Comparison of ionospheric parameters derived from GNSS Radio Occultation and ionosonde data over equatorial and mid-latitude regions

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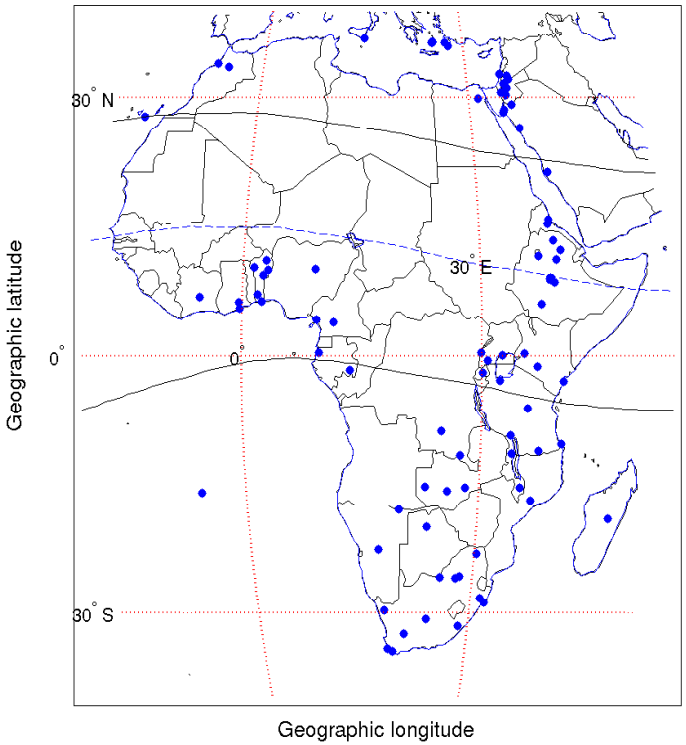
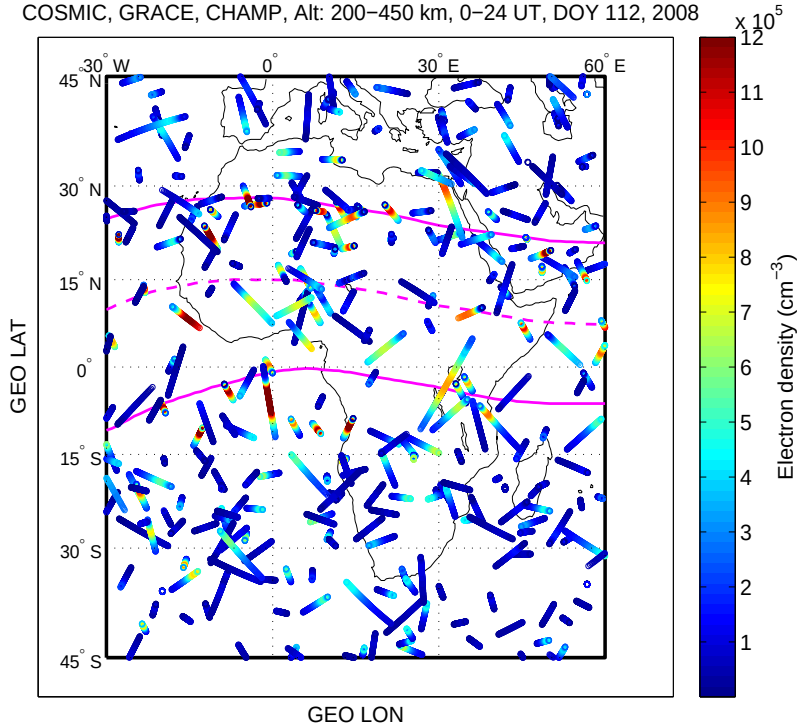
Aim is to supplement African GPS and Ionosonde coverage





- Four ionosonde stations with continuous data records (South Africa), 1 station over the ocean (Ascension Islands)
- Two newly installed ionosondes (Kenya and Ethiopia)
- Two ionosondes with some data (Ivory Coast and Nigeria).

Spatial coverage: Previous studies

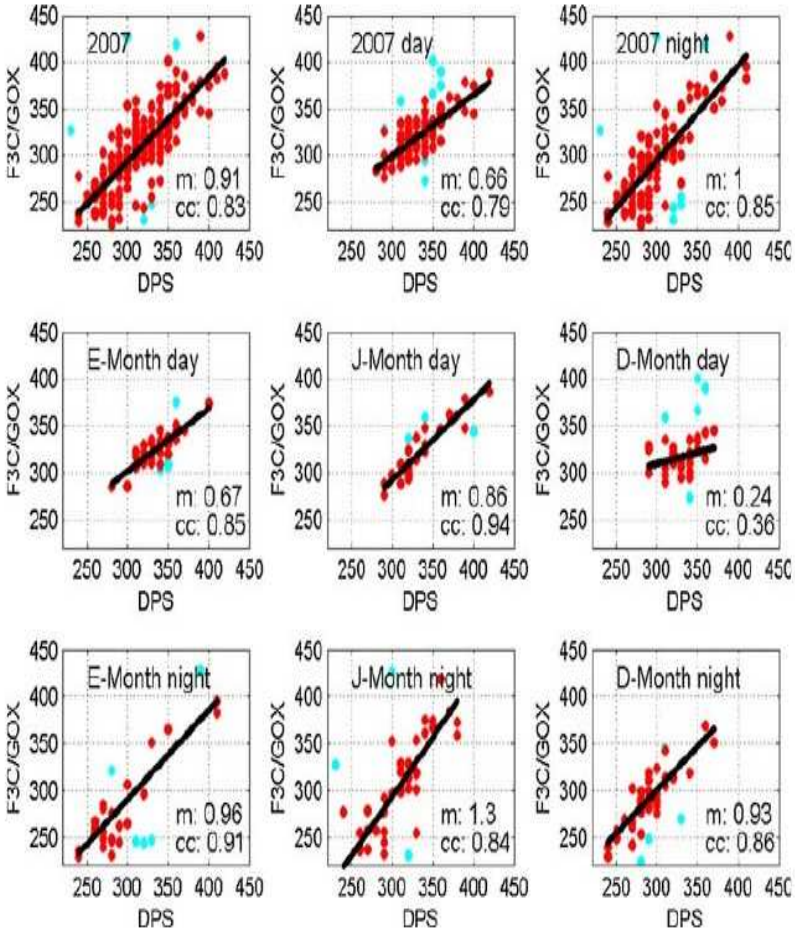
- Satellite passes give little data for direct comparative purposes
- Over any location of interest, there are latitude and longitude considerations:

1. Chu et al., (2010) did a global survey comparing COSMIC and ionospheric parameters using 1^o (latitude/longitude) coverage. Higher hmF2 values were observed for COSMIC data compared to ionosonde data and COSMIC Ne values were systematically smaller.
2. Liu et al., (2011) looked at global features of COSMIC data over mid and low latitudes during solar minimum (2008-2009), and reported complicated seasonal variations of NmF2, hmF2 etc.

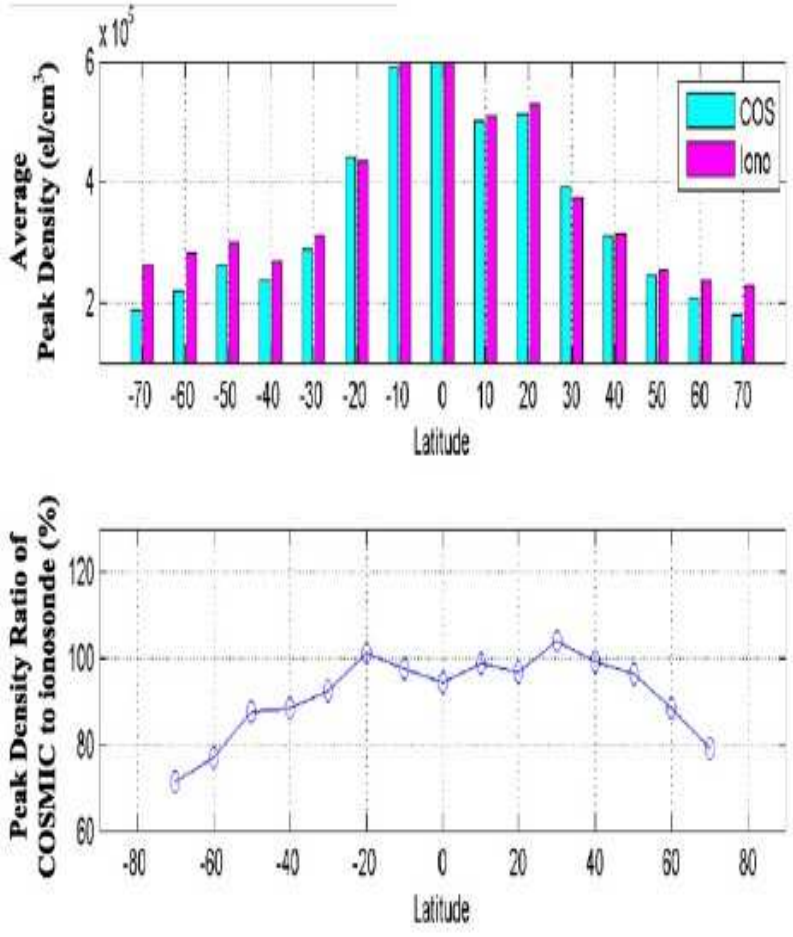
Regional studies

Krankowski et al., (2011) analysed COSMIC Ne and validated it with ionosonde data over Europe, found good agreement between the two data sets using the ionospheric correlation distance of 1000-1500 km

Regional studies ... continued



Liu et al., (2010): Electron density profiles in the equatorial ionosphere observed by the FORMOSAT-3/COSMIC and a digisonde at Jicamarca, GPS Solutions, 14, 75-81: $10^o \times 10^o$ latitude/longitude, 2007



Chu et al., (2010): A global survey of COSMIC ionospheric peak electron density and its height: A comparison with ground-based ionosonde measurements, ASR, 46 431-439: $1^o \times 1^o$ latitude/longitude, July 2006 - Feb 2007

Spatial considerations, what has been done

- Different electron density gradients do not allow uniform spatial choice for validation
- Consider latitudes/longitudes of $4^o \times 4^o$ to $1^o \times 1^o$ in steps of 0.5^o

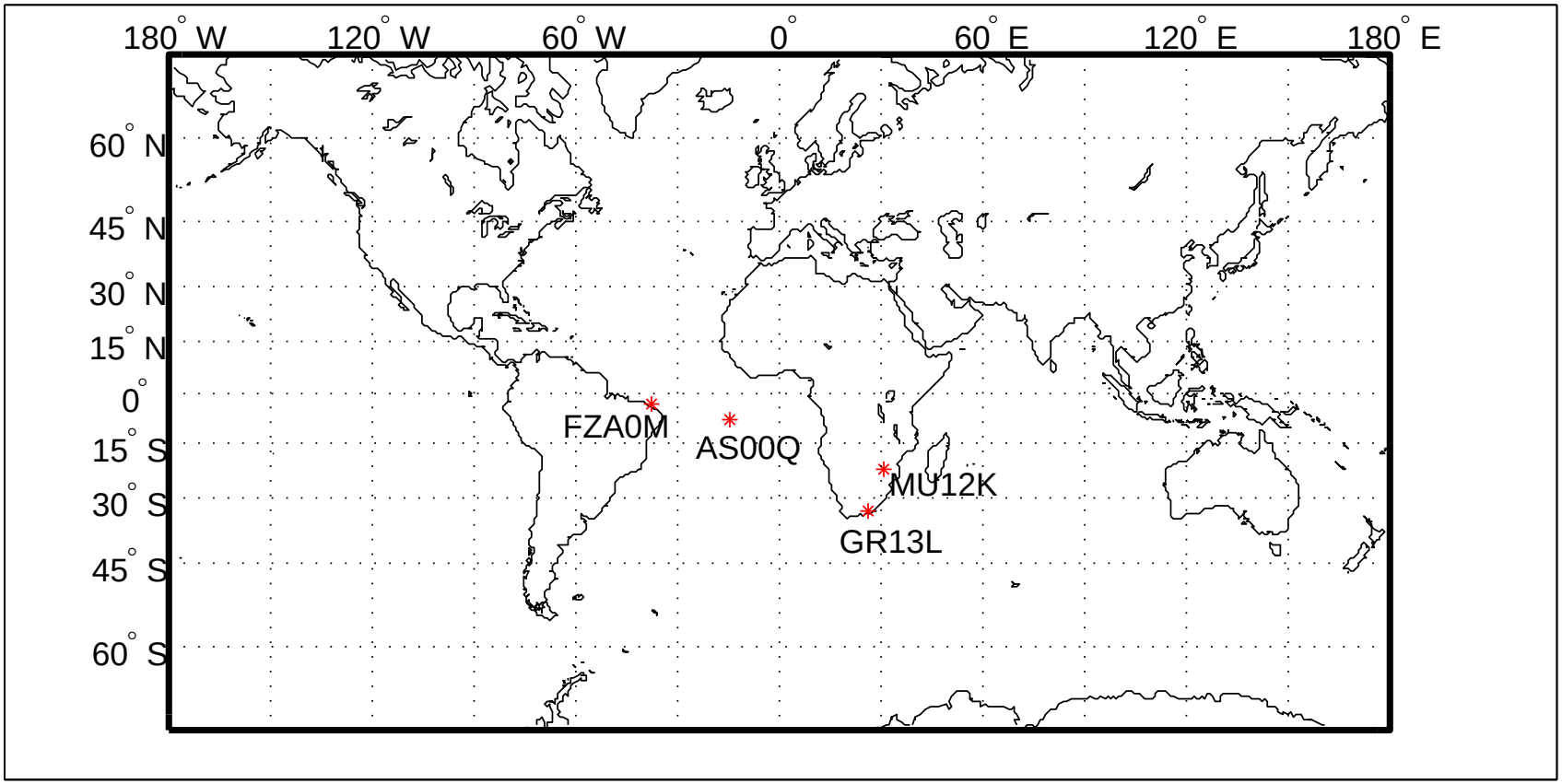
For every latitude/longitude combination find

$$X \approx F_t^i \cap F_t^c$$

where F_t^i is the ionosonde foF2 and time t and F_t^c is the COSMIC foF2 at time t, and compute root mean square errors, as long as the difference in time for both observations do not exceed the sampling time of the ionosonde data

$$R_c^i = \sqrt{\frac{1}{N}\sum_{j=1}^{N}(F_t^i - F_t^c)^2} \tag{1}$$

Study locations



MU12K: Madimbo, South Africa
GR13L: Grahamstown, South Africa
AS00Q: Ascension Islands, Africa (**John Bosco's allocation**)
FZA0M: Fortaleza, Brazil

Statistical results

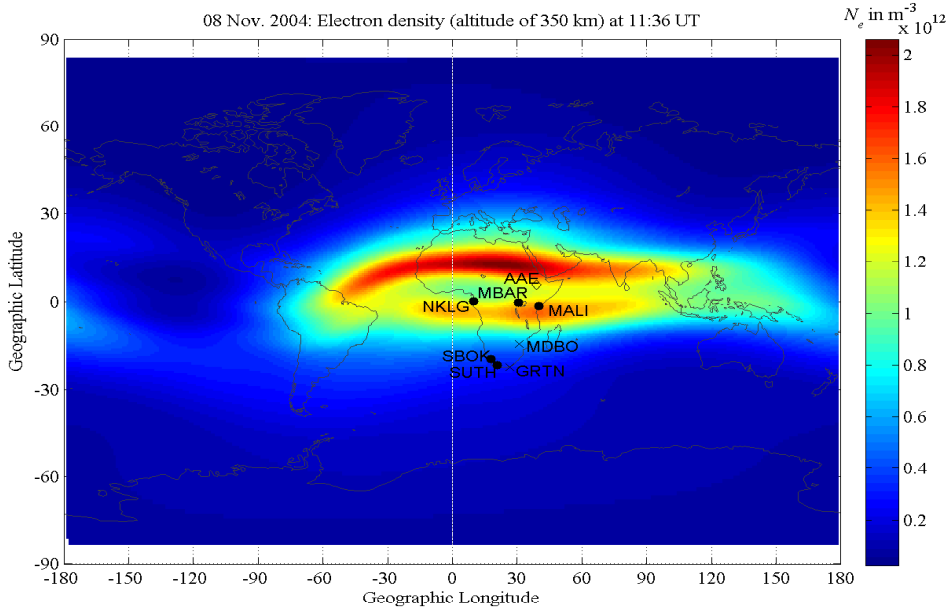
Based on monthly foF2 values from both ionosonde and COSMIC datasets

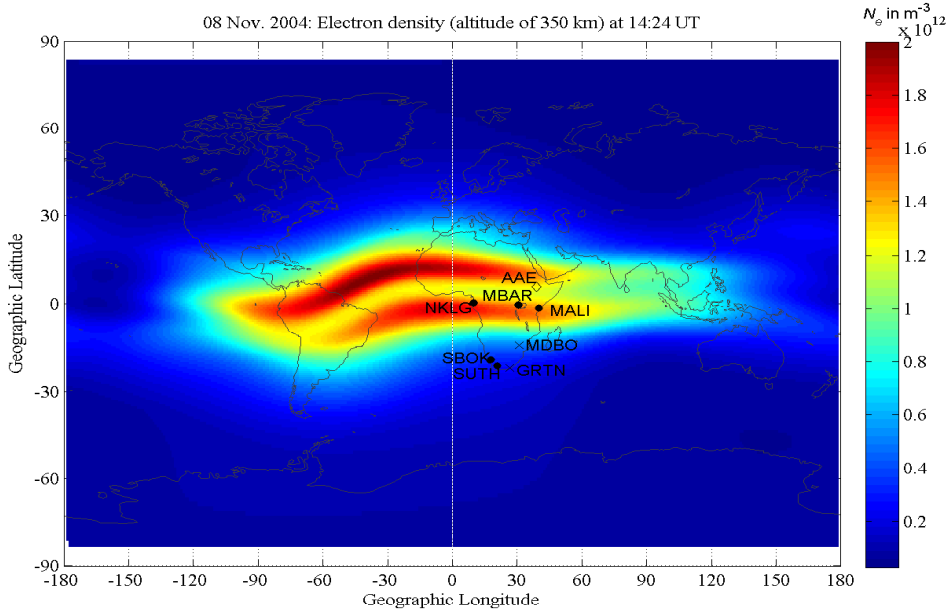
Table: Computed RMSE values between monthly average ionosonde and COSMIC foF2 values over GRL, FZA0M and AS00Q

Lat-Long combination	RMSE (in MHz)			
	GR13L (Jan 2008)	GR13L (Jan 2010)	FZA0M (Jan 2010)	AS00Q (Jan 2010)
$1^o \times 1^o$	1.226	-	2.285	1.967
$1.5^o \times 1.5^o$	1.388	-	2.022	1.462
$2^o \times 2^o$	1.275	-	2.107	2.204
$2.5^o \times 2.5^o$	1.344	-	1.831	**1.666**
$3^o \times 3^o$	**1.192**	-	1.904	2.030
$3.5^o \times 3.5^o$	1.300	-	1.636	1.835
$4^o \times 4^o$	1.298	-	**1.477**	**1.687**
$3^o \times 4^o$	1.330	-	1.668	-

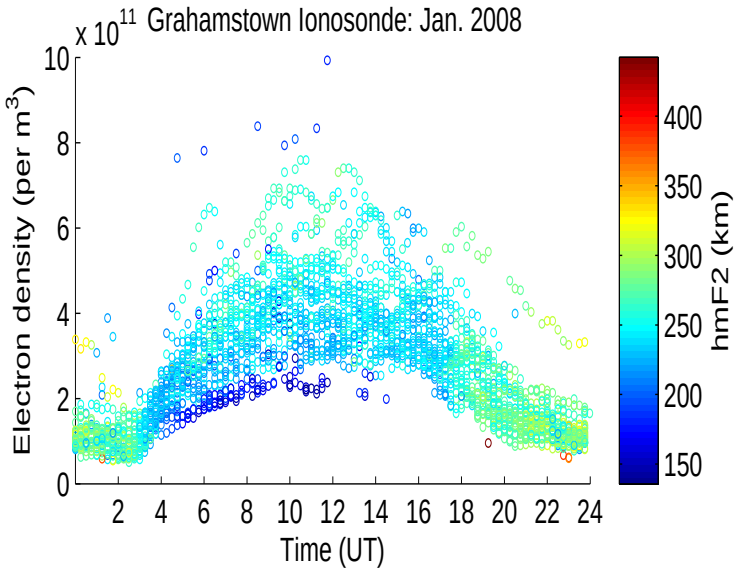
$1^o \approx 110$ km

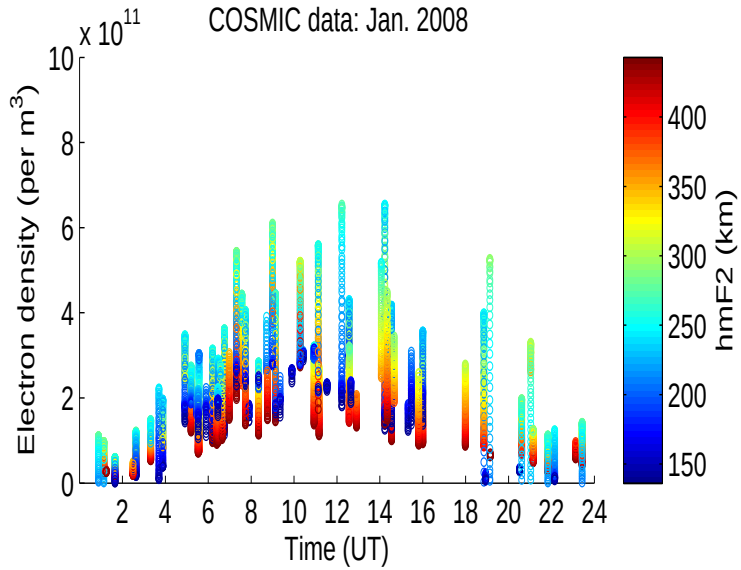
Varying electron density gradients

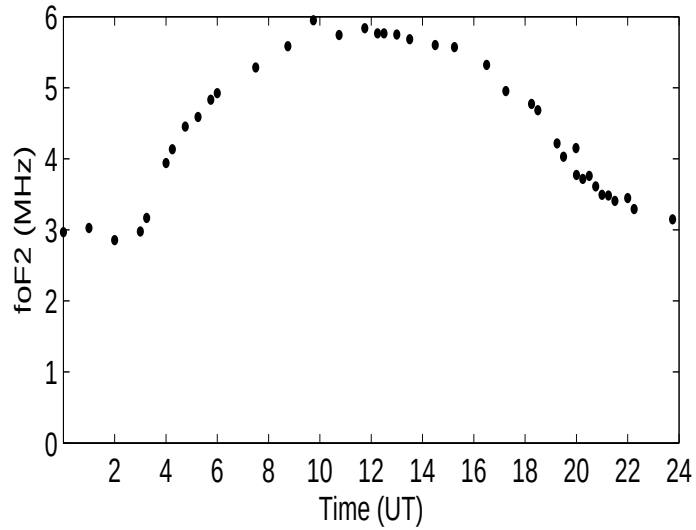


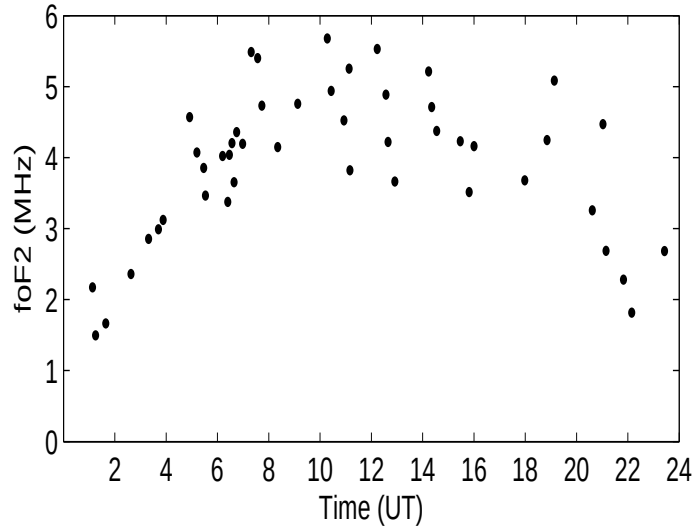


COSMIC and Ionosonde data: GR13L (33.3°S,26.5°E)

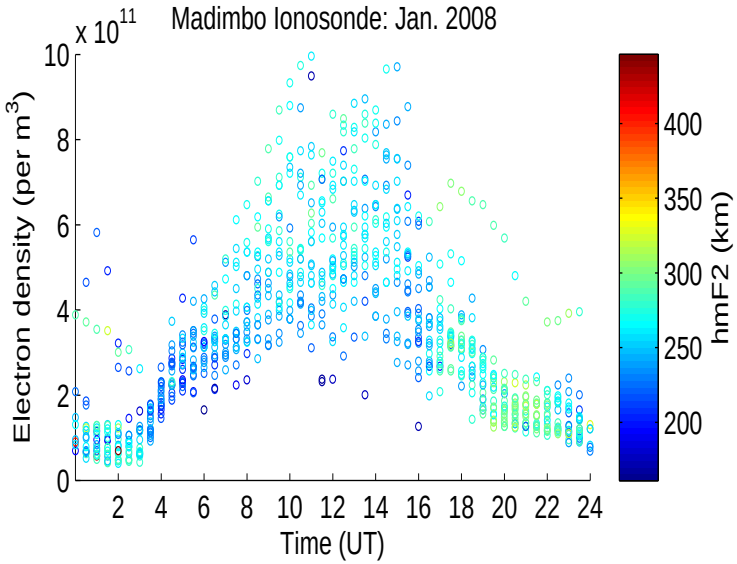


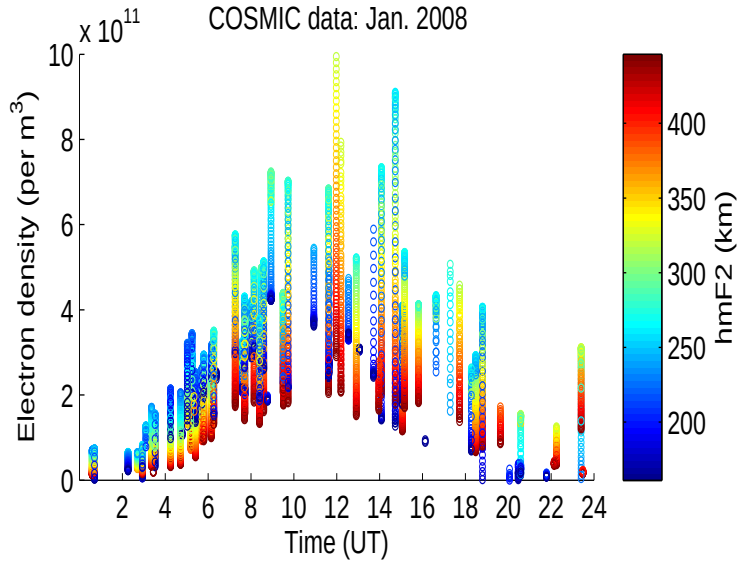


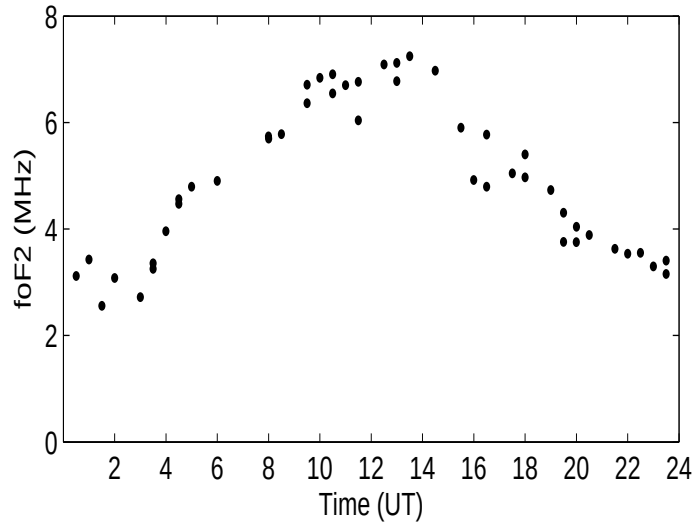


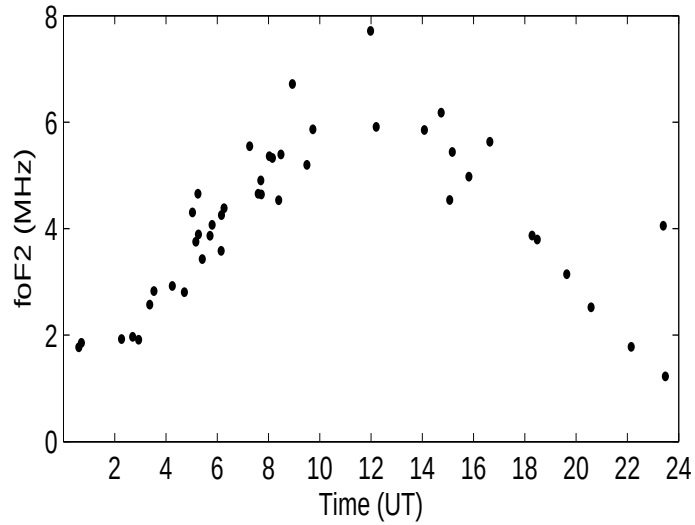


COSMIC and Ionosonde data: MU12K (22.4°S,30.9°E)

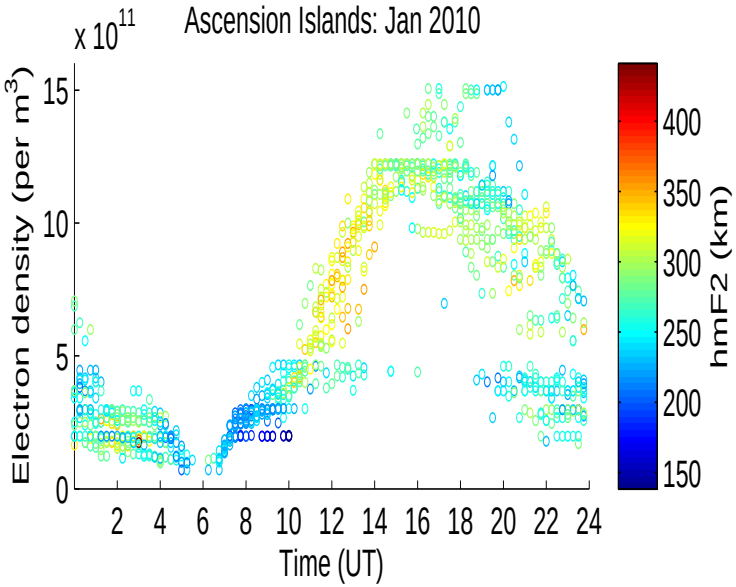


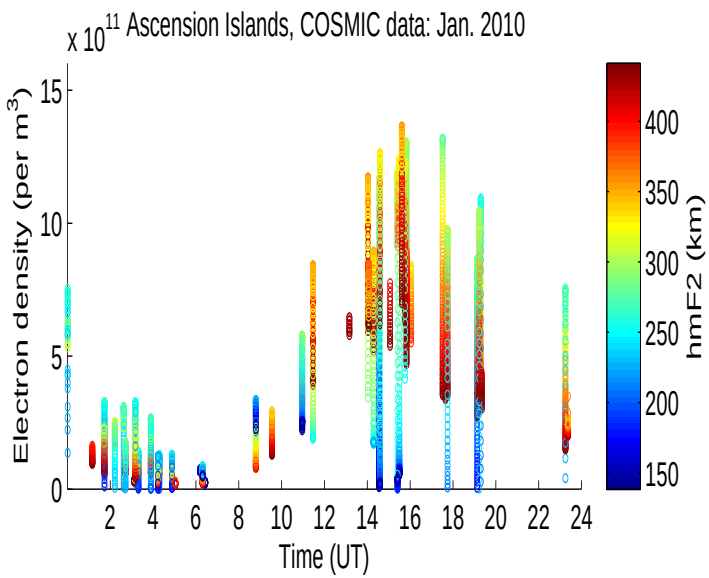


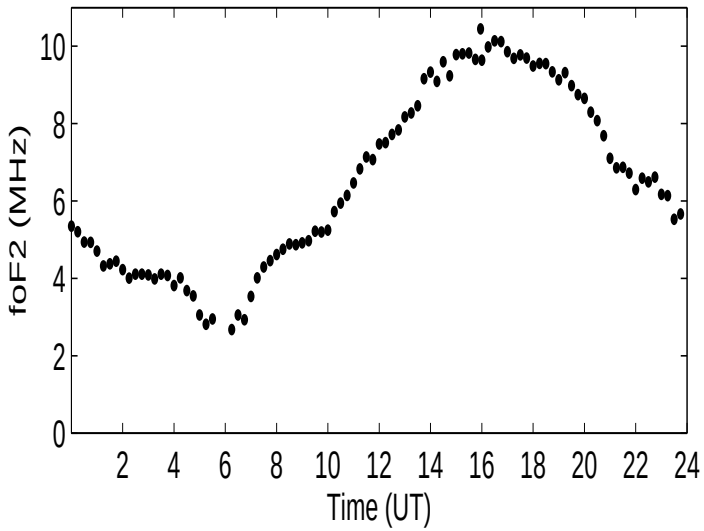


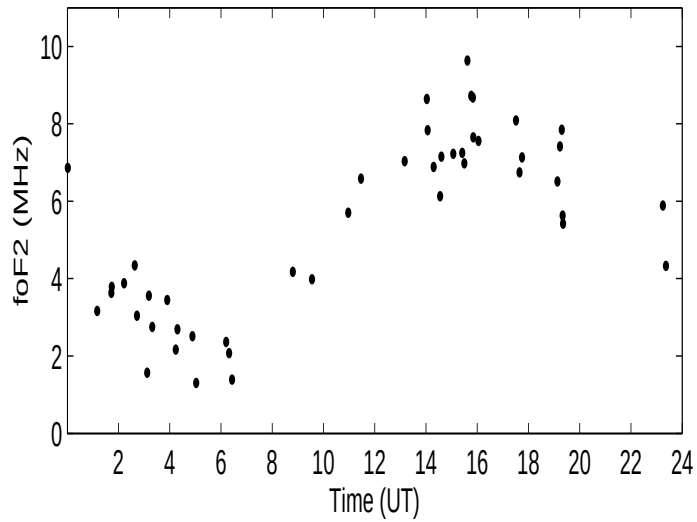


COSMIC and Ionosonde data: AS00Q (7.9°S,14.4°W)

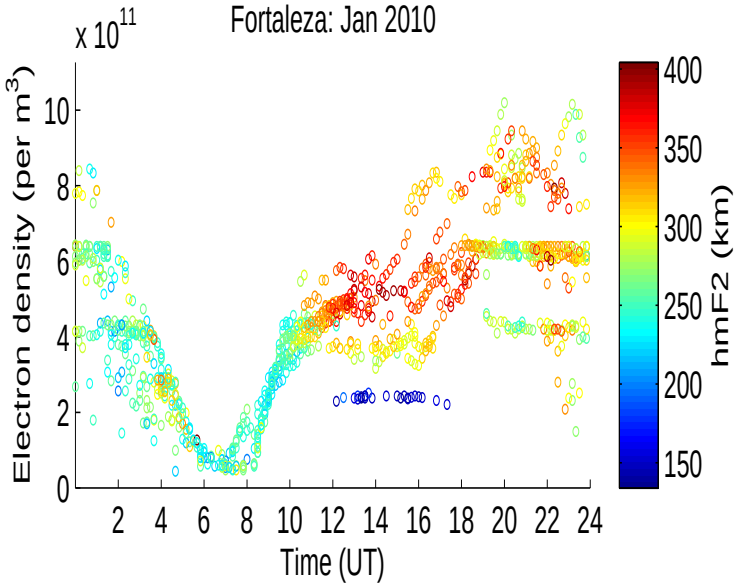


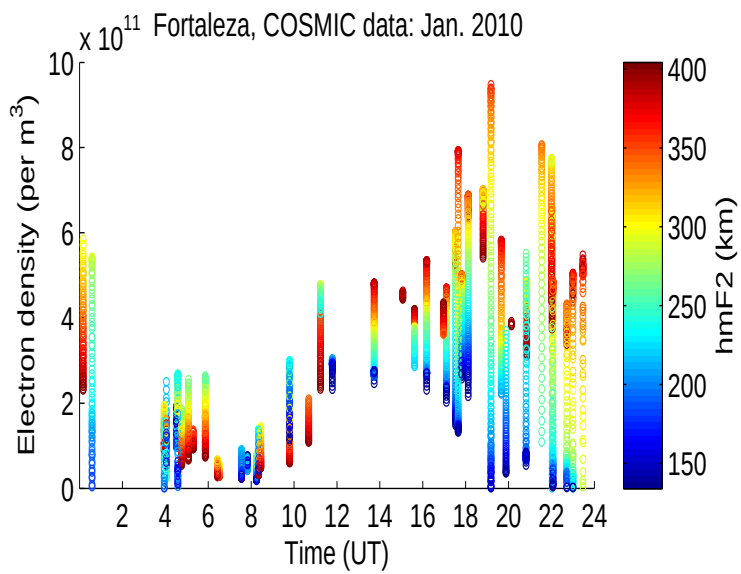


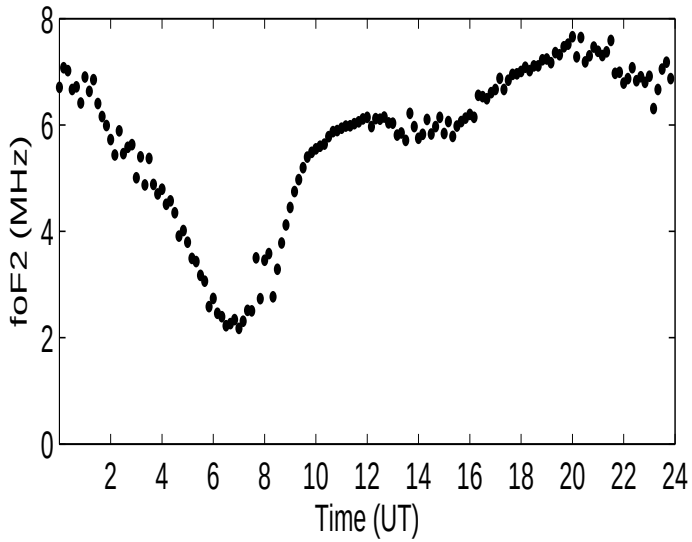


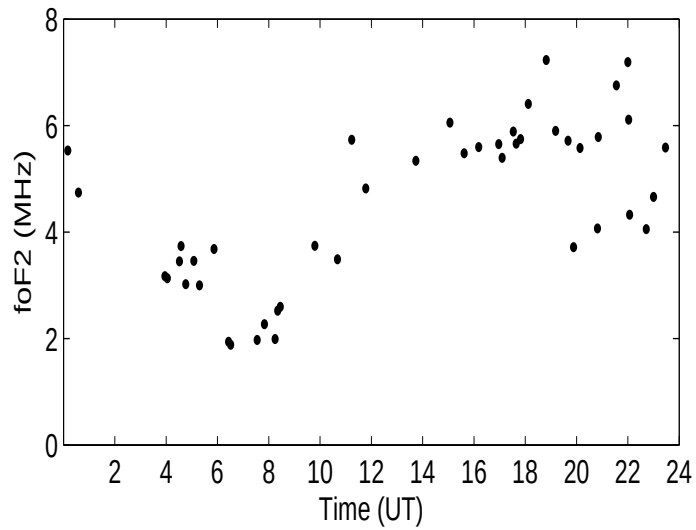


COSMIC and Ionosonde data: FZA0M (3.8°S,38°W)

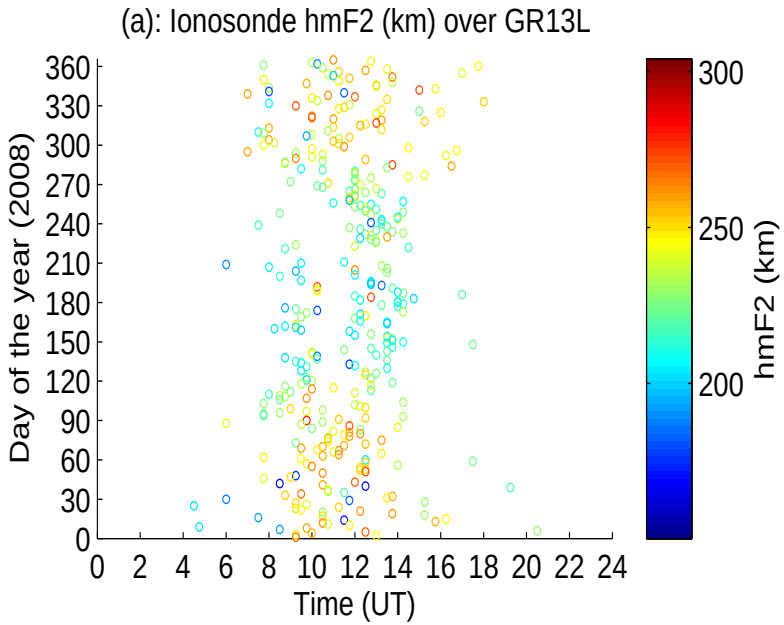


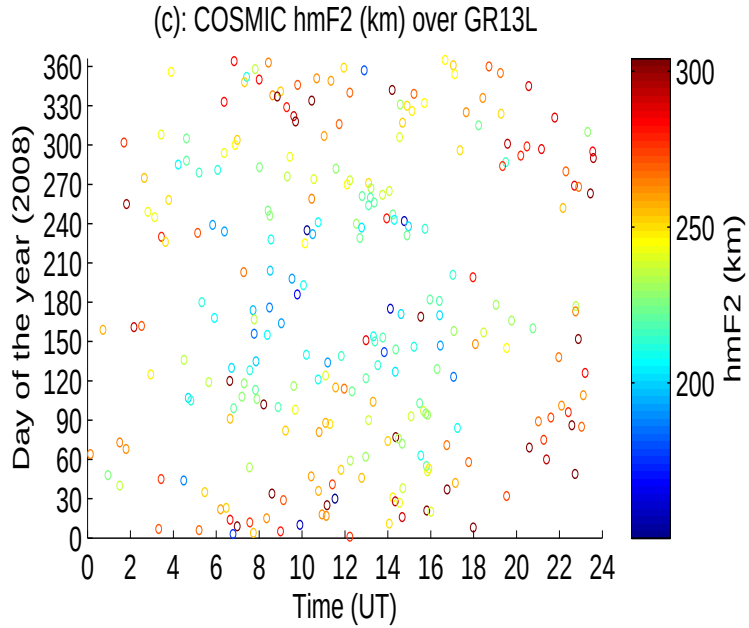


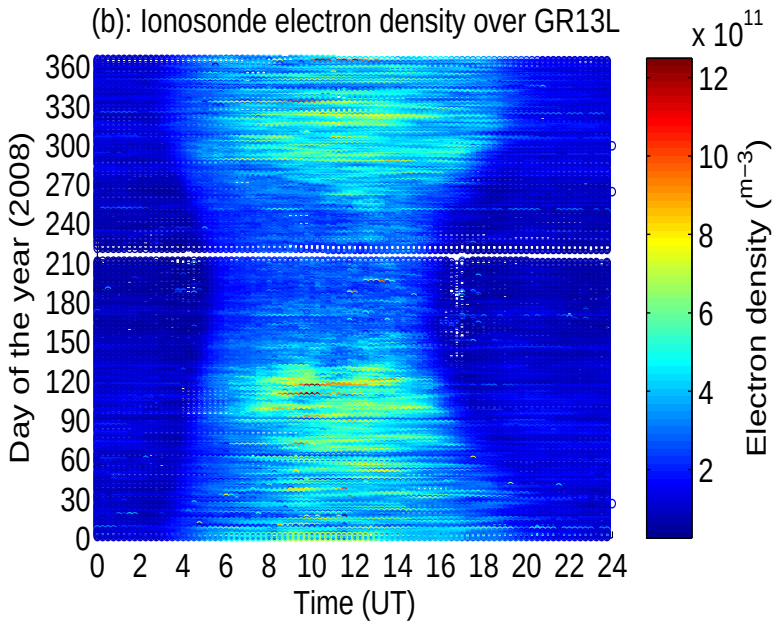


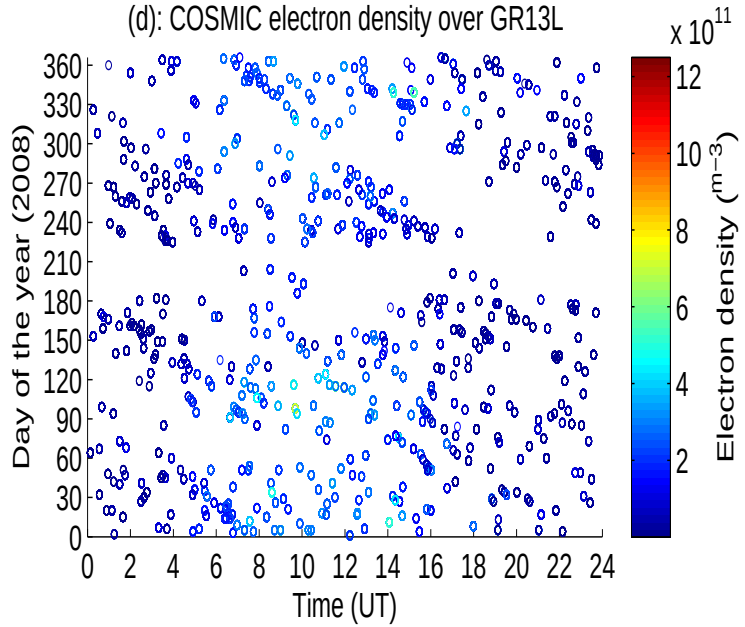


Year 2008 over GR13L, South Africa









Summary

- Spatial coverage differs with respect to region. Easily detectable over mid-latitudes than low latitudes
- COSMIC electron densities are systematically smaller than ionosonde values. Peak height COSMIC hmF2 is higher than ionosonde hmF2
- Performing a direct comparison is a difficult task and so averages are used to derive conclusions

References/Acknowledgements

1. Krankowski et al., (2011): Ionospheric electron density observed by FORMOSAT-3/COSMIC over the European region and validated by ionosonde data: J. Geod, 85, 949-964.
2. Liu et al., (2011): Features of the middle- and low-latitude ionosphere during solar minimum as revealed from COSMIC radio occultation measurements, JGR, A09307, doi:10.1029/2011/JA016691.
3. Yue et al., (2013): GNSS radio occultation (RO) derived electron density quality in high latitude and polar region: NCAR-TIEGCM simulation and real data evaluation, JASTP, 98, 39-49

- *Radio Occultation data was downloaded from ftp://cdaac-ftp.cosmic.ucar.edu/cosmic/level2/ionPrf/*
- *FZA0M and AS00Q data was downloaded from http://spidr.ngdc.noaa.gov*