



# A new approach on the detection of volcanic ash clouds

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## Abstract

In this work we present a new approach on the space-borne detection of volcanic ash. Beside the detection of ash-contaminated and ash-free airspace, the algorithm gives additional information on e.g. the column mass concentration and the top altitude of detected volcanic ash clouds, and a mask of high clouds derived by the COCS algorithm [Kox 2012], which may cover the eruptive ash cloud, so that the ash cloud cannot be detected.

## VADUGS – Volcanic Ash Detection Utilizing Geostationary Satellites

In order to cope the challenges in space-borne and in-situ detection of volcanic ash and to fill gaps within air traffic management procedures the DLR-wide project Volcanic ash impact on the Air Transportation System (VolcATS) was launched in 2012.

One of the main outcomes of this project is a novel approach on the detection of volcanic ash and its nowcasting with geostationary satellites, currently focussing on the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) aboard Meteosat Second Generation (MSG, [Schmetz et al, 2002]). This instrument combines the ability to observe earth's atmosphere during day and night time due to its infrared channels (e.g. 6.2 – 13.4  $\mu\text{m}$ ) with its high temporal resolution of 5 – 15 minutes for a whole „disc“ covering a latitude from around 80° N to 80° S and a longitude of 80° W to 80° E at a spatial resolution of 3 km x 3 km (nadir).

The algorithm introduced here is based on a backpropagation neural network, called VADUGS (Volcanic Ash Detection Utilizing Geostationary Satellites), and is able to retrieve the column mass concentrations [ $\text{kg}/\text{m}^2$ ] of volcanic ash as well as the top altitude [km] of volcanic ash clouds. It is trained by simulated brightness temperatures of the SEVIRI channels, which have been obtained from radiative transfer calculations (libRadtran) [Mayer and Kylling 2005], representing a comprehensive range of different atmospheric conditions. In addition, and to account for volcanic eruptions and their manifold distributions of ash load, a broad range of particle concentrations for different ash types has been included in various layers of the modeled atmospheres, i.e. ash of the Eyjafjalla eruption in 2010 [Helbert 2010], different basic volcanic minerals such as andesite or rhyolite, and a mixture of several basic minerals [Klüser 2011]. The schematic setup of VADUGS is depicted in Figure 1.

The VADUGS algorithm is supported by the highly sensitive Cirrus Optical properties derived from CALIOP and SEVIRI during day and night (COCS) algorithm [Kox 2012]. As an example the cirrus optical thickness retrieved by COCS is shown in Figure 2 for the 17<sup>th</sup> May 2010 at 12:00 UTC.

## Applying VADUGS + COCS

Once the training is finished VADUGS can be applied to SEVIRI data retrieving column mass concentration and top altitude of a volcanic ash layer. As the runtime of both algorithms including data acquisition is less than 600 s on a common office computer, the combination of COCS and VADUGS is well suited to be part of an operational software package.

First results of VADUGS retrieving the column mass concentration and the top altitude of volcanic ash during the Eyjafjalla eruption on the 17<sup>th</sup> May 2010 at 12:00 UTC are shown in Figure 3 and 4.

## Conclusions and Outlook

We have introduced a novel approach to detect volcanic ash and to retrieve its column mass concentration and top altitude in order to support airline controllers, pilots, and authorities. With its low runtime the combination of cirrus cloud and volcanic ash detection has proven its operational character. Within the timeframe of the VolcATS project a detailed validation is planned, focussing on airborne measurements (in-situ and lidar) during the Eyjafjalla eruption 2010 as well as on measurement flights during the Saharan Aerosol Long-range Transport Aerosol-Cloud-Interaction Experiment (SALTRACE), where Saharan dust was measured over Africa, the Atlantic Ocean, and in the Caribbean.

Another major task is the development of a nowcasting method to allow for short term forecasting of the movement and expansion of the volcanic ash cloud.

## References:

Helbert, Jörn und Maturilli, Alessandro und Roush, Ted und Mannstein, Herrmann (2011) *Deriving optical constants of volcanic ash using measurements from the planetary emissivity laboratory at DLR*. Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), Seiten 1-5. IEEE. DOI: 10.1109/WHISPERS.2011.6080907. ISBN 978-1-4577-2202-8.

## VADUGS Volcanic Ash Detection Utilizing Geostationary Satellites

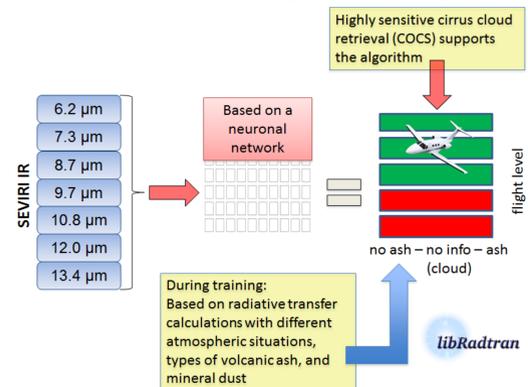


Figure 1: Schematic setup of VADUGS.

## COCS Cirrus Optical properties derived from CALIOP and SEVIRI during day and night time

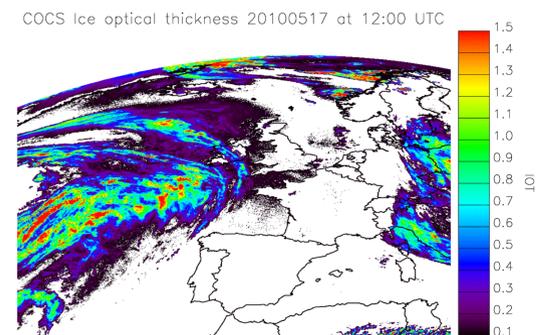


Figure 2: Cirrus ice optical thickness (IOT) derived by the COCS algorithm on 17th May 2010 at 12:00 UTC during the Eyjafjallajökull eruption.

## Applying VADUGS + COCS

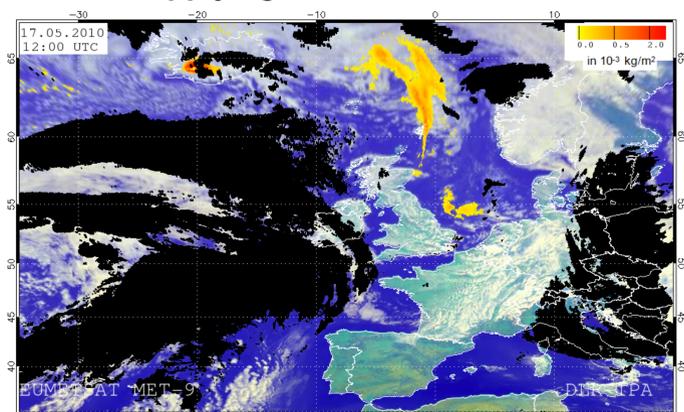


Figure 3: Column mass concentration of volcanic ash clouds during the Eyjafjallajökull eruption on 17th May 2010 at 12:00 UTC. Cirrus clouds masked black.

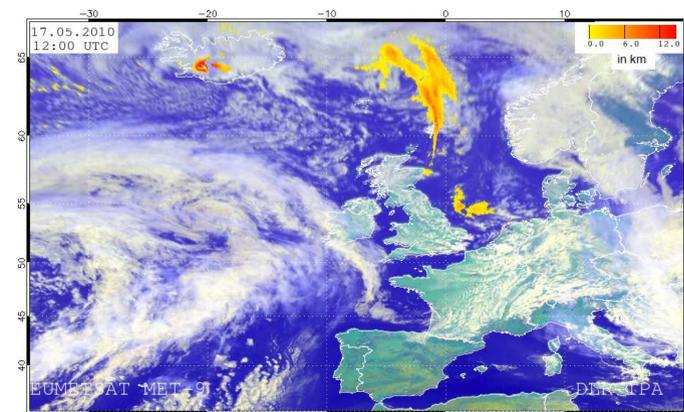


Figure 4: Top altitude of volcanic ash clouds during the Eyjafjallajökull eruption on 17th May 2010 at 12:00 UTC without the information on cirrus clouds.

Klüser, L., Martynenko, D., Holzer-Popp, T., Thermal infrared remote sensing of mineral dust over land and ocean: a spectral SVD based retrieval approach for IASI, Atmos. Meas. Tech., 4, 757-773, doi:10.5194/amt-4-757-2011, 2011.

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Schmetz, J., P. Pili, S. Tjemkes, D. Just, J. Kerkmann, S. Rota, A. Ratier, An introduction to Meteosat Second Generation (MSG), B. Am. Meteorol. Soc., pp. 977-992, 2002.



- The climate models used for the IPCC 4<sup>th</sup> Assessment Report show large differences in global mean ice water path. This is an indicator for a poor and inconsistent ice cloud data basis, as such data is used for the tuning of the models. Thus, it is desirable to reach towards a better understanding of the physical processes that govern the life cycle of ice clouds and to
- The evolution of cirrus clouds is a process with a typical timescale of hours. Their observation therefore requires data with high temporal resolution as provided by sensors aboard geostationary satellites. On the other hand active instruments on polar orbiting satellites provide the higher sensitivity and accuracy. We use the COCS dataset (Cirrus Optical properties derived by CALIOP and SEVIRI during day and night) that combines the advantages of both.
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