Climate Services 9 (2018) 21–32

Contents lists available at ScienceDirect

Climate Services

journal homepage: www.elsevier.com/locate/cliser

What have we learnt from EUPORIAS climate service prototypes?

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A R T I C L E I N F O

Article history:
Received 19 December 2016
Received in revised form 27 April 2017
Accepted 2 June 2017
Available online 3 July 2017

A B S T R A C T

The international effort toward climate services, epitomised by the development of the Global Framework for Climate Services and, more recently the launch of Copernicus Climate Change Service has renewed interest in the users and the role they can play in shaping the services they will eventually use. Here we critically analyse the results of the five climate service prototypes that were developed as part of the EU funded project EUPORIAS.

Starting from the experience acquired in each of the projects we attempt to distil a few key lessons which, we believe, will be relevant to the wider community of climate service developers.

Practical Implications

The paper, which is structured around the experience acquired during the development of the five climate service prototypes, distills a few key reflections which should be of general relevance to a wide community of climate service developers and funders. The top level practical implications can be summarised as:

- The experience of EUPORIAS suggests that the interaction with the users during the development of a climate service cannot be sporadic and cannot simply occur at the beginning (e.g. service definition) and at the end (e.g. service evaluation) of the service development.
- Allocating sufficient time to the dialogue with the user and to the consequential change in the domain definition and scope of the services being developed is essential to the success of these services.
- On top of the objective benefits that users could gain from a climate services tailored to their needs, the access to climate expertise during the development of the service represents an important added value to users.
- Top-down management practices are not necessarily the most suitable for developing climate services. Adopting a flexible management approach (e.g. Agile) can be an advantage in an environment where changes in scope in response to users feedback are to be expected.

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http://dx.doi.org/10.1016/j.cliser.2017.06.003
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- User representation (or lack thereof) in the governance structures of climate service projects and the way in which these projects are linked to downstream business opportunities have a direct impact on their ultimate usefulness to society. If we want climate services to succeed we should be prepared to challenge and possibly change the way in which users are involved in and interact with climate service projects.

1. Introduction

The Global Framework for Climate Services put a new emphasis on the role of users in service development and it is now clear that producing high-quality and credible information about the natural world alone is insufficient to ensure the production of useful climate information for decision support (Hewitt et al., 2012). Producing actionable climate information that addresses users' needs is a complex, highly contextual social process (McNie, 2013). In an attempt to address this critical issue and narrow the usability gap (Lemos et al., 2012) a set of climate service prototypes were developed within the EU funded project EUPORIAS (Hewitt et al., 2013). Starting from the idea of a climate service codesign (Cash et al., 2003), the project was initiated without specifying in advance which case studies or users would be targeted by the project (Buontempo et al., 2014).

EUPORIAS focussed specifically on the climate predictions timescale but whilst the project was open to consider services based on decadal prediction all the prototypes proposed were based on seasonal prediction data. Both hindcast and forecast data used by the prototypes originated from the Global Producing Centres for Long-Range Forecasts (GPCLRFs) of the World Meteorological Organisation operating in Europe namely Météo France, Met Office and ECMWF.

The ambition was to identify and develop only those services that had a tangible user drive and which were also most likely to provide valuable results. Having a user component in the definition of the issue to be addressed was believed to be an effective way to promote a sustained dialogue between users and providers which can itself contribute to the creation of legitimacy and trust (Lemos and Morehouse, 2005; Vaughan and Dessai, 2014). Rather than focusing on the specifics of each of the prototypes that have been developed, the paper attempts a "synoptic" evaluation of some of the most relevant aspects that were common to most prototypes. Section 1 presents the prototype selection and its outcome, Sections 2–5 focus on some of the specific challenges and lessons learnt. These have been clustered under a series of generic headings indicative of the most common challenges encountered. Fig. 1 shows how each of the different prototypes compare with one another in relation to the challenges discussed in the Sections 2–6. Finally Section 7 summarises the main conclusions (see Fig. 2).

1.1. Prototype selection

In most research projects, once funded the individual partners pursue a set of tasks largely agreed at the start of the project, or more commonly, before the project commenced. It is therefore often relatively difficult to follow a work programme which evolves strongly as it progresses, or has resource allocated for undefined tasks, both common features of user-driven research. Whilst changing this status quo is a major challenge within the lifetime of a single research project, involving all partners in the definition of the criteria for the prototype selection was useful for the EUPORIAS project and provided a refreshing perspective to the use-cases. This inclusive approach complemented the ethos of the overall project as, within the constraints of the funding structure (e.g. the allocation of funding across project partners which was defined in the project grant) EUPORIAS sought to involve users directly in the governance of the project and include them in the problem definition.

The prototype selection procedure was structured over two independent and distinct phases. First the general criteria that contribute to the usefulness and success of a climate service were identified and agreed upon by all project participants. Two overarching criteria were given a disproportionate weight: the presence of a well identified user who had a clearly formulated question and the evidence of the existence of sufficient skill in the prediction of the relevant parameters. Then each project partner was invited to submit one or more prototype proposals for evaluation. Finally the management board of the project appointed an external panel made up of three experts to decide on the ranking of each proposal using the criteria selected. Fig. 2 shows a simple flow diagram of the selection procedure.

A copy of the selection criteria is included in the technical annex. The process worked well and, despite initial worries, contributed to building a cohesive environment among project partners. Five prototypes were selected:

- LEAP, led by ENEA in Italy and World food Programme aimed at upgrading an existing food-security early warning platform for Ethiopia through the inclusion of seasonal forecasts.
- SPRINT, led by Met Office, focused on provide advice towards decision-makers operating in the transport sector in the UK about the upcoming winter conditions.
- LMTool, also led by Met Office provided seasonal climate guidances to farmers in the South West of the UK.
- RIFF, led by Météo France, focussed on the management of freshwater water reservoir during summer periods near Paris.
- RESILIENCE, led by BSC in Spain, targeted the provision of global wind predictions for the energy sector on a seasonal timescale.

More information on the specific implementation is available in other papers within this issue

Further to these prototypes there was an additional prototype developed by SMHI for Elforsk about hydropower production in Sweden and a number of case studies which won't be presented in these pages.

A clear limitation of the selection process was the inability to alter the funding allocation among partners depending on the distribution of the prototypes. Although there might have been ways to add flexibility in the administration of the research grant it was felt that it would have been too difficult to manage the project and maintain project cohesion. Our experience could suggest that developing alternative funding streams which link users and providers more directly could have a positive impact on climate model development.

2. Broad or deep?

One of the challenges climate services development faces is to find the right balance between a bespoke service designed for a specific user and the ability to mainstream their production. EUPORIAS was designed as an experiment to overcome some of the limitations identified in the provision of generic, albeit highly

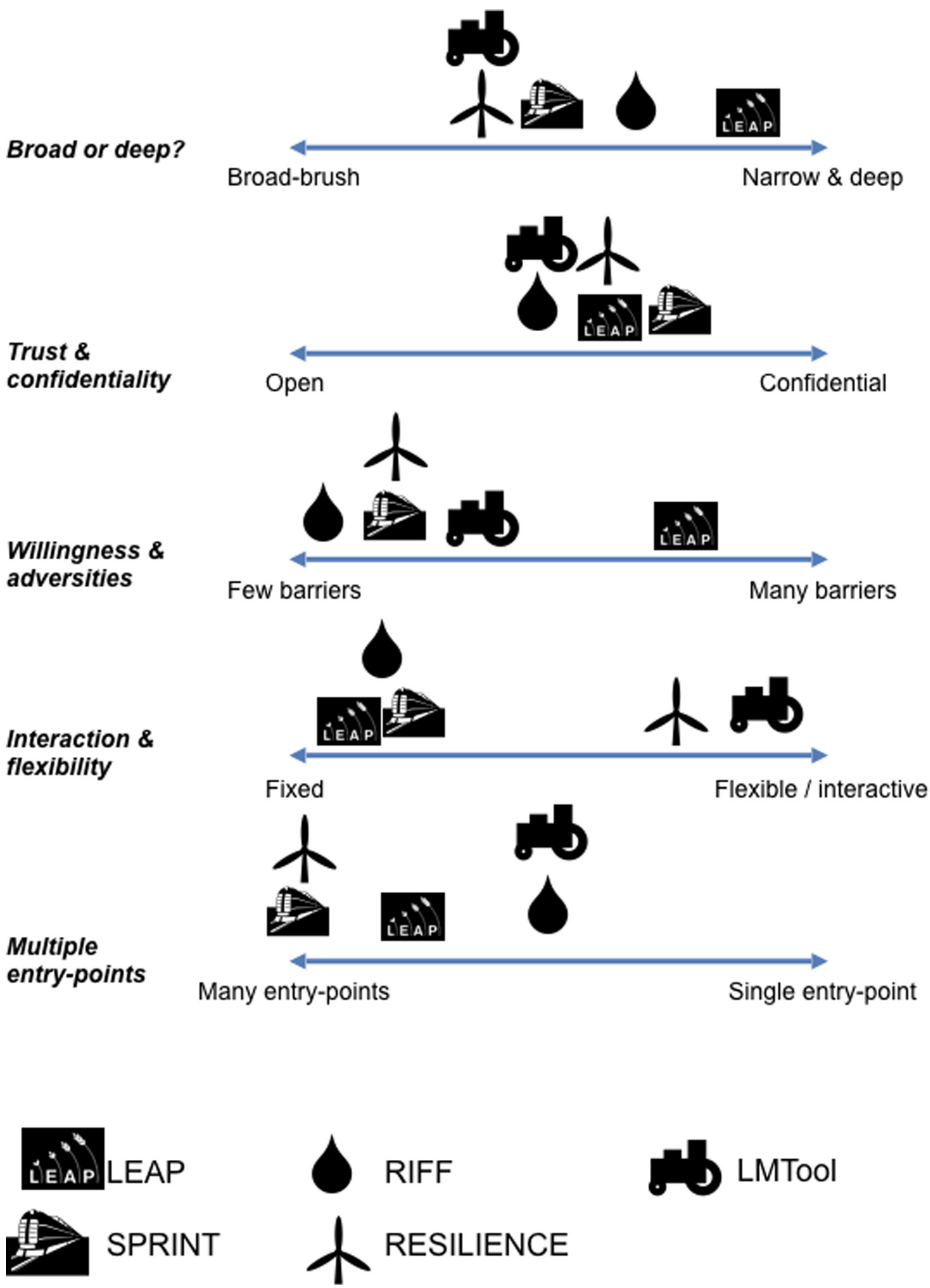

Fig. 1. A schematic representation of how EUPORIAS prototypes relate to the top level challenges identified in the Sections 2–6 of this papers.

sophisticated, climate information to users (Tang and Dessai, 2012).

The prototypes represented a trade-off between two opposite pushes. On the one hand the project was designed to deliver very deep and narrow services addressing the need of a specified user. On the other hand the partners were keen to develop services addressing a variety of users as these are more likely to attract wider attention and consequently facilitate long-term sustainability. For this reason a strong emphasis on the identification of a clear end-user who could benefit directly from the service was maintained throughout the prototypes definition phase.

For example, the SPRINT prototype trialled a new potential service forecasting winter impacts for UK stakeholders in the transport sector. This project was co-funded by the UK Department for Transport and involved multiple transport stakeholders with interests in UK rail, road and aviation. Managing multiple

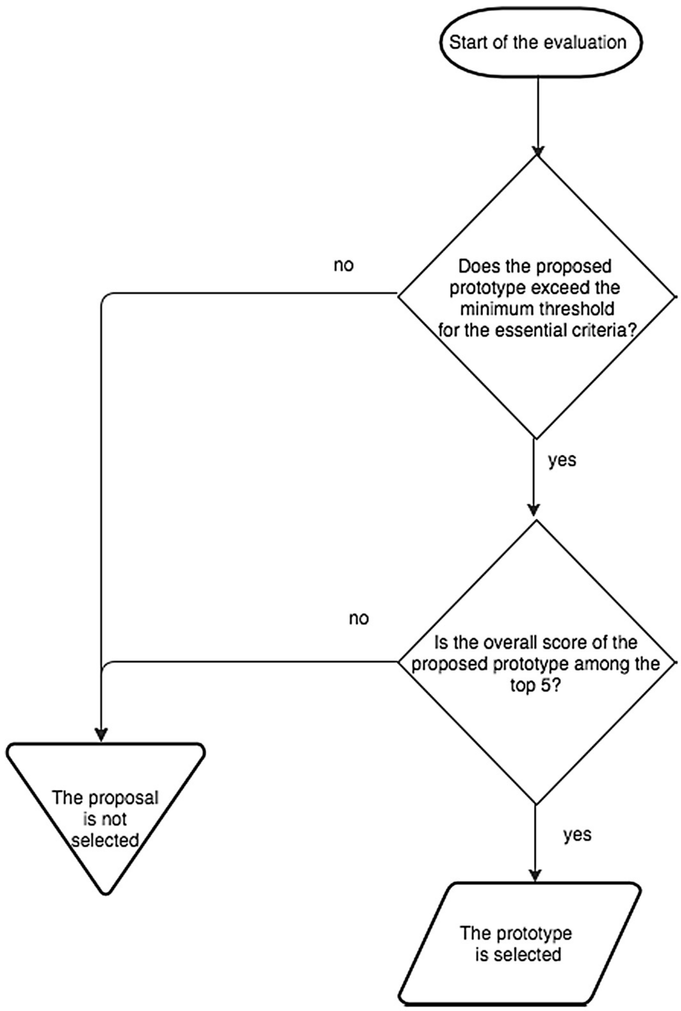

Fig. 2. A schematic flow diagram explaining the procedure followed by the expert panel for selecting the prototypes.

stakeholders with a variety of different requirements and expectations raised some issues, particularly with the format and dissemination of the forecast.

For example, some users wished to receive short, headline-type statements that could be easily disseminated onward in their organisation, whilst others appreciated more detailed information explaining the science behind the headlines. Providing usable guidance required a clear explanation of the uncertainty surrounding the forecast. During the development of this prototype the team worked with the users to determine how best to represent this uncertainty, and made some changes to how the information was visualised in the documentation sent out in response to the comments of the users. It was found that some users felt the longer lead time (3-month lead outlook) information was too uncertain for them to make decisions on whilst others appreciated receiving the 3-month lead outlook despite the greater uncertainty. In general, most participants found the 1-month lead time information accurate and useful for planning decisions. However, the SPRINT team also found that many of the prototype's users required a number of different services spanning different time frames, to aid their decision-making.

Within the SPRINT prototype end-user impact data was combined with the UK NAO forecast, using a statistical model, to create a forecast for that specific impact. A conceptual example of a forecast is shown in Fig. 3. Impact metrics were considered across transport modes (Palin et al., 2016) and included road salt usage, number of weather-related incidents on the railway, and number of British Airways aircraft de-iced at London Heathrow Airport.

The effect of the North Atlantic Oscillation (NAO) on UK climate can be similar for a wide area; however the impact seen at a particular location is dependent not only on the severity of the weather but also on the vulnerability of that location – or the assets/operations employed there – to the climate extreme(s) in question. As such, the impact forecast was most appropriate for the location/asset/function to which the data related. So, if the model were based on impact data from a different location, this would limit the utility of the information to end users elsewhere due to the differing vulnerabilities to weather in different places.

A rather different strategy was followed by the Météo France team developing the RIFF prototype for the water sector. It soon became obvious that each of the three targeted end users responded to different drivers (e.g. managing low flow and/or flood risk), objectives (e.g. dam management) and the economic stakes, factors which were then reflected in a rather different approach to strategic seasonal planning. Rather than delivering a cross-sector service based on seasonal forecasts, something that would not have allowed for an assessment of the usefulness of the prototype, the team decided to focus first on only one stakeholder, EPTB Seine Grands-Lacs (SGL), which showed most enthusiasm for the project and had resources available to support the intensive work required. In a later stage another important stakeholder involved in the project, the Syndicat Mixte d'Etude et d'Aménagement de

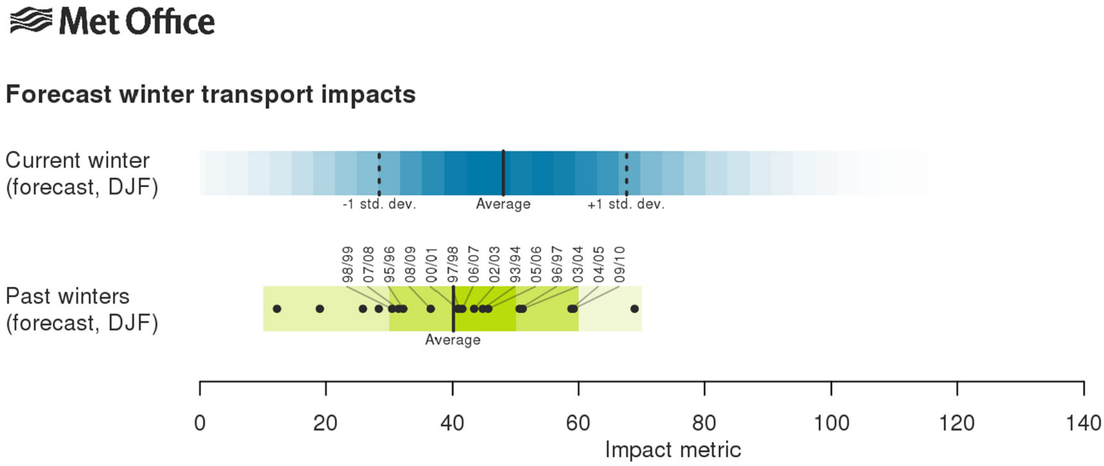

Fig. 3. Example of a transport impact forecast for a particular impact metric. The current forecast (top) includes a measure of the uncertainty across the forecast ensemble, and is compared with retrospective forecasts of mean impacts for previous years (bottom).

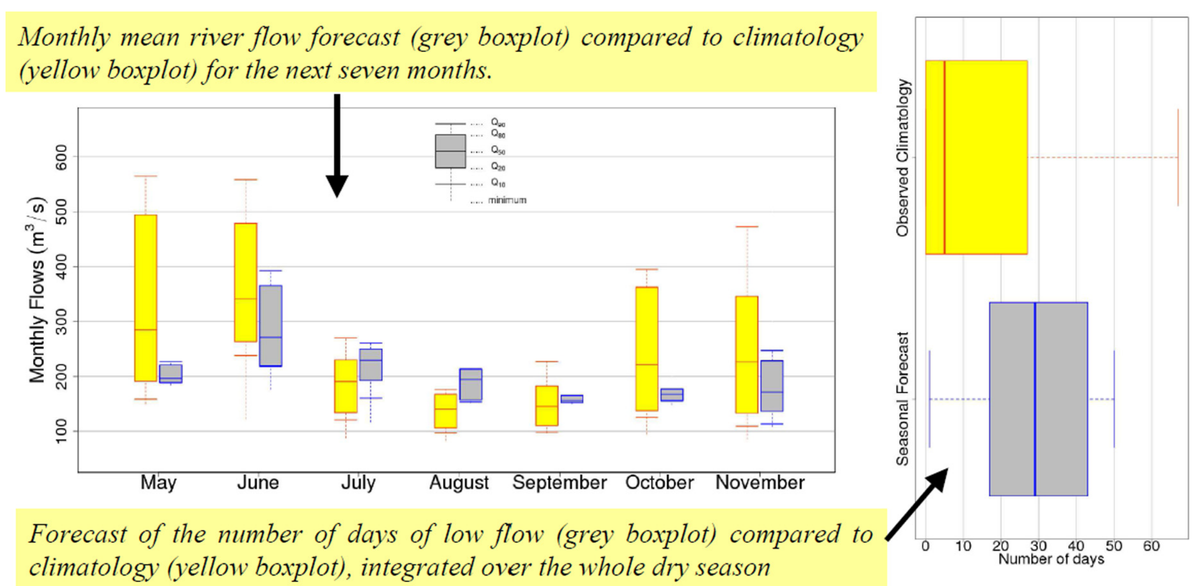

Fig. 4. An example of the comparison between climatological ranges and seasonal predictions of river flow analysed as part of the development of RIFF prototype.

la Garonne (SMEAG), ran the prototype operationally during summer 2016.

3. Trust and confidentiality

One of the most critical aspects of climate service development is the need to develop an environment of mutual trust between the users and providers. The RIFF prototype provides a good example of one of the surprises many of the prototype teams faced during the development of the services. Contrary to initial expectations, the challenge during the prototype development not only related to the transformation of information emerging from a complex suite of physical models developed in a research context to an operational tool operating at a seasonal time scale. It was also related to the need to rapidly learn how to build a trusting collaboration with the users to jointly define a tailored service adapted to their needs. Sharing company specific details and practice is always challenging in a commercial or otherwise competitive environment, particularly where multiple businesses are involved in a common research project. But this becomes utterly impossible in the absence of trust between the parties involved in the development of the service. Trust building has been recognised to be essential to the development of successful services (Brooks, 2013).

Confidentiality was therefore of paramount concern for many stakeholders in the project. Within SPRINT some wanted their operational data to be keep confidential, while for others it was about not openly publishing the actual forecast for their impact before they got a chance to analyse it and make their decisions based on that forecast. All organisations are interested in managing reputational risks as well as financial risks; additionally, some stakeholders in the project may be competing with other similar organisations. Conversely, in line with EC regulation, the ethos of EUPORIAS is to publish and present its findings openly; hence the EUPORIAS deliverables required some flexibility in presenting project outcomes while still respecting confidentiality. This meant a small amount of extra time was needed from the Met Office for rewriting or re- visualising forecasts for the SPRINT prototype, omitting the confidential parts (e.g. presenting a “real” impact forecast, but omitting the details of which impact was shown,

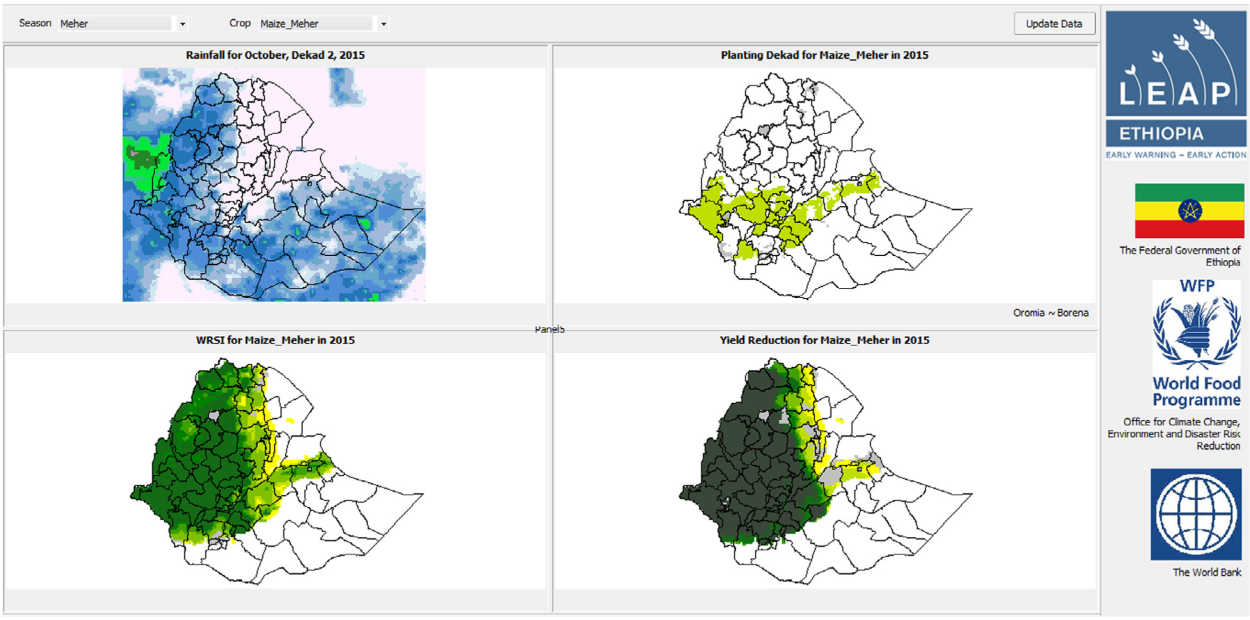

Fig. 5. A snapshot of the main LEAP user interface. The user has direct access to a number of parameters that are useful to monitor the food security situation in real-time: rainfall patterns, farming conditions, drought indices and projected yield.

and/or the range of forecast values). It was also an advantage that stakeholders involved in the group were respectful of each other's confidentiality requirements. Having this trust amongst our stakeholder group allowed us to disseminate the forecasts together in one teleconference and one set of supporting material, rather than preparing and delivering to each individually, which would not have been possible with such a large group. In the case of the RIFF prototype and more widely in the water management sector the details of the Decision Making Process (DMP) have a significant commercial (and more widely societal) value as they are at the core of the all the economical (and environmental) activities on the territory needing water resource. It would not have been possible to have access to those in the absence of trust. At least in this case the trust building activity was a two-way undertaking. On the one hand the team at Météo France was learning about the specific vulnerabilities, decision points and sensitivities of the users, on the other hand, the user gradually familiarised to the main concepts of seasonal forecasts and their limitations.

This trust-building phase was a necessary step for the following one, namely the evaluation of how, if at all, seasonal predictions implemented for RIFF affected the final decision and the benefit of using it. SGL replayed 29 years of decision making as a blind test according to a specific "Placebo protocol" (Viel et al., 2016) defined with the user. A metric based on the number of days spent below their vigilance threshold (Fig. 4) was identified to analyse the success of each decision. This experiment, beyond its results (a little added-value of SF versus historical simulations, but not significant), was probably the most efficient user engagement tool. It sped up many aspects of the project, such as service design, timing, knowledge exchange and recognition of seasonal forecasting limitations. It also positively influence the user uptake of the product. After a common debriefing of this assessment phase, feedback from SGL was very positive, much more than what we would have expect from the quantitative scores of the seasonal forecast alone. Thanks to this collaboration, the users learnt from their own experience that there are opportunities to improve their decisions by including climate information in the decision process. The experiment also provided an opportunity to look more analytically at the DMP within the SGL and its sensitivity to climate information.

4. Willingness and adversities

Even when external constraints make the development of a bottom-up service challenging the adoption of a user-centric perspective can lead to a series of tangible benefits.

The Livelihoods, Early Assessment and Protection project (LEAP) platform (Fig. 5) was developed in 2008 by the Government of Ethiopia with the technical support of the United Nations World Food Programme (WFP) and the financial support of the World Bank to monitor the food security situation in the country (Hoefsloot and Calmanti, 2012).

The software uses agro-meteorological monitoring data to estimate future crop yields and converts these estimates into the number of people, by district and region, projected to be in need of assistance. This number could then be used to calculate the financial resources necessary to scale up the Productive Safety Net Programme (PSNP) in Ethiopia, Sub Saharan Africa's largest social safety net, and enable households to receive early livelihood protection before they start engaging in negative coping strategies. Within EUPORIAS, the LEAP prototype planned the addition of seasonal forecast capabilities to the LEAP platform with the expectation this would have provided tangible benefits to the activities of both the Ethiopian Government and key international relief and development actors, in responding to food security crises.

The potential for rainfall predictability in East Africa has been known for a relatively long time. It has been demonstrated that a simple statistical algorithm based on sea surface temperature (SST) predictors has a ROC skill score (a measure of hits and misses relative to false alarms) as high as 0.92 in the north of Ethiopia (Diro et al., 2011). Currently, SST-based statistical seasonal forecasting algorithms (Korecha and Barnston, 2007) are frequently used at the National Meteorological Agency of Ethiopia.

Indeed, the research provided solid ground for upgrading of the drought early warning system in Ethiopia. However, the full buy-in from the Government of Ethiopia has been slow, mostly due to the complex political processes within the country and climate-driven shocks that have occurred during the life of EUPORIAS. On the political side, a major restructuring took place within the Government, with the department formerly in charge of LEAP (the Disaster Risk

Management and Food Security Sector of the Ministry of Agriculture) being reorganised, with the platform now sitting under the National Disaster Risk Management Commission, and directly reporting to the Prime Minister's Office. Simultaneously, a change of leadership happened at the Government level, with the replacement of senior staff in charge of managing LEAP. At the same time, the El Nino-driven food security emergency of 2015 diverted most of the attention of the Government and of WFP in Ethiopia from improvements and innovations of the early warning system towards actually managing the crisis (Drought Tests Ethiopia, 2016) at a cost of around US$ 1.4 billion (HRD, 2015).

The 2015 agricultural season in Ethiopia witnessed one of the worst drought events in the last thirty years, prompting a massive response from the Ethiopian government and international partners. It is estimated that more than ten million people (http://www.bbc.co.uk/news/world-africa-35038878 retrieved on 13/12/2016) were in need of food assistance due to the drought during the main rainy season. Despite the occurrence of adverse external events during the course of project, there is evidence that EUPORIAS will have a significant impact in improving the response to food security crises in Ethiopia, beyond the duration of the project itself. This is due mostly to the positive outcomes of the LEAP seasonal forecast Cost Benefit Analysis (CBA) conducted during the project. The CBA has been conducted by comparing the cost of late aid, with the cost of an early intervention triggered by forecasts plus the possible remainder which could be needed at the end of the crop season if the forecast did not trigger enough resources. The analysis shows that the introduction of LEAP Forecast could save $125m over a period of eight years compared to a scenario without forecasts, and provides a clear economic rationale for the introduction of such improvements within LEAP. As an outcome, in 2016 WFP renewed its dialogue with the Government of Ethiopia to promote a more systematic use of seasonal forecast products in the national drought early warning system. A renewed dialogue with the Government of Ethiopia is very likely to improve the analysis and factor-in the benefits of other ad-hoc interventions that seasonal forecast could trigger, with a deeper impact on livelihoods and society.

5. Interaction and flexibility

Developing user led services means, among other things, having the ability to respond rapidly to the change in scope to address users' feedbacks. This feature was exemplified within the EUPORIAS Land Management Tool (LMTool). This prototype is a semi-operational climate service providing seasonal climate forecasts (1–3 months ahead) to support land management-related decisions for South West UK (for more see Falloon et al. in this special issue). The tool focuses on the winter months since the prediction of the NAO allows for better seasonal forecasts of the Northern Europe winter climate (Scaife et al., 2014). The tool was developed by an interdisciplinary team of partners – the UK Met Office, University of Leeds, Predictia and KNMI – in close collaboration with the Clinton Devon Estates (CDE) and the National Farmers Union (NFU). The LMTool was iteratively co-developed between January 2014 and May 2016 with farmers and land managers in that region through a range of engagement activities (i.e. workshops, interviews, surveys and feedback forms) informing technical aspects of the tool (cf. Falloon et al. 2018). The LMTool was developed taking into consideration the principles of climate services development (see www.euporias.eu/symposium for more information) which emerged from the ECOMS initiative. These principles underpinned the development of the LMTool throughout its duration and helped guide and frame the work of the team as well as the interactions with the farmers and land managers involved (Fig. 6).

From a methodological perspective, the LMTool employed a mixed methods approach throughout the development of the tool, including survey, interviews and a workshop with the farmers involved. This in turn, allowed the collection and triangulation of data acquired with regards to the farmers' information needs as well as the continuous improvement of the technical aspects of the tool (Gray, 2009). An Agile approach was also implemented with regard to project management which allowed the team to address emerging issues and unpredictable situations in the development of the tool. Using the principles of climate services development (PCSD), together with the methodological approaches adopted, allowed a degree of flexibility and response to changes throughout the whole process of developing the tool. Below we describe a few examples of how the adoption of these principles and approaches allowed the LMTool team to respond and adequately change the direction of the work developed in response to the farmers' requirements and needs. Based on the PCSDs and Agile approach, the project was split into different components: service/product development, stakeholder engagement and external communications activities (which were then subdivided into subtasks as appropriate). This allowed the development team the flexibility required to accommodate changes e.g. redefine the scope of the tool. For example, the initial idea was to engage with farmers in the South West UK (given the involvement and contacts within Clinton Devon Estate in this prototype) with a potential wider application in the farming sector and other regions. A scoping workshop was held with high level representatives of CDE which broadly defined the potential focus of the prototype as winter cover crops. However, following the first interviews conducted with the CDE farmers, the team quickly realised that most of them were not interested in cover crops but rather on other types of land decisions for which seasonal forecasts could be useful. Based on this key finding the team, the flexible approach allowed the team to adjust the scope and focus of the LMTool in order to encompass other types of land-management decisions beyond those related to cover crops.

Also underpinned by the PCSDs and the mixed methods approach adopted, the LMTool development was informed by the needs and requirements of the farmers through a range of engagement activities (interviews, workshops, feedback gathering, surveys). This was an iterative and continual process between the LMTool team and the farmers which allowed not only changes in the scope (as mentioned earlier) but also in service provision (e.g. farmers requested 14-days forecasts alongside the seasonal forecasts). As a direct result of this, the team involved in the service provision changed in response to these evolving demands from the farmers. The changes in the LMTool based on such demands were then communicated back to the farmers regularly, also identifying suggested changes that had not been made, and explaining the reasons why. The close working relationship between the LMTool team and farmers also facilitated transparent discussions about what outcomes were achievable. Another benefit of this close interaction with the farmers was that it helped the project team to understand the (potential) value of the LMTool to the farmers, an important consideration which was explored through interviews and a workshop. The prototype nature of the project also helped the LMTool team to understand better the process of developing a prototype climate service for land managers as well as lessons for future work. As with other EUPORIAS prototypes, the close relationship with the final user enabled the project team to expand on the service delivered to address further user needs, adding extra value to the stakeholder.

6. Multiple entry-points

The primary aim of the RESILIENCE prototype was to provide probabilistic climate predictions for strengthening the efficiency

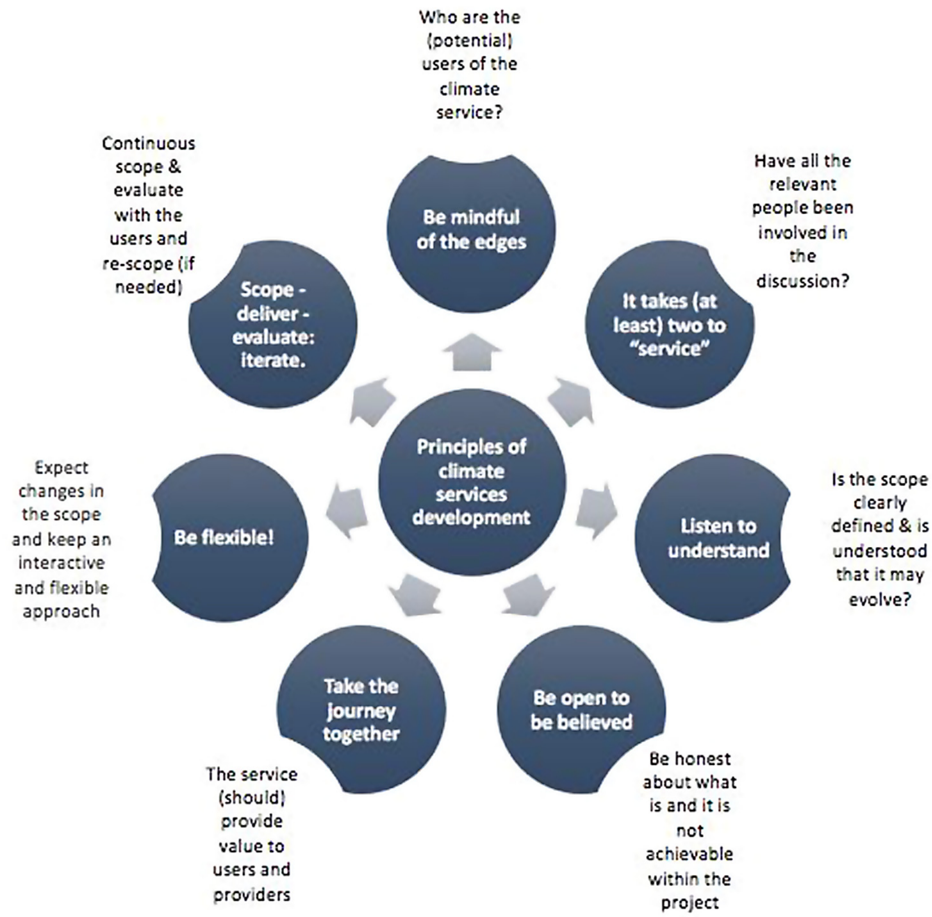

Fig. 6. The principles of climate services development.

and security of power generation and supply within energy networks. However, as the development of the prototype engaged with the energy community, the complexity of the user landscape within the energy sector emerged as a challenge. In order to progress with the prototype design it was necessary to narrow the focus on a specific subset of the energy system. Wind power was selected rather than solar energy or power demand, as these would have required different types of climate information. But despite this narrowing of the scope on wind power generation, the proposition (understanding and quantifying the wind resource), is key to multiple user profiles in the wind energy sector both in pre- and post-construction stages of wind farms. Transmission System Operators, Operations and Maintenance teams, the financial teams of wind farm owners or energy traders, are only some of the user profiles that use wind speed information to forecast future conditions based on retrospective climate information (Landberg et al., 2003; Sanz, 2010) and therefore, they are potential users of the RESILIENCE climate service. For this reason, a progressive further narrowing of the end-user profile and scope of the prototype was needed driven by the question 'Who is the user?'

The situation faced by the RESILIENCE prototype is not new in the development of the climate services field. Despite the effort to focus on a single sector and the recurrent reference to end-users, most solutions aim to provide as much information and cover as many user needs as possible. In fact, the development of climate services is underpinned by a scientific community which is biased towards the provider perspective in a common situation of "a solution in search of a problem". As illustrated with the energy field, many sectors do not consist of an homogeneous group of people but a constellation of professional profiles, economic interests and activities (Dessai and Bruno Soares, 2015). This diversity is found not only across stakeholders but also within a single organisation where each department performs different activities and may have different short-term objectives and priorities. Many user profiles require different types of information (e.g. different regional and temporal scales), and there is no feasible way to satisfy all the needs of this complex users' landscape at a time and with a uniform approach. A user-driven approach requires a bottom-up approach that should start by defining the user and its climate information needs, and that should later define how those needs can be fulfilled using climate predictions. Although working with wind speed predictions seemed initially a narrow and focused objective, user engagement activities demonstrated that there were still a high variety of users and needs, and therefore, of decision types with varying risks and extent of potential losses and benefits. This was made particularly obvious when developing the visualisation tool Project Ukko (www.project-ukko.net), a user interface that provides useful and usable information of the future variability in wind resources for the wind energy sector (Fig. 7).

Although the final user evaluation was positive and indicated interest by the users (Makri, 2015), the decision to focus on a set of users (energy traders) instead of a single user champion limited some parts of the design and development of the interface. A visualisation tool like Project Ukko simply provides relevant information to a user, while a decision support tool is an information system that additionally supports actual decision-making. In order to switch from a visualisation tool to a decision support tool,

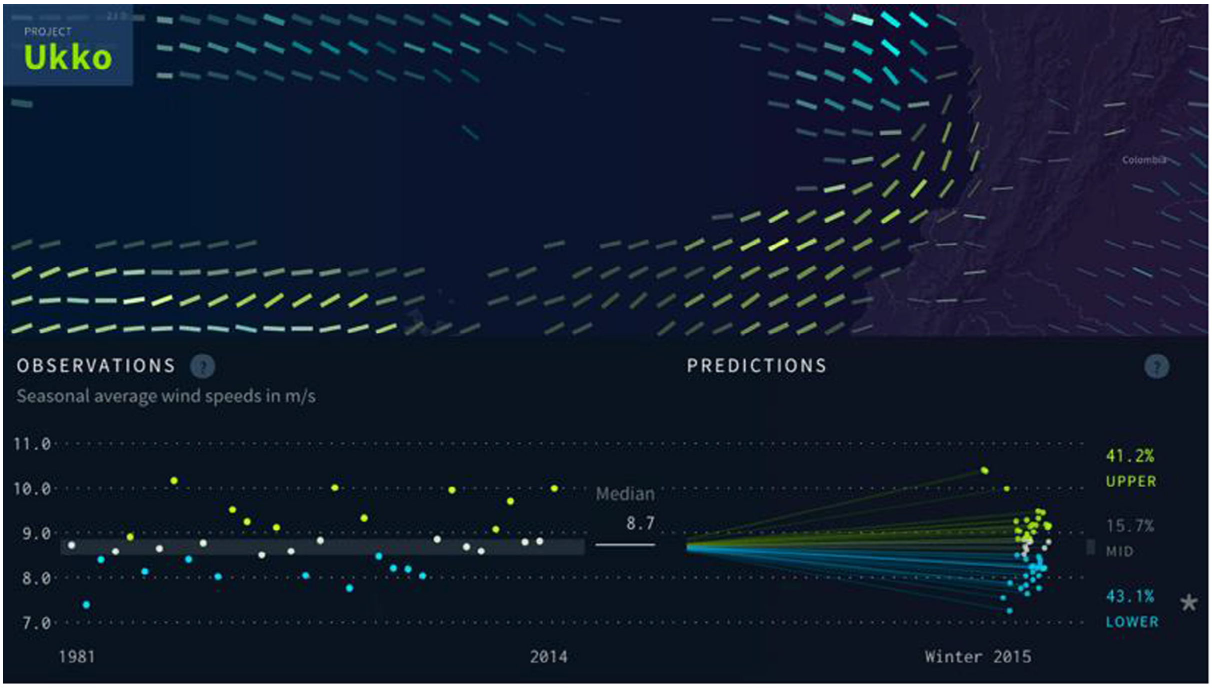

Fig. 7. Project Ukko, RESILIENCE user interface showing the operational wind speed prediction for the winter period December 2015 – February 2016. Above there is the map showing the overview data, and below is the detail information that pops up on demand when the user clicks on a point in the map. On the left there are the historical observations, and on the right the predictions are given in terms of probabilities computed as the percentage of ensemble members under the lower, mid and upper terciles.

intensive work is required to understand the decision-making process undertaken by the end-user. Only when decision-making processes are well described, can a climate service start defining which information is needed and how it can be provided so as to support and improve decision-making.

The need of user-driven approaches is a key lesson learnt from the EUPORIAS project. However, multiple funding entry-points are not always the best setting to promote this approach. The RESILIENCE prototype was built on top of the Barcelona Supercomputing Center (BSC) previous experience with energy users and research development on climate predictions for energy. This sped up the creation of the prototype but it also hindered the process of defining a single final user. In a broader setting, multiple funding entry-points should acknowledge the tension between user-driven approaches and the wide range propositions that aim to build continuity and alignment of the climate services development. Both ends of the climate services development are needed but they require efficient coordination for different timeframes, funding actions and goals. Within public funded bodies such as Copernicus C3S or public research institutions providing climate services, most attention is being paid to enhance synergies among projects, contracts and actions related to climate services and underpinning capabilities that will allow the downstream tailoring. User-driven approaches can only happen in very targeted interactions, for instance for an small-medium enterprise aiming to develop a product tailored to a specific target market. In this context, addressing a single user need can be perceived by public climate services providers as less likely to be useful beyond the experience gained for future developments. Moreover, the timeframe of many EU projects requires early results and outcomes hindering a proper user-engagement strategy that essentially requires time to build trust and willingness to collaborate from stakeholders.

For the SPRINT prototype the user engagement and scientific development were happening in parallel, with customer requirements always in mind from the beginning. The original vision for the service trialled in this prototype was a result of the discovery of NAO skill and existing interactions with DfT. The relationship with DfT was a major benefit as without their support and coordination of the stakeholder group, managing a number of different stakeholders with diverse interests and drivers could have been time consuming and complex.

In principle, setting up a project such as this could be quite a challenge if the goals of the different entry-points vary, but this was not the case for SPRINT – the goal of this prototype was well-aligned with DfT's aims (such as ensuring transport safety and improving journeys) so there was no barrier to joint steering of the project. It was especially pleasing for the prototype team that DfT was interested to be involved in this novel activity, given the multiple demands on both staff time and financial resources within central government departments in recent years. Although collaboration with a central government department required us to follow their existing procedures for developing the service alongside those of EUPORIAS, which were in general free from constraints, this was rarely a complication, which we assert was partly due to the existing relationship with DfT and the level of trust already earned.

Finally, having a diverse group of stakeholders from across the different transport sectors, several of whom provided us with the end-user impact data we required, allowed the development and testing of the science behind these forecasts.

Along with these benefits, there were also challenges to overcome. Testing – and evaluating the skill and utility of – a prototype may involve considering many factors and require a long time commitment, raising the question of whether the stakeholder(s) can sustain the risk during the scientific development stage. Whilst it may be more complicated managing a project with multiple funding sources there are also non-financial benefits. When stakeholders are funding part of the work being done on a research exercise such as this one, they can have more of an interest in getting something or something specific out, specific deliverables can be defined to justify funding and therefore both sides must commit to, and stay involved, in the work to ensure these are delivered.

However, where stakeholders do not have a specific financial investment in the project it is easier for their attention to be diverted when something higher priority in their organisation comes along. An example of this from SPRINT would be the user's willingness to supply historical impact data. From a scientific point of view having impact data provided by the end user has been essential to providing tailored information for them (there can be no impact forecasts without first being able to build the historical NAO/impact relationship). In the more general case, if an end user has a financial stake in the project this may prompt them to share their data more readily.

The result was a broadly successful trial, which received positive feedback from stakeholders who found the service to be useful and to provide opportunities for future operational capability. The reason for this success was effective engagement with all entry-points concurrently, existing relationships and trust, along with the fact that this was not an exercise in turning existing research into a product, nor was it attempting to create science to fit user need but finding two funding sources with overlapping goals.

7. Conclusions

The present paper has introduced a set of climate service prototypes developed within the EU funded project EUPORIAS with the main aim of illustrating the key lessons learnt through the development of those services. Starting from the idea of a climate service codesign, five prototypes were selected: SPRINT, focused on winter transport; RIFF, focused on water management for reservoir dams; LEAP, looking at food security in Ethiopia; LMTool, addressing the needs of farmers in the South West of the UK; and RESILIENCE, looking at wind prediction for the energy sector. Since each prototype was tailored to one specific sector and specific user's need, this work approached the most relevant aspects found on the progress of the prototypes. Through the examples presented in this paper, a broad discussion has been conducted to build up a common document, a reference on climate services, with the final thoughts of the project.

EUPORIAS was designed to include, as much as practically possible, the user perspective in the definition and the development of a climate service. This was done first through a dynamic selection of the prototypes based, among other things, on the strength of the associated use case. Although there may be several alternative ways of promoting an effective use dialogue within climate service development, having a strong and structurally relevant interaction with the end-user at the problem definition stage has undoubtedly contributed to a change in the dynamic between users and providers.

Finding a balance between user specificity and mass production of climate services is one of the aspects faced within EUPORIAS. Overall, the prototypes appeared to be a trade-off between the aspiration to produce a service meeting the needs of a specific user and the desire to produce a service which could potentially be reused or re-shaped for other applications. In this respect, RIFF and SPRINT prototypes are the two opposite points on the spectrum of the services developed. We argue that such a tension is neither trivial nor specific to EUPORIAS, as similar tensions are appearing for instance within Copernicus SIS (Buontempo 2016 personal communication), because the need to appeal to a potentially larger audience than the one originally targeted in the prototype impinges directly on the long term sustainability of the service and the people involved. This could provide a significant challenge to the mainstreaming of climate services.

The experience of the LEAP prototype is a good reminder of the complexity of climate service development namely the capacity within the user's organisation to engage and interact with the development team. This is an issue even when, as in the present case, there is both a genuine interest from the user and a decent chance for the prototype to provide a valuable service. Having someone who understands the issue, is committed to the project and has time to invest to ensure the project reaches its objectives is an asset for the service whose value is difficult to overestimate.

A major challenge for the prototypes has been to use limited end-user data to derive useful, robust information to the users. This was particularly evident in the case of SPRINT but to a lesser extent was true also for the other prototypes. In fact the length of the impact data record is crucial for the assessment of the role of natural climate variability while also providing a way to increase the robustness of the statistical analysis. For climate services to thrive a renewed effort toward the collection the storage and the maintenance of these essential datasets would be needed.

The prototypes represented in this paper show how much user interaction can alter the scope, the setup and ultimately the outcomes of a climate service proposition. User engagement is a continuous process that should not be relegated to the final stage of a project but which should instead be intertwined in the very fabric of the project at all stages. Despite the fact that all the people involved in the development of these prototypes were all quite accustomed to user interaction, the project was more time-consuming that expected in the beginning, but also more relevant to users than initially anticipated. If the European community wants to develop user driven climate services, it is essential that we factor in a sufficient amount of time for fostering the user interaction.

More broadly the experience of EUPORIAS prototypes also suggests we will need to rethink the way in which users are involved in climate service propositions. Going beyond the "solution in search for a problem" approach may require a change in the governance of the projects and a more direct involvement of users in the definition of the problems to be analysed and of the solutions that are being developed. As long as the scientists are driving the project and the users do not have any investment (monetary or otherwise) in the project the outcomes are bound to be biased towards the providers. Our experience in that sense seems to suggest that new funding mechanisms which link users and providers more directly could have a positive impact on climate service development.

Considering the global ambitions in relation to climate services, it is interesting to note that a downstream market for climate services can probably only exist if sufficient space is left between the providers and the users so that purveyors can operate and thrive. However the experience of EUPORIAS may suggest that if the distance with the users becomes too large this may result in the provision of irrelevant data, which in turn would not stimulate the market for intermediaries. Getting and maintaining the right balance between these two forces may well be one of the biggest challenges a climate service will face in its development.

Acknowledgements

The authors wish to acknowledge all of those who contributed indirectly to the development of the EUPORIAS prototypes, through scientific discussion, review, data provision, stakeholder engagement and facilitation: for SPRINT, Adam Scaife, Anca Brookshaw, Alberto Arribas, Emily Wallace, Jeff Knight, Margaret Gordon, Kate Brown, Brent Walker, Mathew Richardson, Jodie Wild, and the DfT-led stakeholder group; for RESILIENCE, Melanie Davis for conceiving the prototype and for her vision on Climate Services. In the LMTool, Clinton Devon Estates, the National Farmers Union, and all the farmers involved in the development of the tool.

The UK Government Department for Transport is acknowledged for providing financial support, in parallel to that received from EUPORIAS, for the SPRINT prototype.

The visualisation, project UKKO, within RESILIENCE prototype was done by Moritz Stefaner.

EUPORIAS was funded by the European Commission through the 7th Framework Programme for Research, grant agreement 308291.

Appendix

Guidelines for the selection of the climate service prototypes

EUPORIAS is a project, funded by the European Commission through its 7th framework programme, whose aim is to promote the development of climate services in Europe. One of the main outcomes of the project is the elaboration and the delivery of a small set of fully working climate-service prototypes operating on a seasonal or decadal time scale. Contrary to other projects these prototypes have not been selected at the onset of the project but have been elaborated through a close collaboration with the final users. The resources available to EUPORIAS allow us to develop up to five prototypes. This means that EUPORIAS will need to make a selection from among all the prototypes that will be proposed. This will be done with through an internal call for proposals open to all project partners or group thereof.

This document summarises the general principles and the main criteria for the selection of the prototypes. To guarantee the maximum level of transparency in the selection process an independent committee will be asked to look at the proposals and score them individually. The top scoring five prototypes will be considered as the official recommendation.

Definitions:

- Climate service:
  Is a way of providing climate information that assists decision making by individuals and organisations.

- Prototype:
  Is a specific implementation of a climate service that addresses a (set of) well identified decision(s) of at least one stakeholder.

- Process recipes:
  Represent a set of instructions highlighting the main steps that have been followed in the development of the prototype.

- Predictability:
  Is the extent to which future states of a system may be predicted based on knowledge of current and past states of the system.

- Skill:
  Represents the relative ability of a prediction system in assessing the likelihood of occurrence of specific events with respect to the ability of other 'less-skilled' systems. Climatology will be the standard benchmark for skill in this document.

- Value:
  Is a measure of the overall benefit to the stakeholder associated with the prototype. In its crudest form it can be approximated by the expected price the stakeholder would be happy to pay for the provision of the service.

- Legacy:
  Is a description of the way in which the outcome of the project/prototype will be used by a wider community after the end of the project.

- Stakeholder:
  Is an individual or an organisation who is interested in the project and who have a critical decision which can be informed by climate information.

General principles:

While the selection of the climate service prototypes that will be developed within EUPORIAS spans a number of different dimensions, the General Assembly identified two general principles as being of primary importance. These are associated with the overall value of the impact predictions and the user engagement. Whilst these two dimensions are not necessarily independent from one another we have here assumed that as a first order approximation they can be considered independent. On one hand we can have users who appear very enthusiastic about the possible use of climate predictions but for whom we cannot deliver a suitable set of valuable predictions (e.g. lack of skill in the underpinning forecast, relevant parameters cannot be predicted, inadequate timeframe for the decision). On the other hand we may have stakeholders for which a clear value can be identified but who lack engagement and enthusiasm (e.g. too busy doing other things, legal or political constraints, personal issues, lack of trust in the science, etc).

The prototype proposals will be scored looking first at these first two dimensions (skill/value and stakeholder engagement). In order to be selected the proposal would need to score at least 2.5 points in these first two dimensions. The secondary dimension will be used to discriminate between the prototypes that have passed the thresholds. The final score will be based on the sum of the score of each dimension. Score increments are set to 0.1 of a point. The member of this committee will be asked to score each proposal fully, irrespective of whether they exceed or not the threshold in the first two dimensions. After receiving the scores, a ranking of all proposals will be put together according to their scores. Only the proposals which have passed the two thresholds for the majority of the reviewers will be evaluated at this stage.

The next few pages provide a overview of each dimension and some additional information on the evidence that are needed from each prototype proposal.

Expected value of the prototype given its expected skill *[0–5] threshold 2.5*	Robustness *[0–1]*
Evidence highlighting the expected skill of the prototype and its implication in terms of the overall value to the stakeholder	A prototype should be based on a well established and understood relationship linking the climate drivers to the impacts. For example, all the rest being equal prototypes for which long series of climate observations and impact/outcome are available, should be preferred to those with shorter records as a way of ensuring a good level of understanding of the driver-impact relationship

User decision *[0–2]*	Stakeholder engagement *[0–5, threshold 2.5]*	Assessment *[0–1]*
Evidence of how the prototype can inform stakeholder's decision-making process (e.g. is there at least one critical decision identified)	Is a stakeholder(s) of reference clearly identified? How solid is the evidence of the commitment, the engagement and the enthusiasm for the prototype on the stakeholder side? For example: is the stakeholder likely to share its data with the project? Is the organisation willing to share their experiences? Is there already an infrastructure service that can be used as a starting point?	What is the strategy for assessing the impact of the prototype on the decision made been identified?

Prototype diversity *[0–2, no threshold]*	Community/spin-off *[0–1, no threshold]*	Project cohesion *[0–1, no threshold]*
Does the proposal address a sector, a region or a timescale that would otherwise be under-represented in the final selection?	How likely it is that other prototypes can be generated on the back of the proposed one? For example: a prototype for the water sector may require information on river flow which can in turn be used by stakeholders in the energy, agricultural and fishing sectors to develop additional prototypes	Does the proposed prototype promote a wide coordination across partners in the project? How likely is it that the prototype will promote a cross-partners approach to the challenge?

Post-project exportability *[0–1] (no threshold)*	Sustainability *[0–1] (no threshold)*
Is the process recipe of the proposed prototype likely to be exportable to other regions and sectors?	Will the prototype build upon existing services or tools? How likely is it that the prototype could have a life after the end of the project?

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