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Predictive groundwater flood hazard mapping in lowland karst

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The management of karst geohazards requires new and novel strategies to address the complexities inherent in karst systems and the challenges posed by a changing climate. The often rapid and widespread interaction between surface and subsurface hydrology can leave karst terrains uniquely susceptible to flooding from groundwater sources. Quantifying the frequency and magnitude of such flooding is a key step in the management of flood risk. Here, we present a novel interdisciplinary approach developed for predictive groundwater flood hazard mapping in the lowland karst plains of Ireland. This approach ties together direct and earth observation-derived hydrograph data, hydrological modelling, stochastic weather generation and extreme value analysis to generate predictive groundwater flood maps for qualifying sites.

The first step in the approach was the collection of hydrological data for sites susceptible to groundwater flooding. A monitoring network of 50 sites was established in late 2016 to provide baseline data over a 30-month period. Additionally, a methodology for delineating historic flood extents and water elevations from multi-temporal Copernicus Sentinel-1 Synthetic Aperture Radar (SAR) imagery was developed. This allowed hydrograph generation for ungauged sites, whilst also allowing observations of the 2015/2016 extreme flood event at gauged sites which predated monitoring. Next, site-specific hydrological models capable of constructing flood hydrographs from antecedent rainfall and soil moisture conditions were calibrated for 393 sites using a combination of observed and SAR hydrographic data (mean NSE: 0.81). A stochastic weather generator calibrated on 70-year meteorological records was used to generate long-term synthetic rainfall data for each site. These stochastic series, together with long-term average evapotranspiration, were used as input to the site models to produce long-term hydrological series from which annual maxima series were derived. Thereafter, flood frequency analysis was used to estimate predictive flood levels and generate predictive flood maps. This novel applied approach has significantly improved our fundamental scientific understanding of groundwater flooding as a geohazard, whilst also informing regional planning and development to limiting future flood vulnerability.