Online Workshop:
Considering High Resolution Climate Change Projections for road infrastructure planning, development and maintenance

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AGENDA

- Climate and Climate Change in the Western Balkan region
- Introduction to the ClimaProof Dataset and Tools
- Climate indicators for infrastructure planning, development and maintenance - general introduction and examples
- Discussion on relevance and prioritization of climate indicators for the Western Balkan region
- Discussion on EU good practices in incorporating climate projections in infrastructure planning and development

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Climate and Climate Change in the Western Balkan region

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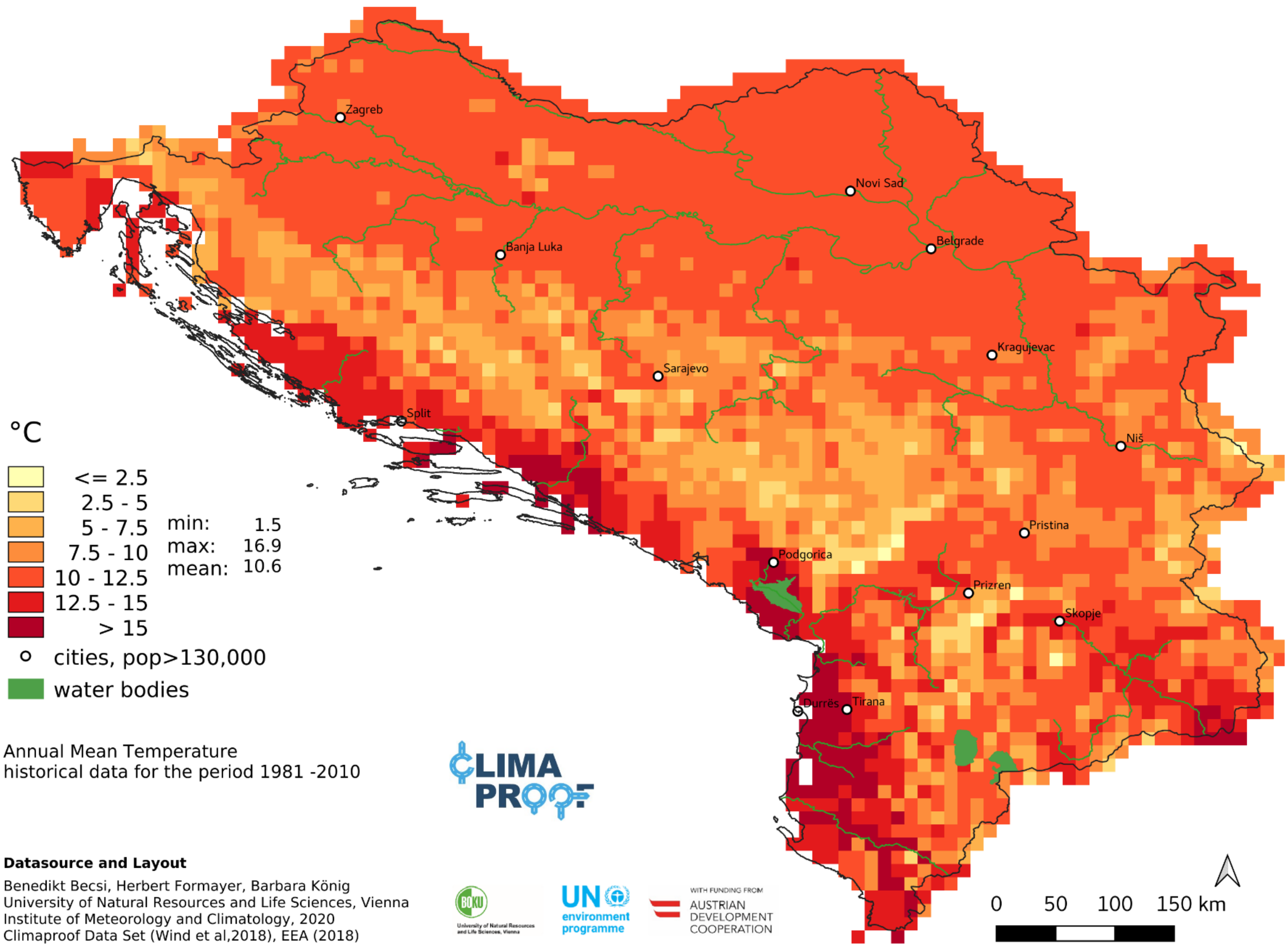
Annual Mean Temperature
Observations 1981-2010



Annual Mean Temperature
historical data for the period 1981 -2010

CLIMA PROOF

Datasource and Layout

Benedikt Becsi, Herbert Formayer, Barbara König
University of Natural Resources and Life Sciences, Vienna
Institute of Meteorology and Climatology, 2020
Climaproof Data Set (Wind et al,2018), EEA (2018)

BOKU University of Natural Resources and Life Sciences, Vienna

UN environment programme

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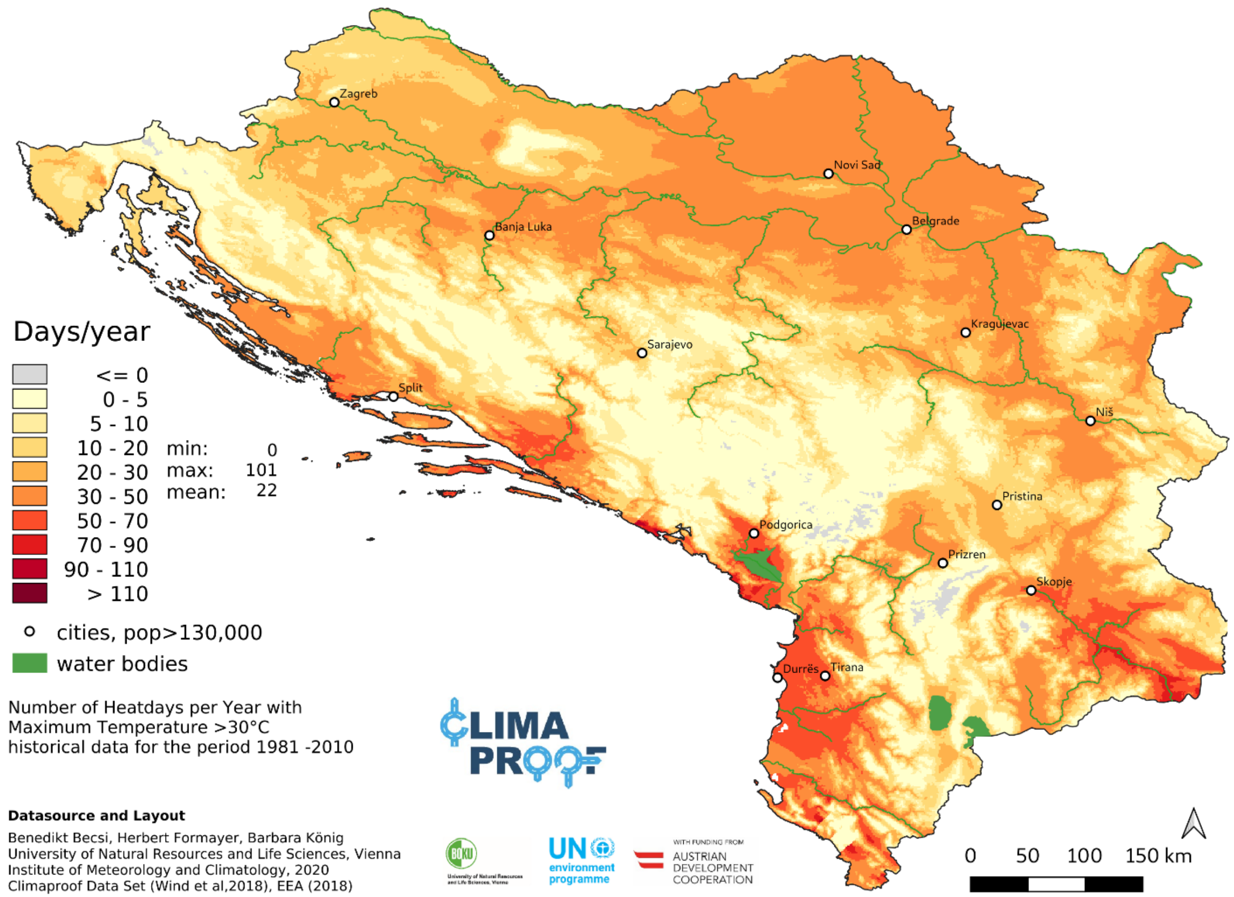
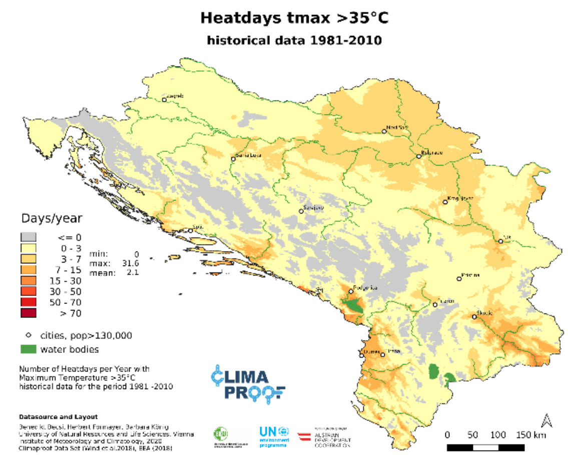
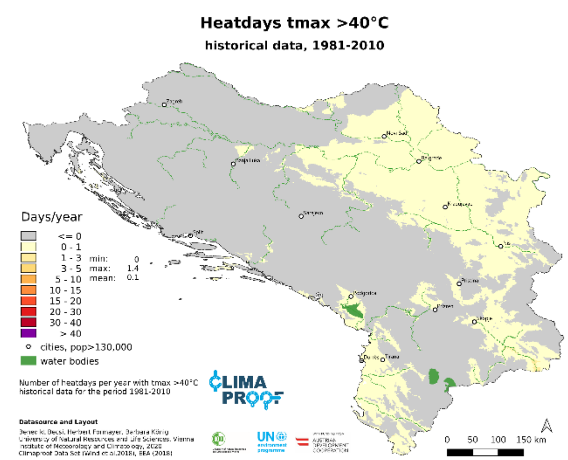
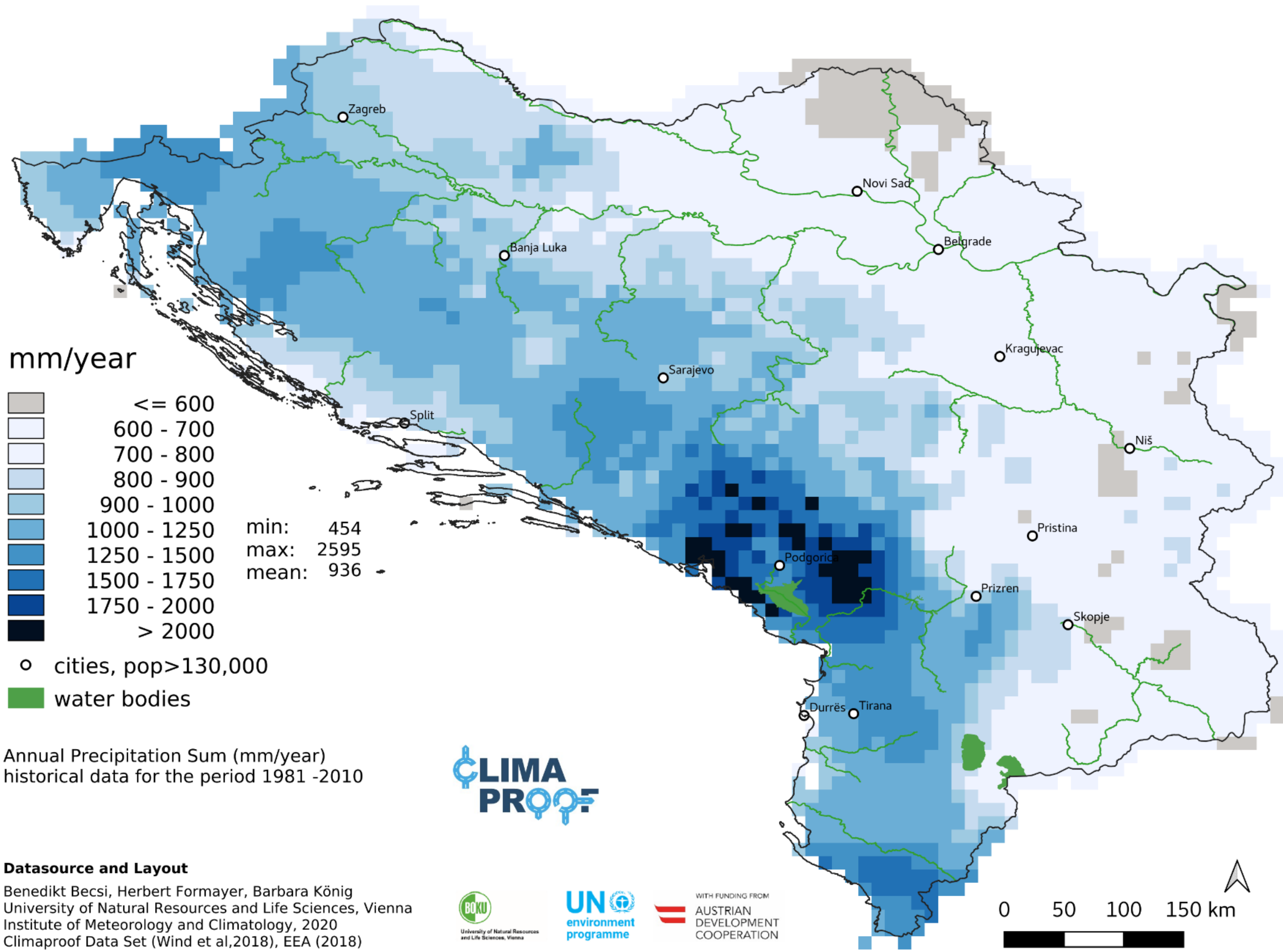
Number of Heatdays >30°C
Observations 1981-2010







Annual Precipitation Sum
Observations 1981-2010

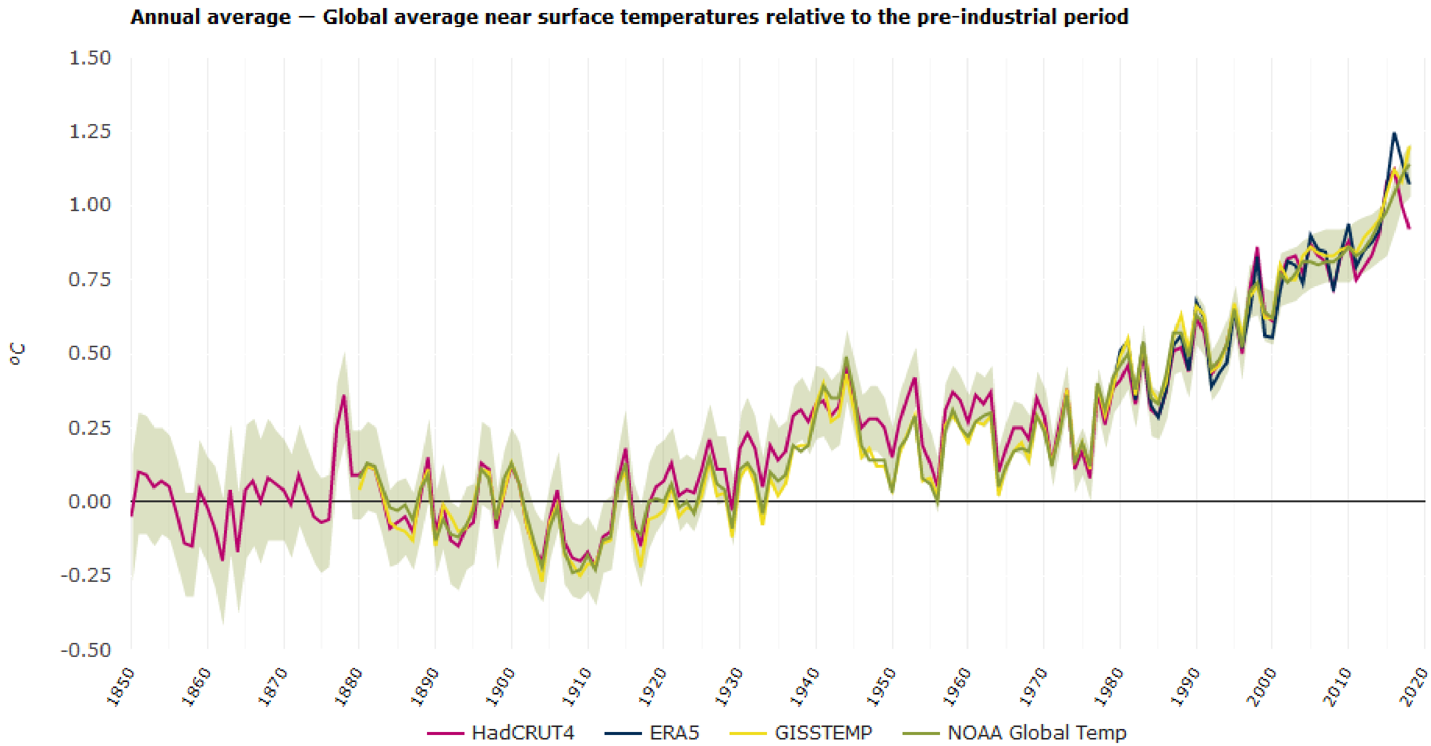


Annual Precipitation Sum (mm/year)
historical data for the period 1981 -2010

Datasource and Layout

Benedikt Becsi, Herbert Formayer, Barbara König
University of Natural Resources and Life Sciences, Vienna
Institute of Meteorology and Climatology, 2020
Climaproof Data Set (Wind et al,2018), EEA (2018)

Global Temperature Change



Data sources:

- Global Surface Temperature Anomalies and Annual Global (land and ocean combined) Anomalies (degrees C) provided by **National Oceanic and Atmospheric Administration (NOAA)**
- Annual Global (Land and Ocean) temperature anomalies – HadCRUT (degrees Celsius) provided by
- NASA – Goddard Institute for Space Studies Surface Temperature Analysis (GISTEMP) provided by **NASA**
- ERA-Interim provided by **European Centre for Medium-Range Weather Forecasts (ECMWF)**

EEA, 2020
https://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature-9/assessment

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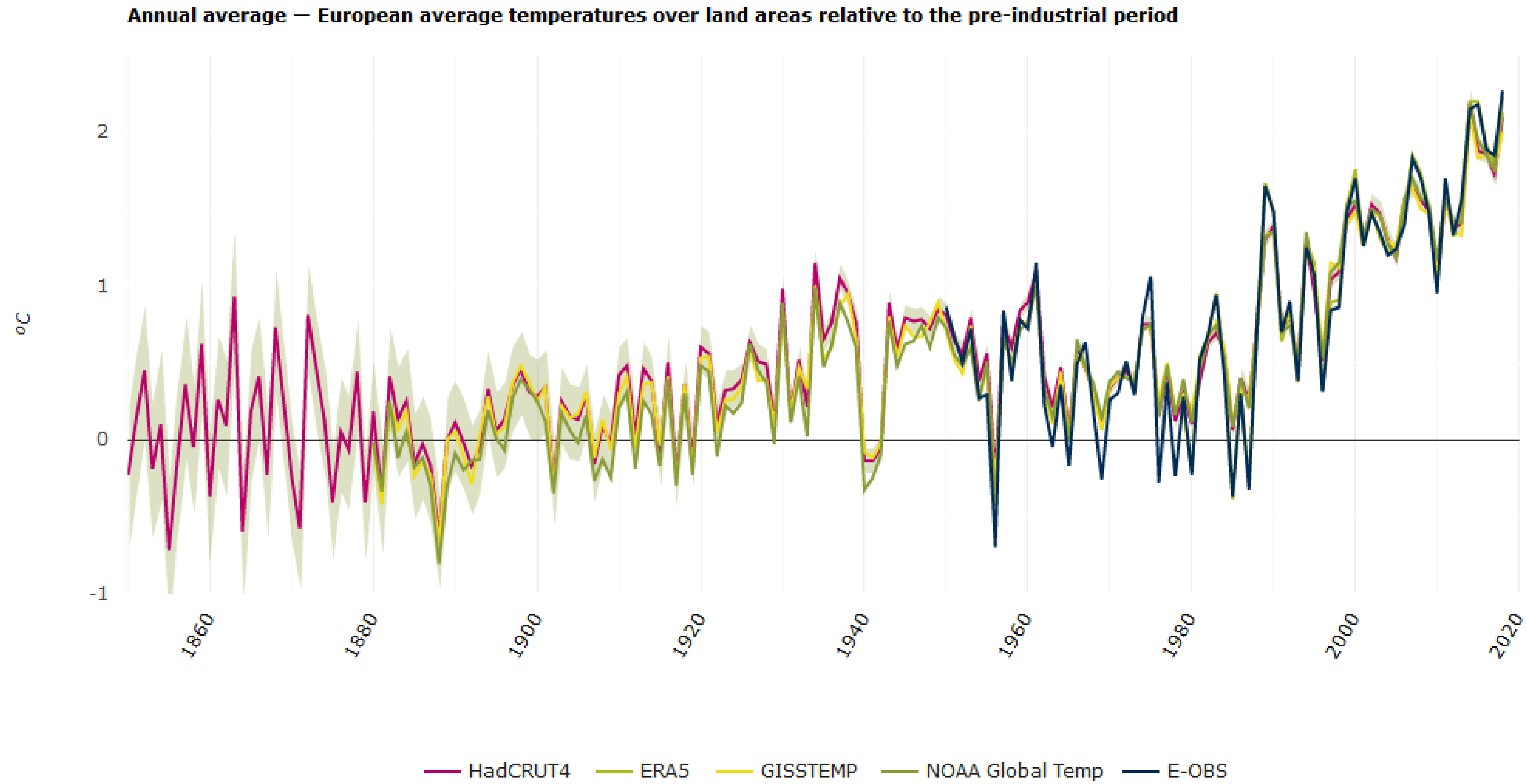
European Temperature Change



Data sources:

- Annual Global (Land and Ocean) temperature anomalies – HadCRUT (degrees Celsius) provided by
- NASA – Goddard Institute for Space Studies Surface Temperature Analysis (GISTEMP) provided by **NASA**
- Global Surface Temperature Anomalies and Annual Global (land and ocean combined) Anomalies (degrees C) provided by **National Oceanic and Atmospheric Administration (NOAA)**

EEA, 2020

https://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature-9/assessment

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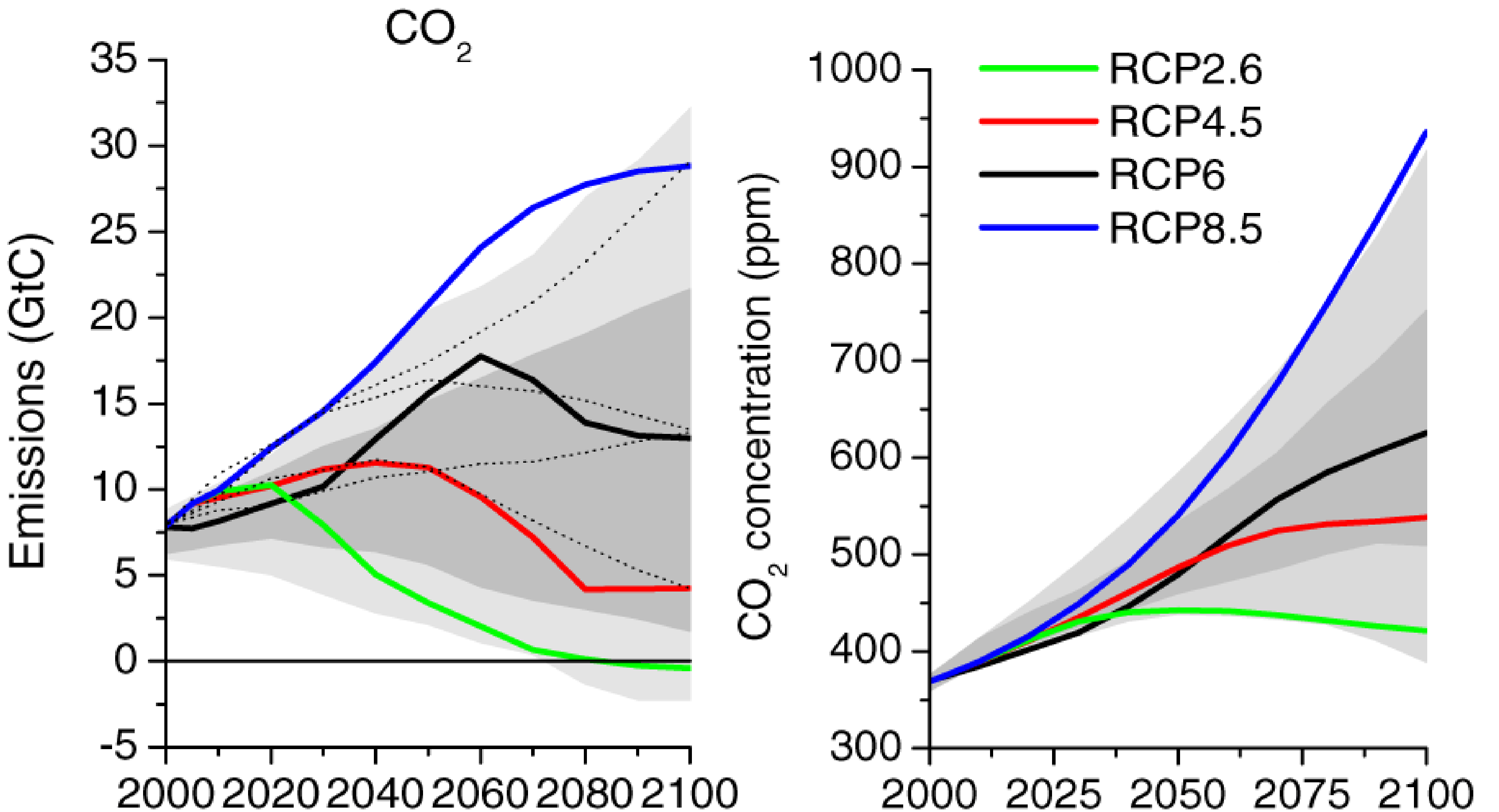
RCPs - Representative Concentration Pathways



Van Vuuren et al, 2011

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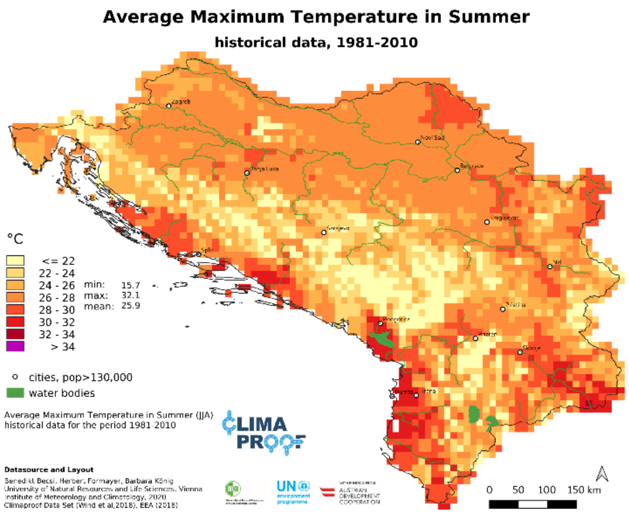
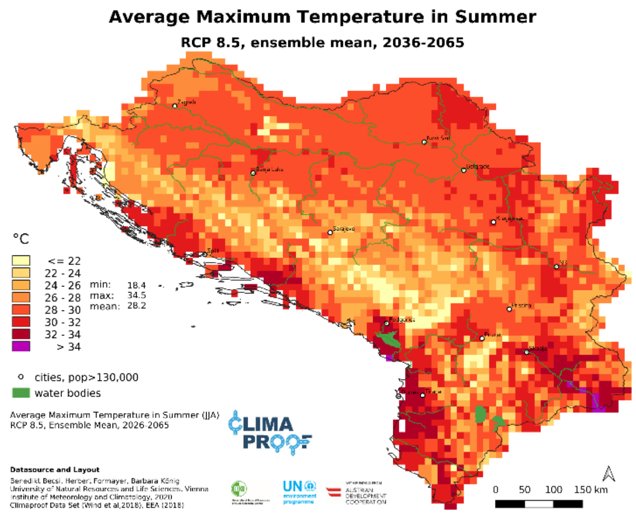
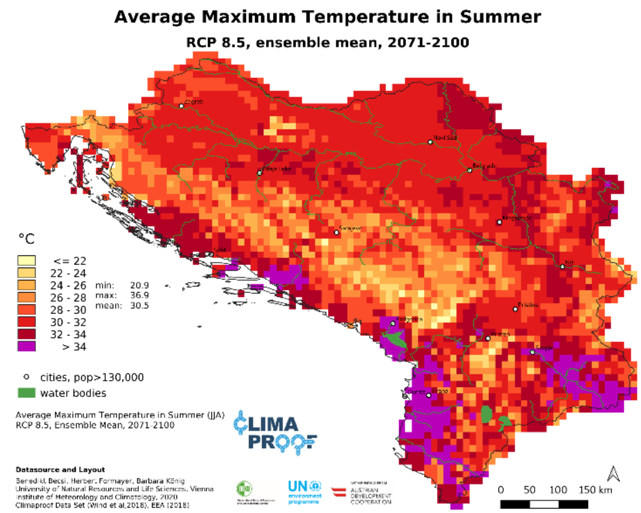
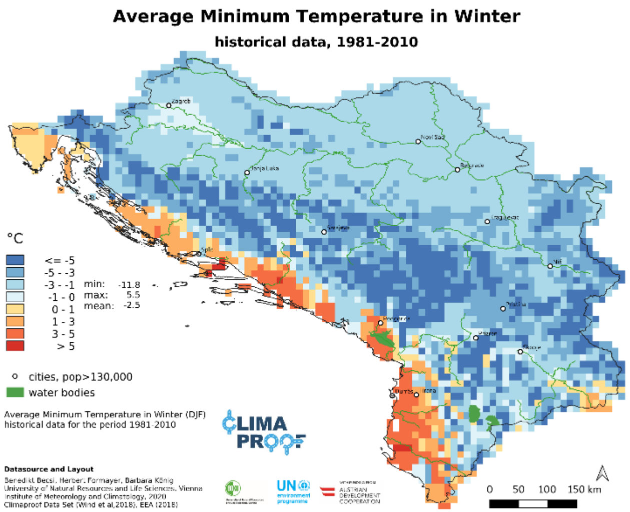
Average Maximum Temperature (JJA)

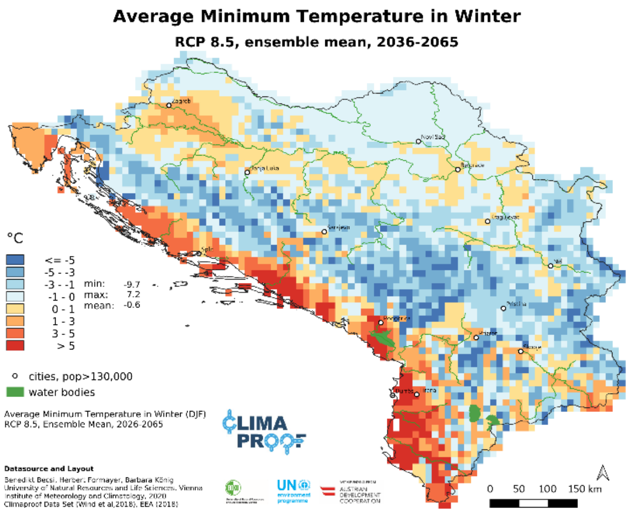


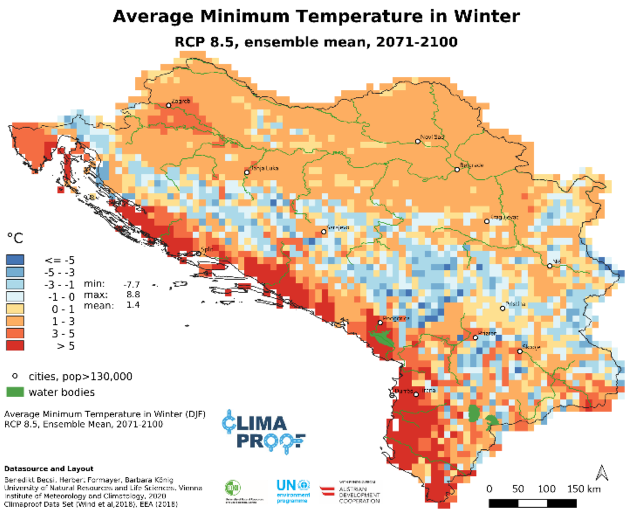




Average Minimum Temperature (DJF)

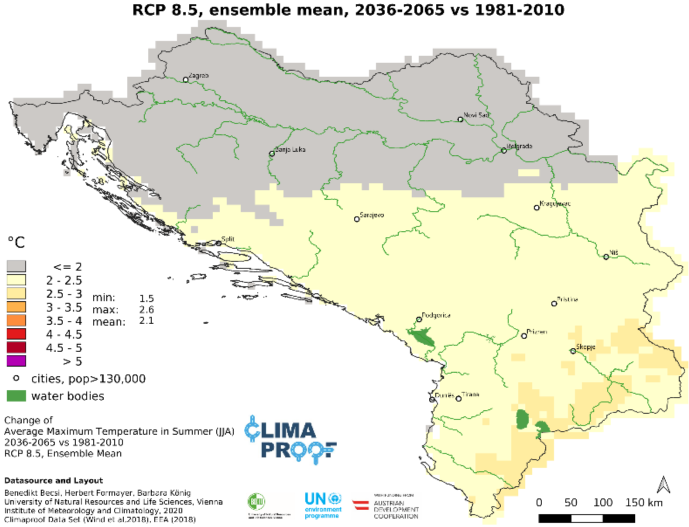




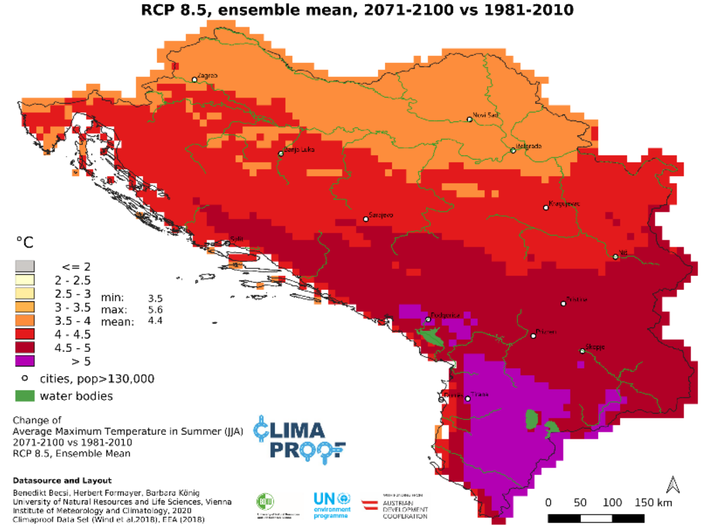


Change of Average Temperature
(Tmax JJA, Tmin DJF)

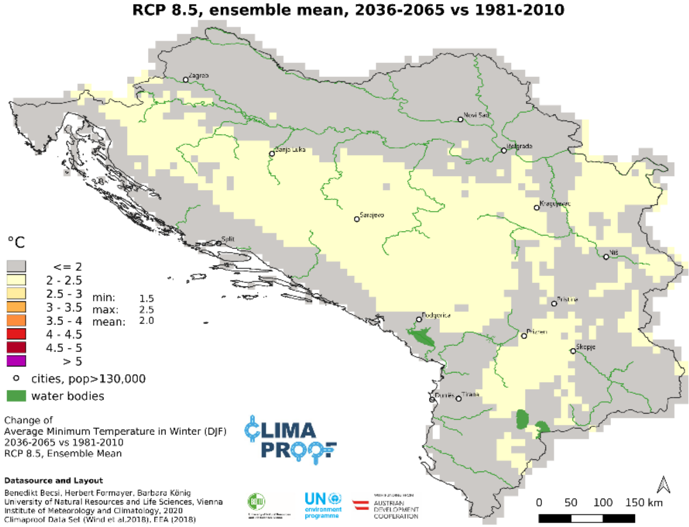
Change of Average Maximum Temperature in Summer
RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010



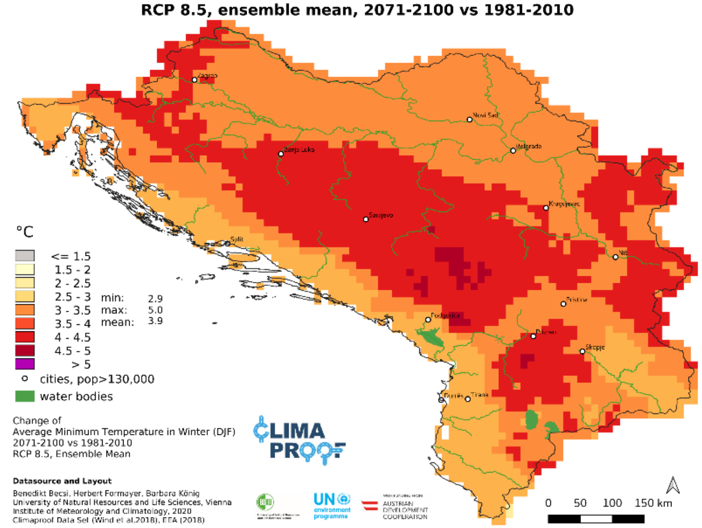
Change of Average Maximum Temperature in Summer
RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010



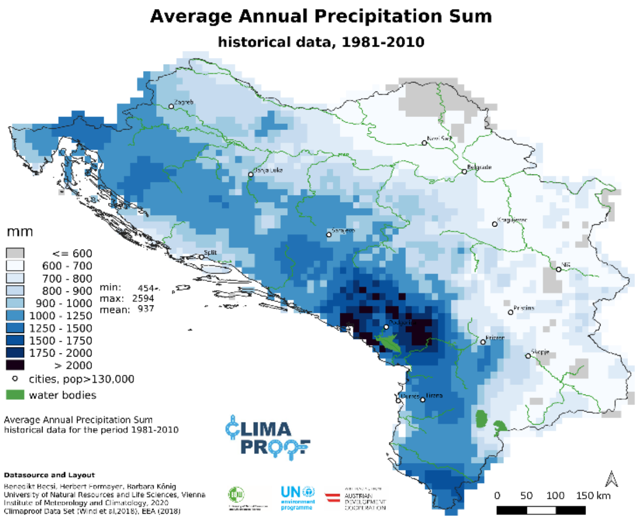
Change of Average Minimum Temperature in Winter
RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010

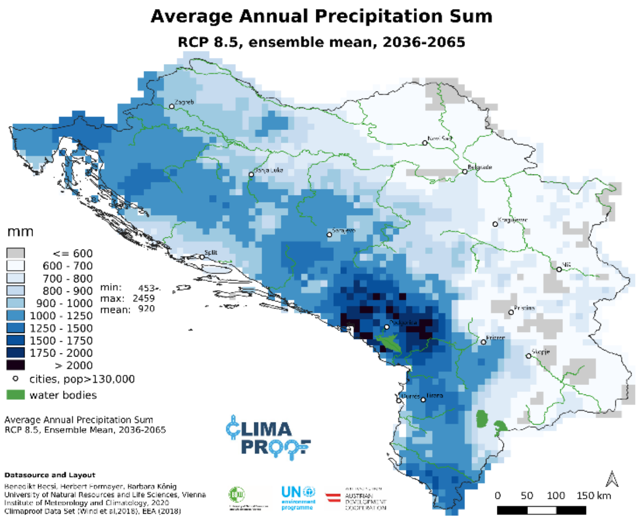


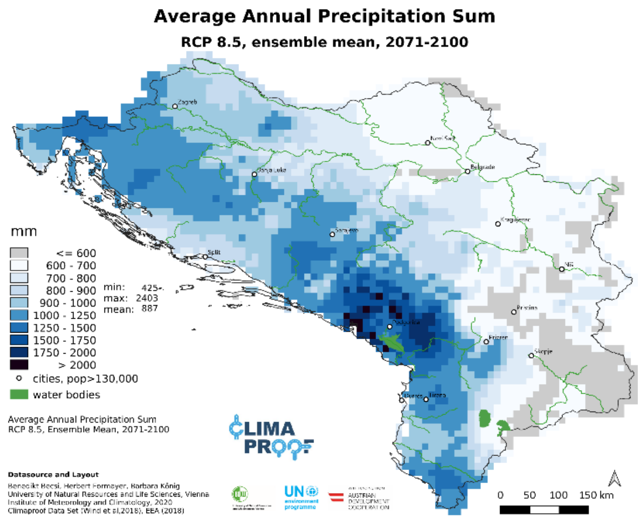
Change of Average Minimum Temperature in Winter
RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010



Precipitation sum – annual

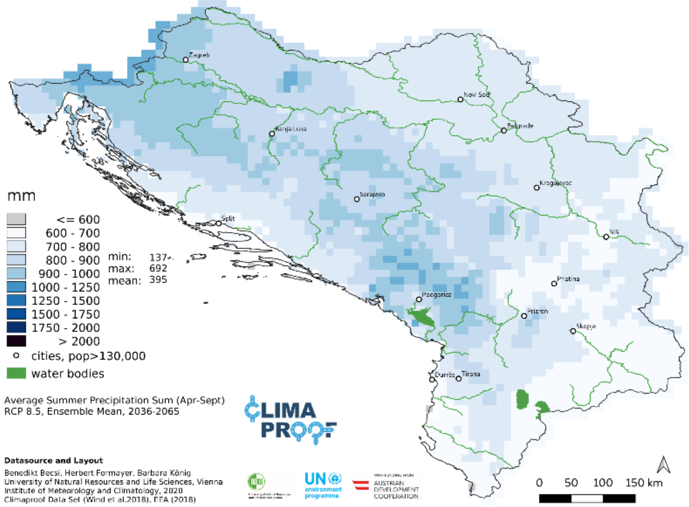




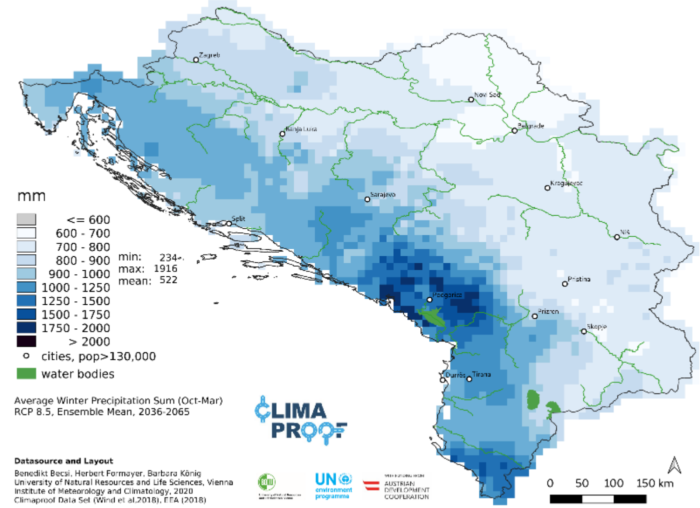


Precipitation sum – summer, winter

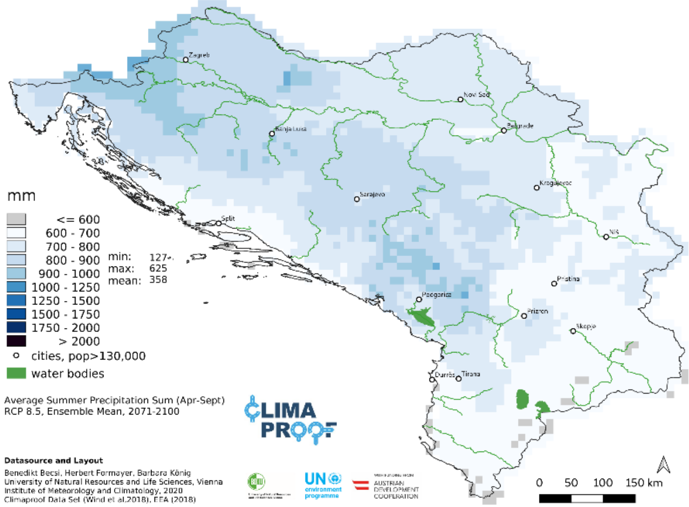
Average Summer Precipitation Sum
RCP 8.5, ensemble mean, 2036-2065



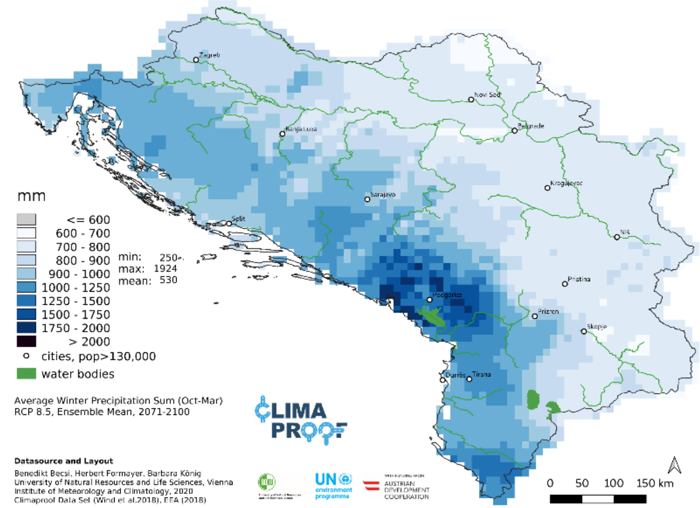
Average Winter Precipitation Sum
RCP 8.5, ensemble mean, 2036-2065



Average Summer Precipitation Sum
RCP 8.5, ensemble mean, 2071-2100



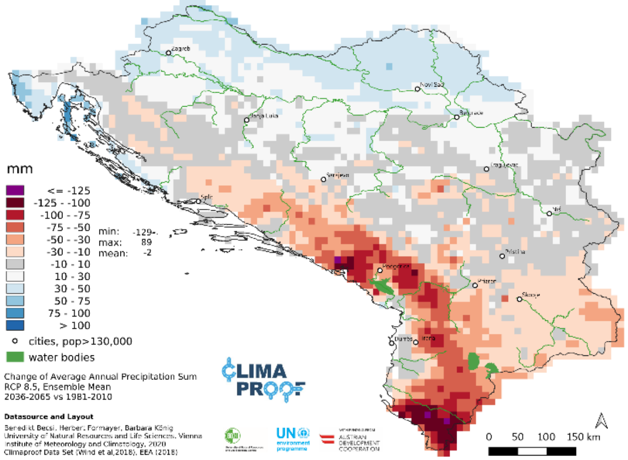
Average Winter Precipitation Sum
RCP 8.5, ensemble mean, 2071-2100



Change of Precipitation

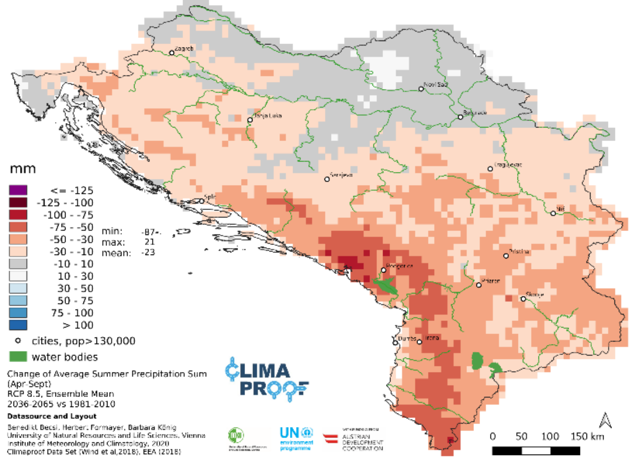
Change of Average Annual Precipitation Sum

RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010



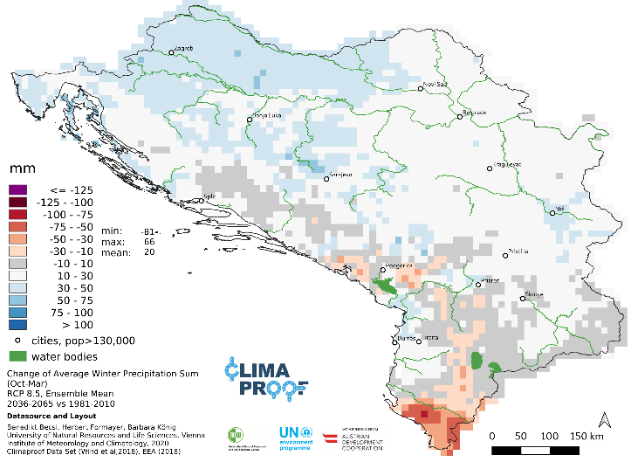
Change of Average Summer Precipitation Sum

RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010



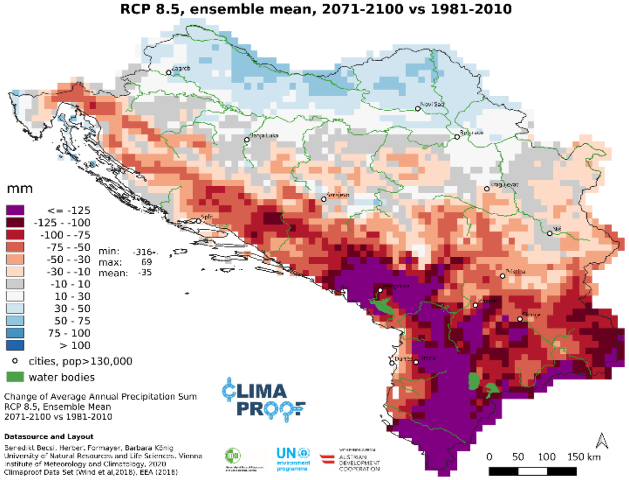
Change of Average Winter Precipitation Sum

RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010



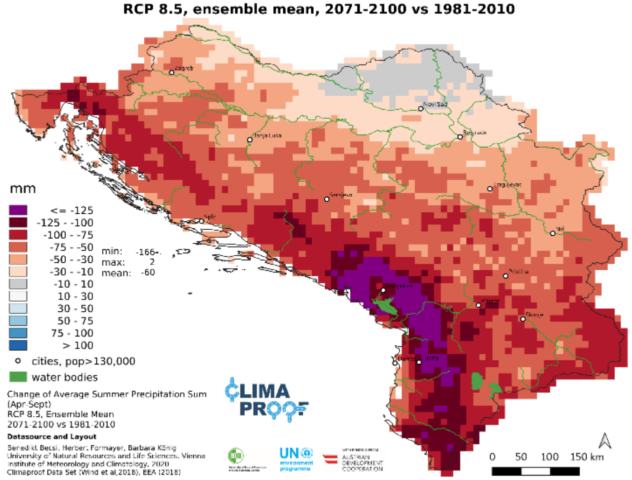
Change of Average Annual Precipitation Sum

RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010



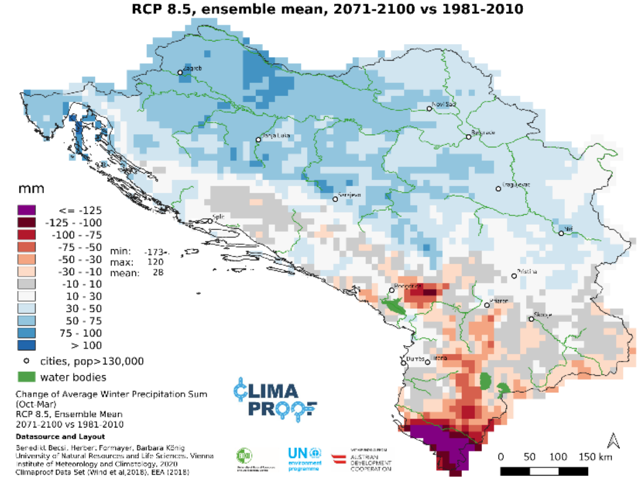
Change of Average Summer Precipitation Sum

RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010

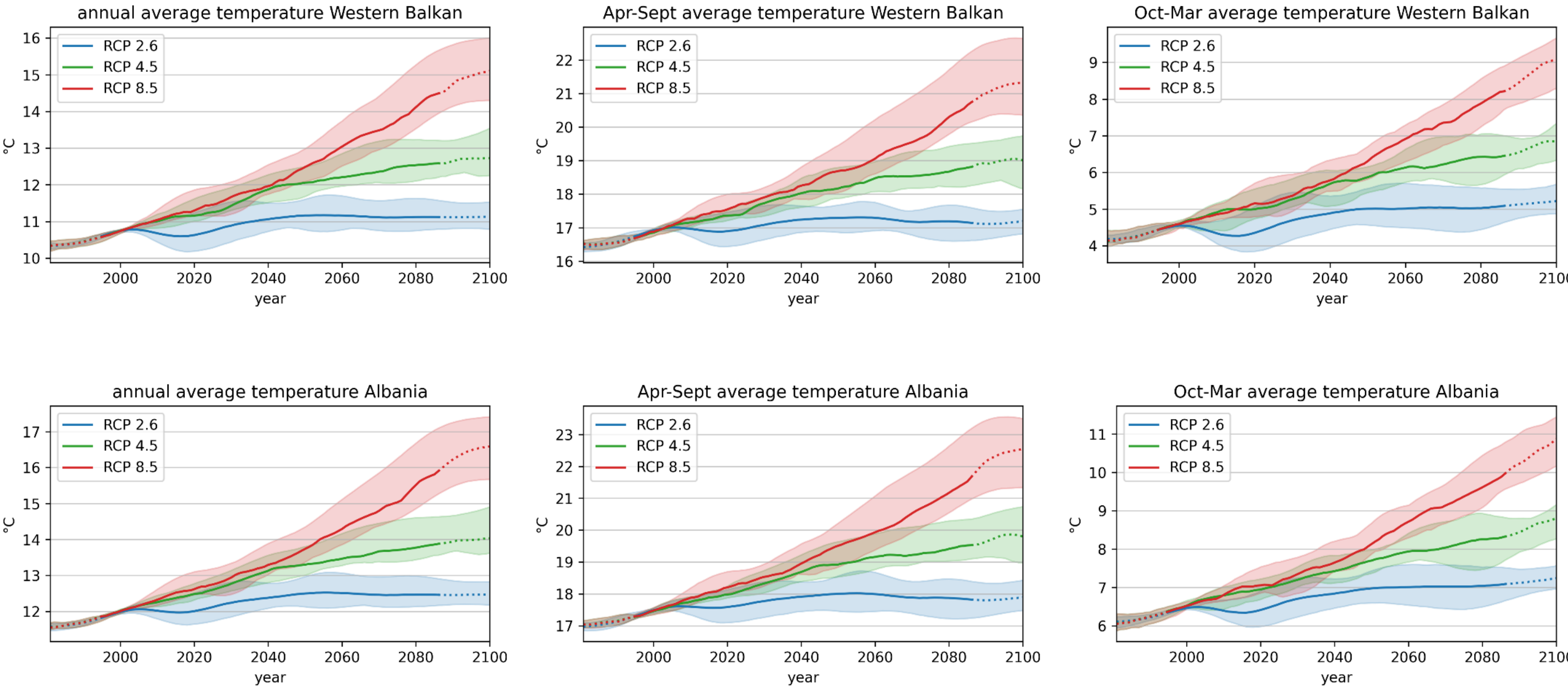


Change of Average Winter Precipitation Sum

RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010



Timeseries temperature



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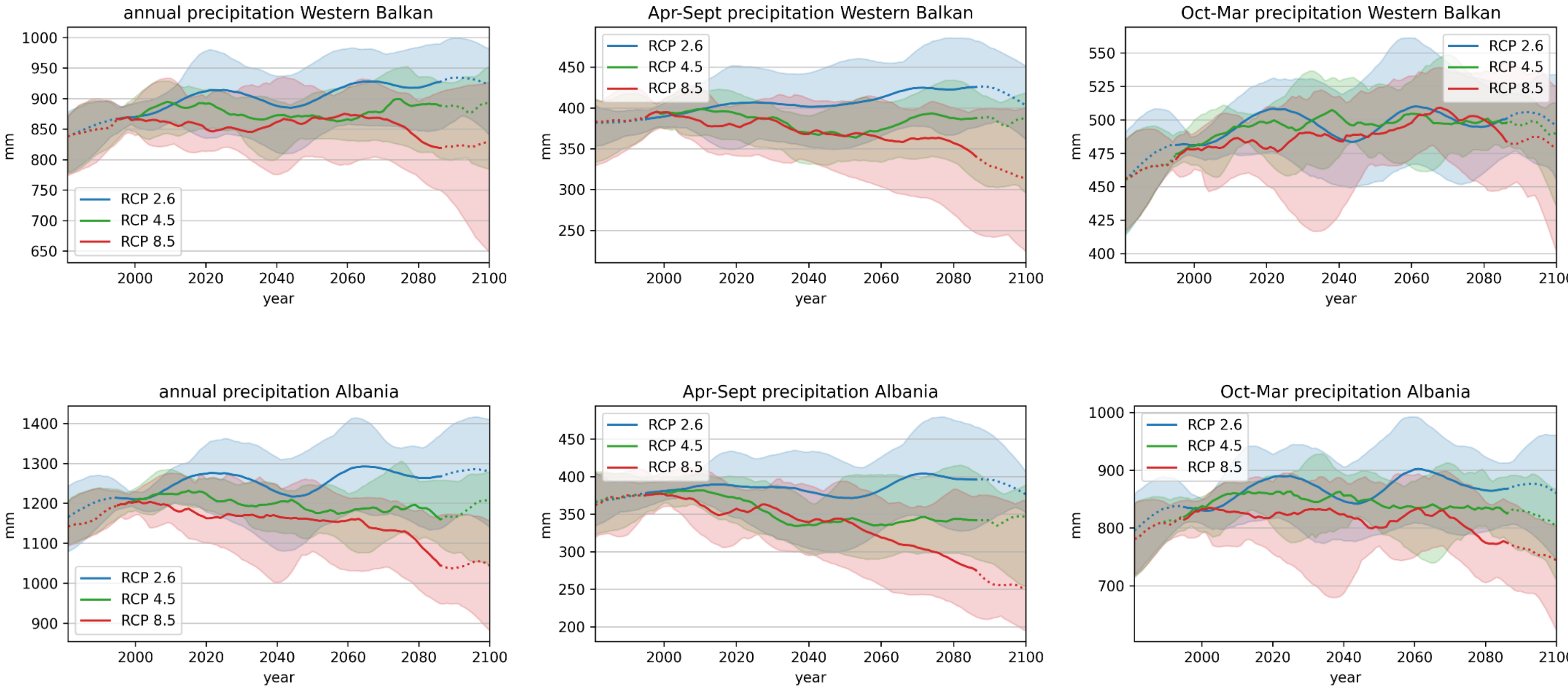
Timeseries annual precipitation



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Keymessages

- Temperature rise in the whole region
  - Annual Tmean and Summer Tmax: north – south pattern
  - Winter Tmin: colder areas (mountains) expect an higher increase

- Precipitation change varies depending on area and season
  - Summer Precipitation: decrease, especially on the coast and in the south
  - Winter Precipitation: decrease in the south, increase in the north

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Questions

Remarks

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ClimaProof Dataset and Tools

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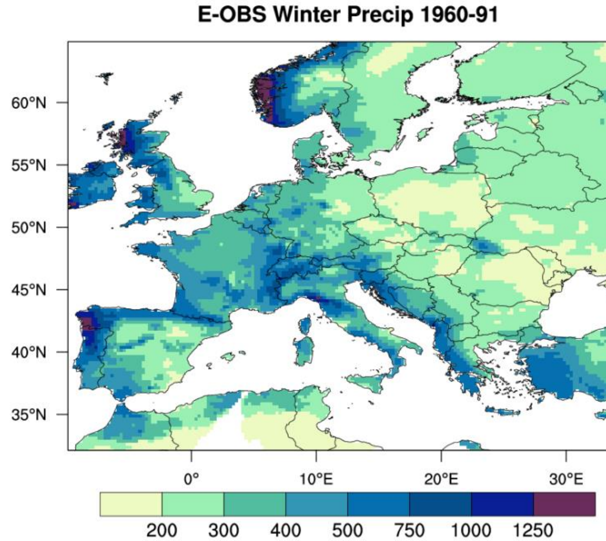
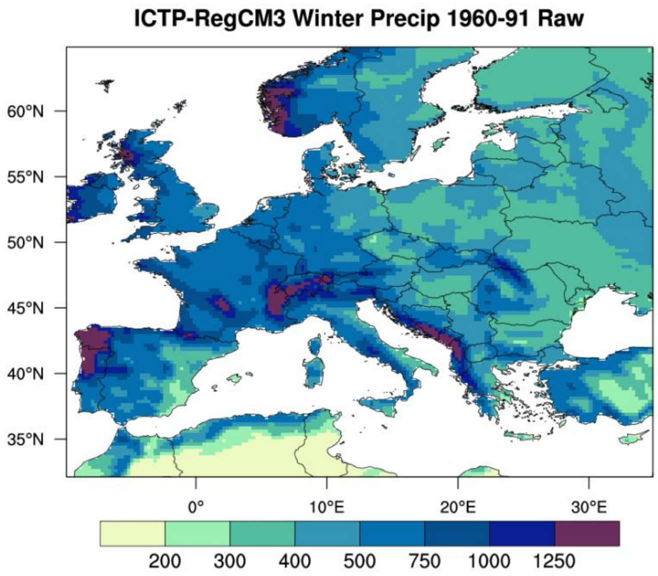
Skills and weaknesses of Regional Climate Models

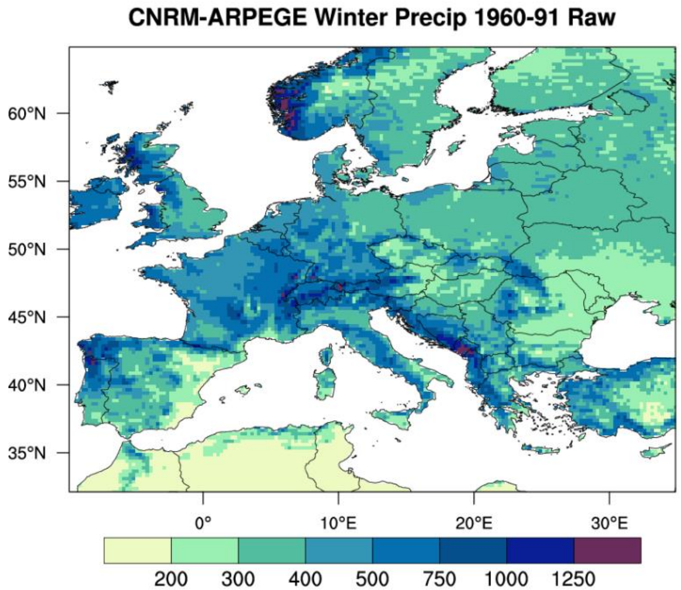


Precipitation bias in RCMs

Winter (Oct-Mar) Precipitation

(left ALADIN right RegCM3)





Data base – Model data

- Euro-Cordex[1] (40) and Med-Cordex[2] (4)
- Resolution 0.11° + Fully-coupled model by the University of Belgrade (0.44°)
- 6 GCMs, 13 RCMs
- RCP2.6 (6), RCP4.5 (18), RCP8.5 (16)

[1] https://euro-cordex.net [2] https://www.medcordex.eu/

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Data base – Observational data

Dataset	Variables used within the Project	Horizontal Resolution	Expansion of original dataset	Download
Carpatclim (Szalai et al, 2013; European Commission JRC, 2013)	tasmax, tasmin, pr, rsds, sfcWind, hurs	0.1°	44°N - 50°N, 17°E - 27°E	http://www.carpatclim-eu.org/
Danubeclim (Szalai et al, 2013; European Commission JRC, 2015)	pr	0.1°	Serbia, Montenegro and Srpska Republic	http://www.carpatclim-eu.org/danubeclim
E-OBS (Haylock et al, 2008; ECA&D, 2018)	tasmax, tasmin	0.25°	25°N -75°N 40°W-75°E	https://www.ecad.eu/download/ensembles/download.php
CHIRPS (Funk et al, 2015)	pr	0.05°	50°N - 50°S, 180°W - 180°E	http://chg.ucsb.edu/data/chirps/
ERA5 (C3S, 2017)	sfcWind (calc. from u and v), hurs (calc. from mean temperature and dew point temperature)	0.28°	global	https://cds.climate.copernicus.eu/cdsapp#!/home
SARAH-2 (Pfeifroth et al, 2017)	rsds	0.05°	65°N - 65°S, 65°W - 65°E	https://doi.org/10.5676/EUM_SAF_CM/SARAH/V002

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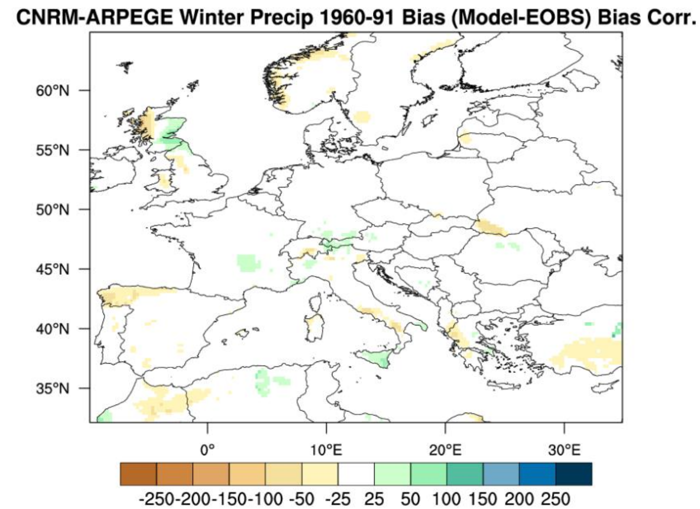
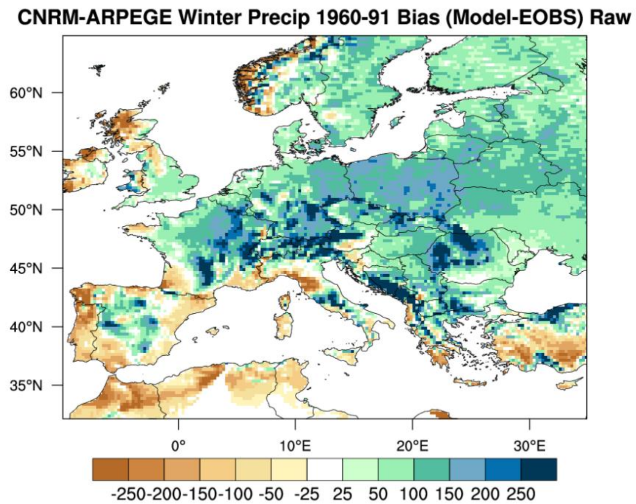
Ensemble of bias-corrected Climate Scenarios

Scaled-Distribution Mapping

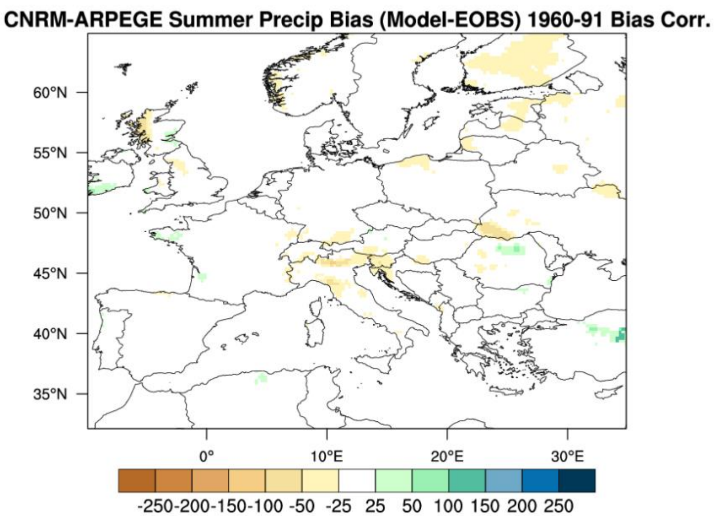


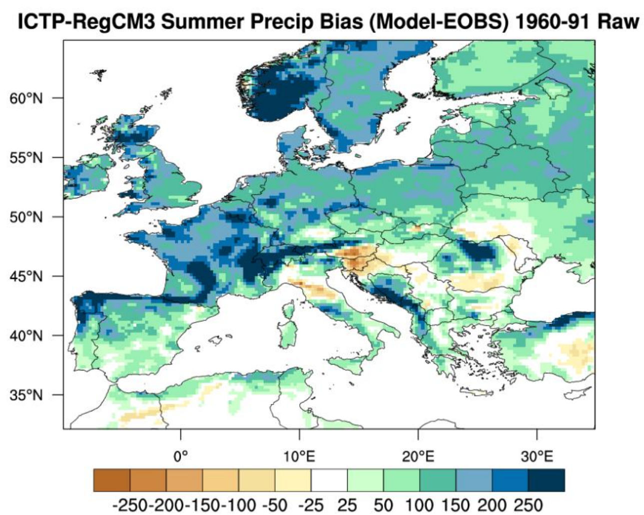


Precipitation-

bias in RCMs

left bias corrected right raw data (up ALADIN down RegCM3)





CCCA Dataserver

https://data.ccca.ac.at/group/climaproof

(Account required)

Available data:

- Bias corrected model data
- Regridded original model data (for the ICC-OBS Tool)
- Observational data (used for bias correction)
- Topography data of the common grid (0.1°)
- High resolution topography data (0.01°) for downscaling

Variable	Unit
tasmax	°C
tasmin	°C
pr	mm
rsds	W/m²
sfcWind	m/s
hurs	%

User Guide: https://github.com/boku-met/climaproof-docs

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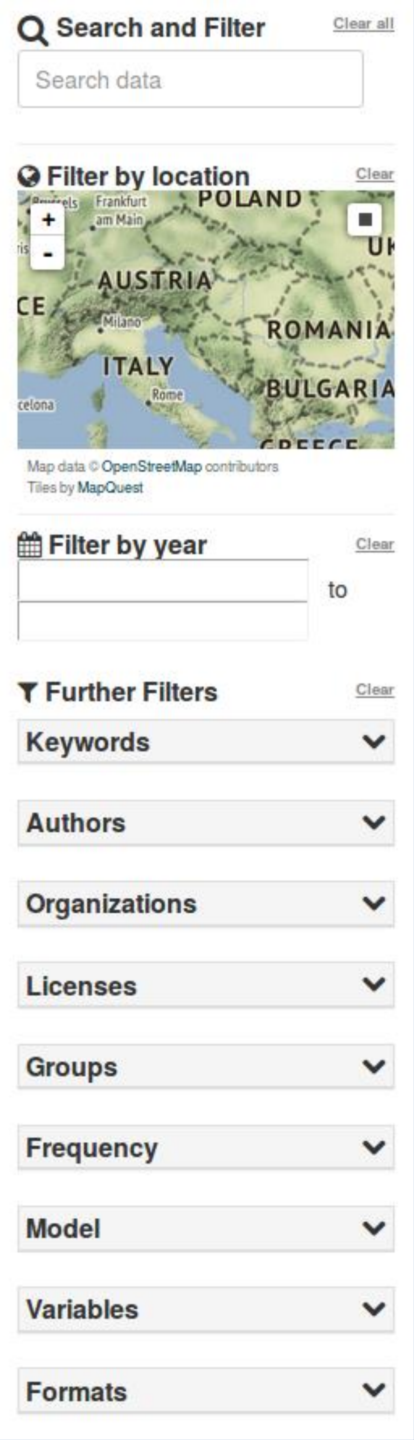
CCCA Dataserver

Hands-on:

- Filter the data
- Explore the metadata of datasets
- Preview data (visualization)
- Create subset of data
- Download data

Need help? Click on the question marks that you can find on the CCCA Data server to get a short online documentation



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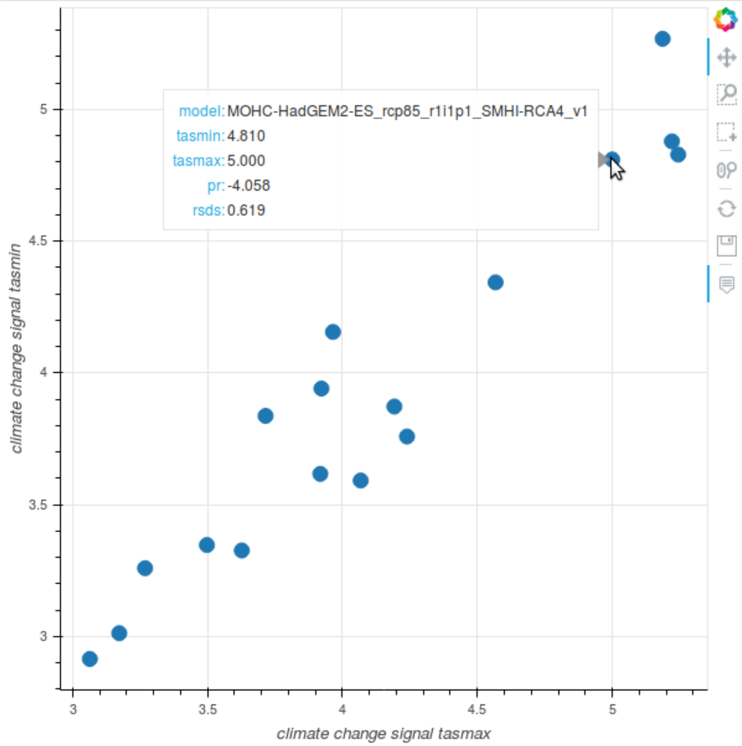
Modell Selection Tool

https://github.com/boku-met/climaproof-tools

X-Axis: tasmax

Y-Axis: tasmin

near (2021-2050) | mid (2036-2065) | far (2070-2099)



Download CSV

model	Tasmax	*Tasmax Perc*	Tasmin	Tasmin Perc.
MOHC-HadGEM2-ES_rcp85_r1i1p1_CLMcom-CCLM4-8-17	5.245	100.000	4.828	88.235
IPSL-IPSL-CM5A-MR_rcp85_r1i1p1_SMHI-RCA4_v1	5.221	94.118	4.878	94.118
MOHC-HadGEM2-ES_rcp85_r1i1p1_KNMI-RACMO22E_v2	5.187	88.235	5.268	100.000
MOHC-HadGEM2-ES_rcp85_r1i1p1_SMHI-RCA4_v1	5.000	82.353	4.810	82.353
ICTP-RegCM4_rcp85_r1i1p1_ICTP-RegCM4-3_v1	4.568	76.471	4.344	76.471
MPI-M-MPI-ESM-LR_rcp85_r1i1p1_MPI-CSC-REMO2009_v	4.239	70.588	3.759	47.059
MPI-M-MPI-ESM-LR_rcp85_r1i1p1_SMHI-RCA4_v1a	4.192	64.706	3.872	58.824
MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-CCLM4-8-17_	4.068	58.824	3.592	35.294
IPSL-IPSL-CM5A-MR_rcp85_r1i1p1_IPSL-INERIS-WRF331F	3.965	52.941	4.155	70.588
ICHEC-EC-EARTH_rcp85_r12i1p1_KNMI-RACMO22E_v1	3.922	47.059	3.941	64.706
MPI-M-MPI-ESM-LR_rcp85_r2i1p1_MPI-CSC-REMO2009_v	3.918	41.176	3.617	41.176
ICHEC-EC-EARTH_rcp85_r1i1p1_KNMI-RACMO22E_v1	3.715	35.294	3.837	52.941
ICHEC-EC-EARTH_rcp85_r12i1p1_CLMcom-CCLM4-8-17_	3.627	29.412	3.327	23.529
CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_SMHI-RCA4_	3.497	23.529	3.347	29.412
ICHEC-EC-EARTH_rcp85_r3i1p1_DMI-HIRHAM5_v1	3.268	17.647	3.259	17.647
CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_CLMcom-CCI	3.172	11.765	3.013	11.765
NCC-NorESM1-M_rcp85_r1i1p1_DMI-HIRHAM5_v2	3.063	5.882	2.915	5.882

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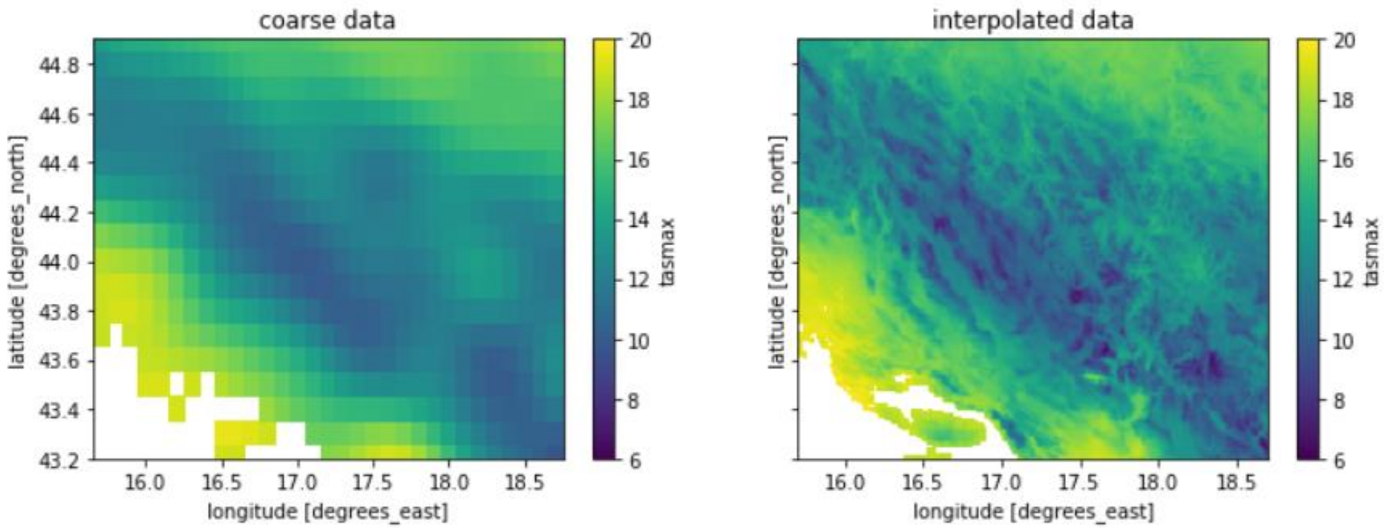
Downscaling Tool

https://github.com/boku-met/climaproof-tools

- For applications that need a higher horizontal resolution
- Easy-to-use tool to **downscale model and observational data** from default (0.1°) to high resolution (0.01°)

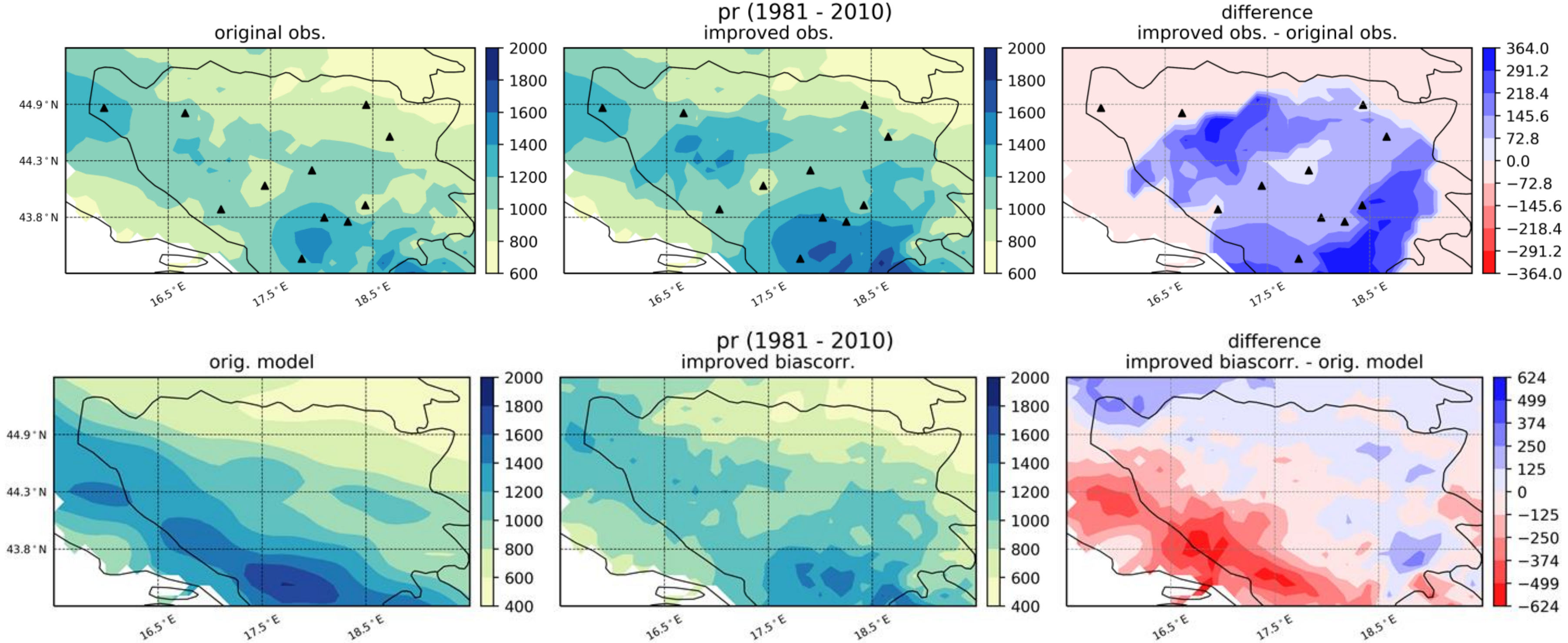


ICC-OBS tool

https://github.com/boku-met/ICC-OBS

Improving bias-corrected **C**limate **C**hange scenarios with local **OBS**ervational data

- Observational Data of 11 Stations for the period 1981-2010
- Interpolation with idw (min. 3 neighbours, 100km radius)



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Summery

- Ensemble of 44 bias-corrected climate change models
- Internationally available
- Free access
- Referenceable data download (DOI)
- Use of functionalities provided by the CCCA dataserver
- National weather services trained in using the data

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Questions

Remarks

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Climate indicators

for infrastructure planning, development and maintenance - general introduction and examples

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Climate indicators

- Climate indicators show trends over time in key aspects of our environment
- help readers understand observed long-term trends related to the causes
- Indicators based on long-term, consistently collected data can be used to:
  - Understand how our climate and environmental conditions are changing
  - Consider and assess risks and vulnerabilities
  - Help to prepare, take action, and improve resilience to the impacts of climate change

- https://www.globalchange.gov/indicators
- https://www.epa.gov/climate-indicators/frequent-questions-about-climate-change-indicator s

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Climate Change Indicators Examples

Heatdays (days with temperature >X)

- Measure for heatstress for humans and animals
- Relevant for heatstress on materials … (e.g. pavings)
- Basis for forestfires

3-day precipitation extreme

- 99 percentile of 3-day precipitation sum
- Heavy rain falls
- Can cause aquaplaning, floods, landslides, muddflows

Concecutive dry days

- Number of days in dry periods with a lentghts of min. 5 days
- Agriculture, forestry
- In combination with heatdays: risk of forestfires

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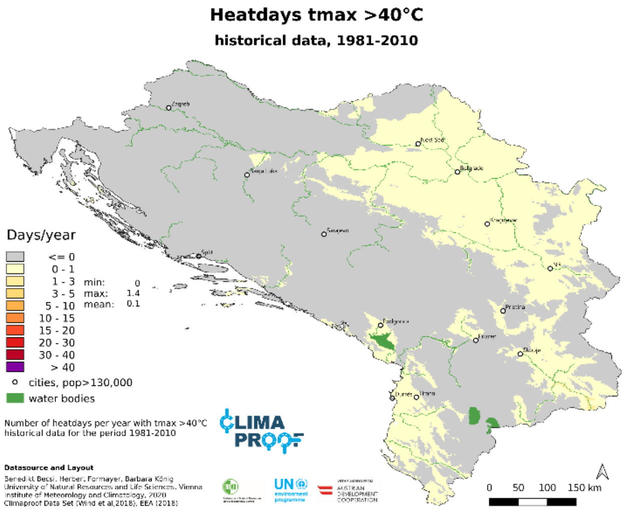
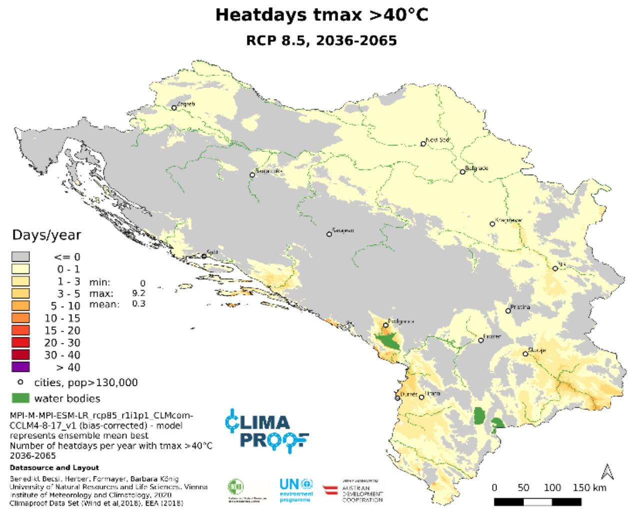
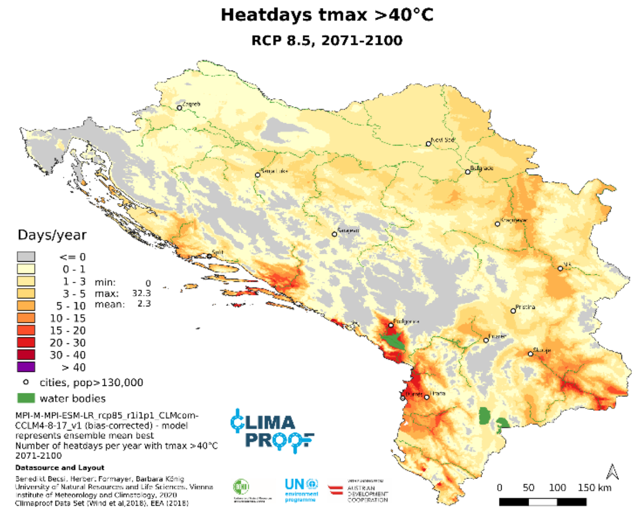
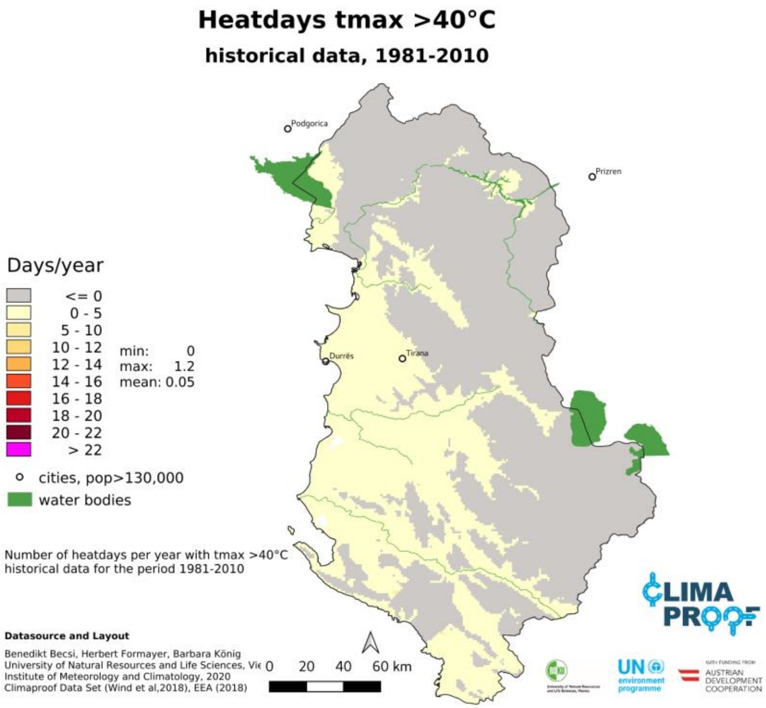
Example 1:
Days with tmax >40°C
model represents ensemble mean best








Heatdays tmax >40°C
historical data, 1981-2010
Podgorica
Prizren
Durrës
Tirana
Days/year
<= 0
0 - 5
5 - 10
10 - 12
12 - 14
14 - 16
16 - 18
18 - 20
20 - 22
> 22
min: 0
max: 1.2
mean: 0.05
cities, pop>130,000
water bodies
Number of heatdays per year with tmax >40°C
historical data for the period 1981-2010
Datasource and Layout
Benedikt Becsi, Herbert Formayer, Barbara König
University of Natural Resources and Life Sciences, Vie
Institute of Meteorology and Climatology, 2020
Climaproof Data Set (Wind et al,2018), EEA (2018)
0 20 40 60 km
CLIMA PROOF
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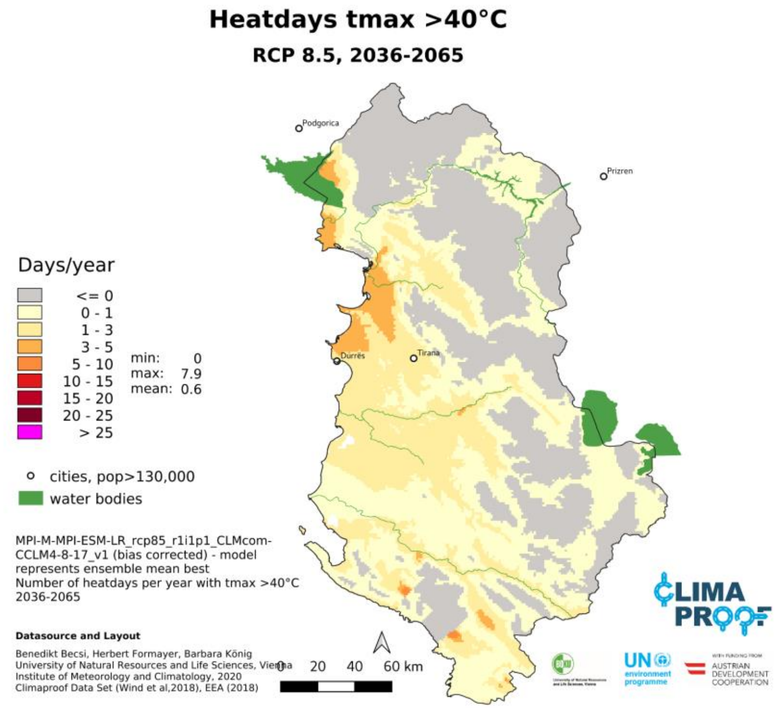
Heatdays tmax >40°C
RCP 8.5, 2036-2065
Podgorica
Prizren
Durrës
Tirana
Days/year
<= 0
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 25
> 25
min: 0
max: 7.9
mean: 0.6
cities, pop>130,000
water bodies
MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-CCLM4-8-17_v1 (bias corrected) - model represents ensemble mean best
Number of heatdays per year with tmax >40°C
2036-2065
Datasource and Layout
Benedikt Becsi, Herbert Formayer, Barbara König
University of Natural Resources and Life Sciences, Vienna
Institute of Meteorology and Climatology, 2020
Climaproof Data Set (Wind et al,2018), EEA (2018)
0 20 40 60 km
CLIMA PROOF
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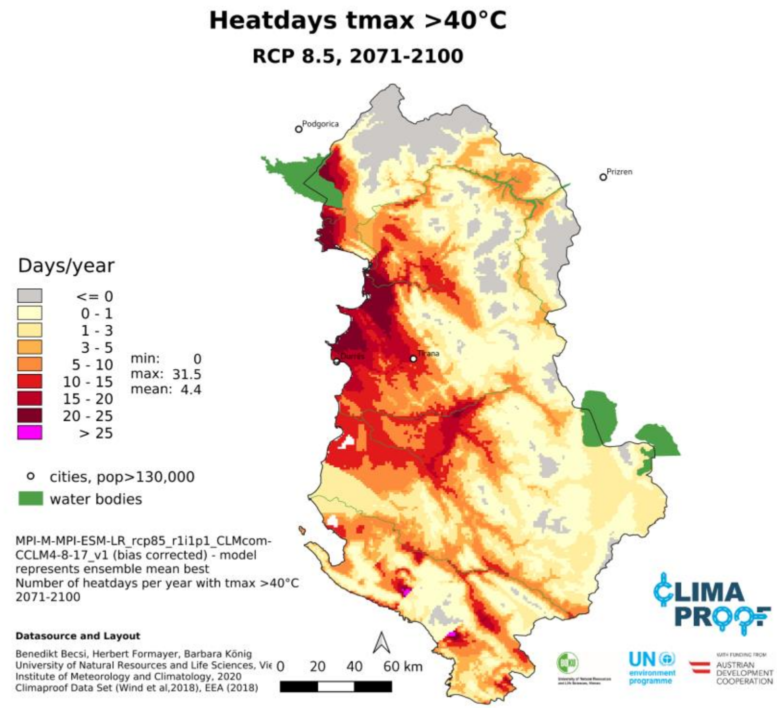
WITH FUNDING FROM AUSTRIAN DEVELOPMENT COOPERATION


Heatdays tmax >40°C
RCP 8.5, 2071-2100
Podgorica
Prizren
Durrës
Tirana
Days/year
<= 0
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 25
> 25
min: 0
max: 31.5
mean: 4.4
cities, pop>130,000
water bodies
MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-CCLM4-8-17_v1 (bias corrected) - model represents ensemble mean best
Number of heatdays per year with tmax >40°C
2071-2100
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0 20 40 60 km
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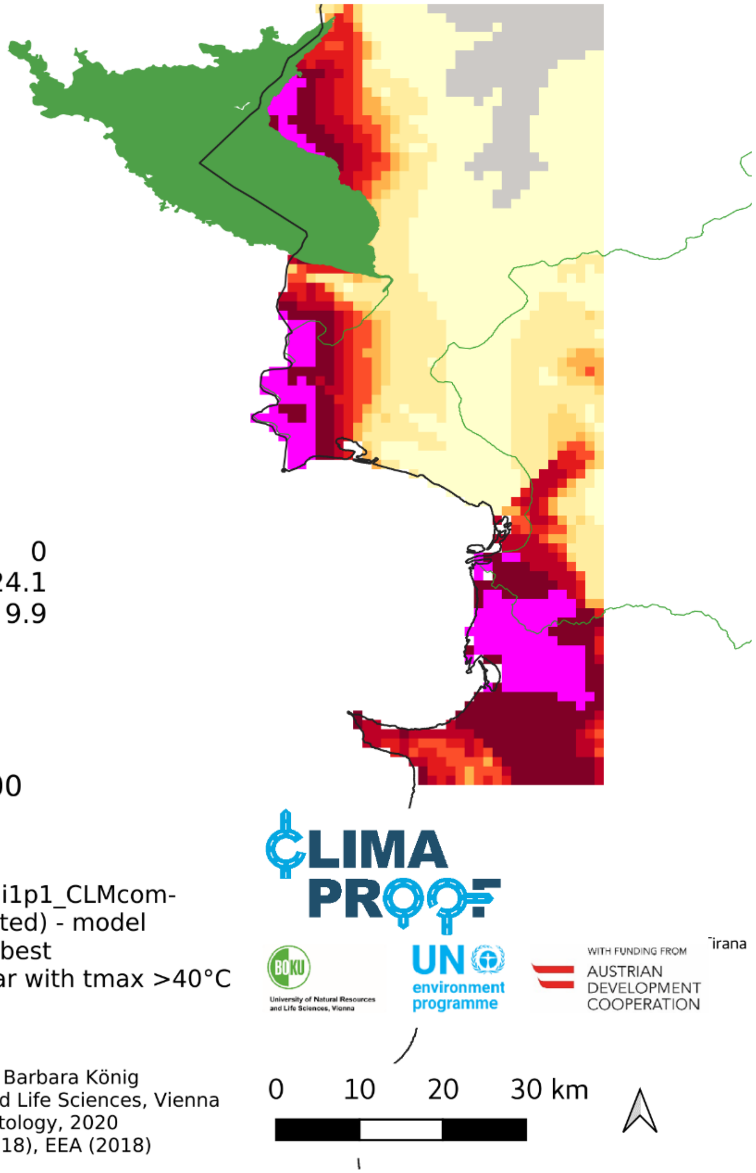
Heatdays tmax >40°C

RCP 8.5, 2071-2100



Days/year

- <= 0
- 0 - 5
- 5 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- > 22
- cities, pop>130,000
- water bodies

min: 0
max: 24.1
mean: 9.9

MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-CCLM4-8-17_v1 (bias corrected) - model represents ensemble mean best
Number of heatdays per year with tmax >40°C
2071-2100

Datasource and Layout

Benedikt Becsi, Herbert Formayer, Barbara König
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Climaproof Data Set (Wind et al,2018), EEA (2018)

CLIMA PROOF

University of Natural Resources and Life Sciences, Vienna

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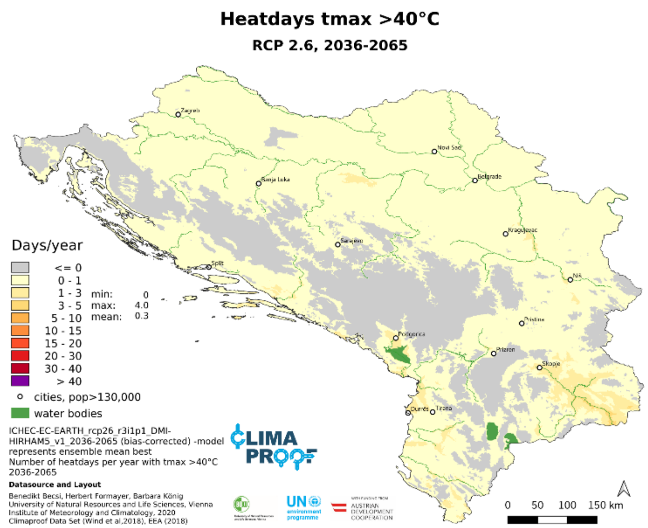
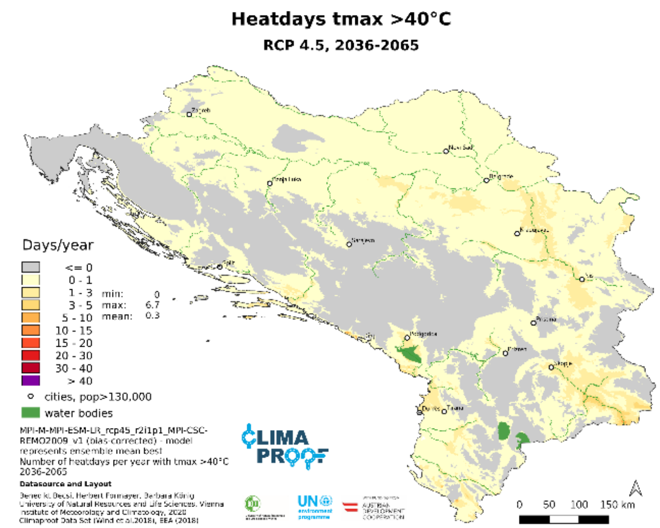
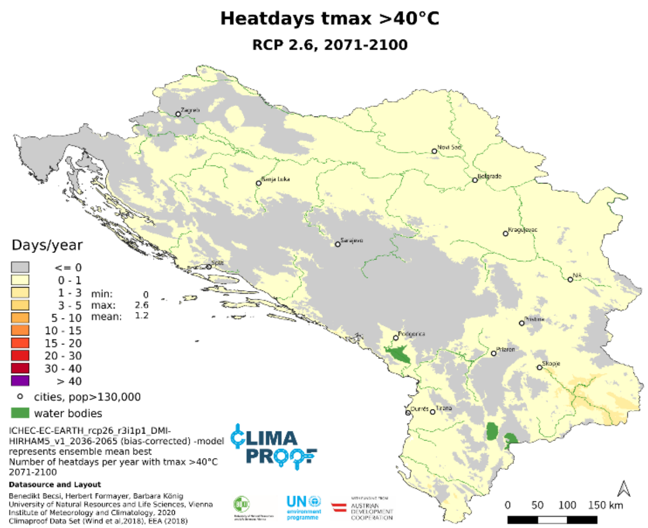
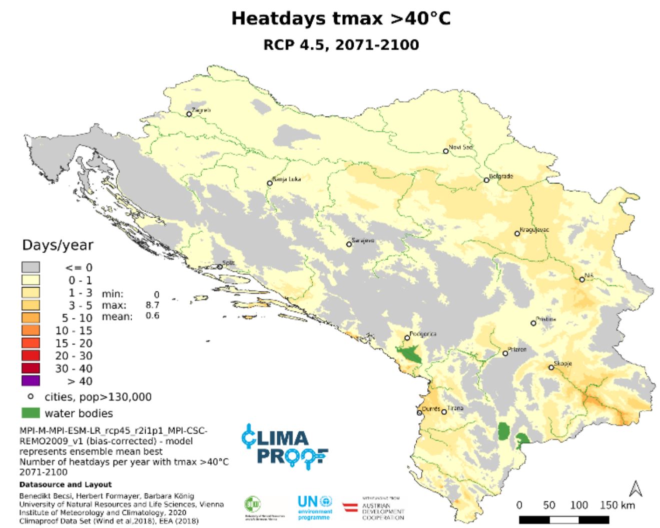
0 10 20 30 km

Example 2:
Days with tmax >40°C
different scenarios: 2.6 & 4.5 (mean)

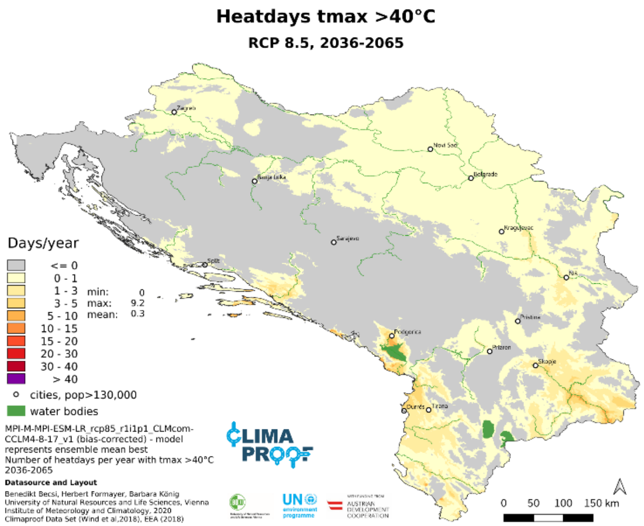


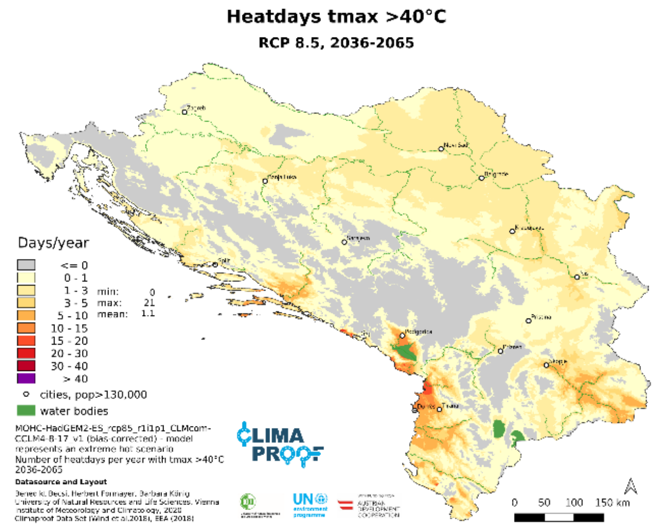


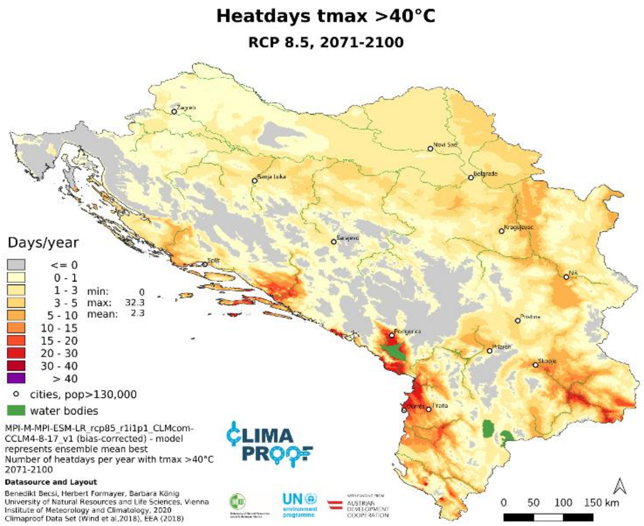


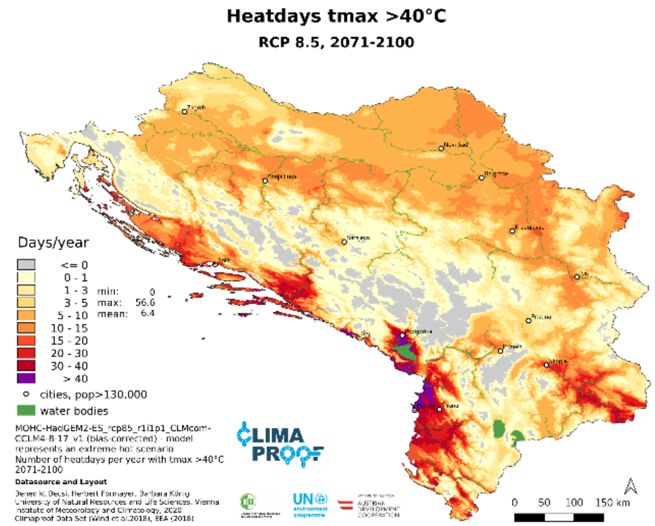


Example 2:
Days with tmax >40°C
different scenarios: 8.5 (mean, extreme hot)

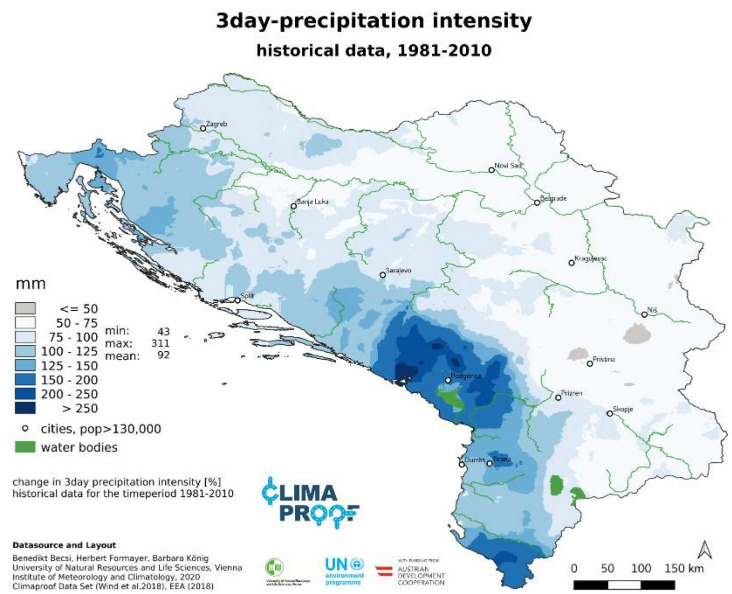


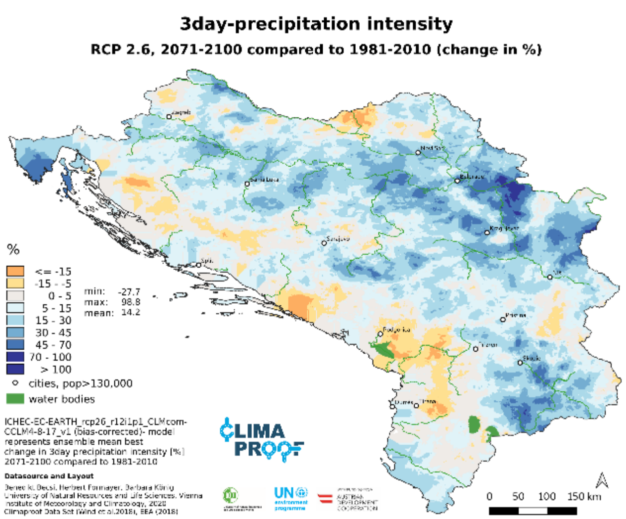


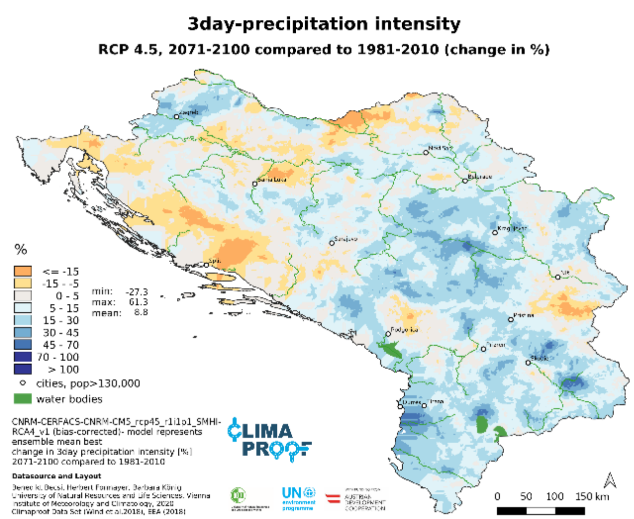


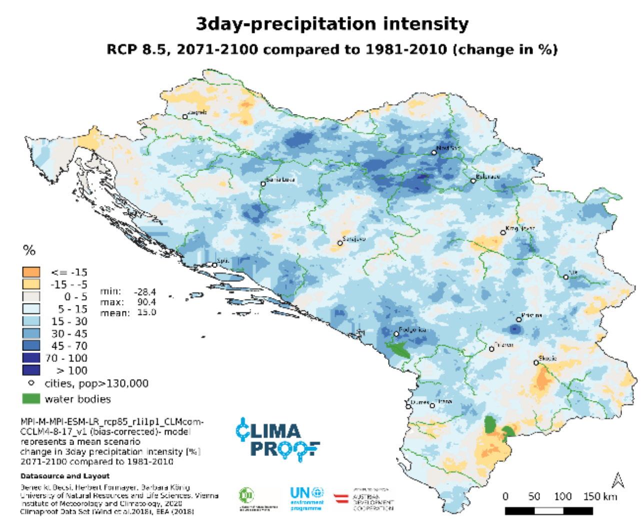


Example 3:
3-day precipitation maximum (change),





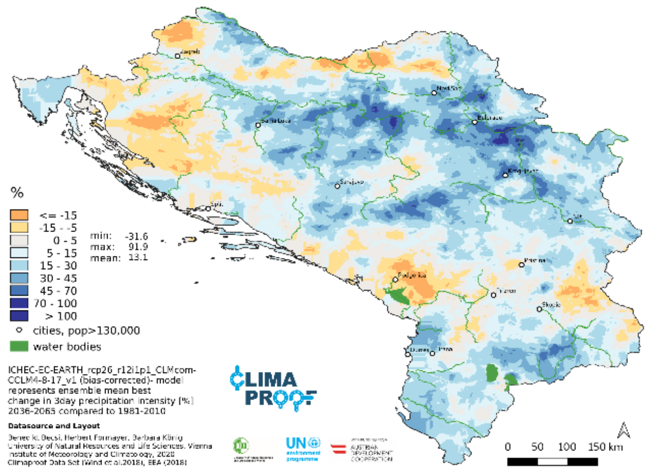




Example 3:
3-day precipitation maximum (change),
different scenarios: 2.6 & 4.5 (mean)

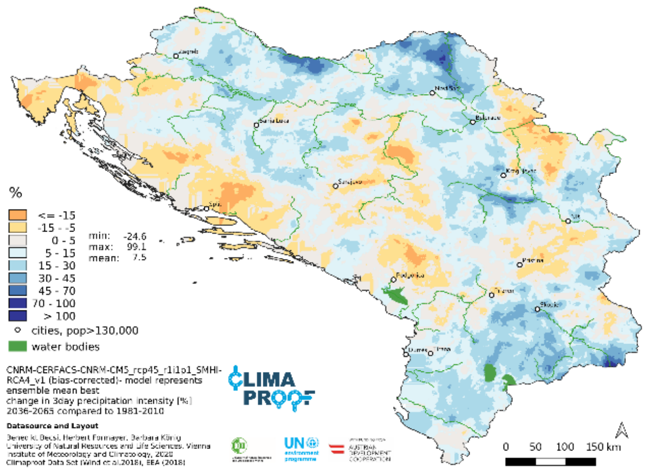
3day-precipitation intensity

RCP 2.6, 2036-2065 compared to 1981-2010 (change in %)



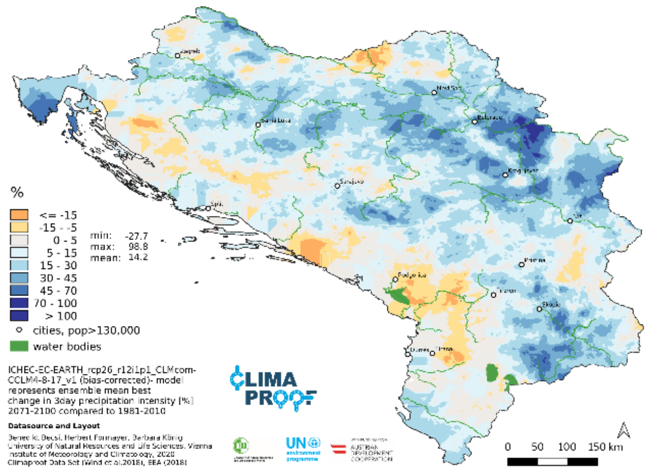
3day-precipitation intensity

RCP 4.5, 2036-2065 compared to 1981-2010 (change in %)



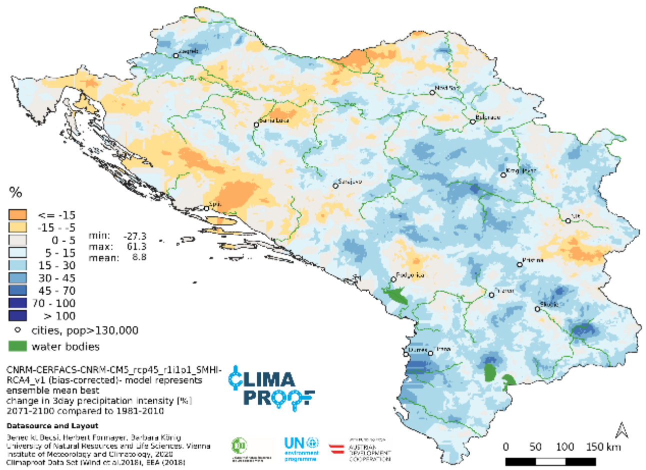
3day-precipitation intensity

RCP 2.6, 2071-2100 compared to 1981-2010 (change in %)

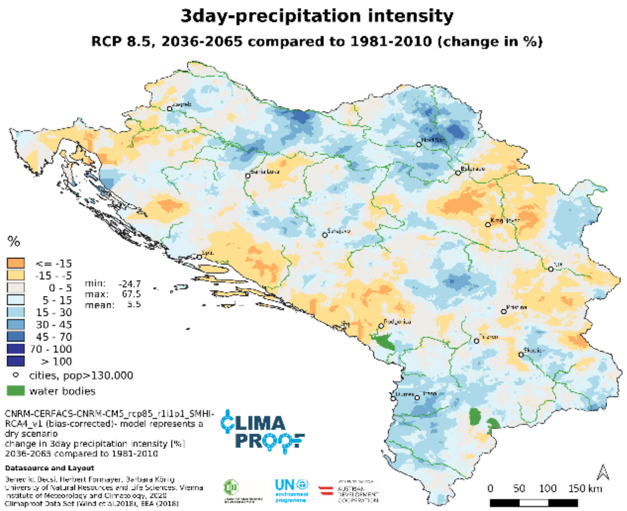


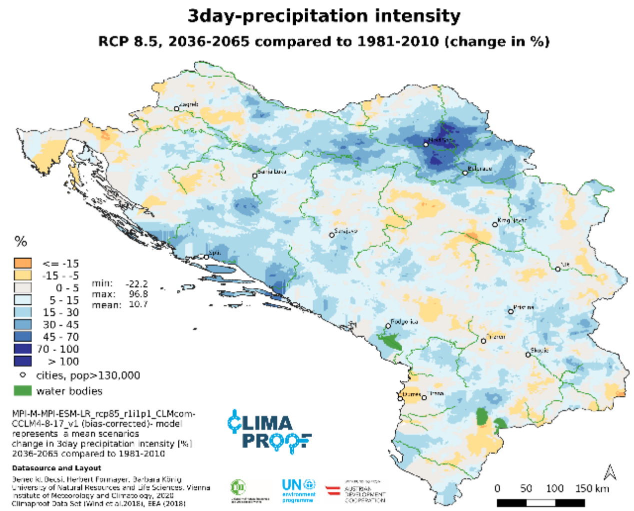
3day-precipitation intensity

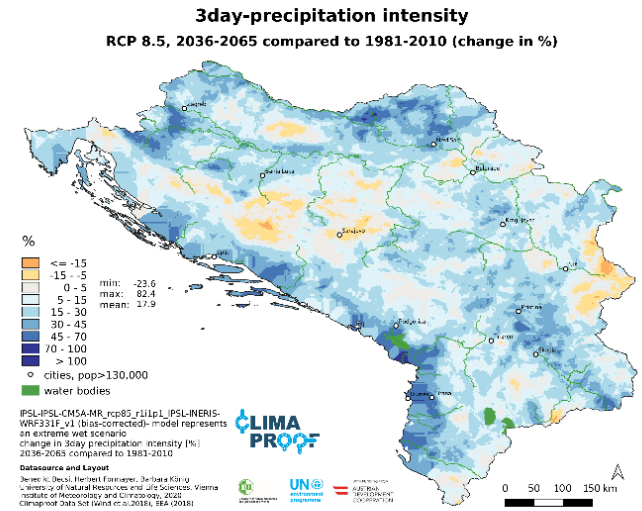
RCP 4.5, 2071-2100 compared to 1981-2010 (change in %)

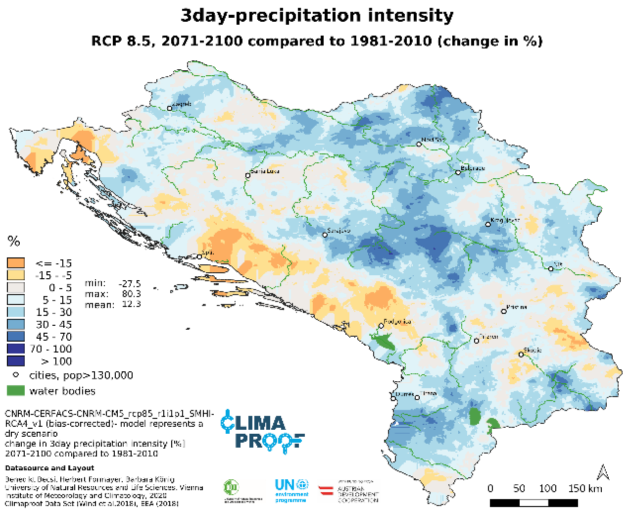


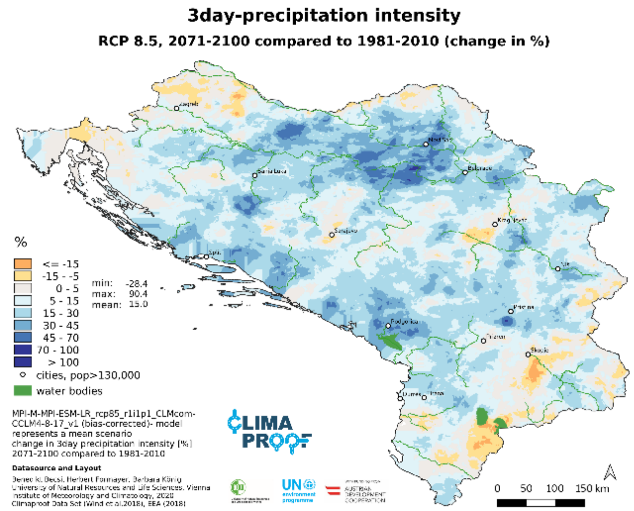
Example 3:
3-day precipitation maximum (change),
different scenarios: 8.5 (dry, mean, wet)

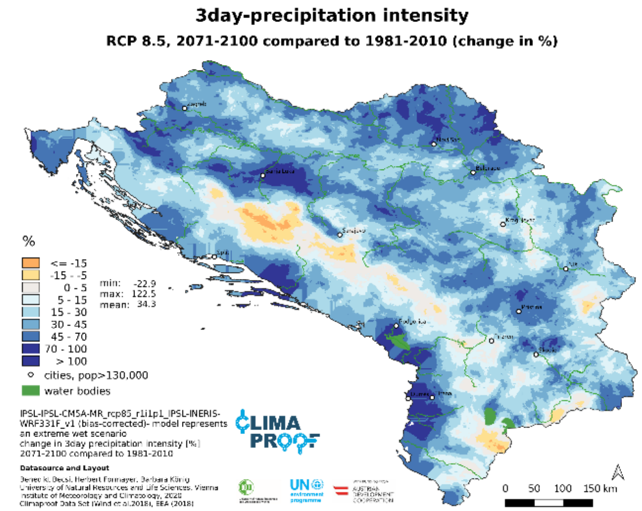






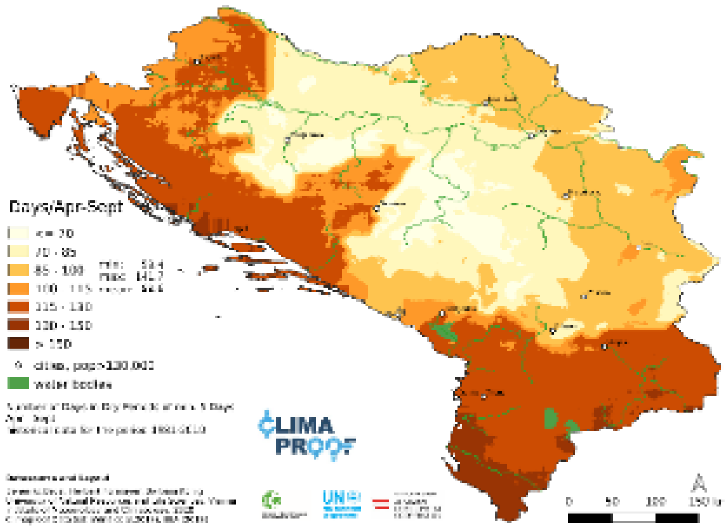




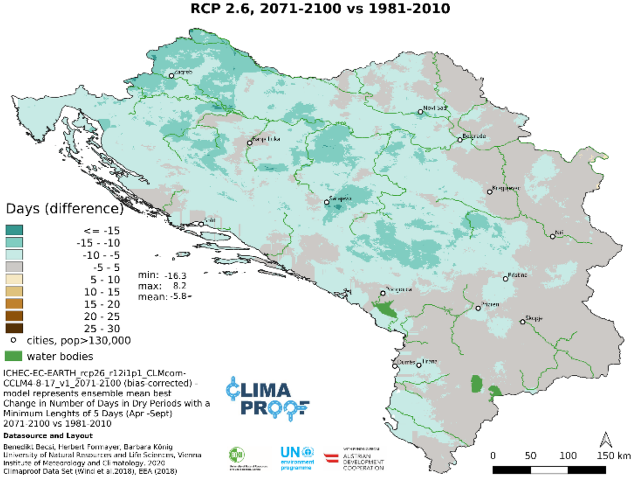


Example 4:
concecutive dry days

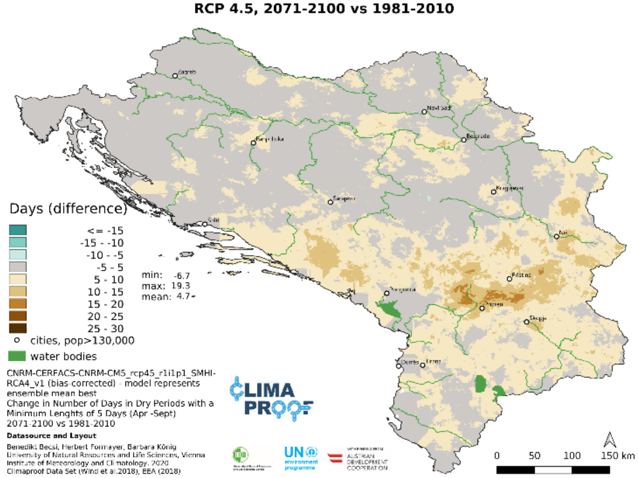
Number of Days in a Dry Period of min. 5 days
historical data, 1981-2010



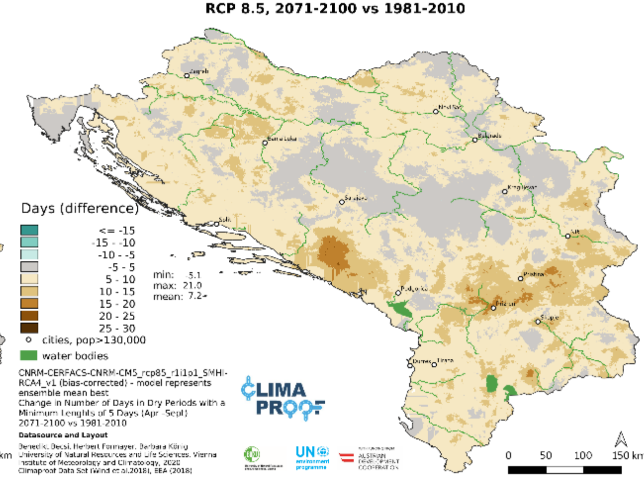
Change in Number of Days in a Dry Periods of min. 5 days
RCP 2.6, 2071-2100 vs 1981-2010



Change in Number of Days in a Dry Periods of min. 5 days
RCP 4.5, 2071-2100 vs 1981-2010

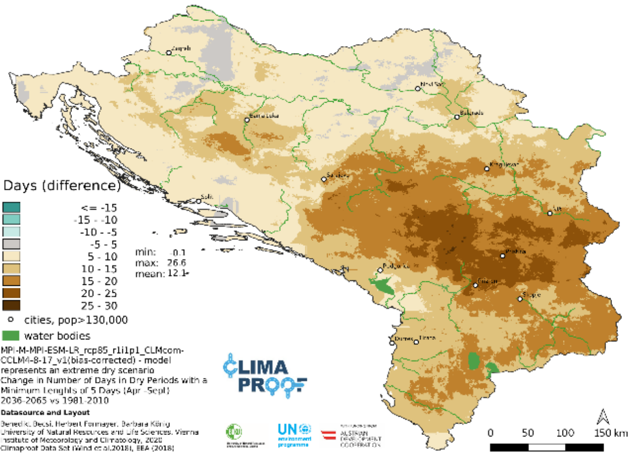


Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2071-2100 vs 1981-2010

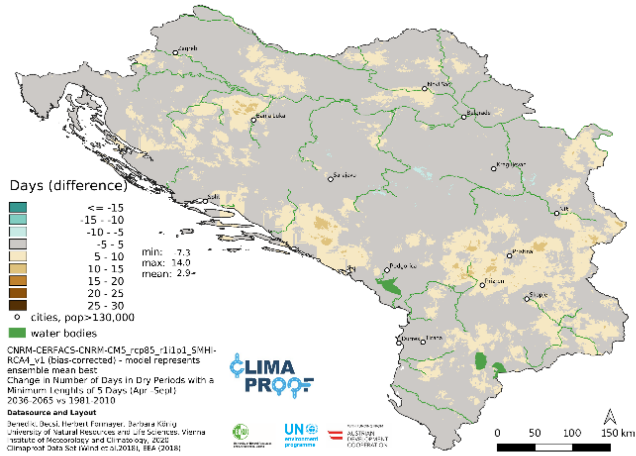


Example 4:
concecutive dry days

Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2036-2065 vs 1981-2010



Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2036-2065 vs 1981-2010



Change in Number of Days in a Dry Periods of min. 5 days
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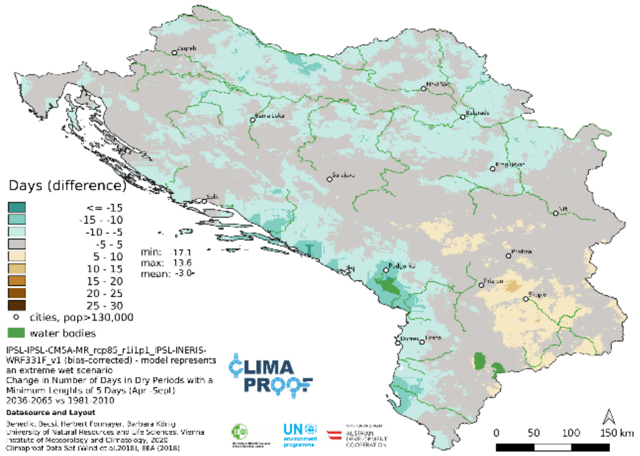
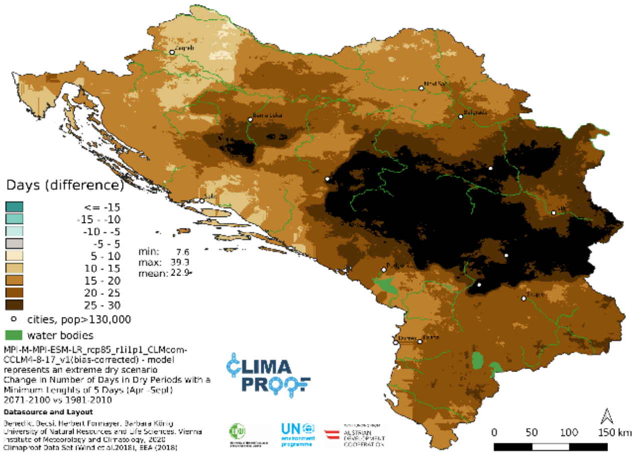
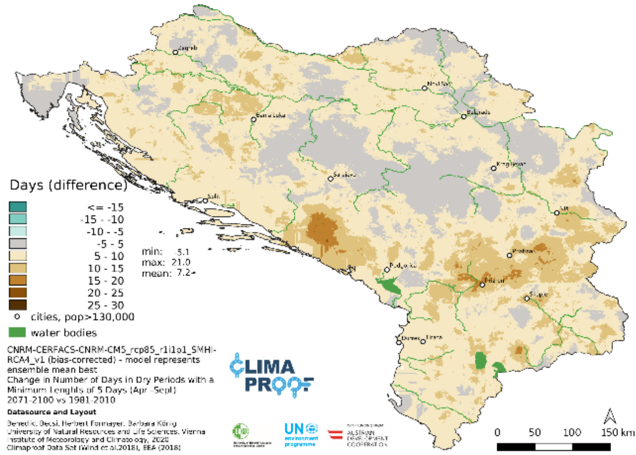


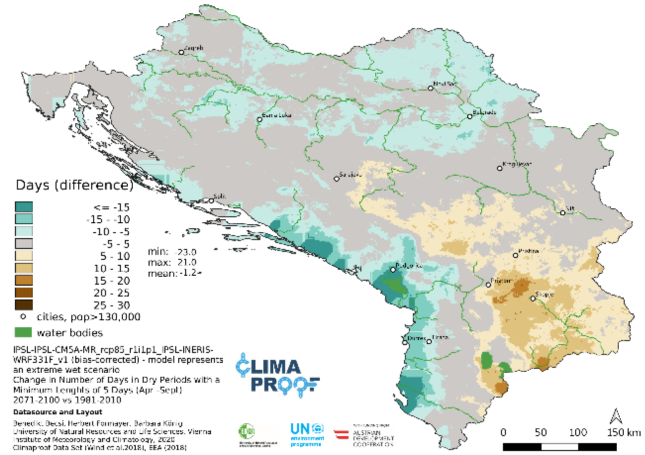
Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2071-2100 vs 1981-2010



Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2071-2100 vs 1981-2010



Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2071-2100 vs 1981-2010



Combination of indicators

- meteorological indicators
  - Heatdays and Dry spell (concecutive dry days) – risk of forest fire

- meteorological indicators and topography
  - Heavy Precipitation and topography – risk of landslides

- meteorological indicators and demographic data
  - Heat and age of population – risk for elderly people

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Indicators with relevance for (road)infrastructure – scientific results

based on Asian Development Bank, 2011, Bessembinder, 2015; Bles, et al., 2010; and Jiricka-Pürrer et al., 2014

- Heavy precipitation (one-day or several days)
  - Flooding
  - Erosion
  - Weakening of road embankements
  - Overloading drainage systems
- Annual or seasonal precipitation sum
  - Structural integrity of roads, bridges and tunnels (soil moisture levels)
  - Risk of floods, landslides and slope failures (if change in precipitation pattern)
- Snowfall
  - Increased maintenance costs (snow removal)
  - Snow avalanches
  - Flooding from snowmelt
- Drought
  - Increased risk of wildfires threatening transport infrastructure
  - Threats from areas deforested by wildfires (decreased soil integrity)

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Indicators with relevance for (road)infrastructure – scientific results

based on Asian Development Bank, 2011, Bessembinder, 2015; Bles, et al., 2010; and Jiricka-Pürrer et al., 2014

- Heatdays and Heatwaves
  - Pavement integrity (Rutting, cracking and blow-ups of asphalt; migration of liquid bitumen)
  - Thermal expansion in bridge expansion joints and pavements
  - Increased risk of forest fires incl. embankment flora
- Cold spells
- Frost & Forst-Thaw-Cycle
  - Cracking due to weakening of the road base
  - Increases risk of stone chipping
- Extreme wind speed
  - Threat to stability of bridges
  - Trees, windmill, noise barriers and trucks falling on the road and reduced vehicle control

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Discussion:
relevance and prioritization of climate indicators for the Western Balkan region

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EU good practices in incorporating climate projections in infrastructure planning and development

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Excursus:

Presentation by Alexandra Jiricka-Pürrer MSc. PhD

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Discussion

When using environmental assessment instuments (EIA, SEA or equivalent):

- Are interdependencies between EU Directives (i.e. national equivalent regulations) and assessment instruments (EIA, SEA) being considered?
- Are interdependencies with regards to climate change being considered?

If not: Where do you see the main obstacles for implementation?

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University of Natural Resources and Life Sciences, Vienna
Departement of Water, Atmosphere and Environment
Intitue of Meteorology and Climatology

Assoc.Prof. Dr. Herbert Formayer

Gregor-Mendel-Str. 33, A-1180 Wien

Tel.: +43 1 476 54 - 81415

herbert.formayer@boku.ac.at , http://www.boku.ac.at/imp/klima/index.html

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