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Treatment of pollutant washout in a regional model at kilometer-scale resolution

Christoph Knote (1) and Dominik Brunner (2)

(1) NCAR, Atmospheric Chemistry Division, Boulder, United States (knote@ucar.edu), (2) Empa, Laboratory for Air Pollution / Env. Technology, Duebendorf, Switzerland

Wet deposition of trace gases and aerosols is the major sink in the atmosphere. The associated reactive environment in cloud and rain droplets can further lead to recombination and even the formation of new compounds. Evaporating droplets can release mass back to the atmosphere, and lead in the case of precipitation to a vertical redistribution of air pollutants. Regional-scale numerical weather prediction models like COSMO or WRF, which most air quality models use as meteorological driver or are even online-coupled to, treat hydrometeors as prognostic quantities. The meteorological community has realized that on horizontal grids with mesh sizes of only a few kilometers or less, horizontal advection of precipitation needs to be considered to accurately represent patterns like e.g. lee-side precipitation. Almost all air quality models however consider washout by precipitation only through diagnosed precipitation rates ("diagnostic" treatment) instead of making scavenged pollutant masses prognostic quantities and applying the respective advection, diffusion and sedimentation terms as done in the meteorological core ("prognostic" treatment). Only few include evaporation of precipitation and subsequent release of pollutants. Where precipitation reaches the ground, and where the associated pollutants are deposited is therefore not the same when a diagnostic formulation is used. The assumptions underlying diagnostic treatment are justified for coarse grid models, where horizontal transport of precipitation is negligible. Further, the additional computational burden of advecting a (large) number of fields for the in-rain chemical compounds can be avoided. Increases in computing power however make prognostic treatment feasible, and increases in horizontal resolution towards kilometer-scale might even require it, as the underlying assumptions of diagnostic treatment do not hold anymore.
In a recent study we have coupled an aqueous-phase chemistry and wet scavenging scheme (SCAV) with the online-coupled chemistry transport model COSMO-ART. The coupling has been made consistent with the cloud microphysics scheme of the underlying COSMO model, and also reproduced how the sedimentation of precipitation is considered in COSMO. Chemical composition of cloud and rain droplets are prognostic quantities. We further included a diagnostic version in which no transport in the aqueous-phase takes place, and wet deposition is based on precipitation rates. In our presentation we show the effects of our coupling on simulations of major air pollutants in general, and investigate the differences in vertical redistribution and wet deposition patterns between diagnostic and prognostic treatment. Our work can help the air quality modeling community decide whether an update of the wet deposition scheme in their models is necessary once simulations on the kilometer-scale are attempted.