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Blame the river not the rain

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The devastating intensity of exceptional floods in some rivers can be anticipated, and surprisingly traces back to the river basins themselves, rather than the amount of rain they receive.

The powerful forces unleashed by floods have been a persistent danger since the birth of human civilization[1]. Floods are consistently among the world's worst natural disasters, ranking first in the number of events and in the number of people affected, second in economic cost, and fourth in total deaths[2]. Future trends are equally concerning, with an increase in the risk of extreme floods expected to accompany ongoing climate warming[3]. Advancing understanding of the causes and areas at risk from major flood events is therefore critical. Writing in *Nature Geoscienc*e, Basso et al.[4] discover that it's not rainfall that's primarily causing catastrophic flooding, but rather the intrinsic properties of river basins themselves. These findings allow for the diagnosis of disaster-prone areas from commonly available hydrologic information, with potentially transformative implications for flood risk assessment and preparedness.

Flooding — at its core — is defined as an overflow of water onto normally dry land, and is often caused by rising water in an existing waterway. The study of floods commonly involves analyzing statistical distributions of extreme hydrologic quantities for the waterways themselves (for example, seasonal maxima in water extent, height, or flow). The intrinsic nature of such distributions is that floods become more catastrophic as their probability of occurrence decreases. In small basins, there is sometimes a step change in the slope of the distribution, whereby the rarest floods are substantially larger than would otherwise be expected[5]. Determining which basins are plagued by this dangerous feature — referred to as 'flood divide' by the authors[4] — is therefore paramount.

Basso et al.[4] use hydroclimatic data for selected river basins in the United States and Germany to identify which basins display a flood divide; both empirically and theoretically. The empirical flood divides are determined from river flow observations. The theoretical approach fits flow and precipitation observations to a mathematical description of peak flow processes[6], before determining the flood divides from emulations. A century-old theorem[7] is then applied to simplify the mathematical description of peak flows by reducing its variables into a smaller number of non-dimensional parameters. The simplification reveals two key non-dimensional and intrinsic properties of river basins as the primary controls for normalized flood divide values. Basso et al.[4] then build a formula which can explain the presence of a flood divide in small river basins based on these intrinsic basin quantities, rather than more commonly used quantities such as current water storage and rainfall conditions. Crucially, river basins with a flood divide can now be determined from common hydroclimatic data records; before the flood divide can even be evidenced by an event (Fig. 1). The absence of catastrophic floods in the past data record therefore no longer impedes knowing where they might one day occur.

Fig. 1 | Flooding in Kordel, Germany, on the 15th of July 2021. The flood was caused by an overflow of the Kyll, the river which runs through the village.

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The two key parameters identified by Basso et al. are the hydrograph recession exponent and the coefficient of variation of daily flows. The hydrograph recession exponent controls the speed at which a river basin drains its water, and has been linked to river network morphology[8]. The coefficient of variation of daily flows quantifies daily flow variability in relation to mean flow, and results from interactions among precipitation, evapotranspiration, soil moisture, and the basin's response time to precipitation[9]. While both quantities can surely be seen as intrinsic properties of river basins, they are not entirely disconnected from the physical processes that drive basin variability. As the authors point out, rainfall intensity and frequency are both included in their formula for daily flow variability. Previous work also suggests relationships between basin storage and stream recession[10]. Some may argue that these two intrinsic properties are impacted — if not driven — by precipitation and by storage conditions, respectively. It's perhaps not so much that rain and existing water storage don't matter, but rather they can be ingeniously included in powerful dimensionless numbers.

Notwithstanding the risks and potentially devastating costs of flooding in relatively small rivers, the basin areas in the study (around 10^3 km^2) are three orders of magnitude smaller than the world's largest river basins (for example, Amazon, Congo, Nile, Mississippi, of size greater than 10^6 km^2) where flooding is equally important. In addition, despite demonstrating an exceptional ability to foretell flood divides outside of previous observations, this study relies on historical observations, and so implicitly assumes that past conditions can be used to plan for the future. Such an assumption of stationarity is increasingly challenged by global environmental change[11].

Flood type and magnitude vary with time and space depending on a variety of mechanisms[1], and advances to the understanding and characterizing of flood risks must be enthusiastically embraced regardless of scale. Which of Earth's processes are to blame for flood divides matters much less than knowing where they are. The discoveries of Basso et al.[4] will hence undoubtedly benefit flood preparedness.

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Competing interests

The authors declare no competing interests.