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Four dimensional variational assimilation of in-situ and remote-sensing aerosol data

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Aerosols play an increasingly important role in atmospheric modelling. They have a strong influence on the radiative transfer balance and a significant impact on human health. Their origin is various and so are its effects. Most of the measurement sites in Europe account for an integrated aerosol load PM_x (Particulate Matter of less than x μm in diameter) which does not give any qualitative information on the composition of the aerosol. Since very different constituents contribute to PM_x, like e.g. mineral dust derived from desert storms or sea salt, it is necessary to make aerosol forecasts not only of load, but also type resolved.

The method of four dimensional variational data assimilation (4Dvar) is a widely known technique to enhance forecast skills of CTMs (Chemistry-Transport-Models) by ingesting in-situ and, especially, remote-sensing measurements. The EURAD-IM (EURopean Air pollution Dispersion - Inverse Model), containing a full adjoint gas-phase model, has been expanded with an adjoint of the MADE (Modal Aerosol Dynamics model for Europe) to optimise initial and boundary values for aerosols using 4Dvar. A forward and an adjoint radiative transfer model is driven by the EURAD-IM as mapping between BLAOT (Boundary Layer Aerosol Optical Thickness) and internal aerosol species. Furthermore, its condensation scheme has been bypassed by an HDMR (High-Dimensional-Model-Representation) to ensure differentiability.

In this study both in-situ measured PM_x as well as satellite retrieved aerosol optical thicknesses have been assimilated and the effect on forecast performance has been investigated. The source of BLAOT is the aerosol retrieval system SYNAER (SYNergetic AErosol Retrieval) from DLR-DFD that retrieves AOT by making use of both AATSR/SCIAMACHY and AVHRR/GOME-2 data respectively. Its strengths are a large spatial coverage, near real-time availability, and the classification of five intrinsic aerosol species, namely water-solubles, water-insolubles, soot, sea salt, and mineral dust which are furthermore size resolved in terms of modes.

The skill of the aerosol 4Dvar system was tested in two episodes: 1) July through August 2003, a dry period with strong wildfire activity in Europe, and 2) October through November 2008, the period of the ZEPTER-2 (Second ZEPpelin based Tropospheric photochemical chemistry expERiment) measurement campaign in the area of Lake Constance. In the latter case one-way nesting has been applied from a horizontal grid resolution of 45 km down to 5 km. Overall, the results showed a significant increase in forecast quality of tropospheric aerosol loads.