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Reply on RC1

Tobias Schnepper et al.

Author comment on "Evaluation of precipitation measurement methods using data from a precision lysimeter network" by Tobias Schnepper et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2022-370-AC1, 2023

We thank anonymous Referee #1 for the constructive feedback and the concerns raised. In accordance with the form of the review, we formulate our responses to the concerns below. All of these responses will be incorporated into the revised text. Comments 12) - 17) will be addressed in the revised text without further remark.

1.) We agree with Reviewer#1 that highly temporal resolved observations from lysimeter are needed to provide reliable reference precipitation data. We are using highly temporal resolved lysimeter records to obtain hourly precipitation. Hourly precipitation data used here was compiled as followed: 1.) six weight observations per minute were averaged and stored as 1-minute lysimeter weight data, 2) application of a state-of-the-art noise reduction filter (AWAT), 3) we used the water balance equation to determine the precipitation or ET per 1-minute interval. Within this step we assume for each 1-minute time step, that only ET or precipitation can occur, which are related to either a decrease (ET) or increase of lysimeter weight (precipitation or NRE). 4.) In a next step we aggregate 1-minute precipitation data to hourly values. A more thoroughly description of the data processing procedure can be found in Schneider et al. 2021. We will provide a more precise description on the data processing procedure in the revised manuscript.

2.) Yes, non-rainfall events (NRE) are included in P in Eq. 2. We did not mention NRE in 2.2.2 because the gauges do not register them, except for disdrometers that can detect fog. As for 2.3, data from lysimeters with NRE are treated like any other hour with precipitation, so we did not mention them. In 2.4, P_{ref} is also calculated for NRE. We will introduce the term atmospheric water input (AWI) in the manuscript and in Eq. 2 to improve the distinction between NRE and regular precipitation.

3.) The methods for distinguishing between NRE and precipitation from lysimeter data without further sensor data are subject to uncertainties. We distinguished between NRE and precipitation in this investigation based on hourly data and mass increases of the lysimeter not concurrent with rain or snow were classified as dew according to Meissner et al. 2007 and Xiao et al., 2009. In previous studies, which focused on determination of non-rainfall water at the same research sites, similar rules have been applied to detect NRE (e.g., Groh et al. 2018, Groh et al. 2019, Forstner et al. 2021). For future studies, leaf wetness sensors and visibility device will be installed at the studied sites to better distinguish between NRE and precipitation and thus to reduce the possible uncertainties. Previous studies for Rollesbroich found that an NRE contributed between 0.013 and 0.017 mm h^{-1} (Groh et al. 2019) compared to the minimum precipitation rate of 0.1 mm h^{-1}

considered in our study. Thus, NRE could possibility co-occur with rain events within 1 hour time intervals, but their overall magnitude at hourly base would be relatively small. Thus, we don't expected that a co-occurrence of NRE and precipitation would distort the results.

4.) The size of the hexagonal area is approximately 49 m² in total, while the lysimeters cover an area of 6 m² and are each installed at a distance of 1.6 m from the nearest lysimeter. The gauges are installed within a range of about 7 m from the hexagon at all sites, except for the TB2 tipping bucket gauge at Rollesbroich, which is installed about 30 m from the nearest lysimeter. However, this gauge shows one of the best correlations with the lysimeter reference data compared to the other TB gauges. The mean of all observations per lysimeter for Ro, with a precipitation rate above 0.1mm h^{-1}, showed a maximum deviation of -0.015 mm h^{-1} from P_{ref} (0.941 mm h^{-1}), and the standard deviation for the mean from all lysimeters was 0.011 mm h^{-1}. For Se, the max deviation from P_{ref} (0.819 mm h^{-1}) in the mean was 0.003 mm h^{-1} and the standard deviation was 0.002 mm h^{-1}. In Dd, the max deviation of the mean average precipitation rate of all lysimeters from P_{ref} (0.822 mm h^{-1}) above 0.1 mm h^{-1} was -0.007 mm h^{-1}, with a standard deviation of 0.007 mm h^{-1}. The differences between the statistics for the different sites could be explained by the distribution of the precipitation rates, since in Ro the precipitation rates have been generally higher (Table 1 and 2). Overall, it can be assumed that measurement errors due to the spatial scale can be neglected, since all devices are installed at a short distance, no shielding can become effective, the temporal resolution is 1 hour and a normal distribution of deviations from the reference due to small-scale spatial influences can be assumed.

5.) The uncertainty estimation based on the standard deviation was only done for the lysimeter data. For the uncertainty ranges within the correlation plots, the uncertainties of the lysimeter measurements have been extended with an additional value of 5 % of P_{ref} to account for uncertainties of the gauge measurements. Therefore, the uncertainties calculated and discussed are only valid for the lysimeters, while the uncertainty ranges visually supporting the scatter plots are not computed for the respective gauges individually.

6.) Statistics (min, max, median, mean, quantiles) on the precipitation rates are given in Table 1 and Table 2. In general, the distribution of the precipitation rates is highly skewed. For Dedelow (Dd), Rollesbroich (Ro) and Selhausen (Se) the precipitation rates within the top 5 % quantile are responsible for 42.6, 38.5 and 35.7 % of the overall observed precipitation at the sites. However, only 40, 63 and 44 observations exceed 5 mm h^{-1} at Dd, Ro and Se, respectively. For precipitation rates above 10 mm h^{-1}, only 4, 10 and 4 hours have been recorded for Dd, Ro and Se.

By mistake, 20 mm h^{-1} has been described as the maximum observed precipitation intensity during the observation period across all sites. In Ro, the value was once exceeded with 23.21 mm h^{-1} and in Dd also a single observation exceeded the value with 32.24 mm h^{-1}. However, this has very little effect on the uncertainty range, as for Ro the uncertainty for this datapoint is 1.62 % and for Dd 1.19 %. The error solely affected the lysimeter uncertainty ranges, since for all other analysis the correct values have been used.

Table 1: Distribution of precipitation rates determined by the lysimeters over the observation period for P_{ref} >= 0.1 mm h^{-1}, as used for the gauge comparison.

Site	Min [mm h^{-1}]	Max [mm h^{-1}]	Mean [mm h^{-1}]	Median [mm h^{-1}]	5%-Quantile [mm h^{-1}]	25%-Quantile [mm h^{-1}]	50%-Quantile [mm h^{-1}]	75%-Quantile [mm h^{-1}]	95%-Quantile [mm h^{-1}]
Dedelow	0.100	32.243	0.822	0.413	0.114	0.202	0.413	0.885	2.813

Rollesbroich	0.100	23.210	0.941	0.519	0.120	0.248	0.519	1.145	2.941
Selhausen	0.100	12.910	0.819	0.446	0.116	0.209	0.446	0.973	2.626

Table 2: Distribution of precipitation rates determined by the lysimeters over the observation period for $P_{ref} > 0$ mm h^{-1}, including water from non-rainfall events.

Site	Min	Max	Mean	Median	5%-Quantile	25%-Quantile	50%-Quantile	75%-Quantile	95%-Quantile
	[mm h^{-1}]	[mm h^{-1}]	[mm h^{-1}]	[mm h^{-1}]	[mm h^{-1}]	[mm h^{-1}]	[mm h^{-1}]	[mm h^{-1}]	[mm h^{-1}]
Dedelow	0.001	32.243	0.177	0.013	0.001	0.005	0.013	0.052	0.883
Rollesbroich	0.001	23.210	0.297	0.017	0.001	0.006	0.017	0.195	1.536
Selhausen	0.001	12.910	0.220	0.014	0.001	0.005	0.014	0.106	1.189

7.) We agree with Reviewer#1 that the correction methods are based on empirical data. The method after Richter has been developed especially for different locations with scarce data coverage. Therefore, the parametrisation is done loosely based on specific location characteristics. Here, the measurement method is important since the original method has been exclusively developed for Hellmann-type gauges. For the Dynamic Correction Method, factors for precipitation type, wind speed and gauge model are defined. The only site-specific factor appears to be the wind speed, which varies according to the site, but since the method has been developed covering a range of wind speeds including those measured at the sites, the factors should cover the issue. Overall, the correction results have been similar for the devices of the same gauge type at the different sites.

8.) The corresponding passage will be adapted in the revised manuscript: "The low bias in hourly lysimeter measurements indicated the suitability of their arithmetic mean as a reference for comparing precipitation methods."

9.) Reference should be to Fig. 2 A, not 2 B. Here the hexagon area is marked across the six lysimeters in equidistance to the control shaft in the middle. Fig. 2 B shows two of the hexagonal lysimeter arrangements in a row. We will add a scale and more information to the plot.

10.) The sum is calculated after the application of Eq. 1, 2 and 3.

11.) n_{ia} are the lysimeters which have been inactive or did not provide reliable data during time interval i. We will adjust the naming of the variables to make them clearer.

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