A Web-based Framework for Accessible Urban Land Surface Model Simulations

Presenter: Dr. Yue Li

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Urbanisation Changes Land Surface Processes

Radiation

Turbulence

Anthropogenic emission

Runoff

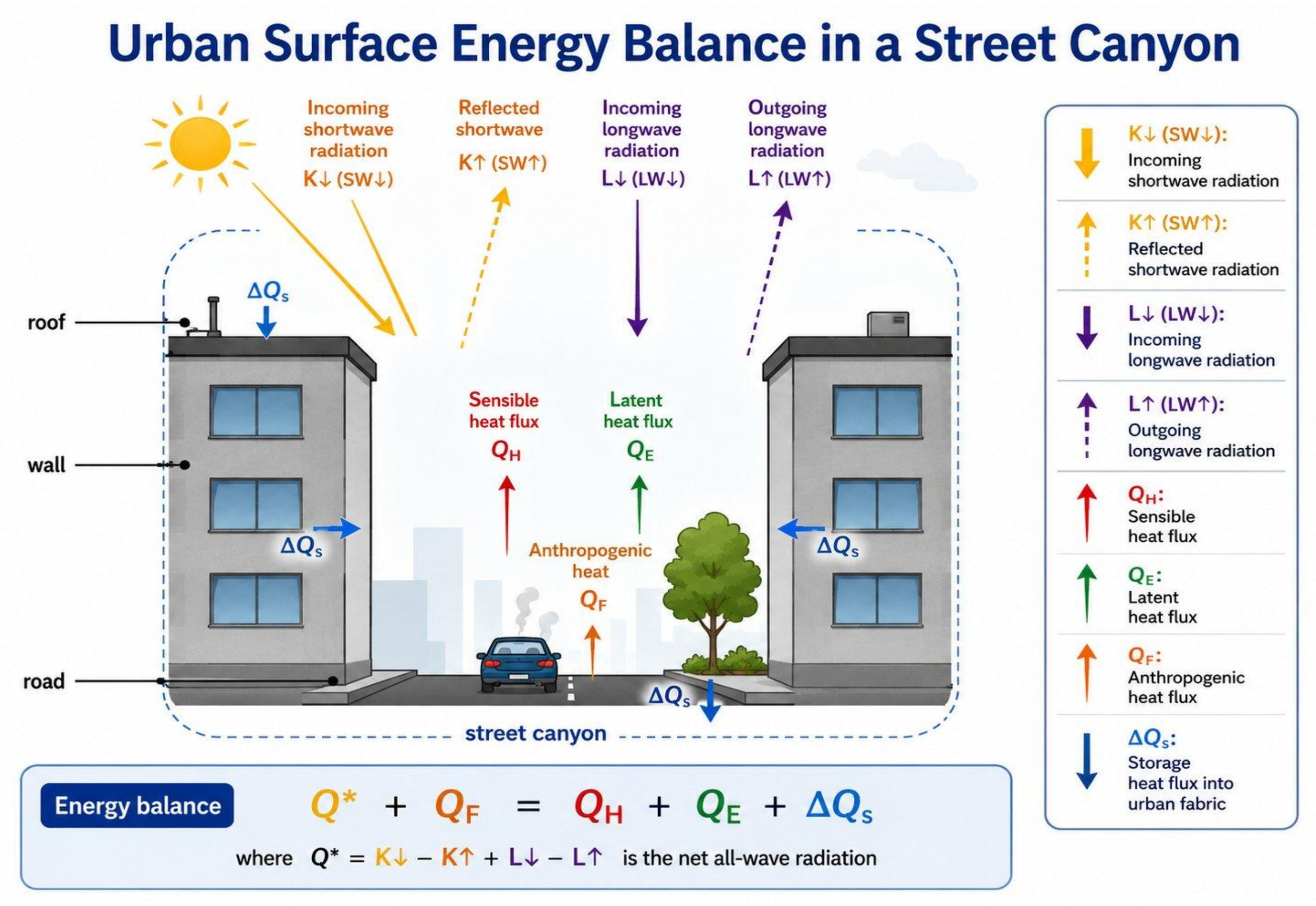
…

Source: Urban Climates (Cambridge University Press)

JULES-Met Office Reading Urban Surface Exchange Scheme (MORUSES)

What JULES-MORUSES simulates

- Radiation exchange within urban canyon.
- Heat and moisture fluxes to the atmosphere.
- Heat storage in roofs, walls and roads.



MORUSES for Understanding Urban Climate

Royal Meteorological Society

Simulations of the London urban heat island

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‡ The contribution of these authors was written in the course of their employment at the Met Office, UK, and is published with the permission of the Controller of HMSO and the Queen's Printer for Scotland.

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ORIGINAL PAPER

Check for updates

Urban signals in high-resolution weather and climate simulations: role of urban land-surface characterisation

Denise Hertwig[1] · Sue Grimmond[1] · Margaret A. Hendry[2] · Beth Saunders[1] · Zhengda Wang[1,3] · Marine Jeoffrion[1,4] · Pier Luigi Vidale[1] · Patrick C. McGuire[1,5,6] · Sylvia I. Bohnenstengel[7] · Helen C. Ward[8] · Simone Kotthaus[9]

Received: 27 November 2019 / Accepted: 8 June 2020 / Published online: 7 August 2020

Abstract
Two urban schemes within the Joint UK Land Environment Simulator (JULES) are evaluated offline against multi-year flux observations in the densely built-up city centre of London and in suburban Swindon (UK): (i) the 1-tile slab model, used in climate simulations; (ii) the 2-tile canopy model MORUSES (Met Office–Reading Urban Surface Exchange Scheme), used for numerical weather prediction over the UK. Offline, both models perform better at the suburban site, where differences between the urban schemes are less pronounced due to larger vegetation fractions. At both sites, the outgoing short- and longwave radiation is more accurately represented than the turbulent heat fluxes. The seasonal variations of model skill are large in London, where the sensible heat flux in autumn and winter is strongly under-predicted if the large city centre magnitudes of anthropogenic heat emissions are not represented. The delayed timing of the sensible heat flux in the 1-tile model in London results in large negative bias in the morning. The partitioning of the urban surface into canyon and roof in MORUSES improves this as the roof tile is modelled with a very low thermal inertia, but phase and amplitude of the grid box-averaged flux critically depend on accurate knowledge of the plan-area fractions of streets and buildings. Not representing non-urban land cover (e.g. vegetation, inland water) in London results in severely under-predicted latent heat fluxes. Control runs demonstrate that the skill of both models can be greatly improved by providing accurate land cover and morphology information and using representative anthropogenic heat emissions, which is essential if the model output is intended to inform integrated urban services.

Keywords JULES · Land surface models · MORUSES · Surface-energy balance · Urban modelling

Bohnenstengel, S. I. et al. (2011) https://doi.org/10.1002/qj.855
Hertwig, D. et al. (2020) https://doi.org/10.1007/s00704-020-03294-1

MORUSES in Urban Climate Application

atmosphere

MDPI

Article

Sensitivity Analysis of Surface Energy Budget to Albedo Parameters in Seoul Metropolitan Area U the Unified Model

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Abstract: The large population growth has significantly altered the thermal characterist
atmosphere, including decreased albedo and increased heat capacity; thus, urban areas e
unique climatic phenomena. We conducted sensitivity experiments using Unified Model L
Assimilation and Prediction-Met-Office-Reading Urban Surface Exchange Scheme (LDAPS-M
to investigate the response of surface energy budget to albedo changes in the Seoul Met
Area. We compared 1.5-m temperature at 56 automatic weather station (AWS) sites and
underestimations of approximately 0.5–2 K, but the diurnal cycle was well simulated. We ch
wall and road albedo parameters by ±50% from the default values for sensitivity experime
increasing albedo, 1.5-m temperature decreased by approximately 0.06 °C and 0.01 °C in u
suburban areas, respectively. These changes are responses to decreased net radiation and ser
during daytime, whereas sensible heat mainly contributes to the surface cooling during r
Furthermore, the decrease in albedo leads to altered vertical structure of potential temper
atmospheric circulations at altitudes of 300–1000 m. Results show that albedo modification
not only surface temperature but also the entire urban boundary layer.

Keywords: LDAPS; MORUSES; albedo sensitivity; surface energy budget

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Quarterly Journal of the Royal Meteorological Society

RESEARCH ARTICLE

Application of MORUSES single-layer urban canopy model in a tropical city: Results from Singapore

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Abstract
A tropical version of the high-resolution (300 m) UK Met Office forecast mode
(UM) using the MORUSES urban canopy parametrization (UCP) is adapte
for Singapore. High-resolution urban surface parameters are determined usin
a methodology based on Voronoi polygons applied to a 3D building database
The model is evaluated for clear sky and calm conditions at the neighbourhoo
scale by comparing its predictions with two sources of observations: energy bal
ance data from an eddy covariance flux tower located in a low-rise residentia
area, and a network of sensors measuring screen-level temperature across th
city. The model is able to reproduce the diurnal cycle of the surface energ
balance fluxes. Net radiation is overestimated which likely follows from ar
underestimation in cloud cover and effective surface albedo. This overestima
tion partly explains the overestimation of the sensible- and latent-heat fluxes
The higher model sensible-heat flux is further hypothesised to be related to th
overestimation of modelled canyon sensible-heat flux. Its peak exhibits a 1 h
delay, similar to simulated roof and canyon surface temperature. The mode
captures the diurnal cycle of temperature at a height of 20.5 m above groun
and at screen level. A night-time cold bias of 0.1–1.1 K and an overestimatio
of the daytime peak value are observed at both heights. These deviations ar
smaller than those predicted by other UCPs reported in the literature. A simpl
method to estimate the capability of an urban model to qualitatively distin
guish screen-level temperature differences across different urban morphologie
is developed which shows that MORUSES is clearly able to represent the impact
of different neighbourhoods on the thermal environment.

KEYWORDS
MORUSES, screen-level temperature, surface energy balance, tropical city, urban canop
parametrization, urban morphological parameters

Received: 20 April 2022 | Revised: 23 September 2022 | Accepted: 4 October 2022 | Published on: 26 November 2022

DOI: 10.1002/qj.4382

Quarterly Journal of the Royal Meteorological Society

RESEARCH ARTICLE

Implementation of the urban parameterization scheme in the Delhi model with an improved urban morphology

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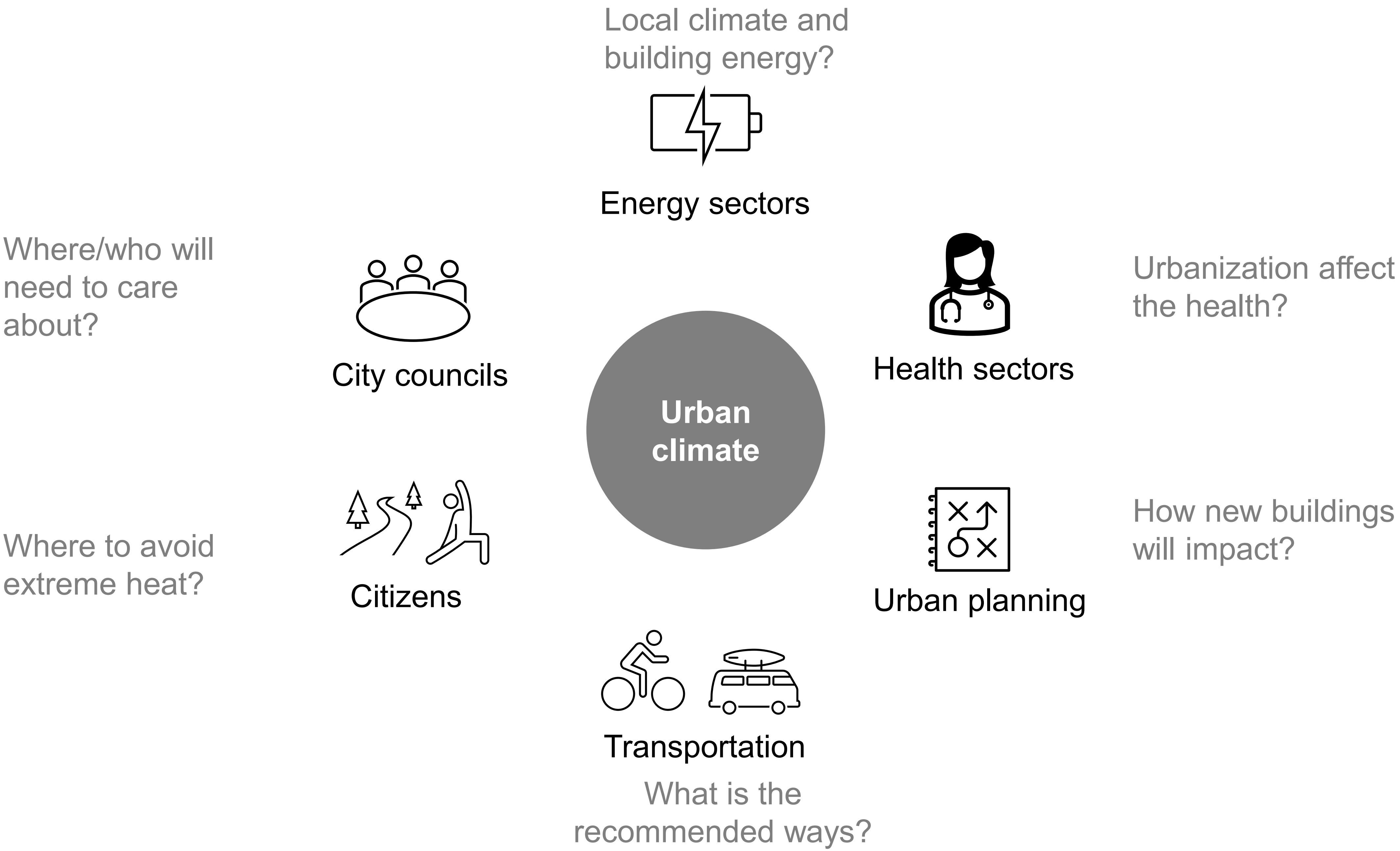
Funding information
UK Government's Newton Fund

Abstract
The current study highlights the importance of a detailed representation of urban processes in numerical weather prediction models and emphasizes the need for accurate urban morphology data for improving the near-surface weather prediction over Delhi, a tropical Indian city. The Met Office Reading Urban Surface Exchange Scheme (MORUSES), a two-tile urban energy-budget parameterization scheme, is introduced in a high-resolution (330-m) model of Delhi. A new empirical relationship is established for the MORUSES scheme from the local urban morphology of Delhi. The performance is evaluated using both the newly developed empirical relationships (MORUSES-IND) and the existing empirical relationships for the MORUSES scheme (MORUSES-LON) against the default one-tile configuration (BEST-1t) for clear and foggy events and validations are performed against ground observations. MORUSES-IND exhibits a significant improvement in the diurnal evolution of the wind speed in terms of amplitude and phase, compared with the other two configurations. Screen temperature (T_{screen}) simulations using MORUSES-IND reduce the warm bias, especially during the evening and night hours. The root-mean-square error of T_{screen} is reduced up to 29% using MORUSES-IND for both synoptic conditions. The diurnal cycle of surface-energy fluxes is reproduced well using MORUSES-IND. The net longwave fluxes are underestimated in the model and biases are more significant during foggy events, partly due to the misrepresentation of fog. An urban cool island (UCI) effect is observed in the early morning hours during clear-sky conditions, but it is not evident on foggy days. Compared with BEST-1t, MORUSES-IND represents the impact of urbanization more realistically, which is reflected in the reduction of the urban heat island and UCI in both synoptic conditions. Future works would improve the coupling between the urban surface energy budget and anthropogenic aerosols by introducing MORUSES-IND in a chemistry aerosol framework model.

KEYWORDS
Delhi model, MORUSES, surface energy balance, urban heat island, urban parameterization

Wie, J. et al. (2020) https://doi.org/10.3390/atmos11010120
Simón-Moral, A. et al. (2020) https://doi.org/10.1002/qj.3694
Theethai Jacob, A. et al. (2023) https://doi.org/10.1002/qj.4382

Who Cares About Urban Climates?



Challenge 1: Installation & Workflow

Software / Environment requirements

- Unix / Linux
- Fortran compiler
- FCM / build configuration
- NetCDF
- JULES source code
- HPC / batch workflow for large simulations

Example setup workflow:

```
cat > ~/setup_ec2.sh << 'EOF'
#!/bin/bash
set -e
swapon --show | grep -q swapfile || {
  sudo dd if=/dev/zero of=/swapfile bs=1M count=2048
  sudo chmod 600 /swapfile; sudo mkswap /swapfile; sudo swapon /swapfile
}
sudo dnf install -y git make gcc gcc-gfortran \
  perl-FindBin perl-File-Copy perl-File-Compare perl-Sys-Hostname \
  perl-IO-Compress perl-Digest-SHA perl-Text-Balanced perl-Time-Piece perl-filetest
[ -d "$HOME/miniforge3" ] || {
  curl -sL -o /tmp/miniforge.sh https://github.com/conda-forge/miniforge/releases/latest/download/Miniforge3-Linux-x86_64.sh
  bash /tmp/miniforge.sh -b -p "$HOME/miniforge3"
}
source "$HOME/miniforge3/bin/activate"
conda install -y -c conda-forge netcdf-fortran
[ -d "$HOME/fcm" ] || git clone -q https://github.com/metomi/fcm.git "$HOME/fcm"
[ -d "$HOME/jules_source" ] || git clone -q --depth 1 https://github.com/MetOffice/jules.git "$HOME/jules_source"
pip install --quiet matplotlib pandas netCDF4 xarray
echo "Setup complete."
EOF
bash ~/setup_ec2.sh
```

```
swap               a t3.micro only has ~900MB RAM; 2GB of swap (disk
                    pretending to be RAM) keeps the build from getting
                    killed when it briefly needs more memory than that
gfortran/git/make  the Fortran compiler and the tools FCM (JULES's build
                    system) drives it with
+ perl modules      FCM itself is written in Perl and needs these
Miniforge/conda     a self-contained Python+package manager, used here
                    just to install netcdf-fortran -- Amazon Linux's own
                    package repos (dnf) don't have it
FCM                 Met Office's build tool -- reads JULES's build config
                    and calls gfortran on the right files in the right order
JULES source        git clone of the actual JULES Fortran source code --
                    the one genuine external dependency here, not part of
                    this repo
matplotlib/pandas/ the Python packages the postprocessing scripts need,
netCDF4/xarray      installed via pip, NOT conda -- see the warning below
```

Challenge 2: Configuration

Configuration

- Urban scheme selection
- Surface fractions
- MORUSES parameters
- Namelist settings

RUNS > era5_default > namelists > ancillaries.nml

```
&jules_frac
  read_from_dump=.false.
  file='/work/.../era5_preprocessed/era5_frac_10tile.nc'
  frac_name='frac'
/
&jules_vegetation_props
/
&jules_soil_props
  const_z=.true.
  read_from_dump=.false.
  nvars=9
  use_file=9*.true.
  file='/work/.../era5_preprocessed/era5_soi
  var='b','sathh','satcon','sm_sat','sm_crit
  var_name='b','sathh','satcon','sm_sat','sm
/
&jules_top
/
&jules_agric
  read_from_dump=.false.
/
&jules_crop_props
/
&jules_irrig_props
/
&jules_rivers_props
/
&jules_water_resources_props
/
&urban_properties
  nvars=7
  use_file=7*.true.
  file='/work/.../era5_preprocessed/era5_urb
  var='wrr','hwr','hgt','albwl','albrd','emi
  var_name='wrr','hwr','hgt','albwl','albrd'
/
&jules_flake
/
&jules_co2
  co2_mmr=5.941e-4
/
```

MODELS > jules-main > src > science > surface > screen_tq_jls.F90

```

!-----------------------------------------------------------------------------
! Diagnose local and GBM temperatures at 1.5 m if requested via ST1P5
! and 10m if requested by l_t10m
! The transitional diagnostic requires that this be done on all
! timesteps as the decoupled screen temperature is prognostic.
!-----------------------------------------------------------------------------
IF (sf_diag%l_t10m .OR. sf_diag%l_q10m) THEN
  ! calculate 10m temp over sea/sea-ice only
  ! also required if 10m q requested due to cloud scheme call in diag_bl

!$OMP PARALLEL DO                                                          &
!$OMP SCHEDULE(STATIC)                                                     &
!$OMP DEFAULT(NONE)                                                        &
!$OMP PRIVATE(j,i)                                                         &
!$OMP SHARED(tdims,flandg,sf_diag,tstar_ssi,grcp,tl_1,z1,z0mssi,z0hssi)
  DO j = tdims%j_start, tdims%j_end
    DO i = tdims%i_start, tdims%i_end
      IF (flandg(i,j) <  1.0 ) THEN
        ! using z_obs_wind for 10m level rather than z_obs_tq
        sf_diag%t10m(i,j) = tstar_ssi(i,j) - grcp * z_obs_wind +           &
                sf_diag%chr10m(i,j) * (tl_1(i,j) - tstar_ssi(i,j) +        &
                grcp * (z1(i,j) + z0mssi(i,j) - z0hssi(i,j)))
      END IF
    END DO
  END DO
!$OMP END PARALLEL DO
END IF
```

Challenge 3: Data

Urban surface data

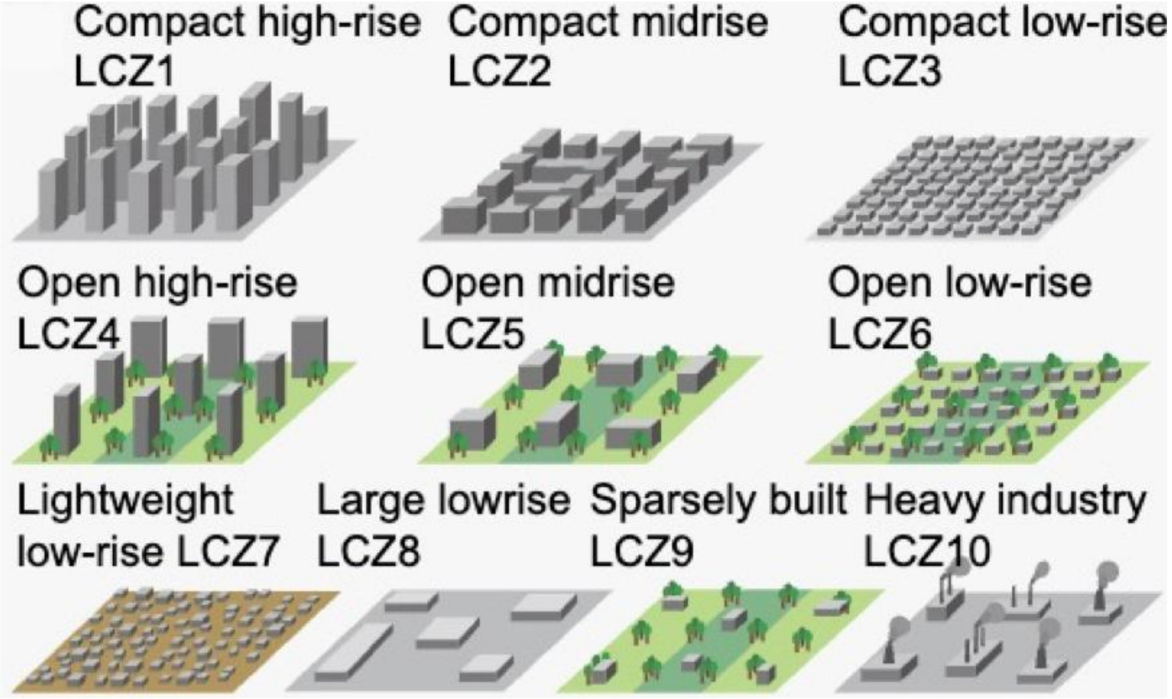
- Building height
- H/W ratio
- W/R ratio
- Albedo
- Emissivity
- Urban fraction

Atmospheric forcing

- Temperature
- Radiation
- Wind
- Humidity
- Precipitation

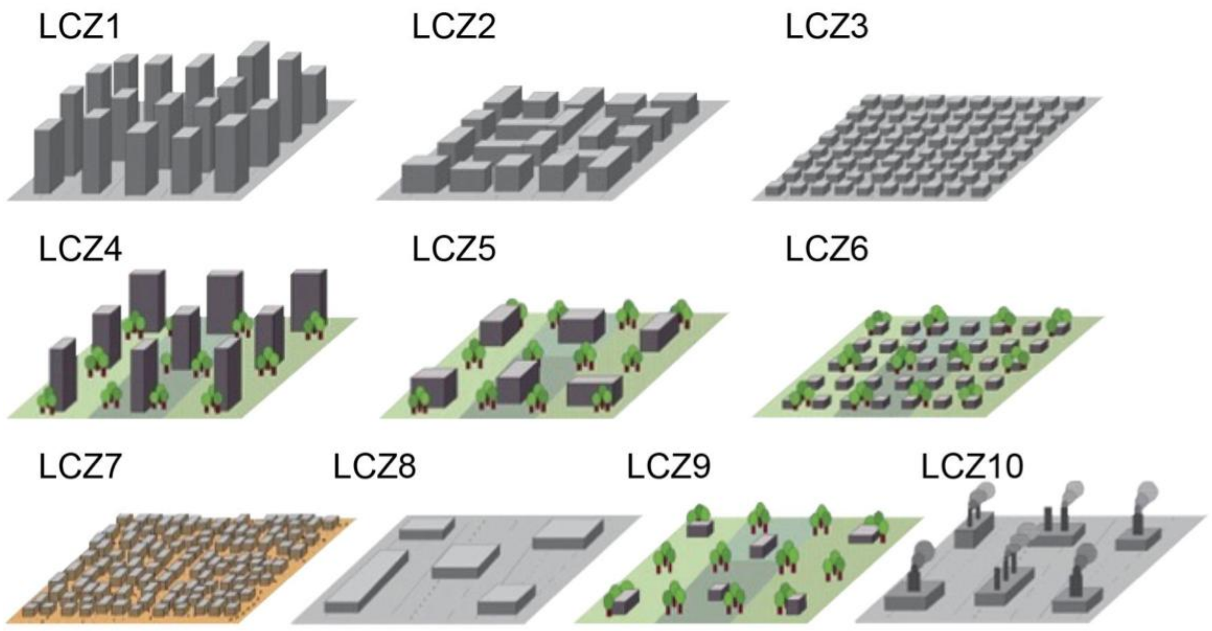
Challenge 4: Integrating urban classification

- **Ten built Local Climate Zone (LCZ) classes**



JULES MORUSES

Local climate zone as a land-cover classification in urban climate study

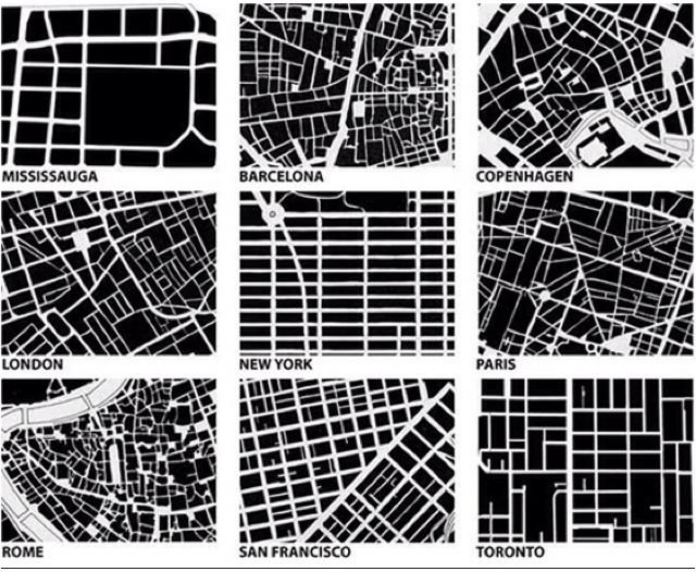


Based on urban forms

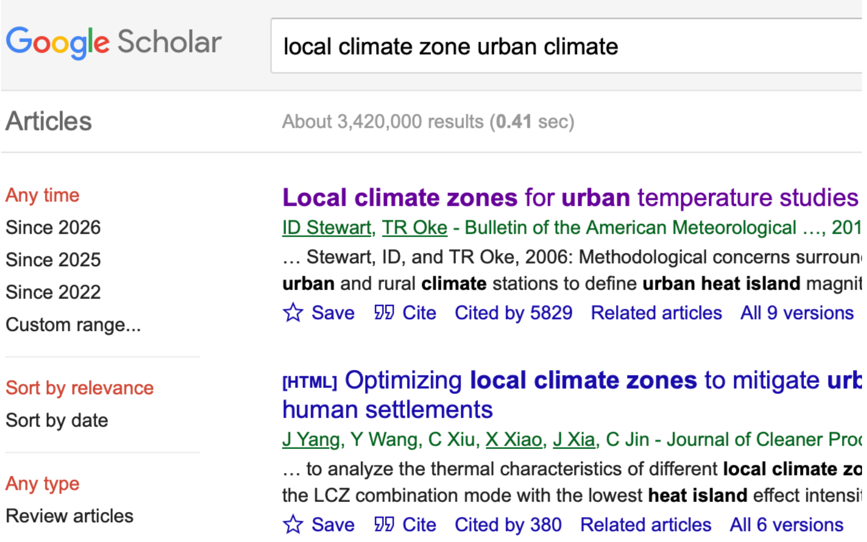
- Local climate zone (10-class)
  - Compact highrise (LCZ1)
  - Compact midrise (LCZ2)
  - Compact lowrise (LCZ3)
  - Open highrise (LCZ4)
  - Open midrise (LCZ5),
  - Open lowrise (LCZ6)
  - Lightweight lowrise (LCZ7)
  - Large lowrise (LCZ8)
  - Sparsely built (LCZ9)
  - Heavy industry (LCZ10)

Why Local Climate Zone (LCZ)?

Better resolving urban morphological diversity



Useful for supporting urban climate community



Consistent global urban database

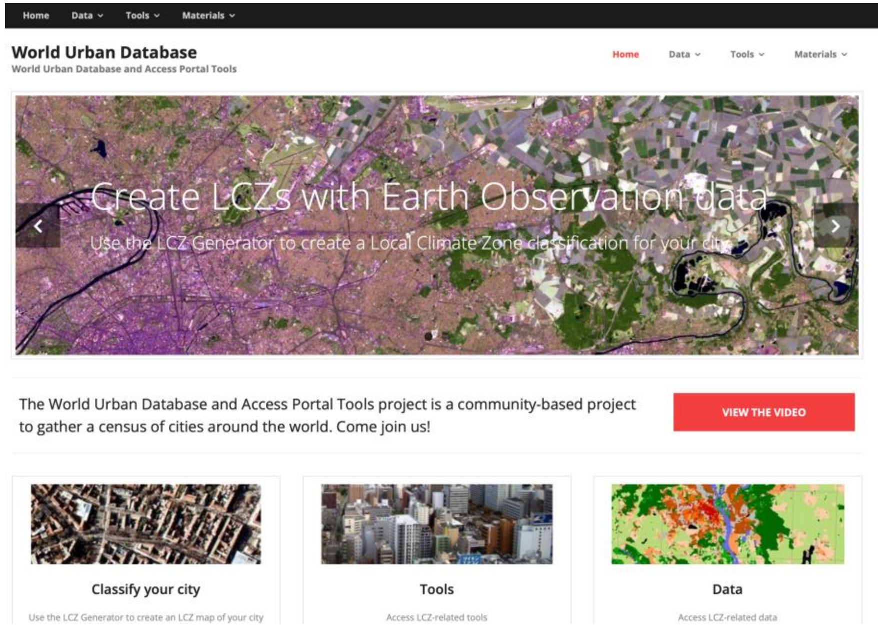
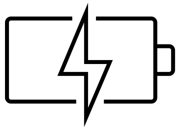


Figure source: (left) https://i.pinimg.com/736x/2b/08/40/2b084005a861fd04a08c9546db222115.jpg, (middle) https://scholar.google.com/, (right) https://www.wudapt.org/

Challenge 5: Accessibility - no coding!

Local climate and
building energy?

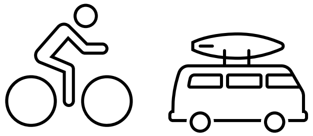


Energy sectors

No Coding

Citizens

Urban planning

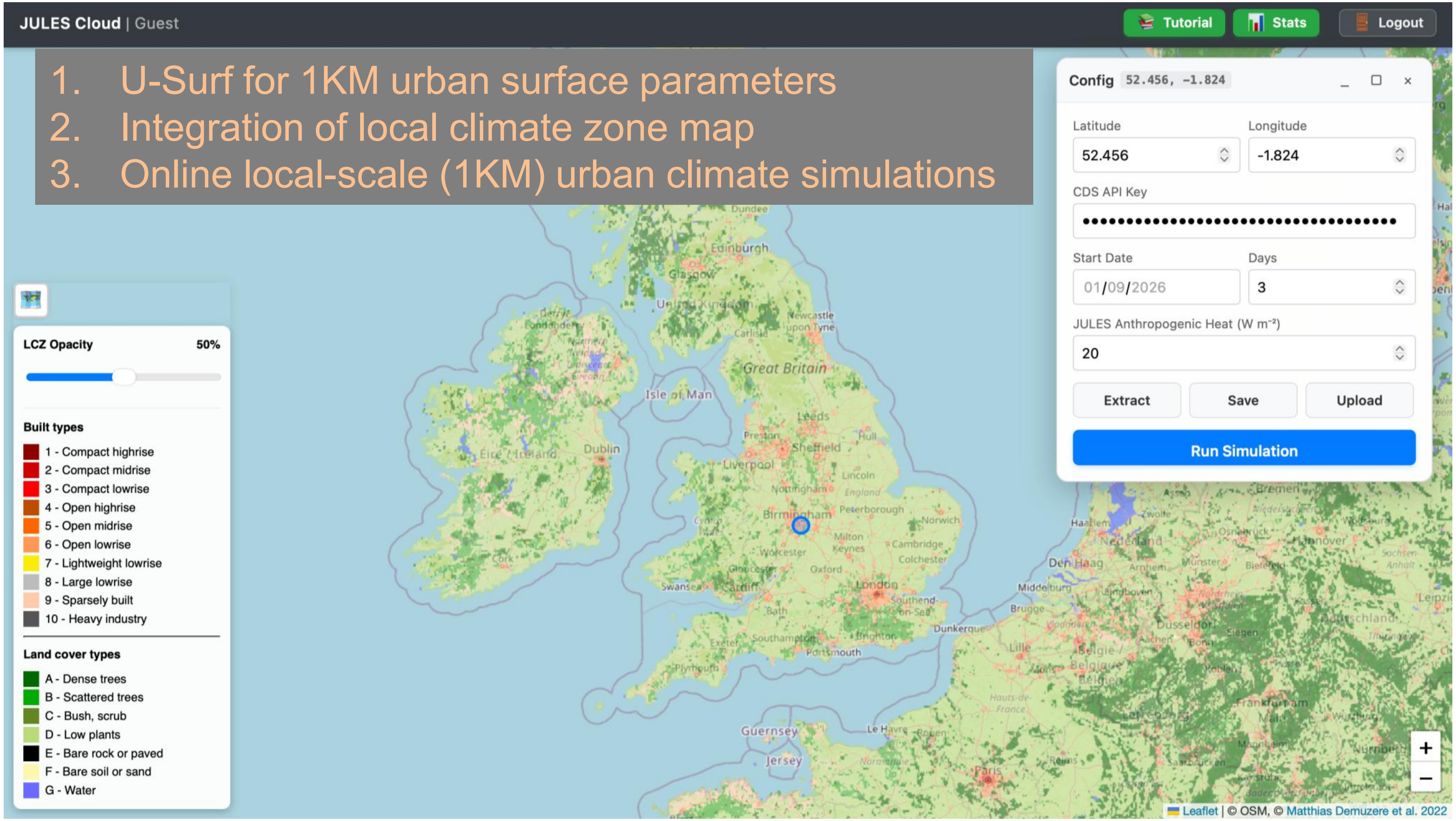


Transportation

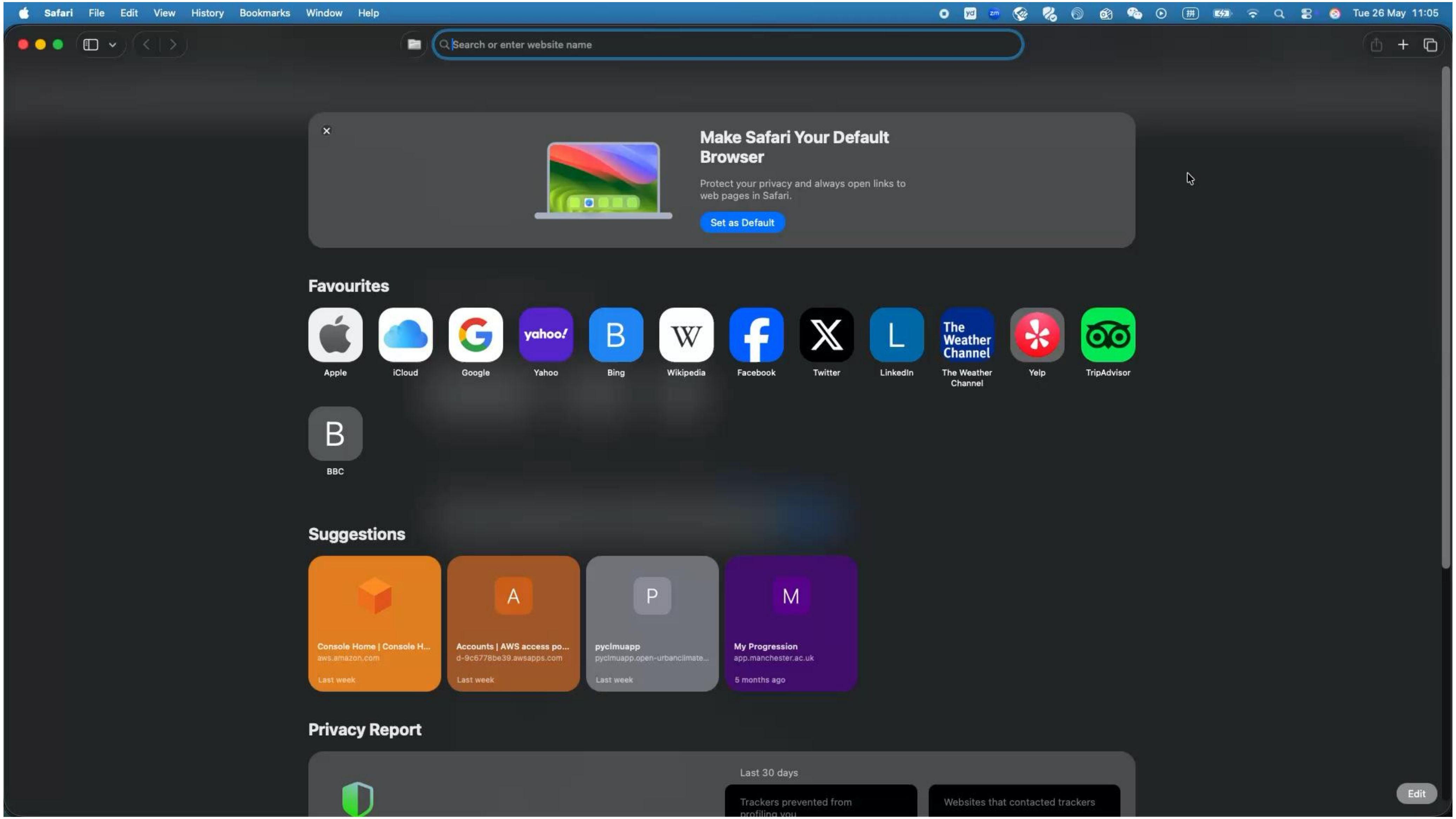
What is the
recommended ways?

Open Urban Climate: JULES/MORUSES on AWS

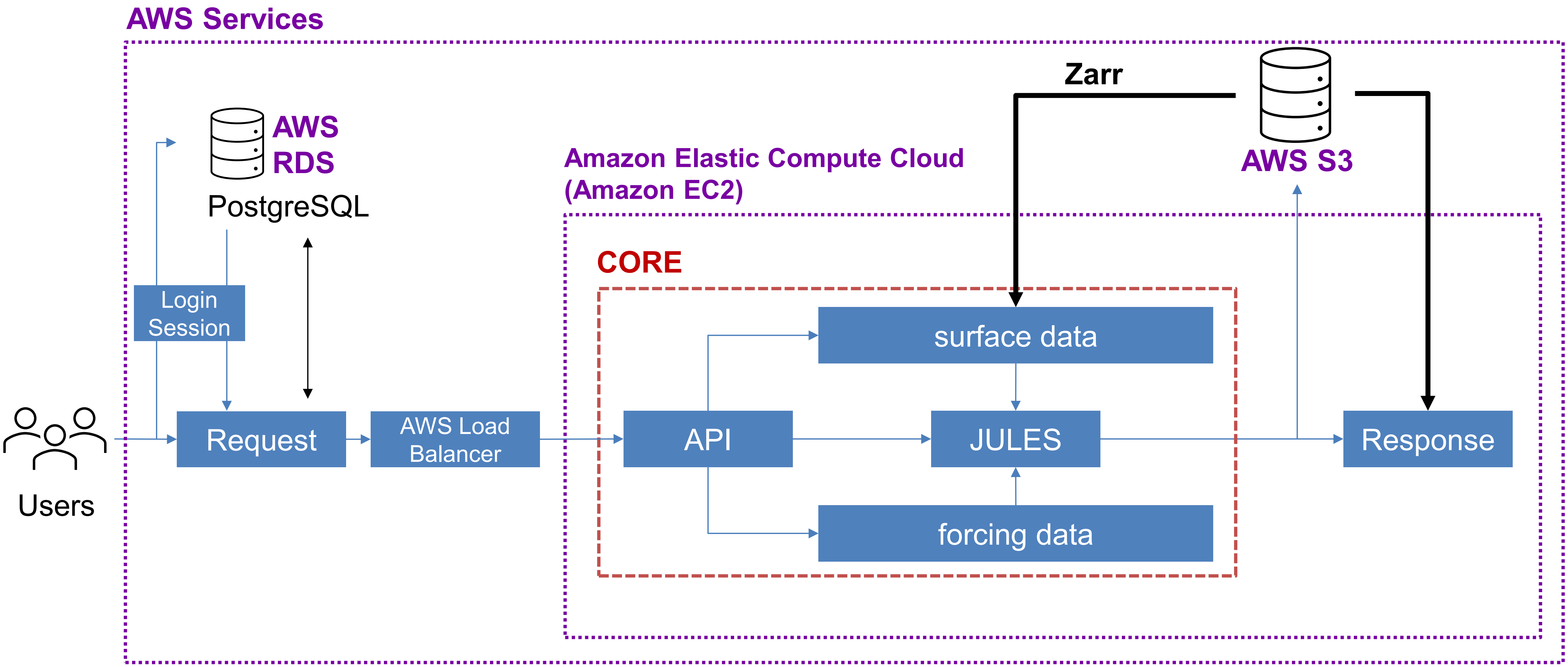
1. U-Surf for 1KM urban surface parameters
2. Integration of local climate zone map
3. Online local-scale (1KM) urban climate simulations



Open Urban Climate: JULES/MORUSES on AWS



Open Urban Climate: JULES/MORUSES on AWS



Questions?

- Contact us:

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  - zhonghua.zheng@manchester.ac.uk

Open Urban Climate Platform

Web Platform Demo