EGU General Assembly 2022

Hydrological signatures to derive process knowledge from in situ soil moisture data

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Session HS2.2.4: Improving hydrological process understanding and model prediction using soil moisture data

24th May 2022

San Diego State University

INRAE

GFZ Helmholtz-Zentrum Potsdam

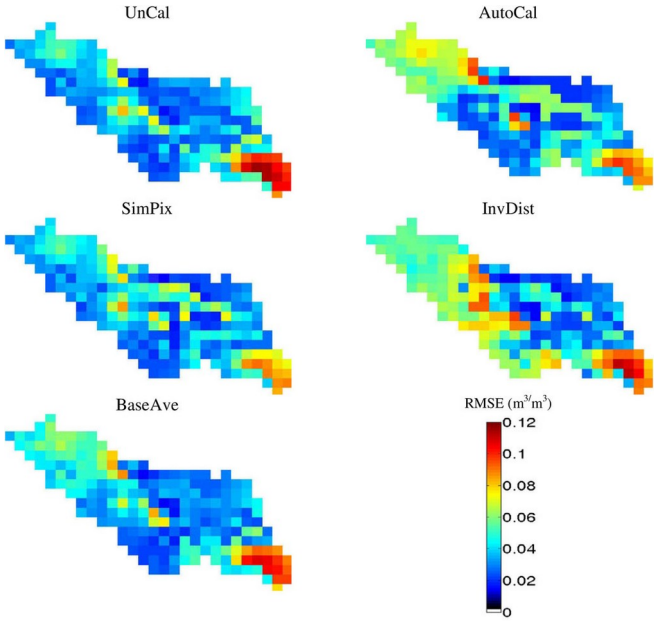
Sharing is encouraged

Using in situ soil moisture data in hydrology

Soil Moisture is a critical control of hydrologic response

In situ observation has many potential applications

But data are not easily (and therefore still rarely) used



Thorstensen et al., 2016

How to extract information from in situ soil moisture observations?

Hydrological signatures quantify & standardize hydrological expertise

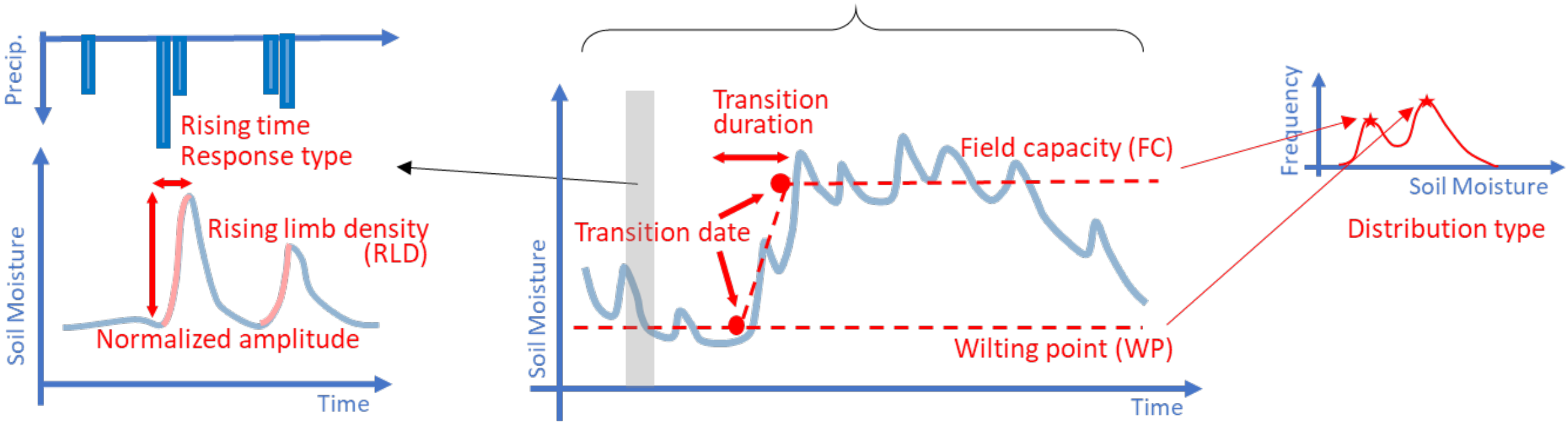
Set of 9 signatures based on soil moisture data, applied to 6 study sites around the world:

- *Can they provide a clear view of dominant processes on a given site ?*
- *Can they discriminate between land uses ?*

Set of soil moisture signatures at 3 temporal scales

4 signatures at the event scale

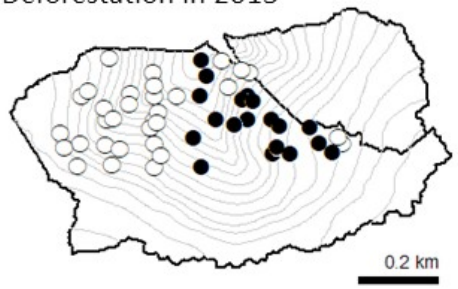
5 signatures based on the annual cycle of soil moisture



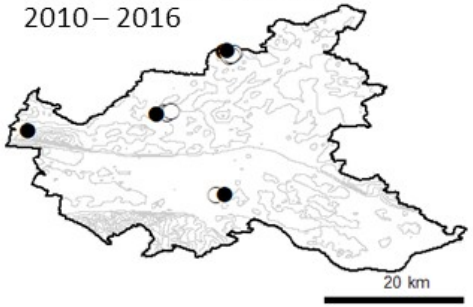
Based on Branger & McMillan (2020), added signatures from Chandler et al. (2017), Graham & Lin (2011), and Sawicz *et al.* (2011)

Study sites & data

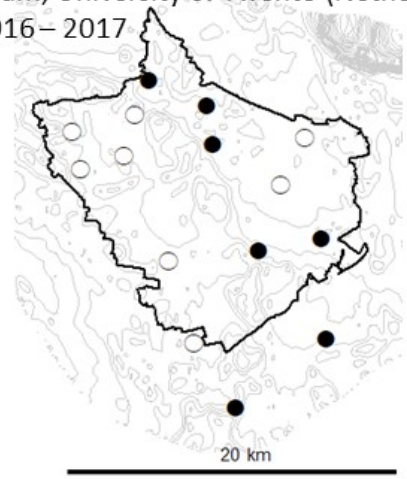
WB
Forested vs. Deforested
Wustebach, TERENO (Germany)
2009 – 2018
Deforestation in 2013



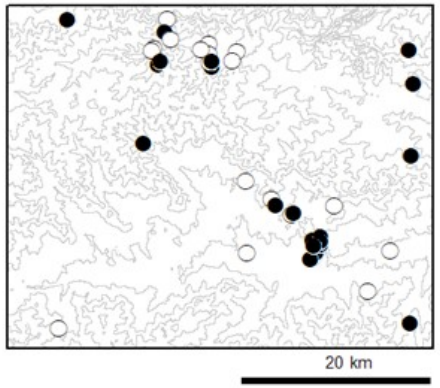
HB
Greenspace vs. Housing
Hamburg Urban Soil Climate Observatory (Germany)
2010 – 2016



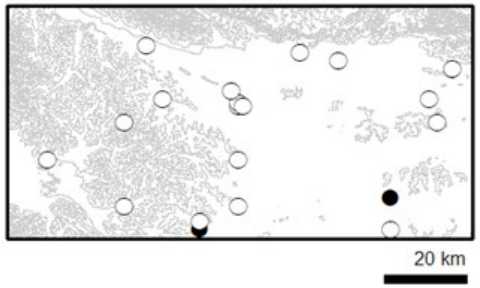
RM
Deep vs. Shallow groundwater
Raam, University of Twente (Netherland)
2016 – 2017



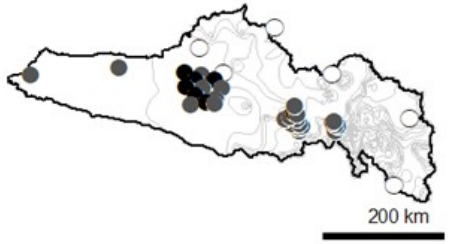
TX
Ungrazed vs. Grazed
TxSON (US)
2014 – 2019

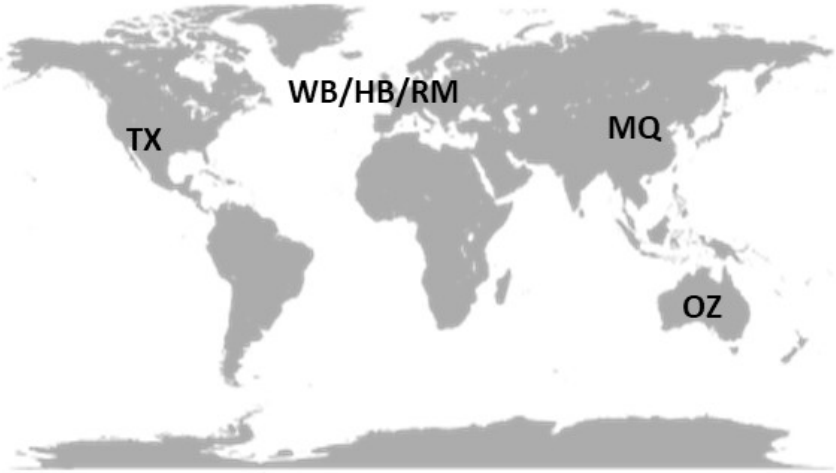


MQ
Non-wetland vs. Wetland
Maqu (China)
2008 – 2010



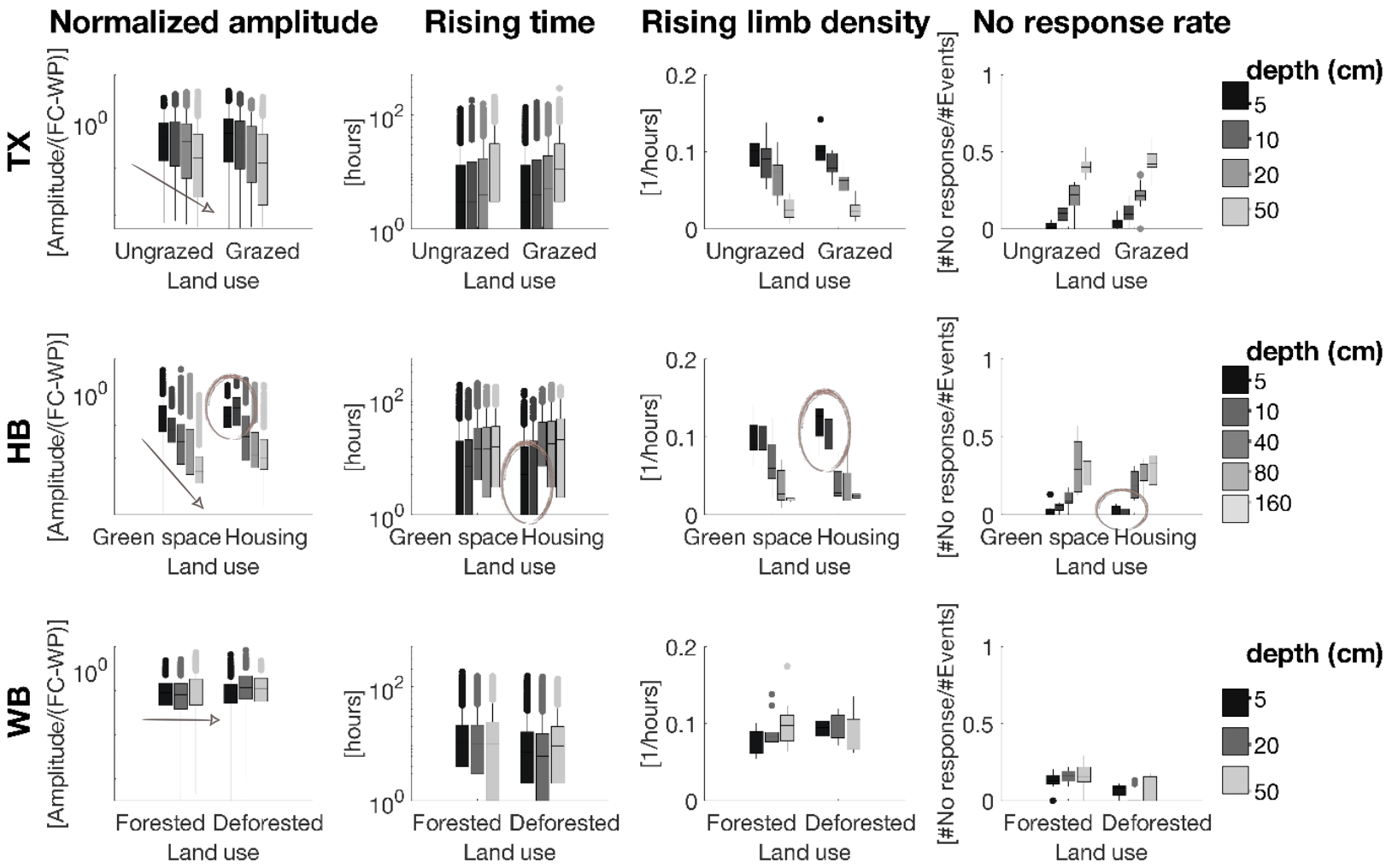
OZ
Grass vs. Grazed vs. Crop
OzNET (Australia)
2001 – 2019



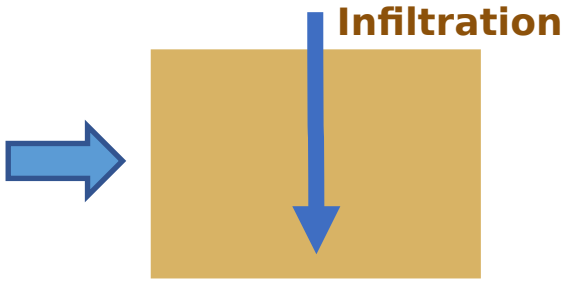


Legend
Site abbreviation
Land-use
Observatory (country)
Observation period
Watershed / network extent
Elevation contour (interval varies)
Sensors (undisturbed land-use)
Sensors (disturbed land-use)

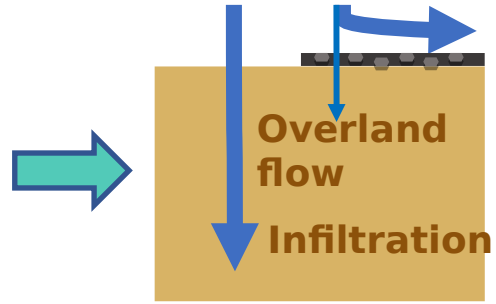
Example of results for event-based signatures: water flow pathways



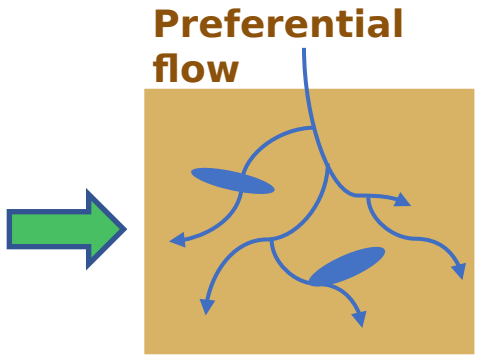
linear response with depth



linear response with depth + different pattern for housing land use

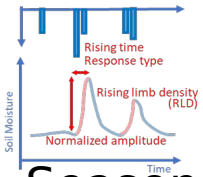
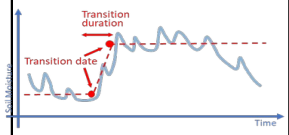
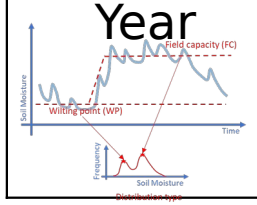


same response / depth and LU



Clear identification of dominant processes + discrimination of land use

Summary & Recommendations

Signature type	Signature performance				Signature applicability		
	Extraction	Dynamics with depth	Dynamics between land-uses	Interpretation	Model calibration & evaluation	Remote sensing data accuracy assessment	Observation data analysis
Event 	✓	✓	✓	✓	✓	Not enough time-resolution & measurement depth	✓
Season 	✓	Not statistically significant	✓	Poor in arid climate & multiple interpretation	✓	✓	Difficulty in interpretation
Year 	Susceptible to data quality	✓	✓	✓	✓	Susceptible to data quality	✓

For more information

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Repository for Signatures calculation code :
https://github.com/RY4GIT/Soil-moisture-signatures-Matlab-ver
(Matlab version, R version coming soon)

Araki, R., Branger, F., Wiekenkamp, I., & McMillan, H.K., 2022. A signature-based approach to quantify soil moisture dynamics under contrasting land-uses. Hydrological Processes 36 (4) e14553. DOI: https://doi.org/10.1002/hyp.14553

Gnann, S.J., Coxon, G., Woods, R.A., Howden, N.J.K., McMillan H.K., 2021. TOSSH: A Toolbox for Streamflow Signatures in Hydrology. Environmental Modelling & Software. DOI: https://doi.org/10.1016/j.envsoft.2021.104983

Branger F, McMillan H.K. (2020). Deriving hydrological signatures from soil moisture data. Hydrological processes 34 (6): 1410–1427 DOI: https://doi.org/10.1002/hyp.13645

Wiekenkamp I, Huisman JA, Bogena HR, Lin HS, Vereecken H. 2016. Spatial and temporal occurrence of preferential flow in a forested headwater catchment. Journal of Hydrology 534: 139–149 DOI: https://10.1016/j.jhydrol.2015.12.050