# In-Situ measurements of pore water stable isotope composition in a semi-arid environment and their implications to spatio-temporal variability

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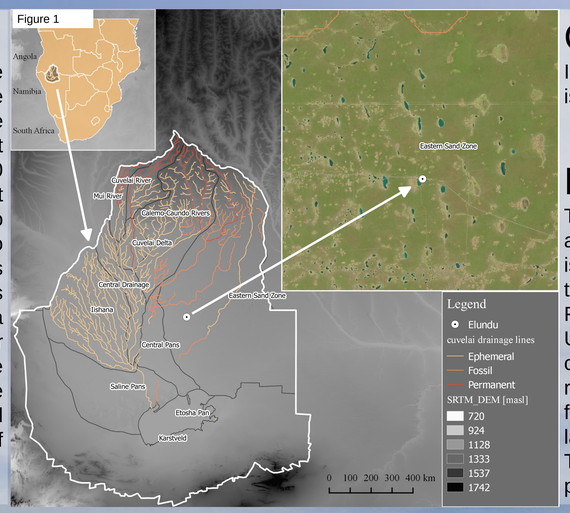
## Study Area:

The study area is located in the north of Namibia and is part of the Cuvelai-Etosha-Basin (CEB). The whole surface water catchment has an extent of about 173,000 km² where the northern part (approx. 52,000 km²) belongs to Angola and the southern part to Namibia. This sedimentary basin is divided into four major sub-basins called Iishana, Niipele, Olushandja and Tsumeb and can be further separated into different drainage zones. Measurements were conducted within the eastern sand zone close to the township of Elundu as indicated in figure 1.

Figure 1




## Objectives:

Improve the understanding of processes in the soil-plant-atmosphere continuum using stable isotopes to:

- identify dominant controls on soil water and vapor transport in the unsaturated zone
- quantify evapotranspiration and recharge

## Methods:

Temperature time series to a depth of 45cm and suction tension depth profiles to a depth of 25 cm are measured after irrigation and the dry out is monitored. In a further campaign soil moisture and isotope depth profiles are measured directly in the field to account for small scale spatial and temporal variability.

For the determination of $\delta^2H$ and $\delta^{18}O$, commercially available soil gas probes (BGL-30, Umweltmesssysteme (UMS), Munich) with a diameter of 9.4 mm and a length of 300 mm were connected to an integrated cavity off-axis liquid water isotope analyser (OA-ICOS, Los Gatos research, DLT100). A simplified wiring diagram is illustrated in figure 2. Each probe is separated from the main transport line with a valve (Clippard Minimatic, USA) which in turn is controlled by a laptop. In addition the laptop is communicating with the OA-ICOS through an RS-232 connection. The laptop mimics the behavior of a laboratory auto sampler via an interface programmed in python.

Figure 2

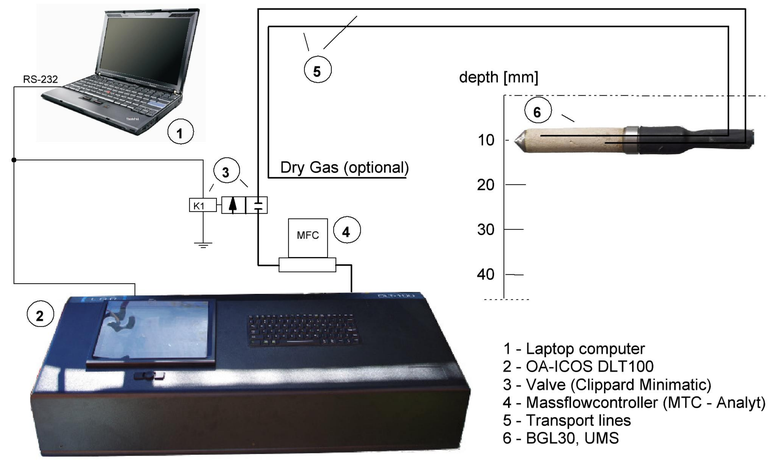



Figure 4

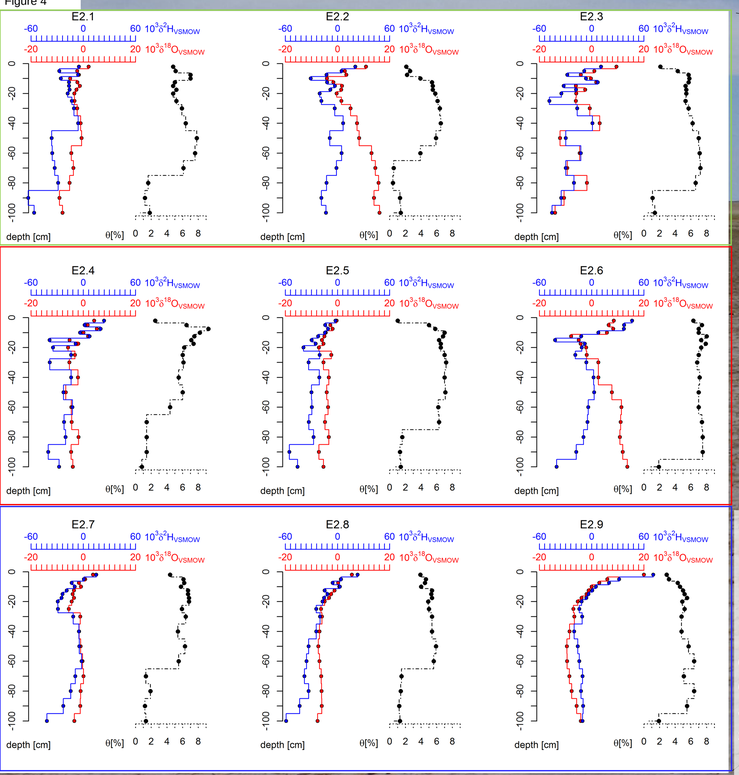



Figure 5

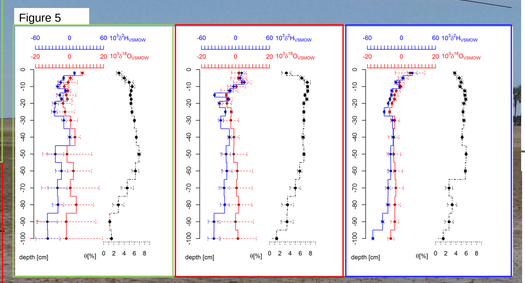


Figure 6

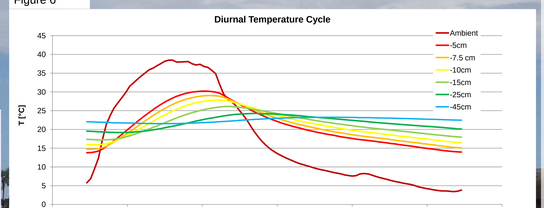



Figure 7

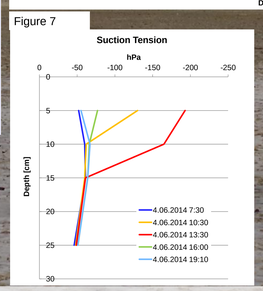
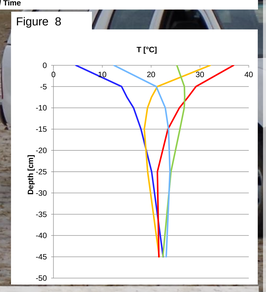



Figure 8




## Results:

It can be observed that both temperature and suction tension is following a diurnal cycle. The drier the profiles becomes the deeper is the effect visible. Stable water isotope measurements of a high spatial and temporal resolution were achieved in the study area with reasonable accuracy and in agreement with laboratory-based cryogenic vacuum extraction (Gaj et al.,2015). using a cavity ring down laser spectrometer (CRDS). After drift correction of the isotope data, precision for over 140 measurements of two consecutive field campaigns in June and November, 2014 were 1.8- 6.6 ‰ and 0.36-1.7 ‰ for $\delta^2H$ and $\delta^{18}O$, respectively. Accuracy using quality check standards was 5.1 ‰ and 0.11 ‰ for $\delta^2H$ and $\delta^{18}O$, respectively. Results support the applicability of an in-situ measurement system for the determination of stable isotopes in soil pore water even under very dry conditions.

Figure 4 illustrates nine individual depth profiles within an area of 9,000 m². The profiles cover different characteristics regarding vegetation patterns. The measured profiles were moist down to a depth between 65 and 95 cm. Water content varied between 0.5% and 9.5 %. The nine profiles are aggregated and mean values for each transect are shown to illustrate a temporal development with intermittent rainfall (figure 5). The first transect (green framed) is affected only from the first set of rain events. The second transect (red framed) is affected by the 16 mm event (17th November 2014) with -0.6 ‰ and 3.0 ‰ for $d^{18}O$ and $d^2H$, respectively. Finally, the last three plots (blue framed) experienced additional precipitation on the 19th November 2014 with an amount of 4 mm and with isotope values of 3.6 ‰ and 28.8 ‰ for $d^{18}O$ and $d^2H$, respectively.

**References:**

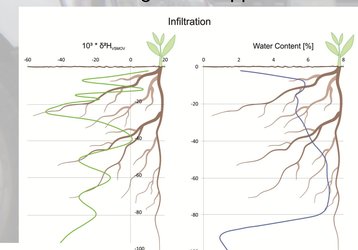
Gaj et al. 2015: HESS discussions (submitted)

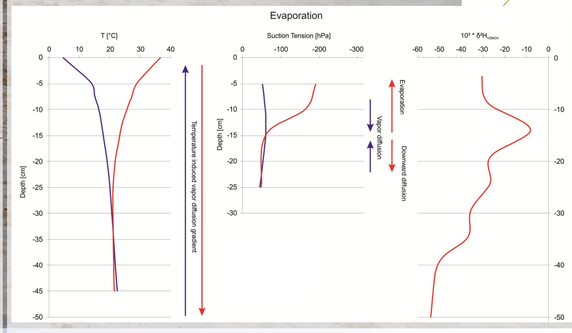
## Discussion:

The measuring scheme presented here shows the applicability of in-situ stable water isotope measurements. Beside this it can be shown that infiltration and evaporation processes can be investigated in more detail using high resolution measurements of stable water isotopes in the unsaturated zone. It can be shown that variability of isotope depth profiles is high even on the plot scale. This is due to heterogeneous infiltration of rain water as well as vapor transport within the unsaturated zone characterized by vegetation, roots canals, exposition and climate.

It can be shown that temperature, humidity and suction tension is the driver for water and water vapor transport. Isotope depth profiles can show soil-atmosphere interactions that are not visible measuring soil moisture only. In addition, isotope depth profiles characterize temperature, humidity cycles and beside this a shape dependence on soil physical properties. The data implies that the peak of the isotope depth profiles is correlated with the characteristic cycles of matrix potential and/or temperature. The data will be used to quantify water fluxes using model approaches.

## Conceptual Model:

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