THEME ENV.2012.6.1-1

EUPORIAS

(Grant Agreement 308291)

European Provision Of Regional Impact Assessment on a

Seasonal-to-decadal timescale

Deliverable 33.*5*

Report describing strategy on communicating level of confidence: Recommendations and Lessons Learnt

Deliverable Title	*Report describing strategy on communicating level of confidence:*	
Brief Description	*Report describing strategy on communicating level of confidence: This strategy will be developed in collaboration with WP41. Target audience for these communications will be stakeholders, end-users and decision-makers.*	
WP number	33	
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Creation Date Version Number Version Date	11/04/2016 3 25/04/2016	
Deliverable Due Date Actual Delivery Date	30/04/2016	
Nature of the Deliverable	X	*R - Report*
		P - Prototype
		D - Demonstrator
		O - Other
Dissemination Level/ Audience	X	*PU - Public*
		PP - Restricted to other programme participants, including the Commission services
		RE - Restricted to a group specified by the consortium, including the Commission services
		CO - Confidential, only for members of the consortium, including the Commission services

Version	**Date**	**Modified by**	**Comments**
1	11/04/2016	Andrea Taylor	Awaiting feedback and approval from prototype leaders/representatives on

			“Lessons Learnt” sections.
2	22/04/2016	Suraje Dessai	
3	25/04/2016	Andrea Taylor	
4	26/04/2016	Carlo Buontempo	Minor correction to section 3

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1. Executive Summary

This report draws together lessons learned about good practice in communicating confidence and uncertainty in climate predictions from both Work Package 33 and four of the Work Package 42 prototypes. In a preliminary survey of user needs and review of existing approaches to communicating uncertainty we identified four key challenges: 1) that there was little existing research systematically testing the efficacy of different ways of presenting information about climate predictions to end users; 2) current users of seasonal predictions perceive them as useful, but not easy to understand; 3) users of climate information vary in their experience of using statistical information, influencing their preference for different ways of representing uncertainty; and 4) information about forecast performance (e.g. skill) was not being adequately communicated to all users. As a step towards addressing these challenges, a set of communication strategies were developed and subsequently tested in a Decision Lab conducted with participants from relevant sectors. The Decision Lab yielded a number of important findings including: 1) the fact that even when forecast skill is generally understood to be negative, forecast probabilities still influence expectations; 2) providing qualitative categories can help users – especially those with less experience of using statistical information – to better understand what skill “means”; 3) the presence of multiple skill scores can be confusing to some users; and 4) that no “one visualisation fits all” solution exists for communicating confidence and uncertainty to the users of climate forecasts.

Drawing on the findings of the Decision Lab and the ongoing work taking place in four of the EUPORIAS prototypes, the following recommendations are made:

Tailoring (where possible)
In both Work Package 33 and the prototypes it has been found that even within the same sector users vary considerably in statistical expertise, time available for consulting climate information, information requirements, and preferences for receiving information about confidence and uncertainty. Hence, where it is feasible to do so, tailored communications produced in collaboration with stakeholders are likely to yield the most useful and best understood formats of communication for specific users.

Layering information
Where it is not possible to provide highly tailored solutions, a tiered provision of information may help to address the needs of users differing in information requirements. Here, documents and tools may be layered so that users can easily view a simple visualisation or summary, or more detail and complex information about the forecast. As attempting to provide advanced users with all of the information that they might wish to view on a single visualisation can render it cluttered and difficult to interpret, tools that allow users to choose which ‘layers’ to view may also help to resolve this issue.

Provide a framework for understanding skill
Even for users with statistical expertise skill scores can be difficult to interpret and utilise without guidance as to “what they mean”. It is therefore strongly recommended that providers give users a framework for understanding how well a forecast performs. This may take the form of qualitative categories (e.g. None, Low, Medium, High) and descriptions, visual cues (e.g. colour or opacity), an ordinal “performance index”, or an agreement between users and providers that forecasts will only be provided when skill exceeds a

certain threshold. It is also to be recommended that where skill is lower than climatology, forecasts should not be provided by default.

Validate communications
When developing strategies for communicating confidence and uncertainty it is not always immediately obvious where misinterpretations and usability issues may arise. It is vital that communications be tested with their intended users, and if necessary revised, to ensure that they are both usable and well understood.

2. Project Objectives

With this deliverable, the project has contributed to the achievement of the following objectives (DOW, Section B1.1):

No.	Objective	Yes	No
1	Develop and deliver reliable and trusted impact prediction systems for a number of carefully selected case studies. These will provide working examples of end to end climate-to-impacts-decision making services operation on S2D timescales.		
2	Assess and document key knowledge gaps and vulnerabilities of important sectors (e.g., water, energy, health, transport, agriculture, tourism), along with the needs of specific users within these sectors, through close collaboration with project stakeholders.		
3	Develop a set of standard tools tailored to the needs of stakeholders for calibrating, downscaling, and modelling sector-specific impacts on S2D timescales.		
4	Develop techniques to map the meteorological variables from the prediction systems provided by the WMO GPCs (two of which (Met Office and MeteoFrance) are partners in the project) into variables which are directly relevant to the needs of specific stakeholders.		
5	Develop a knowledge-sharing protocol necessary to promote the use of these technologies. This will include making uncertain information fit into the decision support systems used by stakeholders to take decisions on the S2D horizon. This objective will place Europe at the forefront of the implementation of the GFCS, through the GFCS's ambitions to develop climate services research, a climate services information system and a user interface platform.	X	
6	Assess and document the current marketability of climate services in Europe and demonstrate how climate services on S2D time horizons can be made useful to end users.		

3. Detailed Report

In seasonal climate predictions uncertainty arises from multiple sources such as model formulation, model initialisation and large scale forcing. To address this uncertainty the forecasts are often formulated in a probabilistic way. In order for seasonal climate predictions to be appropriately utilised in decision making, users should be made aware not only of their probabilistic nature but also of the uncertainty associated to the probabilities themselves (e.g. skill and reliability). This is because a lack of awareness may lead to a false sense of certainty, and consequently a reduction of trust in providers. Hence, providers of seasonal climate predictions are faced with the challenge of communicating about uncertainty (or "confidence") in a way that is understandable, useful and fosters trust amongst users.

The objective of Work Package 33 of the EUPORIAS project has been to develop strategies for communicating confidence and uncertainty in seasonal climate predictions. In this report we set out the key lessons learned and recommendations for good practice that can be drawn from both this work package and EUPORIAS as a whole. Section 3.1 outlines the core challenges identified during a preliminary review of existing approaches to communicating uncertainty and preliminary user needs survey, 3.2 summarises the key findings of a series of Decision Labs conducted with participants in a range relevant sectors, 3.3 builds on this by highlighting lessons from the EUPORIAS prototypes, and 3.4 summarises the recommendations for good practice in communicating confidence and uncertainty in seasonal climate predictions that can be drawn from EUPORIAS. Finally, 3.5 summarises the publications and dissemination activities associated with Work Package 33 that have already been completed, and that are planned for the remaining six months of the work package.

3.1 Challenges

At the outset of this work package, one key challenge that was immediately apparent was the fact that, while many interesting and innovative ways of presenting information about uncertainty in seasonal climate predictions existed, there had been relatively little research that had systematically examined user needs with respect to this (although see McCown 2012, and McCown et al., 2012, for prior work on communicating seasonal predictions to end-user groups in agriculture). However, as the communication of uncertainty is a topic that has received attention in the broader literature on risk, judgement and decision making, a review of is work was conducted. While this was done with the caveat that communications that are appropriate to one specific context, may not be appropriate for others (e.g. what works in health risk communication or even probabilistic weather forecasting may not always work as well for communicating climate predictions), it did highlight several important points to consider in developing strategies for communication. These included: 1) the fact that, even amongst highly educated groups of decision makers, expertise in utilising statistical and graphical information can vary considerably, affecting information needs and preferences (e.g. Reyna et al., 2009; Okan et al., 2012, 2015); 2) that institutions and individuals vary in their tolerance for uncertainty (e.g. Demerit et al., 2010); 3) that just as biases is climate prediction systems can lead to systematic divergences between observation and prediction, "cognitive biases" in human judgement can lead to systematic errors in the interpretation of information about risk and uncertainty (e.g. Kahneman, 2011); 4) that counter-intuitive use of colour and other details in visualisations – such as using red to denote a high chance of lower than average temperatures – can hinder understanding (Kaye, Hartley & Hemming, 2012); and 5) that both expert and non-expert users of weather and climate information may wish to receive information in a way that facilitates Act/Don't Act decision making (Demeritt et al., 2010; McCown 2012, and McCown et al., 2012).

This review also identified potential solutions to some of the challenges posed. For instance, in cases where users may vary in expertise, or the amount of time they have to attend to information about risk and uncertainty, a "Progressive Disclosure of Information Strategy" has been suggested as one way to cater to a broad range of needs (Kloprogge, Sluijs & Wardekker, 2007). Under this framework, information about uncertainty is provided in such a way that a simple "top line" summary highlighting the most important points is provided in a way that can be understood by novice users and those with limited time, but that progressively more complex and detailed information is made accessible to those who require it. Likewise, evidence-based recommendations for the use of colour in climate visualisations have been made (e.g. Kaye et al., 2012). Above all however, the need to test the effectiveness of communication strategies with their intended audience was stressed.

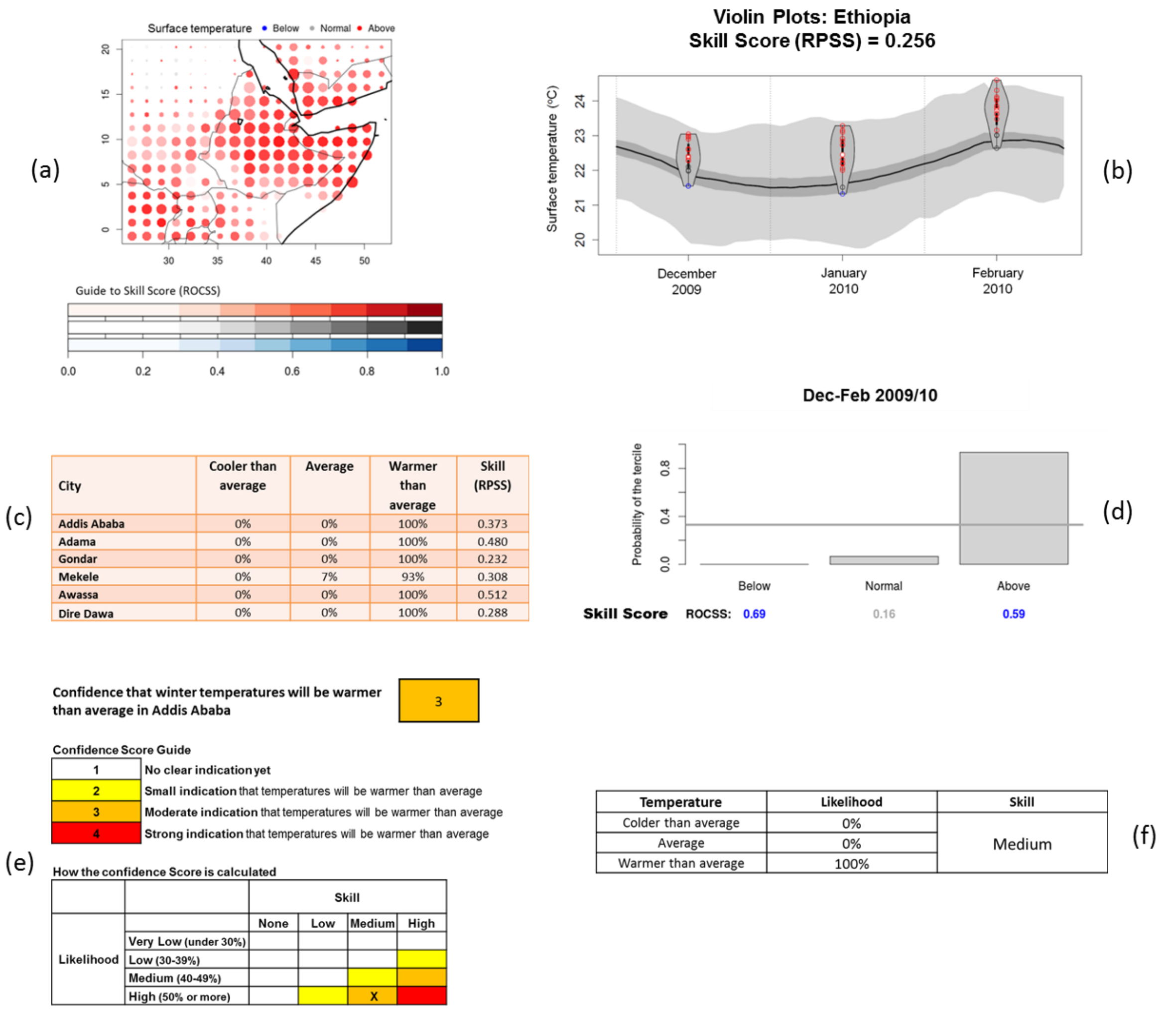
Concurrent with this review of the literature, a survey of user-preferences was conducted with EUPORIAS stakeholders, and people from organisations who had expressed an interest in the project. Amongst this highly engaged group of participants we found that, amongst those who reported that they currently used seasonal climate predictions, this information was perceived to be far more useful than it was accessible or understandable, and that a large proportion were either not currently receiving information about how well forecasts performed relative to observations (reflected in measures of reliability and skill), or were not receiving this information in a way that was readily understandable. It was also found that while users with greater statistical expertise favoured error bar style visualisations, these were not as highly favoured by those with less experience of using statistical information (see Taylor, Dessai & Bruine de Bruine, 2015, for further discussion). Hence, it has been the objective of this work package to identify a range of strategies for communicating uncertainty that address the needs of users varying in statistical expertise, and that make information about forecast performance (i.e. skill) easier to recognise and understand.

Summary of Challenges

- To find ways to bridge the gap between perceived usefulness of climate predictions and perceived ease of understanding.
- To identify effective ways of presenting information about skill.
- To identify communication strategies that meet the needs of users with different levels of statistical expertise.
- To test communication strategies with stakeholder groups and identify both "what works" and "what doesn't".

3.2 Key findings from the Decision Lab

Drawing on the findings of the preliminary user needs survey and review of existing approaches, a set of communication strategies were developed (Taylor et al., 2015) and a subset tested with participants from relevant sectors (Taylor et al., 2016). These are illustrated in Figure 1 below. While the Decision Lab did not identify a “one visualisation fits all” solution to the challenge of communicating confidence and uncertainty in climate predictions, it did yield several important findings.



City	Cooler than average	Average	Warmer than average	Skill (RPSS)
Addis Ababa	0%	0%	100%	0.373
Adama	0%	0%	100%	0.480
Gondar	0%	0%	100%	0.232
Mekele	0%	7%	93%	0.308
Awassa	0%	0%	100%	0.512
Dire Dawa	0%	0%	100%	0.288

Confidence that winter temperatures will be warmer than average in Addis Ababa: 3

Confidence Score Guide

1	No clear indication yet
2	Small indication that temperatures will be warmer than average
3	Moderate indication that temperatures will be warmer than average
4	Strong indication that temperatures will be warmer than average

How the confidence Score is calculated

		Skill			
		None	Low	Medium	High
Likelihood	Very Low (under 30%)				
	Low (30-39%)				
	Medium (40-49%)				
	High (50% or more)			X	

Temperature	Likelihood	Skill
Colder than average	0%	Medium
Average	0%	
Warmer than average	100%	

Figure 1a-f Formats presented in the Decision Lab a-c were presented to expert users of statistics only, d was presented to all participants, while e-f were presented to novice users of statistics. **(a) Bubble map:** colour represents most likely tercile, size of the bubble represents predicted likelihood according to forecast, and opacity indicates skill. Blank space indicates regions for which there is no skill or where all terciles are predicted to be equally probable. This visualisation was based on prior work by Slingsby et al. (2009). **(b) Violin plot:** a “Violin” comprising a pdf representing the spread of the ensemble members of the forecast is overlaid on climatology, coloured dots represent individual ensemble members colour coded to reflect the tercile that they fall into, with a white dot representing the median; **(c) Table:** likelihood of tercile is given as a percentage score, while Rank Probability Skill Score is provided for each region; (d) **Bar Graph:** bars represent tercile probability with a skill score (ROC Skill Score) for each tercile underneath; **(e) Confidence Index:** forecast skill is combined with the likelihood of threshold exceedance to provide a colour-coded index; and **(f) Simple Table:** likelihood of tercile is given as a percentage score, while skill score is given using a qualitative category.

Communicating Likelihood

It was found that where predictions focussed on the likelihood of upper, middle and lower terciles, presenting numeric information is tabular format appeared to facilitate the most accurate interpretation. However, these formats were less useful to those participants who were more interested in spatial data, or the distribution of ensemble members. Conversely, when probability distributions were shown (Figure 1.b, Violin Plot), participants understandably struggled to extract information about the likelihood of specific terciles. This highlights the importance of identifying what kind of probabilistic information users require.

Another key lesson learnt from the Decision Labs was that care must be taken to ensure that other information provided on visualisations (e.g. skill, climatology) is not placed in a position where it might be misinterpreted as probabilistic information. For example, on the bar graph shown in Figure 1.d, a substantial minority of participants mistook the skill scores beneath each bar or the climatology line as information about tercile likelihood.

Communicating Skill

The matter of how skill can be effectively communicated was identified as a core challenge in the early stages of the work package. In the Decision Lab we tested different ways of representing skill. These included: single numeric scores (e.g. RPSS for the prediction as a whole, or ROCSS for a 'most likely tercile'), multiple numeric scores (i.e. ROCSS for each tercile), opacity to denote higher skill (see the Bubble Map in Figure 1.a), and qualitative categories (e.g. None, Low, Medium, High).

- Single versus multiple skill scores

It was found that while providing a numeric skill score for each tercile offers a more detailed insight into where greatest skill lies, presenting multiple scores can be confusing to both novice and more advanced users. Hence, one suggestion emerging from these findings is that, unless a need for multiple scores exists, or users express a clear preference for receiving them, providers should consider giving users a single measure of skill. This could be for either the prediction as a whole (e.g. using RPSS) or for the quantile of greatest interest (e.g. using ROCSS).

- Opacity

In one of the visualisations presented to more advance users (Bubble Map, Figure 1.a), the level of opacity was used to represent skill: with greater opacity representing higher skill and greater transparency representing lower skill. It was found that this method of representing skill was generally well understood when skill was relatively high. However, where the absence of skill led to there being large areas of blank space, some participants struggled to accurately interpret what this meant (i.e. that all terciles should be assumed to be equally likely). Thus, if opacity is used to denote skill, a clear explanation that blank space means is required.

- Qualitative categories

For all visualisations numeric skill scores were accompanied by qualitative guides as to what they represented (e.g. No skill, some skill, good skill). This was done to provide participants – who may not have come across skill scores before – with a way to evaluate the skill information. Indeed, when it came to novice users, findings suggested that providing qualitative skill categories (e.g. No Skill, Low, Medium, and High) only appeared to aid understanding: especially when it comes to distinguishing between forecasts with some skill and those with no skill. Of course, any attempt to classify skill as ‘good’ or ‘low’ is necessarily subjective, and care must be taken in deciding where these thresholds lie as one user group’s perception of what is good skill or reliability, may differ from another’s.

- When there is no skill

While providing qualitative categories to aid interpretation of what skill means does seem to be helpful, it was nonetheless still evident that – even when participants ostensibly understood that a skill score of less than zero or “None” indicated that there was no skill – information about predicted likelihood still affected judgements as to how likely particular terciles would be. This indicates that, when presented with a prediction, many recipients will make an understandable assumption that this information must provide some sort of ‘added value’. It is therefore recommended that, for regions and time periods where no skill exists, providers consider either presenting climatology only or informing users that a forecast cannot be provided with confidence at the present time.

- Combining skill and likelihood (Confidence Index)

The Confidence Index illustrated in Figure 1e merged information about likelihood and skill. This was done by assigning qualitative categories (e.g. low, medium, high) to both likelihood of a particular tercile, and it’s corresponding skill, before combining them to provide a colour coded (1-4) Confidence Score. The goal of this format was to help users with less experience of using complex statistical information to integrate information about these different sources of uncertainty. Findings from the Decision Lab, along with informal feedback from EUPORIAS partners and stakeholders, suggested that this general approach could potentially be tailored to users who are interested in threshold exceedance (i.e. where outcomes can be classified as ‘Event occurred’ vs ‘Event did not occur’). However, as user opinions at to what actually constitutes a ‘high’ likelihood or ‘low’ likelihood can vary considerably, any such system needs to be developed through consultation with specific stakeholders.

Preference

Consistent with other recent work on climate visualisation (Daron et al., 2015; Lorenz et al., 2015), we found that while participants tended to like visualisations and tables more if they were perceived as being more familiar, greater preference did not automatically correspond with greater understanding. Indeed, there was some evidence to suggest that perceiving a visualisation to be more ‘familiar’ can lead to misinterpretation when similarities are superficial. Hence, while climate service providers may understandably want to present information to users in a way that users prefer and are more likely to utilise, it should not be assumed that these will be automatically well understood, and care should be taken to identify areas where misunderstandings might occur.

Advanced users

When it came to the visualisations aimed at more advanced users of climate information (i.e. those with statistical expertise and some existing knowledge of climate prediction), it was found that in trying to incorporate all of the information that these users may wish to receive can make visualisations appear cluttered and difficult to understand. For instance, the violin plots in Figure 1.b contains information about skill, probability distribution (pdf and boxplot), central tendency (median), individual ensemble members per tercile, and climatology. Comments made by Decision Lab participants suggested that while the comprehensiveness of the information was appreciated by some expert participants, many still found them difficult to interpret. The solution to this problem is the creation of tailored methods of communication for specific users; a conclusion supported by the lessons learned from the EUPORIAS prototypes summarised in Section 3.3. However, there will be many instances where this level of tailoring is neither practical nor possible – and even users within the same sector who are interested in the same climate variables or impacts may vary in their expertise and the amount of time that they have available to examine climate predictions. One potential solution may therefore be to provide a tool whereby users can select which ‘layers’ of information they wish to view. Although care must be taken to ensure that the simplest layers do not hide uncertainty when it exists.

Recommendations emerging from the Decision Lab

- If skill is lower than climatology, then consider presenting climatology only, or telling users that a forecast cannot be provided with confidence.
- Providing qualitative categories (e.g. None, Low, Medium, High) can help users to “make sense” of information about skill. Although care should be taken in deciding where these category thresholds should lie.
- If possible, consider providing a single measure of skill, as multiple scores can make interpretation more difficult for users.
- Take care to ensure that skill scores and information about climatology are not placed in areas where they might be confused with information about likelihood.
- Trying to create a single visualisation that captures all of the information that advanced users may require can make it cluttered and difficult to read. Consider providing tools that allow these users to control which “layers” of information are shown.
- If users simply require quantile likelihoods with a measure of skill, then consider using a tabular format.
- **Wherever possible work with users to identify and correct misunderstandings.**

3.3 Lessons from the EUPORIAS prototypes

3.3.1 RESILIENCE

When making risk management decisions, the wind energy sector has traditionally relied on historical data (climatology). Led by IC3, the RESILIENCE prototype focusses on providing robust information about future variability in wind speed based on probabilistic climate predictions (http://resilience.euporias.eu/en/resilience_overview), to aid risk management decisions at both pre-construction and post-construction phases of wind energy production. The development of this prototype has engaged stakeholders including wind farm developers, wind farm operators, and energy traders (see Work Package 41 report by Soubeyroux et al, 2016 for further details).In this prototype, climate information providers have closely collaborated with a visualizer (Moritz Stefaner), design and innovation specialists (Future Everything), and prototype stakeholders in developing Project Ukko: an interactive tool designed to provide information about predicted wind speed across the globe. This tool, which has been created and refined based on iterative stakeholder feedback, incorporates information about the median of the predicted wind speed, predicted trend category (e.g. high probability of increased wind speeds or reduced winds), total installed wind power at sites where wind farms currently exist, and skill (example in Figure 2, but visit http://project-ukko.net/ for a full overview).

Users are initially presented with an interface in which predicted wind speed for each location is represented using the thickness of the bar, the trend category by both colour and line direction, and skill by level of opacity (areas where there is no skill are left blank). This format draws attention to regions where high skill, high predicted speed, and high change in predicted speed exist. However, it is possible for users to drill down to see more detailed information for specific locations, including the spread of past observations, the spread of the current ensemble prediction, and further details about skill. Users may also opt to view a simplified version of the map that incorporates only predicted wind speed and skill, or to mask the ocean – where there may be high skill but wind farms cannot be built.

As noted, this tool has been developed with extensive stakeholder consultation. In early interactions, it became evident that stakeholders did not necessarily have pre-conceived ideas as to how information about forecast uncertainty should be presented. However, it was found that providing examples of what this information could look like gave them a starting point for considering what would and would not be useful, even if the examples themselves were ultimately judged to be insufficient. In evaluating the user interface that was developed in Project Ukko (see Makri, 2015 for full report), one challenge that was encountered was the difficult users had in assessing the usefulness of tool separately from the usefulness of the underlying prediction data. However, it became apparent that while the underlying prediction data may not currently be regarded as very useful for some regions (i.e. where wind farms but no skill exists), the interface itself was judged favourably. The users interviewed generally understand what the skill bars denoted, and that blank areas indicated regions where no useful (i.e. skilful) information currently existed, although suggestions for further revising the interface were made based on user misinterpretations and feedback (e.g. adding informational tooltips to provide a more detailed explanation of the scales in the legend).

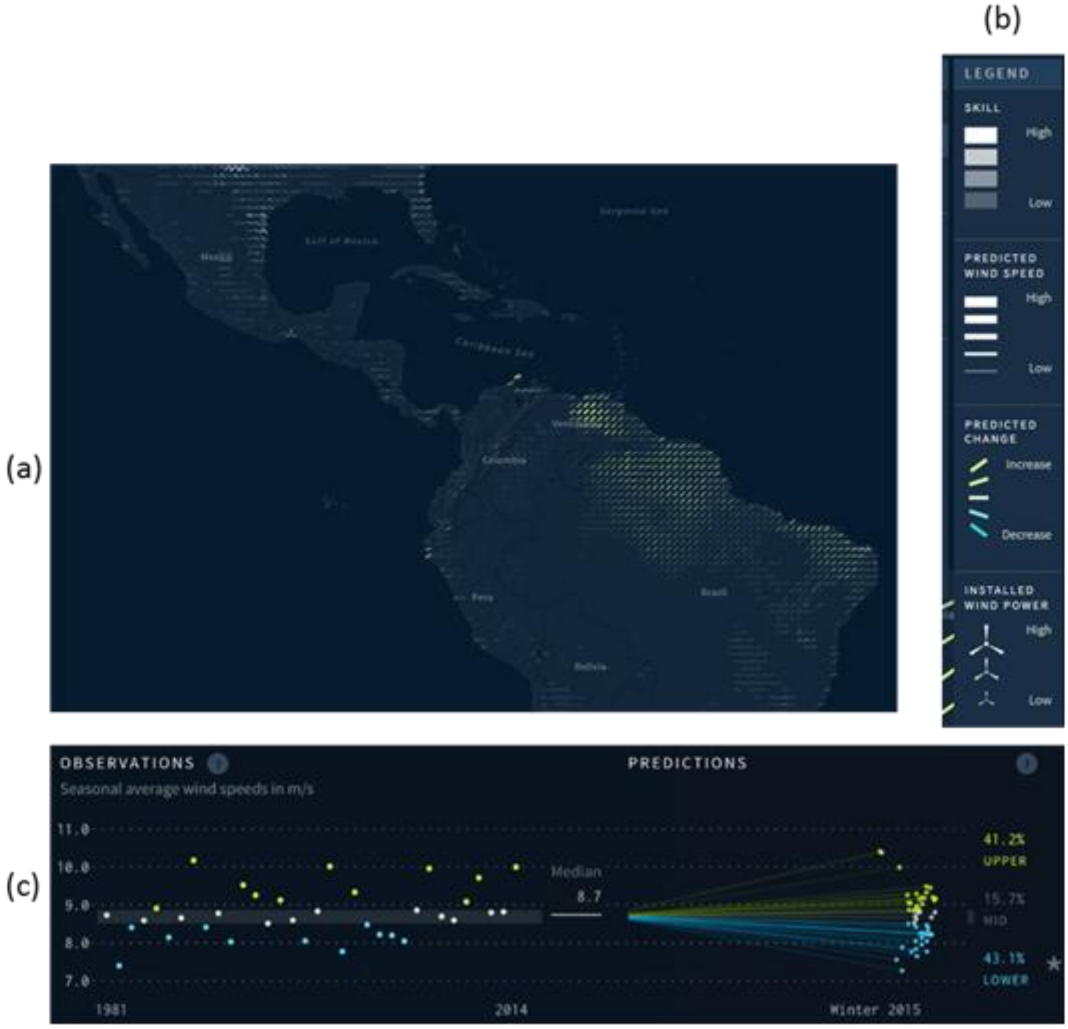


Figure 2 a-c. Screenshots taken from Project Ukko (http://project-ukko.net/). **(a)** The default map shown to users. Thickness of the rectangles at each grid point indicate the median predicted wind speed, colour and orientation of the rectangles show the predicted trend category for speed, opacity indicates level of skill. **(b)** The legend presented with the map. **(c)** Users can examine historical observations (1981-2014) and spread of ensemble prediction for individual points on the map.

Key Lessons from RESILIENCE

- Collaborating with visualisation specialists can help climate service providers to identify and develop communication strategies that go beyond formats that are widely used in the field, thus helping to further bridge the gap between providers and users.
- Iterative user feedback helps providers to identify and address misinterpretations, and ensure that information is presented in a way that is useful for decision making.
- Users may not always have pre-conceived ideas about the kinds of information about uncertainty they would like to receive, and how they would like this to be presented. Presenting examples – even if they are ultimately rejected – can give stakeholders a starting point for thinking about how their needs could be better met.

3.3.2 RIFF

Led by Météo-France, the objective of RIFF is to provide water managers with downscaled near surface temperature and precipitation predictions coming from the Météo-France operational system for seasonal forecasting to feed into probabilistic river flow forecasts for spring and summer (http://riff.euporias.eu/riff_overview). This prototype works closely with two stakeholder organisations to co-produce tailored information fitting the points at which critical thresholds may be crossed; with these thresholds being those for which the stakeholders have established decision making protocols.

Recent user consultations have found that, for monthly forecasts, a boxplot format showing the spread of the predictions compared to climatology was favoured by stakeholders, as it can be used to highlight where critical thresholds may be crossed. With respect to receiving information about skill, stakeholders slightly differed in their preferences. One group indicated that they only need general information about skill, The other group expressed a request for receiving information about mean skill as a categorical (e.g. 1-4) “Performance Index”, similar to the index that is currently used in Météo-France’s medium range weather forecasts, although underpinned by different calculations. In addition to this, both groups were very receptive to Météo-France proposition of a specific indication of the current predictability. It is thus planned that the delivery platform will incorporate two pieces of information about skill: a performance Index, with score being a function of a score calculated on hindcast data (e.g. correlation, Continuous Rank Probability Skill Score), and a more subjective expert appraisal linked to the current situation (provided by Météo-France). Interestingly, the use of opacity to represent the skill calculated on the hindcast was rejected by stakeholders, as it was felt to make the information look “less trustworthy”. The issue of visualisations being judged to have a “trustworthy” appearance was deemed to be particularly important in this instance, as those receiving the forecasts would also have to present them to policy makers. At the time of this report, there is not yet a definitive presentation of the skill for this prototype, as this is an ongoing process that will be refined in the coming months, when stakeholders will have to use it in real situations (see Figure 3 for an example of a potential interface design). Again, this highlights the value of an iterative process of consultation between providers and end-users.

One challenge that has been encountered in the development of this prototype is that, while stakeholders would like to have day-by-day information on the ensemble spread (e.g. presented for instance as a temporally continuous range), forecasts cannot be robustly provided at this temporal resolution. However, as there was a strong preference on the part of users to receive this data, it was agreed that it would be provided as a plausible scenario to aid planning, but that this would come with a strong “health warning” that it should not be treated as a prediction

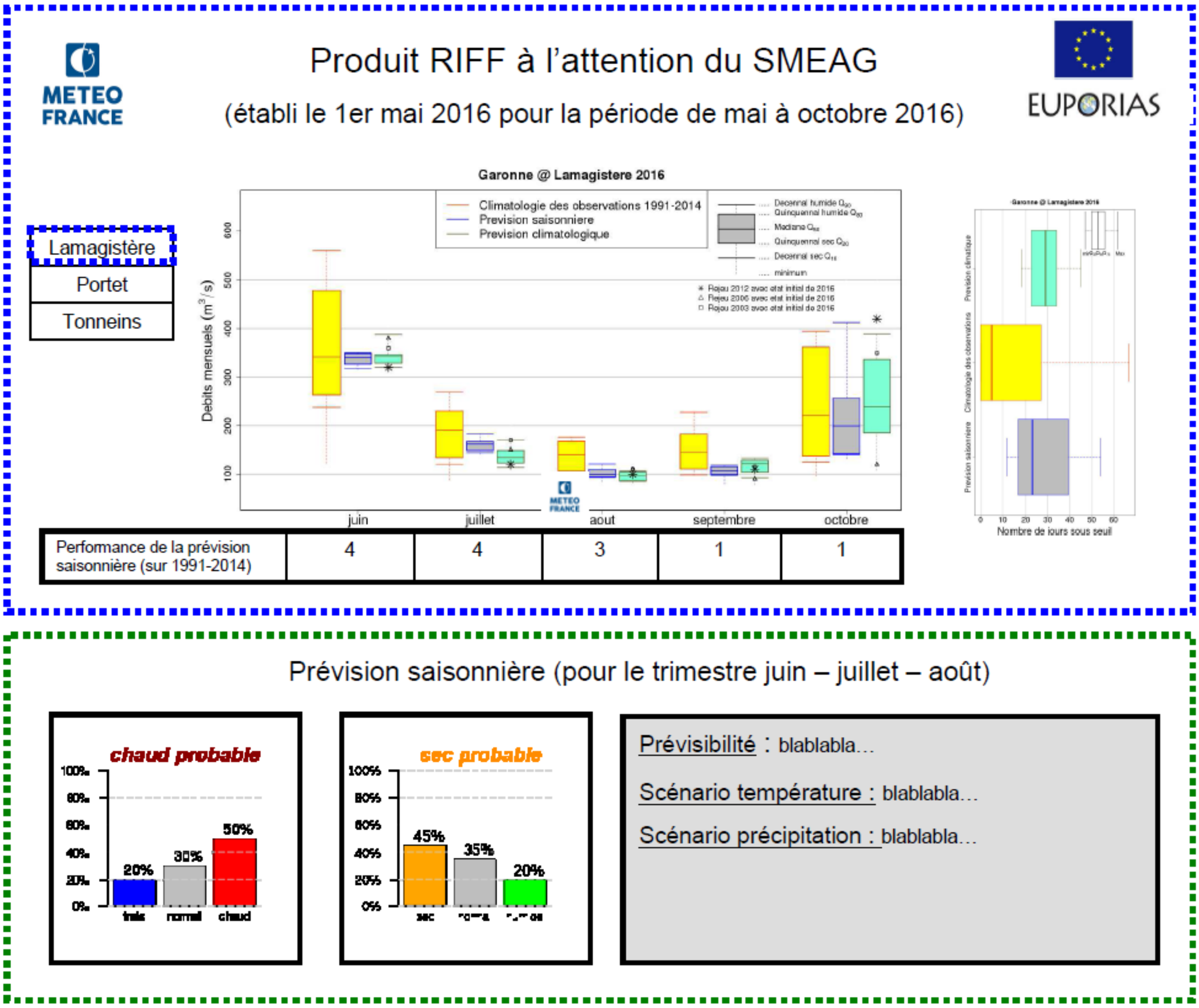


Figure 3 User interface in ongoing development as part of the RIFF prototype. Box-plot style Climagrams are used to show the spread of monthly predictions and historical averages (climatology) relative to critical thresholds. An ordinal performance score is used to reflect skill.

Key Lessons from RIFF

- Even organisations within the same sector, who are tasked with making similar risk management decisions, information preferences and requirements may differ. Where it is possible to do so, working with organisations to co-produce tailored solutions is the optimal way to meet user needs.
- Users of climate information may not only require that the information about uncertainty be provided in a way that they find useful and understandable, but also in a way that they can present to others.
- While it is important that stakeholders are made aware of skill, calculated by robust statistical approaches on a large historical period, the amount of “confidence” that they can have in the forecast has to be modulated by information about the predictability of the current situation according to the seasonal forecast bulletins provided by NMS.
- Where there is a mismatch between the information that users would ideally like to receive, and what climate services can produce with confidence, this should be the start of a conversation about what can feasibly be provided.

3.3.3 SPRINT

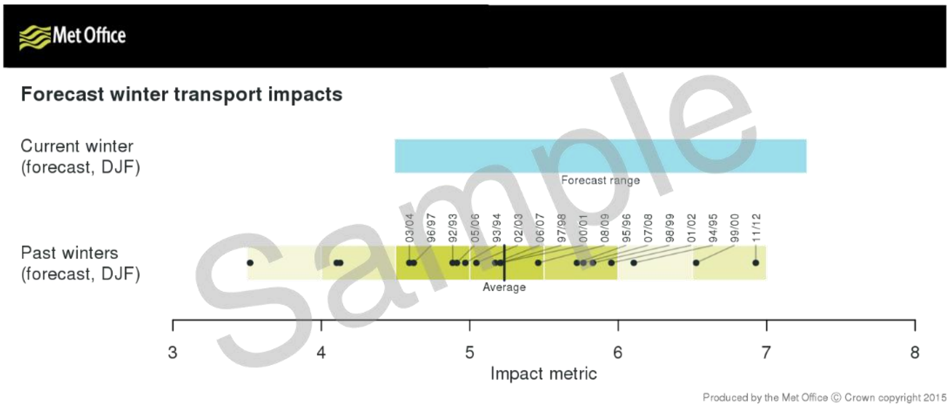
Recent developments in climate predictions for Northern Europe mean that it is now possible to make skilful predictions of the likelihood of occurrence of cold air outbreaks in the UK winter for lead times of weeks to months (Scaife et al., 2014). Co-funded by the UK Government's Department for Transport the objective of the SPRINT prototype is to provide information to aid decisions around de-icing (e.g. stock levels, training, personnel availability, etc.) to a variety of stakeholders in the transport sector (http://sprint.euporias.eu/sprint_overview). While all prototype stakeholders come from the transport sector there is nonetheless a high level of diversity amongst them in terms of area of operation (e.g. aviation, roads, rail, local authorities), existing statistical and climate expertise, and role in decision making (e.g. those tasked with making operational, tactical and/or planning decisions, those tasked with providing information to decision makers). Variations in institutional tolerance for uncertainty have also been observed, with some stakeholders finding the 3-month lead time prediction too uncertain to be useful, while others found it useful despite the uncertainty. Consequently, while RESILLIENCE (3.3.1) and RIFF (3.3.2) have focussed on providing highly tailored solutions to specific stakeholder groups, SPRINT requires that information be provided in ways that can meet the needs of multiple stakeholder groups.

To try and address the communication needs of this broad range of users, two forms of information have been provided: 1) the publicly available Met Office Contingency Planners Outlook[1] combined with a briefing that elaborates on how the outlooks should be interpreted and the science underpinning them; and 2) forecasts for specific impact metrics (Palin et al. 2015; Figure 4). Stakeholder consultations have indicated that many find the briefings to be useful in helping them to better understand the content of the Contingency Planners Outlook – which may not on its own be easily interpreted by all users – and the underlying science. However, while stakeholders generally appreciated receiving information about the science underpinning the forecasts, many also emphasised the importance of ensuring that this does not take precedence over the "take home message" for users. As might be expected, the differences in user roles, expertise, and the amount of time available for examining forecast information was reflected in preferences for the amount and complexity of information provided: with some expressing a wish for detailed technical information, and others a short summary that could be quickly digested. As it is not feasible to produce heavily tailored products for each stakeholder, one possible solution going forward may be to adopt a tiered presentation of information in documents; where a short non-technical summary is provided, but is followed by more detailed information.

With respect to the impact forecast, stakeholders were initially shown the visualisations depicted in Figure 4.a. However, preliminary feedback indicated that the use of a solid blue bar to indicate the forecast range (in this case 70% CI) could be misinterpreted as indicating that there was an equal chance of conditions falling anywhere within the range, or that the forecast range encompassed all possible conditions. The visualisation was subsequently revised so that shading was used to mirror the underlying pdf (Figure 4.b). Once again, this highlights the importance of seeking user feedback on communication strategies.

[1] http://www.metoffice.gov.uk/publicsector/contingency-planners

(a)



(b) Revised impact forecast visualisation

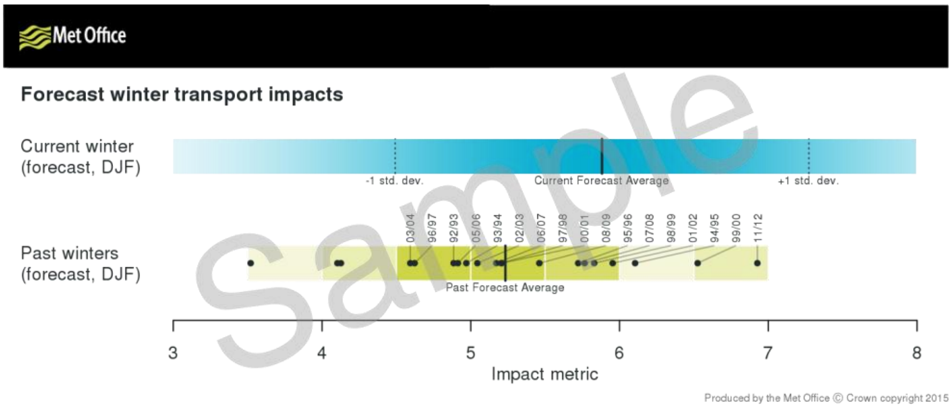


Figure 4 a-b. Initial **(a)** and revised **(b)** impact forecast shown to stakeholders. **(a)** In the initial visualisation the prediction ("current winter") is represented by a solid blue bar showing a 70% CI forecast range, while historical observations (climatology) are represented by the bottom green bar ("past winters"). **(b)** In the revised visualisation the prediction is represented by a bar in which shading is used to represent the underlying pdf.

Key Lessons from SPRINT

- Seeking user feedback on visualisations and other communication formats can help providers to identify and address areas where misinterpretations can occur.
- With respect to visualisation specifically, it was found that displaying forecast ranges as a solid bar can create the misperception that a) all conditions within the range are equally likely; and b) it encompasses the entire range of possible conditions. Using shading to reflect the underlying pdf may help to alleviate this problem.
- Stakeholders indicated that they value having an explanation of the science underpinning the forecasts. However, this should not be perceived as taking precedence over the "take home message" about what this means for users.
- As it is not always possible to provide tailored solutions for all sub-groups, one possible solution could be to adopt a tiered presentation of information.

3.3.4 Land Management Tool (LMTool)

EUPORIAS is working with Clinton Devon Estates and the UK's National Farmers Union to develop a tool (LMTool) to provide seasonal temperature and precipitation forecasts (up to 3 months ahead) in support of land management decision making, with a focus on cover crop planting, choice, and management in South West England (see: http://lmtool.euporias.eu/lmtool_overview). The prototype currently encompasses 14-day forecasts and 3-month outlooks. While many of the stakeholders involved in other prototypes have advanced statistical expertise, the target users of the LMTool are individual farmers who – while used to dealing with uncertainty in their decision making – do not necessarily have extensive experience of using the kind of complex information that often accompanies seasonal predictions. Hence, this tool requires that providers identify effective ways to communicate confidence and uncertainty to users who are educated "non-experts" when it comes to statistics.

At the time of this report, work examining stakeholder-needs for forecast communication is ongoing within the LMTool prototype. However, those user consultations that have taken place to date have nonetheless highlighted important lessons with respect to the communication of confidence and uncertainty. Preliminary feedback on the 3-month outlook provided for winter 2014/15 indicated that some users struggled to extract information from a bar graph that plotted highest, lowest and three middle quintiles against climatology (Figure 5). Hence, the need for further work in this area was recognised, and a range of communication formats for the 14-day forecast and 3-month outlook have recently been examined in an interactive stakeholder workshop.

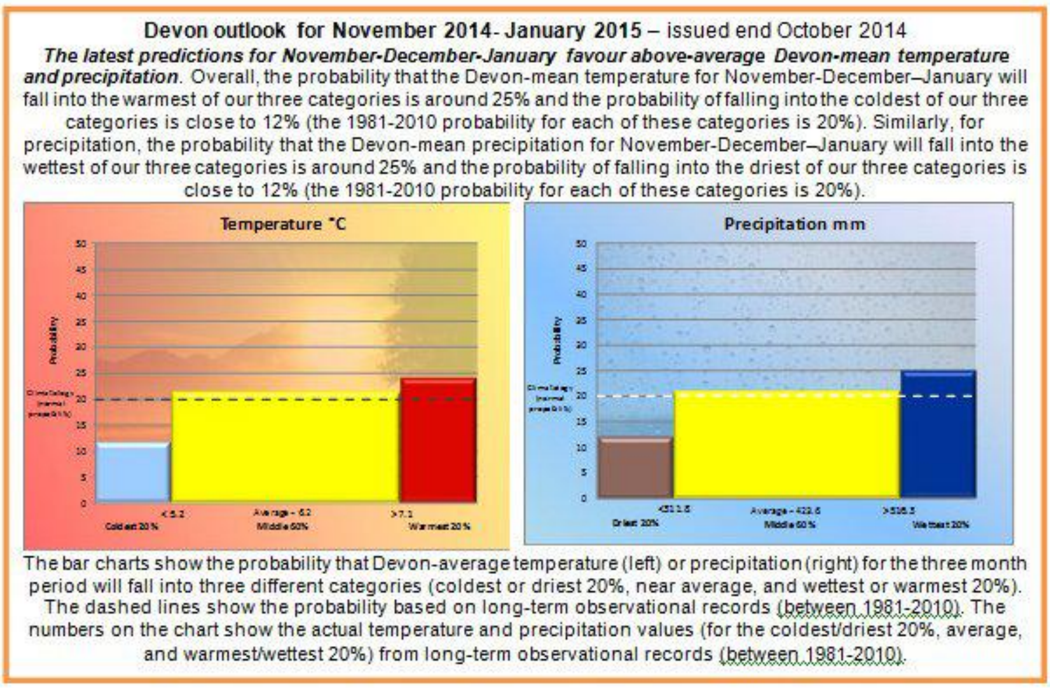


Figure 5 Example of 3-month temperature and precipitation outlook for Devon Winter 2014/15. Bar graphs show the predicted likelihood of upper and lower quintiles, along with three middle quintiles amalgamated into a single bar. The dotted line represents climatology (i.e. that 20% of historical observations have fallen into each quintile).

With respect to the 14-day temperature forecast, it was found that a spaghetti-plot style visualisation showing a measure of central tendency were generally better understood than box and whisker plots and a cumulative box plot (Figure 6a-c). However, when it came to precipitation, the box and whisker plot was better understood than the spaghetti-plot (Figure 7a-b), although some workshop participants did not find ‘whisker’ part of the boxplot to be readily understandable. This highlights the fact that, as trends in different variables and impacts can follow very different patterns, they can be visually very different when plotted on same types of graphs. Hence, a communication strategy that works well for one variable may not work as well for another.

(a) (b)

(c)

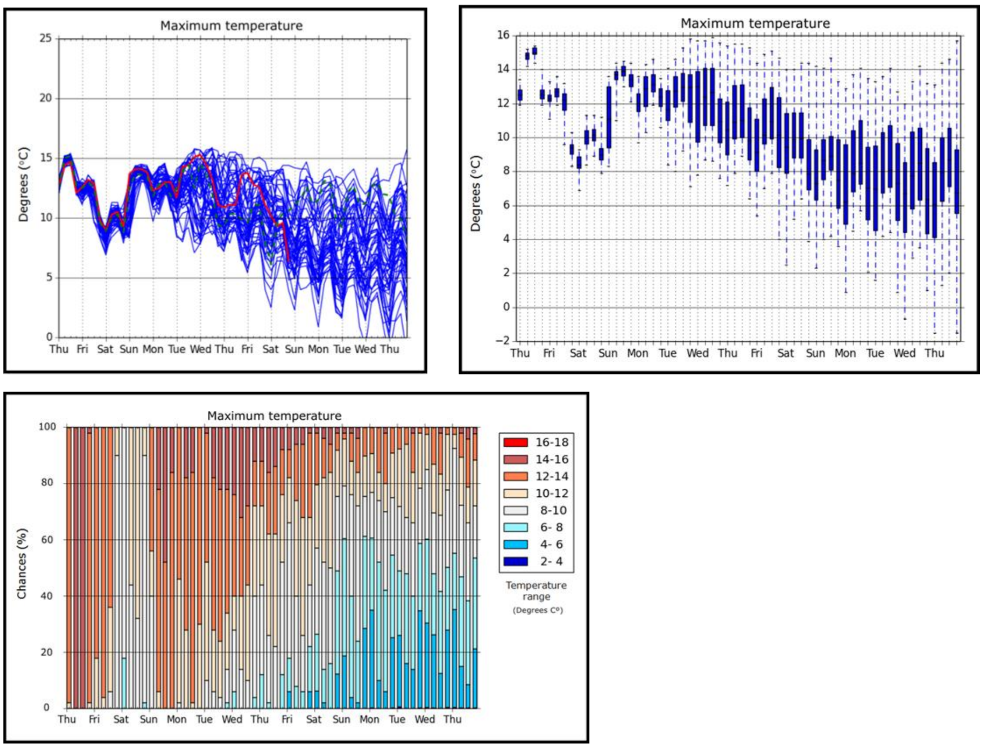


Figure 6 a-c Example 14- day temperature forecasts presented to workshop participants **(a)** Spaghetti style plot showing spread of ensemble members with measure of central tendency **(b)** Box and whisker plot with box representing 25-75 percentile and whiskers representing the full forecast range. **(c)** Stacked bar graph representing proportion of ensemble members falling into each colour coded temperature range

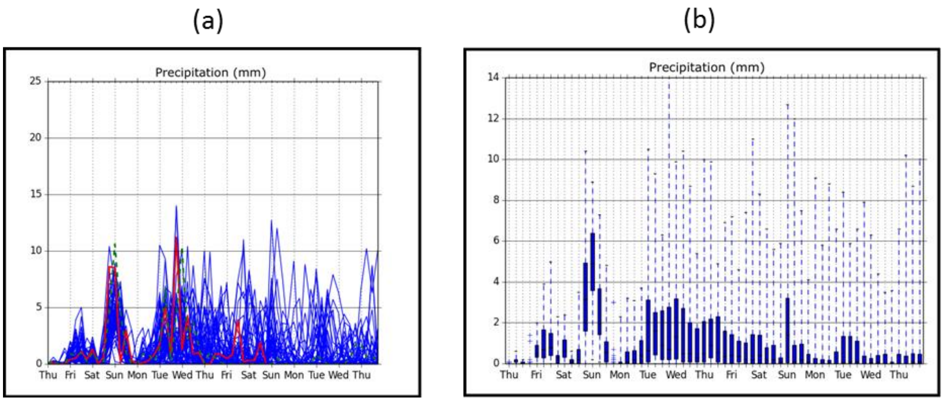
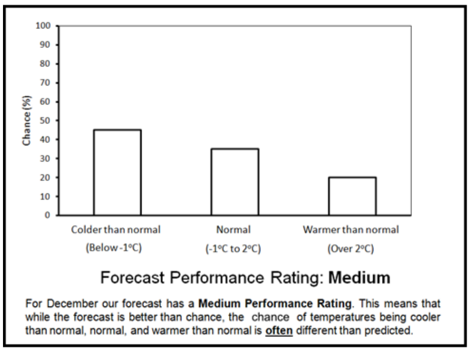


Figure 7 a-b Example 14- day precipitation forecasts presented to workshop participants **(a)** Spaghetti style plot showing spread of ensemble members with measure of central tendency **(b)** Box and whisker plot with box representing 25-75 percentile and whiskers representing the full forecast range.

For the 3-month outlook, a simple bar graph incorporating a brief description of "forecast performance" (e.g. skill), was generally preferred to tabular and text presentations (Figure 8a-c). The bar graph presented was simpler than the one presented in the Decision Lab (e.g. percentage rather than standardised probabilities on the y-axis, no climatology line, a qualitative rather than quantitative indication of skill). However, while participants were generally able to extract the right information from these formats, comments indicated that some found them time consuming to interpret, while others wanted more detail about why the forecast was as it was (e.g. El Nino). This highlights the tradeoff that stakeholders may face in receiving forecasts in a way that can be quickly processed, and receiving more detailed information that will take more time to digest. Going forward it was suggested that a simple bar graph presentation accompanied with "punchier" explanatory text could help to meet the preferences of both those who wanted a simple visualisation and those who preferred to receive some form of written information.

(a)



(b)

Temperature	Likelihood	Forecast Performance Rating for December
Colder than normal *Below -1°C*	45%	Medium
Normal *-1°C to 2°C*	35%	
Warmer than normal *Over 2°C*	20%	

For December our forecast has a **Medium Performance Rating**. This means that while the forecast is better than chance, the chance of temperatures being cooler than normal, normal, and warmer than normal is <u>**often**</u> different than predicted.

(c)

In this region of Europe average December temperatures are considered to be colder than normal if they are below -1°C and warmer than normal if they are above 5°C

Our forecast predicts that it is very likely (95% chance) that average temperatures for this December will fall between -2°C and 1°C.

However, it should be kept in mind that forecasts are not always perfectly reliable, and perform better for some months than for others. By looking at how well forecasts have predicted temperatures for previous years, we can measure how well they are performing and give them a Forecast Performance Rating. This tells us how much confidence we can have in the forecast.

For December the Performance Rating for our forecast is: <u>Medium</u>. This means that while our forecast performs better than chance it <u>often</u> makes errors.

Figure 8 a-c Hypothetical examples of formats used to display a 3-month outlook that were presented to workshop participants. (a) A bar graph showing predicted likelihood of upper, middle and lower terciles. (b) A Table showing predicted likelihood of upper, middle and lower terciles. (c) A text description of the forecast range. All three formats contain qualitative skill categories labelled as Forecast Performance Rating (i.e. High, Medium, Low, None) along with a description of what this means.

Key Lessons from LMTool

- As with other prototypes, the importance of testing the understandability and usefulness of communication strategies with one's intended audience is highlighted.
- Users can face trade-offs between wanting more detailed information, including explanations for why certain conditions might be expected, and wanting information that they can quickly digest.
- Communication strategies that work well for one particular variable or impact may not work for others. Again, the importance of testing communications should be stressed.

3.4 Recommendations going forward

3.4.1 Tailored solutions (where possible)

In reviewing both the key findings from Work Package 33, and the work with stakeholders in Work Package 42 prototypes, one resounding message that has emerged is when it comes to communicating confidence and uncertainty, no single visualisation or format meets the needs of all users. **One visualisation does not fit all.** In a preliminary exploration of user needs, it was found that some visualisations favoured by those with existing statistical expertise, were less favoured by those with less experience of using this type of information (Taylor and Dessai, 2014; Taylor, Dessai & Bruine de Bruin, 2015). Subsequent examination of participant preferences and understanding in the Decision Lab did not find a single ‘favourite' amongst those with existing statistical expertise (Taylor et al., 2016). Indeed, comments made by participants, indicated that features that were appreciated by some (e.g. presentations of climatology, presenting a large volume of information on a single visualisation), others disliked or misinterpreted these. These findings are underscored by work in the prototypes, which have shown that, even within the same sector, the needs and preferences of specific stakeholders and organisations can vary considerably (e.g. in expertise, role in decision making, time available for “digesting” information, protocol for decision making under uncertainty, etc.). **Hence, where the scope and resources exists to do so, the optimal solution to the challenge of communicating confidence and, is to work with specific stakeholders or stakeholder groups with similar needs, to produce tailored communication strategies.**

Of course, from a practical perspective this may not always be possible, and climate information providers will face the challenge of providing this information to larger groups of stakeholders with varying needs. **While this may preclude highly tailored solutions, it is nonetheless important that providers keep in mind that multiple formats for presenting confidence and uncertainty may be required.**

3.4.2 Layering information

In both the SPRINT and LMTool prototypes it has was found that stakeholders vary in the amount of information about confidence and uncertainty – and the factors underlying it – that they would like to receive, and the amount of time they have to devote to this information. Using a tiered approach to presenting information has therefore been suggested as one way to accommodate the needs of multiple users: with a simple visualisation or summary, being presented as part of a more detailed document or tool. Of course, it is important that in providing information in this way one does not mask the presence of uncertainty, or make it difficult for users to access deeper layers of information (e.g. by putting too many page links between users and the information that they require). On a similar note, findings from the Work Package 33 Decision Lab indicated that trying to provide, by default, all of the information on uncertainty that advanced users might require on a single visualisation can lead to graphs and diagrams becoming cluttered and difficult to interpret. One solution to this is to provide users with tools that allow them to select which layers of information they wish to view. RESILIENCE’s Project Ukko provides a practical example of how this can be done, with users being able to either simplify the visual presentation (while always maintaining important information about forecast skill), or drill down to explore detailed information about forecasts for specific geographic locations.

3.4.3 Communicating Skill

One key focus of the research conducted in Work Package 33 has been to identify strategies for integrating information about skill into forecast communications in a way that makes users aware of the “confidence” that can be placed in the forecast, and ensures that trust in providers in maintained. As noted, a single solution for doing this in a way that meets the needs of all users is unlikely to exist. However two key recommendations can be made:

If skill is lower than climatology do not show a forecast (or show climatology only)

When users are presented with information about a forecast there is likely to be an assumption that this information will have some form of “added value”. Even when it is stated that no skill exists, and this is ostensibly understood, presenting the forecast anyway can create an expectation that this is useful information. This was observed in the Decision Lab, where stated forecast likelihood influenced participant expectations about future conditions, even when no skill existed. Hence, it is to be recommended that providers do not provide forecasts where there is no skill, unless users – having been briefed on the limitations of the information – specifically request to see it.

Provide users with a guide as to what skill means

Even for users who have expertise in using statistical and probabilistic information in their decision making, raw skill scores may seem abstract and difficult to interpret (e.g. how confidence should one be in a forecast with an RPSS of 0.35?). It is therefore recommended that providers give users a framework for interpreting this information: whether it takes the form of qualitative categories (e.g. low, medium, high) and descriptions, visual cues such as opacity (as currently used in the RESILIENCE prototype’s Project Ukko), or an ordinal performance index (such as that being developed for use in the RIFF prototype). Of course, one challenge in doing this is that users may vary in terms of what they think constitutes “low confidence” and “high confidence). However, without some form of guidance being provided, many users will struggle to interpret this information.

3.3.4 Test and review

As noted, it may not always be possible to provide heavily tailored communications for individual stakeholders. However, even where this level tailoring is not possible, it nonetheless important that strategies for communicating confidence and uncertainty in climate predictions be tested with intended user groups. In Work Package 33, the Decision Lab highlighted areas where misinterpretations can occur. Many of these misunderstandings had not been anticipated in the development stage of the work package. Likewise, in each of the four prototypes discussed in this report, stakeholder feedback on initial formats for representing uncertainty, has led to these being redesigned or amended to reduce misinterpretations and better meet user needs. Hence, it is to be strongly recommended that a process of testing and review take place when communication strategies are being developed

To summarise

- There is no “one size fits all” solution for effectively communicating confidence and uncertainty in climate predictions to all user groups.
- Where it is feasible to do so, work with stakeholders to develop tailored communication strategies.
- Where it is not feasible to provide heavily tailored solutions, consider adopting a tiered approach to communication.
- Where forecast skill does not exceed climatology, refrain from providing the forecast unless users have been briefed on its limitations and specifically request to see it anyway.
- Provide users with a framework for understanding what skill scores indicate. This can take the form of qualitative categories and descriptions, ordinal confidence scales, or an agreement to provide forecasts only if confidence exceeds a certain level.
- When developing strategies for communicating confidence and uncertainty to climate service users it is strongly recommended that they be tested with users groups and if necessary revised to address misinterpretations.

3.5 Publications and Dissemination Activities

To ensure that the lessons learnt and recommendations emerging from Work Package 33 reach appropriate audiences within the climate service and risk management community, an ongoing programme of dissemination and publication has been undertaken.

Papers published

A paper reporting on the findings of the preliminary user needs survey conducted in Work Package 33 (T33.1) has been published in Philosophical Transactions of the Royal Society A (Taylor, Dessai & Bruine de Bruin, 2015).

Workshops and conferences

The findings of Work Package 33 have been (or will be) disseminated at the following workshops and conferences:

- Society for Risk Analysis: Europe Annual Conference (Bath, 2016 – upcoming)
- GERICS CLIPSE workshop: “Confidence in Climate Services Presenting uncertainty with confidence” (Hamburg, 2016)
- ECMWF workshop: “Quantifying and communicating uncertainty” (Reading, 2015)
- EMS ECAC Annual Conference (Prague, 2014)

Papers in preparation

At least two additional peer review papers reporting on the findings of Work Package 33 will be submitted: a review article based on the review of existing approaches to communicating confidence and uncertainty conducted in Task 33.2, and a research paper reporting the findings of the Decision Lab (Task 33.4)

Additional dissemination activities
A short booklet summarising the key lessons learned from EUPORIAS with respect to the communication of confidence and uncertainty is planned, with the intended audience being climate service practitioners.

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4. Lessons Learnt

The report above summarises the core lessons learned from Work Package 33. More broadly however, the activities that have taken place within this work package as a whole has highlighted the value of ongoing collaboration between climate information providers, stakeholder representatives, and social scientists.

5. Links Built

This report has been developed with input from both Work Package 41 and representatives from four of the Work Package 42 prototypes (RESILIENCE, RIFF, SPRINT, LMTool).