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Assimilating vertical profiles of dust observations with ensemble meteorological initial and boundary conditions

Jeronimo Escribano (1), Enza Di Tomaso (1), Carlos Perez Garcia-Pando (1), Oriol Jorba (1), Francesca Macchia (1), Claudia Urbanneck (2), Holger Baars (2), Albert Ansmann (2), and Ulla Wandinger (2)

(1) Barcelona Supercomputing Center, Barcelona, Spain, (2) Leibniz Institute for Tropospheric Research, Leipzig, Germany

High uncertainties currently exist in the representation of aerosol vertical structure in models, which have implications for the radiation's budget and transport. The assimilation of vertical profiles of aerosols can potentially improve significantly the monitoring and forecast of aerosol 3-dimensional concentrations. To fully exploit the potential of aerosol profile assimilation, it is crucial to accurately estimate forecast uncertainty in the vertical distribution of aerosols. This could help in correcting inconsistencies between the observed aerosol plumes and the simulated ones, which are due to temporal and spatial errors in the simulated emissions and in the underlying dynamical meteorological fields.

In ensemble based methods, forecast uncertainty is derived from the ensemble of model states at the assimilation time, and evolves during the forecast. This uncertainty is under-represented in current systems, particularly in the vertical dimension, because perturbations of the ensemble members are typically applied only to the aerosol source strength. In addition to an ensemble design based on aerosol emissions perturbations, it is possible to design the ensemble by considering different dust emission schemes and boundary and initial meteorological conditions.

In this work we assimilate dust products derived from LIDAR measurements in an ensemble-based scheme, namely a Local Ensemble Transform Kalman Filter (LETKF), coupled with a regional configuration of the MONARCH multi-scale chemical weather prediction system. We consider a heavy dust event in the Eastern Mediterranean in 2017 observed with 3 LIDARs in Crete, Cyprus and Israel, and show how meteorological initial and boundary conditions perturbations affect the 3-dimensional structure of background error covariances. More specifically, they increase the vertical variability of the ensemble, and are beneficial for vertical-targeted dust data assimilation.