WRF-Urban Modeling System: overview, progress, and challenge

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WRF-Urban: International collaborative effort

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RMetS
Royal Meteorological Society

The integrated WRF/urban modelling system: development, evaluation, and applications to urban environmental problems

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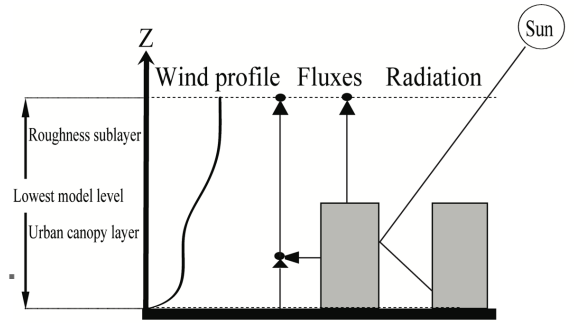
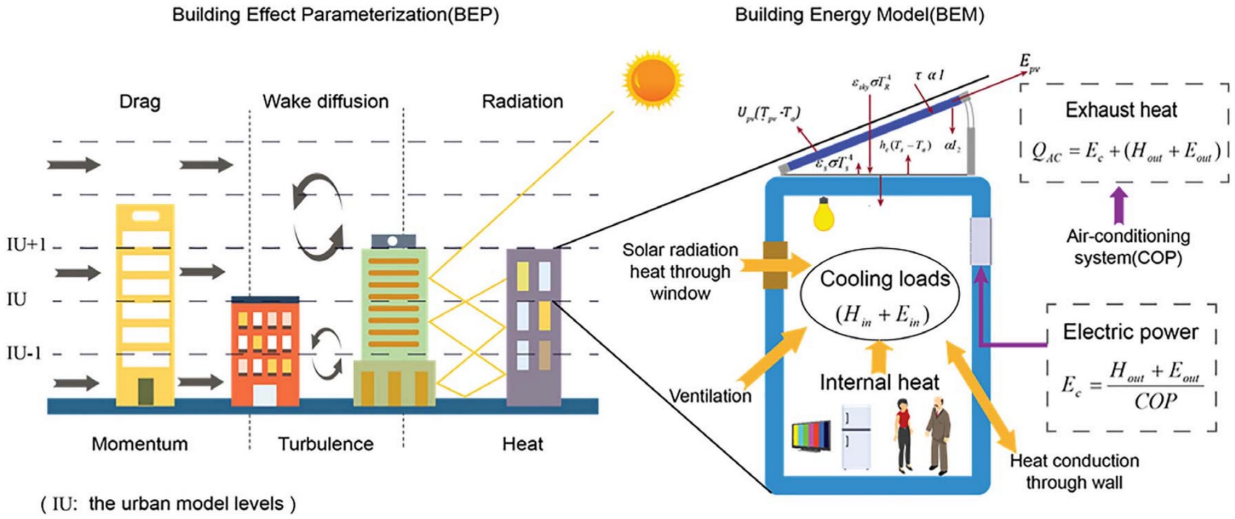
- a suite of urban canopy-process models
- Integrate multi-source multi-scale data of urban land use, building characteristics, and anthropogenic heat
- a companion urbanized land DA system
- able to couple WRF-Urban to urban-scale Computational Fluid Dynamic and Large Eddy Simulation models



Kusaka et al. 2001.

SLUCM



Martilli et al. 2002; Salamanca and Martilli 2010.

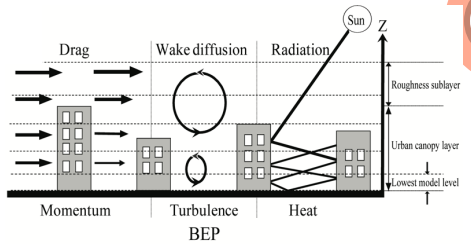
Google Scholar: more than 160 groups in 55 countries have used WRF-Urban

WRF-Urban development milestones

1

2004

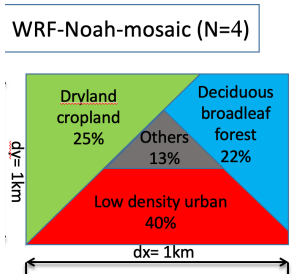
Bulk urban model in WRF v2.0: Liu and Chen



3

2009

BEP/BEM in WRF v3.1 and v3.2: Martillli, Salamanca, Tewari



5

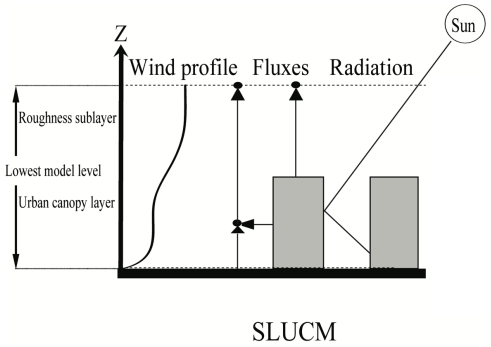
2014

Mosaic in WRF v3.6: Li, Barlage, Chen

7

2017

Coupled UCM with Noah-MP in WRF v3.9: Salamanca, Zhang, Barlage



2

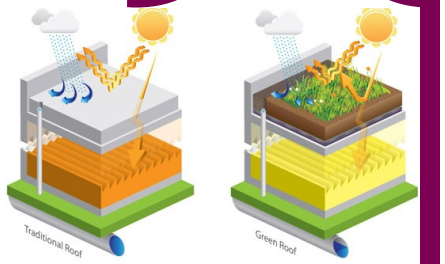
2006

SLUCM in WRF v2.2: Kusaka, Chen, Tewari

4

2013

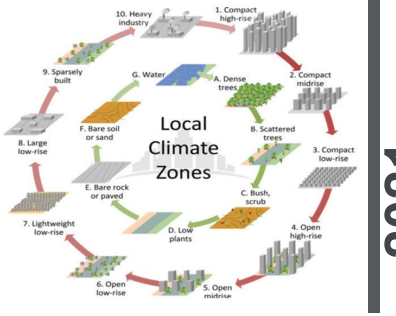
NUDAPT in WRF v3.5: Glotfelty, Ching, Tewari, Chen



6

2015

Enhanced hydrology and greenroof in WRF v3.7; Yang, Miao



8

2021

LCZ and PV Panel in WRF v.4.3: Zonato, He, Martilli

NCAR
UCAR

URBAN CANOPY MODEL

Our goal is to develop an integrated, multi-scale urban modeling system for the Weather Research and Forecast (WRF) model to address various urban environmental issues, which include the impacts of urban heat islands on regional weather, climate, air quality, public health, and water resources and management.

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Single layer Urban Canopy Model

- How to use the WRF/Noah/UCM coupled modeling system

Multi layer Urban Canopy Model

- How to use the WRF/Noah/BEP coupled modeling system

National Urban Data and Access Portal Tool (NUDAPT) Documentation

- How to use NUDAPT dataset in WRF/SLUCM/MLUCM models

Urban Parameters

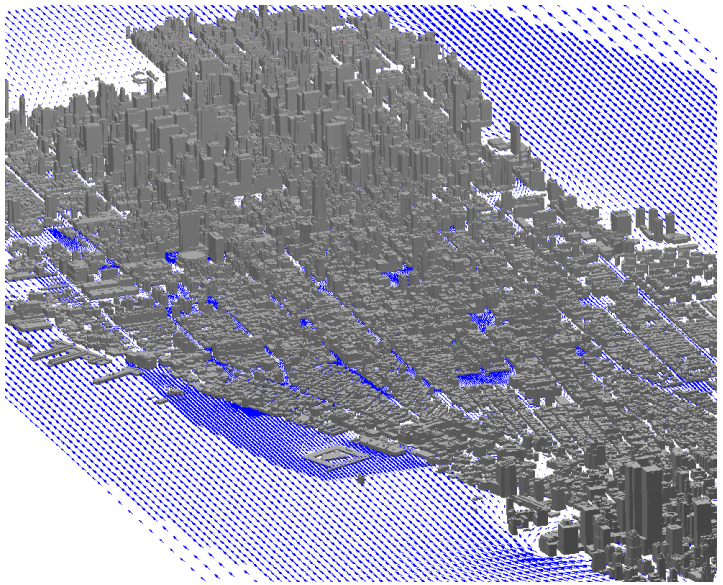
- URBPARM.TBL
- documentation

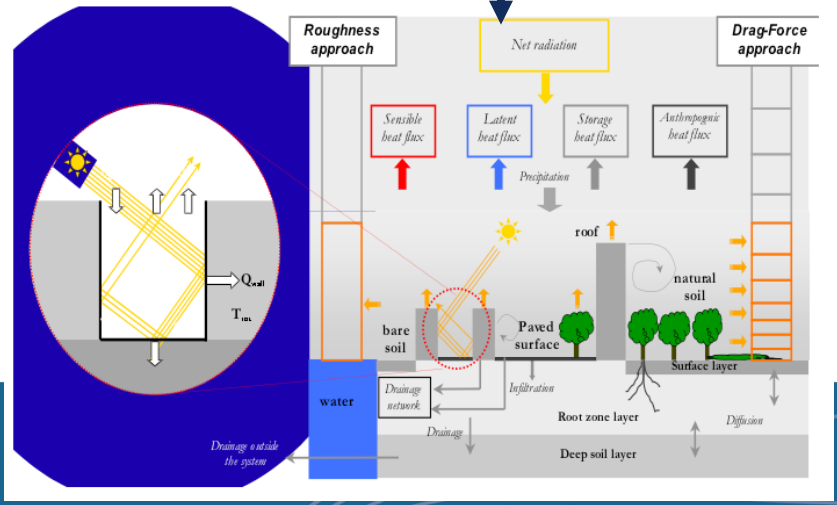
Changes in BEP+BEM and new Local Climate Zone data in WRF 4.3

WRF-Urban documentation website hosted by RAL/NCAR

https://ral.ucar.edu/solutions/products/urban-canopy-model

Challenge: from Real World (highly heterogeneous and human influence) to UCM

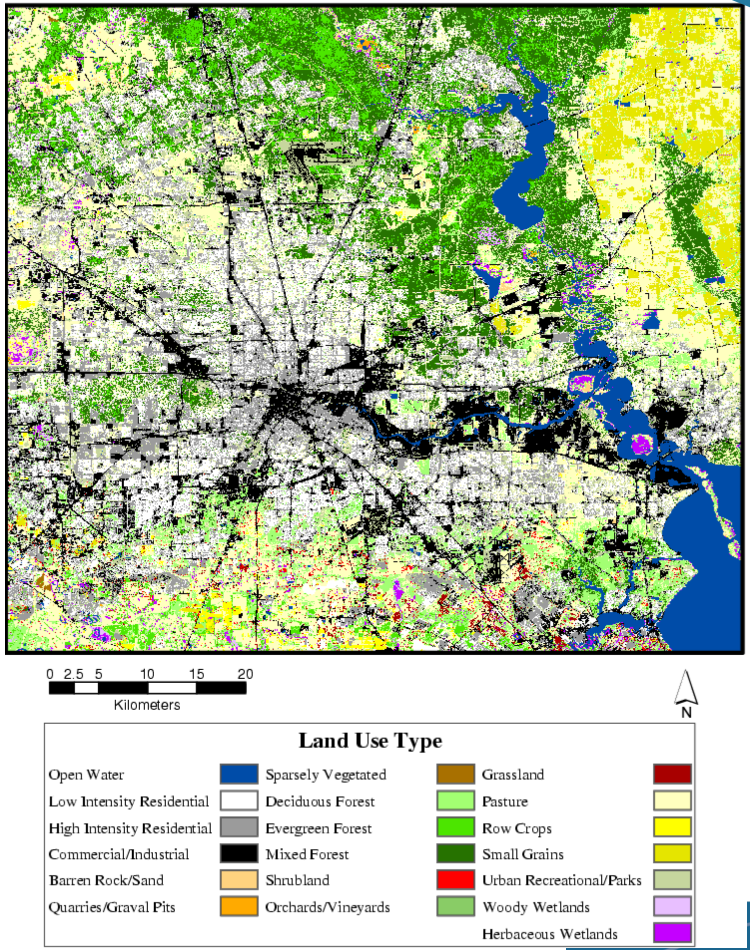




Urban canopy model (UCM) parameter space

```
ndex:      1            2             3            4          5         6              7               8                9              10        11
ype:  Comp High-Rise, Comp Mid-Rise, Comp Low-Rise, Op H-Rise, Op M-Rise, Op L-Rise, Lightweight L-Rise, Large L-Rise, Sparsely Built, Heavy Indus  Asphalt

:  Roof level (building height)  [ m ]
   (sf_urban_physics=1)

37.5, 17.5, 6.5, 37.5, 17.5, 6.5, 3., 6.5, 6.5, 10., 10.

GMA_ZED:  Standard Deviation of roof height  [ m ]
   (sf_urban_physics=1)

A_ZED: 4.0,  3.0,  1.0, 1., 1., 1., 1., 1., 1., 1., 1.

OF_WIDTH:  Roof (i.e., building) width  [ m ]
   (sf_urban_physics=1)

_WIDTH: 31.7, 25.7, 17.6, 17.6, 17.6, 17.6, 17.6, 17.6, 17.6, 17.6, 10.

AD_WIDTH:  road width  [ m ]
   (sf_urban_physics=1)

_WIDTH: 98.9, 39.2, 108.0, 108.0, 108.0, 108.0, 108.0, 108.0, 108.0, 108.0, 108.0

:  Anthropogenic heat [ W m{-2} ]
   (sf_urban_physics=1)

 175.0, 37.5, 37.5, 25.0, 12.5, 12.5, 17.5, 25.0, 5.0, 350.0, 350.0

H:  Anthropogenic latent heat [ W m{-2} ]
   (sf_urban_physics=1)

  20.0, 25.0, 40.0,20.0, 25.0, 40.0,20.0, 25.0, 40.0,20.0, 25.0

KANDA_URBAN:  Coefficient modifying the Kanda approach to computing
urface layer exchange coefficients.
   (sf_urban_physics=1)

DA_URBAN:  1.29 1.29 1.29 1.29 1.29 1.29 1.29 1.29 1.29 1.29 1.29

ZR:  Thickness of each roof layer [ m ]
     This is currently NOT a function urban type, but a function
     of the number of layers.  Number of layers must be 4, for now.
   (sf_urban_physics=1)
```

Method 1: Urban model parameters are specified in the URBPARM.TBL as function of urban land-use types



30-m Landsat land-cover for Houston

Figure 1 - uploaded by Oscar Brousse

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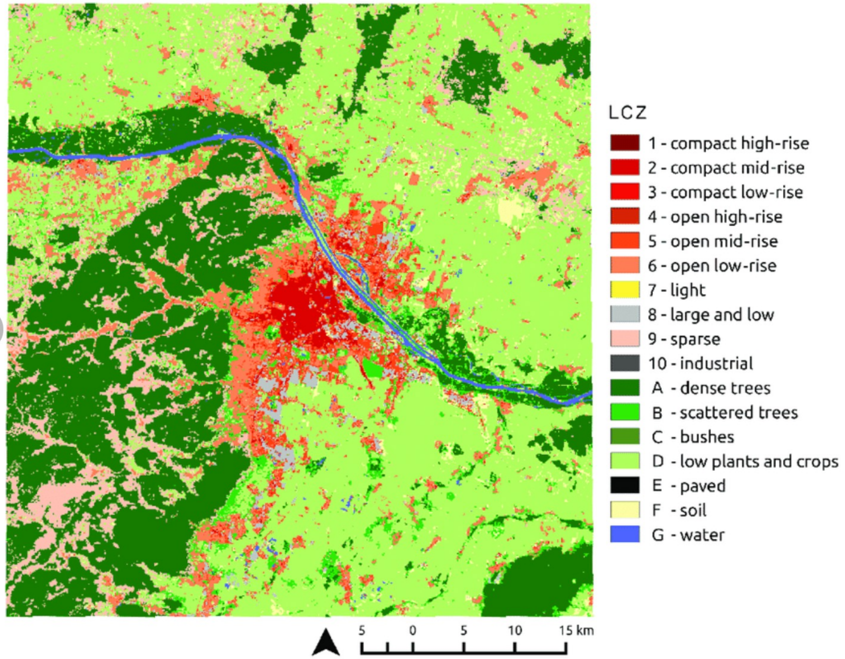
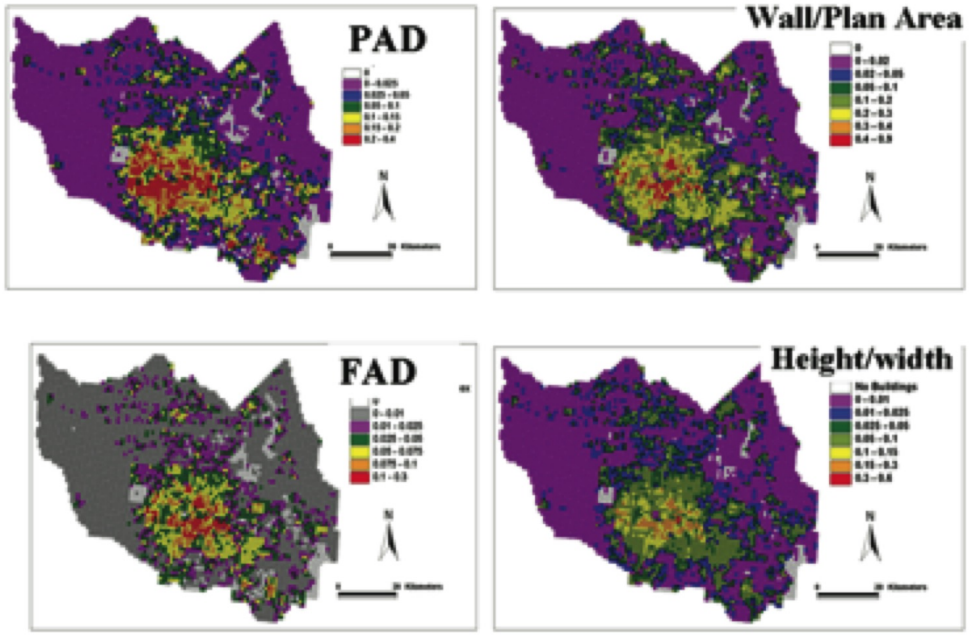


WUDAPT derived LCZ map of Vienna, Austria for the ROI. [Colour figure can be viewed at wileyonlinelibrary.com].

Method 2: Using gridded urban canopy parameters (UCPs) in WRF-Urban

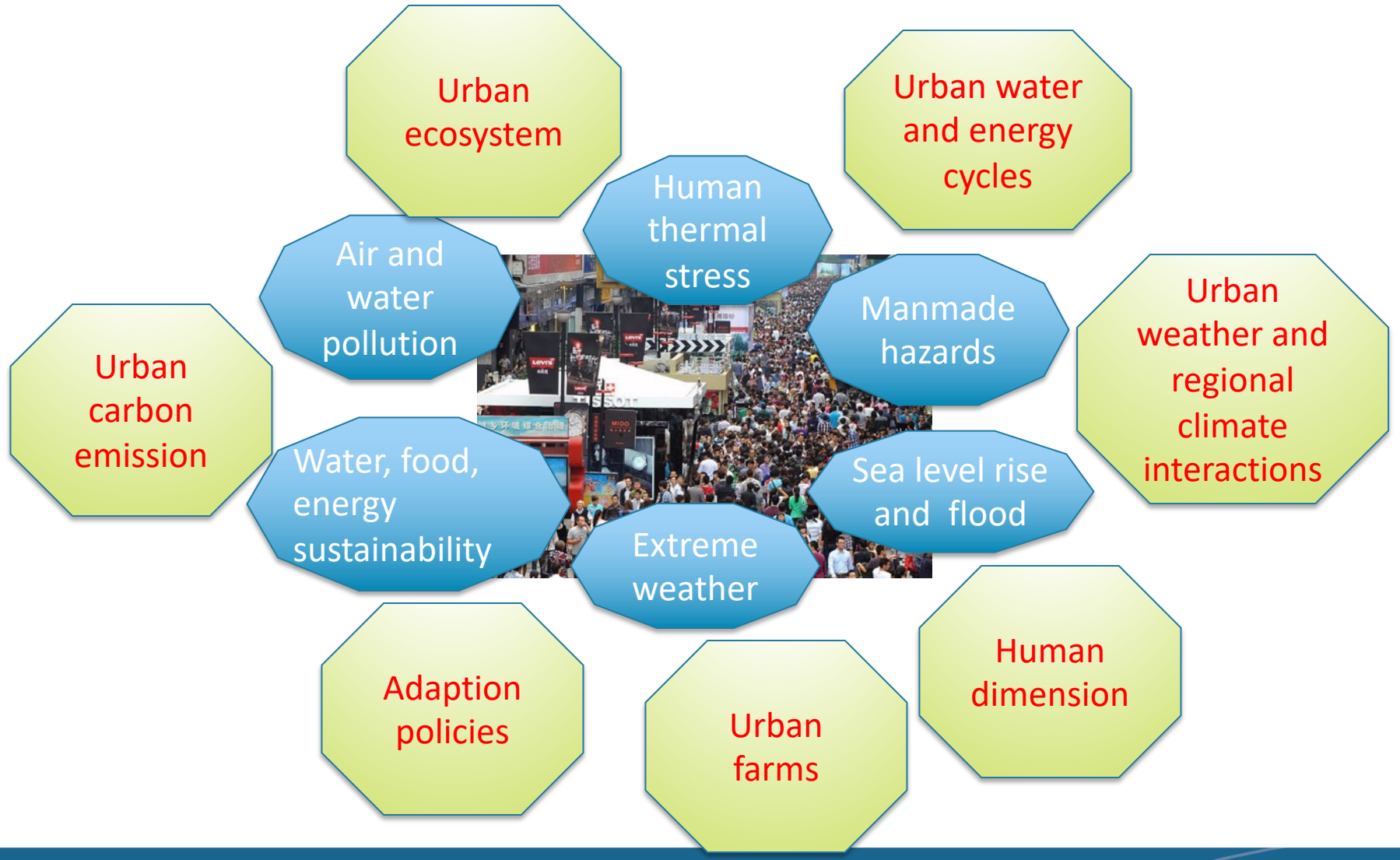
National Urban Database and Access Portal Tool (NUDAPT), led by Jason Ching (UNC). Released in WRF v3.5, April 2013.



NUDAPT gridded urban canon parameters for Houston, Texas.
Plan area density (PAD), frontal area density of the buildings (FAD).

Ching et al., 2009, *Bull. American Meteorol. Soc.*

Integrated Urban System Modeling



need a wide-range and more accurate data

Challenge and future direction

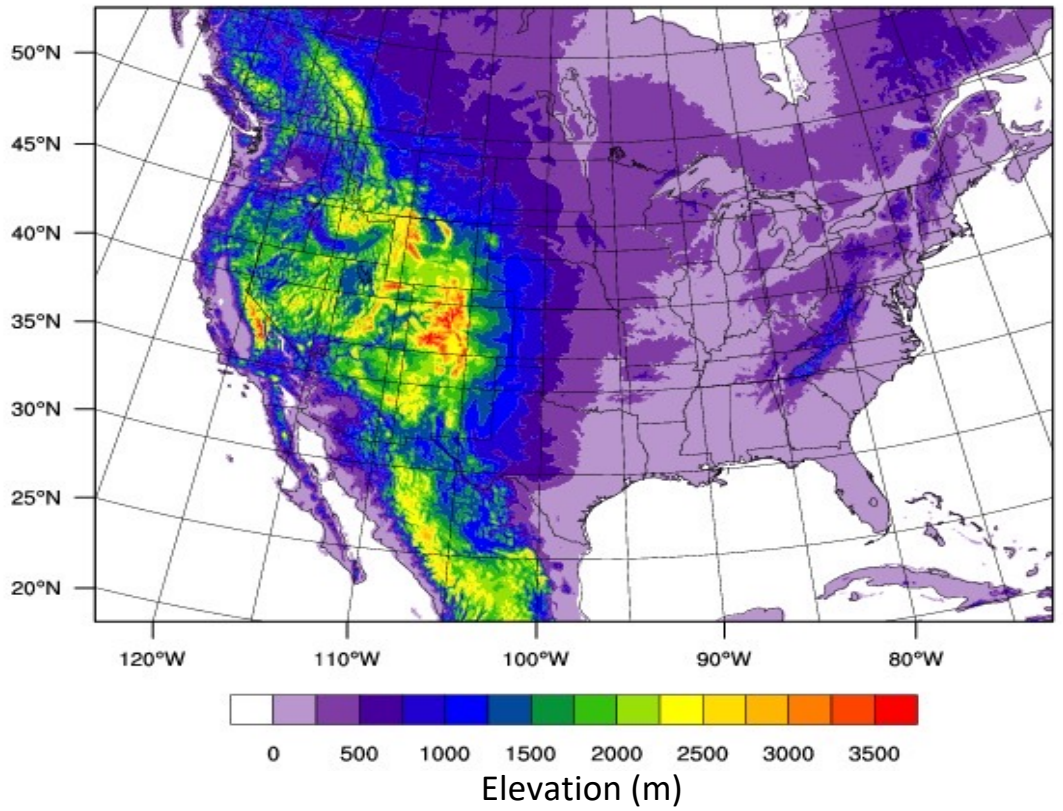
1. Is the LCZ data classification good enough for describing urban characteristics in integrated urban modeling?
2. What are the ability/flexibility need for WRF-Urban to accommodate new-gen data (e.g., WUDAPT level-2 gridded urban canopy parameters)?
3. How to deal with parameters in a mosaic urban model?
4. What are the modeling and data requirements for consistent cross-scale urban modeling?
5. Heterogeneity of human activities (e.g., AC schedule and coverage, anthropogenic heating, and GHG emission) is a dominant uncertainty in urban modeling.

NCAR-USGS CONUS404 project

unprecedented high-resolution (4-km) long-term (1979-2021) high-fidelity reanalysis of hydroclimate over the Continental U.S.

- V3.9.1 WRF model with a 4-km-spacing
- Spectral nudging of large wave numbers (1 and 2) above the Planetary Boundary Layer
- Initial and laterally forced by ERA-5 reanalysis for the current climate simulations
- Use of NDOWN software to create sub-domains generated from CONUS 404
- Physics parameterizations:
    1. Thompson microphysics
    2. Noah-MP land surface model
    3. YSU planetary boundary layer
    4. RRTMG radiation

WRF Model Domain

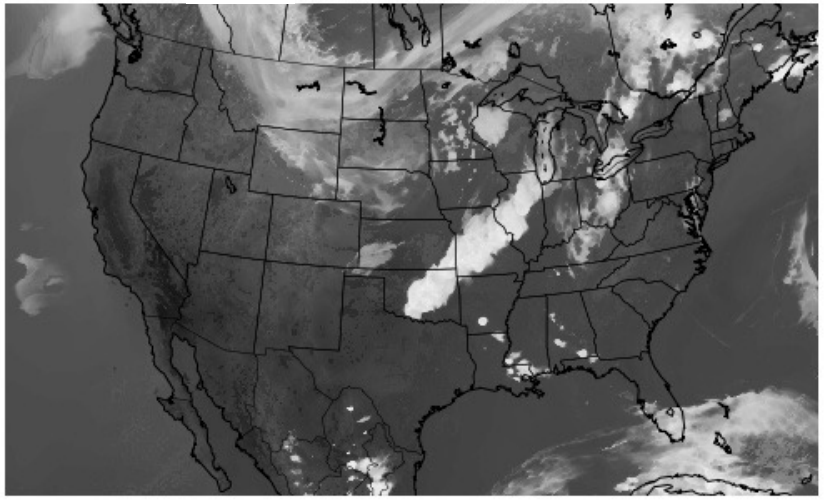


Comparison of Simulated and Observed Cloud Brightness Temperature (CONUS404)

USGS science for a changing world

WRF 4 km

chanel4 - 2013-06-01 00:00:00



GOES14

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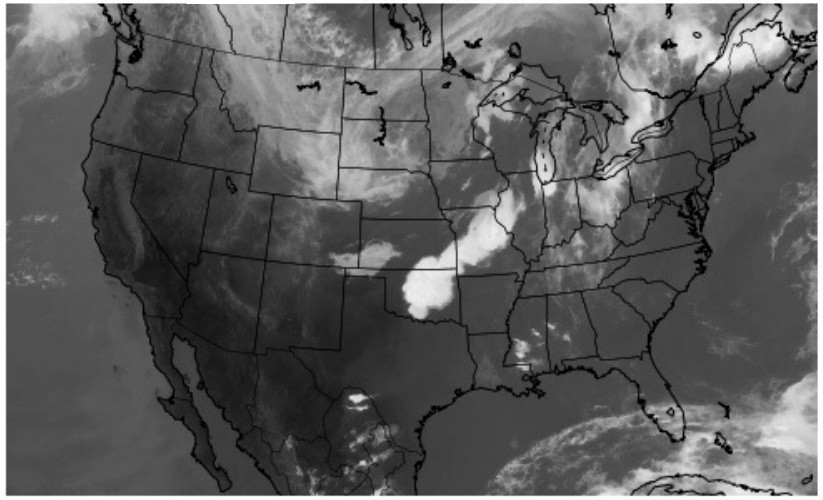
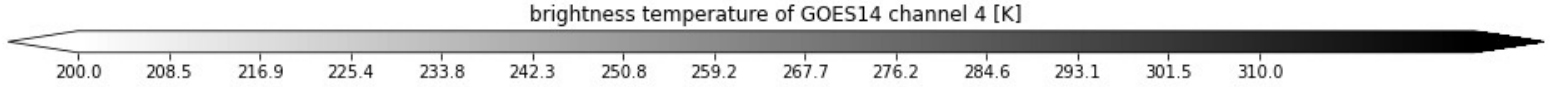
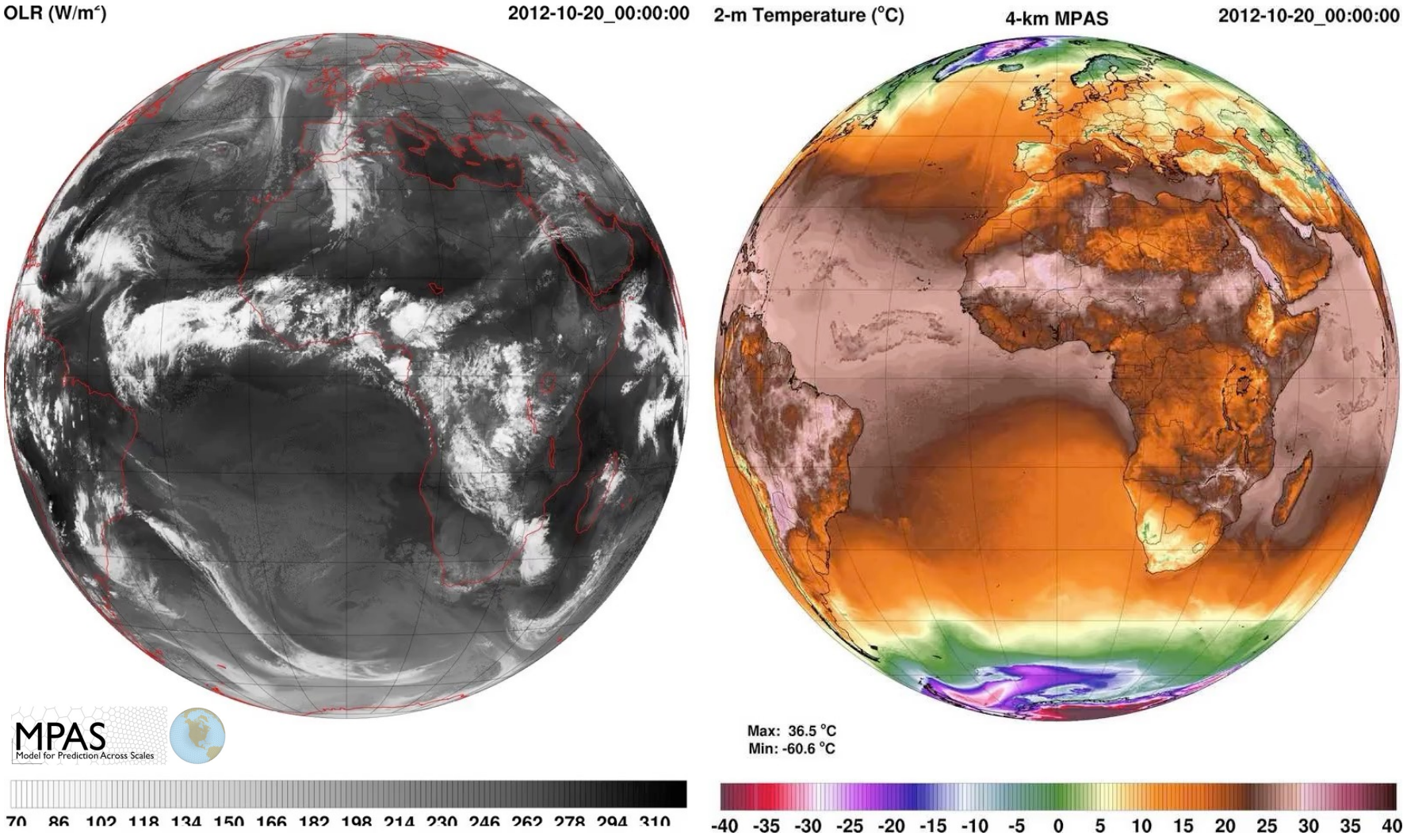
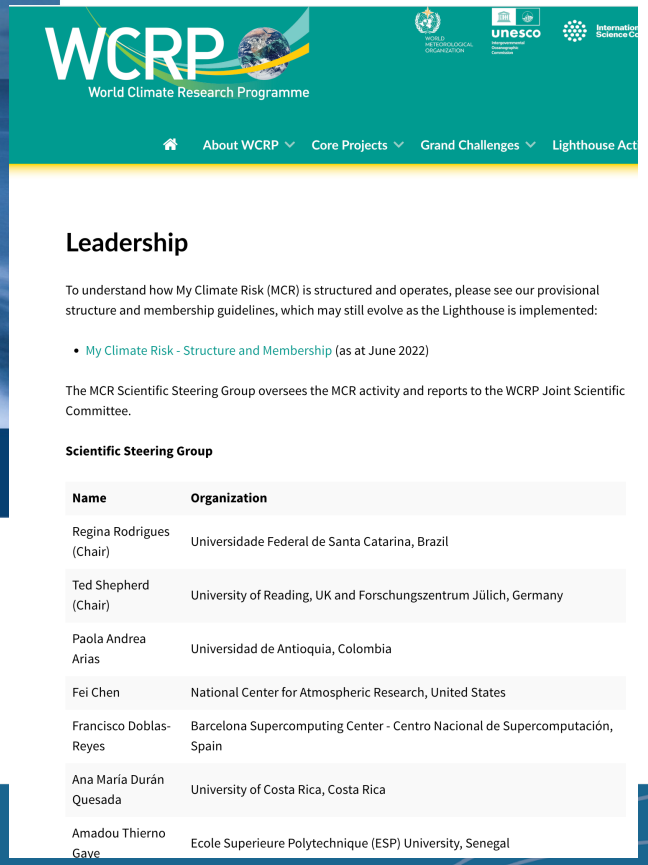




New NCAR MPAS Model: 4-km Global Storm-Resolving Simulation



WCRP (World Climate Research Programme): Five new Lighthouse Activities make critical near-term progress towards meeting WCRP's Vision, Mission, and Scientific Objectives; advance new science and technologies, and institutional frameworks, needed to manage climate risk and meet society's urgent need for robust and actionable climate information more effectively


WCRP
World Climate Research Programme

About WCRP | Core Projects | Grand Challenges | Lighthouse Act

Leadership

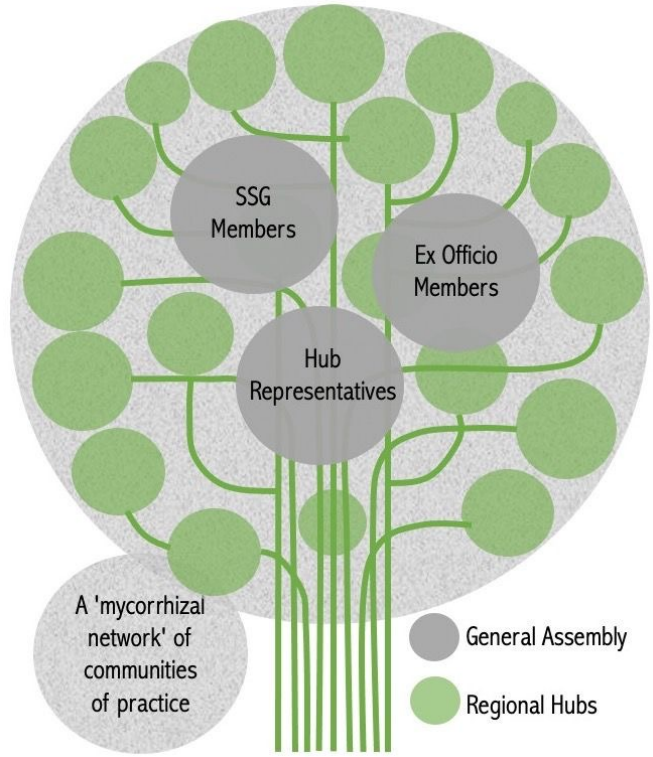
To understand how My Climate Risk (MCR) is structured and operates, please see our provisional structure and membership guidelines, which may still evolve as the Lighthouse is implemented:

- My Climate Risk - Structure and Membership (as at June 2022)

The MCR Scientific Steering Group oversees the MCR activity and reports to the WCRP Joint Scientific Committee.

Scientific Steering Group

Name	Organization
Regina Rodrigues (Chair)	Universidade Federal de Santa Catarina, Brazil
Ted Shepherd (Chair)	University of Reading, UK and Forschungszentrum Jülich, Germany
Paola Andrea Arias	Universidad de Antioquia, Colombia
Fei Chen	National Center for Atmospheric Research, United States
Francisco Doblas-Reyes	Barcelona Supercomputing Center - Centro Nacional de Supercomputación, Spain
Ana María Durán Quesada	University of Costa Rica, Costa Rica
Amadou Thierno Gaye	Ecole Superieure Polytechnique (ESP) University, Senegal



Urban regional hub candidates: Lagos (Nigeria), Tokyo (Japan), Houston (US)

NCAR
UCAR

ICUC 11, [11th International Conference on Urban Climate](), 28 August - 1 September, Sydney, Australia; deadline 31 January 2023; https://app.oxfordabstracts.com/dashboard/events/3742