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OPINION PAPER

The role of experimental work in hydrological sciences – insights from a community survey

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ABSTRACT

This opinion paper summarizes the results of an online survey on the role of experimental work in the hydrological sciences. The 20 survey questions covered various topics, such as advancements, needs, potentials and challenges in the hydrological sciences, and also touched on the issue of data sharing and data publication. A total of 336 hydrologists with both modelling and experimental backgrounds participated.

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Introduction

Several opinion papers have been written in recent years on the current state and future directions of the hydrological sciences, including papers with a specific focus on the importance of experimental or field hydrology, such as "Field hydrologists needed" by Vidon (2015), "Whither field hydrology? The need for discovery science and outrageous hydrological hypotheses" by Burt and McDonnell (2015), "Field observations and process understanding in hydrology: essential components in scaling" by Sidle (2006), and the plea of Kleinhans *et al.* (2010) for more experimentation and hypothesis driven research. Opinion papers are usually written by outspoken members of the community, presenting their personal views on a topic. But wouldn't it also be interesting to know what the wider community thinks and how strongly opinions differ? So we decided not to state our own opinions but instead to present the diversity of opinions held within the community. To achieve this goal, we designed an online survey in which we asked the community about their views on the role of experimental work in our discipline, i.e. studies that involve taking measurements in the lab or in the field (excluding remote sensing). The survey consisted of 20 questions, the first set of which focused on a comparison of various methodological approaches with respect to their capacity to advance the hydrological sciences and our understanding of hydrological processes. The second set of questions dealt with the systems or scales bearing most potential for advancing the hydrological sciences, and the third set focused on data sharing.

The response to the survey was very positive: 336 hydrologists invested their time to answer the questions. Of the respondents, 26% called themselves field hydrologists, 29% modellers, and 45% were involved in modelling as well as experimental work. With respect to career stage, 29% were PhD students, 26% PostDocs/pre-tenure faculty and 44% tenured faculty (1% chose not to answer). As for gender, 75% were male and 25% were female (34% of the PhDs and PostDocs, 22% of the untenured and 18% of the tenured faculty were female). In this paper, we provide a brief summary of the survey results including highlights on where the community feels that advancements have been made and where it identifies needs, potentials and challenges.

Advancements, needs, potentials and challenges

We started off by asking where the respondents see the major advancements in past decades and what the needs, potentials and challenges for the future are. The biggest advancements in the past two decades were seen in measurement and data analysis techniques, while the advancements in hydrological theory were considered small (Fig. 1(a)). There was a strong feeling that combined modelling/experimental studies are most needed and that this would have the highest potential to advance hydrological process understanding and hydrological sciences in general (Fig. 1(b)). Along these same lines, Kirchner (2006) argued: "… *it is worthwhile … to emphasize again that all hydrological knowledge ultimately comes from observations, experiments, and measurements. … Thus the advancement of*

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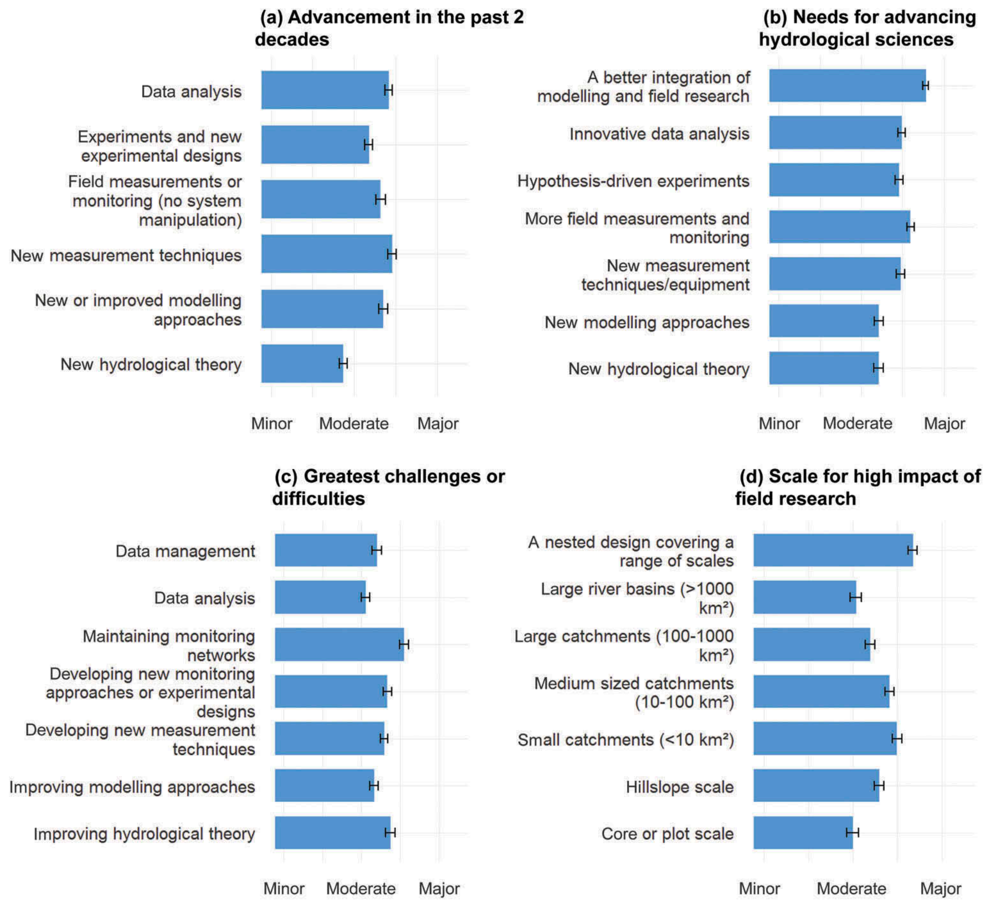

Figure 1. Average ratings and 95% confidence intervals for four of the survey questions: (a) In your opinion, how much advancement was achieved in the past two decades with respect to the fields and techniques listed below? (b) Where do you see the strongest needs for the advancement of hydrological sciences? (c) Where do you see the greatest challenges and/or difficulties? (d) At what scale would field research have the highest impact on advancing hydrological sciences?

hydrological modelling and analysis ultimately depends on supporting new experimental work, new field observations, and new data collection networks." Virtual experiments and new models and model assessment procedures were seen as having less potential for advancing hydrological sciences and process understanding. While remote sensing was considered to have little potential to advance hydrological process understanding, it was nevertheless seen as having the second highest potential to advance hydrological sciences in general. The respondents see a very strong need for monitoring and gave it the second highest rank for advancing hydrological process understanding (Fig. 1(b)), but also consider maintenance of monitoring networks the greatest challenge (Fig. 1(c)). Improving hydrological theory was considered the second biggest challenge, but the need for it was ranked lowest, together with the need for new modelling approaches (Fig. 1(b)).

Scales and systems where experimental studies have a high potential for advancing hydrological sciences

The community seems to be divided on what systems we should focus on to improve our understanding of hydrological processes. Arid, semi-arid and mountainous systems were ranked highest and temperate systems lowest. This ranking seems inversely related to the number of field studies in these systems (see Figure 2 in Burt and McDonnell 2015), but the difference in ranking was not very pronounced. The study of land-surface–atmosphere interactions was considered to have the most potential overall. The small (<10 km^2) and medium-sized (10–100 km^2) catchment scales were considered to be the scales where additional field research would have the strongest impact to advance hydrological sciences. However, a nested design covering a range of scales was seen as even more advantageous (Fig. 1(d)). Both the very small scale (core or plot scale) and the very large scale, i.e. large river basins >1000 km^2 were seen as having the least potential to advance hydrological sciences.

Global change and the Anthropocene

Two questions were asked with respect to global change and the Anthropocene: (a) What is necessary to understand and project the consequences of (global) change and (b) what type of field measurements are most needed to understand hydrological processes in the Anthropocene? For both questions, additional and especially long-term monitoring was ranked highest. Monitoring of catchments undergoing change was also considered very important to understand hydrological processes in the Anthropocene, but maintenance of monitoring networks was seen as being the biggest challenge

(Kundzewicz 1997 see also the observed decline in monitoring networks described by Sidle 2006). Ranked slightly lower than additional field monitoring, remote sensing, modelling, new field experiments and data mining were likewise considered necessary for understanding and projecting the consequences of global change, while virtual experiments ranked lowest.

Data sharing

The survey results and previous opinion papers clearly show that observations and monitoring are needed, and thus the obvious next question is how the collected data should be shared, in particular if data are collected by non-governmental organizations. There is a very clear opinion in the community that all data should be shared: fewer than 10 people considered it not necessary. However, opinions differ on how data sharing should be implemented. While there is a strong vote for making data freely available after a period of three years, with mentioning the data providers in the acknowledgements as the only requirement, an almost equal number of respondents found that working with shared data should be a collaborative or joint effort involving the people who collected the data, thus giving them more credit. A considerable number of respondents also voted for making the data publicly available within one year of collection or lab analysis. Interestingly, the fraction of the modellers that share this opinion was twice as large as that of people doing field work. Almost 60 respondents recommended that every group that collects field data or runs laboratory experiments should employ someone full time for this task. Even without such designated support, the hydrological community seems highly committed to data sharing. When asked how much time they would personally be willing to invest in making their data available, only six of the respondents said they would not invest their time, 26% were willing to invest 1–5 work days per year, 21% were willing to invest 6–10 days per year, 19% would invest 11–20 days per year, 13% would invest 21–30 days per year and 10% would do even more than that (10% of the respondents did not answer this question). The median time that the survey participants were willing to personally invest was 10 days per year, and this did not differ significantly between the modellers and field hydrologists.

Appreciation of experimental work in the hydrological community and career advice

When asked if there is a general tendency of less experimental research and more data mining and modelling projects, as suggested by recent commentaries of Vidon (2015), Burt and McDonnell (2015) and Sidle (2006), there was a clear "yes" from 66% of the respondents. Only 10% did not agree and 21% were undecided (3% did not answer the question). More than half of the respondents (52% of the modellers, 58% of the field hydrologists) feel that experimental work is not valued enough, while about 43% (modellers 47%, field hydrologists 40%) feel that the community values experimental work. Many suggestions were made to overcome under-appreciation of field studies and data collection, including giving a higher value to the publication of data, the need for a cultural change, convincing funding agencies and journal editors to re-assess priorities, and the necessity and importance of also publishing case studies. The large number of text answers and comments to this question suggests that, like data sharing, this is a topic that concerns the community.

Considering the sentiment that experimental work is undervalued and the possibility of greater risks—including difficulty in obtaining funding due to higher project costs, failed experiments or data loss due to technical failures, long time for data collection and thus long time till publication, as well as difficulties in publishing the results when they are considered a case study by the referees—one could expect the community to advise young faculties against a strong experimental focus when they are starting their first academic jobs. However, despite these issues, the majority of the respondents (46%) stated that, while the risks for failure may be higher for experimental work, it is nevertheless imperative for understanding hydrological processes; and 18% of the respondents thought that although the risks are higher, the potential to impact the field is also higher (Fig. 2). These results echo the

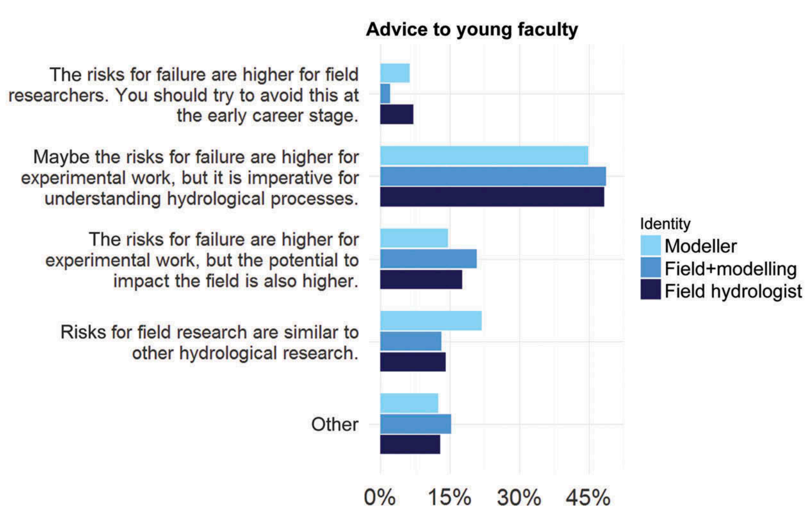

Figure 2. Answers to the question "Would you advise young hydrologists who have just started their first academic job against a strong experimental focus?"

words of Vidon (2015) and Burt and McDonnell (2015), who stated that it is only by field work and practical experience that system understanding and thus also sound modelling can be achieved. Only 4.5% of the survey participants stated that with the higher risks one should try to avoid field studies at the early career stage, and 15.5% of the participants thought that risks are similar to other hydrological research (22% of the modellers, 13% of the field hydrologists). Over 40 people gave very detailed text answers discussing the risks of lower publication output, high time investment and potentially lower funding rates for experimental work, while coming back to the basic necessity of field studies, of modelling only once you have done field work, the need for a cultural change, and the danger of neglecting this issue.

Summary and conclusions

Despite the different backgrounds of the participants, there seems to be a general consensus that field work is imperative: more monitoring is necessary to advance hydrological sciences, to understand hydrological processes and to understand and project the consequences of global change. Yet maintaining monitoring networks is seen as one of the greatest challenges. To improve hydrological understanding and advance hydrological sciences, better integration of field efforts and modelling is seen as vital. However, this is offset by the feeling that experimental efforts are not valued sufficiently and carry an inherent risk of fewer publications. To overcome this discrepancy between the necessity of monitoring to advance hydrological sciences and the current realities of academic requirements, the community should make a conscious effort to point out the necessity and value of field efforts to scientific journal editors, employers, and funding and government agencies. The DOI (digital object identifier) for datasets can be seen as a first small step in this direction, but the production and publication of sound datasets should have a similar (or even higher) merit as that of scientific publications, especially given the fact that a good publicly available dataset can offer the community a multitude of opportunities for scientific advancement, resulting overall in more impact than the average scientific publication.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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