Geophysical Research Abstracts
Vol. 13, EGU2011-10196, 2011
EGU General Assembly 2011
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Detection and retrieval of volcanic ash from IR spectral data by means of Neural Networks approach

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The purpose of this work is to replicate the Brightness Temperature Difference (BTD) algorithm results for the ash detection and ash mass retrieval with a high operational speed Neural Networks (NNs) based technique. Follow the evolution of volcanic clouds is a very important task for aviation safety, that allows to beware the dangerous effects of fine volcanic ash particles on aircrafts.

The recent eruptions of the Icelandic Eyjafjallajokull volcano and of the Java's Mt. Merapi have shown how the tracking of the ash clouds in the atmosphere is of fundamental importance in the mitigation risks phase. Indeed from the accuracy of the algorithms used to identified the presence of volcanic ash and its mass may depend the safety of the passengers. From another point of view the air companies are subject to significant economic losses due to the variation or cancellation of routes, this latter is a further factor that leads the research of rapid and robust algorithms.

The BTD is the mostly utilized procedure for the volcanic ash detection and it's based on the selective absorption properties of the ash particles in the TIR spectral range. The difference between the brightness temperatures of two TIR channels centered around 11 and 12 micron are suitable to distinguish the ash plume from the meteorological clouds.

Furthermore applying the simplifier formulation by Wen and Rose (1994) the ash mass can be retrieved. This computation requires many input parameters and the simulation of the Top Of Atmosphere (TOA) radiances Look-Up Table (LUT). These latter are computed by means of radiative transfer models as for example MODTRAN.

The total computational time for each LUT generation is several hours, a factor that may decrease the effectiveness of the algorithm during the crisis phases.

To overcome this eventuality the potentialities of the Multi-layer Perception NN (MLP-NN) have been considered. A trained MLP-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. The MLP-NN have been used to implement a non-linear regression between the brightness temperature and the presence of ash and its mass. In this work the MODIS channels 28, 31 and 32 have been considered as input for the NN while the results obtained with the BTD procedure have been considered as training information.

The two considered data-sets come from MODIS sensor acquisition over the Mt. Etna volcano during the 2001, 2002 and 2006 eruptive events and the 2010 Eyjafjallajökull eruption. The developed procedure can be divided in three different steps. In the first two steps two different NN have been respectively used to identified the ash plume and to estimate the ash mass. Finally these previous partial results have been intersected in order to obtain a more accurate ash mass map.

The necessity of this latter step is due to the complexity of the mass esteems problem considering a minimum set of MODIS channels. Indeed, in the considered channels 28, 31 and 32, some meteorological clouds may show a similar spectral signature to the ash plume, providing of false alarms. These latter are drastically reduced computing the intersection of the results of the NN for the detection and the NN for the retrieval of the ash mass.

The comparison of the results obtained with the BTD and with the NNs is encouraging, indeed the ash detection has an accuracy greater than 90%. Moreover the ash mass retrieval shows a good agreement with that achieved by BTD procedure, with very advantageous computational time.