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Tracking the Kasatochi SO_2 plume using the Ensemble Kalman Filter and OMI observations

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This paper discusses an application of the Ensemble Kalman Filter (EnKF) data assimilation method in improving prediction of volcanic plumes. Column retrievals of SO_2 from the OMI instrument are assimilated into the SILAM chemistry transport model during 8 days following the 2008 eruption of Kasatochi. The analysis ensemble is shown to accurately capture the observed horizontal distribution of the plume, and moreover, comparison with backscatter profiles from the CALIOP instrument indicates that the analysis recovers the vertical distribution of SO_2 realistically. The total SO_2 burden following the eruption converges to about 2 Tg, which is within the range of previous estimates.

The assimilation scheme uses an 80-member ensemble generated by perturbing the source term and the meteorological input data. The SO_2 emission flux is sampled from a log-normal probability distribution resulting in large initial spread in the ensemble. A prescribed umbrella profile and a power law relation between the injection height and mass flux are assumed. However, despite the assumptions in the source term perturbations, the analysis ensemble is shown to be capable of reproducing complex, multi-layer SO_2 profiles consistent with previous modeling studies on the Kasatochi eruption.

The meteorological perturbations are introduced in the form of random time shifts in the input data, which ensures that the input data for each ensemble member remain physically consistent. Including the meteorological perturbations prevents the ensemble spread from decreasing unrealistically as the simulation proceeds, and consequently, the assimilation remains effective in correcting the predictions throughout the simulated period.

In conclusion, EnKF is a promising approach for assimilating satellite observations in volcanic plume forecasts. An advantage of the ensemble approach is that model uncertainty, which is often difficult to handle in other schemes, can be included by perturbing the ensemble. A second advantage is the straightforward evaluation of analysis uncertainty from the ensemble standard deviation.