Exploring spatiotemporal dynamics of soil moisture: comparison of three model conceptualizations in a subarctic catchment

Jari-Pekka Nousu[1,2], Kersti Leppä[2], Hannu Marttila[1], Pertti Ala-aho[1], Mika Aurela[3], Annalea Lohila[3,4], Samuli Launiainen[2]

[1] Water, Energy and Environmental Engineering Research Unit, University of Oulu, Finland

[2] Bioeconomy and Environment, Natural Resources Institute Finland, Helsinki, Finland

[3] Climate System Research, Finnish Meteorological Institute, Helsinki, Finland

[4] Institute for Atmospheric and Earth System Research INAR, University of Helsinki, Helsinki, Finland

Why interest in soil moisture?

- Key role in earth and climate systems
  - Energy flux partitioning
  - Hydrological and biogeochemical cycles
- Essential for forecasting
  - Floods, droughts, landslides and wild fires
  - Forest trafficability
- Important in NWP and climate modelling

How do we explore soil moisture patterns in space and time?

- Modelling hydrology with three different (groundwater) model conceptualizations built in Spatial Forest Hydrology (SpaFHy, Launiainen et al. 2019) model
- Comparing simulations to Sentinel-1 (satellite) SAR-based spatiotemporal soil moisture estimates (Manninen et al. 2021)

1. **Where and when does lateral ground water flow determine the variability of soil moisture?**
2. **How does influence of lateral flow compare with the effects of vegetation and soil heterogeneity?**
3. **Can we take advantage of novel SAR-based soil moisture estimates in model development and evaluation?**

SpaFHy model

Canopy module

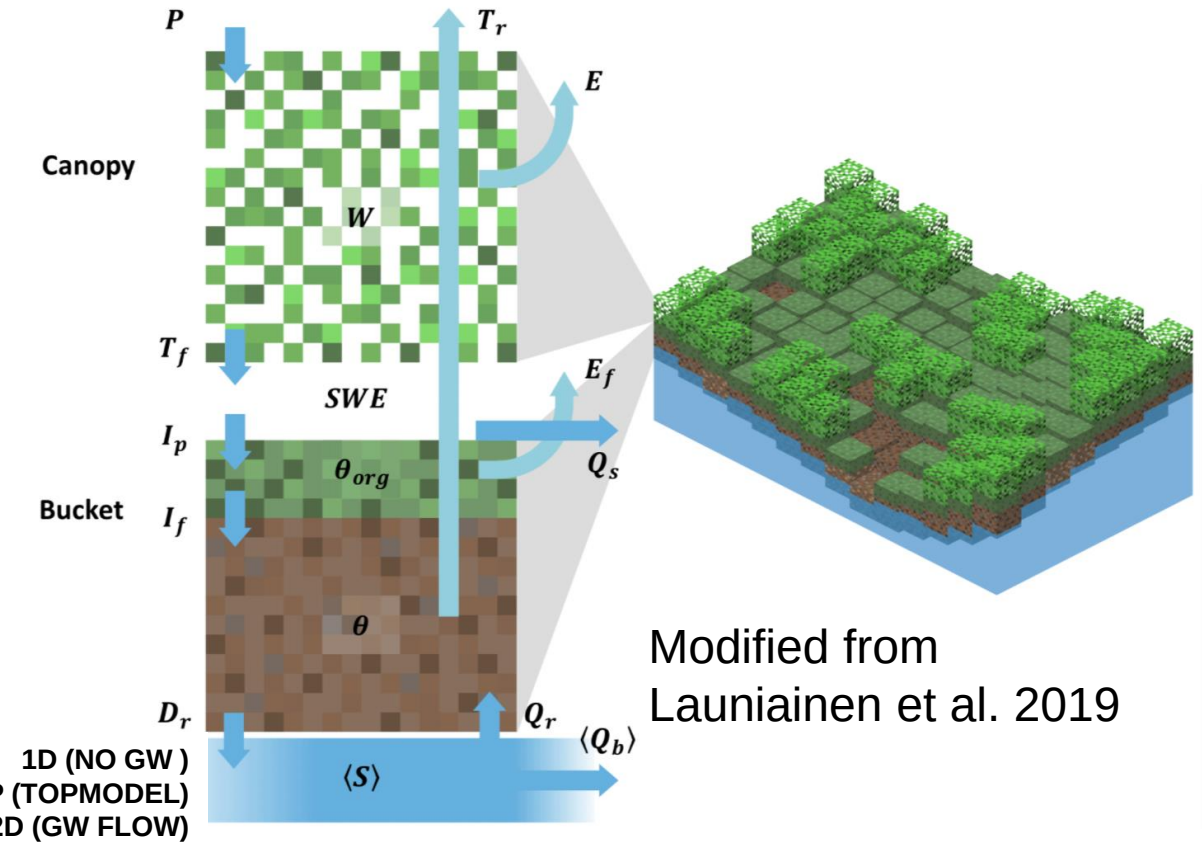
- Hydrology in vegetation and snowpack

Bucket module

- Organic moss-humus layer
- Rootzone layer (soil moisture)

Groundwater modules

- **1D**: Neglecting groundwater storage
- **TOP**: TOPMODEL approach
  - Topography based: return flow from high TWI cells
- **2D**: Lateral flow model
  - Spatially distributed groundwater flow model

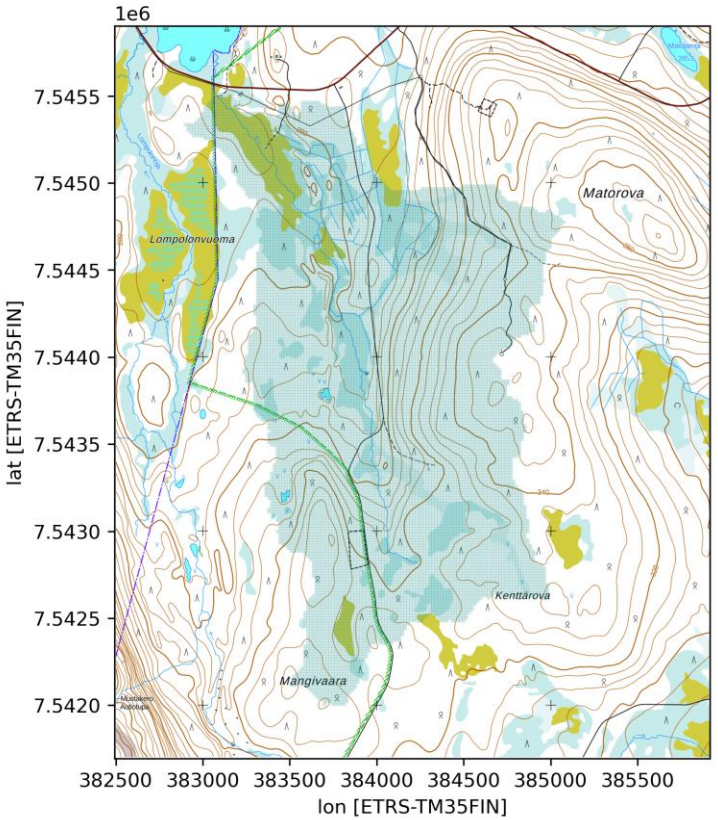


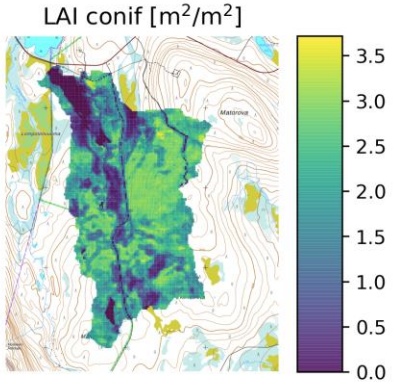
Modified from Launiainen et al. 2019

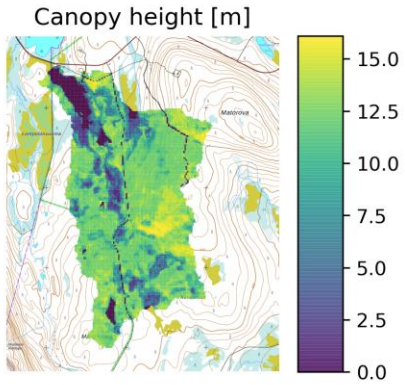
Characteristics of the study catchment

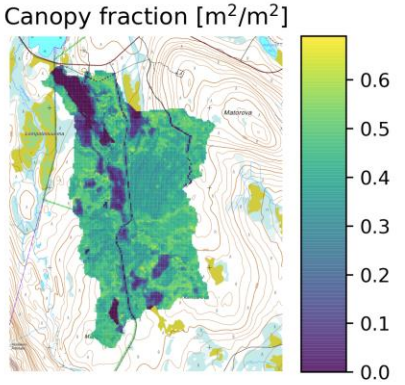
Pallas catchment, ~4.4 km², Northern Finland

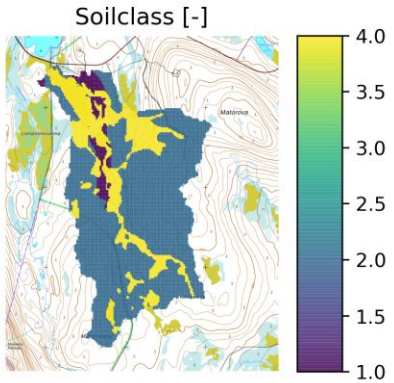
- Subarctic climate (seasonal snow cover)
- Boreal biome (spruce forests, paludified forests, peatlands and hills)

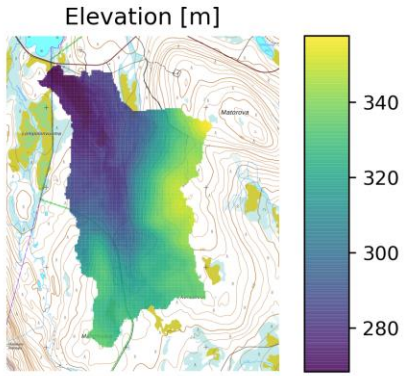


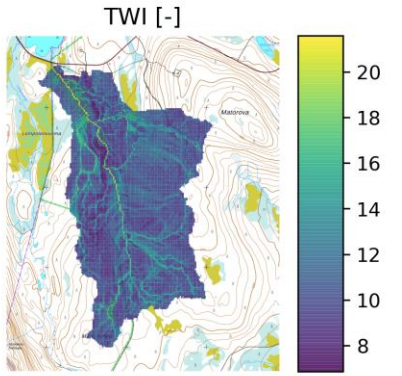




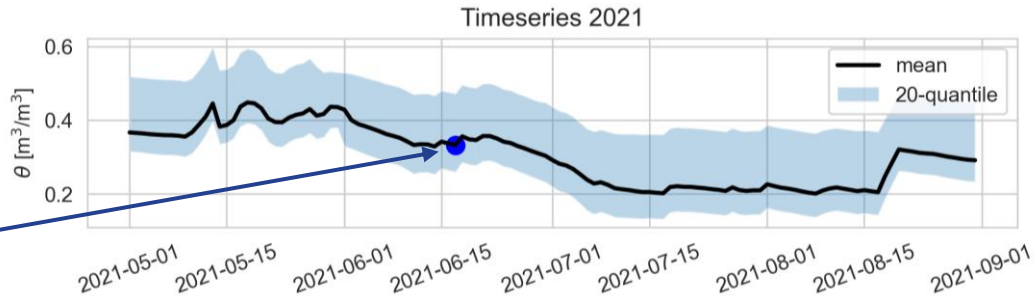


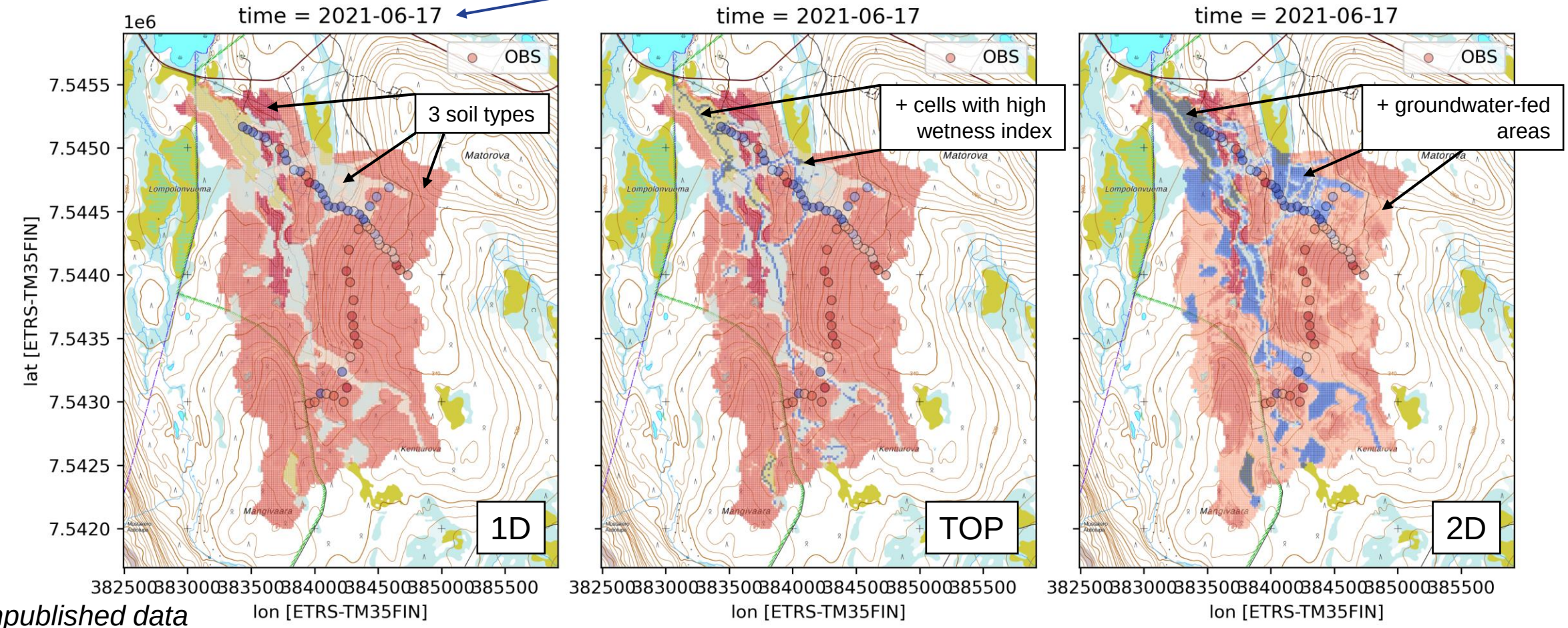






Comparison of model versions





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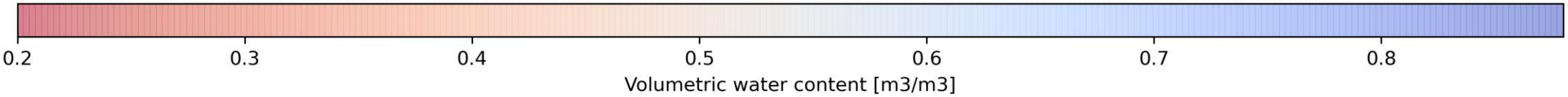
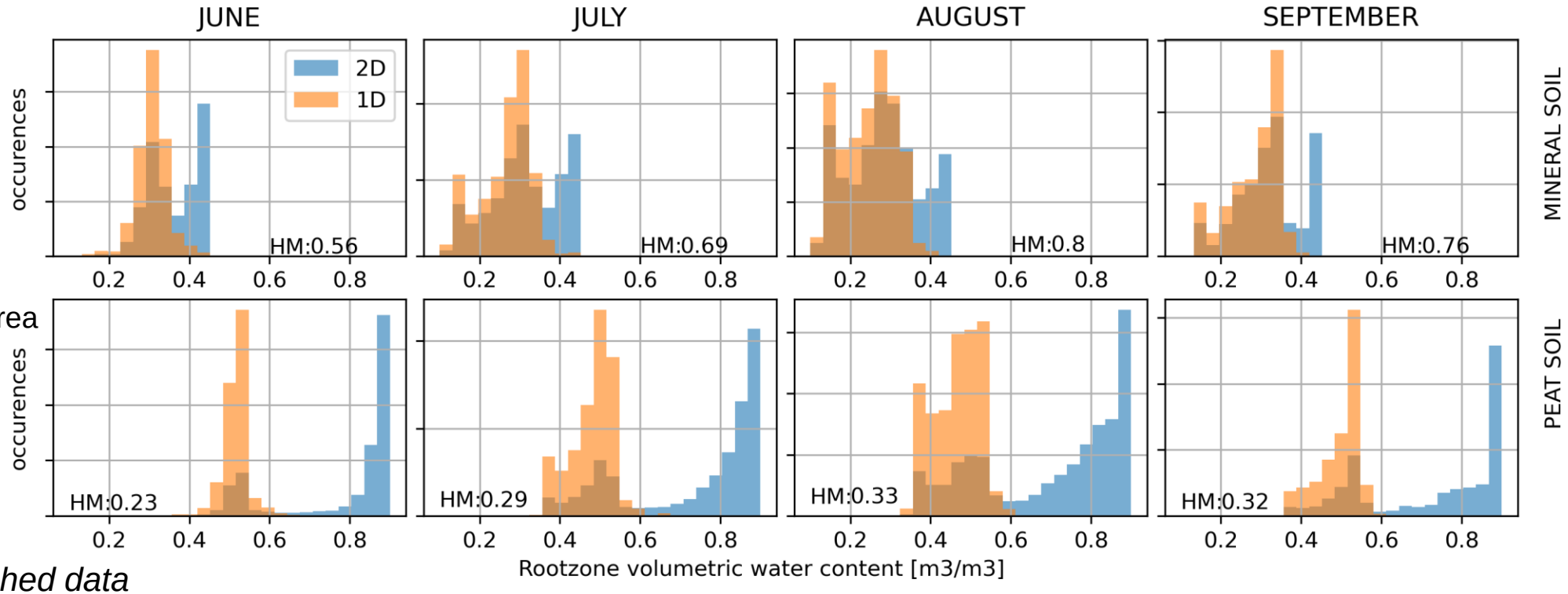


Comparison of model versions

- When and where 2D groundwater flow influences soil moisture?
  - Influence greater in early summer (wet conditions after snowmelt)

*HM = fraction of histogram matching area



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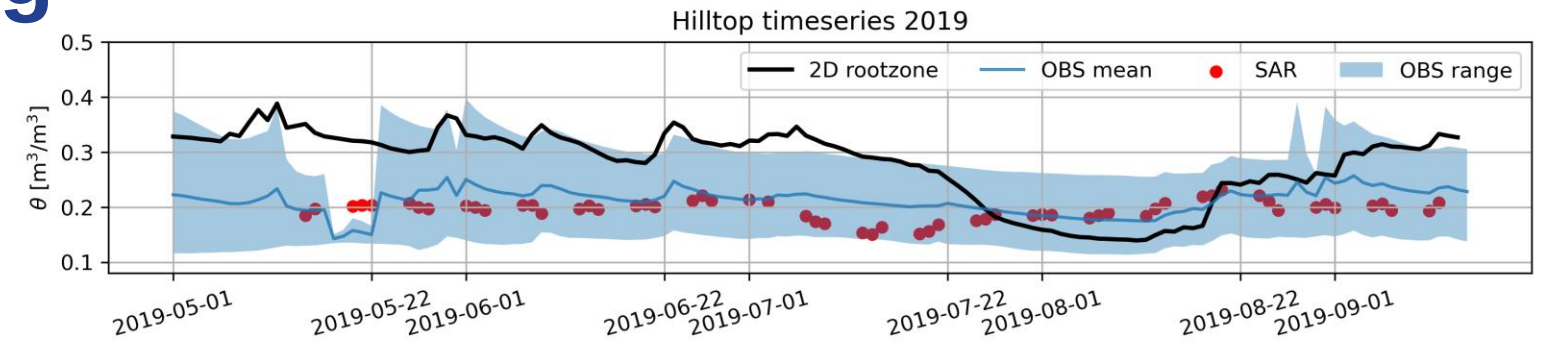
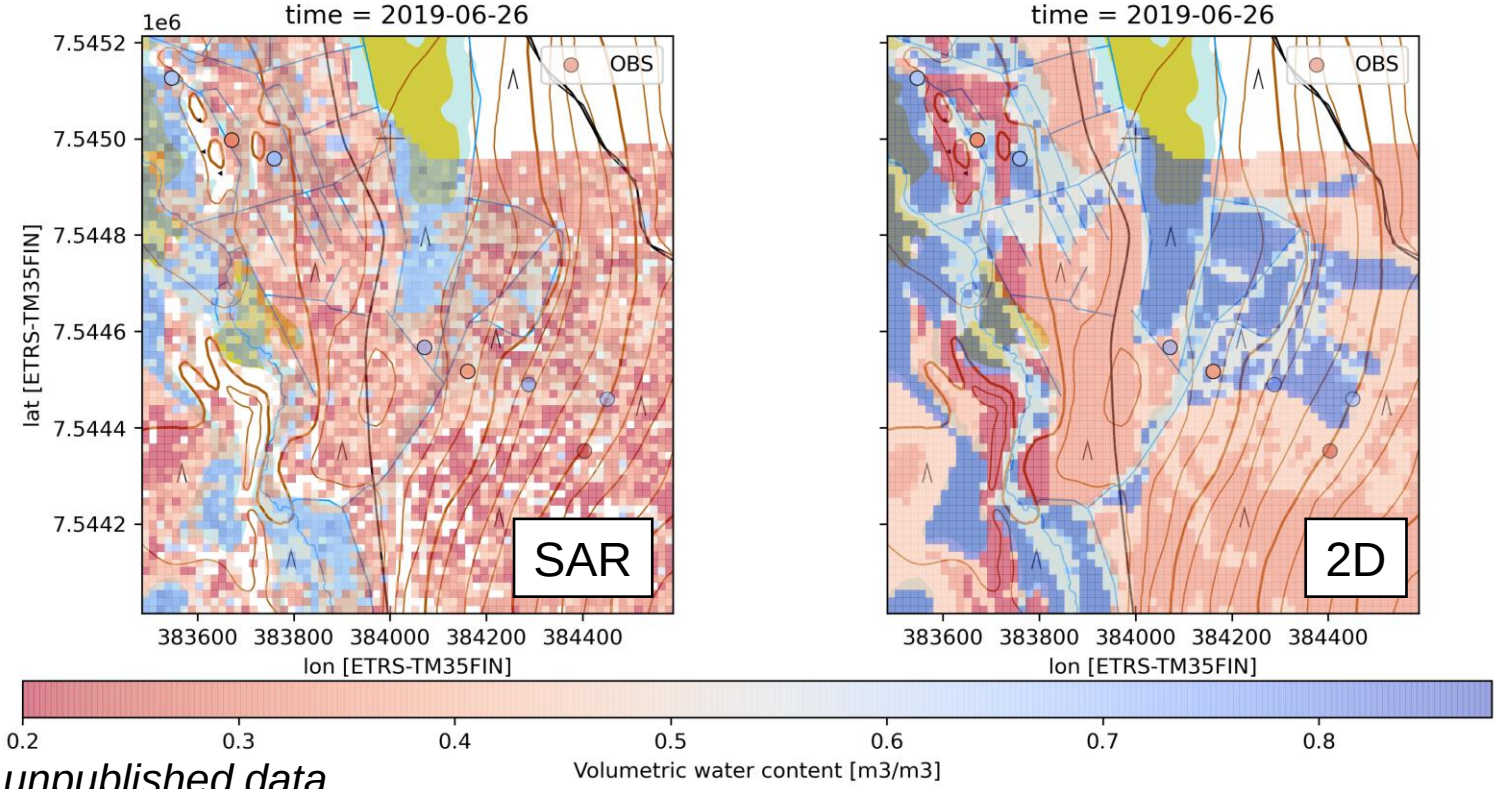
- Influence greater on peatlands compared to mineral soils (forest)

SAR*-based soil moisture estimates to assist modelling

*Synthetic Aperture Radar (SAR)

- SAR-estimates are able to capture the temporal range of observed soil moistures and main spatial patterns
  - ➢ Enables to distinguish spatial variations not covered by manual point observations
- Spatial variability is higher than what can be described by vegetation and soil characteristics commonly implemented in spatial models
  - ➢ Challenging to use for calibration





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Main findings

- ✓ 2D groundwater flow is important driver of soil moisture in the study catchment
- ✓ Influence of 2D groundwater flow becomes greater in early summer, but is evident throughout the season on peatlands
- ✓ Remote sensing based soil moisture estimates can assist spatially-distributed model developments and evaluations

References

- Nousu et al. (in prep). Exploring spatiotemporal dynamics of soil moisture: comparison of three model conceptualizations in a subarctic catchment
- Launiainen, S., Guan, M., Salmivaara, A., and Kieloaho, A. J.: Modeling boreal forest evapotranspiration and water balance at stand and catchment scales: a spatial approach, Hydrology and Earth System Sciences, 23, 3457–3480, https://doi.org/10.5194/hess-23-3457-2019, 2019
- Manninen, T., Jaaskelainen, E., Lohila, A., Korkiakoski, M., Rasanen, A., Virtanen, T., Muhic, F., Marttila, H., Ala-Aho, P., Markovaara-Koivisto, M., Liwata-Kenttala, P., Sutinen, R., & Hanninen, P. (2021). Very High Spatial Resolution Soil Moisture Observation of Heterogeneous Subarctic Catchment Using Nonlocal Averaging and Multitemporal SAR Data. *IEEE Transactions on Geoscience and Remote Sensing*, 1–17. https://doi.org/10.1109/TGRS.2021.3109695