NWP ensembles for volcanic ash plume forecasting

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Numerical Weather Prediction (NWP) models solve a system of equations to provide a forecast of wind velocity, temperature, pressure and precipitation for a future time. NWP models do not capture the smallest scales, therefore there will always be a degree of error in the model forecast for any NWP system. Small differences in initial conditions may lead to large differences in the forecasts.

In this contribution, we extend previous work on addressing the problem of propagation of uncertainties in the volcanic input (source) parameters by additionally propagating uncertainties in the windfields in an ash transport and dispersal model. Windfields as well as source parameters represent major sources of uncertainty in ash transport and dispersion simulations. We thus expect ash transport forecasts to be deeply affected by perturbations in forecast wind speed as well as source conditions.

We hindcast the motion of the ash cloud for the eruption of Eyjafjallajokull, Iceland, which had a peak ash emission in the period 14-18 April 2010. We couple three numerical tools to analyze this issue. The first is the Weather Research and Forecasting (WRF) model used to forecast wind speed. The second tool is a volcanic eruption column trajectory model, *puffin*, employed to incorporate volcano observations and then provide initial conditions for a volcanic ash cloud transport and dispersal (VATD) model. The third tool is thus a VATD model, *puff*, used to propagate ash parcels in the wind field.

Based on our lack of knowledge of the exact conditions of the source, probability distributions are assigned to the parameters which are later sampled in a weighted, Monte Carlo-like fashion using either polynomial chaos quadrature or cut point techniques. For windfields, ensemble methods are sometimes considered to be an effective way to estimate the probability density function of future states of the atmosphere by addressing uncertainties present in initial conditions and in model approximations. We are using the Global Ensemble Forecast System (GEFS) generated by the National Center for Environmental Prediction (NCEP), which is a weather forecast model made up of 21 separate ensemble members. The forecasts are produced four times daily, at 0000, 0600, 1200, and 1800 UTC, starting 0000 UTC April 14 to 0000 UTC April 18 on a 1° latitude by 1° longitude grid. A continuous WRF run/integration with a single GEFS member initialization is done resulting in outputs at every 3 h at each of 74 pressure levels. Output moments and probabilities are then computed by properly summing the weighted values of the output parameters of interest. The results are presented as a forecast envelope and show how volcanic source term uncertainty and windfield stochastic variability can affect the forecast. Thus, we produce a nominally complete probabilistic forecast of ash cloud position.