Field Observations of the Variability of Dust Emission, its Size-Spectrum and Mineralogy

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EXTENDED ABSTRACT

A. *Introduction*

Atmospheric mineral dust consists of tiny mineral particles that are produced by the wind erosion of arid and semi-arid surfaces of the Earth, and it is one of the most important aerosols in terms of mass in the global atmosphere [1].

The physical and chemical properties of dust, that is, its particle size distribution (PSD), mineralogical composition, shape and mixing state determine its impact on the Earth's system. Dust mineralogy in particular has been identified by the Intergovernmental Panel on Climate Change (IPCC) as a key uncertainty in the overall contribution of aerosols to radiative forcing [2] and many studies over recent years have shown its potential importance [3,4].

Despite this, Earth System models typically assume dust aerosols to have a globally uniform composition, neglecting the known local and regional variations in the mineralogical composition of the sources [5,6] and therefore, preventing further understanding of the role of dust in the Earth system. However, this simplification is justified by the current incomplete understanding of the physical processes at emission, the lack of coincident measurements of individual mineral PSDs for emitted dust and the parent soil, the fundamental disagreements among existing dust emission schemes on multiple aspects, the limited global knowledge of soil mineral content and the insufficient knowledge of the mixing state of the minerals.

The ERC Consolidator Grant called FRAGMENT (FRontiers in dust minerAloGical coMposition and its Effects upoN climaTe) aims to address these limitations and to better understand and constrain the global mineralogical composition of dust along with its effects upon climate. This ambitious and multidisciplinary project combines theory, field measurements, laboratory analyses, remote spectroscopy and modelling.

B. *Objectives*

As part of FRAGMENT, my research aims to improve our fundamental and quantitative understanding of the emitted dust PSD and mineralogy along with their relationship to the parent soil properties by fulfilling the following specific objectives:

- Study the size-resolved dust fluxes under different meteorological and soil conditions and its relationship with the emission mechanism.
- Overcome our limited understanding of the size-resolved mineralogy of the emitted dust.

Given the incomplete understanding of the physical processes and the paucity and incompleteness of available measurements, new experimental data are required in order to answer these key scientific questions, and to test, evaluate and extend currently available theories and models.

C. *Methodology*

The FRAGMENT team is performing an unprecedented set of coordinated field campaigns in Morocco, California and Iceland. These regions meet several key criteria including accessibility, variety of soil types, textures and landforms, local/regional collaborators that help with the logistics of the campaigns. This combination of measurement locations and conditions will allow FRAGMENT to tackle the aforementioned and other key research objectives.

The first field campaign took place in September 2019 at "El Bour", a dry lake located at the edge of the Sahara, approximately 15 km west of M'Hamid El Ghizlane in Morocco and 30 km north of the Moroccan-Algerian border. Fig. 1 shows some photos of our experimental set up, which includes a wide variety of instruments to perform a detailed characterization of the soil, dust emission and meteorology. These instruments include, e.g., low volume samplers, cascade impactors, passive aeolian sediment traps, saltation sensors, aerosol spectrometers, water content reflectometers, a fully equipped meteorological tower, a radiometer, an aethalometer and a polar nephelometer. Results presented here focus mainly on the time variation of the particle size distribution, in terms of mass concentrations, and its relationship with meteorological variables.

Fig. 1 Photos of the experimental setup at "El Bour" (Morocco) in September 2019 and small insert showing a map with the measurement site.

D. *Preliminary results of the field campaign in Morocco*

A large number of dust events of varying intensity were recorded during this one-month measurement period (Fig. 2).

The average maximum air temperature at 2 m height during the field campaign was very close to 40ºC and the minimum above 20ºC. In addition, the average daily maximum 2 m wind speed was around 12 m/s and peak wind gusts reached 21.68 m/s.

A few moist convective storms occurred during our period of measurements. After a moist-convective storm on 6th September 2019, results of which we present in the following, the surrounding of our site was flooded to large degree.

Fig. 2 shows an example of data collected on 6th September 2019 by an aerosol spectrometer (Fidas) and a wind sensor placed at 2 m height. The top panel depicts the temporal evolution of the two-minute average Particulate Matter (PM) levels along with their respective ratios (multiplied by a factor of 1000), while wind speed is represented at the bottom. As can be observed, from 8 to 12 UTC, average wind speeds varied around 7.5 m/s, and PM values exhibited several consecutive peaks, the highest one reaching the following values: 5517.09 μg/m^3 of PM total (Particulate Matter 27.38 μm or less in diameter), 3493.72 μg/m^3 of PM10, 1639.57 μg/m^3 of PM4, 795.51 μg/m^3 of PM2.5 and 118.22 μg/m^3 of PM1. If we zoom in this temporal interval, we can first identify very similar patterns between the peaks of wind and PM levels, and second, we observe that the ratios of PM values remain almost constant. The latter gives an idea of the evolution of particle size distribution, which in this case seems not to be much affected by dust emission. From 12UTC onward, both PM levels and wind speed gradually decrease until experiencing a sharp rise at around 16 UTC, which corresponds to one of the strongest dust events recorded during the field campaign. At the beginning of this event, considered as a haboob, we could clearly identify a wall of blowing dust formed from the outflow of a strong convective storm. During this haboob, which lasted around two hours, PM levels reached the following values: 30732.32 μg/m^3 of PM total, 20286.24 μg/m^3 of PM10, 9555.64 μg/m^3 of PM4, 4505.46 μg/m^3 of PM2.5 and 597.99 μg/m^3 of PM1. Besides, PMtot/PM10 and PM10/PM2.5 ratios remained almost constant whereas the ratio PM2.5/PM1 experienced a gradual rise. However, the most striking and steep increase in PM10/PM2.5 and PM2.5/PM1 ratios, which reflect a coarser particle size distribution, occurred around 20UTC when the two-minute average wind speed was below 5 m/s and there were only some gusts of wind close to 7 m/s.

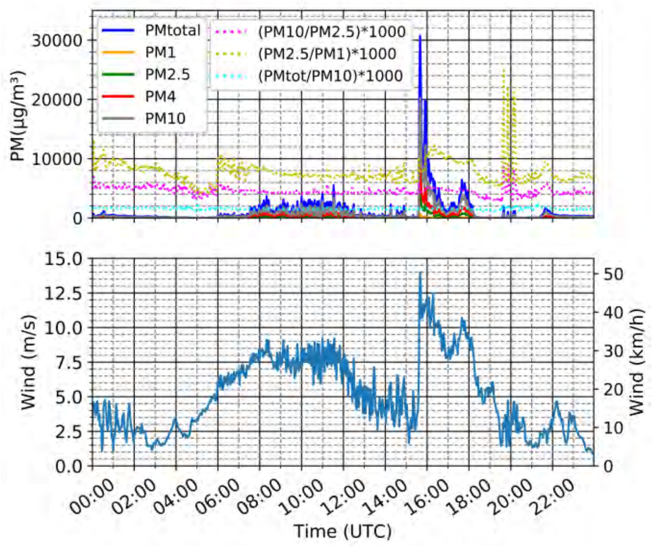

Fig. 2 Data from 6th September 2019. Top (bottom): Two minute-average PM values and their ratios (wind speed) at 2 m height.

E. Outlook

The next steps will focus on (a) analysing the size distribution of measured dust concentration, (b) calculating size-resolved dust emission fluxes, (c) combining the results on dust emission and size-distribution with results on mineralogy determined by other FRAGMENT team members, (d) evaluating existing dust emission theories against the measurement results and (e) evaluating exiting frameworks for mineralogy and expand as needed.

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Author biography

Cristina González Flórez was born in Madrid, Spain, in 1995. She received her BSc degree in Physics (2017) and MSc degree in Meteorology and Geophysics (2018) from the Complutense University of Madrid, Spain. She is currently pursuing her PhD in Environmental Engineering at Universitat Politècnica de Catalunya (UPC) and performing her research at the facilities of the Barcelona Supercomputing Center (BSC), under the supervision of Dr. Carlos Pérez García-Pando and Dr. Martina Klose.