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Lessons learned from current practices in climate service visualisation and recommendations

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1 Why a climate services visualisation workshop?

The visual communication of climate information is one of the cornerstones of climate services. Characteristics that make a climate service self-explanatory rely on the visual modes it employs, e.g. maps, graphs or infographics, and the visual channels applied for the translation of multidimensional data, e.g. combination of colours, shapes or slopes.

Climate scientists have traditionally used predetermined types of visualisations to present climate data, including flood maps, heat maps or choropleth maps. However, such a tradition neglects a plethora of stakeholders (e.g. businesses, policy makers, citizens) that are increasingly involved in climate adaptation and that are less familiar with the traditional ways of presenting these data. In this sense, there is a need to advance towards climate services visualisations that can guide climate change adaptation decisions by helping users to interpret and use the information as simply and quickly as possible.

This report contains the description of a climate services visualisation workshop that counted with the participation of representatives from various projects and initiatives, as well as individual stakeholders from the Climateurope network. The obtained results provide a picture of the current status of the climate services visualisation field in Europe and give recommendations for the development of the next generation of climate services.

2 Description of the visualisation workshop

The climate services visualisation workshop was structured in two parts:

1. Preparatory meeting of the climate services network of projects to discuss different visualisation practices and challenges, organised on the 2nd November 2020.
2. Interactive visualisation workshop organised during the 4th Climateurope webstival on the 19th November 2020.

2.1 Preparatory meeting of the climate services network of projects

We organised a preparatory meeting prior to the actual visualisation workshop, involving climate services projects from the Climateurope network. A survey was first sent to all the projects participating in the network to assess their interest in the activity and to ask for general information on the visualisations they had developed or were still developing. The survey gathered information on: the type or format of visualisation developed (i.e. graph/plot, map, online platform or other), the information provided (i.e. observations, weather forecasts, climate predictions, climate projections or other non-climatic data), the target sector or audience, the decisions that the visualisation is aimed to advise, and the URL to access the visualisation in case it is public. A total of 25 projects indicated their interest in the activity and provided details on their visualisations.

The preparatory meeting was then conducted on the 2nd of November 2020 and had a duration of 2.5 hours. The meeting served to explain the objectives of the activity and to discuss preselected visualization topics in break-out groups. Prior to the preparatory meeting, projects were encouraged to upload images of their visualisations to support the discussions during the meeting. Twenty-five participants from different institutions (plus 5 organizers from the Barcelona Supercomputing Center, BSC) attended the meeting, representing 22 different projects, including EU H2020 and ERA4CS projects and a few national projects and private contracts (see Table 2-1).

Table 2-1: List of participating projects

Project acronym	Project title	Funding scheme
C3S_429g_BSC	Press Data Portal	EU C3S
CIREG	Climate information for integrated renewable energy generation	ERA4CS
Clim2Power	Translating climate data into power plant operational guidance	ERA4CS
Climate-fit.city	Pan-European Urban Climate Services	EU Horizon 2020
Co-CliME	Co-development of climate services for adaptation to changing marine ecosystems	ERA4CS
Digital-water.city	Leading urban water management to its digital future	EU Horizon 2020
eClimViz	Enhanced Visualization of Climate Model Results	Met Office
EVOKED	Enhancing the value of climate data – translating risk and uncertainty utilizing a Living Labs approach	ERA4CS
IMPREX	Improving predictions and management of hydrological extremes	EU Horizon 2020
inDust	International network to encourage the use of monitoring and forecasting dust products	EU COST Action
ISIpedia	The open climate-impacts encyclopedia	ERA4CS
MED-GOLD	Turning climate-related information into added value for traditional Mediterranean grape, olive and durum wheat food systems	EU Horizon 2020
MEDSCOPE	Mediterranean services chain based on climate predictions	ERA4CS

PRIMAVERA	Process-based climate simulation: advances in high-resolution modelling and European climate risk assessment	EU Horizon 2020
RECEIPT	Remote climate effects and their impact on European sustainability, policy and trade	EU Horizon 2020
S2S4E	Sub-seasonal to seasonal climate forecasting for energy	EU Horizon 2020
SECLI-FIRM	The added value of seasonal climate forecasts for integrated risk management decisions	EU Horizon 2020
SENSES	Climate change scenario services: Mapping the future	ERA4CS
VISCA	Vineyards´ Integrated Smart Climate Application	EU Horizon 2020
WATExR	Integration of climate seasonal prediction and ecosystem impact modelling for an efficient adaptation of water resources management to increasing climate extreme events	ERA4CS
KNMI’06 and KNMI’14	KNMI climate scenarios	The Netherlands Meteorological Institute
	Seasonal hurricane predictions	Private contract, AXA XL

During the preparatory meeting, participants were randomly divided in 4 break-out groups and the activity was structured in 4 discussion blocks of 15 minutes. In each of the blocks, the groups discussed various questions related to the visualisation of climate services. The interactive platform miro.com was used to support the interaction with participants, allowing them to be more active during the session since they had the possibility to add sticky notes with their statements if wished. Break-out discussions were recorded for internal use after due notification of the participants by moderators.

The different questions discussed in the 4 discussion blocks are reported below:

Block 1 (15 min)

- ***Communicating probabilities***: Which are stakeholders' preferences for displaying probabilities? (e.g. averages, extreme values, anomalies, terciles, etc.). Did you need to adjust the visualisation of probabilities in your project according to stakeholders’ feedback? how?

- ***Communicating uncertainty***: Is uncertainty shown in your visualisation? How? Why? (e.g. requested by stakeholders)

Block 2 (15 min)

- ***Definition of visualisation***: What do you understand by visualisation in climate services? Do you think a PDF could be considered a visualisation?
- ***Interacting with the visualisation***: Is it useful to have a 'progressive disclosure of information' (dosifying the amount of information initially presented to users)? Can filtering options help to enhance user experience?

Block 3 (15 min)

- ***Terminology***: To what extent choosing the right technical terminology was relevant in your visualisation? (e.g. skill, uncertainty, anomalies, etc.). Give examples of how terminology is adjusted in favour of understanding by non-climate experts.
- ***Language***: English vs local languages. To what extent is language relevant? Are you presenting your visualisation in the local language of stakeholders?
- ***'Failure stories'***: Which aspects of the visualisation did not work when presented to stakeholders? How did you solve it?

Block 4 (15 min)

- ***Multidisciplinarity***: Have you put a multidisciplinary approach into practice when developing your climate service visualisation? (e.g. involving climate scientists, designers, experts in user experience, social scientists, communication experts, etc.). Give details.
- ***Recommendations***: Give your main recommendations to create a climate service visualisation.

After the break-out groups, participants were asked to think about topics not captured during the discussions but that they considered relevant for the visualisation of climate services. Before closing the session, participants were invited to add additional sticky notes to the miro board, which remained open still for a few days in case they came up with further ideas. Participants were also informed that the main outcomes of the preparatory meeting were going to be presented during the Climateurope webstival due to take place a few days later, and were invited to register.

2.2 Visualisation workshop in the Climateurope webstival

The visualisation workshop was conducted by BSC during the 4th webstival organised by Climateurope on the 19th of November 2020. The webstival was attended by climate service providers and beneficiaries. During the workshop, the main highlights identified in the preparatory meeting were shared with the webstival audience, in combination with a poll that called for people's personal views and professional experiences on visualisation.

The Mentimeter application was used to run the poll, which included the following questions:

- Why does visualisation matter for climate services?
- What are the main challenges of climate services visualisations? *Multiple choice: showing uncertainty; communicating probabilities; terminology; language barriers; visual encoding; adapting to users' expertise.*
- How would you show uncertainty? *Options: indicated visually (e.g. transparency); range (e.g. full ensemble range); interactive options (e.g. slider, selectors); mask areas with high uncertainty; better not to show it.*
- How would you show probabilities? *Options: providing an average and the possible range; showing terciles, quintiles, etc.; focussing on the probabilities of extreme events (e.g. p10, p90, return periods, a probability threshold); showing the whole probability distribution; using scenarios*.
- Which technical terms are a challenge for non-climate scientists?
- Have you seen a climate service in your mother tongue? *Options: yes, many (English speakers); yes, many (non-English speakers); yes, but only a few; no, I haven't*.
- Visual encoding options. *Order according to the level of agreement (from strong agreement to strong disagreement): Use intuitive colours; use colour-blind friendly palettes; use of shape and size; use of tilt/angle; use of transparency*.

3 Analysis of the workshop results

We used affinity maps to analyse the information gathered during the break-out group discussions in the preparatory meeting. This is a tool which is commonly used by business and design teams as well as by UX researchers that helps to organize the information into groups of similar items/topics to then be able to analyse qualitative data and extract the relevant information. Based on the main challenges identified during the break-out group discussions, we prepared a poll to be run during the Climateurope webstival. The answers collected during the webstival helped us gather further information to complement and better understand previous findings.

The discussions presented in the following sections are based on both the preparatory meeting and answers collected during the Climateurope webstival.

4 Current practices in climate services visualisation

4.1 Why having visualisations in climate services matters?

There is no unique answer to why visualisation matters in the field of climate services. Purposes such as targeted communication and outreach, storytelling, and easing decision-making are some of the most frequently mentioned, but not the only ones. The answers received during the workshop have been grouped according to the following purposes (see Figure 4-1):

- **Knowledge transfer**: visualisations can transfer knowledge in a user-friendly way, that is, in a simple and clear format, focusing on those aspects that are essential to facilitate user's uptake.
- **Simplify complexity**: visualisations serve to deliver complex information in a simplified way. This also relates to the notion that sometimes less is more, and that rather than showing all the information available, visualisations are a way to focus on the most relevant aspects.
- **Targeted communication and outreach**: visuals often convey messages in a more direct and illustrative way than long texts and have the advantage of reaching wider audiences beyond specialized communities. Participants also mentioned that patterns in data were more easily identified through visualisations. In this line, the motto 'a picture is worth a thousand words' was one of the answers received.
- **Storytelling from data**: visualisations are tools that help extract the information and knowledge that exist behind data. They allow us to tell a story from the data and contribute to building climate narratives which place information in the right context and improve the understanding of users of its real-world application.
- **Ease decision making**: visualisations are tools that can make decision making easier by showing the information that is relevant for the decision at hand in the user's preferred format. They also support the empowerment of users, making it easier for them to deal with the information provided.
- **Attractiveness**: a visualisation is an attractive way to display information that has the capacity to catch people's attention.
- **Add layers of information**: visualisations can be useful to combine different types of information coming from various sources and to find new relationships among different datasets, which can be interpreted more easily in a visual format.
- **Raise awareness/call for action**: since they are often intended to deliver a message, visualisations can help to raise awareness on particular issues, contribute to form people's opinions on a subject or call for action.
- **Engagement**: visualisations are useful tools to engage with audiences, since they can be used as a conversation starter and support the communication process (e.g. allow

looking into particular examples of interest for the potential users) and enhance interaction, resulting in a more proactive sharing of stakeholders' insights.

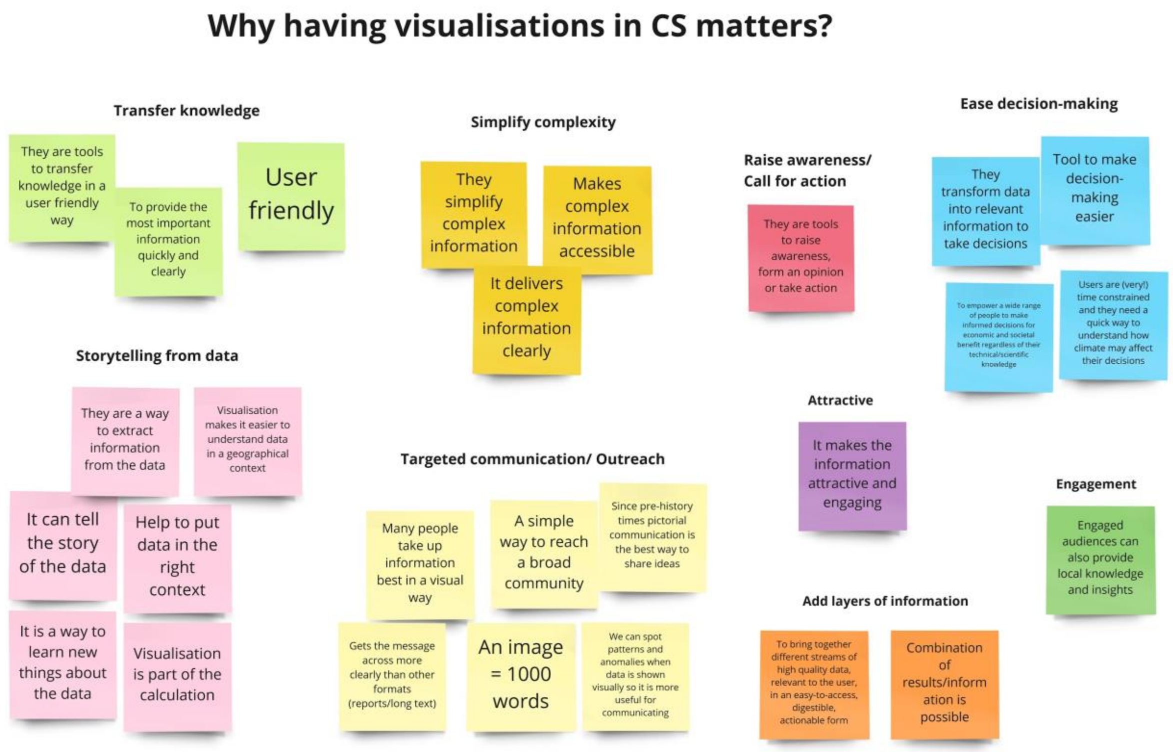

Figure 4-1: Why having visualisations in climate services matters?

4.2 Current visualisation practices of climate services projects

The analysis of group discussions shows that it is difficult to talk about climate services visualisation without referring to other aspects of climate services. Issues such as the challenges of user engagement, multidisciplinarity, or the long-term sustainability of climate services were raised despite not being directly related to visualisation. Different factors are interconnected during the co-production of a climate service which makes it hard to discuss one factor independently from the others.

Current practices in the visualisation of climate services identified during the workshop can be summarised in the following messages:

- There is a tendency of various projects to develop climate service platforms or applications that allow the use of interactive elements[1]
- Visualisations are generally tested with potential users
- There are different ways of visualising information on climate probabilities and uncertainty, however this information is not always shown

[1] This strongly depends on the format of the particular climate service, since there are formats that allow low or no interactivity (e.g. factsheets, newsletters or bulletins, direct advice, etc.)

- ❑ Anomalies are widely used to show climate variability but they are not always well understood by users
- ❑ The dosing or progressive disclosure of information is a widely applied practice
- ❑ Visualisations start to use alternatives to the technical climate terminology
- ❑ Multidisciplinary approaches are applied for the development of climate service visualisations, but there is commonly a lack of social scientists' representation
- ❑ Many existing visualisations are in English, but supporting activities are often conducted in local languages

4.3 Visualisation challenges in climate services

Effective climate service visualisations need a thoughtful design that takes into account aspects such as the scientific knowledge of users, the particular decision to be advised, the way data is presented or how the visualisation is combined with other important elements of the climate service. Different challenges to the development of effective climate data visualisations have been identified during the workshop discussions and are reported in different sections below.

Adaptation of the visualisation to the user's expertise

Adapting the level of complexity of a climate service visualisation to the user profile and expertise, and ensuring the user is not overloaded with unnecessary or difficult-to-understand information can be challenging. It is important to decide beforehand who the visualisation is aimed at (e.g. scientists, policy makers, practitioners, the general public, etc.) and what the salient information is for the target audience.

There was a general agreement in that the use of interactive plots and maps providing options to select and filter the data favours users' understanding. In fact, many climate services projects have developed visualisations in which the users are able to interact with the interface and select the information they are most interested in. In this sense, many visualisations use a progressive disclosure of information and include interactive elements such as filters and sliders.

Workshop participants also mentioned that visualisations should provide different options for downloading data to accommodate the requests of different types of users. For instance, more experienced users might be interested in downloading the raw data, whereas other users with a non-technical background would prefer having access to processed data or images.

Communication of probabilities (first-order uncertainty)

The best way to communicate probabilities to stakeholders (i.e. information on the likelihood of an event happening according to a particular forecast) is a widely debated topic in climate science. This is done in different ways depending on the characteristics and the purpose of the visualisation. Thus, the requirements and level of expertise of users have an important influence on how probabilities are represented. Although more experienced users are comfortable with technical representations and, for the sake of transparency, prefer to see all the information available (probabilities for terciles or percentiles, probabilities for extreme events, etc.), less experienced users need simpler visuals, which in some occasions translate probabilistic data into deterministic information. For users that are less familiar with technical concepts, getting access to the full wealth of data can be overwhelming and even counterproductive. In these situations, participants mentioned that textual and verbal explanations that adopt a narrative approach could be helpful.

The way different projects have dealt with the visual representation of probabilities includes a range of possibilities. Some that have been mentioned during the workshop include:

- Show the whole probability distribution (PDF)
- Focus on extreme events probabilities (p10, p90, return periods, a specific probability threshold, etc.)
- Show terciles, quintiles, percentiles, etc., sometimes indicating the probability for these categories and other times not
- Not show probabilities: Provide an average and the possible range
- Not show probabilities: Show climate variability (e.g. anomalies) and climate change
- Use scenarios[2]

Communication of reliability or skill (second-order uncertainty)

The visualisation of reliability or skill was identified as another important challenge when communicating climate uncertainty, since these are difficult concepts for many stakeholders to understand. Representing this information in a clear and intuitive way also constitutes a challenge for scientists. As it was the case for the communication of probabilities, the request to access information on the reliability or skill of climate information strongly depends on the users' background. General users might find these concepts too complex and therefore not usable for the level of information required. As a result, various climate services visualisations do not show them. On the other hand, experienced users with previous knowledge of climate data may be interested in knowing the 'uncertainty about the uncertainty' as an additional factor to take into account in the decision-making process. Some workshop participants suggested that it would not be fair for stakeholders to receive a climate service product without an indication of its reliability or skill. Communicating this form of uncertainty was also mentioned to be crucial when talking about extreme events.

One of the challenges mentioned by participants referred to how to properly represent the limitations of scientific knowledge in a way that is understandable by users and that, at the same time, does not discourage them from using climate services. One of the comments

[2] Scenarios are often used when no probabilities can be given

received indicated that it is key to make users understand that uncertainty is not a bad thing; instead, when correctly understood, it can add value to decision making.

As with probabilities, the representation of this form of uncertainty has also been solved in different ways depending on the particular projects. Some of the solutions mentioned during the workshop include:

- Indicate uncertainty through visual encoding (e.g. transparency)
- Use interactive options to show/hide uncertainty (e.g. sliders, selectors, etc.)
- Show a range instead of uncertainty (e.g. full ensemble range, standard deviation, confidence intervals, etc.)
- Mask areas with high uncertainty
- Replace uncertain predictions by the climatology (i.e. average observations of the last 20-30 years)
- Not show any information about uncertainty

Terminology-related barriers

Climate service visualisations often contain technical terminology that is complex and requires time for stakeholders to correctly understand. Climate scientists commonly use terms such as *skill*, *anomaly*, *reliability*, *uncertainty*, *percentile*, and many others (see Figure 4.x). Sometimes these concepts are unknown by non-climate experts whereas other times they may be understood in a different way (e.g. a term with different meaning for two disciplines or differently interpreted in academia and the business sector).

Another barrier to understanding which was mentioned during the workshop relates to the differentiation of the time scales of climate predictions (e.g. hindcasts, weather forecasts, sub-seasonal and seasonal predictions, climate projections, etc.). This classification has been established by climate science practitioners and stakeholders are often not aware of such a division nor do they care about it. Even the definition of the 'climate service' concept itself was apparently not always clear for stakeholders.

To be correctly and easily understood, the climate services community should be ready to adapt (or translate, or define) their terminology, even if this means introducing a lack of scientific precision. This may not be straightforward and can induce some tensions during the co-production process but, overall, it will enhance the service uptake.

Workshop participants mentioned that terminology should be as close to the experience and vocabulary of stakeholders as possible. This prevents wasting time explaining complex concepts and allows stakeholders to focus more on the interpretation of the information provided.

Various participating projects found the IPCC approach of providing keywords to describe the level of confidence in a statement or result (i.e. high, medium or low) to be really intuitive by users. It was mentioned that a 'high confidence' statement might increase users' readiness to make decisions based on the information provided.

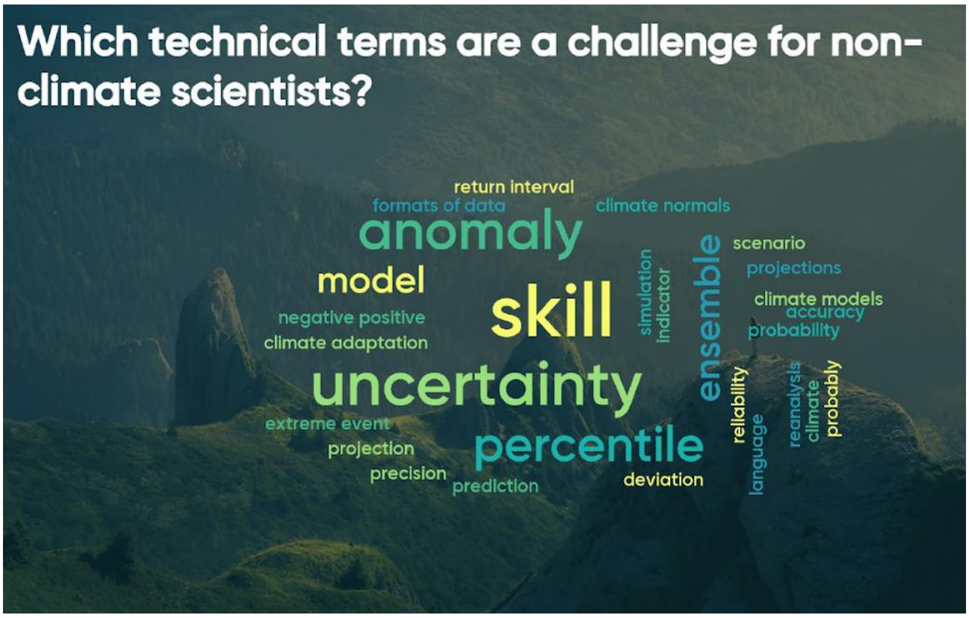

Figure 4-2: Technical terms often included in climate services visualisations

For cases where technical terms are included in visualisations, a common solution applied by various climate services projects consists in the development of glossaries that try to find a common ground between the scientific and stakeholder language. Ideally, the glossary should include examples that are sector-specific. Including a link to the glossary in the visualisation, or a way to interactively view the explanations without having to move back and forth between different pages of the portal is recommended. For instance, using tooltips that explain in short the meaning of specific terms in a visualisation is found to contribute to the common understanding of both climate service provider and user communities. In addition, video explanations or capsules are effective formats to explain terminology in a simple way and to build capacity among the user community.

Language barriers

Language can also be a barrier. This happens when the visualisation is provided in a language that is different from the mother tongue of the potential users, especially if they don't feel comfortable using it.

Workshop participants mentioned that many climate services visualisations use English. Various non-English speakers mentioned they had seen some visualisations in their mother tongue, although others indicated they had seen just a few or none.

Some participants highlighted the need to use local languages when giving instructions and guidance to stakeholders about how to use and interpret the visualisation, in spite of the extensive scientific information being provided in English. In this sense, the provision of summary documents in local languages was mentioned to be a good practice. Participants also highlighted the difficulty to provide multi-language visualisations when working at the European or global scale because of a lack of resources.

The development of visualisations in local languages was identified to be especially important when they are intended to be used by policy makers or local communities, advocating that the definition of an appropriate language should also be considered as part of the co-development of a climate service. Local languages are needed on occasions when it is difficult to translate particular terms related to local climate (e.g. snow types), which do not exist in some languages. The need for local languages may be higher depending on the sector. For instance, agriculture was mentioned to be a sector where many users are not familiar with English.

One participant made a comment about visuals and the fact that often they are more difficult to be translated than text explanations. This is something to be taken into account when providing a climate service. This participant mentioned that changing titles and other annotations from graphs and maps was more time consuming than translating text explanations.

Visual encoding

Visual encoding involves translating the data into a visual element on a chart, map or graph using visual properties as length, position, size, colour, slope, opacity, etc. In general, it can convey a higher amount of information in a single visualisation.

Some of the options for visual encoding that were discussed during the workshop include:

- The use of intuitive colours
- The use of colour-blind friendly palettes
- The use of shape (also including icons) and size
- The use of patterns
- The use of slope/angle
- The use of transparency/opacity

Colour palettes were identified as an important part of the visualisation of climate services, with the potential to help users understand the information; they can also cause confusion if used in the wrong way. Workshop participants mentioned that the choice of the colour palette needs to be intuitive and adequate for the variable or parameter that is represented, without exaggerating the changes. Also, when forecasts are compared to current conditions, the colour palette used for displaying present and future information should be the same, so maps or graphs can be directly compared. Keeping the same legend scale in both visualisations is also recommended. Participants also mentioned that in order to improve the accessibility of the climate service, colour-blind friendly palettes should be prioritised over other colour combinations.

Although the use of shapes and sizes is more common in climate visualisations, using slope and transparency were less familiar options for workshop participants and received less attention. Some climate service visualisations that make use of these elements were mentioned, which have been co-developed with visualisation experts and designers. However, a participant mentioned that in these cases the selected visual encoding did not always work, since sometimes users had some challenges understanding the prediction.

5 Recommendations for the development of the next generation of climate services

This last section contains the main recommendations provided by project participants based on their experience in the development of climate services visualisations. We hope these recommendations, that constitute one of the legacies from the Climateurope project, can support projects working in the development of climate services visualisations and that they can also be taken into account by the next generation of climate services projects.

- ❑ **Follow a user-centered design (UCD) approach**

  It is important to think about the challenges faced by users when using a climate service and to involve them from the beginning of the project. A UCD approach involves users throughout the design process, which gives climate service providers the possibility of improvement while designing the service, which makes the process of creating usable visualization tools based on user needs more efficient.

- ❑ **Add interaction and dosing of information**

  Adding interactive elements (e.g. filters, sliders, clickable options) and providing information progressively to users prevents information overload and increases the effectiveness of the interaction between the user and the visualisation.

- ❑ **Keep it simple**

  It's important to focus on the essential things that we want to communicate with the visualisation and to not overcomplicate. Give attention to the balance between scientific precision and simplicity in understanding.

- ❑ **Consider terminology and language**

  Trying to bring the visualisation closer to the user context means to speak the same language and use the vocabulary the user is familiar with. This allows the climate service user to focus on interpreting the information provided rather than trying to solve other challenges.

- ❑ **Rely on relationship building, storytelling, knowledge transfer, and training activities**

  Taking into account that climate services are constructed by more than just the visual aspects will relieve the pressure of trying to fit everything into one visualisation. Relying on other aspects - such as relationships building that result from an effective user engagement, the use of storytelling and narratives of climate change, and building capacity within the user community - can be an asset.

- ❑ **Put together multidisciplinary and transdisciplinary teams**

It is important to have multidisciplinary teams where social scientists, user experience designers, communication specialists, environmental economists, stakeholders and end users are involved and work together. It would also be helpful to involve different types of social scientists to work towards transdisciplinarity involving actors outside of academia. Take into account that this requires time, resources and predisposition, so plan it accordingly.

- **Think long-term**

  There should be a plan on what will happen to the climate service when the project is over, to avoid ending up with many individual platforms that in many cases are not maintained and that are difficult to find by users. It is important to avoid the fragmentation of knowledge.

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