Application of laboratory thermal infrared emissivity data to the study of opaque volcanic ash plumes *(V23I-0318)*

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Introduction

The extraction of compositional and particle size information from the opaque region of a volcanic plume is challenging, requiring the use of novel methods. Traditional approaches of ash cloud detection using thermal infrared (TIR) data fail in this region because of their dependency on upwelling ground radiance through a transparent plume [1]. However, the potential exists to collect this information using laboratory-derived TIR emissivity spectra coupled with a linear deconvolution spectral model, thus essentially treating the plume top as a solid emitting surface [2]. To unmix the image data successfully, an appropriate end-member library is required. The ASTER Volcanic Ash Library (AVAL), an ever-expanding library of different volcanic ash types ranging from basaltic-andesite to rhyolite in composition, was created for this purpose [3]. Ash samples were separated into 6 size fractions, each serving as different spectral end-member for the model. This library has been used to model TIR data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) of several global volcanic targets.

The ASTER Volcanic Ash Library (AVAL)

- The samples come from several volcanoes with different petrologic characteristics
- Ash samples collected shortly after eruption
- Crushed Mono-Inyo Domes obsidian serves as the pure glass, high SiO_2 end-member
- Samples are then sub-divided into six particle size fractions: > 150, 63 – 150, 45 – 63, 25 – 45, 8 – 25 and < 8 µm
- Particles < 63 µm have unique spectral features caused by photon diffraction and scattering
- < 45 µm fractions are separated using a Micro-Orifice Uniform Deposit Impactor (MOUDI) [4]
- Emissivity spectra are obtained from a Nexus Nicolet 670 FTIR spectrometer using the two-temperature method [5]
- Library is undergoing expansion to include samples currently not represented

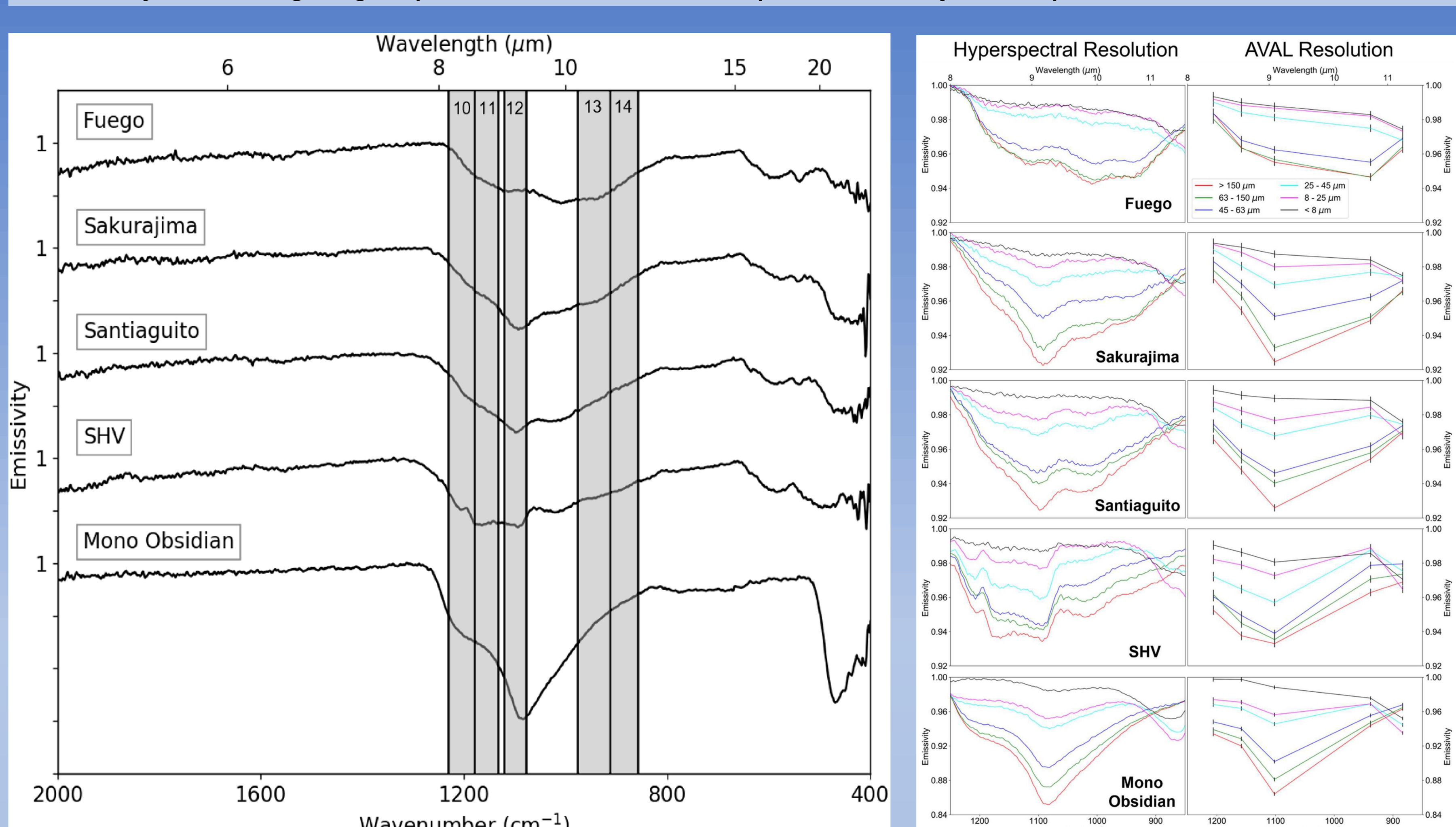

Figure 1 – Laboratory spectra of the first phase of AVAL. Spectra are acquired using a Nicolet Nexus 670 FTIR Spectrometer. Spectra are then resolved to the five-channel ASTER TIR spectral resolution. At this resolution, diagnostic spectral features are still evident. **Left**; The largest particle size fraction (> 150 µm) with the 5 ASTER TIR bands (10-14) overlain; each tick mark represents an emissivity of 0.05, **Right**; Full spectral suite subsampled to 8 – 12 µm and resampled to ASTER (error bars denote NEΔε of the FTIR for each band). Each sample is separated into six size fractions to account for spectral features that occur in particles < 63 µm.

Retrieval of Ash Cloud Properties

- AVAL spectra are used as the end-member library for linear spectral deconvolution [6]
- ASTER AST_05 emissivity product is used, which is the atmospherically corrected AST_09T product processed through the Temperature Emissivity Separation Algorithm (TES [7])
- The mixed spectrum in each pixel is proportional to areal percentage of each end-member
- Per-pixel root mean square (RMS) error is calculated to determine the "goodness of fit"
- Additional temperature and spectral data are used to remove erroneous pixels (Fig. 2)

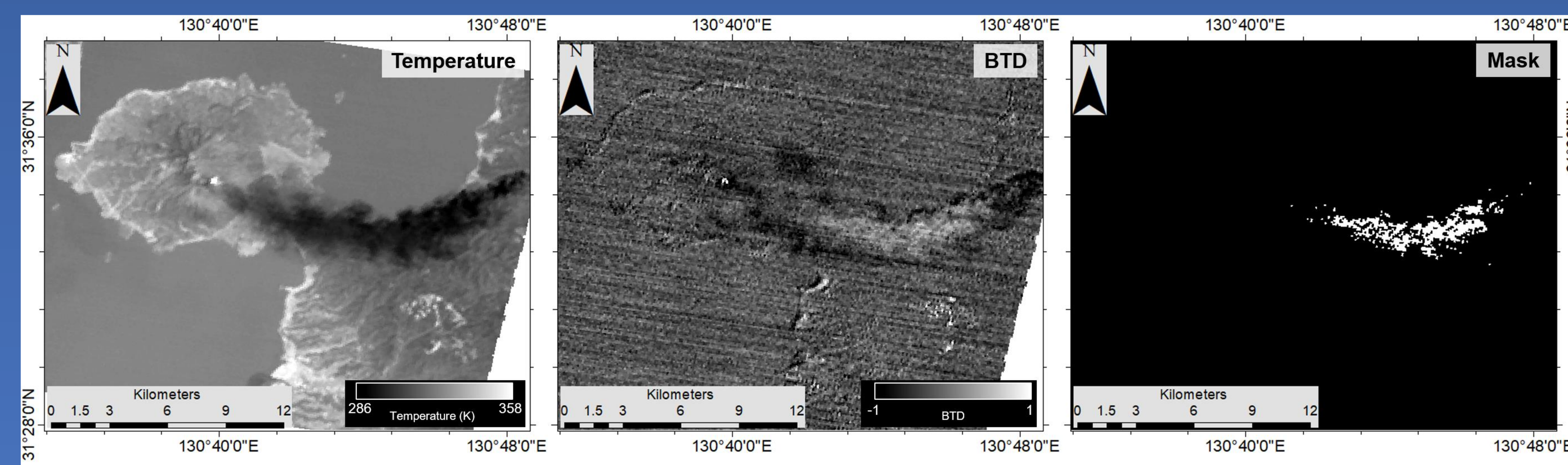

Figure 2 – ASTER data is masked to extract the plume bearing pixels from the image. Firstly, temperature transects are used to define a threshold that denotes that an opaque plume is present. Secondly, a Brightness Temperature Difference (BTD) image is produced by subtracting ASTER channel 13 from 14. Where ash is presented and transmissive, these values will be negative [8]. Those pixels that are below the temperature threshold and have a BTD > 0 are extracted for analysis.

Results

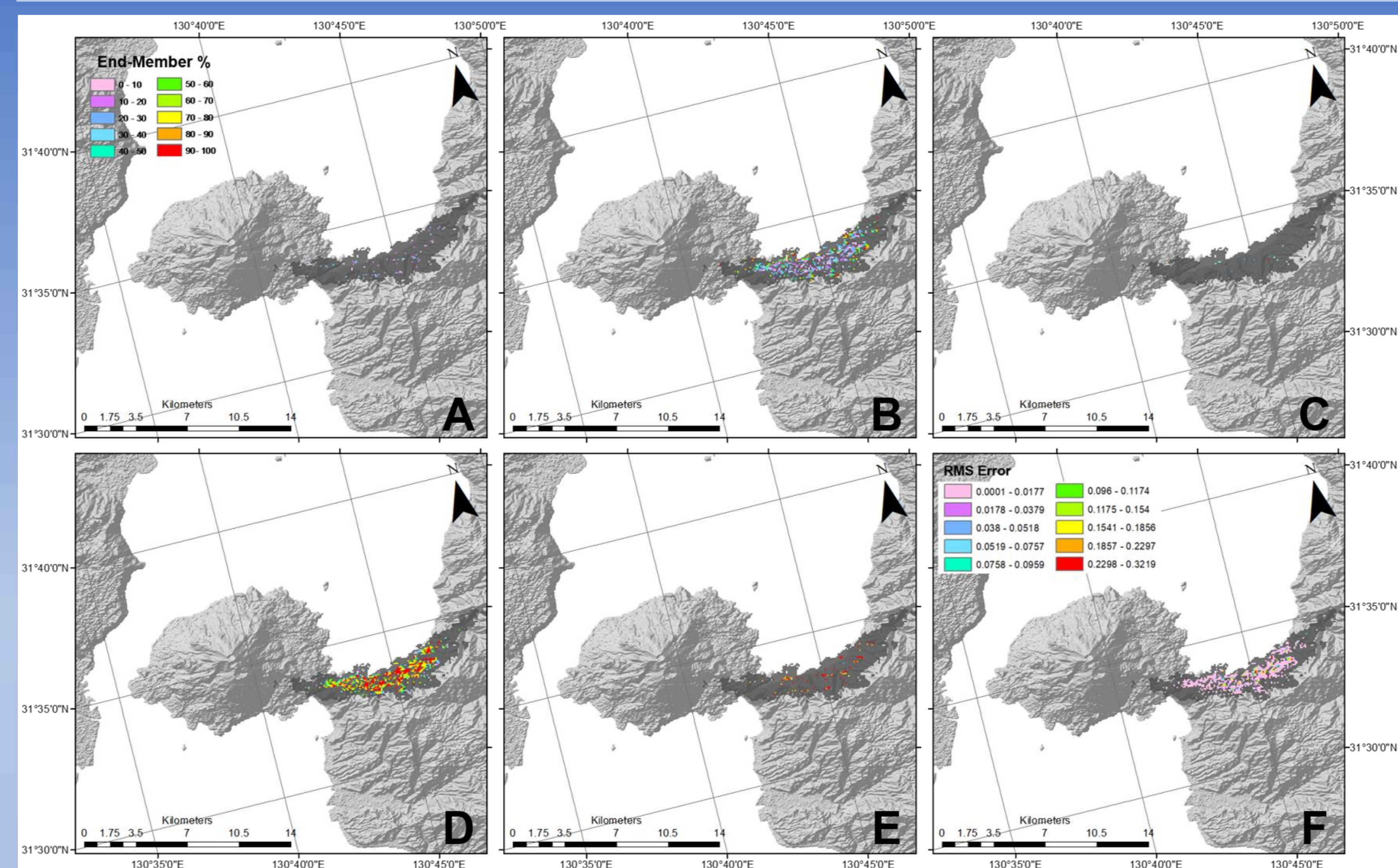

Figure 3 – Data retrieved from Sakurajima volcano, captured by ASTER on 29 April 2010 and overlain on a shaded relief image. These results are using the AVAL Sakurajima end-member. The darker region is the approximate area of the plume based upon the temperature and is shown for retrieved pixel clarity. A) 63 - 150 µm end-member; B) 8 - 25 µm end-member; C) < 8 µm end-member; D) 8 - 25 µm end-member; E) < 8 µm end-member; F) RMS Error. Average error for this retrieval is **2.02%**.

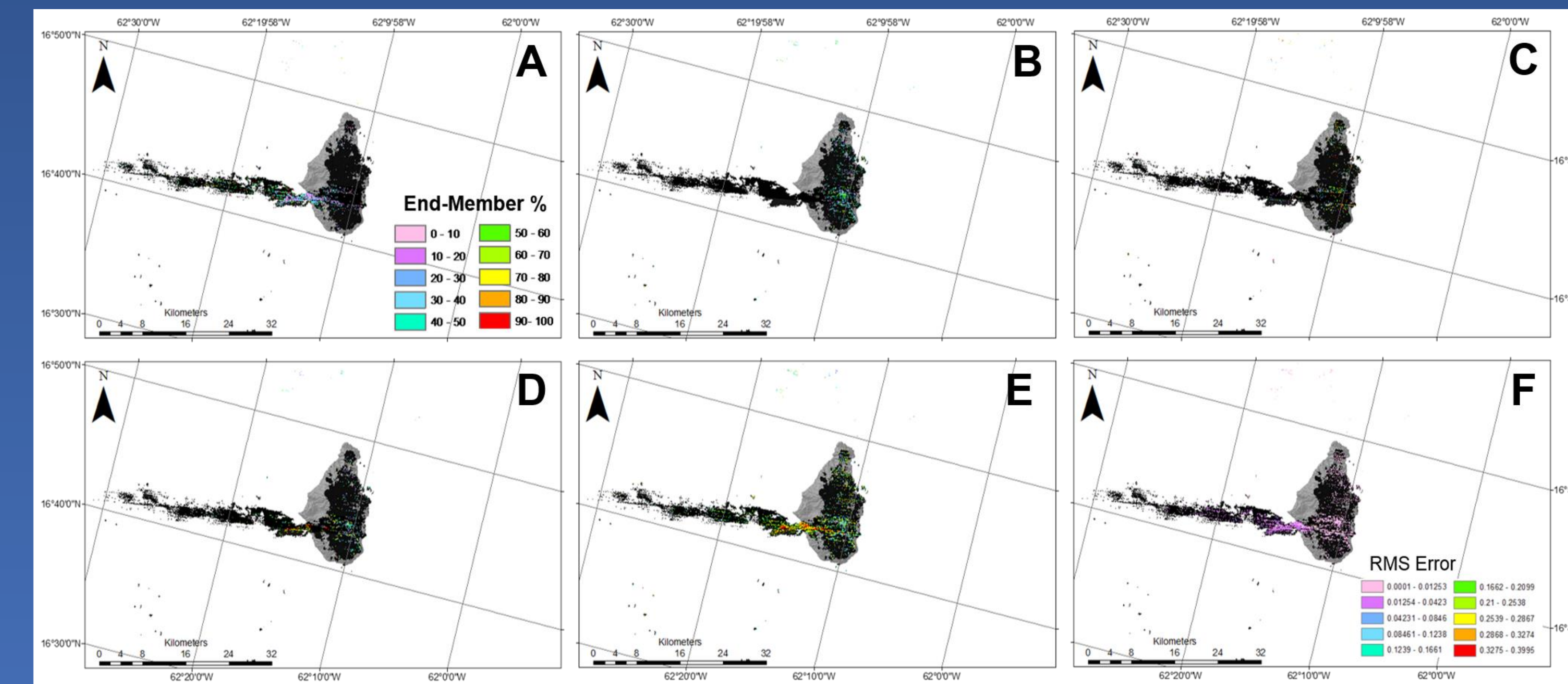

Figure 4 – Data retrieved from Soufrière Hills Volcano (SHV) volcano, captured by ASTER on 2 December 2006. These results are using the AVAL SHV end-member. The darker region is the approximate area of the plume based upon the temperature and is shown for retrieved pixel clarity. A) 63 - 150 µm end-member; B) 8 - 25 µm end-member; C) < 8 µm end-member; D) 8 - 25 µm end-member; E) < 8 µm end-member; F) RMS Error. Average error for this retrieval is **1.97%**.

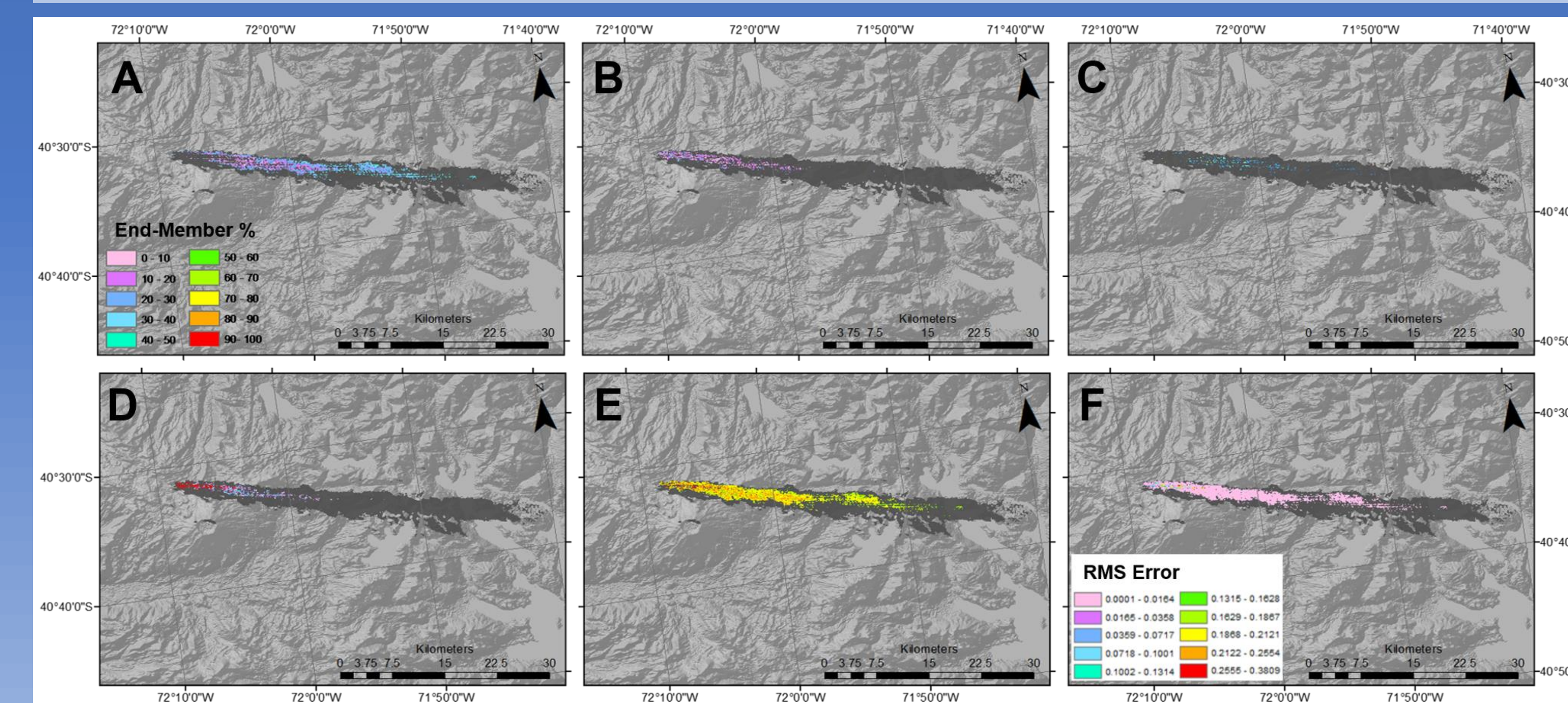

Figure 5 – Data retrieved from Puyehue-Cordón Caulle, captured by ASTER on 13 February 2012. These results are using the crushed Mono-Inyo Domes obsidian end-member. The darker region is the approximate area of the plume based upon the temperature and is shown for retrieved pixel clarity. A) 63 - 150 µm end-member; B) 8 - 25 µm end-member; C) < 8 µm end-member; D) 8 - 25 µm end-member; E) < 8 µm end-member; F) RMS Error. Average error for this retrieval is **1.07%**.

Conclusions

- This work has demonstrated that opaque volcanic ash plumes can be mapped using orbital multispectral TIR data combined with AVAL and a linear deconvolution approach
- Samples collected from the volcanoes and analyzed here provide the best fit end-members, whereas the high SiO_2 glass was a good fit for the Puyehue-Cordón Caulle plume
- Particle size variations are also detectable using this method
- AVAL requires expansion, with basaltic and rhyo-dacitic end-members needed
- We plan to expand this methodology to other satellite sensors at higher temporal (GOES) and spectral (AIRS) resolution
- Furthermore, the opportunity exists to use this method operationally with the ASTER Urgent Request Protocol (URP; [9]) and with future TIR data as part of the NASA Decadal Survey planning.

References

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