Response to Reviewer 2 comments

Interactive comments on "Volcanic cloud detection using Sentinel-3 satellite data by means of neural networks: the Raikoke 2019 eruption test case" by Petracca et al.

We would like to thank the Reviewer for her/his constructive comments and suggestions, which have improved the manuscript.
Please find our replies to each comment below. Referee comments are reported in black. Our replies are given in red.

The study "Volcanic cloud detection using Sentinel-3 satellite data by means of neural networks: the Raikoke 2019 eruption test case" by Petracca et al. introduces a scene classification algorithm for the Sentinel-3 Sea and Land Surface Radiometer data based on neural networks. The classification is applied in a case study of the eruption of the Raikoke volcano in 2019. While the focus is on detecting volcanic ash plumes the classification mask also provides information on the surface, underlying surface under volcanic ash, and clouds. Although the paper is well structured and written I miss substantial information on the neural network. No information on how it was coded nor the source were provided. Moreover the results presented in this study lack a comparison with already published findings on the Raikoke eruption and measurements by other instruments. Hence I'd recommend a major revision before publication.

General comments:

In the introduction solely volcanic ash measurements in the mid-infrared are discussed. However the SLSTR mainly has channels in the VIS to near infrared spectral range. I suggest to also introduce VIS/near-IR volcanic ash measurements.

The volcanic ash measurements discussed in the introduction specifically concern the Thermal Infrared Region (TIR) ranging from 7 to 14 µm, not the mid-infrared region. In the TIR region indeed we find the most important information for volcanic ash measurements, while the VIS/NIR channels do not provide added information.
Besides, the SLSTR instrument has the ATSR sensor as heritage and it was designed around the IR channels. The VIS/NIR channels were added to assist in detecting clouds for the main purpose of using the IR channels to derive SST, and the whole innovation of the dual view was to aid the derivation of SST from the IR channels.

Throughout the manuscript ``weather clouds'' are mentioned. Please specify what you mean. Ice clouds, liquid clouds, mixed phase clouds, or all?

"Weather clouds" stand for all types of meteorological clouds. Now, in the revised version we use always "meteorological clouds".

The description of the case study on the Raikoke eruption lacks references. Please have a look at the publications in this special issue to verify your reconstruction of the plume (in Fig. 1) and to substantiate your estimates of SO2 and ash.

More details on the Raikoke eruption have been inserted and new references have been added. Please find the new references below:

- Bruckert, J., Hoshyaripour, G. A., Horváth, Á., Muser, L. O., Prata, F. J., Hoose, C., and Vogel, B.: Online treatment of eruption dynamics improves the volcanic ash and SO2 dispersion forecast: case of the 2019 Raikoke eruption, Atmos. Chem. Phys., 22, 3535–3552, https://doi.org/10.5194/acp-22-3535-2022, 2022.
- Gorkavyi, N., Krotkov, N., Li, C., Lait, L., Colarco, P., Carn, S., DeLand, M., Newman, P., Schoeberl, M., Taha, G., Torres, O., Vasilkov, A., and Joiner, J.: Tracking aerosols and SO2 clouds from the Raikoke eruption: 3D view from satellite observations, Atmos. Meas. Tech., 14, 7545–7563, https://doi.org/10.5194/amt-14-7545-2021, 2021.
- Muser, L. O., Hoshyaripour, G. A., Bruckert, J., Horváth, Á., Malinina, E., Wallis, S., Prata, F. J., Rozanov, A., von Savigny, C., Vogel, H., and Vogel, B.: Particle aging and aerosol–radiation interaction affect volcanic plume dispersion: evidence from the Raikoke 2019 eruption, Atmos. Chem. Phys., 20, 15015–15036, https://doi.org/10.5194/acp-20-15015-2020, 2020.
- Prata, A. T., Grainger, R. G., Taylor, I. A., Povey, A. C., Proud, S. R., and Poulsen, C. A.: Uncertainty-bounded estimates of ash cloud properties using the ORAC algorithm: Application to the 2019 Raikoke eruption, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2022-166, in review, 2022.

The methodology section I found somewhat confusing. Maybe separate the instrument description from the method description. The description of both instruments, MODIS and SLSTR, lack some information. What is their spectral range? What is their equatorial crossing time? Since when are they operating? What is the oblique view of SLSTR, which is mentioned later? Which data products were used? First I had the impression that the classification categories (Ash over sea, ash over clouds, sea surface, ...) are MODIS products. Only later I realized that you made up these categories manually from MODIS Eyjafjallajökull observations. Please improve the description.

A section (number 3) regarding instruments specifications has been inserted.
The description of the classification categories has been improved and the lack of some of the species (i.e. classification classes) in MODIS standard products has been remarked in the text.

Concerning the neural network, how did you build the network? Did you use Python and some packages? Did you use anything else? Please provide more information.

As added in the Code Availability section, the procedure has been developed in MatLab. In particular, the MatLab Deep Learning Toolbox has been used to implement the NN. The code of the procedure ran with a CPU i7-9850H (6 core, processor base frequency at 2.60 GHz) and it takes about 30 minutes for training the adopted model, and it takes few seconds for applying the adopted model. All these information are now included in the text.

Also you mention the time benefit of using NNs. How much time did it take to train the NN? How long does it take to analyse a scene with the NN compared to the BTD method? When mentioning the speed advantage, please provide numbers/measurements.

The problem is not strictly related to the computation time of BTD which is actually very fast, but to the reliability and the time consumption associated to the choice of the threshold to be used, which is based on a subjective interpretation. Indeed, using simply BTD < 0 °C (as in standard procedure) not always gives good results. The choice of the BTD threshold needs more time (Radiative Transfer Model simulation) and the presence of an operator. We can say that the NN approach, keeping the operation fast, can be more reliable and objective compared with the BTD method in general. NN is indeed able to make the detection of ashy pixels in automatic way, once properly trained (is the training that needs much time, but once done it the application is fast). The time needed to make the classification of ash and other classes of a SLSTR image with our model is of the order of few minutes.

When comparing the results from the BTD-method with the results of the NN-approach, please comment on the sensitivity of both methods (BTD and NN), as well as the manual detection in the VIS, on the ash AOD. Why should the BTD-approach lead to false positives in the case of the Raikoke?

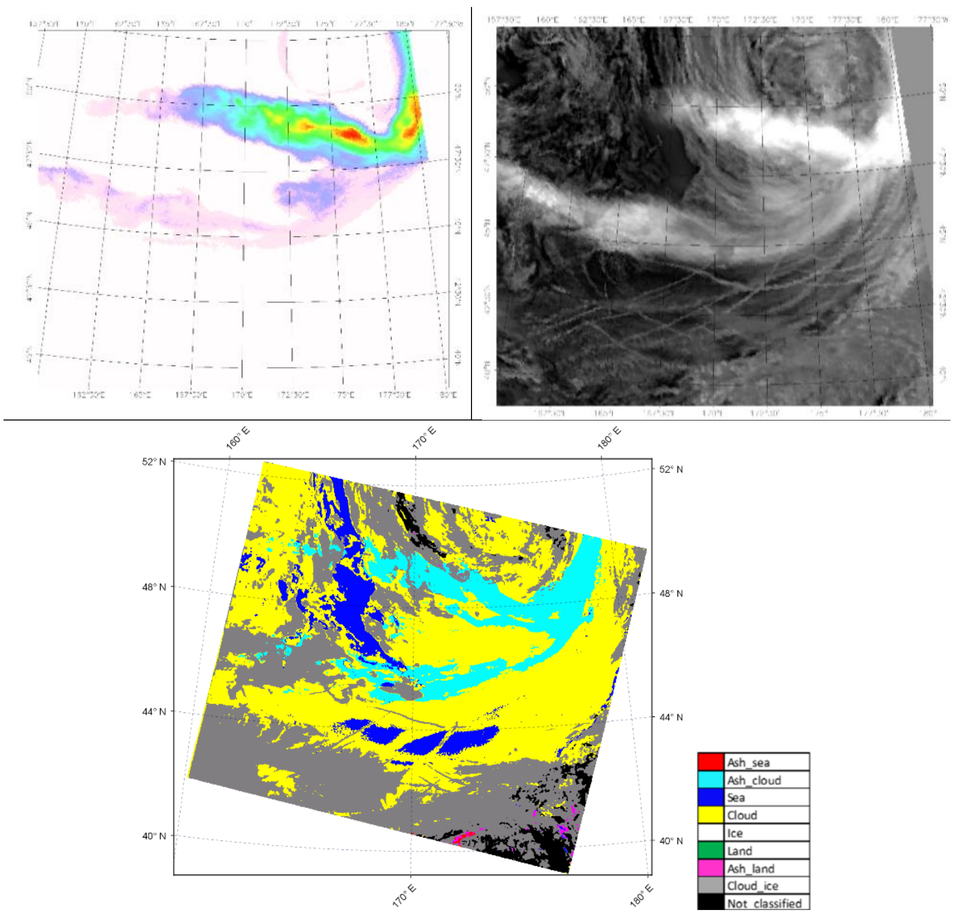
We added quantitative conclusions in Table 4 analysing NN and BTD < 0 °C compared to the Manual Plume Mask.
Probably the main reason for false detections is that there could be low thermal contrast. Detection of ash over cold surfaces can be an issue (ash cloud and underlying surface may have similar temperatures). Another potential issue for geo sensors only is that at high viewing zenith angles there is increased sensitivity up to a critical angle, after which there can be positive differences for ash. This can lead to both false positives and false negatives. It gets very complicated because the pixel size also increases which makes heterogeneity also an issue.
The manual detection is not be made with VIS, but with TIR channels and brightness temperatures, see next comments for detailed discussion.

I clearly disagree that Section 4.1 is a validation of the method. The reference is tuned towards an ash plume discernible in RGB satellite images. The detection sensitivity towards ash/aerosol AOD in nadir geometry and VIS spectral range is different to other wavelengths and satellite measurement geometries. Since the NN method relies on multiple wavelengths ranging from VIS to mid-IR, the results should be compared to VIS to mid-IR standard ash/aerosol detection products. Why don't you compare with measurements of other instruments, e.g. TROPOMI, AIRS, IASI, OMI, GOME-2, CALIPSO?

Although we acknowledge that our comparison is not perfect and pure, as far as we know there are no ash standard product and the manual plume mask we realized is the only way to obtain a benchmark for a quantitative pixel by pixel comparison. However, now we changed the name of that section to "Vicarious Validation".
Moreover, we think we could consider the Sentinel-5P/TROPOMI SO_2 product only for qualitative comparison (see figure and comments below), while a full reliability of an Ash Index or an Aerosol Index product may be debatable. As an example, we report below the Aerosol Index from TROPOMI, but the interpretation of that data appear more complex than the SO_2 layer in this case. There are many issues validating classification results against those obtained with other instruments (Corradini, S., Guerrieri, L., Brenot, H., Clarisse, L., Merucci, L., Pardini, F., ... & Theys, N. (2021). Tropospheric Volcanic SO2 Mass and Flux Retrievals from Satellite. The Etna December 2018 Eruption. Remote Sensing, 13(11), 2225) for example the different acquisition time, the different pixel size, etc.
Moreover, it has to be clarified that the manual plume mask we realized and we took as reference is not tuned towards an ash plume discernible in RGB satellite images but it is obtained from TIR channels (BTD thresholds and brightness temperatures) (see l279-288), this has been now better clarified in the text.

Commentato [ip1]: To be modified at the end

Here a qualitative comparison between S5P/TROPOMI SO_2 and Aerosol Index 354_388 products collected the 23 June 2019 at 02:03 UTC and NN plume mask for the S3/SLSTR data collected the 22 June 2019 at 23:01 UTC is shown.
The S5P/TROPOMI products have been georeferenced in the SLSTR grid (23:01 UTC image).



As we can observe, the NN plume mask derived from SLSTR image is reasonably similar to the SO_2 plume derived from TROPOMI. However, the output of our classification is not the SO_2 plume but the ash plume, even if they are connected to each other.

Moreover, the application of this method to only 2 scenes of a single volcanic eruption, measured on the same day is rather inconclusive. Please consider applying the NN method to other volcanic eruptions (as e.g. Gray and Bennartz, 2015, tested their NN approach to 7 volcanic eruptions). Also, how would you method deal with desert dust, which is a challenge to the BTD approach?

Overall, the main purpose of the paper was to develop a neural network model able to classify SLSTR products for the Raikoke 2019 eruption, investigating the feasibility of training the model with MODIS data at comparable latitudes given the lack of SLSTR products for eruptions at such latitudes. Thus, our work does not present a general and global algorithm for ash classification, but it can be considered a good starting point to develop a technique with broader applicability, for which a deeper investigation is needed. We considered this improvement in future steps, in particular we planned to build different NN models for different latitude belts which can be defined to cover the whole globe. We also have inserted some comments dedicated to the uncertainties and limitations of the proposed model in the section "Results and Discussion" and "Conclusions".
In order to introduce the desert dust class (we have already considered it as a future step) we need to create a dataset comprising pixels affected by desert dust, but in the scenes we considered the desert dust is absent.

Specific comments:

l33-34: Please specify coarse and fine in µm.

We revised and changed in the text (first lines of Introduction) as below:
"In general, from the start of the eruption, volcanic emissions are composed of a broad distribution of ash particles, ranging from very fine ash (particle diameters, d < 30 µm) increasing in size to tephra (airborne pyroclastic material) with diameters from 2 mm up to 64 mm. Larger fragments are also generated which fall out quickly; these and ash with d> 30 µm are not considered in this paper. […]"

l34-35: Volcanic plumes also have a liquid part, as formation of sulfate aerosol starts immediately e.g. see Glasow et al. (2009).

The presence of the liquid part has been inserted in the text.

l60: When mentioning other volcanic ash detection algorithms, please also consider Gangale et al. (2010) and Clarisse et al. (2013).

We added the following reference which talks about volcanic ash retrieval methods:

Clarisse, L., & Prata, F. (2016). Chapter 11—Infrared Sounding of Volcanic Ash. In S. Mackie, K. Cashman, H. Ricketts, A. Rust, & M. Watson (Eds.), Volcanic Ash (pp. 189–215). Elsevier. https://doi.org/10.1016/B978-0-08-100405-0.00017-3

l68: I wonder why you are referring to two studies using NNs for ozone retrievals, although sufficient examples for aerosol and clouds are already mentioned.

We referred to the general use of NNs in atmospheric science for parameters estimation, however those references have been removed according to your suggestion and we added Gray and Bennartz (2015).

l87: What does near the vent mean? Please specify the radius around the volcano from which the BT of the plume was derived. Also what does ``some distance upwind'' mean? Was it always the same distance? Which criteria did you apply?

The coordinates of the box near the vent are:

lon1=153.25

lon2=153.35

lat1=48.32

lat2=48.42

and the coordinates upwind from the vent are:

lon1=153.10

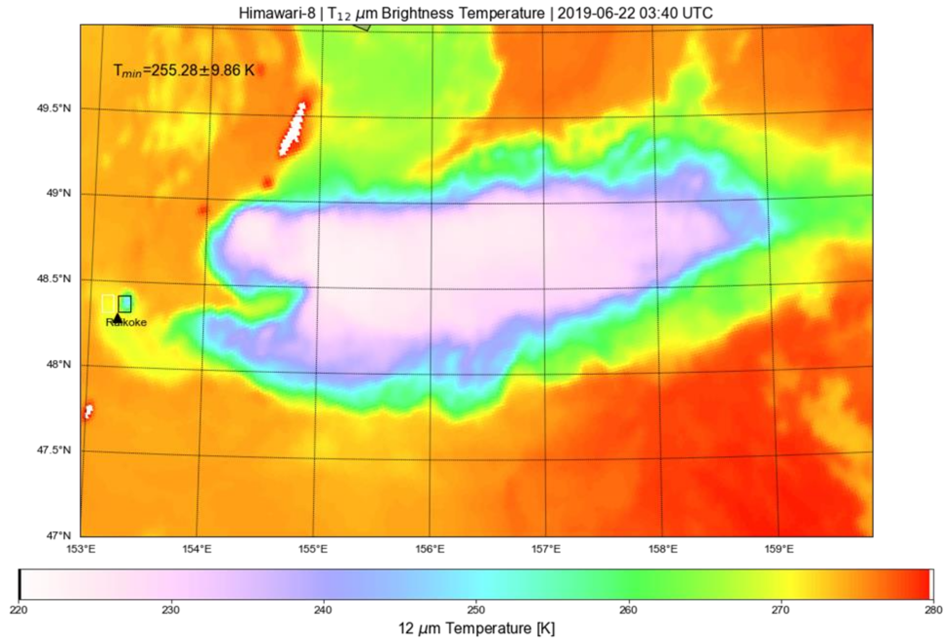
lon2=153.20

lat1=48.32

lat2=48.42

The coordinates of the vent are: lon = 153.24167, lat = 48.29167

Here's an image showing the locations:



The location information have been included in the caption of Figure 1.

l92-94: Please remove speculations about the water vapour.

The paragraph has now been improved and new references about the presence of water vapour in eruptions have been added (listed below), in particular McKee et al., 2021 refers to lightning in the Raikoke eruption and notes the presence of water to enhance lightning strikes.

Rose, W. I., D. J. Delene, D. J. Schneider, G. J. S. Bluth, A. J. Krueger, I. Sprod, C. McKee, H. L. Davies and G. G. J. Ernst, 1995, Ice in the 1994 Rabaul eruption cloud: implications for volcano hazard and atmospheric effects, Nature, 375: 477- 479.

McKee, K., Smith, C. M., Reath, K., Snee, E., Maher, S., Matoza, R. S., … Perttu, A. (2021). Evaluating the state-of-the-art in remote volcanic eruption characterization Part I: Raikoke volcano, Kuril Islands. Journal of Volcanology and Geothermal Research, 419, 107354. doi:10.1016/j.jvolgeores.2021.
(This reference refers to lightning in the Raikoke erption and notes the presence of water to enhance lightning strikes).

Murcray, D. G., F. J. Murcray, D. B. Barker, and H. J. Mastenbrook (1981), Changes in stratospheric water vapor associated with the Mount St. Helens eruption, Science, 211, 823–824.

Glaze, L. S., S. M. Baloga, and L. Wilson (1997), Transport of atmospheric water vapor by volcanic eruption columns, J. Geophys. Res., 102, 6099–6108, doi:10.1029/96JD03125
Sioris, C. E., A. Malo, C. A. McLinden, and R. D'Amours (2016), Direct injection of water vapor into the stratosphere by volcanic eruptions, Geophys. Res. Lett., 43, 7694–7700, doi:10.1002/ 2016GL069918.

Xu, J.; Li, D.; Bai, Z.; Tao, M.; Bian, J. Large Amounts of Water Vapor Were Injected into the Stratosphere by the Hunga Tonga– Hunga Ha'apai Volcano Eruption. Atmosphere 2022, 13, 912. https:// doi.org/10.3390/atmos13060912

Millán, L., Santee, M. L., Lambert, A., Livesey, N. J., Werner, F., Schwartz, M. J., et al. (2022). The Hunga Tonga-Hunga Ha'apai Hydration of the Stratosphere. Geophysical Research Letters, 49, e2022GL099381. https://doi. org/10.1029/2022GL099381

l100: Please explain what is a ``multilayer perceptron neural network"?

A brief introduction to the MLP NN has been inserted in the methodology section as reported below:
"The MLP NN structure (Gardner et al., 1998, Atkinson et al., 1997) consists in a multi-layer architecture with three or more types of layers. The first type of layer is the input layer, where the nodes represents the elements of a feature vector. The second type of layer is the hidden layer, which could be one or more layers composed of nodes. The third type of layer is the output layer and it represents the output data, which are the classes to be distinguished and are set to one (that of the chosen class) or zero (all other nodes) in image classification problems. All nodes (i.e. neurons) are interconnected and a weight is associated to each connection. Each node in each layer pass the signal to the nodes in the next layer in a feed-forward way, and in this passage the signal is modified by the weight. The receiving node sums the signals from all the nodes in the previous layer and elaborates it through an activation function before to pass it to the next layer."

l108: What is the difference between Sentinel-3A and 3B?

Sentinel-3A and Sentinel-3B are two platform carrying the same instrument SLSTR, Sentinel-3B's orbit is identical to Sentinel-3A's orbit but flies +/-140° out of phase with Sentinel-3A. This information has been included in Section 3 regarding the details of the instruments.

l109: Which procedure is meant here? I don't understand why this is mentioned after the instrument description.

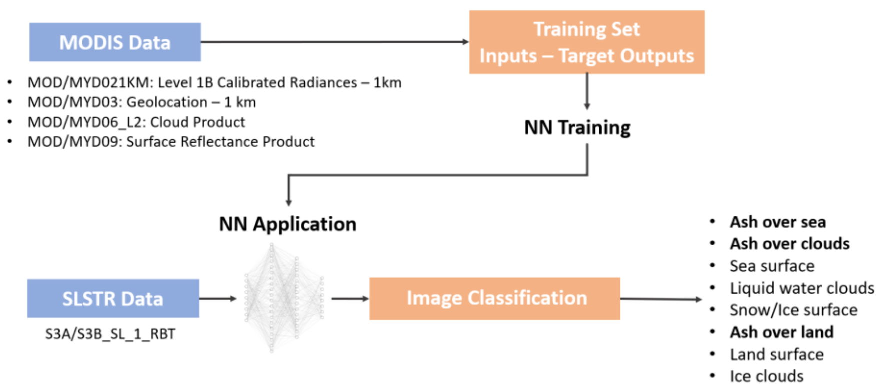
This part has been removed given that it was already discussed in the Introduction.

Table 1: Please provide consistently the bandwidth for both instruments. Did you use all channels in the NN?

We add other information in Table 1, including bandwidth.
Yes, we used all the channels mentioned in Table 1 for the training and the application of NN model, this detail has been also remarked in the text.

Fig. 2: Do the text ``Neural Network'' and the picture mean the same, or are this two different neural networks? Also there are two arrows from SLSTR to both? networks leading to one classification. Are two different networks used for the classification?

The figure has been modified as below. Only one neural network has been used.



l116: What does ``nine MODIS data'' mean? Is it 9 days of data? Is it 9 swathes? Is it 9 images? Please indicate the lat/long region around Eyjafjallajökull that was selected.

"nine MODIS data" has been modified in "nine MODIS granules" in the text. We mean 9 MODIS images.
The coordinates of the region around the Eyjafjallajökull considered for the training dataset generation are reported below:

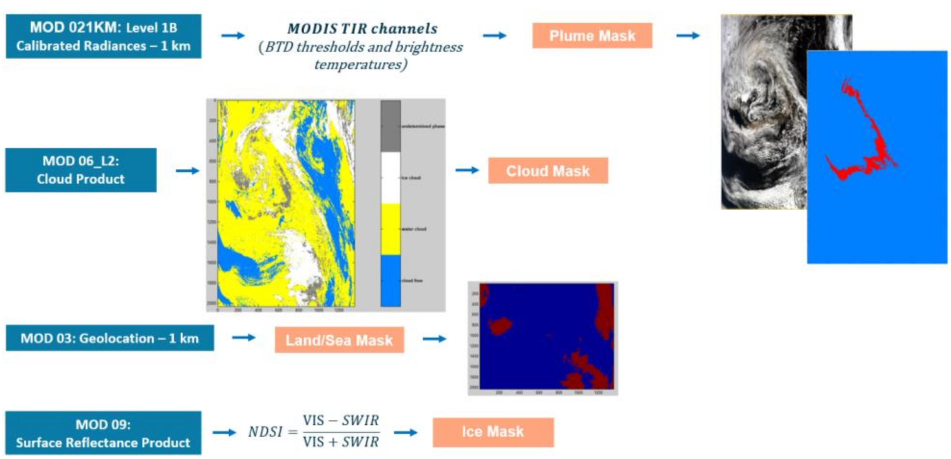
lon1=-15.28°
lon2=-23.91°
lat1=63.25°
lat2=64.07°

l117: What does pattern mean? Is pattern=pixel?

One training pattern (i.e.: training example, i.e.: "ground truth") corresponds to one pixel of a specific target class as identified in MODIS images through the semi-automatic procedure (see text l185-194). This means that we have several patterns for each class, which corresponds to the pixels associated to that class according to the semi-automatic procedure aforementioned. In particular, not all the pixels of the considered MODIS image are included in the training dataset (i.e.: the ensemble of the training patterns), but only a part of them are randomly included.
An explanation has been now introduced in the text (l169-178).

l133-141: Where and how large are the uncertainties of your ground truth? Are you considering the visual classification of RGB-images as the reference?

As already discussed in previous comment the manual plume mask we realized and we took as reference does not come from a visual classification of RGB-images but it is obtained from TIR channels (BTD thresholds and brightness temperatures) (see l279-288).
Regarding the uncertainties of the ground truth, for what concerns the land and sea masks the uncertainty is almost null or however they have the same uncertainty of the MODIS land/sea mask product (since they are taken from it, in particular from MOD/MYD03 Level-1A Geolocation Fields). Also for the cloud mask the uncertainty can be considered equal to the corresponding MODIS product (MOD/MYD06_L2 Cloud Product) which have been used to create it. For the three ash classes and the ice class is more difficult to say the associated uncertainty.
The figure below shows the procedures used to create the training patterns for some target outputs as Plume_mask, Cloud_Mask, Land/Sea_Mask and Ice_Mask. The example is referred to one of the MODIS granule listed in Table 2.



See the following reference on NDSI:
https://ntrs.nasa.gov/api/citations/20100031195/downloads/20100031195.pdf

l153-154: Is the a posteriori filter only applied to the categories ``land'' and ``sea'' or also to ``ash over land'' and ``ash over sea''?

The a posteriori filter is applied only to "land" and "sea" categories according to the land/sea mask available in the SLSTR data as standard product.

Fig. 5: What are the red and cyan color in the RGB image? Was the ``Not classified'' class only applied to ``Sea'' and ``Land'', or also to ``Ash_sea'' and ``Ash_land''?

The red in the RGB view indicate the land according to the colour composite adopted (RED-S3, GREEN-S2, BLUE-S1), the cyan pixels in the RGB view are NaN value.
"Not classified" class is the result of the a posteriori filter, thus it is applied to "sea" and "land" categories.

l181: Does ``... difference between ... channels S8 and S9...'' mean mean radiance (S8) - mean radiance (S9)?

As explained in the text, we mean the difference between the brightness temperatures of the two channels S8 and S9 (l247-248). The S3/SLSTR channels from S7 to S9 are already provided as Brightness Temperatures in the S3/SLSTR product.

Fig. 6: Fig. 6a shows many contrails, but in Fig. 6c only few of them are classified as ``Cloud_ice''. Can you comment on this? Why are so many classified as ``cloud'' that was introduced as liquid cloud and which rather represents low altitude clouds?

As the NN has not received specific training information on contrails, the output classification over these objects may be not consistent.

l189: What do you mean by "pixels identified as volcanic cloud but that are not below the volcanic cloud..."? Please clarify.

We mean “Pixels which are identified by the NN model as belonging to the volcanic cloud while they actually are not part of the volcanic cloud”, it means that they are easily recognizable as false detections of the BTD, i.e. false alarms.

l198-199: Here you state, that some pixels were misclassified as ``ash_land'' instead of ``ask_sea''. But shouldn't it rather be ``ash_cloud''? Most of the area around Raikoke is marked as ``cloud'' or ``ice cloud''. It would be surprising if only the region below the volcanic ash plume is not covered by clouds.

In the text we didn’t state that the pixels classified by the NN as ash on land should instead be classified as ash on sea, we only state that the pixels classified by the NN as ash on land are misclassified. We have now improved this aspect the text.

l206: What do you mean by ``water vapour cloud''? In the RGB images only ice, liquid water, or mixed clouds are visible.

Yes, we mean liquid water cloud class.

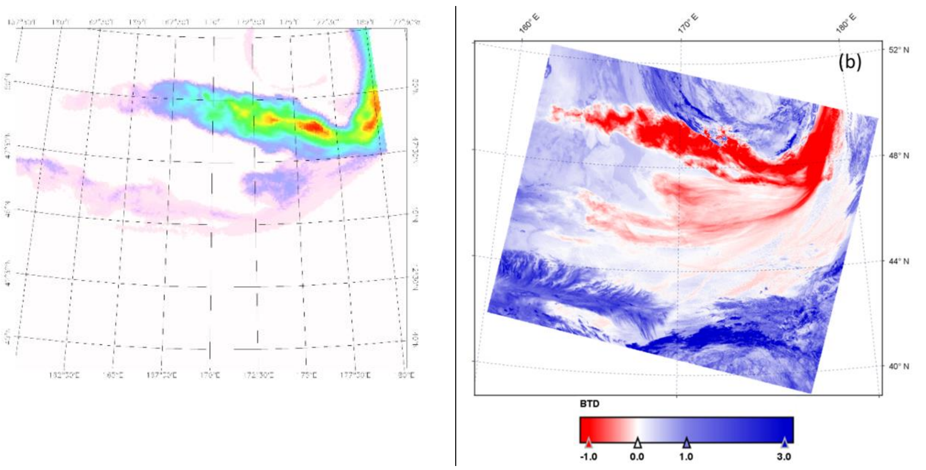
l208: Having VIS RGB images at midnight sounds strange. I assume you mean 0 UTC.

We change in the text. We refer to the SLSTR image collected at 00:07 UTC.

201-214: Why do you think the BTD approach produces wrong positive results in the case of the Raikoke eruption (Fig. 6)? Please explain. I'd rather consider the BTD ash plume realistic, because it pretty much resembles the SO_2 plume shape measured by TROPOMI on 23 June (e.g. Leeuw et al., 2021, Cai et al., 2022). How do you know that there wasn't any ash above the contrails and these underlying clouds enhanced the ash signal of the otherwise ``thin'' ash layer, which remained invisible in regions without underlying cold clouds (=high altitude clouds)?

In the text we referred to false detections in Figure 6 only in relation to aircraft contrails (which actually are not included in the plume of SO_2 from TROPOMI, see image below) and not in relation to the general shape of the BTD plume mask, which we find indeed very similar to the TROPOMI SO_2 plume. However it has to be highlighted that we are comparing two methods (NN and BTD), neither of which can be considered as “truth”.
For what concerns the presence of ash above the contrails we think that the underlying clouds would reduce the ash signal. Clouds (especially ice clouds –contrails) will have a positive BTD which will reduce or eliminate the negative BTDs (Prata, A. J. (1989a), Infrared radiative transfer calculations for volcanic ash clouds. Geophysical Research Letters, 16(11), 1293–1296. https://doi.org/10.1029/GL016i011p01293). The broader question of false positives is probably

related to thermal contrast, and perhaps noise, pixel heterogeneity and viewing angle effects, and it needs a deeper discussion.
Here a reference related to pitfalls with the BTD approach:
Prata, F. Bluth, G., Rose, W. I., Schneider, D. and A. Tupper (2001). Comments on “Failures in detecting volcanic ash from a satellite-based technique”. , 78(3), 341–346. doi:10.1016/s0034-4257(01)00231-0



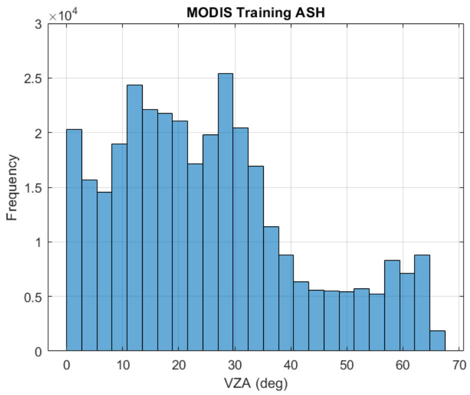
l220: Do you mean higher opacity here?

Yes, thank you. However the sentence has been rephrased and moved to the Conclusions.

Fig. 7c,d: Why are mostly clear regions (43-33N, 170-175E) classified as ``Cloud''? Please comment.

In case of the proposed work our intention was to preliminarily show an additional point with the idea to go in deep in future developments. For this reason we moved the application of the NN model to the oblique view data in the Conclusions section. As an anticipation we think it is interesting to show how the main features of the classification map (represented in Figure 7) obtained using a NN model trained only on near nadir view acquired products and used for classifying oblique view data are mostly conserved.
The complexity of the problem also involves the training dataset generation and this can produce error such as the one pointed out by the reviewer. In fact, below we report the histogram of the View Zenith Angles (VZA) used for MODIS Training (9 images) related to the pixels considered as ash. The VZA's greater than 40 degrees are undersampled with respect to the others and this

could probably have an impact on the results of the off-nadir SLSTR view (SLSTR zenith angle in the oblique view is about 55°).



l224-226: What do you mean by ``different scenario"? In terms of season, latitude, and injection height, the training eruption is similar to the showcase of the Raikoke eruption.

This part of the text has now been improved.

Fig. 9: What does the white colour indicate? Why does the CSCM detect clouds in apparently clear regions?

White pixels in Figure 9 (b,d) indicate the areas for which both NN and CSCM don't detect the presence of cloudy pixels, as now has been introduced in the caption of Figure 9.
The accuracy of CSCM (Cloud Mask product of S3/SLSTR) in detecting cloudy pixels is related to the already known limitations of the Confidence in Summary Cloud mask of S3/SLSTR product.

l274: Again, what are ``meteo clouds" and ``meteo ice clouds"? Liquid and ice clouds?

Yes, "meteo clouds" are liquid water clouds and "meteo ice clouds" are ice clouds. We clarified in the text.

Technical comments:

l26-27: remove ``it" -> ...which is...
Done

l27: manually -> manual
Done

l30: NN, please introduce abbreviations
We introduce abbreviation at line 65

l33: by -> of

Rephrased

l49: region -> regions (2x)
Done

l66: in -> at
Rephrased

l84: AHI, please introduce abbreviations
Done

Fig1 caption: was -> were; does -> do
Done

l198: ash-on-land -> ash-over-land
Done

l212: respect -> with respect
Done

References:

Roland von Glasow, Nicole Bobrowski, Christoph Kern: The effects of volcanic eruptions on atmospheric chemistry, Chemical Geology, Volume 263, Issues 1–4, 2009, Pages 131-142, https://doi.org/10.1016/j.chemgeo.2008.08.020

G. Gangale, A.J. Prata, L. Clarisse: The infrared spectral signature of volcanic ash determined from high-spectral resolution satellite measurements, Remote Sensing of Environment, Volume 114, Issue 2, 2010, Pages 414-425, https://doi.org/10.1016/j.rse.2009.09.007

Clarisse, L., Coheur, P.-F., Prata, F., Hadji-Lazaro, J., Hurtmans, D., and Clerbaux, C.: A unified approach to infrared aerosol remote sensing and type specification, Atmos. Chem. Phys., 13, 2195–2221, https://doi.org/10.5194/acp-13-2195-2013, 2013.

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