How accurately can we retrieve irrigation water amounts from (satellite) soil moisture?

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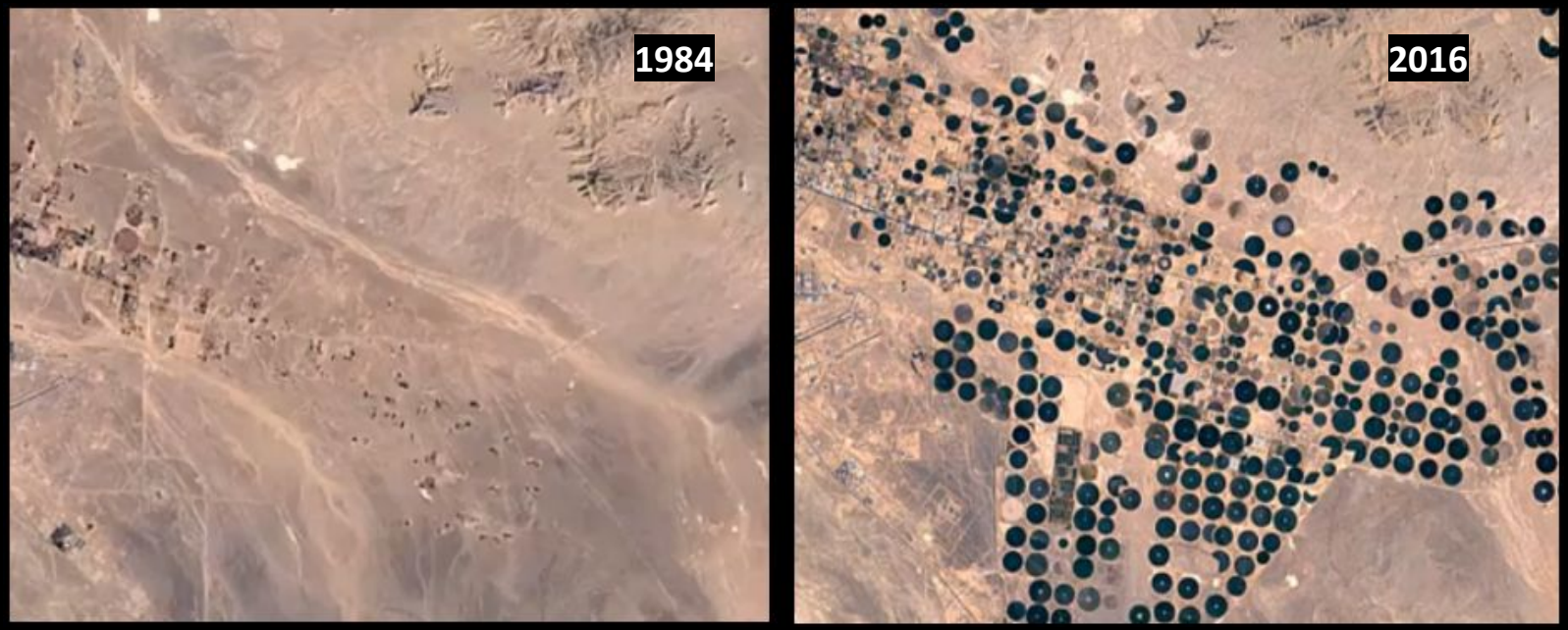
Motivation

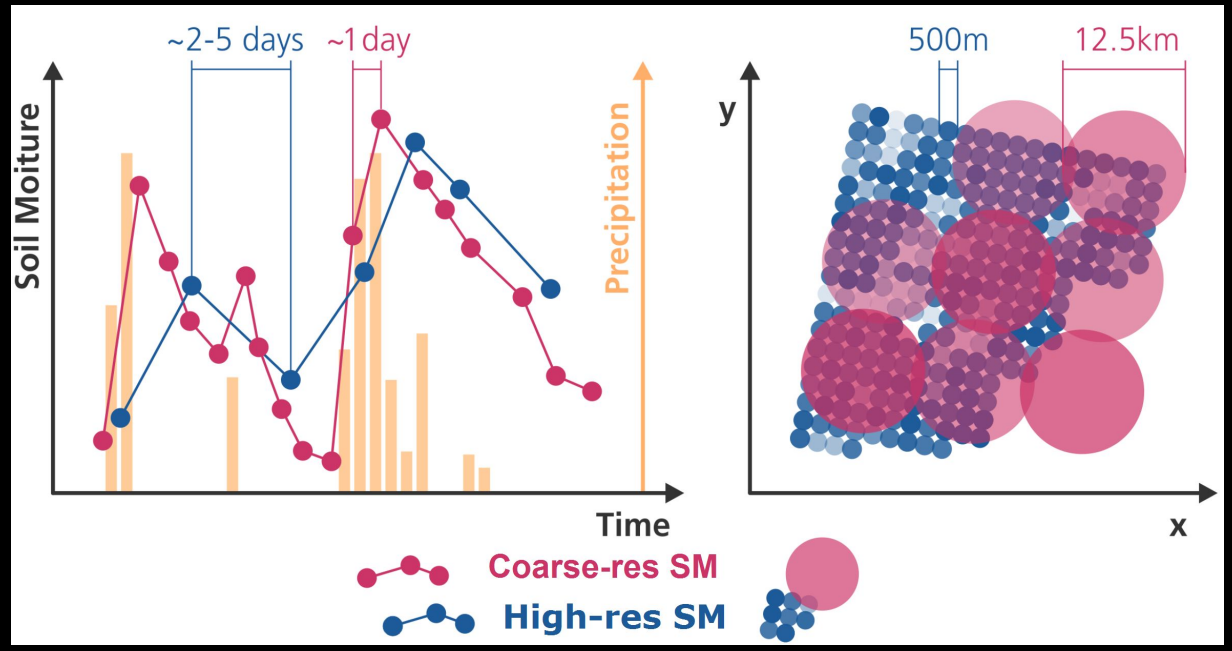
- 70% of freshwater withdrawals used for irrigated agriculture
- population growth, diet changes & warming climate will require further expansion of irrigation



irrigation expansion in Saudi Arabia, 1984-2016

Motivation

- remotely sensed soil moisture (SM) proved a suitable alternative for irrigation monitoring
- trade-off between spatial and temporal resolution



from Bauer-Marschallinger et al. (2018)
Satellite sensors, and derived SM products, with frequent revisit time generally have low spatial resolution, and vice versa

How accurately can we retrieve irrigation water amounts from (satellite) soil moisture?

real world experiment

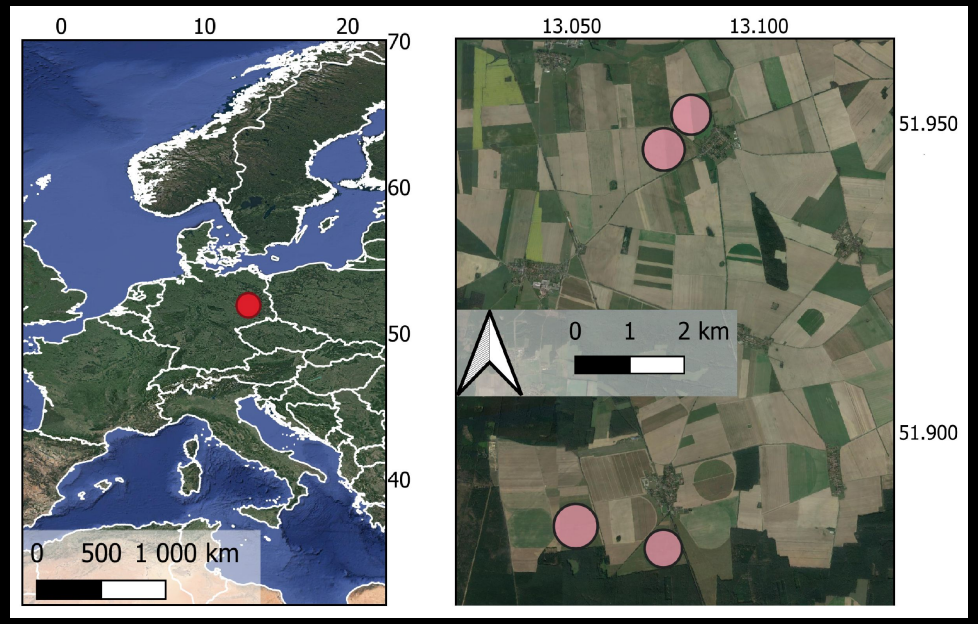
SM simulations forced with *ground measurements* of Prec, Temp, Irr

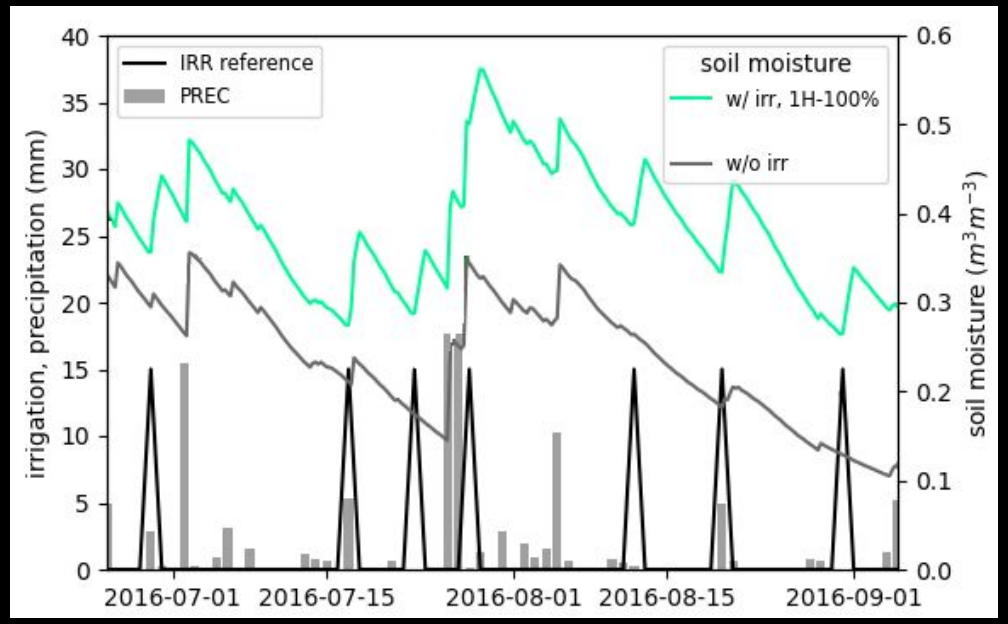
synthetic experiment

SM simulations forced with *prescribed* Irr and defined spatio-temporal resolution

Data - real world experiment

- soil moisture simulations* based on actual observations: P, T, Irr (both with and without)





*Soil Water Balance Model, SWBM (Brocca et al., 2008, 2014)

Data - real world experiment

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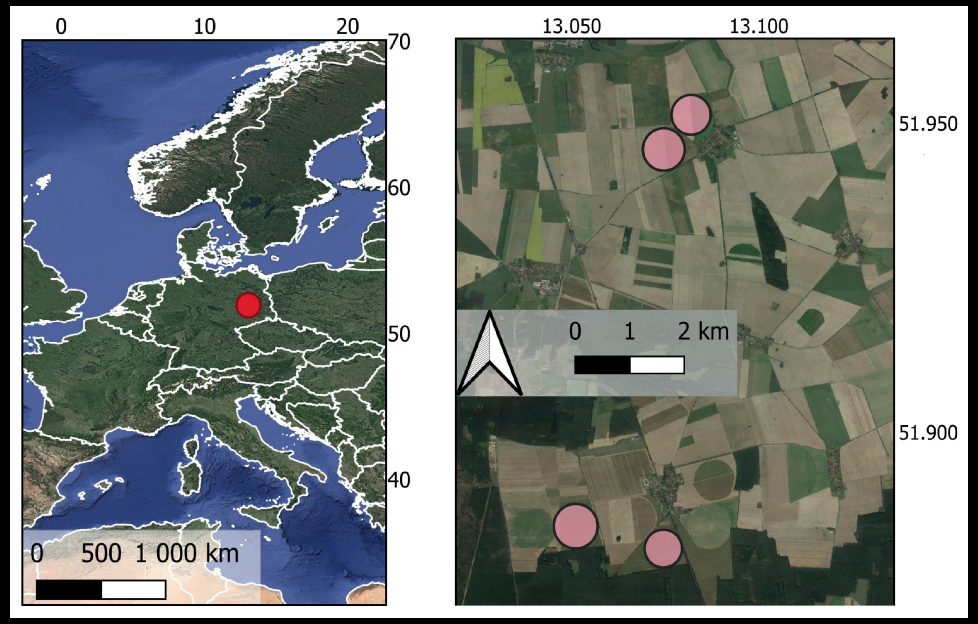
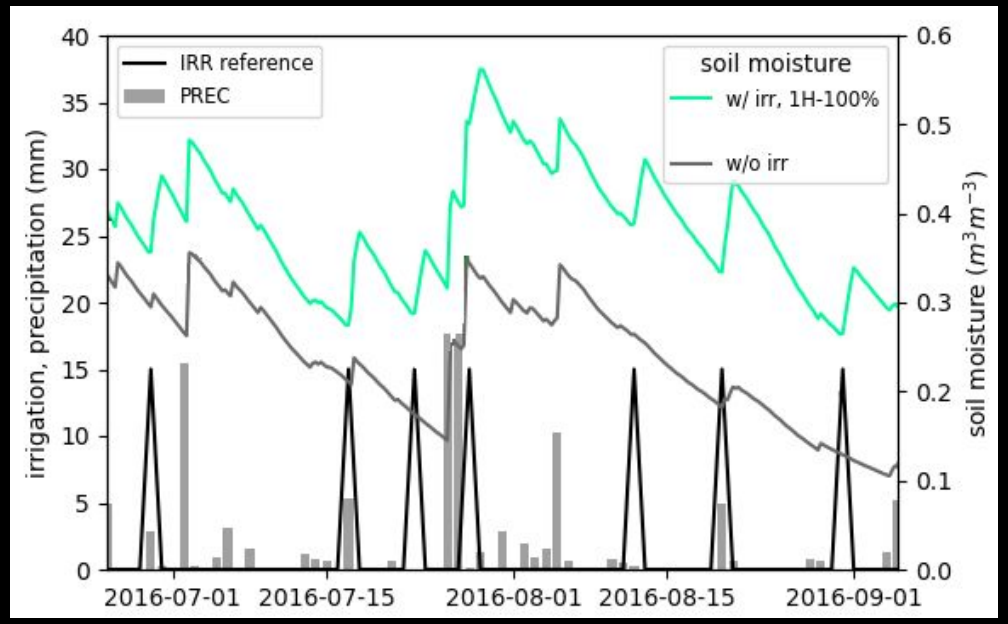


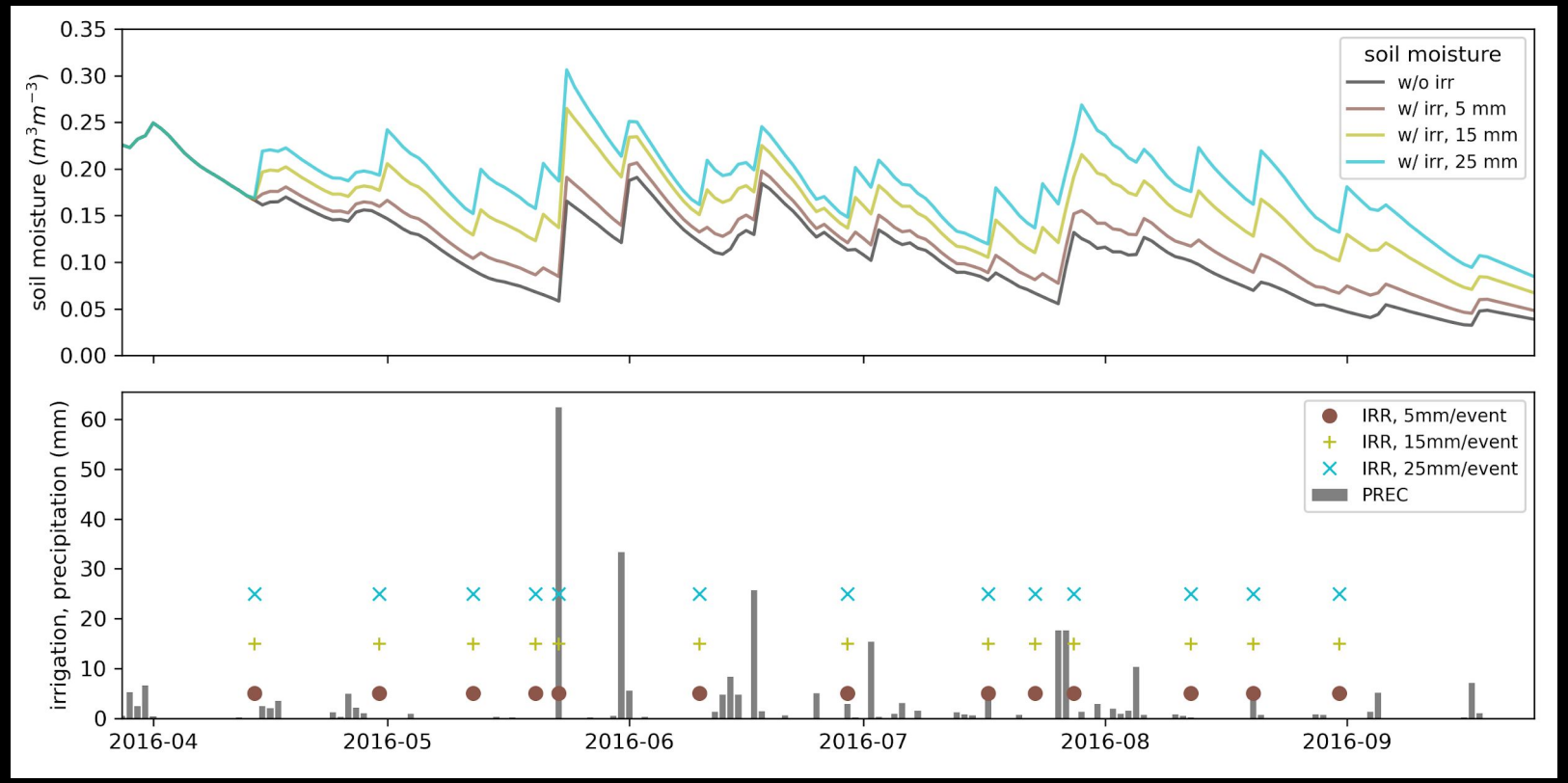


→ compared with satellite SM products

*Soil Water Balance Model, SWBM (Brocca et al., 2008, 2014)

Data - synthetic experiment

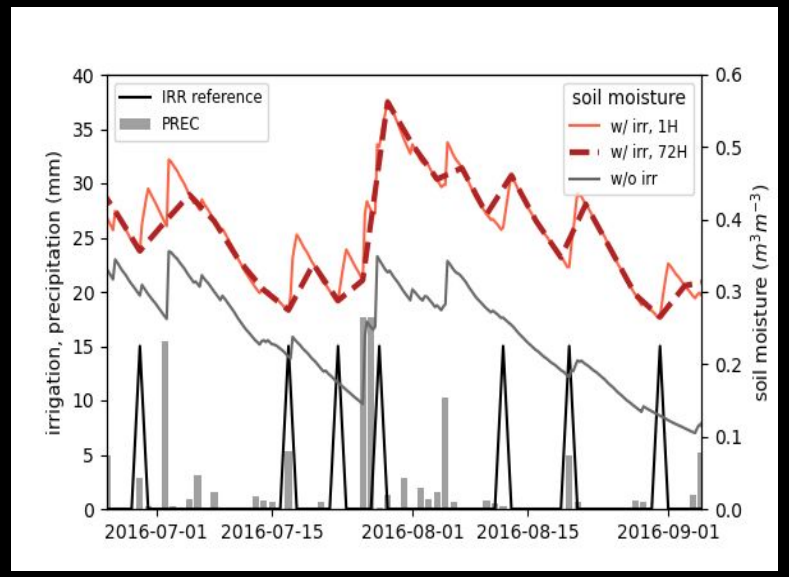
- model simulations allow us to investigate: irrigation water volumes



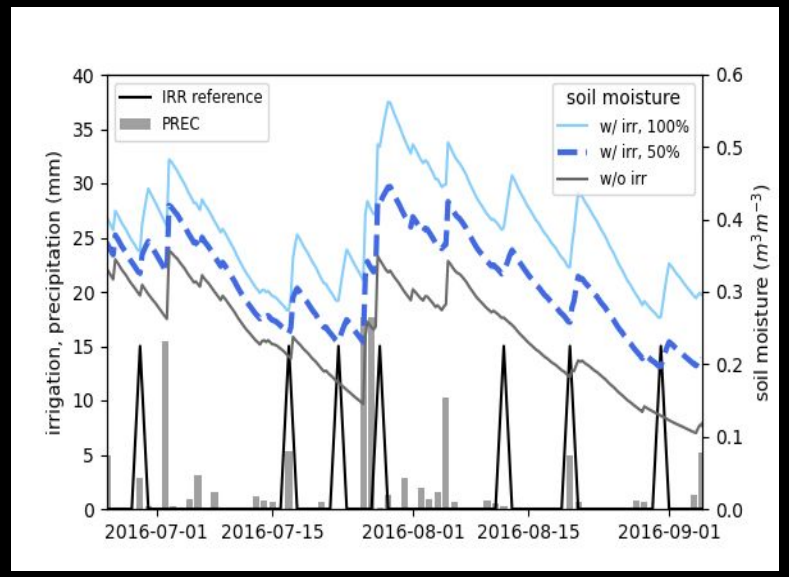
Data - synthetic experiment

- model simulations allow us to investigate:

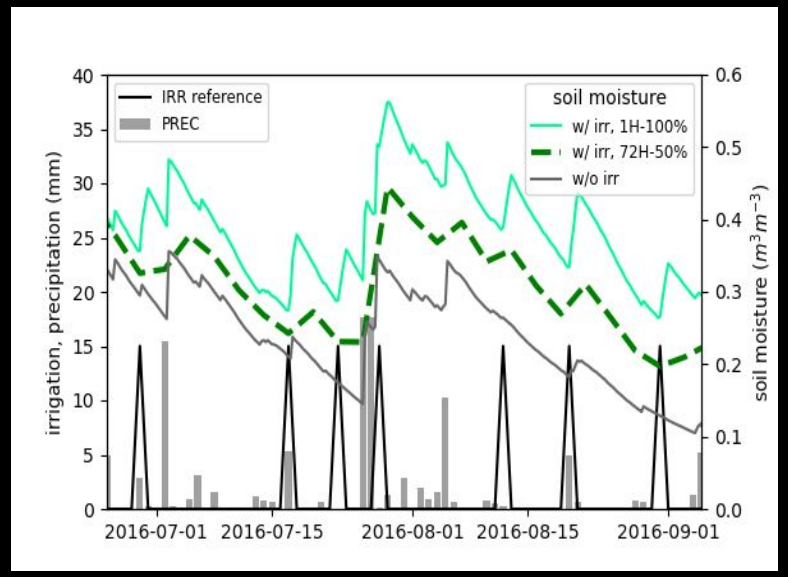
temporal res.



spatial res. (% irrigated)

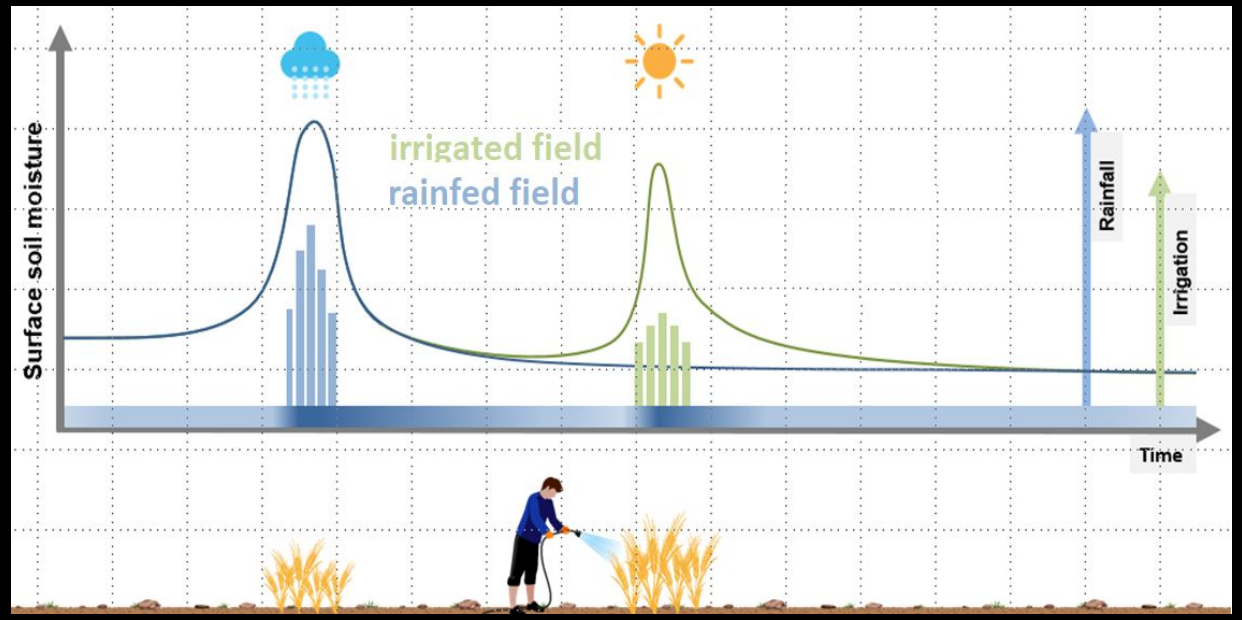


spatio-temporal res.



Irrigation retrieval*

- basic idea: an irrigated field (or satellite pixel) has different SM dynamics compared to surrounding non-irrigated fields (or satellite pixels)



$$\frac{dSM_{w/\,irr}}{dt} = I_t + P_t - ET_t - sr_t - g_t$$

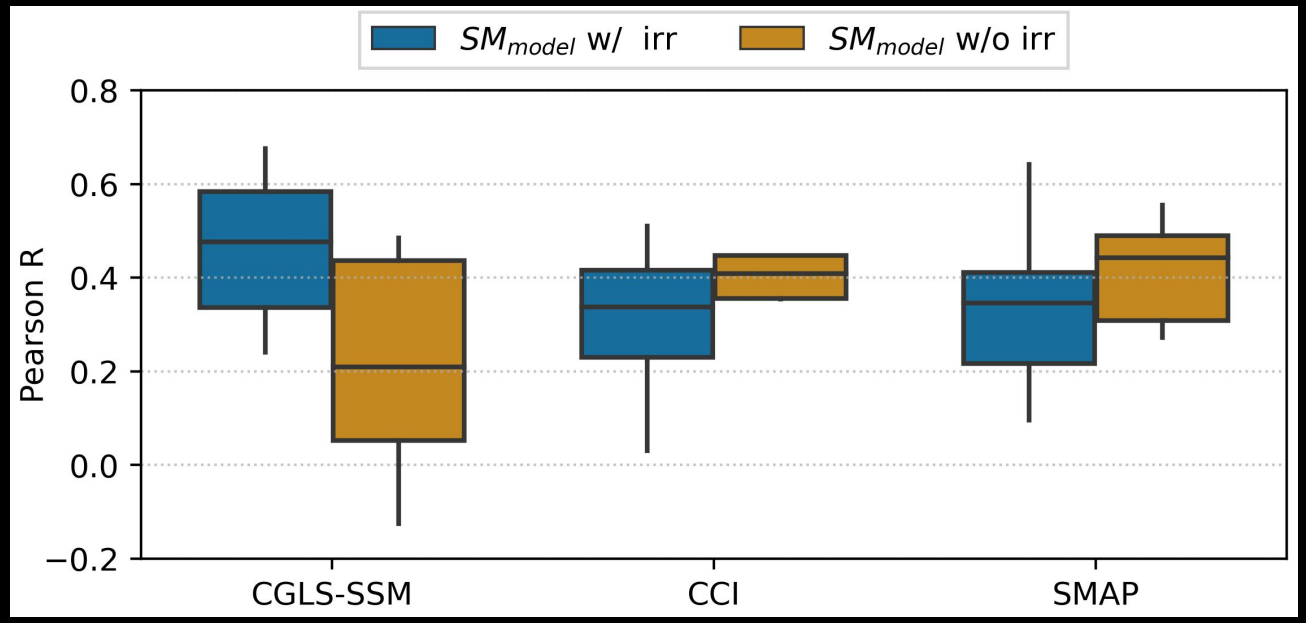
$$\frac{dSM_{w/o\,irr}}{dt} = P_t - ET_t - sr_t - g_t$$

$$I_t = \frac{dSM_{w/\,irr}}{dt} - \frac{dSM_{w/o\,irr}}{dt}$$

** Zappa et al (2021), "Detection and Quantification of Irrigation Water Amounts at 500 m Using Sentinel-1 Surface Soil Moisture"*

Real world experiment

Consistency between SM simulations and satellite products

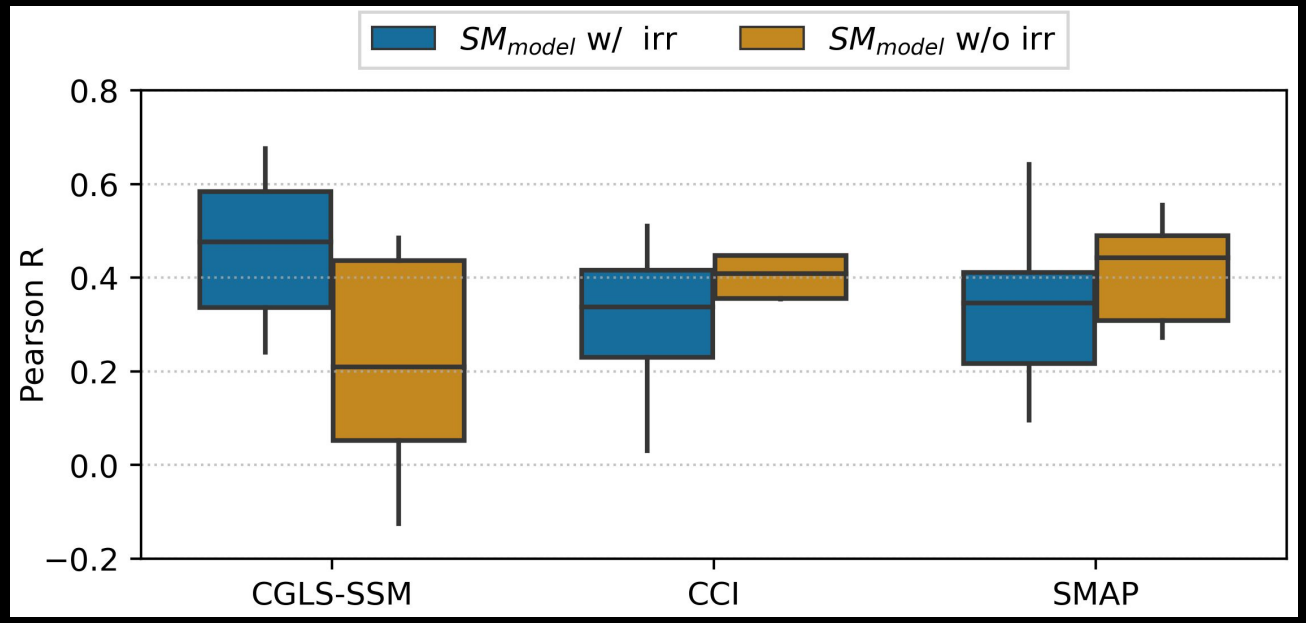


1 km	0.25°	36 km
1.5-4 d	1 d	1-3 d

- CGLS-SSM shows considerably better agreement with simulations including irrigation
- CCI and SMAP are more correlated to large-scale dynamics (rainfed)

Real world experiment

Consistency between SM simulations and satellite products



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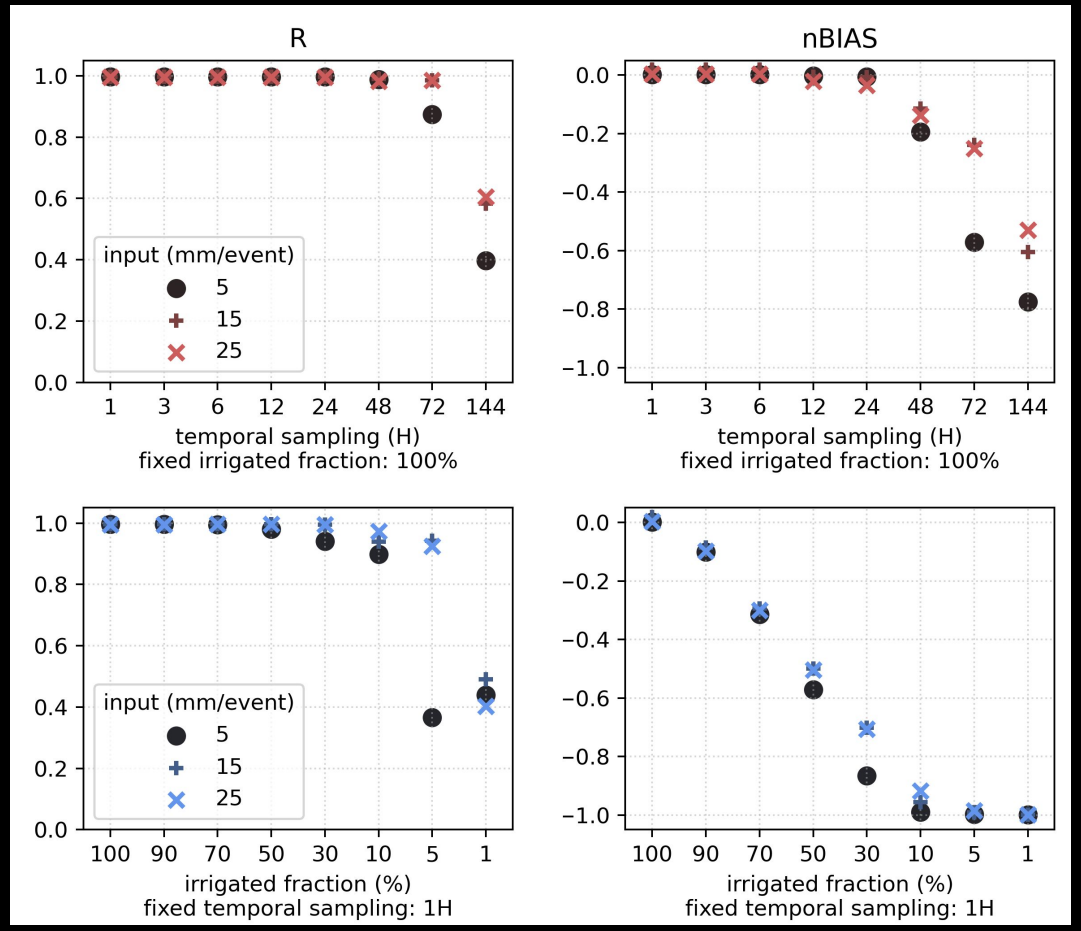
⟶ potential for irrigation monitoring using high-res SM

Synthetic experiment
Impact of temporal and spatial resolution



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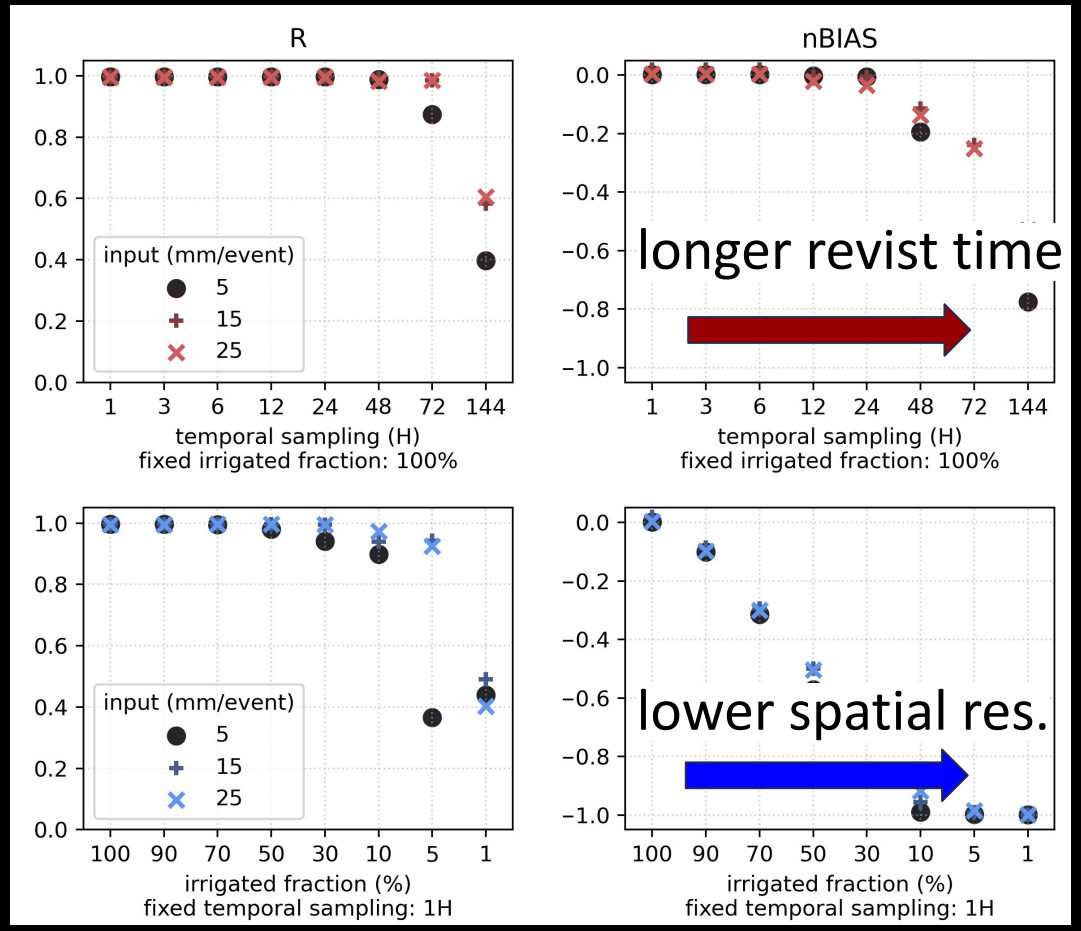
Impact of temporal and spatial resolution



Synthetic experiment
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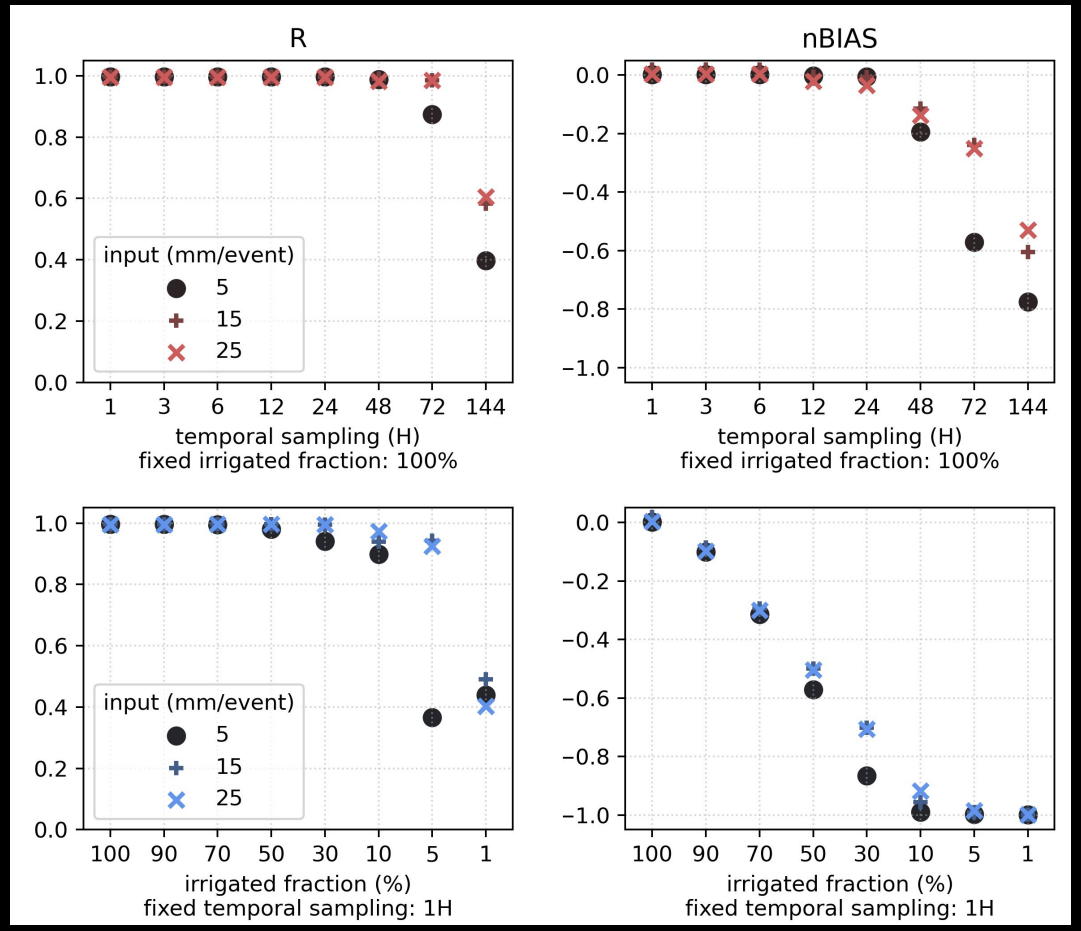

strong correlation, regardless of irrigation rate, with:
- temporal samplings up to 72 hours
- irrigated fractions as small as 10%

negligible underestimations (nBIAS) for:
- temporal samplings up to 48 hours
- irrigated fractions between 70-100%

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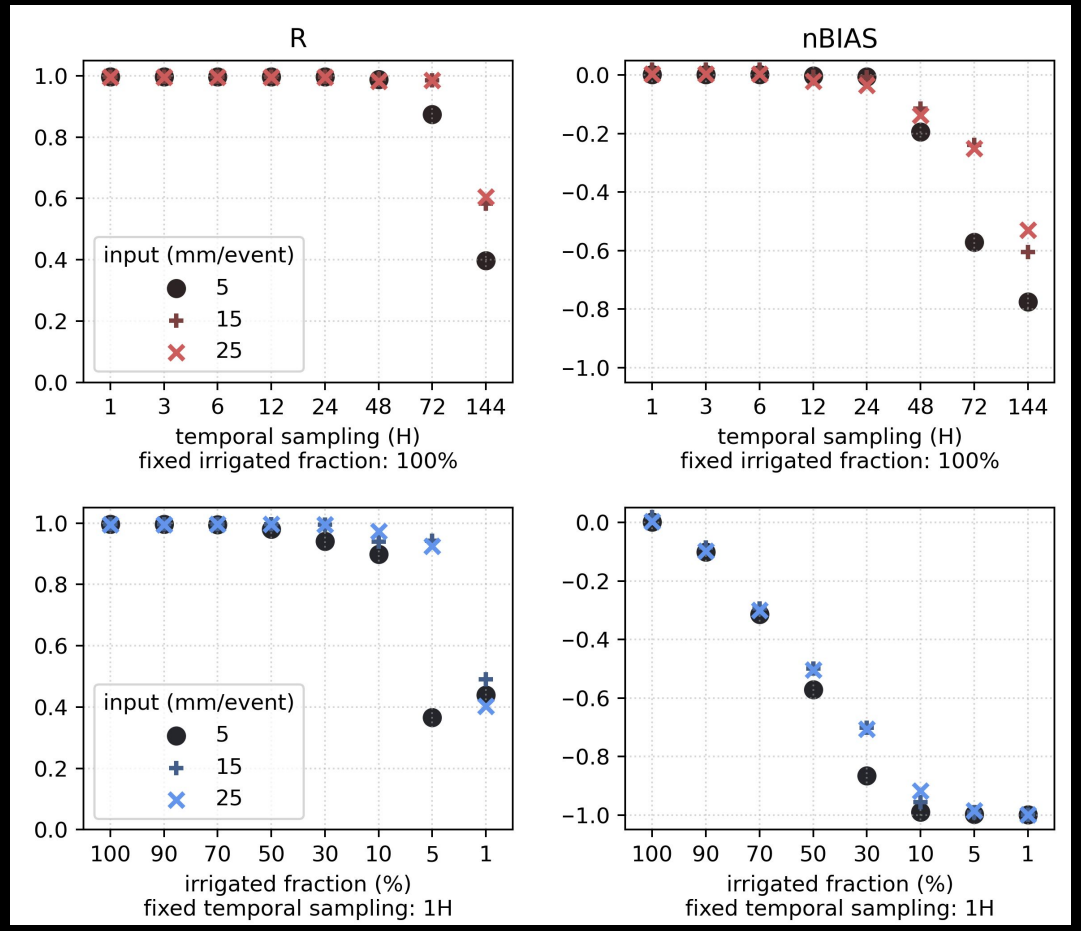
Impact of temporal and spatial resolution



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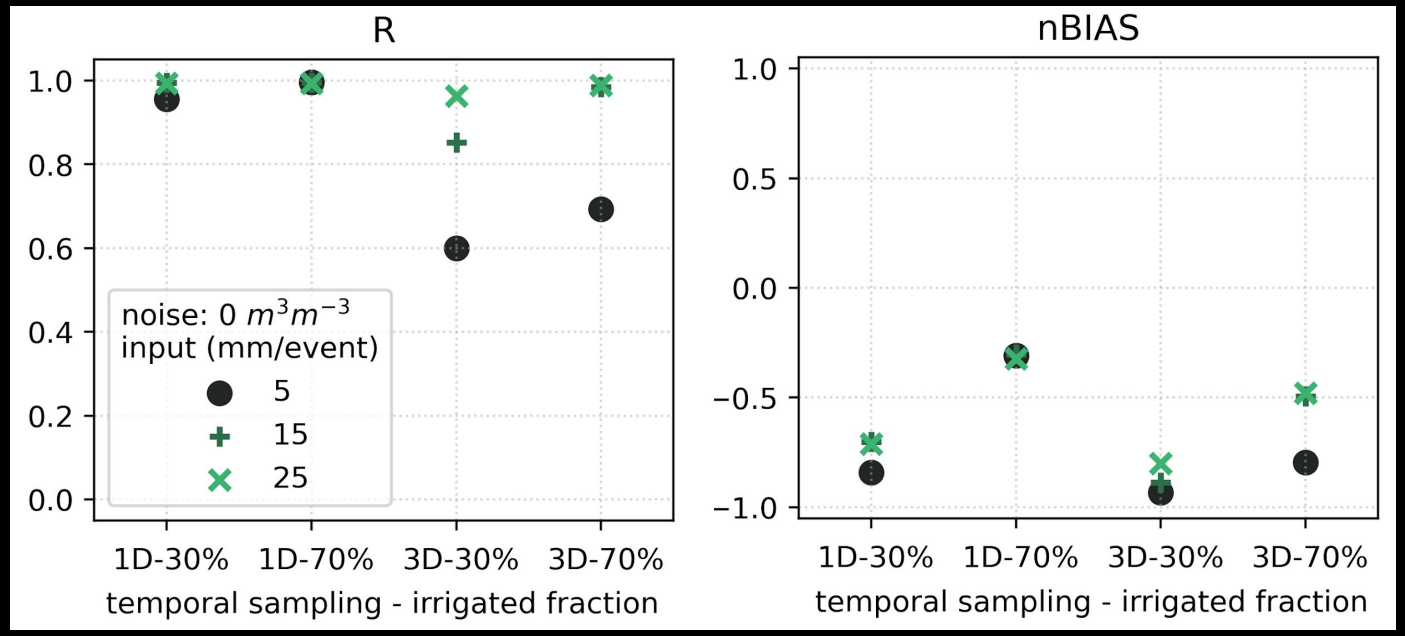
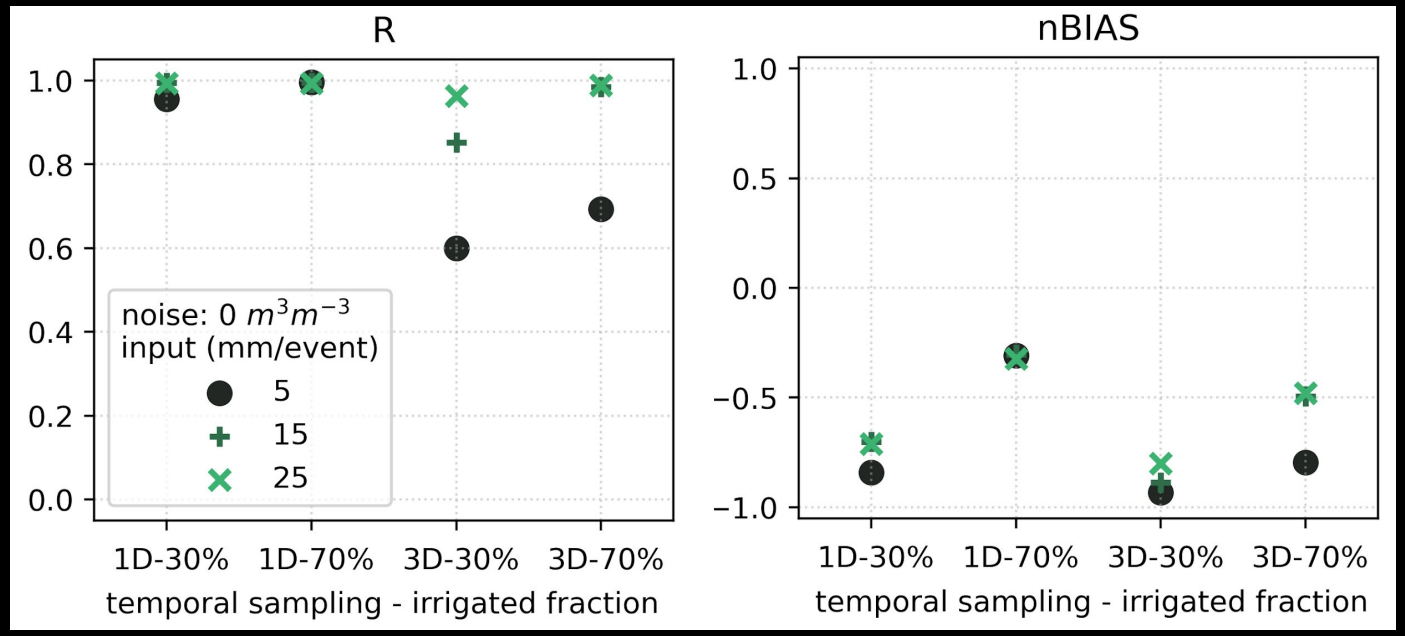
→ results deteriorate with temporal samplings > 2 days, or irrigated fractions ≤ 50%

Synthetic experiment
Combined impact of spatio-temporal resolution



	small field	large field
Sentinel-1 (current)	3d - 30%	3d - 70%
Sentinel-1 (3 satellites)	1d - 30%	1d - 70%

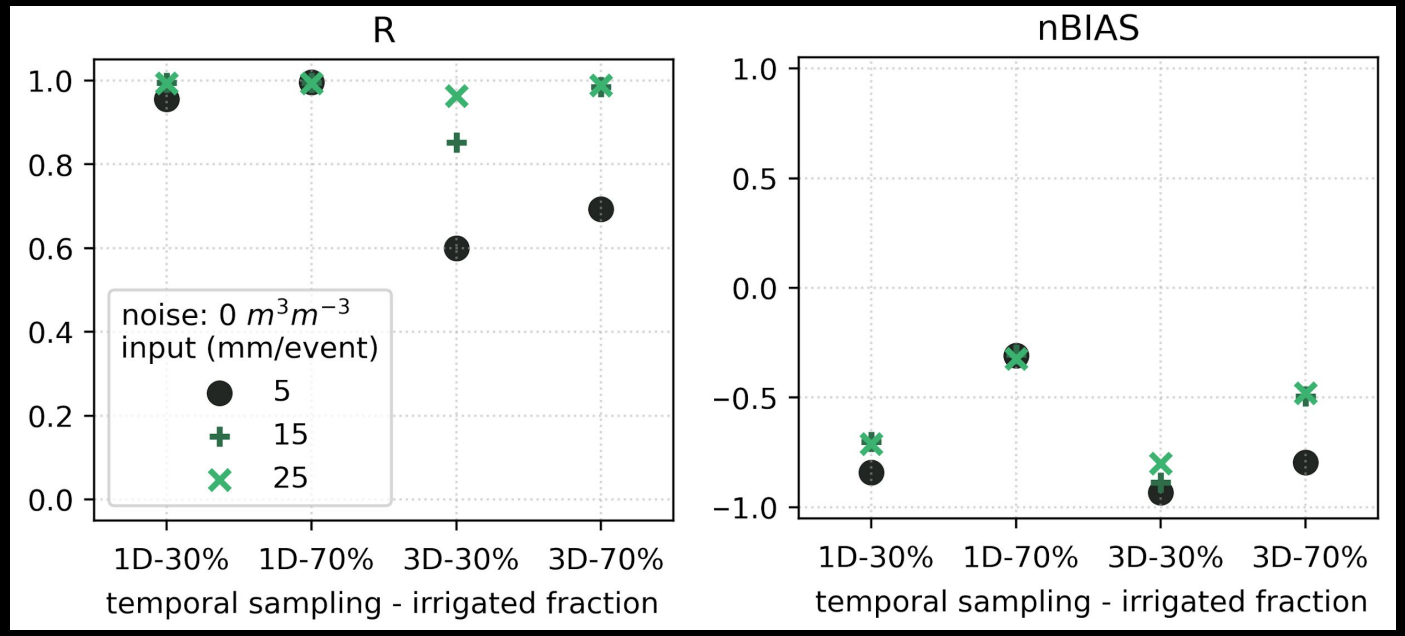
Synthetic experiment
Combined impact of spatio-temporal resolution



strong correlations regardless of spatio-temporal resolution, for irrigation rates ≥ 15 mm/event

considerable under estimations, except for the daily-70% combination

Synthetic experiment
Combined impact of spatio-temporal resolution



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→ longer revisit time together with lower spatial resolution has detrimental effects on the accuracy of estimated irrigation water amounts

Conclusions

- good estimates (*R > 0.9, nBIAS < 0.2*) for temporal sampling ≤ 2 days
  - sub-daily observations not necessary
- the coarser the spatial res., the larger the underestimations
  - irrigation almost not visible if %irrigated < 30%
- current and upcoming missions (e.g. Sentinel-1) only partially meet the spatio-temporal resolution needed for monitoring field-scale irrigation
  - moderate accuracy, potentially large underestimations

- manuscript under review in “International Journal of Applied Earth Observation and Geoinformation”

- short presentation on “*Irrigation water volumes from Copernicus products. A multi-year case study over the Po Valley*”
  openEO Platform User Consultation, today 17.50, Room H-1-07

- poster on “*Towards long-term and high-resolution soil moisture over Europe by downscaling the ESA CCI Soil Moisture*”
  tomorrow, poster session, stand 183