The Development of Climate Scenario Fact Sheets for Engineers on Infrastructure-Relevant Climate Indicators

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INTRODUCTION
The Ouranos Consortium acquires and develops knowledge on regional climatology and the impacts of climate change in order to advise decision-makers and end-users on the best adaptation strategies and measures. To support engineers who are working to adapt the built environment, Ouranos published technical fact sheets that summarize climate indicators relevant to infrastructure in Quebec. The fact sheets provide a summary of available climatic information and present it in a format suitable for an engineering audience.

The fact sheets include observations as well as model results, covering seven climatic indicators in two regions of Quebec. They provide information on observed trends, inter-annual variability, future climate projections, and spatial analogues of future conditions under plausible scenarios to support engineering decisions. They are intended to help assess climate change’s potential effect on infrastructure, such as roads, storm water management systems and buildings. Fact sheets could also be used in the planning stages to assist engineers in “climate-proofing” their design.

The project to develop these fact sheets took nine months from start to finish and was limited to two regions. It began in July 2011 and ended in March 2012. Based on user feedback, the fact sheets will be updated in the coming months.

SOCIOECONOMIC BACKGROUND
Climate change has consequences for the built environment. While the design of many types of infrastructure refer to existing climate parameters and assume a stationary climate, the life of such infrastructural items may span many decades, a time period within which climate conditions are likely to change significantly. In an evolving climate, infrastructure that was previously adequate may fail to provide the same level of service in the future, which is important because such failures may pose risks to public safety or health.

In order to provide the same level of service that citizens are used to, for instance, the design of structures that manage storm water will have to take into account projections of increased precipitation, including intensity, duration, and frequency of events. Building systems and roads will also need to be adapted to changing conditions.

Advances in climatology allow us to quantify the anticipated changes in climate indicators affecting infrastructure. Instead of planning for a stationary climate, engineers must account for an evolving climate that affects infrastructure design and has consequences for the rate of wear on building materials. The fact sheets simplify and synthesize climate change information to help users make better-informed adaptation decisions.

TARGET AUDIENCE
Ouranos designed the fact sheets to be used by civil and water engineers, city and infrastructure planners, and other decision-makers concerned with the built environment.

CLIMATE AND CONTEXTUAL INFORMATION
Fact sheets include information relevant to infrastructure design codes and standards relevant to engineers. For example, engineers refer to the number of degree-days of heating in order to determine the specific characteristics of the insulation or mechanical systems that need to be installed in buildings. Infrastructure maintenance also considers climate information, such as the frequency and type of road maintenance required in wintertime for cold regions.

The fact sheets address seven climate indicators that were identified through a survey completed by professional engineers as the most important climate variables. These variables include:

- maximum daily precipitation
- maximum 5-day precipitation
- number of thaw-freeze cycles
- heat wave freezing index
- winter rain
- snow accumulation

The indicator values are calculated on an annual basis from climatic variables over two regions, Montreal and Saguenay-Lac-St-Jean, using both observational data and climate model projections. Each fact sheet includes a short paragraph describing the indicator and projected changes; a figure showing the historical trends and future climate projections; a figure showing the changes in the distribution of annual indicator values; and another figure showing a map of spatial analogues.

Sources for climatic data are listed below. Most of the data is publicly available at low or no cost, except for Hydro-Québec snow dataset, which is available only to members of the Ouranos Consortium.
The fact sheets were customized using an iterative process. A climate analyst at Ouranos prepared a version and presented it in successive workshops involving engineers, climate experts, and other potential users. Each version was developed based on comments, suggestions, and critics from previous workshops. The success of the tailoring of each version was measured in part by the time it took users to understand the content of the fact sheets.

This previous experience with related research and development activities allowed Ouranos to establish a network that included a range of experts in the engineering world; this gave individuals interested in such a tool the opportunity to get involved and provide feedback throughout the development of the fact sheets.

The stakeholders involved with this initiative were mainly engineers from city governments and private firms, as well as other professionals associated with the built environment, such as city planners and infrastructure managers. The participants came from the Centre d’expertise hydrique du Québec, Engineers Canada, various Quebec government ministries (Ministère du Développement durable, de l’Environnement et des Parcs; Ministère des Transports; Ministère des Affaires municipales, des Régions et de l’Occupation du territoire), the Federation of Canadian Municipalities, the cities of Montreal, Quebec, Trois-Rivières and Ottawa, as well as two consulting firms.
STAKEHOLDER INVOLVEMENT

Ouranos employees involved in producing the fact sheets are divided into two core teams: (1) Climate Science and (2) Impacts and Adaptation (I&A).

The Climate Science team is made up of three sub-groups:

- The simulation group, which is responsible for running and maintaining a regional climate model. They collaborate with the regional climate modeling community and are the main source of climate expertise within Ouranos.
- The hydro-climatic analyses group, which studies results from climate runs and validates them with observed data. They also conduct analyses on climate variability, trends, and extreme events in addition to investigating methods that can be used to quantify uncertainties when producing hydro-climatic scenarios.
- The scenarios group, which is in charge of producing future climate scenarios on the basis of model simulations and observed data. Scenarios can then be used as input information in I&A projects.

The I&A team is responsible for coordinating and participating in research programs that cover a range of climate-affected sectors including, but not limited to, agriculture, the built environment, hydrology, and public health. The I&A team identifies stakeholders and their specific needs and helps to put together research teams that develop projects to respond to these needs. The stakeholders are from government departments and agencies, academia, non-governmental organizations as well as industry. Both the Scenarios and I&A teams assist stakeholders in defining projects related to climate impacts and adaptation and help to coordinate and carry out the projects.

The stakeholders from the network are involved in a variety of ways:

- Organization members, represented by high-level decision-makers, help to set the research agenda by identifying and selecting the priority sectors.
- The Board of Directors, made up of high-level decision-makers within the member organizations, approves the five-year program for each priority sector.
- Members of the network help to prepare, coordinate, and implement the research programs.

Stakeholders are also involved in various ways in the development of the research projects themselves, either as leaders and collaborators or as members of project advisory committees to help ensure that the research remains relevant and the results useful. For this project, stakeholders were involved in making decisions about the project through a series of consultations, which are described in the evaluation section.

Users can access the climate information fact sheets through the Ouranos web site.¹ This first web platform was created and reviewed several times to verify its content and its format. It is currently only available in French, but will eventually be translated into English if there is sufficient demand and funding. When the web site is in its final version, it will be announced to the Ouranos network, both through private emails and the tri-annual newsletter.

EVALUATION

During the development of the fact sheets, Ouranos organized four consultation workshops with engineers and related professionals to obtain comments on the content and form and improve the sheets accordingly. The first session was held with Ouranos employees with expertise in climate science, impacts and adaptation as well as communicating scientific information. They made a number of suggestions that led to significant adjustments. For example, in order to better define analog areas, spatial analogues are now calculated from pairs of indicators instead of only a single indicator. The second workshop brought the collaboration of employees of the Ministère du Développement durable, de l’Environnement, et des Parcs involved in collecting observed weather and climate data.

The third session took place with members of the hydrology and hydraulic division of the Centre d’expertise hydrique du Québec. The project was presented to a panel of engineers specialized in hydraulics and hydrology whose work involves dealing with precipitation extremes, variability, and risk management. The fourth workshop happened at Natural Resources Canada’s office in Ottawa. Participants were from the engineering sector as well as from municipal and higher level government communities. They expressed that the fact sheets were well done and most comments from this workshop focused on the presentation of the information. Additional presentations have been given, including one that was organized for a training session on managing climatic risks for a conference hosted by the Ordre des Ingénieurs du Québec (OIQ) in May 2012.

The project outcome will also be evaluated by users, with Larrivée collecting comments and feedback from her network of stakeholders through the project website, which has been launched between July and September 2012. This will allow the stakeholders who participated in the project to provide feedback, giving them a preview of the fact sheets as well as an opportunity to submit comments and recommendations regarding the site’s content and form. It will then be launched more formally in the fall of 2012.

While it is too early to know if and how the fact sheets will be used, Ouranos is planning to monitor this in a next future. Ouranos is also in the process of evaluating whether there is interest and funding to expand the project with more regions and indicators.

CAPACITIES

EXISTING CAPACITIES

The fact sheet project was developed using Ouranos personnel already in place, with the exception of the web developer contracted to review and improve the web site. More specifically, the project involved direct feedback from a senior climate analyst, a snow-pack specialist, a long-time scenario group manager, a climate analyst, a communications expert, a computing specialist, as well as impacts and adaptation specialists. Most of the actual work was carried out at Ouranos by David Huard, a hydrology specialist working in the Climate Scenarios group. The existing structural capacities employed at Ouranos were climate archives, data storage, and high-end computing facilities.

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¹ https://scenarios.ouranos.ca/fiches_infrastructures. www.ouranos.ca
CAPACITY GAPS
No one already working at Ouranos was equipped to work on the website, so a professional web developer had to be contracted to improve the early version of the site. The project would probably have been more effective if both the web developer and a graphic designer had been involved from the start.

The other main challenge involved designing the fact sheets to fit users’ needs. Linking the engineering community to climatic information providers was difficult because the two groups had very different approaches to problem solving and a very different understanding of similar terms. There was also a large gap between the level of precision that users wanted and the capacity of climate analysts to provide such results with sufficient confidence. In general, users would like climate projections at very small spatial and temporal scales, with a “one-number” result; unfortunately, climate models can only meaningfully project climate on a regional scale and provide a range of plausible futures. This makes it difficult to reconcile user requirements with scientific constraints.

On a related issue, Ouranos found it challenging to effectively communicate robust climate change scenarios and acknowledge uncertainty while still producing an end product that is fairly easy for users to understand. For example, climate scientists know that projections differ significantly and depend on many factors, such as the climate model used, the greenhouse gas emissions scenario applied, and natural variability of the climate system. However, it is difficult to express inherent uncertainty without explaining the details of why it exists. Explaining these issues required considerable time, and undermined the goal of producing an easily understood climate change scenarios fact sheet. A number of approaches were tested and vetted by potential users to find the most effective way to communicate this uncertainty.

INNOVATIONS TO MEET USER NEEDS
The project implemented a number of innovative practices and analyses in different areas. The fact sheets were developed through a series of consultations held throughout the project in collaboration with a range of users. The extent of their involvement was broad and included the selection of the priority regions, the selection/definition of indicators, and the formatting of the information for fact sheets.

Considerable thought was given to the graphical representation of climate concepts. Model uncertainty has been successively depicted by envelopes, spaghetti lines and a box plot. In the end, the box plot won user approval. Trials were made to illustrate changes in year to year natural variability using original graphical elements but that attempt failed at getting the right message across. It seems that familiarity is far more effective in communication than originality.

Other innovations included the design of a general framework used to compute different climate indicators over different datasets and regions in parallel. The project also involved the development of code to create interactive figures using SVG format with Javascript scripting, the computation of climate analogues using the Kullback-Leibler divergence, as well as the analysis of the CCSM3 Large Ensemble Experiment for describing natural variability. Though the results of the latter did not end up in the final product, they helped to validate methodological choices.

LOOKING TOWARD THE FUTURE

GOALS
In the future, Ouranos hopes to engage in the consultation process with a wider range of users, including potential stakeholders who are less familiar with climate science, such as infrastructure planners as well as architects and land use planners. Another goal is to expand the project by adding new regions and different indicators, such as maximum snow fall, cold spells, cooling and heating degree days, and dry spells, depending on user feedback and available funding.

PROJECT EXPANSION
This project could definitely be replicated in other regions and parts of the world as well as in other sectors, such as agriculture.

LESSONS LEARNED
The process of finding effective ways to communicate specialized content to the target audience was a challenge throughout the development of this service. Early attempts to include as much information as possible in the fact sheets were not well received and the content was trimmed accordingly since studies have shown that too much information can lead to confusion and misinterpretation. It was a challenge for the Ouranos climate analyst leading the project to provide users a condensed and simplified version of the climate information without distorting the meaning of the original climate information. However, consultative workshops allowed Ouranos to receive and incorporate feedback, which was essential in developing fact sheets that were accessible to the stakeholders involved.

The definition of indicator variables was an aspect of the work that did not function as expected. Ouranos anticipated engineers would provide a ready-made formula to compute the indicators used in their practice. However, Ouranos later realized that engineers are not familiar with such formulas, as in general they use pre-computed values from existing tables. Thus, while engineers are familiar with the broad meaning of climate indicators, they rarely need to compute them from raw observations; they are consequently less familiar with the specific definitions.

This project was developed based on lessons learned over the last five years. It was important to identify an I&A specialist focused on bringing together users and data providers, always keeping in mind the necessity of regular interactions between the climate science and engineering communities.

THE WAY FORWARD
There are several significant challenges moving forward. It will be crucial to find both the financial and human resources to continue developing the project. It is equally important to maintain stakeholders’ interest by monitoring the use of the fact sheets and helping to answer questions concerning the climate information on the site. Another challenge will be to find ways to provide additional information for users as they grow familiar with the science and are interested in learning more about issues such as other climate parameters and further analyses of the data. Designing interactive figures that can display different levels of information could also answer the needs of both new and advanced users. Measuring the implementation of climate change adaptation measures based on this information will be essential to making sure that the service is suitable and relevant for other applications.
PRINCIPLES OF THE GFCS

Principles 4, 6, are particularly well reflected in the Ouranos fact sheet project.

Principle 1: All countries will benefit, but priority shall go to building the capacity of climate-vulnerable developing countries.

Principle 2: The primary goal of the Framework will be to ensure greater availability of, access to, and use of climate services for all countries.

Principle 3: Framework activities will address three geographic domains; global, regional and national.

Principle 4: Operational climate services will be the core element of the Framework.

Principle 5: Climate information is primarily an international public good provided by governments, which will have a central role in its management through the Framework.

Principle 6: The Framework will promote the free and open exchange of climate-relevant observational data while respecting national and international data policies.

Principle 7: The role of the Framework will be to facilitate and strengthen, not to duplicate.

Principle 8: The Framework will be built through user – provider partnerships that include all stakeholders.