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Lidar data assimilation for improved analyses of volcanic aerosol events

Anne Caroline Lange (1) and Hendrik Elbern (1,2)

(1) Rhenish Institute for Environmental Research at the University of Cologne, Cologne, Germany (al@eurad.uni-koeln.de),
(2) Research Centre Jülich, Institute for Energy and Climate Research – Troposphere (IEK-8), Jülich, Germany

Observations of hazardous events with release of aerosols are hardly analyzable by today's data assimilation algorithms, without producing an attenuating bias. Skillful forecasts of unexpected aerosol events are essential for human health and to prevent an exposure of infirm persons and aircraft with possibly catastrophic outcome. Typical cases include mineral dust outbreaks, mostly from large desert regions, wild fires, and sea salt uplifts, while the focus aims for volcanic eruptions.
In general, numerical chemistry and aerosol transport models cannot simulate such events without manual adjustments. The concept of data assimilation is able to correct the analysis, as long it is operationally implemented in the model system. Though, the tangent-linear approximation, which describes a substantial precondition for today's cutting edge data assimilation algorithms, is not valid during unexpected aerosol events.
As part of the European COPERNICUS (earth observation) project MACC II and the national ESKP (Earth System Knowledge Platform) initiative, we developed a module that enables the assimilation of aerosol lidar observations, even during unforeseeable incidences of extreme emissions of particulate matter. Thereby, the influence of the background information has to be reduced adequately.
Advanced lidar instruments comprise on the one hand the aspect of radiative transfer within the atmosphere and on the other hand they can deliver a detailed quantification of the detected aerosols. For the assimilation of maximal exploited lidar data, an appropriate lidar observation operator is constructed, compatible with the EURAD–IM (European Air Pollution and Dispersion – Inverse Model) system. The observation operator is able to map the modeled chemical and physical state on lidar attenuated backscatter, transmission, aerosol optical depth, as well as on the extinction and backscatter coefficients. Further, it has the ability to process the observed discrepancies with lidar data in a variational data assimilation algorithm.
The implemented method is tested by the assimilation of CALIPSO attenuated backscatter data that were taken during the eruption of the Eyjafjallajökull volcano in April 2010. It turned out that the implemented module is fully capable to integrate unexpected aerosol events in an automatic way into reasonable analyses. The estimations of the aerosol mass concentrations showed promising properties for the application of observations that are taken by lidar systems with both, higher and lower sophistication than CALIOP.