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DEPARTMENT OF **EARTH AND ENVIRONMENTAL SCIENCES**
KU Leuven - BELGIUM

Flanders State of the Art

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Impact of Covariance of Soil Moisture Sensor Measurements on Inverse Estimation of Soil Water Balance Parameters and on Soil Moisture Predictions

Marit G.A. Hendrickx[*1,2], Jan Vanderborght[1,3], Pieter Janssens[4], Jan Diels[1,2]

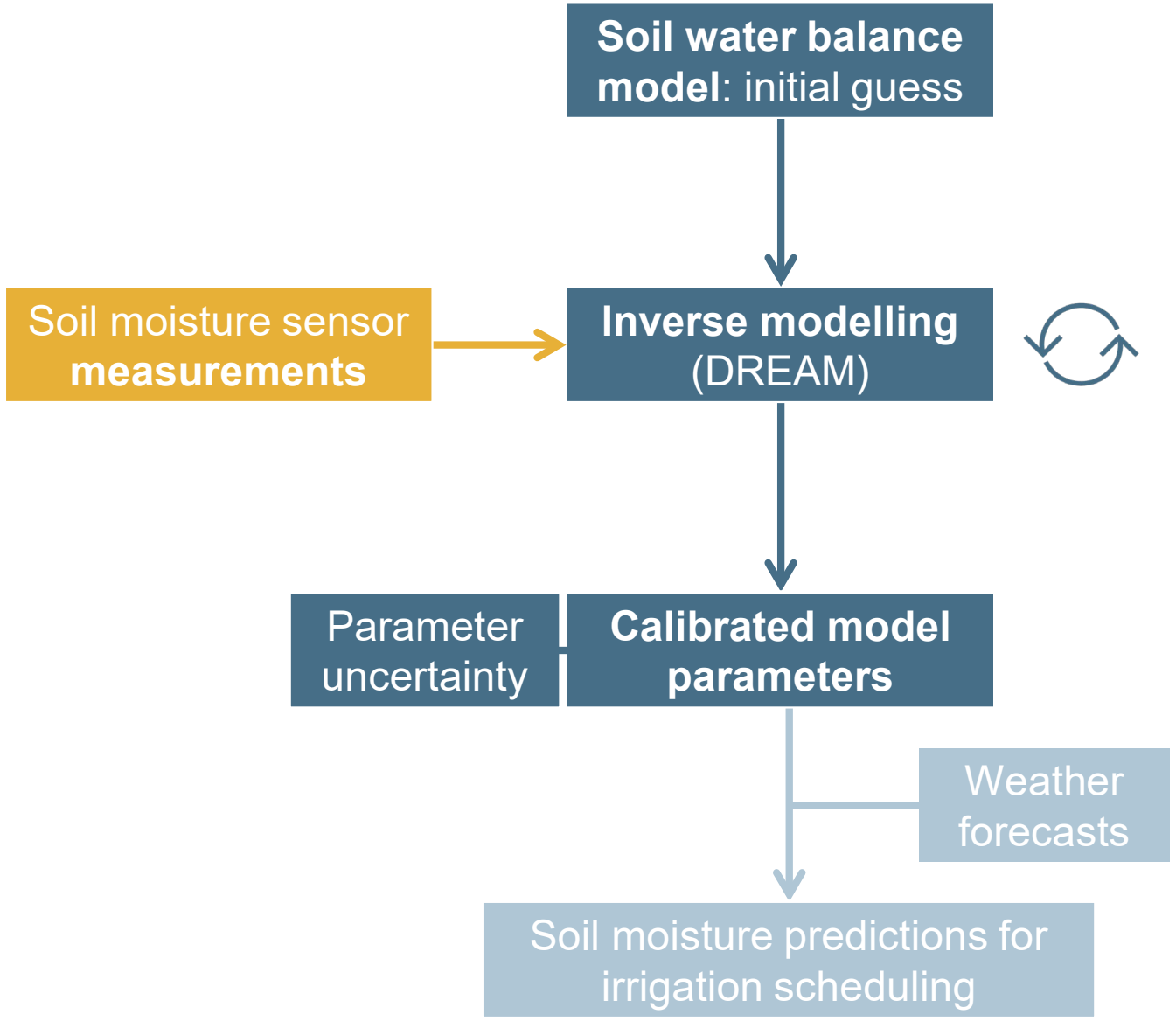
[*] **marit.hendrickx@kuleuven.be**

[1] Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, 3001 Heverlee, Belgium

[2] KU Leuven Plant Institute (LPI), Kasteelpark Arenberg 31, 3001 Leuven, Belgium

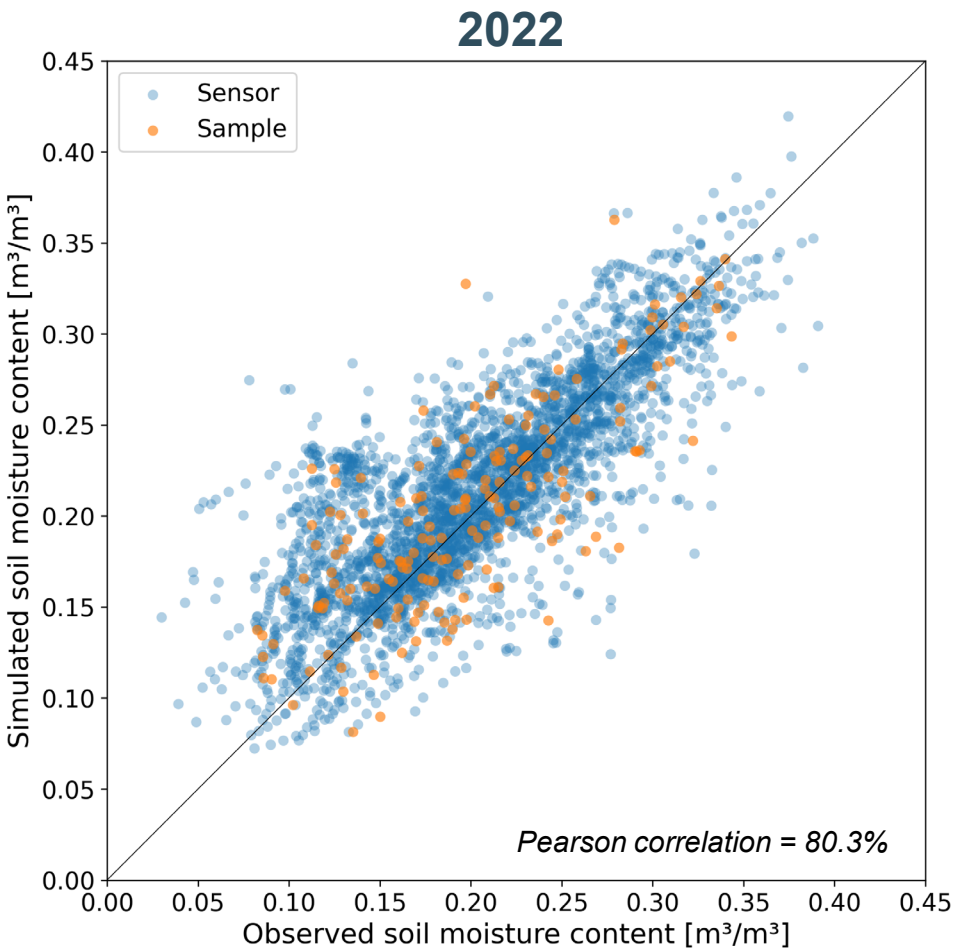
[3] Agrosphere Institute IBG-3, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

[4] Soil Service of Belgium, Willem de Croylaan 48, 3001 Leuven, Belgium


Soil water balance model: initial guess
Soil moisture sensor measurements
Inverse modelling (DREAM)
Parameter uncertainty
Calibrated model parameters
Weather forecasts
Soil moisture predictions for irrigation scheduling

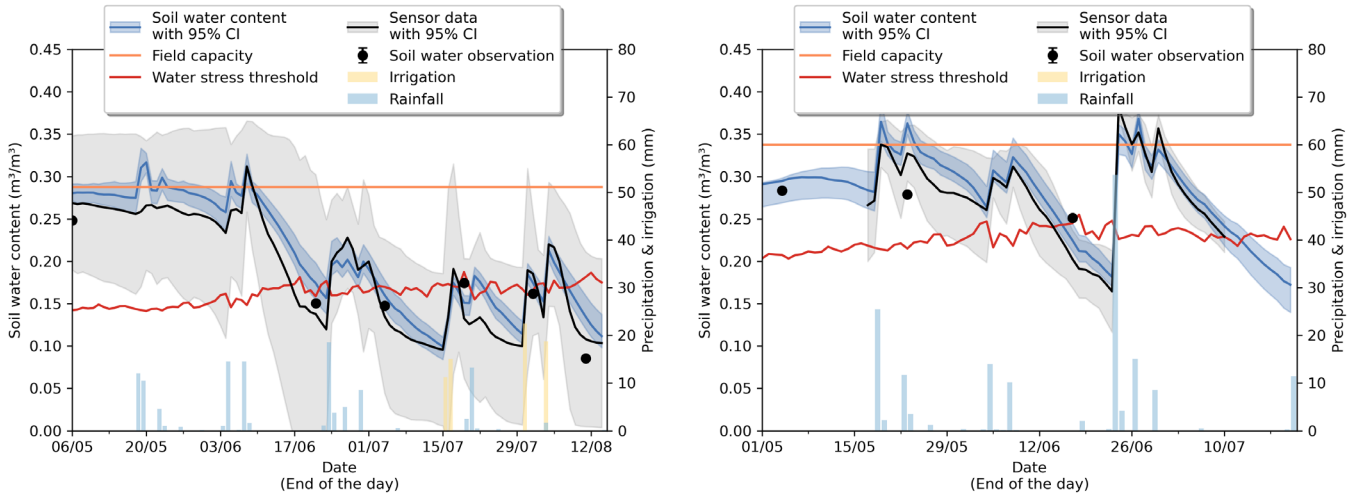
Introduction

Model predictions after inverse estimation



	Sensor data	Soil samples	Both
N [-]	3054	179	3233
ME [m³/m³]	-0.011	-0.005	-0.010
MAE [m³/m³]	0.029	0.031	**0.029**
RMSE [m³/m³]	0.040	0.040	0.040

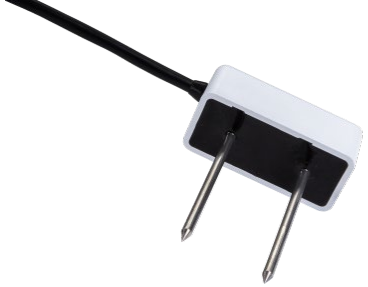
Examples farmers fields 2022

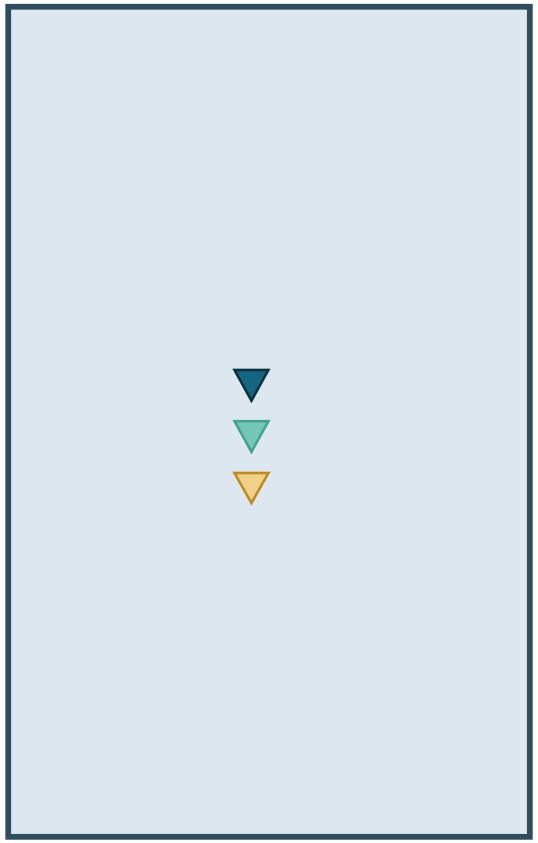


Hendrickx, M., Diels, J., Vanderborght, J., and Janssens, P.: Simulating and predicting soil water content by combining soil water balance calculations, weather forecasts and soil sensors with inverse modelling for optimal irrigation advice: A case study in Flanders, 2022, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-13028, https://doi.org/10.5194/egusphere-egu23-13028, 2023.

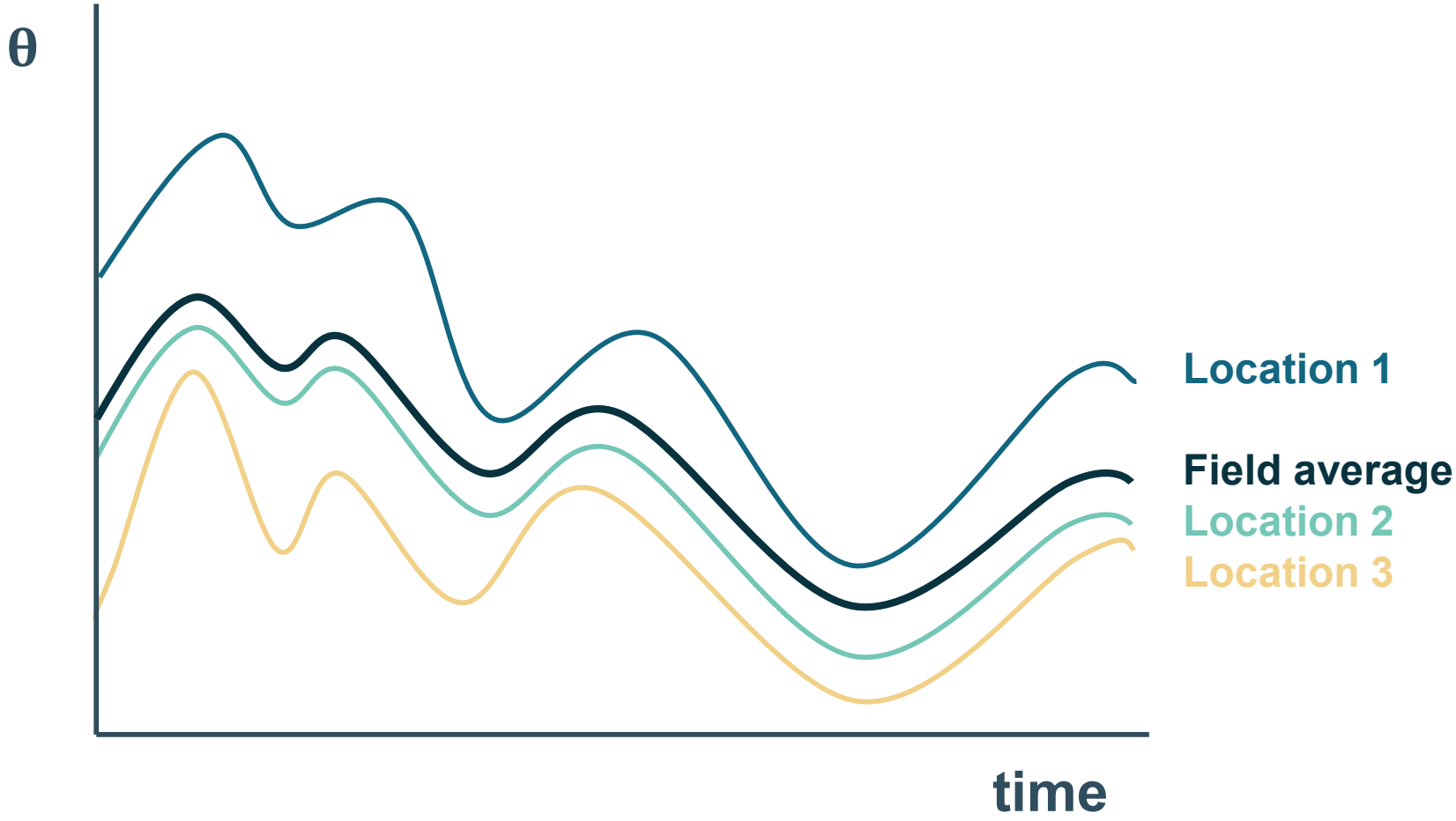
Introduction

Autocorrelated soil moisture sensor measurement errors





▽ Sensor



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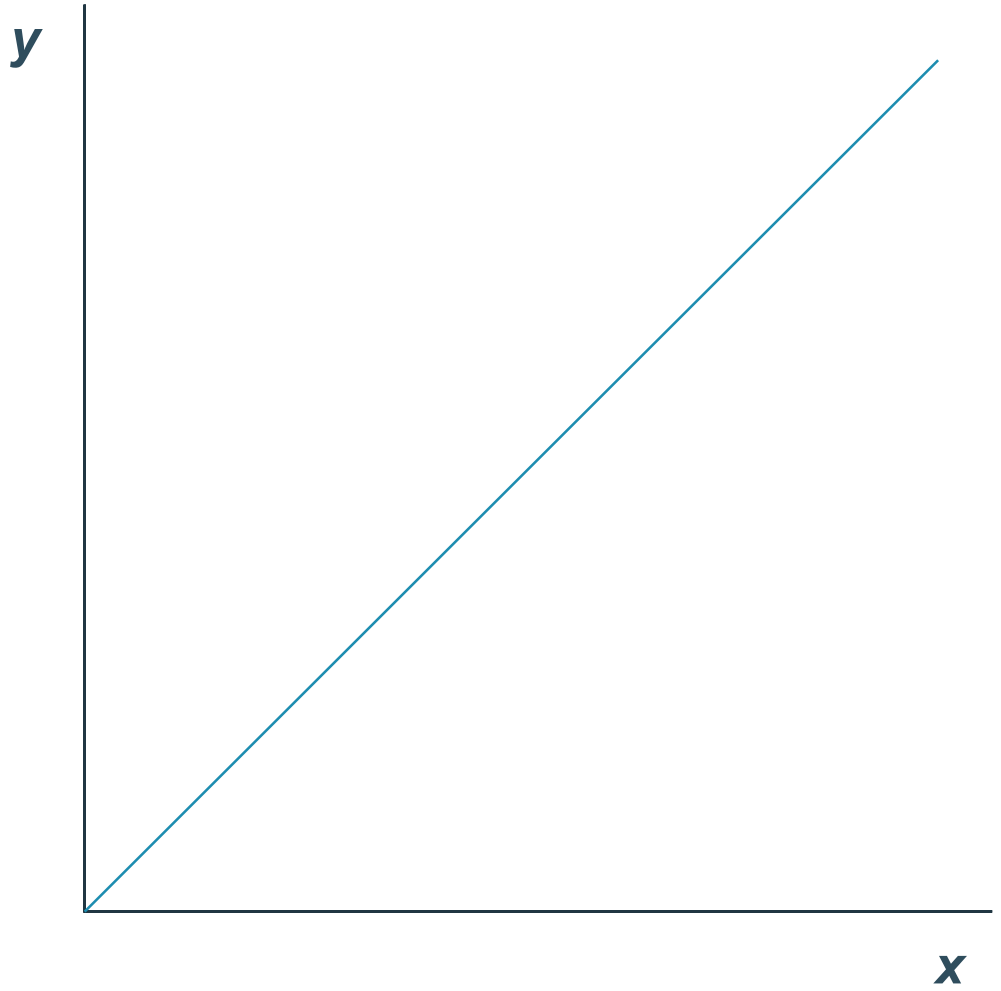
Linear regression (GLS)

Intercept and slope uncertainty depending on measurement error correlation

$y = a + bx$



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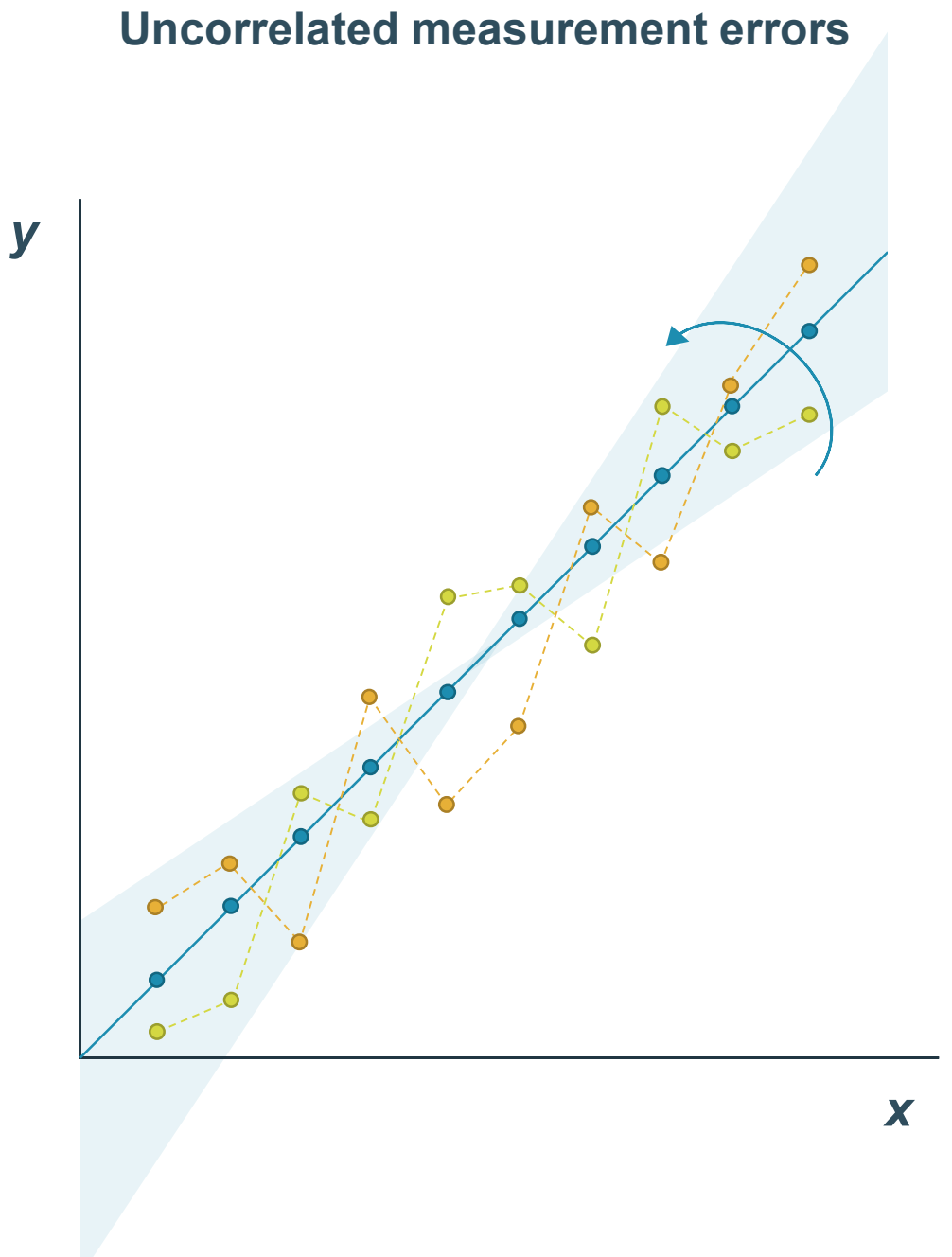

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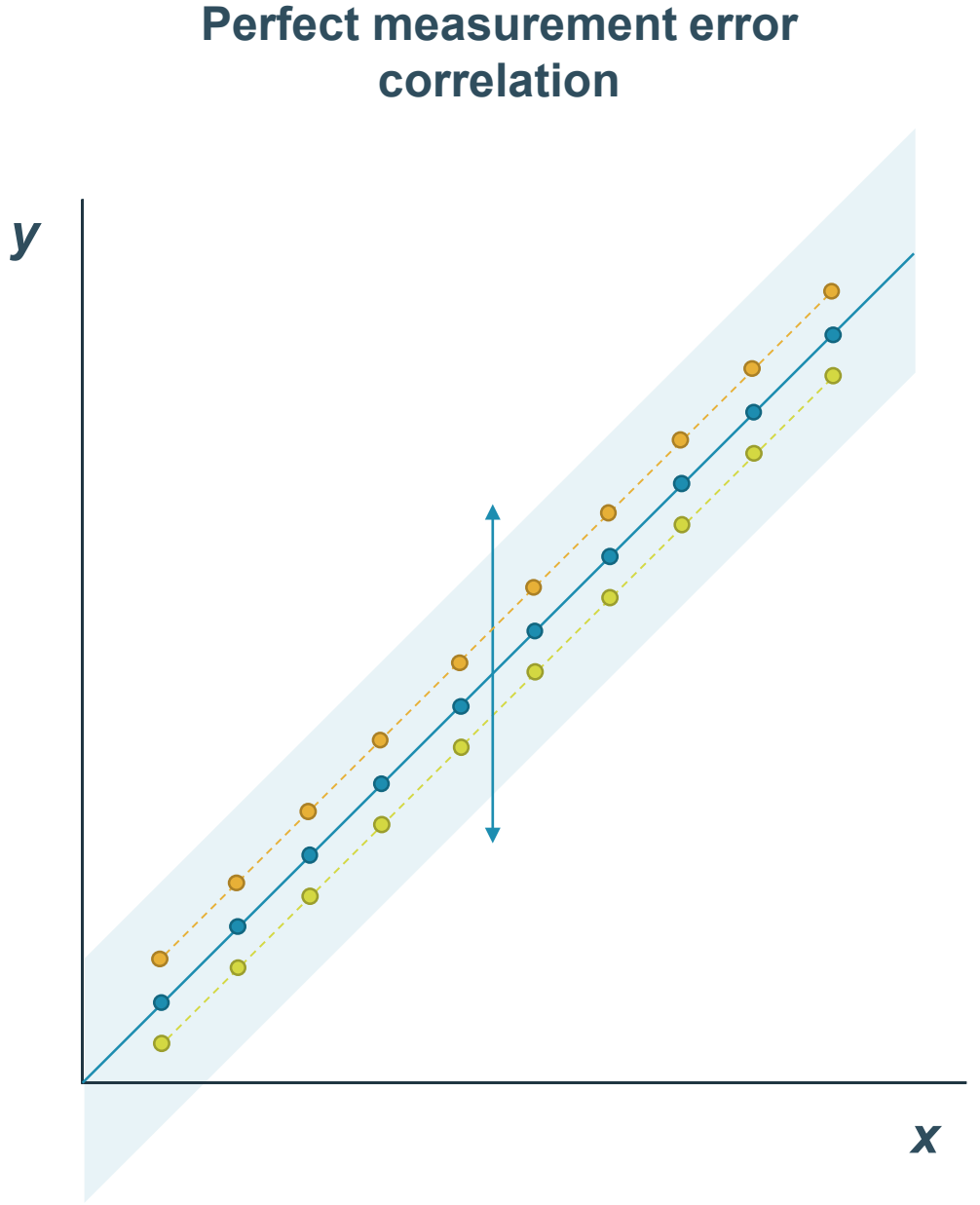
Linear regression (GLS)

Intercept and slope uncertainty depending on measurement error correlation

$y = \mathbf{a} + bx$

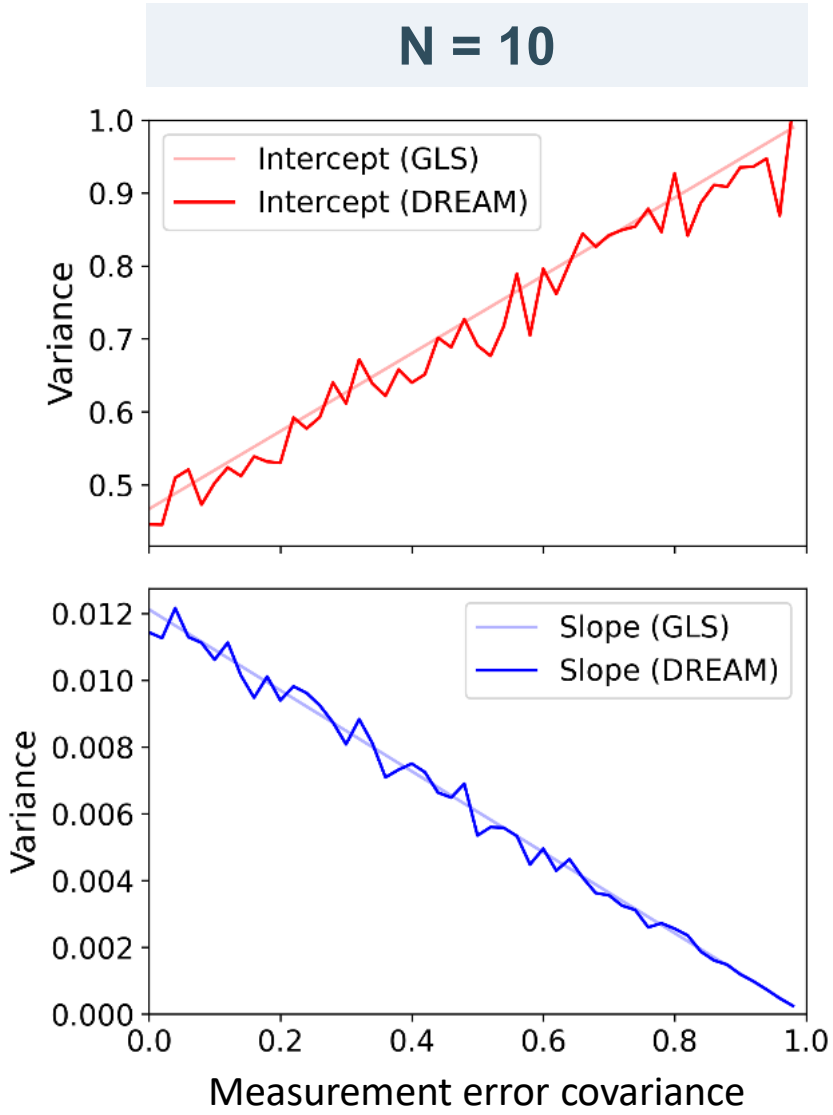
$$COV_{GLS}(a, b) = \sigma^2 (X^T \Sigma^{-1} X)^{-1}$$



Linear regression (GLS)

Parameter uncertainty estimate & approximation with DREAM

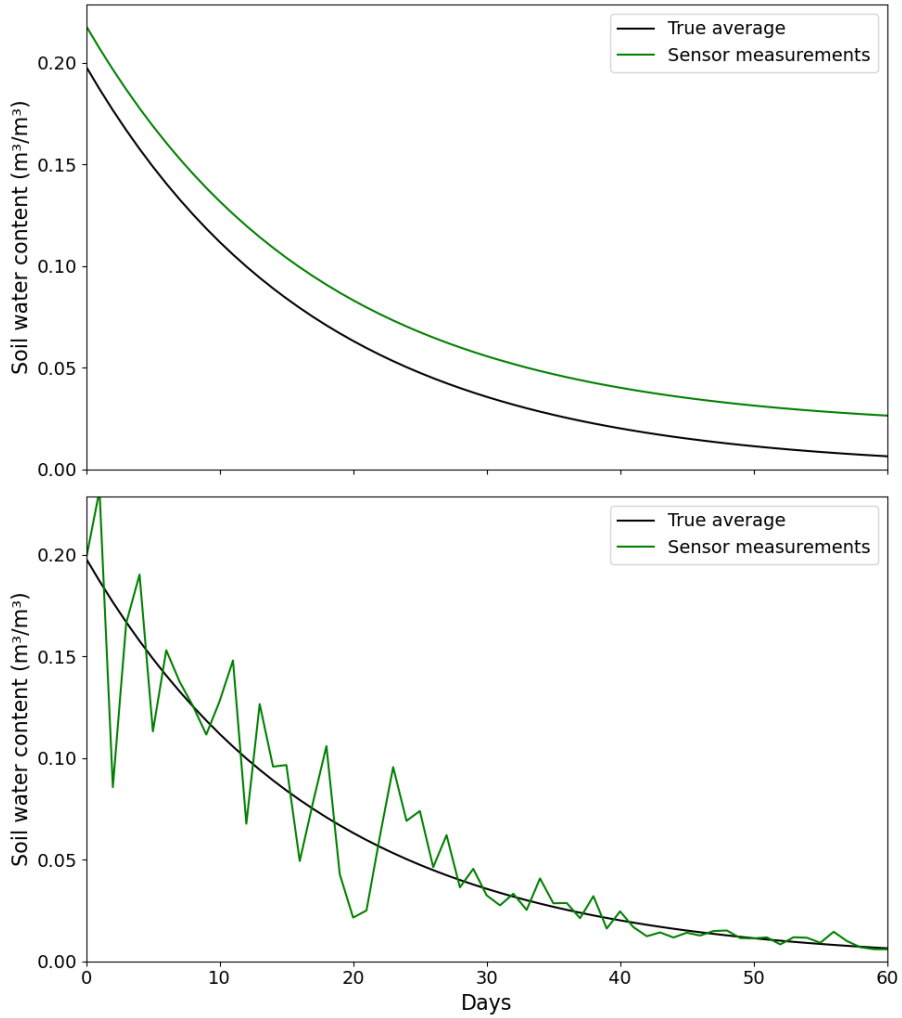
- Homoscedastic errors
- Constant covariance



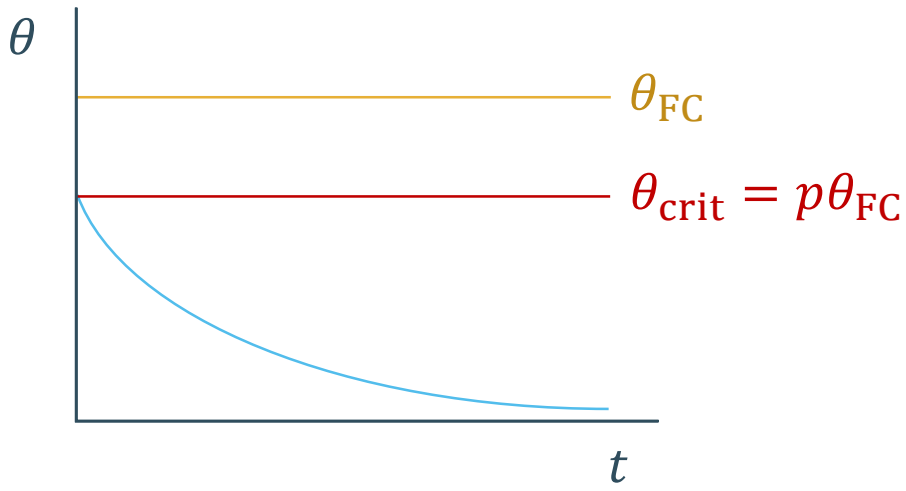
Impact of …

Soil moisture error covariance matrix

$$\begin{bmatrix} \mathrm{Var}(x_1) & \cdots\cdots & \mathrm{Cov}(x_n,x_1) \\ \vdots & \ddots & \vdots \\ \mathrm{Cov}(x_n,x_1) & \cdots\cdots & \mathrm{Var}(x_n) \end{bmatrix}$$



… on a simple soil water balance



Water balance

- Initial soil moisture $\theta_{ini} = \theta_{crit} = p\theta_{FC}$
- Constant ET_o
- Constant root depth Z
- No runoff, no capillary rise
- $\theta_{WP} = 0$

$$\frac{d\bar{S}}{dt} = -\alpha\bar{S}$$

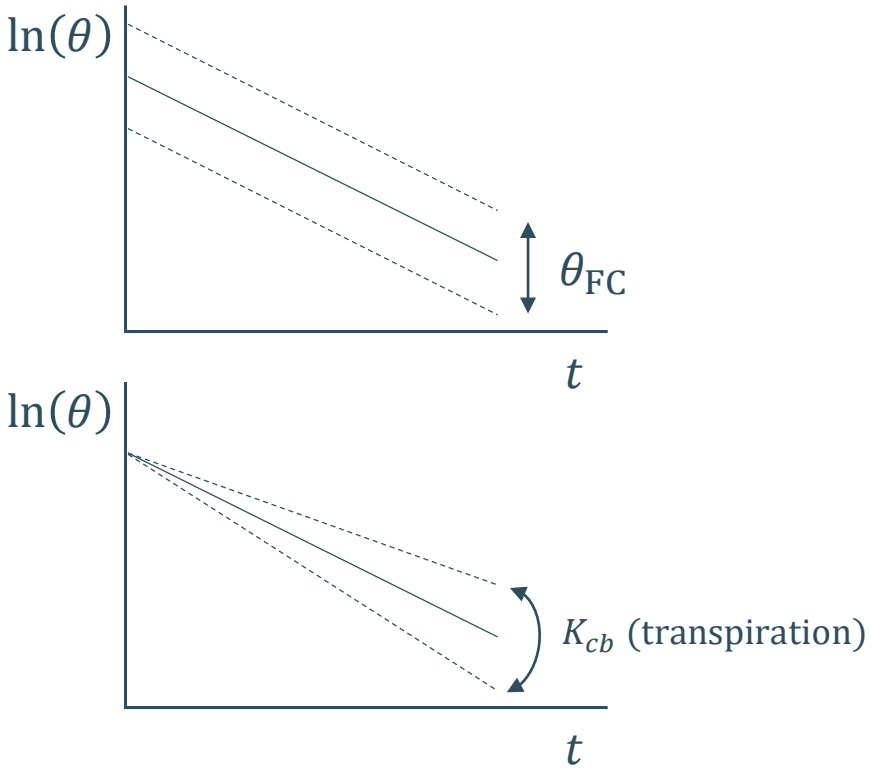
$$\alpha = \frac{K_{cb}\, ET_o}{Z}$$

$$\bar{S} = \frac{\bar{\theta}}{p\bar{\theta}_{FC}} \text{ (for } \bar{\theta} < p\bar{\theta}_{FC})$$

$$\ln(\bar{\theta}) = -\alpha t + \ln(p\bar{\theta}_{FC}) \quad \text{or} \quad \bar{\theta} = e^{-\alpha t}\, p\bar{\theta}_{FC}$$

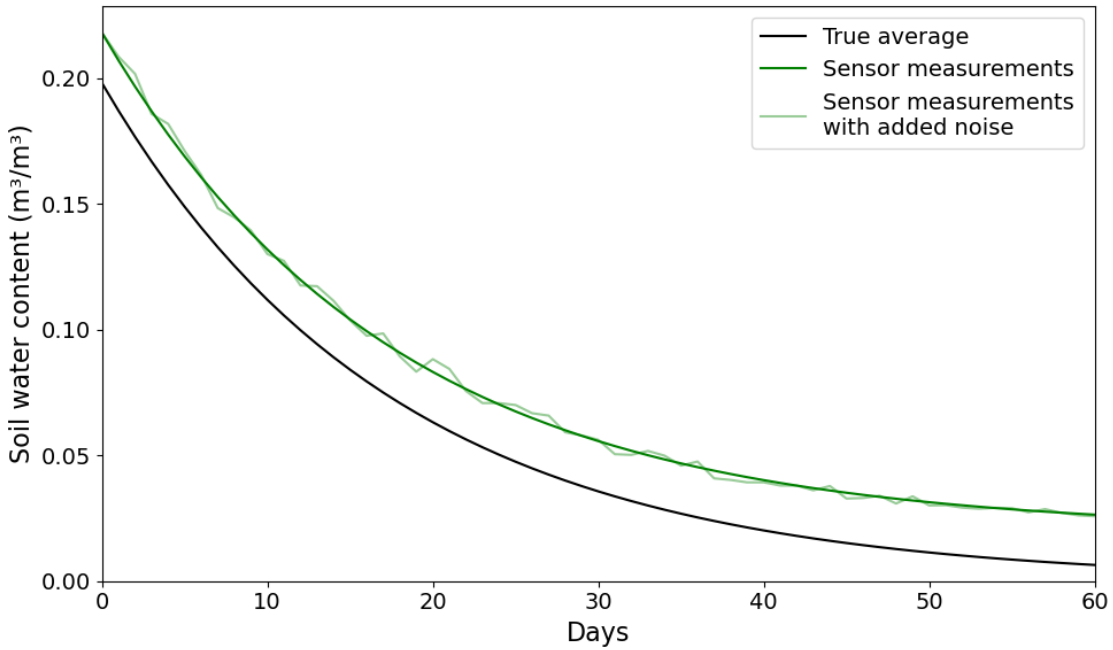
… on a simple soil water balance

$$\ln(\bar{\theta}) = -\alpha t + \ln(p\bar{\theta}_{\mathrm{FC}})$$



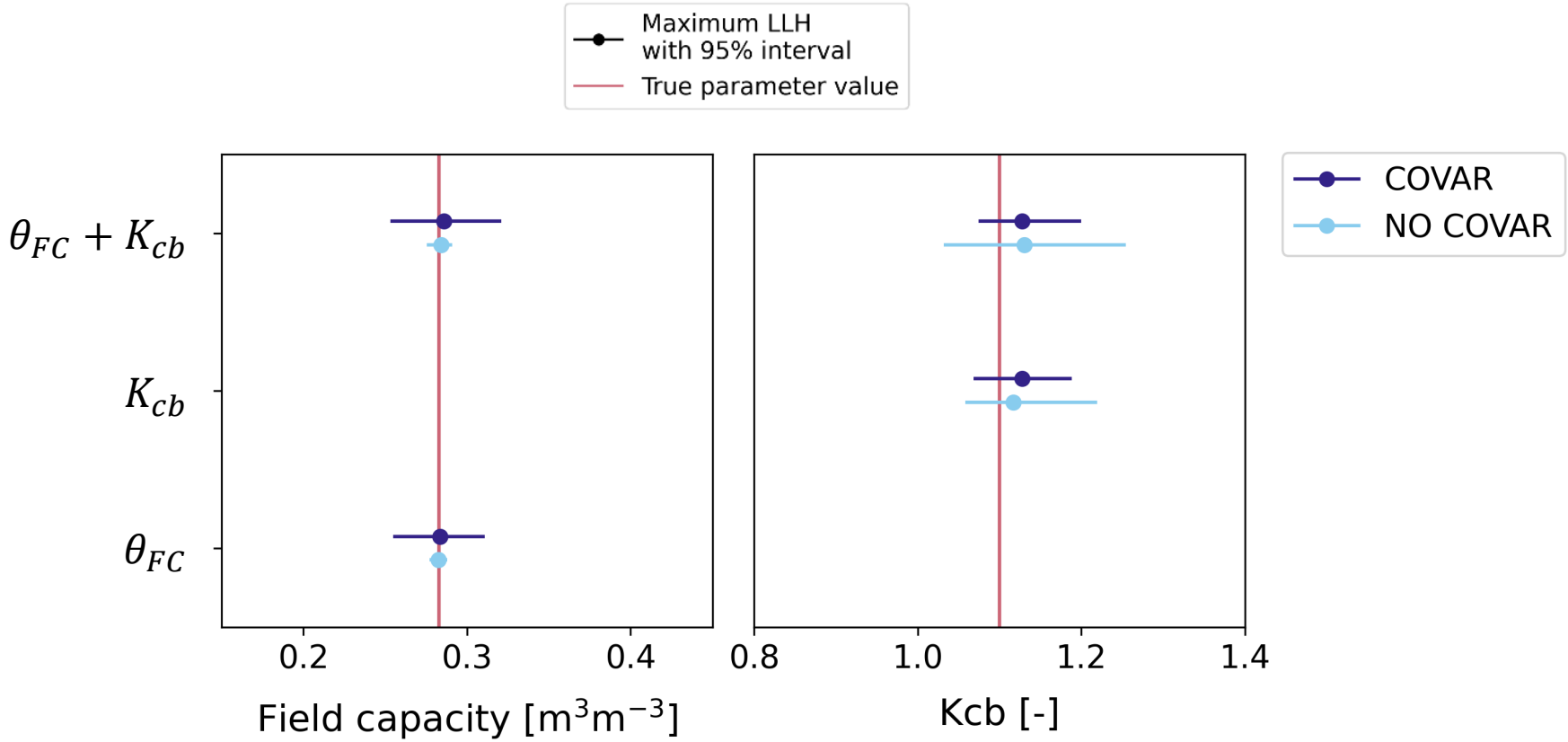
Uncertain parameters estimated in DREAM:

- Field capacity (θ_{FC})
- Crop coefficient (K_{cb})
- θ_{FC} & K_{cb}



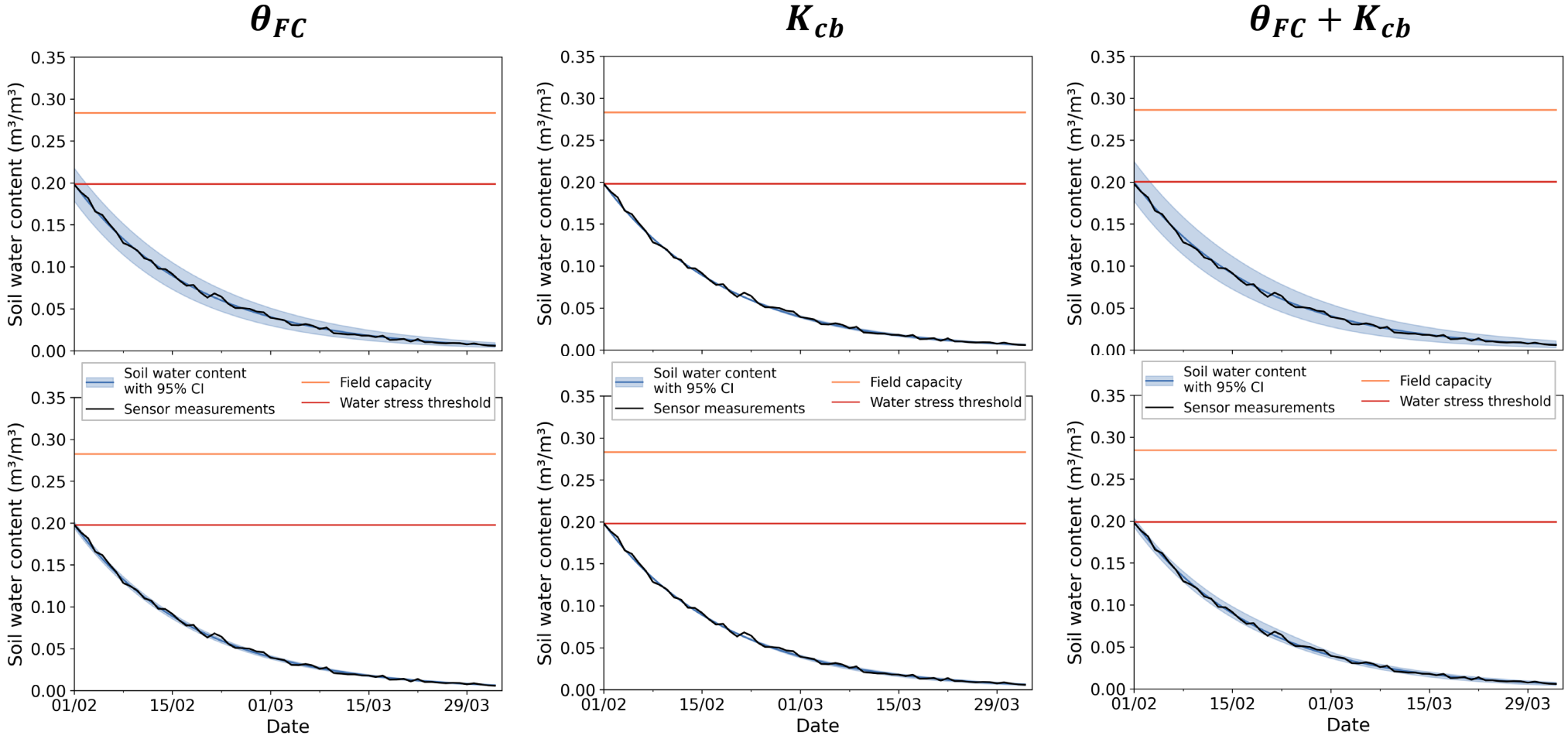
With and without acknowledging error covariance

Parameter estimation • Soil moisture uncertainty • Parameter correlations

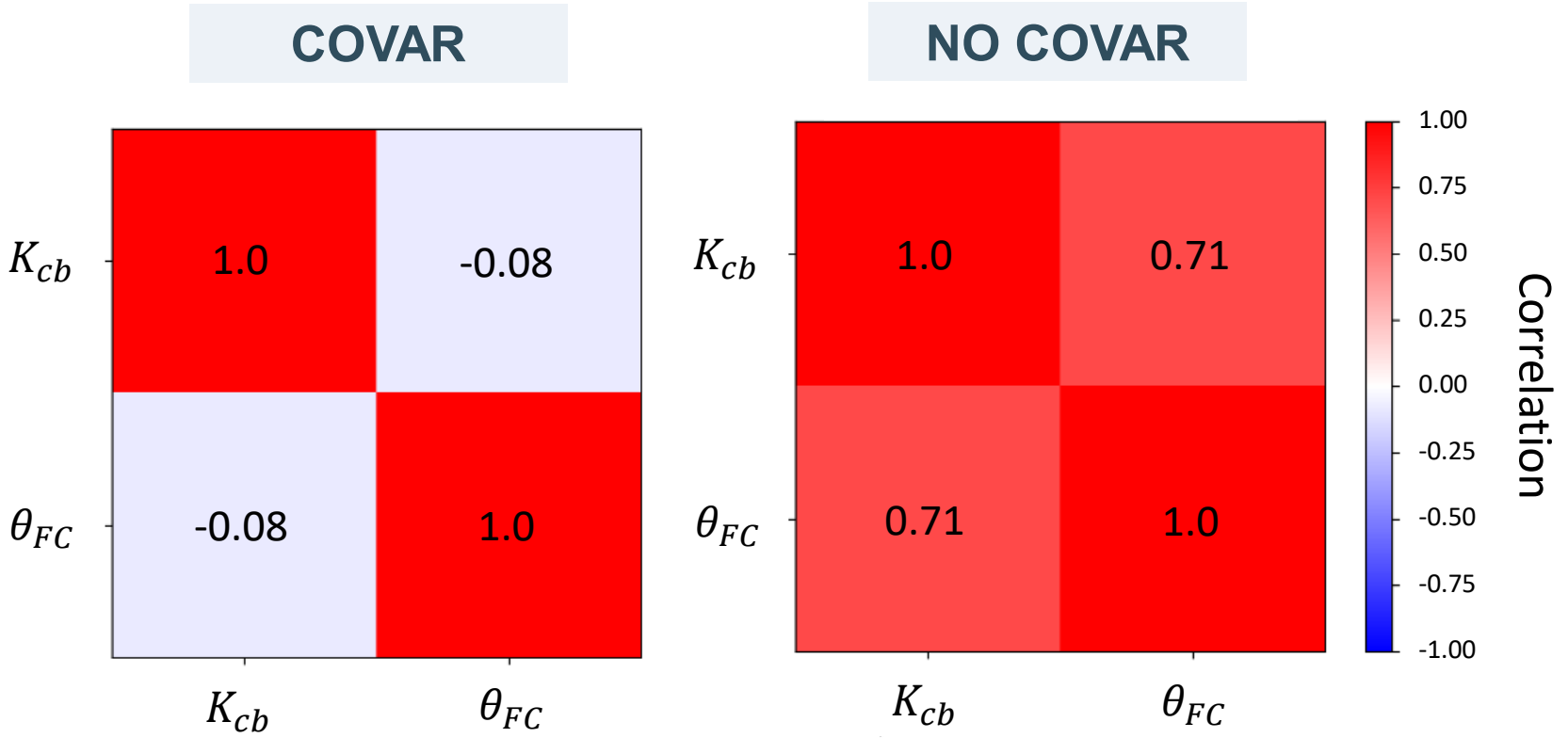


With and without acknowledging error covariance

Parameter estimation • **Soil moisture uncertainty** • Parameter correlations



With and without acknowledging error covariance



Parameter covariance $= \sigma^2 (X^T \Sigma^{-1} X)^{-1}$

Soil moisture sensor measurements

- Measurement errors (i.e. deviations from the field average) exhibit temporal correlation
- Neglecting measurement error autocorrelation is an incorrect assumption

Linear regression: Parameter estimation with GLS or DREAM

- No measurement error correlation
  - → Low intercept uncertainty
  - → High slope uncertainty
- Increasing measurement error correlation
  - → Increasing intercept uncertainty
  - → Decreasing slope uncertainty

Impact of measurement error autocorrelation on a water balance

- Impact on parameter estimation
  - Parameter specific: θ_{FC} acts like intercept, while K_{cb} acts like slope
- Impact on soil moisture uncertainty
- Impact on parameter correlations

marit.hendrickx@kuleuven.be

Soil and Water Management,
KU Leuven (Arenberg)
Celestijnenlaan 200e - box 2411
3001 Leuven

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