Volcanic ash retrieval from IR multispectral measurements by means of Neural Networks

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PURPOSE :

The purpose is to replicate the Brightness Temperature Difference (BTD) algorithm (based on the radiative transfer model) for the Ash detection and Ash mass retrieval with a Neural Networks (NNs) based technique.

The tracking of volcanic clouds is a key task for aviation safety, allowing to beware the dangerous effects of fine volcanic ash particles on aircrafts.

The BTD [*Prata et al., 1989; Wen & Rose, 1994*] requires many input parameters and it can be so time consuming that could prevent the utilization during the crisis phases. A trained NN can process new data in a very fast manner, this characteristic together with the high revisit time of the Moderate resolution Imager Spectroradiometer (MODIS) allows the development of Ash detection and Ash mass maps from the acquired satellite image in quasi real time.

SCENARIO AND DATA SET :

Mt. Etna [37.73°N, 15.00°E] is a massive stratovolcano (3330 m a.s.l.) located in the eastern part of Sicily (Italy). MODIS is a multi-spectral instrument that covers 36 spectral bands, from visible (VIS) to thermal infrared (TIR) with a global coverage in 1 to 2 days. The spatial resolution ranges from 250 m to 1000 m, depending on the acquisition mode.

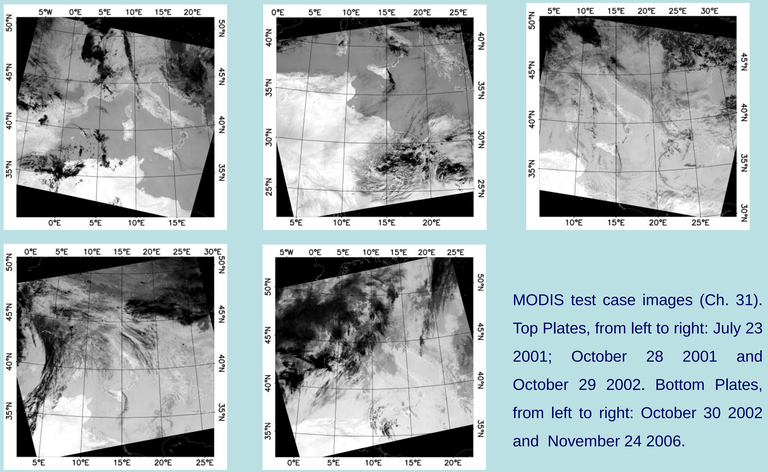
The considered MODIS measurements are representative of different (high and medium) Mt. Etna volcanic ash emissions in different seasons (spring, autumn and winter).

MODIS Channel n°	Center Wavelength (μm)	NEDT (K)	Spatial Resolution (km)
28	7.3	0.25	1
31	11.0	0.05	1
32	12.0	0.05	1

MODIS TIR considered channels and their characteristics.

Acquisition Date
July, 23, 2001 - 10:35 UTC
October, 28, 2002 - 12:15 UTC
October, 29, 2002 - 09:45 UTC
October, 30, 2002 - 12:05 UTC
November, 24, 2006 - 12:20 UTC

The considered Data set



MODIS test case images (Ch. 31). Top Plates, from left to right: July 23 2001; October 28 2001 and October 29 2002. Bottom Plates, from left to right: October 30 2002 and November 24 2006.

REFERENCES

- Corradini et Al.; "Mt. Etna tropospheric ash retrieval and sensitivity analysis using Moderate Resolution ImagingSpectroradiometer measurements", JARS, Vol. 2, 023550 ; DOI: 10.1117/1.3046674.
- Bishop C. M., "Neural Networks for Pattern Recognition", Oxford Univ. Press, pp. 374--375, 1995.
- Del Frate F. et Al.;"Application of neural algorithms for a real-time estimation of ozone profiles from GOME measurements", IEEE Trans. Geosci. Remote Sensing, vol. 40, no. 10, 2263–2270, 2002.

Prata A. J., "Infrared radiative transfer calculations for volcanic ash clouds", Geophys. Res. Lett., Vol. 16, No. 11, pp. 1293-1296, 1989.

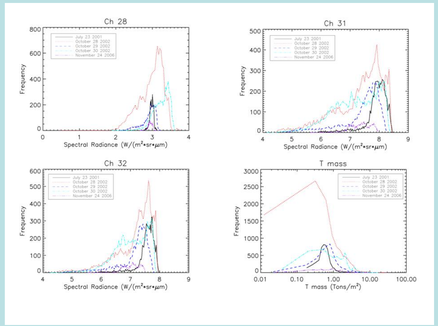
Wen S. and W. Rose, "Retrieval of sizes and total masses of particles in volcanic aerosol clouds using AVHRR bands 4 and 5", J. Geophys. Res., Vol. 99,no. D3, pp. 5421-5431, 1994.

METHODOLOGY :

Two different NNs have been trained for the ash detection and retrieval. The training information (Tr) have been derived from the results obtained by applying the BTD procedure to the MODIS measurements.

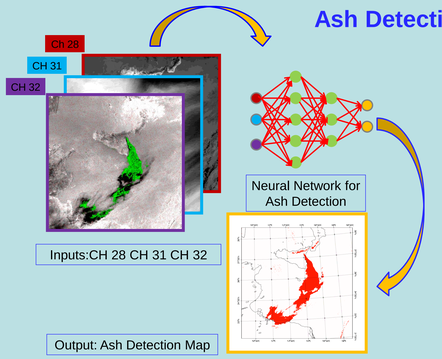
Design of the NNs

- ✓ Input-output pairs: MODIS Ch 28-31-32 – BTD procedure results.
- ✓ Empirical topology selection.



Statistical distribution computed for the three considered channels (CH 28, CH 31, CH 32) and for the Ash total mass BTD results.

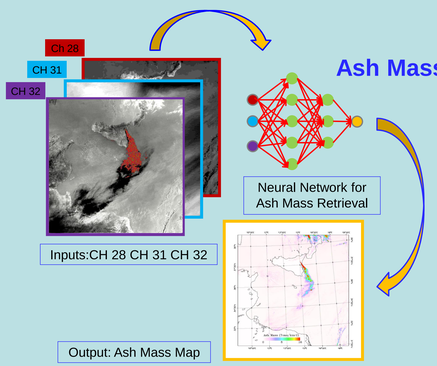
Ash Detection



Data	Tr	Ts	V	Tot
October 28 2002	37416	16306	-	810000
October 29 2002	18918	8108	-	810000
October 30 2002	-	-	810000	810000
November 24 2006	-	-	160000	160000
July 23 2001	-	-	810000	810000

The training (Tr), test (Ts) and validations (V) sets extracted from the data for the ash detection exercise. The dates with the higher statistical representativeness have been considered

Ash Mass Retrieval



The training (Tr), test (Ts) and validation (V) sets extracted from the data for the ash mass retrieval exercise. Different NNs have been trained with an increasing number of samples belonging to each acquisition and have been tested on all independent V sets in order to evaluated the accuracy and generalization at the increase of numbers of training pattern.

Data	Tr	Ts	V	Tot Ash	Tot
October 28 2002	11841	3634	2742	18271	810000
October 29 2002	5780	1774	1338	8892	810000
October 30 2002	8700	2670	2014	13384	810000
November 24 2006	1633	501	378	2512	160000
July 23 2001	6060	1865	1398	9323	810000

EXPERIMENTAL RESULTS

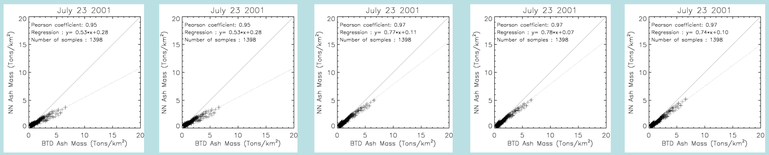
Ash Detection:

November 24 2006		
NN \ BTD	Ash	Not Ash
Ash	2673	4833
Not Ash	937	801468
Overall Accuracy= 99.28%	K Coefficient= 0.47	

November 24 2006		
NN \ BTD	Ash	Not Ash
Ash	2484	397
Not Ash	1126	805904
Overall Accuracy= 98.81%	K Coefficient= 0.77	

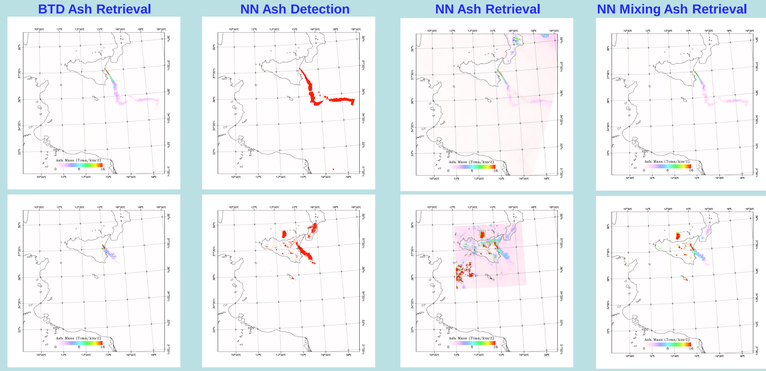
Confusion Matrix for the November 24, 2006 V sets: Left column results of NN. Right column results of NN and post segmentation processing.

Ash Mass Retrieval



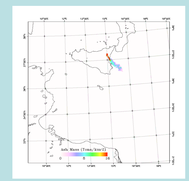
Scatter plots for the July 24 2001 V set. From left to right results from: NN1 (October 28 2002). NN2 (October 28 2002 + October 29 2002). NN3 (October 28 2002 + October 29 2002 + October 30 2002). NN4 (October 28 2002 + October 29 2002 + October 30 2002 + November 24 2006). NN5(October 28 2002 + October 29 2002 + October 30 2002 + November 24 2006 + July 23 2001)

Ash Detection and Mass Maps:



MODIS Ash maps. Top Plates: July 23 2001. Bottom Plates: November 24 2006.

In order to obtain an improved result an automatic segmentation algorithm has been applied before the computation of final Ash map.



CONCLUSIONS

- ✓ We investigated the possibility of applying the NNs to the problems of Ash detection and Ash mass esteems.
- ✓ A minimum set of MODIS channels have been used.
- ✓ The obtained results show that the NNs can replace the BTD procedure in the crisis phase management.
- ✓ Future investigations will concern the study of information content of other MODIS channels to improve the discrimination of meteorological clouds, as well as the inversion of other parameters such as the ash optical thickness (AOT) and the ash effective radius (r_e).