EGU2020-20566, updated on 29 Oct 2020
https://doi.org/10.5194/egusphere-egu2020-20566
EGU General Assembly 2020

3D Reconstruction of Volcanic Ash Clouds Using Simulated Satellite Imagery

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Volcanic ash suspended in the atmosphere can pose a significant hazard to aviation, with the potential to cause severe damage or shutdown of jet engines. Forecasts of ash contaminated airspace are generated using atmospheric transportation and dispersion models, among the inputs to these models are eruption source parameters such as cloud-top height and cloud volume. A potential method to measure these source parameters is space carving – a technique to generate 3D hull reconstructions of clouds using multi-angle imagery.

This paper investigates the potential for 3D space carving reconstruction using multi-angle satellite imagery. This builds on previous work where the authors have applied this technique to ground-based and drone-based imagery. A satellite-based imaging platform has advantages such as global coverage and being safely removed from any damaging effects of a volcanic eruption. However, the accuracy of any potential reconstruction will be affected by the distances and restricted viewing angles of a satellite in orbit.

To assess the general suitability of a satellite-based system for reconstruction, as well as different configurations of the system, a method for simulating satellite imagery and applying a space carving reconstruction scheme was developed. This method allows the analysis of the effects of orbital dynamics (altitude, inclination, etc.), spatial resolutions, and imaging rates on the efficacy of the 3D reconstruction of ash clouds. The model utilises an input 'ground-truth' voxel-based plume model as the imaging target and generates simulated satellite images based on the user defined orbital and camera properties. These simulated images are then used for reconstruction and the resultant plume can be compared against the ground-truth model.

A range of possible observation schemes (controlling number and distribution of images and limits on viewing angles) have been modelled over a range of possible orbital paths and the accuracy of the space carving reconstruction has been measured. Spatial resolution limits for the accurate reconstruction of various plume sizes can be calculated. Limitations of the model are presented, including the sensitivity to the size and shape of the input plume model and the impact of the perfect feature identification in the simulated images. Further work includes the use of additional input models and improvements and validation of the image simulation method.

The methods presented in this study demonstrate the potential of satellite-based 3D reconstruction methods in the forecasting of ash dispersion, leading to potential improvements in airspace management and aviation safety.