HORIZON 2020

THEME SC5-2017

(Grant Agreement 776613)

European Climate Prediction system (EUCP)

Deliverable D4.5

Usability of EUCP service products for end users

Deliverable Title	*Usability of EUCP service products for end users*	
Brief Description	T4.4 validated the usability of WP4 products and reported it in D4.5. End users have been engaged from the start of the project and consulted regularly to tune the EUCP service products and guarantee translation of the climate predictions into actionable indicators and event triggers, where focus has been on the case-studies of Task 4.2. Within Task 4.4 we narrowed down the list of indicators to those most relevant to the potential EUCP end users. The multi-user forum established in WP6 has been the initial user group that participated in the co-design and evaluation of *the EUCP service products.*	
WP number	4	
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1. Executive summary

This report describes the main user engagement activities that were conducted in the context of EUCP case studies and other EUCP data products, such as the data catalogue. The document first presents the concept of knowledge co-production which serves as reference for user engagement and divides the engagement activities in different levels of intensity, such as involvement and empowerment. The report further provides a description of WP4 case studies with particular accent on how the users assessed the usability of the final product, and how this feedback was used to adapt the EUCP outputs. It also presents the engagement with members of the multi-user forum (MUF) and the follow-up interactions with MUF super-users who expressed interest to be involved further. Finally, this report evaluates products from the other work packages (WPs). This evaluation allows to see how results from these WPs feed into WP4 following the data-to-product pathway.

2. Project objectives

These deliverables have contributed to the following EUCP objectives (Description of Action, Section 1.1):

No.	Objective	Yes	No
1	Develop an ensembles climate prediction system based on high-resolution climate models for the European region for the near-term (~1-40 years)		
2	Use the climate prediction system to produce consistent, authoritative and actionable climate information		
3	Demonstrate the value of this climate prediction system through high impact extreme weather events in the near past and near future	X	
4	Develop, and publish, methodologies, good practice and guidance for producing and using EUCP's authoritative climate predictions for 1-40 year timescales	X	

3. Detailed report

Knowledge coproduction is consolidating as a key research field in climate science and more specifically in connection to climate services. This process emerged from the observed gap in scientific knowledge production and the limited use it had for decision-makers and other societal stakeholders, despite the recognized value of strengthening the science-policy interface (Kirchhoff et al., 2013). Although the term has multiple definitions, it always encompasses user engagement activities conducted alongside the development of a product, prototype or project. Here, we adhere to the definition from Norstrom and colleagues for whom it consists of "'an iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future." (Norstrom et al., 2020, p. 2). To apply this definition, the coproduction framework for climate services from Bojovic et al. (2021) offers a richer understanding of coproduction with three principal dimensions: stakeholder engagement, involvement, and empowerment (see Figure 1). Accordingly, and to cite those examples which have been exploited during the EUCP project, the implementation of stakeholder engagement activities allowed to *raise awareness* on the products developed during the course of the EUCP using a wide range of tools such as websites, newsletters and user interface platforms. Secondly, EUCP scientists have *involved the users* at several stages with user forums, workshops, and interviews. Finally, the project has also had a certain extent of *co-developed knowledge* together with both public and private stakeholders during stakeholder dialogues and workshops conducted in the preparation of case studies.

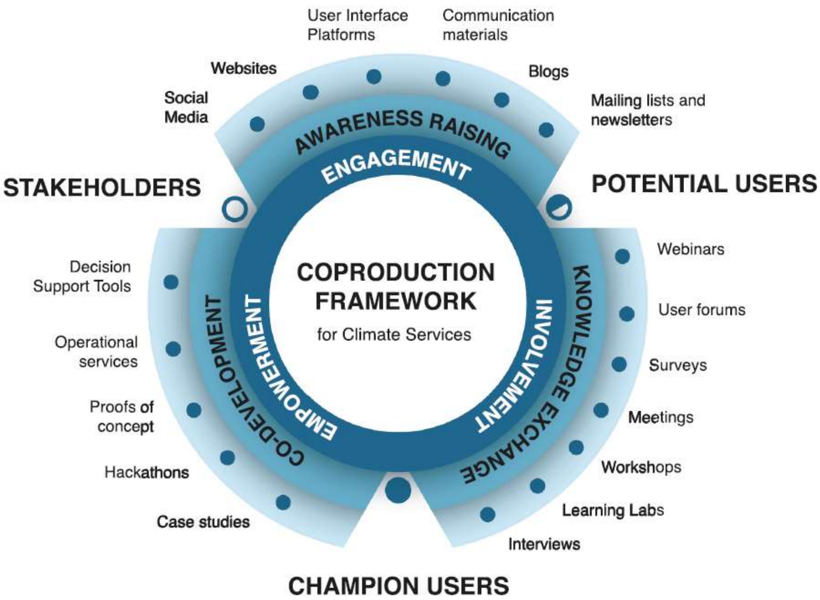


Figure 1. Coproduction framework for climate services

This report provides an overview of these activities, and it assesses the extent to which they addressed the usability of the products generated under EUCP WP4[1]. In the next pages we thus report on knowledge exchange and co-development and how it contributed to the usability assessment of EUCP

[1] Provided that awareness raising with stakeholder engagement has been conducted under WP6, it is out of scope for the current report.

service products for end users. Such a robust approach to knowledge coproduction is key to ensure the usability of climate services for decision-making, policy and planning (Daly and Dilling, 2019).

Usability is a concept which has been increasingly associated to climate services to address the original mismatch between knowledge production and the users' needs to apply this knowledge. Because ultimately usability is considered as a function of both "how science is produced (the push side) and how it is needed (the pull side)" (Dilling and Lemos, 2010, p. 681). In other words, to improve usability of climate knowledge, we need to broaden our product-focused approaches, and introduce process-focussed and demand-driven climate services (Findlater et al., 2021). For this to happen, engagement with the users under different forms is imperial. Across the three scales of knowledge co-production (engagement, involvement, empowerment), EUCP has intensified such efforts to ensure usability.

The GFCS[2] defines users in the following way:

> *"Intermediary users or service co-producers are different from the final end-users of climate services who often do not need climate information/data, but a finished useable climate advisory service or product that they can input into their decision-making. The latter category encompasses farmers, fishermen, vulnerable communities, etc., as well as national decision-makers and planners who need finished climate information products at longer timescales (climate projections)."*

Following this definition, we consider that the term *user* better fits the broad user community that was engaged in the EUCP project, than the term *end-user*, originally used in the project DoA.

The "Guidance of good practices for climate services user engagement" (WMO, 2018), on which the coproduction framework for climate services builds upon, describes different intensity levels that range from passive to active forms of engagement with users. Active engagement involves both (a) a dialogue-based typology with interactive group activities and (b) more intense forms of focused relationships with tailored and targeted forms of knowledge production, which we have adopted through case studies.

3.1. Knowledge exchange: *user involvement*

The activities under knowledge exchange imply the range that allowed us to communicate the results of the EUCP activities and products to the users, and users provided feedback to the scientists. This step is characterized by a more active form of interaction with users, labelled *involvement*. Three main involvement activities were exercised: **user forums (MUF)**, **interviews (I)**, and **workshops (W)**.

3.1.1. Multi-user forums

In the project and especially in the context of the dialogue-based activities such as the multi-user forum (MUF), we have three level of users based on this description and engagement intensities.

[2] *Accessed February 2022*: https://public.wmo.int/en/bulletin/what-do-we-mean-climate-services

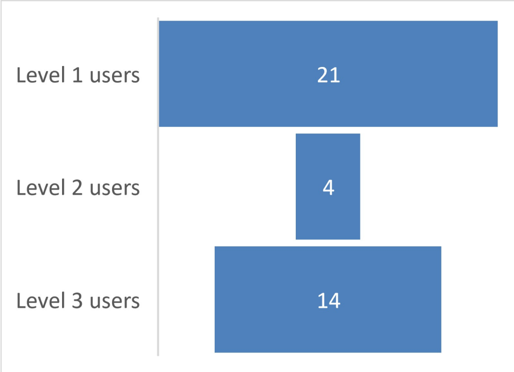


Figure 2. User levels

The engagement with first level users (level 1) is more passive throughout the project. They receive the information on the EUCP project development through the website, newsletters, social media, and publications which are shared with them depending on the sector. The second level (level 2) includes a hybrid profile, with users that, besides receiving information, also have had additional contact with EUCP scientists in the context of co-production activities. Finally, level 3 users are those with a greater collaboration intensity and who have been involved in coproduction during the project lifecycle, some of them through the case-studies or via interviews. An example of a level 3 users were the representatives of C3S or EEA.

Given the variety of the users' interests, we have grouped them in 10 broad groups: from those being more generally interested in climate change to those conducting the specific work on adaptation strategies in cities. Additionally, based on their background, the project identified four main categories of users: (i) public bodies employees, from different governance scales (policy); (ii) purveyors; (iii) practitioners; and (iv) users from the private sector. Among purveyors there are meteorological and climate service providers, and under the category of private users there are consultancies specialized in natural resource management, but also companies that could require the use of EUCP data for own decision processes.

Figures 3 and **4** show the split of end-users by sector and category:

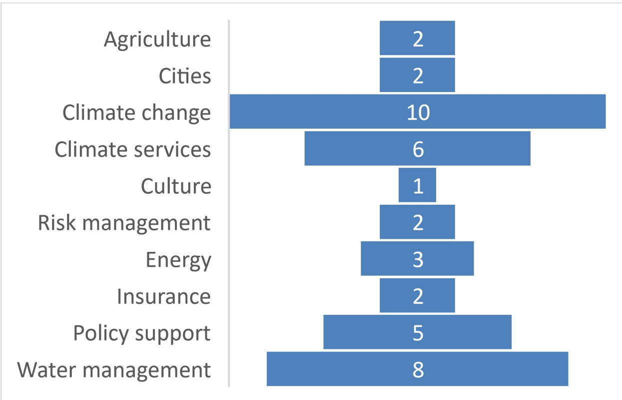


Figure 3. Sector/user group

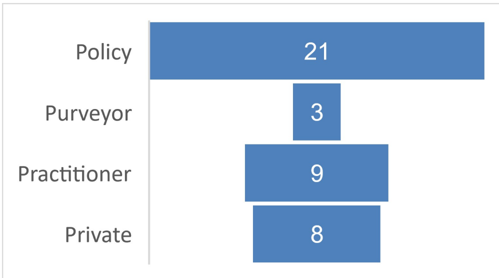


Figure 4. User category

Different data and products of EUCP were divided in three broad categories, and they were differently treated in terms of knowledge exchange with users. The table below shows the type of activity with which users were involved by each of the EUCP innovations, data and products and methodologies.

Table 1. Deployment of user involvement activities by selected EUCP outputs

Category	Title	MUF	W	I
Application of EUCP innovations	Multi-year prediction of drought and heat stress in the wheat sector		✓	
	Sandy beach erosion induced by sea level rise	✓		✓
	Alpine flash floods	✓		
	Estimating regionalized hydrological impacts of climate change over Europe	✓		
	Attribution of a small scale, heavy flash flood event to climate change	✓	✓	✓
	Assessment and attribution of the changes in wind energy in Europe			
EUCP data and products	The EUCP Caribbean runs			
	Infrastructure in support of EUropean Climate Prediction			
	Representation and identification of 3 historic "Heavy Precipitation Events"			
	Atlas of (un)constrained climate projections	✓		✓
	Benefits and added value of convection-permitting climate modeling over Fenno-Scandinavia			
EUCP science and methodologies	Physical storylines of future European drought events		✓	
	Comparing methods to constrain future climate projections	✓		
	Skilful decadal prediction of southern European summer temperature			
	Quasi-stationary intense rainstorms spread across Europe under climate change			✓
	Multiple lines of evidence	✓		

There were several user-centric engagement activities under the MUF umbrella: the first, second and third multi-user forums[3]. The forums presented the advancement of the EUCP scientific outputs, introduced the products that were gradually being developed by the partners and it increasingly provided more intensive collaboration forms with users, with the increase in the level of specificity. In this deliverable we report especially on the 2nd MUF because it centred the debates around usability.

The second MUF and usability

Each of the scientists responsible for the EUCP output was present in the 2nd MUF workshop, and after a flash presentation of the main points, participants were divided in the three categories and the discussion was focused on discussing **usability**.

We based the discussion on the literature of climate services usability. The table below is an illustration of the type of gaps detected across projects, based on Raaphorst and colleagues (2021):

[3] This last 3rd MUF organized for April 2022, after the submission of this current deliverable

	Validity	Readability	Interactivity
Stakeholder	Is the desired action the responsibility of the targeted audience?	Does the visual language, and its possible connotations, match the interpretive frames of the audience?	Is the visual literacy required for interpreting the CS suitable for the target audience?
Purpose	Is the purpose (understand, feel, act) suitable for the phase in the policy cycle?	Is the purpose of the CS clear? (otherwise people act before understanding)	Can the CS be repurposed by the user?
Information	Is the information shown correct/trustworthy?	Is it clear what information is presented in a CS?	Can the information be modified?
Visual format	Does the visual mode enable an accurate representation of the climate phenomenon?	Is the type of mode, and its way of reading, clear? (a story map requires a different viewing than a standard GIS map)	Can aspects of the mode (zoom level, color scheme, etc.) be modified?

Figure 5. Twelve usability gaps detected in climate science
(Raaphorst et al., 2020, p. 6)

Based on this literature, we had three main themes for our discussion, facilitated by the use of *jamboard* as our main interface: (a) usability; (b) for whom and how; and (c) future perspectives. The usability indicated an assessment of the information presented by the product or data, giving as examples its reliability, clarity and the possibility to modify it. Secondly, we did an assessment of the visual format, including the accuracy, readability, and aspects to modify. Finally, there was the possibility to discuss on timeliness and readiness of the products. On the side of "for whom and how", we had the following questions as prompters for supporting the discussion: *for which type of user do you imagine it? For which type of action and which purpose? What is the adequacy with the user's knowledge level, and the factors that could accelerate the use of the product or data*. On the side of future perspectives, to conclude, there was the prompt of possible future actions or interventions that could affect the usability of climate services, such as the ambition within the EU Green Deal or national climate laws.

The figure 6 below shows the results of the word clouding exercise and how the concept of usability was perceived by a group of users (12 participants, both external MUF members and EUCP scientists) as per these discussions during the 2nd MUF. The figure shows how they understand usability and what do the users related the concept with, which includes other concepts such as understandable, reliable or timely. This exercise was used as prompt to initiate the discussions on selected data or products from EUCP scientists.

Figure 6. Word clouding exercise for the term "Usability" during the 2nd MUF workshop (based on answers from 12 participants).

This word clouding exercise confirms what Cash et al. (2002) and later McNie (2012), stated about the three criteria that clarify under which conditions an information is useful i.e. salience, credibility and legitimacy.

- **Salience**. In this case usability relates to the information provided describing how information is context sensitive and relevant to the appropriate temporal and spatial scale. Stakeholders cited "good skill", "coverage", "correct temporal scale" as key structural elements to define whether an information is useful. Generally, the information should be "quick", "fast", "relevant", and "specific". Moreover, other reported not the characteristics of the information itself but how they are produced such as "particular end-users pool". The last definition demonstrates stakeholders have knowledge about coproduction and they value the climate services process as a key factor to generate useful climate information.
- **Credibility**. Directly related to the previous point, it correlates to the quality, accuracy, and validity of the contents of the information. Indeed, stakeholder mentioned "good skill" as one of the characteristics of a useful information. However, many answers deal with how the information is made accessible ("fair data"), or how it is presented ("visualization", "documentation is good"). This clearly suggests the need to deliver "clear", "trustworthy", "accurate", "useful" and "reliable" climate information.
- **Legitimacy**. It describes stakeholders' belief that the information was produced by trusted sources that had not been distorted by different interests. "Assumptions are clear" seems to be a good indicator to demonstrate that the information is trusted.

Moreover, stakeholders consider features that affect the decision-making process too. In this case, the concept of usability is read in connection with decision making. In particular, climate information should "aid decision making" to take "better decisions" based on "timely" additional information.
However, the users' concept of usability is wider than what it is meant in literature (for example Bojovic et al (2021), Christel et al. (2018)). The end users' concept appears as a combination of "usefulness" and "usability", where the former is a prerequisite for the latter (Bremer et al. 2019).

3.1.2. Interviews

The other two user involvement activities were interviews and workshops with EUCP 3rd level users. Interviews were conducted in two rounds: between March and May 2020 and in January-February 2022. The first-round interviews were conducted by WP6 members with an approximate duration of 1 hour. The second-round interviews, instead, were conducted by three partner institutions from WP4 and WP6 and the duration was between 30-45 minutes each (CMCC, Gerics and BSC). A group of 10 users from 6 sectors responds to the same questions. In the first round, questions focused on (i) how climate data are used, (ii) characteristics of data, (iii) what elements can increase the usability of data for their work. In the second round, instead, questions concentrated on (i) how climate information supports the decision making, (ii) enablers and barriers in adopting climate information in general and related to EUCP products specifically. Table 2 reports and summarizes sectors and types of users involved in interviews and their participation to just one or both meetings.

Table 2. EUCP 3rd level users' categories and their participation in interviews

User number	Sector	User category	First- round interview	Second- round interview
R1	Agriculture	Private	✓	✓
R2	Agriculture	Practitioner	✓	
R3	Cities	Practitioner	✓	
R4	Climate services	Practitioner	✓	
R5	Water	Practitioner	✓	✓
R6	Risk management	Practitioner	✓	
R7	Policy support	Purveyor	✓	✓
R8	Water	Practitioner	✓	✓
R9	Policy support	Purveyor	✓	✓
R10	Policy support	Practitioner	✓	✓

Usability for users: A review of level 3 stakeholders' requirements

MUF participants who showed interests and level 3 users, who are those with a greater collaboration intensity as seen above, were contacted for follow-up **interviews** regarding some of the EUCP products.

Level 3 stakeholders have the strongest relations with the scientists inside the EUCP project; they were hence asked to answer an interview focused on their needs and how a product could be used in their decision-making process. Usability is assessed along three main lines:

1. **Describing the action space**. The first element to narrow the usability gap is to clearly state how the information is used by the users. In EUCP we have two typical types of uses, namely providing climate information (with the objective to inform other partners and provide data) and using the information to feed impact models and produce other indices that are used for decision making process (i.e. practitioners). According to how the information is used, the user requires different products and considers different aspects as key attributes. This means that to make it actionable, climate information should be tailored based on its envisaged use. For

instance, the same indicator for water availability should have a different time horizon if it is used to analyse reservoir management rules (i.e. a responsive action) or to assess vulnerabilities and produce a risk plan (i.e. strategic action). Indeed, reservoir management has a short time horizon, but a risk plan involves infrastructures and investments whose profitability has a multi-year perspective. Similarly, when the data are applied for different sectoral analysis, users need different time scales, for instance coastal planning, forestry, and long-lived infrastructures demand longer timeframes.

2. **Defining key characteristics of products**. According to the different uses, usable products could differ in terms of some salient characteristics, such as time scale, geographical coverage (local vs regional vs national scale) and resolution. A mismatch between some of these qualities and the decision climate information supports can lower the usability level. For instance, if climate information is needed to prepare a risk assessment plan for infrastructures, an appropriate time scale should be decadal or even longer timescale as today decisions would affect infrastructures for 20-30 years in the future. Similarly, when climate data are required for a risk plan at the municipal level, users need higher resolution data than for a national risk planning.
3. **Identifying potential barriers and enablers to uptake products**. Although some barriers and enablers act at a higher level and could be defined as "systemic", the way a product is presented, how it is perceived, and how it is delivered can address some barriers, enhance the adoption, and ultimately boost the usability of the climate information. For instance, to increase trust within the user community, additional materials, such as documentation on procedures and assumptions, are needed. Moreover, supporting materials on hot topics could help the user to correctly apply the information and solve issues.

In general, most of EUCP level 3 users use climate information to feed sectoral impact models (R1, R2, R8: *"hydrological models"*, R1, R2: *"crop models"*, R2: "*rainfall and pest modelling",* R3: "*air quality modelling*", R5: "*water and irrigation models*", R6:" *flood modelling*"). They mainly focus on water management and agriculture issues either for private businesses or consultancy works. Users are equally interested in seasonal forecasts (up to 6 months) and longer terms products (such as climate projections, decadal predictions). While seasonal forecasts are mainly applied for assessing seasonal risks, such as to crops or water resources, climate projections are useful in defining strategic planning mainly related to investments whose profitability has a longer time horizon (R1: "*forecasts are needed to adequately warn farmers to the risk of frost in spring; seasonal forecasts inform about any risk of climate-induced hazards to know where and when to buy at the optimal price; climate projections, instead, are used to know where to invest, and where it would be sustainable in terms of production and irrigation system*"). In some cases, users are interested in daily or sub-daily variables for precipitation extremes too. This very short scale of application is useful for hydrological modelling, as well as for flood modelling and urban design (like the sewage system design). Figure 7 summarizes application sectors, decisions, and time scale according to EUCP level 3 users.

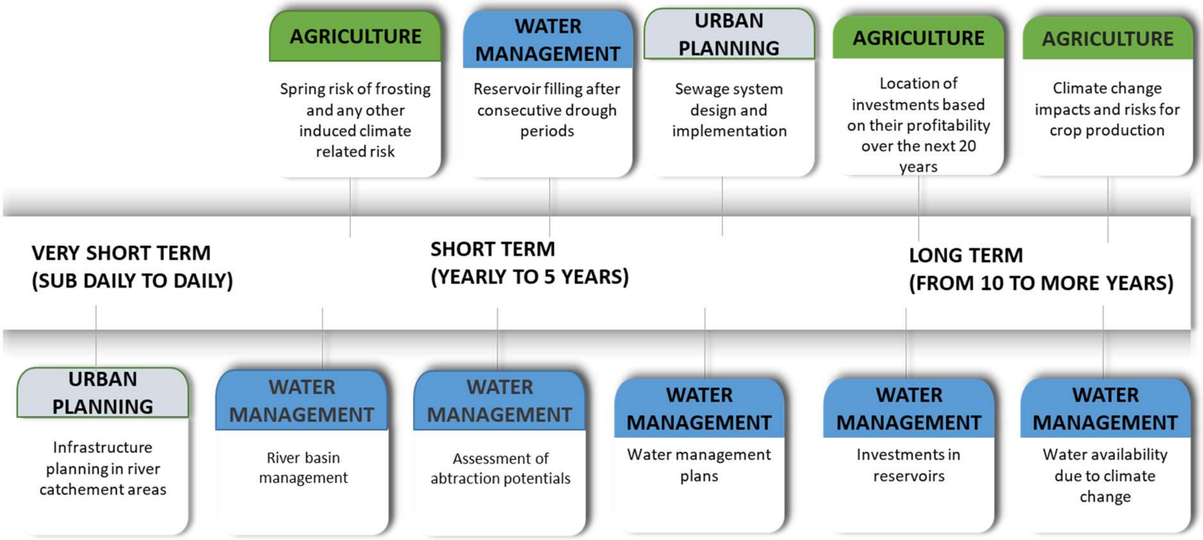


Figure 7. Time scales of sectors and decisions supported by climate information

In some sectors, as in water management, there is the need to reduce the uncertainty range from climate projections. Indeed, climate information is used to plan reservoir infrastructures. As it takes time, investments decided today should consider climate change for the next 15-20 years. However, when the uncertainty range is too wide the investors have concerns in mainstreaming this information in their decision making because the high uncertainty translates into high volatility in future profits (R5: "*uncertainty ranges may lead to overinvestments, and this is a concerns for clients*"). This is not a problem of "skill" of long-term predictions, but it is mostly about whether to have confidence in the range that is presented (R8: "*Understanding the range would be helpful to avoid lock in, to avoid stranded assets etc.*"). Finally, it creates a resistance in following an adaptation path. For this reason, users, especially those working in the water sector, suggest different approaches they apply to reduce uncertainty but providing knowledge for robust decision making. R8, for instance, suggests his organization develops "*a central forecast, a range around this, and a stress test scenario*" For R5 the stress test scenario could be a "*worst-case scenario*". Users in this sector highlight that they "*have to make a judgement about which projections to use*" and the best procedure is "*through a co-production approach*"

In a few cases, instead, EUCP users provide climate information to third parties. In this case they are mostly interested in how data are produced (R4:" co-*create a product with the users otherwise there is a risk to create a product that does not fit the needs of potential users*"), in data availability (R9: "*downloading and analysing data inhouse will become a challenge for very high-resolution ones*"), and characteristics (R7: "*reliable climate information from the ensemble for our region of interest*"). While users applying data for planning and investments are interested primarily in quantitative data, climate information providers require narrative information as well.

Although applied in different contexts and for different purposes, there is a quite wide consensus among the users about what climate data are necessary (Figure 8). Generally, they asked for temperature and precipitation, with the addition of few other variables directly connected to specific needs, such as humidity or surface wind for the agricultural sector (R1), heatwave length and intensity indicators for health planning (R9). Extreme events indices, instead, are transversally required by different sectors (R6, R7, R9). Indeed, they are used for infrastructure planning both in urban areas and river catchment areas. In most cases, the necessity of country or more local data is driven by the scale of application for decision making. When consultancy work is required by Governments, they need country and eventually regional data, but when data are needed for local authorities and sectoral analysis, they need more local information. However, in some cases the users report that when their clients become skilled, they ask for even more local specific data. Some users, especially those providing data for climate change and risk assessments, report that the necessity of country, regional and local data in the same location may lead to inconsistency and opposite data that could be difficult to reconcile. Specifically, R7 reports that "*many users use IPCC numbers, if they see that what we provide is significantly different from what is shown on a global scale in IPCC, we might lose their trust*". It mainly happens in Asian and African countries. Some EUCP users apply climate information outside the EU region, and they sometimes report "*mismatch among regional and global models*" (R5). R2 is an extra-EU user, and he states that "*most datasets are not homogeneous over West Africa and models are diverging*"; in this case he recognizes that the role of EUCP should be "*to provide a clear way of using information from diverging models and to transfer the knowledge from Europe to Africa*". This issue reduces the clients' attitude towards the inclusion of climate information in their decision-making process outside the EU. More generally, users ask for both time and scale consistency of data.

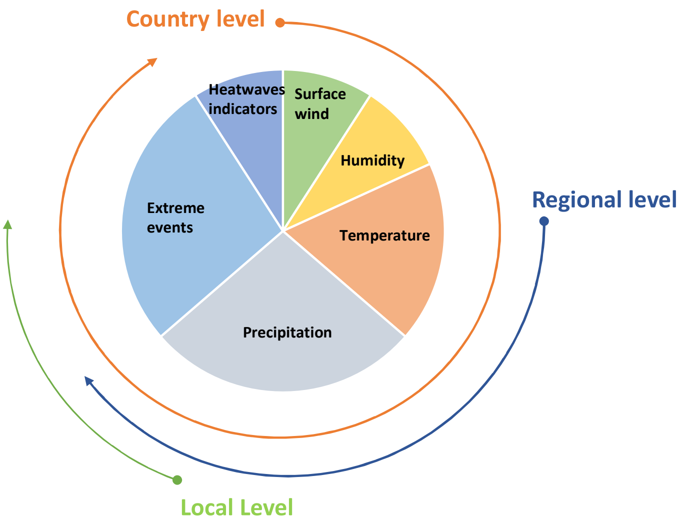


Figure 8. Indicators and their time scale according to level 3 users

Users providing information to third parties are not interested in raw data, but they would like to obtain summary or derived indicators (R10: "*we need summary/derived data (e.g. ETCDDI indices) rather than raw data. An index describing the direction of change of extreme precipitation would be useful and able to summarize information, thus a relatively small ensemble sizes would convey a meaningful information to the audience*"). Additionally, there is a third element to consider for enhancing usability. The perception of the user is fundamental and this individual behaviour together with the ability of the producers to reduce barriers is the final step to adopt the climate information.

During the interviews, level 3 users recognized two main instruments to create added value in the final products and to foster the uptake of the climate information. Firstly, EUCP climate information should be coupled with other resources to promote **knowledge transfers** from scientists to users.

They ask additional materials to explain clearly climatic datasets with their advantages and disadvantages to raise awareness on datasets thus the user can apply them having a full set of information (R1: "*a clear "factsheet" associated with every climatic dataset, which outlines its specifications, pros and cons, will help to get the message across the business*."; R8: "*metadata about where does the data come from, reliability of the data, and multiple standards of data would help*"). This clarity reinforces the perception of the good willingness of the data producers while the users trust more the products. Moreover, additional materials could include clear-cut tailorable examples on how climatic information can be used from different users and in different domains (R5), as well as other resources that focus directly on crucial issues for the whole community, such as uncertainty (R5, R6, R7, R8, R9), selection of information (both models and projections), and bias adjusted variables (R1, R3). Users recognized their limited knowledge about these topics and suggested that clear information would play a key role in deciding to apply a dataset. Nevertheless, some users recognised a coproduction approach in methods, tools, and data as a good way to reduce the learning gap and lower the scientific barriers.

Secondly, the **access to climate data** is a crucial factor. Users require readily available and possibly "plug and play" tools to reduce time in handling large datasets (R1, R5). Specifically, users would like not to download entire datasets but to have tools to subset and average remotely (R9: "[we would be interested in] *a service where we can make calculations where the data sits for the area and the indicators we are interested in*"). The information should be available through a dataset or stored into a Climate Data Store (CDS) (R3: "*information should be reliable and easily available, e.g., from CDS or any other databases*"), although users' experience with existing datastores (i.e. C3S CDS) is not completely positive as they report long time to download data (R7: "*download from C3S CDS is too slow and just derived indices are downloaded from there*"), inefficient accompanying materials, and difficulties in finding what they really need (R7). Complementary to the storage of data, the users highlighted the need for other instruments, such as video tutorials, that explain how to use the digital infrastructure (R9: "*web-applications for remotely analysing data, such as Jupyter Notebook viewer and Thredds data server, could be very useful*"; R9: "*video tutorials for reducing the learning gap with Jasmin, Mistral as well as ESMValTool and alike*").

3.2. Knowledge co-development: *user empowerment*

Knowledge co-development has been more intensively exercised in the context of the case studies from WP4. Some of the EUCP outputs linked to the case studies were at the centre of **workshops**. Workshops can be used as an activity for user involvement or in more active forms of user engagement, for user *empowerment*. For the latter, the user does not only provide feedback to the output but is also part of the co-development of it. In the next section, we describe how these workshops contributed to the usability of the EUCP outputs and provide a description of each case study. Given that a wide range of approaches tailored to the characteristics of each case was implemented, we also show how the process of assessing usability within each case study – either through workshops or through intense user engagement activities – was conducted. Specifically, we present three things: (1) how the usability, but also understandability and usefulness of the EUCP applications was assessed; (2) the specific type of user engagement activity conducted for this assessment, and (3) the outcomes of these interactions.

To gather this data, we conducted some interviews with the EUCP case studies lead scientists and their users when the engagement took more intense forms. These are the interview guidelines:

<u>Questions</u>

1. Could you please provide us with a brief description of your work, especially with regards its relation to the EUCP?
    a. Do you have any role in EU policy related to the topics covered by the EUCP?
2. Could you please describe which EUCP data/products you use and for which purposes?
    a. Description:
    b. Is its use linked to any of the following purposes?
        Advancing science:
        Applied science:
        Policy support:
        Decision-making:
        Other (please describe):
    c. Have you shared any aspect of the product (information, outcomes, etc.) with other stakeholders, and if so, which and how?
    d. Do you foresee to continue using it in the future?
        If you can share further details, we are interested to know also how.
    e. Do you know of other alternatives you could have used instead of this data/product?
        If so, what made you choose the EUCP instead of them?
3. Could you briefly describe the characteristics of the collaboration with your EUCP project scientist contact?
    a. Type (data exchange, modelling, etc.):
    b. Frequency:
    c. Approximate timeline:
    d. Degree of formality/informality:
    e. Additional involved stakeholders:
    f. Other (please describe):
4. In general, have you found this collaboration useful and is this type of collaboration in the context of EU projects usual in your institution?

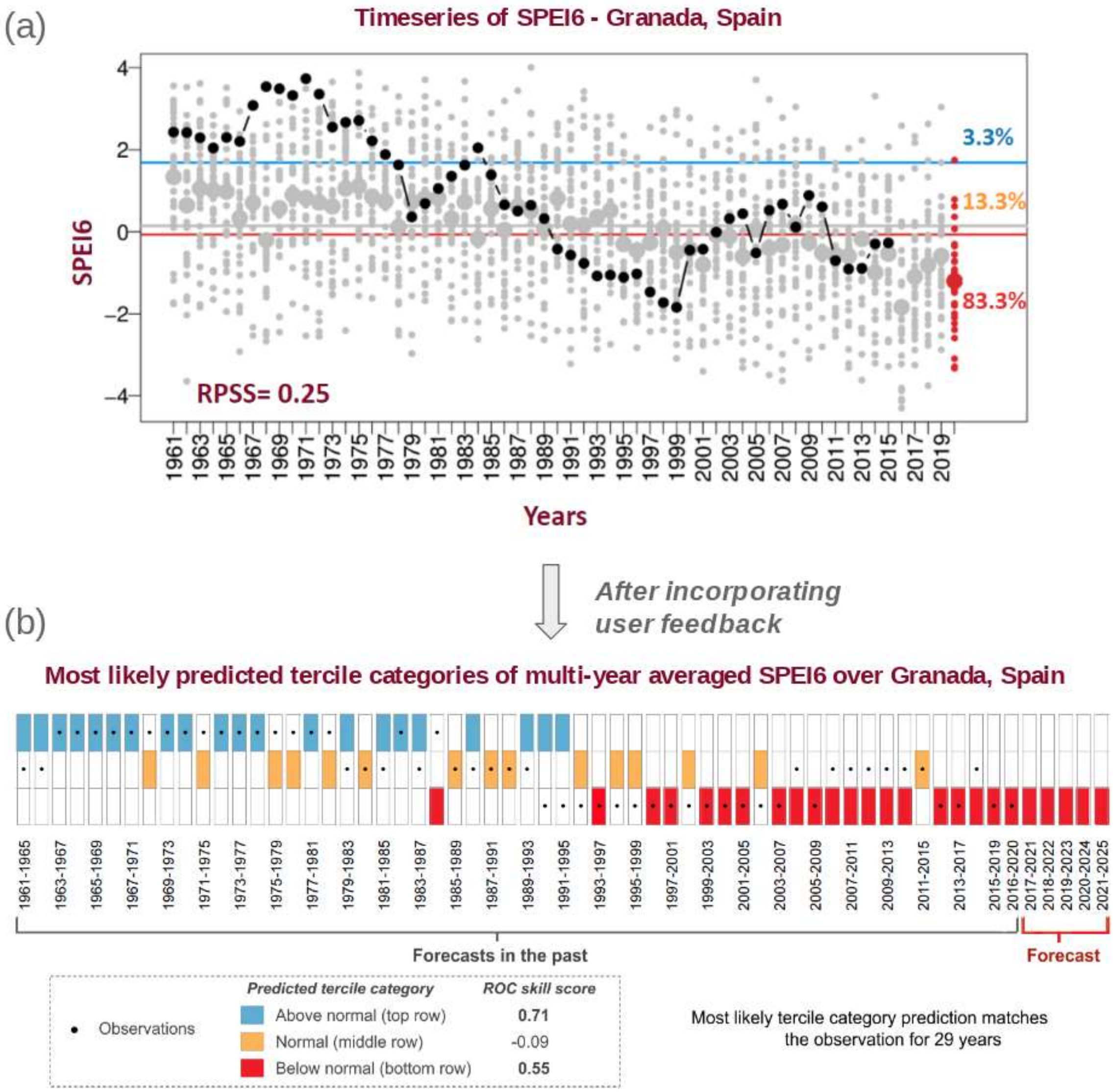
3.2.1. Drought and the agricultural sector

Description	The case study is contextualized within the advancing field of sector-specific decadal prediction as a forecast system. The user engagement consisted of (a) the co-production of decadal climate services with **agricultural sector users** and (b) the organization of a specific workshop to assess the products and outcomes' usability.

Product	**Expected usability**	**Users' assessment**
Multi-year drought forecast for wheat-growing regions	Help decisions on crop planting location and variety, as well as required water resources	Adequate for large landholders in guiding investments and decision-makers to design policy
User engagement	**Type of exchange**	**Frequency of contact**
Workshop with 11 stakeholders related to the agri-food sector	The product was presented in a specific workshop to collect feedback on its usability	Contact with users consisted of an initial phase of information sharing and workshop-led co-production, as well as of the follow up evaluation
User input	**Feedback**	**Response**
Feedback was collected on present and future usability, product clarity & usefulness	Users suggested improvements directed to reducing product complexity	The product was simplified as a result of the feedback, as illustrated below

Further material *Publications, websites*	See an overview of the use case here: https://eucp-project.github.io/usecases/usecase_0/panel_1

Example



Example of data illustration modified to improve the usability of the product

3.2.2. European erosion hazards due to sea level rise

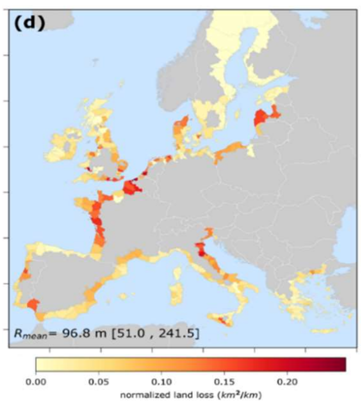
Description	The case study contributed with a large-scale coastal erosion assessment to identify hotspots in Europe and provide an estimation of coastal land-loss at European regional scale. User engagement consisted of (a) information exchange with a super-user, (b) discussions during the MUF workshop, and (c) interview with a super-user.

Product	**Expected usability**	**Users' assessment**
Projections of shoreline retreat with identification of European regional hotspots	For public bodies and decision-makers of the most affected areas of shoreline retreat	Adequate for the development of adaptation and mitigation strategies
User engagement	**Type of exchange**	**Frequency of contact**
Data outputs were used by another super-user for science and policy support, and it was also assessed via the MUF and with user interviews.	Information exchange and discussion with users following the discussion guidelines of the jamboard on usability	With the data user, monthly exchange during the EUCP project span, else, in the occasions of the MUF and interviews
User input	**Feedback**	**Response**
Feedback was collected on information	Users suggested that the map could be zoomable or interactive.	Adjustment of the storyboard interface

Further material
Publications, websites

See an overview of the use case here: https://eucp-project.github.io/usecases/coastal/

Example



- Land loss per NUTS3 region shows erosion hotspots around the European coastline
- Highly vulnerable regions are identified on the
  - Italian Adriatic coast,
  - the French Atlantic coast,
  - Belgium,
  - The Netherlands,
  - Denmark,
  - Lithuania and
  - Latvia

3.2.3. Flash flood projections for the Alps

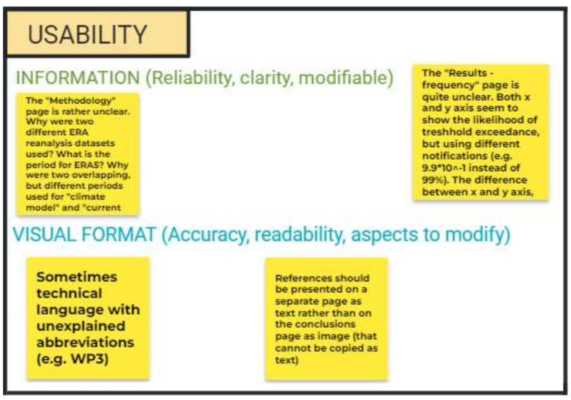
Description	The case study addressed flash foods, which are local floods that come from rainfall of high intensity and short duration. The area selected was in the Alps, which is known for an increase in such extreme events, as well as for the expectation that these event will augment due to climate change. The case study builds upon location-specific flash flood studies for the area, and ten-year transient CP-RCM simulations from WP3.

Product	**Expected usability**	**Users' assessment**
Statistical assessment of future changes in flash flood frequency and magnitude over the European Alps	For public bodies and decision-makers as well as for flood disaster management authorities	See illustration below
User engagement	**Type of exchange**	**Frequency of contact**
The flash floods projections for the Alps is of the lower technical readability comparing to other case studes, and it has not entered the stage yet to pursue user engagement.	Assessment performed during the 2nd MUF workshop	In the occasion of the 2nd MUF
User input	**Feedback**	**Response**
Feedback was collected on the storyboard prepared about the case study	Users suggested clarifications in terms of the information clarity, readability and accuracy	Adjustment of the storyboard interface

Further material
Publications, websites

See an overview of the use case here:
https://eucp-project.github.io/storyboards/flashflood

Example



This **illustration** builds on the comments provided by the users during the 2nd MUF workshop (see previous section for more details).

3.2.4. Pluvial flooding and damages

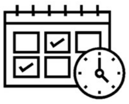
Description	This case study was conducted with the municipality of Milan as the main stakeholder. The study assessed and projected pluvial flooding damage, taking into consideration also the potential socio-economic losses of flooding damages.

Product	**Expected usability**	**Users' assessment**
The data products were on flood impact, flood losses, flood maps	The indicators should help the city of Milan in designing adaptation policies and other strategies.	Municipality of Milan and other regional authorities asked for a data catalogue.

User engagement

Stakeholder workshops and dialogues held face-to-face and online with regional users

Type of exchange



Information sharing, feedback provided to scientific outputs and co-production

Frequency of contact

The EUCP project partners and the stakeholders from the municipality of Milan were in contact monthly

User input

The users co-designed the citizen guidance documents in case of floodings

Feedback

Stakeholders wished a database with all sources of data relative to flood impact, losses and maps

Response

A document was prepared that synthetized all the data sources on flooding for the region of Milan

Further material	NA
Publications, websites	NA

Example

Flood hazard (Source)									
Directive 2007/60/CE	Vector	1:10000	Lombardy Region	WGS84/UTM32	2019	This map service shows Hazard and risk mapping, consisted of a preliminary flood risk assessment, which involved the identification of significant historical events (both in terms of the phenomenon severity and the caused damage) and delimitation of areas with significant potential flood risk. The specific requirements refer to the mapping of the areas or river sectors affected by historical floods and their consequences on human health, environment, cultural heritage and economic activity.	Geoportale Regione Lombardia	http://www.geoportale.regione.lombardia.it/download-ricerca	open
Digital Elevation Model	Raster	5 m	Lombardy Region	WGS84/UTM32	2015	The main input data used to create the DTM are: 1. the regional topographical database for about 80% of the territory (in particular the information layers concerning morphology: contour lines, quoted points and break lines); 2. the Lidar of 1 mx 1 m resolution along the watercourse rods and, for limited portions where the data were not available, with altimetric data from the previous edition of the regional DTM 20 mx 20, from the Regional Technical Charter scale 1: 10,000 edition 1982-1994.	Geoportale Regione Lombardia	http://www.geoportale.regione.lombardia.it/download-ricerca	open
Global flood model	Model	NA	Global	EPSG:4326 - WGS84	NA	GLOFRIS can assess changes in flood risk at the global scale under a wide range of climate and socioeconomic scenarios. Fluvial flood inundation layers from the GLOFRIS global flood model. Flood inundation maps were provided for 8 return periods between 5yr and 1000yr. The unit of the data is inundation depth in meters. The data resolution is 30 arc seconds (approximately 1km at the equator). The data are provided in GeoTIFF raster file format '.tif'	GLOFRIS	https://www.geonode-gfdrrlab.org/people/profile/GLOFRIS/?limit=20&offset=0	open
Hydrological rainfall-runoff model	Model	NA	Europe	NA	NA	The LISFLOOD model is a hydrological rainfall-runoff model that is capable of simulating the hydrological processes that occur in a catchment. LISFLOOD has been developed by the floods group of the Natural Hazards Project of the Joint Research Centre (JRC) of the European Commission.	LISFLOOD	https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/lisflood-distributed-water-balance-and-flood-simulation-model-revised-user-manual-2013	open

3.2.5. Wind Energy

Description	This case study is at the intersect of decadal predictions for the wind energy sector. Climate change is known to impact the variability of surface wind speed, and these changes will affect energy production. The possibility to use decadal predictions of wind energy could facilitate the decision-making process of stakeholders in terms of where to build future wind farms or how the existent will perform – ensuring thus more reliable energy production.

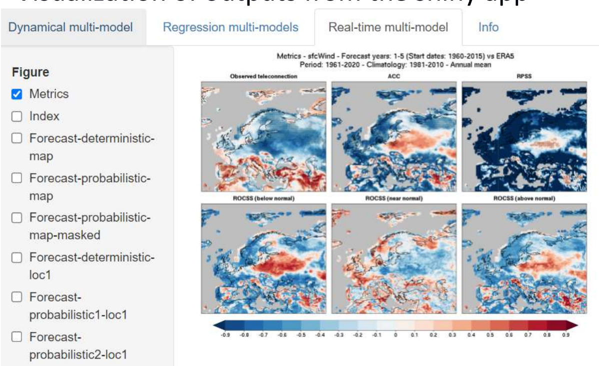
Product	**Expected usability**	**Users' assessment**
Forecast products at interannual to decadal time scales	Wind energy producers and policymakers, to anticipate renewable energy generation (for production or energy security)	Companies could benefit from knowing regions where the surface wind speed is foreseen to change
User engagement	**Type of exchange**	**Frequency of contact**
The outputs are shared through a shiny app, in which the data produced is made available visually with maps and graphs	The user can access always the data from the online path (see below), but there were no yet exchanges until this point.	No reports on the use of the shiny app are yet available, but the platform is permanently available to users
User input	**Feedback**	**Response**
The technical readiness of the product did not allow to receive input at this stage	*idem*	*idem*

Further material
Publications, websites

The complete data catalogue can be accessed in the shiny app: https://earth.bsc.es/shiny/EUCP-wind-case-study/

Example

Visualization of outputs from the shiny app



3.3. Assessment of other products

This section assesses the usability of other products generated under other EUCP WPs. Especially, it illustrates how the scientific outcomes in terms of data from these WPs also feed into the concept of usability and a user-centric approach to climate services development. We selected a range of the products which have a more developed technical readiness and that had a certain intensity degree of user engagement, such as the atlas (WP2), the storylines (WP5) and the storyboards (WP6) as a novel form of scientific communication.

3.3.1. WP2: Atlas of (un)constrained climate projections and user personas

The Atlas offers a visual platform to present data on unconstrained projections developed and validated with historical observations under the EUCP project. This arose from needs identified across the user community. The data is presented online in the form of an atlas[4] as it was considered that it had an added value presenting these outputs due to their skill. The authors of the atlas also included guidance on what user prototypes could benefit from using such data, as well as on how to incorporate it in their decision-making processes. There were four user personas developed:

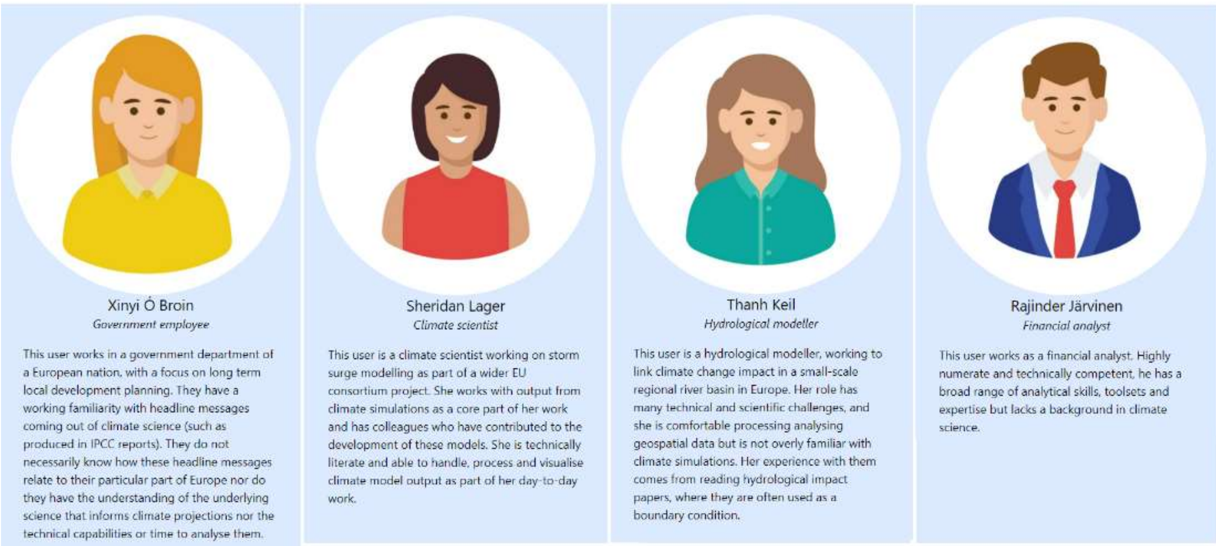


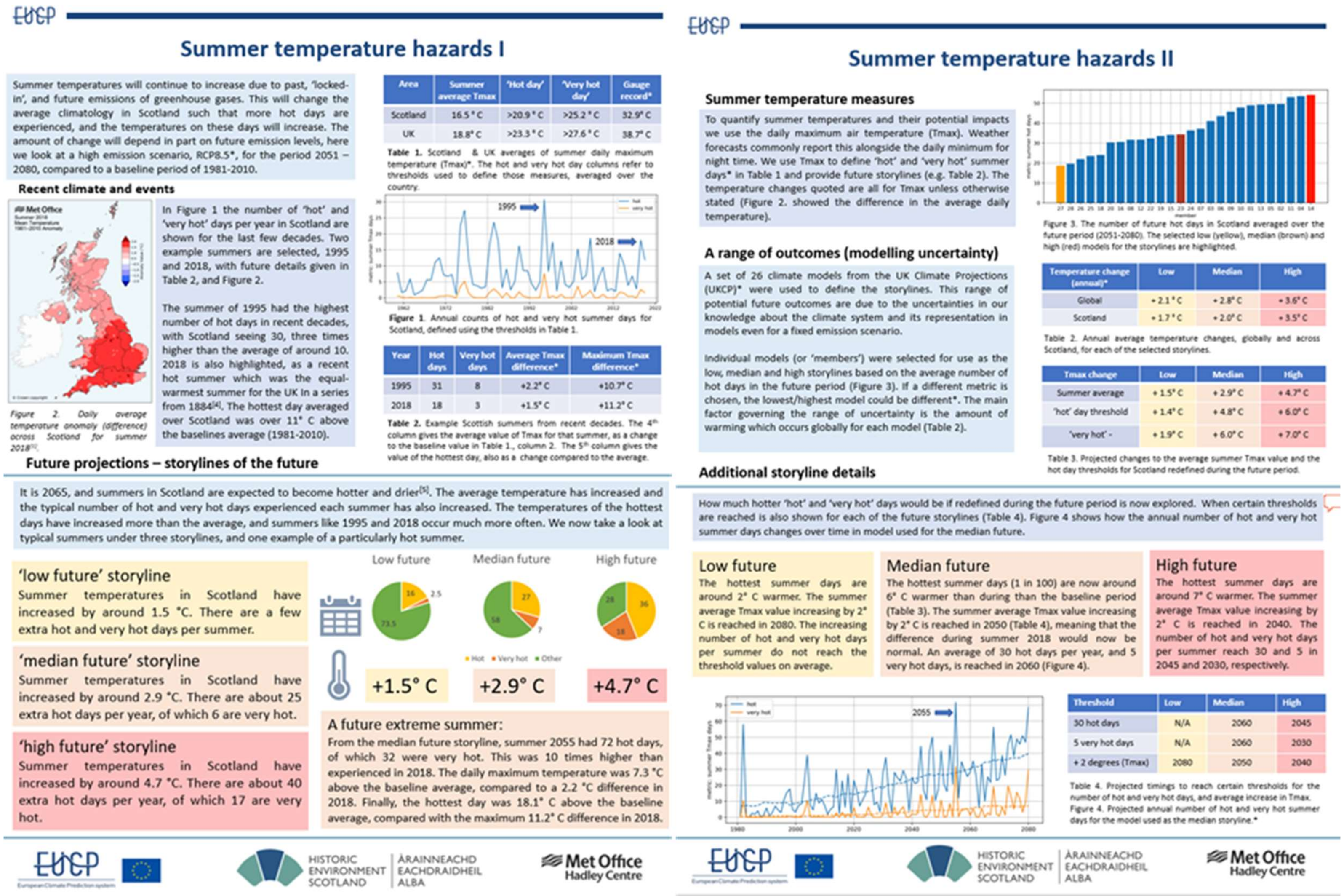
Figure 9. Simulated user personas for the atlas

The atlas was also commented by users during the 2nd MUF. The users considered that the information was presented very clearly, and the Atlas was user-friendly. The users saw the fit of the product for equally researchers and consultants, and policymakers.

[4] The Atlas DOI: 10.5281/zenodo.5654741

3.3.2. WP5: Storylines and user engagement

The storylines produced under WP5 had also a certain component of user engagement, despite being supply-driven in the sense that the technical readiness of the data was low and did not reach the stage required to enable a complete coproduction approach. The types of storylines that were tested were (a) event case studies using pseudo global warming experiments; (b) ‘storylines’ of NAO and internal variability; (c) storylines using event analogues/clusters from ensembles; (d) lines of evidence/robustness assessment, and finally (e) coproduction of climate driver storylines. For the latter, there were two case studies, one of which introduced a light coproduction approach to the construction of the storylines and prepared documentations adapted to the user. This case study was in the field of the cultural heritage sector. The target user was here the entity Historic Environment Scotland (HES), which is preparing adaptation strategies against climate hazards that could impact their assets and operations. The below illustration shows the document adapted for the user, prepared with their feedback during focus group sessions.



Summer temperature hazards I

Summer temperatures will continue to increase due to past, 'locked-in', and future emissions of greenhouse gases. This will change the average climatology in Scotland such that more hot days are experienced, and the temperatures on these days will increase. The amount of change will depend in part on future emission levels, here we look at a high emission scenario, RCP8.5*, for the period 2051 – 2080, compared to a baseline period of 1981-2010.

Area	Summer average Tmax	'Hot day'	'Very hot day'	Gauge record*
Scotland	16.5 ° C	>20.9 ° C	>25.2 ° C	32.9° C
UK	18.8° C	>23.3 ° C	>27.6 ° C	38.7° C

Table 1. Scotland & UK averages of summer daily maximum temperature (Tmax)*. The hot and very hot day columns refer to thresholds used to define those measures, averaged over the country.

Recent climate and events

Figure 2. Daily average temperature anomaly (difference) across Scotland for summer 2018[1].

In Figure 1 the number of 'hot' and 'very hot' days per year in Scotland are shown for the last few decades. Two example summers are selected, 1995 and 2018, with future details given in Table 2, and Figure 2.

The summer of 1995 had the highest number of hot days in recent decades, with Scotland seeing 30, three times higher than the average of around 10. 2018 is also highlighted, as a recent hot summer which was the equal-warmest summer for the UK in a series from 1884[4]. The hottest day averaged over Scotland was over 11° C above the baselines average (1981-2010).

Figure 1. Annual counts of hot and very hot summer days for Scotland, defined using the thresholds in Table 1.

Year	Hot days	Very hot days	Average Tmax difference*	Maximum Tmax difference*
1995	31	8	+2.2° C	+10.7° C
2018	18	3	+1.5° C	+11.2° C

Table 2. Example Scottish summers from recent decades. The 4th column gives the average value of Tmax for that summer, as a change to the baseline value in Table 1., column 2. The 5th column gives the value of the hottest day, also as a change compared to the average.

Future projections – storylines of the future

It is 2065, and summers in Scotland are expected to become hotter and drier[5]. The average temperature has increased and the typical number of hot and very hot days experienced each summer has also increased. The temperatures of the hottest days have increased more than the average, and summers like 1995 and 2018 occur much more often. We now take a look at typical summers under three storylines, and one example of a particularly hot summer.

'low future' storyline
Summer temperatures in Scotland have increased by around 1.5 °C. There are a few extra hot and very hot days per summer.

'median future' storyline
Summer temperatures in Scotland have increased by around 2.9 °C. There are about 25 extra hot days per year, of which 6 are very hot.

'high future' storyline
Summer temperatures in Scotland have increased by around 4.7 °C. There are about 40 extra hot days per year, of which 17 are very hot.

A future extreme summer:
From the median future storyline, summer 2055 had 72 hot days, of which 32 were very hot. This was 10 times higher than experienced in 2018. The daily maximum temperature was 7.3 °C above the baseline average, compared to a 2.2 °C difference in 2018. Finally, the hottest day was 18.1° C above the baseline average, compared with the maximum 11.2° C difference in 2018.

Summer temperature hazards II

Summer temperature measures

To quantify summer temperatures and their potential impacts we use the daily maximum air temperature (Tmax). Weather forecasts commonly report this alongside the daily minimum for night time. We use Tmax to define 'hot' and 'very hot' summer days* in Table 1 and provide future storylines (e.g. Table 2). The temperature changes quoted are all for Tmax unless otherwise stated (Figure 2. showed the difference in the average daily temperature).

Figure 3. The number of future hot days in Scotland averaged over the future period (2051-2080). The selected low (yellow), median (brown) and high (red) models for the storylines are highlighted.

A range of outcomes (modelling uncertainty)

A set of 26 climate models from the UK Climate Projections (UKCP)* were used to define the storylines. This range of potential future outcomes are due to the uncertainties in our knowledge about the climate system and its representation in models even for a fixed emission scenario.

Individual models (or 'members') were selected for use as the low, median and high storylines based on the average number of hot days in the future period (Figure 3). If a different metric is chosen, the lowest/highest model could be different*. The main factor governing the range of uncertainty is the amount of warming which occurs globally for each model (Table 2).

Temperature change (annual)*	Low	Median	High
Global	+ 2.1 ° C	+ 2.8° C	+ 3.6° C
Scotland	+ 1.7 ° C	+ 2.0° C	+ 3.5° C

Table 2. Annual average temperature changes, globally and across Scotland, for each of the selected storylines.

Tmax change	Low	Median	High
Summer average	+ 1.5° C	+ 2.9° C	+ 4.7° C
'hot' day threshold	+ 1.4° C	+ 4.8° C	+ 6.0° C
'very hot' -	+ 1.9° C	+ 6.0° C	+ 7.0° C

Table 3. Projected changes to the average summer Tmax value and the hot day thresholds for Scotland redefined during the future period.

Additional storyline details

How much hotter 'hot' and 'very hot' days would be if redefined during the future period is now explored. When certain thresholds are reached is also shown for each of the future storylines (Table 4). Figure 4 shows how the annual number of hot and very hot summer days changes over time in model used for the median future.

Low future
The hottest summer days are around 2° C warmer. The summer average Tmax value increasing by 2° C is reached in 2080. The increasing number of hot and very hot days per summer do not reach the threshold values on average.

Median future
The hottest summer days (1 in 100) are now around 6° C warmer than during than the baseline period (Table 3). The summer average Tmax value increasing by 2° C is reached in 2050 (Table 4), meaning that the difference during summer 2018 would now be normal. An average of 30 hot days per year, and 5 very hot days, is reached in 2060 (Figure 4).

High future
The hottest summer days are around 7° C warmer. The summer average Tmax value increasing by 2° C is reached in 2040. The number of hot and very hot days per summer reach 30 and 5 in 2045 and 2030, respectively.

Threshold	Low	Median	High
30 hot days	N/A	2060	2045
5 very hot days	N/A	2060	2030
+ 2 degrees (Tmax)	2080	2050	2040

Table 4. Projected timings to reach certain thresholds for the number of hot and very hot days, and average increase in Tmax. Figure 4. Projected annual number of hot and very hot summer days for the model used as the median storyline.*

Figure 10. Draft prototype product prepared with EUCP project partners and users

3.3.3. WP6: Storyboards

For the 2nd MUF a series of storyboards were prepared which allowed to present the main scientific outputs in a format that was user-friendly and brief but conveyed the main points[5]. These storyboards have been updated as a follow-up of user feedback. The feedback was received during the MUF or as part of the one-on-one interviews with interested users. This series of storyboards are explained in the deliverable 6.11, “Data access infrastructure for end-users with appropriate documentation”. The storyboards will remain as the EUCP project legacy. Storyboards can be found here: https://eucp-project.github.io/storyboards/

4. Lessons learnt and links built

The lessons learnt from the EUCP project can serve to inform other technical and scientific projects on best practices about user engagement and collaboration, as well as how to move from scientific data to usable knowledge.

Regarding the links built, the project witnessed strong collaboration between different scientific teams, as well as collaboration with stakeholders and EUCP products users. EUCP has seen multiple developments in the scientific arena and should be perceived as a success on this regard. However, in big part due to the low technical readiness of some of these data and products, the usability of the EUCP science has not reached yet its potential and this remains to be realised in future projects. Even so, efforts have been done to collaborate with some climate data purveyors and create a legacy of the EUCP which can partly address these current weaknesses. A strong collaboration between WP4 and WP6 has positively contributed to strengthening these efforts of user engagement and exploring within this context the concept of usability applied to the EUCP scientific outputs.

The key lessons learnt are:

- In projects that begin with methods at lower technical readiness levels it is important to consider the research community as a key stakeholder, as this community will likely be involved in later raising the technical readiness level.
- Mechanisms that foster close interaction between partners across the project should be developed and implemented from the start, leveraging on the synergies that always exist between the different tasks of a project.
- The collaboration with users should start at the early stage of the project. Preferably, and when possible, the ways of collaboration and knowledge coproduction should already be co-explored with stakeholders at the project preparation phase.
- Usability is an important ambition of climate services initiative. If we aim to reduce the gap in the use of scientific outputs in decision-making processes of societal actors, we need to accept that the climate information provision process needs to integrate strong collaboration and feedback from users, and when possible, apply suitable co-production

[5] See Kaverla, P., “Storyboards for science communication”. Accessed February 2022, here: https://blog.esciencecenter.nl/storyboards-for-science-communication-85e399e5c1b5

processes, which vary across user communities and depend on the time and interest of the users.

The 3rd MUF workshop focussed on lessons learnt with again a user centric approach, focussing upon the concept of usability.

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