Europlanet TA Scientific Report

PROJECT LEADER

Project number: 20-EPN2-050
Name: Jacopo Taddeucci, Elisabetta Del Bello
Home Institution: Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
TA Facility visited: Planetary Environment Facilities-PEF (DK)

Project Title: Turbulent suspensions of volcanic ash: an experimental simulation for eruptive and resuspension ash plumes

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

Ash Injection and settling experiments have been carried out using the environmentally controlled recirculating wind tunnel facility at Aarhus University, in order to understand the processes controlling deposition and segregation of ash from volcanic plumes at stratospheric altitudes. Ash particles erupted from the Campi Flegrei volcano (Italy) and smaller than 63 micron were injected in the wind tunnel either from the upwind extremity in the presence of wind (1 m/s) or from the side in the absence of wind. The atmospheric pressure in the wind tunnel was systematically varied to simulate the corresponding elevation in the atmosphere from 10 to 50 km. The vertical and horizontal velocity of the particles was measured, as well as the plume opacity, proxy for particle concentration over time. Settled particles were sampled at different times during the experiments and then analysed for their abundance and size distribution. Both the opacity measurements and the number of particles sampled over time display the decay of particle concentration over time in the suspended plume. The rate of decay is strongly dependent on the atmospheric elevation in a nonlinear way, with modest changes from 10 to 20 km elevation and much larger changes for higher elevations. From these data we will retrieve experimentally the settling velocity of volcanic ash particles at a range of elevations that is of interest for both aviation and climate modelling implications.

Full Scientific Report on the outcome of your TNA visit

We encourage you to add figures to your report, which should be approx. 1 page of text plus figures.

Ash injection/settling experiments have been carried out using the environmentally controlled recirculating wind tunnel facility at Aarhus University.
The atmospheric pressure in the wind tunnel was systematically varied to simulate the corresponding elevation in the atmosphere (in km): 10 km (342 mbar),20 km (74 mbar), 30 km (15 mbar), 40 km (3.3 mbar), and 50 km (0.86 mbar). All experimental runs were performed at ambient humidity and at constant wind speed values. The samples used for the experiment are: 1) volcanic ash from Campi Flegrei (PPA, see Del Bello et al., 2018 for details), in the size range 0-63 μm,; 2) 'Cospheric' glass beads in the size range 1-8 μm (GB1) and 7-19 μm (GB2).

The experimental procedure of each run is as follows: an empty sampling plate is placed in the measuring section of the wind tunnel, then the wind speed is set to the experimental condition and kept constant throughout the run, and particles are injected through an aerosolization system either from the end of wind tunnel (upwind section) or from the side of the tunnel, forming a suspended plume in the wind tunnel. At the beginning of the experiment the sampling plate is fully covered, then four different portions of it are exposed to sample the particles settling from the plume at four different time intervals during the experiment. A 2D Laser Doppler Anemometer measured the vertical and horizontal wind flow velocity of the particles crossing the target volume, also a laser power meter measured the transmitted laser intensity through the chamber and thereby captured the plume opacity (in %) see Fig. 1.
At the end of each run, the sampling plate is extracted from the tunnel and pictures of the particles from the 4 different plate sections were captured via a portable microscope. A total of 35 experimental runs were performed at different conditions. The first 14 runs were performed adjusting the different experimental variables in order to find the optimal conditions. In the end, 17 experimental runs were selected for further analysis and data processing (Table 1). In these runs the experimental conditions were systematically varied as follows:

1) group 15 to 19 was performed at a constant wind speed of ~1 m/s (60 RPM), and by injecting 10 consecutive shots of volcanic ash (PPA) from the tunnel back section;
2) group 20 to 25 was performed at a constant wind speed of ~1 m/s (60 RPM), and by injecting 10 consecutive shots of glass beads (GB1 and GB2) from the tunnel back section;
3) group 30 to 35 was performed in still conditions (no wind), and by injecting 10 consecutive shots of volcanic ash (PPA) from the tunnel lateral section.

For each experiment, the number and grain size distribution of the particles settled in the 4 different time windows was obtained by performing an image analysis of the acquired plate pictures (Fig. 1). The plot of the number of particles settled as a function of time (Fig 2a) illustrates the dependency of the rate of sedimentation with pressure conditions. Experiments performed at progressively lower pressure conditions (i.e. higher atmospheric altitudes in km) are characterised by progressively steeper decays/trend, indicating a more rapid loss of the suspended particle load over time. The same trend is well illustrated by the plume opacity over time (Fig 2b). These data will be modelled following current theory and previous literature, also in comparison with previous experiments on nonvolcanic particles.

test no	elevation (km)	wind tunnel calculated pressure (mbar)	wind (RPM)	note on wind/experimental conditions	sample collection & pictures	sample used*	injection conditions#	injected mass (g)
15	40	3.3	60	1 m/s constant	yes	PPA_63	10 shots	15,32
16	50	0,86	60	1 m/s constant	yes	PPA_63	10 shots	15,46
17	20	74	60	1 m/s constant	yes	PPA_63	10 shots	15,64
18	10	342	60	1 m/s constant	yes	PPA_63	10 shots	15,05
19	30	15	60	1 m/s constant	yes	PPA_63	10 shots	15,27
20	50	0.86	60	1 m/s constant	no	GB1	10 shots	6,71
21	50	0.86	60	1 m/s constant	no	GB2	10 shots	16,00
22	40	3.3	60	1 m/s constant	no	GB1	10 shots	10,03
23	40	3.3	60	1 m/s constant	no	GB2	10 shots	16,11
24	10	342	60	1 m/s constant	no	BG1+GB2	10 shots	13,04
25	20	74	60	1 m/s constant	no	BG1+GB2	10 shots	13,27
30	50	0,86	0	lateral injection	yes	Ppa	5 shots	8,00
31	40	3.3	0	lateral injection		Ppa	5 shots	8,19
32	20	74	0	lateral injection		Ppa	5 shots	7,31
33	10	342	0	lateral injection		Ppa	5 shots	7,35
34	30	15	0	lateral injection		Ppa	5 shots	7,00
35	40	3,3	0	lateral injection	yes	Ppa	5 shots	7,06

*sample name: GB1= glass beads 1-8 um; GB2= glass beads 11 um;PPA= campi flegrei pomici principali

Table 1. List of experiments selected for further analysis

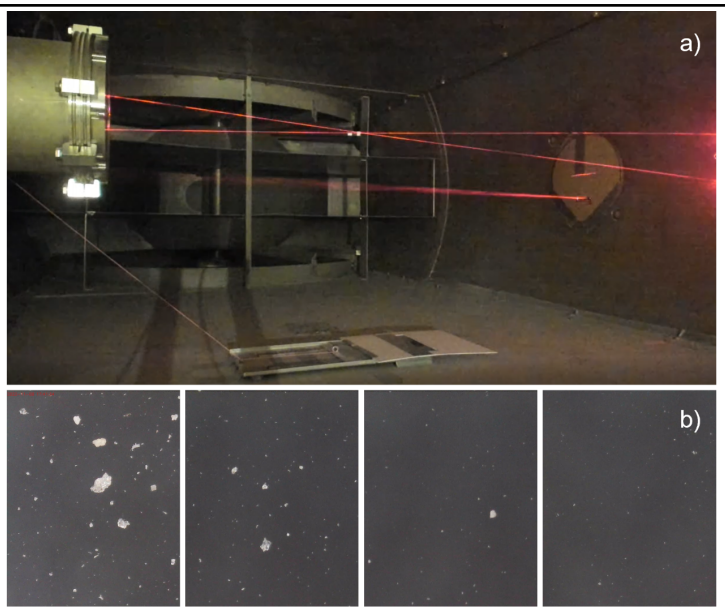

Figure 1: Experiment setup and products. a) Internal view of the Planetary Environment Facilities-PEF (DK) during one experiment. Laser beams from the Lased Dopper Anemometry (crossing upper beams) and the Opacity Measurement (lower beam) illuminate the suspended particles of volcanic ash. On the floor, the ash sampler. b) Microphotographs of areas of the sampler plate after one experiment (Run 15, larger particle is 4 micron across ca.). Note decreasing particle abundance from the first (left hand) to the last (right hand) sector opened.

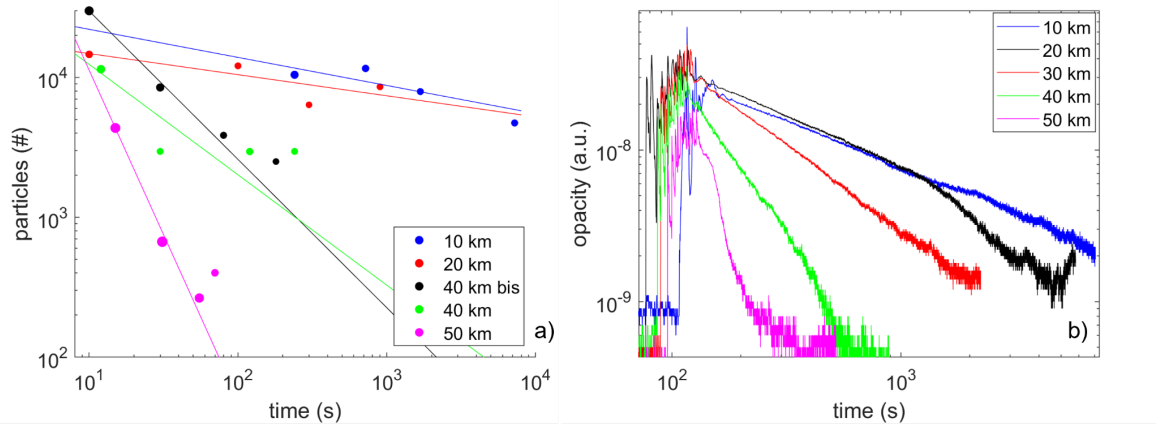

Figure 2: preliminary results of the experiments. a) Sustained wind and bottom injection experiments. Power law decrease in the number of particles collected on the sampler as a function of time since injection (marker size is proportional to mean particle size). 40 km bis is a repetition of the 40 km experiments but from side injection and without wind. b) side injection and no wind experiments. Power law decrease in plume opacity, proxy for the suspended particle load, over time.

- Give details of any publications arising/planned (include conference abstracts etc)

We plan to submit an abstract at IUGG General Assembly, Berlin 2023

- Host confirmation

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Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Departed: Taddeucci: 06-11-22 Del Bello: 07-11-22 Arrived: Taddeucci: 06-11-22 Del Bello: 07-11-22	07-11-22		5		11-11-22	Departed: 12-11-22 Arrived: 12-11-22

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	**Jon Merrison**
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Project Leader Name	**Jacopo Taddeucci**
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Date	**7/2/2023**