



## **Assessing hydroclimatic change in the Budyko-framework: Mathematical derivations, misconceptions, and dangerous parameters**

Peter Greve (1) and Lukas Gudmundsson (2)

(1) IIASA, Water Program, Laxenburg, Austria (greve@iiasa.ac.at), (2) Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland

The Budyko hypothesis, stating that the climatological water and energy balance is foremost dependent on the aridity index (the ratio of potential evaporation to precipitation), is often represented through mathematical functions containing one single, free parameter. This parameter technically alters the position of the Budyko curve within the Budyko space and is often assumed to represent second-order controls of the coupled water and energy balance (with the first-order control being represented through the aridity index). Within the last two decades, a wealth of studies was aiming to determine the most important of such second-order controls, proposing a plethora of potential candidates including soil, vegetation and geographical characteristics, climatic factors and human influences. Based on these - inconclusive and sometimes contradictory - results, the parameter is often assumed to represent the influence of various “landscape” characteristics – and is therefore also referred to as the “landscape” parameter.

Here we revisit both the empirical origin of the parameter in some older Budyko functions as well as the mathematical derivation of the parameter in more recent formulations of the Budyko curve. Based on this meta-analysis we highlight the fact, that the free parameter has no a-priori physical meaning. Moreover, we show that it technically simply represents a mathematical constant that integrates all factors - besides the dimensionless aridity index - which control the coupled water and energy balance over long timescales. We argue that the complex interplay of such factors does barely enable a conclusive physical interpretation of the parameter - even though an evaluation of the parameter might be of practical use in specific catchments and for specific purposes. We, therefore, urge for a more deliberate interpretation and use of the parameter, avoiding e.g. a naive interpretation as a “landscape” control. We outline how this could have prevented misconceptions in recent Budyko-based studies and introduce general principles to avoid any misinterpretations of the parameter for future research.