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Climatic and landscape controls on travel time distributions across Europe

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Travel time distributions (TTDs) are fundamental descriptors to characterize the functioning of storage, mixing and release of water and solutes in a river basin. Identifying the relative importance (and controls) of climate and landscape attributes on TDDs is fundamental to improve our understanding of the underlying mechanism controlling the spatial heterogeneity of TTDs, and their moments (e.g., mean TT). Studies aimed at elucidating such controls have focused on either theoretical developments to gain (physical) insights using mostly synthetic datasets or empirical relationships using limited datasets from experimental sites. A study painting a general picture of emerging controls at a continental scale is still lacking.

In this study, we make use of spatially resolved hydrologic fluxes and states generated through an observationally driven, mesoscale Hydrologic Model (mHM; www.ufz.de/mhm) to comprehensively characterize the dominant controls of climate and landscape attributes on TDDs in the vadose zone across the entire European region. mHM uses a novel Multiscale Parameter Regionalization (MPR; Samaniego et al., 2010 and Kumar et al., 2013) scheme that encapsulates fine scale landscape attributes (e.g., topography, soil, and vegetation characteristics) to account for the sub-grid variability in model parameterization. The model was established at 25 km spatial resolution to simulate the daily gridded fluxes and states over Europe for the period 1955-2015. We utilized recent developments in TTDs theory (e.g., Botter et al., 2010, Harman et al., 2011) to characterize the stationary and non-stationary behavior of water particles transported through the vadose zone at every grid cell.

Our results suggest a complex set of interactions between climate and landscape properties controlling the spatial heterogeneity of the mean travel time (TT). The spatial variability in the mean TT across the Pan-EU generally follows the climatic gradient with lower values in humid regions and higher in semi-arid or drier regions. The results signifies the role of a landscape attributes like plant available soil-water-storage capacity, when expressed in a dimensionless number that also include climate attributes such as average rain depth and aridity index, forms a potentially useful predictor for explaining the spatial heterogeneity of mean TTs. Finally, the study also highlights the time-varying behavior of TTDs and discusses the seasonal variation in mean TTs across Europe.