EUMETSAT ROM SAF - IROWG 2019

Assimilation of FengYun GNOS Radio Occultation Data in GRAPES

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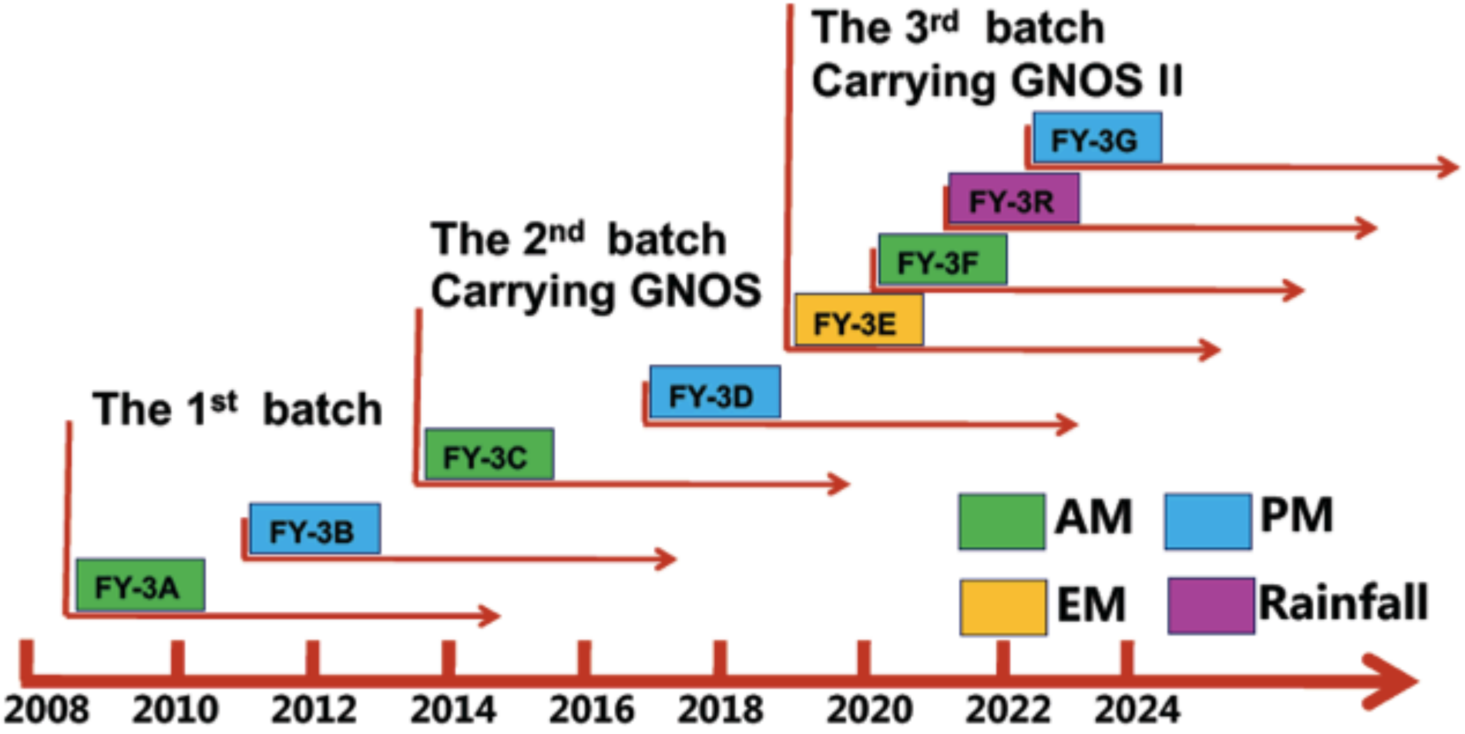
Outline

- Overview of GNOS sounder
- Assessment of GNOS data quality
  - GPS RO data
  - BDS RO data
- Assimilation of GNOS data
- Summary and plan

FY-3 Satellite and GNOS Sounder

- **FengYun satellite:** Chinese meteorological satellite, **Feng** (wind) and **Yun** (cloud)， the FY-3 series is polar orbit satellite.
- **GNOS:** **G**lobal **N**avigation satellite system **O**ccultation **S**ounder, a multi-GNSS receiver, tracking for GPS and Chinese BDS signal.

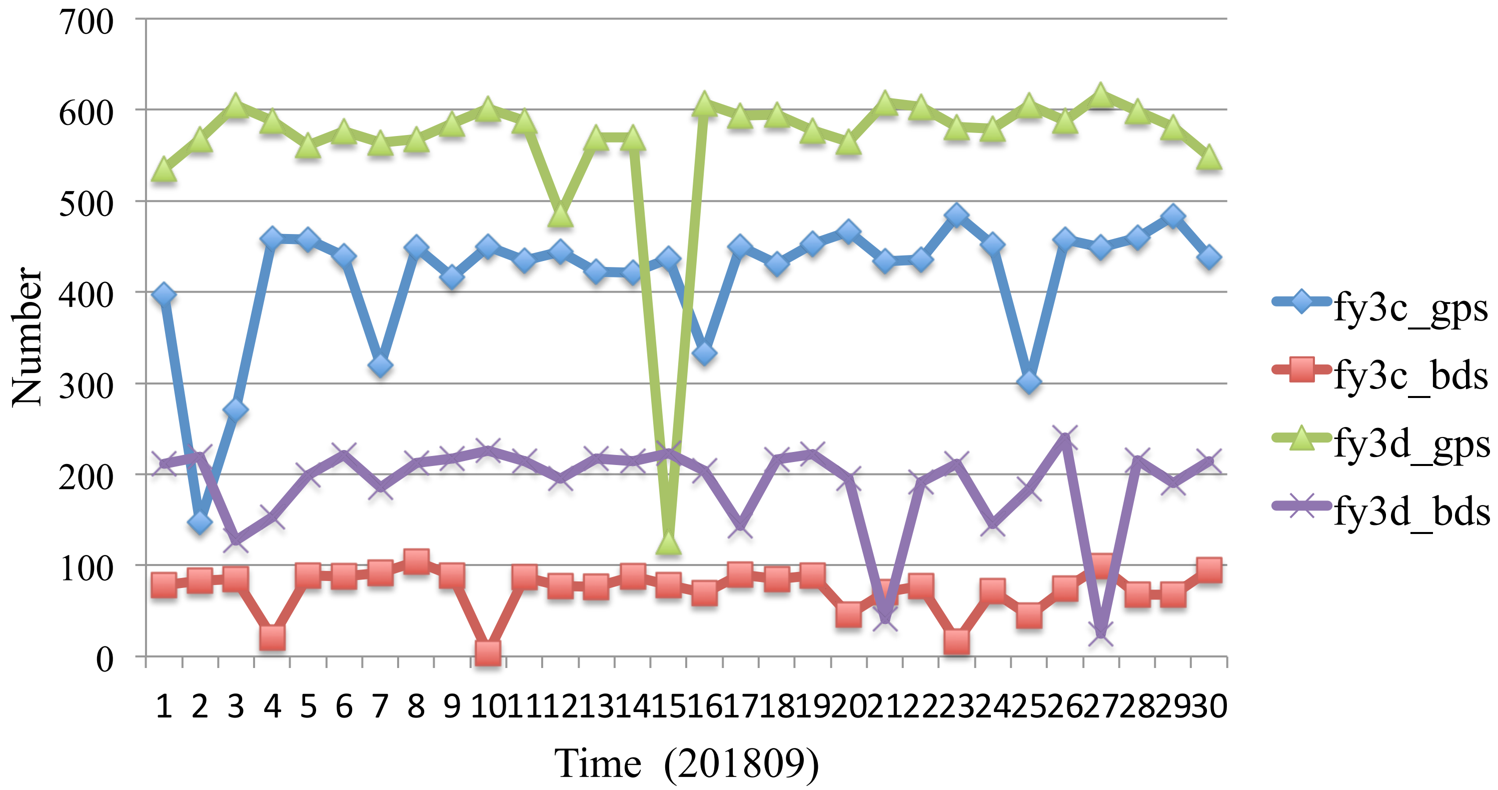

The 3rd batch
Carrying GNOS II
FY-3G
FY-3R
FY-3F
FY-3E
The 2nd batch
Carrying GNOS
FY-3D
FY-3C
The 1st batch
FY-3B
FY-3A
AM
PM
EM
Rainfall
2008
2010
2012
2014
2016
2018
2020
2022
2024

Timeline of FengYun 3 series satellites

Characters of GNOS Payload

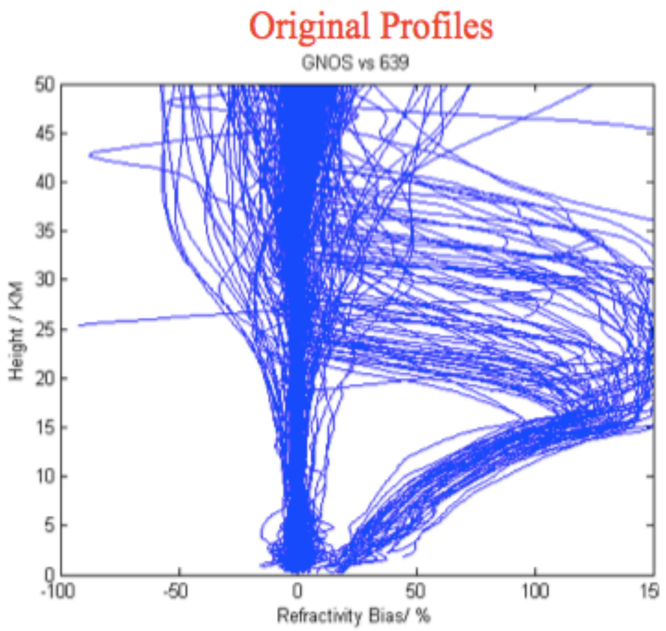
parameters	GNOS Ⅰ	GNOS II
Satellite	FY3C, FY3D	FY3E, ……
Constellation	• GPS L1 C/A, L2 P • Second generation BDS (5 GEO + 5 IGSO + 4 MEO); • Open loop for GPS, closed loop for BDS in FY3C and open loop in FY3D	• GPS/BDS/ GALILEO/ GLONASS(option) • Third generation BDS (5 GEO + 3 IGSO + 27 MEO); • Open loop both for GPS and BDS
Channel number	Positioning: GPS 8 Occultation: GPS 6(FY3C)->8(FY3D) Positioning: BDS 4(FY3C)->6(FY3D) Occulation: BDS 4(FY3C)->6(FY3D)	Positioning: 8 (GPS & BDS) Occultation: GPS 8 BDS 8 strengthen the gain
Receiver	RO	Combination of RO and GNSS-R

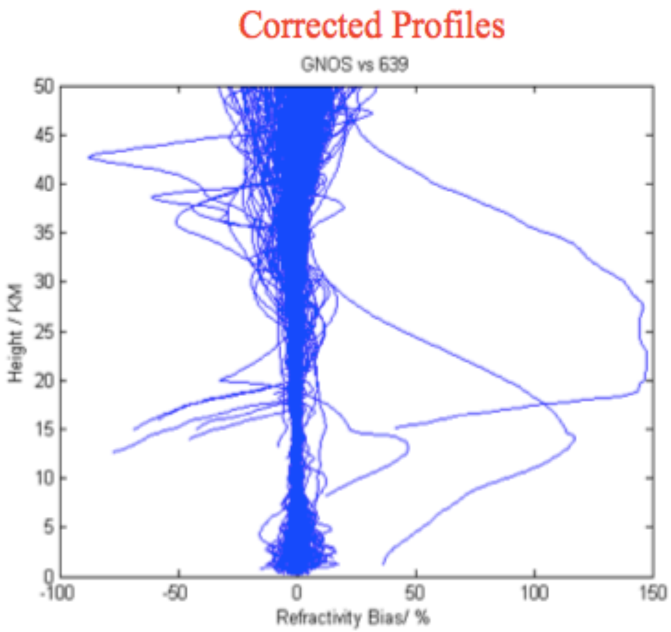
Data Volume



- FY3C GPS RO profiles have been processed by QC, others have no QC.
- Less BDS RO profiles because there are less BDS RO channels and BDS-2 is a regional GNSS.

Problem in Early FY-3C GPS RO Data

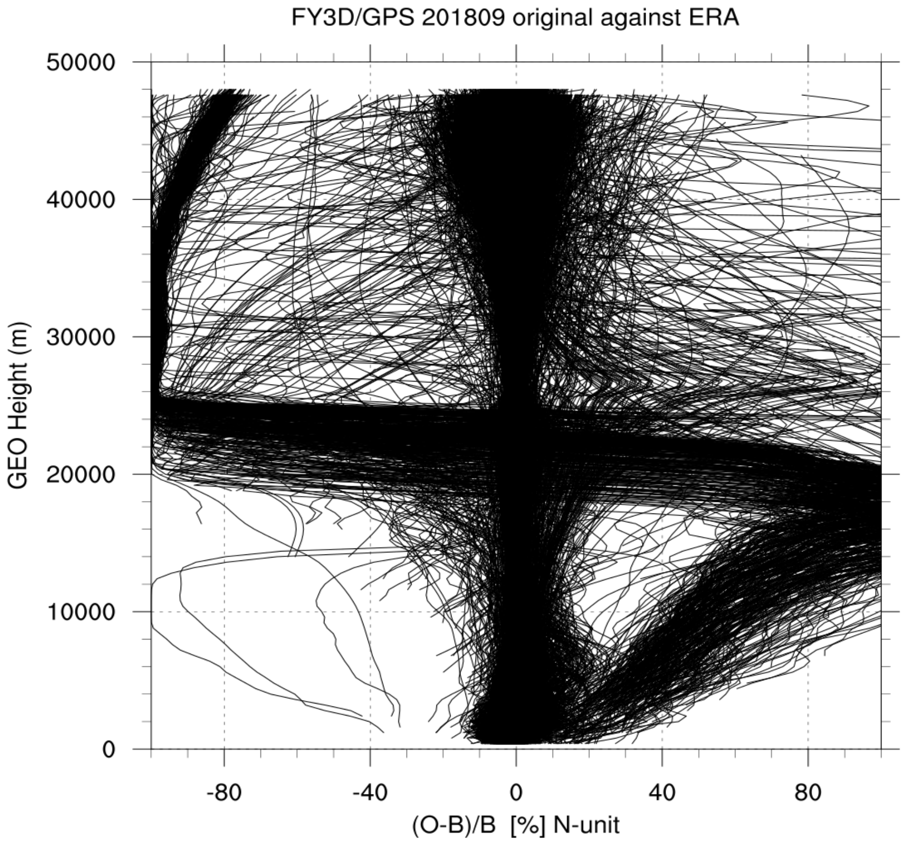




- Both bending angle and refractivity profiles have a extra branch with large bias, no matter compared to reanalysis or radiosonde date.
- The proportion of bad profiles is about 15%.

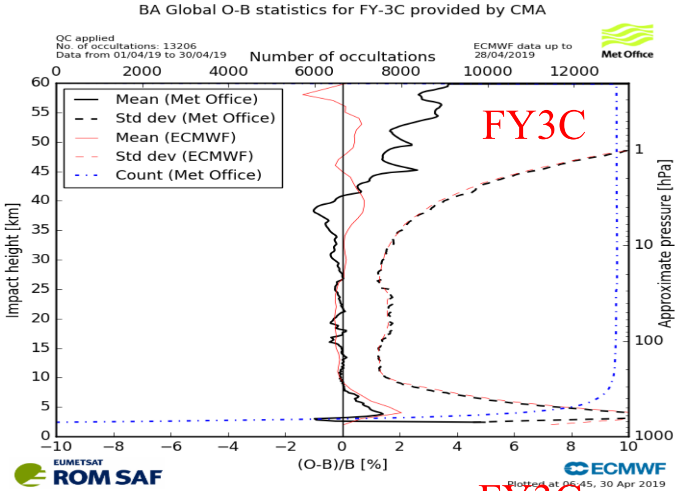
Liao M., Preliminary investigation with GNOS bending angle data: Monitoring, quality control and possible implications for ROPP, http://www.romsaf.org

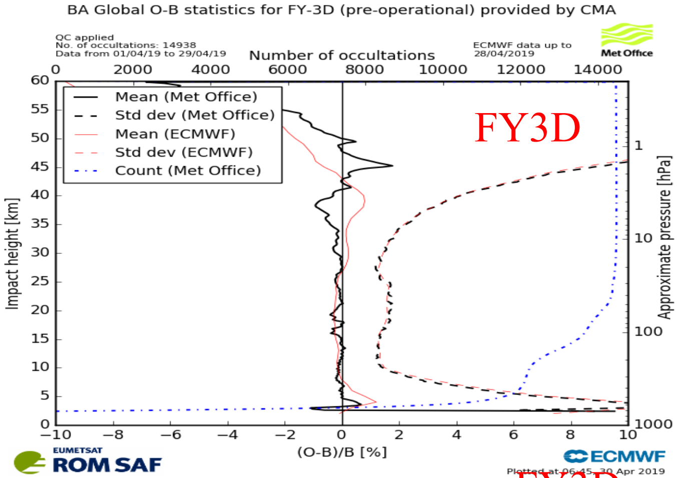
Fractional Refractivity of FY3D GPS RO without QC and Correction

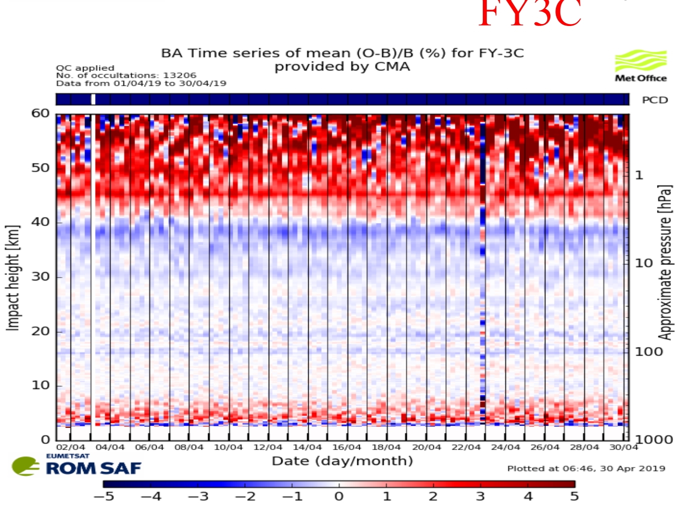


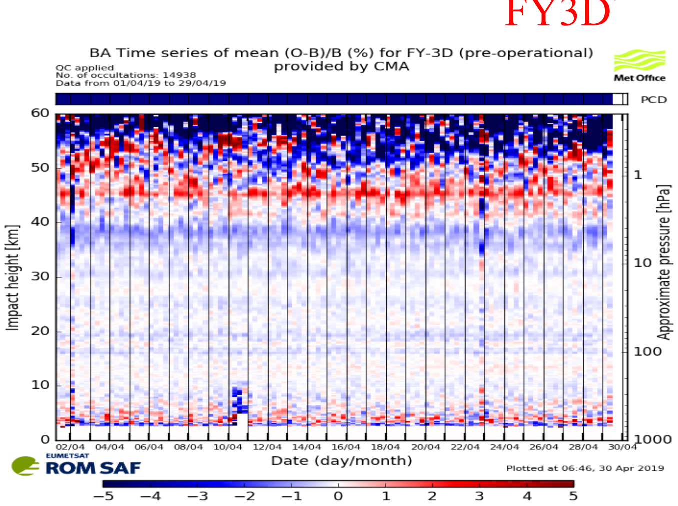
- Similar profiles with large bias near 20Km can be seen. But the ration is less than that of FY3C, about 7%, because the performance of payload has been improved.
- Similar correction algorithm and quality control method will be applied in FY3D GPS RO data, too.

Monitoring of Near Real Time GNOS/GPS Data at ROMSAF



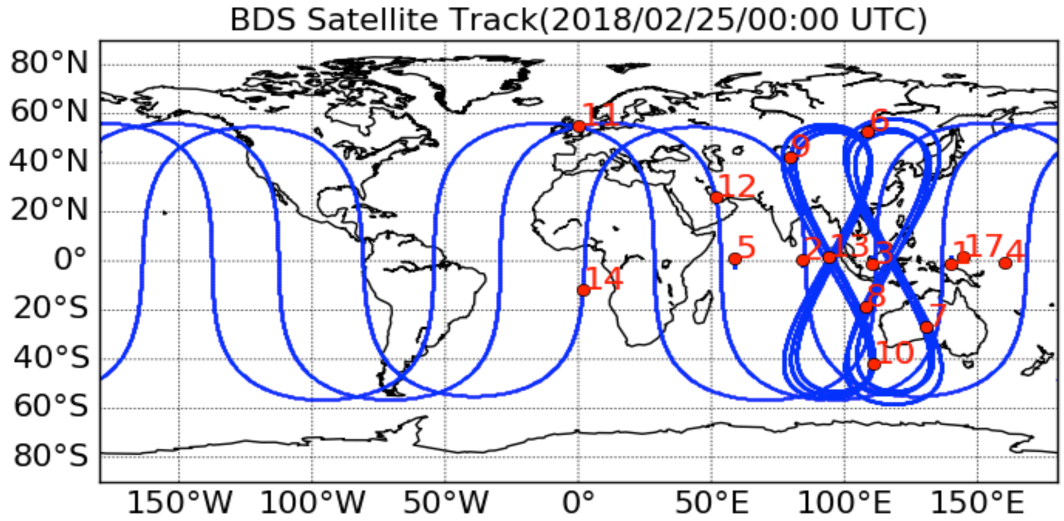




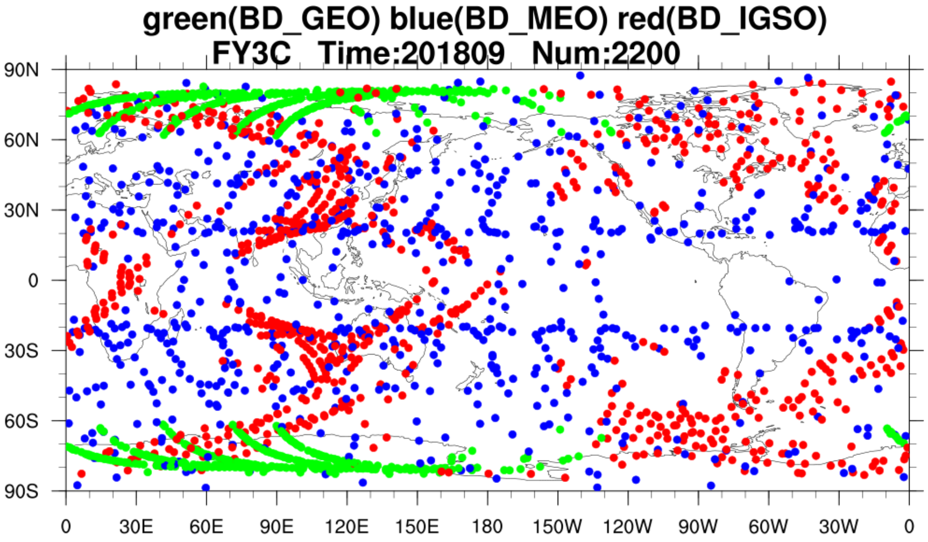


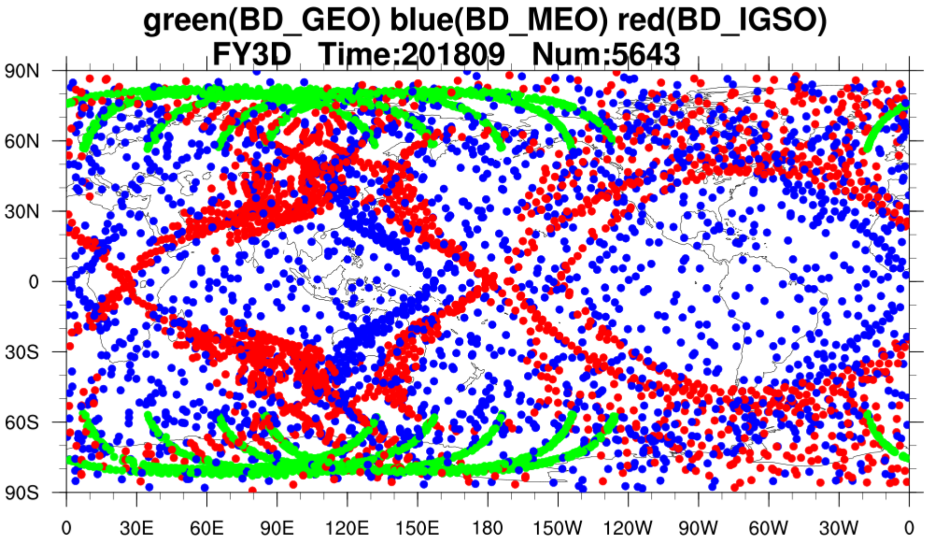
- GNOS/GPS RO data have been disseminated via GTS.
- The quality are similar to other mission RO data.
- Thank ROM SAF for providing the monitoring platform.

BDS Orbits and GNOS/BDS RO Distribution


BDS Satellite Track(2018/02/25/00:00 UTC)
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
150°W
100°W
50°W
0°
50°E
100°E
150°E
11
6
9
12
5
2
13
3
1
17
4
14
8
7
10

- a multi-GNSS receiver.
- **BDS-2 (regional GNSS, 5 GEO + 5 IGSO + 4 MEO)**

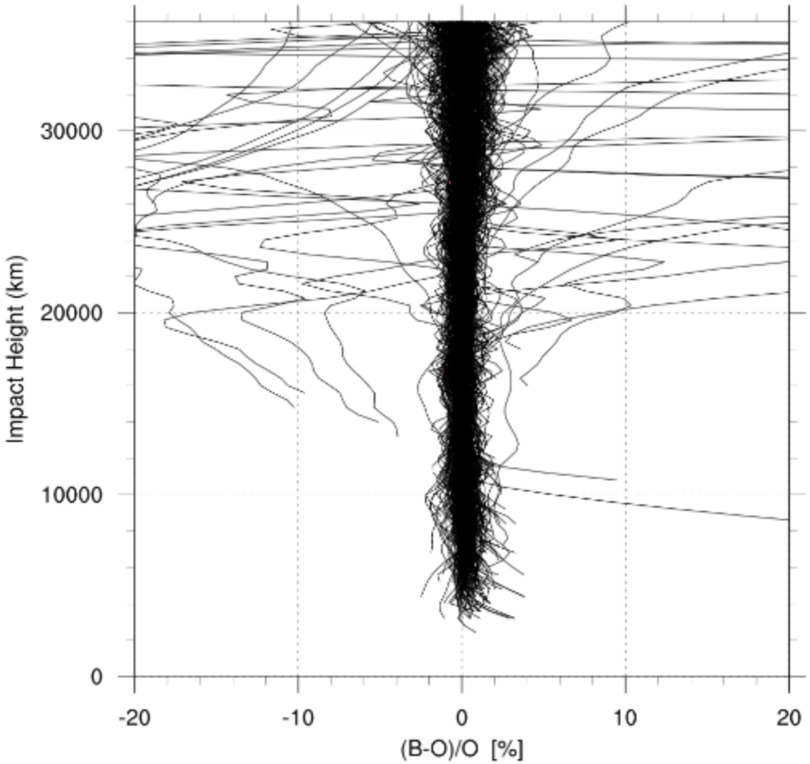

green(BD_GEO) blue(BD_MEO) red(BD_IGSO)
FY3C Time:201809 Num:2200
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0


green(BD_GEO) blue(BD_MEO) red(BD_IGSO)
FY3D Time:201809 Num:5643
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0

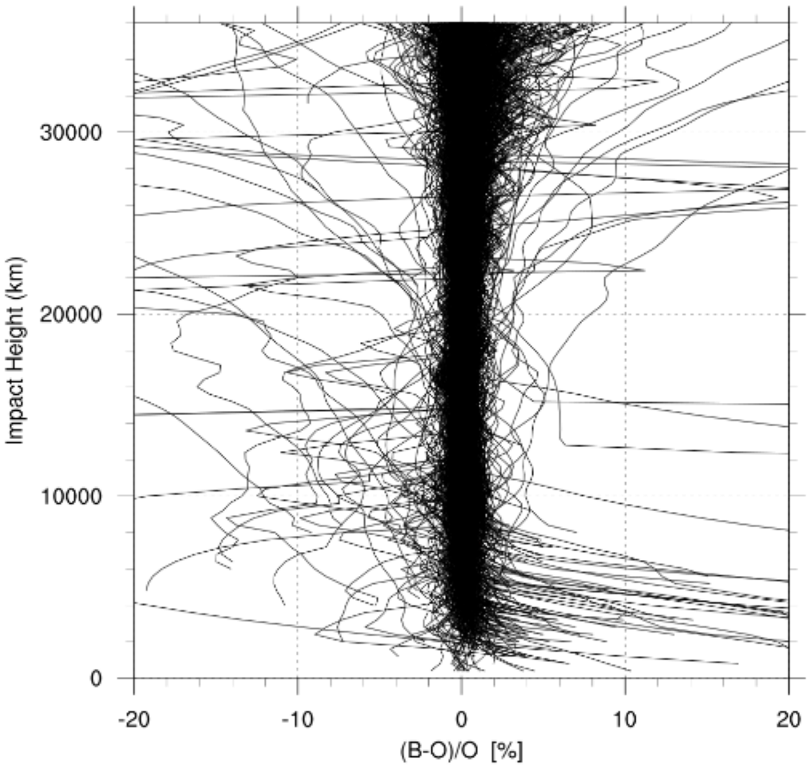
- GEO and IGSO RO have advantages of strengthening the regional weather disaster monitoring .

Fractional refractivity of BDS RO against ERA-Interim analysis

FY-3C BDS RO



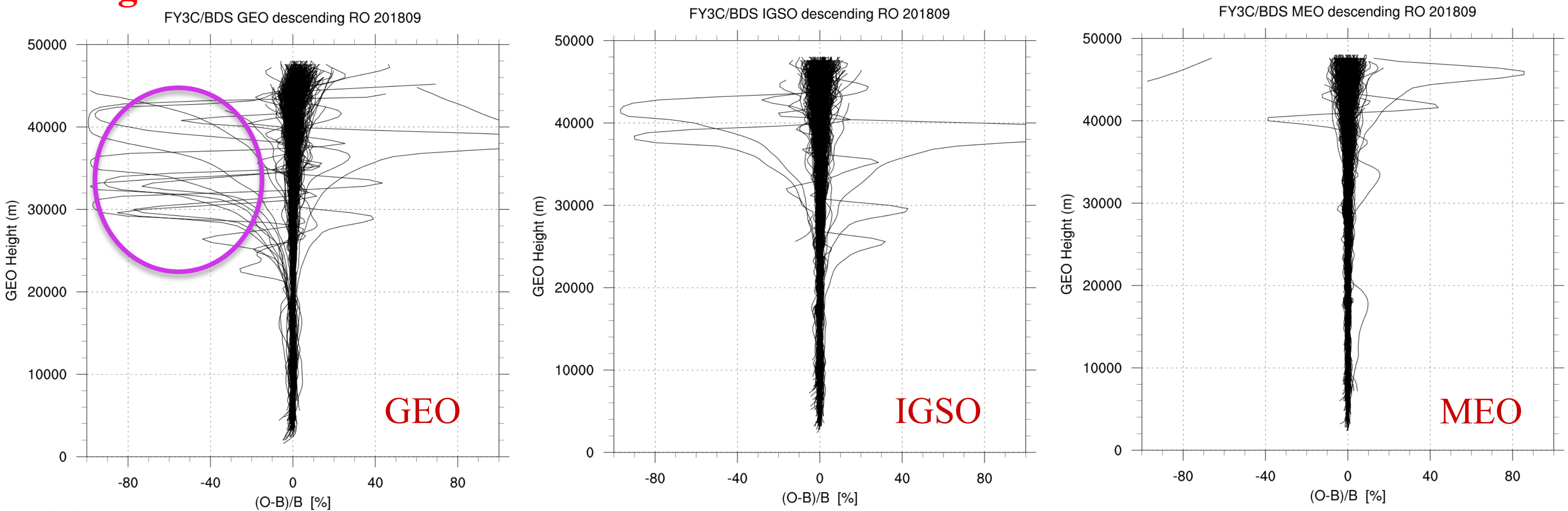
FY-3D BDS RO



- There are no extra branch profiles with large bias like GPS RO.
- Some profiles still have noise.
- Open loop for FY3C and closed loop for FY3D.
- ……

Preliminary Assessment of FY3C BDS RO Data

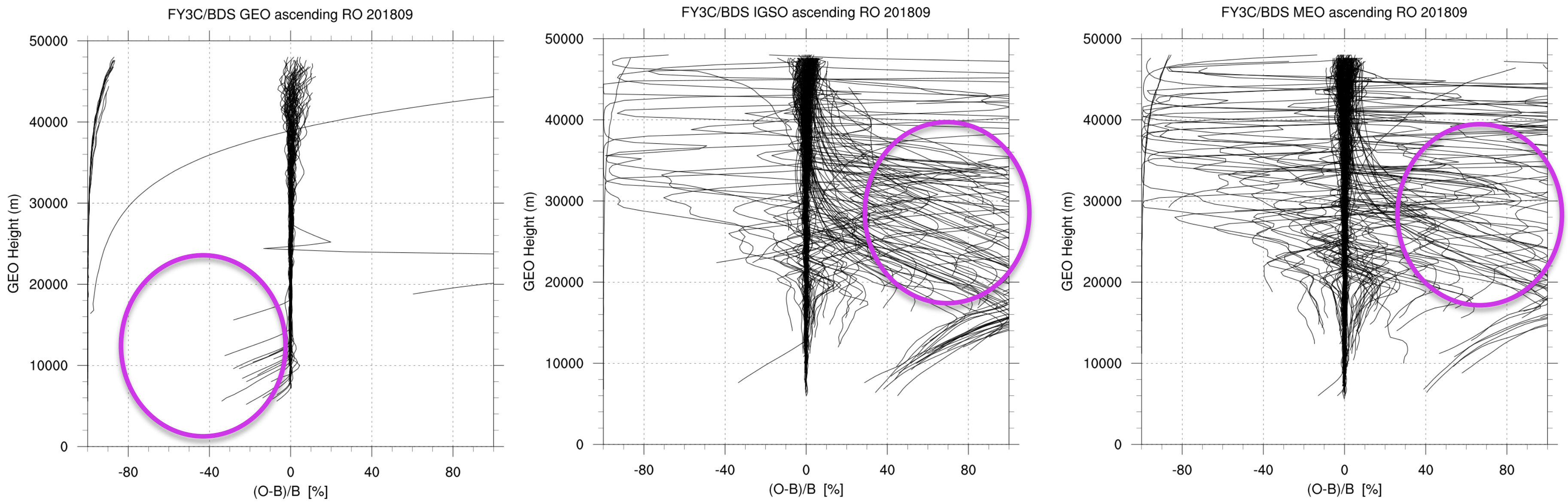
Setting RO


FY3C/BDS GEO descending RO 201809

FY3C/BDS IGSO descending RO 201809

FY3C/BDS MEO descending RO 201809

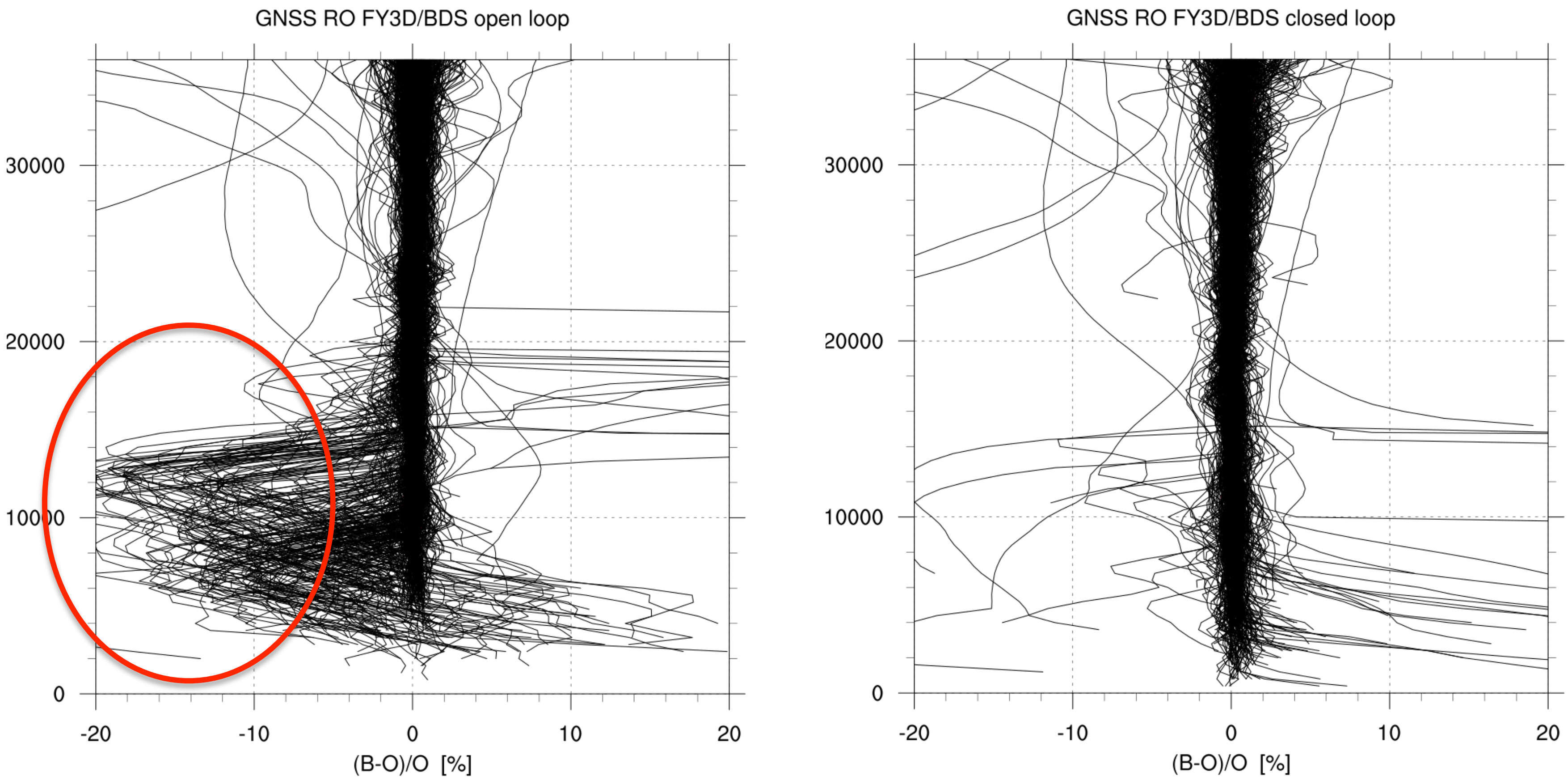
Rising RO


FY3C/BDS GEO ascending RO 201809

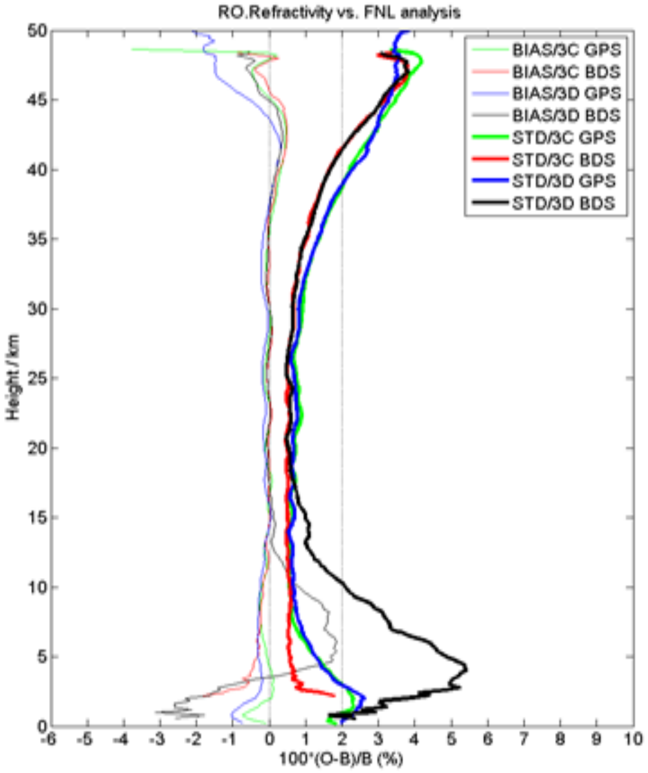
FY3C/BDS IGSO ascending RO 201809

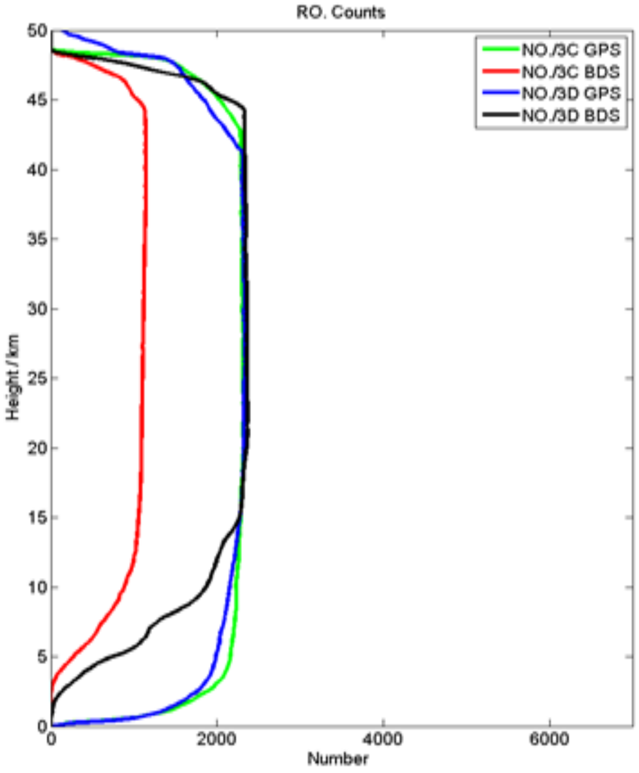
FY3C/BDS MEO ascending RO 201809

Open loop tracking problem for FY3D BDS RO



Fractional refractivity of GNOS RO against FNL analysis





- After the same quality control, the four kinds of GNOS RO data show good agreement during 10–35 Km region with standard deviation of 1%.
- Reconfirming the characteristic of non-bias of RO data.

Issues of GNOS/BDS RO

- BDS RO data quality is similar to GPS RO after QC.
- But further improvements are still needed.
- Open loop tracking has not achieved.
- Data has not been operational due to near real time BDS ephemeris unavailable.

GRAPES (Global/Regional Assimilation Pr*E*diction System) Operational System

Unified framework for global and regional system, including the regional and global deterministic and ensemble system

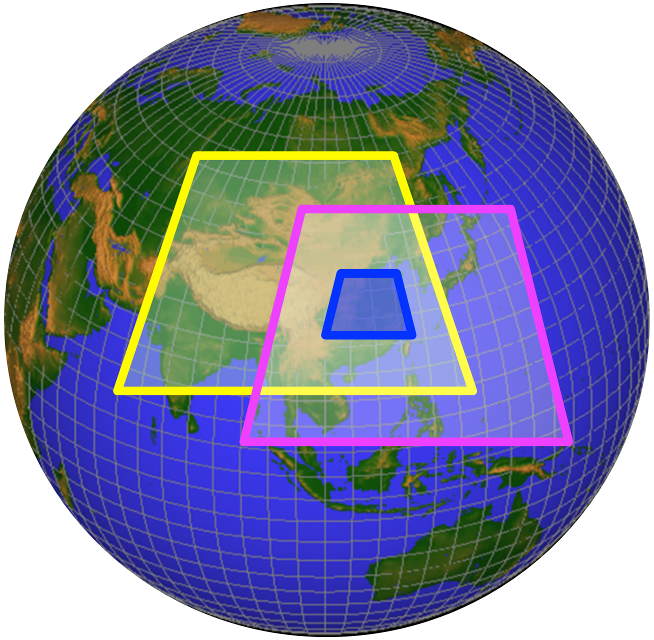
- GRAPES_GFS
  - ➢ 25kmL60/36Km, 10d Fcst., 4times/d
  - ➢ 4DVar, 100km inner loop
- GRAPES_MESO
  - ➢ GRAPES_Meso 10kmL50/3DVar/3h/China
  - ➢ GRAPES_Meso 3kmL50/3DVar/3h/East China
  - ➢ GRAPES_TYM 12kmL50
- GRAPES_GEPS: 50kmL60, 31Members
- GRAPES_REPS: 10kmL50, 15Members

Operational upgrades next year

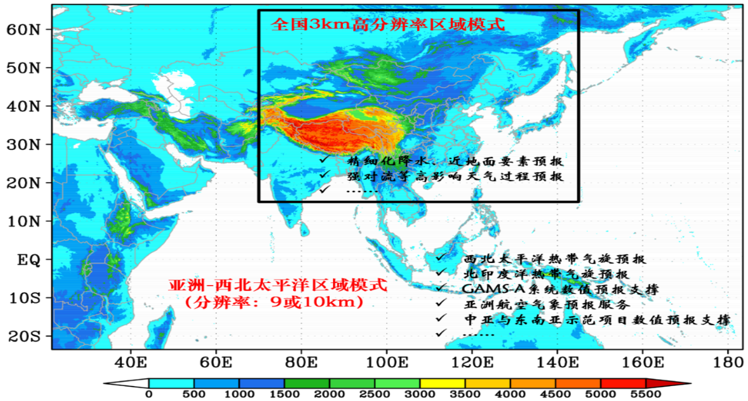
① GRAPES_GFS model top up to 0.1hPa

② 10 and 3Km GRAPES_MESO systems integrated, and became a 3Km China system

③ GRAPES_TYM enlargers domain



Upgrade of regional model


全国3km高分辨率区域模式
✓ 精细化降水、近地面要素预报
✓ 强对流等高影响天气过程预报
✓ ……
亚洲-西北太平洋区域模式
（分辨率：9或10km）
✓ 西北太平洋热带气旋预报
✓ 北印度洋热带气旋预报
✓ GAMS-A系统数值预报支撑
✓ 亚洲航空气象预报服务
✓ 中亚与东南亚示范项目数值预报支撑
✓ ……
60N
50N
40N
30N
20N
10N
EQ
10S
20S
40E
60E
80E
100E
120E
140E
160E
180
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500

RO Preprocessing and Assimilation Method

- use both rising and setting RO
- use data from surface to model top
- QC
  - gross checking
  - super refraction checking
  - background checking
- vertical thinning: 1 datum per analysis vertical layer

- assimilate refractivity for GRAPES currently
- assimilate bending angles for GRAPES_GFS next year
- obs. error: vary with latitude and height

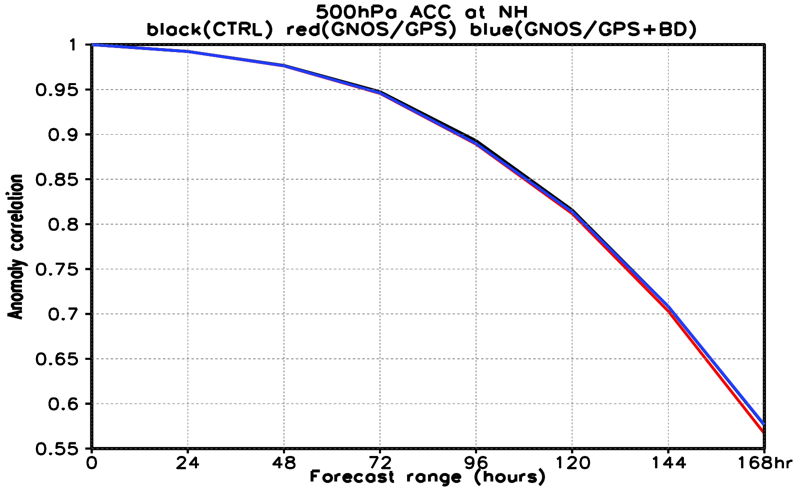
$$N = 77.6 * \frac{P}{T} + 3.73 * 10^5 * \frac{e}{T^2}$$

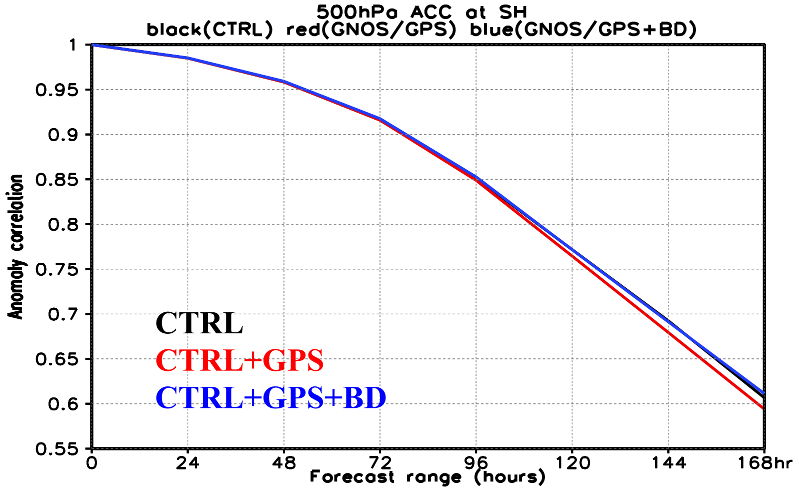
$$\alpha(a) = -2a\int_{r_0}^{\infty} \frac{\frac{d\ln n}{dr}}{\sqrt{n^2 r^2 - a^2}}\, dr$$

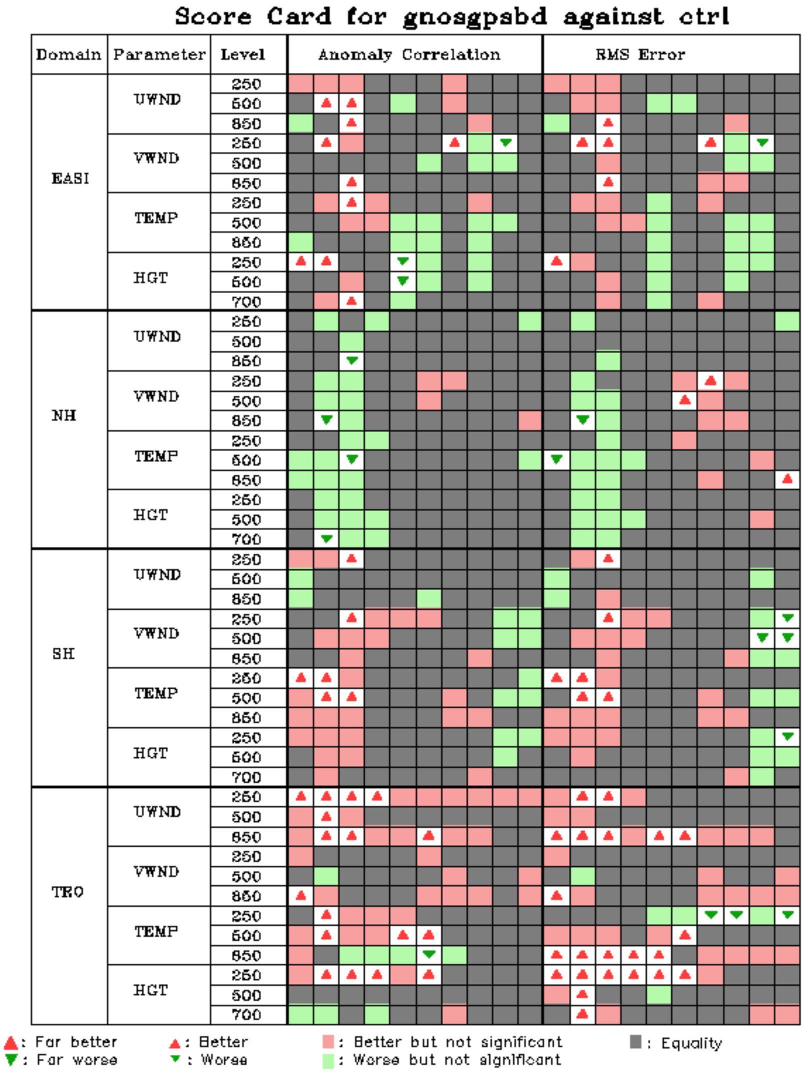
Trial Configurations

- **GRAPES-Var**
  - Observations assimilated : conventional data (radiosondes, synops, ships, AMV and aircraft), GNSS RO, MODIS wind, ASCAT wind, radiances (NOAA15,16,17,18,19,METOP and FY)
  - Regional DA system can only assimilate conventional data
  - Time windows : 6hr
- **Trial Setup**
  - configuration of operational system
  - impact experiments (ctrl+gnos/gps, ctrl+gnos/gps+gnos/bd)
  - cycling time: 1st - 30th, November, 2013 for global
  - cycling time: 9 May- 10 June 2018 for region
- **Assimilation of GNOS data**
  - GRAPES-Var has the ability of assimilating RO data.
  - GRAPES model top is lower (GPAPES_GFS 36Km, GRAPES_MESO 30Km)
  - GNOS quality is good in core region.

Trial Results of Assimilating FY3C/GNOS RO Data in GRAPES_GFS

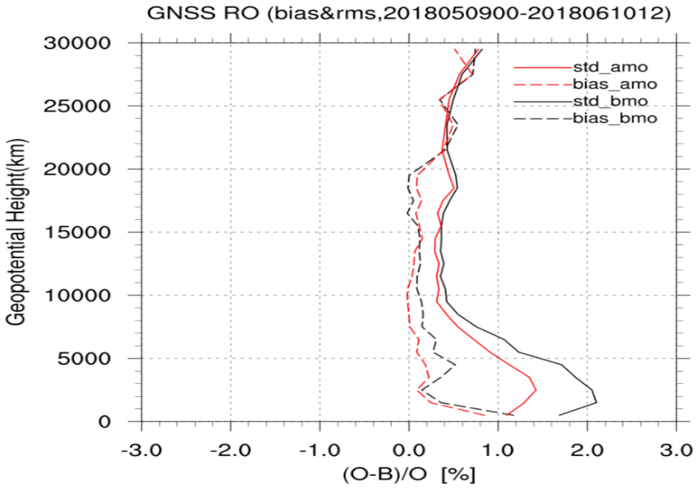






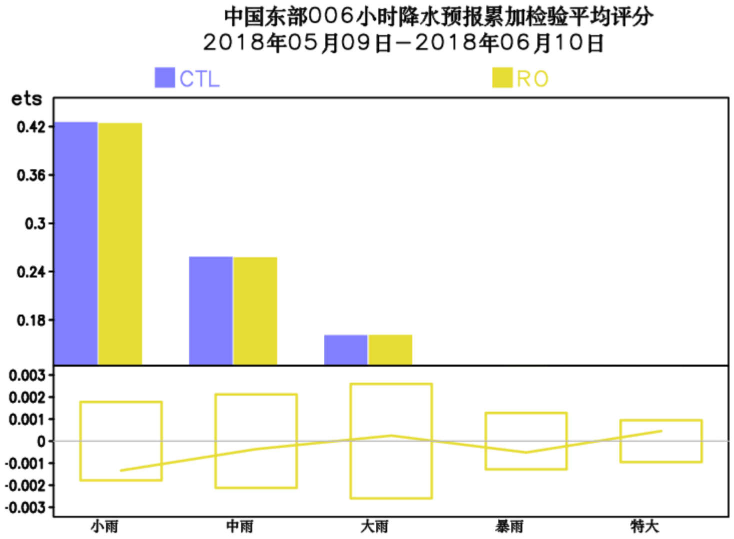
FY3C RO data has an neutral and positive impacts on global GRAPES forecast skill.

Trial Results of Assimilating FY3C/GNOS RO Data in GRAPES_MESO



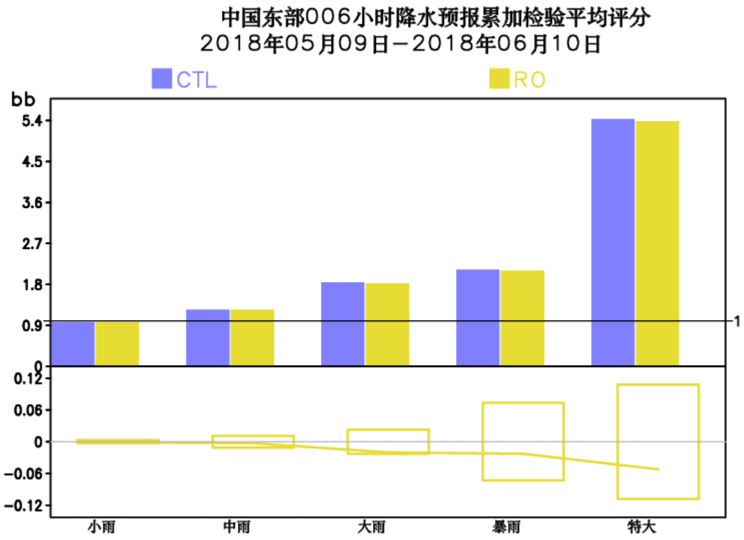
GNSS RO (bias&rms,2018050900-2018061012)

Precipitation score



中国东部006小时降水预报累加检验平均评分

2018年05月09日－2018年06月10日



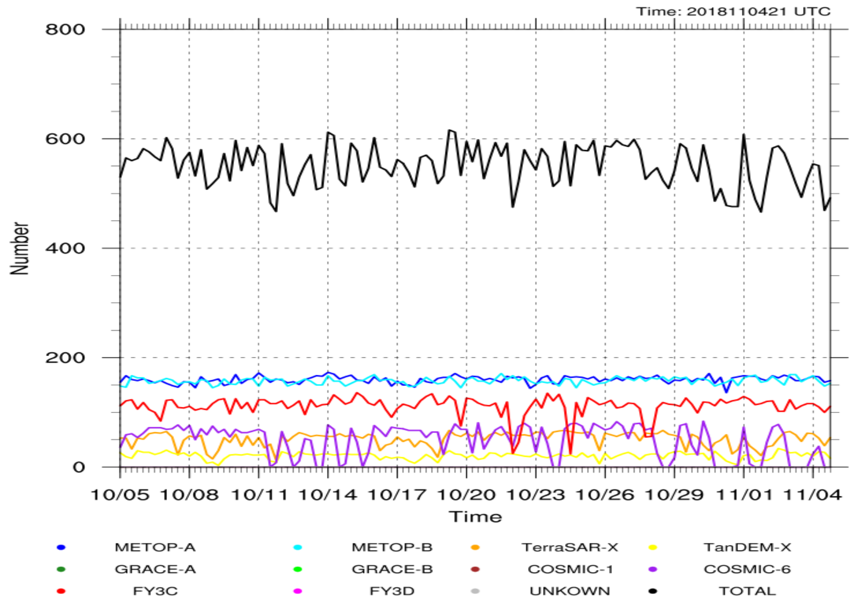
中国东部006小时降水预报累加检验平均评分

2018年05月09日－2018年06月10日

Data volume and distribution

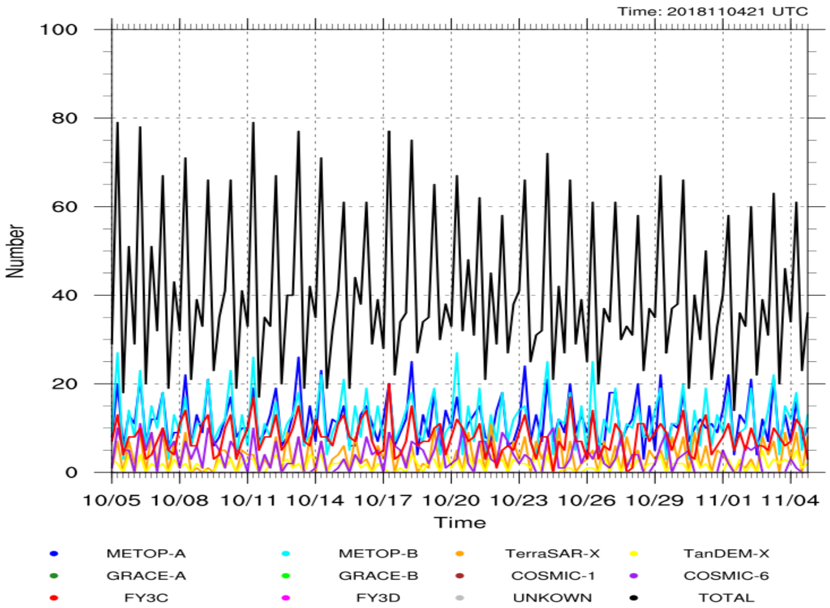
GLOBAL

GNSS RO

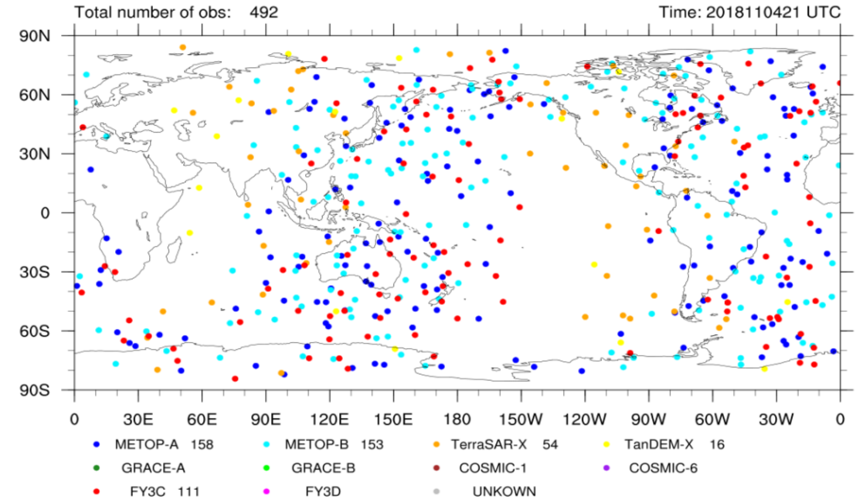


East Asia

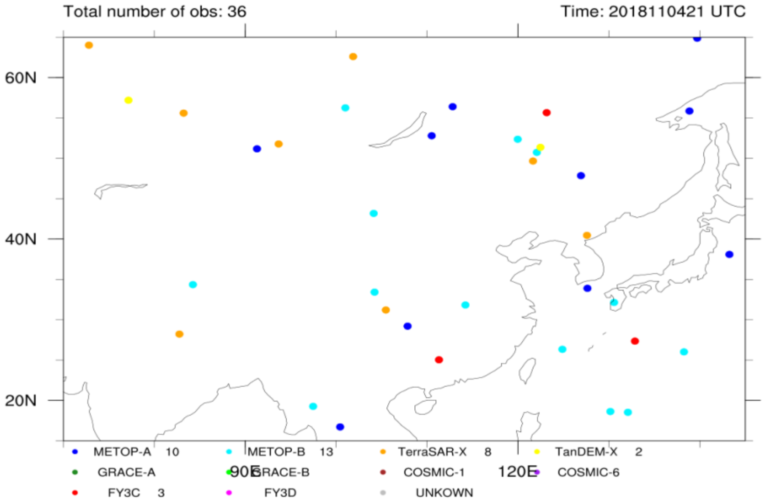
GNSS RO



GNSS RO


Total number of obs: 492
Time: 2018110421 UTC
90N
60N
30N
0
30S
60S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
METOP-A 158
METOP-B 153
TerraSAR-X 54
TanDEM-X 16
GRACE-A
GRACE-B
COSMIC-1
COSMIC-6
FY3C 111
FY3D
UNKOWN

GNSS RO


Total number of obs: 36
Time: 2018110421 UTC
60N
40N
20N
90E
120E
METOP-A 10
METOP-B 13
TerraSAR-X 8
TanDEM-X 2
GRACE-A
GRACE-B
COSMIC-1
COSMIC-6
FY3C 3
FY3D
UNKOWN

Summary and plan

- GNOS RO data show better quality during 10–35 Km core region.
- FY-3 GPS RO data have been operational at GRAPES.
- Push the operation of BDS RO.
- More elaborated observation impact experiments of GNOS shall be done. For example, how the combined impact of morning and afternoon orbit RO data? Because FY3C is morning satellite, FY3D is afternoon satellite and FY3E is a early morning satellite. How the BDS RO assimilation impact the Tibet plateau, north-western pacific and northern India ocean typhoon, and the polar weather prediction.