Optical Properties of Volcanic Ash

Proposed experimental method

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Outline

- Project overview.
- Very small amount of experimental theory.
- Experimental method.
- The sample.
- Issues.
- Some questions.

Project Overview

- Measure the spectral extinction cross-section (σ_{ext}) of the following aerosols:

Conditions	Ash	Saharan dust
Dry	$\surd\surd$	$\surd\surd$
0% $<$ RH $<$ 100%	$\surd$	$\surd$
Ice	$\surd$	$\surd$
H_2SO_4 coated	$\surd$	$\surd$

$\surd\surd =$ primary aim. $\surd =$ secondary aim.

Experimental Theory

- The extinction cross section is related to the optical transmission by:

$$T(\lambda) = \exp^{-\beta(\lambda)x}$$

Where:

T Transmission.

β Volume extinction coefficient.

x Measurement path length.

- And . . .

Experimental Theory

- The volume extinction coefficient is given by:

$$\beta(\lambda) = \int_0^\infty \sigma_{ext}(r, m, \lambda) n(r) dr$$

Where:

r Particle radii.

m Particle complex refractive index.

λ Wavelength.

$n(r)dr$ Number of particles between radii r and $r + dr$.

Experimental Method

- The transmission spectra ($T(\lambda)$) will be measured, though an aerosol sample, this will be achieved in outline by:
  - Using the aerosol cell.
  - Bruker IFS 66/vS Fourier transform spectrometer, and suitable source/detectors/optics/windows optimized for the particular wave length region.
  - The maximum spectral resolution of this instrument is 0.12 cm^{-1}, giving the ability to identify gas contaminates.
  - Measurements of the detected intensity will be obtained with and without the aerosol to calculate the transmission.

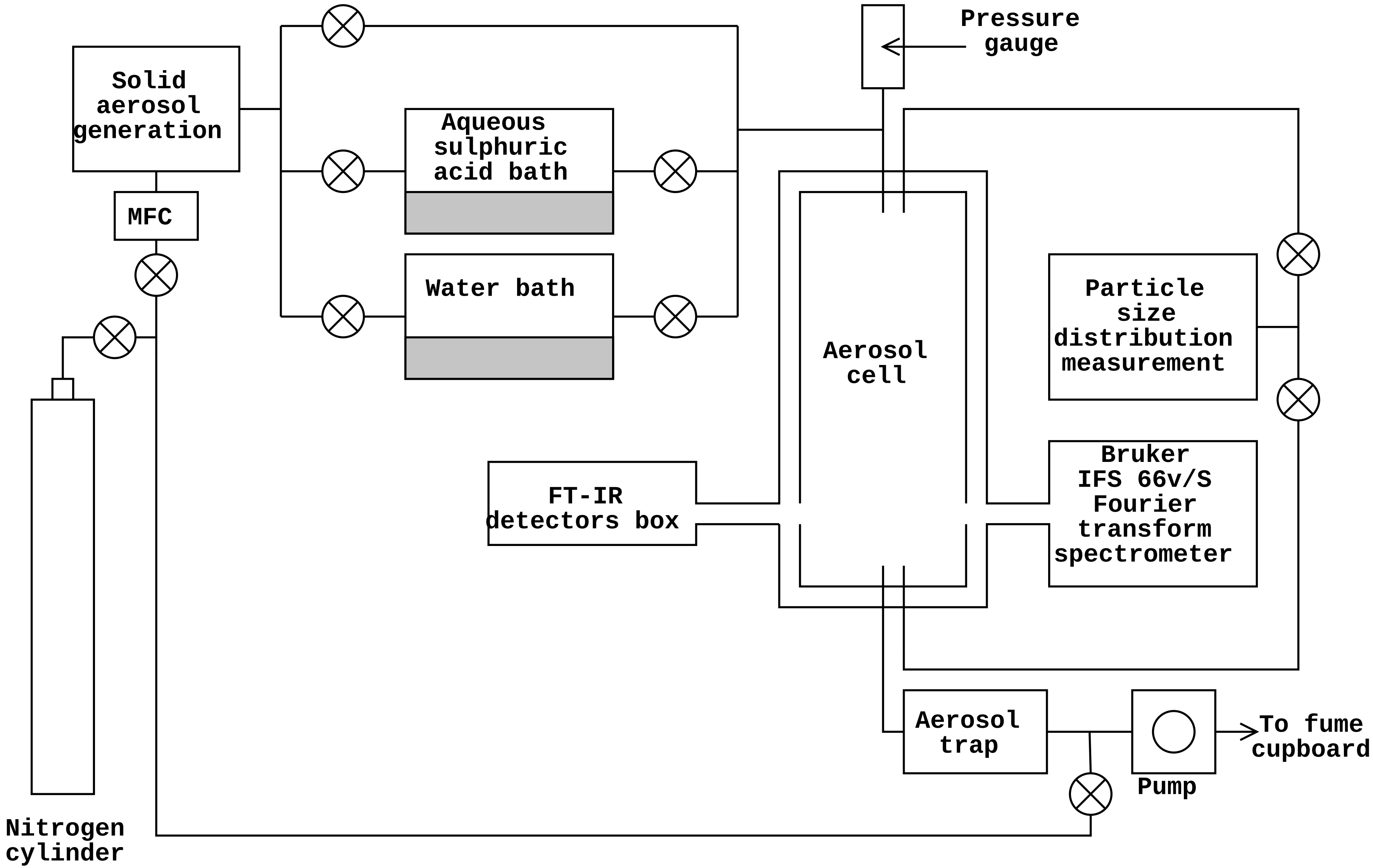
Experimental Method

- Particle size distribution, $n(r)$.
  - A suitable instrument is to be purchased to measure the particle size distribution at the inlet and outlet of the aerosol cell.
  - The baseline instrument is a TSI 3936L10 scanning mobility particle sizer (SMPS). It is capable of:
    - Measuring particles in the range 0.001 μm to 1 μm.
    - Concentrations of up to 10^7 particles cm^{-3}.
  - A previous commercial contract has used an SMPS on the aerosol cell, so some experiance has been gained in the installation of such an instrument.

Aerosols generation

- The method of aerosol generation has yet to be decided.
- The method will need to generate a steady controlled flow of aerosol from our solid sample.
- Possibilities identified so far:
  - Suspending the solid aerosol in a volatile fluid, that is nebulized then dried.
  - Using a fluidized bed generation technique.
- Due to budget constraints we may need to build the aerosol generator.

Baseline configuration



The aerosol cell in use

The samples

- The volcanic ash sample:
  - From Aso Eruptions in 1993.
  - Collected from “bomb-shelters” (where 1-2 m of ash accumulated).

  - Thought to be in a “fresh” state.
  - Thanks to Tony Hurst, for collecting the sample!

The samples

- The Saharan dust samples.

Sample No.	GPS coordinates (deg +dec .min)	Sample location	Comments
1A and 1B	19°25.737'N 13°33.715'W	Rocky quartzite ridge trending 330° and rising c. 6 meters above the surrounding plain west of the Ijibbitene range of hills.	Sample taken from rocky hollow on crest. Dune sand also banked up against the SE flank of the ridge.
2A and 2B	19°03.936'N 13°12.200'W	Steep-sided EW range of quartzite hills c. 30 meters high on the NE of Bou Naga. Apron of wind blown sand on north flank facing salt flats and linear dune belt.	Sample taken from in-filled gully on the crown of the ridge. Area virtually devoid of vegetation.
3A and 3B	19°07.465'N 13°07.700'W	Dune sand on low-lying half-buried/exhumed karstic limestone pavement. Sample location on southern side of ENE-trending dune belt.	Sample selected to provide a comparison. Dune sand contains wind-blown organic debris – possible cultural contamination from nearby bedouin settlements.

Issues

- Partial evolution in cell?
  - Sedimentation.

Radius (μm)	Fall speed (m.s^{-1})
700	9
355	6.4
173	3.2
85	1.9
45	0.64
22*	0.15
11	0.05
5.5	0.012
2.75	0.0025

  - Coagulation.
  - Wall loses.

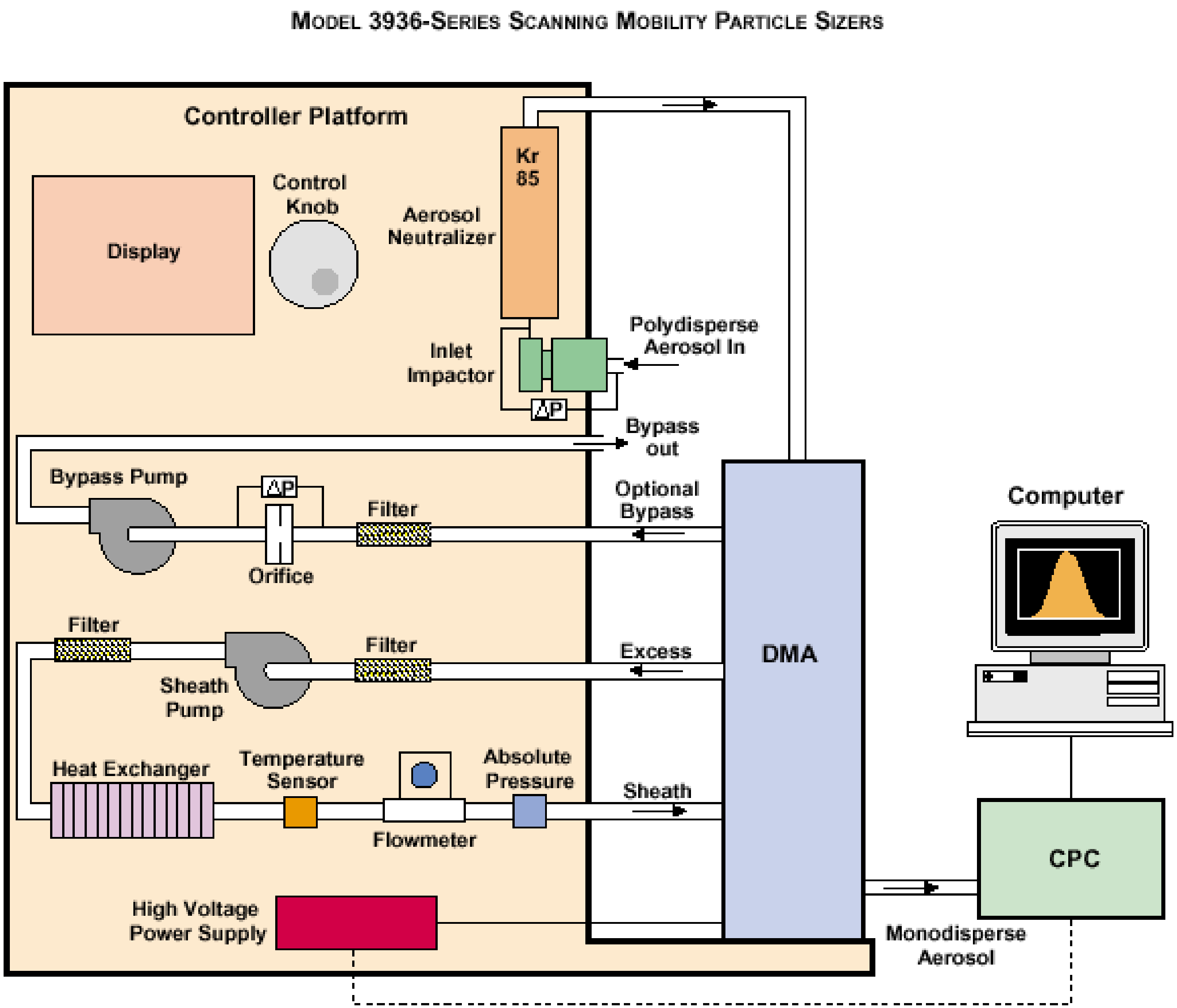
Issues

- Particle size measurements.
  - Sieves
    - Simple.
    - Coarse measurement resolution.
    - Smallest sieve around 20 μm (radii).
    - Could be used to select all particles less than 20 μm.

Issues

- Particle size measurements.
  - SMPS
    - In situ measurement.
    - Size range 0.001 μm to 1 μm.
    - Possibility of dialing a mono distribution, using the Differential Mobility Analyser (DMA).

Issues


Model 3936-Series Scanning Mobility Particle Sizers
Controller Platform
Display
Control Knob
Aerosol Neutralizer
Kr 85
Inlet Impactor
ΔP
Polydisperse Aerosol In
Bypass out
Bypass Pump
ΔP
Filter
Orifice
Optional Bypass
Filter
Sheath Pump
Filter
Excess
Heat Exchanger
Temperature Sensor
Absolute Pressure
Flowmeter
Sheath
High Voltage Power Supply
DMA
Computer
CPC
Monodisperse Aerosol

Issues

- Particle size measurements.
  - Aerodynamic Particle Sizer (APS).
    - In situ measurement.
    - Size range 0.5 μm to 20 μm

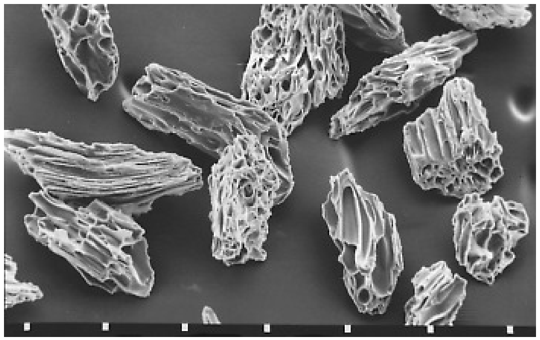
Issues

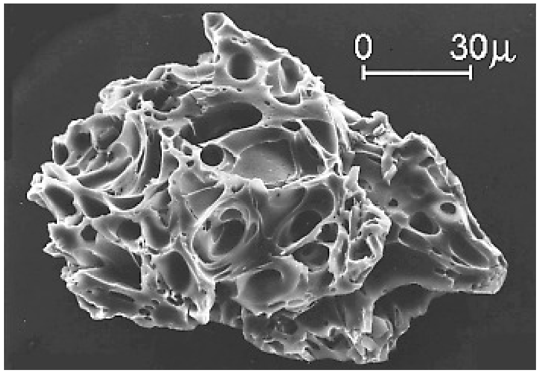
- Particle size measurements.
  - Electron microscope.
    - Would allow us to see what our samples size range is.
    - Will aid in selection of suitable measuring device.
    - Allows some discrimination of structure of particles.

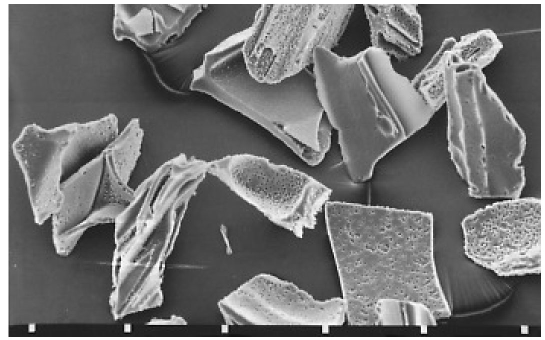
Issues

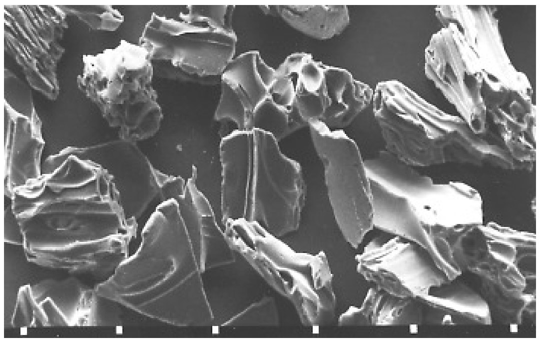
Issues

- Particle size measurements.
  - Electron microscope.









Issues

- Aerosol cell homogeneity.
  - Temperature.
  - Aerosol concentration in optically sampled range.
    - Localized laminar flow down center of cell from inlet to outlet has been seen in previous experments in the aerosol cell.
    - May need to modify inlet to create uniform aerosol in optically sampled region.

Some questions

- Particle size measurement.
  - We will probably need to size our sample first to obtain < 20 μm particles (by sieving).
  - If we chose the SMPS, their is a 1 to 20 μm “gap”.
  - If we chose the APS we have can not measure particles sizes under 1μm.
  - Need to ensure that we are measuring the particle radii.