Retrieval of high spatial resolution black carbon sources: use of the adjoint GEOS-CHEM model in conjunction with WRF-CHEM calculations to improve the emission pattern on a regional scale

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Black carbon (BC), the primary absorbing aerosol species, significantly affects radiative feedback [1], the chemistry of greenhouse gases [2], particularly CO_2 and CH_4, cloud microphysics, and precipitation [3]. However, due to a paucity of long-term and well-constrained observations, the fundamental mechanisms underlying these effects are still not fully known. Identifying the high-resolution sources of BC emissions is thus crucial to understanding the extent of uncertainty surrounding BC's repercussions at both global and regional scales.

Here, we identify BC emission sources across France in the year 2019 using a grid-nesting strategy for Europe with a spatial resolution of 0.25 (latitude) x 0.3125 (longitude) degrees by coupling the GEOS-CHEM global chemistry-transport model and its adjoint with the 4D-Var assimilation technique [4, 5]. For data assimilation procedures, Sentinel-5P/TROPOMI aerosol products developed by the GRASP [6] algorithm as well as in situ measurements of BC surface concentration are employed. The retrieved BC emission sources are then utilized as the initial and periodic boundary conditions for the WRF-CHEM regional chemistry-transport model, together with nudging inside the parent domain. We use a four-step grid-nesting technique to focus on Paris, starting with a spatial resolution of 0.25 degrees, similar to the GEOS-CHEM nesting grid run, to demonstrate BC transport and its regional adverse effects at a spatial resolution of 1 x 1 km^2. For validation purposes, we use separate ground-based measurements gathered from various Parisian sites.

Overall, we demonstrate how to use the 4D-var data assimilation method in conjunction with in situ and space-borne multi-source observations to reconstruct BC aerosol emission sources with high spatial resolution. The accuracy of a posteriori emissions is evaluated using independent multi-scale chemistry-transport models and observations. Additionally, this work is an encouraging step and is consistent with restricting BC emission sources from various countries for an efficient climate mitigation policy with climate intervention strategies.

Keywords: Black carbon, inverse modeling, global atmospheric chemistry-transport model, regional atmospheric chemistry-transport model

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