Urban induced changes on precipitation

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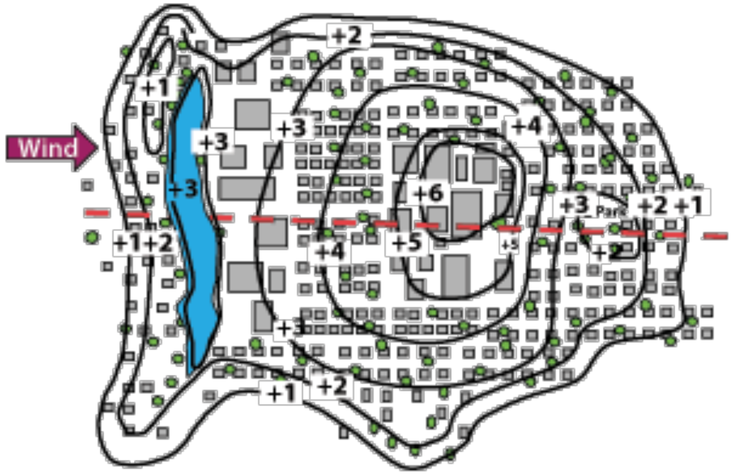
Universitat de les Illes Balears, Palma. Spain.

Universitat de les Illes Balears
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
AGENCIA ESTATAL DE INVESTIGACIÓN

Natural/Rural vs Urban landscape

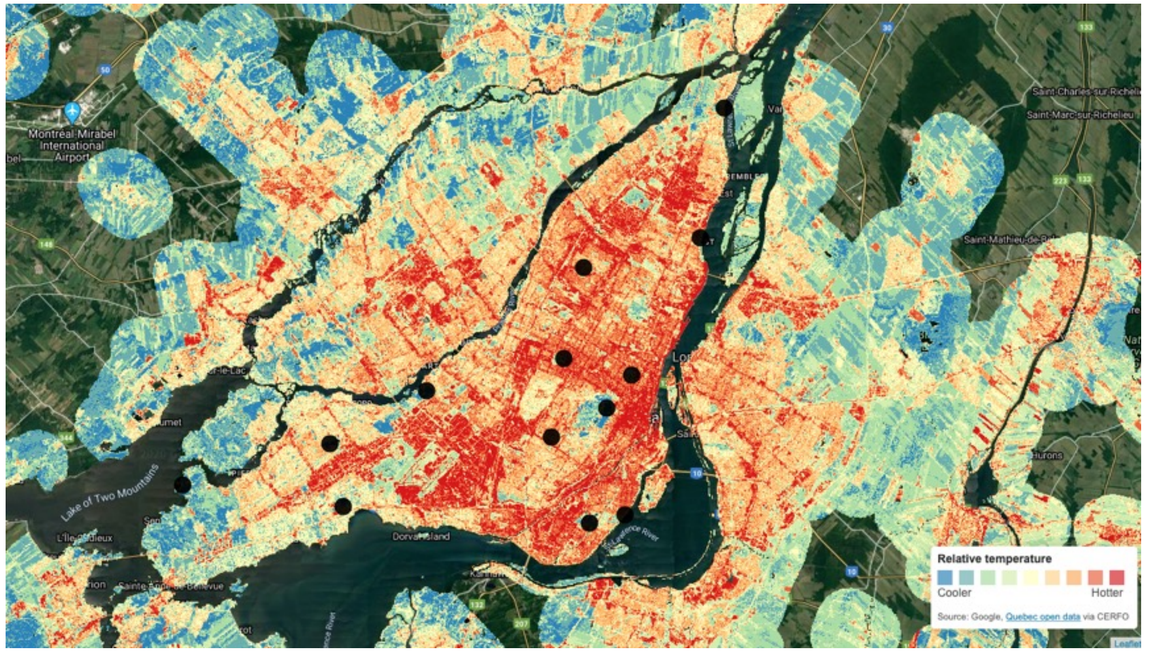
Urban Heat Island

Temperature in cities



Source: US Environmental Protection Agency, from Voogt 2000

Urban Heat Island in Montréal



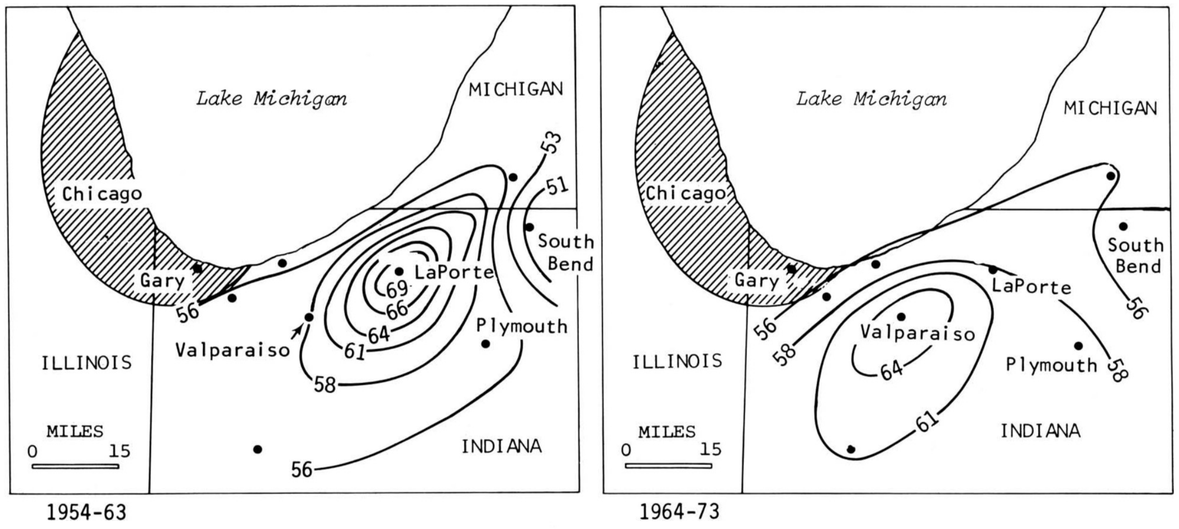
Source: CERFO

From Urban Heat Island to effects on rainfall

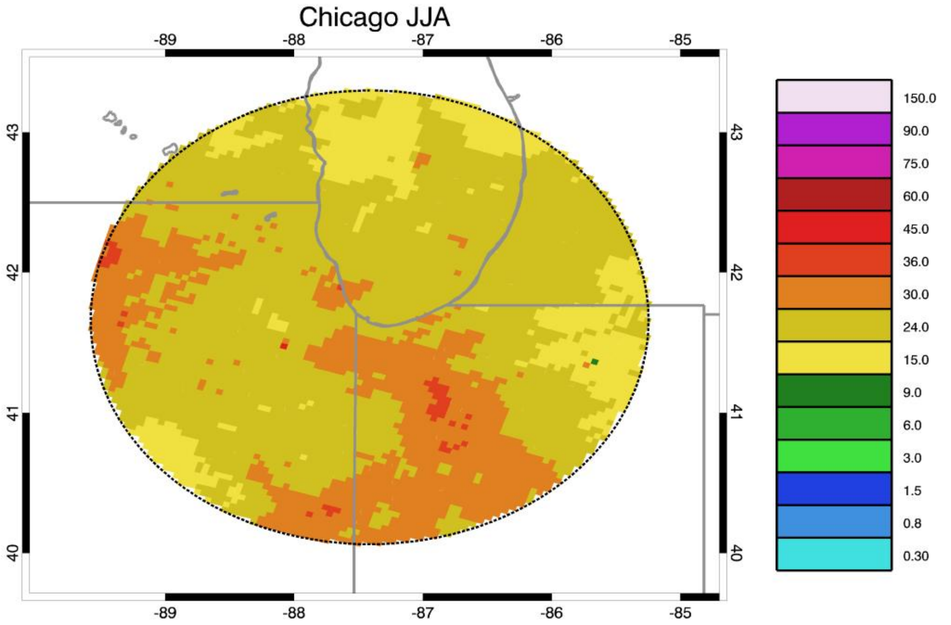
First evidences:

Horton (1921) - Albany

La Porte anomaly (Changnon 1968)



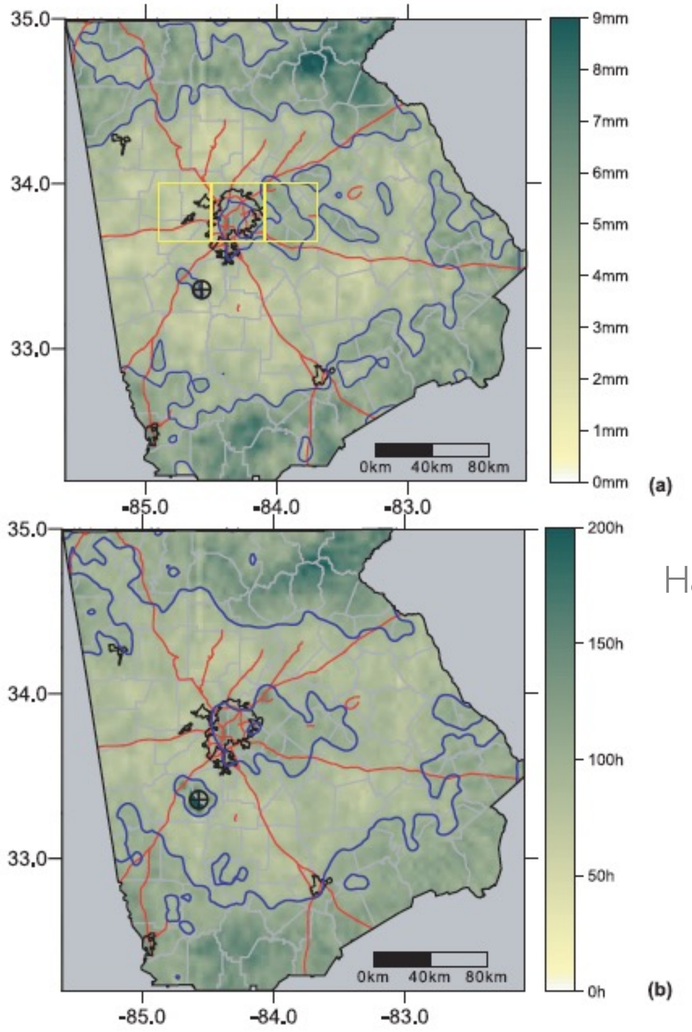
Changnon 1980, BAMS



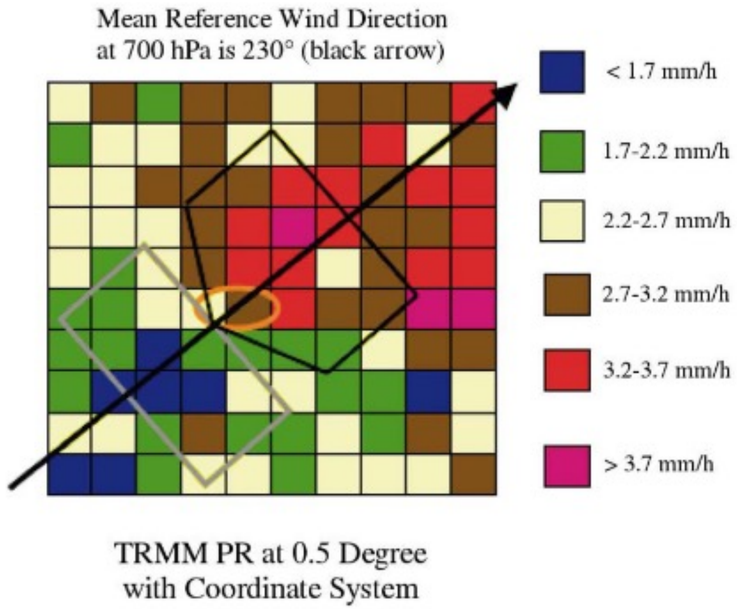
Revisited by Nigoyi (2010)

10-y average

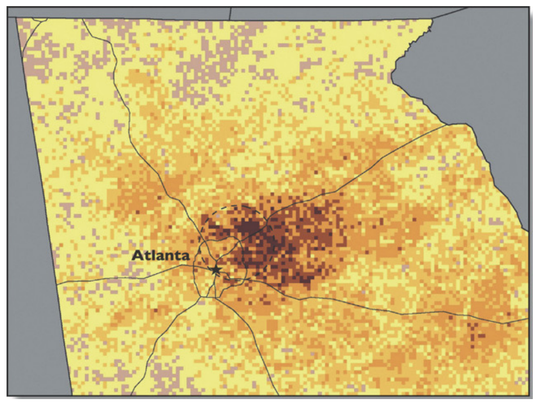
From Urban Heat Island to effects on rainfall



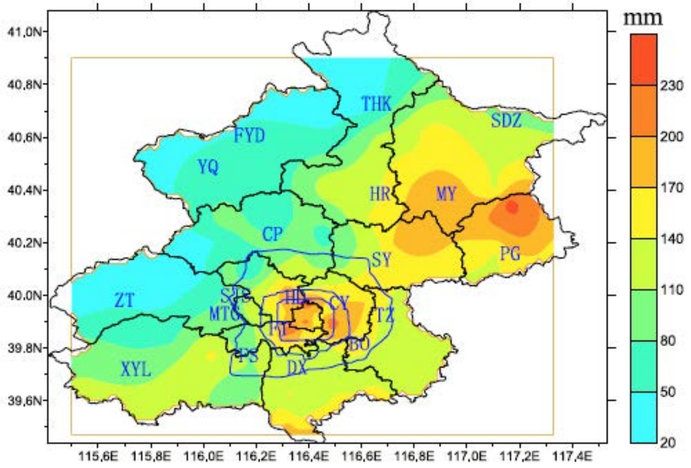
Mote et al. 2007 – GRL. Atlanta



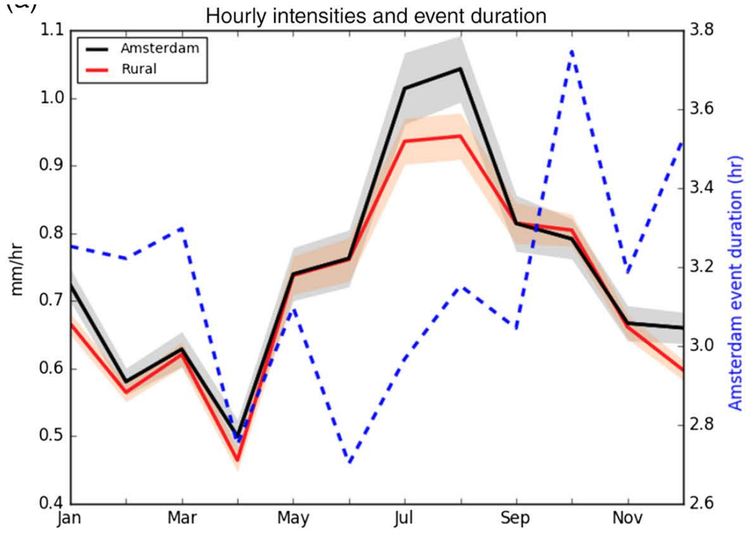
Han et al. 2017; Shepherd and Burian 2003. Houston



Bentley et al. 2010

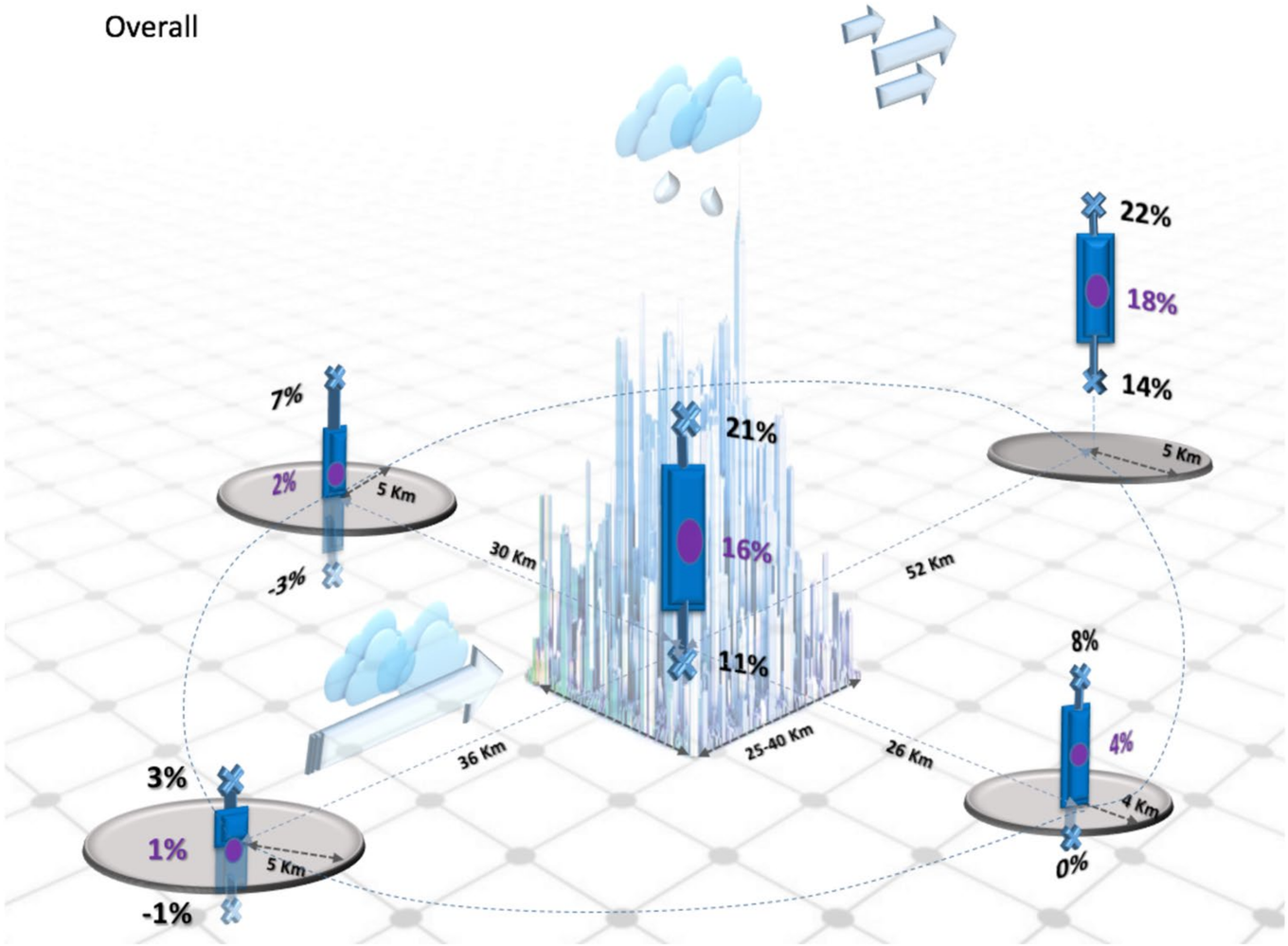


Yang et al. 2017 – JCLIM. Beijing



Manola et al. 2020 – IJC. Amsterdam/

From Urban Heat Island to effects on rainfall



Liu and Niyogi 2019 Sci Rep.

Mechanisms of urban-induced effects on rainfall

Proposed mechanisms:

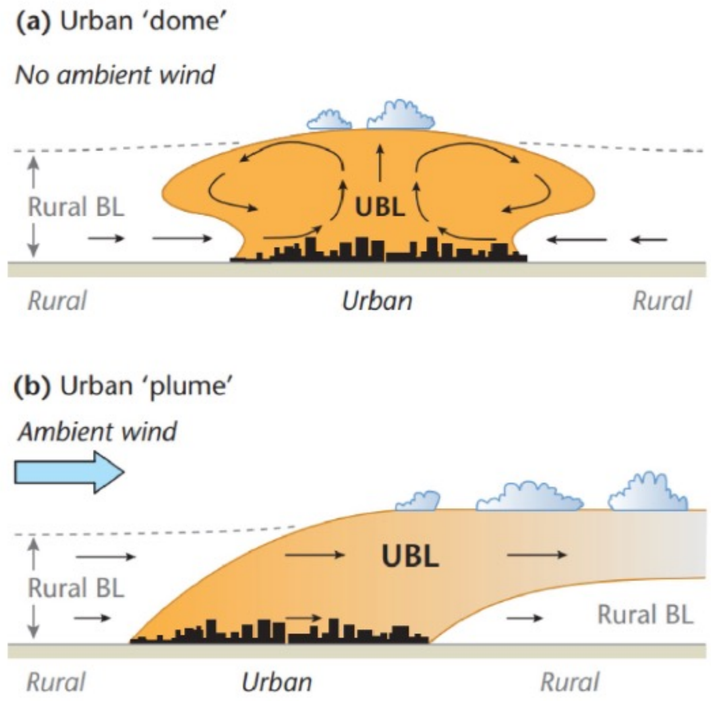
1) Urban Heat Island → Near-surface convergence → updrafts that can initiate moist convection

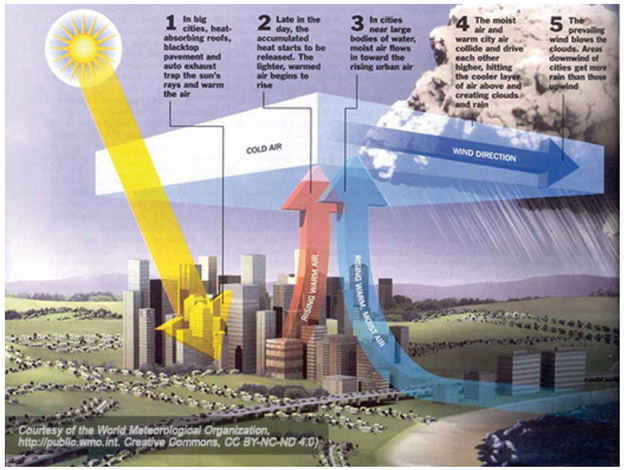
2) Modification of microphysical processes: urban aerosols concentrations alter precipitation

3) Cities are physical obstacles that can alter systems (splitting, deviating, etc).

4) Large surface roughness → increased near-surface convergence

5) Interplay with local circulations: sea-breeze, mountain-valley breezes

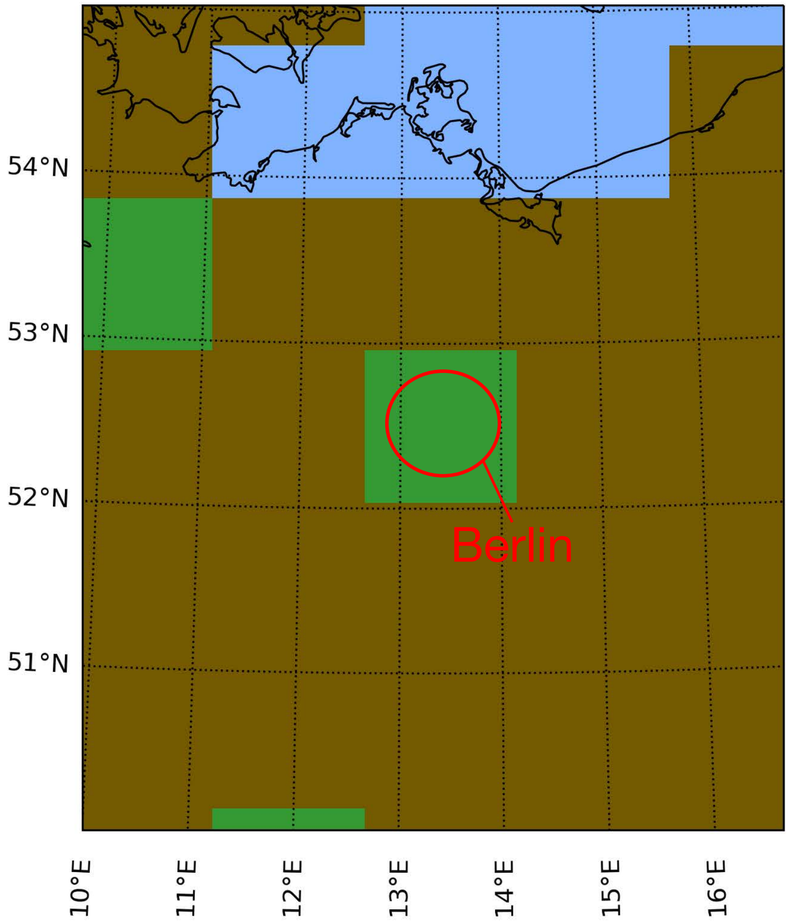




Cities in regional climate models

Representing cities in climate models

GCM (~100 km)

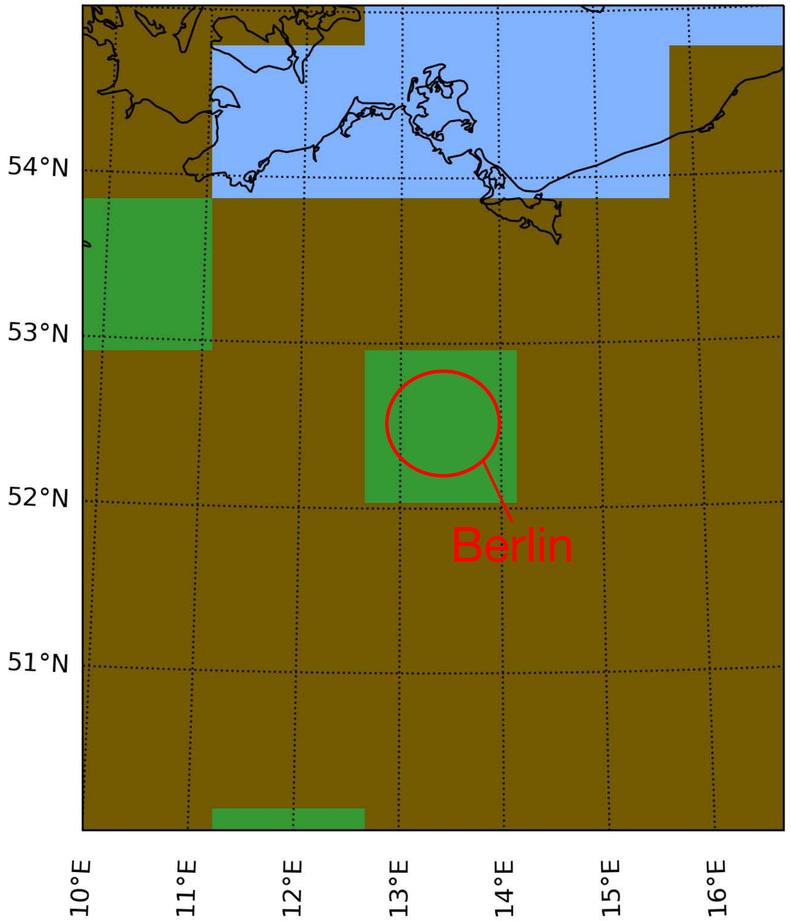


No cities at all

- GCM primary source of Climate change information
- But too coarse to represent cities

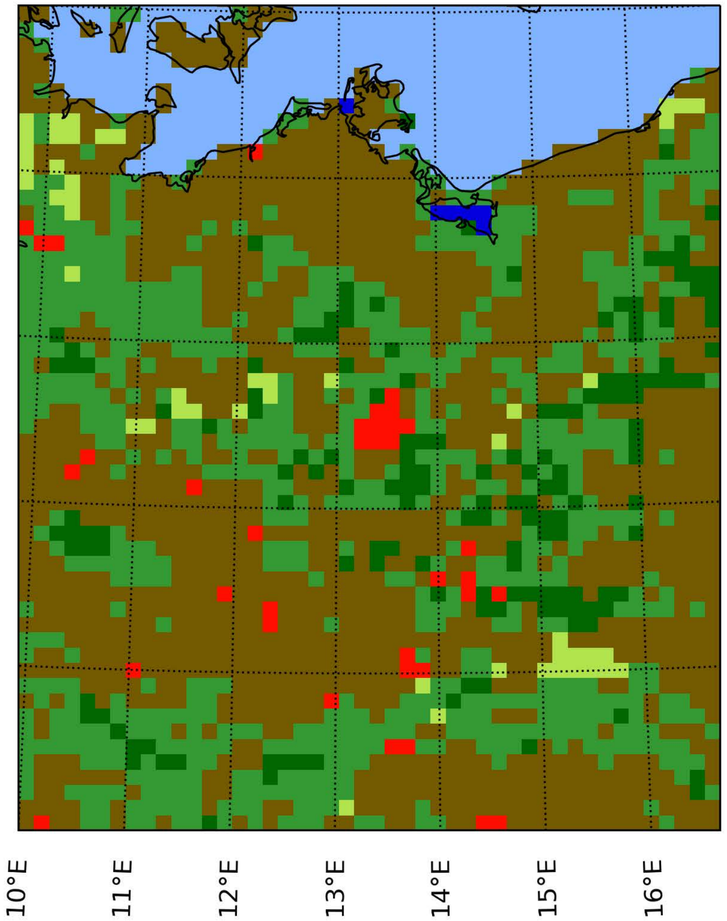
Representing cities in climate models

GCM (~100 km)



No cities at all

RCM (~10 km)

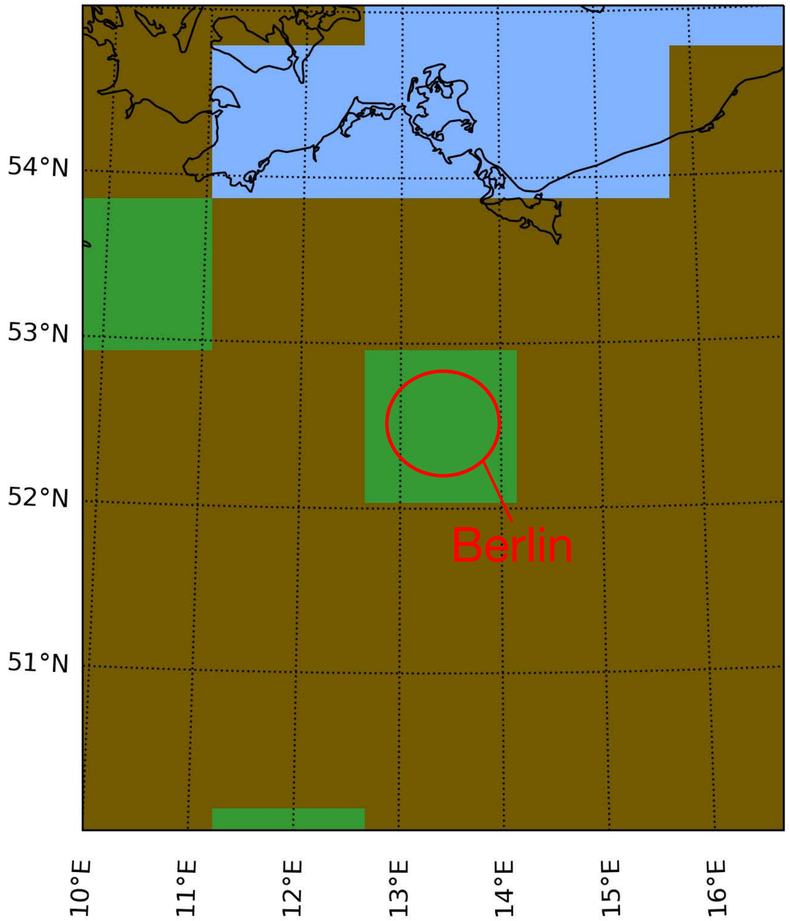


Only urban land use

- RCM 10k capture some features of the city, but cities represented only as different land use.

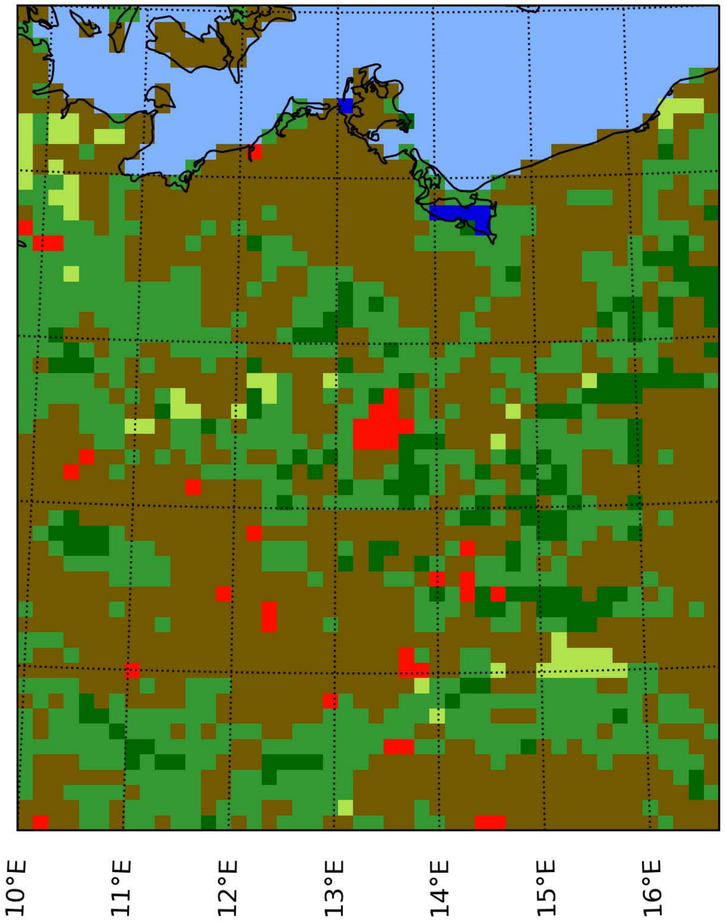
Representing cities in climate models

GCM (~100 km)



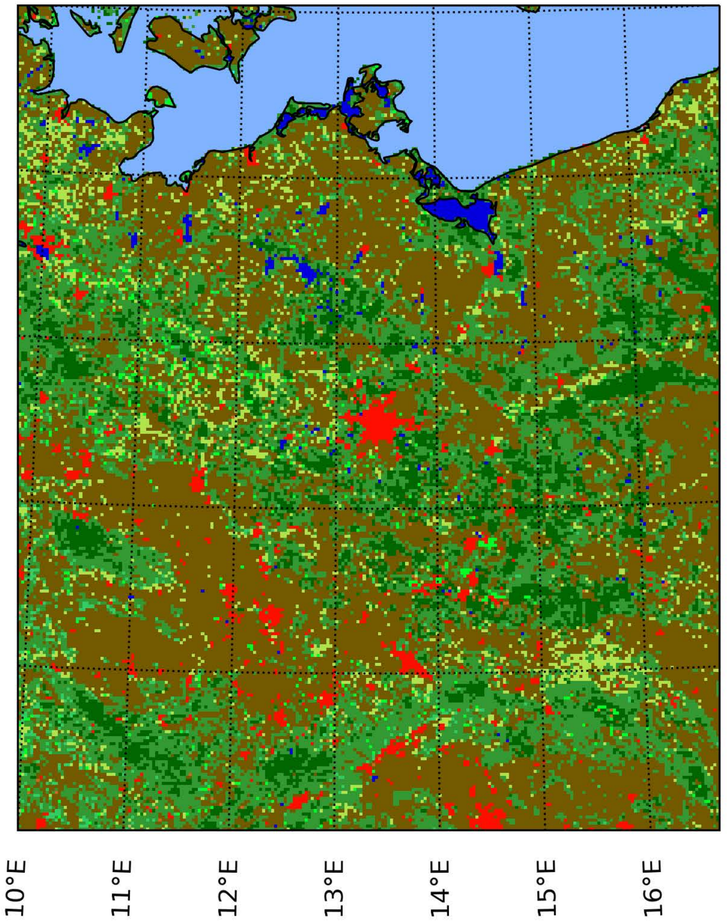
No cities at all

RCM (~10 km)



Only urban land use

CPM (~1 km)



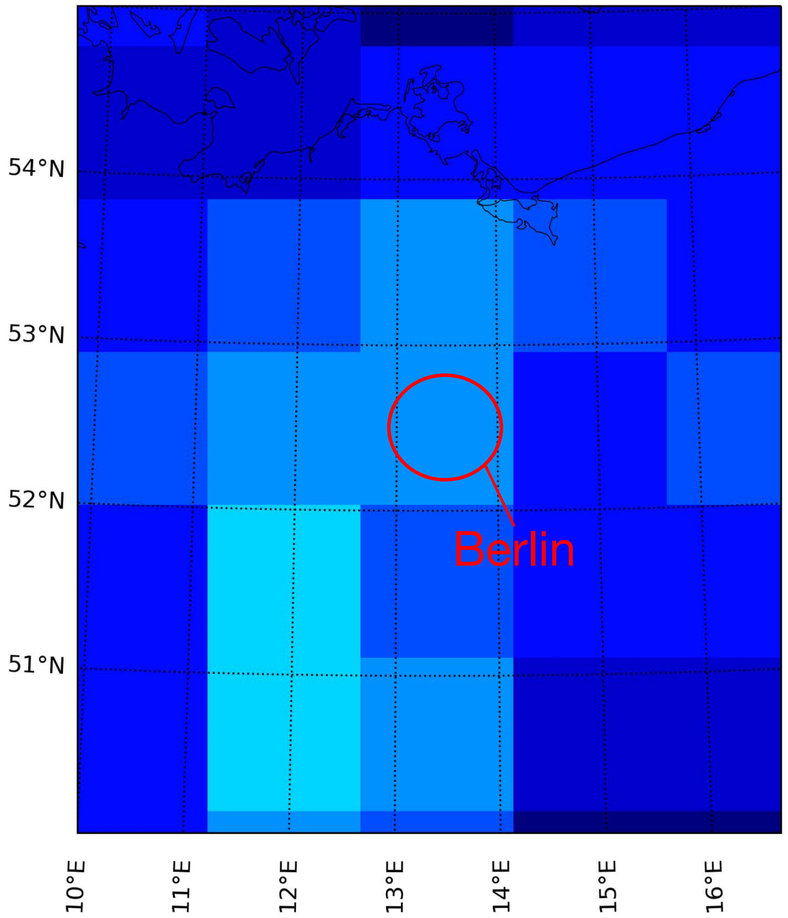
Urban Canopy Model

Representing cities in climate models

GCM (~100 km)

RCM (~10 km)

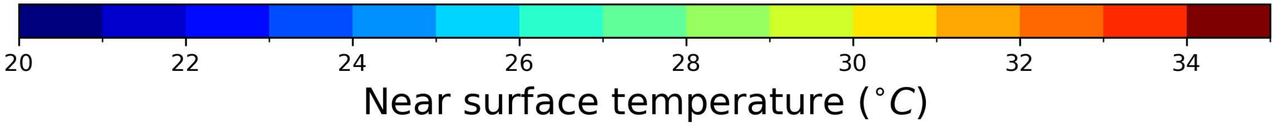
CPM (~1 km)



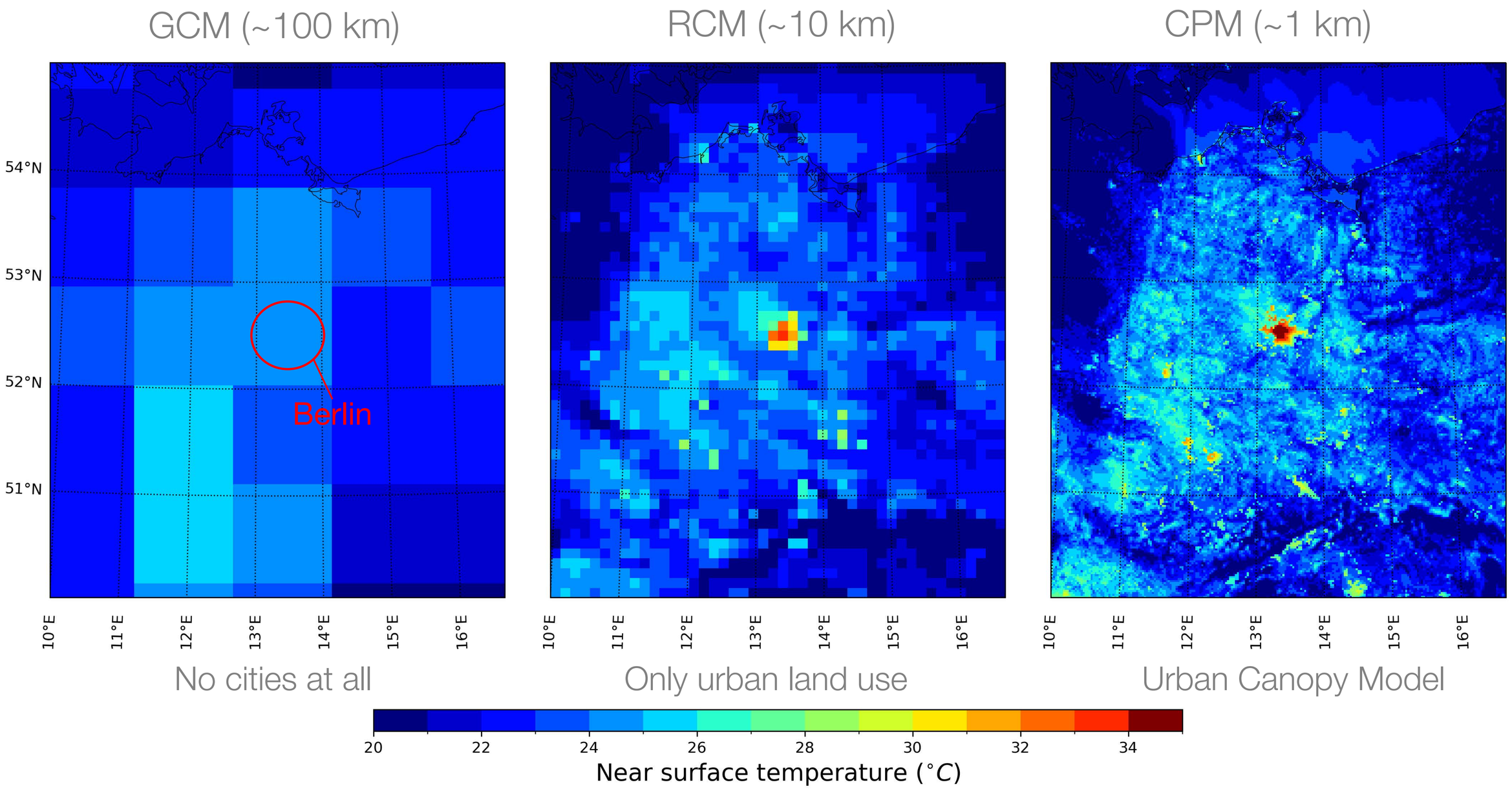
No cities at all

Only urban land use

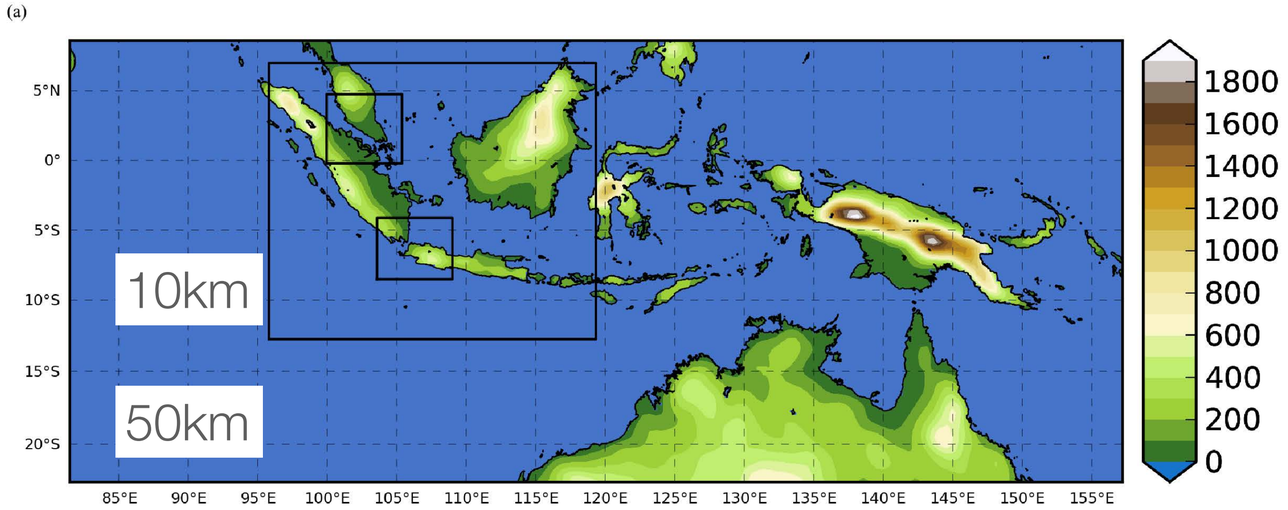
Urban Canopy Model

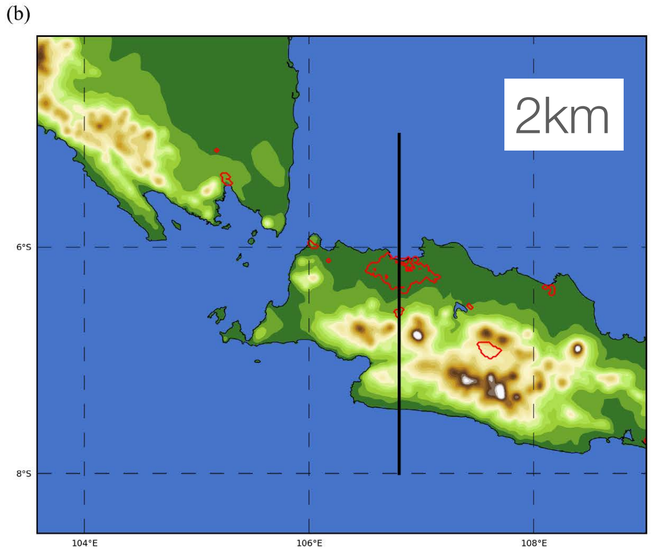


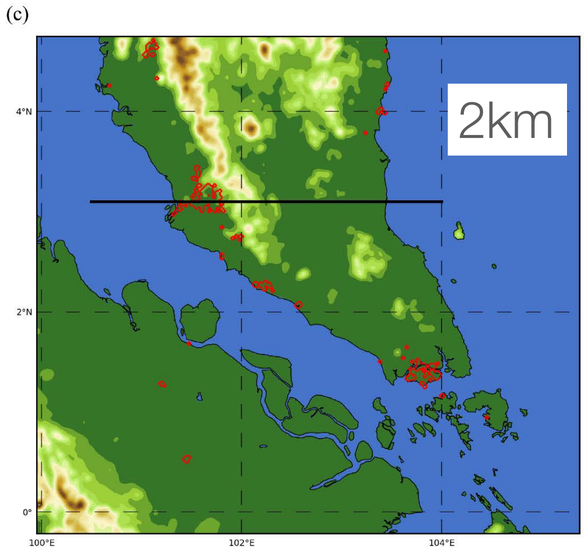
Representing cities in climate models

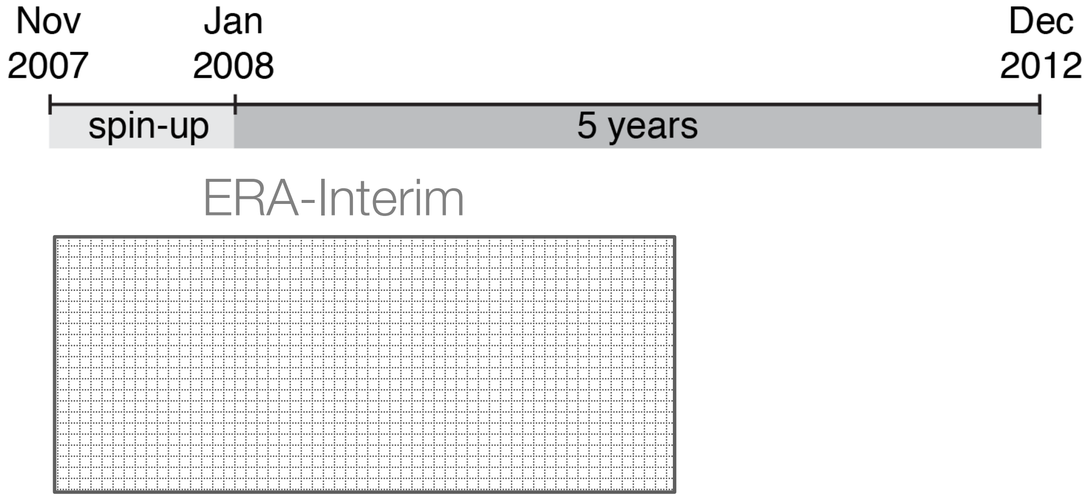


Effects of cities on rainfall as seen by models

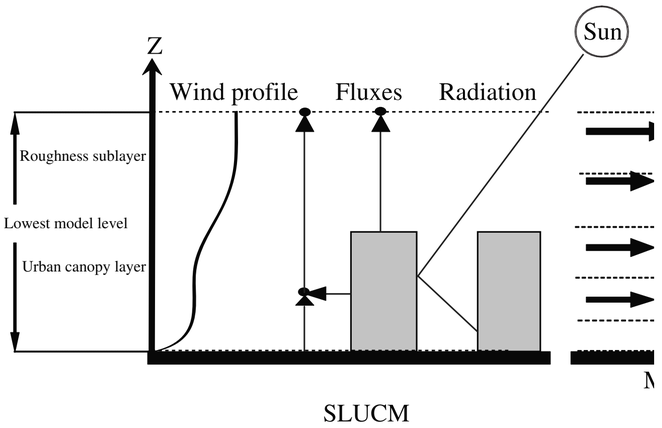








No convection scheme



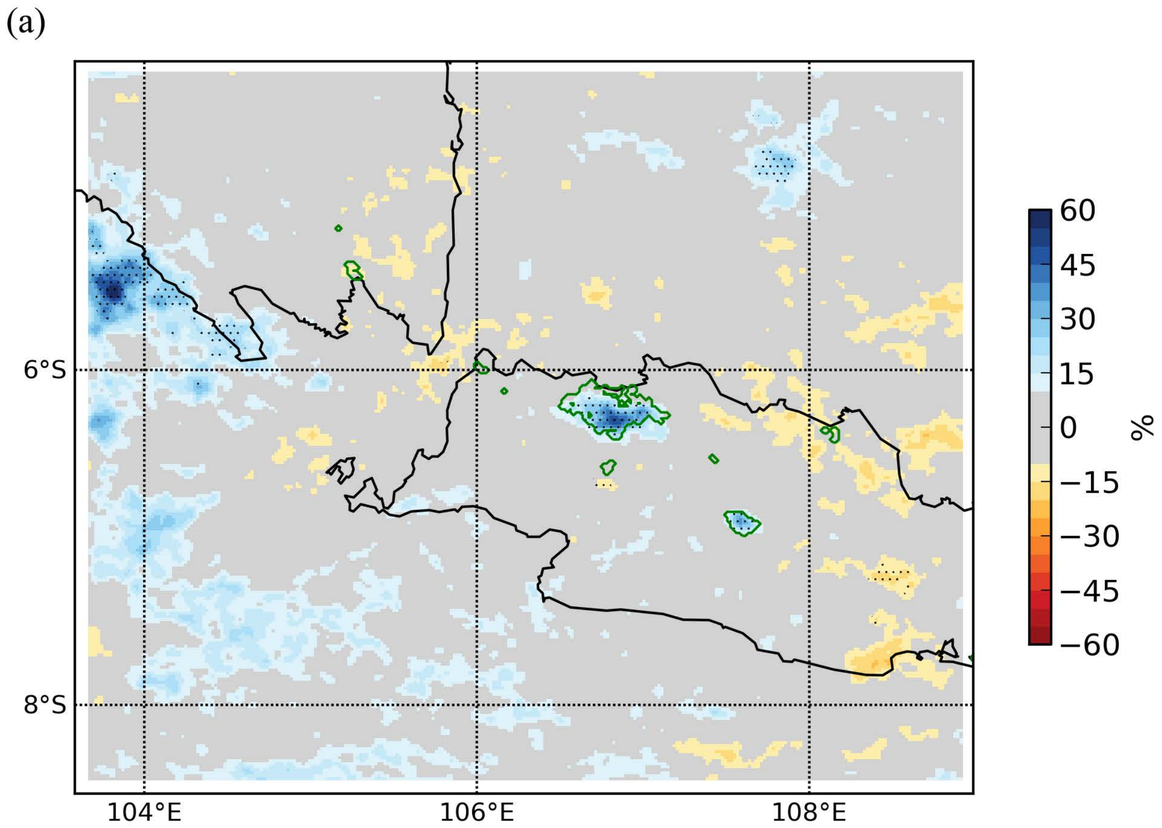
Chen et al. 2011 IJC
Kusaka et al. 2001 BLM

Argüeso et al. 2016 Clim Dyn

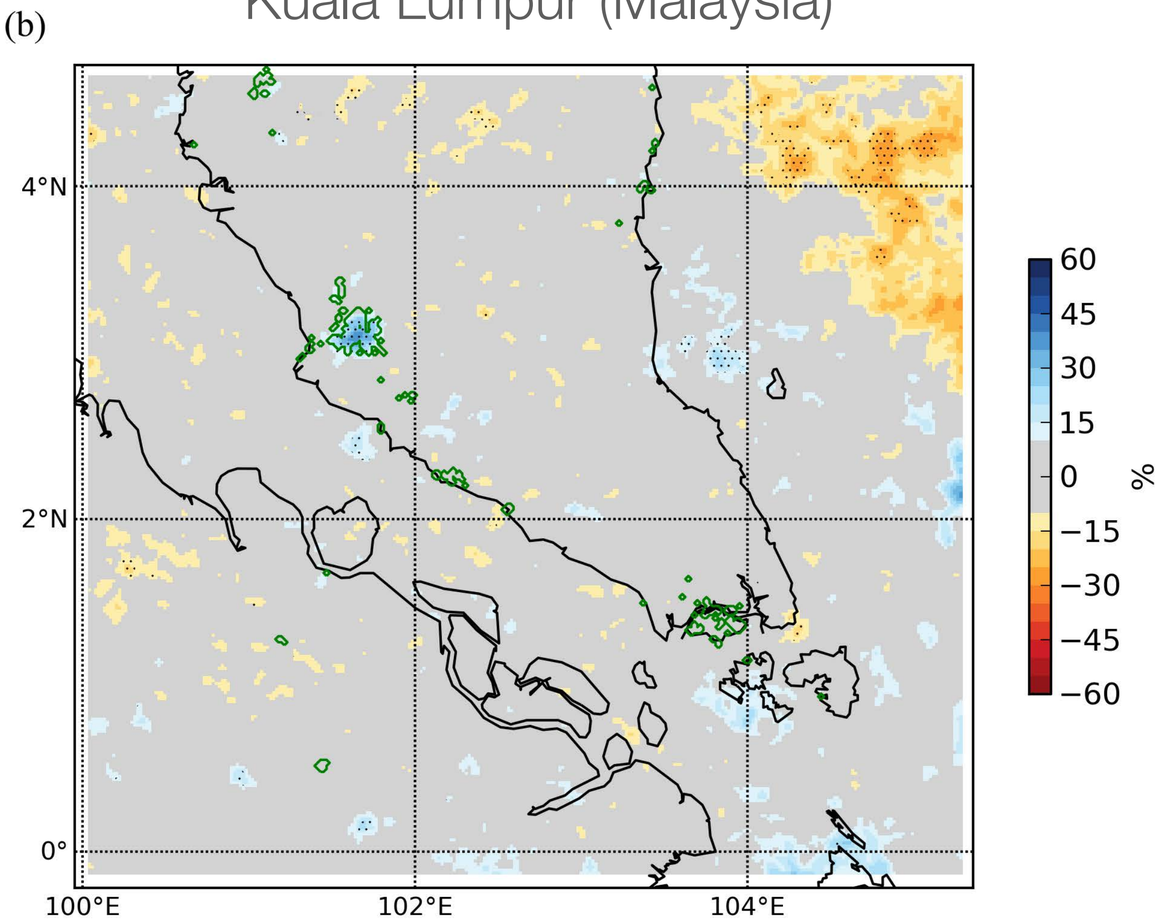
Effects of cities on rainfall as seen by models

Mean precipitation

Jakarta (Indonesia)



Kuala Lumpur (Malaysia)

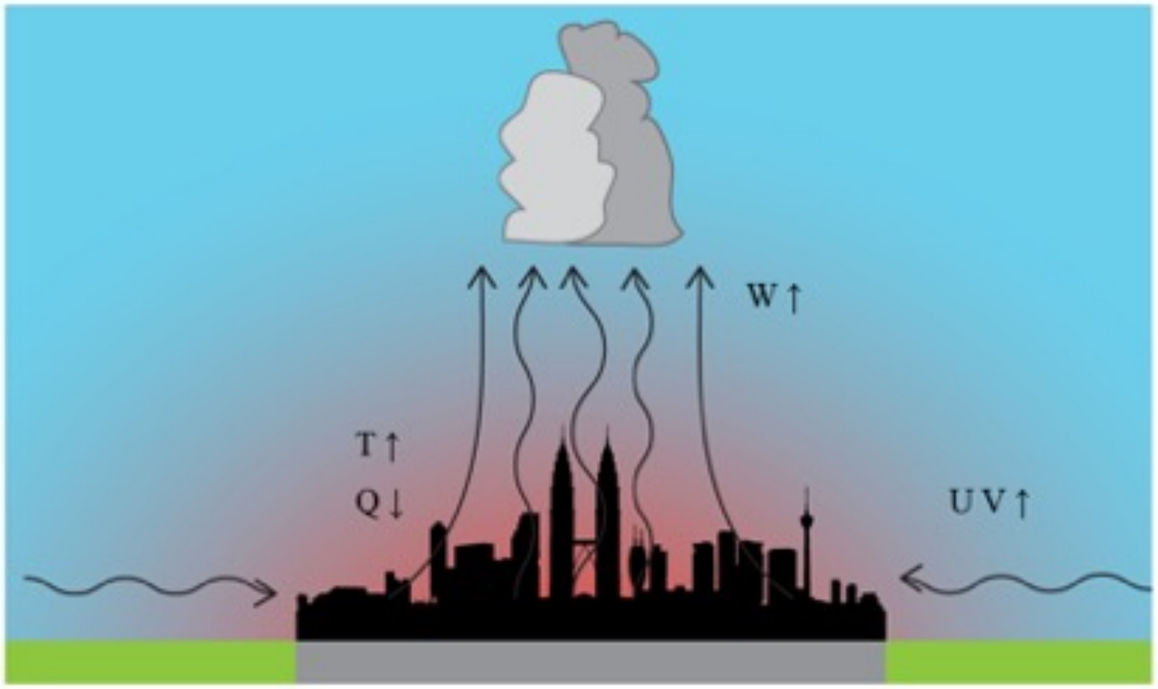


5 years (2008-2012)

Difference = 100 * (CTL-RUR)/RUR

Argüeso et al. 2016 Clim Dyn

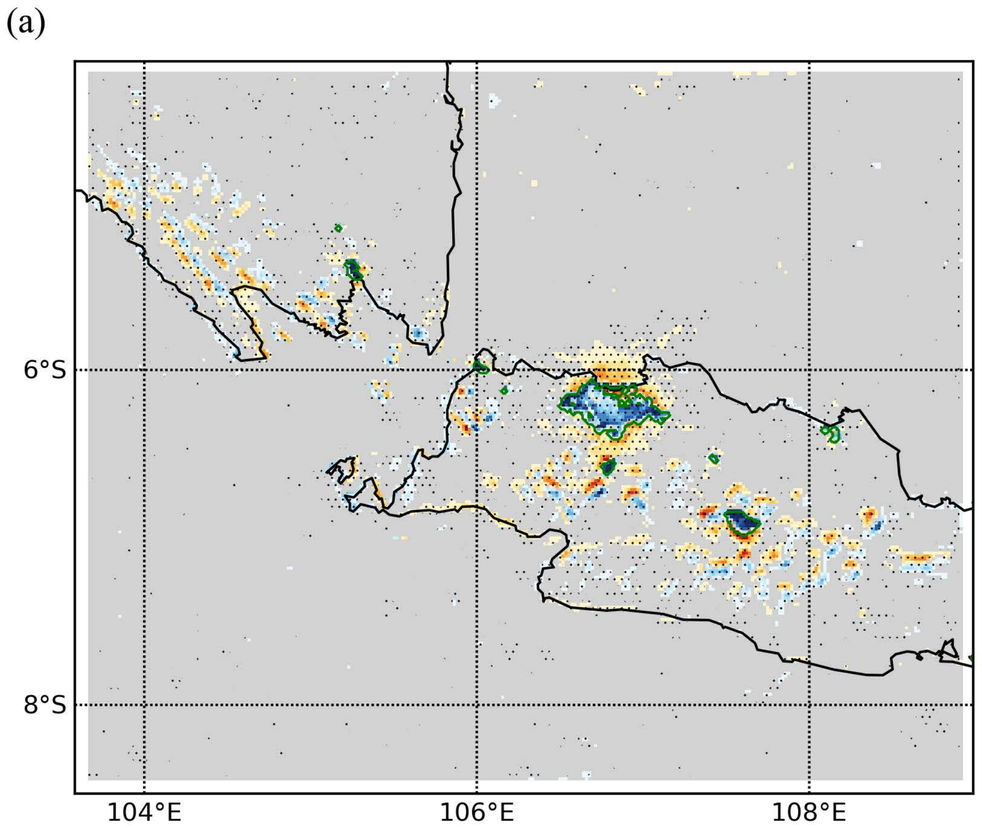
Urban-induced rainfall mechanisms in models



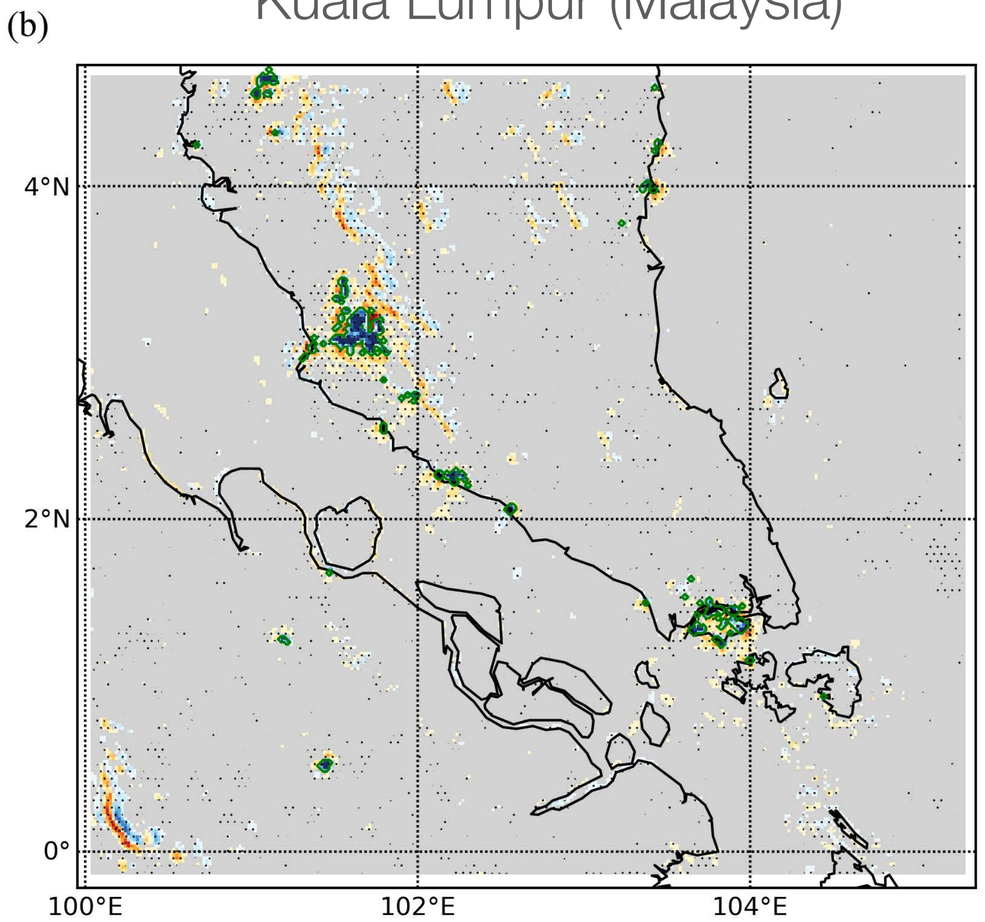
MOISTURE FLUX CONVERGENCE ↑ ??

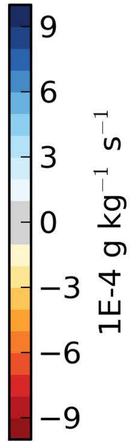
Increased moisture flux convergence

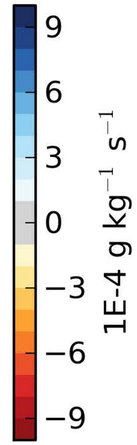
Jakarta (Indonesia)



Kuala Lumpur (Malaysia)





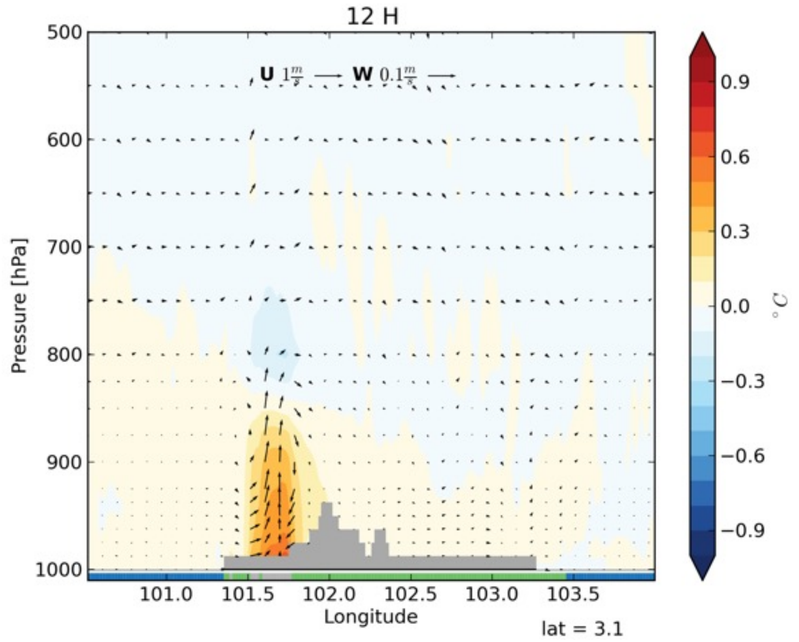


5 years (2008-2012)
Difference = 100 * (CTL-RUR)/RUR

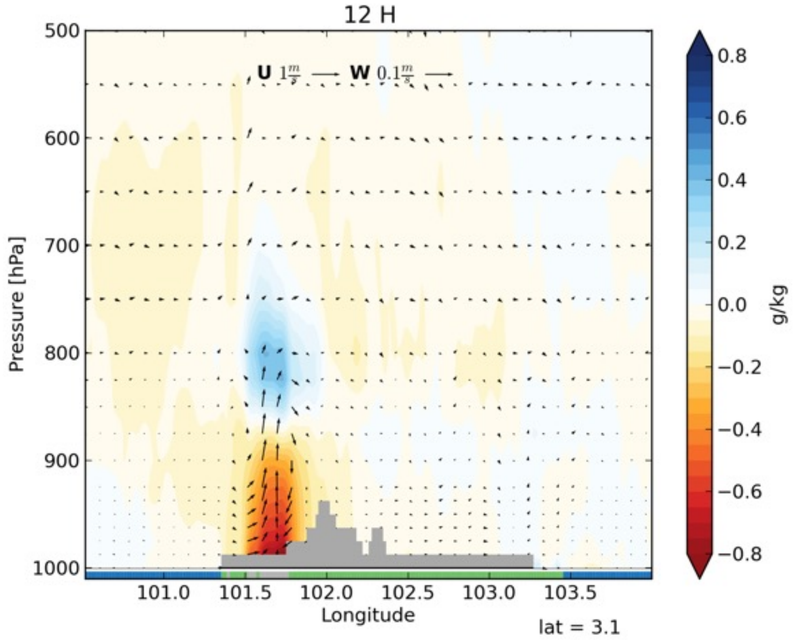
Argüeso et al. 2016 Clim Dyn

Effects of cities on rainfall as seen by models

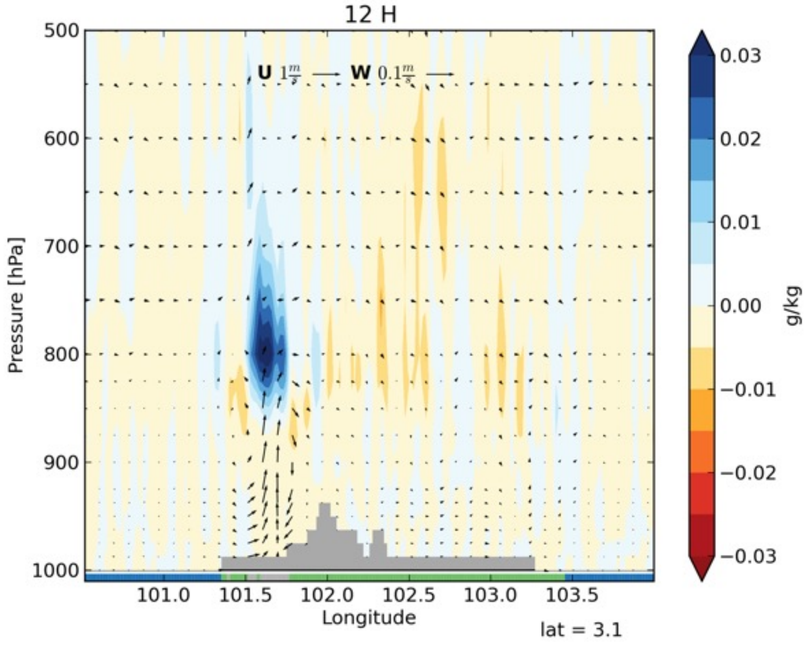
Kuala Lumpur (Malaysia) at 12H LST



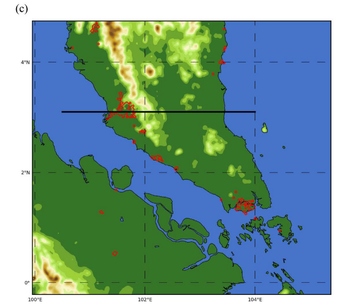
Temperature



Humidity
(mixing ratio)

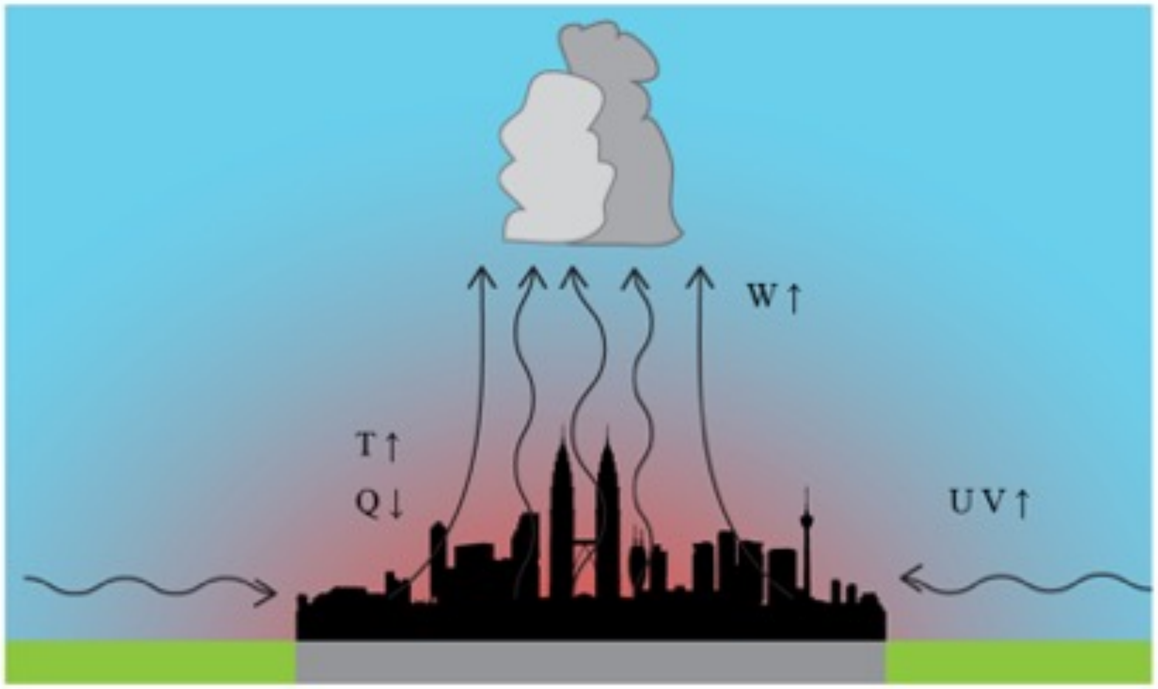


Cloud Mixing
Ratio



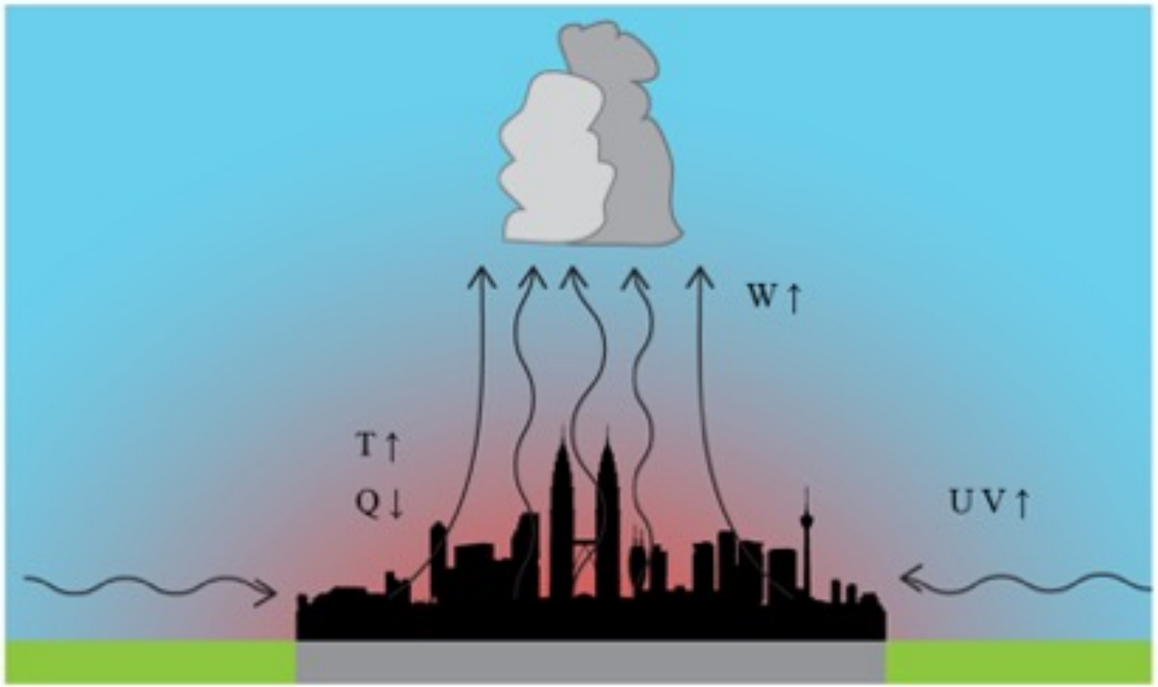
Argüeso et al. 2016 Clim Dyn

Urban-induced rainfall mechanisms in models

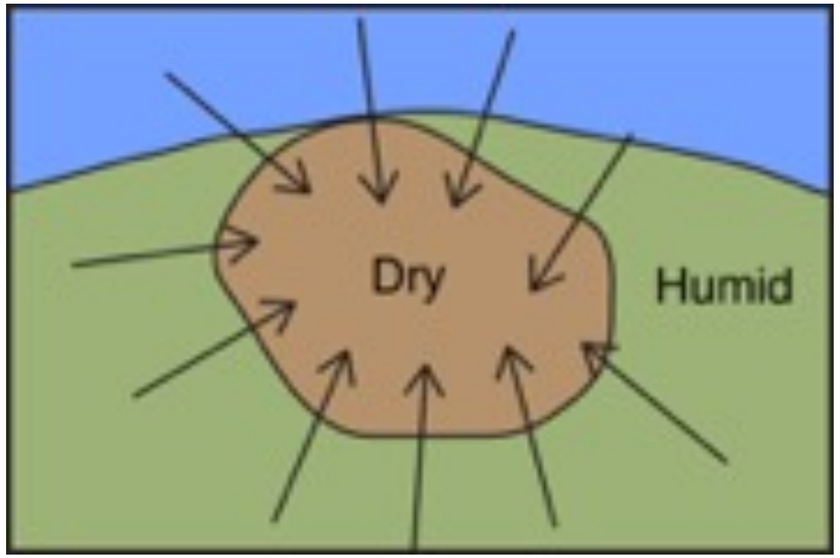


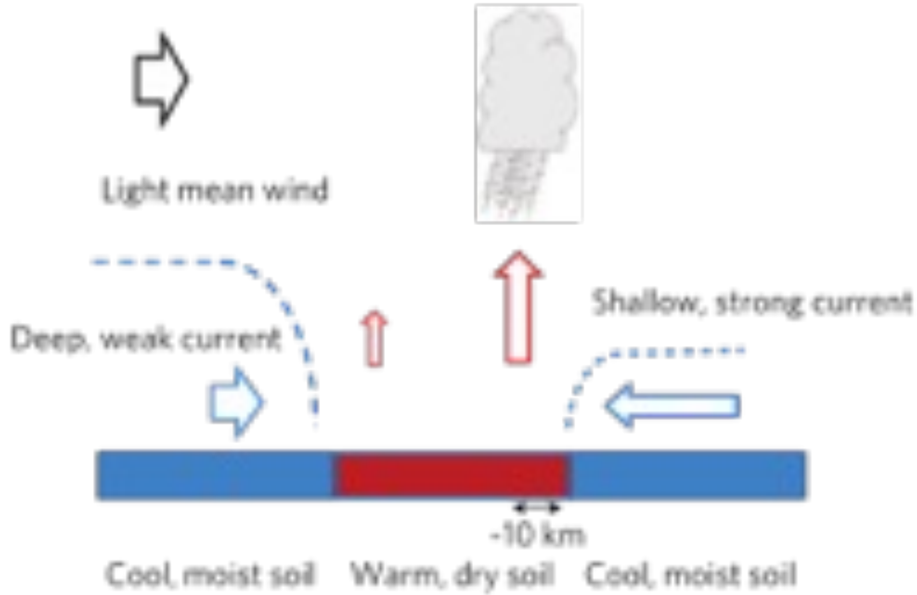
MOISTURE FLUX CONVERGENCE ↑ ??

Urban-induced rainfall mechanisms in models



MOISTURE FLUX CONVERGENCE ↑ ??

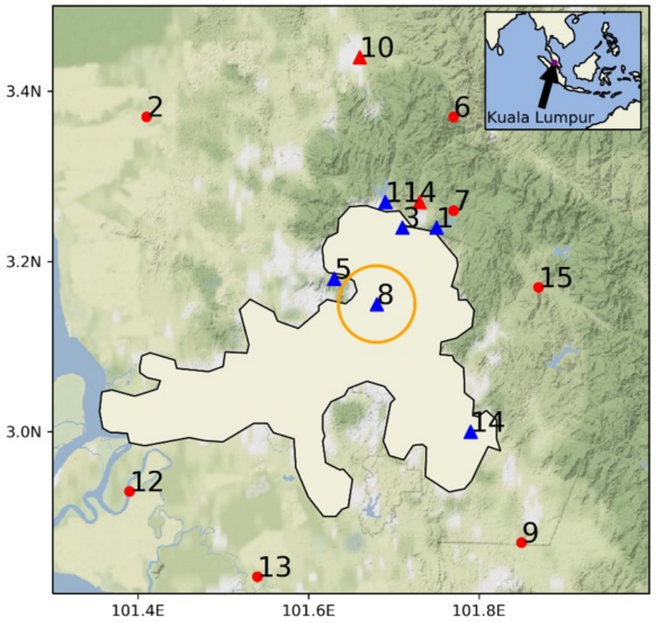




From Taylor et al. (2011) Nat Geoscience

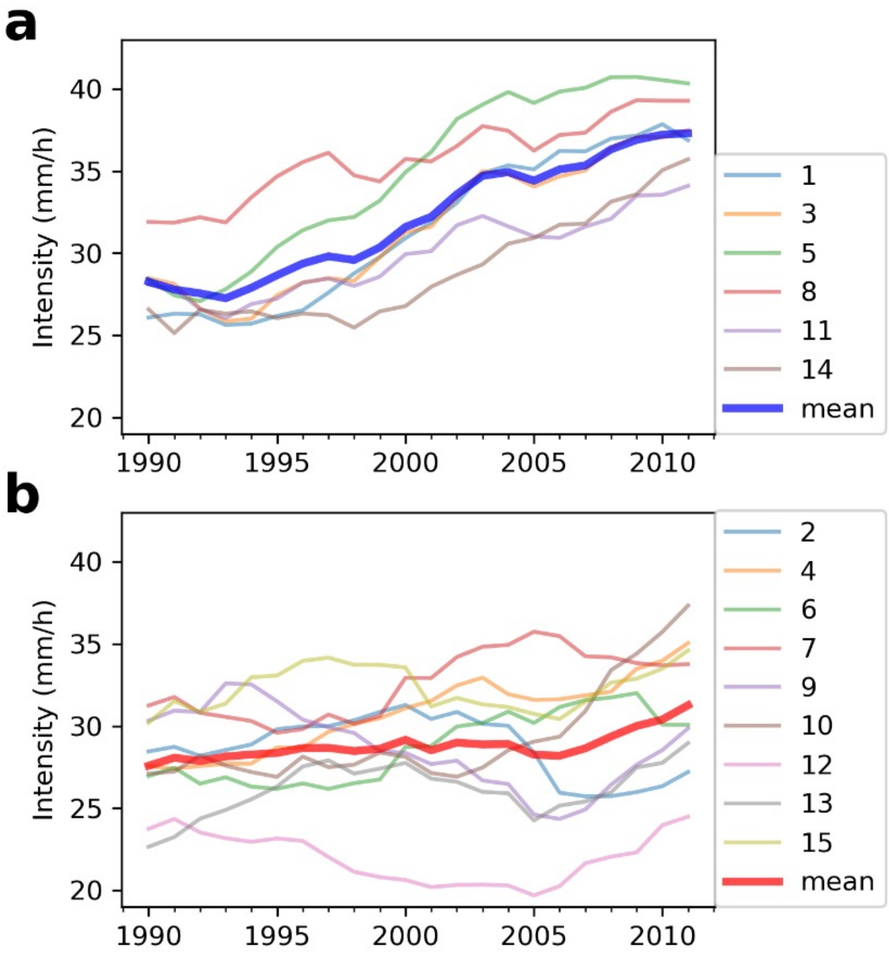
Effects of cities on rainfall extremes

Kuala Lumpur
(Malaysia)



1989 Urban Area

95th Percentile (hourly rainfall)

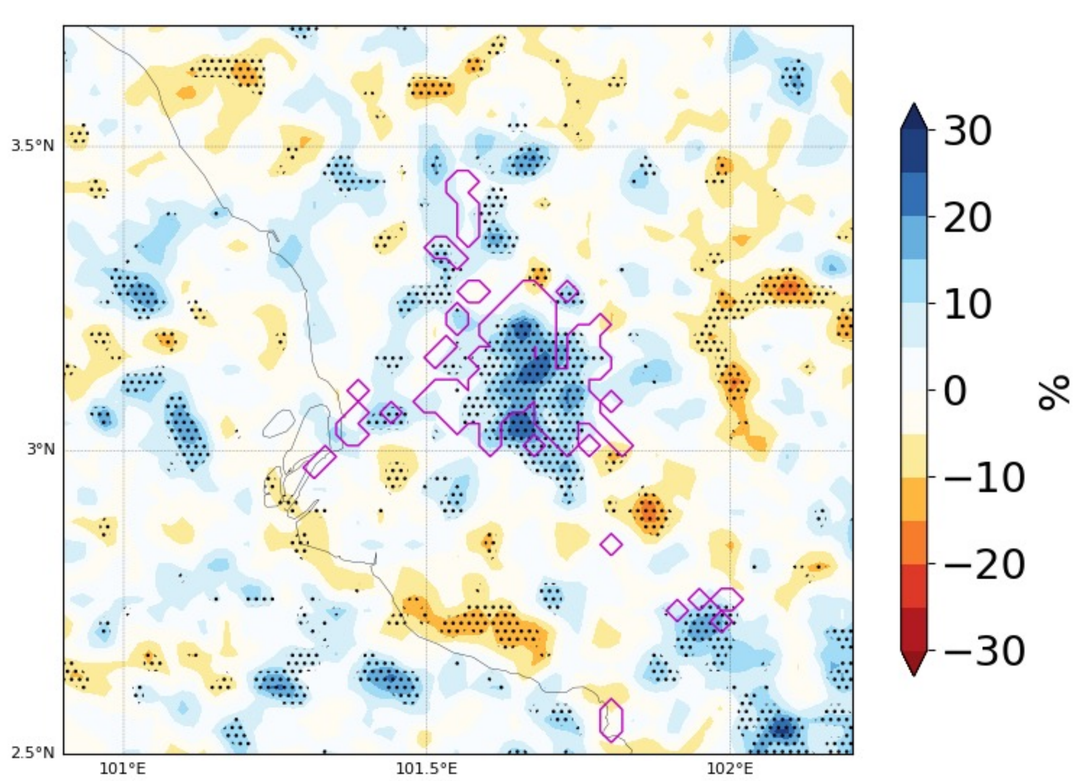


Li et al. 2020 GRL

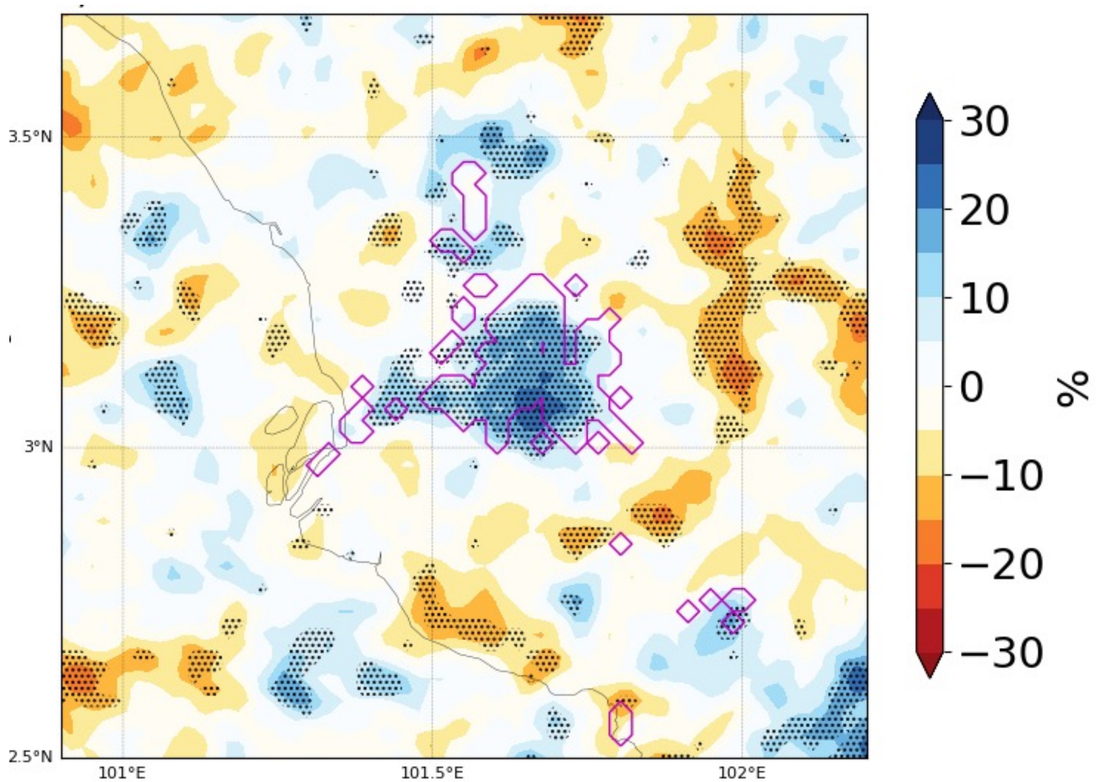
Effects of cities on rainfall extremes

Kuala Lumpur (Malaysia)

95th Percentile (hourly rainfall)



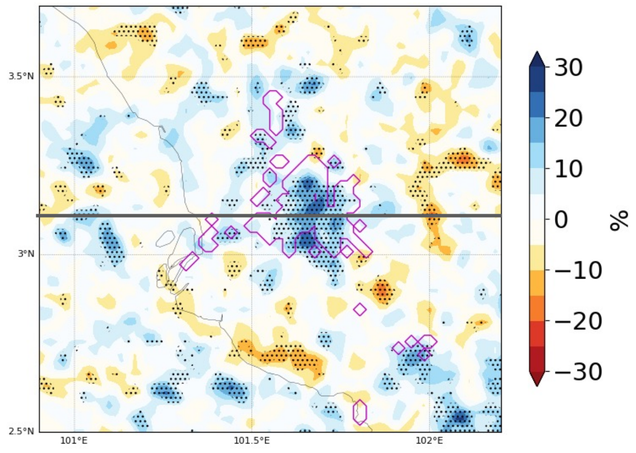
99th Percentile (hourly rainfall)

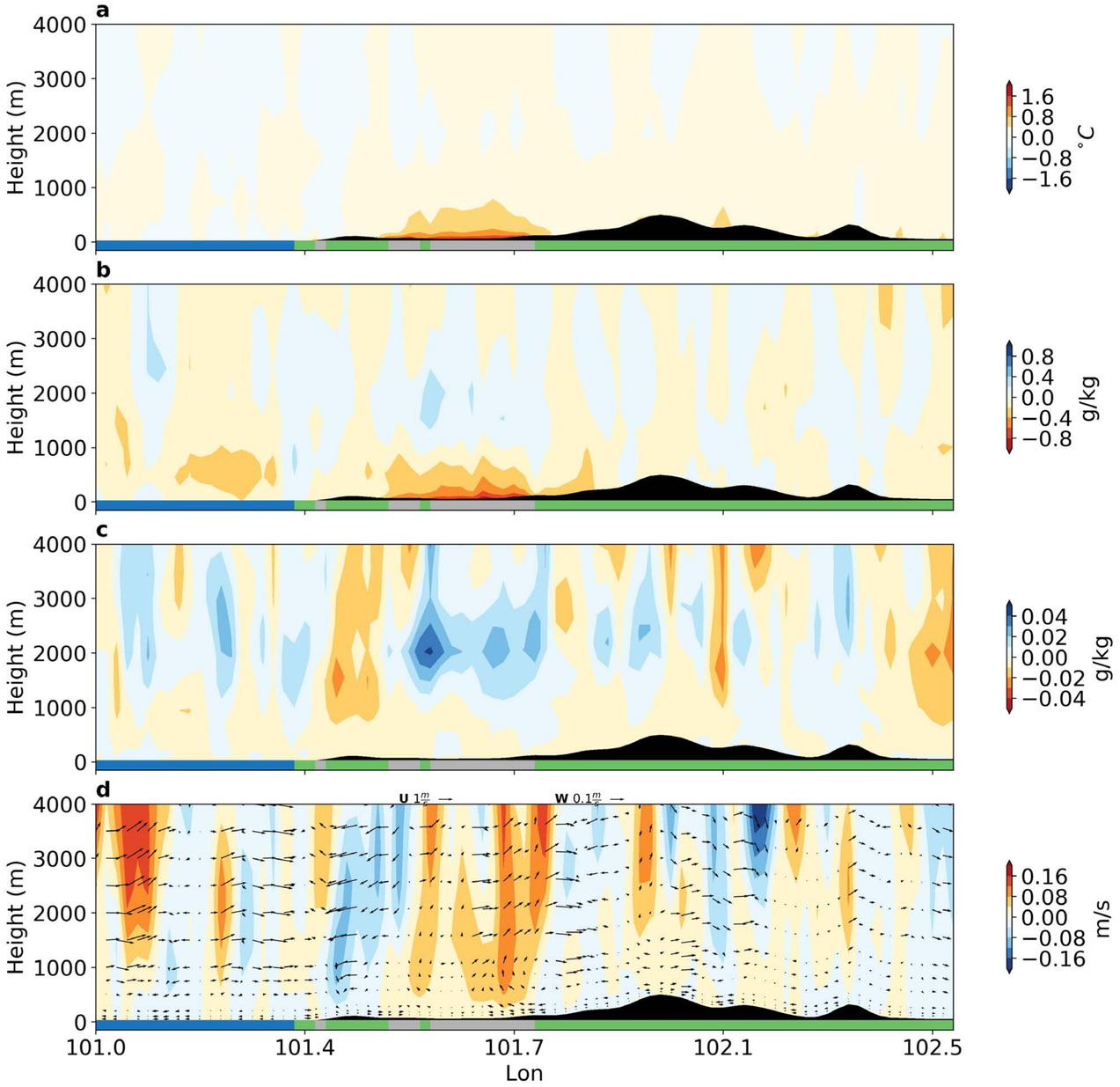


Li et al. 2020 GRL

Effects of cities on rainfall extremes

Kuala Lumpur (Malaysia)





Temperature

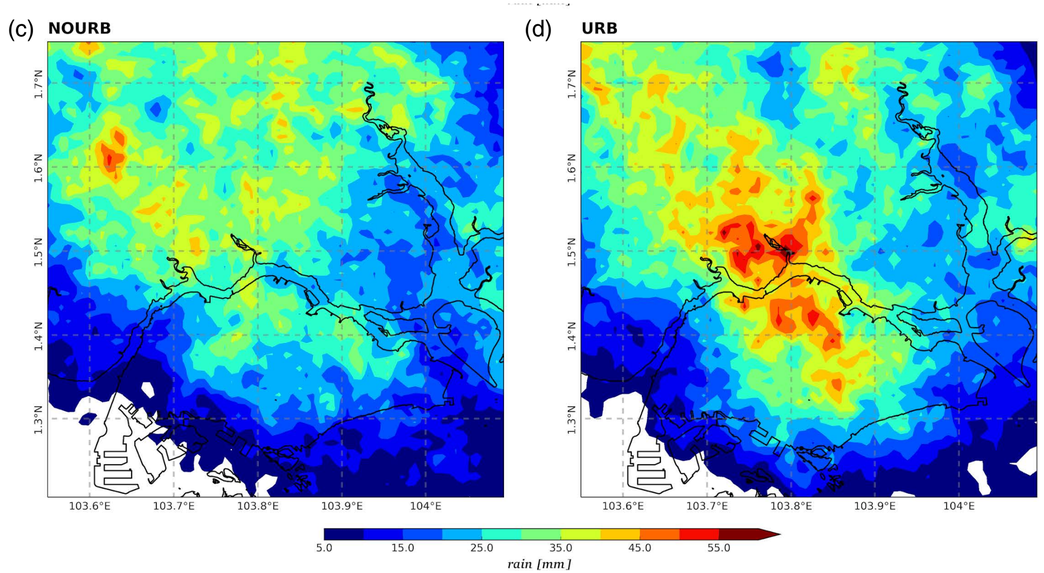
Mixing ratio

Cloud mixing ratio

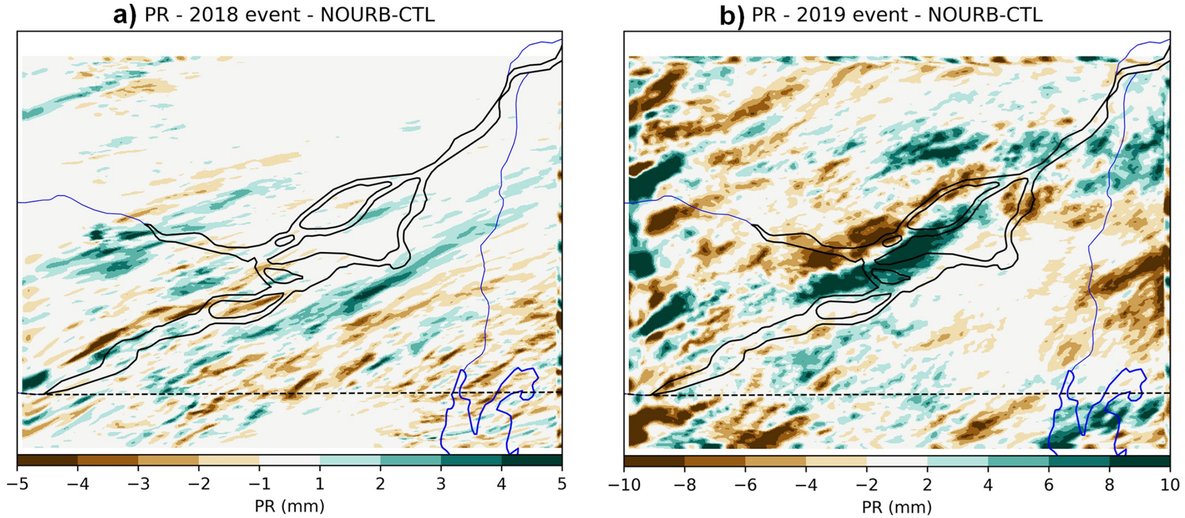
Vertical wind speed

Li et al. 2020 GRL

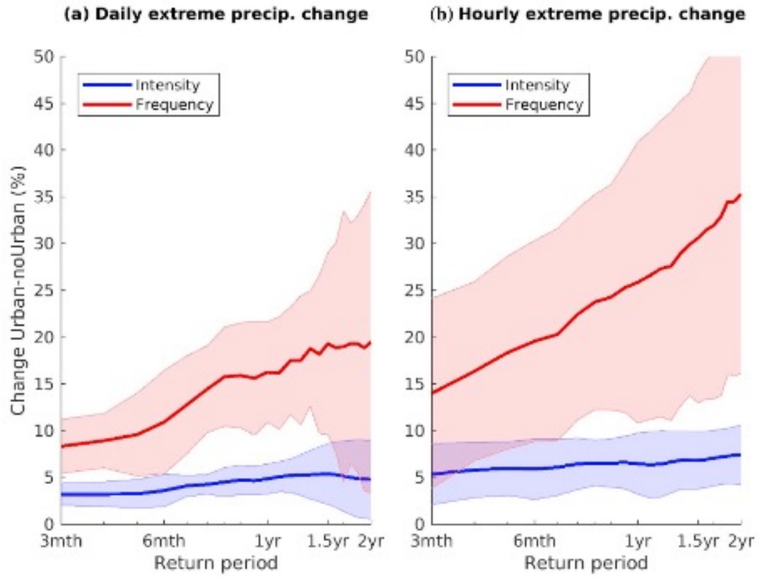
Other studies



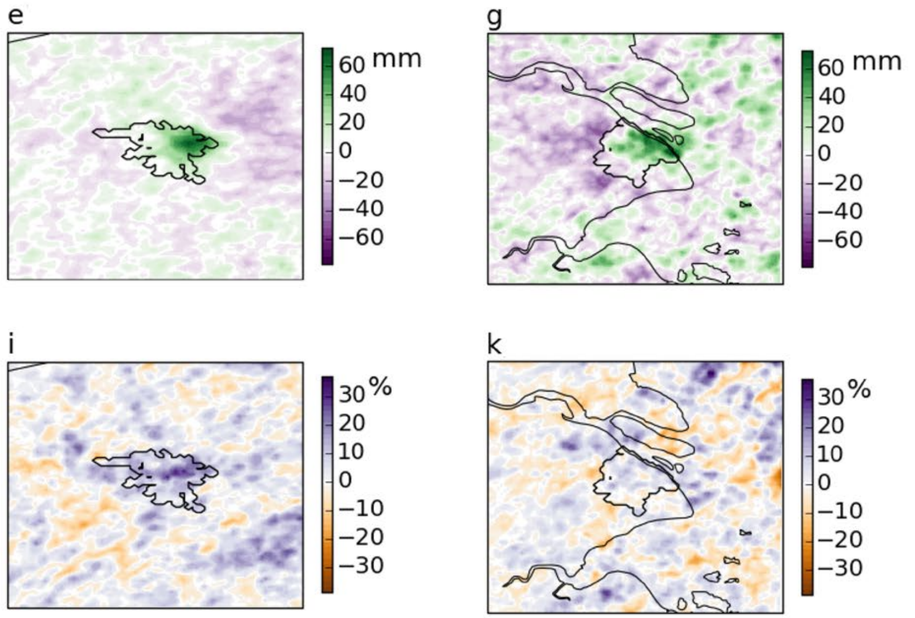
Simon-Moral et al. 2020 QJRMS – Unified Model. Singapore



Lauer et al. 2023 PCLIM – WRF. Montreal

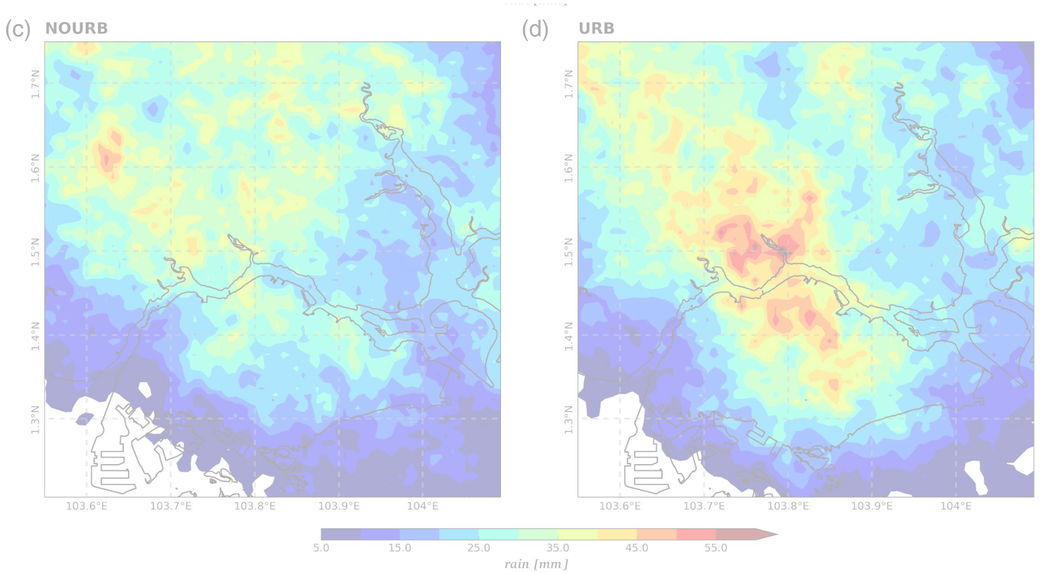


Marelle et al. 2020 ERL – WRF. Paris, New York, Tokyo, Shanghai



Steensen et al. 2022 Clim Dyn – WRF. Paris, Shangai

Other studies



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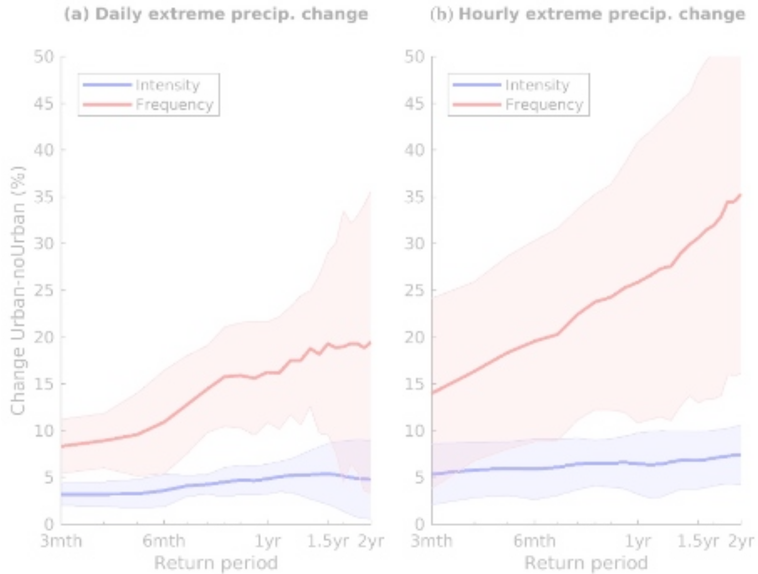
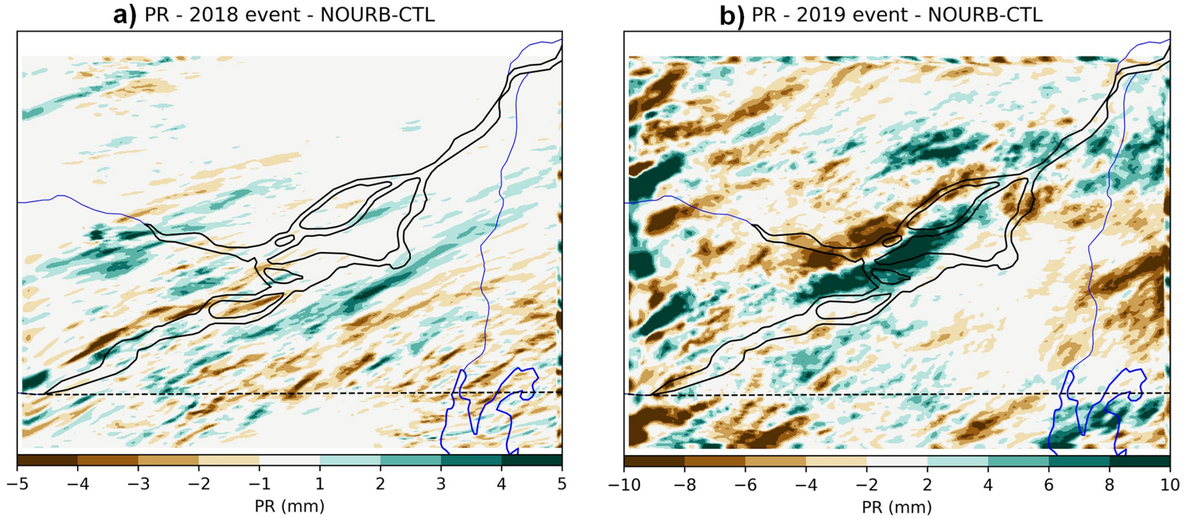
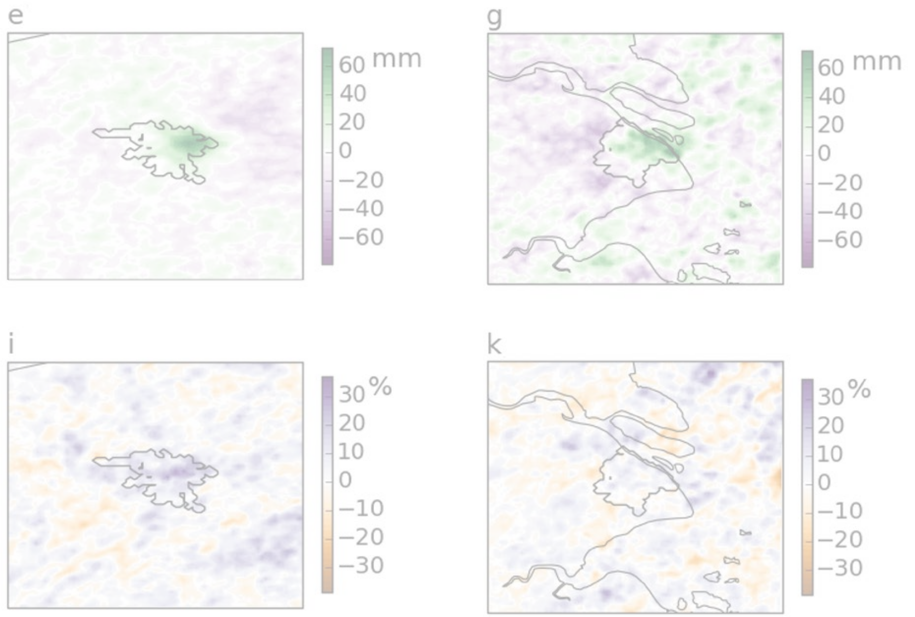


Marelle et al. 2020 ERL – WRF. Paris, New York, Tokyo, Shanghai

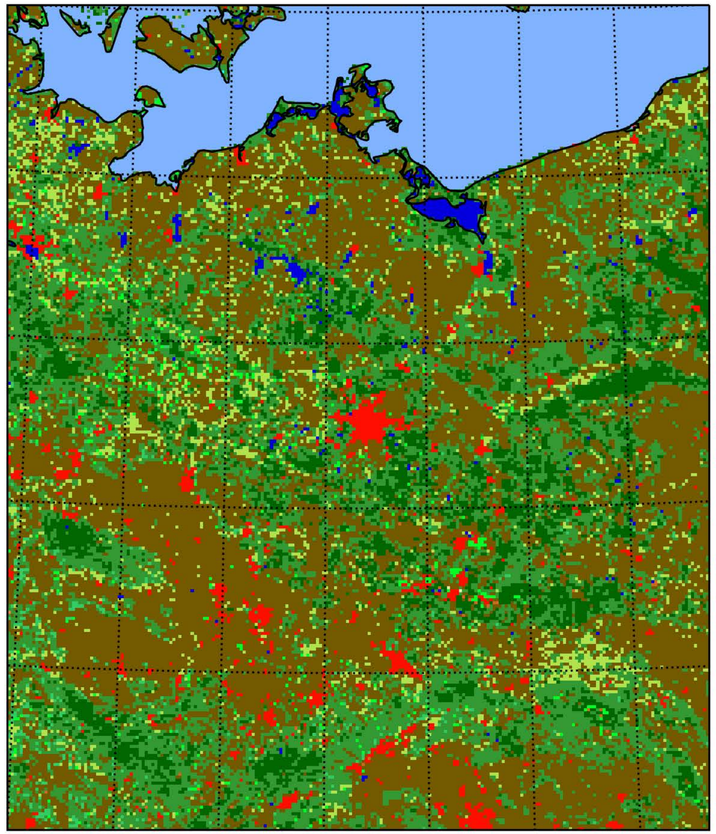


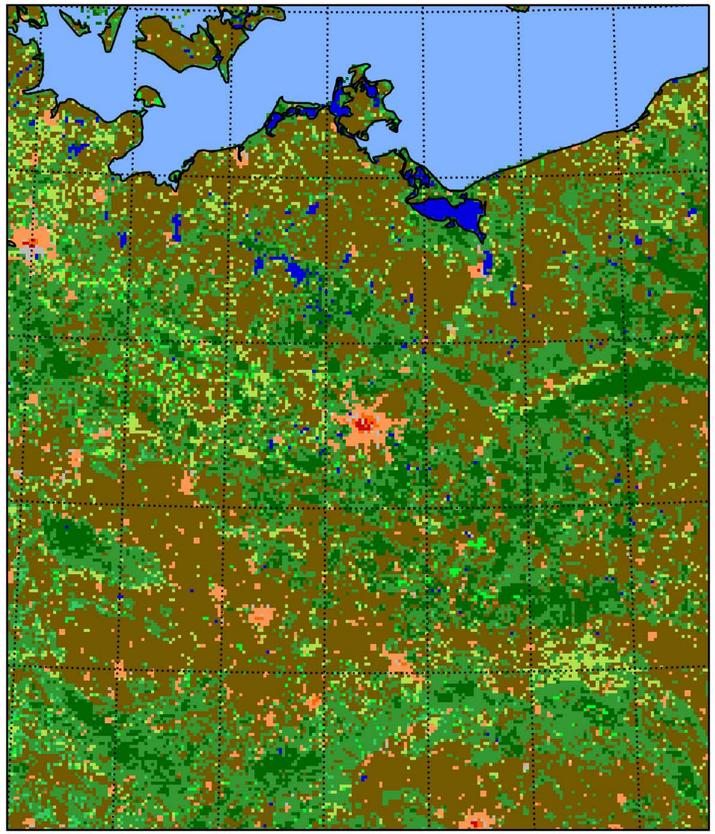
Lauer et al. 2023 PCLIM – WRF. Montreal



Steensen et al. 2022 Clim Dyn – WRF. Paris, Shangai

The role of city heterogeneity





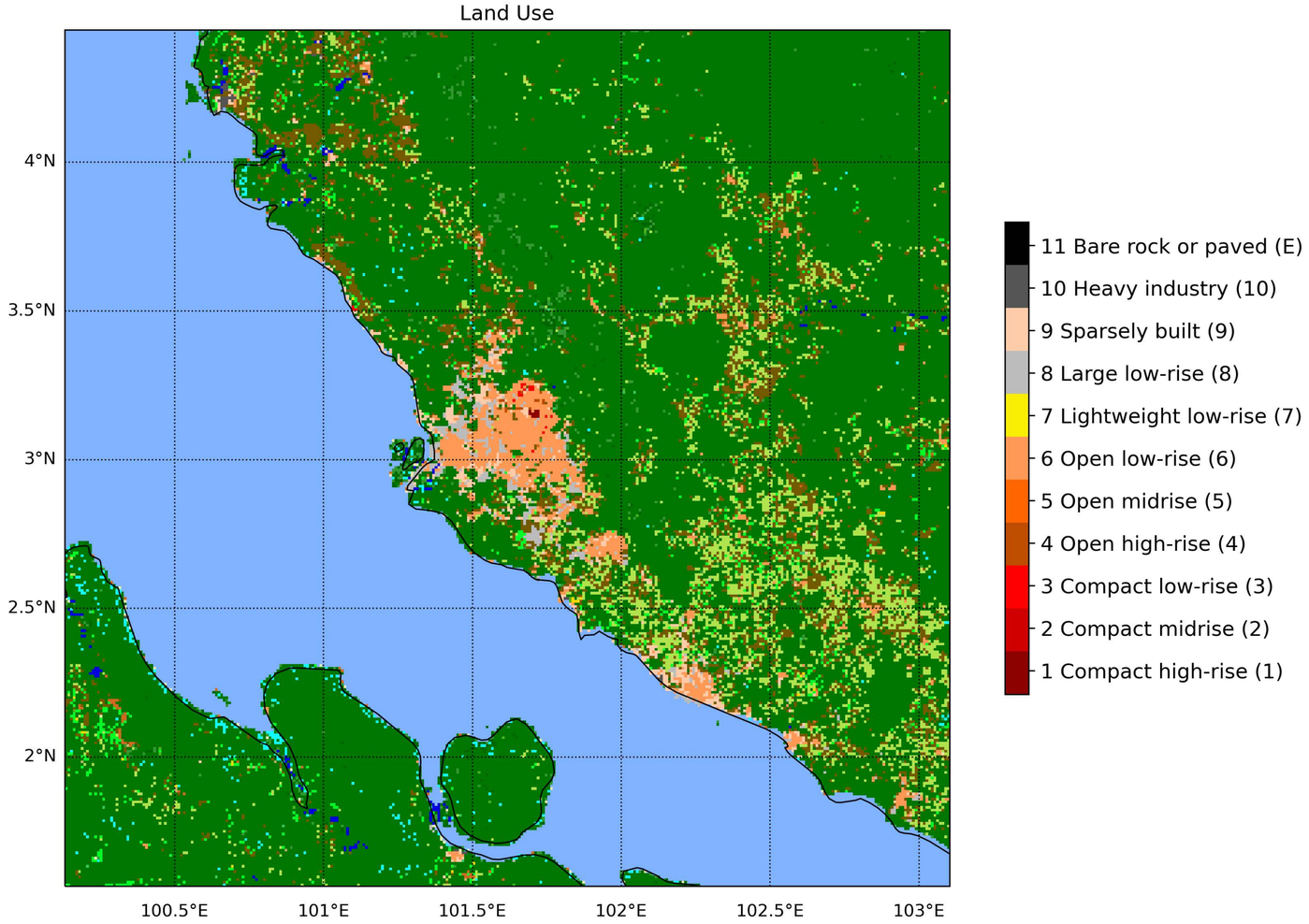
10°E 11°E 12°E 13°E 14°E 15°E 16°E

10°E 11°E 12°E 13°E 14°E 15°E 16°E

Demuzere et al. 2022 JOSS – W2W. Since WRF4.5 LCZ directly from WPS

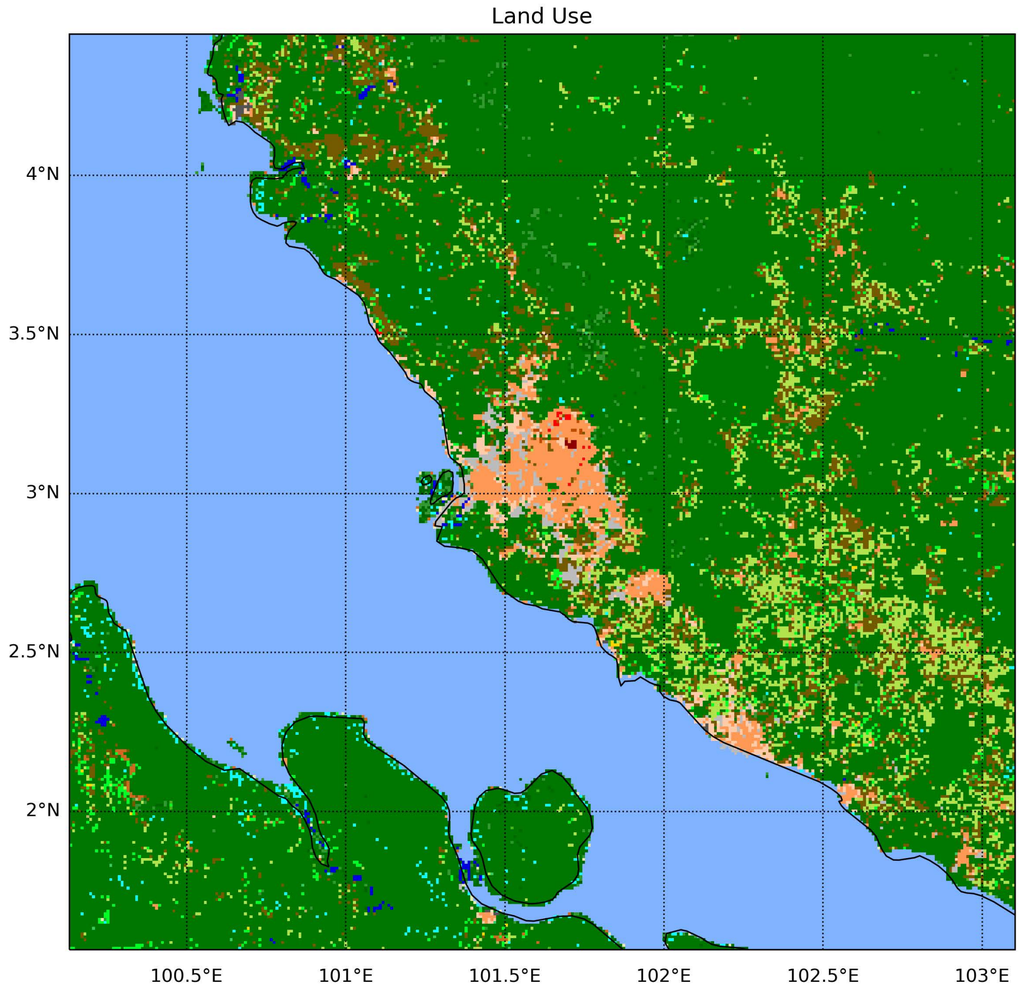
W2W creates different scenarios: No Urban, Only extent, Default and LCZ

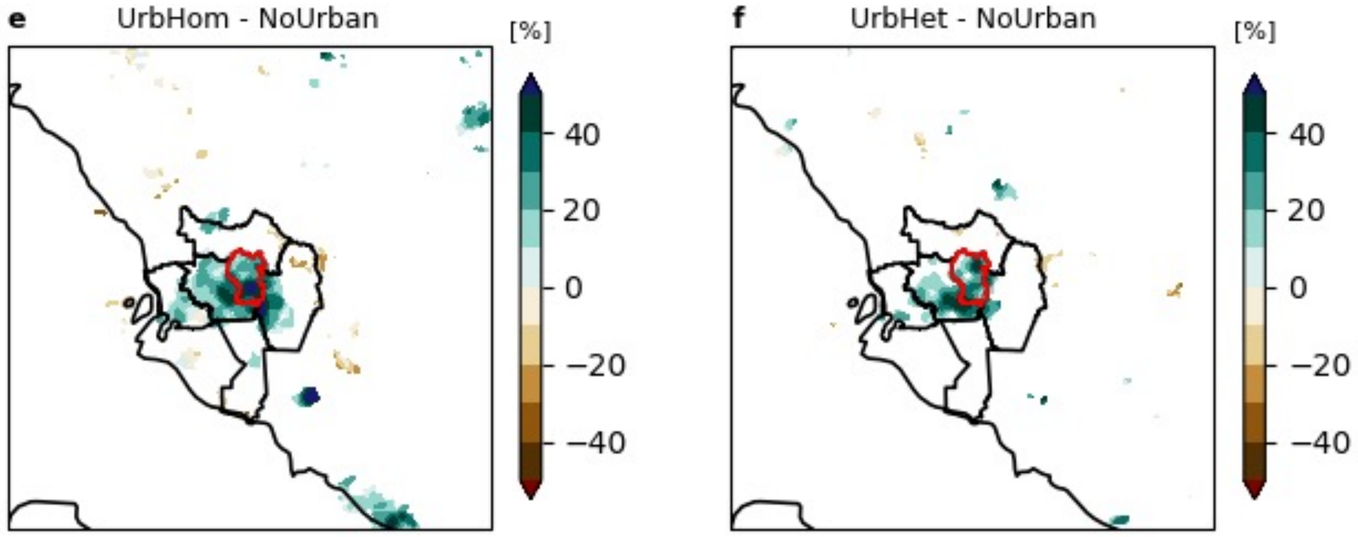
The role of city heterogeneity – Revisiting KL study

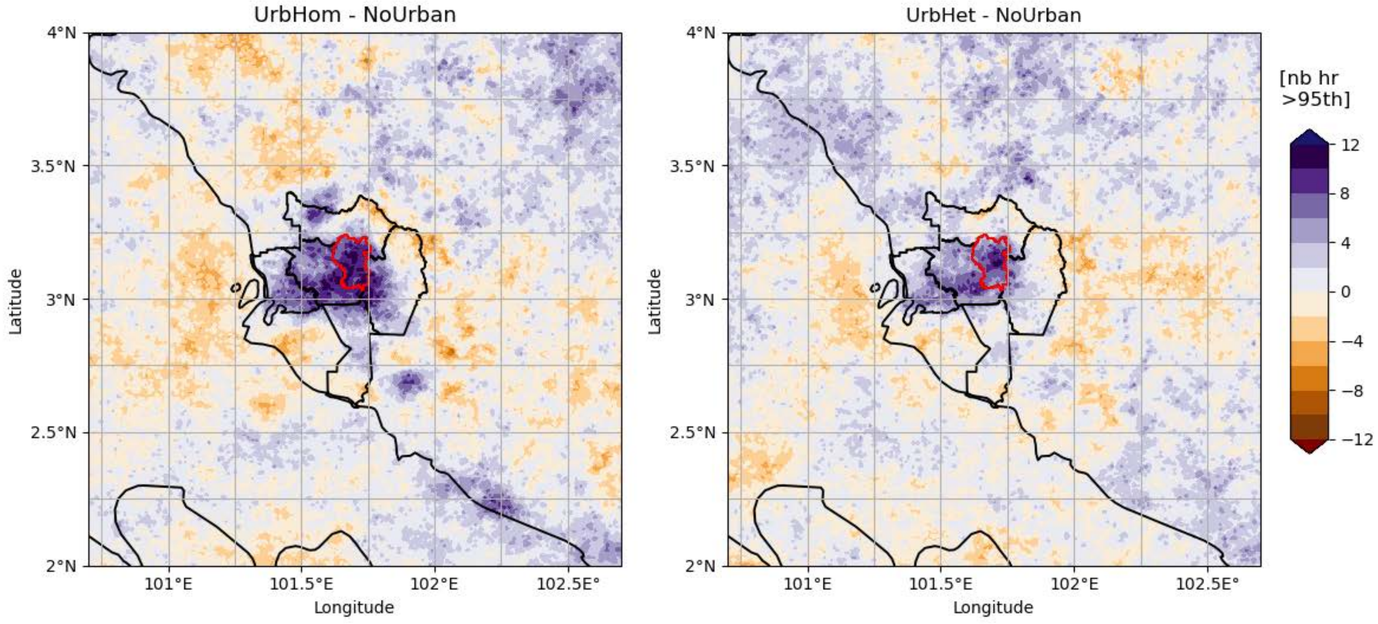


Ghielmini et al. 2023 – Submitted to Urban Climate

The role of city heterogeneity – Revisiting KL study



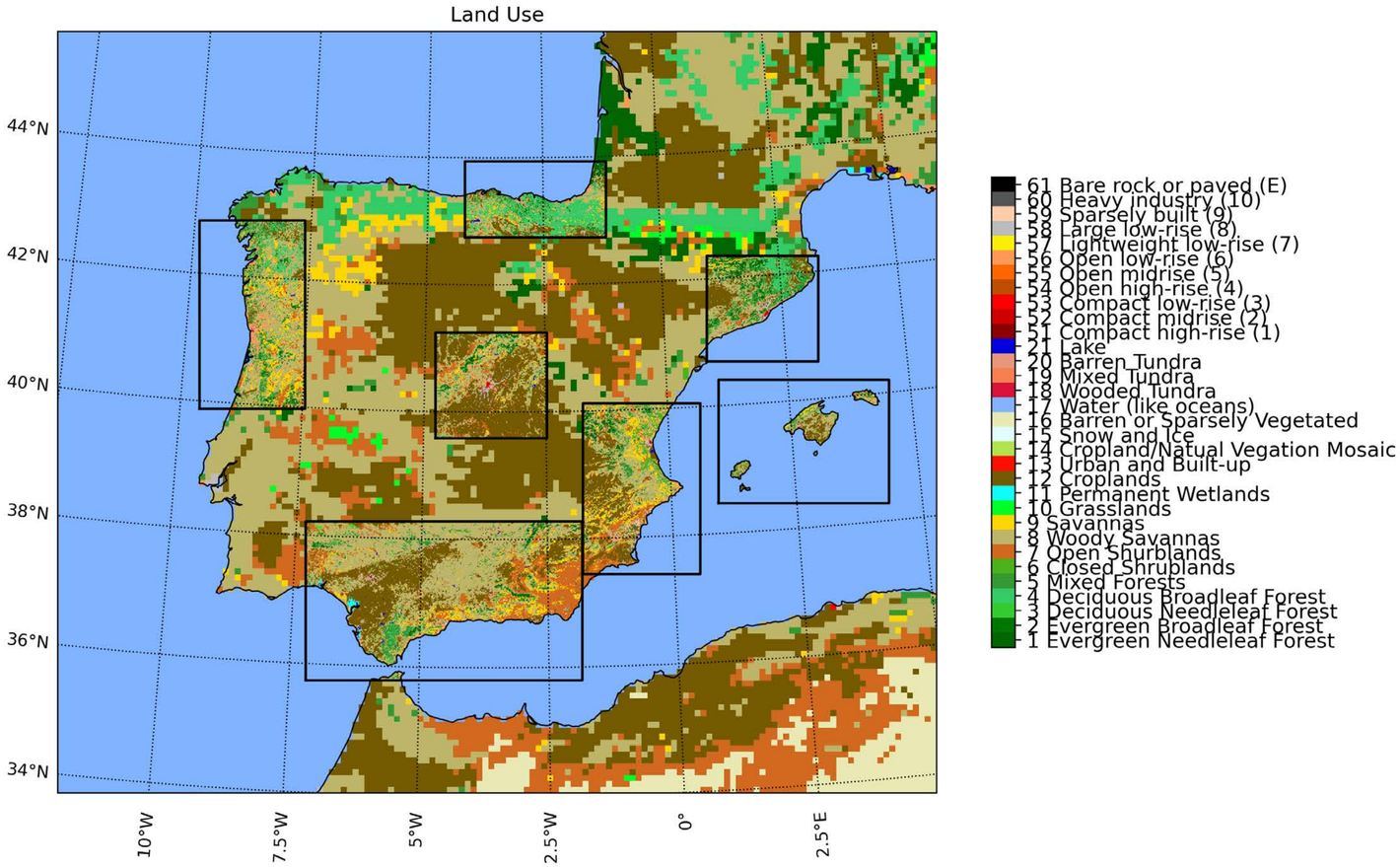


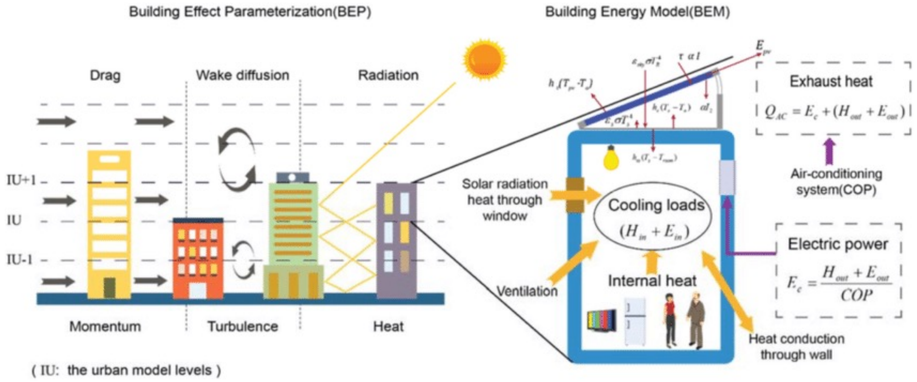


Ghielmini et al. 2023 – Submitted to Urban Climate

The SURFACE project

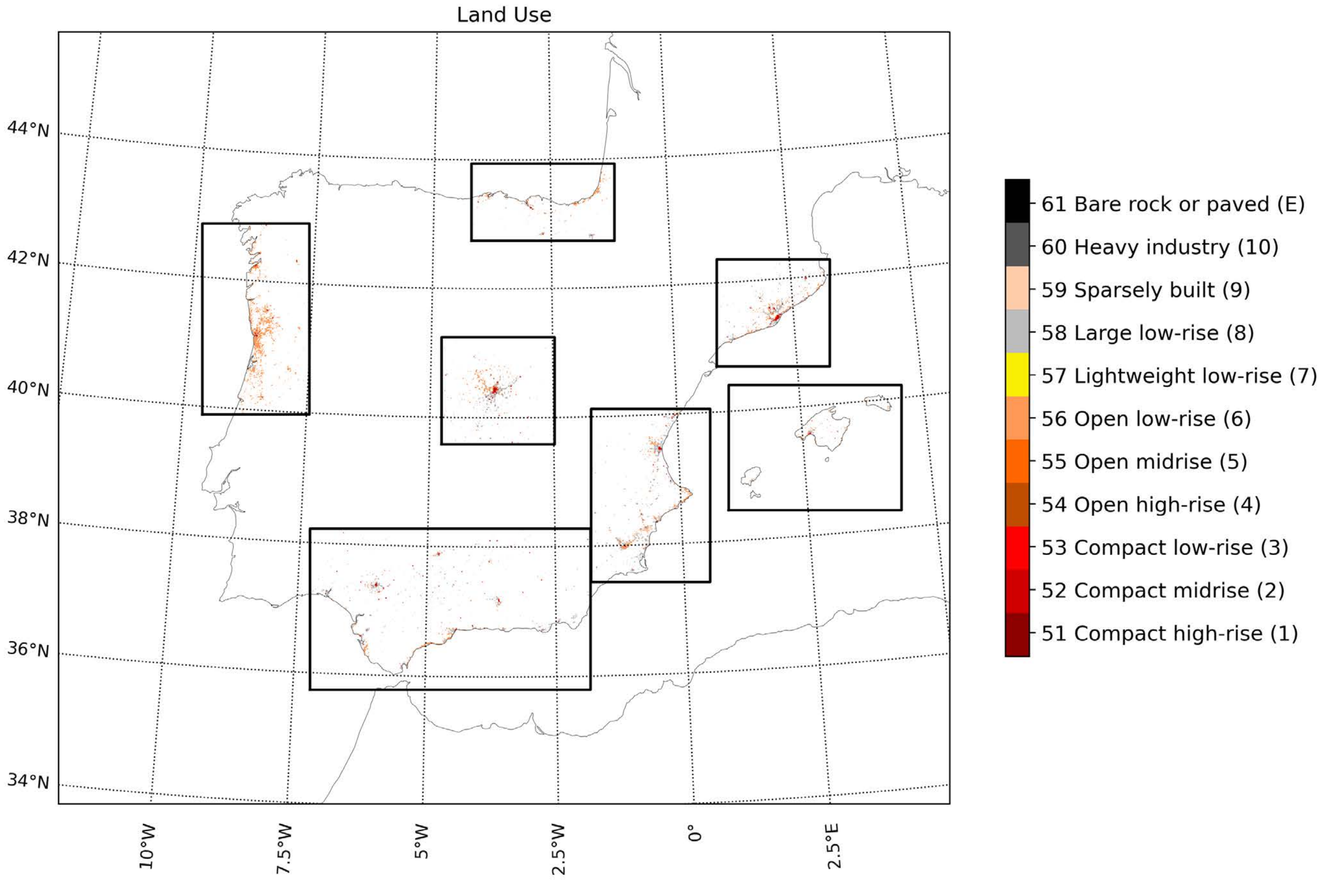
The SURFACE project



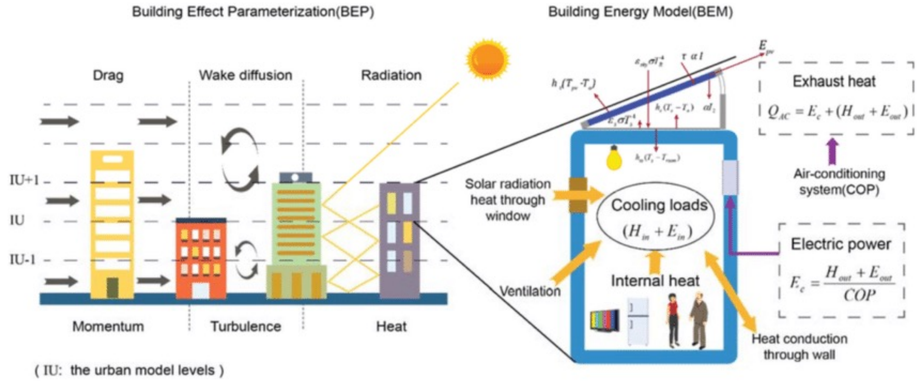


Pokhrel et al. 2020 JESBC; Salamanca et al. 2010 TAC

The SURFACE project



BEP+BEM

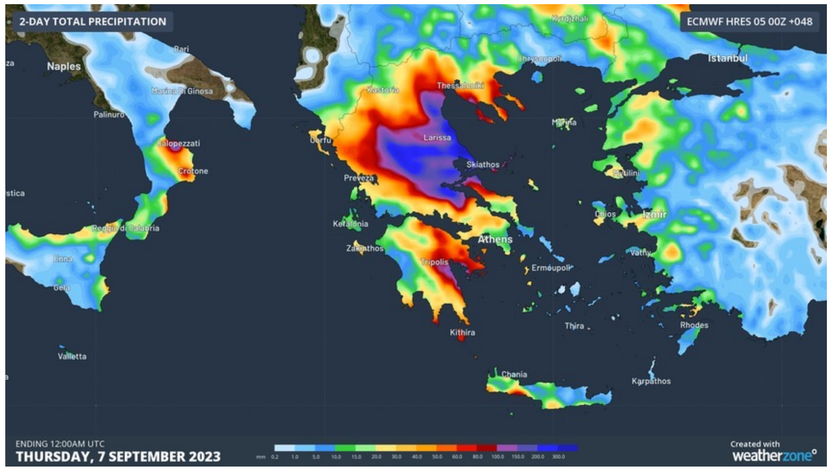


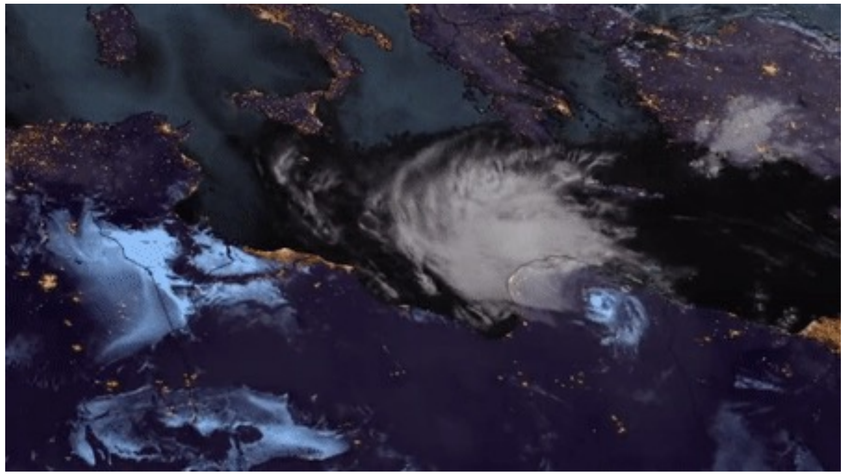
Pokhrel et al. 2020 JESBC; Salamanca et al. 2010 TAC

- 10-year experiments
- 1-km spatial resolution
- Urban heterogeneity (LCZ)
- Multiple south Europe cities
- 3 experiments:
  - Urban present
  - No cities present
  - Urban future (PGW)

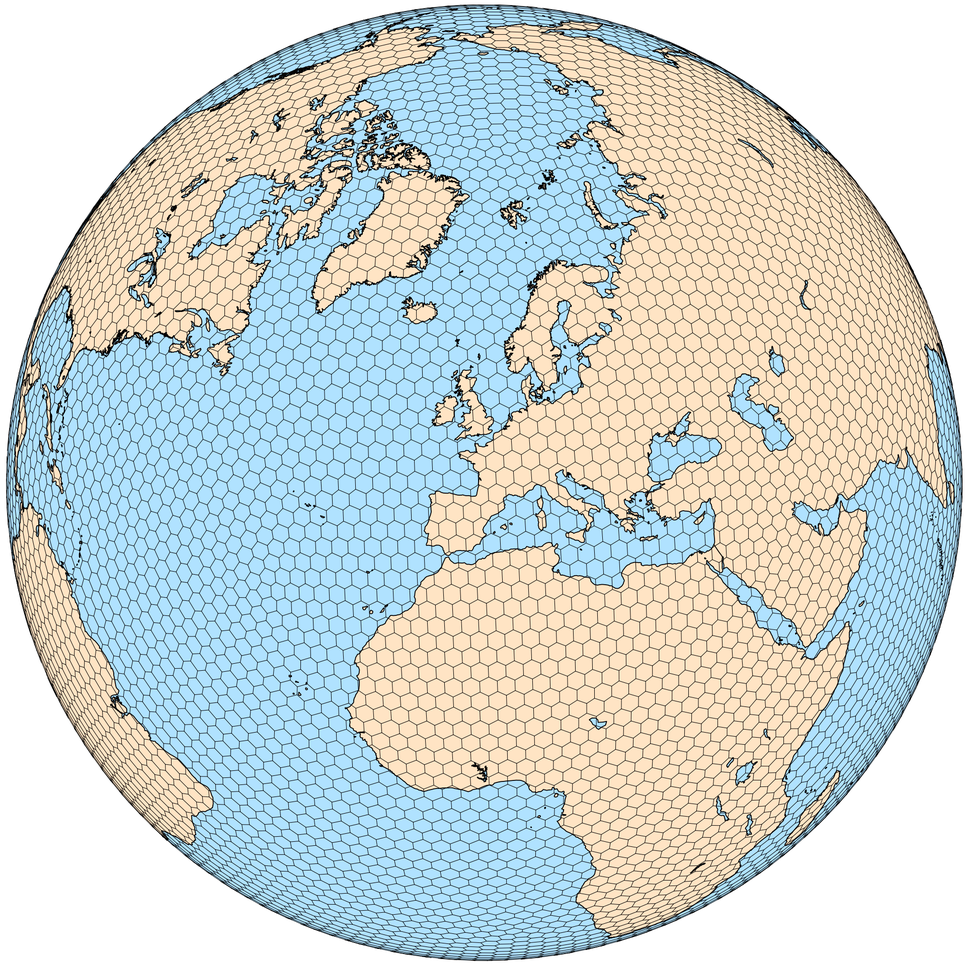
Bonus track: Storm Daniel

Storm Daniel and the effect of SST

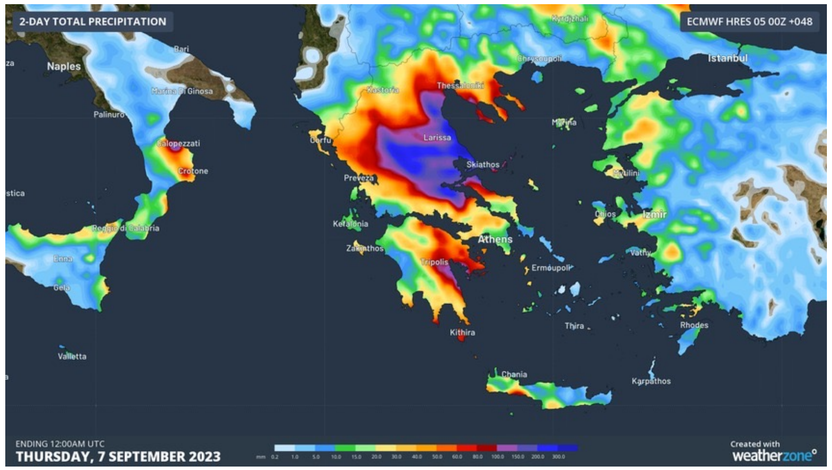


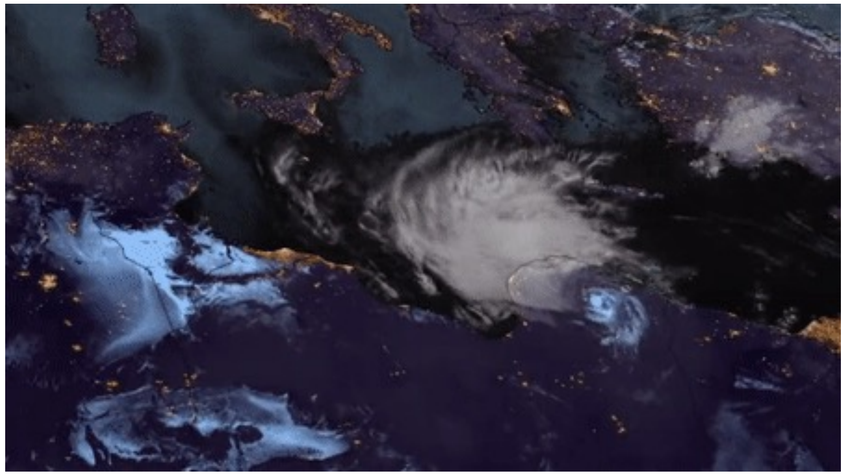


MPAS 240 km



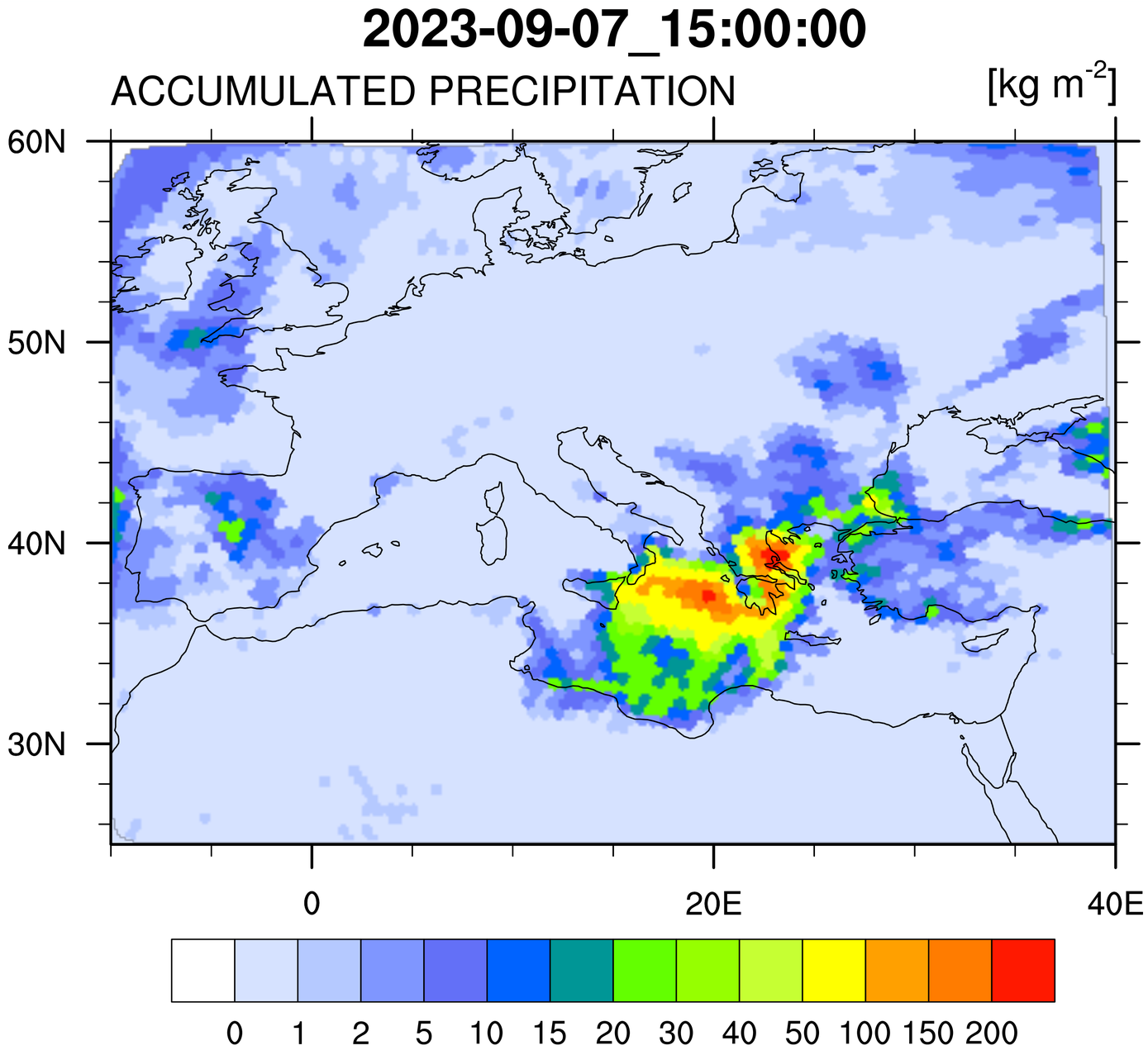
Storm Daniel and the effect of SST





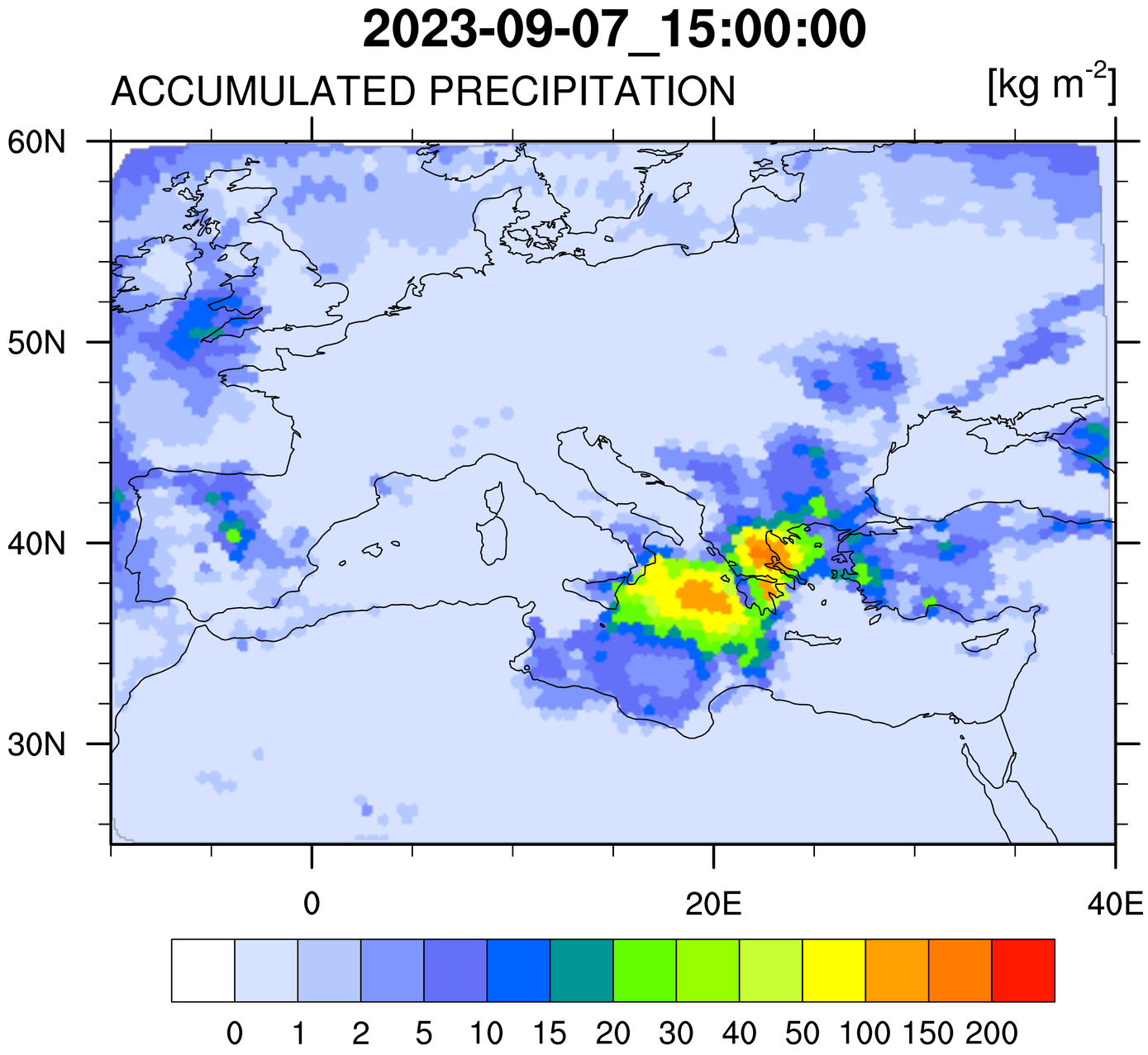
MPAS 60 km

Storm Daniel and the effect of SST



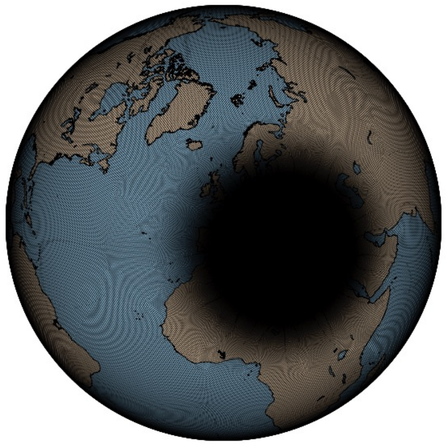
ERA5 -> SST

Storm Daniel and the effect of SST



ERA5 –> SST CLIMATOLOGY

Storm Daniel and the effect of SST



Thanks!

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Universitat de les Illes Balears

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“R+D in numerical modelling with a focus on Mediterranean extreme weather, energy and floods: The triangle-based regional atmospheric model (TRAM) & model for prediction across scales (MPAS) tandem” / Sept 2021-Aug 2024 / http://meteo.uib.es/trampas