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The radiative effects of Saharan dust layer on the marine atmospheric layer

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Abstract
The North African Saharan desert is one of the main sources of atmospheric dust. Since dust can be transported by winds for thousands of miles, reaching the Americas and extending across vast expanses of the tropical Atlantic Ocean, it is important to understand the influence that dust has on the radiative properties and the thermodynamic structure of the atmosphere. For climate models it is important that this is represented since the structure of the atmosphere can have important influences downwind on the development of convection, clouds, storms, precipitation and consequently radiative properties. In this study, we aim to understand the dynamic and thermodynamic properties of Saharan dust on the atmospheric structure of marine environment and to investigate the causes of the observed regions of well-mixed potential temperatures of the marine atmosphere in the presence of Saharan dust layers. We compare the influence of dust to other potentially important influences such as wind shear and air mass.
To investigate this, we simulated the marine atmosphere in the presence and absence of dust using the UK Met Office Large Eddy Model (LEM) based the BOMEX case-study that is provided with the LEM and updated with observation taken during the FENNEC experiments of June 2011 and 2012. We performed LEM simulations with and without dust heating rates for an eight-hour time period. Data for meteorological profiles were used from the FENNEC aircraft measurements taken over the Atlantic Ocean near the Canary Islands. Our LEM results show that using a stratified (typical of non-dusty) atmosphere and then apply a dust heating rate the profile of potential temperature tends towards a well-mixed layer where the heating rates were applied and consistent with the observational cases. While LEM simulations for wind shear showed very little difference in the potential temperature profile and it was clear the well-mixed layer would not result.
LEM simulations using dust heating rates were shown to create and maintain well-mixed layers if we initialised runs with either the dusty or non-dusty profiles; whereas, without the heating rates the layers progressed to a stratified layer consistent with non-dusty day observations. This illustrated independence of the well-mixed layers to the air mass type (other than the dust presence). We conclude from these tests that the well-mixed layers are explained by the presence of the dust.
Until now it was not known if the well-mixed regions were a result of the different air masses, as air masses picking up dust over land then advecting out over the ocean are potentially very different to air masses that have been in more pristine oceanic environments, or other influences such as shear. Evaluation of CAPE and CIN with and without the influences of dust heating rates indicated that the atmospheric structure downwind was significantly altered by the presence of the dust layer. It is important as a follow-on from this work to investigate whether the climate models can capture these dust layer influences and potential impacts downwind.