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Using salinity and temperature data to constrain numerical models of deep topography-driven flow in sedimentary basins

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Heat flow and thermochronological studies frequently document thermal effects that are ascribed to deep groundwater flow. However, the high uncertainty and heterogeneity of subsurface permeability have hampered model studies of the thermal effect of groundwater flow. We incorporate groundwater salinity data and new permeability upscaling algorithms to constrain basin-scale groundwater flow in the Roer Valley Graben in the southern Netherlands. Subsurface temperature data from the Roer Valley Graben show up to 20 °C variation in temperature in the upper 1000 m of the basin's sediments, which do not coincide with any trends in thermal conductivity or crustal thinning and may therefore be related to groundwater flow. In addition, groundwater salinity data from the basin show that the fresh-salt water boundary is located up to 1000 m below the base of Pliocene-Quaternary continental deposits, which suggests freshening of the underlying marine sediments by meteoric water. We explore the extent topography driven flow using the numerical model code Rift2D. Effective model-scale permeability was calculated from the variability of clay content observed in borehole logs, using a new efficient upscaling algorithm. The average temperature change resulting from topography-driven flow in four model scenarios that captured the uncertainty of permeability ranged from -3 to -17 °C. Salinity data provide strong additional constraints on basin-scale flow. The model scenario that matches both the available salinity and temperature data results in an average cooling of 14 °C with maximum values of 40 °C. As the topographic gradients in the Roer Valley Graben do not exceed 1 %, these results imply that topography driven flow can significantly alter subsurface temperatures even in settings where only a limited relief is present.