First ionospheric radio occultation measurements from GNSS Occultation Sounder on the Chinese Feng Yun 3C satellite

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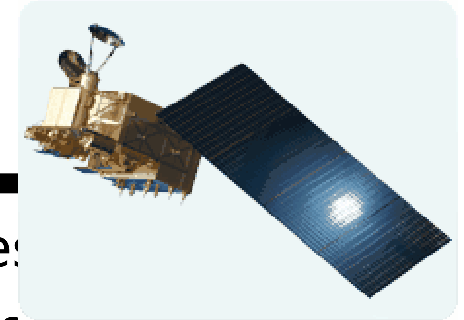
- FY3C/GNOS Description
- Comparison with ionosonde and COSMIC RO
- Comparison with IRI
- The ionization enhancement around E layer
- Summary

Introduction

- Advantages of RO
  - limb sounding geometry complementary to ground or space nadir viewing instruments;
  - high accuracy and precision;
  - high vertical resolution;
  - and full global coverage.
- EDPs of RO
  - Assumptions: straight-line propagation of signal, circular LEO orbit, spherical symmetry electron density, co-plane of occultation.
  - The spherical symmetry assumption is believed to be the main retrieval error source

FY3C/GNOS Description



- Feng Yun (FY) means 'Wind and Cloud' in Chines
- FY3 series — a follow - on mission of China FY1 series satellites
  - is consists of eight second-generation meteorological satellites
  - GNOS has been scheduled to fly on FY3 from FY3C to FY3H
  - The most outstanding feature of FY3C/GNOS is that it can track BDS(BeiDou Navigation Satellite System, also called COMPASS) signals in addition to GPS signals from space for the first time.
  - FY3C satellite was launched at 03:07 UTC on 23 Sep 2013 from Taiyuan Satellite Base, Shanxi Province in China.
  - The FY3C is a morning sun-synchronous satellite with an orbit altitude of 836 km and inclination of 98.75°.Its orbit period is about 104 min and the equatorial crossing time shifts between 10:00-10:20.
  - The FY3D is planned to be an afternoon (14:00 local time over Beijing) sun-synchronous satellite and will be launched in 2016.

FY3C/GNOS Description

- GNOS was developed by CSSAR/CAS
- GNOS data are officially processed and archived by NSMC/CMA
- In fully operational mode, FY3C/GNOS can observe ~500 GPS radio occultations and ~200 BDS radio occultations globally per day.

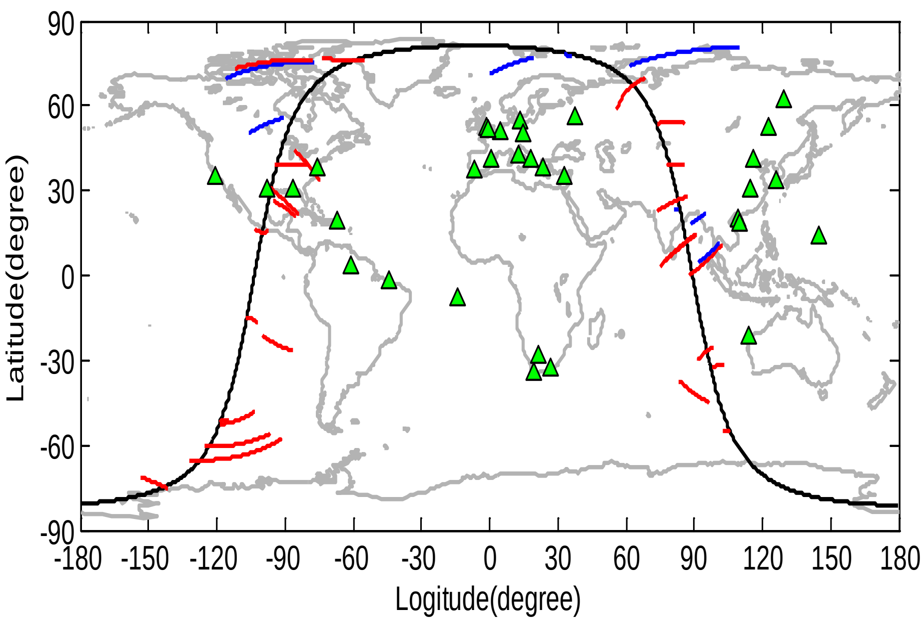


Figure 1. A random FY3C obit (the black line) with the position of tangent point of BDS RO events (blue lines) and of GPS RO events (red lines).

FY3C/GNOS Description

GNOS

- The positioning antenna,
  - ➢ wide beam low gain
  - ➢ Point at zenith with hemispherical coverage
  - ➢ 1-Hz sampling rate.
  - ➢ up to 6 BDS & 8 GPS satellites simultaneously.
- The occultation antennas,
  - ➢ ionospheric occultation in 1 Hz
  - ➢ the atmospheric occultation in 50 Hz of PLL and/or 100 Hz of OL.
  - ➢ up to 4 BDS satellites and 6 GPS satellites.

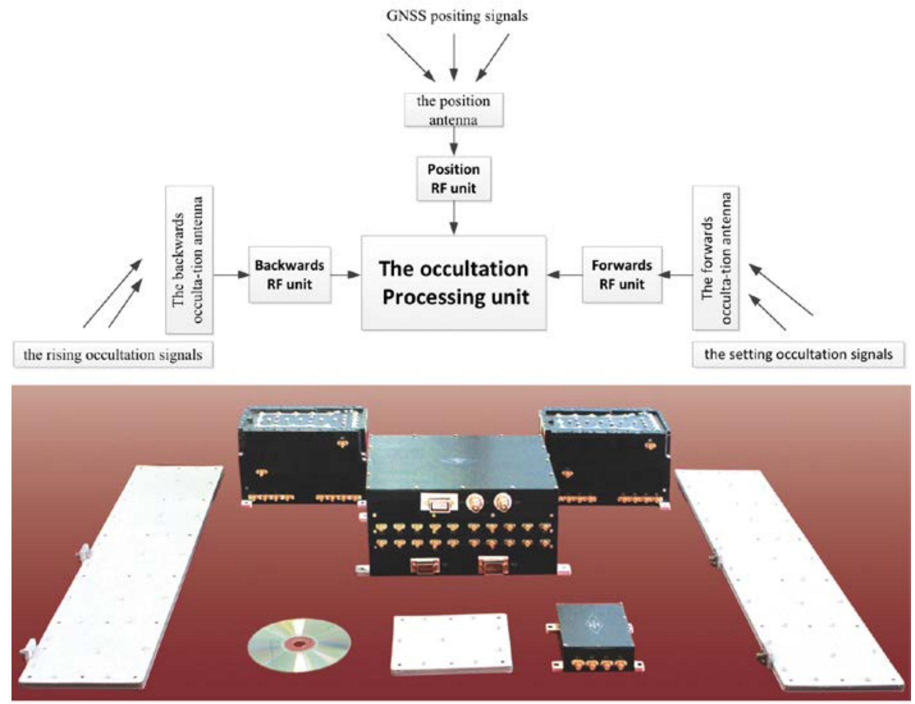


Figure 2. FY3C/GNOS configuration.

Bai et al. , 2014

FY3C/GNOS Description

Generally，the BDS SNR behave similarly to GPS SNR

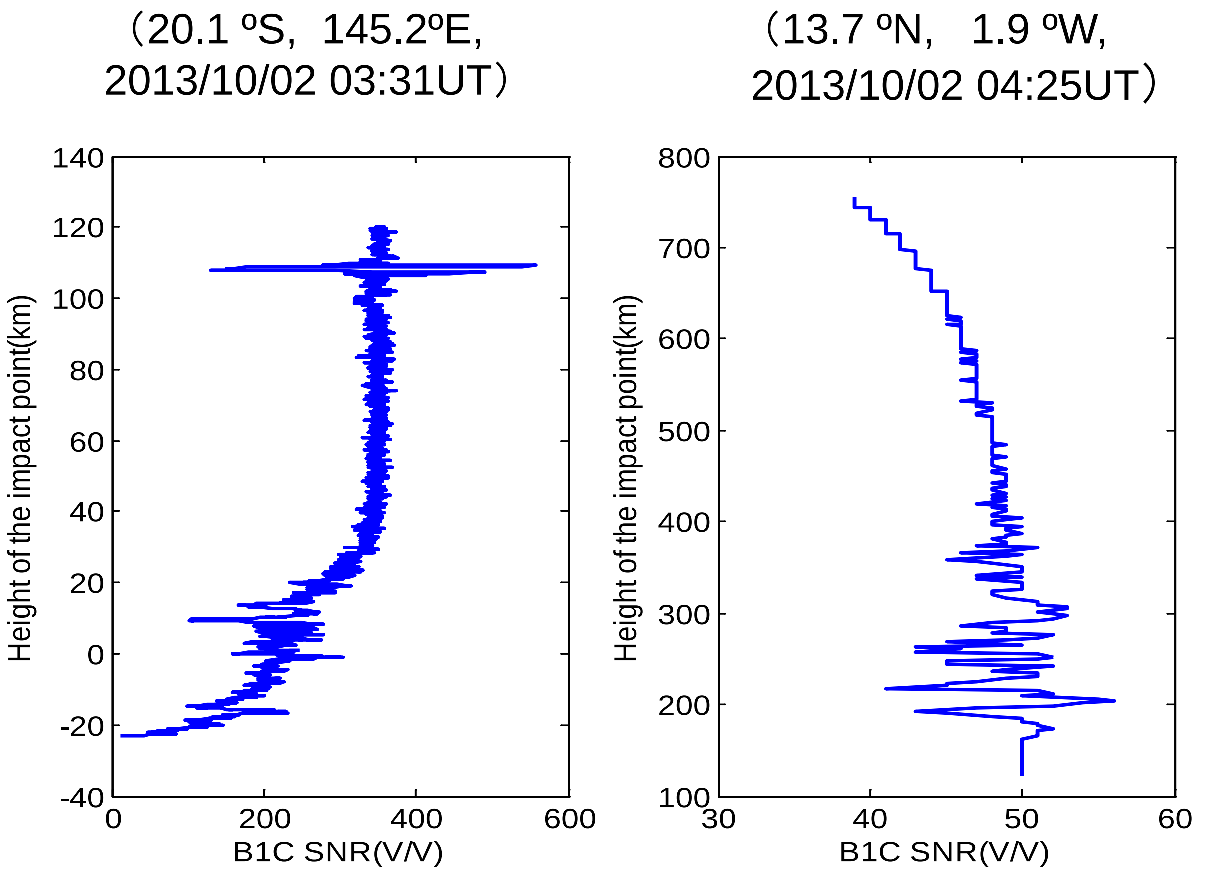


Figure 3. The left panel shows typical SNR oscillations of GNOS BDS B1C due to sporadic E layer observed by the atmospheric occultation (50Hz) antenna. The right panel shows typical SNR oscillations of GNOS BDS B1C due to Spread F observed by the ionospheric occultation (1Hz) antenna.

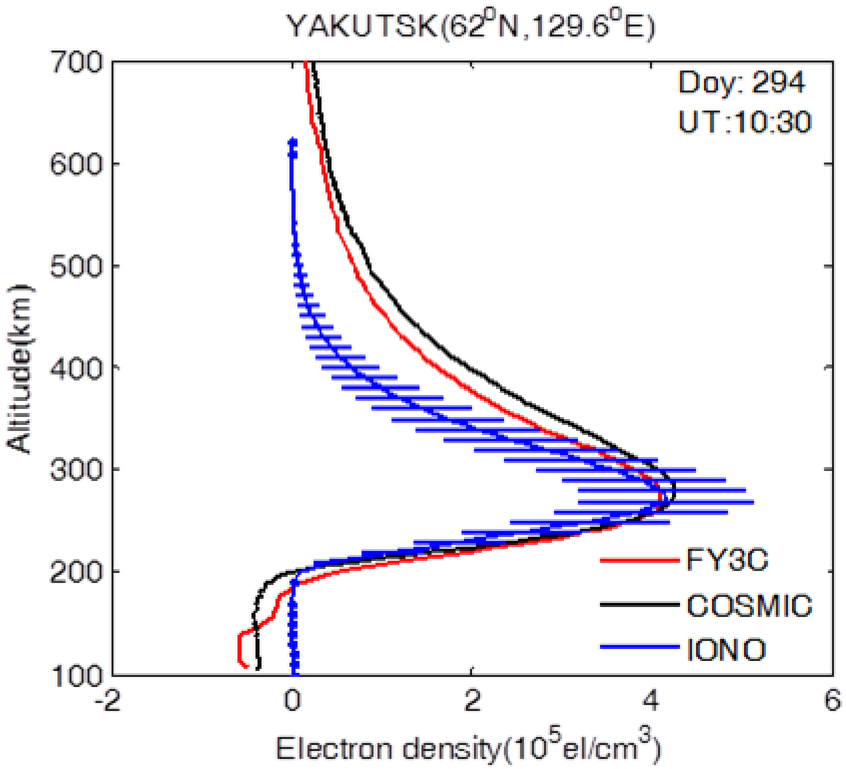
Comparison with ionosonde and COSMIC RO

- In the comparison,
  - the maximum time difference between the two observations is 7.5 min
  - and the maximum space difference is 2.5°.
  - Furthermore, the ionograms with strong spread F or without well-defined traces were discarded.
  - data for periods (until 3 h after or before) with Kp index greater or equal to 5 were also discarded.
  - The error bar indicates the EDP difference of ionosondes between the maximum value and the minimum value at the same height from t-30min to t+30min.

(Ely et al., 2012)

Comparison with ionosonde and COSMIC RO

1.Comparison with ionosonde and COSMIC RO



The rms of the differences:

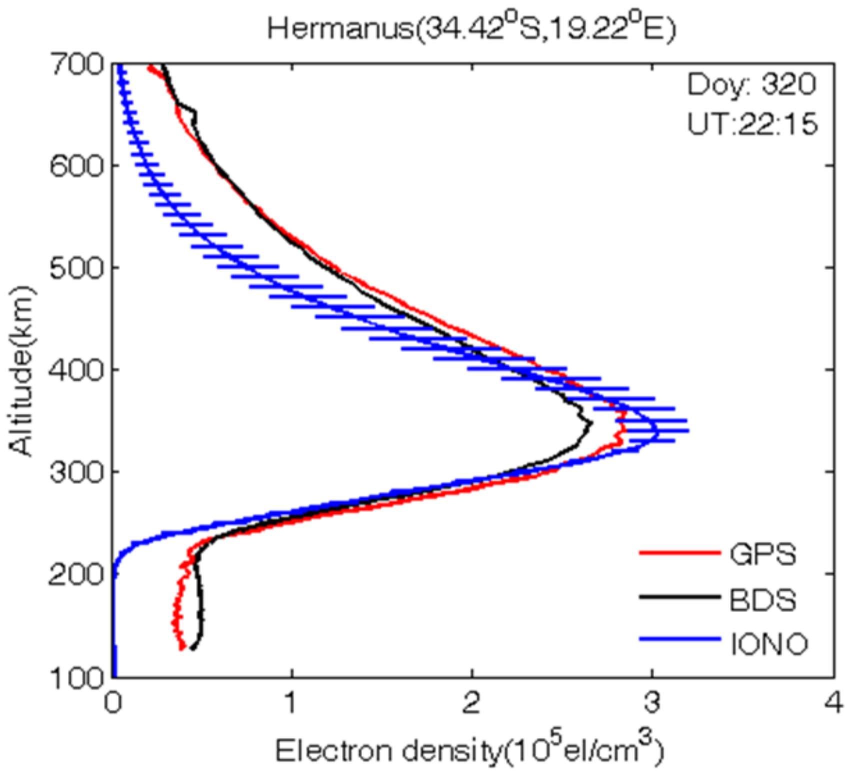
FY3 vs ionosonde <15% / 10%
(from 230 / 240km to peak height)

COSMIC vs ionosonde <10% / 7%
(from 230 / 240km to peak height)

FY3C/GNOS :129.7ºE, 64.1ºN,10:33UT
Ionosonde : 129.6ºE, 62.0ºN,10:30UT
COSMIC/RO: 130.2ºE, 59.7ºN,10:36UT

Comparison with ionosonde and COSMIC RO

2.Comparison of GPS RO and BDS RO



The rms of the differences:

- GPS vs ionosonde <9%

(from 270km to peak height)

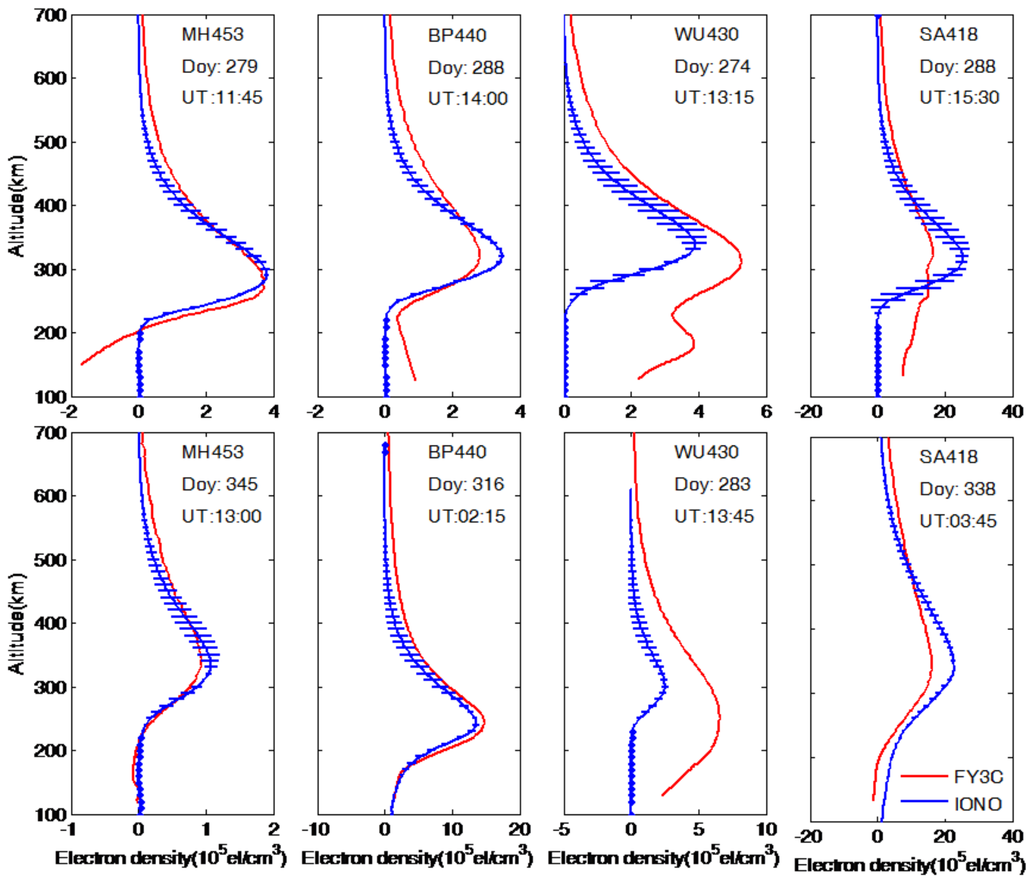
- BDS vs ionosonde <7%

(from 270km to peak height)

FY3C/GPS :16.8ºE, 35.2ºS, 22:10UT
FY3C/BDS :17.1ºE, 36.9ºS, 22:09UT
Ionosonde :19.2ºE, 34.4ºS, 22:15UT

Comparison with ionosonde and COSMIC RO

3.Comparison of EDPS at different latitudes



EIA region has larger ionospheric horizontal gradients, which will result in more significant Abel inversion error .

- Mohe(122.5°E, 52.0°SN)

Almost within the error bars of the ionosonde EDP

- Beijing(116.2°E, 40.3°SN)

Close to the ionosonde EDP

- Wuhan(114.4°E, 31.0°SN)

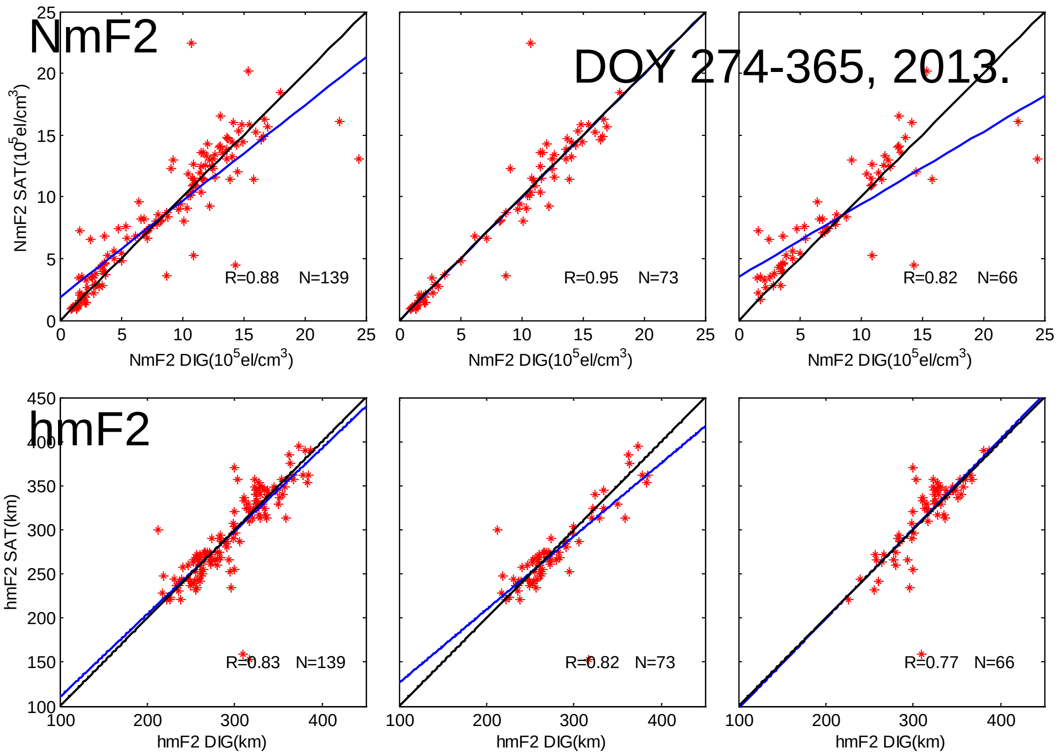
in the same order of magnitude, but are different obviously

- Sanya(109.6°E, 18.3°SN)

in the same order of magnitude, but are different obviously

Comparison with ionosonde and COSMIC RO

4.Comparison of NmF2 and hmF2 at different latitudes



90°S~90°N

90°S~35°S
& 35°N~90°N

35°S~35°N

The black line: the diagonal line
The blue line: a linear fit to the data points.

The correlation coefficients :

Left:

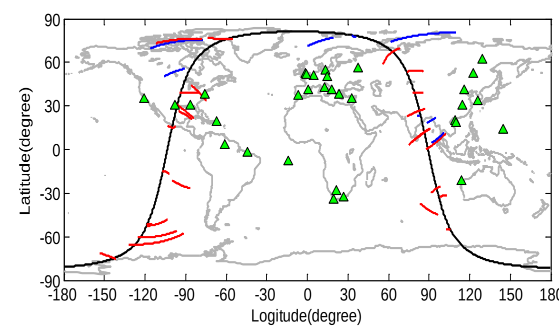
NmF2 R=0.88
hmF2 R=0.83

Middle:

NmF2 R=0.95
hmF2 R=0.82

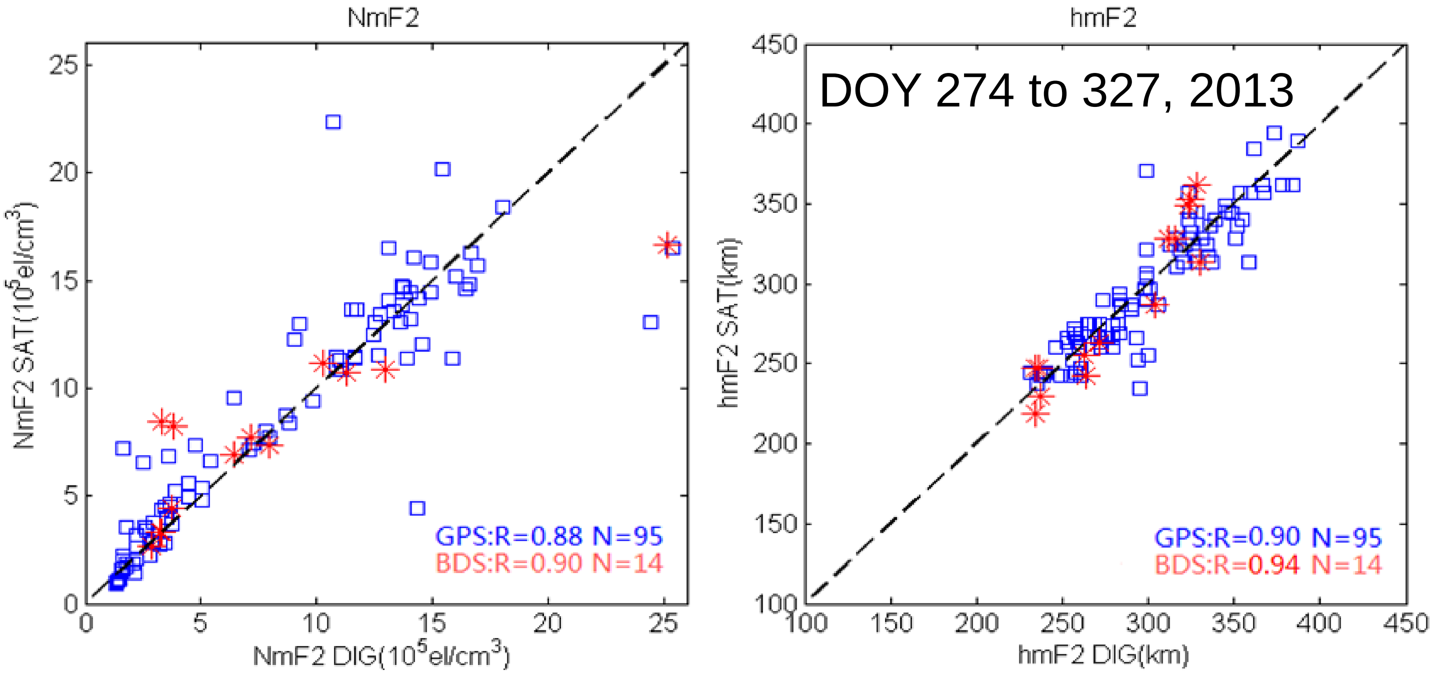
Right:

NmF2 R=0.82
hmF2 R=0.77



Comparison with ionosonde and COSMIC RO

5.Comparison of BDS RO and GPS RO

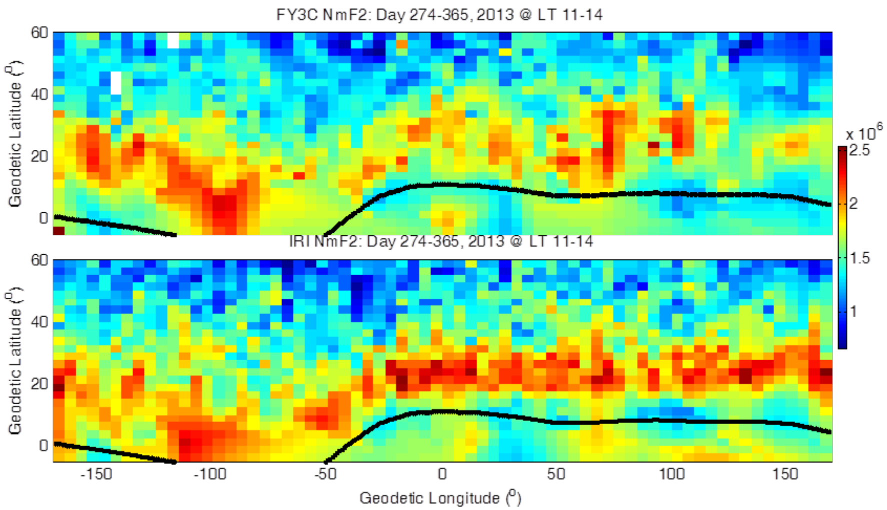


The blue squares are GPS RO observations
The red stars are BDS RO observations.

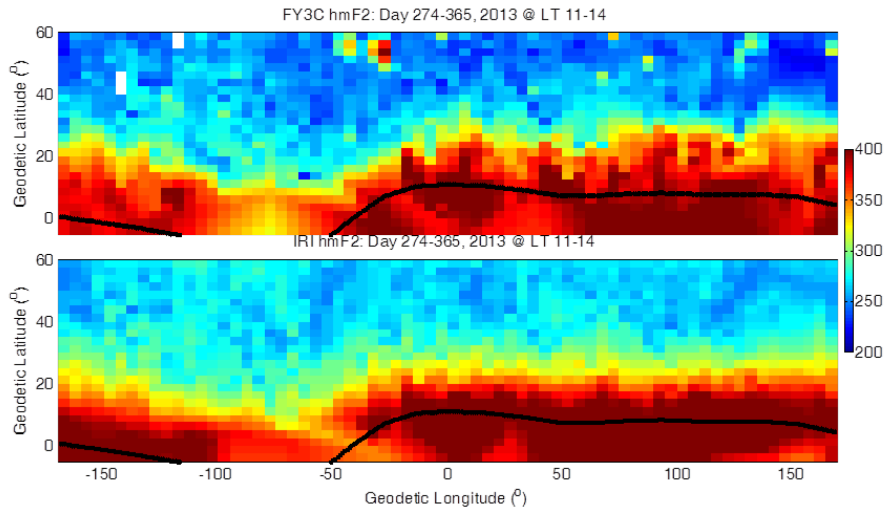
Comparison with IRI

The maps of noontime NmF2 and hmF2 derived from FY3C/GNOS measurements (upper panel) and the International Reference Ionosphere (IRI) model in Northern Hemisphere (days 274-365, 2013).

NmF2

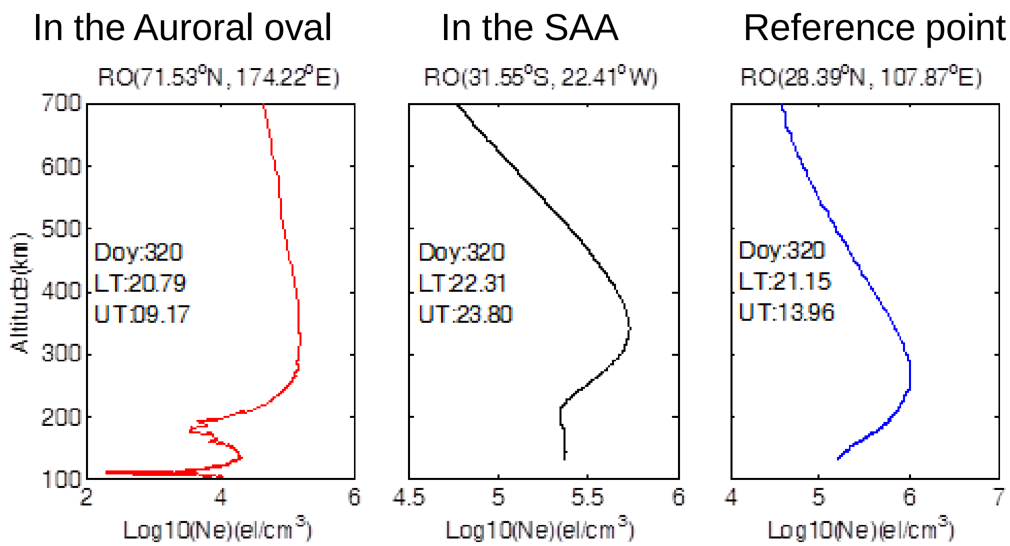


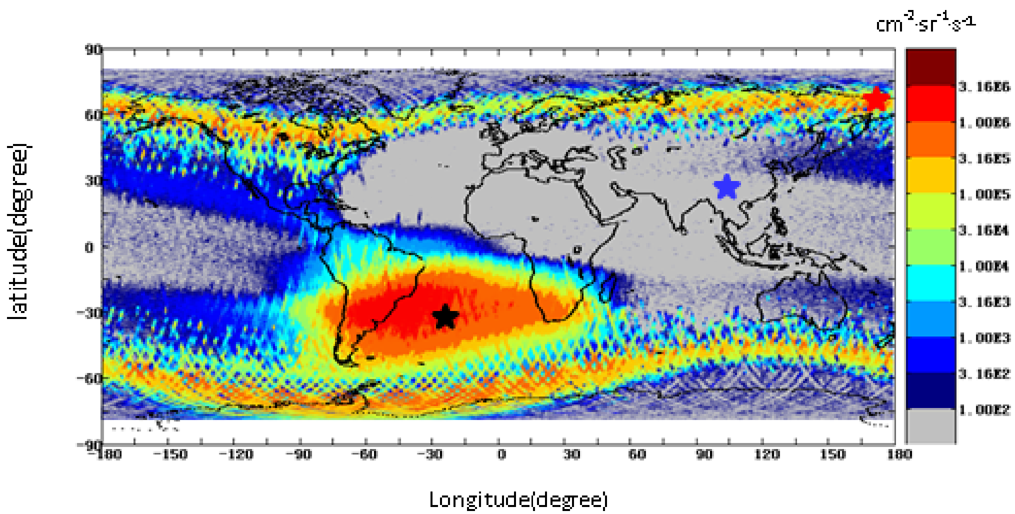
hmF2



- FY3C are mainly in the Northern Hemisphere because the satellite orbits is a solar-synchronization orbit.
- The FY3C results are lower than those modeled by IRI.
- FY3C/GNOS NmF2 of low-latitude ionosphere shows the remarkable longitudinal wavenumber-4 patterns over west Africa, Southeast Asia and Central Pacific Ocean.(Enhancement over South America can not be seen in the FY3C obit)

The ionization enhancement around E layer





- The RO EDPs show significant ionization enhancement around E layer in the Aurora region due to the energetic particle precipitation.
- There also exists enhancements of energetic particle precipitation in the South Atlantic Anomaly (SAA).

Summary

- In this article we gave an overview of FY3C/GNOS measurements.
- We then compared EDPs retrieved from FY3C/GNOS with those observed by ionosonde. These preliminary comparisons show that there is agreement between FY3C/GNOS profiles and ionosondes profiles in the middle-to-high latitude and there are obviously differences in the EIA region.
- Comparisons have also been made between ionospheric peak parameters retrieved by FY3C and those measured by globally distributed ionosondes, and agreement is also obtained in this case. The results indicate that NmF2 and hmF2 retrieved from FY3C/GNOS measurements are reliable and can be used for ionospheric physics studies.
- The comparison between the FY3C/GNOS data and the IRI model is also reasonably good, but the IRI model tends to overestimate NmF2 at the crests of the equatorial anomalies.
- Furthermore, FY3C/GNOS EDPs show ionization enhancement around E layer during nighttime due to the energetic particle precipitation over the Aurora and SAA regions.

Acknowledgements

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Thanks!

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More details:

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FY3C/GNOS Data are available on web:

www.nmsc.org.cn