



Near Real-time Ionospheric Data Products from COSMIC

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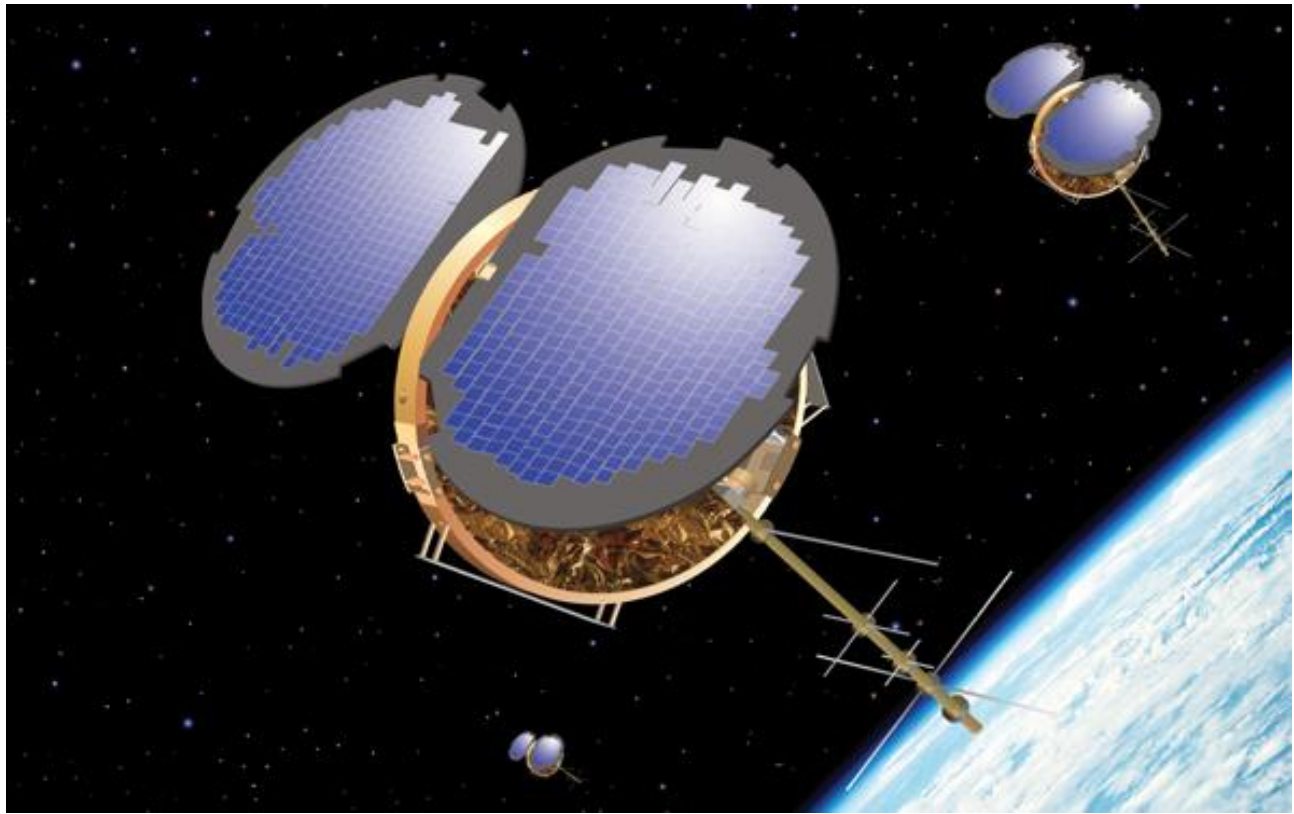
Collaborators

Bill Kuo Chris Rocken
Doug Hunt Bill Schreiner

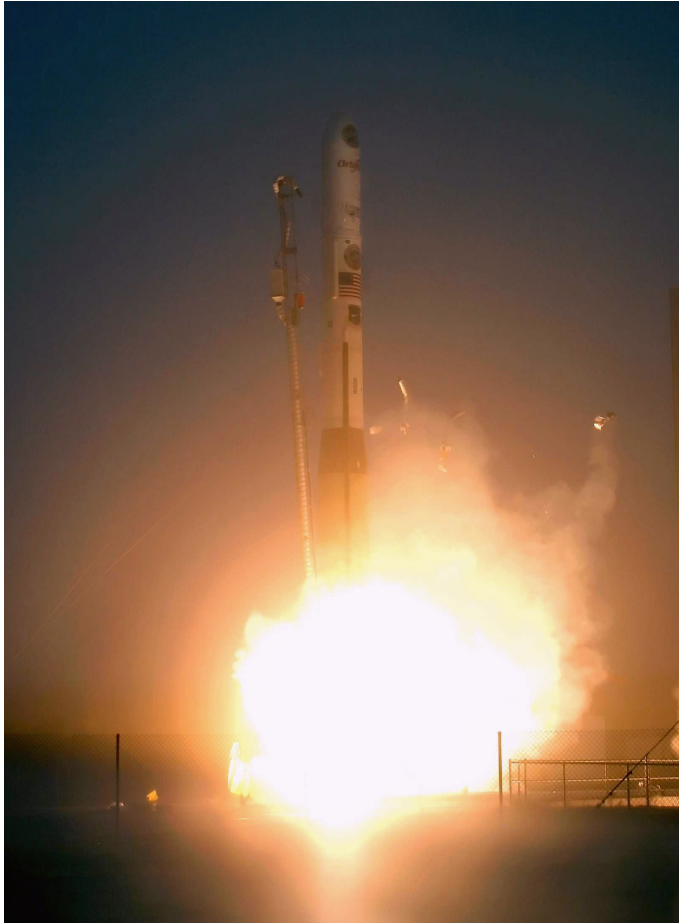
Space Weather Week, Boulder, CO, Apr 25-28, 2006



COSMIC – A Six Satellite Constellation



Launched April 14 2006 – 11 days ago

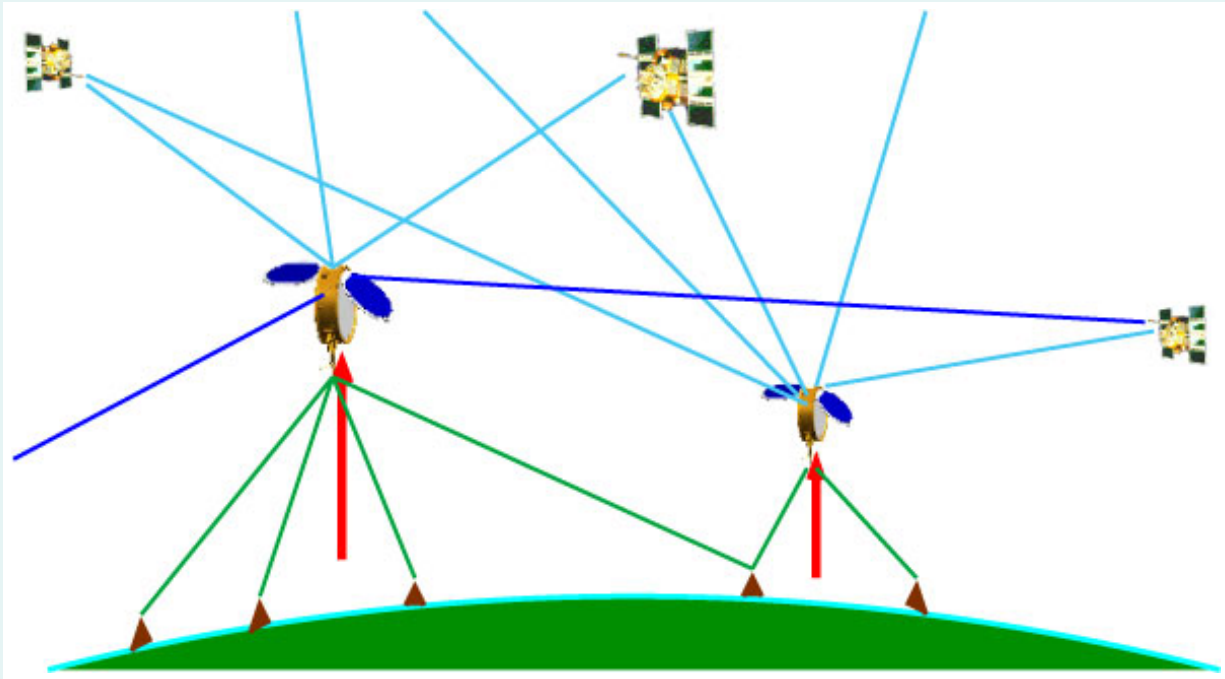


COSMIC launch picture provided by Orbital Sciences Corporation

- All six satellites stacked and launched on a Minotaur rocket
- Initial orbit altitude ~ 500 km; inclination $\sim 72^\circ$
- 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 Ionospheric Measurements



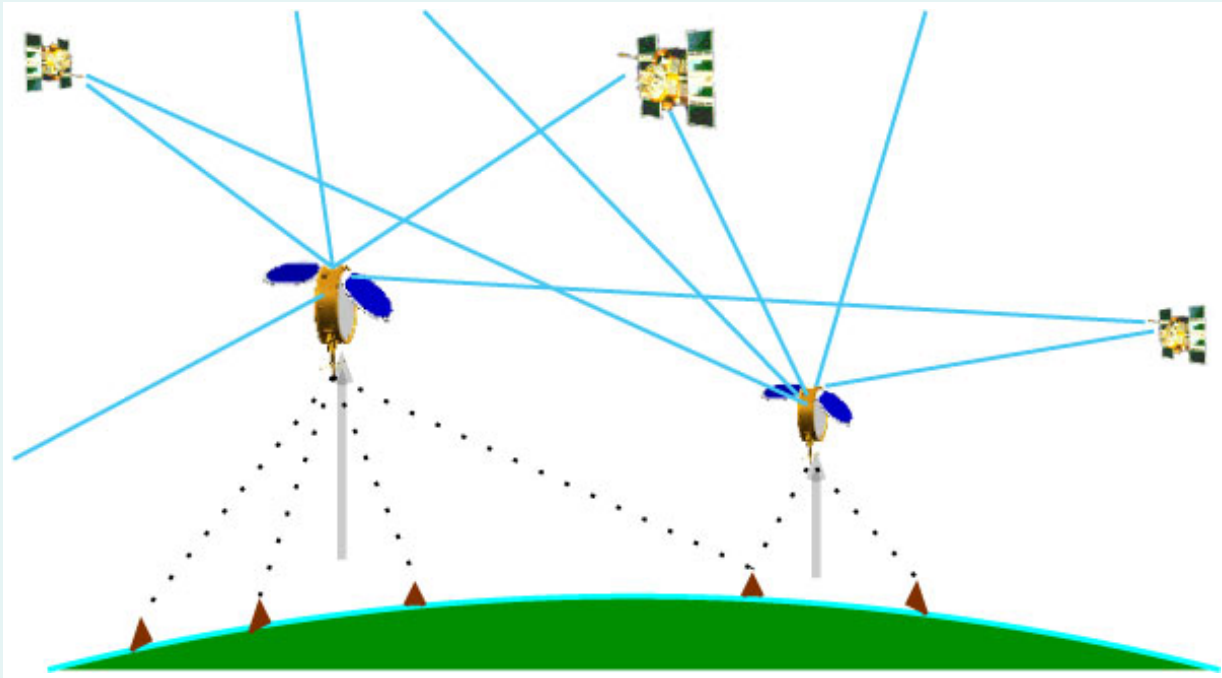
GPS receiver: { Total Electron Content (TEC) to all GPS satellites in view
Ionospheric radio occultations (profiles) & scintillations

Tiny Ionospheric Photometer (TIP): Ultra-violet emission from ionosphere

Tri-Band Beacon (TBB): TEC & scintillations on satellite-to-ground links



COSMIC Ionospheric Measurements

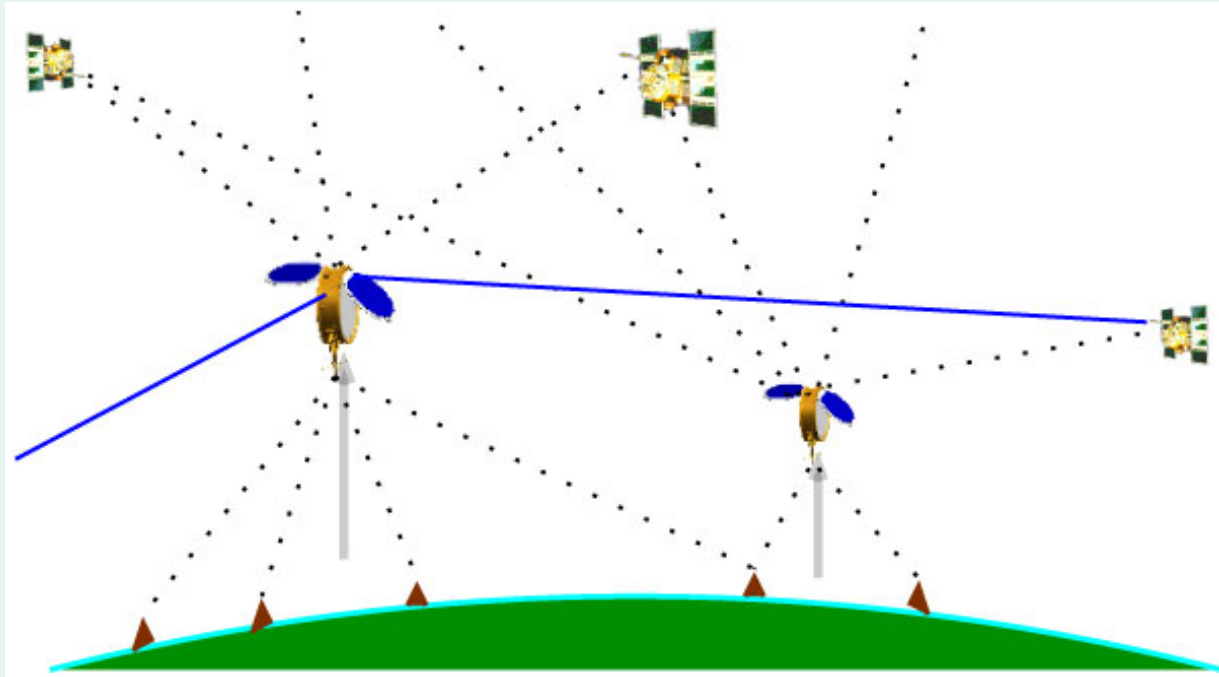


Total Electron Content measurements:

- High-resolution (1 Hz) TEC to all GPS satellites in view at all times
- Can track up to 12 GPS satellites at the same time (9 aft + 4 fore)
- Useful for global ionospheric tomography and data assimilation



COSMIC Ionospheric Measurements

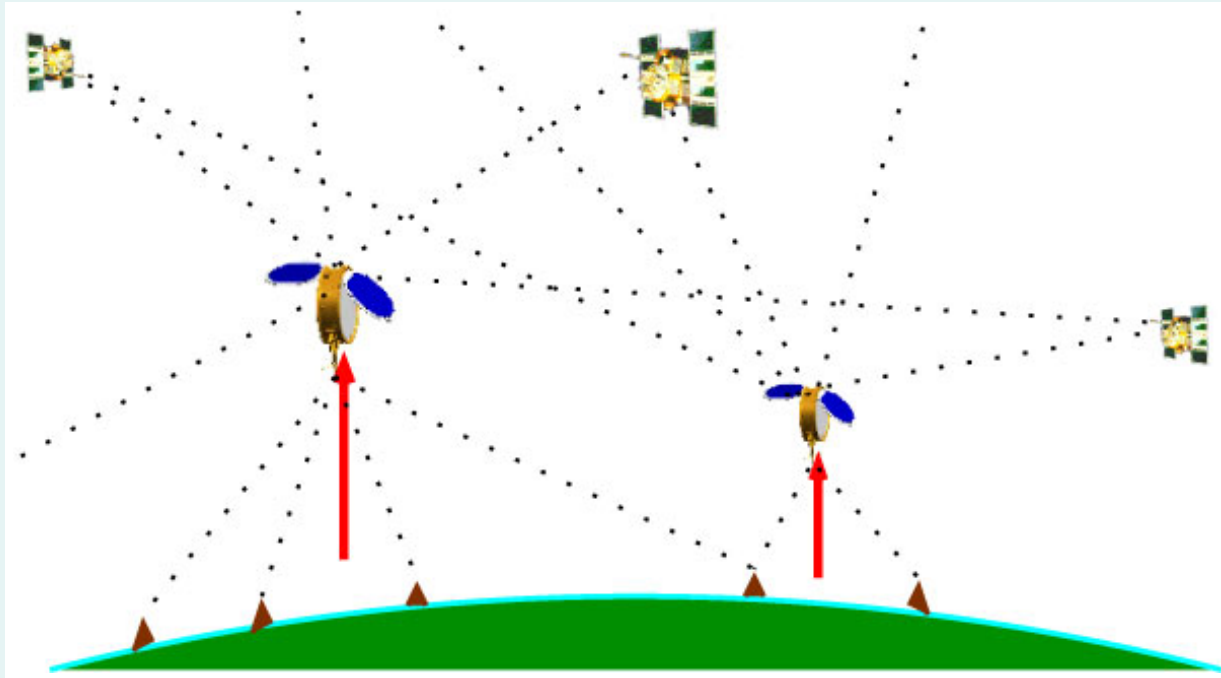


Ionospheric GPS occultation measurements:

- High-resolution (1 Hz) occultation TEC below orbit altitude
- Ionospheric electron density profiles from orbit altitude and down
- Ionospheric scintillations using the two limb antennas (50 Hz)



COSMIC Ionospheric Measurements

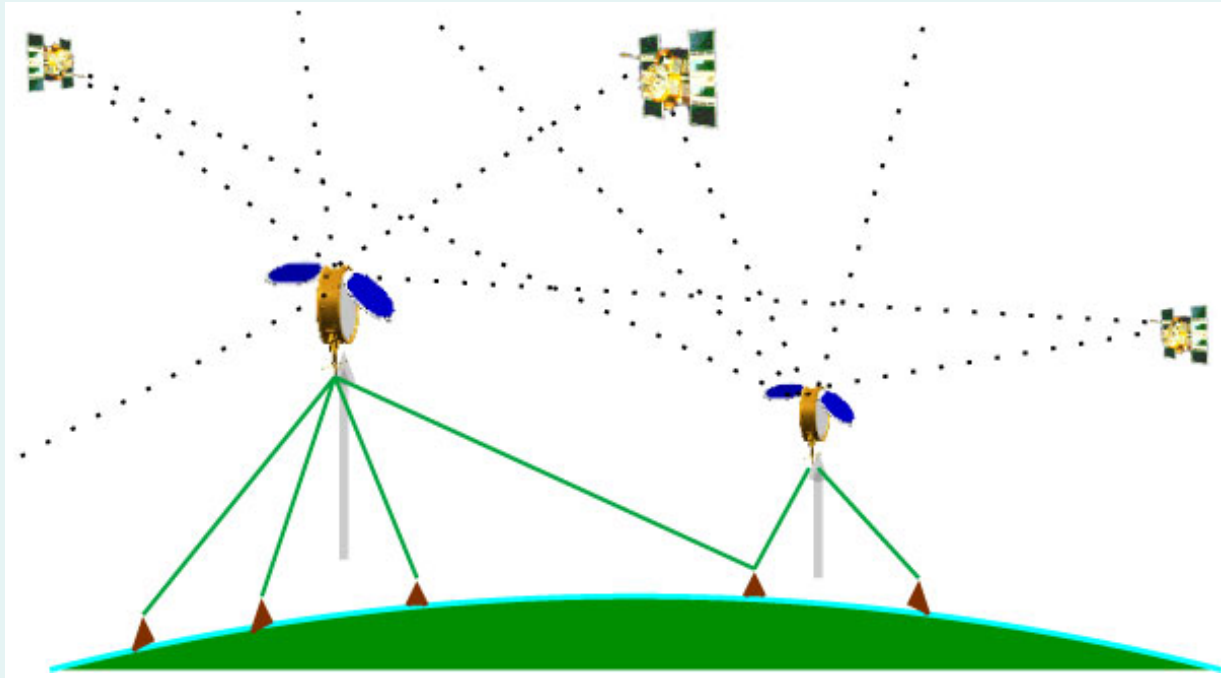


Tiny Ionospheric Photometer measurements:

- Emission (1356 Å) due to recombination of oxygen ions and electrons
- Nadir intensity along sub-satellite track – proportional to $\int N_e^2 dz$
- High quality data on night-side – uncertainty about day-side quality



COSMIC Ionospheric Measurements



Tri-Band Beacon measurements:

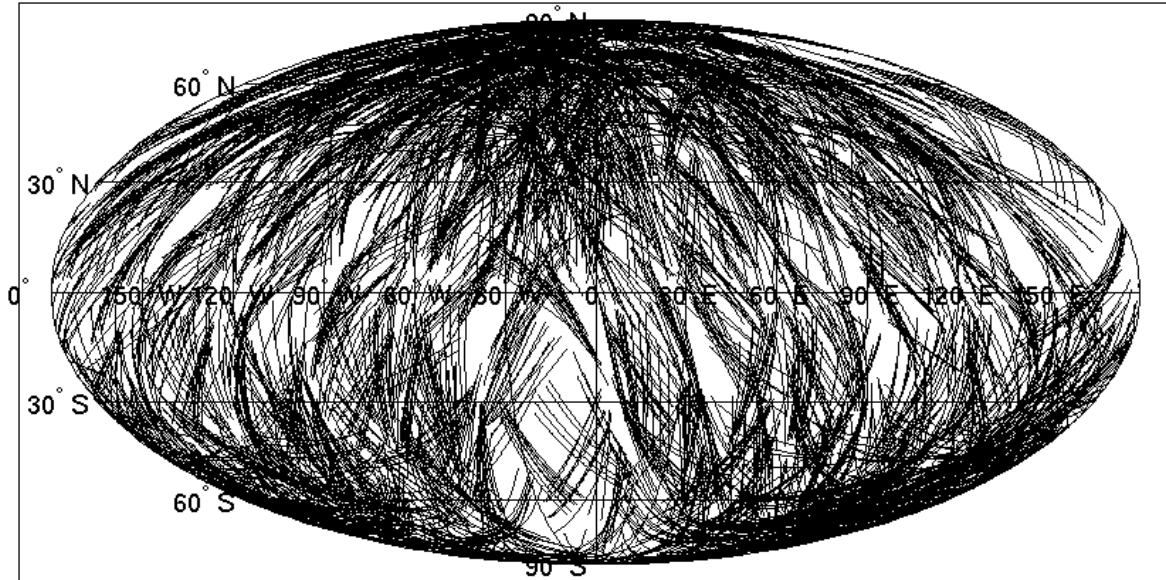
- Radio signals transmitted from COSMIC at 150, 400, and 1067 MHz
- TEC between the COSMIC satellites and chains of ground receivers
- Amplitude and phase scintillations on the satellite-to-ground links



Ionospheric Occultation Global Coverage



Ionospheric Occultation Coverage for COSMIC in Sun-Fixed Frame, 24 hrs, Operational Constellation



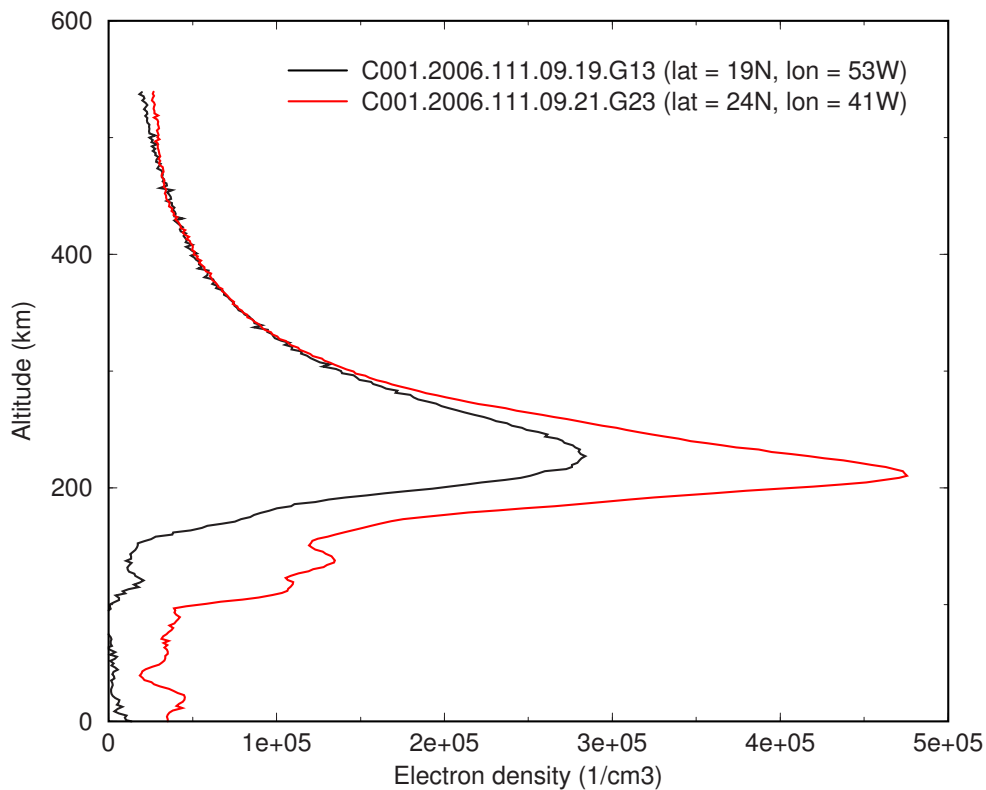
- About 2500 ionospheric occultations per day
- Profiles of electron density between 100 and 800 km
- Total Electron Content to all GPS satellites in view



First Ionospheric Profiles



First COSMIC ionospheric profiles

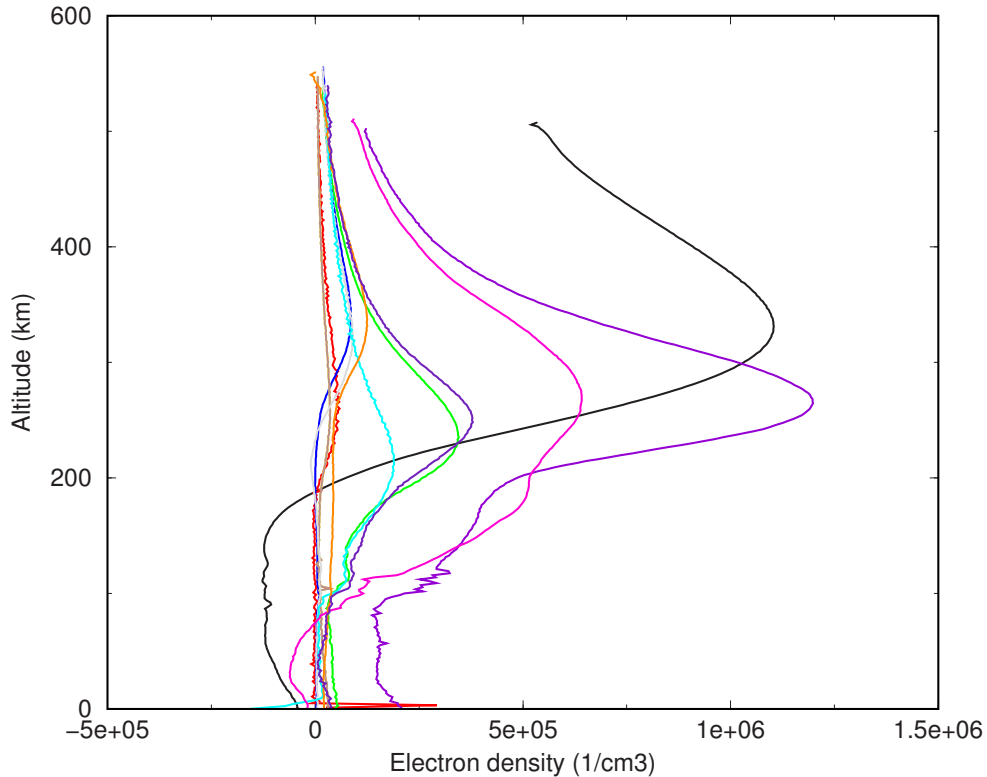




First Ionospheric Profiles



More COSMIC ionospheric profiles

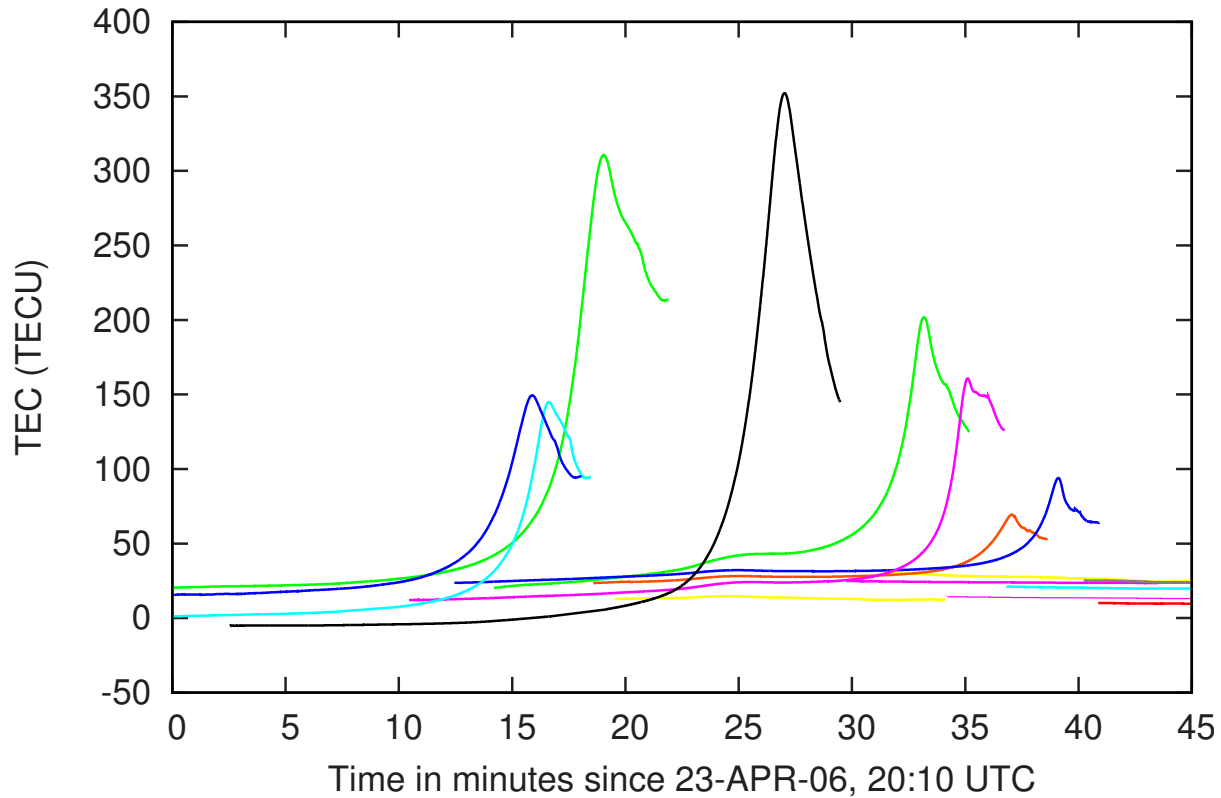




Total Electron Content



LEO-GPS Total Electron Content, Flight Module 4, aft antenna

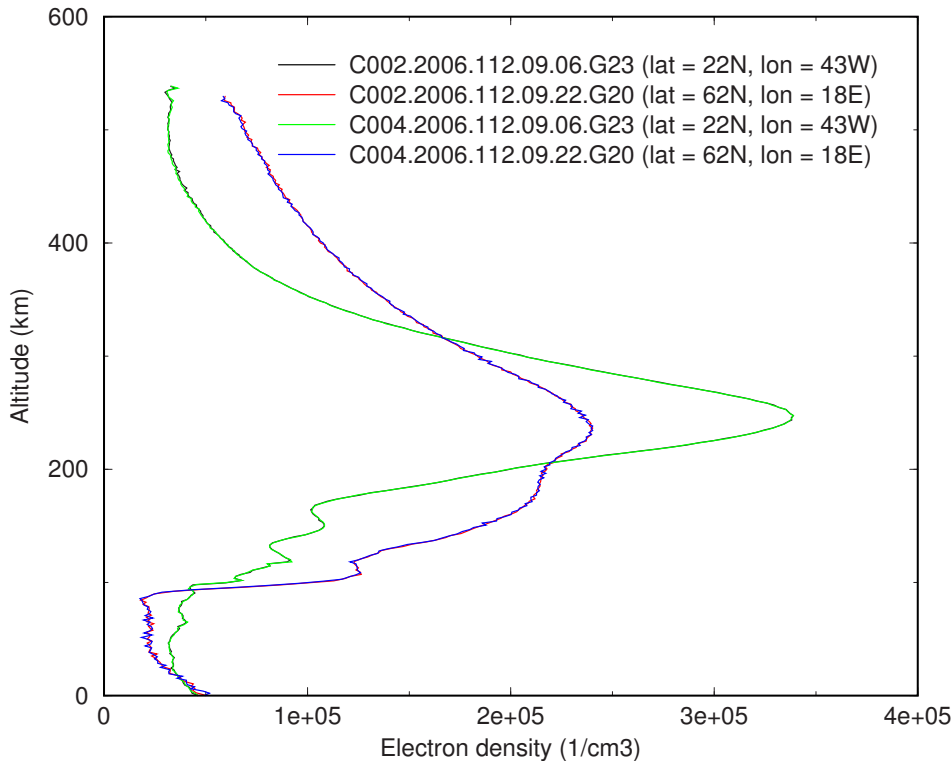




Some Amazing First Comparisons...



Same occultations from two different COSMIC satellites



- FM2 and FM4 within 30 km of each other
- FM2 about 4 seconds behind FM4
- Four seconds later, FM2 is within 1 km of where FM4 was 4 seconds earlier
- FM2 and FM4 orbit altitudes differ by a few hundred meters.



COSMIC Data Products and Formats



Data description	Level/Type	Main products	Resolution	Format	Latency
GPS receiver data from the POD antennae – one file per COSMIC POD antenna per dump	level 1a podObs	- time - phases - pseudo-ranges - SNRs	temporal: 1 sec	RINEX 2.20	\approx 115 min
LEO attitude and orbits (from real time navigation solutions) – one file per COSMIC satellite per dump	level 1a leoAtt	- time - attitude param. - position - velocity	temporal: 10 sec	ASCII	\approx 115 min
Precise LEO orbits – one file per COSMIC satellite per dump	level 1b leoOrb	- time - position - velocity	temporal: 1 min	SP3	\approx 145 min
IGS Ultra-Rapid GPS orbits (including 24 hr predicted orbits) – one file every 6 hr	level 1a gpsOrb	- time - position - velocity	temporal: 15 min	SP3	0 min
Absolute TEC to all GPS satellites in view (QC and bias resolved) – one file per COSMIC satellite per GPS satellite per arc	level 1b podTec	- time - absolute TEC - SNRs - Rx & Tx pos. - code biases	temporal: 1 sec	NetCDF	\approx 145 min



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Ionospheric occultation profiles from orbit altitude and down – one file per GPS occultation	level 2 ionPrf	<ul style="list-style-type: none">- time- lat., lon.- tangent altitude- occ. TEC- electron dens.	vertical: 2-3 km	NetCDF	\approx 145 min
Raw TIP (Tiny Ionospheric Photometer) nadir radiance data – one file per COSMIC satellite per dump	level 1a tipBin	<ul style="list-style-type: none">- time- counts	temporal: seconds	TIP native binary	\approx 115 min
Radiances from the TIP – one file per COSMIC satellite per dump	level 1b tipLv1	<ul style="list-style-type: none">- time- counts- radiances- Rx position- surface lat., lon.	temporal: seconds	NetCDF	\approx 115 min



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Summary and Instrument Status



- Three instruments on board each COSMIC satellite will provide ionospheric data:
 - GPS receiver: TEC, electron density profiles, and scintillations
 - TIP: Nadir intensity from radiative recombination emission along the sub-satellite track
 - TBB: TEC and scintillations on satellite-to-ground links
- COSMIC is in early check-out phase
 - All GPS receivers working; SNRs looking good; about 50 ionospheric profiles acquired so far
 - S/C attitude is currently not optimal; limits initial GPS data collection and data processing
 - Attitude expected to stabilize in a few days when solar arrays are switched to slow speed mode
 - TIP instruments performing well, but apertures not opened yet
 - TBB transmitters not yet turned on
- We anticipate that COSMIC will provide an unprecedented large amount of ionospheric data useful for data assimilation into space weather models and ionospheric research in general



Prospects for COSMIC II



- The expected lifetime of COSMIC is about five years
- COSMIC's latency is not optimal for space weather forecasting
- UCAR has been discussing with NOAA about a possible COSMIC follow-on mission (COSMIC II)
- This would provide the opportunity to design a system that would better support the space weather community needs
- It would be good to receive input from the community with regard to the requirements for such a follow-on mission