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Bred vectors with customizable scale: 'À la carte' ensemble perturbations

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Short-range forecasts of severe weather are one of the most challenging tasks faced by the atmospheric science community. Our persistent failure to generate accurate numerical forecasts of tornadoes, large hail, heavy precipitation or strong wind events is caused by two fundamental aspects of numerical forecast systems: the chaotic nature of the governing equations and the large uncertainties in both the atmospheric state and the models that govern its evolution. Currently, we cope with both sources of error by describing the state of the atmosphere in a probabilistic manner. In this framework, forecasting becomes predicting the probability density function (pdf) of future states, given the pdf of initial states that are compatible with available observations and previous forecasts. This probabilistic perspective is often created by generating ensembles of deterministic predictions that are aimed at sampling the most important sources of uncertainty in the forecasting system. The ensemble generation/sampling strategy is a crucial aspect of their performance and various methods have been proposed. Although global forecasting offices have been using ensembles of perturbed initial conditions for medium-range operational forecasts since 1994, no consensus exists regarding the optimum sampling strategy for high resolution short-range ensemble forecasts with predicting skill in the mesoscale. Bred vectors, however, have been hypothesized to better capture the growing modes in the highly nonlinear mesoscale dynamics of severe episodes than singular vectors or observation perturbations. Yet even this technique is not able to produce enough diversity in the ensembles to accurately and routinely predict extreme phenomena such as severe weather. Thus, we propose a new method to generate ensembles of initial conditions perturbations that is based on the breeding technique. Given a standard bred mode, a set of customized perturbations is derived with specified amplitudes and horizontal scales. This allows the ensemble to excite growing modes across a wider range of scales. Results show that this approach produces significantly more spread in the ensemble prediction than standard bred modes alone. Several examples that illustrate the benefits from this approach for severe weather forecasts will be provided.