# Time-variable vegetation biases in the SMAP soil moisture product
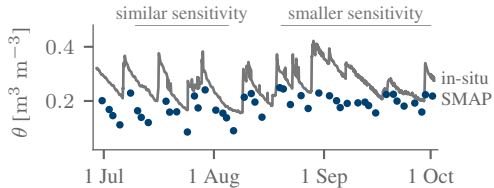
S. Zwieback, A. Colliander, M. Cosh, J. Martínez-Fernández,

H. McNairn, P. Starks, M. Thibeault & A. Berg

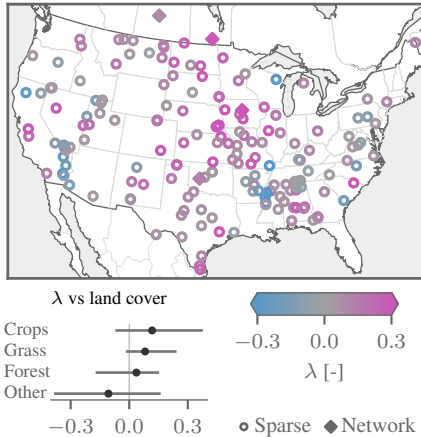23 October 2018

SMAP CalVal Workshop

- Large spurious changes in sensitivity to soil moisture

- Associated with imperfect **vegetation correction**



Summer 2015, South Fork, Iowa

# Particularly pronounced over croplands
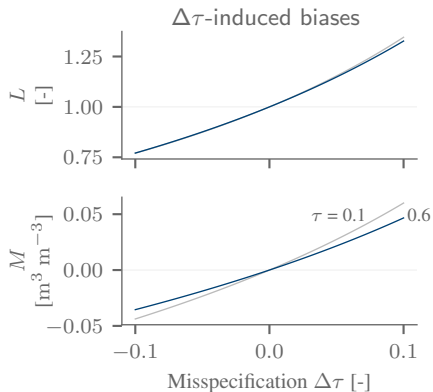
Variability in sensitivity ($\lambda$)



$\lambda$ vs land cover

Crops
Grass
Forest
Other

$-0.3 \quad 0.0 \quad 0.3$

$-0.3 \quad 0.0 \quad 0.3$

$\lambda$ [-]

∘ Sparse  ◆ Network

Ideally: constant sensitivity $\rightarrow \lambda = 0$

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# Erroneous vegetation correction induces biases



Δτ-induced biases

$$y = L(\theta - \theta_0) + \theta_0 + M + \varepsilon$$

$L$: multiplicative bias (sensitivity), $M$: additive bias

$\Delta\tau = \tau_{\mathrm{inv}} - \tau_{\mathrm{true}}$

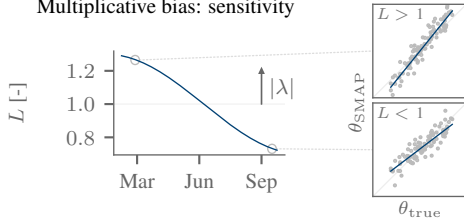error in the vegetation correction in retrieval

## Predicted biases

can be large

linear in $\Delta\tau$ ($\approx$)

independent of $\tau$ ($\approx$)

# Modelling time-variable biases associated with $\Delta\tau$



Multiplicative bias: sensitivity
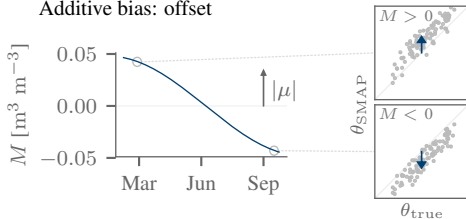
Additive bias: offset

$$L(t) = l + \lambda w_{\Delta\tau}(t)$$
$$M(t) = m + \mu w_{\Delta\tau}(t)$$

$w_{\Delta\tau}$ normalized 0 mean, 1 stdev

## $\lambda$ and $\mu$: bias variability

temporal association with $\Delta\tau$

magnitude: temporal variability

sign: predicted positive

**Triple collocation extended to non-constant error structures**

- no error-free reference product

- in-situ, re-analysis (Merra 2), SMAP

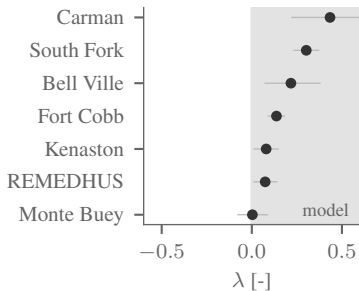Take reference $\tau$ from SMOS (smoothed)

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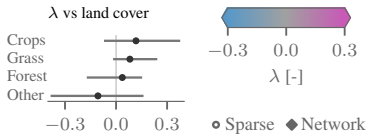
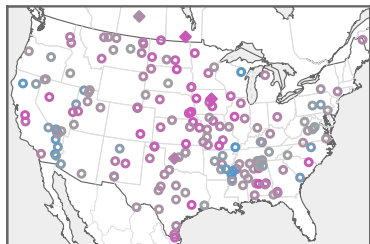# Large changes in sensitivity compared to in-situ networks



## Changing sensitivity at SMAP network sites
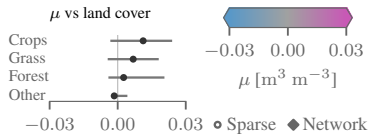
Sensitivity varies by 10 – 40% ($|\lambda|$ of 0.1 – 0.4)

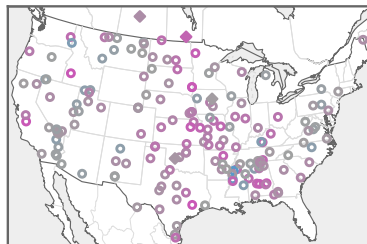$\lambda > 0$, as predicted by $\tau$-$\omega$ model
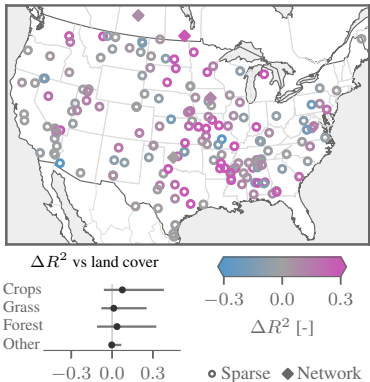
# Spatial patterns: sparse in-situ sites

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# Larger coupling for SMAP than for in-situ



$\Delta R^2 = R^2_{\mathrm{SMAP}\theta,\tau} - R^2_{\mathrm{in-situ}\theta,\tau}$

computed from anomalies

## Distorted coupling estimates

larger coupling than with in-situ
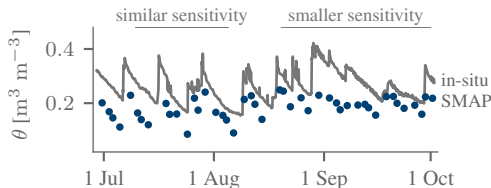
random noise would reduce $R^2$

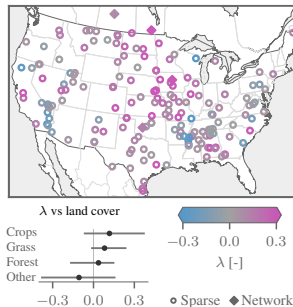patterns match those of biases

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**Biases**

- impede seasonal and inter-annual comparisons

- extremes most affected (e.g. drought)
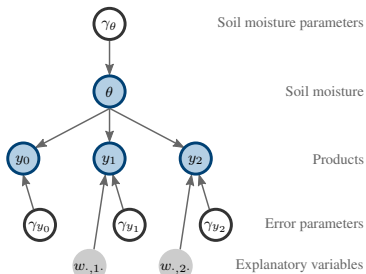
- distort estimates of vegetation-water coupling

- Widespread and large time-dependent biases over croplands

- Associated with imperfect vegetation correction

- Can distort estimates of vegetation–water coupling

# Bayesian triple collocation: Model structure



a) Probabilistic model

$\gamma_\theta$ — Soil moisture parameters

$\theta$ — Soil moisture

$y_0$ $y_1$ $y_2$ — Products

$\gamma_{y_0}$ $\gamma_{y_1}$ $\gamma_{y_2}$ — Error parameters

$w_{\cdot,1\cdot}$ $w_{\cdot,2\cdot}$ — Explanatory variables

b) Inference

Input

$y_0$ $y_1$ $y_2$ $w_{\cdot,1\cdot}$ $w_{\cdot,2\cdot}$

Output

$\gamma_{y_0}$ $\gamma_{y_1}$ $\gamma_{y_2}$ $\theta$ $\gamma_\theta$

Legend

Random variable — Parameter random variable — Explanatory variables