



SENSOR

Towards improvement of remote sensing data products for soil moisture using ground penetrating radar

November 20th, 2014

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Introduction

- Soil moisture
 - Agriculture, soil science, forest ecology, ...
 - Terrain practicability, ...
- Methods to measure soil moisture (RS)
 - Ground Penetrating Radar: ~1m x 1m
 - Synthetic Aperture Radar: ~12m x 6m
 - Drawback: requires speckle filtering
 - Scatterometry (radar): ~20km x 20km
 - Passive radiometry: ~20km x 20km

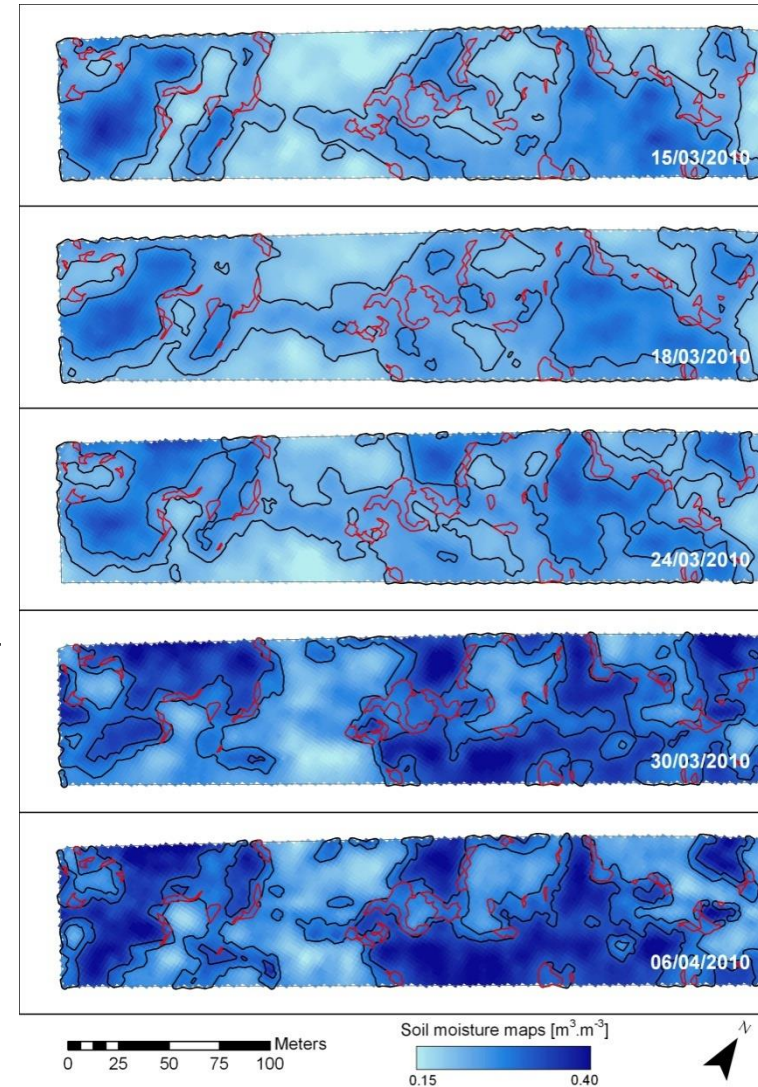
Motivation

- Exploit SAR images to measure soil moisture with a high spatial resolution
 - Issue: speckle
 - = “Random” variation of the backscatter
 - Classical approach: multilooking
 - Degrades resolution
 - Necessary to reduce speckle
 - Model-based method
 - Model the spatial variability of the soil moisture
 - Estimate the unknown of the model from the SAR image

Inversion models

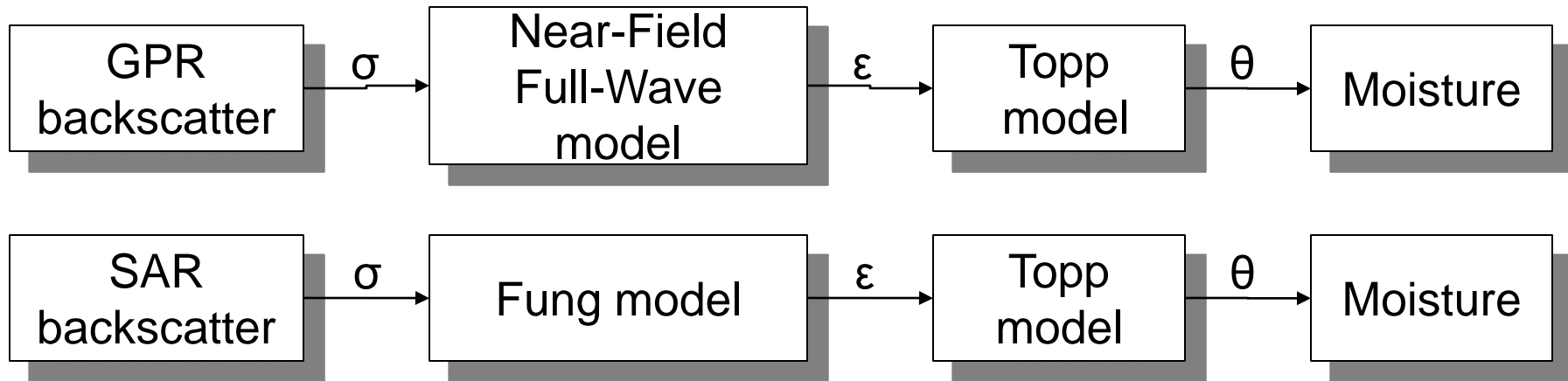
- Reference models:
 - Multilooking-based (7x7, 9x9 windows)
- Landscape-based models:
 - Relative soil moisture difference patterns are preserved (J. Minet et al., 2013)
 - = landscapes
 - Reduces the number of unknowns
 - Relieves the requirement for a homogeneous backscatter

$$\delta = \frac{\theta - \bar{\theta}}{\bar{\theta}}$$



Inversion models

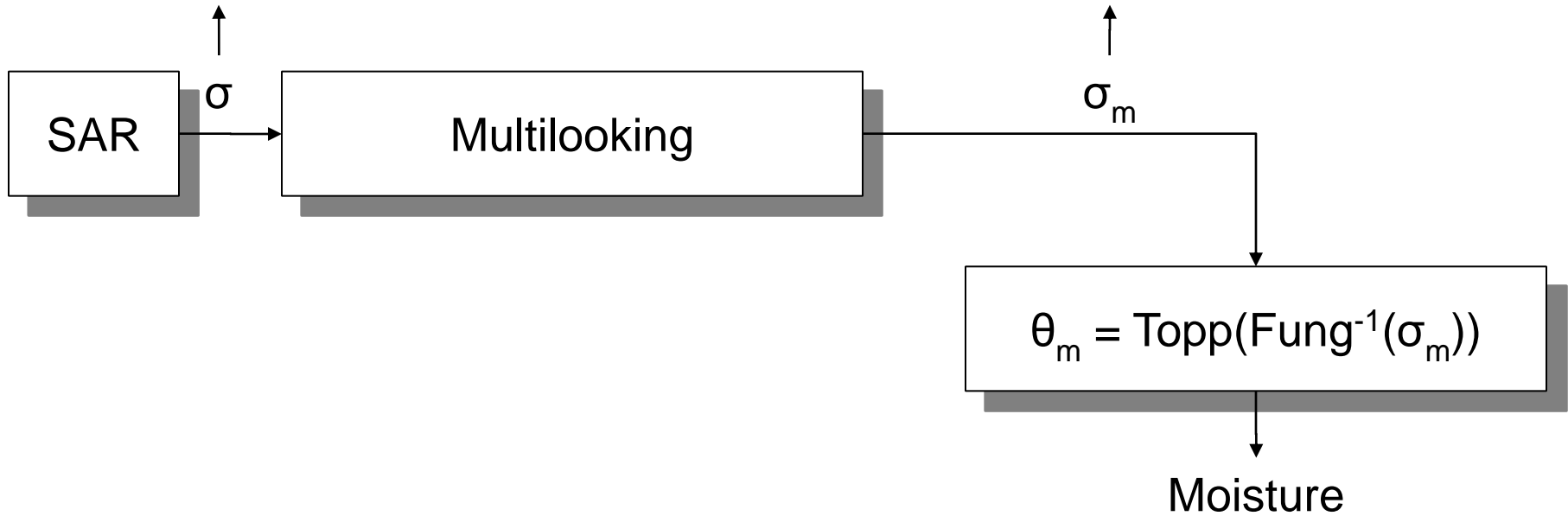
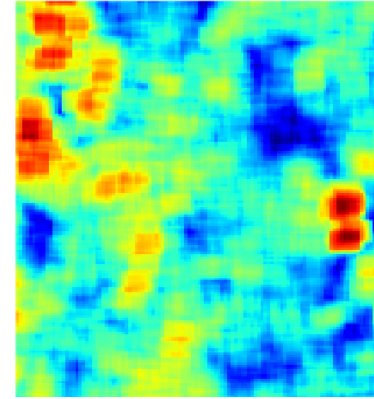
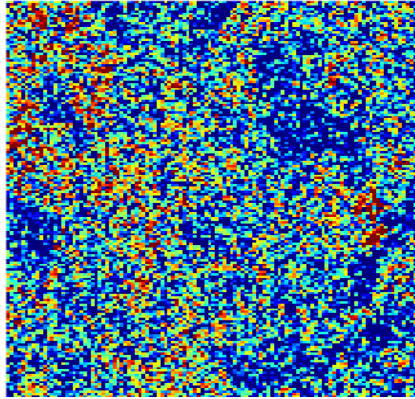
Terminology



- Near-Field Full-Wave model: Lambot and André, 2014
- Topp model: Topp et al., 1980
- Fung model: Fung, 1994

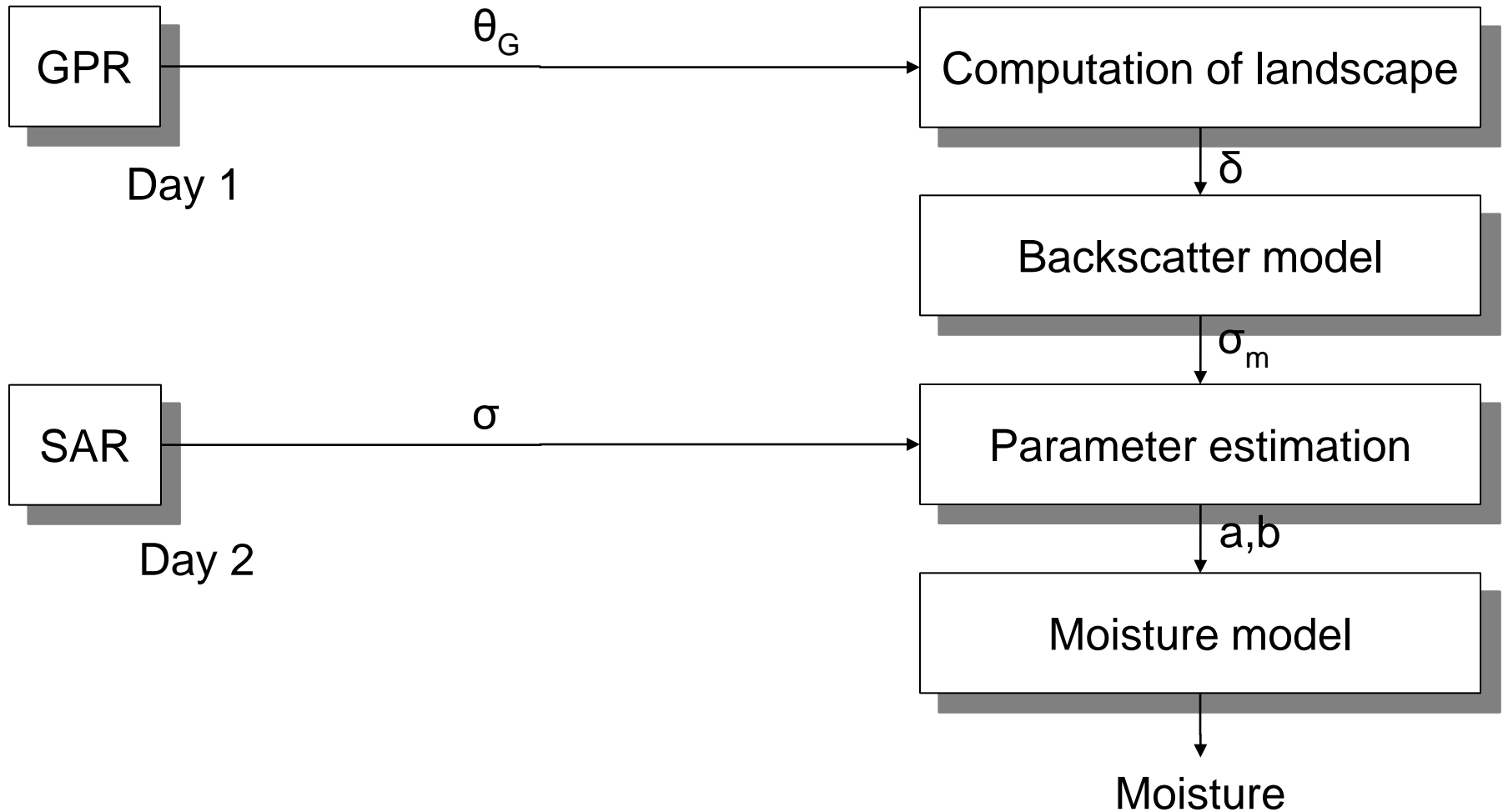
Inversion models

Multilook: used as reference



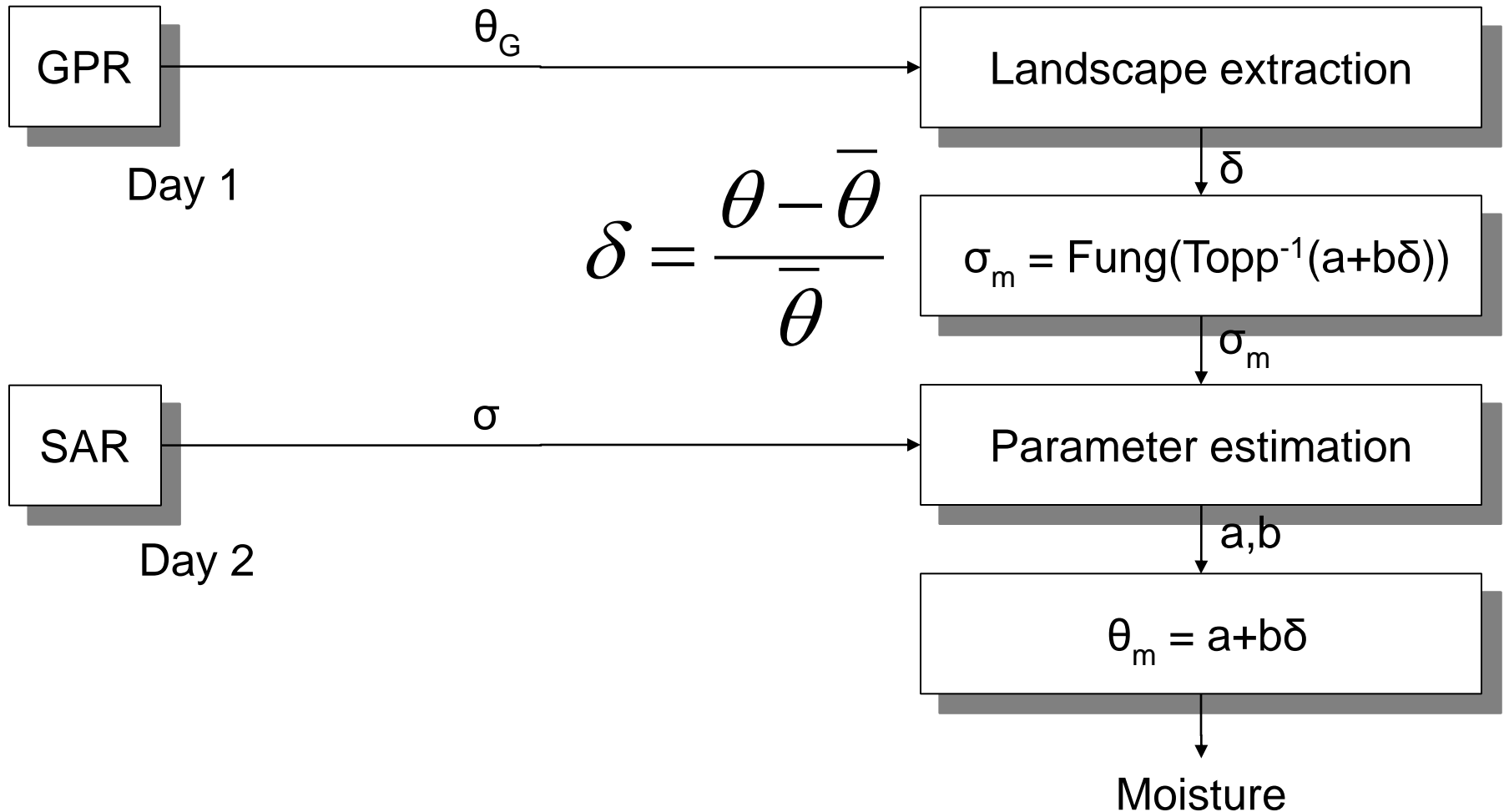
Inversion models

Methodology



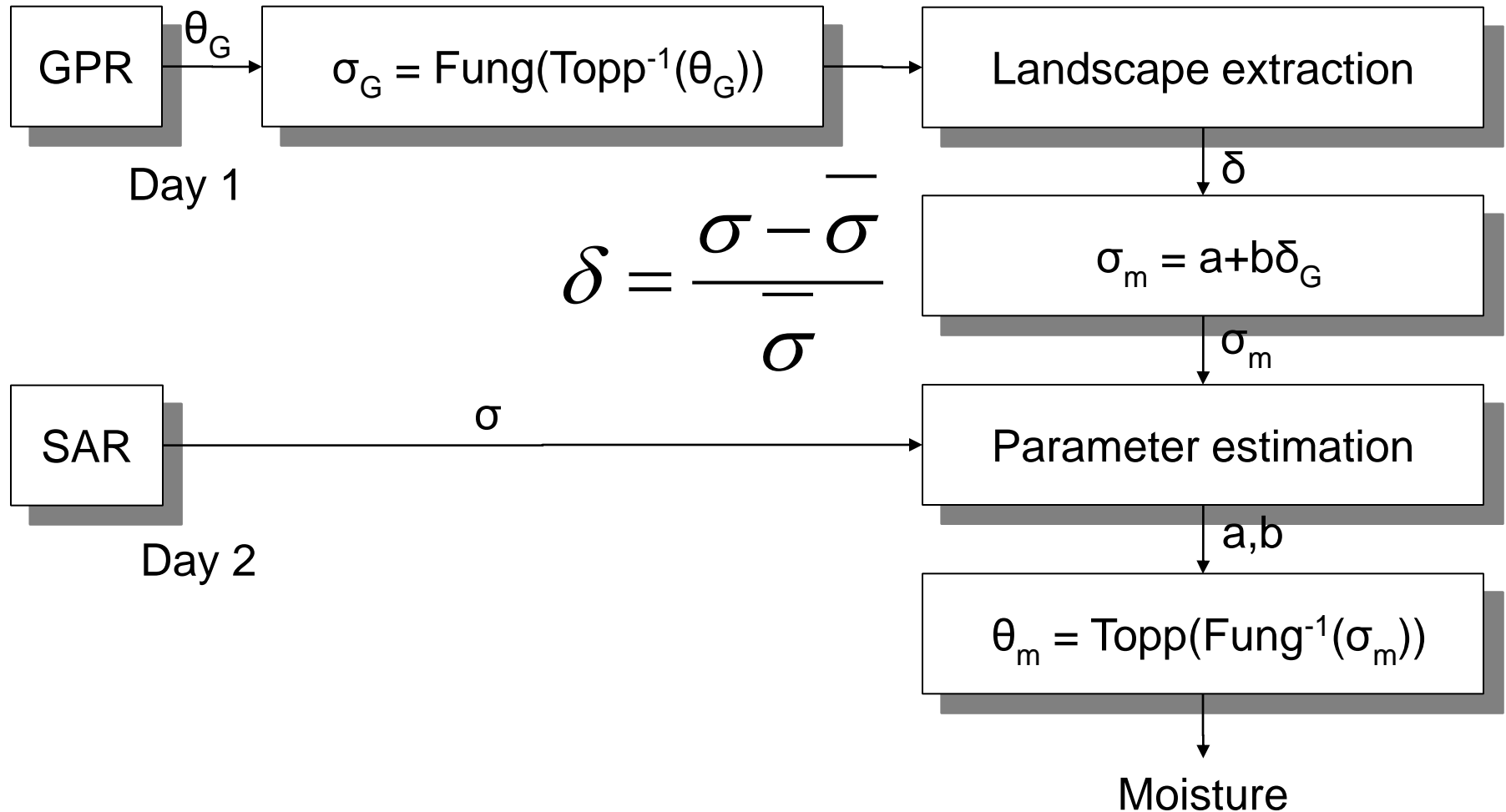
Inversion models

Moisture-based landscape model



Inversion models

Backscatter-based landscape model



Simultaneous measurement of

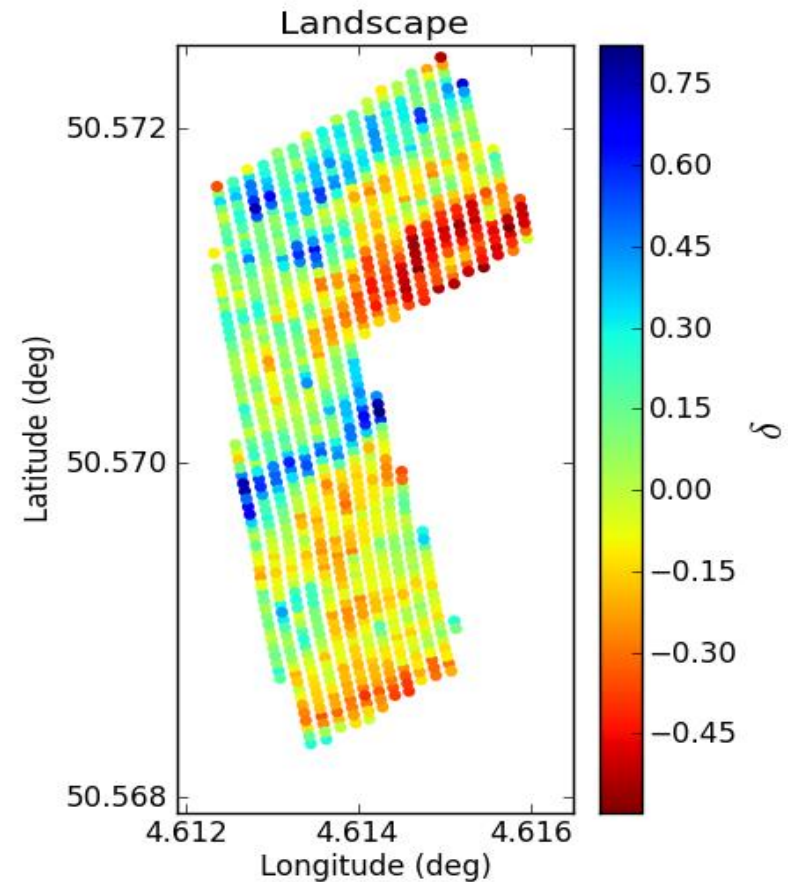
- Soil moisture (Time Domain Reflectometry)
 - Ground truth
- GPR data
 - Stepped Frequency CW GPR: 200-2000 MHz
 - Approximation of the ground truth
- Synthetic Aperture Radar Image
 - Radarsat-2: C-band (5.4 Ghz), SLC, Quad-pol
 - Fine resolution mode (12m x 6m resolution)



Moisture landscape

- Landscape extracted from previous GPR data
- Moisture averaged over 8m radius

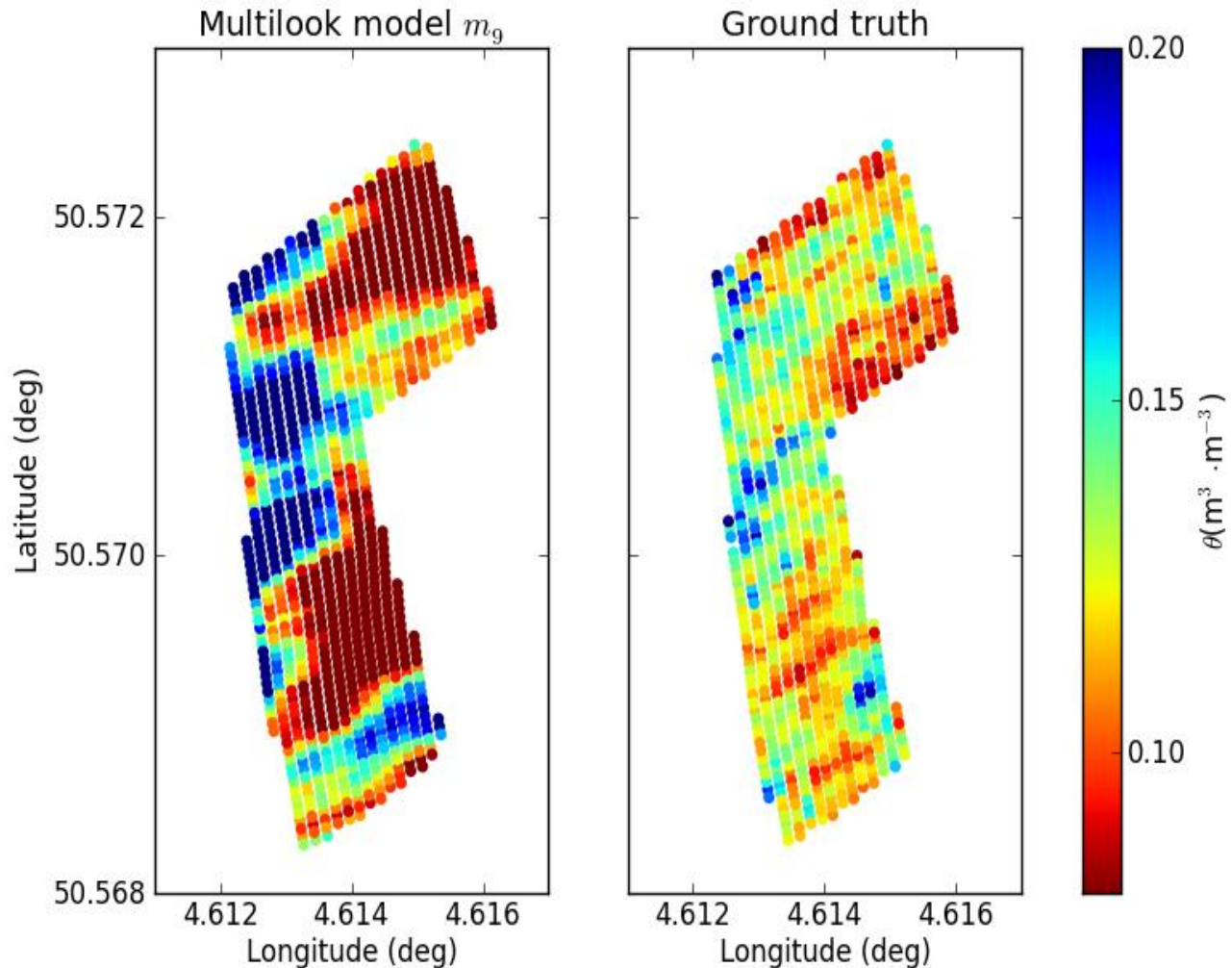
$$\delta = \frac{\theta - \bar{\theta}}{\bar{\theta}}$$



Results

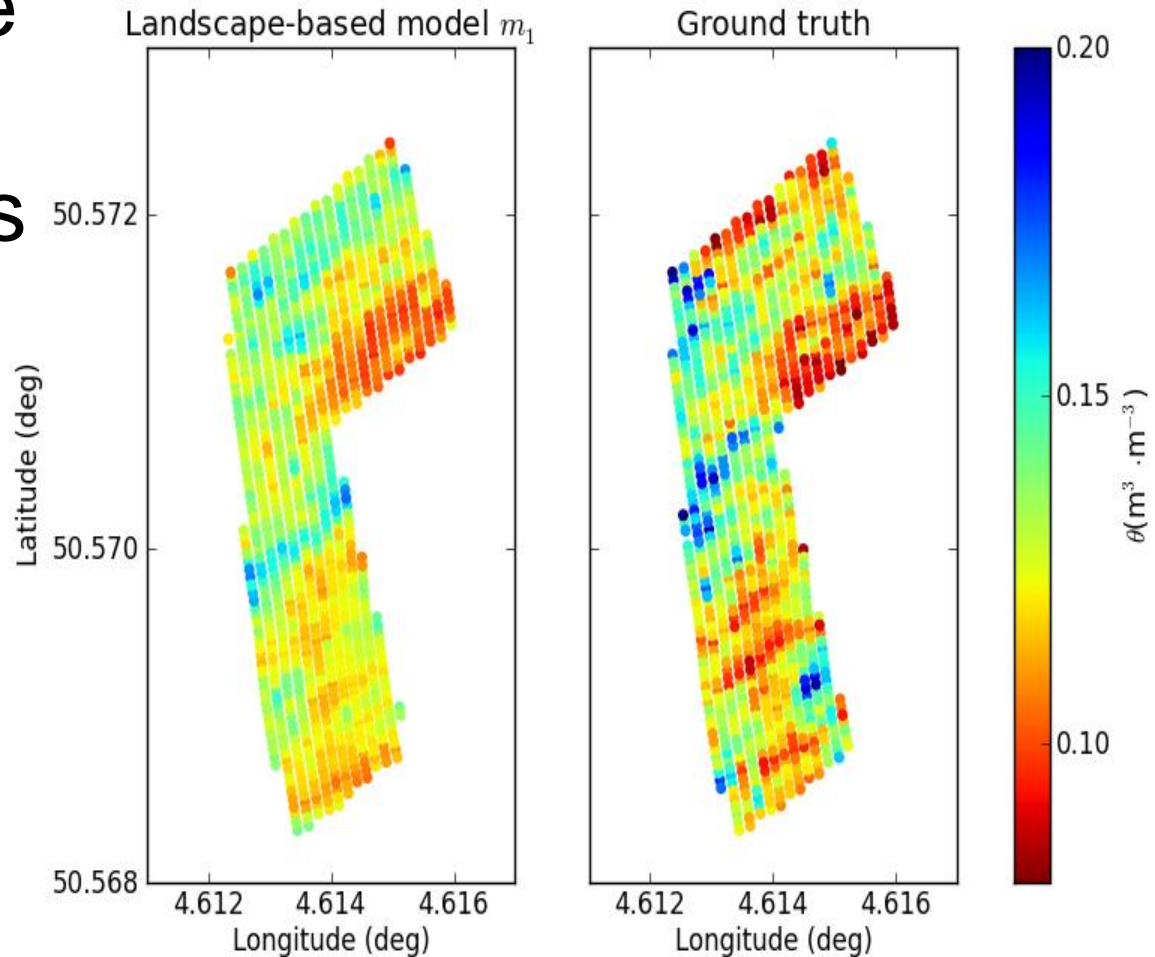
Multilooking 9x9

- The moisture patterns are not well represented



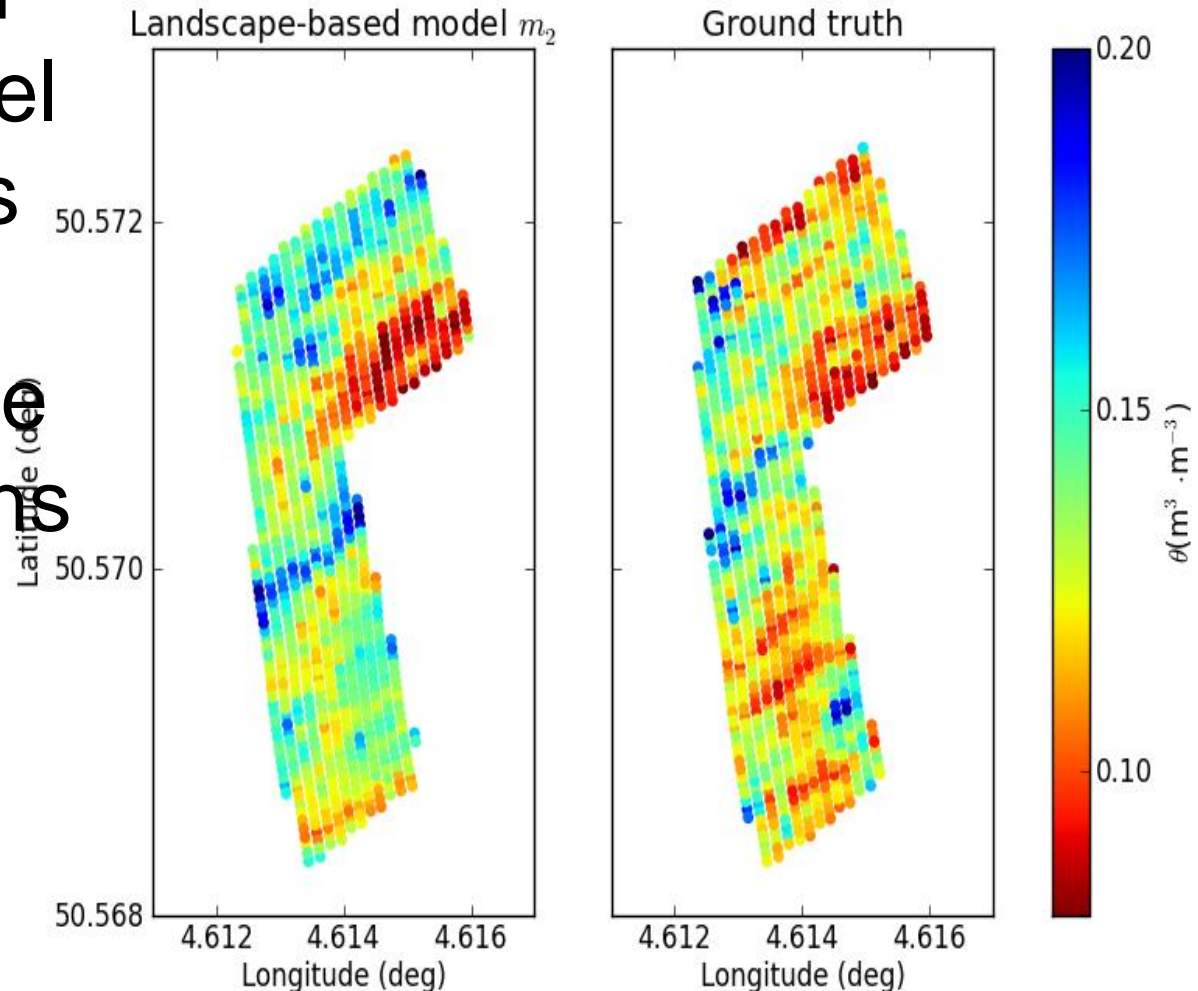
Moisture-based landscape model

- Both the average moisture and the moisture patterns are well represented



Backscatter-based landscape model

- The backscatter-landscape model also reproduces the average moisture and the moisture patterns very well



Results

Model	$\text{std}(\theta_m - \theta_{GT})$
Multilook 7x7	0.070 m ³ .m ⁻³
Multilook 9x9	0.058 m ³ .m ⁻³
Moisture-landscape model	0.021 m ³ .m ⁻³
Backscatter-landscape model	0.024 m ³ .m ⁻³

- landscape-based models provide a much more accurate moisture estimate

Future work

- Future work / opportunities
 - Sentinel-1 SAR image stacks
 - Provide high revisit frequency
 - Opens possibilities for speckle reduction
 - Without spatial resolution loss
- Consider more complex models
- Reduce requirements for initial ground-truth data
 - Avoid scanning of the whole field