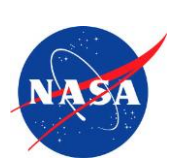# Effect of small scale ionospheric variability on RO data quality

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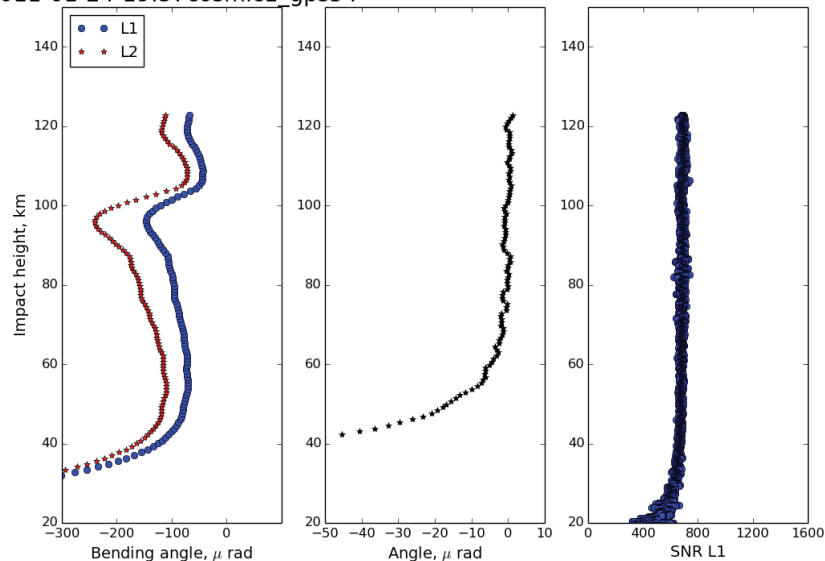*2.* Moog Advanced Missions & Science, Golden, CO, *USA.*

Objectives:

- Focus on retrieved atmospheric refractivity based on COSMIC1 ROs from 20 km to 25 km altitude and relate its uncertainty to SNR characteristics of GPS signal passing through ionospheric E-layer (altitude ~ 100 to 130 km).

- Propose a metric for refractivity bias based on a fractional difference of retrieved refractivity and a <u>reference value</u> taken from the ECMWF.

- Evaluate error bounds and possible biases in atmospheric refractivity retrievals due to small-scale ionospheric irregularities (horizontal size ~100s km, vertical ~ several km)
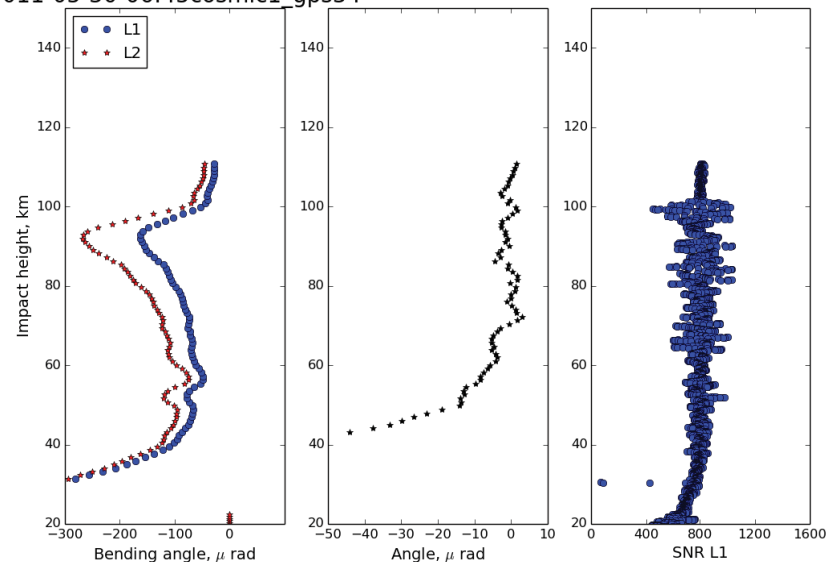
a

b
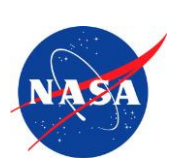
Examples of processing COSMIC-1 setting RO profiles:

(a)   January 24, 2011 at 19:57 UT
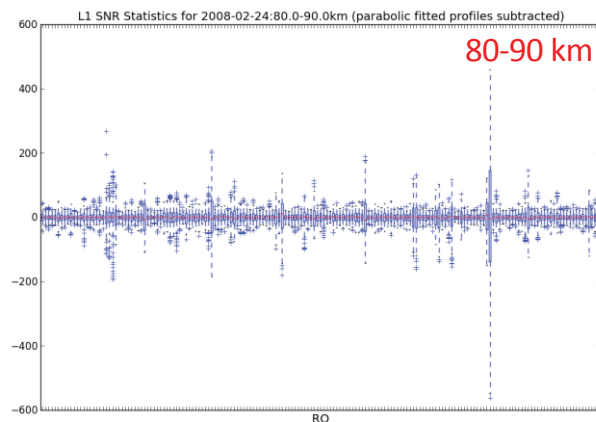
(b)   May 30, 2011 at 06:45 UT.

Left panels show **bending angle profiles for L1 and L2 carrier signals, α_1 and α_2,** correspondingly.

Central panels show **the ionosphere corrected (α_{IC}) bending angle**. Right panels show L1 SNR.
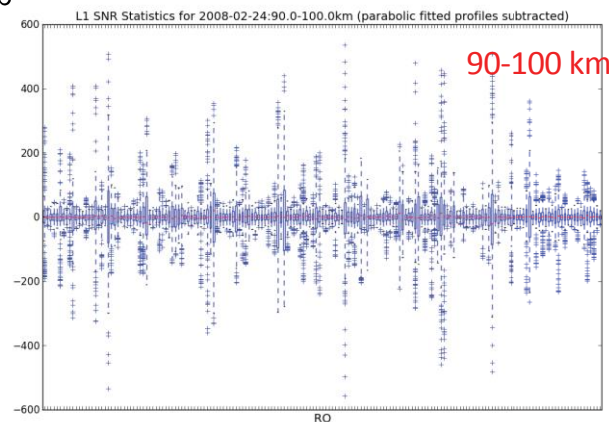
Statistical properties of L1 SNR variability for RO profiles in different altitude ranges
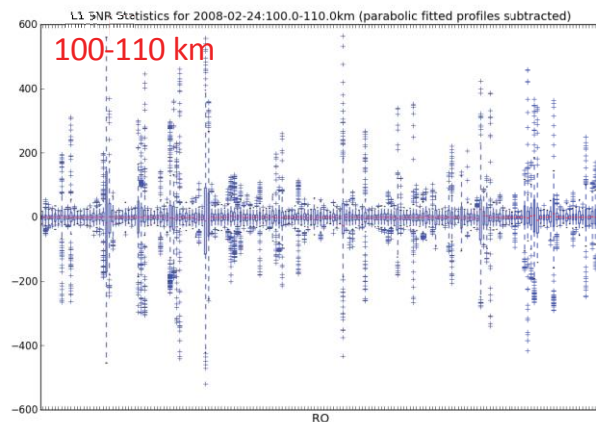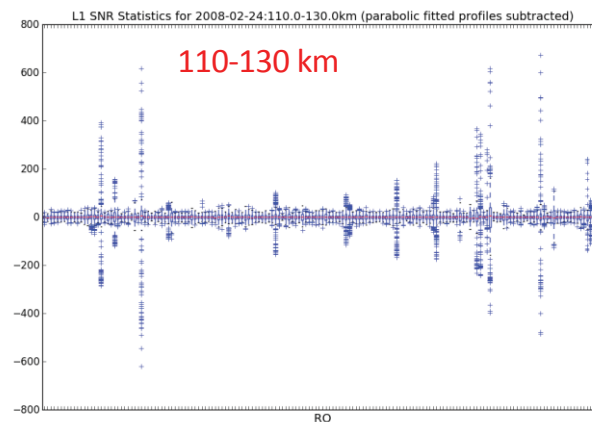
a

b

c

d

Small-scale SNR variability metrics:

- Per each L1 SNR profile a parabolic fit within a certain narrow altitude range is subtracted from the profile.
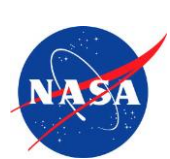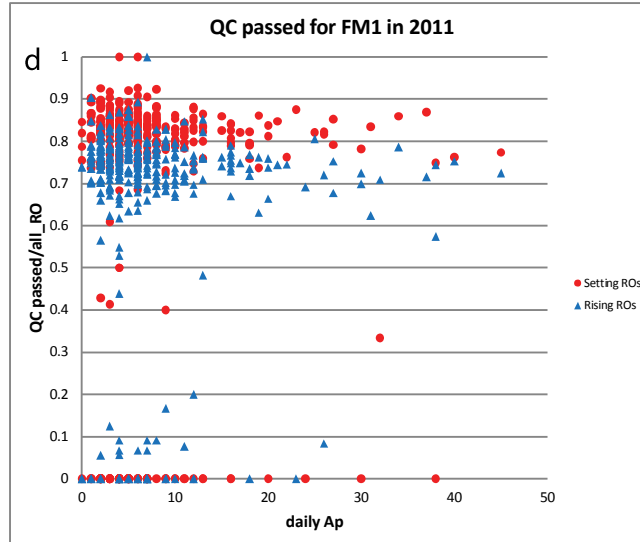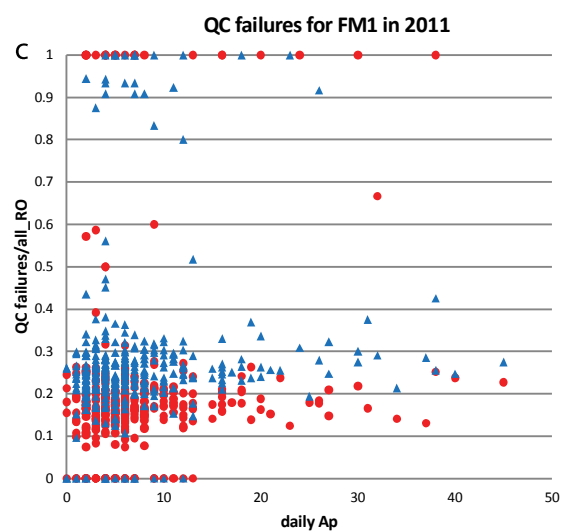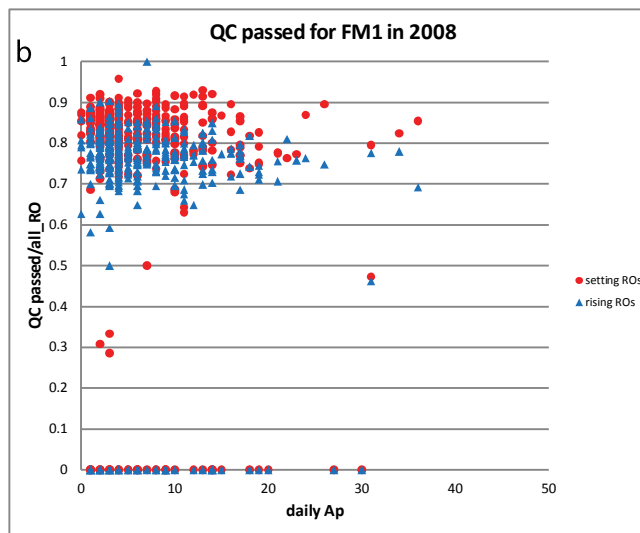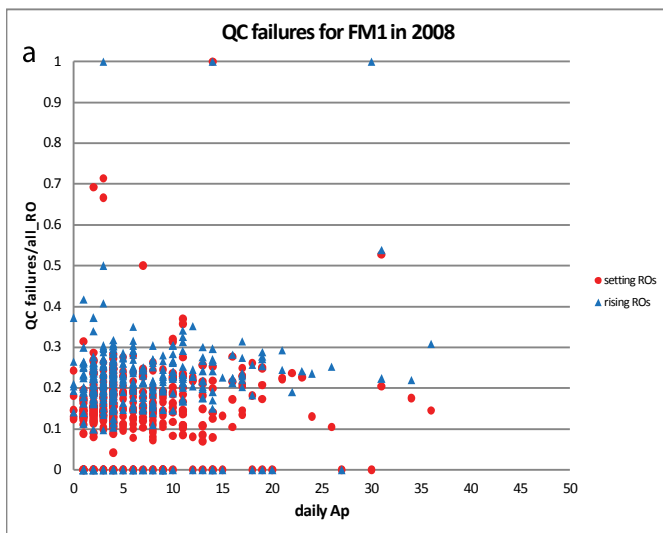- IQR (*inter-quantile range*) is calculated for the residual.

February 24, 2008: **statistical box plots for individual RO profiles** in the altitude ranges
(a) from 80km to 90 km, (b) from 90 km to 100 km, (c) from 100km to 110 km,
(b) (d) from 110 km to 130 km (d).

# Retrieval statistics in solar minimum and solar maximum years

The fraction of COSMIC 1 setting and rising RO profiles that failed or passed the QC procedure relative to the total number of scheduled ROs (setting or rising, correspondingly) depending on geomagnetic activity (Ap index):

a) failed the QC procedure in 2008;
b) passed the QC procedure in 2008;
c) failed the QC procedure in 2011;
d) passed the QC procedure in 2011.

Refractivity bias metrics: ECMWF as a reference model

a. JPL-ECMWF_FM1_2011-11_17LT_90-100km
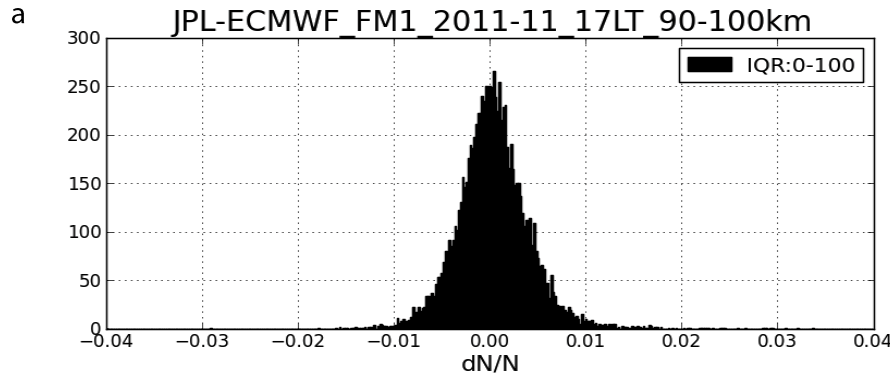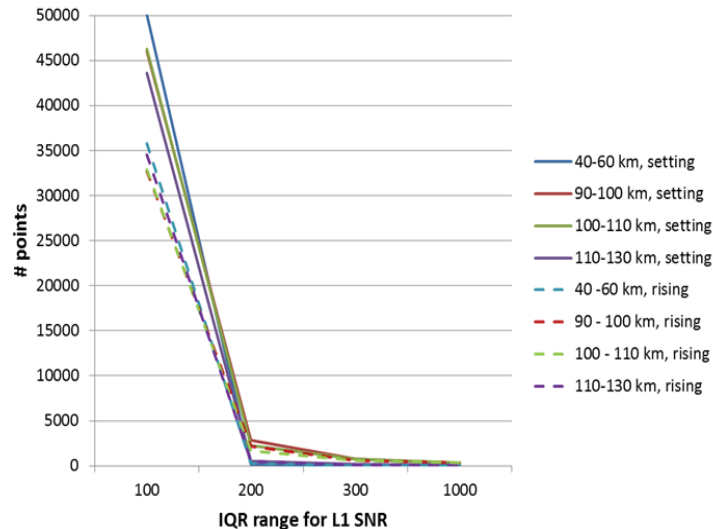
The fractional refractivity "error" (ΔN) is defined as

$$\Delta N = (N_{ECMWF} - N)/ N_{ECMWF},$$

where ΔN is calculated for each individual profile and averaged over the altitude range from 20 to 25 km. We aggregate ΔN values for RO profiles by SNR variability of these profiles in four altitude ranges.
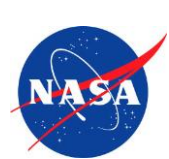

b.

c.
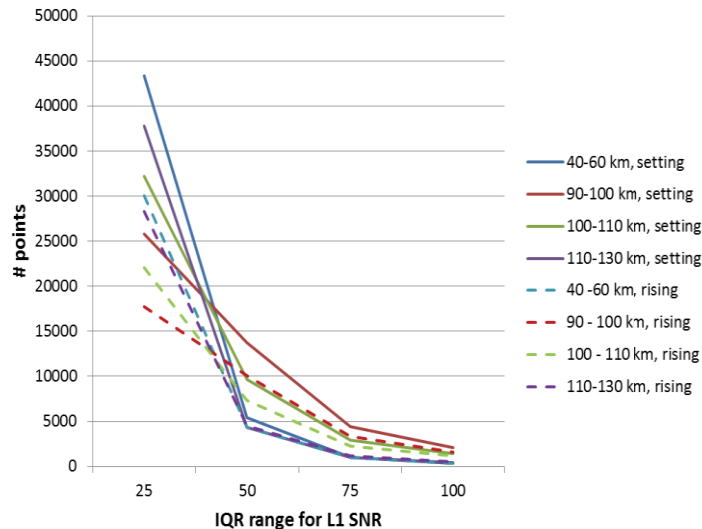
Assumption:
possible ECMWF biases do not correlate with SNR variability, so if the SNR variability introduces biases, we should see variation compared to ECMWF.

Mean values of the fractional refractivity (ΔN) in SNR IQR bins
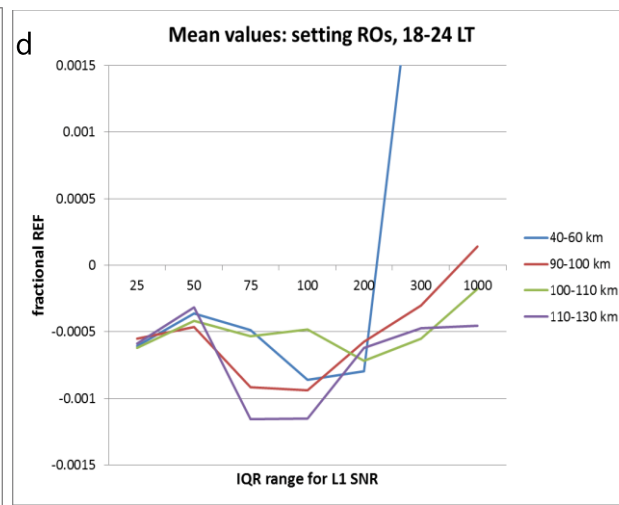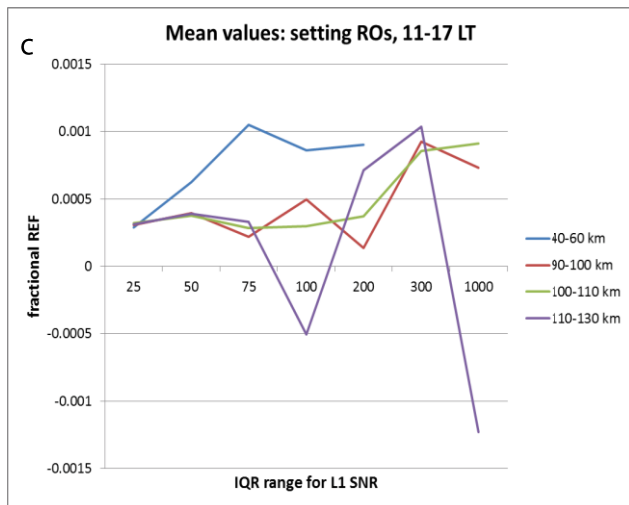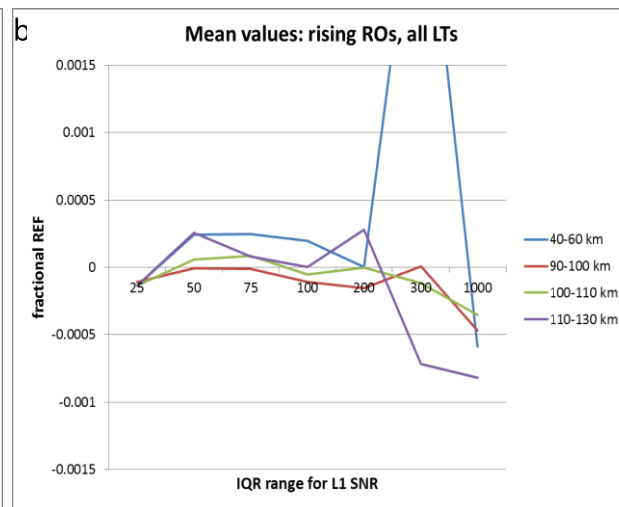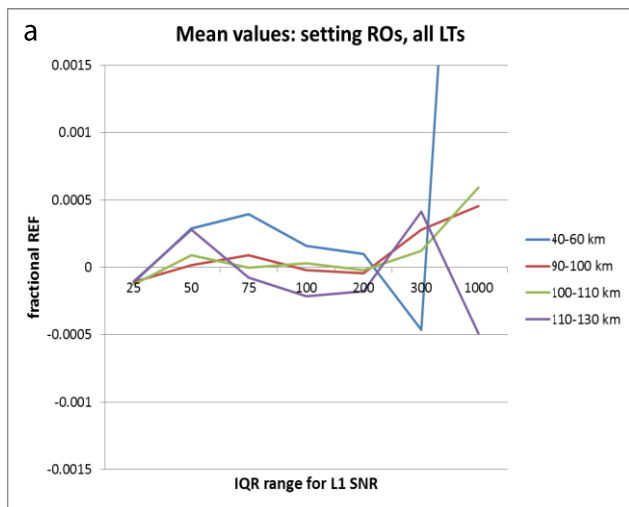
a) COSMIC1 setting ROs at all local times in 2011;
b) COSMIC1 rising ROs at all local times in 2011;
c) COSMIC1 setting ROs at 1100-1700 LT in 2011;
d) COSMIC1 setting ROs at 1800-2400 LT in 2011.

Altitude ranges of SNR variability are from 40 km to 60 km, from 90 km to 100 km, from 100 km to 110 km, and from 110 km to 130 km.

The maximum and minimum values of ΔN for profiles with low SNR variability level (IQR ≤ 100) in the range 90 km to 130 km altitude, which corresponds to ~ 93% of all retrieved profiles.

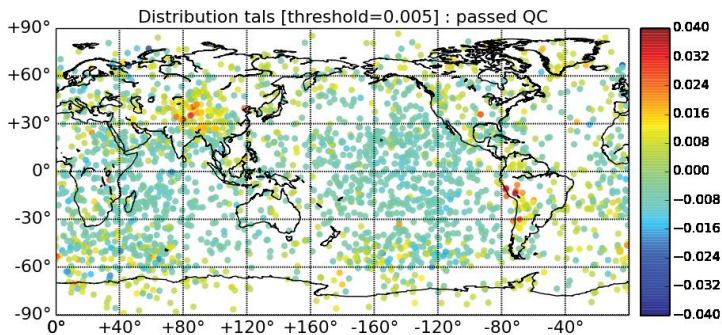|	Setting ROs, all LTs	Rising ROs, all LTs	Setting ROs, 11-17 LT	Setting ROs, 18-24 LT	Setting ROs, all LT, no QC
Max (%)	0.01	0.025	0.06	-0.03	-2.75
Min (%)	-0.02	-0.01	-0.06	-0.12	-22.48
# profiles	186080	135968	53352	48172	28934

a
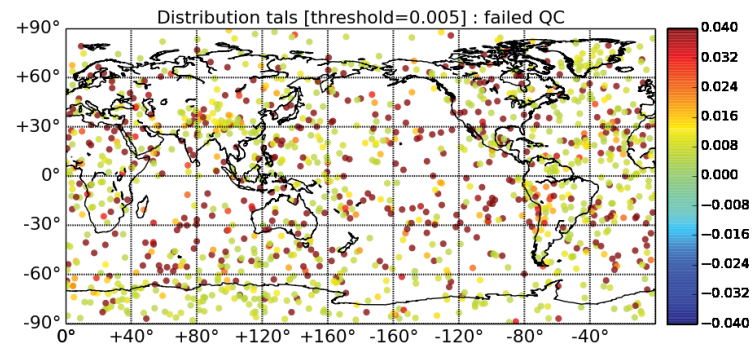

b
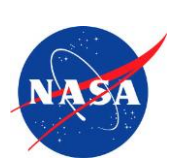

c

d
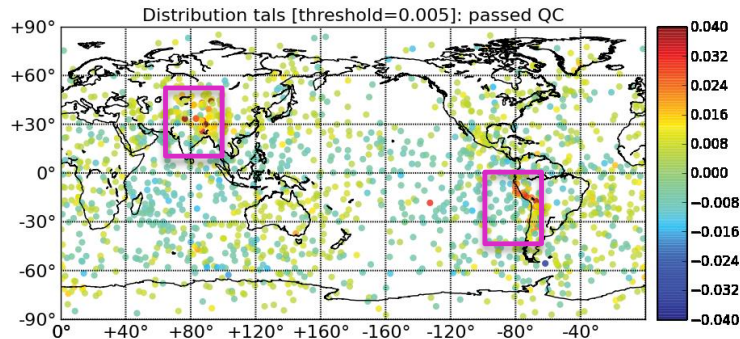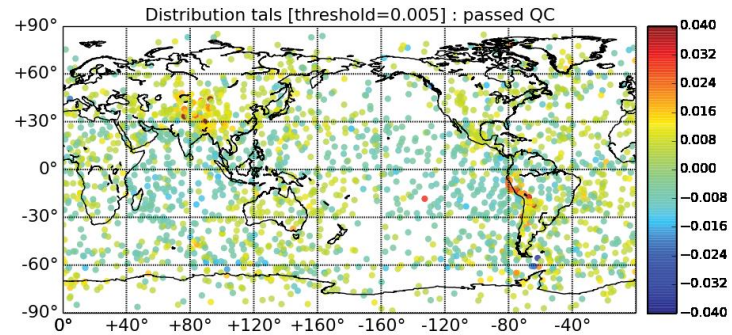
ΔN in the distribution tails (|ΔN |≥0.005) aggregated by all IQRs in the altitude range from 90 km to 100 km: (a) all LTs, (b) for daytime only, (c) nighttime only datasets, (d) retrievals which failed the QC procedure.

Conclusions

- We characterize small-scale ionospheric irregularities through variability of the L1 signal amplitude. Persistently larger variability of the L1 SNR existed in the 90 km to 110 km altitude range.

- We analyzed effects of small-scale ionospheric irregularities in COSMIC 1 refractivity retrievals (rising and setting ROs) in the lower stratosphere (from 20 to 25 km) for 2011 and determined the upper error bounds (in reference to ECMWF) on refractivity retrievals: 0.06% (for daytime local time), 0.1% (for nighttime local time) and ~0.01% (for all local times).

- Distributions of the fractional refractivity are non-Gaussian and show pronounced tails increasing along with the L1 SNR variability. This indicates a re-distribution of ΔN values from the top of the normal distribution towards tails.

- We demonstrated that large distribution tails ($N_{ECMWF} > N$) appear in the Himalaya and the Andes regions, but *for all IQR ranges*. One of the explanations is that this is an orographic feature caused by underlying topology and air convection pattern above high mountain ranges.