Title: A watershed-centric examination of bias in medium-range extreme precipitation forecasts in northern California

Abstract: Forecasts of heavy and extreme precipitation delivered by Atmospheric River (AR) events are becoming increasingly important for both flood 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 climate features of associated AR events. This hypothesis is tested in the Sacramento River watershed, where we construct a database of heavy and extreme precipitation events in the watershed across a 36 year period from 1984 to 2019 coincident with data from the NCEP model 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 climatological variables provide some indication of the event’s occurrence. These results suggest the potential for using medium-range forecasts of mesoscale and synoptic-scale 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 climates in the contiguous United States. A large portion of the annual water budget comes in the form of heavy to extreme precipitation events associated with Atmospheric Rivers, which are plumes of narrow and intense water vapor transport generally originating in the tropics or sub-tropics. Thus, forecasts of such events are becoming increasingly important in managing water supplies at some of the largest and most important reservoir sites in the country, many of which reside in the Sacramento River watershed. In this study, we use the geographical extent of this watershed to examine local forecasts of heavy and extreme precipitation against forecasts of large-scale climatological features associated with ARs and generally connected to these type of events. Our study spans a 36 year period from 1984 to 2019 that is coincident with a high resolution reforecast database and utilizes forecasts out to a 16 day lead time. After deriving a catalog of heavy to extreme precipitation events in the study period, we examine both biases in forecasts of local precipitation and those of large-scale climate features utilizing a novel clustering approach on errors across forecast lead times. These clusters elucidate both the spatial errors in the underlying forecast models as well as the evolution of these errors over forecast lead times. Further, we investigate the hypothesis that the large scale features associated with these events are captured with more regularity by forecast models than those of precipitation, which are subject to a large number of localized effects. Our results suggest the potential to use these heavy to extreme event forecasts, particularly those of large-scale features, as a valuable input to forecast informed reservoir operations at extended lead times.