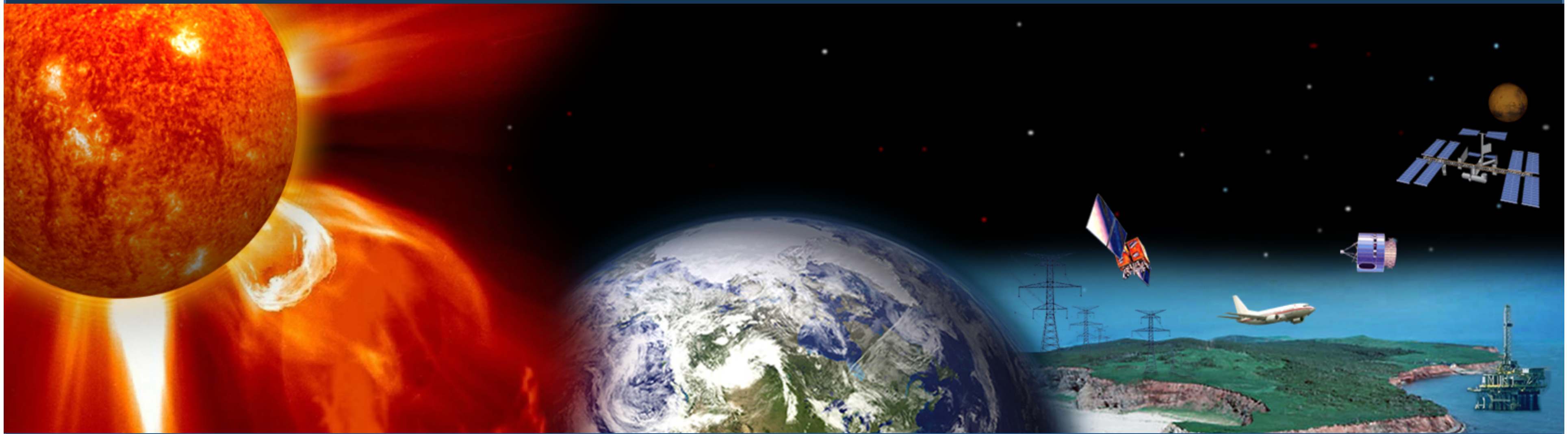
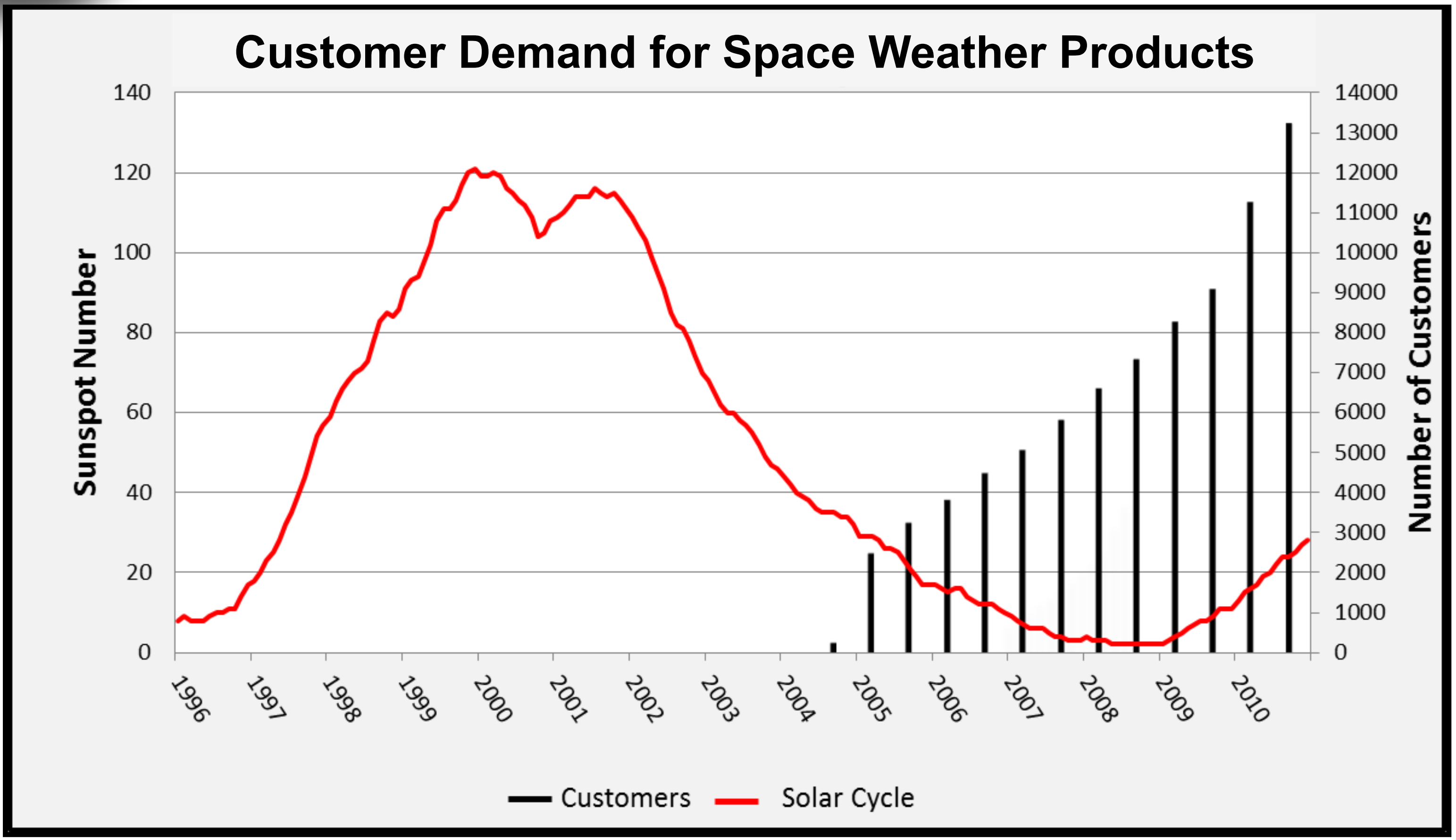
NOAA Experience – Present Products and Services and Plans for Future Improvements



Terry Onsager
National Oceanic and Atmospheric Administration
Space Weather Prediction Center
Director - International Space Environment Service

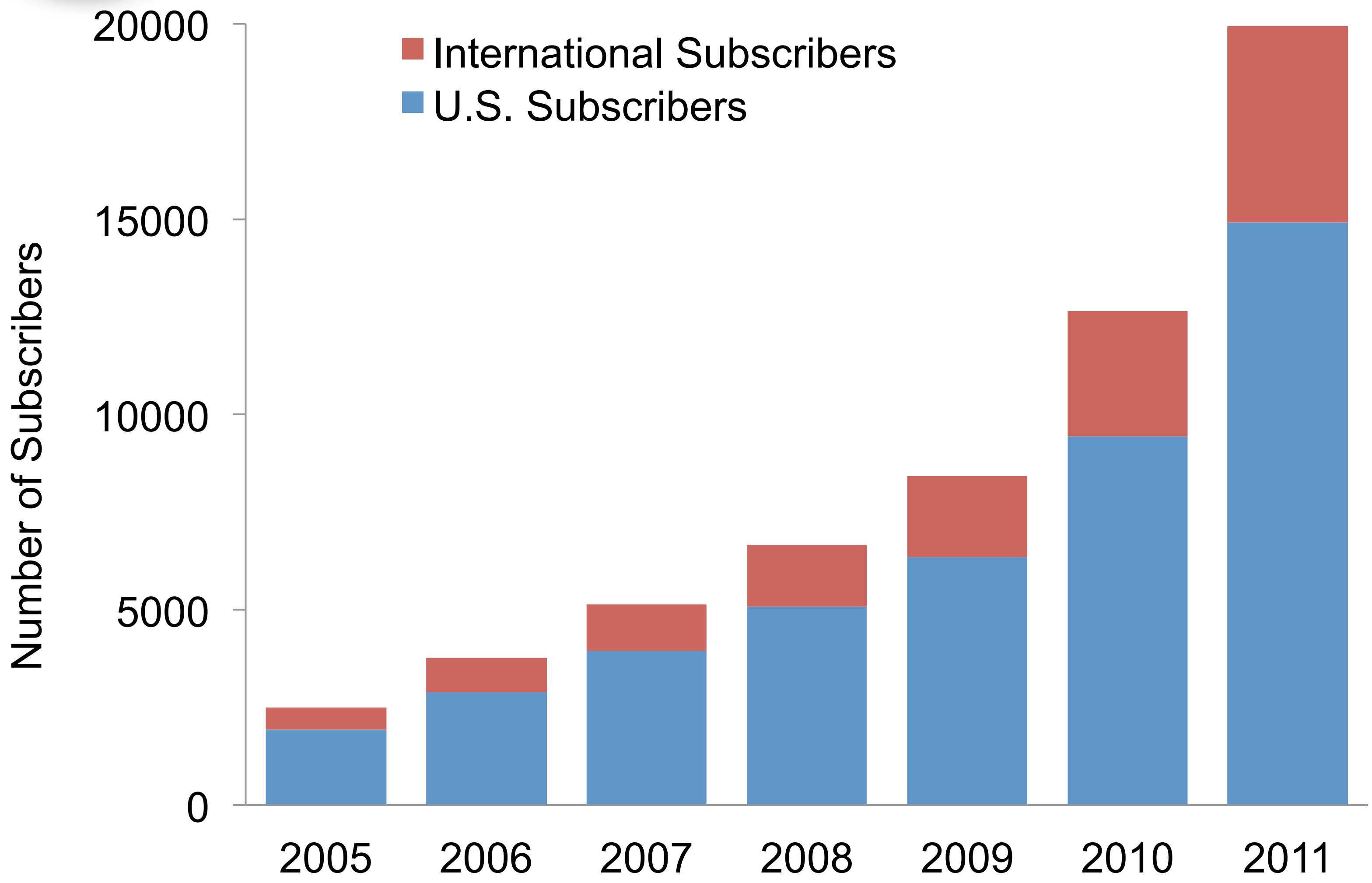
Global Customers for Space Weather Services Continue to Increase



Examples of global airline customers:

Air Canada	Air China	Air New Zealand	American Airlines	British Airways
Cathay Pacific Airway	Korean Air	Lufthansa	Qantas Airways	United Airlines

International and U.S. Subscribers to NOAA Space Weather Products



Major Forecast Center Products

- Daily Forecasts:
  - Solar flares
  - Solar energetic particles
  - Geomagnetic activity
  - 10.7 cm radio flux

- Event-Driven Warnings and Alerts:
  - Warnings: geomagnetic storms, proton events
  - Alerts: solar flare, proton event, geomagnetic storm, electron event, solar radio burst

Real-Time Observations are the Foundation for Products and Services

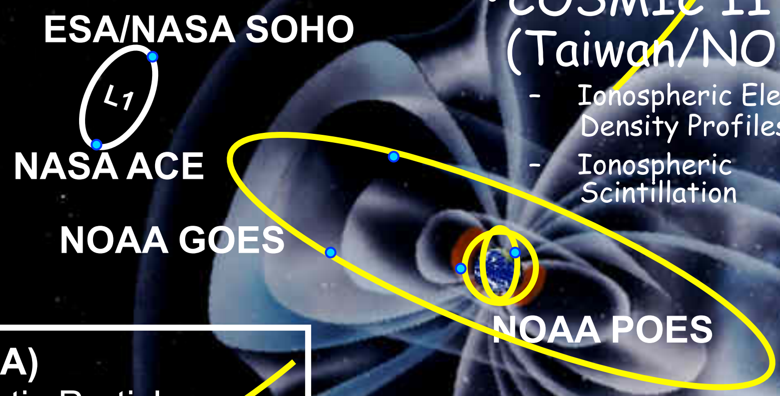
Challenge: Coordinating global data planning, acquisition, and dissemination

NASA STEREO (Ahead)

- **Ground Sites**
  - Magnetometers
  - Riometers and Neutron monitors
  - Telescopes and Magnetographs
  - Ionosondes
  - GNSS

- **SOHO (ESA/NASA)**
  - Solar EUV Images
  - Solar Corona (CMEs)

- COSMIC II (Taiwan/NOAA)
  - Ionospheric Electron Density Profiles
  - Ionospheric Scintillation



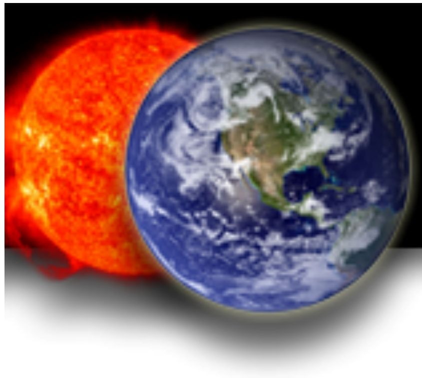
- **ACE (NASA)**
  - Solar wind speed, density, temperature and energetic particles
  - Vector Magnetic field

- **STEREO (NASA)**
  - Solar Corona
  - Solar EUV Images
  - Solar wind
  - Vector Magnetic field

- **GOES (NOAA)**
  - Energetic Particles
  - Magnetic Field
  - Solar X-ray Flux
  - Solar EUV Flux
  - Solar X-Ray Images

- **POES (NOAA)**
  - **High Energy Particles**
  - **Total Energy Deposition**
  - **Solar UV Flux**

NASA STEREO (Behind)

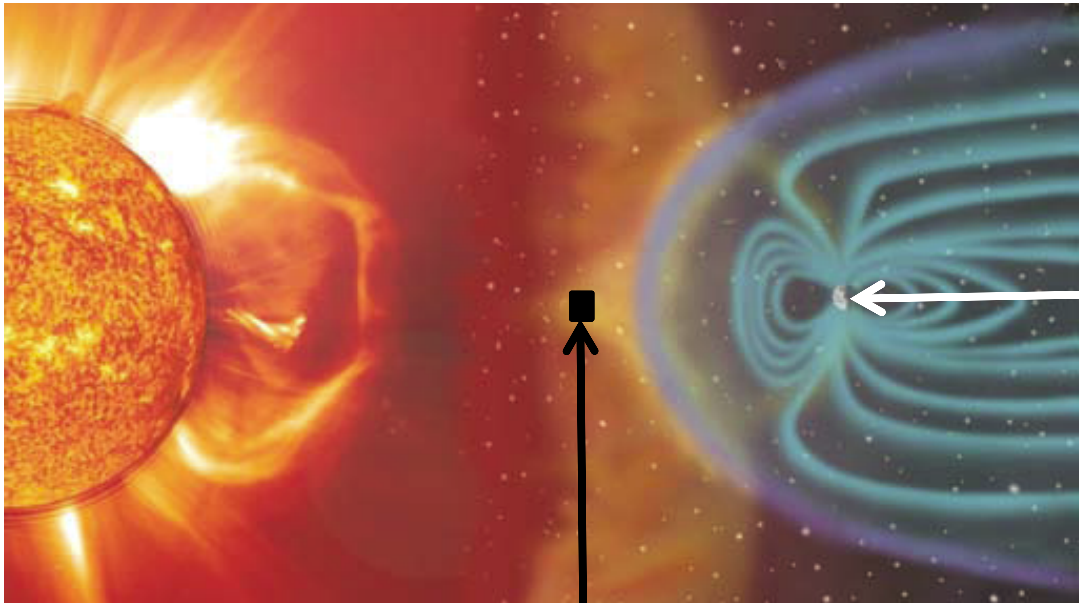


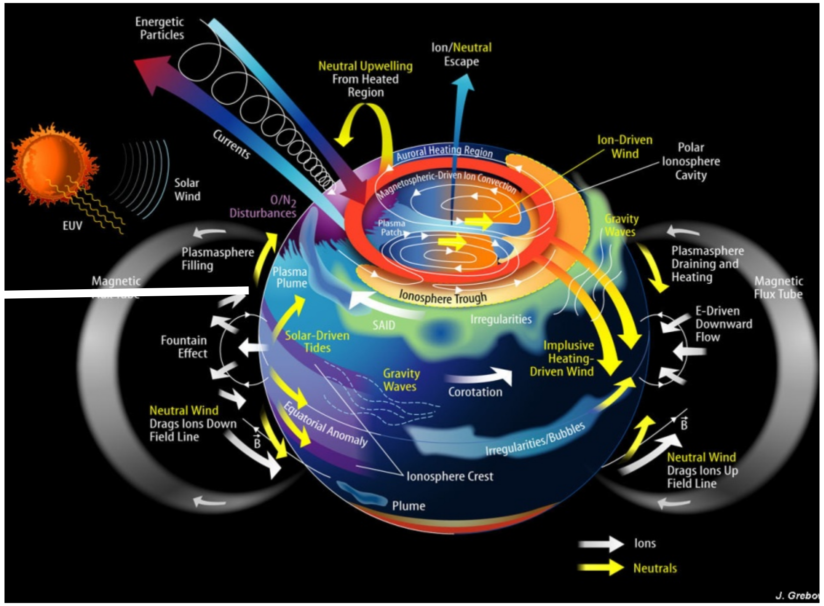
Components of NOAA's Numerical Space Weather Modeling Effort

Solar /Solar Wind

Magnetosphere/ Ionosphere

Atmosphere/ Ionosphere

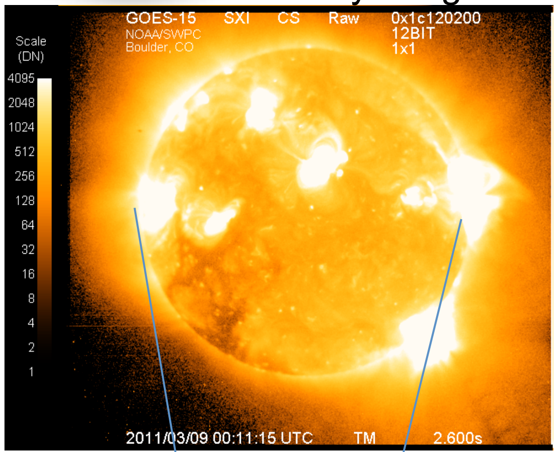




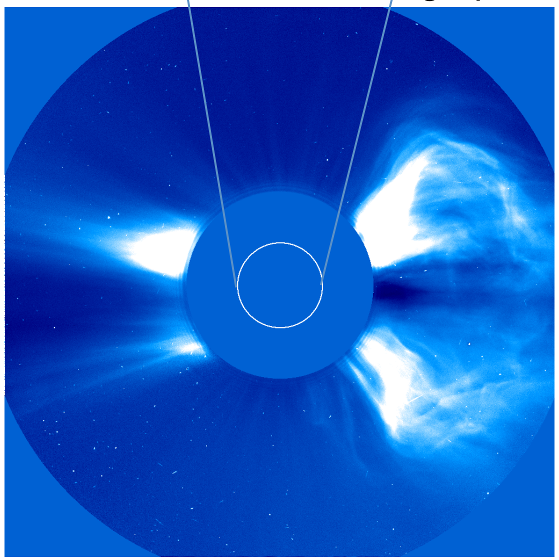
L1 Satellite Location – ACE and Future DSCOVR

Solar Images are Used to Monitor Active Regions and Eruptions

GOES Solar X-Ray Imager



SOHO LASCO Coronagraph



Solar X-ray and EUV Images:
- Active region complexity
- Flare and energetic particle event probabilities
- Flare location
- Coronal hole size and location

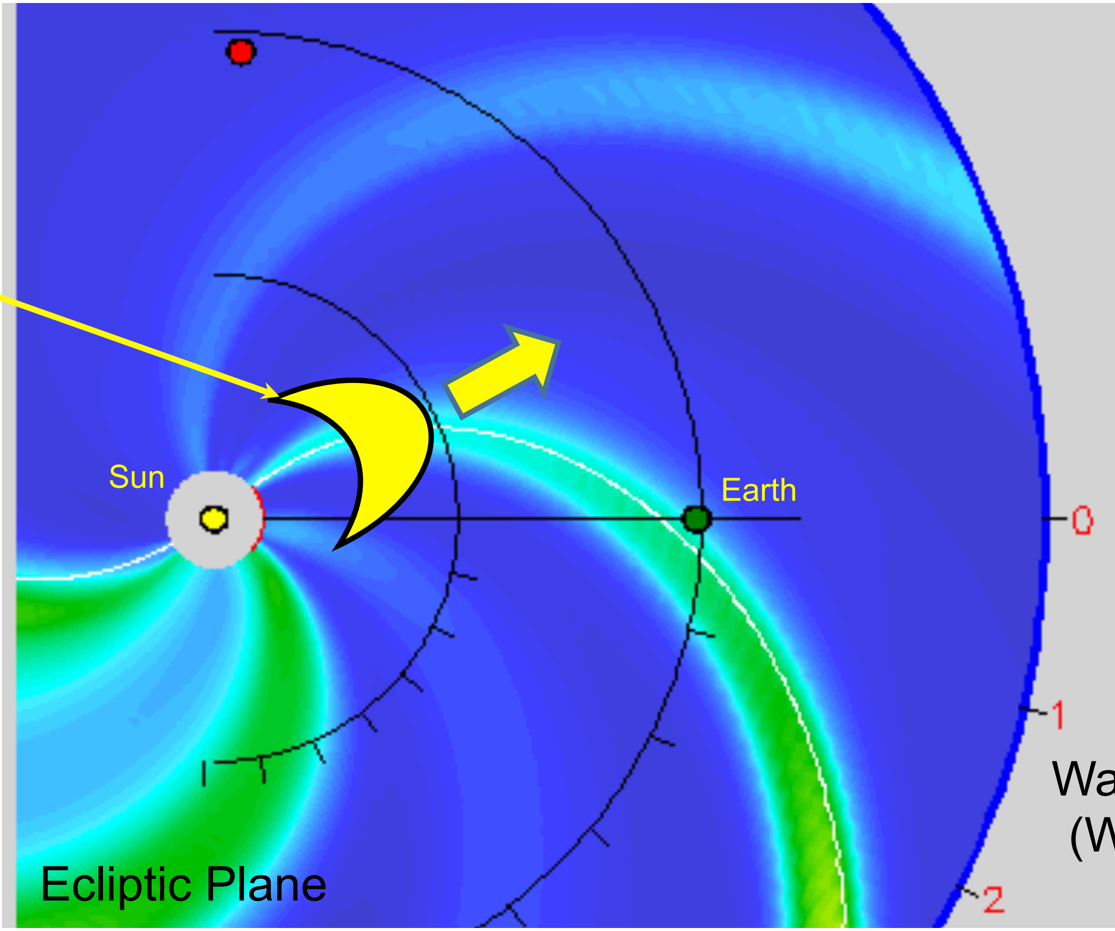
Solar Magnetograms:
- Initialize background solar wind

Coronagraph Images:
- Coronal Mass Ejection occurrence
- CME direction and speed

Numerical Model of the Background Solar Wind and Coronal Mass Ejections

Coronal Mass Ejections can travel to Earth in as fast as 18 hours or may arrive in a few days

Coronal Mass Ejection

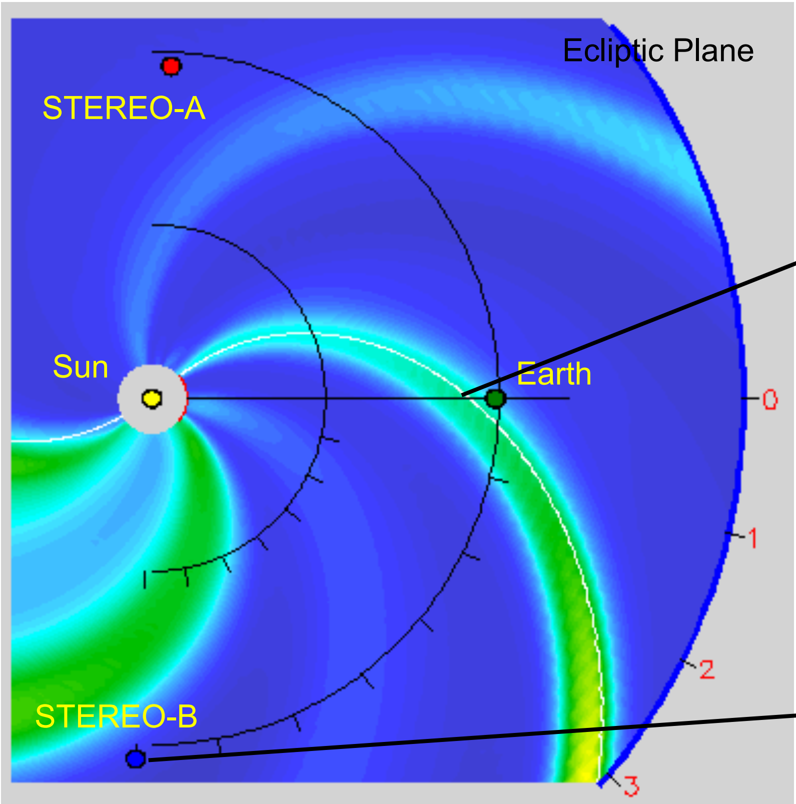


View from above plane of Earth's orbit

Wang-Sheeley-Arge (WSA)/Enlil (Dusan Odstrcil)

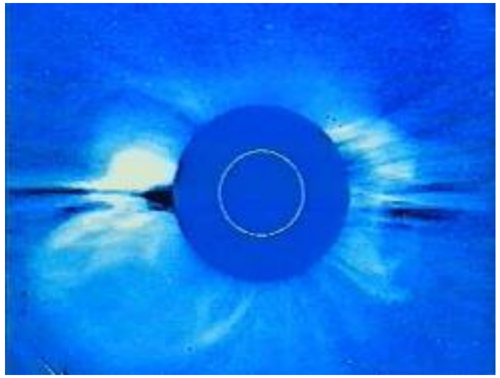
Determining the Initial Properties of CMEs is Important for Predicting Their Arrival

WSA-Enlil Model of Background Solar Wind

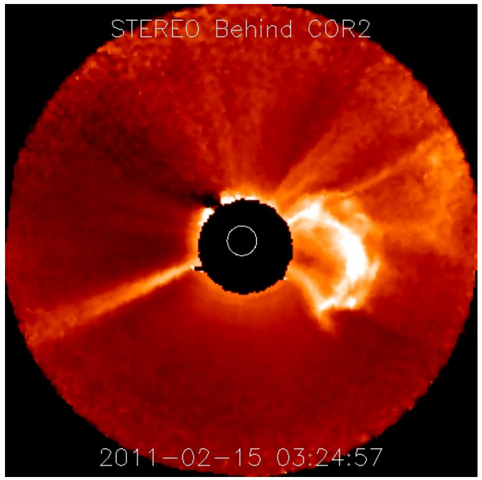


D. Odstrcil

SOHO LASCO Coronagraph

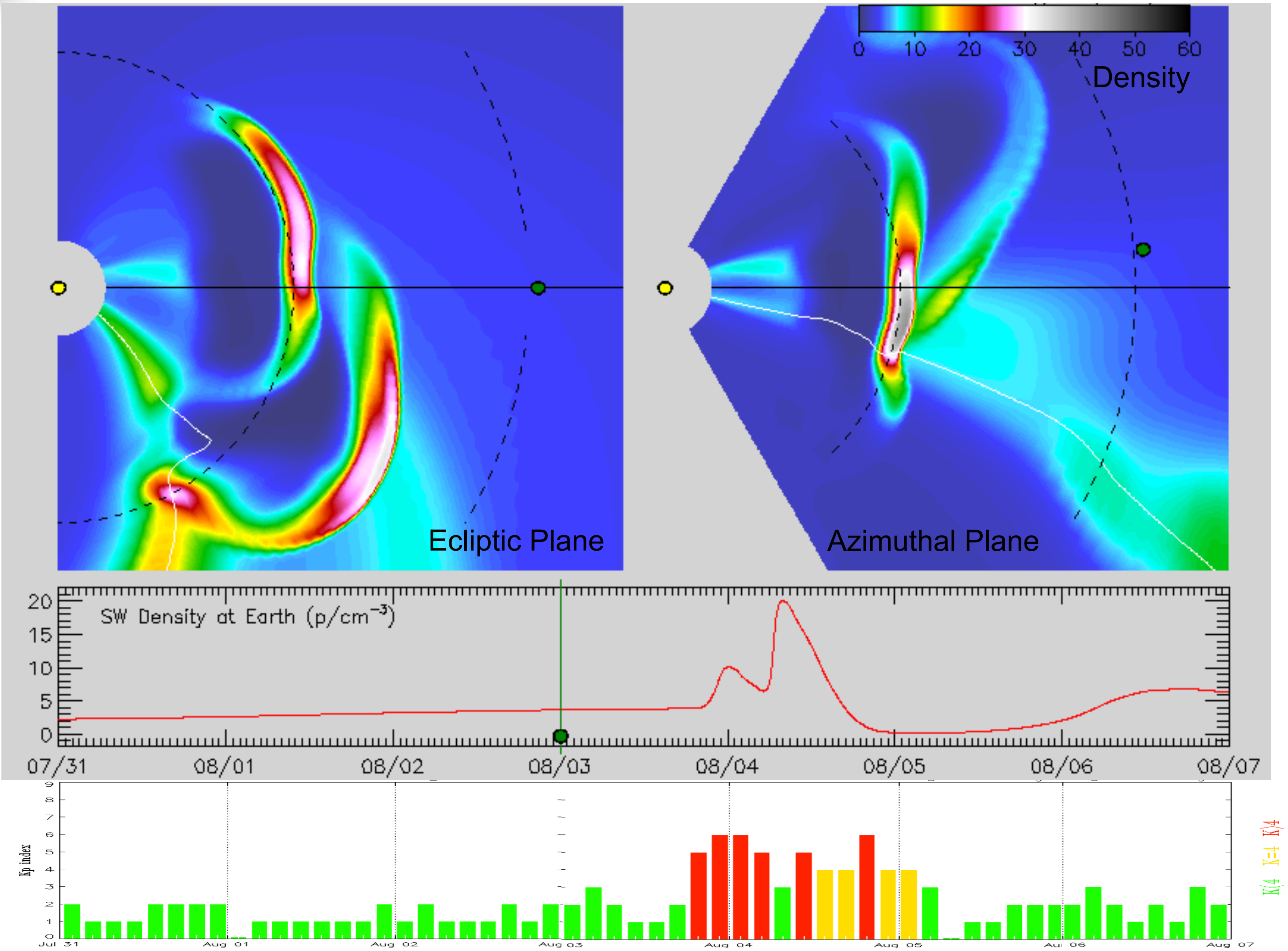


NASA STEREO Coronagraph



CME Predictions Improve Forecasts of Geomagnetic Storms

1 – 4 day advance warning of large storms

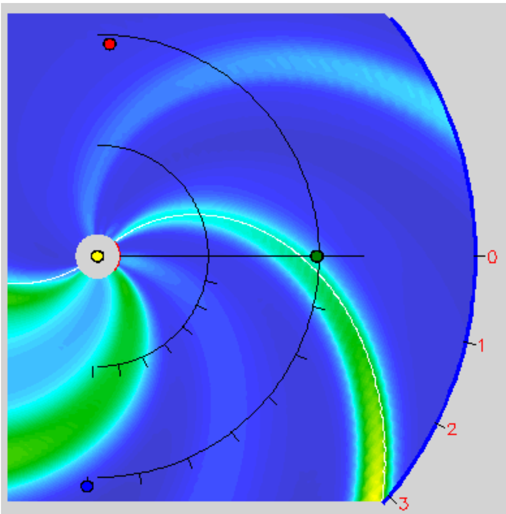


Kp index geomagnetic activity

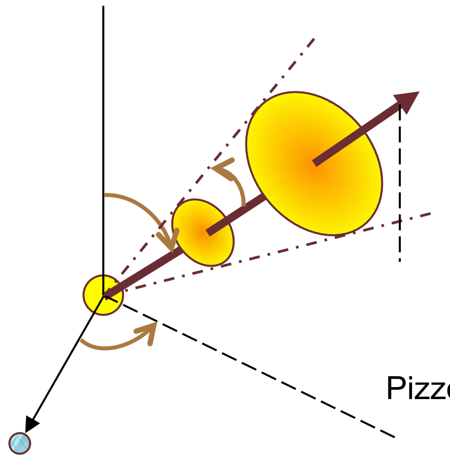
G. Millward, Univ. of Colorado/SWPC

Challenges to Overcome in Predicting CME Arrival Time and Impacts

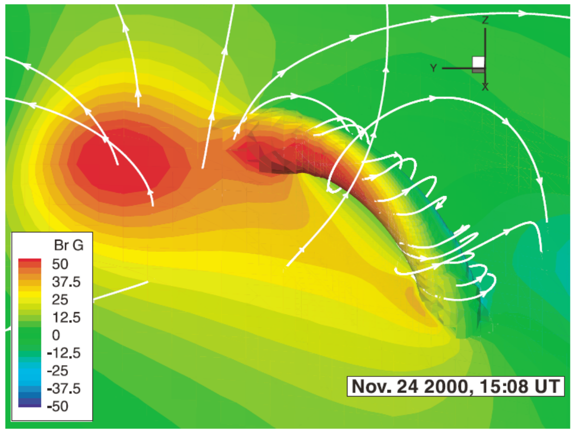
- Satellite-based measurements of Coronal Mass Ejections
- Improved techniques for initializing the background solar wind model
- Improved techniques for initializing the CME model
- Characterization of the internal magnetic field structure within CMEs



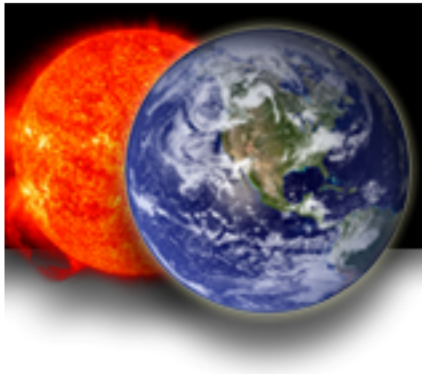
D. Odstrcil



Pizzo



Lugaz et al, 2007



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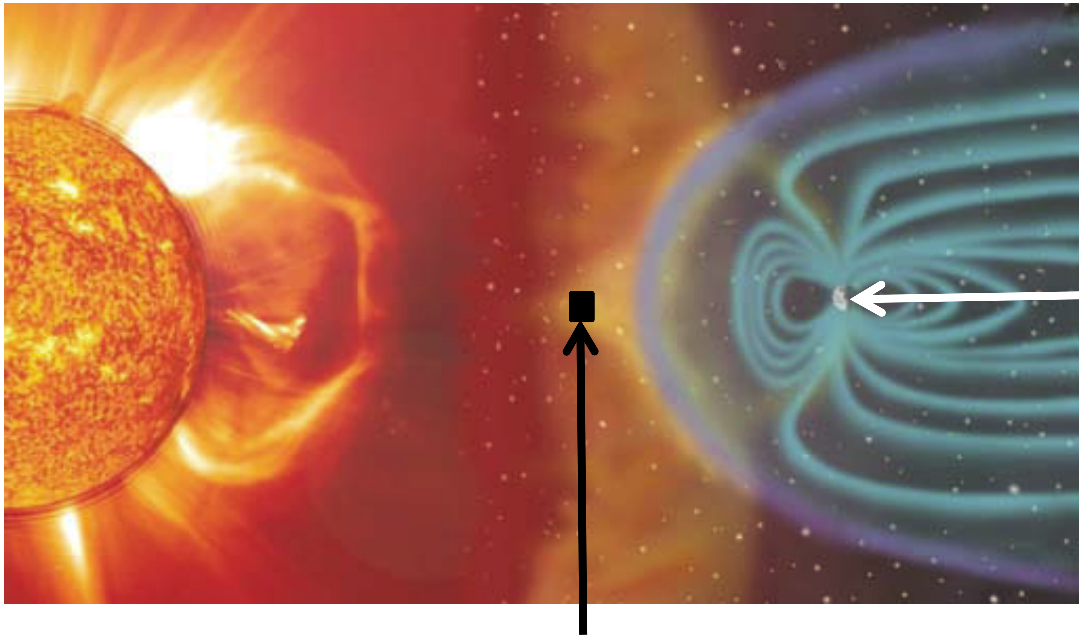
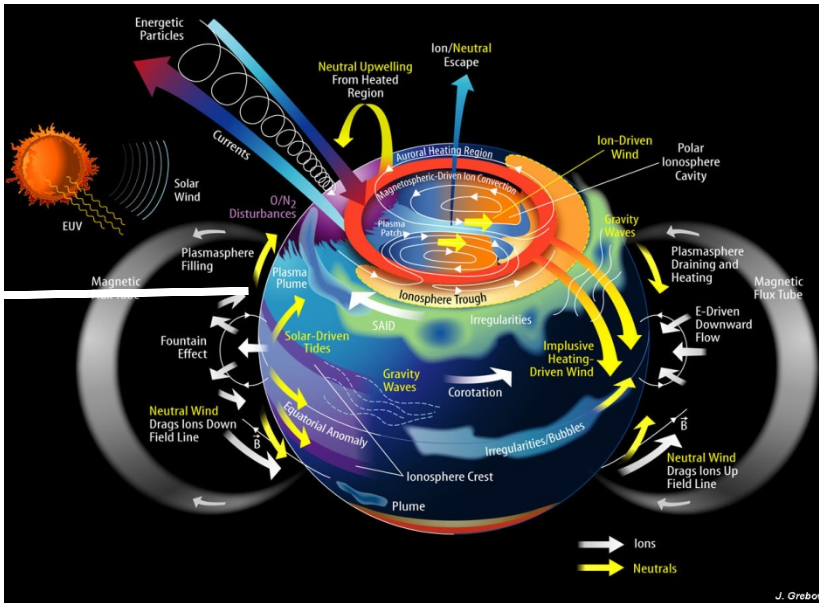




L1 Satellite Location – ACE and Future DSCOVR

Electric Power Impacts – October, 2003

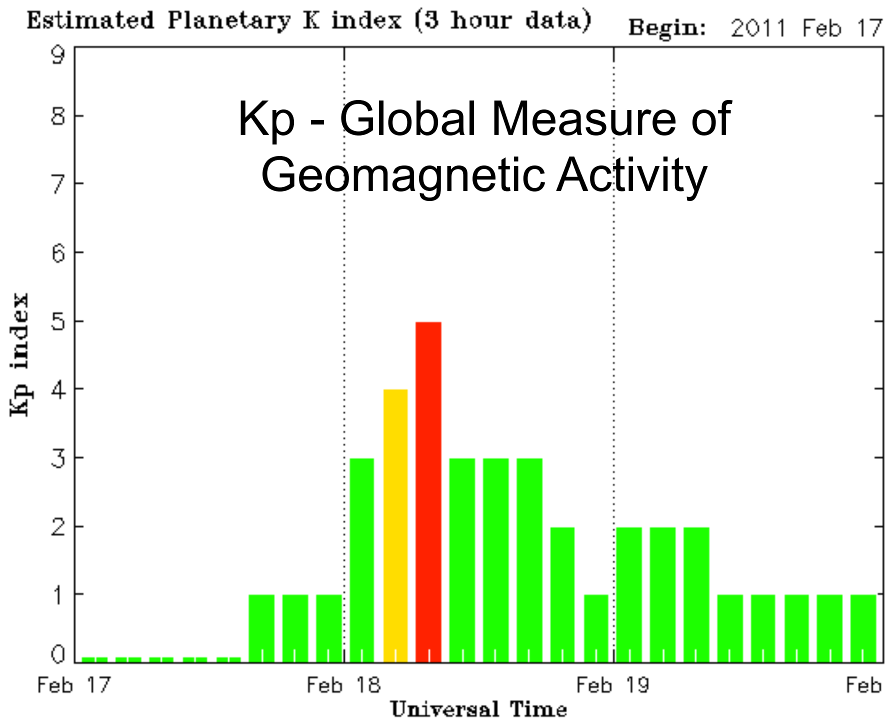
Sweden:
- Power outage
- Transformer heating in nuclear plant

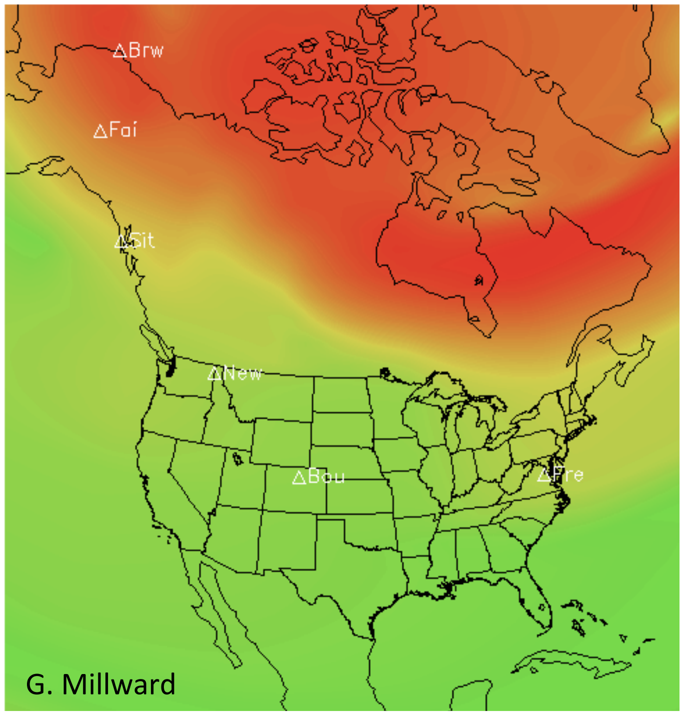
United States:
- Power reduced at nuclear facilities to mitigate impacts

South Africa:
- 14 transformers damaged
- $60 million impact
- Basic commerce and security impaired

Regional Predictions of Geomagnetic Disturbances

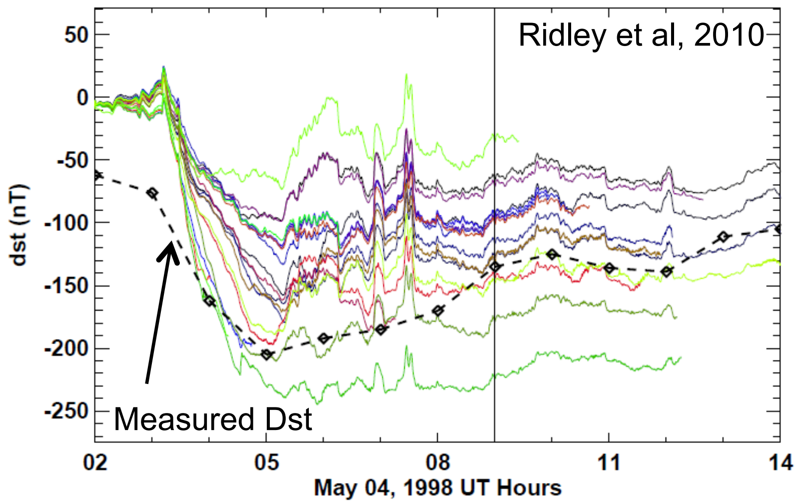
- Current forecasts do not resolve regional differences in activity
- Evaluation of geomagnetic activity models is occurring – involving NOAA, CCMC, MHD modelers, and empirical modelers
- Transition to operations is planned to begin in 2013





Challenges to Overcome in Predicting Geomagnetic Activity

Measured and Simulated Dst Index



Major challenges in magnetosphere modeling:

- Inner magnetospheric physics
- Outflow of ionospheric plasma
- Electromagnetic coupling with the ionosphere
- Grid resolution and numerical schemes affect model output in complex ways

Prediction of storm-time currents (Dst) varies with:

- Grid resolution
- Numerical algorithms
- Implicit/explicit time step
- Ionospheric density

Components of NOAA's Numerical Space Weather Modeling Effort

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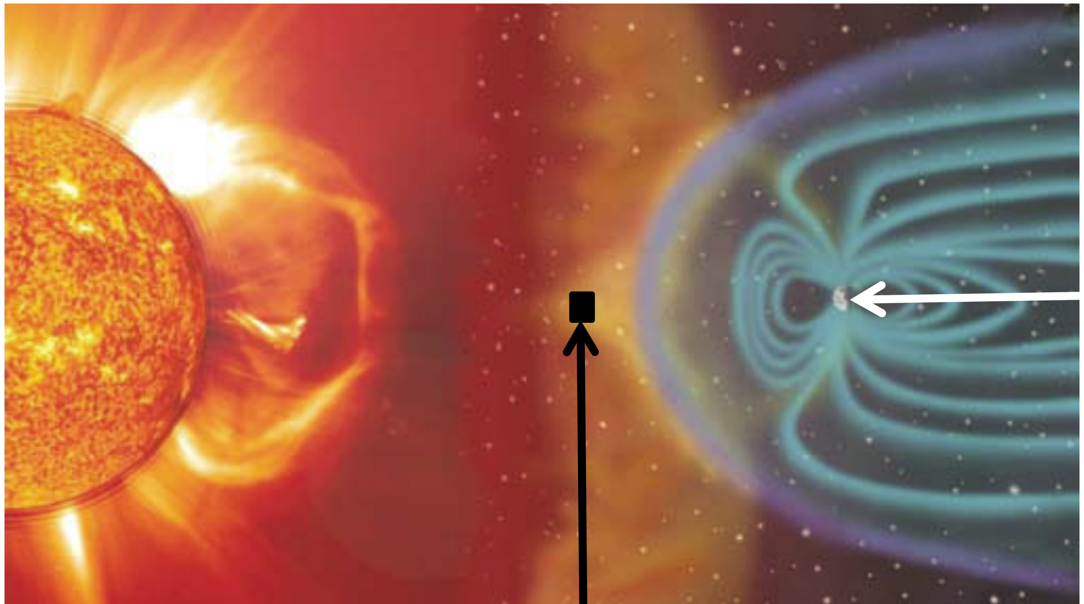
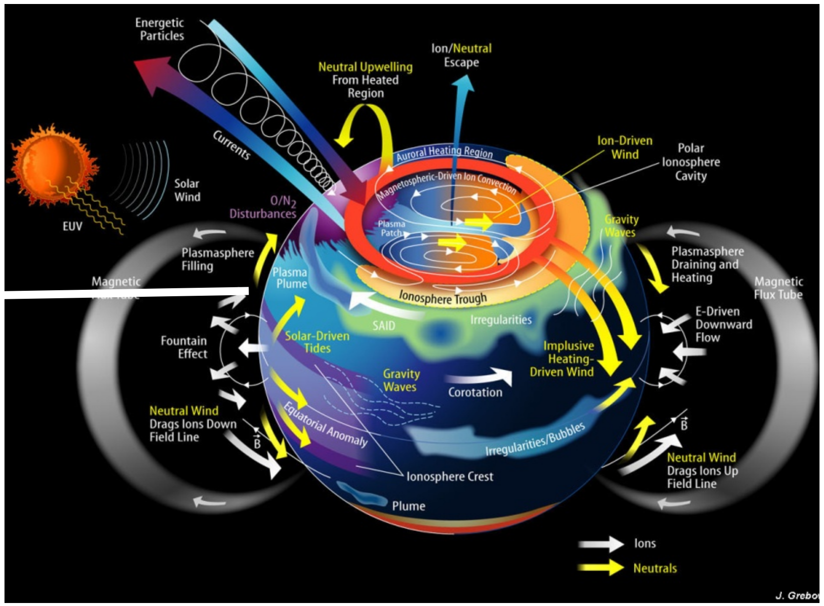
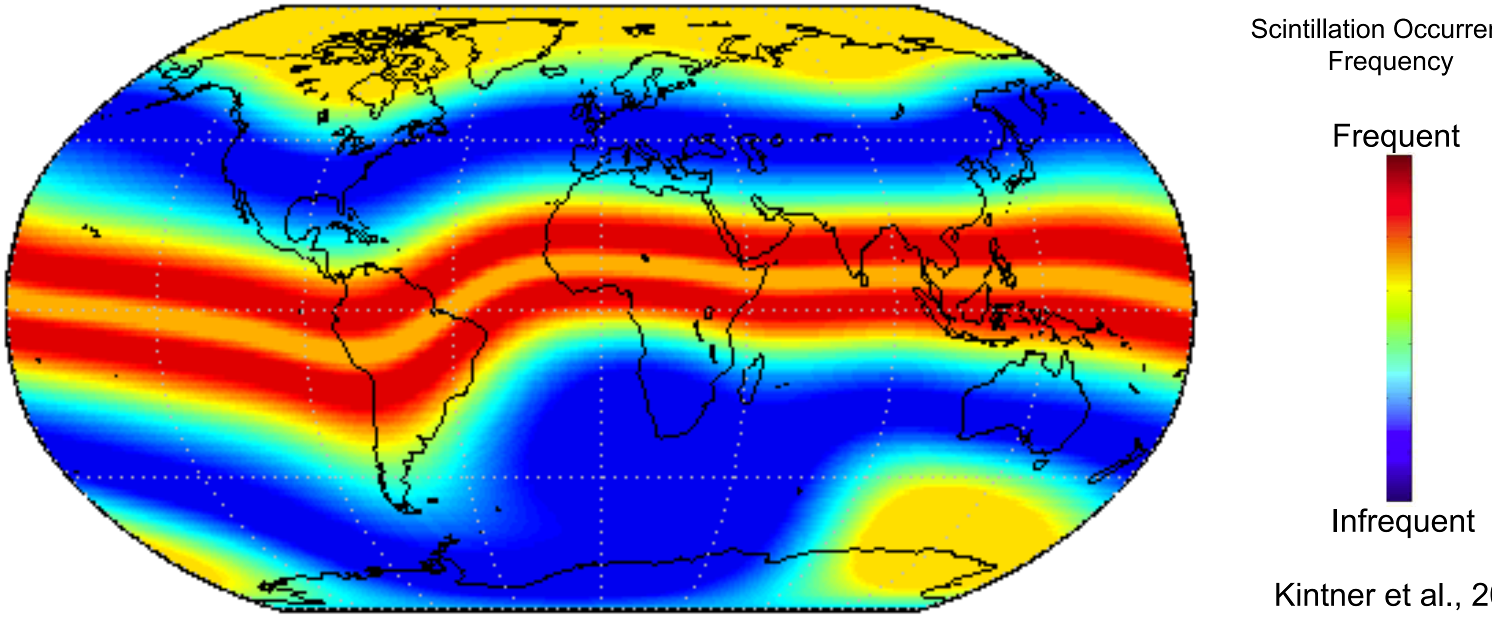




L1 Satellite Location – ACE and Future DSCOVR

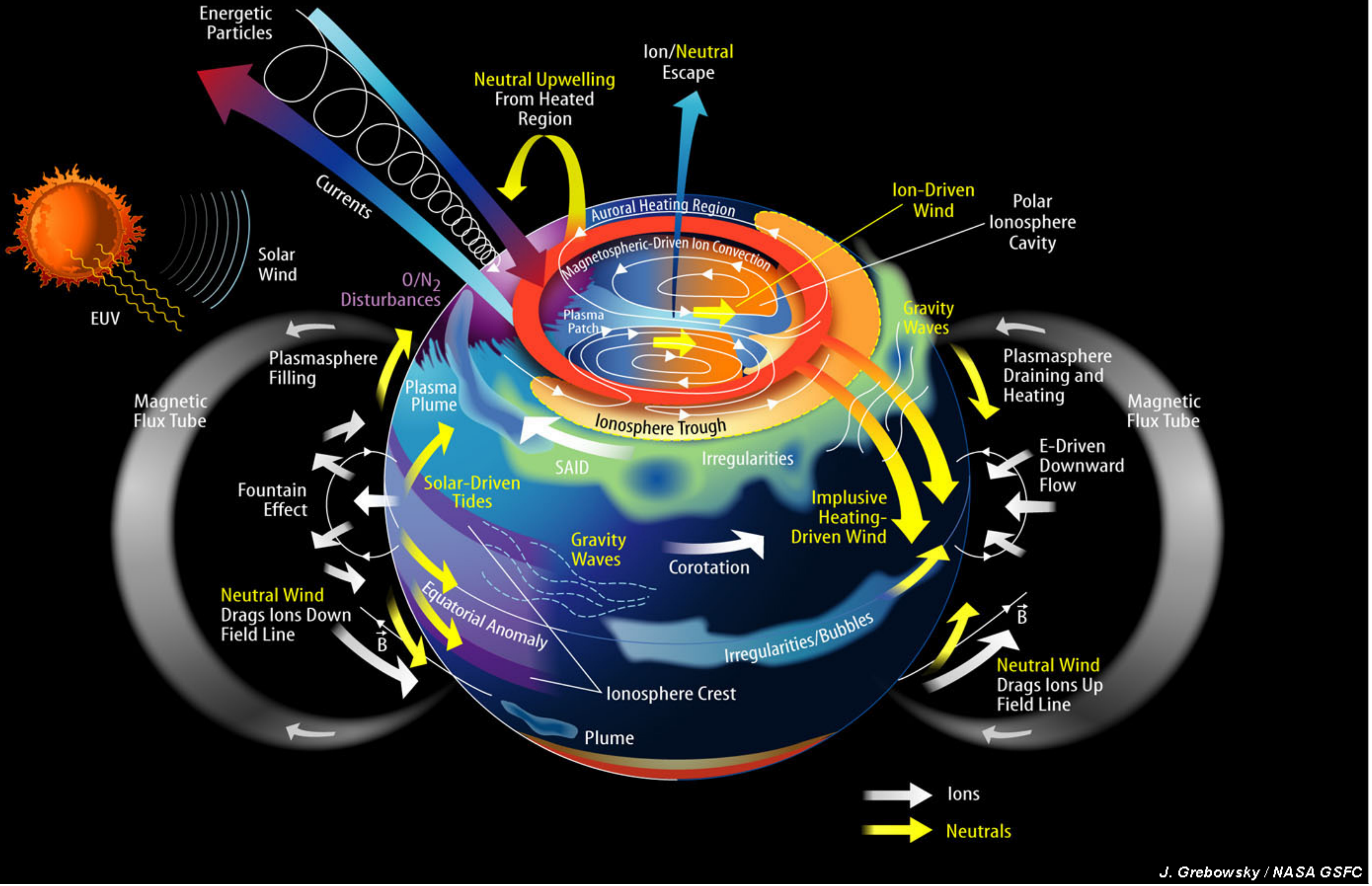
Ionospheric Disturbances Occur at All Latitudes

- Ionospheric disturbances create communication, navigation, positioning, and timing errors and loss of signal.
- Highest occurrence frequency is at low and high latitudes. During large storms, disturbances extend into mid latitudes.



Kintner et al., 2009

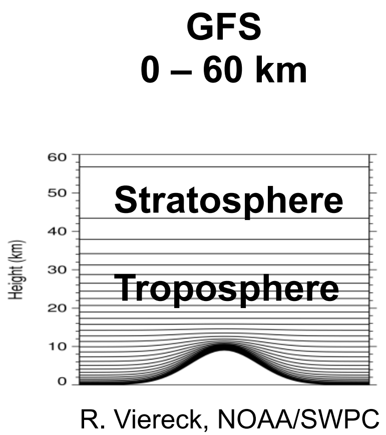
Ionosphere is Driven both from Space and from the Atmosphere

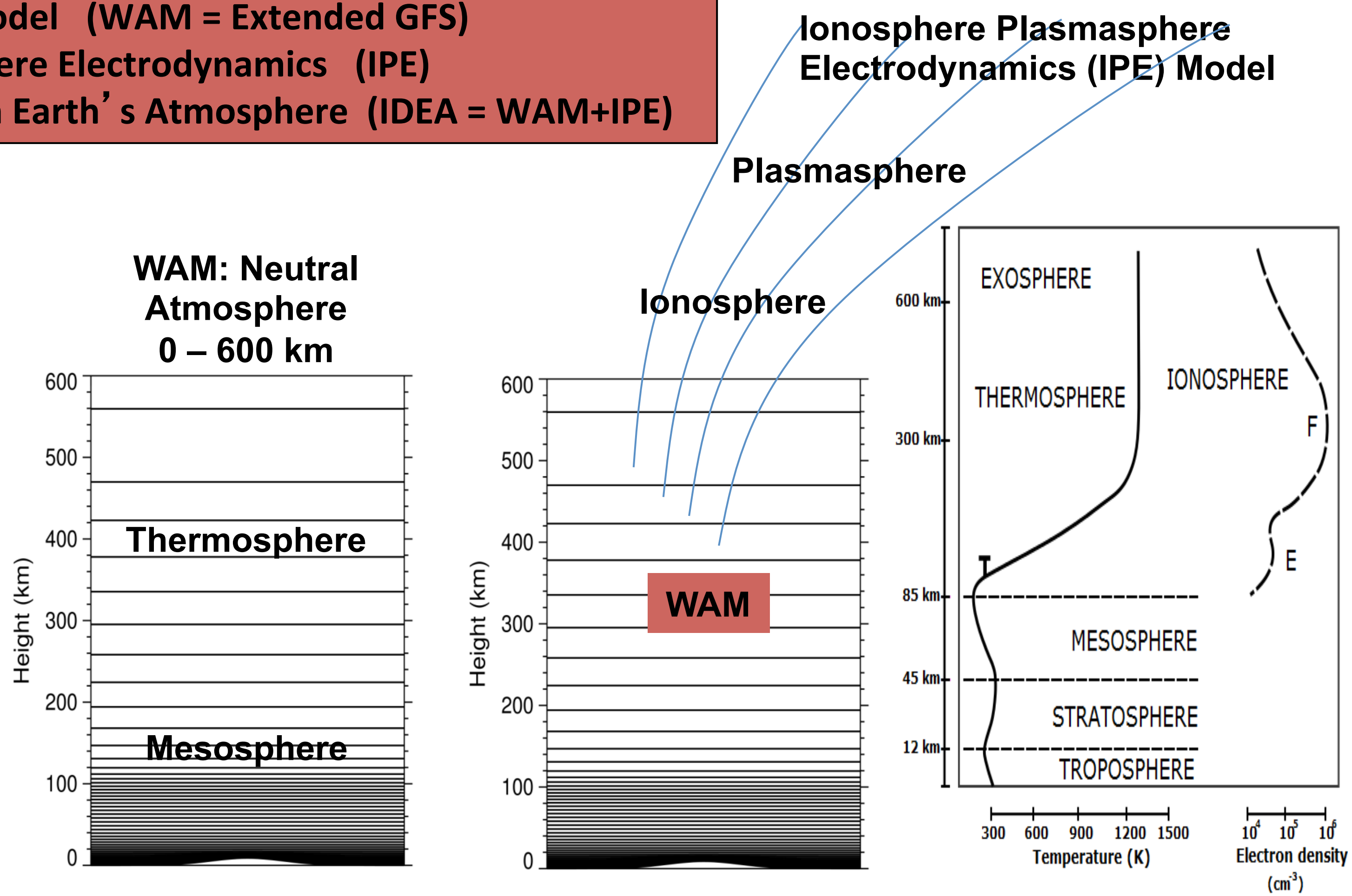


Coupling of Atmospheric Dynamic to the Ionosphere System

Model development includes collaboration with UK researchers and the UK Met Office

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

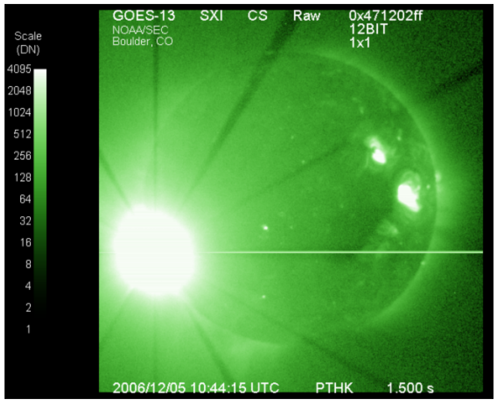


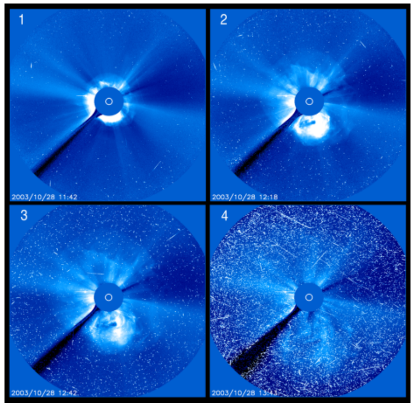


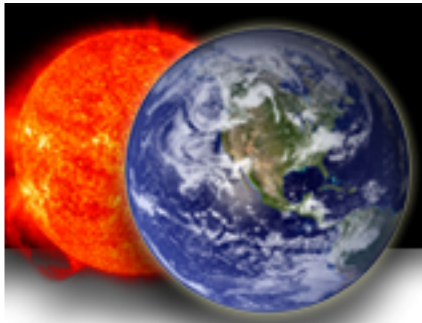
Additional Areas Where Research Advances are Needed

- Solar Active Region Eruption
  - Probability of near-term eruption of solar active region
  - Probability of intense flare x-rays
  - Probability of energetic particle acceleration

- Radiation environment at Earth
  - Probability of solar energetic particles
  - Probability of intense electron radiation belts







Summary

- NOAA has a suite of operational products to support the spectrum of space weather customers
- Space weather products require a global infrastructure of ground-based and space-based instruments
- Numerical prediction models are being developed covering the full Sun-Earth environment
- Significant challenges exist in maintaining a comprehensive observing infrastructure and developing numerical models
- NOAA is eager to work with our international partners on all aspects of the space weather enterprise – observations, research, application development and service delivery