Atmospheric processes affecting the separation of volcanic ash and SO_2 in volcanic eruptions: Inferences from the May 2011 Grímsvötn eruption: Supplementary Material

Fred Prata[1], Mark Woodhouse[2], Herbert E. Huppert[3], Andrew Prata[4], Thor Thordarson[5], and Simon Carn[6]

[1]Visiting scientist, Department of Atmospheric, Oceanic and Planetary Physics, Clarendon Laboratory, University of Oxford, UK

[2]School of Mathematics, University of Bristol, Clifton, Bristol, UK

[3]Institute of Theoretical Geophysics, Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK

[4]Department of Meteorology, University of Reading, Earley Gate, Reading, UK

[5]Faculty of Earth Sciences, University of Iceland, Reykjavik, Iceland

[6]Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI, USA

Correspondence to: Fred Prata (fred_prata@hotmail.com)

1 Supplementary Figures

1.1 FALL3D results

FALL3D v7.0 (Folch *et al.*, 2014; http://bsccase02.bsc.es/projects/fall3d/Downloads/fall3d-7.0.pdf), was run using NCEP re-analysis data. The domain size is 80° longitude from 30° W to 50° E, and 60° latitude starting at 10° N to 70° N. The model grid points are in 0.2° increments giving 401 x 301 total grid cells. There are 101 vertical layers in 100 m intervals up to 10 km. The total run time was varied up to 96 hours from initialisation. The particle granularity distribution was unimodal with a diameter of 16 μm. Particle bulk density was 2500 kg m^{-3}. All particles were assumed to be spherical and particle (wet) aggregation, although available in the model, and break-up were not considered, Removal by gravitational settling/dry deposition are included. For the purposes of examining separation of gas and particles it was beyond the scope of this paper to provide more realistic particle habit. The vent is located at 17.33°W, 64.42°N, 1.74 km (a.s.l.) and the source term used was PLUME (see documentation for details) and a bi-Gaussian vertical distribution. The model solves for the mass flow rate and outputs the mass concentrations at each vertical level at every grid point. The column height for the results shown here was 3.731 km (a.s.l.).

Many other model runs were done to look at sensitivity to various parameters but it is beyond the scope of this paper to discuss all the results. Here we present results that best model the satellite observations and we acknowledge that many processes have been neglected or ignored entirely (e.g. particle habit).

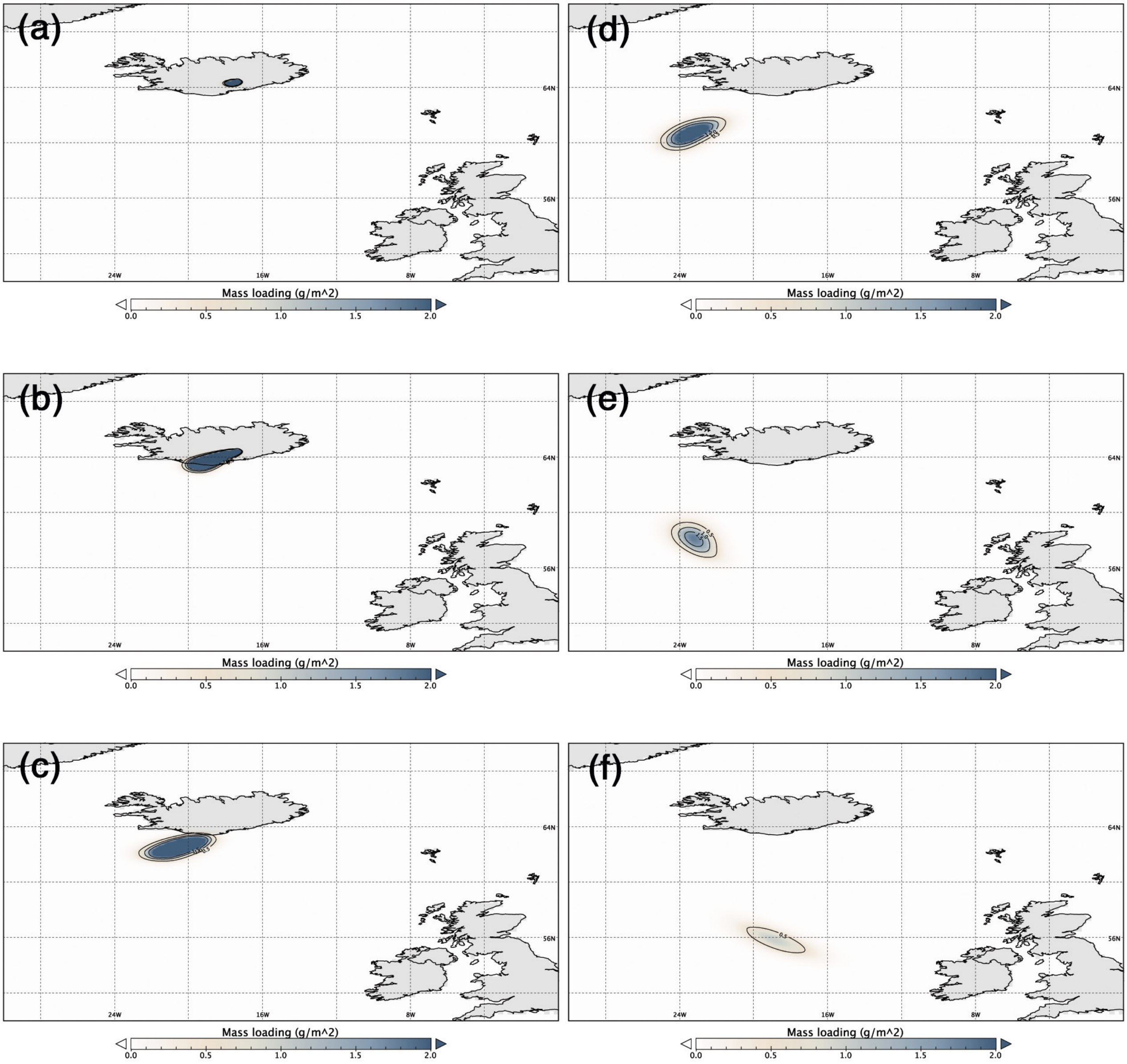

Figure S1. Total ash column mass loading (g m^{-2}) determined from the volcanic ash transport model FALL3D using NCEP wind fields at 6-hourly intervals (except between 13:00–18:00 UTC), starting at; (a) 13:00 UTC, 22 May (b) 18:00 UTC, 22 May (c) 00:00 UTC, 23 May, (d) 06:00 UTC, 23 May, (e) 12:00 UTC, 23 May, and (f) 18:00 UTC, 23 May.

1.2 Satellite data retrievals

The satellite data used in or study is listed in Table 1. Some of the satellite retrievals are shown here and discussed in the main paper. AIRS was utilised to retrieve SO_2 slant column densities (SCDs) and also to investigate the effect of the dense ash column on the AIRS spectral brightness temperatures. OMI data were also used to retrieve SO_2 SCDs using ultra-violet light. MODIS data at higher spatial resolution ($\sim$1 km^2) than either AIRS or OMI were used to retrieve ash mass loadings. Finally, SEVIRI data at decreased spatial resolution ($\sim$4-30 km^2) but high temporal resolution (15 minutes) were used to retrieve ash mass loadings and also to investigate the rapid plume rise (Figure 3) by analysing the single-channel cloud-top brightness temperatures.

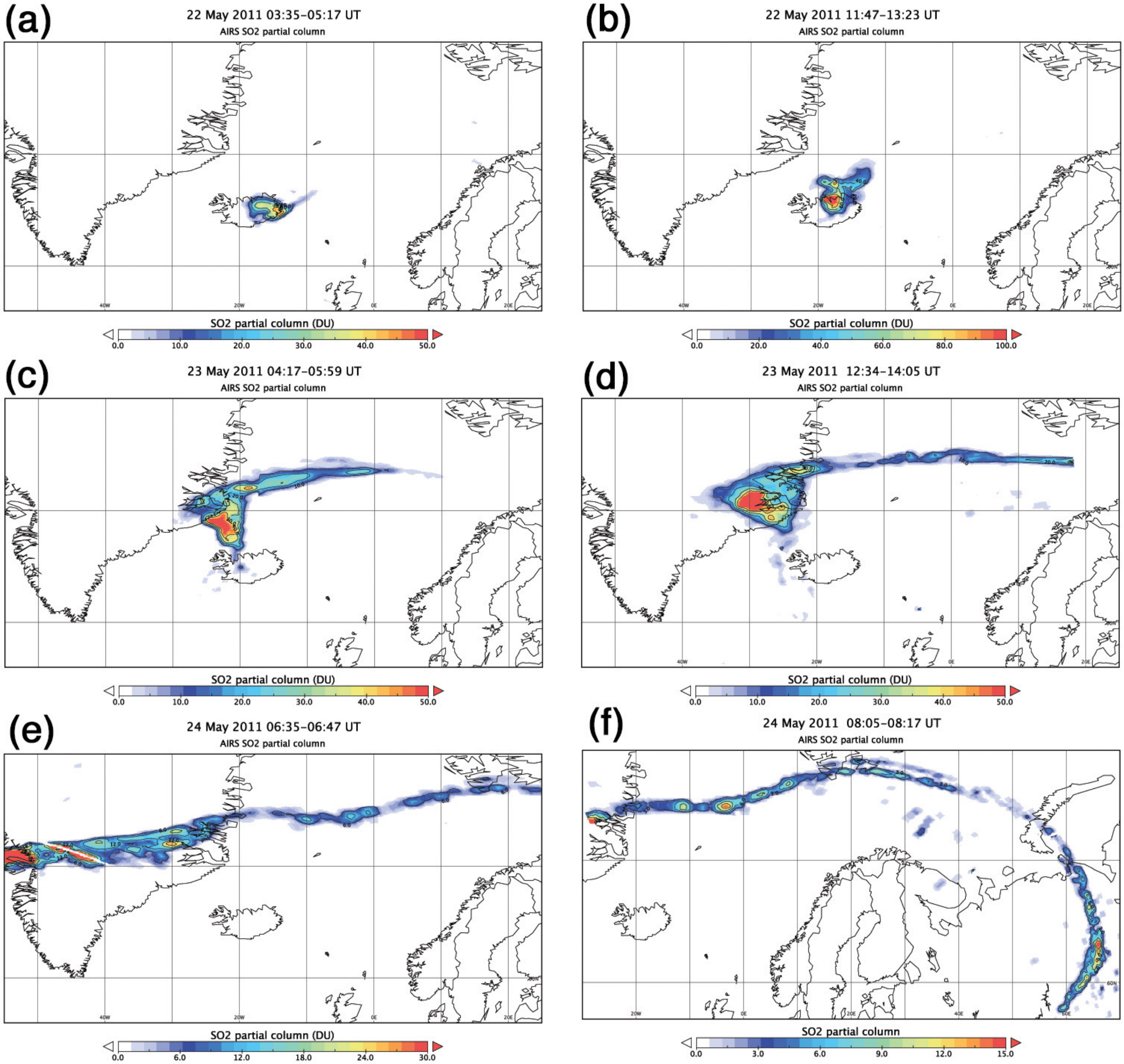

Figure S2. SO_2 retrievals from the AIRS sensor for 22–24 May 2011. Units are DU (Dobson Units; 1 DU $\approx$ 2.69 x 10^{16} molecules cm^{-2}). The AIRS detected SO_2 emissions travelling northwards and then spreading in a long filament eastwards and westwards. Each panel represents more than one granule (i.e. covering a specific time span): (a) 03:35–05:17 UT, 22 May, (b) 11:47–13:23 UT, 22 May, (c) 04:17–05:59 UT, 23 May, (d) 12:34–14:05 UT, 23 May, (e) 06:35–06:47 UT, 24 May, and (f) 08:05–08:17 UT, 24 May. A single AIRS granule corresponds to approximately 6 minutes. Note that AIRS is only sensitive to upper troposphere SO_2.

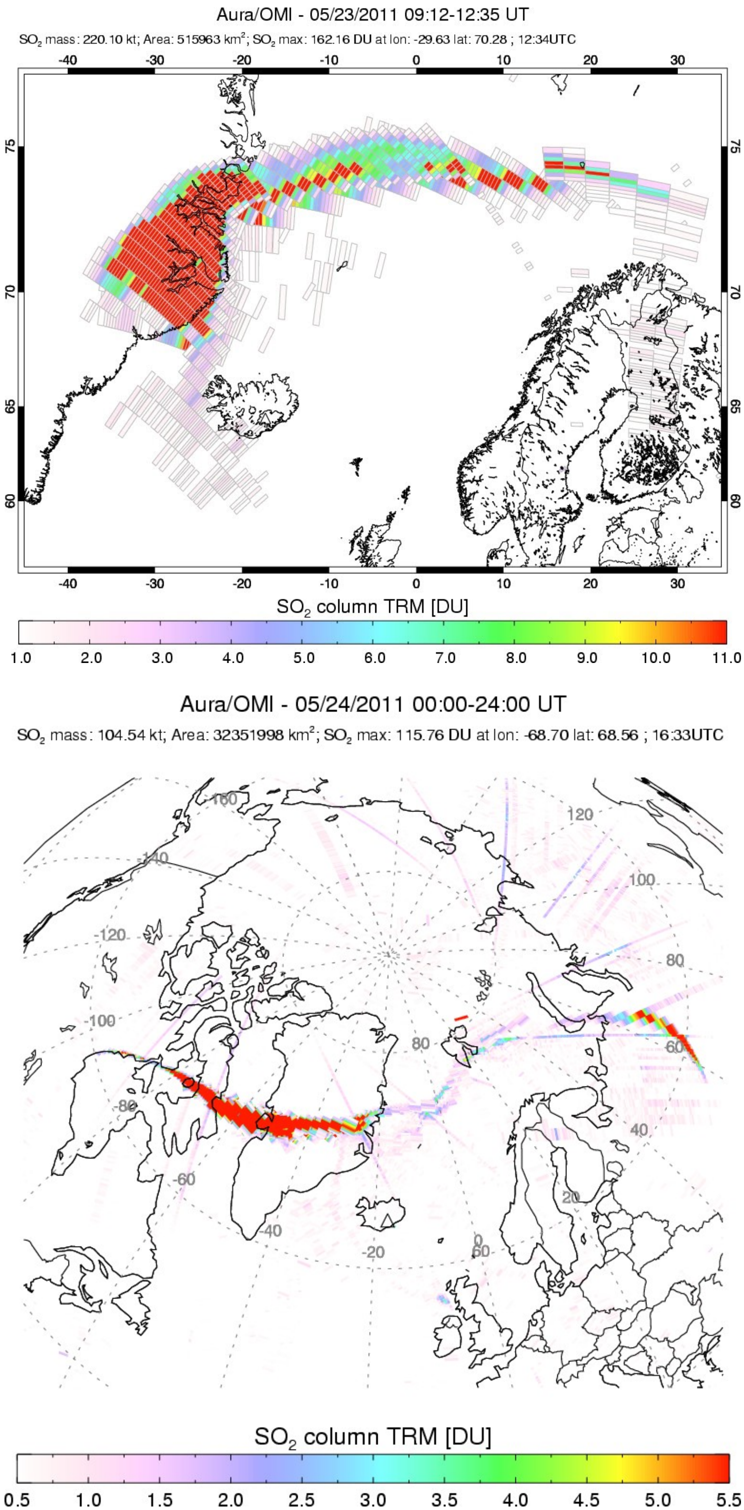

Figure S3. SO_2 retrievals from OMI on 23 and 24 May. Units are Dobson Units (DU). TRM stands for middle tropospheric SO_2 column with a centre of mass altitude of $\sim$7.5 km.

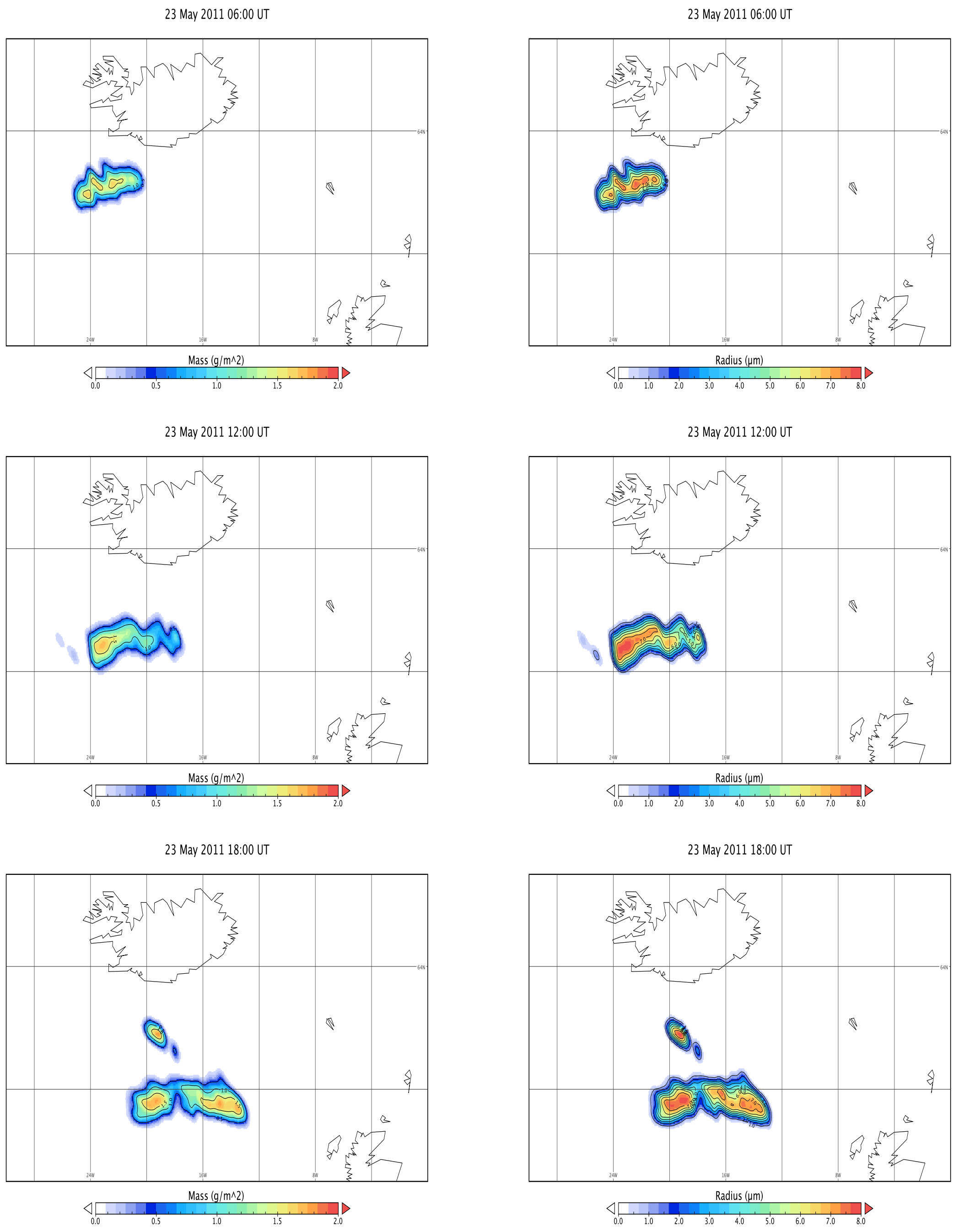

Figure S4. Ash retrievals from the SEVIRI instrument at 6 hour intervals on 23 May 2011. Left-hand panels: ash mass loadings in g m^{-2}. Right-hand panels: Effective particle radius (μm).

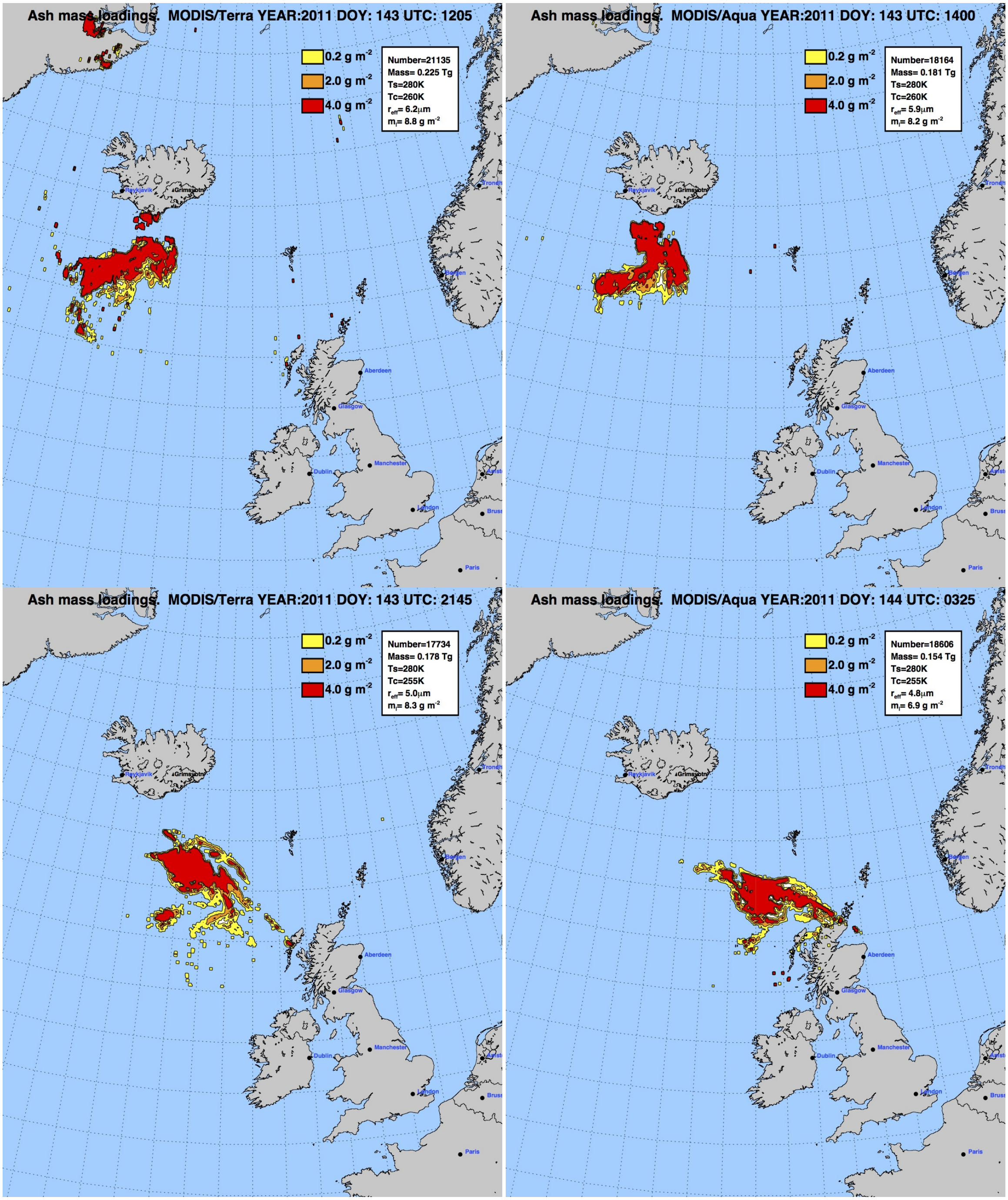

Figure S5. Ash mass loading retrievals using data from the MODIS Terra and Aqua sensors on 23 and 24 May, 2011. Information on the retrieved parameters, mean mass loading, mean effective particle radius, total mass, cloud top and surface temperature are provided in the panel inset on each map. Day 143 corresponds to 23 May.