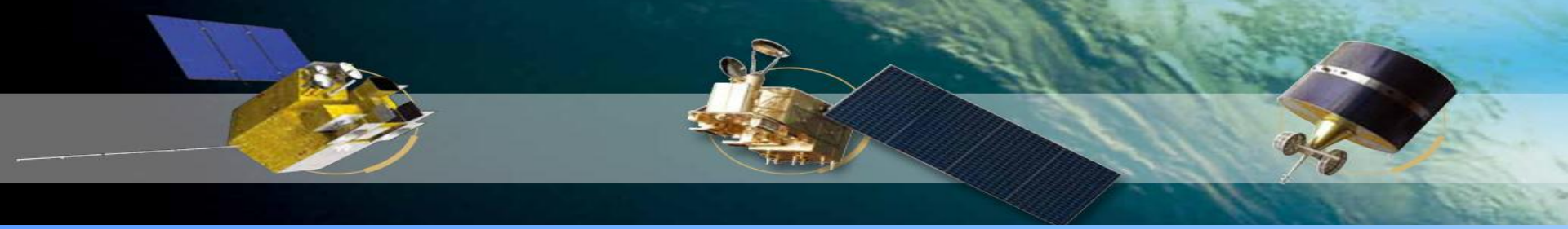

Evaluating model-simulated and satellite-derived soil moisture products using in situ observations under different environment conditions in China

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Background

1. Soil moisture (SM) is a key variable modulating energy and water exchanges at the land and atmosphere interface.

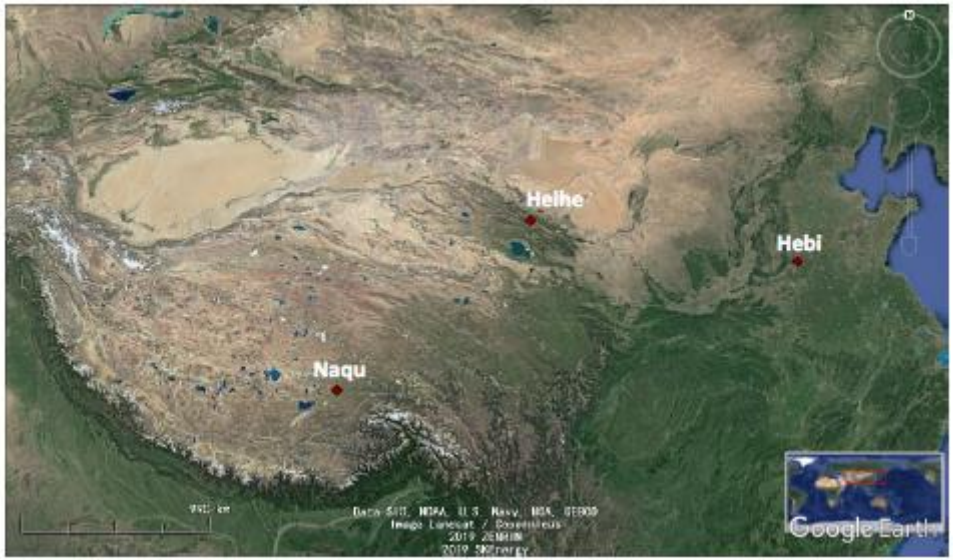
2. For the optimal use of large-scale SM data (satellite-derived or model-simulated), an accurate estimation of the error is of crucial importance.

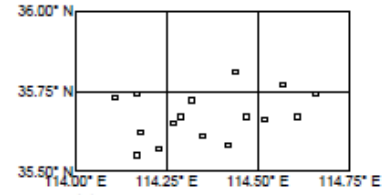
3. Validation of large-scale SM is challenging due to the limited spatial representativeness of point-based observations.

Objectives of this study

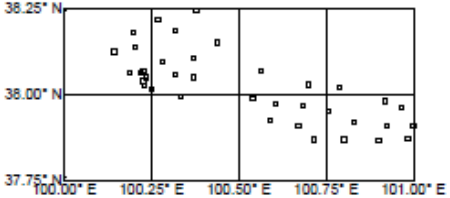
Evaluate ESA multi-satellite-retrieved soil moisture (SM) product (CCI-combined) and the land surface model-simulated SM product from China Land Data Assimilation System (CLDAS) by using three densely instrumented in situ observation networks in China (i.e., the Hebi, Naqu and Heihe sites).

Location of SM (soil moisture) network

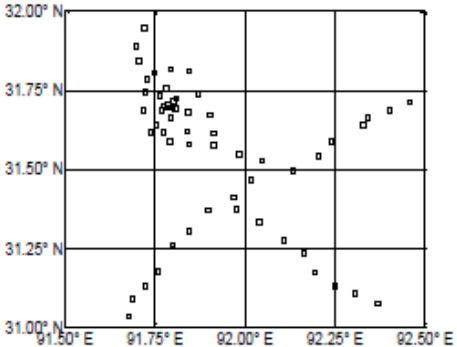




(a) SM sensor network in the Hebi site



(b) SM sensor network in the Heihe site



(c) SM sensor network in the Naqu site

Fig 1. Geographic location of the Hebi, Naqu and Heihe sites and the soil moisture sensor network within each site.

SM observation data

	Hebi	Naqu	Heihe
Network size	75 × 50 km^2	100 × 100 km^2	100 × 50 km^2.
Main land cover type	Cropland (88.65%) Urban (8.04%)	Grassland (98.31%)	Grassland (77.48%) Cropland (10.25%) Barren (9.38%)
Vegetation Optical Depth	0.377	0.221	0.397
Soil porosity (%)	43.193	45.805	46.606
Topographic complexity (%)	2.500	7.938	20.125
Number of SM sensors	16	71	40
Observation depth (cm)	10, 20, 30, 40, 50	0–5, 10, 20, 40	4, 10, 20
Available measurement period	2015–2016	2010–2014	2013–2015
Reference	/	Yang et al. (2013)	Kang et al. (2017)

SM products

	CLDAS 2.0	CCI-combined
Retrieval method	Simulation of land surface models (CLM and Noah)	Combination of active and passive microwave SM products
Spatial resolution	0.625°	0.25°
Temporal resolution	3 hour	daily
Spatial extent	70–150° E, 0–60° N	global
Time series	2010-now	1978-2019
Reference	Shi et al. (2011)	Dorigo et al. (2017).

Data analysis

1. Standard validation method in which observations were averaged and considered as the "ground truth" of area-averaged SM.

$$RMSE = \sqrt{E[(SM_{grid} - SM_{in-situ})]^2}$$

$$ubRMSE = \sqrt{E\left\{\left[\left(SM_{grid} - E\left[SM_{grid}\right]\right) - \left(SM_{in-situ} - E[SM_{in-situ}]\right)\right]^2\right\}}$$

$$BIAS = E\left[SM_{grid}\right] - E[SM_{in-situ}]$$

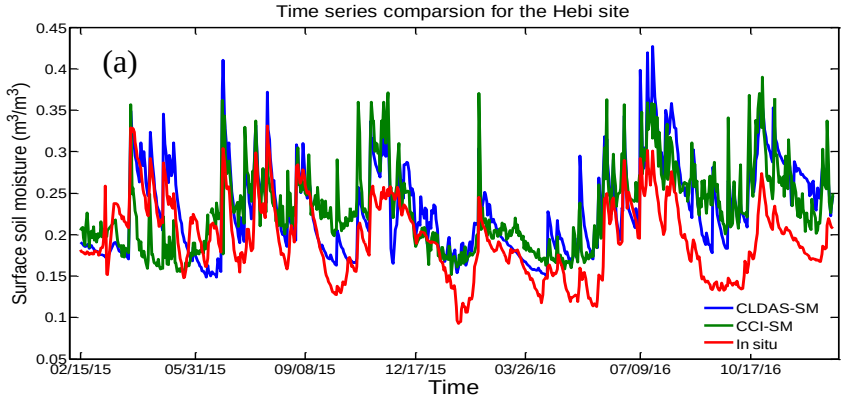
$$R = \frac{E\left[\left(SM_{grid} - E\left[SM_{grid}\right]\right)\left(SM_{in-situ} - E[SM_{in-situe}]\right)\right]}{\sigma_{grid}\sigma_{in-situ}}$$

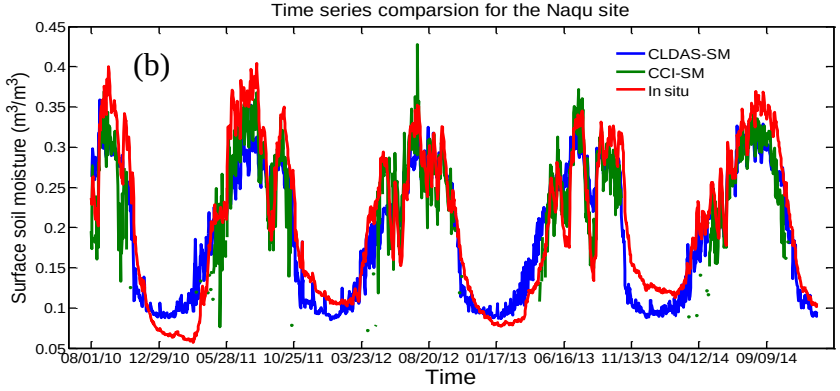
2. Triple Collocation (TC) analysis in which observations are allowed to be inaccurate.

Validation scores (numbers in parentheses indicate sample sizes).

	Hebi (675)			Naqu (778)			Heihe (511)		
	Obs vs. CLDAS	Obs vs. CCI	CLDAS vs.CCI	Obs vs. CLDAS	Obs vs. CCI	CLDAS vs.CCI	Obs vs. CLDAS	Obs vs. CCI	CLDAS vs.CCI
R	0.739	0.547	0.723	0.764	0.812	0.791	0.485	0.444	0.704
BIAS (m^3/m^3)	0.034	0.028	0.006	-0.016	-0.023	-0.007	-0.062	-0.109	-0.047
RMSE (m^3/m^3)	0.051	0.053	0.041	0.043	0.043	0.038	0.079	0.120	0.059
ubRMSE (m^3/m^3)	0.039	0.046	0.041	0.040	0.037	0.037	0.049	0.050	0.035
R_{anom}	0.709	0.514	0.622	0.644	0.646	0.524	0.582	0.479	0.581

Time series comparison





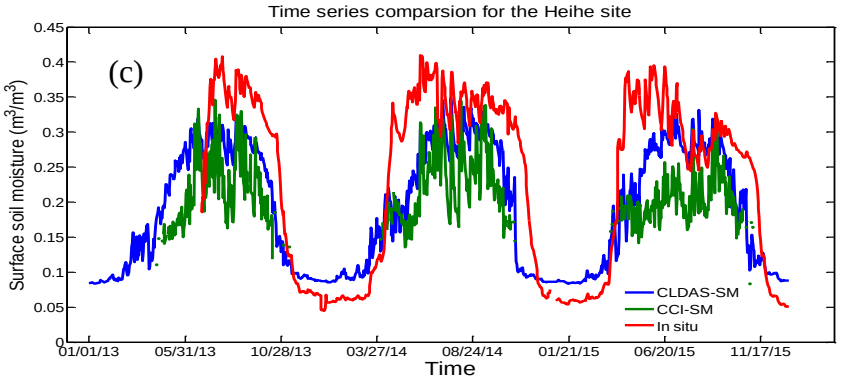


Fig 2. Comparison of soil moisture time series for each site. (a) Hebi; (b) Naqu; (c) Heihe

TC results

R_{TC}	Upscaled in situ observation	CLDAS-SM	CCI-SM
Hebi	0.737	0.921	0.702
Naqu	0.891	0.723	0.725
Heihe	0.692	0.841	0.691

R_{TC} reflects the correlation coefficient of individual data set with the underlying “ground truth” from the triplet.

Main conclusions

(1) For the Hebi site which is located in the North China Plain, CLDAS-SM yields higher accuracy (R=0.739, $ubRMSE$=0.039 m^3/m^3) owing to the high quality of meteorological forcing data.

(2) For the Naqu site which is located in the central Tibetan Plateau, CCI-SM performs better (R=0.812, $ubRMSE$=0.037 m^3/m^3) due to a low level of RFI (Radio Frequency Interference) and VOD (Vegetation Optical depth).

(3) For the Heihe site which is featured with strong land surface heterogeneity, both products do not achieve the targeted accuracy of 0.04 m^3/m^3.

(4) CLDAS-SM for the Hebi and Heihe sites is found to be a better representation of the "ground truth" of area-averaged SM than in situ observations, highlighting that CLDAS-SM is potentially a good reference for validating microwave satellite-based SM products in China.

Make the data better and easier to use !