Analysis of impact of spatial heterogeneity in retrieval of geophysical parameters from low-frequency radars
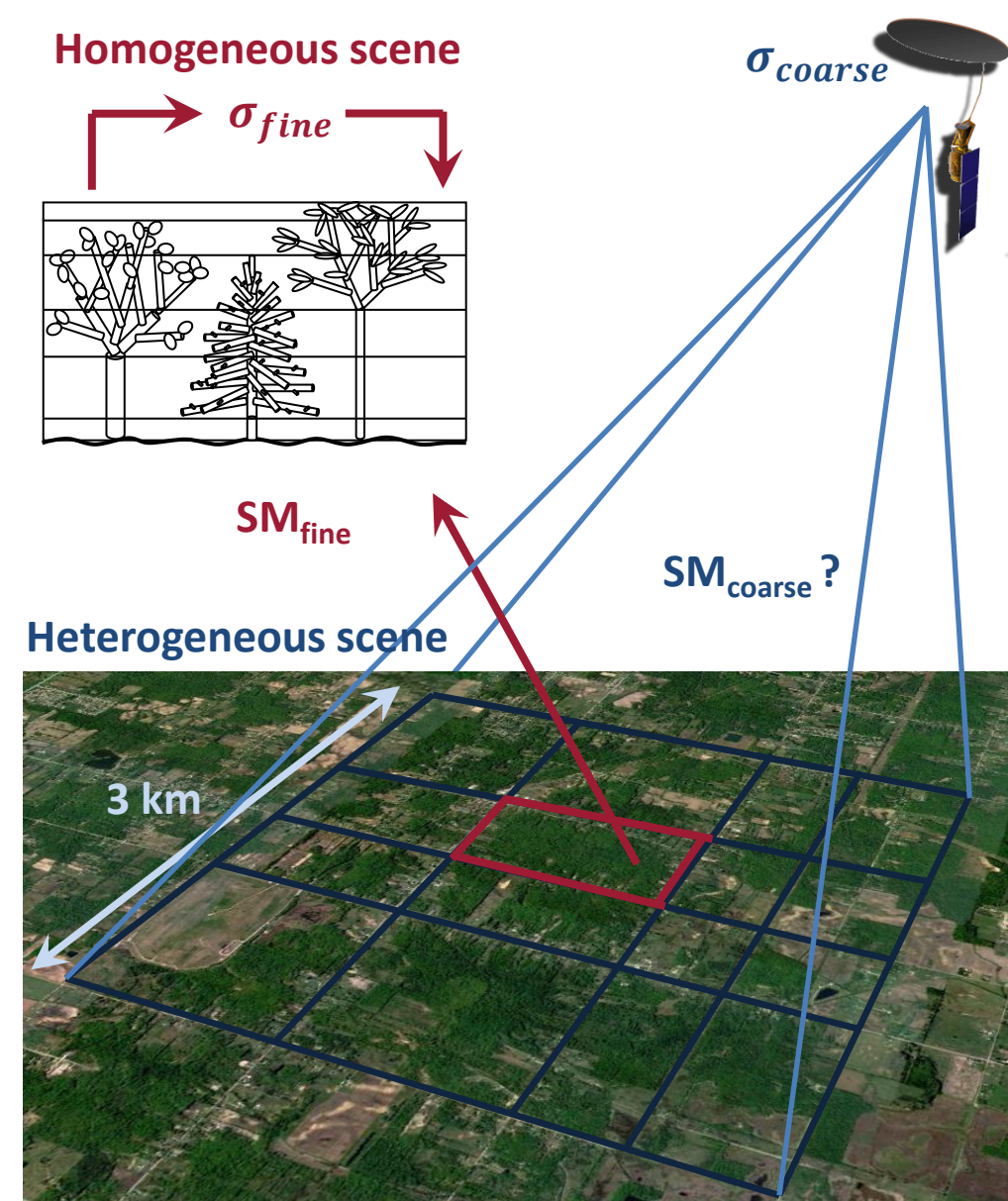
Mariko Burgin, Alireza Tabatabaeenejad, Mahta Moghaddam
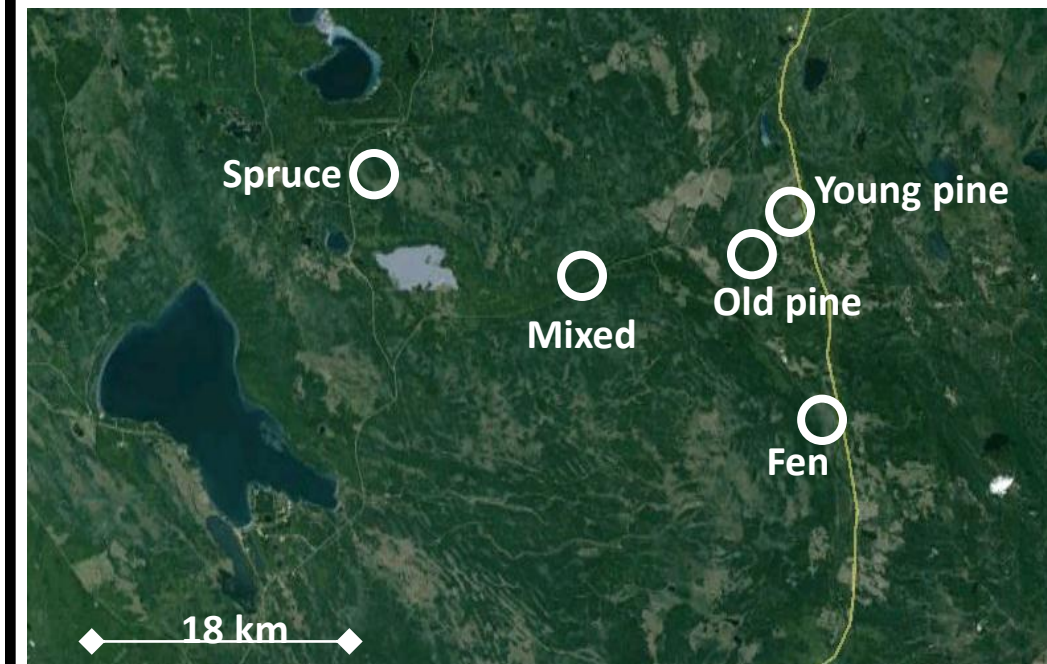Department of Electrical Engineering / Electrophysics

Objectives

Soil Moisture Active Passive (SMAP) mission launching in October 2014 will carry an L-band radar delivering pixel size of 3 km x 3 km
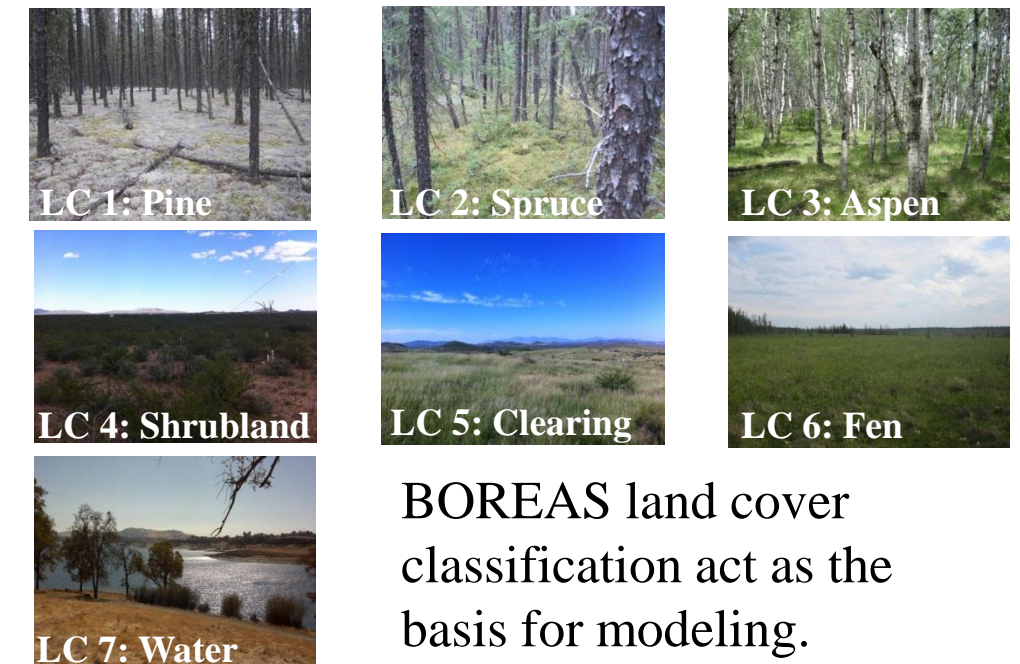
✓ Development of generalized forward model for a fine-scale homogeneous area
✓ Inversion for soil moisture over a fine-scale homogeneous area
☐ Radar measures one radar backscatter value over coarse-resolution image
→ Coarse-scale soil moisture?

Homogeneous scene — σ_{fine} — σ_{coarse} — SM_{fine} — SM_{coarse}? — Heterogeneous scene — 3 km

Sample site in Canada: BERMS / BOREAS

Spruce, Young pine, Mixed, Old pine, Fen, 18 km

BOREAS land cover (LC) classification

LC 1: Pine, LC 2: Spruce, LC 3: Aspen, LC 4: Shrubland, LC 5: Clearing, LC 6: Fen, LC 7: Water

BOREAS land cover classification act as the basis for modeling.

Above-ground vegetation:
• Vegetation parameter obtained through field work
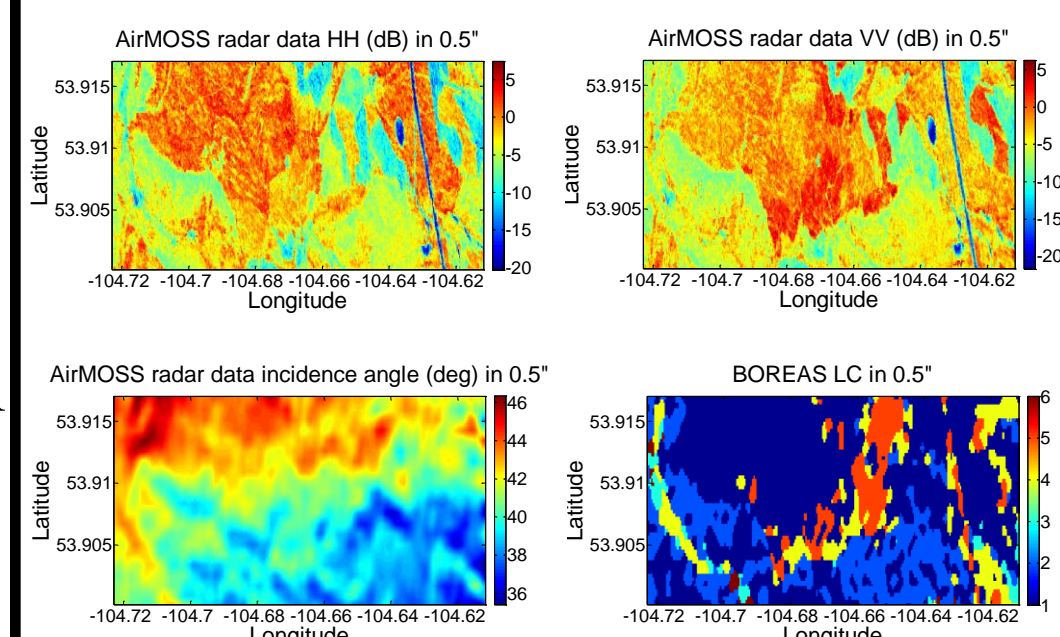
Below-ground soil:
• Single soil layer with sandy soil

Terrain topography
• Sample site is considered flat

Data layers over sample area

AirMOSS radar data HH (dB) in 0.5°; AirMOSS radar data VV (dB) in 0.5°; AirMOSS radar data incidence angle (deg) in 0.5°; BOREAS LC in 0.5°
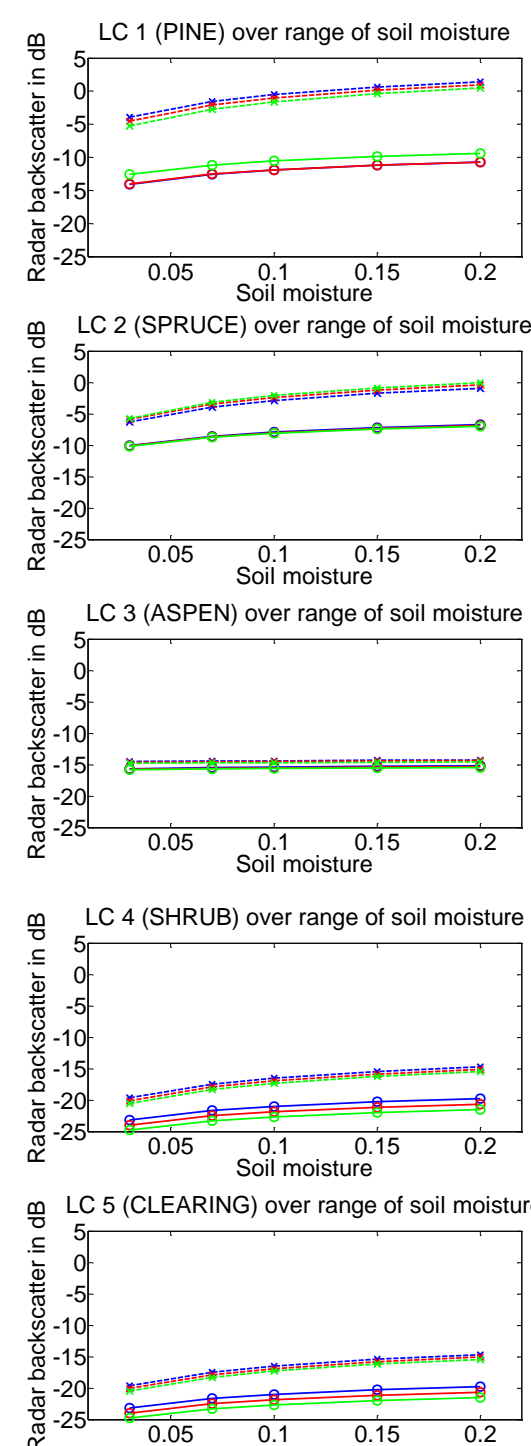
Homogeneous 'scaling' functions

To restrict modeling space, discrete modeling points have been chosen:
• Land cover: 7 distinct types
• Soil moisture: 0.03, 0.07, 0.10, 0.15, 0.20 [m³/m³]
• Radar incidence angle: 38, 40, 42 [deg]

Homogenous 'scaling' functions show radar backscatter over soil moisture (figures to the right)
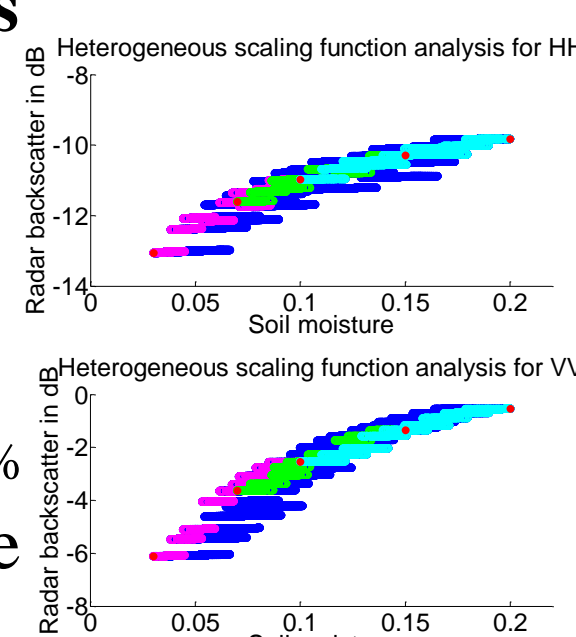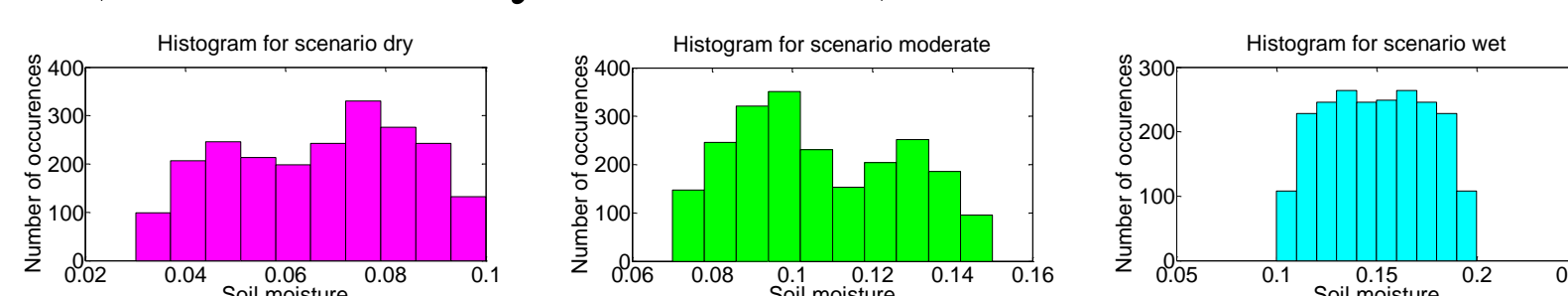
General problem:
• Assume sample area represents coarse-scale image
• Measure total backscatter at coarse-scale resolution
• Want to find soil moisture at coarse-scale
• We know land cover distribution, soil texture and incidence angle
• We don't know fine-scale measurements and fine-scale soil moisture

LC 1 (PINE) over range of soil moisture; LC 2 (SPRUCE) over range of soil moisture; LC 3 (ASPEN) over range of soil moisture; LC 4 (SHRUB) over range of soil moisture; LC 5 (CLEARING) over range of soil moisture

Heterogeneous scaling function II

Looking at all possible soil moisture combinations
• Total of 5^7 combinations of soil moistures
• Each measured coarse-scale radar backscatter value corresponds to range of potential coarse-scale soil moistures:
  Dry: 3%, 7%, 10%, Moderate: 7%, 10%, 15%, Wet: 10%, 15%, 20%
• Necessary to include statistics of the soil moisture distribution (not necessarily Gaussian !) via the weights

Heterogeneous scaling function analysis for HH; Heterogeneous scaling function analysis for VV; Histogram for scenario dry; Histogram for scenario moderate; Histogram for scenario wet

Heterogeneous 'scaling' function

Assuming all land cover types have equal soil moisture
• Total soil moisture is an average over all pixels within the coarse-scale image with N = total number of pixels:

$$SM_{coarse} = \frac{1}{N}\sum_{i}^{N} SM_i$$

• Total radar backscatter is the weighted average of the individual radar backscatter coefficients where M = number of LC types:

$$\sigma_{coarse} = \sum_{i}^{M} w_i \sigma_i$$

• Fine-level pixel radar backscatter is a function of soil moisture, vegetation and incidence angle:

$$\sigma_{fine} = f(SM_{fine}, veg_{fine}, inc_{fine})$$

• Using a nested technique, the total radar backscatter can be calculated as follows:

$$\sigma_{inc38} = w_{LC1}\sigma_{LC1\&inc38} + \cdots + w_{LC7}\sigma_{LC7\&inc38}$$
$$\sigma_{inc40} = w_{LC1}\sigma_{LC1\&inc40} + \cdots + w_{LC7}\sigma_{LC7\&inc40}$$
$$\sigma_{inc42} = w_{LC1}\sigma_{LC1\&inc42} + \cdots + w_{LC7}\sigma_{LC7\&inc42}$$

where w_{LC1} to w_{LC7} are the respective percentage land cover for the coarse-scale image and $\sigma_{LC1\&inc38}$ to $\sigma_{LC7\&inc38}$ etc. are the homogeneous 'scaling' functions.

$$\sigma_{coarse} = w_{inc38}\sigma_{inc38} + w_{inc40}\sigma_{inc40} + w_{inc42}\sigma_{inc42}$$

where w_{inc38} to w_{inc42} are the percentage cover of incidence angle for the coarse-scale image.

This nested technique is separately applied to HH and VV:

Heterogeneous scaling function analysis for HH; Heterogeneous scaling function analysis for VV
· Equal SM over entire image
✕ Weighted scaling function curve (LC and INC)

mariko.burgin@usc.edu, alirezat@usc.edu, mahta@usc.edu