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Simulating the effect of urban planning choices on the spatial variability of net carbon dioxide exchange Helsinki, Finland

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Urban areas are major emitters of carbon dioxide (CO_2) and therefore several cities are seeking sustainable solutions to reduce their CO_2 emissions to the atmosphere. Urban CO_2 emissions are commonly estimated with a bottom-up approach from emission inventories, but the downside of this methodology is the lack of spatial and temporal representativeness of the emissions and information about the biological components contributing to the net ecosystem exchange. Thus, to examine the effectiveness of different urban planning strategies on carbon emissions, ecosystem models including both anthropogenic and biogenic components of CO_2 exchange are needed. In this study, the net CO_2 exchange is included in the Surface Urban Energy and Water balance Scheme (SUEWS), an urban land surface model which resolves the energy and water balances at a neighbourhood scale. The aim is to use the developed model to examine city-level CO_2 surface exchange under different urban planning scenarios.

In the model, the biogenic components, respiration and photosynthesis, are parameterized based on air temperature and light-response curves. Two approaches for anthropogenic CO_2 emissions are enabled: (i) from anthropogenic heat emissions; and (ii) a bottom-up approach from traffic, buildings and human metabolism. The main model development focuses on Helsinki, where the modelled CO_2 exchange is compared against observations made at two eddy covariance (EC) stations located in a semi-urban area and in highly built-up city centre. Additionally, EC data from Minneapolis (USA), Swindon and London (UK) are used to examine the model performance.

To examine the impact of urban planning strategies on net carbon emissions, the model is run for a two-year period in Helsinki using measured meteorological data as forcing. The studied area (6 x 9 km2) is modelled using 250 x 250 m2 grids with the distinct model parameters. The plan area fractions of the surface cover types (buildings, pavements, evergreen and deciduous trees, grass and water), and building and tree heights are obtained from scanning lidar (2 m horizontal resolution). Mean traffic rates, traffic emission factors and population densities within each grid are obtained from Helsinki City Planning Department. In the base-run, true surface cover and anthropogenic activities of each grid are used. These are compared to runs with scenarios with different vegetation amounts and anthropogenic activities.

In Helsinki, the model produces the diurnal pattern of CO_2 exchange well and can simulate differences between surface covers types. For an area with negligible anthropogenic emissions, the model reproduces vegetation uptake and respiration well. In the next steps, SUEWS will be evaluated at the other cities and to examine what are the optimal urban planning solutions to reduce the CO_2 emissions to the atmosphere in Helsinki.