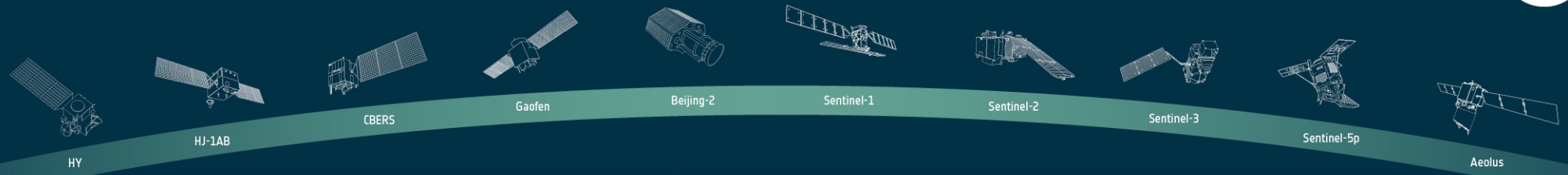


2022 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

[PROJECT ID. 59312]

MULTI-FREQUENCY MICROWAVE REMOTE SENSING OF GLOBAL WATER CYCLE AND ITS CONTINUITY FROM SPACE

<THURSDAY, 20/OCT/2022>

ID. 59312

PROJECT TITLE: MULTI-FREQUENCY MICROWAVE REMOTE SENSING OF GLOBAL WATER CYCLE AND ITS CONTINUITY FROM SPACE?

PRINCIPAL INVESTIGATORS: [YANN KERR, JIANCHENG SHI]

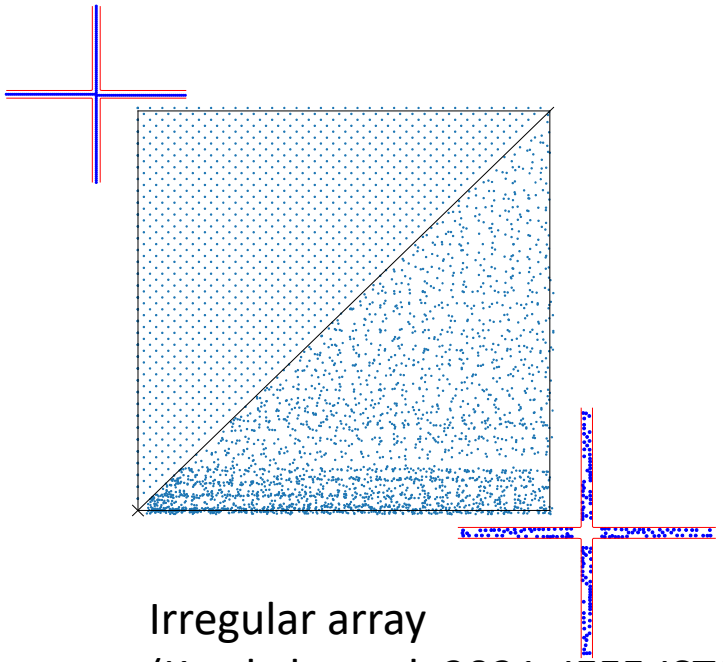
CO-AUTHORS: [NEMESIO RODRIGUEZ-FERNANDEZ, TIANJIE ZHAO, PANPAN YAO, ZHIQING PENG, RUI LI, JINMEI PAN]

PRESENTED BY: [TIANJIE ZHAO]

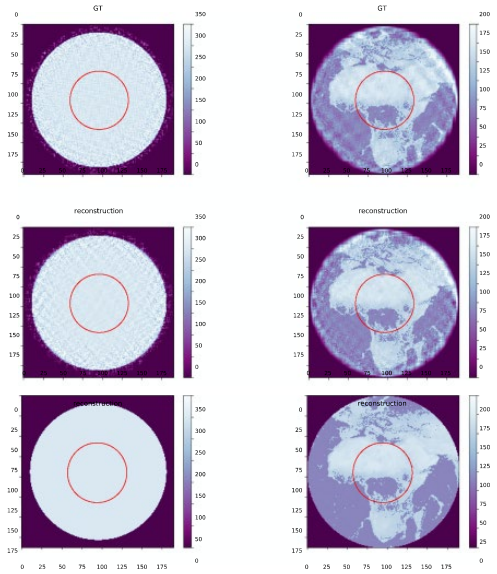
Dragon 5 Mid-term Results Reporting **59312**

- **Task 1**: Brightness-temperature retrieval techniques for synthetic aperture interferometric radiometers and RFI mitigation techniques
- **Task 2**: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions
- **Task 3**: Enhancement of the spatial-temporal resolution of remote sensing products by combine use of multi-source satellites
- **Task 4**: Applications of multiple microwave and optical remote sensing products for eco-hydrological modelling in the Luan river basin
- Planning on field data collection campaigns
- Academic exchanges

- **Task 1: Brightness-temperature retrieval techniques for synthetic aperture interferometric radiometers and RFI mitigation techniques**
- Irregular antenna arrays have been studied to diminish the aliasing of in the reconstructed images (preparation of new missions)



Irregular array
(Krzakala et al. 2021, IEEE JSTARS)

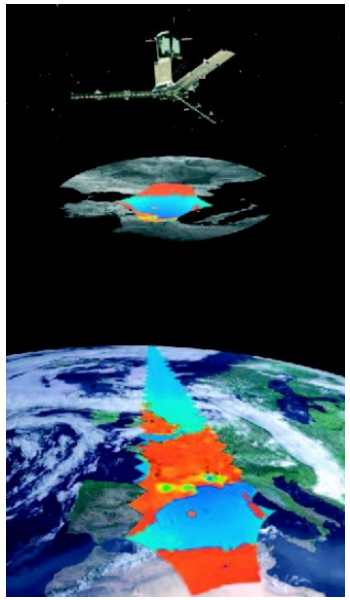


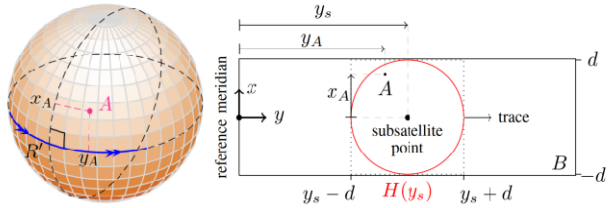
Original image

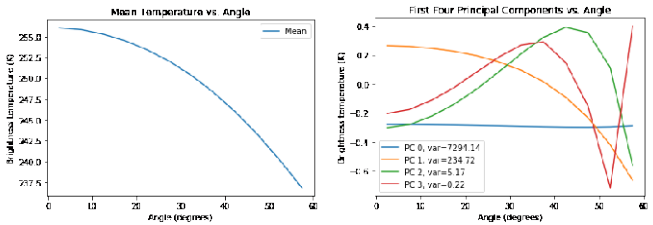
Irregular cross

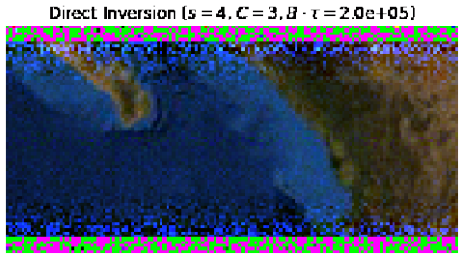
Quincunx cross

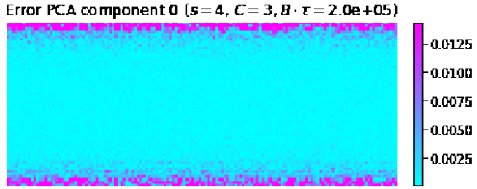
- **Task 1: Brightness-temperature retrieval techniques for synthetic aperture interferometric radiometers and RFI mitigation techniques**
- Simultaneous reconstruction of subsequent snapshots can impose more constrains on the BT images and reduce noise.





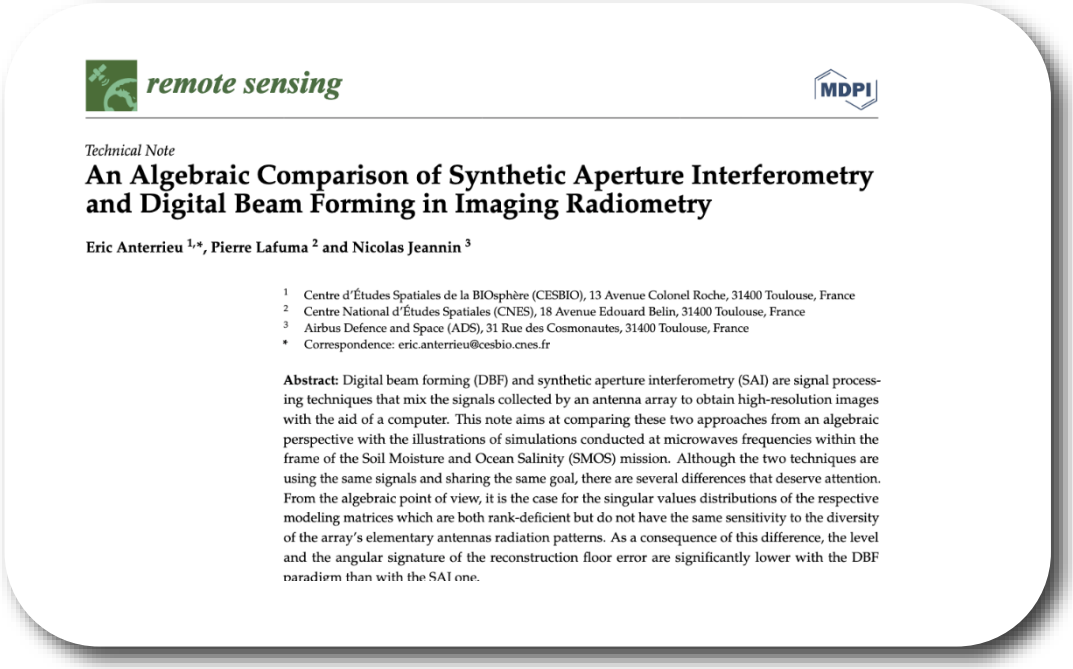






Reconstruction d'image multi-snapshot
(Dunitz et al. 2021, IEEE CAMA)

- **Task 1: Brightness-temperature retrieval techniques for synthetic aperture interferometric radiometers and RFI mitigation techniques**
- Digital beam forming shows promising results as an alternative to aperture synthesis. Less noise in the BT versus incidence angle curves due to less sensitivity to disparities in the antenna power patterns



remote sensing MDPI

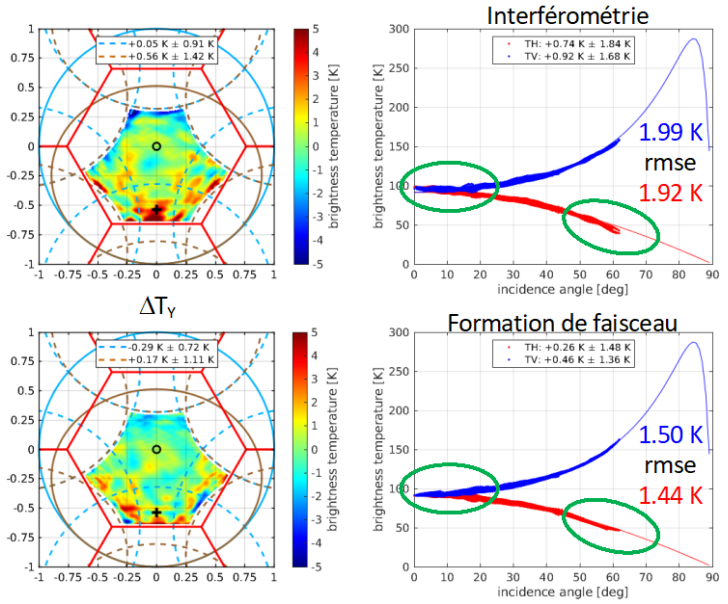
Technical Note

An Algebraic Comparison of Synthetic Aperture Interferometry and Digital Beam Forming in Imaging Radiometry

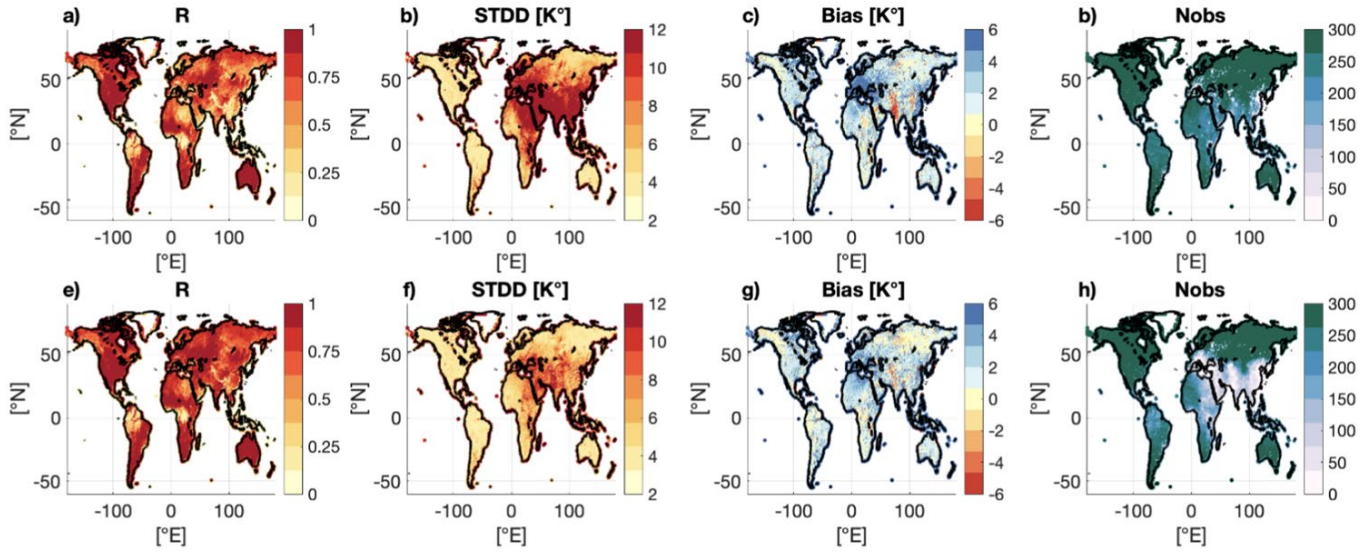
Eric Anterrieu [1,*], Pierre Lafuma [2] and Nicolas Jeannin [3]

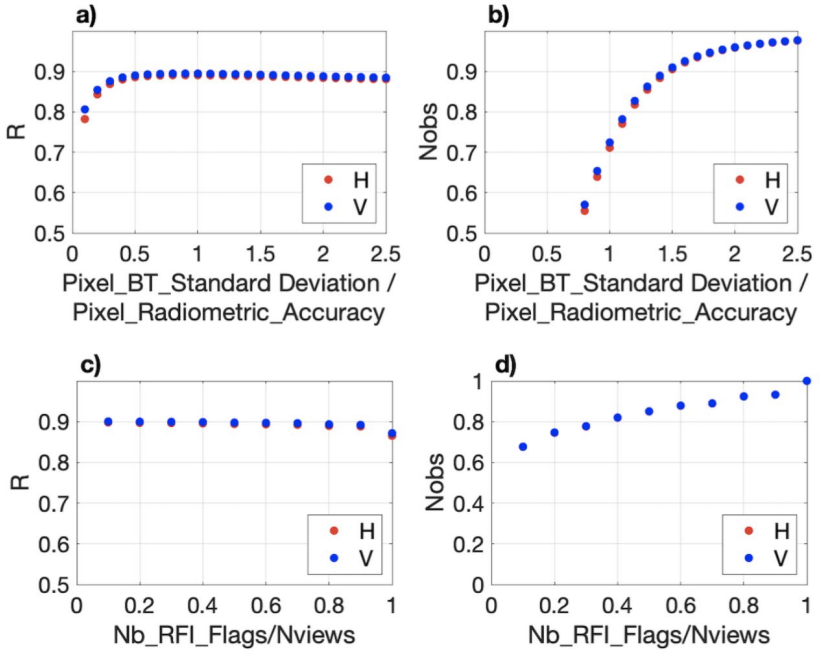
[1] Centre d'Études Spatiales de la BIOsphère (CESBIO), 13 Avenue Colonel Roche, 31400 Toulouse, France
[2] Centre National d'Études Spatiales (CNES), 18 Avenue Edouard Belin, 31400 Toulouse, France
[3] Airbus Defence and Space (ADS), 31 Rue des Cosmonautes, 31400 Toulouse, France
* Correspondence: eric.anterrieu@cesbio.cnes.fr

Abstract: Digital beam forming (DBF) and synthetic aperture interferometry (SAI) are signal processing techniques that mix the signals collected by an antenna array to obtain high-resolution images with the aid of a computer. This note aims at comparing these two approaches from an algebraic perspective with the illustrations of simulations conducted at microwaves frequencies within the frame of the Soil Moisture and Ocean Salinity (SMOS) mission. Although the two techniques are using the same signals and sharing the same goal, there are several differences that deserve attention. From the algebraic point of view, it is the case for the singular values distributions of the respective modeling matrices which are both rank-deficient but do not have the same sensitivity to the diversity of the array's elementary antennas radiation patterns. As a consequence of this difference, the level and the angular signature of the reconstruction floor error are significantly lower with the DBF paradigm than with the SAI one.



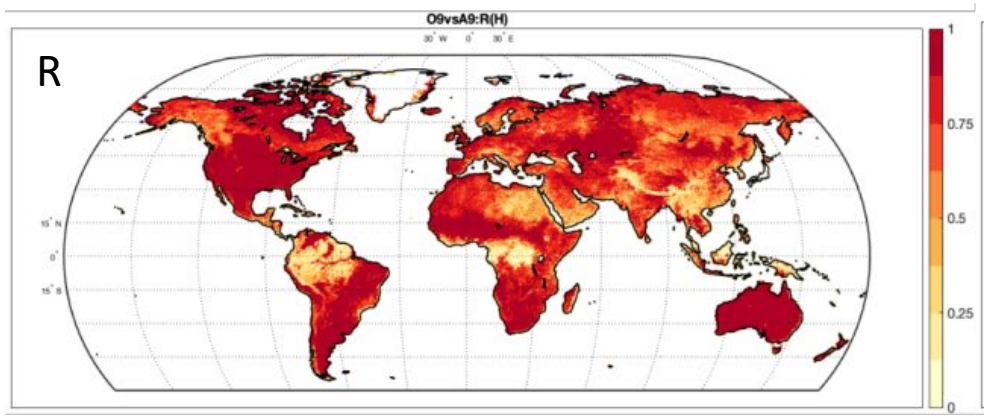
- **Task 1: Brightness-temperature retrieval techniques for synthetic aperture interferometric radiometers and RFI mitigation techniques**
- Using SMAP Tbs to define thresholds to filter SMOS Tbs in regions affected by RFI
- Comparison to SMAP allow to define thresholds using RFI_flags/Nviews and BT_std/BT_accuracy

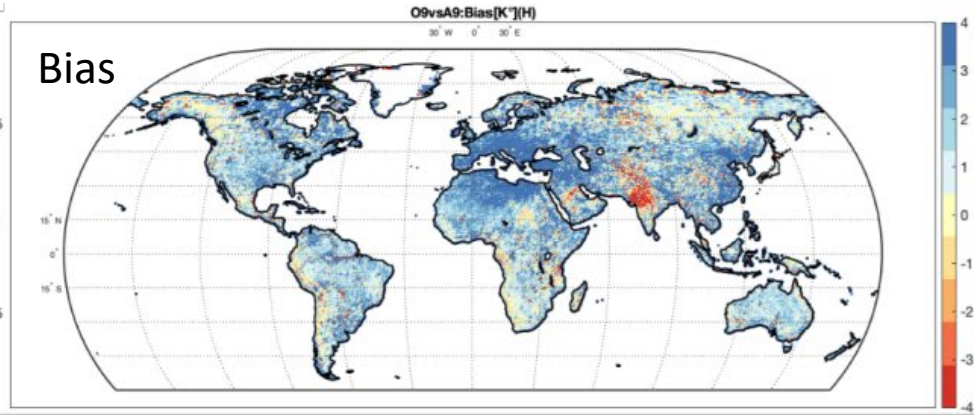


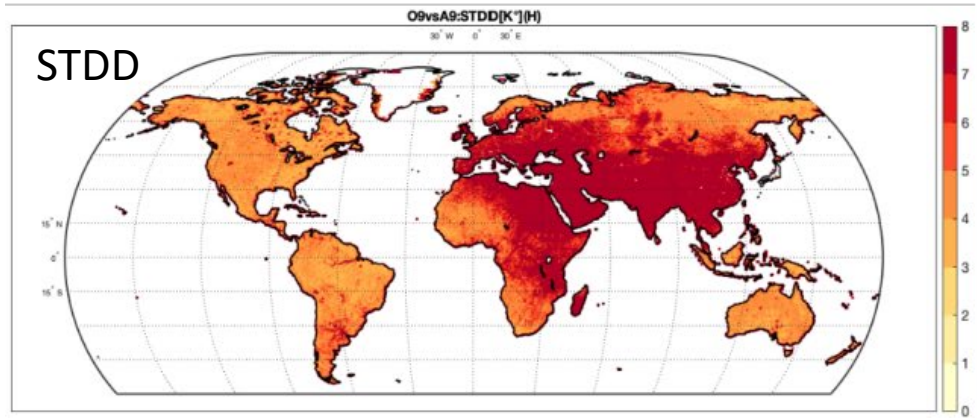


Madelon, Rodriguez-Fernandez et al.

- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
- After applying those filters it is possible to reduce bias in SMOS and SMAP BTs







- Multilinear regression of SMOS BTs from 30° to 45° with respect to SMAP BTs (40°)

Madelon, Rodriguez-Fernandez et al.

- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
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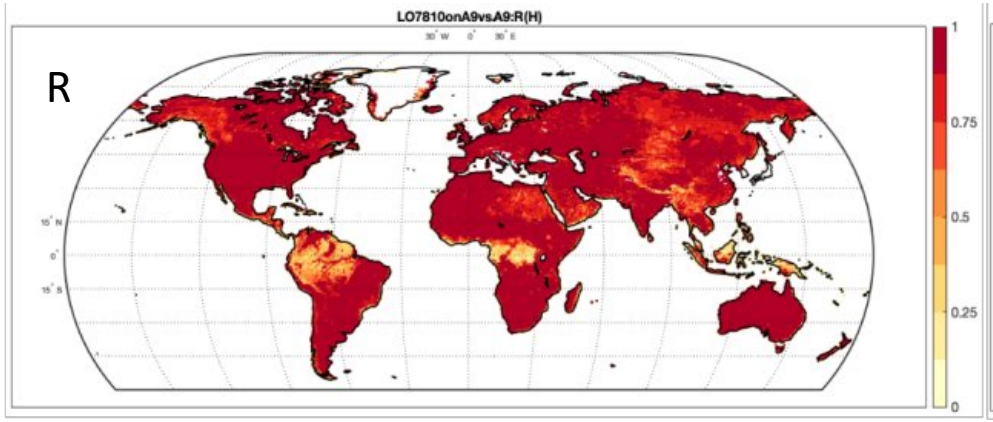
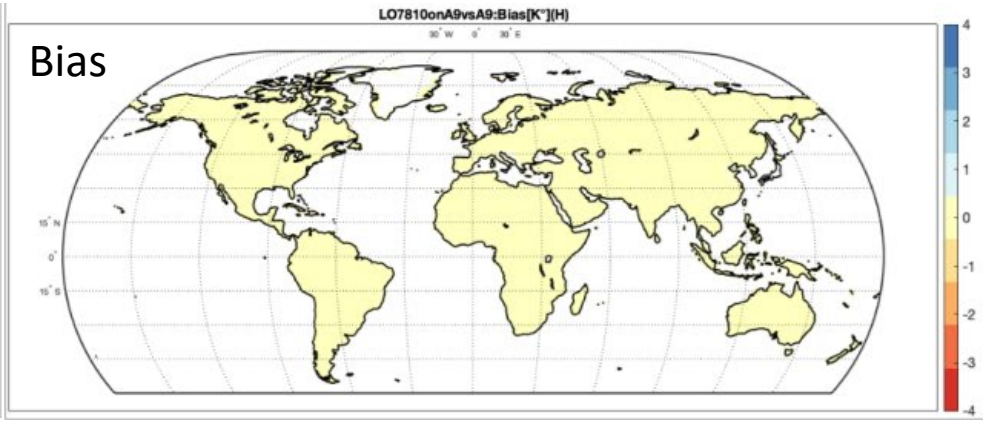
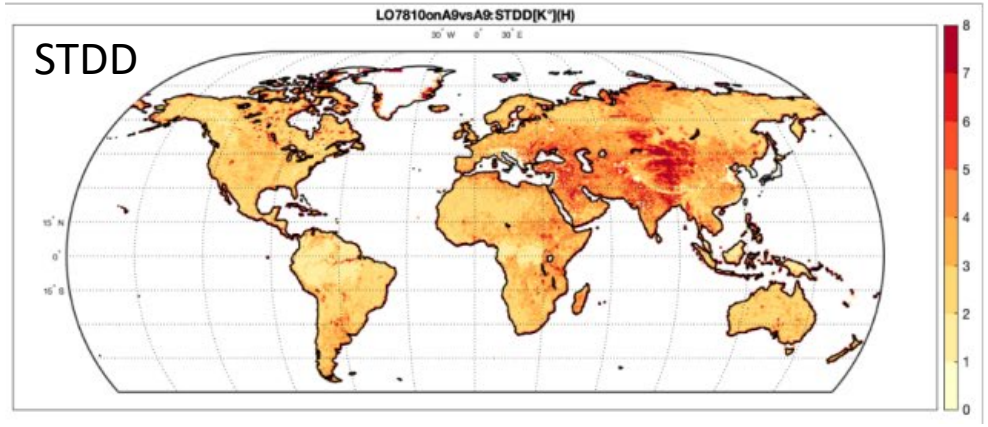






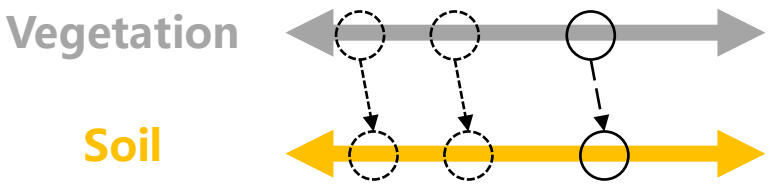
Madelon, Rodriguez-Fernandez et al.

- Multilinear regression of SMOS BTs from 30° to 45° with respect to SMAP BTs (40°)
- Important to have a common L-band time series to be used to rescale time series of other sensors for climate data records

- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
- A general soil moisture retrieval algorithm (multi-channel collaborative algorithm, MCCA) that could be applied to various satellites was developed.

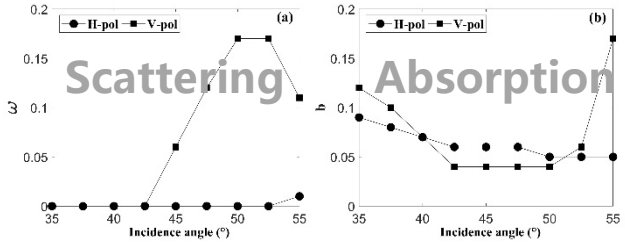
■ (1) Self-constraint relationship between soil and vegetation parameters is used as constraints

$$F_{\omega-\tau}^{-1}:\ \tau_{ch} = -\log\left(\frac{-b' - \sqrt{b'^2 - 4\cdot a'\cdot c'}}{2\cdot a'}\right)\cdot\cos\theta$$



■ (2) Vegetation tau (VOD) is dependent on frequency, polarization and incidence angle

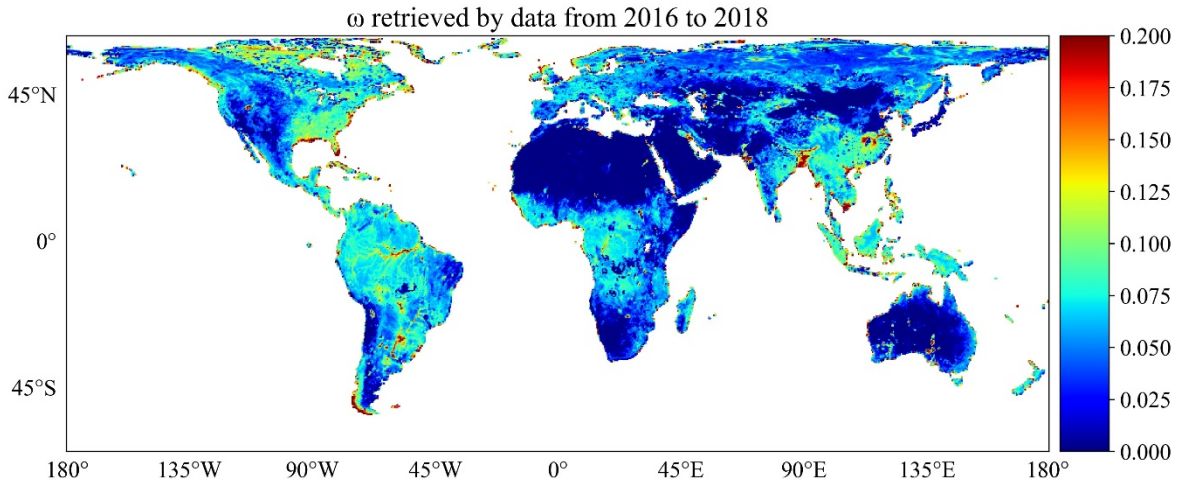
$$F_{asm}:\ \frac{\tau_{ch(1)}}{\tau_{ch(2)}} = \left(\frac{f_1}{f_2}\right)^{C_f}\cdot\frac{\sin^2\theta_1\cdot C_{P_1} + \cos^2\theta_1}{\sin^2\theta_2\cdot C_{P_2} + \cos^2\theta_2}$$



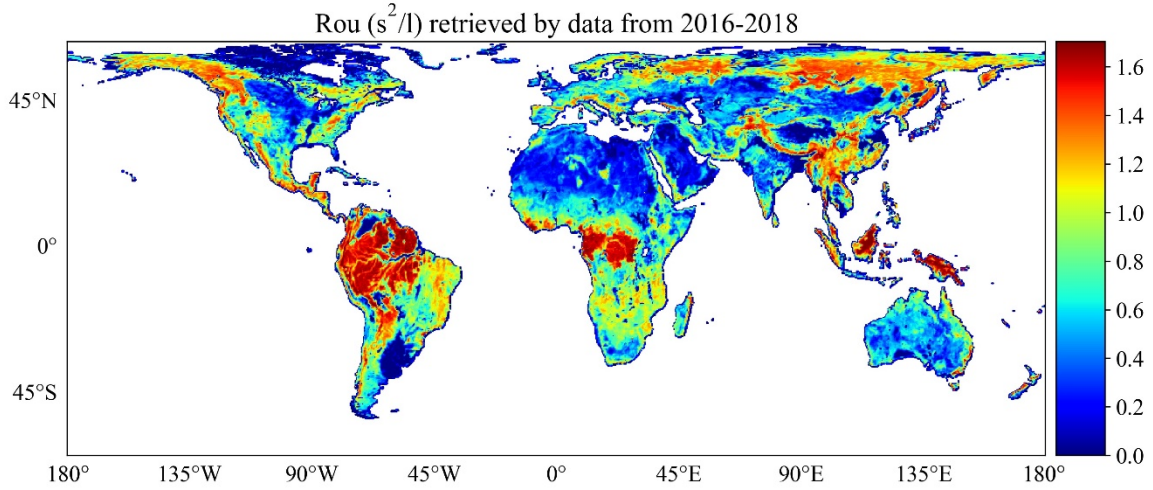
■ (3) for a given Tb and corresponding soil and vegetation parameters, the Tb at another channel can be predicted

$$F_{cond}:\ Tb_{ch(2)}^{total} = V_{ch(2)}^{e} - S_r V_r\cdot V_{ch(1)}^{e} + S_r V_r\cdot Tb_{ch(1)}^{total}$$

- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
- Parameter tuning without using ancillary data when applying the MCCA with SMOS and SMAP BTs
- The main idea is based on the information theory that the mutual information of the retrieved soil moisture and vegetation optical depth should be maximum.
- Although no ancillary data are utilized during the parameter tuning, it found that both albedo and roughness are land-cover dependent.

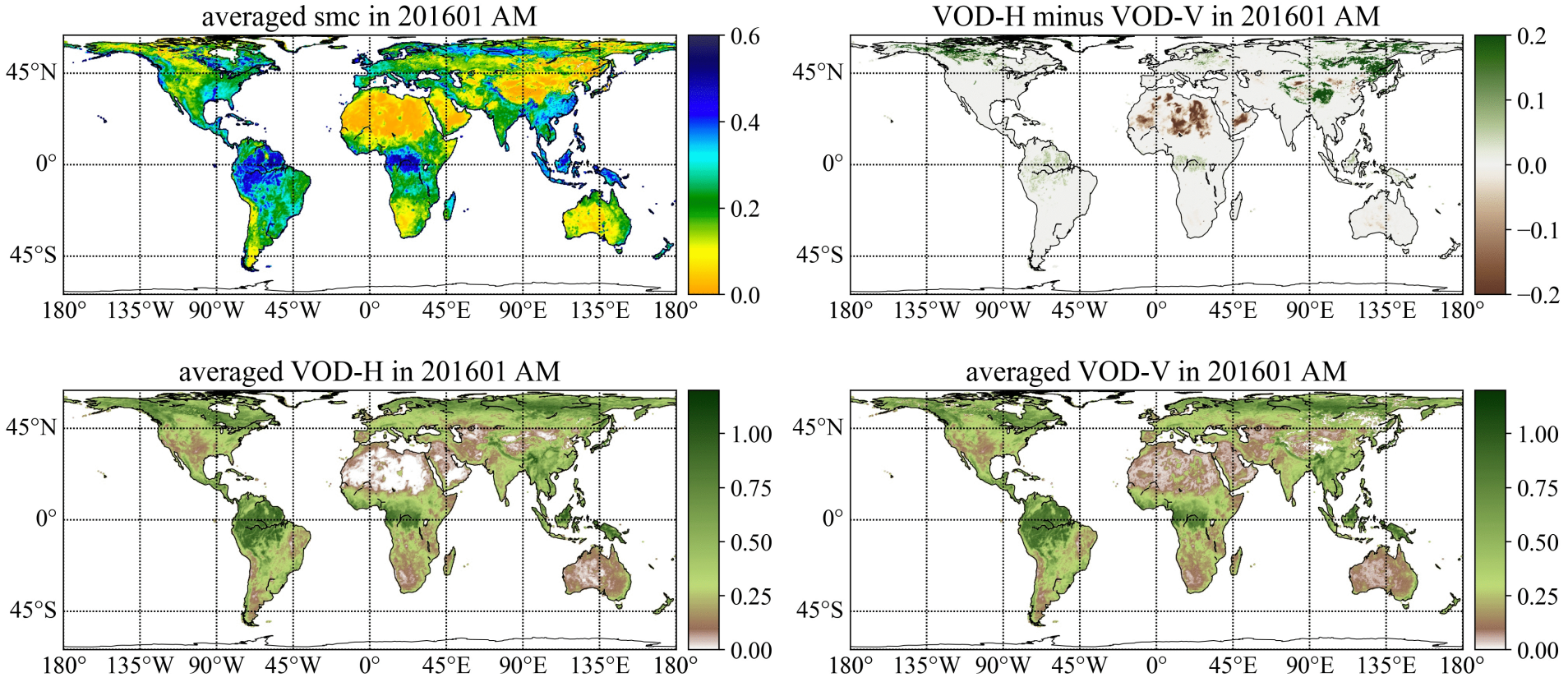


Effective scattering albedo



Roughness

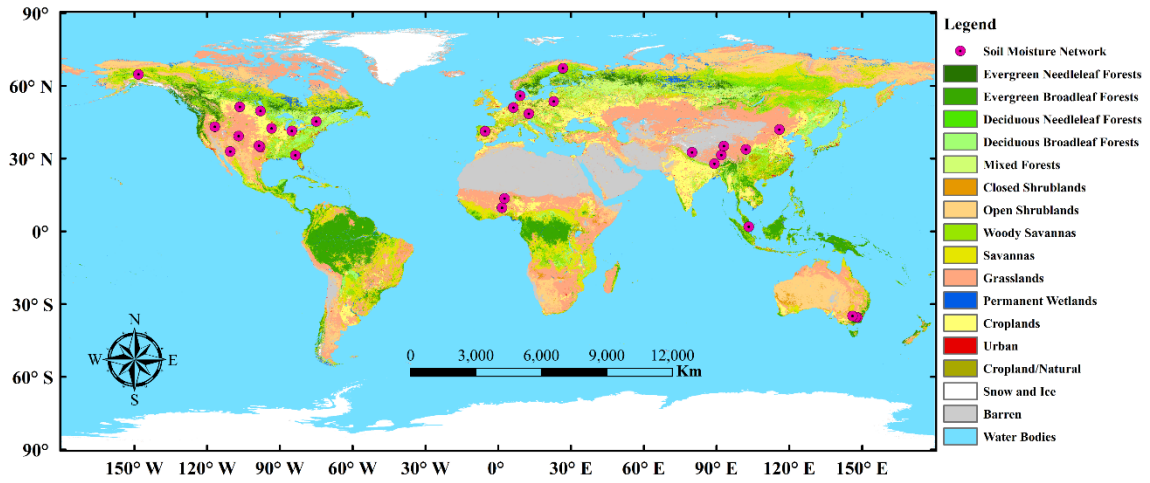
- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
- Global soil moisture content (SMC) and vegetation optical depth (VOD) results from SMAP



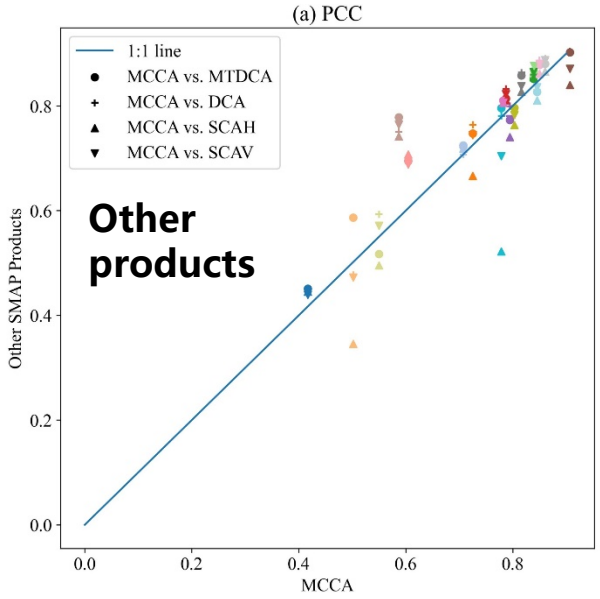
DOI: 10.11888/Terre.tpdc.272088.

- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
- The MCCA retrieved soil moisture generally has a comparable correlation (R) with other SMAP products, while the ubRMSE of MCCA soil moisture is generally lower than that from other SMAP products.

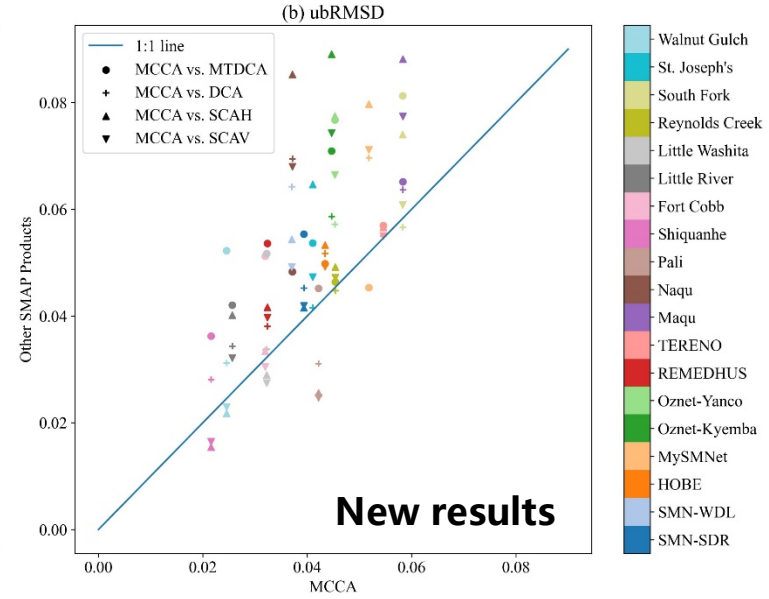
Dense networks from ISMN



Correlation

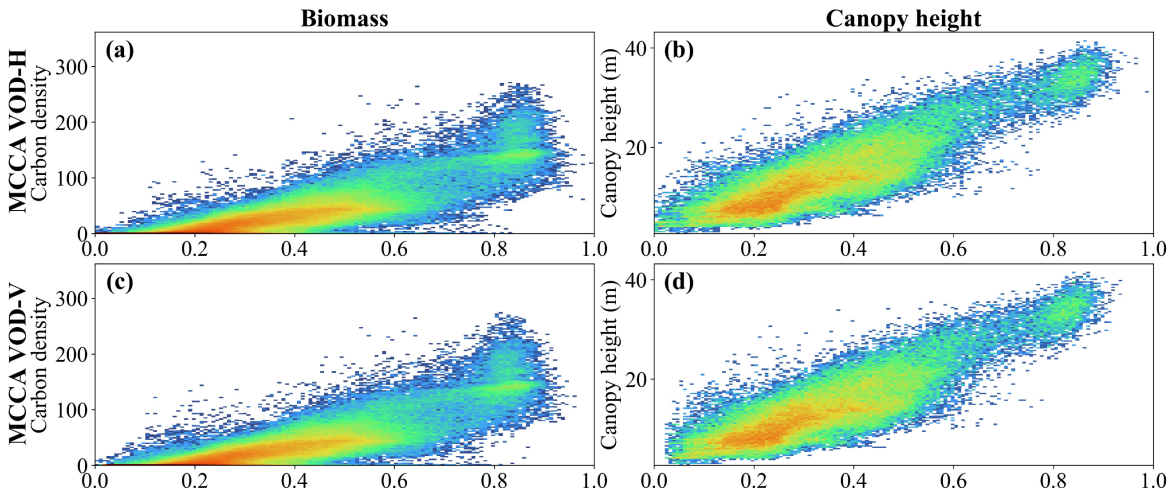


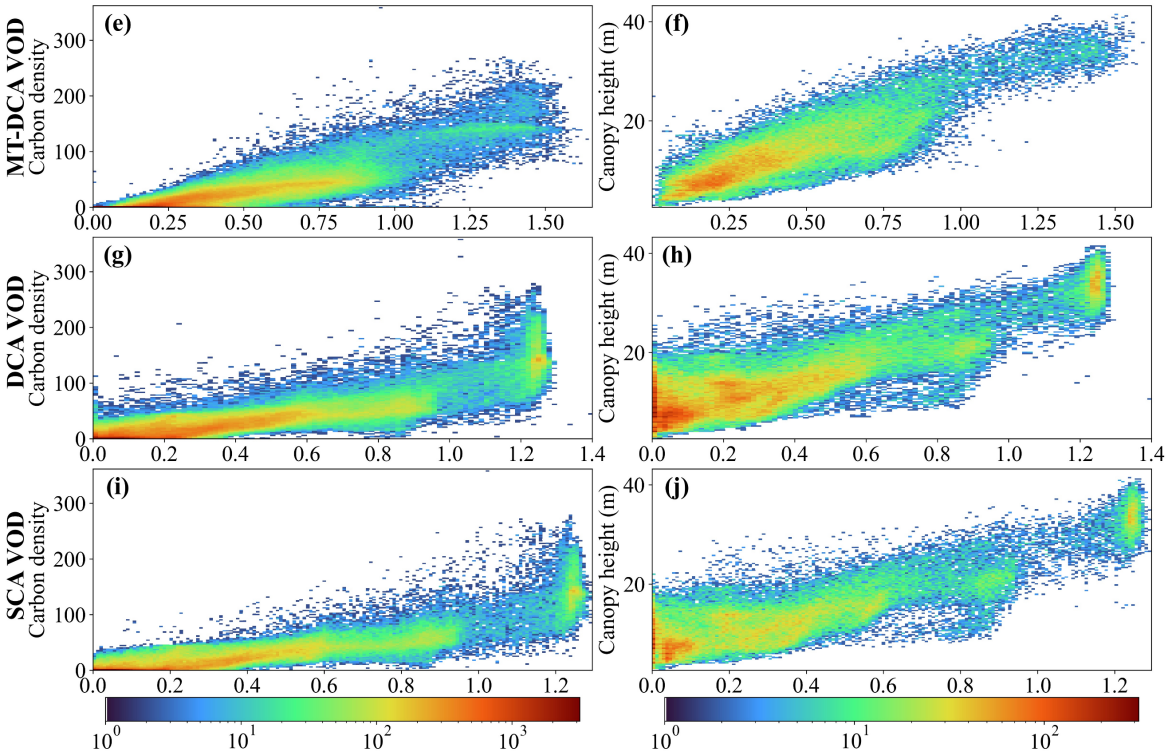
ubRMSD



Peng, Zhao, Shi et al. *2022,*
Remote Sensing of Environment (under revision)

- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
  - All VOD products have a linear correlation with AGB, and a saturation can happen when AGB is very high.
  - No saturation was found when compared with canopy height.

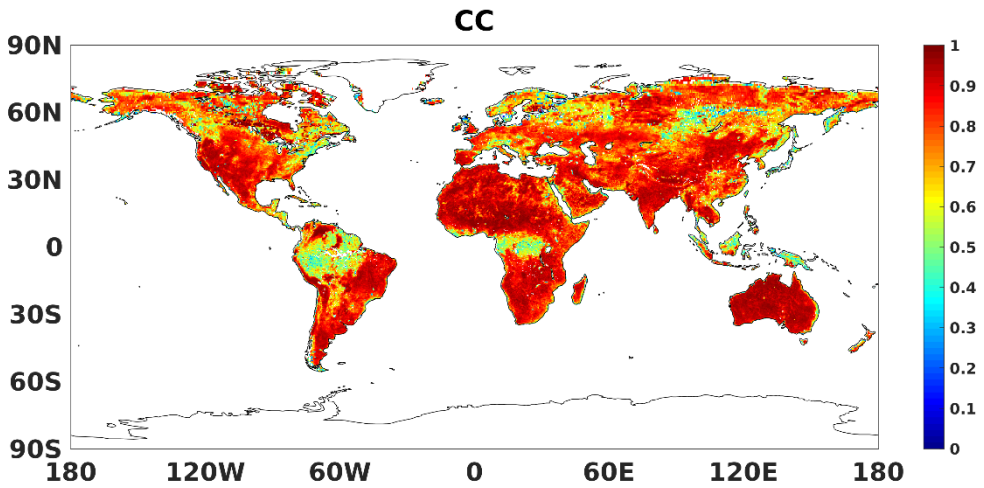




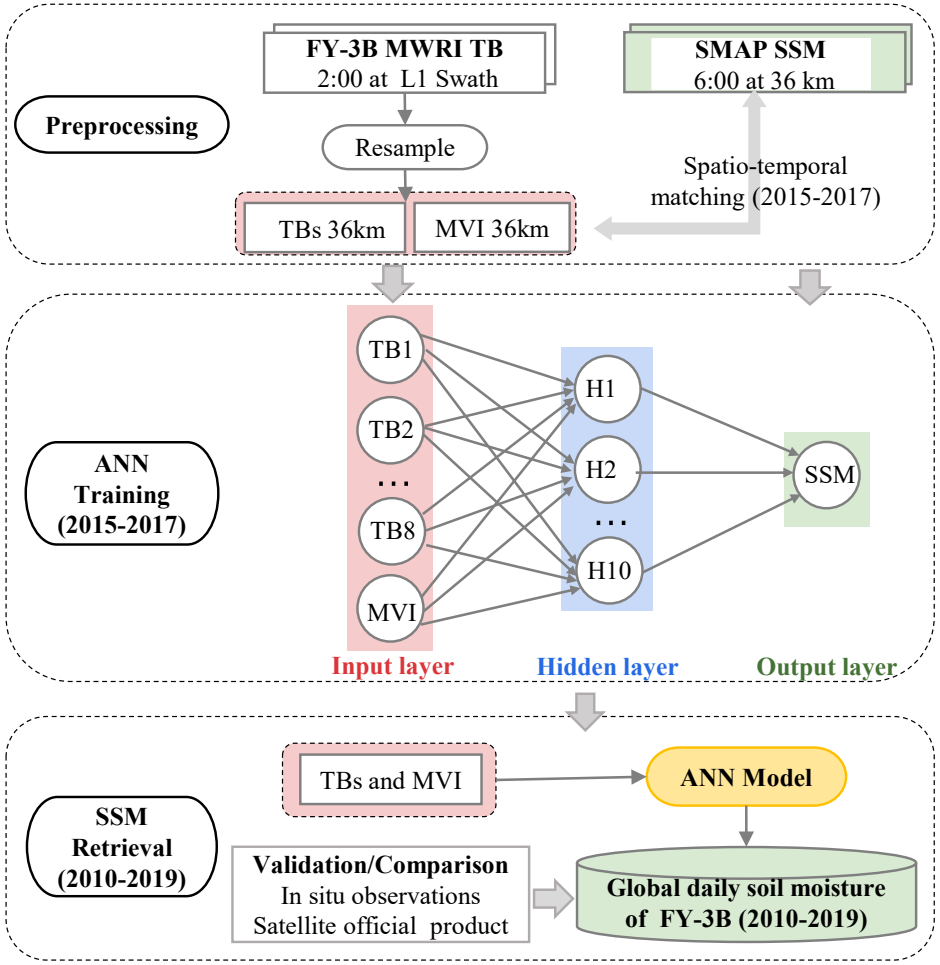
New results

- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
  - A global daily soil moisture dataset derived from Chinese FengYun Microwave Radiation Imager (MWRI)(2010-2019)

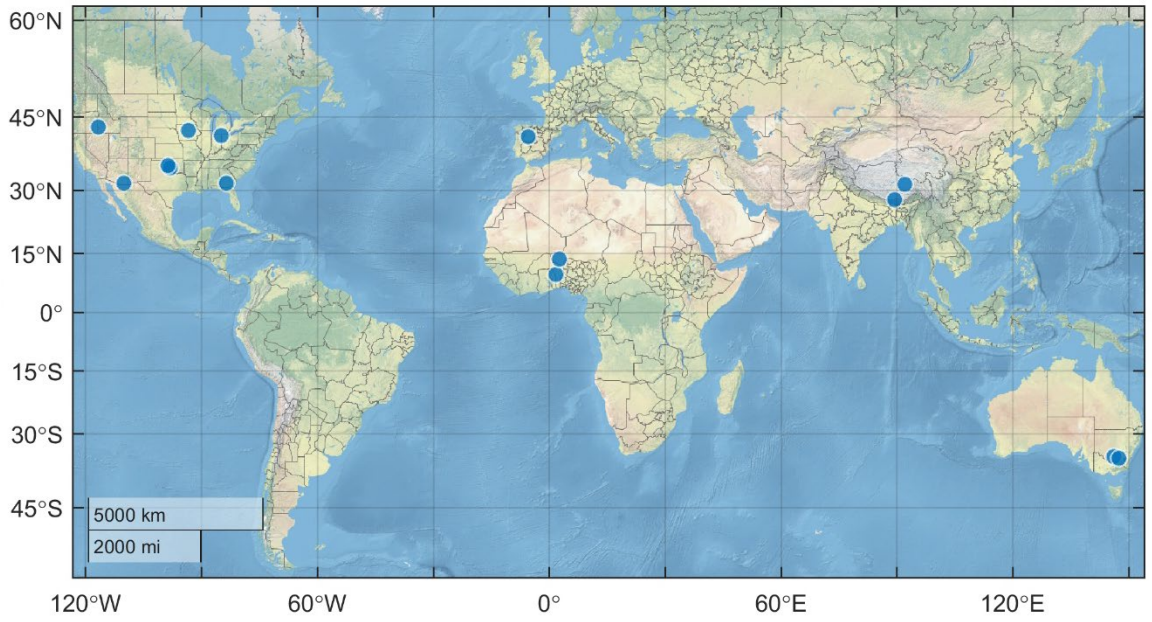
$$\mathrm{MVI}(f_1, f_2) = \frac{\mathrm{TB}_v(f_2) - \mathrm{TB}_h(f_2)}{\mathrm{TB}_v(f_1) - \mathrm{TB}_h(f_1)}$$

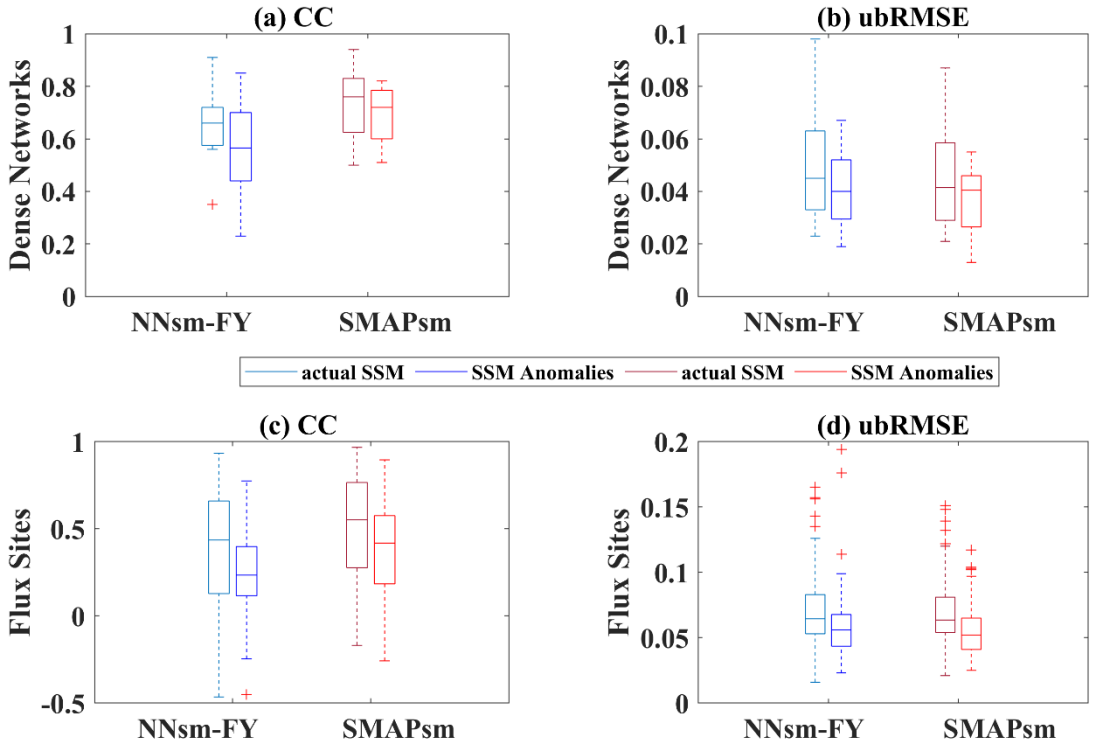


NNsm-FY v.s. SMAPsm

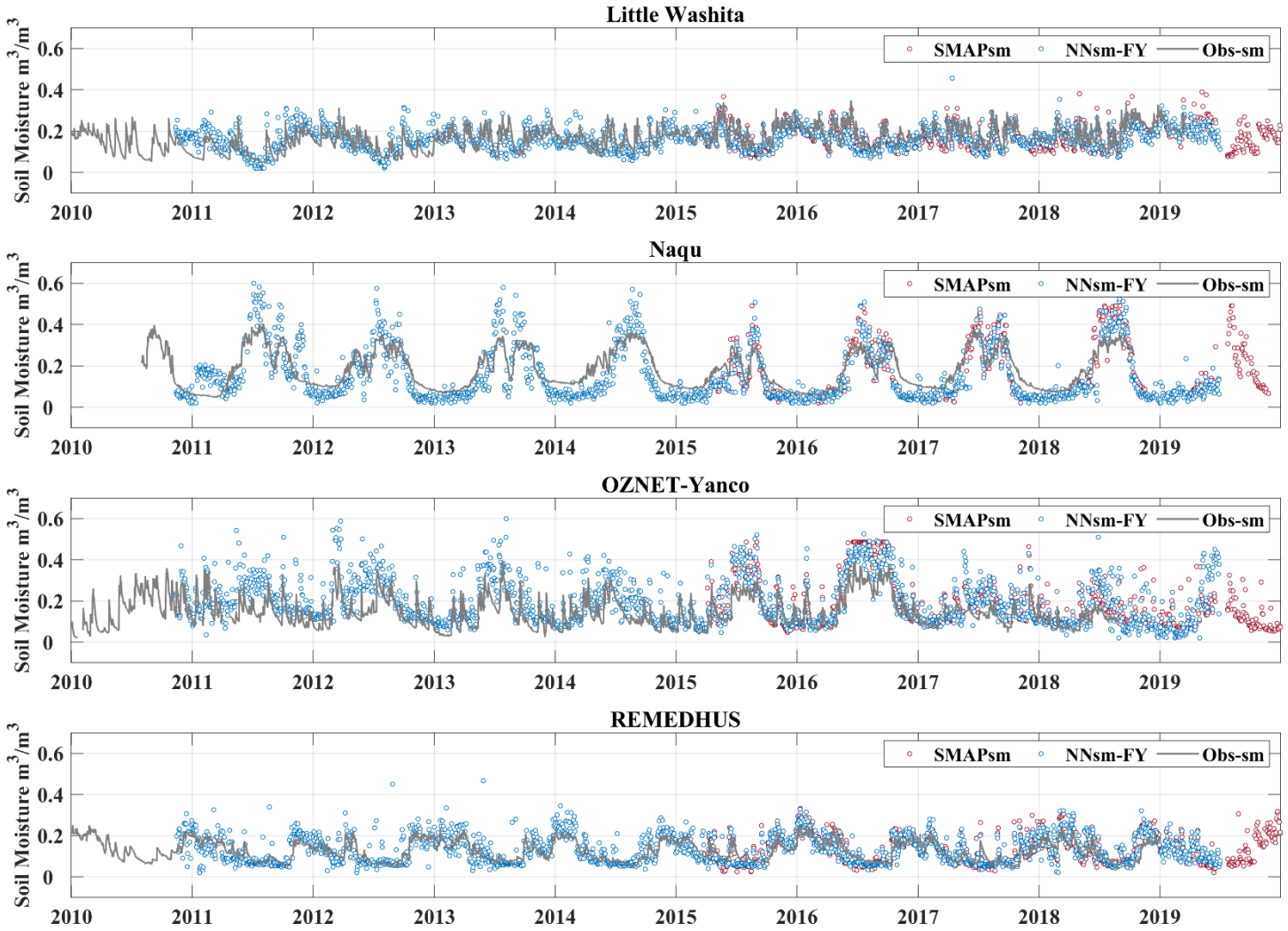


- **Task 2: New retrieval algorithm development and long-term data record development and validation for soil moisture based on current and future satellite missions**
  - NNsm-FY generally have a lower accuracy than SMAPsm for most networks, with lower CC and higher ubRMSE.
  - But the NNsm-FY has a longer time span from the year of 2010.

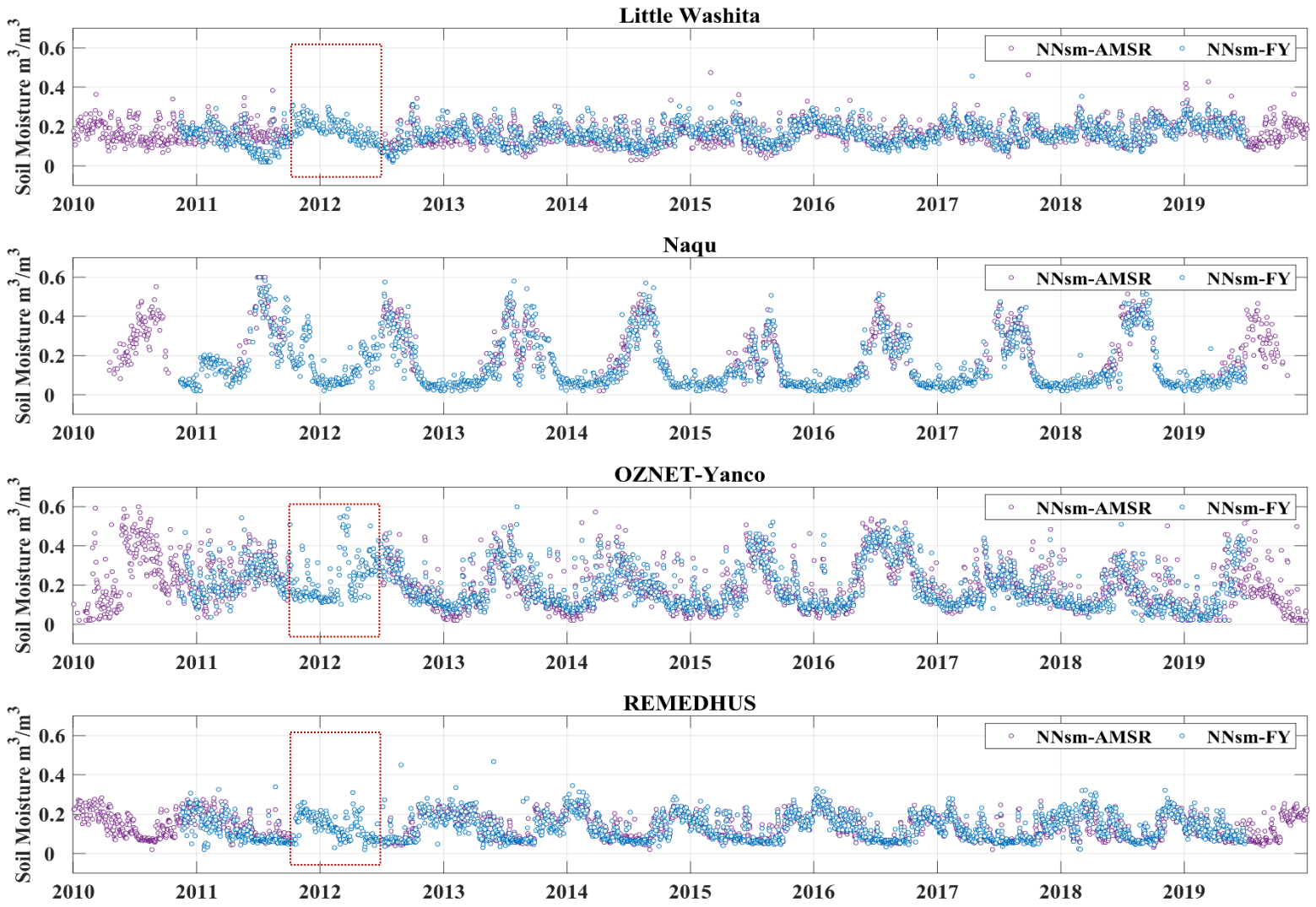




- A global daily soil moisture dataset derived from Chinese FengYun Microwave Radiation Imager (MWRI)(2010-2019)

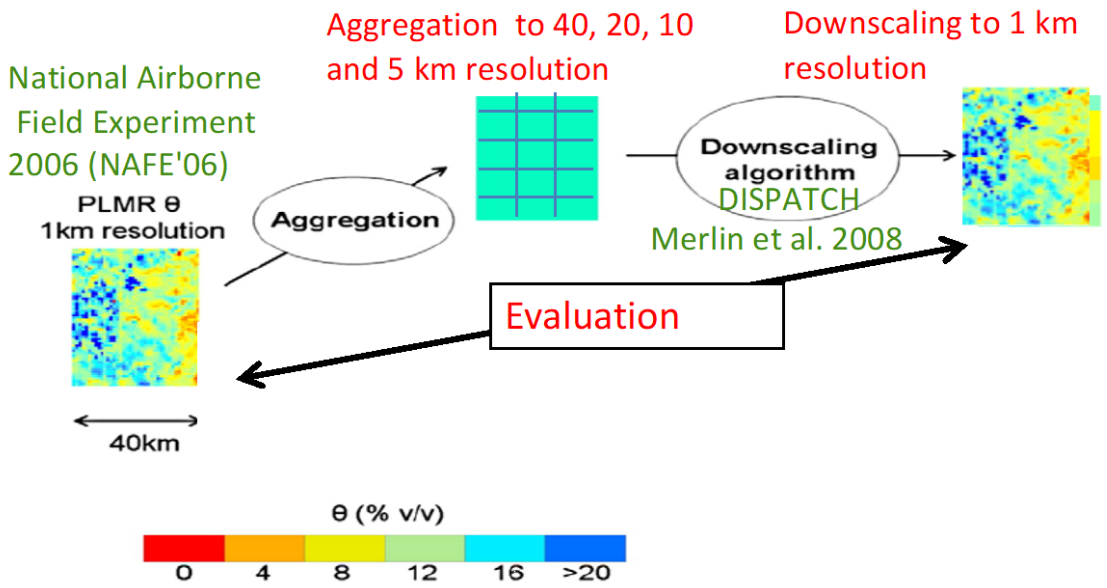


- NNsm-AMSR has a gap in period from Oct. 2011 to Jun 2012. This gap limits application of NNsm-AMSR such as drought analysis and climate change research.
- NNsm-FY dataset developed in this research, spanning from late 2010, exactly fill in this gap.

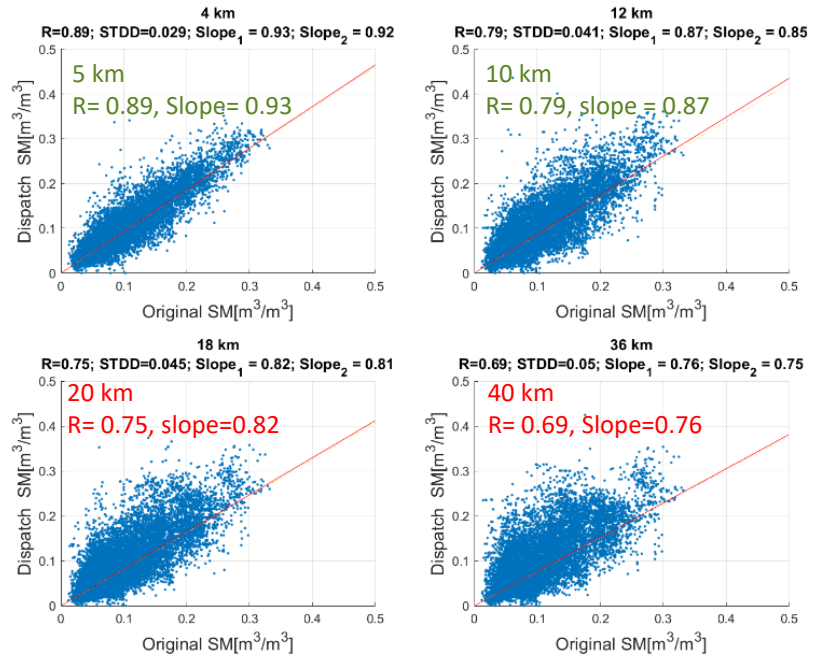


DOI: 10.11888/Terre.tpdc.271954.

- **Task 3: Enhancement of the spatial-temporal resolution of remote sensing products by combine use of multi-source satellites**
- Using NAFE'06, SMAPVEX15, SMAPVEX16 and Luan Basin airborne data to evaluate the impact of the initial resolution on the downscaling results



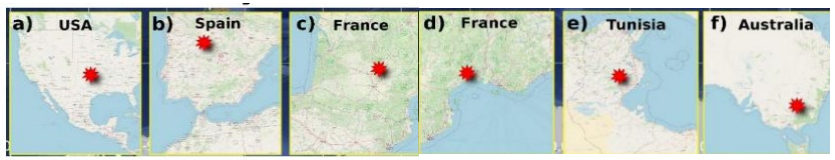
The results are significantly better when the initial resolution goes from 40 to 5 km

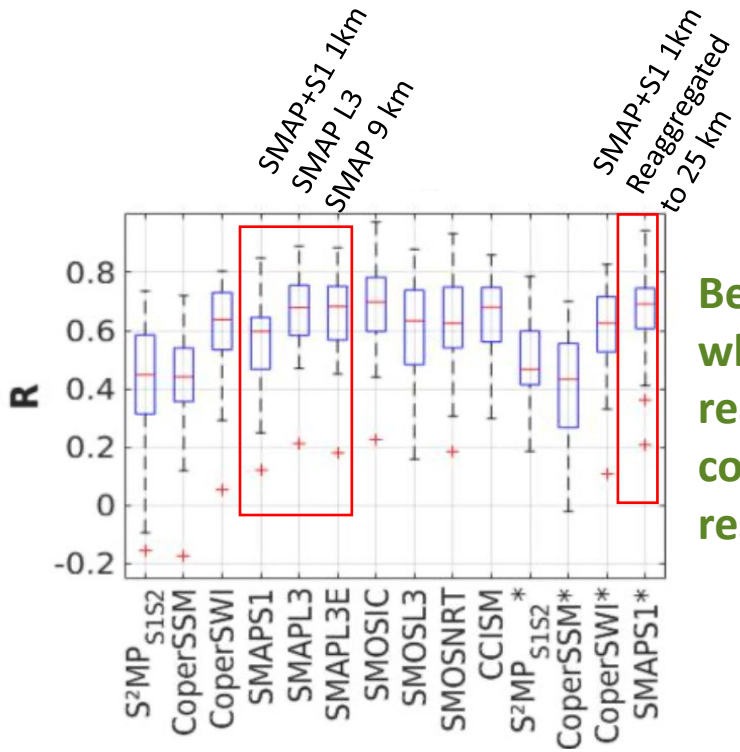


Rodriguez-Fernandez, Zhao, Colliander et al.

- **Task 3: Enhancement of the spatial-temporal resolution of remote sensing products by combine use of multi-source satellites**
- Multi-scale evaluation of different soil moisture data sets with respect to in situ measurements
- Interpolated products (SMAP 9km) give the same results as the original SMAP.
- Downscaled SMAP+S1 gives significantly less good results. When aggregated to 25 km the performances increase significantly

Madelon, Rodriguez-Fernandez et al. *2022, HESS Discussions*

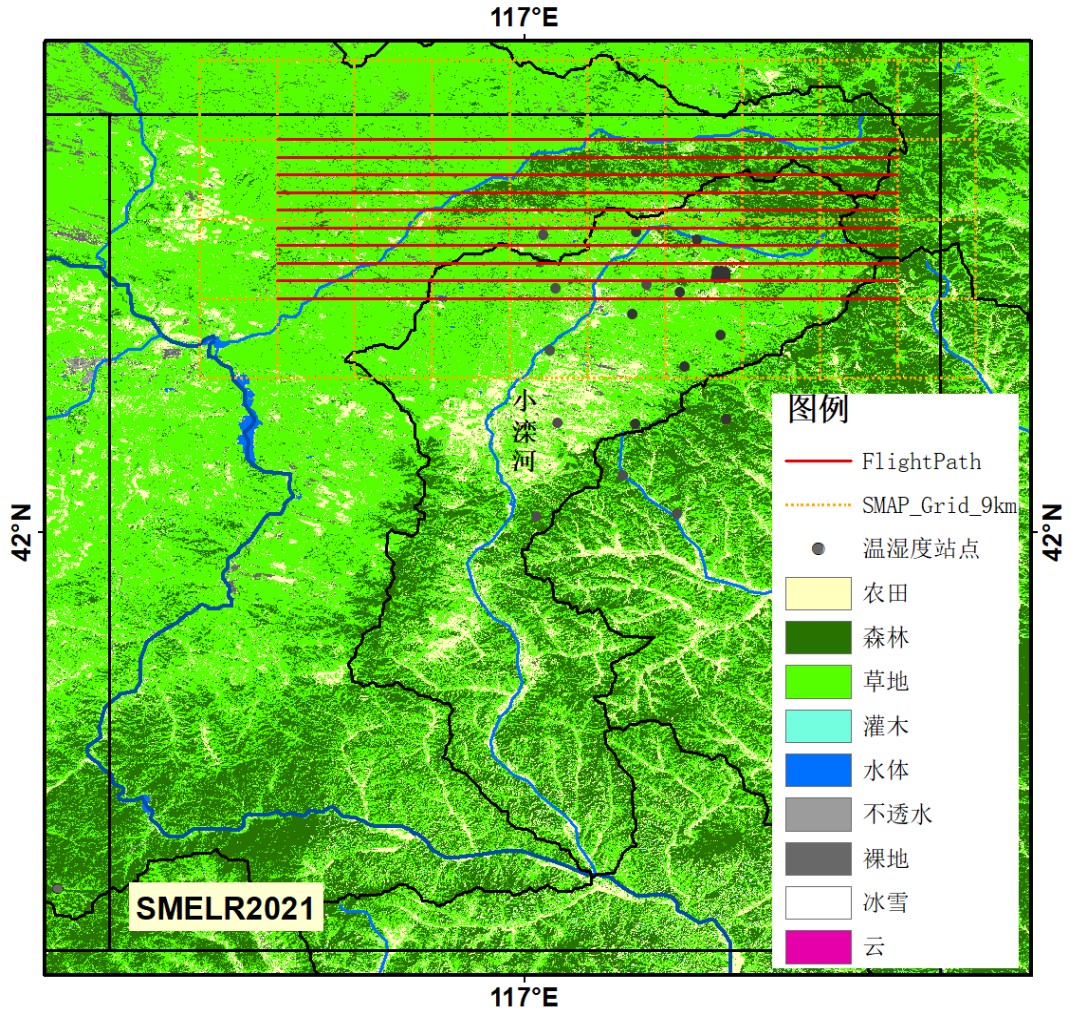


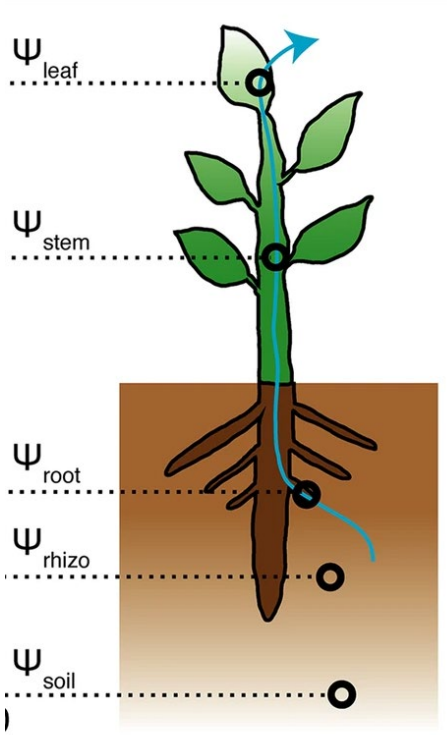


Better results when reaggregated to coarse resolution

Planning on field data collection campaigns

- **The second soil moisture experiment in the Luan River basin was under planning, and it will focus on the soil moisture and vegetation optical depth retrieval over forested areas.**





Academic exchanges

- **Chinese Ph. D student Jingyao Zheng was visiting CESBIO**