Global Navigation Satellite System Occultation Sounder II (GNOS II)

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Outline

- ◆1、GNSS RS Group, NSSC
- ◆2、Performance of FY-3C GNOS
- ◆3、Configuration of GNOS II
- ◆4、Improvements of GNSS RO module
- ◆5、GNSS-R module of GNOS II
- ◆6、Conclusions and Prospects

GNSS RS Group, NSSC

➢Research domains:

- GNSS radio occultation (GNSS RO)
- GNSS reflectometry (GNSS-R)
- LEO-LEO microwave occultation (LMO)

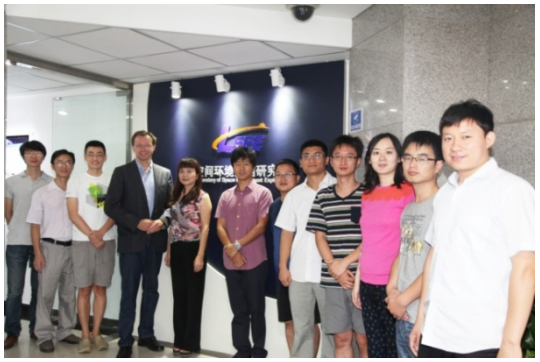
➢Research Goals:

- To develop occultation and GNSS-R instruments
- To apply the GNSS remote sensing data

➢Research partners:

- China Meteorological Administration (CMA)
- Institute of Atmosphere Physics (IAP), CAS
- Wegener Center for Climate and Global Change (WEGC)
- Geo Forschungs Zentrum (GFZ)
- Institut d'Estudis Espacials de Catalunya (IEEC)
- RMIT University
- …

Researchers in GNSS RS Group

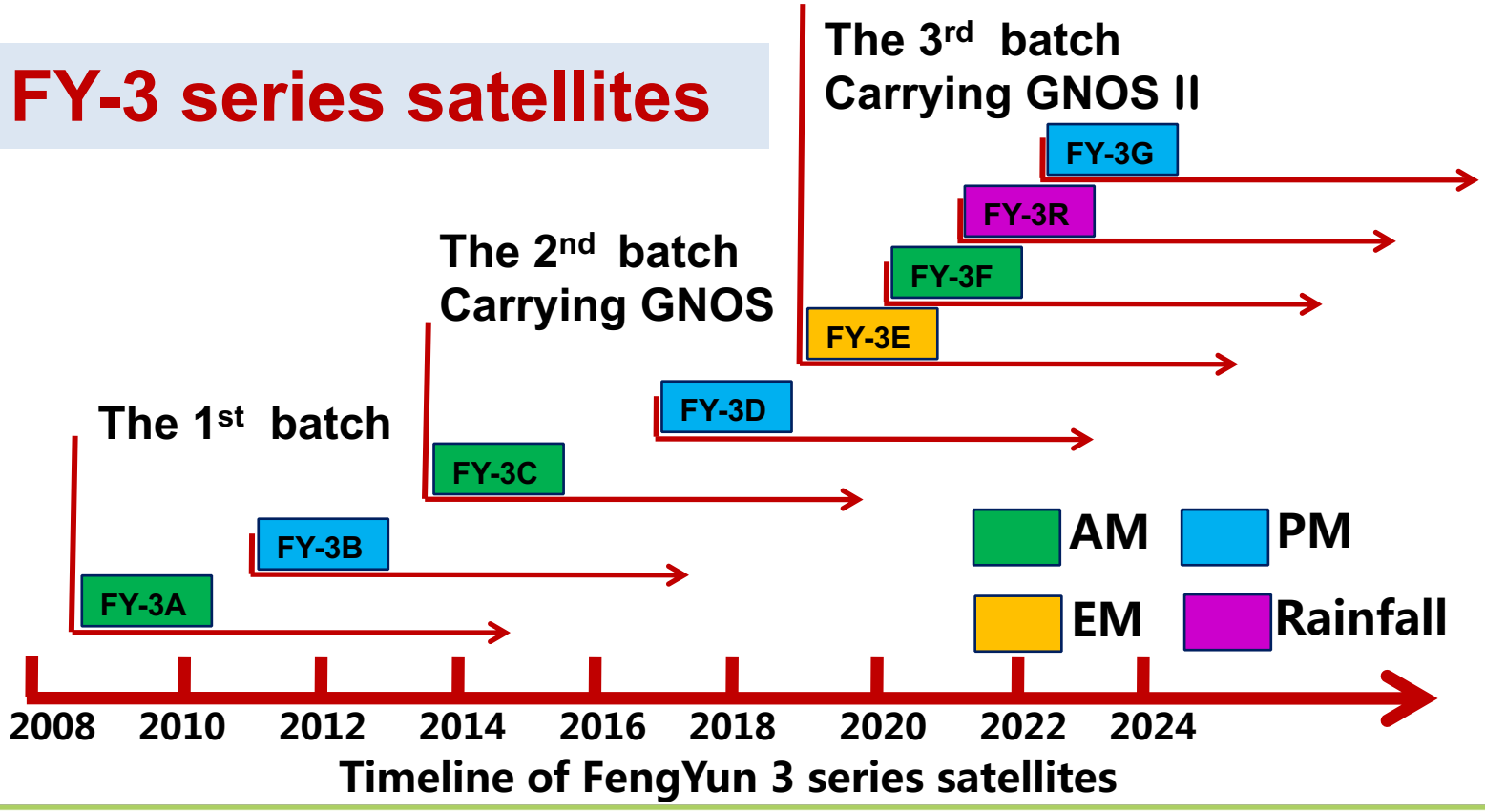


Researchers in GNSS RS Group and Prof Gottfried Kirchengast

Researchers in GNSS RS Group and Prof Martin-Neira

Operational and future missions

FY-3 series satellites



Timeline of FengYun 3 series satellites

- FY-3C GNOS was launched on Sep 23 2013
- FY-3D GNOS will be launched in this Noveber
- FY-3E GNOS II plan to be launched in 2018
- The following FY-3 satellites will carry GNOS II as a key payload…

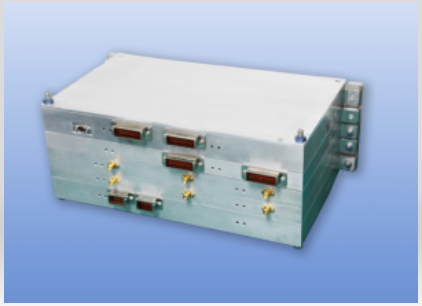
Instrument products

GNSS RO Receivers

GPS RO receivers

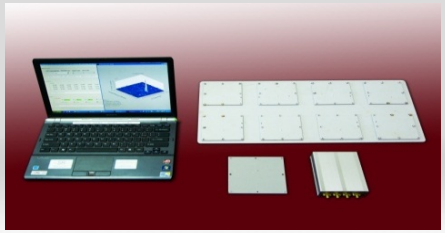
FY3 GPS/BDS compatible flight model

FY-3E GNOS II

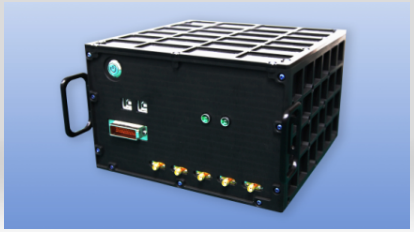


GNSS Reflection Receivers

GPS-R software receiver



FPGA+DSP GPS/BDS/GALILEO compatible ocean reflection receiver

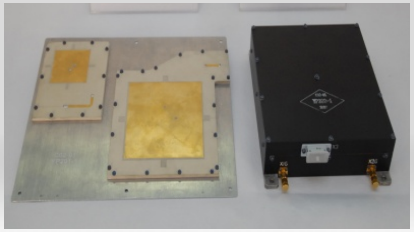


Main characters:
- GPS/BDS/GAL for RO
- GPS/BDS for GNSS-R

Status: Design

LMO Transmitters and Receivers

YH-1 RO receiver flight model for Mars



LMO transmitter receiver for Earth

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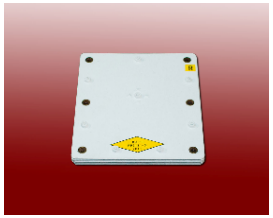
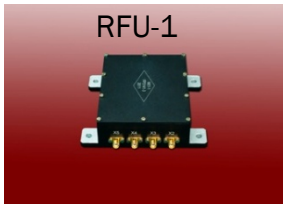
Configuration of FY-3C GNOS

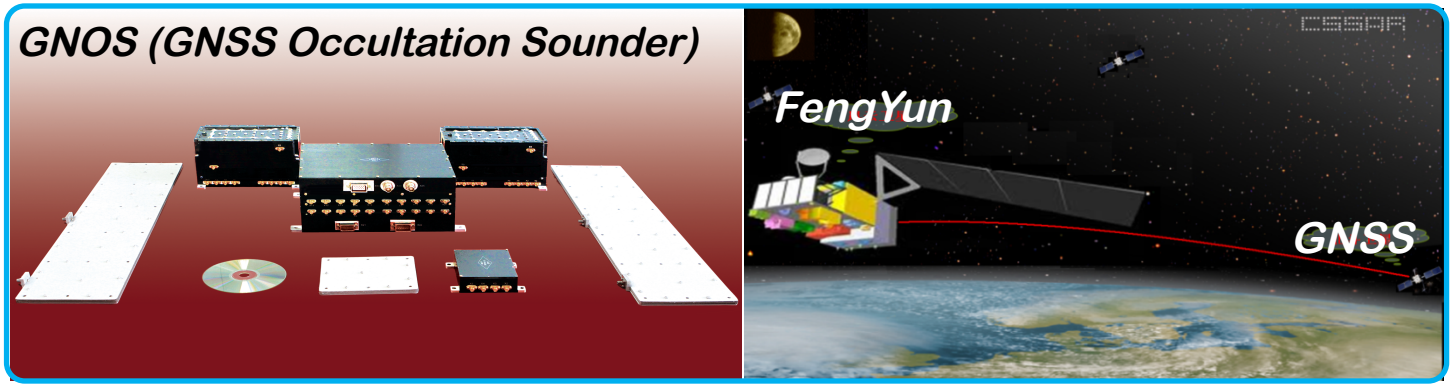




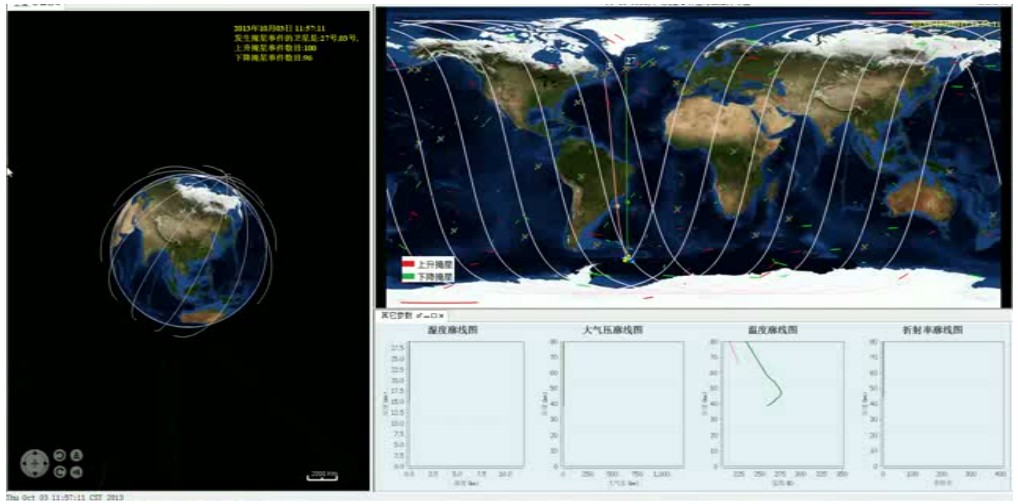
Setting Occultation Antenna

Rising Occultation Antenna

Performance of FY-3C GNOS



FY-3C GNOS:
Launched on 23 September 2013;
Switched on at 21:48 (LT), on 29 Sep, 2013;
Received both GPS&BDS signals;
>500 GPS RO events/day
~200 BDS RO events/day
Main atm&ion RO retrievals: Refractivity (N), density(ρ), pressure (p), temperature (T), humidity (q), ionospheric electron density (Ne) et al.
(Thanks for funding from CMA)



Statistics of the main atmosphere retrievals of FY-3C GNOS

0-30km	N(%) [mean/std]	T(K) [mean/std]	p(%) [mean/std]	q(g/kg) [mean/std]
GNOS vs Radio sound	-0.18/1.58	0.06/2.23	0.06/1.18	<0.3/<1.5
GNOS vs ECMWF	-0.14/0.98	-0.26/1.75	-0.18/1.05	<0.2/<1.2

Ref: M. Liao et al, Preliminary validation of the refractivity from the new radio occultation sounder GNOS/FY-3C, amt, 2016

Performance of FY-3C GNOS

Signal from the up-looking antenna are used for POD of the FY-3C satellite.

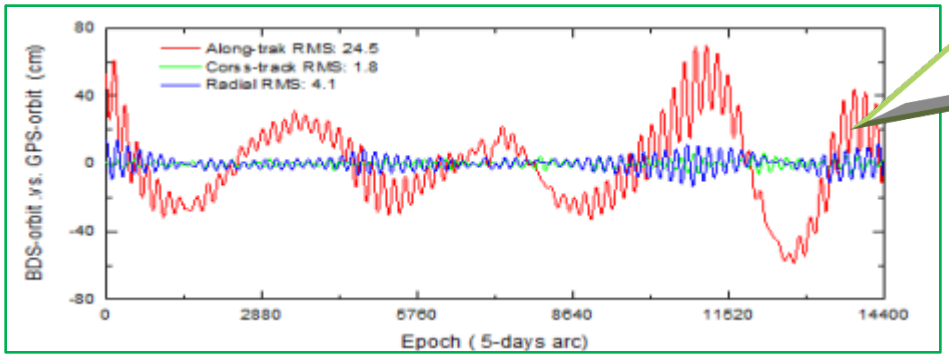
Tab.1 POD Precision Statistics of Position

	Radial RMS(cm)	Along RMS(cm)	Cross RMS(cm)	3D RMS(cm)
MEAN	0.919	1.460	2.232	2.868
MEDIAN	0.925	1.460	2.330	2.911

Tab.2 POD Precision Statistics of Velocity

	Radial RMS (mm/s)	Along RMS (mm/s)	Cross RMS (mm/s)	3D RMS (mm/s)
MEAN	0.018	0.014	0.009	0.025
MEDIAN	0.018	0.014	0.009	0.024

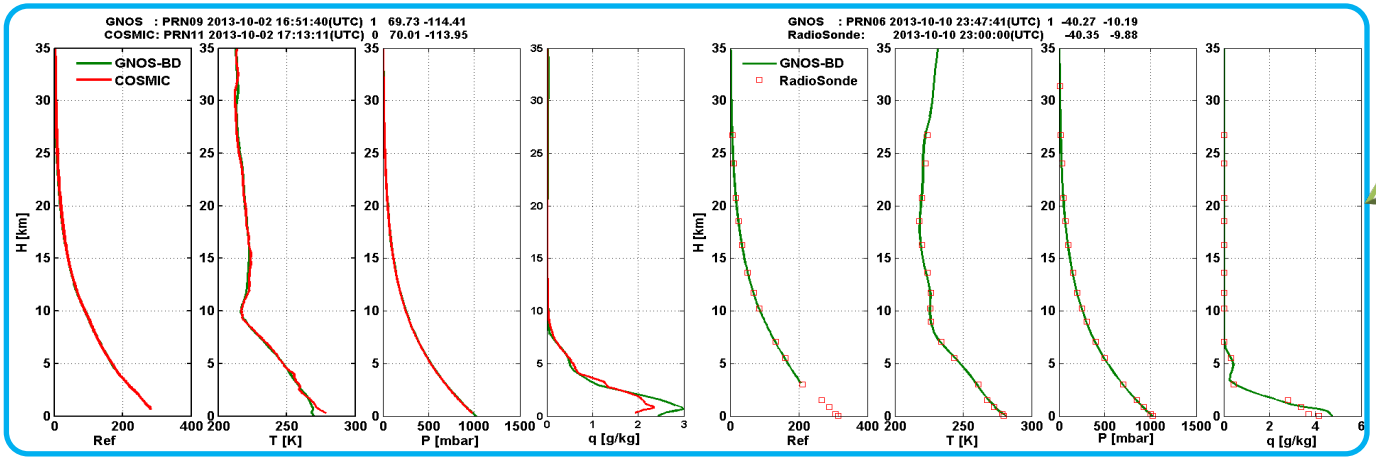
GPS POD:
3D RMS position error is 2.868 cm
3D RMS velocity error is 0.025 mm/s



POD error using BDS (5 days)

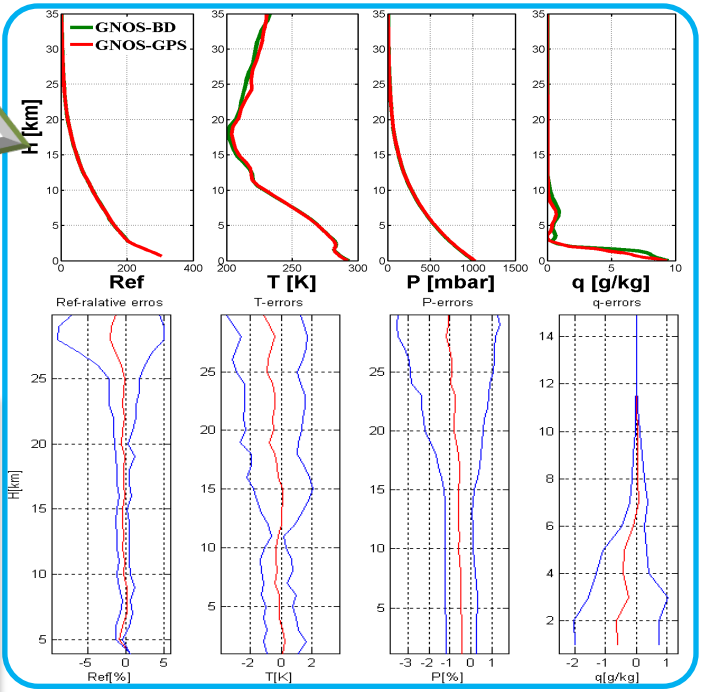
BDS POD :
3D RMS position error is 30 cm
Error Sources:
Regional coverage, BDS channel umber, POD algorithm…

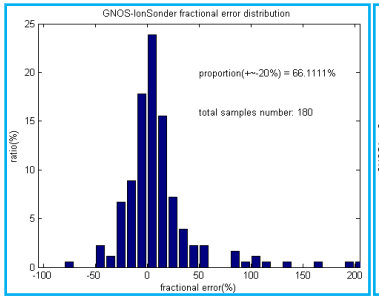
Performance of FY-3C GNOS

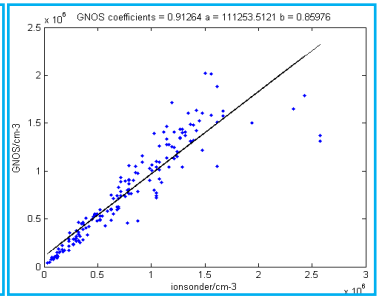


Comparison with COSMIC observation data and radio sonde data

Comparison between GNOS/BDS and GNOS/GPS RO data







Ele. Density peak	Bias	Std	Correlation
GNOS RO	2.8%	18.3%	0.91

For the first time validated the consistence of GPS &BDS RO Data.

The quality of FY-3C GNOS RO data were consistent with other RO missions and other atmospheric observations .

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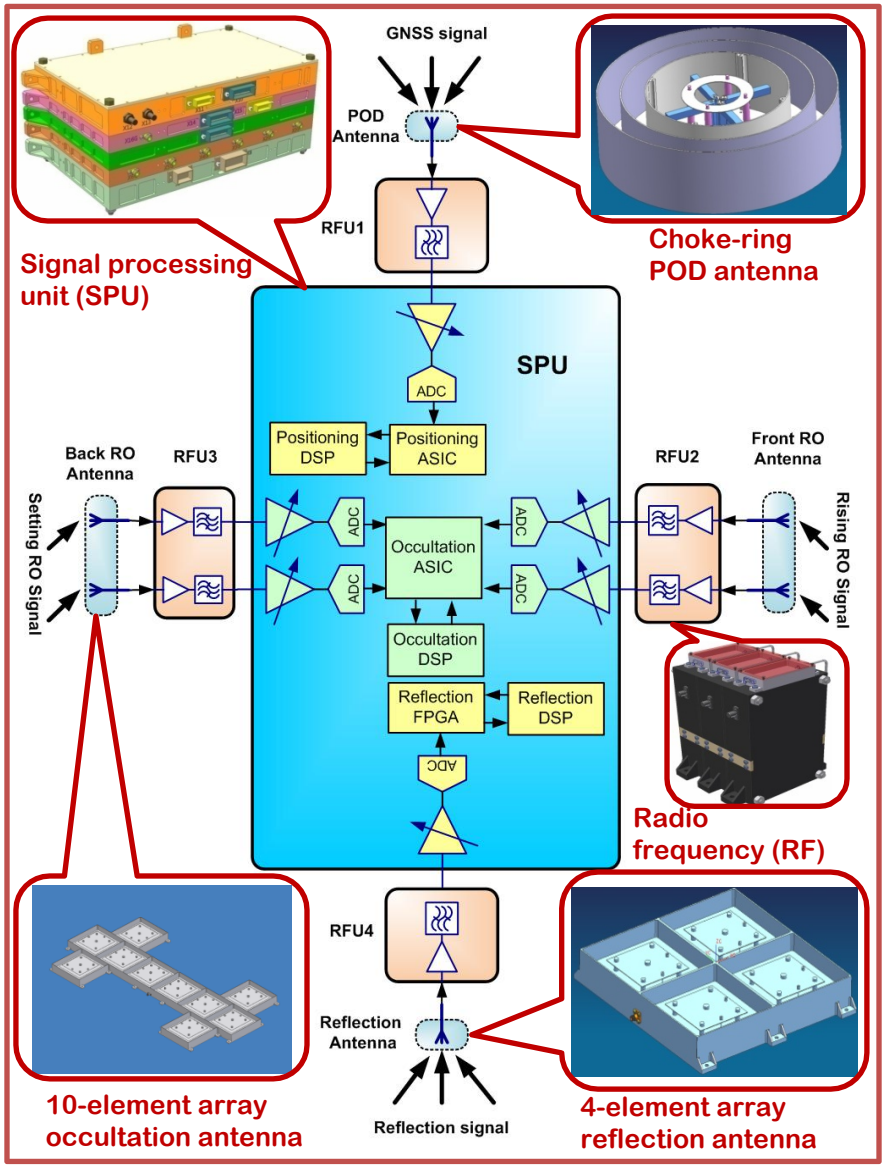
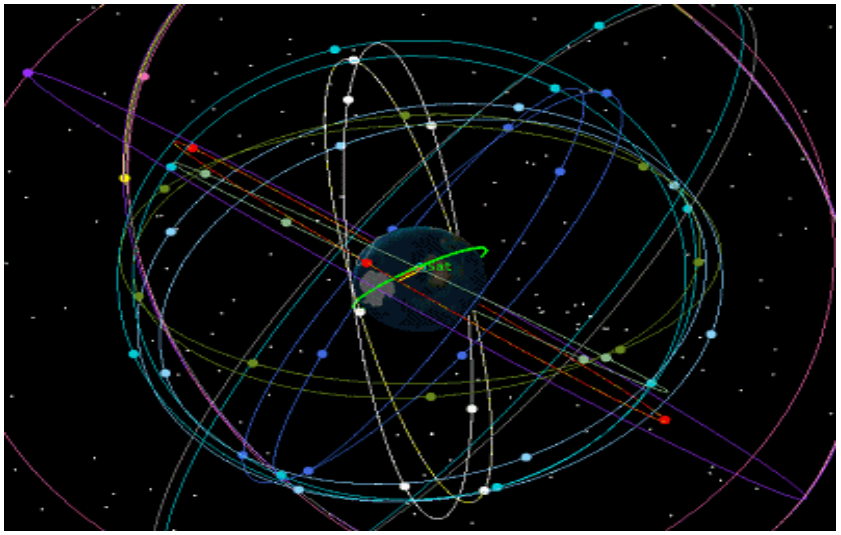
Configuration of GNOS II





Simulation of GNSS-R technique

Main characters:
- GPS/BDS/GAL for RO
- GPS/BDS for GNSS-R

Launch Satellite:
- Altitude: 833km
- Inclination: 98°
- Launch time: 2018

Status: Design

To integrate the GNSS RO and GNSS-R in one payload.

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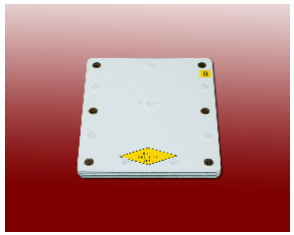
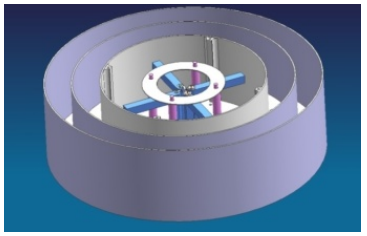
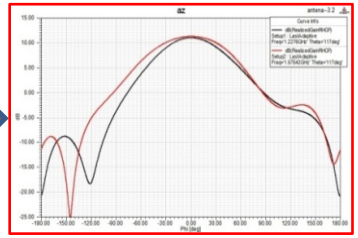
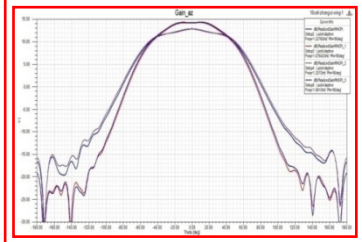
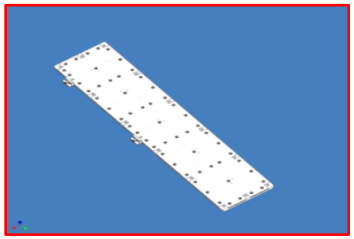
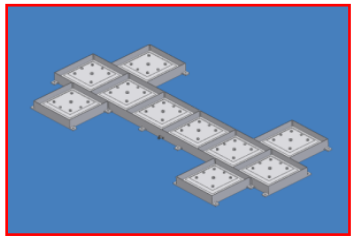
Improvements of GNSS RO

Improvements of GNSS RO module for GNOS II :

■Enhancements of antenna:

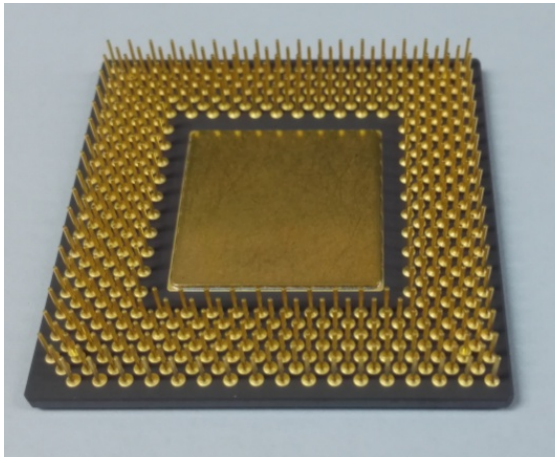
- A choke-ring POD antenna will be used to replace the patch POD antenna.
  - ➢ To reduce the backward and side radian of the antenna.
- 10-element array occultation antenna will be used to replace the 5-element occultation antenna.
  - ➢ To increase the occultation signals coverage and signal-to-noise ratio.

FY-3C GNOS	FY-3E GNOS II
	
Plain POD antenna	Choke-ring POD antenna
	
	
7.0 dBi@40° azimuth	10 dBi@45° azimuth

Improvements of GNSS RO

- **Increase of the channel numbers**
  - GPS, BDS and Galileo single channels for positioning and occultation.
    - ➢ To achieve higher POD accuracy and more RO events
  - Plus L2C and B1I open loop channels
    - ➢ To improve the data quality of atmosphere near the Earth surface
- **Radiation tolerance ASIC**
  - 65-nm bulk silicon technology
  - SEU: 15 MeV•cm^2/mg
  - SEL: 75 MeV•cm^2/mg
  - TID: 100 krad (Si)
    - ➢ To reduce the power consumption, volume and mass of the receiver.

GNOS	GNOS II
14 GPS DF channels: (L1C/A+L2P) 8 for position 6 for occultation 8 BDS DF channels: (B1I+B2I) 4 for position 4 for occultation	26 GPS DF channels (L1C/A+L2C+L2P) 12 for position 14 for occultation 16 BDS DF channels: (B1I+B2I) 8 for position 8 for occultation 6 GAL DF channels: (E1b+E5b) 4 for position 2 for occultation



Application Specific Integrated Circuit (ASIC)

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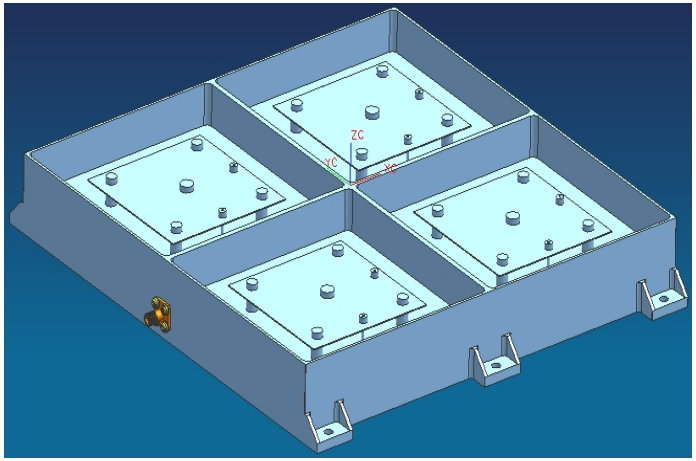
The GNSS-R module of GNOS II

GNSS-R module parameters

The main primary parameters of GNSS-R module

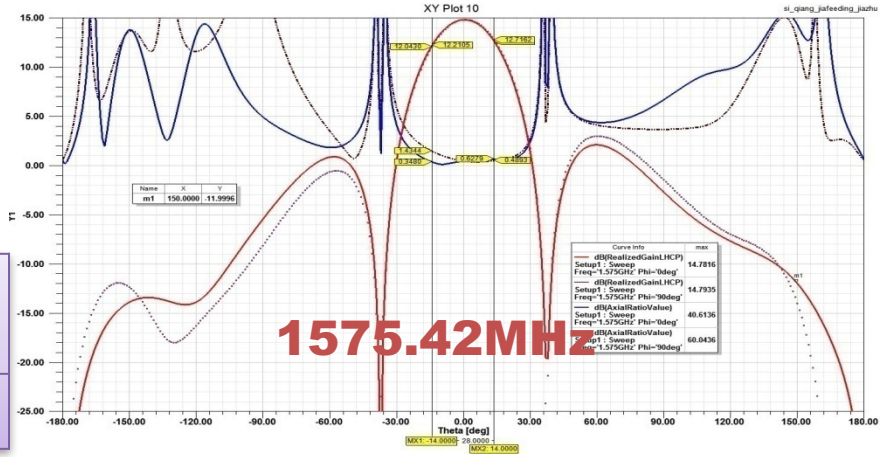
Frequency	GPS: L1 BDS: B1
Channel numbers	8
Sampling rate	61 MHz
Code tag number	122
Code tag interval	0.25 code chip
Code coverage	30.5 chip
Doppler tag number	24
Doppler tag interval	500 Hz
Doppler coverage	12 KHz
Output rate	750 Kbps



The model of GNOS II GNSS-R antenna (LHCP)

The parameters of GNOS II GNSS-R LHCP antenna

Frequency (MHz)	3dB BW (θ)	3dB BW (φ)	Peak Gain (dBi)
1575.42	-16°～16°	-16°～16°	14.79

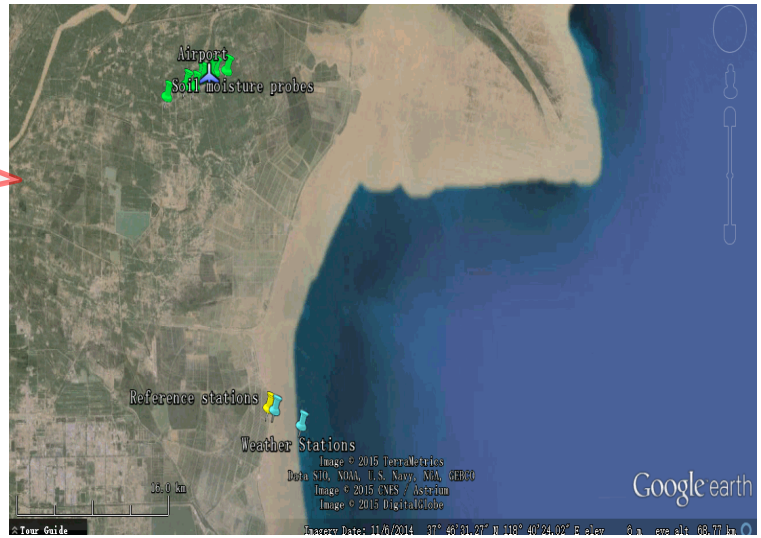


Simulated antenna patterns by using ANSOFT HFSS

The GNSS-R module of GNOS II

Validation airborne campaign

First flight:
2015.11.11 9:30~11:30
Weather: cloudy/fog
wind :~1.5m/s
Height:500m and 2500m



Left circular polarization antenna, 4 dB

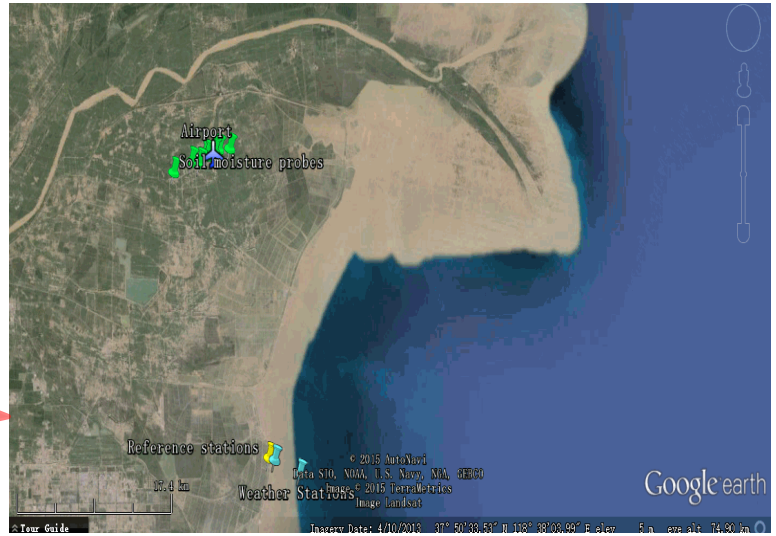
Thermal infrared imaging system

Right circular polarization antenna

Left circular polarization antenna, 13 dB

Air craft and GNSS-R antennas

Second flight:
2015.11.20 10:00~12:00
Weather: cloudy
wind: ~ 5.5m/s
Height: 500m



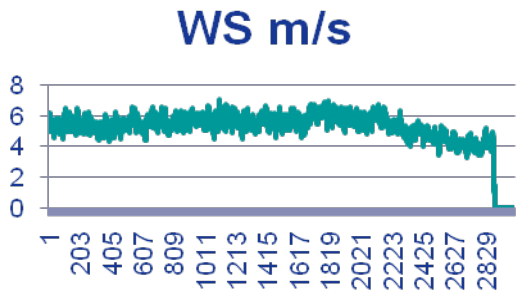
The GNSS-R module of GNOS II

Validation airborne campaign

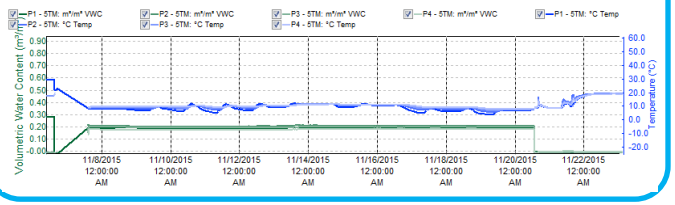
The ground based in-situ observation stations and their measurements:

POD Reference Station

In-situ meteorology station



in-situ soil moisture station

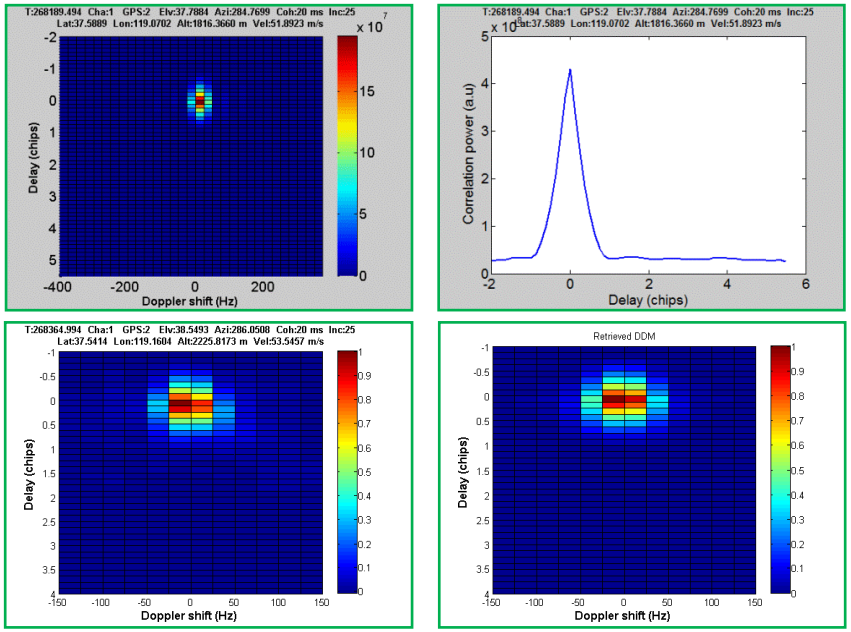


The GNSS-R module of GNOS II

Validation airborne campaign

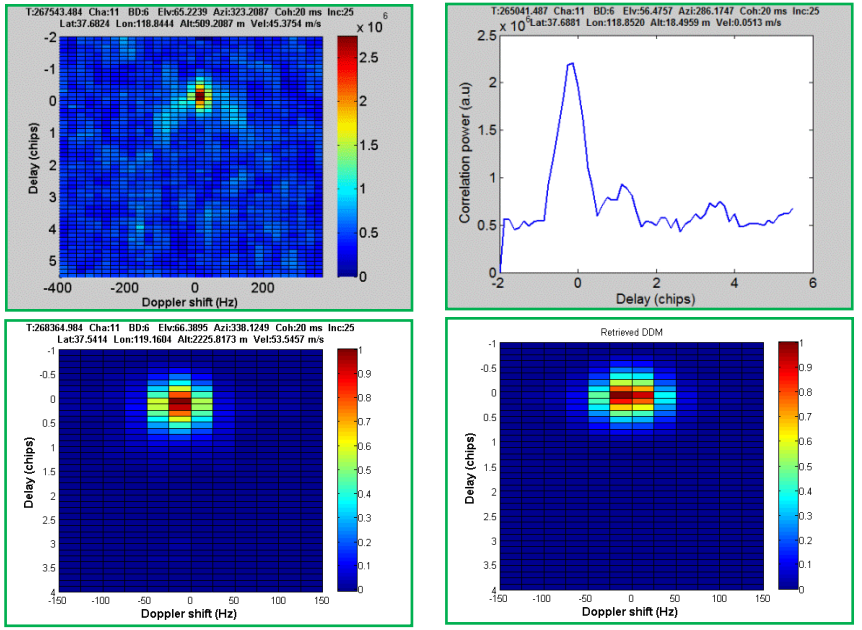
Preliminary results:

GPS: 61 × 32 bins, 1/8 chip, 25 Hz



Situ observed wind speed (average)	Retrieved wind speed (average)
1.7 m/s	2 m/s

BDS: 61 × 32 bins, 1/8 chip, 25 Hz



Situ observed wind speed (average)	Retrieved wind speed (average)
1.7 m/s	2 m/s

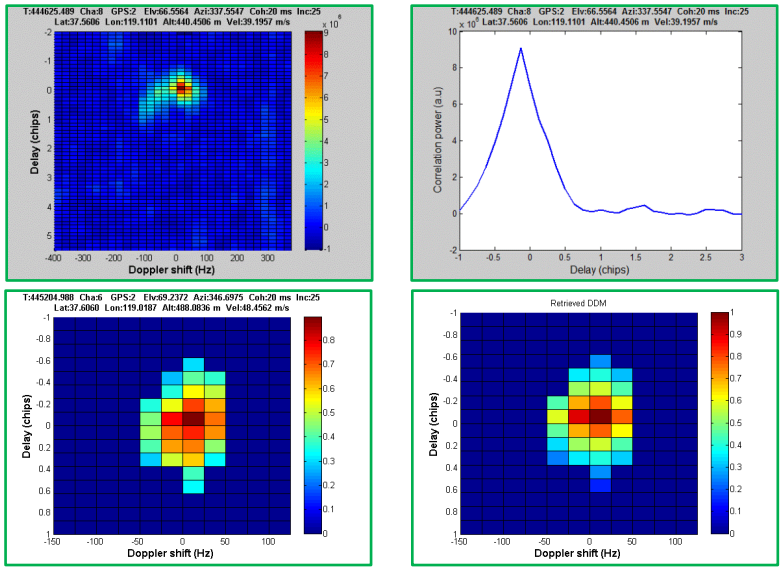
The campaign showed the consistence of the GNSS-R and in-situ observations.

The GNSS-R module of GNOS II

Validation airborne campaign

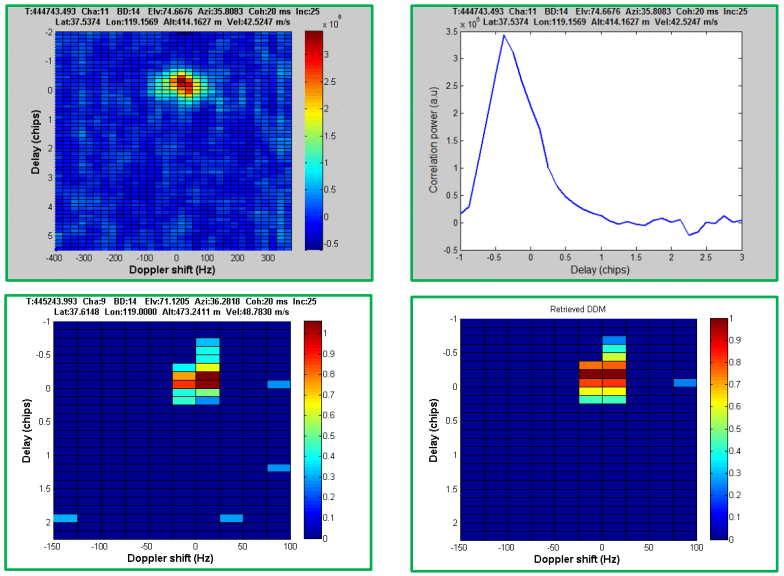
Preliminary results:

GPS: 61 × 32 bins, 1/8 chip, 25 Hz



Situ observed wind speed (average)	Retrieved wind speed (average)
5.6 m/s	5 m/s

BDS: 61 × 32 bins, 1/8 chip, 25 Hz



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Conclusions and Prospects

- Several GNSS RO and GNSS R receivers have been designed and manufactured.
  - ➢ FY-3D GNOS will be launched in this November.
  - ➢ GNOS II is being designed and developed for FY-3E satellite, which will integrate the GNSS RO and GNSS R techniques in one payload. So far, these two modules have been mainly demonstrated by a space-based mission and an air-borne campaign, respectively.
  - ➢ The following FY-3 satellites will carry GNOS II as a key payload.
    - ◆ Will the FY-3C GNOS work well when it's 5-year old?
    - ◆ Will the FY-3D GNOS perform better than the FY-3C GNOS?
    - ◆ Will the FY-3E GNOS II go ahead well in 2018?
    - ◆ What is the status and new results of other missions worldwide? (COMIS[-2], MetOp, CYGNSS, research missions, commercial missions…)
    - ◆ Welcome to Beijing to find them out via a conference.

Preliminary Conf. information

- Meeting plan: IGL-1 2018——Welcome!
- The first Innovations in GNSS and LEO Occultations & Reflections Workshop
- Date: September 2018 Location: Beijing (TBC, offer joint with IROWG-7, to be coordinated with IROWG, ICGPSRO meetings)

Landscapes in Beijng

Thank you!