Geophysical Research Abstracts
Vol. 20, EGU2018-3354, 2018
EGU General Assembly 2018

Groundwater level prediction with the Prophet forecasting approach in an area of the coastal wetlands of Doñana affected by pumping of a tourist resort

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There is an increasing need for accurate groundwater level (GWL) prediction in environmentally sensible and/or pumping areas to support effective water management. Groundwater in irrigated areas in a context of population growth and climate change is becoming a highly dynamic and changeable resource. Strong human pressure (pumping) and extreme climatic events (droughts, heavy rainfalls) are accelerating groundwater dynamics: gradient shifts, large and fast GWL oscillations, sharp decreasing trends, etc. In particular, groundwater dependent wetlands such as Doñana National Park in southern Spain are prone to suffer from increasing stress due to intensive irrigation, industrial development and pollution.

It is desirable that forecasting tools are not only accurate but also accessible for decision-makers, this is, simple and flexible. The Prophet forecasting procedure, an open source software released by Facebook, addresses these challenges. It is based on a generalized additive model considering growth (non-periodic changes), weekly and yearly seasonality and holidays (i.e. to account for the influence of groundwater abstractions), and uses a Bayesian framework with easily-interpretable parameters. Prophet is fast and robust to missing data, shifts in the trend, and large outliers. It frames the forecasting problem as a flexible curve-fitting exercise, which is inherently different from time series models that explicitly account for the temporal dependence structure in the data such as ARIMA.

Daily records of GWL from 2002 to 2017 in three piezometers of the Doñana aquifer near the tourist village of Matalascañas were fitted to the Prophet model with no additional regressors. Irregular local holidays (Eastern and Corpus Christi) were included. Goodness of fit was compared to that of other baseline methods (mean, ARIMA, feed-forward neural networks, forecast with seasonally adjusted data, etc.). To further assess model accuracy we used simulated historical forecasts (SHF) as a surrogate for cross-validation in time series where data is sliced in time segments to measure forecast error using historical data.

Prophet forecasts are customizable in ways that are intuitive to non-experts in time series models but have domain knowledge. There are smoothing parameters for seasonality that allow adjusting how closely to fit historical cycles and holidays, as well as smoothing parameters for trends that allow adjusting how aggressively to follow historical trend changes such as pumping influence.