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# Regional modeling of urban climate: the impact of physical process representation

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## Summary

Cities have strong inevitable impact on the atmospheric environment.
They emit large amount of gaseous species and aerosols into air, having direct impact on the composition and chemistry of the atmosphere. This pathway has, indirectly, impact on the meteorology and climate as well trough interaction with the radiation and clouds. Secondly, urban surfaces are largely covered by artificial objects and are often paved, therefore clearly distinguished from natural surfaces by mechanical, radiative, thermal, and hydraulic properties. These surfaces represent additional sinks and sources of momentum and heat, affecting the mechanical, thermodynamic and hydrological properties of the atmosphere (Huszar et al., 2014). The meteorological conditions are thus clearly different over urban areas than above their rural counterparts.

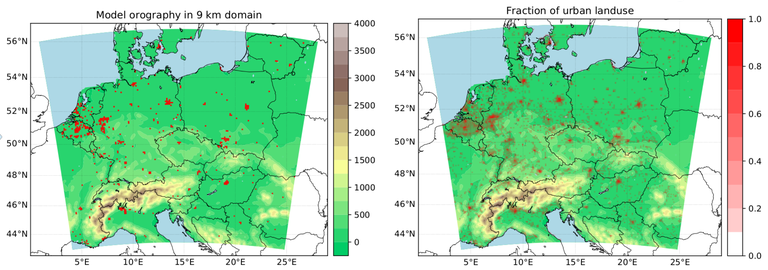
This study looks at the **urban-rural contrast** (**URC**) in terms of different meteorological variables and the **sensitivity on the model representation (parameterization) of different physical processes** like boundary layer turbulence, convection and microphysics is analysed.

## Models

Two regional climate models are used in this study: the Regional Climate Model **RegCM4** (version 4.7; Giorgi et al.,2012) and the Weather Research and Forecast model **WRF** (version 4.1; Skamarock et al., 2019).

Domain covering **central Europe centered over Prague, Czech republic; model resolution: 9 km x 9 km**; vertical extent of model atmosphere: up to 5 mbar; thickness of the lowermost layer: ~ 30-40 m
Period: DEC 2014 – Jan 2017.
Driving data: ERA-interim, landcover – CORINE.

Dominant urban landuse in WRF vs. Fractional landuse in RegCM




## Experiments

Numerous experiments have been performed using different parameterization of urban canopy, PBL, convection, surface physics and microphysics:

**WRF**

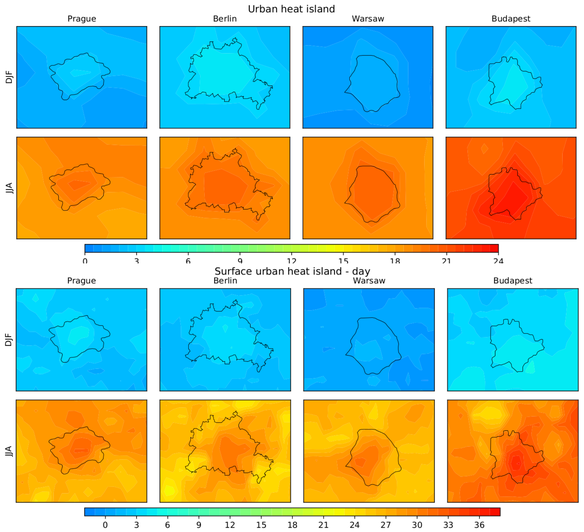
| Experiment | Urban model | # levels | PBL scheme | SFL scheme | Convection |
|---|---|---|---|---|---|
| E1U3L22 | BEP+BEM | 49 | MYJ | Eta | Grell-Freitas |
| E1U3L82 | BEP+BEM | 49 | BouLac | Eta | Grell-Freitas |
| E1U3L81 | BEP+BEM | 49 | BouLac | MM5 | Grell-Freitas |
| E1U1L22 | SLUCM | 40 | MYJ | Eta | Grell-Freitas |
| E1U1L22C5 | SLUCM | 40 | MYJ | Eta | Grell-3D |
| E1U1L22C1 | SLUCM | 40 | MYJ | Eta | Kain-Fritsch |
| E1U1L82 | SLUCM | 40 | BouLac | Eta | Grell-Freitas |
| E1U1L82C5 | SLUCM | 40 | BouLac | Eta | Grell-3D |
| E1U1L82C1 | SLUCM | 40 | BouLac | Eta | Kain-Fritsch |
| E1U1L81 | SLUCM | 40 | BouLac | MM5 | Grell-Freitas |
| E1U1L81C5 | SLUCM | 40 | BouLac | MM5 | Grell-3D |
| E1U1L81C1 | SLUCM | 40 | BouLac | MM5 | Kain-Fritsch |
| E1U0L22 | bulk | 40 | MYJ | Eta | Grell-Freitas |
| E1U0L82 | bulk | 40 | BouLac | Eta | Grell-Freitas |
| E1U0L81 | bulk | 40 | BouLac | MM5 | Grell-Freitas |

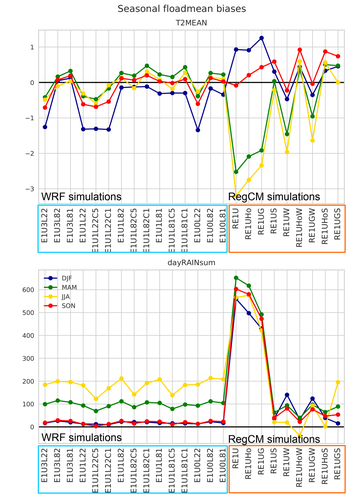
**RegCM**

| Experiment | PBL scheme | Convection | MP scheme |
|---|---|---|---|
| RE1U | UW | Tiedtke | Nogherotto |
| RE1UHo | Holtslag | Tiedtke | Nogherotto |
| RE1UG | UW | Grell | Nogherotto |
| RE1US | UW | Tiedtke | SUBBEX |
| RE1UW | UW | Tiedtke | WSM5 |
| RE1UHoW | Holtslag | Tiedtke | WSM5 |
| RE1UGW | UW | Grell | WSM5 |
| RE1UHoS | Holtslag | Tiedtke | SUBBEX |
| RE1UGS | UW | Grell | SUBBEX |

## Comparison with MODIS

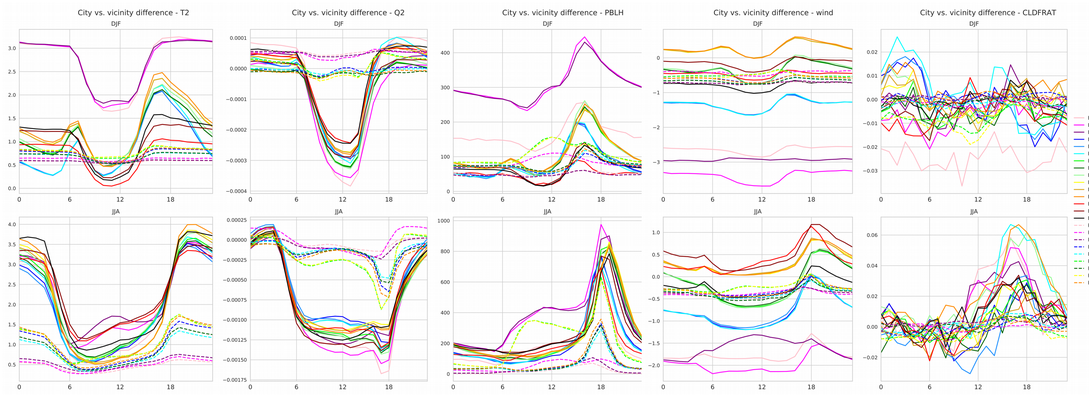
Comparison of model ensemble average of the skin temperarature to MODIS observations [°C]



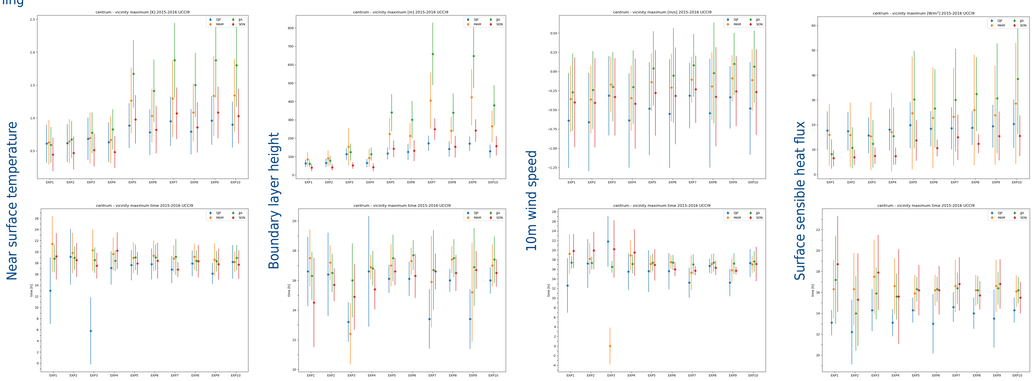




## The urban-rural contrast (URC)

The daily cycle of the URC averaged across 10 selected cities for different physical quantities.

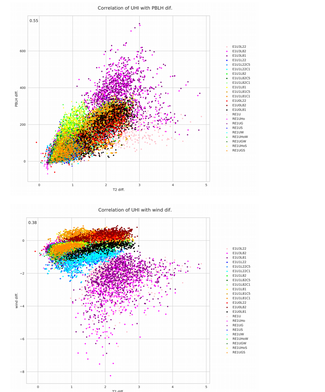



The maximum difference of the urban-rural contrast in daily cycles in the **RegCM** simulations and their timing

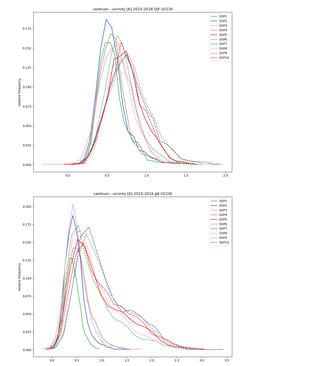



## Correlations

Scatter plots of UHI and selected URC




## UHI distribution



## Conclusions

- The choice of the parameterization of physical processes in models strongly influence its performance and model biases.
- The simulated urban-rural contrast (URC) has a strong dependence on the model set-up choice not only quantitatively but also qualitatively
- The most robust model results is obtained for the temperature (the urban heat island) where models/set-ups perform very similarly, however, the UHI magnitude vary between 1-1.5 K (in RegCM) up to 4K (in WRF)
- WRF tends to predict stronger URCs, especially for humidity, PBL height and cloud fraction.
- In case of wind-speed, simulations usually predict lower winds over urban areas, but certain set-ups provide opposite results pointing to urban breeze features.
- Diurnal cycles within RegCM experiments show high similarity in the timing of the maximum daily contrast however the maximum value shows a large spread, especially for temperature and PBL height.

## References

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- Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, Z. Liu, J. Berner, W. Wang, J. G. Powers, M. G. Duda, D. M. Barker, and X.-Y. Huang, 2019: A Description of the Advanced Research WRF Version 4. NCAR Tech. Note NCAR/TN-556+STR, 145 pp.

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