Upscaling Ground-based Soil Moisture Measurements for SMAP Validation Activities

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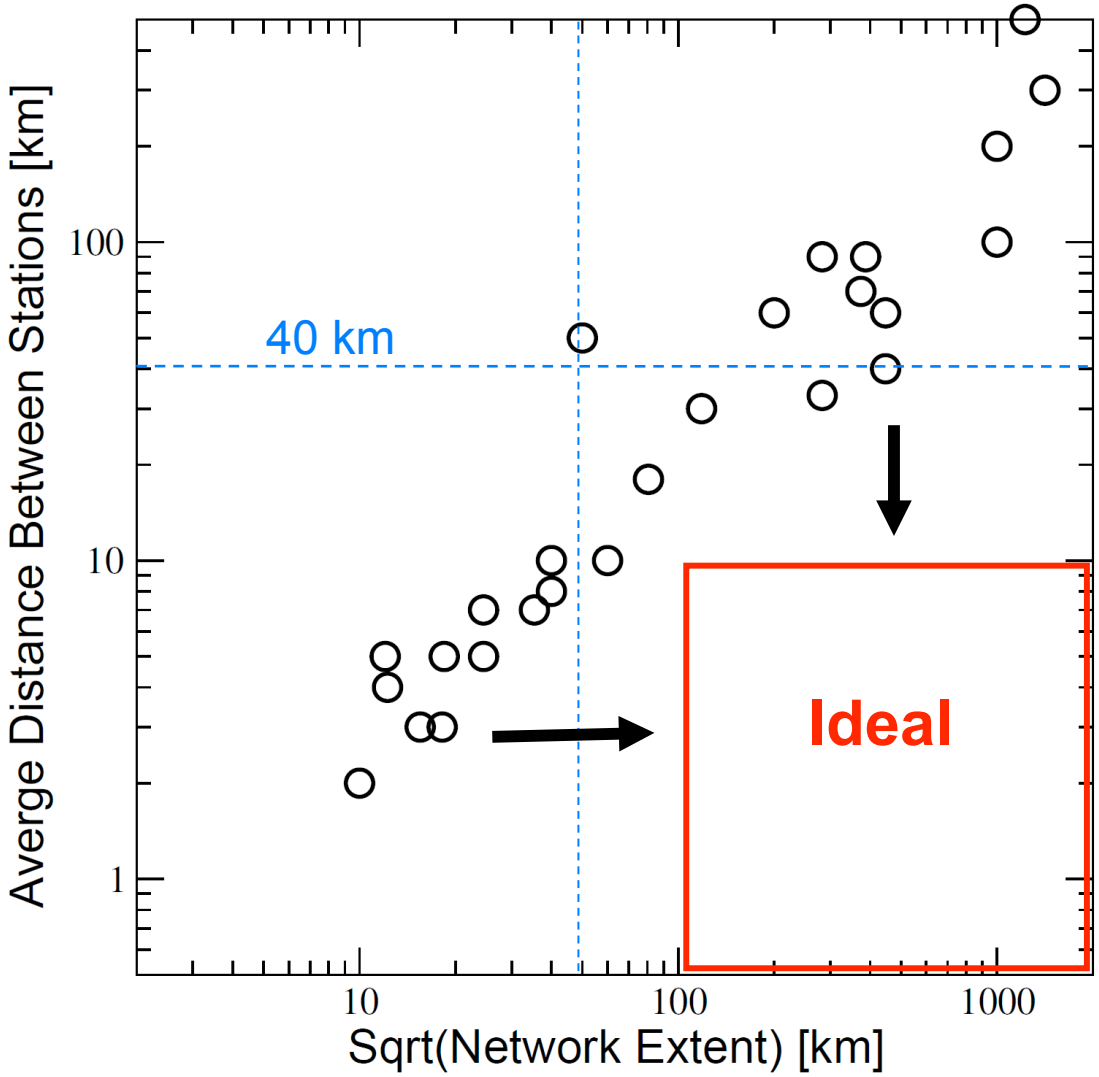
SMAP Val/Cal Working Group on Upscaling

- Established during 2009 SMAP cal/val workshop (35 members).
- Objective: Maximizing the utility of sparse soil moisture network observations for SMAP validation activities.
- First activity: White paper review on existing soil moisture upscaling research.
    - ✓ Co-authors: Aaron Berg, Mike Cosh, Alexander Loew, Binayak Mohanty, Rocco Panciera, Patricia de Rosnay, Dongryeol Ryu and Jeff Walker.
    - ✓ Draft distributed to entire working group last week…input still being sought.
    - ✓ Preparation for future SMAP mission reviews.
    - ✓ Journal review article.

Background motivation for upscaling

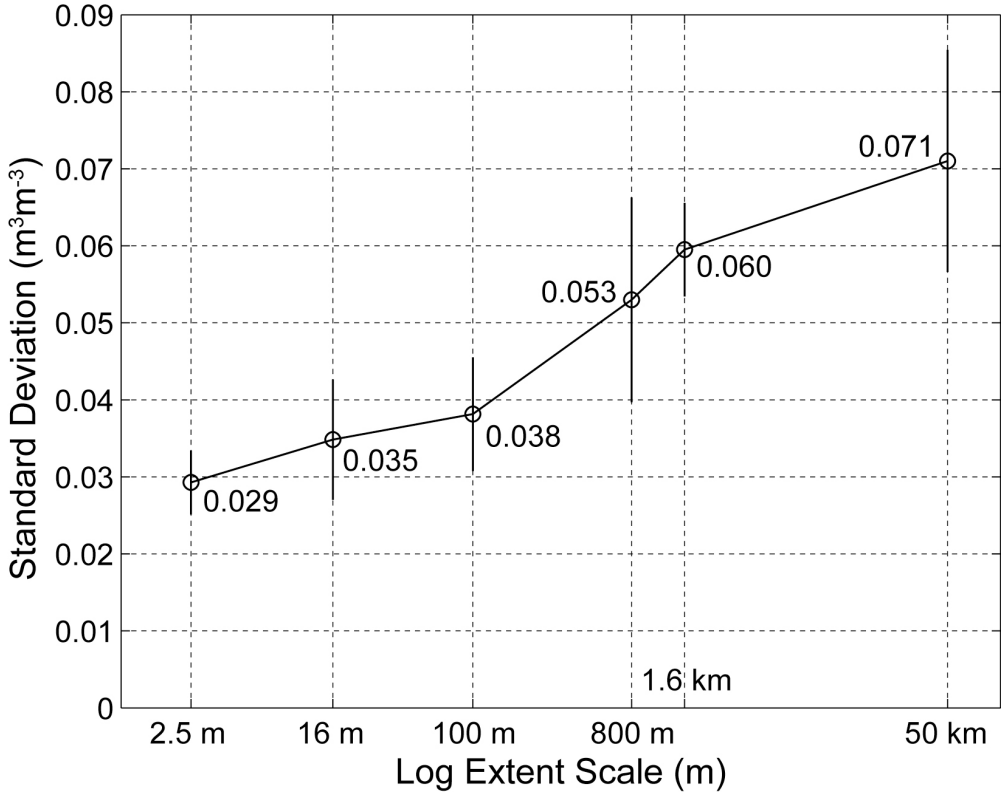


Network Validation Strategies:

1) *Extrapolate* validation results from dense "core" networks to wider geographic areas.

2) *Upscale* measurements from "sparse networks" to satellite footprint-scales.

Scope of upscaling problem/sampling density requirements



(Famiglietti et al., 2008)

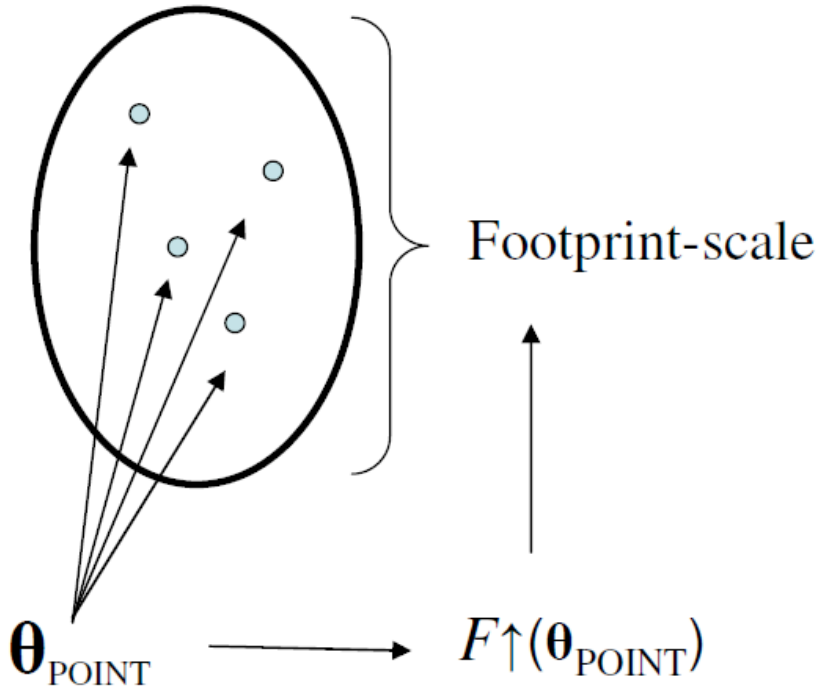
Sub-sampling results in literature:

✓ Required point-scale samples to estimate ***field-scale*** (~800 m) mean to within 0.02 to 0.03 are generally on the order 5-25.*

✓ Required point-scale samples to estimate satellite ***footprint-scale*** (~20 km) mean to within 0.02 to 0.03 are generally on the order of 20-40.*

*Depends on mean soil moisture conditions

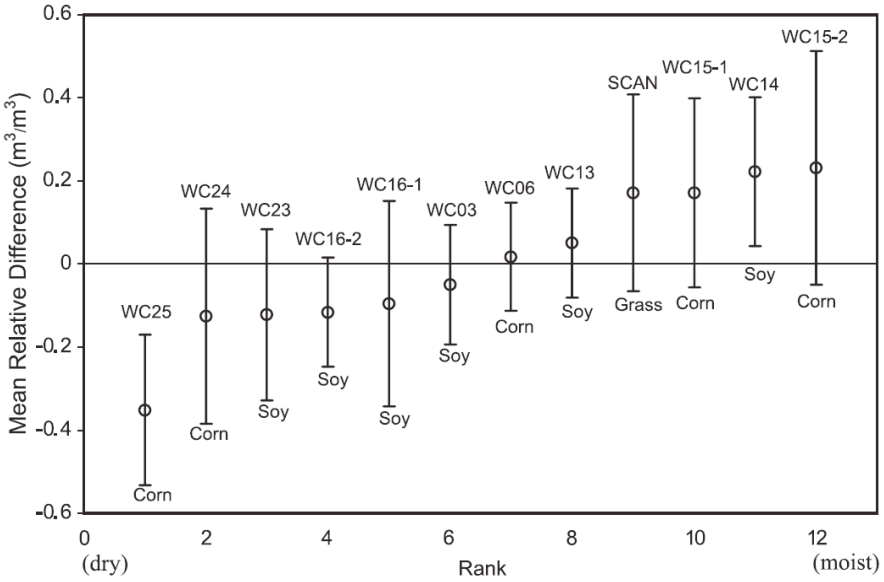
Existing upscaling strategies



Types of Upscaling Approaches:

- ✓ Improve site selection.
- ✓ Improve the functional form of $\boldsymbol{F}\uparrow$.
- ✓ Compensate for error in $\boldsymbol{F}\uparrow(\boldsymbol{\theta}_{POINT})$ on accuracy metrics.

Improve site selection based on temporal stability



~300-km^2 Walnut Creek Watershed in Central Iowa

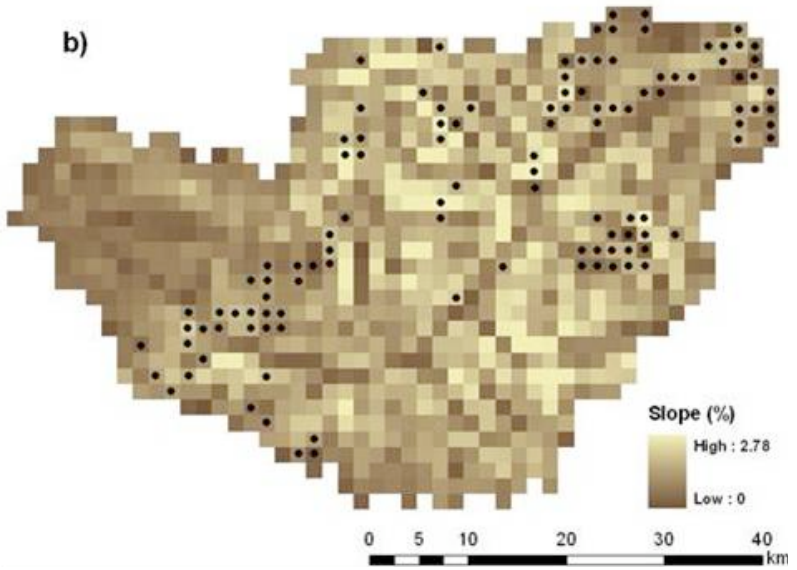
(Cosh et al. 2004)

Mean Relative Difference:

Point – Watershed / Watershed

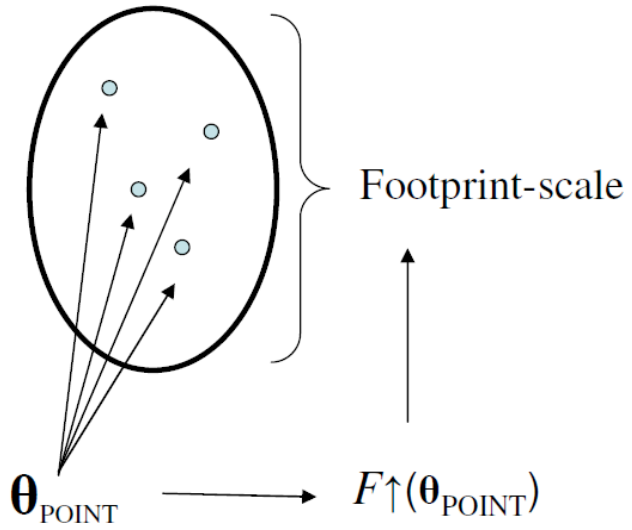
~900-km^2 Little Washita Watershed in Oklahoma

(Joshi et al. 2011)



Improved functional forms for F↑

Default: $\theta_{\mathrm{UPSCALE}} = F_{\uparrow}(\boldsymbol{\theta}_{\mathrm{POINT}}) = N^{-1}\sum_{i=1}^{N}\theta_{i,\mathrm{POINT}}$



1. Improve using block kriging:

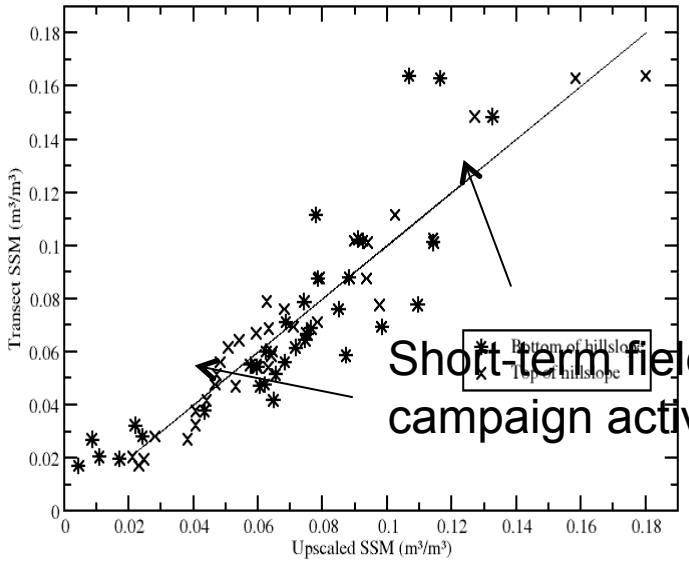
(Vinnikov et al. 1999)

$$\theta_{\mathrm{UPSCALE}} = F_{\uparrow}(\boldsymbol{\theta}_{\mathrm{POINT}}) = \sum_{i=1}^{N} w_i\theta_{i,\mathrm{POINT}} = \frac{1}{\widehat{w}}\mathbf{C}^{-1}\mathbf{D}\,\boldsymbol{\theta}^{\mathrm{T}}{}_{\mathrm{POINT}}$$

Improved functional forms for F↑

2. Improve using empirical relationships derived from field campaign data:

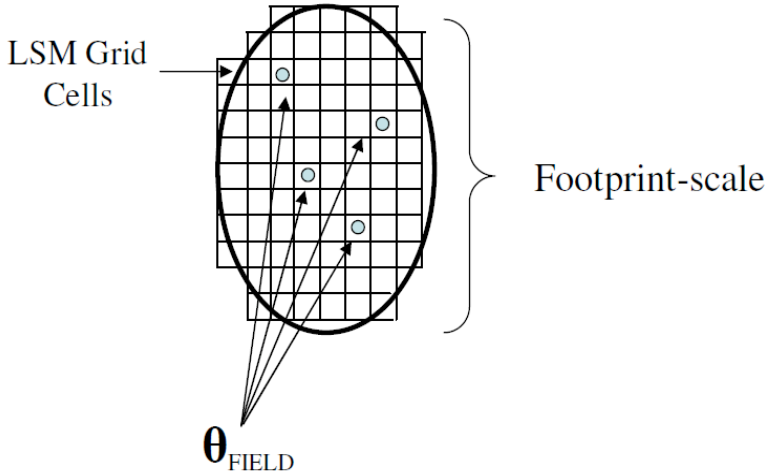
(de Rosnay et al. 2009)



Short-term field campaign activity

3. Improve using Distributed Land Surface Modeling:

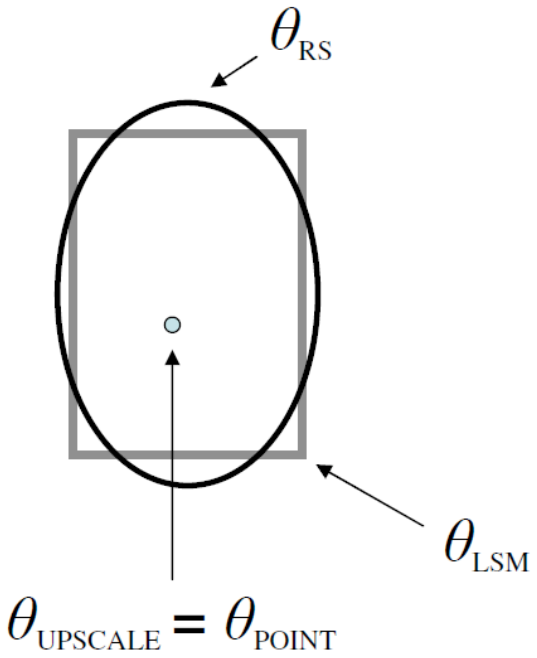
(Crow et al. 2004)

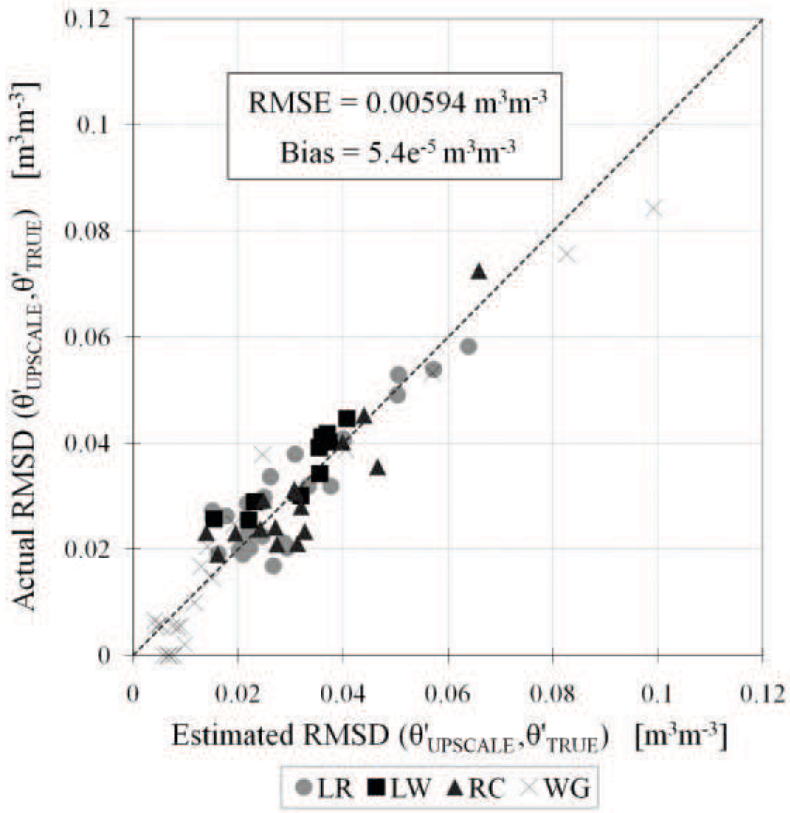


$$\theta_{\mathrm{UPSCALE}} = F_{\uparrow}(\boldsymbol{\theta}_{\mathrm{FIELD}}) = \theta_{\mathrm{FP,LSM}} + N^{-1}\sum_{i=1}^{N}\left(\theta_{i,\mathrm{FIELD}} - \theta_{i,\mathrm{LSM}}\right)$$

Estimating error in F↑

(Miralles et al. 2010)





$$\mathrm{MSD}(\theta_{\mathrm{UPSCALE}}, \theta_{\mathrm{RS}}) = \mathrm{MSD}(\theta_{\mathrm{TRUE}}, \theta_{\mathrm{RS}}) + \mathrm{MSD}(\theta_{\mathrm{UPSCALE}}, \theta_{\mathrm{TRUE}}),$$

Triple Collocation:

$$\mathrm{MSD}(\theta_{\mathrm{UPSCALE}}, \theta_{\mathrm{TRUE}}) = \overline{(\theta_{\mathrm{UPSCALE}} - \theta_{\mathrm{LSM}})(\theta_{\mathrm{UPSCALE}} - \theta_{\mathrm{RS}})}$$

Different strategies can be applied sequentially and may be complementary with regards to strengths e.g.:

✓ Temporal stability is good for point to field upscaling, while model-based upscaling works best from field to footprint.

✓ Short-term field campaign data is good for correcting the bias component of upscaling error, triple collocation is good for addressing the random component.

New measurements strategies (COSMOS, GPS, fiber optic cables) may fundamentally alter the spatial support of ground-based observations.

Future plans:

✓ Finalize white paper by mid-summer (still time for input!).

✓ Opportunities for evaluating upscaling scope/strategies during upcoming field campaigns.