Department of Meteorology

VolcLab: A balloon-borne instrument package to measure ash, gas, electrical, and turbulence properties of volcanic plumes

M. W. Airey | R. G. Harrison | K. A. Nicoll | P. D. Williams | G. J. Marlton

University of Reading

Background

Release of volcanic ash into the atmosphere poses a significant hazard to air traffic. Exposure to appreciable concentrations (≥4 mg m^{-3}) of ash can result in engine shutdown, air data system loss, and airframe damage, with sustained lower concentrations potentially causing other long-term detrimental effects [1]. In addition to these effects, the charging of ash has implications for enhanced risk of lightning strike and electrical damage to aircraft systems. Disruption to flights also has a societal impact. For example, the closure of European airspace following the 2010 eruption of Eyjafjallajökull resulted in global airline industry losses of order £100 million daily and disruption to 10 million passengers. Accurate and effective measurement of the mass of ash in a volcanic plume can be used in combination with plume dispersion modelling, remote sensing, and more sophisticated flight ban thresholds to mitigate the impact of future events.

Project overview

VolcLab is a disposable instrument package, attached to a standard commercial radiosonde, for rapid emergency deployment on a weather balloon platform (Figure 1). The payload includes a newly developed gravimetric sensor using the oscillating microbalance principle to measure mass directly without assumptions about particles' optical properties. The package also includes an SO_2 gas detector, an optical sensor to detect ash and cloud backscatter [2], a charge sensor to characterise electrical properties of the plume [3], and an accelerometer to measure in-plume turbulence [4]. VolcLab uses the established PANDORA interface [5], to provide data exchange and power from the radiosonde. In addition to the VolcLab measurements, the radiosonde provides standard meteorological data of temperature, pressure, and relative humidity, and GPS location. Simultaneous collection of these datasets in multiple locations, and in real time, will provide in situ plume characteristics for airspace risk management planning as well as providing valuable scientific information on plume dynamics.

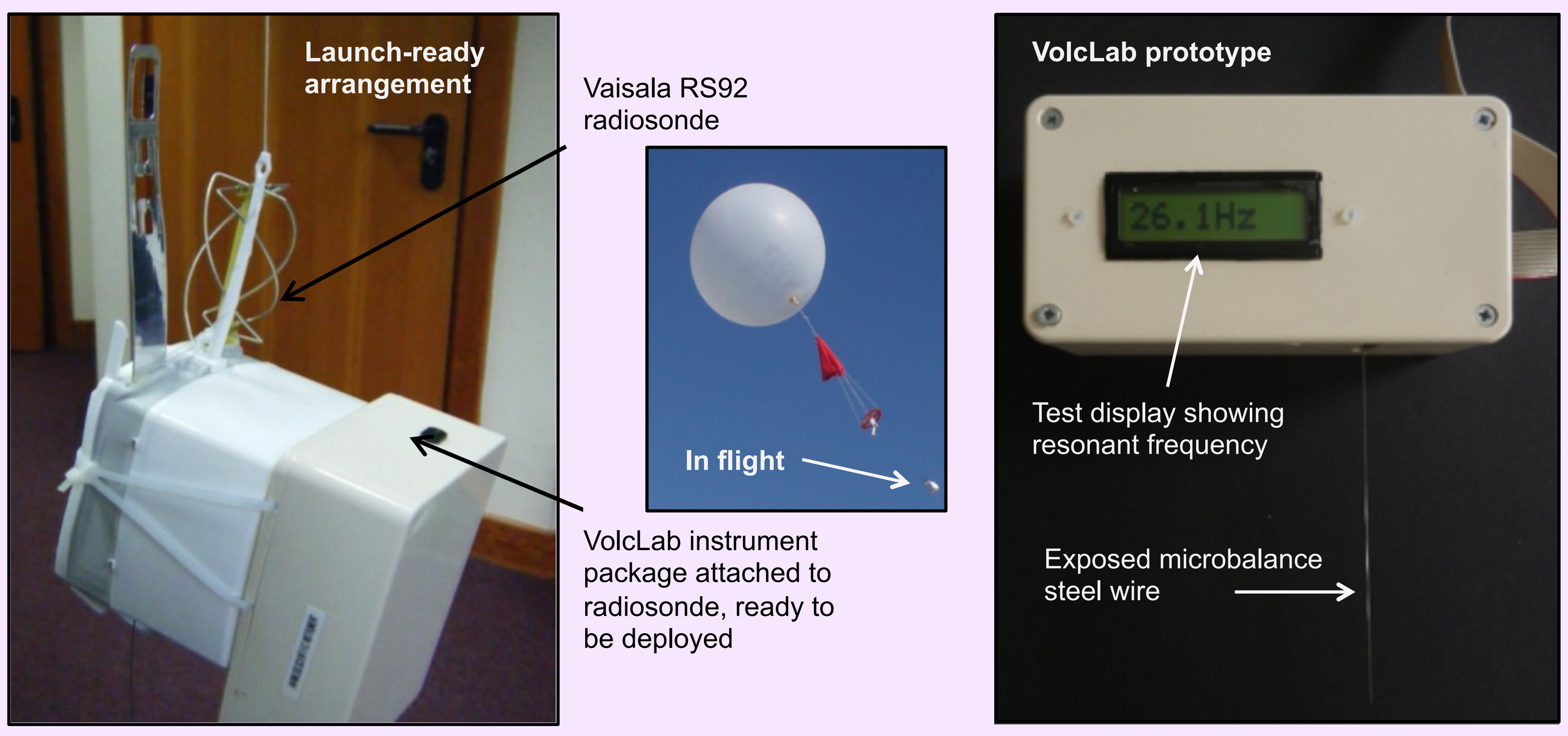

Figure 1. Test versions of the combined instruments and the radiosonde integration system

References

[1] Safety and Airspace Regulation Group, *Guidance regarding flight operations in the vicinity of volcanic ash, CAP 1236 (Third edition)*, 2014, Civil Aviation Authority. [2] Harrison, R.G., et al. (2012) *Rev. Sci. Instrum.*, *83*, 3 [3] Nicoll, K.A. (2013) *Rev. Sci. Instrum.*, *84*, 9, 3 [4] Marlton, G.J., et al. (2015) *Rev. Sci. Instrum.*, *86*, 1 [5] Harrison, R.G., et al. (2012) *Rev. Sci. Instrum.*, *83*, 3

Contact information

- Department of Meteorology, University of Reading, Earley Gate, RG6 6BB
- Email: m.w.airey@reading.ac.uk | http://www.met.reading.ac.uk/userpages/zm913894.php

Instruments

The oscillating microbalance (Figure 2a) exploits the wire's resonant frequency of oscillation, which is dependent on wire properties, including mass. Material in the plume attaches to an adhesive applied to the wire. The wire is excited by a piezosounder before being allowed to oscillate at its natural frequency; the change in mass is measured as interpreted from the peak frequency change as shown in Figure 3. The collection efficiency of the wire through a reference volume will be calculated in order to derive the mass per volume required for risk management decisions.

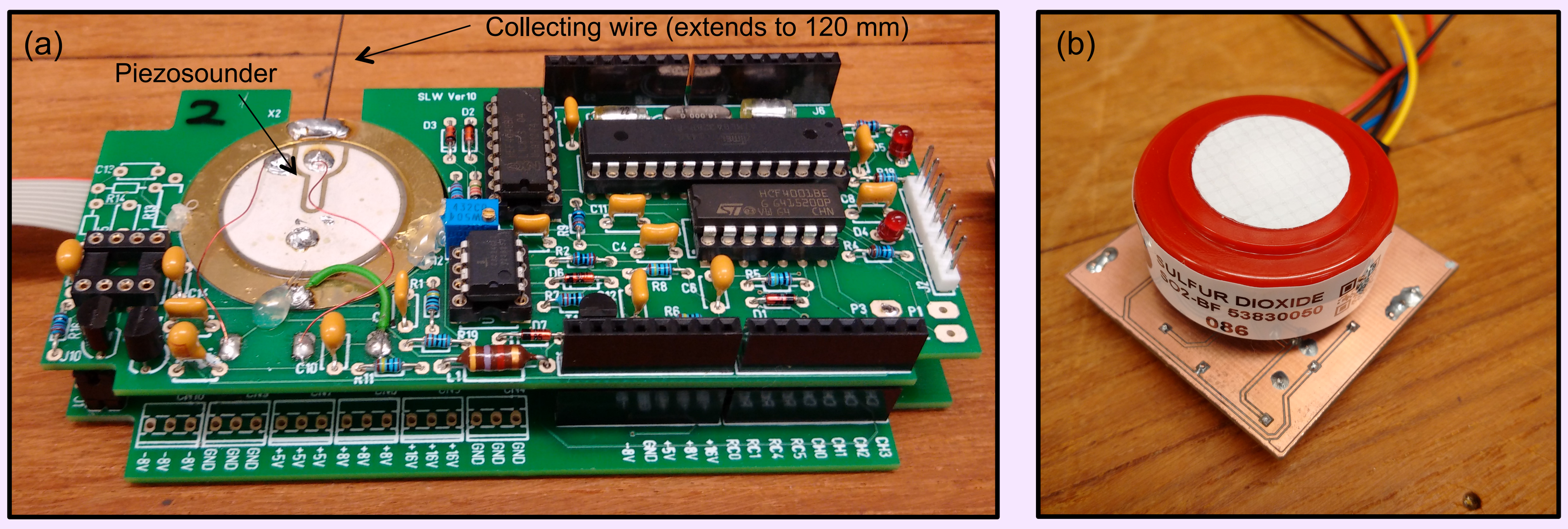

Figure 2. a) The microbalance mounted on a PANDORA board, b) the SO_2 sensor on test board

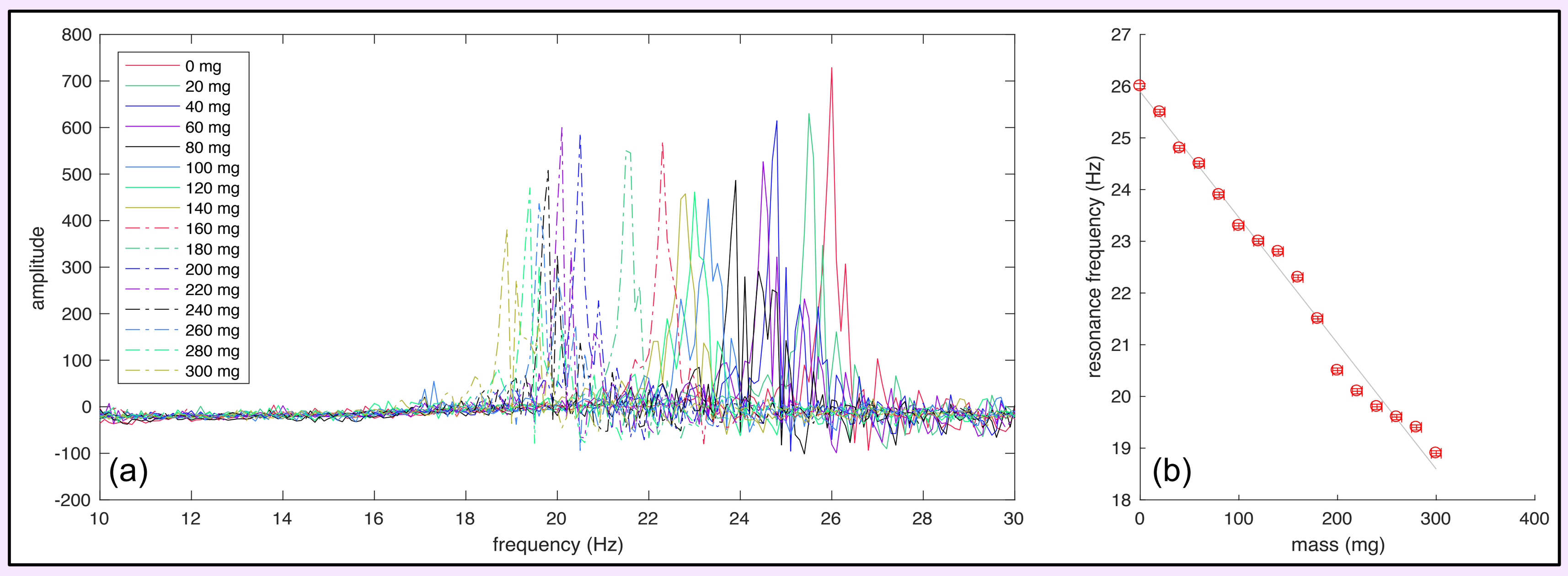

Figure 3. a) Wire oscillation amplitudes over a range of masses and frequencies illustrating the occurrence of resonance, b) plot to show the relationship between resonant frequency and mass

The SO_2 sensor (Figure 2b) is included in order to a) act as a plume identification indicator and b) to measure the concentration of SO_2 in the plume at the instrument location. Initial tests indicate that measurements in excess of atmospheric background concentrations that are indicative of a volcanic plume will be possible at tens of km from the volcanic source. The optical sensor measures the backscatter returned from an array of LEDs on the underside of the instrument box. The backscatter measurement will provide a quantification of the volume density of material in the plume. An electrode emerging from the box will take measurements of charge as the balloon ascends through the plume, allowing any enhanced electric field due to the presence of charged ash to be determined, providing further valuable information. Finally, an integrated accelerometer will measure the motion of the sensor in three axes. The information gathered will be used to characterise the dynamic environment and turbulence properties of the plume.

Key points

- *All-in-one instrument package requiring minimum expertise from end user allowing rapid emergency deployment*
- *Easy integration with commercially available radiosondes*
- *Multiple plume properties measured and transmitted in real time*
- *Simultaneous characterisation of ash mass/volume density, SO_2, plume turbulence, and electrical properties*
- *Network of balloons may be spatially referenced and integrated with remotely sensed data for rapid analysis*