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Stochastic space-time modelling of groundwater level variations in a Mediterranean basin

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Mires basin in the Messara Valley is located on the island of Crete (Greece). It has marginal groundwater resources that are used mainly for agricultural activities. n extensive network of pumping stations has been installed since 1984. As a result, productivity has risen at the price of an alarming drop of approximately 35m in groundwater level during the last 25 years. The basin has been monitored for groundwater level variations, rainfall and surface runoff by the Department of Water Resources Management of the region of Crete for around 30 years. Accurate prediction of the future water table depth is crucial for the management of water resources in the basin and for the prevention of possible desertification effects. Ten boreholes were monitored between the years 1981 and 2003, while others were monitored for shorter periods. Since 2003 the regular monitoring of the boreholes was replaced by the operation of two telemetric stations installed in two selected boreholes.

Our overall goal is to use stochastic methods for the monitoring and prediction of the groundwater level in Mires basin. Time series of mean annual groundwater level data is available from the ten boreholes that were monitored between the years 1981 and 2003 and since then (2003-2010) from the two telemetric stations. First, we model the temporal variation of groundwater level with a discrete time regionalized autoregressive exogenous variable model (RARX) model (Ljung, 1999; Knotters et al., 2001). The term "exogenous" denotes that the model equations incorporate information from auxiliary variables in addition to groundwater level. In this study precipitation measurements and pumping data are used. The RARX model is embedded in a discrete-time Kalman filter to estimate the model parameters and predict the optimal mean annual groundwater level. The RARX model is calibrated for the years 1981 to 2006 and is then used to predict the mean annual groundwater level in the basin for the recent years (2007-2010). The predictions are validated with the available annual averages reported by the local authorities. Secondly, we use a spatiotemporal geostatistical analysis of the groundwater level using space-time Ordinary Kriging (STOK). A space-time experimental variogram is determined from the biannual (wet and dry period) groundwater level time series between the years 1981 and 2003 at the ten sampling stations. We model the variogram with separable (Matérn) and non-separable theoretical spatiotemporal variogram functions (Kolovos et al., 2004). STOK is used to predict the groundwater level at each sampling station onwards (2004-2010) biannually. The predictions are validated for the years up to 2006. The average of the estimates is compared with the groundwater level in the basin predicted by RARX and with the values reported by the local authorities based on the average of the two remotely sensed holes. The RARX estimates, after considerable initial fluctuations, are in good agreement with the measured groundwater level of the basin. The non-separable variogram function delivers more accurate STOK predictions than the separable function. The average of the estimates for the years following 2006 is very close to the reported values and the RARX model results. Both RARX and STOK provide satisfactory predictions, but STOK also provides spatially distributed estimates; furthermore, it can be potentially improved by using other spatiotemporal variogram functions.

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