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Spatiotemporal modelling of groundwater extraction in semi-arid central Queensland, Australia

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The semi-arid Surat Basin in central Queensland, Australia, forms part of the Great Artesian Basin, a groundwater resource of national significance. While this area relies heavily on groundwater supply bores to sustain agricultural industries and rural life in general, measurement of groundwater extraction rates is very limited. Consequently, regional groundwater extraction rates are not well known, which may have implications for regional numerical groundwater modelling. However, flows from a small number of bores are metered, and less precise anecdotal estimates of extraction are increasingly available. There is also an increasing number of other spatiotemporal datasets which may help predict extraction rates (e.g. rainfall, temperature, soils, stocking rates etc.). These can be used to construct spatial multivariate regression models to estimate extraction. The data exhibit complicated statistical features, such as zero-valued observations, non-Gaussianity, and non-stationarity, which limit the use of many classical estimation techniques, such as kriging. As well, water extraction histories may exhibit temporal autocorrelation. To account for these features, we employ a separable space-time model to predict bore extraction rates using the R-INLA package for computationally efficient Bayesian inference. A joint approach is used to model both the probability (using a binomial likelihood) and magnitude (using a gamma likelihood) of extraction. The correlation between extraction rates in space and time is modelled using a Gaussian Markov Random Field (GMRF) with a Matérn spatial covariance function which can evolve over time according to an autoregressive model. To reduce computational burden, we allow the GMRF to be evaluated at a relatively coarse temporal resolution, while still allowing predictions to be made at arbitrarily small time scales. We describe the process of model selection and inference using an information criterion approach, and present some preliminary results from the study area. We conclude by discussing issues related with upscaling of the modelling approach to the entire basin, including merging of extraction rate observations with different precision, temporal resolution, and even potentially different likelihoods.