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Subsurface temperature impacts of groundwater abstraction

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The abstraction of groundwater is in many areas crucial to maintain public water supply. Knowledge on the provenance of the abstraction water is central to safeguard the long-term sustainability of a water supply both in terms of water quality and quantity. Classically, hydraulic head measurements in combination with natural geochemical tracers are used to constrain numerical models of groundwater pumping sites. Surprisingly, subsurface temperature patterns have been used hardly to map groundwater flow patterns and fluxes around groundwater abstraction sites. In this study, we evaluate a dataset of 46 temperature-depth profiles collected around five groundwater abstraction sites in the central part of the Netherlands. All of these stations are sited in a layered aquitard-aquifer system consisting of marine and riverine unconsolidated sedimentary deposits of Holocene and Pleistocene age. Consistently, elevated temperatures directly underneath each pumping station (e.g., 80-120 m depth) show that relatively deep groundwater must be upwelling across aquitard units forming the lower bound of the aquifer from which groundwater is being produced. The magnitude of this 'thermal upconing' can be quantitatively linked to the rates of vertical groundwater leakage across the aquitard. The impact of these abstractions on shallow and phreatic groundwater is harder to establish from thermal data. This is because nearer to the ground surface the effects of surface warming introduce a strongly transient temperature signal that is not easily separable from groundwater flow effects. Our data and analysis shows that groundwater abstraction has a distinct, and generic impact on subsurface temperatures the characterization of which can lead to important quantitative insights into the hydrogeological dynamics in areas of groundwater production.