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Discussion

Comment on "Microlysimeter station 1 for long term non-rainfall water input and evaporation studies" by Uclés et al.

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Non-rainfall atmospheric water input, whether fog, dew, or water vapor adsorption, has indeed been recognized as an important water source in arid and semi-arid environments, as rightly detailed by Uclés et al. (2013). In these environments, the magnitude of latent heat flux during the dry season is very small and largely determined by non-rainfall water inputs (NRWI) and their evaporation, a fact that poses some very special technical measurement difficulties (Ninari and Berliner, 2002). In such conditions, even small measurement errors may result in errors that are of the order of magnitude of the flux itself (Agam et al., 2004).

Measurement methods for detecting the typically small amounts of NRWI have been developed in the last several decades, starting with manual qualitative methods in the 1940s (Duvdevani, 1947) and continuing with various methods based on artificial condensation surfaces (see a review by Agam and Berliner, 2006). A few decades later, a continuous method for the direct measurement of NRWI on the actual soil surface was proposed by Ninari and Berliner (2002), who described and tested the dimensions and characteristics of a weighing micro-lysimeter (ML) for accurate NRWI measurements. Note that Uclés et al. (2013) mistakenly added the paper by Ninari and Berliner (2002) to the list of manually measured lysimeters, while, in fact, their ML was continuously weighed.

In their conclusions, Ninari and Berliner (2002) stated that in order to accurately detect the small amounts of NRWI, the depth of the ML must be at least the depth at which the diurnal temperature is constant, in order to ensure similar temperature profiles inside and outside the ML. The reason for this conclusion is that the depth at which the diurnal temperature is constant is the depth below which the heat conduction and the soil heat flux are negligible. It was shown (Fig. 6 in Ninari and Berliner, 2002) that a significant part of the surface soil heat flux during the night originated from a soil layer depth of 15–30 cm, and that the layers below 15 cm contributed more than 60% of the total flux.

While Uclés et al. (2013) mentioned this conclusion, the y continued with the argument that "However, Jacobs et al. (1999) carried out several tests in the Negev with sampling cups having a 0.06 m diameter and three different heights (0.01, 0.035 and 0.075 m), and found consistent results with the 0.035 and 0.07 m – high sampling cups, reporting that the daily moisture cycle is confined to the upper 0.02–0.03 m of the soil profile. In fact, several studies have been carried out successfully using small sampling cups (Table 1)". A quick check on the cited references in Table 1 of Uclés et al. (2013) reveals that all studies described therein were conducted on sandy to loamy soils with a relatively small fraction of clay minerals (see Table 1 for details). In these soils, heat does not penetrate as deep as in more clayish soils, and the depth at which the diurnal temperature is constant is likely shallower. Nevertheless, in Heusinkveld et al. (2006), for example, a diurnal temperature range of about 5 °C was observed at a depth of 0.20 m (Fig. 3 therein), in Kaseke et al. (2012), the diurnal temperature range at 0.28 mm was ~2 °C, and in Uclés et al. (2014), the depth at which the diurnal temperature was constant was 0.40 m. It is clear that even in sandy soils, a depth of 0.09 m does not fulfil the requirement of constant diurnal temperature.

Uclés et al. (2013) based their decision to use 0.09 m deep MLs on a technical limitation, stating that "Sample dimensions in automated microlysimeters are determined by the load-cell characteristics, since the larger the sample or the load-cell are, the lower the resolution". This is, of course, true in general, and the attempt to measure fluxes and other phenomena at the edge of the detection limits of existing scientific equipment is indeed a challenge. However, recently, a lysimeter system was described in the literature where load cells, combined with a logging system, reached an output separation of 2^{16} (Tripler et al., 2012). For the ML dimensions recommended by Ninari and Berliner (2002), this separation results in a resolution of 0.009 mm, which is adequate for NRWI monitoring. Uclés et al. (2013) further hypothesized that "this sample depth [0.09 m] would provide a good temperature gradient within the soil profile without significantly affecting the soil heat balance". They tested their hypothesis by comparing the soil surface temperature of the ML sample and the surroundings at two sites with different soil characteristics. They stated that "Results confirmed that there were no significant differences between nighttime soil surface temperatures measured in the sample and in the surroundings (Fig. 5)". The data plotted in their Fig. 5 is data measured only during the nighttime, even though the soil heat flux during the day has an important effect on the overall 24-h performance of the sample. Showing only nighttime temperatures reveals only a partial

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Table 1
Soil type used in ML studies of NRWI.

Reference	Soil type
Jacobs et al. (1999)	Fine sandy soil with a 1 mm cracked layer on top consisting of silt and clay
Graf et al. (2004)	Loam
Heusinkveld et al. (2006)	Fine sandy soil with a 1 mm cracked layer on top consisting of silt and clay
Pan et al. (2010)	Sand with and without a 8–20 mm biogenic crust layer on top
Kaseke et al. (2012)	River sand
Uclés et al. (2014)	Alluvial fans
Uclés et al. (2013)	Sandy loam and silty loam affected by surface crusting processes

picture. According to the regression line equation presented in the figure, at a surface temperature of 50 °C (a reasonable maximum surface temperature in the study area), the temperature of the ML soil sample will be more than 1.5 °C higher than the surrounding area. It is very likely that a regression line based on 24-h measurements would be different, and deviations between the sample and the surrounding area may potentially be even larger. As can be seen from the figure, this issue was less critical for the sandy loam soil, compared to the silty loam soil. Since the surface temperature is critical in determining dew formation, and especially in differentiating between dew formation and water vapor adsorption, such a difference may lead to biased measurements.

Finally, in their Table 2, Uclés et al. (2013) show total NRWI and evaporation for a period of 49 days for four different cover types: bare soil, stones, biological soil crust, and plants. The frequency at which the samples were replaced (if replaced) was not mentioned. The root water uptake of plants, within a soil sample of 0.15 m diameter and 0.09 m depth, cannot be equivalent to or representative of the root water uptake of similar plants in the surrounding area, and thus, the evapotranspiration rates measured for the plant MLs are unlikely to be representative of the surrounding flux.

In summary, the measurement of NRWI is undoubtedly a challenging task as the fluxes involved are very small, pushing the limits of conventional methods for measuring latent heat flux. Several attempts have been reported in the literature, some of which may be adequate under the specific conditions in which they were tested. The attempt made by Uclés et al. (2013) to develop "*an automated microlysimeter which may be used for the accurate study of NRWI and evaporation on soils and small plants*" that will be suitable under various soil types, plants, and environmental conditions is ambitious. Additional research is still required, testing a range of soil types, plants, and environmental conditions, before a method can be robustly determined to be a "*useful and effective tool in non-rainfall water input studies*".

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