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Daily disaggregation of simulated monthly flows using different rainfall datasets in southern Africa

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ABSTRACT

Study region: Selected countries in southern Africa.
Study focus: The study uses a combination of a monthly rainfall-runoff model and a daily rainfall based disaggregation method to simulate daily flows. The two models were forced with different rainfall data (local and global) and the results examined to determine the major reasons for modelling success or failure.
New hydrological insights for the region: There are substantial regional differences in the success of the monthly hydrological model, which inevitably affects the success of the daily disaggregation results. There are also regional differences in the success of using global rainfall data sets (Climatic Research Unit (CRU) datasets for monthly, National Oceanic and Atmospheric Administration African Rainfall Climatology, version 2 (ARC2) satellite data for daily). The overall conclusion is that the disaggregation method presents a parsimonious approach to generating daily flow simulations from existing monthly simulations and that these daily flows are likely to be useful for some purposes (e.g. water quality modelling), but less so for others (e.g. peak flow analysis).

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1. Introduction

There are many parts of the developing world where establishing hydrological and water resources estimation models is difficult due to the lack of observed stream flow data for calibration and validation purposes, as well as deficiencies in the available climate input data to force the models. The former can be partially overcome through parameter regionalisation approaches that also include uncertainty assessments (Yadav et al., 2007; Kapangaziwiri et al., 2012). Even when observed stream flow data are available, they often include upstream anthropogenic impacts which are not always adequately quantified (Hughes and Mantel, 2010), or are not included as part of the modelling scheme. The availability of climate forcing data is problematic as a consequence of a lack of observation stations, a situation that is getting steadily worse (WWAP, 2009), combined with difficulties in accessing climate databases from some national authorities. Some data custodians are reluctant or lack the capacity to respond to data requests, and in some cases only summary information is available rather than complete time series of raw data. In other situations, quite substantial charges are levied before the data are released, even if the request is for research purposes. Practical hydrological modellers are therefore faced with decisions related to the choice of model, what data they are going to use to force the model and how they are going to validate or justify the results. All of these issues are strongly interrelated and typically not easy to resolve in many data scarce areas of southern Africa.

From a practical perspective (rather than for research purposes), the selection of a model would typically be based on user experience and the extent to which a model has already been applied successfully in the region of interest. The Pitman monthly rainfall-runoff model is therefore often the model of choice in the southern Africa region (Hughes, 2013) and it is often coupled with water resources system yield models (Basson et al., 1994; Mallory et al., 2008) to cater for many different anthropogenic impacts and to simulate different development scenarios. However, there are also situations where a monthly time-step might be considered too coarse, and either daily modelling or some form of daily disaggregation would be required.

There are many parts of southern Africa where both observed rainfall and stream flow data are limited in terms of spatial coverage and lengths of record. There is little that can be done about the stream flow data, and it is inevitable that many of our hydrological simulations will be impossible to validate and are therefore highly uncertain (Kapangaziwiri et al., 2012). Arguably, one of the only options is to use regionalised catchment response information to constrain the uncertainty as far as possible (Yadav et al., 2007; Tumbo and Hughes, 2015). For rainfall data, the alternative to a lack of local ground-based data is to make use of freely available global datasets that have been compiled through spatial interpolation from existing data, or that use remotely sensed data, such as satellite rainfall data (Voisin et al., 2008; Pombo et al., 2014; Prakash et al., 2014). All of the available data products have different temporal and spatial resolutions and therefore, not all of them are necessarily appropriate for a specific study. They are also potentially biased in relation to local ground-based rainfall data, and the bias is expected to vary depending on the amount of local rainfall data incorporated into the interpolated or merged products. The effects of topography and related orographic rainfall producing mechanisms are expected to introduce further bias in satellite products (Hughes, 2006; Xie and Arkin, 1995).

This paper reports on the results of a study that involved the simulation of both monthly (using the Pitman model) and daily (disaggregating the Pitman monthly simulations) stream flows using different rainfall data products for a group of catchments covering different climate and topographical characteristics in southern Africa and with different degrees of data quality and scarcity. The objective of the study was partly to further test a daily disaggregation approach (Slaughter et al., 2015) and partly to compare the results of applying both models with different rainfall data products. More specifically, the study was designed to try and identify any key limitations of the models coupled with typically available rainfall data for different practical water resources assessment purposes.