Quantifying the impact of urban greenhouse gas emissions for Munich during the COVID-19 pandemic using WRF V3.9.1.1

Xinxu Zhao1, Jia Chen1, Julia Marshall2, Michał Galkowski3,4, Christoph Gerbig3, Stephan Hachinger5, Johannes Gensheimer1, Xiaotian Guo1, Florian Dietrich1, Adrian Wenzel1, and Friedrich Klappenbach1

1Technology University of Munich, Professur für Umweltsensorik und Modellierung, Fakultät für Elektrotechnik und Informationstechnik, Munich, Germany
2Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany
3Max Planck Institute for Biogeochemistry, Department of Biogeochemical Signals, Jena, Germany
4AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Kraków, Poland
5Leibniz Supercomputing Center (Leibniz-Rechenzentrum, LRZ) of Bavarian Academy of Sciences and Humanities, Garching, Germany

During the COVID-19 pandemic lockdowns, human activities are strongly restricted, which results in a reduction in greenhouse gas (GHG) emissions associated with changes in energy consumptions. The Copernicus Atmosphere Monitoring Service (CAMS) reported a 10.3% decrease in CO₂ fossil fuel emissions during the first lockdown (February-July, 2020) of the COVID-19 pandemic throughout Europe. Using our WRF modeling framework built for the Munich area [1,3] and the column measurements from our automated Munich Urban Carbon Column network (MUCcnet, [2]), we aim to quantify the reduction of GHG emissions within Munich during the COVID-19 pandemic.

Our high-resolution modeling framework can simulate the sources, sinks, and emissions of CO₂ and CH₄ at a spatial resolution of up to 400m. The initial and boundary conditions for meteorological fields are taken from ERA5 and CAMS data is used for initializing the initial and lateral tracer boundary conditions. Anthropogenic emissions below ~1 km altitude above the ground level are obtained from TNO-GHGco v1.1 at a resolution of 1 km². Various tagged tracers are included to quantify the contribution from different emission categories (such as biogenic emissions from wetlands, emissions from road transport, industry, etc). By refining the vegetation classification using the Dynamic Land Cover map of the Copernicus Global Land Service at 100 m resolution (CGLS-LC100), the urban biogenic signals of CO₂ can be well captured using the diagnostic light-use-efficiency biosphere model VPRM (Vegetation Photosynthesis and Respiration Model), which is driven by MODIS indices. Moreover, we integrate urban canopy information derived from World Urban Database and Access Portal Tools (WUDAPT) classified by local climate zones (LCZs) [4] into our model infrastructure. Incorporating precise urban land use data in WRF helps to capture more urban transport features, improving the model behavior within urban areas.
We targeted the pandemic period from February to July 2020 and the same period in 2019 to make a comparison. Thanks to our nearly continuous column measurements during the COVID-19 pandemic, we are able to evaluate our simulated GHG concentrations by comparing them to the measurement results. Furthermore, an estimation of GHG emissions reduction in Munich during the targeted period will be obtained by performing a Bayesian inversion approach incorporating the simulated concentration enhancements from tagged tracers in WRF.


