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Use of expert elicitation to assign weights to climate and hydrological models in climate impact studies

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Expert Elicitation Training Material

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1 Introduction

1.1. What is AquaClew?

AQUACLEW sets out to answer the following research questions:

- How do we improve co-development to better incorporate multiple user feedbacks along the entire climate service production chain, from research to production, service use and decision making?
- How should data, quality-assurance metrics and guidance be tailored along the whole data-production chain to closer meet user requirements, including resolution and precision?

The AQUACLEW project is funded by European Research Area for Climate Services (ERA4CS), under the Joint Programming Initiative "Connecting Climate Knowledge for Europe" (JPI Climate), which is a collaboration between the European commission and national research councils in member states, who share the costs.

1.2. Expert elicitation in AquaClew

Expert elicitation is a technique that assesses the probability of events, risks or parameter values, based on the knowledge of experts on the subject. In our context, Expert Elicitation (EE) will use expert judgement to provide a weighted ensemble of models for specific real-world impacts. The aim is to decrease the influence of improbable models in the results, reducing the spread of the projections and easing the decision making process. Both climate and hydrological models will be analyzed in the EE process.

The plan for the expert elicitation in AquaClew is described in more details in an EE protocol, which describes the methodology and the action plan for performing the expert elicitation in AquaClew. Expert Elicitation workshop will be held on March 17th, 2020 (Venue: Irstea[1] located in Antony - South of Paris).

There are no good or bad answers in the EE. However, results from the elicitation can be compared to quantitative approaches to determine whether we have the knowledge and skills to differentiate good-performing models from an ensemble of models for a specific case and location. In case that the simulation uncertainty decreases as a result of the expert elicitation activity, EE could be a potential method to refine the climate-impact production chain and be applied in regions where a quantitative validation of the ensemble is not feasible.

1.3. Training document

This document serves as training for the experts involved in the EE of the AquaClew project. It is divided in four sections: 1) Introduction, 2) Description of the case studies, 3) Training: climate models, and 4) Training: hydrological models. The introduction provides background information about the project. Then, the five case studies involved in the elicitation are described. Subsequently, the climate models used in the elicitation are described along with examples on their skills found in selected literature. Finally, the hydrological models used in three case studies are described along with results from their simulation skill in the selected study sites.

Experts are given the full training material. However, they can choose to go through the entire document or only through the section of their expertise, whether this is climate or hydrological modelling.

[1] Please note that from 1st January 2020, Irstea and INRA became INRAE

2 Description of the case studies

1.1. Agricultural production in central Denmark

Water management issue:

The challenges in the Danish case study are to project the impact of climate change on the foundation for agricultural production. Climate change is expected to affect soil moisture and wetness conditions during winter and spring, where more precipitation is foreseen, and dryness during summer and early fall, where less precipitation is expected. More wetness/higher groundwater levels during winter and spring will adversely affect the farming field work in connection with sowing as well as crop growth on water logged fields leading to needs for increased drainage of fields. Dryer summers will adversely affect crop yield and lead to needs for increased irrigation. Hence, both flooding and drought will be examined together with the resulting effect on the root zone moisture content, the groundwater level and the river discharge. Focus is given to uncertainty of the projections of future conditions which is a function of both emission scenario, and the choice of climate model and hydrological model for decision making regarding agriculture.

Figure S1. Location of the Danish case study (Storå catchment)

Study area:

The Storå catchment is located in western Denmark (Figure S1). The area of the catchment is 1124 km^2. The highest elevations are located at the north, southeast and south of the catchment (Figure S2). The lowest elevations are located in the central region of the catchment, decreasing from east to west. In Table S1, climate characteristics of the catchment are given. In Figure S3, the annual variation in climate is given from 1990 to 2017 and the spatial variation is given in Figure S4.

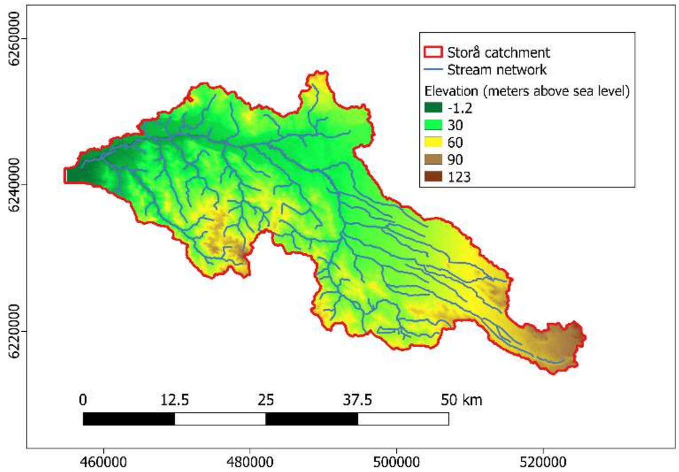


Figure S2. Catchment area, river network and topography

Meteorological features:

The annual accumulated precipitation and mean annual temperature in the catchment have increased from 1990 to 2017 (Figure S3) with a linear trend indicating an increase of 3.7 mm per year over a 30-year period for precipitation and an increase of 0.9 °C over 30 years for temperature (Table S1).

Table S1. Temperature and precipitation statistics

	Temperature	Precipitation
Annual mean	8.8 °C	1003 mm/yr
Annual variability	6.9 °C (in 1996) to 10.1 °C (in 2014)	657 mm/yr (in 1996) to 1190 mm/yr in (2014)
30-year (linear) trend	+0.9 °C	+110 mm

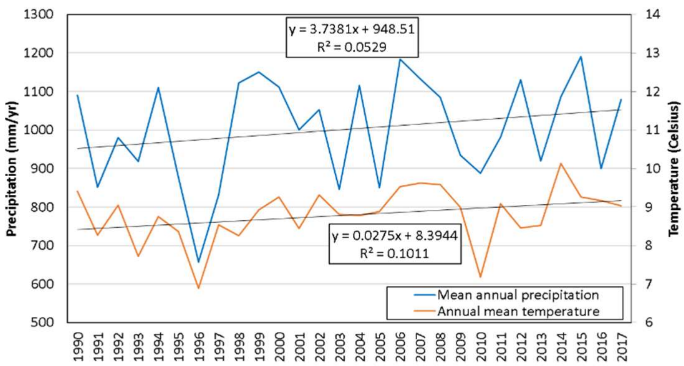


Figure S3. Time series of the annual mean temperature (°C) and annual accumulated precipitation (mm) - Storå catchment

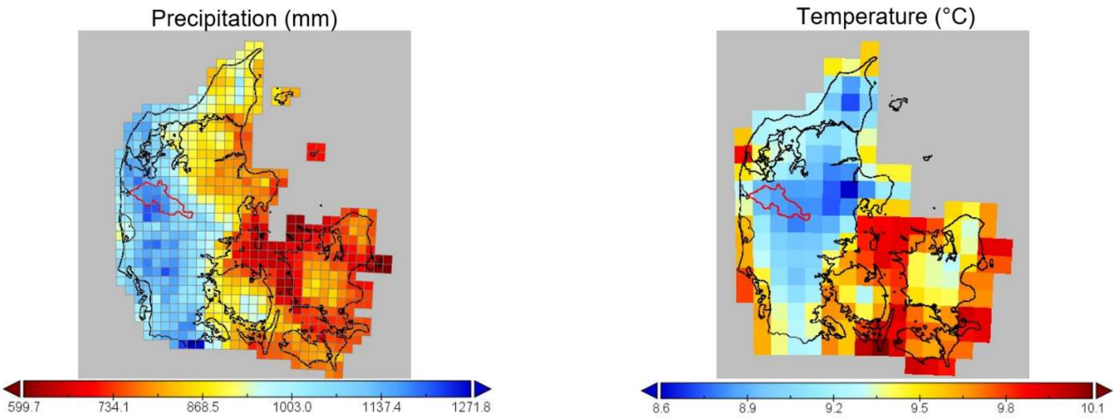


Figure S4. Spatial distribution of the annual mean accumulated precipitation (left) and the annual mean temperature (right)

The accumulated precipitation is relatively larger in West Denmark than in the East (Figure S4). Likewise, the mean annual temperature increases from West to East. Thus, the catchment is located in the wettest and coldest region of Denmark.

Hydrological aspects:

Rivers

The main river of the study catchment is the Storå River, which has an approximate length of 100 km (and a total catchment area of 1000 km^2). The river originates on the southeast of the catchment and flows towards the northeast until it reaches the outlet of the catchment at the Nissum Fjord (Q220062) (Figure S5). There are records of flooding within the catchment, with a great focus on the region surrounding station Q220059 because the main city of the downstream part of the catchment, Holstebro, is located there. Also, on floodplain areas upstream, and around the city of Herning, there are issues with groundwater flooding from the shallow aquifer system and from surface waters.

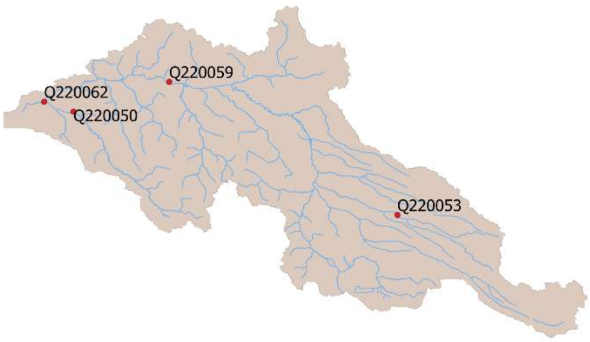


Figure S5. Location of the discharge and head stations

Groundwater

The mean depth to the shallow groundwater table is between 1 and 5 meters for most of the catchment (Figure S6). The depth decreases to below 1 meter in the areas adjacent to the streams and most of the higher depths are located at the upper stream zones. Year-to-year and seasonal variations of the shallow groundwater table are in the range of 1-2 m, following the variations in net precipitation.

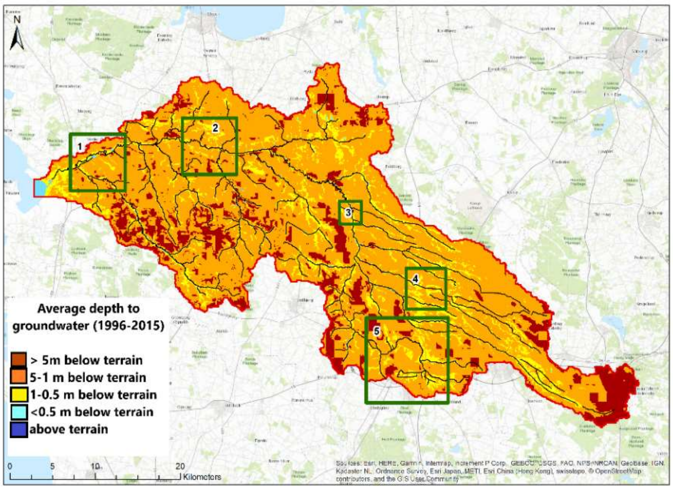


Figure S6. Mean depth to shallow groundwater table. Source: Esri, HERE, Garmin, Intermap, increment P Corp, GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordinance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors and the GIS User Community

1.2. Hydropower production in France: Southern Alps

Water-management issue:

The hydropower sector is sensitive to climate variables, as these directly affect energy generation and consumption. Climate services provide key information to optimize reservoir operations for hydropower production and to manage water storage to meet the needs of other users (for instance, tourism, agriculture, environmental flows). They also provide guidelines for climate change adaptation and to build strategies that incorporate climate resilience into existing hydropower facilities and the development of new projects. With many climate services flourishing across Europe, the challenge today is to develop energy indicators based on these climate services, which can facilitate decision-making at the regional and local levels.

Study area:

The Durance catchment is predominantly snowy or glacio-nival. The drainage area of the catchment at Espinasses is 3580 km². The basin is located at an elevation of 2020 m on average, with 25% of the surface above 2400 m. The Serre-Ponçon reservoir, located at the southwest of the catchment, is one of the most important in France for hydropower production, with a capacity of 1200 millions of cubic meters.

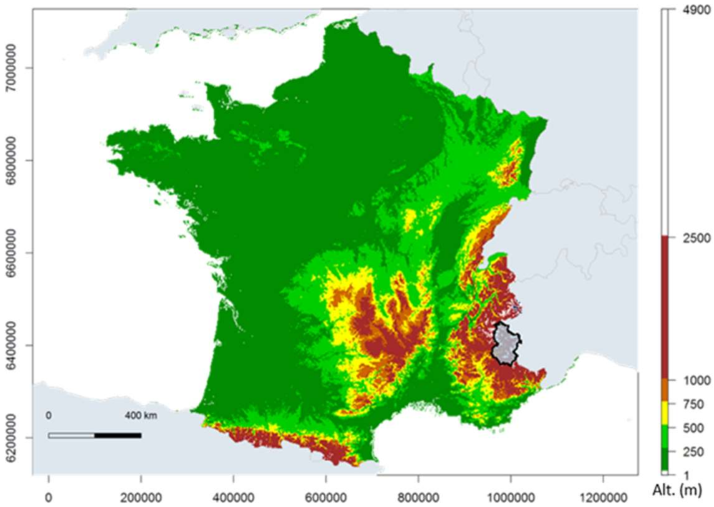


Figure S7. Location of catchment Durance River catchment

Table S2. Characteristics of the catchment

Reservoir	Volume (Mm^3)	Catchment	Area (km^2)	Average elevation (m)	Hydrological regime
Serre-Ponçon	1200	La Durance	3580	2028	Snow

Meteorological features

Table S3. Temperature statistics for the catchment from 1976 to 2005

Temperature	Annual mean	Annual variability	30-year (linear) trend
Durance	3.2°C	2°C (in 1984) to 4.3°C (in 1983)	+0.5°C

Table S4. Precipitation statistics for the catchment from 1976 to 2005

Precipitation	Annual mean	Annual variability	30-year (linear) trend
Durance	1055 mm.yr^{-1}	678 mm.yr^{-1} (in 1989) to 1443 mm.yr^{-1} (in 1977)	-160 mm

Yearly temperature has increased by 0.5°C in average between 1976 and 2005. Conversely, a decreasing trend is observable in the total precipitation during the same period.

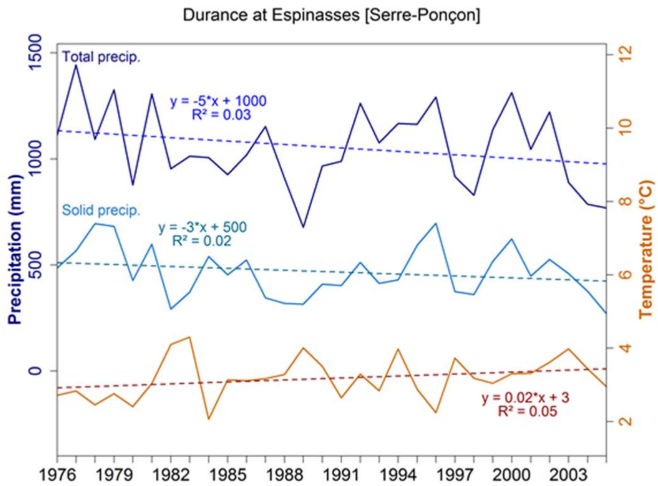


Figure S8. Time series (1976-2005) of annual mean temperature (°C) and the annual accumulated precipitation (mm) in the Durance catchment

Hydrological regimes

The rereservoir is mainly supplied by the Durance River, which is approximately 110-km long. It originates on the northeast of the catchment. The second river supplying the reservoir lake is the Ubaye, which originates at the southeast of the catchment. Flows are recorded at the outlet of the catchment since 1958, and have been reconstructed by Electricité de France to remove the effect of the management of the reservoir lake.

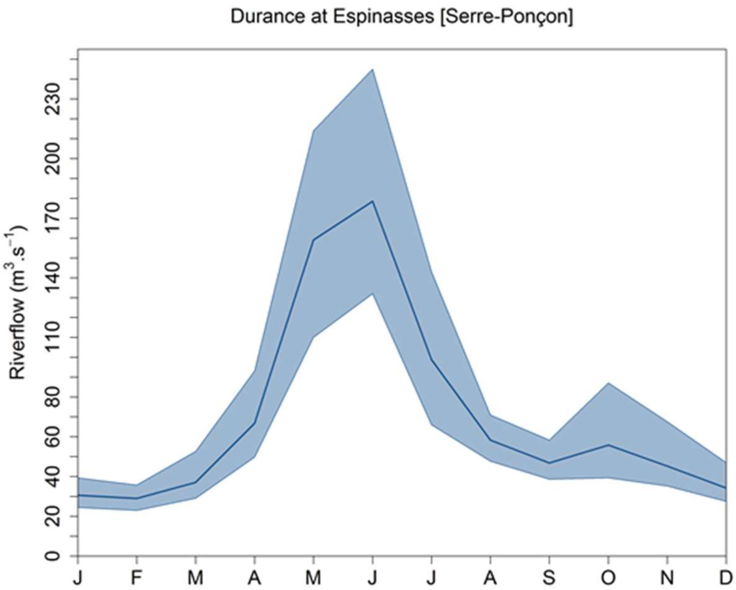


Figure S9. River flow regimes (25th, 50th and 75th percentiles) for the Durance River over the period from 1976 to 2005

1.3. Water resource allocation for tourism, agriculture and energy in Spain

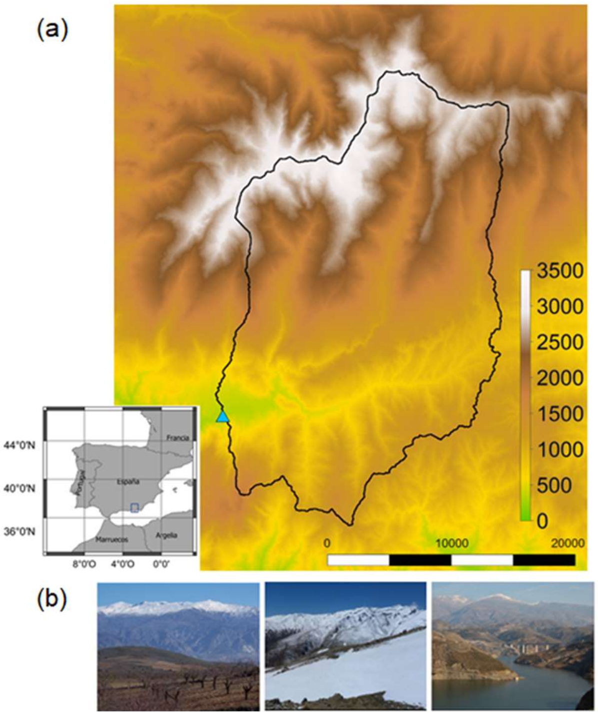


Figure S10. Study catchment in Sierra Nevada (Spain). (a) Topographic area, limits of the catchment (black line); catchment outlet (blue triangle), (b) Some representative views

Water management issue:

Semiarid areas are characterised by a large climatic variability (i.e. alternation of wet and very dry years, torrential episodes of heavy precipitation during late winter and early autumn). Consequently, the hydrological regime is also extremely changeable. Water has been one of the main arguments for the development of these areas. Therefore, water allocation and management constitute a current issue over these areas, where the main productive sectors are traditionally agriculture and tourism.

In this context, this study case is carried out in the Guadalfeo River Basin, a mountainous Mediterranean watershed in Sierra Nevada (Southern Spain), where the highest summits of the Iberian Peninsula are located. Snow plays a key role in the water cycle. Urban supply and its seasonal fluctuations conditioned by tourism, agriculture, together with hydropower generation in small power plants at the mountainous headwaters, are the main sectors competing for water allocation. Then, it is crucial to establish management strategies which assess the risk for the current supply system and water resource availability on a long-term basis in a context of future global warming.

Study area

Description: The catchment selected belongs to the Guadalfeo River Basin upstream the “Puente de Órgiva” (blue triangle in Figure S10), where the longest time series in the area is available. The catchment is representative of a mountainous region in a semiarid area, with high elevation gradients, where both alpine (on the summits) and Mediterranean (lower elevations) climate coexist.

Meteorological features

Precipitation

Precipitation regime is highly variable. In the last 5 decades, annual precipitation on the study area varied from 275 to 1382 mm, with a mean annual value of 745 mm. In the case of snowfall, the variation goes from 4 to 307 mm on an annual basis. Although decreasing evolutions are shown for both variables, no significant trends are found. It is important to notice the alternation of very wet and very dry years during the last analyzed years, which seems to show the presence of a torrential character of the precipitation.

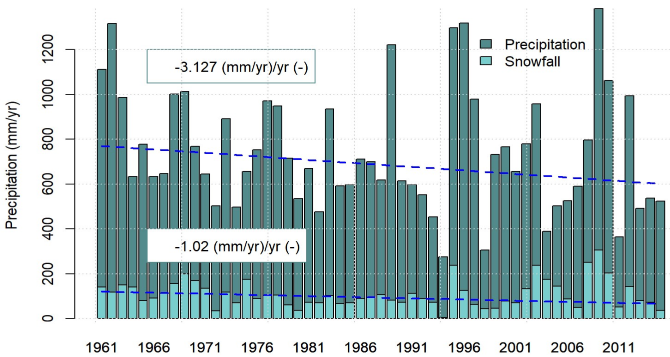


Figure S11. Evolution of the annual precipitation and snowfall averaged over the study area for the period 1961-2015

Table S5. Precipitation statistics in the study area

	Mean (mm/yr)	Variability (mm/yr)	Trend (mm/yr/yr)
Precipitation	745	275-1382	-3.127
Snowfall	109	4-305	-1.02

Temperature

The temperature regime shows an increasing evolution for the three variables analysed, with mean values of 21.4 °C, 12.6 °C and 4.2 °C for maximum, mean and minimum temperature respectively. This evolution can be considered as a trend only for maximum and mean daily temperatures, with increasing values of 0.044 and 0.03 ºC per year respectively. On the contrary, minimum temperature does not present significant trend, since the increasing evolution show in the 90s is attenuated during the last fifteen years.

Table S6. Temperature statistics in the study area

	Mean (ºC)	Variability (ºC)	Trend (ºC/yr)
Tmax	21.4	20.4 - 24.2	0.044 (*)
Tmean	12.5	11.1 - 14.5	0.03 (*)
Tmin	4.2	2.0 - 7.4	0.023 (-)

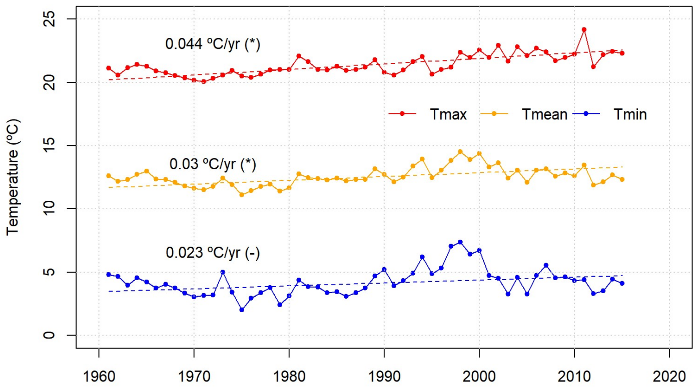


Figure S12. Evolution of the annual mean (Tmean), maximum (Tmax) and minimum (Tmin) daily temperature, averaged over the study area for the period 1961-2015

Hydrological aspects:

Snow

Snow plays a key role in the hydrological regime in the area. It usually appears in elevations higher than 2000 m.a.s.l from November to May, with high variability within and between years, with several accumulation ablation cycle during the year. Its distribution is also heterogeneous; due to the shallow heights its interaction with rocks and bushes favours a characteristic patched distribution.

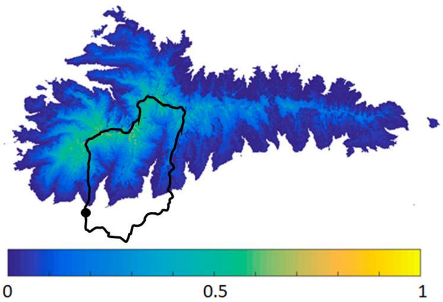


Figure S13. Distribution of the mean fractional snow cover (m2 m−2) over Sierra Nevada mountains during the period 2000–2013 derived from the available Landsat TM and ETM+ applying a spectral mixture algorithm

Discharges

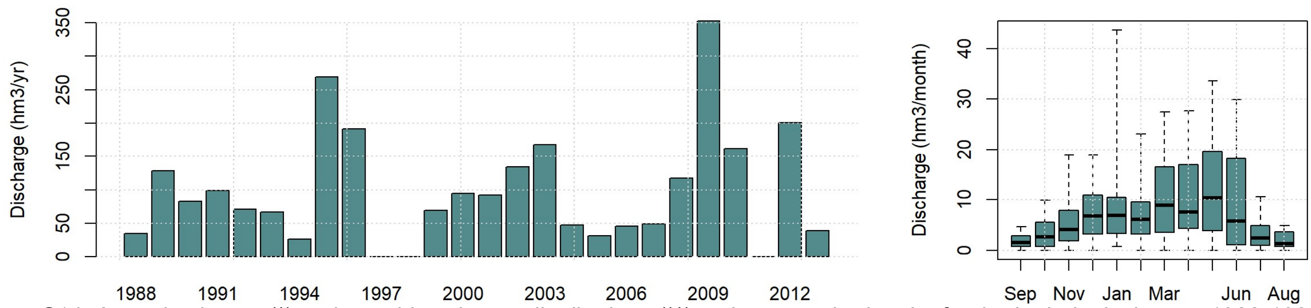


Figure S14. Annual volumes (*) and monthly volumes distributions (**) at the watershed outlet for the hydrological years 1988-1989 to 2013-2014

(*) No information was measured during the hydrological years 1997-1998, 1998-1999 and 2011-2012.

(**) Box plots show the median values (black line), the interval range and the 10th and 90th percentiles (whiskers) of each sample.

The annual mean discharge volume in the catchment during the observation period (1988-2014) was 99.0 hm^3yr^{-1} with high variation between years from 26.4 hm^3yr^{-1} in 2004 to 352.7 hm^3yr^{-1} in 2009. At monthly basis the hydrograph shows higher volumes during spring (March-June) associated to the snowmelt process. The minimum volumes take place during summer and autumn and winter show similar average distribution between years with variation associated to some heavy rain event in specific years.

1.4. Fluvial and coastal interactions under Mediterranean climate conditions in Spain

Water management issue

Deltaic systems are unique landscapes of a high environmental value in continuous transformation due to the sculpting action of marine and fluvial dynamics. In the last two centuries, the growth of tourism and its occupation for agricultural and industrial activities, has favoured the irrational use of their resources. In addition, the regulation of the river flow has led to severe erosion problems. Mediterranean deltas such as those at the Guadalfeo and Adra river mouths (Spain) are especially vulnerable to sea level rise, which is one of the most important causes of delta retreat around the globe. Therefore, the present issues found in these systems and the erosion in the adjacent coasts will become aggravated in a climate change scenario that includes sea level rise and changes in the frequency and persistence of storms and precipitation events.

This case study proposes to analyze the changes in physical processes such as sea waves, fluvial discharges and sediment transport, that interact and control the dynamics of these zones as well as the integrity of the physical environment and ecologic condition under different climate change scenarios to contribute to the quality and usability of climate services at fluvial, coastal and transition zones of semiarid watersheds in this region.

Study area

Figure S15. Location of the Guadalfeo River catchment. Source: SIO, NOAA, U.S. Navy, NGA, GEBCO

The Guadalfeo and Adra rivers are located in Granada and Almería, respectively, in the south of Spain flowing into the Alborán sea. Their basins are semiarid, have a small size (1250 km^2 and 746 km^2, respectively) and show significant gradients of altitude that greatly condition the erosive dynamics and sediment transport to their adjacent coasts (Figure S15).

In the Guadalfeo River catchment, as in other rivers of the Mediterranean coast, the gravel nature and the huge availability of sediment boost the sediment transport and is the main contributor to the supply of coastal sediments. The relatively steep topographic gradients lead to large contributions from a wide range of sediment sizes with varying proportions of sand and gravel. The river was dammed 19 km upstream from the mouth in 2004, regulating 85 % of the basin runoff. As a consequence, the delta currently presents erosion problems and severe coastline retreat.

The continental shelf of the Guadalfeo River is narrow with an average width of less than 5 km. The shelf break is located at a depth of 100 m almost parallel to the delta coastline.

Maritime and atmospheric features

Precipitation

The morpho-hydrodynamic processes at the delta are linked to the passage of low pressure weather systems, responsible of scarce but torrential precipitation events leading to extreme river discharges. Notable spatio-temporal and altitudinal gradients within the basin are observed with average values of 460 and 630 mm.y^{-1} in the valleys (<600–800 masl) and mountain areas (> 1500 masl), respectively, as well as periodic extreme events (Figure S16). At heights > 2500 m, over 70 % of the annual precipitation occurs as snow. Trend analysis of the precipitation points to a scenario that could alter the hydrological behaviour of the headwaters area and, therefore, modified the responses of the erosive and transport processes taking place.

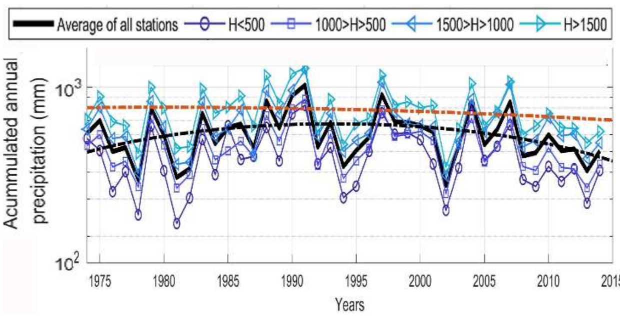


Figure S16. Mean annual precipitation at four stations

Waves and wind

The maritime and atmospheric climate in these regions significantly differs between summer and winter. The region is subjected to the passage of extra-tropical Atlantic cyclones and Mediterranean storms, with average wind speeds of 18–22 m/s which generate wind waves under fetch-limited conditions (approximately 200 to 300 km). The storm wave climate is bimodal with prevailing WSW (extra-tropical cyclones) and ESE (Mediterranean storms) wave directions arriving obliquely to the shore with a differentiated influence on storm surge and which redistribute sediment to the adjacent coast. Total run-up values greater than 1.52 m generate beach erosion. Under these conditions, the formation of the deltas to either side of the mouth are associated with isolated ‘pulses’ alternating coastline advance and retreat at either side of the mouth as a result of the joint action of atmospheric, maritime and terrain forcings.

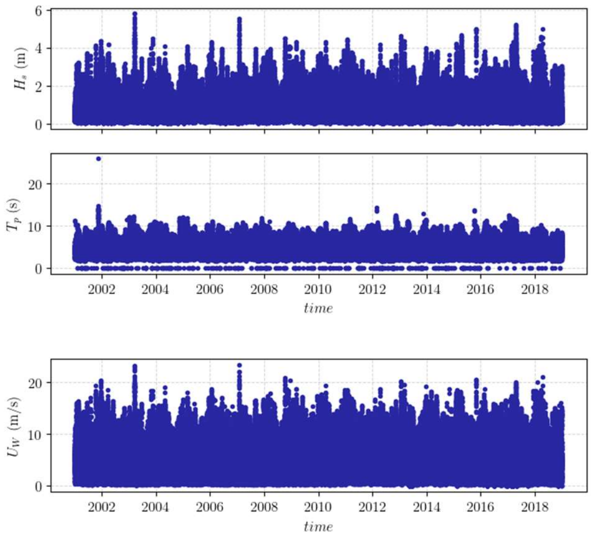


Figure S18. Wave and wind magnitudes

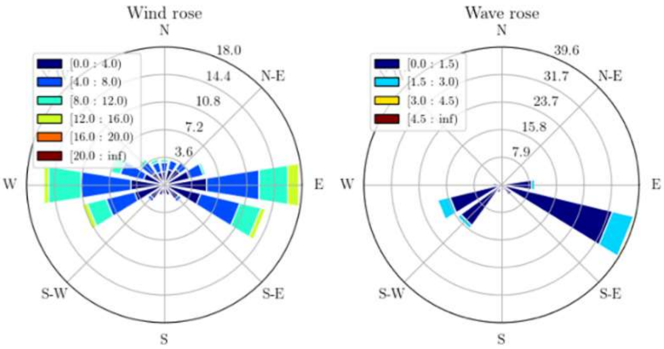


Figure S17. Wave and wind directions

Hydrological aspects:

The hydrological regime of the Guadalfeo River has an average flow of 4 $m^3 s^{-1}$ and peak discharges that exceed 100 $m^3 s^{-1}$. The damming of the river in 2004 modified its natural run and significantly reduced the sediment contribution to the shore resulting in a generalized retreat of the coastline and severe erosion problems (Figure S19).

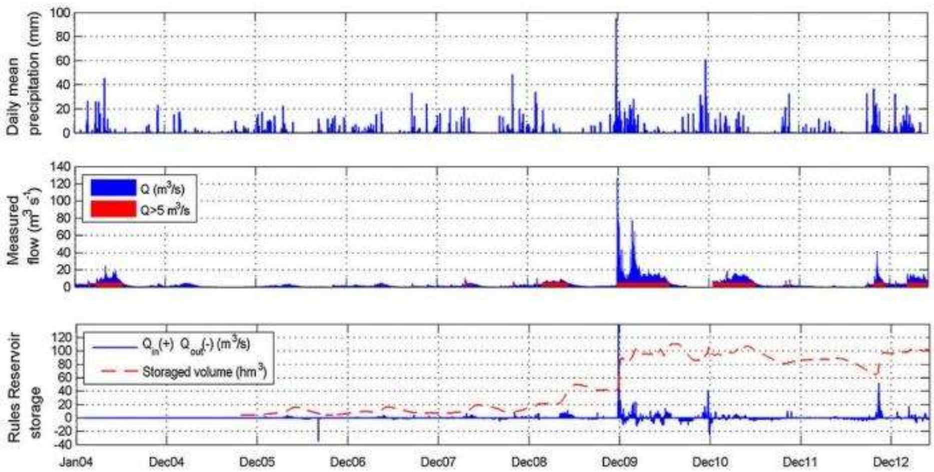


Figure S19. Daily precipitation, flow and river reservoir shortage June 2004-December 2012

1.4.1. Biodiversity change under climate change in Sweden

Water management issue

Jönköping county administration works as a policy maker of environmental protection. There is a need for information on different climate indicators to be easily accessible and comparable with other data sources. Jönköping County administration has the responsibility to detect changes in ecosystems, to describe them as well as to decide on new regulations to protect the environment in a changing climate. They are a part of a regional environmental monitoring program, where they are required to describe the current environmental status, provide supporting documentation and follow up any actions to improve the status. Therefore, changes in climate are relevant to their long-term monitoring and planning.

The county is a 'source area' for water, and has many wetland areas, small lakes and streams. These, as well as the different species that live in and around the water bodies, have intrinsic value. Jönköping County Administration is responsible for decisions regarding ecosystem management within different areas in Jönköping, thus they need indicators that can show changes and when the changes will cross environmental and biological thresholds (for bats, woodpeckers, butterflies, fish populations, water levels and quality).

Study area

Jönköping is an inland county located in the southern half of Sweden covering an area of approximately 10,000 km^2 including thousands of small lakes. The county is to a large part covered with forests and the middle of the county contains a relatively high elevation area – reaching 380 m above sea level. Precipitation and run-off is generally higher in the western part. The county is divided into 8 catchments, which are characterised by high/lowland areas or east/western areas.

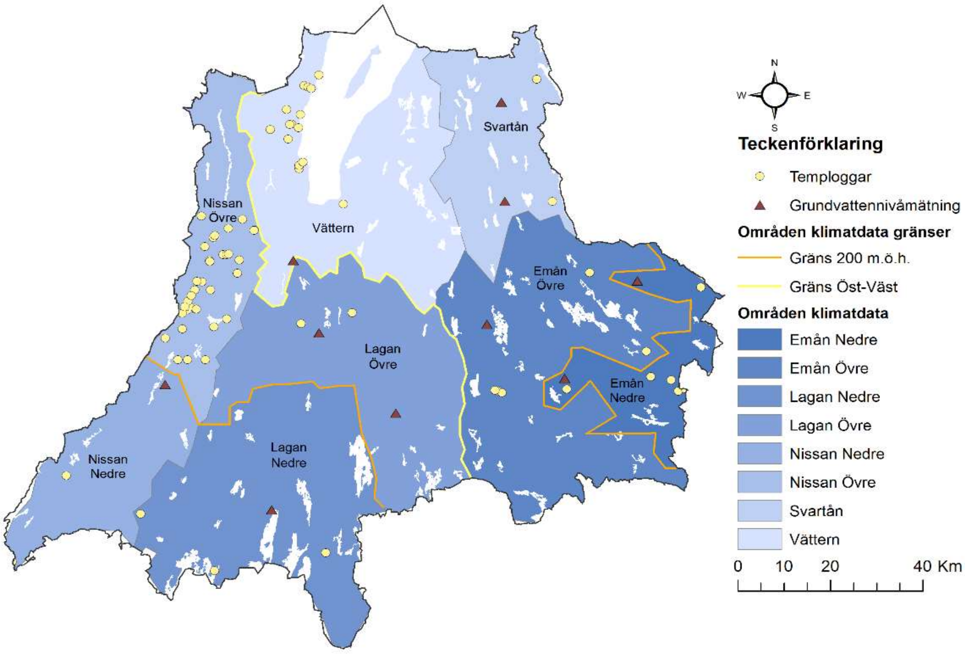


Figure S20. Map of Jönköpingslän, Sweden, showing main catchments, high/low elevation areas and division in western/eastern part based on different precipitation patterns (map from Jönköping County Administration)

Meteorological features

Temperature

The annual mean temperature for Jönköping county in 1961-1990 was 5.6 °C. There were some variations within the county with ~5 °C observed in highland areas and 6 °C close to lake Vättern (Figure S21). During the last 20 years the temperature has increased with almost 1 °C.

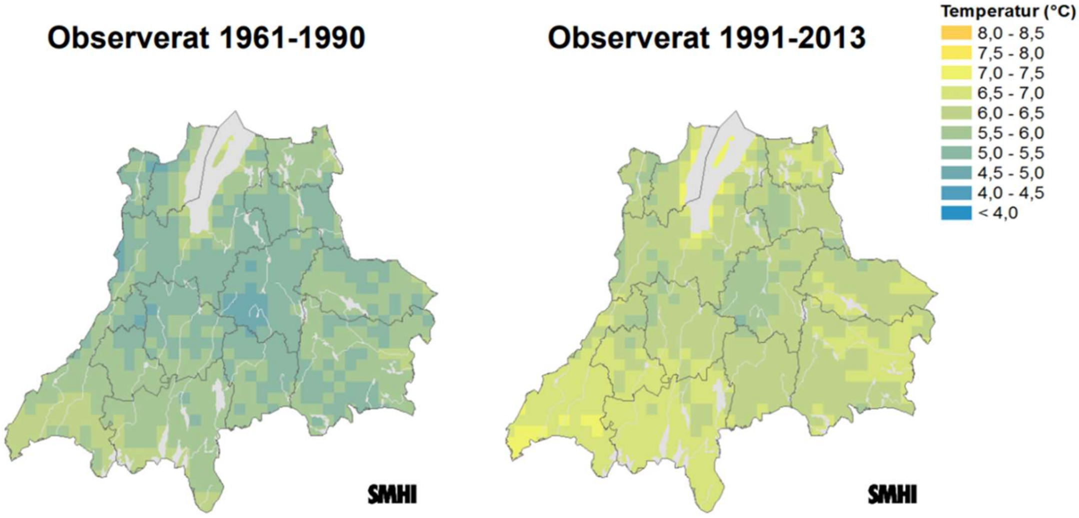


Figure S21. Yearly mean temperature for Jönköping county over the two periods 1961-1990 and 1991-2013. (Maps from Länsanalys Jönköping report nr 25, 2015)

Precipitation

Average annual precipitation in Jönköping county during 1961 – 1990 was 741mm. It rains and snows mostly in the western part of the county, due to weather systems usually approaching from the west before heading over the highland. Inter-annual variability is large (between 590mm and 960 mm). During the last 23 years, there have been many wet years, mostly in the southwestern part of the county (Figure S22).

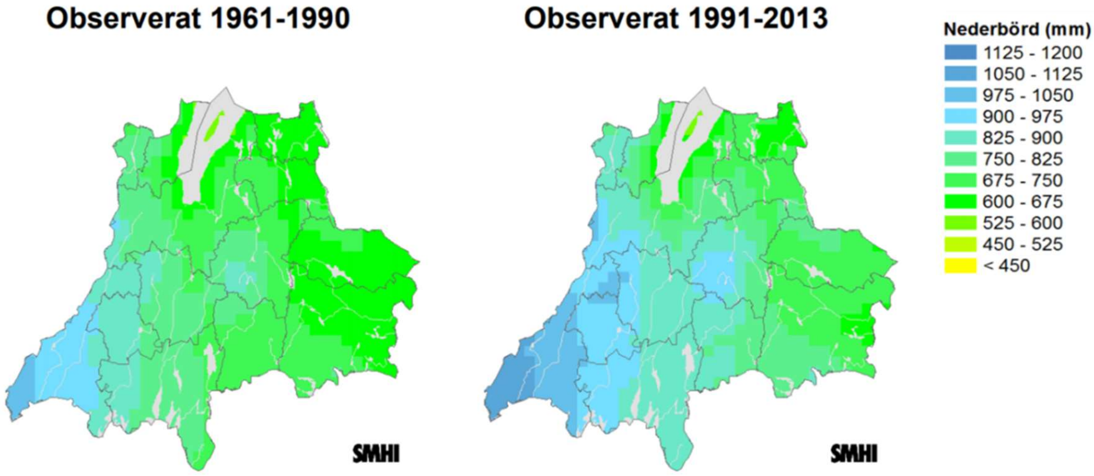


Figure S22. Yearly mean precipitation for Jönköping county over the two periods 1961-1990 and 1991-2013. (Maps from Länsanalys Jönköping report nr 25, 2015)

Hydrological features

Three of the largest rivers in southern Sweden (Nissan, Lagan and Emån) have their source flows within the county and thereafter flow through other counties to reach the sea on the west and east coast respectively. In the northern part of the county, water flows to the great lake Vättern, having its outflow in a different county.

Depth to the ground water generally differs depending on the geology, with levels close to the ground in moraine areas and several meters below ground in eskers and other fluvio-glacial sediments.

3 Training: Climate models

3.1. The ensemble of GCM-RCM simulations

The expert elicitation is limited to discuss the subset of the Euro-CORDEX 0.11 degree ensemble (EUR-11) presented in Table S7, consisting of three GCMs and four RCMs. The ensemble consists of the complete number of models (at the time of writing) that include the following outputs:

- Scenarios following RCPs 2.6, 4.5 and 8.5
- At least daily outputs of precipitation, 2-m air temperature as daily mean, maximum and minimum, 10-m wind speed and sea level pressure.
- At least the time period 1971 – 2099.

The following sections describe key aspects of first the GCMs and then the RCMs.

Table S7. GCM-RCM ensemble from EURO-CORDEX 0.11 (EUR-11), listing the GCM, the RCM and the realization of the GCM

GCM	RCM	Realization
EC-EARTH	RACMO22E	12
EC-EARTH	CCLM4-8-17	12
EC-EARTH	RCA4	12
HadGEM2-ES	RCA4	1
HadGEM2-ES	RACMO22E	1
MPI-ESM-LR	RCA4	1
MPI-ESM-LR	REMO2009	2
MPI-ESM-LR	REMO2009	1

3.2. GCMs

The GCM determines the large-scale conditions in which the RCM then operates. It is thereby setting the first order characteristics for the historical performance as well as the main climate sensitivity. The GCM section of this document is therefore focused on the main components and the circulation performance of each GCM. Evaluations are taken from published literature, and other GCMs are kept in the plots for context, however, with their names masked out to emphasize the current ensemble. Further, the focus is on the atmospheric circulation, as this is the main determinant of the effect on European hydrology through large scale cyclones, blocking patterns, and storminess.

3.2.1. GCM components

The performance of the GCMs is the sum of all parts of the Earth system components, and the parameter setups and choices within each model component. It is not possible to describe all features here, but the main components are listed along with their resolution as it might give a clue to potential limitations.

Table S8. Basic coupled GCM components and their resolution as number of horizontal grid points

GCM	EC-Earth	HadGEM2-ES	MPI-ESM-LR
Atm. Model	IFS (250 km)	Met Office Unified Model (275 km)	ECHAM6 (415 km)
Ocean Model	NEMO (140 km)	Met Office Unified Model (185 km)	MPIOM (180 km)
Surface Model	HTESSEL	TRIFFID	JSBACH

3.2.2. North Atlantic Oscillation (NAO)

The NAO is the major controlling factor for the storm tracks over the Atlantic and has a strong impact on the precipitation climatology over Europe. Bias in the position of the NAO, or the strength of the pattern can affect which parts of Europe that is affected, leading to various bias on related variables. Wang et al. (2017) evaluated several CMIP5 GCMs regarding different aspects of the NAO. The main pattern of the NAO was investigated by computing the empirical orthogonal functions (EOFs) of the sea level pressure, and is shown in Figure S23, with the SLP reconstructed observed sea level pressure as reference. All three GCMs show a similar NAO pattern, but underestimate the explained variance of the EOFs, and the southern part of the dipole pattern is shifted to the east compared to observations. The decadal mean pattern is less pronounced in the EC-Earth model.

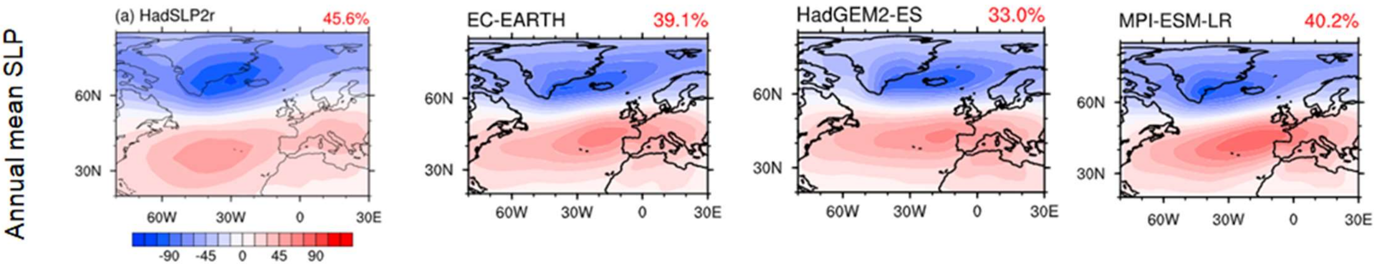


Figure S23. Leading EOF (explained variance percentage indicated in red) of annual mean sea level pressure (SLP). Figure compiled from several figures in Wang et al. (2017)

Wang et al. (2017) further evaluated the correlations between NAO with three main phenomena observationally connected to the NAO: the northern hemisphere temperature (NHT), the Atlantic multi-decadal oscillation (AMO), and the Atlantic meridional overturning circulation (AMOC). The evaluation results are reproduced in Figure S24, with only the current GCMs marked. A solid black dot marks a significant positive correlation, and MPI-ESM-MR stands out among the three by well simulating these linkages to the NAO. In fact, it is outstanding compared to the full range of the evaluated CMIP5 models.

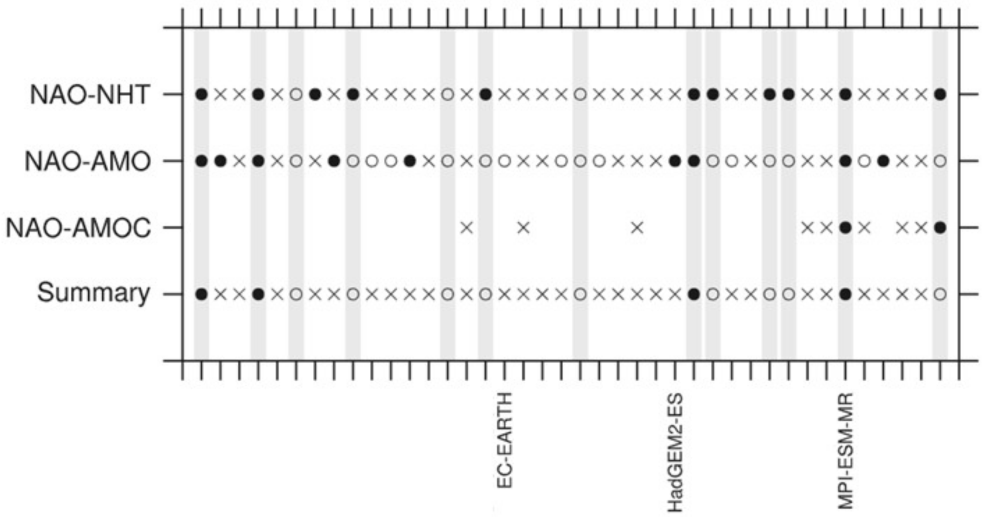


Figure S24. Performance of CMIP5 GCMs in reproducing the NAO linkages to the Northern Hemisphere Temperature (NHT), the Atlantic Multidecadal Oscillation (AMO), and the Atlantic Meridional Overturning Circulation (AMOC). The model is marked by a solid dot if there is a significant positive correlation, a circle for non-significant positive correlation, and a cross for failure in reproducing the linkage. Only the here evaluated models are named. The figure is taken from Figure 11 of Wang et al. (2017)

3.2.3. Reproduction of circulation patterns

The NAO is only one of many important aspects of the European circulation. Further patterns determine, e.g. atmospheric blocking events or other disturbances from the main easterly flow of the atmosphere across Europe. Such events can be quite important for local characteristics, but have too many local aspects for this overview. We therefore provide an overview result from a study by Stryhal and Huth (2019), see Figure S25, where nine major circulation patterns over different parts of Europe were evaluated compared to reanalysis data sets (in color). All GCMs show significant bias in all parts of Europe, and there is no clear pattern of one of the three GCMs to perform better across all of Europe. Compared to the full range of CMIP5 GCMs evaluated, the three selected here are mean or for some regions the best performing models.

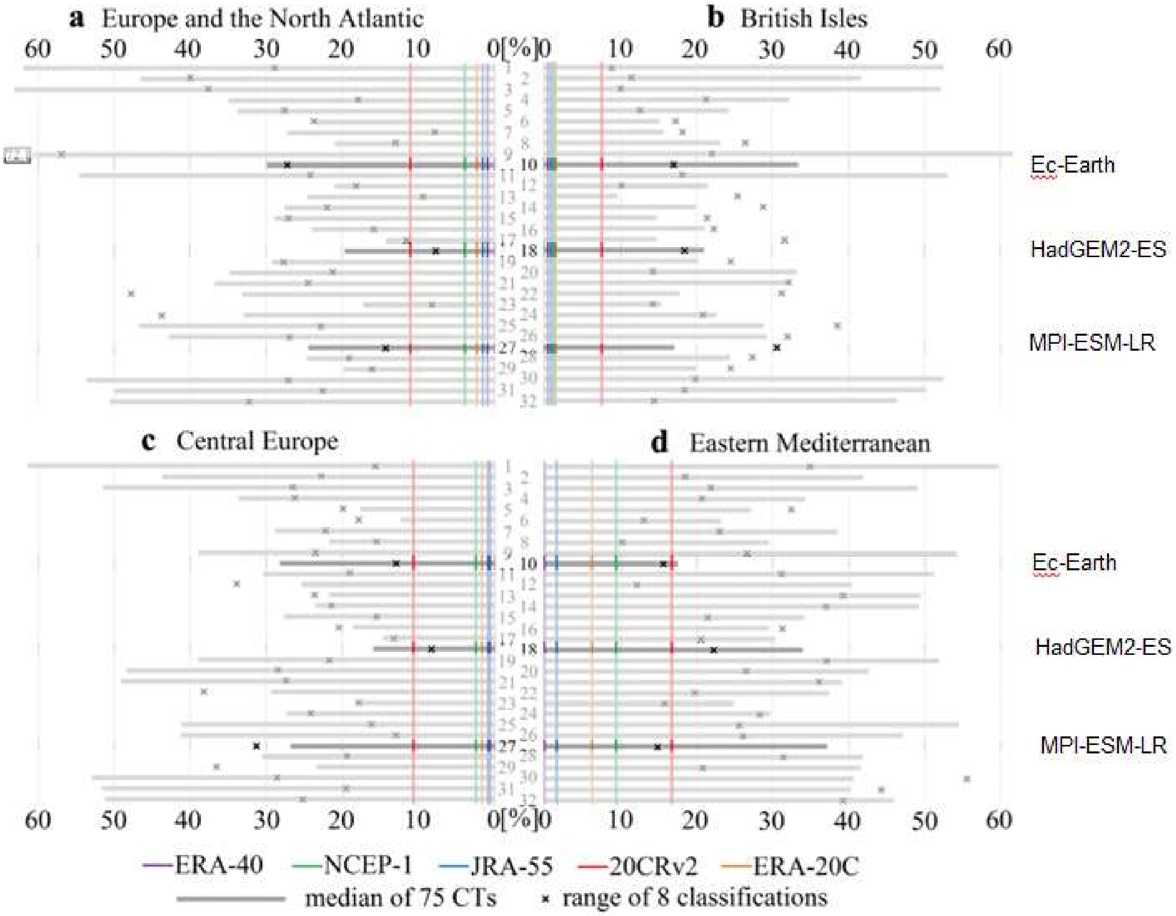


Figure S25. Bias in reproduction of the frequency of nine major circulation patterns in (a) Europe as a whole, (b) the British Isles, (c) Central Europe, and (d) Eastern Mediterranean. Figure taken from Stryhal and Huth (2019), with a transparent mask applied ove over GCMs that are not evaluated here

3.3. RCMs

The RCMs take inputs of atmospheric wind speed and direction, humidity and temperature, as well as sea surface temperature from the GCMs. The circulation can then be modulated by internal variability of the RCM, and local aspects of e.g. precipitation and temperature can differ substantially. Here we focus more on the driving data use in the impact models, i.e. aspects of temperature, precipitation and winds.

3.3.1. RCM components

Common to all of the RCMs is the horizontal resolution of 0.11 degree (12.5 km) on the EURO-CORDEX domain. Table S9 gives some details on the most fundamental parametrizations used for the different RCMs. We do not go through the different parameterizations, but list them mainly as information to experts that are aware of the performance and limitations of the different components.

Table S9. References to the main parameterizations applied in each RCM of the Euro-CORDEX ensemble presented here

	CCLM	RACMO	REMO	RCA
Radiation	*Ritter and Geleyn (1992)*	*Fouquart and Bonnel (1980), Mlawer et al. (1997)*	*Morcrette et al (1986), Giorgetta and Wild (1995)*	*Savijärvi (1990), Sass et al (1994)*
Land-surface	*TERRA-ML: Doms et al. (2007)*	*Van den Hurk et al. (2000), Balsamo et al. (2009)*	*Hagemann (2002), Rechid et al. (2009)*	*Samuelsson et al. (2006)*
PBL	*Louis (1979)*	*Lenderink and Holtslag (2004), Sibesma et al., (2007)*	*Louis (1979)*	*Cuxart et al. (2000)*
Convection	*Tiedtke (1989)*	*Tiedtke (1989), Nordeng (1994), Niggers et al. (2009)*	*Tiedtke (1989), Nordeng (1994), Pfeifer (2006)*	*Kain and Fritsch (1990, 1993)*

3.3.2. Temperature

The RCMs were evaluated by Kotlarski et al. (2014) in ERA-Interim downscaled simulations, i.e. all RCMs use the same forcing conditions close to the historical climate. Evaluation was performed using E-OBS as reference. Figure S26 shows a mosaic of results for the current RCM ensemble from Kotlarski et al. (2014). A similar analysis was performed for each pair of GCM-RCM in the current ensemble, and is shown for wintertime in Figure S27, and for summer in Figure S28. A similar color scale was used as in Kotlarski et al., (2014) to allow for direct comparison.

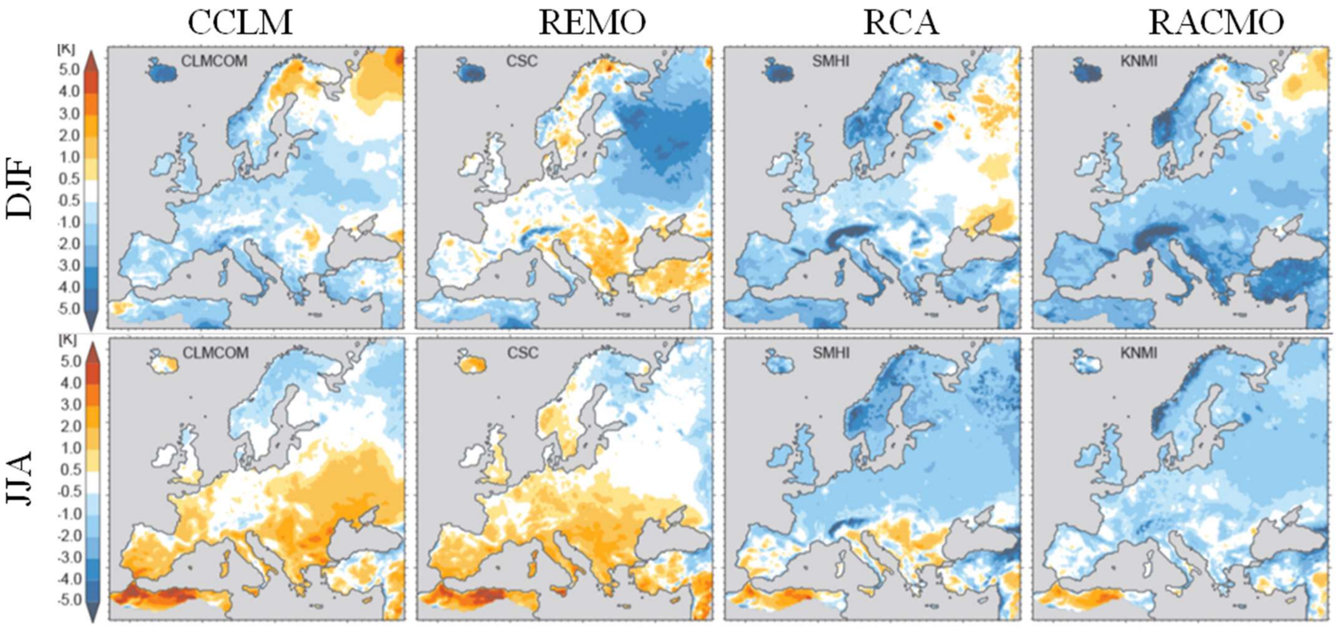


Figure S26. Bias [K] in surface temperature for ERA-Interim driven simulations, in comparison to E-OBS; (top) DJF, (bottom) JJA for the period 1989-2008. Extracted from several images of Kotlarski et al. (2014)

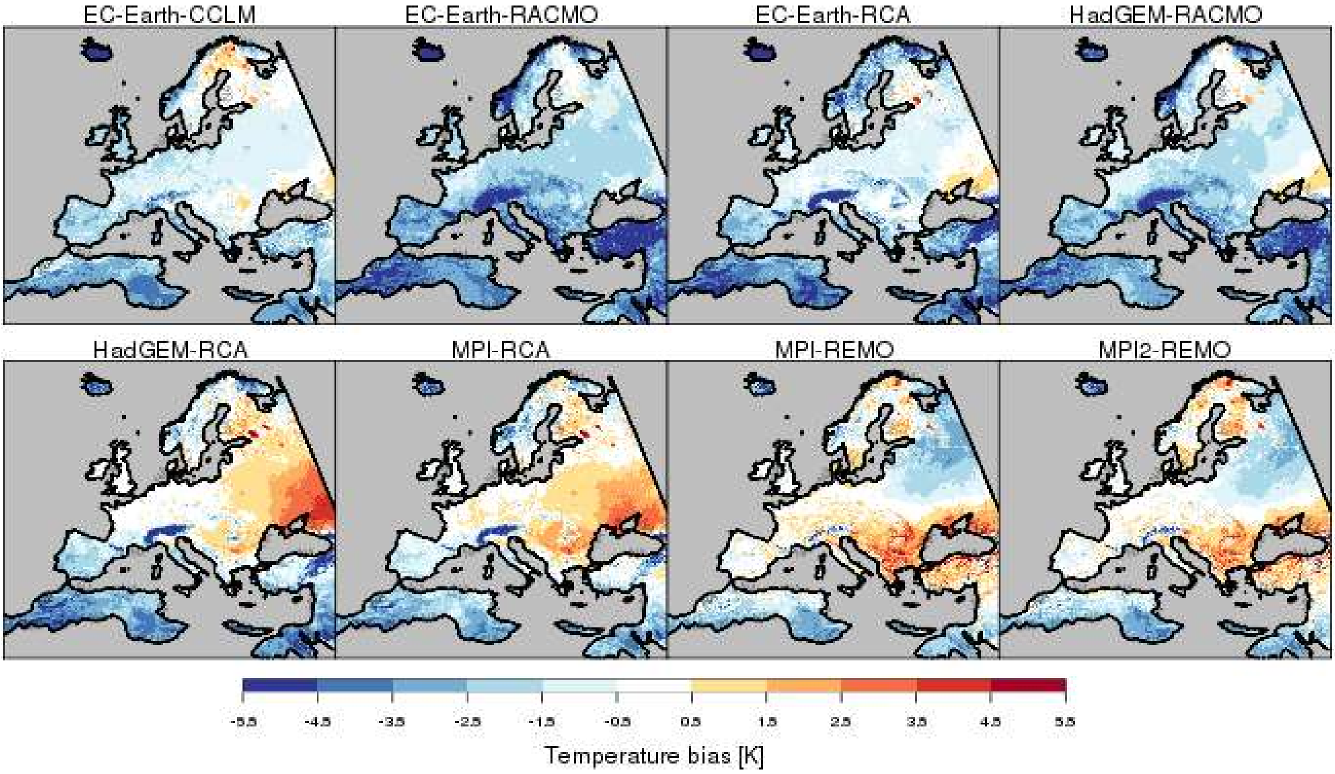


Figure S27. DJF temperature bias of GCM-RCM combinations with E-OBS reference for the period 1971-2000

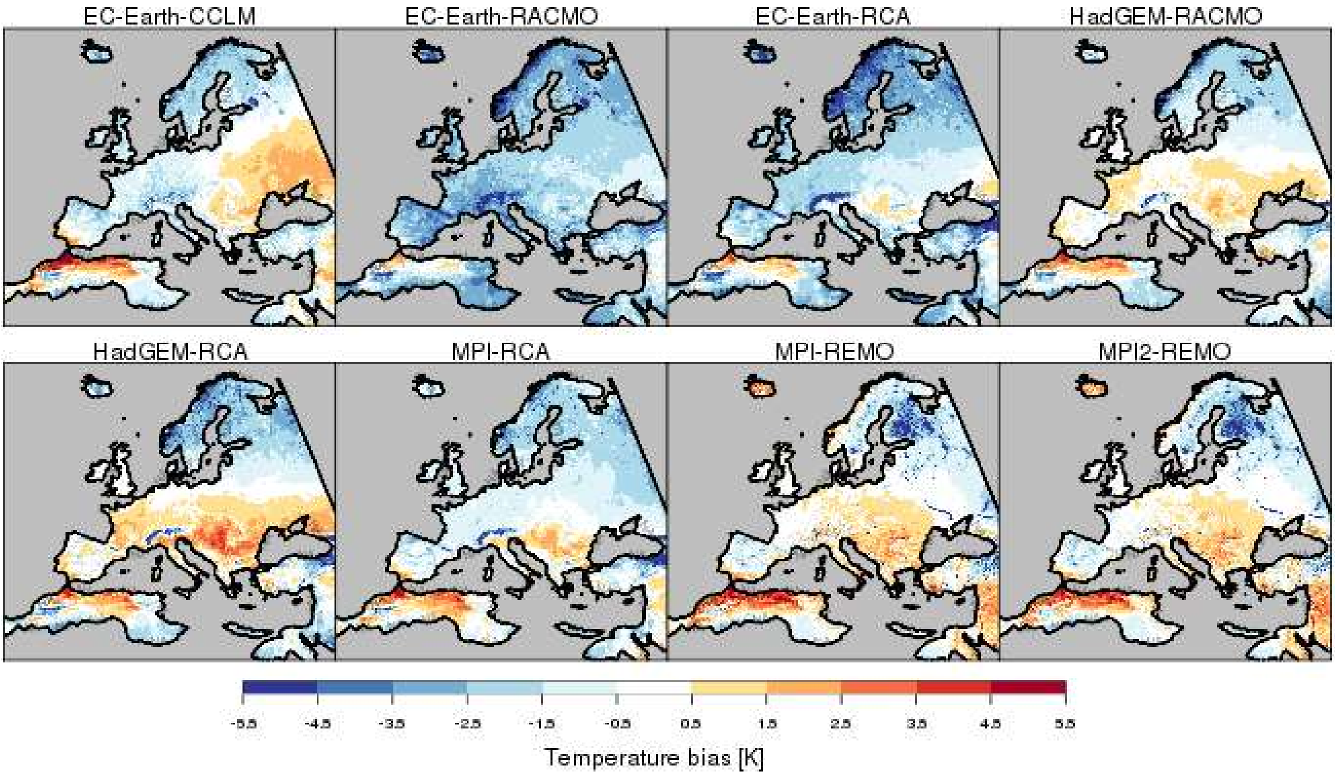


Figure S28. JJA temperature bias of GCM-RCM combinations with E-OBS reference for the period 1971-2000

3.3.3. Precipitation

The RCMs were evaluated by Kotlarski et al. (2014) in ERA-Interim downscaled simulations, i.e. all RCMs use the same forcing conditions close to the historical climate. Evaluation was performed using E-OBS as reference. Figure S29 shows a mosaic of results for the current RCM ensemble from Kotlarski et al. (2014). A similar analysis was performed for each pair of GCM-RCM in the current ensemble, and is shown for wintertime in Figure S30, and for summer in Figure S31. A similar color scale was used as in Kotlarski et al., (2014) to allow direct comparison.

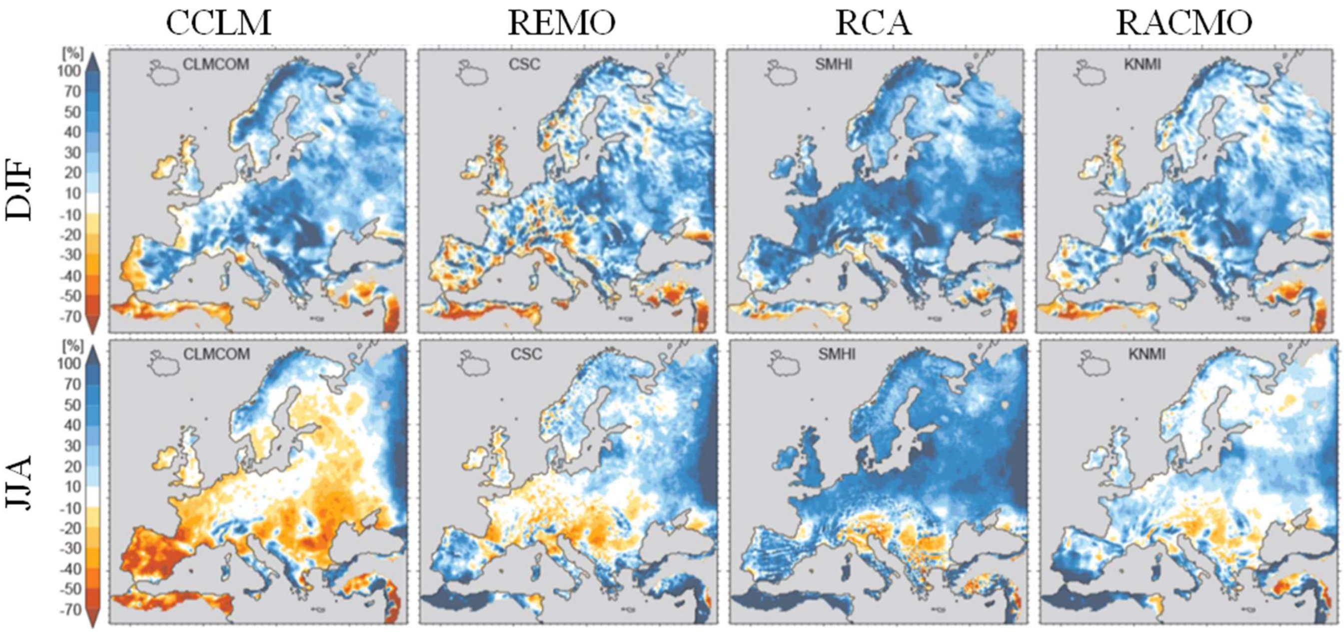


Figure S29. Relative bias [%] in precipitation for ERA-Interim driven simulations, in comparison to E-OBS; (top) DJF, (bottom) JJA for the period 1989-2008. Extracted from several images of Kotlarski et al. (2014)

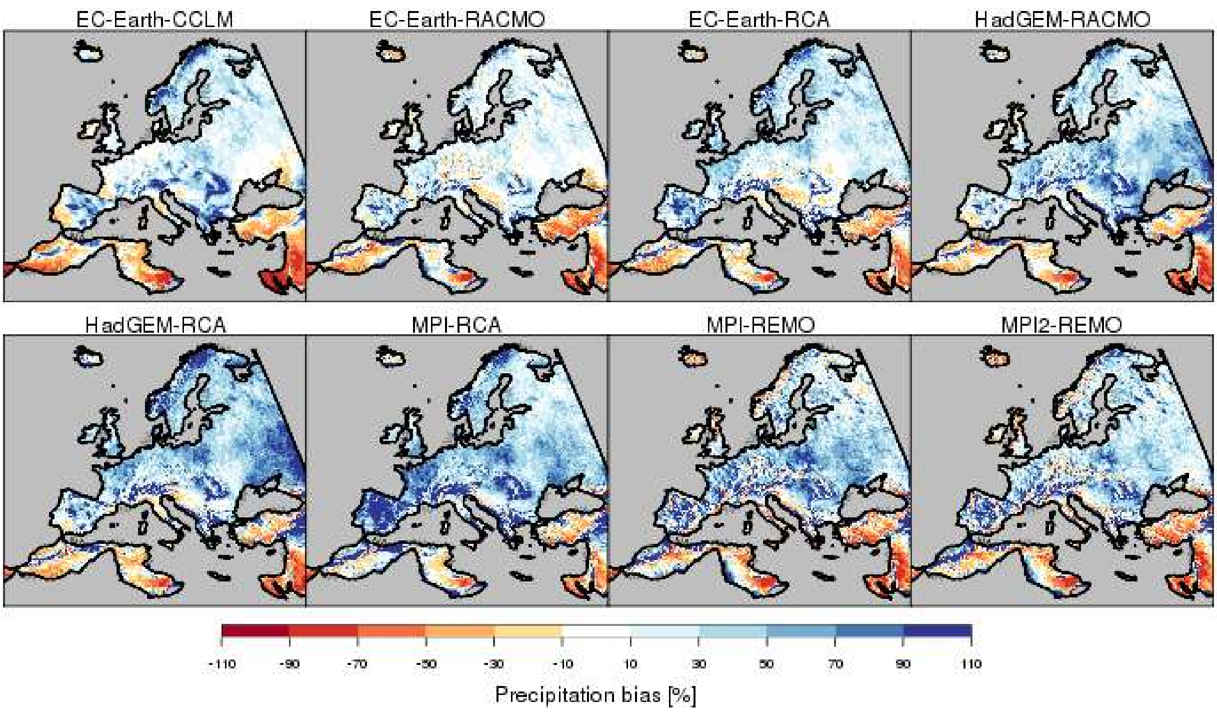


Figure S30. DJF precipitation bias [%] of GCM-RCM combinations with E-OBS reference for the period 1971-2000

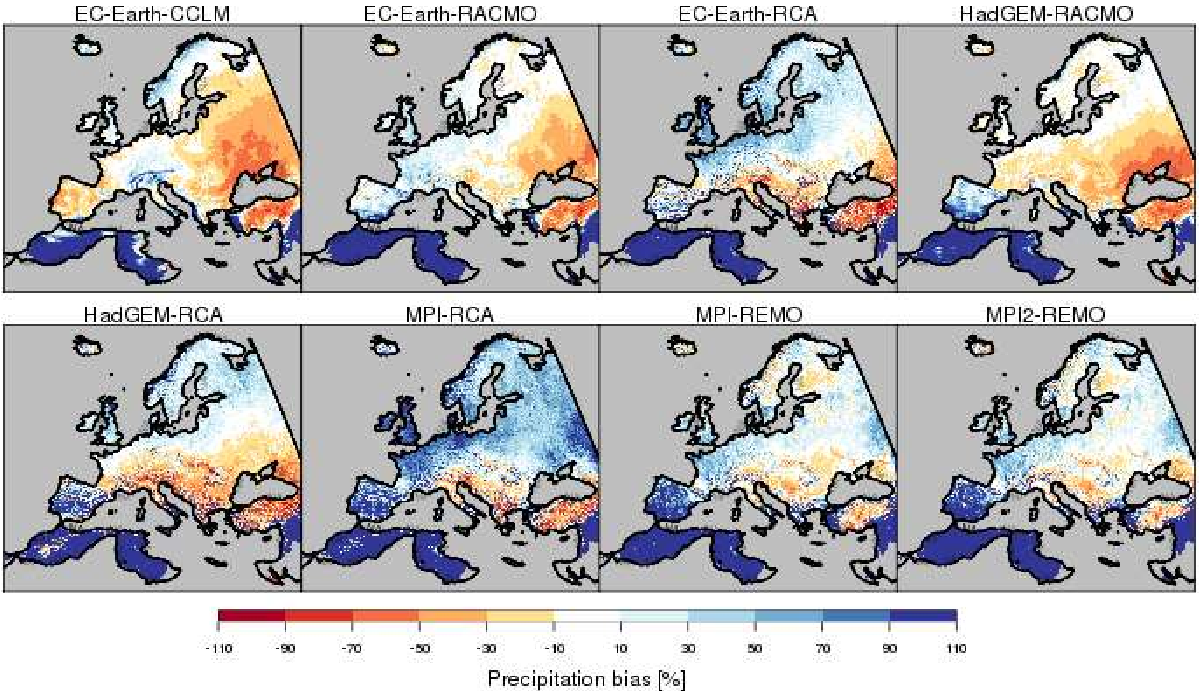


Figure S31. JJA temperature bias of GCM-RCM combinations with E-OBS reference

3.3.4. Dry periods

The reproduction of dry periods is important for some impact models, e.g. regarding low flows in rivers. Figure S32 shows bias in the number of dry periods of at least 5 days duration in the period 1990-2005 for all GCM-RCM combinations, in comparison to the E-OBS data set.

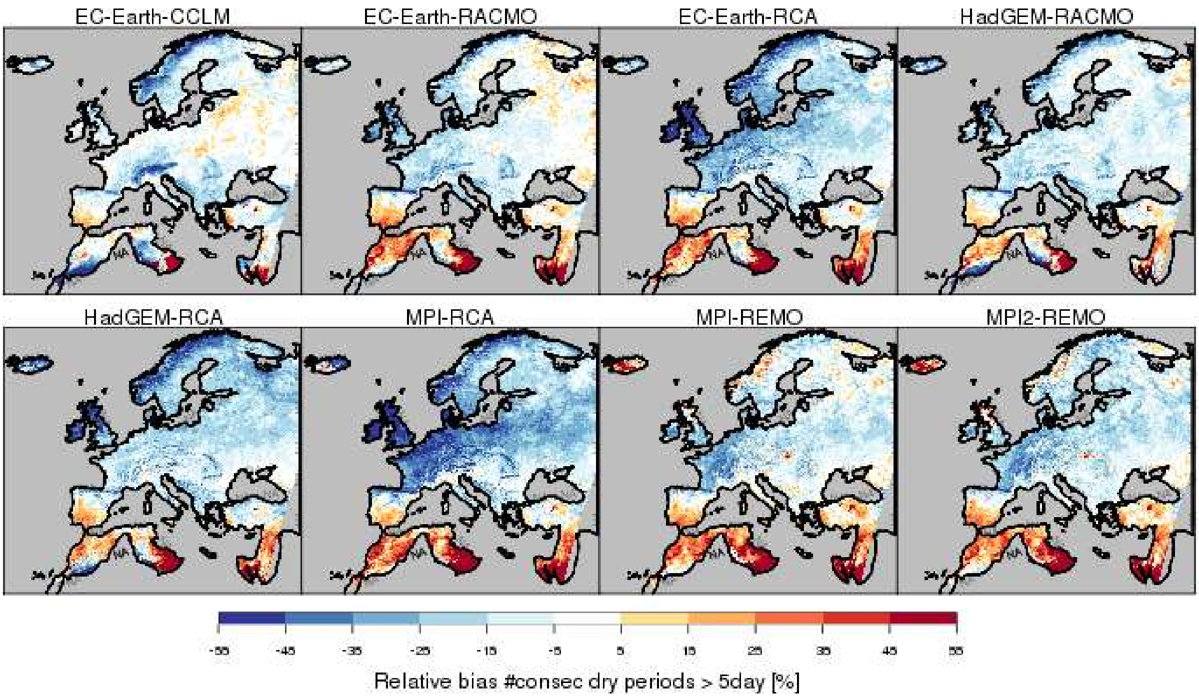


Figure S32. Relative bias of the number of consecutive dry day (<1mm/day) periods of at least 5 days duration. E-OBS is used as reference, and the time period is 1990-2005

3.3.5. Wind speed over Granada, Spain

Figure S33 shows a comparison of 10-m wind speed on land points along the southern coast of Spain. The reference data is here EFAS-Meteo, which is made up of gridded observations (Ntegeka et al., 2013).

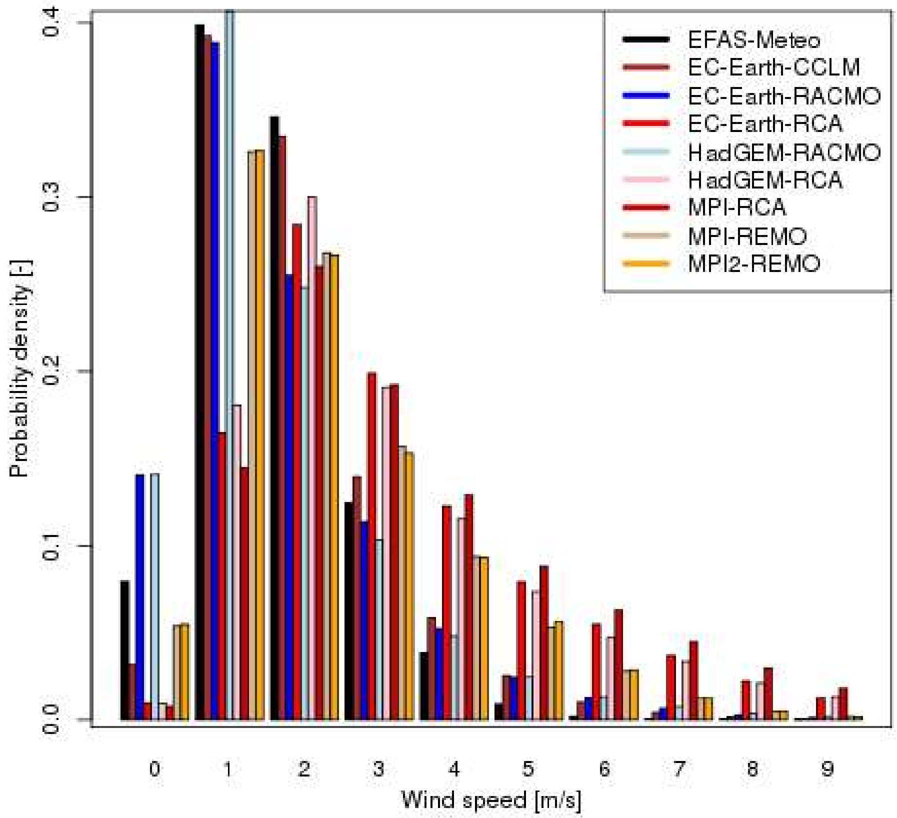


Figure S33. Distribution of wind speeds as an average of 15 grid points along the southern coast of Spain

4 Training: Hydrological models

4.1. Agricultural production in central Denmark

Hydrological models:

MIKE-SHE is a fully integrated surface-groundwater model. In order to simulate the root zone and unsaturated zone for a catchment, MIKE-SHE can be setup with different process descriptions, from using fully distributed 'conceptual approaches' to a simulation of all the processes using 'physical-based' methods.

Three different setups of the MIKE-SHE model are used to simulate the hydrological variables. The models are different in the way the root zone and the unsaturated zone is conceptualized: 1) a simple two-layer water balance, b) a simplified gravity flow process and, c) the full Richards equation. The unsaturated zone flow is calculated assuming one-dimensional vertical flow in MIKE SHE. The **Richards' equation** requires a relationship for the moisture-retention curve and parameters for the effective conductivity. The **gravity flow** is a simplified process description, which assumes a vertical gradient without incorporating capillary forces when simulating vertical fluxes. The **Two-Layer Water Balance** method is a simplified process description that subdivides the unsaturated zone into two layers; the root zone and a layer from the roots to the water table.

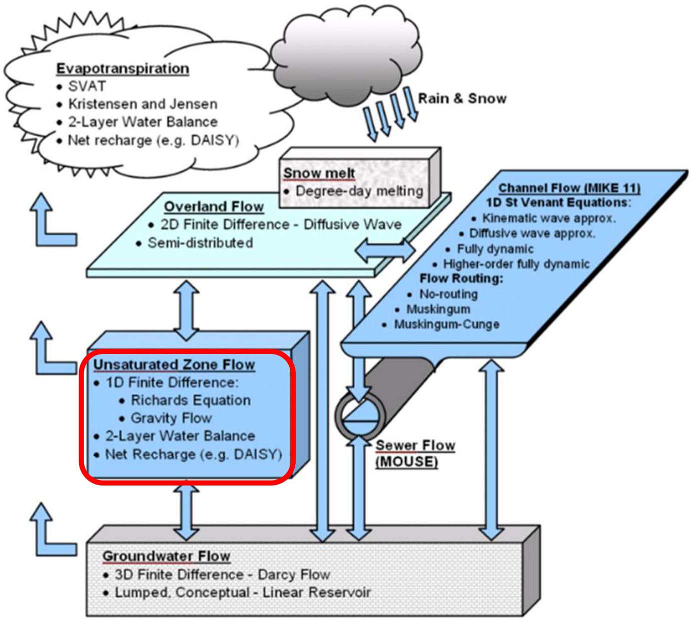


Figure S34. Schematic view of the processes simulated by the MIKE-SHE model

Table S10. Characteristics of the different hydrological models used in the Danish study case

Unsaturated zone	Richards' equation	Gravity flow	2-layer
Saturated zone	3D Finite Difference (14 layers)	3D Finite Difference (14 layers)	3D Finite Difference (14 layers)
Evapotranspiration	Based on actual evapotranspiration after Kristensen and Jensen (1975)	Based on actual evapotranspiration after Kristensen and Jensen (1975)	Two-layer water balance method after Yan and Smith (1994)

Inputs and resolution	Daily precipitation at 10 km grid cells, daily temperature and daily potential evapotranspiration at 20 km grid cells Geological model: Model that simulates the geological layers within the catchment in order to simulate groundwater flow in detail. The resolution of the simulation is daily and at a 250-meter scale
Outputs	Times series of discharge and groundwater head, among other hydrological variables. Spatially distributed values of depth to GW, overland flow, etc.
Differential split sampling test (DSST)	A DSST was used to evaluate the simulation skill of the hydrological models when used in projections in a changing catchment. Calibration in the 1st, 3rd, and 5th driest years (1996, 2003, 1991); validation in the 2nd, 4th and 6th driest years (1997, 2005, 1995); evaluation in the 1st, 3rd and 5th wettest years (2015, 1999, 2007). Results using the DSST model parameters are shown next: hydrograph, monthly river regime in the different calibration periods, flow duration curve, daily observations vs. daily simulations, yearly NSE compared to the accumulated annual precipitation, days above the Q10 and below the Q90, NSE and KGE values for the different calibration periods and groundwater head error in the wet evaluation period.

Simulation skill: 2-Layer model

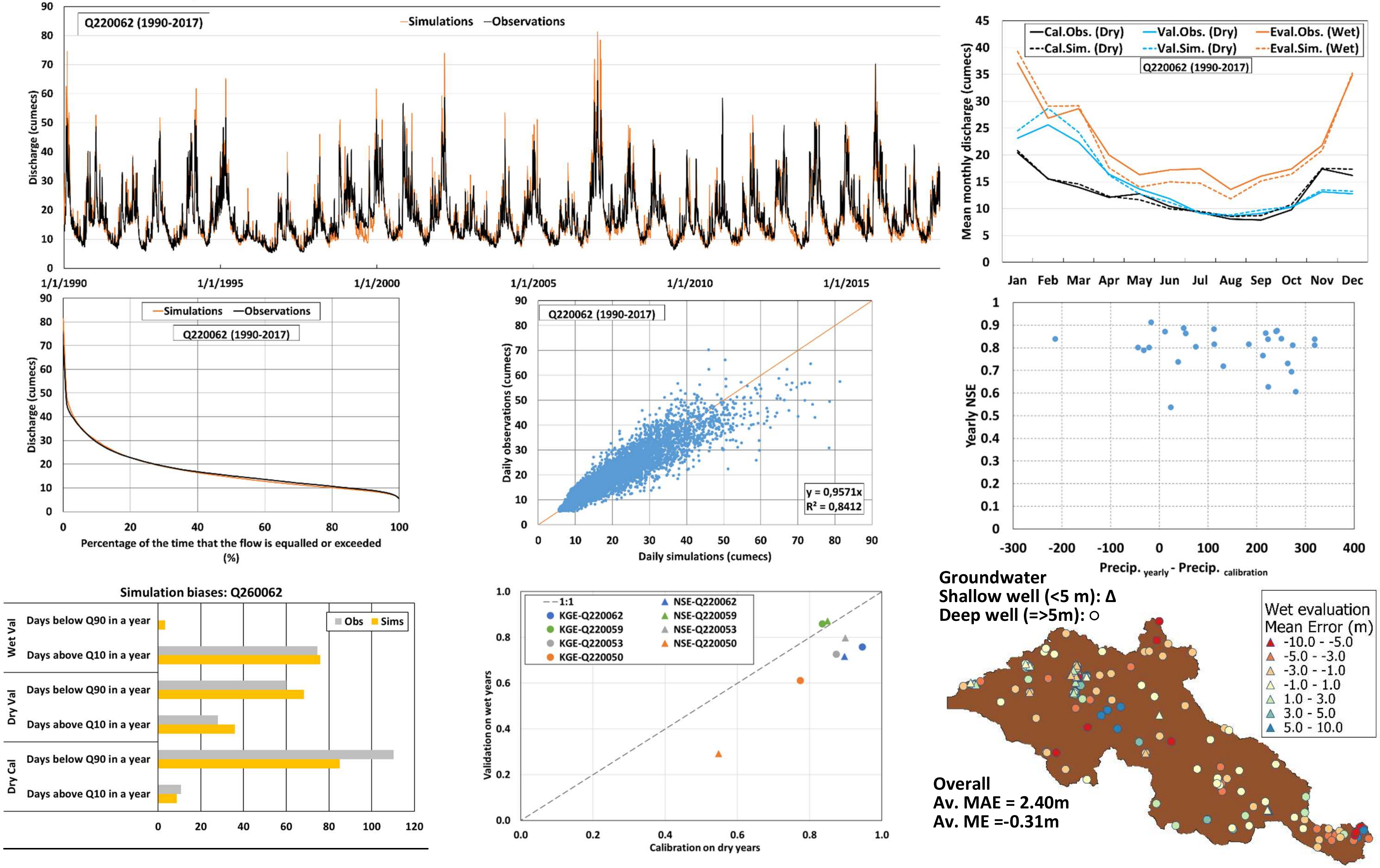


Figure S35. Plots evaluating the simulation skill of the 2-Layer MIKE-SHE model for the DSST calibration

Simulation skill: Gravity flow model

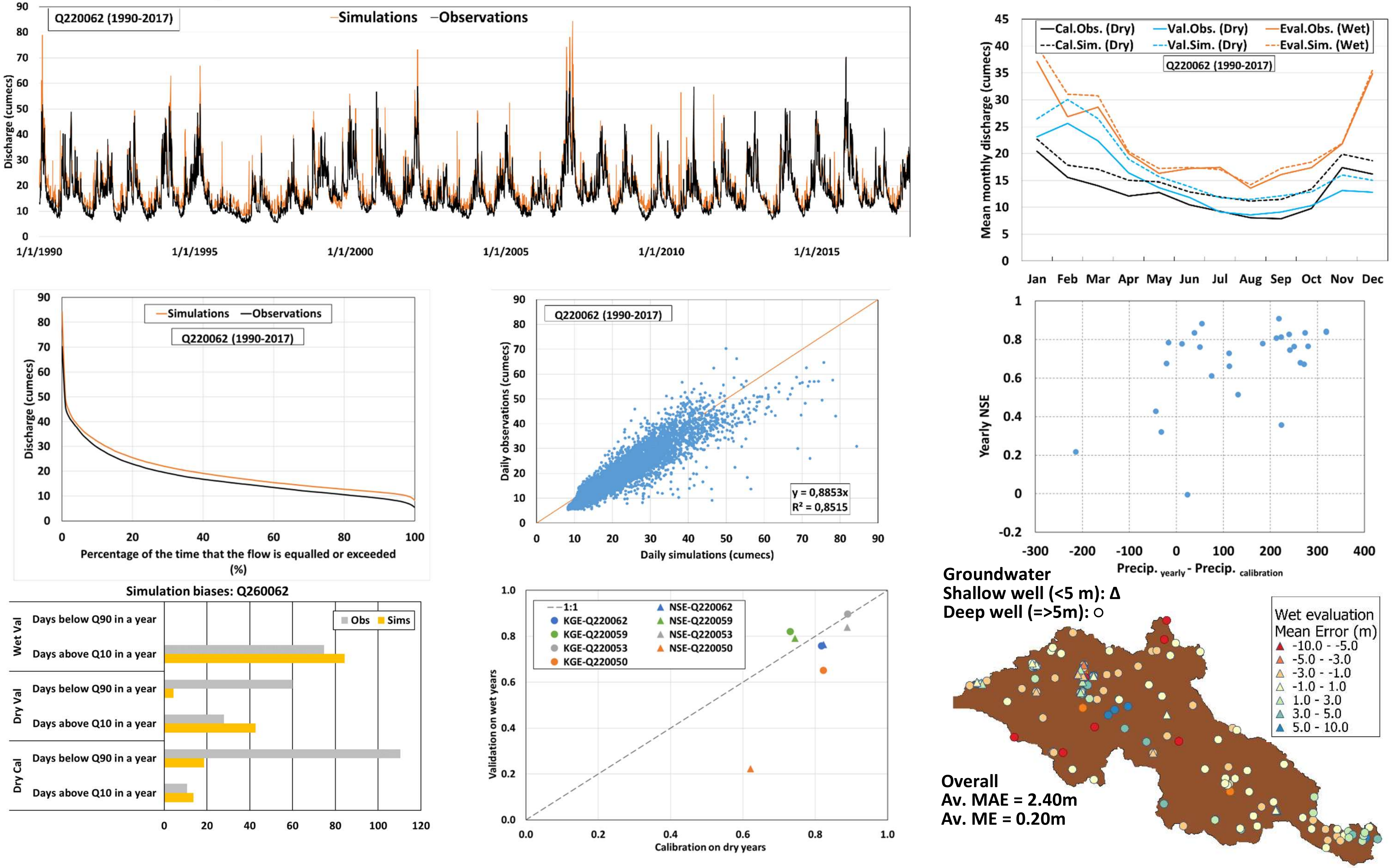


Figure S36. Plots evaluating the simulation skill of the gravity flow MIKE-SHE model for the DSST calibration

Simulation skill: Richard’s equation model

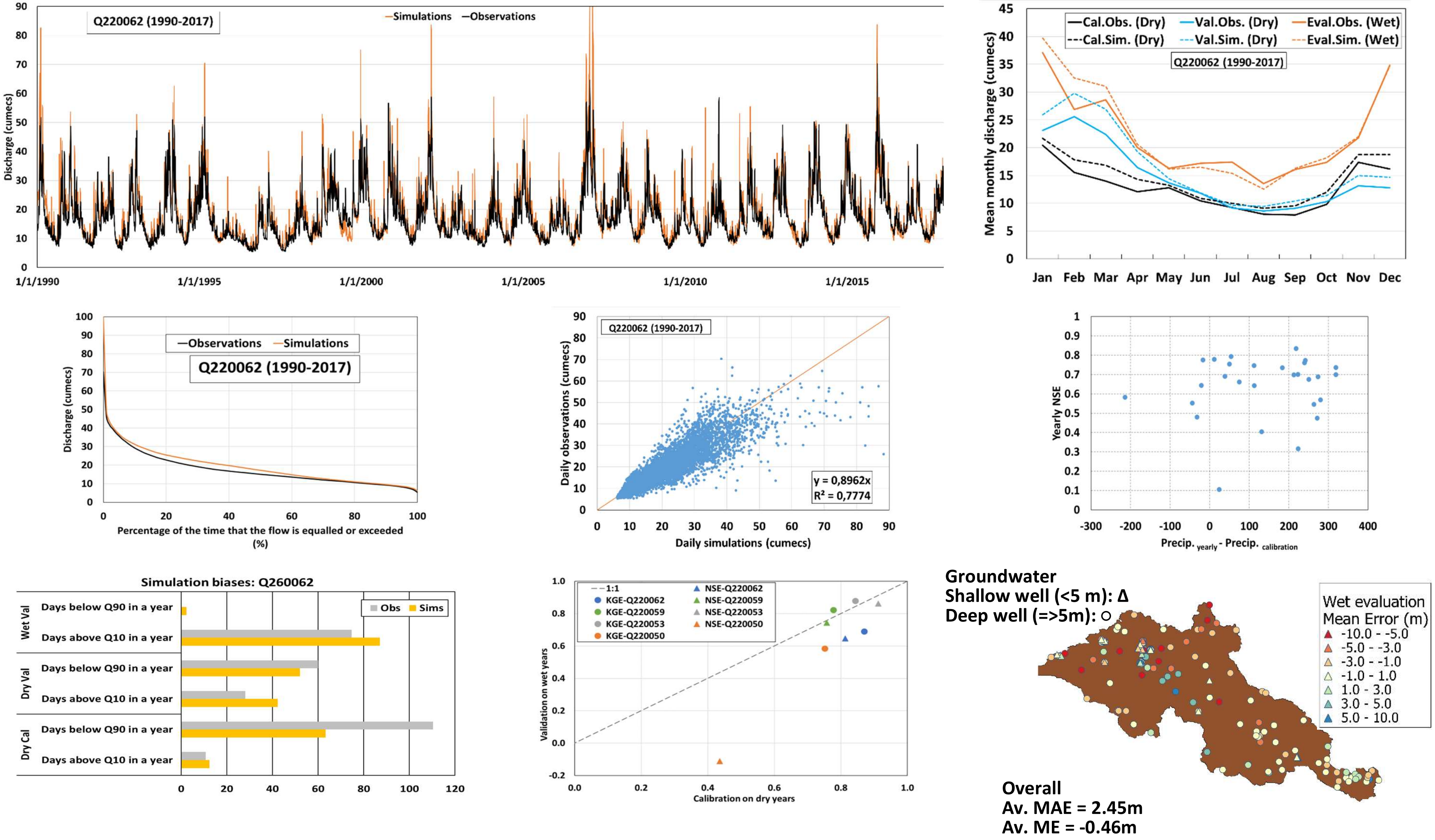


Figure S37. Plots evaluating the simulation skill of the Richard’s equation MIKE-SHE model for the DSST calibration

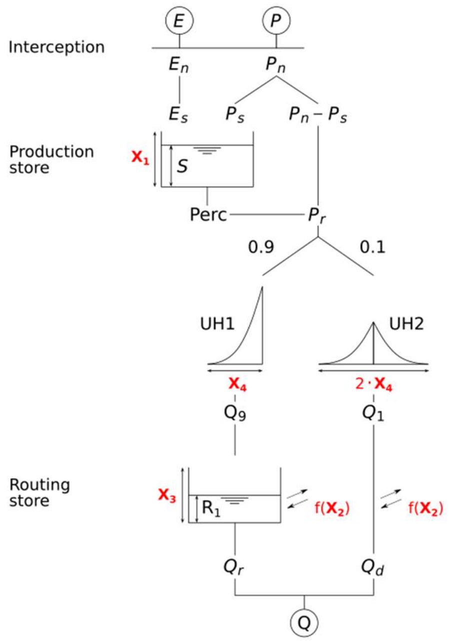
4.2 Hydropower production in France: Southern Alphs

Hydrological models:

Three different lumped conceptual models have been used: GR4J, GR6J, and TOPMO. All three work on a daily time step with precipitations and potential evaporation inputs. To account for solid precipitations, each model was run in association with the CemaNeige snow module.

GR4J

GR4J is a lumped parsimonious model with four calibrated parameters, developed by Perrin et al. [2003]. The structural equations of the daily model result from an integration of time-continuous differential equations, thus reducing equifinality issues in calibration. GR4J has been used in numerous hydrological studies in France and in Australia [Coron et al., 2012; Fowler et al., 2016; Grigg and Hughes, 2018; Oudin et al., 2005b; Perrin et al., 2008].

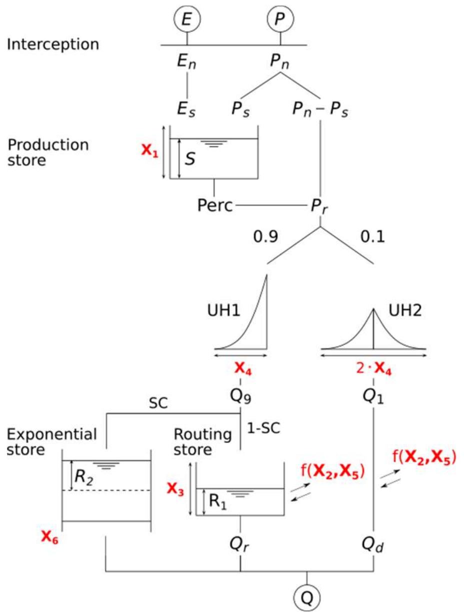


Parameters	
X1	production store capacity [mm]
X2	groundwater exchange coefficient [mm/d]
X3	routing store capacity [mm]
X4	unit hydrograph time constant [d]

Figure S38. Schematic view and parameters of the processes simulated by the GR4J model

GR6J

GR6J is a modified version of GR4J, in which the groundwater exchange function allows a change in the direction of the exchange within the year [Le Moine, 2008] and with an additional exponential routing store to add a degree of freedom in the recession curves and improve low-flow simulations.

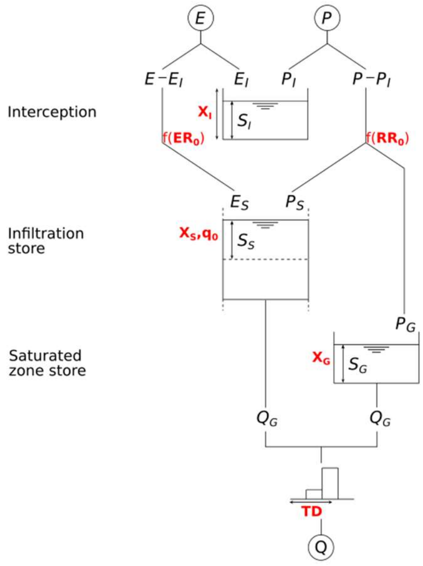


Parameters	
X1	production store capacity [mm]
X2	groundwater exchange coefficient [mm/d]
X3	routing store capacity [mm]
X4	unit hydrograph time constant [d]
X5	threshold for change in F sign [-]
X6	exponential store 'capacity' [mm]

Figure S39. Schematic view and parameters of the processes simulated by the GR6J model

TOPMO

TOPMO [Michel et al., 2003] is a lumped adaptation of TOPMODEL [Beven and Kirkby, 1979] with an additional routing store. Seven parameters determine the operation of the model. TOPMO simulates river runoff as a combination of heterogeneous time response flows. Water balance is solely controlled by evaporation. The model has been widely used across Europe [Brigode et al., 2013; Oudin et al., 2006].

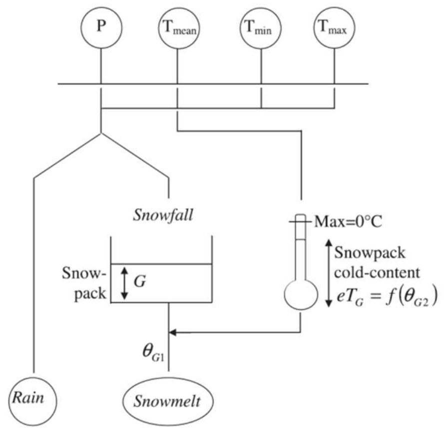


Parameters	
X_i	interception store capacity [mm]
ER_0	Evaporation rate parameter [-]
RR_0	Recharge rate parameter [-]
X_S	Near surface store 'capacity' [mm]
q_0	Infiltration excess overland flow parameter [mm]
X_G	Saturated zone store 'capacity' [mm]
TD	Pure time delay constant [d]

Figure S40. Schematic view and parameters of the processes simulated by the TOPMO model

CemaNeige

CemaNeige is a two-parameter degree-day snow module developed by Valéry et al. [2014]. The module divides a catchment in 5 altitude layers of equal surface. On each layer, the snow cover is represented by a conceptual reservoir filled by solid precipitations and which depletion depends on the temperature and on the computed thermal state of the snow pack. The daily melted water is used as an input to the hydrological model in addition to liquid precipitations.



Parameters	
G	Degree melt-day coefficient [mm/°C/d]
eT_G	Weighting coefficient for snow pack thermal state [-]

Figure S41. Schematic view and parameters of the processes simulated by the CemaNeige model

Complementary information

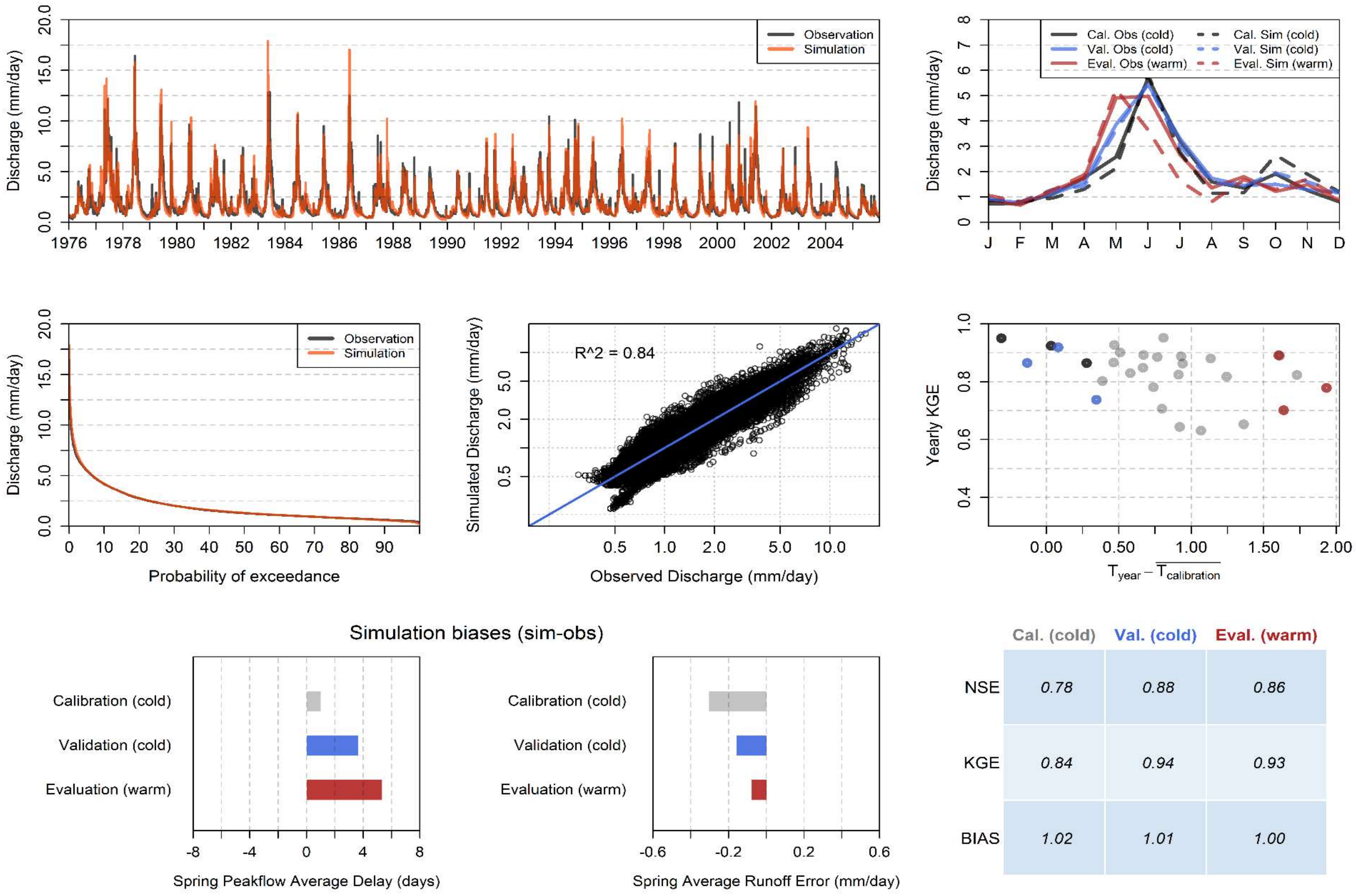
Inputs and Resolution: Daily precipitation and daily temperature at the catchment scale. Daily potential evaporation model is temperature based [Oudin, 2005].

Outputs: Times series of discharge, snowmelt and actual evaporation

Differential Split Sample Test: A differential split sample test was used to evaluate the simulation skill of the hydrological models in a changing catchment. Thus, the models were calibrated in the 1st, 3rd, and 5th coldest years (1984, 1980, 1991), validated in the 2nd, 4th and 6th coldest years (1996, 1978, 1976) and evaluated in the 1st, 3rd and 5th warmest years (1983, 1989, 1994).
The results from that analysis are shown in the following tables for each of the setups of the model.

DSST Results

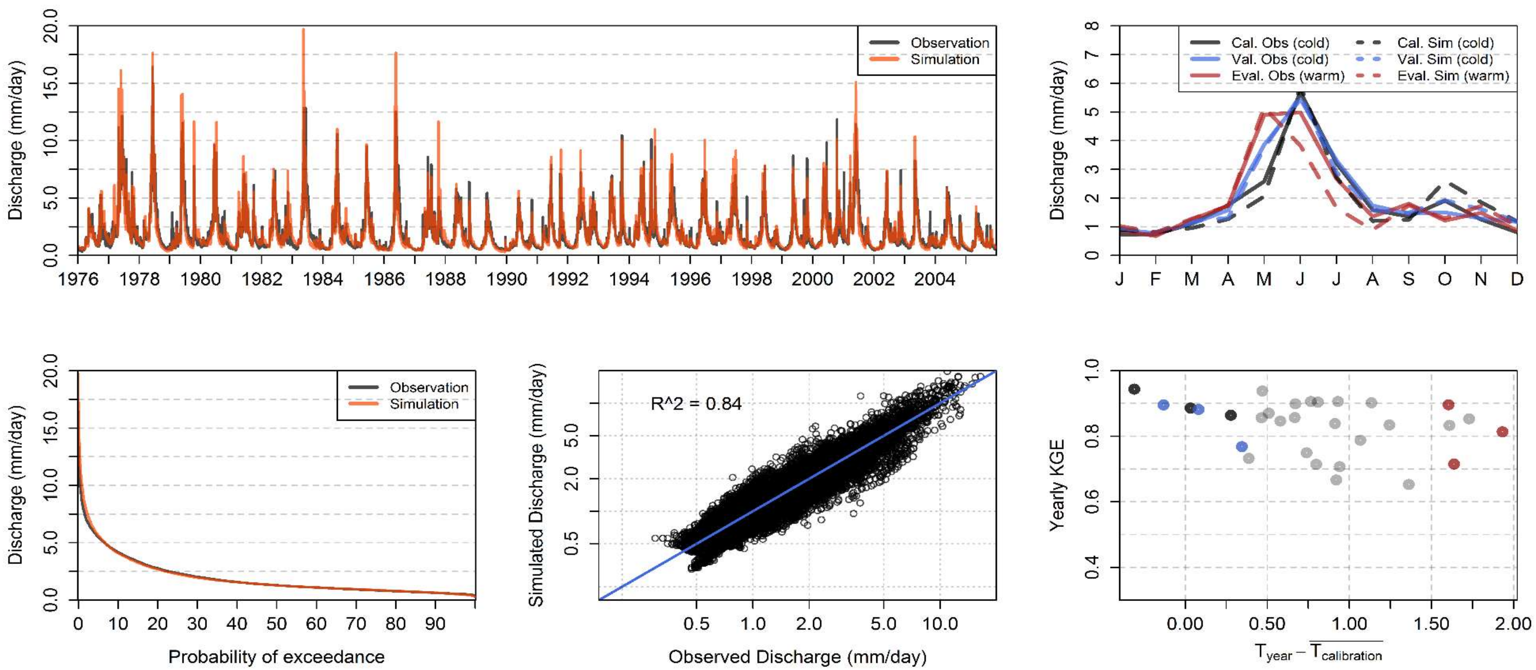
GR4J



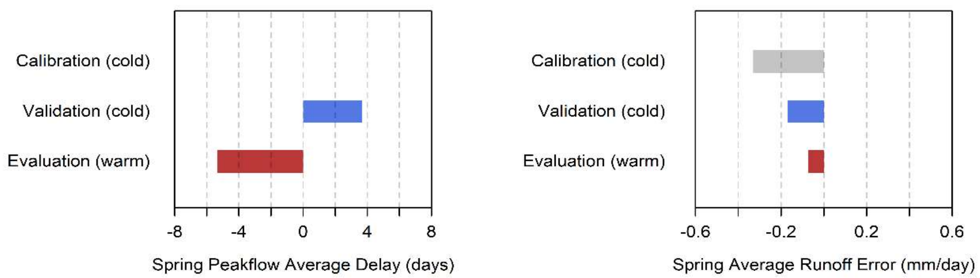
	Cal. (cold)	Val. (cold)	Eval. (warm)
NSE	*0.78*	*0.88*	*0.86*
KGE	*0.84*	*0.94*	*0.93*
BIAS	*1.02*	*1.01*	*1.00*

Figure S42. Plots evaluating the simulation skill of the GR4J model for the DSST calibration

GR6J



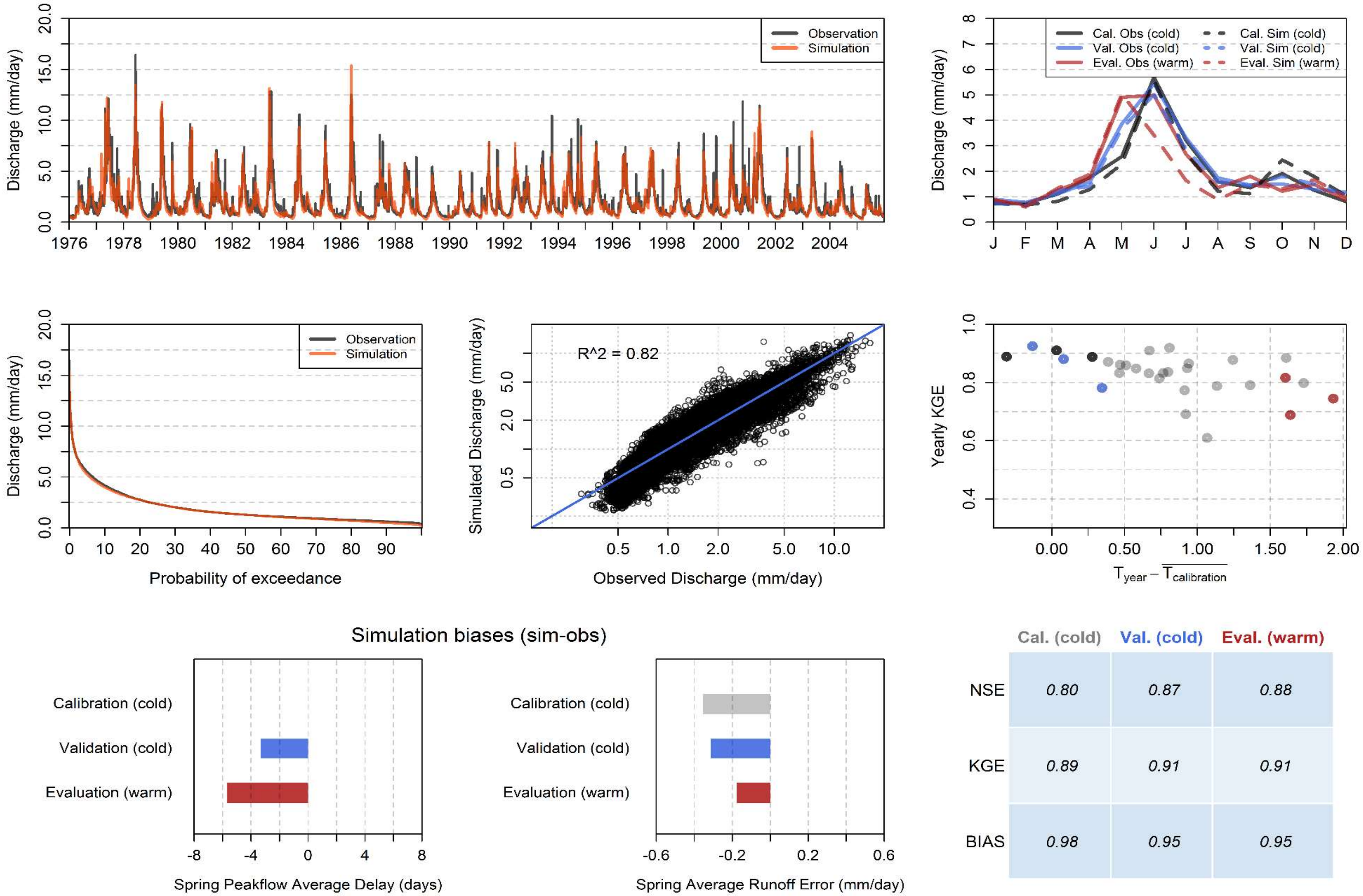
Simulation biases (sim-obs)



	Cal. (cold)	Val. (cold)	Eval. (warm)
NSE	*0.77*	*0.88*	*0.87*
KGE	*0.81*	*0.91*	*0.92*
BIAS	*1.02*	*1.01*	*1.00*

Figure S43. Plots evaluating the simulation skill of the GR6J model for the DSST calibration

TOPMO



	Cal. (cold)	Val. (cold)	Eval. (warm)
NSE	0.80	0.87	0.88
KGE	0.89	0.91	0.91
BIAS	0.98	0.95	0.95

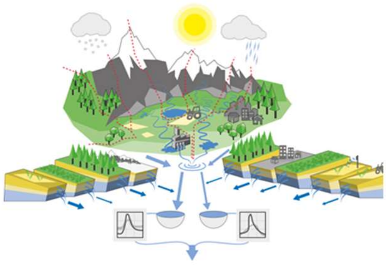
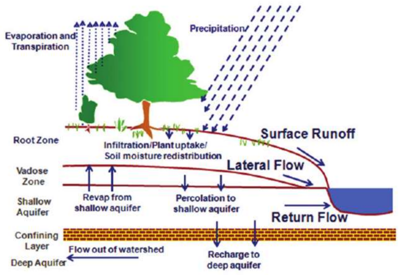
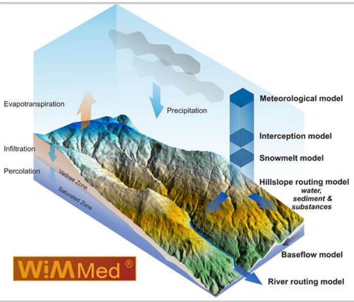
Figure S44. Plots evaluating the simulation skill of the TOPMO model for the DSST calibration

4.3 Water resource allocation for tourism, agriculture and energy in Spain

HYDROLOGICAL MODELS

Three different hydrological models have been used in this study case. Table S11 summarizes the main characteristics of each of them.

Table S11. Main characteristics of the hydrological models used for the Spanish study case

	HYPE Hydrological Predictions for the Environment	**SWAT** Soil and Water Assessment Tool	**WiMMed** Watershed Integrated Model for Mediterranean Environments
			
Type	Semi-distributed process-based model	Conceptual semi-distributed hydrological model	Distributed physically-based model
Temporal Resolution	Daily	Daily	Daily/Hourly
Spatial Resolution	Catchment scale	Hydrological Response Units	30m x 30m
PROCESSES PARAMETERIZATION			
Inceception	There is not a specific routine for interception; although precipitation can be reduced at catchment scale being this effect interpreted as interception.	Initial abstractions following the SCS Curve Number Procedure	Water balance model (Rutter et al., 1979; Gash, 1979)
Snow			
- Snowfall	Threshold temperature	Threshold temperature	Threshold temperature
- Ablation	Temperature-day + Radiation-day + FSC reduction (Samulesson et al., 2016)	Degree-day method	Point water and Energy balance extended at distributed scale using depletion curves (Herrero et al., 2009; Pimentel et al., 2017)
Evapotranspiration	Modified Hargreaves-Samani (1982)	Penman-Monteith (Penman 1948, Monteith et al., 1964)	Penman-Monteith (Penman 1948, Monteith et al., 1964)
Infiltration	3 soil layers: water table discrimination (Lindström et al., 2010)	1 soil layer: Green & Ampt (1911)	2 soil layers: Green and Ampt (1911)
Groundwater	1 bucket	2 bucket with exponential decay (Venetis,1964) to simulated shallow and deep aquifer response	2 linear buckets (Barnes, 1939), simulation quick and slow aquifer response

Hillside routing			
- Links	Defined during catchment delineation	Defined in the catchment delineation	Flow direction
- Method	Specific routing within the catchment (land, ilake, stream, main river, olake)	Lag time	Travel time using Manning
River routing			
- Links	Defined during catchment delineation	Defined during catchment delineation	River cells
- Method	River delay (transit time & damping)	Muskingum-Cunge	Muskingum-Cunge
MAIN MODEL INPUTS			
- Meteorology	Average daily precipitation and temperature at catchment scale.	Daily precipitation, temperature and solar radiation at point scale	Daily and hourly precipitation and temperature and daily solar radiation, wind speed, relative humidity and atmospheric emissivity at point scale.
- Other	Average land cover and soil properties.	Average land cover and soil properties.	Distributed soil properties, land covers, vegetation characteristics.

DSST set up

The hydrological models simulate the entire observed period (May 1989 - May 2014), but calibration is performed for the 1st, 3rd and 5th ranked driest years (1994-1995, 1993-1994 and 2006-2007), validation is performed in the 2nd, 4th and 6th driest years (2004-2005,2005-2006,1992-1993) and the evaluation of the model is assessed for the 1st, 3rd and 5th wettest years (2009-2010, 1995-1996 and 2010-2011). Only those years with discharge observations have been considered in the sorting. Hydrological years have been used. They begin on the 1st of September and end on the 31st of August.

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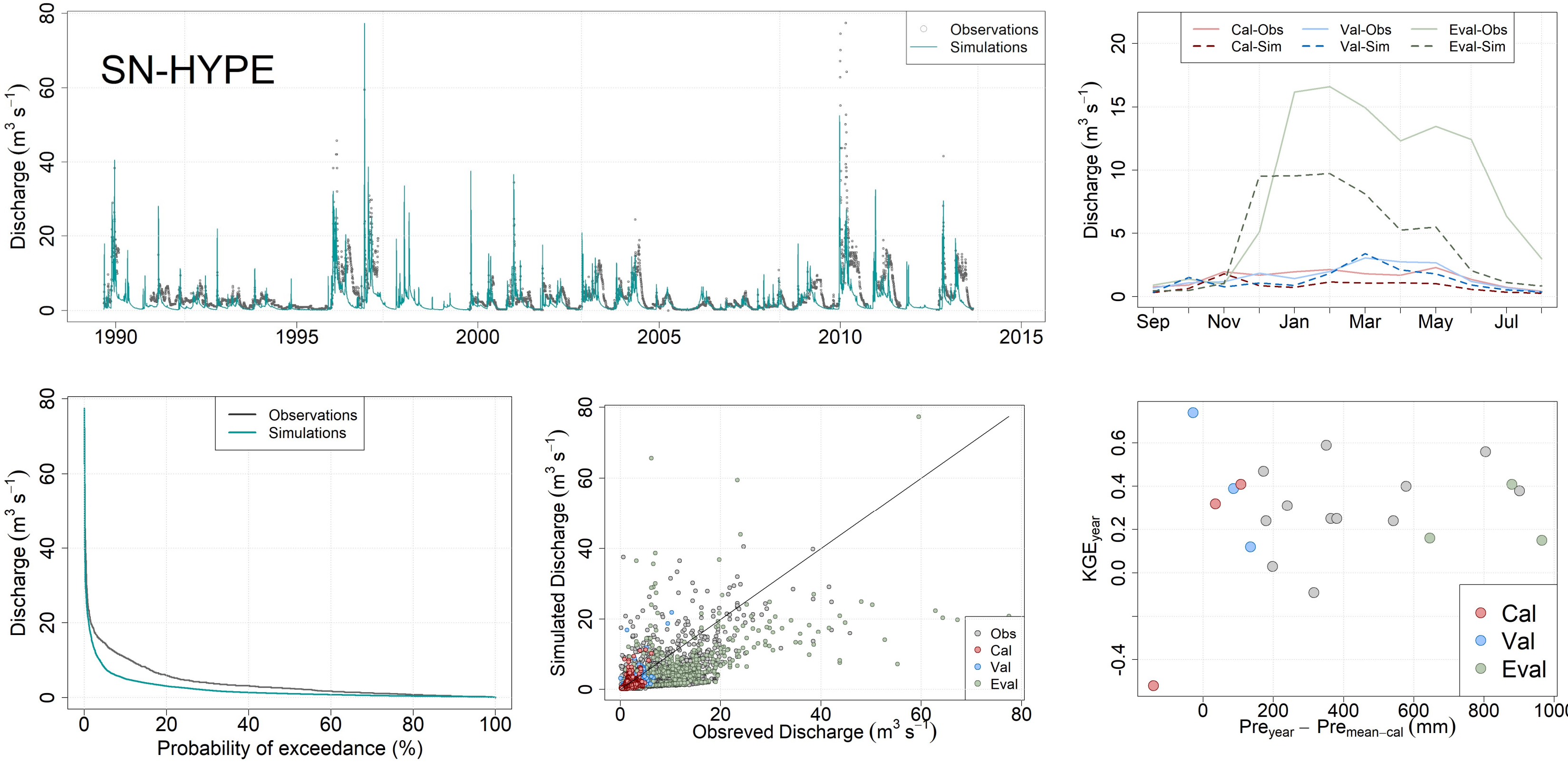
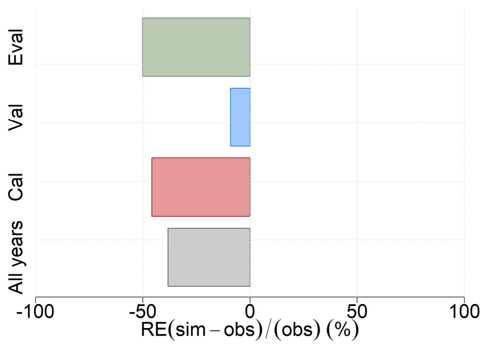


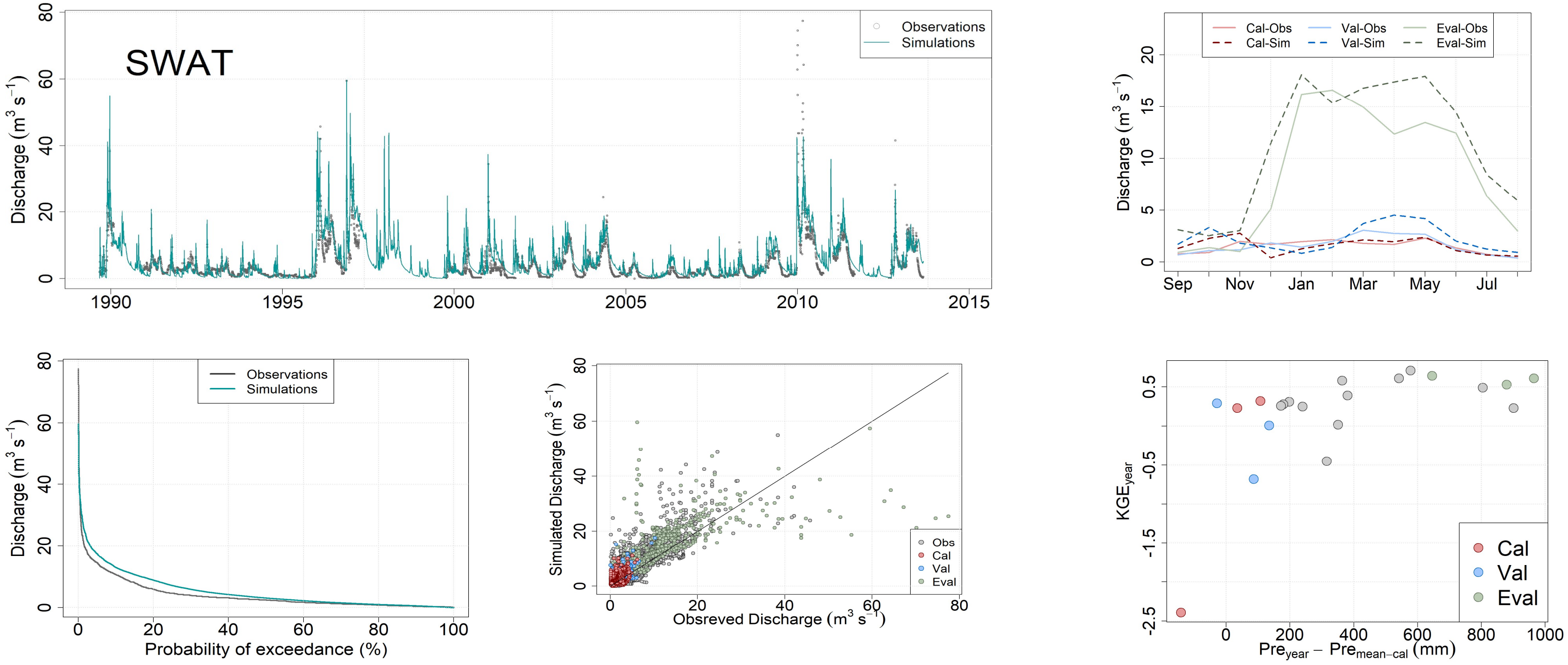


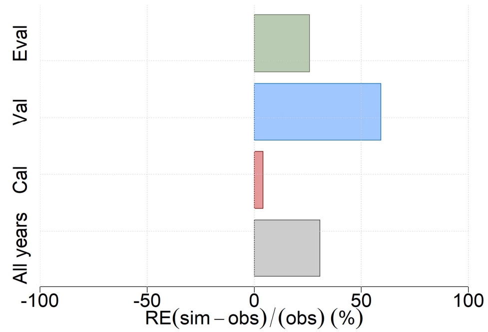
	All yrs	Cal	Val	Eval
KGE	0.28	0,07	0.42	0.24
NSE	-0.70	-2,31	-0.31	0.00
RE	-36.07	-45.80	-9.12	-54.02
CC	0.57	0.50	0.70	0.70

* RE (relative error)
** CC (correlation coefficient)

Summary: (from top to bottom and from left to right) Daily evolution of observed and simulated discharge at the watershed outlet // Comparison of average monthly observed and simulated discharges for the three different periods considered in the study // Observed and simulated flow duration curve // Scatter plot at daily scale comparing observed and simulated discharges // Annual KGE value against variable used for DSST // Annual discharge bias for all years and three different periods selected // Summary table with average metrics in each of the selected periods

Figure S45. Plots evaluating the simulation skill of the HYPE model for the DSST calibration



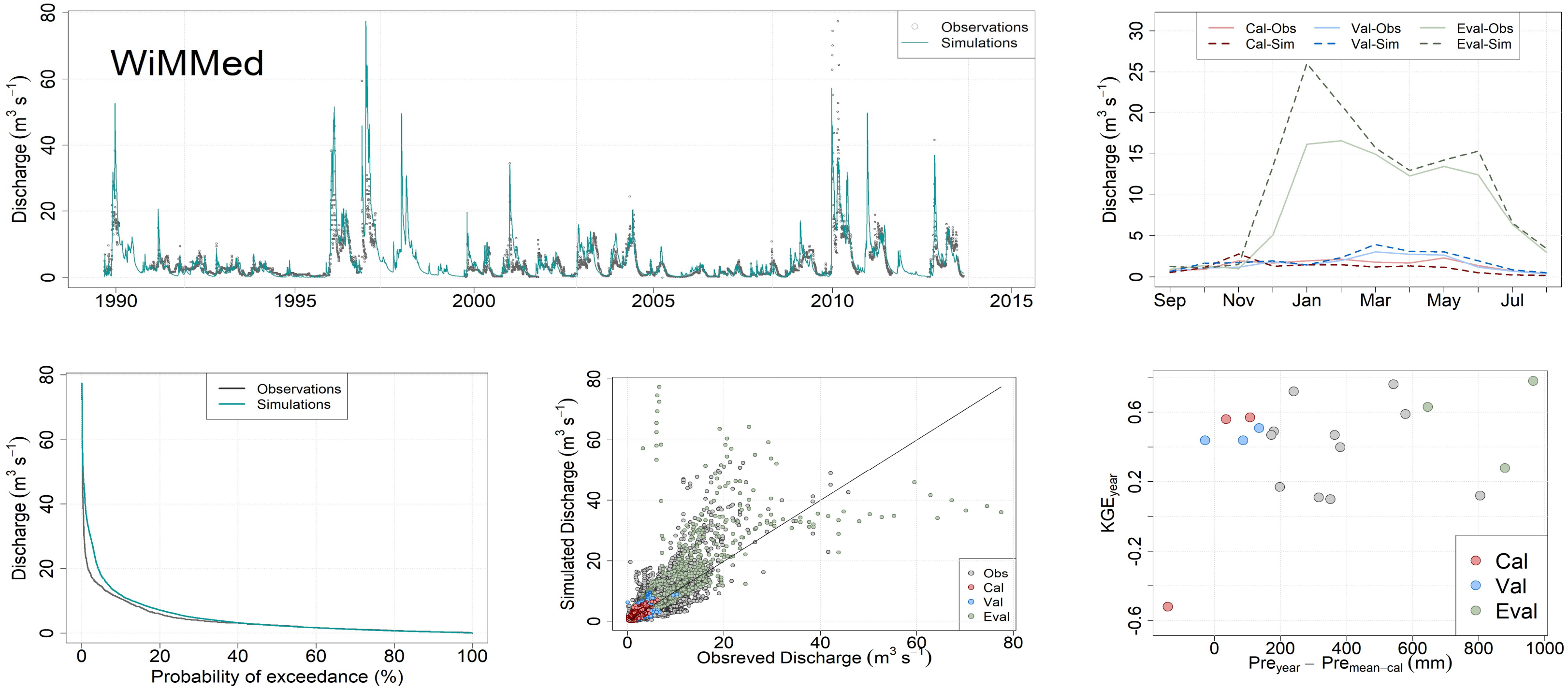


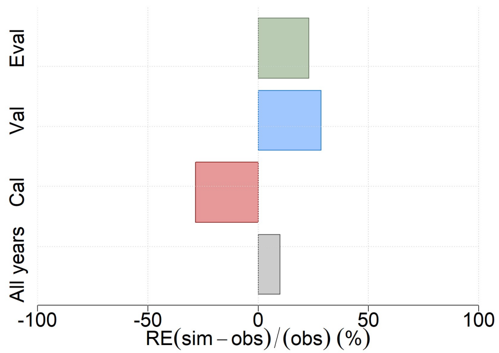
	All yrs	Cal	Val	Eval
KGE	0.15	-0.61	-0.13	0,53
NSE	-1.23	-6.14	-1.51	0,50
RE	33.30	4.15	59.12	26.19
CC	0.70	0.45	0,69	0,84

* RE (relative error)
** CC (correlation coefficient)

Summary: (from top to bottom and from left to right) Daily evolution of observed and simulated discharge at the watershed outlet // Comparison of average monthly observed and simulated discharges for the three different periods considered in the study // Observed and simulated flow duration curve // Scatter plot at daily scale comparing observed and simulated discharges // Annual KGE value against variable used for DSST // Annual discharge bias for all years and three different periods selected // Summary table with average metrics in each of the selected periods

Figure S46. Plots evaluating the simulation skill of the SWAT model for the DSST calibration





	All yrs	Cal	Val	Eval
KGE	0,36	0,20	0,46	0,56
NSE	-0,38	-1,53	0,18	0.36
RE	14,72	-28.47	28.51	18.37
CC	0,70	0,61	0,78	0,79

* RE (relative error)
** CC (correlation coefficient)

Summary: (from top to bottom and from left to right) Daily evolution of observed and simulated discharge at the watershed outlet // Comparison of average monthly observed and simulated discharges for the three different periods considered in the study // Observed and simulated flow duration curve // Scatter plot at daily scale comparing observed and simulated discharges // Annual KGE value against variable used for DSST // Annual discharge bias for all years and three different periods selected // Summary table with average metrics in each of the selected periods

Figure S47. Plots evaluating the simulation skill of the WiMMed model for the DSST calibration

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Elicitation questionnaire

Short introduction to expert elicitation

The idea behind expert elicitation is that the ideas, brainstorms and 'gut feeling' of experts (people with special knowledge about the subject of the study) can be used in decision making and uncertainty assessment. Expert elicitation, however, is not about substituting subjective opinions with hard science. The elicitation itself has to follow a strict, pre-defined protocol that is consciously planned to minimize biases, revise opinions and is well-documented. Moreover, the method is usually applied in complex cases with scarce or unobtainable data where it is otherwise difficult to obtain results. In such complex cases the human mind has an advantage of being capable of simultaneously incorporating and processing numerous types of information into a coherent opinion. The aim of the elicitation is to translate this subjective opinion into probabilistic form. The elicitation therefore is considered successful if the opinion of the expert is well-captured, not if the answers are correct. The differences in expert opinions also help to preserve the range of uncertainty on the results.

As expert elicitation is built on the subjective opinion of experts, it is also subject to biases. Thus, the proportion of experts having a certain view is not proportional to the probability of that view being correct.

When participating in this expert elicitation study please be aware of the most common biases:

- *overconfidence*, being too confident about your opinion unnecessarily shortening the uncertainty ranges
- *anchoring*, hesitating to modify, adjust your opinion
- *availability*, overemphasizing elements that are easily imaginable
- *motivational bias,* being partial to one of the models due to personal involvement

The elicitation in the AQUACLEW project consists of two blocks of questions. Questions in Block 1 assess the models generally, whereas questions in Block 2 are specific to the case studies. The ultimate aim of the elicitation is to reduce the spread of models by selecting the most plausible models based on the probabilities of questions in Block 2, thus this part will provide the most interesting results of the elicitation.

Of course we would like to receive as many answers to our questions as possible, but if you feel that you are not competent to answer a specific question, please feel free to skip it. When filling in the questionnaire please remember that there are no right or wrong answers, what truly matters is your honest opinion on the subject.

Climate models

Block 1 – general questions about each climate model

Please answer each question with letters: H: High, I: Intermediate, L: Low

If you specify low as any of the answers, please explain your arguments for that in more detail in the comments section below the table.

Question	**EC-Earth RACMO**	**EC-Earth CCLM**	**EC-Earth RCA4**	**HadGEM RCA4**	**HadGEM RACMO**	**MPI-ESM RCA4**	**MPI-ESM REMO**
1. Based on the model descriptions, to what degree is each model pair (GCM-RCM) capable of simulating the core global and local processes in a global warming context (**H**igh/**I**ntermediate/**L**ow)?							
2. To what degree does the GCM-RCM combination capture today's circulation and key teleconnection patterns (**H**igh/**I**ntermediate/**L**ow)?							
3. To what degree is the model (GCM-RCM) capable of simulating precipitation amounts (**H**igh/**I**ntermediate/**L**ow)?							
4. To what degree is the model (GCM-RCM) capable of simulating persistency of dry periods (meteorological droughts), and its temporal variations in general (**H**igh/**I**ntermediate/**L**ow)?							
Comments:							

Block 1 – specific questions in relation to applications in case studies

Question	EC-Earth RACMO	EC-Earth CCLM	EC-Earth RCA4	HadGEM RCA4	HadGEM RACMO	MPI-ESM RCA4	MPI-ESM REMO
Danish case: Based on your opinion about the general model structures and the performance metrics of the complete chain of models (GCM-RCM), assess the potential of the model to describe changes in drought conditions (leading to agricultural drought) as well as wet periods (leading to groundwater flooding) as a result of climate change 7a For each model assign an evaluation of the model potential **H**igh/**I**ntermediate/**L**ow							
7b Rank the 7 models (with rank 1 as the most plausible and rank 7 as the least plausible model)							
Spanish (UCO) case: Based on your opinion about the general model structures and the performance metrics of the complete chain of models (GCM-RCM), assess the potential of the model to project changes in snow conditions as a result of climate change? **8a** For each model assign an evaluation of the model potential **H**igh/**I**ntermediate/**L**ow							
8b Rank the 7 models (with rank 1 as the most plausible and rank 7 as the least plausible model)							
French case: Based on your opinion about the general model structures and the performance metrics of the complete chain of models (GCM-RCM), assess the potential of the model to project changes in seasonal precipitation (average amount as well as extremes in the form of droughts and very wet periods) and temperature (average and extremes) as a result of climate change? 9a: For each model assign an evaluation of the model potential **H**igh/**I**ntermediate/**L**ow							
9b: Rank the 7 models (with rank 1 as the most plausible and rank 7 as the least plausible model)							

Swedish case: Based on your opinion about the general model structures and the performance metrics of the complete chain of models (GCM-RCM), assess the potential of the model to project changes in local temperature, precipitation seasonality and drought conditions as a result of climate change? 10a: For each model assign an evaluation of the model potential **H**igh/**I**ntermediate/**L**ow							
10b: Rank the 7 models (with rank 1 as the most plausible and rank 7 as the least plausible model)							
Spanish (UGR) case: Based on your opinion about the general model structures and the performance metrics of the complete chain of models (GCM-RCM),), assess the potential of the model to project changes in sea-level and storms that affect wave height and surges as a result of climate change? 11a: For each model assign an evaluation of the model potential **H**igh/**I**ntermediate/**L**ow							
11b: Rank the 7 models (with rank 1 as the most plausible and rank 7 as the least plausible model)							

Comments:

Block 2 Probability assessment climate models

In this block you will be asked to assign probabilities to the climate models to find the most plausible climate models for the various modeling purposes of the case studies.
For each case study please assign a probability for each climate model which expresses your degree of belief in that the climate model gives plausible/useful results for the case study. The total probability of all climate models for each case study should be equal to 100% (in the vertical column). It is possible to assign zero probability to a climate model and several climate models can have the same probability value.

In the last horizontal column please specify how confident you are in your ranking of the climate models for each case study on a scale of 1-5 (5: meaning very high confidence, 4: high confidence, 3: intermediate confidence, 2: low confidence, 1: very low confidence).
In the last vertical column please specify on a scale of 1-5 (5: meaning very high confidence, 4: high confidence, 3: intermediate confidence, 2: low confidence, 1: very low confidence) your degree of confidence in the climate model in general.

Climate model	**Case study 1 Agricultural production in central Denmark**	**Case study 2 Hydropower production in France: Southern Alps**	**Case study 3 Water resource allocation for tourism, agriculture and energy in Spain**	**Case study 4 Fluvial and coastal interactions under Mediterranean climate conditions in Spain**	**Case study 5 Biodiversity change under climate change in Sweden**	*Confidence in climate model in general (1: low - 5: high)*
1-EC-EARTH RACMO						
2-EC-EARTH CCLM						
3-EC-EARTH RCA4						
4-HadGEM-RCA4						
5-HadGEM-RACMO						
6-MPI-ESM RCA4						
7-MPI-ESM REMO						
Total probability	100%	100%	100%	100%	100%	
Confidence in the ranking of the climate models (1: low - 5: high)						

Comments:

Hydrological models

***Block 1 – general questions about each hydrological model**. Please focus on model structure / process description in this section, don't focus on the three different model versions in each case at this stage. Don't focus on climate change effects here, only on how good the models are in simulating historical period average and extreme values (flow etc.).*

Please answer each question with letters: H: High, I: Intermediate, L: Low

If you specify low as any of the answers, please explain your arguments for that in more detail in the comments section below the table.

Question	**Danish**	**French**	**Spanish**
1. To what degree are the hydrological model assumptions solid and reasonable? (**H**igh/**I**ntermediate/**L**ow)			
2. To what degree does the model (concept, assumptions, implementation and results) agree with your knowledge and experience? (**H**igh/**I**ntermediate/**L**ow).			
3. Based on the description of physical processes and assumptions in the model, to what degree is the model capable of simulating *monthly streamflow and its temporal variations (average runoff, flow duration curve, dynamics)* in general? (**H**igh/**I**ntermediate/**L**ow)			
4. Based on the description of physical processes and assumptions in the model, to what degree is the model capable of simulating *extreme low flow/drought conditions (low flows, low groundwater table)* in general? (**H**igh/**I**ntermediate/**L**ow)			
5. Based on the description of physical processes and assumptions in the model, to what degree is the model capable of simulating *maximum runoff events / groundwater flooding (need for drainage in agricultural soils)* in general? (**H**igh/**I**ntermediate/**L**ow)			
6. To what degree is the model likely to represent conditions under future climate change, against which it cannot presently be calibrated or validated (**H**igh/**I**ntermediate/**L**ow)			
Comments.			

Block 1 – specific questions in relation to applications of different model versions in case studies. *This part refers to the three different model versions. Use performance test results for historical period for assessing the three different models in each case, and how credible they are for climate change predictive simulations on hydrology.*

Question	Model version		
Danish case: Based on your opinion about the general model structure and the performance metrics of the calibrated model: **7a**: to what degree is the model suitable to predict changes in *low flow & drought conditions (low flows, low groundwater table)* as a result of climate change? (**H**igh/**I**ntermediate/**L**ow)	***Two layer***	***Gravitation***	***Richards E.***
7b: to what degree is the model suitable to predict changes in extreme runoff & groundwater flooding (need for drainage in agricultural soils) as a result of climate change? (**H**igh/**I**ntermediate/**L**ow)	***Two layer***	***Gravitation***	***Richards E.***
7c: rank the 3 models (with rank 1 as the most plausible and rank 3 as the least plausible model) which according to your belief are the most suitable for predicting changes in extreme events *(drought and flooding events and need for drainage in agricultural soils)* as a result of climate change. Specify why:	***Two layer***	***Gravitation***	***Richards E.***
French case: Based on your opinion about the general model structure and the performance metrics of the calibrated model, **8a:** to what degree is the model suitable for predicting changes in the hydrological regime in terms of intra-annual distribution of monthly volumes, as a result of climate change? (**H**igh/**I**ntermediate/**L**ow)	***GR4J***	***GR6J***	***TOPMO***
8b: rank the 3 models (with rank 1 as the most plausible and rank 3 as the least plausible model) which according to your belief are the most suitable for predicting changes in the hydrological regime in terms of intra-annual distribution of monthly volumes, as a result of climate change? Specify why:	***GR4J***	***GR6J***	***TOPMO***
Spanish-UCO case: Based on your opinion about the general model structure and the performance metrics of the calibrated model **9a**: to what degree is the model suitable to predict changes in *streamflow and its temporal variations (average runoff, flow duration curve, dynamics)* as a result of climate change? (**H**igh/**I**ntermediate/**L**ow)	***HYPE***	***SWAT***	***WiMMed***

9b: rank the 3 models (with rank 1 as the most plausible and rank 3 as the least plausible model) which according to your belief are the most suitable for predicting changes in *streamflow and its temporal variations (average runoff, flow duration curve, dynamics)* as a result of climate change.	***HYPE***	***SWAT***	***WiMMed***
Specify why:			
Comments:			

Block 2 – probability assessment hydrological models

In this block you will be asked to assign probability values that best represents your confidence in each hydrological model given the model performance and purposes of model application in each case study. The total probability of all hydrological models for each case study should be equal to 100% (in the vertical column). It is possible to assign zero probability to a hydrological model and several models can have the same probability value.

In the last horizontal column please specify how confident you are in your ranking of the hydrological models for each case study on a scale of 1-5 (5: meaning very high confidence, 4: high confidence, 3: intermediate confidence, 2: low confidence, 1: very low confidence).

In the last vertical column please specify on a scale of 1-5 (5: meaning very high confidence, 4: high confidence, 3: intermediate confidence, 2: low confidence, 1: very low confidence) your degree of confidence in the hydrological model in general.

Hydrological model	**Case study DK**	**Case study-FR**	**Case study ES-UCO**	Confidence in general in hydrological models (1:low – 5 high)
1 Two Layer				
2 Gravity flow				
3 Richards Equation				
4 GR4J				
5 GR6J				
6 TOPMO				
7 HYPE				
8 SWAT				
9 WiMMed				
Total probability Confidence in ranking (1: low – 5: high)	100%	100%	100 %	

Comments: