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Simultaneous SO_2 and ash retrievals using the volcanic plume removal (VPR) procedure

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A novel procedure for the simultaneous retrieval of SO_2 and ash abundances in a volcanic plume from MODIS thermal infrared (TIR) images is presented. The proposed procedure is simple, extremely fast and requires as inputs only the plume altitude and temperature. Here it is described and applied on two Mt. Etna (Italy) test case eruptions, but can be easily extended and applied to any volcano.
The core of the volcanic plume removal (VPR) procedure is the calculation of the background radiance obtained by linear interpolation of the radiance measured in the area surrounding the plume. In this way the absorption effect of the volcanic plume can be removed from the image: the VPR procedure computes the radiances that would have been measured by the sensor if the plume was missing and reconstructs a new image without the plume. The difference of the new image and the original data highlights the plume area and allows the computation of the plume transmittance in three TIR-MODIS bands: 29, 31 and 32 (8.6, 11.0 and 12.0 μm). The procedure works very well when the surface under the plume is uniform, as it is often the case with plume widths of few tens of kilometers. As a consequence, it has no problems when the plume is above the sea, but still produces fairly good results in more challenging and not easily modeled conditions, such as images with land or uniform cloud layers under the plume. The plume transmittances are derived in two steps: (1) using a simple model with the plume at a fixed altitude and neglecting the layer of atmosphere above it; (2) refining the first result with polynomial relationships adapted for the geographical region. MODIS bands 31 and 32 are SO_2 transparent and, from their transmittances, the ash particle effective radius (Re) and the aerosol optical depth at 550 nm (AOD550) are computed. A simple relation between the ash transmittances of bands 31 and 29 is demonstrated for the typical ash of Etna and used for the SO_2 columnar content estimation. The parameters of the polynomial relationship have been derived from more than 200 thousands MODTRAN simulations performed to describe the Etna plumes and local situations. The comparison of the VPR procedure results with these more than 200 thousands different cases shows a frequency distribution of the differences saying that: the Re error is less than ± 0.5 μm in more than 60% of the cases; the AOD550 error is less than ± 0.125 in 80% of the cases; the SO_2 error is less than ± 0.5 gm-2 in more than 60% of the considered cases. The VPR procedure has been applied in two case studies of recent eruptions occurred at Mt. Etna volcano and successfully compared with the results obtained with the established SO_2 and ash retrievals based on the look-up tables (LUTs) method (Corradini et al., 2009). By re-computing the parameters of the polynomial relationships, the VPR procedure can be applied to different volcanoes as well as extended to other sensors and ash types.