Multiscale analysis of ash- and water-rich volcanic plumes using linear spectral deconvolution modeling *(V35E-0181)*

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1. Introduction

Analysis of the opaque region of volcanic ash plumes has recently been demonstrated using spectral linear deconvolution modeling [1] of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) thermal infrared (TIR) data to quantify ash composition and particle size [2,3]. This allows these properties to be estimated in a region that otherwise cannot be studied from transmission-based ash retrieval algorithms [e.g., 3]. Here, we expand this analysis by - **1.** Incorporating the TIR spectrum of water ice to quantify its areal percentage, and **2.** Analyze high temporal/low spatial resolution TIR data from the Advanced Baseline Imager (ABI) onboard the Geostationary Operational Environmental Satellite (GOES) using this technique. We present results from two recent eruptions, Nishinoshima, Japan (2020) and La Soufrière, St Vincent (2021), which were analyzed with ASTER and GOES data respectively.

2. Ash and Water Ice TIR Spectra

- The ASTER Volcanic Ash Library (AVAL) is used, a spectral library of ash samples with different petrologic compositions, which are divided up into distinct particle size fractions [3]
- Emissivity spectra are obtained from a Nexus Nicolet 670 FTIR spectrometer using the two-temperature method [4]
- Laboratory measurements are resampled to ASTER/GOES ABI spectral resolutions
- Water ice spectrum [5] was further added to the library and resampled

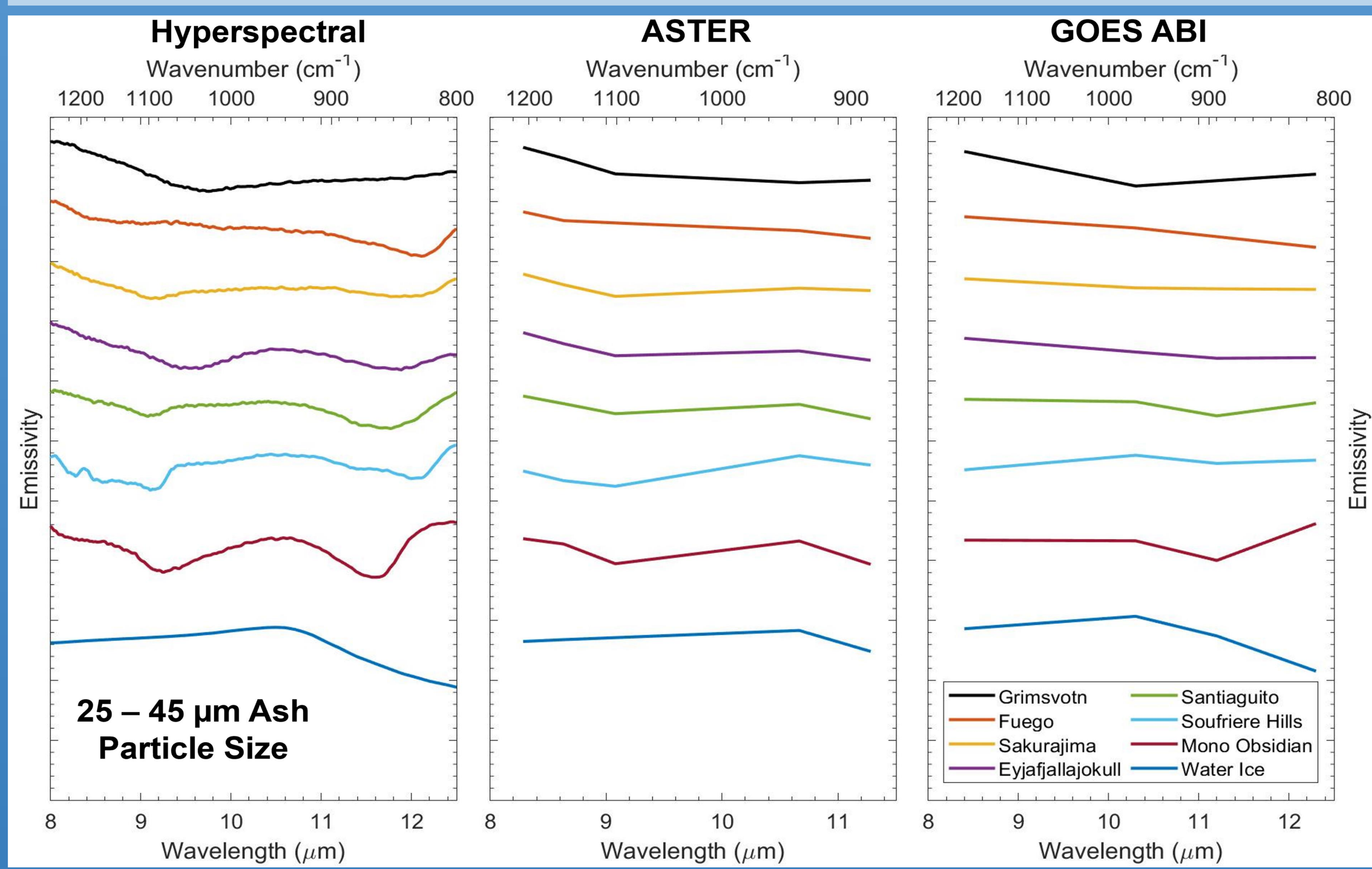

Figure 1. Example spectra from AVAL and water ice resampled to ASTER and GOES resolutions. Even after resampling, diagnostic spectral features are present. Major ticks = 0.05 emissivity.

3. Ash Retrieval Model

- Spectra are used as the end-member library for linear spectral deconvolution [1]
- The mixed pixel spectrum is proportional to areal percentage of each end-member
- Per-pixel root mean square (RMS) error is calculated to determine the "goodness of fit"
- ASTER AST_05 emissivity product is used - AST_09T product processed through the Temperature Emissivity Separation Algorithm (TES, [6])
- ABI data are processed using a modified version of TES to create analogous data products
- Optical Depth (OD) is used to determine opacity [7], calculated by:

$$OD = -\ln\left[1 - \frac{R_s - R_m}{R_s - B_a}\right]$$

where, R_s = ~11 µm surface radiance, R_m = ~11µm per-pixel radiance, B_a = plume top Planck radiance, estimated using Volcano Ash Advisory Center (VAAC) plume height estimates, coupled with local radiosonde temperature data

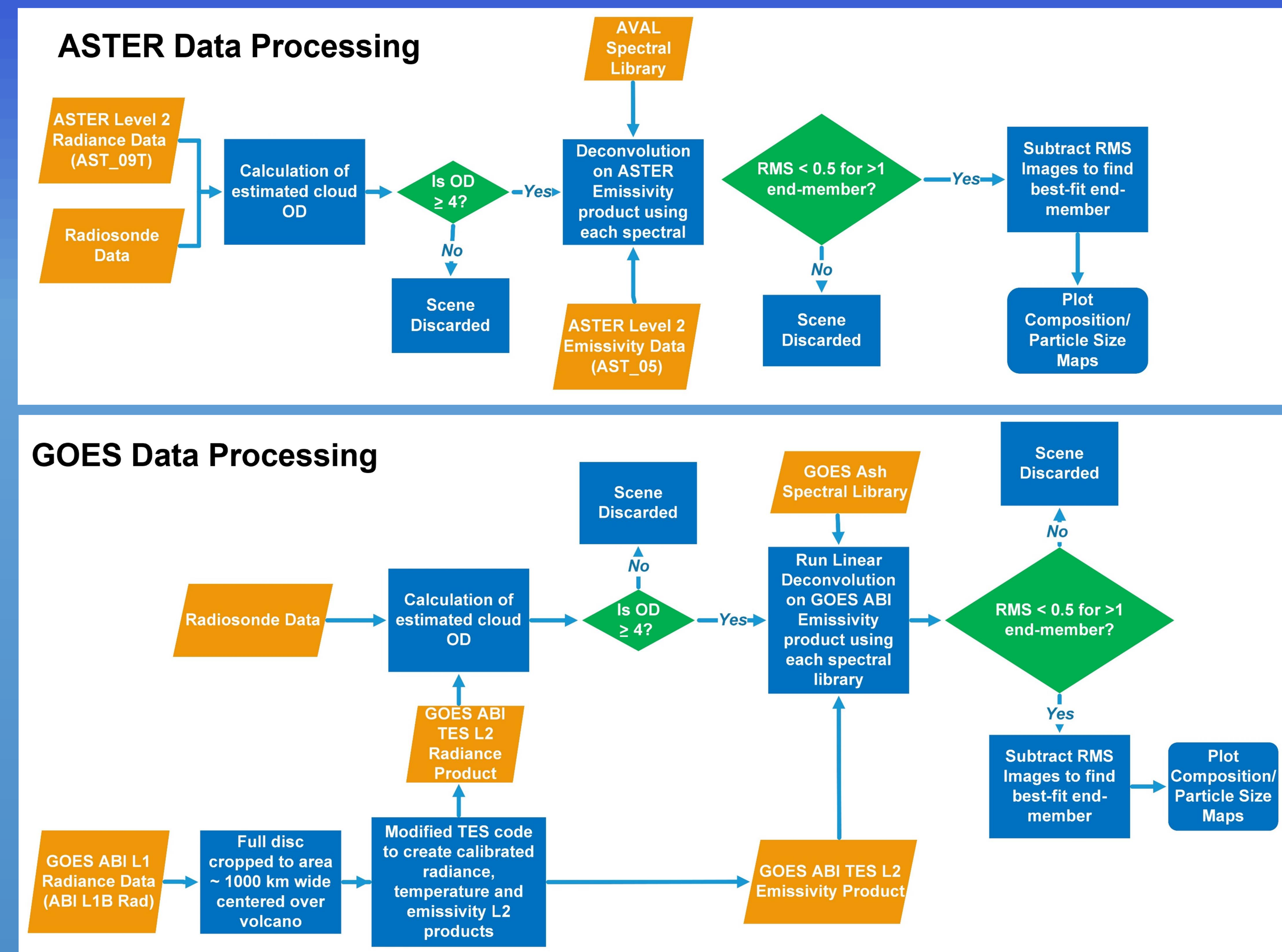

Figure 2. Processing needed to retrieve volcanic ash properties using the linear deconvolution model [3]. Optical depth is estimated to determine which pixels are opaque (OD ≥ 4), from which the images are masked to isolate opaque plume-bearing pixels only.

4. ASTER Results – Nishinoshima, Japan

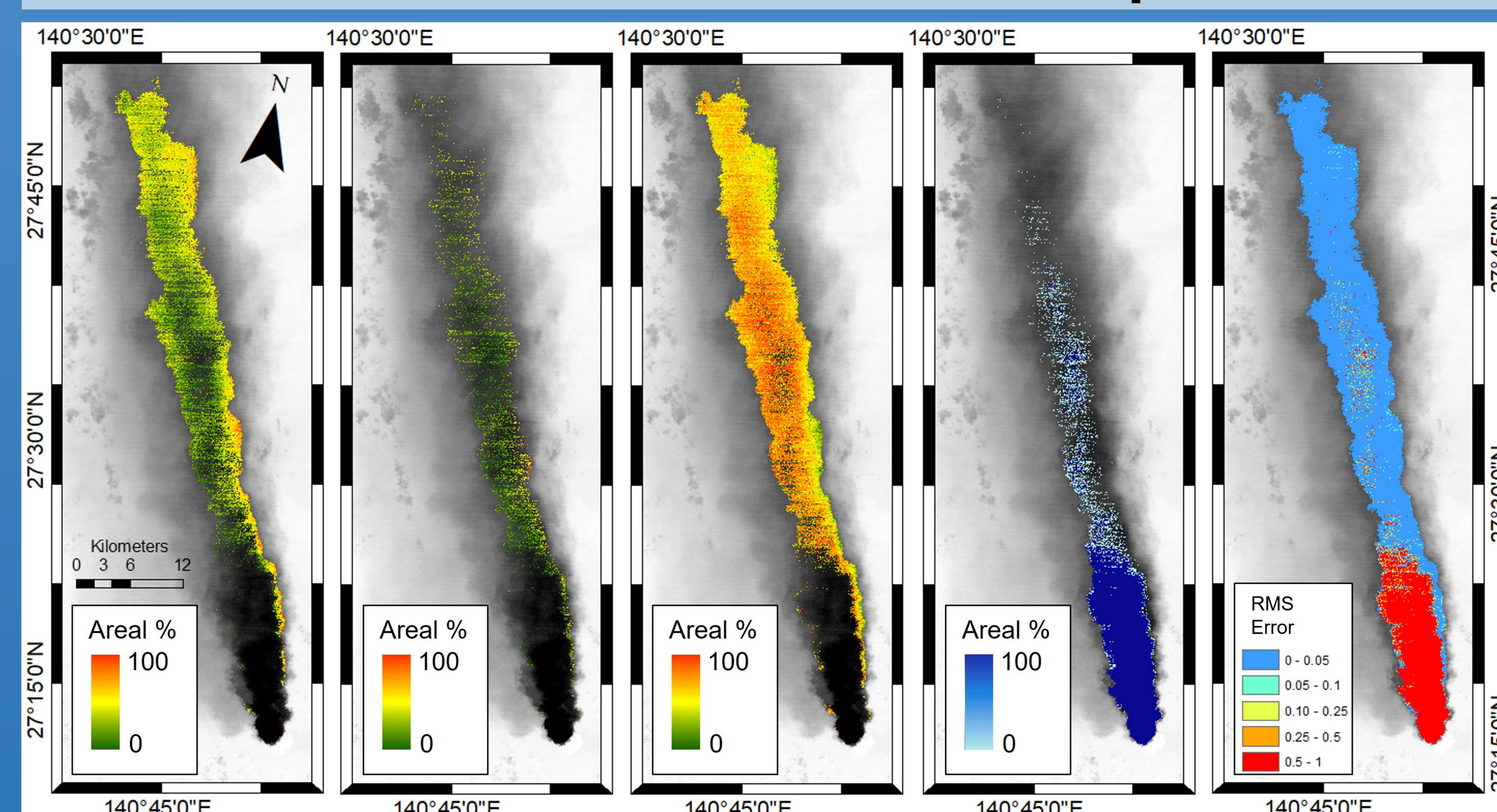

Figure 3. Linear unmixing results of ASTER TIR data obtained of Nishinoshima volcano, 8 July 2020, overlain on band 13 radiance data. Results were obtained using the AVAL Sakurajima end-member, showing the 4 most dominant end-members. **A)** 63 – 150 µm; **B)** 45 – 63 µm; **C)** < 8 µm; **D)** < 8 µm; **E)** RMS errors, showing that errors decrease with distance downwind. Fine particles dominate the retrieval, with increasing coarse particles found downwind of the volcano. Water Ice is dominant closer to the vent, although this is associated initially with much higher RMS errors.

5. GOES Results – La Soufrière, St. Vincent

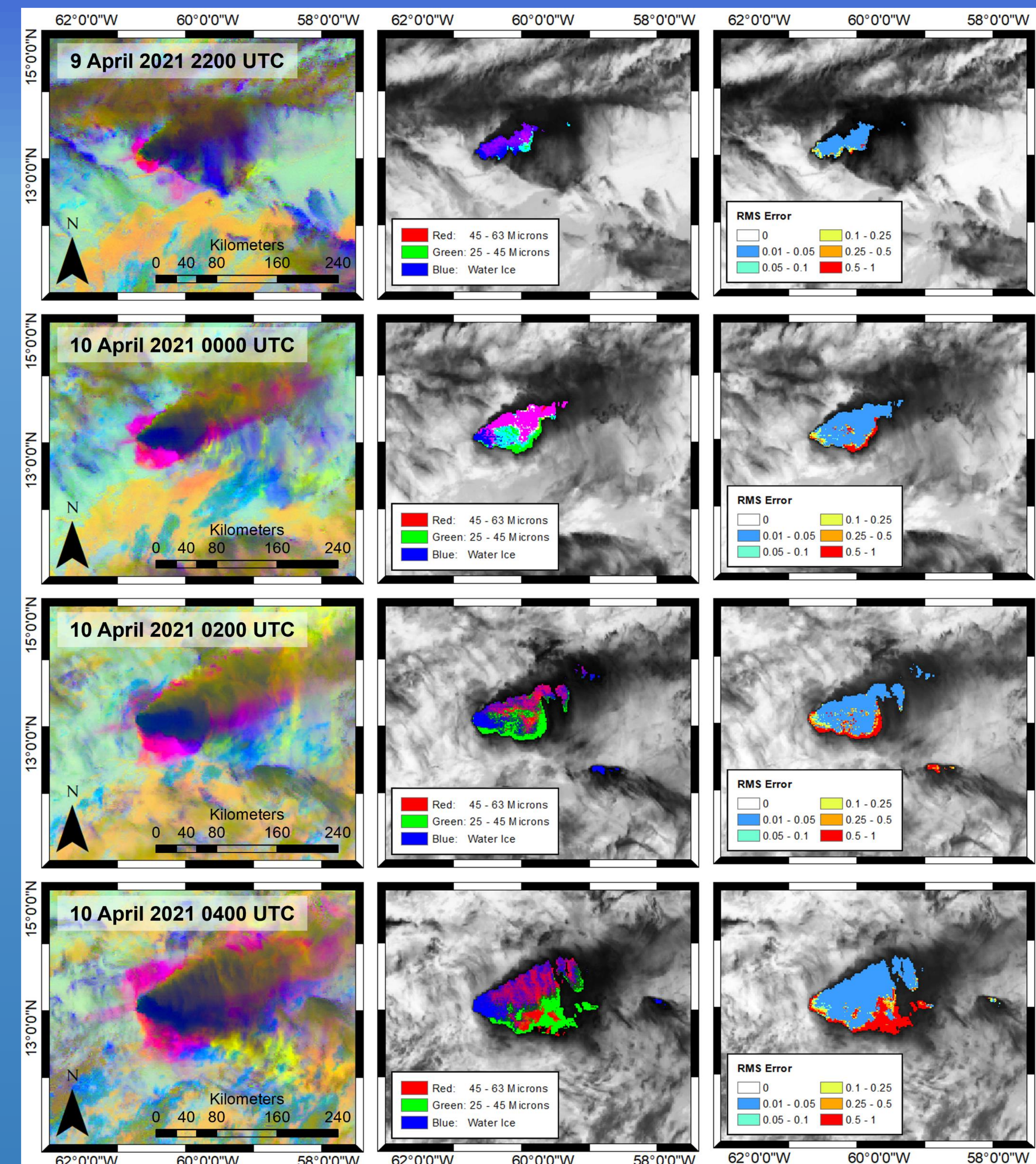

Figure 4. Data retrieved from La Soufrière captured by GOES ABI on 9 and 10 April 2021. Data have been sampled at 2-hour intervals. **Left Column** – Decorrelation stretches performed on L2 radiance images created using ABI Bands 15, 14 and 11, red = ash, yellow = ash/SO_2, blue = water vapor/ice. **Center Column** - Results obtained using the AVAL Fuego end-member overlain on band 14 radiance data, showing the 3 most dominant end-members. Composition and particle size appeared stable given the short duration analyzed. **Right Column** – RMS errors for each scene. For the dense core of the plume, errors are < 0.1, indicating a good fit of the lab spectra to the data.

6. Conclusions

- This work has shown the applicability of linear deconvolution modelling to mapping opaque volcanic ash plumes from orbital multispectral TIR data at different spatial scales
- GOES data of larger eruptions contain enough opaque ash pixels to use this technique
- The inclusion of water ice with the AVAL spectral suite has shown promise, with lower altitude clouds containing less ice than high altitude clouds
- The opportunity exists to use this method operationally with future TIR sensors

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