Knowledge Co-production in a Research-to-Operation (R2O) Process for Development of a Great Lakes Ice Forecast: Reflection from a Stakeholder Engagement Workshop

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Key Points:

- A stakeholder engagement workshop was held to improve the usability of the short-term Great Lakes ice forecast product.
- Scientists, operational forecasters, and stakeholders formed recommendations to the forecast user interface and to the long-term research.
- Stakeholder engagement using social science methods should be formalized in a new standard of R2O transition.

Abstract

In weather forecast products, stakeholder engagement in the research-to-operations (R2O) transition process has been increasingly valued yet it is far from being standardized. Engagement at multiple R2O stages and methods rigorously supported by social science are critical in implementing a practice of knowledge coproduction in such forecast products. With an example of short-term ice forecasts in the North American Great Lakes, this commentary provides a reflection of the stakeholder engagement workshop where two targeted stakeholder groups (shipping industry and U.S. Coast Guard 9th District), operational forecast providers, and scientists worked together to maximize the usability of ice forecast guidance from the National Oceanic and Atmospheric Administration (NOAA)'s Great Lakes Operational Forecast System (GLOFS). The workshop was designed carefully by social scientists to address predominant questions; what decisions do stakeholders make with ice information; what ice information do stakeholders use to support that decision-making; and what are stakeholder usability requirements for a short-term Great Lakes ice forecast? The findings from the workshop provided in-depth information to formulate recommendations to GLOFS on its user interface of the upcoming ice forecast guidance, as well as the future model development. The effort placed a steppingstone toward a new standard of R2O, where participation of stakeholders and social scientists is a formalized part of the process.

Plain Language Summary

Weather forecasts should be easy for people to use. To achieve this, it is important for users to participate in designing the forecast products. However, this is not very common yet. We show an example of the new Great Lakes ice forecast, for which participants from the Great Lakes shipping industry, U.S. Coast Guard, and science community worked together at a workshop to improve the forecast product. The workshop findings not only helped designing the forecast product, but also formed a message that such user participations should be more common in other general forecast products.

1 Introduction

As extreme weather events become more frequent with climate change, forecasts should be easy for the public to use. A typical research-to-operation (R2O) process of numerical weather and coastal forecast models requires several years to complete, starting from research and development (R&D) of a forecast model, its verification, formal skill assessment, demonstration at the associated operational environment, and finally completing its transition to operations to provide forecast guidance to public. Most R2O processes are still based on the 'push-pull' dynamics, where a R&D program responds to the requirements (pull) of the user community and the operational system takes advantage of new results and technologies (push) as a result of the R&D effort (Figure 1). There has been increasing recognition that such R2O processes need systematic stakeholder engagements with structured methods supported by social science (Aguilar-Barajas et al., 2019; Kruk et al., 2017). Engaging stakeholders from the early stage of R&D is particularly important not only because a R2O process is lengthy, but also to minimize 'lost opportunities' (Figure 1).

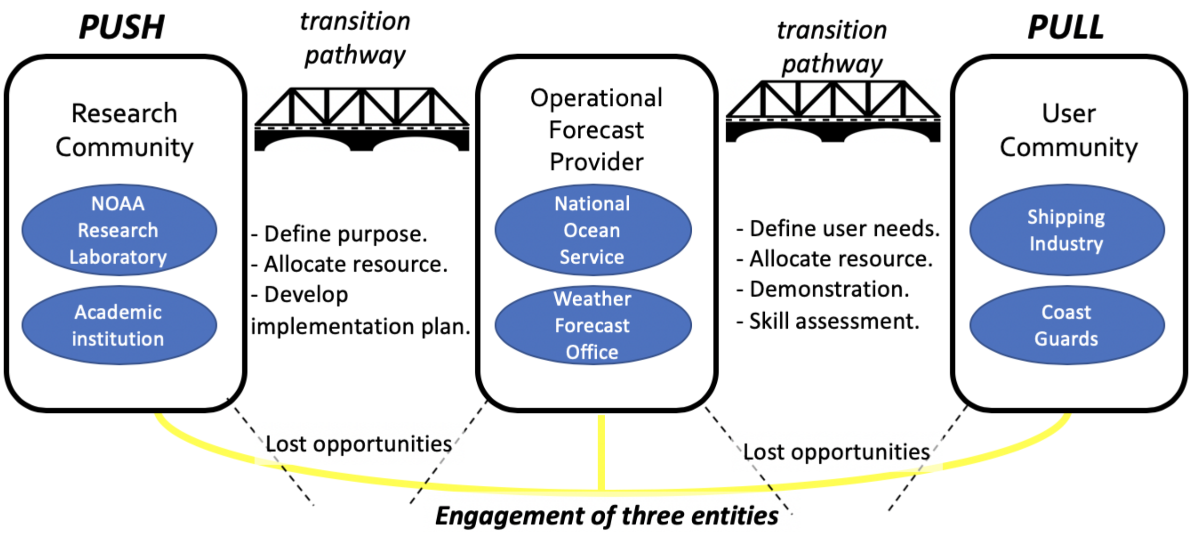

Figure 1. Schematic of a transition pathway from research to operations and the "push-pull" dynamic, adapted to an example of the Great Lakes short-term ice forecast from National Research Council (2003). Bulleted items under a transition pathway are performed by adjacent two entities. Lost opportunities would be reduced by sufficient engagement of three entities.

The upcoming lake ice forecast guidance for the North American Great Lakes (hereafter Great Lakes) presents an example of such R2O processes at the National Oceanic and Atmospheric Administration (NOAA). In the Great Lakes, severe ice cover has direct socioeconomic impacts on commercial shipping and navigation safety (Lake Carrieres' Association 2019). As such, accurate forecast information of lake ice conditions would mitigate these impacts, through enabling shipping community to plan their operations effectively to helping U.S. and Canadian Coast Guards with planning their icebreaking operations. However, an important condition for achieving this is that the forecast product provides a usable interface with appropriate and accurate ice information for user decision-making. While there are several existing resources of Great Lakes ice information (Table 1 in Fujisaki-Manome et al., 2019), the capability of short-term forecast of Great Lakes ice conditions is missing. To fill this gap, the development of an ice forecast model is underway to be added to the existing NOAA Great Lakes Operational Forecast System (GLOFS, Anderson et al. 2018), which provides nowcast and forecast guidance of lake conditions including lake surface temperature, currents, and water levels out to 120 hours four times per day. The physical model is based on the Finite Volume Community Ocean Model (FVCOM, Chen et al. 2006, 2013) and this model is coupled with the unstructured grid version of the Los Alamos Sea Ice Model (UG-CICE, Gao et al. 2011). The GLOFS-ice R2O transition will continue through 2022, and within this timeframe the short-term ice forecast guidance will be implemented into GLOFS. To maximize the usability of the upcoming ice forecast guidance, it is critical to understand what decisions stakeholders make using ice information, what ice information stakeholders use to support that decision-making, and what the stakeholder usability requirements are for a short-term Great Lakes ice forecast.

In this context, a stakeholder engagement project was initiated in January 2019, in parallel with the GLOFS-ice R2O process. The main purpose was to prove a concept of knowledge coproduction (Lemos & Morehouse, 2005) in GLOFS-ice by involving scientists, stakeholders, and operational forecast providers throughout the project, and by using social science methods. The main activity included a focus-group-like workshop with two targeted user groups, members of the Lake Carriers' Association and U.S. Coast Guard (USCG) 9th District, as well as a need-assessment survey. The major goals were to understand the current perception of Great Lakes shipping community and USCG 9th District on Great Lakes ice information, and how the upcoming Great Lakes short-term ice forecast would provide the most useful information for stakeholders' decision making. As the project output, all findings were used to formulate recommendations on the user interface of the upcoming Great Lakes ice forecast guidance, as well as on the future direction of the model development in GLOFS.

2 Great Lakes Ice Forecast Stakeholder engagement workshop

The workshop was held at the City Club of Cleveland, Ohio on July 11, 2019 with 27 participants. From the target user groups, 4 representatives from Lake Carriers' Association (LCA) and 5 representatives from 9th District U.S. Coast Guard (USCG) were in attendance. These groups were targeted, because they represent influential actors in the Great Lakes navigation and shipping sectors. Additional participants included representatives from local Weather Forecast Offices, National Ocean Service, National Ice Center, and the Great Lakes Environmental Research Laboratory. The workshop started at noon with a social lunch, followed by a facilitated panel discussion with the two target stakeholders, a science presentation on Great Lakes ice forecast model development (Figure 2), and a world cafe data collection activity inviting all workshop participants. Questions posed to stakeholders during the facilitated discussion were guided by a semi-structured interview guide. The world cafe activity is a group note-taking exercise wherein participants are assigned to homogeneous groups and asked to rotate to different memo-pad stations located around the room. At each memo pad, the group worked together to write responses to the questions. At the conclusion of the activity, all participants had worked with their group to answer every question posed at each station. Final results were reported out to the group for discussion. This reiterative approach using facilitated discussion and the world cafe activity allowed participants to generate, review, and affirm answers posed to participants during the workshop.

With the informed consent of participants, workshop discussions were recorded, transcribed, and coded using Conventional Content Analysis (Hsieh & Shannon, 2005). Memo-writing throughout the research process was used to support the intellectual rigor of data analysis and identification of salient themes and variables (Charmaz, 2015). To support quality assurance of workshop results, participants completed workshop evaluations, and key stakeholder advisers from the LCA and USCG reviewed study results. The nine stakeholder participants from LCA and USCG 9th District also participated in pre and post evaluation surveys to assess their perceptions of the forecast model and the workshop itself.

The need-assessment survey was mainly designed to aid answering the three primary questions with broader targeted stakeholders. The survey was implemented online using Qualtrics software (Qualtrics, Provo, UT), sent out to the targeted user groups (LCA and 9th District USCG) on 2 July 2019, and was closed on 12 September 2019. A total of 67 valid surveys were collected 35 from LCA and 32 from USCG.

Figure 2. Science presentation on the Great Lakes ice forecast model development during the workshop.

3 Key Findings

Throughout the workshop and survey administration, the following three major questions were addressed. Key findings for each question are highlighted below, while further details are summarized in Fujisaki-Manome et al. (2019) along with recommendations to the user interface of GLOFS-ice formulated based on the findings.

Q1: Which decisions do stakeholders make using ice information?

Participants indicated ice information is crucial for them to navigate during ice conditions. Subsequently, icebreaking, emergency response, rescue missions, law enforcement operations, and buoy retrieval were most frequently reported. Icebreaking operations are particularly important for vessels that operate during ice conditions, and are mainly conducted by USCG 9^{th} District, while there are some private icebreaking as well. All available mariners participate in emergency response and rescue missions during ice conditions with the lead of the USCG 9^{th} District. Law enforcement operations and buoy retrieval are activities typically conducted by the USCG 9^{th} District. Buoy retrieval is conducted at the end of the shipping season to protect aids to navigation and monitoring equipment from becoming entrapped in the ice or otherwise damaged during winter conditions.

Q2: What ice information do stakeholders use to support that decision-making?

Timing of changes in ice conditions and ice movement were found to be the predominant parameters that the participants desire for their decision-making. The participants also reported information gaps in the following areas: measures of information uncertainty, ice thickness, location-specific information, ice type, and whether ice is fixed to shore. Ice pressure was also of participants' interest, but many of them do not understand how to interpret this data.

It was also found that ice information requirements change throughout the season. During ice-on and ice-off, the prime information needs are for specific nearshore locations. During mid-season, information needs are expanded to offshore areas in the lakes. Long-term (from 30-day to seasonal in this case) forecasts are useful for pre- and post-winter lay-up and fit-up planning. Short-term forecasts are needed mid-season when ships are navigating through ice. The participants desire metrics for information uncertainty given the high levels of risk involved with their decision-making while navigating the Great Lakes.

Q3: What are stakeholder usability requirements for a short-term Great Lakes ice forecast?

To be effective, forecasts must provide information at the right geographic scale, time scale, and frequency, and be reliable, accurate, and contain contextual information, such as winds, wave, and surface air temperature. Current mismatch in geographic and time scales between forecasts and user needs presented predominant challenges to using ice forecasts effectively. Currently, the Daily Ice Briefings (daily conference calls hosted by USCG 9th District) are the currently primarily source of the Great Lakes ice information for the winter mariners, but for the upcoming short-term ice forecast product from GLOFS, near real-time frequency is desired for ice information during winter navigation. Coordination with the existing interface/products, such as the Daily Ice Briefings, is also important to obtain trust by the users. As technical concern for forecast accessibility, the ship's limited bandwidth capacity for accessing online forecast tools was raised.

A few opportunities were also identified for the future research. These includes incorporation of forecast uncertainty (e.g. probabilistic forecast), data assimilation approach, definition and evaluation of ice hardness/severity for icebreaking, and evaluation of risks to generate more ice as a result of icebreaking in extreme cold scenarios.

4 Concluding Remarks

In summary, the project demonstrated a 'knowledge co-production' in the R2O process of the GLOFS short-term ice forecast at NOAA. The major outcome was that scientists, operational forecast providers, and stakeholders who were involved in this project expressed favorable altitudes toward this effort and promoted opportunities to collaborate, placing a steppingstone to a new standard of a R2O process where stakeholder engagement with participation of social scientists is formalized. This lines up well with the increasing recognition of the importance of knowledge co-production in weather enterprise in general (Aguilar-Barajas et al., 2019; Kruk et al., 2017), as well as at NOAA (NOAA Social Science Vison and Strategy, 2015).

The workshop activities and the survey with robust social science methods provided in-depth information on needs for the upcoming Great Lakes ice forecast guidance from the next generation GLOFS, which inform the design of the user interface for ice forecast guidance, as well as the direction of the future development of the ice model. While the feasibility of the recommendations from this effort depends on actual resources at the operational environment at NOAA, the new insights on stakeholder needs is critical for the operational forecast providers at NOAA to determine priorities in designing the user interface, as well as for the model developers to prioritize directions of modeling research (i.e. save 'lost opportunities'). Continuing interactions among these entities is essential for a usable Great Lakes ice forecast product, and therefore better decision-making.

Acknowledgments and Data

This work was funded by the Catalyst Grant of the Emergent Opportunities Program at the University of Michigan's Graham Sustainability Institute from January 1, 2019 to August 31, 2019. The project team sincerely thank Mr. Thomas Rayburn at LCA and Mr. Jerome Popiel at USCG 9th District for help with recruitment of workshop participants, workshop preparation, and survey design. The project team also thank representatives from LCA and 9th District USCG for participating in the workshop, sharing their experiences and thoughts on Great Lakes ice information. We also thank representatives from local Weather Forecast Offices, National Ocean Service, National Ice Center, and GLERL for their helpful advice on workshop preparation, as well as their participation in the workshop as observers. We also thank Mr. Raymond Surya at the University of Michigan for assisting with preparing experimental forecast graphics for the workshop and survey. Finally, we thank the team at the Great Lakes Integrated Science + Assessments (GLISA) for helping the logistics at the workshop. This is GLERL contribution XXX and CIGLR contribution XXX.

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