”BABEŞ BOLYAI” UNIVERSITY
FACULTY OF ENVIRONMENTAL SCIENCE AND ENGINEERING

PhD THESIS

Contributions to the study of natural atmospheric hazardous particles. Risk analysis

-summary-

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Table of contents:

Key words: remote sensing, natural aerosols, biomass burning aerosols, mineral dust, volcanic ash, risk analysis.

NOTE: Table of contents, tables and figures numbers were kept as in the full text thesis.

INTRODUCTION

Atmospheric aerosols play an important role in many aspects of daily life. It has both a local impact and being subject to long range transport it may affect distant areas. For example the dust originating in the Sahara desert frequently arrives over Europe and in some specific conditions it may cross the Atlantic Ocean to South America and The Caraibean. The smoke and biomass burning aerosols originating from the Canadian forest fires were also detected over Europe.

The impact of aerosols can be considered positive in some situations, for example the ash from volcanic eruptions or the mineral dust may provide some nutrients for plants. Despite the positive effects, the aerosols have a general negative impact.

Because of the hazardous properties of the aerosols and their large variability in time and space, an assessment of their properties by means of intensive monitoring is necessary.

The **main objective** of this thesis is to characterize the natural aerosols using ground based remote sensing techniques, in order to develop a methodology for risk analysis.

In order to fulfill the main objective, a number of specific objectives were outlined:

O1. Characterization of natural atmospheric hazardousparticles.

O2. Analysethe risks and effects associated to natural aerosols.

O3. Application and intercomparison of LIRIC and POLIPHON algorithms.

O4. Determination of mass and volume concentration of aerosols using the two algorithms.

O5. Spatial – temporal analysis of the natural aerosols at RADO stations.

O6. Development of a risk assessment methodology for natural aerosols intrusions.

The topics addressed in this thesis are of interest to civil society, events like the Saharan dust intrusion from April 2014 and the wildfires in the Chernobyl nuclear power plant area in the spring of 2015 having broad media coverage, the author disseminating information in both local and central media.

Regarding the scientific dissemination, the author published 4 ISI papers, another 2 being submitted for publication. Also 2 BDI articles were published and 1 article in non indexed journals. Also the author contributed to a number of conference papers presented at national and international conferences in Romania, Slovakia, Austria, Bulgaria, USA, and Italy.

CHAPTER 1

Theoretical background regarding hazards and risks

The first chapter provides the theoretical framework used in this thesis. It defines the notions of risk, hazard and vulnerability through a comprehensive literature review. Definitions of a series of terms used are analyzed in order to provide a better comprehension of the terminology and its use in various contexts. The risks are classified according to a series of factors like:

- origin
- affected surface and associated damage
- manifestation
- duration

Taking into account these factors, risks can be analyzed qualitatively or quantitatively in order to mitigate their effects and develop prevention schemes.

This thesis focuses on the analysis of the risks associated with natural atmospheric aerosol by employing qualitative and quantitative methods. Check-lists and dispersion models used for the analysis of natural aerosol were detailed in this chapter.

This analysis of the natural aerosol – mineral dust, volcanic ash, biomass burning – is the starting point in the development of a risk assessment methodology focused on natural aerosol.

CHAPTER 2

The natural atmospheric aerosol: sources, characteristics and associated risks

This chapter provides a complex characterization of the natural aerosol which can have potential hazardous effects. These types of aerosol include mineral dust, volcanic ash and biomass burning.

The aerosol can be of local origin, or it can be subjected to long range transport. The mineral dust arriving over Europe and Romania has its source mainly in the Sahara region and the Middle East. Over Europe biomass burning aerosol originating as far away as Canada has been identified. In Romania however, biomass burning aerosols has a local or regional source, mainly from the Balkans and Eastern Europe. Volcanic ash intrusions are rare, but can happen during volcanic eruptions like Eyjafjallajökull and Grímsvötn in Iceland.

According to the type of aerosol, different optical and microphysical properties can be determined through classical methods and through modern remote sensing methods like LIDAR and sun photometry.

Aerosols can have a negative impact on air quality and on human health, having the potential to cause a series of medical conditions. This lead to a series of regulations focusing on the ambient air concentration limits, mainly aimed towards small fraction aerosols like $PM_{2,5}$ and PM_{10}.

Aerosol has significant effects on climate through direct and indirect radiative forcing. According to the type and properties of the aerosol it can contribute to the warming or cooling of the climate system. Overall, aerosols have a cooling effect in contrast with greenhouse gases. Nevertheless there is still a debate in the scientific community regarding the magnitude of this cooling effect.

Regarding socio-economical risks associated with natural aerosols one must mention the effect of volcanic ash on visibility and aircraft engine performance which can lead to disruptions in air traffic and significant economic losses for the air traffic industry.

CHAPTER 3
Remote sensing of atmospheric aerosols

The remote sensing techniques used for atmospheric aerosol detection are analysed in this chapter. We considered both the passive techniques such as sunphotometry and satellite imagery and the active ones, the lidar technique. The passive techniques use a natural source of light, usually the sun, while the active ones use their own source, usually a laser source.

The sunphotometers, passive remote sensing instruments used in this thesys provide the optical and microphysical properties of aerosols for the entire column. Therefore they are unable to identifyand discriminate between different aerosol layers in the atmosphere. On the other hand, using the lidar systems, active instruments, usefull information regarding the different layers and their specific properties may be obtained.

The most usefull parameters provided by the sunphotometers via AERONET network are the aerosol optical depth, theÅngström coefficient, the single scattering albedo, the complex refractive index, the size distribution, the fine and coarse volume concentration.

The lidar systems, beside the information regarding aerosol layers and their dynamics, provide a series of optical parameters such as backscatter coefficient, extinction coefficient, particle depolarization ratio, color and lidar ratios, as well as Angstrom exponent. By using inversion algorithms the microphysical properties of aerosols such as the size distribution, particle radius, complex refractive index, number, volume and mass concentration cand be retreived.

Worldwide there are various lidar and sun photometers networks(i.e. EARLINET, NASA AERONET), thus enabling a comprehensive analysis of atmospheric aerosols propertiesat a global scale.

In this thesis the author analysed measurements provided by the AERONET sunphotometers present in Romania in different cities: ClujNapoca, Bucharest – Magurele, Eforie Nord, Iași and Timișoara. All the sites are part of the Romanian Atmospheric 3D Observatory – RADO. Also two lidar systems were used: *COLI* –a 532 nm elastic lidar system at the Faculty of Environmental Science and Engineering, Babeș Bolyai University of Cluj Napoca and *RALI* – a multichannel Raman lidar at the National Institute for Optoelectronics, INOE 2000 – Magurele.

Fig. 3.9. The lidar systematthe Faculty of Environmental Science and Engineering, UBB ClujNapoca

CHAPTER 4

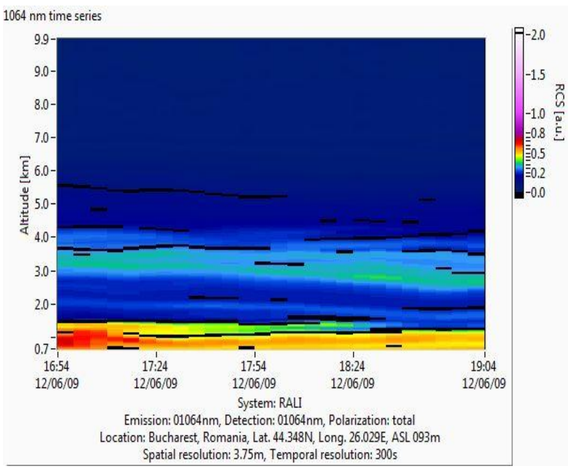
Concentration profiles from optical remote sensing data

In the past years both the scientific community and other stakeholders like air traffic industry and weather services showed an increased interest in obtaining reliable information regarding the mass concentration of aerosols in the atmosphere. Thus a series of methods were developed in order to obtain the concentration profiles. Even if some methods use only lidar data in order to obtain mass concentration of aerosols, like the Veselovskii Code (Veselovskii et al., 2013) which needs multichannel Raman measurements: 3 backscatter (β355, β532 and β1064) + 2 extinction coefficients (α355 and α532) profiles, most of the methods and algorithms use the synergy of two instruments: the multichannel lidar systems and the sunphotometers. In this thesys we applied and intercompared two algorithms used to obtain the aerosol concentration profiles: LIRIC and POLIPHON.

4.1 Determination of aerosol volume concentration using the LIRIC algorithm

4.1.2. Case study: 09.06.2012 dust intrusion

The results obtained with the LIRIC algorithm applied for a desert dust intrusion detected at Magurele on 09.06.2012 in which aerosol layers are present between 3 and 4 km are presentedin fig. 4.3.

(a) 

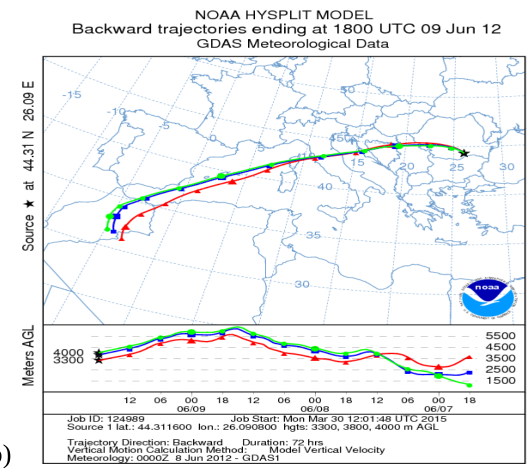
(b) 

Fig. 4.3.RCS 1064 nm, Magurele, 09.06.2012 (a);Hysplit backtrajectory (b)

In fig. 4.4. the first 4 plots represent the reproduction of the backscatter coefficient profiles at 3 wavelenghts 355, 532, 1064 nm and the volume depolarization ratio at 532 nm. The measured profiles must be as similar as possible with the algorithm retrieved profiles.

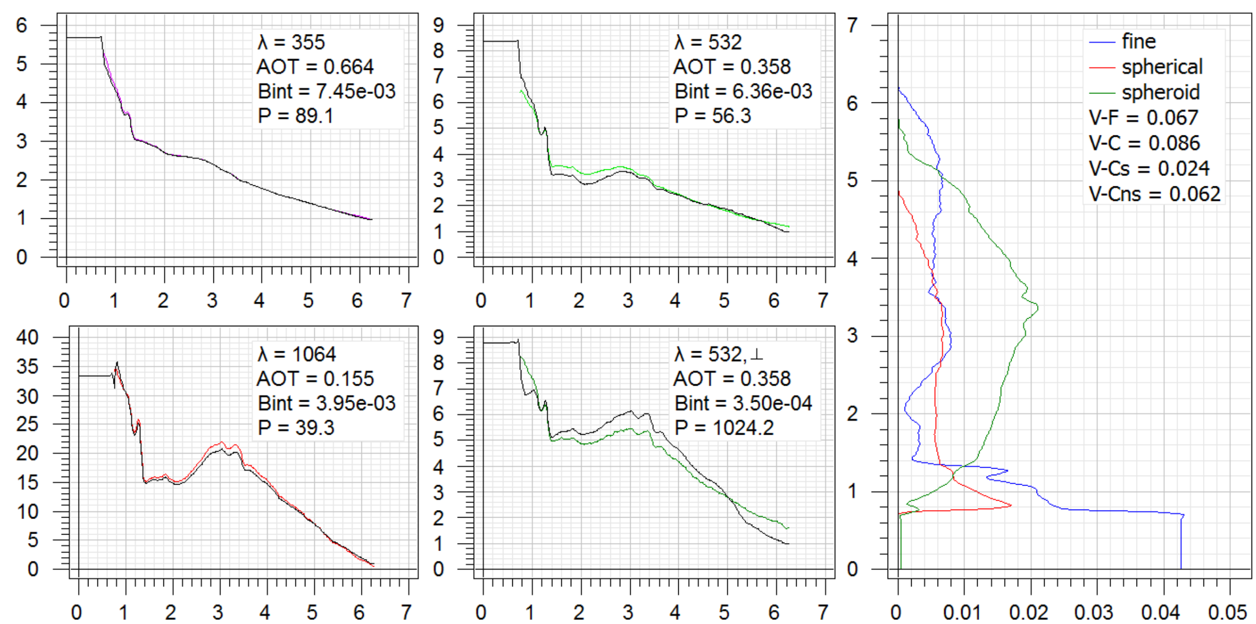


Fig. 4.4. Aerosoltotal volume concentration (μm^3/cm^3). Date: 09.06.2012; 17 - 19 UTC, Măgurele: V-F fine particle concentration; V-C coarse particle concentration; V-Cs sphericalcoarse particle concentration; V-Cns non sphericalcoarse particle concentration(Saharan dust).

The results are provided in μm^3/cm^3, as seen in figure 4.4., right. Multipling the volume concentration with the density of particles (g/cm^3) one can obtain the mass concentration (μg/m^3).

LIRIC algorithm retrieved a maximum concentration of Saharan dust of aprox. 52μg/m^3 at 3.5 km altitude.

4.2 Determination of aerosol mass concentration using the POLIPHON algorithm

4.2.2. Case study: 09.06.2012 dust intrusion

The results obtained with the POLIPHON algorithm applied for the same desert dust intrusion detected at Magurele on 09.06.2012, provided a maximum concentration of aprox. 95 μg/m^{3}as seen in figure 4.5.

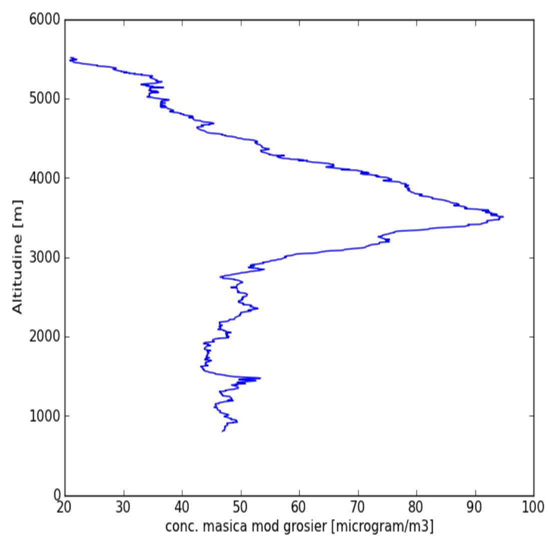


Fig. 4.5. Mass concentration profile for coarse particles retrieved by POLIPHON; Date: 09.06.2012; 17 - 19 UTC, Măgurele

4.3.3. Benefits and drawbacks of the two algorithms

Both LIRIC and POLIPHON algorithms were applied to a series of case studies in order to obtain aerosol concentration profiles for different aerosol intrusions: desert dust and biomass burning aerosol. Some conclusions regarding the use of the algorithms for risk assessmenthave been drawn.In order to use the algorithms, both of them need lidar and sunphotometer measurements from the same location. Even more, the LIRIC algorithm needs simultaneously measurements with the instruments.The LIRIC algorithm provides results for all types of aerosol, while POLIPHON may retreieve results onlyif depolarizing coarse particles like desert dust or volcanic ash are present in the atmosphere.

These algorithms are considered to be the best available techniques for retrieval of aerosols concentration profiles, excluding the insitu measurements. Both of them may be succesfuly applied in the risk analysis methodology in order to derive the concentration of hazardous particles in the atmosphere.

CHAPTER 5

Spatial - temporal distribution of aerosols over Romania

5.1. Temporal variation of aerosols at the Romanian AERONET stations

The main aspect that must be considered when attempting an analysis of the aerosol distribution in a given territory is related to the fact that aerosol may vary greatly in time and space, being strongly influenced by the air masses movement.

Another important aspect is the fact that aerosol in the atmosphere is present most often in the form of a mixture of aerosols from different sources.

In order to identify the presence of natural aerosol intrusions over Romania, data provided by *CIMEL Electronique318 A* sunphotometers via AERONET network were used. We analysed the data from the following stations: Bucharest_INOE, CLUJ_UBB, Eforie Nord, Iasi_LOASL, Timisoara as seen in figure 5.1.

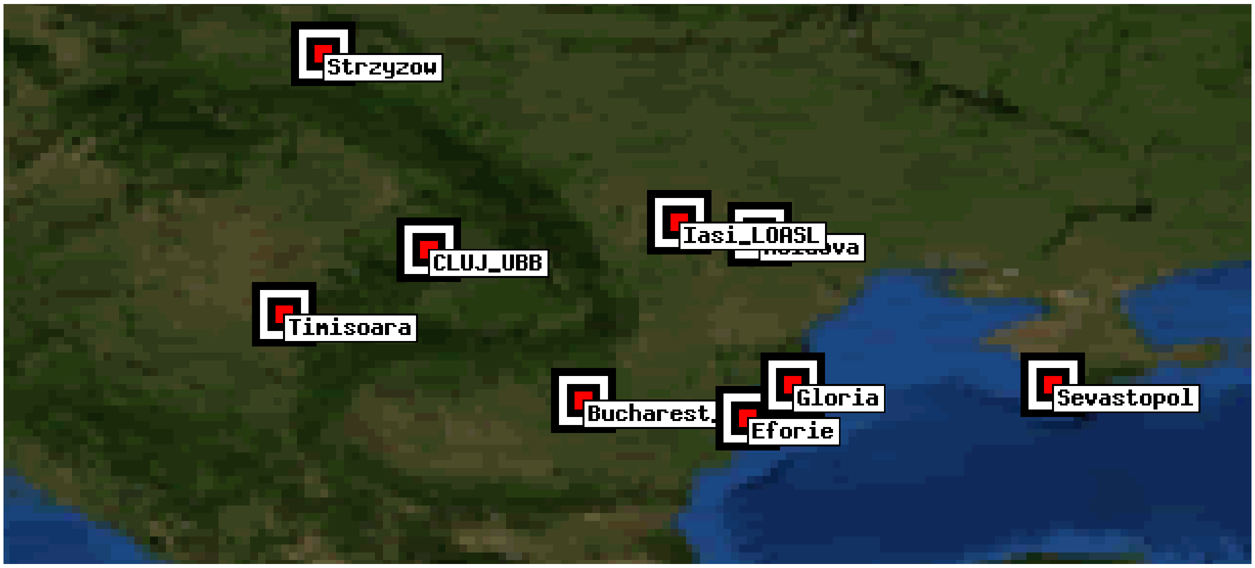


Fig.5.1. AERONET stations in Romania equipped with*CIMEL Electronique 318 Asunphotometers*

In this thesis, all level 2 data measured at the five stations in Romania were analysed. In order to obtain the monthly means, the available daily means for each month were used. The standard deviation is also represented.

5.1.3. Discussions regarding the distribution of aerosols over Romania

The Aeorosol Optical Thickness (AOT) is the main parameter retrieved by sunphotometers. It provides information about the atmospheric aerosol load. The spectral dependency of AOT provides information about the size of the particles. The AOT variation can have many causes. For example, an increase in the AOT values at low wavelenghts indicates a fine aerosol intrusion while a rise in the AOT values at higher wavelenghts indicates a coarse aerosol intrusion.

The minimum, maximum and average values of AOT at 440 nm measured at the five stations in Romania are presented in table 5.13.

Table 5.13.Aerosol Optical Thickness $AOT_{(440\ nm)}$at RADO stations

Station / AOT_{440}	Bucharest_INOE	CLUJ_UBB	Eforie Nord	Iasi_ LOASL	Timisoara
Min.	0,04	0,04	0,04	0,04	0,03
Avg.	0,29 ±0,16	0,25 ±0,13	0,24 ±0,13	0,23 ±0,11	0,28 ± 0,15
Max.	1,11	0,82	0,82	0,71	1,00

TheÅngstrom coefficient provides information about the atmospheric aerosol particle size. A high value indicates the presence of fine mode aerosol, while the lower values are common for the presence of coarse aerosol particles in the atmosphere.

Table 5.14.Ångstrom coefficient - $\alpha_{440-870}$at RADO stations

Station / $\alpha_{440-870}$	Bucharest_INOE	CLUJ_UBB	Eforie Nord	Iasi_ LOASL	Timisoara
Min.	0,05	0,27	0,17	0,30	0,55
Avg.	1,53±0,34	1,52 ± 0,30	1,52 ± 0,30	1,48 ±0,29	1,46 ± 0,28
Max.	2,76	2,15	2,02	2,10	2,00

Starting from these two parameters, we tried to identify possible hazardous aerosol intrusions over the RADO stations. A value lower than 1.3 for theÅngstrom coefficient – ($\alpha_{440-870}$) was considered specific to desert dust intrusions and a value higher than 1.8 was considered specific to biomass burning aerosol intrusions. In order to confirm these intrusions, the NOAA HYSPLIT back-trajectories and the satelitary imagery provided by the MODIS instrument on Aqua and Terra satelites were analysed. The results are presented in table 5.15.

Table 5.15: Number of days with dust and biomass burning aerosol intrusions at the five RADO stations

Station	Total days with measurements	Total days with $\alpha_{440-870} < 1,3$	Confirmed cases	Total days with $\alpha_{440-870} > 1,8$	Confirmed cases
Bucharest_INOE	986	197 (19,9 %)	158 (80 %)	212 (21 %)	151 (71 %)
CLUJ_UBB	855	168 (19,9 %)	132 (78 %)	140 (16 %)	113 (80 %)
Eforie Nord	632	163 (25,7 %)	113 (69 %)	46 (7 %)	42 (91 %)
Iasi_ LOASL	360	83 (23 %)	64 (77 %)	13 (4 %)	13 (100 %)
Timisoara	326	81 (24,8 %)	66 (81 %)	26 (7 %)	22 (84 %)

Regarding the inversion data derived from the sunphotometer via AERONET network, the values agree well with other similar worldwide stations. The real part of the refractive complex index $n_{(438)}$, an indicator for the absorbtion capabilities of the aerosol has average values between 1.40 at Cluj Napoca and Iasi and 1,42 at Eforie. The values are similar with other stations with urban continental aerosol: Paris - 1.40 and Greenbelt, USA -1.39 (Dubovik et al., 2002).

The high values of single scattering albedo - $SSA_{(440)}$ indicates the low absorbtion of the aerosol, the average values at the RADO stations, between 0.92 at ClujNapoca and 0.94 at Bucharest, Eforie Nord and Iasi are similar with the one measured at Paris - 0.94, but lower than the average value from Greenbelt, USA - 0.98, were the local specific fog is almost non absorbing (Dubovik et al., 2002).

5.2. Long range transport of aerosol - case studies

The natural aerosol distribution over Romania was often influenced by long range transport of aerosol. Most often, the Saharan dust was transported over Romania but also the biomass burning aerosol played an important role.

5.2.1. Saharan dust intrusion:1 – 5.042014 over Romania – VOLCEX14/01 campaign

Measurements at ClujNapoca station

As seen in Fig. 5.13 during 1^{st} of April 2014, different aerosol layers were identified between 4 and 6 km.

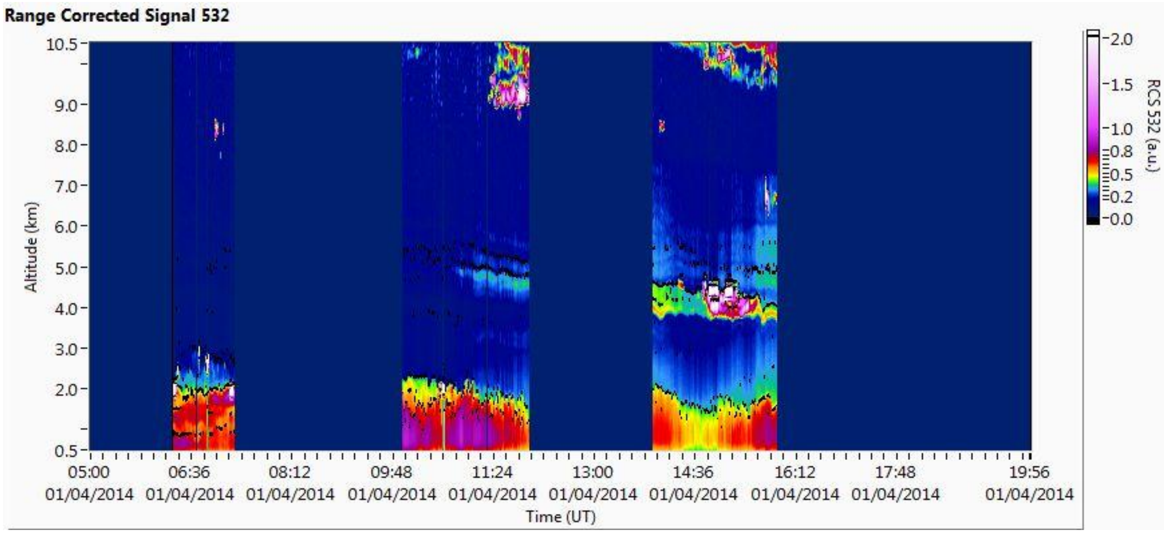


Fig. 5.13. RCS - Date: 01.04.2014; ClujNapoca.

The NOAA HYSPLIT - Hybrid Single Particle Lagrangian Integrated Trajectory Model (https://ready.arl.noaa.gov/HYSPLIT.php) used to obtain the air masses back-trajectories confirms the Saharan origin of the identified aerosol layers as seen in Fig 5.14 (Ştefănie et al., 2015 (a)).

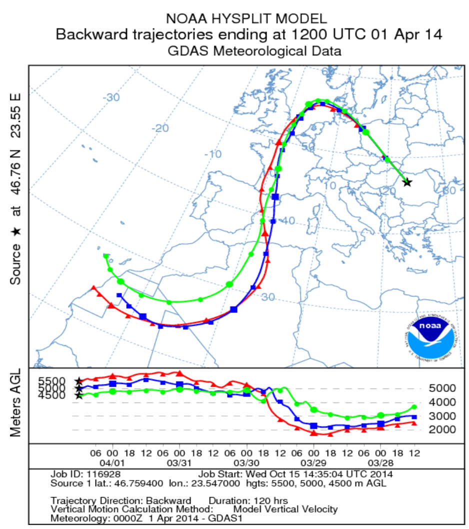


Fig. 5.14. 96 h air masses back-trajectories – HYSPLIT model;
Date: 01.04.2014; ClujNapoca.

During the 04 of April 2014 different desert dust aerosol layers were observed at various altitudes: 3000 m, 3500 m şi 4500 m. At aprox. 7000 - 8000 m some cirrus clouds are detected.

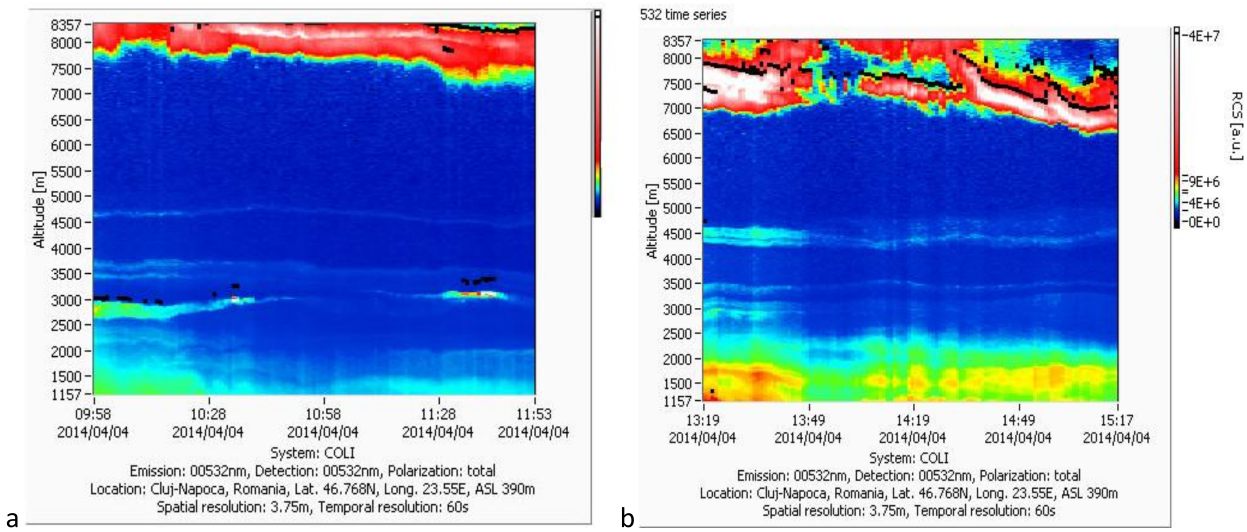


Fig. 5.16 RCS - Date: 04.04.2014. 13-15 (a) and 16-18 (b) (local time); ClujNapoca;

At the same time with the lidar measurements for the vertical profiles, in-situ measurements were performed with a Dusttrack DRX 8533 point monitor in order to measure the local particulate matter concentration at ground level.

The ground measurementens results are presented in table 5.16. On 6th of April, heavy rains washed the atmospheric aerosol, the clean air being visible on 7th of April measurements. (Ştefănie et al., 2015 (a))

Table 5.16. PM_{10}şi $PM_{2.5}$values measured with theDusttrack DRX8533

Date and time		**04.04. 2014 h 10-12**	**04.04.2014 h 13-15**	**05.04.2014 h 11-13**	**07.04.2014 h 12-14**
PM_{10} µg/m^3	**MIN**	**23**	**70**	**43**	**29**
	AVG	**56**	**86**	**60**	**34**
	MAX	**112**	**132**	**128**	**47**
$PM_{2.5}$ µg/m^3	**MIN**	**23**	**68**	**43**	**9**
	AVG	**52**	**80**	**59**	**33**
	MAX	**85**	**126**	**128**	**45**

5.2.2. Biomass burning aerosol intrusion: 11 - 14.07.2012

2012 was the year with the highest number of biomass fires in Romania, beeing affected more than 6500 ha of vegetation (JRC, 2014).

In this case study a biomass burning aerosol intrusion over the city of ClujNapoca is analysed.

The Aerosol Optical Thickness and the Ångstrom$_{440\text{-}870}$ coeficient are presented in table 5.17. During 11th, 12, th and 14th of July 2012 according to the analyse we have biomass burning aerosol over Cluj Napoca, while in 13th of July, the urban continental aerosol is present, but because of the low values of AOT, we can state that the presence of aerosol is low.

Table 5.17. AERONETparameteres - AOT and Ångstrom$_{440\text{-}870}$; 11-14.07.2012; ClujNapoca

Coef./Data	11.07	12.07	13.07	14.07
AOT_{440}	0.233	0.280	0.084	0.483
$\alpha_{440\text{-}870}$	1.80	1.94	1.56	2

The Ångstrom$_{440\text{-}870}$ coefficient evolution for 11th of July 2012 is presented in fig. 5.21. The instrusion arrives over ClujNapoca around noon, when we have a rise in the Ångstrom$_{440\text{-}870}$ coefficient values up to 2. These high values are measured also in the next days, 1.94 for 12th and 2 for 14th of July 2012.

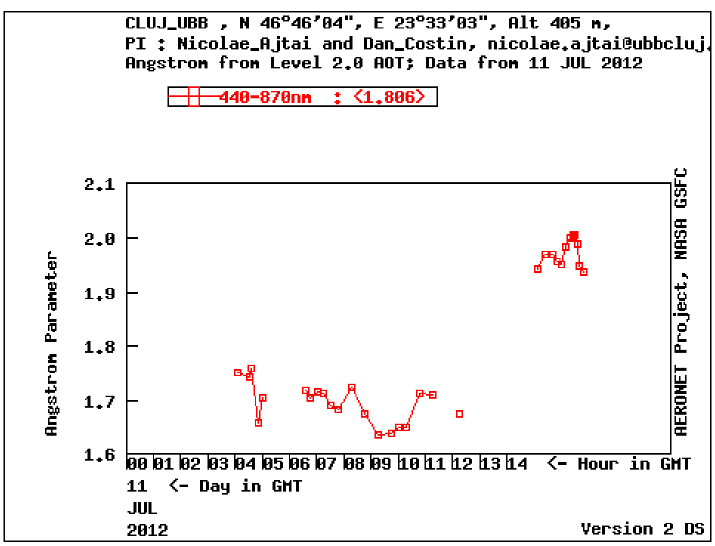


Fig. 5.21. Ångstrom$_{440\text{-}870}$ Coefficient, 11.07.2012, Cluj - Napoca

In figure 5.22 is presented the size distribution for the days with level 2 available data. We have a clear fine mode domination on 11th of July, but for 13th we also have the presence of coarse mode aerosols.

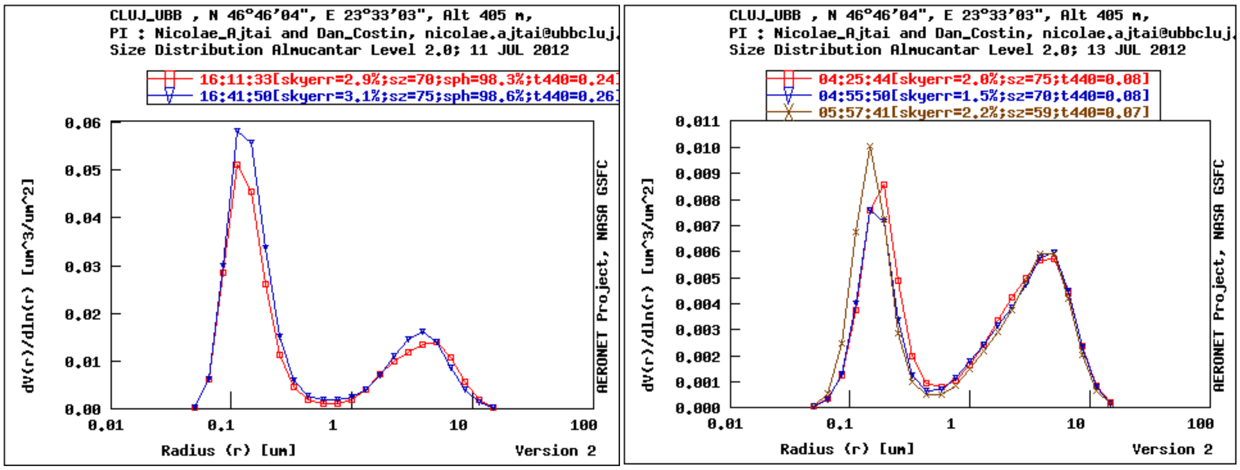


Fig. 5.22.Aerosol size distribution: 11.07.2012 (l) and 13.07.2012 (r) - Cluj-Napoca

In figure 5.23. the MODIS firemap for 10 - 15th of July 2012 is presented. Large fires occured in the Balkan Peninsula, Hungary, Romania and Southern Italy.


Fig. 5.23.MODIS fire map: 10 -15.07.2012

The HYSPLIT back-trajectories confirm the origin of the air masses over Cluj Napoca as being the areas with fires as seen in figure 5.24.

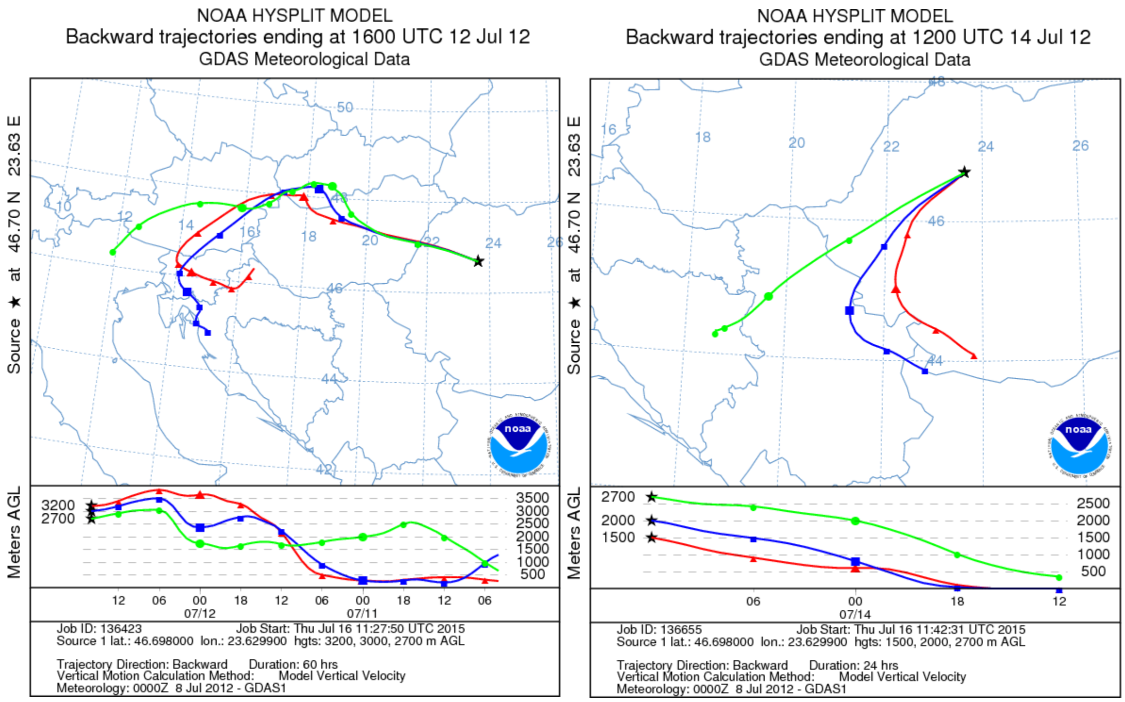


Fig. 5.24. HYSPLIT back-trajectories: 12.07.2012 (l); 14.07.2012 (r)

5.2.3. Volcanic ash intrusions over Romania

In the last several years the main eruptions which affected the air transport industry were those of Iceland`s volcanoes Eyjafjallajokull in 2010 and Grímsvötn in 2011. The volcanic ash resulting from these eruptions arrived over Romania, forcing the authorities to close the air space after the Eyjafjallajokull eruption.

The volcanic ash intrusions over Romania were detected at the RADO stations. The ash from Eyjafjallajokull volcano was identified by the Magurele station with the RALI lidar system during April 2010. The ash from the Grímsvötn eruption arrived only in the Northern part of the country, being identified only at Iasi station with an elastic lidar system.

In 2010 the only functional lidar system was RALI, a multichannel Raman lidar belonging to INOE 2000. The intrusions were detected on several days during April 2010, a series of studies being published (Carstea et al., 2010, Nemuc et al., 2013). The first volcanic ash layers were detected on 18th of April 2010, between 2.5 and 3 km as seen in figure 5.25.

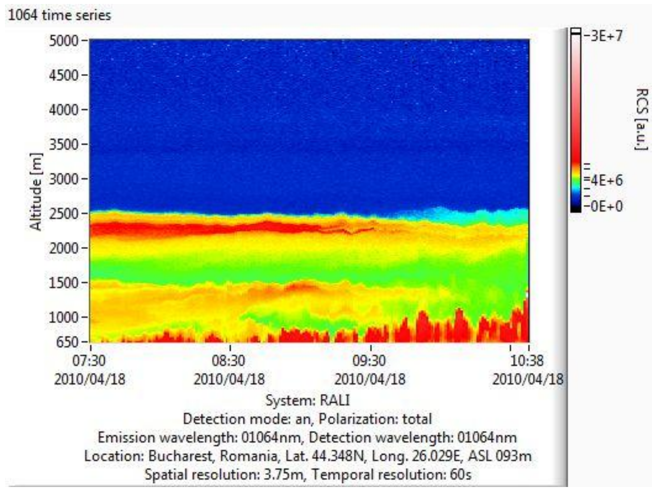


Fig. 5.25. RCS 1064 nm - Date: 18.04.2010;07:30 - 10:30 UT; Măgurele (Carstea et al., 2010)

HYSPLIT back-trajectories confirm the origin of the air masses from 2 - 3 km as being above Iceland during the eruption (Fig. 5.26.).

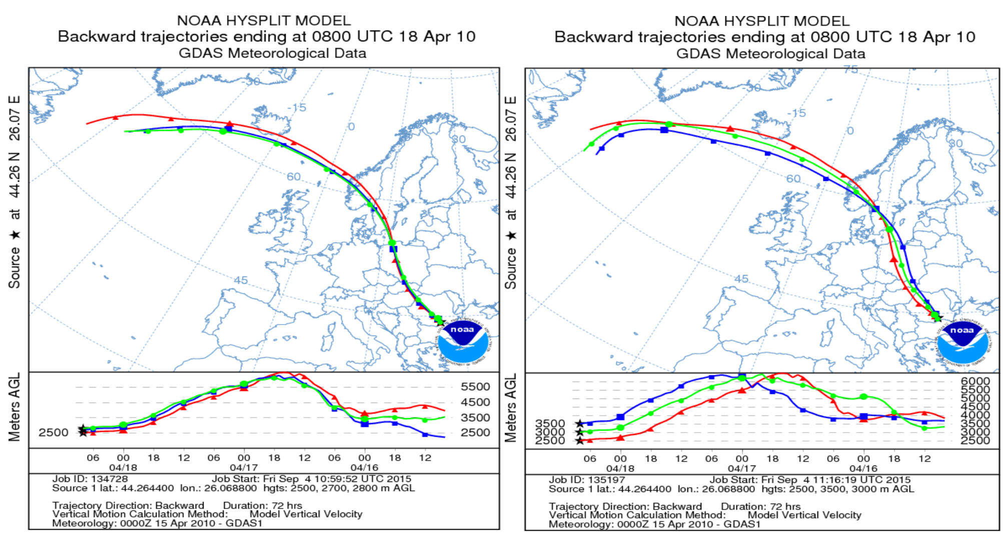


Fig. 5.26. HYSPLIT back-trajectories; 18.04.2010; h 08:00.

The lack of sunphotometer measurements made it imposible to calculate vertical profiles with aerosol concentrations using the two algorithms. Practically the eruption of these volcanoes and the economic losses boosted the scientific community to develop new alghoritms for concentration profiles retrieval such as LIRIC and POLIPHON applied in this thesis.

5.3. Aerosol intrusions risk analysis methodology

In order to identify the hazardous aerosol intrusions over Romania and assess the risk associated with them, in this chapter a methodology for aerosol risk assessment is proposed. The methodology is based on remote sensing measurements and use of different available models.

The proposed methodology follows the risk assessments phases, starting with the identification of the possible intrusions, continuing with their analysis and finally reaching to conclusions about the degree of danger they pose to environment, humans and society.

The first phase propose the identification of the hazardous aerosol intrusions before they arrive over Romania, using the dispersion models or warnings from different international partners (i.e. EARLINET, BSC DREAM model, etc.). The second phase propose the identification of the intrusions by means of direct measurements, both remote sensing and in-situ for ground level. The first two phases are equivalent with hazard identification stage, in our case the hazardous particles intrusions. The third phase propose the thorough analysis of the hazard and the risk assesment. The aerosol intrusion risk assesmentcan provide the information necessary for an extensive impact assesment on both environment and human health.

These 3 phases of the methodology are fulfilled by different means depending on the aerosol intrusions type.

In figure 5.28. the methodology is presentend in a schematic way. Using the methodology at the RADO stations, usefull information may be provided to the stakeholders in order to take the best decisions in a crisis situation related to hazardous particles intrusions like the volcanic ash, desert dust, or radioactive biomass burning aerosol, like the one resulted from the forest fires around Chernobyl nuclear plant.

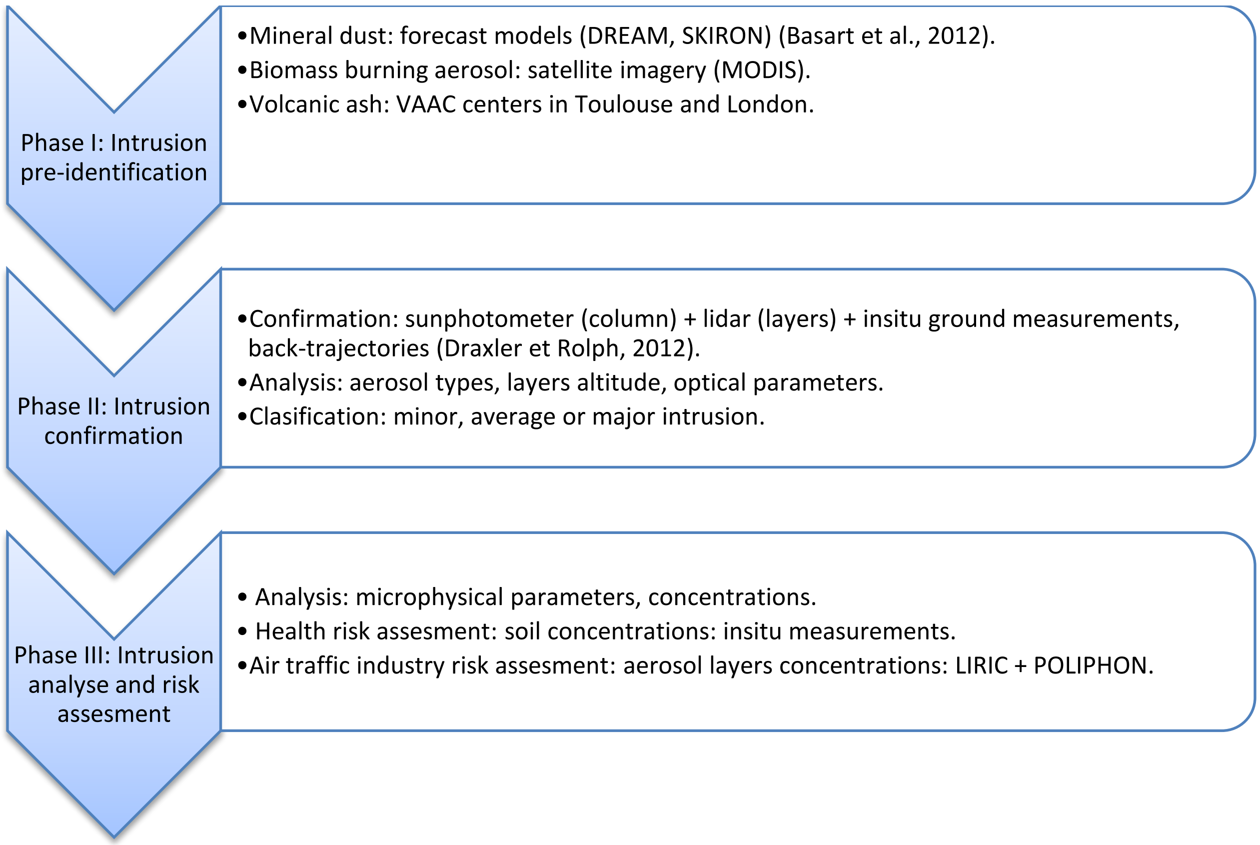


Fig. 5.35. Hazardous aerosol intrusions risk analysis methodology based on remote sensing measurements and modelling

Conclusions, personal contributions and perspectives

General conclusions and personal contributions

Within this PhD thesis, the author intended and succeeded, to elaborate a complex characterisation of atmospheric aerosol coming from natural sources, in order to develop an assessment methodology for the risks associated to potential hazardous aerosol intrusions. For the development of this aerosol analysis, several remote sensing instruments and techniques (active and passive) were used in an integrated manner. Remote sensing data was completed in a synergic way by data obtained following in-situ measurements and different models.

In order to achieve the general objective, several specific objectives were drawn. These objectives were fullfilled, as it is demonstrated below:

O1. *Characterisation of natural potential hazardous aerosol* – within chapter 2, a detailed characterisation of potential hazardous aerosol originating from natural sources was developed. Three types of aerosols were considered: ash from biomass burning, mineral dust and volcanic ash. Regarding the ash coming from biomass burning, this may have a local source, which is the common practice of burning the agricultural lands or from other vegetation fires, as well as a distant source, such as the vegetation fires from Balkan peninsula or Eastern Europe. Mineral dust over Romania is originating mainly from the Sahara Desert, but cases in which the dust came from Middle East, Syria, Jordan and Irak, were also documented. If the two first types of potential hazardous aerosol occur over Romania with a certain frequency, volcanic ash occurs randomly, and is dependent on the specificity of the vulcanic eruption and the movement of air masses over our country. Regarding the optical and microphysical properties, these are similar for mineral dust and mineral volcanic ash, the aerosol beeing characterized by large sizes, being non-spherical and less absorbant. By contrast, the ash originating from biomass burning has small sizes, is almost spherical and very absorbant.

O2. *Analysis of aerosol effects and their associated risks* – within chapter 2 there were analysed the aerosol effects on air quality and climate, as well as industrial and economic risks associated to the types of interest aerosols.

Numerous studies demonstrated that material particulates have a negative effect on human health, the potential of causing adverse effects being directly dependent on particule size, the major problem being the particulates with an aerodinamic diameter of less than 10 µm. As to effect on the climate, the aerosol impacts directly and indirectly the Earth's radiative forcing. In previous IPCC reports (IPCC 1996, 2001, 2007) the radiative effects of aerosols are divided in direct effects and indirect effects. Starting with the IPCC report in 2013, there are defined the *radiative forcing due to aerosol– radiation interaction*, known in previous reports as direct radiative forcing and *radiative forcing due to aerosol – cloud interaction*, known in previous reports as indirect radiative forcing (IPCC, 2013). Generally, the atmospheric aerosol causes a cooling which compensates the heating caused by greenhouse gases. But if each type of aerosol is individually studied, one may say that the mineral dust and the volcanic ash cause a certain cooling, while the aerosol originating from biomass burning causes heating. The associated socio-economic risk and impact refers mainly to a reduction of visibility (fog occurring, etc.), but can come in the form of extreme phenomena, such as violent sand storms, volcanic ash or smoke generated by large biomass fires.The main impact on the socio-economic environment associated to natural aerosol is represented by the negative effects on airplanes, these being affected by visibility reduction and in case of volcanic ash, an intake in the engineswhich can cuase them to fail. The best known cases from recent history are the eruption of the Island volcanoes Eyjafjallajökull in 2010 andGrímsvötn in 2011.

O3. *Analysis and intercomparation of LIRIC and POLIPHON altgorithms* and **O4.** *Determination of mass and volume concentrations of aerosols using the 2 algorithms* were achieved within chapter 4. The two algorithms considered „state of the art" within the remote sensing community are applied, analysed and intercompared in order to identify their potential to offer information on aerosol concentration in the atmosphere. This information is used to evaluate the aerosol intrustions risks. In fact, this interest of the scientific community to obtain concentration profiles using remote sensing techiques was triggered by the lack of clear information during the eruption of the Eyjafjallajökull volcano. The subsequent study showed that the air space was closed without being necessary in some cases, thus generating significant economic loses. The two algorithms use data measured using multichannel lidar systems and sun photometers, being currently the best techniques for concentration estimation, excepting in-situ measurements.

O5. *Space and time analysis of natural aerosol at RADO stations* was elaborated in the first part of chapter 5, being analyzed solar photometry data from 5 stations situated in Romania, in different regions: București -Măgurele, Cluj Napoca, Eforie Nord, Iași and Timișoara. These stations are part of the NASA-AERONET global network of solar photometeres, while the main parameters which characterise the aerosols were analyzed: Ångstrom coefficient – ($\alpha_{440-870}$), aerosols optical depth (AOT_{440}), dimensional distribution, real part of the refractive complex index ($n_{(438)}$), and single scattering albedo ($SSA_{(440)}$).

The average values obtained for these parameters are specific to urban continental aerosol with influences caused by different mineral dust or biomass burning aserosol intrustion generated by vegetation fires. The measured average values are similar to those obtained at other AERONET stations, such as Paris and Greenbelt, U.S.A. The identification of mineral dust or aerosol from biomasss burning intrusions was developed using the Ångstrom coefficient – ($\alpha_{440-870}$), which has specific ranges known in literature for each type of aerosol. The value $\alpha_{440-870}$=1.3 was considered maximum for the occurence of saharian dust, and the value $\alpha_{440-870}$=1.8 as being the minimum for the aerosol generated by biomass burning. The confirmation of the case studies was performed by using the HYSPLIT model for the prognosis of air massess trajectories, DREAM model for the prognosis of dust intrusions, the satellite imagery - MODIS spectrometer and AERONET inversion data where available. At all stations, approximately 80% of the cases were confirmed, most of the unconfirmed cases being registered during days with low AOT values, associated with low atmospheric aerosol loading.

Regarding the inversion data obtained using sun photometry, these have average values corresponding to values measured at other similar stations. The real part of the complex refractive index, which offers information regarding the aerosol absorption capacity, $n_{(438)}$has average values between 1,40 at Cluj Napoca and Iași and 1,42 at Eforie, these being similar to other regions where the urban continental aerosol is predominant: Paris - 1,40 and Greenbelt, USA - 1,39 (Dubovik et al., 2002). The high values of single scattering albedo - $SSA_{(440)}$ show the low absorption capacity of the aerosol, the averages obtained at the 5 stations, between 0,92 at Cluj-Napoca and 0,94 at București, Eforie Nord and Iași being similar to those measured at Paris – 0,94. These are smaller than the values obtained at Greenbelt, U.S.A. -0,98 where the specific fog is almost unabsorbent.

O6. *The development of a methodology for the assessment of risks associated to aerosol intrusions based on determining the concentrations through measurments and modelling* was performed in the last part of chapter 5, where this methodology was proposed. Using remote sensing in sinergy with different models used for dispersion simulation andfor concentration estimation alogside soil measurments, serveral studies may be developed, which allow the identification and analysis of risks posed by these intrusions. The methodology proposed within this chapter corresponds to all the stages in risk assessment, starting with the identification of possible intrusions, then their analysis and ending with conclusions regarding their hazard level for human health, environment and society. The first phase represents the warning, the identification of possible intrusions of potential hazardous aerosol before they arrive over Romania. This is possible by studying several forecast models, dispersion models or by warnings issued by international networks. Phase II consists in the identification of intrusions after they are present in Romanian air space, more specific, above stations with remote sensing equipments. For this, remote sensing instruments will be used and which are available at RADO stations, lidar systems as well as sun photometers. The third phase includes the detailed analysis of aerosol properties, in order to obtain their mass concentration at soil level, using point monitors for aerosol concentrations, and in the atmosphere, using concentration vertical profiles. Depending on the aerosol type present in the atmosphere, one of the two algorithms analysed within this thesis: LIRIC or POLIPHON will be used. Following the obtaining of concentration at soil level, as well as concentration profiles, the stakeholders will be informed: authorities, researchers and the public.

Knowing the type of aerosol present in the atmosphere and its concentration, the impact of these intrusions on the environment, human health and economy can be assessed. Regarding the human health impact, which can occur only in case of direct exposure, that is aerosol particulate reaching soil level. In case the daily average of PM_{10} exceeds the threshold of 50 de $\mu g/m^3$, it is recommended to warn the stakeholders, regarding the type of aerosol in the atmosphere.

As to the impact on airplanes, the threshold at which their engines are affected by ash is considered to be 2 mg/m^3, immediately after the erruption of the Eyjafjallajokull volcano in 2010, and after 4th May, this limit was increased to 4 mg/m^3 (VAAC Toulouse). Therefore, in case this concentration is obtained following the running of the two algorithms for the calculation of concentration vertical profiles, it is recommended to cease flights and the shut down the air space.

Perspectives

From the point of view of researches in remote sensing field, several activities in which the author is involved are currently in development phases. Firstly, the lidar station from the Faculty of Environmental Science and Engineering, UBB Cluj-Napoca will be included in EARLINET network, this being possible after the installation of the new multi-channel Raman lidar system, purchased through the POSCCE project – *Development of research infrastructure for disaster management based on high-performance computing – MADECIP*. The author contributes through his knowledge acquired during the doctoral stage, by using the similar system from the RADO main station, in the National Institute for R&D in Optoelectronics INOE 2000 – Măgurele and by using the Single Calculus Chain algorithm for the unitary processing of lidar data within EARLINET network. This activity was performed during the research stage offered by ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) - Trans National Access, through a scholarship won with the project *AEROCLASS: AEROsol CLASSification based on multiwavelength lidar data* la CIAO-CNR-IMAA, in Potenza, Italy.

Secondly, another activity in the field of remote sensing is the use of AERONET data which characterise the aerosol above Romania analyzed by the author in order to achieve the objectives of the SAMIRA -*SAtellite based Monitoring Initiative for Regional Air quality* project, funded by the European Space Agency, one of its objectives being the elaboration of maps of particulate matter at soil level using remote sensing techniques.

Another research activity is the assessment of risks associated to biomass burning at local level, forest fires as well as other types of fires – agricultural land, grasslands.

Another research field is the study of policies for the prevention of biomass burning and the analysis of training level of population and institutions with responsabilities in emergency situations management generated by vegetation fires and the education/informing level of the population.

The research developed within this thesis will allow the application to research projects in the field of remote sensing used in risk analysis and assessment, at the same time, considering a development of the academic curricula in this field.

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