Interactive comment on "Volcanic ash detection and retrievals from MODIS data by means of Neural Networks" *by* M. Picchiani et al.

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Anonymous Referee #2

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Review: amt-2011-47 Volcanic Ash Detection and Retrievals from MODIS Data by means of Neural Networks M. Picchiani, M. Chini, S. Corradini, L. Merucci, P. Sellitto, F. Del Frate, and S. Stramondo

This paper describes application of neural network (NN) technique to detection and quantification of volcanic ash plumes from Etna volcano. The TIR measurements from MODIS satellite instrument are used to train and validate NN performance. To my

knowledge this is first demonstration of NN technique to volcanic ash detection and column mass retrieval. The NN technique is compared with the established BDT technique applied to the same MODIS measurements. The subject is suitable for AMT and should be published after revisions and correction outlined below.

General comments:

English language should be improved throughout the manuscript.

The manuscript has been entirely reviewed by a native speaker.

More "user-friendly" description of the NN technique would make the paper more interesting for a broader audience. From the practical point of view, the main question is whether the NN technique can be used by other researches (e.g., volcanologists, meteorologists) to study ash emissions from different volcanoes? Is the NN software publicly available and can it be customized for use with other satellite instruments and volcanic clouds?

We have simplified the explanation of the NNs theory. In particular in the introduction we have empathized the ability of NNs to learn a physical behavior from the data set. This concept was recalled in the section 5 from a more explicative point of view of statistical regression. Moreover we have highlighted the importance of the correct choice for the inputs to the net for a specific retrieval. Finally we cited the NNs simulator used for the elaborations.

The confident ash detection using NN technique was demonstrated for plumes in the near vicinity of volcano (p.8). Can the NN technique be improved to track long-range transport of volcanic ash clouds, not attached to the volcano?

The segmentation technique applied to avoid the false positive pixels is only a possible approach indicated to solve the problem. Clearly such a procedure can be used only if the main interest is to study the volcanic emissions near the vent i.e. to give insights on volcanic eruptions. We are now working on a new NN approach that will be able to

avoid the most of the false positive pixels by using also the UV-VIS MODIS channels. Such a new procedure should be able to significantly improve the long-range transport detection.

The success criteria are that NN agrees with the operational BTD technique. How independent is NN technique from the operational BTD technique? Can NN technique detect ash where BTD fails detection or provide false detection?

In this paper we propose a retrieval algorithm based on supervised NN, in principle this means that the accuracy of the results is influenced by the accuracy of the BTD, here used as supervisor. However the NNs results can overcome the performance of the BTD because the BTD detection errors can be discriminated from the NNs on the basis of statistical behaviour of the phenomena, especially if other inputs (UV-VIS MODIS channels) are also considered. At present we try to addressing the topic considering also independent ash detection results.

Can the NN technique trained on this particular volcano be applied to a different volcano/ eruptions? Such demonstration would broaden the application of the method.

The idea is to generalize the NN using different eruptions in different parts of the world. The first results, obtained for the Eyjafjallajokull 2010 Icelandic eruption, have been already presented at the 2011 IGARSS Meeting held in Vancouver (Canada) (Picchiani et al., Paper: 3191, Session: TH1.T07: Satellite-Based Atmospheric Sounding and Imaging).

More general test for NN method would be using completely independent satellite ash measurements from different instrument (e.g., Aura/OMI UV Aerosol Index data).

The referee is right. The NN method could be extended to include the results that can be obtained with other sensors operated in the UV range, but is not the case of the present work. What we want to show is that the NN approach applied to the MODIS measurements can reproduce the results obtained by the standard BTD technique ad

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defined on the Thermal InfraRed bands at 11 and 12 μm.

I suggest validation of the technique on dense dust clouds.

As before: the aim of this work is to show the possibility to use the NN approach to reproduce the results obtained by a standard BTD technique. The BTD technique itself has been already described and discussed in several papers. For a validation by means of the inter-comparison between different satellite instrument measurements and dispersion models see for example Corradini et al. 2010 and 2011.

"specific comments":

I do not agree with the statement that current operational ash detection techniques are "so time consuming to prevent its utilization": SEVIRI ash retrievals during Eyjafjal eruption were available in near real time.

The sentence "While ash cloud detection can be readily obtained, a reliable quantitative ash cloud retrieval can be so time consuming to prevent its utilization" was referred to the ash retrievals by using the technique described in the paper. In such a procedure the simulated radiances (needed for the retrieval) must be computed in real time for each image. Because the processing time is significant (about 4 hours for the case indicated in the paper), this could prevent its utilization. In any case, to avoid misunderstandings, the sentence has been deleted from the abstract (the same concept has been deeply described in the paper).

Current satellite hyperspectral IR measurements (e.g., IASI) allow advanced ash height retrievals, particle composition, etc. Can NN scheme be trained to retrieve additional parameters (e.g. ash height)?

Yes, this is exactly the natural continuation of our work. The MODIS measurements can be used to compute the ash AOD, the ash effective radius and also the ash height (see for example Corradini et al., 2009, 2010, 2011). The NN will be trained to retrieve also this additional parameters.

Technical corrections:

1. Title: : : : [from] -> using MODIS data ?

Done

Abstract: 18-22 : these sentences should move to introduction

The sentence has been removed. The Introduction section already contains the same concepts

25 MODIS [on board which satellite?]

The description of the MODIS instrument has been inserted in Chapter 2. To emphasize that either the MODIS-Terra than the MODIS-Aqua images have been considered, in Chapter 3 (line 24) the sentence "In this work five MODIS images" has been substituted by "In this work five from MODIS-Terra and MODIS-Aqua images"

27 ash [column?] mass

The term "ash mass retrieval" already implicitly means "ash column mass retrieval"

31-32 "confusion matrix" – not clear

The concept of confusion matrix has been better explained changing the sentence: The classification accuracy has also been quantitatively analyzed by confusion matrices, computed with and without the region growing step (see Table 4). "showing the level of agreement between two classifications" with the sentence: "The classification accuracy has also been quantitatively analyzed by confusion matrices, showing the level of agreement between two classifications, e.g. BTD and NN, computed with and without the region growing step (see Table 4)."

Introduction: 9 loss of power [and in extreme cases] failure : : :

The sentence "(loss of power, failure of high-bypass turbine engines, abrasion of turbine blades, windscreens, fuselage, and Pitot static tubes, see Miller and Casadevall,

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2000" has been reworded in: "(abrasion of turbine blades, windscreens, fuselage, and Pitot static tubes, loss of power and in extreme cases failure of high-bypass turbine engines, see Miller and Casadevall, 2000)"

17 explain acronym: BTD

Done

18-21: reword sentence 29-30

Done

Do not agree that traditional physics based retrievals are time consuming. Look up tables can be pre-computed allowing NRT traditional ash retrievals (e.g., BTD, UV Aerosol Index)

See the first answer on "Specific Comments"

Page 3

7 "incorporate a priori knowledge and realistic physical constraints", while on line 2 "independence from a priori constrains " is claimed. Does training dataset plays a role of an a priori constraint in traditional inversion methods?

The sentences are not in contrast because the first one refers to the possibility of incorporate independent a priori known information into the NN, while the sentence "the independence from a priori constrains about the data distributions" is about the independence of the NNs from the assumption of data statistical distribution. In this study an example for the first property could be taking of the sea surface temperature as additional input to the NN, while the second one refers simply to the fact that the Modis channels 31 and 32 may have distributions not known a priori. To clarify this difference the sentence "incorporate a priori knowledge and realistic physical constraints" has been substituted by: "incorporate independent knowledge and realistic physical constraints".

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19 replace "phenomenon" → cloud

Done

21 quasi - > near

Done

27 "morning overpass" – why the second night overpass is not considered?

The sentence "The two satellites have different equatorial crossing times: Terra is characterized by a morning overpass, while Aqua by an afternoon one" has been substituted by "Terra's descending node (from north to south) crosses the equator in the morning while the Aqua ascending node (south to north) crosses the equator in the afternoon"

Page 4

5 [Mt. Etna] is the largest and : :

Done

8 specify which gases ?

Done

20. remove word "description"

Done

21. Description -> Difference

Done

25 what is "negative ash detection"? Change to "missing ash clods".

With the sentence "negative and positive ash detection" the authors would emphasize that the false ash detection is twofold: false positive when some pixels are recognized

as ash affected but in fact no ash is present and vice-versa for negative. The sentence "negative and positive ash detection" has been substituted with "("false positive" when some pixels are recognized as ash affected but in fact no ash is present and vice-versa for "false negative")"

Page 5

19 I wonder if more recent measurements of the ash refractive index exist, they should be quoted. Same for Etna mass density.

Generally two volcanic ash refractive indexes are used for the ash optical properties retrievals: the first derives from Volz (1973) while the second from Pollack et al., (1973). The two refractive indexes are used in case of basaltic and andesitic ash respectively. Because no Etna volcanic ash refractive index measurements, in the TIR spectral range, are available and being the Etna volcanic ash emission mainly composed by basaltic particles, the Volz (1973) refractive index is generally considered a good approximation. However what is important to emphasize is that the results shown in this work take into account the retrieval errors due to the ash refractive index uncertainty, according to Corradini et al., 2008a. As for the ash refractive index, the Etna volcanic ash density is not known. For the different volcanic eruption, density values around 2.6 106 g/m3 are generally considered a good assumption (see for example: Prata and Grant, 2001; Yu et al., 2002; Corradini et al., 2010; Corradini et al., 2011).

27 accordingly => according

Done

Page 6 section 4.1 is too short. Expand or merge with section 4.

The Section 4.1 has been merged in Section 4

11. "most effective channels" – explain 3 channel selection. Are other MODIS channels not useful for ash detection?

The reasons why these three channels have been considered has been described in Chapter 2: "In the present work the bands 31 and 32 have been used for the volcanic ash detection and retrievals by using the Brightness Temperature Difference (BTD) procedure (see section 4). In the NNs approach (see section 5) the band 28 is also used to account for the atmospheric water vapor effect on ash detection (Corradini et al., 2008a)."

13. Provide center wavelengths for MODIS channels used.

Such information has been inserted in Chapter 2.

23-33. Understanding section 5 requires prior reading of all cited references, which limits its audience. I suggest shifting the focus to a more "user friendly" description of the NN model for a broader audience (e.g., volcanologists) and how it should be trained for volcanic ash detection? Is NN software publicly available? If so, how it can be customized and trained for different eruptions ?

We have simplified the explanation of the section 5 theory. In particular the concept of statistical non-linear regression was introduced in the sentence: " The NNs is considered to be a method that realizes a non-linear regression between sets of inputs and outputs, where weights are the free parameters. The regression is done during the learning stage by the progressive and iterative adjustment of the weights, on the basis of a set of examples data, also called training patterns. At each cycle of the learning stage the error, between the outputs computed by the NN and the known true outputs is computed and the weight are changed in order to minimize the error. In this way the information contained in the training set is transferred to the NN architecture." Moreover we have highlighted the importance of the correct choice for the inputs to the NN for a specific retrieval. Finally we cited the NNs simulator used for the elaborations and its suitability for remote sensing application .

33 remove "it"

Done

Page 7

23 This latter .. -> The latter

Done

32 remove "off"

Done

Page 9

16 different NN topologies – explain

Done

19 ": : : all the MODIS" - remove "the"

Done

22 "false positive ash detection" -> false ash detection

"false positive" because some pixels are detected as ash pixels but are in fact artefacts, see the answer before

23 "of the ash : : : " -> to the ash

Done

28 Can BTD ash signal far from volcano be real?

Yes, many papers describe the detection and retrievals of volcanic ash far from the vents (see for example Thomas and Prata, AMTD, 2011).

P10 3 "Confusion matrices" – clarify

The concept of confusion matrix has been better explained changing the sentence:

The classification accuracy has also been quantitatively analyzed by confusion matrices, computed with and without the region growing step (see Table 4). "showing the level of agreement between two classifications" with the sentence: "The classification accuracy has also been quantitatively analyzed by confusion matrices, showing the level of agreement between two classifications, e.g. BTD and NN, computed with and without the region growing step (see Table 4)."

5 "K coefficient parameters" - explain

The sentence: "i.e. a measure of inter-rater agreement (Choen, 1960)" was adding to explain the concept.

13. "is the same of the ash detection" –> is similar to the ash detection

Done

31." always major.." -> always larger

Done

33. remove "it"

Done

Page 11

25 "development" -> processing

Done

29 remove "the"

Done

p18 Table 3 is missing

We have checked and corrected the word file, anyway the table is present in the pdf discussion paper on amtd site.

<div align="center">C1982</div>