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Co-Designing the SnowApp Climate Service for Winter Tourism Industry in Northern Finland

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Abstract. Snowmaking and snow storing are increasingly used as climate adaptation strategies in ski resorts all over the world, including in the Arctic. While the decrease of the number of snow cover days is slower than in the Alps, snow security is decreasing particularly at the beginning of the skiing season in October-November. As there is up to 30-times difference between minimum and optimal conditions in the energy and water consumption in snowmaking, it makes sense to optimize the timing of snowmaking to ensure that snowmaking will not turn into maladaptation. Climate services are user-friendly ways of providing relevant climate information for end-users. Our team co-designed a climate service prototype for winter tourism centers in Northern Finland in 2017-2020 by a transdisciplinary co-design process involving climate science, modelling, tourism research, and practitioners including snowmaking professionals and environmental experts from a pilot enterprise. The versatile co-design methods utilized included e.g. visual methods and workshops, and co-evaluation of the prototype. The resulting climate service prototype SnowApp provides a reliable 4-week forecast on snowmaking conditions and hence it is a decision-support tool for ski resort management. The prototype is applicable in other geographical locations, too, and for other snow dependent businesses.

Keywords. Climate change adaptation, winter tourism, co-design, climate services, transdisciplinary engineering

Introduction

Proper, reliable snow conditions are the key success factor for winter tourism destinations [1, 2]. However, climate change poses challenges to winter tourism in ski resorts across the world [1, 3–6], increasingly also in the Nordic Countries and in the Arctic. While the mean annual snow cover duration in the Arctic and Northern Scandinavia is currently 6 months or more [7], the Arctic is warming 2-4 times faster than the global average, which already influences the snow conditions in the region [7, 8]. Expected future changes include further delay of the first snowfall and onset of winter conditions, more rain-on-snow events, and the decrease of the number of cold days – in essence, shorter and warmer winters and less reliable snow conditions [7, 9, 10].

Snowmaking and storing of snow over the summer have become central adaptation strategies in ski resorts for improving snow security and enabling longer ski seasons – or for enabling economically viable ski operations to continue [4, 5, 11, 12]. Due to their

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dependency on reliable snow conditions, ski resorts have been characterized as "canary in the coalmine" type indicators on the impacts of climate change, as adaptation strategies like investments in snowmaking machines, more versatile selection of activities including snow-independent ones, and new business plans cannot fully shelter the resorts from climate change [1, 12]. On the other hand, some ski resorts located at either higher altitudes or latitudes may experience that climate change brings them competitive advantage, as their snow conditions remain better than in some competing destination areas [4, 11, 13].

For instance in Northern Finland, snow conditions will remain good longer than in many competing destinations such as the Alps [13]. Still, snow cover days are estimated to decrease by 30% by the end of the century [14–16]. While natural snowfall will remain abundant in the next decades, and a thicker natural snow cover is expected for the next decades due to increased precipitation and continuing cold temperatures, changes in the early skiing season conditions have already been observed, including delayed onset of winter conditions and arrival of natural snow cover [14]. Changes in snow patterns also influence other snow-dependent Arctic livelihoods, such as reindeer herding [10, 14].

While snowmaking and snow storage are increasingly used also in Northern Finland for adapting to changing conditions, an important question is whether snowmaking is a sustainable adaptation strategy or, in fact, maladaptation. As Juhola et al. (2016) have pointed out, maladaptation has three types: intentional adaptive actions can increase future vulnerability of the actor itself or external actors, and/or accelerate climate change through greenhouse gas (GHG) emissions [17]. The sustainability of snowmaking as an adaptive strategy may depend on multiple factors ranging from energy consumption and the energy sources used (fossil or renewable) to the availability of water for snowmaking, or the incurred costs. The positive effects of snowmaking can include better snow security resulting in longer skiing seasons, more slopes opened earlier, higher customer numbers, and improved customer experience via better snow quality. However, while doing so, snowmaking can risk delaying the necessary transformative adaptation to acknowledge the new business environment formed by a changed climate.

Up to 30 times difference has been estimated in the efficiency of snowmaking between the minimum and optimal conditions in terms of time and volume of snow produced. This represents a remarkable difference in energy and water consumption, and hence a difference environmental impacts such as GHG emissions if fossil energy is used for operating snow machines in the resort, and depending on the source of water used for snowmaking. Economical aspects such as the costs incurred from energy consumption may influence the economical sustainability of snowmaking.

Climate services for snow management are gaining increasing interest among ski resorts in different geographical locations including the Alps and in Finland, but the markets are not very well developed yet [18, 19].

In our case study reported here, we co-designed a climate service for the winter tourism industry in Northern Finland serving as a decision-support tool that addresses the costs and desirability of snowmaking as a function of weather conditions. We addressed this by a transdisciplinary co-design process over three years as a part of the EU Horizon 2020 funded project Blue-Action: Arctic Impact on Weather and Climate (2016-2021) with a leading ski resort in Northern Finland as the pilot resort. At the pilot resort, the decisions on timing snowmaking are made based on professional expertise in snowmaking and snow management, local knowledge of weather and climate, and relying on 3-4 day weather forecast services. However, as climate change also brings about unusual weather patterns (such as long spells of warm conditions like those experienced in the skiing season 2018-2019 in Northern Finland), new tools are needed for reducing the uncertainty of snow and snowmaking conditions. The beginning of the skiing season 2018-2019 can be used as an example of winters that are expected to become more common in the future.

1. Climate services as climate adaptation support tools

The World Meteorological Organization (WMO), the IPCC and the European Commission define climate services (CS) as a diverse group of ways of providing relevant information on climate and climate change to end-users – including the society at large – in user-friendly ways for assisting decision-making [20–22]. CS are based on scientifically credible information and expertise, are accessible, and involve engagement of users and providers, typically also consultancies and meteorological institutes [22, 23]. Damm et al. (2020) see a growing need to include climate information in everyday decision-making including adaptation and mitigation, and that climate services can help with this [24].

There are several different types of CS. On the supply side, CS and their user interfaces can take varying forms ranging from interactive and continuous to monthly, yearly or one-time publications. A rather conventional way of providing climate information are .pdf documents with regionalized climate projections in the form of graphs and textual descriptions about the expected climatic changes. These can serve e.g. subnational adaptation planning [e.g., 15]. Another type of CS are one-way web applications, such as the cherry blossom forecast services that help tourists with timing their trip to Japan to experience *hanami*, or interactive applications such as our SnowApp prototype.

In a typology by Visscher et al. (2020), CS are categorized as either focused or integrated, and generic or customized. These result in differences in the specificity or generality of the services, how the services are funded and offered to the market (for free, based on public funding, or commercially), the amount of climate expertise required, and whether the services are one-way or include sharing of best practices between peer end-users. While services offered to a large group of customers may have less added value for some users, services customized to the knowledge needs of specific customers may be more useful in complex situations typical for the specific end-user but have a higher price [23].

While CS are still a novel research topic and their markets are in early stages of development, interest in developing them has been demonstrated e.g. by public funding for research (e.g. the Blue-Action; EU-MACS / MARCO; PROSNOW, ToPDAd, Indecis, EUPORIAS projects) including studies among the tourism industry.

1.1. Co-design with a pilot resort in Northern Finland

The SnowApp prototype was co-designed within a case study with a pilot resort that actively participated in the work throughout the process. Rukakeskus Ltd. is a family-owned enterprise with two major ski resorts: Ruka and Pyhä. The company is one of the most important tourism businesses in Finland, responsible for nearly 20 % of annual ski pass sales. Ruka ski resort employs 160 people and generates 22 million euros in revenue.

Our pilot ski resort Ruka is located at Rukatunturi Fell, at 66°09.95 N 29°09.09E, i.e. in Northern Finland, slightly south of the Arctic Circle. With a summit height of 492 m, its longest slope is 1300m. The facility has 34 slopes, 21 lifts, and has a capacity of over 25 000 skiers per hour, which allow them to serve approximately 500 000 skiers per year. Ruka's 200 days skiing season is longer than in any other ski resort in the world, apart from on glaciers.

One key feature of the Ruka ski resort is that its business strategy is to be the most snow secure ski resort in Europe and to open the slopes first in Finland. Ruka relies on both natural and machine-made snow on the slopes. A mix of machine-made and natural snow stored over the summer has enabled Ruka to open the slopes early already during the first week of October for nearly two decades. Snow storage is also energy efficient. Rukakeskus Ltd. is a leader in environmental sustainability among ski resorts in Finland. The resort has been carbon neutral since 2008, and they have joined the Energy Efficiency Agreement also for 2017-2025.

The ski resort management, environmental management, and snowmaking personnel participated in the co-design process in 2017-2019. Moreover, the marketing unit contributed to the co-evaluation of the test round during the winter 2019-2020 season.

1.2. Data

For producing the forecast in the SnowApp, we utilized global climate model data from Deutscher Wetterdienst (DWD). DWD provided us with tailored climate forecast and hindcast data from the new GCFS2.0 global climate model, with a geographical limitation to the grid cell most relevant for Northern Finland. Moreover, hindcast data from Finnish Meteorological Institute (FMI) from measurement points close to Ruka was utilized for validity and reliability analysis.

Other data included the knowledge needs collected from the pilot ski resort by interviews, workshops, and visual methods for CS co-design, and interviews for the co-evaluation of the CS prototype. Other important information was obtained from the manufacturers of the snowmaking machines. Furthermore, we had access to observation data, collected over several years, on snowmaking conditions and snow management activities at the ski resort made by the snowmaking personnel.

When conducting co-design with a real-life enterprise, some data may be sensitive and confidential. This was true in our case study with regard to some data and analytical information regarding the ski resort operations, particularly data directly related to the costs and usage of machine-made snow [25]. Hence, rather than deriving from economic, energy consumption, or skier data, we worked mostly on qualitative basis in the co-design process and co-evaluation in stating the connection of snowmaking conditions and costs, and relying on climate data from DWD and FMI. Transdisciplinary sense-making across disciplinary borders and with winter tourism professionals were in the key role in the co-design process.

2. Transdisciplinary co-design of the SnowApp climate service

2.1. Transdisciplinary co-design as a concept

Transdisciplinarity involves the integration of, and co-creation between, several scientific fields and other knowledge systems such as indigenous, local, or practitioners' knowledge. Transdisciplinarity is increasingly being explored for solving complex problems such as climate change. In our study, the transdisciplinary co-design team consisted of researchers with expertise in tourism research, modelling, web application development, climate science, science communications, environmental social science, collaborative planning methods, and climate change adaptation, as well as ski resort business and snow management professionals from the pilot resort, and, in the last phase, members of the marketing unit.

Co-design, co-creation and co-production are often used interchangeably in research and practice, and Nguyen et al. (2024) refer to them holistically as co-processes or co-approaches [26]. Co-design is used particularly to describe active collaboration between all stakeholders in designing solutions to a pre-specified problem for ensuring usable outputs that meet everyone's needs [27, 28]. Co-design underlines the role of end-users in the design process, where designers work creatively with people not trained in design for reaching the agreed outcomes, through user oriented approaches [29–31]. Clifford et al. (2020) have noted that user input and understanding of the user needs can improve the design of CS across contexts [32]. In co-designing tailored CS, it is essential to consider the end-users' knowledge needs including business specific questions and geographical specificities and collaborate during the entire project time [23, 33, 34].

2.2. Our co-design process and methods

In our project, the multidisciplinary and multiprofessional team engaged in the co-design process for over three years. Based on co-design with the pilot ski resort in Northern Finland, the results were tailored to the geographical location and knowledge needs (business model, business strategy, snow making infrastructure, snow management system, abundant availability of water) of this company, but with applicability to ski resorts also elsewhere, potentially in all snowy countries. The CS prototype is particularly applicable in other snow-dependent industries.

The working methods varied during the co-design process from (1) online and in-person workshops with the end-user, where the researchers familiarized themselves with the practices of the ski resort and found out about their knowledge needs for the CS, including by visual methods for overcoming the borders between fields of expertise, to (2) desktop work including modeling, web application development, analyses on reliability and validity of the CS by e.g. hindcast analysis, and literature research, and (3) testing of the CS during one winter. Based on the test round, the researchers got feedback on the reliability and usefulness of the CS and how the user interface should be developed. Particularly #3 served as co-evaluation of the CS, along with the scientific analyses on its reliability and validity.

On a practical level, the co-design process started with an initial mapping of the knowledge needs and decision-making processes of the end-user related to snowmaking [35]. The initial knowledge needs included forecasts of September-October temperature, humidity, and wind in January; and long-term (5-10 years) forecasts or projections for serving as the basis for investment decisions.

After the initial mapping, the end-user's knowledge needs were iteratively elaborated further during the process, in part using visual methods including an "annual clock" shaped Flow of Information Timeline exercise, where the key snow management related operations in the operational cycle of the ski resort and the optimal time spans of knowledge-needs on snowmaking conditions were visualized (see Figure 1). The key operations included the opening of the skiing season (early October), peak skiing seasons at Christmas time and in February-April, key snowmaking time (December-February) and operations around snow storage over the summer for the next season.

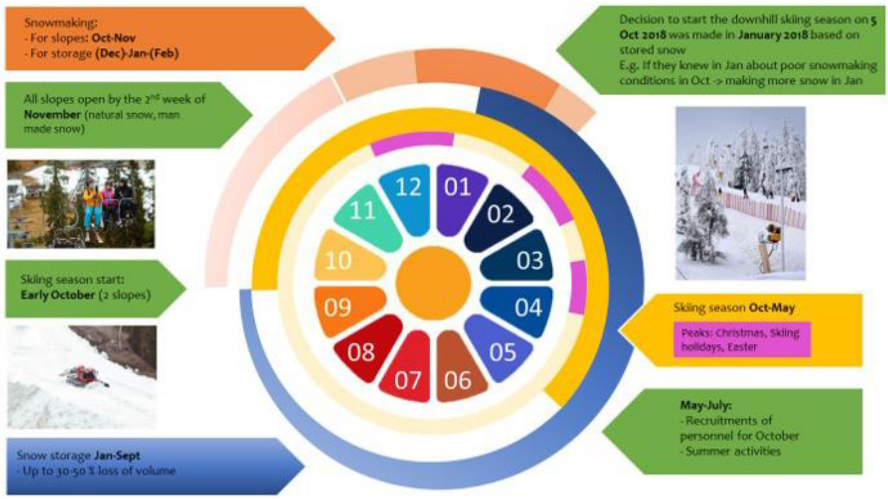

Figure 1. An example of the Flow of Information Timeline (FIT) visualization in the shape of an "annual clock", following the annual operational cycle of Ruka on snowmaking related decision-making and knowledge needs. Photos: Rukakeskus Ltd. and IM [36].

For this end, mutual learning or sense-making for tackling epistemic uncertainty was a key component of our co-design work. As Coath et al. (2021) have described, transdisciplinary co-design by a team whose areas of expertise mostly didn't overlap required building a common frame of reference and the use of accessible language amongst the team to encourage working outside of disciplinary and professional silos and widening of team members' world views by mutual learning and recasting activities. This resulted in mutual insights or epistemic certainty that eventually lead to reaching the goals of the project [28, 31].

The incremental process of mapping the operational cycle and timeline of knowledge needs and putting them in a dialogue on what the climate data offers, brought the knowledge needs and the skill of the climate data closer to each other step by step by repeated discussions as the scientific analysis and modeling evolved.

Besides the researchers learning about ski resort operations, also the ski resort personnel (and the social scientist of the team) learned about climate data and its analysis, such as using hindcasts for validating the CS [25].

The co-design process also involved combining and comparing business data with climate data. The optimal timing of snowmaking refers to not only weather conditions but their impact on the costs and other desirability of snowmaking. An early observation was that while some of the climate data would suggest good snowmaking conditions for March and April, this advice would overlap with peak seasons at the ski resort, and excessive snowmaking might negatively influence the customer experience. This underlines the complexity of decision-making in ski resort management and snowmaking. Hence, rather than aiming at providing an all-encompassing decision-support tool by including business operational considerations, our SnowApp climate service focuses on snowmaking conditions as a function of weather and costs and aims to serve as a supplementary tool that leaves space for professional expertise, managerial decisions and strategic insight regarding the other factors of the industry.

As the final stage of the co-design process, the SnowApp CS prototype was tested by the Ruka Ski Resort during the skiing season 2019-2020 by observing the test version of the SnowApp prototype besides the established decision-making procedures and information sources. Only a hypothetical testing round could be organized, as experience on the reliability and validity of the forecast would be needed for building trust in the new system before economic operations would actually be made relying on the information. The focus was on the overall usefulness of the SnowApp, including the reliability of the forecast, its economic significance, the potential uses of the 4-week forecast at the ski resort, and the user interface. The key question was whether the CS outperforms current information sources and decision-making approaches.

3. Results

Our case study co-designed a CS for winter tourism industry in Northern Finland, with applicability also beyond the pilot enterprise, for the purpose of 1) supporting the profitability of ski resorts facing the impacts of climate change by ensuring early season start while minimizing the costs of snowmaking and 2) helping to optimize the timing of snowmaking for avoid the risk of snowmaking becoming maladaptation by increased GHG emissions or too high costs. The co-design work resulted in a CS prototype called SnowApp.

Based on our analysis, the SnowApp is particularly suitable for forecasting periods of critical or too warm conditions, such as those experienced in the early skiing season 2018-2019. It is less suited for forecasting good natural snow conditions or snowfall, as the 6-month climate data doesn't forecast precipitation very well. Moreover, the SnowApp doesn't follow the accumulation of natural snowfall. Hence, the prototype is particularly well suited to predicting difficult early season conditions, where the arrival of natural snow cover may be delayed or long spells of warm weather may melt also the stored or machine-made snow.

The user-interface of the SnowApp is an application that works in a browser on desktop computers and mobile devices. Figure 2 illustrates the user interface of the prototype.

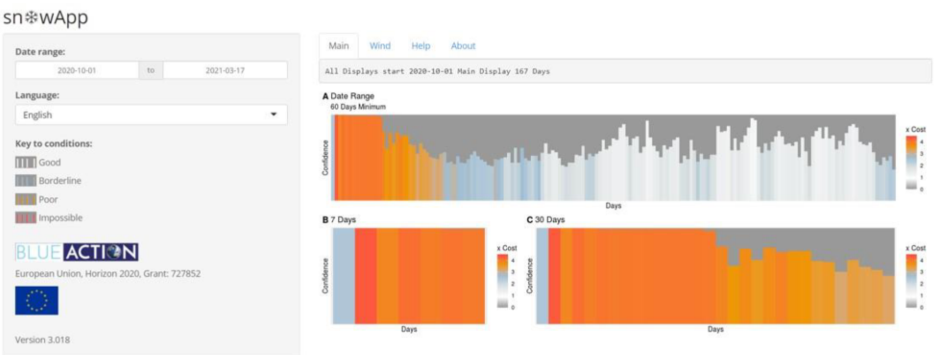

Figure 2. The user interface of the SnowApp climate service prototype.

The orange color in the daily bars indicates poor or impossible snowmaking conditions, and the days marked with white bars denote good snowmaking conditions. The height of the bar indicates the reliability of the forecast. The service shows forecasts for three different time spans: 60 days, 30 days, and 7 days. Moreover, forecasts on wind speed and direction are available. Based on the test round, for actual commercial use, the user interface should be developed to resemble the current weather forecast services that the ski resort uses in their snow making and snow management operations.

With the 4-week reliable forecast on snowmaking conditions, the SnowApp is a decision-support tool for the ski resort management rather than for operational snowmaking personnel. The forecast enables management level decisions such as postponing snowmaking by 1-2 weeks if a long warm spell was forecasted. Based on the co-evaluation, being able to anticipate the opening of more ski slopes with two weeks' notice would enable targeting efficient marketing campaigns to nearby customers.

The SnowApp is in a prototype phase, and it has not been in commercial operation after the project completion. The prototype is applicable in also other ski resorts in Northern Finland and potentially in all snowy countries with ski resorts. At the end of the project, two ski resorts in Finland expressed interest in buying the service, and scientific presentations on SnowApp have been greeted with enthusiastic feedback from scientists from across the globe. It is plausible that the prototype can be applied also in other snow-dependent livelihoods, such as reindeer herding in Northern Scandinavia, for anticipating difficult snow conditions [14, 16].

However, for utilizing the SnowApp prototype in ski resorts in other geographical locations, or for other snow-dependent industries, adjusting the service to the specific knowledge needs and circumstances of the next users by a co-design process is required. As the SnowApp was co-designed with a pilot ski resort in Northern Finland, it is clear that it carries some specificities stemming from this background, both in terms of geography, climatic conditions, the climate models utilized, and the business model of the resort. For instance, at the pilot resort, ecological sustainability related elements like avoiding GHG emissions and saving water were less important features for the CS than they would have been in some other resorts that either use fossil fuels for snowmaking or suffer from water scarcity. Also, while Ruka is a major ski resort with ample snowmaking infrastructure, some smaller ski resorts may lack the necessary equipment and the investment might be too costly. Moreover, analysis on different climate models is needed for choosing the best climate models for new end-users, including the validity and reliability of the forecast.

4. Conclusion

Climate services have a high potential in ski resorts, other winter tourism companies and beyond, as decision-support tools are increasingly needed for climate change mitigation and adaptation. Our transdisciplinary co-design process enabled the inclusion of end-user's knowledge needs and other specific needs in the CS by a lengthy iterative process involving transdisciplinary sensemaking and learning. Co-design processes such as ours are important in making CS tailored and relevant so that they serve even the complex knowledge needs of the end-user. This requires transdisciplinary co-design where time is allowed for mutual learning between scientists, social scientists, designers, and end-users from different industries working together for overcoming epistemic uncertainties and forming joint frames of understanding that lay the ground for successful CS. Despite easier applicability of CS among similar enterprises in similar conditions, CS prototypes can also be adapted to new geographical locations and industries through new co-design rounds. Also the processual learnings on CS co-design are applicable across livelihoods and industries. While CS are not very well known yet and the market is not very well developed, it is plausible that the need for CS will increase in the future, as changing weather patterns challenge the operational cycles of weather-dependent industries.

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