Using Aircraft Observations and Modelling to Improve Understanding of Mineral Dust Transport and Deposition Processes

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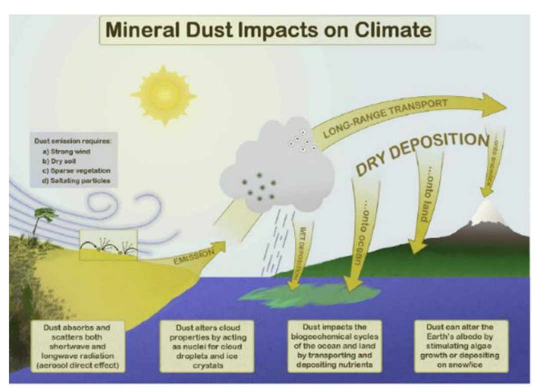
Every year thousands of tonnes of mineral dust particles are uplifted from arid regions by strong winds. While in the atmosphere, mineral dust is a hazard for health, transport and solar energy generation. Dust affects climate by interacting with clouds, radiation and other aerosols and altering the earth's energy balance. In dusty regions such as North Africa and the tropical North Atlantic, dust has been shown to influence the West African Monsoon and Atlantic hurricane development. Dust forms an important climate feedback within the earth system: emissions are driven by land-surface and atmospheric factors, whilst airborne it impacts on the atmosphere, and through deposition it provides a nutrient source to oceanic and terrestrial biogeochemical systems.

Almost all dust processes are highly size dependent, and a realistic representation of the size distribution is critical for the simulation of the dust atmospheric lifecycle. However, models struggle to represent the evolution of dust size distributions. Processes such as triboelectric charging and non-sphericity have recently been shown to be important, yet are not included in dust models. This has knock-on effects on the ability of dust models to accurately represent the impact of dust on human health, infrastructure, weather and climate.

Previously large dust particles (>10 microns) were not thought to be transported over continental distances, and until recently there have been limitations in measuring the larger parts of the size range. However, in the past ten years aircraft observations have utilized new technology to measure the full size range of dust, overcoming previous limitations. Aircraft missions have sampled dust over critical stages of the dust lifecycle, including FENNEC near north African sources, AER-D in the west Atlantic and SALTRACE in both east and west Atlantic. These observations have shown that the presence of large dust particles is universal (Ryder et al., 2019), yet we do not fully understand their transport processes (van der Does, 2018).



Left: The NERC research aircraft with aerosol probes over the dusty Sahara during 2011 fieldwork; Right: the dust lifecycle and climate impacts (Mahowald et al., 2014)

The aim of this studentship is to use the newly published aircraft observations to investigate the effect of deposition and transport processes on the dust size distribution, thereby improving our understanding of dust physics and microphysics. This will be done within the framework of the Met Office Unified Model (UM). Whilst the UM includes large dust particles, until now it has not been possible to determine how well they are represented. Now that observations exist for the full dust size range across a series of stages across the dust life cycle, there is an exciting opportunity to be exploited in order to improve our understanding of dust transport for the first time. The studentship is supported by CASE sponsorship from the UK Met Office and linked to the ACSIS (North Atlantic Climate System Integrated Study) project, since dust transport is important in influencing Atlantic sea surface temperatures.

Initially, the student will use observational aircraft data to evaluate dust in a climate model simulation. Secondly, the contribution of various different processes to the evolution of dust size distribution across the Atlantic will be assessed by disabling each existing model process (e.g. sedimentation, convection) in turn, and by introducing novel processes such as the effects of non-sphericity and of triboelectric charging. Key processes would then be selected for more detailed investigation, using either the UM or a box model, with the aim of understanding the causes of size biases and identifying potential improvements. Finally, recommended developments would be tested on a global scale over climate timescales. The aim is to include any improvements in a future model version and they would also be directly applicable in other model configurations such as the UK Earth System Model or numerical weather prediction. This will deliver fundamental improvements to our understanding of dust transport and representation of dust in weather and climate models.

Training opportunities:
The student will receive training from the Claire Ryder (expert in airborne dust observations) in handling and applying aircraft observations and from Nicolas Bellouin and Stephanie Woodward (experts in aerosol and dust modelling) in running and modifying a large climate model. The student will spend at least 3 months at the Met Office throughout the PhD as part of the CASE award, having the opportunity to be fully immersed in the Met Office working environment. They will be associated with the joint Met Office/NERC UKESM Core Group, working with Stephanie Woodward and receive additional training and support from Ben Johnson, Alistair Sellar and Anthony Jones at the Met Office.

Depending on their academic background the student will take various taught courses within the Meteorology Department as well as taking part in SCENARIO broader training opportunities and UK Aerosol Society courses. NCAS courses will provide technical training on the Met Office Unified Model and its aerosol component. The studentship is linked to the ACSIS project and the student will participate in ACSIS workshops and collaborate with ACSIS researchers.

Student profile:

This project would be suitable for students with a degree in physics, mathematics or a closely related environmental or physical science. The student should have an interest in climate and aerosols. Experience of using aerosol and/or climate models would be an advantage.

Funding particulars:
This project has CASE sponsorship from the Met Office, and is linked to the NCAS ACSIS project (https://www.ncas.ac.uk/en/acsis-home).

References:

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