Modeling unsaturated zone water stable isotope depth profiles in an evaporation dominated environment.

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GEOZENTRUM HANNOVER

Introduction:

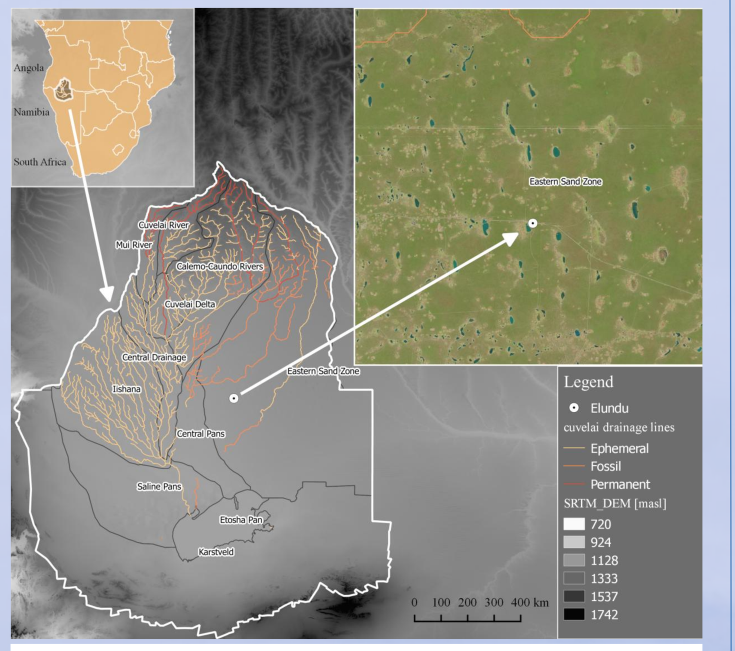


Fig.1: Location of the study site

Northern Namibia is a region with high population growth rate, limited water resources and a transboundary aquifer system where groundwater recharge and groundwater flow processes are not yet fully understood.

The main objective of this study is to get a better understanding of groundwater recharge processes of the shallow aquifer system in the Cuvelai-Etosha-Basin (CEB).

Evaporation, transpiration and root water uptake are dominant factors reducing the quantity of precipitation that contribute to recharge. These in turn, depend on soil type and depth, climate, the distribution, density and type of vegetation, and the depth to the groundwater. Since recharge processes are characterized by unsaturated zone processes stable isotopes appear as a powerful tool to improve processes understanding and modeling approaches (Sprenger at al., 2014).

The present study presents results of a field experiment conducted in northern Namibia.

Isotope depth profiles are included in the calibration process of a SVAT model on a hourly time step. This improved parameter estimations and reduced model uncertainty.

Methods:

Fig. 2: Soil sampling using a hand auger.

Fig. 3: Cryogenic vaccum extraction method for subsequent water stable isotope analysis.

Fig. 4: Custom built soil gas sampler using raspberry pi….

Fig. 5: .. connected to a laser spectrometer LGR DLT-100 ….

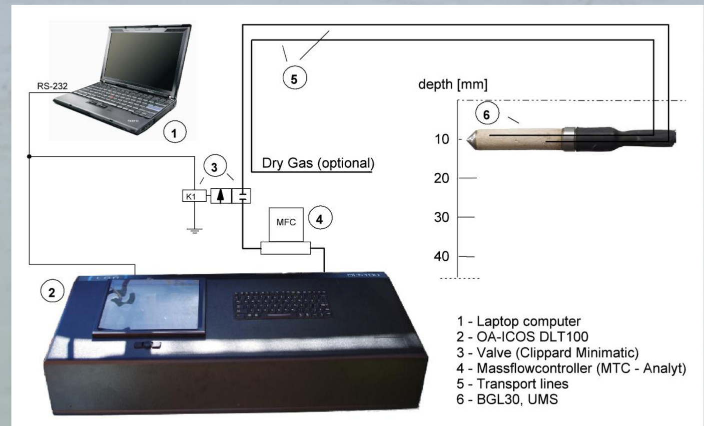


Fig. 6: … to determine water stable isotopes in the unsaturated zone in-situ (Gaj et al .,2015).

Field Experiments:

Fig. 7: Dye tracer experiments

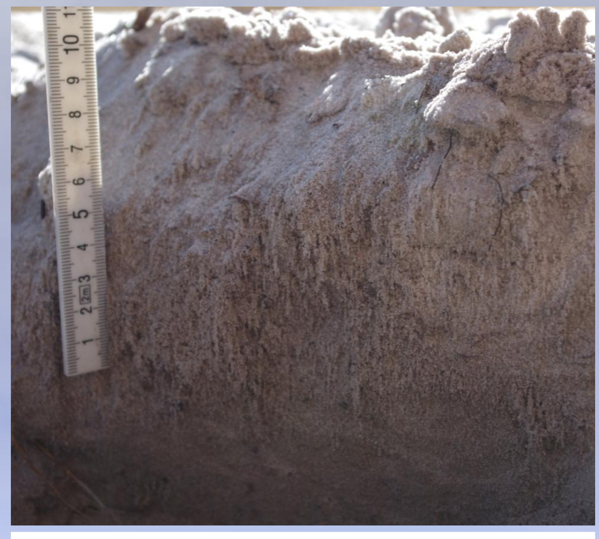
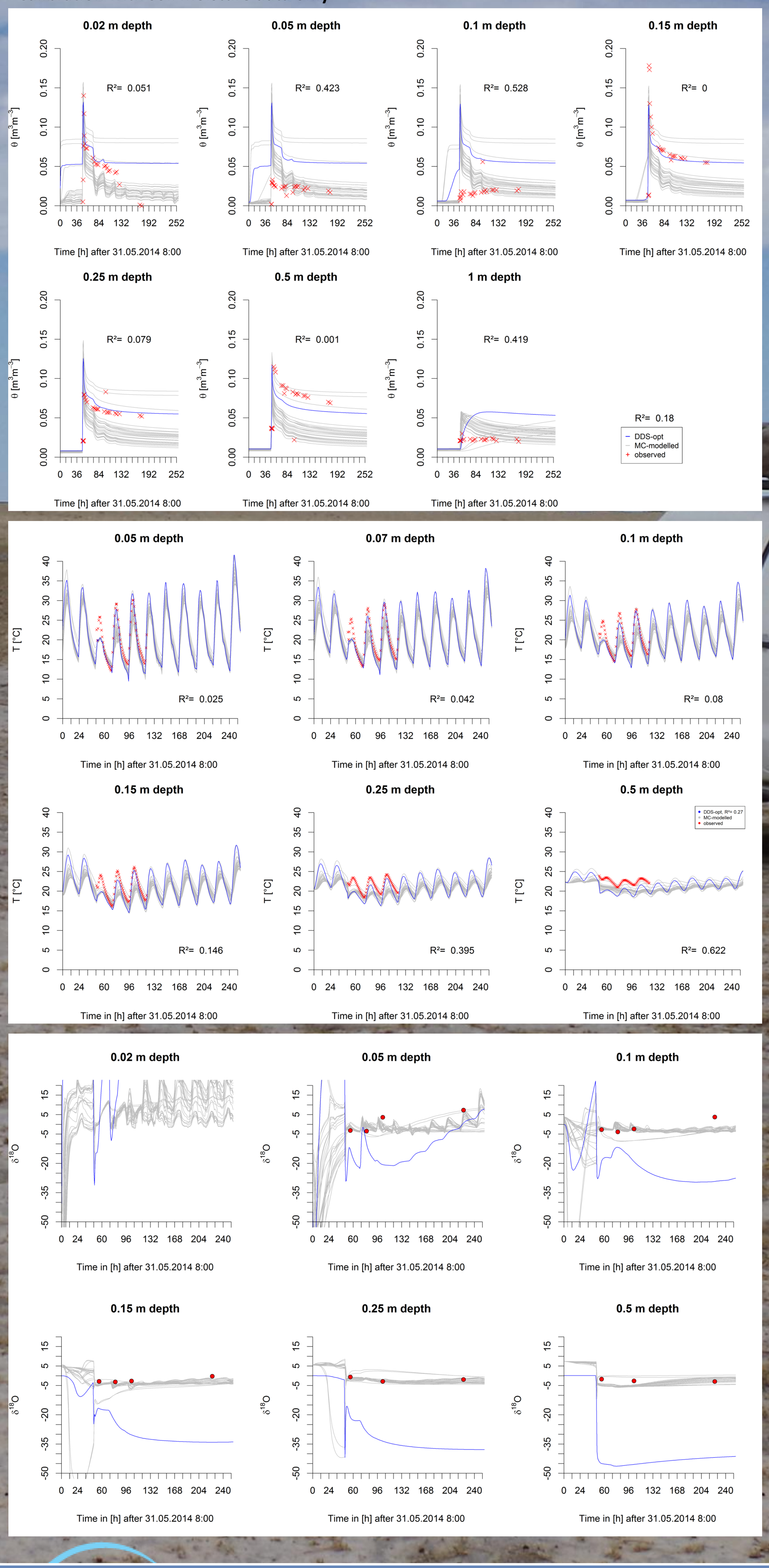


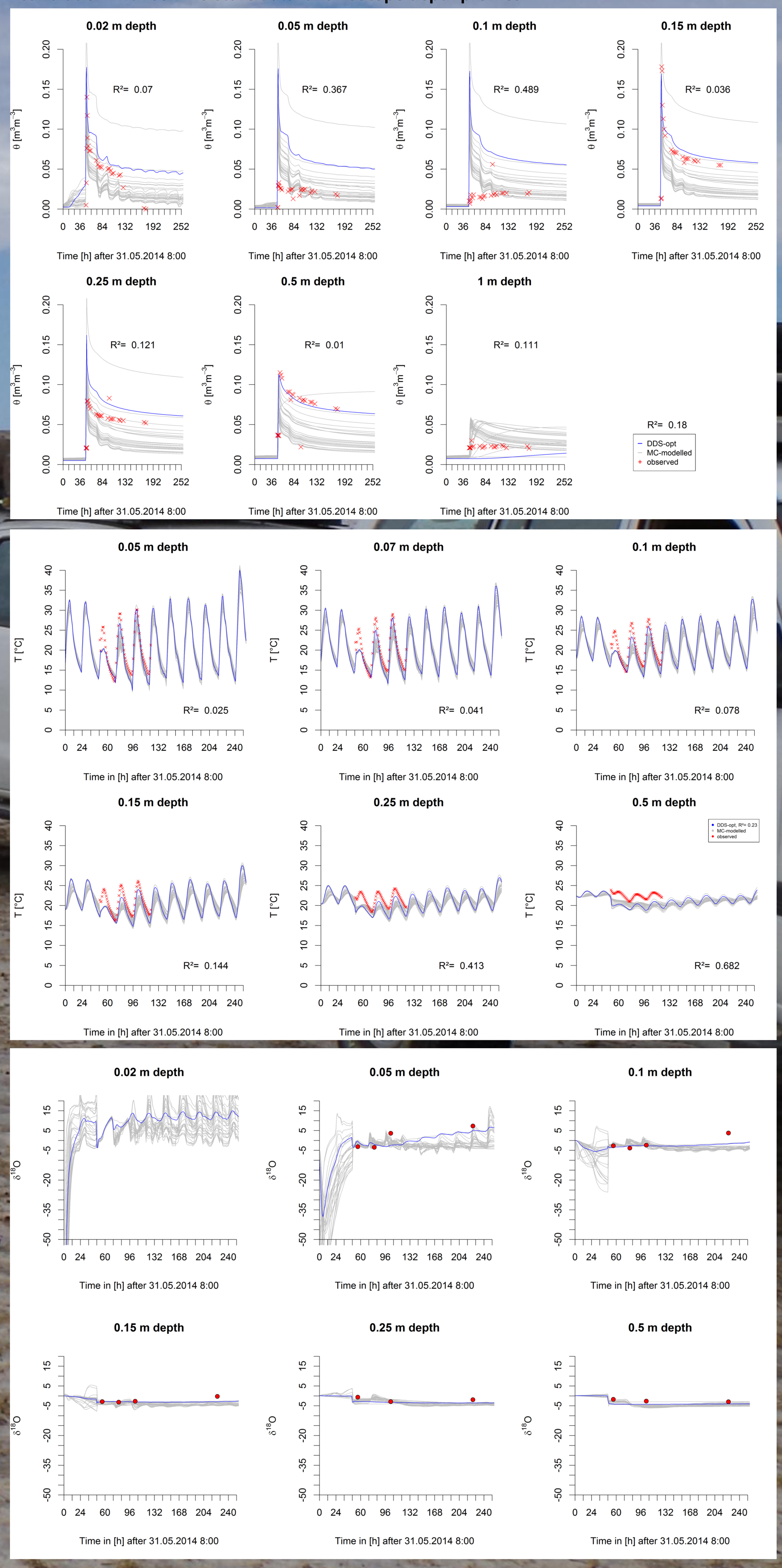
Fig. 8: Water repellency at 5 to 10 cm.

Fig. 9: Thick root mat within the upper 10 cm.

Calibration with soil moisture data only

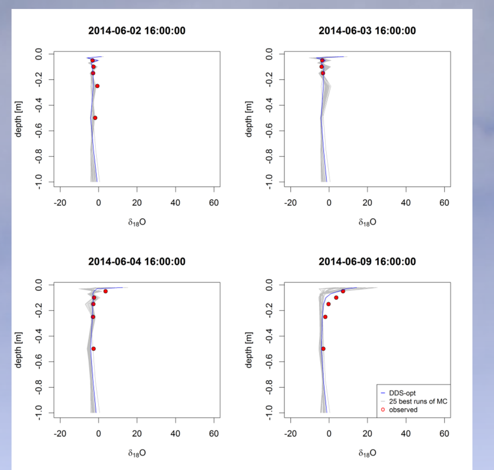


Calibration with soil moisture data and isotope depth profiles



Modelling:

Parameter	Optimized by θ	by θ + δ	Ranges initial	min	max	units
θw	0.0060	0.0099	0.0069	0.005	0.01	[m³/m³]
θFC	0.0277	0.0669	0.0692	0.018	0.12	[m³/m³]
θHE	0.3108	0.3057	0.3505	0.305	0.351	[m³/m³]
θR	0.0040	0.0010	0.0040	0.001	0.004	[m³/m³]
HE	-39.9122	-1.2715	-0.1602	-40	-0.1	[-]
Ke	0.0003	0.0003	0.0010	0.0001	0.0003	[m/s]
LAM	0.1796	0.2062	0.9984	0.1	1	[-]
CSS	830.2571	1040.5965	825.0832	800	2660	[J/(kg*K]
RHO	1692.0451	1699.5022	1697.6367	1692	1700	[g/cm³]
TORTUOSITY	0.6700	0.6697	0.6697	0.6472	0.67	[-]



Results :

A plot was equipped with soil moisture sensors. Readings were performed every 3 hours. The plot was irrigated with 60mm of water. The dry out was monitored over a period of 10 days. Soil moisture temperature and isotope data was collected. An isotope enabled SVAT-model (Haverd and Cuntz, 2010) was calibrated conventionally using soil moisture data and in addition the same model was calibrated with soil moisture and isotope data. Initial parameters and their ranges were kept equal for all model runs. Constraints were derived from soil physical properties derived from laboratory and field experiments.

The model calibrated with soil moisture data does not capture the recession behavior especially of the top most layer. The lower layer is overestimated. Considering stable isotope data for the calibration process improves the representation of the recession behavior in terms of shape. The maximum infiltration depth is slightly underestimated. Both models fail to represent the soil moisture behavior of five and 10cm depth, because water repellent properties were observed in the field (Fig. 8). Further the modeled temperature is better including isotope depth profiles. Both models underestimate temperatures lower 15 cm. However, parameter identifiability and process representation improved by incorporating stable isotope data, for soil moisture and temperature data. Especially, Water quantities at depth improved which is relevant for groundwater recharge estimations.

Outlook:

- Isotope data with higher temporal and spatial resolution using in-situ methods are promising to improve processes understanding and modeling approaches.

-Model runs on a daily time step and the inclusion of seasonal isotope depth profiles are soon to be developed

-Parameter transferability from hourly to daily time steps for regionalization purposes

-Coupled run with LSM including different root water uptake routines

- Long-term recharge predictions using climate projections as input for Groundwater models will be made.

References:

Haverd, V. and Cuntz, M.: Soil–Litter–Iso: A one-dimensional model for coupled transport of heat, water and stable isotopes in soil with a litter layer and root extraction, Journal of Hydrology, 388 (3-4), 438–455, doi:10.1016/j.jhydrol.2010.05.029, 2010.

Sprenger, M., Volkmann, T. H. M., Blume, T., and Weiler, M.: Estimating flow and transport parameters in the unsaturated zone with pore water stable isotopes, Hydrol. Earth Syst. Sci. Discuss., 11 (10), 11203–11245, doi:10.5194/hessd-11-11203-2014, 2014.

Gaj, M., Beyer, M., Koeniger, P., Wanke, H., Hamutoko, J., and Himmelsbach, T.: In-situ unsaturated zone stable water isotope (^2H and ^{18}O) measurements in semi-arid environments using tunable off-axis integrated cavity output spectroscopy, Hydrol. Earth Syst. Sci. Discuss., 12, 6115-6149, doi:10.5194/hessd-12-6115-2015, 2015.

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