INTRODUCTION TO COMMUNITY LAND MODEL 5.0 AND ITS LAND USE DATA

曹畅　赵佳玉　楚淏然

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南京信息工程大学

Outline

- Why using climate model to study climatic effect of urbanization?
- Climate model introduction — CESM and CLM
- CLM application in urbanization study
- Land use data of CLM for future urbanization simulation

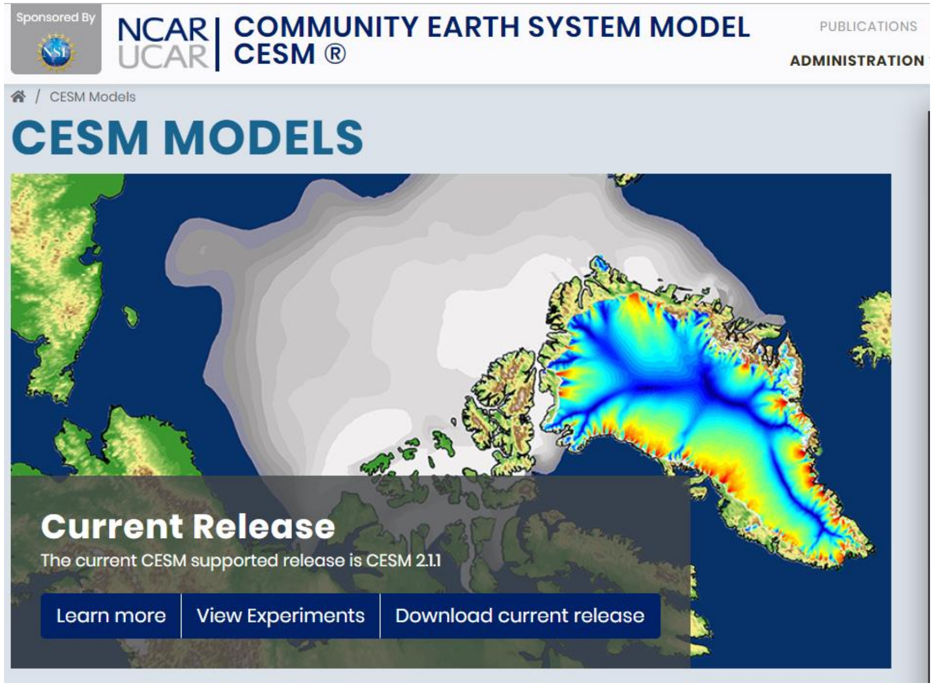
Why using climate model to study climatic effect of urbanization?

- Globally, 55% people reside in urban area in 2018 and it will keep growing in the next few decades.
- Urbanization affects climate system in two ways: biogeochemical (greenhouse gases) and biophysical.
- Climatic effects of biophysical parameters (albedo, evapotranspiration, roughness, anthropogenic heat et al) are multi-spatial (local, regional and global) in nature and the underlying mechanism is still not clear.
- Various climate models are suitable tools to study the multi-spatial biophysical effect of urbanization on climate.
- They are also feasible way for us to predict and estimate future climatic effects caused by urbanization and thus provide valuable scientific support for policy making.

Climate model introduction — CESM

- “The **Community Earth System Model** (CESM) is a fully-coupled, global climate model that provides state-of-the-art computer simulations of the Earth's past, present, and future climate states.”

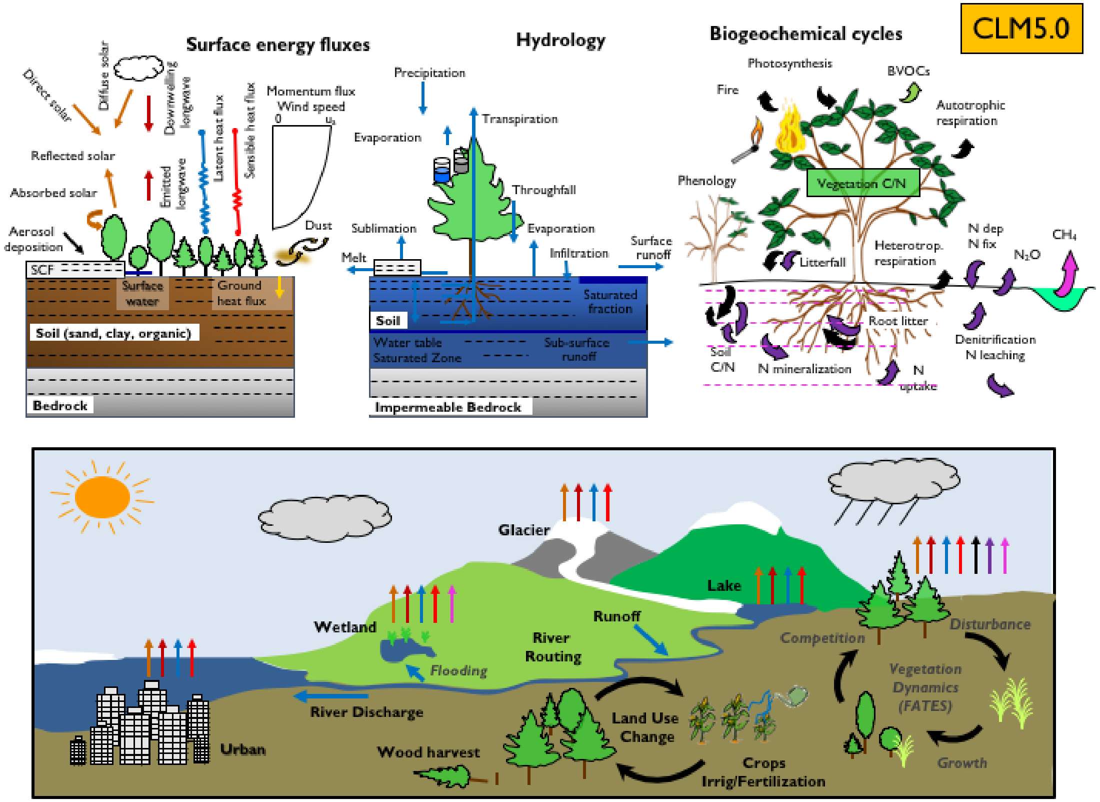
(http://www.cesm.ucar.edu/models/?ref=nav)



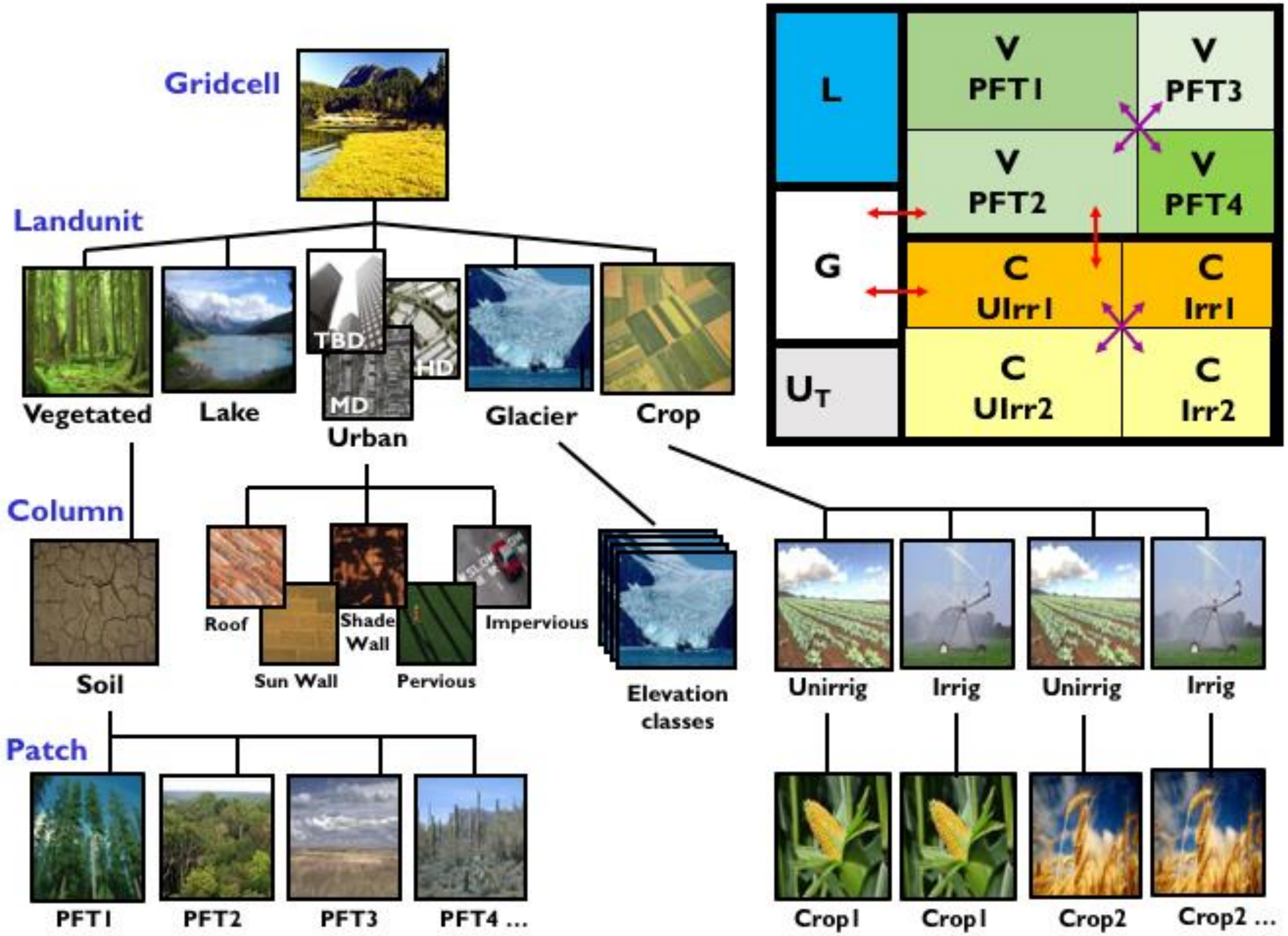
Composed of separate models simultaneously simulating the Earth’s atmosphere, ocean, **land**, river run-off, land-ice, and sea-ice, plus one central coupler/moderator component ...

Climate model introduction — CLM

- Latest version: Community Land Model 5.0 (CLM 5.0)



Nested subgrid hierarchy of CLM5.0



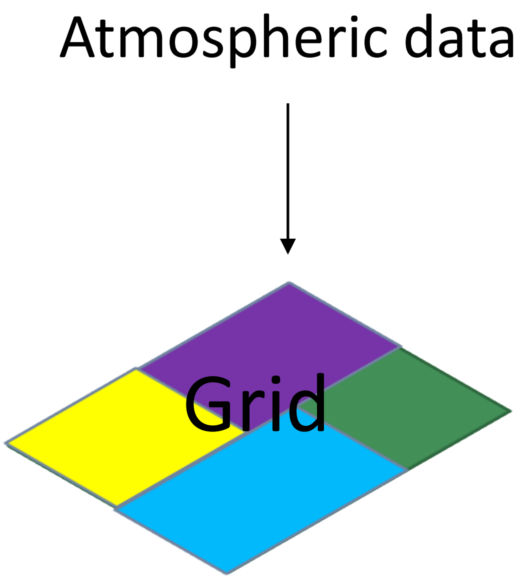


Table 2.4: Atmospheric input to land model

Field	variable name	units
[1]Reference height	z'_{atm}	m
Atmosphere model's surface height	$z_{surf,atm}$	m
Zonal wind at z_{atm}	u_{atm}	m s^{-1}
Meridional wind at z_{atm}	v_{atm}	m s^{-1}
Potential temperature	$\overline{\theta_{atm}}$	K
Specific humidity at z_{atm}	q_{atm}	kg kg^{-1}
Pressure at z_{atm}	P_{atm}	Pa
Temperature at z_{atm}	T_{atm}	K
Incident longwave radiation	$L_{atm}\downarrow$	W m^{-2}
[2]Liquid precipitation	q_{rain}	mm s^{-1}
[2]Solid precipitation	q_{sno}	mm s^{-1}
Incident direct beam visible solar radiation	$S_{atm}\downarrow^{\mu}_{vis}$	W m^{-2}
Incident direct beam near-infrared solar radiation	$S_{atm}\downarrow^{\mu}_{nir}$	W m^{-2}
Incident diffuse visible solar radiation	$S_{atm}\downarrow_{vis}$	W m^{-2}
Incident diffuse near-infrared solar radiation	$S_{atm}\downarrow_{nir}$	W m^{-2}
Carbon dioxide (CO_2) concentration	c_a	ppmv
[3]Aerosol deposition rate	D_{sp}	kg m^{-2} s^{-1}
[4]Nitrogen deposition rate	NF_{ndep_sminn}	g (N) m^{-2} yr^{-1}
[5]Lightning frequency	I_l	flash km^{-2} hr^{-1}

- This atmospheric state is provided by an atmospheric model in coupled mode or from an observed dataset (reanalysis or field observations) in land-only mode
- The same atmospheric forcing is used to force all subgrid units within one grid cell

Atmospheric data

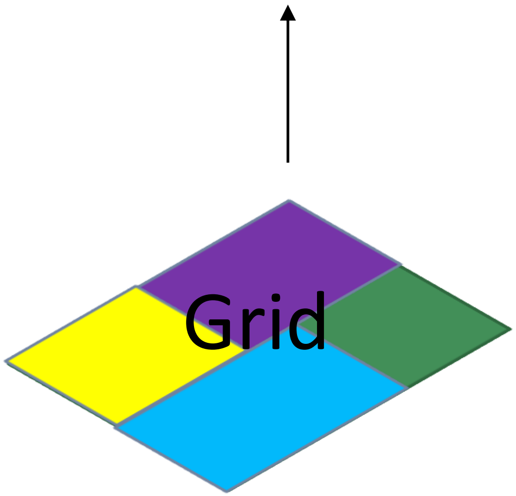


Table 2.5: Land model output to atmospheric model

Field	Variable name	units
[1]Latent heat flux	$\lambda_{vap}E_v + \lambda E_g$	W m^{-2}
Sensible heat flux	$H_v + H_g$	W m^{-2}
Water vapor flux	$E_v + E_g$	mm s^{-1}
Zonal momentum flux	τ_x	kg m^{-1} s^{-2}
Meridional momentum flux	τ_y	kg m^{-1} s^{-2}
Emitted longwave radiation	$L\uparrow$	W m^{-2}
Direct beam visible albedo	$I\uparrow^{\mu}_{vis}$	•
Direct beam near-infrared albedo	$I\uparrow^{\mu}_{nir}$	•
Diffuse visible albedo	$I\uparrow_{vis}$	•
Diffuse near-infrared albedo	$I\uparrow_{nir}$	•
Absorbed solar radiation	$\vec{S}$	W m^{-2}
Radiative temperature	T_{rad}	K
Temperature at 2 meter height	T_{2m}	K
Specific humidity at 2 meter height	q_{2m}	kg kg^{-1}
Wind speed at 10 meter height	u_{10m}	m s^{-1}
Snow water equivalent	W_{sno}	m
Aerodynamic resistance	r_{am}	s m^{-1}
Friction velocity	u_*	m s^{-1}
[2]Dust flux	F_j	kg m^{-2} s^{-1}
Net ecosystem exchange	NEE	$kgCO_2$ m^{-2} s^{-1}

- The area-averaged fluxes are used as lower boundary conditions by the atmospheric model at the next time step.

Surface data

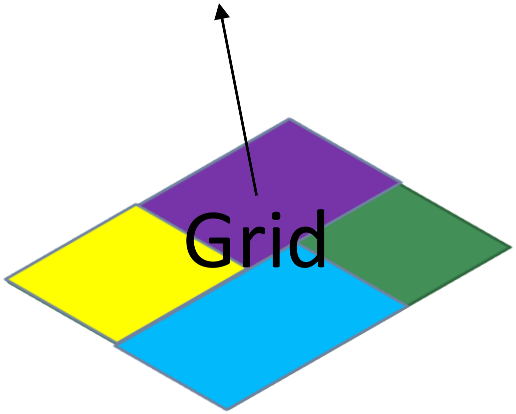
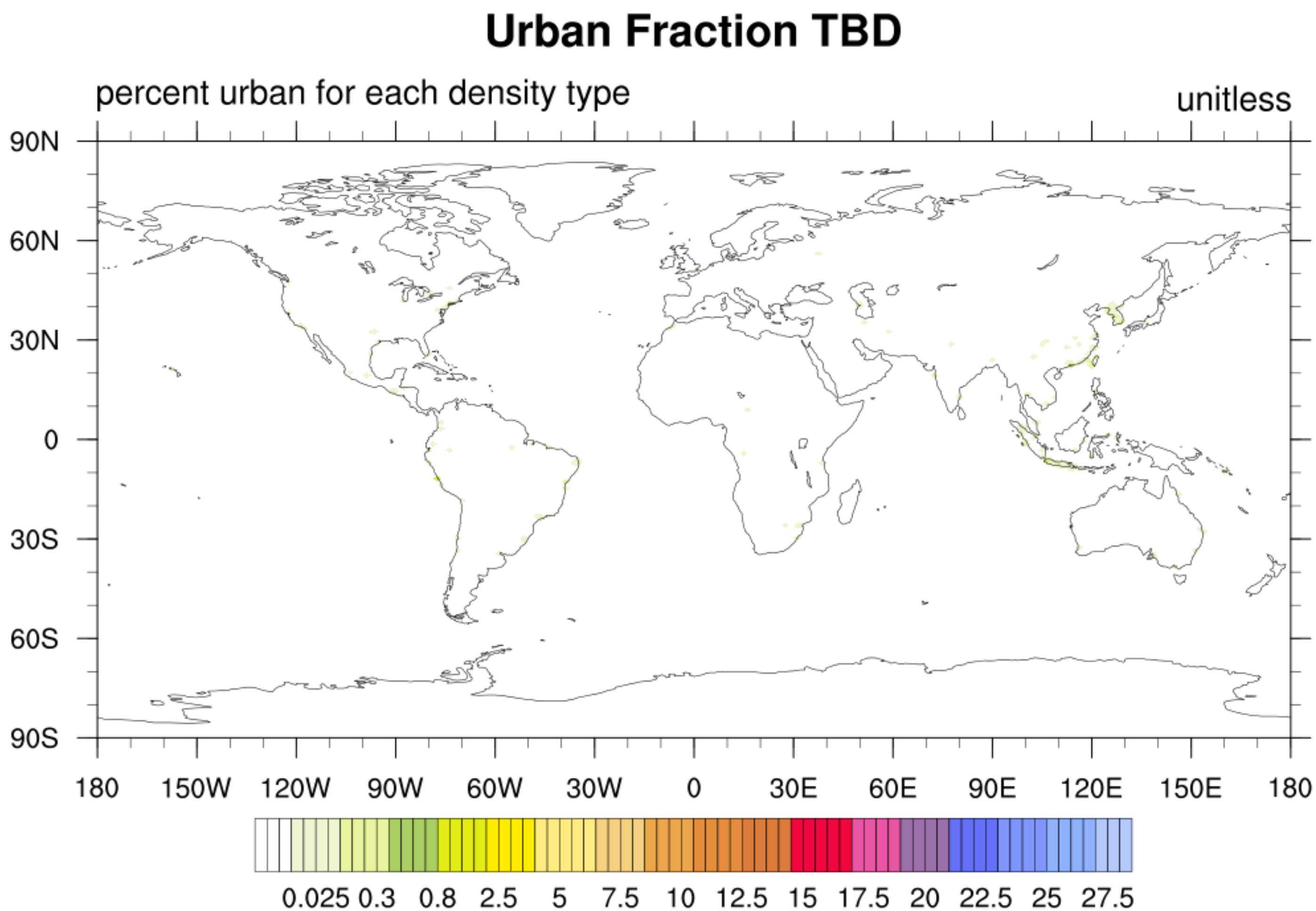
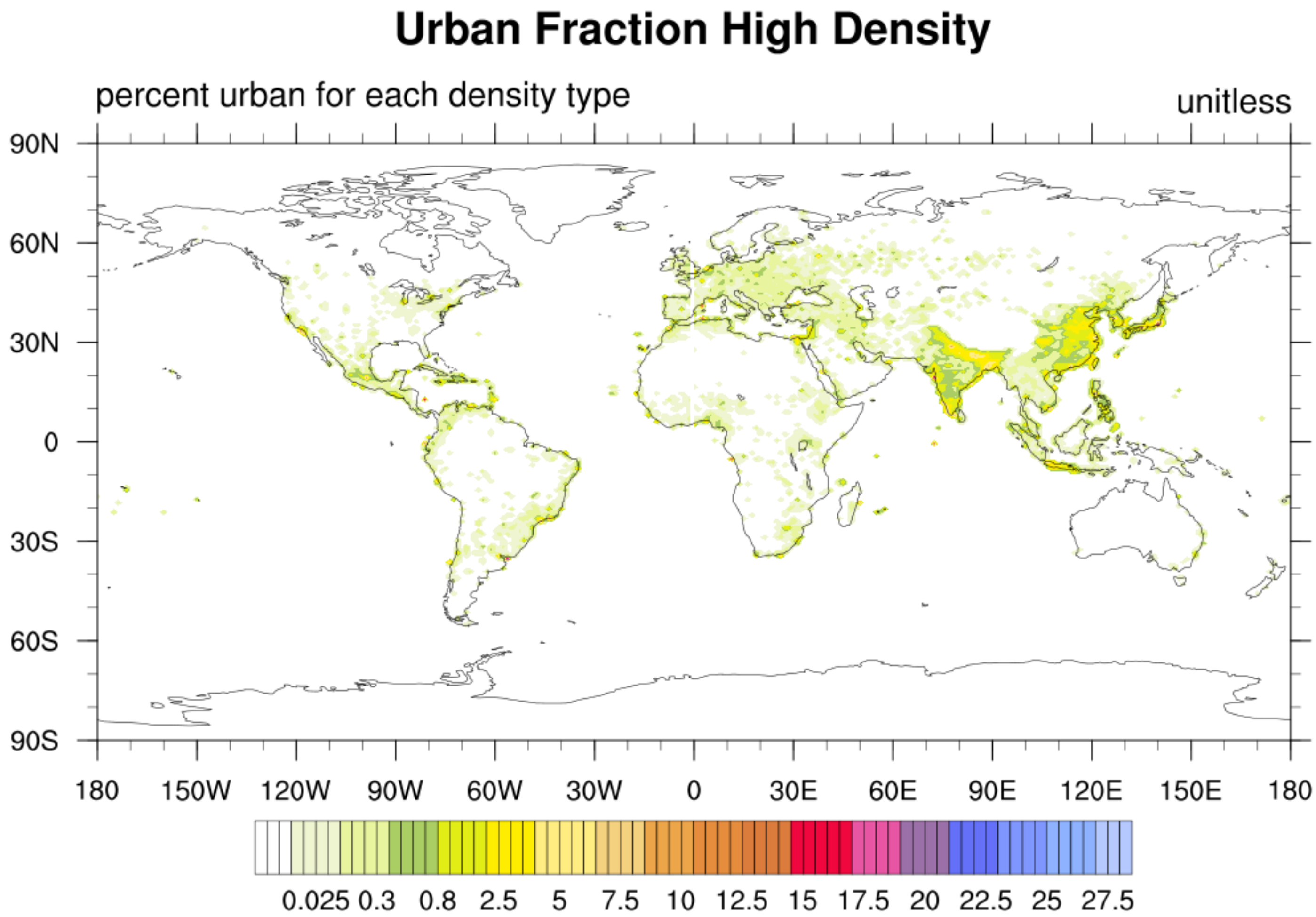


Table 2.6: Surface data required for CLM and their base spatial resolution

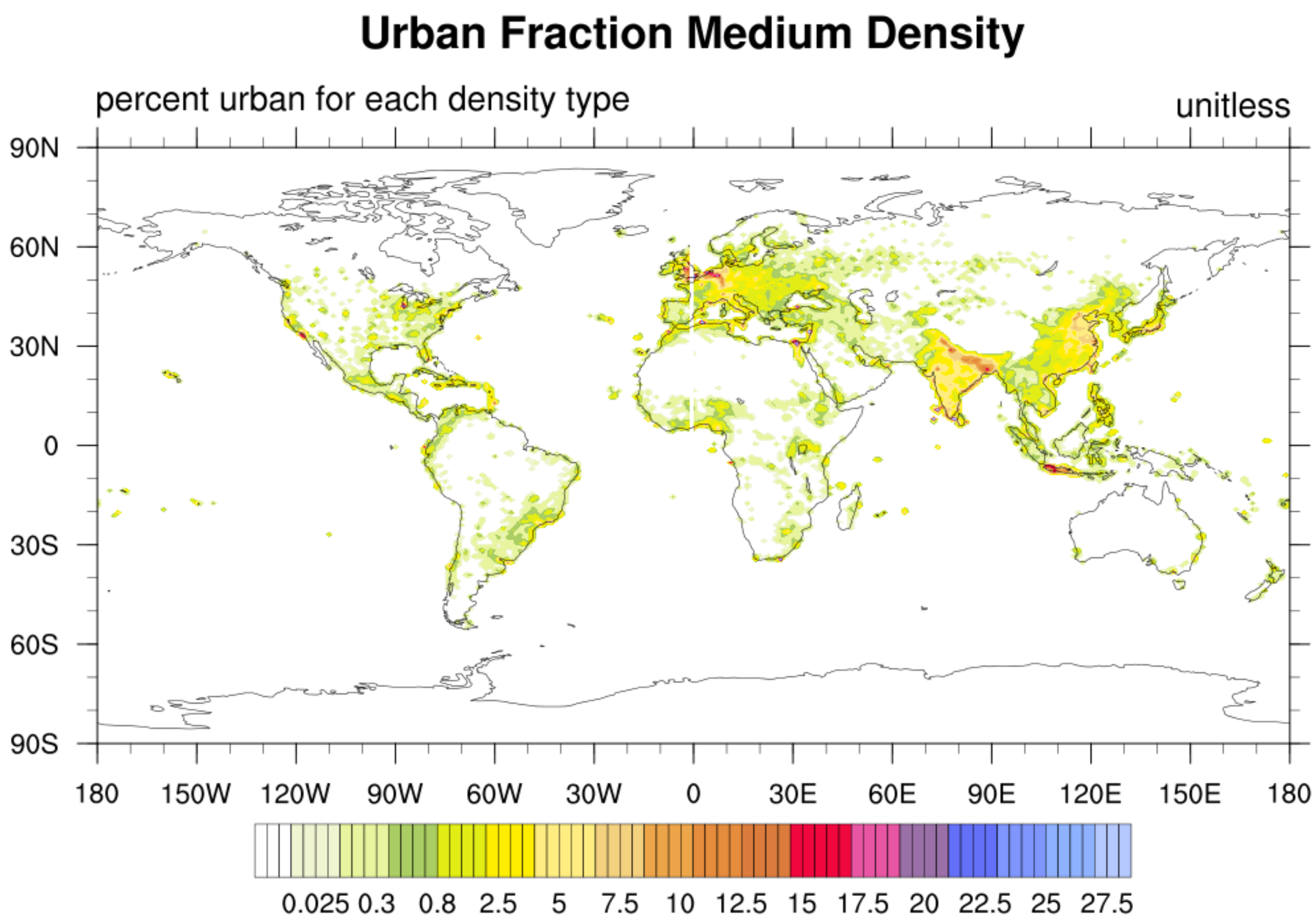
Surface Field	Resolution
Percent glacier	0.05°
Percent lake and lake depth	0.05°
Percent urban	0.05°
Percent plant functional types (PFTs)	0.05°
Monthly leaf and stem area index	0.5°
Canopy height (top, bottom)	0.5°
Soil color	0.5°
Percent sand, percent clay	0.083°
Soil organic matter density	0.083°
Maximum fractional saturated area	0.125°
Elevation	1km
Slope	1km
Biogenic Volatile Organic Compounds	0.5°
Crop Irrigation	0.083°
Managed crops	0.5°
Population density	0.5°
Gross domestic production	0.5°
Peat area fraction	0.5°
Peak month of agricultural waste burning	0.5°



Data from surface data
“surfdata_0.9x1.25_16pfts_Irrig_CMIP6_simyr2000_c170824.nc”



Data from surface data
"surfdata_0.9x1.25_16pfts_Irrig_CMIP6_simyr2000_c170824.nc"

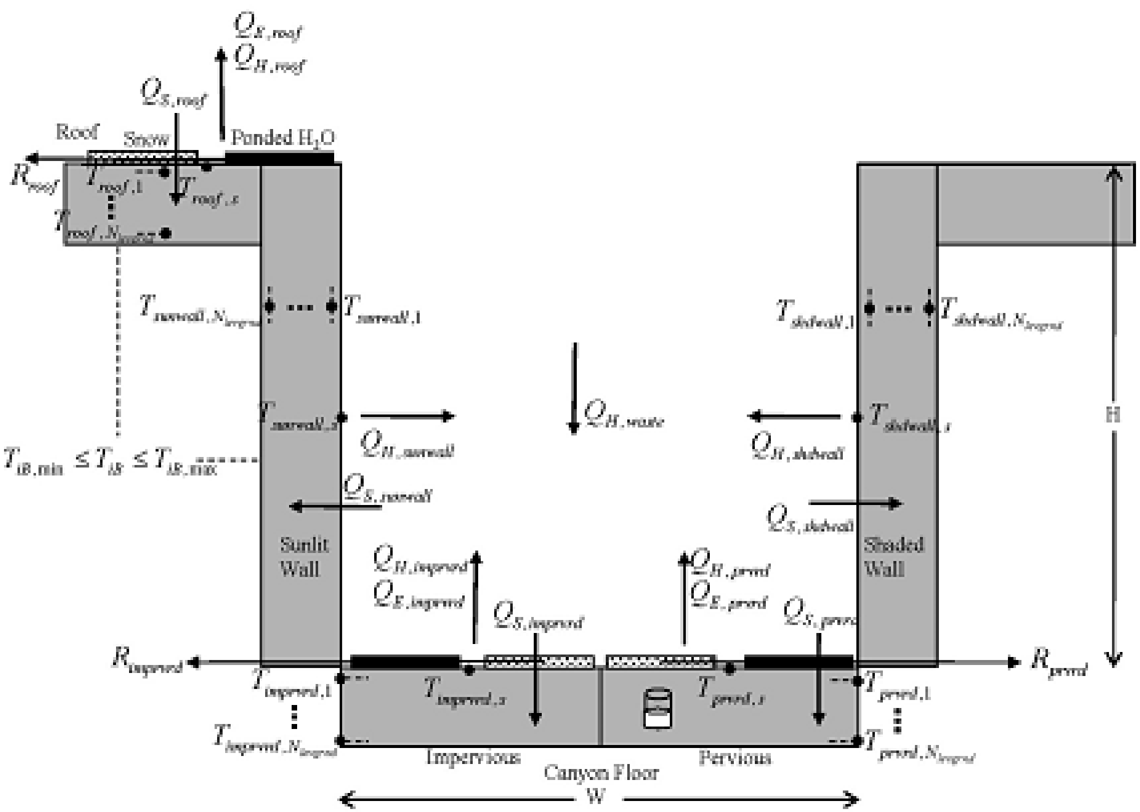


Data from surface data
"surfdata_0.9x1.25_16pfts_Irrig_CMIP6_simyr2000_c170824.nc"

CLM Urban canyon model (CLMU)

- First released in CLM 4.0 in 2010
- A single-layer urban canopy model that is simple enough to be compatible with structural and computational constraints of a land surface model coupled to a global climate model yet complex enough to explore physically based processes known to be important in determining urban climatology (Oleson and Bonan, 2007)
- A minimum of threshold of 0.1% of the grid cell by area is required for urban areas
- Build on “Urban Canyon” concept in which the canyon geometry is described by building height and street width

Urban Canyon



Roof

Sunlit wall

Shaded wall

Pervious canyon floor

Impervious canyon floor

CLMU improvement

- From CLM4.0 to CLM4.5

1) an expansion of the single urban landunit to up to **three landunits per grid cell stratified by urban density types**

2) the number of urban layers for roofs and walls is no longer constrained to be equal to the number of ground layers

3) space heating and air conditioning wasteheat factors are now set to zero by default

4) the elevation threshold used to eliminate urban areas in the surface dataset creation routines has been changed from 2200 meters to 2600 meters

5) hydrologic and thermal calculations for the pervious road follows CLM4.5 parameterizations

(CLM4.5 Technical Note)

CLMU Improvement

- From CLM4.5 to CLM5.0

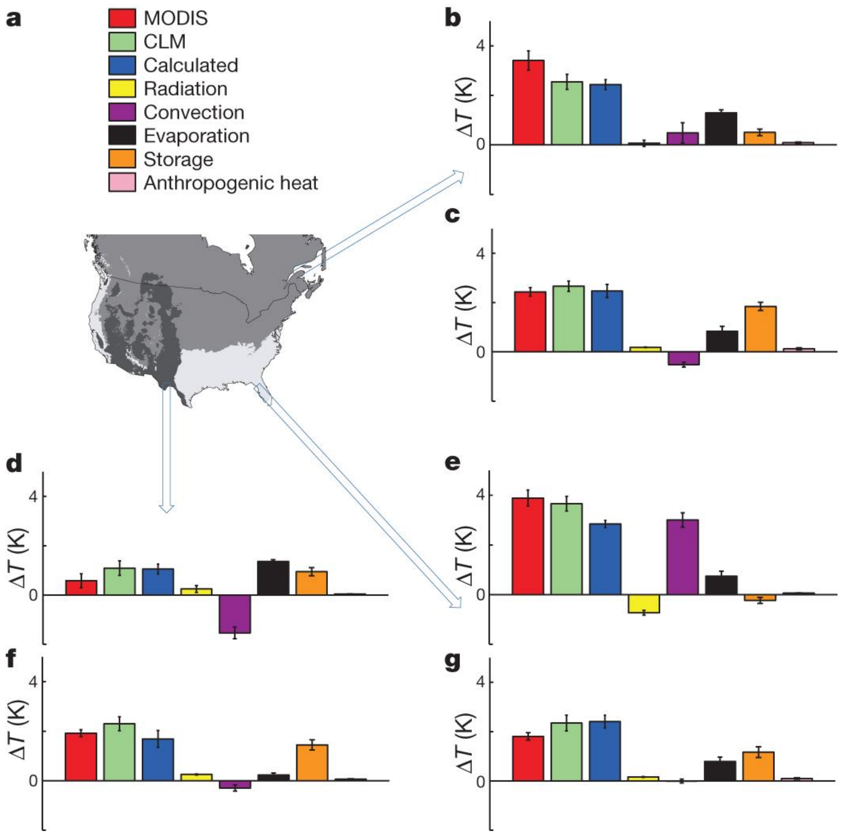
1) a more sophisticated and realistic building space heating and air conditioning submodel

2) the maximum building temperature (which determines air conditioning demand) is now read in from a namelist-defined file which allows for dynamic control of this input variable

3) an optional updated **urban properties dataset and new scenario tool**. In addition, **a module of heat stress indices calculated online** in the model that can be used to assess human thermal comfort for rural and urban areas has been added

(CLM 5.0 Technical Note)

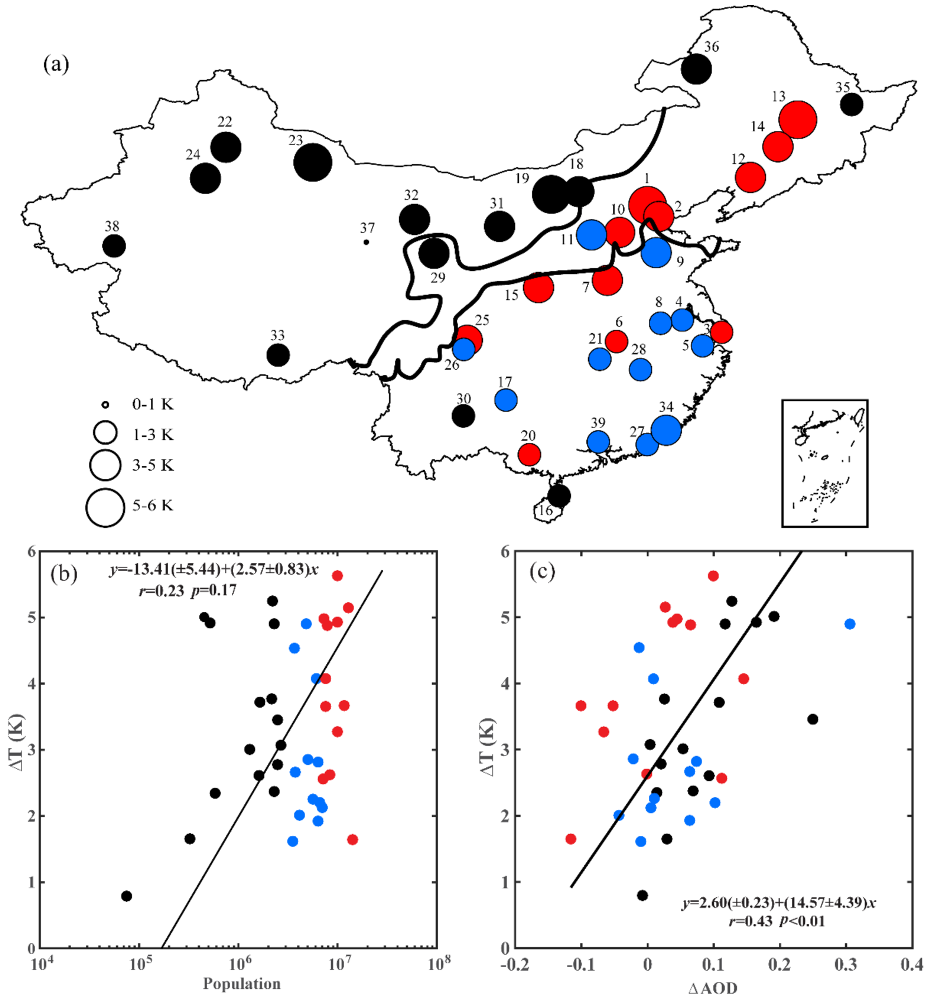
CLM application in urbanization study — Urban Heat Island

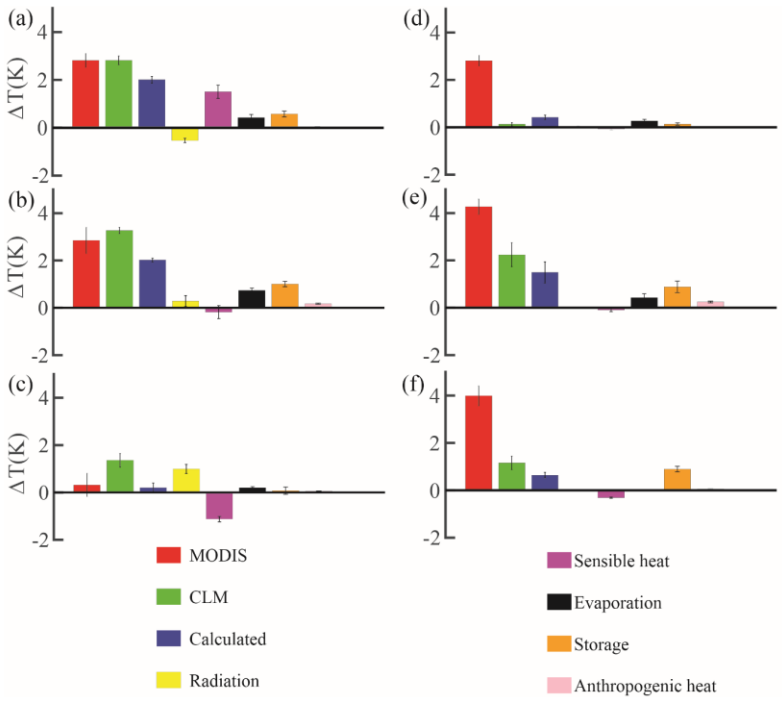


$$\Delta T \approx \frac{\lambda_0}{1+f}\Delta R_n^* + \frac{-\lambda_0}{(1+f)^2}(R_n^* - Q_s + Q_{AH})\Delta f_1 + \frac{-\lambda_0}{(1+f)^2}(R_n^* - Q_s + Q_{AH})\Delta f_2 + \frac{-\lambda_0}{1+f}\Delta Q_s + \frac{\lambda_0}{1+f}\Delta Q_{AH}$$

Zhao *et al. Nature* **2014**

CLM application in urbanization study — Urban Heat Island





Cao *et al. Nature Communications* **2016**

CLM application in urbanization study — Urban Heat Island

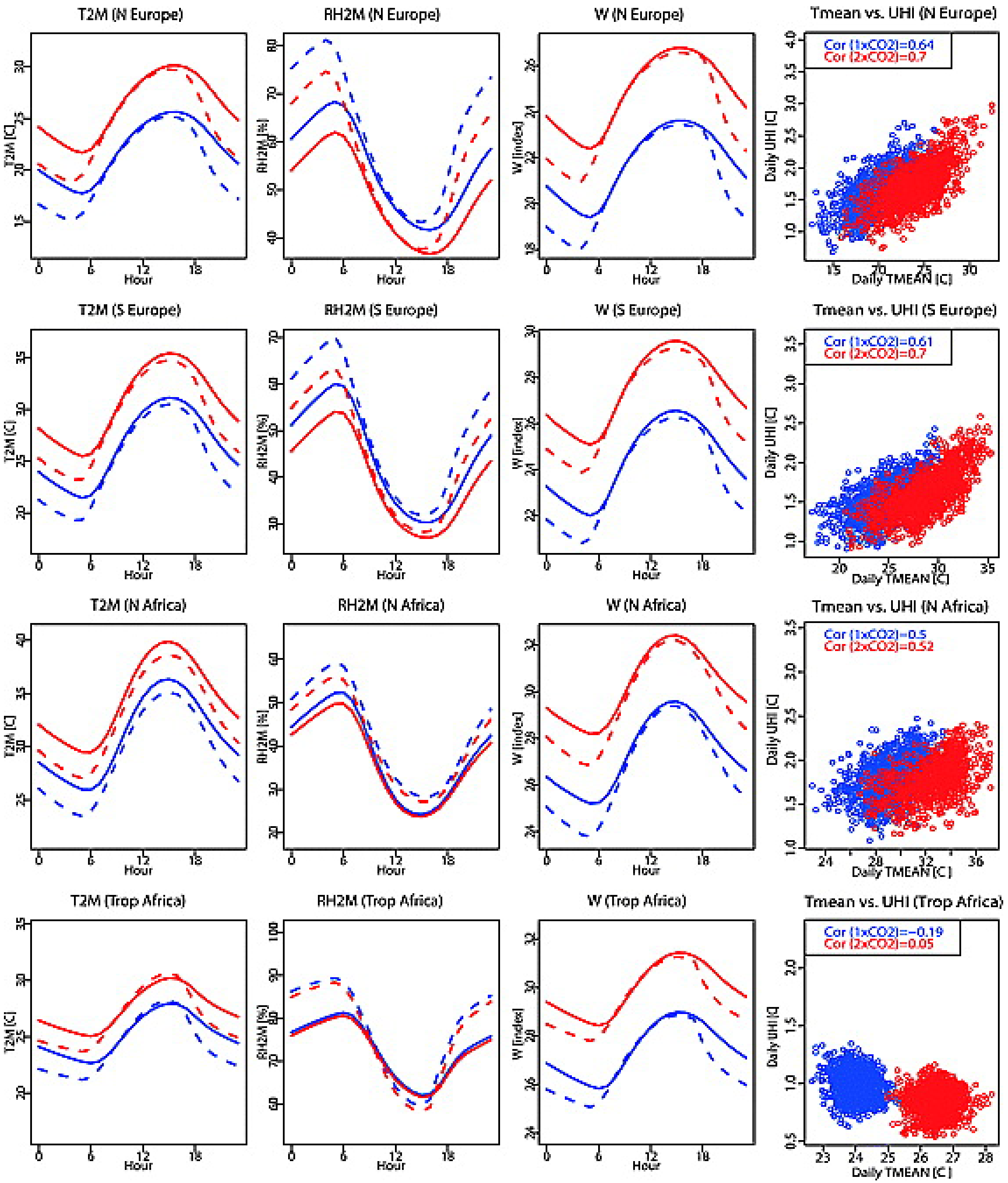
$$\boxed{(\Delta T)_h = (\lambda_0/(1+f))\Delta L_{\downarrow}}$$

	湿润区	半湿润区	半干旱区
AOD敏感度 ($W\ m^{-2}$ / AOD)	31.9±3.0	23.8±4.6	61.8±4.9
ΔAOD	0.033±0.021	0.033±0.020	0.130±0.025
f	3.0±1.8	1.7±0.9	1.3±0.8
$(\Delta T)_h$ (K)	0.05±0.12	0.06±0.10	0.70±0.26

Cao *et al. Nature Communications* **2016**

CLM application in urbanization study — Heat stress

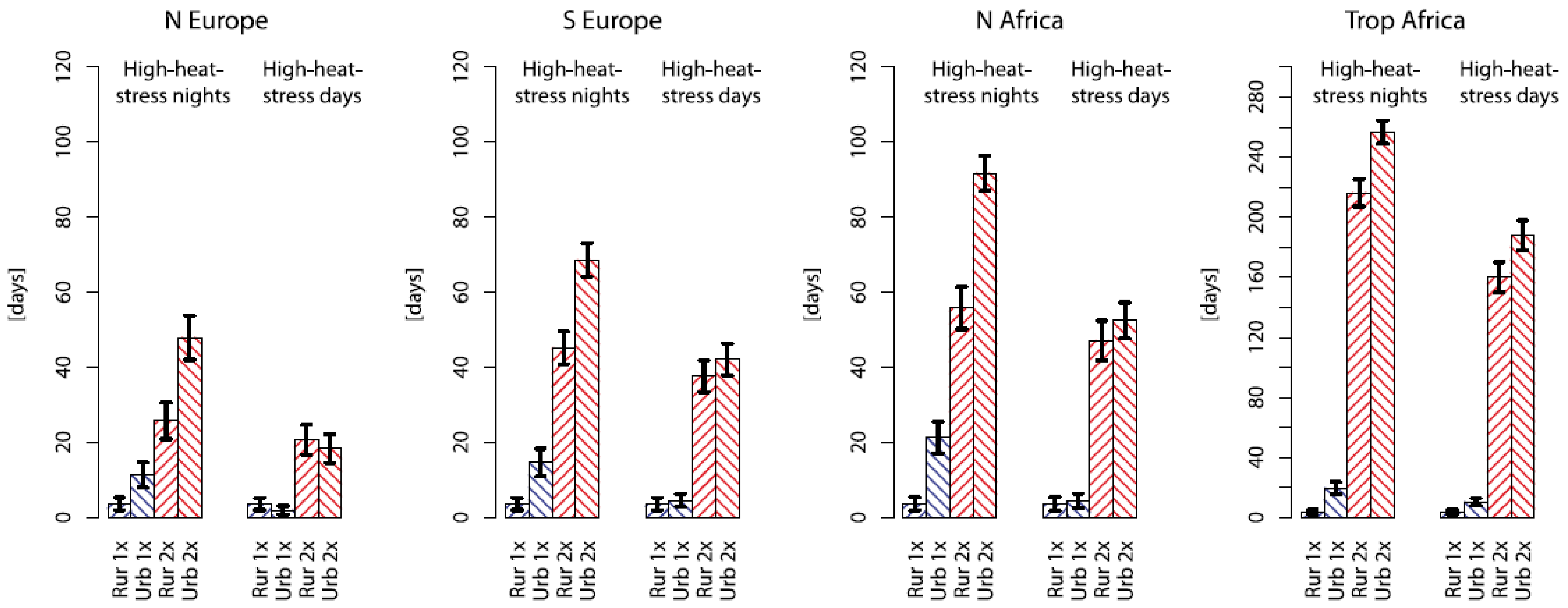
- Heat stress can be magnified in urban areas because of the urban heat island effect.
- Human thermal comfort is a combination of air temperature and humidity.
- High ambient temperatures and humidity reduce the human body's efficiency of transporting away the metabolic heat through evaporative cooling (sweating) and heat conduction (Sherwood and Huber, 2010).



Simplified Wet-Bulb Globe Temperature

$$W = 0.567T + 0.393e + 3.94$$

Fischer *et al. GRL* **2012**



- Note that the urban surface properties in CLM4 mainly represent medium density urban areas. Heat stress in higher urban density classes, such as central business districts, may be underestimated in this study.

Fischer *et al. GRL* **2012**

Geosci. Model Dev., 8, 151–170, 2015
www.geosci-model-dev.net/8/151/2015/
doi:10.5194/gmd-8-151-2015

Geoscientific Model Development
Open Access

Implementation and comparison of a suite of heat stress metrics within the Community Land Model version 4.5

J. R. Buzan[1,2], K. Oleson[3], and M. Huber[1,2]

[1]Department of Earth Sciences, University of New Hampshire, Durham, New Hampshire, USA
[2]Earth Systems Research Center, Institute for the Study of Earth, Ocean, and Space, University of New Hampshire, Durham, New Hampshire, USA
[3]National Center for Atmospheric Research, Boulder, Colorado, USA

Correspondence to: J. R. Buzan (jonathan.buzan@unh.edu)

Land use data of CLM for future urbanization simulation

- Future urban area data
- Data from Beijing Normal University for the year 2020, 2030, 2040, 2050, 2060 and 2070 under five SSPs

Urban Properties Tool

Oleson K. W. (Orcid ID: 0000-0002-0057-9900)

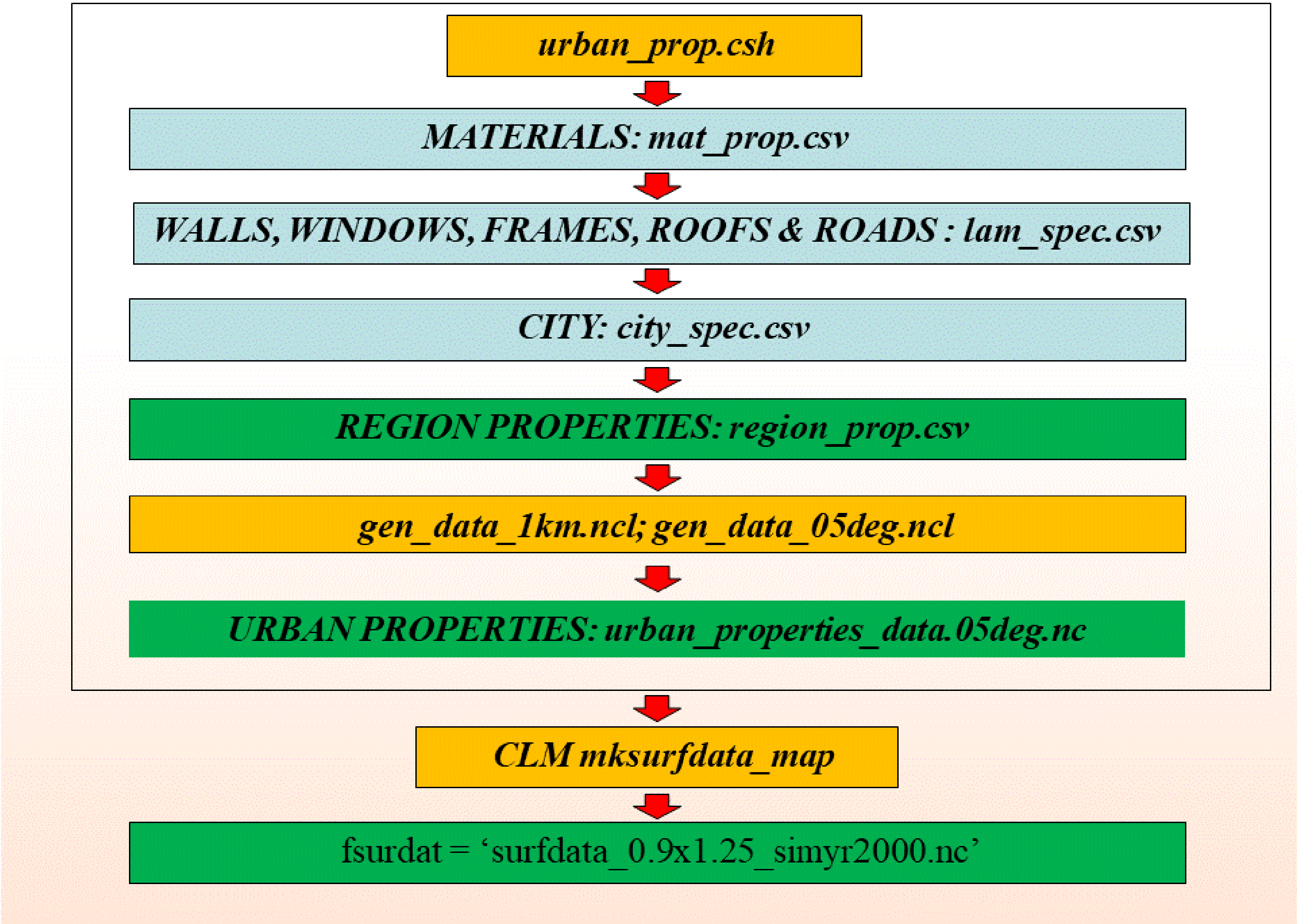
Parameterization and surface data improvements and new capabilities for the Community Land Model Urban (CLMU)

K. W. Oleson[1] and J. Feddema[2]

[1]National Center for Atmospheric Research, Boulder, Colorado.

[2]University of Victoria, Victoria BC, Canada.

Corresponding author: Keith Oleson (oleson@ucar.edu)



urban_prop.csh
MATERIALS: mat_prop.csv
WALLS, WINDOWS, FRAMES, ROOFS & ROADS : lam_spec.csv
CITY: city_spec.csv
REGION PROPERTIES: region_prop.csv
gen_data_1km.ncl; gen_data_05deg.ncl
URBAN PROPERTIES: urban_properties_data.05deg.nc
CLM mksurfdata_map
fsurdat = ‘surfdata_0.9x1.25_simyr2000.nc’

Thank you for your attention!

明德格物 立己达人