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A (not so) random walk through hydrological space and time

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A key philosophical perspective in science is that nature obeys general laws. Identification of these laws involves integration of system conceptualization, observation, experimentation and quantification. This perspective was a guiding principle of John Dalton's research as he searched for patterns and common behaviors; he performed a broad range of experiments in chemistry and physics, and he entered over 200,000 observations in his meteorological diary during a period of 57 years. In this spirit, we examine general concepts based largely on statistical physics – universality, criticality, self-organization, and the relationship between spatial and temporal measures – and demonstrate how they meaningfully describe patterns and processes of fluid flow and chemical transport in hydrological systems. We discuss examples that incorporate random walks, percolation theory, fractals, and thermodynamics in analyses of hydrological systems – aquifers, soil environments and catchments – to quantify what appear to be universal dynamic behaviors and characterizations.