Using Urban Climate Modelling to Support Climate Change Adaptation in Small- to Medium-sized Cities, Austria

ADAPT-UHI, 08.04.2019

Sandro M. Oswald, Brigitta Hollosi, Maja Zuvela-Aloise, Linda See, Stefan Guggenberger, Wolfgang Hafner, Gundula Prokop, Wolfgang Schieder und Alexander Storch

klima+ energie fonds
ACRP10 ADAPT-UHI
Project GZ B769957

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IIASA www.iiasa.ac.at
umweltbundesamt
PERSPEKTIVEN FÜR UMWELT & GESELLSCHAFT
iPaK International Project Management Agency Klagenfurt on Lake Wörthersee GmbH
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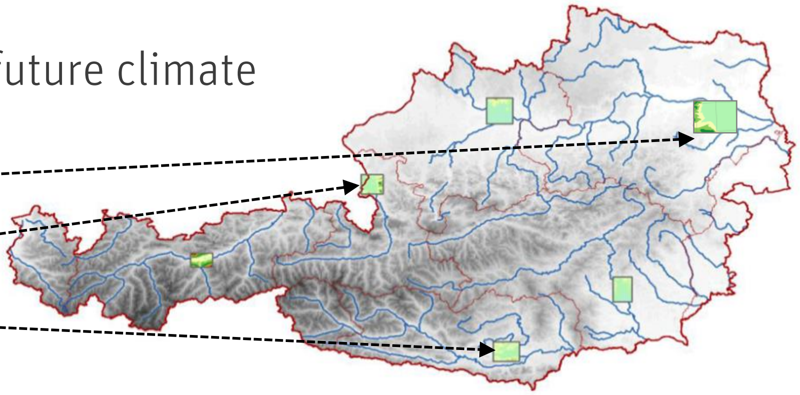
Urban climate modelling within the project ADAPT-UHI

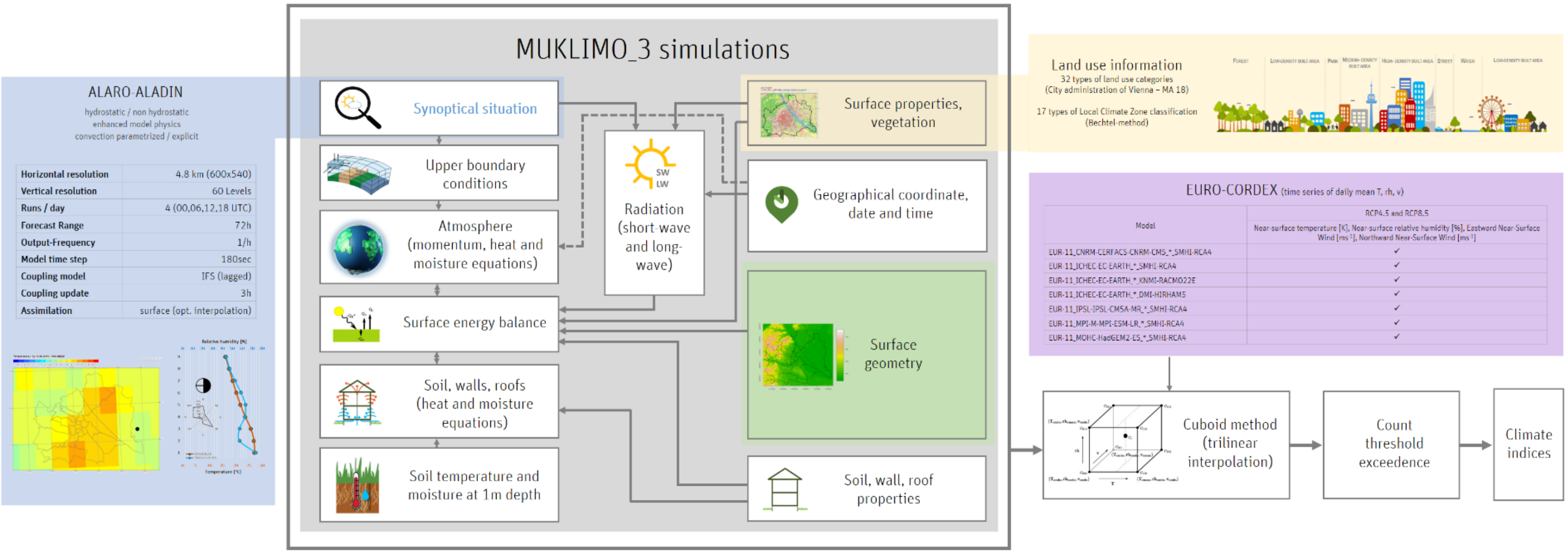


- Identifying „Hot spots“ with past and future climate simulations of each city
  - **Mödling** (21 000 inh.),
  - **Salzburg** (152 000 inh.)
  - **Klagenfurt** (100 000 inh.)
- Modelling local climate with local building typology and vegetation
  - Using actual landuse- and landcover maps (**URBAN ATLAS**, **Land Information System Austria** and **City government**) as input for the microscale model **MUKLIMO_3** (DWD) with varying grid size cell (from **20** to **100 m**)
- Climate adaptations: simulation of changes in **energy balance** at the surface
  - Evaluation of the effectivity of each adaptation measure

Urban climate model MUKLIMO_3

3D **M**icroscale **U**rban **KLI**ma**MO**dell *(Sievers and Zdunkowski, 1986; Sievers, 1990; Sievers, 1995)*

- Resolution: horizontal 20-200 m, vertical 10 – 100 m
- Input: Evaluation model, meteorological and landuse data
- Output: Diurnal cycle of wind, air temperature and relative humidity, short und longwave radiation
- Using cuboid method to derive climate indices *(Früh et al., 2010)*



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Landuse- and landcover data set

shown for Klagenfurt

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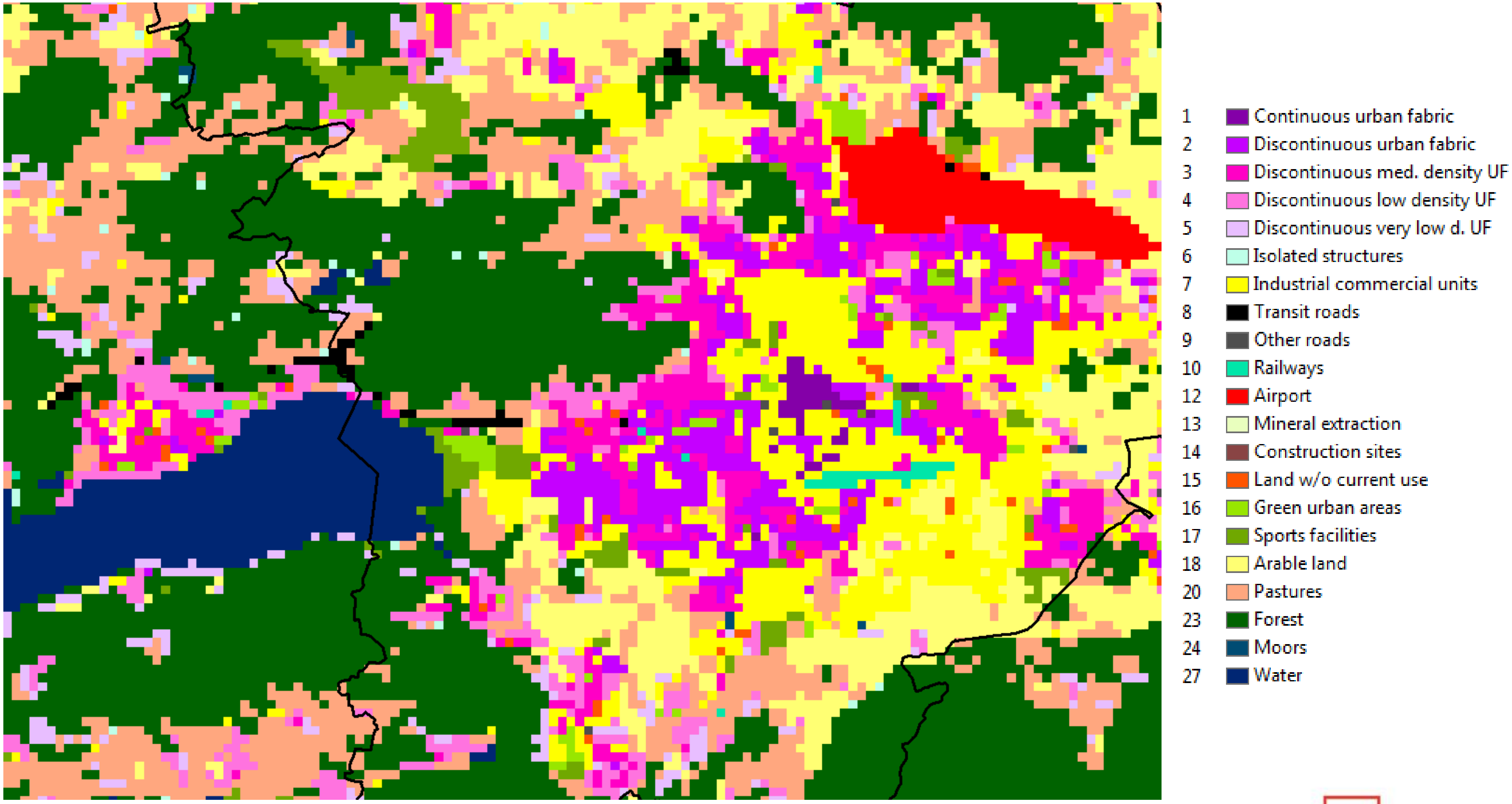
Landuse classification - Klagenfurt

- Initial landuse classification of URBAN ATLAS (100 m spatial resolution)

09.04.2019
Slide 5



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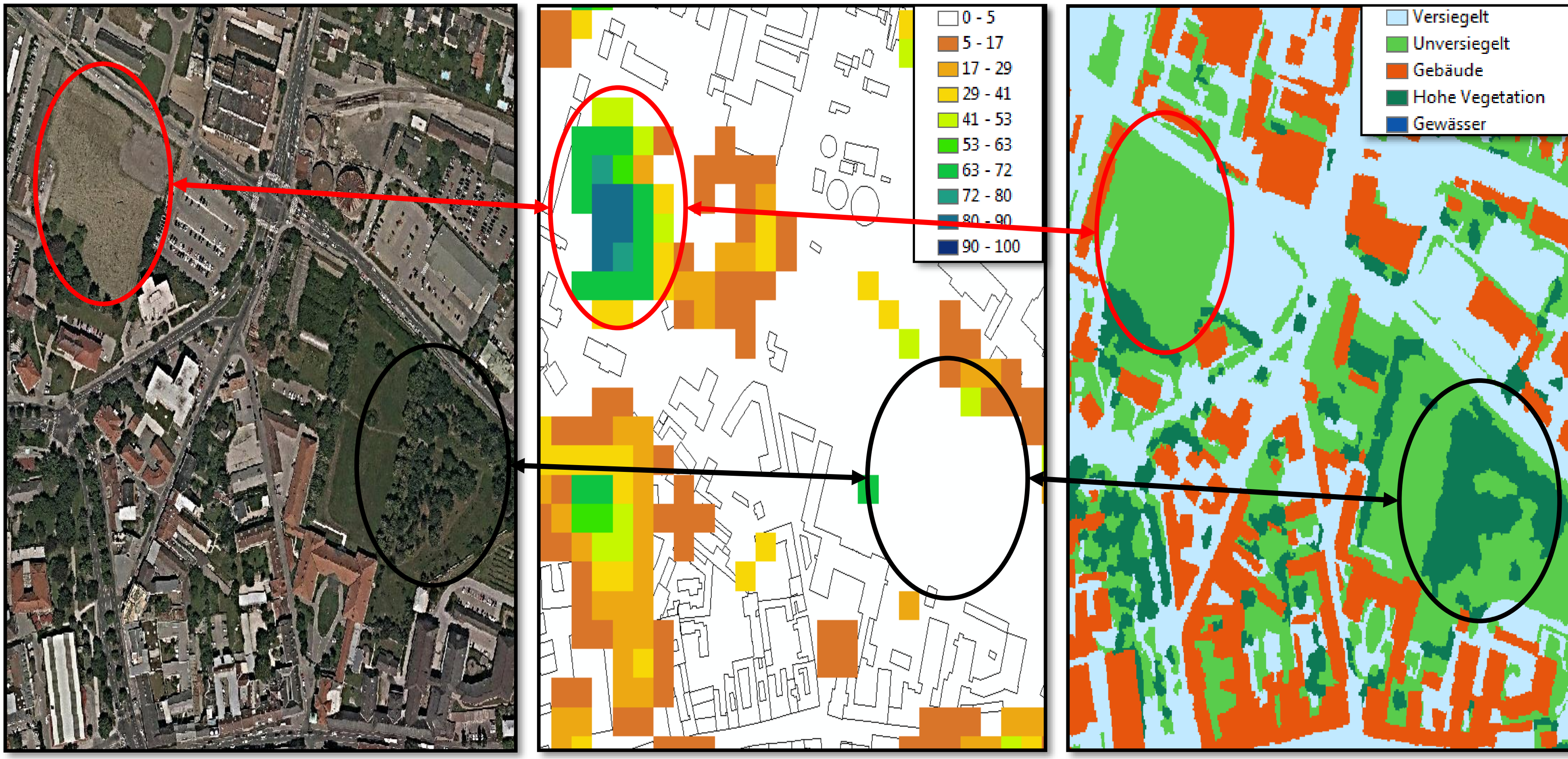
Error source in landuse/landcover - Klagenfurt

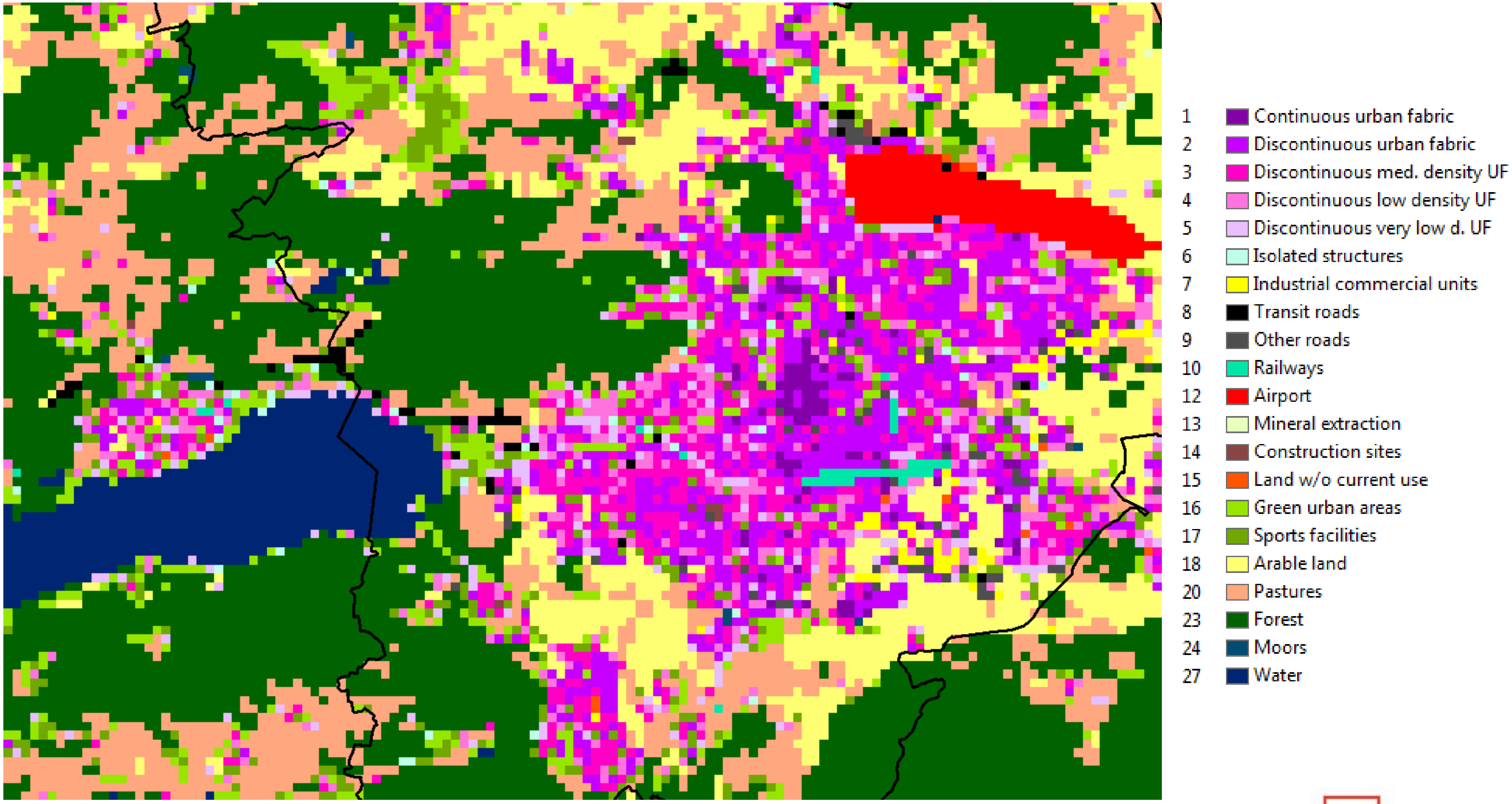
- Reducing errors from **URBAN ATLAS** and **city data sets** using landcover data of **LISA**

Orthophoto – Part of Klagenfurt | Tree cover density [%] | LISA (2016)



Landuse classification - Klagenfurt

- New landuse classification with LISA data set (Land Information System Austria)



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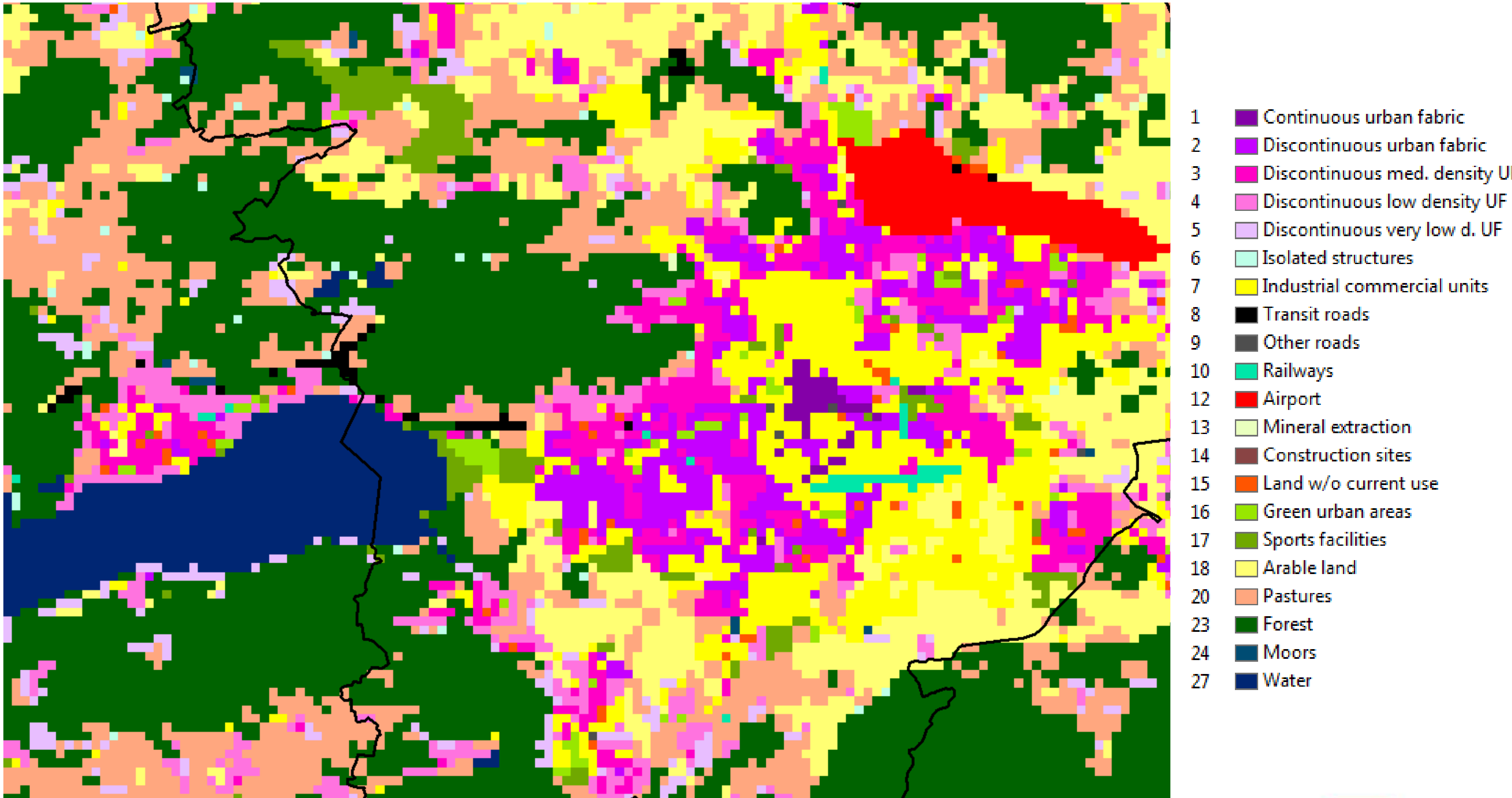
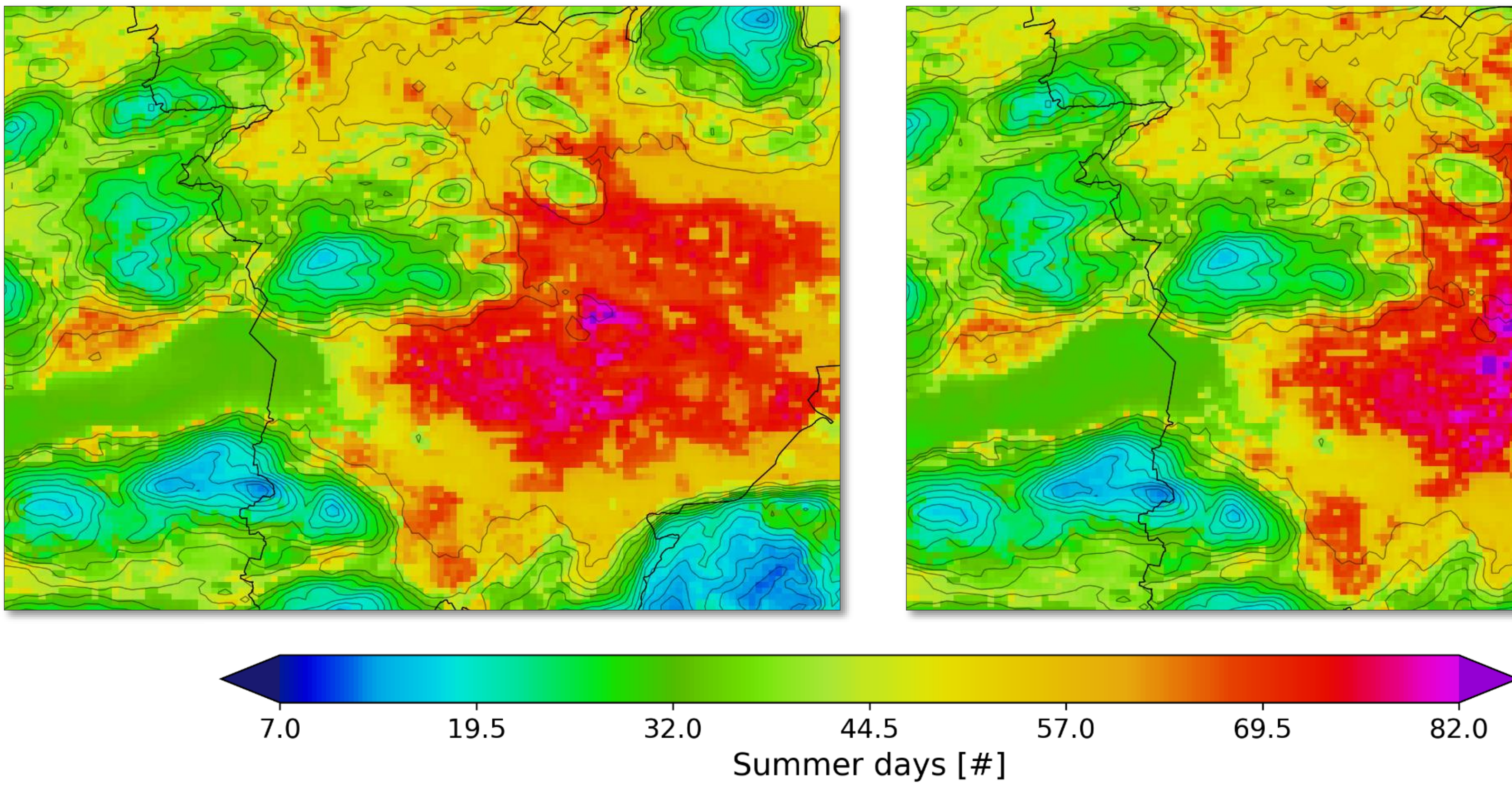
Landuse classification - Klagenfurt

- Initial landuse classification of URBAN ATLAS



Average number of summer days/year (1981-2010)

With **initial** landuse class. (URBAN ATLAS) | With **new, reclassified** landuse class.



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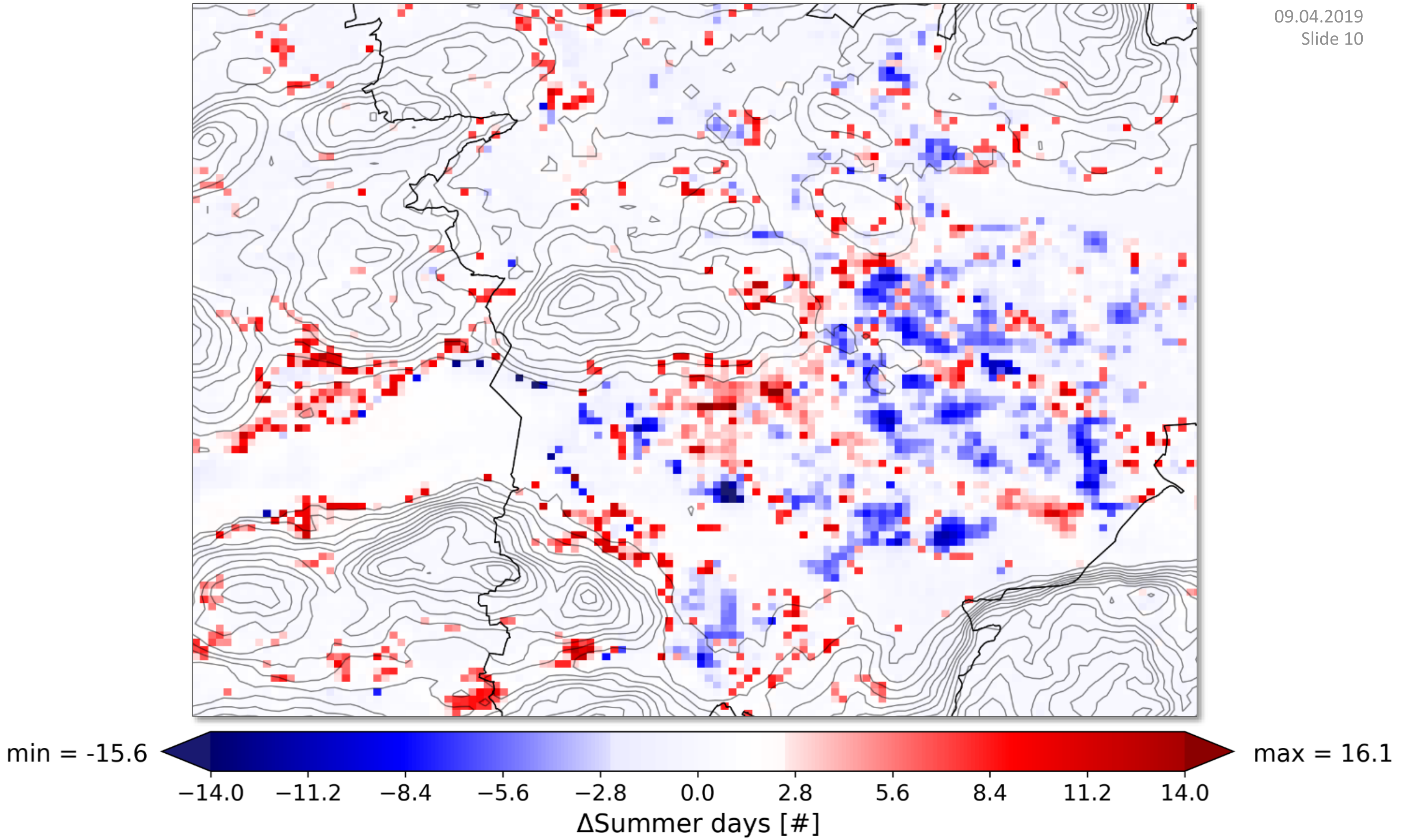
Difference in summer days/year (1981-2010)



Reference simulations

shown for Klagenfurt, Salzburg and Mödling

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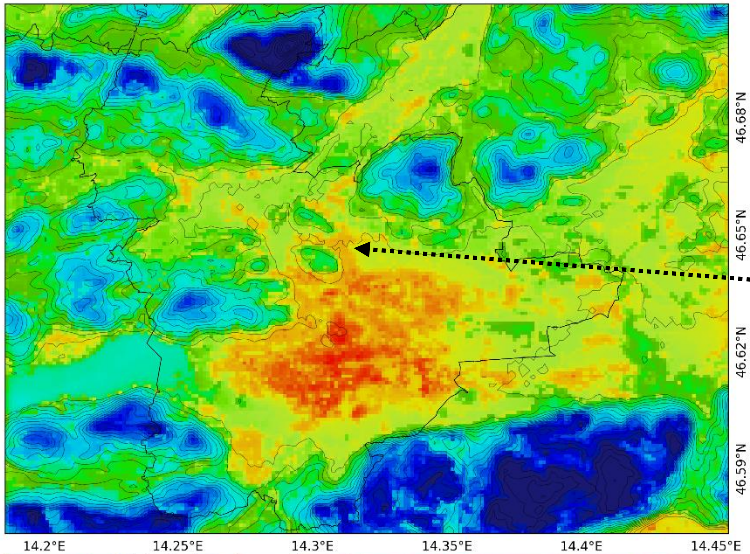
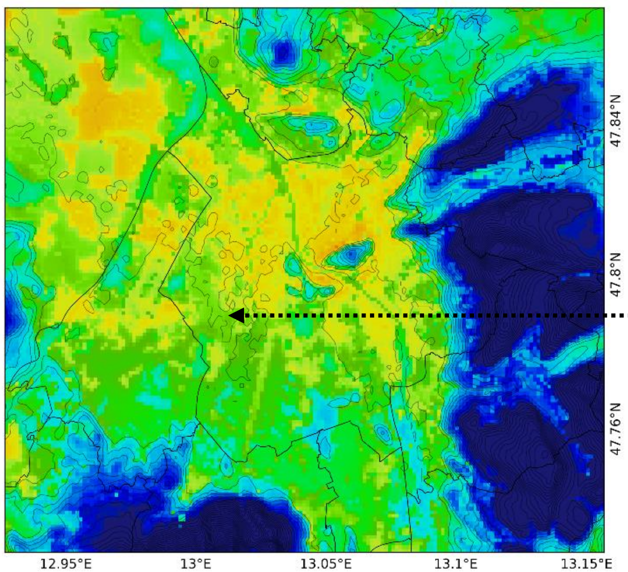
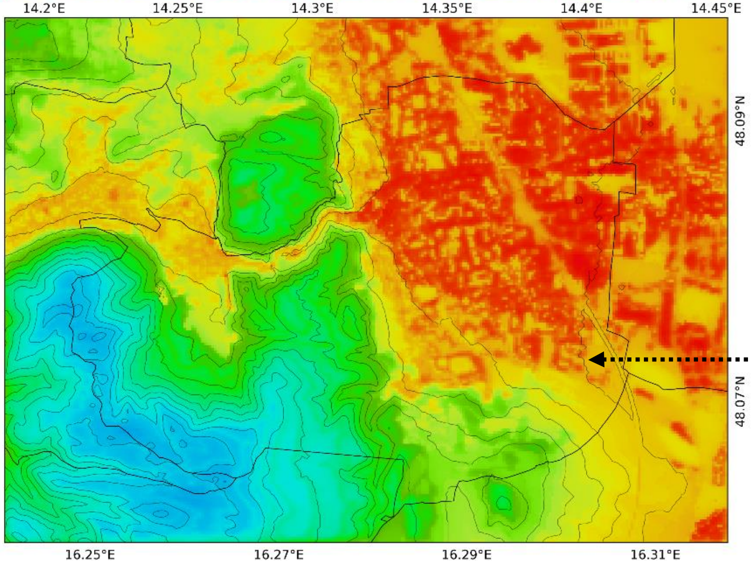
Reference simulations for Klagenfurt, Salzburg and Mödling

Average number of summer days per year (1971–2000)

Station	Meas.	Model	Bias
Airport Salzburg	**50.8**	**47.6**	**-6%**
Airport Klagenfurt	**54.6**	**52.5**	**-4%**
Gumpoldskirchen	**56.0**	**57.6**	**+3%**



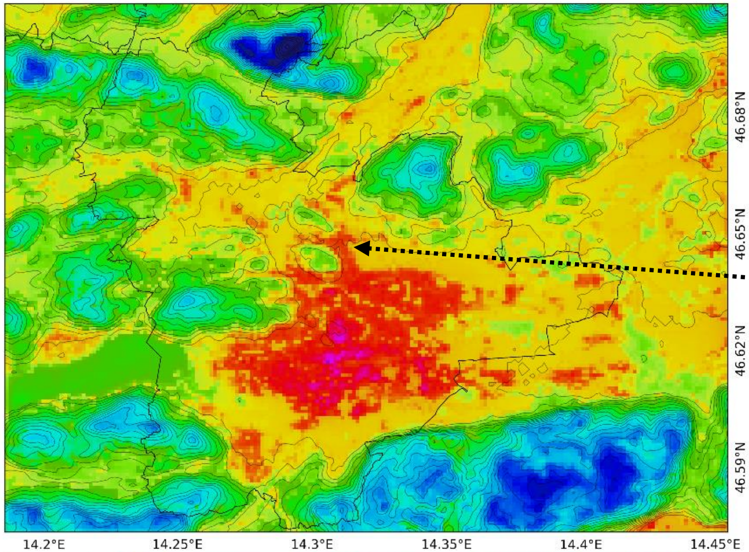


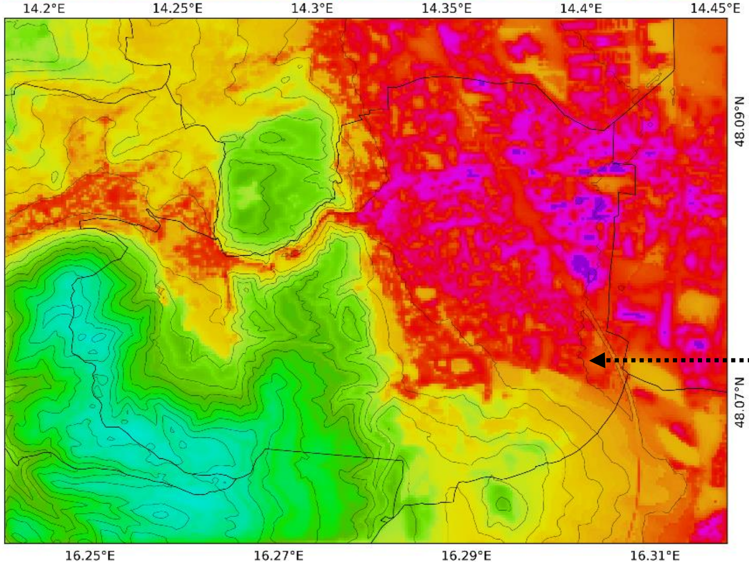


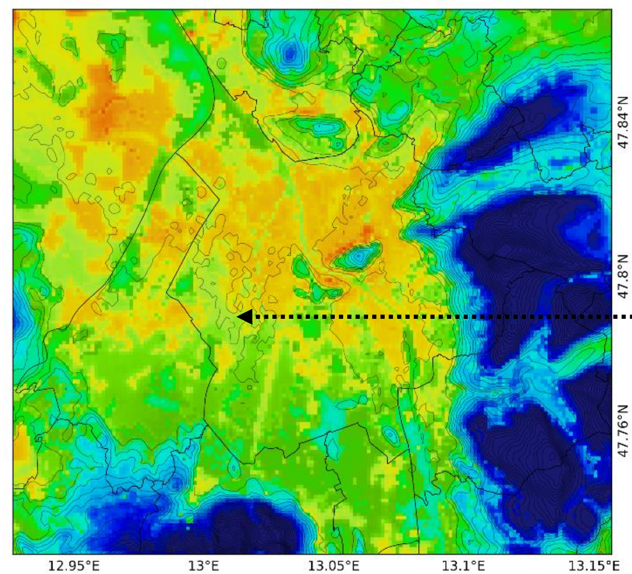
Reference simulations for Klagenfurt, Salzburg and Mödling

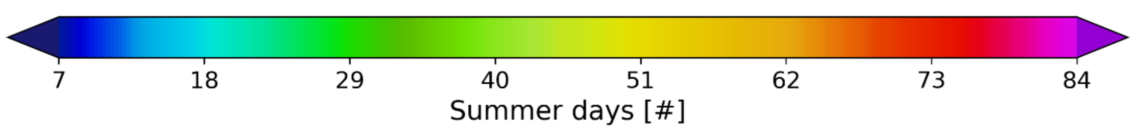
Average number of summer days per year (1981–2010)

Station	Meas.	Model	Bias
Airport Salzburg	**54.8**	**53.7**	**-2%** (-6%)
Airport Klagenfurt	**62.8**	**62.4**	**-1%** (-4%)
Gumpoldskirchen	**62.1**	**66.8**	**+7%** (+3%)









Future scenarios (RCPs)

shown for Klagenfurt, Salzburg and Mödling

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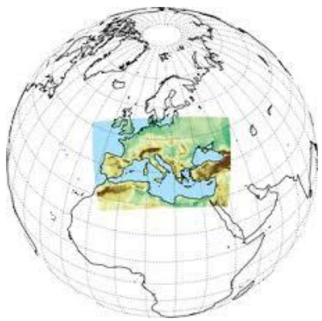
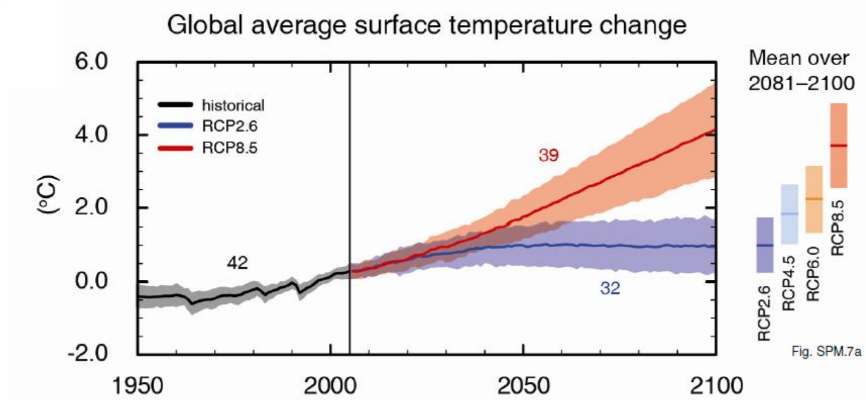
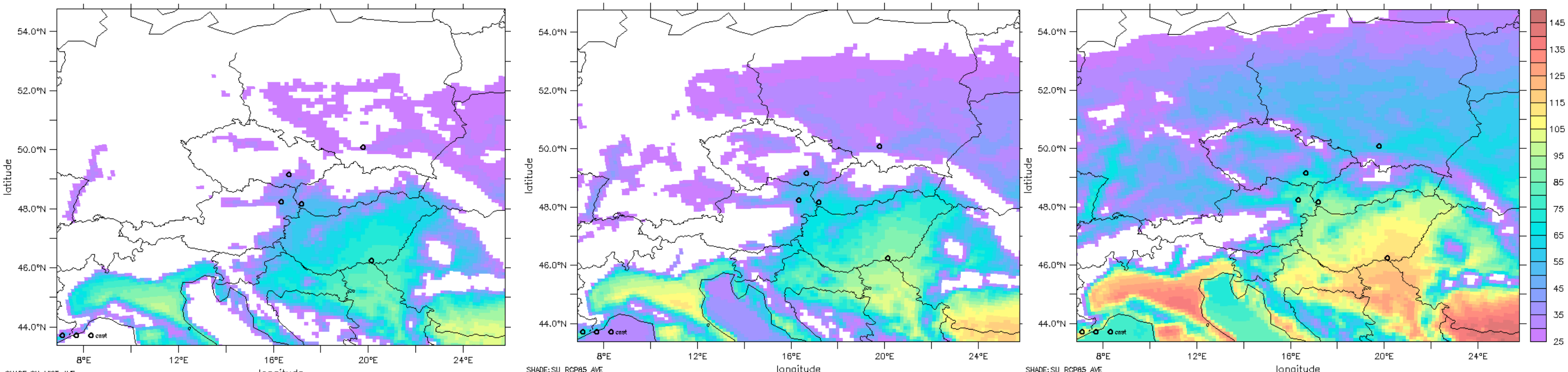
Climate projections with RCP 4.5 und 8.5

- EURO-CORDEX - Coordinated Downscaling Experiment - European Domain (EUR-11)
  - CNRM-CERFACS-CNRM-CM5
  - ICHEC-EC-EARTH
    - KNMI-RACMO22E
    - SMHI-RCA4
    - DMI-HIRHAM5
  - IPSL-CM5A-MR
  - MOHC-HadGEM2-ES
  - MPI-M-MPI-ESM-LR
  - NCC-NorESM1-M





1971-2000 | 2021-2050 | 2071-2100



Average number of summer days/year (Tmax ≥ 25 °C), ensemble average (RCP 8.5)

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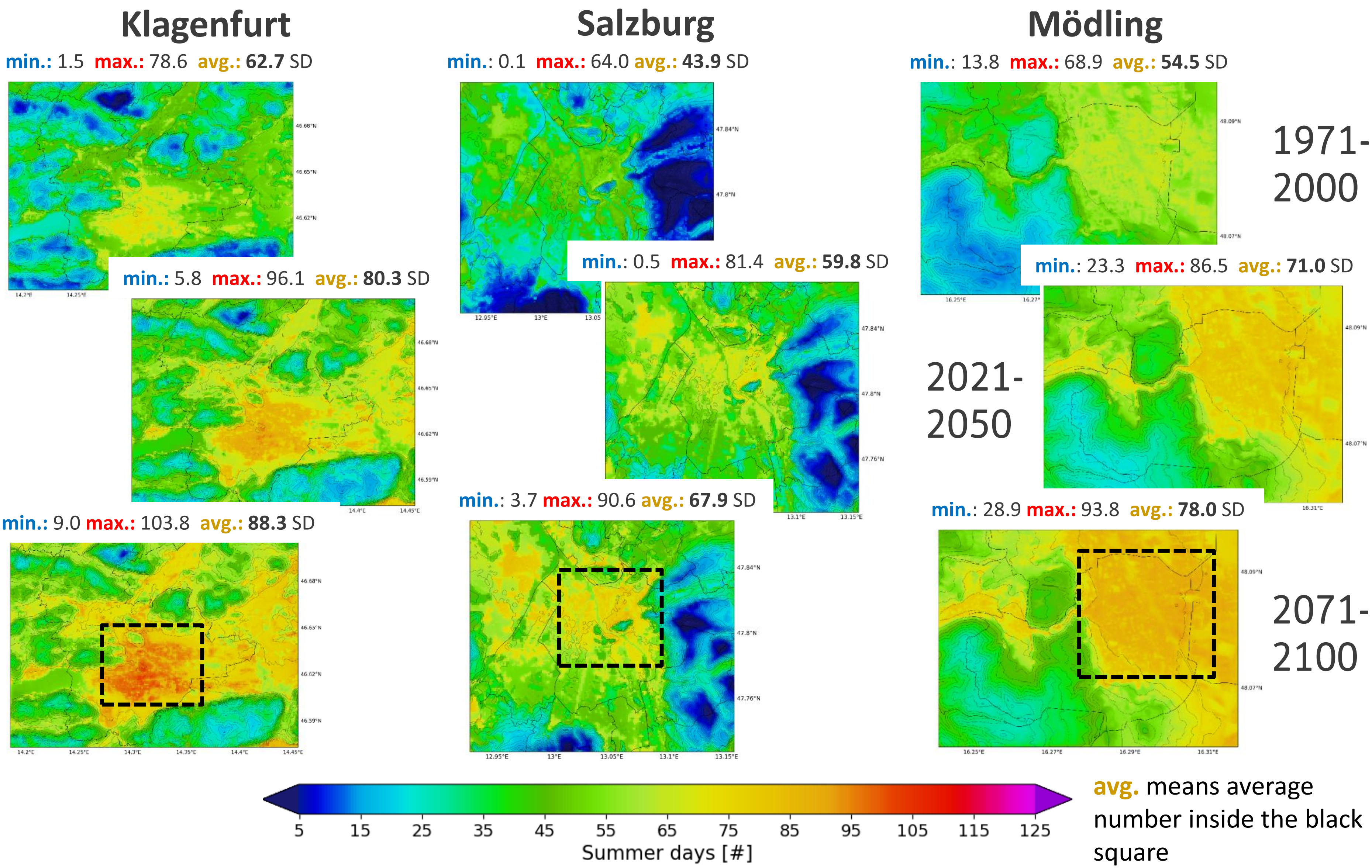
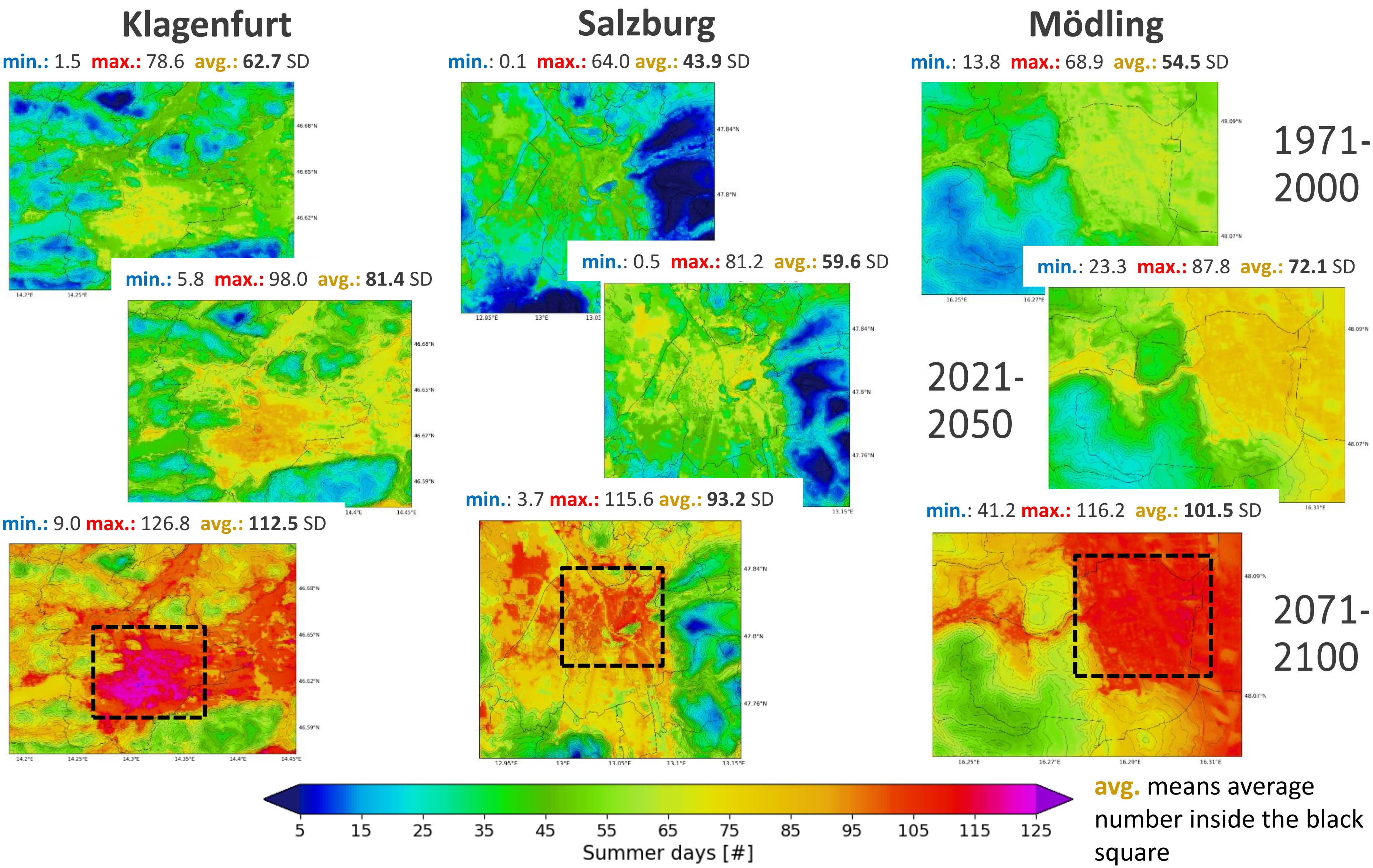
Future scenarios, IPCC RCP4.5



avg. means average number inside the black square

Future scenarios, IPCC RCP8.5



Climate adaptation measures

shown for Klagenfurt, Salzburg and Mödling

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Adaptations for „White City“ and „Green City“

- **Potentially realizable adaptation options** for all 3 cities
  - Albedo impervious areas — from 0.2 to 0.4 (LU-classes 1 bis 7, 13 bis 17)
  - Albedo of walls — from 0.3 to 0.5 (LU-classes 1 bis 7)
  - Albedo of roofs — from 0.2 to 0.5 (LU-classes 1 bis 7)
  - Impervious areas — -30% (LU-classes 1 bis 6)
  - Amount of green roofs — 50% (LU-classes 3, 4, 5 und 7)
  - Amount of trees — +50% (LU-classes 8 bis 10 und 15 bis 19)
  - Low vegetation increased — from 85% to 100% (LU-classes 1 bis 7)


archiexpo


NÖM


JAHN


Stuttgart, researchgate


greenroofsaustralasia

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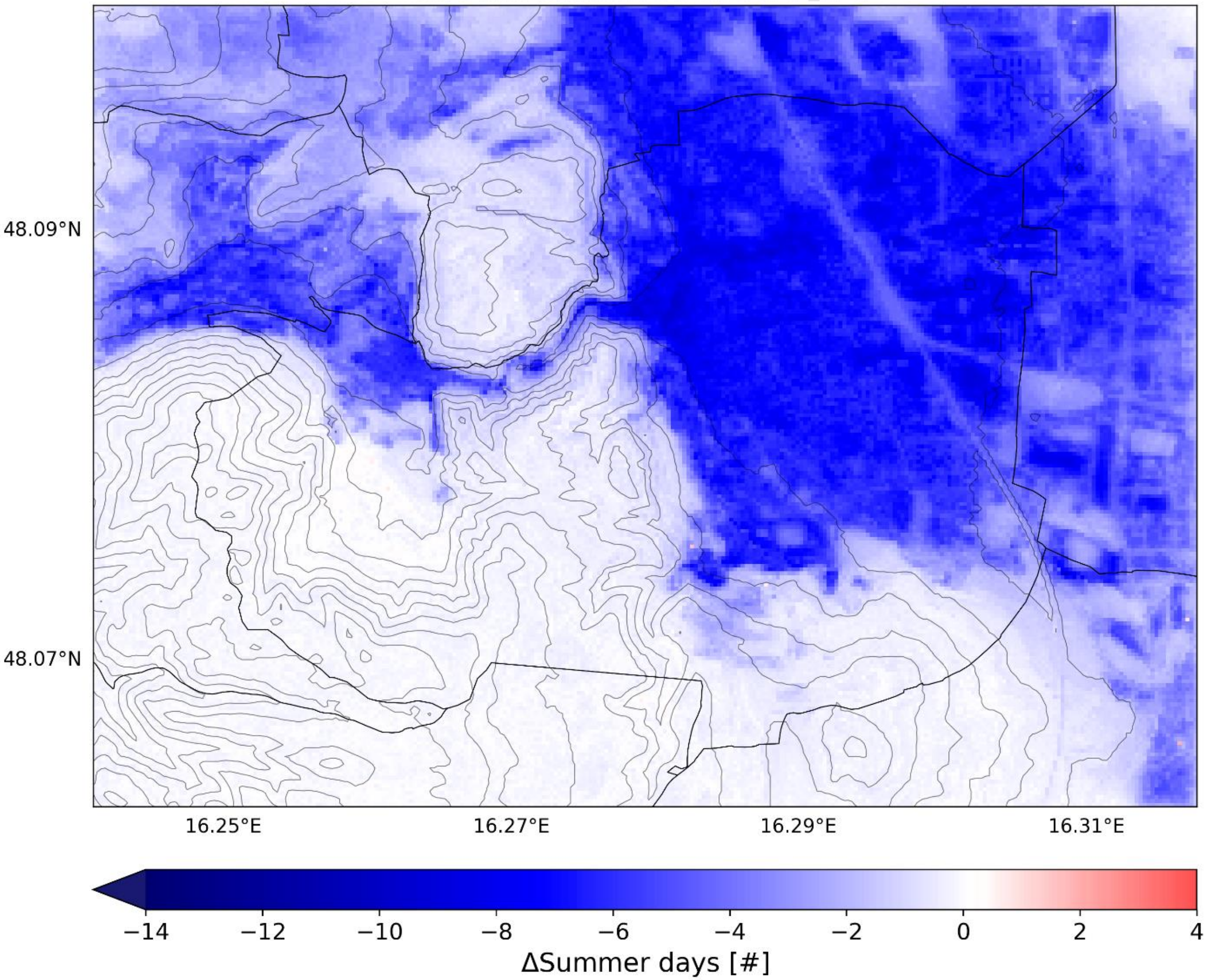
Climate adaptations for Mödling

Difference in average number of summer days per year (**1981-2010**)
through a combination of climate adaptation measures



	ΔSummer days			
Adaptation	**Avg.**	**%**	**Min.**	**%**
a_{roof} = 0.5	**-1.5**	**-2.1**	**-3.7**	**-4.4**
a_{wall} = 0.5	**-0.9**	**-1.3**	**-2.8**	**-3.3**
a_{street} = 0.4	**-0.8**	**-1.3**	**-3.6**	**-4.4**
Impervious area -30%	**-0.3**	**-0.4**	**-1.7**	**-2.7**
Green roofs 50%	**-0.5**	**-0.7**	**-1.8**	**-2.6**
Number of trees +50%	**-0.7**	**-1.0**	**-6.8**	**-11.0**
Low vegetation to 100%	**-0.5**	**-0.7**	**-1.9**	**-2.7**
Combination	**-5.0**	**-7.3**	**-9.9**	**-13.2**

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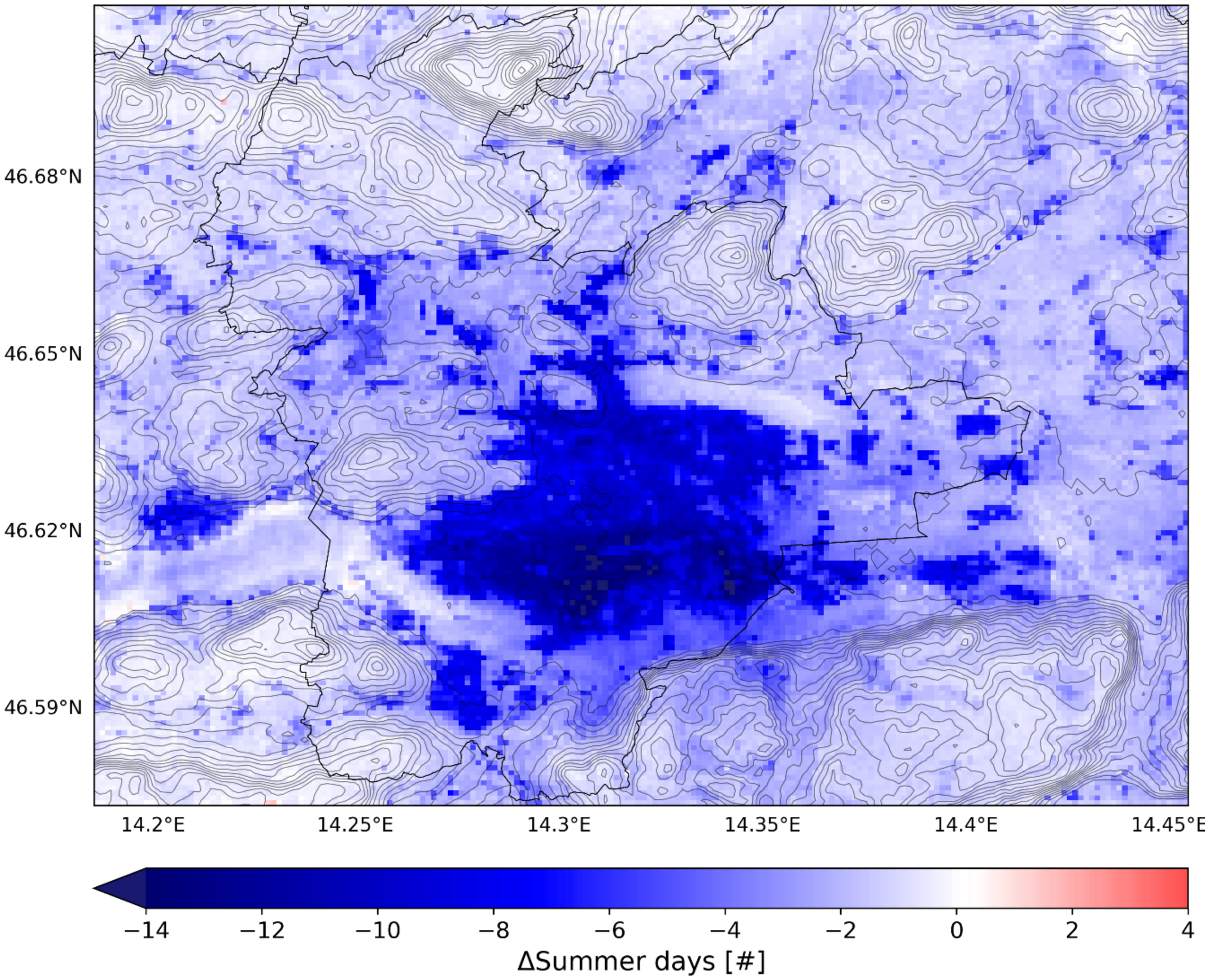
Climate adaptations for Klagenfurt

Difference in average number of summer days per year (**1981-2010**) through a combination of climate adaptation measures



	ΔSummer days			
Adaptation	Avg.	%	Min.	%
a_{roof} = 0.5	-2.7	-4.1	-6.4	-8.4
a_{wall} = 0.5	-0.9	-1.4	-3.3	-4.3
a_{street} = 0.4	-2.1	-3.2	-5.6	-7.3
Impervious area -30%	-0.7	-1.1	-2.0	-2.7
Green roofs 50%	-1.3	-1.9	-4.7	-6.5
Number of trees +50%	-0.5	-0.7	-3.5	-5.8 to -8.2
Low vegetation to 100%	-0.7	-1.0	-2.7	-4.9
Combination	-9.1	-13.6	-15.1	-18.5

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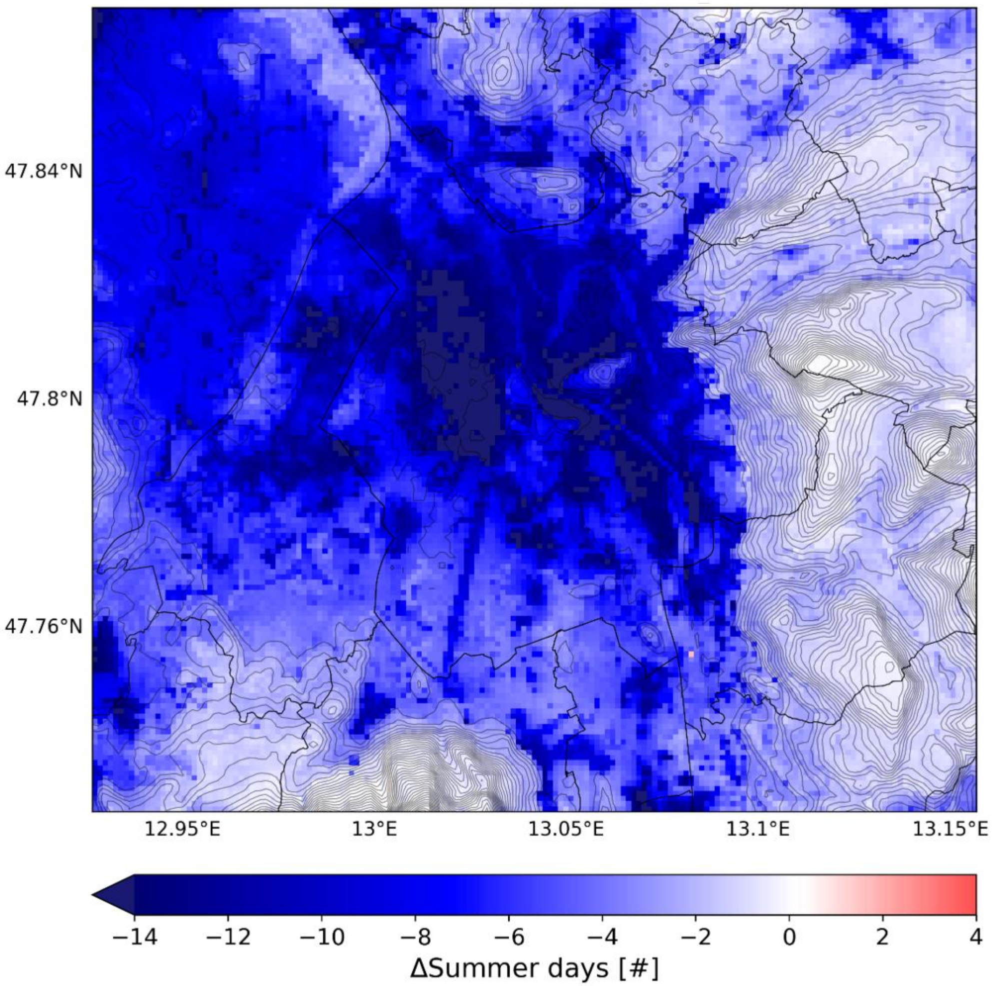
Climate adaptations for Salzburg

Difference in average number of summer days per year (**1981-2010**) through a combination of climate adaptation measures



	ΔSummer days			
Adaptation	**Avg.**	**%**	**Min.**	**%**
$\alpha_{roof} = 0.5$	**-4.2**	**-8.3**	**-9.8**	**-14.5**
$\alpha_{wall} = 0.5$	**-2.0**	**-4.0**	**-4.4**	**-12.9**
$\alpha_{street} = 0.4$	**-2.4**	**-4.8**	**-7.0**	**-13.2**
Impervious area -30%	**-1.4**	**-2.8**	**-4.4**	**-12.9**
Green roofs 50%	**-2.7**	**-5.3**	**-6.3**	**-13.1**
Number of trees +50%	**-1.6**	**-3.2**	**-7.0**	**-20.8**
Low vegetation to 100%	**-2.1**	**-4.1**	**-4.1**	**-6.0**
Combination	**-11.5**	**-22.8**	**-19.3**	**-28.5**

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Motivation for further activities in Klagenfurt

- Forest in soccer stadium (art installation in Klagenfurt)

Picture „The unabated gravity of nature" (1971), Max Peintner

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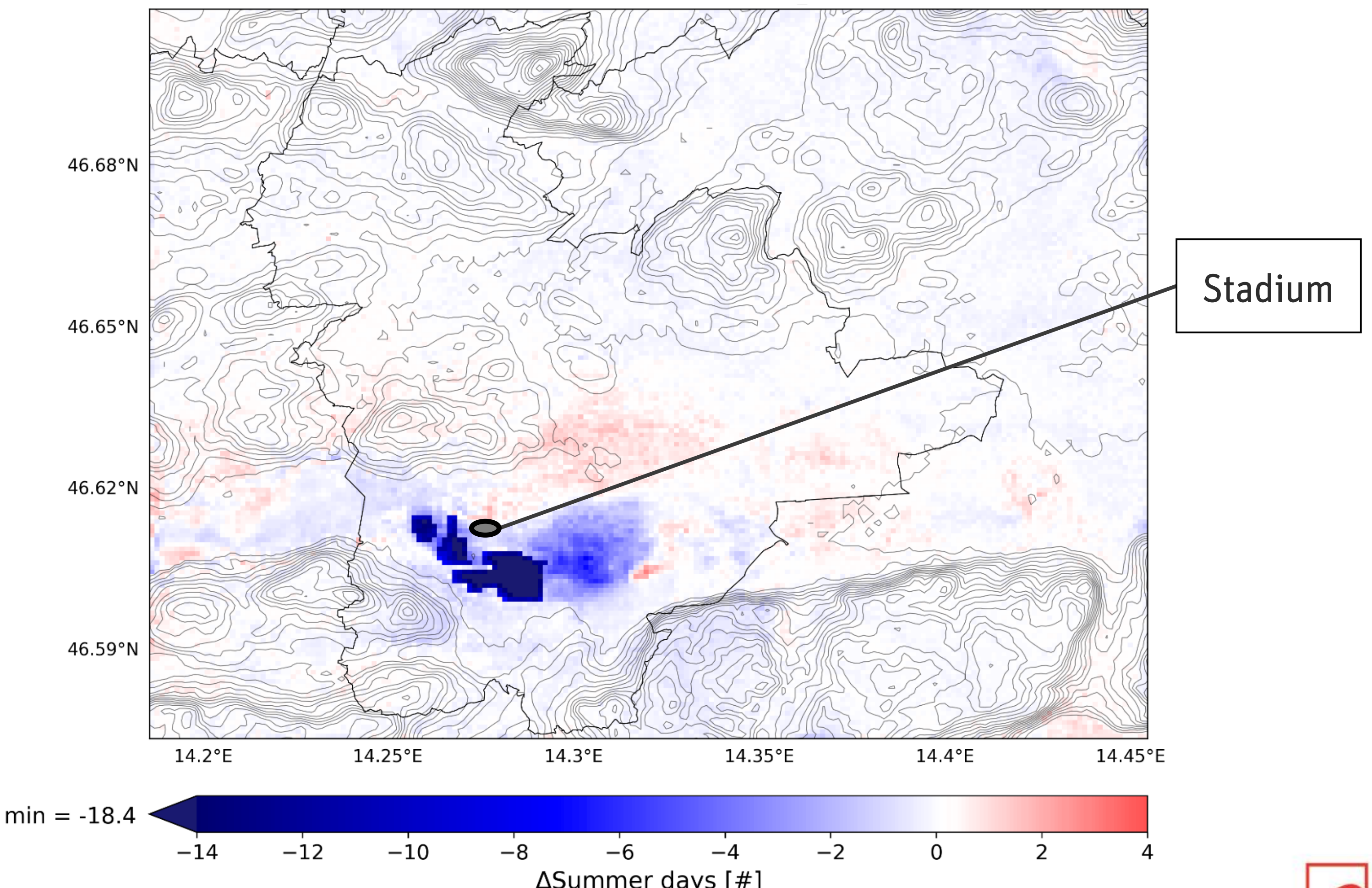
Afforestation in the south-west of Klagenfurt

Difference in average number of summer days per year (**1981-2010**) compared to reference



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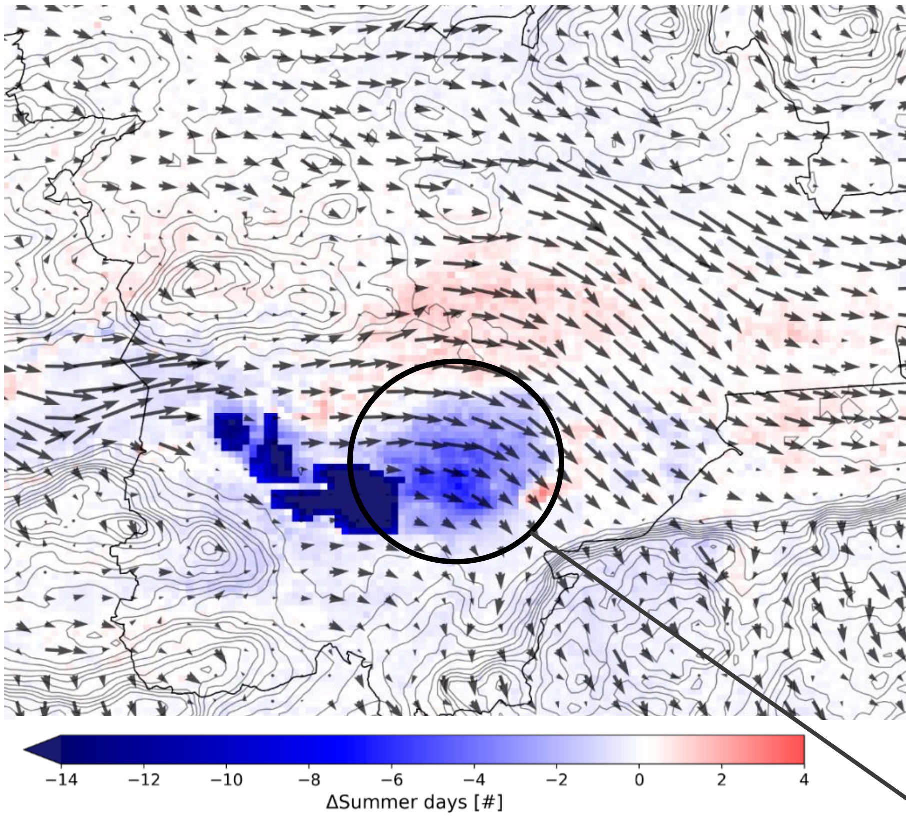
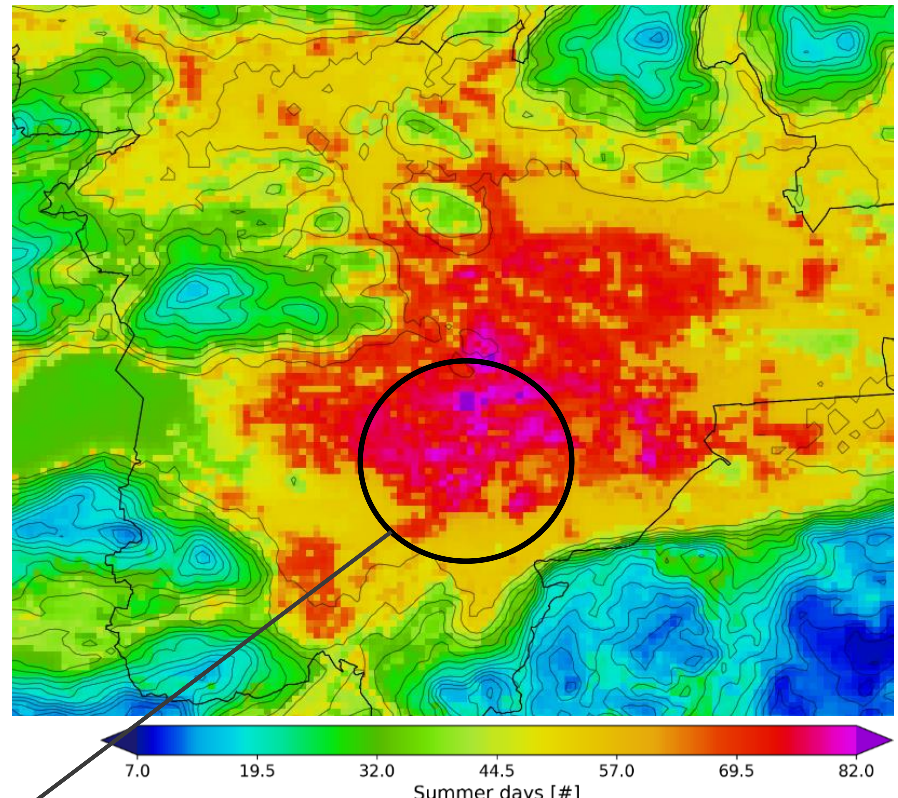
Afforestation in the south-west of Klagenfurt

Prevalent wind directions lead to decrease SD/y



Reference simulation **1981-2010**



Difference is about **-4 to -8 summer days**

Correct realization of these climate adaptation measures

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Correct realization of climate adaptation measures

- Decrease of impervious areas = More meadows
  - Carbon sequestration and greenhouse gas emissions in urban turf (*Townsend-Small A., 2010*)
    - Greenhouse potential (GWP) of ornamentals lawns in range from -108 to +285 g CO_2 m^{-2} yr^{-1}
  - Mowing should happen **CO_2 neutral**

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Correct realization of climate adaptation measures

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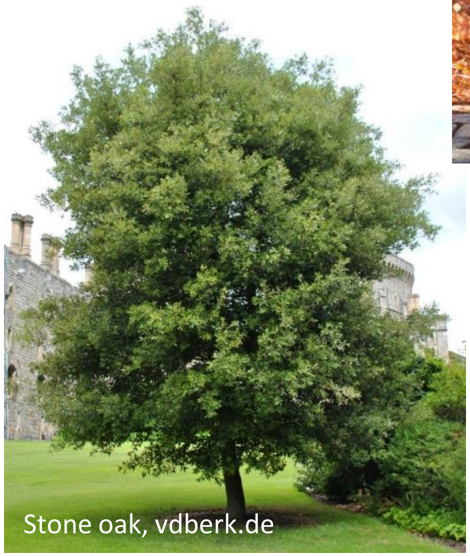
    - Greenhouse potential (GWP) of ornamentals lawns in range from -108 to +285 g CO_2 m^{-2} yr^{-1}
  - Mowing should happen **CO_2 neutral**
- More trees = more foliage care
  - **CO_2 neutral**
  - Use of evergreen trees
    - Citree.de


robomaeher.de


kloenschnack.de


Stone oak, vdberk.de

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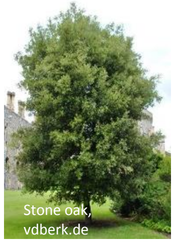
- More trees = more foliage care
  - **CO_2 neutral**
  - Use of evergreen trees
    - Citree.de

- Increase of albedo means more direct reflections
  - Possible, dangerous situations for car drivers (glazed roof tiles) → **dull paint**
  - **Thermal comfort** (UTCI, PET) increases from certain albedo value (0.7-0.8) although air temperature decreases (PALM-4U, TEB)


robomaeher.de


Stone oak, vdberk.de


kloenschnack.de


baumarkt.de

Summary and outlook

for Klagenfurt, Salzburg and Mödling

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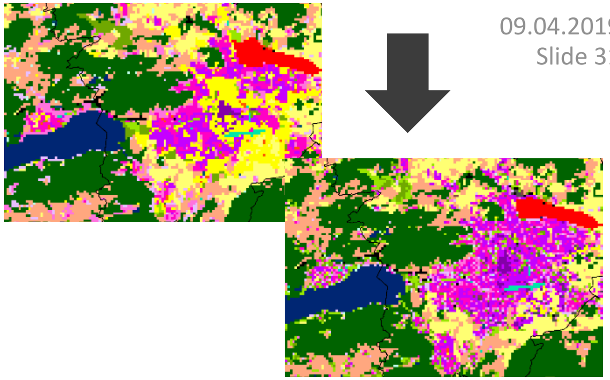
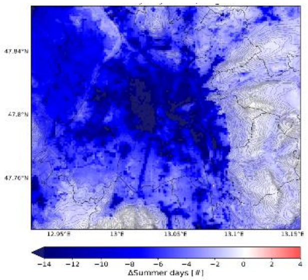
Summary and outlook

Summary

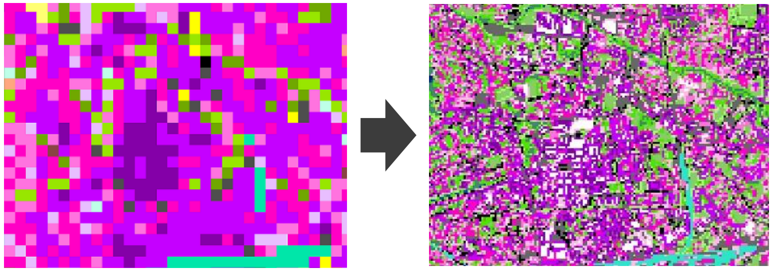
- Input data for urban climate model applications need to be verified and (if possible) reclassified with more detailed landuse data sets
  - › **Use of thresholds**
- Small climate adaptations can have a **big impact when using combination of adaptation measures**
  - › Benefits for dense building structures
- Correct realization of climate adaptations (**CO_2 neutral**) is important





Outlook

- Simulations with various grid size cells for Klagenfurt and Salzburg
  - › 20 m inner city, 100 m rural areas
- City development till 2050 will be considered for future scenarios



Thank you for your attention!

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Urban climate modelling

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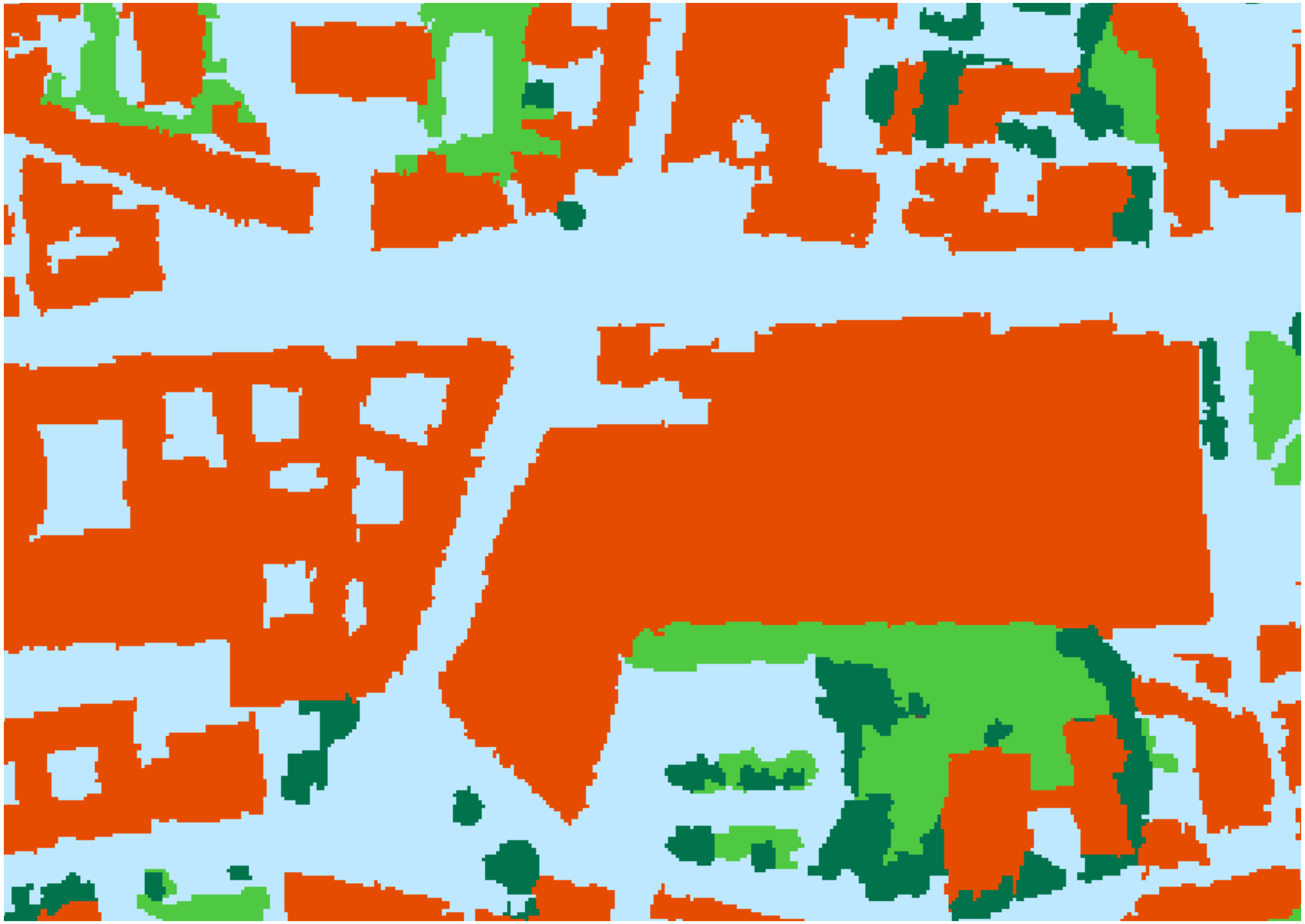
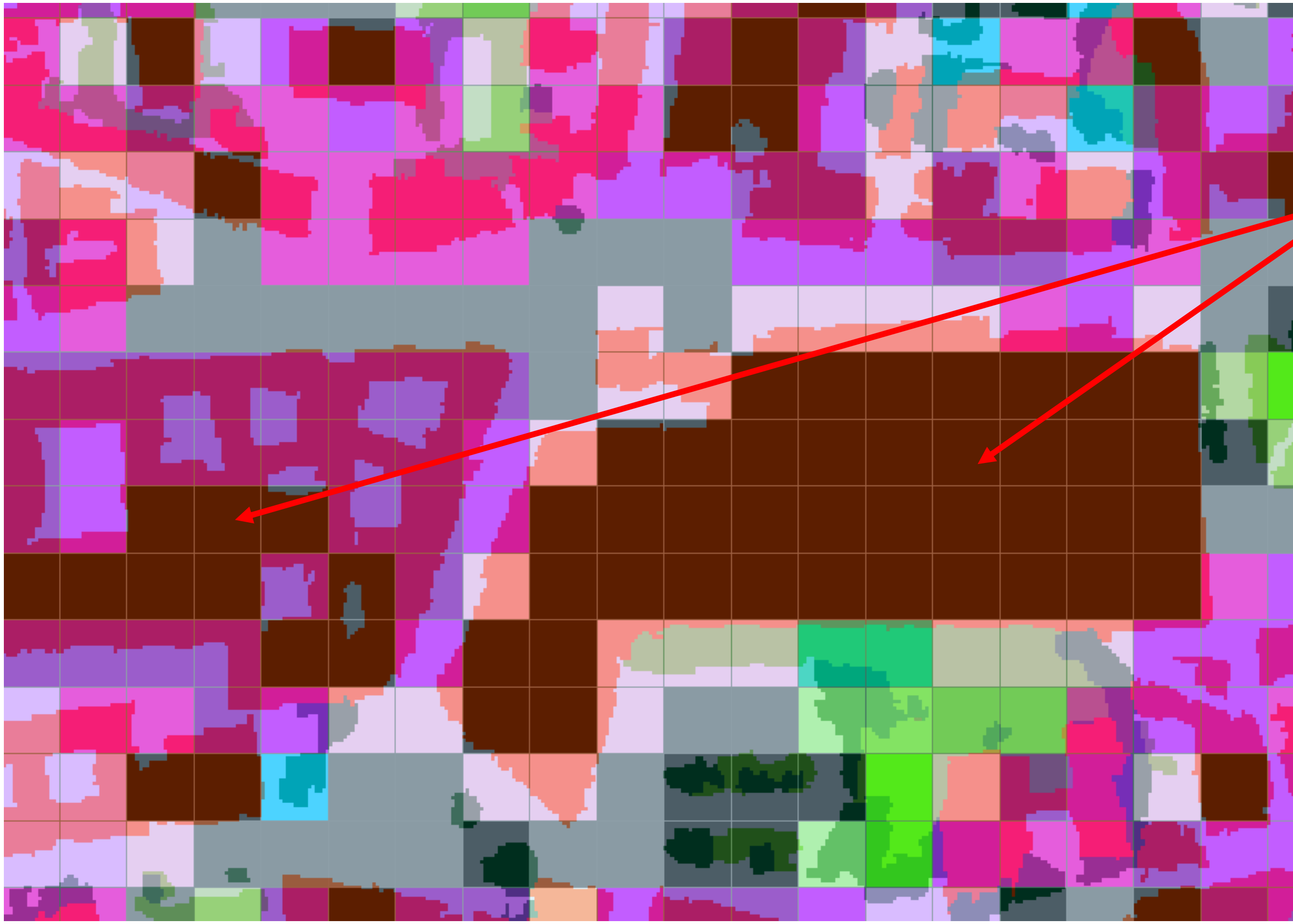
Beispiel für Gitterzellen auf Dachniveau



Beispiel für Gitterzellen auf Dachniveau



- Dunkelbraune Bereiche repräsentieren Dachflächen (Gebäude > 75%)
- Lufttemperatur wäre durch „zu viel“ Gebäude, was eigentlich das Dachniveau ist (=erhöhte Position mit höherer Windgeschwindig-keit), überschätzt

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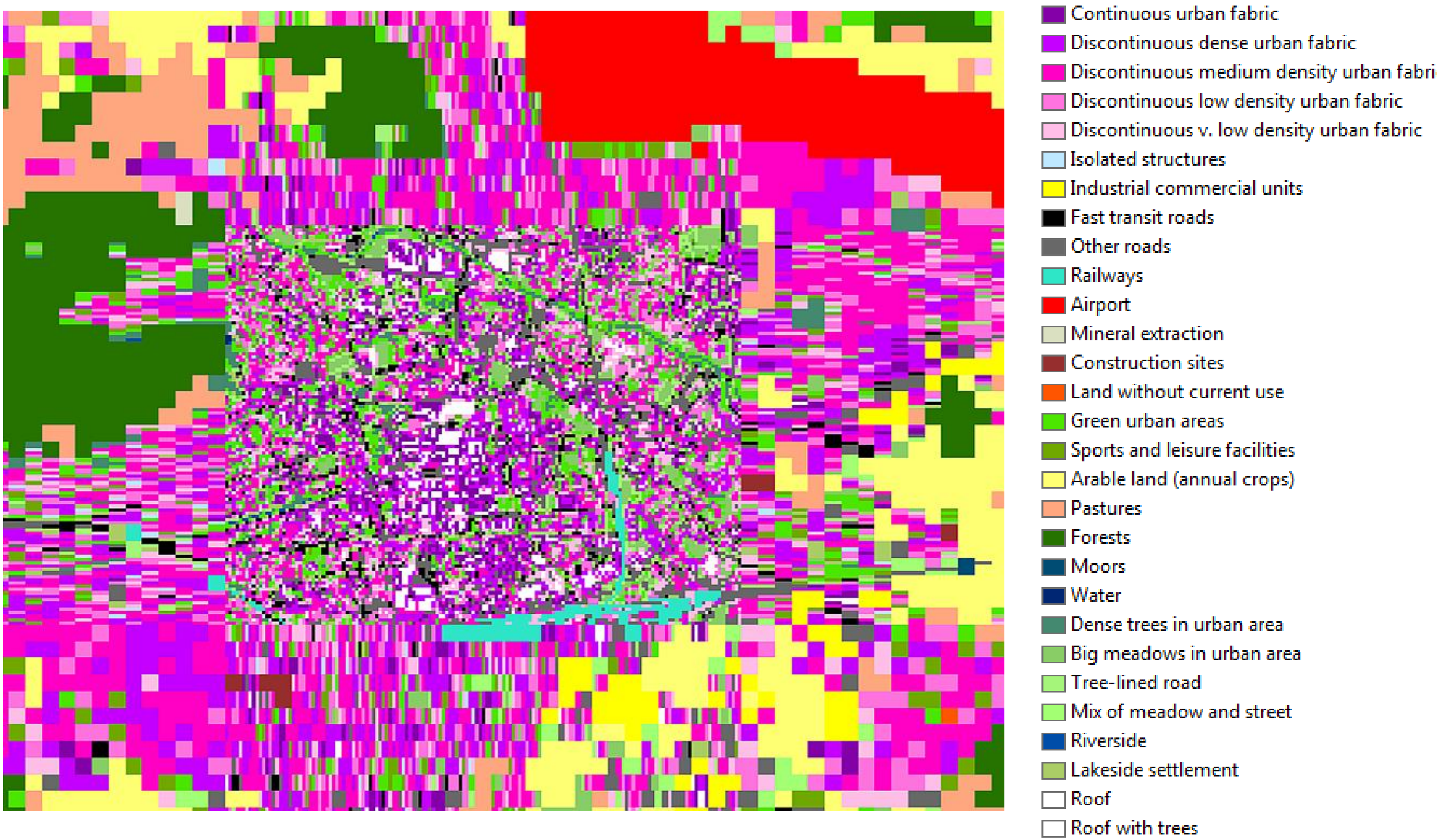
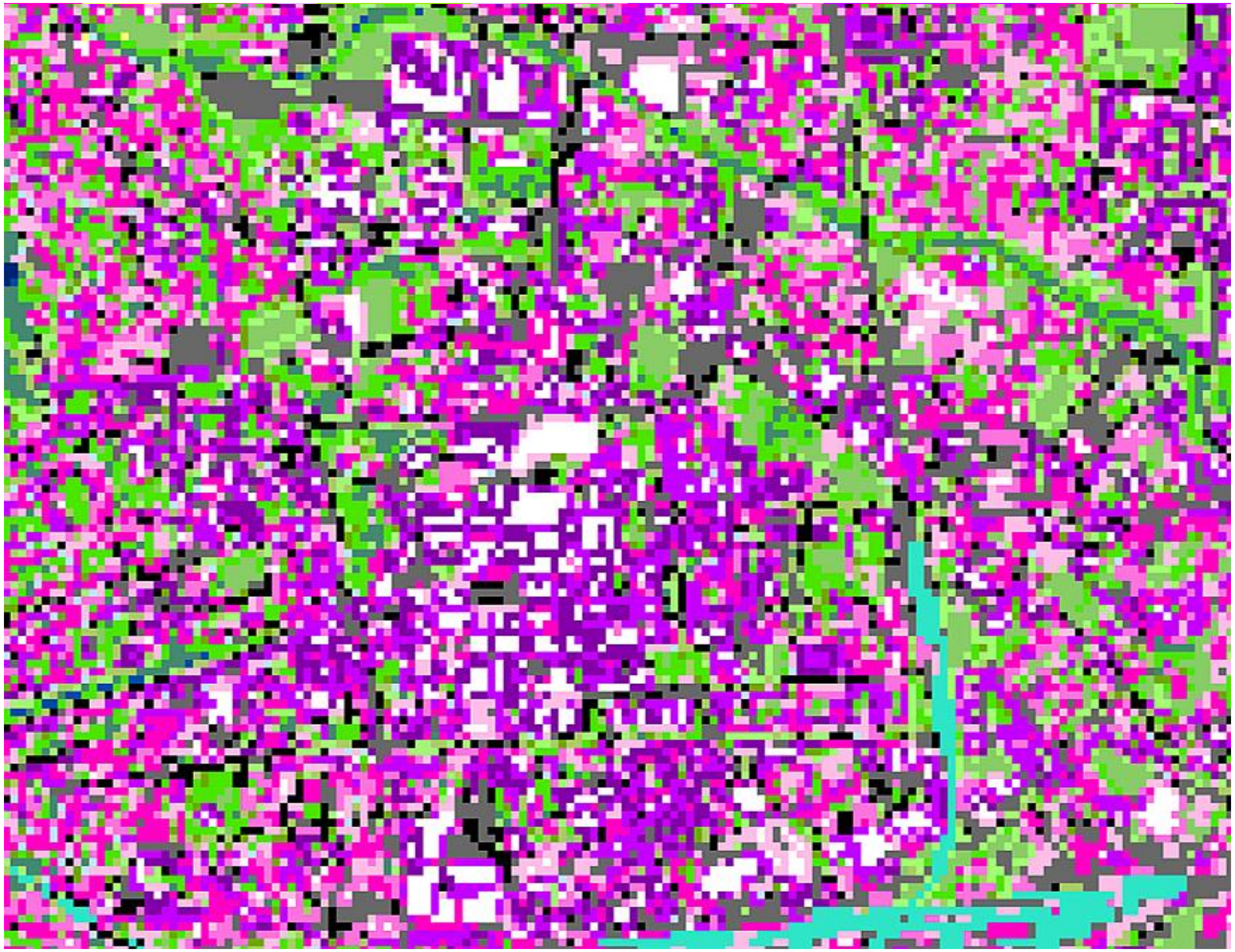
Zusammenfassung und Ausblick



Zusammenfassung und Ausblick



- Continuous urban fabric
- Discontinuous dense urban fabric
- Discontinuous medium density urban fabric
- Discontinuous low density urban fabric
- Discontinuous v. low density urban fabric
- Isolated structures
- Industrial commercial units
- Fast transit roads
- Other roads
- Railways
- Airport
- Mineral extraction
- Construction sites
- Land without current use
- Green urban areas
- Sports and leisure facilities
- Arable land (annual crops)
- Pastures
- Forests
- Moors
- Water
- Dense trees in urban area
- Big meadows in urban area
- Tree-lined road
- Mix of meadow and street
- Riverside
- Lakeside settlement
- Roof
- Roof with trees