Distribution of surface soil moisture within a SMOS pixel by multi-spectral analysis

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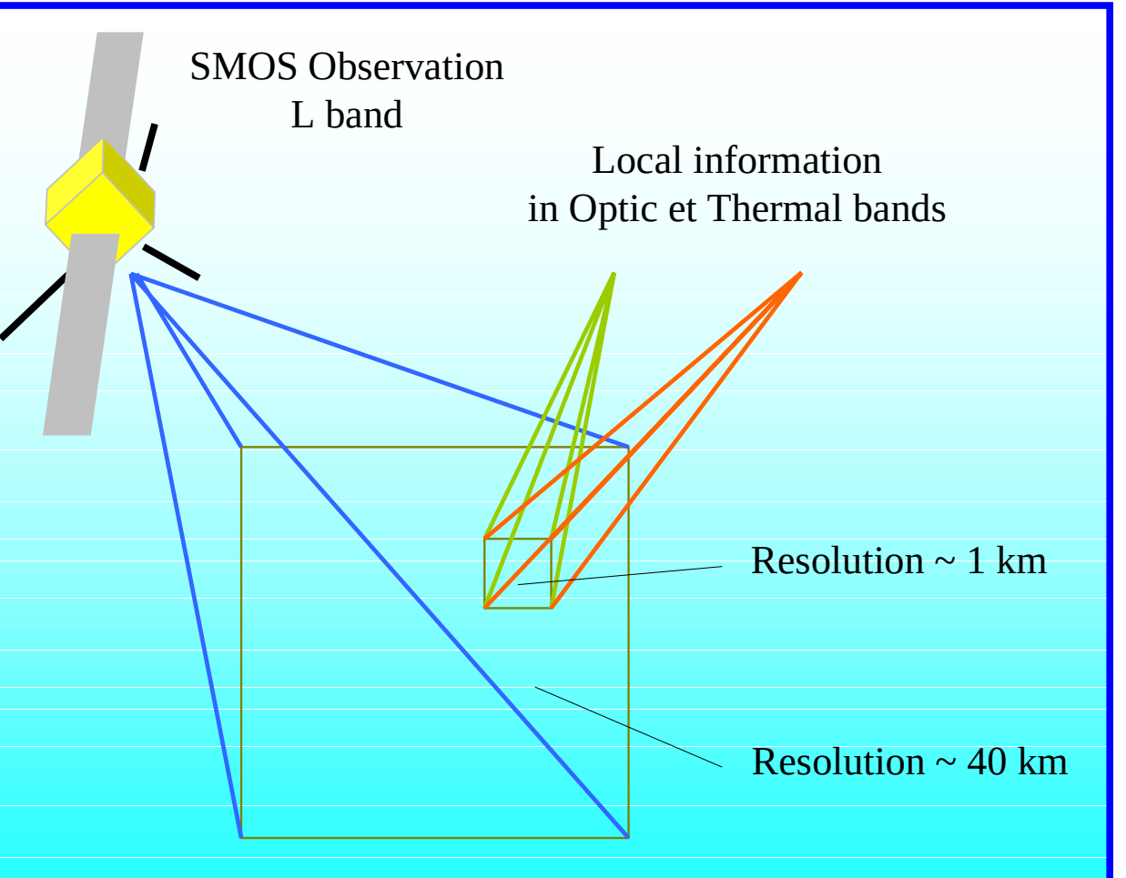
Abstract

In the case of the application of the Soil Moisture and Ocean Salinity (SMOS) mission to the field of hydrology, the question asked is the following: how may the soil moisture retrieved from SMOS at the scale of 40 km be distributed at the hydrological scale of 1 km? To answer this question, the down-scaling scheme used in this study consists in linking local soil moisture to global signature in microwave band – the brightness temperature measured by SMOS – and to local surface temperature that provides information at the scale of 1 km – surface temperature is currently remotely sensed at this scale. The down-scaling technique is based on a scheme that was developed for distributing water storages in heterogeneously cleared large catchments. To apply this method to the field of remote sensing, a radiative transfer model is used to simulate microwave emissions at different scales from global scale (SMOS pixel) to local scale (one sub-pixel). First, soil moisture distribution inside SMOS pixel is linked to surface temperature distribution by a local filter based on the relationship between these two surface variables involved in a radiative process. This point is called the local constraint to the system. Second, soil moisture distribution is normalized so that the mean brightness temperature simulated by all sub-pixels is equal to SMOS brightness temperature. This point is called the global constraint. The general method is tested with a synthetic scene generated with a SVAT model coupled to the radiative transfer model. The results show a good distribution of local soil moisture within the generated SMOS pixel. Finally, the limitations of the down-scaling method are outlined.

I. Objective of the Study

'Are local information obtained in other spectral bands (LAI, surface temperature) sufficient to distribute Soil Moisture given SMOS Observation?'



II. Formulate 3 Constraints to the Distributed System

Relative Distribution Constraint (C1)

$$W^i = f_0 + f_1 X^i$$

Distributed Soil Moisture → W^i

Variable whose space variability is linked to the space variability of surface temperature → X^i

Level Distribution Parameter → f_0

Contrast Distribution Parameter → f_1

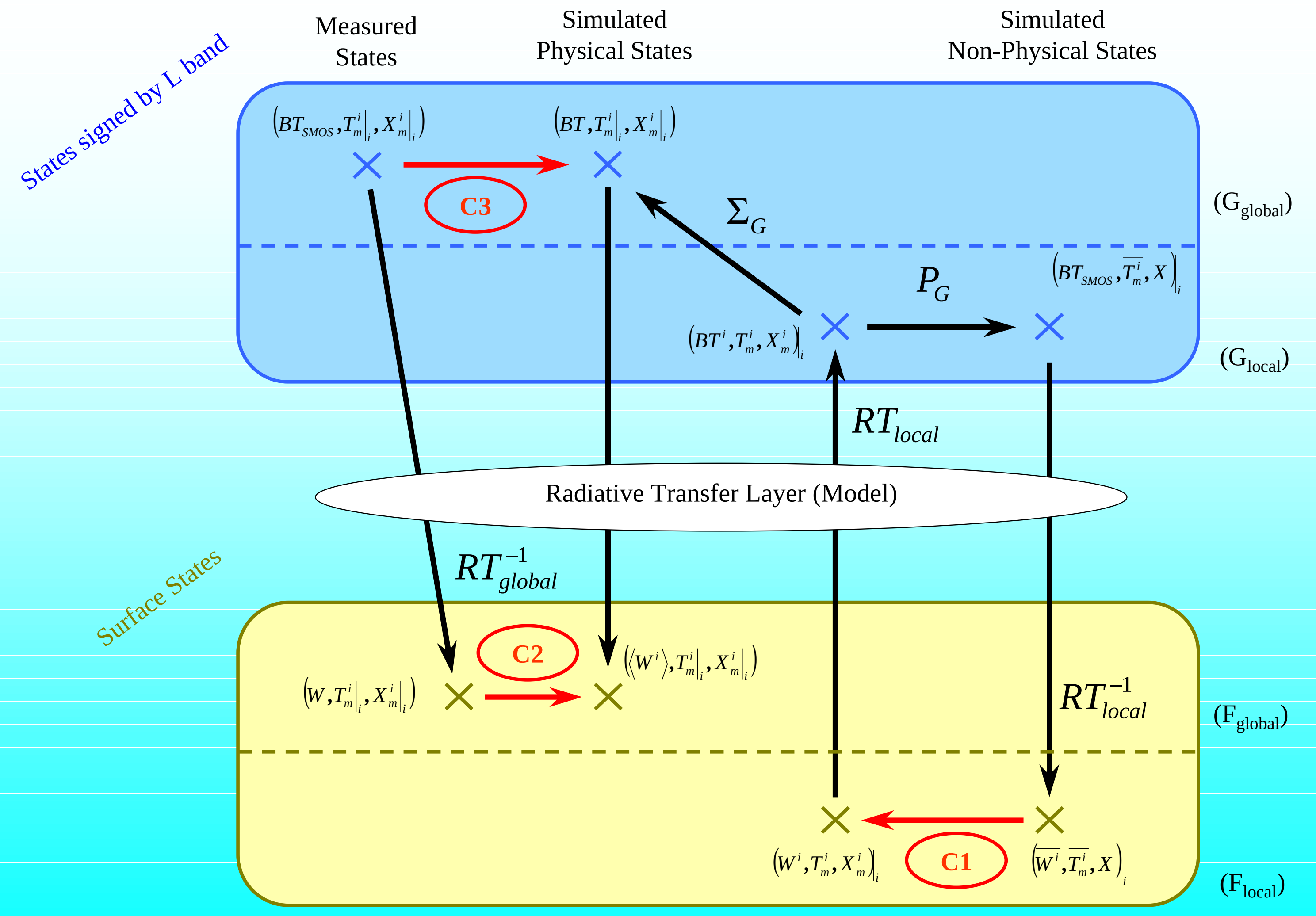
'Surface Temperature varies quasi linearly as a function of Soil Moisture in a specific range of Soil Moisture and in homogeneous Surface Conditions'

Surface Global Constraint (C2)

$$\left\langle W^i \right\rangle = W \quad \Longrightarrow \quad \begin{cases} W^i = W + f_1\left(\overline{W^i} - \left\langle \overline{W^i} \right\rangle\right) \\ \left\langle W^i \right\rangle = W \end{cases}$$

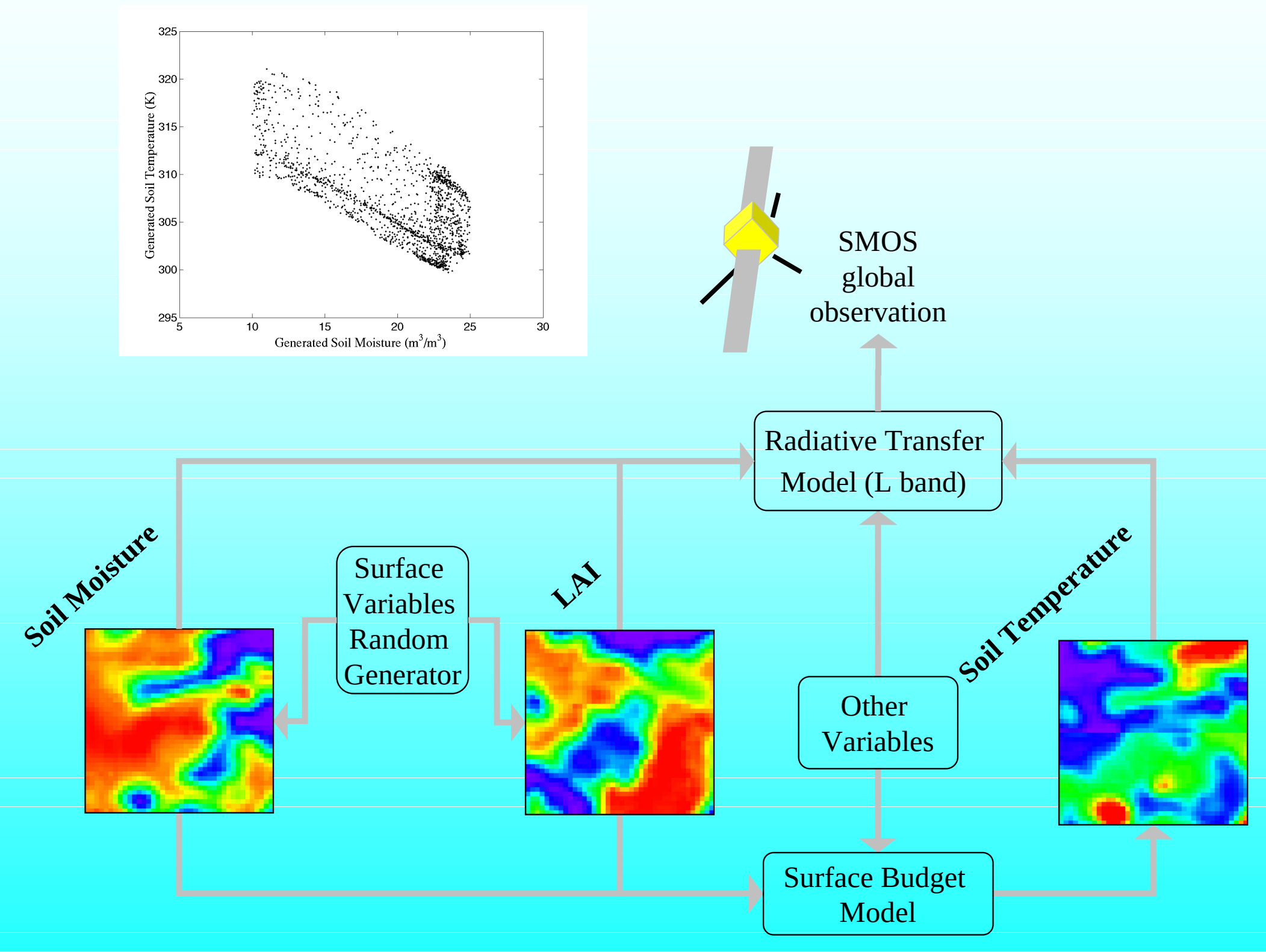
Observation Global Constraint (C3)

$$BT(f_1) = BT_{SMOS} \quad \Longrightarrow \quad \begin{cases} W^i = W + f_1\left(\overline{W^i} - \left\langle \overline{W^i} \right\rangle\right) \\ \left\langle W^i \right\rangle = W \\ f_1 / F = \left|TB_{SMOS} - TB(f_1)\right|^2 \quad \text{minimized} \end{cases}$$

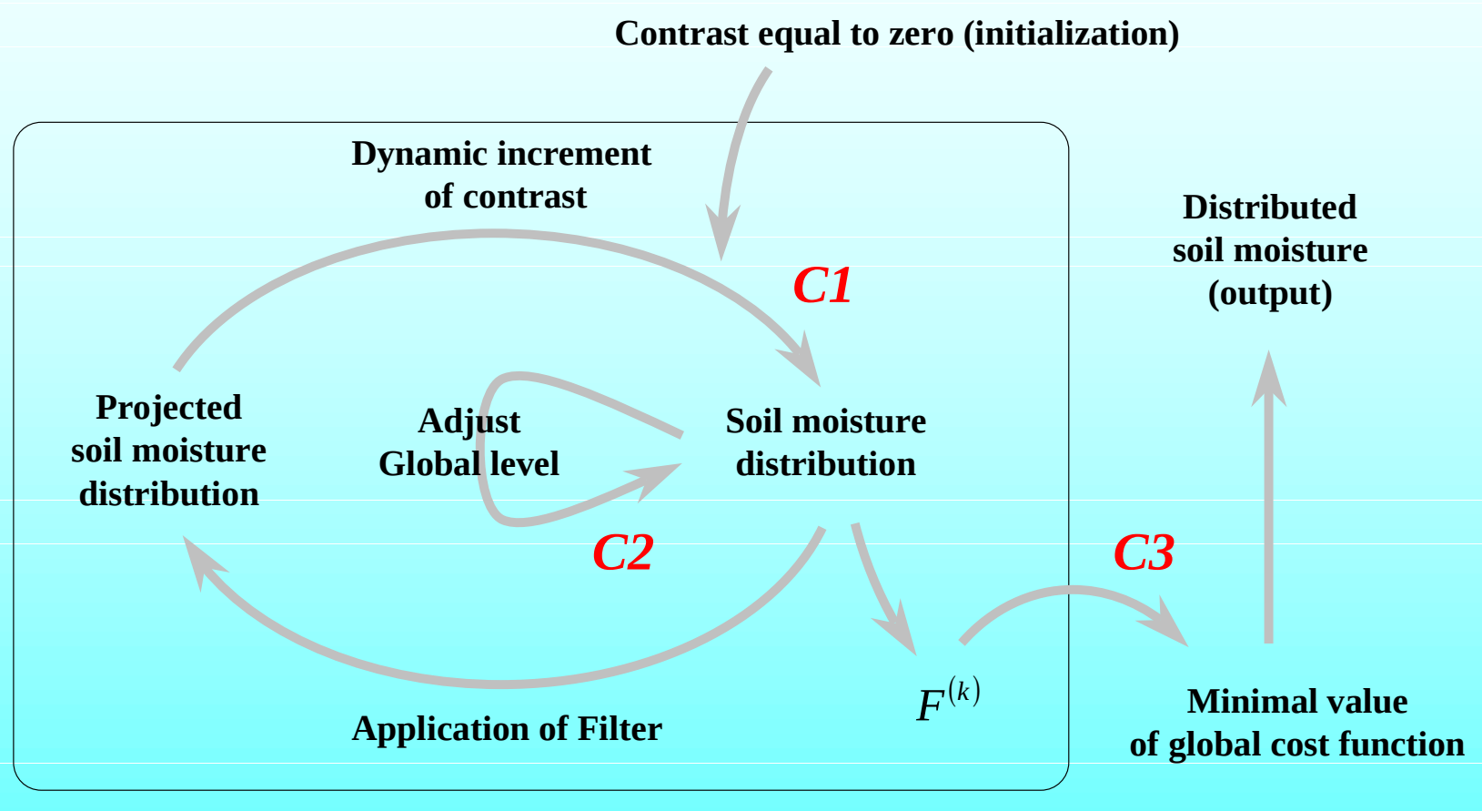


III. Apply the Down-Scaling Scheme

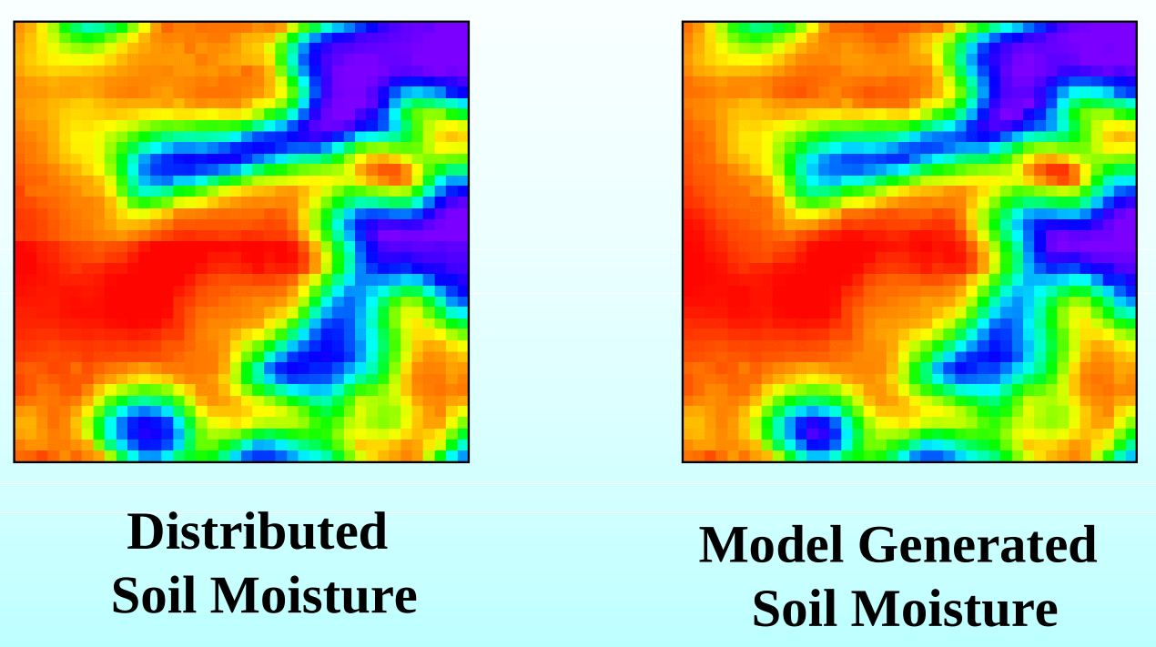
Generate a Synthetic Scene



Algorithm

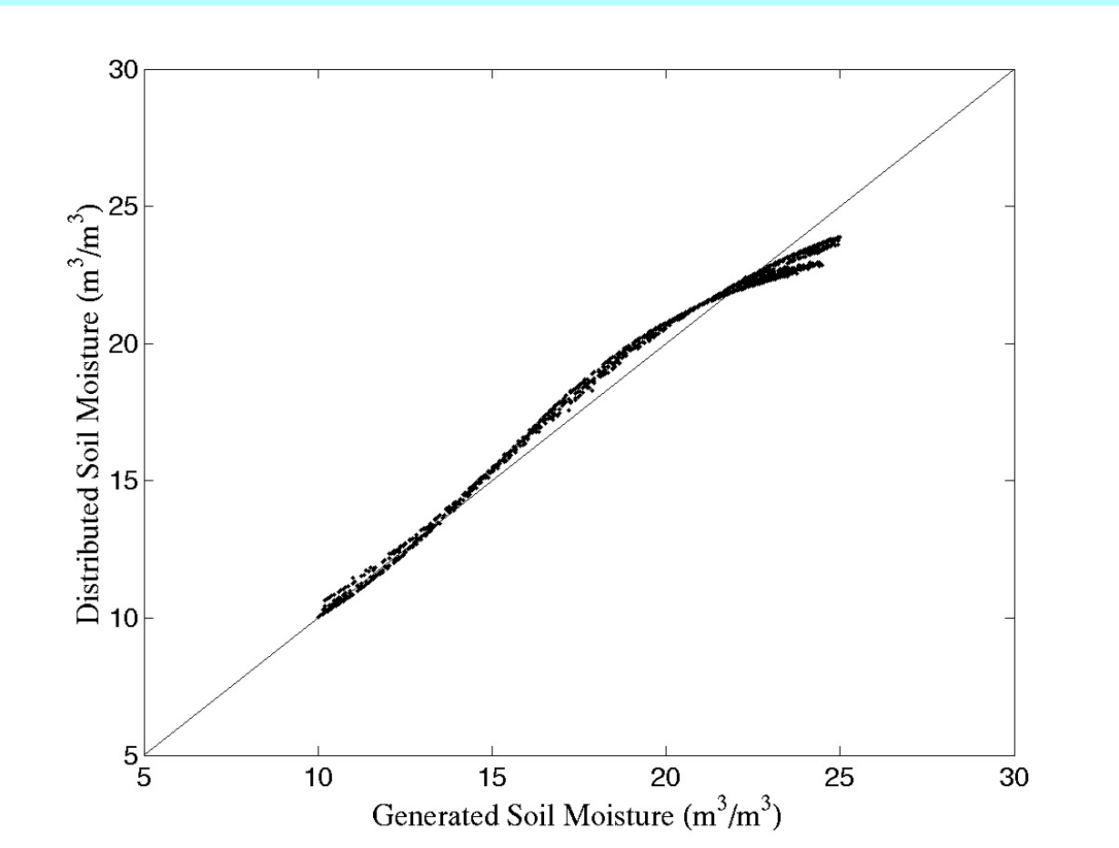


Results



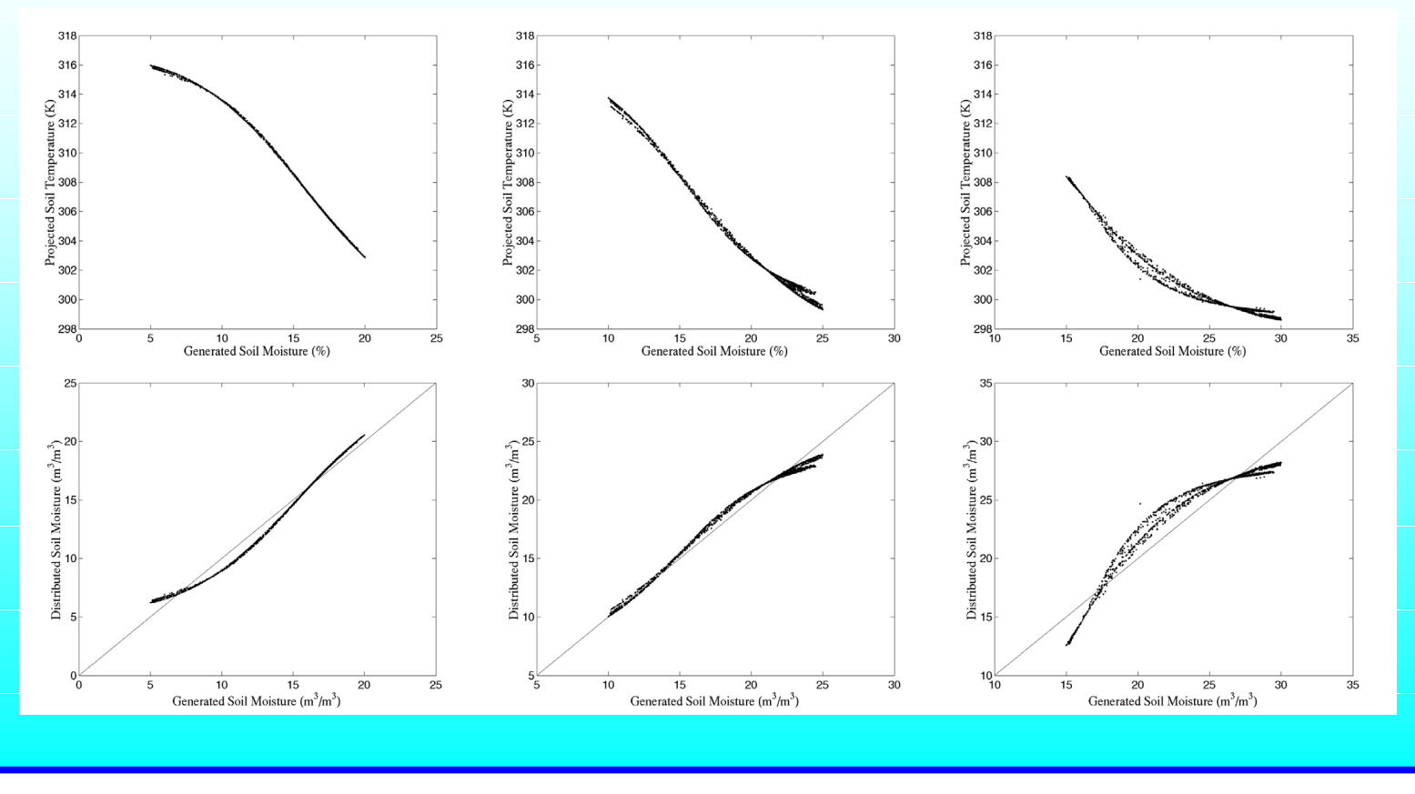
Distributed Soil Moisture

Model Generated Soil Moisture

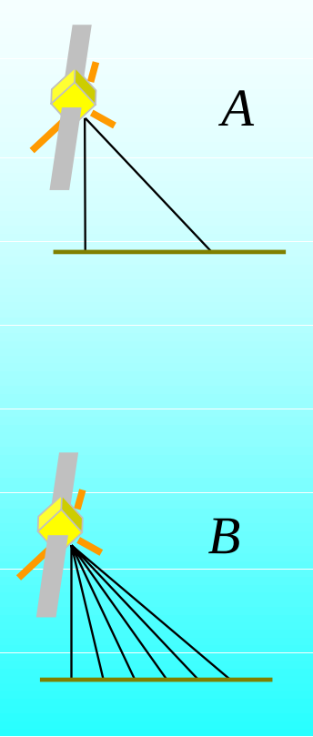


IV. Limitations

Verify Primordial Hypothesis



Sensitivity Analysis



Case	Soil Temperature (K)	LAI (%)	SMOS Observation (K)
Noise 1	2	20	0
Noise 2	4	50	0
Noise 3	0	0	1
Noise 4	0	0	2
Noise 5	0	0	4

Case	Viewing Configuration	W (%)		f1	
		Mean	Standard deviation	Mean	Standard deviation
No Noise	A	19.5	0	-3.0	0
	B	19.5	0	-3.0	0
Noise 1	A	19.5	0.0	-3.0	0.1
	B	19.5	0.0	-3.0	0.1
Noise 2	A	19.3	0.1	-2.7	0.5
	B	19.3	0.1	-2.9	0.4

Case	Viewing Configuration	W (%)		f1	
		Mean	Standard deviation	Mean	Standard deviation
No Noise	A	19.5	0	-3.0	0
	B	19.5	0	-3.0	0
Noise 3	A	19.5	0.3	-2.6	2.3
	B	19.5	0.1	-2.6	2.0
Noise 4	A	19.6	0.5	-3.0	2.5
	B	19.5	0.3	-2.9	2.2
Noise 5	A	19.5	1.1	-3.1	2.7
	B	19.5	0.6	-2.9	2.5

Conclusion

The problem of distributing soil moisture within a SMOS pixel from SMOS observation at global scale and some information on the state and characteristics of the surface at local scale is not well constrained. The choice of estimating soil moisture distribution with surface temperature distribution is based on the following hypothesis: 'surface temperature varies quasi linearly with soil moisture in a given soil moisture range and in homogeneous surface conditions'. From this postulate, it is possible to formulate a local constraint function of two parameters and called the relative distribution constraint. The application of this constraint to the down-scaling problem reduces the dimension of the space of solutions from 1600 to 2. Two is also the number of independent global constraints that is possible to apply on the system: one at surface level and another at observation level. These global constraints may be used to calibrate successively both parameters of the relative distribution, the effective level parameter and the contrast parameter.The application of the down-scaling on a synthetic scene outlines the relevance of the approach. The heterogeneity of surface conditions that is likely to generate a systematic noise on distributed soil moisture is reduced and the spatial structure of generated soil moisture is well restituted. The sensitivity analysis shows a great robustness of the scheme towards uncertainties, which may be important, on local auxiliary information. However, this study shows that a limitation exists as concerned the determination of the contrast parameter when a noise is added on global observation. The multi-angular and bi-polarized capabilities of SMOS captor seem to be not sufficient for determining precisely the contrast of the relative distribution.