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Perspective

Need for a common typology of climate services

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ABSTRACT

A comprehensive typology or characterization of the various types of climate services is needed to give an overview that makes (potential) users aware of which climate services are available and where to look for them. It helps identify existing gaps in terms of unserved needs of the users. Different ways of characterizing climate services are used in practice. The factors used for this characterization differ depending on the intended application of the service, the delivery mechanism and project- or user-specific needs. In this paper we discuss the advantages and challenges of using different characterization factors, such as sectors, themes, regions, purposes, time horizons, data sources, level of processing of climate data, background knowledge and type of climate services providers. Some recommendations are given on the factors to use for a common typology of climate services which are understood by a wide range of users. It may be difficult to create a single common typology that will also be understood by users with little background knowledge on climate data. Intermediaries, providing training resources and guidance at web portals on how to use and interpret climate information, can be essential to overcome this problem. Gap analysis is used to compare available and required climate services. Therefore, we advise to use the same typology for the analysis of gaps in available climate services.

1. Introduction

Climate services have been rapidly emerging in the past few years, as recognised for example in the European Roadmap for Climate Services (EC, 2015). Climate services are described and characterized in several different ways (see for example, WMO, 2009; Hewitt et al., 2012; JPI-Climate, 2016; AMS, 2015; NRC, 2001; EC, 2015). Most of these descriptions share the following common elements: (i) they involve provision of climate information for some form of decision-making, including policy-making, be it to support adaptation, mitigation, or disaster risk management; (ii) they are driven by the needs of users, including decision-makers, indicated by terminology such as useful, of value, customised, tailored, co-developed or co-produced; and (iii) they involve dissemination or guidance for the use of science-based climate information. Such information could include climate data or knowledge based on climate data.

Although there are various initiatives that try to provide an overview of climate services (for example the network for climate service providers Climate Knowledge Hub, the European Climate Adaptation Platform Climate-ADAPT, the Climateurope website), it is still not straightforward for researchers, providers and users to know which climate services have been developed and are available in different countries, in different regions such as Europe, or worldwide. This may result in duplication or underutilization of options to integrate results and extract lessons learned. An example is the large number of projects with inventories of user requirements, which often don't add much to what is already known about the general user needs (Bley et al., 2017). This lack of overview of available climate services also complicates the analysis of challenges and potential gaps between the available climate services and actual user requirements pursued for example by European initiatives such as JPI-Climate, EU-MACS, MARCO or Climateurope (JPI-Climate, 2016; Cortekar et al., 2017; http://marco-h2020.eu/; Joussaume et al., 2019, respectively).

Climate services can be grouped according to different criteria such

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as sector, type of user and background, user requirements, intended use, type of product (either climate[1] data, information on climate change impacts, tools for the visualization of the information), type of provider, etc. Having these different ways of grouping climate services could lead to confusion for potential users trying to determine which information is available and appropriate for them (Vaughan & Dessai, 2014; Capela Lourenço et al., 2016). A major obstacle for finding appropriate information is the technological and conceptual limitations related to users' capabilities and background knowledge. Currently, some users may be using the climate services that they find most accessible, but this does not mean these are the most relevant for their decision-making. Different socio-economic sectors may need different types of information (for example information on short duration rainfall extremes is needed for urban areas for design and adjustment of their sewerage system, whereas for protection against flooding from rivers multiple day rainfall extremes are needed). This applies to different user profiles within the same sector, for example researchers on ecosystems may be interested in time series of climate variables for running their impact models, whereas maps showing where certain species will become endangered would be more relevant for a policy maker. A classification according to time scales (sub-seasonal, seasonal, decadal, multi-decadal) is extremely relevant for climate scientists, but users are often unaware of this distinction. For many impact assessments, resources to digest large volumes of data are limited and, therefore, they would be helped with a relevant selection and processing of available data. In addition, the availability of an ever-increasing set of multi-decadal climate projections often generates challenges either in the selection of such projections or in the lack of ability to effectively translate available information into decision-making.

Typologies of climate services can either be user-driven (allowing experts and non-experts to easily find the data and information they need) or provider-driven (allowing providers to better structure the way data and information are provided). Given that the research on climate services tends to be user-driven (for example development of risk indices tailored to decision-making), it seems logical to favour user-driven climate service typologies.

The work presented here has been developed in the context of Climateurope, a Coordination and Support Action from the European Commission, with the aim to bring together the European climate services community. To do that, the project has built a network of users, providers and stakeholders in the fields of earth system modelling and climate services. Climateurope acts as a main contact point for a diversity of stakeholders and to provide overviews of climate research, climate services and products in Europe. This is done through the materials available on the Climateurope website and various reports (Hewitt et al., 2017; Joussaume et al., 2019; Kotova et al., 2017; Martins et al., 2019; Terrado et al., 2018; Döscher et al., 2017). Climateurope supports the agreement of a standardized classification of climate services in different typologies. This classification will make finding the appropriate information easier, and will promote better matching of user needs with the most suitable information available.

In this paper, we provide an overview of the existing typologies or characterizations of climate services and discuss the challenges to define a common and agreed typology. We analysed several climate services, particularly those developed under the EU-funded ERANet for Climate Services (ERA4CS), projects funded under the European Framework Programme 7 (FP7) and Horizon 2020 (H2020), and the Copernicus Climate Change Service (C3S). The list of climate services analysed in this work does not aim to be exhaustive. However, it aims to gather a diverse sample of semi-operational and operational climate services available to users. This analysis allows to extract some recommendations to support and provide guidance to make a more comprehensive typology of climate services.

2. Existing climate services typologies

Many typologies of climate services are used already on web portals (see table 1) and in reports (e.g. SECTEUR, 2017; Cortekar et al., 2017)[2], but there is no common typology that is used as reference. Below, we briefly discuss the main factors that have been used for differentiation of climate services so far, and highlight some advantages and drawbacks for their utilisation.

Table 1 contains a number of examples of portals and projects with climate services and an indication of which typologies or categorizations are used. Since the available number is very large, we only present a selection of portals. During the selection of examples we looked only at projects that have a (semi-)operational portal or where examples are presented how the future portal will look, or well described case studies, that were developed by organisations based in Europe, and that showed the diversity of the typologies used. Therefore, projects from the EU-funded research programmes FP7 and H2020 are included, as well as projects from ERA4CS, Copernicus Climate Change Services (C3S), but also other national and international portals and portals developed by commercial parties. More detailed information on the portals included in table 1 can be found in the additional information with this paper. In the text below we refer regularly to the examples presented in the table. When more than one option for a factor was included, this was marked with an “X”. For example, a website focusing only on advanced users did not get an “X” under “Background knowledge”, but a website with detailed information for an advanced user and summarized information for a basic user did get a “X”. The characterizations can be either more user-driven (how to make it easier for users to find the data or information that they need, including for users with limited background knowledge on climate data, see for example the Climate Impact Atlas) or more provider driven (how to better structure the provision of available information and data sets, see for example the Climate4Impact portal). As can be seen in the table, sector and region are often combined. Also data source and time horizon are regularly combined.

2.1. Sector-specific information

A typology by sector is often logical from a users' point of view, since users generally look for information specific to their sector of interest. Several web portals and projects provide services tailored to specific sectoral applications such as energy, agriculture, health or disaster risk reduction (for example, Climate4impact, Climate-Adapt, CLIMRUN[3]). C3S develops climate service portals for specific sectors (for example, SWICCA, Clim4Energy). Differences in requirements exist among sectors (for example, tourism has different information needs than coastal protection), and among different user profiles in the same sector (for example, the manager of a ski resort has different information needs than a cruise ship captain, despite belonging both to the tourism sector) or even in the same company (for example, different departments in an insurance company may deal with different types of climate related risks). Different requirements within the same sector are also identified between countries, often related to the sectoral models used and the technical standards and directives. In some countries, the design of water drainage systems along the main roads takes into account return times for extreme rainfall of 10–25 years whereas other countries use return times up to 200–250 years (Bessembinder et al., 2018a). An overview of the context, perception, current and intended

[1] The term “climate” in this article refers to historical and future climate data and for the future this also includes sub-seasonal/monthly and seasonal to decadal data.

[2] climate.copernicus.eu/secteur/ and eu-macs.eu/

[3] Links or references to the mentioned projects in the text are provided in the table.

Table 1
Examples of portals and projects with climate services and factors used to differentiate between various climate services.

Project or platform	Website	Factors used for differentiation of climate services								
		Sector	Region	Impact	Climate variables	Data sources	Back ground knowledge	Time hori zon/ period	Provider	Level processing
C3S related projects										
Clim4Energy	c4e-visu.ipsl.upmc.fr/		X	X	X	X		X		
C3S CDS	cds.climate.copernicus.eu/	X	X		X	X	X	X		X
EdGE	edge.climate.copernicus.eu/		X	X	X	X		X		
GLORIOUS	climate.copernicus.eu/global-climate-impacts	X	X	X	X	X		X		X
SWICCA	swicca.eu/		X	X	X	X		X		X
UERRA	www.uerra.eu/				X	X		X		
WISC	wisc.climate.copernicus.eu/		X		X			X		
FP7/H2020 projects										
ANYWHERE	anywhere-h2020.eu/		X	X	X					X
BASE	base-adaptation.eu/	X	X							
Climateurope	www.climateurope.eu/					X	X			
CLIMRUN	www.climrun.eu	X	X							
EUPORIAS	www.euporias.eu/	X	X							
IMPACT2C	www.atlas.impact2c.eu/	X	X	X	X			X		
IMPREX	www.imprex.eu/	X	X							
INTACT	scm.ulster.ac.uk/~scmresearch/intactnew/ index.php/Extreme_weather_maps		X		X			X		
IS-ENES	climate4impact.eu/	X	X		X	X		X		X
PRIMAVERA	uip.primavera-h2020.eu/	X			X					X
S2S4E	s2s4e.eu/		X	X	X			X		X
JPI-Climate /ERA4CS related projects										
Climate knowledge hub	climate-knowledge-hub.org/		X						X	
Citizen Sensing	citizensensing.itn.liu.se/cs/		X		X					
ISIpedia	www.isimip.org/isipedia	X	X	X				X		
EUPHEME	Eupheme.eu/		X		X			X		
INDECIS	www.indecis.eu/		X		X			X		X
Other projects										
Climate-Adapt	climate-adapt.eea.europa.eu/	X	X	X						
Climate data factory	theclimatedatafactory.com/		X		X					X
Climate Explorer	climexp.knmi.nl/		X		X	X		X		X
Climate Impact Atlas	www.klimaateffectatlas.nl/		X	X	X			X		X
Climate-KIC	www.climate-kic.org/	X	X							
DWD climate data center	cdc.dwd.de/portal/		X		X	X		X		X
ECA&D	www.ecad.eu/		X		X			X		X
EEA data center	www.eea.europa.eu/themes/climate/dc	X	X	X	X					X
KNMI data center	www.knmi.nl		X		X	X		X		
OASIS	https://oasislmf.org/			X						
Swiss NCCS	www.nccs.admin.ch/	X	X	X	X			X	X	X
World Weather Attribution	www.worldweatherattribution.org/		X		X			X		

use of climate information by the users in different sectors is needed to understand their requirements (Bley et al., 2017; Buontempo et al., 2014; Lemond et al., 2011). Some users that ask for a high spatial resolution in climate data (for example, 1 by 1 km), may have this request because they have an application (for example, a hydrological impact model) that needs input data at this resolution, although this does not mean that they expect to see real differences in climate at this particular spatial scale. Knowing from users how they intend to apply climate information and for which purpose is, therefore, essential to understand the type of information they really need. In a typology "intended use" or "type of application" can be included.

The typologies used may differ in the number of sectors that are accounted for and the level of detail used. For instance, forestry is sometimes included as part of the agricultural sector[4], and at other times mentioned as separate sector. In some cases, agriculture and ecosystems are combined, for instance in the water-food-energy nexus. This can be logical from the providers' point of view, since many biological and hydrological processes are common in these sectors, but not necessarily from the users' point of view.

Some web portals define various themes for particular sectors. For example floods, droughts, river runoff and evapotranspiration are addressed, among others, in the IMPACT2C web portal regarding the water sector. Agriculture is strongly related to water management, mainly for irrigation and drainage purposes (see for example case studies from the IMPREX project). Therefore, water is regularly defined as a theme under the agricultural sector.

2.2. Climate information versus impact information

Within some sectors, certain decision-makers will be interested in climate information (for example change in extreme precipitation; sometimes called primary climate data), whereas others may be interested especially in the impacts of climate variability and change (for example the chance that tunnels will flood due to extreme precipitation;

[4] https://climate.copernicus.eu/secteur.

sometimes called secondary climate data). There are different projects and documents that focus on particularly on impacts, such as IMPACT2C (Preuschmann et al., 2017), IPCC WG2 assessment reports (IPCC, 2014) and the Climate Impact Atlas (Goosen et al., 2013). The information on impacts is sometimes grouped under themes such as flooding or heat stress (Climate Impact Atlas). Often, although not necessarily, the impacts are also presented per sector (IMPACT2C) and information is given on the change in climate variables that underlie the change in impacts.

In general, impacts are more directly related to the users' decision-making than the change in Essential Climate Variables (ECVs), such as temperature or precipitation. Impacts provide clearer indications of the effects of climate change on users' personal lives and businesses. However, the impact may be influenced to a higher extent by other factors. Whether a particular extreme precipitation event will lead to local flooding will depend, apart from the total amount of precipitation during that event, on the local differences in altitude or the available drainage capacity of that particular area. For example, when the threshold for heat stress is around 25 °C, an increase of 2 °C in a region with currently an average maximum temperature of 24 °C will cause a much larger increase in the number of days with heat stress, than in a region with an average maximum temperature of 18 °C.

2.3. Region-specific information

Many web portals and projects give information for a specific geographical location (either for a particular country, Europe or the whole globe). They provide the possibility to zoom in or differentiate between different types of regions (for example, coastal areas, mountainous areas, cities, continental waters). Despite being interested in the same geographical region, the users' spatial scale of interest may differ (for example, field lot, municipality, country or continent). Sometimes the regional differentiation of information is combined with a sectoral differentiation. Thus, "Coastal areas" or "Cities" are mentioned beside sectors such as Health, Water, or Ecosystems. This results in a classification that mixes regions and sectors, for example in the IMPACT2C web-atlas. Or as in the case of Climate-Fit[5], sector information is provided for cities.

2.4. Sources of climate data

There are several climate data sources used in climate services, such as observations, reanalysis, (sub-)seasonal to decadal predictions and climate change projections. Portals such as the C3S Climate Data Store and the Climate Explorer distinguish between these sources of climate data. They also distinguish between different types of observations (for example, station data or satellites) and the climate models with which projections are made. Ample climate data sets are available, but many users do not have an overview of the available data, climate models, the advantages and limitations of the various datasets (Goddard, 2016) or are even unaware of certain types of climate data sources. Therefore, a typology based on data sources is often not usable for users without a climate research background. These typologies are more provider-driven. There are several initiatives that provide overviews of available climate data sources (for example ECA&D, Climate Explorer, Climate4impact, C3S Climate Data Store), but most of them give limited guidance for non-expert users to make a selection between the available data sets.

2.5. Time horizon of interest

Climate and weather models can be used to produce climate information at different time scales: long-term or multi-decadal climate projections, (sub-)seasonal-to-decadal predictions and weather forecasts. Climate change projections are estimates of the evolution of possible future climates under the assumptions of future emissions and land use activities (for different policy scenarios). Climate predictions are, on the other hand, estimates of future climate conditions covering monthly, annual to decadal timescales by better accounting for the initial state of the earth system. Weather forecasts are forecasts for the next days up to several weeks into the future. While information for the short term (days, seasons, a few years) is generally useful for operational decisions, climate information is more often used for strategic decision making (medium to long term time horizons ranging from one year to decades), although it can also be applied for decisions involving operations and management[6]. For a sewerage system that has a life cycle of about 40 years information for a different time horizon is needed, than for a bridge with a life cycle of about 80 years.

On most web portals of National Meteorological Services, a distinction is made between weather and climate information. The time horizons used may differ from one web portal to another. For example the time horizons included in national or regional climate scenarios in Europe differ per country (Bessembinder et al., 2018a), although they generally include a near time horizon, a time horizon around the middle of this century and another at the end of the century.

Although logical from the providers or climate researchers point of view, users often do not distinguish between weather and climate information and use the terms interchangeably. Certain users would rather benefit from services that focus on seamless predictions consistent across temporal scales (from sub-seasonal predictions up to climate projections), but their implementation nowadays constitutes a challenge for providers (Allis et al., 2019; Kushnir et al., 2019).

2.6. Type and level of processing of the data and purpose of use

The type of data and information needed by different users depends on the user profile (sector, background, expertise or skills) and the purpose of use of the information. Impact researchers often need different data and information than policy makers and decision makers. Researchers often use time series of temperature, precipitation, and other ECVs requiring relatively little processing (especially downscaling and bias correction) of the direct output from climate models. On the other hand, decision makers will more often use customized information in the form of graphs, maps, indices, summary figures or decision support and best practices. The latter types of customized information require additional processing of the original underlying data (for example ECMWF forecast maps or data[7], EU-MACS value chain; Cortekar et al., 2017). Consequently, the number of intermediaries may also increase and users may need to go to other providers to get the climate services they require, unless all the required knowledge for the customizing is available with the team of one provider. Although there is a link between the type of processing and the purpose of the use or the ways the climate service is used, this is often not made explicit. However, users generally have an idea of what type of product they need. In case studies the link between the type of processing or tailoring and the purpose of the use is made more explicit (for example in the case studies for the IMPREX project). A differentiation according to the type of data processing seems therefore quite interesting from the users' point of view.

[5] https://climate-fit.city/

[6] See for example https://www.med-gold.eu/wp-content/uploads/2018/11/Info-sheet-1_Climate-services-for-grapes-and-the-wine-sector_v4_EN.pdf and https://public.wmo.int/en/resources/bulletin/climate-services-affordable-wind-energy.

[7] www.ecmwf.int/en/forecasts

2.7. Level of background knowledge of the user

The users' background knowledge partially determines how well they understand the various typologies mentioned above (differentiation among data sources, time horizons, climate data processing, etc.), and thus how user-friendly an overview of climate services might be (Overpeck et al., 2011; Hewitt et al., 2017b). Although users may be experts in their own field of work, often they are not climate experts and do not have enough insights of the limitations and uncertainties of climate data and information.

Some web portals and documents make a distinction between basic or advanced users or they indicate explicitly for which type of user the web portal is meant. Other platforms use a progressive disclosure of information, where users initially access a basic information view and, if interested, they have the possibility to open an advanced view with additional and more detailed information. For instance, the Climate4impact and Climate Explorer web portals are meant primarily for advanced users. The C3S Climate Data Store Toolbox has options for more basic users, but offers advanced users the option to adjust predefined options to their own needs. In these cases advanced users are users with considerable background knowledge on climate data resources and often also on processing (statistical methods, programming, etc.).

2.8. Providers of climate services

A first effort to provide some overview of climate service providers in Europe was made by JPI-Climate and further elaborated within ERA4CS (Cortekar & Themessl, 2016). Part of this information can be found through the Climate Knowledge Hub. Although the response from European countries varied a lot, it is clear that there are considerable differences between countries regarding climate service providers, the climate services provided and even on what can be considered climate services. The inventory within the ERA4CS programme gives some indications on the causes for these differences. Each climate service provider can offer a variety of climate services and what they can and are allowed to provide may differ per country[8]. Providers may also play different roles from "research and analysis" to "design and recommend" or "advise strategically" (Mayer et al., 2004). A typology of climate services based on climate services providers in Europe, therefore, will not give a clear overview of climate services that is easy to understand for users. However, a typology based on provider type can inform (indirectly) on aspects related to the trust, credibility and usability of the climate information provided. For example, climate data and information from National Meteorological Services are typically considered reliable and often authoritative, but in some cases the services from consultancy companies may be considered more usable by some users because they tend to be more tailored to specific needs.

3. Challenges

Based on the expertise gathered in Climateurope (available from the website, project deliverables, webinars and literature reviews) several challenges have been identified for making useful typologies of climate services.

3.1. Variety of user groups and themes within one sector

There are many different types of users within a sector, from climate and impact researchers to policy makers. They often need different types of information (for example time series, infographics, maps) on climate change since they have different levels of background knowledge and they will use the climate services for different purposes. Besides this, there may be various themes within a sector that may require different information. If we look at the water sector, we can identify fresh water supply, flooding (due to high river discharge or storms along the coast), droughts, water excess, and urban water management as examples of themes. Information requirements for these themes differ highly. This means that a typology based solely on sectors is not sufficient to create an overview of available climate services. In many cases themes within a sector are required in order for users to find the information or products that they need. Within a theme various types of users (researchers up to decision makers) can be helped by presenting information in different forms (time series, graphs, maps) and by presenting different types of information (impacts per model, summaries and ranges). On some web portals in Table 1 (for example IMPACT2C and IMPREX) various themes are defined per sector.

3.2. Dismantling the influence of background knowledge

Users are often experts in their own field of work and sector, but not necessarily experts in the use of climate data. They are often used to using one type of climate data (for example observations, or statistics for the current climate), but challenges occur when they have to take into account trends in climate, future climate and uncertainties in climate change. As mentioned before, users' background knowledge on climate change varies widely. Users with little background knowledge on climate data need much more help in finding their way in the large amount and different types of climate data available. Only some of the users know the various data sources available, their advantages and disadvantages, the specific terms used to designate them, etc. In this context, the possibilities to make an understandable detailed typology for a broad range of users is limited. It probably requires a hierarchical typology that becomes more detailed with each step[9], starting with some commonly understood differentiations, such as sector, themes within sectors, geographical regions, and purpose for which the climate services will be used. Guidance at web portals (for example written documentation, video tutorials or case study demonstrators), capacity building for the users (for example through training actions) or intermediaries will enhance background knowledge and might help to choose the right climate services.

3.3. Fostering inter- and trans-disciplinarity

Users of climate services often require information that is based on various scientific disciplines (Goddard, 2016; Goosen et al., 2013; Buontempo et al., 2014; Brasseur & Gallardo, 2016; Harrison et al., 2016) involving, for instance, impact and adaptation options (Vulnerability Impact and Adaptation research) and risks (for example economic research) for several climate scenarios (climate science). However, each discipline often has its own jargon and methods, whereas for a common typology preferably terms have to be used that are clear to all involved disciplines. Impact and adaptation researchers often use climate data time series, but they may have limited knowledge on climate change and do not have an extensive overview of available climate data[10]. This might result in improper use or interpretation of the data. Good guidance materials or training courses, or intermediaries with knowledge of several disciplines could help in these cases. Climate researchers, on the other hand, could potentially benefit from the social

[8] In several European countries governmental organizations are not allowed to provide commercial climate services, and instead private companies provide such services.

[9] Such an approach is commonly used, for example also in the IPCC reports, where summaries are followed by the more detailed descriptions that leaded to the summaries (for example IPCC, 2014).

[10] This is why courses of C3S User Learning Services and training events within the IS-ENES3 project focus among others on impact researchers to increase their background knowledge on climate data.

sciences for understanding user requests, communicating results and translating their information into usable information (for example Von Storch, 2009; Capela Lourenço et al., 2016; Golding et al., 2019). Although necessary, interdisciplinarity may not suffice for climate services. The integration of different scientific disciplines with other non-scientific knowledge will advance the field of climate services towards trans-disciplinarity (Schuck-Zöller et al., 2018), which considers users' domain knowledge, needs and interests and defines a common dialogue that facilitates mutual learning.

3.4. Time scales of climate information

For users it is not always clear where "weather" services (on time-scales covering days to up to a month) become "climate" services (on timescales covering months to decades)[11]. They often use the terms interchangeably and they are not concerned about (or aware of) their distinction. With the development of Sub-seasonal to Seasonal (S2S) and Seasonal to Decadal (S2D) predictions the distinction between weather and climate forecasts also becomes less clear. However, climate service providers know that the data sources and methods used for "weather forecasts", "climate predictions" or "climate projections" (current and future climate) may differ: a climate projection for, for example, the period around 2040 is made with a different method than a decadal prediction for the period around 2040. The results of these simulations also have to be interpreted in different ways, and cannot be used equally. When discussing with users the development of climate services, it is not that useful to differentiate between weather and climate. Conversely, it is much more effective to understand what users may want to do with the climate services product and then look for the most relevant weather or climate data source. Statistics for extreme precipitation around 2040–2050 for a high Representative Concentration Pathway (RCP) may help some users to understand the potential impact of climate change and to see what is needed for designing adaptation measures. For other users that want to make the general public aware of the impact of climate change, a simulation of a past event with known impact under a 2 °C higher temperature[12] gives more insight and is more appealing. Guidance regarding interpretation of the types of climate information, the life cycle of a construction and the relation with time scales may help users identify the most suitable climate information for their decisions.

3.5. Data sources

A differentiation in data sources would be very logical from the point of view of climate researchers or climate data providers, who often differentiate between the various sources of observations (in situ stations, satellites, radar, etc.) and model data (re-analysis, projections, S2D predictions). However, users regularly do not know all these data sources, and often they need combined data from various sources (data from stations for the current climate, model projections for the current and future climate). However, a distinction between data sources is only relevant to users when they have considerable knowledge about climate data. Than they understand the advantages and disadvantages of the various sources of climate data and the link with the various purposes of use.

4. Recommendations and discussion

Climate change is considered as one of the biggest challenges the world currently faces (COP, 2015). At national and European levels the development of climate services is promoted with the idea that they are needed to mitigate and adapt to climate change (EC, 2015). Descriptions and definitions of climate services available in the literature are quite broad and some lead to different interpretations of what are climate services and what are not. The term climate services is often used without further specification and, therefore, it can be confusing for (potential) users. Many users, among which decision-makers, don't know what climate services are available, where to find them and whether they fit their requirements. This means that they cannot compare the climate services alternatives and decide which is the most relevant for their purposes. A good overview as well as better access to climate services and products may help to get the information to the users and to promote the use of the climate services. With this idea, Climateurope encourages the creation of a common and agreed vocabulary for climate services that would provide such and overview and would help identify potential gaps with user requirements. This identification of gaps may boost innovation of climate services and may result in new suggestions for further research.

We acknowledge that it is probably unrealistic to make a one-stop-shop or web portal to provide overview of potential climate services for all users, since they differ too much in their interests, requirements and background knowledge on climate data. However, a common typology of climate services would guide users more easily through the web portals available online.

After analysing the examples of existing typologies of climate services used by different web portals and projects (Table 1), we provide some recommendations for a possible classification:

- More than one factor is needed to make a relevant and usable typology or classification of the various types of climate services, either to provide an overview for users or for gap analysis. Table 1 shows that in existing typologies factors are often combined. From the point of view of users, it is logical to use at least the factors "sector" and "purpose of the use of the data" (can partly be described with the time horizon and the "themes" within a sector) as a basis for a typology of climate services. It might also be useful to use geographical location, since many users require information for a specific location, region or country. These factors are easily understandable for all users, even with limited background knowledge of climate data. For the majority of the users this is also a natural way to subdivide the climate services. For themes where sectors overlap it may be less obvious. The same "themes" and "purposes of use" may return under different sectors and in such cases users could use both or one sector.
- To develop a clear and common typology that is considered relevant, usable and legitimate from the perspective of the users, but also from the perspective of the providers and researchers from different disciplines, engaging with users, providers, purveyors and researchers is needed (co-design).
- Guidance at portals and providing training resources can be essential for users with little knowledge of climate data, as we have indicated that limited background knowledge on climate data makes it more difficult for user to find and compare climate services. This guidance can also be provided by intermediaries with more knowledge and good knowledge of the context in which the user wants to use the climate services products.
- Gap analysis is focusing directly or indirectly on the gaps in climate information related to user requirements, and delivery of useful and actionable information. Therefore, it seems logical that a similar differentiation is used for giving overview to users and for gap analysis. Such a typology would also be useful for climate scientists and service providers in the sense that it provides a framework for the development of usable climate services.

An adequate typology of climate services may seem to differ from the providers' or the users' point of view. When the providers are

[11] https://www.wmo.int/pages/prog/www/DPS/GDPS-Supplement5-AppI-4.html

[12] In the Netherlands this was done for a 2 day event in August 2010 (KNMI, 2015)

researchers they may look more at what data sources and processing level of data is needed to deliver the required climate services for users. The importance of the various factors mentioned for a common typology indeed differs along the value chain of climate services. Although we argue that a common typology should be user-driven, at the end it is most important to achieve a relevant, usable and legitimate classification of climate services for a wide range of users. A parallel typology based on data sources and level of processing may still be useful, but it should clearly consider the links with the typology of climate services from the users' point of view.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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