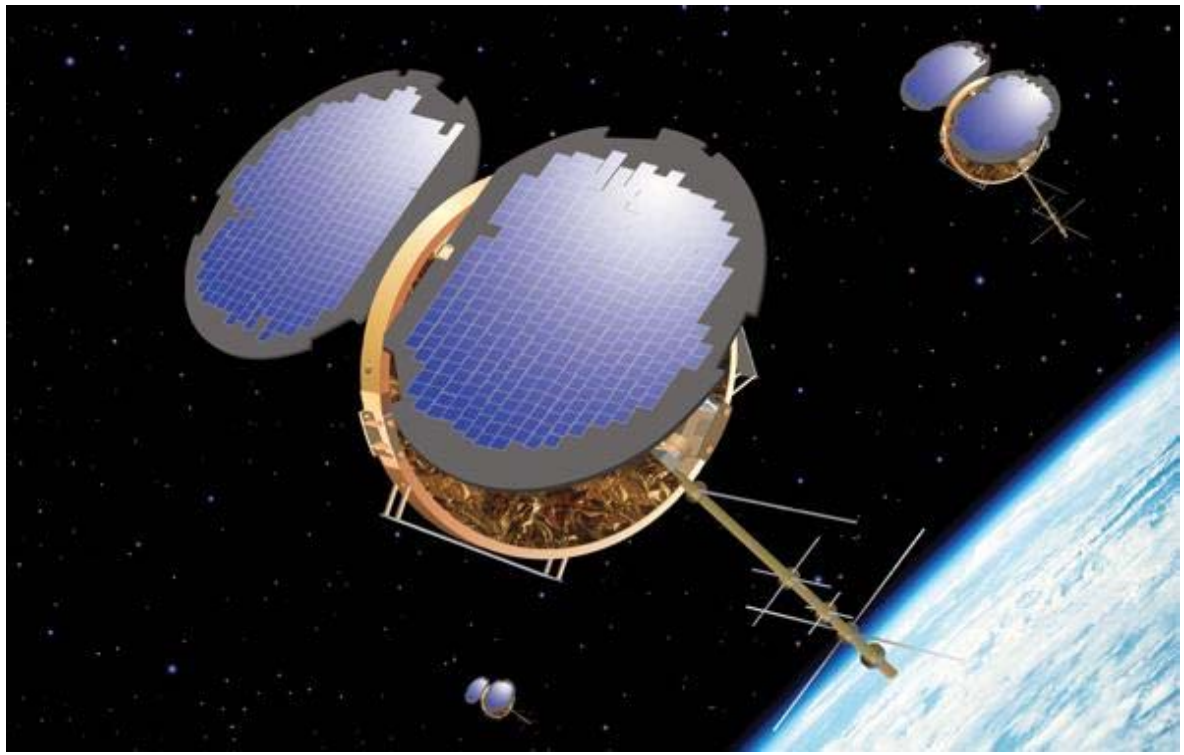
COSMIC / FormoSat 3

Overview, Status, First results, Data distribution



Outline

- COSMIC Introduction / Status
- Early results from COSMIC
  - Neutral Atmosphere profiles
    - Refractivity
    - Temperature, Water vapor
    - Planetary Boundary layer
  - Ionospheric results
    - GPS Electron Density Profiles
    - Global maps of Scintillation
    - TIP and TBB (CERTO)
- Summary
- On-line Data Tool Demonstration

COSMIC/Formosat 3 at a Glance

- **C**onstellation **O**bserving **S**ystem for **M**eteorology **I**onosphere and **C**limate (Formosat-3)
- 6 Satellites launched in April 2006
- Orbits: alt=800km, Inc=72deg, ecc=0
- Weather + Space Weather data
- Global observations of:
  - Refractivity
  - Pressure, Temperature, Humidity
  - TEC, Ionospheric Electron Density
  - Ionospheric Scintillation
- Demonstrate quasi-operational GPS limb sounding with global coverage in near-real time
- Climate Monitoring
- Geodetic Research

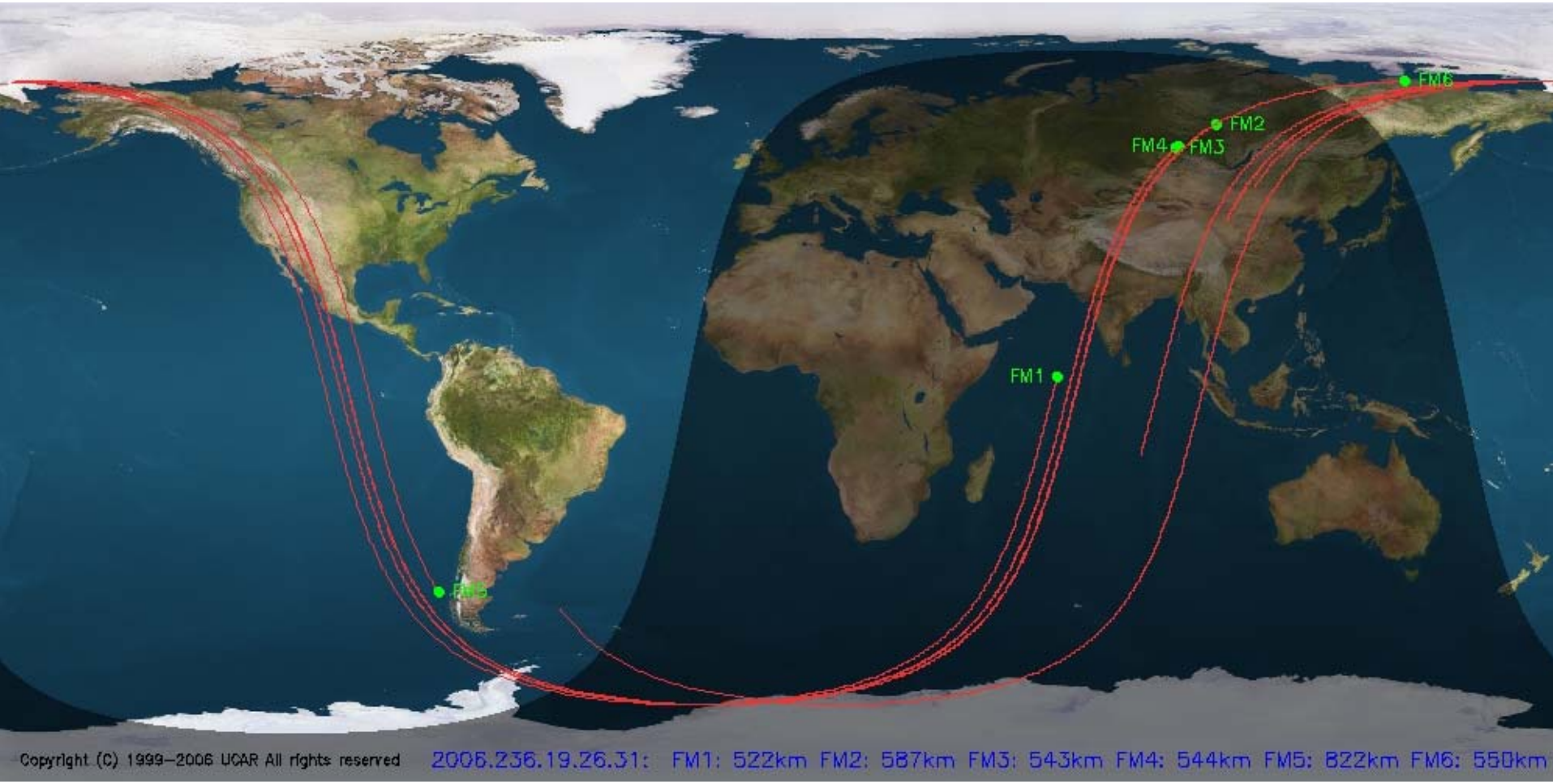
COSMIC launch picture provided by Orbital Sciences Corporation

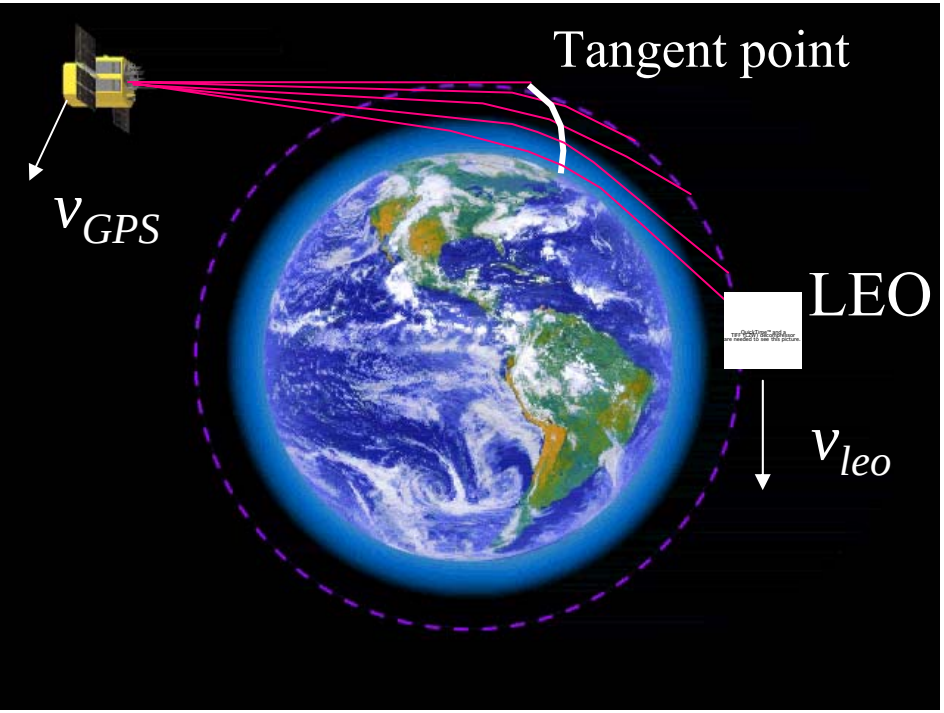
Launch on April 14, 2006 Vandenberg AFB, CA

- All six satellites stacked and launched on a Minotaur rocket
- Initial orbit altitude ~500 km; inclination ~72°
- Will be maneuvered into six different orbital planes for optimal global coverage (at ~800 km altitude)
- All satellites are in good health and providing initial data

COSMIC Satellite Ground Tracks

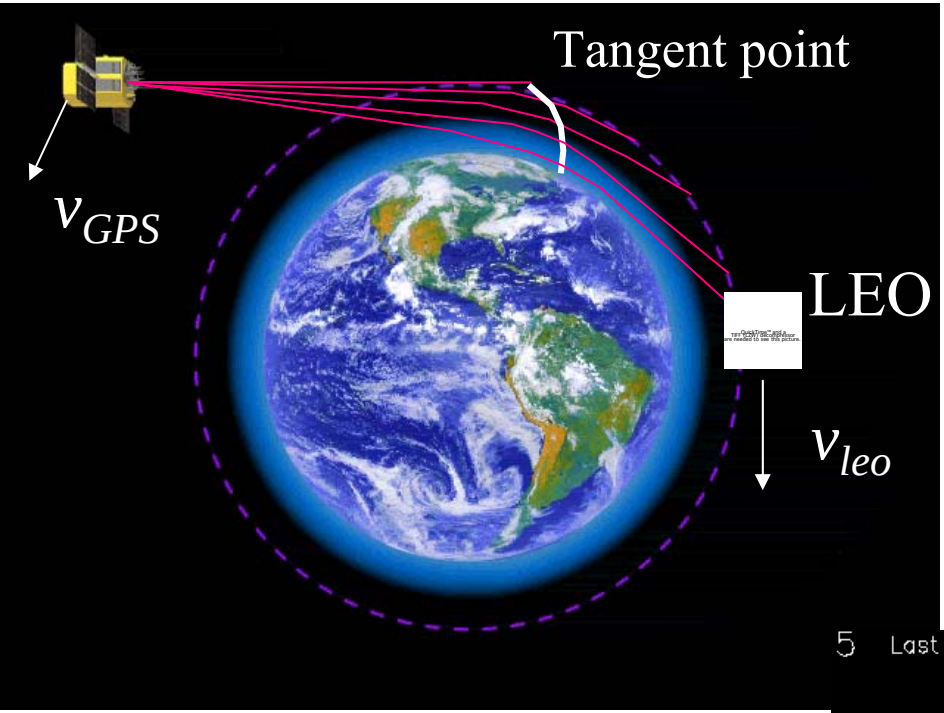
mid-August 2006





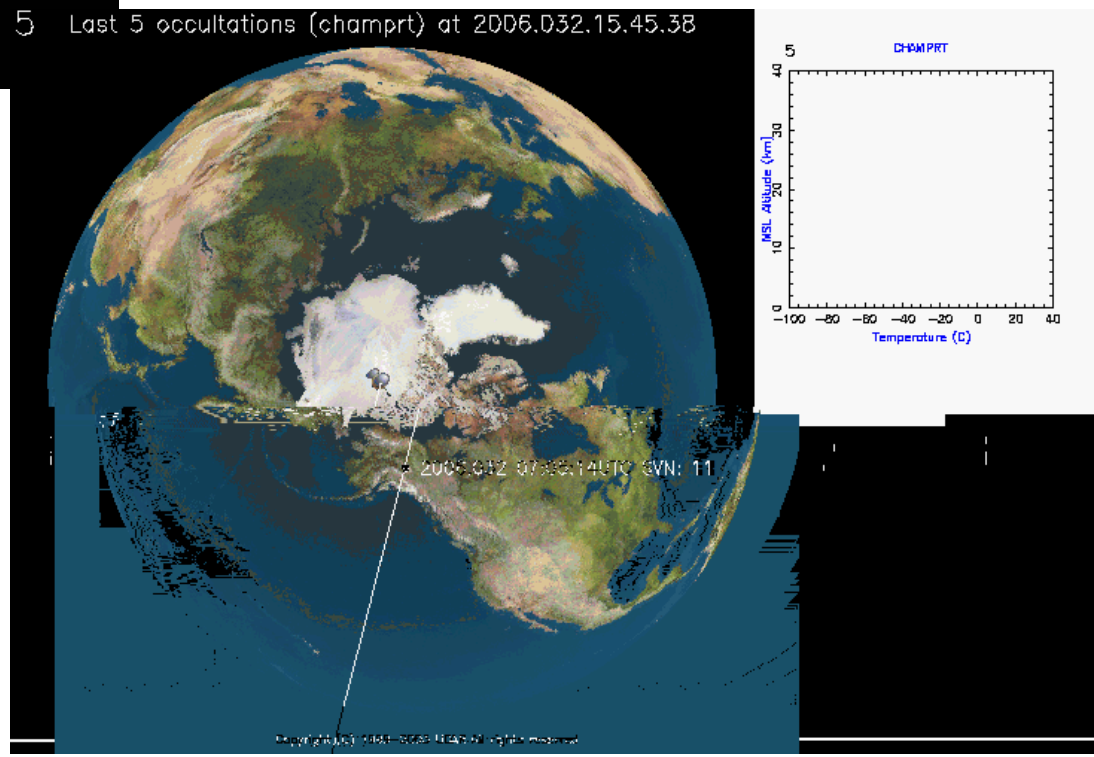
The LEO tracks the GPS phase while the signal is occulted to determine the Doppler

The velocity of GPS relative to LEO must be estimated to **~0.2 mm/sec** (velocity of GPS is ~3 km/sec and velocity of LEO is ~7 km/sec) to determine precise temperature profiles



The LEO tracks the GPS phase while the signal is occulted to determine the Doppler

The velocity of GPS relative to LEO must be estimated to **~0.2 mm/sec** (20 ppb) to determine precise temperature profiles



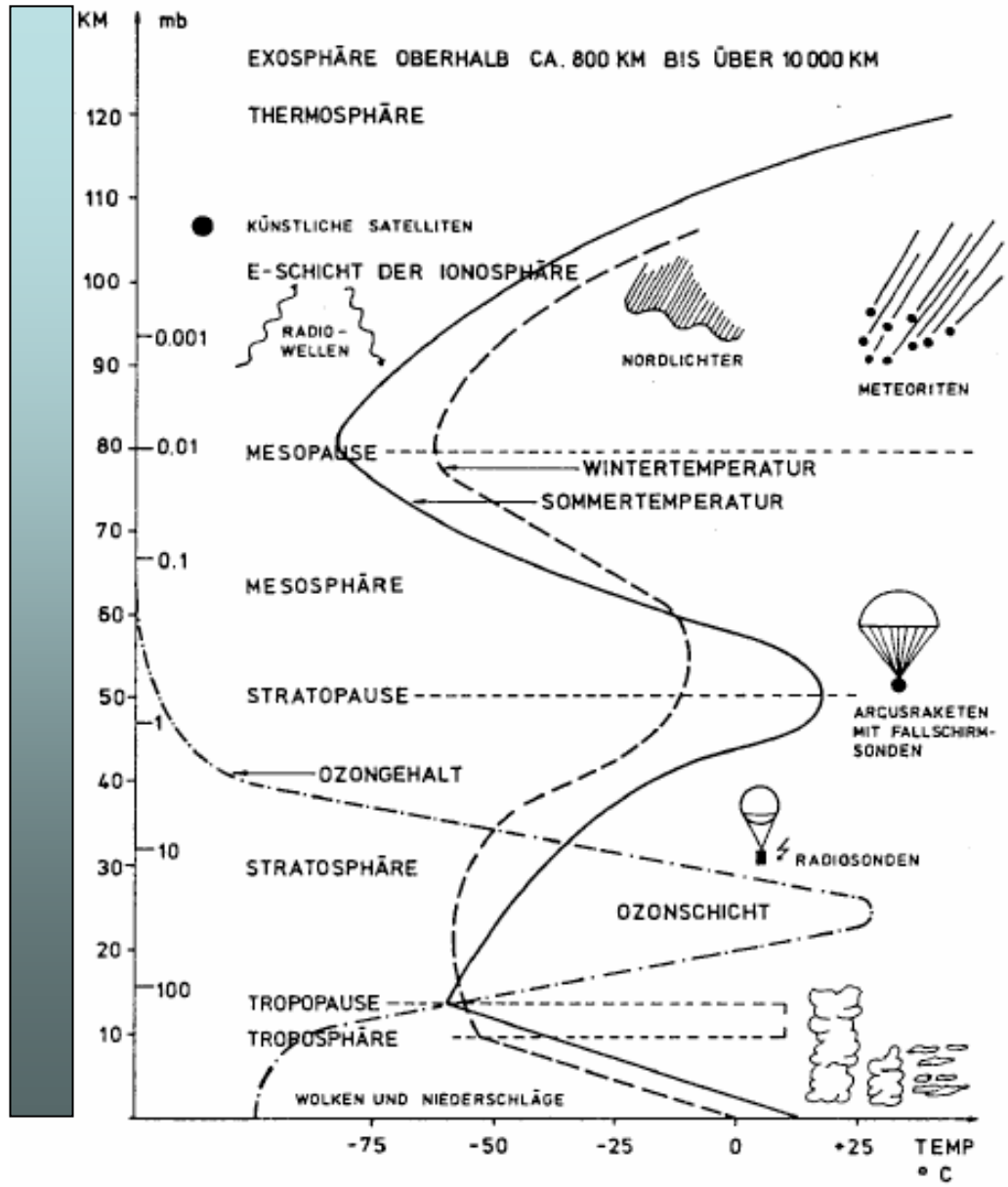
Profile the (sporadic) ionospheric E-layer with ~1-km vertical resolution

Area dominated by noise - used for noise calibration of profile

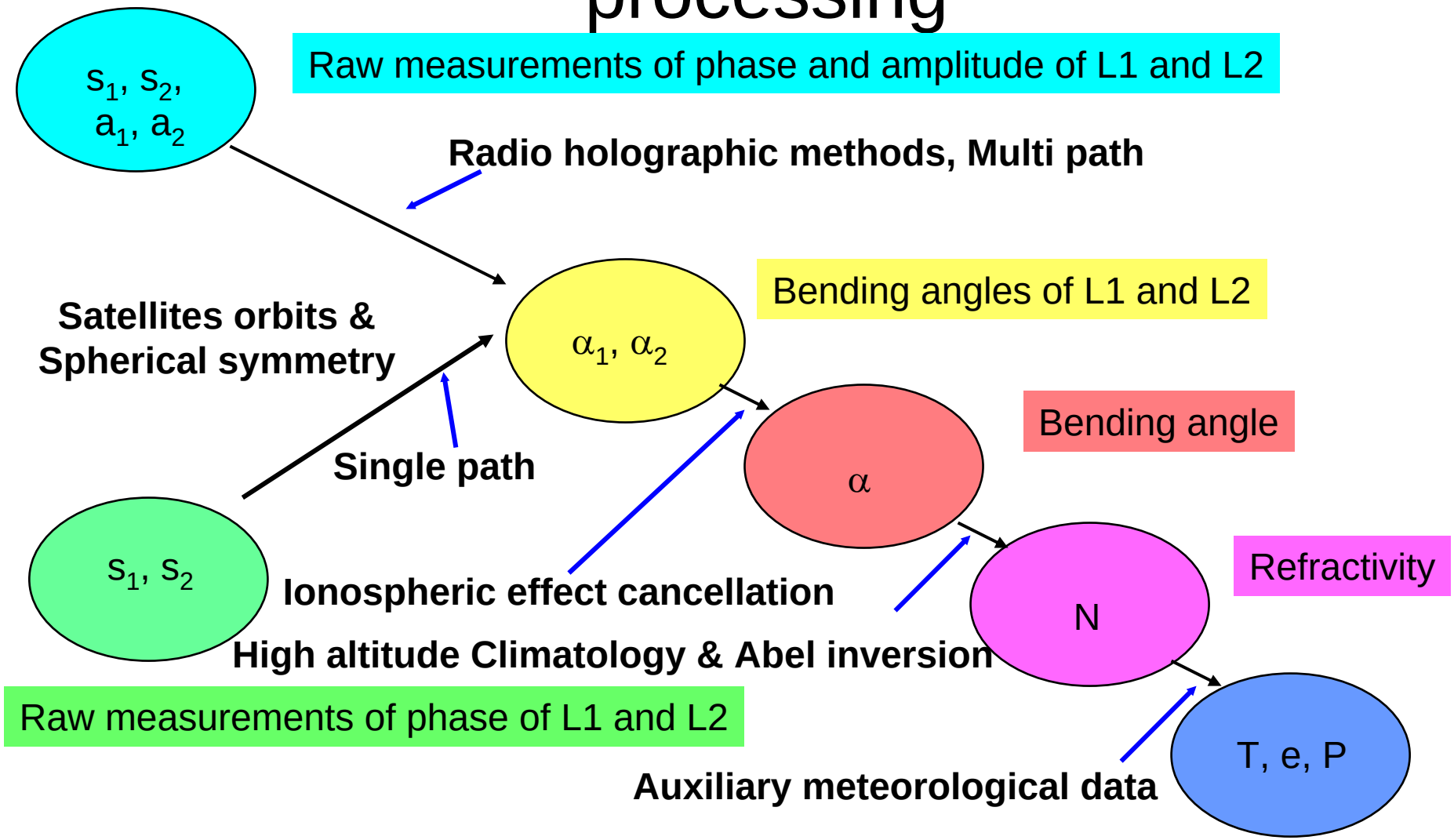
Area affected by noise - profiles are noisy and/or affected by climatology

Highest quality profiles 5-30 km

Some profiles affected by boundary layer effects (super refraction)



GPS radio occultation measurements & processing



Atmospheric refractive index $n = c / v$ where c is the light velocity in a vacuum and v is the light velocity in the atmosphere

Refractivity $N = 10^6 (n - 1)$

$$N = 77.6 \frac{P}{T} + 3.73 \times 10^5 \frac{P_w}{T^2} - 40.3 \times 10^6 \frac{n_e}{f^2}$$

(1) (2) (3)

- Hydrostatic dry (1) and wet (2) terms dominate below 70 km

- Wet term (2) becomes important in the troposphere and can constitute up to 30% of refractivity at the surface in the tropics

- In the presence of water vapor, external information information is needed to obtain temperature *and* water vapor

- Liquid water and aerosols are generally ignored

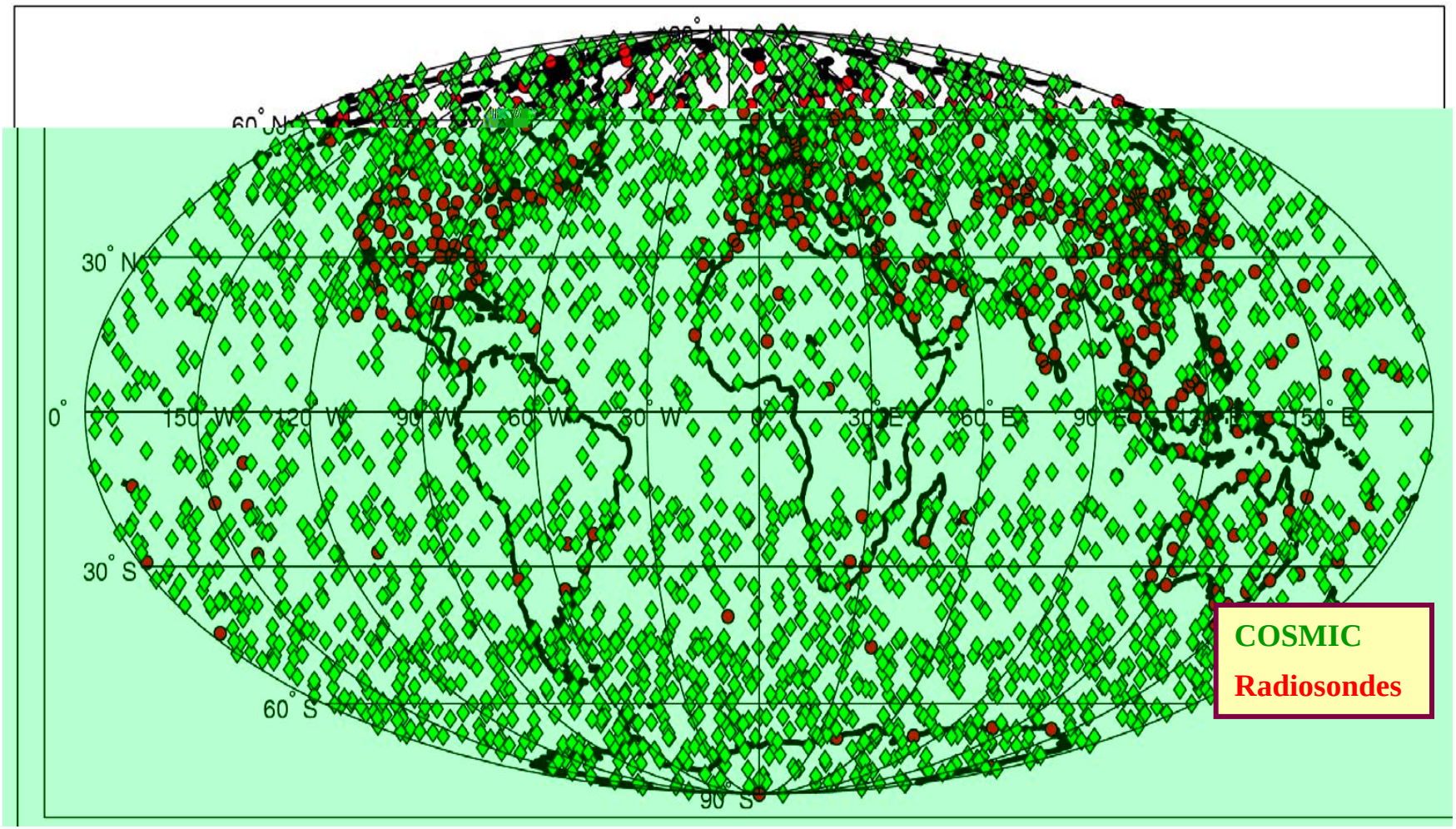
- Ionospheric term (3) dominates above 70 km

On-line Tutorial on Radio Occultation

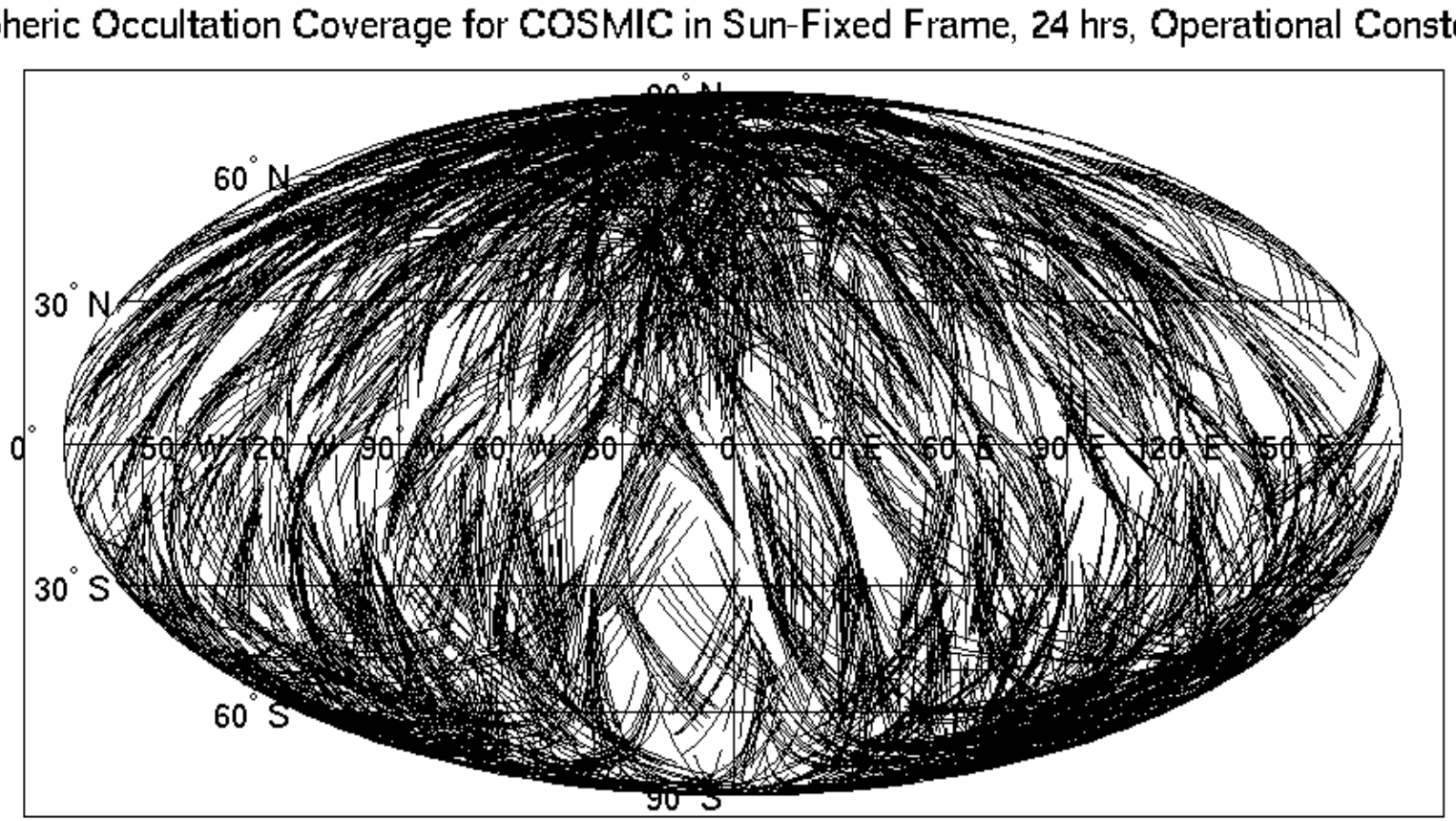
http://www.meted.ucar.edu/COSMIC/

COSMIC Soundings in 1 Day

Occultation Locations for COSMIC, 6 S/C, 6 Planes, 24 Hrs

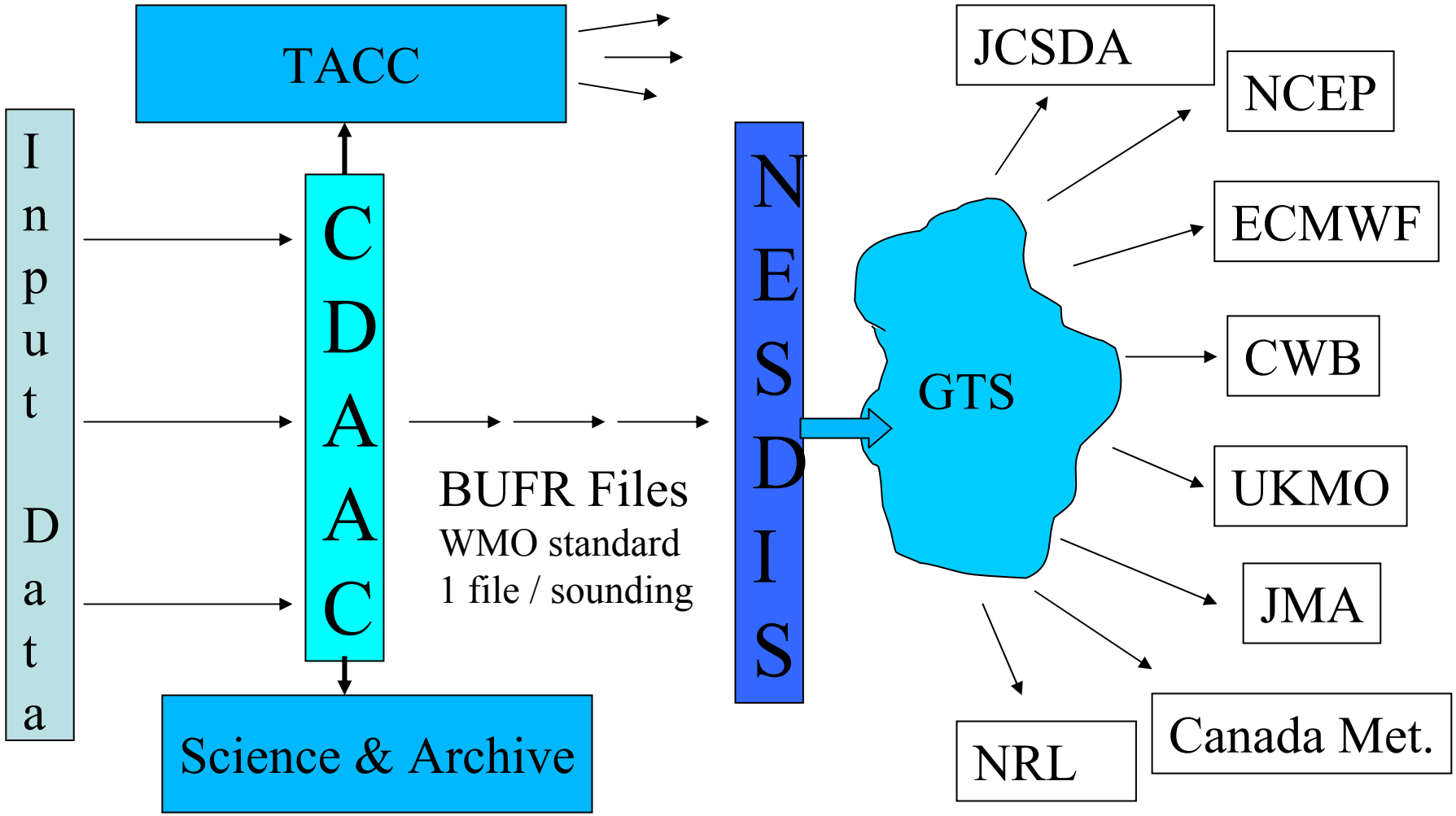


Ionospheric Occultation Global Coverage



- About 2500 ionospheric occultations per day
- Profiles of electron density between 100 and 800 km
- Total Electron Content to all GPS satellites in view

Operational Processing



Data available to weather centers within < 180 minutes of on-orbit collection

COSMIC Data Availability

- Data opened up to public in July 2006
- All Data (including raw data) available at the end of each day
- Real-time products (profiles of bending, refractivity, …) in WMO standard format available via the GTS
- Post-processed data for climate research will be updated every few months
- Data use agreement with NSPO required for use of all data and data products (via TACC or CDAAC website)

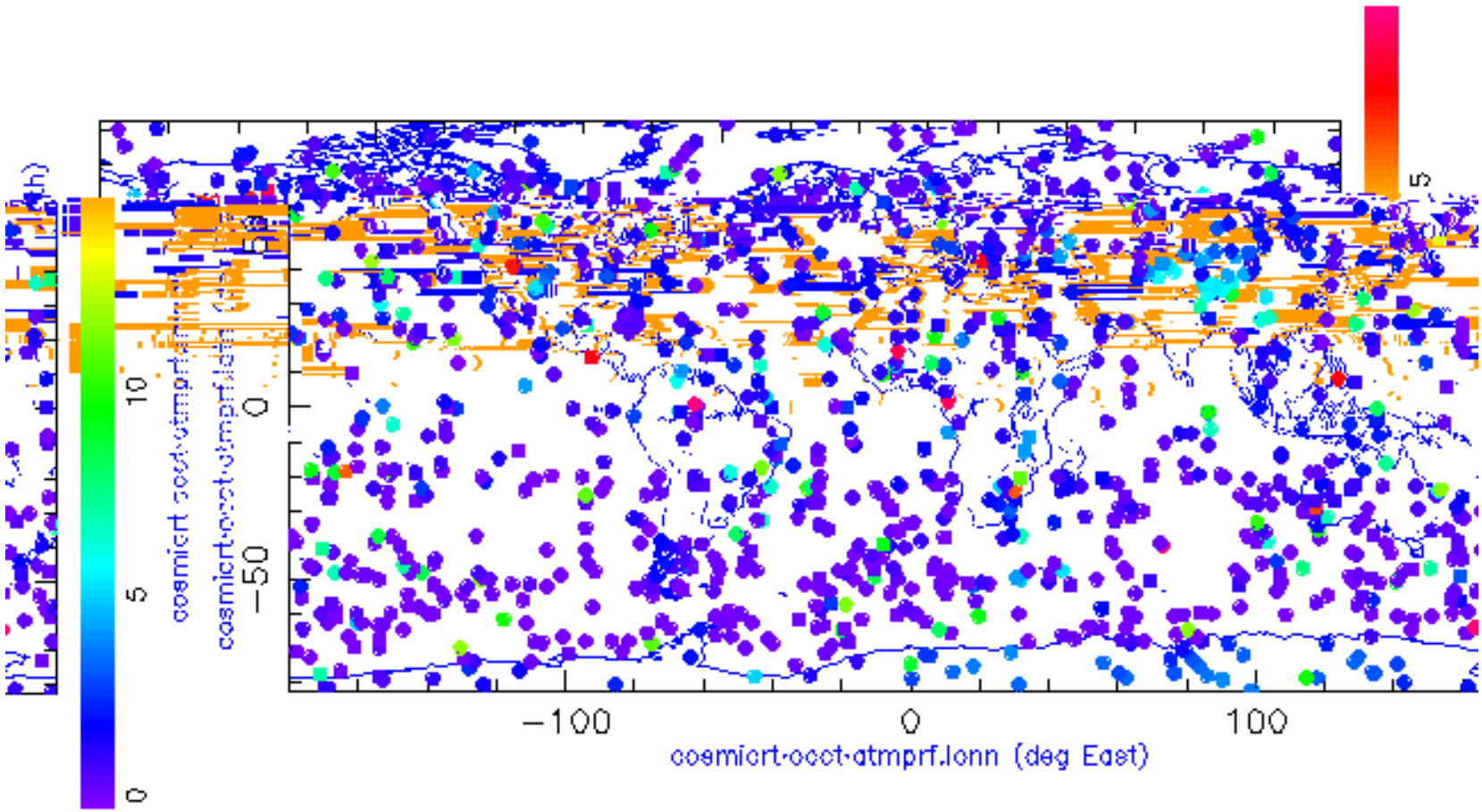
COSMIC Data Policy

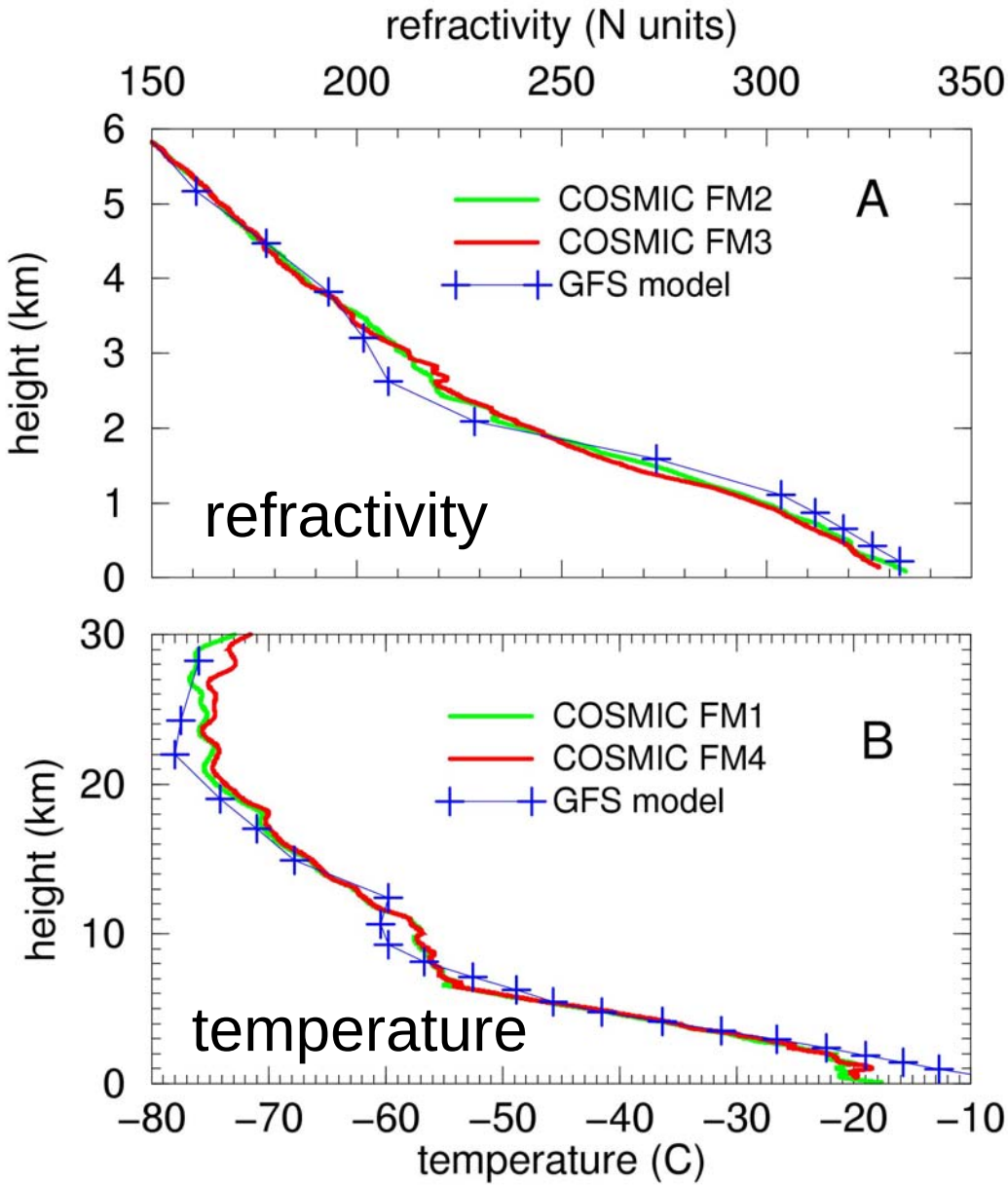
- Real-time data (raw data, excess phase data, etc.) available upon approval of letter request to NSPO director and UCAR president
- All requests have been approved
- Next slide shows how to sign up (or go directly to:)

  http://tacc.cwb.gov.tw/service/policy.htm

COSMIC Sounding Penetration (Day 239, 2006)

1316 Matches



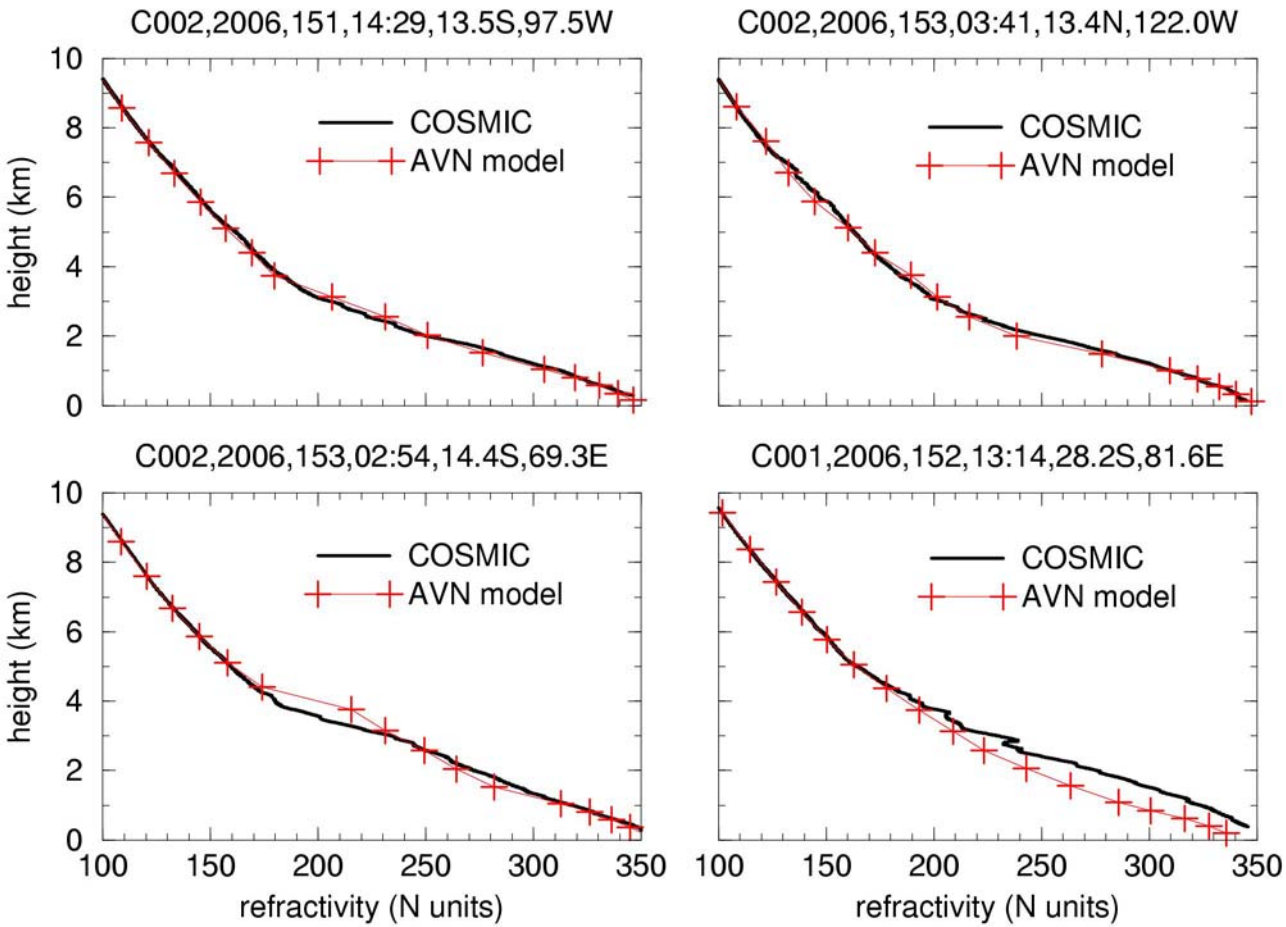


Atmospheric refractivity
Tropical Sounding

"Dry" Temperature
Polar Sounding

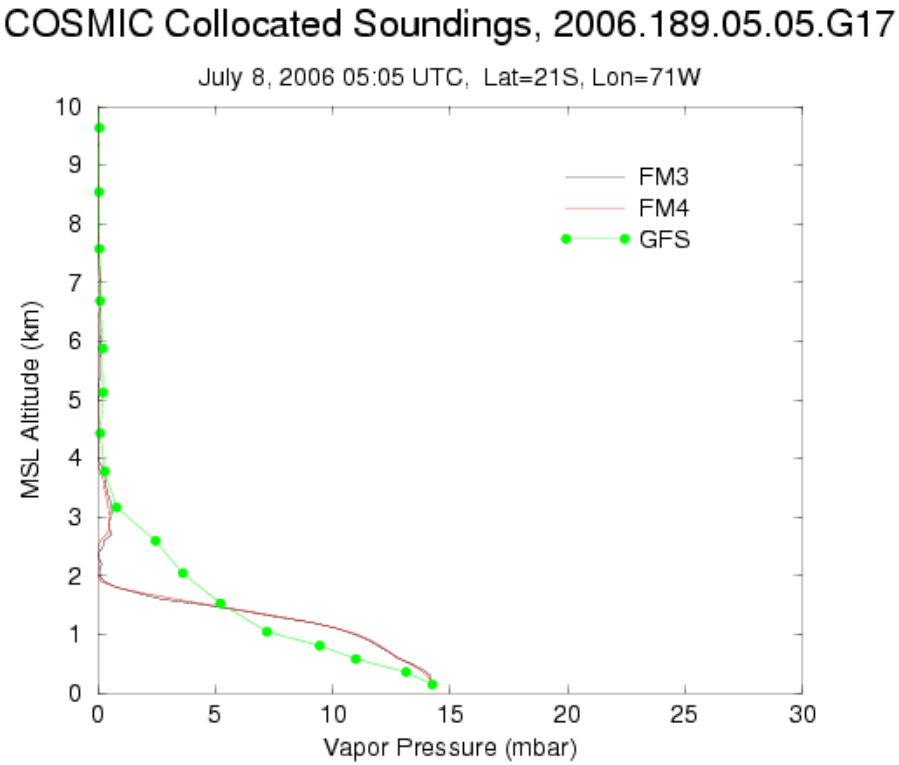
Precision of Radio Occultation Measurements: 0.2% or ~0.5 deg in temperature (between 10-20 km)

Penetration of Planetary Boundary layer with COSMIC

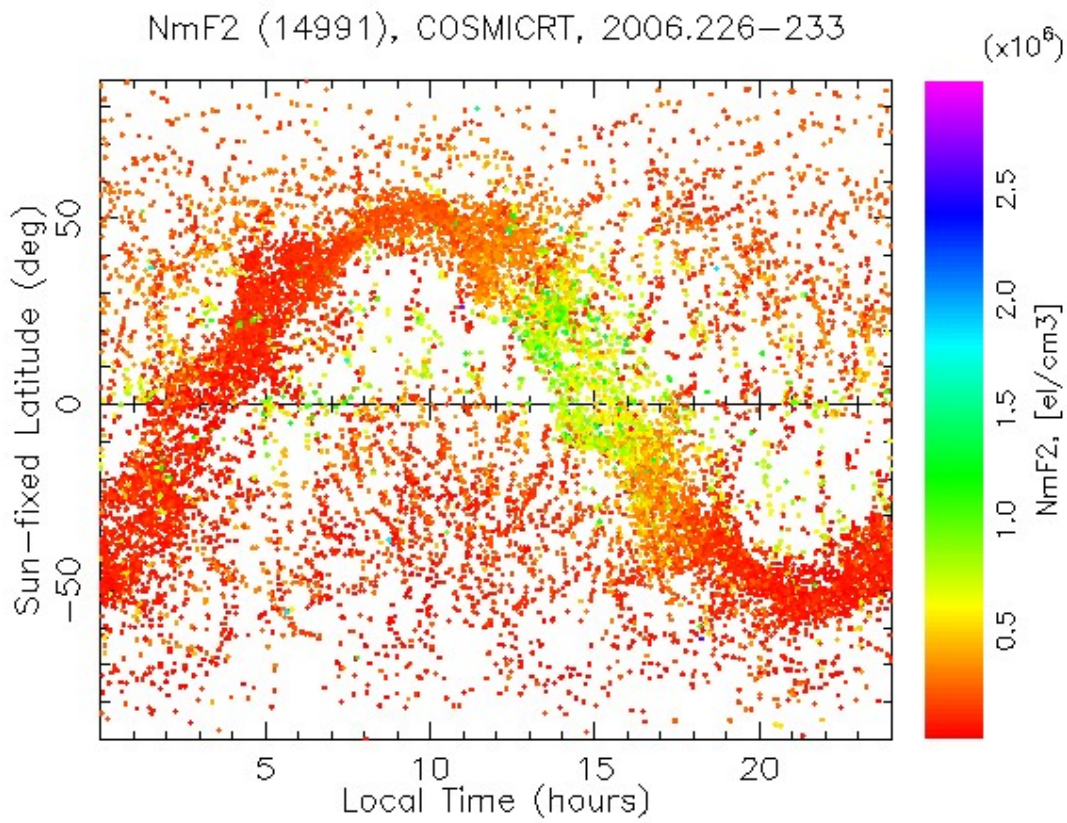


Comparison of Refractivity with GFS (AVN)

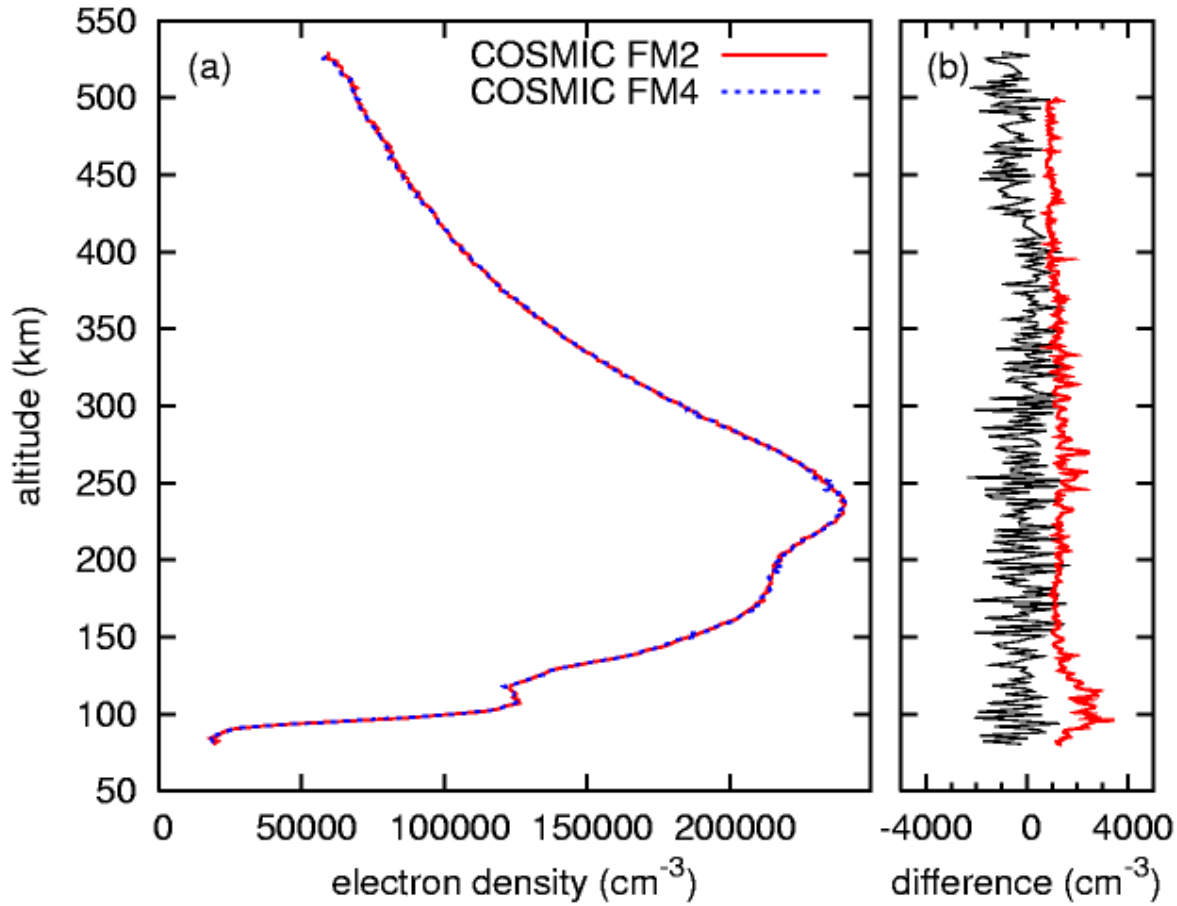
Water Vapor Pressure Comparison
COSMIC (FM3 and FM4) vs. GFS



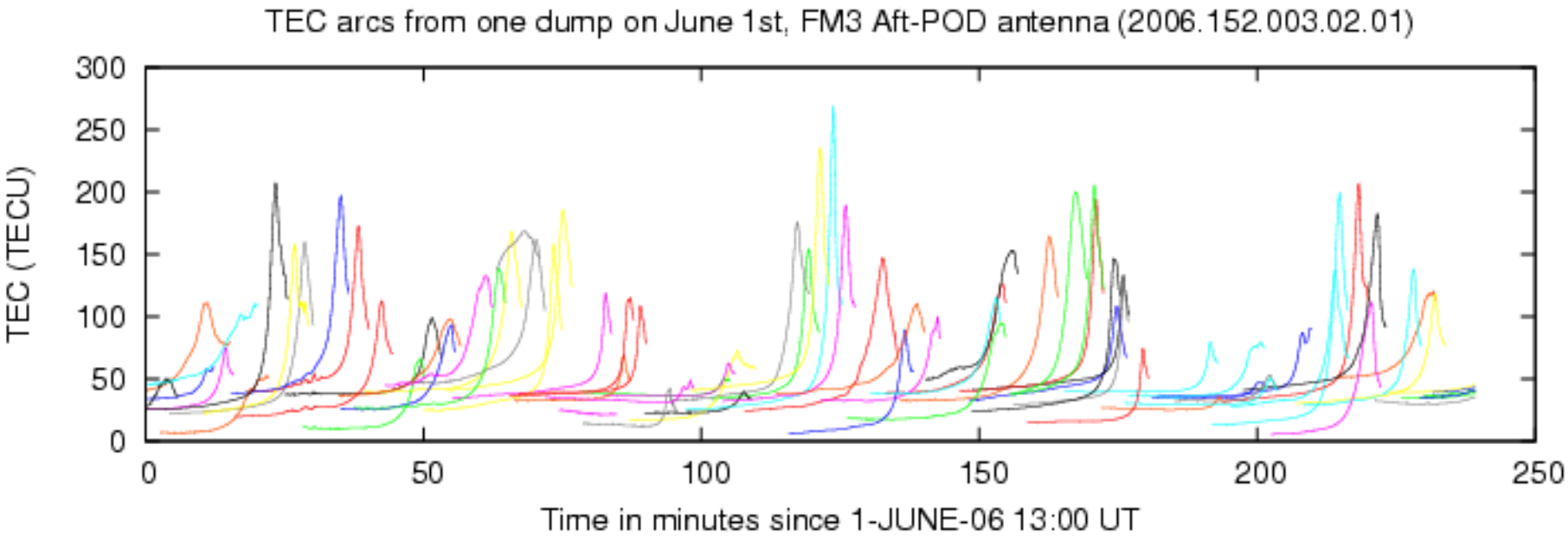
COSMIC Ionospheric NmF2 - 1 week



Comparison of 2 Ionospheric Profiles

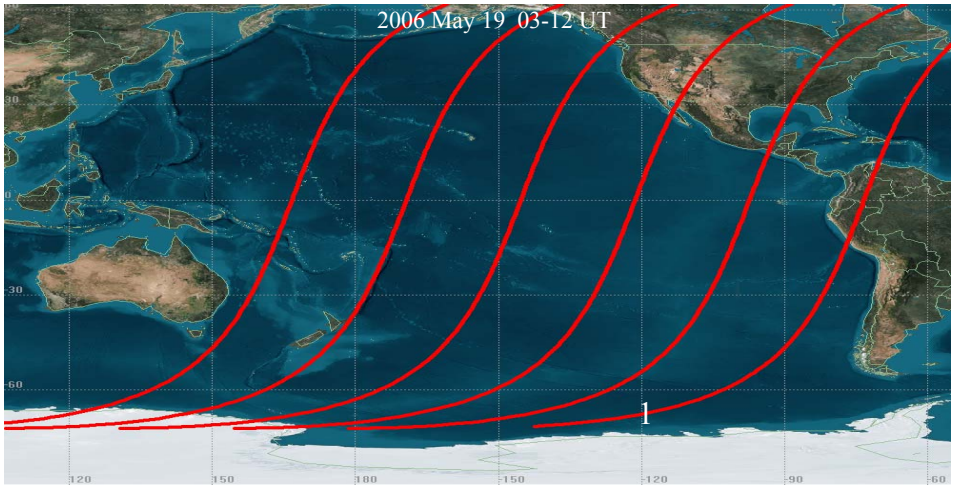


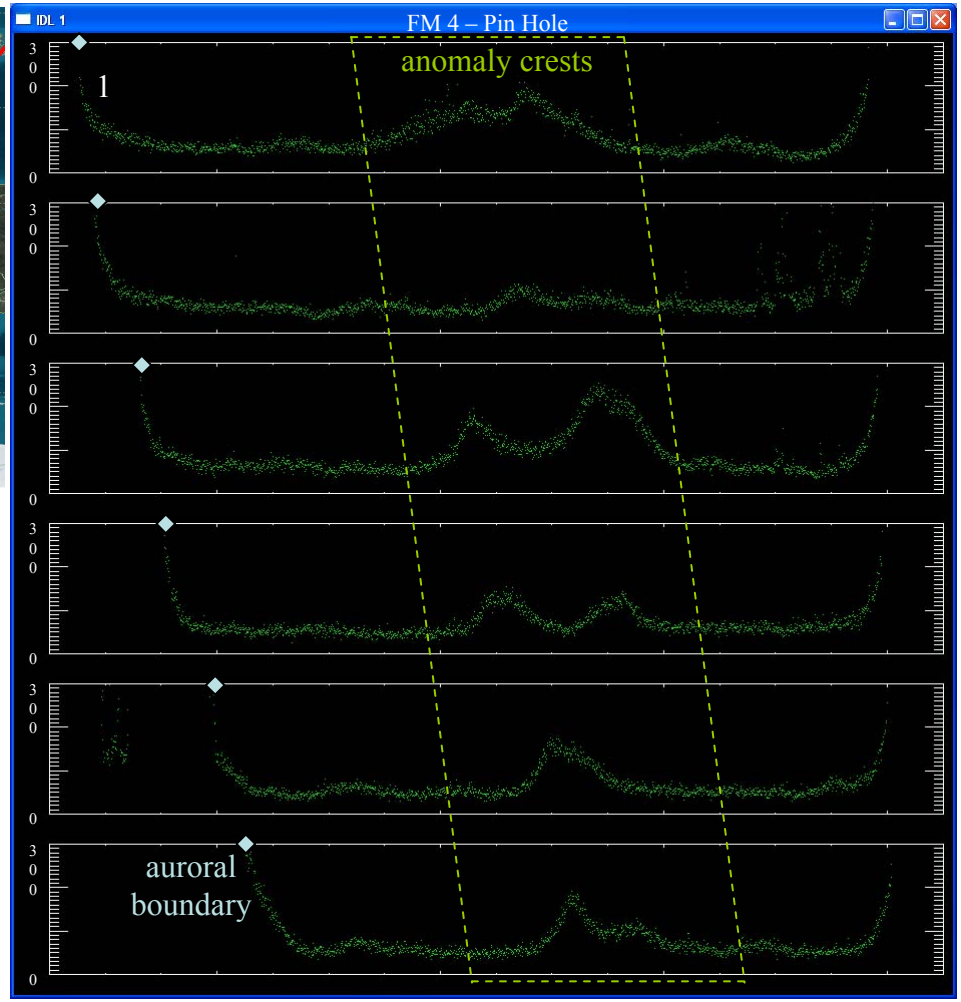
Ionospheric Total Electron Content Data



In addition to electron density profile information COSMIC also provides ~3000 daily LEO - to - GPS TEC arcs

Longitudinal variability of ionosphere

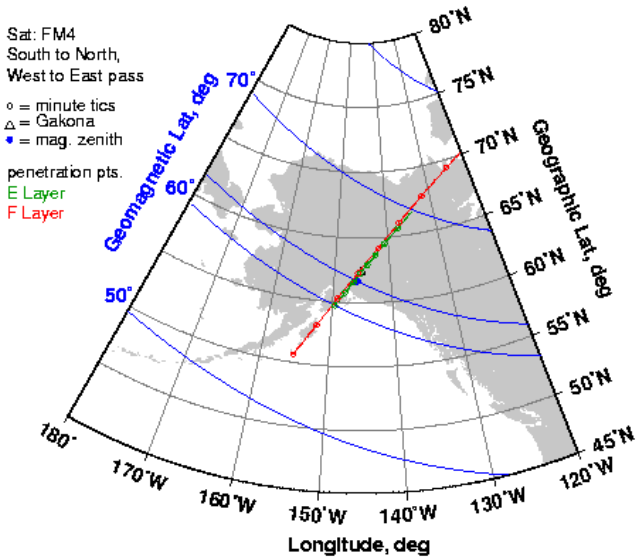


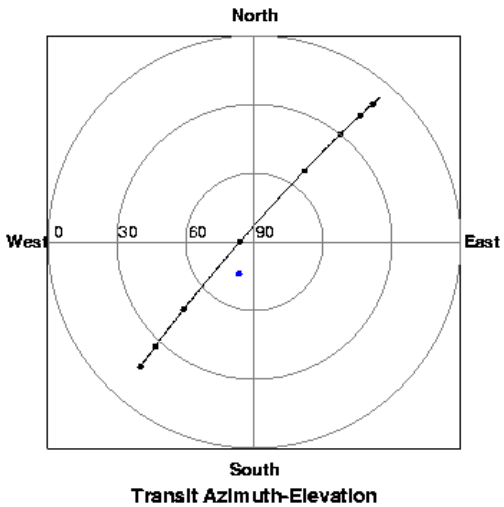


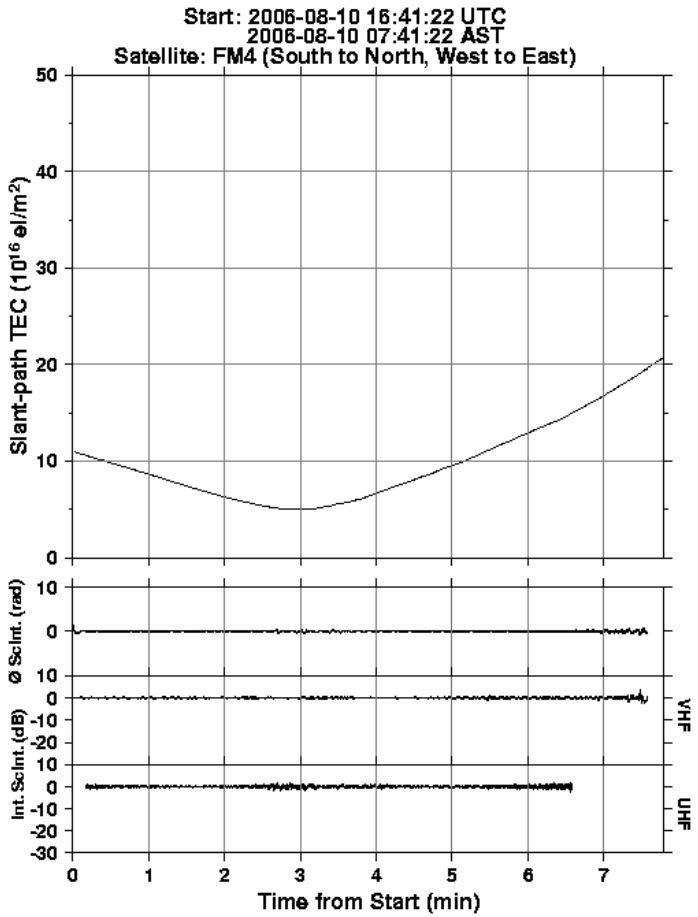
- Low latitude density crests and trough are a product of photoionization, recombination, and transport
- Electric fields interact with the Earth's magnetic field to transport plasma vertically at the equator, which diffuses downward along the magnetic field lines
- Meridional neutral winds also transport plasma along magnetic field lines
- TIP reveals the complexity of these ionospheric drivers as a function of longitude

Clayton Coker, NRL

FM4







Paul Bernhardt, NRL

Summary

- COSMIC was launched on-schedule and on-budget
- All 6 GPS receivers are working
- TIP and CERTO (TBB) instruments working
- CDAAC automated processing is working
- Obtaining good radio occultation profiles in ionosphere (~2500 /day) and neutral atmosphere (~1200 / day)
- Data freely available (registration required)
- About 220 users have signed up so far
- Transferred 519 Gb of data (1.7 million files) to 106 different users between Aug.1 - 28