Algorithm to retrieve SO$_2$ layer height from UV backscattered measurements: Application to OMI and TROPOMI and comparison with other satellite datasets

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1. Abstract

Here we introduce an algorithm to derive an effective SO$_2$ layer height (LH) which can be activated for enhanced SO$_2$ vertical columns (typically $>$25 DU). It is based on an iterative SO$_2$ optical depth fitting procedure. Although it makes use of a large look-up-table (of SO$_2$ optical depth spectra), the scheme is adequately fast for an operational environment. We demonstrate the technique based on synthetic spectra and apply the algorithm to OMI and TROPOMI for a number of volcanic eruptions. Results are compared to other satellite datasets, such as CALIOP attenuated backscattered profiles and SO$_2$ height estimates from MLS and IASI (Clarisse et al., 2014). In general, we find an excellent agreement with differences on the retrieved height of less than 1-2 km. The results for TROPOMI are discussed in more details because SO$_2$ plume height data derived at high spatial resolution can provide added-value information on the eruption chronology. Plans for future work, including the possible implementation of a near-real-time SO$_2$ plume height algorithm in the Support to Aviation Control Service (SACS)/EUNADICS-AV Early Warning System, are addressed.

2. Algorithm

Joint SO$_2$ LH and VCD retrieval: iterative SO$_2$ optical depth fitting

$$\tau_{\text{meas}} = P + \text{SO}_2 + \tau_{\text{ring}}$$

$$\tau_{\text{meas}} = \log(I/I_0)$$

P: 3rd order polyn  
$\tau_{\text{SO}_2}$: 4 O$_3$ xs (2T + 2 Pukite terms)  
$\tau_{\text{SO}_2}$: fct(LH, VCD, $\lambda$) splined from large LUT with 9 entries (TO3, SZA, VZA, RAA, Surf Refl, SurfH, SO2 LH, SO2 VCD, $\lambda$)  
$\tau_{\text{ring}}$: Molecular Ring correction fct(O$_3$,SO$_2$)

$$\tau_{\text{meas}} = \tau_{\text{SO}_2,i} + \tau_{\text{O}_3} + \alpha.d\tau_{\text{SO}_2,i}/d\text{LH} + \beta.d\tau_{\text{SO}_2,i}/d\text{VCD} + \tau_{\text{Ring}}$$

Fitting interval: 310.5-326 nm  
Surf Refl: retrieved from 340 nm intensity  
Maximum iterations: 10

3. Results from synthetic elastic spectra (closed-loop retrievals)

Input  
SO$_2$ VCD: 5-1000DU  
SO$_2$LH: 2.5, 6.5, 13.5 km

Results  
Mean+std retrieved SO$_2$ LH for 100 noisy spectra (SNR:1000)

Findings  
Good precision and accuracy (few 100s of meters) for all conditions with SO$_2$>25DU, in line with previous study (Nowlan et al., 2011).

4. OMI results: 2008 Kasatochi eruption

Comparison with IASI, MLS and CALIOP indicates agreement on plume height with differences not larger than 1-2km, except for plume edges.

5. TROPOMI results

Sinabung eruption: 19.02.2018  
Raikoke eruption: 25.06.2019

6. Conclusions and Future work

• SO$_2$ layer height retrievals applied to OMI and TROPOMI. Good agreement with other satellite plume height estimates (IASI, MLS, CALIOP) with differences less than 1-2km.

• Important information on eruptions can be obtained from high-resolution TROPOMI data which reveals SO$_2$ injections at various heights.

• More validation and development is needed for fresh ash-laden plumes. Preliminary SO$_2$ height results for both synthetic and real spectra indicates strong underestimation for those cases.

• The LUT approach makes the implementation of the SO$_2$ plume height algorithm (e.g., in the Support to Aviation Control Service (SACS)) possible in near-real-time (current processing time: 0.1s/spec).

References


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