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Evaluation of a statistical-dynamical downscaling methodology for the urban heat island, building energy consumption and human thermal comfort

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It is well known that the urban climate differs from the rural climate, the urban heat island (UHI) being the most widely described urban climate phenomenon. The UHI interacts with human thermal comfort and building energy consumption. During the cold season, the presence of an UHI can be beneficial to human thermal comfort and reduce the heating energy demand whereas during the warm season the UHI can exacerbate heat stress and increase the energy demand for air conditioning. Mesoscale atmospheric models coupled with Urban Canopy Parametrisations (UCPs) are a suitable tool to quantify the urban heat island, building energy consumption and human thermal comfort in the urban environment (e.g. in a street canyon) at horizontal resolutions in the order of 100x100 m^2 to 1x1 km^2. They can be used to quantify the urban climate for the present climate and urban morphology as well as for the quantification of the modification of urban climate due to regional climate change and urban development (urban morphology, building architecture, human behaviour related to building energy consumption).

Simulations of urban climate using mesoscale models can be made for idealised meteorological conditions like a sunny summer day. However, more complex approaches are required to represent the full complexity of regional climate for the urban agglomeration of interest. The simplest solution would be to apply mesoscale models in climate mode (e.g. for a 30-year-period) and investigate the statistics of the urban heat island or other parameters for this period. However, this approach consumes a lot of computation time and it is not clear whether a full 30-year time series is really required to derive the desired information on the small-scale processes that shall be investigated. A promising approach is to use a so-called statistical-dynamical downscaling. It consists of selecting typical meteorological situations with relevance to the small-scale process of investigation (e.g. the UHI) and to perform short-term simulations for these situations. The results are then statistically recombined in order to obtain an information on the climatological distribution of the parameter of investigation. The statistical-dynamical downscaling encompasses various uncertainties like the selection of the meteorological situations, the number of situations to simulate and their representativeness. Such a method therefore needs to be critically evaluated.

In this contribution, we evaluate a statistical-dynamical downscaling for the urban heat island, building energy consumption and human thermal comfort. We perform long-term simulations with the mesoscale atmospheric model MésoNH coupled to the Urban Canopy Parametrisation (TEB) of one (two) years for the French urban agglomerations of Toulouse (Dijon). For these agglomerations, observations of the near surface air temperature and relative humidity with a dense station network are available, which allows to evaluate the simulated urban heat island. For Toulouse, the building energy consumption simulated by the building energy model in TEB is evaluated against an inventory of energy consumption. The long-term coupled MésoNH-TEB simulations serve as a reference to evaluate the statistical-dynamical downscaling methodology. We use a weather type classification to select meteorological situations discriminating the intensity (e.g. dry days with clear sky vs. cloudy days) and the spatial pattern of the UHI (e.g. due to different wind directions). By comparing the UHI patterns obtained for the cluster centroids against the UHI pattern obtained via the long-term simulations, we investigate to which degree the spatial distribution of the UHI can be represented by simulating the cluster centroids only.

For the building energy consumption and the human thermal comfort, long-term simulations are required in order to determine annual values of energy consumption or the frequency of situations with heat and cold stress in different seasons. For this reason, we perform simulations with TEB in Offline mode forced by reanalysis data. In order to consider the urban heat island at roof-level, we add the UHI pattern per weather type to the coarse reanalysis data. We use the long-term coupled MésoNH-TEB simulations to evaluate the statistics of building energy consumption and human thermal comfort determined via this Offline approach.