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The Saharan atmospheric boundary layer: Turbulence, stratification and mixing

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High-resolution large-eddy model simulations, combined with aircraft and radiosonde observations from the Fennec observational campaign are used to describe the vertical structure of the Saharan atmospheric boundary layer (SABL). The SABL, probably the deepest dry convective boundary layer on Earth, is crucial in controlling the vertical redistribution and long-range transport of dust, heat, water and momentum in the Sahara, with significant implications for the large-scale Saharan heat low and West African monsoon systems. The daytime SABL has a unique structure, with an actively growing convective region driven by high sensible heating at the surface, capped by a weak ($\leq$1K) temperature inversion and a deep, near-neutrally stratified Saharan residual layer (SRL) above it, which is mostly well mixed in humidity and temperature and reaches a height of $\sim$500hPa.

Large-eddy model (LEM) simulations were initialized with radiosonde data and driven by surface heat flux observations from Fennec supersite-1 at Bordj Bardji Mokhtar (BBM), southern Algeria. Aircraft observations are used to validate the processes of interest identified in the model, as well as providing unprecedented detail of the turbulent characteristics of the SABL. Regular radiosondes from BBM during June 2011 are used to generate a climatology of the day-time SABL structure, providing further evidence that the processes identified with the LEM are recurrent features of the real SABL.

The model is shown to reproduce the typical SABL structure from observations, and different tracers are used to illustrate the penetration of the convective boundary layer into the residual layer above as well as mixing processes internal to the residual layer. Despite the homogeneous surface fluxes and tracer initialization, the large characteristic length-scale of the turbulent eddies leads to large horizontal changes in boundary layer depth (which control the formation of clouds) and significant heterogeneity in tracer concentrations, demonstrating the potential for variability in, for example, dust concentrations independent of external forcings. The residual layer, where long-range transport can take place, is analyzed in particular detail. Various processes which can lead to transport into and mixing within the residual layer are explored, including shear-driven turbulence at the residual layer top and the potential for detrainment from the convective boundary layer top due to the combination of a weak lid and a neutral layer above.