

The Dust Doctoral Network



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Introduction

Mineral dust is a major atmospheric aerosol, and it gives us one of the most visible and detectable aspects of transboundary transport of atmospheric constituents, impacting visibility, radiation and climate [1]. This aerosol type is very often detected at some of the reference lidar sites. What is less evident are the quantitative impacts of dust on health, transportation and energy production. Atmospheric dust is not fully understood at the fundamental level (microphysical properties, dust emissions, source regions), and therefore atmospheric models fail to fully reproduce its impacts. Moreover, dust observations using ground-based instrumentation, remote sensing (lidar and others) and aircraft are abundant, but not evenly distributed; in particular they are missing near the major dust sources. The techniques and methodologies to study dust are still under development, with each giving a different picture of a phenomenon with multiple facets. For example, it is now known that super-coarse and giant dust particles [2] have gone undetected for a long time due to limitations in the measurement and modelling tools that have been in use for decades, and this misdetection alters the understanding and the prediction of a number of processes. Finally, dust affects the environment, society, and several economic sectors, with impacts on the transportation and energy sectors for example, the nature and cost of which is not fully understood and quantified. Several methodologies exist to study mineral dust, each giving its own differing picture of a complex phenomenon: numerical modelling, remote sensing, in-situ observations, laboratory research.

Table 1. Scientific facilities and spaceborne missions that Dust-DN can benefit from.
 Mod=Modelling; IS=atmospheric in-situ observations; RS=atmospheric remote sensing; Lab=laboratory;
 En=energy production facility. Grey background = facilities that include lidar

Facility	Methodology	Operator
Marenostrum 5 HPC with MONARCH + EC-EARTH model	Mod	BSC
Cyclone HPC with WRF-Chem model	Mod	CyI
HoreKa HPC with ICON-ART model	Mod	KIT
Unmanned Systems Research Laboratory	airborne IS	CyI
Cyprus Atmospheric Observatory	RS + IS	CyI
Panhellenic Geophysical Observatory of Antikythera	RS	NOA
Electron Microscopy Center	Lab	TUDa
Particle Settling Laboratory	Lab	UoR
Solar rad. and aerosol meas. facilities (incl. GAW PFR network)	RS	PMODWRC
Concentrating technologies and solar energy generation facilities	En	PSA
Évora Atmospheric Sciences Observatory	RS + IS	UÉ
Biochem lab and cell culture lab	Lab	UÉ
Solar Radiation Monitoring stations of Évora and Beja	RS	UÉ
Laboratory for controlled cell exposure to aerosol at air-liquid interface	Lab	ZAUM
Cyprus Atmospheric Remote Sensing Observatory	RS	ECoE
Earth Surface Mineral Dust Source Investigation (EMIT) mission	satellite RS	NASA
Earth Clouds, Aerosol and Radiation Explorer (EarthCARE) mission	satellite RS	ESA/JAXA

Methodology

To address some of these challenges, the first doctoral network on a European scale (to our knowledge) on the topic of dust has started its activity, bringing together expertise on mineral dust in the atmosphere, combining multidisciplinary aspects. The Dust Doctoral Network (Dust-DN) is a strategic international, interdisciplinary and intersectoral alliance of high-profile partners, able to leverage on unique state-of-the-art facilities and recent innovative spaceborne missions (including several lidar facilities and spaceborne lidar): see Table 1. Dust-DN will provide a careful blend between individual research projects and integrated combined training and networking, and a critical mass on dust-focused studies using complementary methodologies. Seventeen doctoral candidates will be exposed to differing research and working environments, multiple technologies and methodologies. They will be trained in remote sensing, the atmospheric sciences, dust science questions, transferable skills and on the partners' unique research infrastructure, enabling to tackle the bigger picture of dust challenges. The network comprises dedicated applied research projects, with direct contributions and impacts embedded with the societal and industrial sector. It involves 8 leading partners and 15 associated partners, from research, academia and industry, and representing 9 countries and the World Meteorological Organisation (Fig. 1).

The network is built around four research objectives, and seventeen PhD projects have been proposed to advance in these scientific questions (Table 2). Several of these projects are relevant to lidar research, and this is why it is useful to present the network here, where the lidar technique is used together with several other methodologies and facilities in pursuing general advances in the science of dust. Doctoral candidate DC3 will work towards a global lidar estimate of the pure-dust atmospheric component, making use of the novel EarthCARE mission [3] and ground-based lidars, and leveraging on the legacy of LIVAS; DC15 will identify the source-dependent radiative properties of dust and will make use, amongst others, of the synergistic use of solar spectral, sun photometric and lidar measurements towards aerosol classification with the GRASP algorithm; DC17 will study dust mineralogy and ice nucleation, making use of ground-



Figure 1. Dust-DN partners. The acronyms are defined in the affiliations.
 Red: leading partners; white: associated partners.

based remote sensing with lidars and sunphotometers; DC7 will focus on the dust radiative effect and will make extensive use of lidar-derived profiles in combination with flux observations, in-situ sampling, and radiative modelling; DC5 will study the impact of mineral dust on aircraft engines, making use (amongst others) of ground based lidars/ceilometers and spaceborne lidars; DC10 which will improve knowledge of the scattering properties of non-spherical particles, with an aim to improve the exploitation of advanced lidar systems; DC14 will study the behavior of dust in turbulent flows, making use amongst others of extensive field campaigns that combined several in-situ observations with wind-Doppler lidar.

Conclusions

The strength of addressing the scientific questions with a doctoral network, as opposed to individual specialised projects, resides in the international, interdisciplinary and intersectoral approach, which valorises each methodology (including lidar) and the specialisations of each partner to address the thematic of atmospheric dust from several points of view. This will be reinforced through advanced training and networking opportunities for the doctoral candidates. Each of them will be supported through an individualised career development plan and a number of mobilities to be carried out during the project, and all of them will be gathered together for network-wide schools and workshops. They will also be encouraged to build team spirit through more frequent virtual networking opportunities.

Dust-DN officially started operations in November 2024, and it already attracted a lot of interest in very motivated potential doctoral candidates, having received 226 applications, some of which of a very high standard, and which could unfortunately not all be selected. Dust-DN is more than a collection of 17 very visionary PhD projects on mineral dust and it will create a dust science community that will enhance the potential of a number of unique techniques and facilities, including ground-based and spaceborne lidar. It is expected that the network will advance the science of atmospheric dust, it will further develop scientific synergies and complementarities, and it will train a cohort of dust experts of tomorrow.

Table 2. Dust-DN research objectives and PhD projects.
 Grey background = projects relevant to the lidar community (see text).

Research objectives	PhD projects	
Understanding of the fundamentals of dust microphysical properties and processes	DC2	Dust particle shape, aspect ratio and orientation: new information from UAV campaigns
	DC4	Atmospheric Sedimentation of Non-Spherical Dust Particles: Developing knowledge for improvement of models
	DC10	New scattering database for desert dust, with realistic size, shape and refractive index measured in-situ
	DC14	Size-dependent turbulent dust transport in idealised and realistic high-resolution simulations
	DC17	Ice nucleating dust particle concentration profiling and effects on ice crystal formation
Identifying the influence of source regions on atmospheric dust properties	DC12	Modelling the effects of dust upon regional climate with constrained dust-source mineralogy
	DC13	Variability of dust composition, shape and size distribution across the Mediterranean, based on single-particle analysis
	DC15	Identification of dust properties from different sources using sun-photometry and their effects on spectral solar irradiance
	DC16	Quantification and characterisation of dust microphysical properties in the Mediterranean and Middle East, through the novel Aertape technology
Socio-economic impacts of dust on health, aviation and energy production	DC1	Modelling impacts of aeolian dust towards air quality policy planning
	DC5	The impact of mineral dust on Aircraft Engines in the Middle East
	DC6	Modelling and assessment of the impact of atmospheric dust on solar resource for energy applications
	DC8	Assessment of the respiratory health impact of atmospheric dust
Dust in the global climate system	DC3	Global dust estimation from novel space missions
	DC7	Enhancing the understanding of dust direct radiative effect
	DC9	Modelling of dust transport processes. Bridging the gap between theory, observations, and models
	DC11	Modelling super-coarse dust and its effect upon climate

Acknowledgements

Dust-DN is funded by the European Union under the Marie Skłodowska-Curie Actions (grant agreement 101168425), and by the corresponding national agencies of the United Kingdom (UKRI) and Switzerland (SERI). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union and Marie Skłodowska-Curie Actions (MSCA). Neither the European Union nor MSCA can be held responsible for them.

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