Author's Response to Mariana Adam, CC1 (05 May 2021):

In this author's response, the text (normal style) answers point by point to the comment of Mariana Adam (text in bold). The text in blue corresponds to the authors' change in the manuscript.

CC1 from Mariana Adam:

I have several observations and it would be very nice if there will be some clarifications. Regarding Table 5, it will be very useful to have the numerical values of the thresholds given.

Issuing alert can require the use of several criteria. Table 5 provides an indicator of the type of criteria used, e.g. "Threshold", "Triggered" or "Relay". With respect to "Threshold", this doesn't always mean the use of a single threshold/value. To clarify this, we added superscripts to guide the reader for finding more explanation about the criteria used. Whenever possible, thresholds have been added.

See this new Table 5 bellow

Table 5: Overview of EUNADICS alert products from ground-based [GB], satellite [SAT] and in situ [IS] instruments.

Quantity	Instrument [GB]	Instrument [SAT]	Instrument [IS]	Responsible institute	Source alert	Alert criteria	Access
High resol. lidar data (att. backscatter, vol. depolarization ratio)	Lidar			EARLINET / ACTRIS - CNR	Volcano / Dust	(1) Threshold on particle backscatter coeff. and particle depolarization ratio	Off-line
Backscatterig power	Radar			INGV-OE / OPGC	Volcano	Manual analysis (volcanologist on duty check the increase of the echo power in respect to the background)	Off-line
Backscatterig power	Radar			IMO	Volcano	General threshold at -20 dBz (but specific volcano dependent thresholds are also set: -31/-30 dBz)	NRT
Plume height	Radar			IMO	Volcano	Triggered by backscatt. power	NRT
Thermal images	TIR camera network			INGV-OE	Volcano	(2) Dynamical threshold (no fixed threshold)	NRT
SO_2 profiles	UV spectro. network			INGV-OE	Volcano	SO_2 thresholds are 1000-2000 tons/day (low), 2000-4000 tons/day (medium) and >4000 tons/day (high)	NRT
SO_2 column amount	DOAS			IMO	Volcano	SO_2 threshold depends on a variety of factors (type of sensors, its orientation); currently 100 pmm-m and 200 ppm-m are set as reference thresholds for DOAS in Hekla and in Fagradaslfjall.	NRT
Plume height	Web camera			INGV-OE	Volcano	(3) Intensity contrast pixels (estimation of the column height is made qualitatively by an operator, i.e., the volcanologist on duty)	NRT
Plume height	Web camera			IMO	Volcano	Manual analysis (identification of specific features); plume height obtained using a graphical interface	NRT

Ash index	AQUA / AIRS	ULB	Volcano	(4) NOP required	NRT
SO_2 VCD	AQUA / AIRS	AIRES / BIRA	Volcano	(5) Threshold (SO_2 > 3 DU), coeff.	NRT
SO_2 VCD	AURA / OMI	NASA	Volcano	(5) Threshold (SO_2 >1.25 DU), nb. pixels	NRT
SO_2 VCD	MetOp-A&B / GOME-2	DLR	Volcano	(5) Threshold (SO_2 >1.45 DU), nb. pixels	NRT
AOD (dusts)	MetOp-A&B / IASI	ULB	Dust	Threshold (AOD > 0.5)	NRT
Ash index	MetOp-A&B / IASI	ULB	Volcano	(4) NOP required	NRT
SO_2 BT index	MetOp-A&B / IASI	ULB	Volcano	(5) Threshold (BT < 2.9K)	NRT
SO_2 VCD	MetOp-A&B / IASI	ULB	Volcano	Trigerred by BT	NRT
SO2 plume height	MetOp-A&B / IASI	ULB	Volcano	Trigerred by BT	NRT
Ash mask	MSG / SEVIRI	DLR	Volcano	Threshold	NRT
Ash column load	MSG / SEVIRI	DLR	Volcano	Trigerred by Ash mask	NRT
Ash top height	MSG / SEVIRI	DLR	Volcano	Trigerred by Ash mask	NRT
SO_2 VCD	S5P / TROPOMI	BIRA / DLR	Volcano	(5) Threshold (SO_2 > 0.5 DU), nb. pixels	NRT
SO_2 VCD	Suomi-NPP / OMPS	NASA	Volcano	(5) Threshold (SO_2 > 0.75 DU), nb. pixels	NRT
Aerosol index	Sentinel-3A&B / SLSTR	FMI	Volcano / Dust	Thres. Ash index (BT < -3K)	NRT
Aerosol top height	Sentinel-3A&B / SLSTR	FMI	Volcano / Dust	Trigerred by Ash index	NRT
Thermal anomaly	Terra & Aqua / MODIS	NASA - FIRMS	Fire	Relay (through FIRMS)	NRT
Thermal anomaly	Suomi-NPP / VIIRS	NASA - FIRMS	Fire	Relay (through FIRMS)	NRT
Seismicity	SIL seismic network	IMO	Volcano	Relay (through VONA)	NRT
Volcanic tremor	Seismic stations	INGV-OE	Volcano	(6) Relay (through reports)	NRT
Gamma radiation	Network of detectors	EURDEP / ZAMG	Nuclear	Relay (through EURDEP)	NRT

(1) See Papagiannopoulos et al. (2020) for more details.
(2) See Behncke et al. (2009) for more details.
(3) The uncertainty due to a different operator is less than 2% (Scollo et al., 2019). The uncertainty in the column height is instead ± 0.5 km (see Scollo et al. 2014; 2019).
(4) Number of medium or high LOC (Level of Confidence) pixels in the area in the threshold radius; see See Brenot et al. (2014) for more details.
(5) See Brenot et al. (2014) for more details.
(6) Reports are sent to the Italian Civil Protection during the volcanic crisis and available at the INGV-OE web-site (https://www.ct.ingv.it/index.php/monitoraggio-e-sorveglianza/prodotti-del-monitoraggio/comunicati-attivita-vulcanica); see Agostino et al. (2013) for more details about alert of volcanic tremor based on RMS amplitude.

The line of Table 5 related to alert from Attenuated Backscattered Coefficient (from E-PROFILE) has been removed (see explanation below), as quicklooks should not be considered as alert.

Why don't you use particles extinction and backscatter coefficients from lidars (as mentioned in Table 3)? Moreover, the example from Fig. 13 uses particle backscatter coefficient.

Fig. 13 shows 3 graphs (particle backscatter coefficient at 532 nm, particle depolarization ratio at 532 nm, and alert for aviation). The alert for aviation uses threshold criteria on the particle backscatter coefficient at 532 nm and the particle depolarization ratio at 532 nm. See Papagiannopoulos et al. (2020) for more details. Table 5 has been updated accordingly.

Does the example given in Fig. 14 represent a hazard? I see it just as an illustration of the Eprofile capability. Please mention if you have any criteria for attenuated backscatter from which you can set a warning.

The event shown there does not directly present a hazard, the smoke concentrations involved are far too low to cause any issues to aviation, but are nevertheless well detected by the ALC network so that this case can illustrate what can be achieved with E-PROFILE. Cases with large scale presence of high concentrations of hazardous aerosols are rare (but have very high socio-economic impact as we all know), so that the E-PROFILE network did not yet have the chance to capture such an event due to its young age.

No threshold of attenuated backscatter for issuing warnings has been defined up to now. Only quicklooks (and data) are available. Therefore we have decided to remove the line related to E-PROFILE in Table 5. For issuing alert using attenuated backscatter, a synergy with information on aerosol typing is required and would be judicious (unless the event is extremely strong). For the time being, we rather consider the E-PROFILE network as a tool for precisely determining the 4D (lat, lon, altitude, arrival and dissipation time) presence of aerosols, once their type has been identified by other means.

What do you mean by 'Range of att. backscatter' in Table 5? To me, what is of interest is the pollution layer geometry (layer altitude and depth).

We agree that attenuated backscatter is very well suited to track lat/lon/altitude/depth/timing of pollution. The line related to E-PROFILE and range of att. Backscatter has been removed from Table 5. We could define a range where we would for sure issue a warning, but this would suffer from large uncertainty (either a high false alarm rate or a lot of missed events depending on tuning), due to the impossibility to do aerosol typing with the single-wavelength elastic lidars. Therefore, we would argue that a high aerosol attenuated backscatter should best be used in combination with some typing information in order to issue a warning, hence some synergy in the EWS would need to be exploited. The big advantage of automatic lidars and ceilometers is that in contrast to EARLINET they are up and running 24/7 with very high timeliness and their spatial distribution is dense, the disadvantage, of course, is that they cannot do typing.

Please mention the timeliness for EWS, i.e., when the warning will be issued after the event (hours).

Information about timeliness for EWS is presented in Table 6 (i.e. Time delivery and resolution). It is not our goal to provide the time delay of the alert with respect to the start of the event. Our objective is to provide situational awareness of an event and alert data product. However about the time delay of observations, we provide:

- The time delivery, i.e. the time delay between the time of measurement and the NRT availability of data retrievals.
- The time resolution, i.e. the time delay between 2 consecutive observations of the same region. For the instruments onboard polar orbiting satellites, it depends on the latitude and the type of sensors, e.g. UV-vis or IR.

I am a bit confused about Fig. 13. You mention that the alert uses mass concentration based on backscatter coefficients thresholds. According to Papagiannopoulos et al. (2020), the thresholds are for particle backscatter coefficients, based on given mass concentrations (eq. 9). Please correct and cite the reference. Please comment on uncertainty.

Correct. The text has been updated accordingly. The particle backscatter coefficient is retrieved following Di Girolamo et al. (1999) with an overall error of no more than 50 %. For the estimation of the alert thresholds, the methodology employs the POLIPHON method (Ansmann et al. 2012) with known uncertainty of 20-30%. Uncertainties are discussed in detail in Ansmann et al. (2019) and Papagiannopoulos et al. (2020). The text of section 4.2.1 has been modified:

A tailored alerting product from the European Aerosol Research Lidar Network (EARLINET; https://www.earlinet.org) has been developed during the EUNADICS project (Papagiannopoulos et al., 2020). It has been designed for NRT EWS applications. Using a stand-alone lidar-based method for detecting airborne hazards (volcanic ash and desert dust; no discrimination), this product is based on the EARLINET Single Calculus Chain (version 5.1)~~, and that~~ provides temporally high-resolved, calibrated attenuated backscatter and volume depolarizsation ratio (at 532 nm), and cloud mask. The vertical resolution is 7.5 m, and the temporal resolution is 30 s. From these calibrated data, further particle~~-like~~ products (particle~~-like~~ backscatter coefficient and particle depolarizsation ratio) can be retrieved that act as the basis of the tailored product. The final product (to be used by EUNADICS EWS) is the aviation alert for desert dust/volcanic ash with a three colour-codes. This alert product uses particle mass concentrations (pmc) based on backscatter coefficient thresholds. High level detection appears in red (almost certain detection of ash or dust aerosol with pmc ≥ 4 mg/m³). Medium level in orange (4 mg/m³ > pmc ≥ 2 mg/m³). Low level is in yellow (2 mg/m³ > pmc ≥ 0.2 mg/m³). An example of alert from EARLINET is shown in Fig. 13. On 21-22 March 2018, the eastern Mediterranean, in particular Crete island, was under extreme effects of warm southerly winds pushing enormous amounts of Saharan dust – and hot air – northwards. The desert dust storm caused the closure of Heraklion airport (Crete, Greece) on 22 March 2018, and was~~, in particular,~~ detected by the ground-based LIDAR from EARLINET.

Please comment on plumes heights. So far, you give examples for ash top height and SO2 plume height estimated from satellites (Figs. 3 and 5). How this information corroborates with the total SO2 concentration (threshold of mass loading of 5 kt, page 38).

At the moment, only SO_2 and ash plume height is tackled by the alert data products of our EWS. SO_2 column and height are simultaneously retrieved by IASI and provided in our alert data products. A threshold of 5 kt is used to determine the level of an SO_2 notification (i.e., HIGH versus LOW).

On the other hand, why no lidar or ALC system is used to determine the plumes geometry?

This is a good point about the interest of using lidar and ALC to determine the plume geometry. We plan to use such information and create alert data products in the future. For the time being, it needs more investigations, as mentioned previously, to include plume height information from lidar and ALC in this study. Note however that quicklooks (provided in NRT) are already good for providing situational awareness related to the plume geometry.

Why the lidars are not used for smoke identification? There are many papers on aerosol type, mostly based on lidar ratio and extinction Angstrom exponent. Again, why is just volume depolarization ratio used? Moreover, why not particle linear depolarization ratio?

Here, we applied the methodology introduced in Papagiannopoulos et al. (2020) that focuses on irregular-shaped particles such volcanic ash and desert dust. Their methodology is based on a single-wavelength depolarization lidar with no spectral information; thus, smoke plumes would be challenging to identify following their approach. The methodology uses particle depolarization ratio for the estimation of the EWS.

We hope this answer clarifies the point addressed by your observations.

Thank you for these comments and your interest for our study. Best regards,

Hugues Brenot and co-authors.