The NOAA Space Weather Prediction Center:

Rodney Viereck
Head of Research
Space Weather Prediction Center
NOAA, National Weather Service, Centers for Environmental Prediction

Outline:

Modeling and Products

Solar/solar, Magnetosphere

Ionosphere/Thermosphere

Legislation on Space Weather

Space Weather Prediction Center

established 1949

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

R & D – Space Weather Prediction Testbed

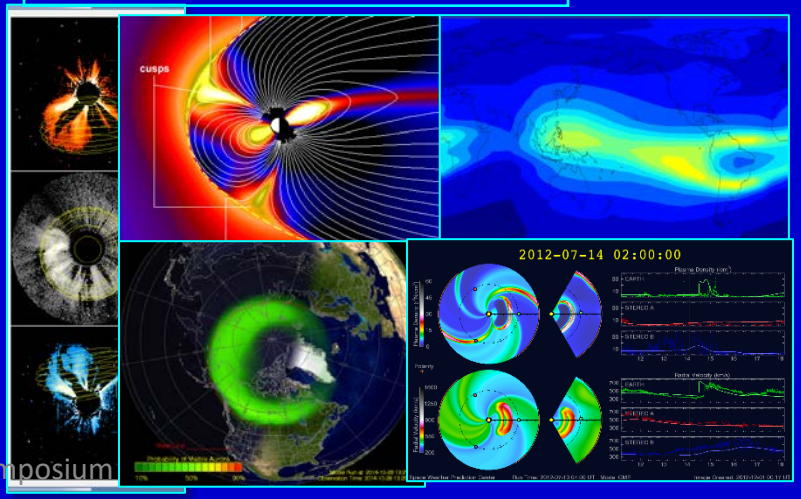
Transitioning models into operations

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



NOAA Space Weather Prediction Center Data and Models

Data
Operational Model
Models Under Development

Sun:
GONG (NSO)
ADAPT (USAF)
WSA (USAF/NASA)
Flare Prediction (SBIR)
Fareside Imaging (SBIR)
X-Ray and EUV Irradiance (GOES)
Solar/Coronal Images (GOES, SDO, SOHO)

Ionosphere:
IPE (U. Colorado)
US-TEC
NA-TEC
Global TEC
Equatorial Scintillation (U. Colorado)
GPS Error Product (SBIR)
Ground GPS (CORS)
GPS RO (COSMIC)

Solar Wind:
Enlil (George Mason U.)
L1-Earth Transit (U. Colorado)
Solar wind (DSCOVR, ACE)

Aurora:
30 Minute Forecast (JHU/APL)
3 Day Forecast

Magnetosphere:
Space Weather Modeling Framework (U. Mich.)
GOES Magnetopause Model (U. Colrado)
DREAM (Los Alamos)
Energetic Electrons and Protons (GOES)
Radiation Belts (Van Allen Probes)

Thermosphere
WAM (U. Colorado)
CTIPe

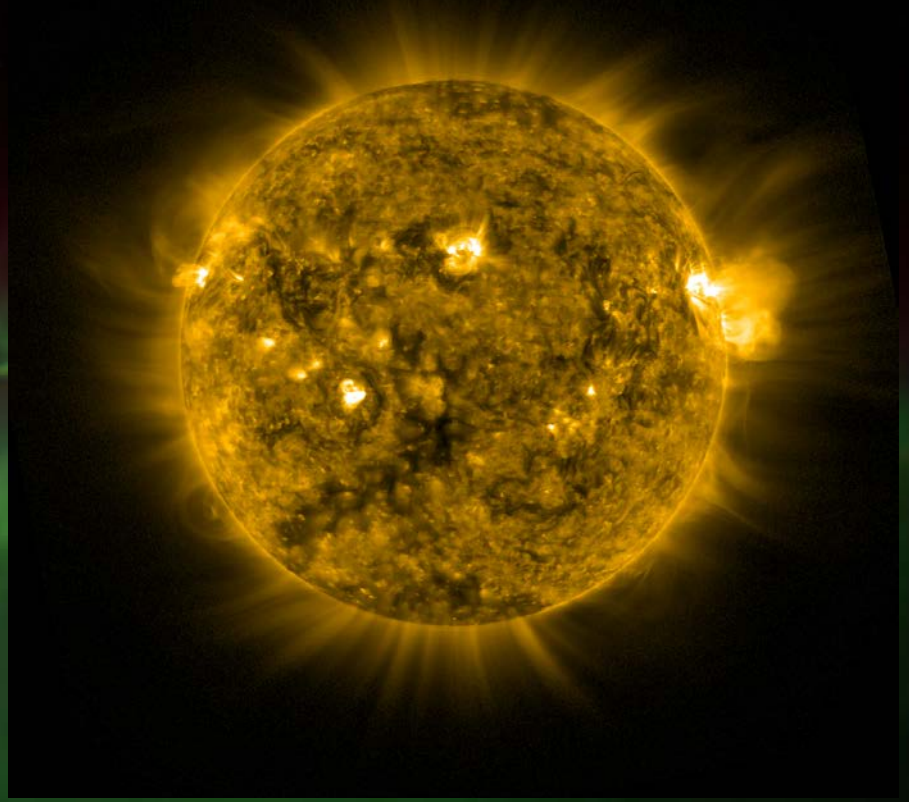
Ground:
E-Field Specification
Airline Radiation
Ground Magnetometer (USGS)

Note: SBIR = Small Business Innovative Research

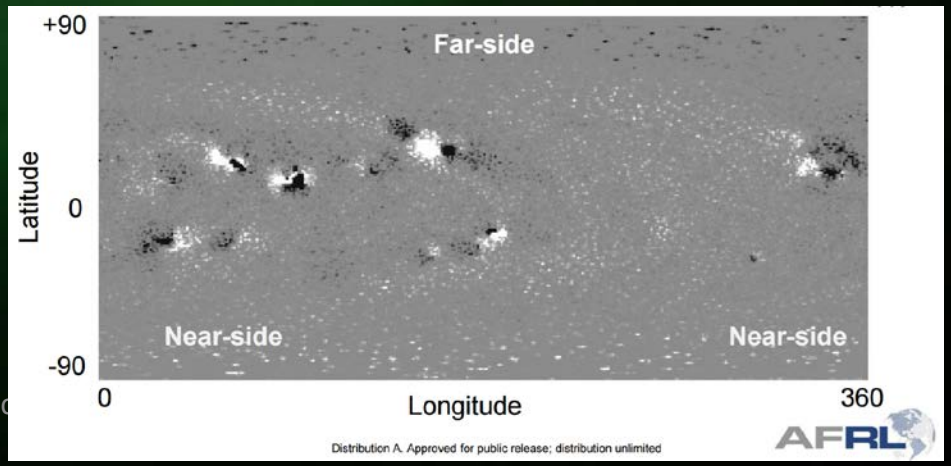
Solar/Solar Wind Models and Products

- Data:
  - GOES 16 solar images and irradiance
    - Operational late 2017.
  - Space Weather Follow On requirements process
    - Replace DSCOVR and ACE
  - GONG Real-time data processing
    - Improve reliability.
- Models:
  - ADAPT model begins transition
    - Improve upon the modeling of background solar wind.
    - Developed at AFRL
- To improve forecasts of space weather

GOES 16 SUVI image at 195 Å



GONG/ADAPT Solar Magnetogram Map



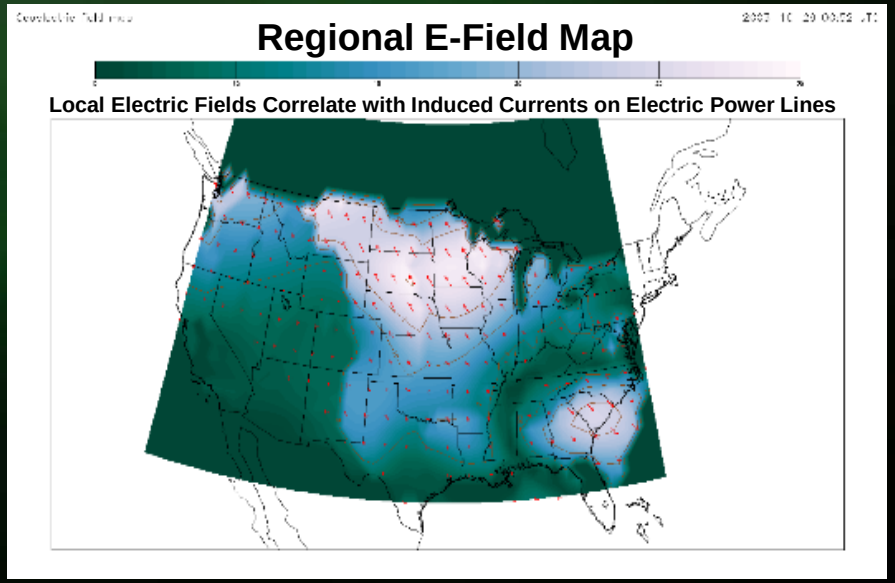
Geospace Models and Products

St. Patrick's Day Storm 3/17/2015 Predicted delta B's

- Regional Electric Field Product
  - Provides local E-Field information for power grid operators
  - Currently a real-time test product using ground magnetometer data
  - In the future it will be driven by the SWMF Geospace model to provide a short-term forecast

Geospace Model Becomes Operational

- U. Michigan SWMF
- Driven by solar wind conditions at L1
- Provides 30 min forecasts of local geomagnetic field perturbations for electric power Industry
- Will someday drive other models

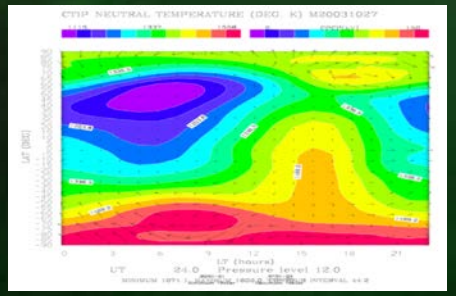


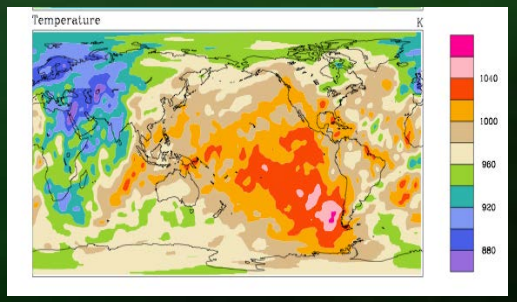
Ionosphere-Thermosphere Models and Products

- Whole Atmosphere Model
  - Thermosphere response to tropospheric inputs
  - Based on the National Weather Service GFS weather model
- Ionosphere Plasmasphere Electrodynamics Model
  - 3D version of the FLIP model (Richards)

- Schedule: WAM and IPE coupled and running in real-time by the end of September (2017)

Without Tropospheric Forcing





With Tropospheric Forcing

See presentation by Tim Fuller-Rowell Session 9B at 10:40 on Thursday

Ionosphere-Thermosphere Models and Products:

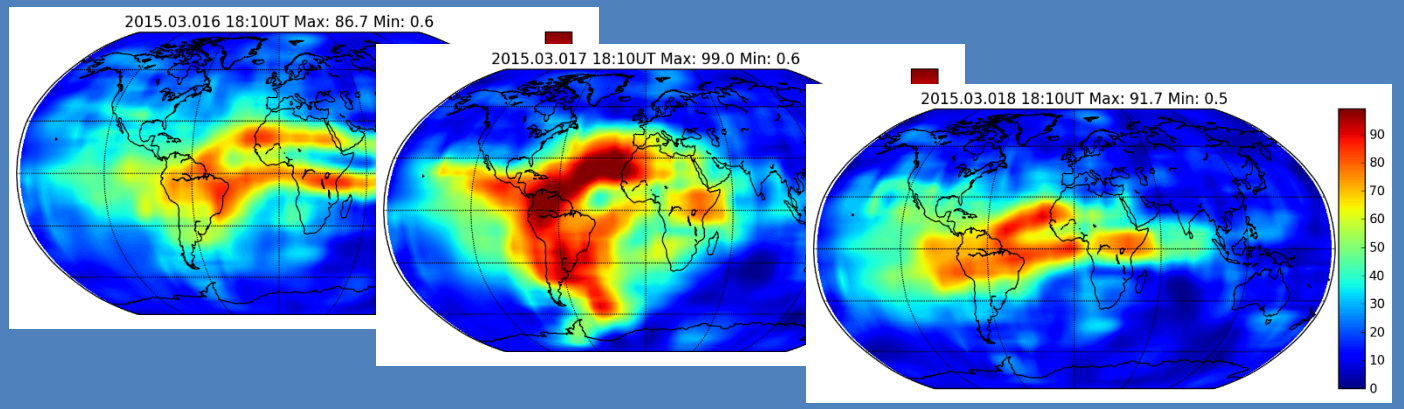
Global TEC (GloTEC) Specification Model

- Input Data
  - Space-based GPS radio occultation data
    - Vertical profiles
  - Ground based GPS line-of-site TEC
    - Horizontal structure
- Output
  - Global 3-D map of ionospheric electron density
  - Resolution 2.5° x 5° (lat lon) 10 km height
  - Cadence 5-15 minutes
- Kalman filter data assimilation
- Background ionosphere is IRI

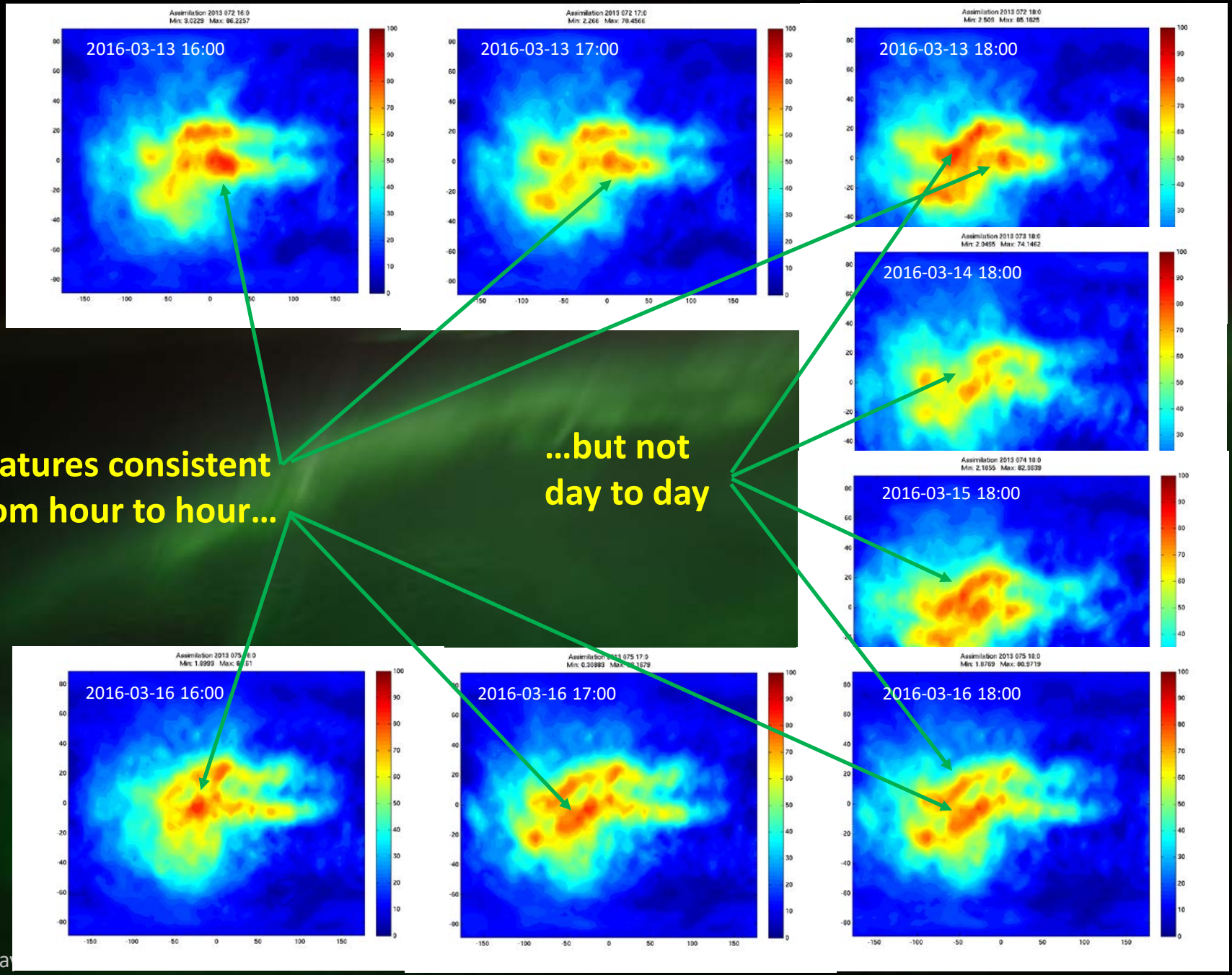
- Developed by Xinan Yue, Dominic Fuller-Rowell, and Tim Fuller-Rowell

GLOTEC

TEC on 16, 17, 18 March 2015



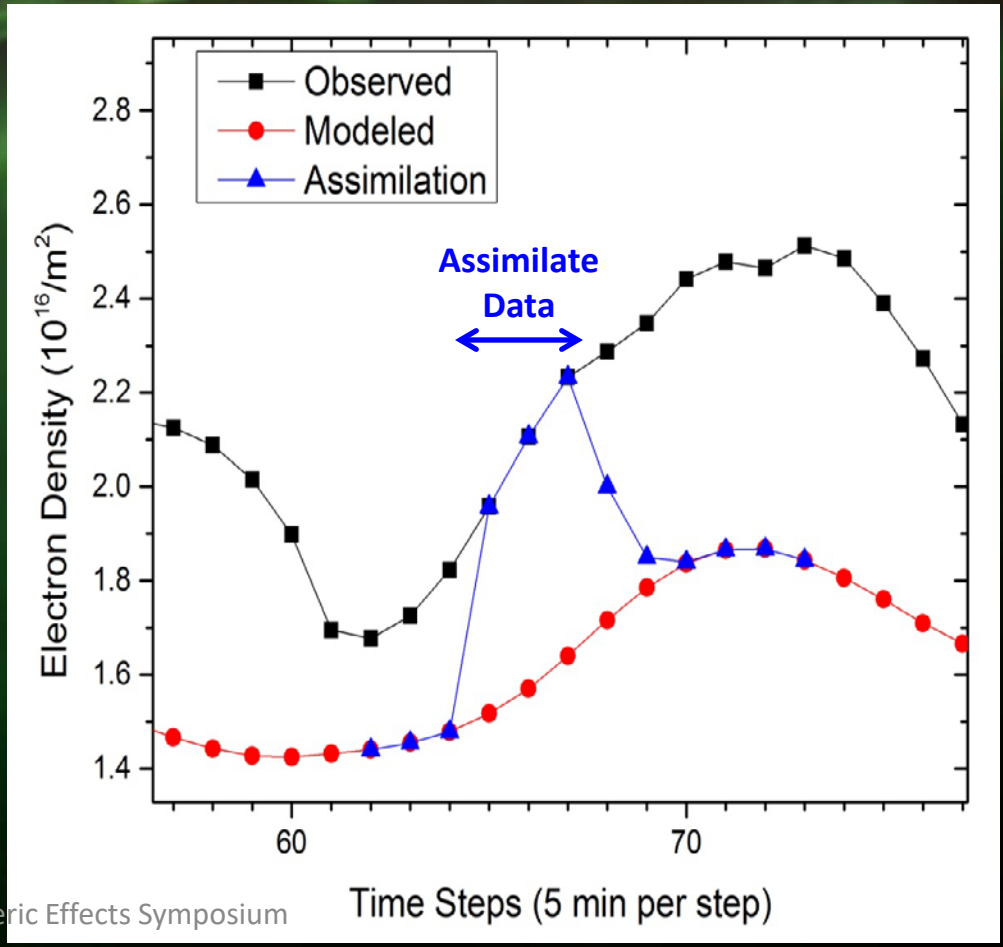
New Global TEC Product Developed by Yue, Fuller-Rowell, and Fuller-Rowell Using COSMIC RO and Ground GPS data


2016-03-13 16:00
2016-03-13 17:00
2016-03-13 18:00
2016-03-14 18:00
2016-03-15 18:00
2016-03-16 16:00
2016-03-16 17:00
2016-03-16 18:00
Features consistent from hour to hour…
…but not day to day

Ionosphere-Thermosphere Models and Products:

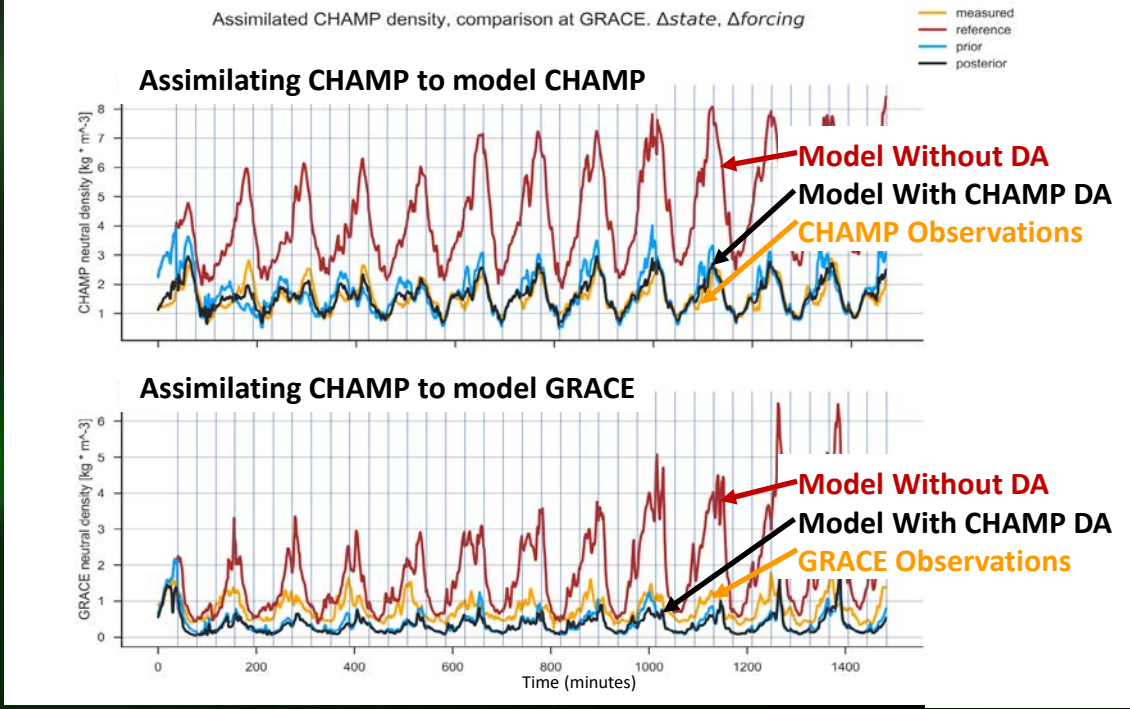
Data Assimilation Challenge

- The Ionosphere-Thermosphere system is a strongly driven system
  - Order of magnitude electron density changes…
    - Driven by order of magnitude changes in solar EUV and Geomagnetic activity.
    - Occur on timescales of minutes.
- Data assimilation in a driven system is challenging
  - Adjusting initial conditions to match observations
  - The ionosphere quickly returns to its original state.
- A number of Data Assimilation Schemes to Choose From
  a. Extended GSI/hybrid (3D EnVar)
  b. Extended 4D hybrid (4D EnVar)
  c. Separate Iono-Thermo ensemble Kalman Filter



Thermosphere Data Assimilation

- Assimilating satellite drag data into CTIPe:
- One measurement per minute from GRACE and CHAMP.
- Vertical lines indicate the 30 minute assimilation time steps.
- Ensemble Kalman Filter for CTIPe, run with 75 members each having ~200000 elements in the state vector and 30 minute assimilation time steps
- Developed by Stefan Codrescu and Mihail Codrescu



Space Weather Legislation

- Oct. 2015: Release of the Space Weather Strategy and Action Plan
- Oct. 2016: Executive Order on Space Weather
- May 2017: Space Weather Research and Forecasting Act

Executive Order 13744 – Coordinating Efforts to Prepare the Nation for Space Weather Events

- Establishes a national policy for space weather
- Establishes interagency coordination body within the National Science and Technology Council to implement the national space weather policy
- Articulates agency roles and responsibilities with respect to space weather research, operations, and planning
- Reinforces the need to work with non-Federal entities, including international partners, to achieve national preparedness for space weather

the WHITE HOUSE PRESIDENT BARACK OBAMA

BRIEFING ROOM | ISSUES | THE ADMINISTRATION | PARTICIPATE

The White House
Office of the Press Secretary

For Immediate Release October 13, 2016

Executive Order -- Coordinating Efforts to Prepare the Nation for Space Weather Events

EXECUTIVE ORDER

COORDINATING EFFORTS TO PREPARE THE NATION FOR SPACE WEATHER EVENTS

By the authority vested in me as President by the Constitution and the laws of the United States of America, and to prepare the Nation for space weather events, it is hereby ordered as follows:

Senate Bill 141:
Space Weather Research and Forecasting Act

Develops a formal mechanism to transition NASA and NSF research findings, models, and capabilities, as appropriate, to NOAA and DoD space weather operational forecasting centers

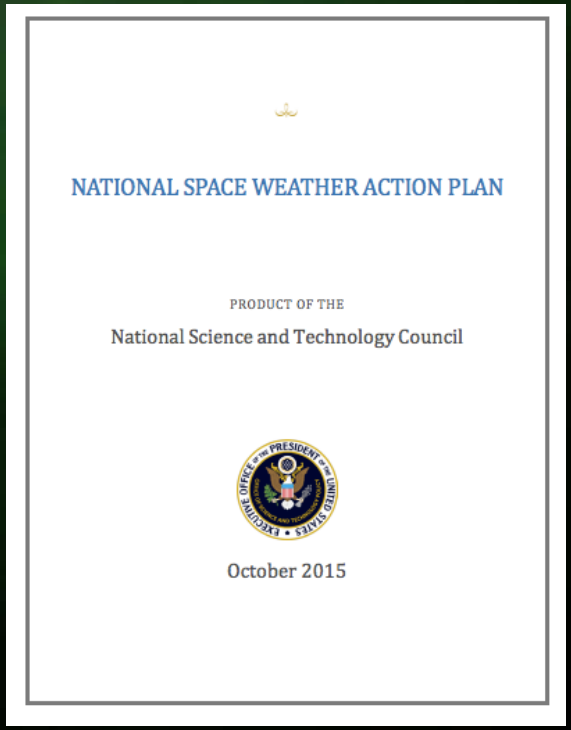
Identify and prioritize the needs of space weather forecast users, including space weather forecast data needed to improve services and inform research priorities and technology needs

Directs agencies to identify opportunities to address the needs through collaborations with academia, the private sector, and the international community

National Space Weather Strategy and Action Plan

Articulates six high-level goals

1. **Establish Benchmarks for Extreme Space-Weather Events**
2. Enhance Response and Recovery Capabilities
3. Improve Protection and Mitigation Efforts
4. Improve Assessment, Modeling, and Prediction of Impacts on Critical Infrastructure
5. **Improve Space-Weather Services through Advancing Understanding and Forecasting**
   - **Establish Baseline Observations**
   - **Directed Space Weather Research**
   - **Improve R2O2R**
6. Increase International Cooperation


NATIONAL SPACE WEATHER ACTION PLAN

PRODUCT OF THE

National Science and Technology Council

October 2015

SWAP Goal 1: Benchmarks

1.1 Induced Geo-Electric Fields
- What could and extreme event do to our electric power grid?

1.2 Ionizing Radiation
- How severe could the radiation environment be for satellites and aviation

1.3 Ionospheric Disturbances
- How will extreme ionospheric conditions impact radio communication and satellite navigation

1.4 Solar Radio Bursts
- How could solar radio bursts impact radio communication and satellite navigation?

1.5 Atmospheric Expansion
- How severe could extremes in satellite drag become

- Participation from DOC, DOD, DOI, NASA, NSF, FAA, etc…

SWAP Goal 5:

Action 5.6 – Improve Effectiveness and Timeliness of the Process that Transitions Research to Operations

Action 5.6.1 R2O:

- NASA and NSF, in collaboration with DOC and DOD, will develop a formal process to enhance coordination between research modeling centers and forecasting centers.

Action 5.6.2 O2R:

- DOC and DOD, in collaboration with NASA and NSF, will develop a plan (which may include a center) that will ensure the improvement, testing, and maintenance of operational forecasting models.

- One Concept: A Space weather modeling center based on a community models.
  - Transition new models and products into operations
  - Improve existing operational models
  - Use operational models for research
  - Identify knowledge and capability gaps

Summary

- NOAA Space Weather Prediction Center continues to introduce new space weather models, products, and data to support critical customer needs and requirements.

- Recognition of the importance of space weather at high levels in government is providing leadership and guidance for agencies to coordinate
  - Observations
  - Research
  - R2O2R…