CORDEX Flagship Pilot Studies
URB-RCC
FUTURA Funded by the EU (GA 101295156)
IMPETUS 4CHANGE Funded by the EU(GA 101081555)
CSIC Consejo Superior de Investigaciones Científicas
UC
IFCA Instituto de Física de Cantabria

Land-atmosphere feedback in urban enviroments:

Sensitivity analysis of FPS-URB-RCC STAGE-0 sub-ensemble of WRF simulations

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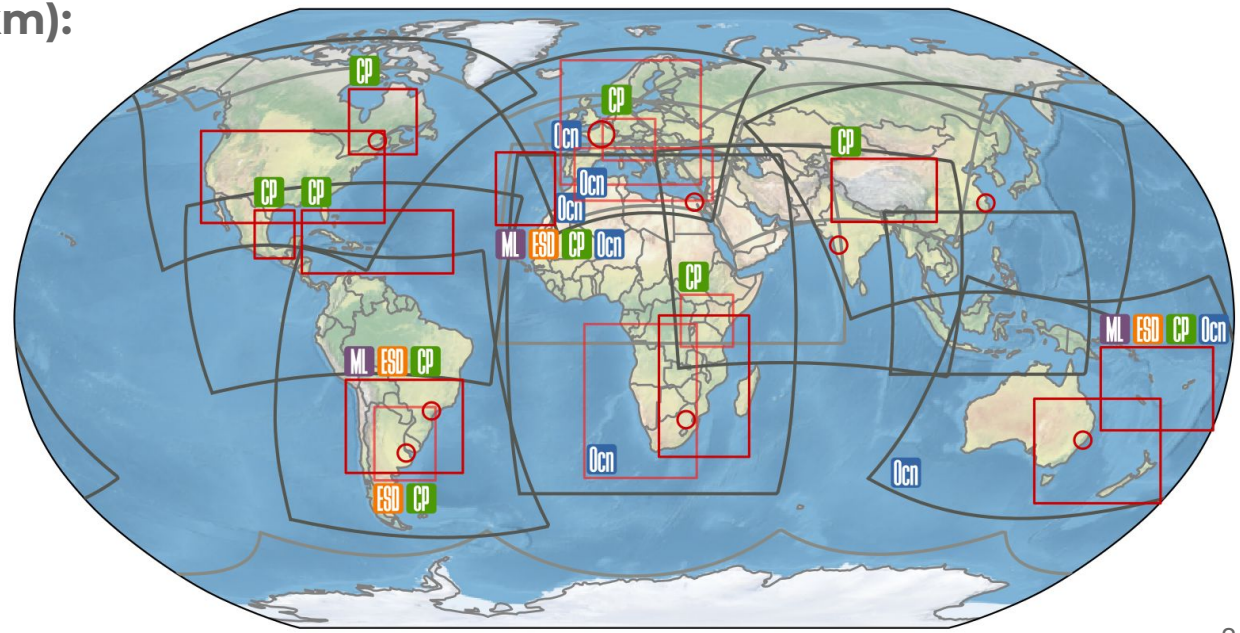
CORDEX

The Coordinated Regional Downscaling Experiment (CORDEX) is a part of the World Climate Research Programme (WCRP) global effort for regional climate insights.

CORDEX domains (12-50 km):

- Africa (AFR)
- Europe (EUR)
- North America (NAM)
- Central America (CAM)
- South America (SAM)
- Asia (SEA, EAS, WAS)
- Australasia (AUS)



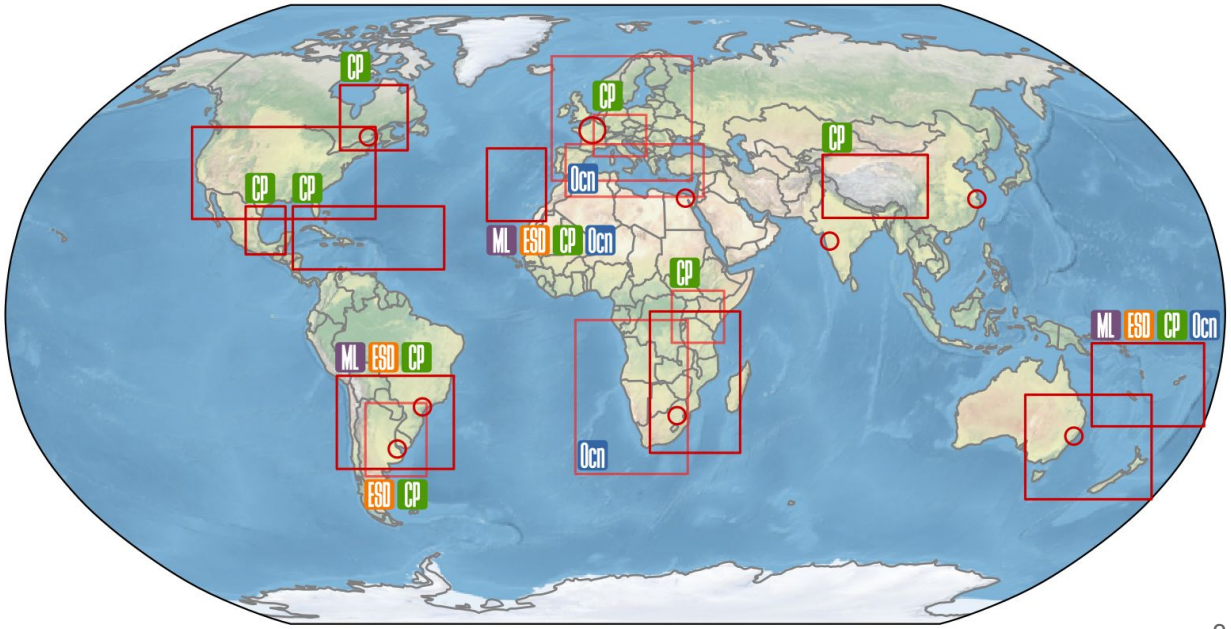
CORDEX FPS initiatives

Flagship pilot studies (FPS) are CORDEX activities which target higher resolution (2-4 km) experiments over areas smaller than CORDEX domains:

- Link to impact assessments, adaptation planning and decision-making at regional to local scales
- 3 types of downscaling: ML, ESD, CP, and coupling with ocean Ocn

FPS-SHEP
FPS-I-Mac
FPS-IC-Pac
FPS-TC-Car
FPS-URB-RCC
FPS-NA-Storyline
FPS-SEAfrica
FPS-CPTP

FPS-ELVIC
FPS-SWAfrica
FPS-SESA
FPS-CONV
FPS-LUCAS
FPS-Aerosol
FPS-AirSea



FPS-URB-RCC objectives

01	PRODUCE	coordinated ensemble of CP RCMs with improved representation of urban areas
02	INVESTIGATE	interactions of cities with climate change at regional scale
03	IDENTIFY	key processes and recommend physics parameterizations for further use within the CORDEX community
04	IMPROVE	understanding of the vulnerability of the cities under climate change
05	SHARE	share the knowledge with the climate services and all end users

FPS-URB-RCC: From idea to realisation

Phase 1 (completed)

- Analysis of urban effects and parameterization schemes incorporated in available RCMs
- Setting the simulation protocols and criteria for city(ies) selection for coordinated experiments

Phase 4 (planned)

- STAGE-2 coordinated experiments under future scenarios
- Assessment of the added value of regional and local urban effects on climate change

Phase 2 (ongoing)

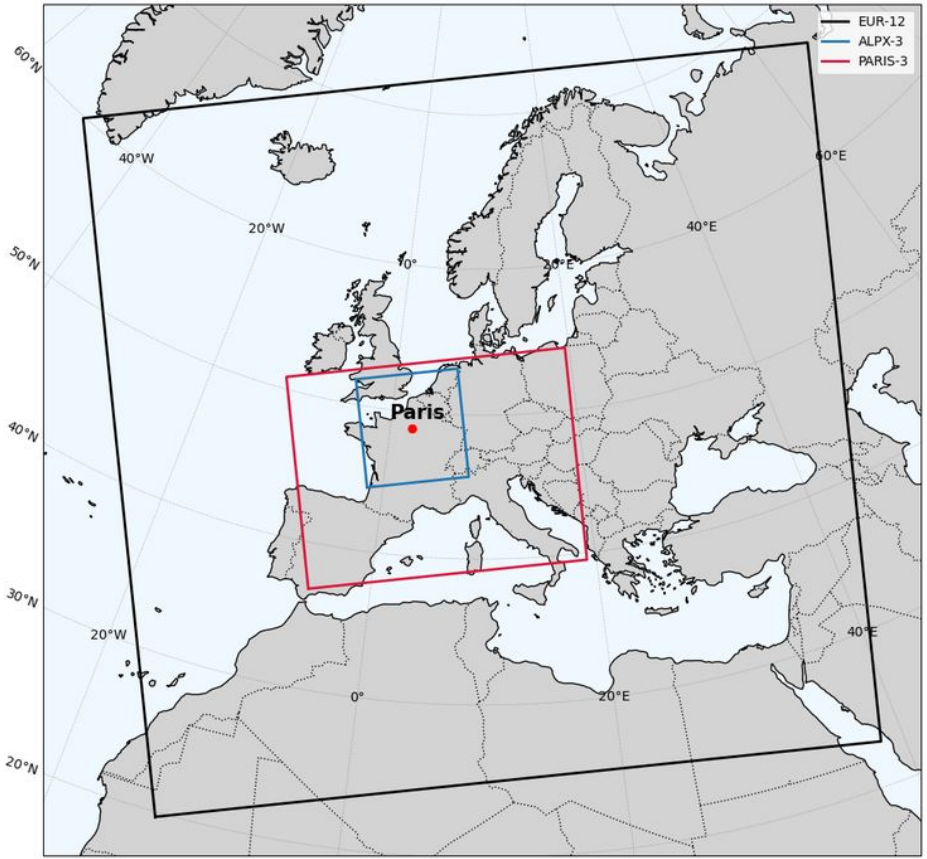
- STAGE-0 coordinated short experiment at 2-4 km spatial resolution (simulation completed, analysis ongoing)
- STAGE-1 coordinated evaluation run at 2-4 km spatial resolution (ongoing)
- Identify urban processes needed to be included in future RCM simulations (planned)

Phase 3 (ongoing)

- Coupling to chemical transport models (ongoing)
- Urbanization scenarios (planned)

Concept presented in [*Langendijk et al. 2024*]

Domains in WRF



Outer domain at 12 km:
EUR-12

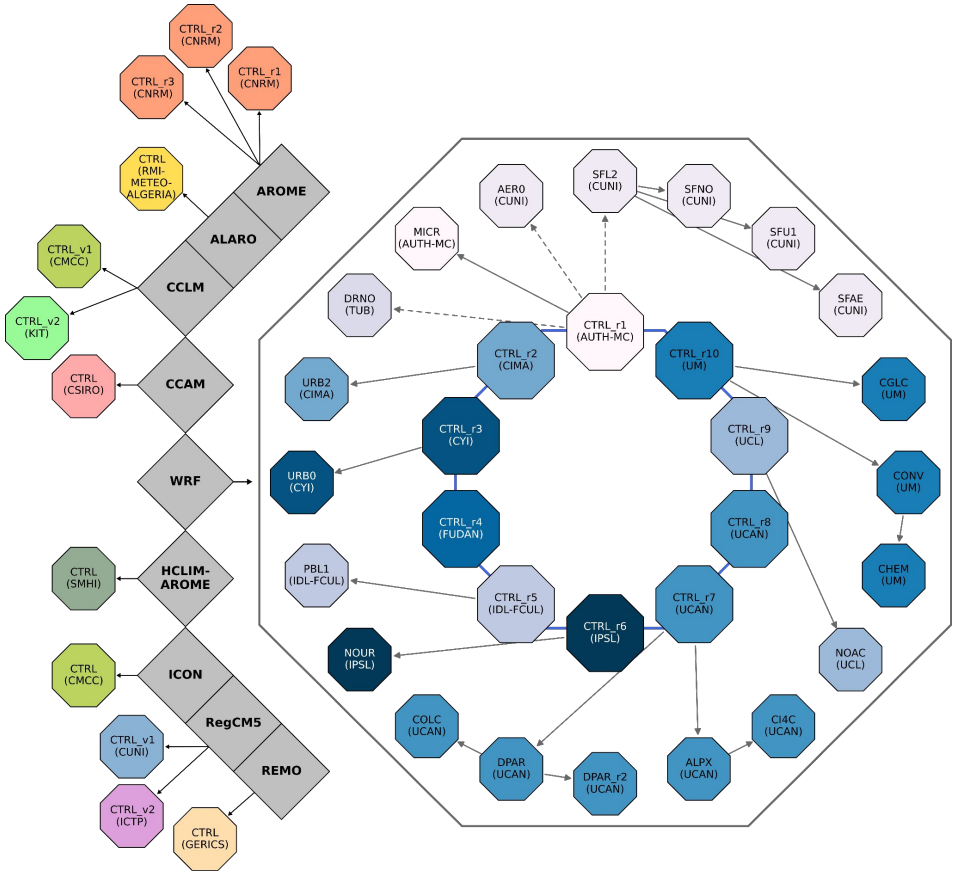
2 versions of inner 3km domains:
PARIS-3
ALPX-3

1-way nesting, ERA5 forced

Simulation period:
01.05.2020-01.09.2020
\+ 2 months of spin-up

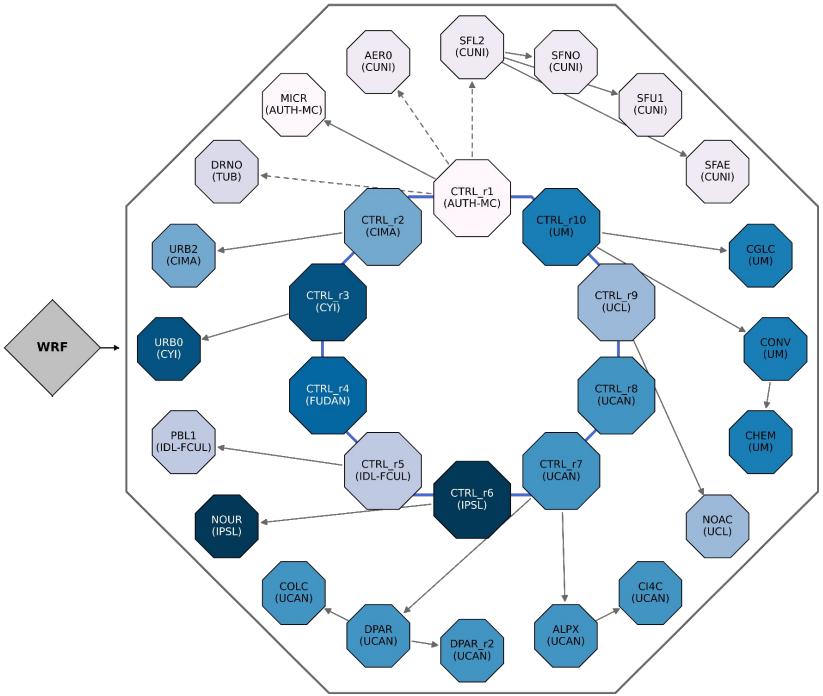
Period covers 2 extreme events:
- extreme convective precipitation in May
- HW in August

FPS-URB-RCC STAGE-0 simulations



9 RCMs
Ensemble of **42** simulations

WRF STAGE-0 simulations



WRF ensemble with **30** runs:

- **10 CTRL** (BEP+BEM Urb & Boulac PBL)
- **20** sensitivity runs

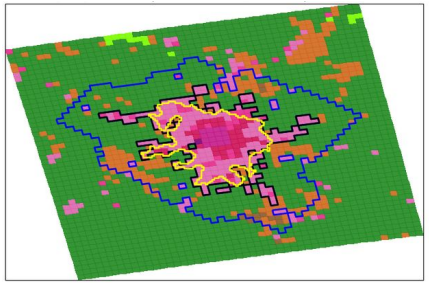
Sensitivity runs:

Convection & Microphysics	MICR, CONV
Urban parameters	NOAC, DPAR, DPAR_r2
SFC & PBL schemes	SFL2, ALPX PBL1, CI4C
Land use input maps	NOUR, COLC, CGLC
Chemistry & Aerosols	CHEM, SFAE, AER0
Urban schemes	URB0, URB2, CI4C, SFU1, SFNO, DRNO, NOURB

Delineation of urban from rural environments

Urclimask: Diez-Sierra et. all, 2025 (10.5281/zenodo.17257445)

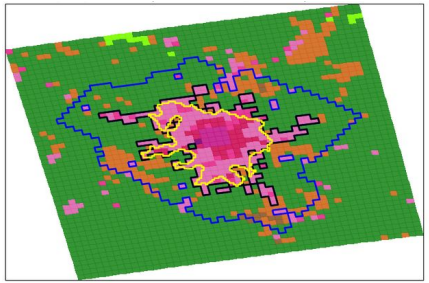
PARIS



Delineation of urban from rural environments

Urclimask: Diez-Sierra et. all, 2025 (10.5281/zenodo.17257445)

PARIS



A set of tools developed within FPS-URB-RCC to delineate urban and rural surrounding taking into account information on: orography, land-sea mask, and urban fraction

Several parameters such as orography difference, urban fraction threshold, number of grids in urban vs rural areas can be adjusted by a user.

Urclimask tool: (https://github.com/FPS-URB-RCC/urclimask/tree/v1.1.0)

Cities in WRF: Static LULC data input

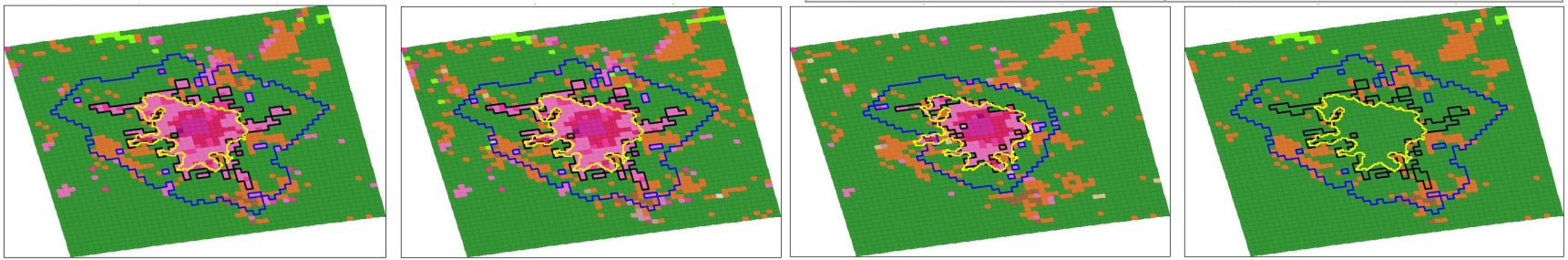
LULC maps with LCZ overlaid:

- Static maps based on satellite observations: MODIS, CORINE (2006), LANDMATE_PFT (2018)

LULC with no urban category (NOUR)

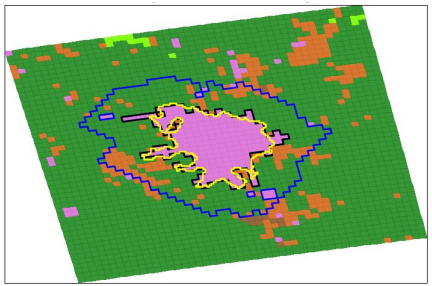
Convection & Microphysics	MICR, CONV
Urban parameters	NOAC, DPAR, DPAR_r2
SFC & PBL schemes	SFL2, ALPX PBL1, CI4C
Land use input maps	NOUR, COLC, CGLC
Chemistry & Aerosols	CHEM, SFAE, AER0
Urban schemes	URB0, URB2, CI4C, SFU1, SFNO, DRNO, NOURB

PARIS



LANDMATE_PFT (CTRL) | CORINE 2006 (COLC, CI4C) | CGLC (CGLC) | NO URBAN (NOUR)

Cities in WRF: Urban schemes



BULK
(URB0, SFNO, DRNO)

Increased **surface roughness**
Reduced vegetation fraction
Higher heat storage capacity

Modified sensible and latent heat fluxes

SLUCM
(CI4C, ALPX, SFU1)

Urban input:
building height, street width, and canyon orientation

Surface Types:
Roofs, walls, road

Processes:
Radiative exchange,Heat storage in building materials, turbulent heat exchange, shadowing and reflection, wind profile in the urban canyon

BEP
(URB2)

Multi-layer vertical discretization

Turbulence and drag effects more detailed

Heat and radiation exchanges better represented (multi-layered walls)

Adds vertical heterogeneity in urban areas!

BEP+BEM
(CTRL)

BEP
+
Indoor building physics represented

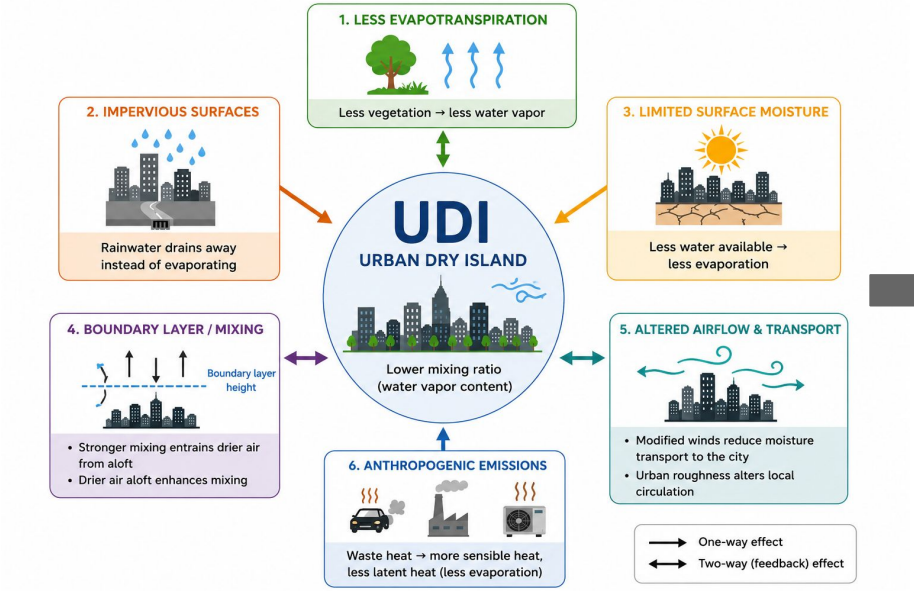
Indoor-outdoor interactions taken into account

Convection & Microphysics	MICR, CONV
Urban parameters	NOAC, DPAR, DPAR_r2
SFC & PBL schemes	SFL2, ALPX PBL1, CI4C
Land use input maps	NOUR, COLC, CGLC
Chemistry & Aerosols	CHEM, SFAE, AER0
Urban schemes	URB0, URB2, CI4C, SFU1, SFNO, DRNO, NOURB

Research questions

How different representation of urban area affects atmospheric dynamics in a convection-permitting regional climate model - sensitivity to model configuration:

- Urban dry island (UDI): spatial mean and mean diurnal cycle

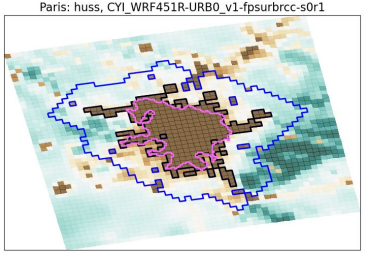


Combined effect of reduced moisture input in urban areas and enhanced drying leads to UDI

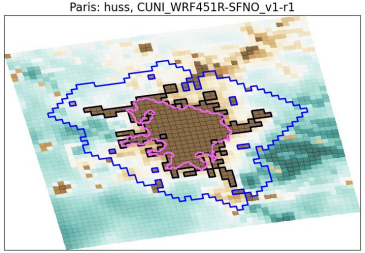
UDI over Paris: Sensitivity to Urban schemes

URB0

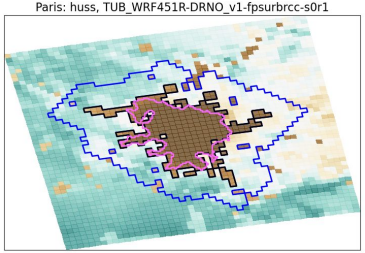
Paris: huss, CYI_WRF451R-URB0_v1-fpsurbrcc-s0r1



Paris: huss, CUNI_WRF451R-SFNO_v1-r1

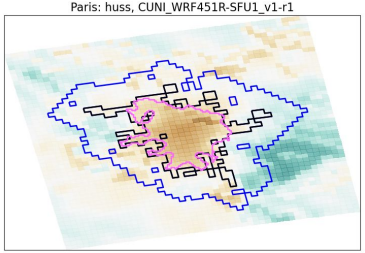


Paris: huss, TUB_WRF451R-DRNO_v1-fpsurbrcc-s0r1

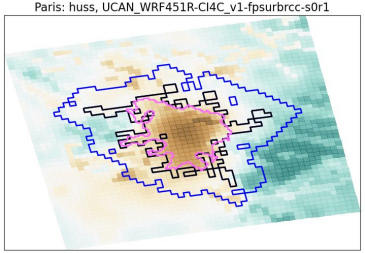


SLUCM

Paris: huss, CUNI_WRF451R-SFU1_v1-r1

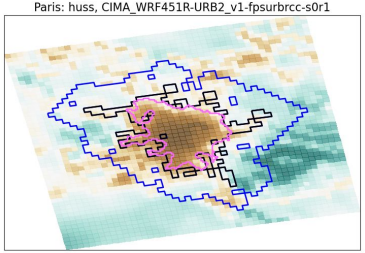


Paris: huss, UCAN_WRF451R-CI4C_v1-fpsurbrcc-s0r1



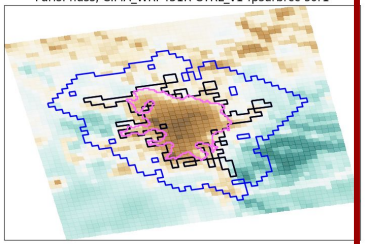
BEP

Paris: huss, CIMA_WRF451R-URB2_v1-fpsurbrcc-s0r1



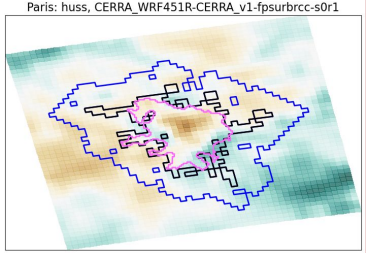
BEP+BEM

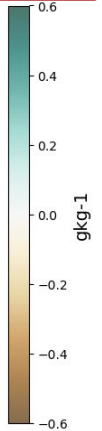
Paris: huss, CIMA_WRF451R-CTRL_v1-fpsurbrcc-s0r1



CERRA

Paris: huss, CERRA_WRF451R-CERRA_v1-fpsurbrcc-s0r1

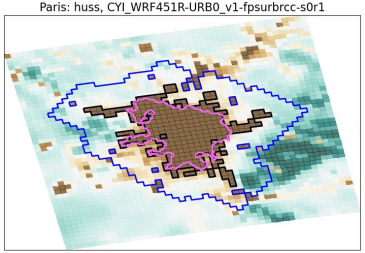




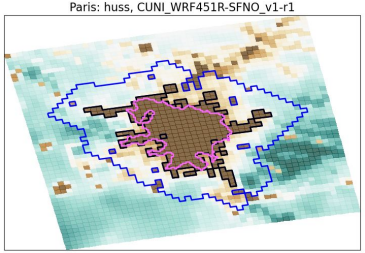
UDI over Paris: Sensitivity to Urban schemes

URB0

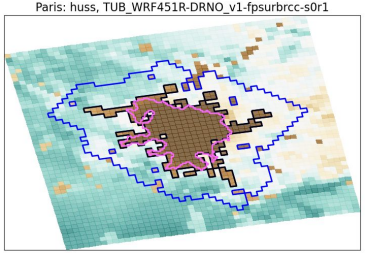
Paris: huss, CYI_WRF451R-URB0_v1-fpsurbrcc-s0r1



Paris: huss, CUNI_WRF451R-SFNO_v1-r1

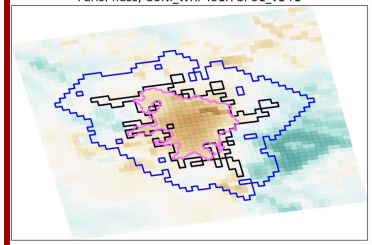


Paris: huss, TUB_WRF451R-DRNO_v1-fpsurbrcc-s0r1

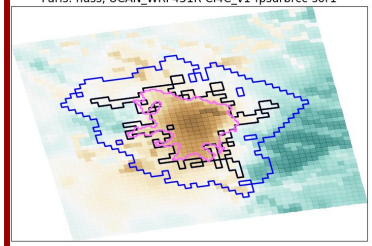


SLUCM

Paris: huss, CUNI_WRF451R-SFU1_v1-r1

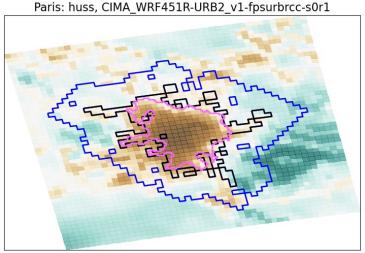


Paris: huss, UCAN_WRF451R-CI4C_v1-fpsurbrcc-s0r1



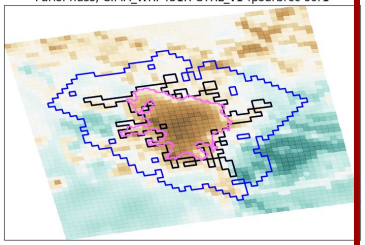
BEP

Paris: huss, CIMA_WRF451R-URB2_v1-fpsurbrcc-s0r1



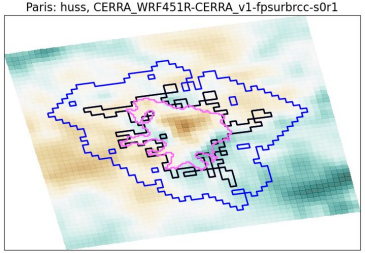
BEP+BEM

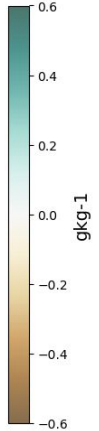
Paris: huss, CIMA_WRF451R-CTRL_v1-fpsurbrcc-s0r1



CERRA

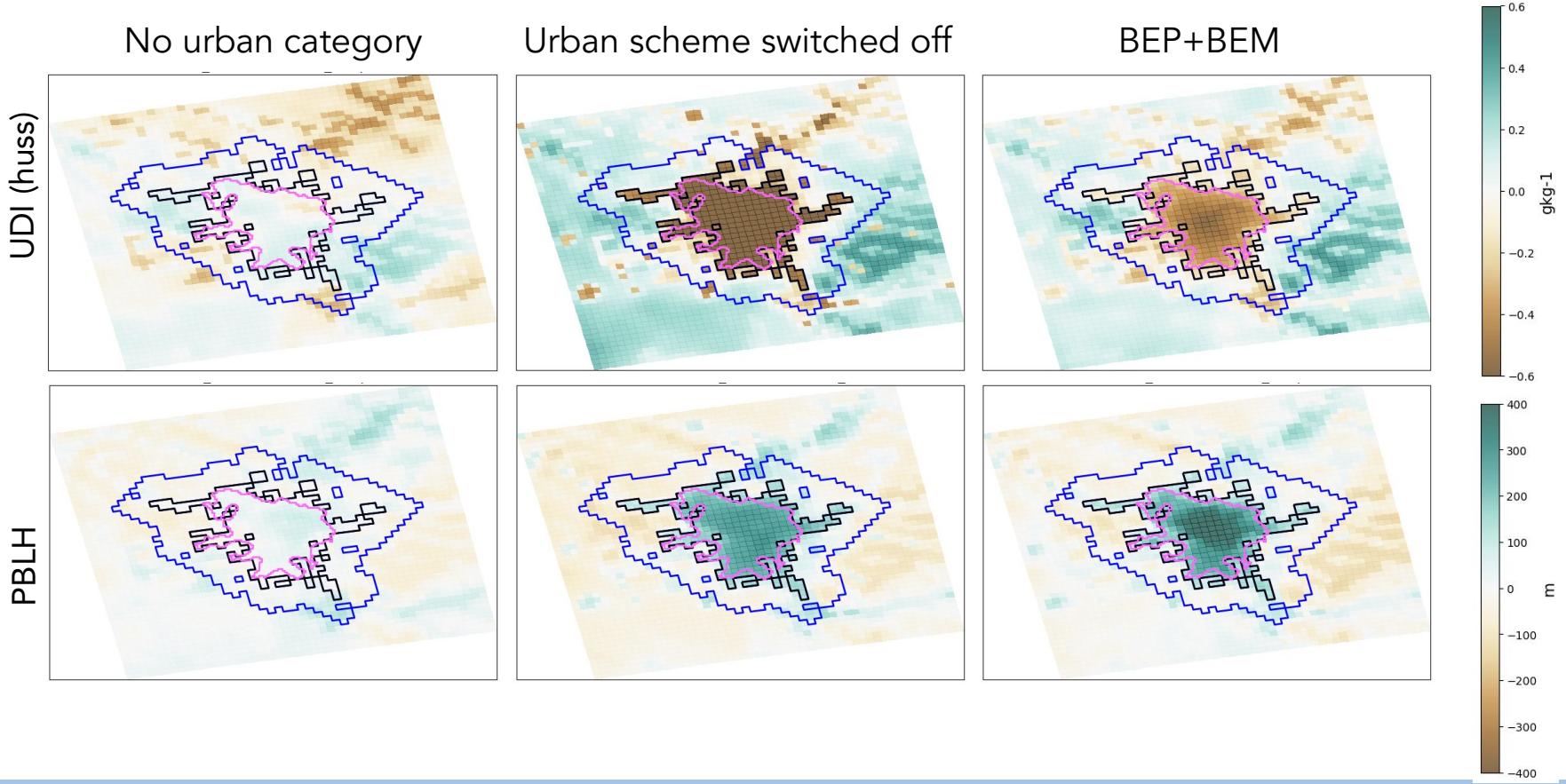
Paris: huss, CERRA_WRF451R-CERRA_v1-fpsurbrcc-s0r1



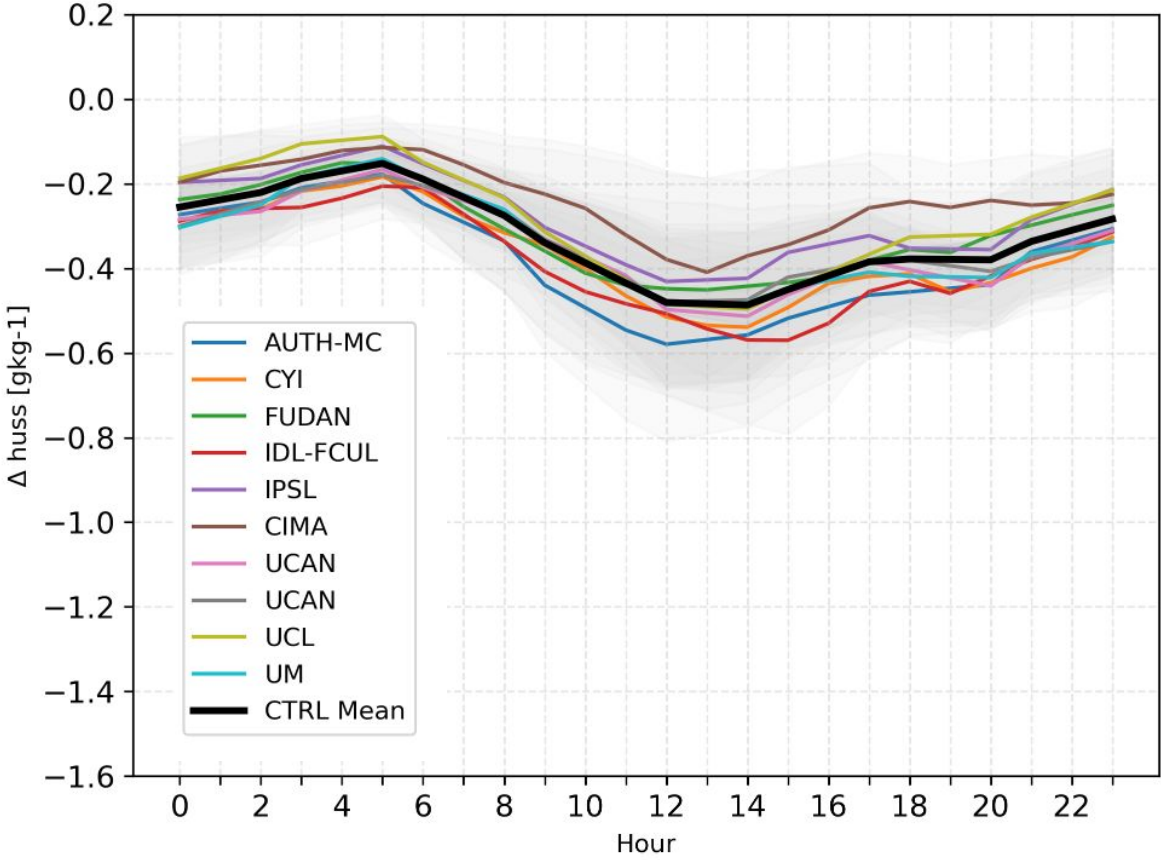


Urban parametrizations introduce heterogeneity within the urban areas

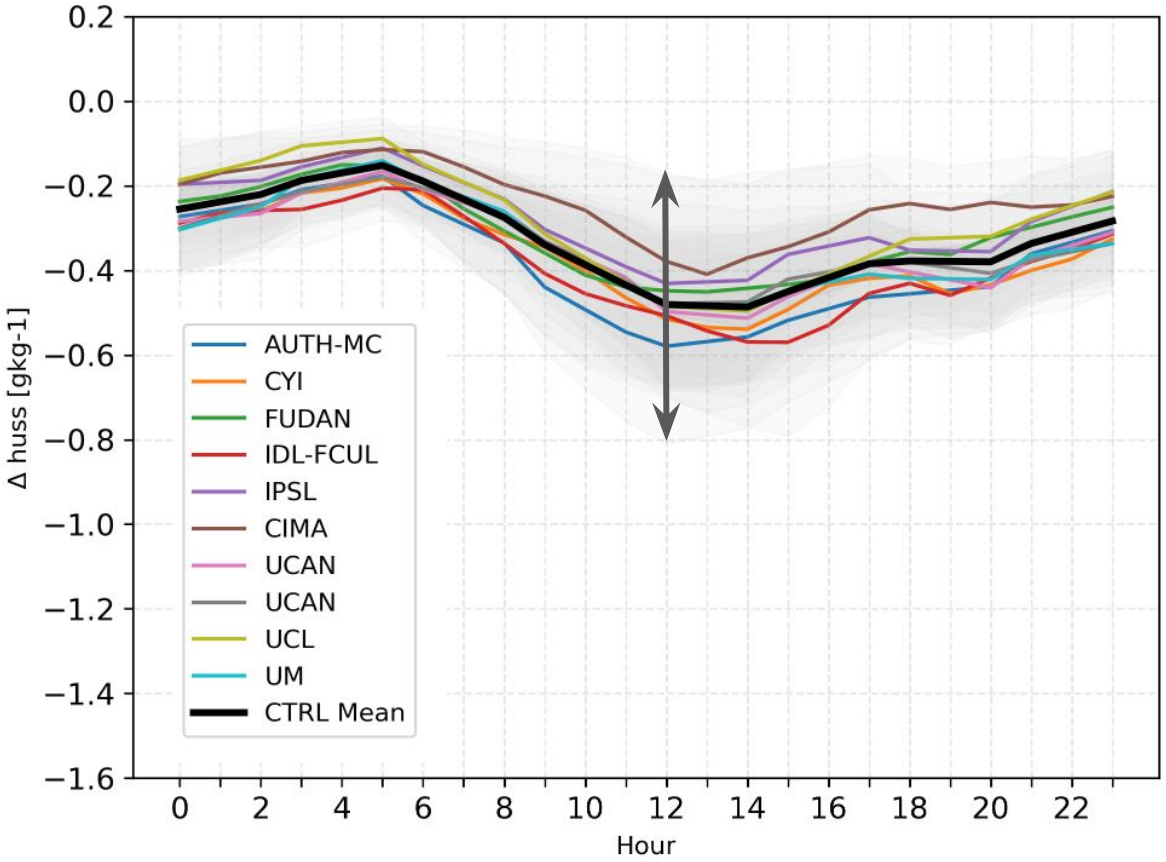
UDI and PBL height anomaly



UDI diurnal cycle: CTRL runs



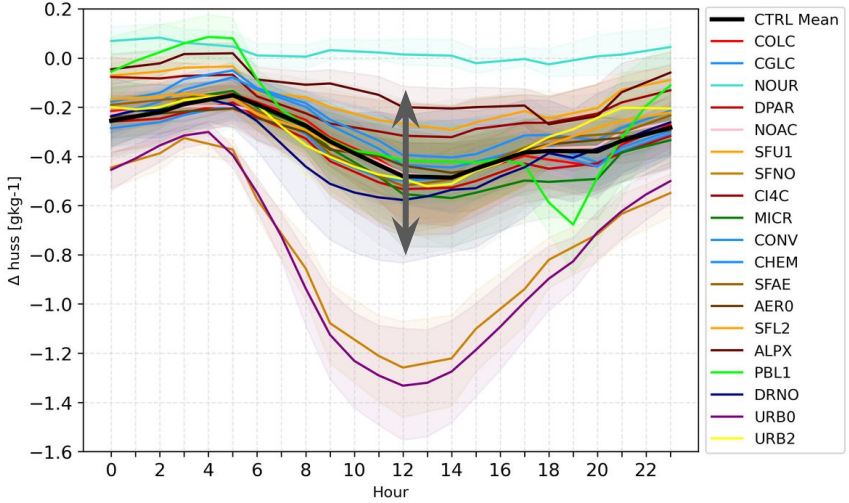
UDI diurnal cycle: CTRL runs



The spread among CTRL runs allows to quantify the model's **internal variability** introduced by different HPC platforms

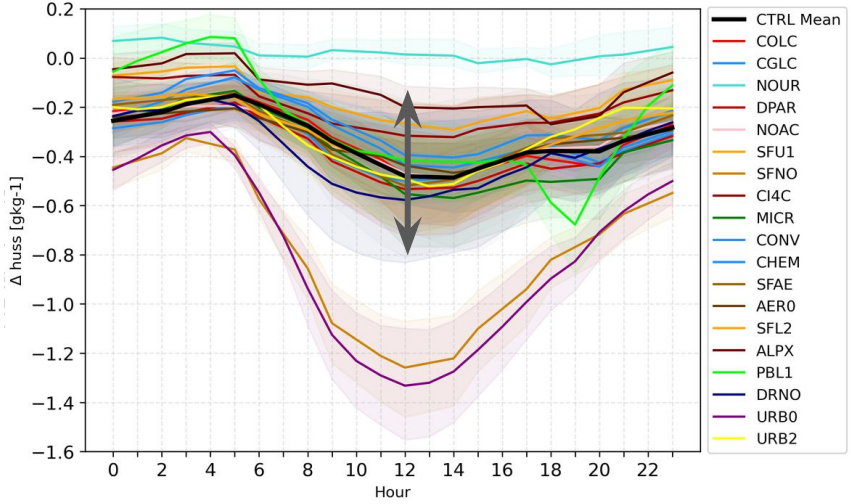
Results exceeding the CTRL spread show sensitivity to the model settings

UDI diurnal cycle



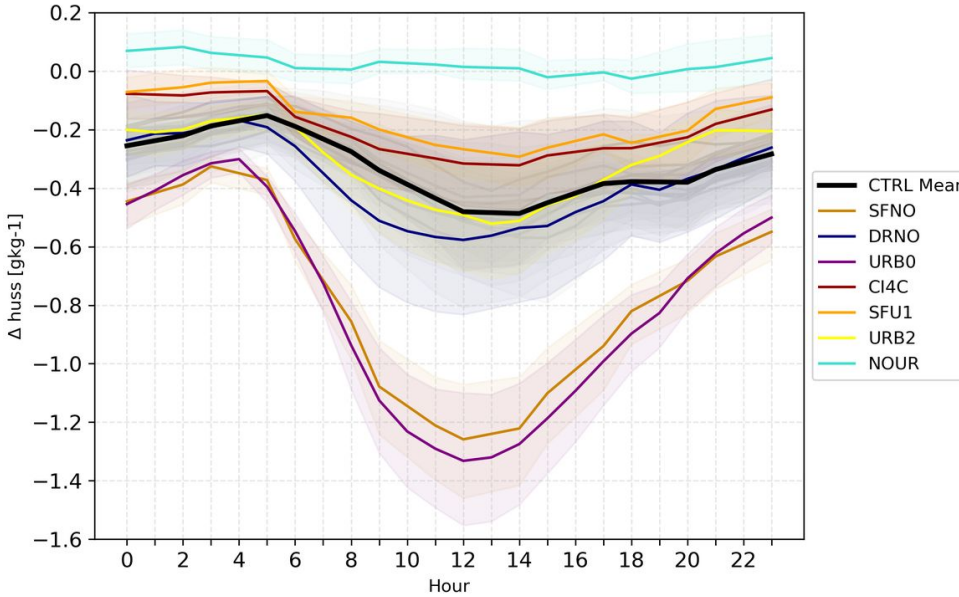
UDI: Highest sensitivity to urban parameterization scheme

UDI diurnal cycle

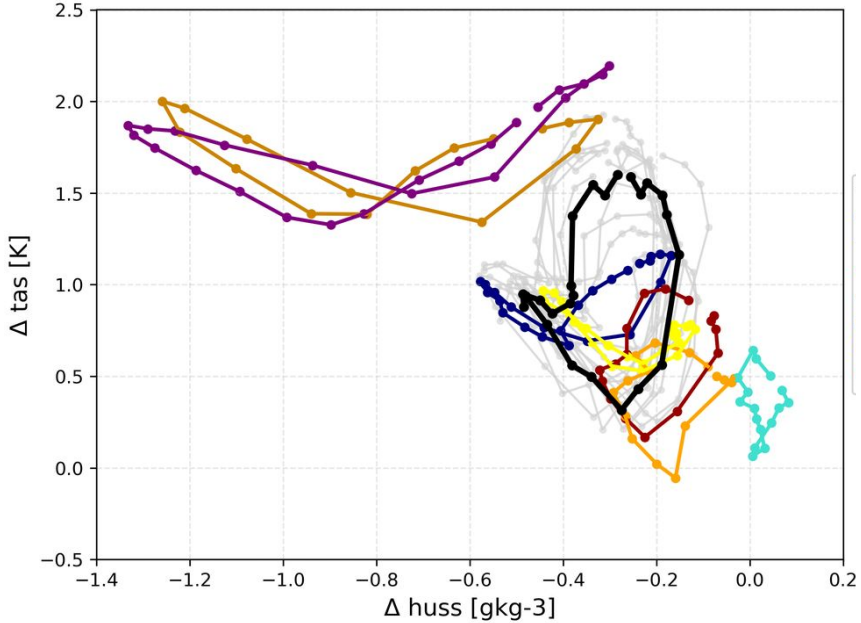


UDI: Highest sensitivity to urban parameterization scheme

UDI for the different urban parameterization scheme

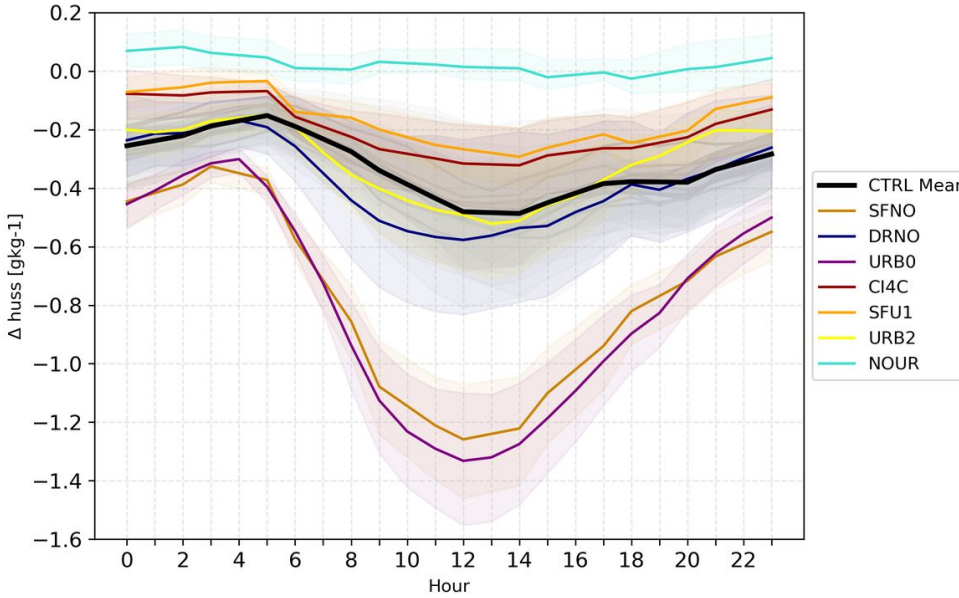


Coevolution of humidity and temperature anomalies



Sensitivity of **UDI-UHI coevolution** to urban schemes

UDI for the different urban parameterization scheme



Key findings

Urban parameterization scheme significantly alters key urban features at the convection-permitting scale
Introduced heterogeneity within the city translates to the PBL dynamics
More complex urban parameterizations required modifications for the longterm runs:

- Efficient data handling
- Temporal generalization of urban inputs

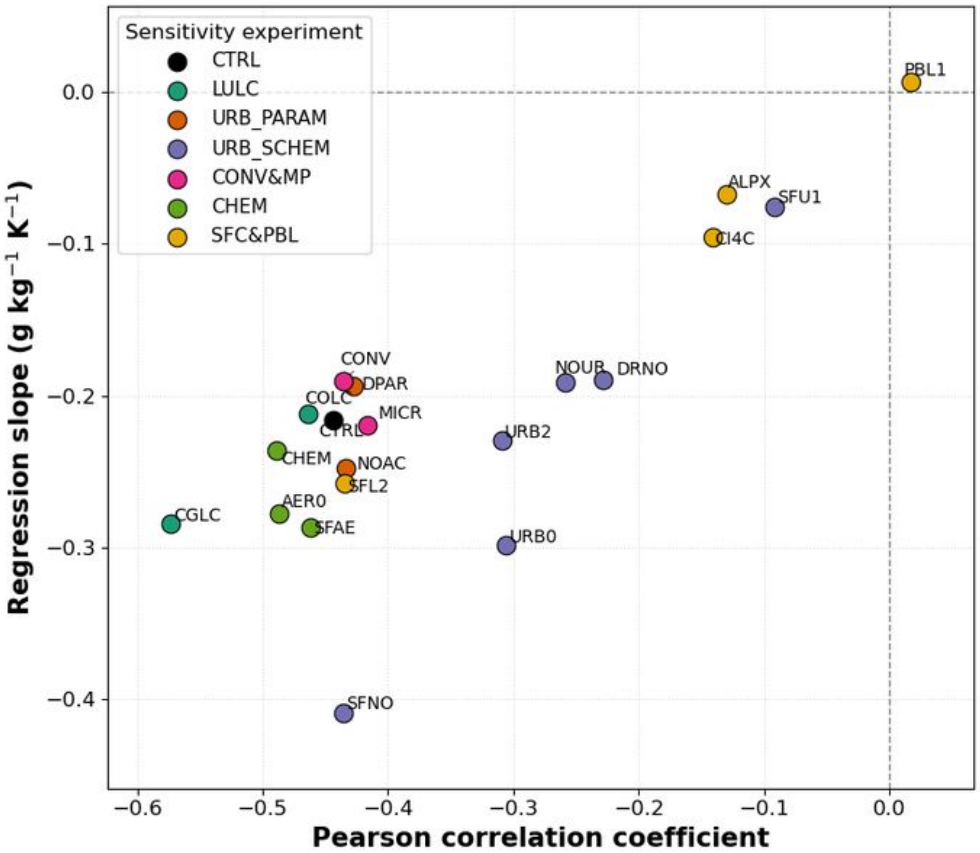
Future work

- Focus on relations of UDI to the PBL height and evaporative fraction
- Include station observations into the analysis
- Extend the analysis to the available STAGE-1 evaluation 10-year run

Thank you for your attention

J.M gratefully acknowledges the support of Horizon Europe project Impetus4Change (I4C, grant id. 101081555)

UDI vs UHI correlations



UHI-UDI mostly negative correlation

Magnitude of response varies a lot depending on model configuration (~0.01 -> ~0.57)

Many experiments cluster around correlation ≈ -0.5 to -0.3 and slope ≈ -0.3 to -0.1.

PBL sensitivity experiments and and those with SLUCM

UDI vs UHI correlations