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Design of a Satellite Observational Operator (SOO) for ensemble-based data assimilation to improve volcanic plume forecasts

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Using data assimilation (DA) is efficient to improve volcanic model forecast accuracy. Infrared satellite measurements of volcanic ash mass loadings are often used as input observations for the assimilation scheme. However, because these primary satellite-retrieved data are often 2D and the ash plume is usually vertically narrow, thus directly assimilating the 2D ash mass loadings in a 3D volcanic ash model (with an integral observational operator) can usually introduce large spurious vertical correlations.

In this study, we look at an approach to avoid the spurious vertical correlations by not involving the integral operator. (We focus on the case study of the 2010 Eyjafjallajökull volcanic ash plume.) By integrating available data of ash mass loadings and cloud heights, and data-based thickness assumptions, a Satellite Observational Operator (SOO) is proposed that translates satellite-retrieved 2D mass loadings to 3D concentrations. The SOO makes the analysis step of assimilation comparable in the 3D model space.

Ensemble-based data assimilation is used to assimilate the extracted measurements of ash concentrations. The results show that satellite data assimilation with SOO can improve the estimate of volcanic ash state better than the standard assimilation without SOO. Comparison with both satellite retrieved data and aircraft in situ measurements shows that the effective volcanic ash forecasts can be obtained after assimilation with SOO.

In addition, this study provides an idea in the sense of incorporating many available measurements. We expect the SOO can be potentially improved by incorporating more data, but at the moment DA with SOO has shown its advantage than the standard way (without SOO) in dealing with passive satellite data assimilation.