Influence of soil structure on the spatiotemporal variability of subsurface water flows in a volcanic ash-derived soil

Sebastián Bravo-Peña[1,2] , José Dörner[2,3], and Loes van Schaik[1]

[1] Soil Physics and Land Management Group (SLM), Wageningen University & Research, Droevendaalsesteeg 3, 6708 PB, Wageningen, The Netherlands

[2] Instituto de Ingeniería Agraria y Suelos (IIAS), Universidad Austral de Chile, Federico Saelzer building, Isla Teja Campus, Valdivia, Chile

[3] Centro de Investigación en Suelos Volcánicos (CISVo), Universidad Austral de Chile, Federico Saelzer building, Isla Teja Campus, Valdivia, Chile

WAGENINGEN UNIVERSITY & RESEARCH

SLM Soil Physics and Land Management

Centro de Investigación en Suelos Volcánicos

POSTER´S ABSTRACT
Author: Sebastián Bravo-Peña
Contact: sebastian.bravopena@wur.nl
Soil Physics and Land Management Group
Wageningen University and Research

Background

Understanding the soil water dynamics is essential for accurate projections of future climate change scenarios, where the frequency of droughts, floods, and wildfires is expected to increase. Predicting the spatiotemporal variability of soil moisture dynamics at different scales is a major challenge. Moreover, multimodal soil hydraulic properties resulting from complex soil structures, such as those exhibited by volcanic soils, still lack realistic parameterisation. This work aimed to shed light on the spatiotemporal heterogeneity of subsurface water flows and soil water distribution during wet and dry conditions in volcanic ash-derived soil.

Methods

The volumetric moisture content (VMC) at 10, 20, and 60 cm depth was measured from September 2019 to January 2022 (10-minute resolution). The analysis of soil moisture dynamics using three times series at 10 cm depth is presented in this poster. These time series were separated into wet (WP) and dry (DP) periods based on the mean VMC. Subsequently, the spatiotemporal variability in moisture content within the soil profile was analysed using spectral analyses, which describe the process variability in different periodicities (scales). The propagation of periodicities from $Prate$ to the three topsoil VMC time series as well as the time scales in the correlation of the VMC between sensors were described. Finally, the time dependency of wetting slopes (St) on $Prate$ was assessed by the cross-correlation function (CCF).

Results

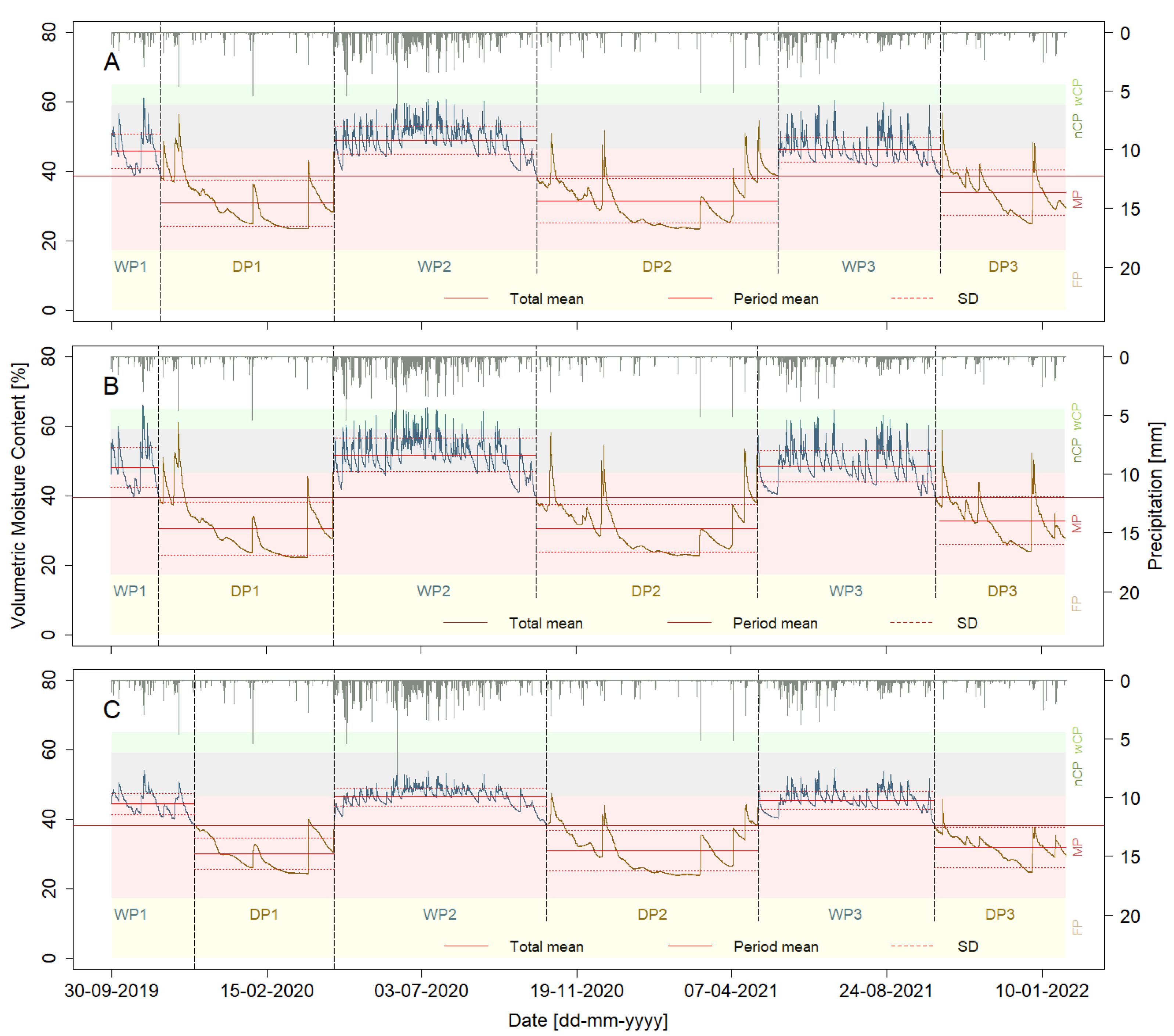


Figure 1. Wet periods (WP) and Dry periods (DP) determined for time series at 10 cm depth. A, B, and C correspond to the sensors r1, r2, and r3, respectively. Coloured areas describe the pore size distribution.

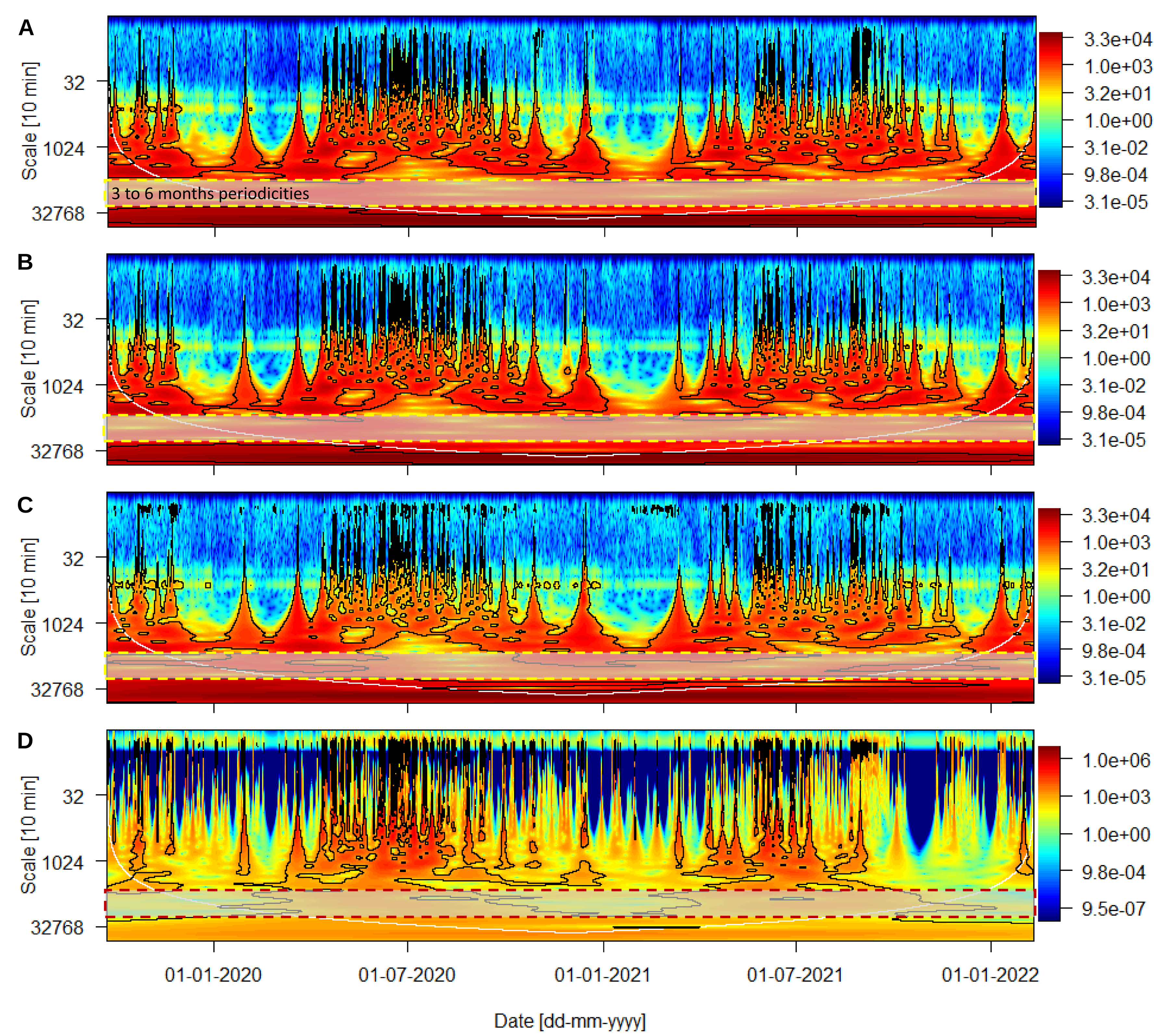


Figure 2. Continuous Wavelet Transform of precipitation (D) and three VMC time series at 10 cm depth. A, B, and C correspond to r1, r2, and r3, respectively. Scale of colours describes the contribution to the total variance. Black-contoured areas represent 95% of significance.

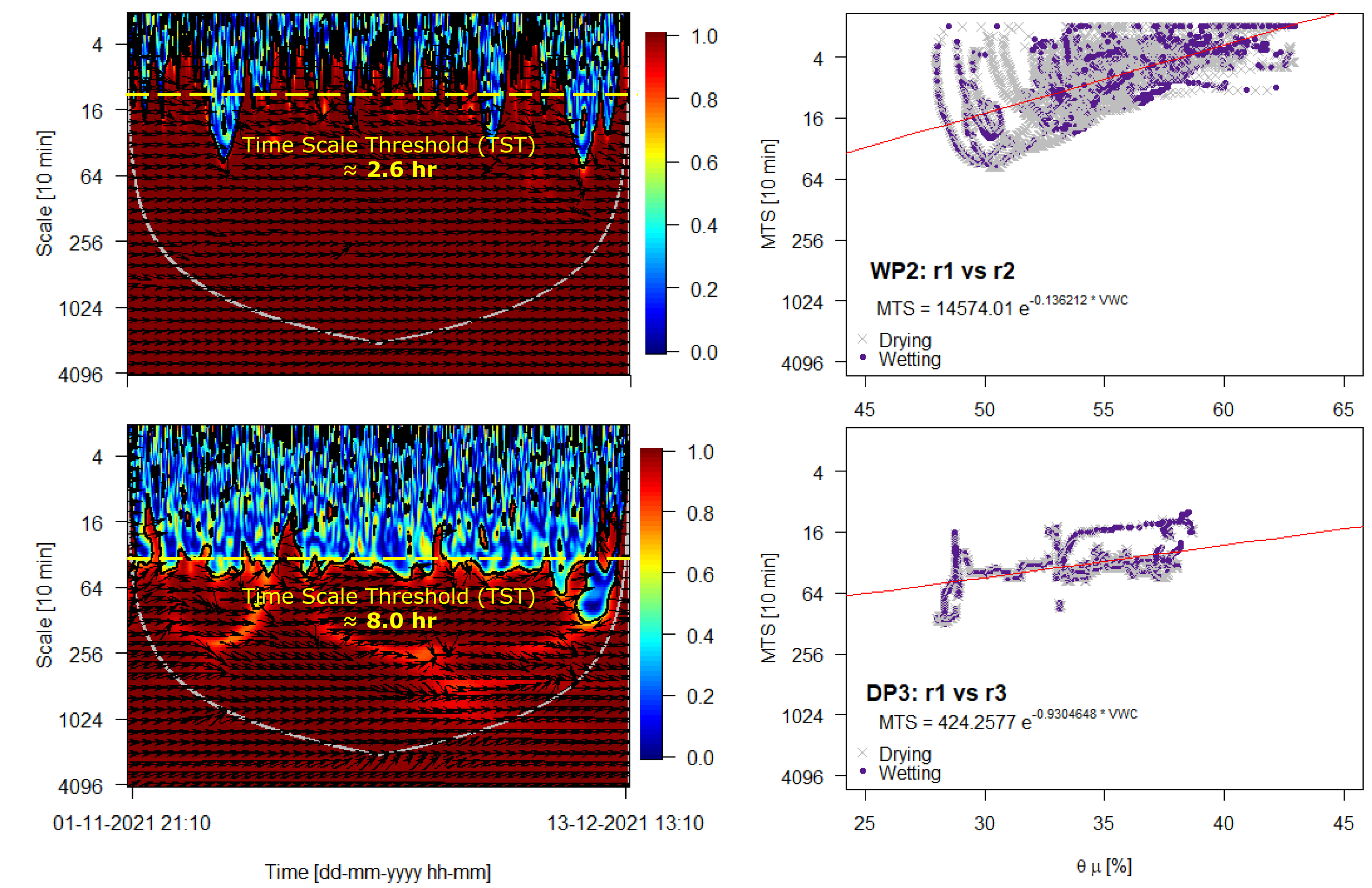


Figure 3. Spatiotemporal variability of VMC in wet and dry periods. Left: Wavelet Coherence spectrum of two time series at 10 cm depth. Right: Minimum time scale (MTS) of high correlation (>0.9) as a function of the VMC state ($\theta\mu$) of two paired time series. Purple and grey colours represent wetting and drying processes, respectively.

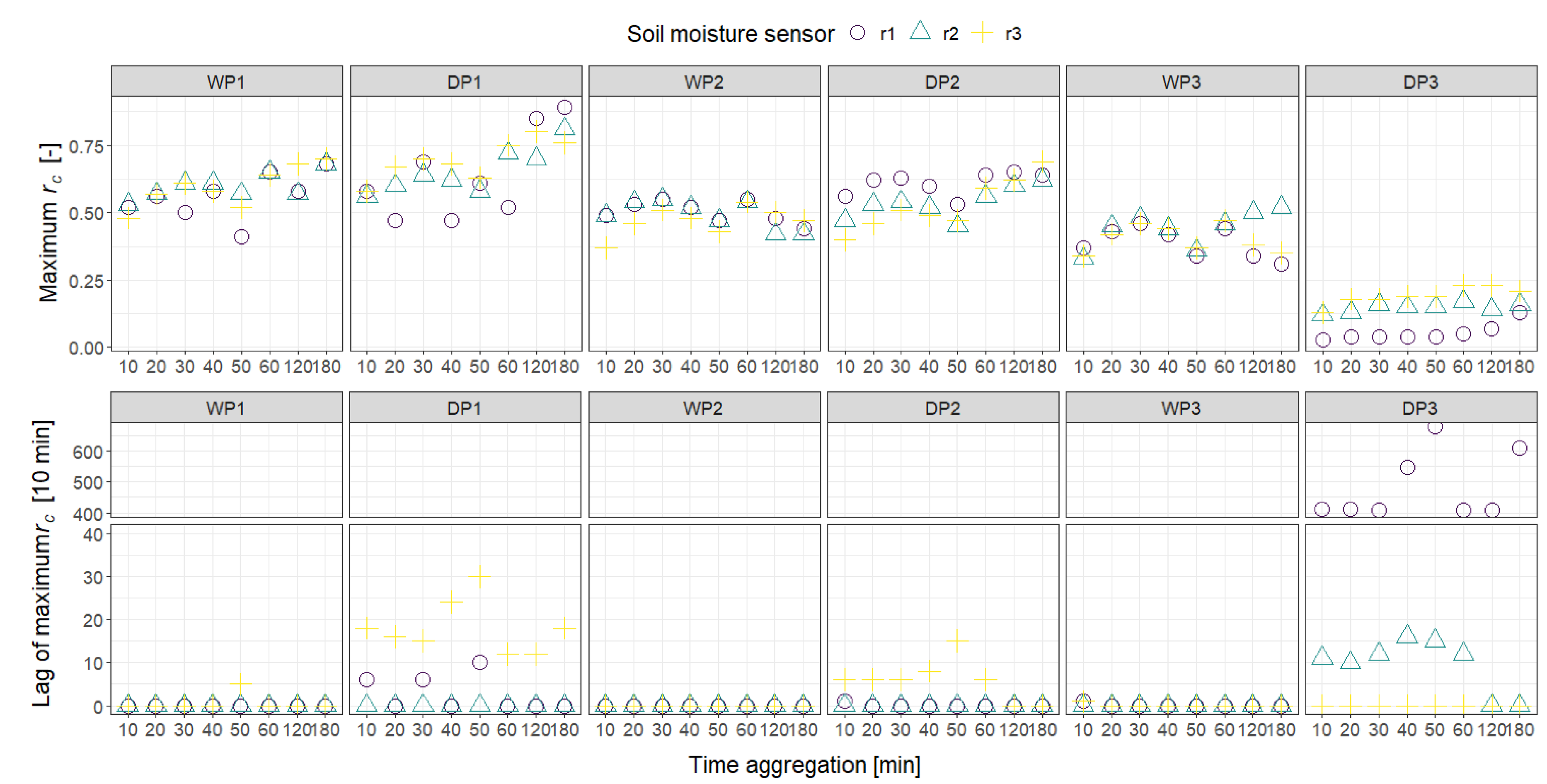


Figure 4. Cross-correlation coefficients between St and $Prate$: Maximum cross-correlation (r_c) in the upper plot. At the bottom, the respective lag of the highest correlation is shown. For each period, aggregated observations are presented in 10 (base resolution), 20, 30, 40, 50, 60, 120, and 180 minutes. The lag values of aggregated data were transformed to the base resolution unit: 1 lag = 10 min.

Conclusions

- The VMC response to $Prate$ is **notably faster during wetter conditions than in dry periods**.
- Different ranges of pore size and related hydraulic properties produced by **contrasting conditions influence the soil moisture variability**.
- Hydraulic properties experience a **dynamic shift from a heterogeneous to a homogeneous system**, proposed as Time Scale Threshold (TST).
- Time scale of correlation of soil moisture dynamics within the topsoil described an **exponential relationship** as a function of the moisture content.
- **Changes in the temporal correlation** of the VMC measured within the topsoil, along with an accurate description of the time dependency of St on $Prate$, **can be valuable for further understanding of the hysteresis** of soil moisture variations in a soil profile.

Acknowledgements

The authors thank to the "Agencia Nacional de Investigación y Desarrollo (ANID); Beca Chile n°72200251. We Also thank to Prof. Dr. José Dörner to provide the required data set (Fondecyt project 1191057) and to the Soil Physics and Land Management group of Wageningen University & Research, for supporting this participation in the EGU23.

References

Bravo, S., Gonzalez-Chang, M., Dec, D., Valle, S., Wendroth, O., Zuñiga, F., & Dörner, J. (2020). Using wavelet analyses to identify temporal coherence in soil physical properties in a volcanic ash-derived soil. Agricultural and Forest Meteorology, 285. https://doi.org/10.1016/j.agrformet.2020.107909

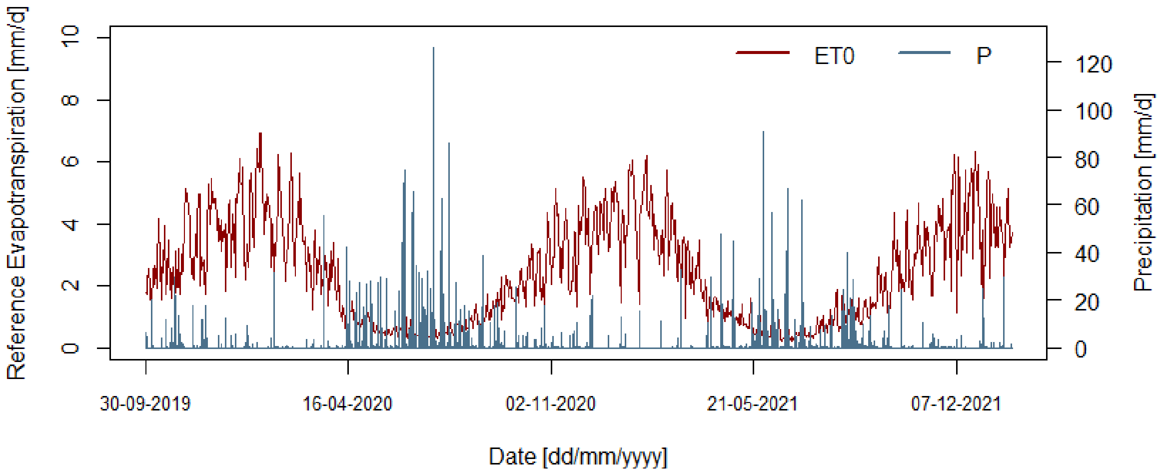
Jarvis, N., J. Koestel, J., & Larsbo, M. (2016) Understanding Preferential Flow in the Vadose Zone: Recent Advances and Future Prospects. Vadose Zone Journal, 15(12). https://doi.org/10.2136/vzj2016.09.0075

Influence of soil structure on the spatiotemporal variability of subsurface water flows in a volcanic ash-derived soil

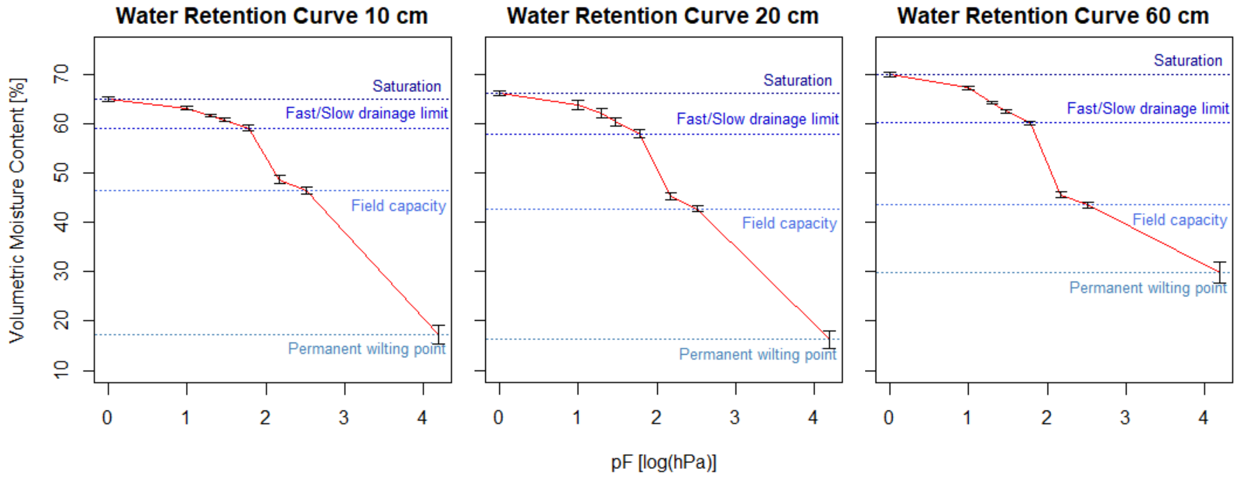
Sebastián Bravo-Peña[1,2], José Dörner[2,3], and Loes van Schaik[1]

[1] Soil Physics and Land Management Group (SLM), Wageningen University & Research, Droevendaalsesteeg 3, 6708 PB, Wageningen, The Netherlands
[2] Instituto de Ingeniería Agraria y Suelos (IIAS), Universidad Austral de Chile, Federico Saelzer building, Isla Teja Campus, Valdivia, Chile
[3] Centro de Investigación en Suelos Volcánicos (CISVo), Universidad Austral de Chile, Federico Saelzer building, Isla Teja Campus, Valdivia, Chile

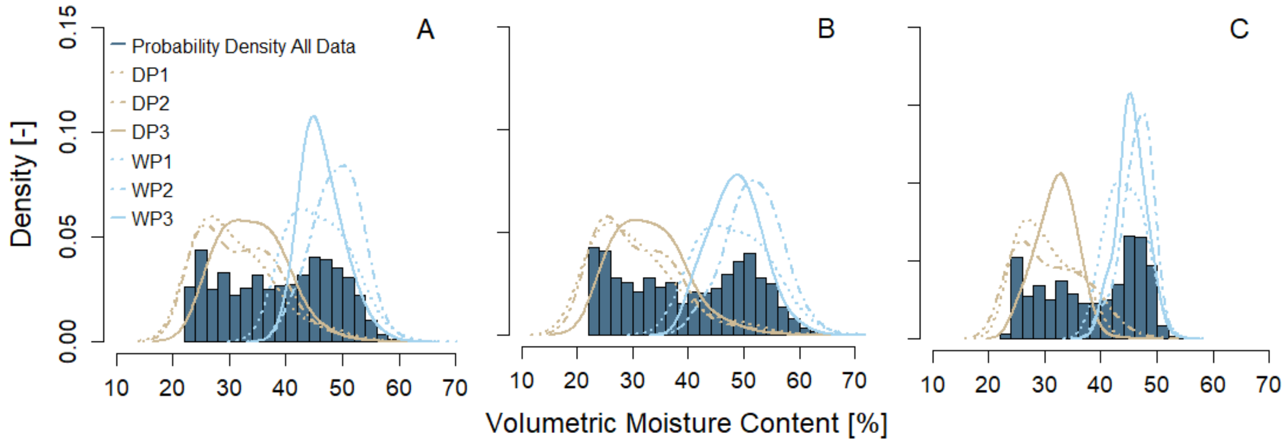
Supplementary Materials (SM)



SM 1. Reference evapotranspiration [ET0, mm/d] consulted from "*Red de Estaciones Agrometeorológicas de INIA*" (Austral Station, https://agrometeorologia.cl) and precipitation [P, mm/d] measured at the experimental field in EE.AA (Universidad Austral de Chile).



SM 2. Water retention curve for three depths in a volcanic soil in Valdivia, Chile. From left to right: 10, 20, and 60 cm depth, respectively. Error bars represent Standard Error (n = 7).



SM 3. Histograms of three time series at 10 cm depth (A, B, C correspond to r1, r2, and r3 respectively). Coloured lines describe the probability density function (pdf) of each determined period.

Influence of soil structure on the spatiotemporal variability of subsurface water flows in a volcanic ash-derived soil

Sebastián Bravo-Peña[1,2], José Dörner[2,3], and Loes van Schaik[1]

[1] Soil Physics and Land Management Group (SLM), Wageningen University & Research, Droevendaalsesteeg 3, 6708 PB, Wageningen, The Netherlands
[2] Instituto de Ingeniería Agraria y Suelos (IIAS), Universidad Austral de Chile, Federico Saelzer building, Isla Teja Campus, Valdivia, Chile
[3] Centro de Investigación en Suelos Volcánicos (CISVo), Universidad Austral de Chile, Federico Saelzer building, Isla Teja Campus, Valdivia, Chile

Supplementary Materials (SM)

SM 4. Mean, maximum wetting slope, and the number of observations (N) for wet and dry periods in three soil moisture sensors at 10 cm depth. The conditional format shows the differences in maximum wetting slopes in a scale of colours.

Sensor:	r1			r2			r3		
Period	mean (S_t) [%/min]	max (S_t) [%/min]	N	mean (S_t) [%/min]	max (S_t) [%/min]	N	mean (S_t) [%/min]	max (S_t) [%/min]	N
WP1	0.00472	0.1979	4295	0.00568	0.1966	1951	0.00263	0.0985	4295
WP2	0.00796	0.2842	7280	0.00946	0.3057	7834	0.00341	0.1164	10594
WP3	0.00686	0.4967	6721	0.00717	0.4902	7091	0.00359	0.1816	8549
DP1	0.0021	0.2902	8099	0.00225	0.4561	8121	0.00163	0.1064	7274
DP2	0.00229	0.2812	12157	0.00229	0.5261	10950	0.00199	0.0869	11018
DP3	0.00224	0.2563	5900	0.00257	0.3525	6248	0.00155	0.1013	6632

Subsurface Water Flows ranges
(SSWF; %/min):
Low = $0 < St \leq 0.005$
Medium = $0.005 < St \leq 0.05$
High = $0.05 < St$

SM 5. Cumulative density distribution of wetting slopes [%/min] for WPs (left) and DPs (right) for r1, r2, and r3 (top, middle, bottom rows, respectively) at 10 cm depth. Vertical (red and dark red) dashed lines describe the main found limits to separate subsurface water flows. Horizontal (goldish) dashed lines depict the main found proportions of wetting slopes.