Verification and Comparison of SMOS Ascending and Descending Soil Moisture Observations at a Catchment Scale: Implications to Hydrology

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Motivation

Soil moisture has been widely recognised as a key variable in hydrological processes and plays an important role in real-time flood forecasting, which is now possible to be retrieved by remote sensing techniques. However most previous studies only focused on their evaluations against point-based observations and utilised only one overpass (mostly ascending orbit). Therefore this study particularly focused on a catchment scale evaluation of the SMOS soil moisture datasets (both ascending and descending orbits), by using a three-layer Xinanjiang (XAJ) model as the hydrological benchmark for all the comparisons.

Our objectives:

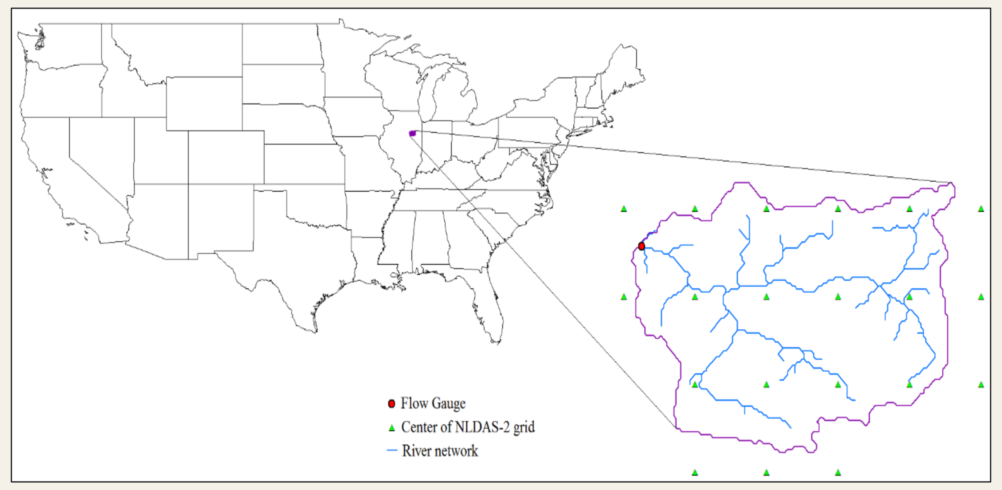
- to evaluate SMOS ascending and descending observations through XAJ model derived soil moisture (soil moisture deficit (SMD)), at a medium sized catchment in the midU.S.
- to judge whether SMOS soil moisture is suitable for hydrological modelling
- to see if there exist any substantial differences between the two orbits
- to investigate the performance of the SMOS soil moisture over time

Study area and methodologies

Catchment:

The Vermilion River at Pontiac, (1500 km^2) is chosen as the study catchment, which is located in the mid Illinois of the U.S. (40.878ºN, 88.636ºW).

Pontiac catchment	
area	1500 km^2
climate	hot summer continental
land cover	cropland
soil type	mollisols
altitude	188 m MSL
annual rainfall	867 mm



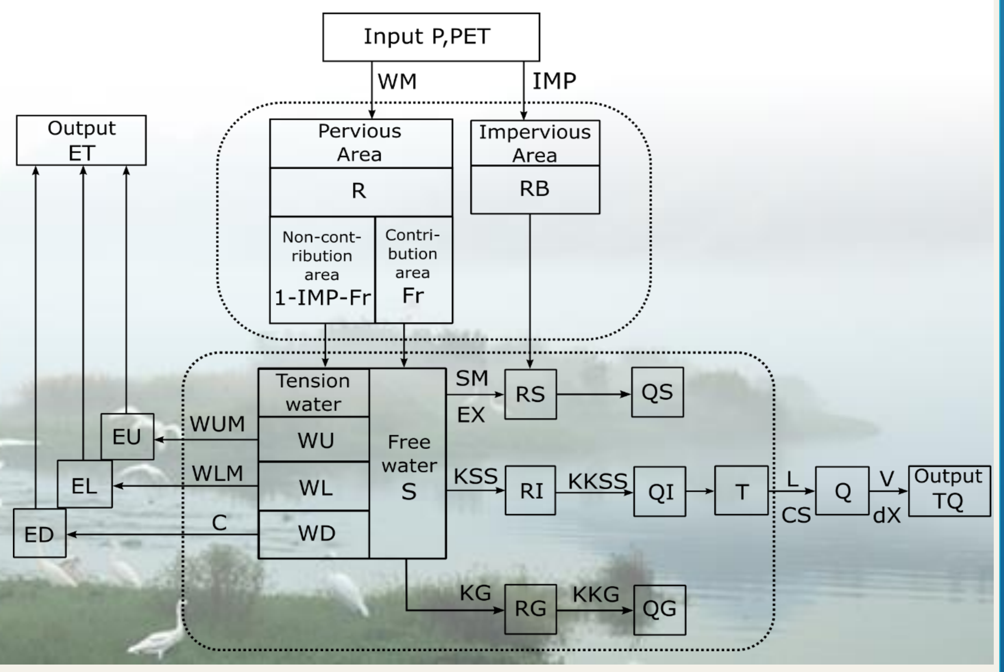
layout of the Pontiac catchment, along with the location of its flow gauge

Performance indicators:

NSE	Nash-Sutcliffe Efficiency	$NSE = 1 - \frac{\sum_{i=1}^{n}(y_i - x_i)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$
r	Pearson product moment correlation coefficient	$r = \frac{n(\sum x_i y_i) - (\sum x_i)(\sum y_i)}{\sqrt{[n\sum x_i^2 - (\sum x_i)^2][n\sum y_i^2 - (\sum y_i)^2]}}$
r_{sp}	Spearman rank correlation coefficient	$r_{sp} = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n^3 - n}$

XAJ hydrological model

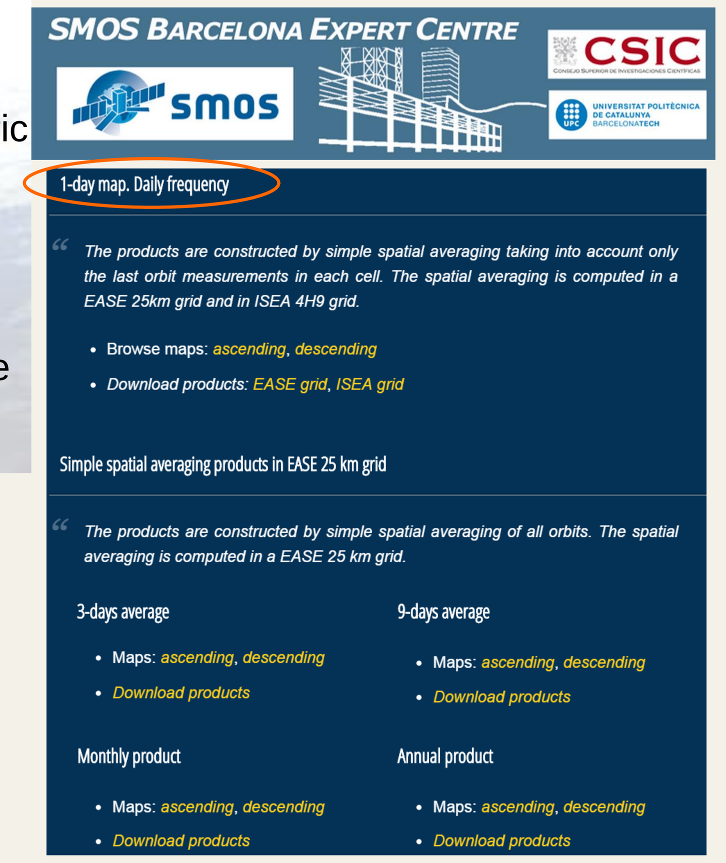
- The XAJ model is a fairly general conceptual lumped rainfall-runoff model.
- Its main concept is the runoff generation on repletion of soil water storage.
- The structure of the XAJ model comprises an evapotranspiration module, a runoff production module and a runoff routing module.



esa SMOS

Working theory

- the large contrast between the dielectric properties of water (~80) and dry soil (<5)
- detects the brightness temperature (T_B)
- T_B is a function of the emissivity (*e*)
- *e is* a function of the near surface soil moisture



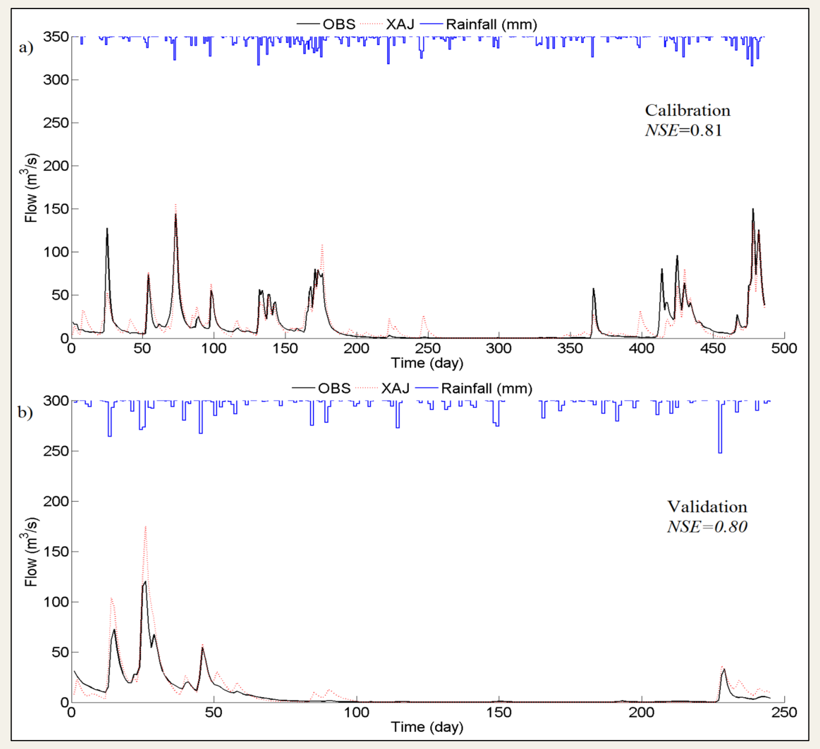
http://cp34-bec.cmima.csic.es/land-datasets/

Frequency	1.4GHz (L-band)
Wavelength	21 cm
Spatial resolution	35-50 km
Soil depth	~ 5 cm
Revisit time	3 days
Time	6 am & 6 pm

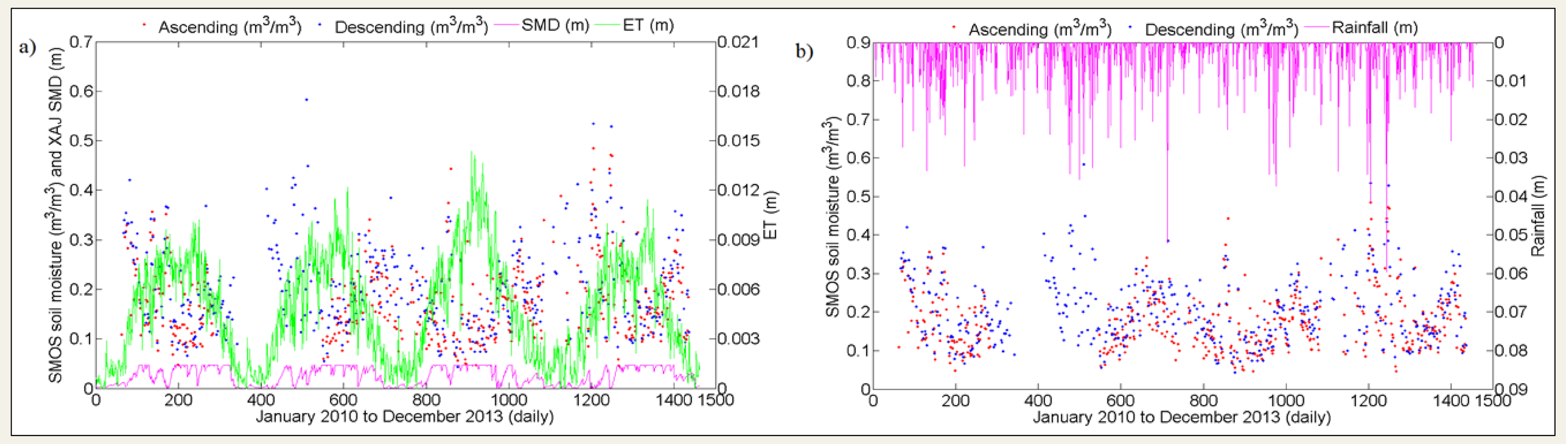
XAJ performance

Key findings:

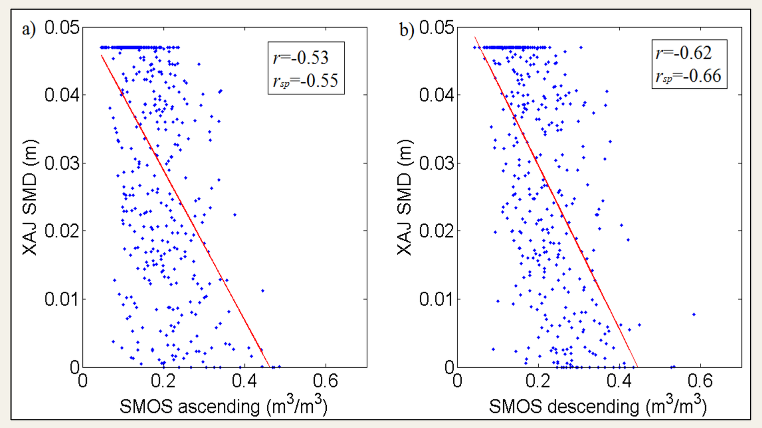
- a slight overestimation of low flows during the calibration.
- an overestimation of the overall flow simulation during the validation
- At some parts of the flow simulation, the model is incapable of calculating the non-linear behavior of the hydrological processes, and this is particularly evident in the recession curves and low flows.
- Generally, the XAJ model gives a relatively good performance



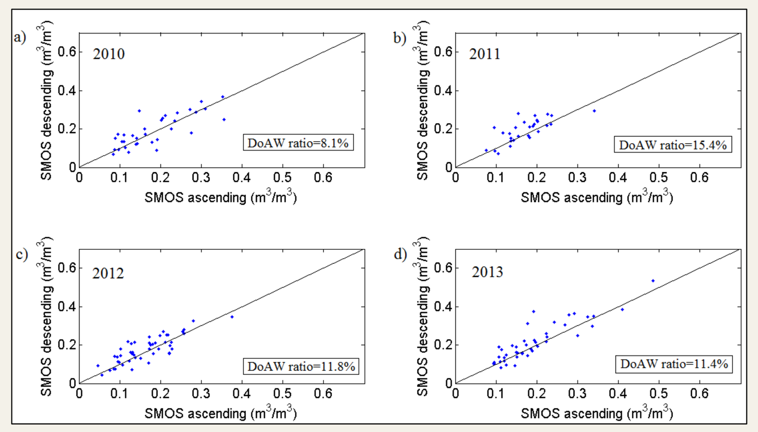
SMOS hydrological evaluation (2010-2013)



Key findings: total number of observations for the ascending and descending overpasses are 464 and 432 observations respectively. The SMD and the two SMOS overpasses are highly responsive to the ET and rainfall events. There are no soil moisture measurements during the frozen seasons.



Key findings: The performance of descending retrievals is better than ascending's (approximately 10 % better)



Key findings: SMOS retrievals from descending overpass are consistently about 11.7% by volume wetter than ascending retrievals.

SMOS soil moisture accuracy over time

In order to examine the accuracy of the SMOS soil moisture over time, an additional investigation is carried out by diving data into four individual years, to see if the correlation with XAJ SMD has changed through time.

Key findings:

	r		r_{sp}	
	A	D	A	D
2010	-0.67	-0.63	-0.63	-0.59
2011	-0.39	-0.63	-0.54	-0.69
2012	-0.48	-0.70	-0.55	-0.74
2013	-0.65	-0.64	-0.59	-0.63

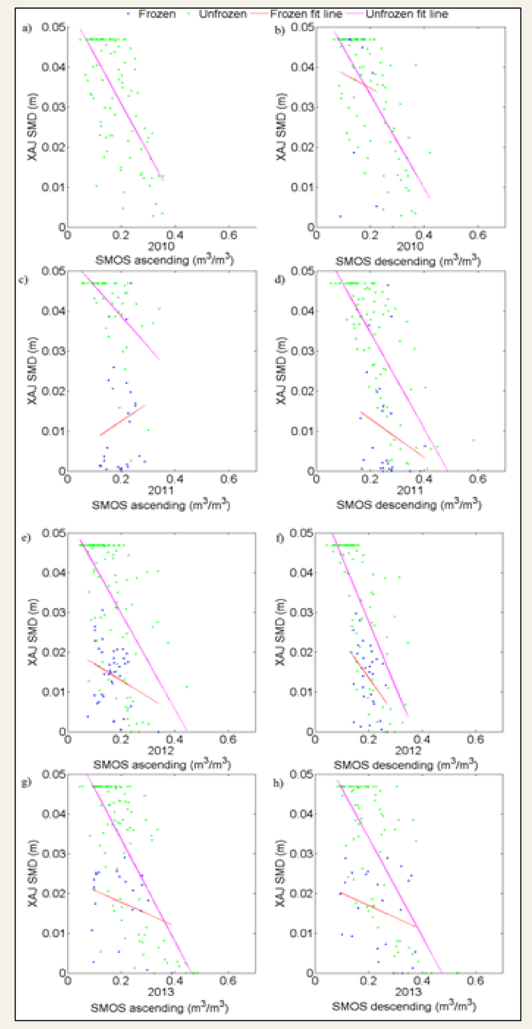
- the soil moisture accuracy oscillates every year.
- influenced by the change of catchment conditions and the maintenance of the instrument itself.
- the descending orbit surpasses the ascending orbit in most years
- the descending orbit has a relatively steady performance throughout
- the ascending orbit gives rather unstable results

Impacts from frozen soil

Key findings:

- the inclusion of frozen soil data can have a significant impact on the overall evaluation.
- improvements of both orbits are remarkable by excluding the frozen datasets
- especially on the ascending orbit
- the descending orbit is preferable for hydrological applications at this catchment conditions

		r		r_{sp}	
		A	D	A	D
Frozen	2010	--	-0.09	--	-0.14
	2011	0.16	-0.21	0.22	-0.35
	2012	-0.27	-0.43	-0.20	-0.43
	2013	-0.29	-0.28	-0.19	-0.27
	All	-0.11	-0.39	-0.13	-0.45
Unfrozen	2010	-0.67	-0.69	-0.63	-0.65
	2011	-0.53	-0.72	-0.66	-0.75
	2012	-0.58	-0.73	-0.63	-0.76
	2013	-0.74	-0.73	-0.70	-0.70
	All	-0.65	-0.70	-0.64	-0.70



Conclusions

- Both SMOS ascending and descending overpasses demonstrate a high variability with seasons and follow a strong seasonal cycle.
- They are correlated reasonably well with the XAJ modeled surface SMD during the whole monitoring period.
- The SMOS soil moisture accuracy is not improved with time as we expected.
- None of the soil moisture products provide reliable estimates in the frozen season especially for the ascending orbit.
- SMOS retrievals from the descending overpass are consistently wetter (about 11.7% by volume) than the ascending retrievals.

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