User-relevant climate change information from regional climate predictions and projections

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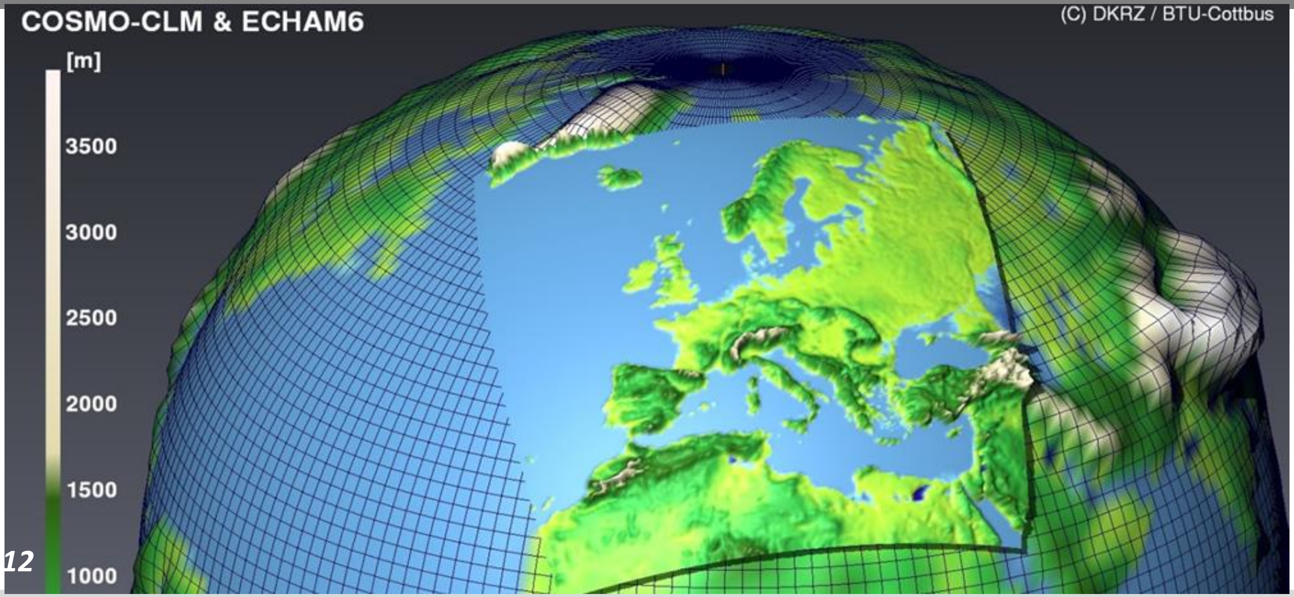

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Outline

- User relevant climate information from
  - Regional decadal predictions
  - EURO-CORDEX Climate Projections
- The NUKLEUS/RegIKlim Framework

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User relevant climate information from regional decadal predictions

User relevant climate information from decadal predictions

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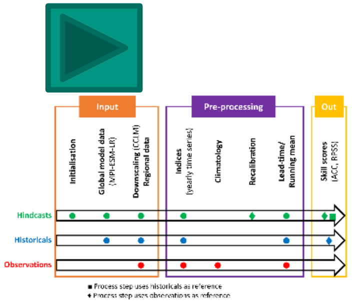
- Initialized decadal predictions are used to improve estimates of climate change up to 10 years ahead
- Especially in phases with strong impact of natural variability pattern on the trend (e.g. Atlantic Multi-decadal Variability AMV, but also from sea-ice, QBO etc.) decadal predictions may provide an added value compared to climate projections
- The skill is established mainly for the global mean temperature
- The German Research Program MiKlip (Marotzke et al., 2016) developed an operational decadal prediction system including a regional downscaling option with CCLM (Feldmann et al., 2019; Reyers et al., 2019)
- The regional MiKlip hindcasts have been analysed to estimate the predictive skill for temperature, precipitation and wind-derived climate indicators, which may provide user-relevant climate information (**Moemken et al., 2020**, Feldmann et al., 2019).

The MiKlip Decadal Prediction System

- Global decadal prediction system based on MPI-ESM
- Regional component for Europe
  - Dynamical downscaling with COSMO-CLM (CCLM) to 0.22°/0.44° resolution
- Several (regional) ensemble generations available

Generation	Setup	Start-years	Sim. Years
baseline1 (b1)	10 member CCLM4, 50km MPI-ESM-LR	1960 – 2017	5900 + 880
20C	3 member CCLM5, 25km MPI-ESM-LR	1900 – 2010	3000
preop	5 member CCLM5, 25km MPI-ESM-HR CMIP5 forcing	1960 – 2016	2850
dcppA	10 member CCLM5, 25km, MPI-ESM-HR CMIP6 forcing	1960 – 2019	6000



Temperature derived climate indicators

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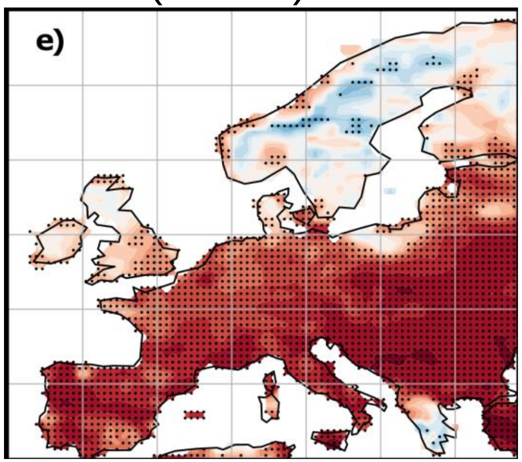
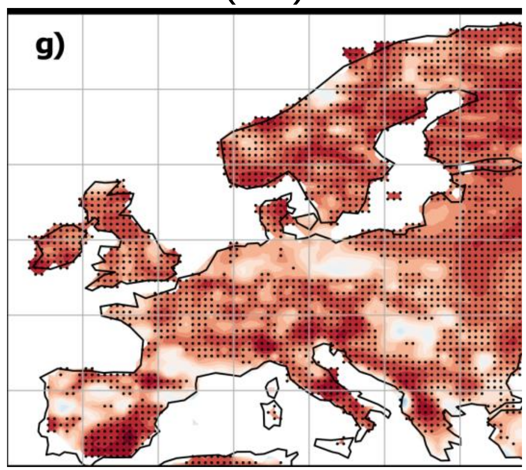
Examples

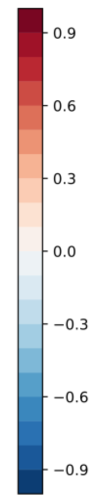
Correlation (ACC)

Heat Wave Days (HWDS)



Frost Days (FD)





Correlation of the regional decadal CCLM hindcasts compared to E-OBS

- start years 1965-2011
- lead-time year 2-5
- dots indicate significant skill at the 95% level

Index	Variable	Definition
Heat Wave Days (HWDS)	Daily max. temperature TX	Annual count of days with TX > 90th percentile of May-Oct
Frost Days (FD)	Daily min. temperature TN	Annual count of days with TN < 0°C

- High skill for temperature based variables
- Due to representation of trend and variability
- Highest skill in Southern Europe
- Higher prediction potential for heat-related indices (summer days, heat wave days, etc.) than for cold indices (frost days)

Precipitation derived climate indicators

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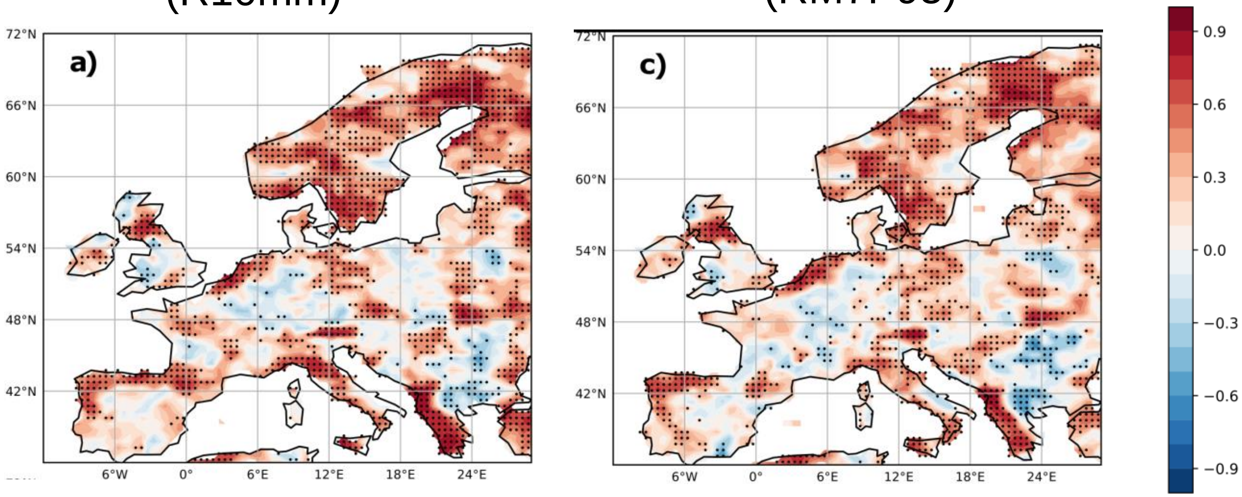
Examples

Correlation (ACC)

Heavy Precipitation Days (R10mm)

Flood Index (RM7P95)



Correlation of the regional decadal CCLM hindcasts compared to E-OBS

- start years 1965-2011
- lead-time year 2-5
- dots indicate significant skill at the 95% level

- Skill scores lower and patchier than for temperature indices
- Scandinavia is the largest area with significant skill
- Potentially useful information for several river catchments

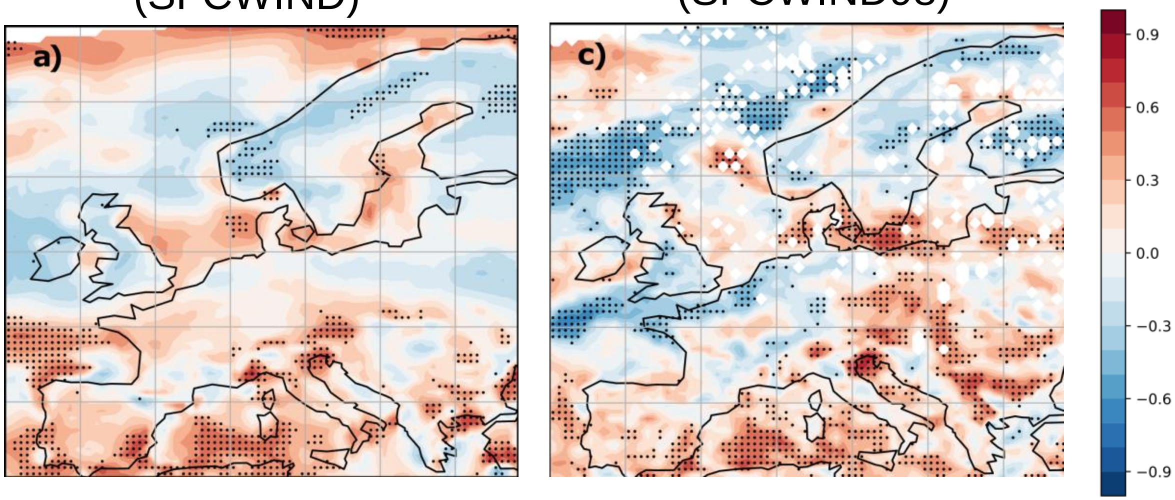
Index	Variable	Definition
Heavy Precipitation Days (R10mm)	Daily precipitation RR	Annual count of days with RR ≥ 10mm
Flood Index (RM7P95)		95th percentile of 7-day running mean of RR

Wind derived climate indicators

Examples

Correlation (ACC)

Winter Surface Wind Speed (SFCWIND) | Storm Days (SFCWIND98)



Correlation of the regional decadal CCLM hindcasts compared to a CCLM ERA-driven simulation

- start years 1965-2011
- lead-time year 2-5
- dots indicate significant skill at the 95% level

- Skill scores lower and patchier than for temperature indices
- Significant skill mostly in Southern parts of Europe and coastal regions

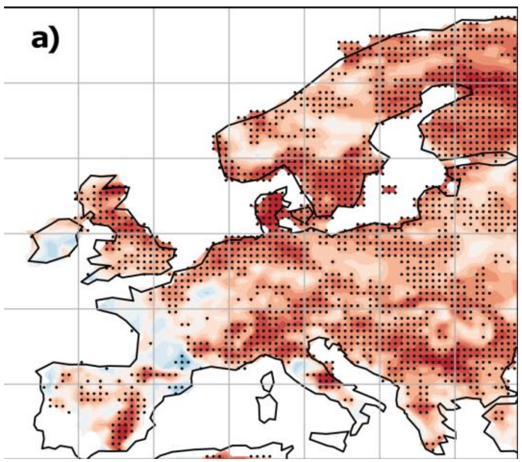
Index	Variable	Definition
Surface Wind Speed (SFCWIND)	Surface Wind Speed V	Winter (ONDJFM) mean of daily V
Storm Days (SFCWIND98)		Winter count of days with V > 98th percentile

Agriculture related climate indicators

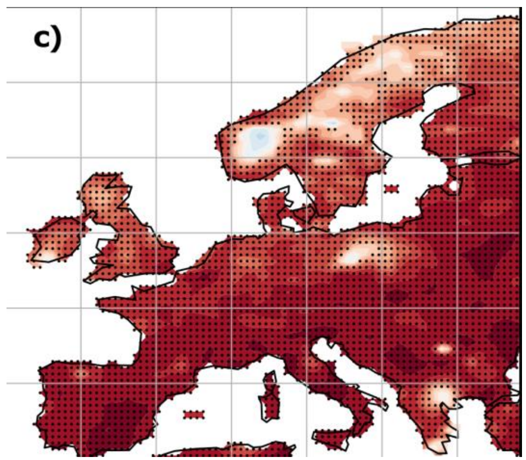
Examples

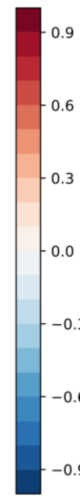
Correlation (ACC)

Growing Season Length (GSL)



Growing Degree Days (GDD)





Correlation of the regional decadal CCLM hindcasts compared to E-OBS

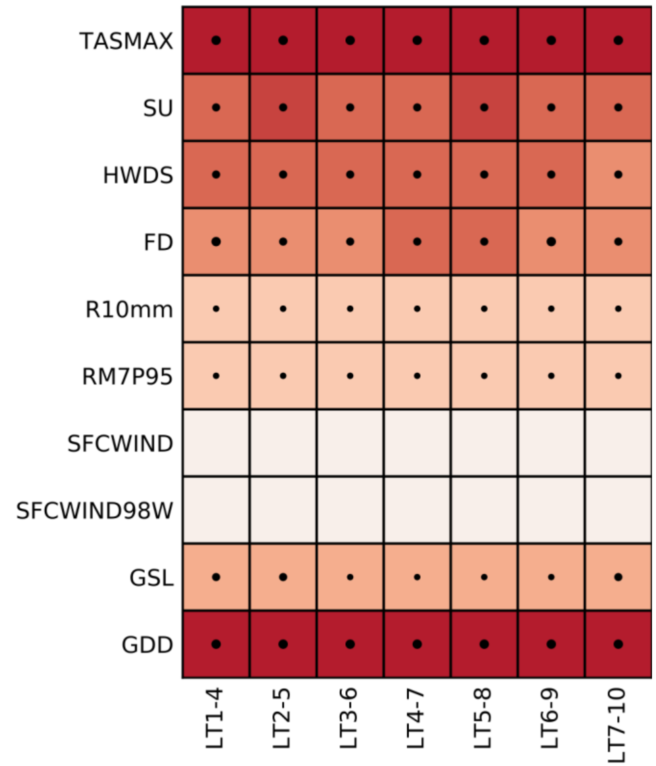
- start years 1965-2011
- lead-time year 2-5
- dots indicate significant skill at the 95% level

- High skill since the indices are derived from temperature
- Higher prediction potential for climate indicators, which use yearly integrated values (e.g. GDD or Heating Degree Days HD)

Index	Variable	Definition
Growing Season Length (GSL)	Daily mean temperature TG	Number of days between first occurrence of at least 6 consecutive days with TG > 5°C and first occurrence of at least 6 consec. days with TG < 5°C after July 1st
Growing Degree Days (GDD)		$GDD = \sum_{Apr}^{Oct} max(TG - 10°C, 0))$

Summary Regional Decadal Predictions

- High and significant predictive skill for temperature derived climate indicators (including heat wave and agriculture related indices) indicate application potential
- Lower skill for precipitation and wind related indices, which may only regionally provide useful information
- Reference: Moemken et al., 2020



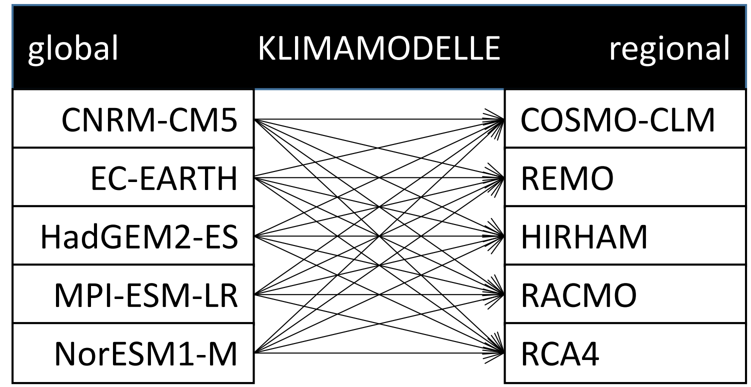
Correlation (ACC) averaged over Europe by index and lead-time. Black dots indicate the area fraction of significant grid points: no marker if less than 25% of the GP are significant, small dots if 25-50% are significant, medium-sized dots if 50-75% are significant and large dots if more than 75% are significant.

User relevant climate information from EURO-CORDEX projections

Euro- CORDEX Ensemble (EUR-11)

- Analysis of a „full matrix“ EURO CORDEX ensemble
  - 5 RCMs downscaling 5 GCMs
- Aims:
  - Applied to basic (T, Prec) and user-oriented variables (Hackenbruch et al., 2017)
  - Contribution of RCMs and GCMs to overall spread
  - Uncertainties and „processing challenges“

EUR-11 Ensemble Matrix



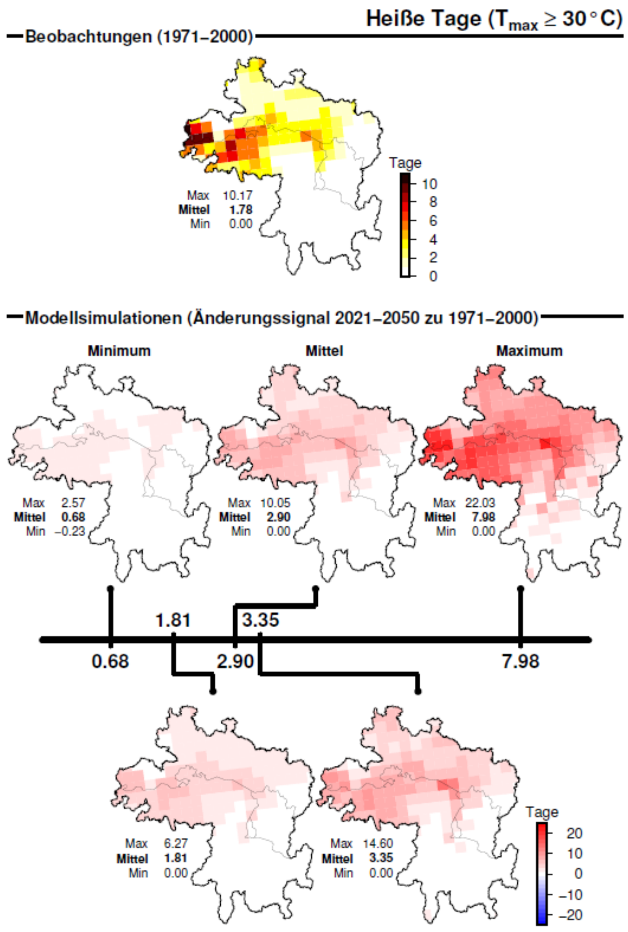
Global models	
G1	CNRM-CM5
G2	EC-EARTH
G3	HadGEM2-ES
G4	MPI-ESM-LR
G5	NorESM1-M
Regional models	
R1	CCLM4-8-17[1]
R2	HIRHAM5
R3	REMO2015
R4	RACMO22E
R5	RCA4

Regional Analysis of the climate change signal

Example: EURO-CORDEX Ensemble, Bodensee-Region, Hot Days with T_{max} > 30°C

Observed state
1971-2000 E-Obs 0.1°

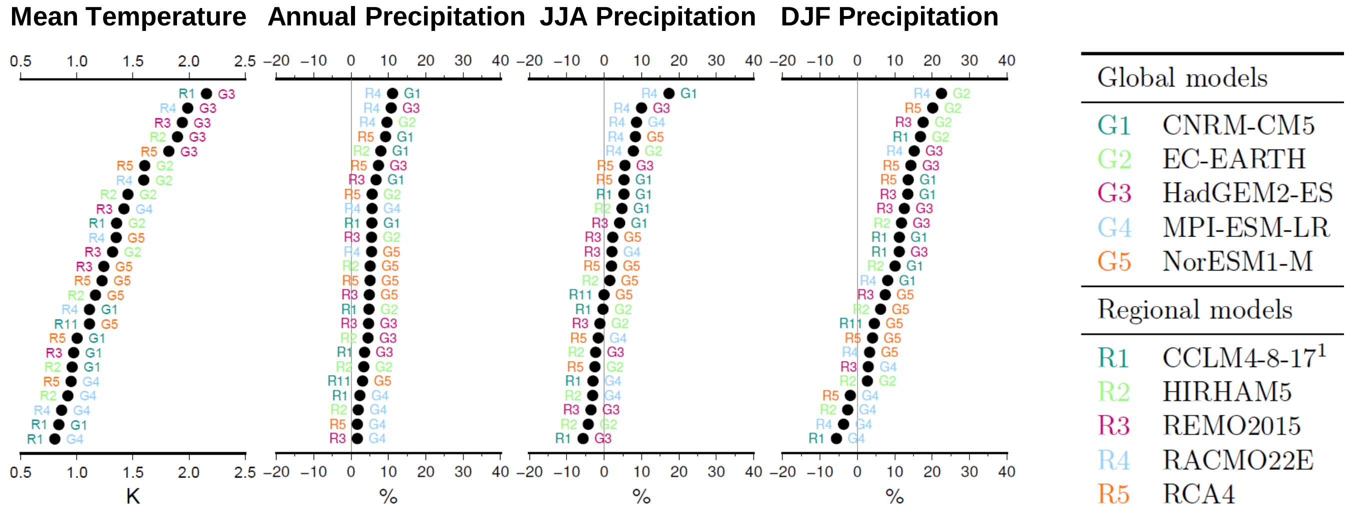
Range Climate Change Signal
2021-2050 vs. 1971-2000



GCM/RCM contribution to the climate change signal

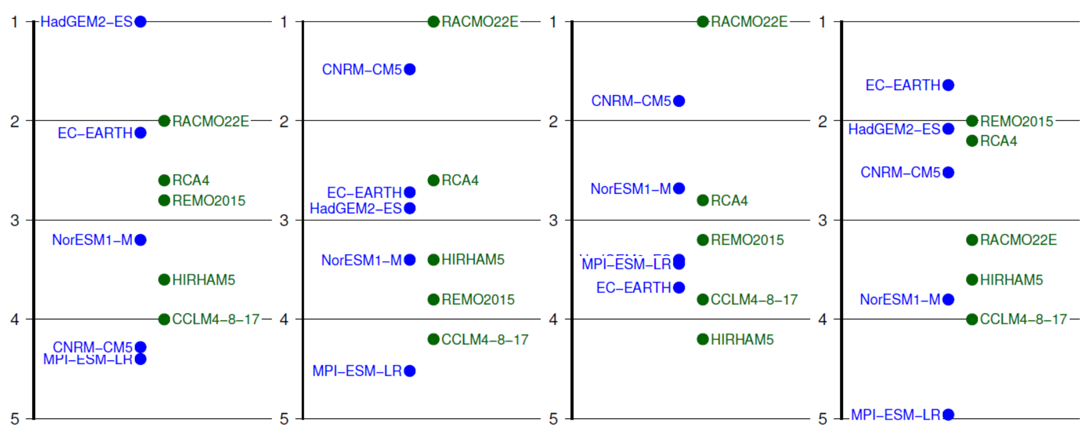
Example: EURO-CORDEX Ensemble, Europe, Basic Variables

Climate change signal for each GCM/RCM combination



(a) annual mean temperature change (b) annual precipitation amount change (c) precipitation amount change in summer (JJA) (d) precipitation amount change in winter (DJF)

Ranking of the change signal among GCMs and RCMs



(a) annual mean temperature change (b) annual precipitation amount change (c) precipitation amount change in summer (JJA) (d) precipitation amount change in winter (DJF)

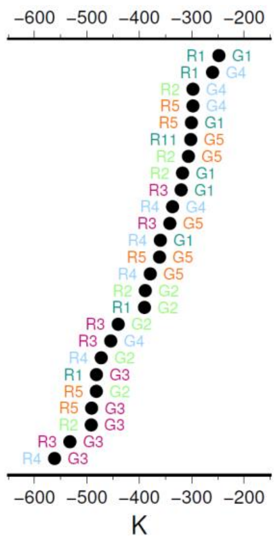
GCM/RCM contribution to the climate change signal

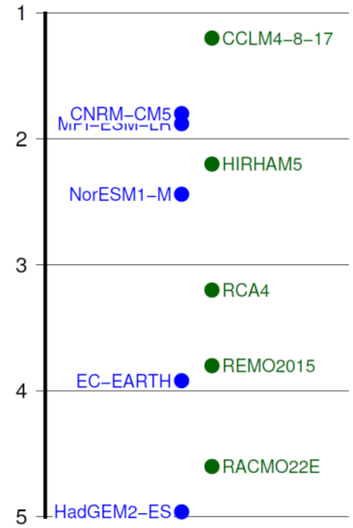
Example: EURO-CORDEX Ensemble, Europe, Heating Degree Days (HD)

Index	Variable	Definition
Heating Degree Days (HD)	Daily mean temperature TG	$HD = \sum_{Apr}^{Oct} max(17°C - TG, 0°)$

Left:
Climate change signal for each GCM/RCM combination

Right:
Ranking of the change signal among GCMs and RCMs





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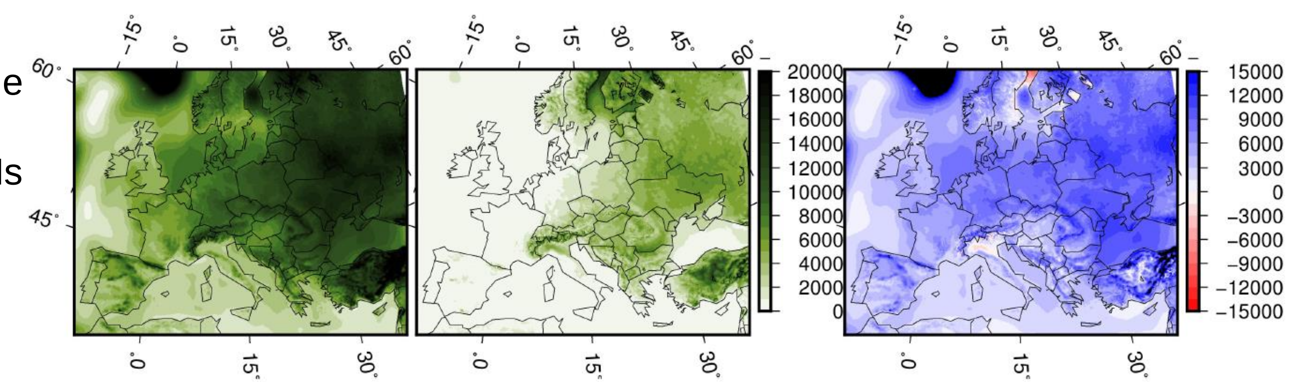
Regional models	
R1	CCLM4-8-17[1]
R2	HIRHAM5
R3	REMO2015
R4	RACMO22E
R5	RCA4

Spread of climate change signal HD

- left: among the GCMs
- middle: among the RCMs
- right: Difference



Summary User Oriented Climate Projections

- Contributions of the GCMs and RCMs to the spread of the climate change signal strongly depends on the basic variables und the season
  - The temperature sensitivity can be mostly attributed to the GCM
  - For summer precipitation the RCM contribution is higher, as well in more continental climate regions
- Processing of the data (e.g. bias adjustment) is necessary to adjust for systematic biases
  - The impact of biases on the (absolute) climate change signal *depends* on the type of climate indicator: Threshold (e.g. Hot Days) and integrated values (e.g. Heating Degree Days) are more strongly affected than mean quantities
- Most user-tailored climate indicators are only applicable in specific climate regimes and are not suitable for all of Europe, but they may reflect the shift of these regimes under climate change

The BMBF Research Program

RegIKlim

(Regional Information for Climate Action)

including cross-cutting activity

NUKLEUS

(Usable local climate information for Germany)

The BMBF research project NUKLEUS/RegIKlim

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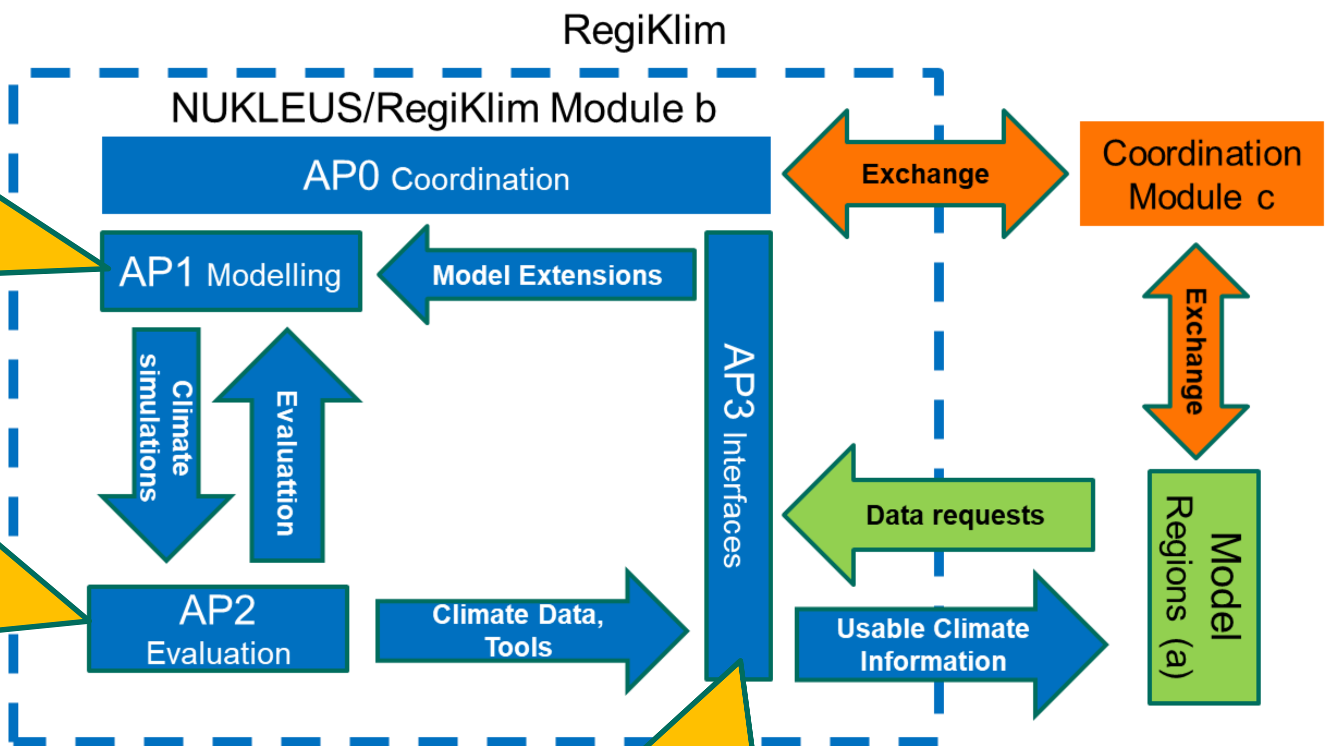
- RegIKlim: Interdisciplinary project to transfer climate information to local climate action in Germany
- It consists of three Modules:
  - RegIKlim a (Model Regions): Develop and implement decision support systems for the local and regional administration and economy for climate action
  - ***NUKLEUS (= RegIKlim Module b): Provide actionable climate information on regional to local scales (climate cadastre, km-scale)***
    - ***Major Contributions from the CLM Community (BTU, HZG, KIT)***
    - ***COSMO-CLM, ICON-CLM and REMO are used to establish a high-resolution ensemble for Germany (forced by CMIP6 GCMs)***
  - RegIKlim c: Coordination and outreach

1st Phase 2020 - 2023

Structure of RegIKlim/NUKLEUS

Generation of high-resolution ensembles
- with CCLM, ICLM and REMO
- dynamical and statistical downscaling
- CMIP6 forcing



Evaluation and analysis
- process oriented
- tailored to user requirements
- using existing and newly generated simulations
- Post-processing and bias-adjustment

Interface to the model regions
- via a common FREVA analysis and exchange infrastructure
- enabling additional user-oriented model output

End

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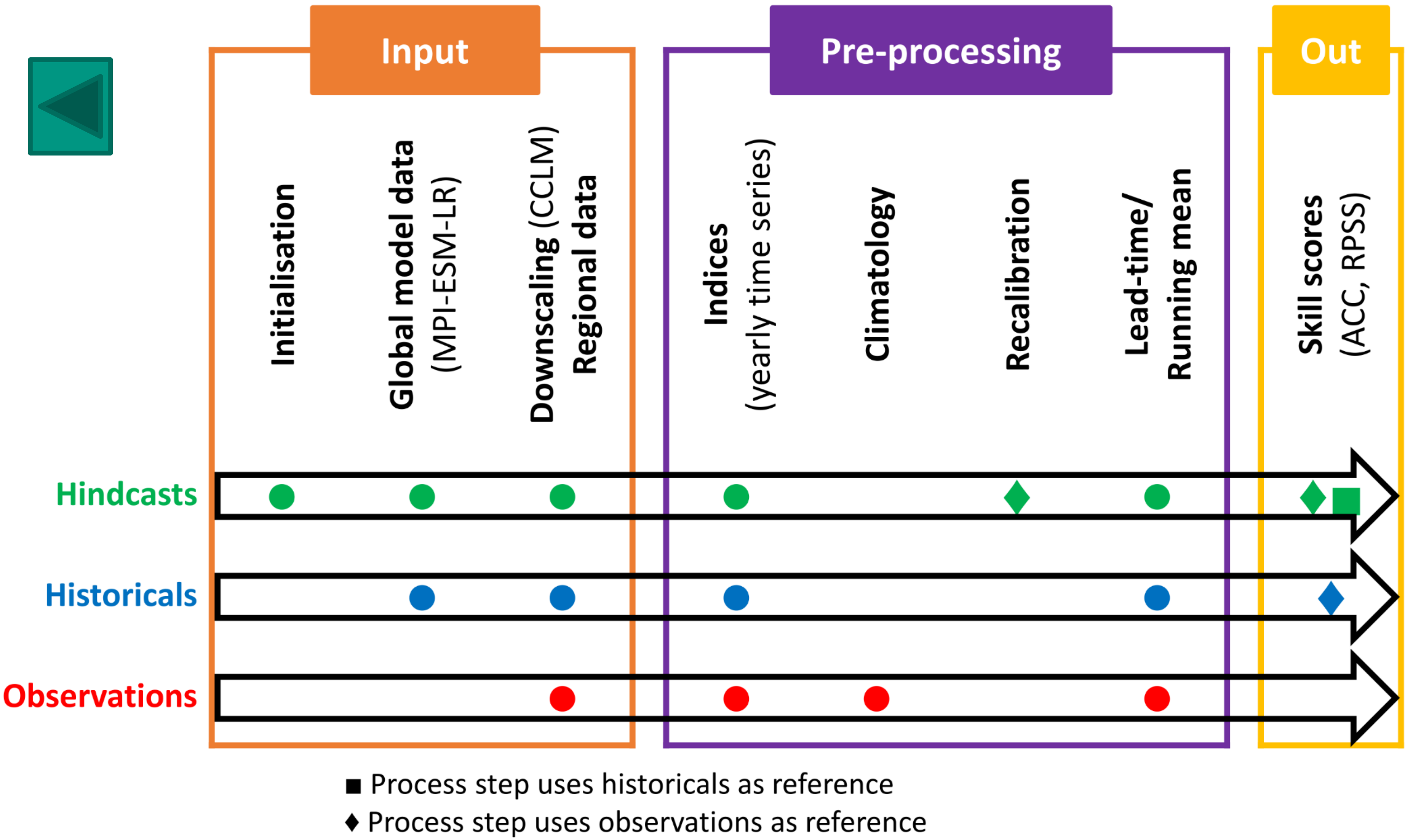
Workflow for the generation, post-processing and verification of the MiKlip regional climate ensembles



Recalibration using DeFoRest (Pasternack et al., 2018)

RegIKlim Model Regions

- 6 selected exemplary regions with specific challenges
  - Coastal region
  - Agriculture and forrestry
  - Lower mountain ranges
  - Pre-Alpine area
  - Rivers: Rhine and port of Duisburg
  - Cities: Stuttgart