

Understanding mineral dust through a doctoral alliance

Article

Published Version

Creative Commons: Attribution 4.0 (CC-BY)

Open Access

Marenco, F., Amiridis, V., Costa, M. J., Kandler, K., Kazadis, S., Klose, M., Garcia-Pando, C. P., Ryder, C. ORCID: <https://orcid.org/0000-0002-9892-6113>, Antunes, C. M., Basart, S., Bortoli, D., Bouris, D., Brooks, M., Buters, J., Canhoto, P., Carra, M.-E., Choutris, P., Christoudias, T., Clarkson, R., Dacre, H. ORCID: <https://orcid.org/0000-0003-4328-9126>, Dubovik, O., Fragkos, K., Francis, D., Fuertes, D., Ageitos, M. G., Johnson, B., Llopis, E., Mallios, S., Mamouri, R. E., Marinou, E., Meleti, C., Pozzer, A., Rimell, A., Sciare, J., Shumake-Guillemot, J., Tembhekar, N., Tsekeri, A., Vogel, A., Wessels, I., Westbrook, C. ORCID: <https://orcid.org/0000-0002-2889-8815>, Wienhold, F., Wild, M., Tschorn, K. M., Kolintziki, E. and Moncada, F. (2025) Understanding mineral dust through a doctoral alliance. *Environmental and Earth Sciences Proceedings*, 35 (1). 78. ISSN 3042-5743 doi: [10.3390/eesp2025035078](https://doi.org/10.3390/eesp2025035078) Available at <https://centaur.reading.ac.uk/127101/>

It is advisable to refer to the publisher's version if you intend to cite from the work. See [Guidance on citing](#).

To link to this article DOI: <http://dx.doi.org/10.3390/eesp2025035078>

Publisher: MDPI

All outputs in CentAUR are protected by Intellectual Property Rights law, including copyright law. Copyright and IPR is retained by the creators or other copyright holders. Terms and conditions for use of this material are defined in the [End User Agreement](#).

www.reading.ac.uk/centaur

CentAUR

Central Archive at the University of Reading

Reading's research outputs online



Understanding Mineral Dust Through a Doctoral Alliance [†]

Franco Marengo ^{1,*} , Vassilis Amiridis ² , Maria João Costa ³ , Konrad Kandler ⁴ , Stelios Kazadzis ⁵ , Martina Klose ⁶, Carlos Pérez García-Pando ^{7,8}, Claire Ryder ⁹, Célia M. Antunes ^{3,10} , Sara Basart ¹¹, Daniele Bortoli ³ , Demetri Bouris ¹² , Melissa Brooks ¹³, Jeroen Buters ¹⁴, Paulo Canhoto ³ , Maria-Elena Carra ¹⁵, Panos Choutris ¹⁶, Theodoros Christoudias ¹, Rory Clarkson ¹⁷ , Helen Dacre ⁹, Oleg Dubovik ¹⁸ , Konstantinos Fragkos ¹, Diana Francis ¹⁹, David Fuertes ²⁰, María Gonçalves Ageitos ^{7,21}, Ben Johnson ¹³, Eliot Llopis ²⁰, Sotirios Mallios ² , Rodanthi Elisavet Mamouri ²², Eleni Marinou ² , Charikleia Meleti ²³, Andrea Pozzer ^{1,24} , Andrew Rimell ¹⁷ , Jean Sciare ¹, Joy Shumake-Guillemot ¹¹, Noorani Tembhekar ¹⁷, Alexandra Tsekeri ², Andreas Vogel ¹⁷, Inga Wessels ¹⁴, Chris Westbrook ⁹, Frank Wienhold ²⁵ , Martin Wild ²⁵ , Kenneth M. Tschorn ^{1,4}, Eleni Kolintziki ¹ and Francesco Moncada ⁷

- ¹ Climate and Atmosphere Research Centre, The Cyprus Institute, 2121 Nicosia, Cyprus; t.christoudias@cyi.ac.cy (T.C.); k.fragkos@cyi.ac.cy (K.F.); andrea.pozzer@mpic.de (A.P.); j.sciare@cyi.ac.cy (J.S.); k.tschorn@cyi.ac.cy (K.M.T.); e.kolintziki@cyi.ac.cy (E.K.)
- ² Institute for Space Applications and Remote Sensing, National Observatory of Athens, 11810 Athens, Greece; vamoir@noa.gr (V.A.); smallios@noa.gr (S.M.); elmarinou@noa.gr (E.M.); atsekeri@noa.gr (A.T.)
- ³ Center for Sci-Tech Research in Earth System and Energy—CREATE, University of Évora, 7000-803 Évora, Portugal; mjcosta@uevora.pt (M.J.C.); cmma@uevora.pt (C.M.A.); db@uevora.pt (D.B.); canhoto@uevora.pt (P.C.)
- ⁴ Institute for Applied Geosciences, Technical University of Darmstadt, 64289 Darmstadt, Germany; konrad.kandler@tu-darmstadt.de
- ⁵ Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center, 7270 Davos, Switzerland; stelios.kazadzis@pmodwrc.ch
- ⁶ Institute of Meteorology and Climate Research, Troposphere Research (IMK-TRO), Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany; martina.klose@kit.edu
- ⁷ Barcelona Supercomputing Centre, 08034 Barcelona, Spain; carlos.perez@bsc.es (C.P.G.-P.); maria.goncalves@bsc.es (M.G.A.); francesco.moncada@bsc.es (F.M.)
- ⁸ Catalan Institute for Research and Advanced Studies, 08010 Barcelona, Spain
- ⁹ Department of Meteorology, University of Reading, Reading RG6 6AH, UK; c.l.ryder@reading.ac.uk (C.R.); h.f.dacre@reading.ac.uk (H.D.); c.d.westbrook@reading.ac.uk (C.W.)
- ¹⁰ Planetary Health Lab, Centro Académico Clínico do Alentejo, 7000-671 Évora, Portugal
- ¹¹ World Meteorological Organization, 1211 Geneva, Switzerland; sbasart@wmo.int (S.B.); jshumake-guillemot@wmo.int (J.S.-G.)
- ¹² School of Mechanical Engineering, National Technical University of Athens, 15780 Athens, Greece; dbouris@fluid.mech.ntua.gr
- ¹³ Science Directorate, Met Office, Exeter EX1 3PB, UK; melissa.brooks@metoffice.gov.uk (M.B.); ben.johnson@metoffice.gov.uk (B.J.)
- ¹⁴ Center of Allergy and Environment, Helmholtzzentrum München Technical University of Munich, 80802 Munich, Germany; buters@tum.de (J.B.); inga.wessels@tum.de (I.W.)
- ¹⁵ Ciemat—Plataforma Solar de Almería, 04200 Almería, Spain; maria.elena.carra@gmail.com
- ¹⁶ EY Cyprus, Climate Change and Sustainability Services, 1087 Nicosia, Cyprus; panos.choutris@cy.ey.com
- ¹⁷ Engine Environmental Protection, Rolls-Royce plc, Derby DE24 8BJ, UK; rory.clarkson@hotmail.com (R.C.); andrew.rimell@rolls-royce.com (A.R.); noorani.tembhekar@rolls-royce.com (N.T.); andreas.vogel@rolls-royce.com (A.V.)
- ¹⁸ LOA—Laboratoire d’Optique Atmosphérique, CNRS—Université de Lille, 59655 Villeneuve d’Ascq, France; oleg.dubovik@univ-lille.fr
- ¹⁹ The Environmental and Geophysical Sciences Lab, Khalifa University, Abu Dhabi 127788, United Arab Emirates; diana.francis@ku.ac.ae
- ²⁰ Remote Sensing Developments, Generalized Retrieval of Atmosphere and Surface Properties, 59000 Lille, France; david.fuertes@grasp-earth.com (D.F.); eliot.llopis@grasp-earth.com (E.L.)
- ²¹ Project and Construction Engineering Department, Universitat Politècnica de Catalunya, 08028 Barcelona, Spain
- ²² Department of Environment & Climate, Eratosthenes Centre of Excellence, 3036 Limassol, Cyprus; rodanthi@eratosthenes.org.cy
- ²³ Laboratory of Atmospheric Physics, Physics Department, Aristotle University of Thessaloniki, 54636 Thessaloniki, Greece; meleti@auth.gr



Academic Editors: Panagiotis T. Nastos and Diofantos G. Hadjimitsis

Published: 27 October 2025

Citation: Marengo, F.; Amiridis, V.; Costa, M.J.; Kandler, K.; Kazadzis, S.; Klose, M.; Pérez García-Pando, C.; Ryder, C.; Antunes, C.M.; Basart, S.; et al. Understanding Mineral Dust Through a Doctoral Alliance. *Environ. Earth Sci. Proc.* **2025**, *35*, 78. <https://doi.org/10.3390/eesp2025035078>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

²⁴ Atmospheric Chemistry Department, Max Planck Institute for Chemistry, 55128 Mainz, Germany²⁵ Institute for Atmospheric and Climate Science, ETH Zurich, 8092 Zürich, Switzerland; frank.wienhold@env.ethz.ch (F.W.); martin.wild@env.ethz.ch (M.W.)

* Correspondence: f.marenco@cyi.ac.cy

† Presented at the 7th edition of the International Conference on Advanced Technologies for Humanity (ICATH 2025), Kenitra, Morocco, 9–11 July 2025.

Abstract

We present an example of how a doctoral network can bring together multidisciplinary expertise and novel scientific advances in atmospheric dust. This network (Dust-DN) has started operations and is a strategic alliance of high-profile partners, able to leverage unique facilities for atmospheric research and innovative space missions. The network aims to improve our understandings of dust processes and microphysics, identify the signature of source regions, address the socio-economic impacts of dust transport and improve the quantification of the role of dust in the climate system. The first results have already been achieved and are shown here, and many more are expected to follow.

Keywords: dust; microphysics; source regions; climate; socio-economic impacts; environmental health; Earth observations; airborne research; remote sensing

1. Introduction

Mineral dust is a major atmospheric aerosol, and it represents one of the most visible and detectable aspects of transboundary transport of atmospheric constituents, impacting visibility, radiation and climate [1]. What are 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 and source regions), and therefore, atmospheric models fail to fully reproduce its impacts. Moreover, dust observations using ground-based instrumentation, remote sensing and aircraft are abundant, but not evenly distributed; in particular, they are missing near major dust sources. The techniques and methodologies used to study dust are still under development, with each giving a different picture of this 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, for example, on the transportation and energy sectors, the nature and cost of which are 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 and laboratory research.

2. Methodology

To address some of these challenges, the first doctoral network on a European scale (to our knowledge), researching the topic of atmospheric dust, is now active, bringing together expertise on mineral dust in the atmosphere and combining multidisciplinary aspects. The Dust Doctoral Network (Dust-DN) is a strategic international, interdisciplinary and intersectoral alliance of high-profile partners, able to leverage unique state-of-the-art facilities and recent innovative spaceborne missions; see Table 1. The network comprises dedicated applied research projects, with direct contributions and impacts embedded within the societal and industrial sector.

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.

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 [3]	Satellite RS	ESA/JAXA

Seventeen Ph.D. projects have been proposed to advance the corresponding scientific questions (Table 2). With this network, we aim to provide significant scientific advances in the four research objectives outlined in the table:

- RO1 is about understanding the fundamentals of dust microphysical properties and processes, and, in particular, we aim to tackle the impact of non-spherical particles, which are not always considered due their complexity; moreover, we will investigate the effect of turbulence on atmospheric residence times and the impact of ice nucleation on dust.
- RO2 will focus on the influence of source regions on dust properties, overcoming some simplifications that see dust as a homogeneous aerosol type, combining experimental approaches (source-dependent composition, microphysical properties and spectral signatures) with modelling efforts (climate–mineralogy relationships).
- RO3 will tackle some of the socio-economic aspects, and, in particular, we aim to advance knowledge on impacts on health, air quality planning, aviation and solar energy production.
- RO4 will address the role of dust in the climate system, aiming to exploit novel spaceborne observations and modelling tools together with gaining a better understanding of processes (radiative effects and transport mechanisms).

Table 2. Dust-DN research objectives and Ph.D. projects.

Research Objectives	Ph.D. Projects
RO1: Understanding 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
RO2: 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
RO3: 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
RO4: 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

3. First Results

The first experiments and first modelling simulations for the anticipated advances in dust science have started and are outlined here.

In April–May 2025, the Cyprus Spring Campaign 2025 was carried out to advance measurement techniques for dust sample collection and to investigate the composition, size, shape and orientation of atmospheric dust particles. A mix of ground-based remote sensing and airborne in situ and ground-based instrumentation was used, including the collection of high-altitude dust samples. Some major dust events were captured (see example in Figure 1) and the analysis of the datasets collected is ongoing.

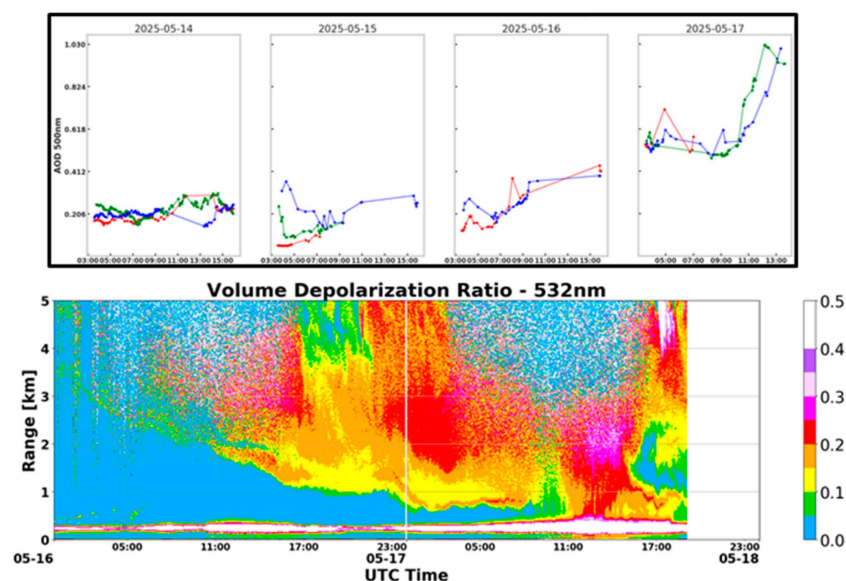


Figure 1. Aerosol optical depth (AOD) in Cyprus on 14–17 May 2025, and volume depolarization ratio observed during 16–17 May. The large AOD (increasing up to 1) and large depolarization ratio (up to 0.3) clearly identify the dust event. High-altitude dust samples taken in these atmospheric conditions will be analysed using scanning electron microscopy. Blue line: Nicosia; Red line: Agia Marina Xyliatou; Green line: Limassol.

During this campaign, moreover, observations using AEROTAPE (Oberon Sciences, Grenoble (Villard-Bonnot), France), a novel cost-effective scientific instrument, sampled the atmospheric dust on the ground at high resolution, providing novel imagery of the dust particles that is very useful for their quantification (see examples in Figure 2).

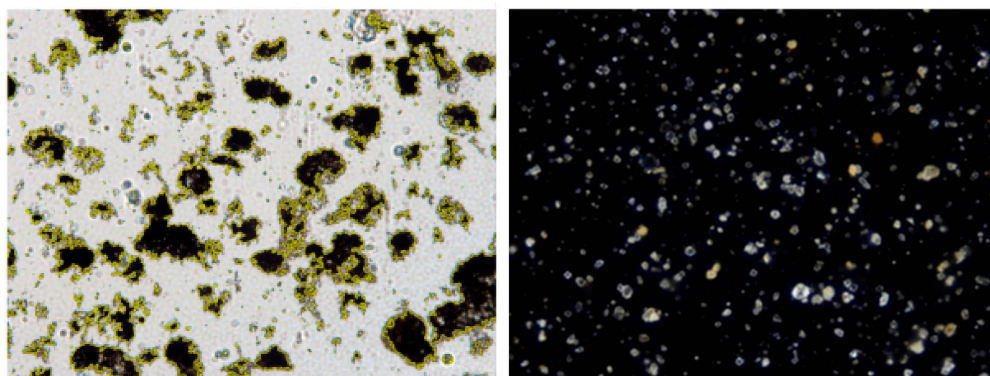


Figure 2. Images of dust particles collected by AEROTAPE during the Cyprus Spring Campaign 2025. AEROTAPE uses an onboard camera to capture images every ten minutes, and is able to analyse them automatically to provide their count, size, shape and colour.

At the same time that these experiments were carried out in Cyprus, simulations started at the Barcelona Supercomputing Centre using the Multiscale Online Nonhydrostatic Atmosphere Chemistry (MONARCH) model, with the aim to integrate them with high-resolution satellite observations from the NASA EMIT mission, providing information about surface mineralogy at the major dust source regions (see example in Figure 3).

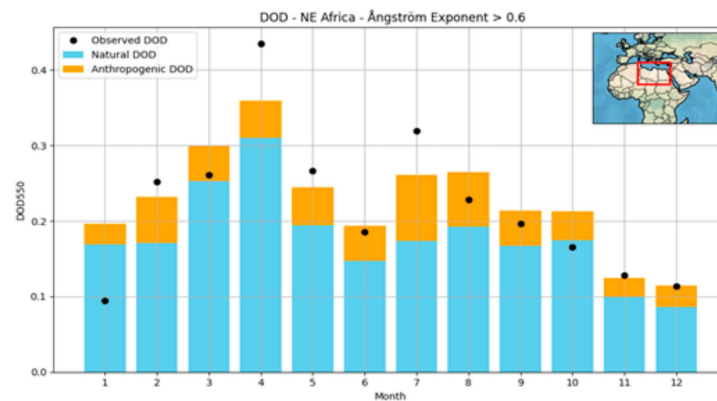


Figure 3. Comparison between the dust optical depth (DOD) over Northeast Africa simulated using MONARCH and the observations available from AERONET.

4. Conclusions

The strength of addressing research objectives with a doctoral network, as opposed to individual specialised projects, resides in the international, interdisciplinary and intersectoral approach, which valorises each methodology and the specialisations of each partner to address the topic 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 secondments to be carried out during the project, and all of them will be gathered together for network-wide schooling and workshops. They will also be encouraged to build team spirit through more frequent virtual networking opportunities.

Dust-DN is more than a collection of 17 visionary Ph.D. projects on mineral dust; it will create a dust science community that will enhance the potential of a number of unique techniques and facilities. It is expected that the network will advance the science of atmospheric dust, will further develop scientific synergies and complementarities, and will train a cohort of dust experts of tomorrow.

Author Contributions: Conceptualization: F.M. (Franco Marengo), V.A., M.J.C., K.K., S.K., M.K., C.P.G.-P. and C.R.; coordination and finalisation of proposal: F.M. (Franco Marengo); coordination of network: K.F. and F.M. (Franco Marengo); investigation: F.M. (Franco Marengo), V.A., M.J.C., K.K., S.K., M.K., C.P.G.-P., C.R., C.M.A., S.B., D.B. (Daniele Bortoli), D.B. (Demetri Bouris), M.B., J.B., P.C. (Paulo Canhoto), M.-E.C., P.C. (Panos Choutris), T.C., R.C., H.D., O.D., K.F., D.F. (Diana Francis), D.F. (David Fuertes), M.G.A., B.J., E.L., S.M., R.E.M., E.M., C.M., A.P., A.R., J.S., J.S.-G., N.T., A.T., A.V., I.W., C.W., F.W., M.W., K.M.T., E.K. and F.M. (Francesco Moncada); writing—original draft preparation: F.M.; writing—review and editing: F.M. (Franco Marengo), V.A., M.J.C., K.K., S.K., M.K., C.P.G.-P., C.R., C.M.A., S.B., D.B. (Daniele Bortoli), D.B. (Demetri Bouris), M.B., J.B., P.C. (Paulo Canhoto), M.-E.C., P.C. (Panos Choutris), T.C., R.C., H.D., O.D., K.F., D.F. (Diana Francis), D.F. (David Fuertes), M.G.A., B.J., E.L., S.M., R.E.M., E.M., C.M., A.P., A.R., J.S., J.S.-G., N.T., A.T., A.V., I.W., C.W., F.W., M.W., K.M.T., E.K. and F.M. (Francesco Moncada) All authors have read and agreed to the published version of the manuscript.

Funding: 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). The views and opinions expressed are 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. The research on AEROTAPE is also funded by the AERODUST project, of the Agence Nationale pour la Recherche (grant agreement ANR 24 CE04 0814 01).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analysed in this study. Data sharing is not applicable to this article. Data to be created in the future by Dust-DN will be openly available in a dedicated repository.

Conflicts of Interest: The authors Rory Clarkson, Andrew Rimell, Noorani Tembhekar and Andreas Vogel were employed by the company Rolls-Royce when the paper was written. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The funding agencies have no role in the design of the project; in the collection, analysis or interpretation of data; in the writing of the manuscript; or in the decision to publish it. The views and opinions expressed are 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.

Abbreviations

The following abbreviations are used in this manuscript:

Dust-DN	Dust Doctoral Network
DC	Doctoral Candidate

References

1. Kok, J.F.; Storelvmo, T.; Karydis, V.A.; Adebisi, A.A.; Mahowald, N.M.; Evan, A.T.; He, C.; Leung, D.M. Mineral dust aerosol impacts on global climate and climate change. *Nat. Rev. Earth Environ.* **2023**, *4*, 71–86. [[CrossRef](#)]
2. Adebisi, A.; Kok, J.F.; Murray, B.J.; Ryder, C.L.; Stuut, J.-B.W.; Kahn, R.A.; Knippertz, P.; Formenti, P.; Mahowald, N.M.; Pérez García-Pando, C.; et al. A review of coarse mineral dust in the Earth system. *Aeolian Res.* **2023**, *60*, 100849. [[CrossRef](#)]
3. Wehr, T.; Kubota, T.; Tzeremes, G.; Wallace, K.; Nakatsuka, H.; Ohno, Y.; Koopman, R.; Rusli, S.; Kikuchi, M.; Eisinger, M.; et al. The EarthCARE mission—Science and system overview. *Atmos. Meas. Tech.* **2023**, *16*, 3581–3608. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.