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Urban Climate and CO2 Simulations with the New Atmospheric Model ICON-ART Accounting for Spatially Varying Urban Morphology and Material Properties

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Over the last decade, numerous urban canyon schemes have been developed, aiming to reproduce the interactions between the urban surface and the atmosphere. They have either used a bulk approach, where the general urban surface characteristics are modified, or a layered approach, in which single or multiple canyon levels are adopted, taking into account the contributions of individual urban facets: such as roofs, walls, and floors. Bulk schemes have often been the preferred approach in numerical weather prediction and climate models for their cost-efficient way of representing key atmosphere-canopy interactions and other important urban characteristics.
TERRA_URB is one of these bulk urban canopy models (UCM), originally developed for the COSMO atmospheric model. It has recently been integrated into the Icosahedral Non-hydrostatic Weather and Climate Model (ICON). In this study, we extended the preliminary implementation in ICON with the capability of representing morphological and material properties of the urban surfaces as spatially varying (instead of constant) fields in order to better represent the variability of energy, moisture, radiation, and momentum fluxes between the canopy and the atmosphere across a city. The spatially varying properties were derived from the Ecoclimap Second Generation (ECOCLIMAP-SG) land cover dataset, which is the latest version of ECOCLIMAP, incorporating local climate zones with a relatively high resolution of 300 meters. To assess the performance of ICON with TERRA_URB, we simulated the hot and dry summer period of mid-July to mid-August 2022 over the cities of Zurich and Basel in three configurations, (i) without TERRA_URB, (ii) with TERRA_URB in the preliminary and (iii) in the enhanced version. The three versions were compared against each other and evaluated against different types of observations, including standard weather stations, temperature sensor networks, and flux tower measurements.
Overall, our results reinforce the importance of incorporating accurate characterization of urban morphological and material properties into UCMs. Going forward, we will further improve these urban parameters by incorporating local datasets not accessible to a global product like ECOCLIMAP-SG. This will include, among others, detailed 3D building information, building material properties, surface reflectance (albedo) properties derived from remote sensing, and anthropogenic heat fluxes estimated from a detailed CO2 emission inventory. Our ultimate goal is

to develop a comprehensive ICON-based urban modeling system that can be run with either a bulk UCM or the multilayer UCM BEP-Tree, previously developed in our group for COSMO. This novel modeling system will allow us to study the feedback between vegetation, carbon, energy, and water cycles in the urban environment.