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Brief Description	This deliverable presents the results of a comparative analysis of 28 existing climate services. The objectives of this report are 1) to give an overview of the current situation and the status quo of existing data-oriented climate services, 2) to give an overview of the AQUACLEW case studies in relation to climate data provision and 3) to identify important aspects for the improvement of the provision of water-related climate services.
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Executive Summary

The overall goal of the AQUACLEW project is to both improve data quality and better tailor climate data and adaptation knowledge to prospective users. This report presents the results of a comparative analysis of 28 existing climate services. The objectives of this report are 1) to give an overview of the current situation and the status quo of existing data-oriented climate services and 2) to identify important aspects for the advancement of the climate services.

Methods

1. The project partners identified relevant climate services both at the European, national and regional level.
2. Assessment of the individual climate services.
3. Comparative evaluation of the climate services with focus on the following parameters: origin and focus of the climate services, data availability, data properties, data accessibility, data documentation and usability aspects.

Results of the comparative evaluation:

- Most of the examined climate services are provided by governmental organizations.
- Most of the examined climate services have a national geographic focus.
- The most examined climate services target the sectors agriculture, forestry and water management.
- There is a wide range of target groups.
- The most examined climate services provide both observation and model data.
- Temperature and precipitation data are mostly offered.
- The most examined climate services offer gridded data, some with a resolution of less than 1 km.
- The most examined climate services offer a good temporal resolution (seasonal, monthly or better) – especially for observation data.
- The most examined climate services use the method of Representative Concentration Pathways as underlying scenario for model data.
- Almost all examined climate services investigated provide online maps; many also offer diagrams and tables.
- The most examined climate services offer a download possibility for data in different formats.
- The most examined climate services provide both metadata and background papers or glossaries as well as links to further data and information sources.
- Hardly any examined climate services offer training or consulting services or special features to interact with data providers.

Recommendations for the advancement of a climate service portal:

- A climate service portal should focus on knowledgeable and experienced data users in the water sector entirely and their high level of expertise.
- A climate service portal should offer both, high resolution data and appreciate data aggregated at river basin or administrative units.
- The observation and model data of a climate service portal should correspond in order to enable long-term comparisons.
- A climate service portal should provide the data download of georeferenced data such as GIS shape files or netCDF data for further process.
- A climate service portal should provide detailed metadata.

1. Introduction

Climate services often combine user needs with climate information to provide customized climate information, tools and analysis to facilitate mitigation and adaptation decision making by individuals and organizations. The European Research and Innovation Roadmap for Climate Services (Street et al. 2013) has stimulated the development of many pan-European climate services addressing climate impacts in different sectors, including water resources.

However, uptake of climate services for adaptation is still considered insufficient (Klein/Juhola 2014, Brasseur/Gallardo 2016). This is partly due to the fact that data and information in present climate services reflect high uncertainties and low resolution, which is difficult to use in practical climate adaptation work (e.g. Olsson et al. 2016). Furthermore, many climate services were developed in a top-down fashion, i.e. without significant user involvement. Hence the datasets offered and the way they are provided do not sufficiently cater to the needs of potential users of such climate services.

The overall goal of the AQUACLEW project is therefore to both improve data quality and better tailor climate data and adaptation knowledge to prospective users. Through co-development with users in both research and information production the project aims to advance the quality and usability of climate services in water management. Among others AQUACLEW will develop and apply new methods based on the most recent research to tailor choices of climate model ensemble, bias-correction methods and the hydrological model ensemble used to make predictions. As a result, AQUACLEW will decrease the influence of improbable models in impact results thus narrowing the spread of projected outcomes and, moreover, permit user interaction along the climate data production line.

Against this overall background this report presents the results of a comparative analysis of 28 existing climate services. The objectives of this report are 1) to give an overview of the current situation and the status quo of existing data-oriented climate services, 2) to give an overview of the AQUACLEW case studies in relation to climate data provision and 3) to identify important aspects for the improvement of the provision of water-related climate services.

The report is structured into four main chapters: Chapter 2 gives an overview of the methodology for assessing the identified climate services. Chapter 3 presents the main results in regard to origin and focus of the studied climate services, data availability, data properties, data accessibility, data documentation and further usability aspects. Chapter 4 presents the case studies of the AQUACLEW project with a focus on their climate data needs. Finally, Chapter 5 draws conclusions and derives recommendations for the development of water-related climate services. The Appendix includes summary tables presenting the detailed results along each assessment category and the assessment matrix that was used for analyzing the various climate services.

2. Methods of evaluation of climate services

This chapter gives an overview of the various steps undertaken to assess relevant climate services for the AQUACLEW project. The methods consisted of three steps, namely selection of relevant climate services, assessment of the individual climate services and comparative evaluation of all climate services.

2.1 Selection of relevant climate services

As a first step all project partners identified relevant climate services both at the European, national and regional level. In addition to the data-oriented climate services presented in this report, there are also climate services that are more qualitative in nature and e.g. present case studies or give general overviews and explanations about key climatological and hydrological issues. Such services are valuable resources for learning about climate change and water related impacts. But decision-makers like the ones represented in the AQUACLEW case studies are more advanced users and most of all require accurate and timely data for planning and day-to-day operational decisions. Therefore, this report concentrates on data-oriented climate services. The following are climate portals/platforms, called climate services, that were identified and later analysed by the project partners:

Climate services with a global or European geographic coverage

- Climate scenarios SMHI (global)
- KNMI Climate Explorer (global)
- PRIMAVERA (Europe and North Atlantic Ocean)
- Clim4Energy - beta version (Europe)
- CLIP-C (Europe)
- EDgE (Europe)
- HYPE (Europe)
- IMPACT2C (Europe)
- SWICCA (Europe)

Climate services with a pan-national or national geographic coverage

- HISTALP (Greater Alpine Region)
- Klimaatlas Tirol (Provinces of Tirol, Alto-Adige, Trentino and Belluno)
- AEMET (Spain)
- Climate Ireland (Ireland - Republic of Ireland and Northern Ireland)
- ClimatHD (France)
- County wise Climate Analysis SMHI (Sweden)
- Drias (France)
- DWD Climate Data Center (Germany)
- eHYD (Austria)
- Klimatanpassningsportalen (Sweden)
- Klimatilpasning (Denmark)
- ÖKS15 (Austria)
- Portus (Spain)
- Visor C3E (Spain)

Climate services with a regional or local geographic coverage

- DHCMA (Spain - Provinces of Cádiz, Málaga, Granada and Almería)
- Klimaatlas Nordrhein-Westfalen (Germany - State of North Rhine-Westphalia)
- REDIAM (Spain - Andalusia)
- S.A.I.H. (Spain - Guadalquivir basin)
- Urban SIS (Bologna, Stockholm, Amsterdam)

2.2 Assessment of the individual climate services

In consultation with all project partners, a questionnaire for the data-based climate services was prepared (see Appendix A 'Excel-sheet to assess climate services'). The aim of the questionnaire was to make the climate services comparable with each other using common criteria and indicators and to enable a quantitative and qualitative assessment. The contents of the completed questionnaires can be found in Appendix B 'Contents of completed climate services'. The questionnaires comprised the following parameters:

- **Basic information:** Name of climate service, type of service provider (governmental organization, research), language, year of commissioning, regular update of the climate service
- **Focus of the climate service:** Objectives, target groups and targeted sectors of climate service, geographic scale and coverage
- **Provided data:** Due to their relevance for the individual case studies (see 2.1), the indicators and data for temperature, precipitation, hydrology and oceanography were specifically queried. Information on socio-economic data such as land use, population, impacts and other indicators were also requested.
- **Data accessibility:** It was asked about how the data is displayed in the climate services, the format of downloadable data, access restrictions etc.
- **Documentation:** This section queried about metadata and access to supporting documents etc.
- **Other usability aspects:** The questionnaire also inquired about possibilities for interaction with data provider or other users**,** about offering training or consulting services, and about any innovative features of the climate service.
- **Overall assessment:** In addition, the reviewers were asked to give their subjective, more qualitative impression of the strengths and weaknesses of the studied climate services in terms of provided data**,** data accessibility**,** documentation**,** layout and navigation.

2.3 Comparative evaluation of the climate services

On the basis of the individual assessments of the 28 climate services surveyed for this report an overall comparison was conducted. For this purpose, all results were summarised in tables and then analysed in regard to the parameters listed below. The analysis sought to identify similarities as well as differences between the studied climate services and also highlight typical and exemplary achievements.

A. Origin and focus of the climate services

- Type of climate service providers
- Geographic coverage
- Target sector
- Target groups

B. Data availability

- Number of datasets of observation and model data (temperature, precipitation, hydrology, oceanography)
- Standard and special datasets of observation and model data (temperature, precipitation, hydrology, oceanography)

C. Data properties

- Typical grid resolution of each climate service (for observation and model data separately)
- Other spatial references (e.g. station data or catchment areas)
- Typical temporal resolution of each climate service (again for observation and model data separately)
- Regular data update of observation data
- Underlying scenarios of model data (e.g. SRES or RCP)

D. Data accessibility

- Provision of maps
- Provision of diagrams or tables
- Data format for further statistical processing (data download)
- Data format for further GIS processing (data download)

E. Data documentation

- Provision of metadata
- Provision of background paper or glossary
- Provision of interpretative documents or policy briefs
- Provision of links to further resources

F. Usability aspects

- Provision of user guides or tutorials
- Provision of training or consulting
- Possibilities for interaction with provider or other users
- Case studies

3. Results of comparative evaluation of climate services

This chapter presents the results of the comparative assessment of the studied climate services. The chapter breaks down into six sections that focus on 1) origin and focus of the climate services, 2) data availability, 3) data properties, 4) data accessibility, 5) data documentation and 6) further usability aspects.

3.1 Origin and focus of climate services

This section provides an overview of the origin and focus of the climate services assessed, e.g. which institution provide the climate services, what are the spatial foci and which sectors and users are addressed?

Type of climate service providers

Of the 28 studied climate services

- 21 climate services are provided by governmental organizations (e.g. ministries, national met offices etc.),
- 5 climate services are provided by research organizations (e.g. universities, research institutes, individual research projects etc.) and
- 2 climate services are provided as a cooperation of governmental and research organizations.

Geographic focus of the service providers

As Figure 1 shows, most of the assessed climate services have a national or European focus. This might be due to the fact that the operation of a climate service is very complex and requires significant monetary resources and highly skilled staff. Regional or local organizations are rarely able or willing to take on the task of setting up and operating a climate service. In contrast, national and international meteorological institutes often already had the required expertise and data and had been 'in the businesses of making climatological data available to the public anyway. Setting up and operating a climate service became one more channel for fulfilling their institutional mission.

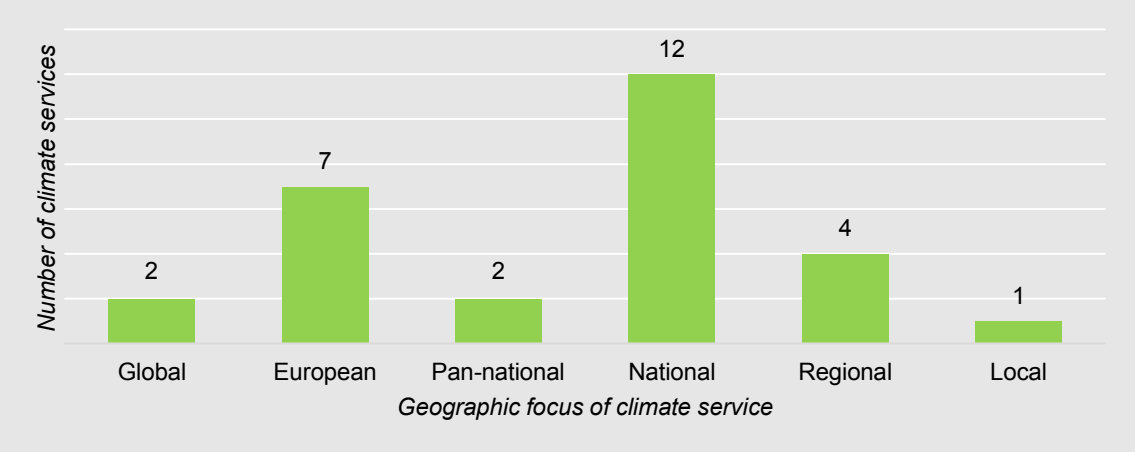


Figure 1. Number of climate services by geographic focus

Target sector

Most of the climate services assessed have several target sectors. As Figure 2 shows, agriculture, forestry and water management are targeted by most climate services. This could be explained by the fact that these sectors are highly dependent on accurate and timely climatological or hydrological data. To a slightly lesser degree this is also the case for the energy, health, coastal management and tourism sectors.

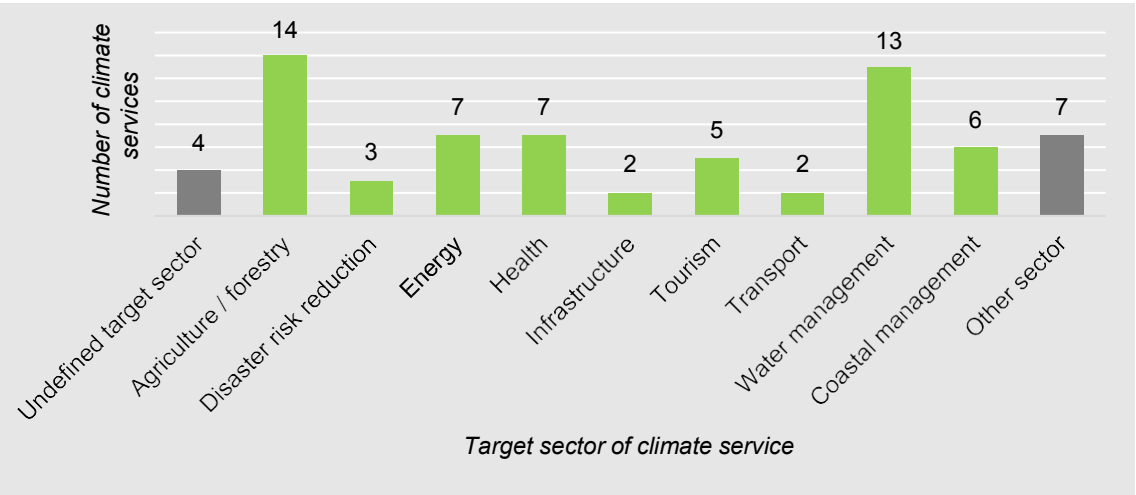


Figure 2. Number of climate services by target sectors (multiple entries possible per climate service)

Target groups

As shown in Figure 3, climate services have a wide range of target groups. Many of the climate services have several target groups. Overall, no target group stands out particularly. This is probably due to the fact that the providers of climate services usually do not define or focus on one specific target group. Consequently, the services typically try to cater to a wide range of possible users, following a "one size fits all" approach. It has to be noted, that the classification below is based on the assessment of each climate service by partners of the AQUACLEW project.

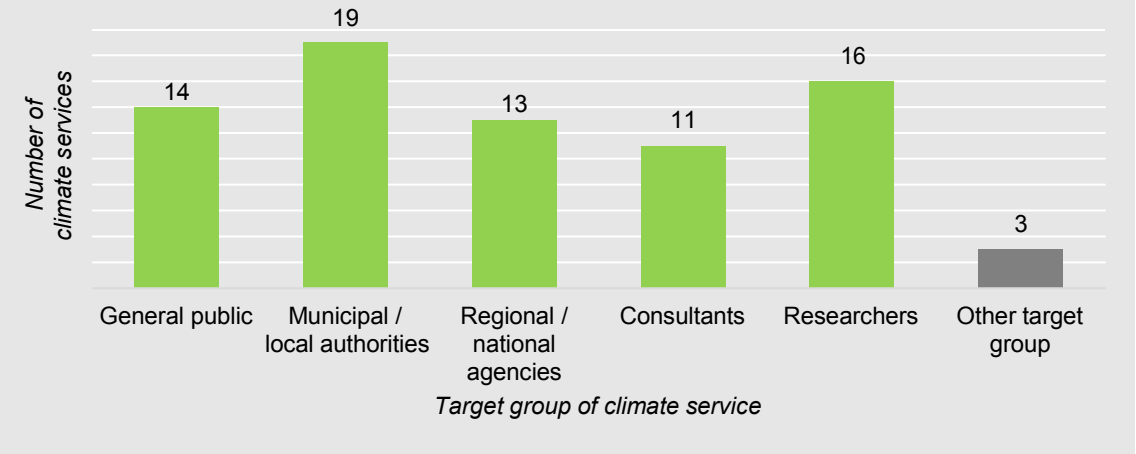


Figure 3. Number of climate services by target groups (multiple entries possible per climate service)

3.2 Data availability

This section presents the results of the climate services assessment in regard to data availability. First the results for observation data then for model data are presented. In both cases data on precipitation, temperature, hydrology and oceanography were considered.

A. Data availability of observation data

Temperature related observation data

- 23 of the 28 climate services provide temperature datasets.
  - 14 climate services provide less than five temperature datasets.
  - 4 climate services provide between five and nine temperature datasets.
  - 5 climate services provide ten or more temperature datasets.
- The climate services that provide the most temperature datasets were *Drias*, *CLIP-C*, *Klimaatlas Tirol* and *DWD Climate Data Center.*
- Standard datasets provided by most climate services were mean, maximum and minimum temperature.
- Additional data sets typically related to heating degree days, frost days, ice days, frost free days, summer days, tropical nights, heat waves, cold spells, global warming index.

Precipitation related observation data

- 24 of the 28 climate services provide precipitation datasets.
  - 15 climate services provide less than five precipitation datasets.
  - 7 climate services provide between five and nine precipitation datasets.
  - 2 climate services provide ten or more precipitation datasets.
- The climate services that provide the most precipitation datasets were *CLIP-C* and *Klimaatlas Tirol.*
- Standard datasets provided by most climate services were sum of precipitation (e.g. annual, daily), annual average of precipitation, number of days with precipitation.
- Further data sets typically related to number of heavy precipitation days, solid precipitation, snowfall, type of precipitation, maximum rainfall on 1 day / 5 days.

Hydrology related observation data

- 13 of the 28 climate services provide hydrology datasets.
  - 6 climate services provide less than five hydrology datasets.
  - 4 climate services provide between five and nine hydrology datasets.
  - 3 climate services provide ten or more hydrology datasets.
- The climate services that provide the most hydrology datasets were *DHCMA*, *County wise Climate Analysis SMHI* and *eHYD.*
- Standard datasets offered by most climate services are mean, min, max of streamflow / river discharge, total runoff, groundwater.
- Additional data sets offered by some climate services are soil moisture, evapotranspiration, water level, infiltration, water quality, duration of snow cover, 100-year flood return level

Oceanography related observation data

- 6 of the 28 climate services provide oceanography datasets.
  - 4 climate services provide less than five oceanography datasets.
  - 2 climate services provide ten or more oceanography datasets.
- The climate services that provide the most oceanography datasets were *Portus* and *Visor C3E.*
- Standard datasets offered by most climate services are surface temperature, sea level, salinity.
- Additional data sets offered by some climate services relate to wave height and wave direction, peak periods, currents, tide parameters.

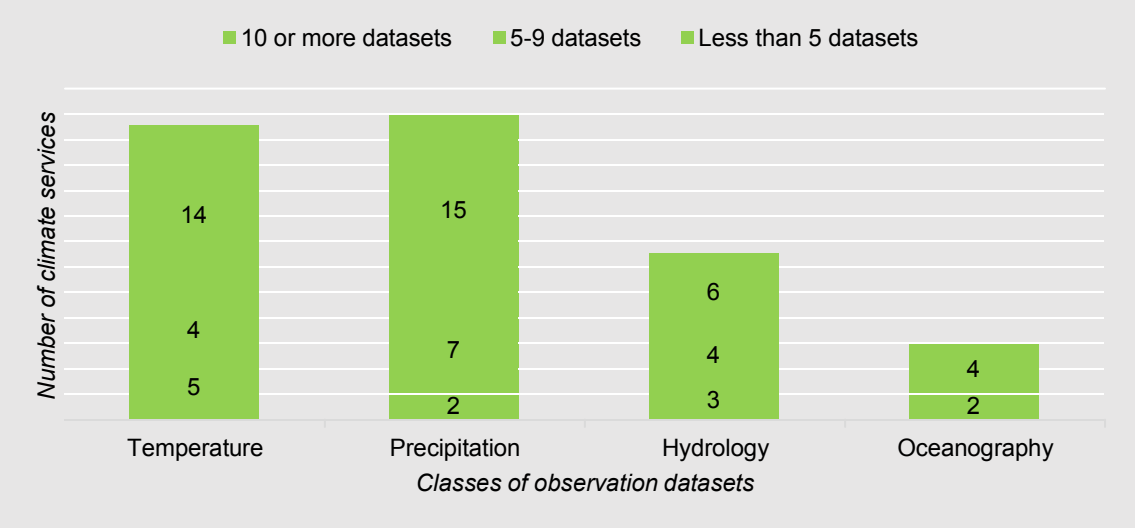


Figure 4. Number of climate services by number of observation datasets (classes)

In summary the highest number of indicators offered by the analyzed climate services relate to precipitation and temperature. These indicators are offered by almost all climate services that were studied. Hydrological data are also offered by many climate services. However, data related to oceanography are only offered in a few climate services (see Figure 4).

CLIP-C is the only climate service, which offers observation data for all four considered fields. For land-based data temperature, precipitation and hydrology *Klimaatlas Tirol*, *County wise Climate Analysis SMHI*, *REDIAM* and *Urban SIS* also stand out. Table A1 (Appendix A) shows the number of temperature, precipitation, hydrological and oceanography indicators for observation data that are available in each climate service.

B. Data availability of model data

Temperature related model data

- 21 of the 28 climate services provide temperature datasets.
  - 11 climate services provide less than five temperature datasets.
  - 4 climate services provide between five and nine temperature datasets.
  - 6 climate services provide ten or more temperature datasets.
- The climate services that provide the most temperature datasets were *Klimaatlas Tirol*, *AEMET*, *Drias* and *ÖKS15.*
- Standard datasets: mean, max and min temperature and relative change to observation
- Additional data sets often also offered relate to heating degree days, frost days, ice days, frost free days, summer days, tropical nights, heat waves, cold spells

Precipitation related model data

- 21 of the 28 climate services provide precipitation datasets.
  - 12 climate services provide less than five precipitation datasets.
  - 7 climate services provide between five and nine precipitation datasets.
  - 2 climate services provide ten or more precipitation datasets.
- The climate services that provide the most precipitation datasets were *Klimaatlas Tirol*, ÖKS15, *CLIP-C* and *DWD Climate Data Center.*
- Standard datasets: sum of precipitation (e.g. annual, daily) data, annual average of precipitation, number of days with precipitation and relative change to observation
- Outstanding / additional data sets: number of heavy precipitation days, snowfall, maximum rainfall on 1 day / 5 days, longest dry and wet period, duration and return indicators of heavy precipitation

Hydrology related model data

- 10 of the 28 climate services provide hydrology datasets.
  - 4 climate services provide less than five hydrology datasets.
  - 4 climate services provide between five and nine hydrology datasets.
  - 2 climate services provide ten or more hydrology datasets.
- The climate services that provide the most hydrology datasets were *SWICCA* and *County wise Climate Analysis SMHI.*
- Standard datasets typically offered relate to mean, min, max of streamflow / river discharge, total runoff, groundwater.
- Additional datasets sometimes offered relate to soil moisture, evapotranspiration, 100-year flood return level.

Oceanography related model data

- 6 of the 28 climate services provide oceanography datasets.
  - 4 climate services provide less than five oceanography datasets.
  - 2 climate services provide 10 or more oceanography datasets.
- The climate services that provide the most oceanography datasets were *Portus* and *Visor C3E.*
- Standard datasets relate to sea level and sea level surface pressure.
- Additional data sets offered by only some climate services relate to salinity, wave height and wave direction, peak periods, currents and surface water temperature.

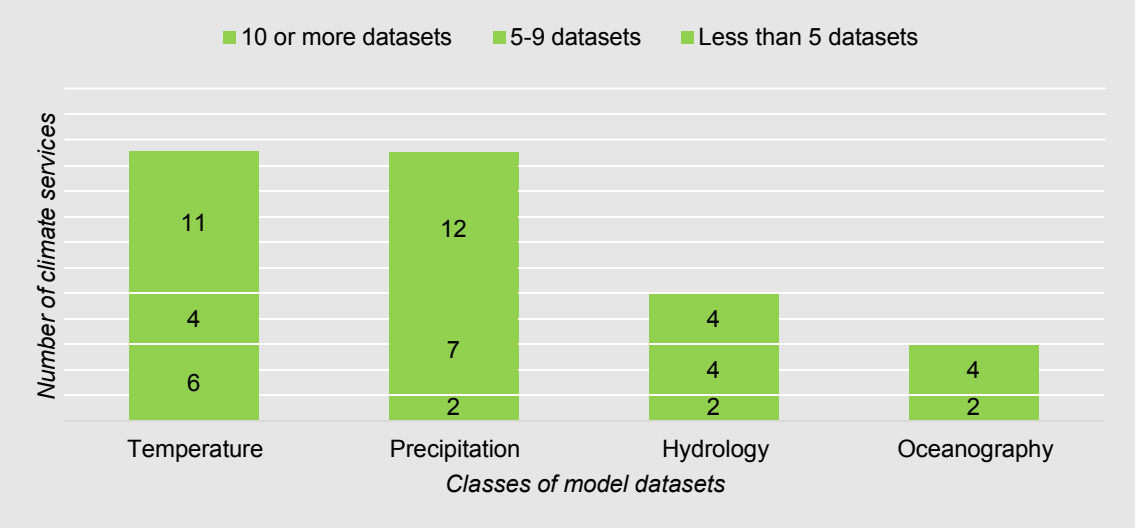


Figure 5. Number of climate services by number of model datasets (classes)

As with observation data, Figure 5 shows that precipitation and temperature data are featured the most. They are also offered by almost all climate services. Hydrological model data are also offered by many climate services, but data related to oceanography are only offered by a few climate services.

CLIP-C and *AEMET* are the only climate services with model data for all four fields. For the land-based data temperature, precipitation and hydrology *SWICCA*, *County wise Climate Analysis SMHI* and *Urban SIS* also stand out. Table A2 (Appendix A) shows the number of temperature, precipitation, hydrological and oceanography indicators for model data that are available in each climate service.

3.3 Data properties

This section presents the results of the climate services assessment in regard to data properties, first regarding observation data then regarding model data. The grid resolution and temporal resolution of the data and whether other spatial references such as station data or catchment areas are provided are considered. Furthermore, the regular update of observation data and the underlying scenario type of model data are considered.

A. Data properties of observation data

Grid resolution of observation data

- 26 of the 28 climate services provide observation datasets.
  - 8 climate services do not provide gridded data, but data e.g. for stations, catchment areas or regions.
  - 18 climate services provide gridded data.
    - 5 climate services have a typical grid resolution of less than 10 km.
    - 7 climate services have a typical grid resolution between 1 km and 10km.
    - 6 climate services have a typical grid resolution of 1 km or better.
- The climate services that provide the datasets with the best typical grid resolution were *Klimaatlas Tirol*, *Climate Ireland*, *DWD Climate Data Center*, *Klimaatlas Nordrhein-Westfalen*, *Portus* and *Urban SIS.*

Other spatial references of observation data

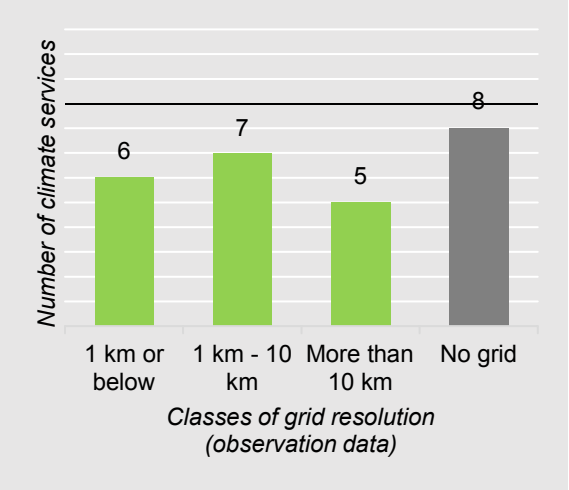
- 26 of the 28 climate services provide observation datasets.
  - 11 climate services have another spatial reference.
    - 3 climate services have countries or regions as other spatial reference.
    - 2 climate services have catchment areas as other spatial reference.
    - 6 climate services provide station data or data of coastline points.

Temporal resolution of observation data

- 26 of the 28 climate services provide observation datasets.
  - 4 climate services have only a general time reference (average values or decades).
  - 5 climate services have a yearly resolution.
  - 10 climate services have a seasonal or monthly resolution.
  - 7 climate services have a daily resolution.

Data update of observation data

- 26 of the 28 climate services provide observation datasets.
  - 15 of these 26 climate services regularly update their observation data.



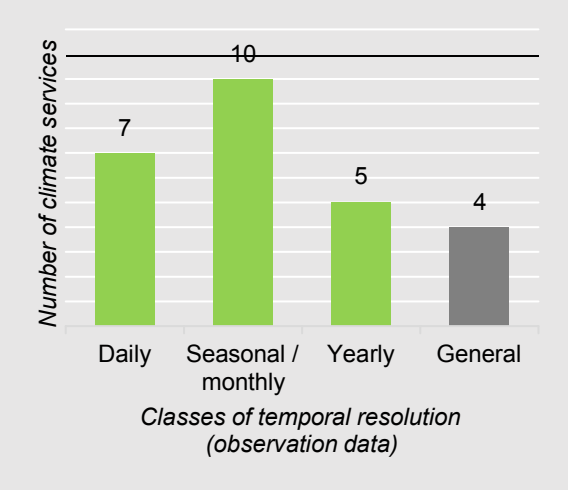


Figure 6 (left). Number of climate services in regard to grid resolution of observation data
Figure 7 (right). Number of climate services in regard to temporal resolution of observation data ('general' means a general time reference like average values or decades)

In summary, Figure 6 shows that most of the 26 climate services that offer observation data provide gridded data. Half of these climate services offer a grid resolution of less than 10 km. As Figure 7 shows, the majority of climate services have a good temporal resolution (seasonal, monthly or better). Furthermore, more than half of the examined climate services regularly update their observation data.

Among the observation data, the two climate services *DWD Climate Data Center* and *HISTALP* stand out. Both offer high grid resolution and temporal resolution as well as station data. Furthermore, these climate services regularly update their data. In addition, the climate services *Klimaatlas Tirol*, *Klimaatlas Nordrhein-Westfalen*, *Urban SIS* and *Climate Ireland* should be highlighted with regard to the data properties, even if they do not offer regular updates of their data. Table A3 (Appendix A) shows the grid resolution and temporal resolution of the observation data, whether other spatial references such as station data or catchment areas are provided and whether the data are updated regularly.

B. Data properties of model data

Grid resolution of model data

- 23 of the 28 climate services provide model datasets.
  - 2 climate services do not provide gridded data, but data e.g. for stations, catchment areas or regions.
  - 21 climate services provide gridded data.
    - 9 climate services have a typical grid resolution of less than 10 km.
    - 8 climate services have a typical grid resolution between 1 km and 10km.
    - 4 climate services have a typical grid resolution of 1 km or better.
- The climate services that provide the datasets with the best typical grid resolution were *REDIAM*, *HYPE*, *ÖKS15* and *Urban SIS.*

Other spatial references of model data

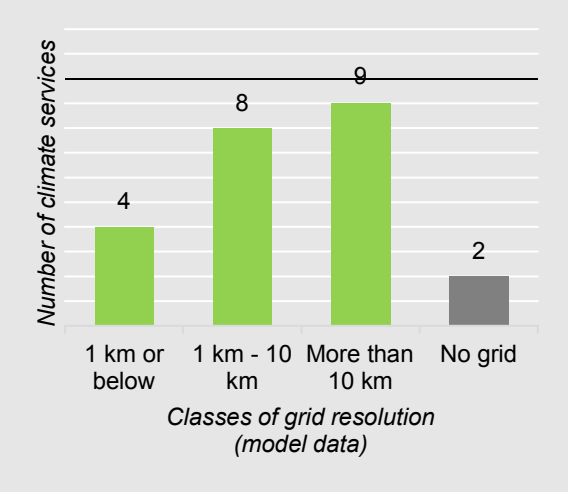
- 23 of the 28 climate services provide model datasets.
  - 5 climate services have another spatial reference.
    - 1 climate service has regions as other spatial reference.
    - 2 climate services have catchment areas as other spatial reference.
    - 2 climate services provide station data or data of coastline points.

Temporal resolution of model data

- 23 of the 28 climate services provide model datasets.
  - 7 climate services have only a general time reference (average values or decades).
  - 5 climate services have a yearly time resolution.
  - 7 climate services have a seasonal or monthly time resolution.
  - 4 climate services have a daily time resolution.

Underlying scenarios of model data

- 23 of the 28 climate services provide model datasets.
  - 3 climate services were not clear about their underlying scenarios.
  - 4 climate services use scenarios of the IPCC's Special Report on Emissions Scenarios (SRES).
  - 11 climate services use Representative Concentration Pathways (RCP) as underlying scenarios.
  - 5 climate services use both RCP and SRES scenarios.



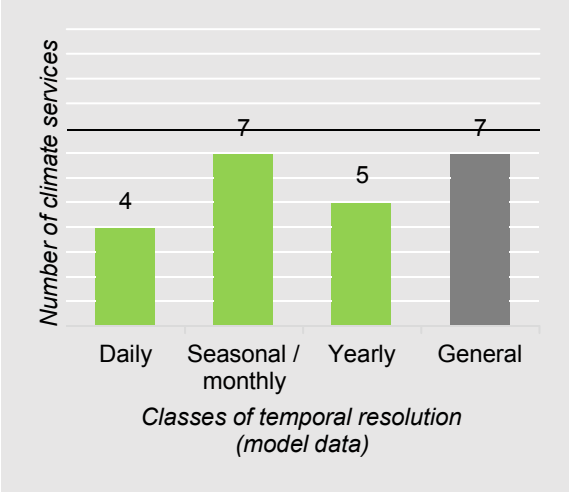


Figure 8 (left). Number of climate services in regard to grid resolution of model data
Figure 9 (right). Number of climate services in regard to temporal resolution of model data ('general' means a general time reference like average values or decades)

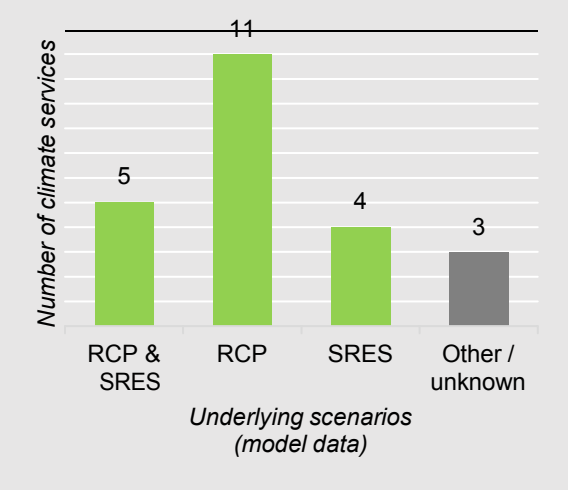


Figure 10. Number of climate services in regard to underlying scenarios of the model data

In the summary, Figure 8 shows that nearly all of the 23 climate services that offer model data provide gridded data. More than half of these climate services offer a grid resolution of less than 10 km. As figure 9 shows, nearly the half of climate services have a very good temporal resolution (daily, monthly or seasonal or even better). The majority of the climate services that offer model data use the method of Representative Concentration Pathways as underlying scenario (see Figure 10).

Among the model data, the two climate services *Drias* and *ÖKS15* stand out. Both offer a very good grid resolution and temporal resolution. Furthermore, these climate services use the latest RCP scenarios. Additionally, the climate service *AEMET* offers station data with a daily resolution and also uses RCP scenarios. Table A4 (Appendix A) shows the grid resolution and temporal resolution of the model data, whether other spatial references such as station data or catchment areas are provided and which model approach is used.

3.4 Data accessibility

This section presents the results of the climate services assessment in regard to data accessibility. It was considered whether online maps, diagrams and tables are offered and whether there are possibilities for downloading data.

- 24 of the 28 climate services provide online maps of the offered data.
- 15 climate services provide displayed online diagrams or tables of the offered data contents
- 20 climate services provide data for download
  - 2 climate services provide data download in an unknown format
  - 13 climate services allow to download data in a format suitable for further statistical processing (e.g. Excel-data)
  - 10 climate services allow to data download in a format suitable for further GIS processing (e.g. shapes files)
  - 6 climate services allow to download data in netCDF format

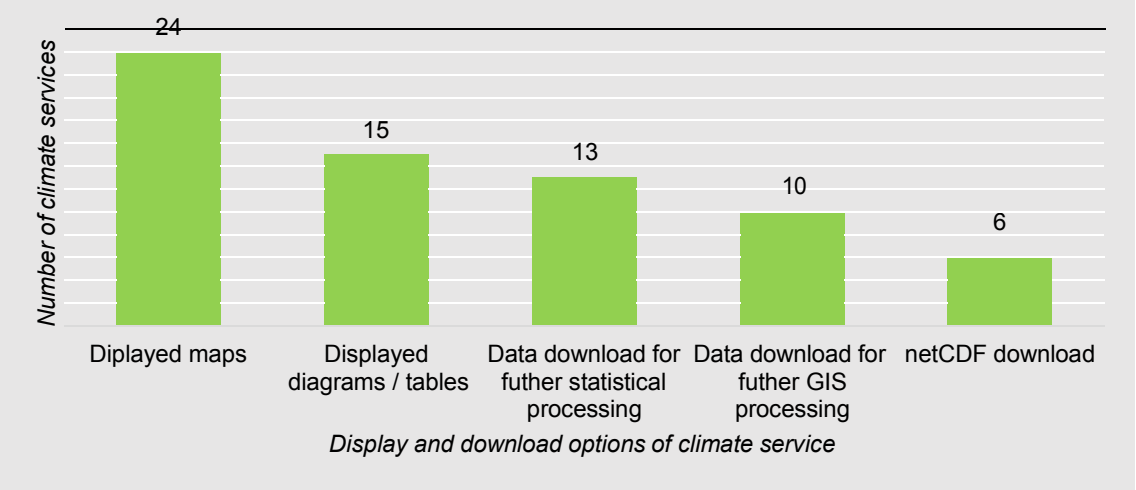


Figure 11. Number of climate services in regard to display and download options

Almost all climate services investigated provide online maps, many also offer diagrams and tables. Furthermore, the majority of the climate service offers a download possibility for data in different formats (see Figure 11).

The climate services *Climate scenarios SMHI*, *KNMI Climate Explorer*, *CLIP-C* and *REDIAM* stand out due to the data accessibility as this climate services provide displayed maps, diagrams or tables and offer the possibilities to download the data in netCDF or GIS format. Table A5 (Appendix A) shows which climate services provide maps, diagrams and tables online. Furthermore, it is shown which climate services allow to download data in which format.

3.5 Data documentation

This section presents the results of the climate services assessment in regard to data documentation. It was considered whether metadata, background papers or glossaries, interpretative documents or policy letters are offered as well as links to further data and information sources.

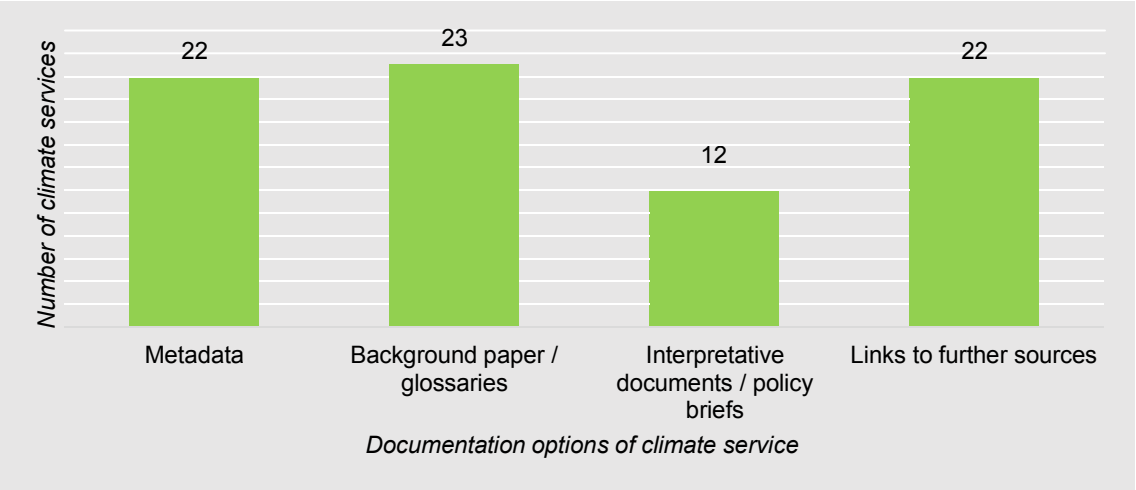


Figure 12. Number of climate services in regard to documentation features

Overall, the results in regard to data documentation are rather positive (see Figure 12). The majority of climate services provide both metadata and background papers or glossaries as well as links to further data and information sources. The studied climate services employ many good approaches to documenting their data and making further material available to their users.

Table A6 (Appendix A) shows whether the climate services provide metadata, background papers or glossaries. Furthermore, it is shown which climate services offer interpretative documents or policy briefs as well as links to further data and information sources.

3.6 Usability aspects

This section presents the results of the climate services assessment in regard to usability aspects. It was considered whether the climate services provide user guides and tutorials and which offer training or consulting services. It was also examined whether the climate services offer users to interact with the service providers or other users and whether exemplary case studies are offered.

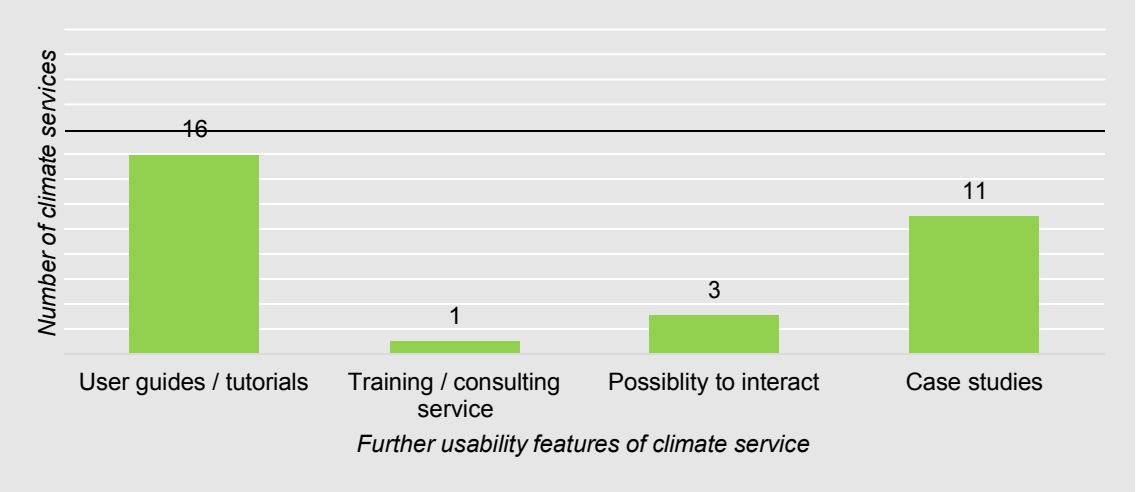


Figure 13. Number of climate services in regard to further usability features

As Figure 13 shows, more than half of the climate services that were analysed provide user guides or tutorials that help the users make full use of the offered services. Many also provide case studies that show the users how the offered data are utilised in real world use cases. In contrast, hardly any climate services offer training or consulting services or special features to interact with data providers (e.g. forums etc.).

In regard to usability aspects, the three climate services *Climate Ireland*, *SWICCA* and *Urban SIS* should be highlighted as they offer user guides or tutorials and the possibility to interact with the provider or other user. As the only climate service examined, *Climate Ireland* offers the possibility to attend workshops and seminars. *SWICCA* is the only examined climate service to provide an online forum for users. Table A7 (Appendix A) shows whether the climate services provide user guides and tutorials and which offer training or consulting services and exemplary case studies.

4. Climate data needs of the case studies

This chapter focuses on the seven case studies of the AQUACLEW project and their perspective on climate data. The chapter first introduces the case studies, identifies the climatic and non-climatic data required in each case and then summarizes data quality and data availability aspects that were highlighted by key informants. The findings are based on the case study descriptions and the respective interviews with the end users in each case study (see Milestone M3.2).

Agricultural production in Central Denmark

In this case study, the impacts of climate change on agricultural production will be analysed. It is expected that climate change will strongly affect soil moisture and groundwater levels due to higher precipitation in winter and longer dry periods in summer. Therefore, both floods and droughts will be studied, with the resulting effects on the root zone moisture content, groundwater level and river discharge. The focus is on the uncertainty of forecasts of future conditions, which depends on the emission scenario, the choice of climate model and the agro-hydrological model.

With regard to the four main themes of climate data (temperature, precipitation, hydrology and oceanography), the following (climatic) data are most relevant for the case study:

- Temperature
  - Drought indicators
- Precipitation
  - Flood indicators / precipitation
- Hydrology
  - Groundwater indicators
  - Data on soil moisture
- Oceanography
  - Sea level rise

The most important and most used climate services / climate data of the individual use case in the case study are the Danish meteorological institute and the climate service klimatilpasning.dk. Future projection data are used with only one scenario. In the field of data quality, a daily temporal resolution and a spatial resolution of 5 x 5 km are used.

In the context of the use case of the case study, the following suggestions and requests for improving the data provision were made: In the field of data properties, a generally higher spatial resolution of the data and less uncertainty of the projected data is required; in the field of data documentation more and better metadata and simple explanations of uncertainty level is required.

Biodiversity decline (Sweden)

Jönköping county administration works as a policy maker of environmental protection. With the responsibility to detect changes in ecosystems, to describe them as well to decide for new regulations to protect environment in a changing climate there is a need for information on different climate indicators to be easily accessible and comparable with other data sources. The results will lead to better supported decisions on environmental protection in a changing climate with focus on supporting different habitats and environments to conserve and maintain biodiversity. The results will also be used in the environmental monitoring program at the County and is saved in databases together with other local data.

With regard to the four main themes of climate data (temperature, precipitation, hydrology and oceanography), the following (climatic) data are most relevant for the case study:

- Temperature
  - Air temperature
  - Growing degree days
- Precipitation
  - Precipitation
  - Snow cover
- Hydrology
  - Water discharge
  - Water temperature
  - Groundwater level
- Oceanography
  - Water temperature

The most important and most used climate services / climate data of the individual use case in the case study are the Portals of SMHI and SWICCA. Future projection data for early, mid and late century with several scenarios are used. Gridded climate data and raw data are used; the temporal and spatial resolution of the data used is adequate for the case of use

In the context of the use case of the case study, the following suggestions and requests for improving the data provision were made: In the field of data properties, downscalable data and the possibility of comparing projected data with observation data is required; in the field of data accessibility an easy-to-use interface and Clear outcomes that are easily accessible and understandable by general public is important; in the field of data documentation, more information, how the climate data is produced is required.

Drought and Water resource allocation for tourism, agriculture, energy sectors (Spain)

The Guadalfeo River Basin is a Mediterranean mountainous coastal watershed in the Sierra Nevada National Park in the Southeast of Spain. Its highly variable precipitation and snow regime determines water availability at the seasonal and annual scales. Urban supply, tourism and agriculture, together with hydropower generation at the headwaters compete for water during the warm season. The future climatic context poses a risk for the current supply system and water resource availability on a long term basis. Climate services provide an open framework to assess the seasonality expected shifts associated to changes in the snow regime, and to estimate their impact on the decision making process. Also, they allow developing operational strategies both in the medium and long term. Results will assess the prevision of water allocation success on an annual and decadal basis in the new planning hydrological cycle, and they will provide a deeper insight on the potential future seasonal regime.

With regard to the four main themes of climate data (temperature, precipitation, hydrology and oceanography), the following (climatic) data are most relevant for the case study:

- Temperature
  - Temperature
  - Radiation
- Precipitation
  - Precipitation
- Hydrology
  - River discharge

The most important and most used climate services / climate data of the individual use case in the case study are AEMET and the tool “meteologica”, which provides local information close to the hydroelectric plan.

Only historical data of the last ten years, but no future projection data are used. A daily and subdaily temporal resolution of the observed meteorological data is used.

In the context of the use case of the case study, the following suggestions and requests for improving the data provision were made: In the field of data properties, downscalable data – basin scale is not enough – and the using of future development trends and multiple scenarios with less uncertainty is required; in the field of data documentation a better explanation of the data and methods e.g. improving metadata and examples is required.

Fluvial and coastal interactions under Mediterranean climate conditions (Spain)

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. Sometimes they are also suffering severe erosion problems due to the regulation of their rivers’ flows. 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. It is proposed to analyse 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.

With regard to the four main themes of climate data (temperature, precipitation, hydrology and oceanography), the following (climatic) data are most relevant for the case study:

- Temperature
  - Temperature
  - Radiation
- Precipitation
  - Precipitation
- Hydrology
  - River flow
  - Reservoir discharges
- Oceanography
  - Sea level pressure
  - Sea level height
  - Significant wave height
  - Wave period
  - Wave direction
- Other data
  - Wind velocities
  - Wind directions

The most important and most used climate services / climate data of the individual use cases in the case study are AEMET, REDIAM, the SICA network, the database of Puertos des Estado and historic data from buoys.

Only historical data from buoys and numerical models, but no future projection data are used. In some use cases, historical data and 4-days predictions are used from REDIAM and AEMET. The temporal resolution of the data of REDIAM and AEMET are daily, monthly and yearly. In other use cases, hourly data from the database of Puertos des Estado is used.

In the context of the use case of the case study, the following suggestions and requests for improving the data provision were made: In the field of data properties, prediction times longer than 4 days would be useful (e.g. 15-30 days).

Hydropower production (France)

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.

With regard to the four main themes of climate data (temperature, precipitation, hydrology and oceanography), the following (climatic) data are most relevant for the case study:

- Temperature
  - Temperature
- Precipitation
  - Precipitation
- Hydrology
  - River flow

The most important and most used climate services / climate data of the individual use cases in the case study are CMIP5, ECMWF, data of Météo-France and ECEM. In addition, the internal EDF service is used.

The spatial resolution of regional to local data as well as the temporal resolution of hourly to annual data depends on the needs of the use case. Future projection data from CMIP, Météo-France and ECEM is used. In the context of the internal EDF service, own forecasting tools and tailored climate services are provided as well as bias correction, post-processing and downscaling to local climate projections.

In the context of the use case of the case study, the following suggestions and requests for improving the data provision were made: In the field of data properties, the improvement of bias correction and the methods of downscaling is required. Furthermore, the reduction of data uncertainties and the provision of local information at catchment scale is important.

Pluvial Flash Floods in pre-Alpine Regions (Austria)

Rain related flash flooding that occurs away from permanent watercourses (pluvial flash flooding) is a topic that has gained a lot of attention over the last years. Not only urban areas with a high percentage of sealed surfaces, but also rural areas have been adversely affected by these phenomena in the recent past. Besides causing a substantial amount of material damage and monetary losses, these pluvial flash floods can also present a threat to the lives of people in the affected areas. Previous studies indicate that pre-alpine areas are especially susceptible to this type of flooding. Consequently, government authorities on different levels of administration are currently working on strategies to manage the risks associated with pluvial flash floods. Within this context it is important to assess the availability and usability of data sets from national and pan-European climate-services for pluvial flash flood hazard and risk assessment on different spatial scales (regional to local).

For pluvial flash flood hazard assessment, the definition of representative scenarios is an important topic. This includes the choice of appropriate precipitation-scenarios and their spatial distribution as well as initial conditions (e.g. antecedent soil moisture content, disposition of different areas of land use and soil types to produce surface runoff). Depending on the scale of a study the choice of scenarios can be either pragmatic (e.g. regional scale hazard indicator maps) or has to be more elaborate (e.g. design of mitigation structures). In either case information about the availability and quality of respective datasets is indispensable for the involved stakeholders. Currently in Austria design-precipitation sums are available in approx. 6km x 6km resolution for return-periods between 1 and 100 years and durations ranging from 5 min up to 6 days. On national level currently no future projections of climate change are included in the provided datasets.

With regard to the four main themes of climate data (temperature, precipitation, hydrology and oceanography), the following (climatic) data are most relevant for the case study:

- Precipitation
  - Design-Precipitation values

The most important and most used climate service / climate data of the individual use case in the case study are the national Climate Service EHyd and time-series data from weather-stations.

The focus is on observational data and statistical indicators for historical data (design precipitation with a given recurrence interval for different event durations, e.g. 100yr precipitation sum for an event with 60min duration). The dataset on design precipitation do not have a temporal resolution, since they are results of extreme-value statistical analysis of historical data. If data from weather-stations is used a sub-hourly temporal resolution is required to capture short duration/high intensity rainfall events. For the design precipitation data is available for grid cells with approx. 6km by 6km resolution.

In the context of the use case of the case study, the following suggestions and requests for improving the data provision were made: In the field of data properties, the improvement of future projections of climate change for design-precipitation with different scenarios based on historical data is required. Furthermore, an update of the values in regular intervals is desirable in order to include also recent observations.

Urban flash floods (Germany)

The Hagen case study focuses on local heavy rainfall events and how the negative impacts on the city's urban areas can be mitigated. For planning purposes, the municipality so far uses data of observed rainfall events and added a flat 10% increase in heavy rainfall precipitation due to climate change based on extrapolations from the observation data. For investigating which areas of the city would be flooded in the event of e.g. a 100-year return period event, runoff simulations it would be good to make use of the latest climate projections. On this basis simulations could be carried out that more accurately calculate the flood depths and flow velocities of stormwater in Hagen. The results could then be used as a basis for developing adaptation strategies at neighbourhood and city level by integrating other information e.g. on land use, population distribution etc. The more accurate rainfall and run-off simulation data are of particular interest to Hagen's Urban Development department and Civil Protection department.

With regard to the four main themes of climate data (temperature, precipitation, hydrology and oceanography), the following (climatic) data are most relevant for the case study:

- Precipitation
  - Design-Precipitation values (20-yearly events up to 100-yearly events)

The most important and most used climate services / climate data of the individual use cases in the case study are from Germany's National Meteorological Service (DWD) and data of twelve local weather stations in Hagen. Civil Protection department uses also up-to-date weather data and extreme weather warnings from Germany's National Meteorological Service (DWD).

In the context of the use case of the case study, the following suggestions and requests for improving the data provision were made: In the field of data properties, the improvement of future projections of climate change for design-precipitation (currently only a 10 percent surcharge on the rainfall is used to represent climate change) and the improvement of downscaling is required.

5. Conclusions

This chapter presents the conclusions of the report: 1) Overall results, 2) Recommendations for improvement of climate services in relation to case studies, and 3) General recommendations for the provision of water-based climate services.

5.1 Overall discussion of the results

This section summarises and discusses the results presented in Chapter 3. Therefore, the discussion is arranged according to the sections of Chapter 3.

Climate service providers

The studied climate services are mostly operated by governmental organizations. This ensures long-term sustainability, regular maintenance and data updates. Also, as Lemos (2012) noted, users may have greater trust in the reliability of information provided by public authorities. On the other hand, they often have more of a top-down approach to providing data, whereas portals set up by research projects/institutions may have taken a more participatory, bottom-up approach with active consultation of users right from the start (see Brasseur/Gallardo 2016). This has sometimes also resulted in innovative features that could inspire other climate information platforms as well.

The climate services analysed in this study were mostly operated by national organisations and thus provided mainly data at a national level. This is understandable from a language and user base point of view, but at the same time raises the important question how transboundary issues were dealt with. In this sense pan-European data are much more preferable.

Data availability

Most of the studied climate services provide both observation and model data (projections) – at least for temperature and precipitation indicators. Many climate services also provide data on hydrology, whereas only a few offer data on oceanography. The latter mostly has to do with the location of the country in which the service is located, i.e. whether the country has a coastline or not.

The studied climate services differ significantly in regard to how many indicators they offer data for. But a large number of indicators is not necessarily better. As Lemos (2012), Streets (2015) and Brasseur and Gallardo (2016) have all pointed out, the climate data as such need to be accompanied by customized products that include explanations, case study descriptions, counselling on best practices etc. in order not only to be useful but truly usable. This is even more important if – as our study has shown – climate services try to cater to a wide range of users with very different needs and skill levels. In this case guidance becomes even more important than raw data and sophisticated technical tools (Sigel et al. 2016).

Data properties

Our study revealed significant differences between climate services in terms of spatial resolution. While a high spatial resolution is in general better, this also comes at a cost, e.g. when observation data are downscaled by using interpolation techniques, which increases

inaccuracy. Therefore, some climate services opted to (also) provide station data e.g. hydrological data on rivers. For non-scientists it is helpful if data are processed and aggregated to units that are particularly relevant for them, e.g. river catchment areas. Thus, a few services decided to offer aggregated data for administrative units or catchment areas in addition to point or interpolated data – or they provide tools for doing such aggregations 'on the fly'.

As regards the temporal resolution of data, Brasseur and Gallardo (2016) have highlighted the difference between users' expectations (daily, monthly or at most yearly resolution) and the resolutions typically offered by climate services (yearly, decadal or multi-decadal resolution). Several of the studied climate services have therefore decided to provide very fine grained, i.e. daily observation data. This may be good for scientists or advanced users who do further processing with these data. But for more applied users it is actually preferable to have more aggregated data, e.g. seasonal data. However, since climate change influences e.g. the onset of spring, the seasons are changing as well. Therefore, it might be advisable that in addition to seasonal data monthly data are also provided.

The value of frequent data updates also depends on the user, e.g. dam operators have other needs than cities that need the data for long-term planning. But it is generally important that current data and new procedures are regularly integrated into a climate service, otherwise the climate service can be outdated quickly. The latter may occur when a climate service only has short term funding (e.g. a research project) as is the case with some of the studied climate services. This highlights the advantage of more institutionalised climate services.

Data accessibility

Pretty much all studied climate services offer ready-made online maps and diagrams help the user get an overview of key indicators. Furthermore, most services also provide detailed and in-depth information for download. In this regard Brasseur and Gallardo (2016) found that one of the most important weaknesses of climate services was that they offered inappropriate data formats. Of course such data accessibility requirements depend on the type of user: Advanced users need detailed data for downloading and further processing. Thus, data in common formats for geographical, climatological or hydrological evaluation (e.g. common GIS-formats or netCDF) are the most suitable for them. On the other hand, less experienced appreciate data in the form of online maps, predefined diagrams or simple xls files.

In our study only a little more than half of the climate services offered more advanced data formats. On the one hand, this would be inappropriate for less skilled users. On the other hand, the advanced users would not find appropriate data in the other half of the studied climate services. This would call into question the 'one stop shop' philosophy of most climate services. They may be better advanced to focus on a more narrow user group and offer the appropriate data formats for them or – if they decide to keep a more encompassing approach – they need to offer several data formats. In both cases it is important to offer flexible catalogue search functions that let users quickly find data that they are interested in.

Data documentation

Metadata are an essential component of climate services. It is very important for both researchers and applied users to be able to accurately understand the origin and content of the data they are interested in. Three quarters of the studied climate services include full metadata – but one quarter still does not. A glossary of key terms and procedures is likewise very important for users who are not experienced in handling climate data. Interpretive documents and further links can be important for all user groups in order to draw the right

conclusions from the data or to be able to follow up certain topics in more depth. Almost all of the climate services examined offer e.g. a glossary and many also provide links to further information resources.

Usability aspects

As already pointed out above, the usability of climate services and their data is perhaps more crucial than the sheer availability of their data. Narrowing the usability gap, as Lemos (2012) put it, is the key to making a climate service truly relevant for users. To this end many of the examined climate services offer e.g. user guides, tutorials or case study descriptions that show how the provided data can be used in a real world context. However, training or consulting services as well as interaction with service providers or other users are typically not provided by the studies climate services. This may have to do with the level of human resources that is necessary for such an 'active stewardship' approach (Brasseur/Gallardo 2016).

It also helps to have a well-defined target group so that one can tailor specific services and their interface to their specific needs and skill level. Some climate services (especially those set up by research projects) take this route by adopting a participatory co-development approach with their prospective users, but the range of users they try to cater to is sometimes still very wide, which makes prioritising and tailoring the services still rather difficult. At the same time, it is impossible to meet all the needs of all users, so a large and diverse user group should be surveyed to combine and prioritise user feedback to more effectively meet the needs of most. AQUACLEW will address this by using an interactive approach in the climate service production to survey the needs of a wide user community, but then summarise and prioritise these needs to optimise the climate service design for the greater benefit of most.

5.2 Recommendation for improvement of climate services in relation to the case studies

This section takes up the needs of the case studies in relation to climate data and data quality (Chapter 4). The recommendations are structured according to the topics data properties, data accessibility and data documentation.

Data properties

The proposals for the improvement of data properties relate mainly to the improvement of spatial resolution or downscaling of climate data and to the improvement of the accuracy of forecasting model data. The necessity of a high spatial resolution, the possibility of downscaling the data and the improvement of the methods of downscaling is pointed out. In addition, the importance of information on catchment scale is highlighted in water-relevant case studies. As suggestions for improving the forecasting model data provided, the need for less uncertainty of this data is mentioned above all. There should be further multiple scenarios selected for the model data. The data structure of this model data should be comparable to the data structure for observation for a long-term view. In particular, the improvement of future projections of climate change for design-precipitation is mentioned. Last but not least, the improvement of the bias correction is highlighted.

Data accessibility

For data accessibility, the use of an easy-to-use interface is highlighted to ensure easy access to data with a clear outcome.

Data documentation

The proposals for improving the data documentation are extensive and relate on the one hand to the field of metadata and on the other hand to a clearer approach for explaining uncertainties for future projections. Important for the provision of data are the corresponding metadata and information on how the data and the outputs has been produced. This also includes a better explanation of the data and methods of data generation. This is to ensure that the data is understood and traceable for all users, ideally also for the general public. On the other hand, it is pointed out to describe the level of uncertainty in future projections in a simple and understandable way and ideally do quantification of this level.

5.3 General recommendation for provision of water-based climate services

This section puts forward some general recommendations that emanated from the detailed assessment of the 28 climate services. This section is foremost intended to provide ideas and suggestions for developing water-based climate services in general.

Providers of climate services should be very aware of who they are specifically targeting with their service. Scientists need different content and depth of information than for example decision makers or interested citizens. A 'one size fits all' design should be avoided as much as possible. The target group(s) should be explicitly named in the climate service online portal, in order to assure users that this is – or is not – a climate service tailored to their needs and level of expertise.

Data availability

A climate service designed to provide water-related data in an adequate form should provide a balance between the four relevant fields of temperature, precipitation, hydrology and oceanography and should not be limited to only very specific aspects.

Data properties

Model data should be offered that as much as possible correspond to the offered observation data and allow comparisons and long-term time series. Model climate data should mostly be based on Representative Concentration Pathways, because they represent the state-of-the-art and allow better linkage with the latest socio-economic scenarios.

Data in a good spatial resolution are very useful for further processing, but also always contain inaccuracies. Thus, it is important to find a pragmatic middle ground. Scalable resolutions, e.g. 5 km and an additional 50 km, can be very useful for this. For certain users, aggregated data at the level of river basins or at the level of cities or other administrative boundaries are much more useful and should therefore be provided as well.

Data accessibility

Online maps and ready-made diagrams are very useful for inexperienced users to get relevant information quickly and to give scientists an overview of the existing data patterns.

The possibility of downloading data is indispensable for a climate service that is catering to scientists. For this user group a higher number and more detailed datasets should be downloadable than what the climate service might offer as online maps. Especially raw data like station data should be made available for download. Common data formats for further geographical, climatological and hydrological processing should be provided for download.

Data documentation

Essential for the data download is a very clear catalogue of the available data. Detailed metadata e.g. of the online maps and especially the data for download are indispensable for a good climate service.

Usability aspects

A clear and self-explanatory menu is desirable, then only short user guides are necessary and the acceptance for the climate service increases. A user forum for specific questions about how to deal with the climate service or the data content and for suggestions for improvement is very useful. Here, the climate service SWICCA offers a good practice example. In any case, such a forum must be maintained regularly by the climate service provider so users don't perceive it as a 'dead end'.

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Appendix A: Summary tables with individual results

Table A1. Number of temperature, precipitation, hydrology and oceanography observation datasets for each climate service
(climate services with especially high number of datasets are highlighted in green)

	Geogr. coverage	Temperature	Precipitation	Hydrology	Oceanography
Climate scenarios SMHI	global	1	1	-	2
KNMI Climate Explorer	global	3	1	5	-
PRIMAVERA	Europe & North Atlantic	4	1	-	1
Clim4Energy (beta version)	Europe	2	2	-	-
CLIP-C	Europe	18	14	1	4
EDgE	Europe	1	2	4	-
HYPE	Europe	-	-	-	-
IMPACT2C	Europe	1	2	7	-
SWICCA	Europe	2	2	3	-
HISTALP	pan-national	3	3	-	-
Klimaatlas Tirol	pan-national	15	14	7	-
AEMET	national	3	5	-	-
Climate Ireland	national	3	1	-	-
ClimatHD	national	7	2	-	-
County wise Climate Analysis SMHI	national	10	8	11	-
Drias	national	19	8	-	-
DWD Climate Data Center	national	15	7	-	-
eHYD	national	-	4	10	-
Klimatanpassnings-portalen	national	1	1	2	2
Klimatilpasning	national	3	1	-	-
ÖKS15	national	-	-	-	-
Portus	national	1	-	-	25
Visor C3E	national	-	-	-	10
DHCMA	regional	1	7	13	-
Klimaatlas Nordrhein-Westfalen	regional	7	2	-	-
REDIAM	regional	9	5	4	-
S.A.I.H.	regional	-	8	2	-
Urban SIS	local	5	2	6	-

Table A2. Number of temperature, precipitation, hydrology and oceanography model datasets for each climate service
(climate services with especially high number of datasets are highlighted in green)

	Geogr. coverage	Temperature	Precipitation	Hydrology	Oceanography
Climate scenarios SMHI	global	8	5	-	2
KNMI Climate Explorer	global	3	1	5	-
PRIMAVERA	Europe & North Atlantic	4	1	-	1
Clim4Energy (beta version)	Europe	2	2	-	-
CLIP-C	Europe	12	9	1	3
EDgE	Europe	1	2	4	-
HYPE	Europe	1	1	7	-
IMPACT2C	Europe	1	2	7	-
SWICCA	Europe	3	7	29	-
HISTALP	pan-national	-	-	-	-
Klimaatlas Tirol	pan-national	32	27	-	-
AEMET	national	20	3	4	1
Climate Ireland	national	3	2	-	-
ClimatHD	national	4	1	-	-
County wise Climate Analysis SMHI	national	10	8	11	-
Drias	national	19	8	-	-
DWD Climate Data Center	national	-	9	-	-
eHYD	national	-	-	-	-
Klimatanpassnings-portalen	national	-	-	-	-
Klimatilpasning	national	3	1	1	-
ÖKS15	national	18	10	-	-
Portus	national	1	-	-	10
Visor C3E	national	-	-	-	10
DHCMA	regional	-	-	-	-
Klimaatlas Nordrhein-Westfalen	regional	5	1	-	-
REDIAM	regional	6	7	-	-
S.A.I.H.	regional	-	-	-	-
Urban SIS	local	5	2	6	-

Table A3. Data properties of the observation data offered for each climate service (climate services which stand out are highlighted in green; typical resolution means the most used grid resolution and temporal resolution for each climate service)

	Geogr. coverage	Typical grid resolution	Other spatial reference	Typical temporal resolution	Regular data update
Climate scenarios SMHI	global	4 km	-	yearly	yes
KNMI Climate Explorer	global	-	country	monthly	yes
PRIMAVERA	Europe & North Atlantic	25 km	-	daily	no
Clim4Energy (beta version)	Europe	12 km	-	seasonal	yes
CLIP-C	Europe	12 km	-	yearly	no
EDgE	Europe	5 km	catchment area	monthly	no
HYPE	Europe	no observation data			
IMPACT2C	Europe	12 km	-	general	no
SWICCA	Europe	5 km / 50 km	catchment area	daily	no
HISTALP	pan-national	5‘‘ / 1°	station data	daily	yes
Klimaatlas Tirol	pan-national	0.5 km	-	monthly	no
AEMET	national	-	station data	monthly	yes
Climate Ireland	national	1 km	-	monthly	no
ClimatHD	national	-	regions	seasonal	yes
County wise Climate Analysis SMHI	national	4 km	-	general	no
Drias	national	8 km	-	monthly	yes
DWD Climate Data Center	national	1 km	station data	daily / monthly	yes
eHYD	national	-	station data	daily	yes
Klimatanpassnings-portalen	national	unknown	unknown	yearly	yes
Klimatilpasning	national	10 km	-	general	yes
ÖKS15	national	no observation data			
Portus	national	1 km	-	daily	yes
Visor C3E	national	55 km	coastline points	yearly	no
DHCMA	regional	-	region	general	yes
Klimaatlas Nordrhein-Westfalen	regional	1 km	-	monthly	no
REDIAM	regional	unknown	unknown	yearly	yes
S.A.I.H.	regional	-	reservoir / control points	daily	yes
Urban SIS	local	1 km	-	monthly	no

Table A4. Data properties of model data offered by the studied climate service (climate services which stand out are highlighted in green; typical resolution means the most used grid resolution and temporal resolution for each climate service)

	Geogr. coverage	Typical grid resolution	Other spatial reference	Typical temporal resolution	Underlying scenario
Climate scenarios SMHI	global	50 km	-	yearly	SRES / RCP
KNMI Climate Explorer	global	50 km	-	monthly	RCP
PRIMAVERA	Europe & North Atlantic	25 km	-	daily	unknown
Clim4Energy (beta version)	Europe	12 km	-	seasonal	RCP
CLIP-C	Europe	12 km	-	yearly / general	RCP
EDgE	Europe	5 km	catchment area	monthly	RCP
HYPE	Europe	1 km	-	general	RCP
IMPACT2C	Europe	12 km	-	general	RCP
SWICCA	Europe	5 km / 50 km	catchment area	general	RCP
HISTALP	pan-national	no model data			
Klimaatlas Tirol	pan-national	10 km	-	seasonal	SRES
AEMET	national	-	station data	daily	SRES / RCP
Climate Ireland	national	4 km	-	seasonal	SRES / RCP
ClimatHD	national	-	regions	yearly	RCP
County wise Climate Analysis SMHI	national	4 km	-	general	RCP
Drias	national	8 km	-	monthly	SRES / RCP
DWD Climate Data Center	national	8 km	-	general	-
eHYD	national	no model data			
Klimatanpassnings-portalen	national	no model data			
Klimatilpasning	national	25 km	-	general	SRES / RCP
ÖKS15	national	1 km	-	daily	RCP
Portus	national	5 km	-	daily	-
Visor C3E	national	55 km	points at coastline	yearly	SRES
DHCMA	regional	no model data			
Klimaatlas Nordrhein-Westfalen	regional	22 km	-	seasonal	SRES
REDIAM	regional	75 m	-	yearly / general	SRES
S.A.I.H.	regional	no model data			
Urban SIS	local	1 km	-	general	RCP

Table A5. Data accessibility of the data offered by the studied climate services (climate services which provide netCDF data download are highlighted in green)

Climate scenarios	Geogr. coverage	Displayed maps	Displayed diagrams / tables	Data format for further statistical processing (download)	Data format for further GIS processing (download)
SMHI	global	yes	yes	XLS	netCDF
KNMI Climate Explorer	global	yes	yes	-	netCDF
PRIMAVERA	Europe & North Atlantic	yes	no	-	-
Clim4Energy (beta version)	Europe	yes	yes	XLS	-
CLIP-C	Europe	yes	yes	-	netCDF
EDgE	Europe	yes	yes	yes - unknown data format	
HYPE	Europe	yes	no	XLS	netCDF
IMPACT2C	Europe	yes	no	-	-
SWICCA	Europe	yes	yes	XLS	-
HISTALP	pan-national	no	no	ASCII	netCDF
Klimaatlas Tirol	pan-national	yes	yes	-	-
AEMET	national	yes	yes	yes - unknown data format	
Climate Ireland	national	yes	no	-	-
ClimatHD	national	yes	no	-	-
County wise Climate Analysis SMHI	national	yes	no	-	GIS
Drias	national	yes	no	TXT	-
DWD Climate Data Center	national	no	no	TXT / ASCII	GIS
eHYD	national	yes	yes	CSV	-
Klimatanpassnings-portalen	national	no	yes	XLS	-
Klimatilpasning	national	yes	no	-	-
ÖKS15	national	no	no	-	netCDF
Portus	national	yes	yes	-	-
Visor C3E	national	yes	yes	XLS	-
DHCMA	regional	yes	yes	-	-
Klimaatlas Nordrhein-Westfalen	regional	yes	no	-	WMS
REDIAM	regional	yes	yes	XLS	GIS
S.A.I.H.	regional	yes	no	XLS	-
Urban SIS	local	yes	yes	CSV	-

Table A6. Data documentation of the studied climate service

	Geogr. coverage	Metadata	Background paper / glossary	Interpretative documents / policy briefs	Links to further resources
Climate scenarios SMHI	global	no	yes	yes	yes
KNMI Climate Explorer	global	no	yes	no	yes
PRIMAVERA	Europe & North Atlantic	no	yes	no	yes
Clim4Energy (beta version)	Europe	yes	yes	no	yes
CLIP-C	Europe	yes	yes	yes	yes
EDgE	Europe	yes	yes	no	yes
HYPE	Europe	yes	yes	yes	no
IMPACT2C	Europe	yes	yes	yes	yes
SWICCA	Europe	yes	yes	yes	yes
HISTALP	pan-national	yes	yes	yes	yes
Klimaatlas Tirol	pan-national	yes	yes	yes	yes
AEMET	national	yes	yes	no	yes
Climate Ireland	national	yes	yes	yes	yes
ClimatHD	national	yes	yes	no	yes
County wise Climate Analysis SMHI	national	yes	no	no	yes
Drias	national	yes	yes	no	yes
DWD Climate Data Center	national	yes	yes	no	no
eHYD	national	yes	yes	yes	yes
Klimatanpassnings-portalen	national	no	no	yes	no
Klimatilpasning	national	yes	yes	no	yes
ÖKS15	national	yes	no	yes	no
Portus	national	yes	yes	no	yes
Visor C3E	national	yes	yes	no	no
DHCMA	regional	no	yes	yes	yes
Klimaatlas Nordrhein-Westfalen	regional	yes	yes	no	yes
REDIAM	regional	yes	yes	no	yes
S.A.I.H.	regional	no	no	no	yes
Urban SIS	local	yes	no	no	no

Table A7. Usability aspects of the studied climate services (climate services which provide training, consulting or interaction with providers or other users are highlighted in green)

	Geogr. / coverage	Userguide/ tutorials	Training consulting	Interaction with provider / other users	Case studies
Climate scenarios SMHI	global	yes	no	no	yes
KNMI Climate Explorer	global	yes	no	no	no
PRIMAVERA	Europe & North Atlantic	no	no	no	yes
Clim4Energy (beta version)	Europe	yes	no	no	yes
CLIP-C	Europe	yes	no	no	yes
EDgE	Europe	yes	no	no	yes
HYPE	Europe	yes	no	no	no
IMPACT2C	Europe	yes	no	no	yes
SWICCA	Europe	yes	no	yes	yes
HISTALP	pan-national	no	no	no	no
Klimaatlas Tirol	pan-national	no	no	no	no
AEMET	national	yes	no	no	no
Climate Ireland	national	yes	yes	yes	yes
ClimatHD	national	yes	no	no	no
County wise Climate Analysis SMHI	national	yes	no	no	yes
Drias	national	yes	no	no	yes
DWD Climate Data Center	national	no	no	no	no
eHYD	national	no	no	no	no
Klimatanpassnings-portalen	national	no	no	no	no
Klimatilpasning	national	no	no	no	no
ÖKS15	national	no	no	no	yes
Portus	national	yes	no	no	no
Visor C3E	national	yes	no	no	no
DHCMA	regional	no	no	no	no
Klimaatlas Nordrhein-Westfalen	regional	no	no	no	no
REDIAM	regional	no	no	no	no
S.A.I.H.	regional	no	no	no	no
Urban SIS	local	yes	no	yes	no

Appendix B: Assessment matrix for analysing the online climate services

Basic information

Name of the climate service (CS)	
URL of the CS	
Organization(s) who set up and operate the CS	
Type of service provider	
Language of the CS	
CS operational since (year)	
CS regularly updated?	

Focus of the CS

					...if you choose "others", please specify
Mission/objectives of the CS					
Main target group/users (as defined by the provider)					
.... if undefined target group, what is your impression who is targeted:					
Targeted sectors (as defined by the provider)					
.... if undefined target sectors, which sectors do you think are targeted:					
Geographic scale of the CS					
Geographic coverage of the CS (name the area(s))					

Provided data

Observation data (including re-analysis data)	*Number of indicators*	*Qualitative overview*	*Time period covered*	*Spatial resolution(s)*	*Temporal resolution(s)*
Temperature					
Precipitation Hydrology Oceanography					
Socio-economic data (e.g. land-use, population, economy)					
Impact indicators (e.g. impacts on land, built-enviroment, population, economy)					
Others (please specify)					

Model data	*Number of indicators*	*Qualitative overview*	*Based on which SRES/RCPs*	*Ensemble / individual model data (or both)*	*Spatial resolution(s)*	*Temporal resolution(s)*
Temperature						
Precipitation Hydrology Oceanography						
Socio-economic data (e.g. land-use, population, economy)						
Impact indicators (e.g. impacts on land, built-enviroment, population, economy)						
Others (please specify)						

Usability

Data accessibility

Data displayed as (e.g. tables, maps, diagrams, etc. ...)	
Data downloadable as (e.g. NetCDF, xls, GIS...)	
Access restrictions (e.g. free or pay service, requires password login, accessible only for certain organisations...)	

Documentation

Metadata available Glossary, background papers Interpretative documents, policy briefs based on the CS data	
Links to further resources	
User guide, tutorials Case studies/examples available how CS data could be used?	

Other usability aspects

Ability to interact with data providers or other users?	
Training or consulting service offered to users? Any innovative feature(s) of the CS (e.g. user-defined overlays, animated displays...)?	

Overall assessment	*Rating: 1 (poor) to 5 (very good)*	*Short explanation*
Data provided		
Data accessibility		
Documentation		
Layout and navigation		

Screenshots of CS