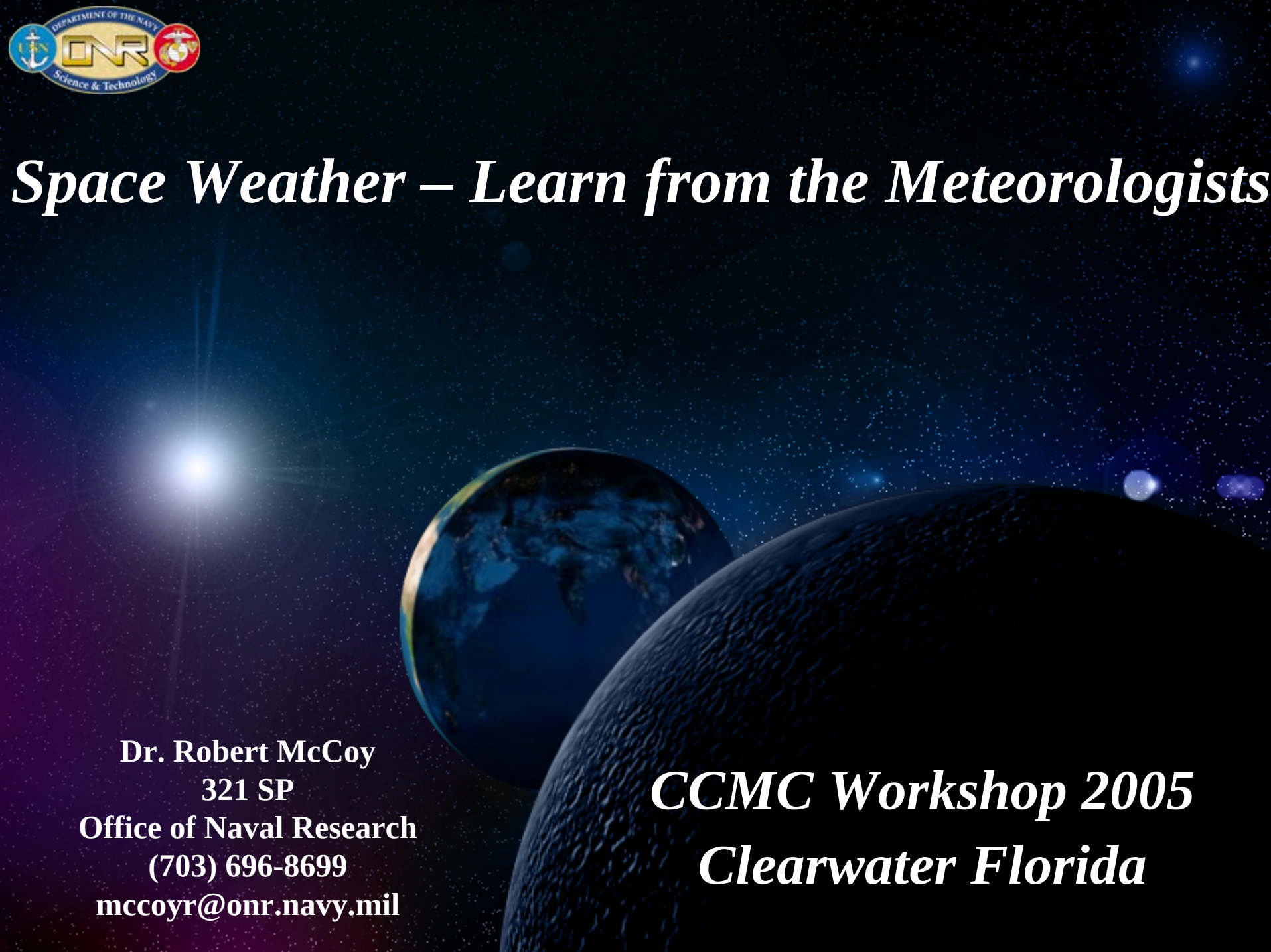


Space Weather – Learn from the Meteorologists

Dr. Robert McCoy
321 SP
Office of Naval Research
(703) 696-8699
mccoyr@onr.navy.mil

CCMC Workshop 2005
Clearwater Florida

Naval Needs In Space:

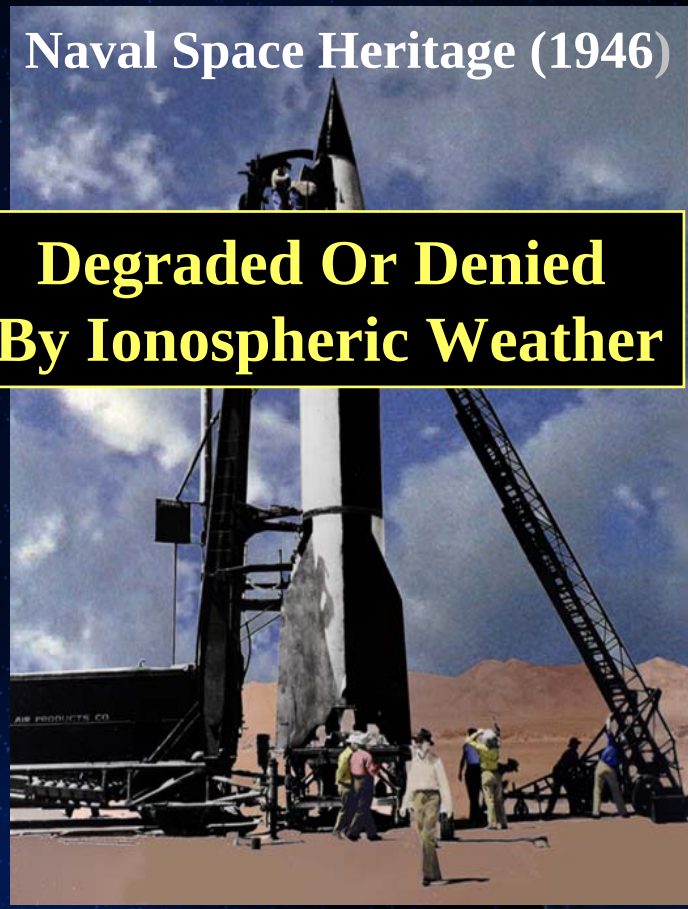
Navy Is Permanently Forward Deployed and *Critically Dependent* on Space for:

- **Communication - (ELF - HF - UHF)**
- **Navigation - (GPS & Autonomous Celestial)**
- **Surveillance, Precision Geolocation, Space Rad**
- **Space Tracking, National Missile Defense**
- **Satellite Meteorology & Oceanography**
- **Satellite Ocean Altimetry**

Degraded Or Denied By Ionospheric Weather

Strategy: Leadership in Targeted Basic Research

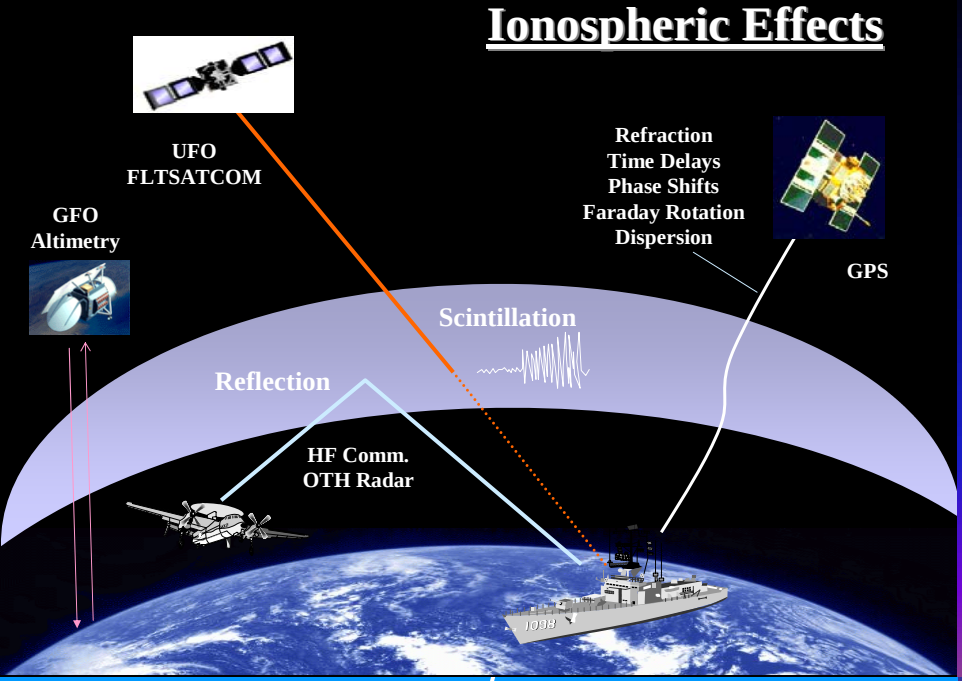
- **Influence Space Acquisition/Operations**
- **Transitions (Often 6.1) To AFWA Or NOAA SEC**



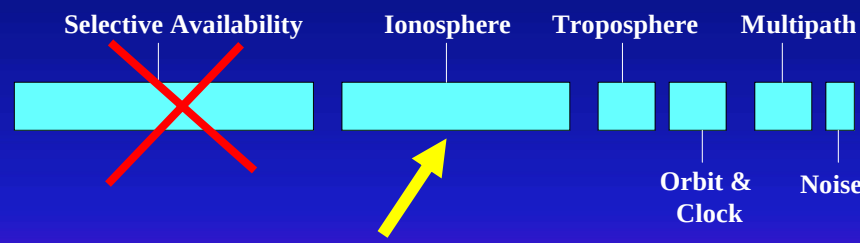
Outline

- Motivation for Improved Ionospheric Specification & Forecast
- Ultraviolet Remote Sensing of the Thermosphere & Ionosphere
  - RAIDS, HIRAAS, GIMI, SSULI Operational Sensors on DMSP
  - RF Satellite Instruments (GPS Occultation, CIT)
- Global Assimilation of Ionospheric Measurements (GAIM)
- Ionospheric Scintillation & Imaging from Geosynchronous Orbit (IMAGER)
- Ocean to Space Seamless Models

Ionospheric Effects

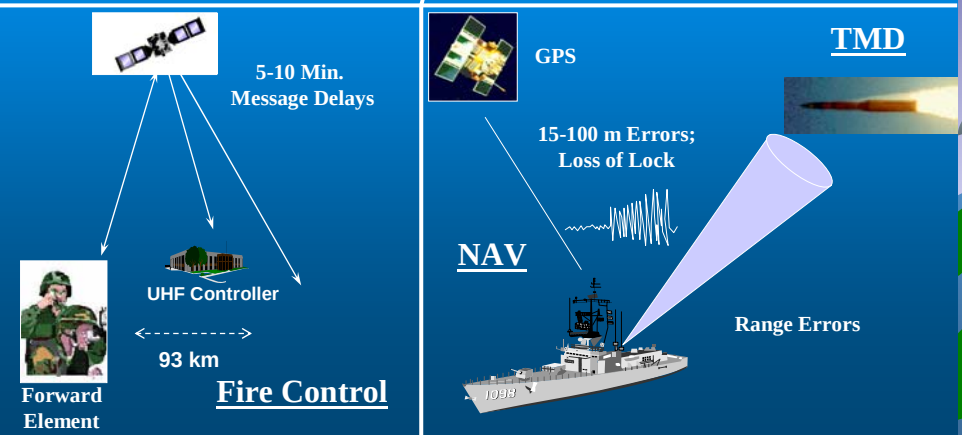


GPS Navigation Error Budget

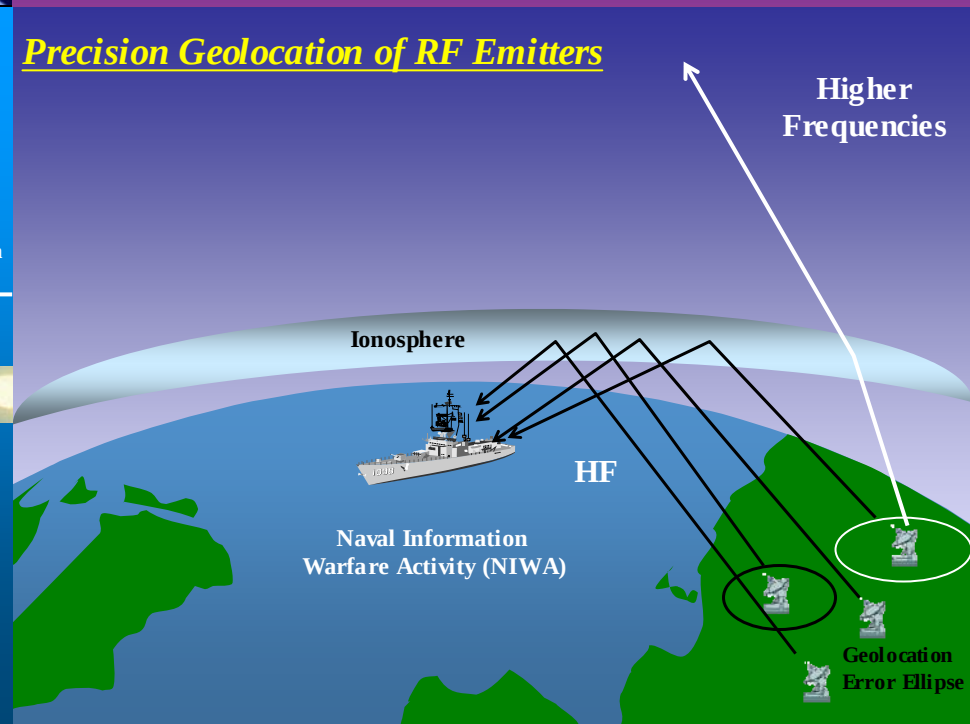


Largest single source of error

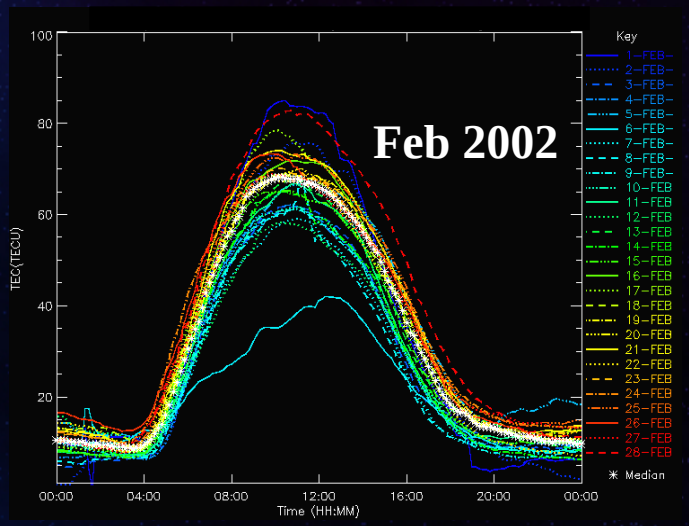
Ionospheric & Scintillation Effects on Naval Systems

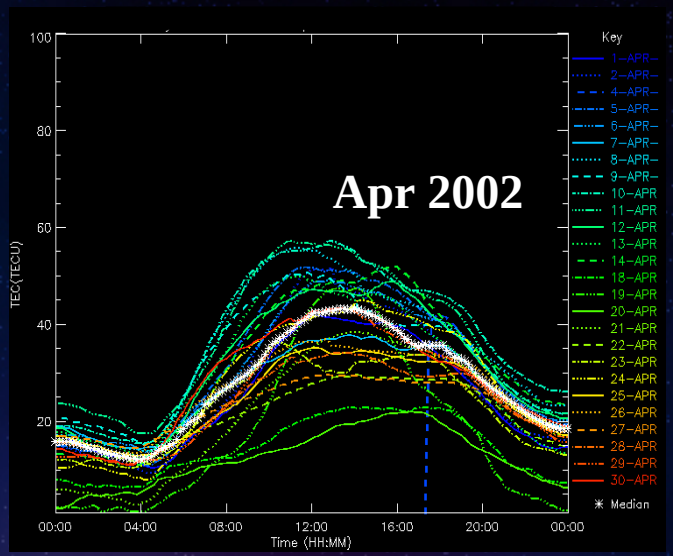


Precision Geolocation of RF Emitters



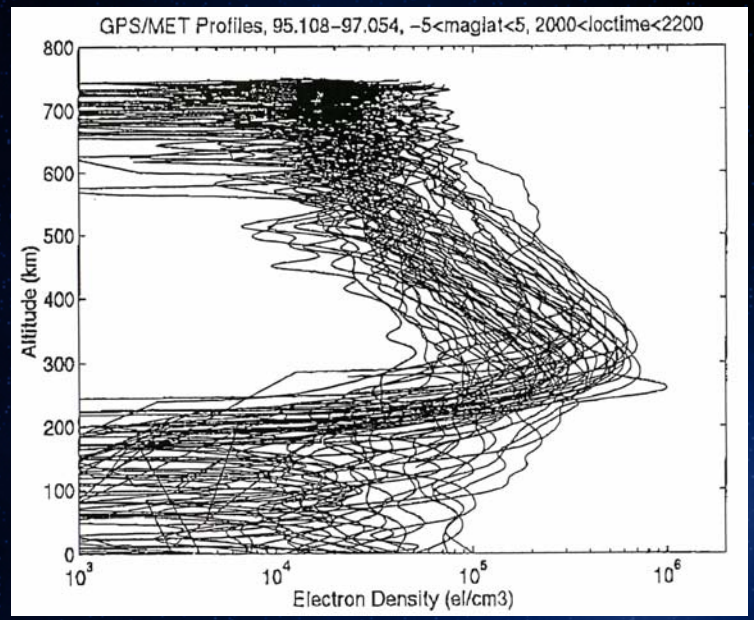
Difficulties for Ionospheric Models





TEC e cm^{-2}

Daily Measured Values



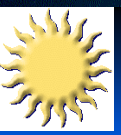
Variability: Daily, Seasonal, Solar Cycle

Forcing:
Solar EUV, X-ray, Solar Wind, Winds, Fields, Tides, Convection, Dynamics

"Weather"

Meteorological Weather Specification & Forecast
Basic Physics Algorithms + Continuous Observations

Naval Operational Global Atmospheric Prediction System (NOGAPS)



>5.5 Million Observations/Day

GOES

DMSP, POES

Rocketsondes

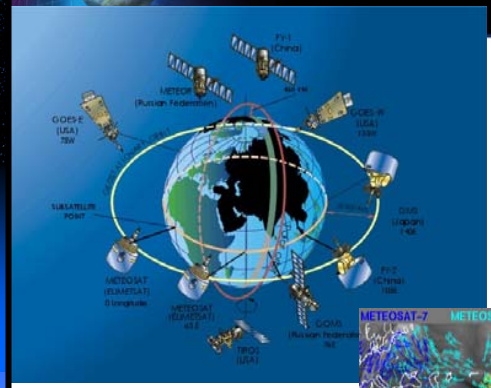
Aircraft

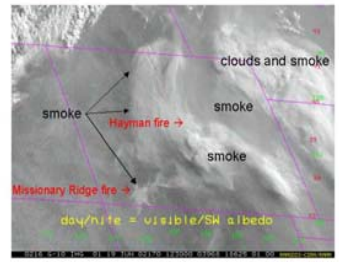
Surface

Buoys

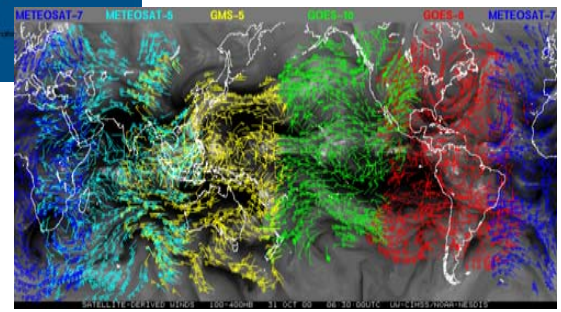
Balloons

Observations: Global Satellite Systems





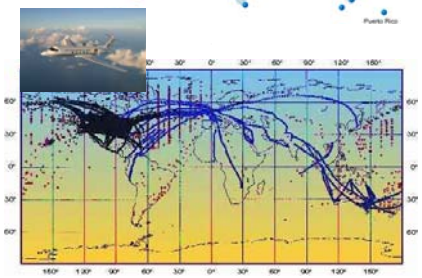
Colorado forest fires – 19 June 2002 1230 UTC (morning)



Winds from five geos are being processed every six hours to produce vectors of comparable accuracy (hi winds compare within 7 m/s of raobs); GOES and Meteosat winds are being produced every three hours on most days

Regional Observations: Atmosphere

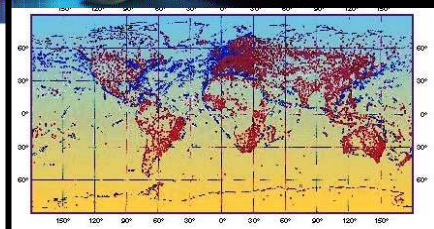
158 Operational sites, providing humidity, reflectivity information, in a 250 mile radius around each site



Over 3000 aircraft provide reports of pressure, winds and temperature during flight.

From a network of roughly 900 upper-air stations, radiosondes, attached to free-rising balloons, make measurements of pressure, wind velocity, temperature and humidity from just above ground to heights of up to 30km

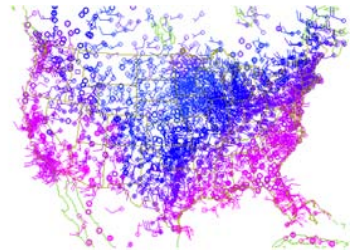
Regional Observations: Surface and Hydrological



The backbone of the surface-based sub-system continues to be about 10,000 stations on land making observations of meteorological parameters such as atmospheric pressure, wind speed and direction, air temperature and relative humidity.

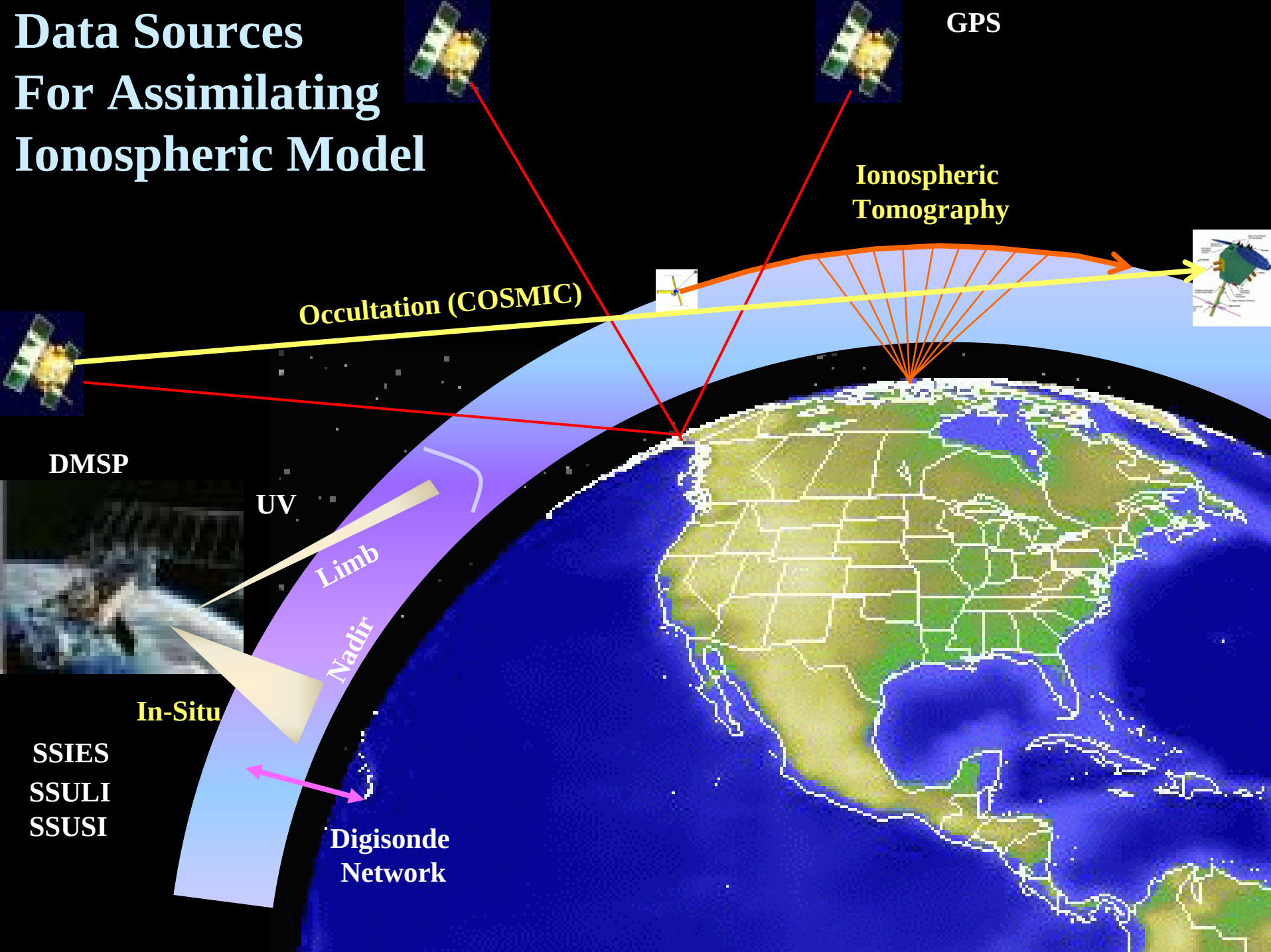
Automated Surface Observing System provides weather observations which include: temperature, dew point, wind, altimeter setting, visibility, sky condition, and precipitation up to approx 10,000 ft. 569 FAA-sponsored and 313 NWS-sponsored ASOSs are installed at airports throughout the country

Cooperative Observer Network: 11,400 volunteer observers provide 24 hr max/min weather observations which include: temperature, precip, snow, and hydrology at non-airport locations



Courtesy Marie Colton

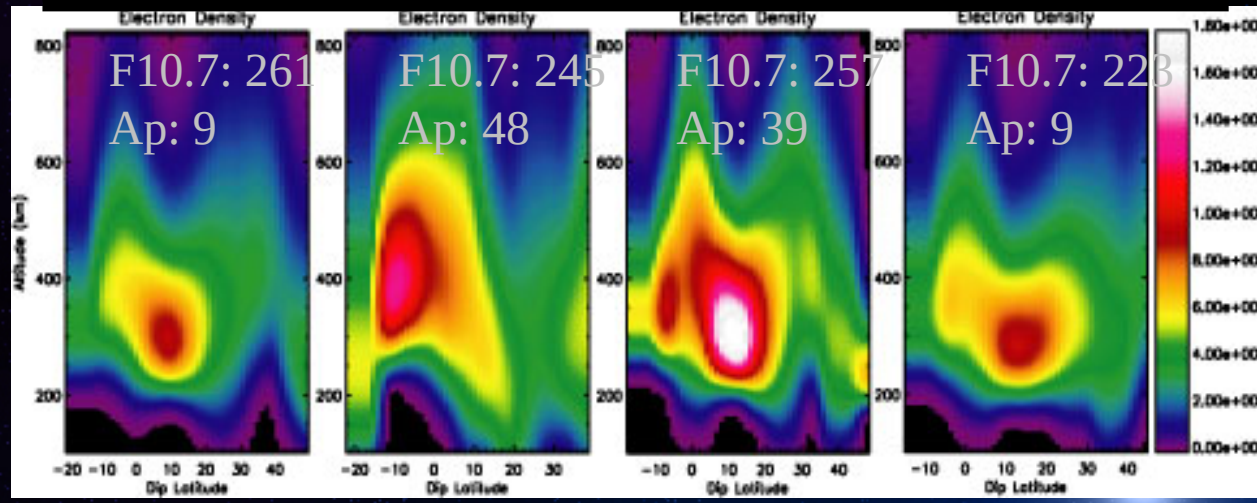
Data Sources For Assimilating Ionospheric Model



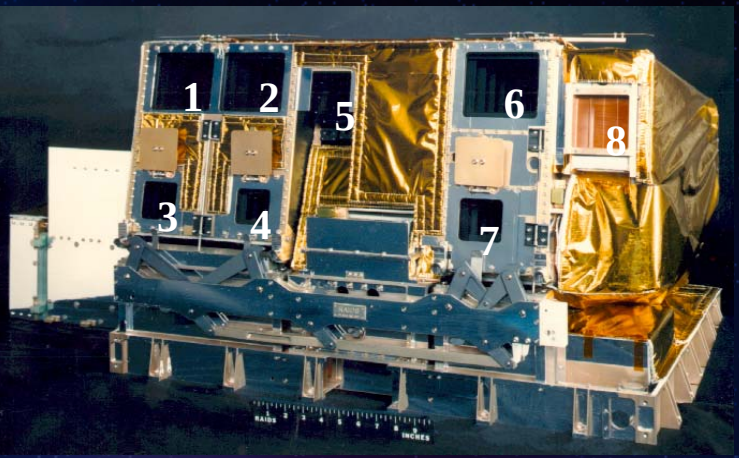
New Optical Data Sources

ARGOS
23 Feb, 1999

HIRAAS



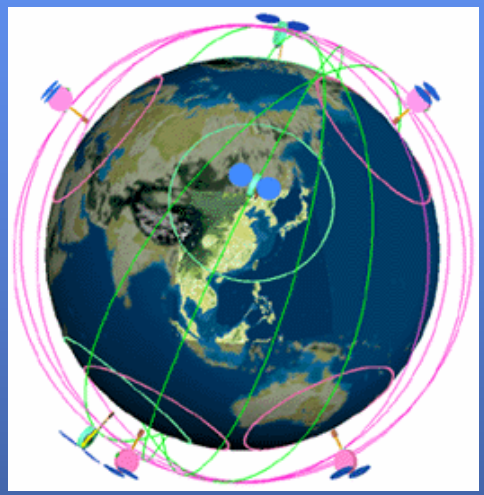
29 Mar 31 Mar 01 Apr 03 Apr

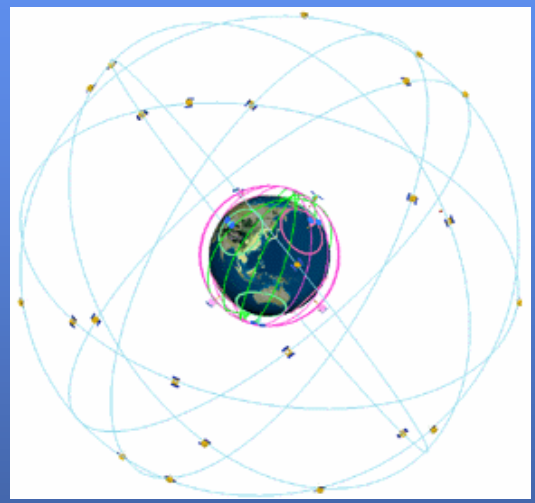


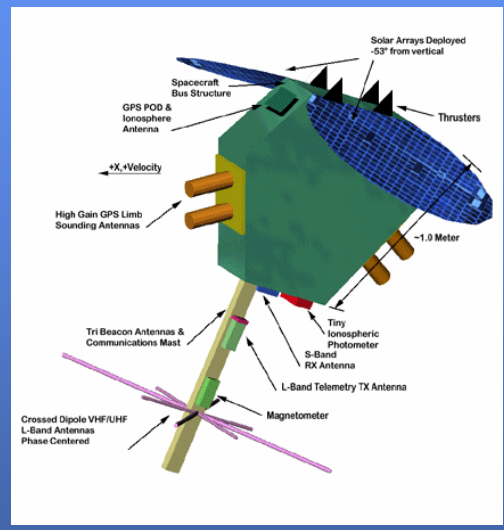
RAIDS

Constellation Observing System for Meteorology, Ionosphere & Climate (COSMIC) (UCAR) 1

Profiles of Ionospheric Electron Density
Lower Atmospheric Refractivity (Temp, Pressure & Water Vapor)







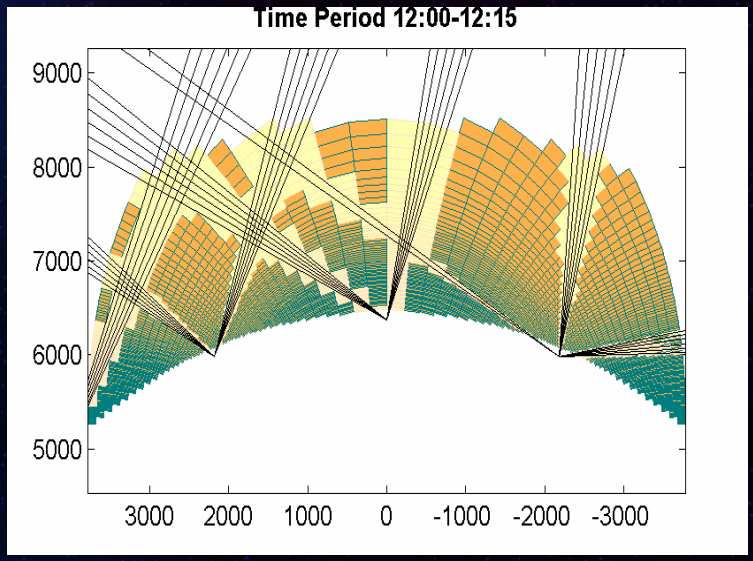
6 Satellites In 3 Orbital Planes; 700 km;
3000 Occultations/Day

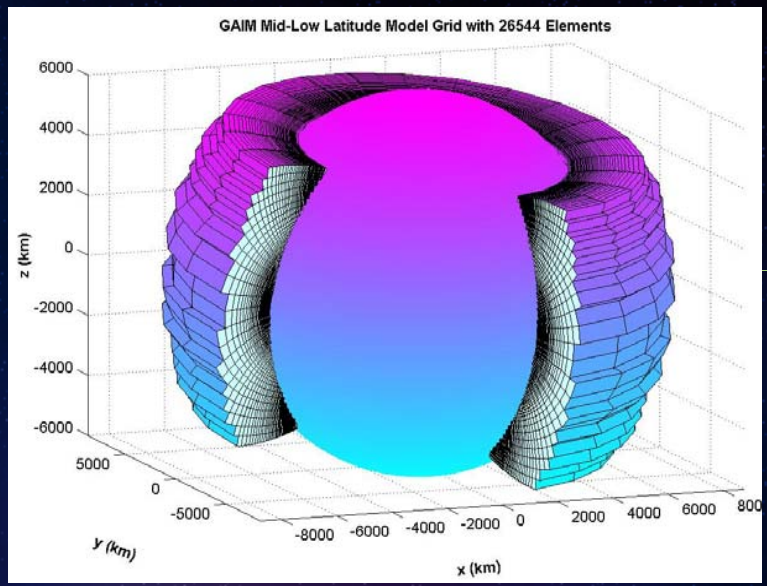
GPS Occultation Receiver
Nadir UV Photometer
3-Frequency Beacon (TRANSIT)

Sponsors:

Taiwan NSPO ($80M) + U.S. Consortium($16M): NSF, NOAA, NASA, STP, USAF, ONR

Assimilating Ionospheric Model

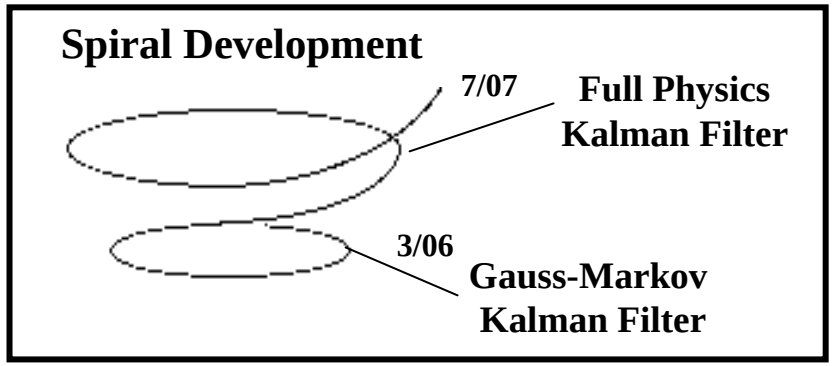




- First Principles Physics
- Multiple Data Sources
  - GPS, UV, In-situ, Digisondes, CIT, GPS Occultation, C/NOFS
- 3-D Time-Dependent Parameters
  - NO^+, O_2^+, N_2^+, O^+, T_e, T_i
- Adaptive Grid System
  - Global, Regional, Localized, 90-1600 km
- Plasmasphere Model
  - H^+: 1,600 - 30,000 km
- 1999 Multidisciplinary University Research Initiative: USU, USC, UC, UTD, UW/APL
- 2004 Spiral 1: Global Assimilating Ionospheric Model (GAIM) Transition to AFWA

GAIM Transition

Global Assimilation of Ionospheric Measurements



CCMC

V&V

Customer

Utah State

NRL

NOAA SEC

Customer

NG

AFWA

V&V

AFRL

NSF

NASA

MDA

SPAWAR

DTRA

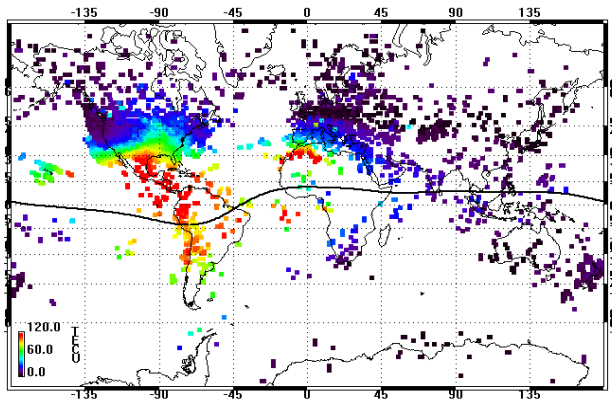
Sponsors

Transition Path

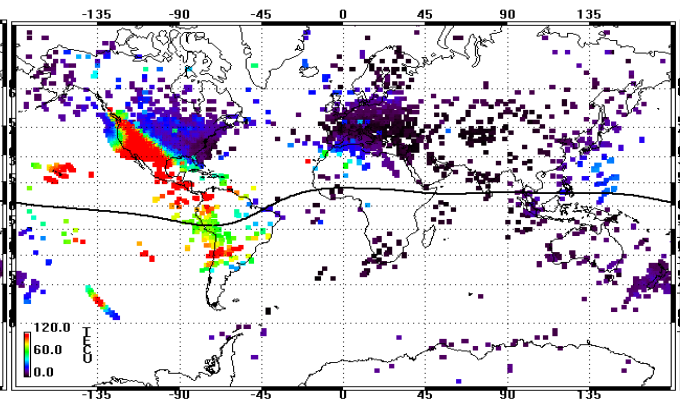
CCMC: Community Coordinated Modeling Center
SMC: Space & Missile System Center
NG: Northrop Grumman
AFWA: Air Force Weather Agency
SEC: Space Environment Center

Halloween Storm Oct 2003

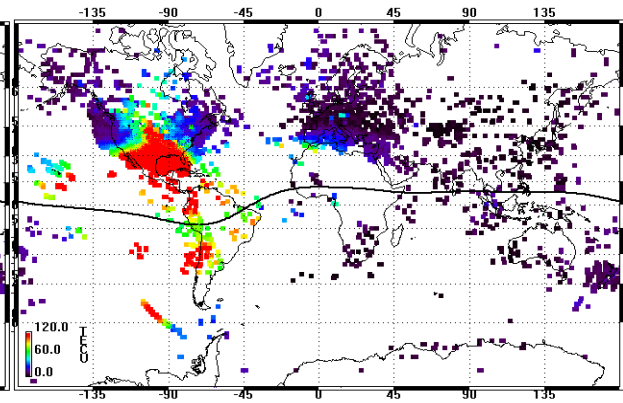
1915 UT



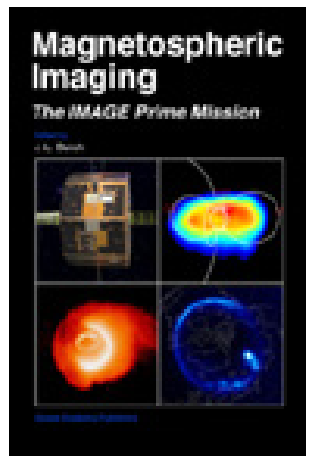
2025 UT



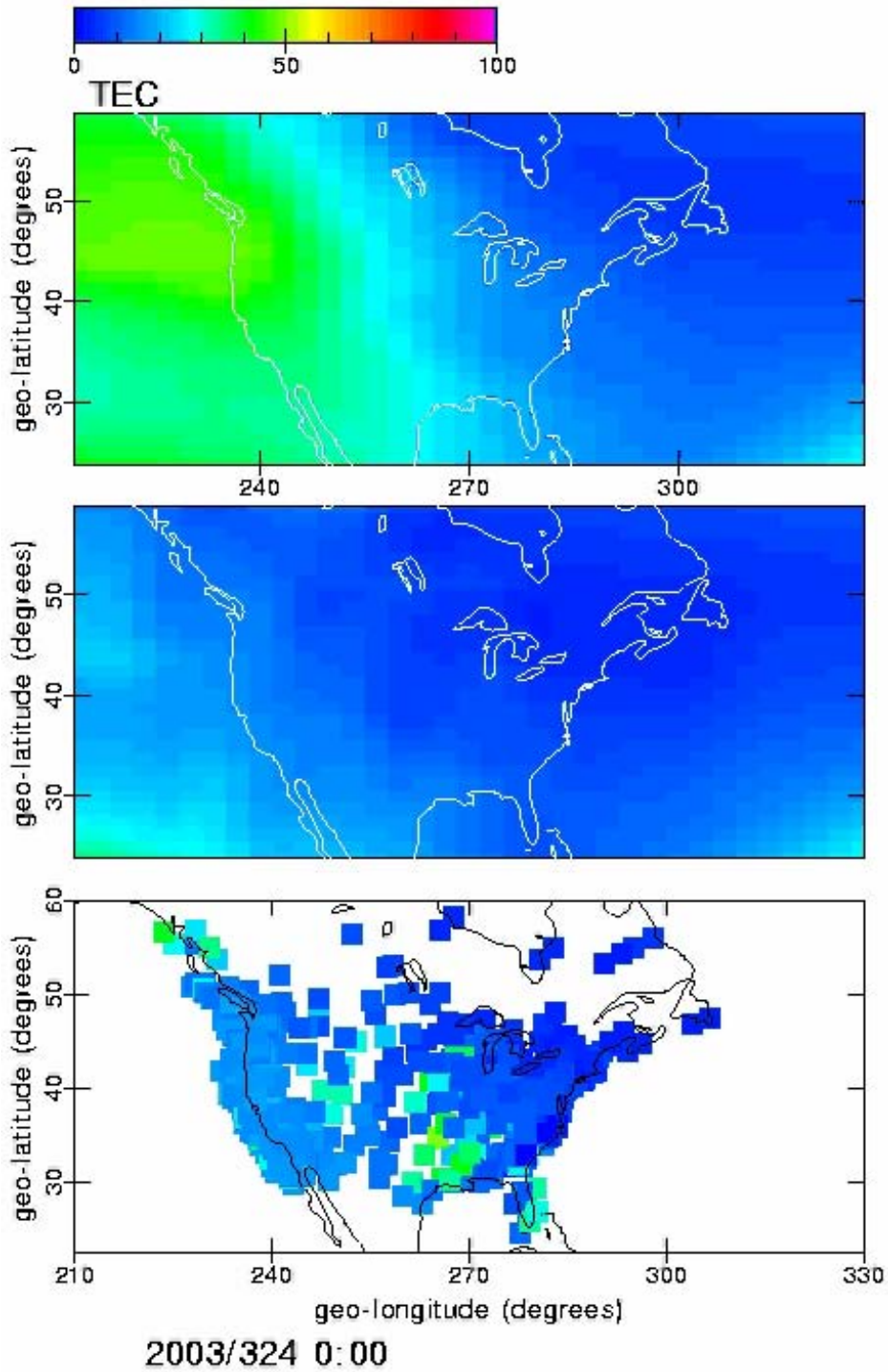
2215 UT



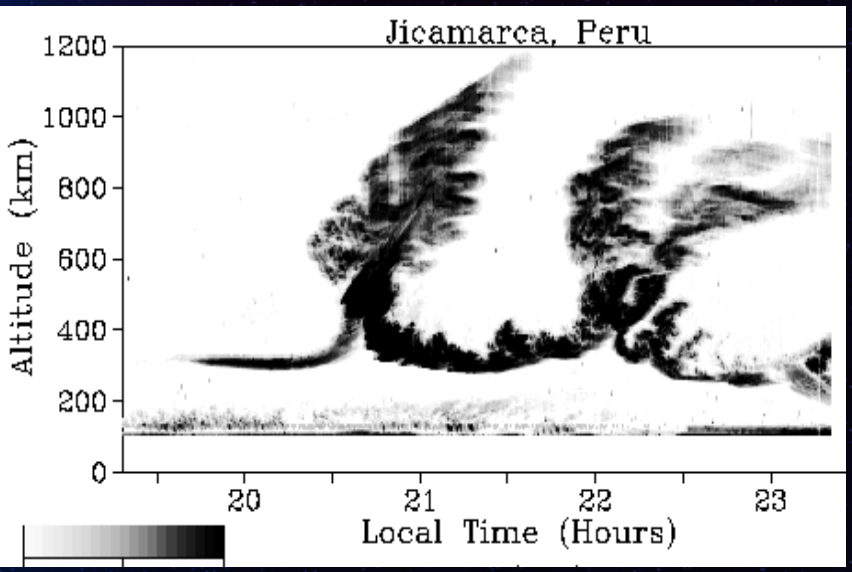
- **Storm Enhanced Density (SED) Plumes**
  - **– Illustrated by Total Electron Content (TEC) from 900+ GPS Receivers & TOPEX (Southern Hemisphere)**
  - **– Penetration of Magnetospheric Electric Fields into Midlatitude Ionosphere**
  - **– Shut Down $4.5B FAA WAAS System for 30+ hours**

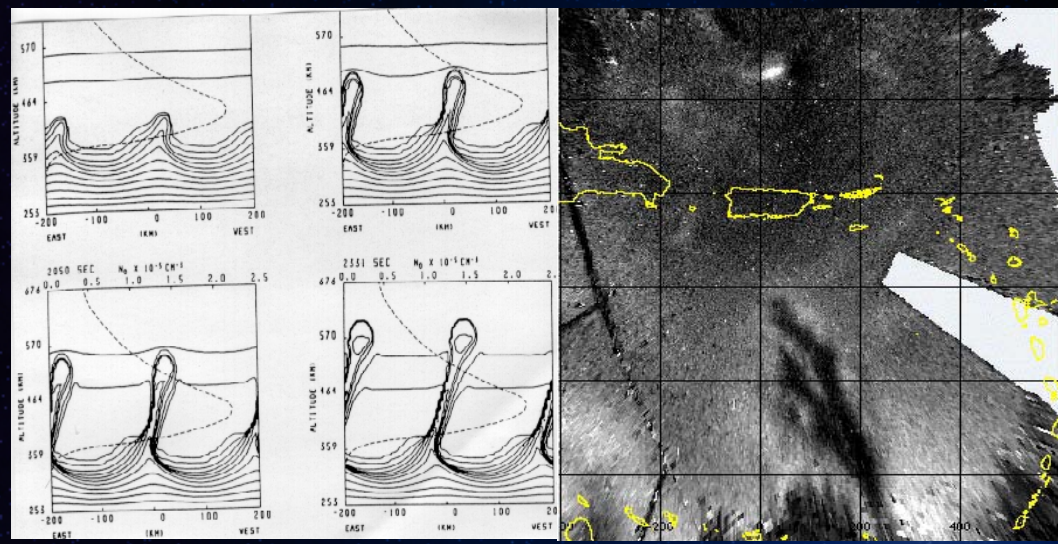


Basu - B. U.

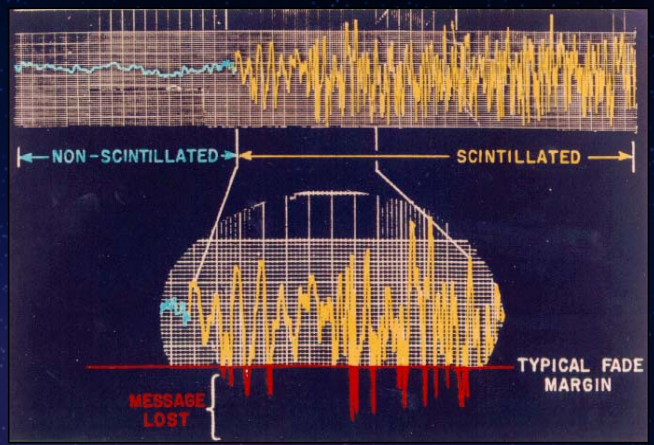

0
50
100
TEC
geo-latitude (degrees)
50
40
30
240
270
300
geo-latitude (degrees)
50
40
30
geo-latitude (degrees)
60
50
40
30
210
240
270
300
330
geo-longitude (degrees)
2003/324 0:00

Ionospheric Bubbles & Scintillation





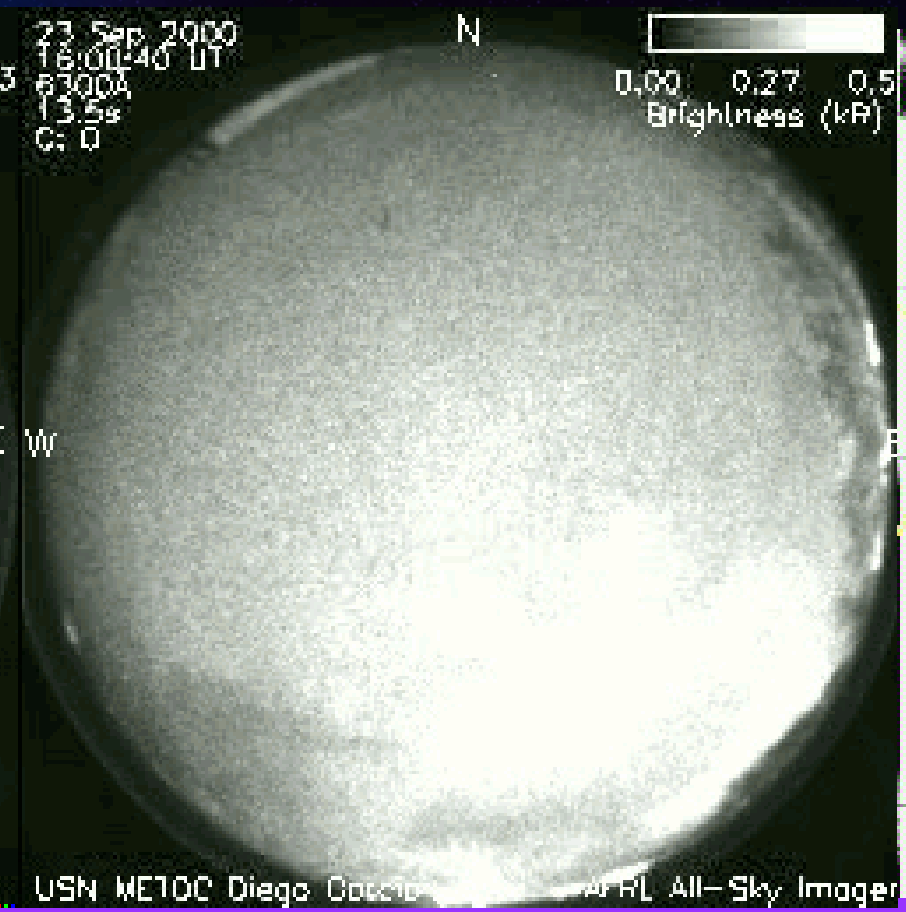
Radar Echoes over Jicamarca Peru

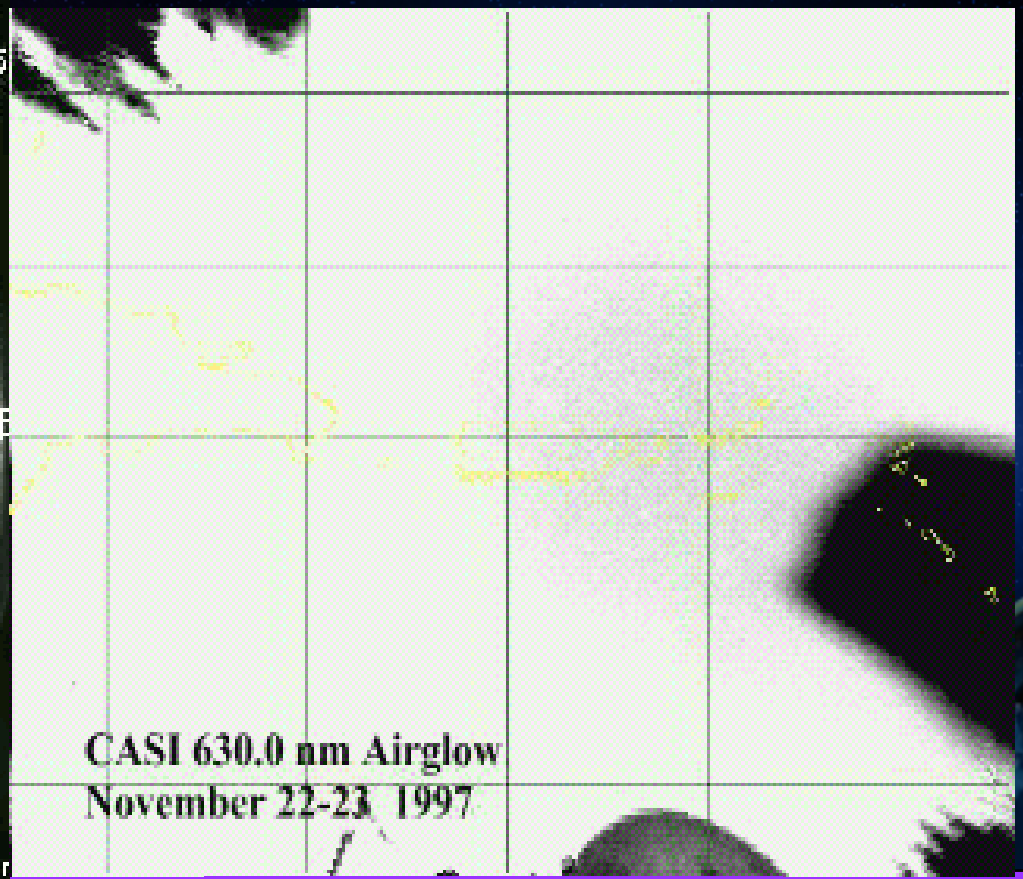


NRL Model Simulation of the Development Of An Ionospheric Bubble Leading to Ionospheric Scintillation

Ionospheric Irregularities & Scintillation

High Space/Time Resolution Ionospheric Imaging

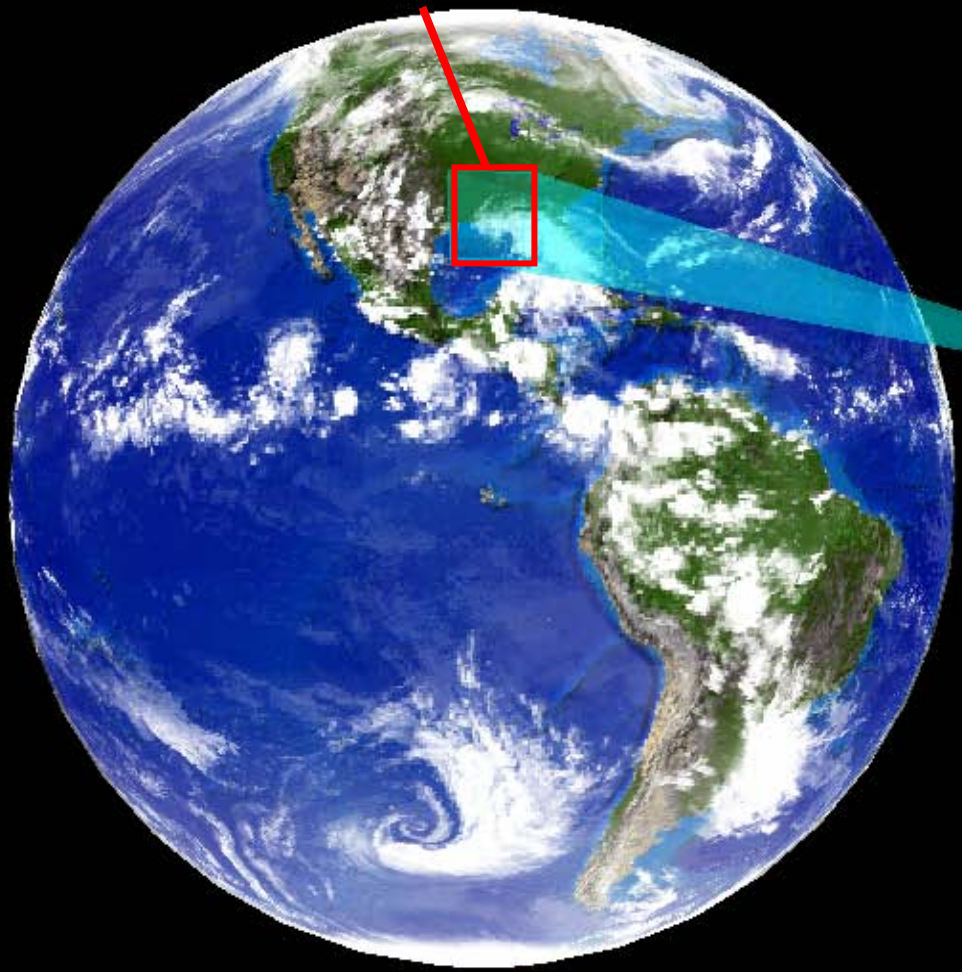


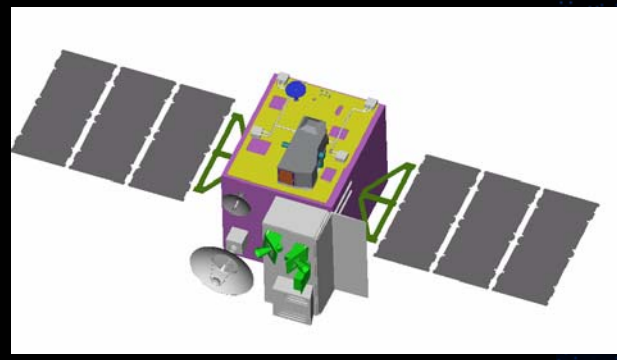


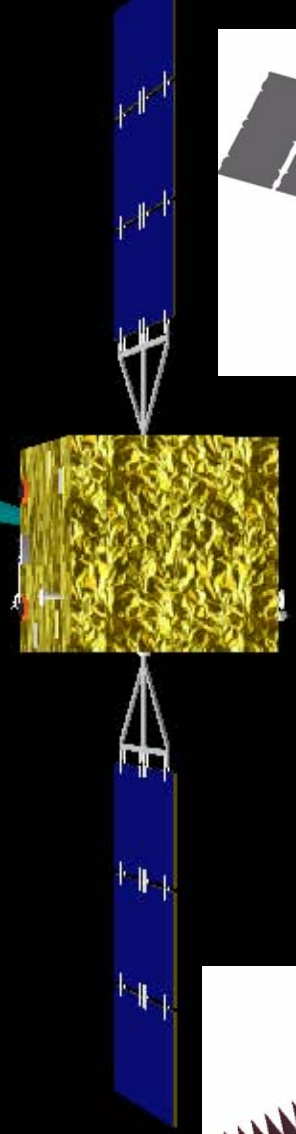
Low Latitudes (Diego Garcia)

Mid Latitudes (Puerto Rico)

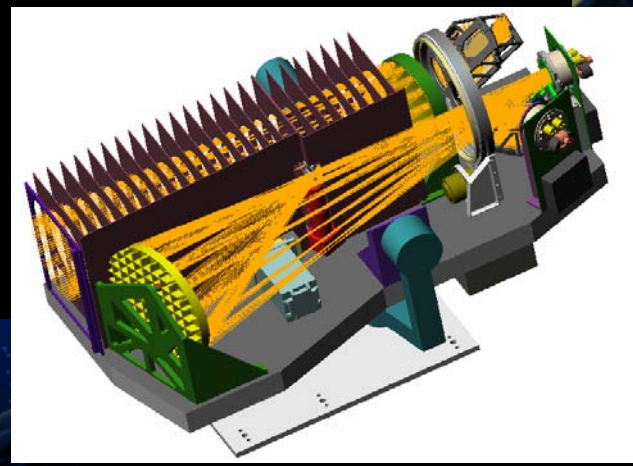
1000 km x 1000 km







Ionospheric Mapping and Geocoronal Experiment (IMAGER)

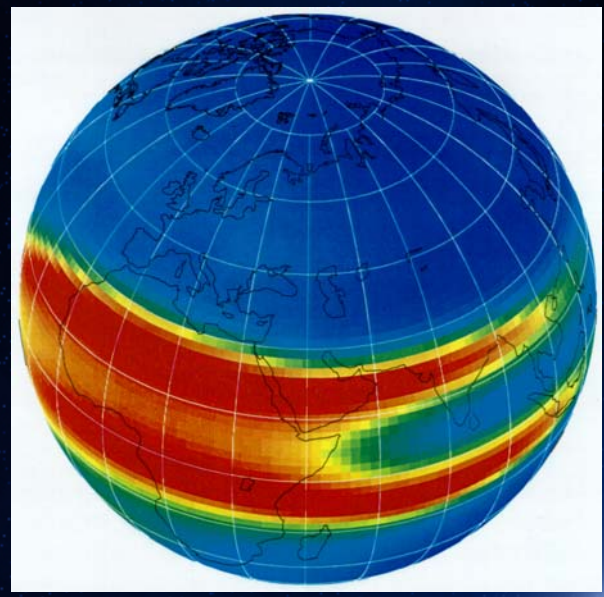


Extreme and Far-Ultraviolet Camera

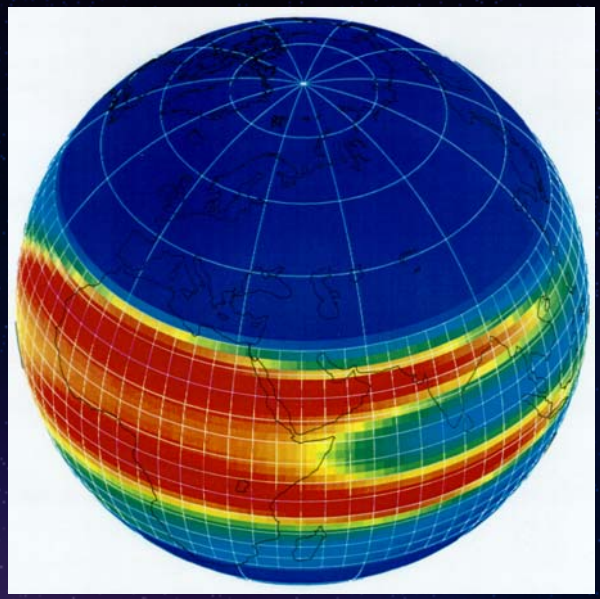
- **1000 km by 1000 km field of view**
- **10 km by 10 km spatial resolution**
- **100 second temporal resolution**

Assimilating Model Grid Sizes

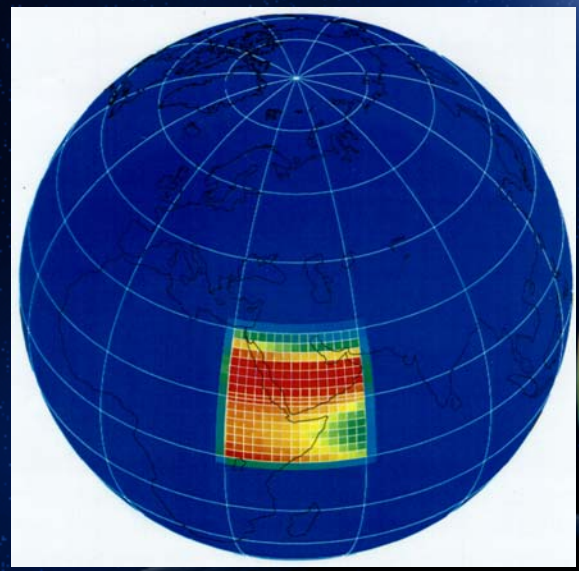
Global Grid



Regional Grid



Synoptic Grid



New Modeling Initiative: Ocean to Space Defense Threat Reduction Agency (DTRA)