Towards standard urban parametrization for COSMO(-CLM)

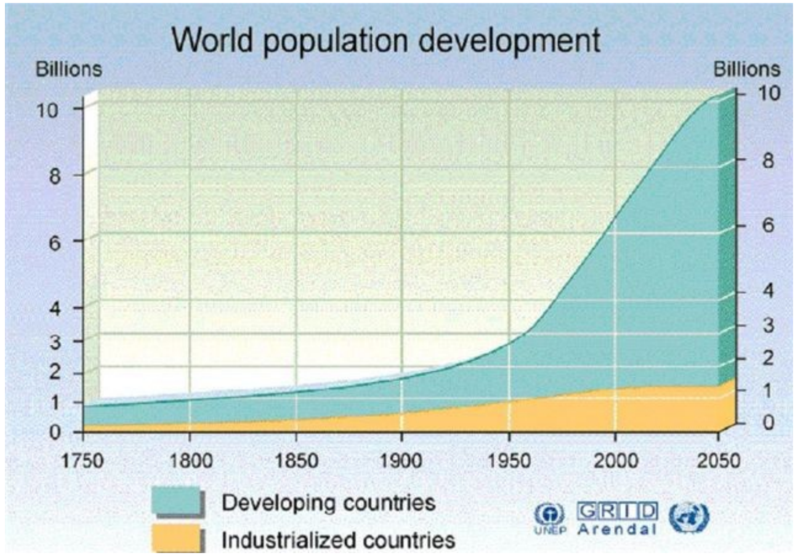
Hendrik Wouters, Ulrich Blahak, Jürgen Helmert, Matthias Raschendorfer, Matthias Demuzere, Barbara Fay, Kristina Trusilova, Dmitrii Mironov, Daniel Reinert, Daniel Lüthi, Ekaterina Machulskaya, Jan-Peter Schulz

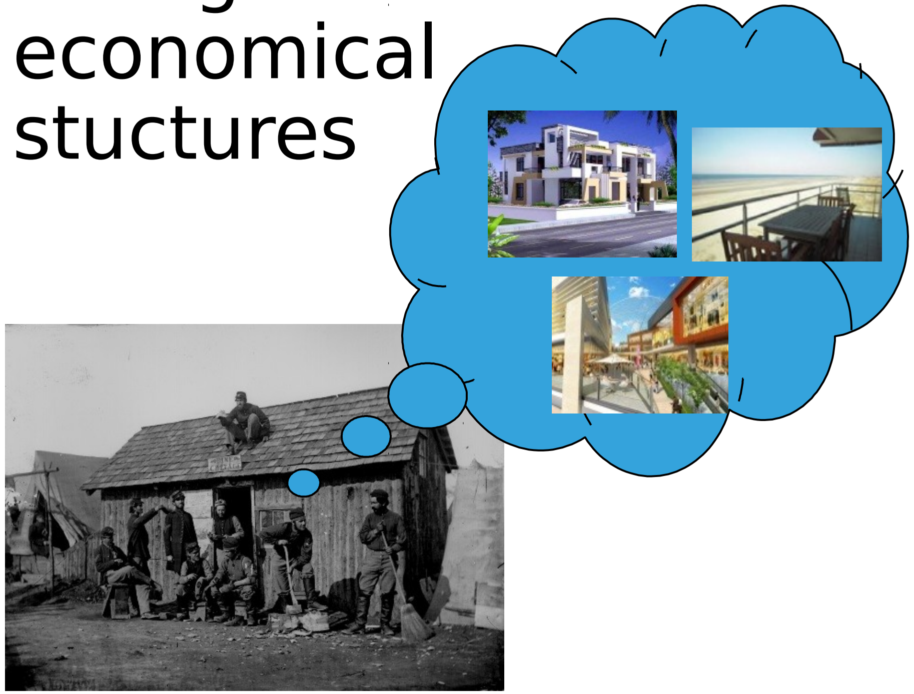
COSMO / CLM / ART - User Seminar 2015

Offenbach, March 2 – 6, 2015

Changes in global society

- Growing population
- 1800 -> 2014
  - 1 billion -> 7 billion
- Growing wellfare, changes in socio-economical stuctures

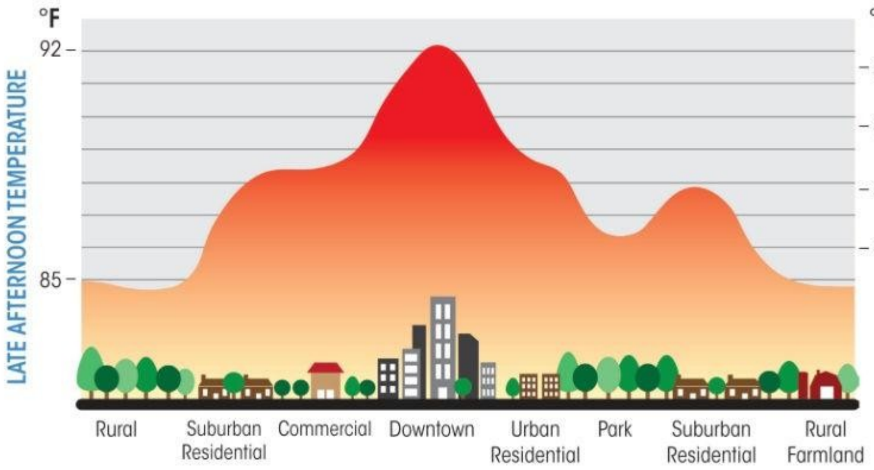




Result: urban expansion

The consequence…

- Drastic local climate changes at the scale of cities → Urban heat island (UHI)



The consequence…

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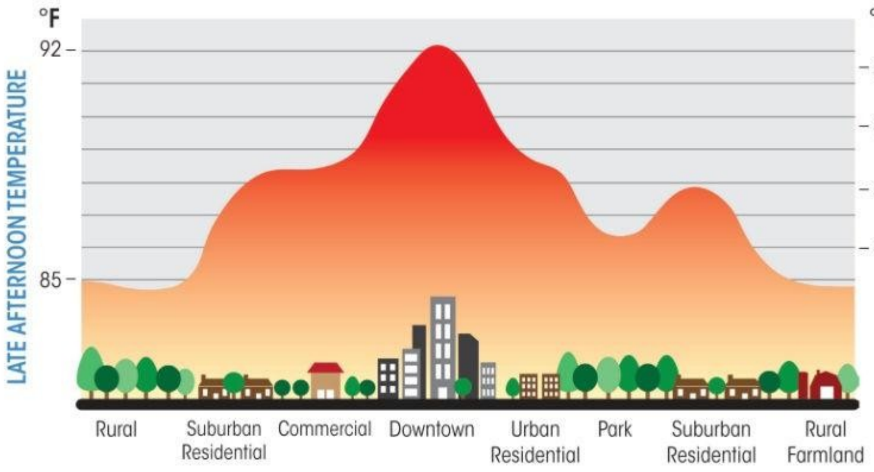
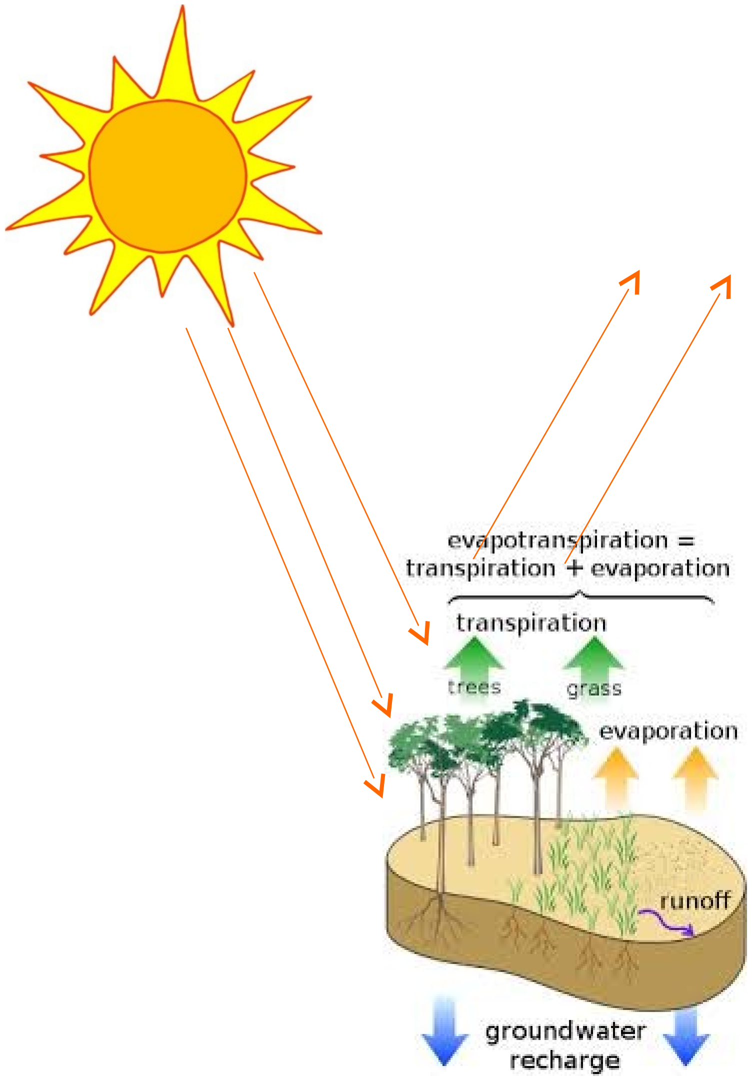
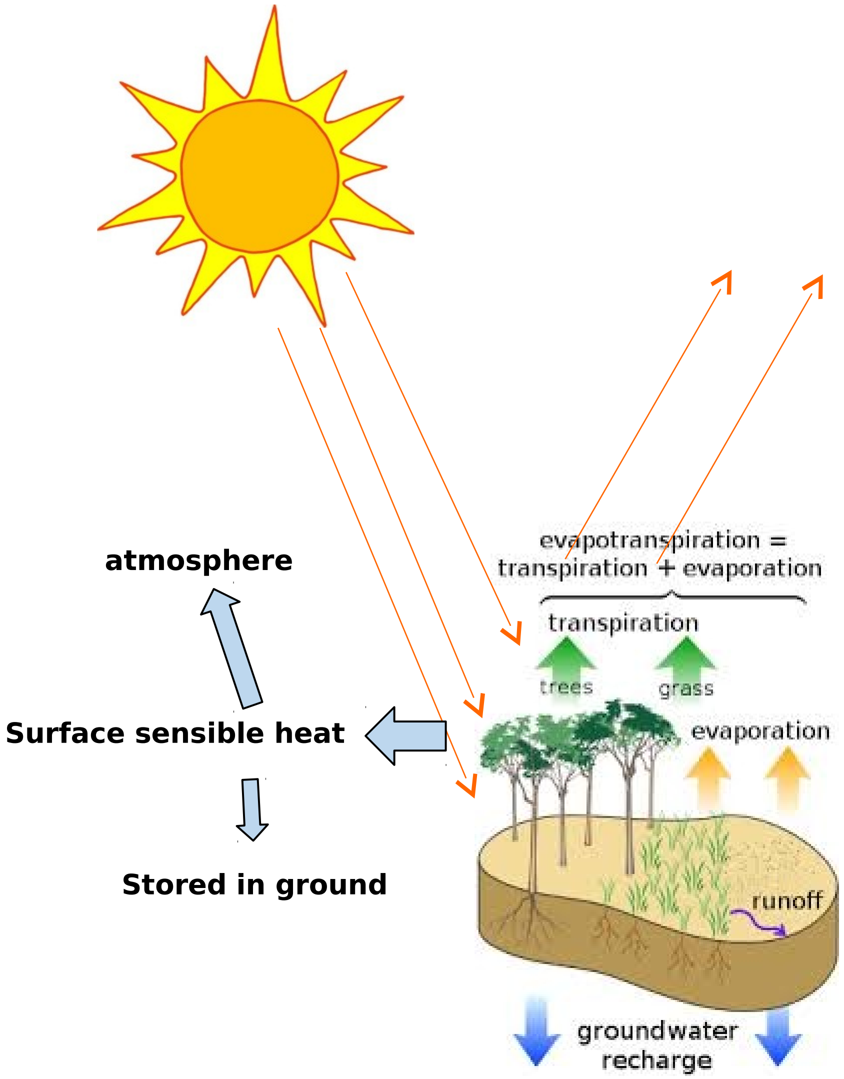
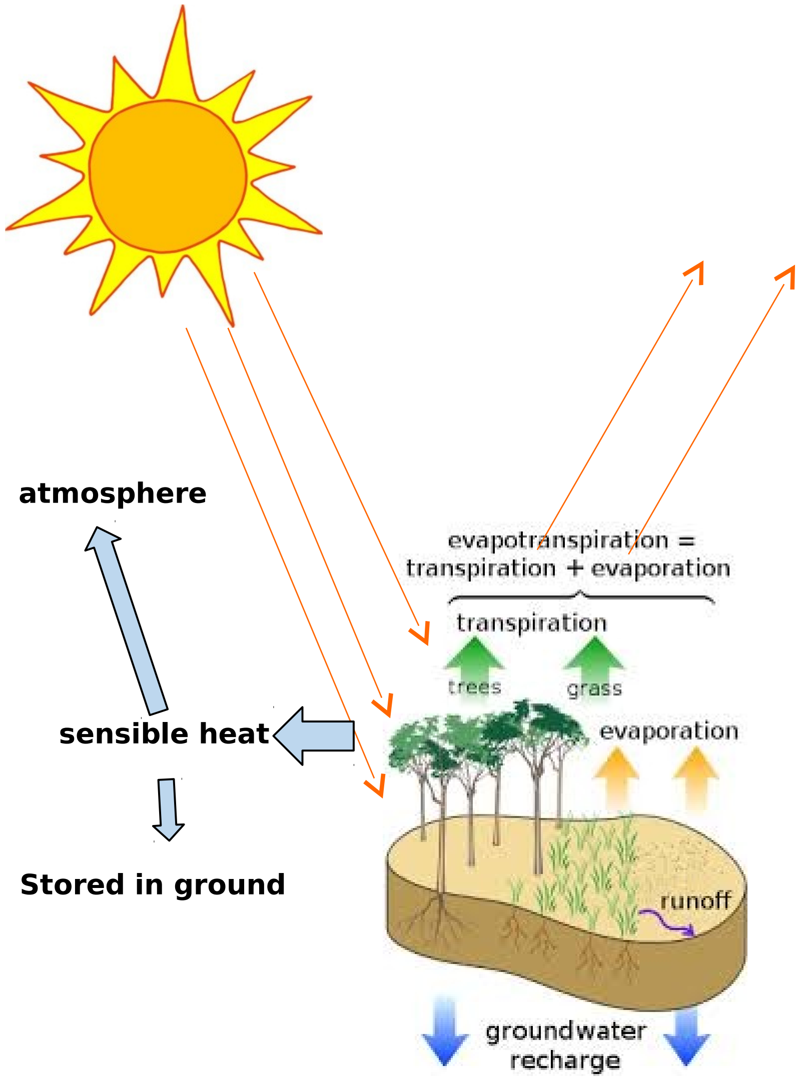


- Mainly, two processes are involved: UF HE


evapotranspiration =
transpiration + evaporation
transpiration
trees
grass
evaporation
runoff
groundwater
recharge


atmosphere
Surface sensible heat
Stored in ground
evapotranspiration =
transpiration + evaporation
transpiration
trees
grass
evaporation
runoff
groundwater
recharge


atmosphere
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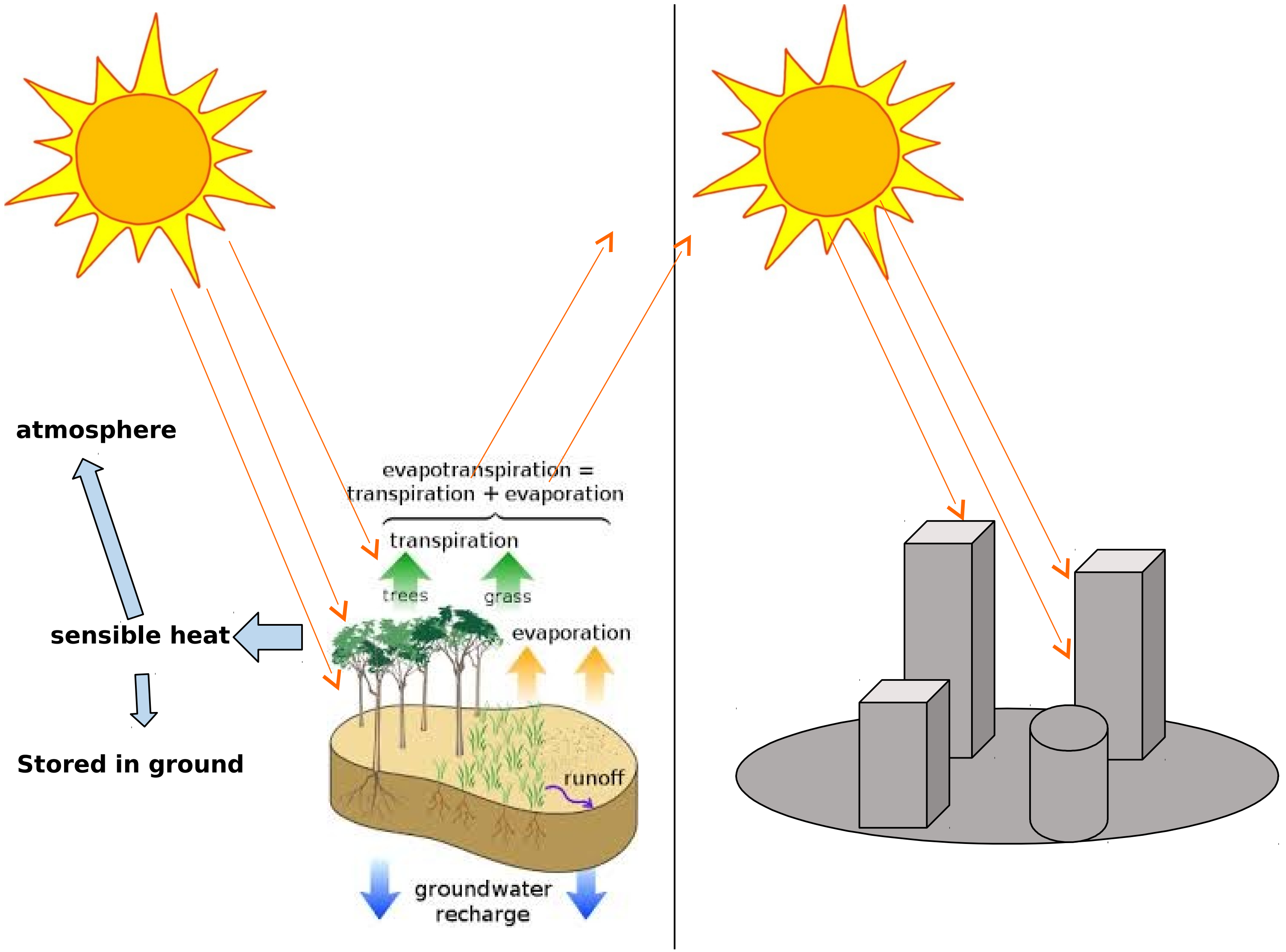
atmosphere
sensible heat
Stored in ground
evapotranspiration =
transpiration + evaporation
transpiration
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grass
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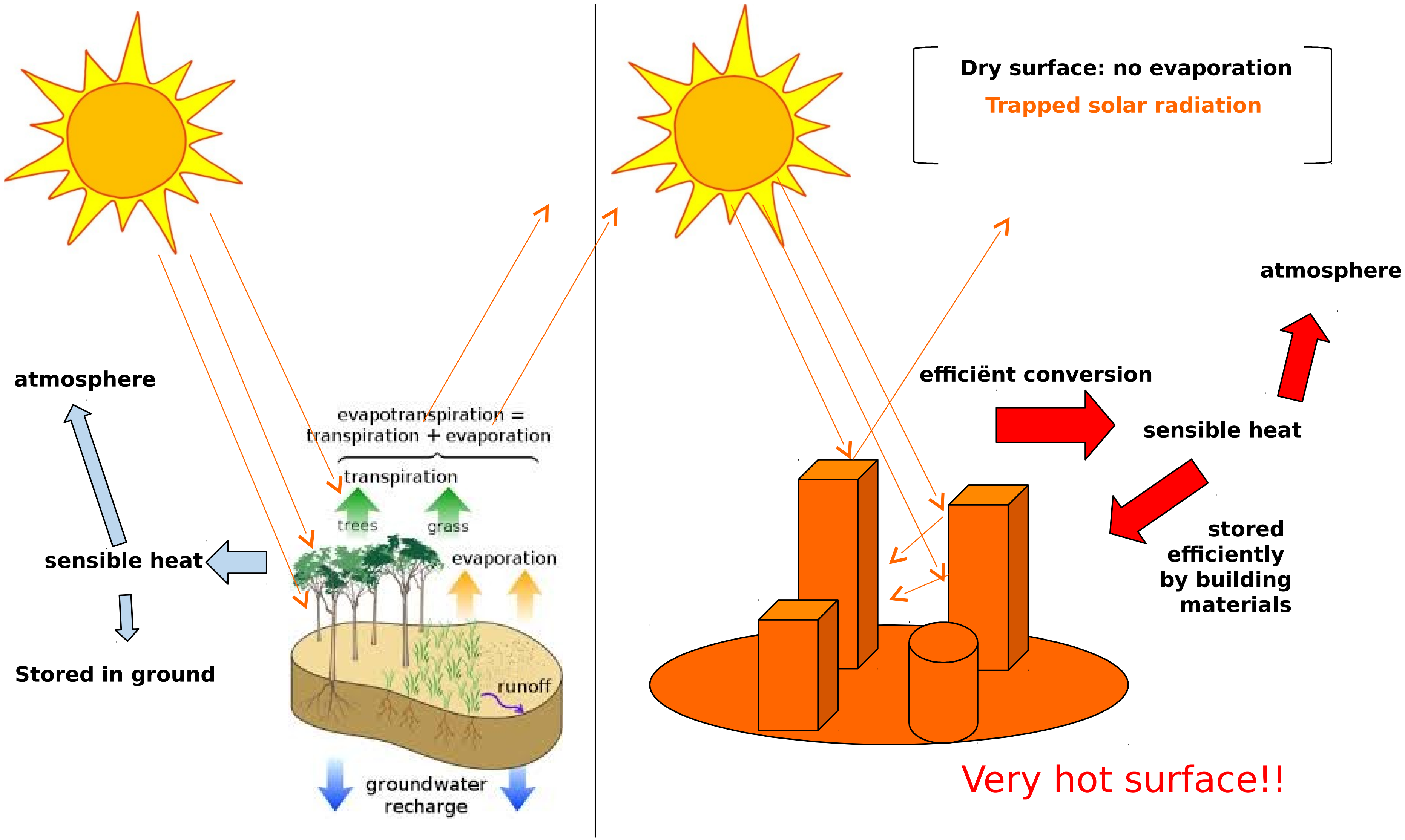
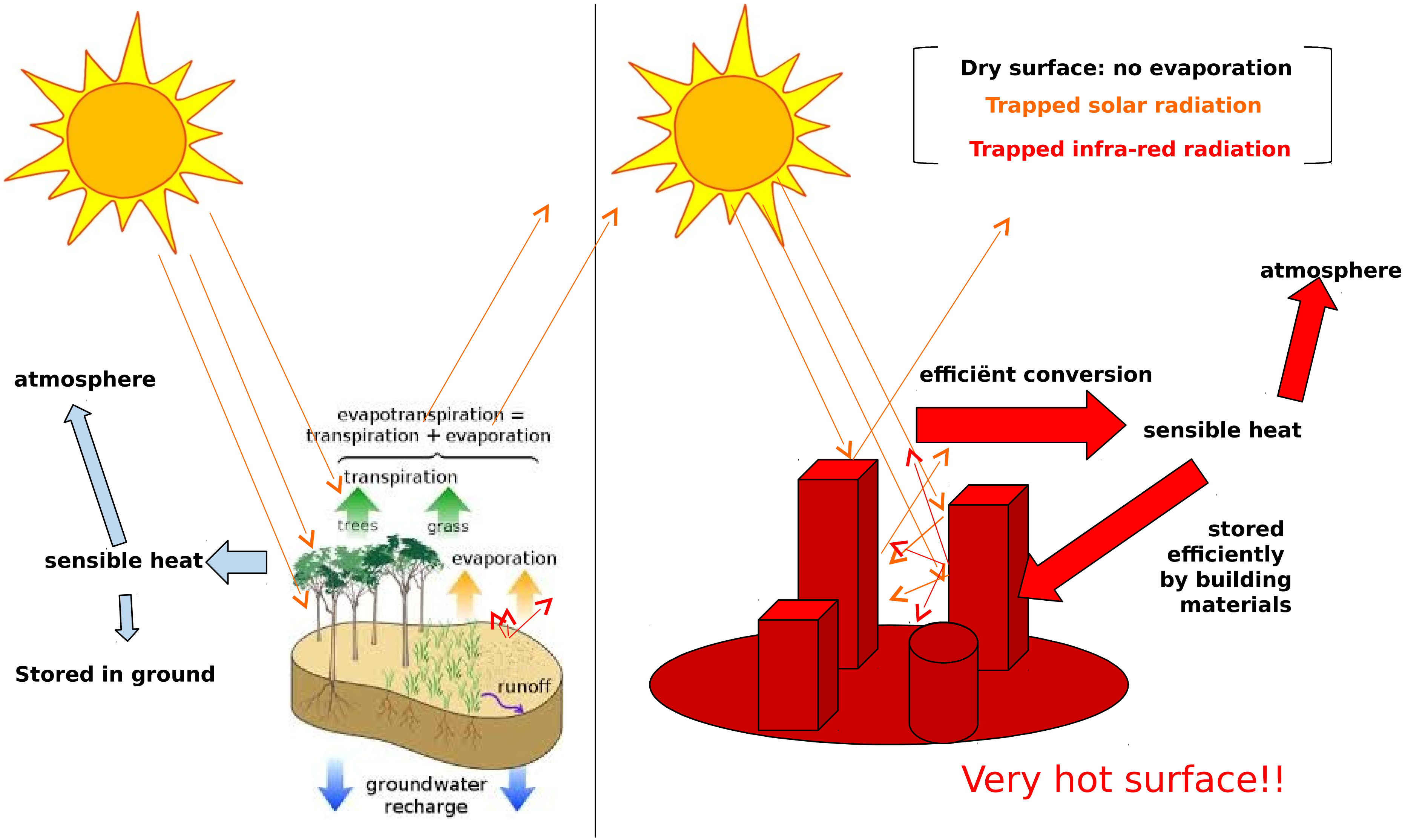
runoff
groundwater
recharge

2


atmosphere
sensible heat
Stored in ground
evapotranspiration =
transpiration + evaporation
transpiration
trees
grass
evaporation
runoff
groundwater
recharge
Dry surface: no evaporation
Trapped solar radiation
atmosphere
efficiënt conversion
sensible heat
stored
efficiently
by building
materials
Very hot surface!!

2



atmosphere
sensible heat
Stored in ground
evapotranspiration =
transpiration + evaporation
transpiration
trees
grass
evaporation
runoff
groundwater
recharge
Dry surface: no evaporation
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atmosphere
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Very hot surface!!

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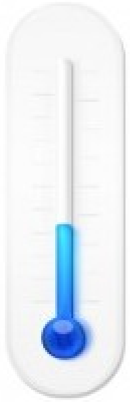
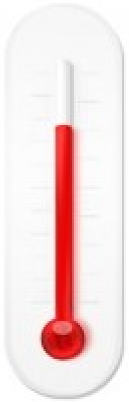


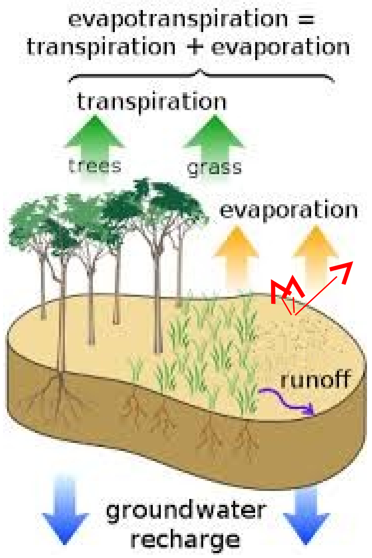


Drag on wind
-> decreased wind speeds

atmosphere

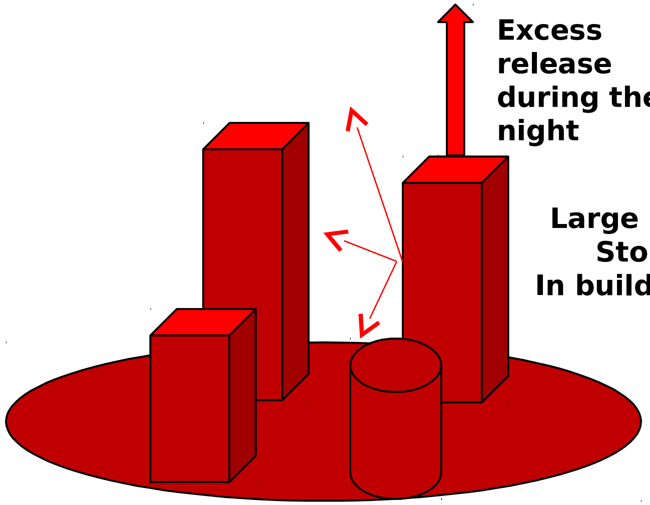
sensible heat

Stored in ground



atmosphere

Excess release during the night



Large heat Storage In buildings

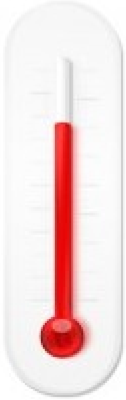
UF

Hot Surface is cooling

2. Human activity

Human activity

HE



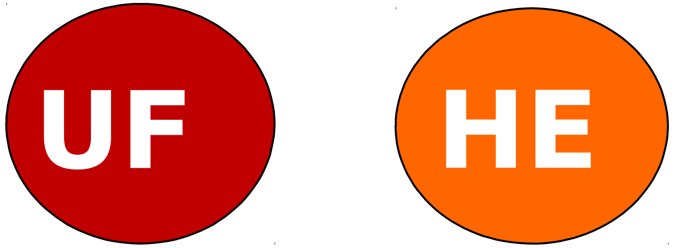
Energy usage gets converted to heat -> emitted to the atmosphere!

importance of urban parametrization

- When increasing resolution, both NWP as RCM applications need to account for urban climate features!
- NWP: better forecasts for temperature and precipitation in urban environments where many people live
- RCM: urban heat-stress and precipitation assessment for present-day climate and future scenarios

What about COSMO(CLM)?

- A demand for a **standard** urban parametrization
- It should be:
  - Reliable
    - The physical processes need to be resolved

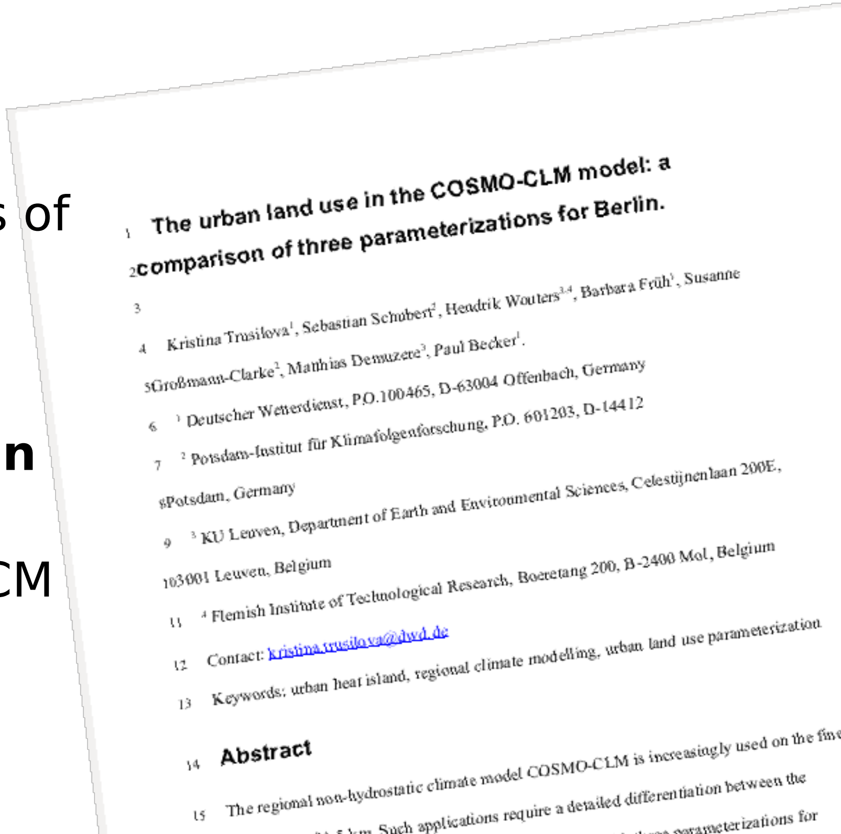


  - Efficient:
    - Both in terms of input parameters and computational cost

→ Three urban parametrizations

(DCEP+BEP vs. TEB vs. TERRA-URB) *coupled to COSMO-CLM* are compared

- results for Berlin (Trusilova et al., accepted for SI MetZeit): In terms of urban/rural contrast in T_2M, performance of **TERRA-URB is comparable** to TEB and BEP/DCEP, despite the **reduced computational cost** and **number of input parameters**
- The approach in **TERRA-URB** has been chosen for **standard urban parametrization** in COSMO(-CLM)
- TEB and BEP/DCEP are provided as extensions for more detailed RCM applications (eg., street canyon temperatures)


The urban land use in the COSMO-CLM model: a comparison of three parameterizations for Berlin.

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[2] Potsdam-Institut für Klimafolgenforschung, P.O. 601203, D-14412 Potsdam, Germany

[3] KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium

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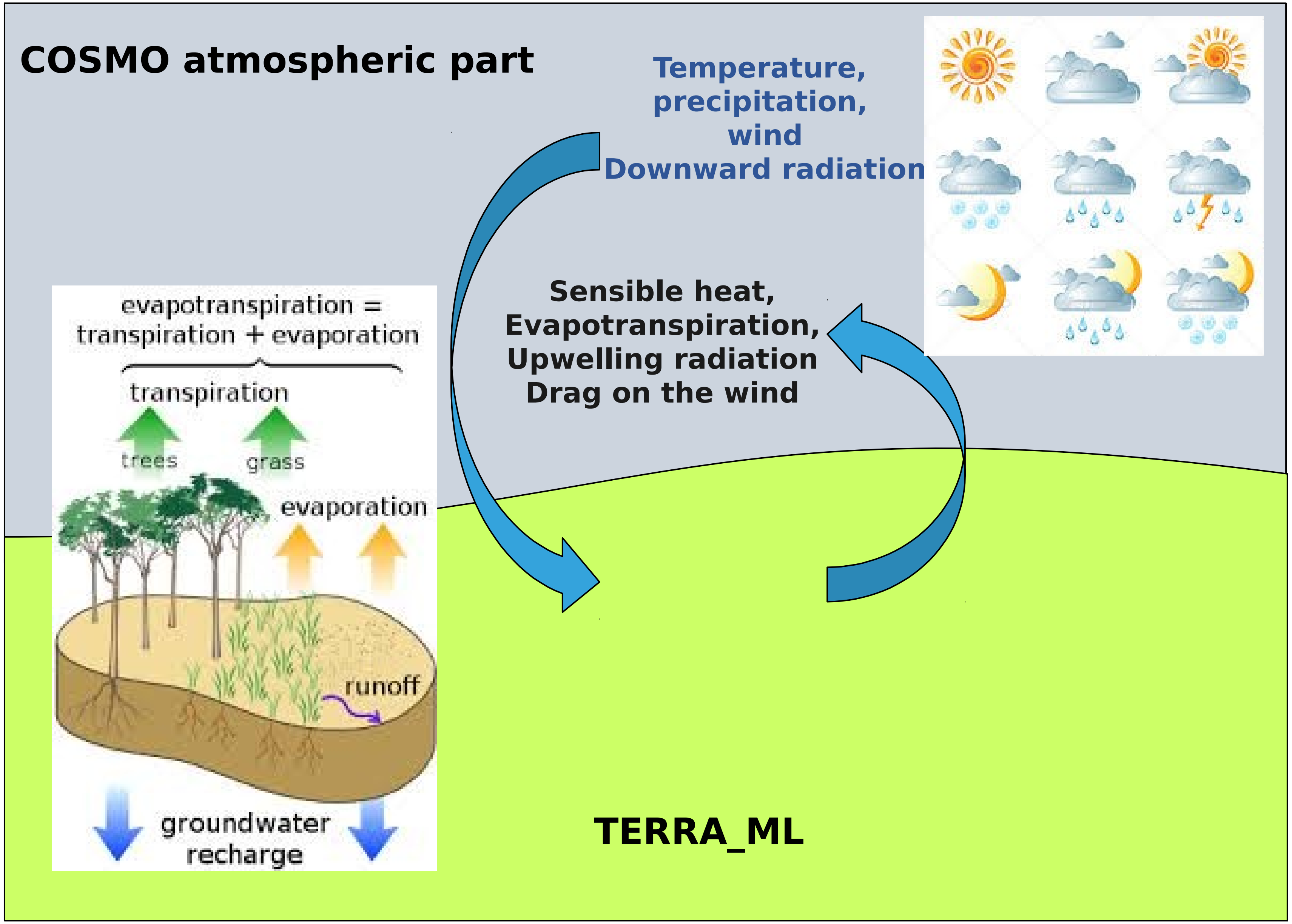
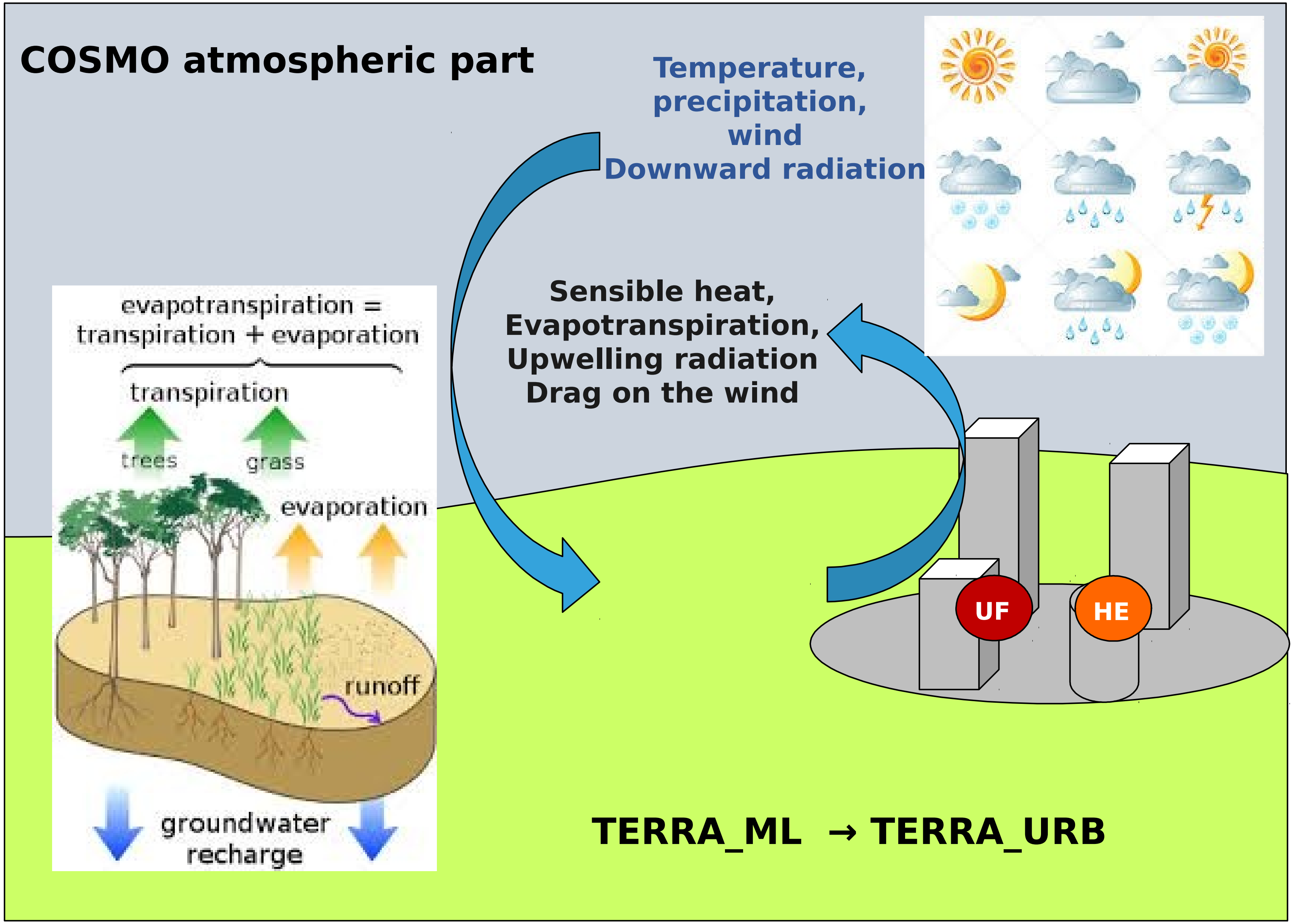
Keywords: urban heat island, regional climate modelling, urban land use parameterization

Abstract

The regional non-hydrostatic climate model COSMO-CLM is increasingly used on the fine ... Such applications require a detailed differentiation between the ... parameterizations for

TERRA_URB coupled to COSMO-CLM4.8_clm19 (development version)


COSMO atmospheric part
Temperature,
precipitation,
wind
Downward radiation
Sensible heat,
Evapotranspiration,
Upwelling radiation
Drag on the wind
evapotranspiration =
transpiration + evaporation
transpiration
trees
grass
evaporation
runoff
groundwater
recharge
TERRA_ML


COSMO atmospheric part
Temperature,
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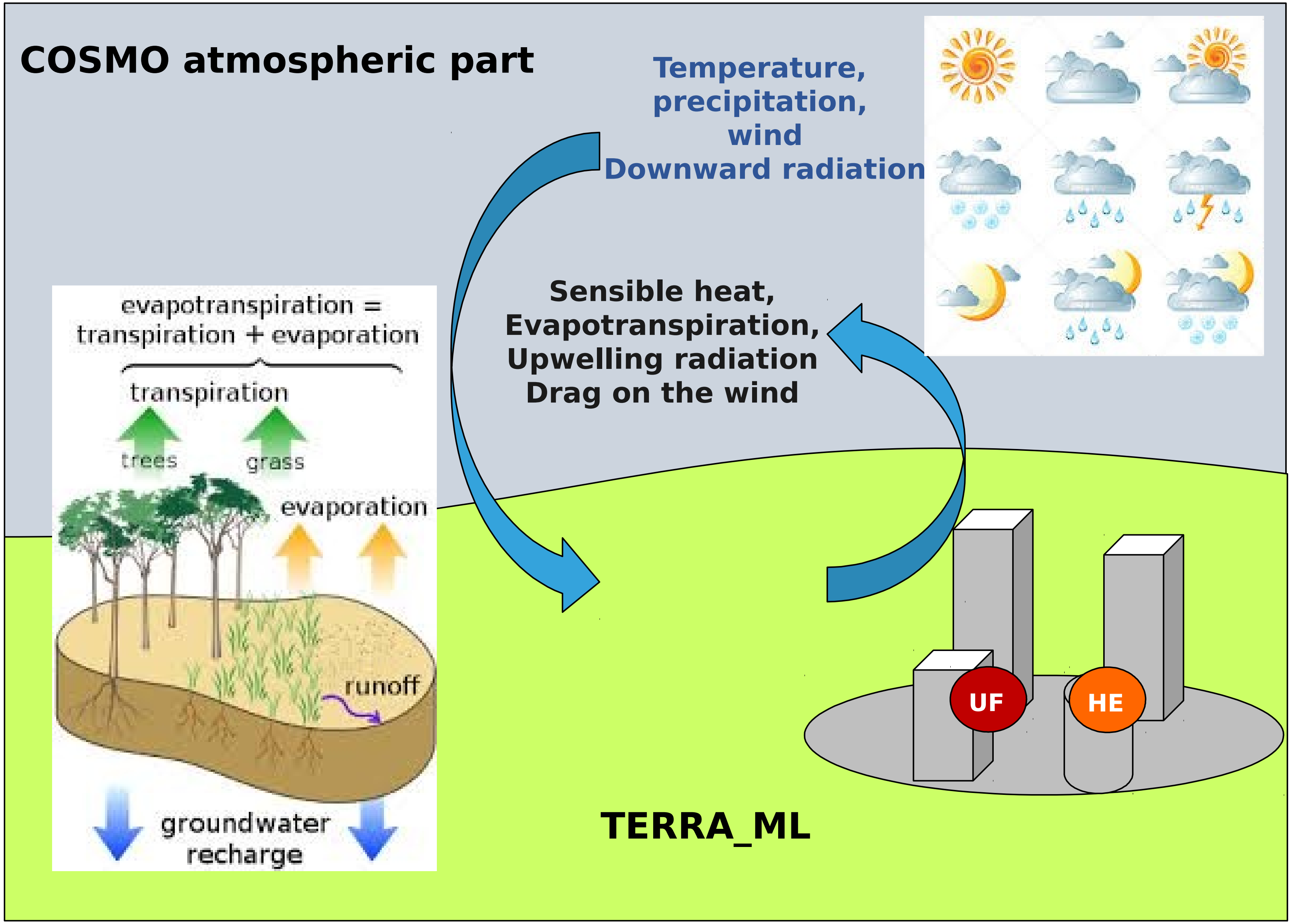
UF
HE
TERRA_ML → TERRA_URB


COSMO atmospheric part
Temperature,
precipitation,
wind
Downward radiation
Sensible heat,
Evapotranspiration,
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Drag on the wind
evapotranspiration =
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groundwater
recharge
UF
HE
TERRA_ML

The urban fabric...

UF

- ***A simple bulk approach: buildings and streets*** *are represented* ***as a rough water-impermeable slab*** *with distinct surface(-layer) characteristics compared to the natural surface*
- *by means of* ***a new impervious surface type in TERRA-ML****:*

  - **High surface roughness** depending on averaged building height Sarkar and De Ridder, 2010) → drag on wind, enhanced turbulent transport
  - **low albedo** (Sarkar and De Ridder, 2010) → Solar radiation trapping
  - **high value for thermal inertia** (De Ridder et al., 2013; Demuzere et al. 2008) → Infra-red radiation trapping + enhanced surface heat transfer and storage in the surface
  - **thermal roughness length parametriation for 'bluff-bodies'** (De Ridder et al., 2013; Demuzere et al., 2008; Kanda et al., 2008) → decreased surface-layer turbulent heat exchange with the atmosphere, hence an additional increase in surface heat uptake
  - **PDF-based impervious water-storage parametrization** (Wouters et al., 2015), including reservoir parameter estimates → no evaporation during dry periods
  - ***No vegetation*** *→ no transpiration*
  - **New Surface-layer transfer coefficients** (Wouters et al., 2012) → consistent treatment of vertical turbulent transport in the urban environment

- **Tile approach**: Urban pixels are represented by 2 tiles: impervious surfaces, and natural surfaces (gardens, parks…)
- Combined effect leads **to Heat buffering**: excess daytime surface heat storage for clear calm days is released during the night

Anthropogenic heat emission

HE

- Additional surface sensible heat release to the atmosphere.
- This acts as a heat source to the first model layer above the ground
- Global distribution of annual mean (Flanner, 2009)
- latitudinally-dependent annual and diurnal cycles

TERRA_URB coupled to COSMO-CLM4.8_clm18 (development version)

Low level of complexity, yet the main features of urban heat islands are captured

TERRA_URB coupled to COSMO-CLM4.8_clm18 (development version)

Applications....

Urban climatic drivers of heat islands in Belgium

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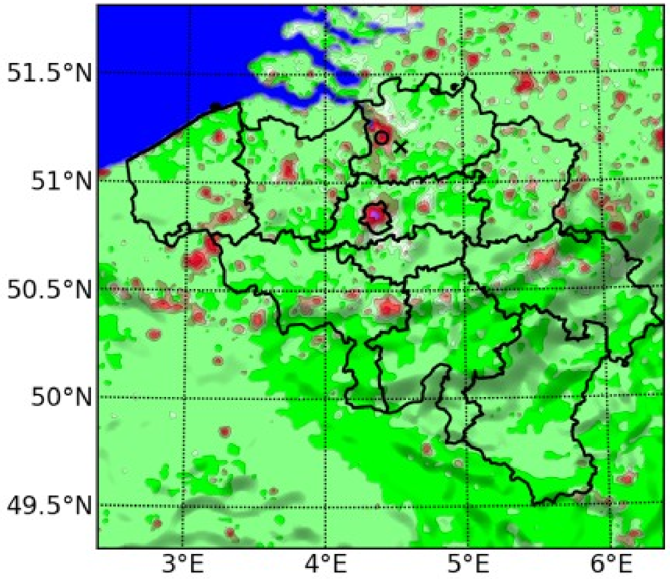
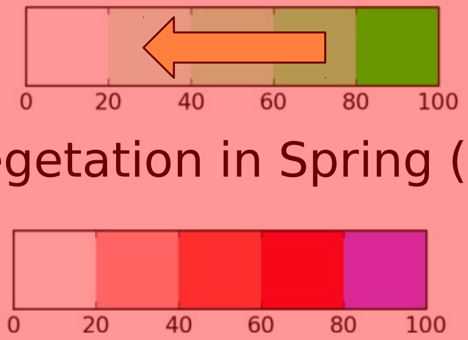
ECMWF forecast fields for summer 2012 and winter 2013

COSMO-CLM4.8 + TERRA-URB (DV)





Vegetation in Spring (%)

Impervious surface Area (%)

UF

+

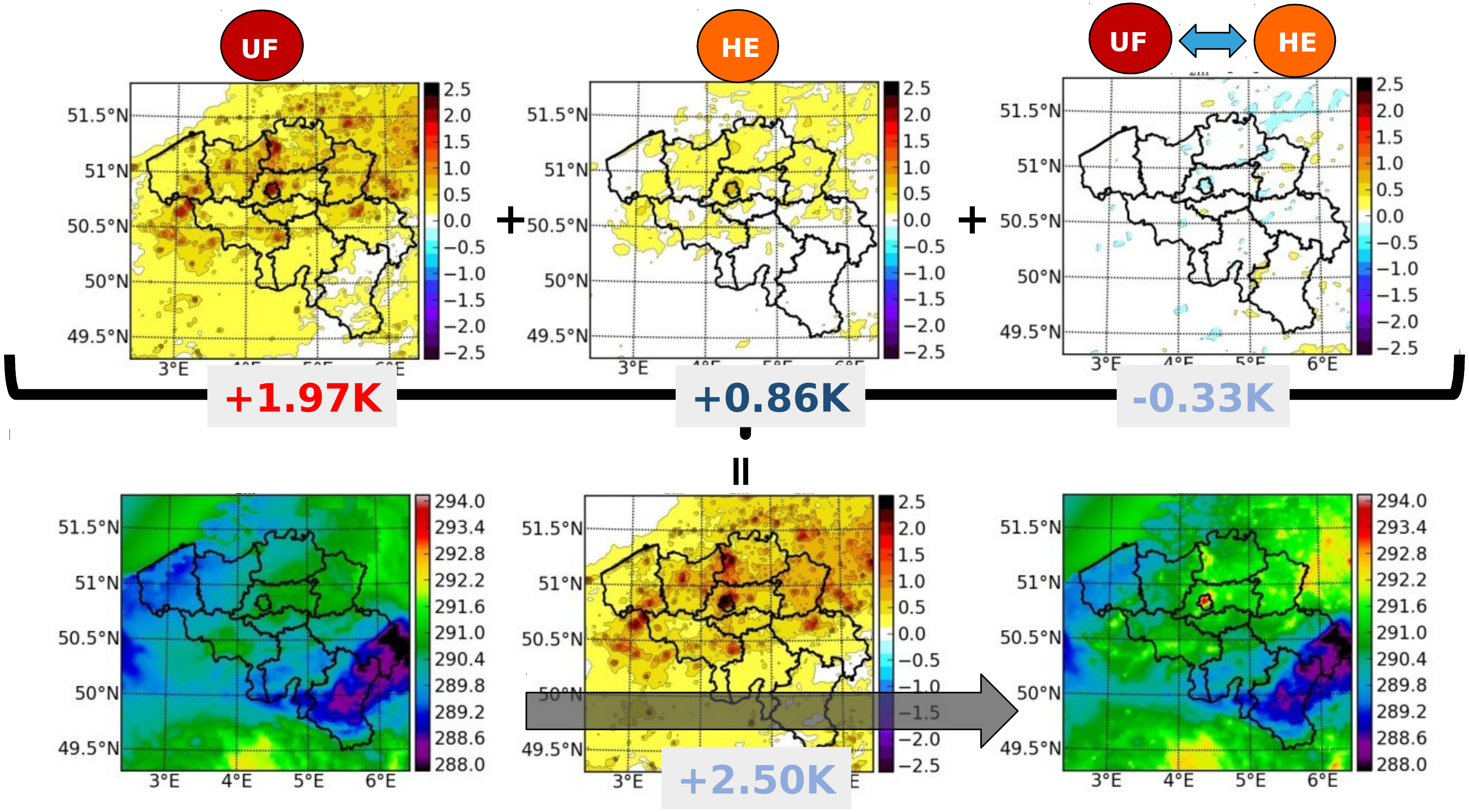
HE

Wouters, H., Demuzere, M., Blahak., U., De Ridder, K., van Lipzig N. 20XX,
The seasonal dependency of urban heat islands and their climatic drivers at the mid-latitudes:
A model-based case study for Belgium (submission pending)

Climatic drivers

Midnight
Average mid-summer

Brussels



Wouters, H., Demuzere, M., Blahak., U., De Ridder, K., van Lipzig N. 20XX,
The seasonal dependency of urban heat islands and their climatic drivers at the mid-latitudes:
A model-based case study for Belgium (submission pending)

Seasonal dependency

Midnight

Average mid-winter

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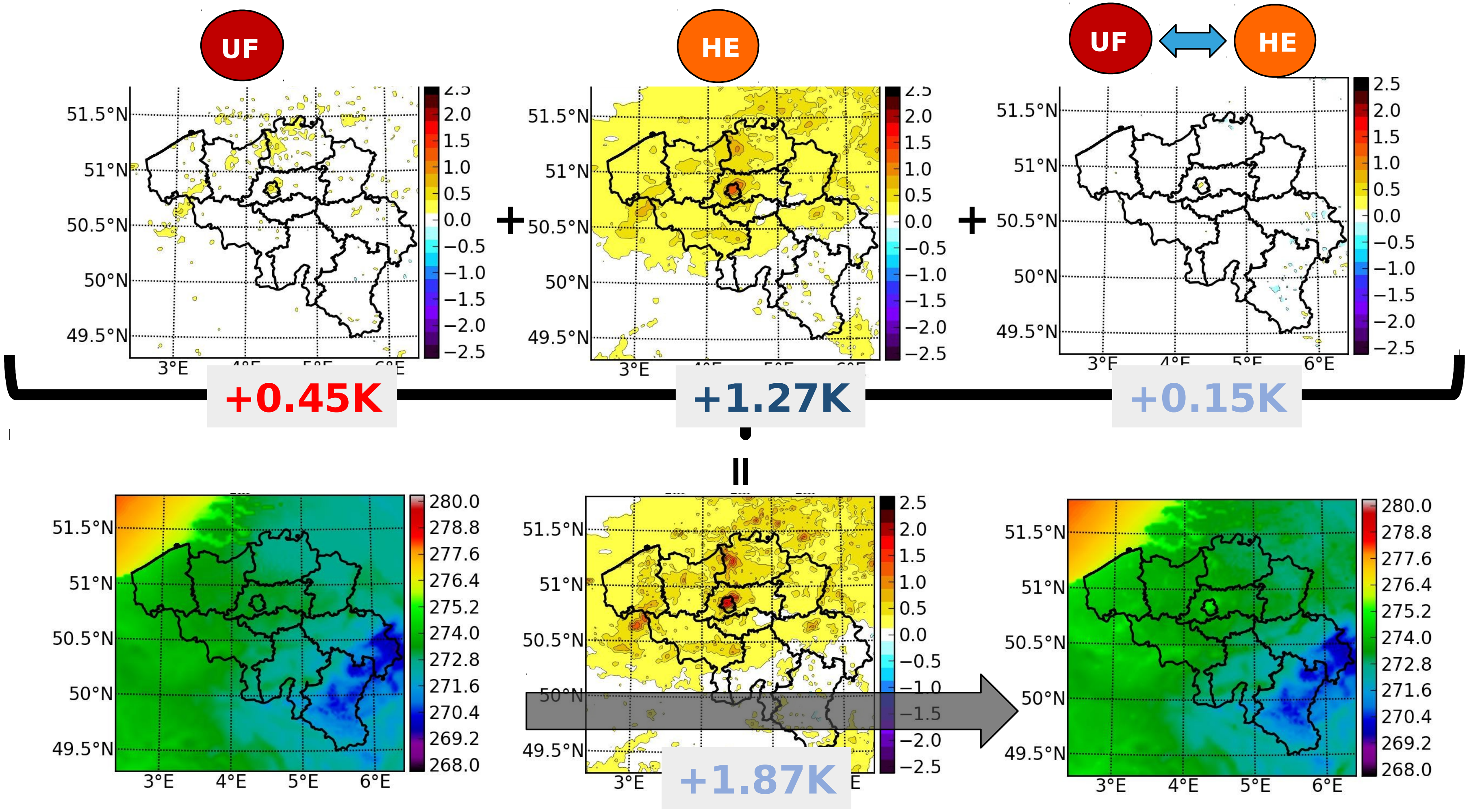
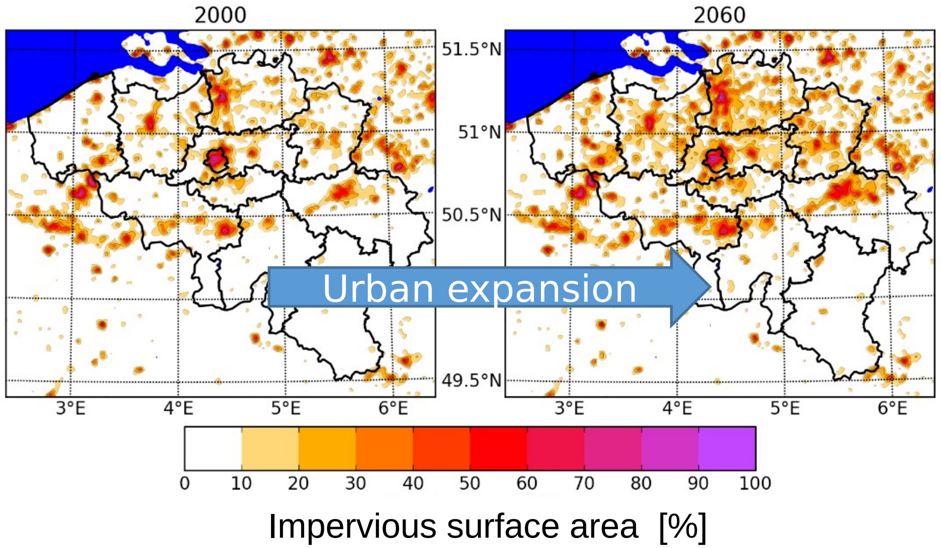
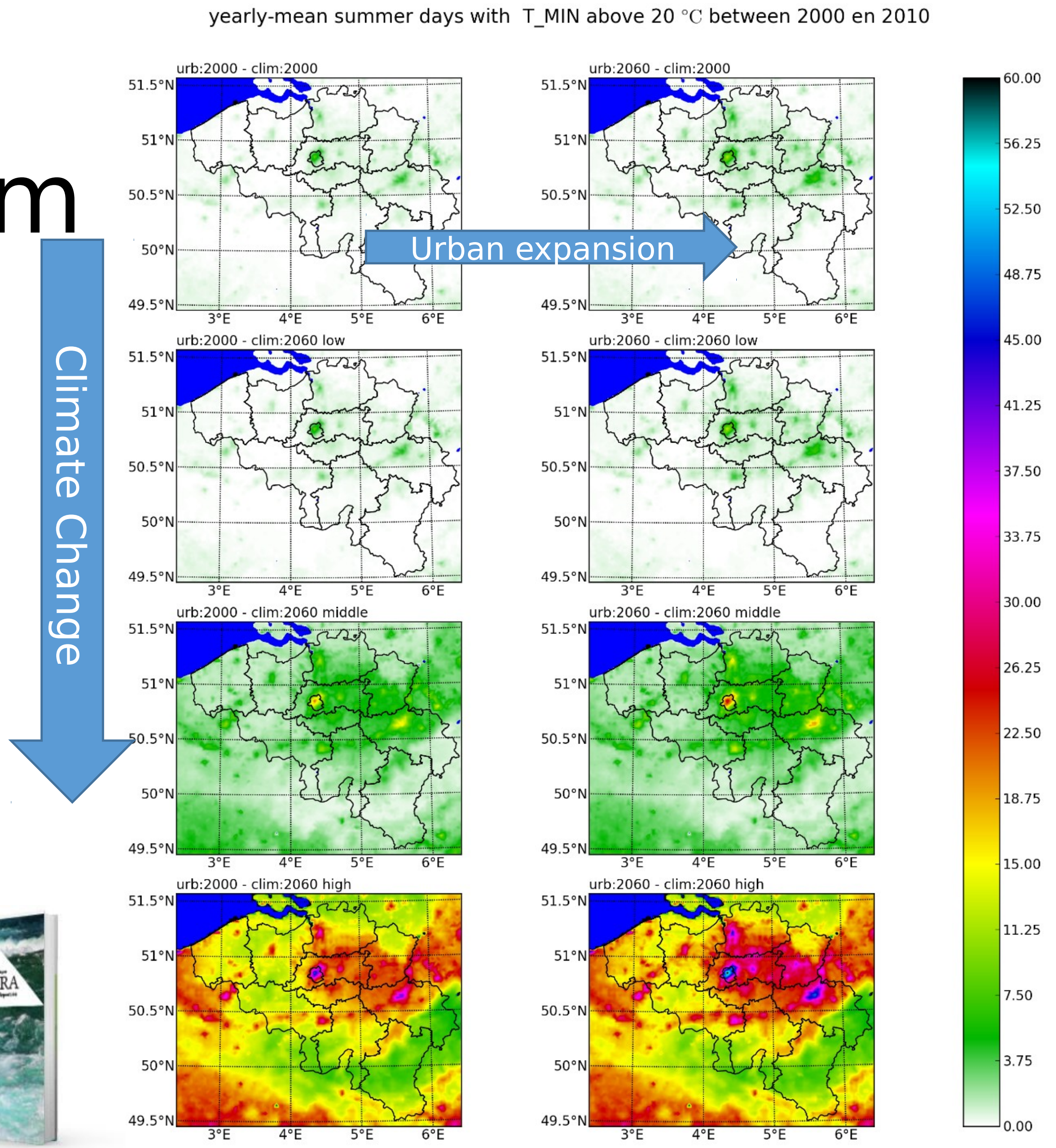
Brussel



Wouters, H., Demuzere, M., Blahak., U., De Ridder, K., van Lipzig N. 20XX,
The seasonal dependency of urban heat islands and their climatic drivers at the mid-latitudes:
A model-based case study for Belgium (submission pending)

Heat waves
for cities in Belgium





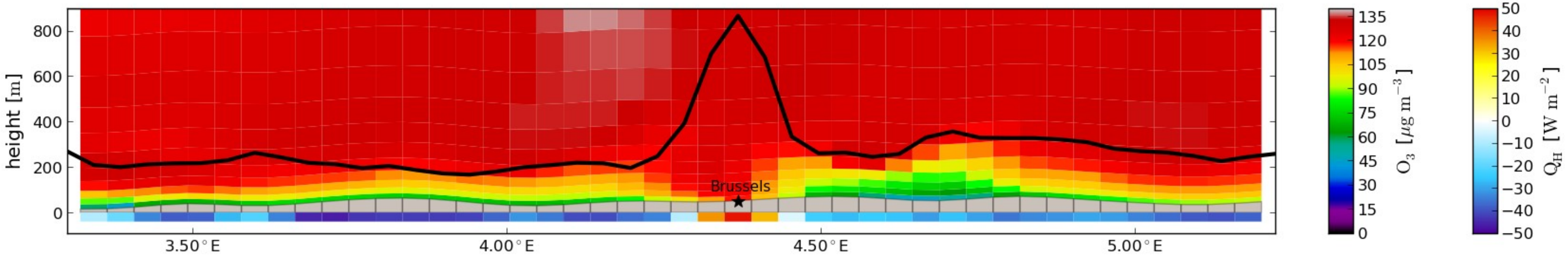
MACCBET
Modelling atmospheric composition and climate for the Belgian territory

Belgian Science Policy Office
belspo
.be

VLAAMSE
MILIEUMAATSCHAPPIJ

Vlaanderen
is milieu

COSMO-CLM + TERRA-URB coupled to an **air-quality model**



Test version COSMO 5.1 + TERRA_URB

- Based on current development version → Positive Vote from CSSM and CSMC for standard implementation in COSMO
- Workshop held on 3-5 November 2014
- Implementation Test Version (TV) is ongoing

Steps of Code Development for CLM Community model versions

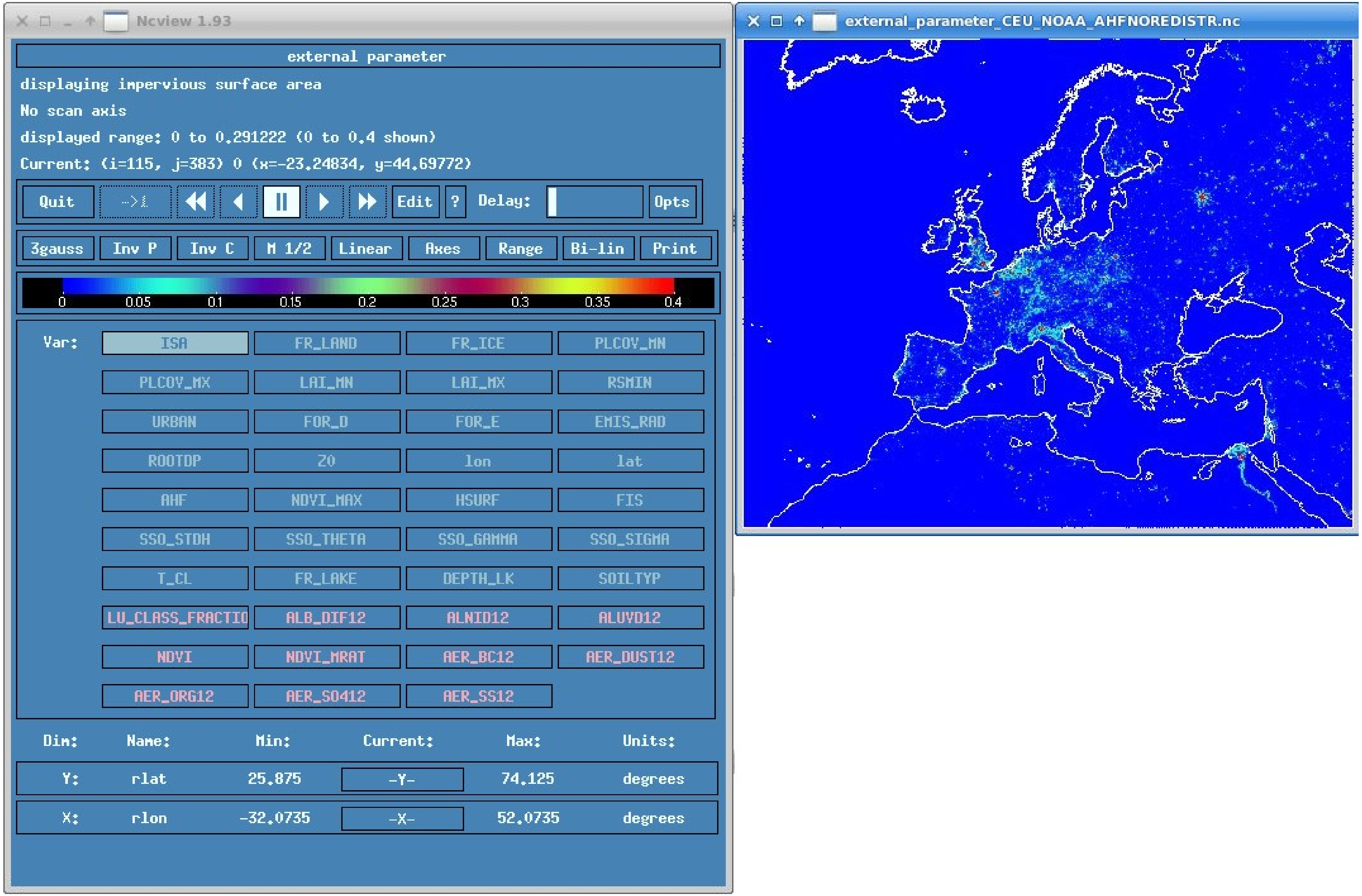
Date: 24.8.2012

Contact the Technical Advisory Group in the case of further questions.

	SCM statusss	Steps	What to do	CSSCD Chapters	Tab. 6.1
☐	Info1	**Inform the CLM-Community coordination group about your plans**	Contact a member of the CLM coordination group. Add information about the intended development to the CLM topic browser.	2.2 6.1	1
☐		**Get a released version**	Download a version available from the CLM-Community home page Model System Sources. Contact the CLM_TAG if you want to use another COSMO version.		
☐		**Implement your changes**	Right from the implementation of your first changes the "released version" becomes a "private version". Although a private version is not subject to the conditions of the *COSMO-Standards for Source Code Development (CSSCD)*, it is good practice to follow them right from the beginning. For new program units (FUNCTIONs , MODULEs, PROGRAMs, SUBROUTINEs,) use the available templates.	2.3, 4, 7, A	2.1
☐	d-test	**Pe[illegible]elopment specific tests [illegible]lations**	The developer should define and apply some development specific tests and simulations exhibiting the effect of the code development on his or her "private version". The tests and simulations should be applicable also to the community model version in which the final implementation of the development will be included.	2.3	(3.5)
☐	Report	**Write a short[illegible]**	The developer summarizes the development and the development specific tests in a short report and provides it to the coordination group. Use the development report template for your report.		2.1
	DV		**The coordination group discusses the report and recommends the implementation in a community model version (or not).**		
☐		**Port the development int[illegible] last released version**	If necessary, port the implemented and tested development in the last released version (2nd private version). The CSSCD are mandatory now.	4, 7, A	2.1 and 2.2
☐	t-test	**Technical test suite**	Apply the technical test suite on the 2nd private version. Contact the source code administrator in order to know how to do that.	4, 7, A	3.1
☐		**Repeat the development specific tests and simulations**	Discuss with the responsible member of the coordination group, which development specific simulations need to be repeated with the 2nd private version, conduct the simulations, compare the effect with that of the original implementation and update the short report.		3.5
	TV		**The coordination group discusses the updated report and recommends the implementation in a community model version (or not).**		
☐		**CSSCD check**	Provide the development to the source code administrator (SCA) together with the test results and the internal and process documentation. The SCA checks whether the coding rules of CSSCD are respected. In case the check is negative, the code has to be revised and the revised version has to be sent to the SCA again.	4, 5.3	3.2 and 8
☐	e-test	**Standard evaluation suite**	Contact the coordinator of the evaluation group. Discuss the evaluation procedure for the development. The evaluation group decides on and conducts the evaluation runs.		3.6
	RV		The evaluation group discusses the results and recommends the implementation in a released version (or not).		
☐	Pres	**Presentation of results**	The development should be presented to the corresponding CLM Working Group, if possible during the COSMO/CLM User Seminar or the CLM Community Assembly.	Tab 6.1, Nr.4	4

Test version COSMO 5.1 + TERRA_URB

- Upgrade EXTPAR (testing phase)
  - Implementation of needed additional fields in EXTPAR 1.13:
    - ISA: Impervious Surface Area
      - *roads, parking lots, buildings, driveways, sidewalks and other manmade surfaces…*
      - **Default source** (Global): NOAA, reference year 2010, 1km resolution
      - **Alternative source** (Europe): EEA, reference year 2006, 100m resolution
    - AHF: Anthropogenic Heat Flux
      - *Annual-mean heat emission to the atmosphere*
      - **Default source**: from Flanner, 2009
      - **Alternative source**: Redistribution of default source at the scale of 25km according to NOAA ISA
  - code is being cross-checked
  - and being tested for COSMO and ICON grids


Ncview 1.93
external parameter
displaying impervious surface area
No scan axis
displayed range: 0 to 0.291222 (0 to 0.4 shown)
Current: (i=115, j=383) 0 (x=-23.24834, y=44.69772)
Quit
Edit
?
Delay:
Opts
3gauss
Inv P
Inv C
M 1/2
Linear
Axes
Range
Bi-lin
Print
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Var:
ISA
FR_LAND
FR_ICE
PLCOV_MN
PLCOV_MX
LAI_MN
LAI_MX
RSMIN
URBAN
FOR_D
FOR_E
EMIS_RAD
ROOTDP
Z0
lon
lat
AHF
NDVI_MAX
HSURF
FIS
SSO_STDH
SSO_THETA
SSO_GAMMA
SSO_SIGMA
T_CL
FR_LAKE
DEPTH_LK
SOILTYP
LU_CLASS_FRACTIO
ALB_DIF12
ALNID12
ALUVD12
NDVI
NDVI_MRAT
AER_BC12
AER_DUST12
AER_ORG12
AER_SO412
AER_SS12
Dim:
Name:
Min:
Current:
Max:
Units:
Y:
rlat
25.875
-Y-
74.125
degrees
X:
rlon
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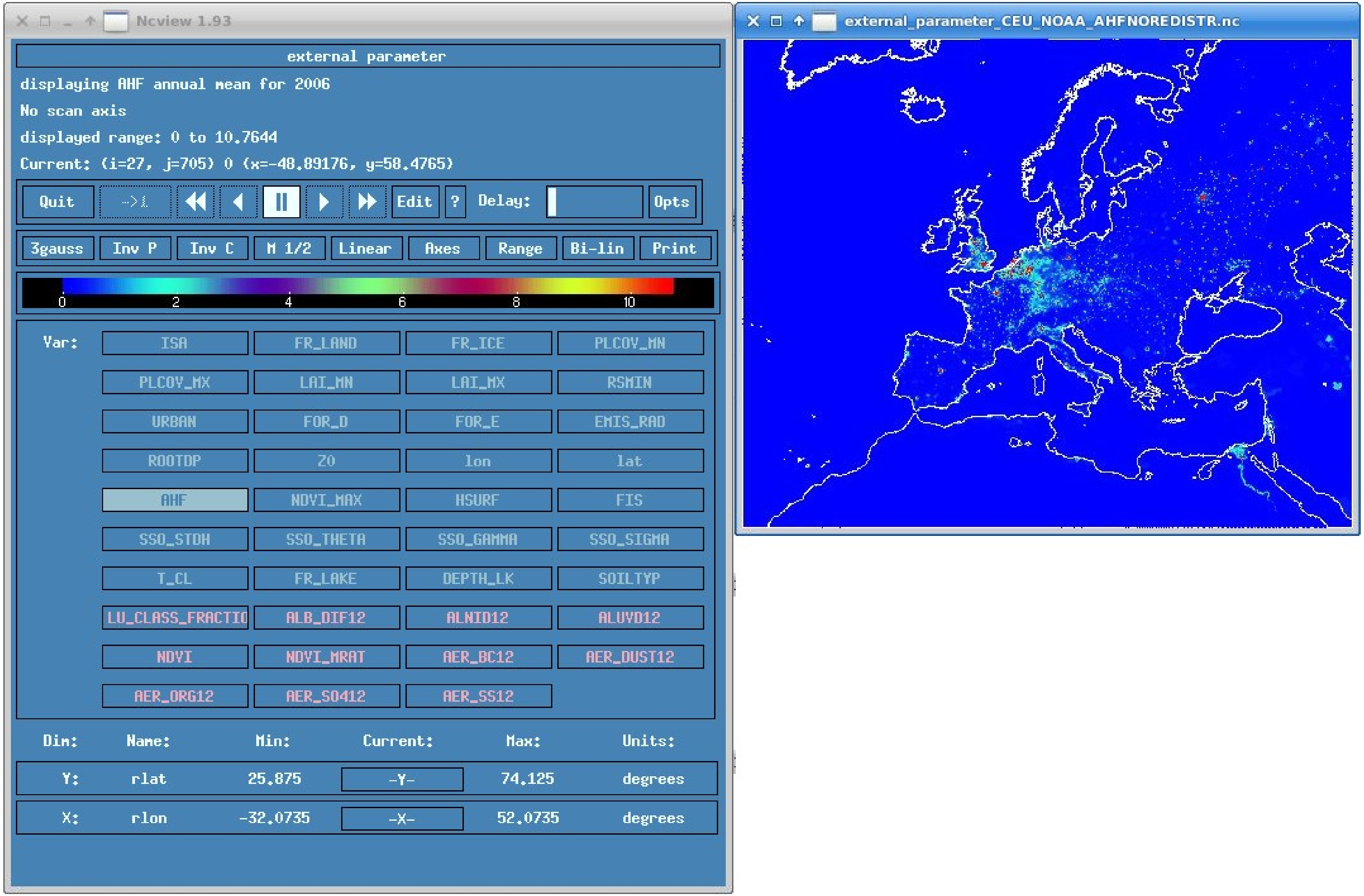
-X-
52.0735
degrees
external_parameter_CEU_NOAA_AHFNOREDISTR.nc


Ncview 1.93
external parameter
displaying AHF annual mean for 2006
No scan axis
displayed range: 0 to 10.7644
Current: (i=27, j=705) 0 (x=-48.89176, y=58.4765)
Quit
Edit
?
Delay:
Opts
3gauss
Inv P
Inv C
M 1/2
Linear
Axes
Range
Bi-lin
Print
0
2
4
6
8
10
Var:
ISA
FR_LAND
FR_ICE
PLCOV_MN
PLCOV_MX
LAI_MN
LAI_MX
RSMIN
URBAN
FOR_D
FOR_E
EMIS_RAD
ROOTDP
Z0
lon
lat
AHF
NDVI_MAX
HSURF
FIS
SSO_STDH
SSO_THETA
SSO_GAMMA
SSO_SIGMA
T_CL
FR_LAKE
DEPTH_LK
SOILTYP
LU_CLASS_FRACTIO
ALB_DIF12
ALNID12
ALUVD12
NDVI
NDVI_MRAT
AER_BC12
AER_DUST12
AER_ORG12
AER_SO412
AER_SS12
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Current:
Max:
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-Y-
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degrees
X:
rlon
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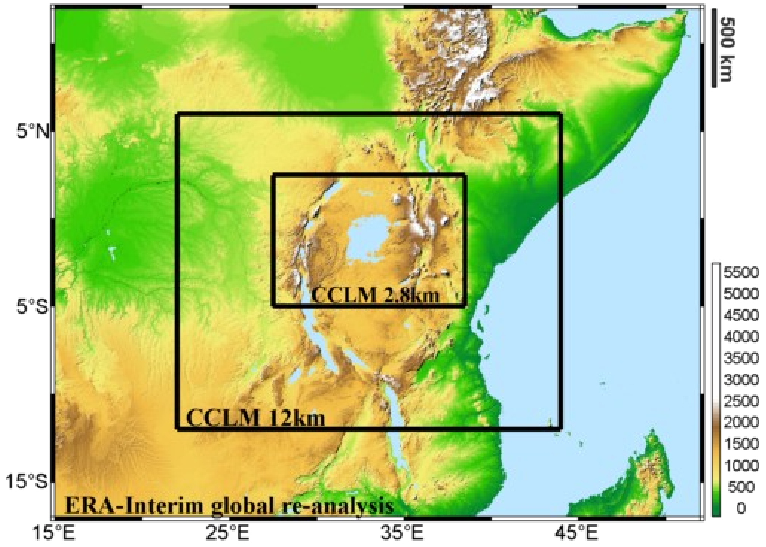
-X-
52.0735
degrees
external_parameter_CEU_NOAA_AHFNOREDISTR.nc

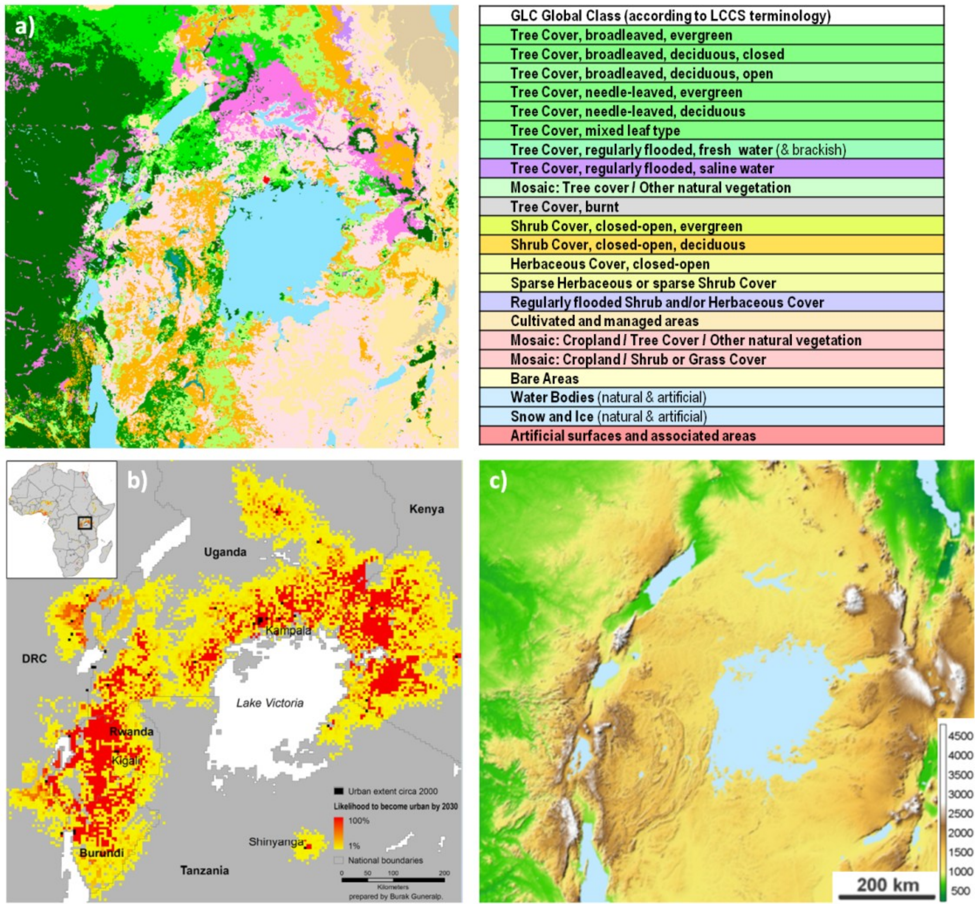
Test version COSMO 5.1 + TERRA_URB

- Urban Upgrade INT2LM (implementation phase)
- Urban upgrade COSMO 5.1 (implementation phase)
  - Update TERRA-URB to the default prognostic TKE-Based surface-layer scheme
- Full Test Version is expected in autumn (September) this year.

Application planned with test version

- Urbanization climate scenarios for Kampala (Africa) at Lake Vicoria





Thank you for your attention!