Grímsvötn Volcano: atmospheric volcanic ash cloud investigations, modelling-forecast and experimental environmental approach upon the Romanian area

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The volcanic ash (from Grímsvötn volcano, South - Eastern Iceland) cloud dispersion over Iasi county (North-Eastern Romania) and its vertical distribution have been analyzed during the 21st and 28th of May 2011. Because of numerous air pollutants with variable concentrations, size and chemical compositions depending not only on space and time but also on meteorological data, satellite data and forecasting models must be taken into account. The monitoring of the air pollutants is performed using the new 3D Atmospheric Observatory of the "Alexandru Ioan Cuza" University of Iasi, part of national LIDAR system network implemented within ROLINET (ROmanian LIdar NETwork) and RADO (Romanian Atmospheric 3D Observatory) projects.

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1. Introduction

Grímsvötn (64.416 N, 17.333 W), Iceland's most active volcano, lies largely beneath the vast Vatnajökull icecap [1]. Its previous eruptions have lasted between a day and several weeks, its last one being in 2004 [2]. A new eruption began on the 21st of May 2011 at 19:25 UTC. With 18 km high plumes accompanied by multiple earthquakes [2], 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 22nd and the 25th of May 2011 [3,4]. This makes this volcanic eruption ten times more powerful than Grímsvötn's last eruption in 2004 [5]. Until the 25th of May, the eruption scale has been larger than that of the 2010 eruption of Eyjafjallajökull. The eruption paused at 02:40 UTC on the 25th of May 2011, although some explosive activity from the tephra vents affected the area around the crater [6,7].

Meteorological satellite images can offer improved observational data. Thus, the Meteosat Second Generation (MSG) satellite provides images of the volcanic ash emissions in the vicinity of Iceland, using infrared data. Because cloud and volcanic ash particles interact with the infrared radiation differently, data corresponding to different IR wavelengths can be combined to identify the main ash plume. However, it should be noted that only the thicker parts of the plume are detected with this method. In addition, the ash plume is often masked by higher clouds, therefore it might not appear in the satellite image [8].

The additional information that can be highlighted by the most simple LIDAR system is the altitude of layers with different density or/and compositions [9, 10, 11].

This paper presents results of lidar monitoring of the Grimsvotn volcanic dust, dispersed over Iasi (47.19 N, 27.56 E), during the 25th and the 27th of May 2011.

2. Methodology

For the monitoring of the ash cloud, satellite images, meteorological and LIDAR data were used. The satellite images helped us follow how the ash cloud expanded and dispersed, from its source.

The eruption of the Grímsvötn volcano and its long range influence on the environment have been studied by means of specialized instruments (optical remote sensing technology), thus confirming the transportation over great distances of sulphates and ash aerosols produced by the volcano in question [12]. Using the LIDAR methodology [13], the moment of intrusion (fine ash particle intrusion), height of the observed local ash cloud and the atmospheric strata have been observed.

Our LIDAR system was developed in the framework of ROmanian LIdar NETwork (ROLINET) research project and is mainly used to monitor the atmospheric aerosols and clouds in the troposphere (from 700 m to 12 - 15 km altitude). This is a multi - wavelength mini-LIDAR system with the transmitter based on a coaxial UV (355 nm), VIS (532 nm) and NIR (1064 nm) emission of a powerful and stable Nd:YAG laser with a variable repetition rate up to 30 Hz. The initial divergence of the 6 mm laser beam of 0.75 mrad was improved 5 times, by using a 3λ beam expander (BE) resulting in a beam of 30 mm diameter and a final divergence of 0.15 mrad. These features of the laser offer the possibility to measure at high altitudes (12 km during daytime and 15 km during night) for one minute integration time and a spatial resolution of 3.75 meters [14].

Different experimental results, satellite data and models have been analyzed and compared as follows: forecasting maps from the European Centre for Medium-Range Weather Forecasts (ECMWF), synoptic maps at the ground level, forecasting ash maps from Met Office London Volcanic Ash Advisory Centre (VAAC) [8], LIDAR data, geostationary MSG satellite data, dispersion models (RIU, ZAMG) and the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model for backwards trajectories [15 - 20]

In order to analyze the satellite images, we used SEVIRI High Resolution Visible channel combined with the IR10.8 channel data.

3. Results and discussion

Romania was under the influence of a high pressure field on the 26th of May 2011 (the day before that, our territory was crossed by a cold front). Central-Eastern part of the continent was in a relatively high pressure field.

In the western part of the continent, a field of low pressure was present, having a depression center of 1000 hPa, located in the North Sea (Fig. 1).

During the measurements, the atmospheric pressure at sea level, at Iasi Meteorological Station was above 1020 hPa, the highest value being 1024.7 hPa.

Initially, the day started with a lot of cloudiness, between 6/8 and 8/8 with Cumulus and Stratocumulus clouds and the cloud ceiling being quite low (somewhere around 1000 m), then the sky cleared gradually. In the afternoon the cloudiness was between 1/8 - 4/8, with Cumulus Humilis and / or Cumulus Fractus clouds.

During this period, simulations and forecasts of ash cloud intrusion above our territory were quite contradictory. On the one hand, the Met Office London VAAC (that provides forecast guidance up to 24 hours ahead to support decision-making) gave us no signs that our territory will be affected by the ash cloud. On the other hand, simulations of Rheinisches Institut für Umweltforschung (RIU) [19] and ZentralAnstalt für Meteorologie und Geodynamik (ZAMG) [20], showed that on 26th of May 2011 our territory will be affected by this event (Fig. 4).

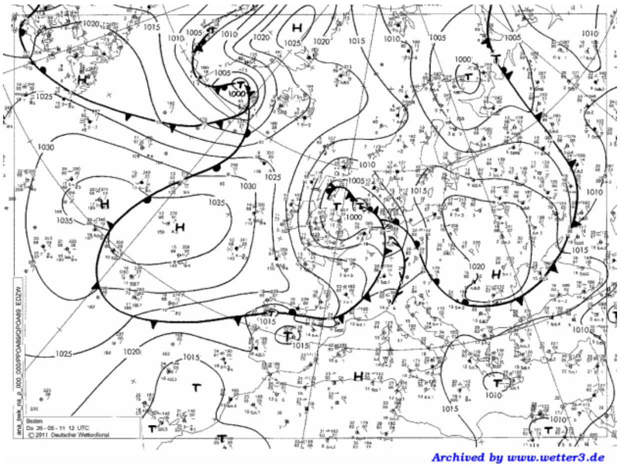

Fig. 1 Synoptic situation at the ground level (from DWD), on 26.05.2011 at 12 UTC.

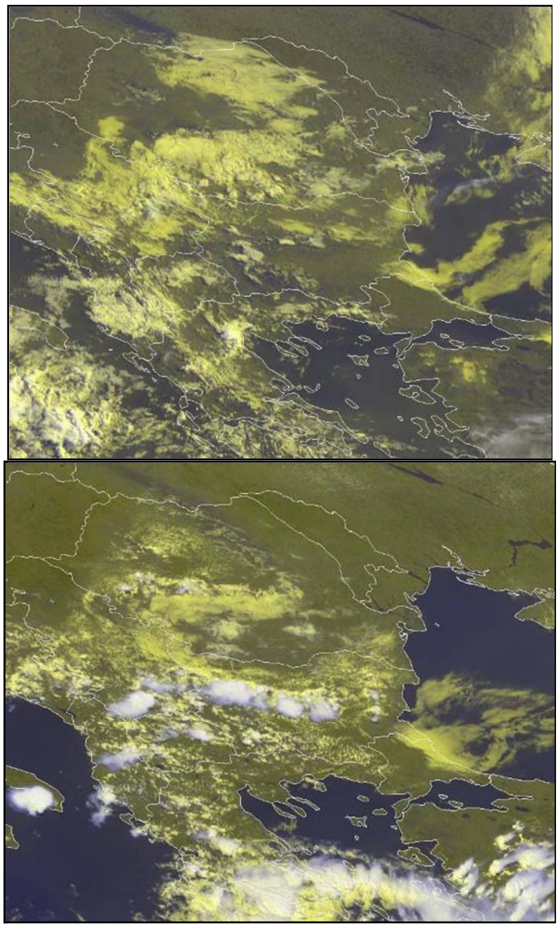

Fig. 2. MSG satellite images- based on data from the SEVIRI High Resolution Visible channel combined with data from the IR10.8 channel (EUMETSAT)- 06 UTC (up), respectively 12 UTC (down)

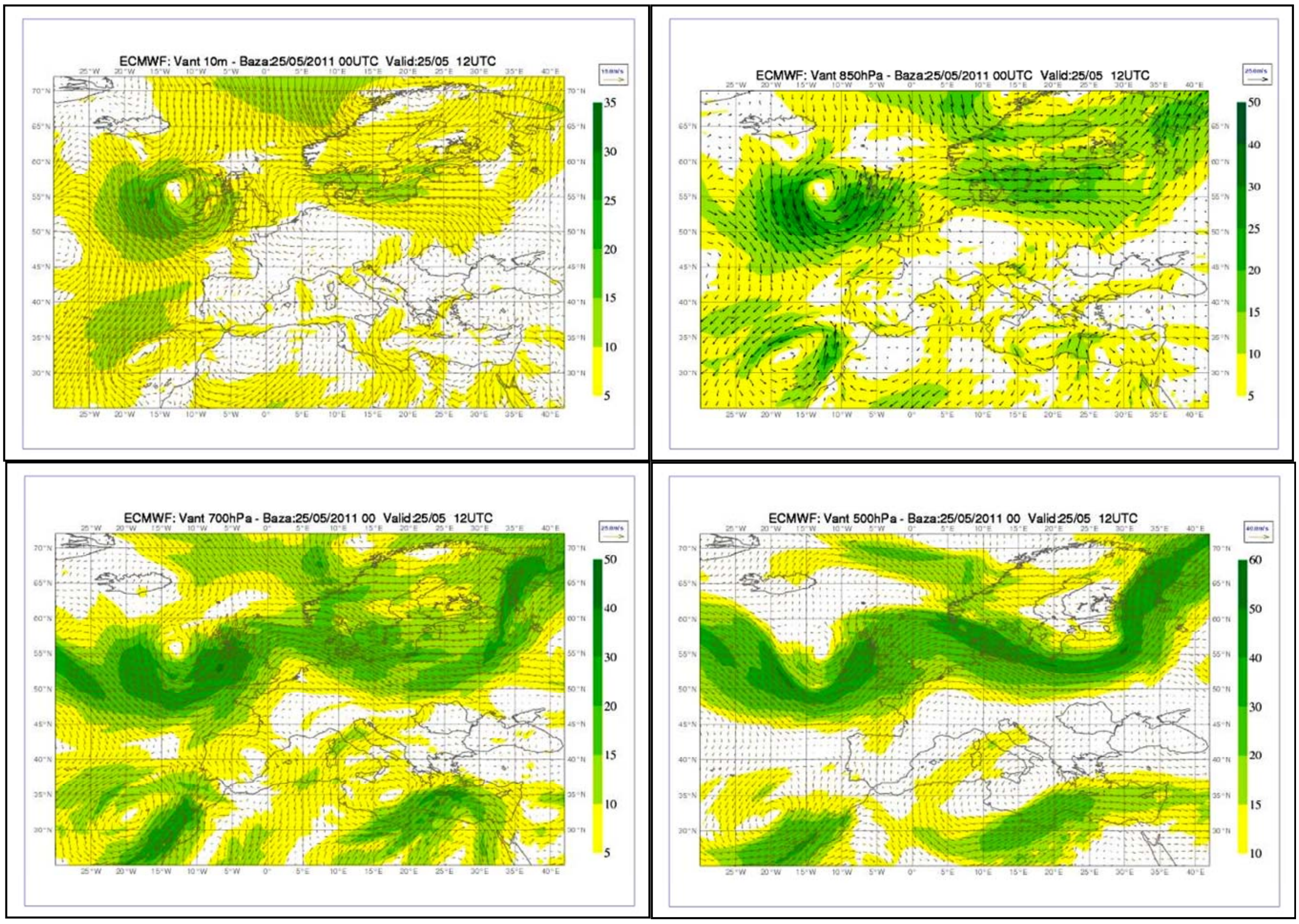

Fig. 3. Images from ECMWF - wind direction at 10 m, 850 hPa, 700 hPa and 500 hPa

The Met Office dispersion model forecasts are routinely validated, considering all available data observations, such as: satellite, RADAR, LIDAR and aircraft data [8].

The EURopean Air Pollution Dispersion (EURAD) model system from RIU, simulates the physical, chemical and dynamical processes which control emission, production, transport and deposition of atmospheric trace species. As a result EURAD provides concentrations of these trace species in the troposphere over Europe and their exclusion from the atmosphere by wet and dry deposition [24, 25, 26].

From ZAMG operational simulations of the ash cloud spread from the Grimsvötn volcano eruption on the 22nd of May 2011, according to the simulations of sulphate aerosols (SO_4) concentration, results were diluted form of the ash cloud over Eastern Europe [20].

Furthermore, because in this period no precipitations were recorded (acid rain), we were able to conduct a concrete analysis, reducing the interpretation errors (Fig. 5). Thus, we concluded that on the 26th of May 2011, at our observation point (RADO-Iasi station), at 15 UTC, we noticed the presence of fine dust (fine volcanic ash with a diameter under 0.063 mm) [27].

By taking advantage of the fact that the sky gradually cleared, and that some simulations signalled the presence of ash traces over our territory, we performed LIDAR measurements, presented in Figures 6 – 8.

It can be seen that the backscattering signals are quite intense between 1500 and 2000 m. During this period (06 - 13 UTC) low clouds have been reported also in the observation data from the meteorological station Iasi, (Cumulus and Stratocumulus clouds).

After the sky cleared, we got an intense layer at an altitude of 1700 - 2000 m (Fig. 8).

In Figure 7 are observed thin layers at altitudes of 2000, 3500 and 5000 m. The backward trajectories were performed at these altitudes, in order to determine the source's origin.

As shown in Fig. 9, the red trajectory corresponds to the air masses coming from Iceland from an altitude of 5000 m.

On 24th of May 2011 (00.00 UTC) due to the air currents circulation, the backward trajectories intersected, thus on 26th of May (18.00 UTC), layers from 3500 m and 5000 m were contaminated with volcanic dust. The LIDAR data was processed in LabView, the RCS time series (Range Corrected Signal) being calculated and graphically represented considering the signal correction parameters such as: overlap function, noise correction, background correction, etc [28].

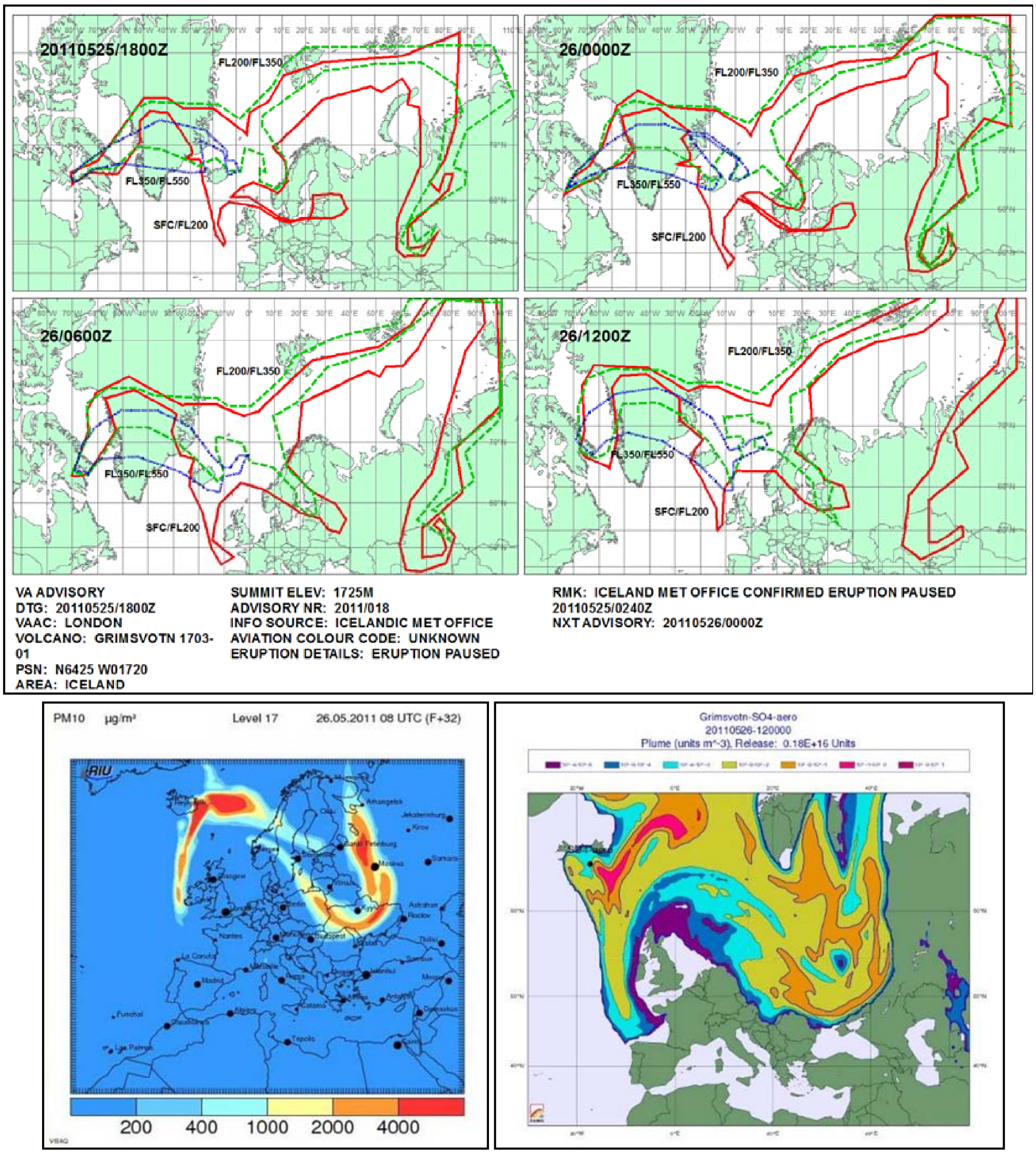

Fig. 4. Met Office's Volcanic Ash Advisory forecast (top), RIU simulation (bottom left) and ZAMG simulation (bottom right) from 26.05.2011

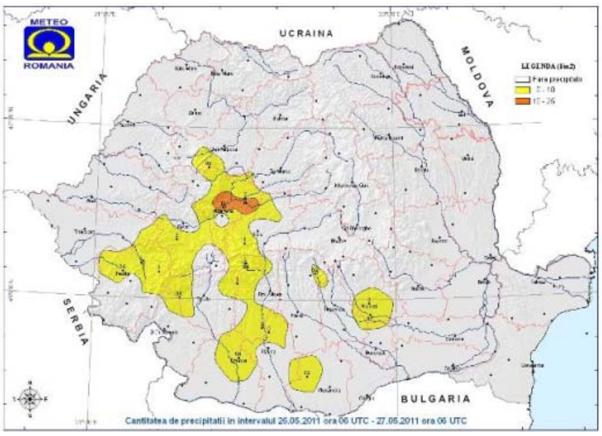

Fig.5. Rainfall from 26-05.2011, 06 UTC- to 05/27/2011 UTC.

From qualitative analysis of LIDAR data (Fig. 7, 8), we can see the distribution of ash traces, even though the simulation's (Fig. 4) concentrations seem to be quite low.
We used the HYSPLIT back trajectories model (Fig. 9), to track the trajectories of air masses moving towards our observation point from the volcano Grímsvötn, still erupting.

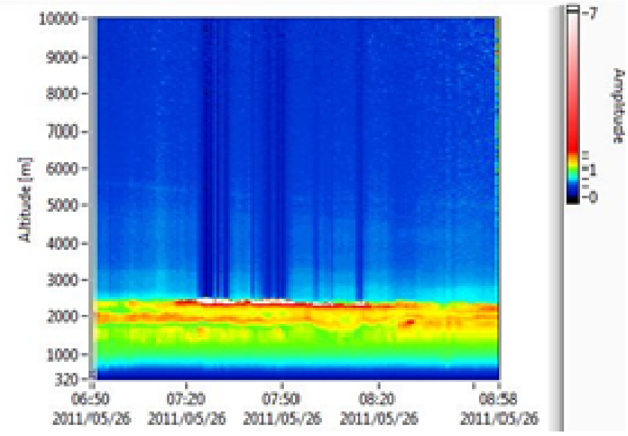

Fig. 6. RCS Time series, before the appearance of volcanic dust. Detection wavelength: 532 nm, Spatial resolution: 3.75 m, Temporal resolution: 60 s, Location: Iasi – 47.2 N, 27.6 E.

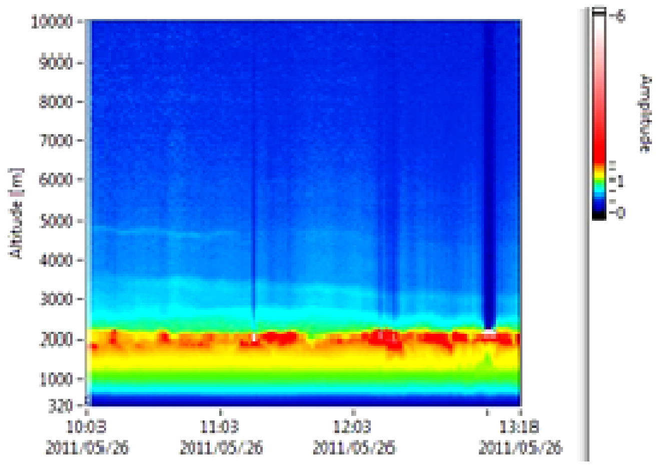

Fig. 7. RCS Time series that highlighting the thin volcanic dust layers up to 5km – Detection wavelength: 532 nm, Spatial resolution: 3.75 m, Temporal resolution: 60 s, Location: Iasi – 47.2 N, 27.6 E.

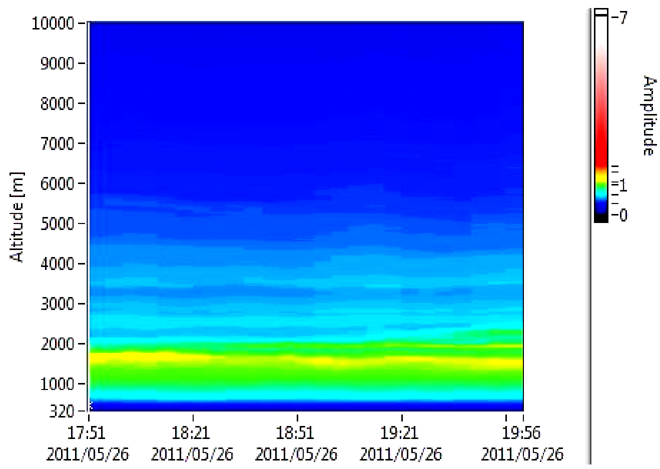

Fig.8. RCS time series (night profiles) for highlighting thin volcanic dust layers above the planetary boundary layer– Detection wavelength: 532 nm, Spatial resolution: 3.75 m, Temporal resolution: 300 s, Location: Iasi – 47.2 N, 27.6 E.

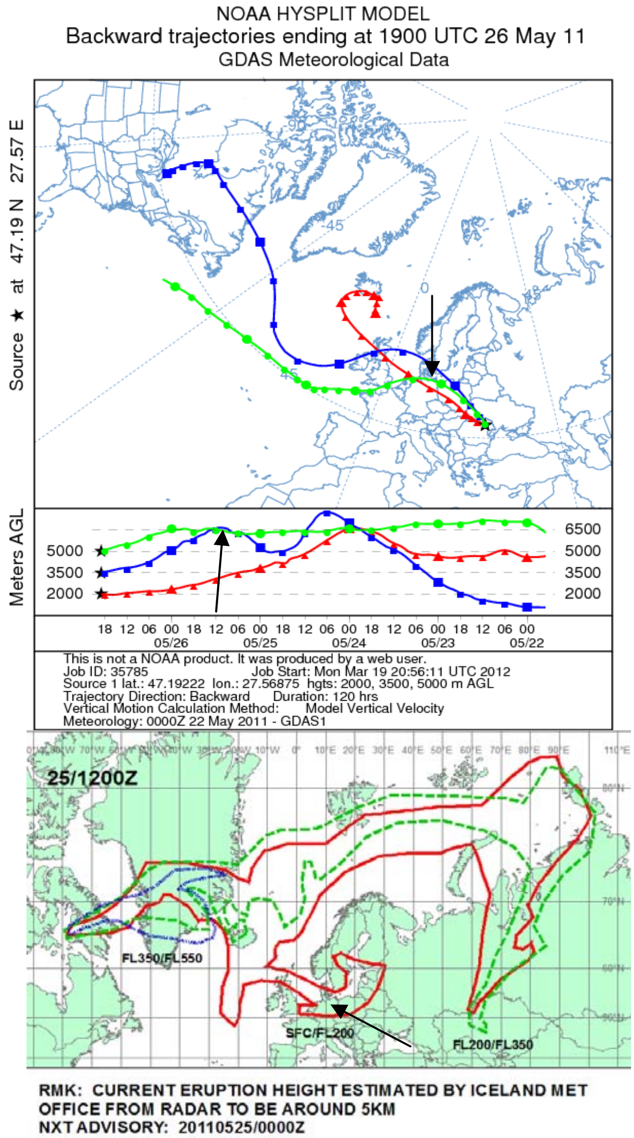

Fig. 9. Backward trajectory – HYSPLIT model (top) and Met Office's Volcanic Ash Advisory forecast (bottom) for 25.05.2011/ 12.00 h

4. Conclusions

Volcanic ash (Grímsvötn, South-East Iceland: Lat: 64.42°N;Lon: 17.33°W) cloud dispersion over Iasi county and its vertical distribution have been analyzed. During our observations, low clouds Cumulus and Stratocumulus have been reported and after the sky cleared, we got a relatively intense signal at an altitude of 1700 - 2000 m from volcanic dust layer. We also found thin layers of volcanic dust between 3000 m and 5000 m. Moreover, the back trajectories HYSPLIT model confirms the origin of the air masses, as they are moving towards our measuring site from the volcano Grímsvötn, still are erupting.

We found a good correlation between observed data (weather, satellite and lidar data) and data obtained through weather forecasting models (ECMWF), volcanic ash forecasting models (ZAMG, RIU and MetOffice – Volcanic Ash Advisory) and HYSPLIT model.

Acknowledgments

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