Geophysical Research Abstracts
Vol. 14, EGU2012-10915, 2012
EGU General Assembly 2012

Satellite SO_2 retrievals from ash rich volcanic plumes: Comparison between different correction procedures

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Observations of volcanic degassing yield insights into the magmatic processes which control volcanic activity during both quiescent and eruptive phases. SO_2 is an important volcanic gas because of its effects on the environment (e.g. acid rain, effects on plants and public health) and also because once it has reached high altitudes it can be transported over long distances, has a great residence time and can be oxidized to form sulphates. The sulphates are capable of reflecting solar radiation and causing surface cooling. For these reasons there is great interest in improving the quality and frequency of volcanic SO_2 retrievals.

Satellite observations have been used for a long time to monitor globally distributed volcanic activity because they offer a practical and safe source of valuable data. While no satellite sensor has been developed explicitly for volcanic observations, continuous technological improvement has achieved spatial resolutions and acquisition frequencies that allow increasingly detailed volcanological studies at local scales. Monitoring of volcanic SO_2 is one of the key facilities offered by satellite remote sensing techniques both in the UV and in the TIR spectral range.

During volcanic eruptions ash and gases can be emitted simultaneously. The plume ash particles (from 1 to 10 micron) tend to reduce the top of atmosphere radiance in the entire Thermal InfraRed spectral range (7–14 micron), including the channels used for the SO_2 retrieval. The net effect is a significant SO_2 column abundance overestimation.

In this work three different ash correction procedures for SO_2 volcanic plume retrieval are compared. These procedures, applied to MODIS and ASTER TIR measurements, has been used to retrieve the SO_2 emission from the 2010 Eyjafjallajokull (Iceland) and the 2011 Mt. Etna (Italy) eruptions.

The first procedure (P1), based on Corradini et al. 2009, needs the simultaneous presence of the 8.7 micron SO_2 absorption bands, as well as the split window bands centered around 11 and 12 micron used for ash retrieval. This implies the possibility of a simultaneous retrieval of both volcanic SO_2 and ash in the same data set. The procedure is based on computing the plume atmospheric terms, taking into account the ash content of the different pixels, by using MODTRAN 4 radiative transfer model.

The second procedure (P2), based on Campion et al. 2010, consists of adjusting the SO_2 column amount until the ratios of radiance simulated on several ASTER bands match the observations. The selected band ratios depend much less on atmospheric humidity, sulfate aerosols, surface altitude and emissivity than the raw radiances.

The third (P3) is a novel procedure which determines the radiance at the sensor if no plume was in the scene and then the plume transmittance at each band. A relationship, of the ash transmittance at 8.7 versus 11 micron transmittance, is used to retrieve the SO_2 abundance.

The P1 procedure has been considered as a reference. Its main drawback is the time required to compute the simulated atmospheric terms Look-Up Tables. The P2 procedure, valid for ASTER images, gives a very good spatial resolution but, because of that, the plume is generally not completely observed. The P3 procedure is very fast and can be used for a volcanic early warning, but seems too sensitive to the plume temperature.

Even if the P1 procedure tends to overestimate the SO_2 amounts with respect to the P2 and P3 procedures, the results show a good agreement in both the the SO_2 flux trends and total mass for all the different eruptive events considered.