In situ study of volcanic ash resuspension using a portable wind tunnel

J. Taddeucci[1], E. del Bello[1], J.P. Merrison[2], K.R. Rasmussen[2], J.J. Iversen[2], P. Scarlato[1], T. Ricci[1], D. Andronico[1]

1) Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy; 2) Aarhus University, Denmark

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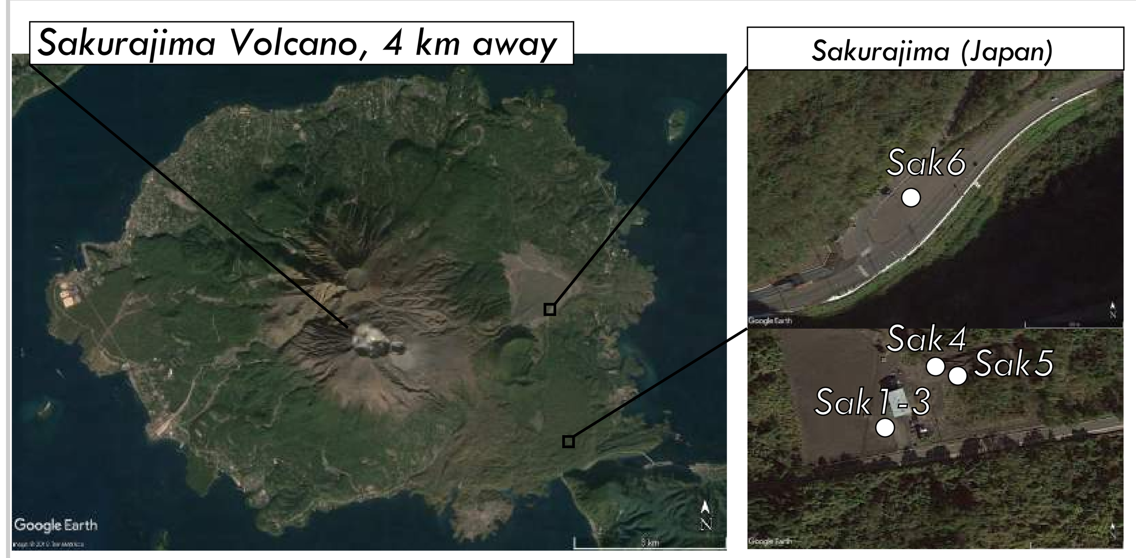
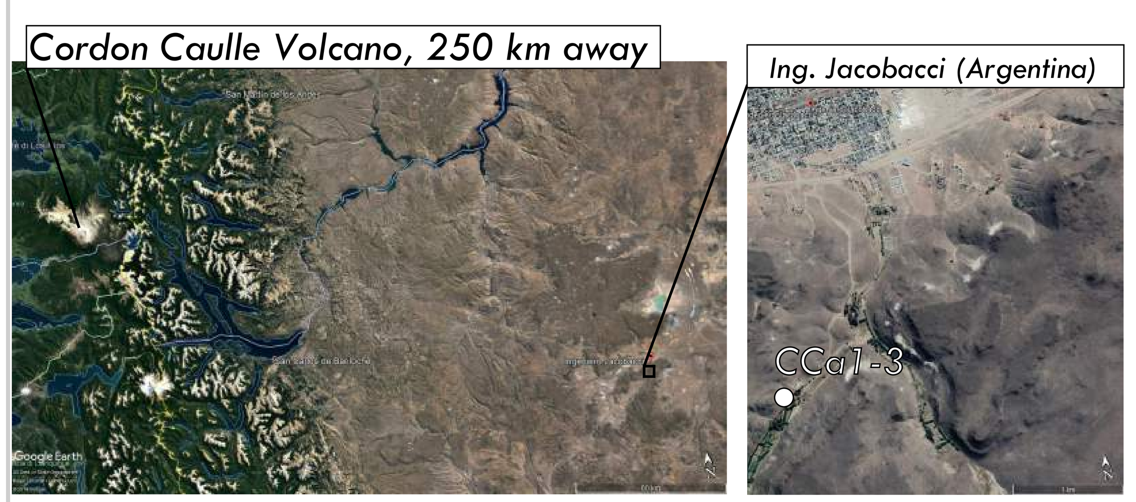
INTRO

The wind-induced resuspension of volcanic ash deposits is a well-known source of hazard following explosive eruptions. Besides the mail control exerted by the local wind field, ash resuspension is also influenced by: 1) atmospheric humidity; 2) features of the deposit (grain size distribution, sedimentary structures, etc.), and 3) features of the substrate (i.e. moisture, roughness). Ash resuspension is modelled using numerical simulations, which however require physical characterisation and identification of the critical parameters controlling ash resuspension. Wind tunnel studies on volcanic particles are very limited and restricted to laboratory parameterizations, with in-situ effects not been parameterized. We deployed a custom-designed portable wind tunnel in two geographic areas most affected by ash resuspension and studied the in-situ resuspension of relic volcanic ash in a variety of the above conditions.

FIELD TEST SITES

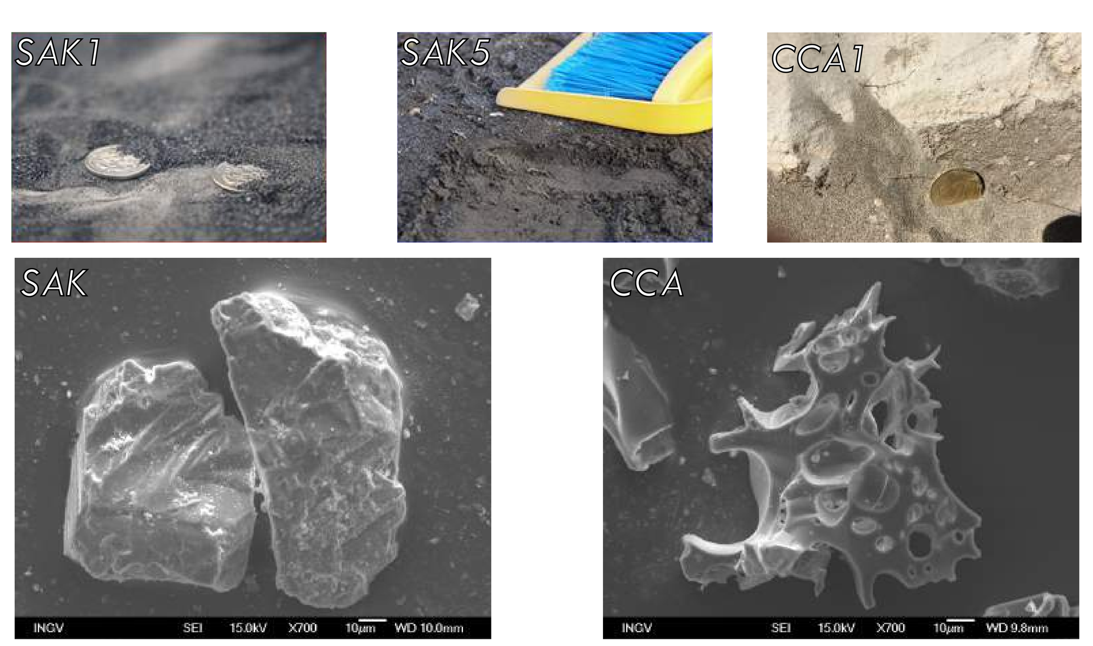


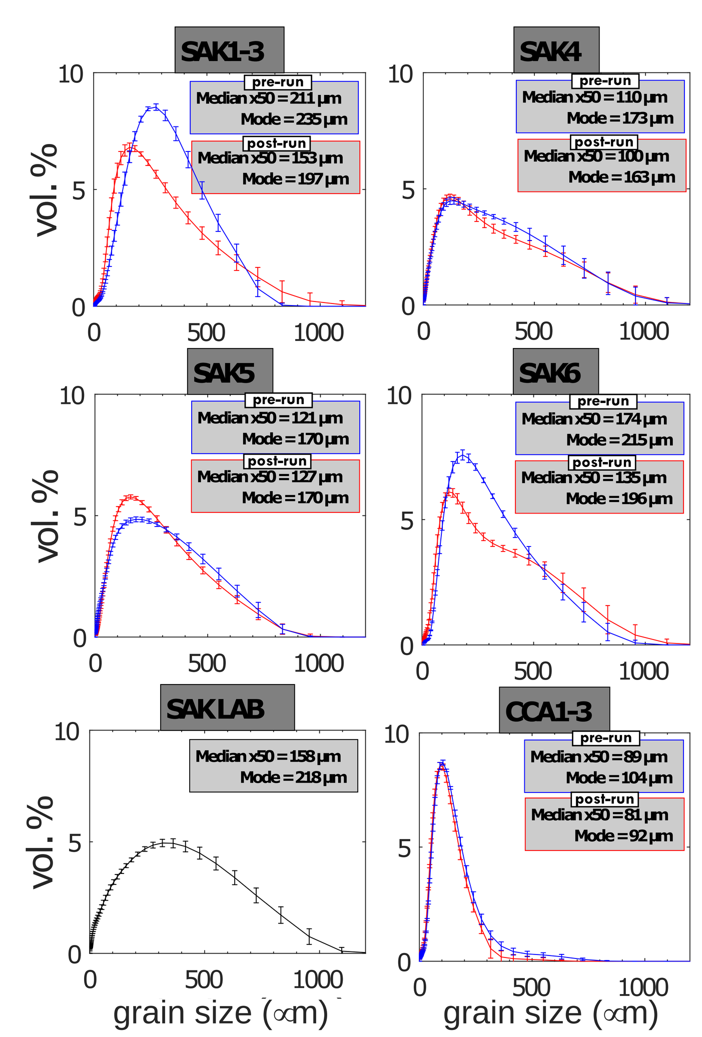
Sakurajima volcano (Japan) erupts on a daily basis, producing ash which settles in the proximal areas of the volcano. This deposited ash is continuously resuspended by winds, causing trouble to people living in the surrounding villages, and, depending on the wind strength, carried over into the nearby city of Kagoshima.



Puyehue-Cordón Caulle complex (Chile) erupted in June 2011, producing a huge ash cloud that injected thousands of kilos of ash into the atmosphere, that was blown across Chile and Argentina, and was mostly settled in the rural regions of Patagonia, causing massive economical disruption. The 5 cm thick ash deposit was largely eroded by the strong, constant eastward blowing winds, but some patches remain in valleys.

ASH PROPERTIES



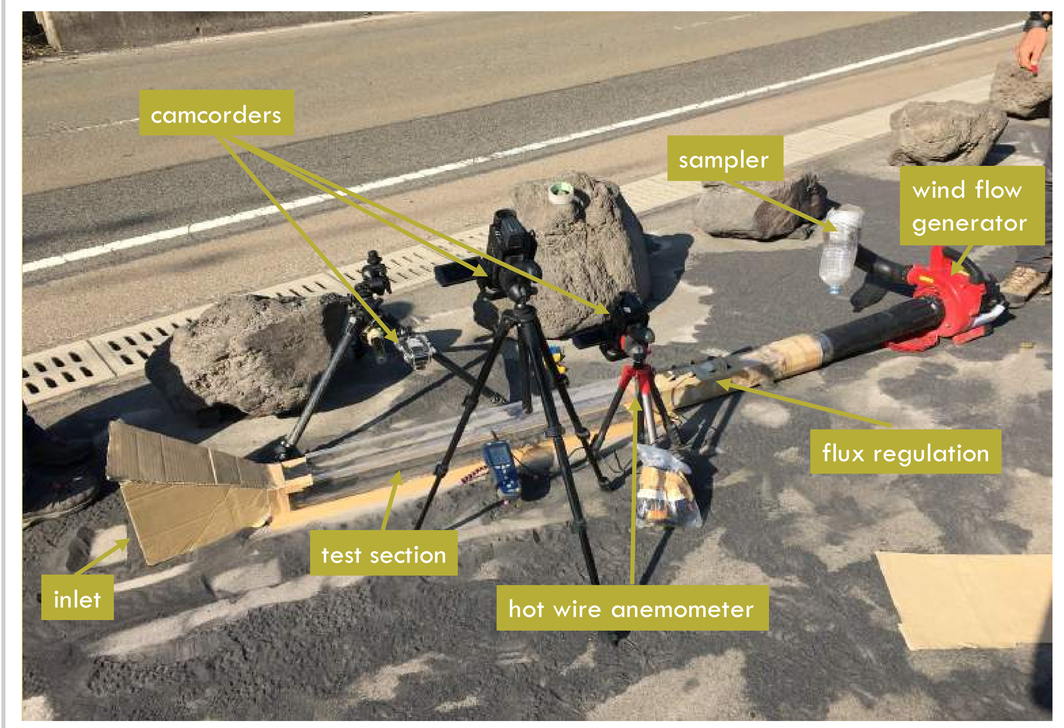


Ash features for Sakurajima (Sak) and Cordon Caulle (CCa) ash deposits. Sak deposits show variation in their moisture content, going from lose and dry (Sak 1-3) to sticky and wet (Sak 4-5). CCa deposit is lose and dry. SEM images show differences in particle morphology and vescicularity of the two ash types. Grain size distributions performed on the pre (blue) and post (red) experimental deposits show that depletion of coarser particles occurred during the experimental runs.

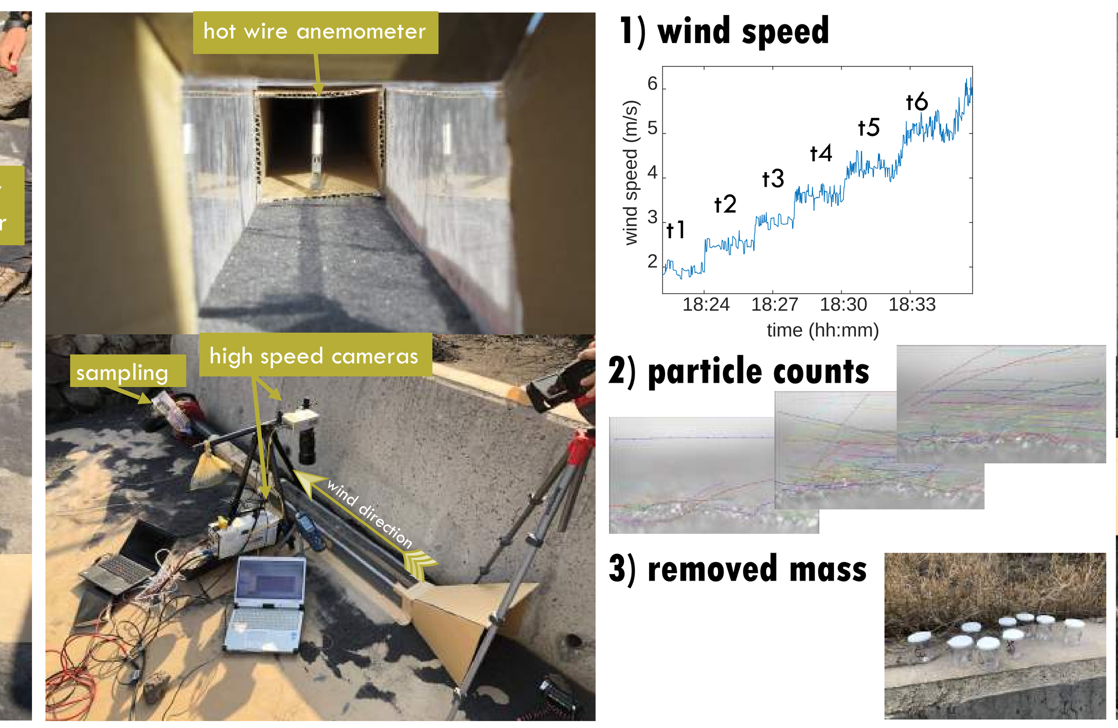
PoWAR: a Portable Wind tunnel facility for Ash Resuspension

The custom-designed wind tunnel allows generating a controlled wind profile within a 110x12x12 cm test section, which is placed directly on an untouched test bed of naturally deposited ash. Ramp up speed experiments experiments were performed, where the wind speed is increased until reaching the threshold friction speed on different substrates. At each wind speed step: 1) the wind speed is measured with a hot wire anemometer, 2) the movement of resuspended ash is detected by means of multiple high speed and high definition digital camcorders, and 3) the removed mass of ash is sampled. The device is calibrated with both LDA and pitot tubes measurements to retreive the friction or shear velocity U^*, linked to the shear stress $\tau = \rho_f U^{*2}$ (ρ_f is the fluid density).

A disposable prototype of the wind tunnel

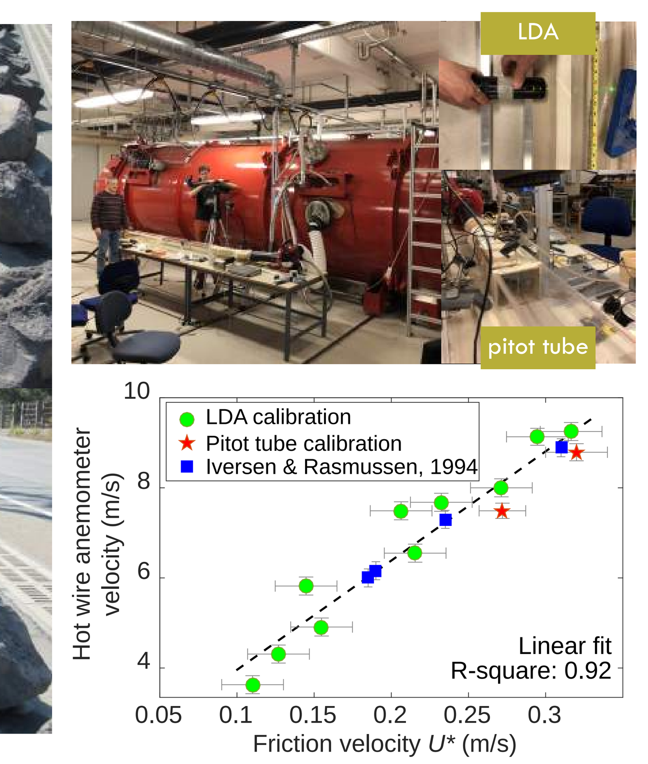


Data acquisition



Ash deposit observation

Device calibration



RESULTS

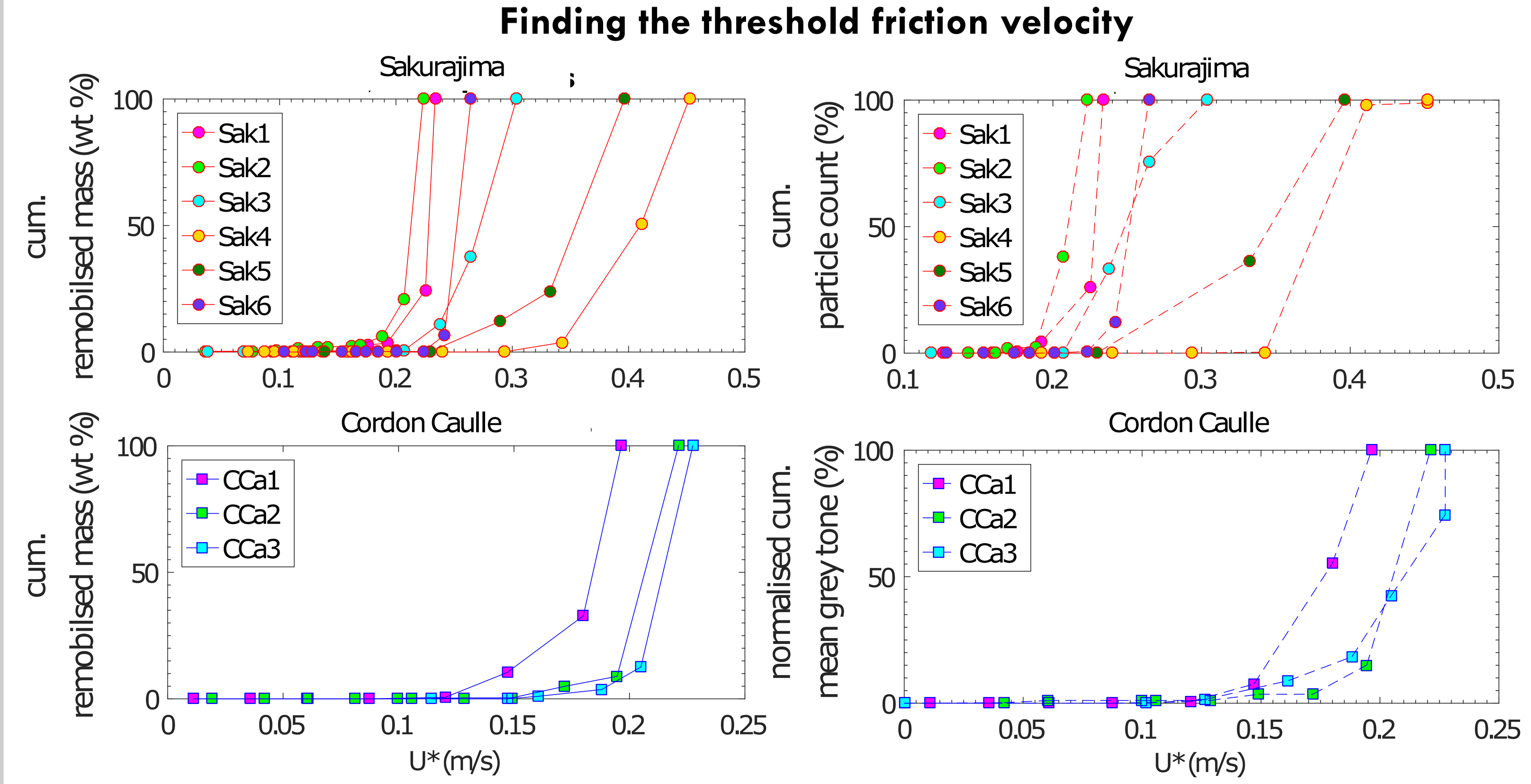
Threshold friction velocity values were estimated with two independent methods. First, by weighting the collected samples, we quantified the mass of ash removed from the deposit at each friction velocity u*. Second, from video analysis, we estimated particle counts and mean grey tone at each friction speed for Sakurajima and Cordon Caulle experiments, respectively. These quantities are plotted as u*dependent cumulative distributions, and the threshold friction velocity (Uth*), i.e. the u* value beyond which erosion begins, is quantified by taking the 10th percentile of the distributions. The two methods provide very consistent results. Experimental runs that were repited at the same site (runs 1-3) show progressive increse in the U_{th}* values, indicating that, in the residual sample, a progressive depletion in coarse particles occurs.

U_{th}* is plotted as a function of particle size (distribution median), with horizontal error representing the width of the grain size distribution (25th and 75th percentiles). Fit to data is provided by the Force Balance Model (Merrison et al., 2007) using variable adhesion (C_{adh}) and fixed torque (C_T= 3.3x10⁶) and lift (C_L=160) coefficients.

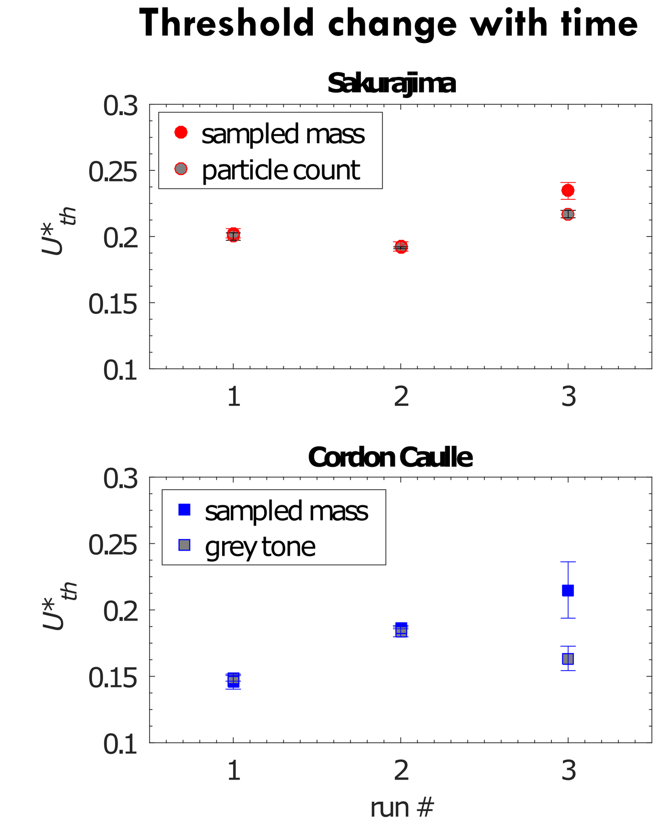
$$U^*_{th} = \left(\frac{\tau_{th}}{\rho_f}\right)^{0.5} = \left(\frac{\frac{4}{3}\pi g\rho r^3 + 2C_{adh} r}{C_L r^2 + C_T r^3}\cdot\frac{1}{\rho_f}\right)^{0.5}$$

In-situ measured threshold friction velocities are compared to laboratory determination of threshold friction speed in controlled environmental conditions. Laboratory measurements performed for Sakurajima ash (Sak) show very good agreement with field data, despite differences in the deposit features. Laboratory data from experiments on Eyjafjallajökull (Eyj) and Campi Flegrei (CFl) ash performed in 'dry' (white symbols) and 'wet' (black symbols) humidity conditions (Del Bello et al. 2018) are also resported for comparison.

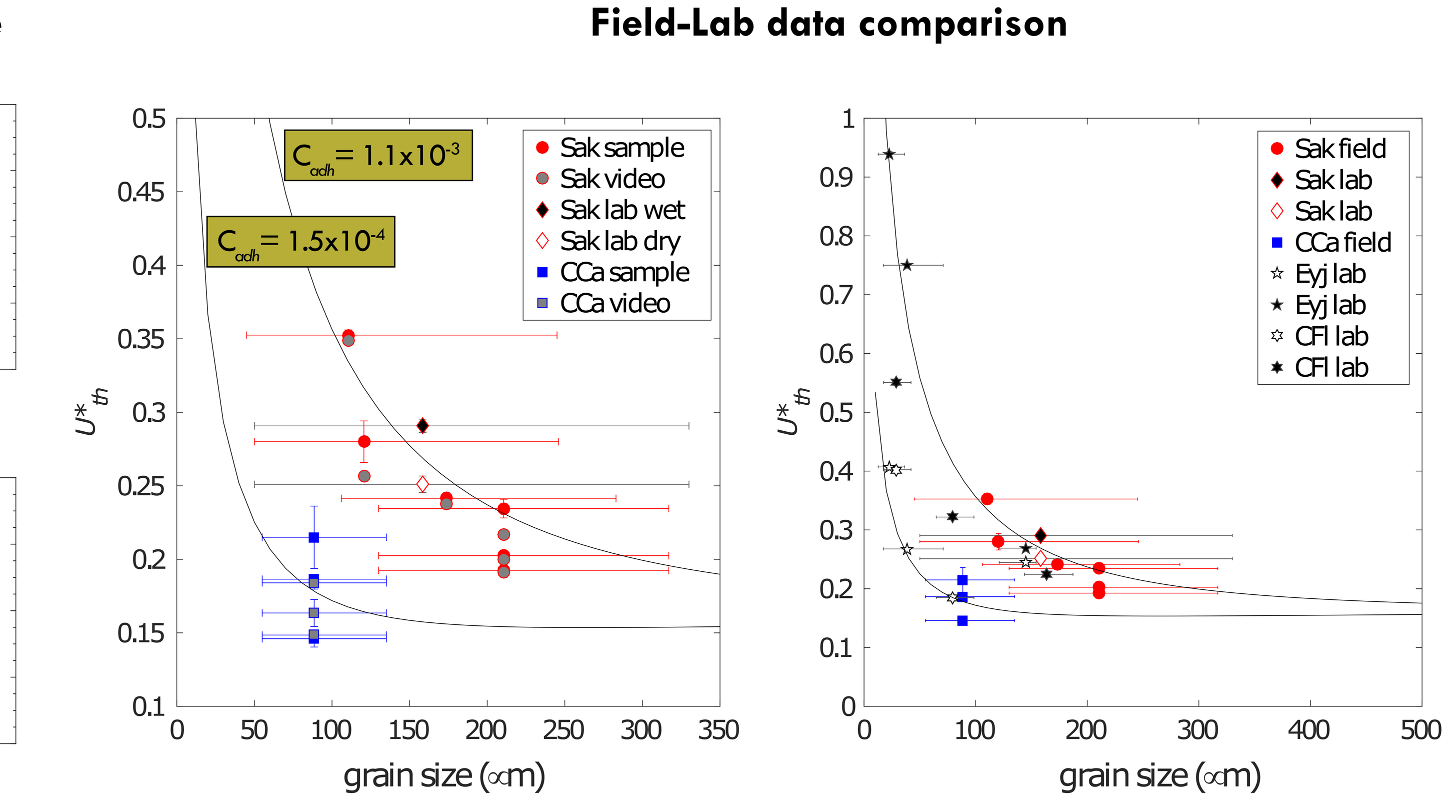
Finding the threshold friction velocity



Threshold change with time



Field-Lab data comparison



MAIN OUTCOME

When comparing U_{th}* values derived for volcanic particles at different volcanoes and at a range of test conditions, including atmospheric humidity, grain size distribution, sorting, deposity features, it appears that all are ranging within a consistent range of values, that can be modeled by varying the adhesion coefficient by a maximum factor of 7.