High-resolution global topographic index values for use in large-scale hydrological modelling

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Abstract

Modelling land surface water flow is of critical importance for simulating land-surface fluxes, predicting runoff and water table dynamics and for many other applications of Land Surface Models. Many approaches are based on the popular hydrology model *TOPMODEL*, and the most important parameter of this model is the well-known *topographic index*. Here we present new, high-resolution parameter maps of the topographic index for all ice-free land pixels calculated from hydrologically-conditioned *HydroSHEDS* data using the *GA2* algorithm. At 15 arc-sec resolution, these layers are four times finer than the resolution of the previously best-available topographic index layers (*HYDRO1k*) and we hope that they will be widely used in land surface modelling applications in the future.

Introduction

Land Surface Models (LSMs) are widely used for predicting the effects of global climate change on vegetation development, runoff and inundation, evapotranspiration rates and land surface temperature (e.g. Dadson *et al.* 2010). However, the simulation of hydrological dynamics within LSMs remains relatively simplified because these models are usually run at coarse spatial resolution (up to 300 km grid boxes) and the physics they follow is based predominantly on approximations of processes that occur at much finer spatial scales. Correctly characterising hydrology is very important because landscape-scale water movements (~10-100 km scale) and changes in the water cycle control many effects ranging from local energy and carbon fluxes to land-atmosphere feedbacks to the climate system to potentially-catastrophic changes in vegetation distributions.

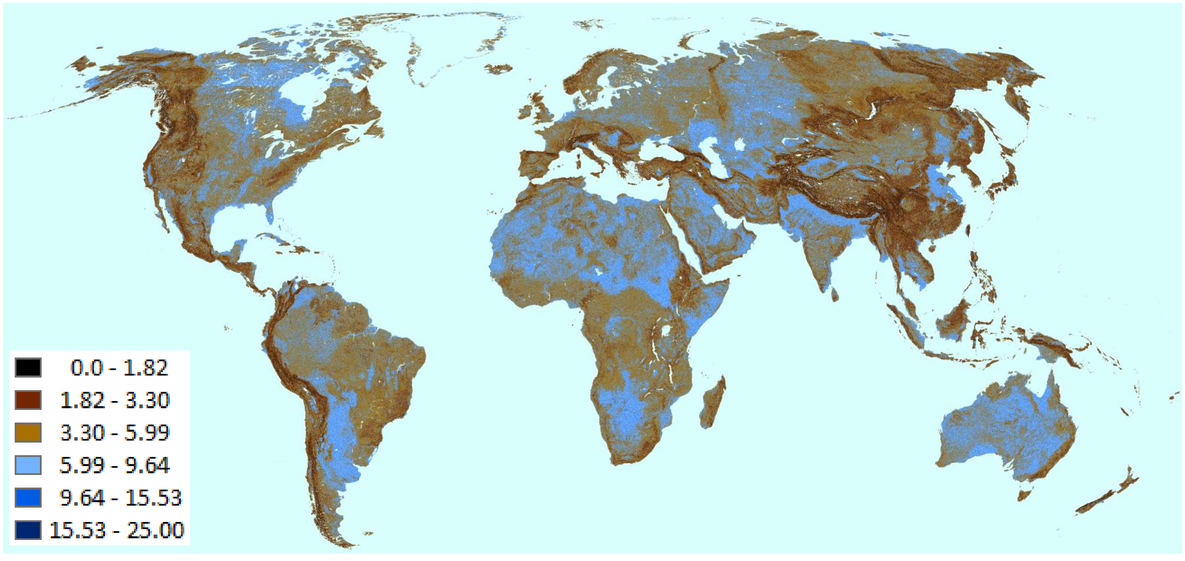
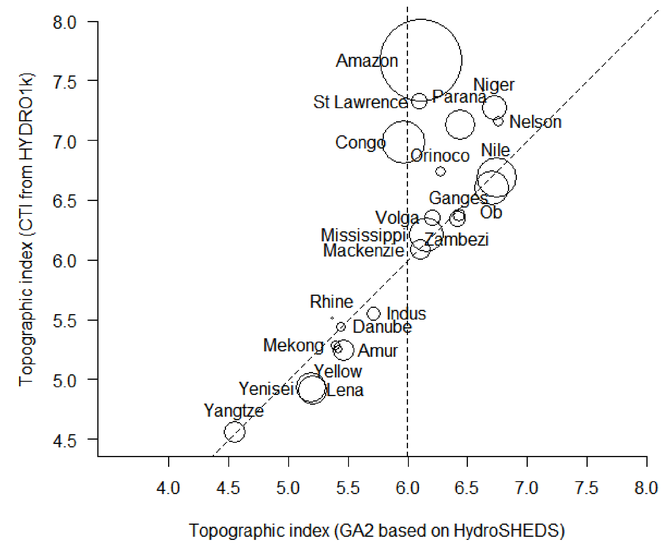


Fig. 1: Global topographic index values based on GA2 appplied to HydroSHEDS base data (Appx. A). Blue shades indicate pixels with index values above the global mean (5.99) and brown shades indicate below-average values.

Currently, the most common approach to inundation prediction is to use a runoff production scheme such as *TOPMODEL*, which partitions runoff from the soil column into surface and subsurface components (Beven 2012). One of the most important configurational parameters for *TOPMODEL* is the well-known *topographic index*, which is widely used in hydrology and terrain-related applications. In this study, we respond to the need for higher-resolution data for use in LSMs: We calculate the topographic index using the *GA2* algorithm based on high-resolution global *HydroSHEDS* data and discuss current developments in large-scale hydrological modelling and how models can benefit from higher-resolution parameter maps such as these.

Results and discussion

We produced a layer of topographic index values for all ice-free land pixels worldwide (Fig. 1). Index values calculated this way are not just relative measures but consistent and comparable between catchments, so we may compare global values (Fig. 2). Index values at 15 arc-sec resolution are available at http://doi.org/10/t7d in NetCDF format (Marthews *et al*. 2015).



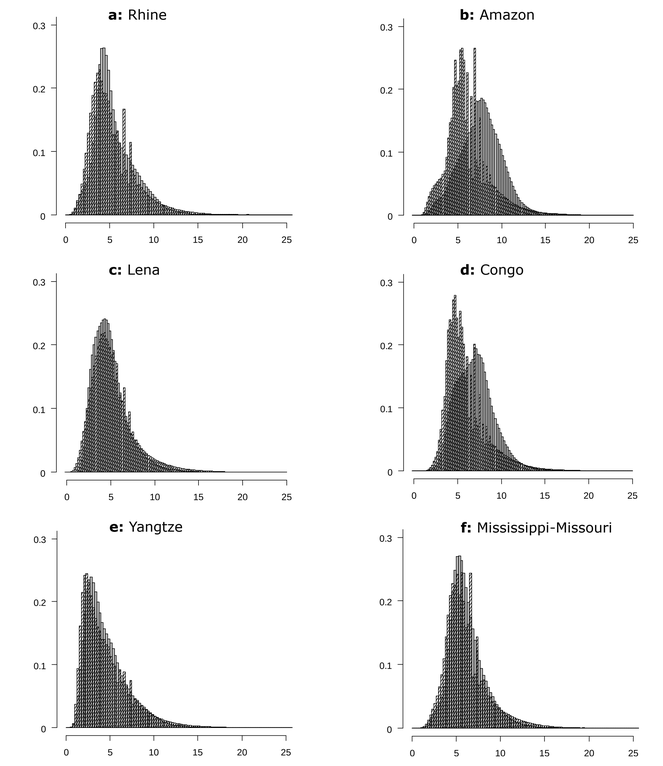


Fig. 2: Comparison of the CTI and GA2 calculations of the topographic index (TOP), showing that CTI values (Compound Topographic Index values from HYDRO1k) are larger for some catchments, most notably the Amazon, Congo, Paraná, Niger and St. Lawrence. Circle areas are proportional to catchment area and a one-one line is shown for reference. Histograms are shown for six catchments (a-f): the Rhine, Amazon, Lena, Congo, Yangtze and Mississippi-Missouri (each grey histogram shows CTI values, hatched histogram shows GA2; Axes on all histograms are omitted: all are Topographic Index (horizontal) and Fraction of Pixels (vertical)).

Modelling soil water flow and runoff generation is of critical importance for simulating land-surface fluxes, predicting water table dynamics, wetland inundation and river routing and, at a regional scale, quantifying surface evaporation rates and the growth, transpiration and seasonality of vegetation. Landscape-scale hydrological processes are therefore key elements in modelling land surface-atmosphere exchange processes and critical to the successful use of coupled LSMs to predict the effects of climate change at larger scales.

This study offers a new high-resolution, spatially consistent data layer of topographic index values for all ice-free land pixels worldwide based on the hydrologically-conditioned HydroSHEDS data. We believe these data layers represent the most accurate global-scale calculation of topographic index values that exists to date.

References

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