State of regional climate modelling in Belgium with the ALARO model

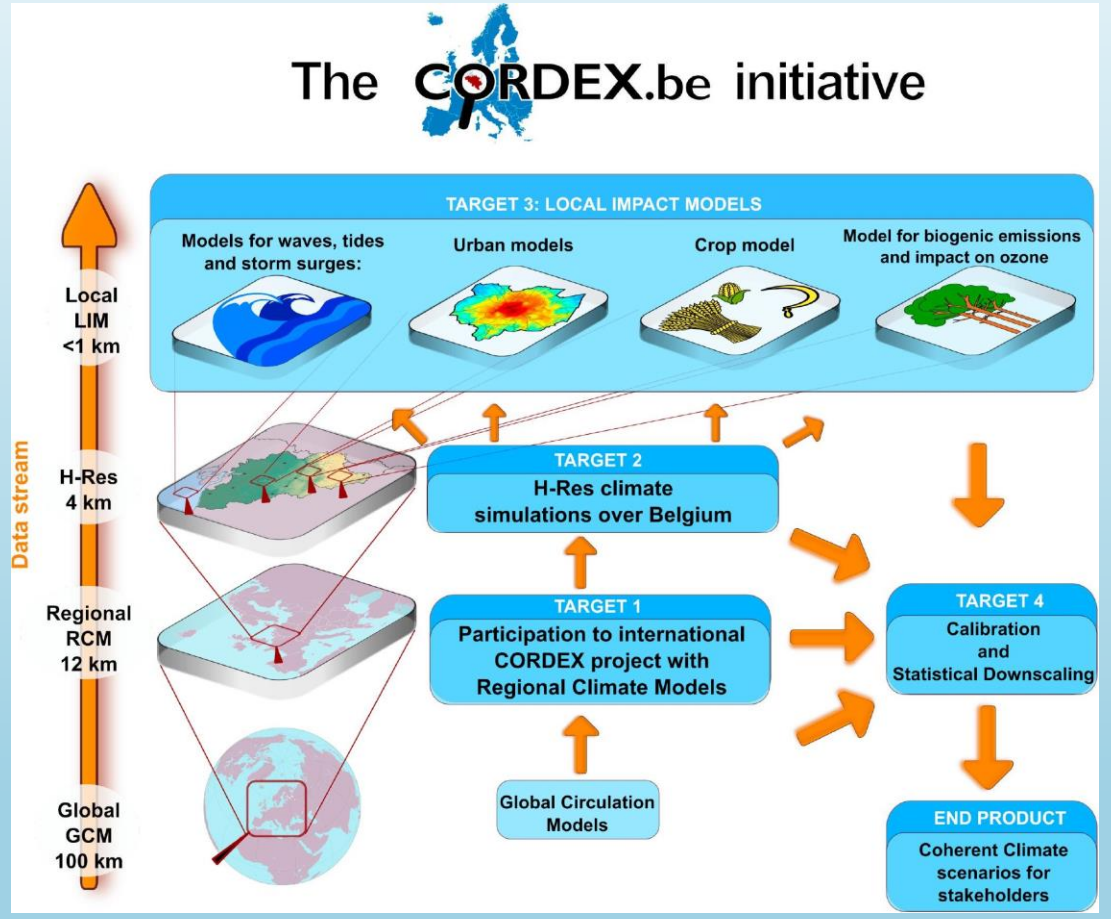
Wout Dewettinck, Kobe Vandelanotte, Nicolas Ghilain, Daan Degrauwe, Rafiq Hamdi, Hans Van De Vyver, Michiel Van Ginderachter, Bert Van Schaeybroeck, Steven Caluwaerts and Piet Termonia

Why use the ALARO NWP model for regional climate modelling?

- To study impact of climate change on **precipitation extremes** (flooding) we need convection-permitting models
- Higher resolution is needed to compute **very local features**, e.g., in the case of urban effects.
- Coordinated regional climate model ensembles (**CORDEX**) can only run at mesoscale resolutions
- **NWP models** are pioneering in the convection-permitting scales
- ALARO has a **grey-zone convection scheme,** so has resolution-adaptive deep convection parametrization
- **Climate validation** is an alternative validation of the model:
  - Identify model biases
  - Does the model correctly construct the climatology?
  - Does the resolution add value?

Previous works

- Validation of ALARO-0 in **EURO-CORDEX** (*Giot et al. 2016*)
- Evaluation of ALARO-0 over **CAS-CORDEX** domain (*Top et al. 2021*)
- **CORDEX.be I** project (*Termonia et al. 2018*)



Current projects

1. Convection-permitting model downscaling to study extreme precipitation over Belgium
2. CORDEX.be II
3. Contributions to EURO-CORDEX
   - Aerosols in ALARO-1
   - Land cover adaptation tools

Convection-permitting model downscaling to study extreme precipitation over Belgium

ERA-5 global reanalysis

↓

25 km Europe

↓

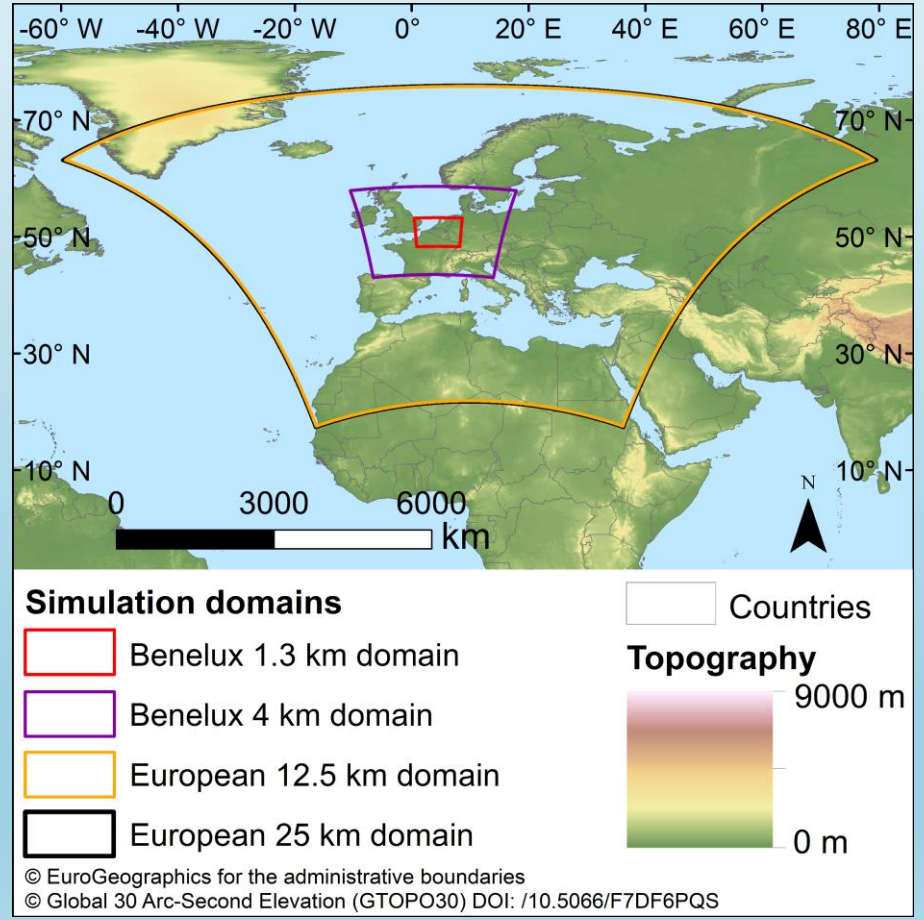
12.5 km Europe

↓

4 km W-Europe

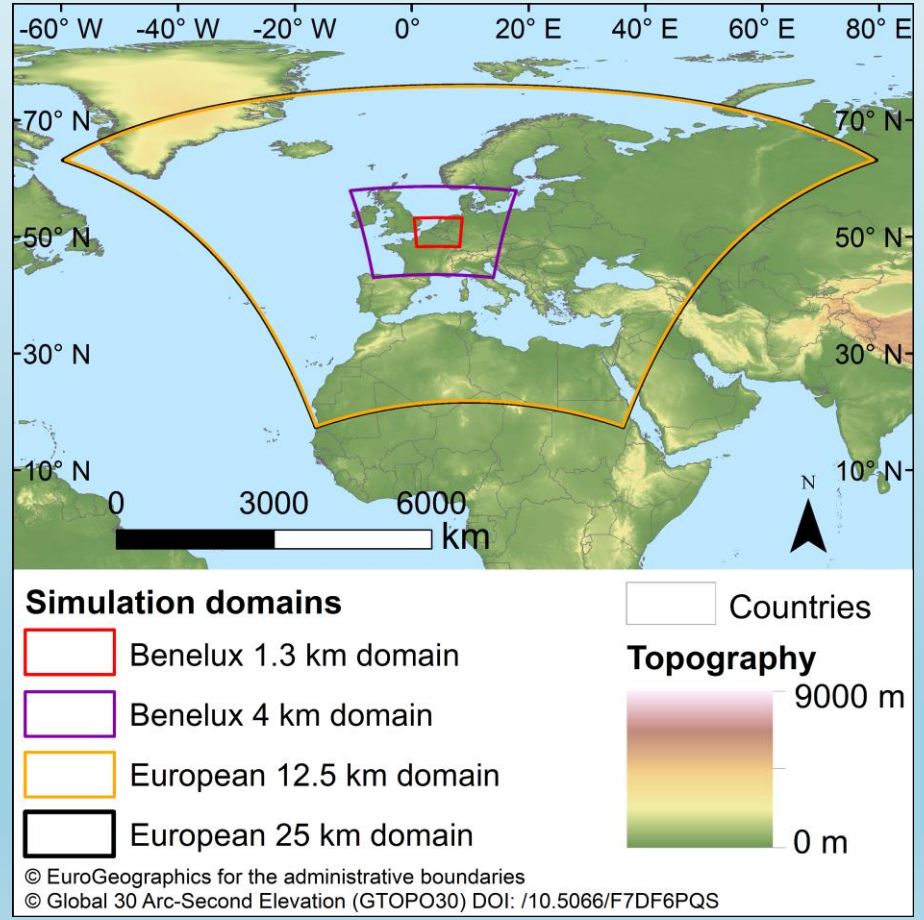
↓

1.3 km Benelux



Convection-permitting model downscaling to study extreme precipitation over Belgium

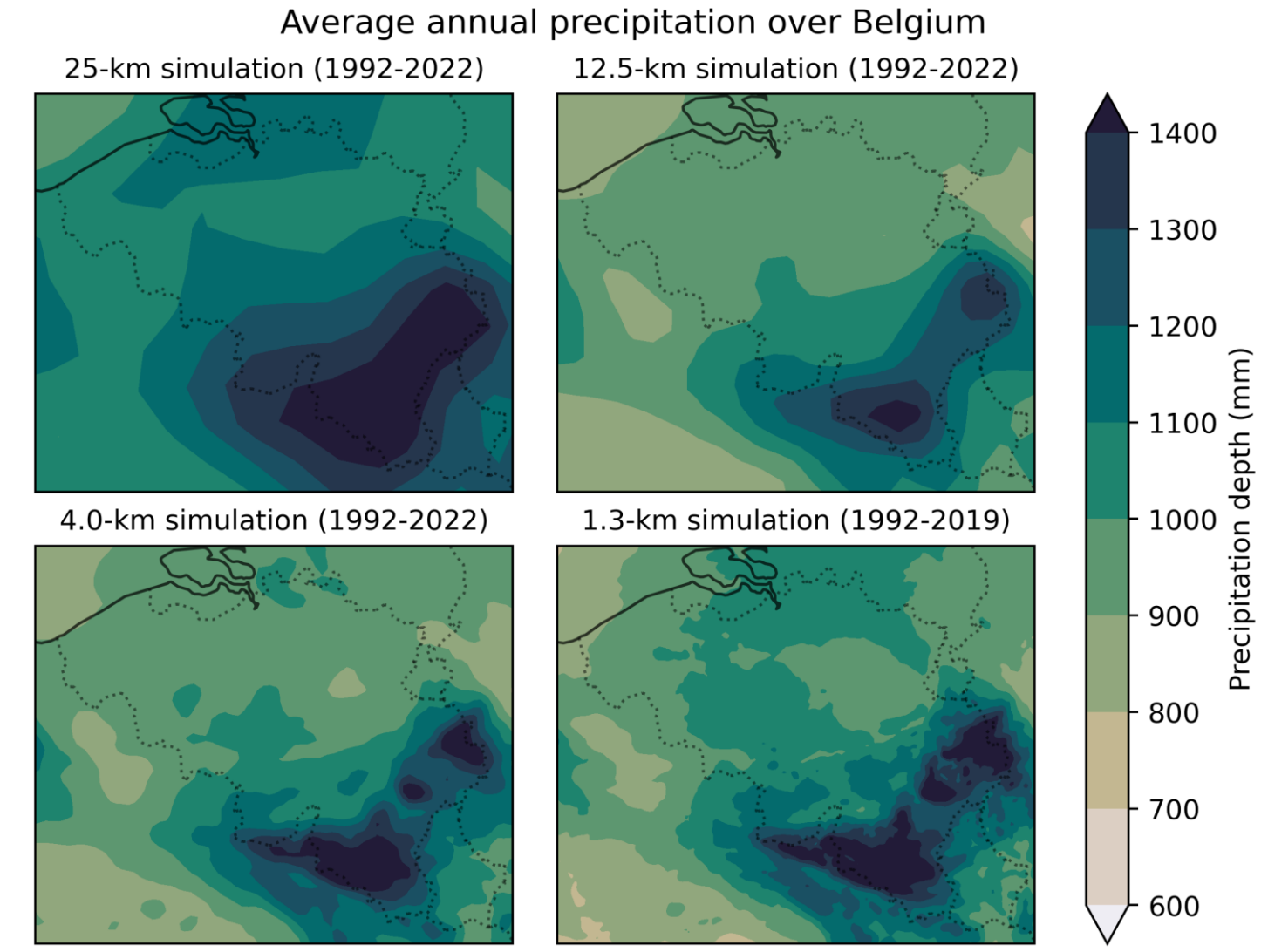
- Long, continuous simulations
- 1992 – 2022 (31 years)
- Coupled to ERA-5 reanalysis
- ALARO-1 (CY43T2)
- SURFEX v8.0 coupled in-line (for some resolutions)
- 4 different resolutions



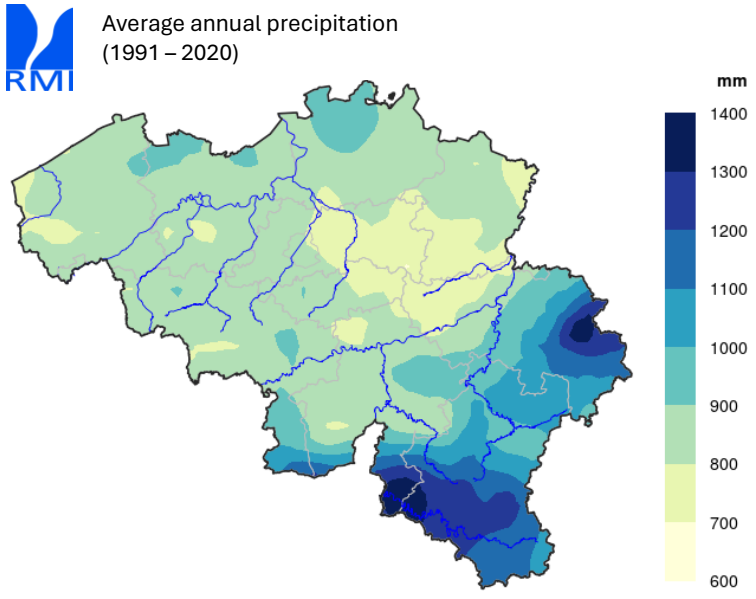
Details of simulations

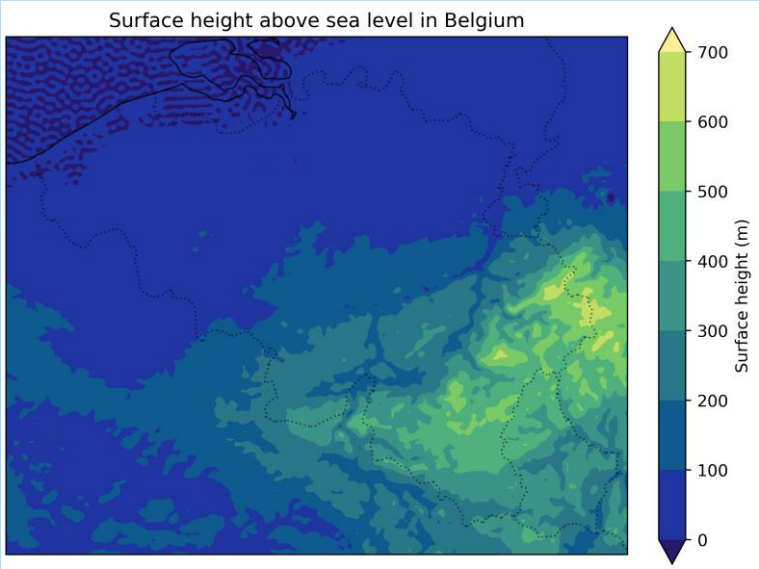
Resolution	Domain	Period	SURFEX	Coupling	Time-step	Number of vertical levels	Hydro-static
25 km	251 x 251 points (EURO-CORDEX)	1992 – 2022	No	ERA-5 reanalysis data	450 s	46	Yes
12.5 km	499 x 499 points (EURO-CORDEX)	1992 – 2022	Yes, v8.0 (TEB, ISBA, SEAFLX, WATFLX)	25-km simulation	300 s	46	Yes
4 km	421 x 421 points (Belgian operational NWP domain)	1992 – 2022	Yes, v8.0 (TEB, ISBA, SEAFLX, WATFLX)	12.5-km simulation	180 s	46	Yes
1.3 km	421 x 421 points	1992 – 2022 (ongoing)	Yes, v8.0 (TEB, ISBA, SEAFLX, WATFLX)	4-km simulation	45 s	87	No

Average annual precipitation

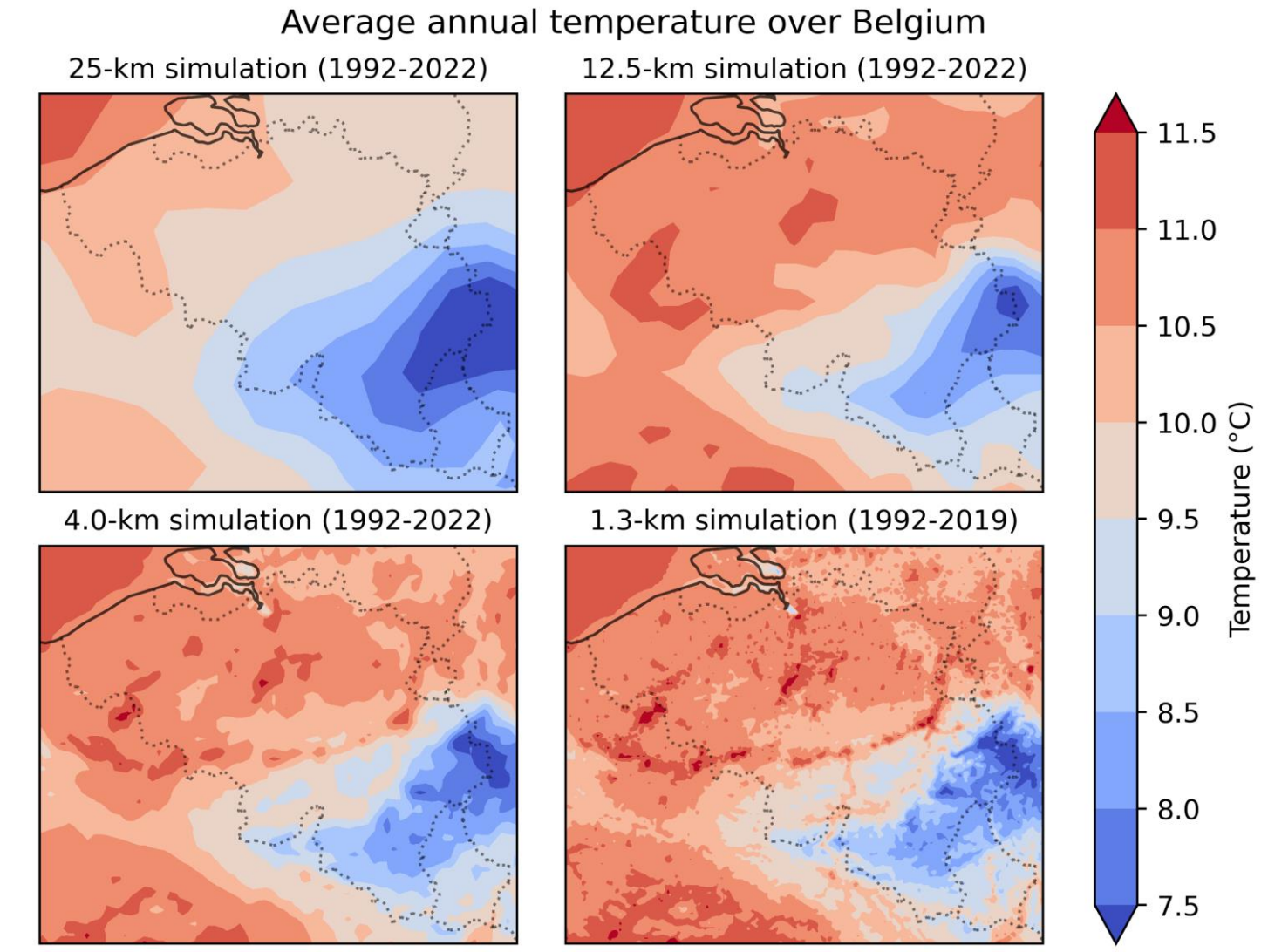


Observations

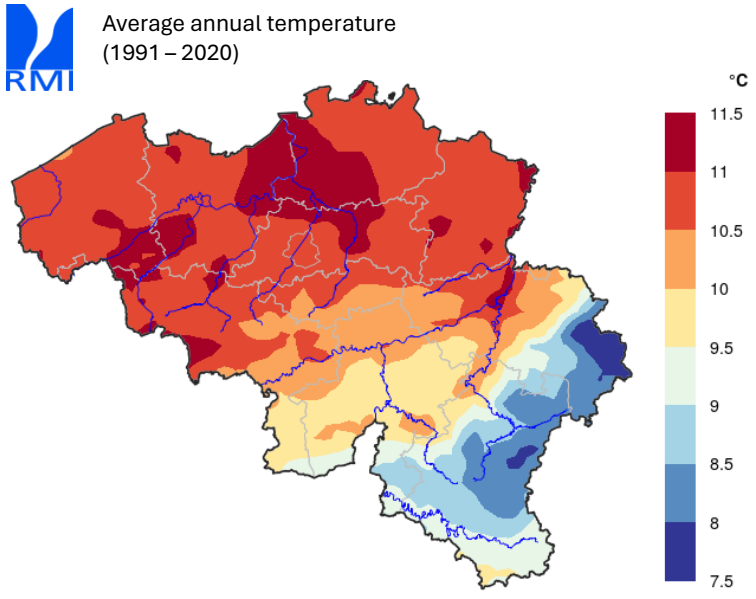


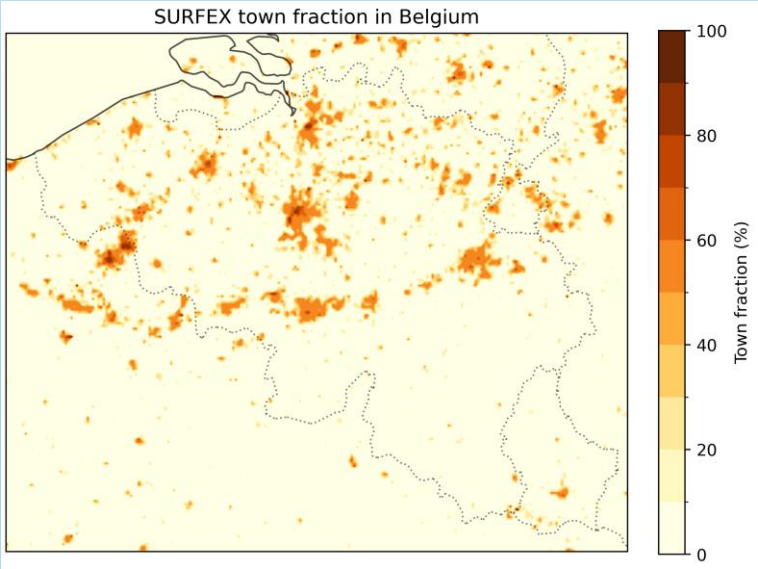


Average annual temperature

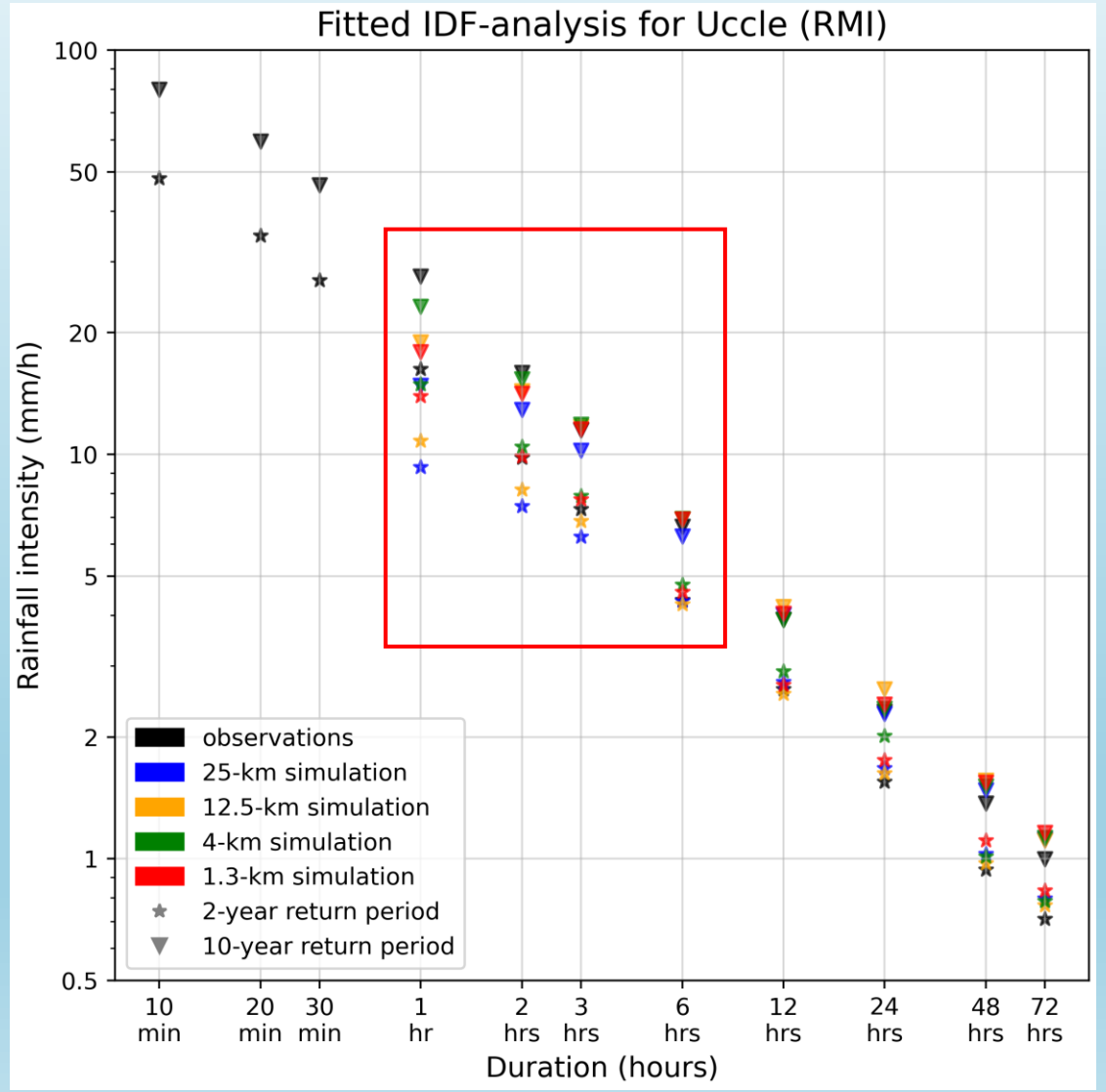


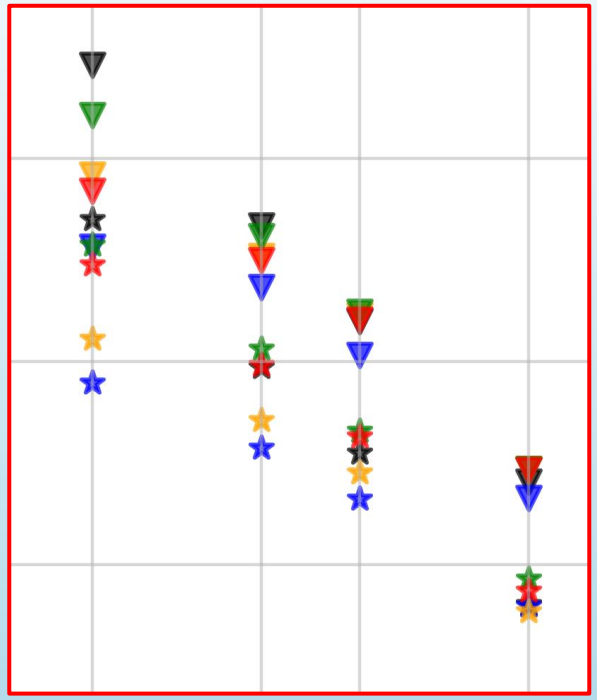
Observations





IDF curves from simulations





Downscaling CMIP6 GCMs with ALARO

ALARO will downscale 3 CMIP6 GCMs at 4km resolution over Belgium.

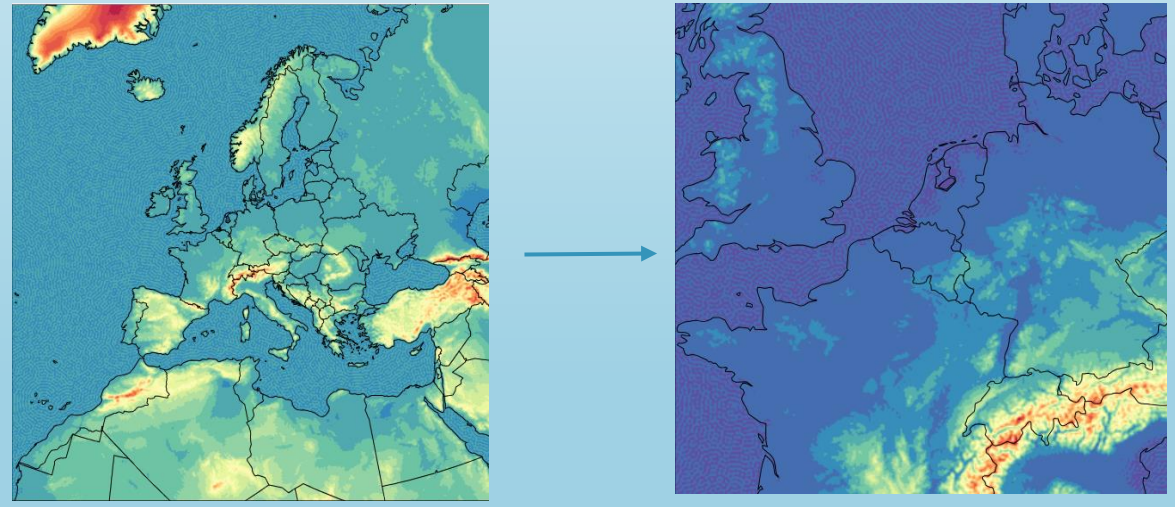
3 GCMs
- CNRM-ESM2-1
- EC-Earth3-Veg
- TBD

GCM Coupler* used to couple to EC-Earth3-Veg
GCM selection procedure see website.

Future Periods
two 20-year periods:
- +2°C GWL
- +3°C GWL

Double Nesting approach

GCM (SSP) → 12km EURO-CORDEX Domain → 4km (Large) Belgian Domain



*Developed by Meteo France.

CORDEX.be II

GHENT UNIVERSITY vito KU LEUVEN LIÈGE université RMI

COmbining Regional Downscaling EXpertise in Belgium

Goal
Update Belgian climate scenarios

How
Develop a convection permitting ensemble for Belgium.

ALARO will downscale 3 CMIP6 GCMs at 4km resolution over Belgium as part of this project.

Belgium CPM ensemble:
3 RCMs, 8 GCMs, 4 SSPs and
Two 20year Future periods (+2°C GWL & +3°C GWL)

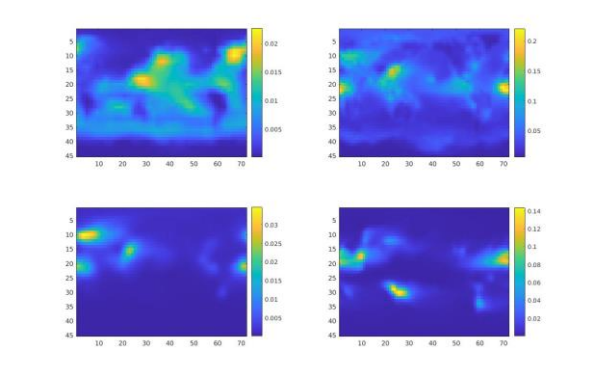
RCM	ALARO1-SFX	COSMO-CLMv6	MARv3.14
driving_GCM			
CMCC-CM2-SR5			SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5, hist
CNRM-ESM2-1	SSP2-4.5, SSP5-8.5, hist		
EC-Earth3-Veg	SSP2-4.5, SSP5-8.5, hist	SSP2-4.5, SSP5-8.5, hist	SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5, hist
ERA-5	evaluation	evaluation	evaluation
IPSL-CM6A-LR			SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5, hist
MIROC6		SSP2-4.5, SSP5-8.5, hist	SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5, hist
MPI-ESM1-2-HR			SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5, hist
NorESM2-MM			SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5, hist
TBD	SSP2-4.5, SSP5-8.5, hist		

Illustration of the periods downscaled by the respective RCMs for each included GCMs SSP pair.

EURO-CORDEX CMIP6: Aerosols in ALARO-1 (climate)

ACRANEB1 (Masek et al (2016): https://doi.org/10.1002/qj.2653)

- Broadband radiation scheme
- Accepts 6 classes of Aerosols (Maritime, Continental, Desert, Urban, Volcanic, Sulphate)
- Inherent Optical Properties (IOP): AOD (Aerosol Optical Depth), SSA (single scattering albedo), ASY (asymmetry factor)



Current climatology

- (1) Maps (latlon 4X5deg) AOD@550nm, 4 species (Tegen1997) [Files: tegen_mxx step9 e923]
- (2) IOPs 61 SW bands Hess (1998) → Avg into 1 broadband [Hard Coded]

Goal: first solution to meet CMIP6 Euro-CORDEX requirements

- Verification (ERA5) run: MERRA2 $AOD_{monthly}$ (1980 –)

→ ALARO1: total column AOD by class + replace clim files (no change other IOPs) (contact with J. Masek (CMHI))

- CMIP6 runs: GCM $AOD_{monthly}$

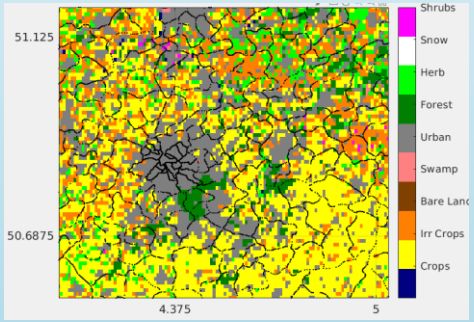
→ ALARO1: adoption of HCLIM solution (contact with G. Nikulin (SMHI))

Land cover change: mitigation scenarios

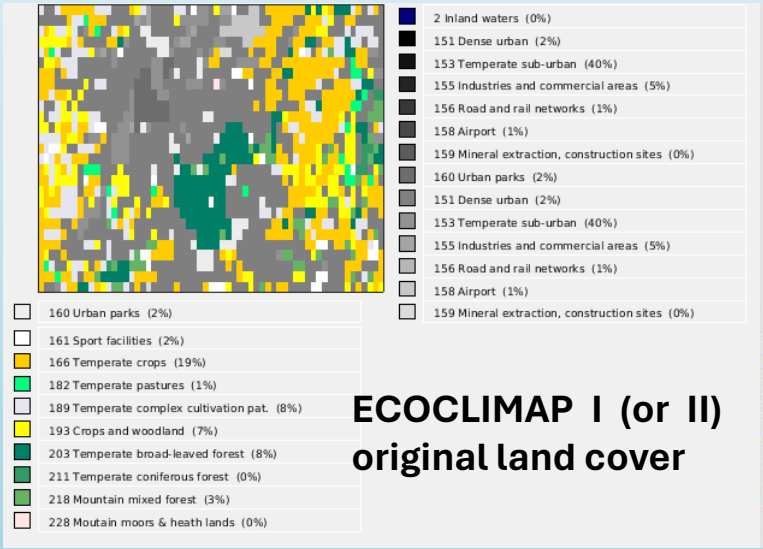
Adapting tools for ALARO 1-SURFEX v8.0 simulations

1. User-defined changes: user-interface tool to easily modify ECOCLIMAP (I & II) land cover & parameters

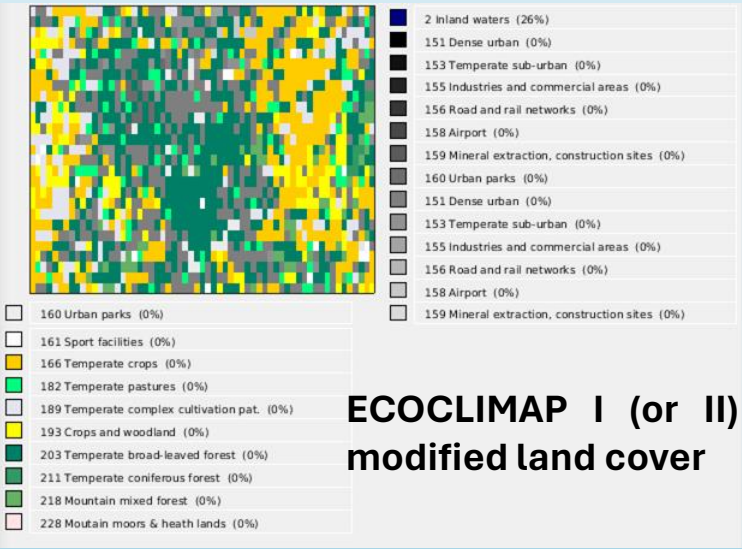
Sub-domain selection:



Example: over Brussels
50 % reduction of urban tiles:
convert to nature (80% F, 15% G, 5% C)



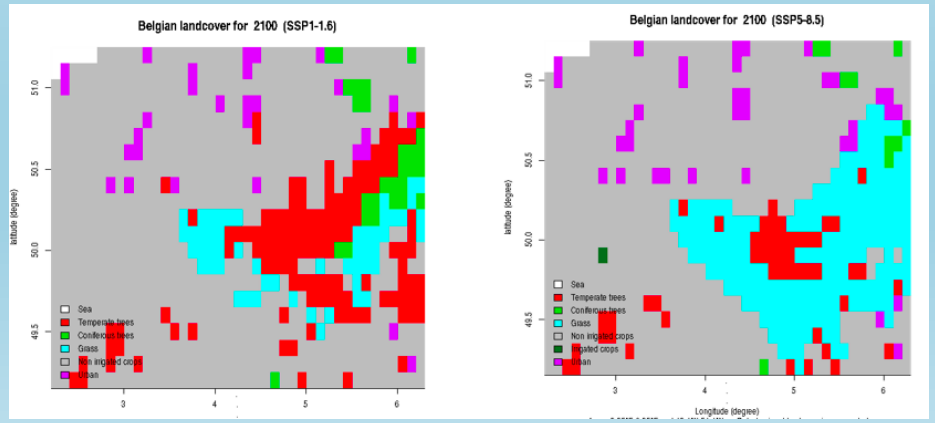
ECOCLIMAP I (or II) original land cover



ECOCLIMAP I (or II) modified land cover

Possibility to change the COVER parameters for a sub-domain!
Rewrite necessary files for PGD: ECOCLIMAP_I_GLOBAL_V1.5.dir &
ecoclimapI_covers_param.bin

2. **FPS LUCAS**: yearly land cover change experiment
12.5 km over EURO-CORDEX domain
Scenario SSP1-2.6
Scenario Land Use (LUCAS PFT (Hoffman 2022) → “Ecoclimap”)



Conclusions

- Going to high resolution adds value for climate runs
  - by better representing precipitation extremes
  - by computing very local features such as urban heat island
- ALARO will downscale 3 CMIP6 GCMs at 4 km resolution over Belgium as part of CORDEX.be II project
- ALARO will contribute to EURO-CORDEX
  - by modifying aerosol scheme to meet CMIP-6 requirements
  - by participating in LUKAS FPS with yearly land cover changes

Thank you for your attention!

Contact: wout.dewettinck@ugent.be