



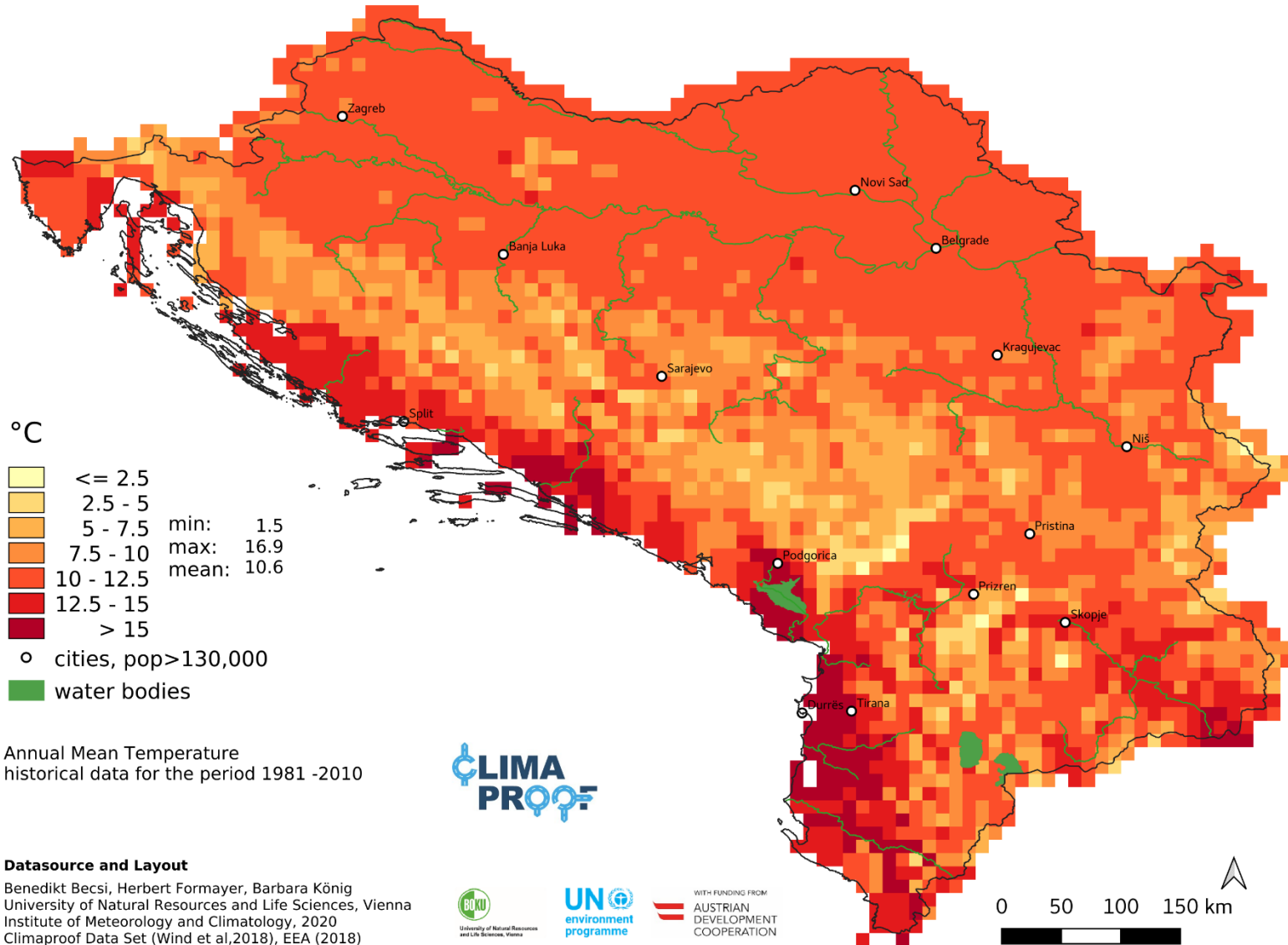
Online Workshop: Considering High Resolution Climate Change Projections for road infrastructure planning, development and maintenance

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**

Climate and Climate Change in the Western Balkan region

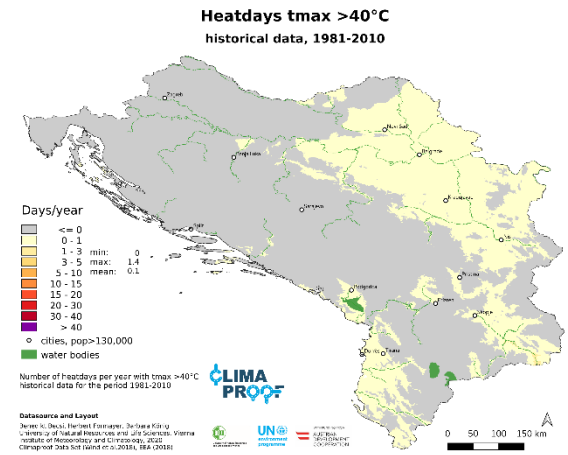
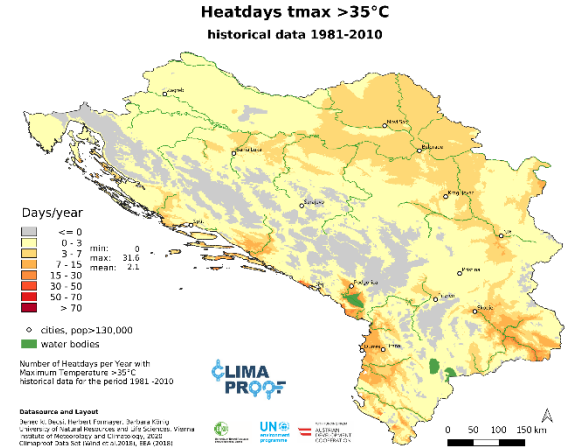
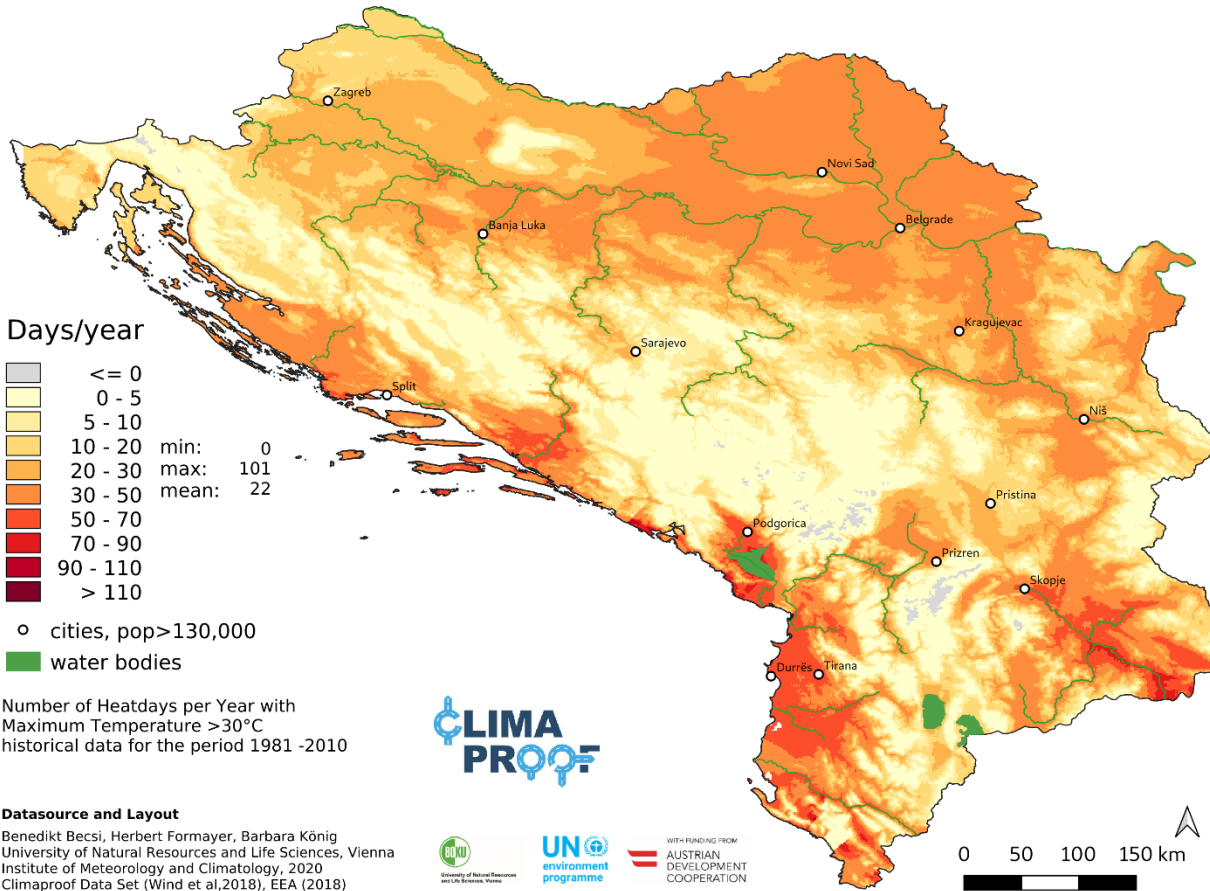
Annual Mean Temperature Observations 1981-2010



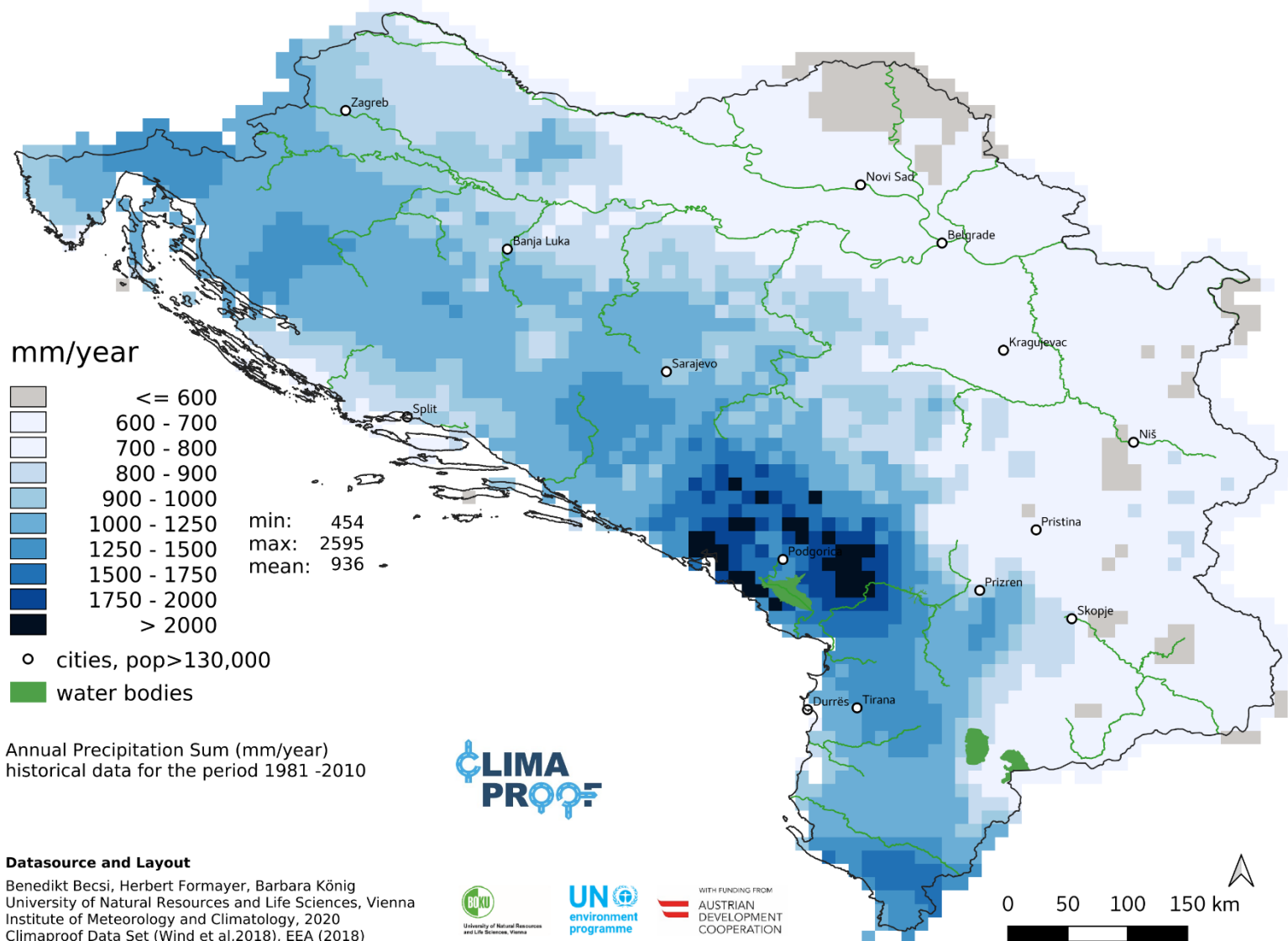
Datasource and Layout

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)

Number of Heatdays >30°C Observations 1981-2010



Annual Precipitation Sum Observations 1981-2010

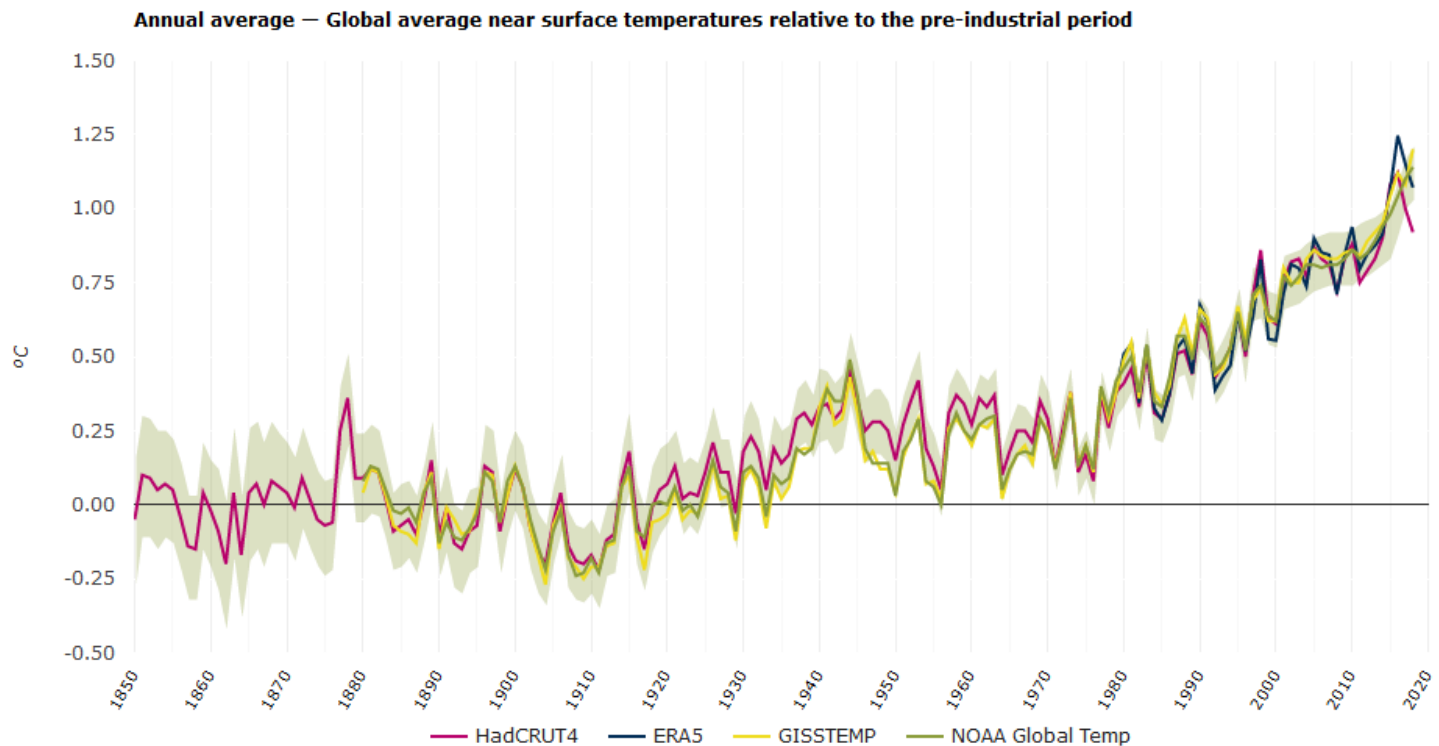


Datasource and Layout

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University of Natural Resources and Life Sciences, Vienna
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Climaproof Data Set (Wind et al,2018), EEA (2018)



Global Temperature Change



Data sources:

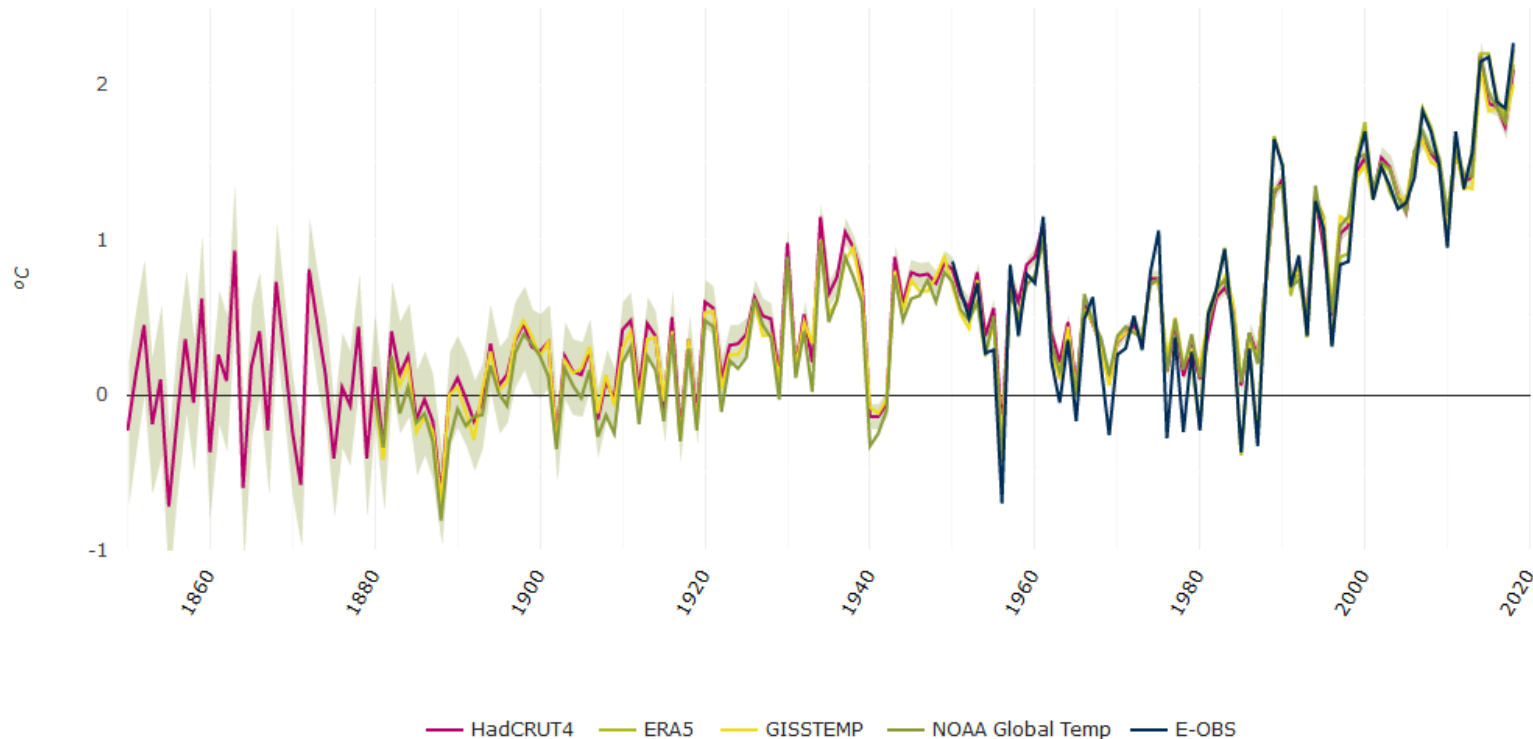
- Global Surface Temperature Anomalies and Annual Global (land and ocean combined) Anomalies (degrees C) provided by **National Oceanic and Atmospheric Administration (NOAA)**
- Annual Global (Land and Ocean) temperature anomalies - HadCRUT (degrees Celsius) provided by
- NASA - Goddard Institute for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

European Temperature Change

Annual average – European average temperatures over land areas relative to the pre-industrial period



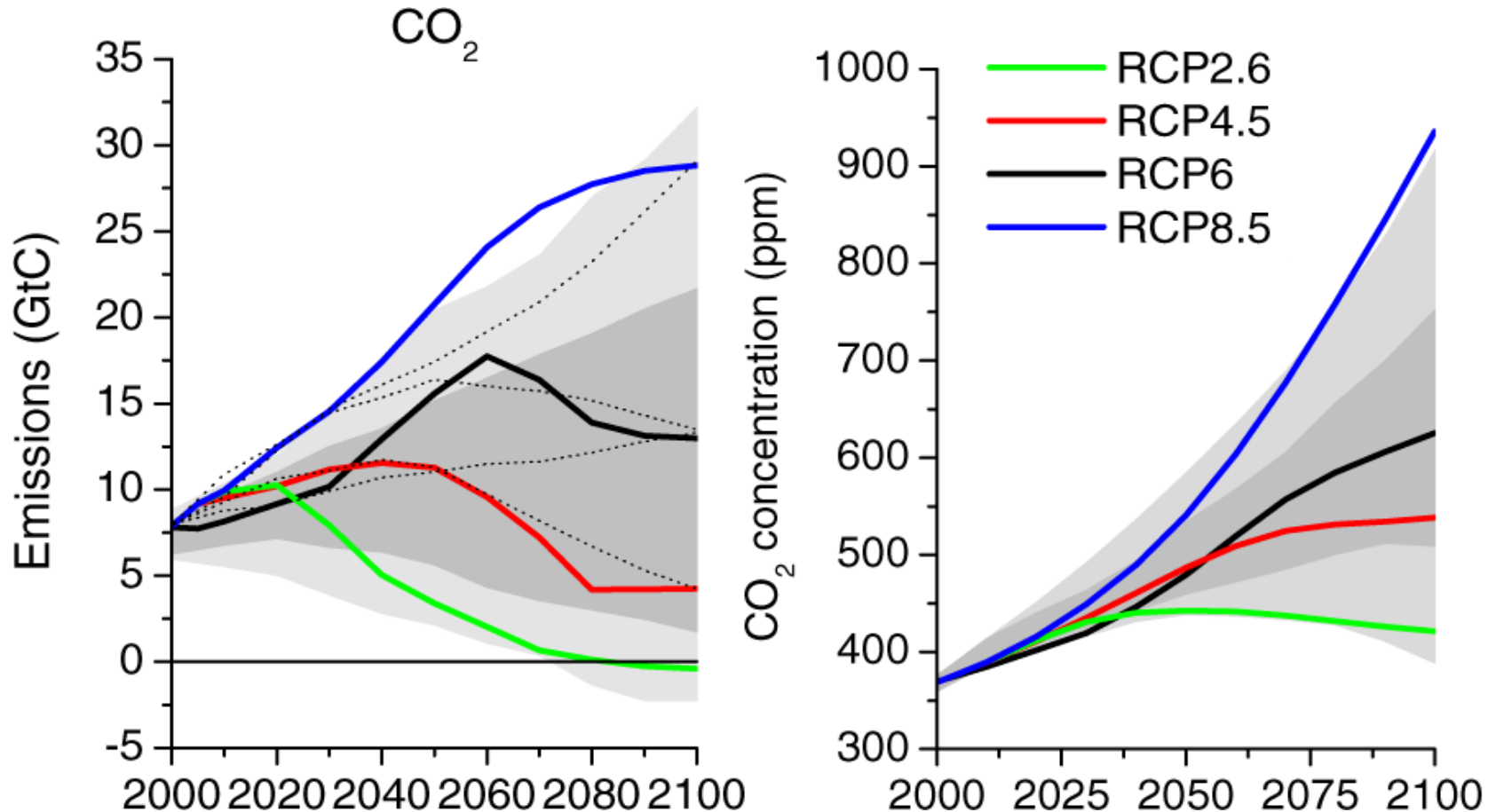
Data sources:

- 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>

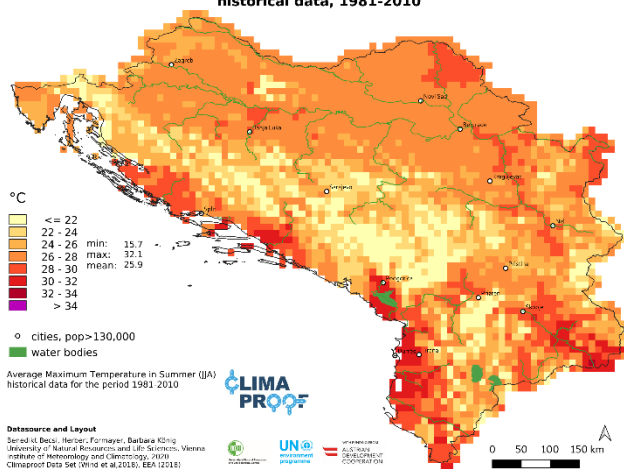
RCPs - Representative Concentration Pathways



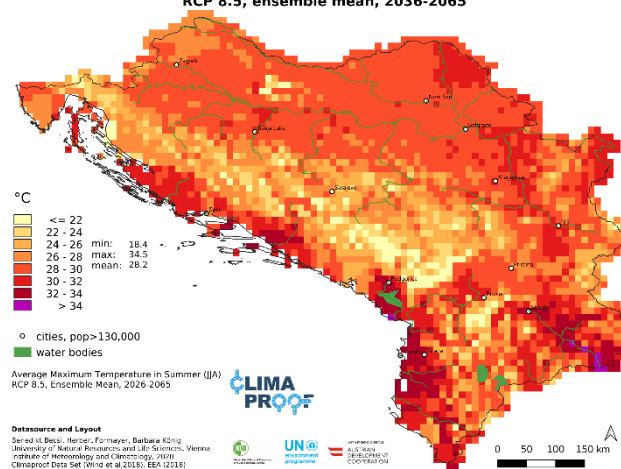
Van Vuuren et al, 2011

Average Maximum Temperature (JJA)

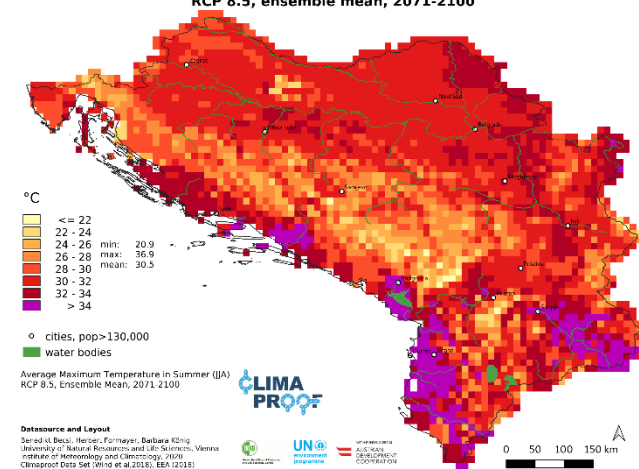
Average Maximum Temperature in Summer
historical data, 1981-2010



Average Maximum Temperature in Summer
RCP 8.5, ensemble mean, 2036-2065



Average Maximum Temperature in Summer
RCP 8.5, ensemble mean, 2071-2100



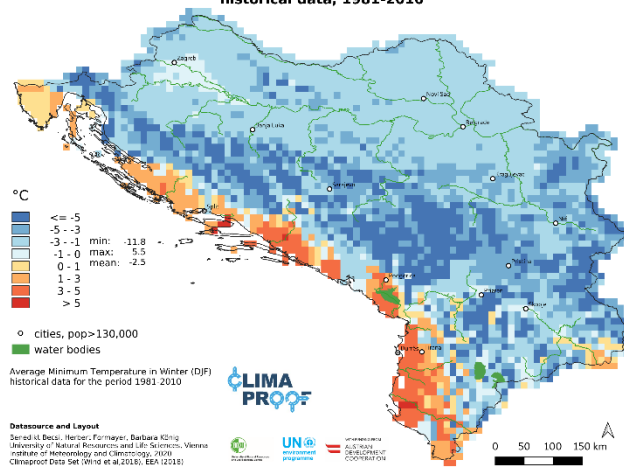
Dataset and Layout
Serdar Besi, Herber Formayer, Barbara Krieger
University of Natural Resources and Life Sciences, Vienna
Institute of Meteorology and Climatology, WUWI
Climaproof Data Set (Wilo et al. 2018), EEA (2018)

Dataset and Layout
Serdar Besi, Herber Formayer, Barbara Krieger
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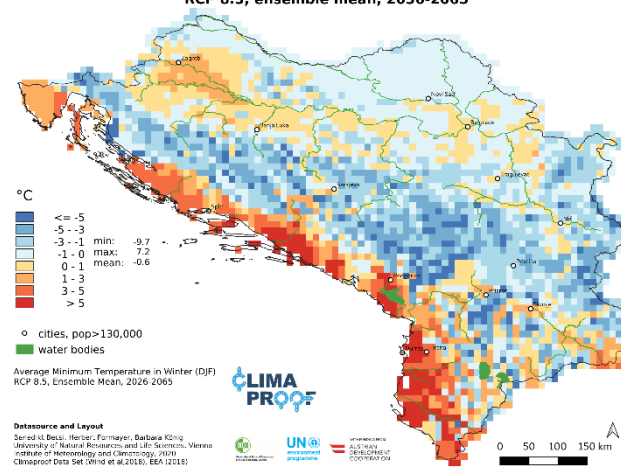
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Institute of Meteorology and Climatology, WUWI
Climaproof Data Set (Wilo et al. 2018), EEA (2018)

Average Minimum Temperature (DJF)

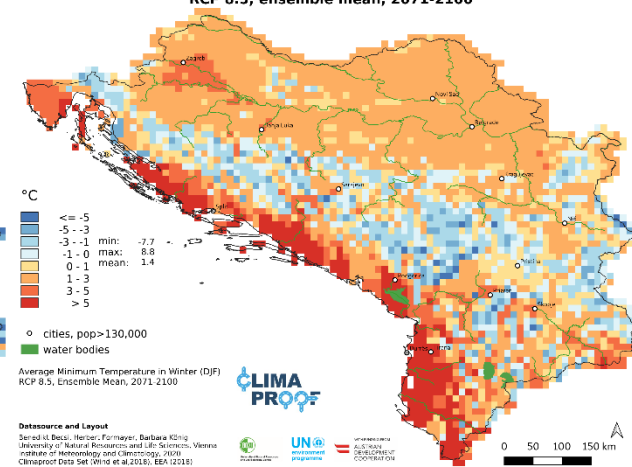
Average Minimum Temperature in Winter
historical data, 1981-2010



Average Minimum Temperature in Winter
RCP 8.5, ensemble mean, 2036-2065



Average Minimum Temperature in Winter
RCP 8.5, ensemble mean, 2071-2100



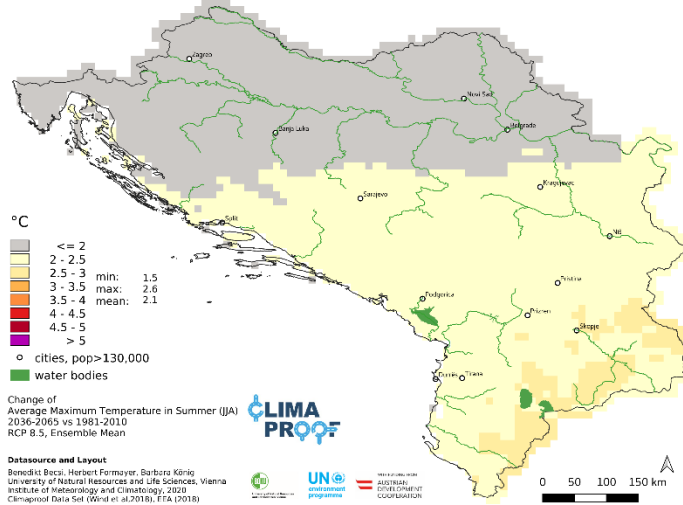
Data source and Layout
Serdar Al. Beci, Herzer, Formayer, Barbara König
University of Natural Resources and Life Sciences, Vienna
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ClimatePro Data Set (Wind et al. 2018); EEA (2018)

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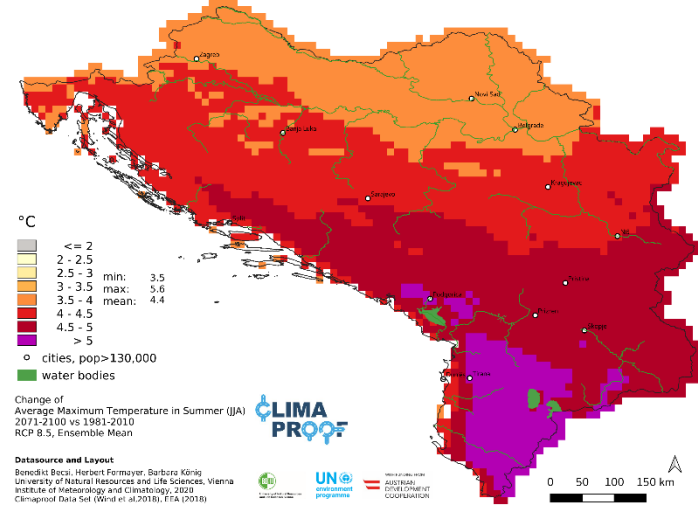
Data source and Layout
Serdar Al. Beci, Herzer, Formayer, Barbara König
University of Natural Resources and Life Sciences, Vienna
Institute of Meteorology and Climatology, 2020
ClimatePro Data Set (Wind et al. 2018); EEA (2018)

Change of Average Temperature (Tmax JJA, Tmin DJF)

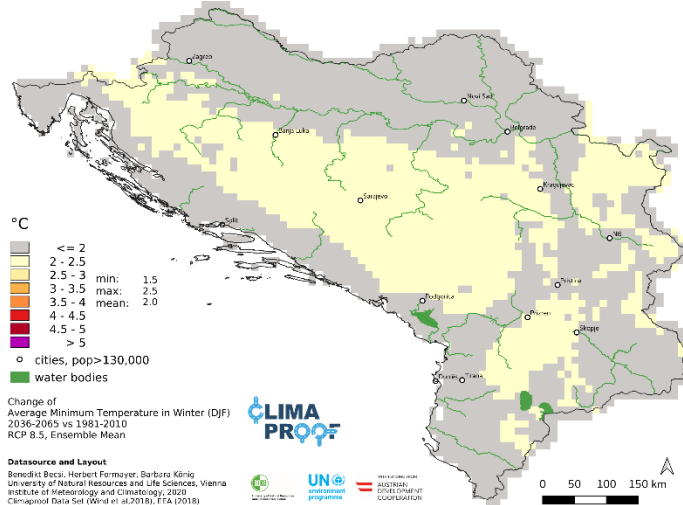
Change of Average Maximum Temperature in Summer
RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010



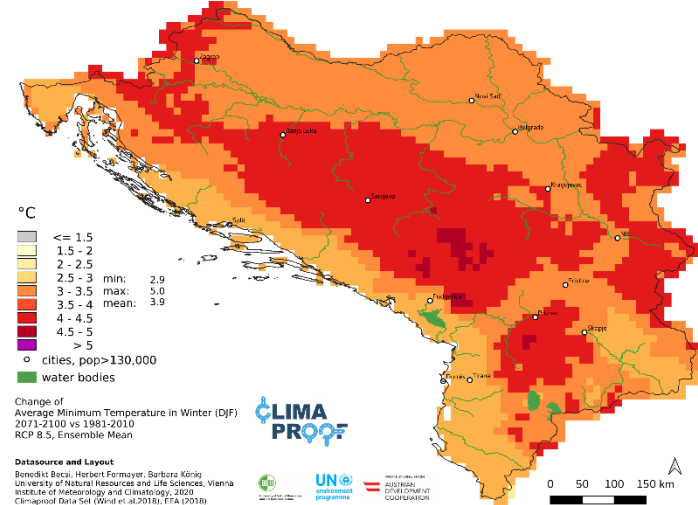
Change of Average Maximum Temperature in Summer
RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010



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

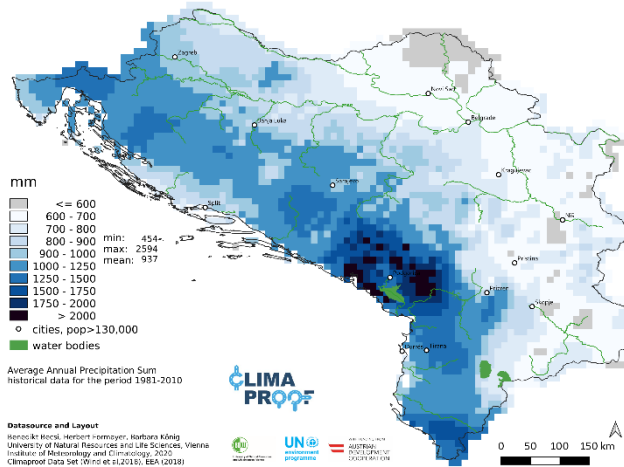


Change of Average Minimum Temperature in Winter
RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010

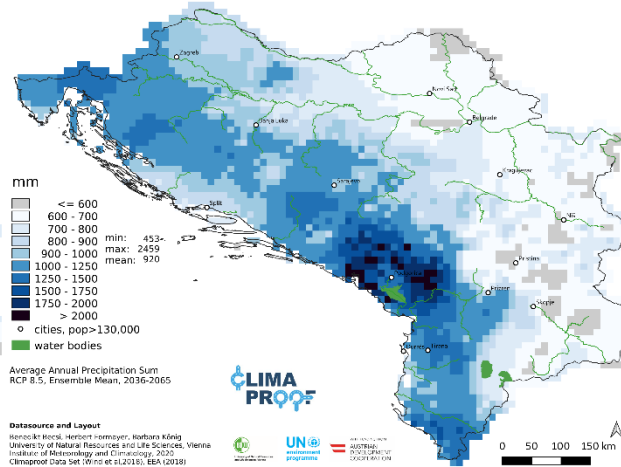


Precipitation sum – annual

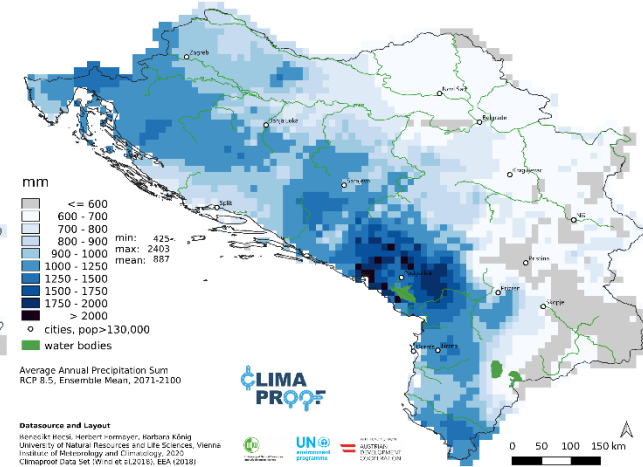
Average Annual Precipitation Sum
historical data, 1981-2010



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

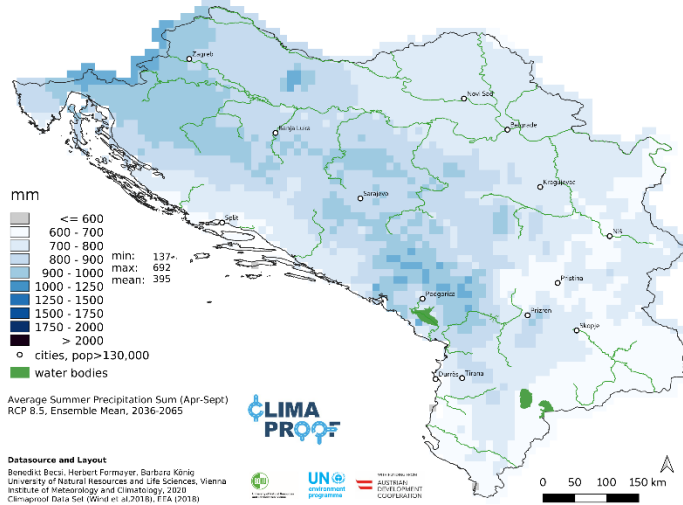


Average Annual Precipitation Sum
RCP 8.5, ensemble mean, 2071-2100

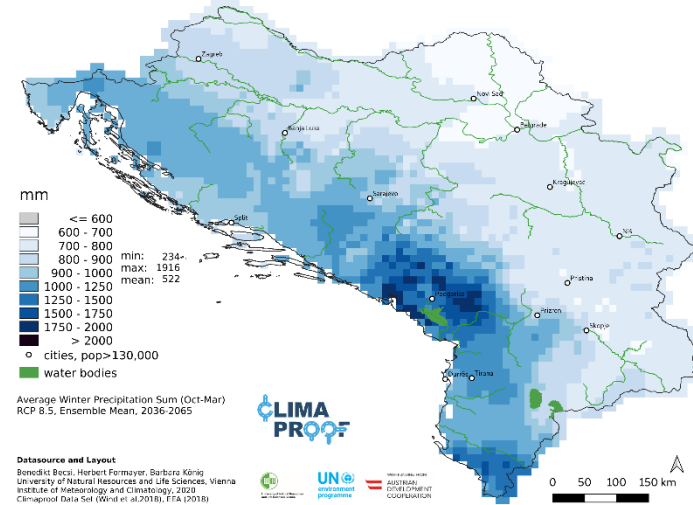


Precipitation sum – summer, winter

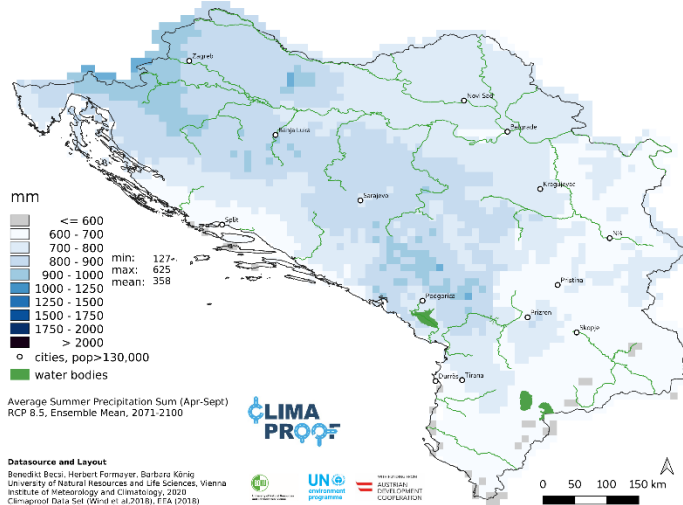
Average Summer Precipitation Sum
RCP 8.5, ensemble mean, 2036-2065



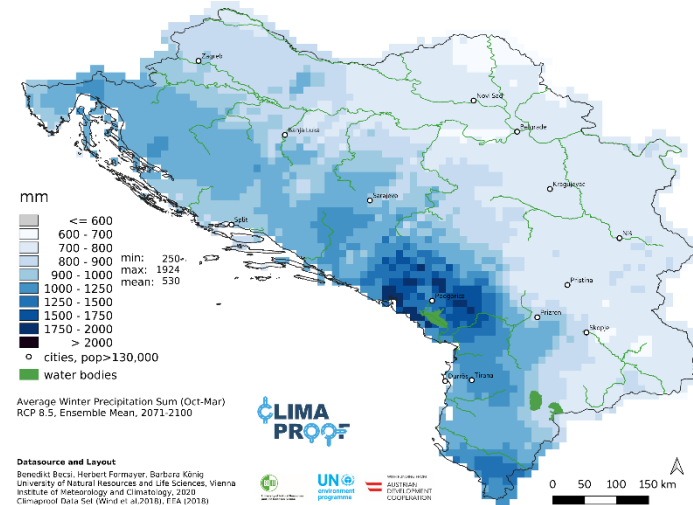
Average Winter Precipitation Sum
RCP 8.5, ensemble mean, 2036-2065



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

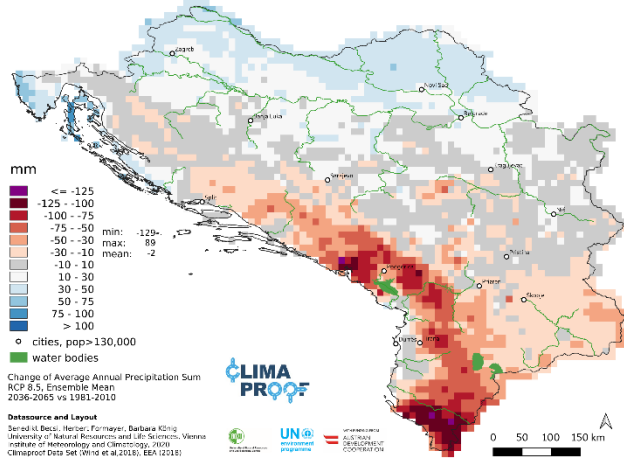


Average Winter Precipitation Sum
RCP 8.5, ensemble mean, 2071-2100

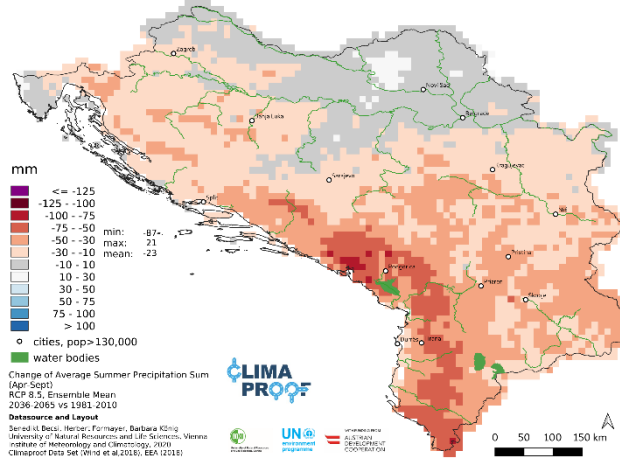


Change of Precipitation

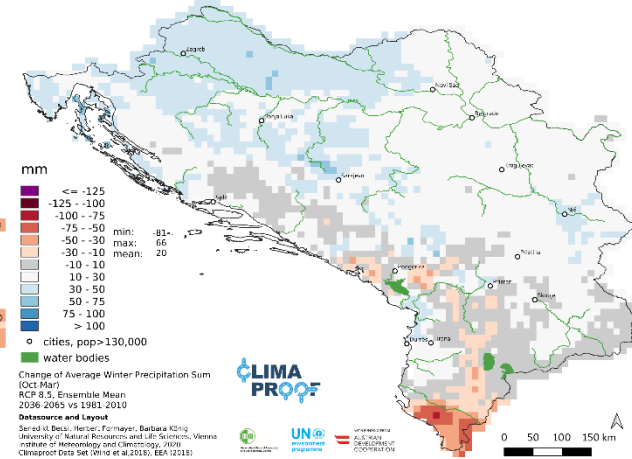
Change of Average Annual Precipitation Sum
RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010



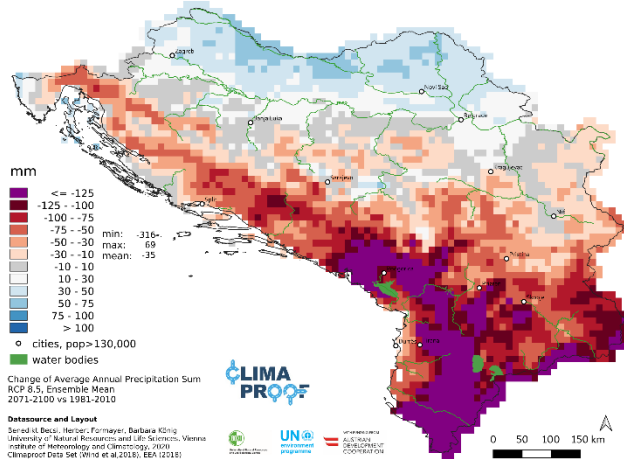
Change of Average Summer Precipitation Sum
RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010



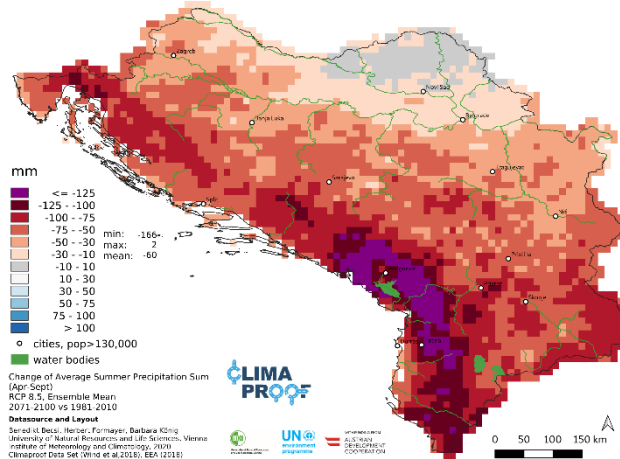
Change of Average Winter Precipitation Sum
RCP 8.5, ensemble mean, 2036-2065 vs 1981-2010



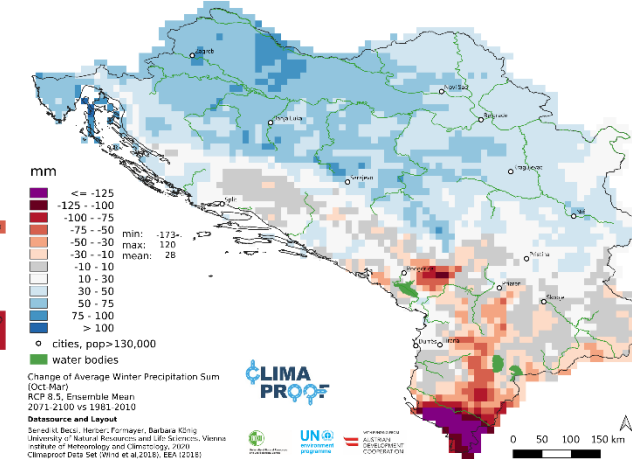
Change of Average Annual Precipitation Sum
RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010



Change of Average Summer Precipitation Sum
RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010

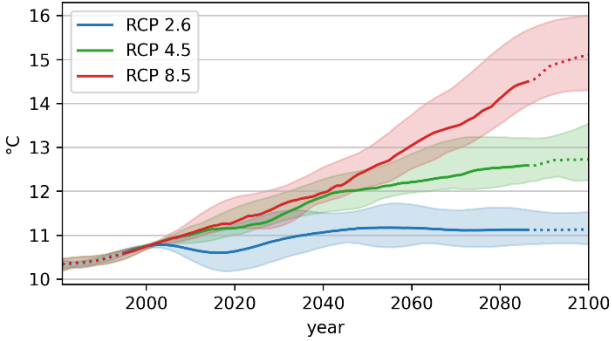


Change of Average Winter Precipitation Sum
RCP 8.5, ensemble mean, 2071-2100 vs 1981-2010

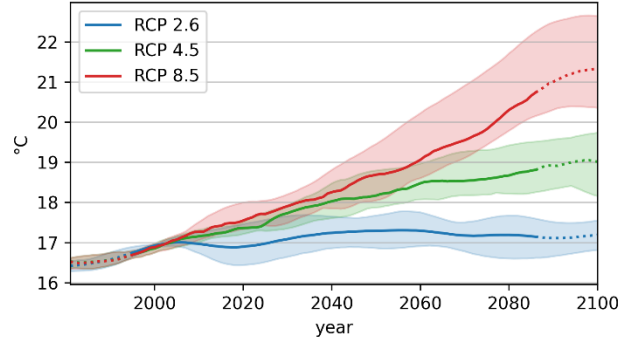


Timeseries temperature

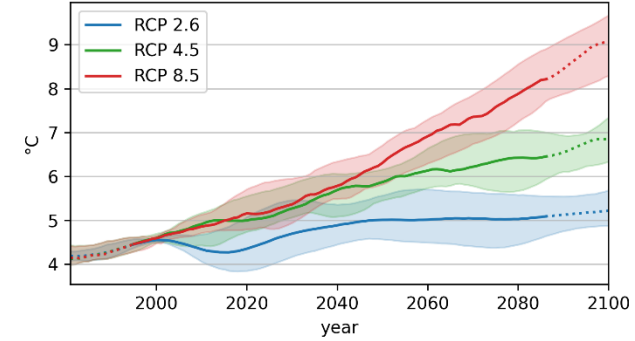
annual average temperature Western Balkan



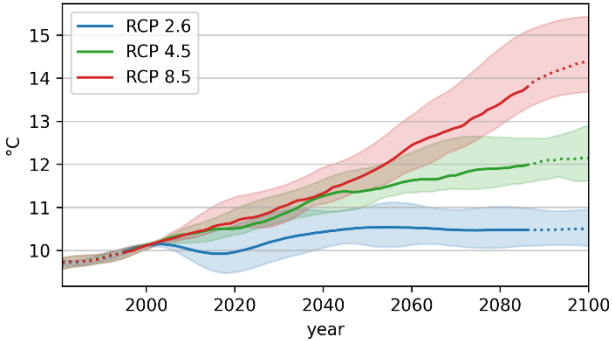
Apr-Sept average temperature Western Balkan



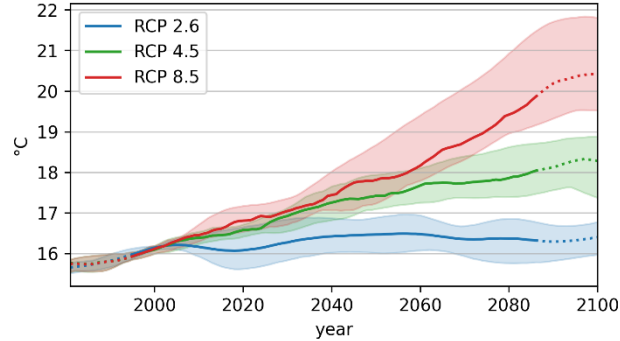
Oct-Mar average temperature Western Balkan



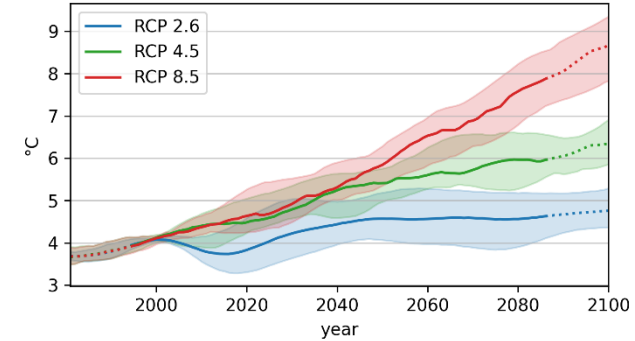
annual average temperature BiH



Apr-Sept average temperature BiH



Oct-Mar average temperature BiH

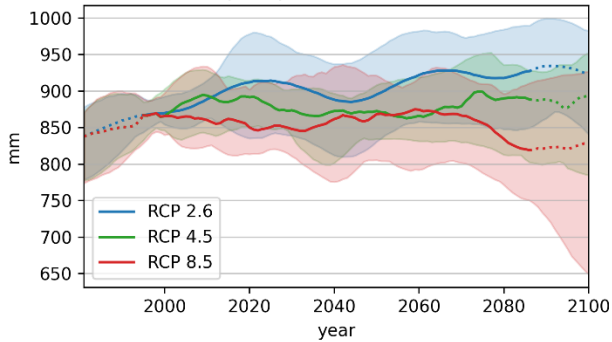


WITH FUNDING FROM

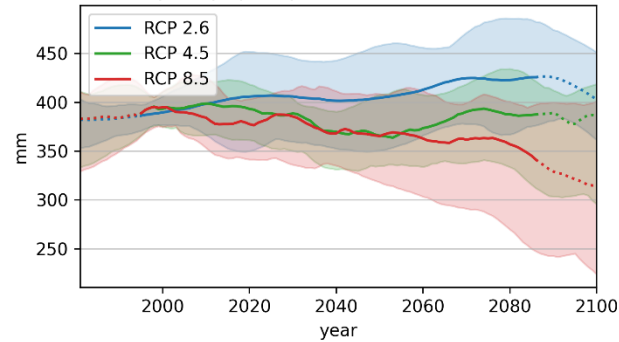


Timeseries annual precipitation

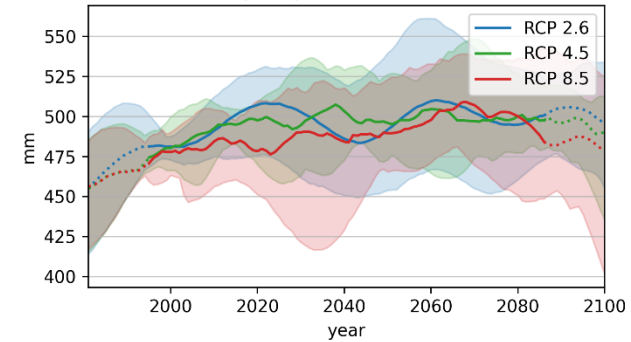
annual precipitation Western Balkan



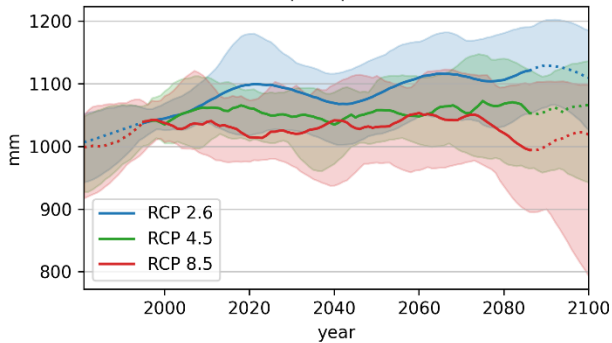
Apr-Sept precipitation Western Balkan



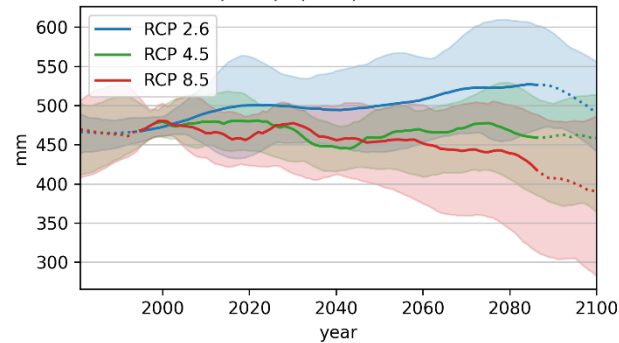
Oct-Mar precipitation Western Balkan



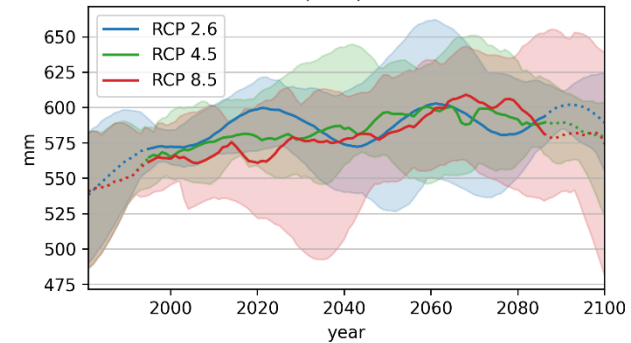
annual precipitation BiH



Apr-Sept precipitation BiH



Oct-Mar precipitation BiH



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



Questions

Remarks



WITH FUNDING FROM
AUSTRIAN
DEVELOPMENT
COOPERATION

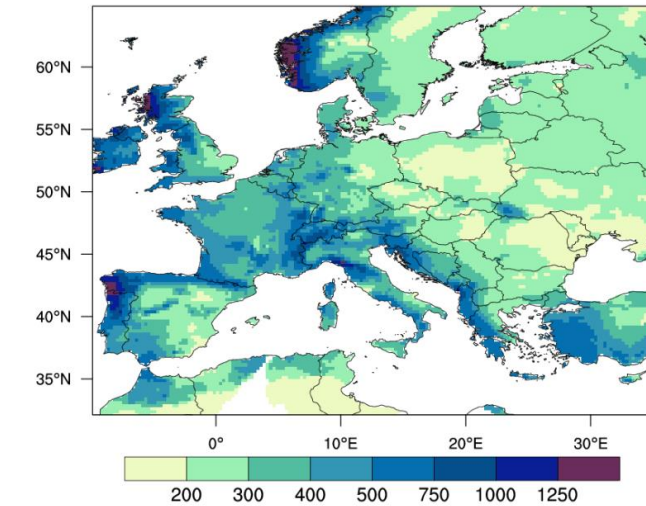


UN 
environment
programme

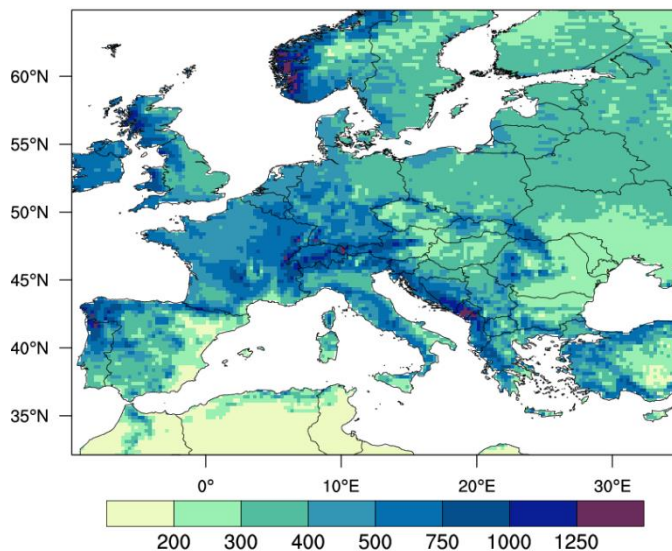
ClimaProof Dataset and Tools

Skills and weaknesses of Regional Climate Models

E-OBS Winter Precip 1960-91

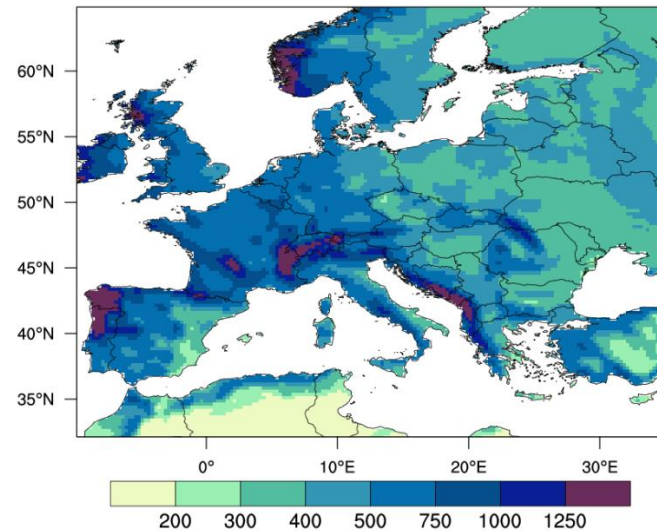


CNRM-ARPEGE Winter Precip 1960-91 Raw



Precipitation bias in RCMs
Winter (Oct-Mar) Precipitation
(left ALADIN right RegCM3)

ICTP-RegCM3 Winter Precip 1960-91 Raw



Data base – Model data

- Euro-Cordex¹ (40) and Med-Cordex² (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/>

WITH FUNDING FROM

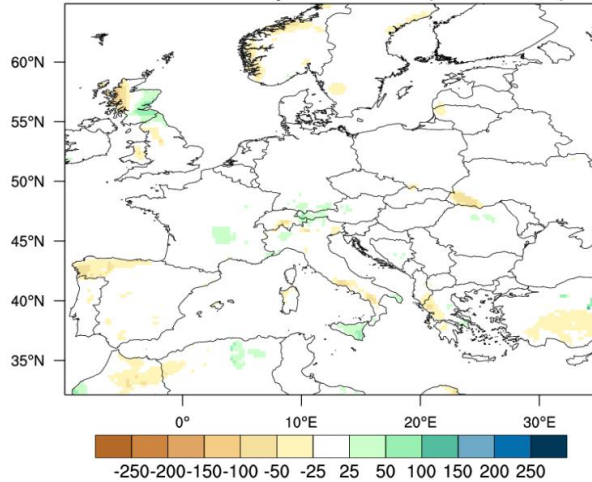
Data base – Observational data

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

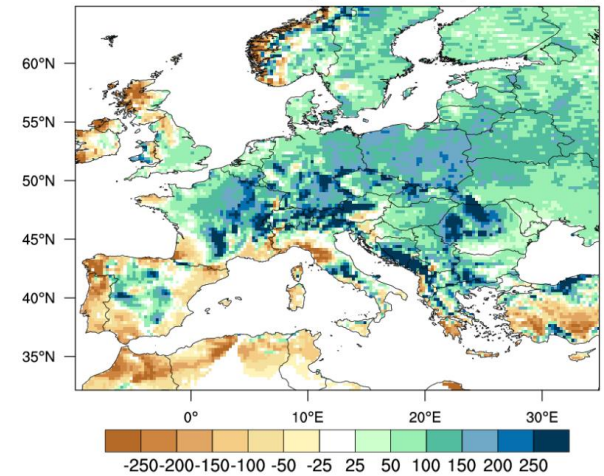
Ensemble of bias-corrected Climate Scenarios

Scaled-Distribution Mapping

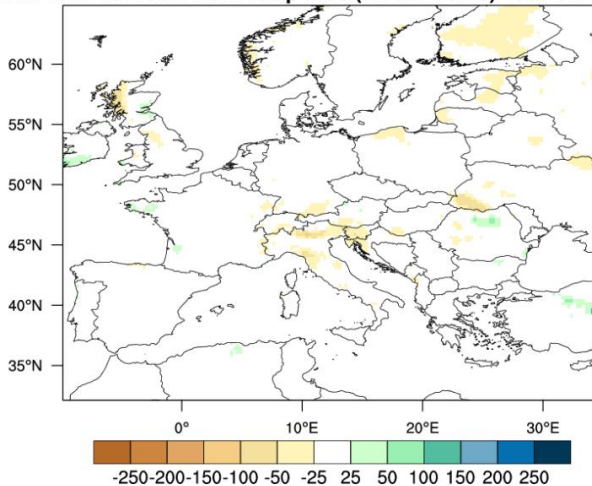
CNRM-ARPEGE Winter Precip 1960-91 Bias (Model-EOBS) Bias Corr.



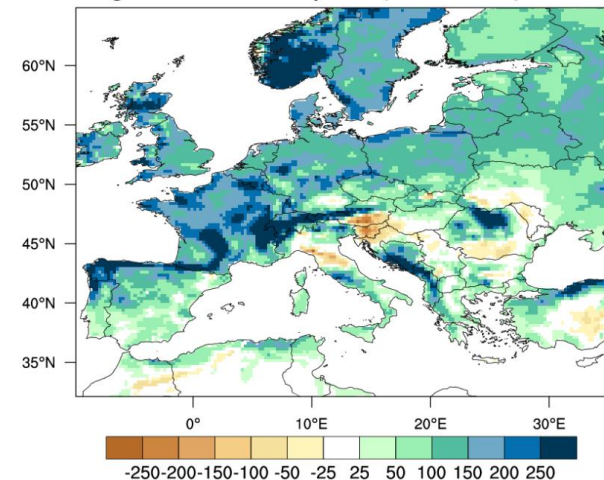
CNRM-ARPEGE Winter Precip 1960-91 Bias (Model-EOBS) Raw



CNRM-ARPEGE Summer Precip Bias (Model-EOBS) 1960-91 Bias Corr.



ICTP-RegCM3 Summer Precip Bias (Model-EOBS) 1960-91 Raw



**Precipitation-
bias in RCMs
left bias
corrected right
raw data (up
ALADIN down
RegCM3)**

CCCA Dataserver

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

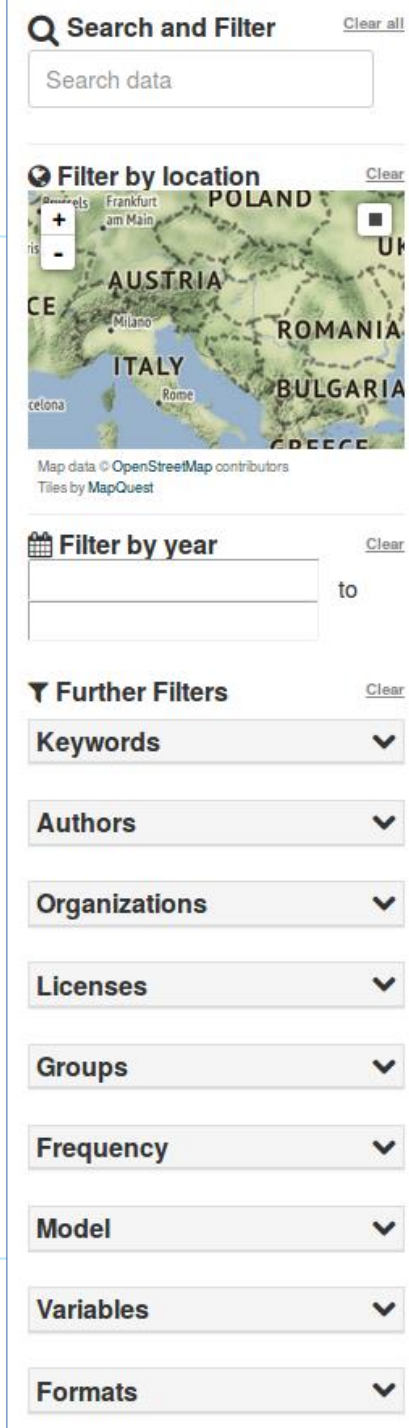
(Account required)

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/m ²
sfcWind	m/s
hurs	%

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



CCCA Dataserver

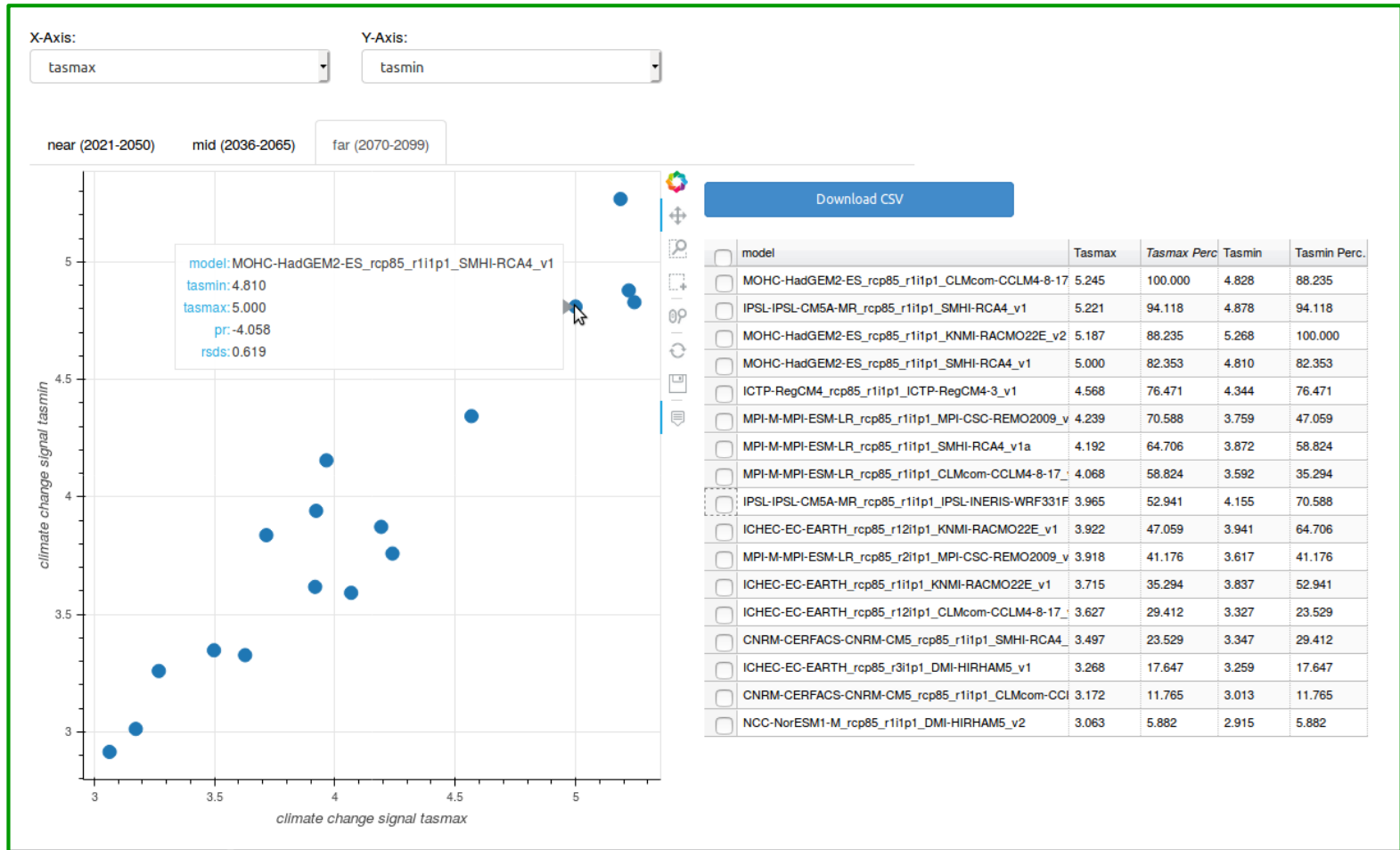
Hands-on:

- 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

Modell Selection Tool

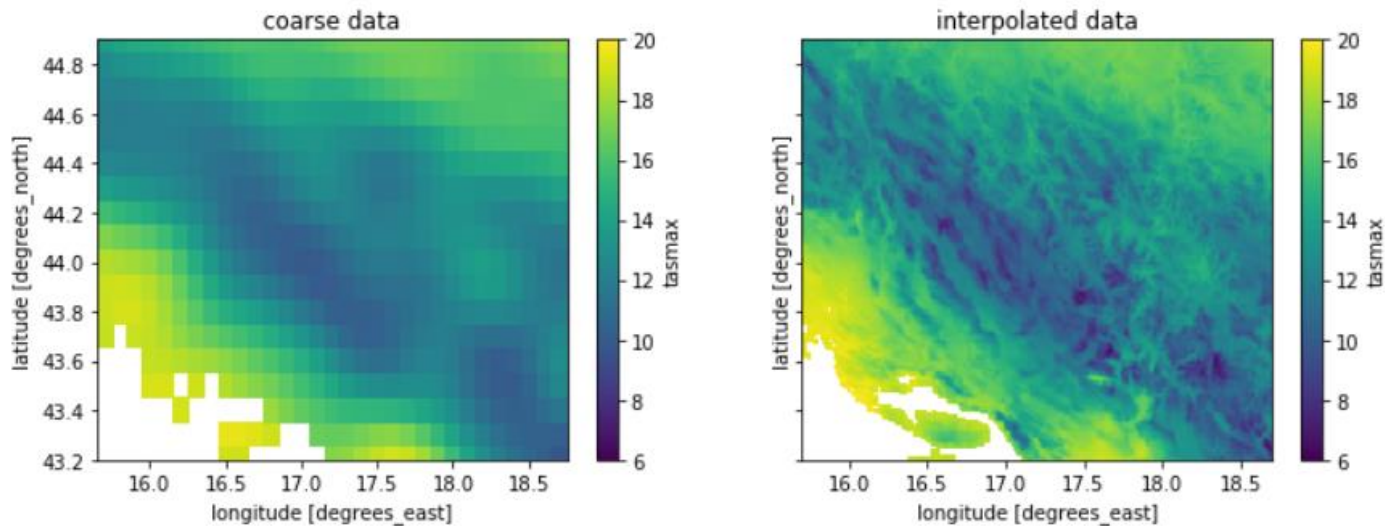
<https://github.com/boku-met/climaproof-tools>



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°)



WITH FUNDING FROM



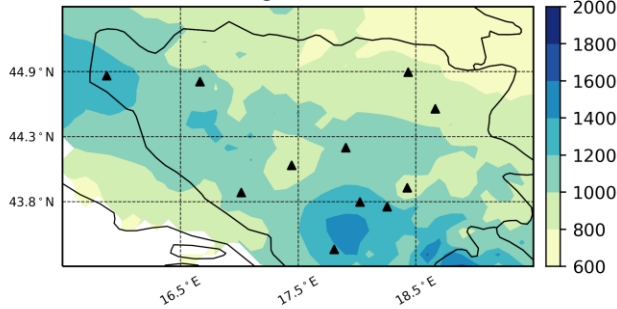
ICC-OBS tool

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

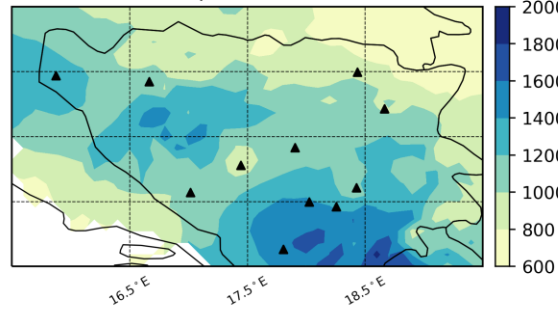
Improving bias-corrected Climate Change scenarios with local OBServational data

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

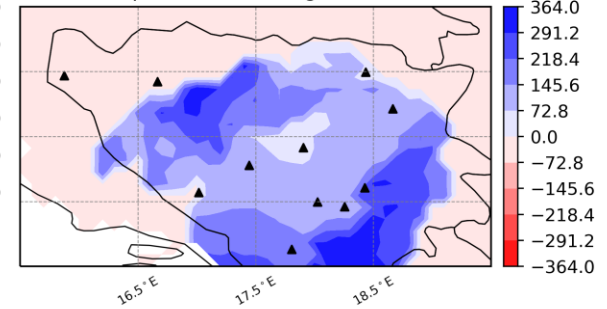
original obs.



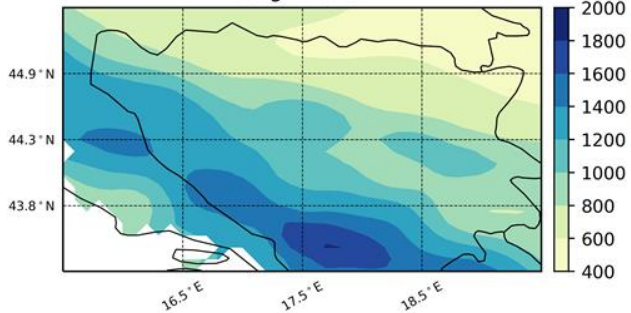
pr (1981 - 2010)
improved obs.



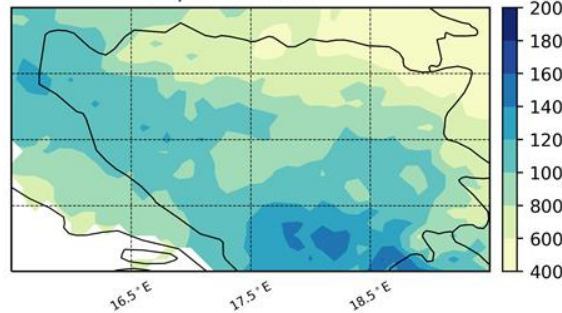
difference
improved obs. - original obs.



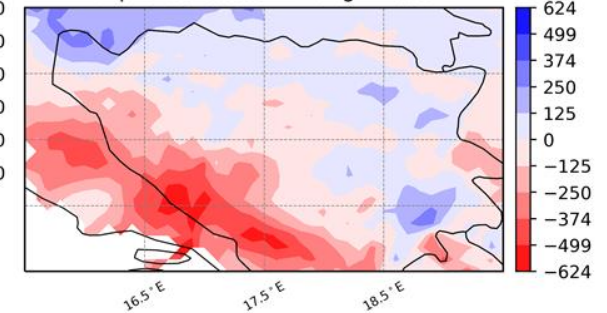
orig. model



pr (1981 - 2010)
improved biascorr.



difference
improved biascorr. - orig. model



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Summary

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



Questions

Remarks



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UN 
environment
programme

Climate indicators

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

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-indicators>

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

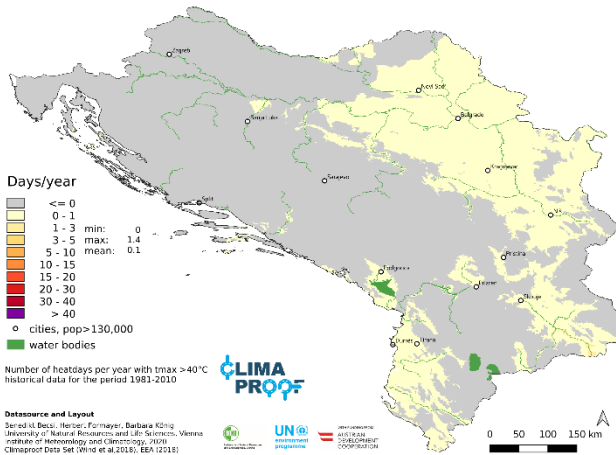
- 99 percentile of 3-day precipitation sum
- Heavy rain falls
- Can cause aquaplaning, floods, landslides, muddflows

Consecutive dry days

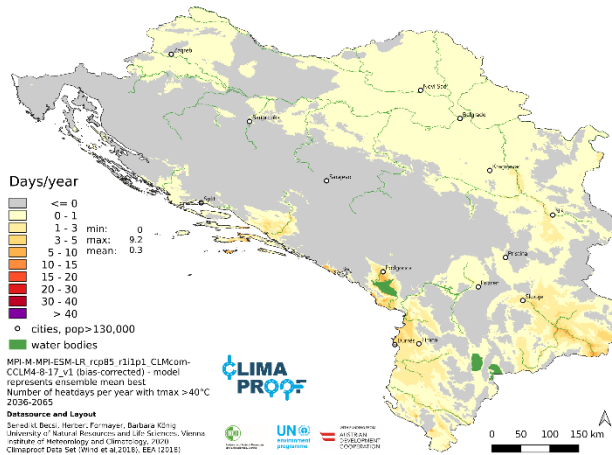
- Number of days in dry periods with a length of min. 5 days
- Agriculture, forestry
- In combination with heatdays: risk of forestfires

Example 1: Days with $t_{max} > 40^{\circ}\text{C}$ model represents ensemble mean best

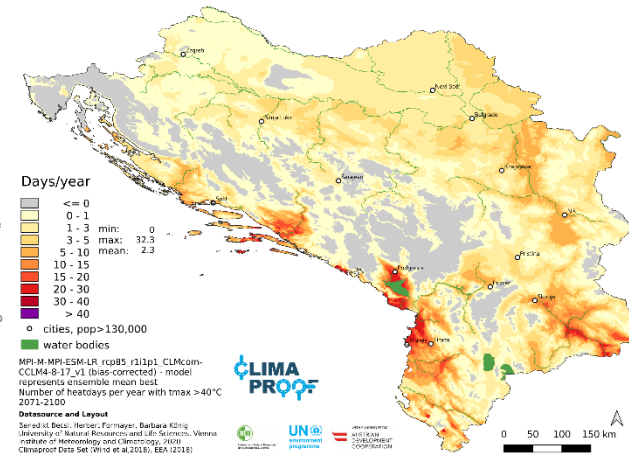
Heatdays $t_{max} > 40^{\circ}\text{C}$
historical data, 1981-2010



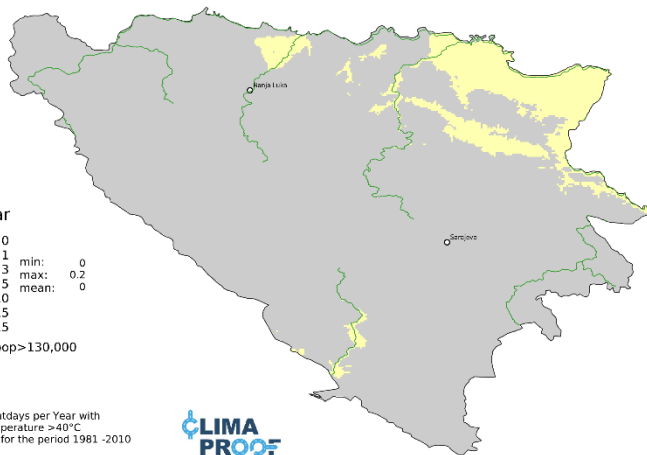
Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 8.5, 2036-2065



Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 8.5, 2071-2100



Heatdays tmax >40°C historical data 1981-2010



Days/year

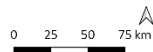
<= 0	
0 - 1	min: 0
1 - 3	max: 0.2
3 - 5	mean: 0
5 - 10	
10 - 15	
> 15	

○ cities, pop>130,000

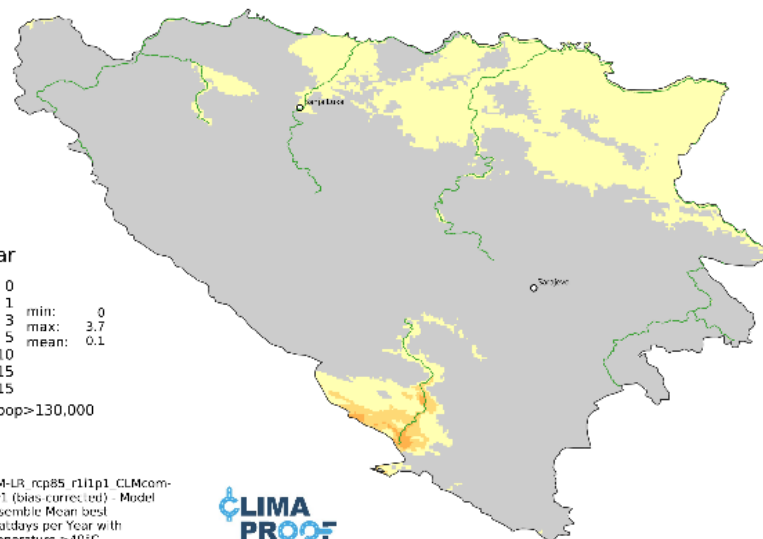
Number of Heatdays per Year with
Maximum Temperature >40°C
historical data for the period 1981 -2010



Datasource and Layout
Benedikt Reesl, 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)



Heatdays tmax >40°C RCP 8.5, 2036-2065



Days/year

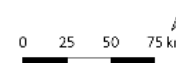
<= 0	
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3 - 5	mean: 0.1
5 - 10	
10 - 15	
> 15	

○ cities, pop>130,000

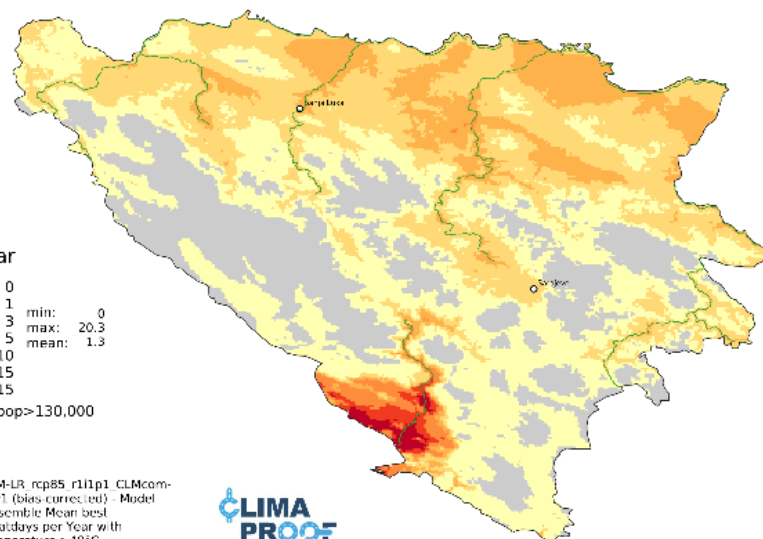
MPI-M-MPI-ESM-LR_rcp85_r11i1p1_CLMcom-
CCIM4.8.17_w1 (bias-corrected) - Model
represents Ensemble Mean best
Number of Heatdays per Year with
Maximum Temperature >40°C
2036-2065

Datasource and Layout

Benedikt Reesl, 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)



Heatdays tmax >40°C RCP 8.5, 2071-2100



Days/year

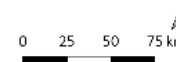
<= 0	
0 - 1	min: 0
1 - 3	max: 20.3
3 - 5	mean: 1.3
5 - 10	
10 - 15	
> 15	

○ cities, pop>130,000

MPI-M-MPI-ESM-LR_rcp85_r11i1p1_CLMcom-
CCIM4.8.17_w1 (bias-corrected) - Model
represents Ensemble Mean best
Number of Heatdays per Year with
Maximum Temperature >40°C
2071-2100

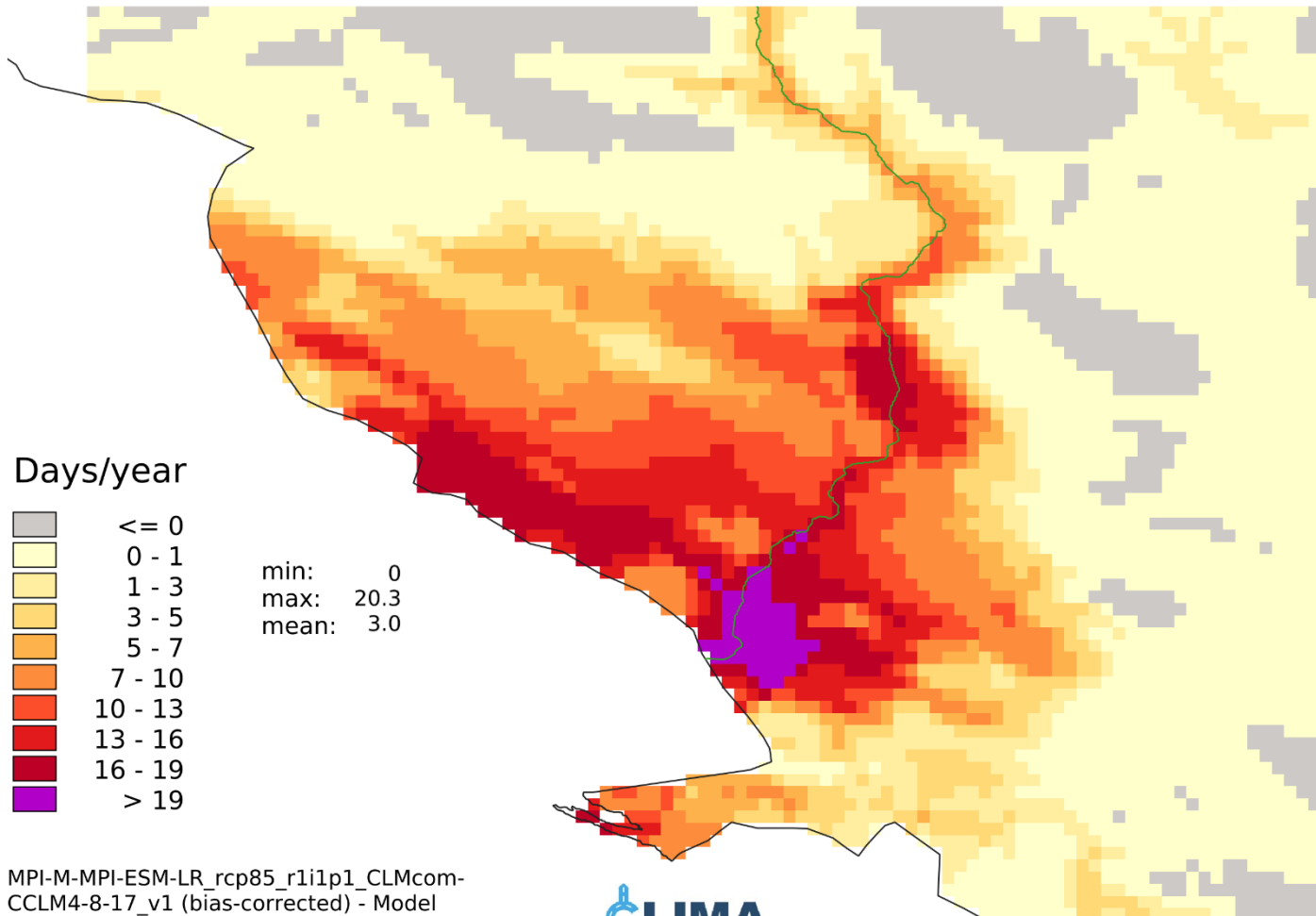
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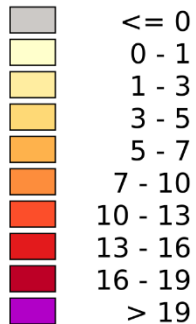


Heatdays tmax >40°C

RCP 8.5, 2071-2100



Days/year

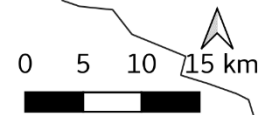


min: 0
max: 20.3
mean: 3.0

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 Maximum Temperature >40°C 2071-2100

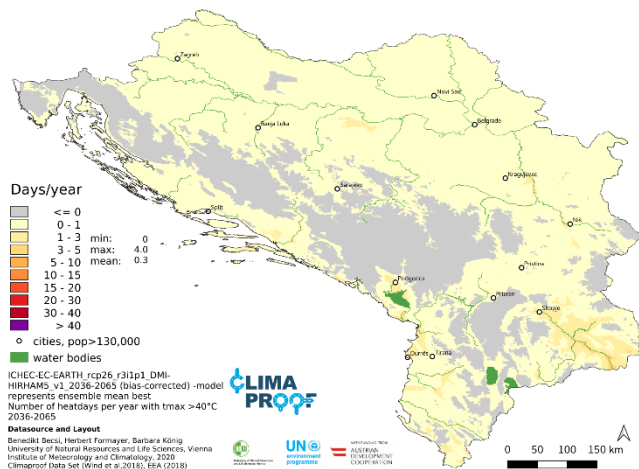
Datasource and Layout

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

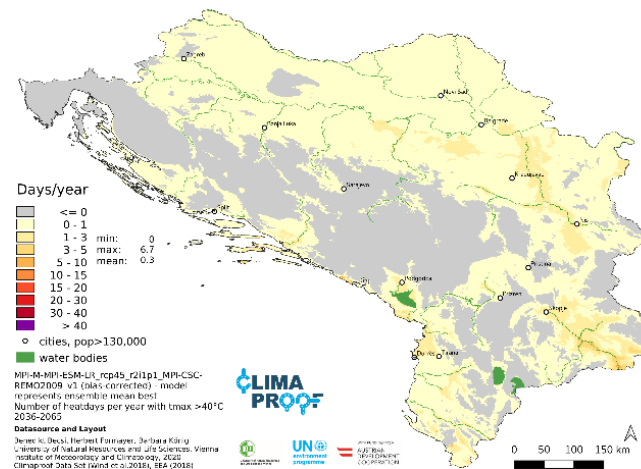


Example 2: Days with $t_{max} > 40^{\circ}\text{C}$ different scenarios: 2.6 & 4.5 (mean)

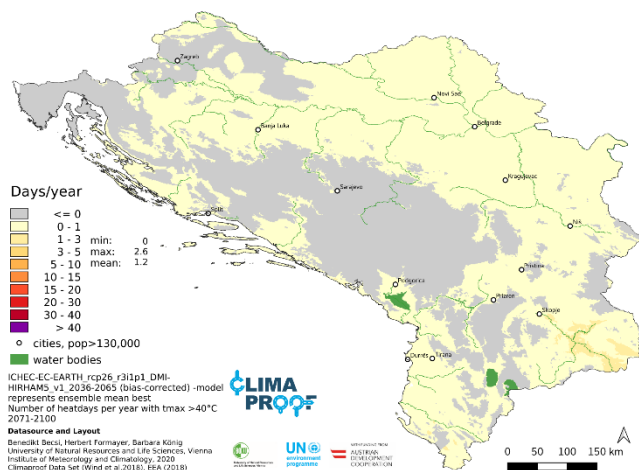
Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 2.6, 2036-2065



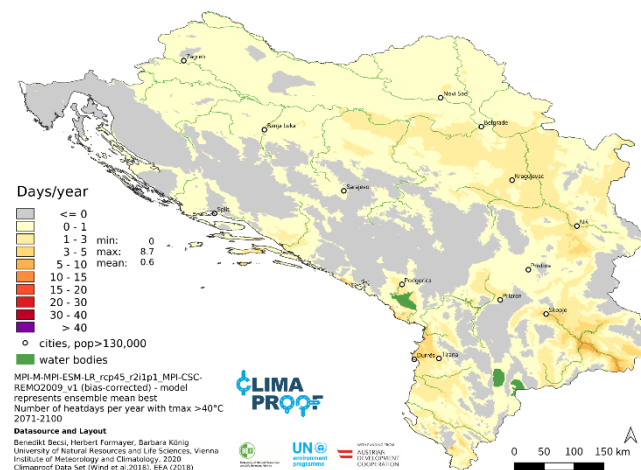
Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 4.5, 2036-2065



Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 2.6, 2071-2100

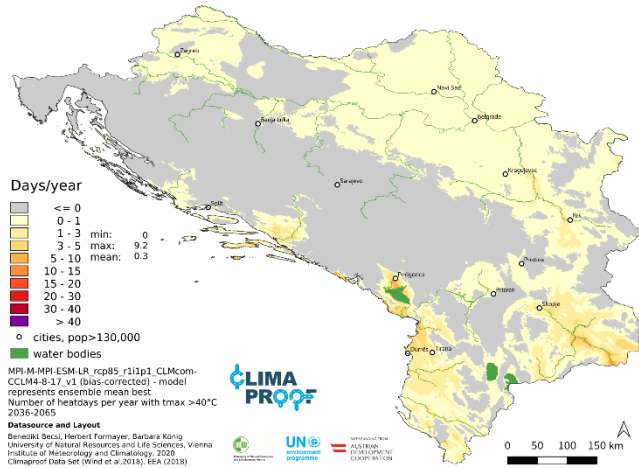


Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 4.5, 2071-2100

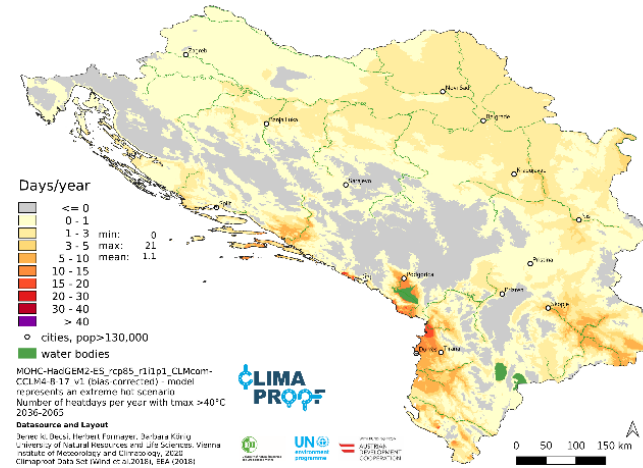


Example 2: Days with $t_{max} > 40^{\circ}\text{C}$ different scenarios: 8.5 (mean, hot)

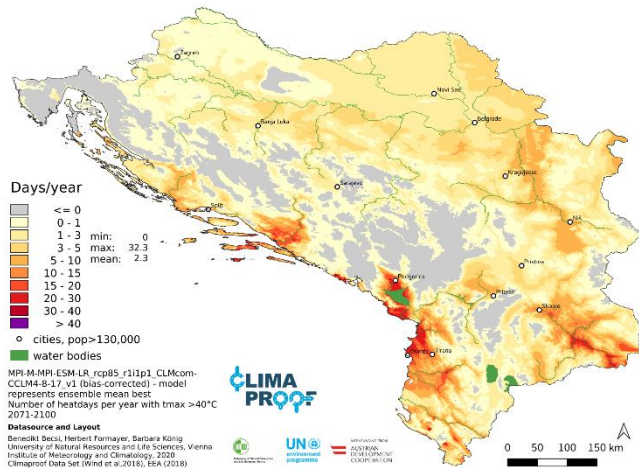
Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 8.5, 2036-2065



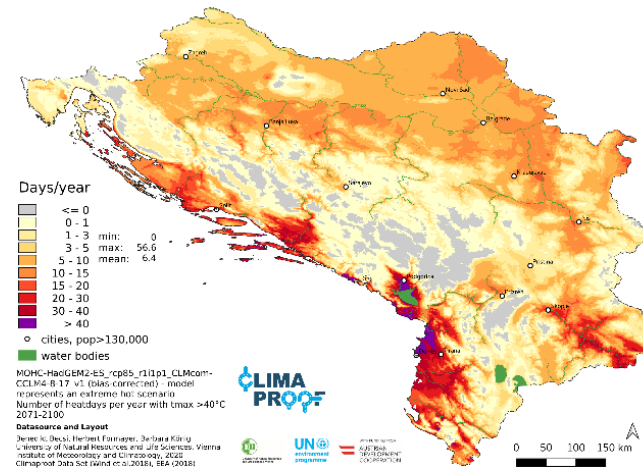
Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 8.5, 2036-2065



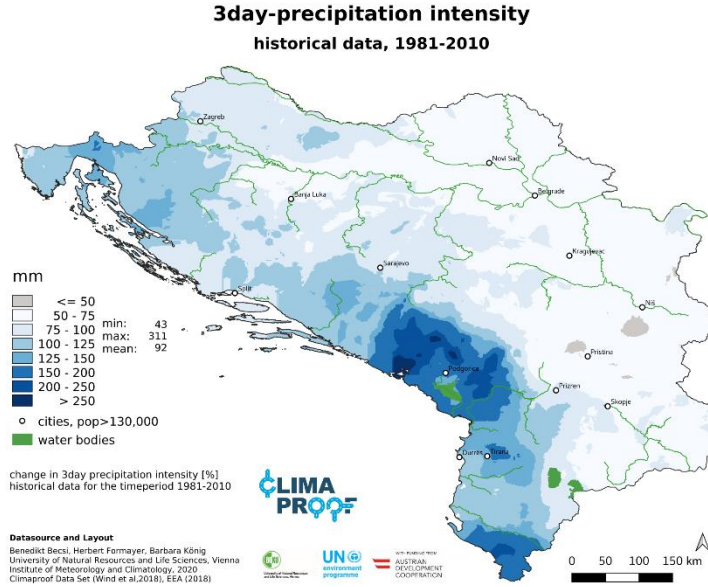
Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 8.5, 2071-2100



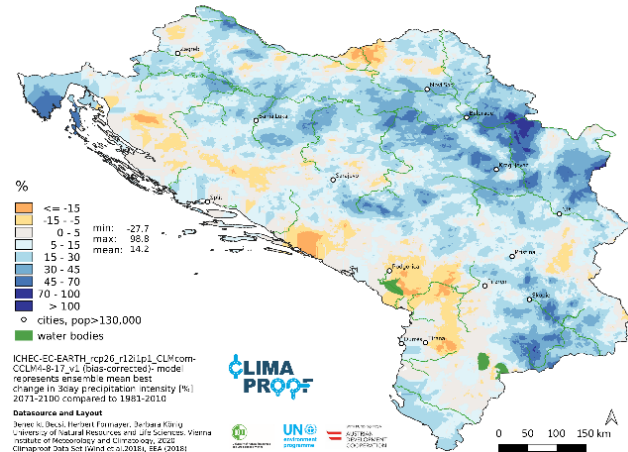
Heatdays $t_{max} > 40^{\circ}\text{C}$
RCP 8.5, 2071-2100



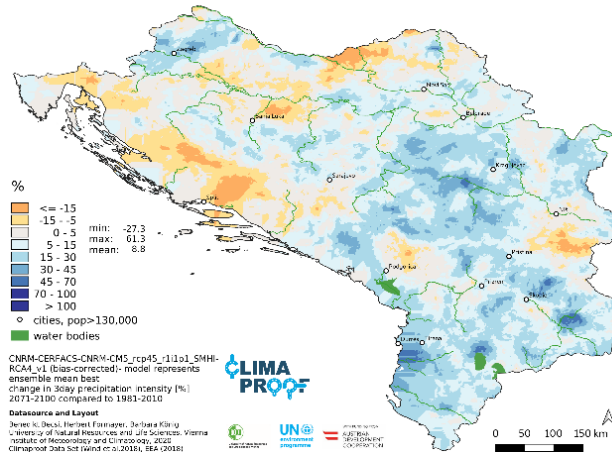
Example 3: 3-day precipitation maximum (change),



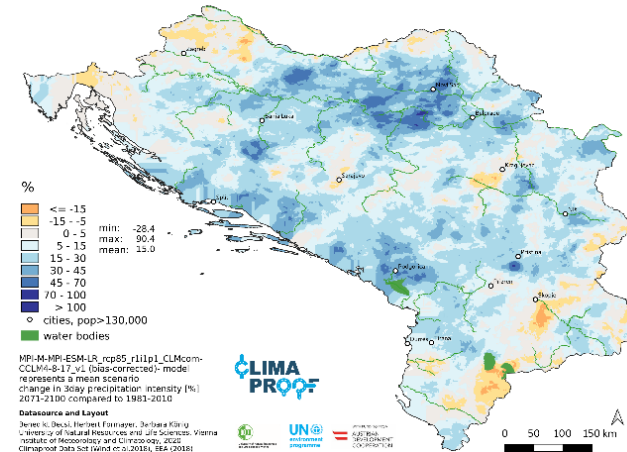
3day-precipitation intensity
RCP 2.6, 2071-2100 compared to 1981-2010 (change in %)



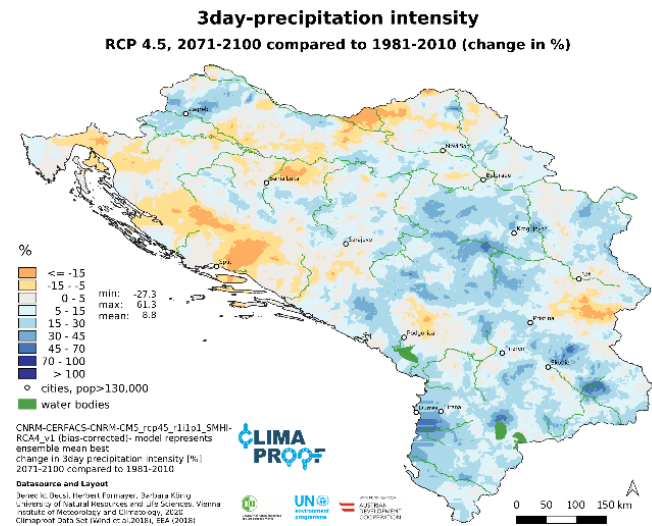
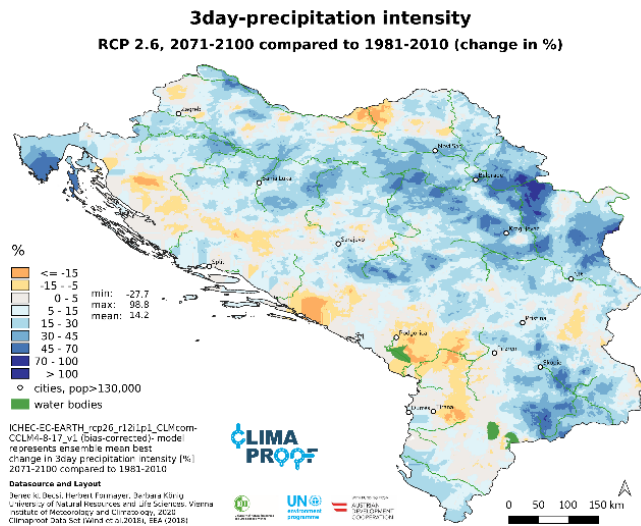
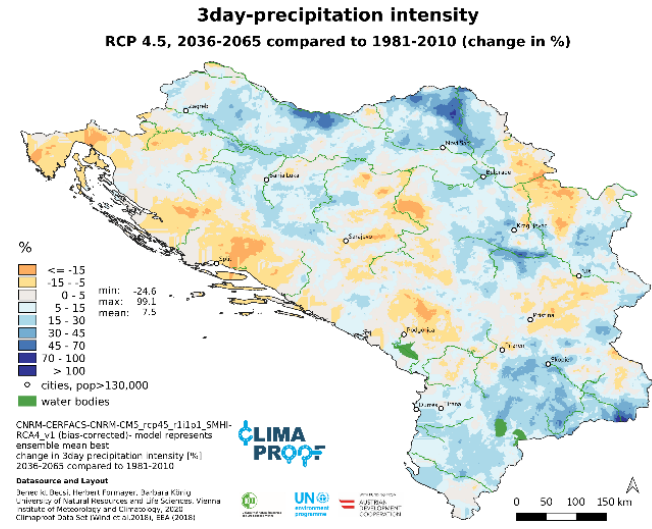
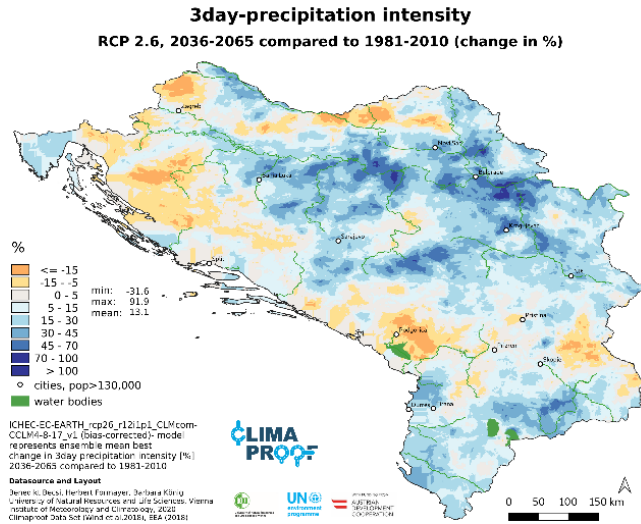
3day-precipitation intensity
RCP 4.5, 2071-2100 compared to 1981-2010 (change in %)



3day-precipitation intensity
RCP 8.5, 2071-2100 compared to 1981-2010 (change in %)



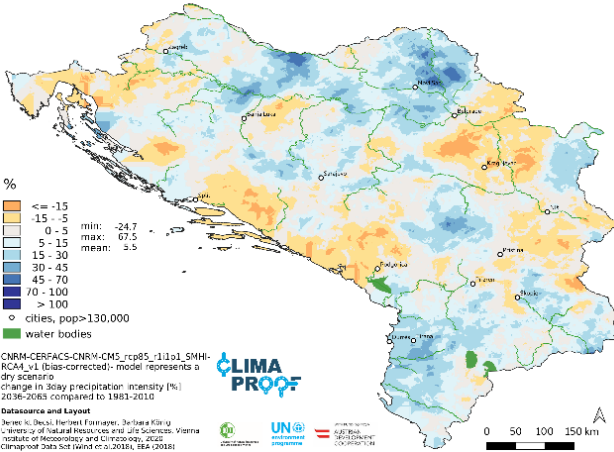
Example 3: 3-day precipitation maximum (change), different scenarios: 2.6 & 4.5 (mean)



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

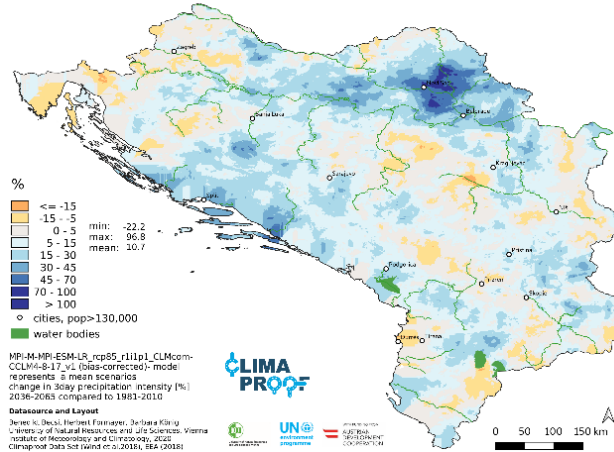
3day-precipitation intensity

RCP 8.5, 2036-2065 compared to 1981-2010 (change in %)



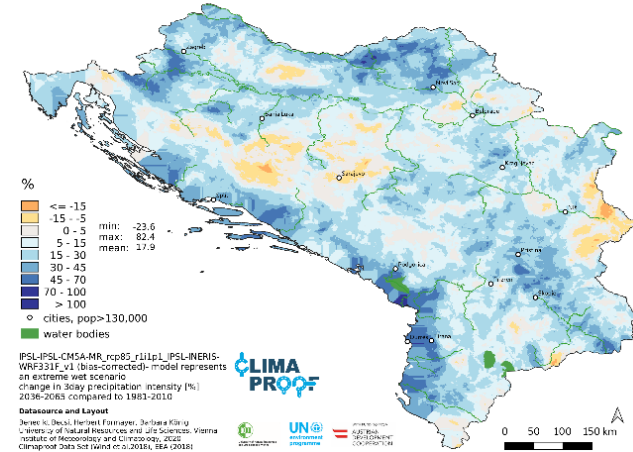
3day-precipitation intensity

RCP 8.5, 2036-2065 compared to 1981-2010 (change in %)



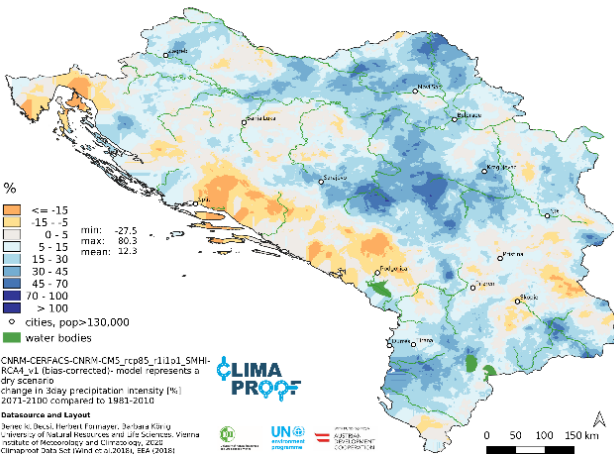
3day-precipitation intensity

RCP 8.5, 2036-2065 compared to 1981-2010 (change in %)



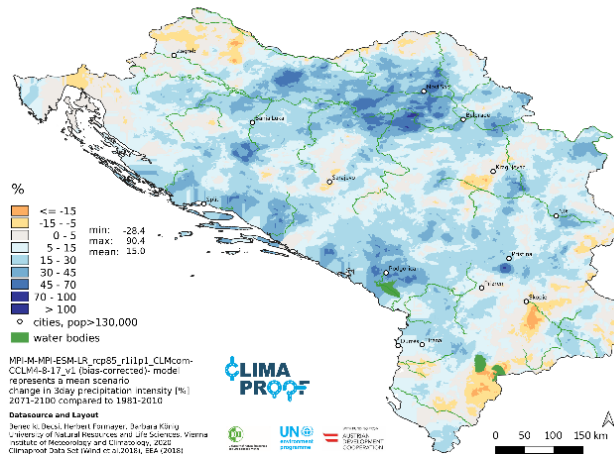
3day-precipitation intensity

RCP 8.5, 2071-2100 compared to 1981-2010 (change in %)



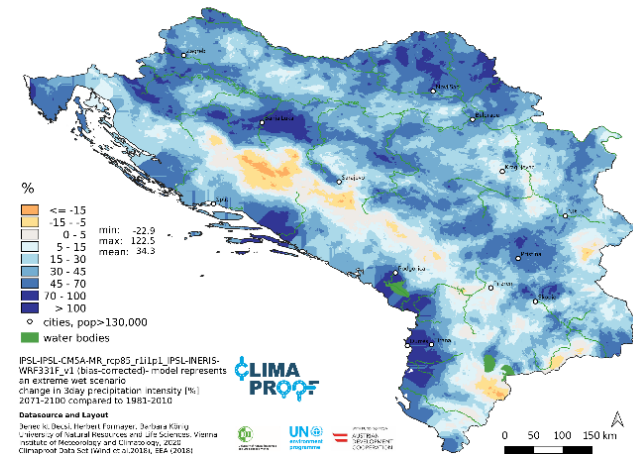
3day-precipitation intensity

RCP 8.5, 2071-2100 compared to 1981-2010 (change in %)



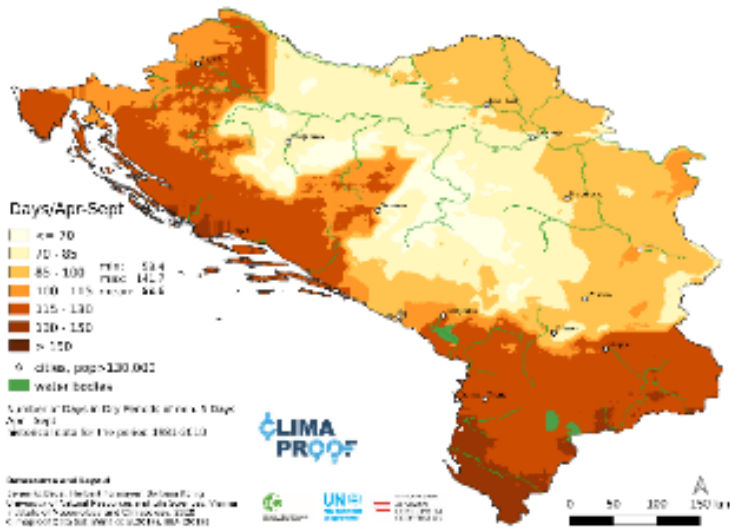
3day-precipitation intensity

RCP 8.5, 2071-2100 compared to 1981-2010 (change in %)

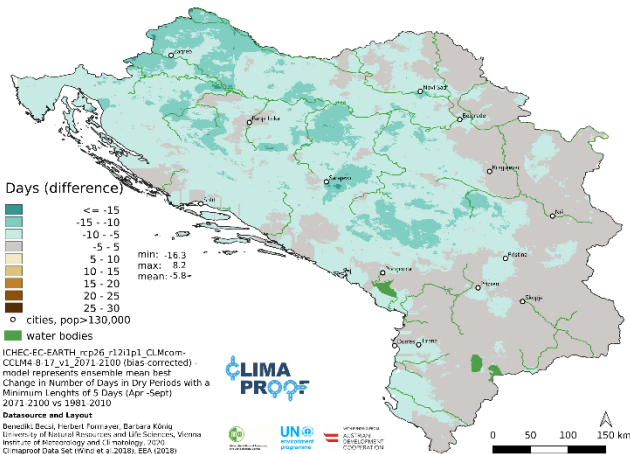


Example 4: consecutive dry days

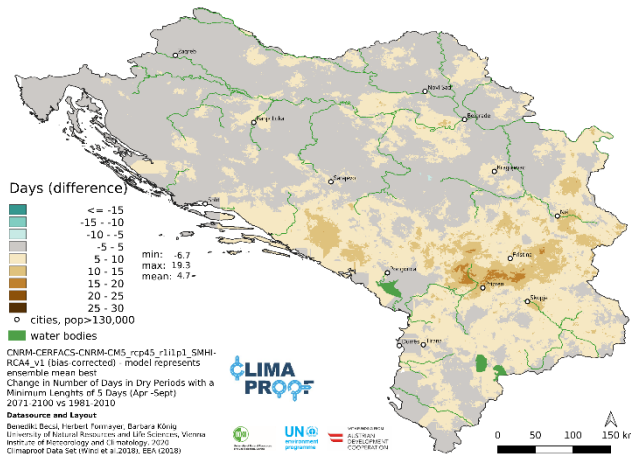
Number of Days in a Dry Period of min. 5 days
historical data, 1981-2010



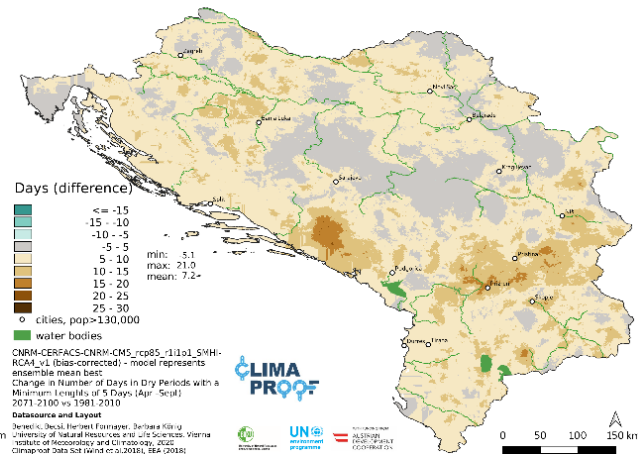
Change in Number of Days in a Dry Periods of min. 5 days
RCP 2.6, 2071-2100 vs 1981-2010



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

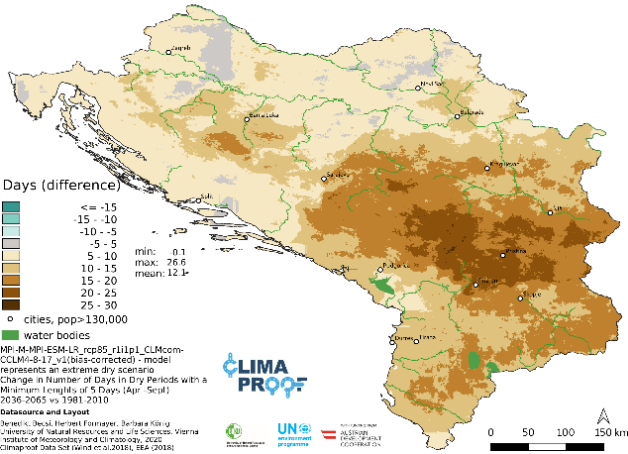


Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2071-2100 vs 1981-2010

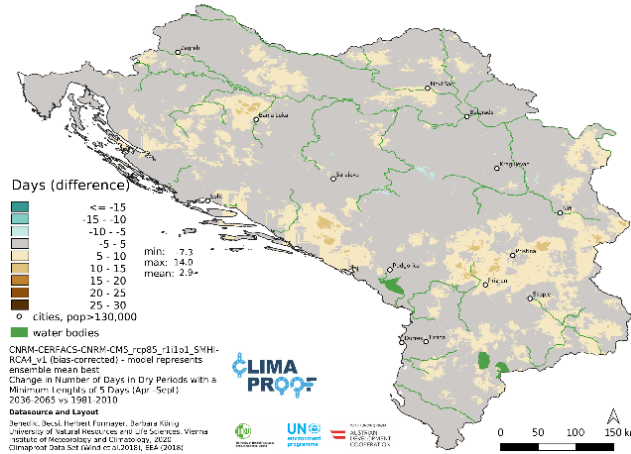


Example 4: consecutive dry days

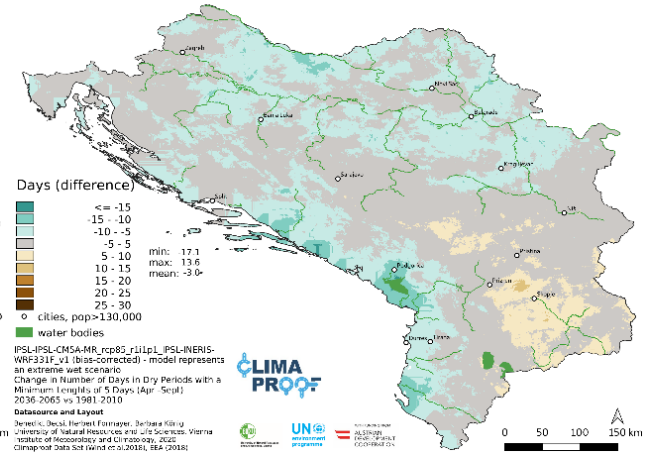
Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2036-2065 vs 1981-2010



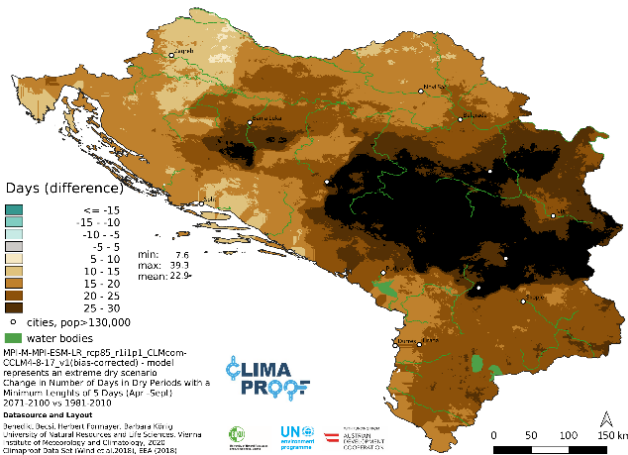
Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2036-2065 vs 1981-2010



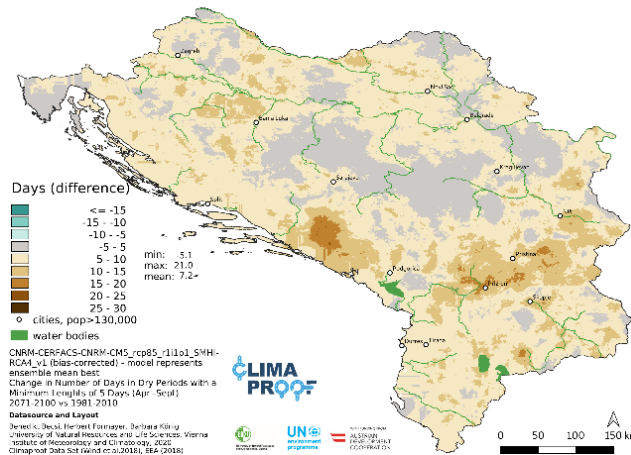
Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2036-2065 vs 1981-2010



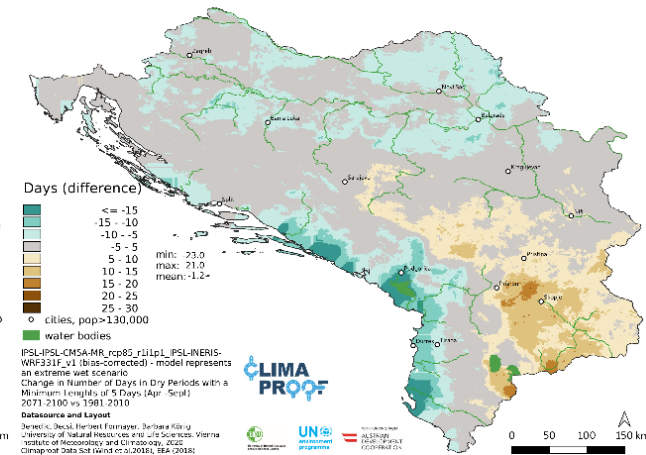
Change in Number of Days in a Dry Periods of min. 5 days
RCP 8.5, 2071-2100 vs 1981-2010



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



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 (consecutive 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

Indicators with relevance for (road)infrastructure – scientific results

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

Indicators with relevance for (road)infrastructure – scientific results

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

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

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



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COOPERATION



Excursus:

Presentation by Alexandra Jiricka-Pürerer MSc. PhD

Discussion

When using environmental assessment instruments (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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Tel.: +43 1 476 54 - 81415

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