Measurements of Microphysical and Optical Properties of Volcanic Ash

Anin Puthukkudy[a,b,*], Adriana Rocha Lima[b,c], W. Reed Espinosa[c], J. Vanderlei Martins[a,b], Lorraine Remer[a,b], Oleg Dubovik[d] & Peter Colarco[c]

[a]Department of Physics, University of Maryland Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250, USA.
[b]Joint Center for Earth Systems Technology, University of Maryland Baltimore County, 5523 Research Park DR, Baltimore, MD 21228, USA. [c]NASA Goddard Space Flight Center, Greenbelt, MD.
[d]Laboratoire d'Optique Atmosphérique, UMR8518, CNRS - Université de Lille 1, 59655, Villeneuve d'Ascq, France. *Presenting author (*aputhukkudy@umbc.edu*)

Volcanic Ash

- Volcanic ash has the potential to cause a variety of severe problems for human health and the environment
- Effective monitoring of the dispersion and fallout from volcanic ash clouds and characterization of the aerosol particle properties are essential for assessing the hazard and its effect on Earth's radiation budget
- One way to acquire information from volcanic ash clouds is through satellite remote sensing
- Size distribution, sphericity and optical properties of volcanic ash are often a pre-requisite for making accurate and quantitative retrievals
- The same kind of information is also needed for atmospheric transport models to properly simulate the dispersion and fallout of volcanic ash
- The micro-physical and optical properties vary significantly between eruptions, which can occur under very different conditions

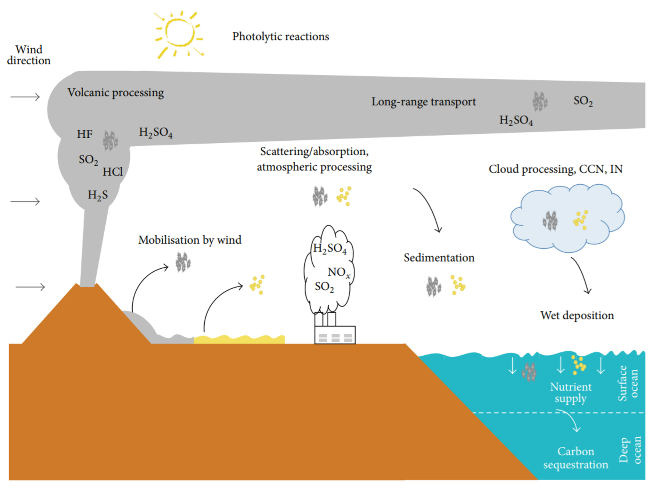

Figure 1: Schematic diagram showing the important environmental and climate effects of volcanic ash (in grey) and mineral dust (in yellow). (CCN: cloud condensation nuclei; IN: ice nuclei) [1]

Method

- Presented here is a laboratory method to determine the micro-physical and optical properties of volcanic ash samples collected from different volcanic eruptions with markedly different compositions
- Some samples are measured at different humidity levels (dry and wet conditions) to study the effect of humidity of the particles
- The technique uses a Fluidized bed Aerosol Generator to re-suspend ash particles that are then sampled by a CPC and polar nephelometer before being impacted on a Nucleopore Filter
- Using a reflectance measurement setup, mass absorption efficiency is measured[2]

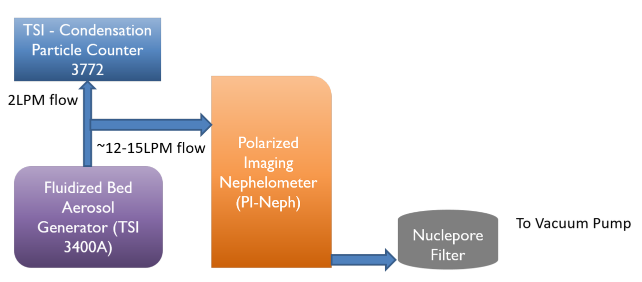

Figure 2: Schematic diagram of the experimental setup

PI-Neph(Polarized Imaging Nephelometer)

- The PI-Neph measures angular light scattering and polarization of the resuspended particles from 3° to 175° in scattering angle, with an angular resolution of one degree [3]
- The PI-Neph uses a three wavelength laser system, polarization optics, and a wide field of view imaging camera
- Measures P_{11} and P_{12} elements of the scattering matrix
- Size distribution, sphericity and the refractive index of the aerosol will be retrieved using the GRASP algorithm [4]
- Used in NASA aircraft campaigns - SEAC[4]RS[5], DC3, DEVOTE and DISCOVER-AQ

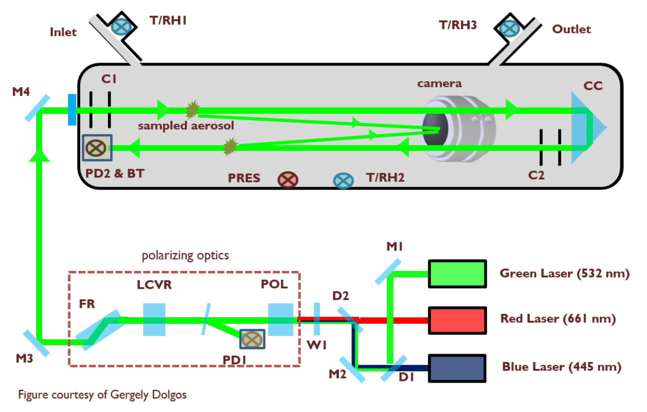

Figure 3: Polarized Imaging Nephelometer(PI-Neph)

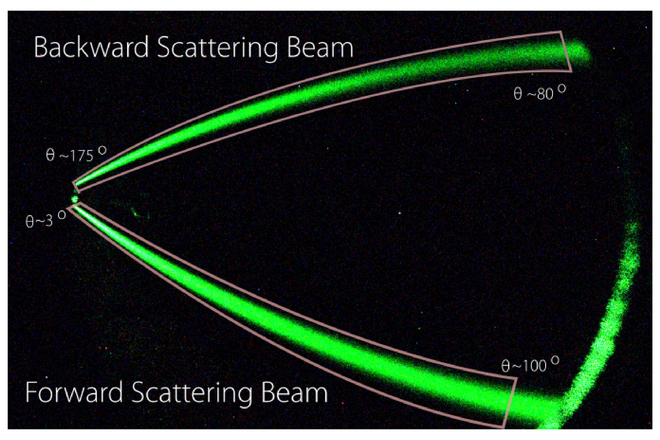

Figure 4: Forward and backward scattered light imaged using wide FOV camera

Result & Discussion

P_{11} and $-P_{12}/P_{11}$ of volcanic ash samples measured using PI-Neph and the retrieved PSD are plotted in this section. The list of ash samples includes:

- Novarupta(1912)
- Mt. Spurr (1992)
- Mt. Okmok (2008)
- Mt. St. Helens(1982)
- Mt. Eyjafjallajokull (2010)
- Mt. Pinatubo (1991)
- Volcán de Fuego (2012)

Mt. St. Helens and Mt. Eyjafjallajokull samples are measured at dry and wet condition by changing the humidity of the sample

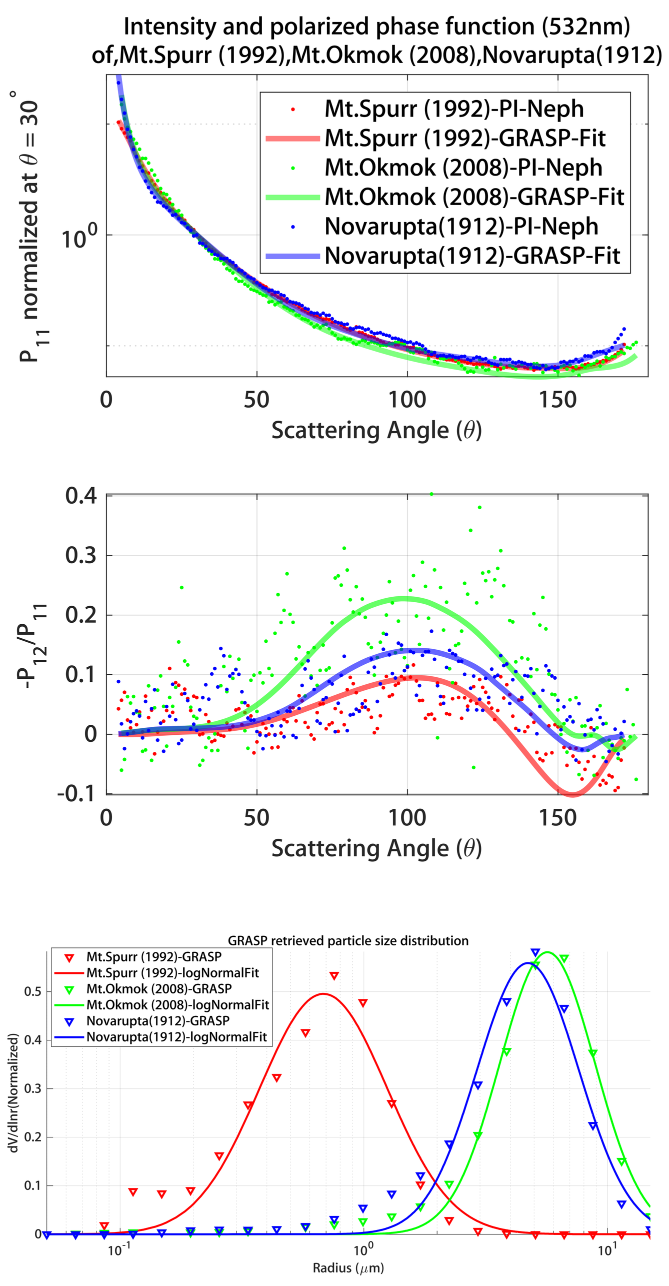

Figure 5: Mt. Spurr, Mt. Okmok and Novarupta ash measurement and retrieved PSD

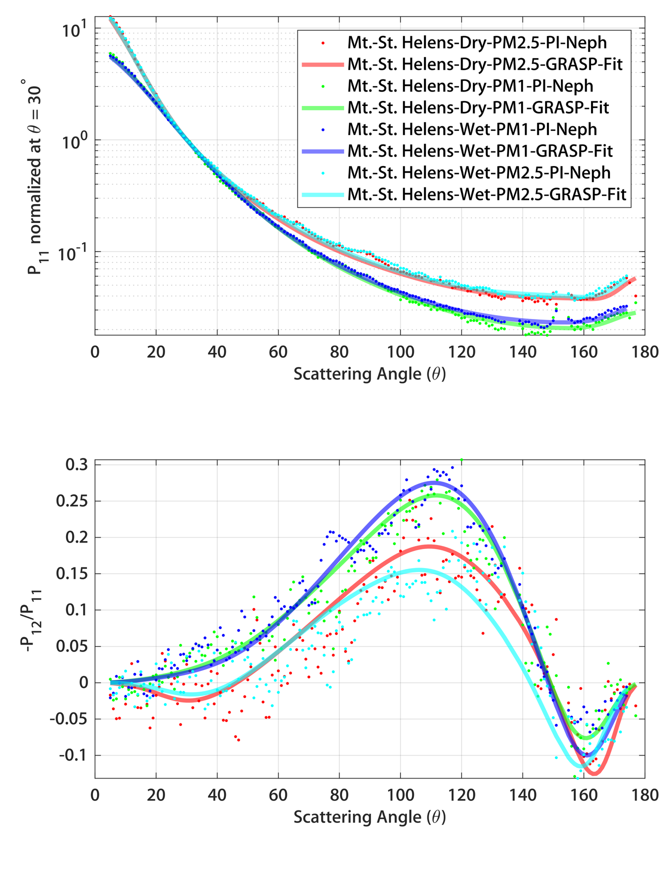

Figure 6: P_{11} and $-P_{12}/P_{11}$ of Mt. St. Helens' ash samples measured using PI-Neph. For this experiment, cyclone was used for separating PM1 and PM2.5 particles. Also, two humidity levels are used, RH<10 (Dry) and RH>40 (Wet) for the measurements

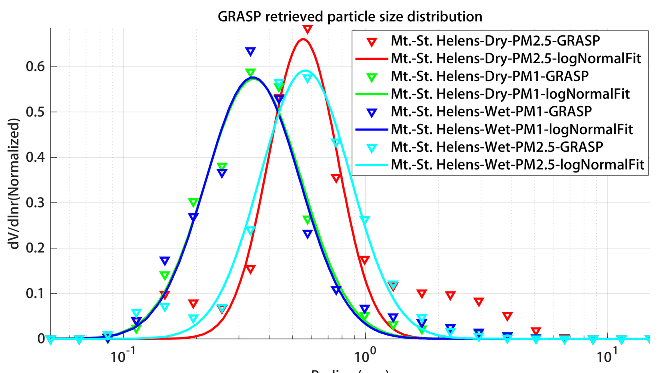

Figure 7: PSD retrieved using GRASP for the Mt. St. Helens ash samples with different humidity levels

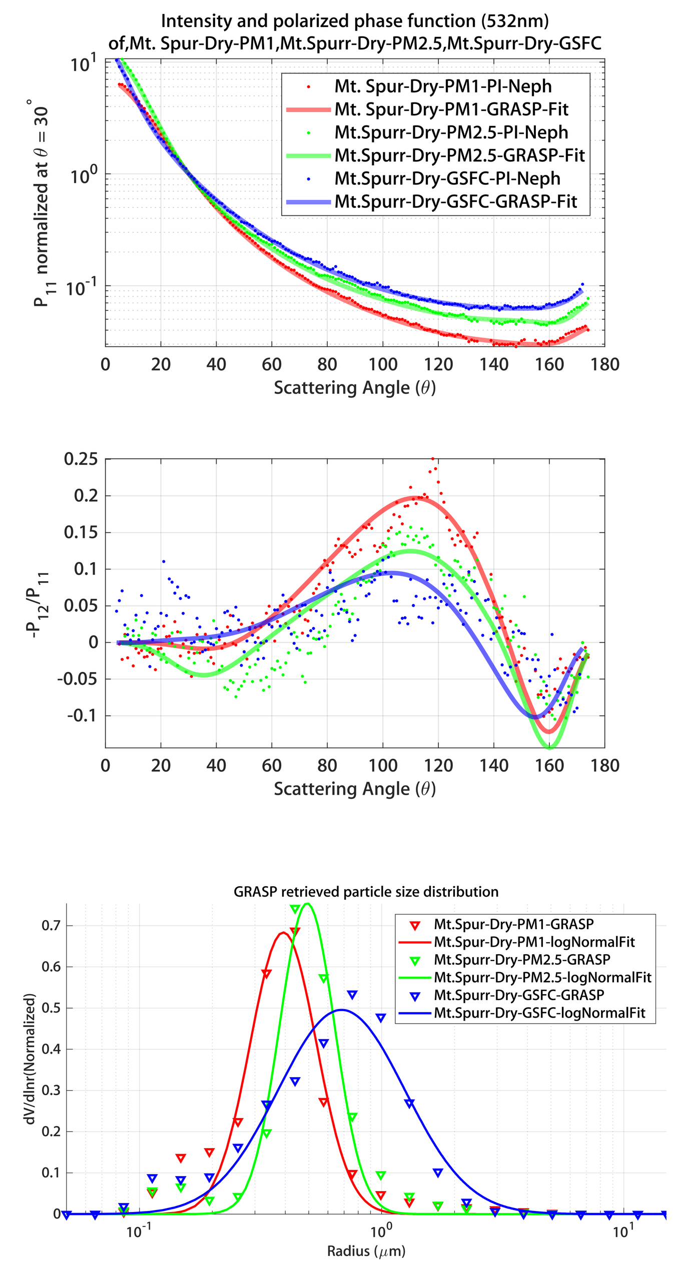

Figure 8: Mt. Spurr ash measured at different cut off limits (No cut off(Blue), PM1(Red), PM2.5(Green)

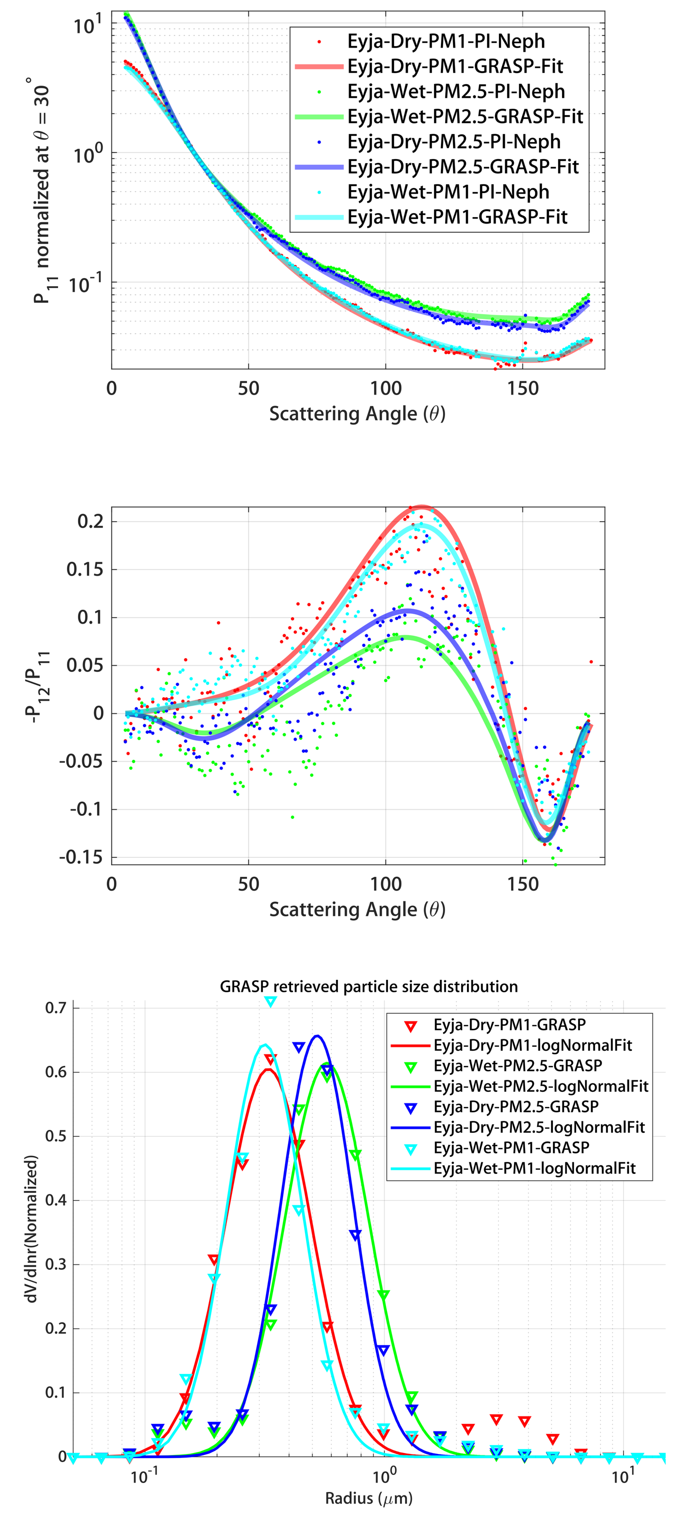

Figure 9: P_{11} and $-P_{12}/P_{11}$ of Mt. Eyjafjallajokull ash samples measured using PI-Neph. For this experiment, cyclone was used for separating PM1 and PM2.5 particles. Also, for each case two humidity levels are used RH<10(Dry) and RH>40 (Wet)

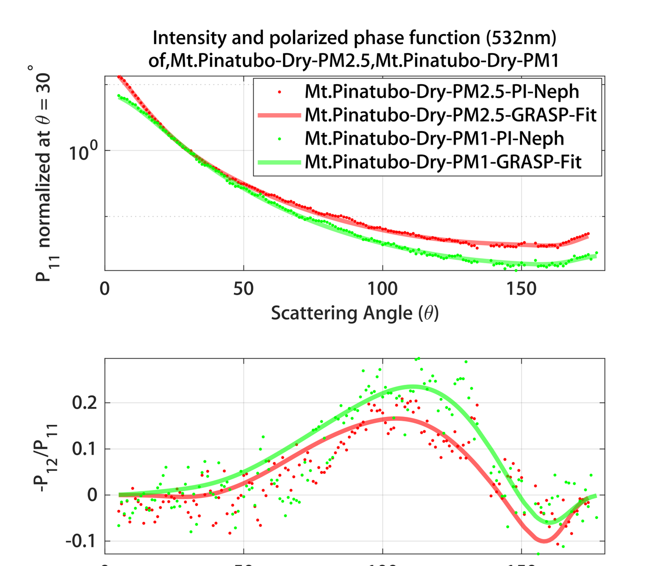

Figure 10: P_{11} and $-P_{12}/P_{11}$ of Mt. Pinatubo ash samples measured using PI-Neph. Dots are measurements and solid lines are GRASP fit

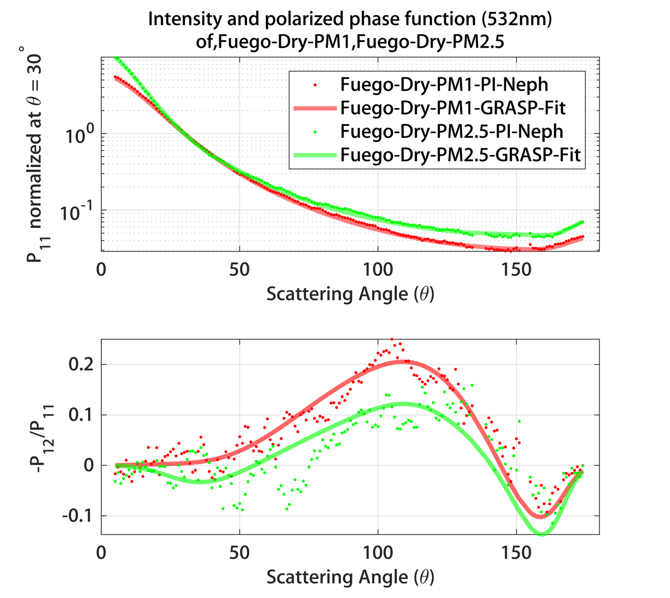

Figure 11: P_{11} and $-P_{12}/P_{11}$ of Volcán de Fuego ash samples measured using PI-Neph

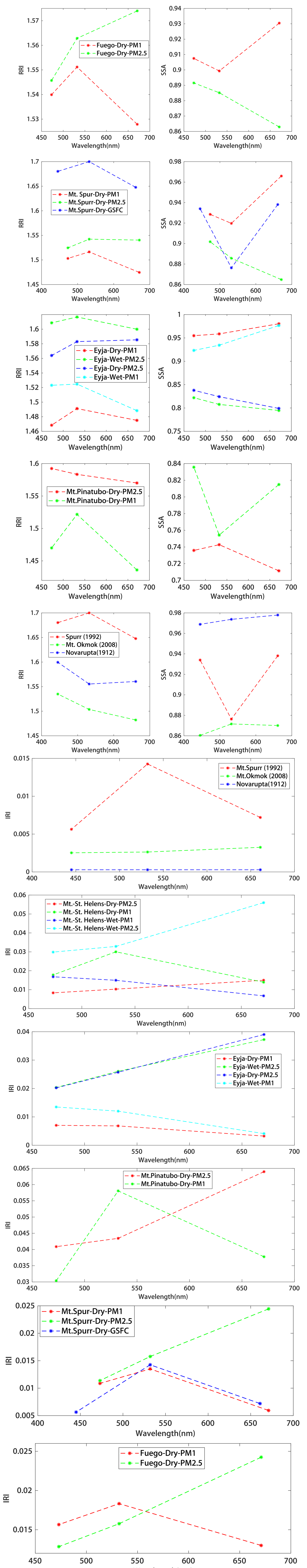

Figure 12: Retrieved real refractive index(RRI), imaginary refractive index(IRI) and Single scattering albedo (SSA) for different samples

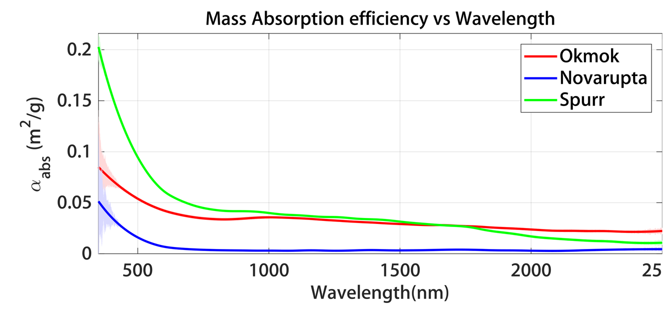

Figure 13: Mass absorption efficiency α_{abs} of the volcanic ash samples measured using a reflectance measurement setup mentioned in technique described by Rocha-lima et. al 2014[6]

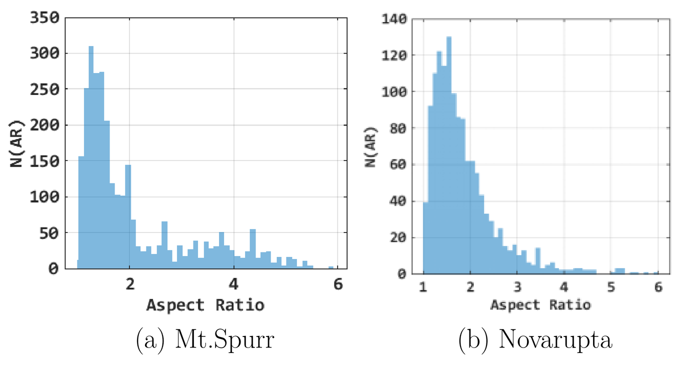

Figure 14: Particle shape distribution derived using ImageJ and 2D SEM images of ash samples collected on a Nuclepore filer

Preliminary Observations

- The imaginary part of refractive index retrieved using GRASP for three Alaskan volcanic ash samples are consistent with the mass absorption efficiency spectrum measured using particles collected on a filter and a reflectance measurement setup
- Mt.Spurr ash have much smaller particles than the Mt. Okmok and Novarupta ash
- Highly non-spherical particles, sphere fraction ≈ 0
- Minimal spectral dependence in the visible region for P_{11} and $-P_{12}/P_{11}$
- In the near UV wavelengths ash absorption decreases monotonically with wavelength

Future Research

- Derive particle size and shape distribution using SEM images and ImageJ software
- Measure the chemical composition of ash sample using Energy-dispersive X-ray spectroscopy to find its relationship with micro-physical and optical properties of volcanic ash
- Asses the assumptions in satellite retrieval algorithms and improve the accuracy of quantitative estimates of the ash mass loading and other properties using the micro-physical and optical properties derived from this study

Acknowledgement

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Some of the ash samples were measured during STEAR lab experiment

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