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Preserving extremes in GCM downscaling, multi-sensor observation merging, and data assimilation

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Downscaling of large-scale GCM outputs or optimal integration of multi-sensor multi-scale precipitation observations promises a posteriori estimates of precipitation with increased accuracy and resolution that can potentially lead to more accurate hydro-meteorological forecasts and impact assessments. Methodologies that preserve extremes in downscaling or multi-scale data merging and data assimilation of hydro-meteorological fields are lacking and yet are important as we prepare for a future of accelerated extremes. We propose a new approach, based on Gaussian Scale Mixtures (GSM) on the wavelet domain, which has the following advantages: (1) it preserves the non-Gaussian heavy-tailed structure of rainfall gradients at multiple scales and thus the organization and location of high intensity raincells; (2) it is conditionally Gaussian and thus can take advantage of optimal linear estimation theories; and (3) it is local (in space and scale) and thus computationally efficient over large domains. The proposed methodology is demonstrated in a case study of downscaling satellite precipitation observations and also in merging TRMM-PR and ground based weather surveillance Doppler radars. The advantages of the proposed methodology compared to commonly used approaches are quantified.