Black Carbon on a High-Resolution Map with Coupled Chemistry-Transport Models: Improving Regional Emissions with Adjoint GEOS-Chem and WRF-CHEM Calculations

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Black carbon (BC), a type of soot particle, affects climate by strongly absorbing light and darkening snow covers, causing them to melt faster. It also worsens air quality. Understanding how BC affects clouds and precipitation presents many challenges. Therefore, elucidating the atmospheric abundance and physicochemical properties of BC is essential to unravel the multifaceted consequences it exerts on our ecosystem. Finding where it comes from and how much is released regionally is crucial.

Inverse modeling is an efficient approach for retrieving BC emissions globally and at high spatial resolutions using a top-down approach. In this study, we use a one-way grid-nesting system to enhance BC emissions estimation over Europe during 2019 and 2020. Our strategy uses a spatial resolution of 0.25° (latitude) by 0.3125° (longitude). The coupling of the GEOS-Chem global chemistry-transport model (CTM) and its adjoint with the 4D-Var assimilation technique allows the correction of emissions at fine spatial scales. Data assimilation is achieved by using Sentinel-5P/TROPOMI aerosol optical products, generated by the GRASP algorithm, with a particular emphasis on absorbing aerosols (e.g., BC, organic matter), complemented by in situ measurements of BC surface concentration obtained through the framework of ANR BLACKNET project.

In this offline aerosol CTM simulation, we analyze various aerosol components, including BC, organic matter, sulfate, nitrate, sea salt, and desert dust. We use a lognormal size distribution model with external mixing of aerosols to evaluate the cost function based on their optical properties while assimilating TROPOMI/GRASP aerosol optical products into the CTM simulation. Subsequently, we use the retrieved high-resolution BC emissions to initialize and force periodically at the boundary of the WRF-CHEM regional CTM simulation. Using grid nesting, as a case study, we focus on the Paris area, achieving a spatial resolution of 1x1

km^2. This endeavor aims to refine BC emission characterization, aligning to curtail BC emission sources across multiple nations to enhance the efficacy of climate mitigation policies and intervention strategies.

The developed strategy can be of high potential for benefiting from future Multi-Angular Polarimeter missions that would provide the maps of retrieved detailed aerosol characteristics.

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