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Review papers

on the performance of satellite precipitation products in riverine flood modeling: A review

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ABSTRACT

This work is meant to summarize lessons learned on using satellite precipitation products for riverine flood modeling and to propose future directions in this field of research. Firstly, the most common satellite precipitation products (SPPs) during the Tropical Rainfall Measuring Mission (TRMM) and Global Precipitation Mission (GPM) eras are reviewed. Secondly, we discuss the main errors and uncertainty sources in these datasets that have the potential to affect streamflow and runoff model simulations. Thirdly, past studies that focused on using SPPs for predicting streamflow and runoff are analyzed. As the impact of floods depends not only on the characteristics of the flood itself, but also on the characteristics of the region (population density, land use, geophysical and climatic factors), a regional analysis is required to assess the performance of hydrologic models in monitoring and predicting floods. The performance of SPP-forced hydrological models was shown to largely depend on several factors, including precipitation type, seasonality, hydrological model formulation, topography. Across several basins around the world, the bias in SPPs was recognized as a major issue and bias correction methods of different complexity were shown to significantly reduce streamflow errors. Model re-calibration was also raised as a viable option to improve SPP-forced streamflow simulations, but caution is necessary when recalibrating models with SPP, which may result in unrealistic parameter values. From a general standpoint, there is significant potential for using satellite observations in flood forecasting, but the performance of SPP in hydrological modeling is still inadequate for operational purposes.

Contents

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1. Introduction

Riverine flooding occurs either when excessive rain falls over an extended period of time and leads a river to exceed its capacity or because of heavy snow melt. There are two main types of riverine flooding: overbank floods, which occur when water overflows over the edges of a river or stream, and flash floods, which are caused by heavy rainfall in a short amount of time (usually less than 6 h) and characterized by an intense, high velocity torrent of water that rips through river beds, urban streets, or mountain canyons.

Floods are among the most dangerous and costly natural disasters causing extensive economic and social damages worldwide (Wake, 2013; UNISDR, 2015). The recent intensification of extreme precipitation events has the potential to aggravate the frequency and intensity of floods (IPCC, 2012). In a recent study, Janssen et al. (2014) observed an overall increasing trend in extreme precipitation events from 1901 to 2012 across the United States (U.S.). Similarly, Blöschl et al. (2017) found a clear climate signal in flood timing change when they analyzed river floods in Europe over the past five decades. Specifically, they observed that higher temperatures caused earlier spring snowmelt floods in Northeastern Europe, delayed winter storms caused later winter floods in the North Sea region and along the Mediterranean coast, and earlier soil moisture maxima caused earlier winter floods across Western Europe. Future projections of Earth System Models (ESMs) suggest further increases in extreme precipitation frequency in a high-emission scenario. However, model simulations often show an underestimation of extreme events when compared to observations (Asadieh and Krakauer, 2015). This highlights the pressing need for improved methods for predicting and mitigating the impact and risk of floods globally (e.g., Feyen et al., 2012).

Hydrologic early warning systems are the main tool for assessing flood risk and reducing damages by forecasting flood events using real time data obtained through ground monitoring networks (e.g., rain gauges and radars; Artan et al., 2007). However, the use of such data, mainly rainfall, is affected by several limiting factors: 1) the limited spatial representativeness of local measurements (Kidd et al., 2012), 2) the network density (Fig. 1), and 3) reflectivity issues related to radar data. A way to overcome these issues was suggested more than 30 years ago by Barret and Martin (1981), that is, the use of satellite precipitation products (SPPs) that are nowadays available on a global scale at increasing spatial and temporal resolution. The use of these products in hydrologic applications has opened new venues to support water management globally. Especially in poorly gauged basins and large basins with larger concentration times, SPPs may be the only input data to allow flow predictions downstream with enough lead time to implement management and response actions (Serrat-Capdevila et al., 2014).

Despite the abundance of SPPs, spaceborne rainfall data are scarcely used in hydrologic applications. This work discusses the main reasons for which the use of SPPs in hydrology is not operational yet, including their insufficient latency and spatial/temporal resolution (Serrat-Capdevila et al., 2014). Recent research work has shown that, even in poorly gauged regions, hydrologic simulations using SPPs are equal or inferior in performance to simulations that employ even just a few ground-based rain gauges (Yilmaz et al., 2005; Harris et al., 2007, Stisen and Sandholt, 2010). Model reanalysis precipitation products are the only choice above 60° latitude and an effective alternative above ~35° latitude – where they ingest a high number of ground observations – and during cold periods because of their ability to capture fairly well large-scale weather systems, which represent the dominant source of precipitation in these regions (Beck et al., 2017a, 2017b). Conversely, these products perform very poorly in the tropics because of the small-scale high-intensity nature of rainfall, which cannot be reliably simulated by numerical weather prediction models. Reanalysis products are of particular interest especially for estimating snow and rain on snow, which are often poorly quantified by SPPs (Tian et al., 2014). However, this work focuses only on the

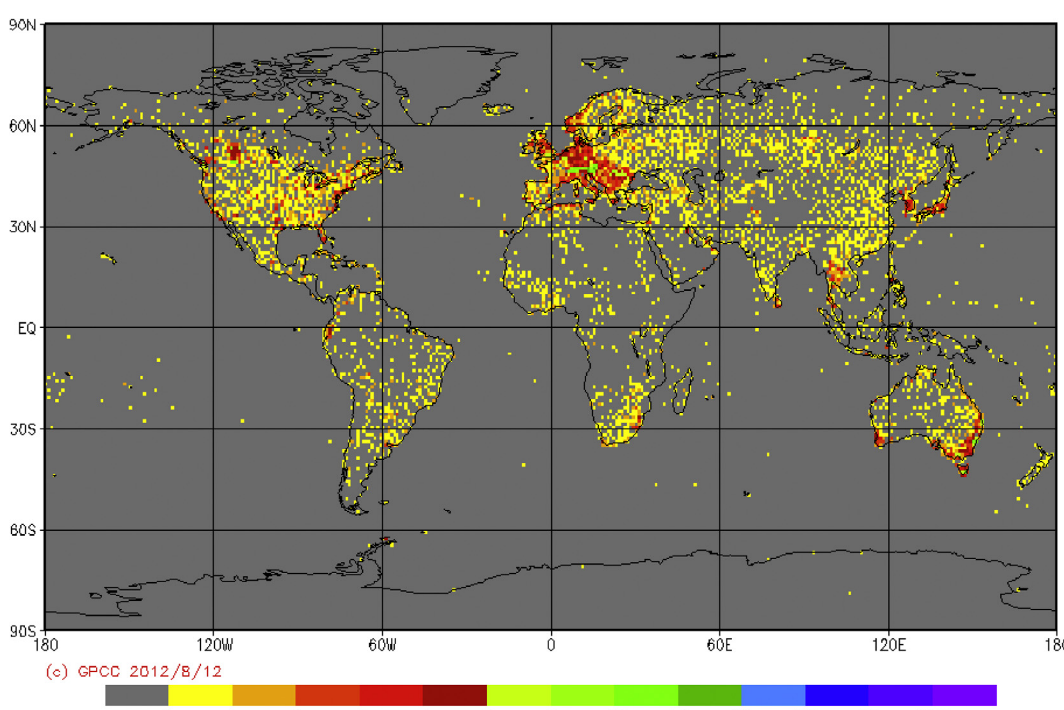

Fig. 1. Number of stations used by the Global Precipitation Climatology Centre (GPCC; Rudolf et al., 2005) in May 2012. Courtesy of the National Center for Atmospheric Research Staff (Eds). Last modified 29 Oct 2015. "The Climate Data Guide: GPCC: Global Precipitation Climatology Centre". Retrieved from https://climatedataguide.ucar.edu/climate-data/gpcc-global-precipitation-climatology-Center).