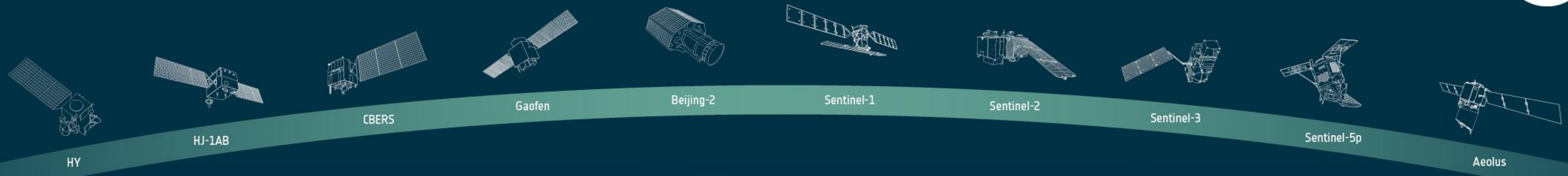


2022 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

PROJECT ID. 58070

CALIBRATION AND VALIDATION OF THE FIRST CHINESE GNSS-R MISSION—BUFENG-1 A/B

20/OCT/2022, 8:30AM - 10:00AM CEST

ID. 58070

PROJECT TITLE: CALIBRATION AND VALIDATION OF THE FIRST CHINESE GNSS-R MISSION—BUFENG-1 A/B

PRINCIPAL INVESTIGATORS: LI, WEIQIANG; JING, CHENG

CO-AUTHORS: LU, FENG; NIU, XINLIANG; CHEN, XIUWAN; WAN, WEI; ANTONIO RIUS; ESTEL CARDELLACH; SERNI RIBÓ; LIU, BAOJIAN; RUI, JI; NAN, YANG

PRESENTED BY: JING, CHENG

Objectives

- Collocation of integrated ESA-CHINA EO data products and BuFeng-1 data preprocessing
- Calibration of the BuFeng-1 A/B main observables, including NBRCS, power DDM, and SNR
- Validation of the calibrated results from BuFeng-1 A/B;
- Optimization and improvements of future spaceborne GNSS-R instruments

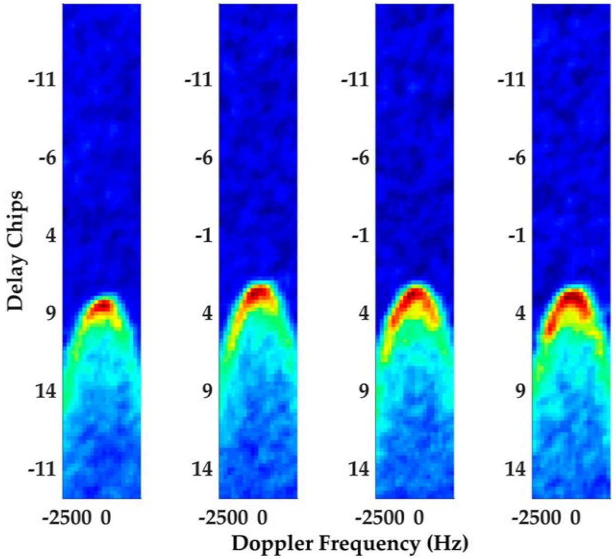
Details of data utilization

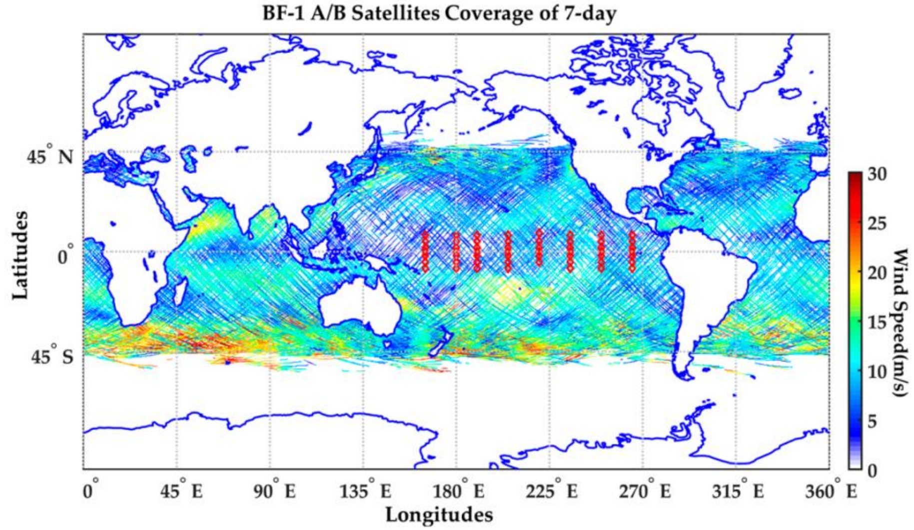
- ESA EO data: SMOS (MIRAS), CRYOSAT-2 (SIRAL)
- CHINA EO data: FY Series (MWRI), CFOSAT (SCAT)， HY-1&2 (COCTS)
- Meteorological reanalysis data: ECMWF ERA-5, CMA CRA
- In-situ data: ISMN sites
- Others: SMAP, DTU MSS

the results after 2 years of activity

BF-1 Mission

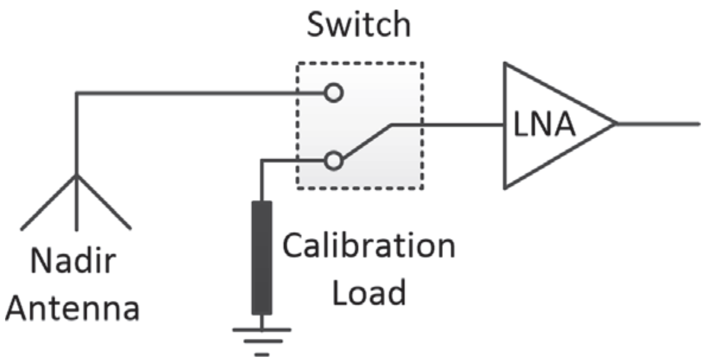
Launch date: June 5th, 2019
Frequency: GPS L1 & BeiDou B1
Antenna gain: 14 dBi
Mass: 10 kg
Power consumption: 30 W
Specular Points: 4/s





X. Niu, F. Lu, Y. Liu, et al. Application and Technology of Bufeng-1 GNSS-R Demonstration Satellites on Sea Surface Wind Speed Detection. China Satellite Navigation Conference (CSNC) 2020 Proceedings: Volume I

Calibration and Error Analysis



NBRCS Calibration:

$$\sigma_{0,\tau,f} = \frac{P^{g}_{\tau,f}(4\pi)^3 R_t^2 R_r^2}{P_t \lambda^2 G_t G_r} / \iint_A \Lambda^2(\tau) S^2(f) dA,$$

Where,

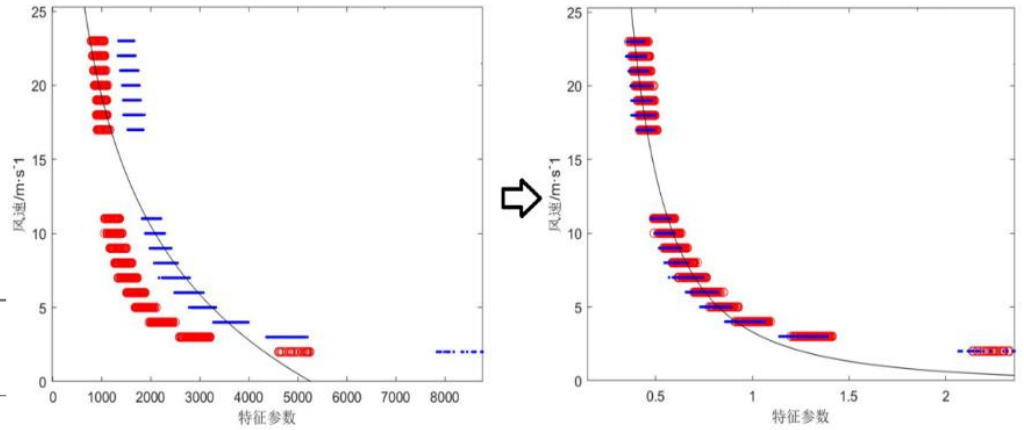
$$P_g = \frac{C - C_N}{C_B}(P_B + P_r)$$

Table 1. Power calibration error terms (dB)

Error term	$E(C)$	$E(C_N)$	$E(C_B)$
Error	0.18	0.08	0.009
Error term	$E(P_b)$	$E(P_r)$	**RSS**
Error	0.017	0.25	0.32

Table 2. Geometry calibration error terms (dB)

Error term	$E(P^g_{SP})$	$E(L_{SP})$	$E(R^R_{SP} R^R_{SP})$	$E(P_T G^T_{SP})$
Error	0.32	0.04	0.005	0.40
Error term	$E(G^R_{SP})$	$E(A_{SP})$	Margin	**RSS**
Error	0.47	0.06	0.25	0.74



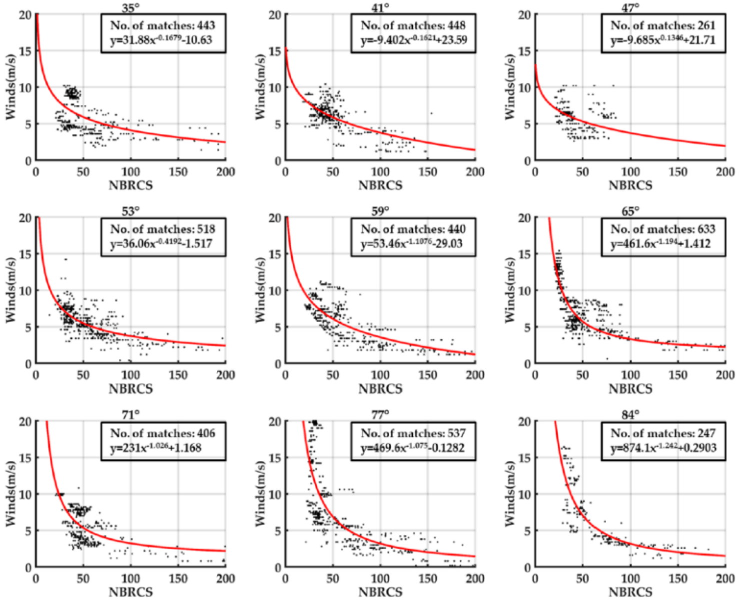
Gleason, S.; Zavorotny, V. Bistatic radar cross section measurements of ocean scattered gps signals from low earth orbit. In Proceedings of the 2006 IEEE International Symposium on Geoscience and Remote Sensing, Denver, CO, USA, 31 July–4 August 2006; pp. 1308–1311.
B. Wan, X. Niu, C. Jing, et al. Calibration and Error Analysis of the BF-1 Demonstration GNSS-R Satellites. China Satellite Navigation Conference (CSNC) 2020 Proceedings: Volume I: 196-205

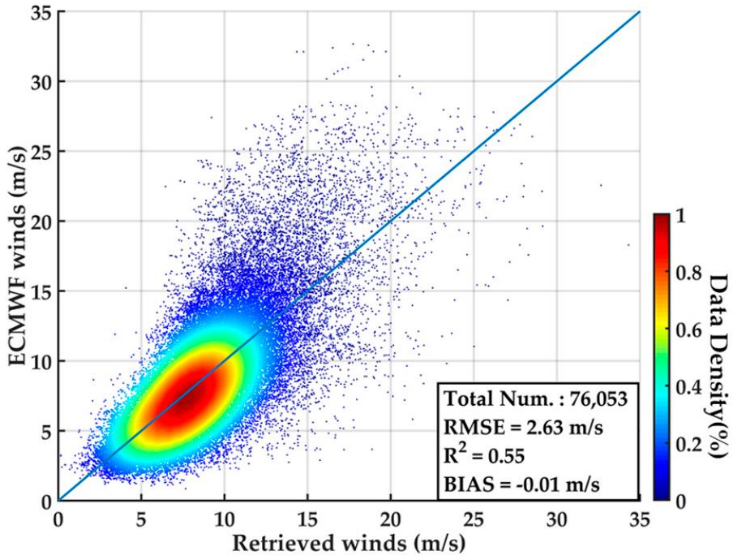
the results after 2 years of activity
Sea surface winds

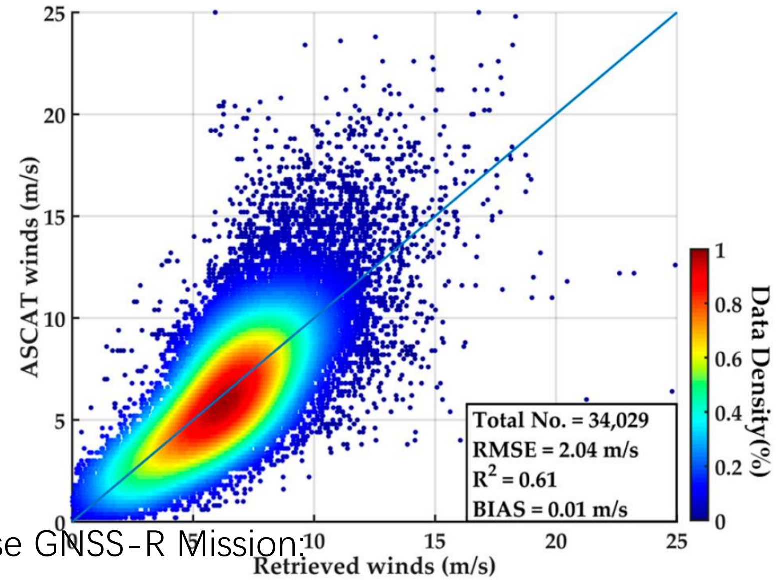
Sea Surface Wind Retrieval

The Geophysical Model Function (GMF):
NBRCS vs Winds by:
ECMWF ERA5 and ASCAT
Follow the power function($y=Ax^b+c$)

GMF:
NBRCS
Platform: A/B
Antenna: starboard/port
Elevation:28:1:90
QC: SNR>4







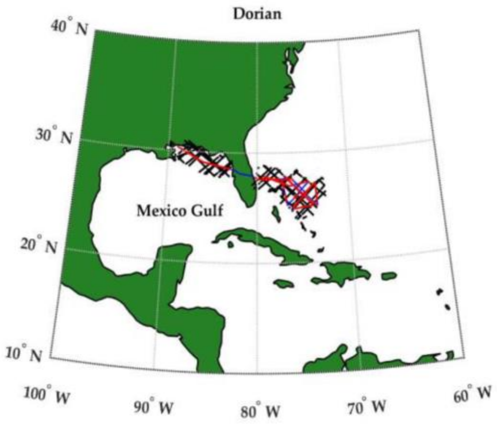
C. Jing, X. Niu, C. Duan, F. Lu, G. Di, and X. Yang, “Sea Surface Wind Speed Retrieval from the First Chinese GNSS-R Mission: Technique and Preliminary Results”. Remote Sensing, 11(3013), 2019.

Sea Surface Winds under Hurricane

Data: SFMR by NOAA hurricane 2019
Wind range: 0.4 – 99.4 m/s
Aligned pairs: 5,708
QC: SNR>2
R=0.78

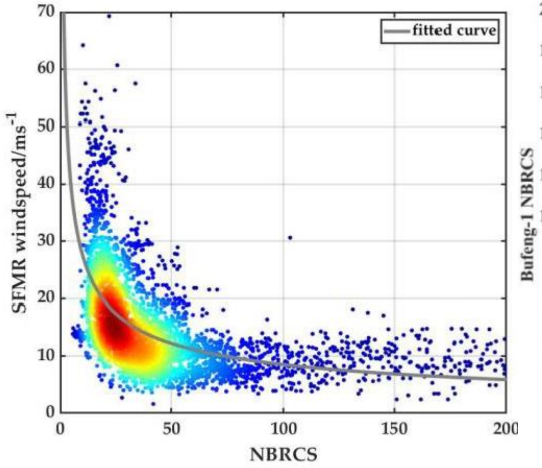
Table 1. NOAA Hurricane Season Data 2019

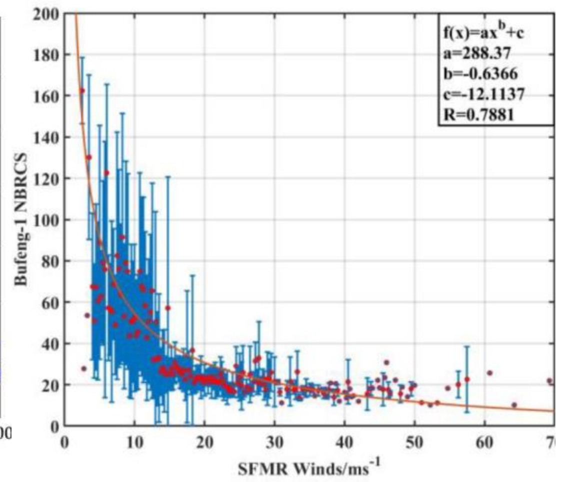
Name	Date	Volume
Barry	7/11-7/23	9
Dorian	8/26-9/6	35
Humberto	9/13-9/19	10
Ivo	8/17-8/24	5
Jerry	9/19-9/24	12
Karen	9/22-9/26	7
Lorena	9/19-9/21	3
Lorenzo	9/28-9/29	2

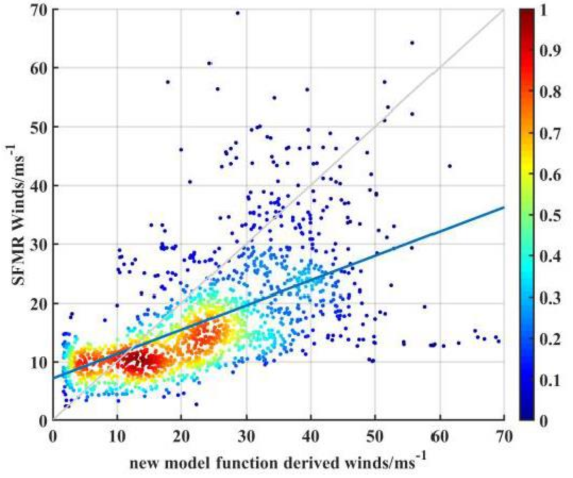


Also follow the power function ($y=Ax^b+c$)

Using the average of different elevation bins







C. Jing, X. Niu, F. Lu, et al. "GNSS-R FROM THE BUFENG-1 TWIN SATELLITES FOR SEA SURFACE WINDS UNDER HURRICANE CONDITION".IGARSS 2021 received.

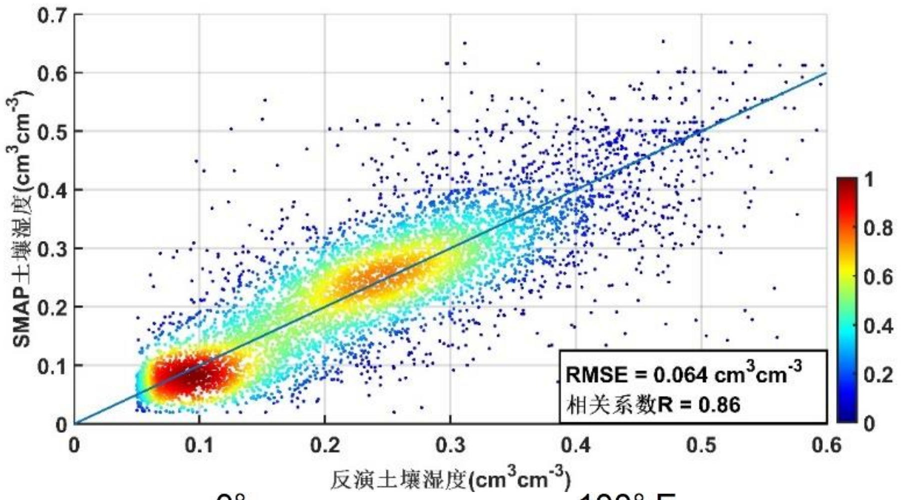
the results after 2 years of activity
Inland applications

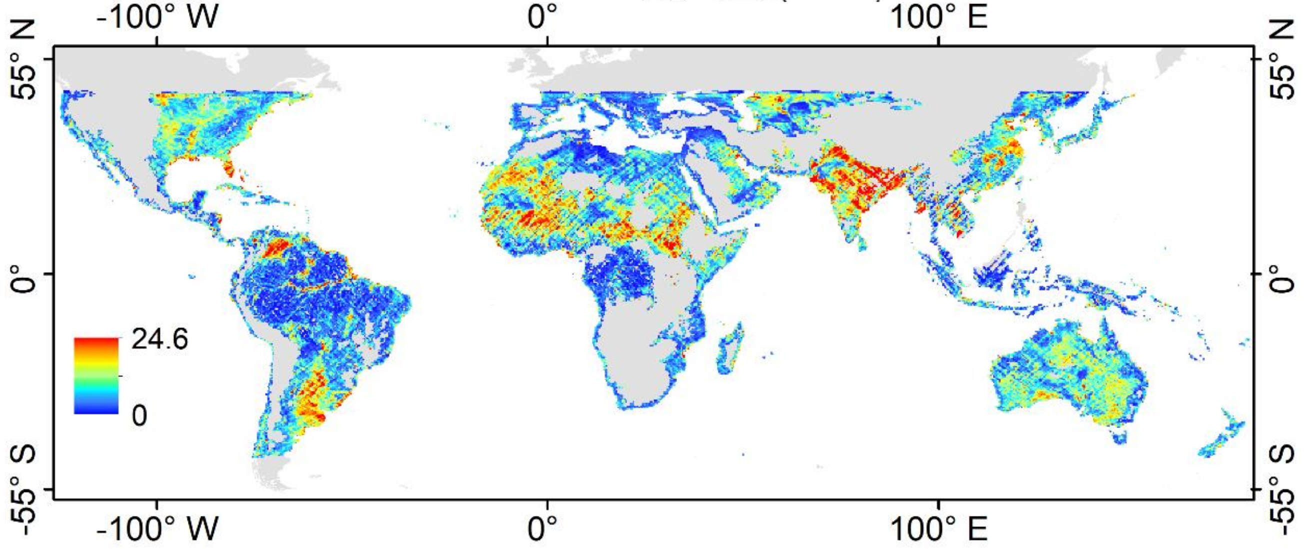
Inland Soil Moisture by BF-1 Mission

Observable: Reflectivity(Chew et al, 2016)

$$P_{coh}^{r} = \frac{P^{T}G^{T}}{4\pi(R_{TS}+R_{SR})^{2}}\frac{G^{R}\lambda^{2}}{4\pi}\Gamma(\varepsilon_{S},\theta)$$

Study area: latitude -45 to +45
Aligned data: SMAP
R=0.86
RMSE=0.064 cm³/cm³





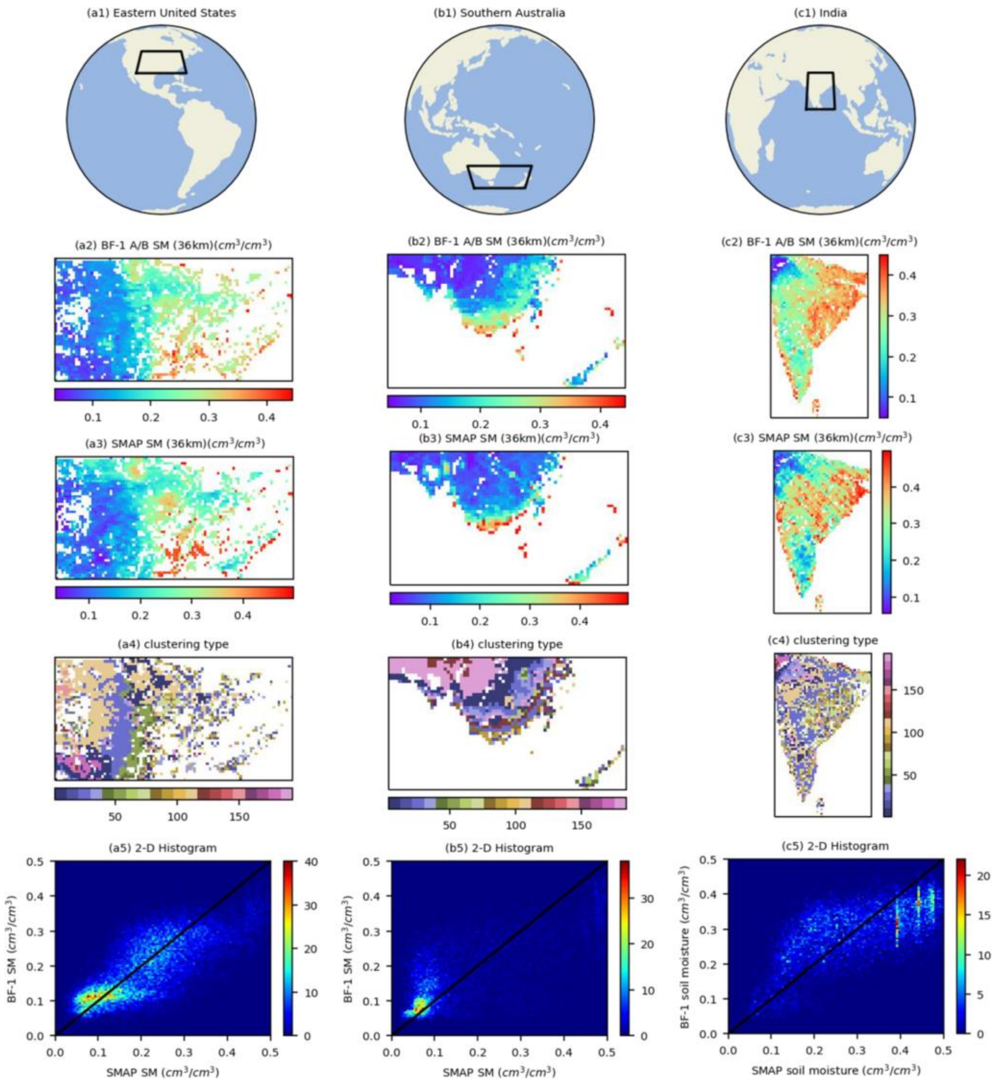
W. Wan, B. Liu, X. Chen, et al. “Initial evaluation of the first Chinese GNSS-R mission BuFeng-1 A/B for soil moisture estimation”.GRSL received.

Land Surface Clustering Algorithm

Observable: GNSS-R equivalent specular reflectivity (Chew et al, 2020):

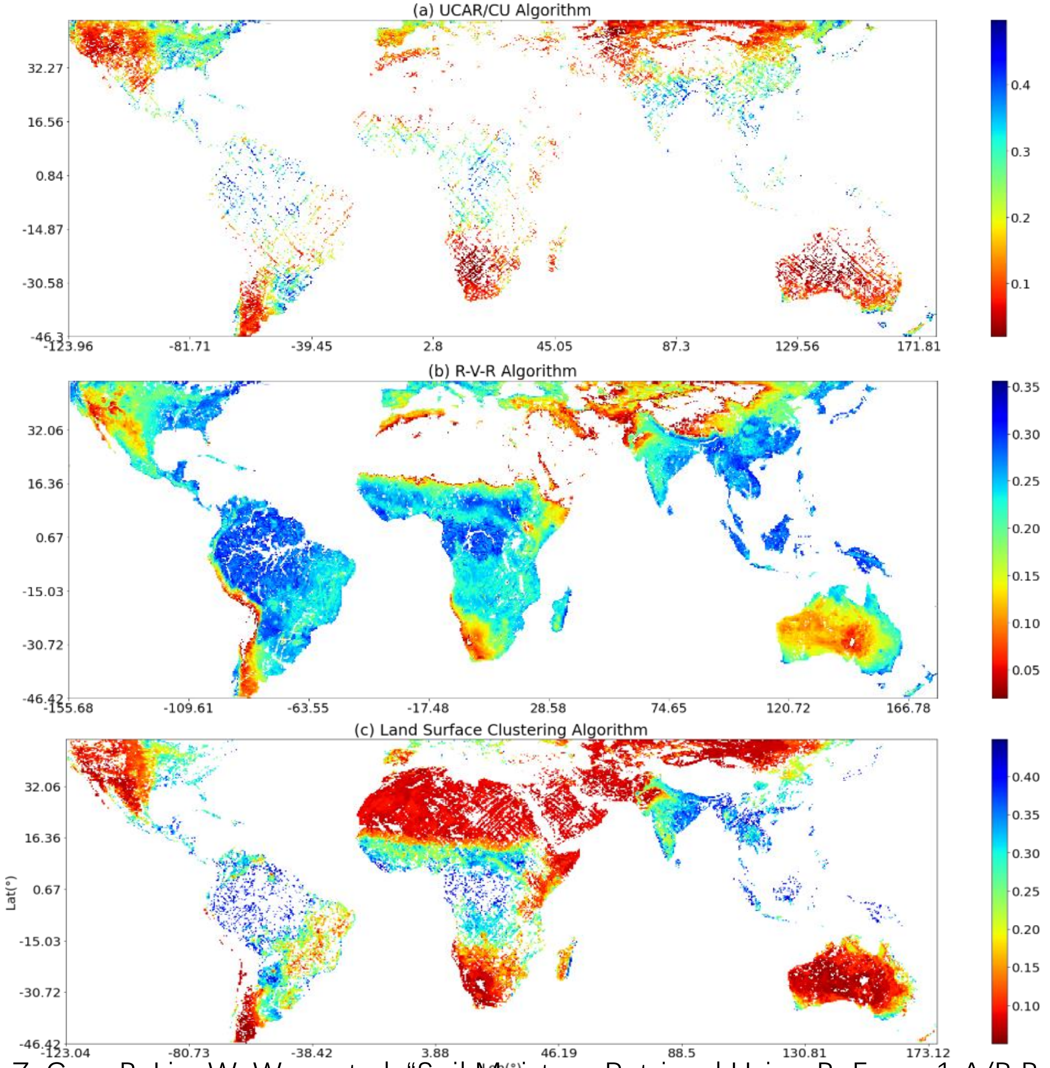
$$\Gamma = \frac{\sigma\left(R_{st} + R_{sr}\right)^2}{4\pi\left(R_{st}R_{sr}\right)^2}$$

Study area: Eastern United States, Southern Australia, and India
Aligned data: ISMN sites, SMAP
Performances:
SMAP vs BF-1: ubRMSE=0.07 cm^3/cm^3, R=0.82
ISMN sites vs BF-1: ubRMSE=0.036 cm^3/cm^3



Z. Guo, B. Liu, W. Wan, et al. “Soil Moisture Retrieval Using BuFeng-1 A/B Based on Land Surface Clustering Algorithm”. IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING,2022.

Comparison of the performances of SM retrieval algorithms



UCAR/CU products
ubRMSE=0.057 cm^3/cm^3, R=0.86
Available SM area percentage(%) = 17.06

RVR(the reflectivity–vegetation–roughness)
ubRMSE=0.09 cm^3/cm^3, R=0.69
Available SM area percentage(%) = 47.38

PKU algorithm
ubRMSE=0.07 cm^3/cm^3, R=0.82
Available SM area percentage(%) = 35.63

Z. Guo, B. Liu, W. Wan, et al. "Soil Moisture Retrieval Using BuFeng-1 A/B Based on Land Surface Clustering Algorithm". IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING.2022.

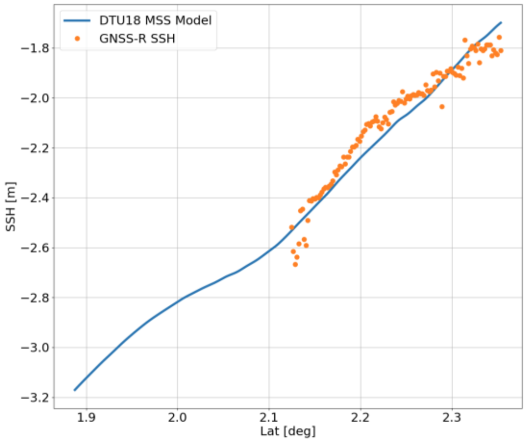
the results after 2 years of activity
Sea surface height measurements

Sea Surface Height (SSH) Measurement

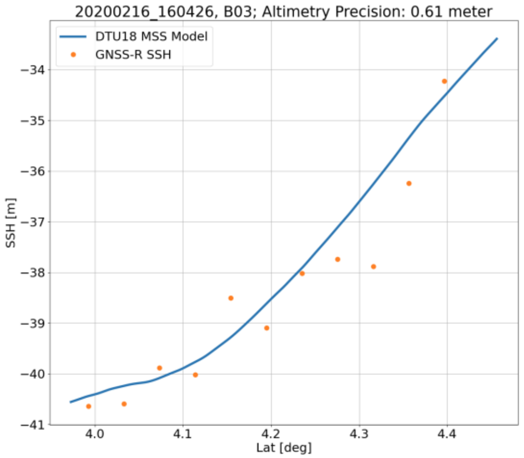
Study area: Indonesia
Data: BF-1 IF raw data
Signal: BDS-R

Two basic observation:

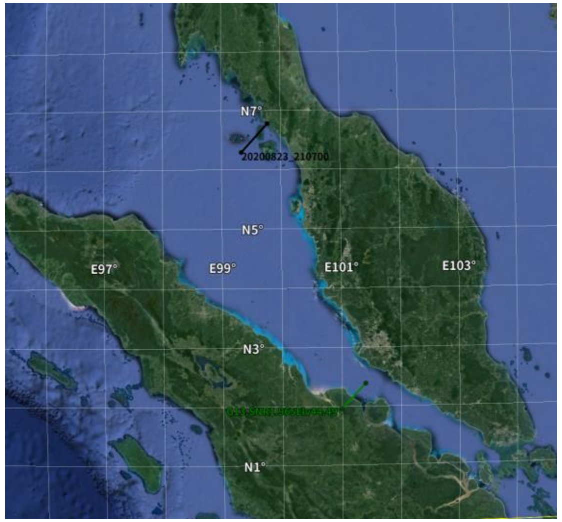
- Group Delay Altimetry
  RMSE = 0.61 m@1Hz
- Phase Delay Altimetry
  RMSE = 0.035 m@1 Hz
  Windspeed = 4.3 m/s

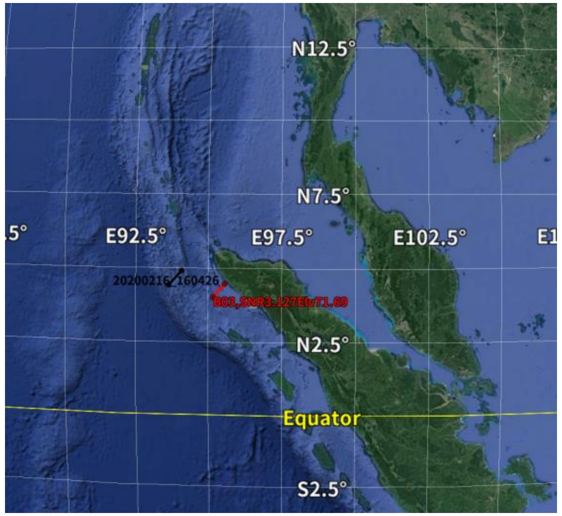


Phase Delay Altimetry



Group Delay Altimetry





W. Li, E. Cardellach, F. Fabra, et al. "Assessment of Spaceborne GNSS-R Ocean Altimetry Performance Using CYGNSS Mission Raw Data". TGRS 2019
W. Li, A. Rius, F. Fabra, et al. "Revisiting the GNSS-R Waveform Statistics and Its Impact on Altimetric Retrievals". TGRS 2017

SCHEDULE & PLANNING:

SCHEDULE & PLANNING:

- Phase 1: Preparation: Kick Off (KO) - KO+18
- Phase 2: Data Acquisition: KO - KO+42
- Phase 3: Calibration and validation: KO + 6 - KO + 48
- Midterm Theme Workshop 2022
- Phase 4: Showcases KO +32 - KO+48
- Phase 5: Integration KO +42 - KO+48
- Final Theme Workshop 2024
- Final project reporting

YOUNG SCIENTISTS CONTRIBUTIONS

European Young scientists :

Dr. Yang Nan received the B.S. degree and M.S. degree in geomatics from Chang'an University, Xi'an, China, in 2012 and 2017 respectively. After Since 2019, He has studied at the Earth Observation Research Group, Institute of Space Sciences (ICE), Spanish National Research Council (CSIC), Institut d'Estudis Espacials de Catalunya (IEEC), Barcelona, Spain as a PhD students. He has been involved in Spaceborne GNSS-R retrieve wind field.

Chinese Young scientists :

Dr. Baojian Liu has received his Ph.D. degree in photogrammetry and remote sensing at Peking University. His research activity includes using spaceborne GNSS-R data and SMOS data to retrieve ocean salinity.
Mr. Zhizhou Guo is pursuing his Ph.D. degree in photogrammetry and remote sensing at Peking University. His research activity includes using spaceborne GNSS-R data to retrieve soil moisture content.

ONGOING AND FUTURE ACTIVITY

Ground Observation of BDS Signals

Ground-based EIRP monitoring, follow the Friis formula:

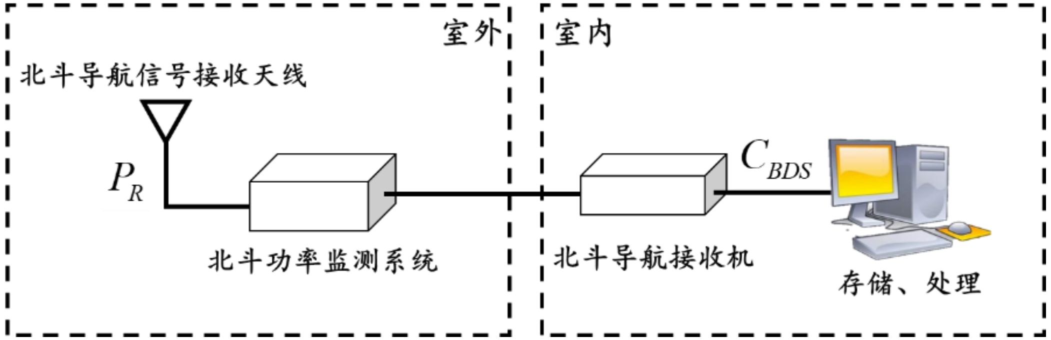
$$P_R = \frac{E}{4\pi R^2 L_a}\left(\frac{\lambda^2}{4\pi}\right)G_R$$

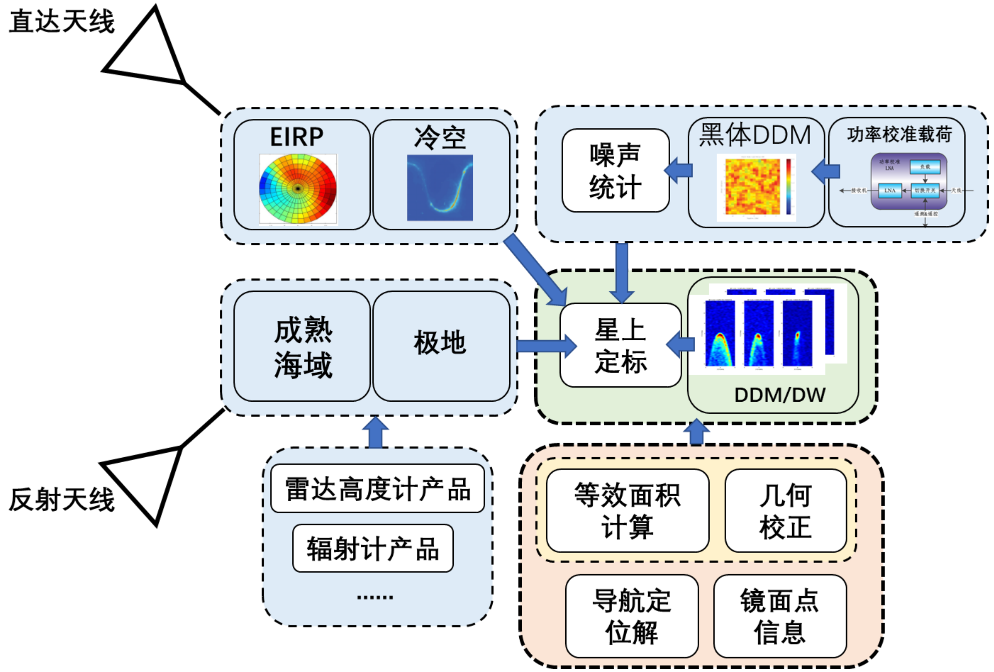
The observed value is illustrated:

$$P_{R,\mathrm{PRN}}(\theta,\phi) = S_B C_{BDS}$$

By applying the EIRP product, the BDS NBRCS and Reflectivity can be easily calculated.

This project has been supported by NSFC 2021



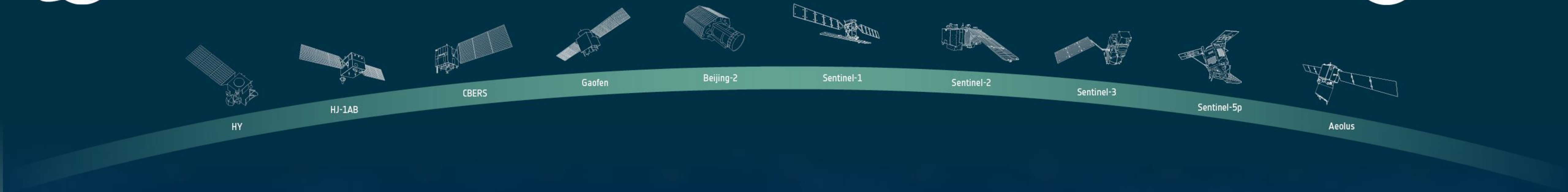


T. Wang, C. Ruf, S. Gleason, B. Block, D. McKague, D. Provost, Development of GPS constellation power monitor system for high accuracy calibration/validation of the CYGNSS L1B data, 2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), IEEE, 2017, pp. 1008-1011.

FUTURE ACTIVITY

- the eight bias corrections are studied for future GNSS-R SSH products: sea states bias, atmospheric corrections, ionosphere corrections, sea tides, pole tides, solid tides, dynamic bar corrections.
- the instruments, high gain antennas and high rate receivers, are designed and developing for future ground validation experiments.
- the simulations of spaceborne GNSS-R bistatic waveforms and DDMs has been developed for ongoing and future space missions.
- experiments of GNSS-SAR and airborne GNSS-R are expected in the next year.

2022 DRAGON 5 SYMPOSIUM



Thanks for your attention