SCIENTIFIC REPORT

- short version -

Summary of the stage

Stage 2 / 2021
Set-up of the NanoAir experimental parameters and measurement procedures. Implementation of technical and theoretical solutions and data correlation for NanoAir concept
Act 2.1 - Set-up the experimental parameters for analytical microscopy and nano–FTIR spectroscopy analyses
Act 2.2 - Set-up the experimental parameters for ground based and remote sensing instruments
Act 2.3 - Identification of proper spectroscopic range for aerosols properties
Act 2.4 - Synergy implementing of the NanoAir concept and optimizing the technical and theoretical solutions
Act 2.5 - Correlation of the inversion products, analytical microscopy and nanoscale imaging & spectroscopy data.
Act 2.6 - Implementation of regular and special measurement schedule

This stage includes six activities with are part of the general objective in reducing uncertainties regarding the optical absorption of mixture-type atmospheric aerosols and to evaluate their relation to optical absorption at different wavelengths. NanoAir shall attempt to add complementary and original answers through using a synergy between teledetection inversion products [by using ACTRIS-RO infrastructure], spectroscopy, analytical microscopy and nanometric scale imagistics & [using both the most advanced dispersion-type optical microscopy (s-SNOM), and SEM/EDAX]. s-SNOM combines atomic force microscopy with optical imagistics and nanometric scale microscopy (nano-FTIR) in order to better understand the fundament of a critical physico-chemical transformation of atmospheric aerosols (pollutants). For an analysis of the behavior of these pollutants we will also account for meteorological conditions. Given the complexity of the analysis, it presupposes a description of the mode in which pollutants behave in their environment and an analysis of environment quality after the impact with the studied pollutant.

Set-up the experimental parameters for analytical microscopy and nano–FTIR spectroscopy analyses. Set-up the experimental parameters for ground based and remote sensing instruments

These two activities were started in the previous stage. Also these activities have included finalizing equipment parameters that were bought in this stage. Based on studies found in the literature, we expose the technical and scientific context.

Air pollution is among the greatest risk factors for human health, but also presents risks for food security, economy and the environment. The majority of pollutants emitted by human activity come from the production and use of fossil fuel energy. The quality of our life on Earth is strictly correlated with and influenced by air quality. The bodily consequences of polluted air are varied and complex. Bringing awareness towards these effects has needed the implementation of certain environmental protection measures which are designed to reduce air pollutant concentration to attain certain national and regional goals.

Even if the impact of meteorological conditions on air quality (both in the cold and the hot season) is significant, the influence of air pollution on certain meteorological parameters, such as aerosol radiation absorption, must not be excluded.

Another example is the relation between aerosol and rain, which depends on the balance between microphysical effects and processes and radiative processes; conditions linked to this balance are analyzed in various studies.

Although emissions have a direct impact on air pollution, meteorological processes can influence the concentration of pollutant released in the atmosphere, and the transfer of pollutant to the environment, given that the only way of controlling air pollution directly is controlling emission rates. In these studies, in which the tight relation between atmospheric pollution and meteorological condition is analyzed, we must account for the scale at which atmospheric dynamics take place [1].

At a synoptic scale (the scale at which circulations hundreds or thousands of kilometers in scale dominate, and the timescale is on the order of days or weeks [2]), certain weather regimes are linked to pollution episodes. Rain associated with cold fronts determine the decrease of particulate concentration [1,3]. Cold frontal passes usually favor the elimination of atmospheric pollutants. Hu et. al. have noticed a decrease of air pollution during cold front passes, since the surface velocity and the height of the planetary boundary layer have increased [1,4]. At the same time, cold fronts could be seen as potential carriers of atmospheric pollutants. An example is given by Kang et al., in which they noticed that particles in suspension can enter the free troposphere in the Northern Plains of China because of a cold front pass [5].

The anticyclonic regime brings unfavorable conditions for pollutant dispersal, thus for example in January 2006, in a Polish study, high concentrations of gaseous pollutants were detected in winter. During summer, this effect was obvious for tropospheric ozone and for suspension particles of PM type [6].

Air quality depends first of all on air temperature and wind speed. Temperature explains ozone variability during summer and particle emission, and also the sulphur dioxide variability during winter. Given this information, however, wind speed also has a role as a dispersion factor, affecting nitrous dioxide emissions in both hot and warm seasons and particles in suspension during winter.

In August 2003, a very large level of tropospheric ozone (O_3) was detected in Europe which, along with other pollutants and a heatwave, led to a considerable increase in mortality [6,7]. Filleul et al. (2006) have proven that between 3 and 17 August 2003, the risk of death due

[1]Pérez, I. A., García, M. Á., Sánchez, M. L., Pardo, N., & Fernández-Duque, B. (2020). Key Points in Air Pollution Meteorology. International journal of environmental research and public health, 17(22), 8349. https://doi.org/10.3390/ijerph17228349
[2]Curs intern- Meteorologie generală- Circulații locale, Școala Națională de Meteorologie, București
[3]Andreão W.L., Trindade B.T., Nascimento A.P., Reis N.C., Andrade M.F., Albuquerque T.T.D.A. Influence of Meteorology on Fine Particles Concentration in Vitória Metropolitan Region During Wintertime. Rev. Bras. Meteorol. 2019;34:459–470.
[4]Hu Y., Wang S., Ning G., Zhang Y., Wang J., Shang Z. A quantitative assessment of the air pollution purification effect of a super strong cold-air outbreak in January 2016 in China. Air Qual. Atmos. Health. 2018;11:907–923. doi: 10.1007/s11869-018-0592-2.
[5]Kang H., Zhu B., Gao J., He Y., Wang H., Su J., Pan C., Zhu T., Yu B. Potential impacts of cold frontal passage on air quality over the Yangtze River Delta, China. Atmos. Chem. Phys. Discuss. 2019;19:3673–3685. doi: 10.5194/acp-19-3673-2019.
[6]Czarnecka, M. & Nidzgorska-Lencewicz, Jadwiga. (2011). Impact of weather conditions on winter and summer air quality. International Agrophysics. 25. 7-12.
[7]Solberg S., Hov Ø., Søvde A., Isaksen I.S.A, Coddeville P., DeBacker H., Forster C., Orsolini Y., and Uhse K., 2008.European surface ozone in the extreme summer 2003. J. Geo-phys. Res. Atm., 113, 7-15

to large concentrations of O_3 associated with large temperatures increased[6,8]. The so-called black smog that appears during the winter and the photochemical smog observed in the spring and summer are correlated with the weather imposed by the anticyclonic regime, with the vertical thermal structure of the planetary boundary layer, and with the circulation type. Topography which hinders natural air circulation in a city can contribute to the appearance, accumulation and length of smog episodes. Tall buildings, represent an additional barrier for pollutant dispersion in metropolitan areas [9].

Sometimes, meteorological conditions directly determine air pollution since they can aggravate pollution episodes, such as recirculating air particles trajectories. However, certain meteorological conditions can also improve air quality, for example the inverse relation between particle concentration and the ventilation factor (given by estimating the mixed layer and obtaining wind at $10m$ height), first observed in Santiago, Chile [10].

Urban environments deserve special attention since a large number of people live, work, meet or spend time in general in these areas. Urban activities are sources of pollutants, and the emissions depend on installations and population. Pollution dispersion is conditioned by urban characteristics, but also by cultural and geographic conditions. As a consequence, the impact of city pollution varies from a micro to a mesoscale, and this must be taken into consideration in studies.

Urban heat islands need to be carefully studied, since the extension of certain urban structures can modify the appearance of turbulence. The absorption and emission of radiation in urban environments (by urban surfaces) differs from processes that take place in rural areas. Even more, there is an increased roughness determined by buildings. The urban heat island can increase vorticity and can produce direct thermal circulation and mesovortices at the surface [11].

For an analysis of the behavior of atmospheric pollutants in certain meteorological conditions we must keep in mind pollution sources, environment properties and the influence of the perception location of atmospheric emission. The totality of physical phenomena that the pollutant suffers in its movement towards the receptor is influenced by certain factors, such as topography, air temperature, cloud coverage, atmospheric stability, windspeed and direction.

Yuval et al. have studied the relative impact of two atmospheric variables – atmospheric stability and regional scale turbulence – in determining air pollutant concentration. It was considered that the location was affected by a large variety of sources which emanate very different pollutants. It was found that traffic was responsible with the greatest part of local pollution [12]. However, the impact of meteorological factors can also be dominant and can dictate pollutant concentration. P. Fischer et al. have evaluated if the effects of pollution on mortality show an increase during Dutch heat waves. These sever occurrences in 2003 and 2006 have probably provoked a surplus of tens of thousands of deaths all across Europe and have led to a series of publications about the effect of heat on

[8] Filleul L., Cassadou S., Medina S., Fabres P., Lefranc A., andEilstein D., 2006.The relation between temperature, ozone,and mortality in nine French cities during the heat wave of2003. Environ. Health Perspect., 114, 1344-1347
[9] Xie X., Huang Z., and Wang J., 2005.Impact of building con-figuration on air quality in street canyon. Atm. Environ., 39,4519-4530
[10] Muñoz R.C., Corral M.J. Surface Indices of Wind, Stability, and Turbulence at a Highly Polluted Urban Site in Santiago, Chile, and their Relationship with Nocturnal Particulate Matter Concentrations. Aerosol Air Qual. Res. 2017;17:2780–2790. doi: 10.4209/aaqr.2017.05.0190
[11] Sfîcă, L., Ichim, P., Apostol, L. et al. The extent and intensity of the urban heat island in Iași city, Romania. Theor Appl Climatol 134, 777–791 (2018). https://doi.org/10.1007/s00704-017-2305-4
[12] Yuval, T. et al., *Emissions vs. turbulence and atmospheric stability: A study of their relative importance in determining air pollutant concentrations*, Science of The Total Environment, Vol. 733, 2020, 139300, https://doi.org/10.1016/j.scitotenv.2020.139300

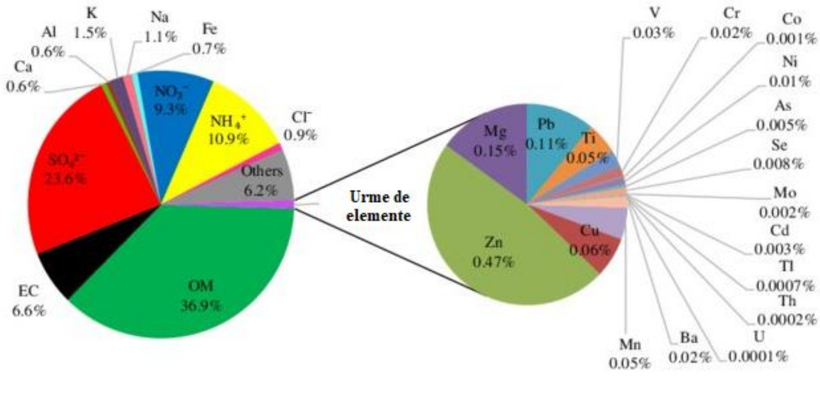
mortality. One of these suggests a modification of pollution effects during the heat waves. Results show that there is an interaction between temperature and air pollution, in that daily mortality due to pollution increased in the heat wave episode [13]. A similar episode, although weaker, was detected from concentrations of benzene and toluene. Sources outside the city are responsible for the majority of CO, PM1 and PM2.5 pollution, but during winter nights, which are characterized by atmospheric stability, their concentrations are increased due to local emissions and decreased turbulent diffusion [3].

A significant proportion of Europe's population lives in areas, mostly urban, where there appear unsuitable increases of pollutants and improper air quality: ozone pollution, nitrous dioxide and PM-type particles can induce grave health risks. This has been true for many countries for many years at a time. Thus, the reduction of atmospheric pollution remains important [14].

Identification of proper spectroscopic range for aerosols properties

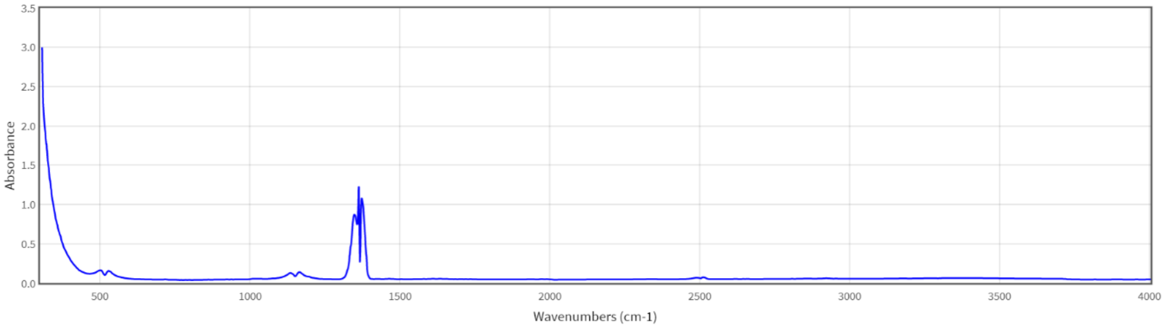
In the following segment, the chemical analysis performed through characteristic energy spectroscopy of fine air particles in an urban environment is performed. This is done through X-ray dispersive energy spectroscopy (EDS Bruker, X-Flash, Esprit software while using Automatic, Element List și Mapping).

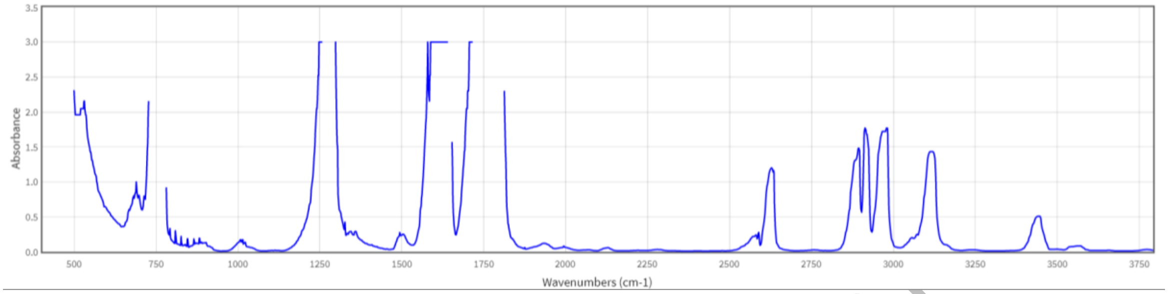
In order to identify the proper spectroscopic domain regarding aerosol properties and to characterize them using the s-SNOM technique, which combines atomic force microscopy with optical imagistics and nanoscale spectroscopy (nano-FTIR) to better understand the fundament of certain physiochemical transformation of pollutants, IR absorption spectres were studied. A predominant percentage from the samples is given by the presence of sulphur dioxide in the air with 23.6% and of nitrous dioxide with 9.3%, and the IR figure is shown below [15]. Also, the main chemical reactions (selected in the preliminary analysis of air samples) that can take place in ambiental air were studied [16][17][18].



Chemical composition of particles which contain OM - organic mass and EL - elemental carbon

[13] Fischer P. et al., *Effect of Interaction Between Temperature and Air Pollution on Daily Mortality During Heat-waves*, Epidemiology, Vol. 19(6), 2008, S379, doi: 10.1097/01.ede.0000340495.00450.fb
[14] https://www.eea.europa.eu/, European Environment Agency Website
[15] https://webbook.nist.gov/
[16] Jain, R. K., Cui, Z. "Cindy," & Domen, J. K. (2016). Environmental Impacts of Mining. *Env. Imp.Mining & Mineral Processing*, 53–157.
[17] Lin, C., Xu, W., Yao, Q., & Wang, X. (2018). Nanotechnology on Toxic Gas Detection and Treatment. *Novel Nanomaterials for Biomedical, Environmental and Energy Applications*, 275–297.
[18] Năstase, G., Șerban, A., Năstase, A. F., Dragomir, G., & Brezeanu, A. I. (2018). Air quality, primary air pollutants and ambient concentrations inventory for Romania. *Atmospheric Environment*, *184*, 292–303.





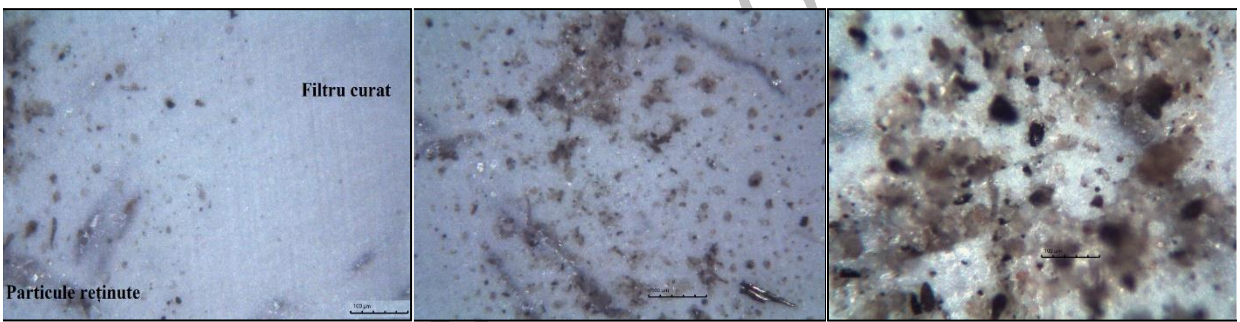
Analyzing SEM electron microscopy data, in the sampling air exist the following chemical elements: in a lower percentage: Al, K, Na, Fe, Ca, for nitrogen oxides we have a percentage of 9.3%, and for sulphur oxides a higher percentage representing approx. 23.6%. The presence of a high percentage of sulphur oxide in the air can have a visible effects in a short period of time such as severe breathing difficulties, the main category affected being children, the elderly and people with chronic diseases, and long-term exposure to low concentrations of Sulphur dioxide can cause respiratory tract infections. Regarding nitrogen dioxide depending on its concentration, the effects can also be long-term or short-term: exposure to very high concentrations can be fatal and lower concentrations affects the lung tissue. The most affected category by the existence of this pollutant in the air are children. With a percentage of 10.9% we have NH4 + ammonium present. The percentage of 6.2% is represented by other chemical elements such as heavy metals: Pb, metals: Cu and other chemical elements such as Mg, Zn, Ti. These are represented in a very small, even negligible concentration. The percentage of 6.6% is represented by elemental carbon. The highest percentage is made up of organic mass 36.9%. Highlighting the area in which the measurements were made it can be concluded that this organic mass may include volatile organic compounds but also persistent organic pollutants. Persistent organic pollutants are organic compounds resistant to the chemical, biological and photolytic action of environmental agents, so they are resistant to degradation. As a by-product of combustion these 2 persistent organic pollutants can result: dioxins and furans, which due to bioaccumulation and long half-life, chronic exposure can lead to health consequences such as: thyroid disorders, diabetes, impaired immune systems and the nervous system. The main problems raised by the presence of VOCs (volatile organic compounds) in the environment are the following: ozone depletion; photochemical formation of ground-level ozone; carcinogenic, toxic and other health problems as well as increasing the overall greenhouse effect; their accumulation and persistence in the environment.

Synergy implementing of the NanoAir concept and optimizing the technical and theoretical solutions

The microstructural and chemical analysis of the experimental filters was done using basic techniques: optical microscopy (Zeiss with a MotiCam digital camera to sample and analyze images), electronic microscopy (VegaTescan LMHII with an SE secondary electron detector, work distance of 15.5mm, and 10 to 30kV voltage), and chemical analysis through X-ray dispersive energy spectroscopy (EDS Bruker, X-Flash, Esprit software using the Automatic, Element Lista and Mapping modes). Optical microscopy was performed on a normal light with the filter situated between two glass slides and at different amplification powers for recording at various macro and microscopic dimensions of the particles in the samples.

During this activity sampling experiments of emissions were performed of certain pollution sources in an urban-type ambiental environment after the burning of various combustibles found both in the context of heating and public traffic.

Sampling was performed in accord with existing scientific literature [19], using a sampling system which contains a separator and a collector of ambiental air particles for five dimension fractions [20], a pump [21] and dedicated filters for the particle collector. A part of the obtained images are exemplified below.



(a) (b) (c)

Optical images a) and b) 100x, c) 200x

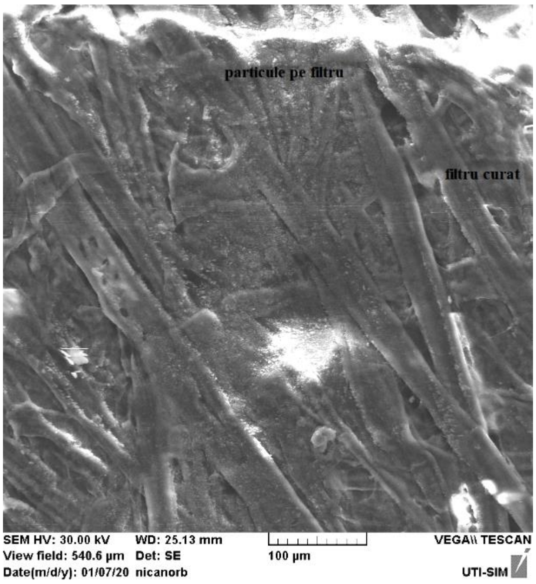
[19] Unga, F. et al. Microscopic Observations of Core-Shell Particle Structure and Implications for Atmospheric Aerosol Remote Sensing. Journal of Geophysical Research: Atmospheres 123, 13,944-13,962 (2018).

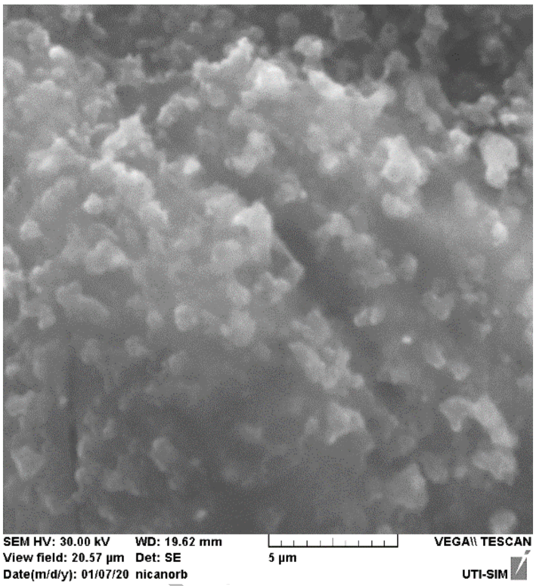
[20] https://www.skcinc.com/products/sioutas-five-stage-cascade-impactor

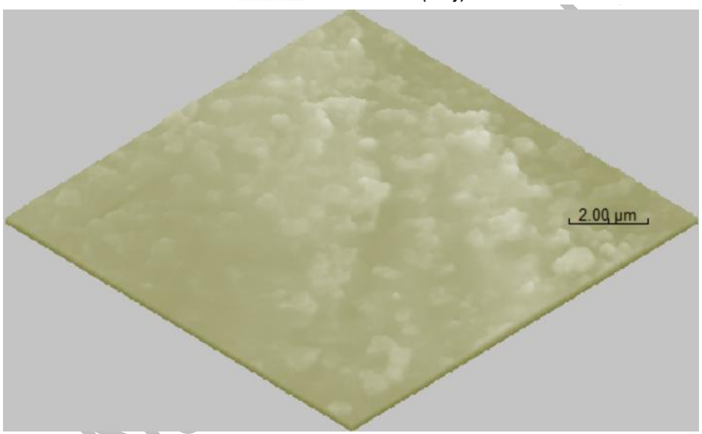
[21] https://www.skcinc.com/products/leland-legacy-personal-sample-pump

Correlation of the inversion products, analytical microscopy and nanoscale imaging & spectroscopy data.

Microstructural analysis by electron microscopy (SEM)







Particle dimensionalization on one of the samples

Value	x [µm]	y [µm]	r [µm]	d [µm]	C [µm]	A [µm^2]
Obj. count	100	100	100	100	100	100
Summation	961.87	843.37	48.28	96.56	303.37	77.48
Min. value	0.35	0.36	0.28	0.57	1.78	0.25
Max. value	20.08	19.86	0.89	1.79	5.61	2.50
Mean val.	9.62	8.43	0.48	0.97	3.03	0.77
Std. dev.	6.11	5.52	0.12	0.23	0.73	0.40

Correlation with inversion products (using experimental data from teledetection techniques and theoretical models)

The substances released in the atmosphere become pollutants when their concentrations exceed certain levels. These threshold values can be reached not just through emission increase, but also in certain meteorological conditions. The main difference between emission roles and meteorological conditions is that emissions can be controlled [22], while the same cannot be true for meteorological conditions. On a mesoscalar level, certain sea, mountain and valley breezes can sustain pollution and recirculation processes can be favorized by orographical characteristics. One can also take into consideration urban heat islands, since the formation of mesovortices determines the entry of pollutants in urban atmospheres.

In the case of atmospheric pollution propagation studies, it is necessary to assimilate the atmosphere in an intelligible physical and mathematical framework, which is also concrete and coherent. In general, the attempt to model atmospheric dynamics is begun with a combination of physical theories and computer simulations. The theoretical aspect of these models can be difficult to render, because the chaotic conditions that describe the majority of turbulent flows slows the discovery of classes of mathematical universality. However, since even the computer simulations use specific algorithms found through theoretical efforts, such studies are important. Recently, a new class of models used to describe atmospheric dynamics, reliant on scale relativity theory and using multifractal dynamics was developed. A scale transition relation can be used to build such models [23,24,25,26,27].

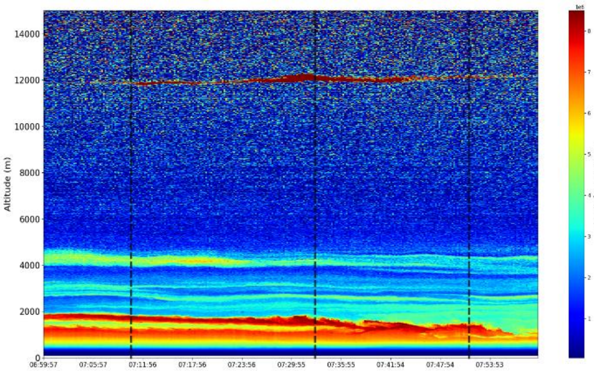
The model used in the following segment is a typical yet modified β-constant model; the standard one presupposes that energy dissipation is homogenously distributed through uniformly-dimensional fractal vortices [28]. It is found that this model belongs to a class of models found through multifractal scale transition [29]. By maintaining the scale ratio β constant but by also adding a scale resolution parameter we obtain the following equation: $l_n(n,s) = l_0 2^{-ns^2}$. This can produce multiple turbulent structures that have their own fractal dimension, thus reaching a multifractal atmospheric flow. Because of the scale resolution dependency, s practically shows how quickly the scale decreases. More turbulent flow parameters can then be calculated through this model, the results of which are published in our previous studies. Furthermore, this theory was applied to lidar data, thus obtaining temporal profiles of various turbulent atmospheric parameters, and it has been found that these results correspond with existing scientific literature, especially regarding the planetary boundary layer [23, 30].

For a practical analysis of the system, experimental data obtained through a lidar platform are introduced to apply the theorem so far, and to verify it. The method used to process these data is described in greater detail in previous works, but it is based upon obtaining the structure coefficient of the atmospheric refraction index C_N^2 in the following

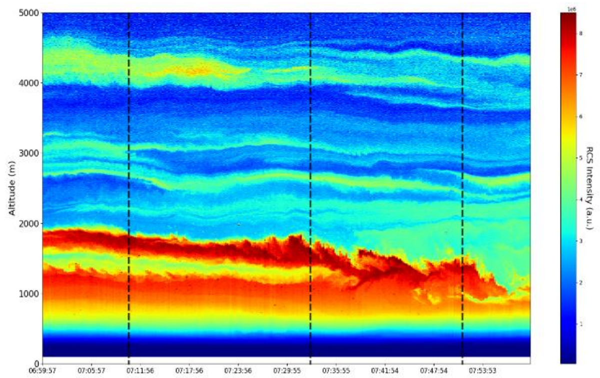
[22]Cheng N., Cheng B., Li S., Ning T. Effects of meteorology and emission reduction measures on air pollution in Beijing during heating seasons. Atmos. Pollut. Res. 2019;10:971–979. doi: 10.1016/j.apr.2019.01.005.
[23]Bar-Yam, Y., McKay, S. R., & Christian, W. Dynamics of Complex Systems (Studies in Nonlinearity). Computers in Physics, 12(4), 335-336, 1998.
[24]Mitchell, M. Complexity: A guided tour. Oxford University Press, 2009.
[25]Badii, R., & Politi, A. Complexity: hierarchical structures and scaling in physics (No. 6). Cambridge University Press, 1999.
[26]Flake, G. W. The computational beauty of nature: Computer explorations of fractals, chaos, complex systems, and adaptation. MIT Press, Cambridge, MA, 1998.
[27]Ţîmpu, S., Sfîcă, L., Dobri, R. V., Cazacu, M. M., Nita, A. I., & Birsan, M. V. (2020). Tropospheric Dust and Associated At-mospheric Circulations over the Mediterranean Region with Focus on Romania's Territory. Atmosphere, 11(4), 349.
[28]Boffetta, G., Mazzino, A., & Vulpiani, A. (2008). Twenty-five years of multifractals in fully developed turbulence: a tribute to Giovanni Paladin. Journal of Physics A: Mathematical and Theoretical, 41(36), 363001.
[29]Roșu, I. A., Nica, D. C., Cazacu, M. M., & Agop, M. (2021). Towards Possible Laminar Channels through Turbulent Atmos-pheres in a Multifractal Paradigm. Atmosphere, 12(8), 1038.
[30]Roșu, I. A., Cazacu, M. M., & Agop, M. (2021). Multifractal Model of Atmospheric Turbulence Applied to Elastic Lidar Data. Atmosphere, 12(2), 226.

manner [24, 31]: $\sigma_I^2(L) = 1.23\, C_N^2(L) k^{\frac{7}{6}} L^{\frac{11}{6}}$. Where σ_I^2 is the scintillation of the intensity of a source of light observed at a distance represented by the optical path L.

The RCS data („Range Corrected Signal") used to apply these equations were obtained using the RALI „Multiwavelength Raman Lidar Platform", belonging to RADO (Romanian Atmospheric 3D research Observatory) and ACTRIS – RO (Aerosol, Clouds and Trace gases Research InfraStructure) - Romania in the framework of the National Institute for Research and Development in Optoelectronics INOE 2000 in Bucharest, Romania.



RCS timeseries, Bucharest, Romania, 13/06/2019



RCS timeseries, Bucharest, Romania, 13/06/2019 (zoomed-in, inferior region of interest).

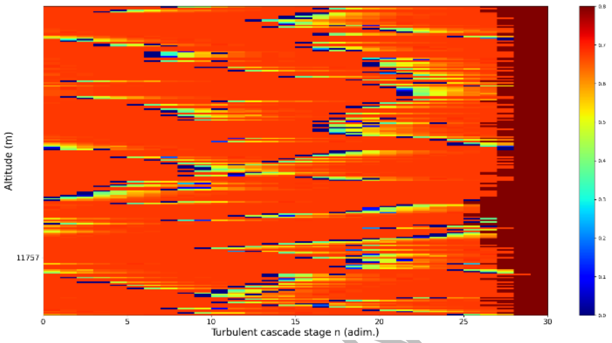
The emission wavelength used in this study is $1064nm$ at a $50mJ$ pulse energy. Pulse duration is between $7ns$ and $9ns$, repetition rate is $10Hz$, and spatial resolution is $3.75m$. Reception is performed with a Cassegrain telescope with a $400mm$ diameter and a "photon-counting" acquisition system. The RALI system has been used and tested in many other studies [32, 33, 34].

A careful examination of these profiles will show what has been called „laminar channels", and their presence is a consequence of the fact that, at certain altitudes, a bifurcation parameter calculated through a logistic scalar model applied to lidar data corresponds to a region of the logistic map characterized by a negative Lyapunov exponent, and then, at a different altitude, the phenomenon repeats itself. Thus, it is possible to identify ascending and descending laminar channels that can explain transport phenomena of atmospheric pollutants; horizontal channels with indeterminate effects and opposing channels can also be found. The areas in which channels are horizontal or opposite should indicate stable sections of the profile in which atmospheric structures, either pollutant plumes or clouds, neither go up nor down. It is worth mentioning that the absence of laminar channels implies a strong turbulent activity. In our studies [35, 36] we have launched a hypothesis that states that ascending laminar channels represent ascending vertical transport, while descending laminar channels represent descending vertical transport since the turbulent

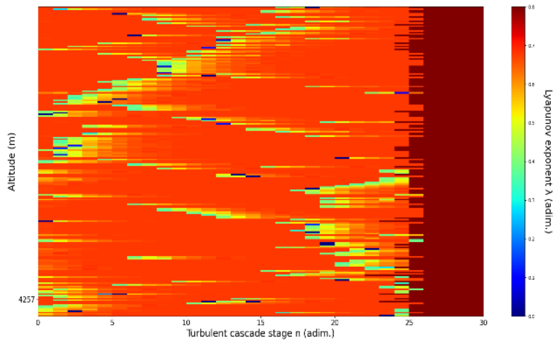
[31]Rosu, I.A.; Cazacu, M.M.; Prelipceanu, O.S.; Agop, M. A Turbulence-Oriented Approach to Retrieve Various Atmospheric Parameters Using Advanced Lidar Data Processing Techniques. Atmosphere 2019, 10, 38.
[32]Adam, M., Nicolae, D., Belegante, L., Stachlewska, I. S., Janicka, L., Szczepanik, D., ... & Peshev, Z. (2020). Biomass burning events measured by lidars in EARLINET. Part II. Results and discussions. Atmospheric Chemistry and Physics Discussions, 1-45.
[33]Belegante, L., Bravo-Aranda, J. A., Freudenthaler, V., Nicolae, D., Nemuc, A., Ene, D., ... & Pereira, S. N. (2018). Experimental techniques for the calibration of lidar depolarization channels in EARLINET. Atmospheric Measurement Techniques, 11(2), 1119-1141.
[34]Nicolae, D., Vasilescu, J., Talianu, C., Binietoglou, I., Nicolae, V., Andrei, S., & Antonescu, B. (2018). A neural network aero-sol-typing algorithm based on lidar data. Atmospheric Chemistry and Physics, 18(19), 14511-14537.
[35] Roșu, I. A., Nica, D. C., Cazacu, M. M., & Agop, M. (2021). Towards Possible Laminar Channels through Turbulent Atmos-pheres in a Multifractal Paradigm. Atmosphere, 12(8), 1038.
[36] Roșu, I. A., Cazacu, M. M., & Agop, M. (2021). Multifractal Model of Atmospheric Turbulence Applied to Elastic Lidar Data. Atmosphere, 12(2), 226.

cascade naturally develops from an initial to a dissipation scale. Thus, it is logical that the following step might be a preliminary analysis using lidar data. The first set of figures shows temporal lidar profiling with the aforementioned lidar platform. A series of atmospheric features and bodies can be directly observed, including cirrus-type stratospheric clouds, cirrus-type plumes, pollutant plumes and the planetary boundary layer.

After the visual analysis of the data, three important points are chosen, more precisely 07:10:00, 07:33:00 and 07:51:00, that are name “point A”, “point B”, and “point C”. These have been chosen as they are the initial moments of certain visible evolutions of the atmosphere. The position and profiles associated to these three points was consecutively delineated with three broken black lines. The RCS profiles can also be used to show a much more clear image of the atmosphere in comparison to the laminar analysis, especially connected to various atmospheric formations such as the planetary boundary layer. The laminar and turbulent environment is analyzed next to the following points: for point A: 11900m, 4500m, 4000m, 3051m, 2939m, 2689m, 2217m and 1900m; for point B: 12000m, 4520m, 4223m, 3099m, 2614m, 1693m and 1300m; for point C: 1500m. Point C presents just one altitude of interest since the higher altitude atmospheric dynamics appear to be more or less the same compared to the other points. The presence of large stratospheric structures through all the sets shows that such structures can be used as an important indicator for future studies in different datasets. In the figures below, just two correlations between RCS profile dynamics and laminar channels are exemplified.



Lyapunov exponent per turbulent cascade stage colormap altitude plot, Bucharest, Romania, 13/06/2019, 07:10:00; point of interest: 11900m.



Lyapunov exponent per turbulent cascade stage colormap altitude plot, Bucharest, Romania, 13/06/2019, 07:10:00; point of interest: 4500m.

As a conclusion, the analysis of the figures made in relation with atmospheric evolution produces 5 instances of strong correlation, 7 instances of correlation, 2 instances of null correlation, and 1 instance of negative correlation. These are promising results for our theory, but more aspects of this comparison must be considered. First of all, so far the correlation has been visual and arbitrary – a more quantifiable approach must be taken regarding the differences between RCS evolution and laminar channel trends, and the process must be automatized. Also, the number of analyzed cases is quite low. Both aspects appear as a consequence of the difficult computational and conceptual nature of the analysis itself, and this will be addressed in a future work. There is also the problem of using other models and methods to quantify atmospheric dynamics directions – this might be solved by coupling our model to models such as NOAA HYSPLIT, which have been successfully used in other studies of aerosol dynamics investigation [37, 38].

The following compressed conclusion of the used theory after a qualitative analysis of the results is that there are atmospheric laminar channels which can control atmospheric aerosol concentration and movement and monitoring these channels can lead to a detailed evaluation of pollutant and other unwanted corpuscles dynamics. But this monitorization does not always have to be done with telemetric platform – it is possible to show that quantitative and qualitative predictions of exposure risk to such atmospheric aerosol and harmful corpuscles (viruses, bacteria, even dangerous airborne toxins) can be measured through basic turbulence mechanisms and simple meteorological measurement, because every macroscopic or microscopic component of the atmosphere must behave according to the laws of atmospheric physics [39]. Given the fact that most atmospheric flows, both at ground level and at higher altitude, are turbulent, the mechanisms of turbulence can be used to understand such components [40].

Implementation of regular and special measurement schedule

At the basis of these activities are the monitoring platforms of ambiental air quality and of meteorological parameters. The data measured and processed by the monitoring system are accessible through Internet cloud. One of the monitoring points is a part of the „Gheorghe Asachi" Technical University of Iasi [41, 42]. Based on multiple monitoring points in Iasi (framework which is still in an extension phase: 4 of the 8 monitoring points supported by this project are active) we will be able to establish exactly what areas are worthy of focused air sampling. Furthermore, through pollution alerts, we are able to issue valuable momentary sampling decisions. Even more, identifying pollution sources will be done with a greater accuracy. Given the fact that the equipment is mobile, these will be moved to interest points, such that teledetection correlation is possible. Manual photometers will add complementary answers regarding atmospheric optical parameters.

[37] Cazacu, M. M., Tudose, O., Boscornea, A., Buzdugan, L., Timofte, A., & Nicolae, D. (2017). Vertical and temporal variation of aerosol mass concentration at Magurele–Romania during EMEP/PEGASOS campaign. Romanian Reports in Physics, 69, 706.
[38] Timofte, A., Cazacu, M. M., Radulescu, R., Belegante, L., Dimitriu, D. G., & Gurlui, S. (2011). Romanian lidar inves-tigation of the Eyjafjallajokull volcanic ash. Environmental Engineering & Management Journal (EEMJ), 10(1).
[39] Drossinos, Y., Stilianakis, N. I., What aerosol physics tells us about airborne pathogen transmission, Aerosol Science and Technology, 54(6), 639-643 (2020).
[40] Roșu, I. A., Cazacu, M. M., & Agop, M. (2021). Multifractal Model of Atmospheric Turbulence Applied to Elastic Lidar Data. Atmosphere, 12(2), 226.
[41] https://iasi.aqi.eco/ro/all
[42] https://www.aqmesh.com/products/aqmesh/

The disseminated results in the framework of this stage contain both experimental and theoretical aspects. Semi-empirical models use atmospheric data obtained with a lidar system in order to calculate altitude profiles of the structure coefficient of the atmospheric refraction index, as well as other turbulent parameters through using the notion of „multifractality”: assuming that the structural units that make up turbulent flow are described by continuous and non-differentiable functions. The results bring important answers regarding the physico-chemical characterization of atmospheric particles at a nano scale, with important effects on a macro scale.

The results have been disseminated through the publishing of 5 ISI indexed papers, 4 of those with an impact factor, and by participating at national and international conferences with 6 scientific works. These results initiate perspectives which shall be finalized through this project, highlighting certain physico-chemical nanoscale transformations. Other perspectives target air probes sampling from industrial environments, or from other specific environments in order to follow aimed classes of pollutants, given the complexity of the compounds that can enter the atmosphere, both at soil level and at higher altitudes. This particle complexity, as expected, was seen from initial sampling, and spectral identification of the chemical species regarding these particles must be performed, by eliminating the cumulative effect of known sources of pollution.

The degree of achievement of the activities of stage 2 / 2020 [Act 2.1, Act 2.2 and Act 2.3: complete (according to the NanoAir organigram, activities Act 2.4, Act 2.5 and Act 2.6 will be finalized during stage 3 / 2022)].

Scientific publications (2020 - 2021):

ISI papers:

1. **Roșu, I. A., Cazacu, M. M.**, & Agop, M. (2021). *Multifractal model of atmospheric turbulence applied to elastic lidar data. Atmosphere*, 12(2), 1–25. https://doi.org/10.3390/atmos12020226, Impact factor: 2.686, Article influence score: 0.625
2. **Roșu, I.-A.,** Nica, D.-C., **Cazacu, M. M.**, & Agop, M. (2021). *Towards Possible Laminar Channels through Turbulent Atmospheres in a Multifractal Paradigm*. Atmosphere, 12(8), Article 1038. https://doi.org/10.3390/atmos12081038, Impact factor: 2.686, Article influence score: 0.625
3. Sioustis, I. A., Axinte, M., Prelipceanu, M., Martu, A., Kappenberg-Nitescu, D. C., Teslaru, S., Luchian, I., Solomon, S. M., **Cimpoesu, N.**, & Martu, S. (2021). *Finite element analysis of mandibular anterior teeth with healthy, but reduced periodontium*. Applied Sciences, 11(9). https://doi.org/10.3390/app11093824, Impact factor: 2.679, Article influence score: 0.409
4. Cimpoeșu, R., Vizureanu, P., Știrbu, I., Sodor, A., Zegan, G., Prelipceanu, M., **Cimpoeșu, N.**, & Ioanid, N. (2021). *Corrosion-resistance analysis of ha layer deposited through electrophoresis on ti4al4zr metallic substrate*. Applied Sciences, 11(9). https://doi.org/10.3390/app11094198, Impact factor: 2.679, Article influence score: 0.409
5. **Cazacu, M. M.**, Pelin, V., Radinschi, I., Sandu, I., Ciocan, V., Sandu, I. G., & Gurlui, S. (2020). *Effects of meteorological factors on the hydrophobization of specific calcareous geomaterials from Repedea - Iasi area, under the urban ambiental air exposure*. International Journal of Conservation Science, 11(4), 1019–1030.

BDI Papers:

6. **Roșu, A. I.**, Cazacu, A., Bodale, I., **Cazacu, M. M.**, (2020). *Developing a concrete inequality condition for Taylor's hypothesis in common turbulent atmospheric flows*. Bulletin of the Polytechnic Institute of Iasi, Section Mathematics. Theoretical Mechanics, Physics, 66(70)(4), 49–55.
7. Braniște, M.-V., Ștefan, I., Ana, M., **Unga, F., Cazacu, M. M.**, (2020). *Particle air pollution (PM10) monitoring and public opinion on air quality. A case study in Northeastern Romania*. Bulletin of the Polytechnic Institute from Iaşi: Chemistry and Chemical Engineering Section, 66(70)(4), 55–67. https://www.eea.europa.eu/;
8. **Roșu, A. I., & Cazacu, M. M.** (2020). *Further developments of a multifractal model of atmospheric turbulence*. Bulletin of the Polytechnic Institute of Iasi, Section Mathematics. Theoretical Mechanics, Physics, 66(70), 77–91.

Conferences:

1. **I. A. Rosu, M. M. Cazacu, A. Timofte**, M. Agop, *Exploring the application boundaries of stochastic theories regarding turbulent atmospheric ceilometer data*, European Lidar Conference 2021, Granada, Spain, oral presentation.
2. **I.A. Roșu**, M. Agop, **F. Unga, L. Mihăilă, N. Cimpoesu, M.M. Cazacu**, *Employing atmospheric sensors and turbulent energy cascade theory to quantify hazardous airborne transmissibility*, European Aerosol Conference – 2021, Bristol, United Kingdom, oral presentation.

3. A. Cernescu, N. **Cimpoesu, A.I. Rosu, L. Mihaila, F. Unga, D.P. Burduhos Nergis, M.M. Cazacu**, *Nanoscale IR-imaging and spectroscopic characterization of air-filtered pollution nanoparticles using s-SNOM*, virtual workshop organized by "Cyprus Institute", Cyprus and "Finnish Meteorological Institute" (ACTRIS Head Office), Finland, 2021, oral presentation.

4. A.M. Roman, R. Chelariu, R. Cimpoeșu, I. Știrbu, I. Ioniță, **M.M. Cazacu**, B.A. Prisecariu, C. Paraschiv, *Analyze of the Corrosion Rate of Fe-Mn-Si Biodegradable Materials*, International Conference on Innovative Research - EUROINVENT ICIR 2021, Iasi, Romania, 2021, oral presentation.

5. C. Panaghie, R. Cimpoeșu, M. Benchea, A.M. Roman, V. Manole, A. Alexandru, **N. Cimpoeșu, M.M. Cazacu**, *Preliminary Results of in Vitro Tests on New Biodegradable Metallic Material Based on ZnMgY*, International Conference on Innovative Research - EUROINVENT ICIR 2021, Iasi, Romania, 2021, oral presentation.

6. M. Luțcanu, M. Coteață, D.L. Chicet, C.D. Nechifor, **M.M. Cazacu**, P. Paraschiv, B. Istrate, **N. Cimpoeșu**, *Obtaining and Analyze of Zro2-Al2O3 Ceramic Layers on Metallic Substrate*, International Conference on Innovative Research - EUROINVENT ICIR 2021, Iasi, Romania, 2021, poster presentation

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