Application of probabilistic precipitation forecasts from a deterministic model towards increasing the lead-time of flash flood forecasts in South Africa

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ABSTRACT

Flash floods are some of the most devastating weather-related hazards in South Africa. The South African Flash Flood Guidance (SAFFG) system is a hydro-meteorological modelling system that provides forecasts for the next 1 to 6 h of potential flash floods in support of the flash flood warning system of the South African Weather Service (SAWS). The aim of this paper is to investigate the increase in the lead-time of flash flood warnings of the SAFFG using probabilistic precipitation forecasts generated by the deterministic Unified Model (UM) from the United Kingdom Met Office and run by the South African Weather Service (SAWS). As a first step, calculations of bias-corrected, basin-averaged rainfall from the UM model are provided. An ensemble set of 30 adjacent basins is then identified as ensemble members for each basin (the target basin), from which probabilistic rainfall information is calculated for the target basin covering the extended forecast period. By comparing this probabilistic rainfall forecast with the expected Flash Flood Guidance (FFG) of each basin, an outlook of potential flash flooding is provided. The procedure is applied to a real flash flood event and the ensemble-based rainfall forecasts are verified against rainfall estimated by the SAFFG system. The approach described here is shown to be able to deal with the uncertainties associated with UM rainfall forecasts, particularly regarding location and onset-time of convection. The flash flood outlook for the 18-h extended forecast period investigated was also able to capture the location of the flash flood event and showed its ability to provide additional lead-time for flash flood warnings to disaster managers.

Keywords: deterministic model ensembles, disasters, early warnings, flash floods, flash flood guidance, numerical weather prediction

INTRODUCTION

The flash flood warning system

The impact of weather on human livelihood is undisputed (Auld, 2008; ISDR, 2005a; ISDR, 2005b; Parry et al., 2008; Pelling, 2011). The atmosphere, while providing resources for life in the form of water, can become extremely hostile and violent in the form of hazards such as heavy rain, gales, thunderstorms or tropical cyclones. It is when these severe natural events impact negatively on humans and aggravate livelihood that it can become disastrous. An analysis of disasters in South Africa between 1900 and 2014, from the international disaster database hosted by the Centre for Research on the Epidemiology of Disasters (CRED), revealed that of all natural hazards occurring in South Africa, floods were more numerous (34% of the number of disasters), caused the most deaths and resulted in the most significant impact to people, their livelihoods and infrastructure (CRED, 2014).

The Inter-Governmental Panel on Climate Change (IPCC) Special Report on Managing the Risks of Extreme Events and Disasters issued in 2012 (IPCC, 2012) projected, with various levels of confidence, that climate change and climate variability could lead to changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events. South Africa will not be spared these possible changes and, though the annual total precipitation change is variable, heavy precipitation (that is the magnitude of the rainfall event) is expected to increase which could lead to an increase in flood events. As population numbers grow and increasing numbers of people settle in flood-prone areas or try to make a living in marginal regions, the risk of natural hazards becoming disasters increases (ISDR 2005a). This has motivated the call for more and improved early warning systems to contribute to enhanced resilience to changing climate and weather (IPCC, 2012).

Flash floods are neither strictly hydrological nor purely meteorological in nature. They are typical hydro-meteorological problems largely due to their nature as a hydrological hazard with a rapid response (within 6 h) to a meteorological phenomenon (e.g. rainfall) (WMO, 2008; WMO, 2011; AMS, 2012). For this reason, the South African Weather Service (SAWS), operating a 24-h, 7 days a week monitoring service, takes the lead in issuing flash flood warnings in South Africa.

The general flash flood warning system of SAWS depends on a number of supporting systems and datasets, including rainfall forecasts from Numerical Weather Prediction (NWP) models, as well as radar and satellite information. Since October 2010, the South African Flash Flood Guidance (SAFFG) system provides additional information to weather forecasters, hydrologists and disaster managers in support of the flash flood warning system. Note that the SAFFG is the intellectual property of the Hydrologic Research Center (HRC), a non-profit public-benefit corporation based in San Diego, USA, and that the SAFFG was developed and implemented by HRC.

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