Subseasonal Prediction of Tropical Cyclone Precipitation

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ABSTRACT: The accurate prediction of tropical cyclone precipitation (TCP) at an extended range could be crucial to mitigate the impacts of TC-related flooding. This study examines probabilistic predictions of weekly accumulated TCP and total precipitation using 11 subseasonal forecast systems. Raw, uncalibrated, categorical forecasts of basinwide TCP are only skillful in the ECMWF model and only up to 15 days in advance, except in the northern Indian Ocean and the South Pacific where ECMWF is not skillful even at short leads. Calibration, through linear regression, improves forecasts and makes several forecast systems [Goddard Earth Observing System (GEOS) and UKMO] skillful up to 15 days in advance but only in some basins. In most models and basins, such as the GEOS model in the Atlantic basin, the bias in the forecast probability of TC occurrence is the main factor driving biases in TCP and decreasing forecast skill. At the regional scale, calibrated ECMWF forecasts are skillful beyond 15-day leads and globally. The poor prediction of TCP in raw forecasts is shown to affect total precipitation prediction skill. Therefore, biases in the TC occurrence probability forecast are the leading cause of low skill of TCP and may play a role in the skill of total precipitation.

SIGNIFICANCE STATEMENT: Tropical cyclone (TC)-related flooding is a significant hazard, and accurate extended-range predictions of tropical cyclone precipitation (TCP) are vital for risk mitigation efforts. This study assesses 11 subseasonal forecast systems, finding that uncalibrated models struggle with TCP prediction, with only the ECMWF model being skillful beyond 15 days in some basins. Calibration improves forecast skill, particularly for models like GEOS and UKMO, but biases in TC occurrence forecasts remain a major challenge. These biases reduce TCP prediction skill and affect total precipitation forecasts. Improving TCP prediction could significantly enhance preparedness for TC-related flooding events in key regions of the tropics.

KEYWORDS: Precipitation; Tropical cyclones; Hurricanes/typhoons; Forecast verification/skill; Probability forecasts/models/distribution; Seasonal forecasting

1. Introduction

Landfalling tropical cyclones (TCs) cause severe impacts such as loss of life, property damage, and economic disruption due to storm surges, strong winds, and the intense precipitation rates found around a TC (Villarini et al. 2014; Needham et al. 2015; Lenzen et al. 2019). TC precipitation (TCP) is a major influence on flood frequency and flood-related hazards, such as flash floods and landslides, in several tropical coastal regions (Hu et al. 2018; Smith et al. 2023). For example, TC-related rainfall is estimated to account for about 30% of TC-related deaths in the United States (Rappaport 2014). TCP impacts are exacerbated by local vulnerabilities (Dominguez et al. 2021) which in marginalized populations can lead to population displacement and migration (Black et al. 2013; Heslin et al. 2019). The destructive potential of TCs and TCP makes the skillful prediction of both quantities a key element of disaster preparedness and early alert systems.

For this purpose, numerical weather prediction (up to 72 h) of TCP has steadily improved in recent years (Luitel et al. 2018), partially due to reduced errors in track forecasts and increased model resolution (Cangialosi et al. 2020). Reliable information at longer leads, such as extended range forecasts (e.g., 6–20 days) on TCP could be useful to guide decision-making and inform users on how to manage risk and mitigate TC rainfall-related impacts (Beatty et al. 2019; Nkiaka et al. 2019; White et al. 2022). However, our understanding of the limitations and capabilities of subseasonal-to-seasonal (S2S) (2–6 weeks) predictions, especially of TCP and total precipitation P, is still in its infancy compared to seasonal and weather forecasts (Camargo et al. 2019; Domeisen et al. 2022).

In the context of S2S TC forecasting, case studies have shown skillful forecasts of genesis at lead times of 10–15 days (Xiang et al. 2015; Gregory et al. 2019). However, verification studies

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