Model Information Utilization Report

Blue-Action Case Study Nr. 1

Blue-Action: Arctic Impact on Weather and Climate is a Research and Innovation action (RIA) funded by the Horizon 2020 Work programme topics addressed: BG-10-2016 Impact of Arctic changes on the weather and climate of the Northern Hemisphere. Start date: 1 December 2016. End date: 1 March 2021.

The Blue-Action project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 727852.

About this document

Deliverable: D5.2 Case Study Nr. 1 Model Information Utilization Report
Work package in charge: WP5 Developing and Valuing Climate Services
Actual delivery date for this deliverable: Project-month 11
Dissemination level: Public

Lead authors
Arctic Centre, University of Lapland (AC UoL): Roxana Contreras, Ilona Mettiäinen
Rukakeskus Ltd (Ruka): Jusu Toivonen

Other contributing author
Arctic Centre, University of Lapland (AC UoL): Martin Coath

Reviewer
Danish Meteorological Institute (DMI): Chiara Bearzotti

We support the Blue Growth!
Visit us on: www.blue-action.eu
Follow us on Twitter: @BG10Blueaction

Index

Summary for publication

Northern Finland is one of the fastest warming regions in Europe with the greatest increases in temperature being seen in November, December and January. For the winter tourism sector, proper winter conditions are key to commercial success: information on future climate and specific local weather conditions is fundamental for preparing and adapting to future change. Long-term business planning for Northern Finnish winter tourism industry therefore needs to account for the increased likelihood of the October-December season being too warm and plan for alternatives to winter sports. Forecast data is required to plan for the next season, especially at the beginning of the season with the need for snowmaking and snow storage and plan mid-term operations and investments that allow their businesses to adapt to the changing and variable climate (semi-decadal scale). Furthermore, weather and climate information is required to assess the competitive position of Northern Finland relative to other major European Ski Centres.

The task of this case study in Blue-Action WP5 is to “assess the value of improved weather and climate predictions for short-term and mid-term planning of operations for ski centres in Northern Finland”. In this deliverable D5.2, Model Information Utilization Report, a general procedure for generating and delivering data and associated uncertainties in a format useful for the Rukakeskus Ltd (Ruka) company, the end-user of this case study, is presented. This procedure has been developed in collaboration between the case study (CS1) participants: Arctic Centre, University of Lapland (AC UoL) and Rukakeskus Ltd (Ruka).

In this report we summarize discussions regarding data use, which took place during meetings held in 2017, with partner Ruka. The first group meeting was organized in March of 2017, at the Arctic Centre of University of Lapland, Rovaniemi. The second meeting was the workshop organised by WP5 in Hamburg on 10 - 12 July 2017. During these meetings, several topics were discussed, including the use and need of data, both modelled and observed meteorological data. Additionallly, , several group skype meetings have been held with the purpose of obtaining useful information from the ski resort and help develop a working methodology for the coming years.

As of 2017, our group has acquired a large (global) sample of temperature data from ECHAM6, an atmospheric general circulation model developed at the Blue-Action partner Max Plank Institute for Meteorology[1]. The data provided are ensemble-based hind-casts corresponding to the period November of 1981 - April of 2017, which are initialized every May 1st and November 1st for each 6-months forecast. The data extracted corresponds to daily surface temperatures and 2m temperatures. Also, meteorological measurements were provided by the Finnish Meteorological Institute, corresponding to temperature, dew point temperature, wet-bulb temperature, relative humidity, wind direction, 10-minute average wind speed, wind gust speed, atmospheric pressure at the station level, and atmospheric pressure at the sea level[2]. On average, six hourly measurements are provided from November of 1993 until May of 2017, from the stations Kuusamo Rukatunturi (latitude 66.1661566, longitude 29.15171953) and Kuusamo Ruka Talvijärvi (latitude 66.171503, longitude 29.136395).

The main result achieved is the development of a raw methodology draft for the coming months and years, which refers mainly to obtaining useful information from the ski resort operations, and how to use the data available to strengthen them. This is an important step in the collaborative and iterative design process, which will result in a climate service for the end-user for reducing uncertainty on conditions for snowmaking for enabling an early season start. The task is not easy because while there is a formal decision-making procedure on snowmaking in Ruka (Lesser et al. 2017), decisions on snowmaking in Ruka are largely based on experience and even “gut feeling”, therefore there are very few databases or records to study and work with, and hence, obtaining information relies heavily on interviewing Ruka staff, which may be time consuming and difficult to schedule. Nonetheless, until now it has been established that snowmaking by machines will be a key topic and a basic model will be developed to enhance the predictability of this process (based on forecasts, to optimize when it is feasible from the economic point of view to make snow). Also the interaction with their new strategy of storing snow from the previous seasons will be considered, but at a later stage. This will be supported by other data, such as the detailed statistics on number of visitors per day, of which there are good databases available.

Work carried out

Background: Vulnerability of Ski Centers to Climate Change

The tourism industry is strongly linked to climate, since the potential for developing tourism in a region is intrinsically defined by its climate and weather conditions[3]. Other general aspects that influence the success of tourism include the availability of services and infrastructure, accessibility, price level, and safety. In Northern Finland, tourism is generally nature-based and hence particularly based on attraction attributes provided the northern nature and its amenity values like beautiful landscapes, snow, northern lights and midnight sun, and the potential for outdoor activities. Many tourism attractions’ attributes or their qualities in nature-based tourism rely on weather and climate, and some of them are potentially threatened by climate change. Particularly winter tourism, including skiing industry is vulnerable to the impacts of climate change. Haanpää et al. (2015) call downhill skiing a “canary in a coalmine” type indicator for the impacts of climate change on the winter tourism industry due to its strong dependence on the climatic conditions for economically successful operation[4].

Generally, it is expected that climate change will affect outdoor recreation in three main ways:

- the availability of recreation activities through longer summer seasons and shorter winter seasons;
- the overall comfort and enjoyment of recreation activities and
- the quality of the recreation experience [5,6].

Studies suggest that Northern Fennoscandia is one of the fastest warming regions in Europe; in Finland for example, one of the fastest warming rates over the last half century has been observed, with the highest increases in temperature in the months of November, December and January[7].

In Finland, climate change is expected to enhance winter tourism in Lapland in the near future as the projected lack of snow will adversely affect skiing conditions in central Europe (Kietäväinen and Tuulentie, 2013)[8]. On the other hand, snow cover days are expected to decrease by 20 – 30 % by the end of the century also in Northern Finland as compared to the 1961-1990 time period, according to Finnish Meteorological Institute[9] (FMI and Regional Council of Lapland 2010). This is less than in some competing destinations further South, but means delay of the arrival of snow cover i.e. delay of skiing season if relied only on natural snowfall.

Even though the amount of studies dedicated to the potential impact of climate change on the ski industry has been steadily growing during the past decade, there is a notorious lag with respect to knowledge acquired in other sectors such as forestry and agriculture for example[10]. Nonetheless, there is consensus on the number of impacts that have been clearly identified and a number of impacts have been clearly identified: decreasing snow reliability, shortening ski season lengths, increased snow making requirements, decreasing in visitors, increased operational costs, potential for decreasing profits and eventual loss of ski area operations[10]. The majority of the studies dedicated to the vulnerability of the winter ski sector to climate change predict negative consequences, particularly, the reduction of the ski season length[11].

Adaptation strategies for ski resorts are discussed by various authors. It is suggested that one of the most promising strategies could be to develop all-year tourism activities, and it has been established that the most common adaptation measure to lack of snow is snowmaking[6,11]. Nonetheless, Scott et al. and Dawson & Scott (2006, 2007)[11,12] highlight that most of the studies (to that date) regarding climate change and ski tourism, fail to include snowmaking as a climate adaptation measure in their assessment of climate change impact. In fact, the first generation of studies on the effect of climate change on the ski industry may have overestimated the negative trends by ignoring this adaptation measure. For example, taking into account the technology improvement of snowmaking machines, the modelled season losses were reduced between 1% and 21% (Scott et al 2006)[11].

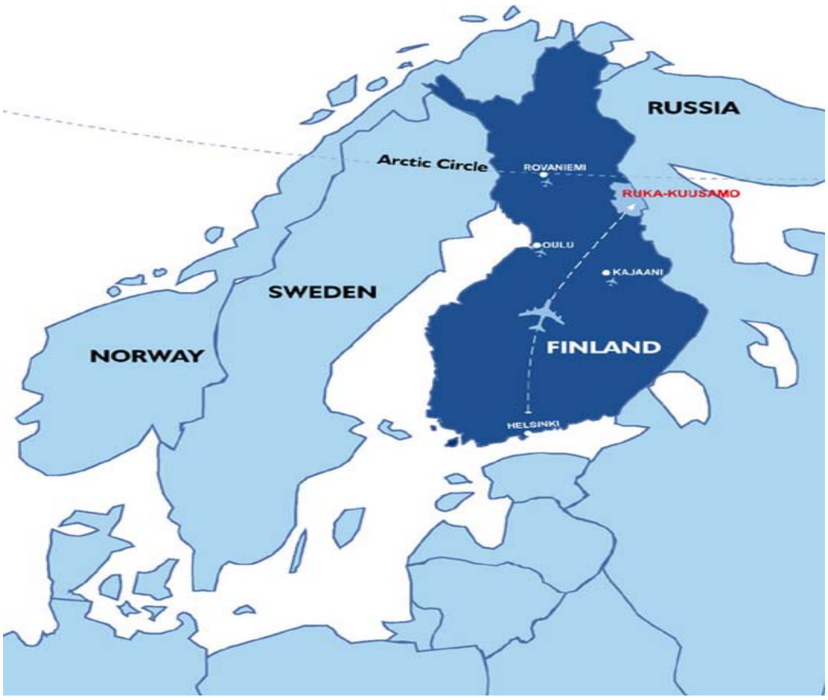
However, in more recent literature, snowmaking is listed as one of the most popular adaptation strategies in ski centres. For instance, Haanpää et al. (2015) regard snowmaking a “key adaptation strategy to respond to uncertain snow conditions” for lowering the vulnerability of the skiing areas to the impacts of climate change. However, for instance Damm et al. (2017) point out that many tourism regions are sensitive to natural snow conditions despite the widespread use of machine-made snow. Nevertheless, the profitability of snowmaking has also been proven under future climate conditions for individual ski resorts. (ibid.)

On the other hand, snowmaking as an adaptation strategy can be also questioned, as it requires energy. High energy costs may raise issues on competitiveness of ski tourism across Europe (Damm et al. 2017)[13]. Moreover, the high energy consumption may, in fact, make machine-made snow “maladaptation”, which is a term used for activities that are adaptive but have adverse impacts on the work to mitigate climate change. Comparable to some extent to air conditioning, a widely used example of maladaptation, the energy consumption required by snowmaking for ensuring early beginning of skiing seasons is a factor that influences the carbon footprint of ski centres. While weather conditions such as temperature, humidity and wind, influence the energy consumption of snowmaking and snow storing, by optimally timing the snowmaking activities it is possible to reduce energy consumption of snowmaking and thus reduce costs and adverse impacts on climate.

Most of the articles so far cited refer to case studies applied to ski resorts located at relatively low latitudes like Central Europe, United States, and Australia for example. Those focused on higher latitudes, such as Scandinavia and Finland are very rare, and therefore this case study from Northern Finland offers an opportunity to acquire knowledge on the effect of weather variability and climate change on a ski resort located in arctic conditions.

Case Study: Weather and Climate Data Use for Northern Finnish Winter Tourism Center

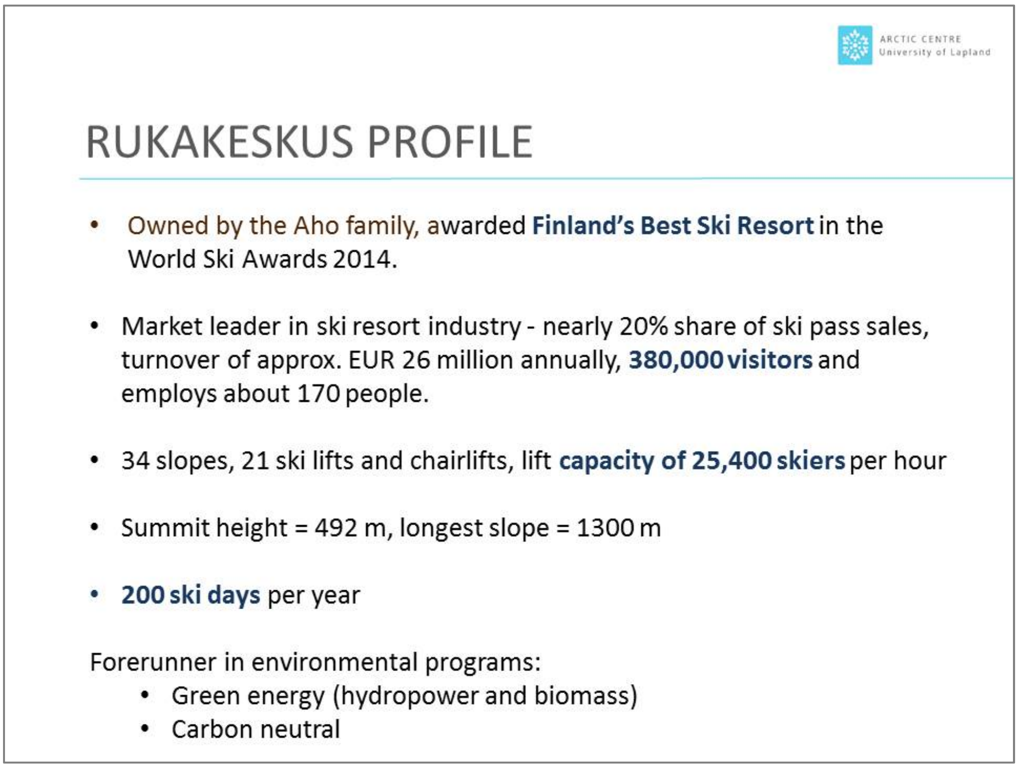
Rukakeskus Ltd. is one of the most important tourism companies in Finland, employing close to 200 people and generating approximately 26 million euro in revenue. Rukakeskus Ltd. operates two ski centres in Northern Finland: **Ruka and Pyhä**. Of these two destinations, **Ruka is the case study site**. Ruka is located at 66°09.95 N 29°09.09E, i.e. in Northern Finland close to the Russian border, slightly south of the Arctic Circle (66°33N).



Picture 1 The case study site, Ruka, is located at 66°09.95 N 29°09.09E

The **resort Ruka** is located at Rukatunturi Fell, with summit height of 492 m. The longest slope is 1300 m long. Ruka comprises 34 slopes, 21 lifts, and has a capacity of 25 400 skiers per hour, which allow them to serve approximately 380 000 visitors per year.

Picture 2 Ruka resort: Map of the slopes. Courtesy of Rukakeskus Ltd



Picture 3 Courtesy of Pamela Lesser (AC UoL) and Rukakeskus Ltd

For the slopes, Ruka uses both natural snowfall and machine-made snow. One key feature of Ruka ski resort is that it is in its business strategy to open the slopes **first in Finland.** For instance in 2017, the first slopes were opened on 6 October i.e. just in time for the schools' autumn vacation. Stored snow that is used for opening the skiing season is a mix of both

natural and machine made snow, but it is also possible to have a situation when there are several slopes open but no natural snow on the ground at all. This situation is expected to become more common, as the arrival of the natural snowfall is expected to be delayed in the coming decades9.
Machine-made snow is a central factor in this study, as it will be explained in the next sections. Currently Ruka is experimenting with stored snow, which is made during the season and stored for the next season (over the summer), by piling it and covering it with sawdust and gauze. Currently the amount saved is only enough for two slopes, therefore is not a critical parameter for this analysis, but it is an important step towards the sustainability of this activity in the future, and it will be considered but to a lesser extent than snowmaking itself.
An important point to consider, regarding Ruka, is that their main concern is not how climate change will affect snow fall (at least it is not a central issue), because they operate also with machine-made snow anyway, but the main concern is instead the possible changes in temperature and humidity profiles, for example, which are critical for snowmaking and the costs of running the business. For example, making snow in October, which is very important for opening this early, may cost 30 times as much as making snow in January[14].

Methodology Development

Iterative Service Co-design by Transdisciplinary Team work and Learning Cycles

The development of a climate service for winter tourism takes place within a transdisciplinary and iterative co-design process that involves close collaboration within the case study team. The team consists of scientists that are experts in climate related and other modelling, development director of Rukakeskus Ltd., and social scientists with expertise in science-policy interface, climate adaptation issues and tourism research.
Stemming from the definition on climate services as “the provision of climate information to assist decision-making” (Buontempo & Hewitt 2017)[15] it is of crucial importance to co-design a knowledge system in the interface of climate models and the practices of winter tourism business.
In this climate service co-design process, science communications is in a central place. Dealing with climate model data has been seen in previous studies as a potential source of challenges, as the end-user typically does not have the technical or scientific education needed for interpreting the climate models themselves. However, climate service co-design aims at ensuring the usefulness of the end-product to the end-user, as multidimensional learning takes place within the knowledge co-production process while developing the climate service. Hence, besides communicating climate science to the end-user, it is important to translate it to fit the actual questions of the end-user. A potential and desired outcome is also a change in the decision-making procedure of the end-user organization as the forecast information reduces uncertainty and reliance on informal knowledge or “gut-feeling”.

Hence, following the idea of service co-design, we have started an iterative learning process, in which, following Baek et al. (2017), **learning cycles take place**.

Whereas the project plan shows a path of deliverables for reporting progress in this work in chronological order, when looked more closely, the work goes largely in cycles. Hence it is natural that the climate service that is expected to result from this case study will only be finished (potentially into a prototype model that still requires e.g. some graphic design or other refinement of the user-interface of the application) in the end of the project.

As a step towards this, first the end-user needs were identified in the **Blue-Action deliverable D5.1**.[1] In our present report we have focused on how the information provided by climate models available in this project will be utilized.

Towards Identifying Methods for Utilizing Climate Model Information

During the first months of this project, the main challenge has been creating a common ground for proper communication between the scientists and the end user. First, communication between our WP5 group and the Blue-Action WP1 teams established the type of model and data that can be made available to work with the end user, and then exchange between WP5 and Ruka has been developed during 2017, building step by step from the previous discussions the methodology to use the data available, request more suitable data in the future and develop a basic model to achieve the main goal of this work package: namely, to identify and quantify the value of climate services for Ruka, a case study of the tourism industry.

The first experience with modelled data for Ruka is being currently tested. Our group obtained ensemble-based hind-casts from an atmospheric general circulation model developed at the Max Plank Institute for Meteorology, ECHAM6. The data provides daily global surface and 2m temperature and consists of an ensemble of 30 members for the period November of 1981-April of 2017, which are initialized every May 1st and November 1st for each 6-months forecast. Also, meteorological measurements were provided by the Finnish Meteorological Institute, corresponding to temperature, dew point temperature, wet-bulb temperature, relative humidity, wind direction, 10-minute average wind speed, wind gust speed, atmospheric pressure at the station level, and atmospheric pressure at the sea level. On average, six hourly measurements are provided from November of 1993 until May of 2017, from the stations Kuusamo Rukatunturi (latitude 66.1661566, longitude 29.15171953) and Kuusamo Ruka Talvijärvi (latitude 66.171503, longitude 29.136395)[2].

Currently, correlation is being studied between the modelled and measured data. More variables can be obtained from the model; however, the resolution is rather coarse (1.875 degrees), therefore the analysis including the hind-casts will be delayed until the next model with improved resolution is available, later in 2018. As of now, the temperature variables are being used for illustrative purposes only (for the end user), until the improved model is available. Because the data does not include the exact location of interest, we use interpolation methods, such as inverse distance weighting, in order to represent RUKA and study correlations between modelled and observed parameters. The model will be used mainly for reducing the uncertainty associated with the process of making snow: having reliable 2-week weather forecasts would have impact on planning the work hours, sales and marketing. First, information related to decision making in Ruka in the past seasons will be gathered (this is a

[1] Lesser, Pamela, Toivonen, Jusu, Coath, Martin, & Contreras, Roxana. (2017). End-users Needs Report: Weather and climate data for Northern Finnish winter tourism centers (D5.1).

current issue). This information is at the moment scattered but some variables such as water usage or the days when snow was made or electricity usage, which are correlated with weather conditions, will be available before May of 2018. Then, this data will be analysed together with the hind-casts mentioned and meteorological observed data, with the purpose of understanding the value of having this weather information in deciding when to make snow. In other words, we are working on using information of the past to study how would have the decision been affected if the forecasts were available. Using the hind-casts for this and the data gathered from previous seasons will allow us to assign value to the forecast services which will be available in the coming years. The most critical variable for making snow is the wet-bulb temperature, which is a function of temperature and relative humidity (wet-bulb temperature of -12 C is ideal). Wind speed may also have influence on snow-making, therefore the most relevant variables that will be obtained from the models are the temperatures, humidity and wind speed.

At the moment, priority was given to developing a conceptual model for the costs of snowmaking. One of the key aspects that was identified after several discussions and meetings, was the role of making snow for the ski center by machines, which depends heavily on the wet-bulb temperature (which is determined by both, the temperature and humidity) [17, 18]. In simple terms, it is possible to make snow with sub-zero temperatures as long as humidity is relatively low, and the capability of forecasting snowmaking will have a direct impact on the value of the service, since it represents a major expense.

Challenges

Despite the progress in linking snowmaking costs and weather conditions, even a conceptual model was found to be challenging in this case before solving first the communication gaps between scientists, social scientists and business. In previous climate service development projects the involvement of the end user has been identified as a key success factor (e.g. Buontempo et al. 2017, Christel et al. 2017). This calls for participatory working methods of all the service co-design parties in the case study. Hence, we have identified science communication and learning across disciplinary and professional borders as key factors in order to proceed with the project as planned.

Some challenges concerning participatory co-design have been encountered. Before the start of the project, the fact that the depth and detail of collaboration required could be hard without regular (and face to face) contact between the parties, had not been predicted. Neither was considered the possibility of having difficulties communicating scientific ideas. In other words, these issues arose during the execution of the project and required immediate action, or correction by redirecting the efforts towards including science communication and service co-design in the methodology, indeed as a necessary first step before even making progress with either meteorological or modelled data.

The new, or updated methodology includes also fieldwork and will heavily rely on methods of social sciences and service design, such as workshops, interviews, and on-site observation for learning about decision-making and practices of snowmaking.

Main results achieved

The most important result achieved here is the development of a basic methodology for the interaction and understanding between the different actors involved in this project: scientists, social scientists and representatives of the ski industry. With this case study team, a collaborative co-design process takes place. This involves a continuous collaborative process including knowledge exchange and learning among the case study team, potentially added with social sciences and design methods including observation of snowmaking and interviews as well as collaborative working in workshop(s) with Ruka snowmaking people.

The methodology is still general and in development; however, these ideas will constitute the basis of our future work, during this project, and hopefully also during future follow ups and spin off projects or even start-ups that may result from this work. We expect also that these ideas will be a contribution to the other groups of this work package, as they may be experiencing similar challenges in developing methodologies with this particular inter and transdisciplinary approach.

The methodology, which is still being developed and under discussion while flexibility and responsiveness to the unique nature of this development process must be allowed, derived directly from the identification of end user needs, which was presented in D5.1. Also, progress was made in developing a rough conceptual model of the costs of machine-made snow, with the use of the existing meteorological data (provided by the Finnish Meteorological Institute). However, one of the key problems identified is the lack of data or analytical information regarding the operation of the Ruka ski resort , at least data directly related to their costs and usage of machine-made snow. A secondary challenge is that some of that information, if available, may be sensitive and confidential.
Progress has been made in connecting weather conditions and the costs of snowmaking. This progress is still at a very early stage, and assessment and evaluations methods for economic feasibility, which will confer value to the climate service or end-product to be provided towards the end of this work, are still being reviewed (see deliverable D5.3)[2].

With this deliverable, a basis for developing the end-product of this project has been made. While this deliverable is done in an early stage of this project, it lays the foundation for successful implementation of the project plan.

Progress beyond the state of the art

The question identified here is of significant importance for winter tourism in North Finland and other comparable destinations in North Scandinavia and other snowy countries. While climate change is expected to lead to 20-30 % decrease of snow cover days in Northern Finland by the end of the century (Finnish Meteorological Institute 2010), this means particularly the

[2] Available in Zenodo Blue-Action community in open access https://www.zenodo.org/communities/blue-actionh2020/

shortening of winters from the beginning, i.e. delay of the arrival of snow. Meanwhile, being able to open the skiing season early is of great importance for many ski centres. While machine-made snow can be used as an adaptative action for ensuring early season start for downhill skiing, many other winter tourism activities like snowmobile and reindeer safaris still rely on natural snowfall.

While at this stage the work to produce the climate service for winter tourism centres is in progress and in relatively early stage, the end result is expected to have significant economic and environmental importance, as snowmaking can be optimized in a way that ensures the opening of the ski season early while energy consumption and hence economic costs as well as greenhouse gas emissions are reduced.

Also scientifically, knowledge co-production, science-policy nexus and service design are emerging and developing research settings, and this research contributes to understanding of those by providing experience and knowledge on the interfaces of climate modelling and business related decision-making. How science could inform societal and business related decision-making is a highly policy-relevant question, and thus this research has potential to create and identify good or best practices for collaboration between scientists and businesses.

Impact

How has this work contributed to the expected impacts of Blue-Action?

One of the goals of Blue-Action is to reduce risks and support decision-making in the Arctic. This was approached by creating a work package (WP5) consisting of five case studies which require scientists to work together with SMEs or stakeholders in order to co-design products based on climate services, through the translation of model outputs developed by other work packages into sector-specific tools. This particular case study refers to Arctic businesses, more precisely, the ski industry in Northern Finland, and their need of improved weather and climate data for reducing risks in their decision-making (namely, snowmaking).

Nature-based tourism is very critical in Northern Finland because this sector generates more jobs than any other industry in the regions; therefore, failure to adapt to possible future change may have immense societal impact.

Impact on the business sector

The climate service will help winter tourism centres with adapting to climate change. The service will, on a shorter time span, help to ensure opening of the ski centre early in the season also in the future, which supports the profitability of the skiing industry. By better foresight, timing of snowmaking to the optimal weather conditions helps winter tourism centres to save money by reducing energy consumption in snowmaking as well as ensures the sustainability of snowmaking as an adaptation strategy by helping to reduce greenhouse gas emissions. Moreover, the climate service can assist in making informed long-term investment decisions.

Lessons learned and Links built

One of the main lessons learned is that there is a lack of tools for proper communication between scientists and the end user, and therefore these must be developed before feeding climate-related information to the end user. The current situation creates difficulties for example in obtaining key information from their operations such that this information can be used to build the service that is expected. This first challenge is being approached by creating tools proper of social sciences and science communication, which are currently under development.

Our case study will need improved climate model data from other WPs in Blue-Action and also benefit from Copernicus later on in 2018. The scientists in the case study team will communicate about our data needs with WP1 and WP4.

We have read articles about other climate service development projects, including EUPORIAS, and have learned from them. However, a majority of the cases reported in scientific articles seem to be directed to authorities and public planning officials, and **climate services tailored for businesses are rare.** Based on our literature search, no previous climate services for winter tourism industry exist. While the case studies in Blue-Action WP5 are quite different from each other, we expect to be able to identify good practices of creation of climate services and at a later stage to be able to compile together a handbook for climate service co-design (D5.6).

Contribution to the top level objectives of Blue-Action

This deliverable contributes to the achievement the following objectives and specific goals indicated in the Description of the Action, part B, Section 1.1: http://blue-action.eu/index.php?id=4019

Objective 7 Fostering the capacity of key stakeholders to adapt and respond to climate change and boosting their economic growth

This type of collaboration between scientists and ski industry has never been tested before in Ruka. This means that any new information generated during this project may contribute to their knowledge about climate change and therefore it may contribute to secure their economic growth by making decisions based on improved forecasts, in a climate change scenario.

Adaptation measures are key for the success of winter-based businesses. Ruka is already using adaptation measures, such as experimenting with snow storage from one season to the next.

Being able to use improved forecast for optimising snowmaking will have an economic impact, since this is one of their main expenditures.

Objective 8 Transferring knowledge to a wide range of interested key stakeholders

This case study has already been planned to attract the attention of other actors. For example, there is a plan to participate in the Lapland Tourism Parliament in 2019 to communicate the project´s goals to other relevant audiences. As it was mentioned several times, tourism is the most important industry in Northern Finland, therefore, developing this kind of knowledge will have a broader impact, not only on the end-user Ruka, but it is expected that most of the players will need to develop adaptation measure in the future, in order to remain competitive.

References (Bibliography)

These are the papers or publications you consulted during the researches.

1. M.A. Giorgetta, E. Roeckner, T. Mauritsen, J. Bader, T. Crueger, M. Esch, S. Rast, L. Kornblueh, H. Schmidt, S. Kinne, C. Hohenegger, B. Möbis, T. Krismer, K.H. Wieners, B. Stevens. The atmospheric general circulation model ECHAM6. Model description. Max Planck Institute for Meteorology, Reports on Earth System Science, 135, 2013.

2. Finnish Meteorological Institute, 2017.

3. J. Saarinen and K. Tervo. Perceptions and adaptation strategies of the tourism industry to climate change: The case of Finnish nature entrepreneurs. Int. J. Innovation and Sustainable Development, Vol. 1 No. 3, 2006.

4.Haanpää, Simo, Sirkku Juhola & Mia Landauer. 2015. Adapting to climate change: perceptions of vulnerability of down-hill ski area operators in Southern and Middle Finland. Current Issues in Tourism 18:10, 966-978, DOI: http://dx.doi.org/10.1080/13683500.2014.892917. Routledge.

5. Mendelsohn, R. and Markowski, M. (1999) The impact of climate change on outdoor recreation. In R. Mendelsohn and J.E. Neumann (eds) The Impact of climate change on the United Stated economy. New York : Cambridge University Press.

6. Jon Moen and Peter Fredman. Effects of climate change on Alpine skiing in Sweden. Journal of Sustainable Tourism, Vol. 15, No. 4, 2007.

7. S. Mikkonen, M. Laine, H.J. Mäkelä, H. Gregow, H. Tuomenvirta, M. Lahtinen, A. Laaksonen. Trends in the average temperature in Finland, 1847-2013. Stochastic Environmental Research and Risk Assessment, 2015, Vol. 29, Issue 6, pp 1521-1529.

8. A. Kietäväinen and S. Tuulentie (2013). Tourism strategies and climate change: rhetoric at both strategic and grassroots levels about growth and sustainable development in Finland. Journal of Sustainable Tourism, 21:6, 845-861.

9. Finnish Meteorological Institute, 2010. & Regional Council of Lapland. 2010. Lapin ilmastonmuutoskuvaus. Ilmastoennuste eri säätekijöistä vuoteen 2099 asti eri päästöskenaarioilla. Lyhyesti ilmastomalleista, eri päästöskenaarioista ja ilmaston luonnollisesta vaihtelevuudesta. (Information package about Lapland's climate, produced for the regional climate strategy process)

Available online at http://www.lappi.fi/lapinliitto/c/document_library/get_file?folderId=250745&name=DLFE-15511.pdf

10. Jackie Dawson and Daniel Scott. Systems analysis of climate change vulnerability for the US Northeast ski sector. Tourism and Hospitality Planning & Development, Vol. 7, No. 3, 219-235, 2010.

11. Scott, D., McBoyle, G., Mills, B., Minogue, A. (2006) Climate change and the sustainability of ski-based tourism in eastern North-America: A reassessment. Journal of Sustainable Tourism 14, 376-398.

12. Jackie Dawson and Daniel Scott.Climate change vulnerability of the Vermont ski tourism industry (USA). Annals of Leisure Research, 2007 Vol10 No 3&4 (Editors J. Jenkins, C. McCormack, I. Patterson)

13. Damm, Andrea, Wouter Greuell, Oskar Landgren & Franz Prettenthaler. 2017. Impacts of +2 C global warming on winter tourism demand in Europe. Climate Services 7 (2017) 31-46. Elsevier.

14. J. Toivonen, P. Lesser, I. Mettiäinen, R. Contreras. 2017, Private Communication.

15. Buontempo, Carlo & Chris Hewitt. 2017. EUPORIAS and the development of climate services. Climate Services. Elsevier. (Article in press, accessed via ScienceDirect on Jan 9, 2018).

16. Baek, Joon Sang, Sojung Kim, Yoonyee Pahk, Ezio Manzini. 2017. A sociotechnical framework for the design of collaborative services. Design Studies.

17. R. Steiger and M. Mayer. Snowmaking and Climate Change. Future options for snow production in Tyrolean ski resorts. Mountain Research and Development, Vol 28, No 3/4 Aug-Nov 2008: 292-298.

18. Spandre,P. Francois, H., Morin, S. George-Marcelpoil, E. Snowmaking in the French Alps: Climatic context, existing facilities and outlook. Journal of Alpine Research 103-2 (2015).

19.Christel, Isadora, Drew Hemment, Dragana Bojovic, Fernando Cucchietti, Luz Calvo, Moritz Stefaner & Carlo Buontempo. 2017. Introducing design in the development of effective climate services. Climate Services. Elsevier. (Article in press, accessed via ScienceDirect on Jan 9, 2018).

Dissemination and exploitation of Blue-Action results

Dissemination activities

Type of dissemination activity	Title	Date and Place	Estimated buget	Type of Audience	Estimated number of persons reached
Participation to a conference	Rovaniemi Arctic Spirit 2017, Participant: Ilona Mettiäinen (AC UoL) with the poster "Payne, Mark, Keil, Kathrin, Kolstad, Erik, Ballester, Joan, Mettiainen, Ilona, Vangsbo, Peter, … Olsen, Steffen. (2017). Translating advances in Arctic climate science to climate services across the Northern Hemisphere (Version November 2017). Zenodo. http://doi.org/10.5281/zenodo.1065467	Rovaniemi (FI) 14-16 November 2017 http://www.rovaniemiarcticspirit.fi/EN	See form C of partners involved.	Scientific Community (higher education, Research), Industry Civil Society, Policy makers, Media	300
Publication	Dale, Thomas, Miller, Raeanne, Vangsbo, Peter, Mettiäinen, Ilona, Ballester, Joan, Kolstad, Erik, … Nikitina, Elena. (2018, January 18). Climate Service Case Studies Booklet. Zenodo http://doi.org/10.5281/zenodo.1154792	18 Jan 2018	See form C of partners involved.	General public, policy makers	200
Poster	Payne, Mark, Keil, Kathrin, Kolstad, Erik, Ballester, Joan, Mettiainen, Ilona, Vangsbo, Peter, … Olsen, Steffen. (2017). Translating advances in Arctic climate science to climate services across the Northern Hemisphere (Version November 2017). Zenodo http://doi.org/10.5281/zenodo.1065467 Presented at the EASME workshop „Climate services at work, Projects exchange and networking lab, Brussels (BE)" Presenter: Steffen Olsen (DMI)	29-30 Nov. 2017, Brussels (BE)	See form C of partner involved.	General public, policy makers	200
Poster	Miller, Raeanne, Payne, Mark, Keil, Kathrin, Kosltad, Erik W., Ballester, Joan, Lesser, Pamela, & Vangsbo, Peter. (2017). Translating advances in Arctic climate science to climate services across the Northern Hemisphere. Zenodo. http://doi.org/10.5281/zenodo.827081 5-9 June 2017, 3rd European Climate Change Adaptation Conference, Glasgow (UK) Presenter: Raeanne Miller	5-9 June 2017, Glasgow (UK)	See form C of partners involved.	Scientific community and policy-makers	200
Participation in a workshop	WP5 workshop on Climate Services, 10-12 July 2017, Hamburg (DE)	10-12 July 2017, Hamburg (DE)	See form C of partners involved.	Scientific community	30

Peer reviewed articles

No peer-reviewed articles so far.
One article on "Snowmaking as an adaptation strategy in ski tourism centers – from maladaptation to adaptigation by development of a climate service" (working title) is under progress. First author: Ilona Mettiäinen. Examples of possible journals: Climate Services; Tourism Management; Journal of Sustainable Tourism.

Uptake by the targeted audiences

As indicated in the Description of the Action, the audience for this deliverable is the general public.

This is how we are going to ensure the uptake of the deliverables by the targeted audiences:

Despite of the PU nature of the deliverable, priority in dissemination will be given to the consortium and Arctic cluster partners:

- This deliverable will be shared with the consortium in the project intranet.
- We plan to share it with the Arctic Cluster project teams and EU-PolarNet CSA.
- We also plan to share this document the RIAG and SEG advisors of Blue-Action.

For reaching out to the general public, the contents of this deliverable will be taken up by WP8 and disseminated broadly using the social media of the project.
Additionally, the deliverable will be archived in Zenodo for granting open access to larger audiences.

Intellectual property rights resulting from this deliverable

For the time being, we keep on monitoring the development of the work performed by RUKA and The Univ. Lapland and the connection with the Blue-Action WP1-4: we will check if the IP emerging from the research need to be protected and how with the legal advisors of the organisations involved.