Sensor for measuring the average of a spatial distribution of the relative air humidity

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Due to the current expansion of arid regions, the pressure on available water resources is increasing. A suitable measure for water availability and dynamics in dry soil is the relative humidity (RH) of the soil air as shown in Goss and Madliger (2007). Due to the heterogeneity of soil, water inputs, and root water uptake, the humidity of soil air will vary in space. Therefore, area-representative measurement methods are needed to find a representative measure of the soil water status. Existing sensors for the direct determination of relative humidity only represent a single location with a spatial extent of up to several cm.

We introduce a new measuring principle that averages over a spatially heterogeneously distributed relative humidity (Lazik et al., 2019). It is based on the selective steady-state diffusion of water vapor through closed semipermeable membrane tubes. The resulting pressure changes within the tubes are sensitive to the respective vapor pressures. One tube is exposed to the environment while two further tubes enable observing reference states of vapor pressure for same (p,T)-conditions. The relative humidity of interest follows immediately from the comparison of the measured pressure changes.

We show that the new type of membrane-based relative humidity sensor (MHS) is able to work without any external calibration. An important conclusion from our theory is that RH measurement using an MHS does not depend on temperature. This independence could be confirmed experimentally for laboratory conditions (temperature 22 to 28 °C, air pressure 993 to 1015 hPa). The comparison of our first laboratory prototype with calibrated RH reference sensors in a range of 4 to 100% RH proves the linearity of the measuring method and its accuracy.

A potential application is the improvement of water use efficiency in irrigated agriculture. As demonstrated in Goss and Madliger (2007) the RH readings can be converted to a water potential. If the sensor is buried in/above the root zone of an irrigated agricultural field, it can help schedule irrigation to maintain the water potential in the root zone within a range that maximizes the crop yield per volume of irrigation water. If the sensor is buried in dry soils, it may contribute to improved estimates of vapor-based water transport and groundwater recharge. In case large-scale data are needed that can realistically only be acquired by remote sensing, such data will probably require calibration with ground-truth data. Our technology can deliver such data with a much larger footprint than typical mm to cm-scale humidity sensors that measure the humidity within a measurement chamber with a volume below 1 cm³ that is in contact with a poorly defined but tiny
soil volume.
