The impact of high resolution modelling on mineral dust forecasts over West Africa using the ECMWF integrated forecast system

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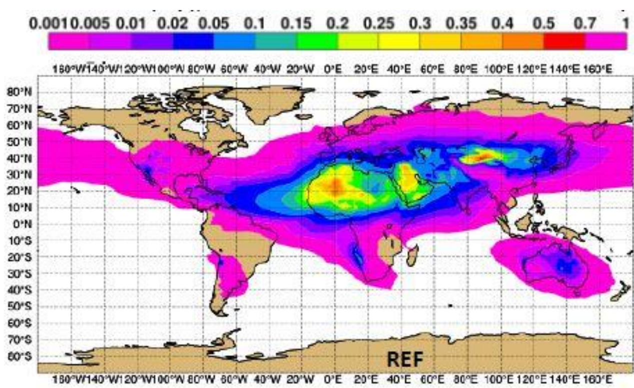
Dust storms are a major driver of poor air quality in many parts of the world, particularly in West Africa. During dust storms particulate matter thresholds are regularly exceeded, contributing to premature mortality. Accurately forecasting dust storms remains a challenge in weather forecast models because many features which drive dust storms occur at smaller scales than are typically represented in forecast models, such as surface wind gusts, convective outflows, diurnal cycles and surface dust sources.



Left: ECMWF CAMS dust optical depth forecast for 18th October 2021; Right: Dust storm impacts air quality

Currently, the European Centre for Medium Range Weather Forecasting (ECMWF) runs a world-leading operational numerical weather prediction (NWP) model at 9km horizontal resolution, but it does not predict dust uplift and transport using forecast winds. However, wind-driven dust is included in the lower resolution (40km) ECMWF Copernicus Atmosphere Monitoring Service (CAMS) model (see figure). The timing and magnitude of dust storms can be inaccurate in the CAMS forecast due to poor representation of small scale wind features which pick up dust from the surface and transport it away from sources.

The successful student will add the representation of wind-driven dust to the 9km NWP model. The student will assess the improvements in forecast dust as a result of higher model resolution. This will be achieved by selecting dust storm case studies, such as events which had large humanitarian impacts or high dust concentrations. The student will run the dust scheme within both high and low resolution versions of the model, and then compare meteorology and dust forecasts against observational data, such as previously gathered aircraft in-situ measurements, satellite observations and ground-based measurements in order to assess the extent of any improvements. This will pave the way for a transition towards higher resolution forecasting of atmospheric composition and demonstrate key benefits.

The student will address the following research questions:

- By which processes, and to what extent, does increased model resolution improve the representation of extreme dust events?
- How is this related to improved representation of surface wind gusts, convective outflows, low level jets, diurnal cycles and surface source representation?
- How and why do factors such as column dust load, surface concentration, spatial structure, vertical distribution, size distribution and radiative effect of dust differ?
- Are health and socioeconomic impacts of dust storms better forecast, such as exceedance of air quality thresholds?

Training opportunities:
Dr Claire Ryder's expertise spans many aspects of mineral dust, from observations of dust (both aircraft and satellite) to the representation of dust in models, and she will provide training and supervision in these aspects throughout the PhD. Professor Helen Dacre complements this with an expertise in the transport and dispersion of gases and aerosols.

The project is co-sponsored via an internship placement at the ECMWF. The student will be based at ECMWF during model-intensive phases of the PhD, such as when the student is porting the dust scheme across model configurations. This is an excellent opportunity to be immersed into the ECMWF working environment. Support and co-supervision will be provided by Dr Angela Benedetti during this time, as well as additional training and support from Dr Zak Kipling and Dr Samuel Rémy (ECMWF/Hygeos), all of whom have expertise in modelling aerosol processes within CAMS and the Integrated Forecast System.

The studentship also benefits from CASE sponsorship from the Red Cross Climate Centre (RCCC), with co-supervisor Dr Kiswendsida based in Ouagadougou, Burkina Faso. During the CASE placement (towards the end of the PhD), the student will work closely with Dr Kiswendsida. Collaborating with climate experts from the RCCC, the student will work on the predictability of major dust events which had considerable humanitarian impacts. There will be opportunities for the student to collaborate with the Red Cross Climate Centre on how the understanding and improved predictability of dust in West Africa could be translated into early actions. The Red Cross Climate Centre is a virtual centre, but the student would have the opportunity to visit Dr Kriswendsida in Burkina Faso.

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 atmospheric composition, and its impact on weather and climate, and/or an interest in African meteorology.
- Experience and an interest in programming and/or model development is essential for this PhD. Strong motivation to develop skills in this area is also important.

Funding particulars:
This project benefits from both of the following:

1. Co-sponsorship via an internship placement at the ECMWF
2. CASE sponsorship with the Red Cross Climate Centre