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Discussions

Forecasters priorities for improving probabilistic flood forecasts

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Abstract

Hydrological ensemble prediction systems (HEPS) have in recent years been increasingly used for the operational forecasting of floods by hydrometeorological agencies. The most obvious advantages of HEPS are that more of the uncertainty in the modelling system can be assessed; and that ensemble prediction systems generally have better skill than deterministic systems both in the terms of the mean forecast performance and the potential forecasting of extreme events. Research efforts have so far mostly been devoted to the improvement of the technical aspects of the model systems themselves. However, in this paper we argue that there are other areas of HEPS that need urgent attention; such as assessment of the full uncertainty in the forecast chain, multimodel approaches, robust forecast skill assessment and further collaboration and knowledge exchange between operational forecasters and the model development community. In light of limited resources we suggest a simple model to classify the identified priorities in terms of their cost and complexity to decide in which order to tackle them This model is then used to create an action plan of short-, medium- and long-term research priorities with the ultimate goal of an optimal improvement in operational HEPS.

1 Introduction

Flood forecast systems are the chief instrument used to inform decision makers of oncoming floods. In operational flood forecasting coupled hydro-meteorological prediction systems are widely used to combine observations and forecasts in together with hydrological and hydraulic models (Schaake et al., 2006; Addor et al., 2011; Pappenberger et al., 2011; He et al., 2011; Demeritt et al., 2013; Pappenberger and Brown, 2013). These systems are constantly developed through improvements in: choice and combination of meteorological inputs (Olsson and Lindström, 2008; He et al., 2009; Liu et al., 2013; Liechti et al., 2012), weather forecasting model resolutions (Marty et al., 2013a), probabilistic ensemble techniques, (Cloke and Pappenberger, 2009; Marty et al., 2013; Pagano et al., 2013), pre-processing (Schaake et al., 2010; Gaborit et al., 2013) radar blending (Parkes et al., 2013; Liechti et al., 2013), pre/postprocessing (Wilks, 2006; Bogner and Pappenberger, 2011; Bogner et al., 2012; van Andel et al., 2013; Brown and Seo, 2013), data assimilation (Liu et al., 2012), hydrological model development (de Roo et al., 2000; Lindström et al., 2010), verification (Brown et al., 2010; Liguori and Rico-Ramirez, 2013) and communication and understanding of forecasts (Pappenberger et al., 2013; Demeritt et al., 2010; Ramos et al., 2010).

There are always challenges in balancing the integration of new research and the development of forecasting systems according to operational priorities. Implementing and adequately testing state-of-the-art research developments within operational systems can be very rewarding, as evidence of improving forecast skill demonstrates (Pappenberger et al., 2011). However, often resources for development of operational systems are limited, and subsequently only individual elements of a system can be prioritised for developments. There is a lack of guidance on what improvements are most crucial for operational forecasting systems and how research and development are focused to accommodate these. We propose a simple model of ranking priorities in terms of financial cost and technical complexity to optimise the resources available for HEPS development. This paper sets out to: (1) to provide a discussion of the user preferences in current HEPS, (2) to identify the most important development and research priorities in operational HEPS; and (3) to suggest a strategy to achieve these priorities and map the road to future forecasting tools with the limited available resources in mind.

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2 Background

2.1 Areas of potential improvements of HEPS

Priorities on what improvement is necessary vary according to system and/or forecaster needs and is often triggered by recent floodings (e.g. Pitt, 2008) and can be broadly divided into four categories: (1) *process driven improvements*; a desire to include more of the hydrological processes of flooding in the system, e.g. better representation of snow melt processes, flood wave routing or parameterisation of unrepresented processes such as debris blocking and ice jams. This may be driven by a forecasting system not adequately capturing a recent flood event. (2) *Expansion of the limits of the forecasting system*; for example the redesign and use of the system for the detection of a wider range of phenomena, such as to capture local flash floods or urban surface water flooding or to provide forecasts in areas where verification is difficult (Liechti et al., 2013; Brown et al., 2010; Silvestro and Rebora, 2012). (3) *Improving the dissemination platform*; for example to include uncertainty information and tools to evaluate skill in the forecast of predicting previous events. This can also include adding other kind of metadata, such as system performance during calibration/validation and geographic layers of population density and economically valuable areas. (4) *Need for decision support information*, e.g. how to translate river discharge forecasts into preventive action or mitigation.

2.2 Forecast dissemination and communication

The decision to act on forecast information is often guided by experience, but as systems become more complex there is also an increasing need for a more rigorous and structured guidance of what actions to take in specific situations and how to best interpret forecasts (Zappa et al., 2013; Demeritt et al., 2007, 2013; Pappenberger et al., 2013; Frick et al., 2011; Ramos et al., 2010). With the technology available today an automatic system can provide forecasts and raise alarms, but unforeseen errors can

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still cause false alarms, such as errors in the driving data, the observational network or the modelling system itself. Human interaction is always needed in any early warning systems at the final dissemination step. The dissemination is also a way to add information that is not contained within the EWS, such as local conditions at the time of flooding. However, a fully streamlined and consistent procedure to issue forecasts would make it easier to evaluate and improve the performance of the system.

Nobert et al. (2010) underlined the importance of effective communication and collaboration in the development of an ensemble forecasting system. They found that the success of a HEPS relied on (1) a close working relationship between national forecasters and local institutions, (2) locally tailored and delivered training for HEPS users, (3) active involvement of end-users in the design of HEPS and (4) that end-users will embrace HEPS if they can see the added value in their daily operational routines. All of these factors are thus essential to consider when attempting prioritising future developments in HEPS.

2.3 The European Flood Awareness System (EFAS)

The European Flood Awareness System (EFAS; Thielen et al., 2009; Bartholmes et al., 2009) provides its members pan-European overview maps of flood probabilities up to 10 days in advance as well as detailed forecasts at stations where the National services are providing real time data. Since 2011, EFAS has been part of the GMES Initial Operations Emergency Management Service and was transferred to operational service in late 2012. More than 30 hydrological services and civil protection services in Europe are part of the EFAS network. The majority of these are hydrological forecasting centres of the European Member States with national, regional or local responsibilities and a few civil protection agencies whose access is coordinated through the forecasting centres.

Since conception in 2006, each year an EFAS annual workshop has been organised, including interactive training sessions for the partners covering topics on meteorological and hydrological ensemble prediction, communication of probability and uncertainty

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for early warning systems, and communication to decision makers. This opinion paper was spawned from a group exercise at the 7th annual EFAS workshop which was held 12–13 June 2012 at the Swedish Meteorological and Hydrological Institute (SMHI) in Norrköping, Sweden, followed by an individual survey conducted via email to the workshop participants.

3 Gauging forecaster priorities: a user preference exercise

To start of the discussion we decided to engage with operational forecasters within the EFAS network to gauge their preferences regarding research and development of HEPS. The first part involved a group exercise in prioritisation at the EFAS meeting, and the second part was a follow-up questionnaire.

3.1 Part 1: pitching your chosen priority in front of a jury

The first part of the exercise was designed to encourage the meeting participants attending the workshop to come up with areas that would need to be prioritised in order to improve flood forecasting and to present one area of priority in front of a scrutinizing jury of "expert forecasters", modelled after the popular TV series "Dragon's Den™". 30 participants from 15 institutions attended the meeting; the representatives being operational forecasters, operational managers or researchers involved in developing forecast tools.

Each participant was given written directions one day in advance to define their research priorities for EFAS development. In the directions, the participants were asked to consider what their priorities were, including a brief description and also to identify why this was their choice. The following day the participants were randomly divided into 5 groups and given the instructions that each group had 45 min in order to prepare a 5 min pitch for the one research priority which they all considered to be the most

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important. The first task for the group was to agree on which topic they would advocate in the pitch.

In the next stage, each group pitched their priority in front of the rest of the participants, including the panel of 5 “Experts”, each of whom asked one question following the pitch. After all of the groups had made their pitch, each participant was given 10 Swedish kronor to represent money available for investing in the presented priorities. They were then to reward the priorities that they thought most worthy of investment by putting a voluntary sum of money in boxes, which represented the 5 presented priorities. They were also given the option not to invest in any priority and keep the money for themselves. The group who had the best pitch based on the financial investment of the participants was crowned as finding the most important research priority, and rewarded with a prize.

The most successful pitch suggested a multi-model approach (D; Table 2), and this priority received almost twice as much financial investment as the least favourite, to improve standardisation of hydrological data (B). After the winning priority there were three that were closely grouped together, namely (A) report on past performance, (E) building a European infrastructure and (C) improving the physical model representations.

3.2 Part 2: questionnaire

Part 1 was followed up by an email questionnaire in which all the priorities that came up during the discussions in the EFAS meeting were collected. When analysing the priorities, five categories emerged: (i) cooperation, training and dissemination (ii) improved tools for decision making; (iii) improved skill of forecast; (iv) new tools to evaluate and compare forecasts and (v) data collection and processing (Table 1). The priorities were put into each category (for a full list see Supplement).

The first question in the questionnaire was to rank the five categories listed above in importance from 1 to 5, where 1 was the most important. Respondents were then asked to rank a further 23 priorities according to their importance as “Very important”,

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"Important", "Neutral", "Not so important", "Unimportant" or "No opinion". The categorisation was not visible for the respondents. The questions were asked in random order so as to not bias the results towards a certain category.

The response frequency was 83 %, and the results from the survey partly confirms the results from first exercise in terms of the most popular priorities, however, the highest ranked priority from the survey was number 18 "Report past performance of forecast skill", which was voted as the second most important in part 1 (Table 1). The most popular priority from part 1, a multimodel system forecasting system (D) was the second (hydrological models) and fifth (meteorological models) most popular in part 2 (in the questionnaire the questions were divided between the NWP multi-model system and hydrological multi-model system). Also the other pitched priorities from part 1 scored high in part 2. The other priorities in top 5 in part 2 were "10. Increase the skill of the forecast" and "3. Education and training on how to use forecasts".

3.3 A note on limitations in undertaking forecaster workshop exercises and surveys

In this piece we have built our discussion based on the opinions provided in an exercise and survey undertaken as part of the EFAS annual workshop. We would note that the results from part 2 (survey) are not independent of the results in the part 1 (workshop exercise) since the participants already had the priorities presented to them, and they were for obvious reasons deemed important already. Also, there were some time to digest the discussions and results from the exercise, and the votes after the presentation in the Dragon's Den should be considered a first guess.

In part 1 there was very limited time given to prepare the presentations (1 h), and this could have had an influence (although perhaps positive) on how each group selected their respective priority. In some groups there was a thorough discussion, followed by a voting of the most popular priority to be put forward as their pitch. This often led to time constraints in the preparation of the pitch. Other groups quite quickly settled on the most important issue, and had time to prepare the presentation. Furthermore, language barriers, the composition of each group, and particularly dominant individuals could have affected the choice of pitch from each group.

How individuals placed their financial investment was most probably influenced by how the pitch was performed and how they perceived the person doing the pitch, not only on how much they agreed with the priority. This was also a reason to follow up with a survey, where the priorities were presented more anonymously without the layer of the presentation as well.

It was not within the scope of the survey to ask in-depth questions on the reasons behind each forecaster's choice, which could have revealed underlying agendas to their preferences. For example, the inclusion of more hydrological models in the system could be governed by the wish to include the forecaster's hydrological model of choice, and not necessarily the idea of a full uncertainty system. Such in-depth exploration of priorities is something that is planned for future exploration within the EFAS context.

4 What can be learned from the exercises?

The priorities differ substantially between groups, and they were classified to belong to 5 different categories, which were focussed on improving: (1) cooperation and collaboration and training between forecasters and modellers, (2) existing decision making tools (3) the general performance of the forecast (4) tools to evaluate and compare forecasts and (5) data quality checking, collection and processing (Table 1). This could imply that there is no consensus on the most important priority, but rather a number of different aspects of the forecasting system that are important. All the suggested topics are fairly separate from each other and require different types of resources. With a relatively large group of forecasters from different organisations in the room this is not considerably surprising. However, interestingly the results from the first gauging of the forecasters priorities (blue line, Fig. 1) differ somewhat in comparison with the results from the individual questions when they are summarised according to category (black line, Fig. 1). In both cases improving the general performance of the forecast (category

3) is seen as most important, but "better tools to evaluate and compare forecasts" (category 4) and "improve data collection and processing" (category 5) both become more important when the individual questions are summarised in comparison to the initial ranking in the first question. Also, "more cooperation, training, workshops etc." (category 1) is seen as important in the individual questions, but not in the first question of the survey. The mean of category 1 suffers from the unpopularity of question 2 (dissemination and communication through social media). The dotted line (Fig. 1) shows that this category would rank as the most important with the results from this particular question omitted. The difference in results from first ranking question in comparison with the others from part 2 could reflect the fact that the forecasters have a predetermined view that increasing forecast skill is the most important part to improve in the forecast chain. However, this is challenged when the results of the individual questions are ordered in their respective category. Here other areas emerge as more important, such as better communication and training, and the need for a tool to assess the general skill of the model.

Certainly the forecasters as a group have varying priorities and on close inspection, particular aspects of a priority area may be more or less important than the category as a whole. However, to in order to discuss thematic priorities with ease they will hereafter be discussed according to the categories in Table 1. These categories are not always clear-cut and there are some priorities that fall in more than one category, but they should be seen as merely a means for discussion.

4.1 Improve cooperation between forecasters

There are networks and steps taken to improve cooperation between forecasters, but there is much more effort needed in this area, such as further development of a European Flood forecasting infrastructure as well as training and knowledge exchange between forecasters. Such developments would be important in ensuring forecasters were all aware and trained in state of the art forecasting techniques and that the computational, communicational, educational and personnel exchange networks around

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Europe are all improved. These priorities were both considered to be very important in our forecaster exercise, especially the education and training priority. This implies that the EFAS network is deemed very important and that the efforts to build a working infrastructure should continue and even more focus should be put into training courses and exercises.

The use of social forums as a means to disseminate results was the least popular priority, although this could be an effective way to reach a new audience with forecast information. The question was not split into dissemination and information, and this could have influenced the result. Social forums are increasingly used in real-time during crisis situations by civil protection agencies (for example during the Sandy Hurricane), but since EFAS is an early warning system, this may not apply here. However, as a forum where news and updates on the present hydrological situation are presented social media can be a very effective information source during flood situations. However, forecasters have their channels and communicate to CP and can be confusing for the public if there are too many sources of information.

4.2 Improve existing decision making tools

Having sufficient decision making tools is naturally important for forecasters and areas of priorities ranged from improving the dissemination platform to enhancing the product generation and visualisation of forecasts. This category was the least popular with the forecasters in the exercise taken as a whole, which could imply that the tools available today are sufficient. Priorities of a more technical nature, such as to increase the temporal resolution and the frequency of issuing forecasts (4 and 5) ranked amongst the least important, and the priority to increase the spatial resolution of the forecast also ranked low. However, the priority to improve the forecast dissemination ranked as the ninth most important overall. This indicates that more effort is needed to develop the existing dissemination platforms.

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4.3 Improve the general performance of the forecast

Improving the general performance of the forecast is a demand usually made by forecasters of their tools, as it is easy to see from a scientific point of view how improving the reliability and skill of forecasts makes a forecaster's life easier. However, further improvements to any forecasting system are usually expensive in terms of resources and time, and the benefit can be difficult to measure.

The priorities that belong to this category were also in majority in the pitches. From this it is clear that the most important area of priority is to improve the general performance of the systems. What is not clear is whether the forecasters are unhappy with the current performance of the systems they are using, or whether they think it is sufficient, but that it can be further improved. It should also be noted that it virtually impossible to build a completely failsafe system, and that there will also in the future be missed floods and false alarms. The million dollar question is whether it is really worth the effort to improve the systems, or if it is other areas that should be prioritised instead.

In our exercise, the priorities noted in this category were diverse, ranging from very broad priorities such as "increase the skill of the forecast at certain time ranges" to very specific requests such as improvements of model physics (better representation of snow water equivalent) and multi-model approaches (hydrological as well as meteorological) which was also the most successful topic in terms of financial investment (Table 2).

The inclusion of more models was deemed the most important priority, which indicates the desire for a better quantification of uncertainty, rather than a sharp forecast. In part 2, meteorological and hydrological multimodel systems were two separate questions and the forecasters thought it more important to prioritise a hydrological multimodel system. However, the survey was done within the EFAS framework, where forecasters are already using meteorological multi model system, which could have influenced the results in terms of their priority.

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It is a more important priority for the forecasters to improve the forecast in the medium-range (> 3 days), rather than the short-range. This could also have been biased since the EFAS system is an early warning system, and that the national centres often have their own systems for short lead-times. However, this contradicts in part the wish for more hydrological models, since most of the skill in the longer lead times depends on the driving meteorological model rather than the hydrological.

4.4 Better tools to evaluate and compare forecasts

Having better tools to evaluate and compare forecasts means that decision making by the forecaster can be made more straightforward and perhaps more transparent. This is especially important as multimodel probabilistic systems become more and more complicated, meaning that forecasters must be able to interpret advanced forecast results and a multitude of sometimes contradictory information.

The priorities in this category range from reporting the skill of the model to having more robust ways to calculate flood frequencies. The priority that received third most financial investment in the pitching exercise and the most prioritised form the survey was the priority to include past performance of the model as an aid in the forecasting. Also the priorities to recalculate probabilities and to include more historical data in the system were prioritised.

Clearly, there is a need for tools to evaluate forecast, but the priority to see past performance could also be seen as demand for a more transparent system. To have access to previous skill scores can give you some information on the reliability of the forecast system and also its accuracy. These measures can be used to create more trust in the forecast system and guide a forecaster to make the right decision. However, skill scores are mostly a tool to improve the performance of the forecast and cannot provide information on single events a priori predictability.

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4.5 Improve data collection and processing

Data collection and processing are the bugbears of hydrological science (Hannah et al., 2011) and it is not surprising that this issue was prioritised by our forecasters. This category deals with data collection, quality checking and processing. The priorities ranged from adding national forecasts to defining a standard for hydrological data exchange. Although, the priority to standardise hydrological data format was selected as least popular out of the five topics pitched, one should not forget that it was actually a top five contender (thus seen as more important than other topics). It was also among the top 10 priorities from the survey. This point to the problem of different data formats, and how much effort goes into harmonising databases.

The other priority in this category was the blending of national and EFAS forecasts, which received a very low priority. It is clear that the national systems and EFAS should stay in parallel in the opinion of the forecasters.

5 A strategy to improve the forecasting system

Scientific and technical improvements of operational forecast systems are often driven by either the model developers themselves or through catastrophic events that show weaknesses in the system. Even though the former can be justified through a scientific analysis of what is needed to improve the system, it might not always be what the forecasters need. The most important priority for forecasting system development is currently a generally improved forecast skill, as shown by our exercise respondents, but as the other priorities discussed show other issues are also important for development. Therefore more resources should be put into developing and improving the dissemination and interpretation of the forecasts.

As a way forward, priorities can be organised according to their complexity and cost in order to consider which can be addressed immediately and which would need large financial and development investment. Figure 2 shows how the ten highest ranked priorities would fall within such diagram. The cost is the estimated effort in terms of resources, which can be both financial and human. The complexity is the estimated level of technical and/or scientific development that is required. This also suggests the expected level of success, meaning that a high level of complexity implies a risk of not accomplishing the goals. The obvious suggestion is to first pick the "lowest hanging fruits", in terms of cost and complexity, which will yield the highest return from the investment. The more costly and/or complex improvements should be addressed, but on longer time scales and with well allocated resources. With this information it is necessary to review the current operational framework and make sure that resources are used optimally.

5.1 Secure funds for the priorities that yields most benefit to a low cost and with low complexity

Some of the points can fairly easily be addressed, for example there is already an on-going effort in training and collaboration between forecasters at national and international level through the EFAS and HEPEX networks. These trainings and collaborations needs to be further developed and maintained to ensure that the forecasts and warnings issued are consistent and that new operational forecasters quickly can gain an understanding of their forecasting tool. A "User guide" for hydrological probabilistic forecasting could be on way to improve interpretation of forecasts. Also e-learning tools designed to show the added benefit of using HEPS could be a useful tool (Ramos et al., 2012).

5.2 Plan and coordinate activities to deal with intermediate cost/complexity priorities

Reporting on past performance through forecast verification scores would be a useful tool to show the benefit of the forecasting system as well as increasing trust in the forecasts. This would allow the forecaster to assess the long-term performance at

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specific points, as well as how the system HEPS behaves in typical situations. Also clearly showing calibration and validation results would potentially increase the trust in the system. Research activities are already initiated to address this issue. The issue of a multimodel system is to some extent fulfilled in the meteorological part of many systems (including EFAS) but can be further extended and optimised, for example by including freely available NWP's into the EFAS system.

5.3 Setup a long-term strategy to coordinate research and development activities to address the priorities that are costly and/or complex

A multimodel hydrological system would to a large extent benefit the decision making, albeit the decisions would potentially have to be taken under larger uncertainty than in the current format. Such a system would also take longer time to implement, unless the existing systems agree to share data where they overlap and blend local systems with global and/or regional. However, this kind of development was not seen as a priority within the study, and for the time being the systems should be kept separated. Standardisation of hydrological data collection has already been identified as a key element to facilitate the exchange of data for testing and validation of models as well as real-time observations for forecasts. There are a number of projects that are directly or indirectly trying to create standards and databases of easily accessible data, but these efforts needs to be coordinated and extended beyond the lifespan of individual projects.

The priority to improve forecast dissemination would need to both address the technical development of the tools themselves, and also the understanding how decision are best made under uncertainty. Many of the suggested priorities in HEPS are not dealing with improvement in the models themselves, but rather in the way HEPS are presented and how the output is interpreted. This issue was not covered in the survey, but previous research has pointed to the existing gap between theory and practice when it comes to HEPS (e.g. Demeritt et al., 2010; Nobert et al., 2010). This area

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is perhaps not receiving enough attention in terms of funds and efforts, and it is our opinion that more projects and funding are directed to address these issues.

5.4 Collaboration with the scientific community on long-term improvements of HEPS

The final points on the "wish list" of priorities are concerning either to improve the physical representations in the used models and improve the forecast on lead times > 3 days. Both these priorities are questions that needs to be addressed by the research community as a whole, both academic and institutional, and one approach for the operational forecast community is to carefully monitor the scientific progress and incorporate new changes into their system. However, it is also very important to point to deficiencies in the modelling system, both to the hydrological and meteorological research community, to stimulate research in the areas which would benefit the HEPS community.

6 Conclusions

This opinion paper is the result of an expert workshop during the annual meeting of the partners of the European Flood Awareness System. It was developed from the opinions of a large group of professional flood forecasters in which we consider the best way to improve existing operational flood warning systems. Often considerable effort and resources are focused on the technical aspects of forecasting systems, whereas dissemination, collaboration and education receive less attention. Other areas that need more attention are verification of past performance, uncertainty assessments and multi-model approaches. Given the limited resources we propose a simple model to identify the costs and levels of complexity associated with the most urgent priorities in terms of improving HEPS. From this, a "road map" was derived, where the identified priorities are organised in different categories and dealt with accordingly:

1. Secure funds to address the identified priorities that have low cost and complexity
2. Plan and coordinate activities that are dealing with the priorities with intermediate cost and/or complexity
3. Set-up a long term strategy to coordinate research and development to address the priorities that are costly and/or complex
4. Collaborate with the scientific research community to stimulate activities that have potential to lead to better hydrological forecasts.

The first point focuses on increasing collaboration, training and knowledge exchange between forecasting centres and researchers. The second point addresses relatively straight forward changes to the existing systems, such as verification tools for HEPS and including more NWPs. The priorities that fall in this category are achievable with relatively moderate funding and at a low risk. The priorities in point 3 need more concerted research efforts to accomplish, such as joint research collaboration under the framework programme of the European commission. Examples of priorities here are how to implement a full multi-model system and better understanding of the decision making under uncertainty. The fourth category consists of priorities that are not achievable through individual projects, but rather through a close collaboration with the research community to emphasise the need to improve the parts of the forecasting chain that are most crucial for HEPS. The Hydrological Ensemble Prediction Experiment (HEPEX, www.hepex.org) can provide such a framework and address many of the issues raised.

Supplementary material related to this article is available online at: http://www.hydrol-earth-syst-sci-discuss.net/10/2215/2013/hessd-10-2215-2013-supplement.pdf.

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Table 1. Categories of the research priorities for the EFAS forecast system.

Category	Description
1	More cooperation, training, scenarios, workshops etc. to improve cooperation between forecasters
2	Improve your existing decision making tools (better graphics, visualisation, frequency of forecasts etc.)
3	Improve the general performance of the forecast
4	Better tools to evaluate and compare forecasts
5	Improve data collection and processing, e.g. blending techniques, satellite data, remote sensing (radar) data

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Table 2. Result after the voting with 10 s after the pitch before the expert panel. 268 of originally 300 Krona was recovered, meaning a total of 32 Krona was kept by the participants. The column Cat. denotes which category each priority belongs to, and Rank which rank the priority was given in the questionnaire.

Priority	Money	Cat.	Rank
Report past performance for the hydrological and meteorological forecasts	55	4	1
Improve standardization of hydrological data	41	5	7
Improve physical model representations (in particular snow) including better snow forecasting	51	3	12
Introduce more NWP ensembles for meteo input and introduce multi-model approach for hydrological modelling	70(65[a])	3	2/5
Building a European Flood Forecasting infrastructure	56	1	6

[a] This topic had a 5 Krona piece (and none were distributed).

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Table 3. The 5 most popular and least popular priorities from the survey.

Best voted	Cat.	Importance	Worst voted	Cat.	Importance
Report past performance for the hydrological and meteorological forecasts	4	1.77	Replace/expand web forum by social networks	1	3.83
Introduce multi-model approach for hydrological modelling	3	1.86	Distinguish between different flood situations	4	3.09
Increase the average skill of the medium range forecast (> 3 days)	3	1.90	Increase the frequency of forecasts	2	3.08
Education and training of how to use and interpret forecasts	1	1.91	Increase the temporal resolution of the forecast	3	2.91
Improve physical model representations	3	1.96	Blending of national and EFAS forecasts	5	2.68

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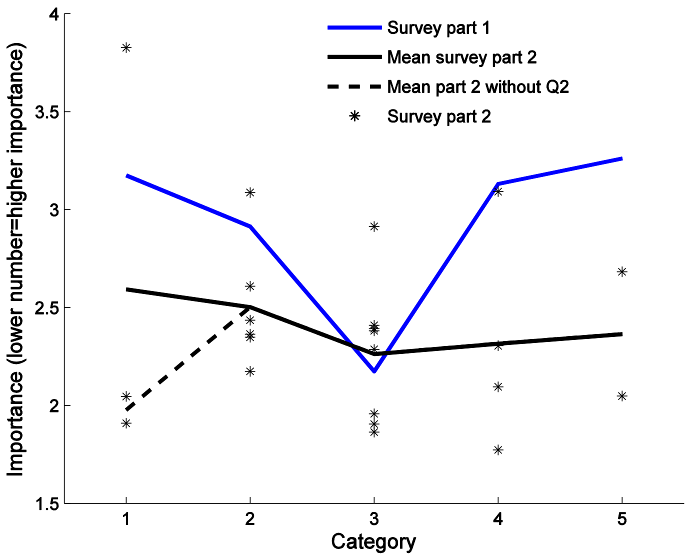

Fig. 1. The black line portrays the results from the ranking of the different categories and the blue line the results of the second part of the survey with the questions ordered according to the categorisations. The dotted line denotes the mean of the questions in category 1, excluding question 2. The figure also shows the importance of the individual answers according to their categorisations.

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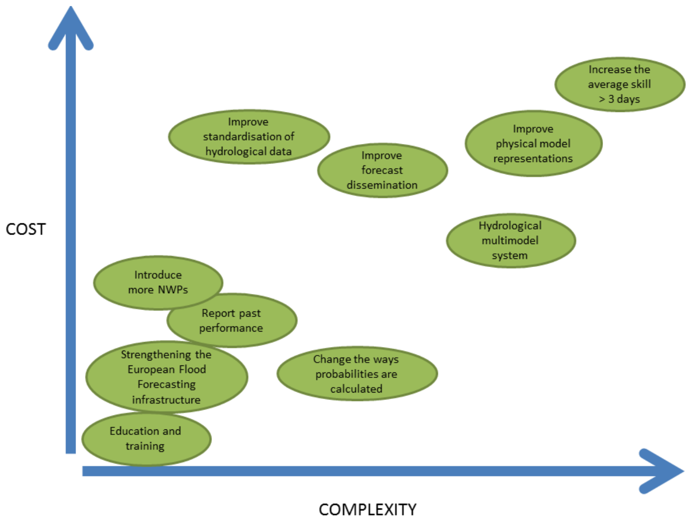

Fig. 2. Schematic view of the relative cost and difficulty of the top 10 priorities from the survey.

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