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The role of subsurface storage on departures from the Budyko curve

Laurent Pfister^{1,2}, Stan Schymanski¹, Remko Nijzink¹, and Jeffrey McDonnell³

¹Luxembourg Institute of Science and Technology, ERIN, Catchment and eco-hydrology research group, Esch-sur-Alzette, Luxembourg (laurent.pfister@list.lu)

²University of Luxembourg, Faculty of Science, Technology and Medicine, Esch-sur-Alzette, Luxembourg

³University of Saskatchewan, School of Environment and Sustainability, Saskatoon, Canada

The Budyko framework is a widely used empirical concept in hydrology and climatology. However, catchment water balances that plot along the curve are often noisy and scattered, with some catchments plotting above the curve and some below the curve. Here we examine one of the possible causes for such scatter: subsurface storage. We bring together data from 38 experimental catchments in Luxembourg where all climate and landuse factors are roughly constant, except for subsurface storage.

We leverage diverse catchment geology represented by the large differences in bedrock porosity and permeability with resulting large differences in storage and streamwater transit times across our set of nested catchments. This setting enables us to test the null hypothesis that departures (offset) from the Budyko line along the evaporative index (i.e. actual evapotranspiration / potential evapotranspiration) axis has no relation to below ground storage. We then ask the following questions:

- Where do the 38 Luxembourg catchments plot in the Budyko space?
- How do subsurface storage metrics vary across the 38 Luxembourg catchments?
- How are these subsurface storage metrics related to the Budyko offset?

And secondarily,

- What might explain scatter on the precipitation / PET axis in the Luxembourg catchments and how is this related to catchment area?

Our main finding is that subsurface storage—driven by differences in catchment geology—explains approximately 60% of the departure from the Budyko curve. Furthermore, scatter along the aridity index axis (i.e. precipitation / potential evapo-transpiration) is explained by an east-west gradient in precipitation amount within an otherwise low seasonality environment.