The simultaneous retrieval of volcanic sulphur dioxide and sulphate aerosols from TIR spectra: analysis of satellite and ground-based observations

Henda Guermazi [1,2], Pasquale Sellitto [2], Bernard Legras [2], Mohamed Moncef Serbaji [1], Farhat Rekhiss [1], Elisa Carboni [3], Gordon R. Grainger[3], Mike Burton [4], Richard Siddans[5]

[1] *National School of Engineers of Sfax, Water, Energy and Environment Laboratory L3E, University of Sfax, B.P 1173, 3038 Sfax, Tunisia*

[2] *Laboratoire de Météorologie Dynamique, Ecole Normale Supérieure, PSL Research University, 24 rue Lhomond, 75005 Paris, France*

[3] *Atmospheric, Oceanic and Planetary Physics, University of Oxford, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, UK*

[4] *School of Earth and Environmental Sciences, University of Manchester, M13 9P Manchester, UK*

[5] *UKRI-STFC Rutherford Appleton Laboratory, Chilton, UK*

Volcanic eruptions are one of the main sources of perturbation of the atmospheric composition by increasing the gaseous and particulate sulphur loading and has the potential to cool the planet. Quantifying the total amount of upper-tropospheric and lower-stratospheric aerosols and their evolution with time using Thermal InfraRed (TIR) remote sensing is important for climate studies. Retrieval methods of volcanic sulphur dioxide (SO_2) usually neglect the impact of the subsequently formed Secondary Sulphate Aerosols (SSA) and vice-versa. In the first part of this study, we assess the combined sensitivity of pseudo-observations, i.e. synthetic observations produced with a dedicated simulator, to the SO_2 emissions and the subsequently formed SSA after an idealized simulated stratospheric eruption. Three TIR satellite instruments are used as target observing systems: the Infrared Atmospheric Sounding Interferometer (IASI), the MODerate resolution Imaging Spectro radiometer (MODIS) and the Spinning Enhanced Visible and InfraRed Imager (SEVIRI). The results of these sensitivity analyses show that the radiative interferences, produced by the simultaneous presence of SO_2 and SSA on the outgoing TIR, is significant after few days from the eruption. In particular, neglecting SSA may bias SO_2 retrievals. The broad band instruments SEVIRI and MODIS present high uncertainties. However, using high spectral resolution like IASI, SO_2 and SSA masses can be retrieved as independent quantities and with limited uncertainties. In the second part, we apply the outcomes of this sensitivity analysis to the retrieval of the SO_2 and sulphate aerosols total masses from IASI and a ground-based Fourier Transform InfraRed (FTIR) spectrometer measurements using an optimal estimation algorithm. The evolution of SO_2 to SSA in space and time is studied using this algorithm. The retrieval output vector is composed by the aerosol and SO_2 masses as well as the altitude of the hypothetically-collocated layer. With a similar technique, SO_2 and SSA retrievals from ground-based FTIR measurements (for selected volcanoes) are also achieved for the first time. Finally, we discuss the importance of considering the micro-physical processes at the basis of volcanic aerosols formation/evolution, if we want to correctly quantify SO_2 burdens from volcanic eruptions.
Key words: volcanic emissions, SO_2, SSA, remote sensing.