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LIDAR MEASUREMENTS COMPARISON OF TWO VOLCANIC ERUPTIONS: ENVIRONMENTAL INFLUENCES UPON THE ROMANIAN TERRITORY

Mihai Nicolae Dănilă[1], Florin Unga[1], Marius Mihai Cazacu[1], Adrian Timofte[1,2], Mitachi Strat[1], Dan Gheorghe Dimitriu[1], Silviu Gurlui[1]

[1]*"Alexandru Ioan Cuza" University of Iasi, Faculty of Physics, 11 Carol I Blvd., 700506 Iasi, Romania*

[2]*National Meteorological Adm., Regional Forecast Center Bacau, 1 Cuza Voda Str., 600274 Bacau, Romania*

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Abstract
The eruption of both the Eyjafjallajokull (April 2010) and Grimsvotn (May 2011) volcanoes cumulated with two moments that gave headaches to the authorities and air traffic, and their impact on the environment upon Iasi region have been studied by means of different tools evidencing the complexity of the phenomena. In order to evidence the intrusion of pollutants in the cloud systems and to obtain additional data on the intrusion when the ash cloud was over our country, LIDAR measurements, meteorological (NMA), Satellite data (EUMETSAT), and various forecasting models (ECMWF, VAAC-Met Office, HYSPLIT) have been used. The new 3D Atmospheric Observatory Site of the Alexandru Ioan Cuza University of Iasi, as part of RADO (Romanian Atmospheric 3D Observatory) is presented, too.

1. Introduction

The Alexandru Ioan Cuza University of Iasi is part of the first Romanian LIDAR Network and has the only LIDAR system in the North-Eastern region of Romania. The ground installation is composed of modern environment pollution monitoring equipment, this equipment adding up to the so called 3D Atmospheric Observatory. At the national level, five such observatories were created.

FIGURE 1. The Romanian LIDAR Network (ROLINET)

Small jagged pieces of rocks, minerals, and volcanic glass the size of sand and silt erupted by a volcano are called volcanic ash. Very small ash particles can be less than 0.001 millimeters across. Volcanic ash is not the product of combustion, like the soft material created by burning wood or paper. Volcanic ash is hard, abrasive, mildly corrosive, it's not water soluble and conducts electricity when wet. Eyjafjallajokull volcano, situated north of Skogar and west of Myrdalsjokull in Iceland, has erupted at a relatively frequent rate since the last ice age. It's most recent eruption, on 14^{th} of april 2010, caused an almost complete disruption of air traffic over western, central and northern Europe for several days. The volcanic ash plumes reached Europe on the 16^{th} of April 2010 and had the highest concentrations ever measured in Europe [1].

Grimsvotn (64.416 N, 17.333 W), Iceland's most active volcano, lies largely beneath the Vatnajökull icecap. Its last eruption began on the 21^{st} of May 2011 at 19:25 UTC. This eruption resulted in the cancellation of 900 flights in Iceland, as well as in the United Kingdom, Greenland, Germany, Ireland, Norway and Scotland between the 22^{nd} and the 25^{th} of May 2011. The eruption scale has been larger than that of the 2010 eruption of Eyjafjallajökull.

Besides traditional data (forecasting maps, satellite images, meteorology data), this paper will present complementary measurements made with a LIDAR system confirming the volcanic ash plumes intrusion over Romania, in Bucharest from the Eyjafjallajokull volcano and in Iasi from Grimsvotn.

2. Analysed Data

Forecasting data from the European Centre for Medium - Range Weather Forecasts (ECMWF) [2][3] and Met Office's Volcanic Ash Advisory Centre [4] together with the satellite data obtained with the help of the Meteostat Second Generation (MSG) satellite from EUMETSAT [5], helped us extract information about the atmospheric air circulation. With the help of the LIDAR system we were able to precisely determine the volcanic ash plume's intrusion over Romanian territory.

We also used the Hybrid Single Particle Lagrangian Integrated Trajectory tool (HYSPLIT) [6] in order to determine the source of pollutants.

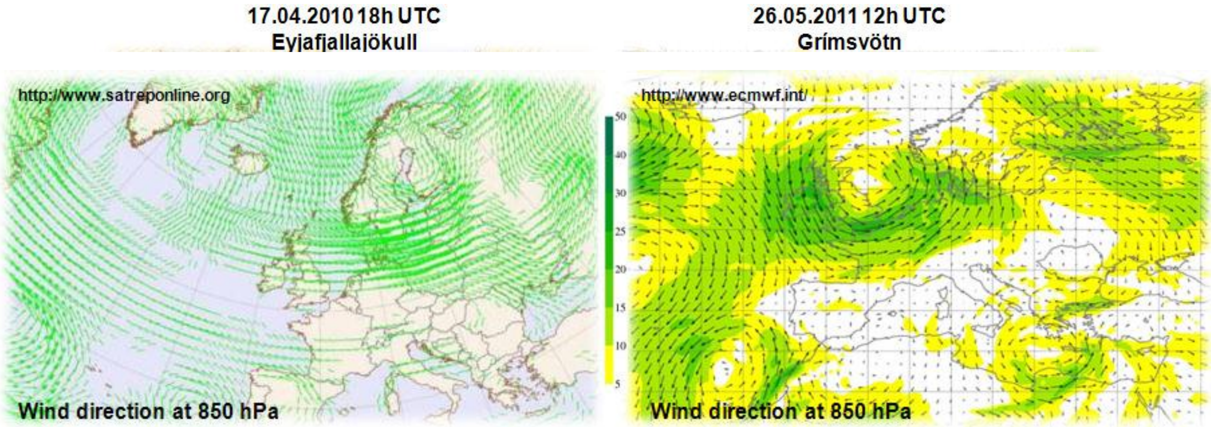

FIGURE 2. Wind direction and speed data from ECMWF

In Fig. 2 we have wind data from ECMWF for both volcanoes, on the 17th of April 2010 and the 26th of May 2011, respectively. On both cases we can see that the wind circulation was favorable for the volcanic ash plumes spread over our territory. Also, on the 17th of April 2010, ECMWF forecasted a relative humidity with values up to 40%, which is a good indicator for the appearance of nebulosity at 700 hPa.

Data from Met Office's Volcanic Ash Advisory (VAA) predicted that the volcanic ash plume from Eyjafjallajokull would be over our observation point at six o'clock PM on the 17th of April 2010 (Fig. 3) [4]. The same can't be said about the forecasting model's prediction in the case of the Grimsvotn eruption, although other simulations, from Rheinisches Institut für Umweltforschung (RIU) [7] and ZentralAnstalt für Meteorologie und Geodynamik (ZAMG) [8], showed that on the 26th of May 2011 our territory will be affected by this event (Fig. 4).

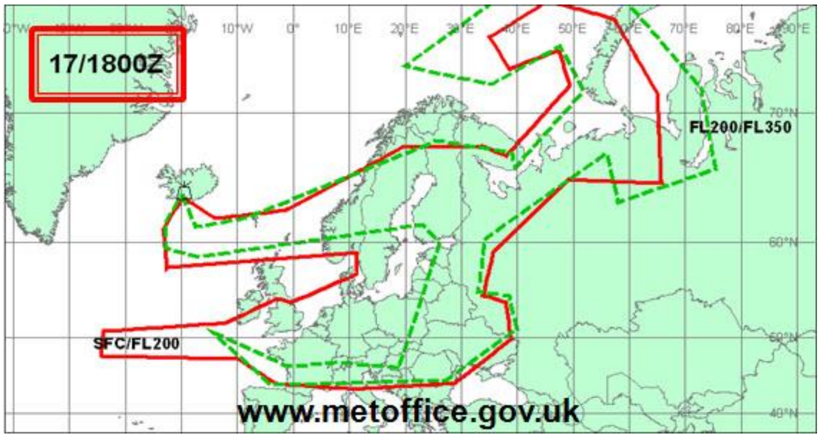

FIGURE 3. VAA prediction of the volcanic ash's spread in the case of Eyjafjallajokull eruption on the 17th of April 2010.

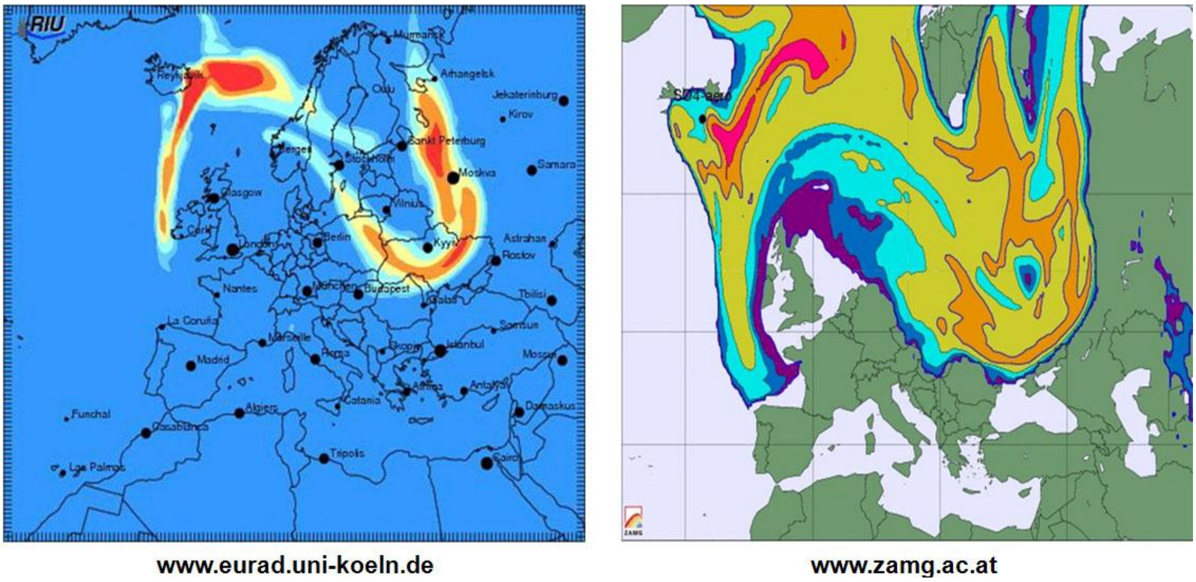

FIGURE 4. Predictions of the volcanic ash's spread in the case of Grimsvont eruption from RIU and ZAMG, on the 26th of May 2011

Using the multi-channel imagery technique we can distinguish a normal clout from a dust intrusion. In our research we used the difference between the 10.7 µm and 12.0 µm channels. Volcanic ash clouds with a high concentration of silicate particles exhibit optical properties in the infrared spectrum (8 - 13 µm) and this can be used to discriminate them from normal clouds.

The emissivity of silicate particles is lower at 10.7 µm than at 12.0 µm and the emissivity of water/ice particles is higher at 10.7 µm than at 12.0 µm, therefore the brightness temperature 10.7-12.0 is negative for ash and positive for water/ice (Fig. 5).

Seen from above, like in the case of the satellite images taken by the MSG satellite, an ash intrusion can be obscured by normal clouds. In this case, a ground LIDAR system can effectively identify an ash cloud over the observation point.

In the visible domain, the atmosphere shows a large transparency window and we can study the scattering phenomena on aerosols with the help of lasers that emit in the visible spectrum. A small window in the IR spectrum, around 1000 nm, allowed the use of solid state lasers.

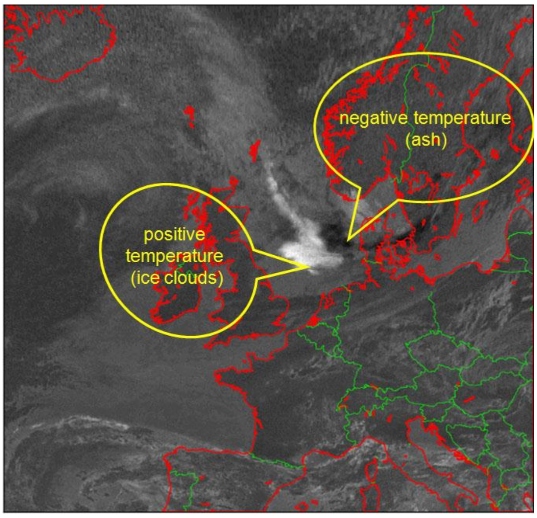

FIGURE 5. Satellite image MSG2, 16th of April 2010, 23:45 UTC Brightness Temperature 10.7 - 12.0 [5]

As preliminary results, for the 17th of April 2010, we have three RCS time series, for 355, 532 and 1064 nm wavelengths, shown in Fig. 6. These can show the presence of small, medium and large particles in suspension. At 3000 meters we see an intense scattering layer followed by another one at 5000 meters. Between 8000 and 10000 meters we can observe some Cirrus clouds.

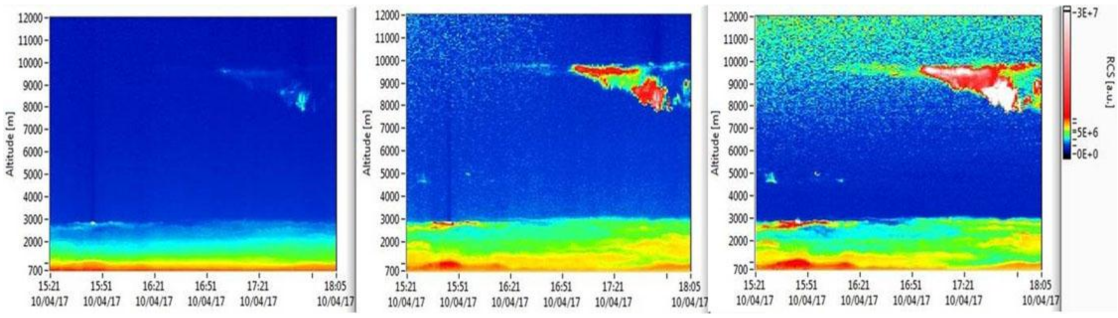

FIGURE 6. 3D RCS LIDAR Profiles at 355, 532 and 1064 nm with a spatial resolution of 3.75 meters and a temporal resolution of 60 seconds, on the 17th of April 2010.

The clouds are easy to identify because they backscatter a large portion of the signal, often saturating the photosensitive element of the reception system. The LIDAR signals can provide information about dust clouds, water vapors, aerosol presence, their base and height.

Between 4000 and 8000 meters we can see other aspheric particles which, we think, are volcanic ash particles. These particles are not confined in a well defined layer, but scattered in altitude.

According to the RCS time series we can observe that the detected formation from 8000 meters can be a hybrid between ice crystals and ash particles. Sulfur emissions are often in the form of sulfur dioxide, although other species can be present. Volcanic sources are an important factor in filling the superior troposphere with sulfur aerosols, where they can contribute to ice particle nucleation. Because of the shape of the ice crystals, Cirrus clouds give a high LIDAR ratio and a high degree of depolarization. On the other hand, ash particles give a smaller LIDAR ratio and a smaller degree of depolarization. Therefore, the LIDAR system can determine the aerosol distribution in the atmosphere and the thickness of the particulate suspension with a higher precision than other methods.

The 26th of May 2011 started with a lot of cloudiness, the cloud ceiling being quite low (1000 meters), then the sky gradually cleared. Taking this into account and the fact that simulations from RIU and ZAMG showed the possibility of volcanic ash intrusion over our observation point in Iasi, we did some LIDAR measurements. Figure 7 presents our results.

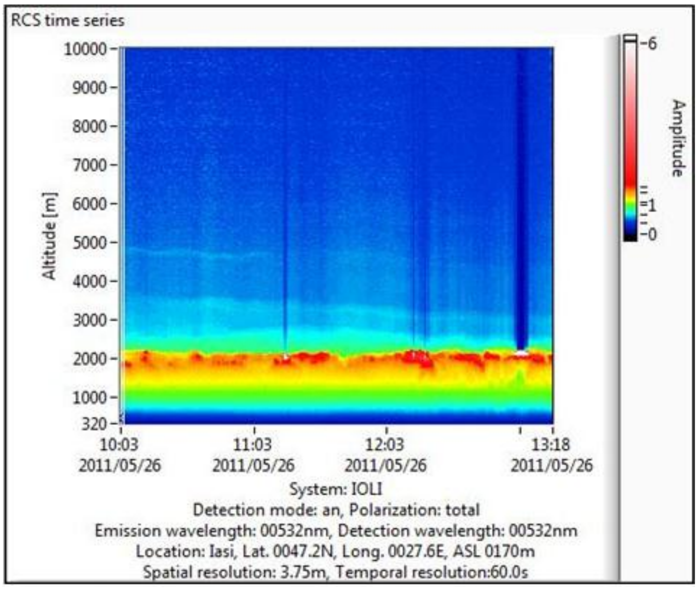

FIGURE 7. 3D RCS LIDAR profiles from the 26th of May 2011

Here we can see particle traces at 2500, 3500 and 5000 meters, traces that we think are volcanic ashes.

To bring further arguments to our research we used the National Oceanic and Atmospheric Administration's HYSPLIT model [6]. With this tool we can run the backward trajectories of air masses in order to determine the particulate source.

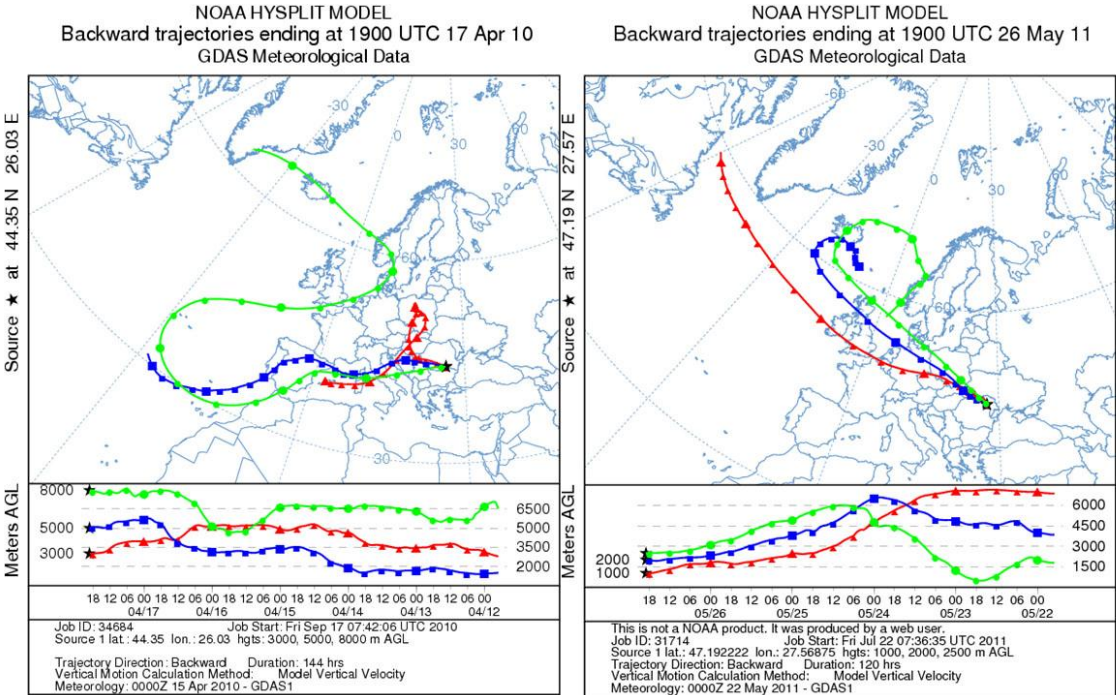

FIGURE 8. HYSPLIT Backward trajectories

In both our cases, the backward trajectories point to Iceland (Fig. 8), thus proving that the particulates detected with the LIDAR system were indeed volcanic ashes.

Conclusion

With the LIDAR measurements we were able to monitor the ash cloud, determining its altitude and intrusion moment over our observation points and the satellite images allowed us to monitor the ash plume's evolution. The forecasting tools that can predict ash cloud dynamics were of great help and proved to be, in most cases, in consensus with the reality. Finally, with the HYSPLIT model we determined the particle source, confirming our LIDAR measurements, of ash traces.

Further research in this filed will lead to a better interpretation of LIDAR findings, for a better understanding of atmospheric dynamics. Also, the next step in our studies is to create a database based on the methods presented in this paper in order to alert the population in the case of future eruptions with possible effects on human health.

Acknowledgements

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