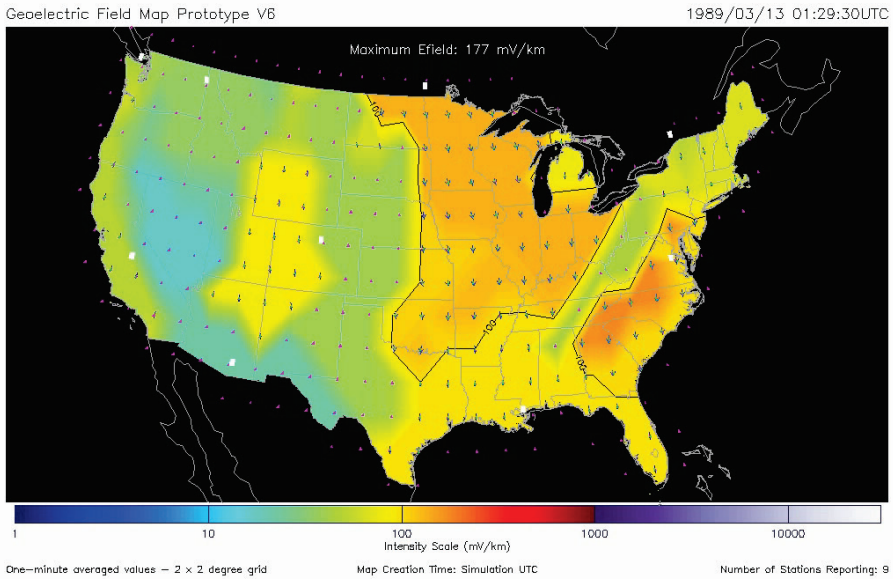
- SWPC currently working with industry on validation

Nowcast development steps

- Use real-time magnetometer data as input
- Interpolate geomagnetic field variations between observatories
- Calculate Electric field 'locally' using appropriate conductivity models
- Apply electric field to a power grid model to calculate geomagnetically induced currents
- User assesses system stability and transformer vulnerability

Forecast development steps

- Use Geospace model to predict real-time magnetic field variations.
- Calculate the corresponding geo-electric field at each point.



Nowcast model operational in 2017

Conclusion

Forecasting Space Weather will advance through:

- **New and sustained Observations**
- **Advances in space science understanding and Research**
- **Improved/Accurate Numerical Prediction Models**
- **The transition to operations: improved models and post-processing through effective R20/O2R.**

These actions, along with an understanding of user needs, will enable NOAA to serve users/partners with consistent, accurate, and actionable information