SAHARAN DUST TRANSPORT OVER ROMANIA

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ABSTRACT. – Saharan dust transport over Romania. The paper analyses the synoptic process of Saharan dust or sand transport which might affect Romanian territory too. The main cause of Saharan dust transport on large distances is associated to an intense Mediterranean cyclone, as well as to a specific configuration of the jet stream. The rainfall occurring in these periods were called „dirty rains" or „blood rains". The presence of the Saharan dust over Romania is quite frequent in transition seasons (especially in spring), as well as in summer, less often during winter. In cases of high intensity, the phenomenon might have significant economic consequences, especially affecting the air transport, and people's health too. Under the circumstances of the intensification of actual climate warming, the transport of Saharan dust or sand may become more intense and more frequent. The paper is useful for all the people interested in climate changes and their consequences.

Keywords: *aerosols, Saharan dust and sand, Mediterranean cyclone, jet stream, tropical circulation, rainfalls, consequences, Romania*.

1. INTRODUCTION

Atmospheric air comprises some liquid or solid particles in suspension, called *aerosols*. They are bigger than the gas molecules and can determine light dispersion and refraction (gases transmit and absorb it). Atmosphere clear aspect indicates a small quantity of aerosols, and foggy aspect shows a higher concentration. Aerosols can be of different types: clouds, fog, dust, smoke, soot, pollen, smog. Their occurrence is due to the release or direct injection in atmosphere through different processes: condensation of water vapours (fog, clouds), chemical reactions with atmosphere gases (photochemical smog), scattering from ground due to the strong wind (dust, sand) etc. Aerosols are in the atmosphere all the time, but their excessive accumulation can lead to serious effects on human health. Consequently, it is necessary to monitor the concentration of aerosols, by assessing several parameters.

Coefficient of haze (COH) is determined by filtering 300 linear meters of air and comparing the filter optical density with standard values. The aerosols with sizes between 5 and 10 μm are especially monitored, because the particles with sizes smaller than 10 μm are inhalable, and those with values exceeding 6 μm are considered dangerous for health.

Total mass of particles in suspension in the air. If the values are higher than 60 $\mu g/m^3$, the concentration is considered dangerous.

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Total dust fall (TDF) is measured in g/m^2/month, by weighing the dust fall deposited on a certain surface during a month. A value higher than 7 g/m^2/month is considered dangerous for human health. Dust is composed of microscopic particles, with a dimension varying from less than 1 pm to about 50 pm (1 picometer=10^{-12} m).

The dust from atmosphere has different origins: deserts, volcanic eruptions, anthropic activities. Dust particles higher than 10 pm fall relatively fast near production areas. Small particles can be taken by the wind on long distances (hundreds or even thousands of kilometres), especially in lower troposphere, but they can reach up to 5-6 km altitude. *Dust and sand storm* takes place when an atmospheric front with a strong wind, scatter the sand and dust on a dry surface. In big Earth deserts and semi-arid regions, including in temperate areas, sand and dust storms are quite frequent, being considered medium-term climatic risk phenomena (between 3 and 10-15 days) (Moldovan, 2003). The disastrous effects of dust storms are also mentioned by historical sources. Thus, the archaeological investigations has led to the identification of the remains of famous lost army of the King Cambyse the IInd, which according to Herodotus himself, the father of history, would have perished completely, 50.000 Persian soldiers being were buried alive by a catastrophic sand storm in 525 BC.

A wrong management of dry Earth areas, such as neglecting the cultivated system or excessive deforestation, leads to the increase of sand storms frequency and intensity inside and at the edges of desert, causing the change of local climate (with a negative impact on the economy of the corresponding regions), as well as the global climate. Dust storms spring up rarely in steppe regions, very rare in forest-steppe and extraordinarily rare in forest (in the two latest, especially during the summer, when the drought is extremely severe). In steppe and forest-steppe regions, dust storms can spring up early in spring, after a winter with little snow and a dry autumn. Sand/dust storm usually occurs on a dry ground, when the wind speed is 10 m/s or higher. The vertical expansion of storm varies from several meters to 1-4 km.

2. DATA AND METHODS

For the analysis of the dust transport and its consequences, we used synoptic maps from international weather forecast centres, materials from Romanian National Administration of Meteorology (NAM) website, satellite information. To monitor the distribution of these phenomena across the Globe, we used bibliographies and articles from written press on the Internet, synoptic maps, data provided by the archive of satellite and radar images, as well as the Office facilities. The case studied refers to the interval 28th February-16th April 2016.

3. RESULTS AND DISCUSSIONS

Dust and sand storm areas on different continents. There are many arid and semiarid areas on the Earth with dust and sand storms: Asia (Central Asia, Aral-Caspian region, Gobi Desert, North-West of China, Thar Desert, Afghanistan, Turkey, Arabian Peninsula, etc); North America (Great Basin, Colorado Plateau,

South of Prairie Plateau, etc.); South America (Atacama Desert, dry pampas of Argentina); Australia (inside deserts); Africa (Sahara); Europe (South and Centre of Ukraine, South of Russian Plain) (Bryant, 1991, quoted by Moldovan, 2003). Some concrete situations are presents further below.

Black Sunday occurred on 14th April 1935, especially in Oklahoma and Texas, also known as the Dust Bowl (a period of the thirties '30, with a high frequency of dust storms in North-American prairies). Some sources say that it has been the most severe dust storm in the history provoked by local causes (supra-exploration of sandy fragile soil, which was scattered by wind in the droughty period from that spring). On 23rd September 2009, Australia was affected by a huge sand storm. After this storm, the ecologists were worried of the danger of polluting the atmosphere with Uranium. Frequent dust and sand storms reach the North-West and North of China, including Beijing region, the most recent being those from 20th March 2010, 7th January 2012, 17th December 2013, 18th April 2015, 8th April 2016. Furthermore, there were situations in which the dust from China reached Hawaii Islands, even Alaska, to a distance of 10.000 km (id. ibid.). For Europe and, in general, Northern Hemisphere, Sahara Desert is the greatest dust reservoir. Together with the desert region from Arabian Peninsula, the vast Saharan surface (9.400.000 km²) is a real threat for the European continent regarding the pollution with significant quantities of dust. According to some sources, almost 108 tons of dust are transported annually from Sahara towards Europe, and the impacts are many and different (environment, health, transport, etc.) (Kallos, 2015). The very smooth sand and dust from Sahara have been were identified also in Bermuda Islands, namely in Bahamas, to a distance of about 7.000 km. In some synoptic contexts, dust and sand from the North Africa or Arabian Peninsula go over Europe, and even over Great Britain.

In the South and South-East of Europe the phenomenon is quite frequent, and it is easily highlighted in the transition seasons. Dust and sand deposits in the warm season except rain can hardly be observed due to the mixture of dust coming from local sources. In winter, these kinds of storms bring a yellowish-reddish snow layer. Small dust, sand or ash storms can occur when, during the periods with severe drought, wind gusts scatter the ash from storage heaps or the sand and dust from sandy lands (for example, in Oltenia region, situated in the South-West of Romania).

Sand or dust transport over Romania. In Romania, dust and sand transport is usually associated to Suhovei wind generated by Asian Anticyclone, highly affecting Bărăgan and South of Moldavia, as it had happened in April 1928, when, after the storm from Ukrainian steppe, dust and sand suspensions reached Poland and Romania (Bâzâc, 1985). Other examples of this type are those from 23rd April 1960, and 18th April 1965. Dust transport is also caused by African winds (Sirocco, Khamsin), which move northwards ahead of eastward-moving depressions (Barry, Chorley, 1998). These storms transport smooth dust and sand particles to high altitudes (4-5000 m). Sometimes the particles are coloured in red because of the iron oxides, so that, when there are precipitation, a „blood rain" occurs, as it had happened on 23rd April 1973 (Geography of Romania, 1983). However, regardless dust origin (African or Asian), atmospheric circulation is favoured by the interaction between an anticyclone and a Mediterranean cyclone

situated over the basin of Mediterranean Sea, Balkan Peninsula or Black Sea. Dust and sand storms of Saharan origin, recently signalled in Romania, occurred on 20th April 2012, 30th May 2013, 3-5th April 2014, 29th February -1st March 2016, 9th April 2016.

Cross-border pollution with radioactive substances or volcanic ash in Europe. The nuclear accident from Chernobyl (Ukraine) on 26th April 1986 produced a radioactive cloud, which affected many countries in Europe, including Romania. A significant event occurred in the March-April 2010 period, when the volcano Eyjafjallajökull in Iceland erupted. Actually, the seismic activity began in the end of 2009, the volcano erupting on 20th March 2010, after almost 200 years of inactivity. A very serious consequence of this extended eruption was the interruption, for many days, of flights over Europe, namely above the Northern basin of the Atlantic Ocean.

Sand or ash storms occurred in Romania due to local causes. These storms affect more restricted areas. For example, in Craiova (Oltenia region), especially in summer, there are wind gusts, the ash on storage heap from Işalnița power plant is scattered by wind and covers broad surfaces, and if the wind blows from West (direction with a frequency exceeding 47%), the ash is brought to some outskirts neighbourhoods. Furthermore, on 31st May 2014, a dust cloud rose from Halânga power plant and covered all neighbourhood villages. Another case was reported in Timişoara (in the South-West of Romania, also), on 14th August 2014, when a construction site in the city centre caused a huge dust cloud.

3.1. Results

Studying the synoptic macro-process of dust transport over Europe, several aspects were observed. The main cause of Saharan dust transport on large distances is associated to an intense Mediterranean cyclone. The phenomenon is complex, being related to the atmosphere structure on a large scale and to the corresponding atmospheric circulation. Therefore, when over the front of atmospheric dust from Sahara or Arabian Peninsula overlaps the atmospheric front of a Mediterranean cyclone, or when that front of dust is enriched in water vapours transported from Mediterranean Sea or even from Black Sea, in some territories of Europe the phenomenon of „dirty rain" or, sometimes, „blood rain" occurs[4]. After the cessation of the rain, cars, roofs of the houses, objects on the ground, etc. are covered by a thick layer of yellowish-reddish dust.

In spring, thermal equator of the Earth moves towards North, but in the beginning of spring, cold air still covers large area of the European continent. Polar climatic front slowly withdraw towards North (Marinică, Marinică, 2014, 2016). The early delay of warm air movement towards North is due to the mountainous relief in the North of Africa. Consequently, there are frequent cold air advections from North, which initiate cyclogenetic processes in the North of Africa, namely in Sahara. Initially, the generated cyclone has atmospheric fronts with a thermal contrast and differences of pressure (the contrast in the field of moisture is either weak or

[4] Initially, the designation of ***dirty rains*** was given by mass-media, and subsequently the researchers have taken it over (Robert-Alexandru Balasz, Scientific Journal of NAM, 2012/2013, Bucharest.

inexistent), and without or few precipitation phenomena. Therefore, especially before the cold front, severe dust and sand storms might occur and raise the smooth dust and sand towards the high levels of the atmosphere. The natural macro-process of atmospheric circulation leads the cyclone movement above the Mediterranean Sea and, thus, the water vapours of those frontal systems are enriched. Satellite pictures often highlighted the presence of dust clouds simultaneously with the clouds due to the water vapours. This simultaneous presence of Saharan dust and rain clouds cause, subsequently, „dirty rains" over some large enough areas of Europe.

In autumn, that macro-process has a reverse development, thermal equator as well as extremely warm air retreat towards South. Polar climatic front slowly moves towards South, leading to the advance of polar cold air to lower latitudes and, therefore, of the cold air advections above the North of Africa and the beginning of cyclogenetic processes. According to analysed data, in the last years many dust, sand, ash, radioactive powders occurred in Romania and worldwide due to the global warming.

3.2. Discussions. Case study: the interval 28th February-16th April 2016

G. Kallos, in a 2015 study, established the transport directions of the Saharan dust and pollutants over Europe (fig. 1). As far as it can be observed, the transport directions of Saharan dust towards Romania are the same for all seasons and coincide with the directions of atmospheric circulations of tropical-continental and southern type. The South-East direction may be added for the dust transport of Arabian Peninsula, but it is less frequent. Sometimes, the dust transport of Saharan dust over Europe is lasting for many weeks.

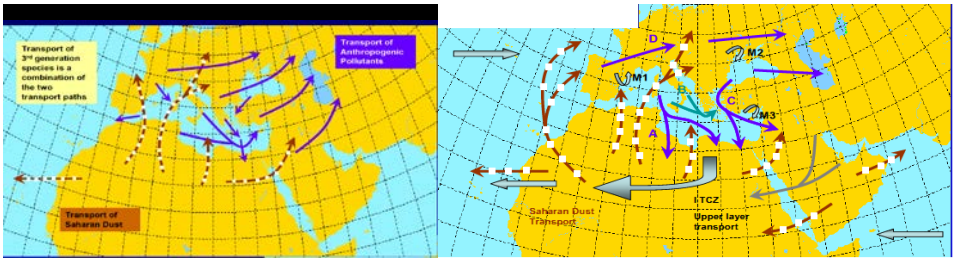


Fig. 1. ***Transport directions of Saharan dust (interrupted arrows) and pollutants (continuous arrows) over Europe, in transition seasons (left) and summer (right), (according to Kallos, 2015)***

This situation was encountered in the interval 28th February-16th April 2016, when the cloud of Saharan dust affected a large part of Europe. „Dirty rains" occurred in many cities of Western Romania, on 28th February and, especially, on 16th April 2016 (Reşiţa, Timişoara, Arad, Oradea, etc). Attention is drawn to the fact that NAM issued a meteorological warning for the interval 9th April, at 08 UTC, until 11th April, at 20 UTC, stating the following: *In the above interval, there will be periods with severe atmospheric instability on Saturday (9th April) in the Western half of territory and mountainous areas, and starting with Saturday night (9/10th April) especially in Southern regions and subsequently in Eastern regions. Water quantities will locally*

exceed 20 l/m^2, and in small areas, especially in hilly and mountainous regions, 40…50 l/m^2. There will be pouring rains with lightings and sparsely hail. ***Therewith, precipitation forecasted for the interval 8 – 11th April 2016 can conduct the particles of Saharan dust on the ground, but in small concentrations.*** The cyclogenesis in the North of Africa occurred on the cold front of a Mediterranean cyclone was visible on synoptic ground maps on 27th February 2016, at 18 UTC (fig. 2).

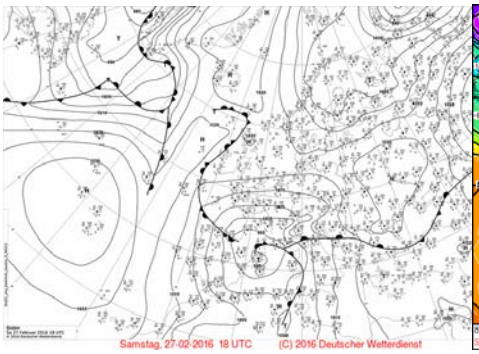


Fig. 2. ***Synoptic map at ground level on 27th February 2016, 18 UTC (Source: http://www1.wetter3.de)***

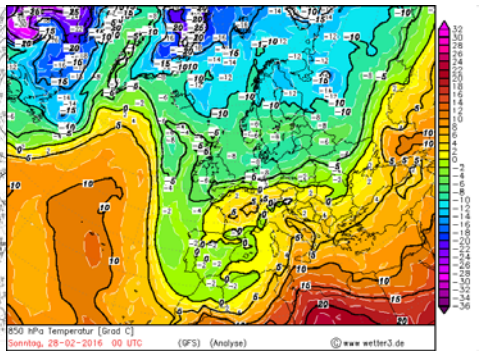


Fig. 3. ***Advection of cold air behind cold front on 28th February 2016, 00 UTC (Source: http://www1.wetter3.de)***

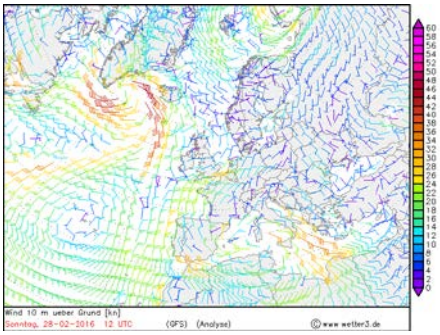


Fig. 4. ***Weather gusts on 28th February 2016, 12 UTC (Source: http://www1.wetter3.de)***

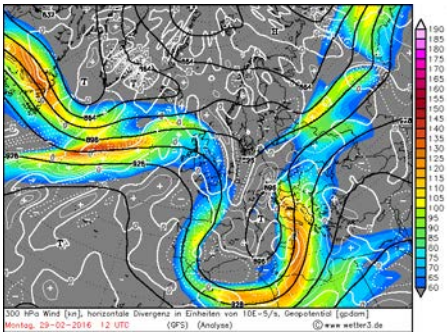
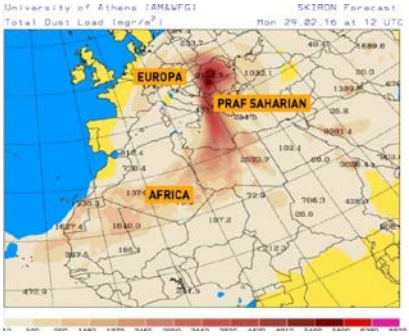


Fig. 5. ***Position of jet stream on 28th February 2016, 12 UTC (Source: http://www1.wetter3.de)***



The advection of cold air from the North of Europe towards the North of Africa was intense and began on 26th February. This advection on meridian direction has affected the lower levels of the Mediterranean cyclone, sustaining wind gusts in the North

Fig. 6. ***Maximum intensity of the Saharan dust advection over Romania on 29th February 2016, 12 UTC (Source: http://forecast.uoa.gr)***

of Africa and causing the continuous entailment of the Saharan dust (fig. 3 and 4). The maximum of Saharan dust advection towards the North, over Europe, coincides with an important extension to the South of the jet stream (fig. 5).

In Romania, air circulation in lower troposphere was from South-South-West, transporting the warm air from the North of Africa, together with the clouds of Saharan dust and cloudy systems of the Mediterranean cyclone (fig. 6). Thus, an intense nucleus of dust advection can be observed over Romania, centred above Transylvania, with a value of 6102.5 mg/m^2, higher than the values registered in the Northern Africa at the same time. The concentration of this nucleus over Romania (Transylvania) is related to the physical process due to the orographic barrier represented by the Carpathian Mountains.

Obviously, not all the Saharan dust is deposited immediately on the ground, such as it continued to persist in the atmosphere. Mediterranean cyclones subsequently formed, continued to transport the Saharan dust at the level of cloudy systems. These cyclones are formed through Mediterranean cyclogenesis, which is usually produced on the cold front of Atlantic cyclones whose trough is located above the Mediterranean Sea or through shelter cyclogenesis developed to the South of the Alps, in Genova Bay or in Venice Bay.

Rain showers were produced on the continent in different intervals of March and April 2016 and deposited on the ground the Saharan dust existing in the atmosphere. A large part of these particles constituted condensation nuclei to form fine water drops, which, subsequently, by coalescence and combination, formed rain drops. Consequently, after a first assessment, dust particles may have a positive role in the physical process of forming rains, but, depending on their chemical composition, they can cause erosion processes on ground objects, damages of different types of surfaces (roofs, cars). These dust particles can transport even the germs of diseases and fungi, which could affect people, animals and plants.

4. CONCLUSIONS

In Europe, including Romania, „dirty rains" or „blood rains" due to the dust and sand transport from the North of Africa occur more often in transition seasons and in the beginning of summer, and less frequent in winter. They are the result of dust storms taking place in Sahara Desert or Arabian Peninsula, which raise the dust in the troposphere (usually in lower troposphere, under the level of 500 hPa), and it is driven towards Europe by a tropical circulation (from South or South-East). Most often, these dust and sand storms are connected to an intense Mediterranean cyclone. Also, the position of the jet stream over Europe is very important. Moreover, dust and sand may be transported from Eastern Europe or even from Aral-Caspian region, by an Eastern circulation.

In rainfalls formation, dust particles have the role of condensation nuclei. Depending on their composition or biological charge (transported

germs), these particles can be dangerous for health or can affect flights, as well as other activities on the Earth surface. The macro-processes described above take place at a large scale, and the annual quantities of dust transported over the European continent are important. On the background of the actual global warming, dust and sand transport phenomena can increase and cause environmental and health problems. The global model for the forecast of dust transport on Earth, which is used at Athens University within SKIRON projects, has a good accuracy in the corresponding prognosis.

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