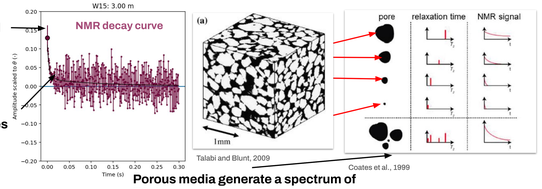
Using time-lapse borehole NMR relaxation measurements to investigate the relationship between bedrock weathering and plant-available water storage

Logan Schmidt and Daniella Rempe
The University of Texas at Austin, loganmschmidt@utexas.edu

$$M(t)_{\text{pore dist.}} = \sum_i \mathbf{M}_i(0) \exp\left(\frac{-t}{T_{2i}}\right) \qquad \frac{1}{T_2} = \rho\frac{S}{V}$$

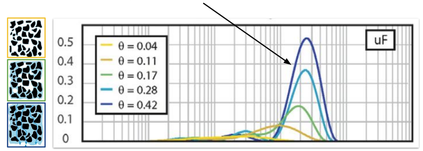
Initial amplitude is directly proportional to water content

The decay rate is controlled by material properties

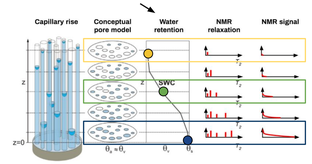


Porous media generate a spectrum of T2 times related to spectrum of pore sizes

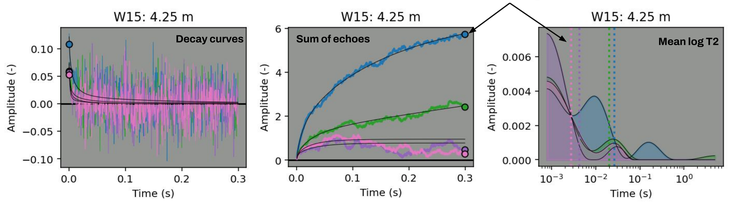
T2 distribution is saturation dependant



T2 saturation-dependance is related to water-retention



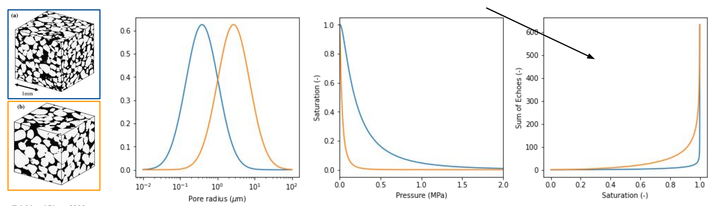
The full T2 spectrum can be characterized with a single value

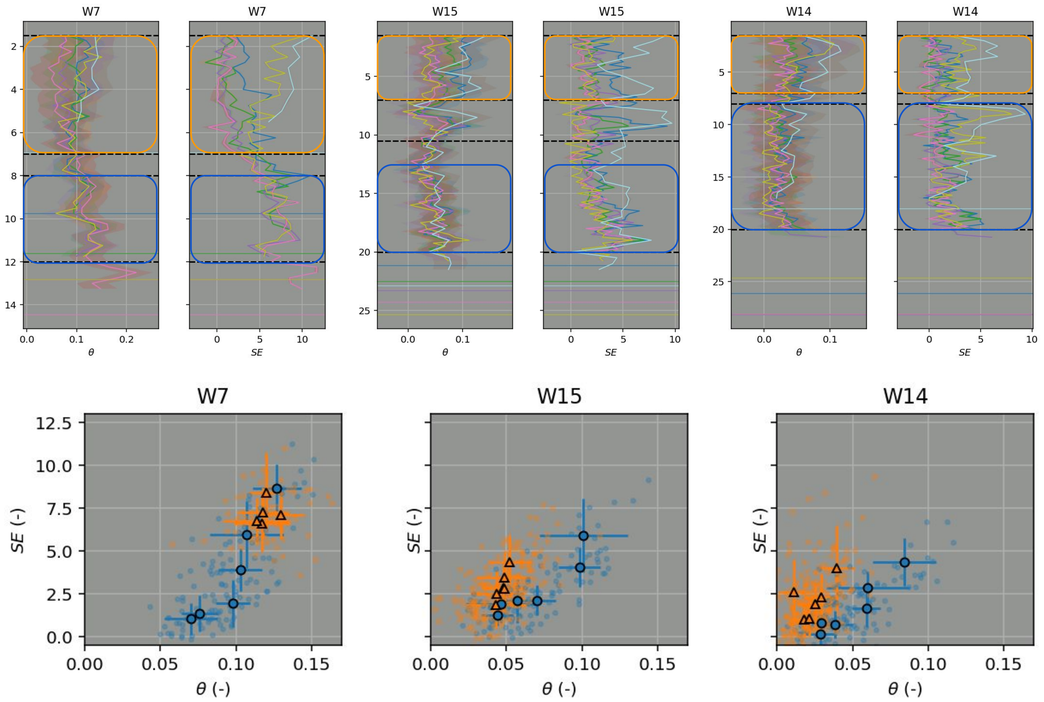


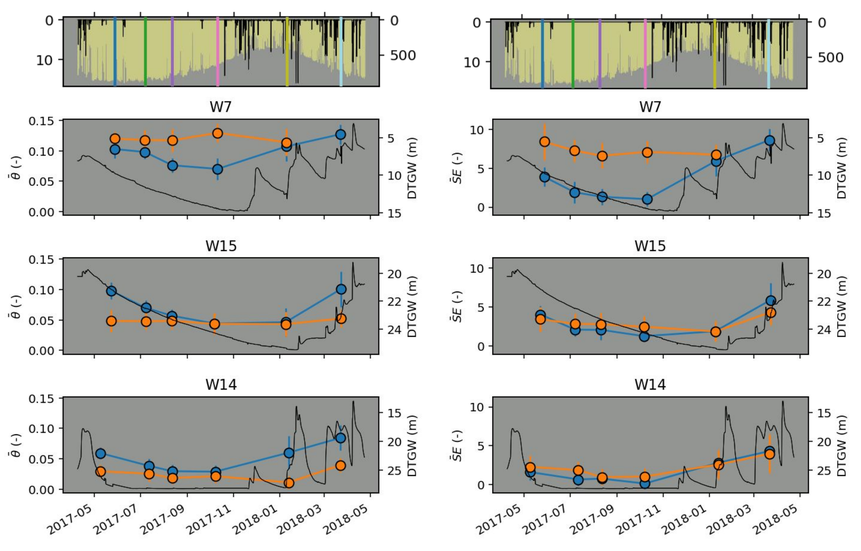
$$SE \propto \theta \cdot |T_2|$$

The sum of echoes has important advantages for characterizing NMR relaxation time in unsaturated conditions

NMR characteristic curves describe the relationship between T2 relaxation times as a function of water content and can be used to infer differences in material properties

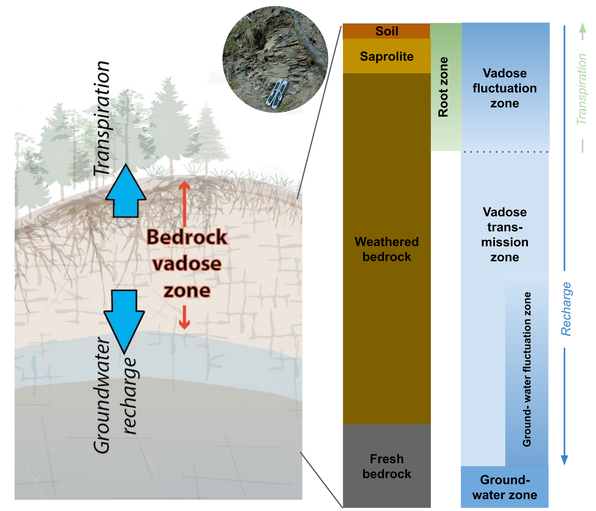






- Used repeat **borehole nuclear magnetic resonance** well logging to monitor **unsaturated water content changes** in highly weathered mud-rich bedrock within a hillslope in seasonally dry Northern California
- Unsaturated water storage in the upper 6 m of bedrock is seasonally dynamic (vadose fluctuation zone). Unsaturated storage in deeper bedrock is seasonally non-dynamic (vadose transmission zone).
- Goal is to interrogate this behavior via link between NMR relaxation and pore structure and water potential
- **Low signal to noise**, resulting from low water contents, precluded conventional inversion processing approach
- Opted for simple, convenient processing approach: the **sum of echoes**

- Sum of echoes has **improved contrast and precision** relative to other NMR products, making it
- Deep, non-dynamic unsaturated water storage is associated with longer relaxation times than shallow, dynamic storage, for the same water content
- In the deepest wells, evidence that the sum of echoes is sensitive to groundwater recharge in the transmission zone



References
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Falzone, S., & Keating, K. (2016). The NMR relaxation response of unconsolidated sediments during drainage and imbibition. Vadose Zone Journal, 15(6), vzj2015-11.

Talabi, O., & Blunt, M. J. (2010). Pore-scale network simulation of NMR response in two-phase flow. Journal of Petroleum Science and Engineering, 72(1-2), 1-9.

Acknowledgements
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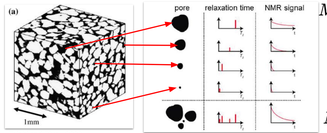
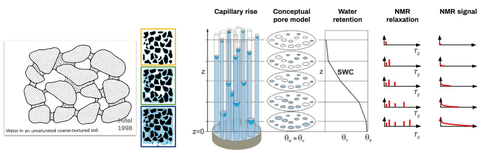


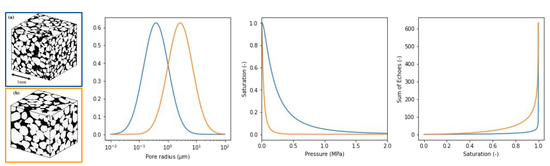
Talabi and Blunt, 2009

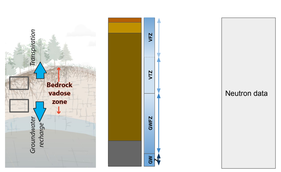
Coates et al., 1999

$$M(t)_{\text{single pore}} = \mathbf{M}(0)\exp\left(\frac{-t}{T_2}\right)$$

$$M(t)_{\text{pore dist.}} = \sum_i \mathbf{M}_i(0)\exp\left(\frac{-t}{T_{2i}}\right)$$







Neutron data