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TERRA_URB developments/upgrades on urban canopy and vegetation parameters

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Motivation for the recent code developments

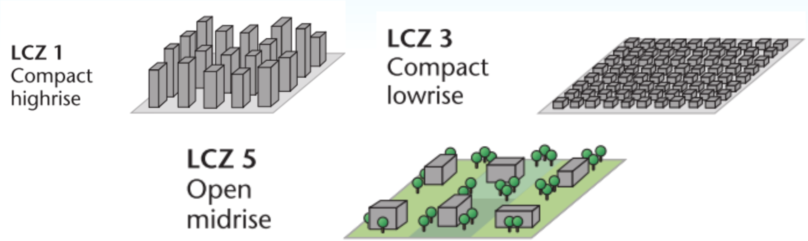
Urban canopy parameters used by SURY (Semi-empirical URban canopY dependency) in TERRA_URB (Wouters et al., 2016)

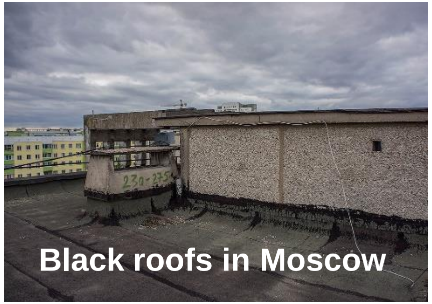
Urban canopy parameters (input of SURY)		
Parameter name	Symbol	Default values
Surface albedo	α	0.101
Surface emissivity	ϵ	0.86
Surface heat conductivity	λ_s	$0.767\,\mathrm{W\,m^{-1}\,K^{-1}}$
Surface heat capacity	$C_{v,s}$	$1.25 \times 10^6\,\mathrm{J\,m^{-3}\,K^{-1}}$
Building height	H	15 m
Canyon height-to-width ratio	$\frac{h}{w_c}$	1.5
Roof fraction	R	0.667
Bulk parameters (output of SURY)		
Parameter name	Symbol	Surface values corresponding to the defaults
Albedo	α_{bulk}	0.081 (snow-free)
Emissivity	ϵ_{bulk}	0.89 (snow-free)
Heat conductivity	λ_{bulk}	$1.55\,\mathrm{W\,m^{-1}\,K^{-1}}$
Heat capacity	$C_{v,\text{bulk}}$	$2.50 \times 10^6\,\mathrm{J\,m^{-3}\,K^{-1}}$
Thermal admittance	$\mu_{\text{bulk}} \left(= \sqrt{C_{v,\text{bulk}}\lambda_{\text{bulk}}}\right)$	$1.97 \times 10^3\,\mathrm{J\,m^{-2}\,K^{-1}\,s^{-1/2}}$
Aerodynamic roughness length	z_0	1.125 m
Inverse Stanton number	kB^{-1}	13.2 (in case that $u_* = 0.25\,\mathrm{m\,s^{-1}}$)

Tthermal and radiative parameters of urban materials

Building morphology parameters

Cities and their parts are very different!





Main idea was to replace hard-coded constants to 2D external fields with a useful namelist controls

Implementation of new parameters

Description and units	Default value	Old variable in COSMO code	New variables in COSMO code	COSMO namelist parameters	INT2LM namelist parameters	External parameter name
Building area fraction with respect to an urban tile [1]	0.67	c_roof	curb_bldfr, curb_bldfr_d, curb_bldfr(:,:)	curb_bldfr	lurb_bldfr	URB_BLDFR
Building height [m]	15	c_uf_h	curb_bldh, curb_bldh_d, urb_bldh (:,:)	curb_bldh	lurb_bldh	URB_BLDH
Street canyon aspect ration (H/W) [unitless]	1.5	c_htw	curb_h2w, curb_h2w_d, urb_h2w(:,:)	curb_h2w	lurb_h2w	URB_H2W
Anthropogenic heat flux [W/m2]	-1 (to use external parameter)	ahf_an	curb_ahf, curb_ahf_d, ahf_an (:,:)	curb_ahf		**AHF**
Urban material thermal albedo [1]	0.14	ctalb_bm	curb_talb, urb_talb_d, urb_talb (:, :)	curb_talb		**URB_TALB**
Urban material shortwave albedo [1]	0.1	csalb_bm	curb_salb,curb_salb_d, urb_salb (:, :)	curb_salb		**URB_SALB**
Volumetric heat capacity of urban material (capacity * density) [J · m^{-3} · K^{-1}]	1.25E6	c_rhoc_bm	curb_hcap, curb_hcap _d, urb_hcap (:, :)	curb_hcap		**URB_HCAP**
Heat conductivity of urban material [W · m^{-1} · K^{-1}]	0.777	c_ala_bm	curb_hcon, curb_hcon_d, urb_hcon (:, :)	curb_hcon		**URB_HCON**
Skin-layer conductivity for rural areas [???]	10 or 30 (now 30)	calamrur	cskinc, cskinc_d, skinc (:,:)	cskinc	lskinc	SKC
Skin-layer conductivity for urban areas [???]	1000	calamurb	cskinc_urb	cskinc_urb		

Status update on COSMO+TERRA_URB development

- **cosmo_191107_5.05_urb5**: a basic stable version with TERRA_URB which we have as an outcome from AEVUS PT
- **cosmo_191107_5.05_urb5 + update from Ulrich Schättler:**
  - Fixed bug with lwrite_const
  - Option for writing tiled variables to Netcdf output (not tested yet)
- **cosmo_191107_5.05_urb5up* with my new developments (November 2019, distributed before Naples meeting):**
  - New 2D external parameters for urban morphological and thermal properties (URB_BLDH, URB_H2W, …)
  - Skin-layer temperature scheme is controlled in the same way as in v5.06a using **cskinc** namelist parameter
- **cosmo_191213_5.05_urb6**
  - Resent updates for 5.05urb5 from Ulrich Schättler + support of new external parameters from 5.05urb5up
  - **Bug found:** model crashes when new urban canopy parameters are not defined for grid cells with FR_PAVED = 0.
- **cosmo_191213_5.05_urb6up3 (February 2020):**
  - Fixed bug for COSMO 5.05urb6
  - Additional developments on the new external parameters (radiative parameters as 2D fields + scaling coefficients)
- **cosmo_191213_5.05_urb6up4sh (July 2020, sent to Ulrich Schättler as a candidate for further GitHub development) :**
  - Minor inconsistency between TERRA_URB in code and paper description is found and fixed
  - Tuning coefficients for soil hydrology introduces (csoilhyd and crootdp2 as soilhyd and fac_rootdp2 in COSMO-CLM 5.0).
- **cosmo_191213_5.05_urb6up5sh** (September 2020):**
  - Bug found and fixed for the case when TERRA_URB = true and lemiss = true

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- **int2lm_190524_2.06up2*** which supports all new 2D external parameters (July 2020)

*up means urban parameters,
**sh means soil hydrology

Some insights on the recent bug fixes

sfc_terra.f90

```fortran
    !
    ! Because of the curvature of the surface, the uppermost soil layer heat
    ! transfer is larger compared to the heat conductivity of a plan area.
    ! As a result, the effective heat conductivity of the upper surface is increased.
    ! This is also the surface layers beneath in which the effect heat conductivity
    ! decreases with depth.

    ! this modification decreases with depth with respect to the
    ! natural soil below the buildings.

    !$acc parallel
    DO kso = 1, ke_soil
      !$acc loop gang vector
      DO i = ivstart, ivend

        zalpha_uf  = MAX (0.0_wp, MIN(zmls(kso)/urb_bldh(i),  1.0_wp))
        zalpha_lnd = MAX (0.0_wp, MIN(zmls(kso)/c_lnd_h,      1.0_wp))

        ! zalam(i,kso) = sa_uc(i) * c_ala_bm     * ( ai_uc(i)*(1.0_wp - zalpha_uf ) + zalpha_uf ) + &
        !        (1.0_wp-sa_uc(i)) * zalam(i,kso) *    ( c_lnd*(1.0_wp - zalpha_lnd) + zalpha_lnd)
        ! Change by MV
        ! MV UP2
        !zalam(i,kso) = sa_uc(i) * urb_hcon (i)   * ( ai_uc(i)*(1.0_wp - zalpha_uf ) + zalpha_uf ) + &
        !       (1.0_wp-sa_uc(i)) * zalam(i,kso) !!!*    ( c_lnd*(1.0_wp - zalpha_lnd) + zalpha_lnd)

        ! Changed by MV to be consistend with eq. (5) from Wouters et al., 2016
        zalam(i,kso)  = sa_uc(i) * (urb_hcon (i) * ai_uc(i) * (1.0_wp - zalpha_uf) + &
                             zalam(i,kso) * zalpha_uf) +                          &
                      (1.0_wp - sa_uc(i)) * zalam(i,kso)


      ENDDO

    ENDDO
    !$acc end parallel
  END IF
```

Inconsistence between code and eq. (5)

Below the surface, the urban substrate layer with a thickness equal to the building height h is considered for representing the thermal mass of the urban canopy in thermal contact with the natural soil below. The bulk heat capacity in this layer considers a vertical linear gradient between the surface value ($C_{v,\mathrm{bulk,s}}$) and the value of the natural soil below ($C_{v,\mathrm{soil}}$):

$$C_{v,\mathrm{bulk}}(z) = \left(1 - \frac{z}{h}\right) C_{v,\mathrm{bulk,s}} + \frac{z}{h} C_{v,\mathrm{soil}}, \quad \text{for } 0 < z < h. \quad (5)$$

Below the urban substrate layer, the bulk heat capacity is equal to $C_{v,\mathrm{soil}}$:

$$C_{v,\mathrm{bulk}}(z) = C_{v,\mathrm{soil}}, \quad \text{for } z \geq h. \quad (6)$$

An analogous formulation is considered for the vertical profile of the bulk heat conductivity $\lambda_{\mathrm{bulk}}(z)$:

$$\lambda_{\mathrm{bulk}}(z) = \left(1 - \frac{z}{h}\right) \lambda_{\mathrm{bulk,s}} + \frac{z}{h} \lambda_{\mathrm{soil}}, \quad \text{for } z < h \quad (7)$$

$$\lambda_{\mathrm{bulk}}(z) = \lambda_{\mathrm{soil}}, \quad \text{for } z \geq h, \quad (8)$$

where λ_{soil} is the heat conductivity of the natural soil and $\lambda_{\mathrm{bulk,s}}$ is the bulk surface heat conductivity:

Bug fixed in 5.05urb6up4

Some insights on the recent bug fixes

radiation_utilities.f90

```fortran

!-------------------------------------------------------------------------------
! Begin subroutine surface_albedo
!-------------------------------------------------------------------------------

  DO jp = jsta_comp, jend_comp       ! loop over nradcoarse points in j-direction
                                     !   is loop from 1 to 1 without coarse grid
    !$acc parallel
    !$acc loop gang vector
    DO  ip = ista_comp, iend_comp    ! loop over grid points in the block in i-direction

      ! get i/j indices for 2D COSMO data structure
      i = mind_ilon_rad(ip,jp,ibc)
      j = mind_jlat_rad(ip,jp,ibc)

      IF (lemiss) THEN
        ralth(ip,jp) = 1.0_wp-emis_rad(i,j)  ! geographical dependent thermal albedo
      ELSE
        IF (lterra_urb .AND. lurbfab) THEN
          ! MV UP2
          ralth(ip,jp) =            tl_sa_uc(i,j,0)  * urb_talb (i,j) * alb_red_uc(i,j) &
                       + (1.0_wp - tl_sa_uc(i,j,0)) * ctalb
        ELSE
          ralth(ip,jp) = ctalb
        ENDIF
      ENDIF

      ist = 10
```

Urban modification of the emissivity is not applied when lemiss = true

Bug fixed in 5.05urb6up5

Further planned/discussed developments

1. **To make variable names consistent with GRIB standards (discussed with Liermann Dörte in May)**

2. **To test consistency with itype_vdif = -1/1**

3. To check interaction between TERRA_URB and snow cover?

4. Thermal parameters for different facets (roofs, walls, road) as separate external parameters?

   - For better consistence with WUDAPT-to-COSMO tool
   - For climate-related studies, e.g. to allow modelling scenarios with white roofs, etc.

5. **Improved representation of urban vegetation and paved/built up fractions (proposed for PP CITTA)**

shortName (proposal)	Array name
URB_FR_BLD	URB_BLDFR
URB_H2W	URB_H2W
URB_H_BLD	URB_BLDH
URB_ALB_TH	URB_TALB
URB_ALB_SO	URB_SALB
URB_HCAP	URB_HCAP
URB_HCON	URB_HCON

Towards an improved representation of paved/built areas

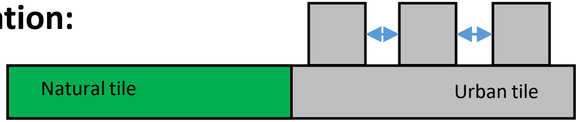
- **Inconsistency between different physical parameters: ISA and urban / built up area**
- **Key drivers of urban climate features:**
  - Impervious unvegetated surfaces
  - Urban canopy 3D geometry
- **Real world:**
  - Built up area >= paved area (vegetated urban environment)
  - Paved, but not built up areas (airfields, roads)
- **Current limitation:** build up area = paved area

100 % built up, 100% paved

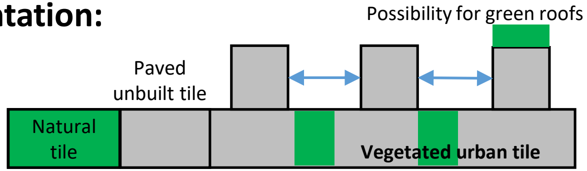
≈100 % built up, ≈50% paved

0 % built up, ≈50% paved

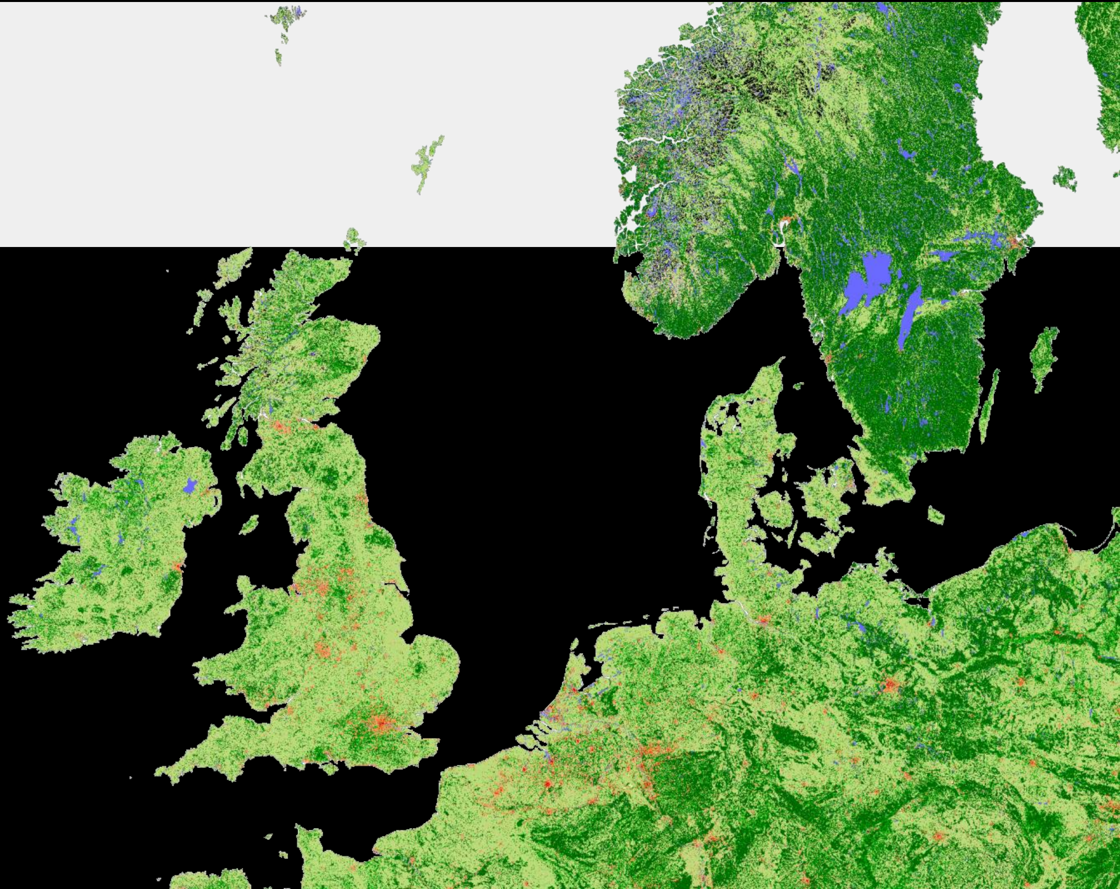
Current representation:



Proposed representation:



WUDAPT 2 COSMO



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Updated and presented
and by Mikhail Varentsov

04 September 2020 @ Online meeting

Motivation: to use a standardized urban description

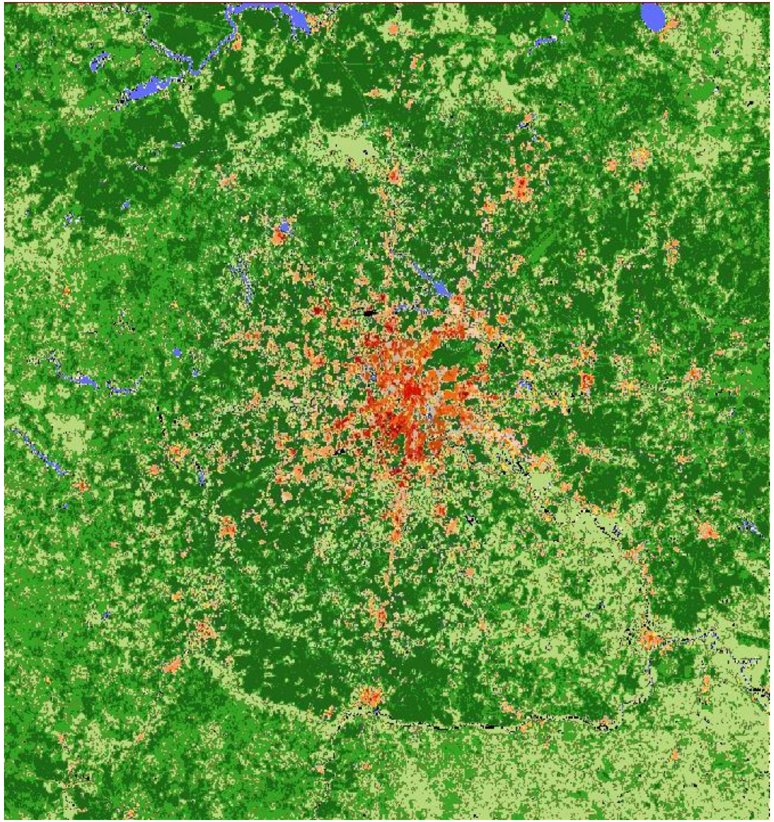
Ching et al., 2018)

WUDAPT
An Urban Weather, Climate, and Environmental Modeling Infrastructure for the Anthropocene

J. Ching, G. Mills, B. Bechtel, L. See, J. Feddema, X. Wang, C. Ren, O. Brousse, A. Martilli, M. Neophytou, P. Mouzourides, I. Stewart, A. Hanna, E. Ng, M. Foley, P. Alexander, D. Aliaga, D. Niyogi, A. Shreevastava, P. Bhalachandran, V. Masson, J. Hidalgo, J. Fung, M. Andrade, A. Baklanov, W. Dai, G. Milcinski, M. Demuzere, N. Brunsell, M. Pesaresi, S. Miao, Q. Mu, F. Chen, and N. Theeuwes

WUDAPT is an international community-generated urban canopy information and modeling infrastructure to facilitate urban-focused climate, weather, air quality, and energy-use modeling application studies

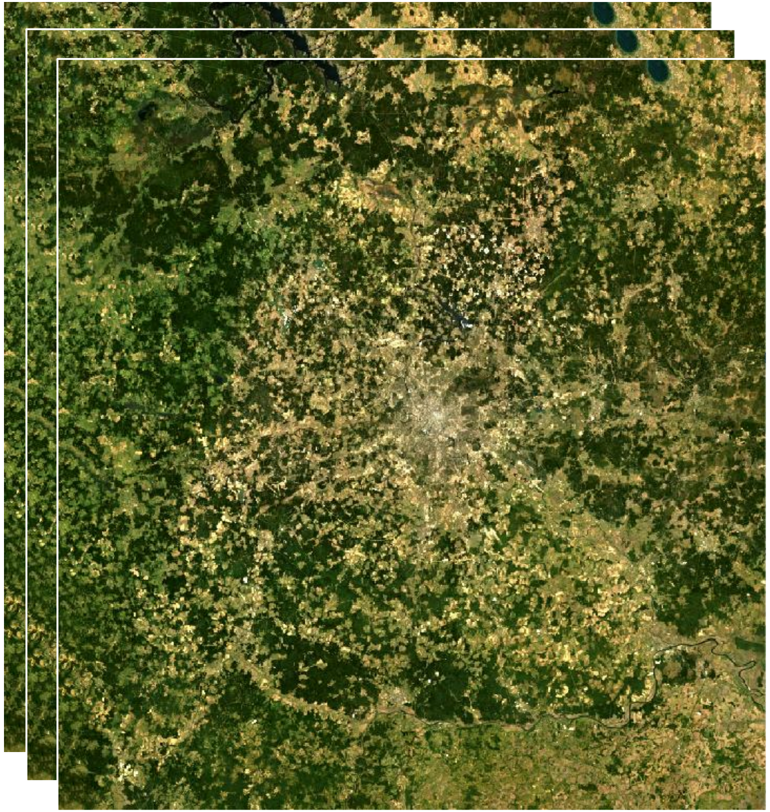
LCZ concept



Local Climate Zone (LCZ) Map

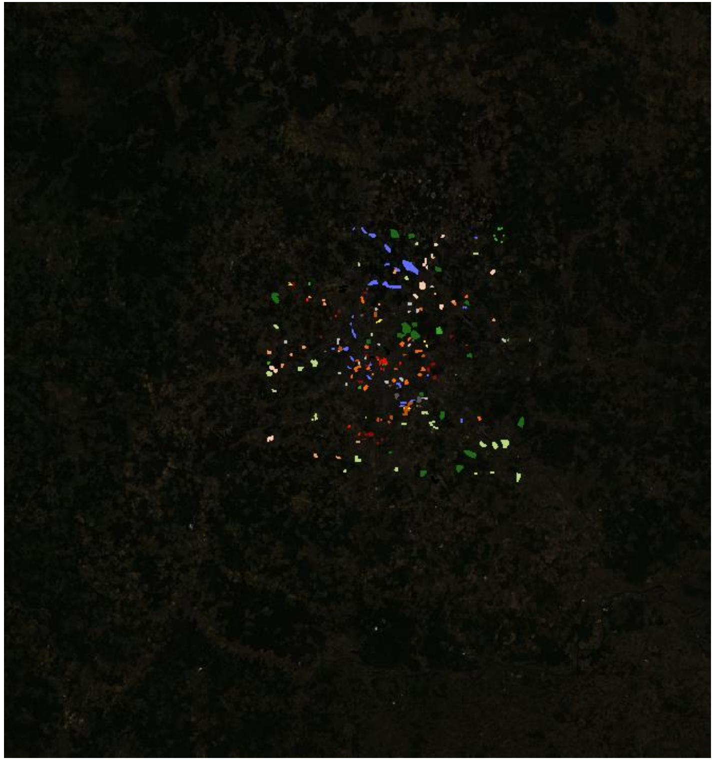
10 Urban LCZ classes

LCZ development



Input features: Landsat 8, Sentinel 1 & 2, Other ...

Random forest classifier



Training Polygons

LCZ Urban Parameters

Table 3. Values of geometric and surface cover properties for local climate zones. All properties are unitless except height of roughness elements (m).

Local climate zone (LCZ)	Sky view factor[a]	Aspect ratio[b]	Building surface fraction[c]	Impervious surface fraction[d]	Pervious surface fraction[e]	Height of roughness elements[f]	Terrain roughness class[g]
LCZ 1 *Compact high-rise*	0.2–0.4	> 2	40–60	40–60	< 10	> 25	8
LCZ 2 *Compact midrise*	0.3–0.6	0.75–2	40–70	30–50	< 20	10–25	6–7
LCZ 3 *Compact low-rise*	0.2–0.6	0.75–1.5	40–70	20–50	< 30	3–10	6
LCZ 4 *Open high-rise*	0.5–0.7	0.75–1.25	20–40	30–40	30–40	>25	7–8
LCZ 5 *Open midrise*	0.5–0.8	0.3–0.75	20–40	30–50	20–40	10–25	5–6
LCZ 6 *Open low-rise*	0.6–0.9	0.3–0.75	20–40	20–50	30–60	3–10	5–6
LCZ 7 *Lightweight low-rise*	0.2–0.5	1–2	60–90	< 20	<30	2–4	4–5
LCZ 8 *Large low-rise*	>0.7	0.1–0.3	30–50	40–50	<20	3–10	5
LCZ 9 *Sparsely built*	> 0.8	0.1–0.25	10–20	< 20	60–80	3–10	5–6
LCZ 10 *Heavy industry*	0.6–0.9	0.2–0.5	20–30	20–40	40–50	5–15	5–6

Table 4. Values of thermal, radiative, and metabolic properties for local climate zones. All values are representative of the local scale.

Local climate zone (LCZ)	Surface admittance[a]	Surface albedo[b]	Anthropogenic heat output[c]
LCZ 1 *Compact high-rise*	1,500–1,800	0.10–0.20	50–300
LCZ 2 *Compact midrise*	1,500–2,200	0.10–0.20	<75
LCZ 3 *Compact low-rise*	1,200–1,800	0.10–0.20	<75
LCZ 4 *Open high-rise*	1,400–1,800	0.12–0.25	<50
LCZ 5 *Open midrise*	1,400–2,000	0.12–0.25	<25
LCZ 6 *Open low-rise*	1,200–1,800	0.12–0.25	<25
LCZ 7 *Lightweight low-rise*	800–1,500	0.15–0.35	<35
LCZ 8 *Large low-rise*	1,200–1,800	0.15–0.25	<50
LCZ 9 *Sparsely built*	1,000–1,800	0.12–0.25	<10
LCZ 10 *Heavy industry*	1,000–2,500	0.12–0.20	>300

Stewart & Oke (2012)

LCZ Urban Parameters

Parameter	Local climate zone (LCZ)				
	LCZ 1 Compact high-rise	*LCZ 2* Compact mid-rise	*LCZ 3* Compact low-rise	*LCZ 4* Open high-rise	*LCZ 5* Open mid-rise
Land cover					
Building plan area fraction	0.5	0.5	0.55	0.3	0.3
Pervious surface fraction	0.05	0.1	0.15	0.35	0.3
Geometric					
Mean building height (m)	45	15	5	40	15
Mean canyon aspect ratio	2.5	1.25	1.25	1	0.5
Roof thickness (m)	0.3	0.3	0.2	0.3	0.25
Wall thickness (m)	0.3	0.25	0.2	0.2	0.2
Road thickness (m)	0.25	0.25	0.25	0.25	0.25
Aerodynamic					
Building roughness length, z_0 (m)	6.75	1.5	0.4	5.25	1.25
Displacement height, z_d (m)	27	10	4	23	6.9
Roof roughness length (m)	0.15	0.15	0.15	0.15	0.15
Road roughness length (m)	0.05	0.05	0.05	0.05	0.05
z_{0m}/z_{0h} [a]	200	200	200	200	200
Radiative					
Roof albedo	0.13	0.18	0.15	0.13	0.13
Wall albedo	0.25	0.2	0.2	0.25	0.25
Road albedo (dry, wet)[b]	0.15, 0.15	0.16, 0.15	0.18, 0.16	0.20, 0.17	0.20, 0.17
Roof emissivity	0.91	0.91	0.91	0.91	0.91
Wall emissivity	0.9	0.9	0.9	0.9	0.9
Road emissivity	0.95	0.95	0.95	0.95	0.95
Thermal					
Roof thermal admittance ($J\,m^{-2}\,s^{-1/2}\,K^{-1}$)	1500	1500	1200	1500	1500
Wall thermal admittance ($J\,m^{-2}\,s^{-1/2}\,K^{-1}$)	1400	2000	1600	1700	1700
Road thermal admittance (dry, wet)[c] ($J\,m^{-2}\,s^{-1/2}\,K^{-1}$)	1157 1239	1106 1287	1060 1330	992 1397	964 1425

Heat conductivity and heat capacity values for individual facets (roof, road, wall) retrieved via Scott Krayenhoff.

Stewart, I. D., Oke, T. R., & Krayenhoff, E. S. (2014). Evaluation of the 'local climate zone' scheme using temperature observations and model simulations. *International Journal of Climatology*

Note on thermal (LCZ) Urban Parameters

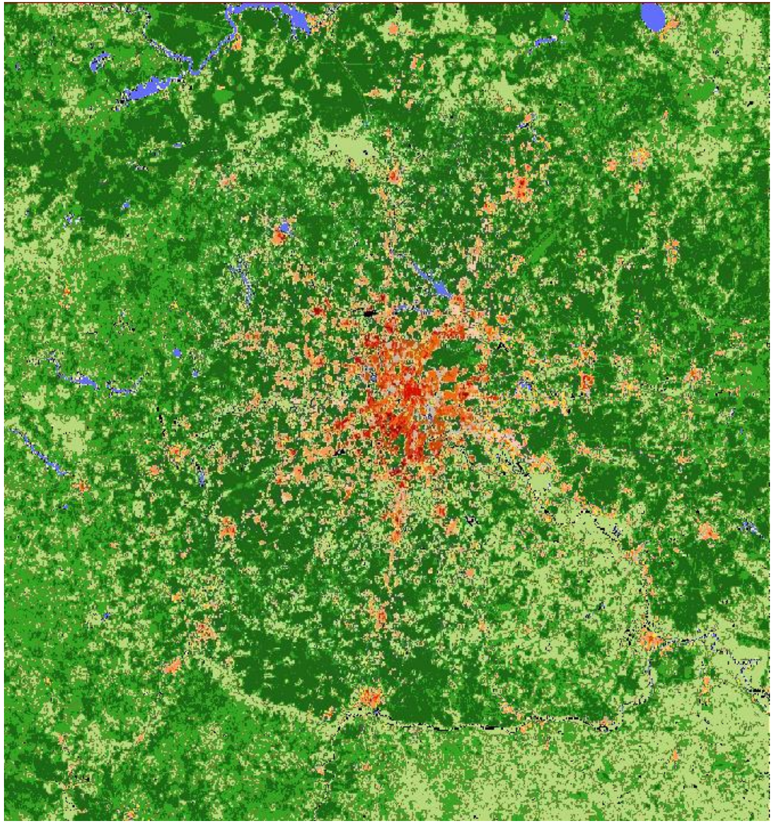
- The thermal values provided by Ian Stewart and Scott Krayenhoff: "are the result of **many hours of discussion between them and Tim Oke, including consultation with a number of sources (Boundary-Layer Climates, among others)**.

- the remainder of the details are in the Appendix of Stewart et al. 2014.

- One simplification that we made is the assumption of uniform material properties across the depth of each facet (e.g., no inclusion of insulation, for example) - the reason being that surface thermal admittance was presumed to be most important. That is clearly a first order approach, in many climates.

- Keep in mind that such thermal values are highly uncertain yet do have an important impact on the modelled thermal behaviour (see also sensitivities in Wouters et al., 2016).

LCZ Urban Parameters



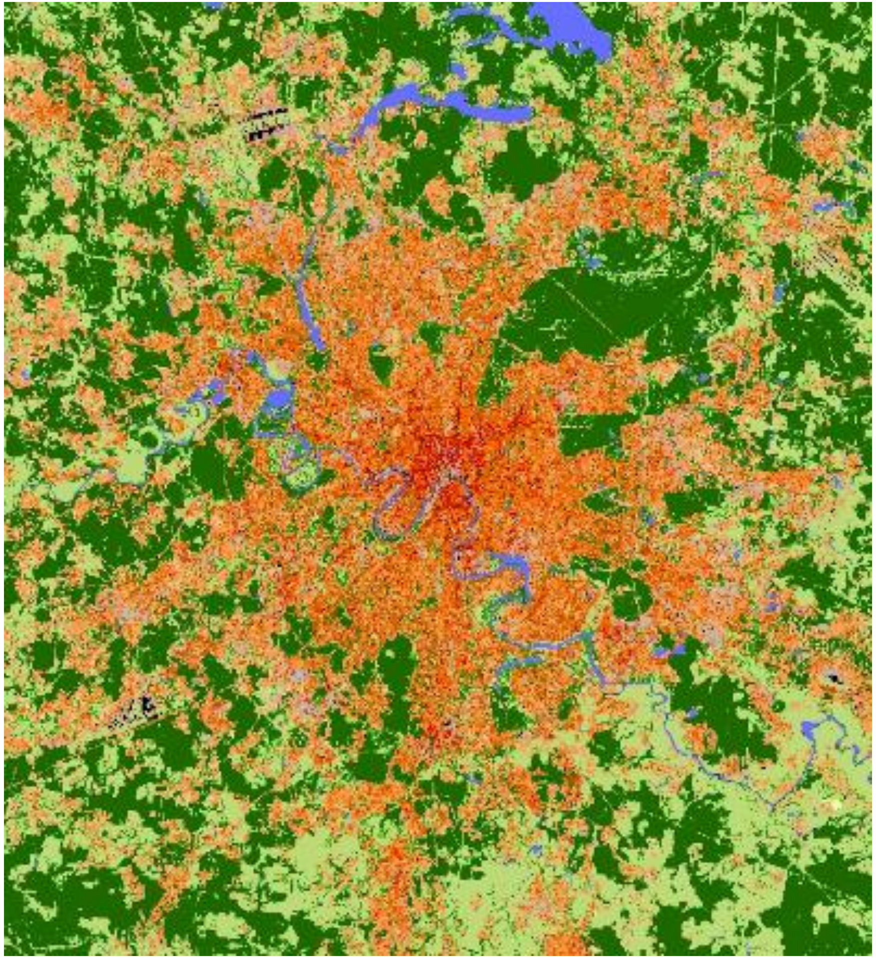
Local Climate Zone (LCZ) Map

Assign UCP (e.g. ISA) to LCZ classes

Notes:

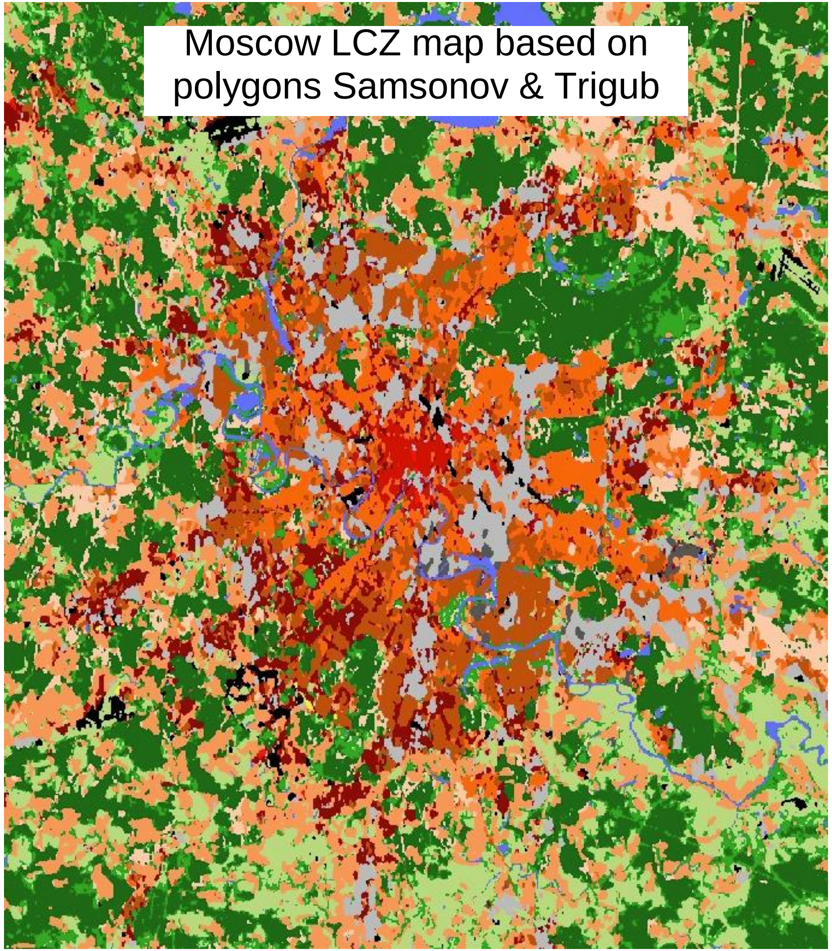
- Resulting LCZ map **may contain errors**, meaning confusion between classes. Efforts are ongoing by a large community to improve the classification process / results.

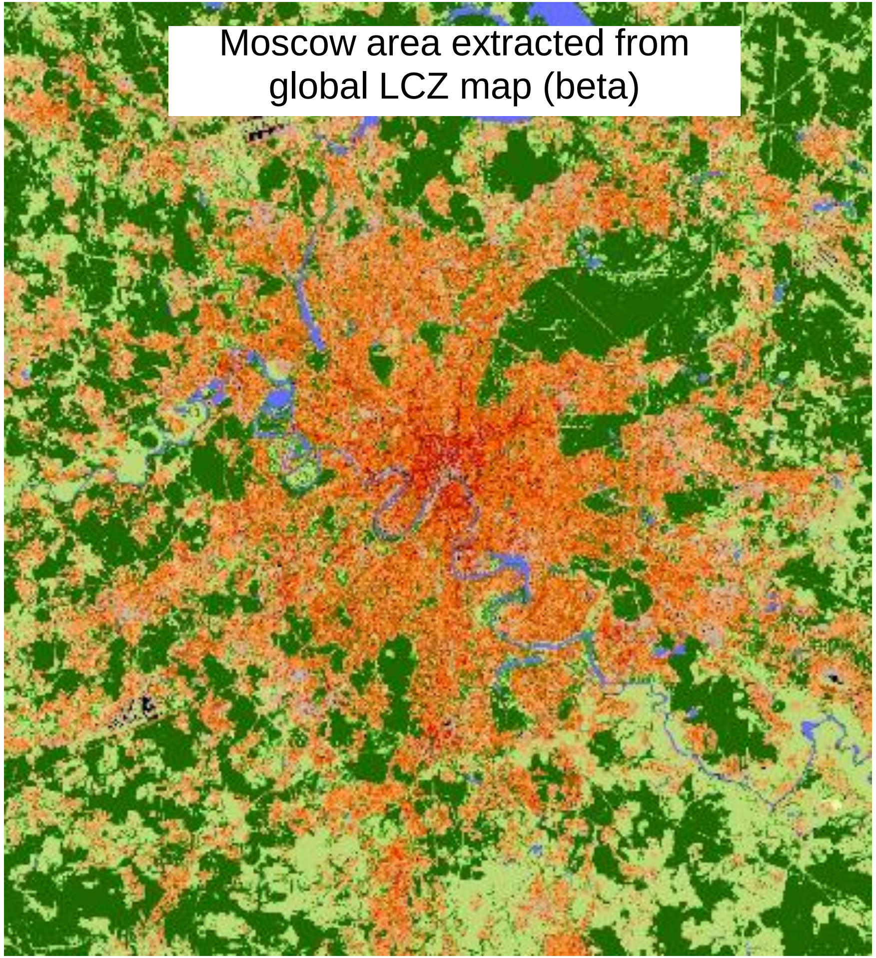
Mikhail: "the building height from the LCZ-based data set seems to bee too low. There should be a lot of LCZ4 in Moscow, where the building are quite high (> 25 m)"



Moscow area extracted from global LCZ map (beta)

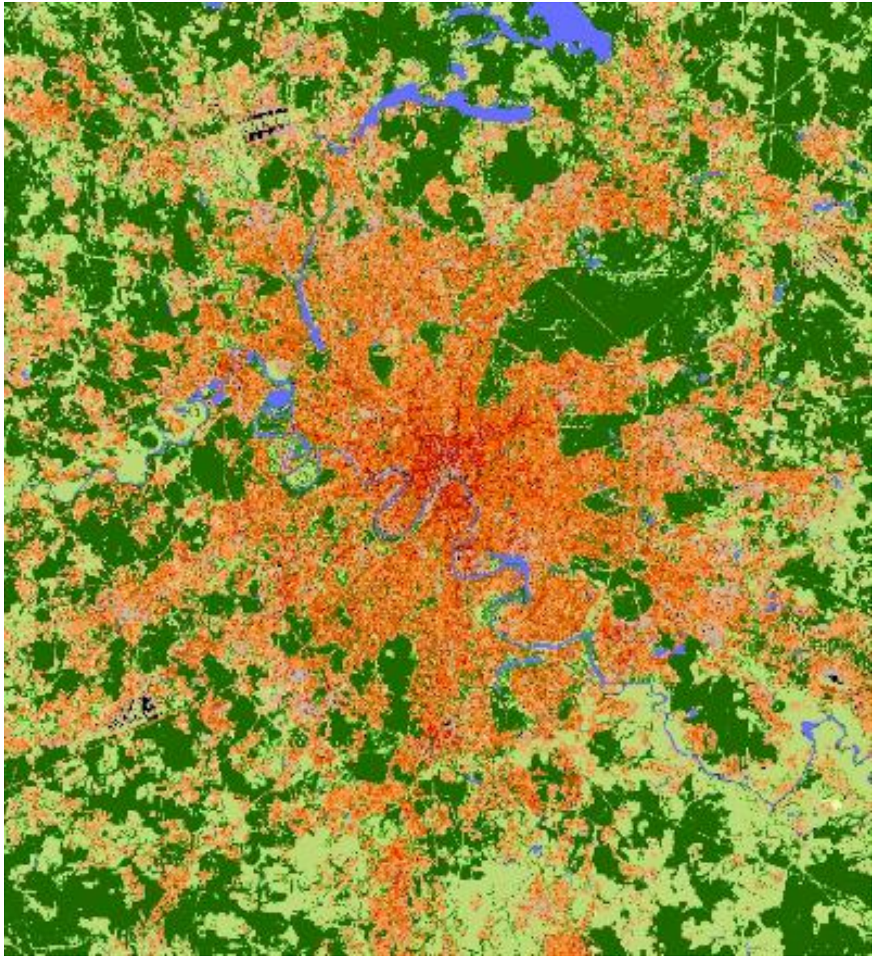
Notes:


Moscow LCZ map based on polygons Samsonov & Trigub


Moscow area extracted from global LCZ map (beta)

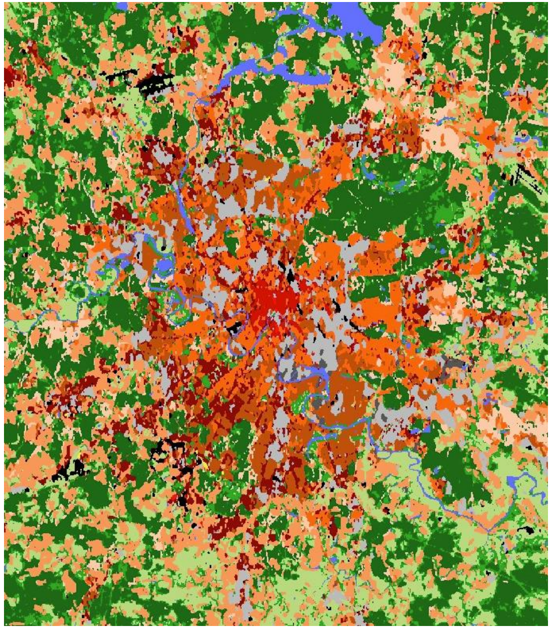
Notes:

- The urban parameters are **generic and universal**, and might not reflect specific local characteristics of a specific city.
- They should thus be considered as a first-order approximation for consistent morphological and thermal information for urban areas.
- As such, this approach is especially suited for data-scarce areas.
- In case site-specific LCZ urban canopy parameters are available, the look-up tables could be adjusted if required.



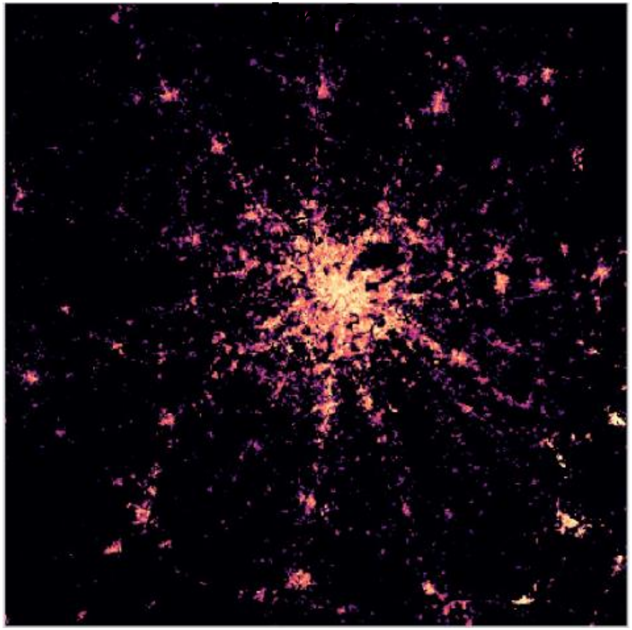
COSMO-CLM conversion

LCZ, 100 x 100 m2



LCZ ISA, 100 x 100 m2

COSMO ISA, ~ 1 x 1 km



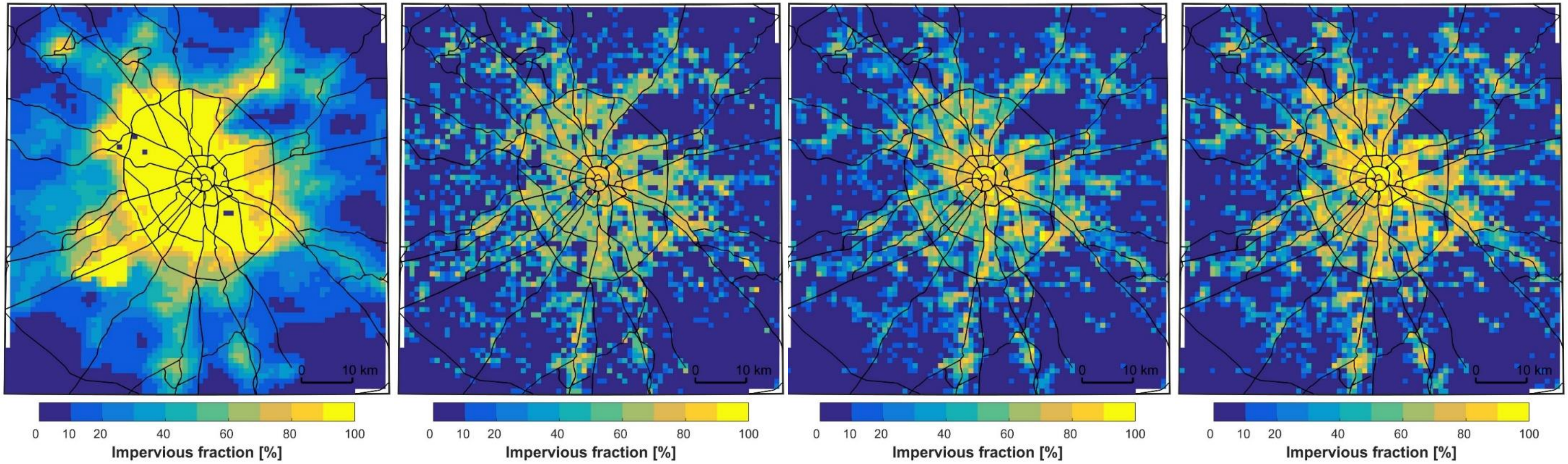
Two-step procedure:

- first aggregation to half the resolution of the CLM grid (a)
- resample (a) to COSMO-CLM grid via linear interpolation
- UCP are weighed by ISA to conserve the city characteristics after remapping

COSMO-CLM conversion: Moscow, ISA/FR_PAVED

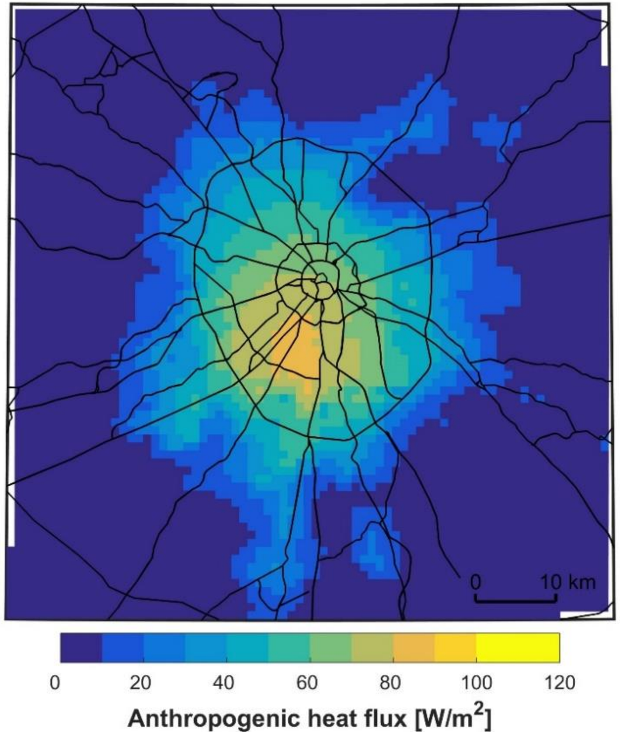
Custom GIS-based estimates (REF, more details latter)

Default values from EXTPAR (DEF) | **LCZ-derived ISA** | **REF1** | **REF2**

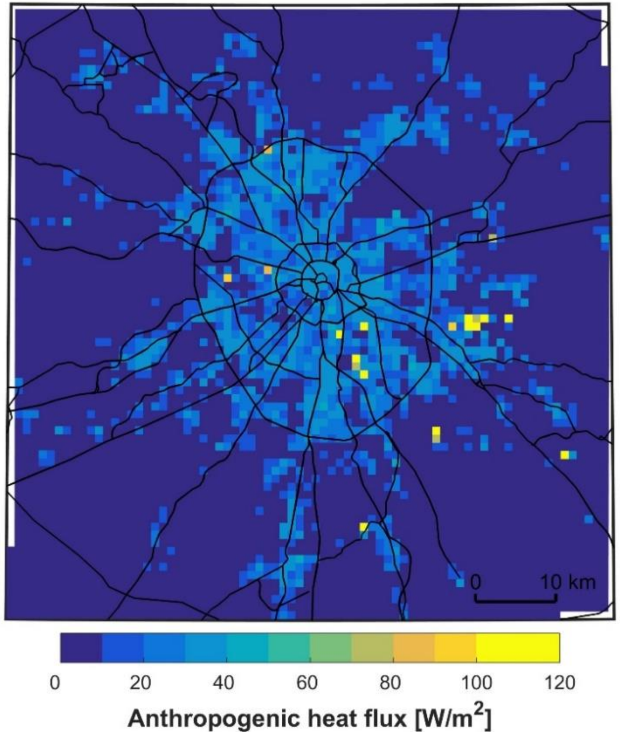


COSMO-CLM conversion: Moscow, AHF

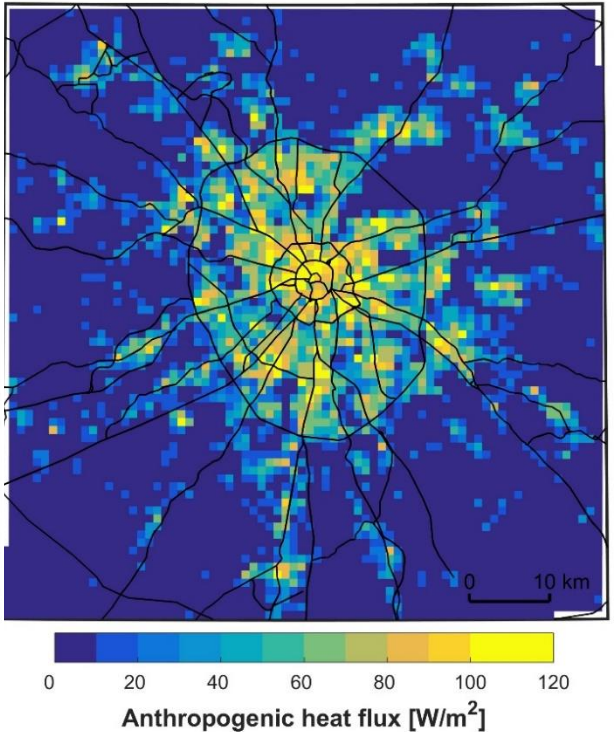
Default values from EXTPAR (Flanner et al., 2009)



LCZ-based AHF



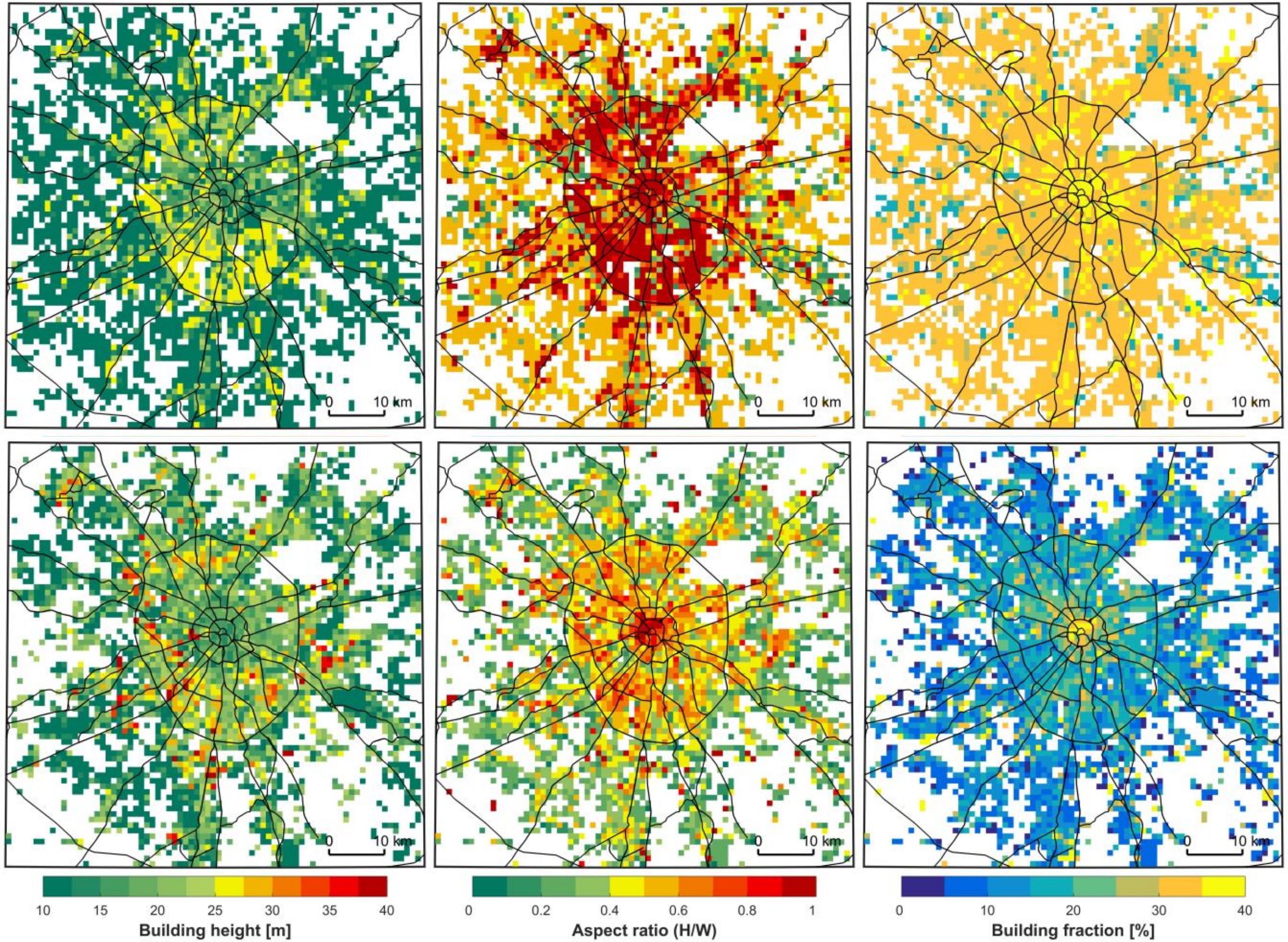
Custom estimate (REF)



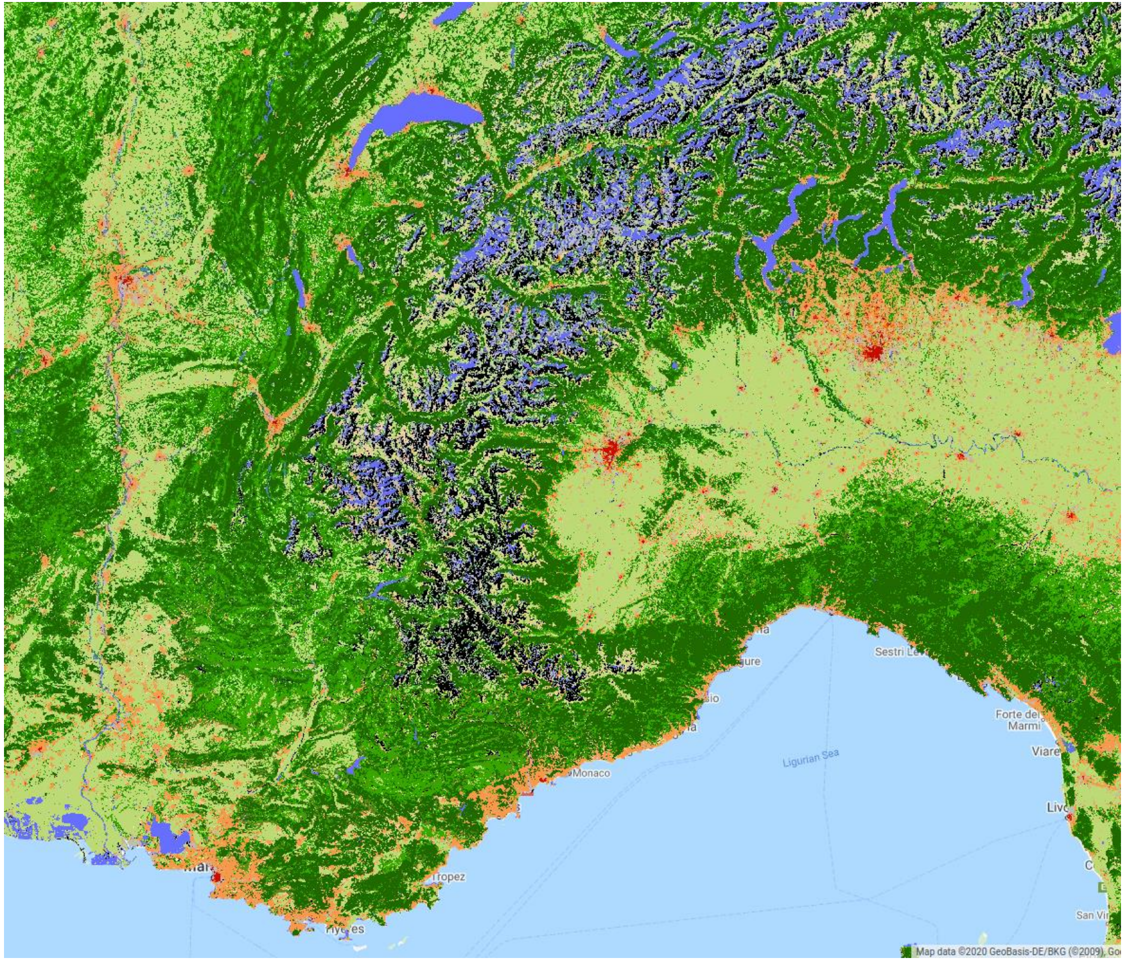
COSMO-CLM conversion: Moscow, morphological UCPs

LCZ-based UCP
→

Custom-made UCPs (based on OpenStreetMap data)
→



LCZ-to-COSMO conversion (Turin)



- No training areas for Turin, so LCZ map extracted from EU map (Demuzere et al., 2019)

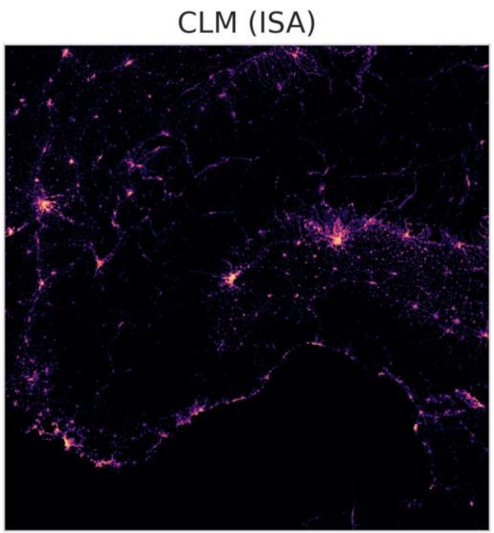
Notes:

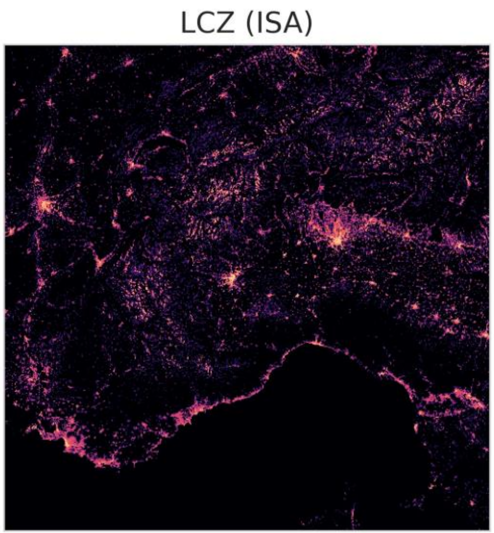
- Snow is mapped as water, no LCZ class for snow (not a problem, only interested in urban classes)

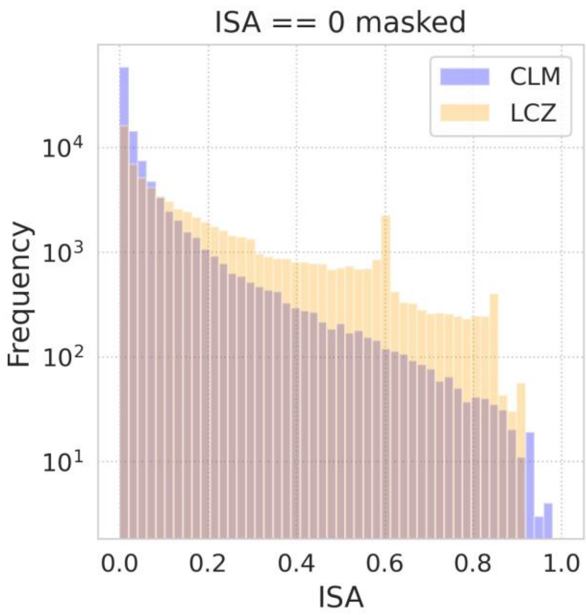
- Dry mountain slopes sometimes mapped as urban classes (e.g. LCZ 6, 8, 9). This needs to be addressed.

LCZ-to-COSMO conversion (Turin)

Data sources Turin (correct?): ISA from EEA?



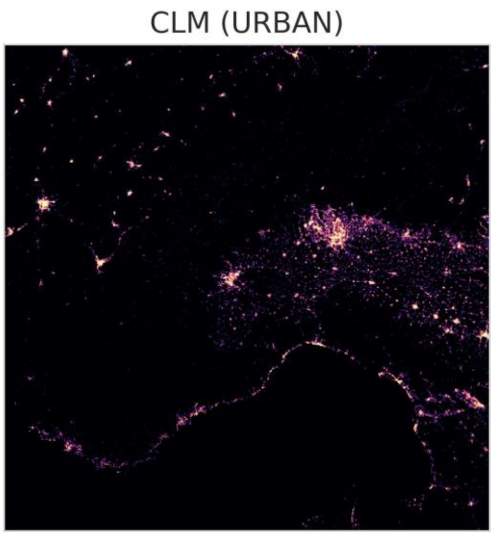


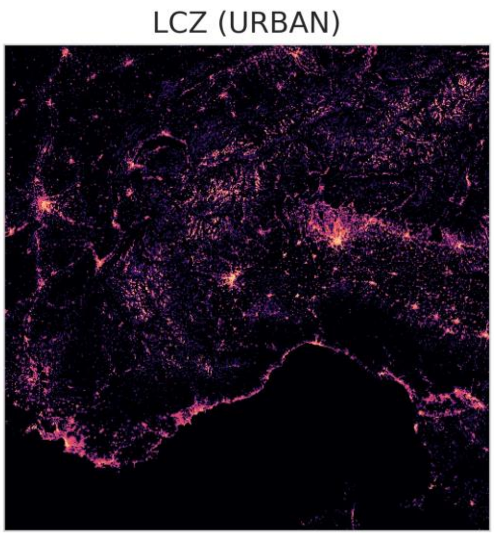


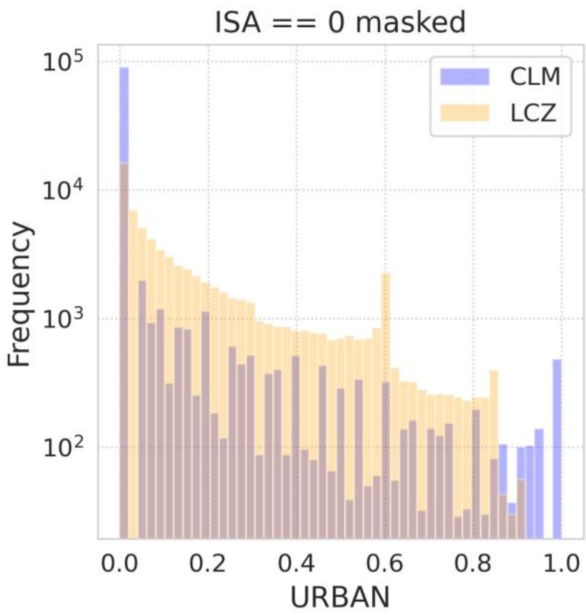
This is ISA from EXTPAR

LCZ-to-COSMO conversion (Turin)

Data sources Turin (correct?): ISA from EEA?



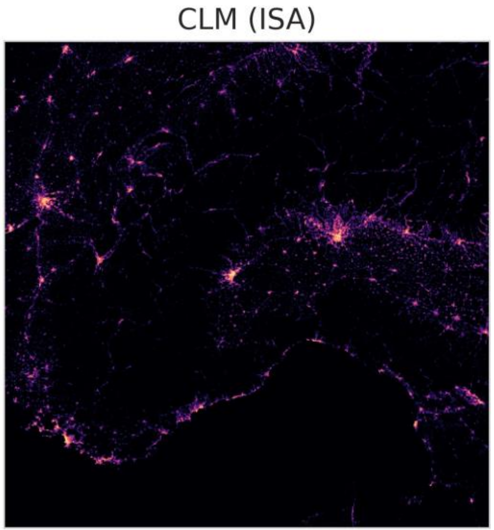


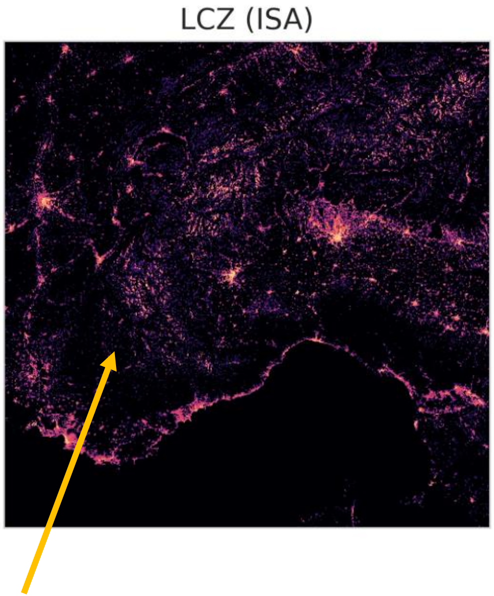


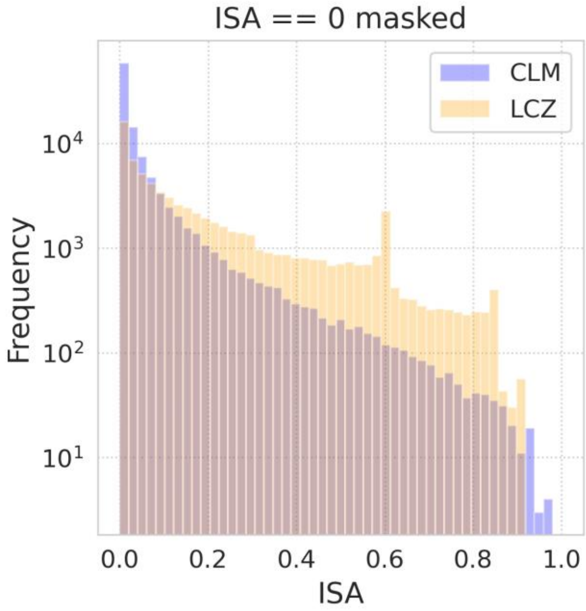
This is URBAN from EXTPAR (Globcover)

Quick test post-classification filtering

Data sources Turin (correct?): ISA from EEA?

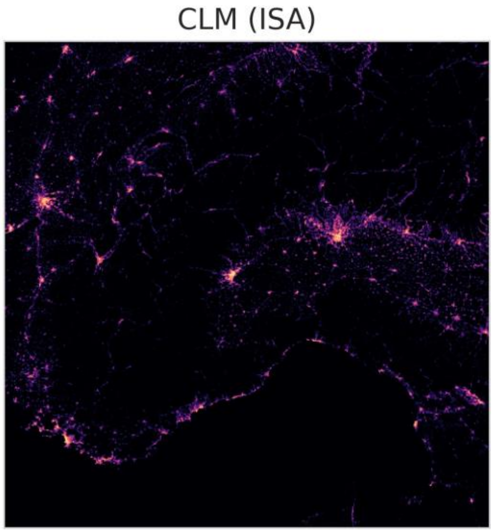


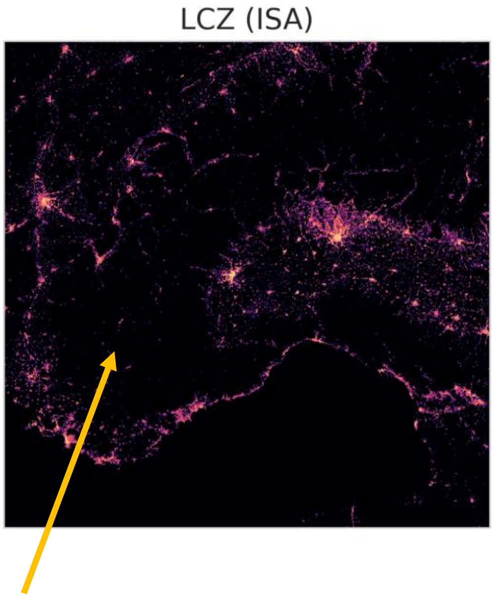


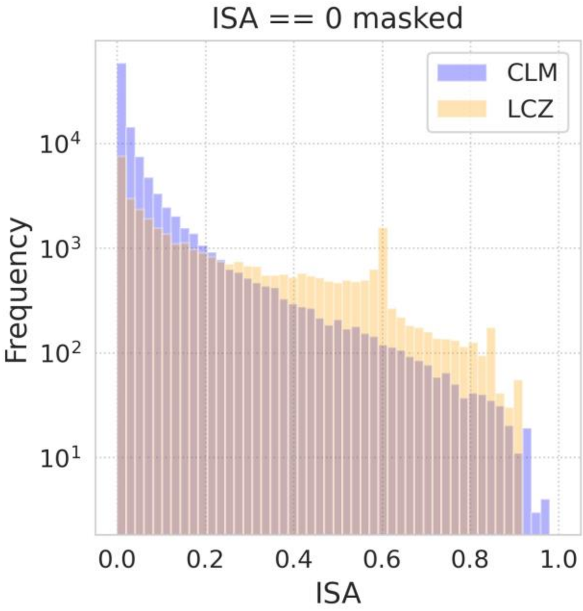


NO filtering

Quick test post-classification filtering

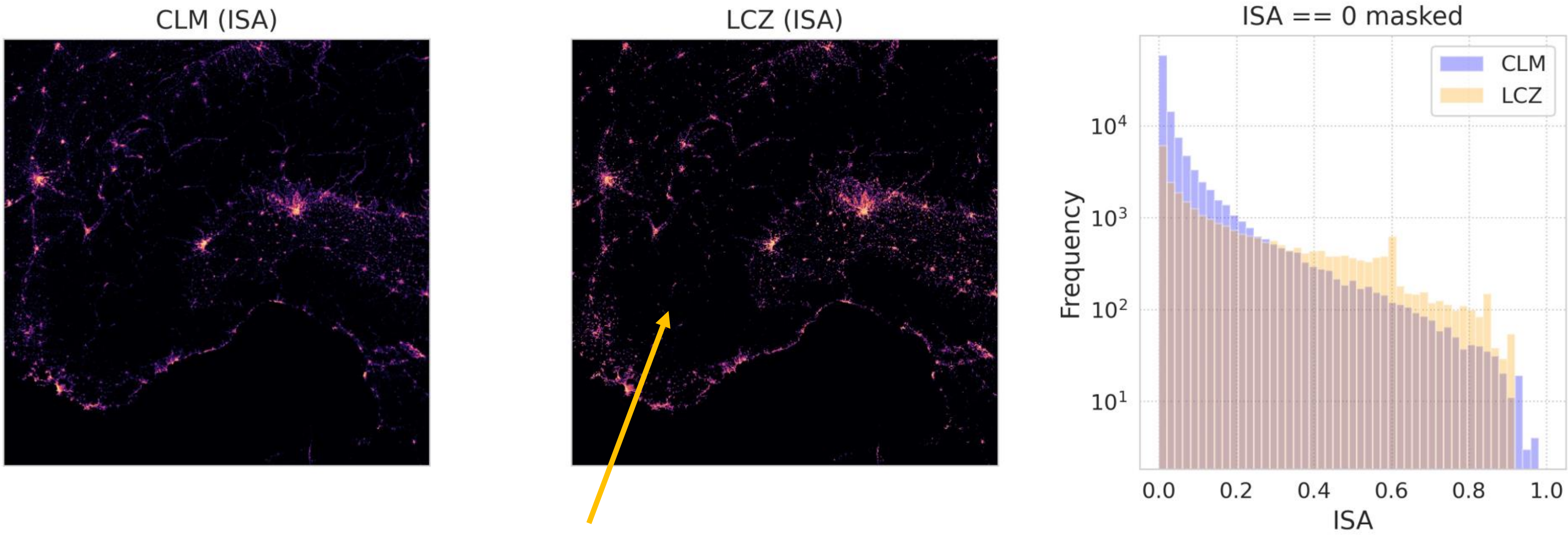






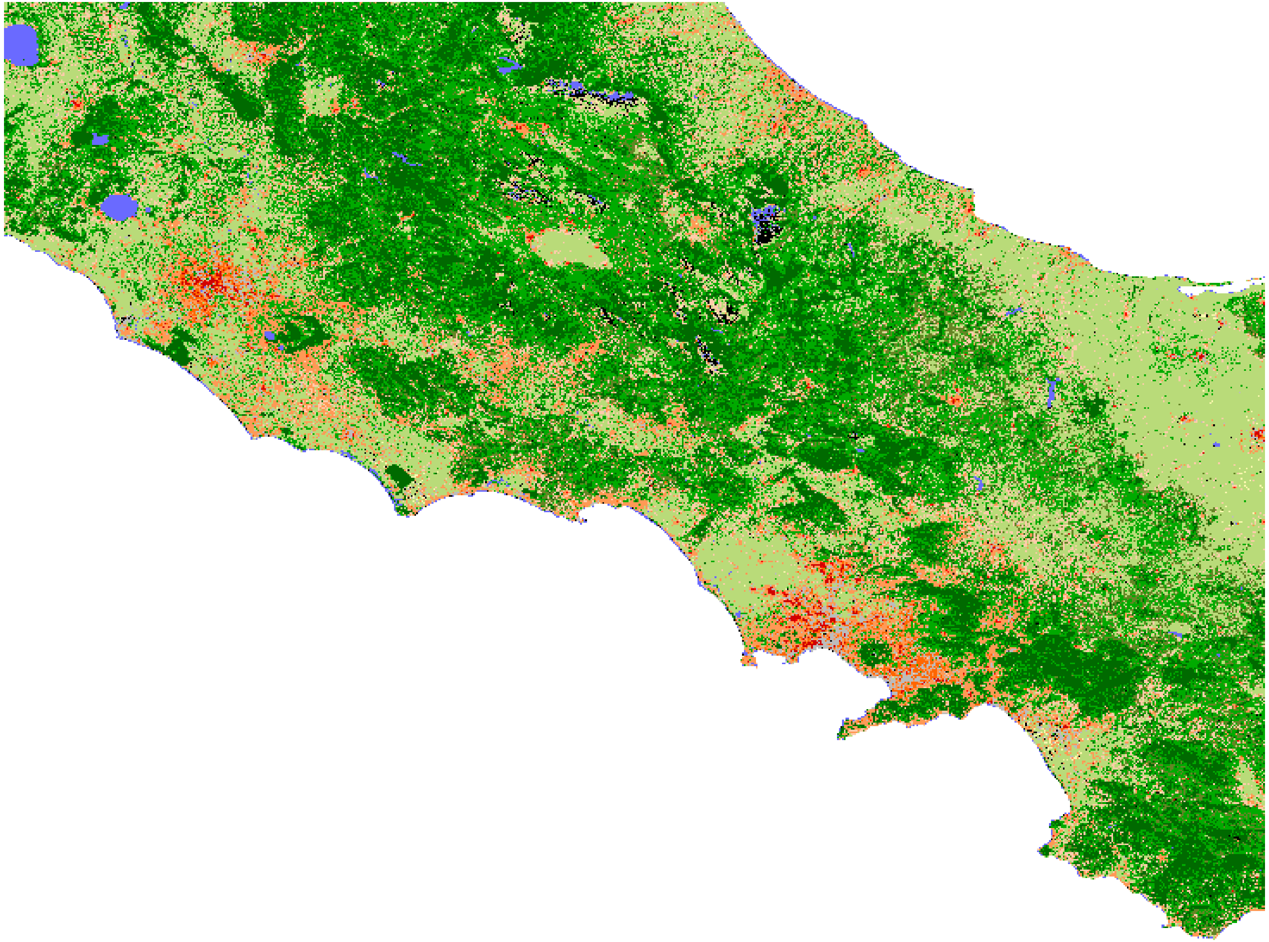
Filtering with Copernicus Global Land Cover

Quick test post-classification filtering



Filtering with global artificial impervious area (Gong et al., 2020)

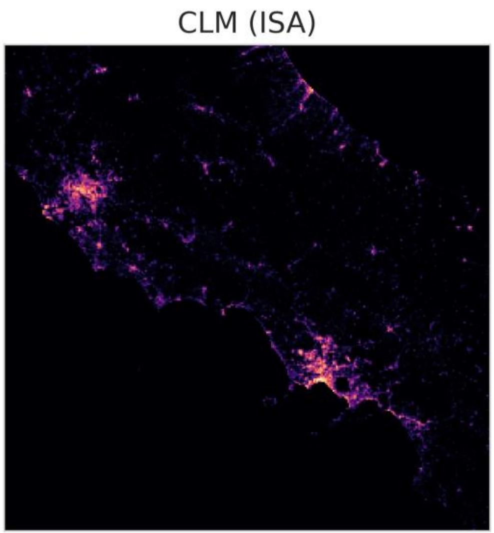
COSMO-CLM conversion (Naples)

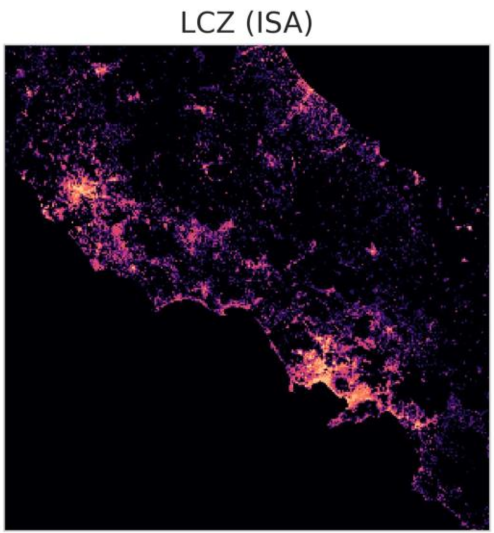


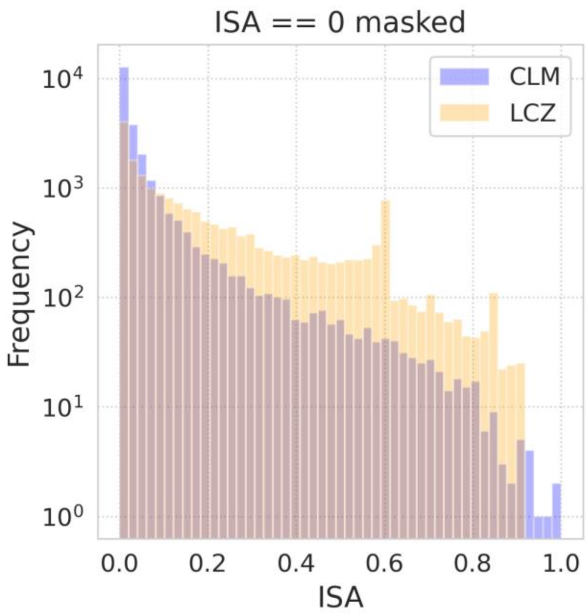
No training areas for Turin, so LCZ map extracted from EU map (Demuzere et al., 2019)

COSMO-CLM conversion (Naples)

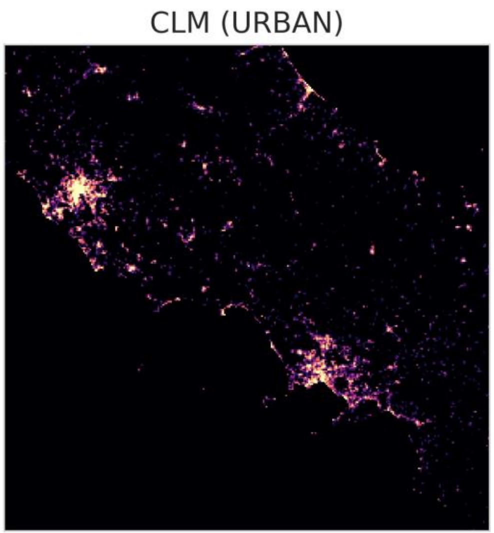
Data sources Naples (correct?): ISA from EEA, AHF from Flanner (2009)

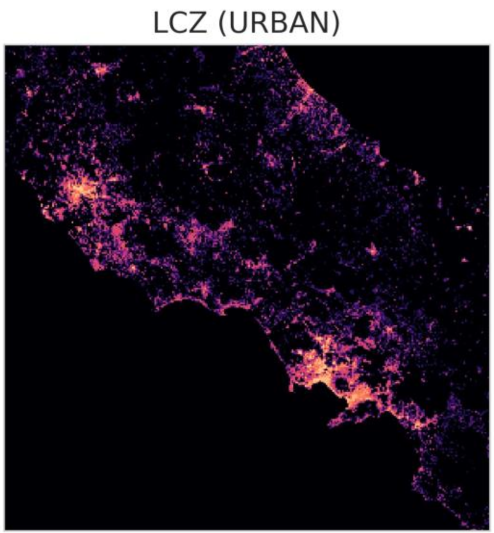


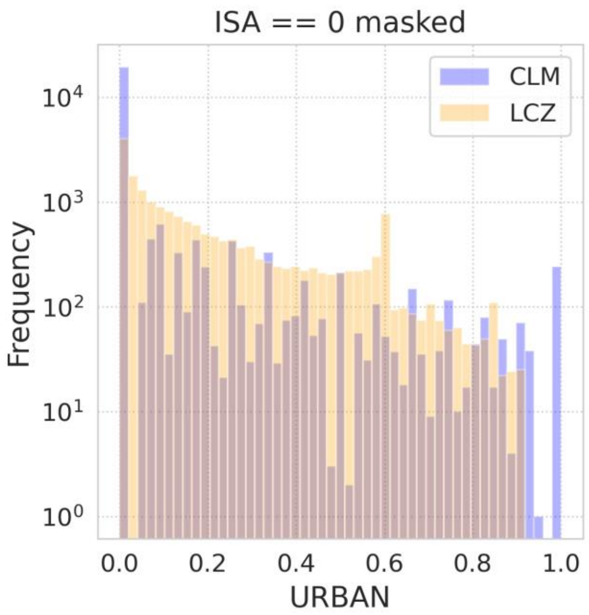




COSMO-CLM conversion (Naples)



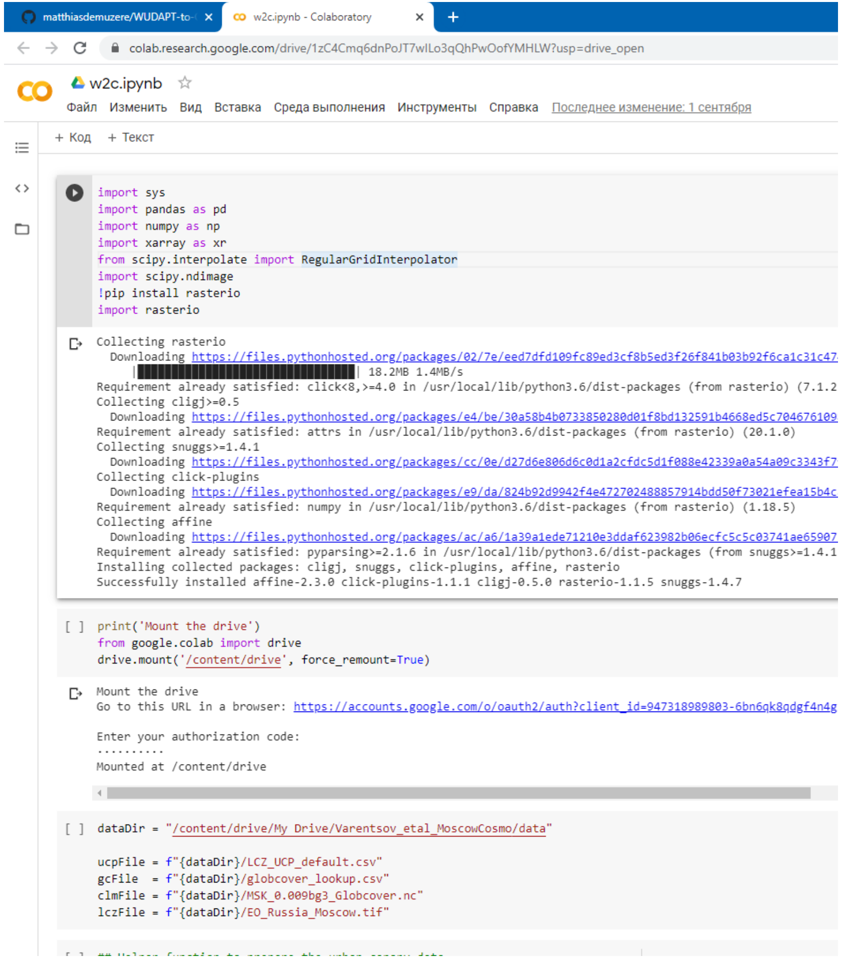




Is this URBAN from GLOBCOVER?

WUDAPT to COSMO: Current status

- **WUDAPT-to-COSMO** tool (Python script) is available at GitHub: https://github.com/matthiasdemuzere/WUDAPT-to-COSMO
  - Converts LCZ urban classes to urban canopy parameters
  - Interpolates information to COSMO grid
  - Fixes the "double counting" effect
- Could be launched as Jupiter notebook in GoogleCollaboratory & Google drive (not need to configure Python & libraries on local machine)
- **Recent update** (end of August, still not in GitHub)**:** fixed inconsistencies for radiative urban canopy parameters; bulk albedo/emissivity output values changed to facet-level values. **To be discussed with Hendrik.**
- Radiative parameters (URB_SALB, URB_TALB) calculated by the previous version are not consistent with model and should not be used



WUDAPT to COSMO: bulk or facet-level thermal parameters?

- **LCZ-approach provides mean facet-level values for roof, road and walls**
- **Originally Matthias proposed to calculate bulk parameters, but the model needs mean facet-level values (bulk values are calculated inside the code)**

```
## Canyon albedo reduction factor, eq. 15 Wouters et al. (2016)
psi_canyon = np.exp(-0.6 * ucp['URB_H2W'])
psi_canyon[10:] = 0 # Set to zero for non-urban LCZs
```

```
## Bulk shortwave albedo
alb_roof_snow = ucp['URB_RfALB'] * (1. - snow_f) + alb_snow * snow_f
alb_road_snow = ucp['URB_RdALB'] * (1. - snow_f) + alb_snow * snow_f
alb_wall_snow = ucp['URB_WaALB'] * (1. - snow_f) + alb_snow * snow_f
ucp['URB_SALB_BK'] = (alb_road_snow + 2. * ucp['URB_H2W'] * alb_wall_snow) / \
                     (1. + 2. * ucp['URB_H2W']) * psi_canyon * (1. - ucp['URB_BLDFR']) \
                     + alb_roof_snow * ucp['URB_BLDFR']
```

- **Facet-level thermal parameters**
- **urban geometry**

→ **bulk thermal parameters**

$$\psi_c\left(\frac{h}{w_c}\right) = \exp\left(-0.6\frac{h}{w_c}\right). \qquad (15)$$

- **Eq. for mean facet-level values of heat capacity/emissivity (not valid for albedo)**

```
## Calculate Surface Area Index from geometrical considerations (Eq. 3)
SAI = (1. + 2. * ucp['URB_H2W']) * (1. - ucp['URB_BLDFR']) + ucp['URB_BLDFR']

## Get mean Heat capacity and conductivity, using eq. 10, 11 and 4.
ucp['URB_HCON'] = ((1-ucp['URB_BLDFR']) / SAI ) * \
          (2*ucp['URB_H2W']*ucp['URB_WaHCON'] + ucp['URB_RdHCON']) + \
          ( ucp['URB_BLDFR'] / SAI * ucp['URB_RfHCON'])
ucp['URB_HCAP'] = ((1-ucp['URB_BLDFR']) / SAI ) * \
          (2*ucp['URB_H2W']*ucp['URB_WaHCAP'] + ucp['URB_RdHCAP']) + \
          ( ucp['URB_BLDFR'] / SAI * ucp['URB_RfHCAP'])
```

$$C_{v,s} = \frac{1-R}{\mathrm{SAI}}\left(2\frac{h}{w_c}C_{v,\mathrm{wall}} + C_{v,\mathrm{road}}\right) + \frac{R}{\mathrm{SAI}}C_{v,\mathrm{roof}} \qquad (10)$$

$$\lambda_s = \frac{1-R}{\mathrm{SAI}}\left(2\frac{h}{w_c}\lambda_{\mathrm{wall}} + \lambda_{\mathrm{road}}\right) + \frac{R}{\mathrm{SAI}}\lambda_{\mathrm{roof}}, \qquad (11)$$

- **How to calculate mean material albedo to be provided to TERRA_URB? My suggestion bases on eqs. 13 and 16:**

```
## Effective facet-level albedo derived from eqs 13 and 16

ucp['URB_SALB'] = ucp ['URB_SALB_BK'] / (psi_canyon * (1 - ucp['URB_BLDFR']) + ucp['URB_BLDFR'])
ucp['URB_TALB'] = ucp ['URB_TALB_BK'] / (psi_canyon * (1 - ucp['URB_BLDFR']) + ucp['URB_BLDFR'])
ucp['URB_EMIS'] = 1 - ucp ['URB_TALB_BK']
```

Mean material albedo (→ α)

$$\alpha_{\mathrm{bulk}} \simeq ((1-f_{\mathrm{snow}})\alpha + f_{\mathrm{snow}}\alpha_{\mathrm{snow}})\,\psi_{\mathrm{bulk}}\left(\frac{h}{w_c}, R\right), \qquad (13)$$

$$\alpha_{\mathrm{bulk}} \simeq \frac{\left[\alpha_{\mathrm{road,snow}} + 2\frac{h}{w_c}\alpha_{\mathrm{wall,snow}}\right]}{\left(1+2\frac{h}{w_c}\right)}\psi_c\left(\frac{h}{w_c}\right)(1-R) + \alpha_{\mathrm{roof,snow}}R, \qquad (16)$$

Questions

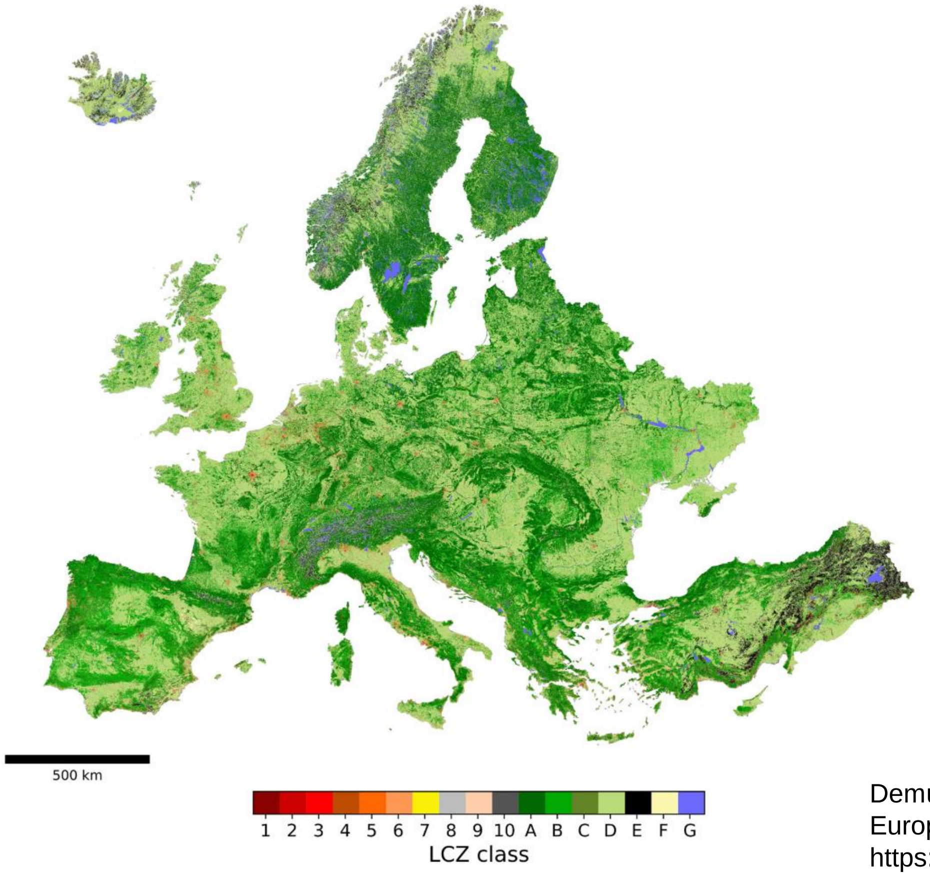
- How to deal with the "double-counting" via the URBAN field (globcover). This is still unclear to me.

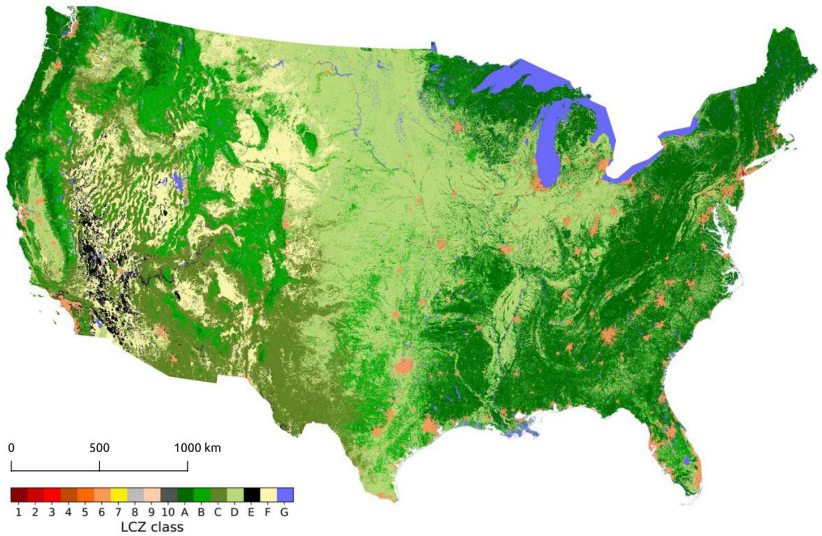
- Correct for misclassification in mountainous areas via a global (urban) land cover product?

- Do we need option to work with bulk parameters?

- ➢ An additional advantage would be that the urban fields of the "LCZ version" would be consistent with the urban field of the "normal" procedure in case a new global (urban) land cover would become the default urban field in EXTPAR.

WUDAPT 2 COSMO: LCZ maps



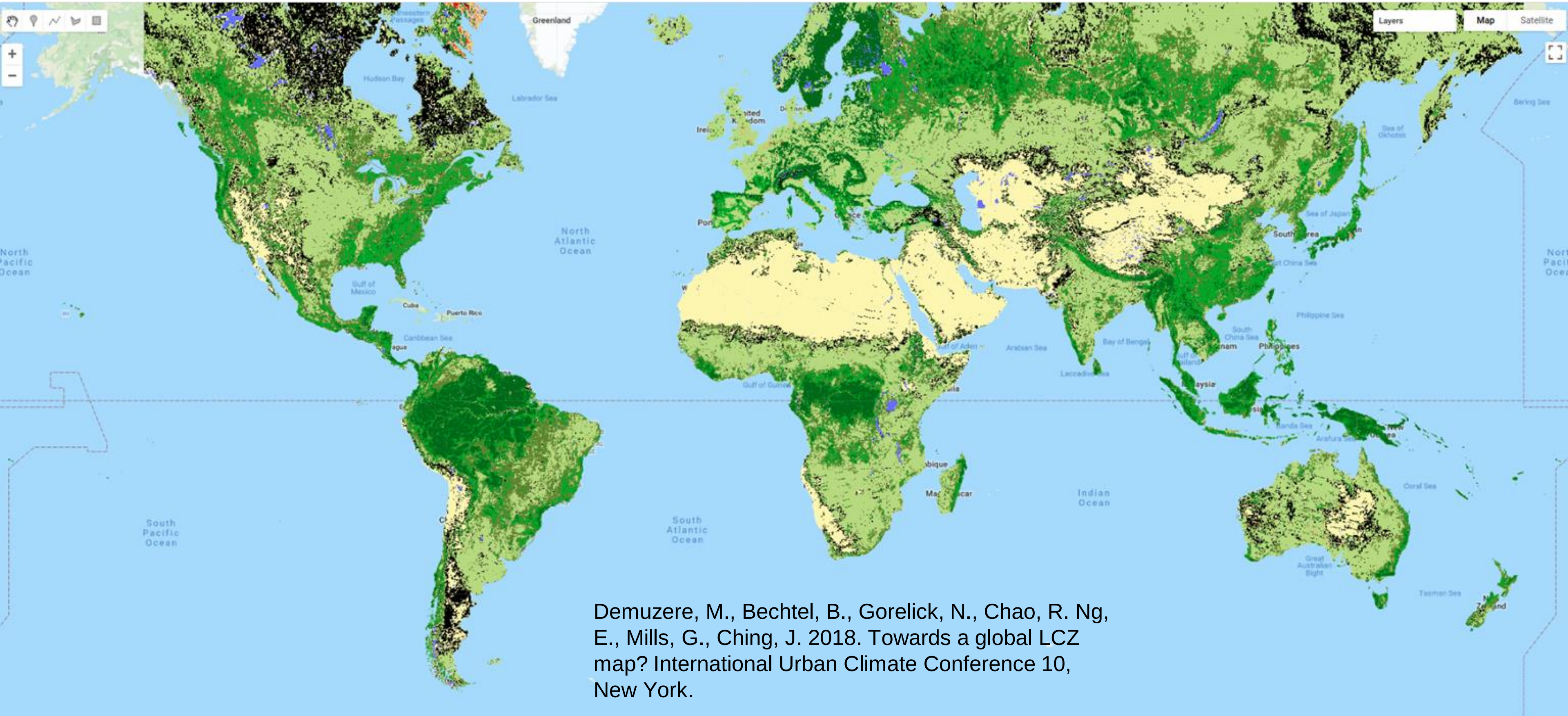


Demuzere, M., Hankey, S., Mills, G., Zhang, W., Lu, T., & Bechtel, B. (2020). Combining expert and crowd-sourced training data to map urban form and functions for the continental US. Scientific Data, 7(1), 264. https://doi.org/10.1038/s41597-020-00605-z

Demuzere, M., Bechtel, B., Middel, A., & Mills, G. (2019). Mapping Europe into local climate zones. PLOS ONE, 14(4), e0214474. https://doi.org/10.1371/journal.pone.0214474

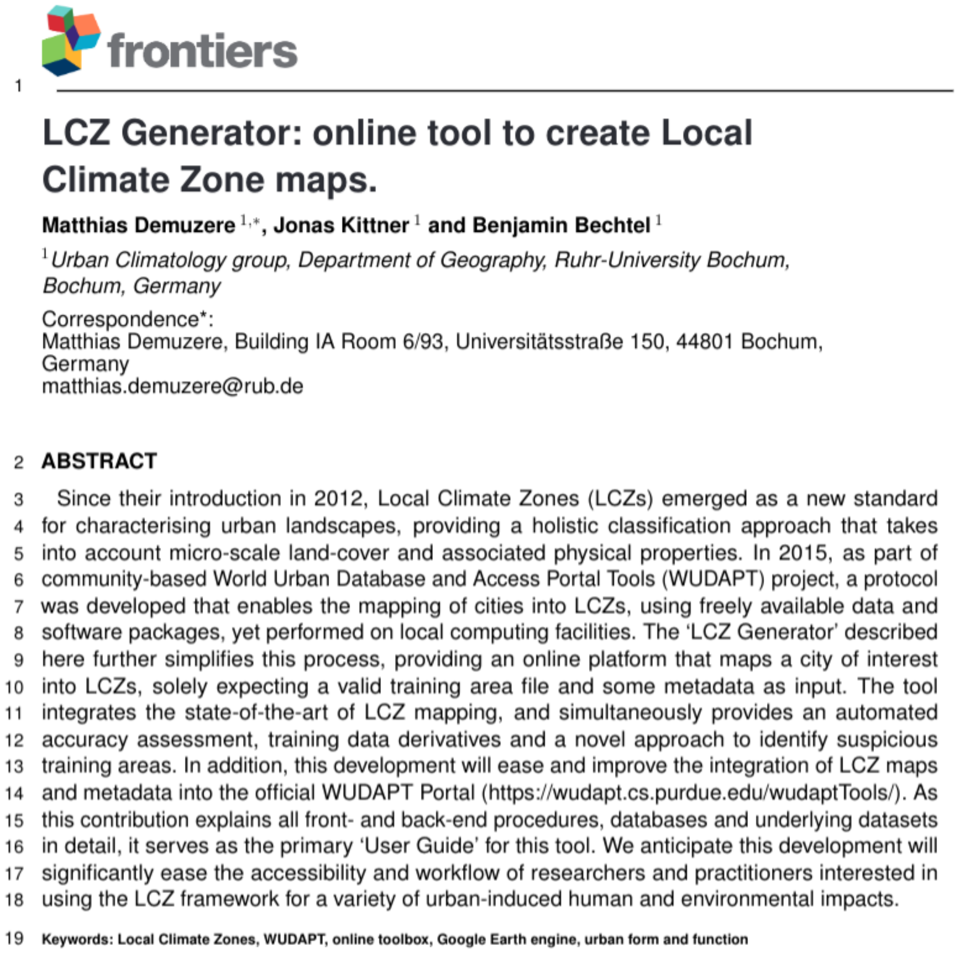
WUDAPT 2 COSMO: LCZ maps

Global ~100 m Beta version, not publicly available yet.



Demuzere, M., Bechtel, B., Gorelick, N., Chao, R. Ng, E., Mills, G., Ching, J. 2018. Towards a global LCZ map? International Urban Climate Conference 10, New York.

WUDAPT 2 COSMO: LCZ maps



frontiers

LCZ Generator: online tool to create Local Climate Zone maps.

Matthias Demuzere [1,*], **Jonas Kittner** [1] **and Benjamin Bechtel** [1]

[1] *Urban Climatology group, Department of Geography, Ruhr-University Bochum, Bochum, Germany*

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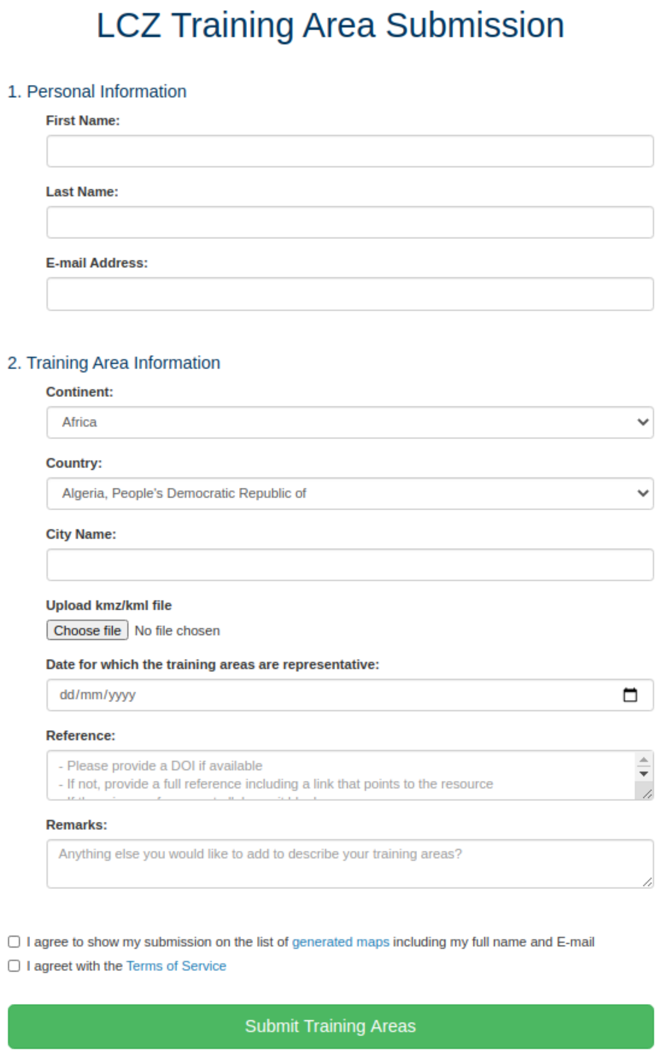
ABSTRACT

Since their introduction in 2012, Local Climate Zones (LCZs) emerged as a new standard for characterising urban landscapes, providing a holistic classification approach that takes into account micro-scale land-cover and associated physical properties. In 2015, as part of community-based World Urban Database and Access Portal Tools (WUDAPT) project, a protocol was developed that enables the mapping of cities into LCZs, using freely available data and software packages, yet performed on local computing facilities. The 'LCZ Generator' described here further simplifies this process, providing an online platform that maps a city of interest into LCZs, solely expecting a valid training area file and some metadata as input. The tool integrates the state-of-the-art of LCZ mapping, and simultaneously provides an automated accuracy assessment, training data derivatives and a novel approach to identify suspicious training areas. In addition, this development will ease and improve the integration of LCZ maps and metadata into the official WUDAPT Portal (https://wudapt.cs.purdue.edu/wudaptTools/). As this contribution explains all front- and back-end procedures, databases and underlying datasets in detail, it serves as the primary 'User Guide' for this tool. We anticipate this development will significantly ease the accessibility and workflow of researchers and practitioners interested in using the LCZ framework for a variety of urban-induced human and environmental impacts.

Keywords: Local Climate Zones, WUDAPT, online toolbox, Google Earth engine, urban form and function



Conclusions on WUDAPT2COSMO

- LCZ maps are already available: an **European lcz map** is published (Demuzere et al., 2019); a **USA-wide version** is underway (Demuzere et al., in review).

- So far, only a beta version of a **global LCZ map** is available, yet work is ongoing for an official release of such a map.

- M. Demuzere is developing a tool for online LCZ mapping: LCZ map generation more accessible!

- The classification in mountainous regions **can suffer from confusion** between bare rock areas and urban areas. An additional filtering step based on an existing global (urban) land cover product might solve this issue.

- Based on these few test cities, the resulting urban canopy parameters seem in-line with those that are custom-made (Moscow) and seems to be even more reasonable than defaults from Wouters et al. (2016).

- Next step(s):
  - quantify is the impact of these LCZ-derived parameters on the modelled climate?
  - Benchmark the impact against all previous tuning efforts?

Other EXTPAR-related issues

Suggestions to replace urban fields currently available in EXTPAR:

- Update EEA imperviousness with new products (100m, state of 2006, 2009, 2012, 2015) (EUROPE)
- global artificial impervious area (GAIA) (30m, globally, 1985-2018, paper, download)
- ESA CCI urban land cover (300m, per year from 1992-2018) (viewer) (Global)
- Copernicus Global Land Cover (100m, 2015) (viewer) (GLOBAL):
- Explore use of Dong et al. (2017) anthropogenic heat flux (hourly, ~1km, state of 2013)

But we need to remember that urban/paved fraction are different parameters…