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# Exploring the use of seasonal climate forecasts in Europe through expert elicitation

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ABSTRACT

The importance of climate information for decision-making in sectors susceptible to climate variability and change is widely recognised. Advancements in climate science have led to an increased interest in seasonal climate forecasts (SCF) although in Europe very little is known about the practical use of these forecasts. To start filling this gap we conducted a workshop with experts in this subject area in order to elicit their knowledge and experiences regarding the current use of SCF in Europe.

We found that although the use of SCF across Europe is fairly limited, particular sectors such as energy, water, insurance, and transport are taking the lead. The central role of the European Centre for Medium-Range Weather Forecasts and National Meteorological Services as the main providers of SCF in Europe was also highlighted. Perceived barriers to their uptake tend to be associated with factors such as accessibility, relevance, and usability of SCF by the end-users.

Some of our findings are consistent with other experiences outside Europe where the uptake of SCF for decision-making has a longer history. For example, the interaction between actors, the usability of the information provided, and the influence of institutional and social factors have all been noted as important aspects influencing the use of these forecasts in Europe. However, as these findings are based on experts' knowledge further research with decision-makers and end-users is needed to better understand the use and potential benefits of SCF in Europe.



## Introduction

Climatic conditions have shaped societies for millennia. Since the emergence of Numerical Weather Prediction (NWP) and computer models in the 1950s, it has become possible to anticipate future weather a few days ahead. Climate models, developed from NWP models, produce forecasts, predictions or projections at a range of temporal and spatial scales. While in Europe, long-term climate change projections have received the most attention from decision-makers (Kovats et al., 2014; Biesbroek et al., 2010), developments in the science and models underpinning the study of climate variability and change have led to an increased interest in seasonal climate forecasts (SCF) (Hewitt et al., 2013; Buontempo et al., 2014). These forecasts cover "the next month up to a year into the future" and the information is provided as monthly or seasonal means (Goddard et al., 2012, p. 622). SCF have the potential to respond to the needs of a wide range of sectors and activities which are susceptible to, and influenced by, climate variability and change by helping to inform decision-making, improving operational activities, and enhancing profitability (Harrison et al., 2008a). For example, the susceptibility of the agricultural

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sector to weather conditions and the potential to use SCF to inform decisions and plan activities in agricultural systems is widely recognised by for example improving the timing for sowing, ploughing, and harvesting of crops (Doblas-Reyes et al., 2006; Cantelaube and Terres, 2005; The World Bank, 2008). Other European sectors such as water resources management, energy, insurance, disaster management, forestry, and health have also been identified as potential beneficiaries of such forecasts (Harrison et al., 2008b; The World Bank, 2008).

However, there is a lack of empirical studies and literature regarding the practical use of SCF in Europe (see Dessai and Bruno Soares, 2013). Given the paucity of knowledge in this field, the aim of this study was to elicit information from experts regarding their knowledge and experiences of the current use of SCF in Europe. To achieve this we conducted an expert elicitation workshop with European climate service providers representing a total of 11 countries, two European organisations, and various sectors including water, energy, tourism and health. The next section describes the methods used to elicit experts' knowledge during the workshop. "Results" Section presents the main findings from the workshop including the users and the producers of SCF in Europe, the chains of information (i.e. from providers to the users), and the perceived barriers and solutions to the uptake of SCF in Europe. "Discussion" Section discusses the key issues that arise from our findings and draws parallels with experiences from other parts of the world where the use of SCF has a longer history. "Conclusions" Section provides some concluding remarks.

## Methods

The aim of this research was to elicit the knowledge and experiences from experts working at the interface between the production of SCF and the users of such information to better understand the use of SCF in Europe. The workshop was held in the Royal Netherlands Meteorological Institute (KNMI), in De Bilt, in The Netherlands in March 2013. A total of 24 experts from a range of European climate services providers attended, including National Meteorological and Hydrological Services (NMHS) as well as other organisations working at this interface (see Appendix A). These experts were selected based on their knowledge and expertise in the subject area (cf. Meyer and Booker, 1991) including through their involvement in European projects and initiatives focusing on SCF but also looking at the use of climate information and the development of climate services.

Experts' knowledge and expertise was captured by methods of knowledge elicitation (cf. Ericsson, 2006) which can be used in novel and emergent areas of research to help determine what is currently (un)known as well as what is worth investigating in a particular field (Meyer and Booker, 1991). These included interactive small groups discussions to probe and elicit experts' knowledge (Hoffman et al., 1995). The elicitation focused on three key issues: (1) identifying users of SCF in Europe; (2) identifying the flows of information from providers to users (here described as chains of information); and (3) identifying barriers and solutions to the use of SCF in Europe. The workshop was run and facilitated by both authors and one more person. Experts worked in mixed groups. Having mixed groups allowed forming groups with participants from different sectors of expertise (e.g. meteorology, tourism, health; see Appendix A) and geographical areas and hence contribute with a range of experiences and knowledge regarding the users. Each group were asked to identify and describe SCF users in Europe and to place each SCF user in a matrix according to prediction lead times and type of SCF use. The prediction lead time ranged from forecasts up to a month (sub-seasonal forecasts), from a month up to a year (seasonal forecasts), and annual (annual forecasts). SCF use were categorised as: those aware and using SCF (including advance and moderate users); aware of SCF and potential to use SCF; and not aware but potential to use. Each group then discussed their matrix and reported in plenary to all workshop participants. Discussing the groups' findings in plenary allowed all experts to be aware of what was being discussed in each group (e.g. to identify users that were being named by other experts such as the case of Electricité de France (EDF) which was put forward by different experts/groups as a current user of SCF) but also allowed further contributions to the wider discussion from everyone involved.

To identify the providers and the chains of SCF in Europe, experts were asked to describe a known chain of SCF provision i.e. from its production to its use in decision-making. Working in groups, experts were then asked to discuss the various chains and try to merge them by finding commonalities and linkages between them. This merging exercise allowed experts to identify organisations common to the various chains of SCF identified (when applicable) and cluster and converge them as much as possible. This in turn, permitted identifying those organisations that were most prominent in the chains of SCF provision.

To identify barriers to the use of SCF and solutions to overcome those barriers, participants were arranged in small groups and asked to brainstorm in their group, discuss, and cluster the main barriers to the use of SCF using post-its.

Each group was then asked to do the same with regard to solutions to overcome the barriers identified. As this was a brainstorm/discussion exercise the barriers and solutions identified by experts ended up being quite general in nature (rather than identifying barriers related to particular user/s). They then reported back the main findings from their table at the end of the session.

## Results

### *The users of seasonal climate forecasts in Europe*

During the workshop, a total of 35 users of SCF across a range of European sectors were identified by name. Fig. 1 illustrates these users where each icon corresponds to an organisation identified by participants according to the sector of their

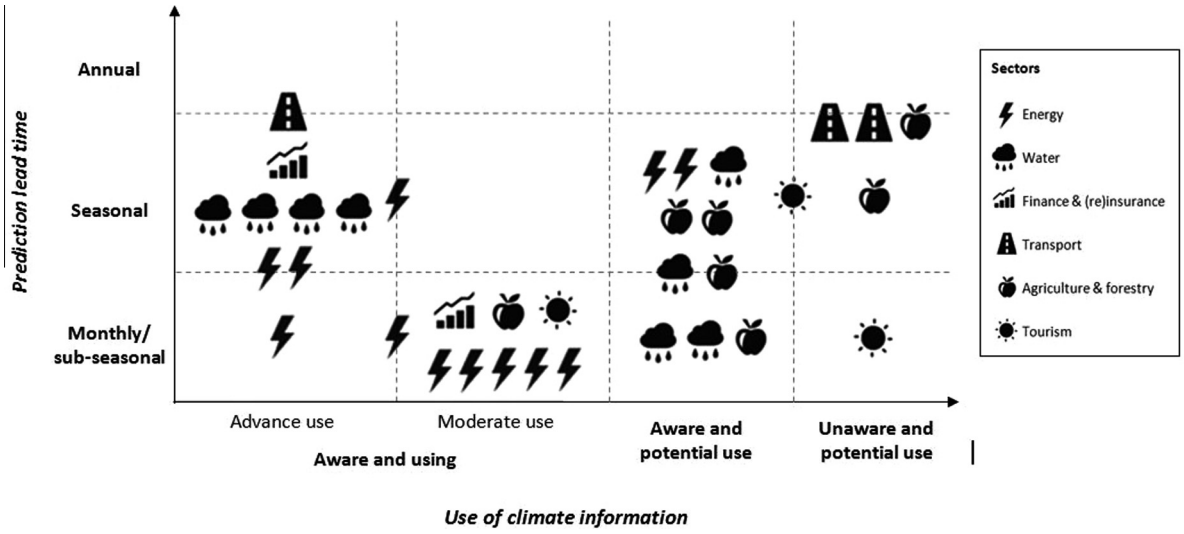


**Fig. 1.** Organisations identified by experts according to their sector of activities, the use of climate information, and prediction lead time.

main activities, the prediction lead time of the SCF, and how they use that information within the organisation. Those organisations that are aware or unaware of SCF but where the potential to use this type of climate forecasts was identified by experts were also included in the figure below. In some cases, experts inserted organisations between categories (e.g. between advance and moderate use of SCF, between seasonal and annual prediction lead time).

Organisations already aware and using SCF were described with a greater level of detail by experts than those not currently using SCF. These 'early adopters' of SCF were largely associated with the energy, water, finance and insurance, and transport sectors which mainly use forecasts with a lead time prediction of a month up to a season. The energy sector was prominent amongst these early adopters with 10 organisations identified by experts although in some cases different experts identified the same organisation (i.e. EDF). The majority of these early adopters of SCF were large companies working at international or national level with a level of capacity and expertise to ingest climate information. For example, in some organisations post-processing and/or tailoring of data is performed in-house given the existence of expertise and resources (e.g. AXA, EDF). These organisations use SCF to improve the management of their activities, products, and outputs with a view to improve efficiency and, for those in the private sector, increase profitability. As a result, the uptake of SCF is generally associated with a degree of relative advantage (e.g. increased efficiency, economic profit) amongst those adopting and using these forecasts (Rogers, 2010).

However, the use of SCF ranged from those using it in an advance manner (i.e. the information is used in operational/dynamical models to support specific decision-making processes within organisations) to a more moderate use of SCF (i.e. SCF are used as qualitative information which organisations consider but not actively integrate in any operational model or automated decision-making process). For example, the National Hydrological and Water Management Institute of Romania integrates SCF into their operational model to make hydrological predictions (i.e. advance use of SCF) whilst the Environment Directorate General of the European Commission (DG Environment) uses SCF as qualitative information to support their decision making process when implementing emergency measures for addressing drought (i.e. moderate use of SCF).

Some of the users (10 out of 35) identified included organisations that were aware of SCF and could potentially benefit from using such information particularly in the water, agriculture, and energy sectors. The remaining organisations (6 out of 35) were not aware of SCF but, in the experts' opinion, could potentially gain from using SCF.

### *The flows of information from producers to users of seasonal climate forecasts*

During the workshop a total of 37 chains of climate information provision were identified by experts. In 27 out of the 37 chains identified, ECMWF consistently emerged at the beginning of the chains providing weather and seasonal forecasts (which go up to 7 months prediction lead time) to its members including European NMHS (e.g. French, Spanish, German, Norwegian, Portuguese) but also directly to private organisations and national research centres. In most cases, NMHS carried out post-processing and/or tailoring of data for specific customer needs before being used by end-users. In other cases, post-processing and/or tailoring of data were performed in-house by organisations with an existing level of resources, capacity and expertise.

In some chains, rather than ECMWF, NMHS were identified as the main provider of climate information with others acting as intermediary organisations between the NMHS and the end-user. For example, the Norwegian NHMS currently provides statistical forecasts to an energy consultant who then tailors those forecasts into specific data for energy traders. As a result,

NMHS were identified as the producers of climate information and data to other organisations but also as the main users of climate information provided by ECMWF.

In addition, not all chains of climate information provision were constrained to European providers. For example, the Climate Prediction Centre, one of the National Centers for Environmental Prediction (NCEP) of the US National Oceanic and Atmospheric Administration also appeared in some of the chains, alongside ECMWF. However, when this information is translated and/or tailored by others to fit specific users' needs these services tend to have a cost attached. An example is the Weather Services International – a private company with headquarters in the United States – which provides climate information to the financial sector in Europe.

Fig. 2 below illustrates three distinct chains of sub-seasonal (i.e. weather forecasts up to a month prediction lead time) and seasonal forecasts provision in relation to multiple users at one large organisation (EDF) as identified by experts.

Each of these chains corresponds to different uses of seasonal and sub-seasonal forecasts in three distinct areas of activity and decision-making processes within EDF (i.e. system operation managers, hydro-power managers and Research & Development). The figure above also illustrates the range of organisations involved in the provision of SCF within EDF. For example, both Météo-France and EDF's Technical Division act as intermediary organisations by performing post-processing of ECMWF's data and communicating it to system operation managers and hydro-power managers in EDF, respectively; whilst the R&D division within EDF receives SCF directly from the World Climate Service, a private company based in the USA. This example, although far from providing an exhaustive picture, lends a glimpse of the complexity of the chains of SCF provision and its potential (and different) application within organisations, particularly large organisations such as EDF.

*Barriers and solutions to the uptake of seasonal climate forecasts in Europe*

A range of barriers and solutions to increase the use of SCF in Europe were identified by the experts. These were clustered by the authors (after the workshop) into four broad categories: accessibility, communication, and training; capacity, relevance, and usability of information; skill and reliability; and other barriers (Table 1). By categorising the barriers (and the solutions below) we were able to identify linkages between the various barriers identified as well as their association to the solutions proposed by experts.

A significant proportion of the barriers identified related to non-technical issues particularly those related to the accessibility to, communication of, and training on SCF (Table 1). These included aspects such as the lack of an interface between the users and the producers (and other actors in between) for sharing information regarding SCF in Europe; lack of accessibility and/or awareness of available climate information by users; and the use of technical and scientific language and the

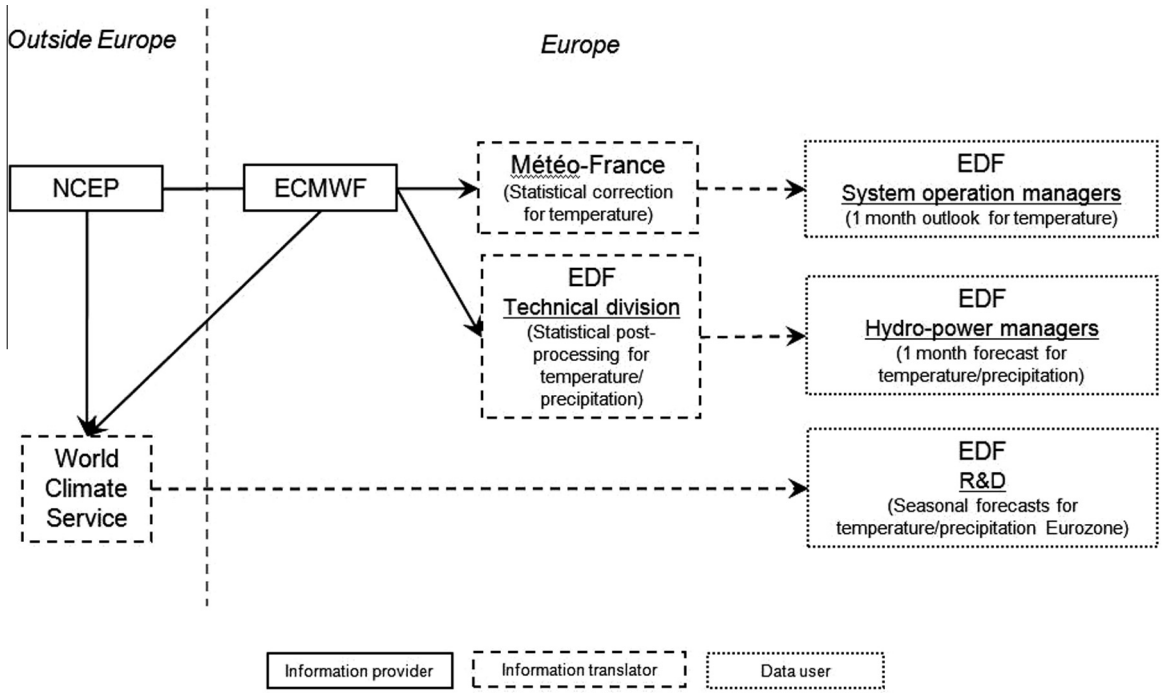


**Fig. 2.** Three chains of climate information provision identified by experts.

**Table 1**
Experts' elicited barriers to the uptake of seasonal climate forecasts.

| | |
|---|---|
| Accessibility, communication, and training | • Lack of awareness<br>• Accessibility to SCF<br>• Lack of tools to exploit SCF<br>• Technical and scientific language<br>• Communicating uncertainty<br>• Complexity of the products<br>• Lack/limited support<br>• Lack of/interface with boundary organisations |
| Capacity, relevance, and usability | • Limited resources/capacity (both from users and producers)<br>• Inadequacy of available/requested information<br>• Inability to exploit and demonstrate benefits of SCF to users |
| Skill and reliability | • Unknown skill<br>• Low reliability<br>• Not exploring 'windows of opportunity'<br>• Lack of deterministic skill<br>• Marginal value of SCF |
| Other barriers | • Reluctance in changing existing practices<br>• Culture of risk aversion<br>• Lack of knowledge on climate science<br>• Lack of financial investment<br>• Costs of climate information<br>• Complexity of climate-related impacts<br>• Perceptions of climate impacts and vulnerability |

difficulties in conveying in simple ways the complexity of the science (e.g. explaining the probability of the climate predictions and the limitations and assumptions in the models).

The lack of capacity and resources to respond to users' needs as well as the lack of capacity of the users to ingest and apply climate information were also identified as barriers (under the category of capacity, relevance and usability). Other barriers linked to this included the inadequacy of existing SCF (i.e. regarding temporal and/or spatial resolution), focusing on variables that are not relevant to the users, and the inability to demonstrate the potential benefit of SCF to users.

The poor skill of models and the lack of reliability of SCF were also noted as existing technical barriers. An interesting issue raised related to the reliability of SCF was the notion of 'windows of opportunity' in Europe. This idea relates to the fact that at times, certain influences/factors which confer predictability will be stronger and/or act in concert. In such situations, signals in the forecast are likely to be stronger and the confidence in climate predictions may be greater than the average skill information would indicate. Those 'windows of opportunity' may enhance the usability of climate predictions for some users depending on the phenomenon, thresholds, and decisions involved (Brookshaw, 2014).

Other perceived barriers included the reluctance to change existing working practices and protocols in the organisations, a culture of risk aversion from both producers and users, complexity of climate-related impacts, and costs of climate information. Simplifying access to seasonal data (i.e. cost, technical) and breaking through existing practises were suggested by experts as potential solutions to such barriers. For example, the insurance sector was perceived by a few of the experts as one sector where the need to break with existing practices constituted a barrier to the uptake and use of SCF.

Similarly to the barriers, the experts also suggested a range of solutions that could be considered in order to increase the use of SCF in Europe. These are presented in Table 2 below based on the same four categories used to present the barriers above (see Table 1).

Many of the solutions proposed were underpinned by the need to enhance the interface between the producers and the users of SCF in order to not only increase the uptake but also raise awareness of this type of climate forecasts in Europe (Table 2).

The need for new/improved interface(s) between users and producers was also identified. For example, the idea of creating a climate service partnership or alliance in Europe (i.e. with a shared proposal, publications, and academic credibility) was suggested as well as a joined programme and development of services (such as for example the European Climate Observations, Modelling and Services (ECOMS) initiative and Joint Programming Initiative (JPI) Climate). The co-production of SCF services and products (e.g. working together on real case-study examples) was also proposed as a way to improve the interactions between these groups as well as increasing the relevance of the information through better understanding users' needs and how SCF can potentially be used in decision-making. The use of professional organisations (e.g. boundary organisations) to help mediate these interfaces was also proposed although details on existing organisations or how this could be addressed in Europe was not provided.

Other solutions suggested included the development of data portals (e.g. such as the KNMI Climate Explorer) for sharing and disseminating information, events and case studies based on the development of factsheets and graphical illustrations; and using simple language and convenient formats to communicate with users. Improving scientific models to increase SCF

**Table 2**
Experts' elicited solutions to increase the uptake of seasonal climate forecasts.

| | |
|---|---|
| Accessibility, communication, and training | • New/improved interfaces between users and producers<br>• Boundary organisations as information 'pushers'<br>• Education, training, and regular engagement between users and producers<br>• Use plain language and convenient formats to communicate (e.g. factsheets, graphical illustrations)<br>• Clear information on limitations and assumptions in models and products |
| Capacity, relevance, and usability | • Co-production of services, products, and support to improve interactions between users and producers<br>• Understand users' needs and how the information is used<br>• Share guidance and best practises Demonstrate benefits and added value of using SCF (e.g. success stories, case studies) |
| Skill and reliability | • Improve models and SCF skill in Europe<br>• Invest in R&D<br>• Develop forecasts that go beyond the usual temperature/precipitation forecasts |
| Other solutions | • Break existing practises<br>• Simplify access to data (technical, cost, policy) |

skill and reliability in Europe accompanied by an investment in R&D were solutions put forward with regard to the scientific basis and modelling of SCF.

## Discussion

Experts identified a few sectors as those taking the lead in the uptake of SCF in Europe such as the energy, water, insurance, and transport sectors to improve their efficiency and profitability. Ideal typical 'early adopters' tend to be perceived as role models in the uptake of new ideas, concepts, or information (Rogers, 2010). In this case, the early adopters of SCF differ between those already using SCF in an advance or moderate way depending on how they integrate this information (i.e. in operational models or simply use it as additional qualitative information, respectively).

According to the experts, the main drivers for the uptake of SCF (by the identified organisations) were largely linked to the potential to improve their efficiency and productivity and, in some cases, the competitive advantage (particularly in the energy sector). It is important to note however, that many of these were large organisations with a considerable level of resources and capacity in-house that allowed them to use SCF (cf. Bolson and Broad, 2013; Dilling and Lemos, 2011; Pagano et al. 2002). A large number of potential users which are aware of SCF but currently not using it were also identified (cf. Fig. 1). Although, the specific reasons underpinning this lack of use by these potential users were not made clear we believe that these relate to many of the barriers discussed during the workshop.

In the context of SCF provision, complex interactions between different actors (that go beyond the users-producers dichotomy) are already taking place and organisations such as ECMWF and NMHS play important roles in the provision of SCF in Europe. Although it was only possible to capture some of that complexity during the workshop it was clear for example that the provision of SCF in some of these European organisations was supplied by organisations outside Europe which relates to the globalised nature of climate information production and provision.

The range of actors involved and the different roles that these play in the chains of climate information provision in Europe was also recognised. For example, NMHS were identified as the producers and/or providers of climate information to other organisations but also as the main users of climate data provided by ECMWF. Thus, it is important to address terms such as 'producers' and 'users' as fuzzy concepts given the complex relationships and chains of climate information provision.

The barriers identified as those undermining the uptake and use of SCF in Europe are also similar to those recognised in other regions where the reliability and use of SCF is higher e.g. USA, Brasil and Australia (see Dilling and Lemos, 2011 and Kirchhoff et al., 2013b for an overview of studies looking into the use of SCF in other parts of the world). For example, the inadequacy of the SCF provided to the users, a lack of understanding regarding the decision contexts where the climate information is supposed to be used and the lack of interface between the users and producers were all barriers mentioned by experts and which are directly related with experiences elsewhere (cf. Lemos et al., 2012).

In this context, the importance of boundary organisations is widely recognised in the literature (McNie, 2007; Buizer et al., 2010; Kirchhoff et al., 2013a; Kirchhoff et al., 2013b). Such organisations can help to bridge and mediate the divide between the producers and users of SCF or take on the role of knowledge broker who translates and communicates knowledge between different groups (Meyer, 2010). In Europe, such boundary/brokerage work is still emerging particularly in the context of SCF. However, since the workshop, a European Climate Services Partnership (ECSP) was launched with the aim of acting as a network for collaboration and knowledge sharing between producers and users of climate information in Europe (Hewitt and Buontempo, 2014). The ECSP is aligned with the international Climate Services Partnership which acts similarly but at the international level (Vaughan and Dessai, 2014). At the national and regional levels, the German Climate Service Centre and the North German Climate Office, respectively are also examples of collaborative interfaces between climate scientists and practitioners (Meinke and Von Storch, 2008; Krauss and Von Storch, 2012).

The lack of skill and reliability of SCF in Europe (which varies considerably depending on the geographical area, the time of the year and the climate variable) was also identified as a considerably barrier to the use of SCF. In the European context, existing 'windows of opportunity' as previously described can challenge conventional notions that consider low skill and reliability as an immutable barrier to the use of SCF. As a result, perhaps rather than aiming to achieve higher levels of skill in the models future research should also focus on exploring how existing 'windows of opportunity' can be used to satisfy current users' needs and inform their decision-making (cf. McNie, 2007). Institutional barriers such as difficulty in changing existing practices in the organisations as well as a culture of risk aversion which can potentially limit the use of SCF in the organisations were also described by experts.

The findings presented here are based on the knowledge of experts. As a result, this study was bound by methodological factors that influenced both the collation process and the analysis performed. For example, data collated as a function of the experts present and at a snapshot in time of experts' knowledge and experiences (cf. Meyer and Booker, 1991).

Our analysis provides an important starting point for understanding and tracing the (emergent) landscape of the use of SCF for decision-making across Europe. However, further research is required to advance our understanding and knowledge of the current use and potential use of SCF in Europe. Such research could focus on examining the drivers underpinning the use of SCF by organisations in their decision-making; investigate the interplay of SCF with other types of (climate) information and its relative weight in the decision-making process (aligned with the work by Lemos et al., 2012); analysis of the actors involved in the chains of information provision and the processes through which value is added to make the information 'usable' to the end-user; and examine the intricacies of such complex relationships in order to improve our understanding of the various roles that intermediary organisations play, the typologies of networks and collaborations, and the institutional arrangements that currently exist or are being developed in the emerging context of SCF in Europe.

## Conclusions

To advance our understanding and knowledge of the use of SCF in Europe an expert elicitation workshop was conducted. Findings from this study have highlighted the central role of the ECMWF and NMHS as the main providers of SCF in Europe whilst current users are found in small numbers in sectors such as energy, water, insurance, and transport. Although existing skill and reliability of SCF in Europe is low, many perceived barriers to the uptake of these types of forecasts are linked to non-scientific aspects. These included for example, the lack of communication and engagement between the producers and users of SCF and the need to improve the relevance and usability of SCF to users across Europe.

Further research is therefore critical to help advance knowledge and explore some of the critical issues highlighted in the discussion. For example, the chains of climate information provision identified unveiled some of the complexity of the relationships and actors involved in the production, translation, and use of SCF in Europe. In addition, given the fluid nature of the relationships and roles played by actors in different contexts it is fundamental to understand at which points in these chains of information provision value is added as well as the contribution of such processes and interactions to decision-making.

Given the limited empirical evidence on the uptake and use of SCF in European organisations it is important to reflect on the experiences and legacies of using seasonal information beyond Europe. An important lesson to retain is that the provision of SCF to users is not, in many instances, enough to ensure that such information will be used in practice. Institutional factors, social aspects, communication and collaboration between actors, and the adequacy and usability of the information are just some examples of the barriers to the uptake of SCF outside Europe. Such empirical contributions need to act as a reference in the emerging context of SCF in Europe if we are to avoid similar obstacles in the uptake and diffusion of these SCF for the benefit of society.

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**Table A1**
List of workshop participants.

| Organisation | Sector of expertise | Participant | Country |
|---|---|---|---|
| AEMET | Meteorology | Ernesto Rodríguez-Camino | Spain |
| CETaqua | Water | Laurent Pouget | Spain |
| ECMWF | Meteorology | Laura Ferranti | Europe |
| Electricité de France | Energy | Laurent Dubus | France |
| ENEA | Energy | Matteo De Felice | Italy |
| Climate Service Center | Climate | Teresa Zölch | Germany |
| IPMA | Meteorology | Mariana Bernardino | Portugal |
| KNMI | Meteorology | Janette Bessembinder | Netherlands |
| KNMI | Meteorology | Roeland van Oss | Netherlands |
| UK Met Office | Meteorology | Anca Brookshaw | UK |
| Meteo Norway | Meteorology | Rasmus Benestad | Norway |
| Météo-France | Meteorology | Jean-Pierre Ceron | France |
| Meteo-Romania | Meteorology | Roxana Bojariu | Romania |
| MeteoSwiss | Meteorology | Christoph Spirig | Switzerland |
| Predictia | Roads | Daniel San Martín | Spain |
| Predictia | Roads | Max Tuni | Spain |
| SMHI | Meteorology | Lars Bärring | Sweden |
| TEC | Tourism | Adeline Cauchy | France |
| University of Cantabria | Meteorology | Maria Dolores Frias | Spain |
| University of Cantabria | Meteorology | Maria Eugenia Magarino | Spain |
| University of East Anglia | Research | Clare Goodess | UK |
| UKCIP | Climate | Roger Street | UK |
| World Health Organisation | Health | James Creswick | Europe |
| Climate-Insight | Climate | Mike Harrison | UK |

## Appendix A

See Table A1.

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