

Volcanic ash and SO₂ retrievals using multispectral satellite sensors in the thermal infrared spectral range: error assessment and perspectives

S. Corradini⁽¹⁾, L. Merucci⁽¹⁾, W. Di Nicolantonio⁽²⁾, A. Cacciari⁽²⁾

⁽¹⁾ INGV, Rome – Italy
⁽²⁾ CGS-OHB, Bologna, Italy

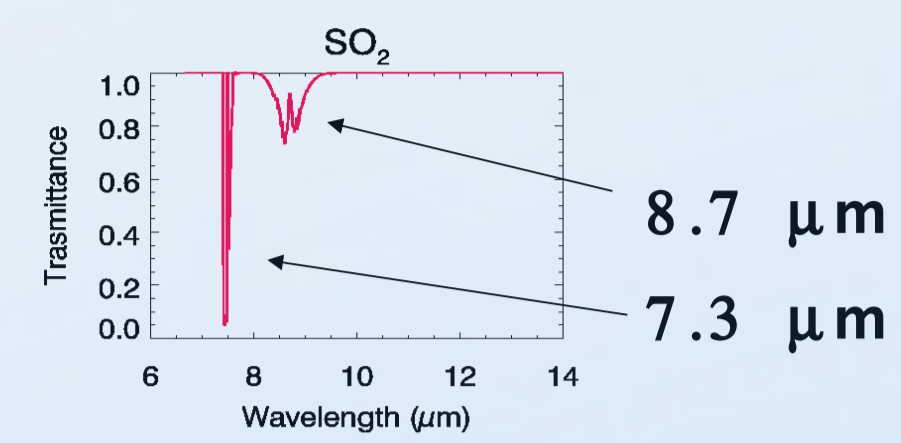


November 18-20, 2013
 Geneva, Switzerland

SATELLITE INSTRUMENTS

The Spinning Enhanced Visible and Infrared Imager (**SEVIRI**) and the Moderate Resolution Imaging Spectroradiometer (**MODIS**) are satellite multispectral imaging radiometers. SEVIRI, aboard the geostationary platform EUMETSAT-MSG, provides an image every 15 minutes in 12 channels from VIS to TIR. MODIS, on board the polar satellites NASA-Terra and NASA-Aqua, collect data on a specific area at each overpass in 36 channels from VIS to TIR. Both instruments have the IR bands needed for the volcanic ash (11 and 12µm) and SO₂ (7.3 and 8.7µm) retrievals.

SO₂ & ASH RETRIEVALS DESCRIPTION



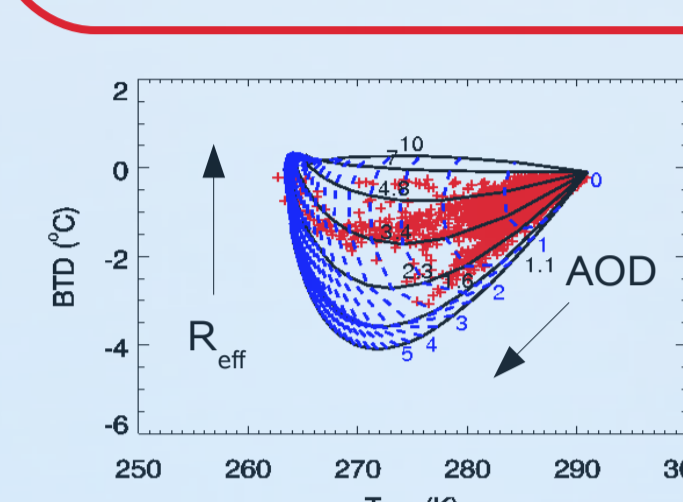
The SO₂ columnar abundance is computed using a weighted least squares fit procedure [Realmlou et al., 1994]:

$$\chi^2_{cs} = \sum_{i=1}^n \left[\frac{R_{s,i} - R_{m,i}(c_s, 0, 0)}{R_{s,i}} \right]^2 w_i$$

The ash detection is based on Brightness Temperature Difference algorithm applied on 11 and 12µm channels [Prata, 1989].

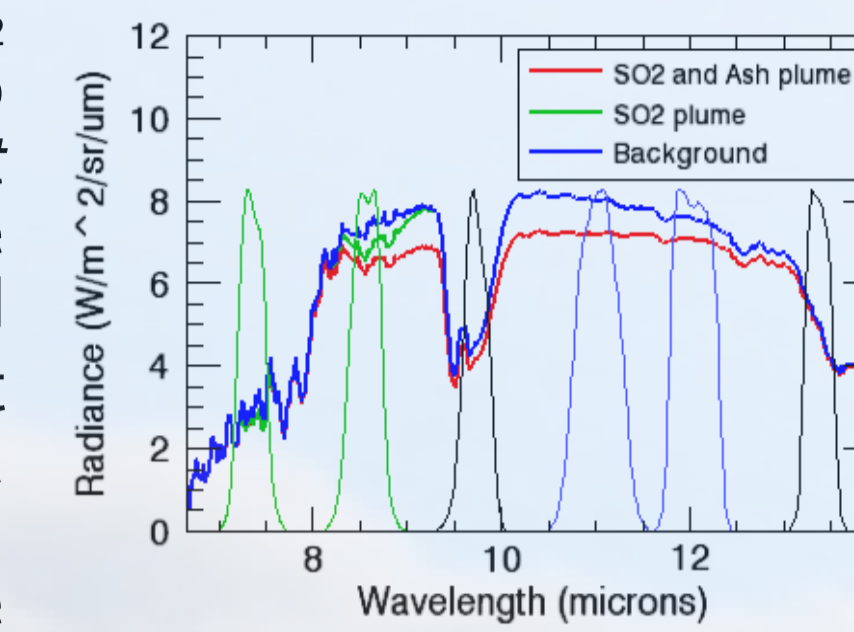
The retrieval is based on computing the simulated inverted arches curves "BTD-T_s(11µm)" varying the AOD and the particles effective radius [Wen and Rose, 1994]

The TOA simulated Radiances (R_m), needed for the SO₂ and ash retrievals, are computed using MODTRAN 4 RTM



ASH CORRECTION

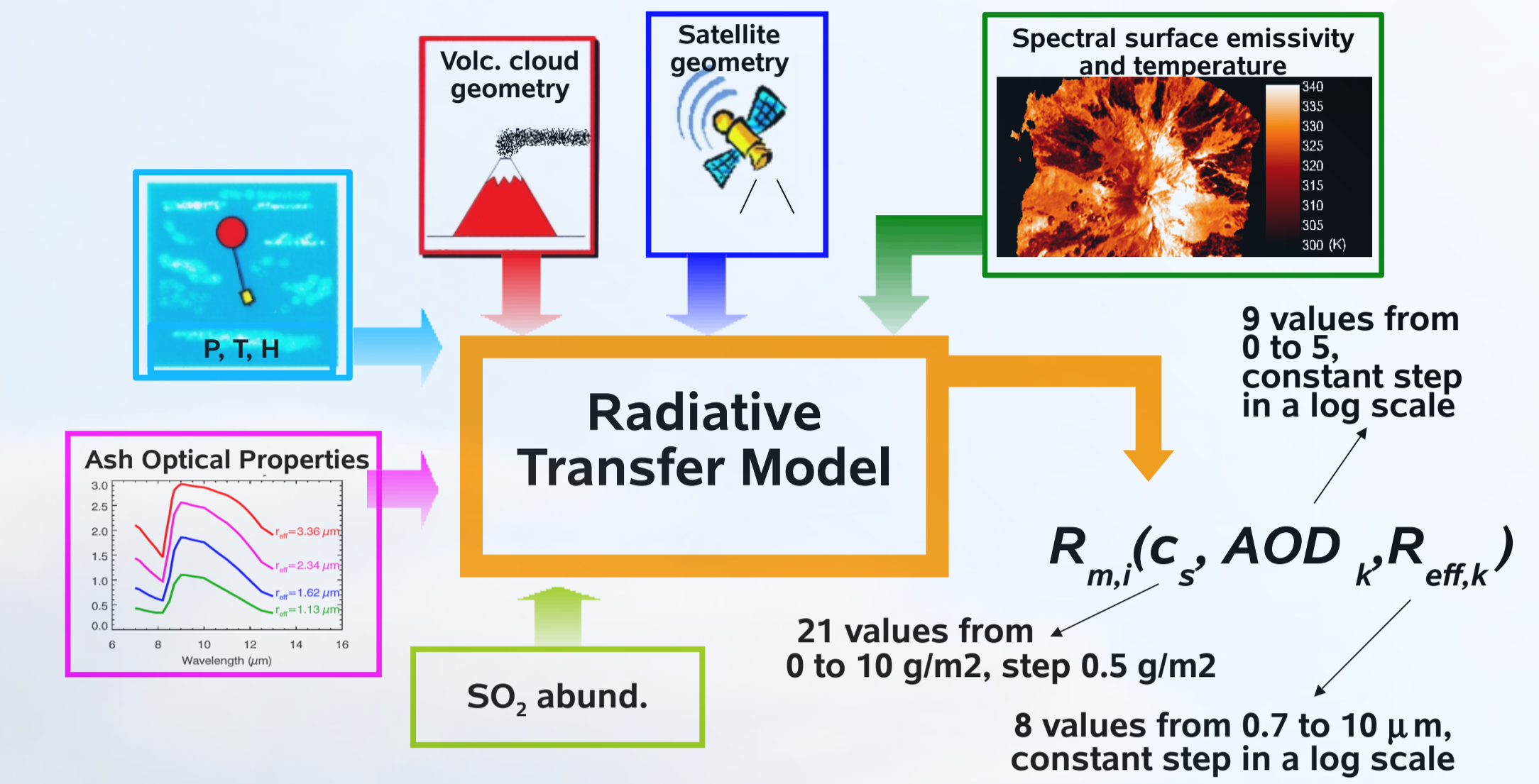
The ash correction is needed to avoid the 7.3 and 8.7µm SO₂ retrieval overestimation due to the ash presence [Corradini et al., 2009]. For each image pixel, containing both SO₂ and ash, the least square fit procedure is applied with a simulated radiance interpolated using the AOD and the effective radius computed from the pixel itself.



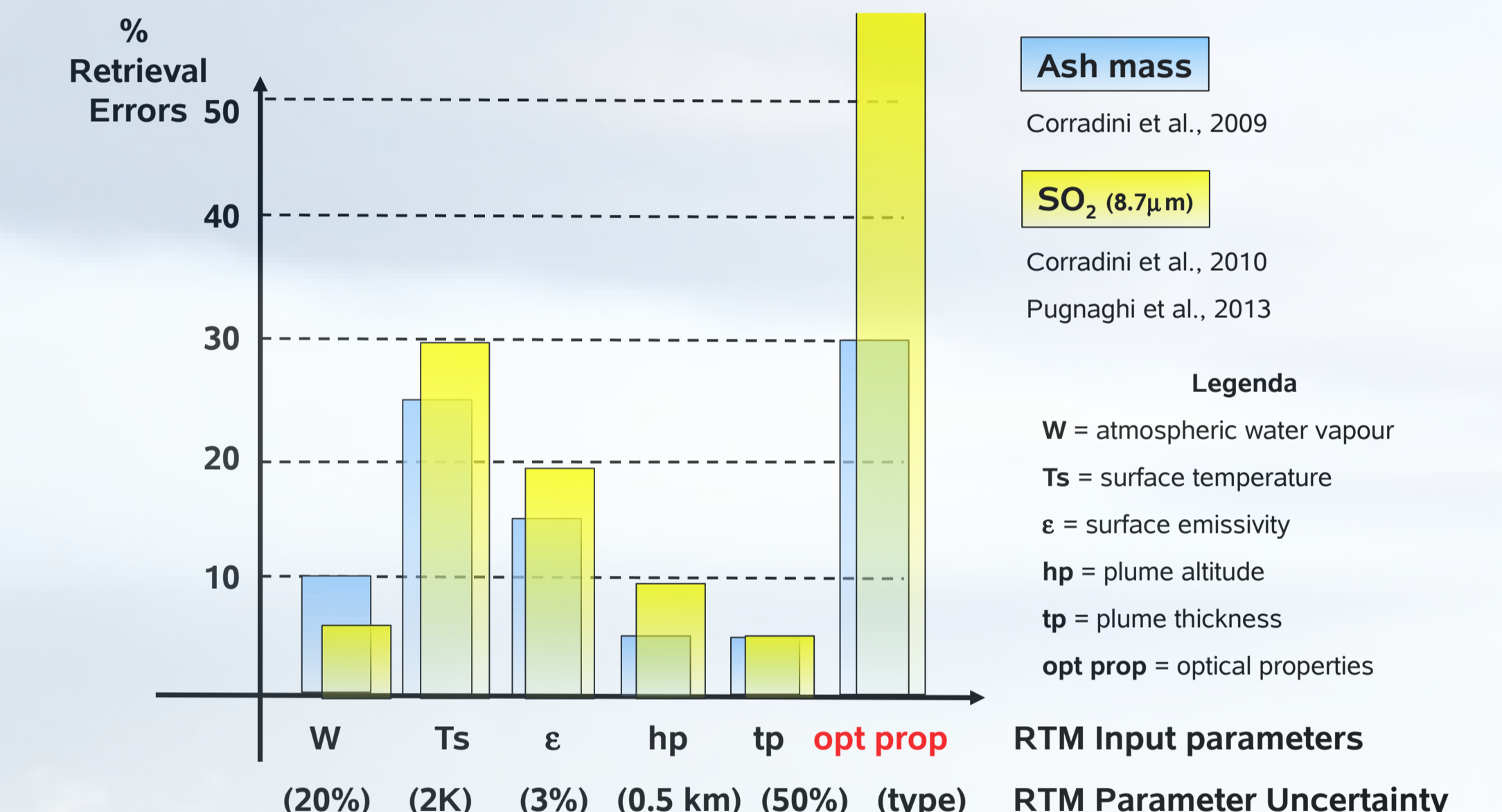
$$\chi^2_{cs} = \sum_{i=1}^n \left[\frac{R_{s,i} - R_{m,i}(c_s, AOD_k, R_{eff,k})}{R_{s,i}} \right]^2 w_i$$

ERROR ASSESSMENT

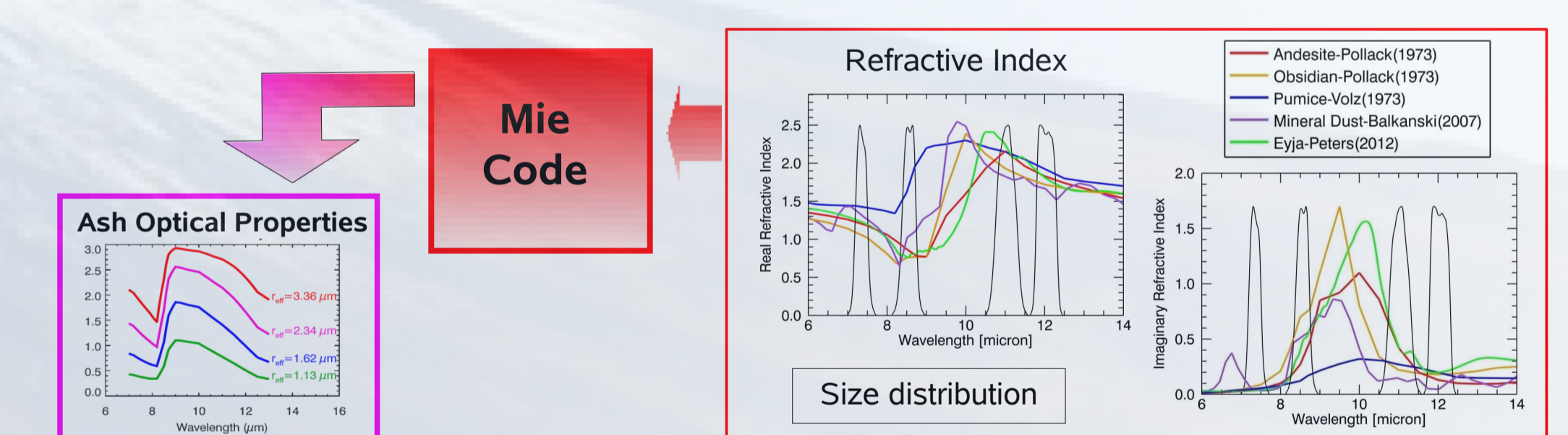
The TOA simulated Radiances needed for ash and SO₂ retrievals are computed using Radiative Transfer Models



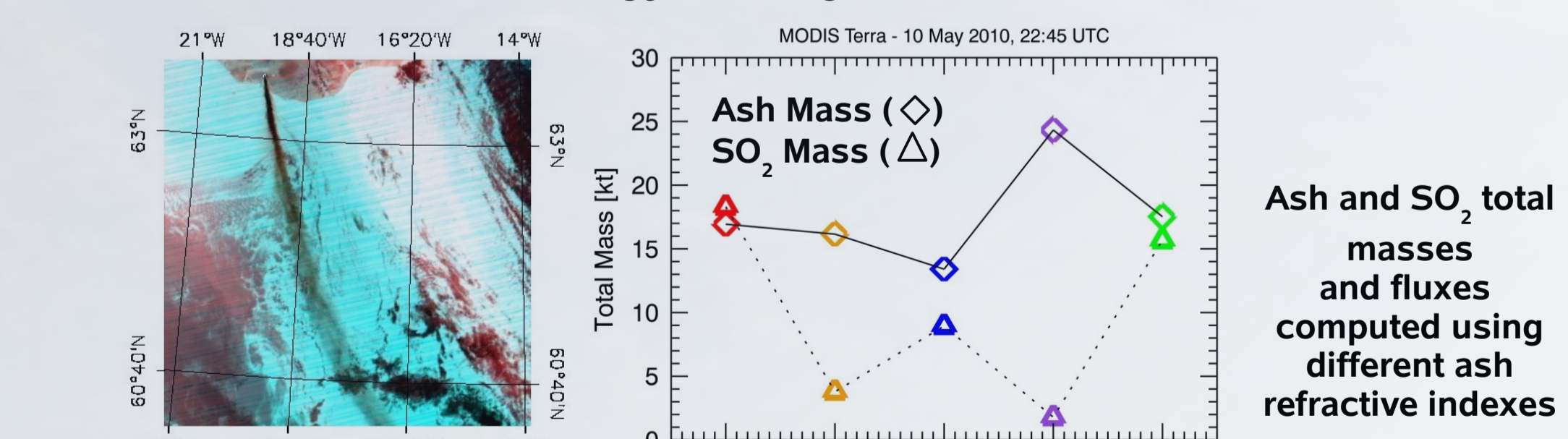
Each RTM input parameter has an uncertainty that lead to ash and SO₂ retrieval errors



Optical Properties Uncertainties



MODIS, Eyja, 10 May 2010, 22:45 UTC

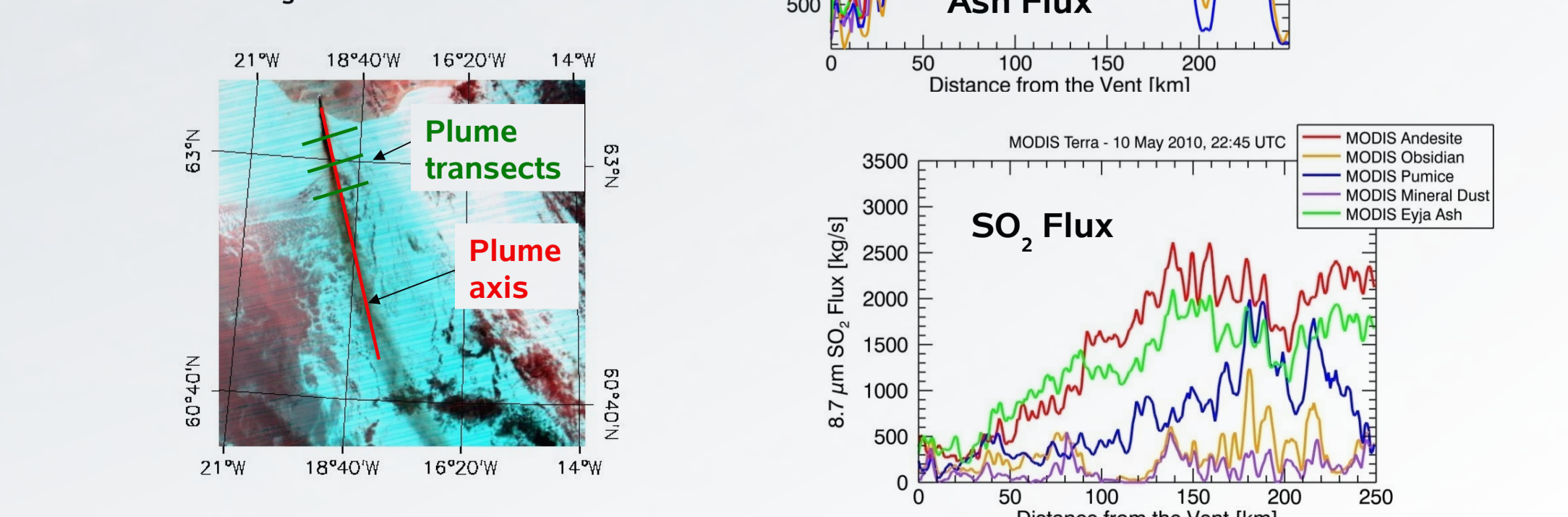


Flux (F_t) Computation

$$F_t = m_t * w_s$$

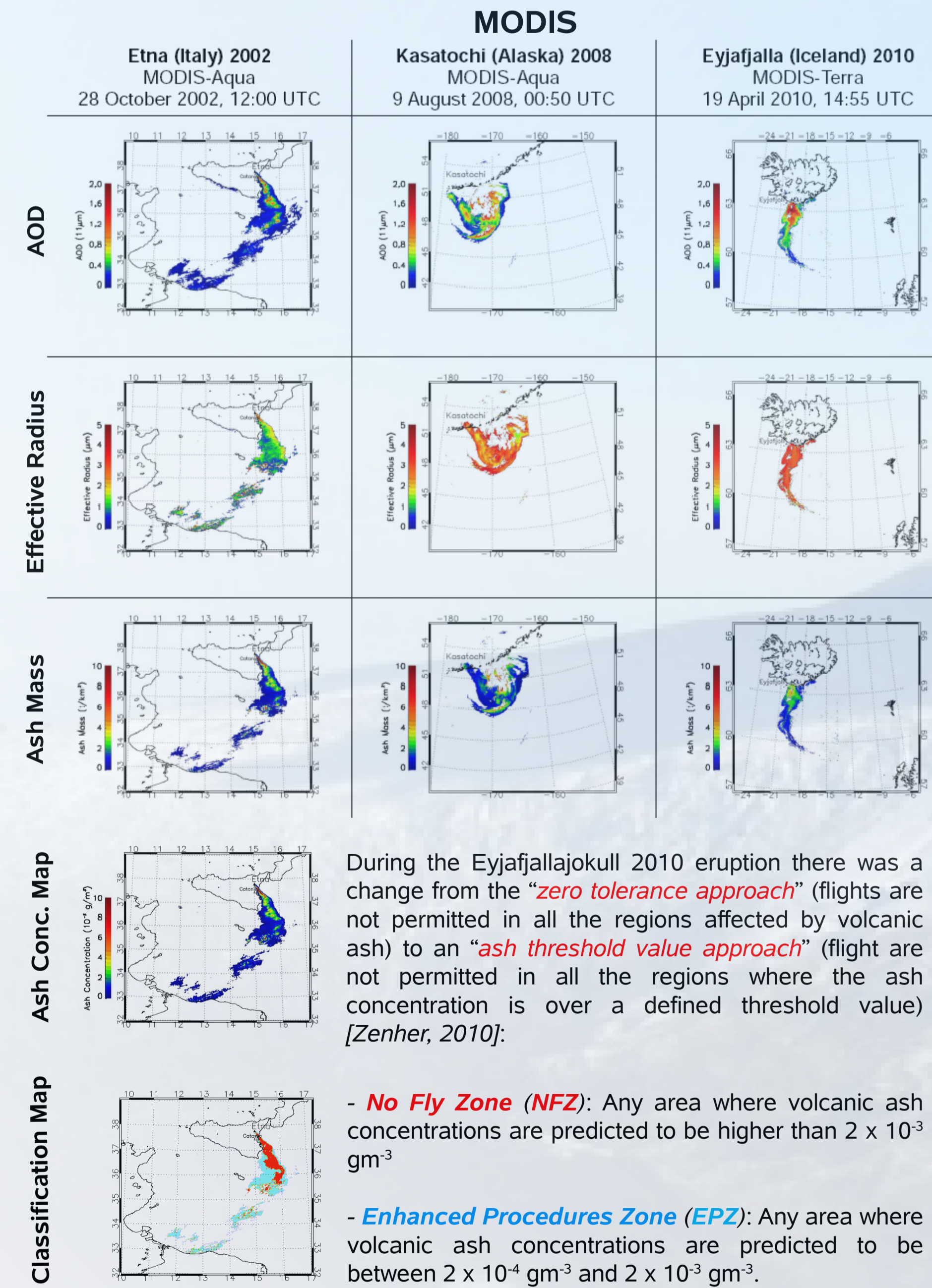
$$m_t = \text{mass on transect}$$

$$w_s = \text{wind speed}$$



STANDARD PRODUCTS

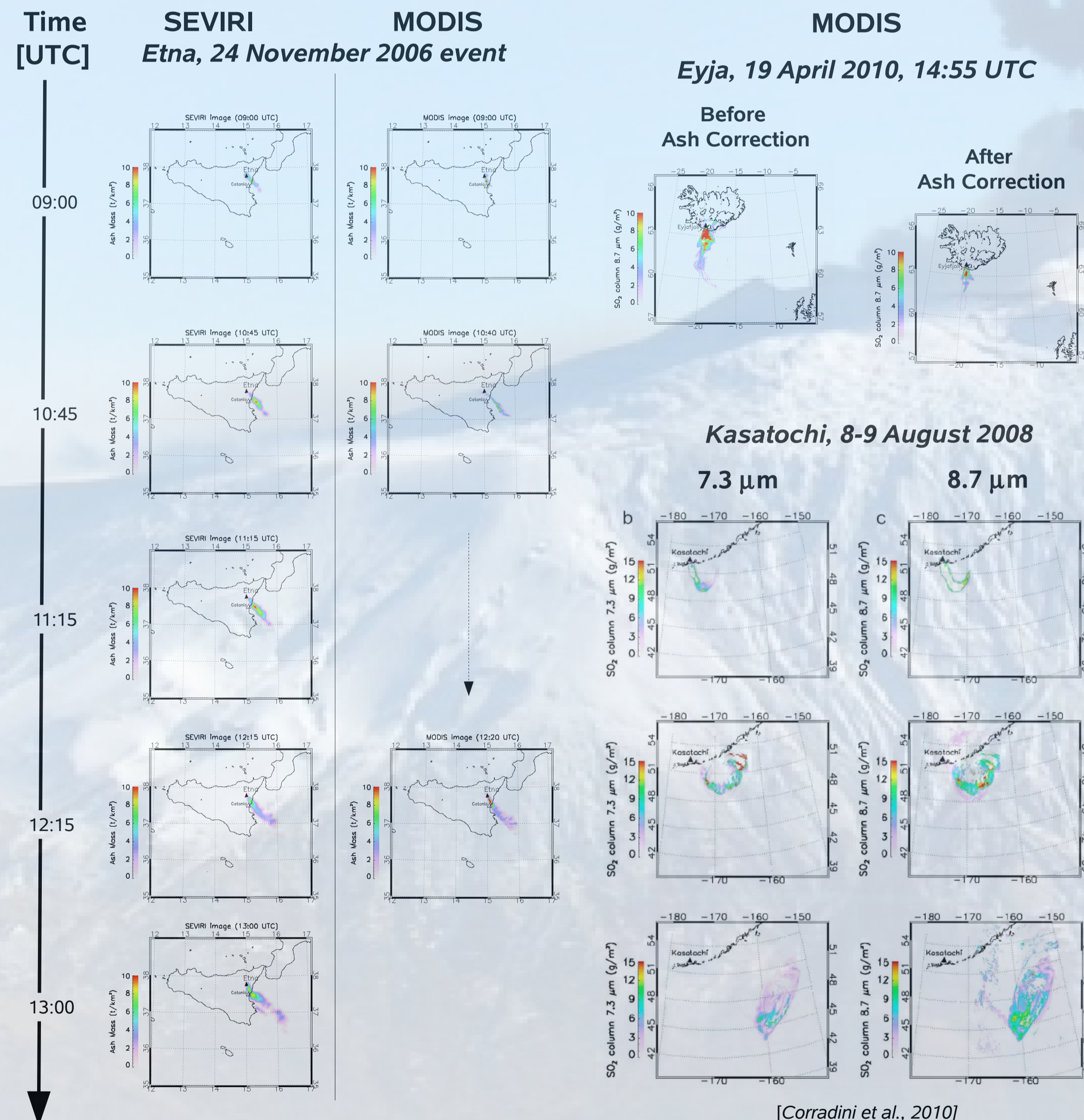
ASH



During the Eyjafjallajökull 2010 eruption there was a change from the "zero tolerance approach" (flights are not permitted in all the regions affected by volcanic ash) to an "ash threshold value approach" (flight are not permitted in all the regions where the ash concentration is over a defined threshold value) [Zenher, 2010]:

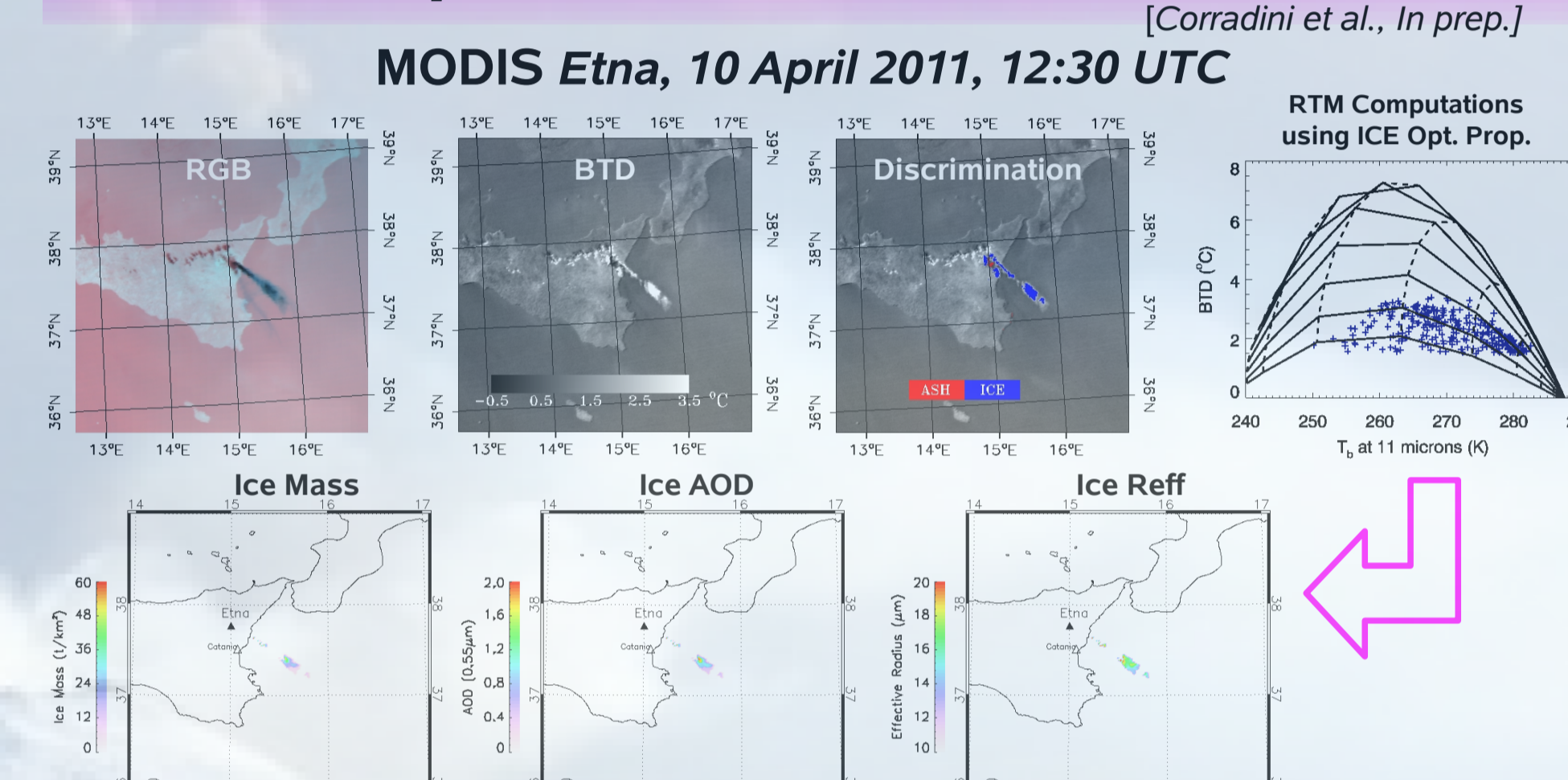
- **No Fly Zone (NFZ)**: Any area where volcanic ash concentrations are predicted to be higher than $2 \times 10^{-3} \text{ gm}^{-3}$
- **Enhanced Procedures Zone (EPZ)**: Any area where volcanic ash concentrations are predicted to be between $2 \times 10^{-4} \text{ gm}^{-3}$ and $2 \times 10^{-3} \text{ gm}^{-3}$.

SO₂

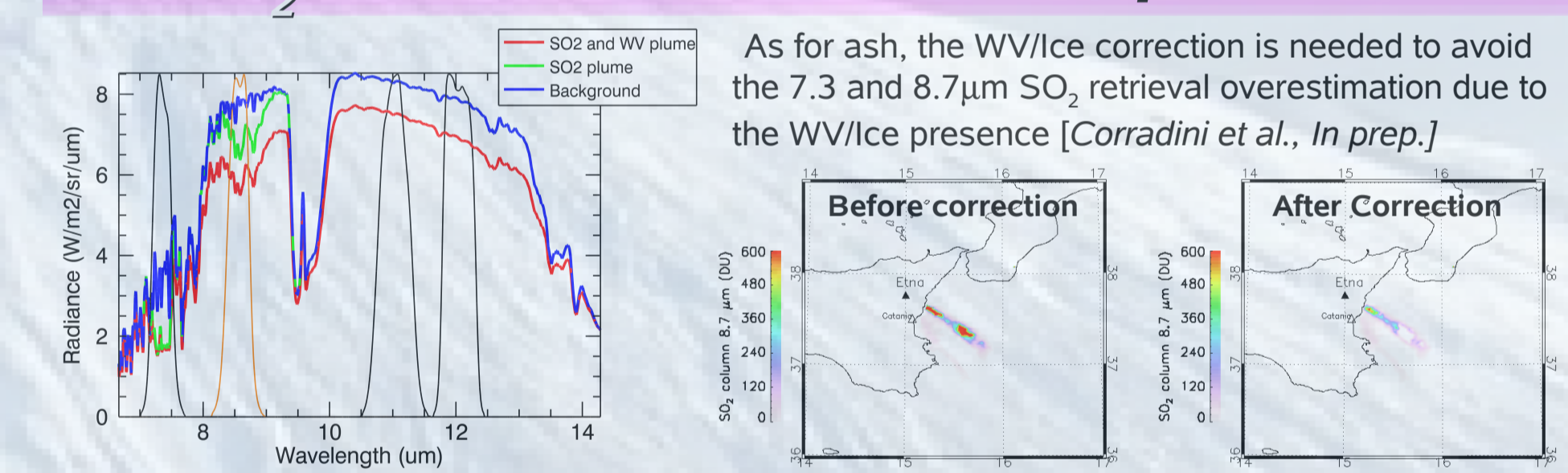


NEW PRODUCTS

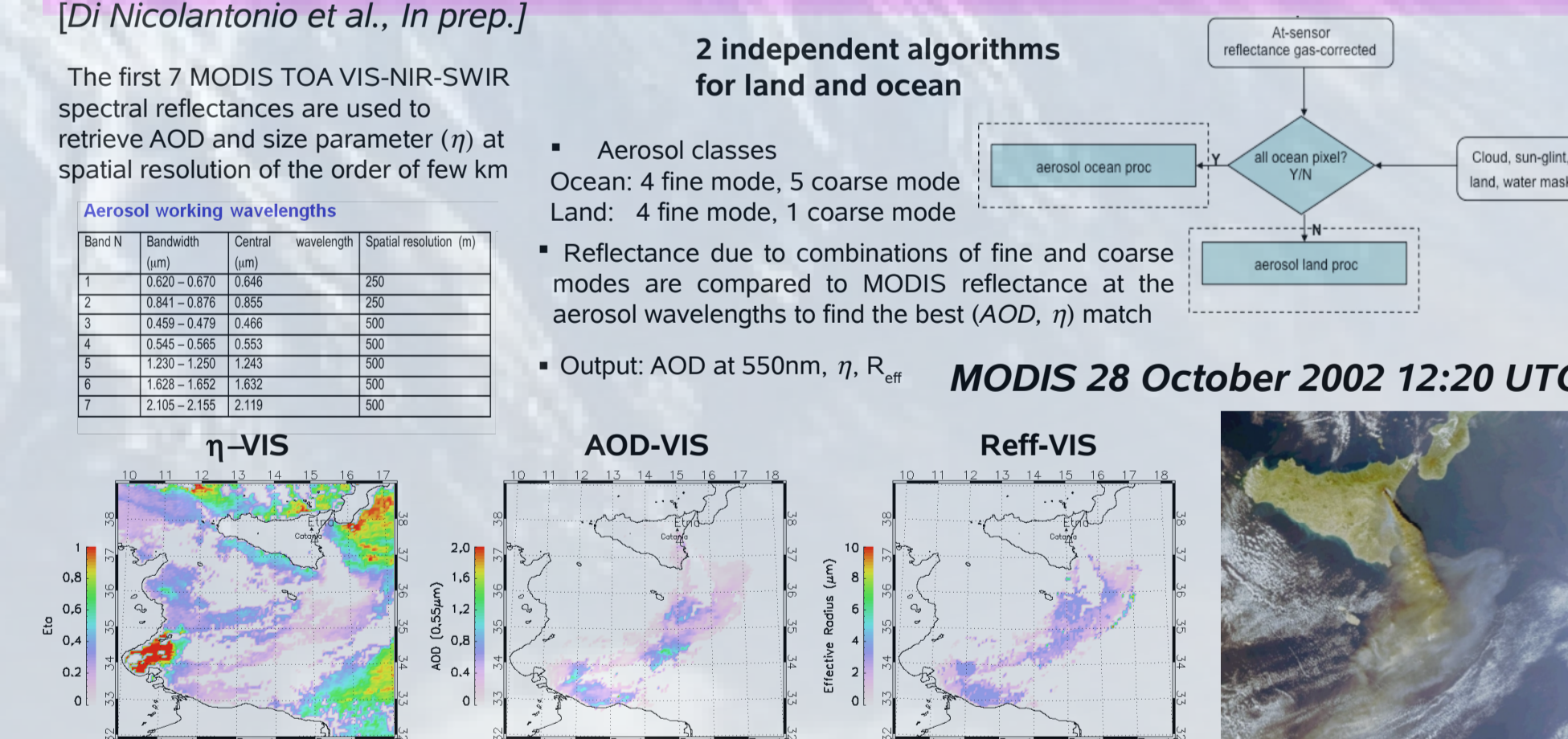
WV/ICE plume detection and retrieval



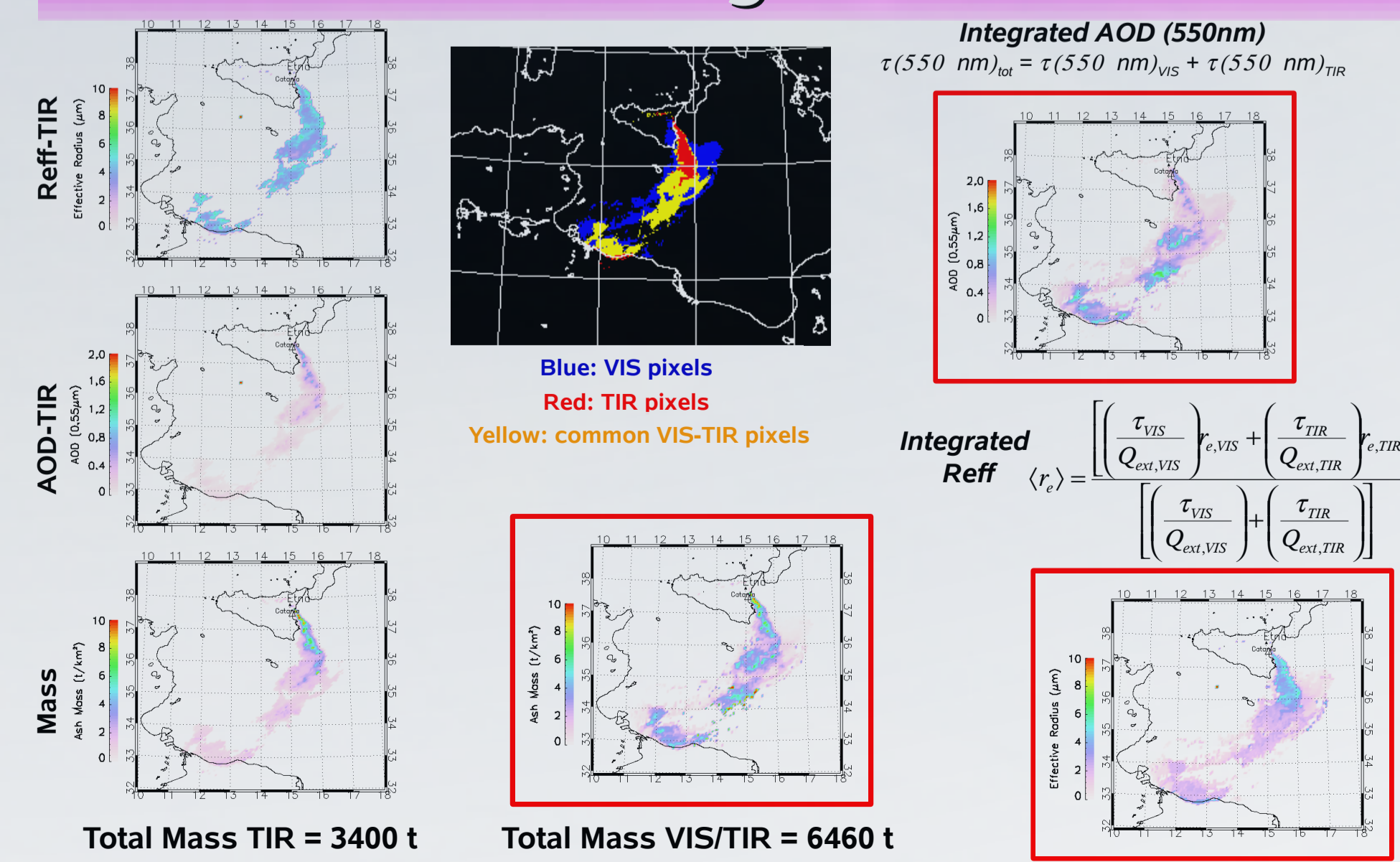
SO₂ correction for WV/ICE presence



VIS Ash Retrievals



VIS/TIR Ash Integrated Products



CONCLUSIONS & PERSPECTIVES

→ The most pressing challenges:

- complete the sensitivity study on ash and SO₂ retrieval errors induced by uncertainty on refractive indexes and size distribution;
- complete the databases by measuring the refractive index from ash samples of different volcanoes;
- find a link between the ash composition and the complex refractive index;
- find a link between the ash transmittance and the ash type [Scollo et al., 2013];
- evaluate the retrieval errors induced by the ash spherical particles approximation (Mie theory) [Kylling et al., 2013];
- increase the satellite and ground LIDAR systems and developed new satellite retrieval techniques to retrieve the ash thickness;
- improve the integration and fusion of the ash cloud parameters retrieved with different methods and data;
- improve the integration of modelled dispersal and transport forecasts and satellite retrievals.

→ Efforts being made to overcome it:

Different projects have been founded to give answer to the previous challenges as the on going projects **ESA-SMASH**, **ESA-SACS2**, **NERC-VANAHEIM** and the **FP7-APHORISM** (for this latter see **P- 10**).