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IDENTIFICATION CHEMICAL AIR POLLUTANT SOURCES OVER EGYPT ON 10 MAY 2010

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Abstract

Mineral dust particles are considered one of the most important types of aerosols in the atmosphere which can be lifted to high altitudes and transported widely. It can mix with polluted air masses during transport and become coated with soluble chemical substance. Thereby, it can contribute to the radiative forcing and the precipitation formation. For this article, we have collected airborne Saharan dust by gravitational settling on a clean surface during sand storms events over Egypt on spring 2010 on 10 May the sample of mineral particles was taken from Port said, Dabaa, Elarish, 6 October, Aburdees and Kaha Cities. We collected six samples of airborne mineral dust which had been carried by the winds from the Sahara desert to sampling different points which are located and analyzed by Ion chromatography. It was found that the airborne Saharan dust samples had accumulated soluble coatings during transport by interaction with air pollutants. Cation and Anion are (Na^+, NH^+_4 , K^+, Ca^{2+}, Li^+ , Mg^{2+}, No^-_2 , No^-_3 , Cl^- , Br^-, F^-, SO^{2-}_4) on May 2010. Possible source regions of airborne mineral dust particles were determined by using the air mass back - trajectories model and the aerosol optical depth (AOD) through Deep Blue AOD in the range 550 nm.

1. Introduction

Mineral dust aerosol particle are considered the most important types of aerosols in the atmosphere and are represented a major factor affecting the Earth's radiation budget (Kishche et. al., 2005). Recent studies have shown that a significant proportion of mineral dust in the atmosphere may be the results of anthropogenic activities, and therefore it may play an important role in climate change by exerting a significant direct radiative forcing (EL-Hussainy et al., 1998) and (Tanre et al., 2003). Different authors believe that 20% (Sokolik and Toon, 1996) or up to 30 and even up to 50% (Tegen and Fung, 1995) of the total mineral dust in the atmosphere originates from anthropogenic activities. However, more recent work of Tegen has reduced this estimate to 10%. The African desert (Sahara) is our interested subject and can be considered the principal source of African dust having variable emissions from year to year (Moulin and Chiapello, 2004; Yoshioka et al., 2005). Sahara dust is transported to many different zones on Earth's surface (Talbot et al., 1986; Li et al., 1996). It is transported from North Africa across the North Atlantic Ocean into the Caribbean region (Colarco et al., 2003; Reid et al., 2002; Chiapello and Moulim, 2002; Petit et al., 2005; Ginoux and Torres, 2003; and Kaufman et al., 2005) and was observed also in the air masses over Florida (De Mott et al., 2003). Europe and the Mediterranean region is the other zone which is

affected strongly by the presence of desert dust from the North African Desert (Levin et al., 1996; Wurzler et al., 2000; Yin et al., 2002; Blanco et al., 2003; Rosenfeld et al., 2001; Barkan et al., 2005; Israelevich et al., 2003; Kubilay et al., [1999, 2000]; Barnaba et al., 2004; Kimberly et al., 2003; Emin et al., 2001). The Eastern and the northern eastern Mediterranean marine is strongly affected by intense Sahara dust pulses during the transition seasons in spring, March-May, and autumn, September-November, from the Sahara and the middle east (Verkoussis et al., [2000, 2003], Kocak et al., 2004) and in winter, December-February, and spring (Emin et al., 2001). Because the largest values of the aerosol index (AI) occur along the main trajectories of the mineral dust plumes, Israelevich et al., (2003) have plotted the distribution of the largest aerosol index AI that is observed above North Africa and the Eastern Mediterranean during the period 1996-2001. They reported African dust aerosol loadings above the eastern Mediterranean with different size distributions and refractive indices during the following three seasons, spring, summer and autumn. The differences are attributed to different source regions and desert dust trajectories during these periods. In the first season desert aerosol from the source in Chad is transported to the eastern Mediterranean predominantly along the North African coast, associated with so-called sharav (Kubilay et al., 1996; Levin et al., 1980; Alpert and Ziv, 1989; and Emin et al., 2001) or co-called Khamsin (by El-Fandy, 1940) cyclones. The aerosols are transported to the eastern Mediterranean across Egypt from the sources near the Red Sea in the second period, while the dust arriving at the eastern Mediterranean during the third period originates from the Libyan coast. Levin et al., (1980) have measured the aerosol size distribution in a dust storm using a Royco optical counter during and after the passage of the front reported that it peaks sharply around 1 μm during the passage of the front disappears gradually afterwards. However, more recent work of Kubilay et al., (2003) showed that the mineral dust particles exhibit a bimodal size distribution along the Turkish coast of the Mediterranean with volume mean radii of 0.008 μm and 2.2 μm for fine and coarse particle respectively. Blanco et al., (2003), on the other hand, found that the Total Ozone Mapping spectrometer TOMS aerosol index data was in the range 0.7-2.2 over southern Italy during dust outbreaks from April to June 2002. Also the particle size and shape were analyzed using a scanning electron microscope SEM. It was found that the particle diameter was between 0.3 and 30 μm with median diameters between 1.7-2.4 μm and roundness factors varying from 0.8 to 2.5. Barkan et al., (2005) analyzed also TOMS aerosol index data in Juty 1988 and lidar measurements in Rome in July 2001-2003. They conclude that the Saharan dust plume often reaches Italy. Saharan dust was also observed over eastern Spain in west Europe where it caused high levels of suspended particulate matter. It is well known that dust from the Sahara is not only occasionally transported to the Mediterranean coast of Europe but also to Central Europe which a particularly spectacular Saharan dust event has been recently observed in Switzerland and close to the Bavarian Alps and even northern Europe, reaching the shores of the Baltic Sea (Barkan et al., 2005).

Figure (1): Egypt Map.

1.1 The Mechanisms of condensate Gasses on the dust grains

Hygroscopic growth due to chemical transformations which occurred during long-range transport (Perry et al., 2004) or when they pass through heavily industrial regions (Ookoi and Uematsu, 2005). These particles are also become coated with soluble sulphates, nitrates and other electrolytes when passing over marine or polluted continental regions (Zhang and Carmichael, 1999; Takemura et al., 2002; Sugimoto et al., 2002, and Laskin et al., 2005), or they may originate from evaporating cloud drops which were originally nucleated on sulphate cloud condensation nuclei and subsequently collected dry interstitial mineral dust particles (Levin et al., 1996). Recently, there are lunched many scientific projects to investigate the modifications of the chemical characteristic of the mineral dust particles. One of them is related to Asian mineral dust particles on the west shore of Pacific when they pass through heavily industrial regions in china to the western North Pacific (Ookoi and Uematsu, 2005). Ookoi and Uematsu, (2005) are concluded that nitrate with Asian mineral dust particles was dominant acid substance beside a high adsorption of HNO_3 on mineral dust particles and would change their surface properties to become hygroscopic (Wang et al., 2005; and Sun et al., 2004).

1.2 MINOS (Mediterranean Intensive Oxidant Study)

Is the other scientific project which is also related to our investigation and was launched at Finokalia, Crete, Greece between 26 July and 24 August, 2001 to investigate the high ozone concentration which is observed regularly during summer season in this region in addition to the transported polluted air from Europe to the south part of the Mediterranean Sea (Schneider et al. 2003; Metzger et al., 2005; and Roelofs et al., 2003). The observations at Finokalia were strongly influenced by the transport of polluted air from the South-East part of Europe (Metzger et al., 2005;

and Schneider et al., 2003), their sources included industrial activity, high traffic area, biomass burning and an intense solar radiation as a results of a few cloud that contribute a photochemical reactions and leading to a formation of a high level of SOA (Lelieveld et al., 2000; and Metzger et al., 2005), this lead them to the haze particles over the Mediterranean Sea was not sea salt but also sulphate particles. (Metzger et al., 2005) reported that the most observed aerosols particles are Ammonia, Sulphuric acid and nitric acid, while NH_3 is emitted by farming, fertilization and auto exhaust (Yamaguchi et al., 1996; and El-Gammal and Shakour, 2001). Sulphuric and nitric acid are formed due to photochemical reactions. They are found the corresponding ions are Ammonium, Sulphate, bisulphate, nitrate, chloride expect NH^+_4 that are dominated with the formations of SOA particles, while the major cations come from natural source such as Na^+ from sea spray while Ca^{2+}, Mg^{2+} and K^+ originating from mineral dust particles from Sahara. Kocsk et al., (2004) measured the seasonal chemical composition of the aerosols for 4 years period between 1996 and 1999 at Erdemli on the Mediterranean cost of Turkey that is closed to Finokalia, Crete, Greece; the concentrations of water-soluble ions were measured in a total of 610 samples. They are found that followed by, Cl^-, SO^{2-}_4, NH^+_4, Ca^{2+} and Na^+, contributed 90% to the sum of ions many species had maximum values during dust storm when air masses originated generally from North Africa and occasionally from the Middle East.

2. Data Collection

For this study the authors collected six samples of airborne mineral dust which had been carried by the winds from the Sahara desert to a sampling different points which are located at Cities of Egypt according to table (1).

Table (1): Description of sampling locations.

No.	ID _ WMO	Station name	Latitude	Longitude	Elevation of station (H) or (Ha)
1	HOME ROOF	Kaha	30° 17′ N	31° 12′ E	36
2	62374	6 OCTOBER (A.P)	29° 48′ N	30° 49′ E	242.34
3	62309	DABAA	30° 57′ N	28° 26′ E	91.34
4	62332	PORT SAID (A.P)	31° 33′ N	31° 05′ E	3.35
6	62336	EL ARISH	31° 05′ N	33° 49′ E	45
7	62458	ABU RDEES	28° 54′ N	33° 11′ E	5.19

2.1 Data Source

These samples were collected during 24 hours by gravitational settling on a clean horizontal surface of aluminum foils have been used for 1×1 m^2 which was exposed in Meteorological observing station outdoor, during dust episode is observed in Egypt in 2010 on 10 May. The method of gravitational settling has been previously applied by De Tomasi et al., (2003) to collect and characterize Saharan dust, which was transported to a LIDAR site at Lecce, south-eastern Italy, on May 2001. It has

the advantage that the relatively large mineral dust particles settle much more efficiently than small aerosol particles from local sources, which remain airborne. We collected the samples were stored in Clear Self Adhesive Seal Plastic Bags for further analysis at Protection Unit of air pollution at the National Center for Research.

Table (2): Abbreviation name of sampling locations according to the day.

Abbreviation name of sampling locations according to the day	Station	PORT SAID (A.P)	DABAA	EL ARISH	6 OCTOBER (A.P)	ABU RDEES	Kaha
	10/05/2010	P3	D3	E3	O3	A3	K3

2.2 Ion Analysis

Ion chromatography is the only technique that can be used to analyze anions in aqueous solution at the ppb level. We used this technique to determine water-soluble ionic coatings on the particle surfaces of dust samples. The following inorganic ions were analyzed by Ion Chromatography (Dionex ICS–1100 RFIC) System was employed to determine the cations from the dust samples. From this study we get , six elements were detected (Na^+, NH^+_4 , K^+, Ca^{2+}, Li^+ and Mg^{2+}) and for anions, Ion Chromatography (Metrohm) we get also six elements were detected (No_2^-, No_3^-, Cl^-, Br^-, F^-, SO_4^{2-}). For our analyses, weight by mg of each dust sample were extracted with 25 ml deionised water to dissolve ions from the particle surfaces as follows. The particle suspensions were treated 10 minutes in an ultrasonic bath, and the solutions were separated from the leached particles by filtering the suspensions through 0.2 µm. The obtained filtrates were analyzed by injecting 25 ml into the IC to start the analysis process, which took about 25 minutes per injection.

2.3 The Sources of African Airborne Mineral Dust Samples

The chemical and mineralogical composition of airborne desert dust depends on the source region of the material and on possible interactions with pollutant gases during transport. It is therefore important to specify the original source regions of the airborne mineral dust particles Cities according to table (1) and table (2), which had been transported to the sampling point to each city. This information can be derived by combining trajectory model calculations with remotely sensed satellite data, as explained in sections 2.4. and 2.5. below. Similar techniques have recently been applied by Sodemann et al., (2006) to identify the source regions of dust events, which were archived in a glacier in the Swiss Alps, and could be dated to October and March (2000) from the depth of the dust layers.

2.4 Trajectory Model Calculations

We used the HYSPILT4 trajectory model to calculate air mass back trajectories at the sampling point of each city according to table (1). The (HYSPLIT) is HYbrid

Single-Particle Lagrangian Integrated Trajectory model is a complete system for computing both simple air parcel trajectories and complex dispersion and deposition simulations. The model calculation method is a hybrid between the Lagrangian approach, which uses a moving frame of reference as the air parcels move from their initial location, and the Eulerian approach, which uses a fixed three-dimensional grid as a frame of reference. In the model, advection and diffusion calculations are made in a Lagrangian framework following the transport of the air parcel, while pollutant concentrations are calculated on a fixed grid. Through a joint effort between NOAA and Australia's Bureau of Meteorology, the model uses advection algorithms, updated stability and dispersion equations, a graphical user interface, and the option to include modules for chemical transformations. HYSPLIT can be run interactively on ARL's READY (Real-time Environmental Applications and Display System) web site, or it can be installed on a PC from this web site and run using a graphical user interface.

2.5 Satellite Observations

Satellite instruments for remote sensing are powerful tools to detect, on a global scale, the transport of dust clouds over sea and -in some cases, see below- over land, with high resolution in space and time. The Moderate Resolution Imaging Spectroradiometer (MODIS) Terra and Aqua satellites are operating for this purpose with resolutions of 0.25, 0.5, 1, and 2 km at nadir.

Aerosol optical depth is a measure of radiation extinction due to scattering and absorption by aerosol particles in the atmosphere. Deep Blue AOD land only at 550 nm for MODIS calculates AOD over bright areas such as deserts where the standard MODIS AOD algorithm does not work.

3. Aerosol Optical Depth Analysis on 10 May 2010

On the other hand we see Figure (4.3 A, B and C) denoted to Aerosol Optical Depth. One of the most common satellite measurements related to air quality is Aerosol Optical Depth (AOD), a quantity that indicates the amount of aerosol particles in the atmosphere. The Moderate Resolution Imaging Spectroradiometer (MODIS) provides daily observations of (Deep Blue AOD) over much of the Earth's surface. ADB Aerosol Deep Blue data from MODIS on NASA's Terra satellite were used in the Giovanni data analysis system to create a series of running 4-day averages from 07 through 10 May over North Africa Figure (4.3 A). The location of Egypt is shown in each figure. Many cities in northeastern Egypt, including the Port Said, Dabaa, El-Arish, 6 October, Abu Rdees and Kaha are Indicate to P3, D3, E3, O3, A2 and K3. The location of these cities on Egypt's are a factor in their air quality problems. The passage of dust-loaded air masses across the sampling area is qualitatively confirmed by the ADB data, as it can be seen on the Figure (4.3 A). We conclude from these considerations that the mineral dust sampled as P3, D3, E3, O3, A2 and K3 originated dust aerosol particles produced by wind erosion in arid and semi arid regions effect climate and air quality most likely from the west desert of Egypt, and may have already been contaminated by particulate matter when moving from the north Atlantic ocean , Cape Verde islands, north Morocco, Algeria and central of Libya to Egypt desert and the sample point.

3.1 MODIS Satellite Images Analysis on 10 May 2010

Thick dust defines a storm system over Egypt in this natural-color image from 10 May 2010. Terra and Aqua/MODIS satellite images are shown on the Figure (4.2 B and C). The distinctive green vegetation that outlines the Nile River is faded behind of thin veil of dust. Thicker dust blows north along the west and east desert of Egypt, also moved toward north the Mediterranean Sea and over Red Sea to north Sinai. The large image, which covers a wider area, shows the dust plume extending several hundred kilometers to the south. The previous day, the dust storm had been over the border between Egypt and Africa desert. The storm kept its comma shape as it moved from south to east and north.

3.2 Wind Rose Analysis on 10 May 2010

The wind rose in the Figure (3.3 P3, 3.3 D3, 3.3 E3 and 3.3 A3) show the 31 day wind rose for 1 to 31 day On May 2010. Wind directions with high frequency have spread widely and have changed significantly every month. According to the wind rose, one can clearly see the main wind direction and the relevant wind speed. For examples, all figure show that on May 2010, South-southeast was the prevailing wind direction with the average month wind speed at 5-7 meters per second and some day was the prevailing wind direction with the average monthly wind speed at 8-11 meters per second; and few day wind speed north direction at 6-10 meters per second transporting mineral dust from the Sahara south regions to north Egypt and Sinai by southern strong wind.

Table (3): Ion content (weight %) on 10 May 2010.

Ion	P3	D3	E3	O3	A3	K3
Li+	5.40E-05	4.31E-05	3.09E-04	1.14E-04	1.16E-05	2.38E-04
Na+	8.92E-01	1.28E-02	3.11E-01	9.91E-03	2.68E-01	1.50E-01
K+	3.57E-02	2.26E-03	9.86E-02	2.34E-03	1.72E-02	1.04E-01
Mg2+	6.10E-02	2.56E-03	5.03E-02	2.01E-03	1.95E-02	1.98E-02
Ca2+	4.37E-01	3.10E-02	5.47E-01	3.47E-02	3.33E-01	2.76E-01
NH4+	0.00E+00	8.45E-03	3.14E-02	2.27E-03	3.84E-05	6.00E-02
F-	-1.85E-04	9.09E-03	-5.99E-03	-4.55E-05	-5.93E-05	-4.76E-03
Cl-	2.06E-01	3.74E-01	3.18E-01	1.06E-02	5.63E-01	2.37E-01
NO2-	1.02E-04	9.17E-05	1.24E-04	5.42E-06	0.00E+00	2.04E-04
Br-	3.19E-03	1.36E-02	2.97E-04	1.84E-05	1.48E-05	3.05E-04
SO42-	2.52E-01	2.42E-01	4.74E-01	7.58E-02	7.86E-01	3.44E-01
NO3-	0.00E+00	0.00E+00	8.77E-02	2.18E-03	1.39E-02	1.04E-01

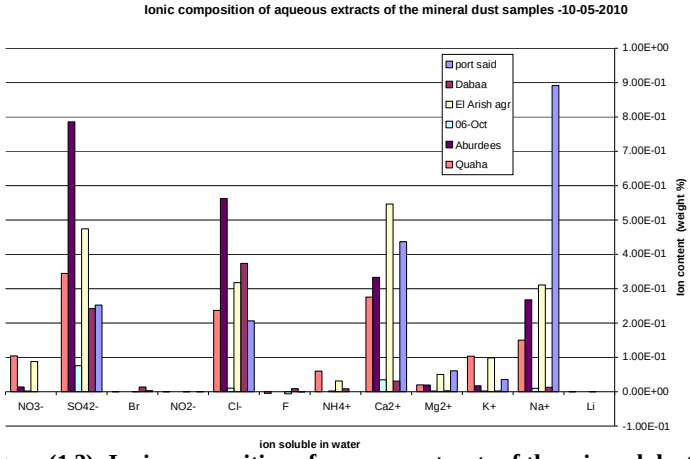


Figure (1.3): Ionic composition of aqueous extracts of the mineral dust samples.

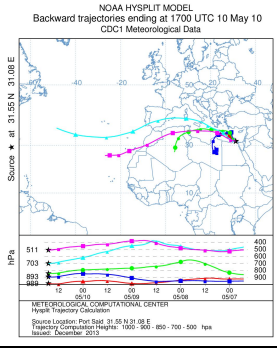


Figure 2.3. P3

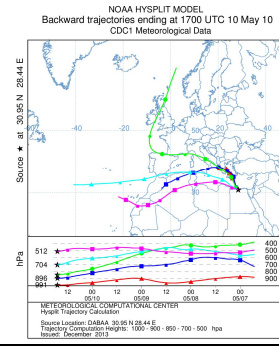


Figure 2.3. D3

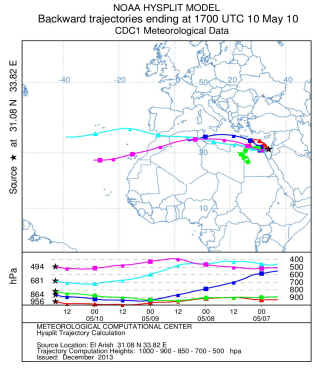


Figure 2.3.E3

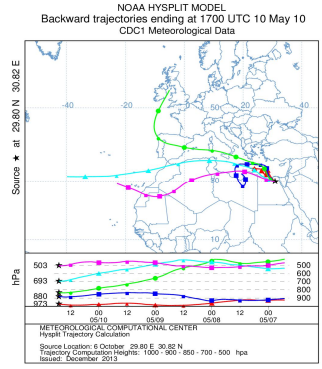


Figure 2.3.O3

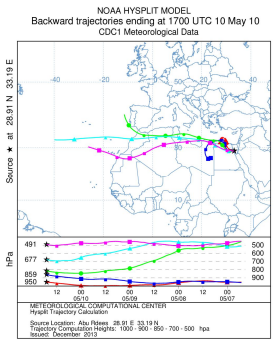


Figure 2.3.A3

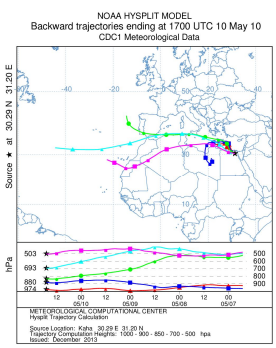


Figure 2.3.K3

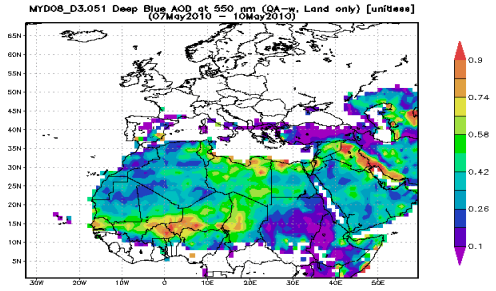


Figure 4.3.A : 7_10 May 2010 _ ADB

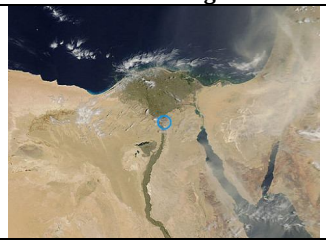


Figure 4.3.B : 10 May 2010 _ AQUA

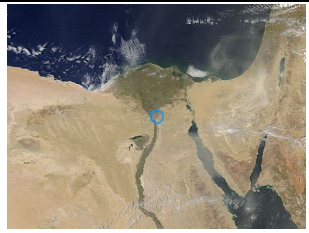


Figure 4.3.C : 10 May 2010 _ TERRA

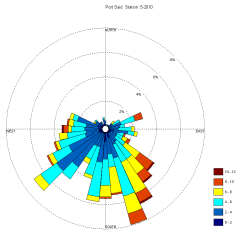


Figure 3.3.P3

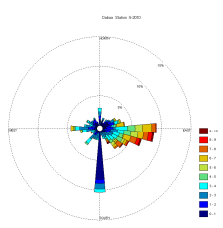
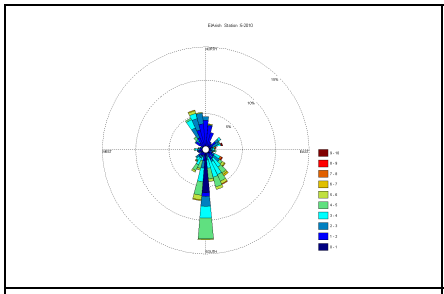


Figure 3.3.D3



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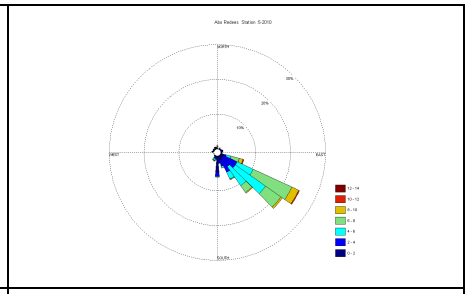

Figure 3.3.A3

4. Conclusions

Our simulations show that during the study period May 2010, the main dust sources over Egypt are the Southwest Africa, Morocco, Mauretania, Niger, Chad and Algeria, Tunisia, Libya, Western Sahara, Western Europe and Iceland. High amounts of dust are expulsed from Africa typically in the lower layers of the troposphere. These simulated dust loadings correspond with those observed in this season near the African coast. Four main pathways of dust expulsion have been identified by our simulations in agreement with the observations: Western Mediterranean, North Atlantic via Canary Island, Tropical Atlantic Ocean via Cap Verde Islands, and Gulf of Guinea. We focused particularly on the calcite concentrations of transported dust. It appears that the Northern Egypt, Libya and Western Sahara and Niger, Chad source produces rich calcite dust, but the highest calcite contents transported by dust are found during the events where dust was expulsed over the North Atlantic from the Western Sahara. Thus, these two regions seem to be the most favourable to study the heterogeneous reactivity of dust which is directly based on calcite content (Dentener et al., 1996). The supply of sulphate from the European and Iceland Eyjafjallajökull source is mainly directed towards the Mediterranean up to Northern Maghreb and over the North Atlantic close to the coasts of the Iberian Peninsula. The observed trends of a high European SO_2 influence in Mediterranean and Maghreb are realistically reproduced. Finally, our model results on dust and SO_2 transport are in good agreement with the behaviour typically observed in Africa and over the Atlantic Ocean and the Mediterranean in this season. Based on these arguments, we can conclude concerning the coating phenomenon of dust by sulphate in these regions that:

the most favorable zones of mixing process between dust and sulphate are:

1- The Eastern Mediterranean basin due to the concomitance of high concentrations of dust and sulphate.
2- The North-Eastern Atlantic Ocean due to the high amount of calcite in the expulsed dust which is, therefore, reactive;
3- The coating process is mainly centred on these regions, even if coated dust is observed up to the Caribbean and American coasts.
4- The Spring period is the most favorable time period for this phenomenon in this region since it represents the period where the majority of dust expulsions are observed, accompanied by high SO_2 concentrations from.

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