



Impact of Time-Varying Soil and Vegetation Parameters on Passive Microwave Soil Moisture (SM) Retrieval

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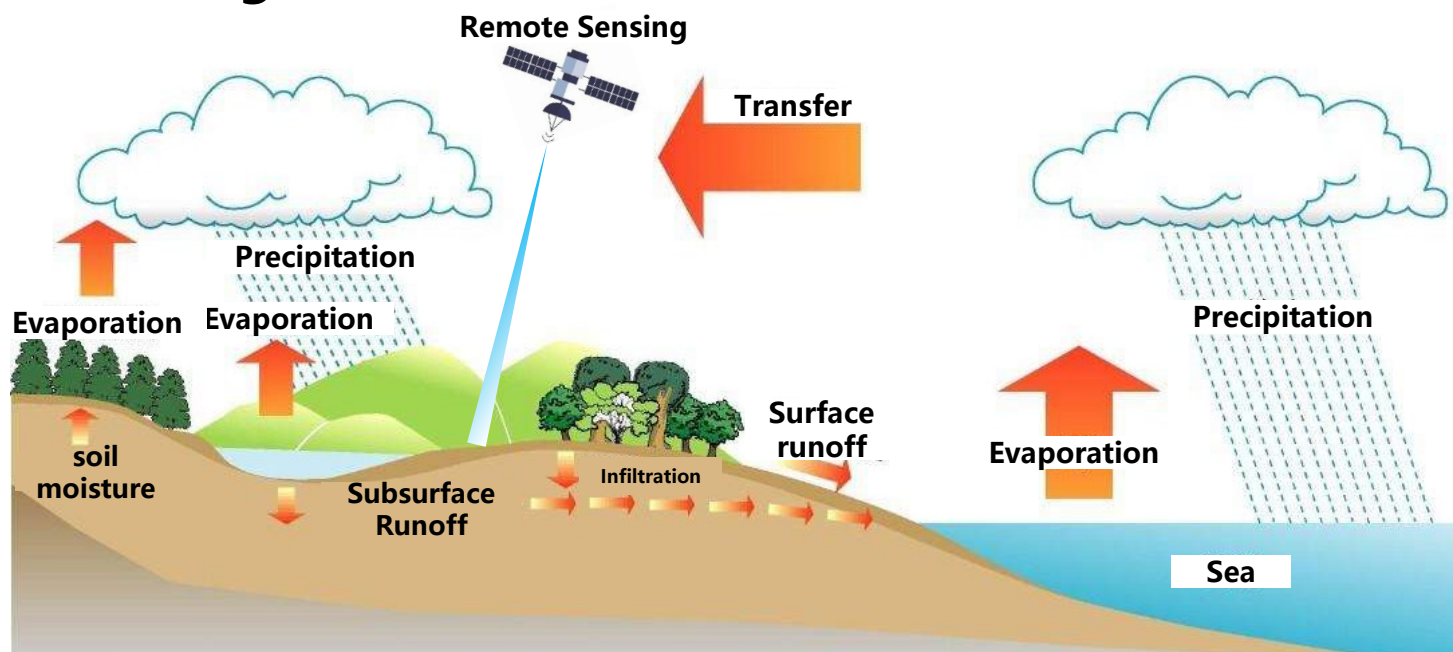
Research Background

Remote Sensing Inversion of SM



Research Background

Soil moisture (SM), also known as soil water content, is a key variable in the surface water and energy cycles. Remote sensing inversion is currently a primary method for monitoring SM.



Meteorology	<p>Climate change</p> <p>Weather forecast</p>
Hydrology	<p>Water cycle</p> <p>Flood simulation</p>
Agriculture	<p>Drought</p> <p>Crop yield</p>

Temperature

$$T_{Bp} = T_s \times e_p \times \epsilon$$

Brightness Temperature Emissivity Dielectric Constant



Air	ϵ_{air}
Water	ϵ_w
Soil Particle	ϵ_p

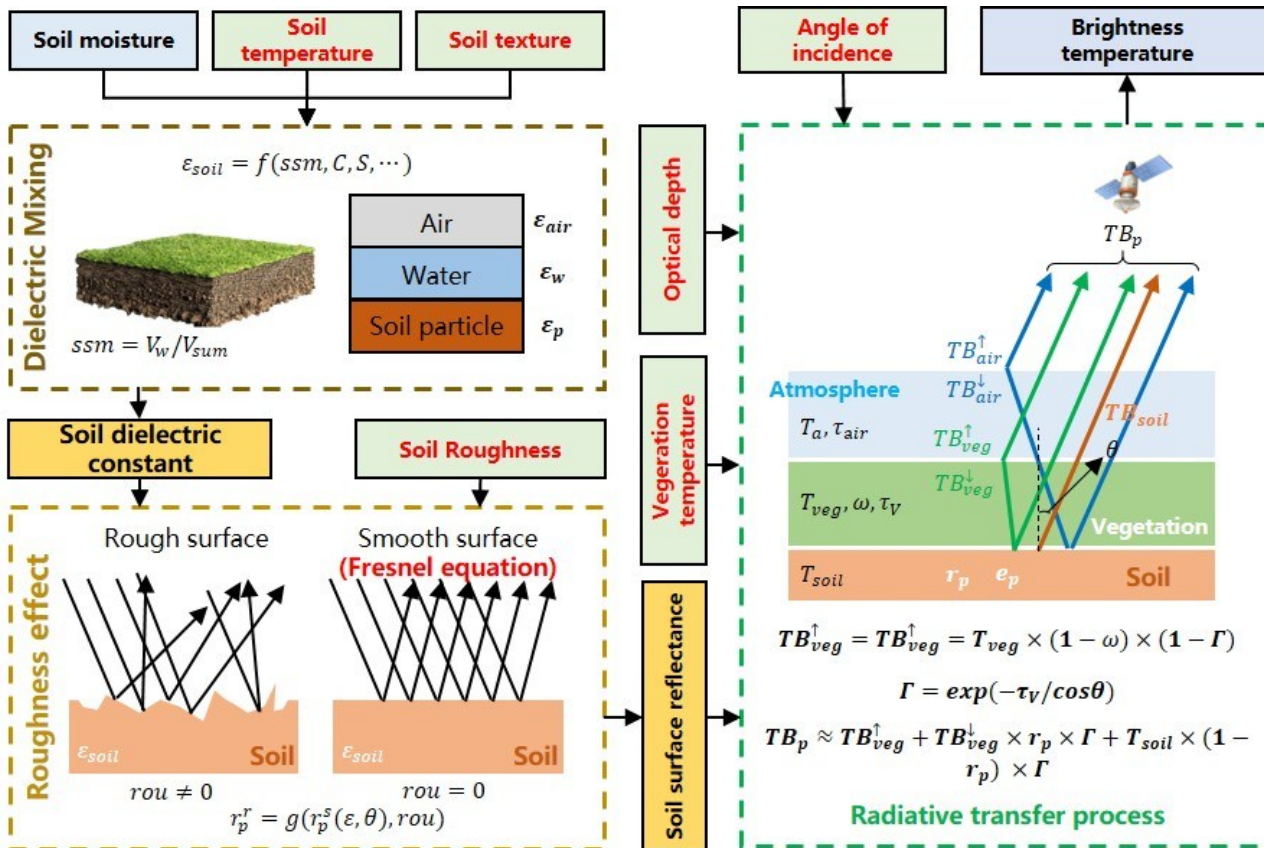
$$V_w / V_{sum}$$

Soil Moisture

Main Problems

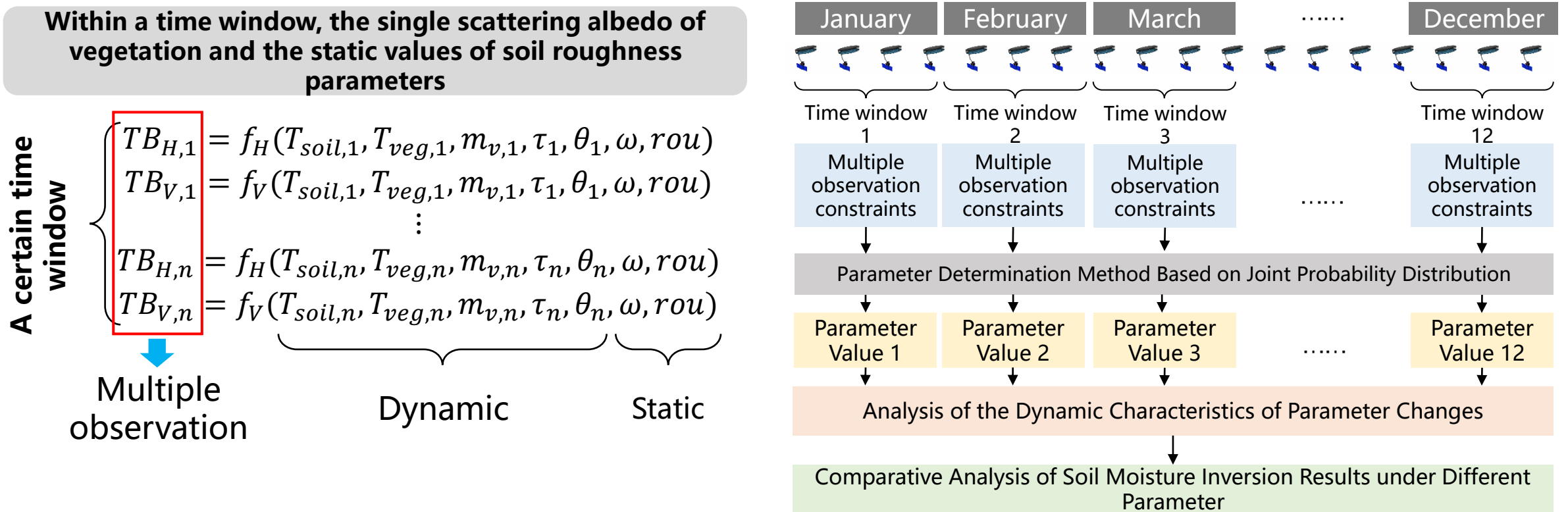


From the perspective of the inversion mechanism, the passive microwave SM inversion process involves various surface and vegetation parameters, while the constraint information provided by remote sensing observations is relatively limited, making it difficult to accurately resolve some parameters.



Parameter name	Basis for parameter values
Soil texture	Soil composition components; Based on the values of mature products
Soil temperature	Thermodynamic temperature of the soil; Based on the values of mature products
Vegetation temperature	Thermodynamic temperature of the vegetation; Based on the values of mature products
Soil moisture	Parameters to be inverted, calculated according to the functional relationship constructed based on the inversion mechanism
Vegetation temperature	Parameters to be inverted, calculated according to the functional relationship constructed based on the inversion mechanism
Angle of incidence	Provision of remote sensing products
Vegetation single scattering albedo	The ratio of scattered energy to total energy; Static parameters, assigned based on experience
Soil roughness parameter	Soil surface undulation; Static parameters, assigned based on experience

Therefore, the objective of this study is to analyze the characteristic patterns of temporal changes in two parameters: single scattering rate of vegetation and soil roughness. On this basis, we compare the differences in SM inversion results under different parameter setting strategies, evaluate the impact of parameter handling methods on soil moisture inversion results, and thereby provide a reasonable basis for parameter settings in subsequent SM inversion research.

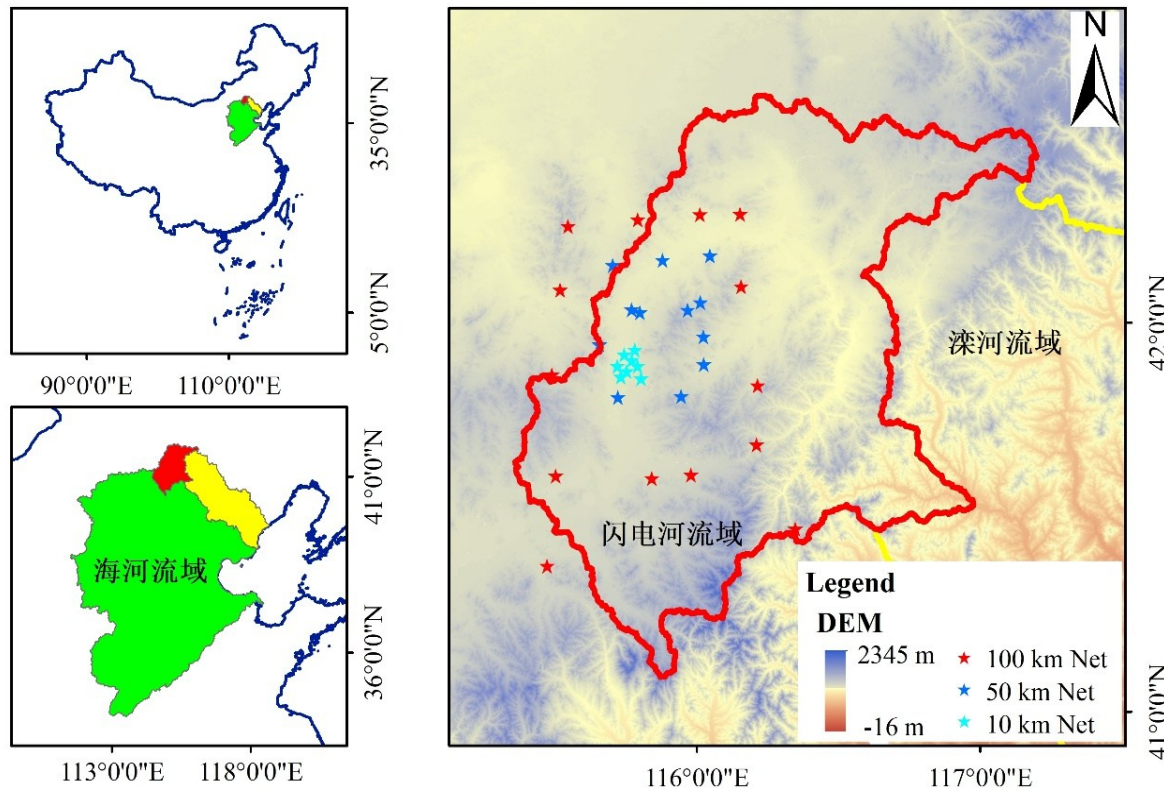




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Methodology

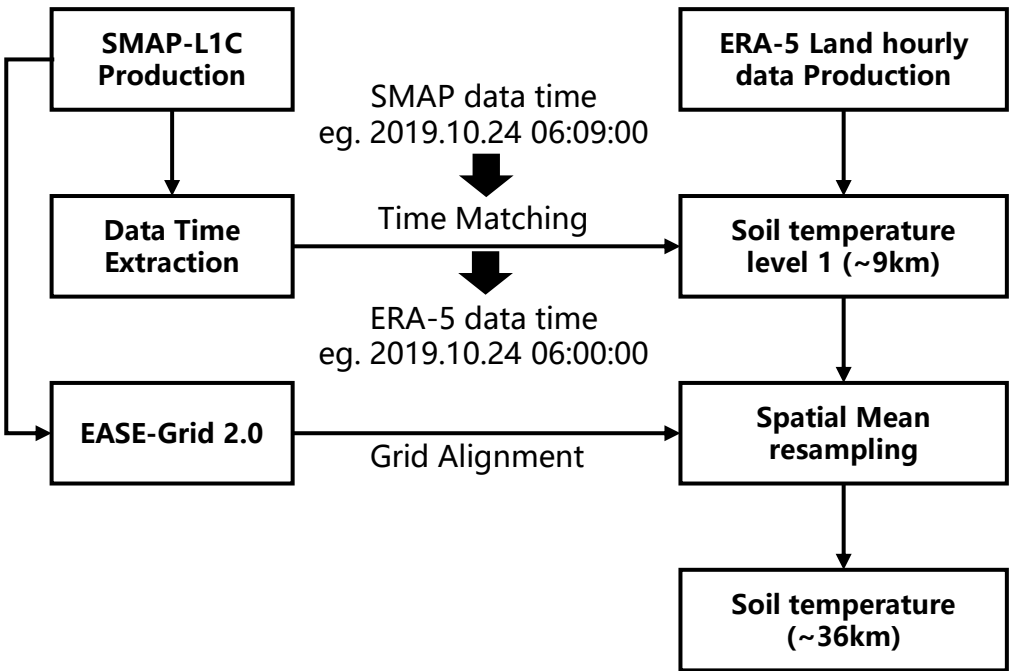
The Shandian River is located in the upper reaches of the Luan River, spanning the provinces of Inner Mongolia and Hebei, with a drainage area of approximately 4,000 km². The basin has a typical temperate continental grassland climate, with cold winters and hot summers, large diurnal temperature variations, low annual precipitation, and distinct seasonal characteristics.



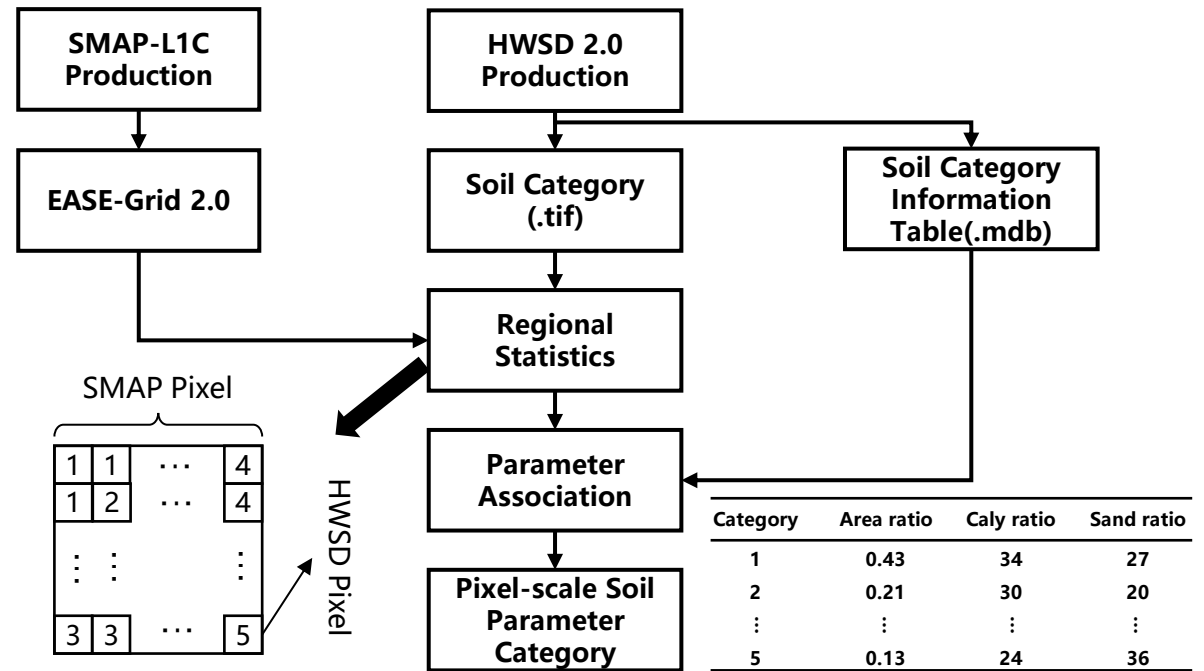
Characteristics of the research area

Seasonal changes	Wet in summer, dry in winter
Topography	High in the southwest, low in the northeast
Underlying surface	Primarily grassland and farmland
Others	multiple in-situ soil moisture measurement stations

This study mainly uses **SMAP-L1C products**, **ERA-5 products**, and **HWSD2.0 products** to carry out parameter inversion and impact analysis research on passive microwave soil moisture. Among them, the SMAP-L1C product provides dual-polarization brightness temperature and incidence angle information, the ERA-5 product provides soil surface temperature information, and the HWSD2.0 product mainly provides soil texture parameters.

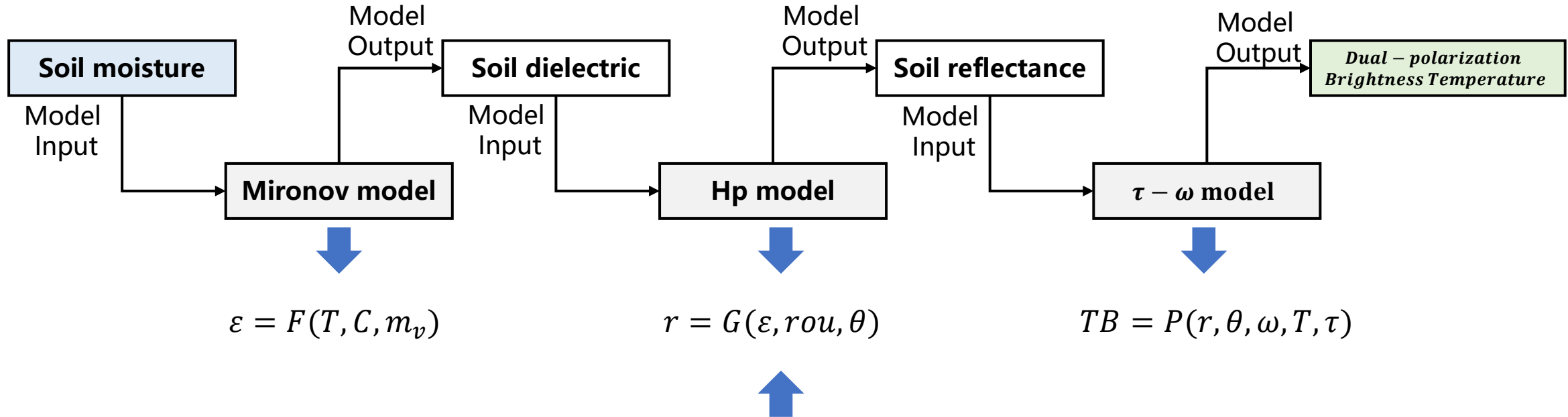


ERA-5 product process

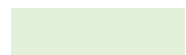


HWSD2.0 product process

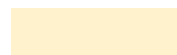
Forward Model for Passive Microwave SM Retrieval



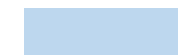
Parameters related to the forward model



Known parameters



Unknown parameters

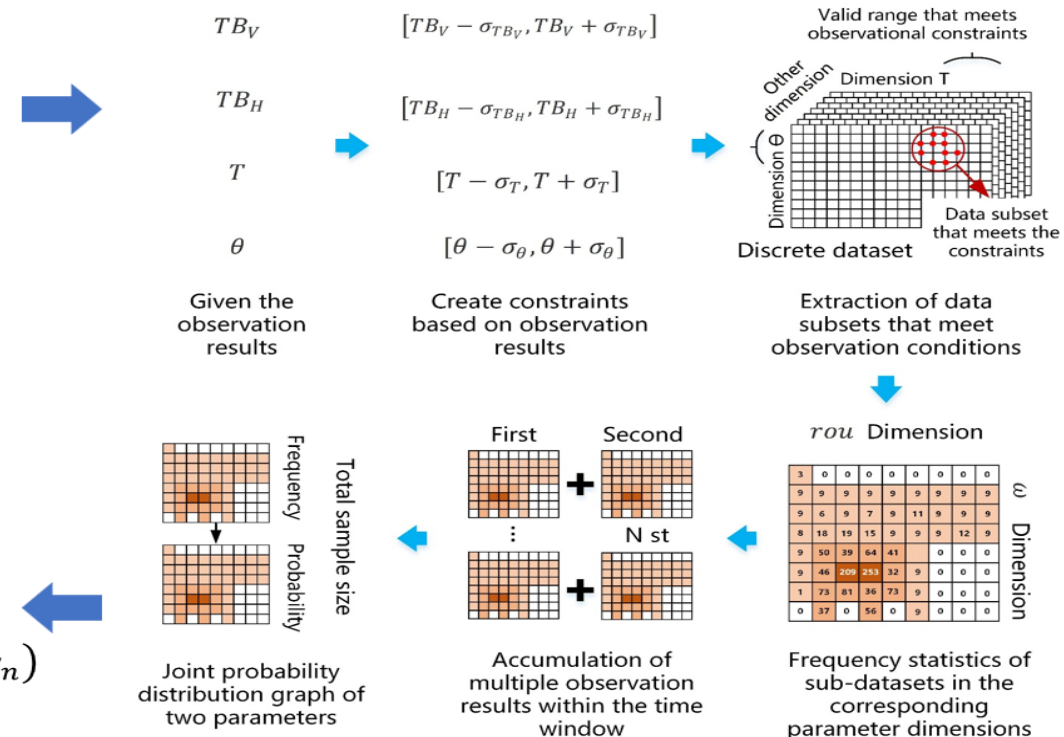


Parameters to be inverted

- We assume that within a certain time window, the soil roughness slope parameter and the single scattering albedo of vegetation remain constant, and treat each remote sensing observation as a constraint on these two parameters.
- By discretizing the dataset and performing probability calculations, we obtain the probability distribution of the two parameters under multiple remote sensing observation constraints.
- Finally determine the values of the two parameters based on the expected value calculated from their probability distribution.

$$\begin{cases} TB_{H,1} = f_H(T_{soil,1}, T_{veg,1}, m_{v,1}, \tau_1, \theta_1, \omega, rou) \\ TB_{V,1} = f_V(T_{soil,1}, T_{veg,1}, m_{v,1}, \tau_1, \theta_1, \omega, rou) \\ \vdots \\ TB_{H,n} = f_H(T_{soil,n}, T_{veg,n}, m_{v,n}, \tau_n, \theta_n, \omega, rou) \\ TB_{V,n} = f_V(T_{soil,n}, T_{veg,n}, m_{v,n}, \tau_n, \theta_n, \omega, rou) \end{cases}$$

$TB_{H,i}$	$TB_{V,i}$	$T_{soil,i}$	θ_i
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$$\omega_{final} = \sum \omega_i P(\omega = \omega_i, rou | obs_1, obs_2, \dots, obs_n)$$

$$rou_{final} = \sum rou_i P(\omega, rou = rou_i | obs_1, obs_2, \dots, obs_n)$$

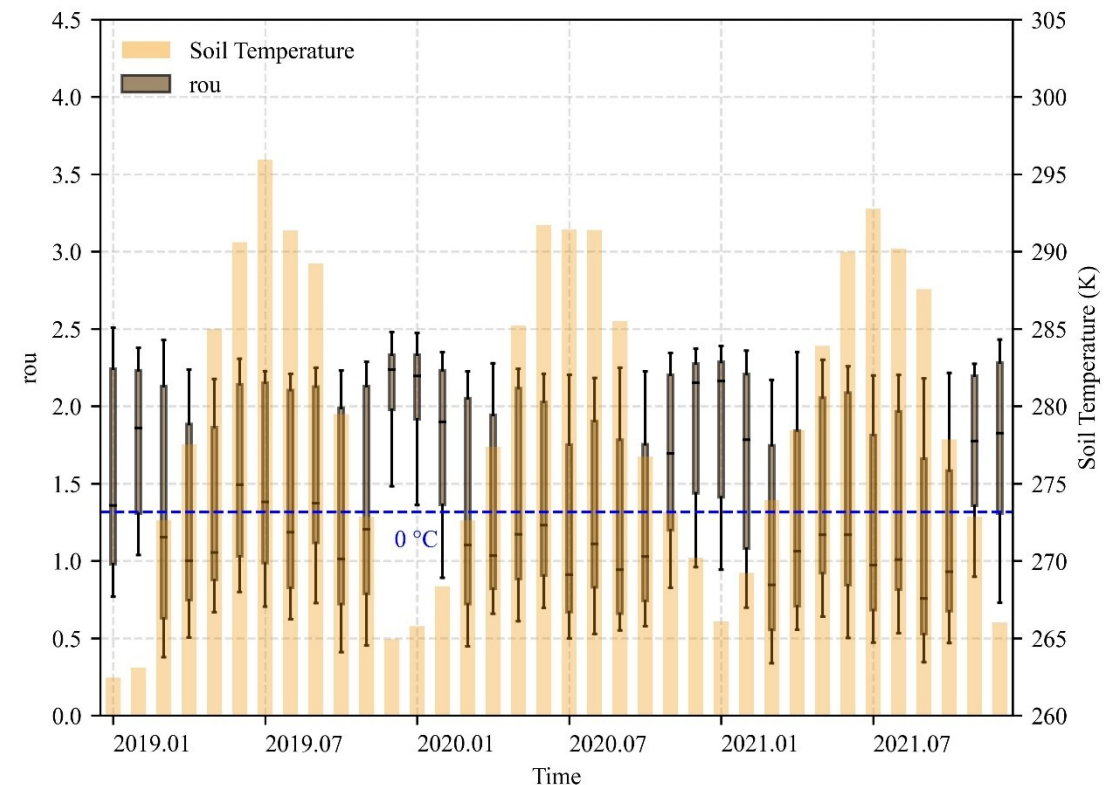
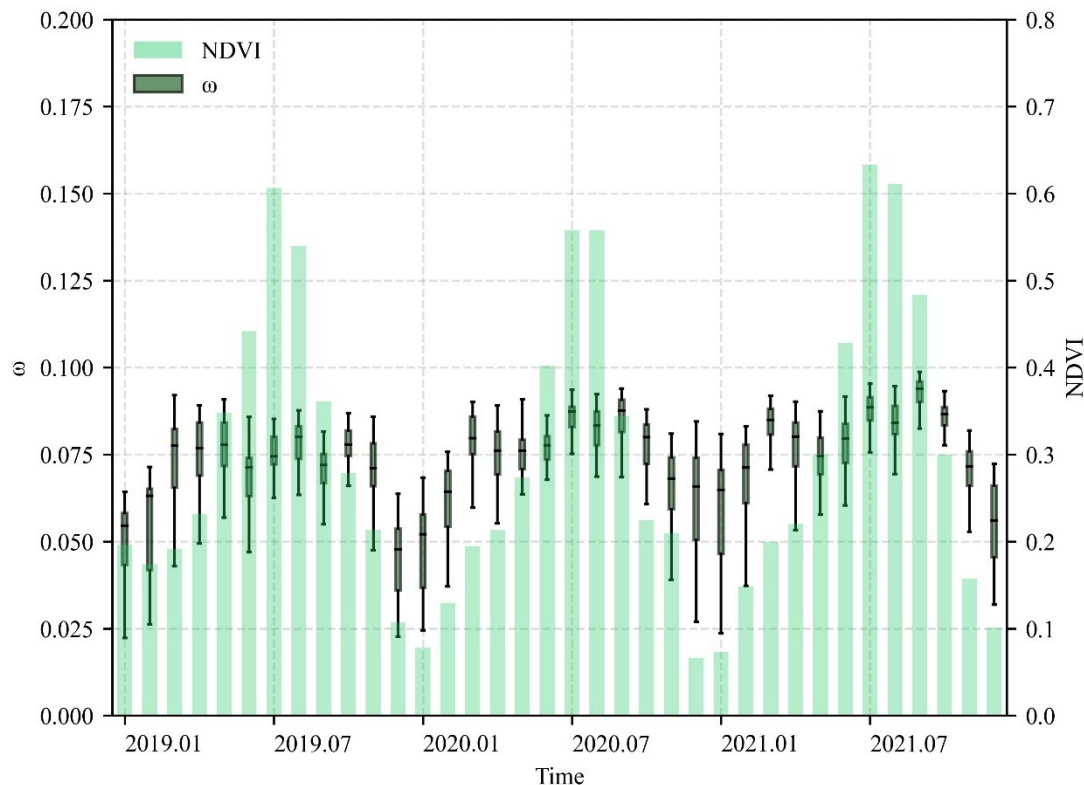


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Results



Based on the parameter determination method, we carried out the determination of two parameters in the Shandian River Basin. The figure below shows the monthly variation trends of the two parameters in the Shandian River Basin over three years from 2019 to 2021.



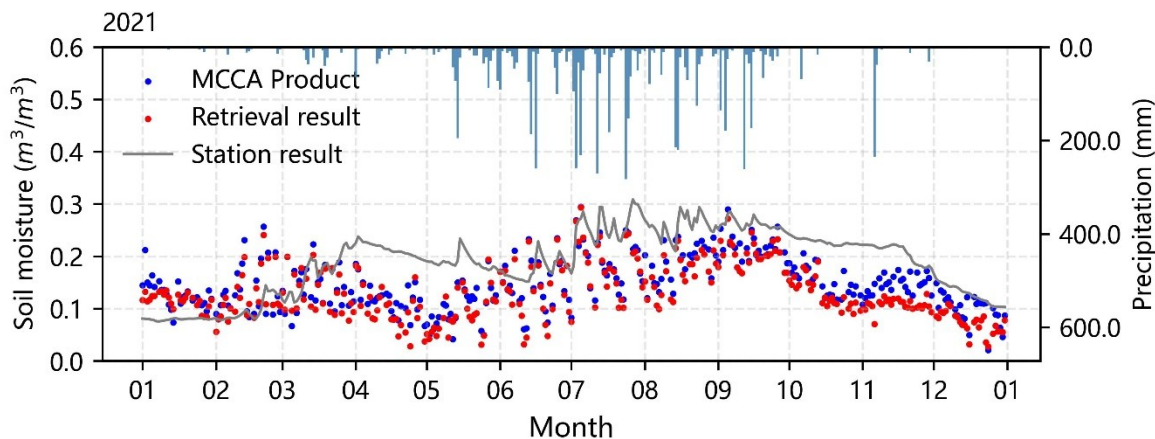
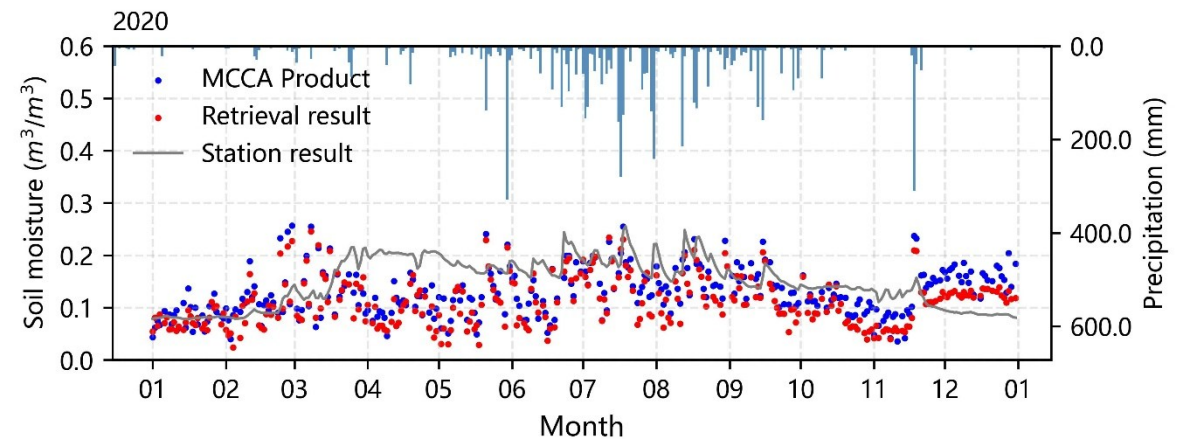
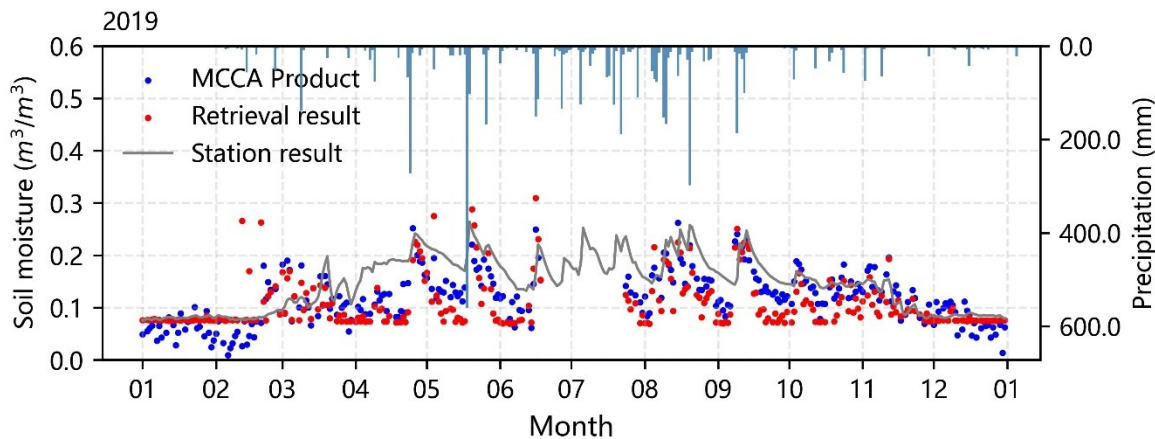


the SM Inversion results verify



Results

This study uses dynamic parameters to carry out SM inversion in the Shandian River Basin, and validates the inversion results using site network observation data and MCCA products. The results are as follows:



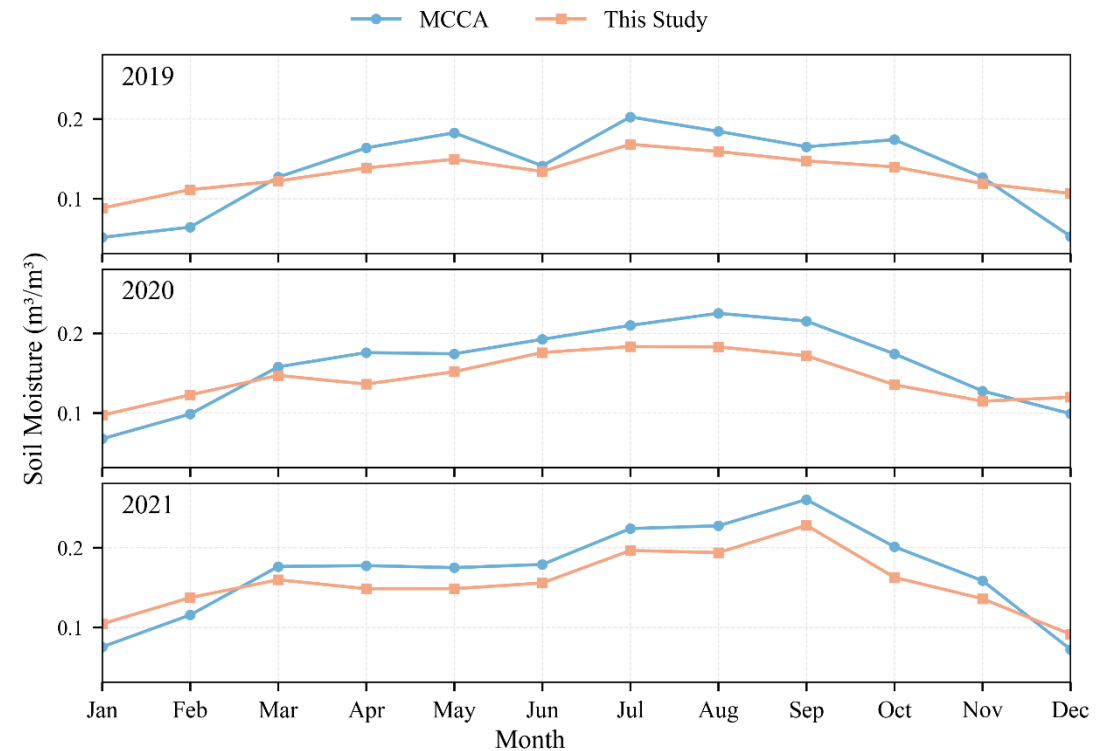
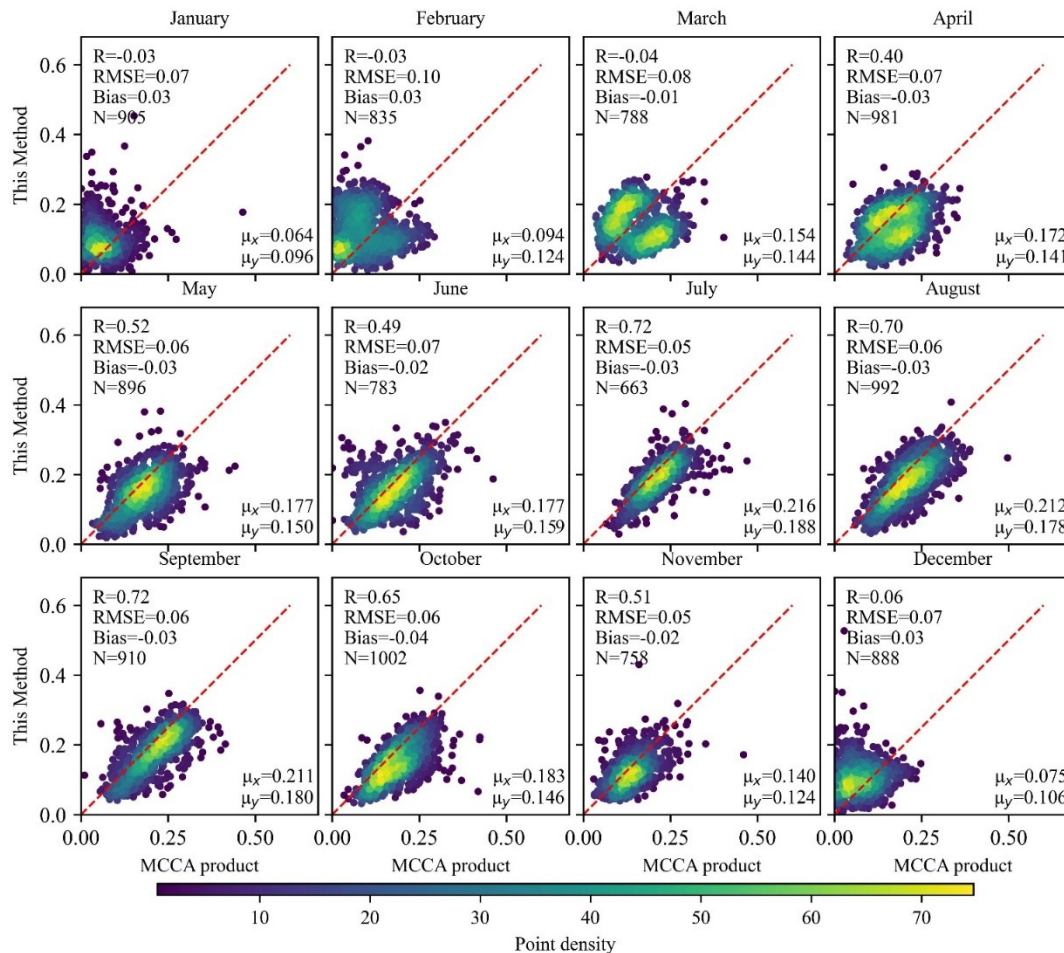
Year	RMSE		MAE		Bias	
	MCCA	Research	MCCA	Research	MCCA	Research
2019	0.057	0.061	0.038	0.033	0.048	0.046
2020	0.062	0.070	0.026	0.040	0.051	0.056
2021	0.077	0.091	0.050	0.067	0.068	0.081
SUM	0.066	0.076	0.036	0.047	0.056	0.062



the SM Inversion results verify



MCCA products are the inversion results obtained using static parameter settings. This study analyzes the impact of dynamic parameter changes on soil moisture inversion through comparison between products.





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Conclusion

Conclusion 1

Soil roughness and single scattering albedo of vegetation show significant temporal variation characteristics throughout the year.

Conclusion 2

After considering the time-varying characteristics of the two parameters, the overall accuracy of soil moisture inversion results is comparable to the MCCA product.

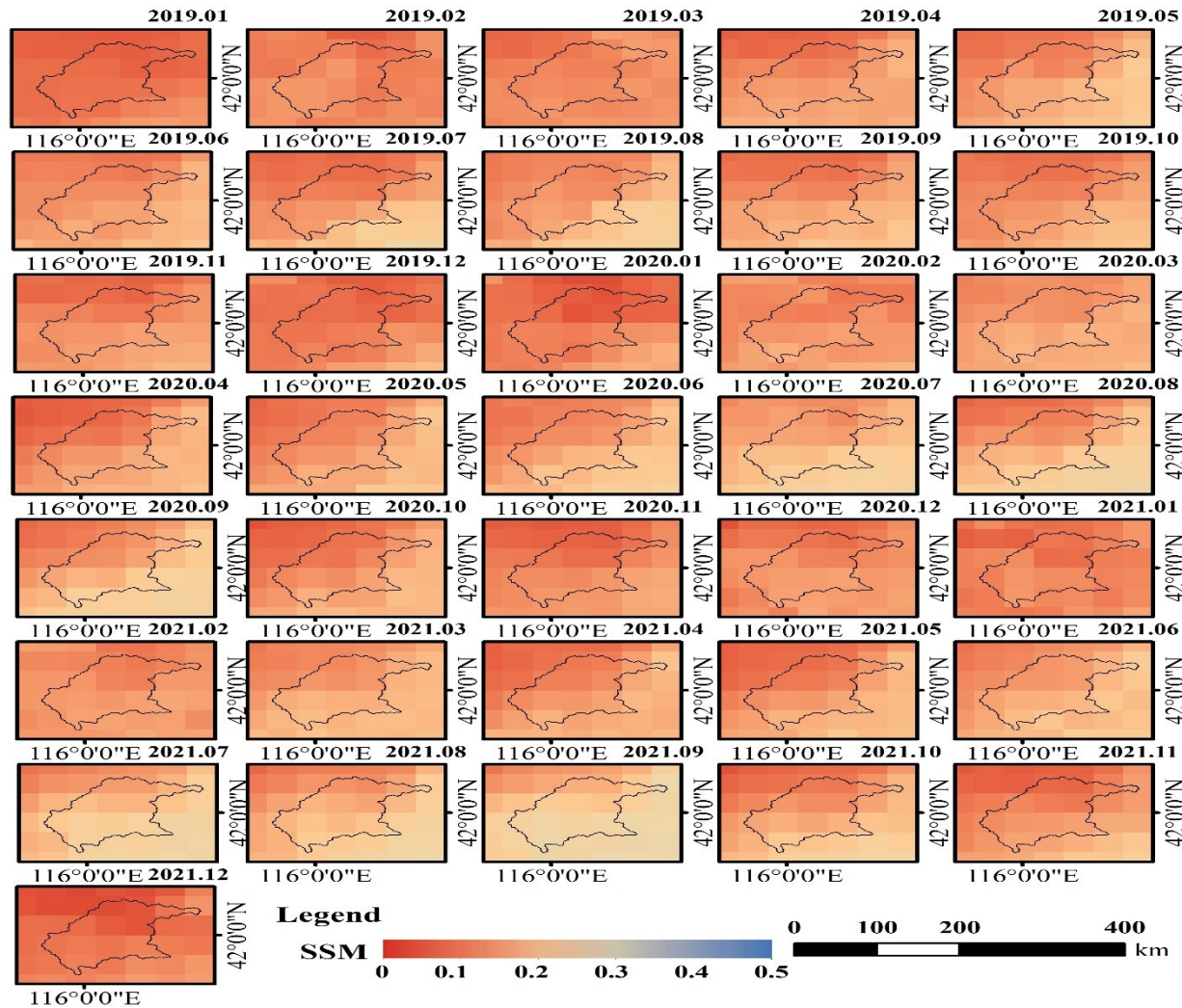
Conclusion 3

Part of the changes in the brightness temperature signal is explained by the time-varying characteristics of the parameters, thereby reducing the annual variation range of soil moisture inversion results.

Outlook

The seasonal variation characteristics of the parameters still need support and verification from ground measurement data.

THANKS FOR YOUR ATTENTION!



Monthly Mean Synthesis
of SM Inversion in the
Shandian River Basin
from 2019 to 2021