Space Weather Prediction Testbed

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Space Weather Prediction Center

Space Weather Workshop 2012

Outline

- What is the Space Weather Prediction Testbed (SWPT)?
- What are the current SWPT Research-to-Operations activities (R2O)?
  - Solar
  - Heliosphere
  - Magnetosphere
  - Ionosphere/theremosphere
- What are the Operations-to-Research requirements (O2R)?

SWPT Objectives and Mission

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.**

Objectives:

- **Identify and investigate new modeling capabilities, research developments, and observational advances.**
- **Test and validate promising numerical codes and forecast techniques emerging from the research community**
- **Conduct and support focused research on forecast models and observational systems**
- **Develop usable customer-based metrics for model evaluation and forecast performance**
- **Identify operational requirements and translate them into research requirements for future scientific support**

SWPT Objectives and Mission

Mission:

Research to Operations (R2O)
Operations to Research (O2R)

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Organization

Research Developments
Research to Operations

Requirements
Operations to Research

NOAA
NGDC
NCEP/EMC
…

Government Agencies
NASA
USGS
NSF
Air Force
…

Academia
U. Colorado
NCAR/UCAR
George Mason
…

International
UK
Germany
Belgium
…

NASA CCMC
NSF CISM
AFRL
…….

R2O

O2R

Space Weather Prediction Center

Space Weather Prediction Testbed

Development and Transition

Space Weather Forecast Office

R2O

O2R

O2R

R2O

Customers
Electric Power
Airlines
Satellites
GPS
…

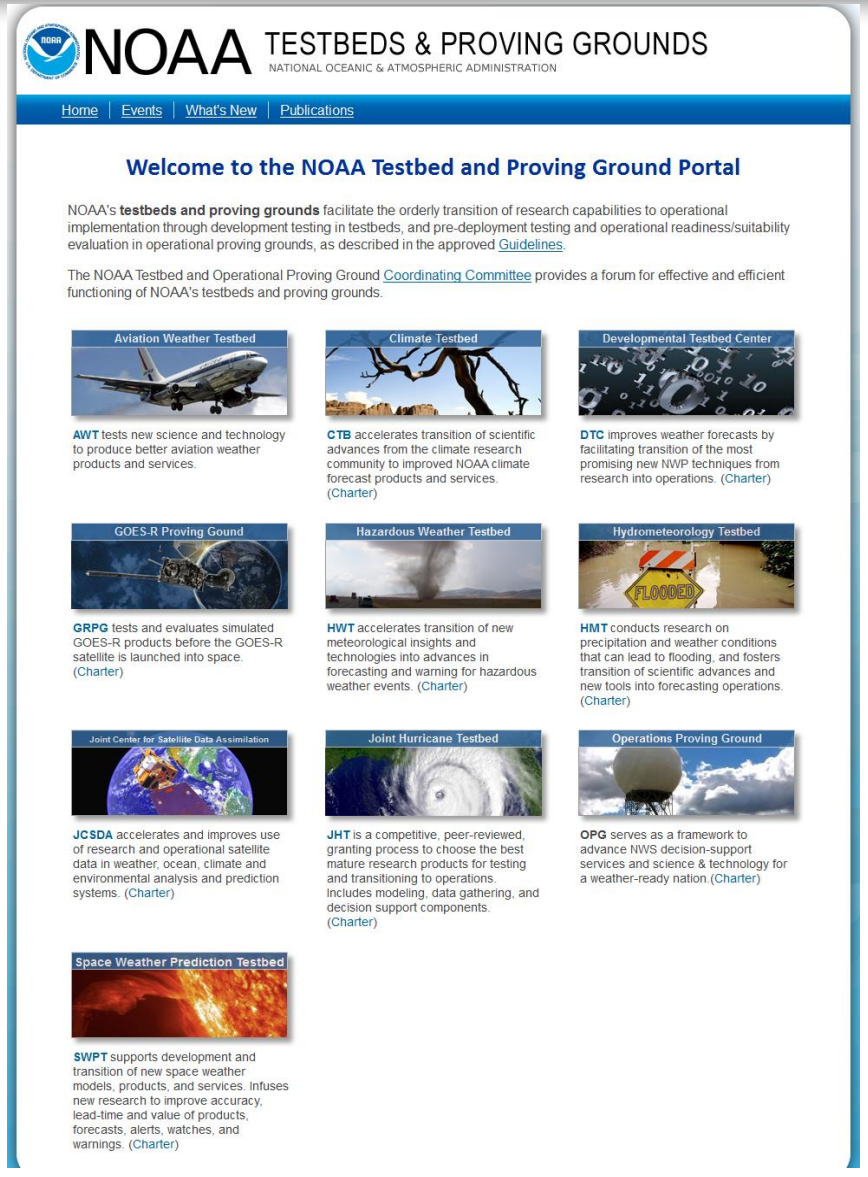
Forecasters
AFWA
UKMet
ISES
…

SWPT Staff
6 Fed Scientists
21 CU/CIRES
(Scientists/Students)

SWPT Funding
NOAA Base Funds
NASA/NSF Grants
DOD Grants

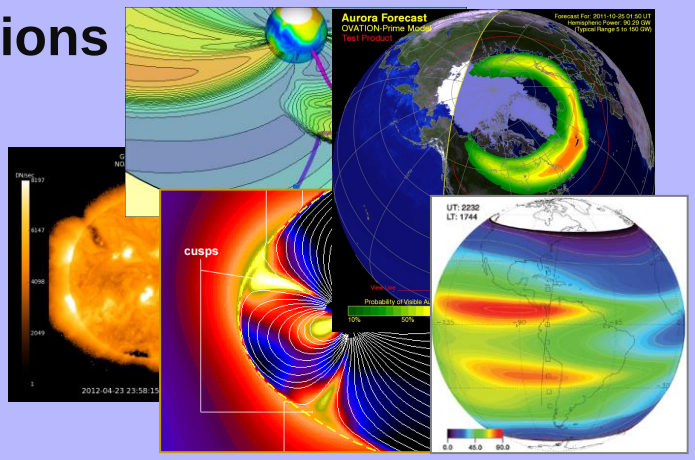
NOAA Testbeds and Proving Grounds

- **SWPT becomes the tenth NOAA Testbed/Proving Ground**
  - **Aviation Testbed**
  - **Climate Testbed**
  - **Development Testbed**
  - **Hazardous Weather Testbed**
  - **Hydrometeorology Testbed**
  - **Hurricane Testbed**
  - **GOES R Proving Ground**
  - **Operations Proving Ground**
  - **Joint Center for Satellite Data Assimilation**
- **NOAA's testbeds and proving grounds facilitate the orderly transition of research capabilities to operational implementation**

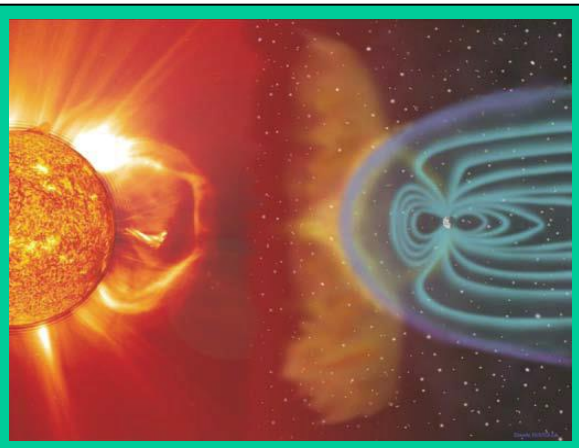


Testbed Activities

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

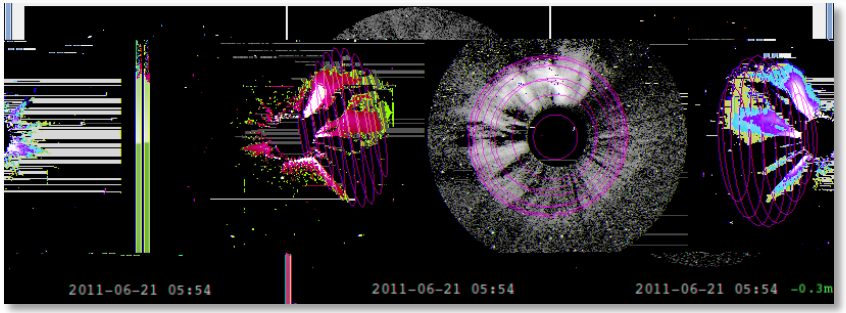


Operations-to-Research
- Customer Requirements
- Observation Requirements
- Research Requirements

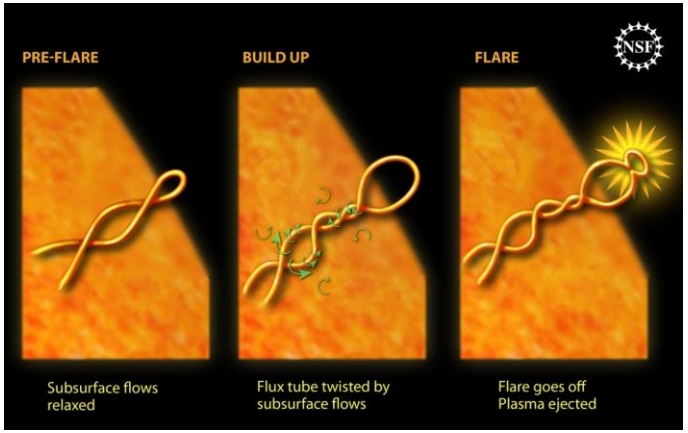


Sun-to-Earth
- Solar
- Heliosphere
- Magnetosphere
- Ionosphere
- Thermosphere
- Atmosphere

Research to Operations: Solar-Heliosphere

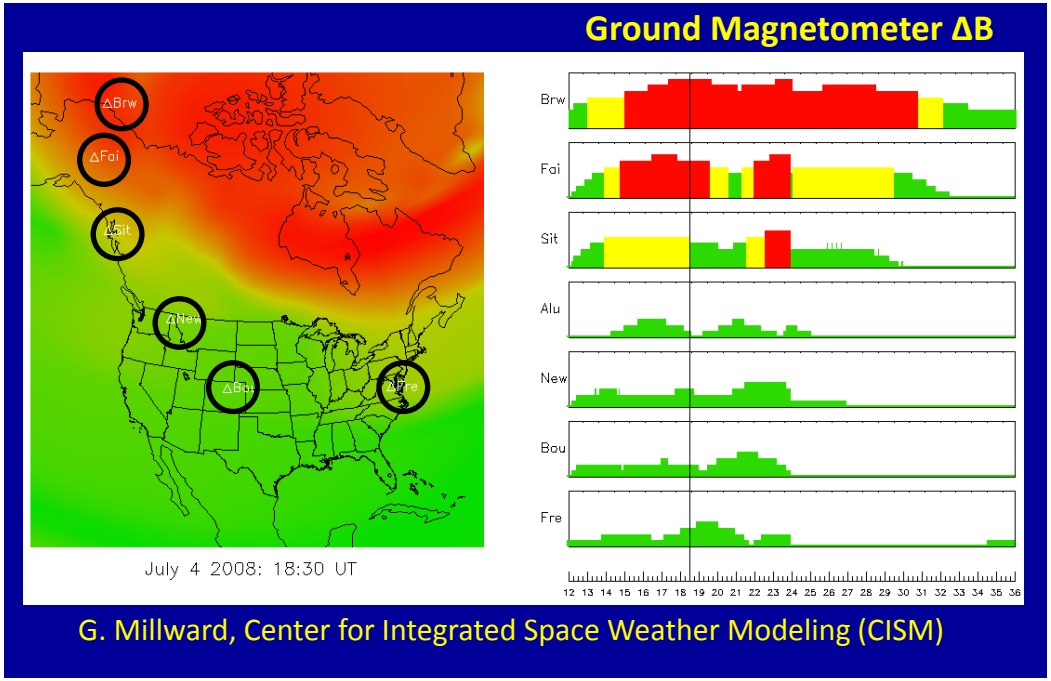


- **Upgrades to WSA-Enlil Model**
  - Improve CME parameterization
    - STEREO/LASCO three view
    - STEREO HI
  - Improve background solar wind with continuous updates
    - Update WSA with ADAPT
- **DSCOVR Mission**
  - Define mission requirements
  - Develop algorithms for real-time data processing
- **Solar Flare Forecasting**
  - Precursors based on helioseismology



Requirement: Regional Predictions of Geomagnetic Disturbances

- **Power Grid operators want local information on Ground Induced Currents (Local K-values, dB/dt, E-Field).**
- **Current forecasts provide only global indices (Kp) and do not resolve regional differences in activity**
- **Need for Geospace/Magnetosphere model to forecast local geomagnetic conditions**



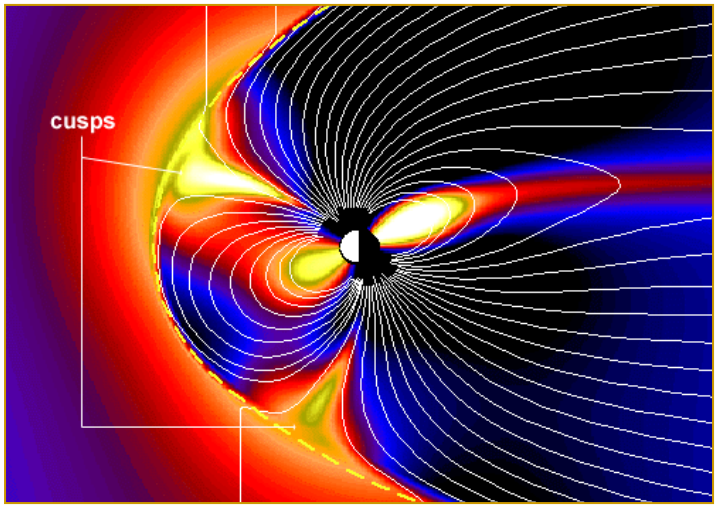
G. Millward, Center for Integrated Space Weather Modeling (CISM)

Challenges:

- **Inner magnetospheric kinetic physics is necessary to model mid- and low-latitude disturbances.**
- **Accurate electromagnetic coupling between the ionosphere and magnetosphere requires computational-expensive high grid resolution.**
- **Grid resolution and numerical schemes affect model output in complex ways**

R2O: Magnetosphere-Geospace

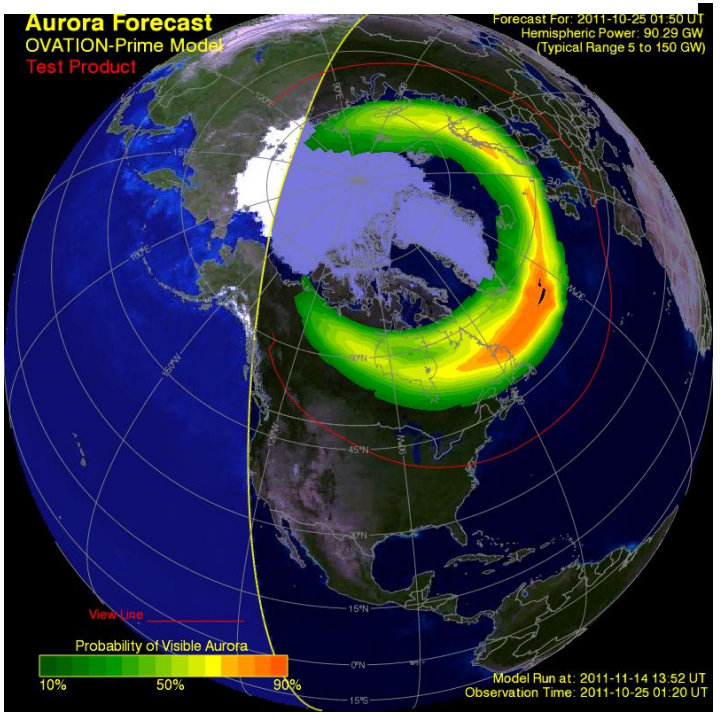
- **SWPT is working with CCMC to evaluate Geospace models.**
  - **Empirical and physics-based models undergoing test and evaluation.**
  - **Attributes to consider**
    - **Performance**
      - **Accuracy, timeliness, products that meet customer needs**
    - **Reliability**
      - **Robustness, documentation, operational readiness**
    - **Resources**
      - **Computational, CPU, Memory requirements**
    - **Supportability**
      - **Complexity, fixes, upgrades, improvements, agreements with model developers**



R2O: Magnetosphere-Geospace

- **Requirement: Specification and forecast of aurora (location, energy input to ionosphere, etc…)**
- **Solution: OVATION Prime, an empirical model of auroral particle precipitation based on correlations between solar wind conditions and observed particle precipitation.**

- **Task 1: Transition the current Ovation model from research to operations.**
  - **Validation of model performance**
  - **Developing outputs for customers**
- **Task 2: Improve the model**
  - **Expand to full range of geomagnetic storms**
  - **Develop fall back capability when ACE solar wind not valid (e.g. proton contamination)**
  - **Develop long-range forecast capabilities using WSA-Enlil**



Requirements for Ionosphere/Thermosphere

Requirement: Specification of Current Ionospheric Conditions

Developing new products

Now	Future
TEC Maps	Gradient TEC
USTEC	N. America TEC
Eqt. Scint.	Global Scint.

Exploring New Data

Scintillation

GOLD

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

COSMIC-2 moving forward!

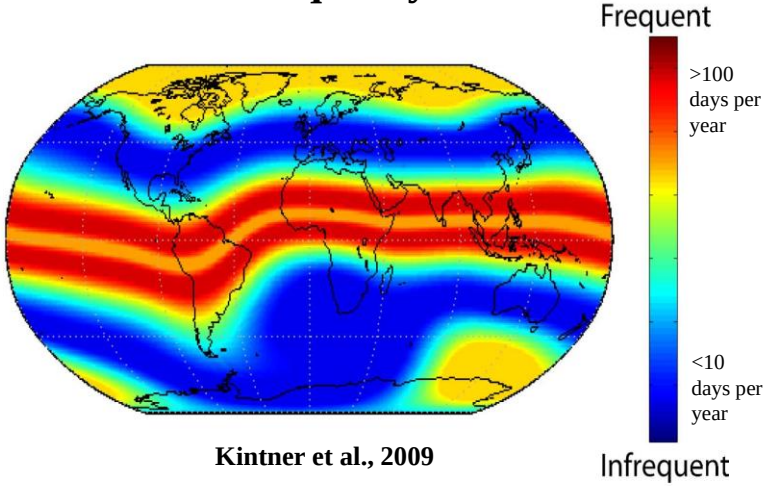
COSMIC- 2 Operational Mission

- Supporting both space and terrestrial weather
- Taiwan building the spacecraft
- US Air Force Building the Sensors
- NOAA establishing downlink and processing
- 6 – Equatorial (Launch 2016)
- 6 – Polar (Launch 2018)
- 15,000 Ionospheric Soundings per Day

Requirements for Ionosphere/Thermosphere

- **Requirement: Forecasts of GPS/GNSS errors and outages**
- **Solution: Forecast of the I/T conditions**
- **Requires forecasts of the three primary drivers of the I/T system…**
  - **WSA-Enlil provides improved Geomagnetic Forecasts.**
  - **GOES EUVS provides better solar EUV observations and (along with SDO-EVE) will lead to improved EUV forecasts**
  - **Weather models can provide forecasts of the forcing from below.**

Scintillation Frequency at Solar Max



Kintner et al., 2009

Whole Atmosphere Model

Extending the Global Forecast Systems Model

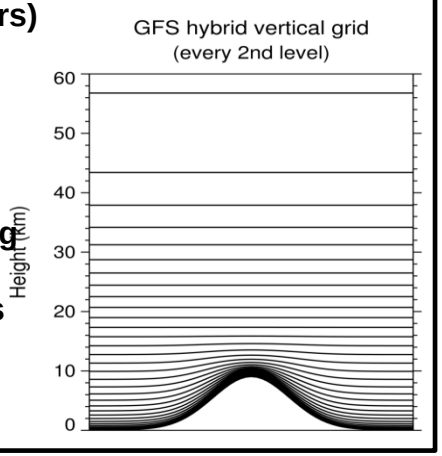
WAM models the neutral atmosphere up to 600 km altitude to include the mesosphere and thermosphere

Global Forecast System (GFS) model

- Operational weather model
- T382L64 (~0-60 km Res.)
- 4 forecasts daily
- Global ensemble (14 members) forecasts up to 16 days

Physics

- O3 chemistry & transport
- Radiative heating and cooling
- Cloud physics & hydrology
- Surface exchange processes
- Orographic gravity waves
- Eddy mixing and convection

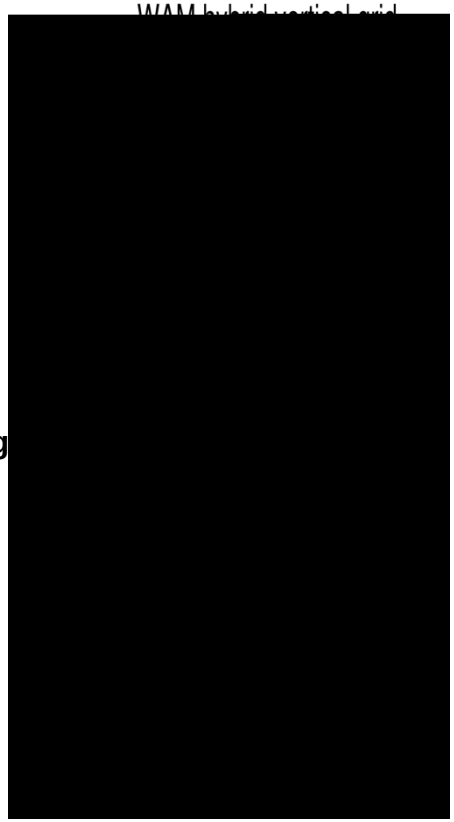


Whole Atmosphere Model (WAM)

- T62L150 (0 – 600 km Res.)
- Variable Composition ? thermodynamics
- Timing ~ 1 Day requires 8 min/day on 32 nodes

Physics

- Horizontal & vertical mixing
- Radiative heating (EUV & UV) and cooling (non-LTE)
- Ion drag & Joule heating
- Major species composition
- Non-orographic gravity waves
- Eddy mixing



R2O: Integrated Dynamics in Earth's Atmosphere

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

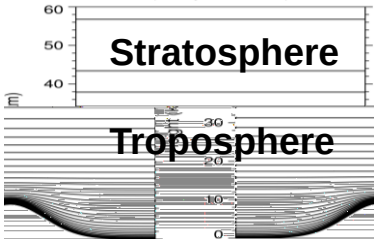
Ionosphere
Plasmasphere
Electrodynamics
IPE Model

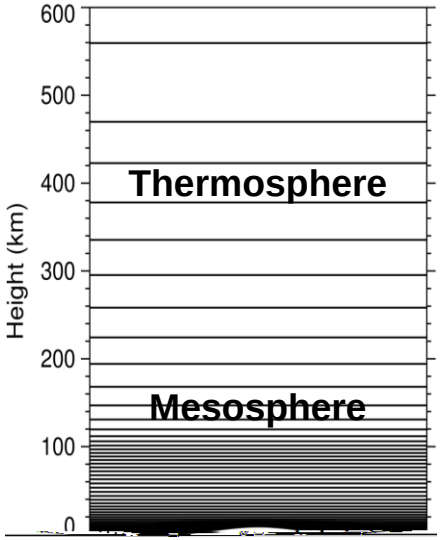
Plasmasphere

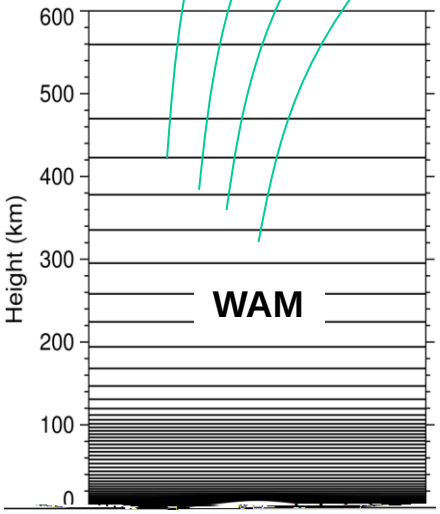
Ionosphere

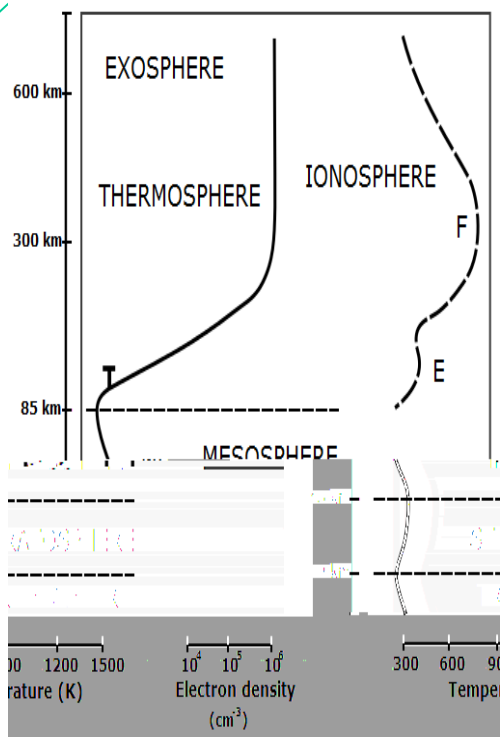
WAM
Neutral
Atmosphere
0 – 600 km

GFS
0 – 60 km









O2R: High Priority Goals for Space Weather Research

- **Forecasts of Solar Flares (timing and magnitude)**
  - **Flares are the precursor to all major space weather storms**
- **Forecasts of Solar Energetic Particle events and Radiation Storms**
  - **Research required to insert energetic particles and electromagnetic shock physics into heliospheric models such as WSA-Enlil**
- **Long lead-time warning of Coronal Mass Ejection arrival**
  - **Improvement to initialization of background and CMEs in WSA-Enlil**
  - **Challenge: Forecast of Bz at Earth!**

O2R: High Priority Goals for Applied Space Weather Research (cont.)

- **Spatially resolved forecasts of geomagnetic activity**
  - **Requires magnetosphere model driven by solar wind.**
- **Forecasts of the location and intensity of the Aurora**
  - **Coupling WSA-Enlil output to the OVATION Prime model**
  - **Challenge: Forecasting Bz**
- **Prediction of ionospheric scintillations and TEC gradients**
  - **Coupled atmosphere-ionosphere models**
  - **Challenges:**
    - **Coupling with magnetospheric drivers**
    - **Forecasting solar energy inputs**
    - **Developing space weather data-assimilation schemes**

SWPT Issues

- Staffing for Geospace Model test, evaluation, transition, support
- Securing resources ($) to support sustained “applied” research capability
- Developing appropriate Intellectual Property Rights Agreement
  - Protecting the integrity of the code and the intellectual value within it.
  - Providing flexibility for SWPC to test, transition, and maintain the code
    - Experiment with adjustable parameters
    - Improve code for better operability and maintainability
    - Expand the use of the code to allow for improved forecasts through data assimilation or ensemble modeling

Summary

- **Space Weather Prediction Testbed**
  - **R2O: Bringing new research into the operational forecast center**
  - **O2R; Bringing the needs of customers and forecaster to the research community**

Bridging the gap between research and operations