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Spatial dependence in floods and extreme precipitation

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Spatial risk assessments of flooding are important for the planning of flood mitigation activities and for the reinsurance industry. However, past research has mainly focussed on flood estimation at a single site, and the statistical techniques available for estimating spatial dependence and collective risk of flooding have not been as well developed. The present study uses a dependence measure based on the Heffernan and Tawn (2004) model for estimating multivariate dependence of extreme values. Heffernan and Tawn developed a two parameter model, one parameter describing the overall strength of dependence and the other how the dependence changes as the variables become more extreme. The latter is required as empirical evidence suggests that dependence weakens as flows get larger. Using the fitted model, new "pseudo-observations" are simulated taking into account the dependence behaviour. This means that pseudo-observations can be simulated outside the range of the observed data, and the dependence subsequently estimated between the variables at very extreme levels. In this study, the Heffernan and Tawn method was modified to be suitable for hydrological applications by accounting for (i) missing observations and (ii) temporal dependence in the data. The dependence measure is applied to observations of daily mean river flows at 271 sites in Great Britain, and separately, to daily precipitation totals at 256 sites. The average record lengths are about 40 years for both datasets. Given that an extreme event has occurred at one site, the spatial dependence measure characterises the extent to which neighbouring locations are affected. For both river flow and precipitation it is quantified how dependence weakens as the return periods of these events get longer at a site of interest. More generally, the spatial dependence in precipitation is weaker in the upland north and west than in the rest of Great Britain, in response to precipitation amounts varying with altitude and windward/leeward effects. The dependence is weaker in summer than in winter, presumably because of a higher proportion of localised convective events compared with widespread frontal events in summer. The topographic influence on the dependence in precipitation is not clearly carried through to the spatial dependence in river flows, which shows a more variable pattern at smaller scales. The local variability appears to mainly be related to differences in catchment characteristics, with areas encompassing diverse catchments exhibiting lower levels of dependence.

Reference

Heffernan, J. E. and Tawn, J. A. 2004. A conditional approach for multivariate extreme values (with discussion). J. R. Statist. Soc. B, 66, 497-546.