Wavelet Covariance Approximations for Wildfire Data Assimilation using SFIRE

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With wildfires burning tens of millions of acres per year and threatening the lives and property of numerous people. There is increasing interest in predicting the spread and intensity of these outbreaks with precision. New data sources from satellites and airborne cameras provide an opportunity to improve the fire forecasts with accuracy unattainable using computational modeling alone. Naturally, researchers have begun exploring the application of data assimilation to these models to improve their accuracy in real time predictions.

While robust data assimilation methods have been developed for traditional weather forecasting domains, these methods tend to fail when applied to wildfire models due to the unique nature of the error statistics. In particular, standard localized sample covariance estimates can be shown to provide particularly poor representations of the true error statistics using reasonable sized ensembles. We show that one can improve sample correlation estimates dramatically by representing the covariance matrix as diagonal in a wavelet basis similar to the method presented in [2]. This representation provides the same benefits as covariance tapering at a significantly reduced computational expense. In addition, the wavelet basis can better reproduce local correlations with fewer samples than tapering alone. It can also be demonstrated that the wavelet method is capable of resolving non-uniform error distributions and local features of the fields making it much more suitable for covariance estimation of wildfire models than other related methods based on the Fourier transform.

The wavelet-based covariance estimate can be used in the ensemble Kalman filter (EnKF) in place of the sample covariance to produce a method with many of the same benefits as other localized filtering methods[1]. However, the wavelet EnKF is much more computationally efficient and easier to implement because the covariance is represented by a simple block diagonal structure. In this form, the EnKF becomes simply a manipulation of diagonal matrices for each pair of variables in the model.

The results obtained here use a large number randomly generated fires from the non-coupled SFIRE wildfire model[3]. Each sample is generated from a randomly chosen ignition point and model parameters. We compare the covariance and cross-covariance estimates derived from various methods to a large sample estimate calculate the representation error for a variety of cases. Finally, we apply this covariance representation to the wavelet EnKF as in in a simple experimental framework showing benefits compared to standard tapered covariance estimates.

References

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