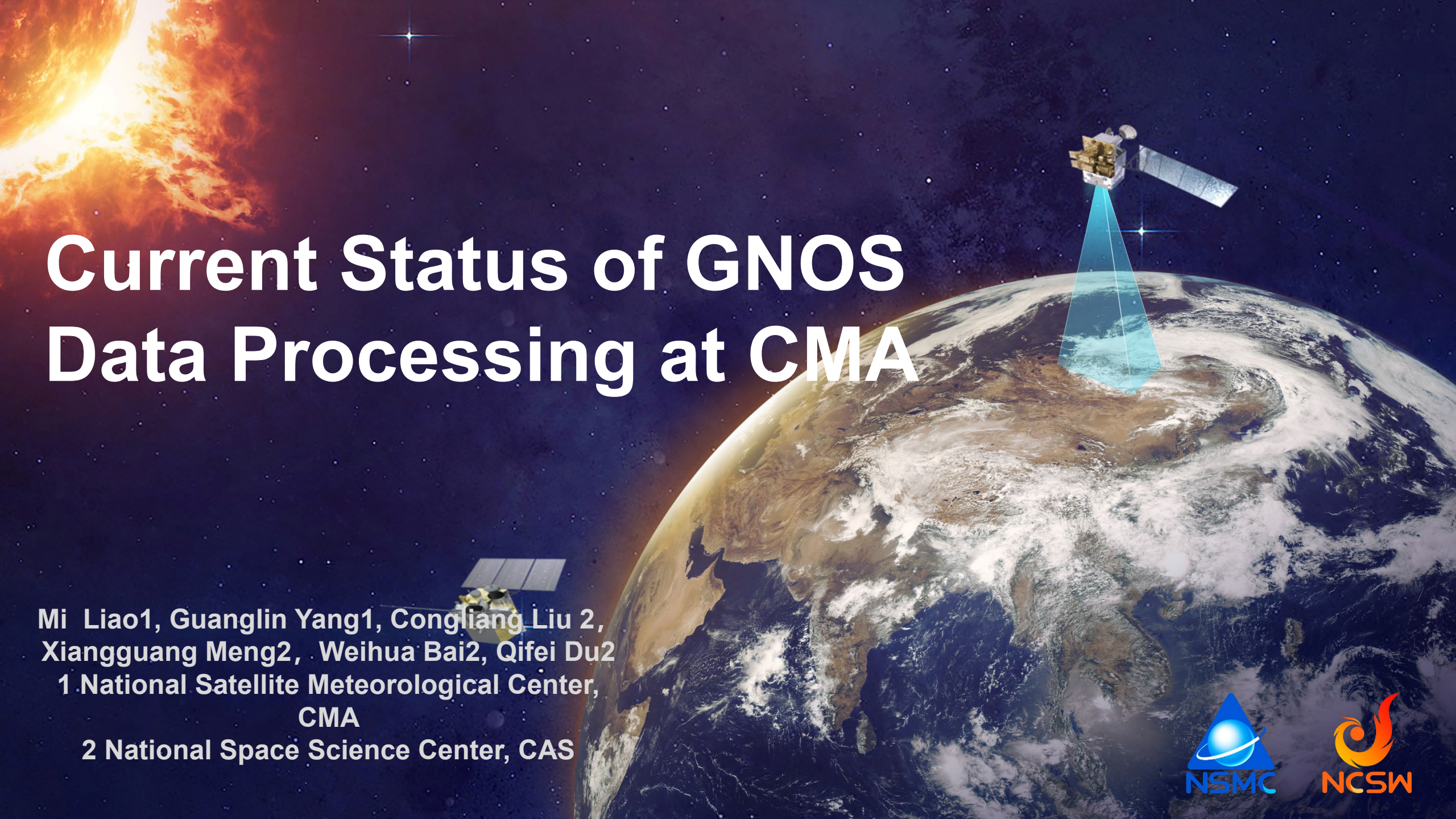
Current Status of GNOS Data Processing at CMA



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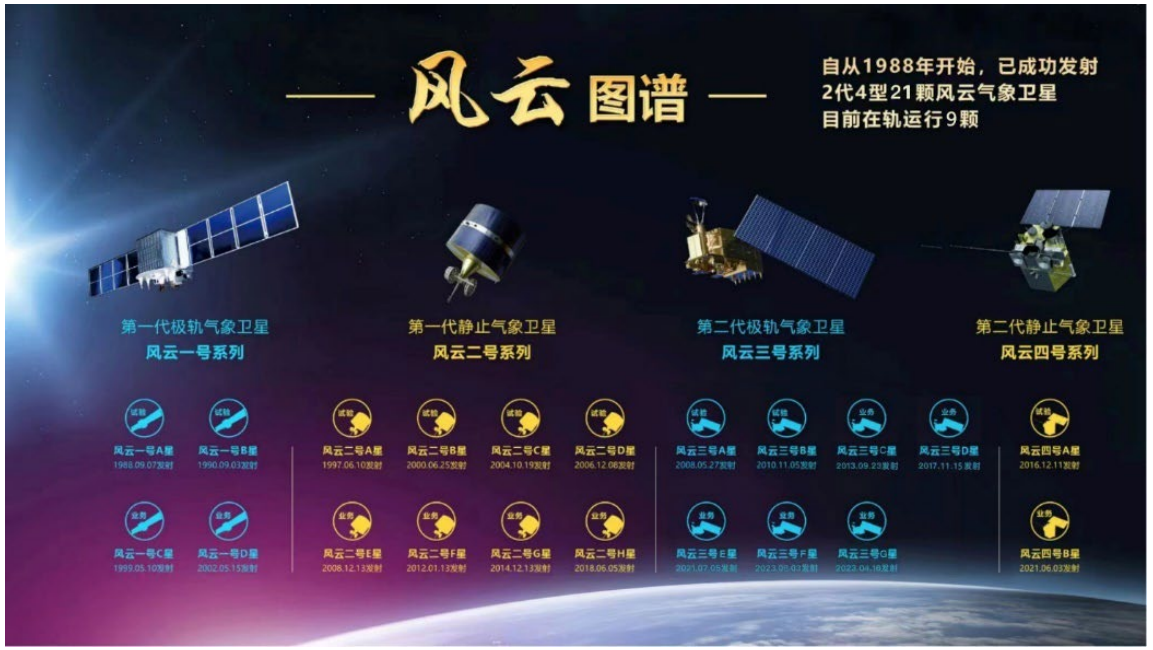
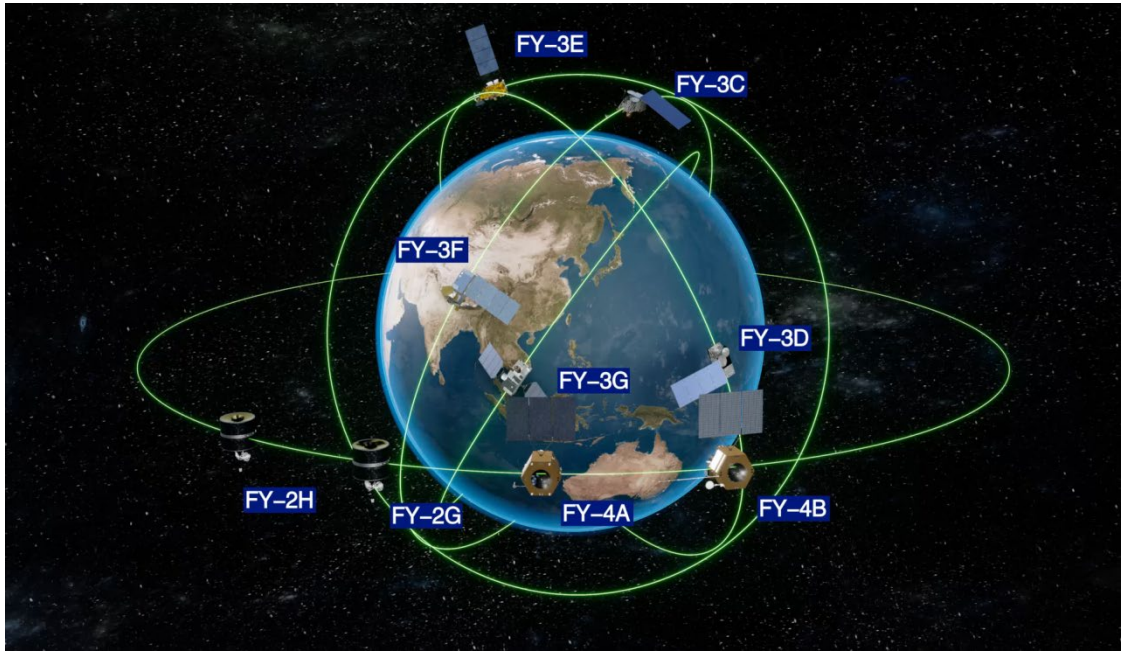
Contents

1. Current FY3 RO

- The first RO sounder loaded on FY3C was launched in 2013, ended in 2024 25th March
- FY3C/3D GNOS
- FY3E/3F/3G GNOS-Ⅱ



21 satellites, Two generations and Four types



9 FengYun satellites on duty

1. Current FY3 RO

- FY-3D 2017 launched.
- FY-3E was successfully launched on July 5, 2021, which is world's first meteorological satellite in early morning orbit for civil service
- FY-3G launched on Apr.16 2023, is the first precipitation measurement satellite of the FY-3 series, operates in a non sun-synchronous orbit at a 50° inclination angle
- FY-3F launched on Aug.3, 2023 is the latest member of FengYun Constellation, replace with FY-3C.

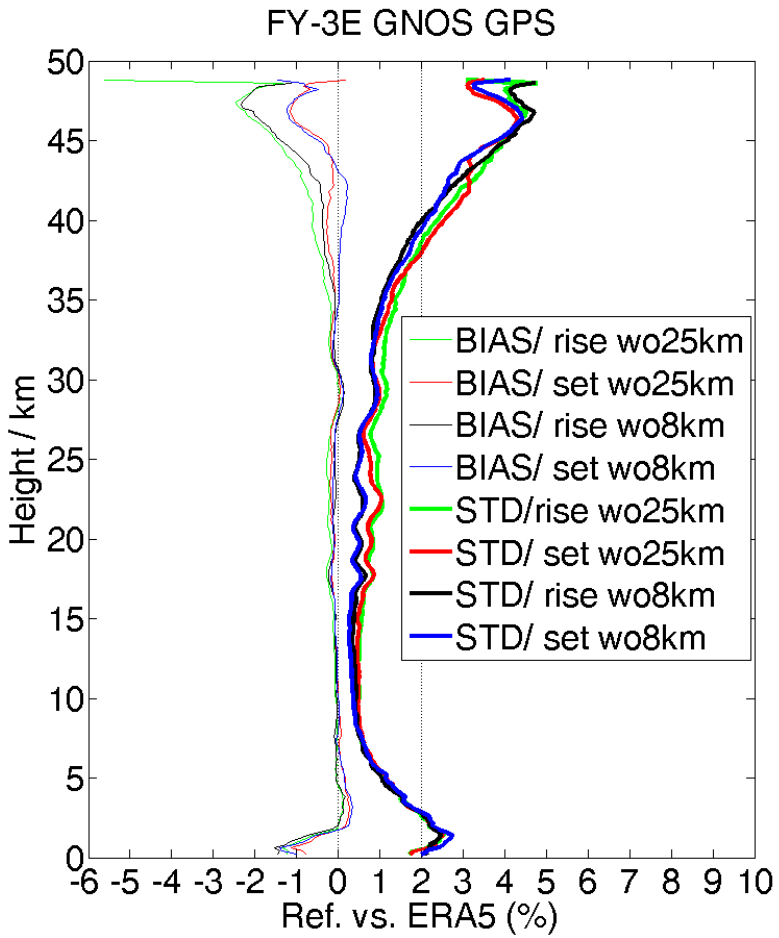
Four different orbits

parameters	FY-3D	FY-3E	FY-3G	FY-3F
Physic parameters	BA, ref, T,P,Vp, EDP	BA, ref, T,P,Vp, EDP, sea surface wind		
Constellation	GPS L1,L2;BDS B1 B2	GPS L1,L2;BDS B1 B2a	GPS L1,L2 ; BDS B1,B2a ; GAL: E1	as FY-3G
Channels	14 for pos; 12 for occ.	24 for pos. ; 20 for occ.	28 for pos; 24 for occ.	as FY-3G
Clock stability	5e-12			
Pseudo-range precision	L1CA:10.5cm;L2C:15.5cm; L2P: 10.6cm	L1CA:8.2cm;L2C:7.4cm;L2P: 7.4cm;B1:6.7cm;B3 :3.9cm	L1CA:8.0cm; L2C:7.3cm L2P: 7.4cm ;B1:6.1cm B3 :3.0cm	as FY-3G
Carrier phase precision	LB1-B2 :0.51 mm; L1CA-L2C:0.41mm; L1CA-L2P:0.2mm	B1-B3 :0.717 mm; L1CA-L2C:0.733mm; L1CA-L2P:0.504mm	B1-B3 :0.806 mm; L1CA-L2C:0.349mm; L1CA-L2P:0.924mm	as FY-3G
PCV of POD antenna	Less than 2mm	Less than 2mm	L1:0.56mm; L2:0.76mm B1:0.61mm; B3:0.57mm	as FY-3G
Beam width of atm. occultation antenna	≥±40°			
antennas	1for POD, 2 for Occ. 2 for eletron.	2 for POD, 2 for Occ. 2 for eletron. 1 for reflec.	1for POD, 2 for Occ. 2 for eletron. 1 for reflec.	as FY-3G
Sampling rate	POD:1 Hz;Electron: 1 Hz; Close loop: 50Hz; Open loop:100Hz			
Reflective Frequency	\	GPS L1; BDS B1	GPS L1; BDS B1; GAL; E1	as FY-3G
Reflective antenna gain	\	≥15dBi		
Reflective channels	\	GPS 4; BDS 4	GPS 3; BDS 4; GAL 1	as FY-3G
Code resolution	\	GPS:1/8; BDS:1/8	GPS:1/8; BDS:1/8; GAL:1/8	as FY-3G

2. Data processing status --- neutral RO

- Single difference technics for obtaining excess phase (GPS/BDS)
- Geometric optics (above 15 km)
- Wave optics (below 15 km)
- Dual frequency combination (GPS/BDS)
- Single frequency (Galileo)
- Statistical optimization (MSISE-90)
- L2 extrapolation(GPS)
- Abel integral (linear variation)
- 1D-VAR using CMA-GFS as BG

2. Data status --- FY3E

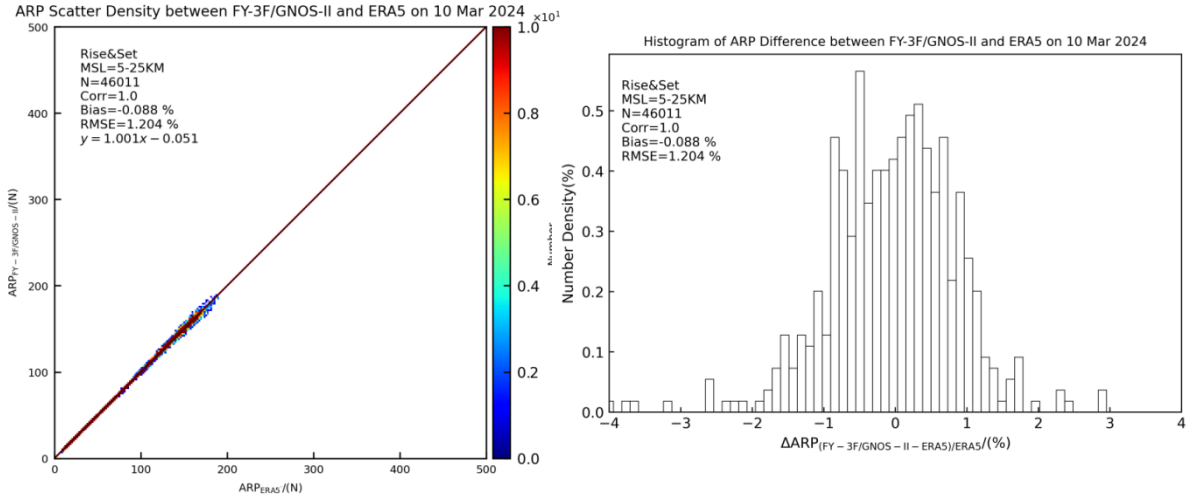


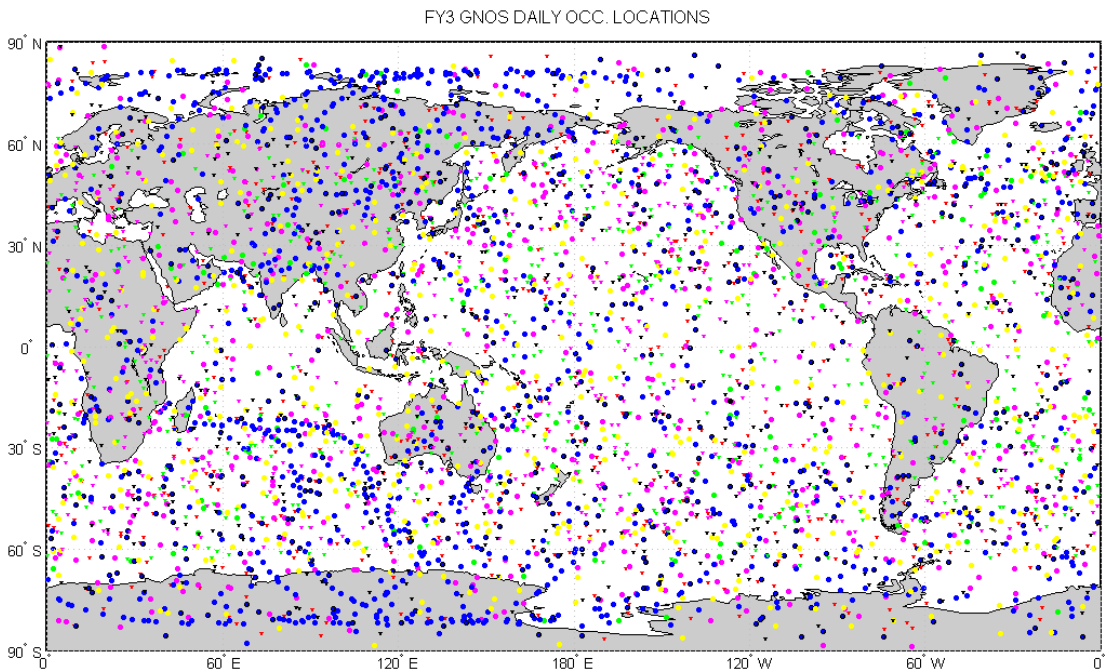
- Based on refractivity profiles, the kick like in the Ref. statistics is not obvious, which is probably obscured by the vertical intervals.
- Wave Optics starting height setting from 25km to 8km, showing smaller std in the range of 15-25km.

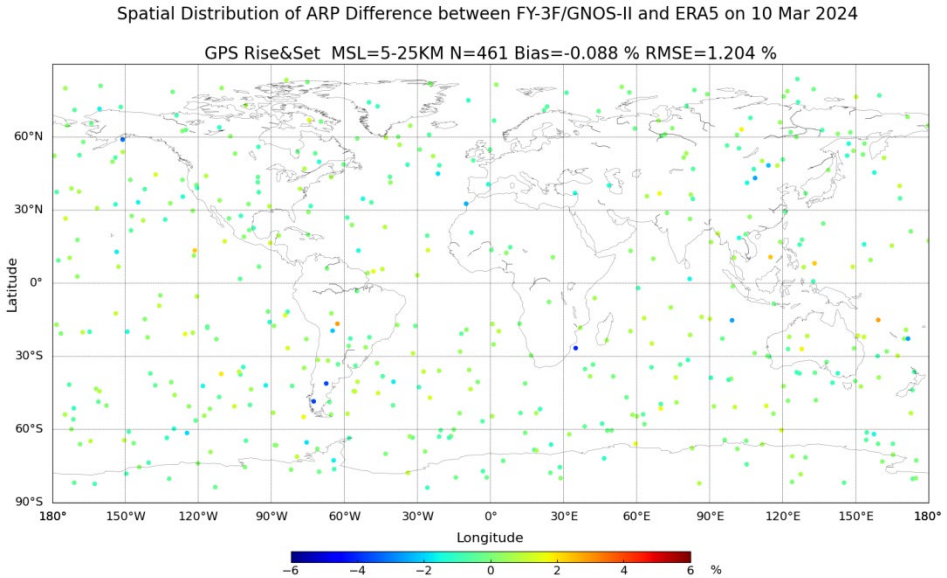
2. Data status --- FY3F

❖ Latest Progress:

- GNOS instruments on FY-3D/3E/3G/3F contribute to more than 3800 profiles per day.
- The daily quality of FY3F



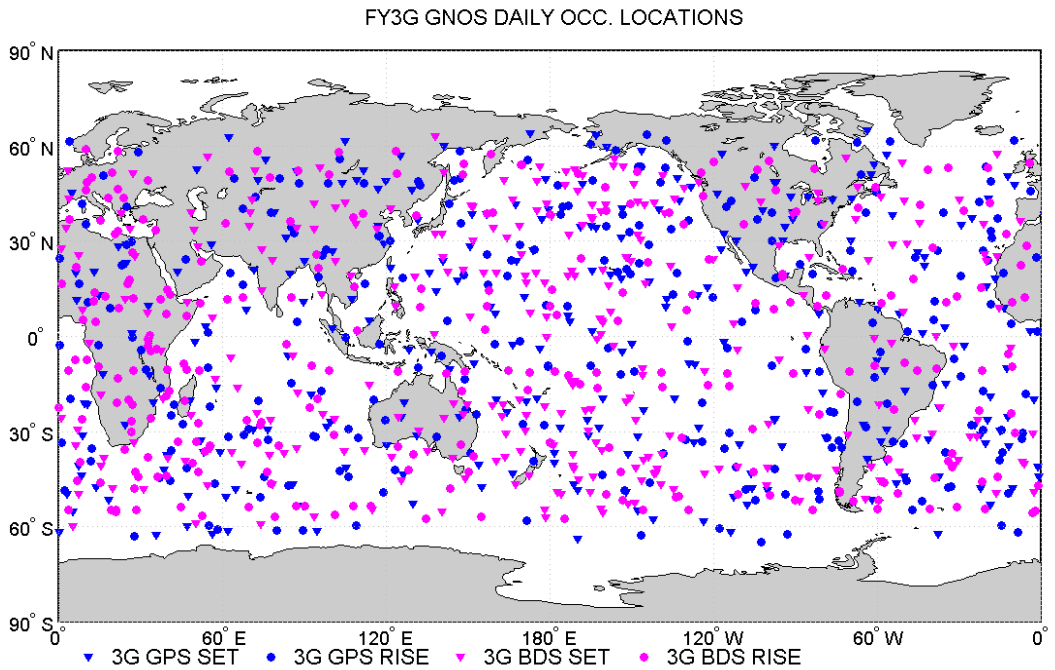


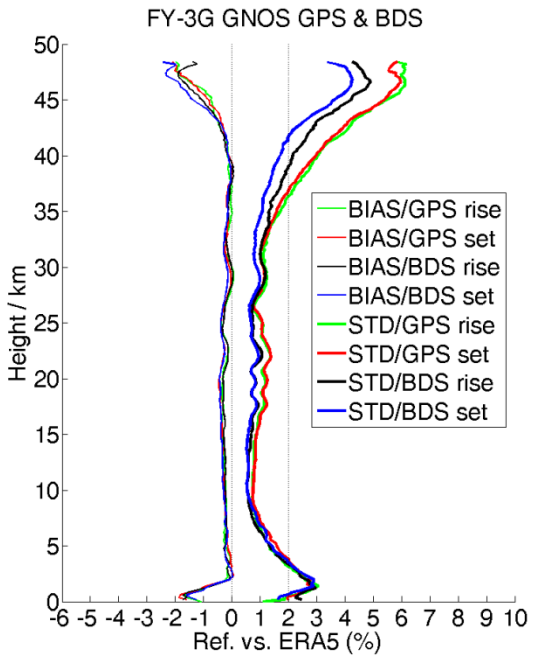


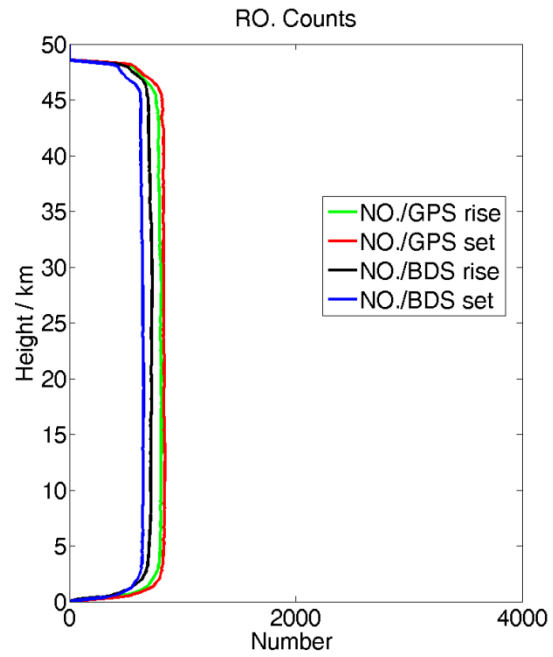
2. Data status --- FY3G

❖ Latest progress:

- Due to non **sun-synchronous orbit** at a 50° inclination angle, FY3G RO events distribute within the range of 60 degrees north and south latitude.
- BDS radio occultation improved above 35km, due to better BDS-3 signal (more RO events and higher quality)

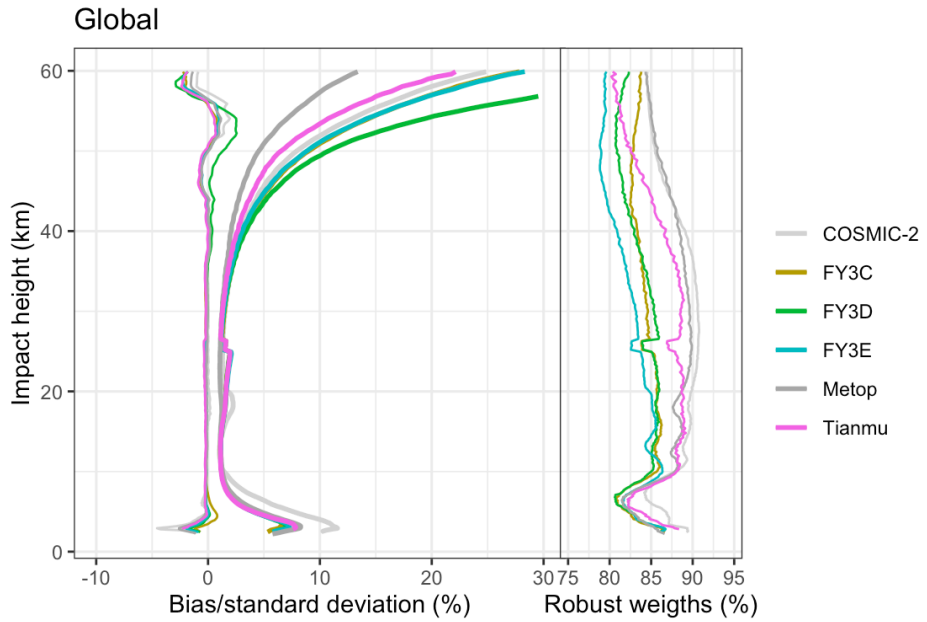


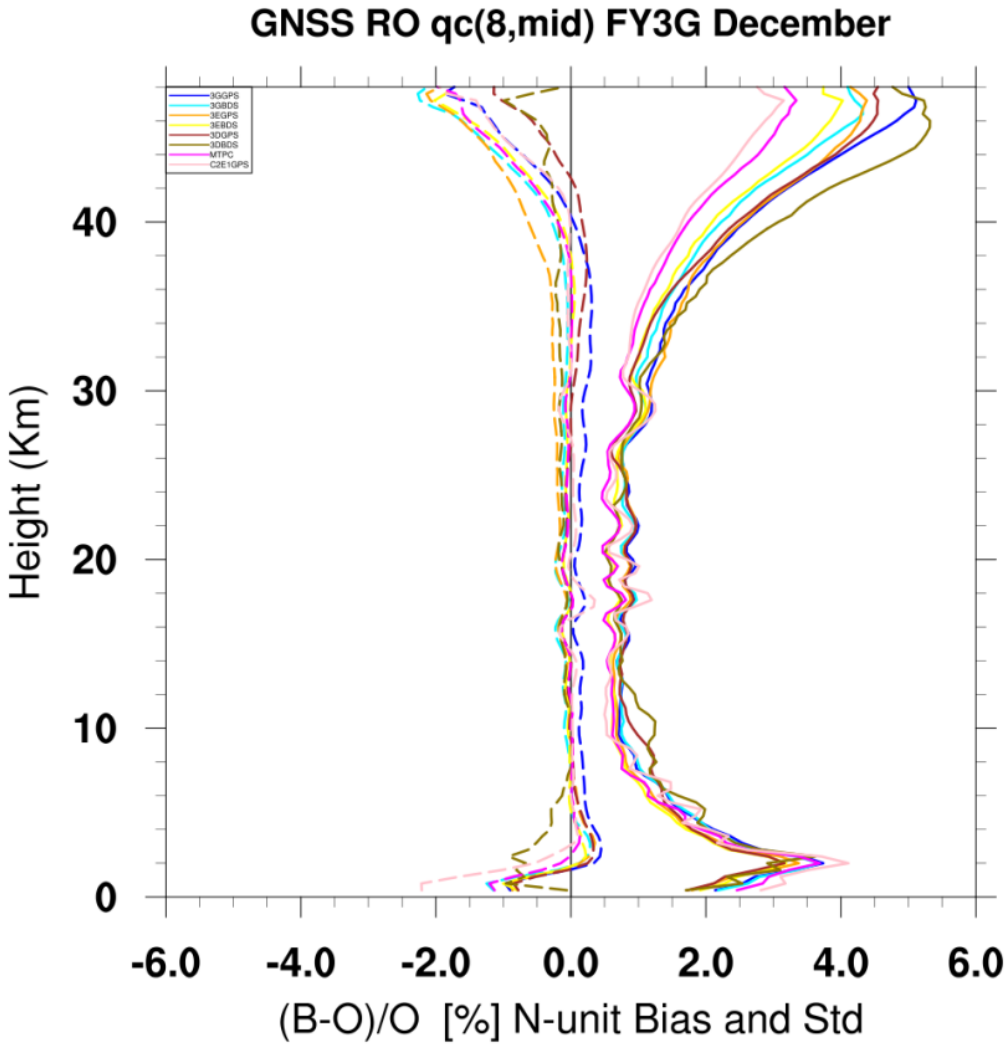




2. Data status --- Cross validation

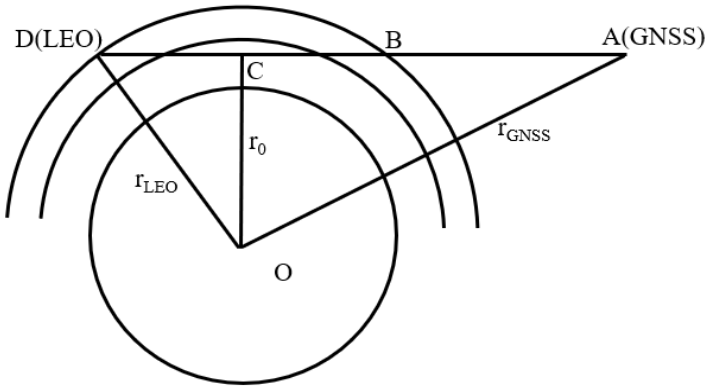
- Latest Progress:
  - Compared to MetOp and COSMIC2, GNOS performs similarly below 30km
  - From FY3D to FY3E/3G, the standard deviation gets small above 30km, but still bigger than MetOp and COSMIC
  - Join ROMEX mission to explore more technical





2. Data processing status --- Electronic RO

❖ TEC-Calibrated algorithm inversion process



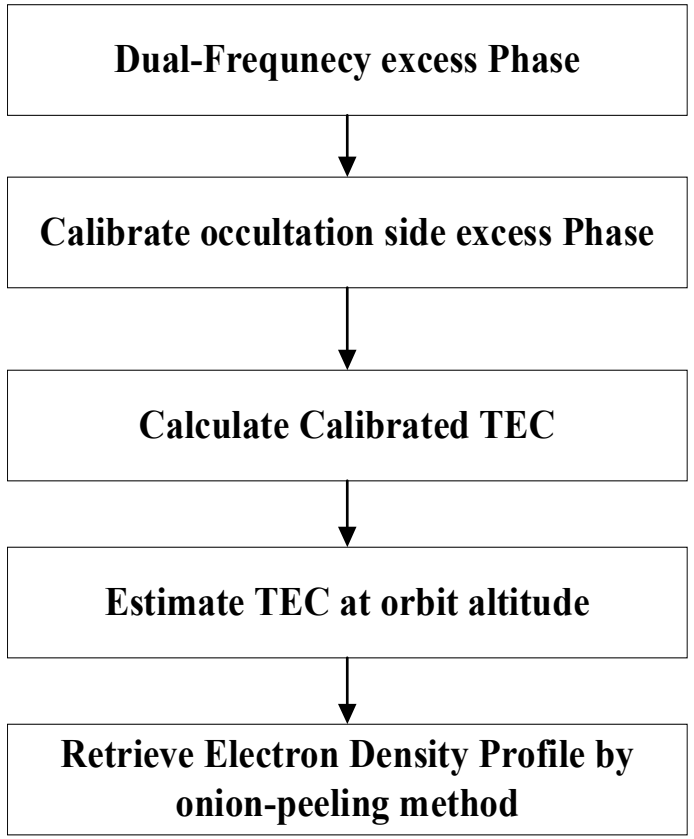
$$TEC = \frac{f_1^2 f_2^2}{C(f_1^2 - f_2^2)}(L_1 - L_2)$$

$$TEC_{BD} = TEC_{AD} - TEC_{AB} = 2TEC_{BC} = 2\int_{r_0}^{r_{LEO}} \frac{rN_e(r)}{\sqrt{r^2 - r_0^2}}dr$$

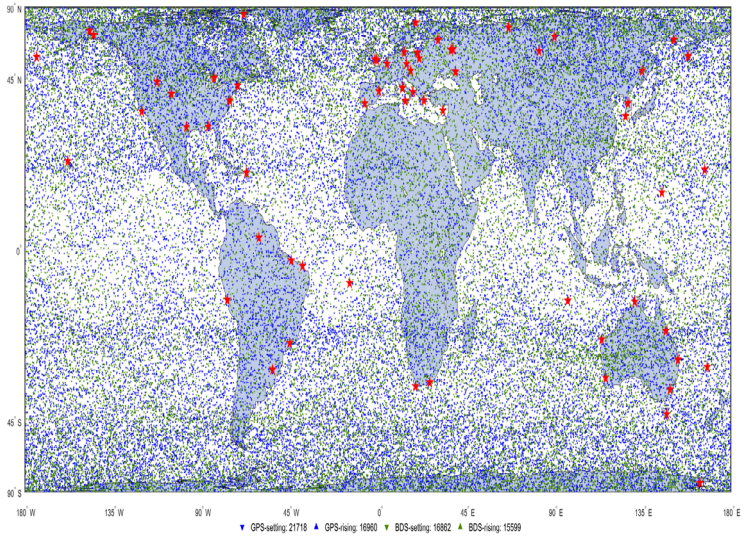
$$\mathrm{TEC}(p) \approx 2N_e(p_{\max})\sqrt{2p_{\max}(p_{\max} - p)}$$

$$N_e(p_i) = \frac{3}{4}\frac{\mathrm{TEC}(p_i)}{\sqrt{2p_i(p_{i+1} - p_i)}} - \sum_{k=1}^{n-i} c_{k,i}N_e(p_{i+k})$$

● EDP Inversion Algorithm

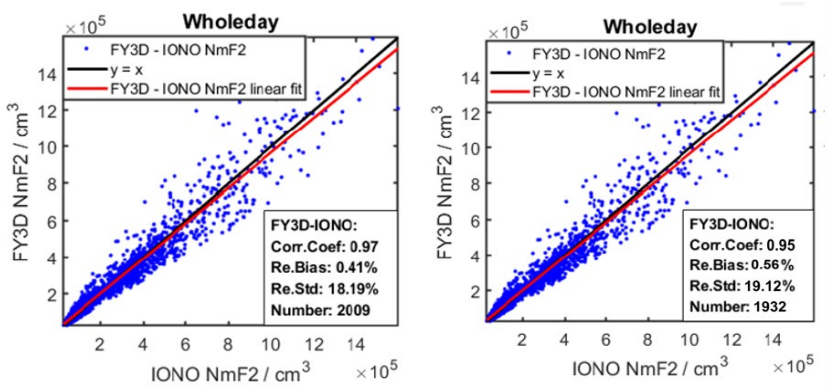


EDP Product Validation

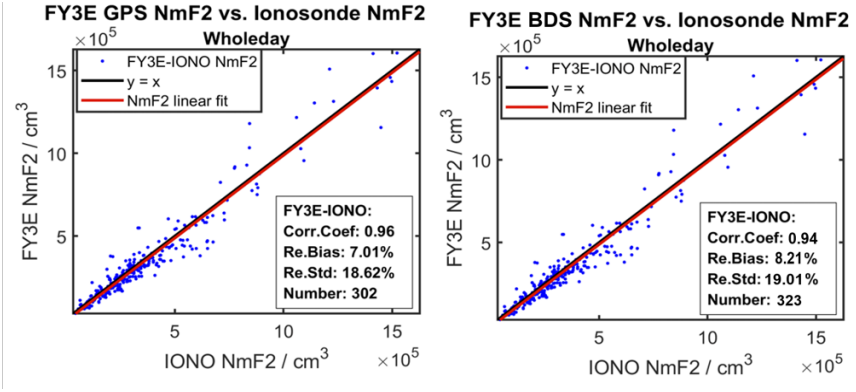


Time-Space Matching condition:
1.The distance between the occultation tangent point and the ionosonde is <200km
2. Observation time difference <30min

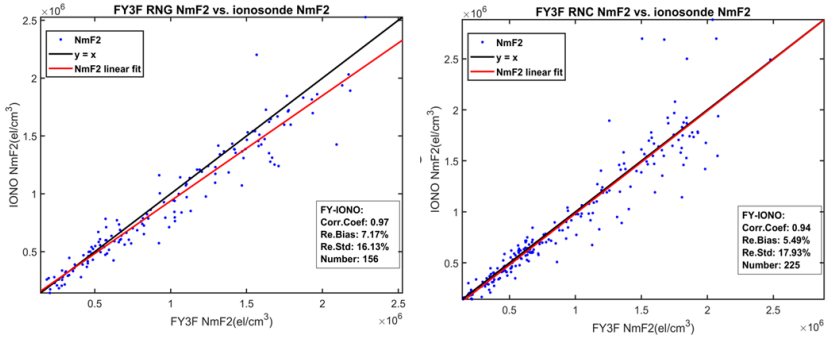
NmF2	Bias	Std
NmF2(FY3C-GPS)	6.62%	18.39%
NmF2(FY3C-BDS)	8.31%	17.24%
NmF2(FY3D-GPS)	0.41%	18.19%
NmF2(FY3D-BDS)	0.56%	19.12%
NmF2(FY3E-GPS)	7.01%	18.19%
NmF2(FY3E-BDS)	8.21%	18.76%
NmF2(FY3G-GPS)	4.49%	16.31%
NmF2(FY3G-BDS)	3.74%	18.46%
NmF2(FY3F-GPS)	7.17%	16.13%
NmF2(FY3F-BDS)	5.49%	17.93%



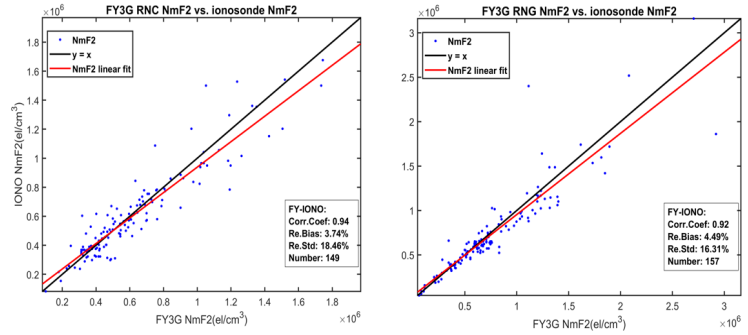
FY3D



FY3E



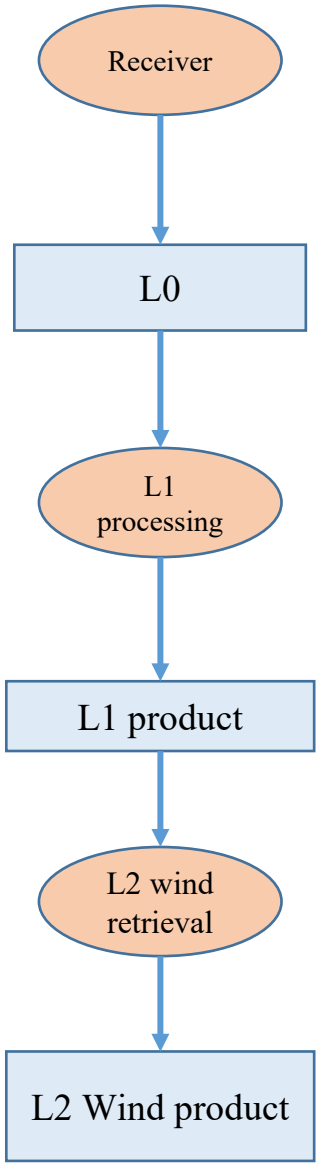
FY3F



FY3G

NmF2 std < 20% vs. ionosonde

2. Data processing status --- Reflection(Ocean Surface Wind)

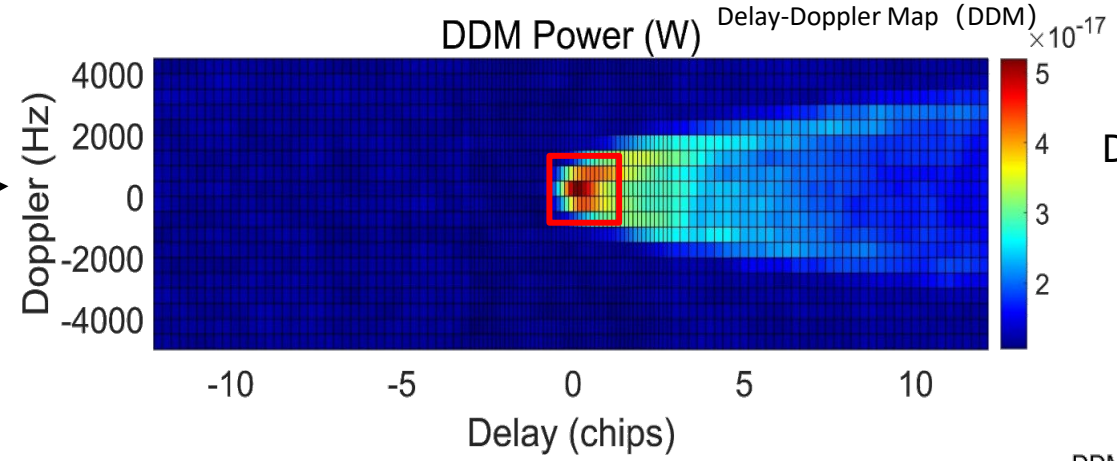


Calibration

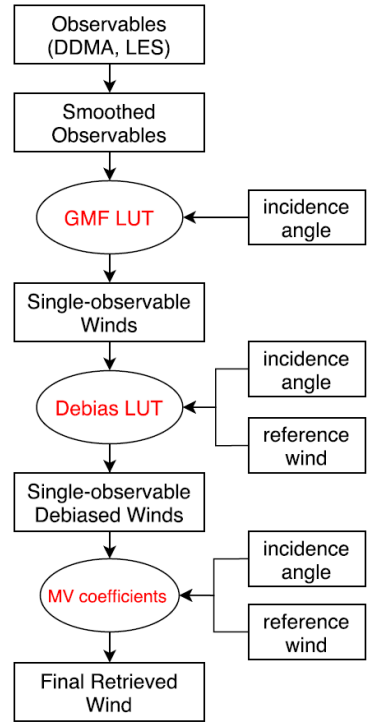
Calibated DDM
DDMA, LES observable

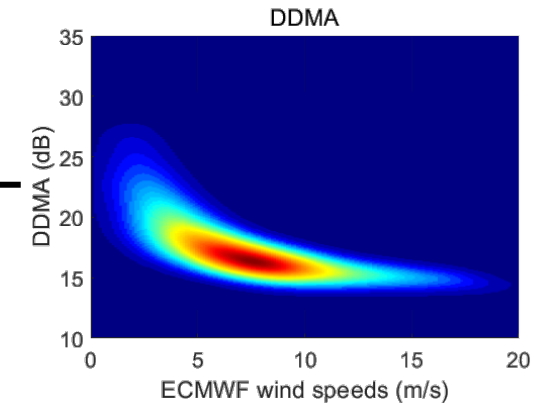
Retrieval by GMF

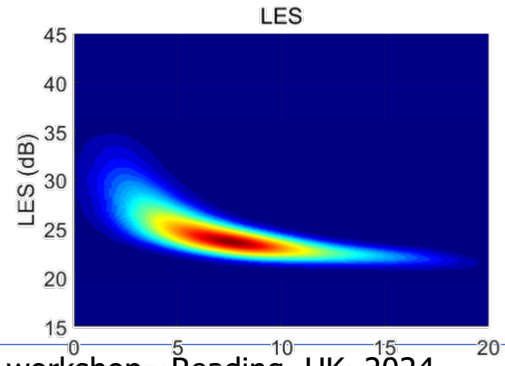
Ocean Surface Wind



122 time delays x 20 Doppler frequencies

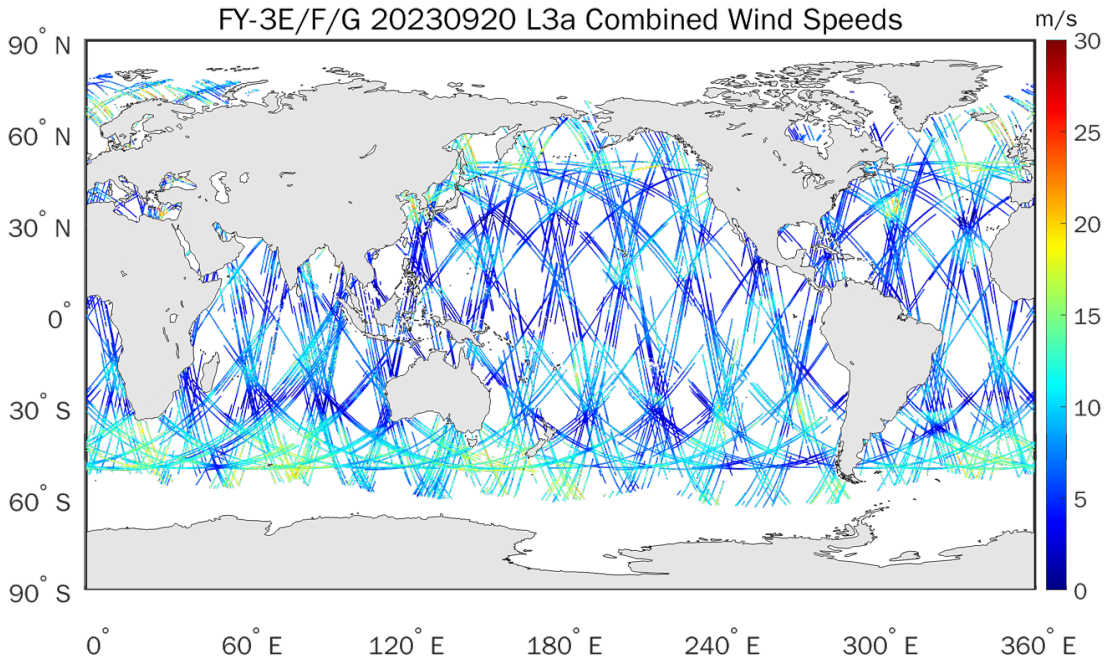






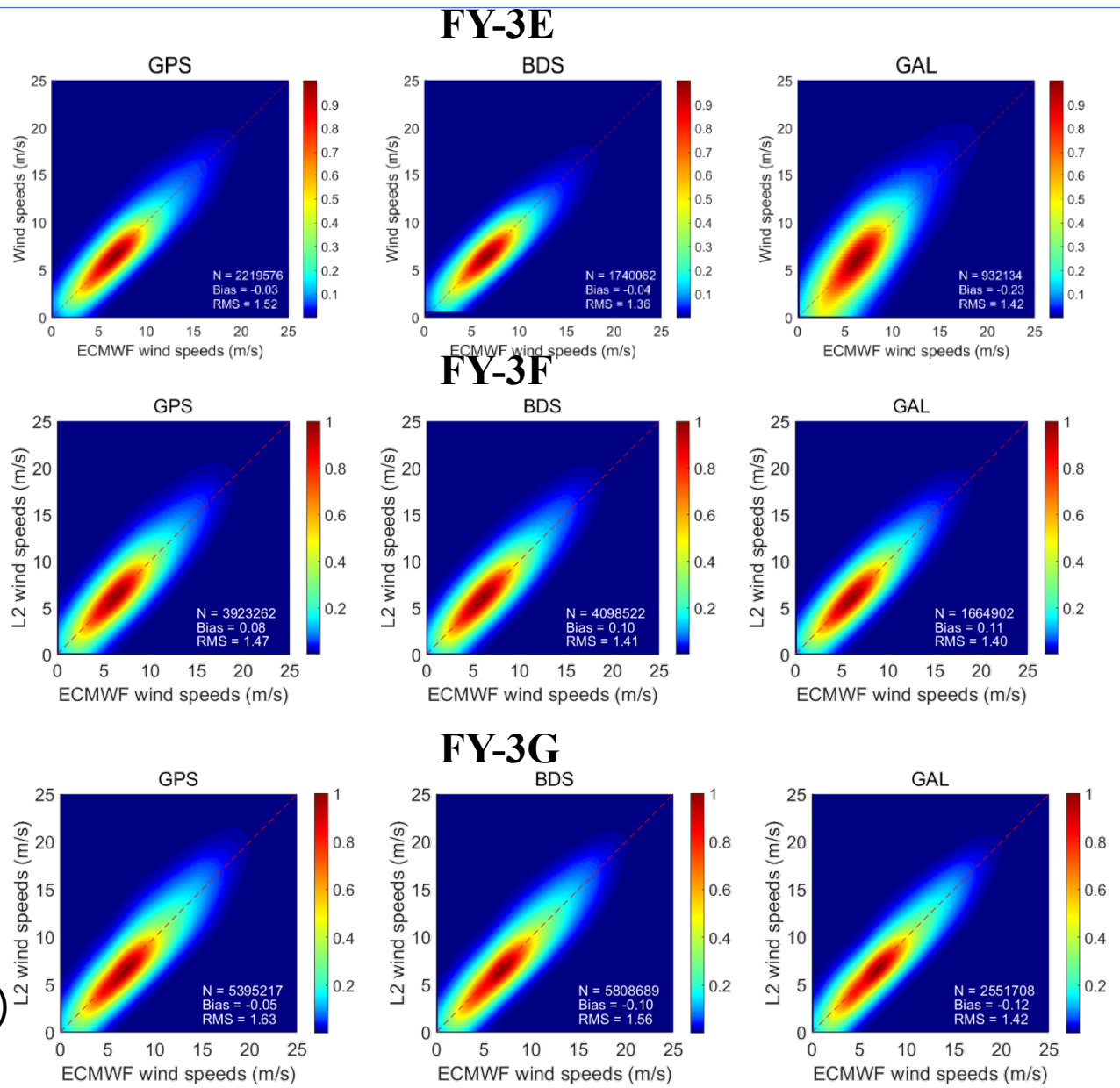
Ocean Surface Wind validation

Using ECMWF wind speed data valid FY3E/F/G

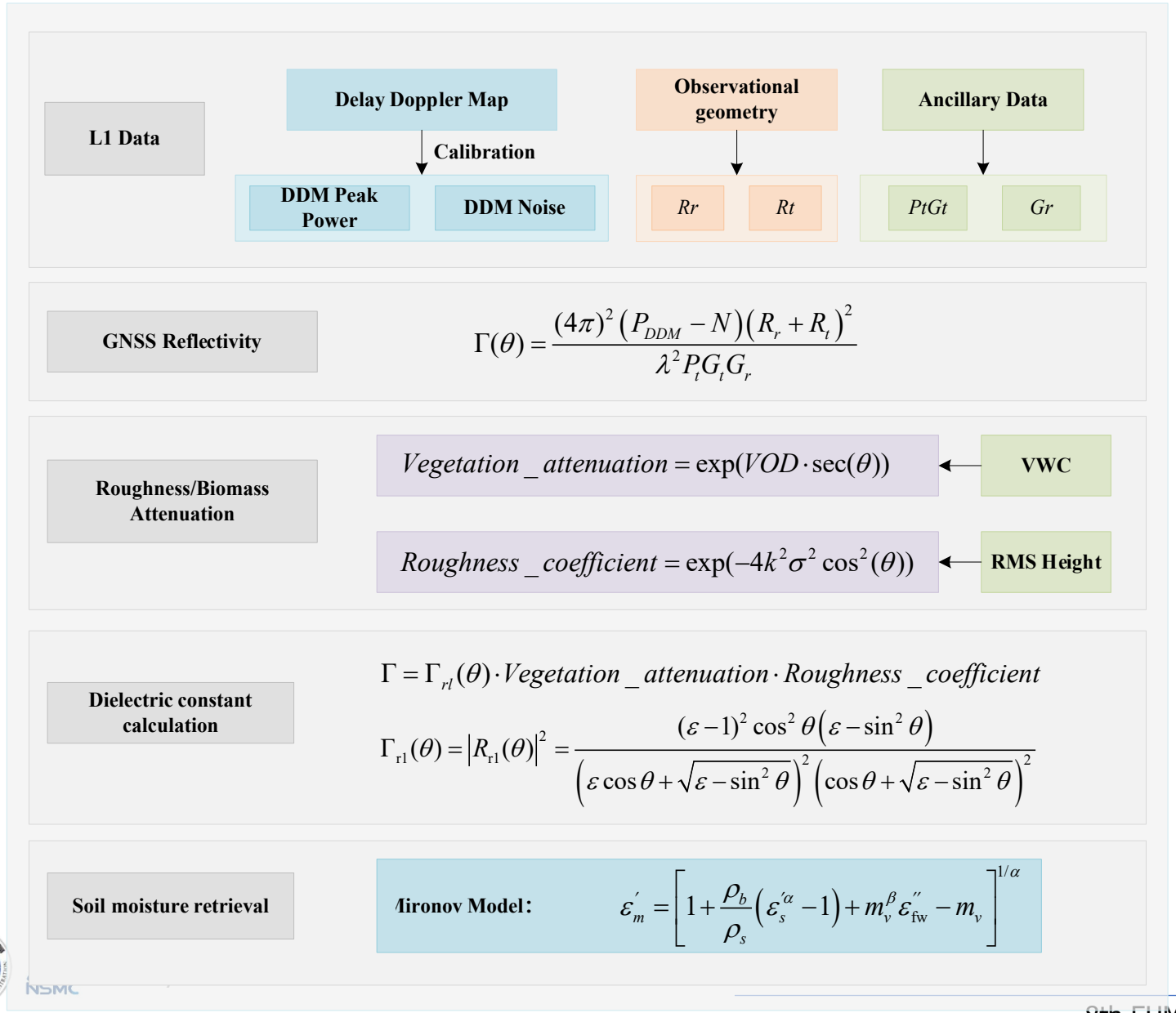


The Level 2 wind speed product can cover the Earth between the latitude ±85 °.

Average RMSE <1.5 m/s (wind speed below 20m/s)

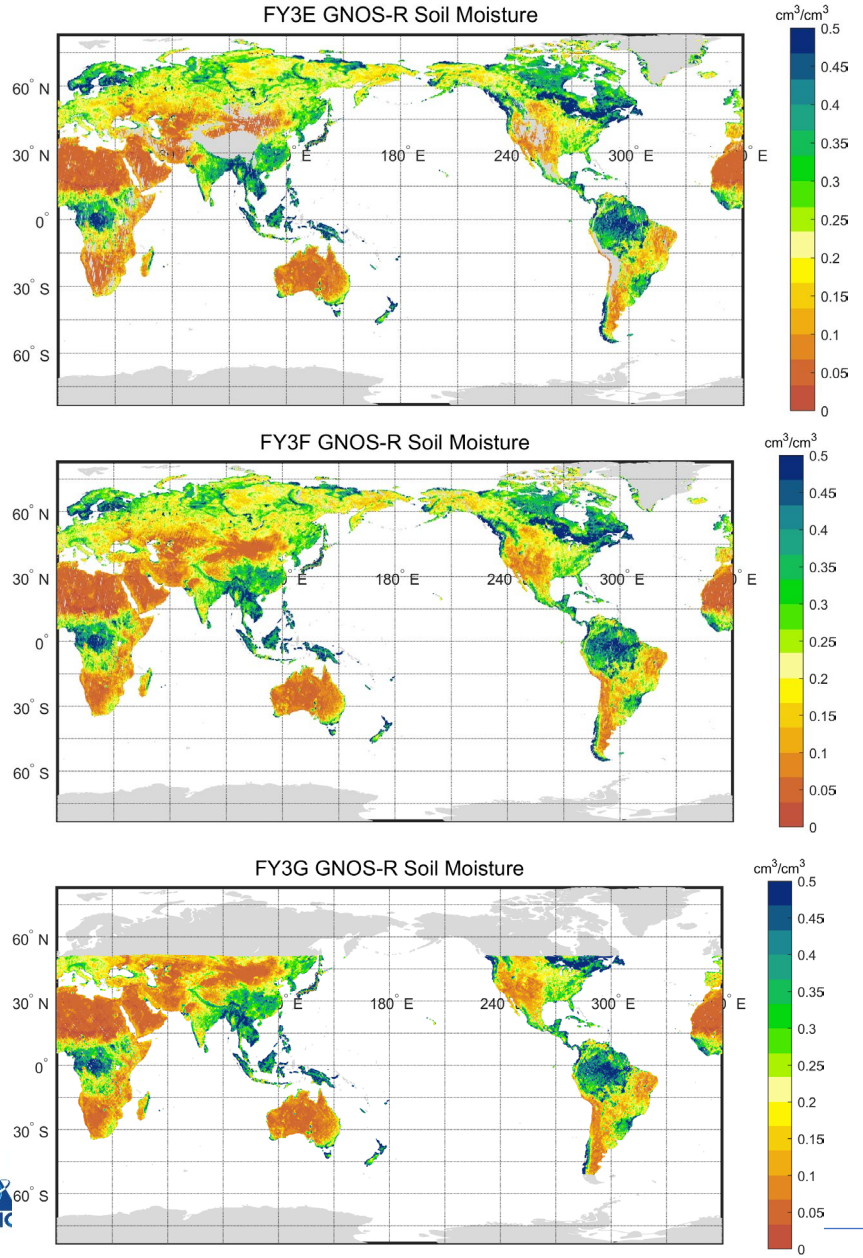


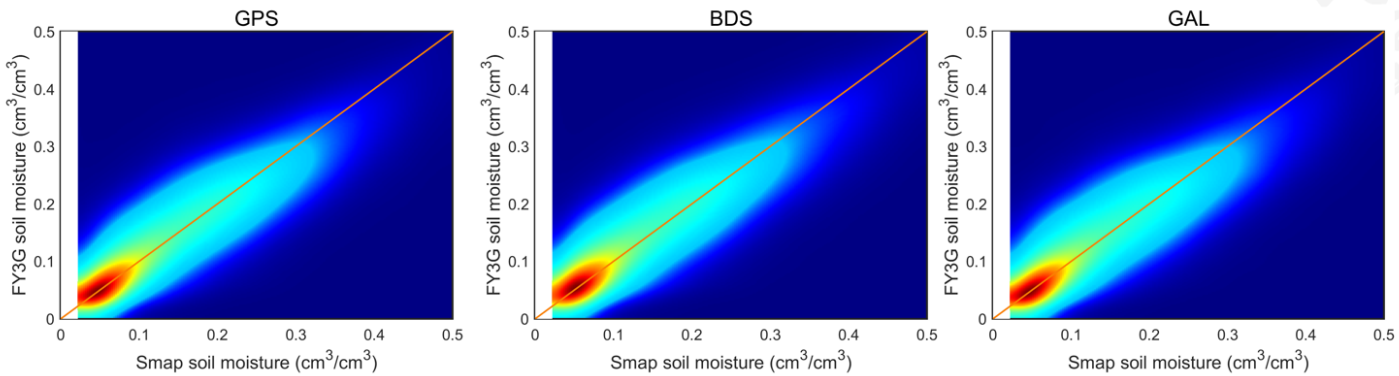
2. Data processing status ---GNSS-R Land Soil Moisture

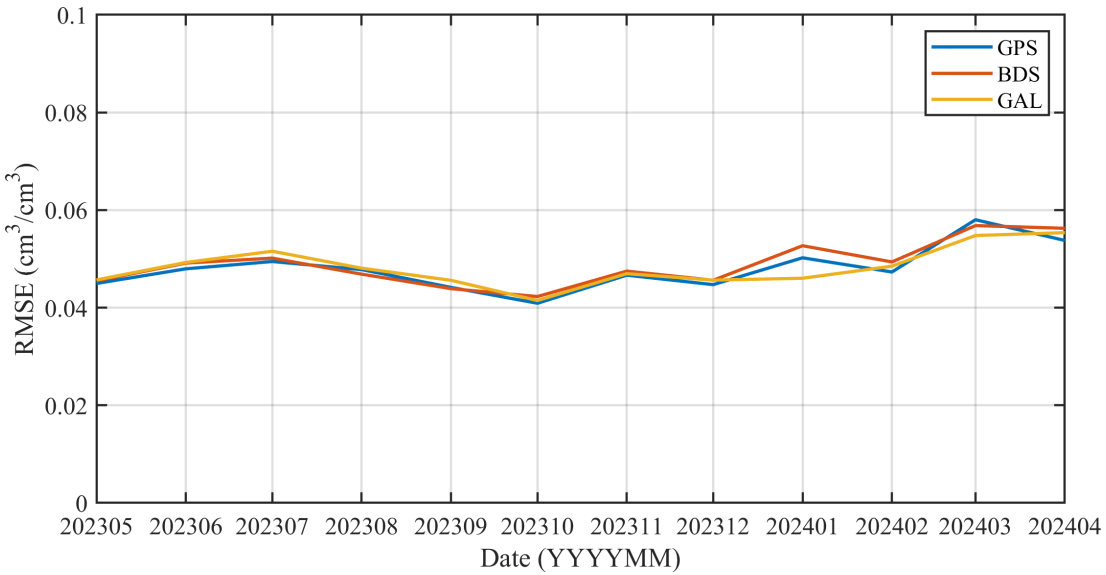


- Read L1 data
- Compute reflectivity
- Compute surface roughness and vegetation attenuation
- Compute dielectric constant
- Compute soil moisture

Land Soil Moisture Validation







Average RMSE ~0.05 cm3/cm3

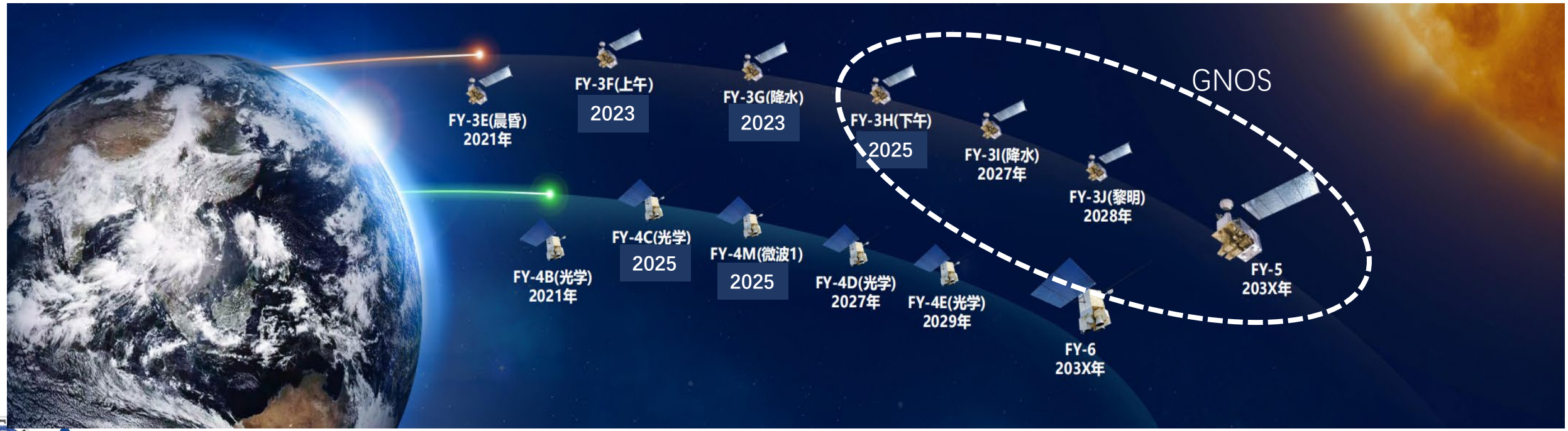
3. Future plans

2025-2030 RO instruments will be mounted on:

- 2025: FY3H afternoon orbit
- 2027: FY3I inclination angle orbit, like FY3G
- 2028: FY3J early morning orbit, like FY3E

203X FY5:

- FengYun Plus conception
- Small satellite constellation + reference satellite



4. Conclusions

- GNOS was affected by different FY3 satellite platforms, due to different platform characteristics.
- Radio occultation profiles, sea surface wind and soil moisture could be retrieved through GNOS-II observations .
- BDS RO is promising with its higher quality and quantity than before.
- RO sounding is standard configuration of FY3 and future FY5.

Thank you for your listening !