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Estimating trajectory uncertainties due to flow dependent errors in the atmospheric analysis

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Atmospheric trajectory calculations is a widely used method to determine the origin or fate of air parcels in the atmosphere. For example, the use of back trajectories is common in atmospheric chemistry to determine source regions of sampled air at a particular site. The uncertainty of a calculated trajectory is dependent on the uncertainty in the atmospheric analysis. The errors in meteorological analyses are partly due to observation errors and the fact that observations can include local phenomena that are not representative for an entire grid box. In order to produce a best estimate of the atmospheric state, numerical weather prediction centers use advanced data assimilation systems. In data assimilation, the information from observations combined with a background (usually a short forecast valid at the time of the analysis) is used to obtain an analysis. However, both of these components contain uncertainties. Thus the resulting analysis will not perfectly match the current atmosphere and will therefore impact on the calculated trajectory path.

Using the Ensemble Transform method (originally adapted for ensemble forecasting) we sample the analysis uncertainty in order to create an ensemble of analyses where a trajectory is started from each perturbed analysis. This method, called the Ensemble analysis method (EA), is compared to the Initial spread method (IS), where the trajectory receptor point is perturbed in the horizontal and vertical direction to create a set of trajectories used to estimate the trajectory uncertainty. The deviation growth is examined for one summer and one winter month and for 15 different geographical locations. We find up to a 40% increase in trajectory deviation in the mid-latitudes using the EA method. A simple model for trajectory deviation growth speed is set up and validated. It is shown that the EA method result in a faster error growth compared to the IS method. In addition, two case studies are examined to qualitatively illustrate how the flow dependent analysis uncertainty can impact the trajectory calculations. We find a more irregular behavior for the EA trajectories compared to the IS trajectories and a significantly increased uncertainty in the trajectory origin. By perturbing the analysis in consistency with the analysis uncertainties the error in backward trajectory calculations can be more consistently estimated.