COE CST Sixth Annual Technical Meeting:

Task 186: Mitigating threats through space environment modeling/prediction

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Center of Excellence for Commercial Space Transportation

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Task Description

Goal:

1. Knowledge of the environmental conditions and their impact on flight conditions from the ground to 600 km, including forecast of:

2. Neutral density, variability, and structure, for spacecraft drag for orbit prediction and collision avoidance, and forecast of near-surface and space weather conditions (winds, wind shear, temperature, variability and turbulence, storms, lightning, etc.),

3. Plasma density, D-region absorption, total electron content, ionospheric structure and irregularities, for communications and navigation

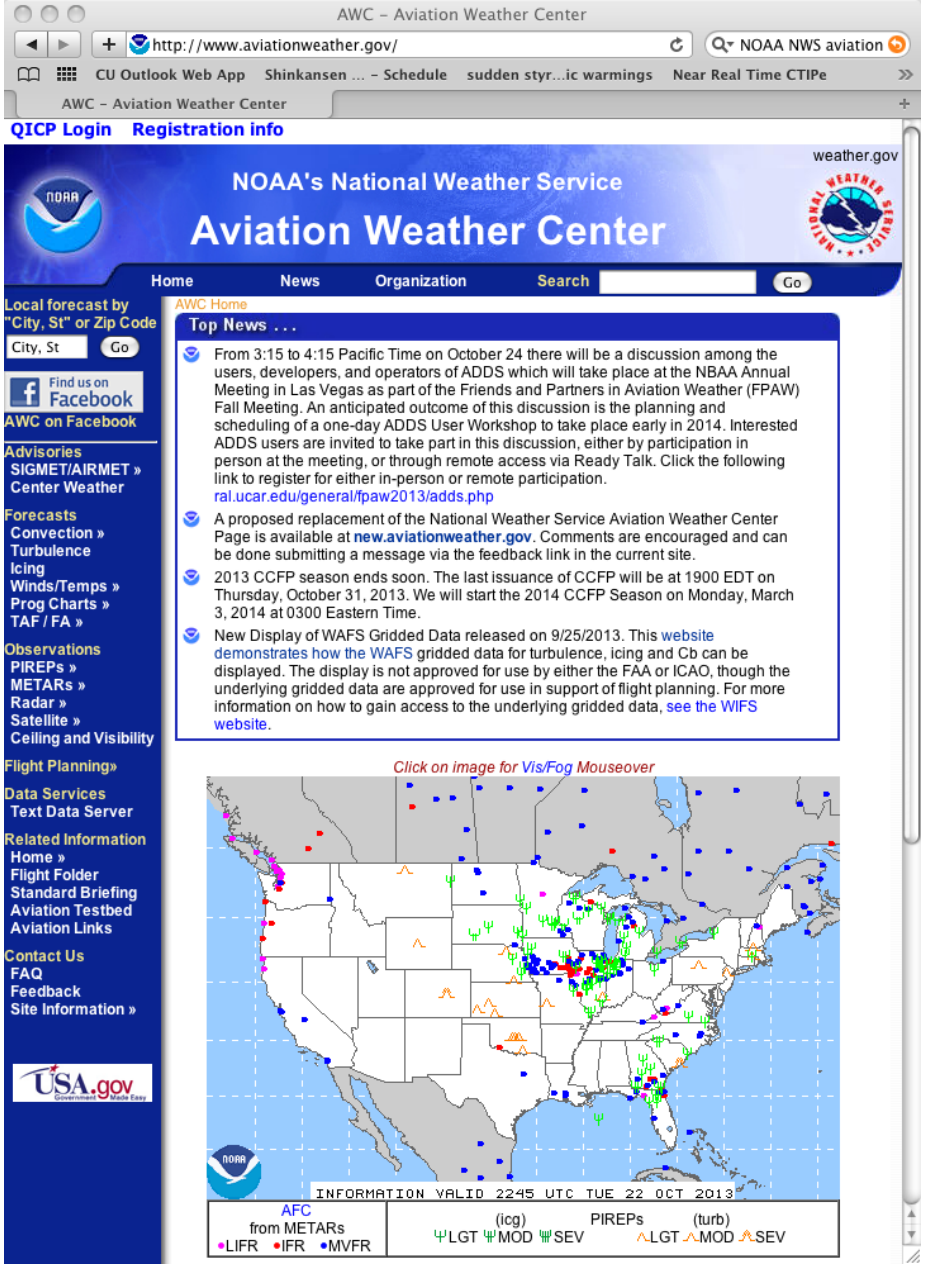
Objectives: *Fill the gap between terrestrial and space weather forecasts and develop a "weather" prediction model extending from Earth's surface to the top of the atmosphere*

Outcome: *Predict the environmental conditions needed for safe orbital, sub-orbital, re-entry, descent, and landing*

Current:
Aviation Weather Support

: conditions below 50 km from National Weather Service Global Forecast System (GFS) model and Gridpoint Statistical Interpolation (GSI) data assimilation system

- Winds and temperature
- Turbulence
- Icing
- Analysis and Forecasts



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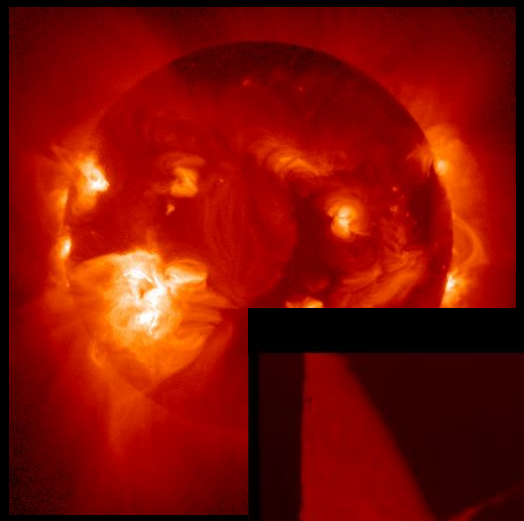
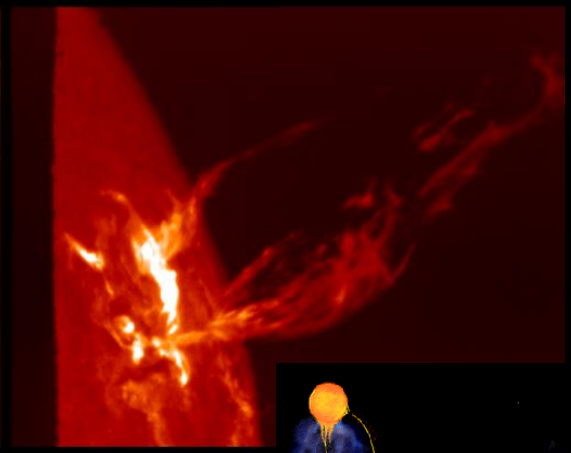
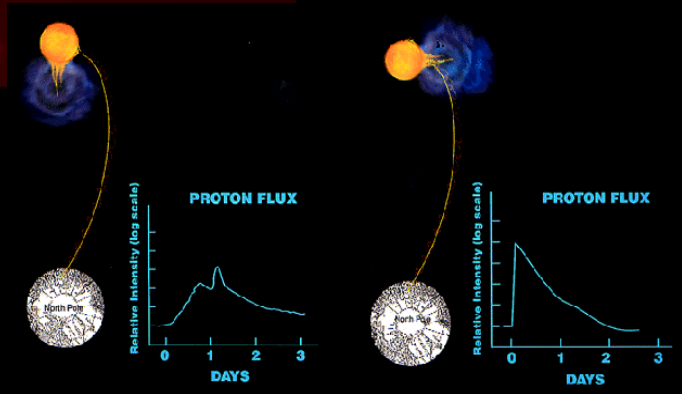
So what is Space Weather?



Solar Flares (increased X-ray flux)
Arrives: 8 mins; Duration: 1-2 hrs
Impacts: D-region ionization, High Frequency (HF) radio absorption, geolocation, low-frequency navigation, GPS navigation



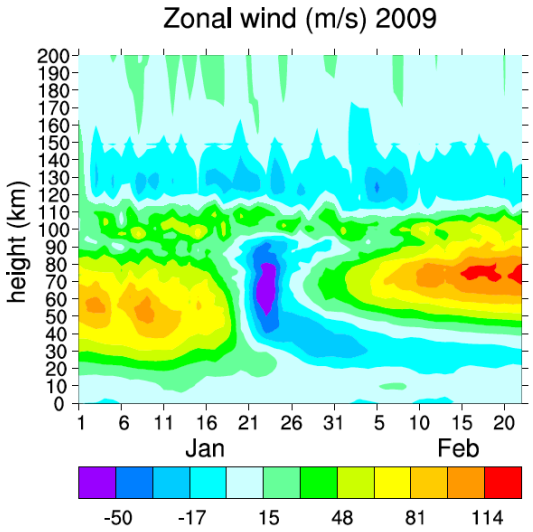
Coronal Mass Ejections (plasma)
Arrives: 1-3 days; Duration: 1-2 days
Impacts: Drives a geomagnetic storm, satellite charging, drag, communication, navigation (e.g., GPS), HF communication, ground induced currents (power outages)

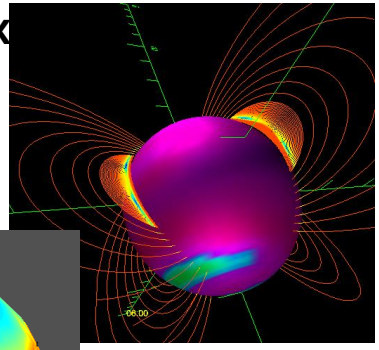


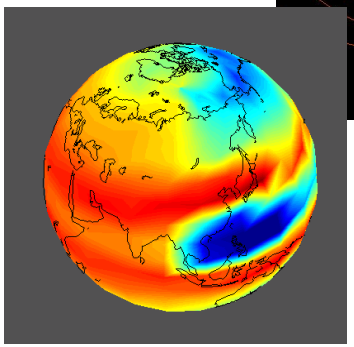
Solar Proton Events (energetic particles)
Arrives: 15 mins to a few hours; Duration: days
Impacts: Polar HF absorption, satellite anomalies, radiation hazard

Filling the Gap – weather and space weather

- We have developed a global seamless neutral whole atmosphere model (WAM) 0-600 km, 0.25 scale height, 2° x 2° lat/long, hydrostatic, 10-fold extension of Global Forecasting System (GFS) US weather model.
- O_3 chemistry and transport
- Radiative heating and cooling
- Cloud physics and hydrology
- Sea surface temperature field and surface ex processes
- Orographic gravity wave parameterization
- Eddy mixing and convection
- Diffusive separation of species
- Composition dependent C_p
- Height dependent g(z)
- EUV, UV, and non-LTE IR
- Ion drag and Joule heating

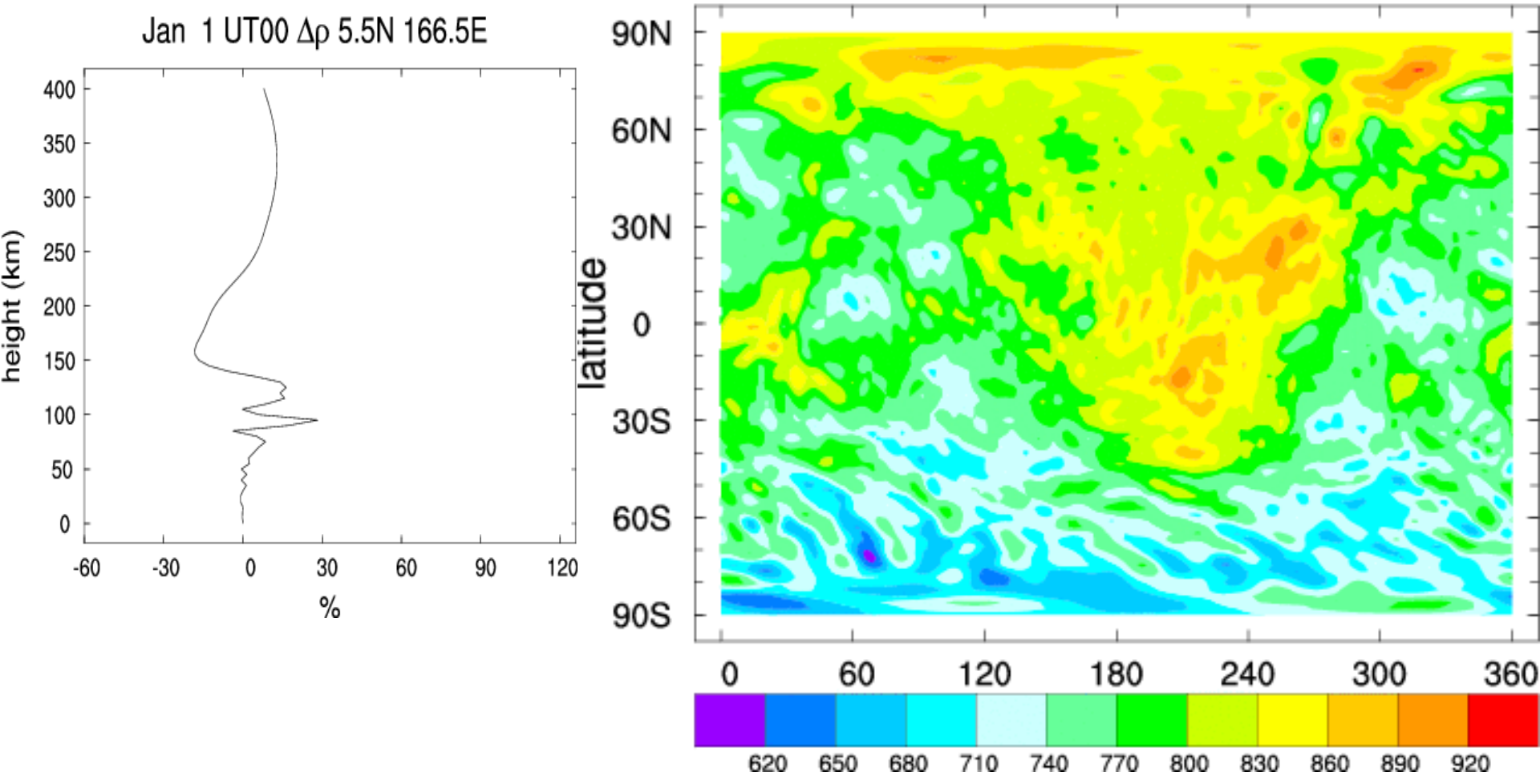




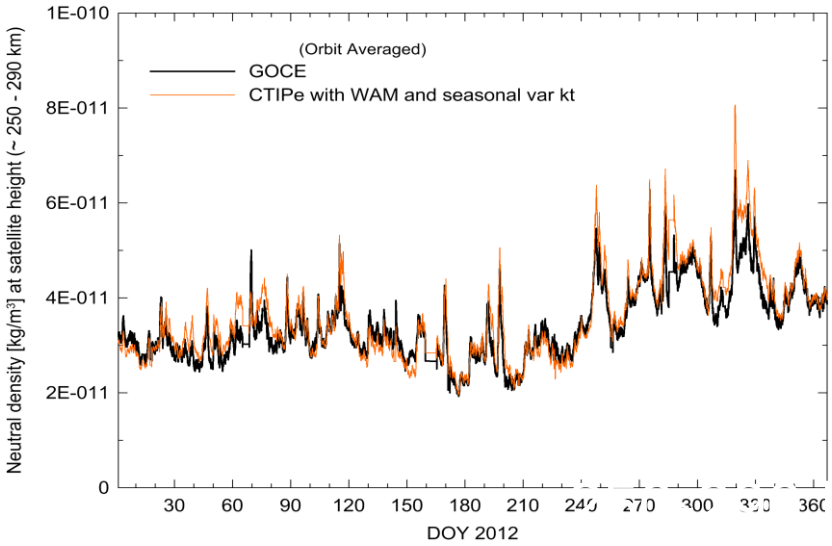


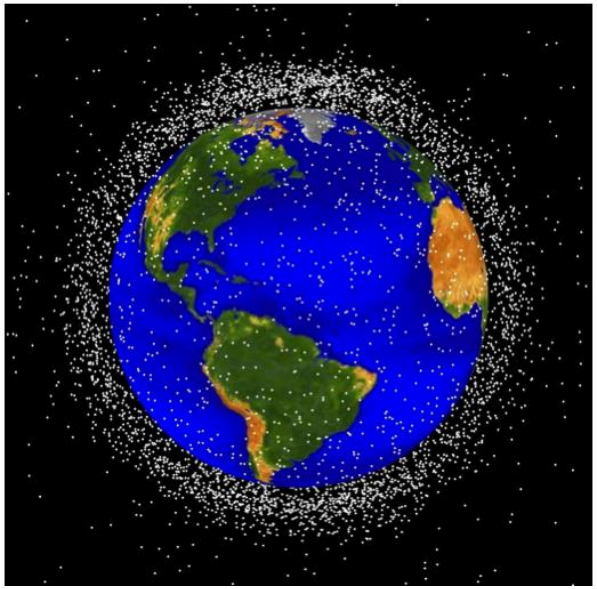
Coupled to a global ionosphere, plasmasphere, electrodynamics module (IPE) for plasma parameters

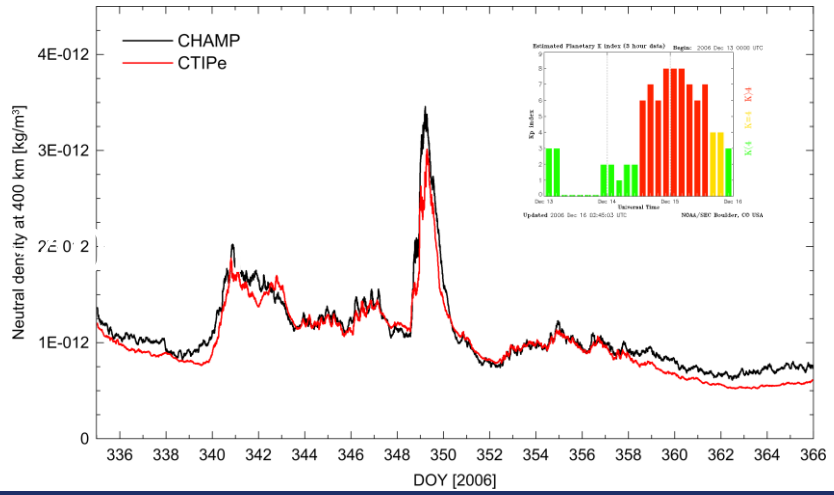
Temperature 200 km altitude

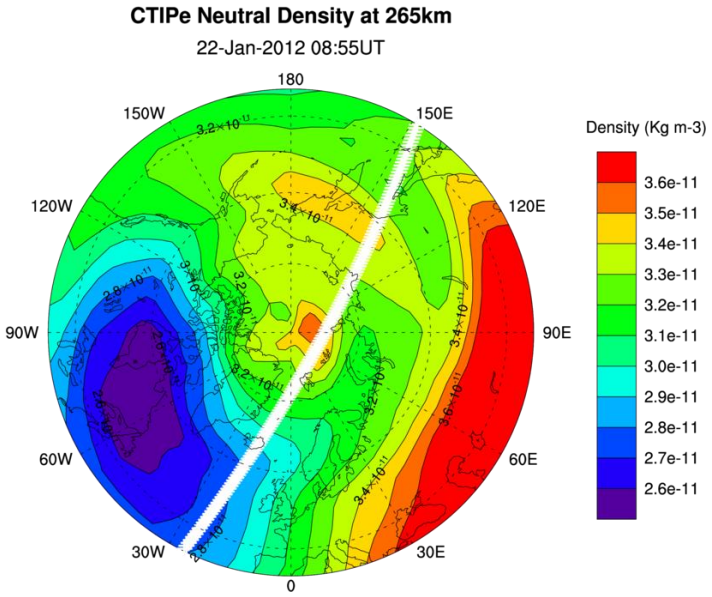


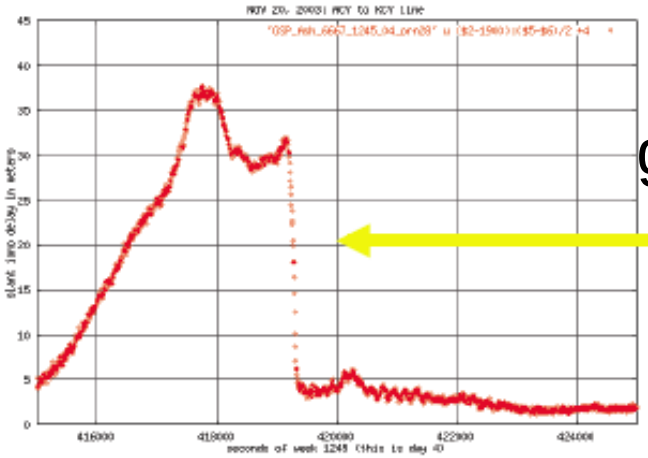
Neutral density
CTIPe vs GOCE and CHAMP



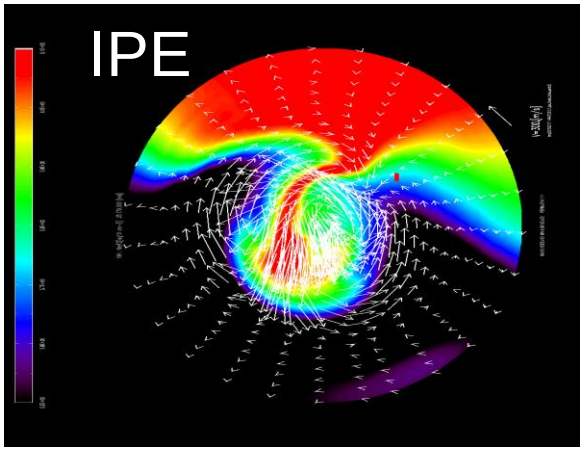




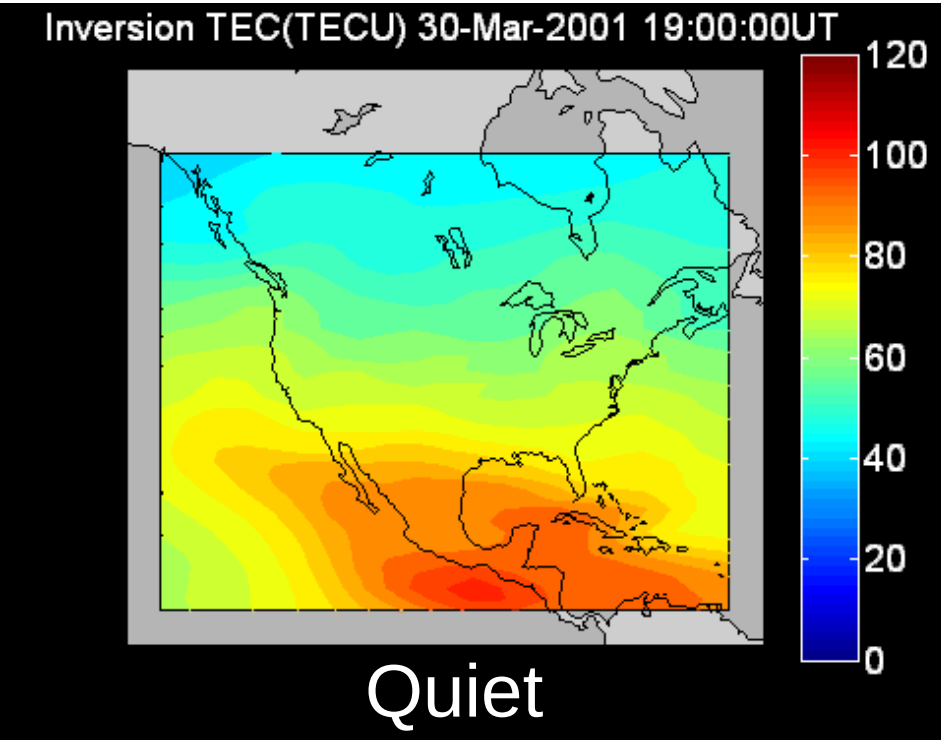




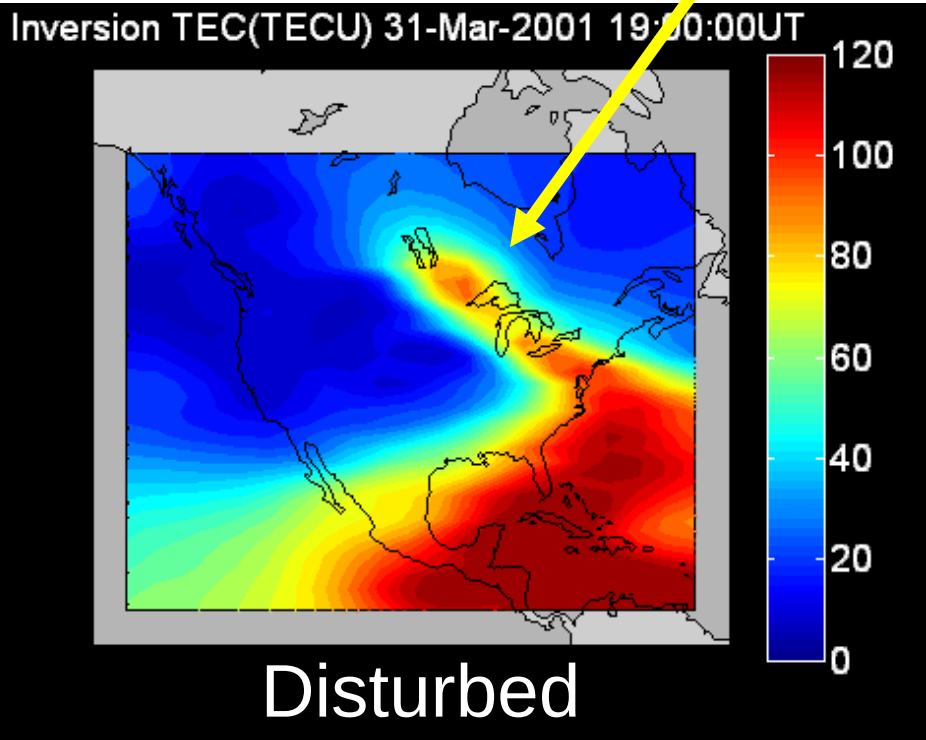
Steep gradients of TEC disrupt GNSS



SED
Storm enhanced density



Quiet



Disturbed

Summary

- Goal is to define the weather and space weather conditions for orbital and suborbital flights for commercial space transportation
- Integrate the terrestrial and space weather conditions (from one coordinated source)
- Are developing a seamless model from the ground to 600 km altitude coupled to the plasma to fill gap between conventional weather and space weather
- Provide neutral atmosphere weather forecast for winds, temperature, density, turbulence, wind shears, deviations from average, and vehicle drag
- Ionospheric space weather forecast for plasma density, ionospheric structure, and irregularity conditions for communications and navigation
- Radiation hazard (e.g., NAIRAS potential new start)