Supplementary Material for: Pore-scale fluid dynamics resolved in pressure fluctuations at the Darcy scale

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TABLE I: Flow rates and Capillary numbers for the experiments used in this work. The Capillary number $Ca = \frac{q}{\sigma\lambda}$, as defined by [1].

Experiment	**Flow rate NWP (ml/min)**	**Flow rate water (ml/min)**	**Total flow rate (ml/min)**	**Ca number**
gas/water pore	0.015	0.085	0.1	1.6×10^{-7}
oil/water pore	0.05	0.05	0.1	2.2×10^{-6}
gas/water core	5	1	6	2.0×10^{-8}
oil/water core	3	0.6	3.6	5.4×10^{-7}

I. CORE-SCALE EXPERIMENTAL METHODOLOGY

Prior to any injection, the sample is loaded into a core holder that allows pressurisation of the fluids, and placed in the medical CT scanner used to image the core and the fluid distributions within. A confining pressure is applied that is always 2 MPa above the pressure in the core. Before an experiment begins the sample is filled with water and pressurised to 8 MPa (the outlet of the core is held constant at 8 MPa during an experiment).

For the co-injection experiments, a drainage sequence is performed with both fluids (gas or oil, and water) injected at a constant flow rate, and fractional flow, for 60 minutes. The flow rates chosen are given in Table I. The flow rates were chosen to observe flow in the capillary dominated regime, and to have similar capillary numbers for the different fluid pairings. CT imaging occurred during flow, and at the end of both the drainage and imbibition cycles.

Between the gas/water experiments the core is depressurised and flushed with water, before the system is re-pressurised. This removes gas from the system, as confirmed by the wet scans prior to next experiment. For the oil/water experiment, the sample orientation was not reversed as it is difficult to completely remove oil from the sample.

II. CONTINUOUS WAVELET TRANSFORMATION (CWT) FIDELITY

To test the fidelity of the transformations, we calculated inverse wavelet transforms using all frequencies and using only low frequencies (a form of low-pass filtering). Error was $< 2.5\%$ for full inverse transforms (i.e. including all frequencies; see Equation 4). Filtered inverse wavelet transforms that only include low frequency contributions to the signals are shown in Figure 1 and discussed in the body text of the main manuscript. These results indicate that continuous wavelet transforms can yield fair representations of pressure series in the time-frequency domain, and that nearly all signal power is concentrated at low frequencies (see caption to Figure 1 and Figures 2–4).

[1] Spurin, C., T. Bultreys, B. Bijeljic, M. J. Blunt, and S. Krevor, Intermittent fluid connectivity during two-phase flow in a heterogeneous carbonate rock, *Physical Review E*, *100*(4), 043,103, 2019.

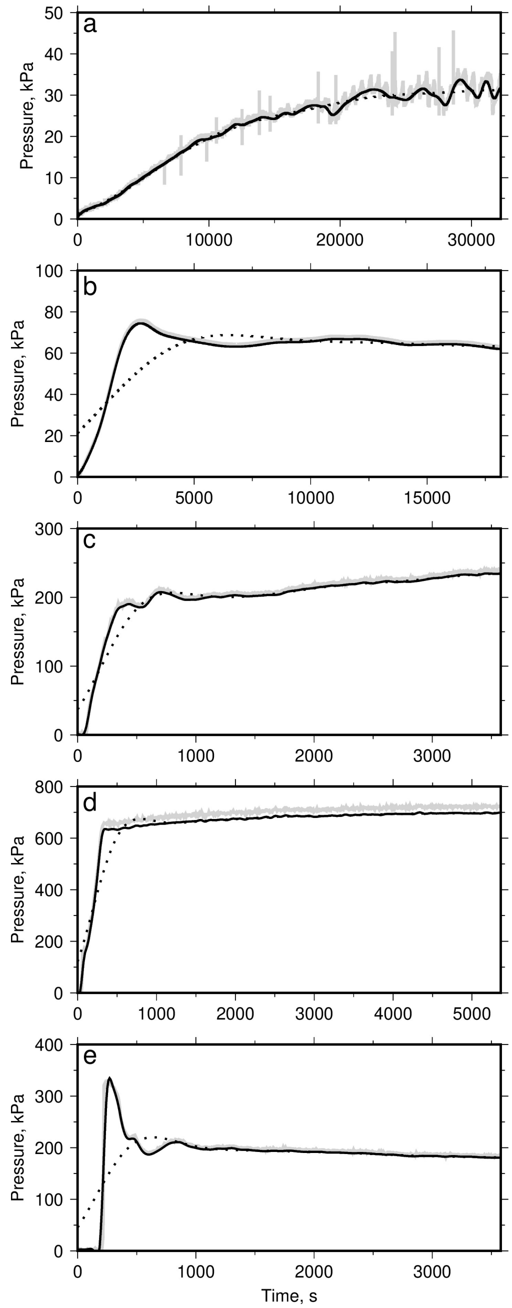

FIG. 1: Pressure time series (gray curves) and inverse wavelet transforms. Black solid and dotted curves = inverse wavelet transforms for periods $> 10^3$ s and $> 10^4$ s (panels a-b), respectively, or $> 10^2$ s and $> 10^3$ s (panels c-e). (a) Pore-scale gas/water experiment (see Figure 2a-d). (b) Pore-scale oil/water experiment (Figure 2e-h). (c) Core-scale gas/water experiment (Figure 3a-d). (d) Core-scale oil/water experiment (Figure 3e-h). (e) Core-scale gas/water experiment with the sample reversed (Figure 4).