# Introduction to SWPC and Space Weather Supercomputing Needs

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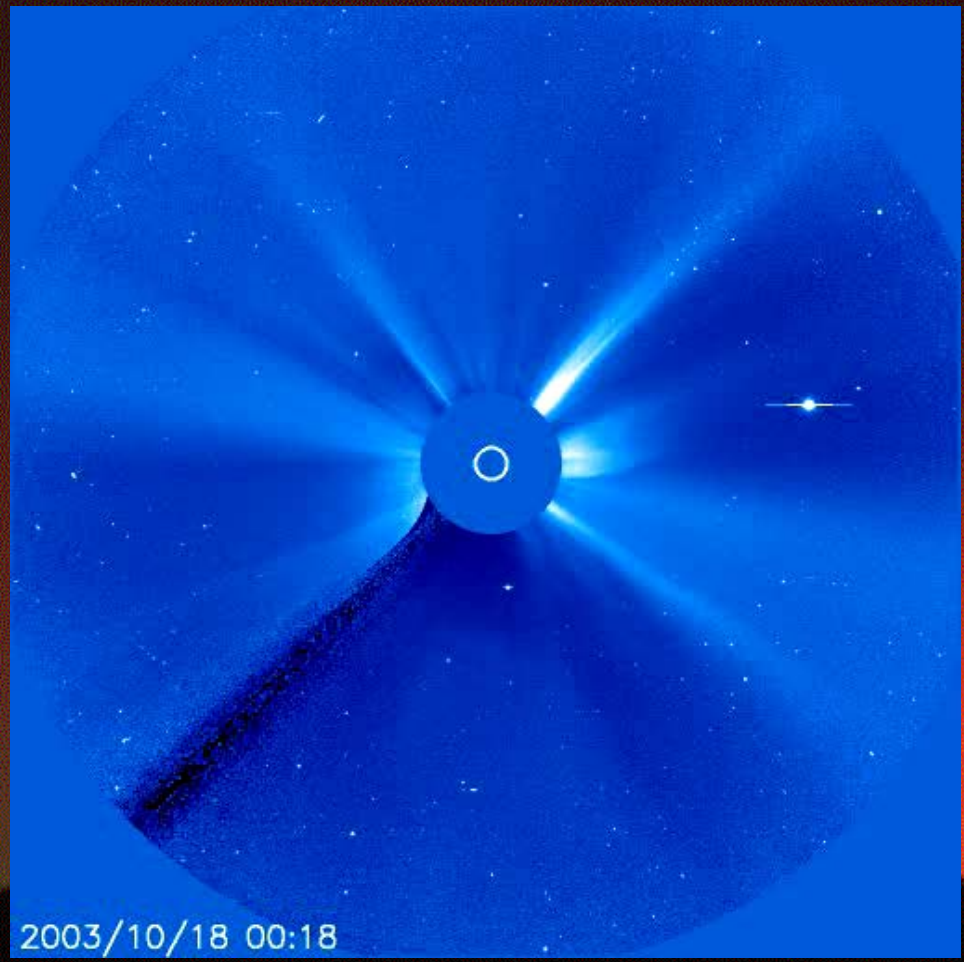
# Space Weather Models

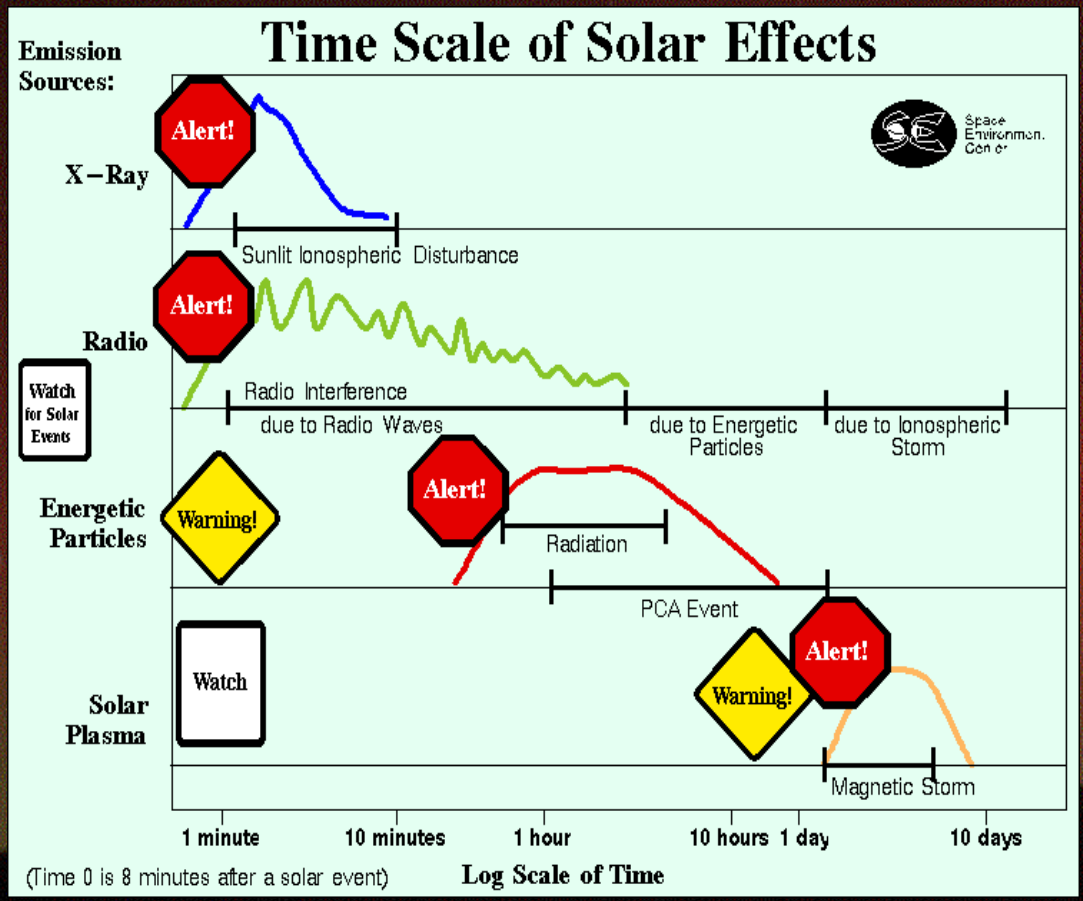
- What is space weather
- Space Weather Models for NCEP
  - IDEA
    - Whole Atmosphere and Ionosphere
  - WSA/ENLIL
    - Solar Atmosphere and Heliosphere
  - CMIT
    - Magnetosphere, Ionosphere, and Thermosphere
- Summarizing SWPC Future Needs

# Storms From the Sun



# Space Weather Products and Services

**SEC produces 42 Alert products**



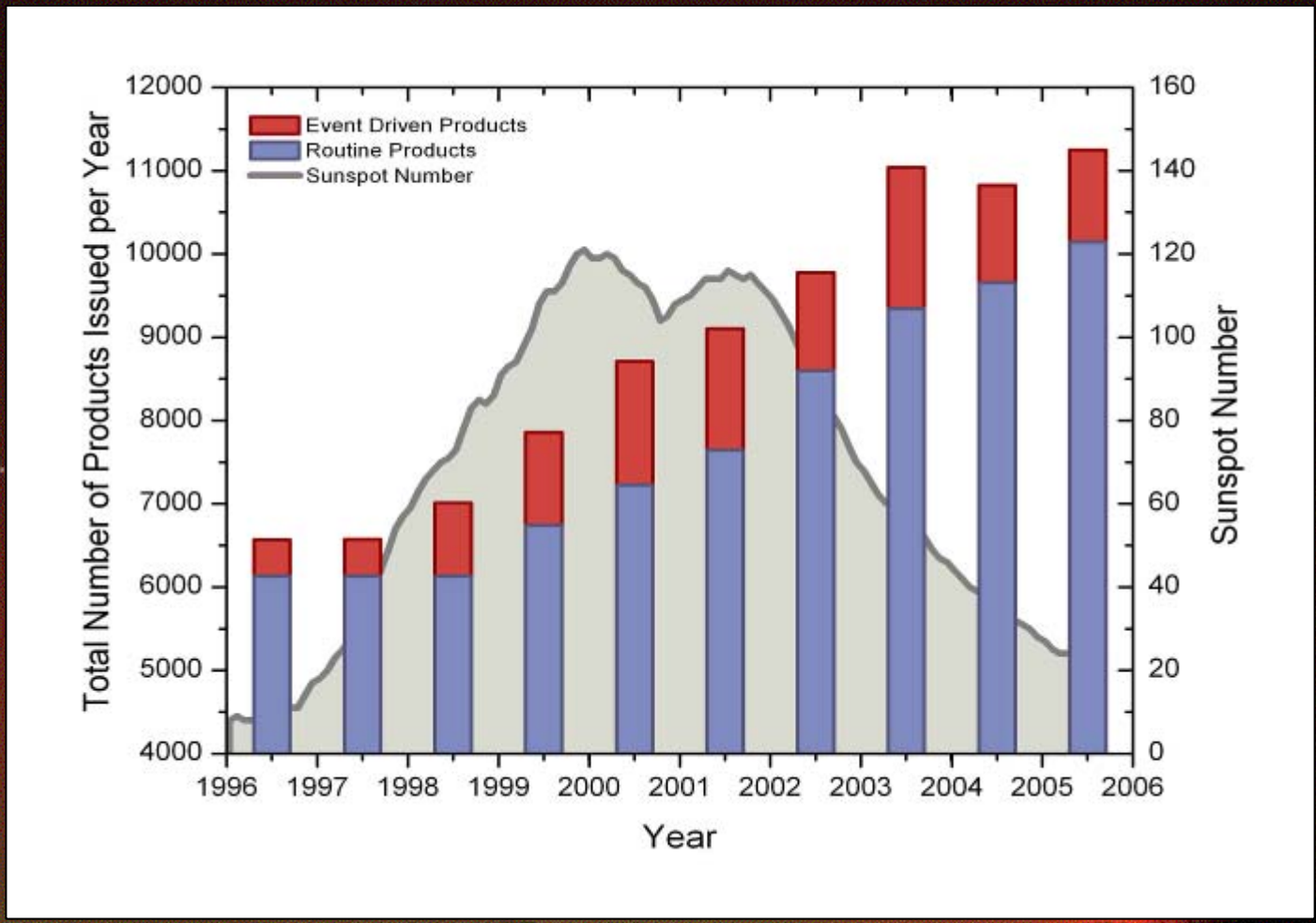

**Watches;** expected disturbances, events that are forecast (i.e. The conditions are favorable for occurrence)

**Warnings;** disturbances that are imminent, likely, expected in the near future with high probability

**Alerts;** observed conditions meeting or exceeding thresholds

**Summaries;** report issued as storm thresholds change/end-of-event

# Annual Number of Space Weather Products Issued during Solar Cycle 23




- The number of products above does not include the NOAA POES and GOES, or NASA ACE real time solar wind data sets, which account for over 14 million file transfers per month

# Sample of Space Weather Economic and Societal Impacts

| Impact Area | Customer (examples) | Action (examples) | Cost (examples) |
|---|---|---|---|
| **Spacecraft**<br>(Individual systems to complete spacecraft failure; comm and radiation effects) | Lockheed Martin, Orbital, Aerospace Corp, Boeing, Digital Globe, Sciences Corp, Space Systems Loral, NASA, NOAA, DoD | - Postpone launch<br>- In orbit - Reboot systems; Turn off/safe instruments and/or spacecraft | Loss of spacecraft can exceed $500M<br>Commercial loss exceeds $1B<br>Worst case storm - $100B |
| **Electric Power**<br>(Equipment damage to electrical grid failure and blackout conditions) | U.S. Nuclear Regulatory, Northeast Power Coordinating Council, Allegheny Power, Central Maine, American Transmission Company | Many mitigating actions:<br>- adjust/reduce system load<br>- disconnect components,<br>- postpone maintenance. | -Estimated loss ~$400M from unexpected geomagnetic storms<br>- $3-6B loss in GDP (blackout) |
| **Airlines (Communications)**<br>(Loss of flight HF radio communications) | United, Continental, Northwest, American, Lufthansa, Qantas Virgin, British Airways, Fedex, Air New Zealand, ExecuJet, etc. | Divert polar flights, change flight plans<br>Change altitude | Cost ~ $100k per diverted flight<br>$10-50k for re-routes |
| **Airlines (Radiation)**<br>(Radiation dose on crew and passengers) | United, Continental, Northwest, American, Lufthansa, Qantas Virgin, British Airways, Fedex, Air New Zealand, ExecuJet etc. | Divert polar flights, change flight plans<br>Change altitude (even at mid-latitudes) | - Cost ~$100k per diverted flight<br>- Health risks |
| **Surveying & Navigation**<br>(Use of magnetic field or GPS could be impacted) | FAA-WAAS, New York and Texas Dept. of Transportation, BP Alaska, Schlumberger, GlobalSantaFe, etc. | Postpone activities; Redo survey; Use alternate or backup navigation tools | BP Alaska cost $10,000 per day, other surveys have similar costs |
| **Vendor Industry**<br>(Servicing the Northeast Power Coordinating Council (NPCC), and National Grid) | Northwest Research Assoc., INC<br>Solar Terrestrial Dispatch<br>Metatech Corp. | Data used in real time to alert electric power companies of significant geomagnetic storms | |

# Towards weather prediction in the whole atmosphere-ionosphere system: A coupled model of Integrated Dynamics through Earth's Atmosphere (IDEA)

R. A. Akmaev,
T. J. Fuller-Rowell, F. Wu, A. F. Anghel, H. Wang,
and N. Maruyama (CU/CIRES & NWS/NCEP/SWPC)

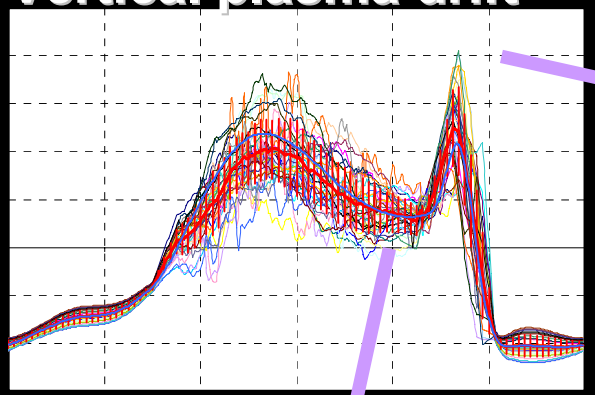
M. D. Iredell, S. Moorthi, H.-M. Juang, and Y.-T. Hou (NWS/NCEP/EMC)

G. H. Millward (CU/LASP)

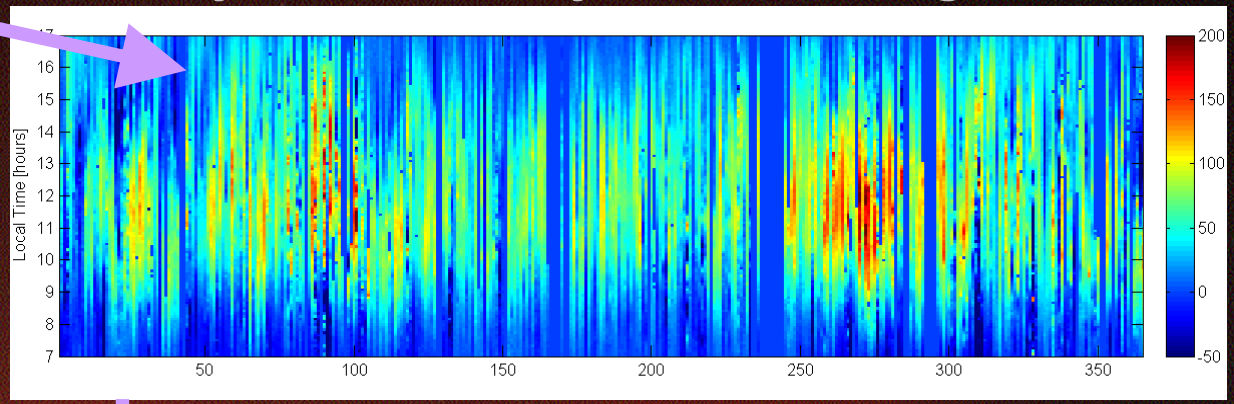
Sponsored by NASA Heliophysics Theory Program & NWS/NCEP/EMC

# Planetary wave periodicities in dayside ionosphere

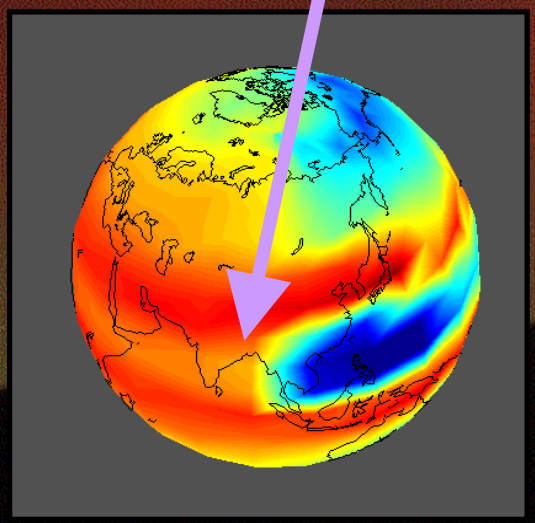
## Vertical plasma drift



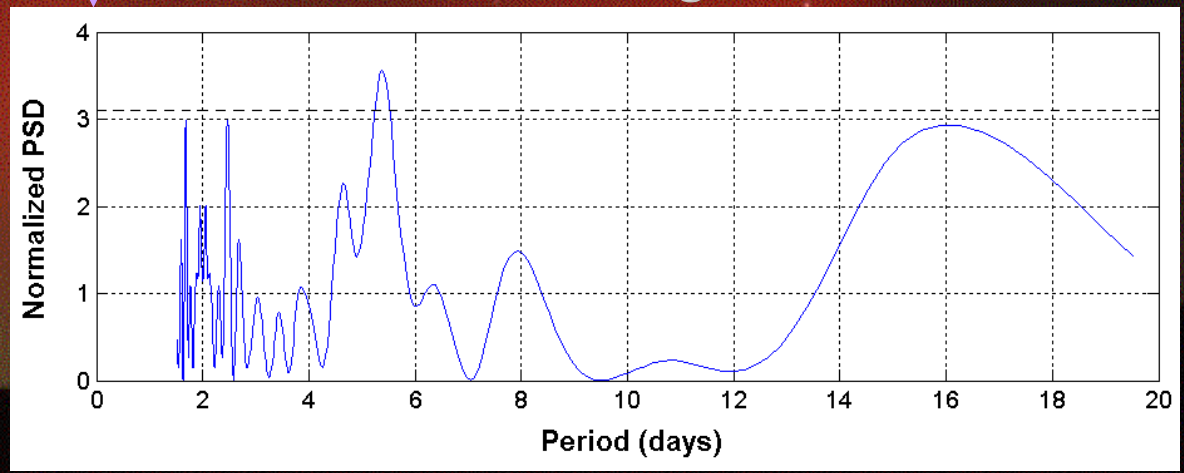
## Dayside electrodynamics during 2001




## Electrodynamics ⇒ drift ⇒ EIA ⇒ scintillations (?)

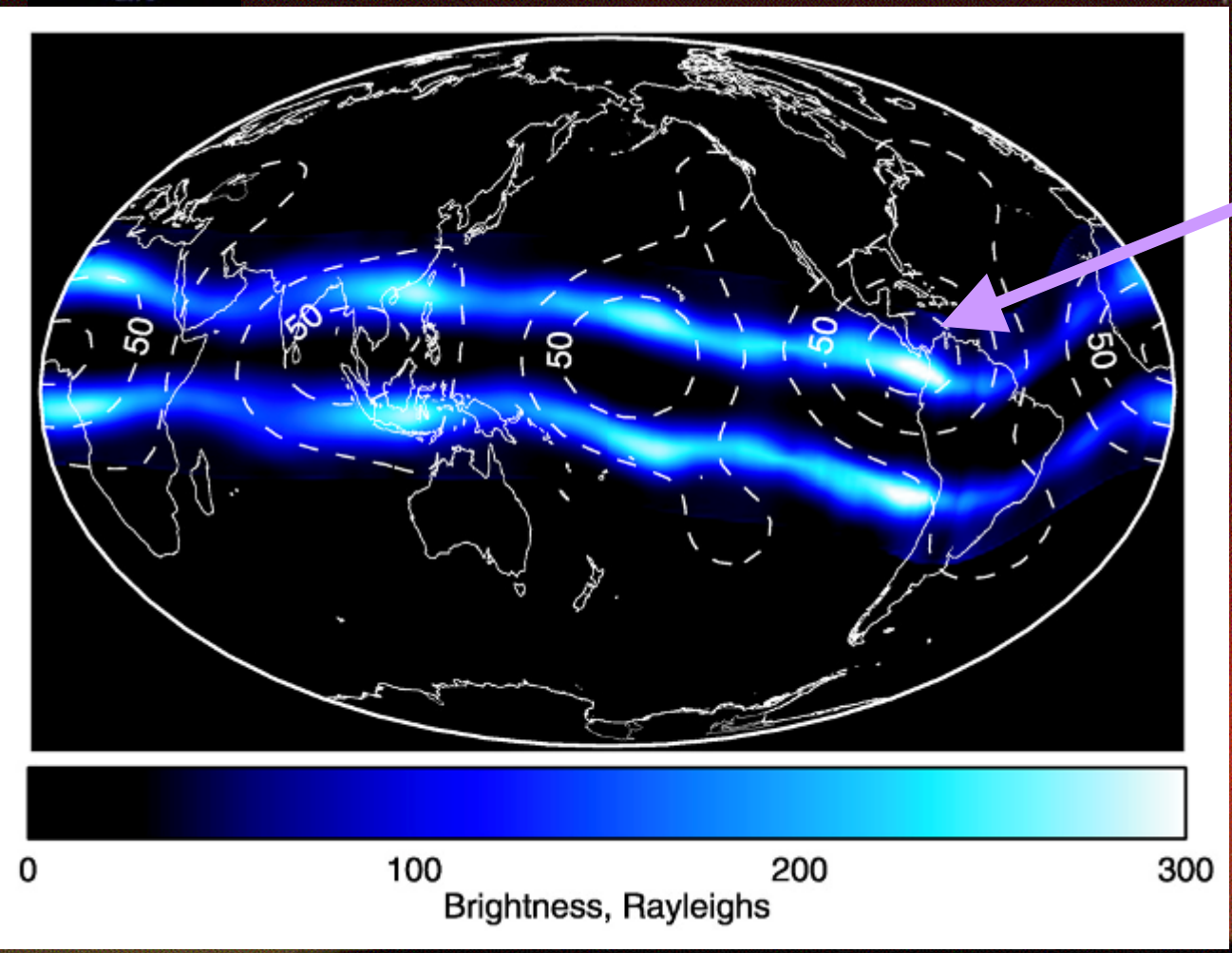


## Possible PW signatures




Courtesy D. Anderson

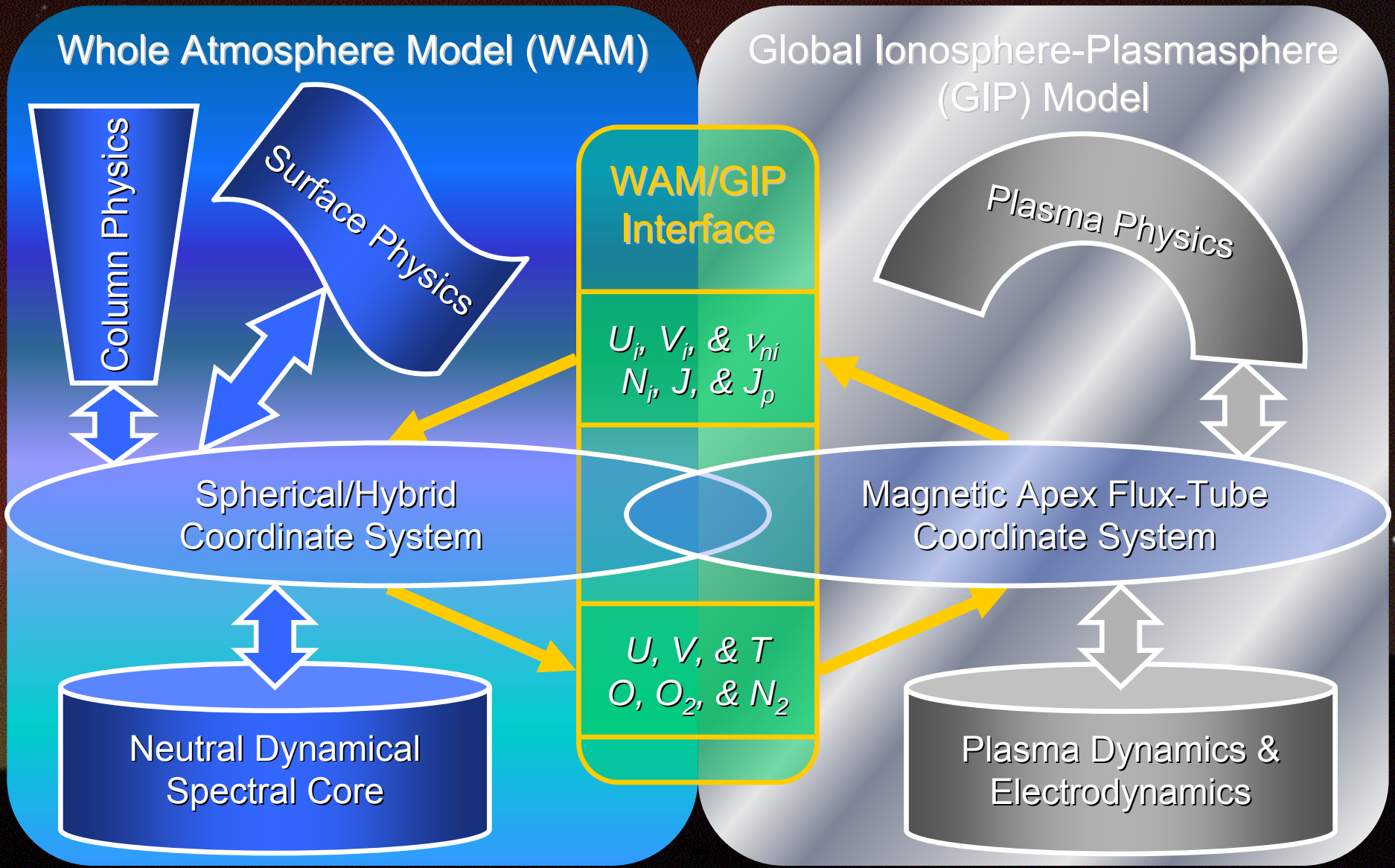
# Tidal signatures in nightside Equatorial Ionospheric Anomaly



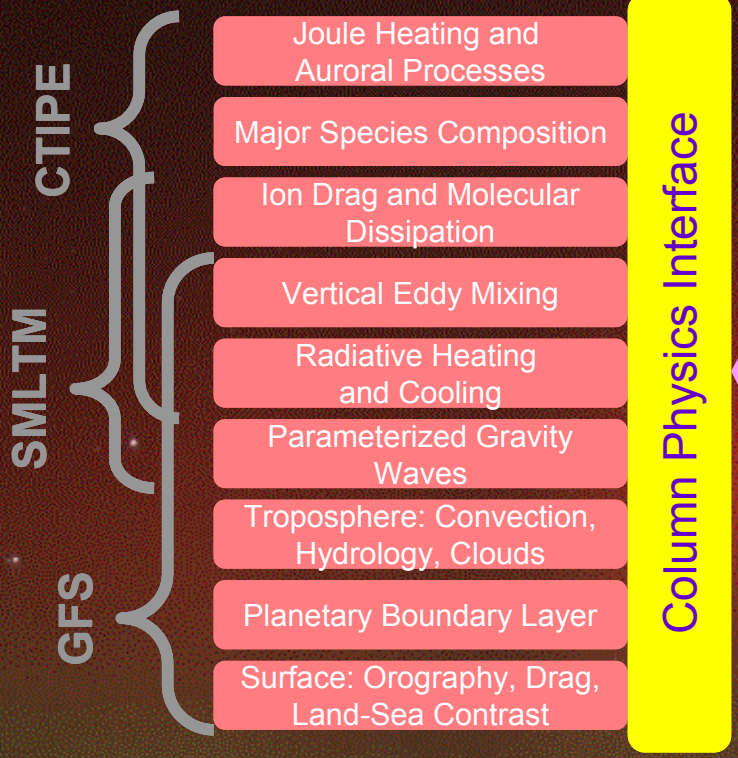

The four peaks in diurnal temperature amplitude result from superposition of the migrating (to the west) tide (DW1) and nonmigrating eastward mode with zonal wavenumber 3 (DE3).

IMAGE composite of 135.6-nm O airglow (350 – 400 km) in March – April 2002 and amplitude of simulated diurnal temperature oscillation at 115 km (Immel et al., 2006).

# Coupled IDEA model



# WAM = Extended GFS + Physics



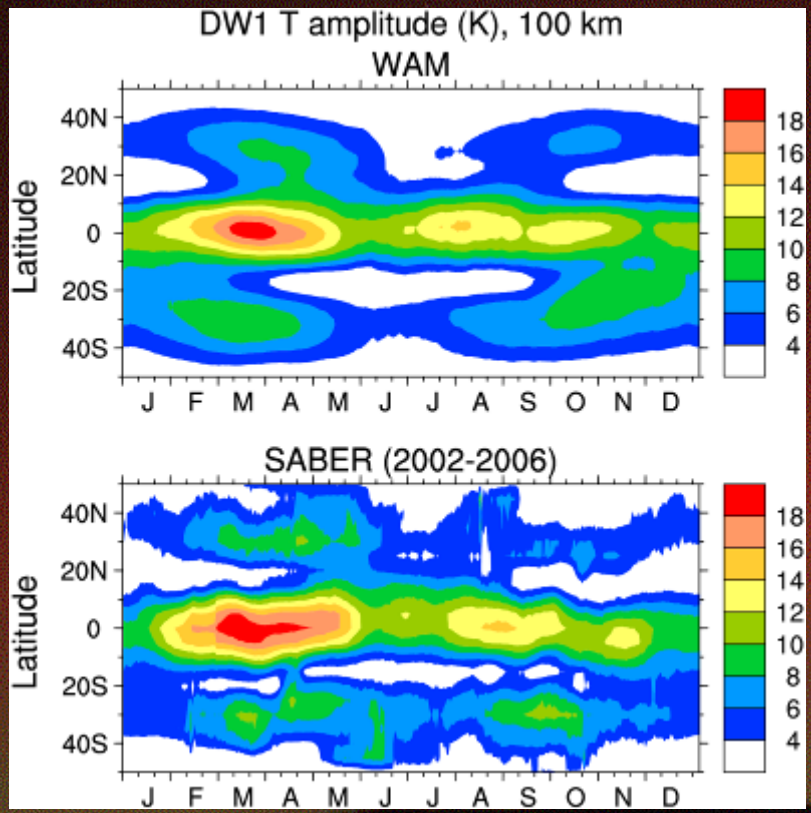

**Operational Global Forecast System**

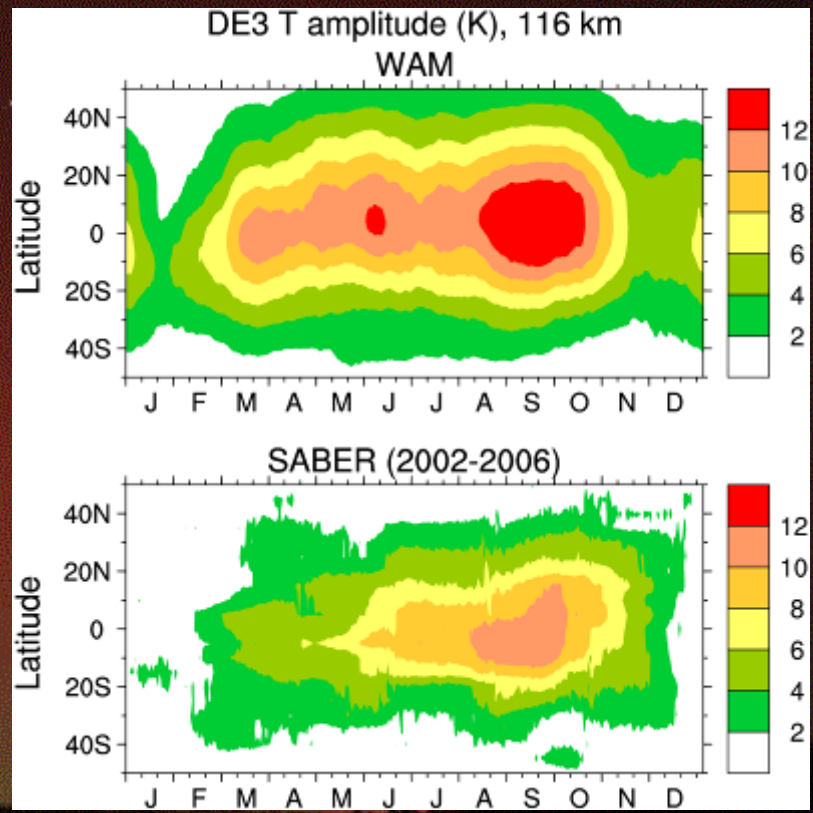
- T382L64 (~ 0.3°×0.3°, ~ 0 – 62 km)
- Hydrology, surface exchange processes, ozone transport, radiation, cloud physics, etc.
- 4 forecasts daily
- Ensemble (14 members) forecast up to 16 days

**WAM**

- 150 layers (~ 0 – 600 km) $\Rightarrow \rho_S/\rho_T \sim 10^{13}$
- Numerical stability issues
- Variable composition $\Rightarrow$ thermodynamics
- Column + surface physics
- Timing: ~ 18 min/day on 32 nodes @ T62L150

# Validation: Migrating Diurnal T amplitude




TIMED/SABER amplitude courtesy J. M. Forbes

# IDEA Future work

## ~ 3 – 5 yrs

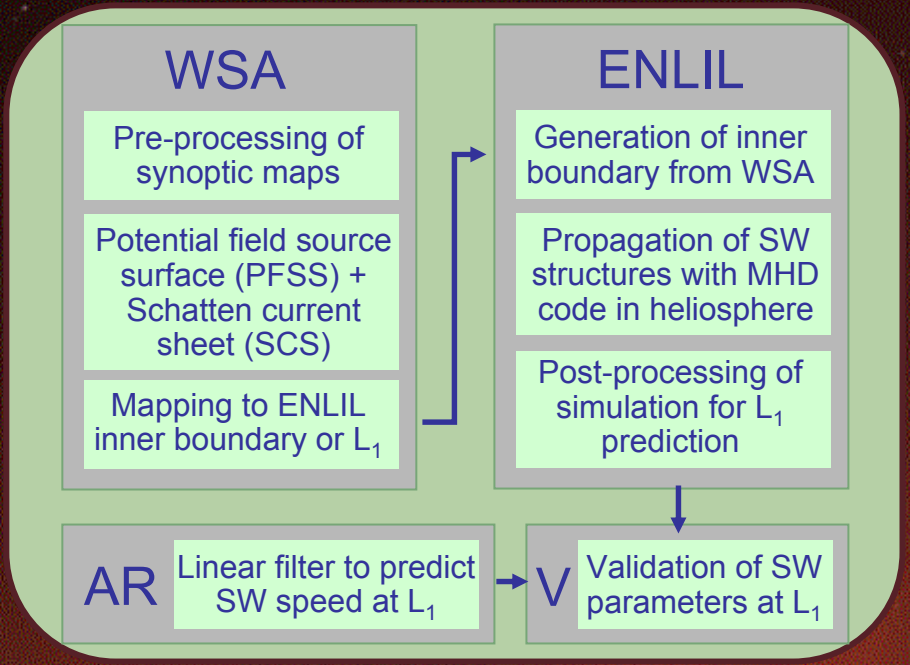
(Newly funded joint NASA grant: CU/EMC/NRL/SWPC)

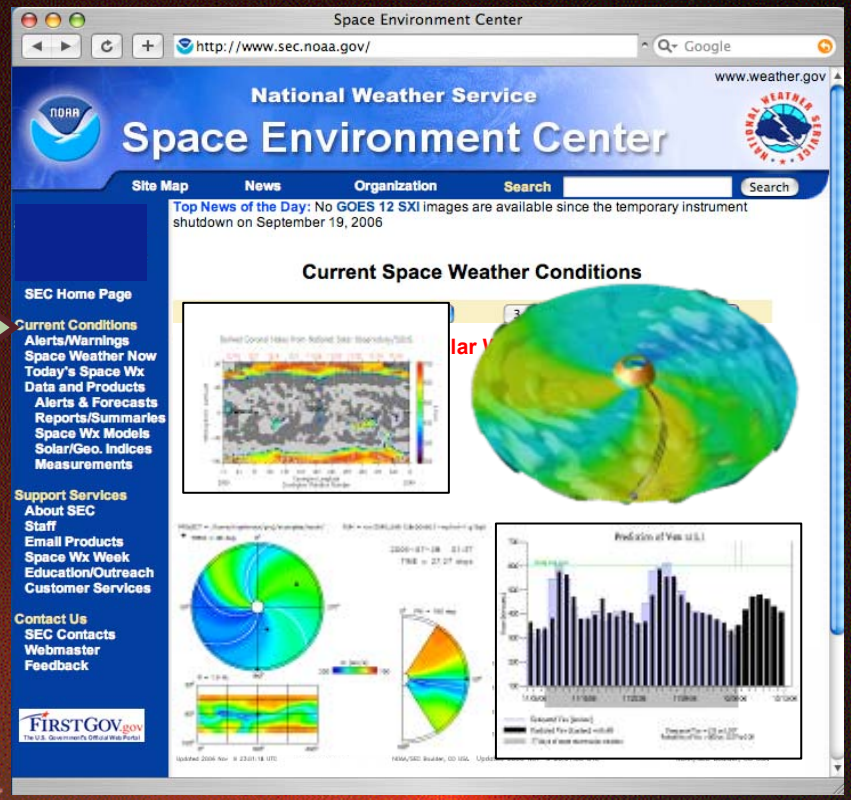
- Simple upward extension of GSI: assess operational potential of WAM (extended GFS)
- Finish development and validation of the coupled model

## ~ 5 – 10 yrs

- Incorporate IDEA into an advanced data assimilation scheme, including assimilation of ionospheric measurements
- Transition of the coupled model to operations?

# WSA/ENLIL Solar Wind Forecast Model



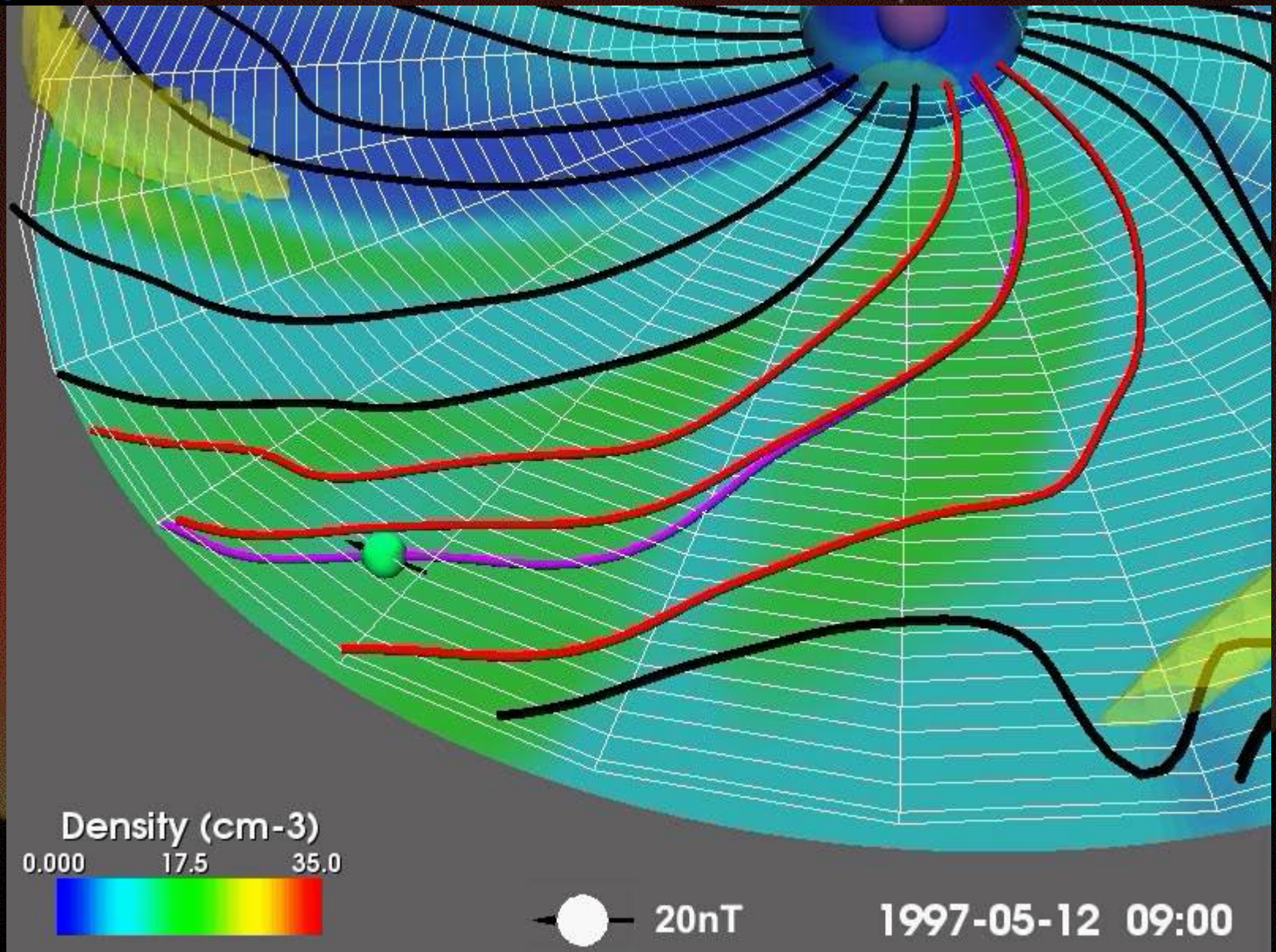

Currently being ported to NOAA Forecast Systems Lab JET supercomputer

FY10 start at EMC

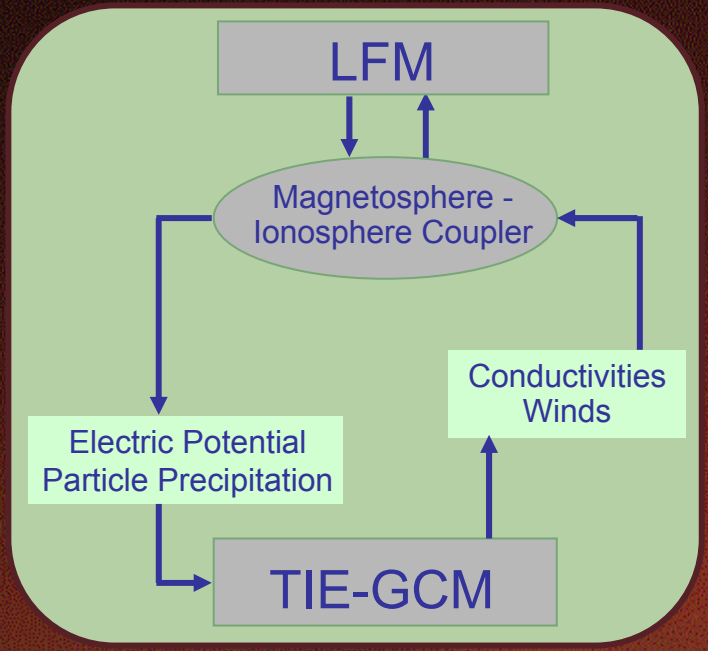
CPU: 32 (continuous operations)

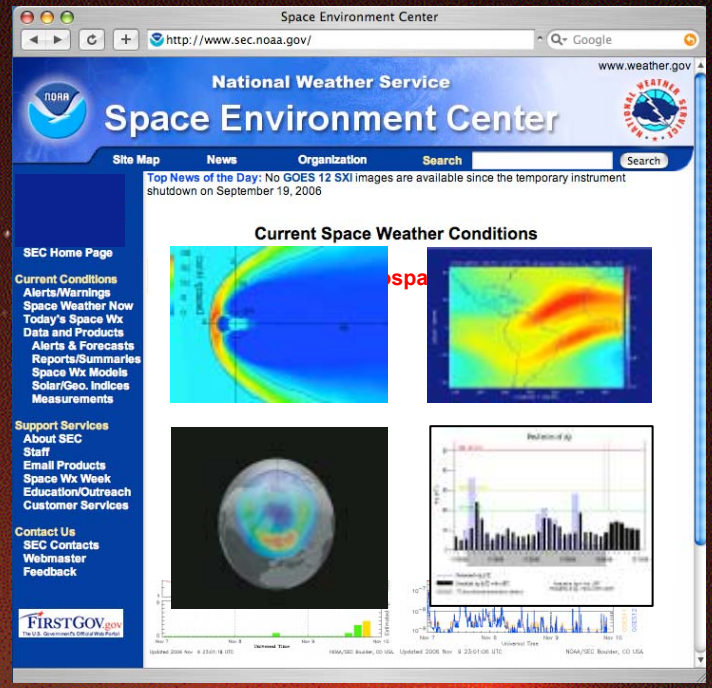
Data output: 200 GB/day

# WSA/ENLIL



# CMIT
# Geospace Forecast Model



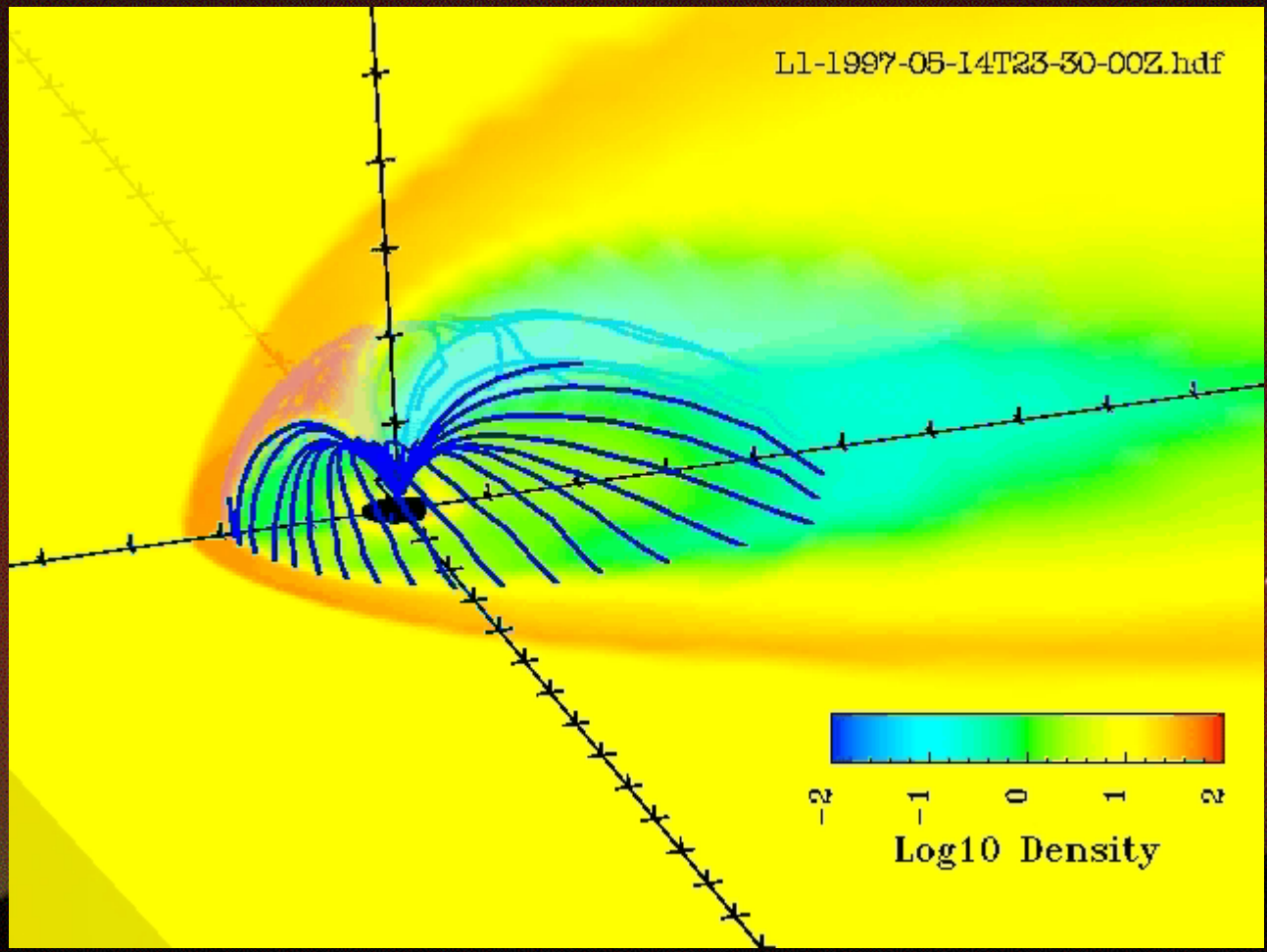




FY12 start at EMC

CPU: 64 (continuous operations)

Data output: 100 GB/day

# CMIT



# Expected SWPC Computing Costs

| | FY10 | FY12 | FY14 | FY17 |
|---|---|---|---|---|
| # CPUs (continous operation) | 32→ 128 | 160 → 256 | 256 → 512 | 512 → 1024 |
| Data output GB/day | 200 +IDEA | 300 +IDEA | 600 +IDEA | |
| Budget request through EMP POP | $2.95M | $4.58M | $4.58M | |

Includes margin to account for computing needs and runs per day