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EUPORIAS

(Grant Agreement 308291)

PRO-SNOW

A seasonal forecasting system for snowfall and snow depth in France's Alpine ski resorts

EUPORIAS

European Provision Of Regional Impact Assessment on a

Seasonal-to-decadal timescale

Deliverable 42.1

Report summarising the (expected) usefulness of a prototype

Deliverable Title	*Report summarising the usefulness of a prototype*	
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Contents

Introduction

This report analyses the relevance and feasibility of a seasonal forecasting service for snowfall and snow depth in ski resorts in the French Alps.

For mountain tourism stakeholders, seasonal snow forecasts could be useful in decision-making, managing ski areas, promoting mountain destinations and communicating with clients. This report therefore aims to identify stakeholders' expectations and needs, establish whether climatological and meteorological knowledge and tools can supply relevant answers and determine the form this service would take.

This analysis has been carried out as part of a case study completed for EUPORIAS, a European project that seeks to improve the resilience of business and society in the face of climate-related hazards. It will develop reliable predictions of the impacts of future climatic conditions on a number of key sectors (including (including water, energy, health, transport, agriculture, and tourism) on seasonal to decadal (S2D) timescales (for more information see www.euporias.eu).

This case study builds on other project activities, including:

- Earlier research carried out under WP1.2
- Specifications for PROSNOW, one of the project's proposed prototypes, prepared by TEC with support from key project stakeholders (Rhône-Alpes Tourisme and Savoie-Mont-Blanc Tourisme)
- Regular interaction with mountain tourism stakeholders during interviews carried out by TEC in 2013 and a workshop held in Grenoble on 16 March 2014.

Ghislain Dubois and Marie Lootvoet wrote this report on behalf of the consulting agency TEC Conseil, one of EUPORIAS' project partners.

1. Demand for seasonal snow forecasts by mountain tourism stakeholders

1.1 The impacts of weather and the climate on ski resorts and winter tourism

The structure of the mountain tourism industry

In France, mountain tourism takes place in six mountain ranges, which cover 25% of the country's surface area. Mountain regions generate 15% of tourism GDP, 120,000 jobs and 55.3 million skier days each year. France has 357 resorts, over 200 of which are located in the Alps. They range in size from village facilities to large international stations. Experts generally distinguish between the Northern and Southern Alps, which together account for around 80% of the country's ski areas. The Alps are spread across two administrative *régions* (Rhône-Alpes and Provence-Alpes-Côte d'Azur) and eight administrative *départements* (Savoie, Haute-Savoie, Isère, Hautes-Alpes, Alpes-de-Haute-Provence, Alpes-Maritimes, Drôme and even Vaucluse, which has two small resorts).

Economic conditions in mountain resorts are almost entirely dependent on tourism. In Northern Alpine resorts especially, winter is often the main season.

Unlike other less centralised forms of tourism, mountain tourism involves a range of relatively well-identified and structured stakeholders. These include:

- **Ski areas**, which manage ski trails and ski lifts. They are key players in resorts and central to economic activity. Some 44% of operators are publicly owned, 43% are private companies and 13% are semi-public companies (*sociétés d'économie mixte* or SEMs, where the local government holds a majority interest). Almost all resorts are members of Domaines Skiables de France (DSF), an association of French ski areas.
- **Municipalities**, the administrative areas in which resorts are located, which are members of the Association Nationale des Maires de Stations de Montagnes (ANMSM), an association for mayors of mountain resorts.
- **Socio-economic stakeholders**, which run activities in resorts: accommodation providers, restaurant owners, transporters, ski-hire companies, shopkeepers, instructors, activity providers, etc.
- **Communication and promotion organisations**, which range in size from local tourist offices to regional tourism boards such as Savoie-Mont-Blanc-Tourisme (which operates across both Savoie *départements*) and Rhône-Alpes Tourisme (which operates across the entire *région*). These structures are all members of the

France Montagne association, which promotes French mountain tourism on the national and international levels.

- **Academic, research and consulting bodies**, which examine natural and anthropogenic factors affecting Alpine environments, snowfall and mountain tourism. They include the Snow Research Centre (Météo-France/CNRS), laboratories linked to the Université Joseph Fournier in Grenoble and the Université de Savoie, the National Research Institute of Science and Technology for Environment and Agriculture (*Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture* or IRSTEA), the Alpine Network of Natural Hazards and Risks Prevention (*Pôle Alpin d'études et de recherche pour la prévention des risques naturels* or PARN), public works agencies (such as Rhône-Alpes Tourisme and CEREMA) and private companies (consulting agencies, etc.).

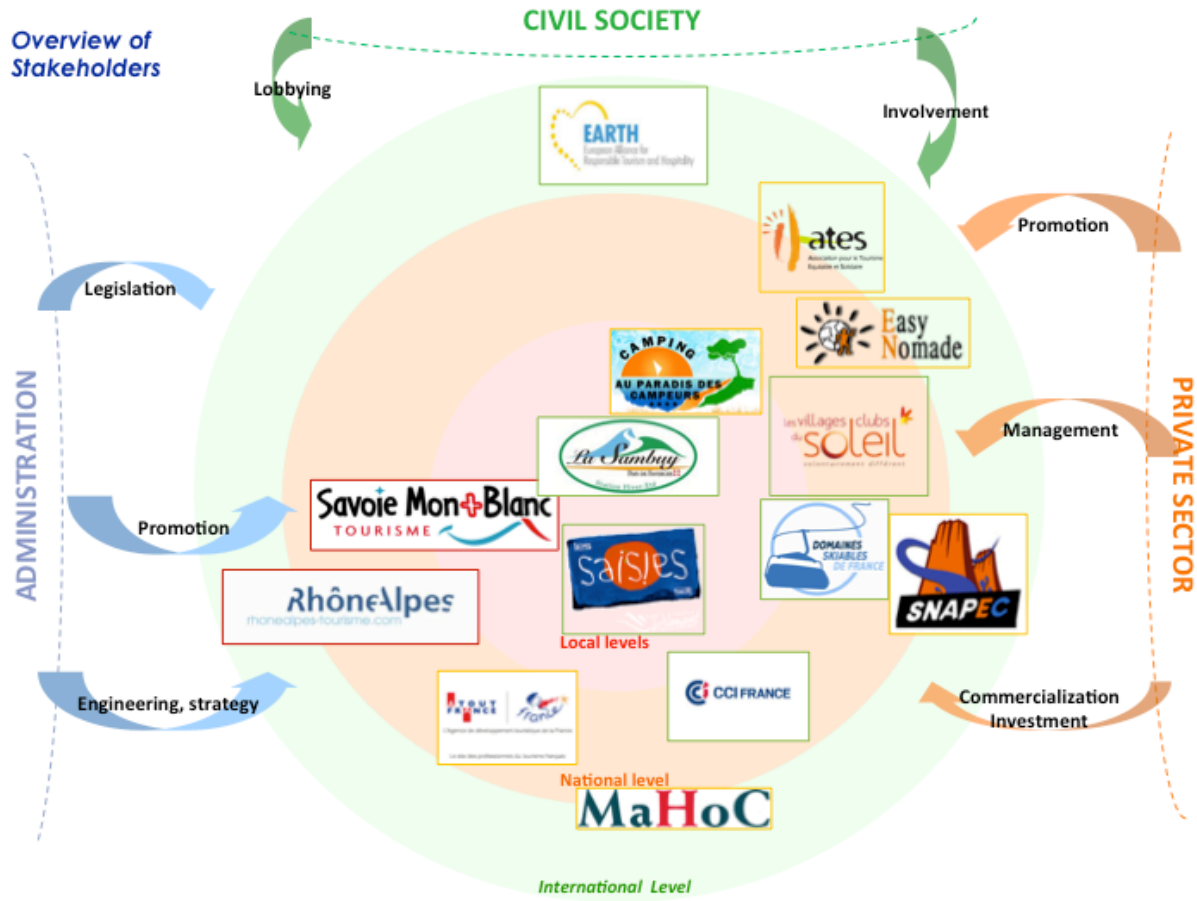

Figure 1: Tourism stakeholders. TEC, 2013

1.2 Snow dependency and seasonal forecasting

Economic conditions, employment and earnings at hundreds of Alpine winter sports resorts depend almost entirely on one thing: snow. Winter tourism is, by nature,

seasonal. **It is therefore affected by inter-annual variations in snowfall frequency and duration, as well as snow cover quality**. While the term "ski resort" is still widely used, activities are now being diversified in response to this variability – for some stations at least – and customer demand.

Managing communication

Communication is extremely important from an economic point of view. **This is because most of a resort's turnover is generated during the winter season**, in particular the French school holiday periods: two weeks at Christmas and four weeks in February and March. In one of these weeks, a resort earns 9% of its annual turnover. Visitor numbers during these weeks are therefore a major concern for most socio-economic stakeholders.

From September onwards, tourism promotion agencies and resorts face questions from the media about the upcoming winter season: questions about visitor number forecasts are raised. Then, in early December, just before the Christmas holidays, the focus turns to snow quality and conditions for snow-related activities. Resorts' answers to these questions can affect customer decision-making and therefore turnover. In addition to providing this information, effective promotion strategies could be timed in accordance with climate forecasts for the following months, as well as past and present weather conditions in tourists' countries of origin.

Major difficulties arise in extreme situations, for example, during warm winters without snow or when no snow has fallen by Christmas. Tourism stakeholders regularly have to deal with crisis situations where effective communication becomes an even more crucial issue. **Professionals would benefit from being able to anticipate major climate anomalies as early as possible in autumn.**

Managing ski areas

In recent decades, considerable progress has been made in managing ski areas. Ski trails can now be kept open with three times less accumulated snowfall than before.

Climate information is essential for managing ski areas. It has an impact on financial performance, through the quality of skiing offered and the optimisation of operating costs, which depend on effectively managing human resources, maintenance vehicle fleets and snow machines.

> *"Is winter going to be early or not?"*

Preparations begin mid to late October, when snowmaking resources are first mobilised. Around this time, decisions must be made regarding snow production: whether to put machines on standby, start snowmaking, etc. **These decisions depend on first snowfall dates (if snow arrives late, snowmaking must be**

intensified to ensure some trails can open), temperature (it must be cold enough) and, potentially, indications concerning seasonal snow quantities.

Some ski trails may open around 10 November. However, it is the period before Christmas that is central to resorts' economic performance. This is when decisions must be made regarding grooming machines and schedules to ensure good trail quality and optimised operating costs. **Reliable short-term snowfall and temperature forecasts are essential, and monitored on a daily basis by resort manager**s.

Snow cannons or snow guns make snow from water and compressed air when temperatures are cold enough. Water droplets generally freeze between -6 and -10 °C. It is more difficult to make snow between -6 and -2° C. For this reason, additives are sometimes used to induce freezing.

Towards the middle of the season (late January), resort managers analyse the quality of snow cover, predictions on snow cover evolution for the next two or three months and temperature forecasts for April to anticipate end-of-season conditions for trail maintenance and snowmaking.

Les Saisies ski resort in figures (2015)

Les Saisies ski area is made up of one main resort and two outlying resorts. It features a downhill skiing area of 77km (providing access to the *Espace Diamant* and its 192km of ski trails) and a cross-country skiing area of around 120km. It opens between 120 and 130 days per year. The ski area has 180 employees in winter, including 26 permanent staff, and an operating budget of around €14 million (excluding tax).

An artificial snow network, which produces snow for 20km of trails thanks to 220 snow machines, ensures that 30% of Les Saisies' ski trails are open during the season.

It costs €2 (excluding tax) to produce 1m³ of snow. On average, the resort uses around 140,000m^3 of water each season, at a cost of around €560,000 (it takes around 1m³ of water to produce 2m³ of snow).

Seven machines equipped with GPS systems carry out trail maintenance and grooming. Each machine costs around €350,000 and consumes about 30L of fuel per hour. Machines operate around 8,800 hours per season, and use up to 268,000L of off-road diesel, at a cost of €190,000 (excluding tax).

Weather and climate information can be used to optimise costs by making it possible to:

- Plan and monitor trail grooming, and establish circuits that minimise machine use
- Plan snowmaking activities, manage snow stocks and determine required water quantities
- Put in place the human resources required to manage these operations by deciding whether or not to recruit seasonal employees.

Managing resort activities

Climate information is not only useful for the technical management of ski areas. Socio-economic stakeholders also require this information to prepare for the season. The activities they offer depend on the weather, skiing conditions, promotions, communication needs, human resource requirements, etc. Early knowledge of general snow trends (in late October and November) could be factored into decision-making before the season starts, allowing these stakeholders to optimise resources and improve performance.

Using climate information

Mountain tourism stakeholders make relatively limited use of climate information.

During the winter season, stakeholders rely on short-term forecasts (for the next six or seven days) to manage resorts on a daily basis. They use specialist websites (such as meteo-france.fr or meteo-alpes.org) and local weather services (such as Bourg-Saint-Maurice).

For medium-term information (from ten days to a season), they have few options, especially at the start of the season. **They mainly use reference climatology, plus information from historic data series based on local records. They also consult monthly and seasonal forecasts on Météo France's website as well as specialist blogs and forums to try and identify trends.** This type of information is mainly collected and analysed by ski area managers, who have had to develop appropriate skills. The resort's other socio-economic stakeholders rely on their expertise. The complexity of products and difficulties in interpreting scientific data mean that stakeholders without the required technical skills make limited use of medium-term climate information. They see the information as unreliable (because of uncertainty or low predictability) and therefore unusable. The geographical scope is not always suitable for mountain areas, where each valley and slope has its own microclimate.

Regardless of the information used, **tourism stakeholders must adopt a clear and coherent position** to reassure customers and attract visitors. Using fluctuating scientific data, they must attempt to provide the media with answers. Their understanding and interpretation of information supplied by forecasters determines what the general public actually understands, which has varying and sometimes counterproductive results. **To improve the consistency and efficiency of the industry's communication activities, mountain tourism stakeholders need researchers who can provide informed opinions on available climate information and help them adjust their positioning.**

Météo-France has an agreement to supply some mountain tourism stakeholders (including DSF members) with regular forecasts from 15 November onwards. However, this agreement, which is currently being revised, does not cover all industry needs. Relationships between forecasters and mountain tourism stakeholders must be better structured.

1.3 Demand for seasonal forecasts by mountain tourism stakeholders

Mountain tourism stakeholders would ideally like to have seasonal forecasts taking into account the following parameters.

- Climate information, including:
  - One month's notice of the first predicted snowfall.
  - In mid September, temperature and precipitation trends, as well as the probability of deviations from reference climatology, for three- to six-month outlooks.
  - In early November, confirmation of the above information, with more detailed temperature information for one- to four-month outlooks.
  - For the entire season, a one-month outlook for the predicted quality of snow cover (depth and quality/density), taking into account ski area management requirements (such as grooming and snowmaking).
  - For the entire season, one-month outlooks for all parameters, especially temperature. These forecasts, somewhere between classic forecasts and seasonal forecasts, help stakeholders manage snow stocks and plan snowmaking activities.
  - Between mid January and mid February, April temperature trends allowing stakeholders to anticipate the end of the season and manage snowmaking activities to ensure skiing is still possible during this month.
- A geographic scope that corresponds to the mountain range, modulated in line with slope and altitude.
- Information that has been interpreted and explained by weather and climate experts, rather than raw data. This information is provided to all tourism stakeholders (through networks), allowing them to develop a single, clear message.

2. Supply of seasonal snow forecasts

2.1 Seasonal forecasting

Parameters and limits

Seasonal forecasts are based on different climate forcings, which influence general atmospheric circulation in the North Atlantic – Europe region, including surface sea temperature, sea ice, El Niño – Southern Oscillation (ENSO) and the stratosphere. Increased or decreased average circulation creates local climate change: as centres of action change position, they create preferred trajectories for the perturbations that determine weather type (anticyclone, unsettled weather, ocean flux, continental flux, etc.). This information is used to develop temperature, precipitation and wind trends. The slow evolution of these forcings, over several weeks or months, is a source of seasonal predictability.

Seasonal forecasts seek to determine future climate conditions, including average trends, the probability of exceeding thresholds and the probability of climate events. However, beyond ten days, it is impossible to establish a chronological order for weather events.

The ocean has a strong influence on seasonal forecasts. Consequently, most models are based on coupled oceanic-atmospheric parameters (one example is Météo-France's ARPEGE model). They use a probabilistic approach: a large number of scenarios are tested by slightly changing parameters for periods of several months. Scenarios are generally tercile (based on three categories). For example, they may attempt to determine the probability of below-normal, normal or above-normal temperatures.

DEFINITION

Score: a model's score is its ability to describe reality.

A model's overall performance is tested by running it on past periods using:

- Climate parameters
- Geographic grids
- Predictive timescales.

The model's score is calculated by comparing its output with observations for past series.

A model may receive several different scores based on:

- **Geographic region**: models are generally better at predicting conditions near the tropics than in temperate areas.

> The quality of forecasts depends on two parameters: temperature (a parameter that models predict better than climatology in Europe) and precipitation (a parameter that models have difficulty predicting).
>
> In France, for example, there is a considerable difference between the averages observed and the averages forecast by the model. This difference is caused by a certain number of biases. Models also produce less inter-annual variability than is actually observed (real variability).

- **Season**: in the middle latitudes, forecasts are generally better in winter than in summer.
- **Year**: forecasts improve with strong forcings (for example, the El Niño phenomenon). With 30 years' hindsight, there are only five or six examples of very strong signals. In some years, it is impossible to communicate any information at all.

Currently, seasonal forecasts still have limited added value, because biases and variability must be corrected. In the past ten years, seasonal forecasts have outperformed reference climatology six times in Alpine areas. **Therefore, only long-term users benefit from using these forecasts**. Nevertheless, even limited added value can be useful in the long term, and it is this comparative performance (see diagram) that must be taken into account in decision-making.

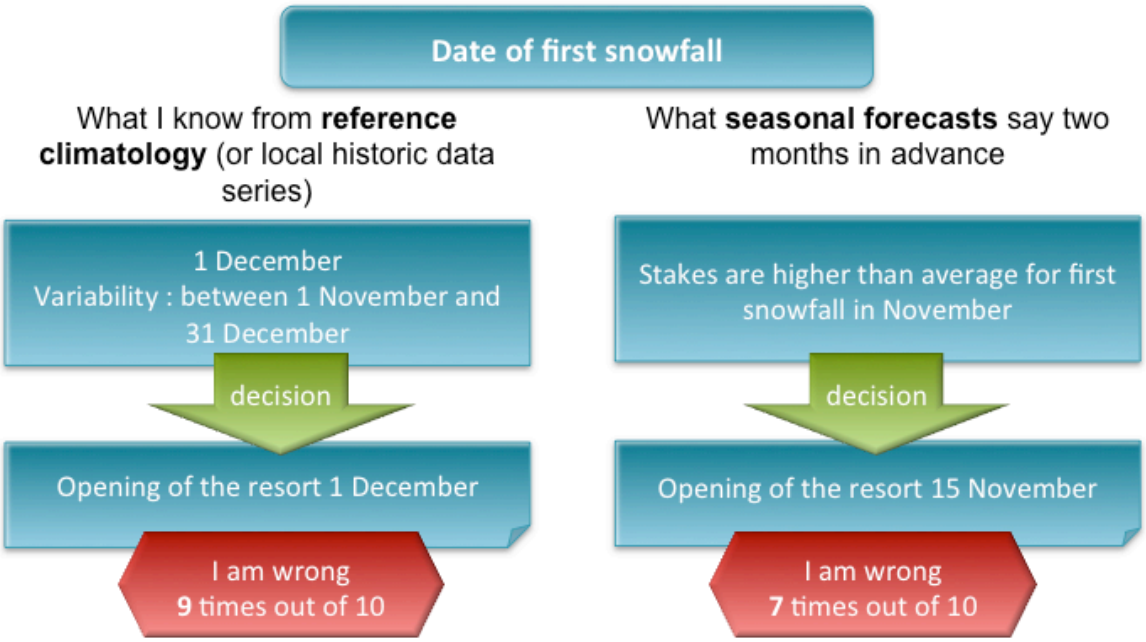

Figure 2: Using seasonal forecasts in decision-making. TEC, 2015

Using seasonal forecasts

Given this situation, the seasonal forecasts produced by regional models must be modified to reflect users' needs. This includes:

- **Adapting forecasts for local areas by using downscaling methods**. This makes them easier to use – predictions can be calibrated to provide information on a spatial and temporal scale suitable for applications.
- **Encouraging a transition from climate variables to user-interest variables by developing impact models** (hydrological models, crop yield models, snow cover models, etc.).

2.2 Snow cover knowledge and forecasting

In addition to the seasonal snowfall forecast, a model forecasting snow cover could be developed. Based on ground temperature and snow transformation (snow pack and melt), it predicts snow cover quality, which would be useful for decision-makers.

Modelling snow cover

Modelling snow cover is of central importance at Météo-France's Snow Research Centre, because this information has been used to predict avalanche risks since the 1990s. **Models have used nivo-meteorological observations, the Météo-France network and meteorological models to produce the most accurate event chronologies since 1960.**

In these models, the Alps are split into mountain ranges (the same ranges used for avalanche risk forecasts). **Data on altitude and slope orientation are integrated to adapt surface climatological models to the mountainous landscape**.

In this way, the SAFRAN-Crocus model calculates snow cover evolution over time in relation to meteorological parameters. The model runs daily, and its results are compared with observations by ski patrols and scenarios based on conditions in previous years. This makes it possible to evaluate the probable evolution of snow cover. Nevertheless, the resulting predictions are still subject to high levels of uncertainty.

Using this information to manage ski areas

This modelling only covers natural snow. The transition from forecasting natural snow cover evolution to providing useful information to ski area managers is not an easy one. For example, data on snow depth is not useful if there is no indication as to snow quality. Snow cover that is thick but not dense does not improve skiing conditions.

Research is underway to integrate snow management activities (such as grooming) and snowmaking into models. Using a spatial database of the technical

and socio-economic characteristics of winter sports resorts (BD Stations), this research focuses on integrating strategies implemented by managers. The aim is to create a simulation of natural and man-made or managed snow cover.

To make forecasts concerning snow cover evolution, models use an initial situation at a given date. Scenarios using past meteorological conditions (from average or extreme years) are then applied to this situation. Using this initial situation narrows the field of possibilities. However, without it (for example, before the season starts), it is difficult to make forecasts without high levels of uncertainty. Once snow cover has been established, it is easier to make more stable forecasts but, by then, managers have less need for them. A climatology-based "seasonal forecast" (which is actually a projection based on past climate conditions rather than a modelled seasonal forecast) is an interesting research possibility. It could lead to an intermediary product that is not strictly speaking a seasonal forecast.

2.3 Perspectives for seasonal snow forecasts

Natural and man-made snow cover models make it possible to analyse and predict (to a certain extent) snow cover evolution over a season based on altitude, orientation and slope. Research is currently underway on several aspects, including improving the integration of snowmaking and climatology-based forecasts.

Using seasonal forecasts as data in snow cover models is an idea that deserves further research. In the Alps, these forecasts are strongly influenced by the North Atlantic Oscillation (NAO), which is characteristic of ocean circulation in the Northern Atlantic. However, their connection with the climate is not that simple. While there is a relatively well-identified correlation with temperature, the same cannot be said of precipitation. Research on this type of forecast needs improvement, in particular with respect to statistical studies.

Regardless of the above, seasonal forecasts on temperature parameters are of direct interest to ski area managers, who can use this information to manage snowmaking activities.

3. PROSNOW, a climate service providing seasonal snow forecasts for tourism professionals

A service providing seasonal forecasts for snowfall and snow depth in the Alps would satisfy one of the demands of mountain tourism stakeholders by building on and improving existing tools.

In this section, we outline a number of actions that could be undertaken to develop this service.

3.1 Services offered by PROSNOW

Type of information

The type of information provided by PROSNOW must take into account utility to tourism stakeholders and actual capabilities in scientific and technical terms.

Consequently, the service focuses on the following actions:

- Providing initial information in mid September as to whether a winter signal exists (three- to six-month outlook). If a signal exists, further information could be provided on initial temperature and precipitation trends, expressed as the probability of deviating from reference climatology.
- Confirming the above information in early November then early December and providing more precise information as to temperature (one- to four-month outlook).
- Monitoring one-month outlooks for all parameters for the duration of the season.
- Identifying the trend with respect to snow cover evolution for the winter holidays and end-of-season period (based on conditions at 15 January), taking into account ski area management activities.
- Identifying the temperature trend for the month of April at some point between mid January and mid February (two-month outlook).

Not all stakeholders' demands can be satisfied. It is not possible to provide:

- Information on the chronology of weather events, such as first snowfall dates or snowfall periods during the season.
- Systematic information on clear temperature trends or cumulative precipitation for the season, given that the signal is not detectable every year.

- Early-season indications as to snow cover depth and quality at different points in the season, given that knowledge of snow cover evolution requires existing snow cover.

At each step, detailed information and clear explanations are provided on:

- Trends and forecasts (temperature, snow precipitations, snow cover thickness, etc. for each time scale)
- The uncertainty of this information, degrees of probability, signal strength, etc.
- The main mechanisms at work (forcings, states, weather type, etc.) to improve skills and educate tourism stakeholders.
- The interpretation and communication of this information.

Ultimately, this service must make it possible for professionals to adopt a coherent, shared and clear stance on seasonal climate forecasts. For example, messages must be adjusted in years with clear forecasts as opposed to years with unclear forecasts. This raises issues as to the acceptability of this message, which depends on training users.

Service objectives and targets

The PROSNOW service only targets tourism professionals. The information provided is too complex and too uncertain to be transmitted to the general public, who would probably make erroneous interpretations.

The service's target audiences can be divided into two groups:

Ski area managers	Technical management Media requests
Communication and promotion organisations	Promotion campaigns Communication Media requests

Socio-economic stakeholders at resorts (accommodation providers, restaurant owners, activity providers, transporters, etc.) are another important but indirect target. They are only indirectly concerned as they depend on the ski area for climate and weather information.

The final target group is mountain resort users: tourists. They receive information from the media, who obtain it from the above target groups.

The PROSNOW service must anticipate the different steps involved in broadcasting information by offering explanations and suitable language for each target audience. This is especially relevant given the potentially large number of intermediaries in information channels. It is important that the message is not deformed.

Geographic scope

The service operates on the mountain range level (or at least large “homogenous” zones) for the French Alps.

Communicating and broadcasting information

Users demand information that is precise, well interpreted and reliable (reliable information as opposed to reliable forecasts). For this information to be correctly supplied, broadcasting channels must be well controlled.

The service could be run by a task force bringing together forecasting and climate specialists (from Météo-France and other organisations) and key mountain tourism stakeholders (France Montagne, DSF and ANMSM, for example).

It is important to create a stable group whose members are able to quickly develop skills and correctly broadcast information to users.

The group could meet on the basis of the following schedule:

- A short meeting in September to discuss communication needs
- A longer meeting in early November to present and explain trends for the winter season
- Regular meetings to share information every 10 to 15 days between early December and late March
- Crisis meetings called on a flexible basis to react to emergency situations and decide jointly on the messages to be broadcast (for example, if no snow has fallen by mid December or before holiday periods)
- A meeting in mid January to discuss the first part of the season and trends up until April.

At each step, the task force would prepare the information to be broadcast and the language to be used in communicating with each of the service’s target audiences.

The task force would broadcast information to:

- DSF (95% of ski areas), which would then transmit it to local branches, followed by resorts (the network’s structure already allows information to flow in this way), ski area managers and, finally, socio-economic stakeholders at the resort
- France Montagne, which would then transmit it to mountain tourism communication and promotion organisations (tourism boards for administrative *régions* and *départements*).

3.2 Improving information through preliminary research

Before new research begins, several issues must be clarified or examined using existing research and knowledge. These include:

- Establishing intermediary geographic areas that are somewhere between large areas (such as Europe) and local areas (such as the resort, local snow cover and the ski area). In other words, different parts of the Alps must be put in relation with different atmospheric circulation and weather types (for example, snowfall in the Northern Alps depends on north-westerly winds, while snowfall in the Southern Alps depends on the Mediterranean flow and snowfall in the Eastern alps depends on easterly winds).
- Improving the transition from natural snow to man-made snow in snow cover models.
- Better evaluating snow cover depth in Météo-France's seasonal forecast system.
- Studying ways of calculating past snow depth scores.
- Testing different correlations between anomalies (NAO) and indices such as production conditions.

Our feeling is that a seasonal snow forecasting system could have added value for users, but this must be verified by targeted analyses.

Research priorities include the three following points:

- **Developing a seasonal forecast system for snow cover evolution based on climatology.** This system would start with an initial situation, and apply climatology data for past snowfall levels.
- **Calculating snowfall predictability scores using existing seasonal forecast systems** (owned by Météo-France and others).
- Defining thresholds and methods to determine at what point information is considered "useful" for users (for example "trend" / "no clear trend").

Research work must not lose sight of users' needs. This raises the following points:

- **At the start of the season, demands are less concerned with modelling snow cover than with forecasting weather patterns likely to produce snow** (this information is characterised by high demand and weak predictability), in addition to establishing past scores and determining whether or not there is a winter signal. It is also possible to use the NAO's known anomaly phases, which create some predictability and reinforce information produced by models.

- During the season, demands benefit from higher predictability, which is the result of the thermal inertia caused by snow cover. In this situation, snow cover must be modelled to take into account future conditions (this information is characterised by average demand and average predictability). Statistical downscaling methods can be used (such as DS-CLIM) – although they do not add to information on trends, they do allow each resort to gain a better idea of snow cover in the light of local parameters.

As far as products are concerned, statistical thresholds (terciles, etc.) must be converted into quantities, which are easier to understand (for example, the probability of over 1 metre snowfall at altitudes of 2,000 metres). This is to:

- Develop an initial verbal message on predictability to encourage users to seek further information ("signal" / "no signal")
- Implement effective transmission channels:
  - Météo-France / Climatology Department >> inter-regional bodies >> local centres
  - Domaines Skiables de France >> resorts >> socio-economic stakeholders
  - France Montagne >> tourism authorities for *régions* and *départements* >> tourist offices
- Draft early season bulletins and seasonal reports.

3.3 Financing

Financing the service

A financial model must be established to cover the cost of providing information demanded by mountain tourism professionals. This is especially true given that the service does not provide raw or formatted data – it provides data that have been interpreted and adapted to a specific target audience.

Météo-France currently has an agreement with some stakeholders (in particular DSF) for the provision of short-term forecasting services. This agreement could be modified to cover the PROSNOW service. Alternatively, the service could be the subject of a new agreement with the operator groups identified by the task force. The cost of providing the service would be co-financed and include contributions from the following groups:

- The public sector: contributions from local authorities' tourism policies (promoting destinations) or economic policies (supporting economic activity at resorts)
- The private sector: Domaines Skiables de France (financing shared tools optimising ski area management).

Financing the R&D phase

Preliminary research to develop the product could be managed by the relevant departments at Météo-France and CNRM-GAME.

Financing could be sought for a doctoral thesis on the project, if necessary.

As future beneficiaries of the service, ski areas could be involved in research work by contributing their observations and helping to collect data for research teams.

TEC could play a coordinating role in this preliminary phase before helping to run the forecasting system.

Conclusion

As this study has shown, mountain tourism stakeholders have a real interest in seasonal forecasts, which would be an additional indicator helping them to manage activities. Given current climatological knowledge, it is scientifically and technically feasible that these forecasts could at least partially satisfy users' demands. All stakeholders recognise that designing and implementing such a service would hinge upon interaction between tourism stakeholders and weather and climate specialists. This interaction is essential in ensuring the product meets requirements and encouraging the best use of information that can be difficult to understand and interpret.

Before the product can be developed, several actions must be completed. These include the improvement of scientific and technical knowledge and the implementation of a suitable organisational structure and financing. The next steps in the project's development could be:

- Launching preliminary research (internships for engineers and Master's students, plus a doctoral thesis on the subject)
- Creating a mixed working group (with members representing the tourism and climate sectors) to define expectations in terms of information provided and service design
- Writing specifications for the PROSNOW service (information provided, organisational structure and operating procedures for the task force, etc.)
- Creating the task force (identifying potential members and validating the organisational structure, operating procedures and financing).

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