Operational products of volcanic SO2 layer height

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***Abstract*— Volcanic emissions, like Sulphur dioxide (SO_2), can be a major risk for the management of air traffic. In the frame of OPAS (Operational alert Products for ATM via SWIM) project, KTN Engage Catalyst funded project related to Thematic Challenge 3, a new product (SO_2 layer height from TROPOMI) is currently in development, with the aim of including it in an existing early warning system, so called SACS [1]. This system is dedicated to support aviation control and ATM, and was recently under development in the frame of EUNADICS-AV project. This poster presents first results of SO_2 layer height retrievals from TROPOMI satellite sensor, launched in October 2017.**

Volcanic emission, SO_2 layer height, TROPOMI satellite instrument, Alert products for ATM, Early warning system.

I. Motivation

Volcanic SO_2 emissions are not so frequent (e.g., as severe weather) however, their effects can be extremely disruptive the management of air traffic. Volcanic ash and SO_2 are major hazards to aviation, causing windscreen abrasions, reduction of visibility, damage to aircraft instrumentation and systems, hot corrosion (when sulphate's coat inside/outside engine surfaces) that calls for extra maintenance, and most importantly stalling of engines due to the melting ash [2][3]. As an example, the eruptions of the Icelandic volcanoes Eyjafjallajökull in April–May 2010 and Grímsvötn in May 2011, both caused partial or total closure of airspace over many European countries and led to social and economic upheaval across Europe [4]. The closures caused millions of passengers to be stranded across the world. The International Air Transport Association (IATA) estimated that the airline industry worldwide lost about €150 million a day during such a disruption. IATA stated that the total loss for the airline industry was around €1.3 billion. The Airport Operators Association (AOA) estimated that airports lost about €90 million over six-and-a-half days of Eyjafjallajökull eruption impact on air traffic. Over 95000 flights had been cancelled all across Europe during the six-day travel ban, with later figures suggesting 107000 flights cancelled during an 8-day period, accounting for 48% of total air traffic and roughly 10 million passengers. On 22 June 2019, a vast plume of ash and volcanic gases shot up from the crater of Raikoke volcano (Kuril Islands, on the south side of Kamchatka Peninsula). This eruption emitted a huge ash cloud with a gigantic amount of SO_2 (mass loading of 1.5 Tg and concentration up to more than 1300 DU [Dobson Units], as observed by the TROPOspheric Monitoring Instrument – TROPOMI). This is the most important eruption affecting long lines air traffic in the Pacific region since Sarychev eruption in 2009. The SO_2 cloud is still detected, even two months after the end of Raikoke eruption (23 June). This event highlights the importance of knowing the concentrations of airborne hazard at flight levels.

A significant difficulty in mitigating impact of volcanic SO_2 clouds on aviation is that these gas emissions can rapidly be transported over long distances (>1000 km), often not along the forecasted path of the cloud. The use of space-based instruments enables the global monitoring of volcanic SO_2 emissions (total column and layer height) in an effective, economical and risk-free way.

II. SO_2 Height Layer: Overview of the Algorithm

Here we introduce an algorithm to derive an effective SO_2 layer height (SO_2 LH) which can be activated for enhanced SO_2 vertical columns (typically for SO_2 total column >25 DU); see operational algorithm of SO_2 retrievals [5]. The algorithm of SO_2 LH 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 (Ozone Monitoring Instrument) and TROPOMI for a number of volcanic eruptions.

III. FIRST RESULTS OF SO_2 LH FROM TROPOMI

Results of SO_2 LH retrievals from OMI sensor have been compared to other satellite datasets, such as CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) attenuated backscattered profiles and SO_2 height estimates from MLS (Microwave Limb Sounder) and IASI (Infrared Atmospheric Sounding Interferometer) instruments [6]. In general, we find an excellent agreement with differences on the retrieved height of less than 1-2 km. Figure 1 presents TROPOMI first results of our algorithm applied to Raikoke eruption on 25 June 2019.

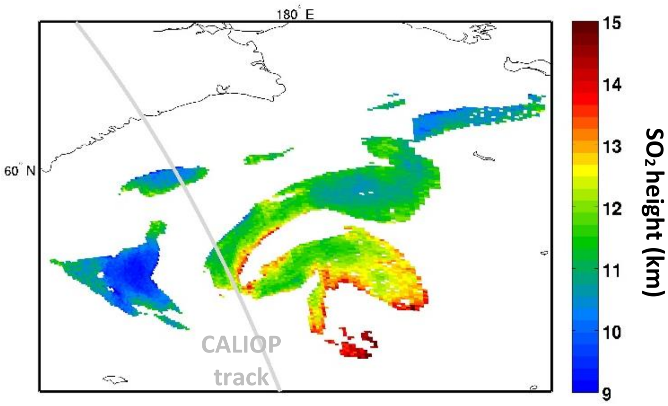

Figure 1. SO_2 LH from TROPOMI on 25 June 2019 (Raikoke eruption).

The spread of the SO_2 plume from Raikoke over North Pacicfic is shown in Figure 1, with information of the SO_2 LH.

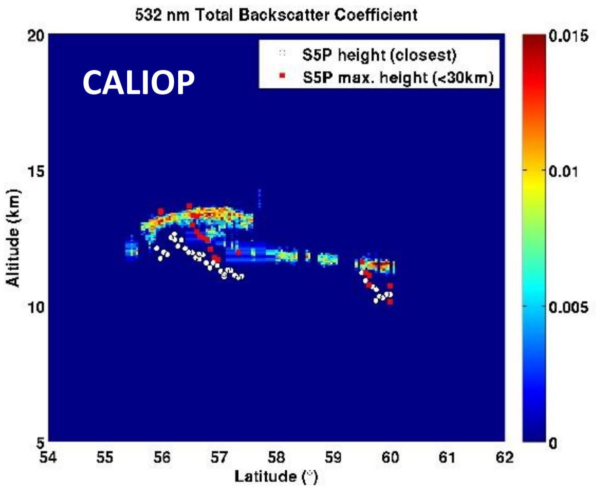

Figure 2. Comparison of SO2 LH from TROPOMI with Total Backscatter Coefficient (due to ash) from CALIOP track.

Figure 2 illustrates a good agreement between SO_2 LH from TROPOMI and Total Backscattered Coefficient (height of ash) from CALIOP. This interesting first result will be discussed in more details. SO_2 plume height data derived at high spatial resolution provides added-value information on the eruption chronology and the impact on aviation air space.

IV. NEXT WORK IN THE FRAME OF OPAS

After further investigations and validations, we plan to include the operational implementation of a near-real-time SO_2 plume height algorithm from TROPOMI in SACS alert system (Support to Aviation Control Service; http://sacs.aeronomie.be) / EUNADICS-AV (European Natural Airborne Disaster Information and Coordination System for Aviation; http://www.eunadics.eu).

The TROPOMI SO_2 LH alert product will be transferred to SWIM (yellow service), complementing the existing transfer of EUNADICS-AV alert products. This will consolidate the bridge between SACS / EUNADICS-AV and SWIM.

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