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Definition of Ensemble Error Statistics for Optimal Ensemble Data Assimilation

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Next generation data assimilation methods must include the state dependent observation errors, i.e., the spatial and temporal variations produced by the atmospheric turbulent field. A rigorous analysis of optimal data assimilation algorithms and ensemble forecast systems requires a definition of model "truth" or perfect measurement which then defines the total observation error and forecast error. Truth is defined as the spatial average of the continuous atmospheric state variables centered on the model grid locations. To be consistent with the climatology of turbulence, the spatial average is chosen as the effective spatial filter of the numerical model. The observation errors then consist of two independent components: an instrument error and an observation sampling error which describes the mismatch of the spatial average of the observation and the spatial average of the perfect measurement or "truth". The observation sampling error is related to the "error of representativeness" but is defined only in terms of the local statistics of the atmosphere and the sampling pattern of the observation.

Optimal data assimilation requires an estimate of the local background error correlation as well as the local observation error correlation. Both of these local correlations can be estimated from ensemble assimilation techniques where each member of the ensemble are produced by generating and assimilating random observations consistent with the estimates of the local sampling errors based on estimates of the local turbulent statistics. A rigorous evaluation of these optimal ensemble data assimilation techniques requires a definition of the ensemble members and the ensemble average that describes the error correlations. A new formulation is presented that is consistent with the climatology of atmospheric turbulence and the implications of this formulation for ensemble forecast systems is discussed.