Title: A river basin-centric examination of bias in medium-range forecasts of heavy and extreme precipitation in Northern California

Abstract: Forecasts of heavy and extreme precipitation delivered by atmospheric river (AR) events are becoming increasingly important for both flood control and water supply management in reservoirs across California. This study examines the hypothesis that medium-range forecasts of heavy and extreme precipitation at the basin scale exhibit recurrent spatial biases that are driven by mesoscale and synoptic scale features of associated AR events. This hypothesis is tested in the Sacramento River basin, where we construct a database of heavy and extreme precipitation events in the basin across a 36 year period from 1984 to 2019 coincident with data from NCEP subseasonal-to-seasonal reforecasts. For each event we cluster precipitation forecast error across Western North America for lead times ranging from 1 to 16 days. The resulting clusters are used to characterize common, large-scale spatial patterns of precipitation forecast error during the largest observed precipitation events in the Sacramento basin. Integrated vapor transport (IVT), 500 hPa geopotential height anomalies, and landfall characteristics of ARs are composited across days categorized into each error cluster and lead time to further diagnose the causes of precipitation forecast biases. Finally, we investigate the temporal evolution of error clusters to determine whether specific spatial structures of error are persistent across forecast lead times. Our results show that consistent spatial patterns of precipitation forecast error emerge in the historical record that highlight prominent biases in the underlying model reforecasts. Moreover, we find instances where basin-scale, medium-range forecasts of precipitation miss an event entirely, whereas forecasts of ARs and their synoptic-scale properties provide some indication of the event’s occurrence. These results suggest the potential for using medium-range forecasts of large-scale climate features across the Pacific-North American sector, rather than just local forecasts of basin-scale precipitation, whendesigning forecast-informed reservoirs.

Plain Language Summary: Watersheds in Northern California are subject to some of the most variable precipitation regimes in the contiguous United States. A large portion of the annual water supply comes in the form of heavy and extreme precipitation events associated with a specific type of storm known as an atmospheric river (AR). Thus, forecasts of intense precipitation and ARs are becoming increasingly important to manage flood risk and water supplies at some of the largest reservoirs in the state, many of which reside in the Sacramento River basin. In this study, we examine forecasts of heavy and extreme precipitation in the Sacramento River basin at multiple lead times, and try to identify patterns of precipitation forecast error associated with these events (e.g., instances when heavy or extreme precipitation is consistently forecasted too far north, too far south, or not at all at a particular lead time). For each pattern of precipitation forecast error and lead time, we examine properties of observed and forecasted ARs associated with the precipitation events. This work is particularly focused on understanding whether large scale features associated with ARs are captured with more regularity by forecast models than those of precipitation. If so, there may be potential to improve reservoir operations at long lead times by using forecasts of ARs and their properties across the Pacific Ocean and Western North America, rather than just local precipitation over a watershed.