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Testing data evaluation strategies for estimating precipitation and actual evaporation from precision lysimeter measurements

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Weighing lysimeters have long been recognized as valuable tools not only for monitoring of groundwater recharge and solute transport, but also for the determination of the soil water balance and quantification of water exchange processes at the soil-plant-atmosphere interface. If well embedded into an equally-vegetated environment, they reach a hitherto unprecedented accuracy in estimating precipitation (P) by rain, dew, fog, rime and snow, as well as actual evapotranspiration (ET). At the same time, they largely avoid errors made by traditional micrometeorological instruments, such as the wind error of Hellman rain samplers or the influence of subsurface heterogeneity on readings from in situ instrumentation of soil water state variables.

Beginning in 2008, the Helmholtz Association established a network of terrestrial environmental observatories (TERENO) that aim at long-term monitoring of climate and land-use change consequences. A total of 126 identically designed large weighing lysimeters, operating at a sampling frequency of 1 min-1, were installed for this purpose, which raises the demand for standardized data processing methods. In theory, estimating P and ET from these measurements is straightforward: An increase in the combined mass of the soil monolith and the collected seepage water indicates P, while a decrease indicates ET. However, in practice, lysimeter data are prone to numerous sources of error, including, but not limited to, outliers, systematic errors due to plant growth and removal, data gaps, and stochastic fluctuations. The latter pose a particularly challenging problem – if we would directly calculate P and ET from a time-series that is affected by random noise, every positive fluctuation would be interpreted as P and every negative one as ET. Consequently, we would overestimate both quantities by far.

The aim of this study was to evaluate algorithms that focus on eliminating the effect of these fluctuations and to estimate actual fluxes across the soil-atmosphere boundary from lysimeter data. To test how different strategies of data processing perform under various circumstances, we used numerical simulation to generate synthetic data and corrupted these with three different noise patterns of increasing complexity. We found that traditional low-pass filtering approaches are not very well suited for our use case. However, an additional threshold-based separation of P and ET after initial smoothing appears to work considerably better and more robust, while still being straightforward to implement. A third, more sophisticated approach proposed by Peters (2013) that extends on this method by data driven parameter scaling, should be subject to further research. Based on our preliminary findings, we suggest reducing degrees-of-freedom of this strategy.