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The challenge of measuring rock moisture: A laboratory experiment using eight types of sensors

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Weathering is a key component of the geomorphological process system and poses a major threat to cultural heritage, such as building structures and rock art sites. Since almost all rock decay is enhanced by the presence of water, research on moisture content and flow is crucial to understanding weathering processes. Nevertheless, measuring rock moisture and its fluctuations is difficult as there is no universally used sensor that meets the requirements of non-destructiveness, reliability, repeatability, and applicability at field sites. Therefore, this work aims to evaluate several moisture measurement techniques under different natural conditions and to provide recommendations for their use. We tested seven types of methods (1D resistivity, 2D resistivity, TDR, borehole humidity, microwave reflectance, IR thermography, and uranine probes) under controlled conditions in a sandstone block that was subject to a slow wetting and drying cycle and to a series of freeze-thaw cycles.

Overall, the methods measuring dielectric properties of the rock (TDR, microwave) can be generally recommended for their reliability, repeatability, and applicability at field sites. Precise observation of moisture dynamics in deeper subsurface however remains a challenge, especially when moisture contents are close to drier states. Therefore, to get reliable water content data, it is vital to drill inside the rock rather than to use surface sensors, which are particularly sensitive to surface moisture and surface roughness. Nonetheless, out of the non-destructive surface methods, dielectric sensors using the microwave spectrum with a greater penetration depth (>10 cm) should be considered as they have the advantage of interacting the transmitted signal into a larger volume of material, therefore making the influence of surface less pronounced. Furthermore, the use of electrical resistance methods is less recommended because of mainly two factors: they need to be calibrated for each sensor pair, and they are prone to erroneous measurements in the presence of salts. Concerning the other methods, probes using a reactive dye, and borehole humidity sensors can be used to determine the location of the subsurface evaporation front where salt crystallisation takes place, and the IR imaging for studying evaporation dynamics needs either highly controlled environment or continuous measurement. In conclusion, this work provides new insights into rock moisture measurements and further research should focus on subsurface moisture measurements and the improvement and calibration of available techniques.