Modelling reduction of the Urban Heat Island effect by improving radiative properties of buildings and districts

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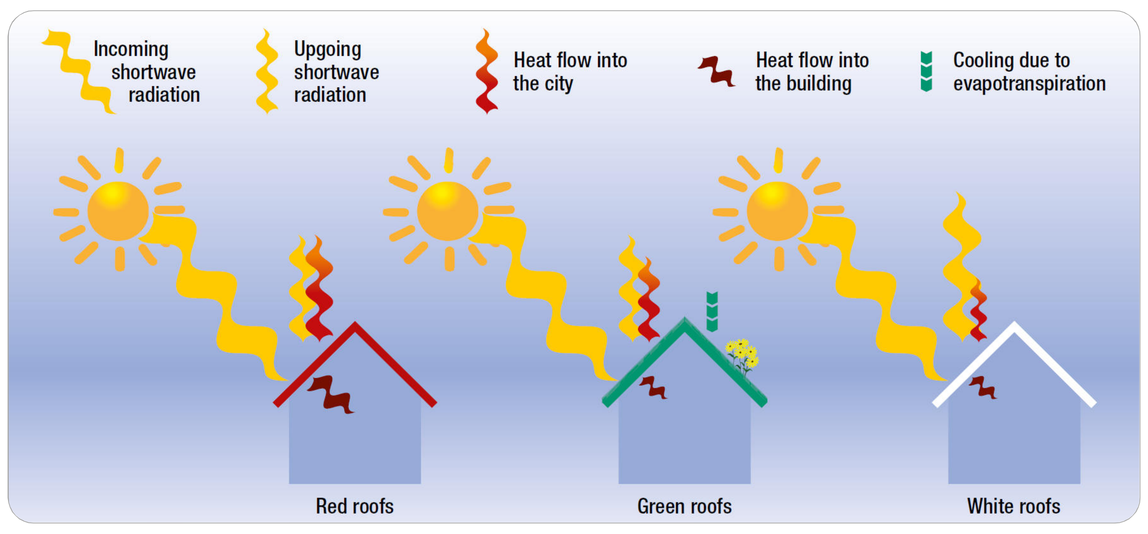
General

The increased intensity and/or frequency of heat waves due to a changing climate could have far reaching implications. The phenomenon of Urban Heat Islands (UHIs) observed in cities is expected to strengthen and will further contribute to heat stress, creating an increased need for energy for cooling and ventilation as well as lowering human comfort.

The KELVIN project studies the effects of modifying the reflective properties of buildings and urban areas to reduce the UHI-effect. The improvement of the reflection properties of roofs and other surfaces is one possible way to increase the energy efficiency in urban areas and at the same time adapt to climate change by addressing the problem of the UHIs. Within the project, low-cost adaptation measures to reduce heat stress are investigated. These measures are constrained, in historical city centres, because the colouring of tile roofs should not be changed significantly, and the appearance should remain as unchanged as possible.

The project examines the potential of a climate adaptation measure to reduce the UHI-effect through changes in properties of the urban surfaces (roof albedo, green roofs etc.) and related emission-reduction through decreased cooling demand. It uses the city of Vienna as an example. The input parameters required for climate modelling, such as surface albedo, are determined based on the satellite image time series for Vienna from 2000 to 2014. Urban climate model simulations are conducted using high-resolution topography and land use data for Vienna. Potential changes in local climate in the urban environment resulting from the changes in surface albedo are examined and the possibility of reducing the heat load on a city scale is quantified.

Results of modelling the city climate serve as a basis for calculating the potential reduction in electricity demand for cooling (including CO_2-equivalent savings) in metropolitan landscapes. In addition, the potential change in radiative forcing induced by changing the surface albedo is estimated.



The effects of changing the albedo of urban roofs and the potential to reduce the phenomenon of urban heat islands (UHIs):

Red roofs have low albedo and absorb more solar radiation which is converted into long wave radiation (heat).

Green roofs have an albedo similar to the red ones, but have in addition benefits of cooling due to evapotranspiration. As a result, less heat flows into the city.

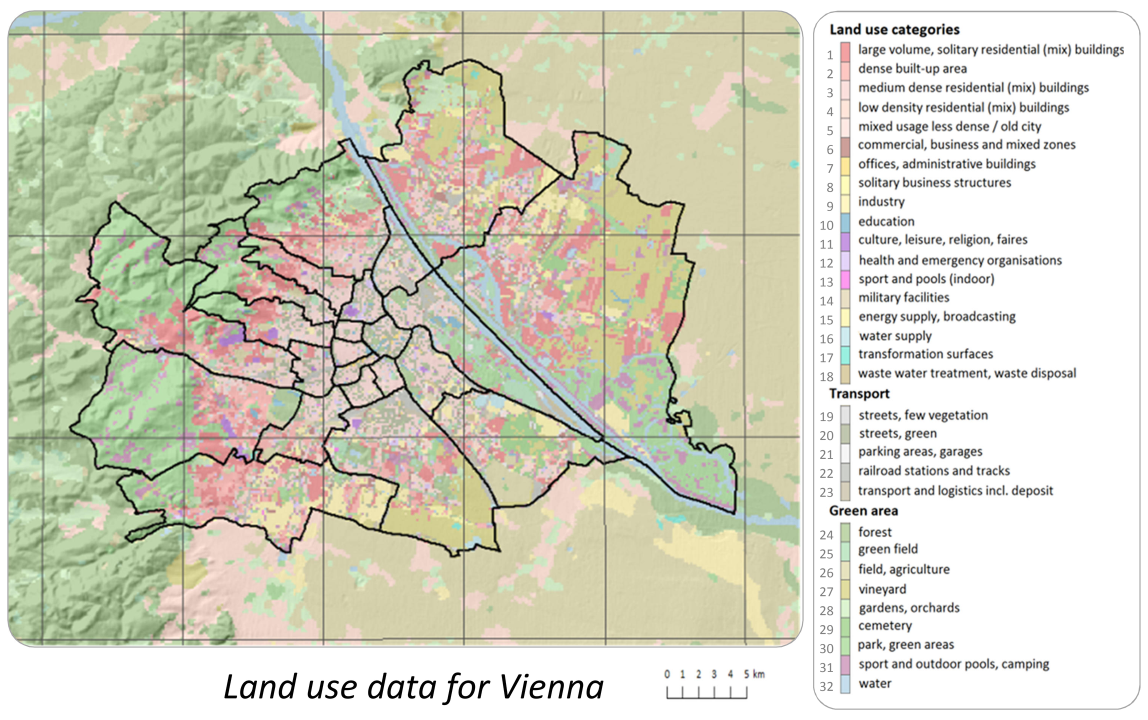
White roofs have high albedo and reflect more solar radiation in the short wave band and therefore could lower UHI effects.

Data & Method

The modeling approach applies the method developed at the German Weather Service (DWD) which combines dynamical modeling of the atmospheric conditions in an urban environment with the urban climate model MUKLIMO_3 (Sievers and Zdunkowski, 1986; Sievers, 1990; 1995) and the so-called ''cuboid method'' which allows the calculation of climatic indices based on the meteorological parameters from a reference station outside of the city (Früh et al., 2010).

The model domain covers an area of 31 km • 24 km with an equidistant grid of 100 m horizontal resolution. In vertical direction, the model has 39 levels with resolutions varying from 10m to 100m with denser grid spacing near the surface reaching a vertical height of about 1000 m. The initial and boundary conditions are given by a time-varying 1D profile of atmospheric conditions representative for a station outside of the city. The model simulates the daily cycle of temperature, wind, relative humidity and energy fluxes in an urban area for potential situations where a summer day (T_{max}≥25°C) in the urban center could occur. Eight idealized simulations with duration of 24 h for two prevailing wind directions (NW and SE in case of Vienna) are calculated. The simulations represent the cuboid corners.

Calculation of mean annual number of summer days for 30-year climatic periods is based on maximum temperature fields derived by a tri-linear interpolation between the eight single-day simulations using daily meteorological data from a reference station as input. The relationship of summer days and the parameter set (T, rh, v) was tested on the data collected from five urban observational stations in Vienna. The range for the cuboid axes was defined as: T_{cmin} = 15°C, T_{cmax} = 25°C; rh_{cmin} = 42%, rh_{cmax} = 80% and v_{cmin} = 0.7m/s, v_{cmax} = 4m/s.

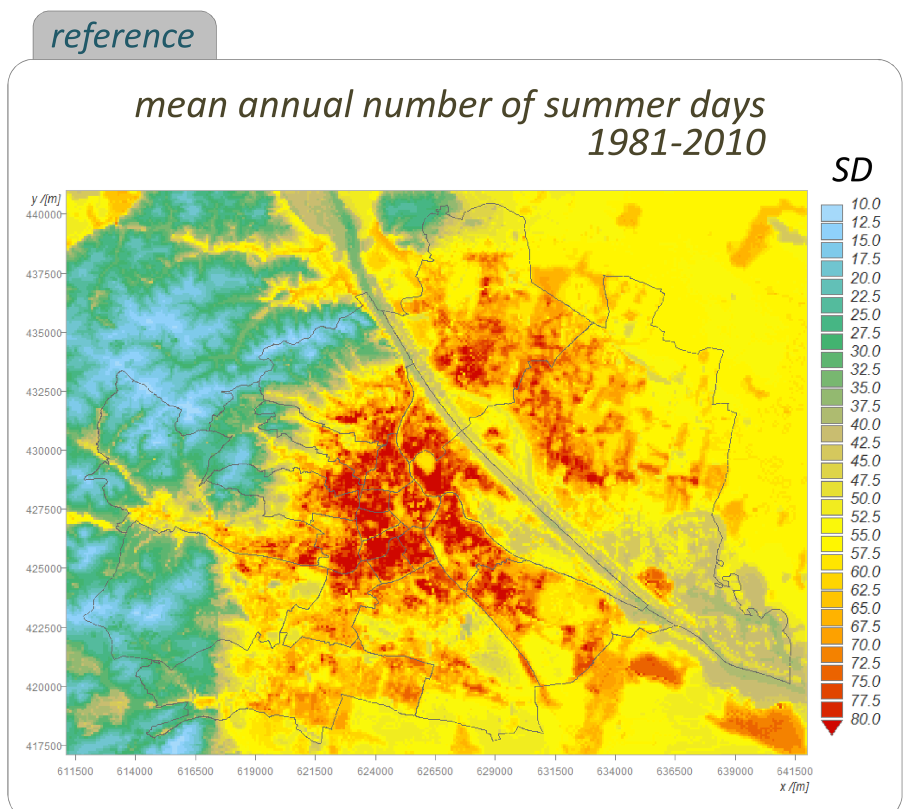


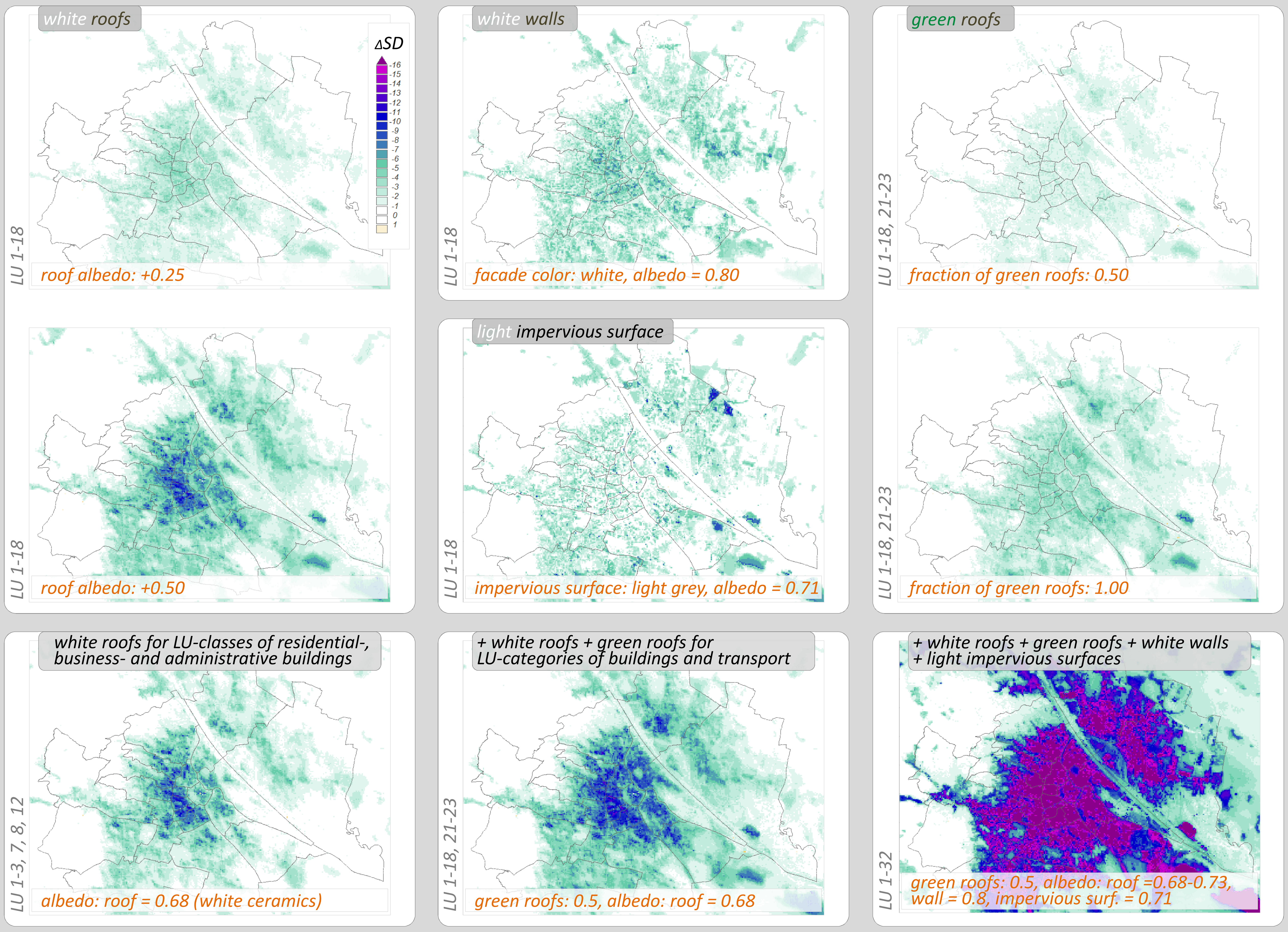
Land use data for Vienna

Results

Within several experiment simulations, the change of different surface properties is being investigated, and their impact on the mean annual number of summer days for the climate-period 1981-2010 is being calculated as an indicator.

The pictures on the right show the change in number of summer days for a selection of experiments within which modifications applied on land use *(LU)* classes of the buildings (LU 1-18) - and transport (LU 21-23) category.





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Acknowledgements

The Authors would like to thank their project partners at the Joanneum for their help and support, the DWD and the Vienna city administration (MA18) for providing the topography and land use data. Further we wish to acknowledge the Federal Ministry for Transport, Innovation and Technology (BMVIT) and the Austrian Research Promotion Agency (FFG) for funding this project.

STADT der Zukunft
Project number: FFG-ID 845136

bmvit
Federal Ministry for Transport, Innovation and Technology

References

Früh B, Becker P, Deutschländer T, Hessel J-D, Kossmann M, Mieskes I, Namyslo J, Roos M, Sievers U, Steigerwald T, Turau H, Wienert U (2010): Estimation of Climate-Change Impacts on the Urban Heat Load Using an Urban Climate Model and Regional Climate Projections. J. Appl. Meteor. Climatol. 50: 167–184. doi: 10.1175/2010JAMC2377.1

Sievers U (1990): Dreidimensionale Simulationen in Stadtgebieten. Umwelt-meteorologie, Schriftenreihe Band 15: Sitzung des Hauptausschusses II am 7. und 8. Juni in Lahnstein. Kommission Reinhaltung der Luft im VDI und DIN, Düsseldorf. S. 92-105.

Sievers U (1995): Verallgemeinerung der Stromfunktionsmethode auf drei Dimensionen. Meteorol. Zeitschrift 4: 3-15.

Sievers U, Zdunkowski W (1986): A microscale urban climate model. Beitr. Phys. Atmosph. 59: 13-40.

Žuvela-Aloise M, Koch R, Nemec J, Früh B (2012): Dynamical modelling of urban climate of Vienna. ICUC8 – 8th International Conference on Urban Climates, Dublin

Žuvela-Aloise M (2013) FOCUS-I: Adaption and mitigation of the climate change impact on urban heat stress based on model runs derived with an urban climate model ZAMG, ACRP final report

Žuvela-Aloise M, Koch R, Neureiter A, Böhm R, Buchholz S (2014): Reconstructing urban climate of Vienna based on historical maps dating to early instrumental period. Urban Climate 10 (2014): 490-508