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How does North Atlantic Oscillation modify summer urban heat load in Zagreb (Croatia)?

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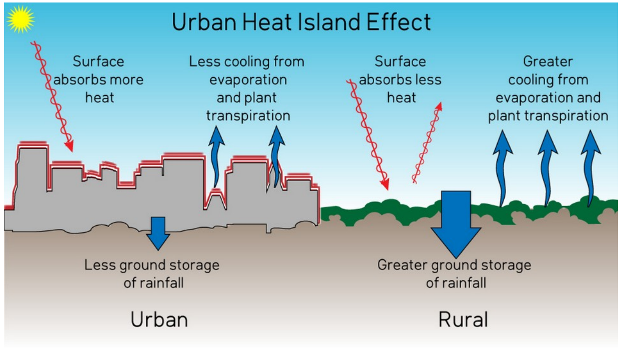
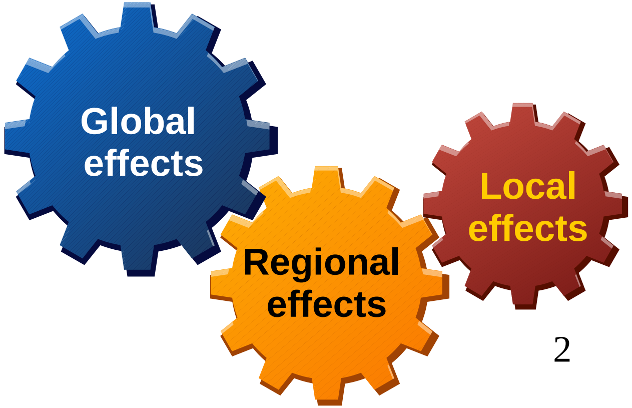
Motivation

- Urban sprawl and development → increase in urban population (UN 2019)
- Artificial materials in construction → alteration in surface energy balance and water balance
  - ➢ Urban heat island (UHI)
  - ➢ Urban floods
- UHI affected by factors and processes on different spatial and temporal scales → interactions and feedbacks within the climate system
  - Characteristics of the city (size, shape, land-use/cover)
  - Climate zone, vicinity of the mountain, sea
  - Synoptic systems
  - Heat waves, droughts, North-Atlantic Oscillation (NAO), El-Nino Southern Oscillation (ENSO)



(source: https://dozr.com/blog/urban-heat-island)



In this research

- Importance of surface intitial conditions for the development of an extreme event
- Response of the urban heat load to different combinations (in terms of preceding and concurent component):
  - winter and summer NAO
  - dry/wet conditions in late winter-spring and summer season
- The results published in the paper:

Nimac, I., Herceg-Bulić, I., Žuvela-Aloise, M., & Žgela, M. (2022). **Impact of North Atlantic Oscillation and drought conditions on summer urban heat load - a case study for Zagreb**. *International Journal of Climatology*, 1– 18. https://doi.org/10.1002/joc.7507

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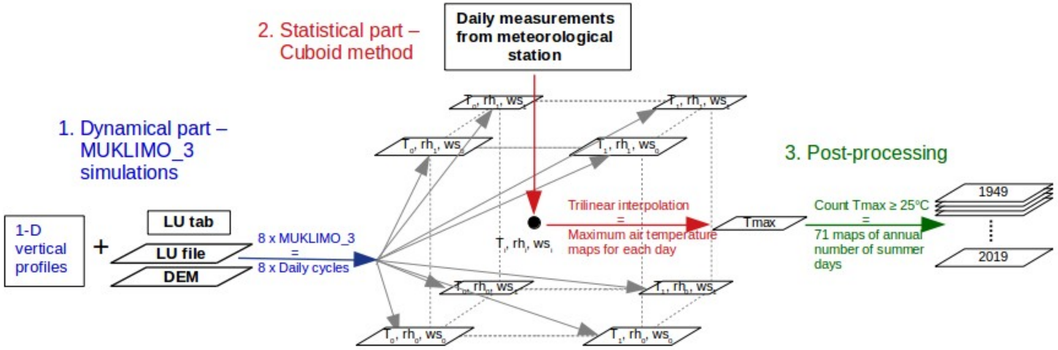
Data

- **Time period:** 1949–2019
- Hurrel (2003) PC-based **NAO** index for winter (DJF) – wNAO and summer (JJA) – sNAO season
- Drought conditions defined by standardized precipitation evapotranspiration index (**SPEI**) for summer – AugSPEI3 and late winter-spring – MaySPEI5 season based on the data measurements from meteorological station Zagreb-Maksimir
- Heat load represented as number of days with maximum air temperature equal or higher than 25 °C, i.e. summer days (**Tx25**)

Methods

- **Correlation analysis** for different combinations of preceding and concurrent NAO (SPEI) conditions in regard to Tx25 based on the station data
- **MUKLIMO_3** urban climate model (dynamical component) + **cuboid method** (statistical component) = spatio-temporal investigation
- Land surface temperature (LST) **Landsat-8** satellite data for representative situations



Correlation analysis

- Significant correlation between wNAO and both winter and summer SPEI mainly due to significant correlation with Tmax
- Significant correlation between Tx25 and sNAO
- Even stronger correlation after including wNAO in multiple linear regression
- Similar results for SPEI analysis, but with stronger correlation

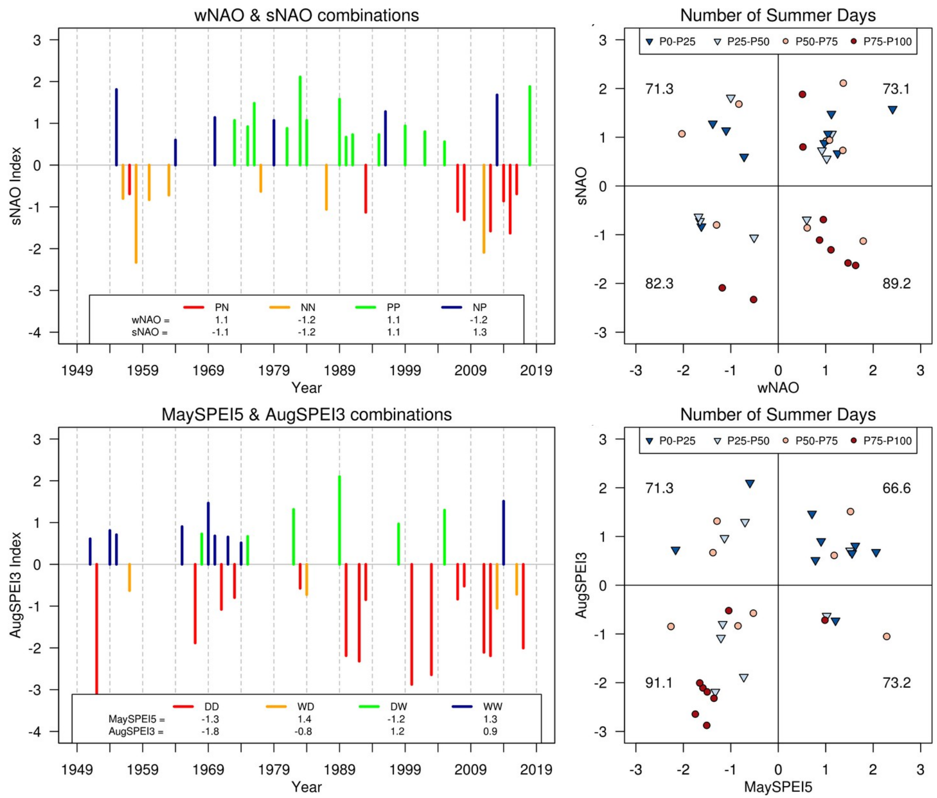
	wNAO				sNAO
	DJF	MAM	JFMAM	JJA	JJA
Tmax	**0.40**	**0.37**	**0.46**	*0.24*	**-0.33**
Tmin	0.17	*0.27*	*0.27*	0.20	-0.18
Prec	**-0.40**	-0.18	*-0.28*	-0.17	0.21
SPEI	**-0.40**	*-0.26*	**-0.35**	*-0.25*	*0.24*

Tx25 (days)	NAO		SPEI	
	LR	R	LR	R
Preceding	$78.0+3.0*x_p$	0.19	$77.7-6.0*x_p$	**-0.37**
Concurrent	$78.7-5.1*x_c$	**-0.32**	$76.0-6.4*x_c$	**-0.48**
Both	$78.7+3.5*x_p-5.5*x_c$	**0.39**	$76.1-3.8*x_p-5.4*x_c$	**0.53**

Statistically significant values at 1% (5%) significance level are written in bold (italic).

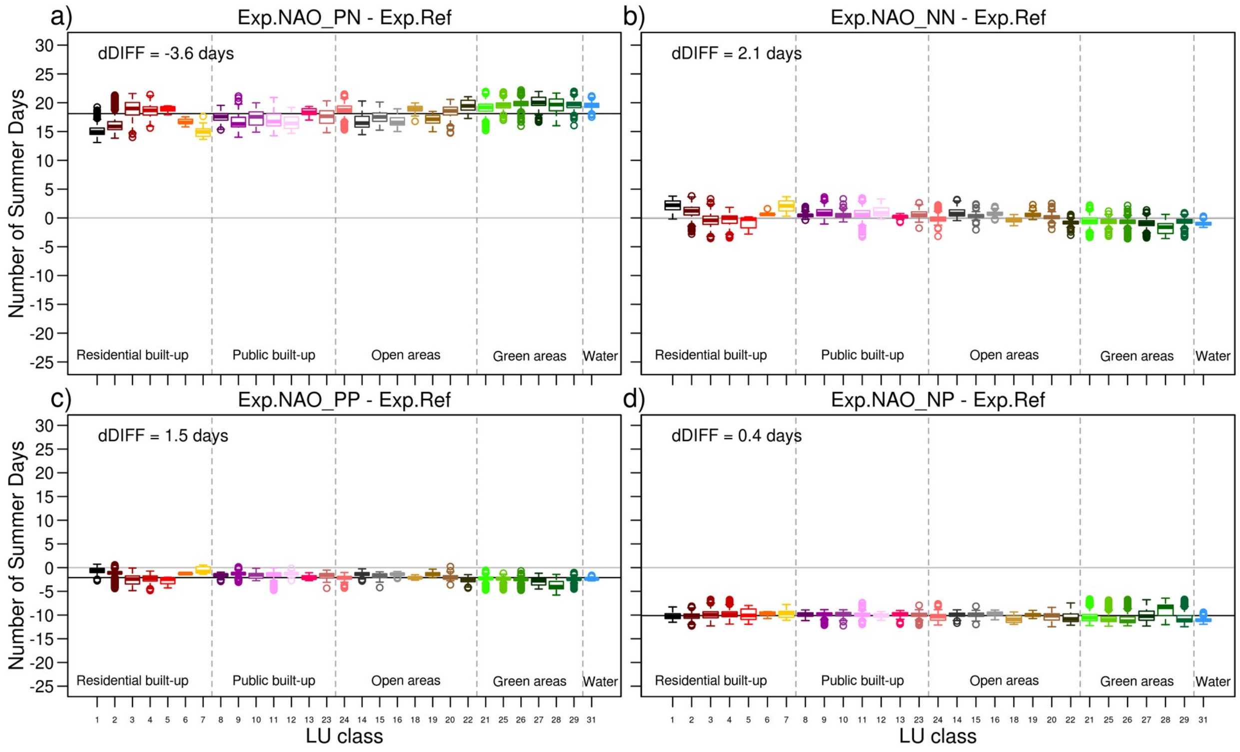
NAO/SPEI effect (station data)

- Four NAO/SPEI composites
- NAO experiments
  - The largest (lowest) Tx25 number for Exp.NAO_PN (Exp.NAO_NP) combination
- SPEI experiments
  - The largest (lowest) Tx25 number for Exp.SPEI_DD (Exp.SPEI_WW) combination



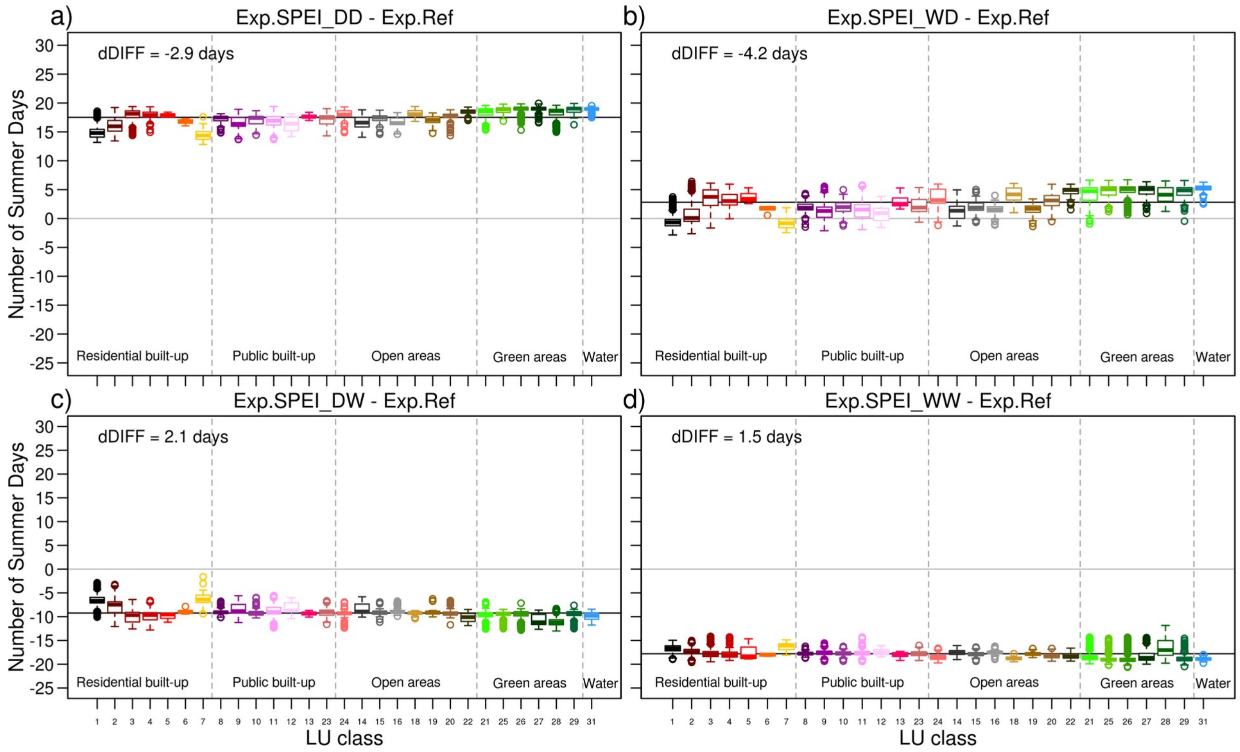
NAO effect (modelling)

- Changes in Tx25 amplitude – the strongest increase (decrease) for PN (NP) situation
- Changes in Tx25 spatial gradient – decrease for PN combination
- Somewhat different response in forest areas compared to other vegetation classes, except for PN situation



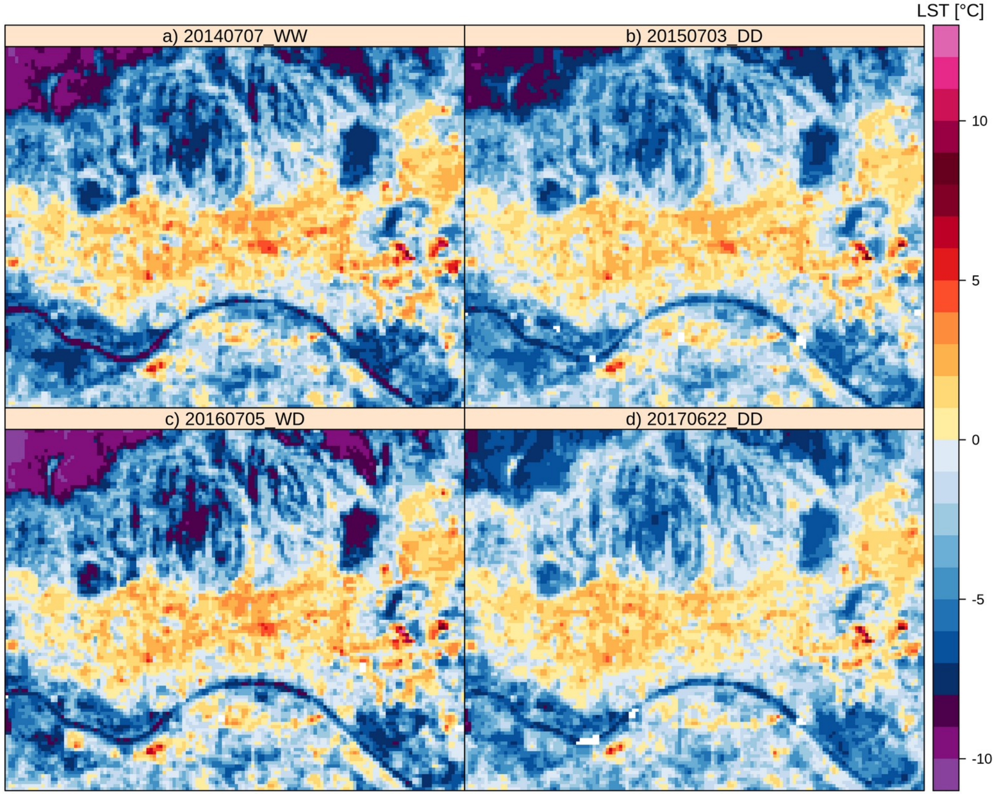
SPEI effect (modelling)

- Analogously to NAO analysis
- Changes in Tx25 amplitude – the strongest increase (decrease) for DD (WW) situation
- Changes in Tx25 spatial gradient – decrease for DD combination
- Similarly, somewhat different response for forests



LST analysis (satellite data)

- Similar field to heat load distribution obtained by modelling – the highest values in the densely built-up areas, lower values along slopes of Medvednica mountain, in the forests, parks and water areas
- Stronger spatial gradient for situations when preceding conditions were wet compared to ones preceded by dry conditions



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Conclusion

- Significant effect of North-Atlantic oscilation and drought conditions on the urban heat island
- The role of the soil moisture as a link between winter NAO and summer heat load situation
- Importance of slower components of the climate system for the development of an extreme event
- Cooling efficiency of vegetation depends on the drought conditions
- Preparation of irrigation system when seasonal forecast points to conditions drier than average

Mitigation of impacts of extreme weather situations

- ➔ **Short-term measures** (e.g. planing of energy and water consumption and demand)
- ➔ **Long-term measures** (e.g. implementation of green infrastructure, planning of irrigation system)

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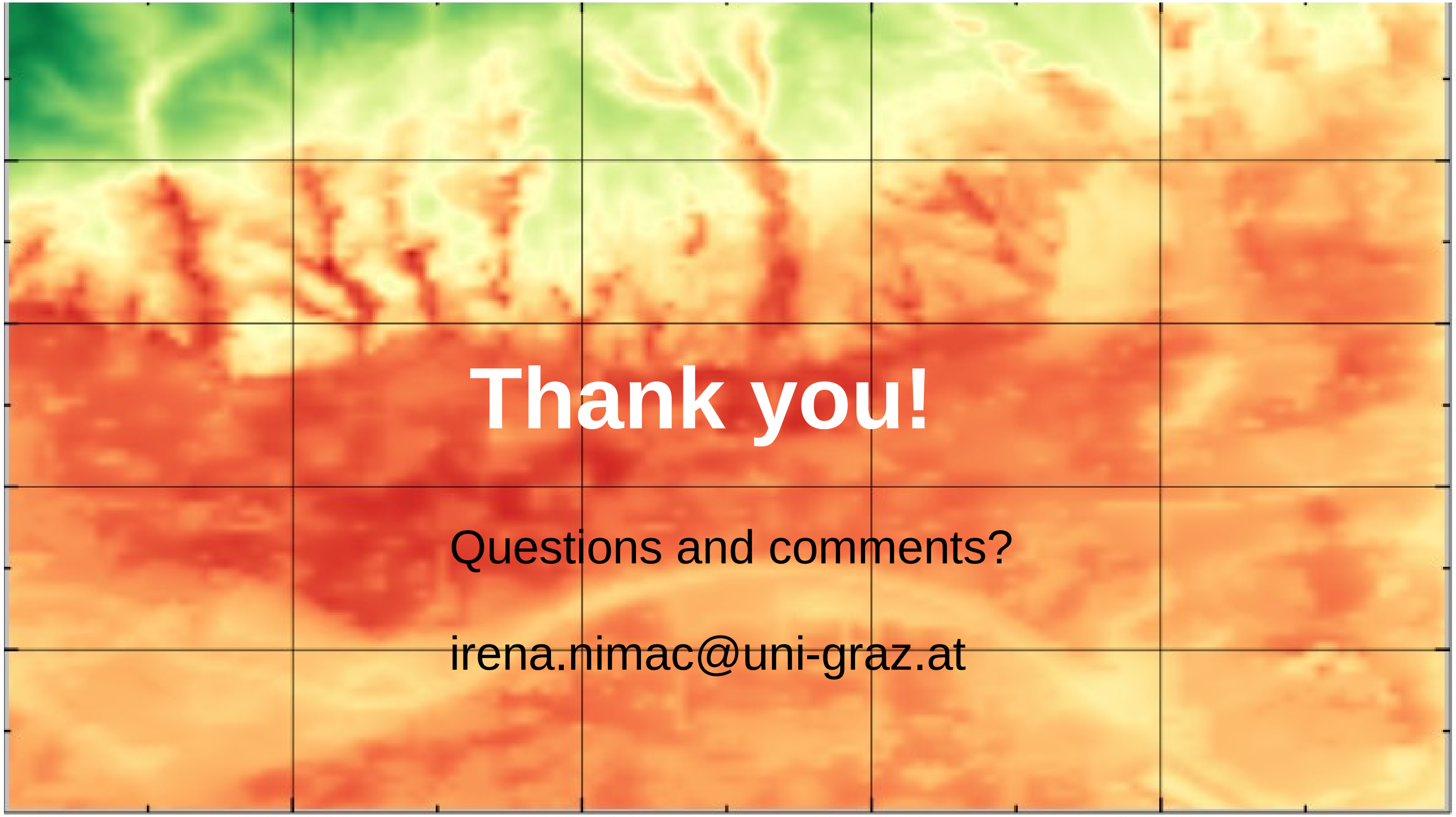

Thank you!

Questions and comments?

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