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Review

Comparison of downscaling methods for mean and extreme precipitation in Senegal

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ABSTRACT

Study region: The study considers six precipitation stations located in Senegal, West Africa. Senegal is located in the Sahel, an area that is threatened by climate variability and change. Both droughts and extreme rainfall have been an issue in recent years.
Study focus: Two different statistical downscaling techniques were applied to the outputs of four regional climate models at six selected precipitation stations in Senegal. First, the delta-change method was applied to the mean annual precipitation as well as the 5, 10, 20, 50 and 100-year return period daily precipitation events. Second, a quantile–quantile transformation (QQ) was used to downscale the monthly distributions of precipitation simulated by regional climate models (RCMs). The 5, 10, 20, 50 and 100-year daily precipitation events were afterward calculated. All extreme events were calculated assuming that maximum annual daily precipitations follow the generalized extreme value (GEV) distribution. The two-sided Kolmogorov–Smirnov (KS) test was finally used to assess the performance of the quantile–quantile transformation as well as the GEV distribution fit for the annual maximum daily precipitation.
New hydrological insights for the region: Results show that the two downscaling techniques generally agree on the direction of the change when applied to the outputs of same RCM, but some cases lead to very different projections of the direction and magnitude of the change. Projected changes indicate a decline in mean precipitation except for one RCM over one region in Senegal. Projected changes in extreme precipitations are not consistent across stations and return periods. The choice of the downscaling technique has more effect on the estimation of extreme daily precipitations of return period equal or greater than ten years than the choice of the climate models.

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Contents

1. Introduction

Senegal is a semi-arid country located in the extreme west of the African continent. Its climate is characterized by a dry season from November to April and a wet season from May to October, regulated by the migrations of the InterTropical Convergence Zone (ITCZ) (Leroux, 1970). During the wet season, the ITCZ completely covers the study area as it moves towards the north to the edge of the Sahara until the months of August and September. Most of the rainfall is recorded in August, followed by July and then September (Sarr et al., 2013, 2014). As part of the Sahelian zone, Senegal has been hit by recurrent droughts leading to food shortage. Recently, the country also experienced frequent episodes of intense precipitations leading to urban flooding and casualties in Dakar, the country's capital, and in other urban centres. Between August 16 and August 22, 2005, Dakar has recorded 367 mm of rain, which is more than half of the average annual total rainfall. On August 26, 2012, Dakar received one quarter of the annual precipitation (168 mm) in less than an hour (Dacosta, 2012, personal communication). These precipitation events have caused considerable psycho-social and health impacts, which are eventual losses to vulnerable sectors such as agriculture, infrastructures and trades. The perceived increase in climate-related disasters has triggered fears that the frequency of extreme precipitations will be triggering more extreme events, characterized by their infrequency and their high magnitude.

The best way to develop cost-effective coping strategies is to generate information about future changes in mean and extreme precipitation indices (Nicholls and Murray, 1999; Manton et al., 2001). These indices are generally calculated with the outputs of a climate model running under a given scenario. Different emission scenarios and climate models simulations are available. In addition, different downscaling techniques exist, ranging from statistical methods (delta-change, regression-based, weather typing, neural networks, etc.) to the use of regional climate models (RCMs). Statistical downscaling can be applied to RCMs in an attempt to correct their biases. Given that for practical reasons an end user in a given region can only apply a few of the available techniques available, inter-comparison studies are helpful in pointing out the uncertainty associated with the choice of the downscaling technique. Burger et al. (2012) showed for the same location that downscaled climate extremes are more sensitive to the choice of the downscaling technique than the emission scenario, the RCM and the location. The choice of the downscaling technique, mainly in the field of regional planning and decision-making, is very important. Even if there are many downscaling techniques, they can be classified into two categories: dynamical and statistical (Hewitson and Crane, 1996; Miller et al., 2009). Dynamical downscaling is physically related to regional climate