A10

Current state of volcanic ash dispersion prediction

Jonas Eliasson and Junichi Yoshitani

1. Introduction

All volcanic eruptions in the VAAC London area happen in Iceland. Eyjafjallajokull 2010 and Grimsvotn 2011 eruptions created great problems for commercial aviation in the North Atlantic because of the large extent of the predicted ash clouds from these eruptions. The visible ash cloud was more often than not photographed by satellites. The comparison of the satellite pictures and the predicted ash clouds showed the predicted clouds very much larger than the ash cloud. No official explanation of this discrepancy exists. Papers on simulation of the Eyjafjallajökull Ash cloud in peer reviewed journals, usually tried to simulate the VAAC predictions rather than the satellite pictures. This paper focuses on the current state of prediction technology and how it relates to the results obtained in the airborne measurement campaigns of the volcanic ash emitted by Sakurajima.

2. Simulations and visible clouds

All volcanic eruptions in the VAAC London area happen in Iceland. Eyjafjallajokull 2010 and Grimsvotn 2011 eruptions created great problems for commercial aviation in the North Atlantic because of the large extent of the predicted ash clouds from these eruptions.

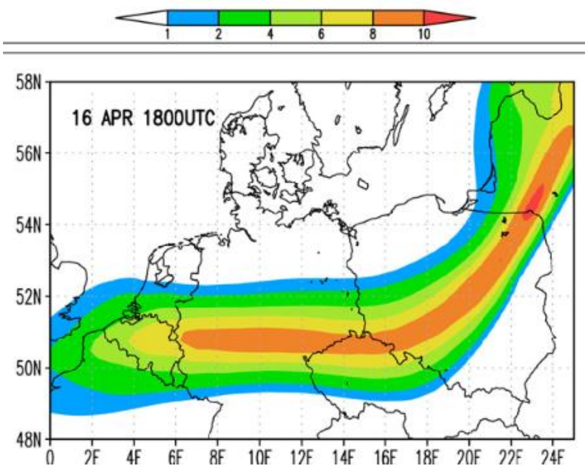

Fig. 1 Simulation by Folch et al

The visible ash cloud was more often than not photographed by satellites. The comparison of the satellite pictures and the predicted ash clouds showed the prediction very much larger than the ash cloud. No official explanation of this discrepancy exists. Papers on simulation of the Eyjafjallajökull Ash cloud in peer reviewed journals, usually tried to simulate the VAAC predictions rather than the satellite pictures as is done in Fig. 1. This one is predicting a cloud 8 – 10 milligrams/m^2 (ash column value) over central Europe. Such a high concentration ash cloud would have been characterized as dangerous. Measurements showed much lower ash concentrations over Europe than the predicted (Weber et al. 2012). The newest eruption in Iceland (Holuhraun – Bardarbunga) is less productive than Eyjafjallajokull but has lasted longer. However, it is producing lava, not ash. If its output had been ash, it could have produced similar problems for the aviation. The plume contained mostly S02; it was successfully modeled using the WRF-chem model

3. Dispersion modeling and dispersion physics.

Two weak points in ash cloud prediction have been studied in Kyoto University's measurements and research of eruptions in Sakurajima. They are gravitational deformation of the plume and the streak fallout process. It turns out that both make ash content of clouds estimated with horizontal diffusion theory, larger than the actual. This makes it important to use airborne measurements of volcanic ash to improve prediction methods. The streak fallout process is most active close to the source where the plume is becoming horizontal and its temperature is cooling down. In dispersion models all fallout is modeled as grains falling down with the terminal velocity of the grains. Aerosol size particles (< PM10) have so low terminal velocity that there is practically no fallout. But streak fallout takes all grain sizes as it is a vertical flow of air. Tropospheric plumes tend to ride in stable inversions where the top layer of ambient air is slightly lighter (not necessarily hotter but with slightly less density) than the lower layer. The plume must have approximately the average density of the two layers to be buoyant. Under these conditions there will be slight overpressure in the center that forces the plume to flatten out like oil drop on water. However, data for the relative density difference (Δ) and the correction factor (B) necessary to compute the plume time constant (Tp) may be difficult to obtain. In horizontal diffusion the whole plume is a mixing layer where ambient air is mixed into the plume. Gravitational flattening spreads the plume out in the horizontal direction but the mixing layer is just a boundary between the plume and the ambient air. The diffusion coefficient in gravitational flattening is an order of magnitude smaller than in the diffusion case.

4. Future aspects

New rules from ICAO, effective from November 2014, stress that jetliners should avoid visible ash. The main interest here is the yellow circle, Current area of interest. It circles jet engine operation for 6 minutes up to 10 hours in concentrations 200 μg to 10000 μg/m^3. This is almost the same concentration interval as the visible ash threshold. Most VAAC´s use satellite pictures to localize visible ash. The procedure used by JMA´s Tokyo VAAC is very advanced. A picture shows an example of how this information is evaluated and put into practical use in forecasting. The Tokyo VAAC is a unique approach. When we observe ash clouds on satellite imagery, we set 'initial particle distribution' in accordance with the observed ash cloud boundaries, and start the dispersion model from the observation time, not going back to the origin. Assimilation of airborne measurements may be the future technology on prediction.

5. Conclusions

The ash cloud predictions are done using the horizontal advection-diffusion equation in Lagrangian or Eulerian models, mostly with the plume height and the S/M equation as source data and atmosphere data from NWP models. Not including gravitational flattening and streak fallouts cause concentration to become higher in the predictions than in nature. This can make source models too inaccurate. We need adjustment of source data using satellite photos to a larger extent. Change of method may need radiosonde data not available in the NWP models. New technology based on measurements needed

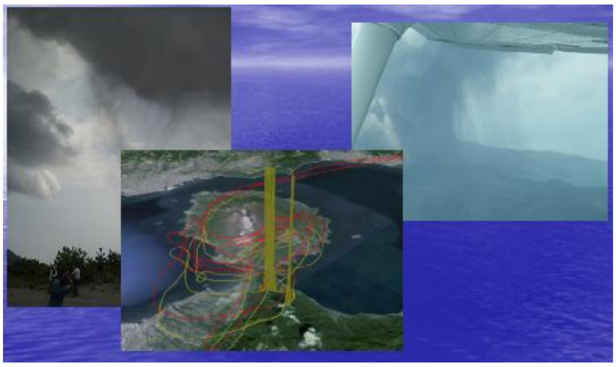

Fig. 2 Streak fallout Sakurajima 07/27

References

Eliasson, J., Yoshitani, J., Weber, K., Yasuda, N., Iguchi, M., & Vogel, A. (2014). Airborne Measurement in the Ash Plume from Mount Sakurajima: Analysis of Gravitational Effects on Dispersion and Fallout. International Journal of Atmospheric Sciences, 2014.

Folch, A., Costa, A., Basart, S.; Validation of the FALL3D ash dispersion model using observations of the 2010 Eyjafjallajökull volcanic ash clouds, Atmospheric Environment, 48, (2012), 165-183.

Weber, K., J. Eliasson, A. Vogel, C. Fischer, T. Pohl, G. van Haren, M. Meier, B. Grobéty, and D. Dahmann, 2011: Airborne in-situ investigations of the Eyjafjallajökull volcanic ash plume on Iceland and over North-Western Germany with light aircrafts and optical particle counters. Atmospheric Environment Volume 48, March 2012, Pages 9–21.