Significant changes in the Arctic are underway with profound implications for the future. There is an opportunity to improve our ability to observe and understand ongoing changes in the Arctic sea ice cover and to project future changes through a greater synthesis of observations and models. There is a strong group of researchers observing Arctic sea ice and another strong group modeling Arctic sea ice, but these two groups have remained largely distinct. While each group is expert in its own area, there are knowledge gaps. For example, observers may not be fully aware of some of the issues regarding the treatment of sea ice in large-scale models, thus limiting their ability to formulate observation strategies and networks. Modelers may have never seen and may not fully appreciate the heterogeneous complexity of sea ice and its importance for coupled interactions. These limitations are not just isolated to early-career scientists, but can exist across all career stages because of specialization of expertise. Overcoming these impediments and advancing Arctic science requires a more collaborative scientific community that is able to bring the combined power of models and observations to bear on the question of Arctic change.

As a step toward building a more knowledgeable and integrated sea ice research community, a sea ice summer camp was held in Barrow, Alaska (now known as Utqiaġvik), in May 2016. The ultimate goal of the camp was to advance our ability to observe, understand, and project changes in the Arctic sea ice cover. The activity focused on educating researchers from the observational and modeling communities about the challenges and complexities involved in these different approaches to studying Arctic sea ice and its role in the larger system. All workshop participants had research expertise in sea ice processes, allowing us to focus on strengthening the link between the observational and modeling sciences. Participants had an opportunity to perform experiments with a hierarchy of models and make a variety of in situ sea ice observations. A final project allowed for a participant-designed collaborative study that involved the synthesis of models and observations. Follow-on activities are broadening the reach of this workshop by engaging and educating additional scientists.

THE SUMMER CAMP. The summer camp was conducted in Barrow, Alaska, from 25 May to 1 June 2016. It was based at the former Naval Arctic Research Laboratory (NARL). Scientific studies have been conducted in Barrow for several decades, and there is a major research infrastructure available. At the time of the camp, the melt season was underway and the surface of the shorefast ice was a variegated mix of melting snow, bare ice, ridges, and melt ponds, with open water present at a nearby lead. Most of the ice was first year, with a few embedded multiyear floes. There was easy access to the ice and excellent logistical support, with lodging, vehicles, staging areas, and conference rooms provided. Guides provided support for on-ice activities and were an excellent source of local knowledge regarding ice conditions.

Camp activities consisted of an intense program on sea ice observations and models designed to
foster future collaborative interdisciplinary activities. Each day included time in the classroom working on model practical exercises and time on the ice taking a variety of observations. This classroom–on-ice combination enhanced both scientific understanding and team integration. These activities were performed in teams that included a mix of modelers, observers, and remote sensing specialists at different career stages. Participants remained within the same groups throughout the workshop, allowing them to get to know each other quite well and providing opportunities to share their expertise in some depth.

Scheduled evening activities with local community members provided insights into the vast local knowledge of ice conditions. The last day consisted of a grand challenge in which the entire group formulated a hypothesis, developed an observational and modeling strategy to test the hypothesis, and then synthesized observations and model results. During the camp there was ample time for discussion, interaction, and just getting to know one another.

Classroom activities. Morning sessions focused on modeling presentations and practical sessions. Remote sensing tools and techniques were discussed one morning. The presentations addressed the standard components that are part of any large-scale sea ice model and how they are used to test hypotheses. The practical sessions provided hands-on experience with modifying code, running experiments, and analyzing output. A hierarchy of models, including a single-column ice model, an idealized climate model, and a global coupled Earth system model, were used in the sessions. This allowed participants to learn about the appropriate uses for different types of models. The classroom sessions focused on using models to (i) assess sensitivity, (ii) test hypotheses, and (iii) predict future change. Issues such as the importance of coupling between sea ice and the larger system and the role of natural variability in the presence of anthropogenic change were highlighted in the practical exercises and follow-on discussions. An additional classroom session focused on remote sensing, including the strengths and weaknesses of different sea ice products and providing participants with experience in analyzing data from different products (Fig. 1).

On-ice activities. After a hearty and leisurely group lunch, participants made their way to the sea ice to take a variety of sea ice measurements (Fig. 2). The measurements were taken just offshore, in close proximity to the classroom and lodging of the NARL campus, allowing participants to walk onto the ice for most activities. Experienced field researchers led the activities and provided guidance on appropriate measurement technique, possible issues that could arise with equipment or its use, and common sources of error. There were four on-ice activities aimed at studying (i) ice physical properties, (ii) ice albedo, (iii) ice thickness and snow and pond depth, and (iv) ice morphology. The four participant teams focused on one specific activity each day, rotating through all activities over the course of the week. In addition to taking the measurements, the teams analyzed the data, considering issues such as the spatial representativeness and reasons for measurement outliers. The emphasis of the on-ice work was on learning by doing, with all team members using the equipment and making the measurements.

The grand challenge. In the final days of the camp, the participants were provided with a grand challenge: to develop a hypothesis and design a measurement and modeling strategy to address it. With only a single evening of preparation, the groups rose to the challenge, hypothesizing that ice conditions would be quite different at a less disturbed site farther from the NARL campus, and that this would influence initialized predictions of ice melt. Observations were then taken at a more remote site and used to initialize sea ice model predictions. Uncertainties in the predictions associated with the evolution of future weather conditions and initial-state errors were quantified. Observational and modeling results were synthesized and presented, showing that indeed the ice melt prediction differed significantly, primarily

![Image](image-url)
because of a different initial-state albedo at the less disturbed site. The modeling results predicted less melt at the undisturbed site because of a larger initial albedo.

**Community engagement.** A number of activities in our sea ice camp were designed to begin a dialogue with Barrow residents. Barrow is a community where sea ice has a central presence in everyday life. As such, there is a tremendous storehouse of sea ice knowledge in Barrow and a profound awareness of the changes occurring to the ice and the impact of those changes. An evening discussion with local whaling captains highlighted this local knowledge, including descriptions of the environmental and ecological changes that they have observed and how these are impacting the local way of life. Camp organizers also gave a public lecture on sea ice measurements and modeling that initiated a lively and very informative discussion with local residents.

**Lessons learned and paths forward.** The sea ice summer camp was very successful in educating sea ice researchers about the opportunities and challenges in combining models and observations to understand ongoing sea ice variations and predict its future change. The opportunity to synthesize observational and modeling results in a hypothesis-driven exercise helped to cement the value of integrating different approaches to understanding the system. Much of the success of the camp was in providing participants the opportunity to “learn by doing” as a team for both modeling and measurement exercises. Through these activities, researchers obtained firsthand knowledge of some of the challenges inherent in these different approaches to understanding the sea ice system. They also were able to better appreciate the appropriate use of different research tools and data and the value in integrating different perspectives to advance the science.

An important outcome of the summer camp was the community building that occurred, resulting in a more integrated and collaborative sea ice research community. Camp community building was facilitated by mixing people with different areas of expertise and at different career levels in small teams. This allowed each participant to be both a teacher and a student throughout the week. It also allowed early-career scientists to be the expert for some activities. The campers worked together, lived together, ate together, and got to know one another. This helped to break down barriers that can inhibit real collaboration and led to a mutual respect among participants. As a result, we believe that future collaborative activities among camp participants will result (and through personal communication, it is clear that some collaboration is already happening). The value of this is hard to quantify, but we expect it will have long-lasting benefits and ultimately lead to important new insights on Arctic sea ice conditions and their future change.

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