Processing, Quality Control and Performances of FY3C/3D GNOS data

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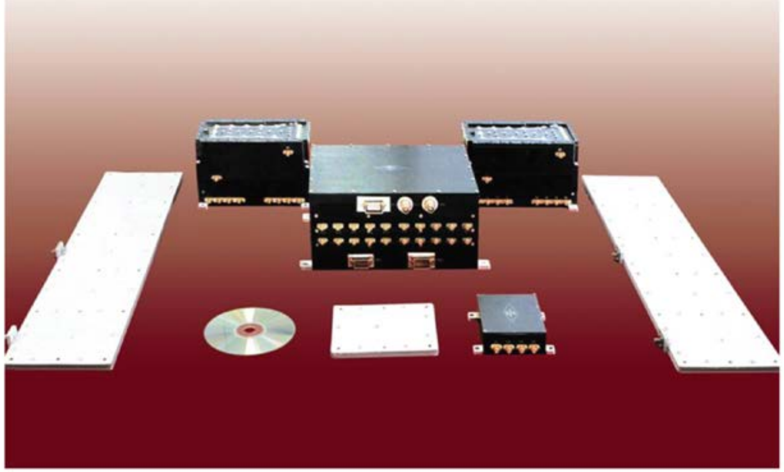
CONTENTS

1. Introduction

GNOS on FY3C



- Launched on Sep. 23rd 2013;
- GPS 14 channels, BDS 8 channels;
- GPS L1 open loop tracking;
- GPS L1C/A + L2P, B1 + B2
- Antenna 5 units for per direction, setting and rising;
- 7.0dBi@45° azimuth;
- Via GTS since Jun. 30th 2017

GNOS on FY3D

- Launched on Nov. 15th 2017;
- GPS 17 channels, BDS 12 channels;
- GPS L1 and BDS B1 open loop tracking;
- GPS L1C/A + L2P + L2C, B1 + B2;
- Antenna 6 units for per direction, setting and rising;
- 8.5dBi@45° azimuth.Peak gain increased;
- Via GTS since Nov. 30th 2018

2. Key issues of GNOS on FY3C/3D

FY3C has been assimilated into several operational NWP models, including Chinese GRAPES model, ECMWF, Met Office, DWD and Canada, et al.

FY3C (in the past)

- Large bias departure
- Systematic bias between rising and setting

FY3D (in the past)

- Large standard deviation above 40km;
- Lower samples for rising profiles below 10km;

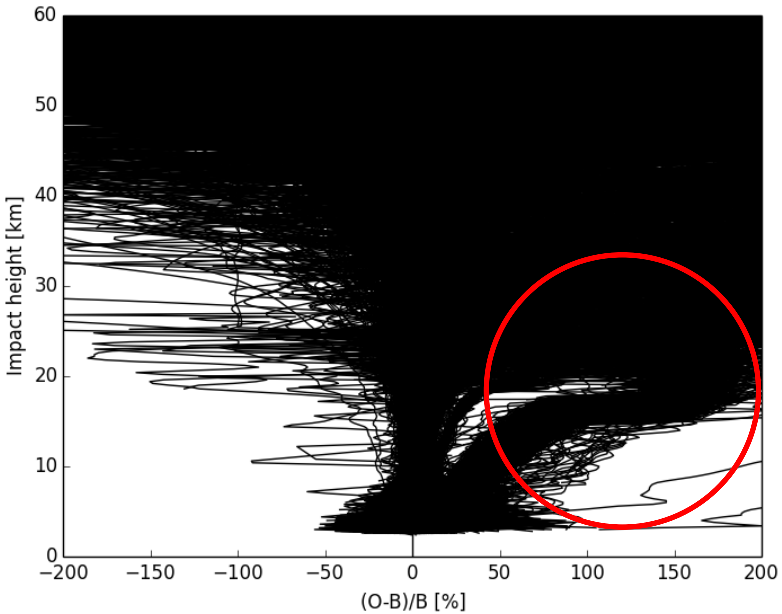
FY3D (current)

- Small bias of setting above 50km;

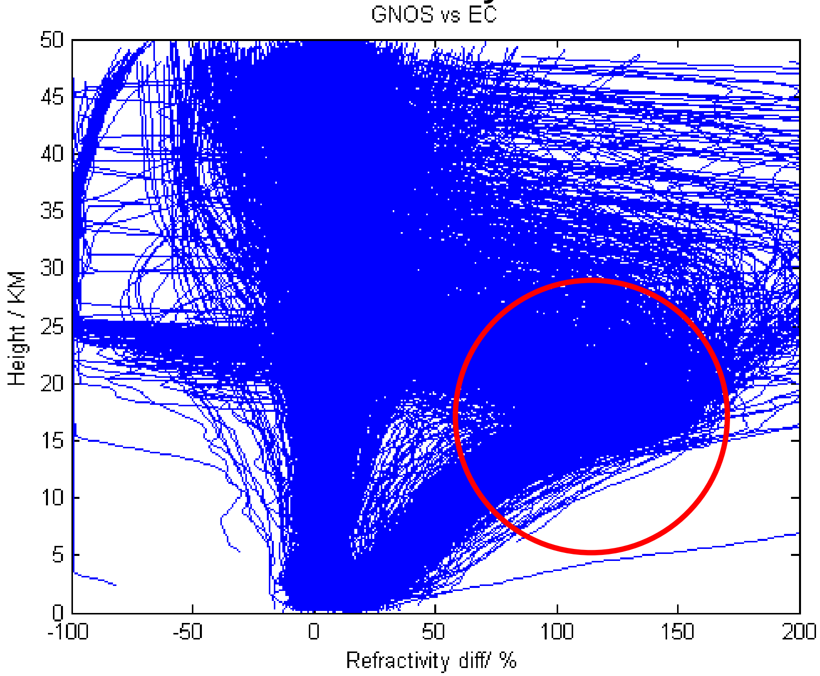
1) Large bias departures of FY3C GNOS

Bending angle and refractivity both have large bias when compared with background data. In proportion of 13~15%

Bending angle

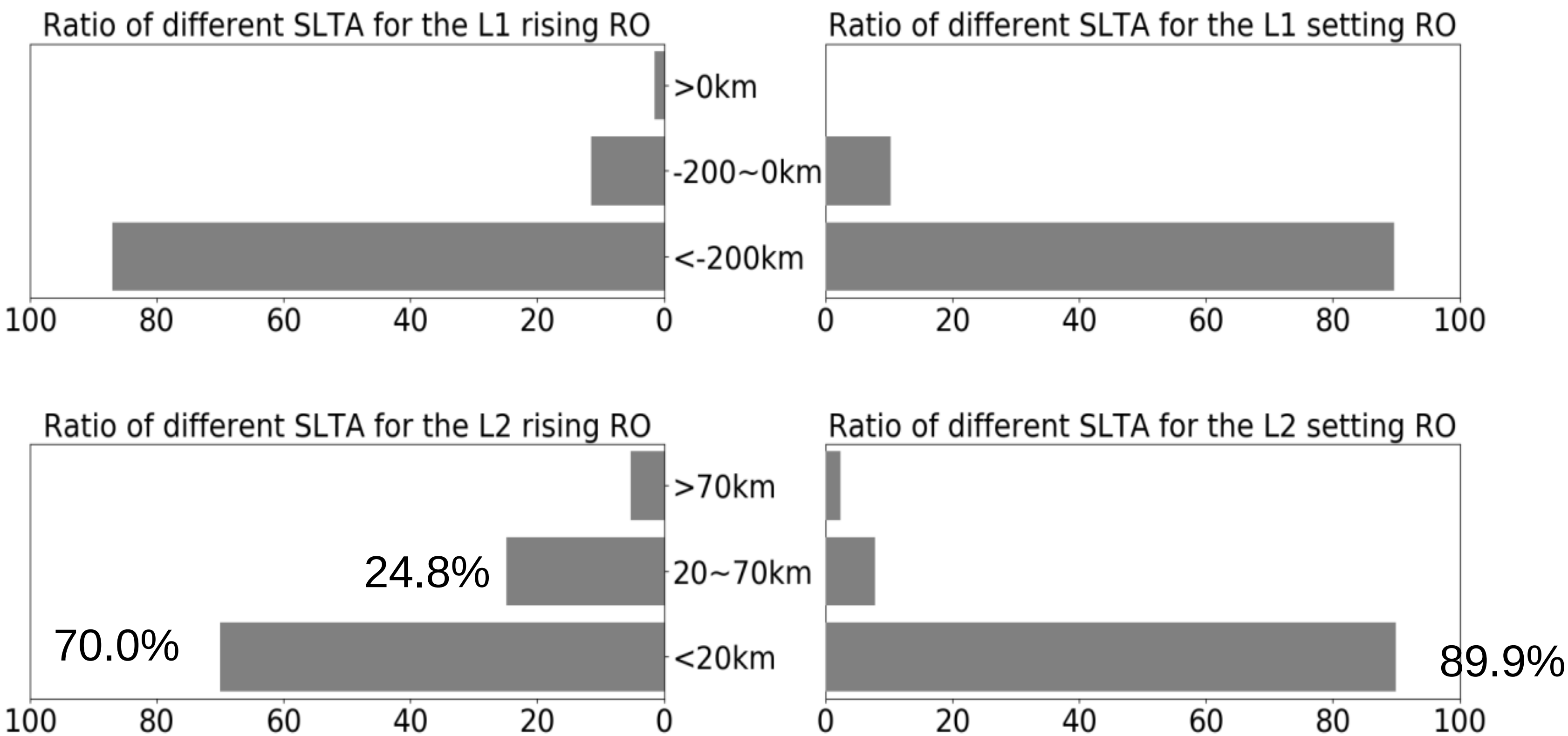


Refractivity



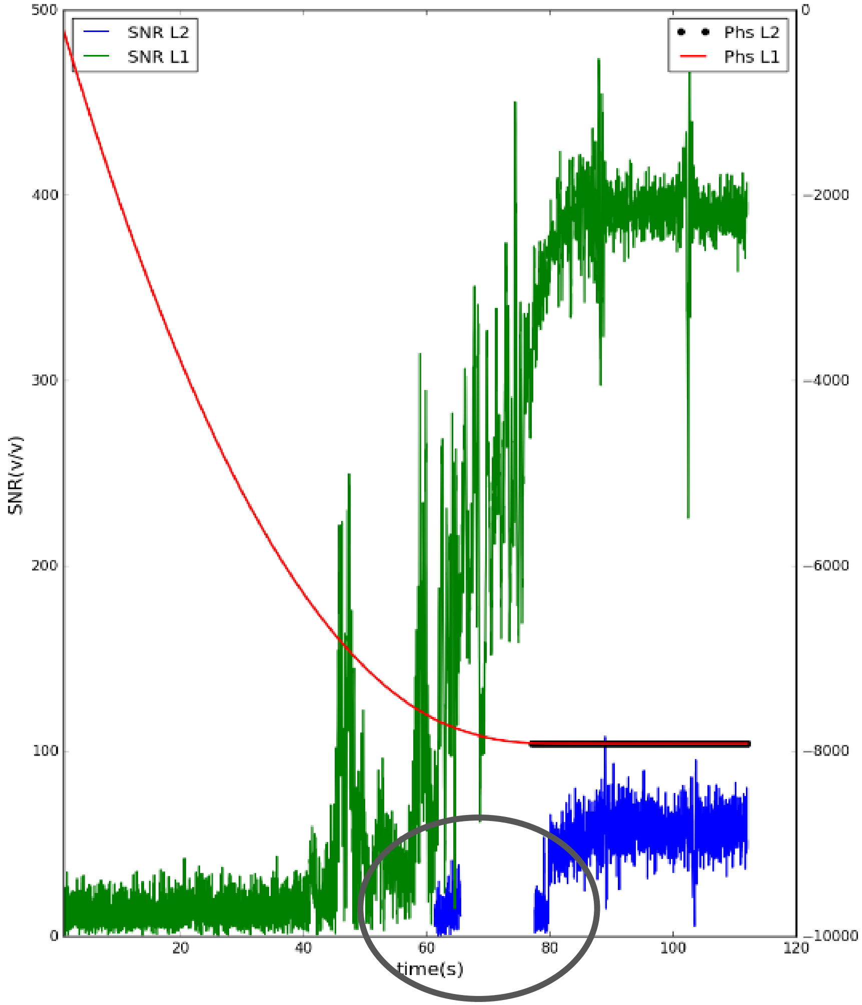
Reason for the large bias

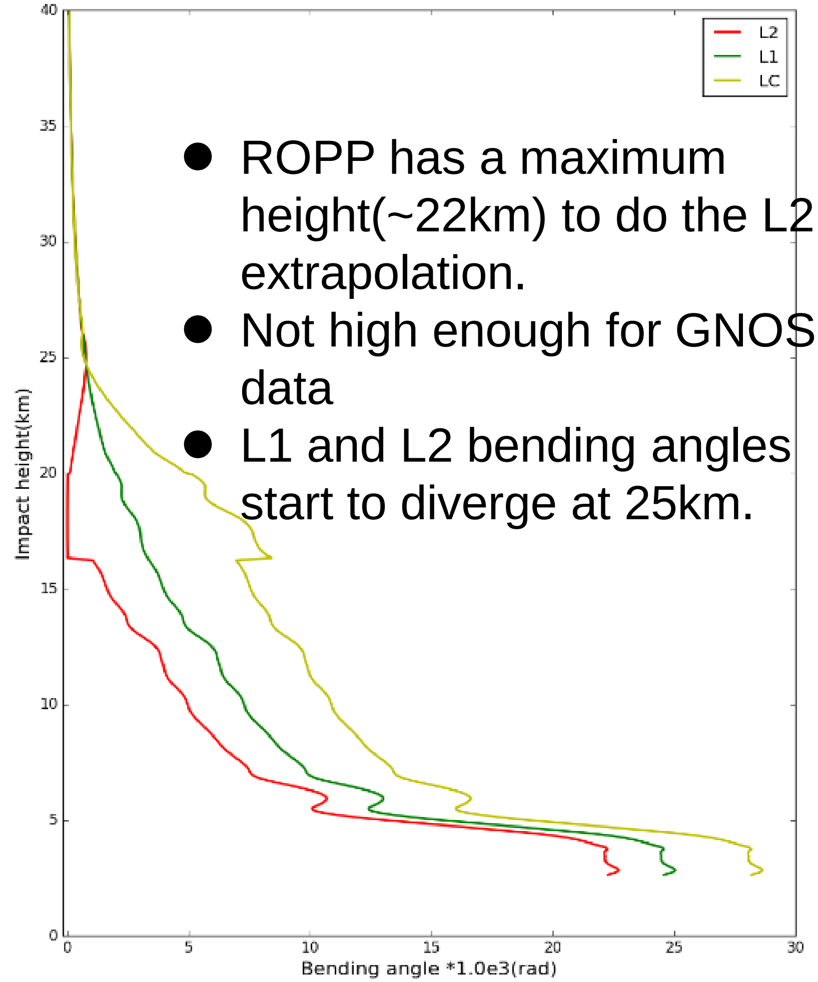
- More than 98.5% of L1 C/A can reach below 0 km SLTA
- L2P is only about 70% of profiles can reach below 20km.



BAD PROFILE CASE

A rising profile
(FY3C_GNOSX_GBAL_L1_20170128_0332_AEG15_MS.NC)





- ROPP has a maximum height(~22km) to do the L2 extrapolation.
- Not high enough for GNOS data
- L1 and L2 bending angles start to diverge at 25km.

Method for the large bias correction

Based on a "thin" ionospheric shell model

the ionospheric contribution to the bending angle

$$\alpha(a) = 2a\frac{k_4}{f^2}\int_a^{\infty}\frac{x n_e(x)}{(x^2-a^2)^{\frac{3}{2}}}dx$$

Culverwell and Healy (2016)

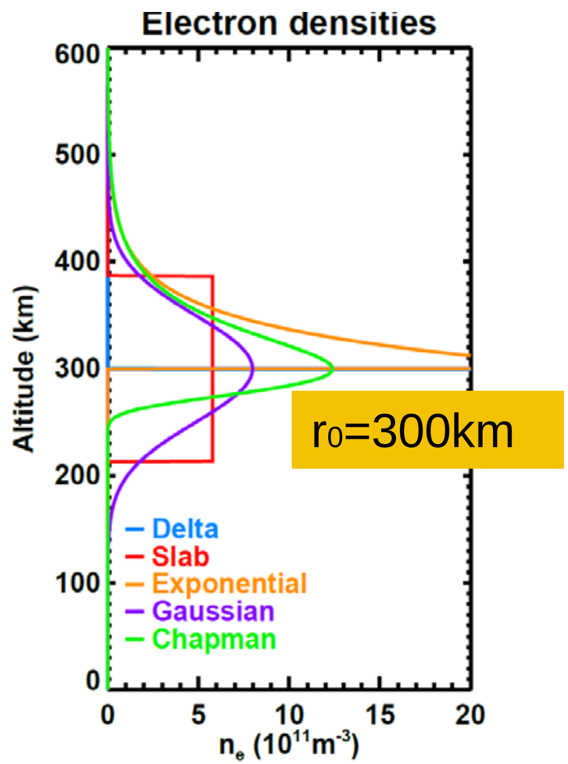
$$TEC = \int n_e dr$$

$$\alpha(a) = 2a\frac{k_4}{f^2}TEC\frac{r_0}{({r_0}^2-a^2)^{\frac{3}{2}}} \quad (for\ a < r_0)$$

$$\alpha_2(a) - \alpha_1(a) = 2ak_4TEC(\frac{1}{f_2^2}-\frac{1}{f_1^2})\frac{r_0}{({r_0}^2-a^2)^{\frac{3}{2}}}$$

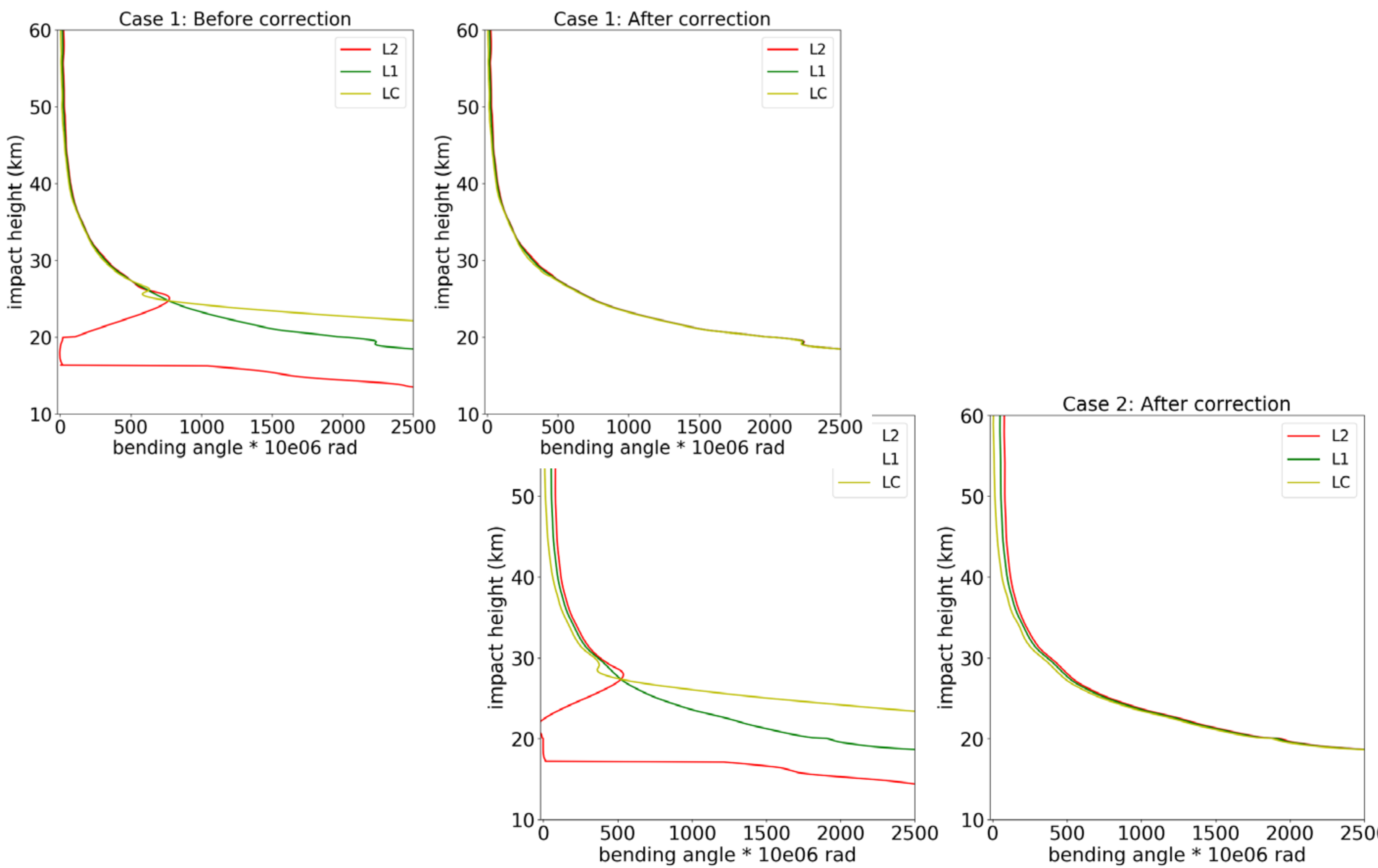
$$x_{so} = 2ak_4TEC(\frac{1}{f_2^2}-\frac{1}{f_1^2})$$

$$\alpha_2(a) = \alpha_1(a) + x_{so}\frac{r_0}{({r_0}^2-a^2)^{\frac{3}{2}}}$$

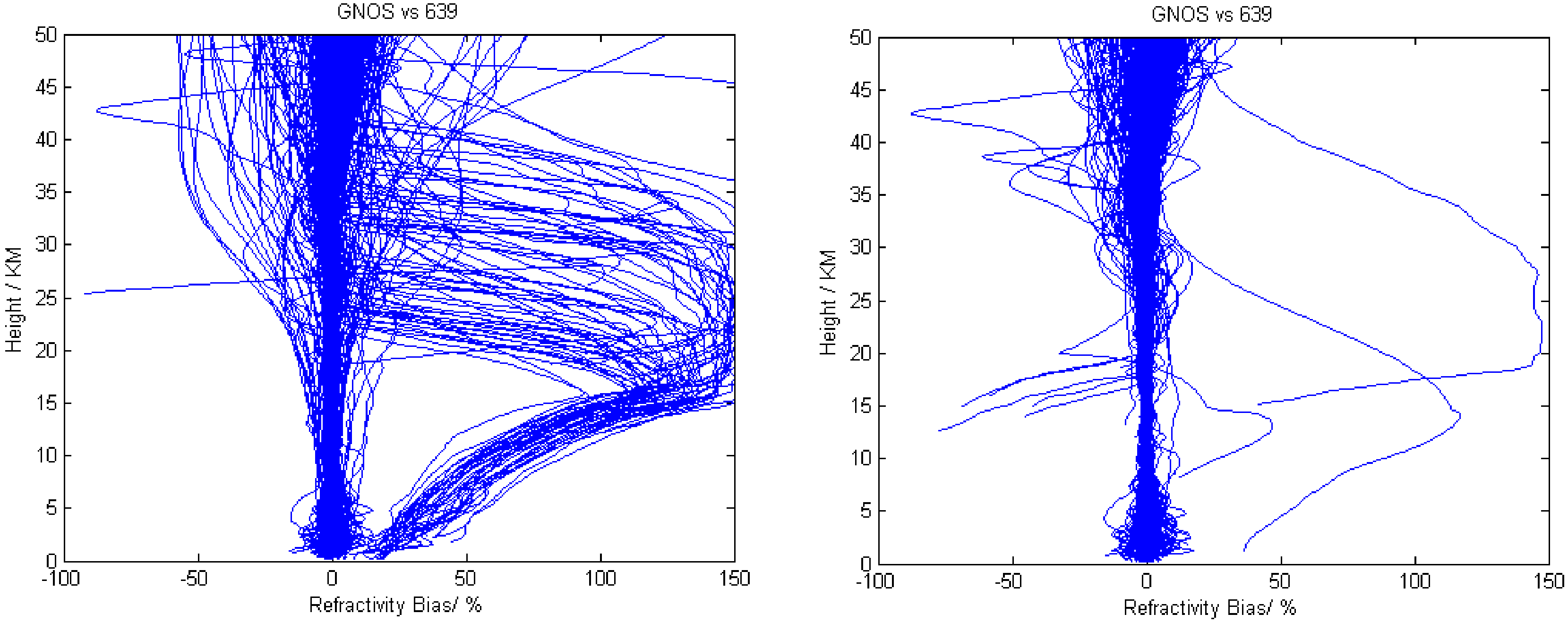


x_{so} a least-square fit based on observed L1 and L2 bending angle differences produced with geometrical optics.

Examples of large bias correction

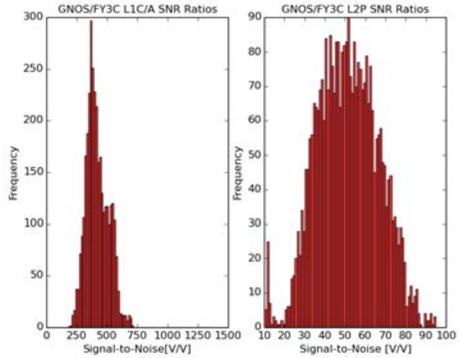


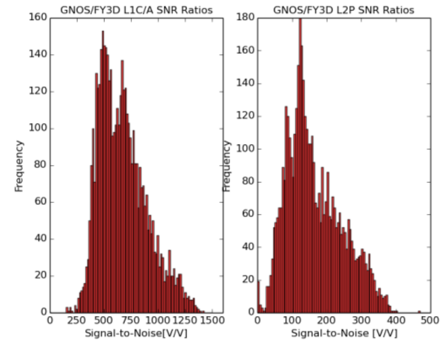
Result of one day data

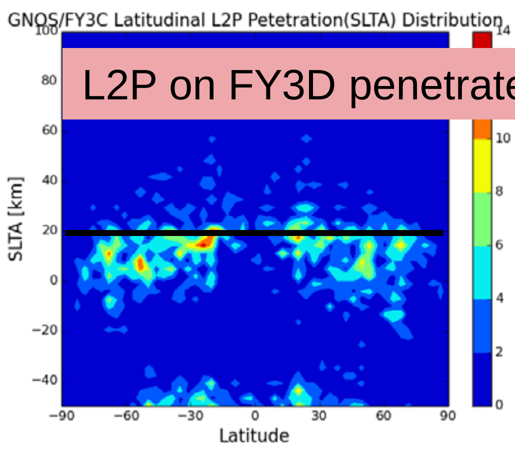


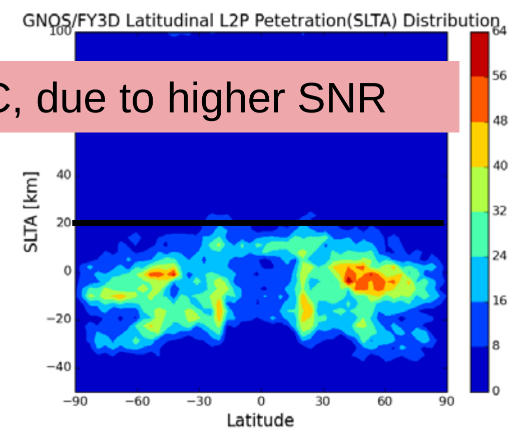
- After correction, large bias profiles only account for about 2.77%;
- The remaining is that L2 stops higher than 70km, which can not be applied using the method；
- The latest version of ROPP9.1 can process GNOS data from excess phase.

Large bias profiles account for about 5.65%. It decreases to 1.23% after correction， the remaining profiles due to the stopping height higher than 70km in terms of SLTA.

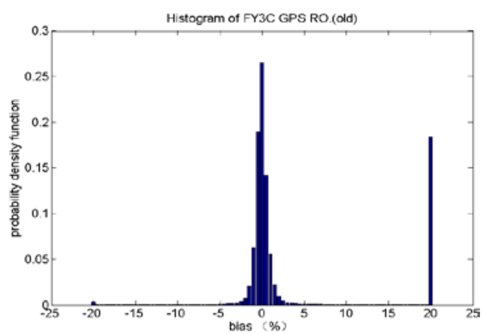


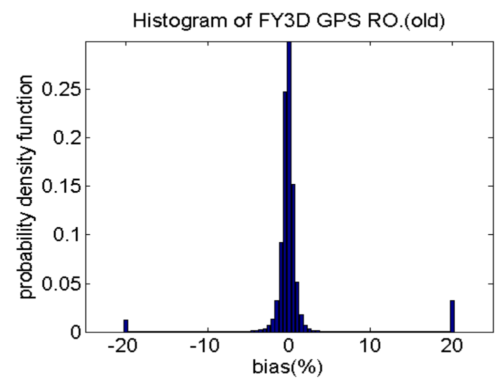




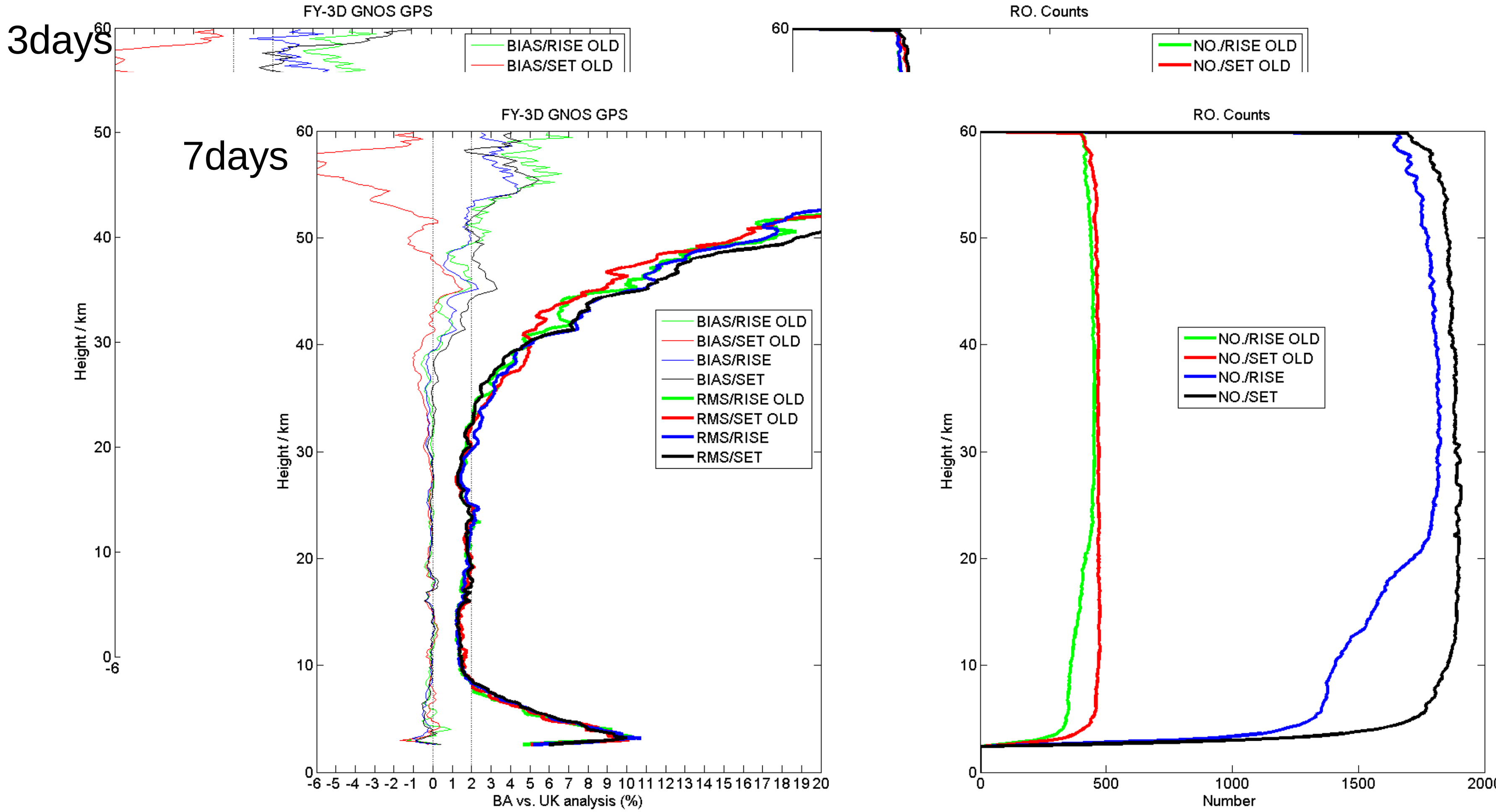


L2P on FY3D penetrates lower than FY3C, due to higher SNR





Small bias in the setting profiles above 50km—FY3D



Affected by multipath

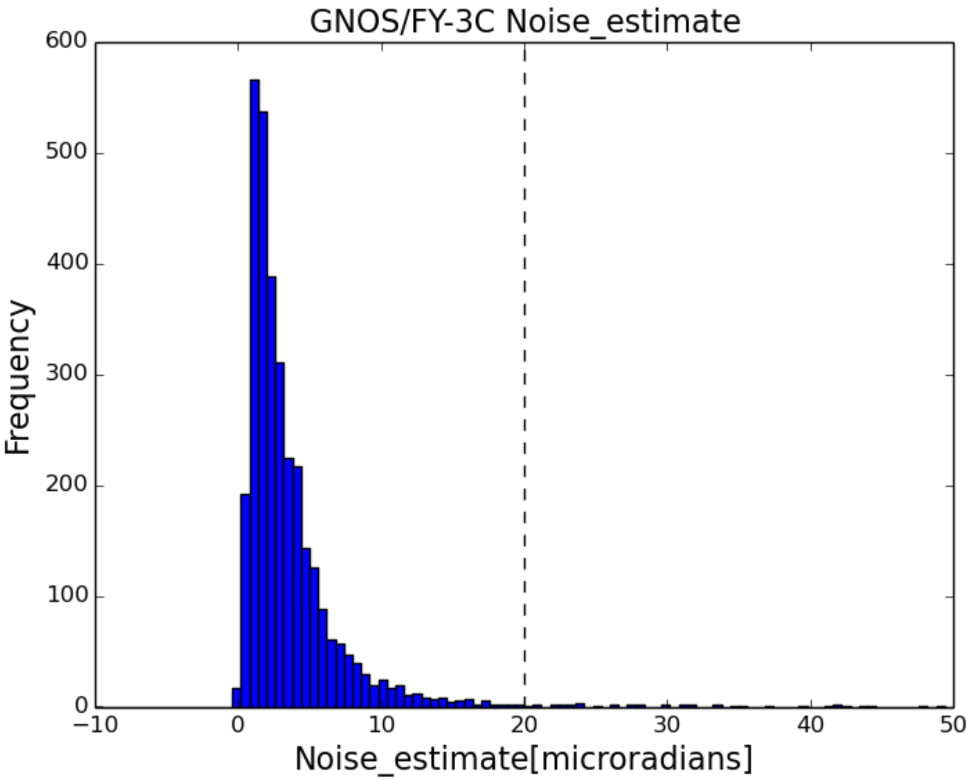
3. Quality control of FY3C GNOS

（1） Noise estimate for the L2 correction

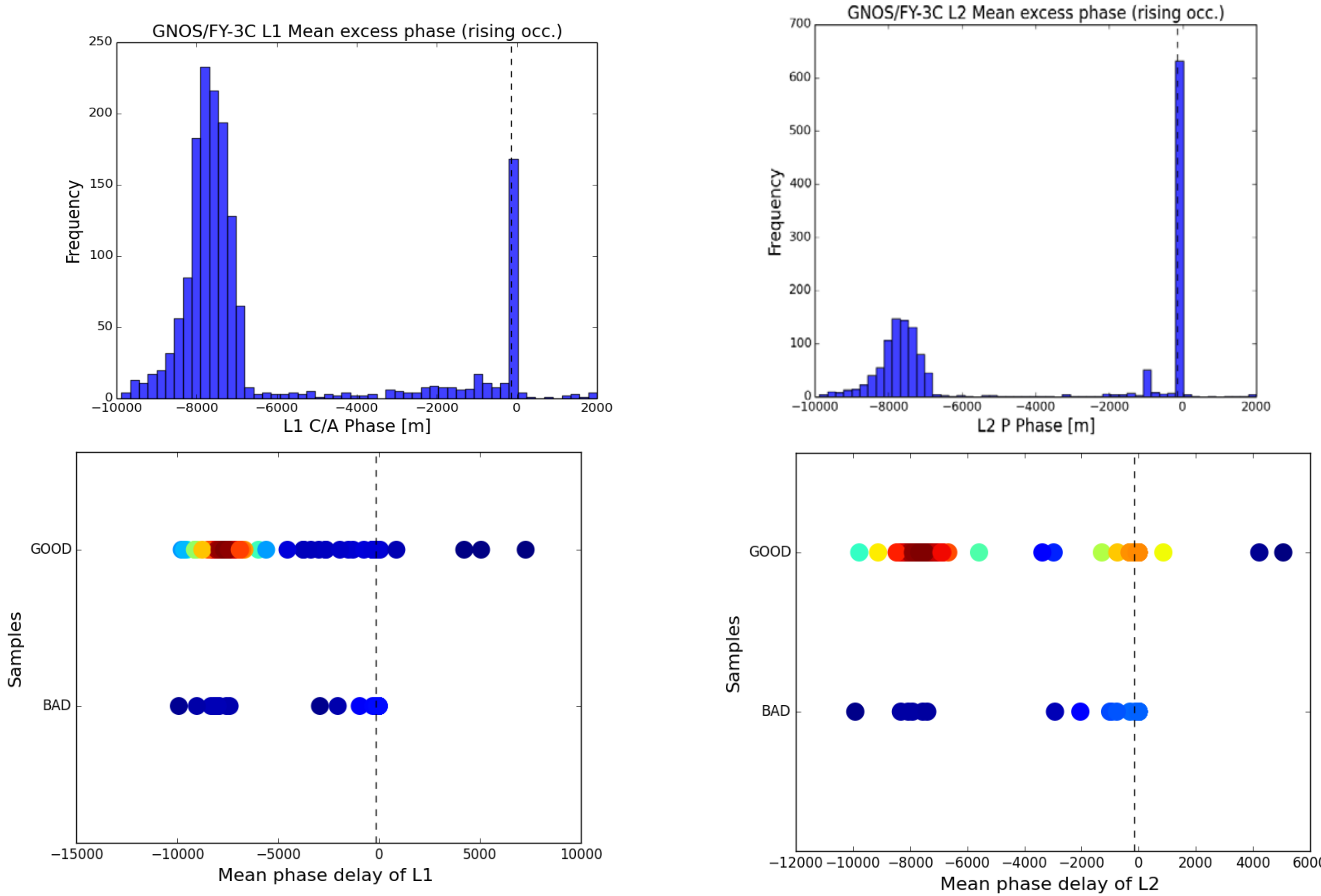
$$\sigma = \frac{\sqrt{\sum(x_{so} * \frac{r_0}{({r_0}^2 - a^2)^{\frac{3}{2}}} - \Delta\alpha(a))^2}}{n} * 10^6$$

the standard deviation of the difference between the fit and observations above the extrapolated height.
σ named as noise estimate.

noise_estimate = ?



Mean delay phases of L1 and L2---rising Occ.



Combined with L1 and L2 rising occultations, if their values are greater than - 150 at the same time, most of the bad profiles can be identified. Unavoidably, a few of the good profiles could be wrongly detected as well and few bad ones could be missed.

Quality control scheme of FY3C GNOS

(1) If the value of *noise_estimate* is greater than 20 microradians, the profile will be identified as “bad”;

(2) If the occultation is rising, and the both mean phase delays of L1 and L2 are greater than -150m, the profile will be identified as “bad”;

(3) If the lowest SLTA of L2 is greater than 50 km, the profile will be identified as “bad”.

Quality control scheme of FY3C GNOS

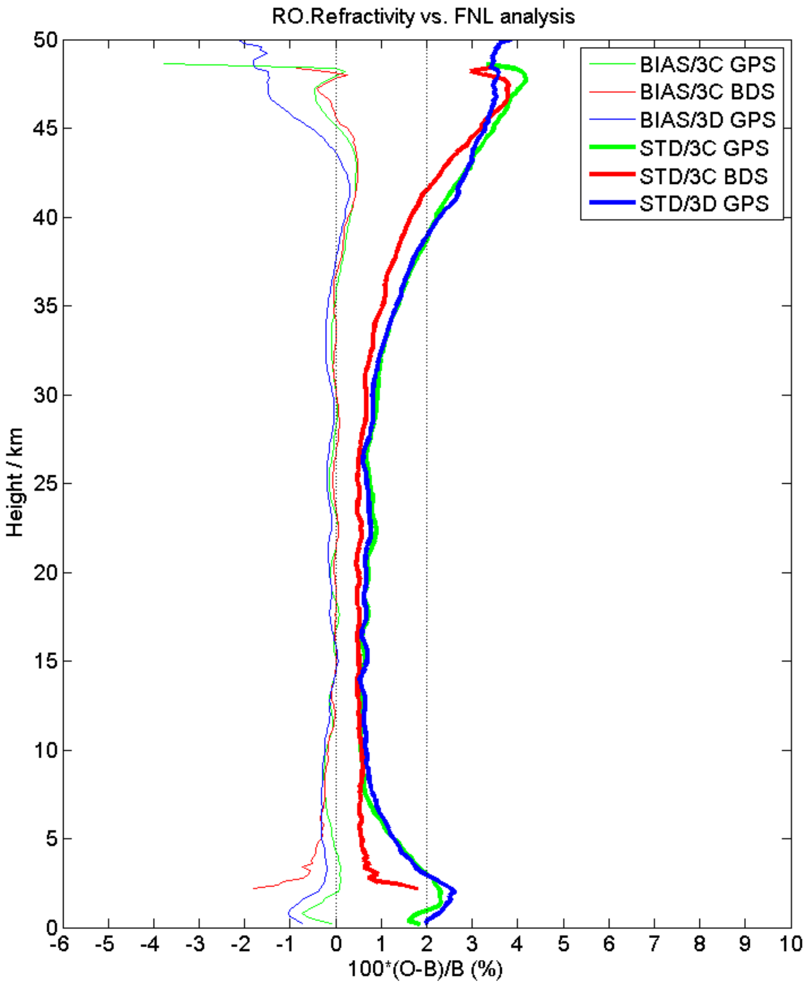
(1) If the value of *noise_estimate* is greater than 20 microradians, the profile will be identified as “bad”;

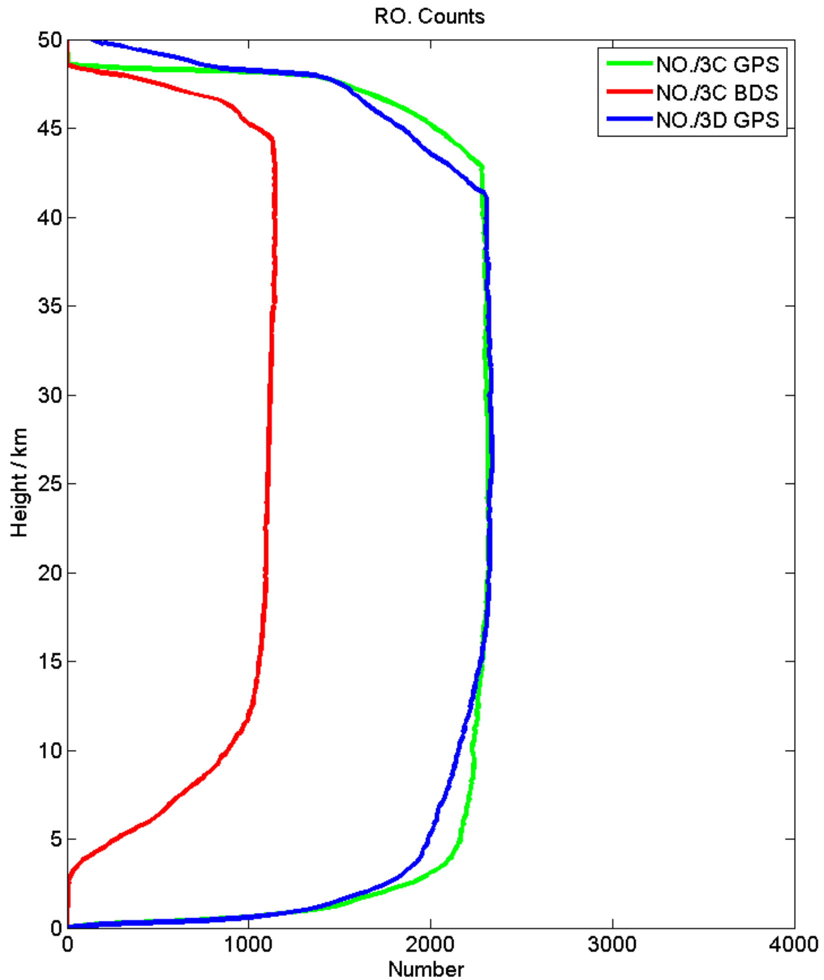
(2) If the lowest SLTA of L2 is greater than 50 km, the profile will be identified as “bad”.

The “bad” profiles are not disseminated via GTS, but full samples with qc flag are public on data service website.

4. Results and future plans

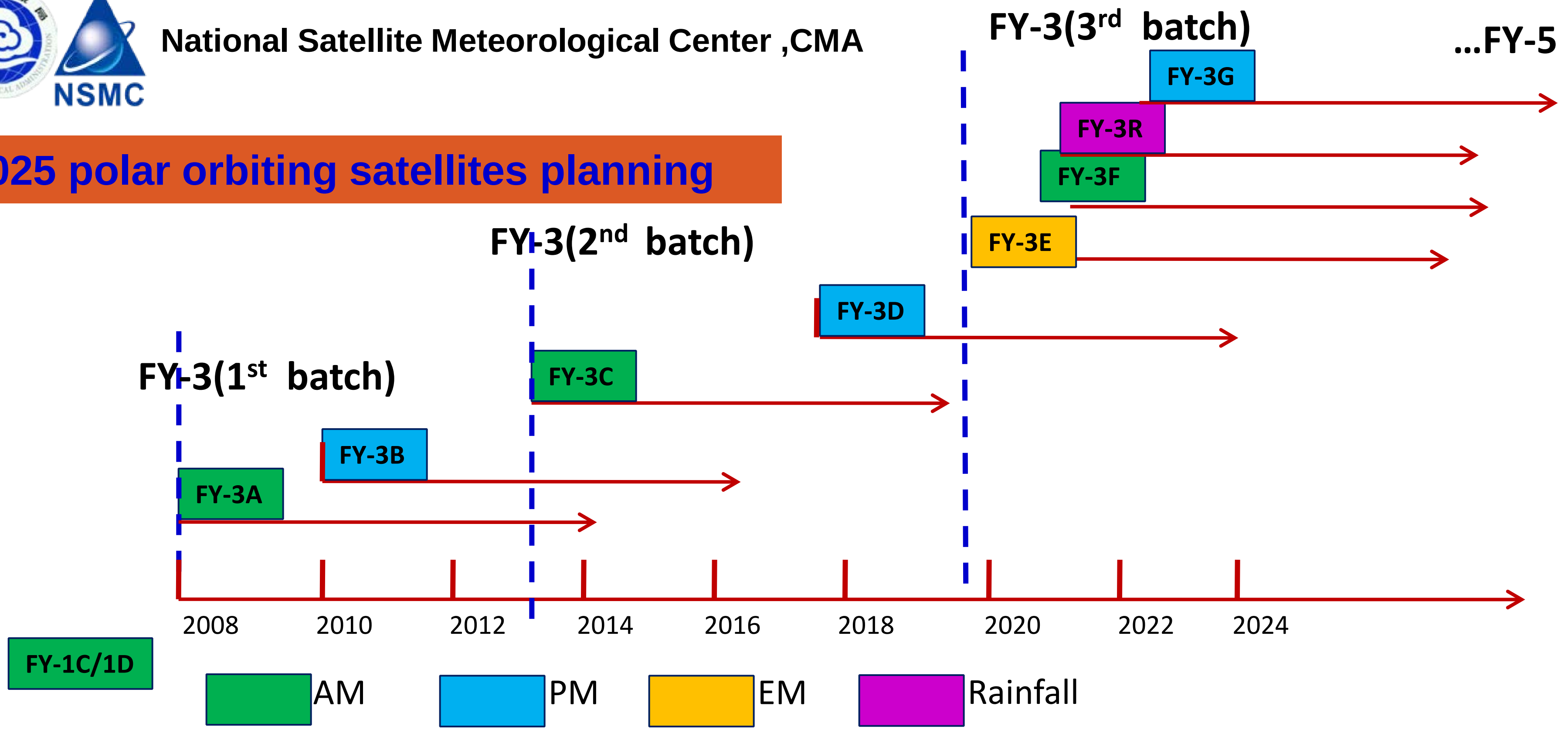
Statistics of FY3C/3D GPS/BDS RO compared with NCEP reanalysis





National Satellite Meteorological Center ,CMA

2025 polar orbiting satellites planning



Payloads Configuration for FY-3E/F/G and Rainfall Mission

NO.	Sensor Siute	Satellite / Sensor	FY-3E (05) EM Satellite	FY-3F (06) AM Satellite	FY-3G (07) PM Satellite	FY-3R (08) Rainfall Satellite
		Scheduled Launch Date	2020	2021	2022	2021
1	Optical Imagers	MERSI	√（III-Low Light）	√（III）	√（III）	√（III-Simplified）
2	Passive Microwave Sensors	MWTS	√	√	√	√
		MWHS	√	√	√	√
		MWRI		√	√	√
3	Occultation Sounder	GNOS	√	√	√	√
...	...	...				

FY-3E/F/G GNOS ----2ND GENERATION

Parameters	Content
Constellation	GPS L1, L2(L5,optional) BDS B1I,B2I Galileo E1, E5b (E5a,optional)
Channel number	30 for Positioning (3 systems), 24 for Occultation (3 systems),
Clock stability	1×10^{-12}（1secAllan）
Pseudo-range precision	≤30cm
Carrier phase precision	≤2mm
PCV of POD antenna	≤2mm
Beam width of atmosphere occultation antenna	≥±45°(azimuth)

Occultation events:

- ✓ 590 occ./per day/per LEO for only GPS system
- ✓ up to 1700 occ. taking into account BDS and Galileo

Another innovation:

Integrate one antenna for reflective signals on GNOS!!

- ☐ Share power and data down link with RO
- ☐ ~13dBi
- ☐ Only for monitoring sea surface wind
- ☐ For experiments, not operation

5. Summary

- **Perform a new L2 extrapolation for GNOS GPS-RO profiles,** and it has been implemented in ROPP software to mitigate the problem. Such method removes about 90% of the large departures. The remaining poor cases are mostly due to the L2 being completely missing;
- **Find suitable QC methods for GNOS after applying the new L2 extrapolation;**
- **FY3D performs basically as good as FY3C with more daily occultation;**
- **FY3C GNOS data has been assimilated into ECMWF, Met office, DWD and GRAPES.**
- **This work is partly supported by ROM SAF.**

Thank you ！

谢 谢！