Current Practice in Climate Service Visualization
Taking the Pulse of the Providers’ Community

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Climateurope Workshop on the Visualization of Climate Services

*What:* Barcelona Supercomputing Center’s (BSC) Earth Sciences Department organized the workshop in the framework of the Horizon 2020–funded Coordination and Support Action Climateurope. The workshop aimed to discuss different aspects of the state-of-the-art of visualizations used in climate services and produce a publication on the synthesis and recommendations. We invited participants from different projects linked to the Climateurope network, including EU Horizon 2020 (H2020) and European Research Area for Climate Services (ERA4CS) projects as well as a few national projects and private contracts. The workshop was attended by representatives of 22 projects.

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*Where:* Online

**KEYWORDS:** Climate services; Communications/decision making; Adaptation; Uncertainty
Effective visualizations of climate information that can be easily understood by non-climate experts are strongly needed. At present, the absence of a common or standardized visualization approach for climate services results in the application of different practices by climate service providers, sometimes leading to users’ misinterpretation or misuse of climate information. In this report, we analyze the outputs from a workshop with climate service providers that had the aim to identify current practices and challenges faced when developing visualizations in the field of climate services. The analysis of the results obtained depicted the current status of the climate services visualization field, identified the main lessons learned by different projects, and highlighted challenges that required further research efforts. Insights obtained from the analysis are valid for climate service providers worldwide.

The visualization workshop was organized in the framework of the EU-funded Horizon 2020 (H2020) Climateurope Coordination and Support Action on climate services. The workshop was attended by representatives from 22 projects working in climate services, including EU H2020 and European Research Area for Climate Services (ERA4CS) projects and a few national projects and private contracts. During the 2.5-h interactive session, participants were divided in breakout groups to discuss their experiences in the development of climate service visualizations and to share the lessons learned throughout the process. Breakout group discussions included topics on different visualization aspects, such as the added value of inter- and transdisciplinary approaches, different ways to visually communicate uncertainty, the use of interactive elements, and the importance of an appropriate terminology and language in visualizations. The feedback gathered during the discussions was analyzed using affinity maps, a qualitative analysis method using a coding technique that helped organize the information gathered in the discussion session into groups or themes of similar items and topics to categorize and extract relevant knowledge (Lucero 2015). The role of visualization in the field of climate services was also discussed (Fig. SB1 in the sidebar). Further details regarding the workshop can be found in Terrado et al. (2021).

**Current practice in climate service visualization**

The lack of clear guidelines for the development of climate service visualizations has resulted in climate service providers displaying information in different ways, depending on factors such as the level of visualization expertise of the working team, the level of user engagement applied, or the type of feedback received during the codesign process. Despite the specificities of the different climate services projects, some common patterns emerged from the discussions and are presented in the sections below.

**Moving toward transdisciplinary coproduction approaches.** Discussions during the workshop revealed that the development of climate service visualizations often applied interdisciplinary approaches, which involve coordinated collaboration among different disciplines (Max-Neef 2005). In addition to climate scientists, some project teams counted with experts in science communication, social sciences and humanities, and sometimes experts in user experience, which made it possible to define an interdisciplinary collaboration space.
ever, many projects acknowledged a lack of representation of particular profiles (e.g., data visualization experts, interface designers, specific expertise gathered under the umbrella of social sciences and humanities), making particular requirements for the codevelopment of the visualization more challenging to fulfill. In general, projects were aware of the importance of bringing stakeholders’ perspectives and experience into the design of climate service visualizations, which is a necessary step to move from interdisciplinary to transdisciplinary approaches (Max-Neef 2005; Bojovic et al. 2021). However, not all projects attained full transdisciplinarity and, in various instances, stakeholders were only reached out for final visualization testing.

**Testing visualizations with potential users.** Testing visualizations with potential users emerged as a common practice in the climate services field. However, not all the projects acknowledged an active involvement of stakeholders during the whole visualization design process, with some projects only performing the evaluation with the stakeholders at the end. Although this is still useful to identify some issues and ensure that the information is interpreted as intended by climate service providers, a truly collaborative and transdisciplinary codesign goes beyond final testing and entails involving stakeholders from the very beginning and throughout all the stages of the climate service codevelopment (McInerny et al. 2014; Lorenz et al. 2015; Grainger et al. 2020).

**A plethora of approaches to represent uncertainty in climate data.** Different ways of visualizing uncertainty were identified according to the visualization purpose, the target audience, and the time scale of the information provided. This applied to both first- and second-order uncertainty (Spiegelhalter et al. 2011; Taylor et al. 2015). Whereas first-order uncertainty refers to information on the likelihood of an event happening according to a particular forecast (i.e., probabilities or risk), second-order uncertainty refers to “uncertainty about the uncertainty” or ignorance (i.e., skill or spread), and exists because forecasts are not able to capture all the factors influencing the climate. Information on first- and second-order uncertainty can either be integrated in the same visual representation or presented separately using two different visualizations. Regarding first-order uncertainty, while some projects opted for showing the mean or median value of the modeled results without an indication of its probability of occurrence (Figs. 1a,b), other projects decided to display the information as anomalies (Fig. 1c), that is, the variation of a variable relative to the climatological normal or long-term average. Additional options to represent first-order uncertainty used by climate services projects included showing information through a number of categories, such as terciles or quintiles, either indicating the most likely category (Fig. 1d) or reporting the probability of the different categories to occur (Fig. 1e). An alternative option consisted in providing the probability distribution function (Fig. 1f), which gives an overview of the different amounts of change in a climate hazard and their respective likelihoods for a single point in time and a specific geographical area.

Even though showing second-order uncertainty was generally considered an exercise of transparency, some workshop participants considered that this information could be overwhelming or confusing for some users. For this reason, this information was not generally provided by climate services projects. When second-order uncertainty was not presented, some projects used scenario approaches displaying average values for different pathways, capturing the various plausible descriptions of how the system and/or its driving forces may develop in the future (Fig. 2a). In other cases, projects decided to keep particular climate information hidden from the visualization when the level of uncertainty was too high to use this information meaningfully in decision-making (Fig. 2b). In such cases, applied practices ranged from not providing any information about uncertainty, to replacing uncertain forecasts by a reference value (e.g., climatology). Further alternatives consisted in giving users the
possibility to hide or show high-uncertainty information (Fig. 2c) or allowing them to select a specific uncertainty threshold should they have an idea of the level of uncertainty they were ready to bear (Fig. 2d). Some projects also integrated second-order uncertainty through visual encoding (e.g., through transparency) (Fig. 2e) or showed it as a range in the plot, be it the full ensemble range, the standard deviation, confidence intervals, or the signal-to-noise ratio (Fig. 2f). Figures 1 and 2 show a nonexhaustive sample of ways to represent first- and second-order uncertainties in some climate service visualizations.

Use of interactive elements. A clear trend toward developing visualizations that allow the user to interact with the different elements was observed, in line with the assumption that understanding of information can be improved through greater interaction (Yi et al. 2007). The progressive disclosure of information, which aims at the initial simplification of information followed by the possibility to reveal additional options and content, was identified as a commonly applied technique in the field of climate service visualization, which also grants users a more active role (Bostrom et al. 2008; Spiegelhalter et al. 2011). However, in the case of particular types of services (e.g., dashboards), participants pointed out that users had explicitly indicated their need to access all resources simultaneously. For particular formats that allow low or no interactivity (e.g., factsheets, newsletters or bulletins, direct advice), it was also indicated that they could be effectively used. In the end, understanding when and how to integrate interactivity requires careful considerations of both users’ requirements and tool’s functionality.

Differences in terminology used by scientific and stakeholder communities. The climate services community involved in the workshop identified more than 25 technical terms commonly used in the field of climate science that are confusing or not well understood by stakeholders outside academia. The more frequently repeated terms were “skill,” “anomaly,” “reliability,” “uncertainty,” “percentile,” “ensemble,” and “model” (Fig. 3). Project representatives also mentioned that the use of conventions such as “likely” or “unlikely” or the distinction between temporal forecasting scales (e.g., hindcasts, climate predictions, climate projections) can make sense in the context of climate science, but that stakeholders are not aware of such distinctions. Participants agreed that more resources should be put in place to overcome the terminology barrier, both among different academic disciplines and between academia and stakeholders, since the same term can be differently understood by these groups. Discussions indicated that terminology should be adapted when possible, even if it involves compromising scientific precision. Otherwise, explanations in lay language should be offered. Although this may not be straightforward and can induce some tensions during the coproduction process, overall, it will prevent wasting time discussing complex terminology concepts and will allow stakeholders to focus on the interpretation of the information. The use of glossaries and thesauruses emerged from the discussions as a good practice to try to find a common ground between the different communities. These tools can also include use case examples to illustrate the term in the context of the target users. Using elements such as tooltip hints, defining technical terms, and hyperlinks to additional explanation were also mentioned to help build a greater understanding.
Fig. 2. Representation of second-order uncertainty in different climate service visualizations: (a) forecast information shown, no indication of uncertainty, (b) high-uncertainty information not shown (e.g., replaced by a reference), no indication of uncertainty, (c) possibility to hide/show high-uncertainty information (e.g., activation of a mask), (d) possibility to hide/show information with different levels of uncertainty (e.g., filter by threshold), (e) uncertainty integrated in the visualization through visual encoding, and (f) uncertainty represented as an additional parameter (e.g., uncertainty range). Source projects: (a) C3S Press Data Portal (https://climate.copernicus.eu/press-data-portal), (b) VISCA (Marcos-Matamoros et al. 2020), (c) MED-GOLD (https://dashboard.med-gold.eu), (d) S2S4E (www.s2s4e-dst.bsc.es), (e) Project Ukko (www.project-ukko.net), and (f) CIREG.
Taking the vernacular language of target audiences into account. An additional factor for misinterpretation arises when the native language of stakeholders is different from that of the producer of the climate information (WMO 2008). Many of the projects involved in the workshop were run at the European or multicountry scale. To adhere to users’ preferences, such scales require a multilanguage approach that can become a challenge for the development of visualizations. Therefore, English was a dominant language used in the visualizations developed by the different projects. However, the proportion of climate services in local languages may be substantially higher when moving to the national, regional, and local scales. Despite many climate service visualizations being available in English, project representatives mentioned that, when needed, engagement activities with stakeholders were conducted in local languages to ensure understanding. For that, summary documents, including user guides and illustrative figures, were developed in stakeholders’ languages. Related to the use of figures, one of the participants mentioned that the translation of text labels in visuals tends to be more time consuming than translating text explanations. Participants also mentioned that having visualizations in local languages was particularly needed for specific terminology lying in the traditional knowledge domain of local and indigenous communities (e.g., Arctic regions, Pacific Islands). Such terms, that for instance can refer to the characteristics of the local climate, often lack a translation in other languages (e.g., snow types in polar regions; see Eira et al. 2013). Discussions suggested that the definition of an appropriate language should be considered as part of the coproduction of a climate service. This involves tailoring information to match the language in which intended users are accustomed to working as well as the consideration of other elements that enhance usability (Miraz et al. 2016).

Lessons learned
Data visualizations, like charts, graphs, and maps, make it easy for many audiences to identify and understand patterns in climate data. But when not done properly, they can exclude audiences with visual or cognitive disabilities or those that lack appropriate background knowledge. This work analyses the current status of the climate service visualization field and identifies challenges to be tackled for the development of more effective visualizations. The main challenges include the advancement of the climate services field toward a real...
The role of visualization in climate services

The climate services community highlighted nine main purposes (Fig. SB1):

1) **Targeted communication and outreach**: Convey messages in a more direct and illustrative way and give the advantage of reaching wider audiences beyond the specialized ones.

2) **Storytelling from data**: Support data exploration and help to extract the underlying information and patterns in data, which makes it possible to tell a story and develop climate change narratives.

3) **Ease decision-making**: Increase understanding, allow users to reach conclusions, and ultimately, enhance their ability to complete a task or make an informed decision.

4) **Simplify complexity**: Deliver complex information in a simplified way, which may require transforming data into a smaller and more manageable dataset or paying special attention to visual encoding, encompassing the representation of information with graphical features.

5) **Transfer knowledge**: Reach various audiences with the aim to facilitate understanding and boost knowledge uptake.

6) **Raise awareness/call for action**: Raise awareness and elicit affective responses, improving the likelihood for action.

7) **Attractiveness**: Aspect worth considering if striving to create something memorable that helps to catch people’s attention or increase trust.

8) **Engagement**: Stimulate public willingness to engage with a particular issue and visualization used as a conversation starter and to support the communication process.

9) **Add layers of information**: Combine information coming from various sources and find new relationships among different datasets, which can be interpreted more easily in a visual format.

### Fig. SB1. The identified purposes of visualization in climate services.

transdisciplinary approach by effectively involving other disciplines and stakeholders in the visualization coproduction process, a better coevaluation of visualizations, a more effective representation of uncertainty in climate data, and bringing the terminology and language closer to those used by target audiences. For the development of more effective climate service visualizations, the climate science field may benefit from advances in other disciplines with a well-founded tradition, such as user experience, data visualization, graphic design, or psychology, which are strongly based on stakeholders’ needs. Only by including the expertise from other disciplines will climate service visualizations be able to build trust, prevent misuse of climate knowledge, and boost the uptake of climate information by society. This is a necessary step to move toward the codevelopment of common and agreed guidance and best practices necessary to achieve coherent and effective visualizations in climate services.
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References


