A NEURAL NETWORK ALGORITHM FOR VOLCANIC ASH DETECTION IN THE 2019 RAIKOKE ERUPTION

TOR VERGATA UNIVERSITÀ DEGLI STUDI DI ROMA

GEO-K

INGV

esa

ATMOS 2021

VISTA VOLCANIC MONITORING USING SENTINEL SENSORS BY AN INTEGRATED APPROACH

I. Petracca [1], D. De Santis [1], S. Corradini [2], L. Guerrieri [2], M. Picchiani [3], L. Merucci [2], D. Stelitano [2], F. Del Frate [1], F. Prata [4], G. Salvucci [1] and G. Schiavon [1]

[1] «Tor Vergata» University of Rome, DICII, 00133 Rome, Italy

[2] Istituto Nazionale di Geofisica e Vulcanologia, ONT, 00143 Rome, Italy

[3] GEO-K s.r.l., Via del Politecnico 1, 00133 Rome, Italy

[4] AIRES Pty Ltd., Australia

INTRODUCTION

In recent years, many studies concerning the monitoring of volcanic activity have been carried out in order to better manage the emergency phase related to an eruption event. The main issue which such events involve is related to the aviation security, the ash particles may indeed cause engine stall and other structural damages to other parts of the aircraft. For this reason, a fast and reliable method which allows to monitor the volcanic plume is mandatory in order to define as soon as possible no-fly zones. Satellite instruments, with their large coverage and high revisit time, and Neural Networks (NNs), with their brief processing time once properly trained, represent suitable tools for this purpose.

In our work we deal with the volcanic ash detection by means of a NN-based model trained with Terra-Aqua/MODIS (MODerate resolution Imaging Spectroradiometer) data and then applied to Sentinel-3/SLSTR (Sea and Land Surface Temperature Radiometer) data, given that the two sensors have similar spectral characteristics and spatial resolutions. Since the wide availability time series of MODIS data [2], they have been used to extract the training patterns from which the NN has to learn during the training phase. As test case the 2019 Raikoke eruption has been considered. The Raikoke volcano is located in the Kuril Island chain, near the Kamchatka Peninsula in Russia (48.3°N, 153.2°E). On June 21, 2019 at about 18:00 UTC Raikoke started erupting and continued erupting until about 03:00 UTC on 22 June, 2019. During this period, Raikoke released large amounts of ash and SO2 into the stratosphere.

Raikoke eruption on 22 June 2019 – ISS image

MATERIALS & METHODS

A MultiLayer Perceptron Neural Network (MLP NN) [1] has been trained with MODIS data collected during the 2010 Eyjafjallajökull (Iceland) eruption, and then applied to SLSTR data collected during the 2019 Raikoke eruption to classify SLSTR pixels in eight objects/surfaces. A semi-automatic procedure which exploits MODIS radiances and standard products has been developed in order to create the training dataset to be used during the learning phase. The patterns extraction for the ash class is realized through the BTD (Brightness Temperature Difference) method [3].

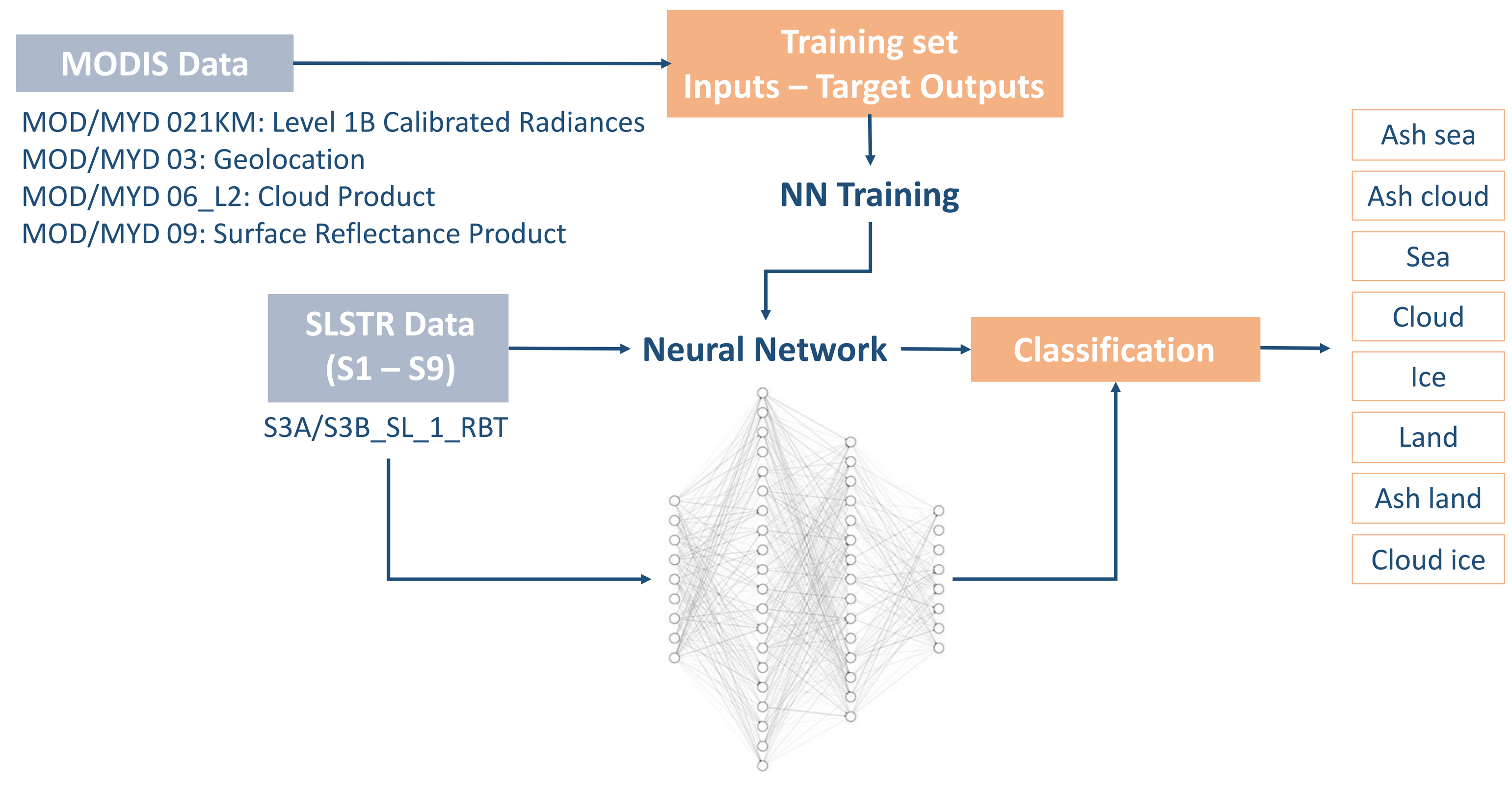
MODIS and SLSTR images considered

Date	Time UTC	Platform
6 May - JD 126	11.55	Terra
9 May - JD 129	12.25	Terra
11 May - JD 131	12.10	Terra
11 May - JD 131	13.50	Terra
11 May - JD 131	14.05	Aqua
12 May - JD 132	12.55	Terra
13 May - JD 133	12.00	Terra
13 May - JD 133	13.40	Terra

Date	Time UTC	Platform
22 June	00.07	Sentinel-3A
22 June	22.00	Sentinel-3A
22 June	23.01	Sentinel-3B
22 June	23.40	Sentinel-3A

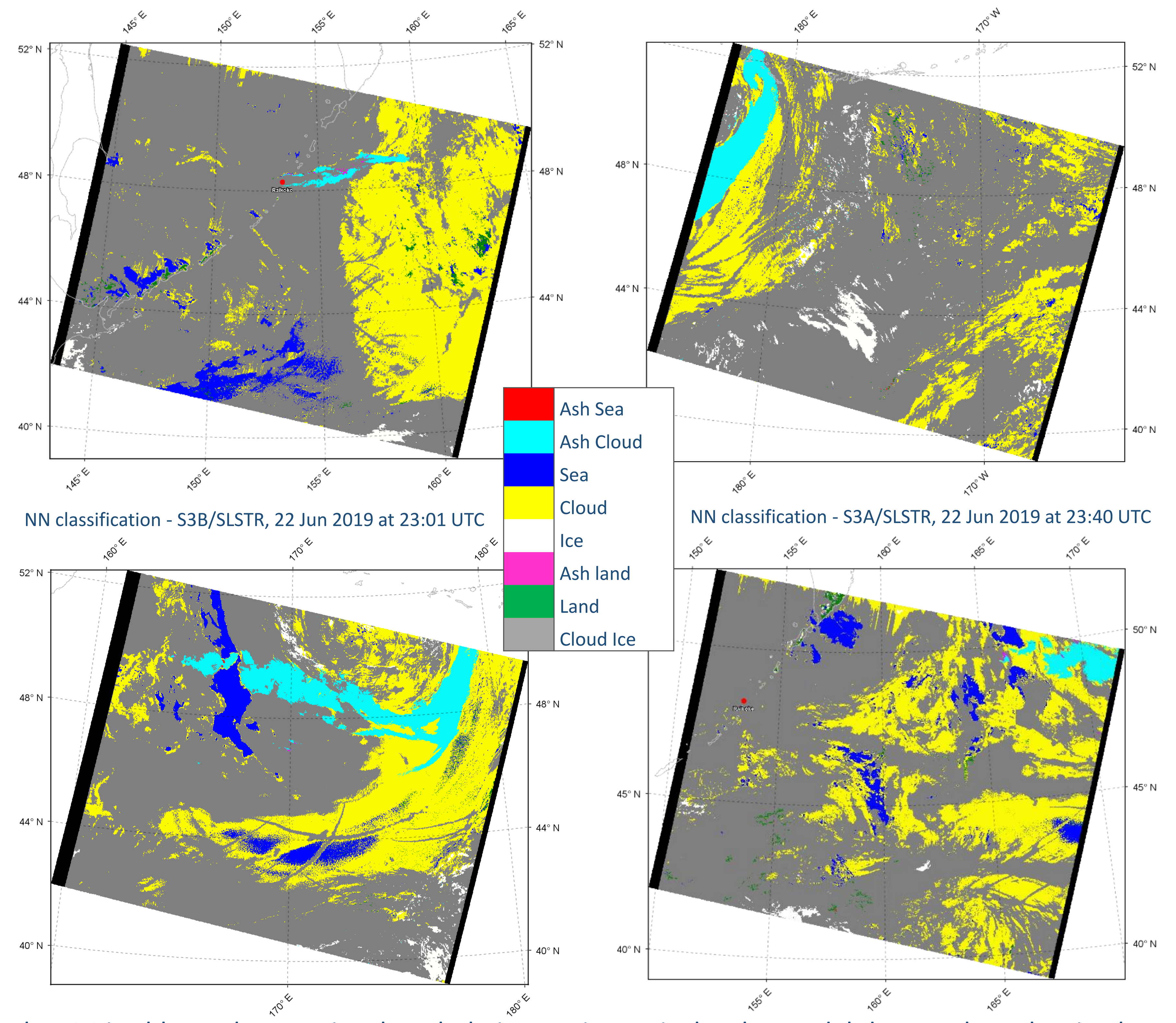
NN characteristics

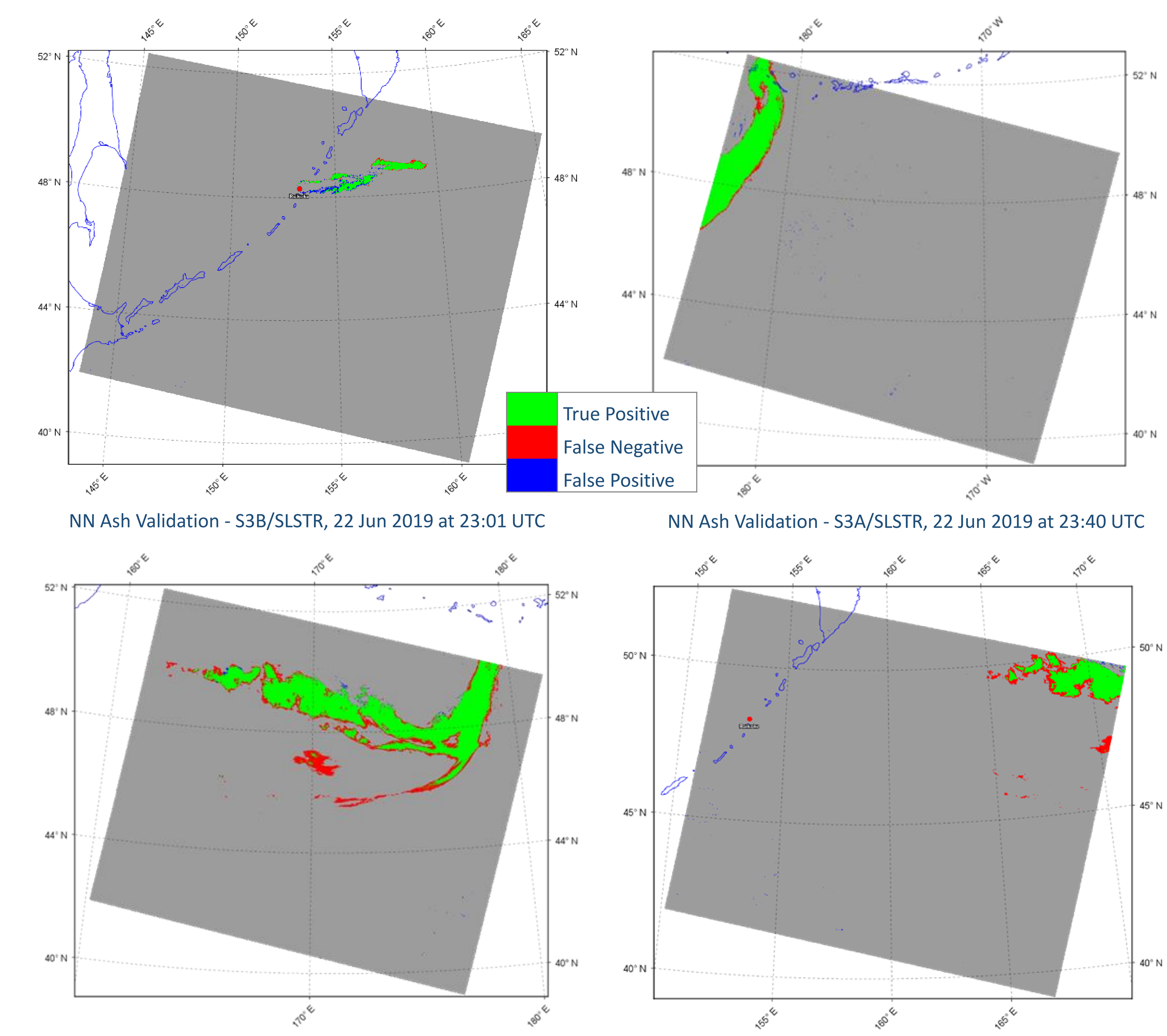
Training Set (MODIS)	Eyjafjallajökull (Iceland) 2010 eruption
Tot. Patterns	~5000
Accuracy (Validation)	93.1%
Net Parameters	• Topology: 2 hidden layers with 20 and 15 neurons respectively • Perc. Training: 75% Perc. Validation: 20% Perc. Test: 5%
Applied on (SLSTR)	Raikoke (Russia) 2019 eruption



Overall scheme of the NN detection procedure

RESULTS





The NN is able to characterize the whole image, in particular the model detects the volcanic plume as ash above meteorological clouds (cyan pixels). Despite the challenging scenario with a wide distribution of weather clouds, the comparison between the standard technique and the NN classification shows an overall good accuracy with a percentage of true positive (i.e. pixels classified as ash by both NN and BTD) always higher than 70% except for one case.

Classified Product	True Positive	False Negative	False Positive
S3A/SLSTR - Raikoke 22 June 2019 at 00.07 UTC	71.8 %	8.2 %	20 %
S3A/SLSTR - Raikoke 22 June 2019 at 22.00 UTC	89.1 %	9.5 %	1.4 %
S3B/SLSTR - Raikoke 22 June 2019 at 23.01 UTC	74.3 %	24.9 %	0.9 %
S3A/SLSTR - Raikoke 22 June 2019 at 23.40 UTC	66.7 %	32.1 %	1.2 %

Classification accuracy of the ash class for each SLSTR classified product.

Petracca et al., in preparation

CONCLUSIONS

In this work a new approach for volcanic particles detection procedure, based on satellite's sensors (MODIS and SLSTR) and neural networks, are described. The algorithm has been developed for the SLSTR instrument on board of the Sentinel-3 satellite.

The proposed algorithm allows the full characterization of the SLSTR image by identifying, among the volcanic cloud, the surfaces under the cloud itself, the meteorological clouds (and phases), land and sea surfaces.

As test cases some SLSTR products collected over the Raikoke volcano area during the 2019 eruption have been considered.

The results show that BTD standard procedure (threshold of BTD < -0.4 C°) and NN based approach identify the volcanic cloud nearly in the same area of each SLSTR image.

Further developments are under consideration in order to improve the NN accuracy and ability to generalize even over other eruptive scenarios.

REFERENCES

[1] Gardner, M. W., & Dorling, S. R., 1998. Artificial neural networks (the multilayer perceptron) – a review of applications in the atmosphere sciences. Atmospheric Environment, 32(14-15), 2627-2636.

[2] Picchiani, M., Chini, M., Corradini, S., Merucci, L., Piscini, A. and Del Frate, F., 2014. Neural network multispectral satellite images classification of volcanic ash plumes in a cloudy scenario. Annals of Geophysics, Special Issue on "Atmospheric Emissions from Volcanoes", Vol. 57, Fast Track 2. doi: 10.4401/ag-6638.

[3] Prata A. J., (1989b) Infrared radiative transfer calculations for volcanic ash clouds, «Geophysical Research Letters»,Vol. 16.

AKNOWLEDGEMENTS & CONTACT

The results presented in this work have been obtained in the sphere of the VISTA (Volcanic monItoring using SenTinel sensors by an integrated Approach) project, funded by ESA and developed within the EO Science for Society framework [https://eo4society.esa.int/projects/vista/, https://www.geo-k.co/home/projects/vista/].

Ilaria Petracca
ilaria.petracca@uniroma2.it
Via del Politecnico 1, 00133 Rome (Italy)