Climate change science knowledge transfer in support of vulnerability, impacts and adaptation activities on a North American regional scale: Ouranos as a case study

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Abstract

This paper provides an overview of how climate change science knowledge transfer is achieved at Ouranos in support of Vulnerability, Impacts assessments and Adaptation (V&I&A) activities. Ouranos is a Canadian consortium on regional climatology and adaptation to climate change, launched in 2002 by the Government of Québec, Hydro-Quebec and the Meteorological Service of Canada to coordinate climate change research in Québec. This paper presents, via Ouranos' ongoing V&I&A projects in coastal regions, the knowledge transfer environment in place. It also demonstrates how the development of climate indices and indicators of vulnerability, following a Pressure State Response (PSR) framework, form a useful knowledge transfer tool. Two specific case studies address the development of a set of temperature trend indices for southern Québec and climate-social indicators for the assessment of risks to public health due to extremely high temperature events. The first case study illustrates how a systematic analysis of climate variability and relevant extremes indices can be useful for decision-makers at regional scales (southern Quebec). The second case study examines the potential and the feasibility of a Risk Assessment Framework approach for regional impacts and adaptation climate change studies.

1. Introduction

Reducing the adverse impacts of climate change requires both mitigation and adaptation efforts. Indeed, even if CO2 emissions stabilized at Kyoto levels, the planet would experience warming for the next 100 years (IPCC, 2007) and require the implementation of adaptive measures. Dessai et al. (2004) show how climate adaptation policy is at the confluent of an estimation of physical vulnerability, from data and scenarios at both global and local scales, and social vulnerability, from adaptive capacity based on socio-economic indicators.

Adaptation to climate change is a wide-ranging and complex issue involving numerous technical and scientific challenges, as well as the need for effective communication and knowledge transfer between researchers and decision-makers. This knowledge transfer is needed to address issues like compatibility of spatial and temporal scales, multidisciplinary and integrated approaches, language used by researchers and users of study results, treatment and integration of uncertainties, etc. Climate adaptation policy requires timescale and planning horizons to be put in place. Recently, according to the IPCC (2007) WGI Fourth Assessment Report, numerous long-term changes in climate statistics have been observed not only at continental but also at regional and ocean basin scales. These include changes in annual and seasonal Arctic temperatures and ice cover, widespread changes in precipitation amounts, level of ocean salinity, wind patterns and aspects of extreme weather events including droughts, heavy precipitation, heat waves as well as the intensity of tropical cyclones. Thus, regional and institutional adaptation actions should be anticipatory and planned so as to minimize costs and optimize opportunities. The question is how to tackle climate change issues to adequately address scientific and management challenges at the regional level, and define the required interface between theory and practice.

In Canada, in order to better address these multiple challenges, a consortium on regional climatology and adaptation to climate change was created in 2002 by a group of prominent stakeholders, namely eight Government of Québec ministries, Hydro-Québec, the Meteorological Service of Canada and Valorisation-Recherche Québec. Four universities, already involved at a scientific level, officially joined the non-profit organisation in 2004, namely the Université du Québec à Montréal (UQAM), McGill University, Université Laval, and the Institut national de la recherche scientifique (INRS). Seen as a critical mass of expertise on applied climate change science, Ouranos' mission is to develop knowledge a xnd coordinate the required multidisciplinary initiatives that will help decision-makers integrate adaptation to climate change into decision making processes. This unavoidably involves developing structures for analysis of multidisciplinary problems, promoting synergetic work, developing or optimally applying tools like the Canadian Regional Climate Model (CRCM) or climate and socio-economic scenarios required to support vulnerability and impacts assessments and develop adaptation strategies (V&I&A). The first phase of Ouranos (2001-2005) concluded with the establishment of a flexible organisation with facilities, computer resources and basic infrastructure, financial and human resources contributions from its members (Ouranos, 2007), a scientific program (Figure 1) and a synthesis of current climate change adaptation knowledge (Ouranos, 2004).

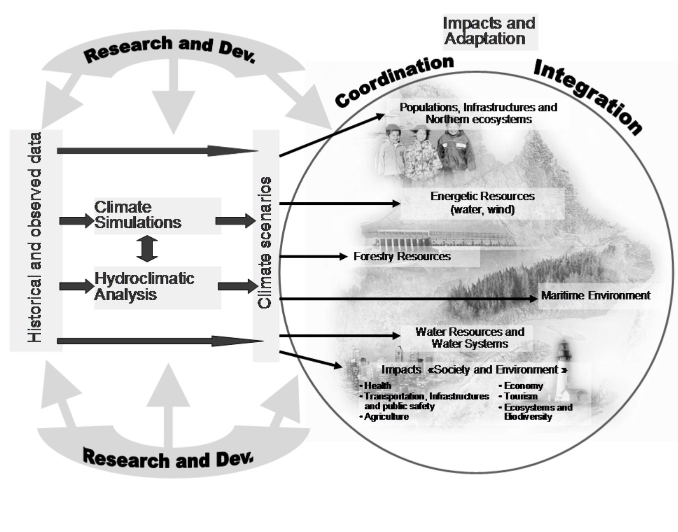

Figure 1 Ouranos: geographic coverage and scientific programs

By working at a regional scale and enabling direct links among experts developing V&I&A activities, Ouranos provides/creates opportunities for innovative dialogue and facilitates knowledge transfer. To illustrate this, below are presented (1) the structure of a coastal region V&I&A project as well as (2) two case studies discussing the use of indicators as a potential knowledge translation tool from science to environmental management practices.

2. Knowledge transfer from science to practice: the Ouranos approach

One of the greatest challenges regarding knowledge transfer is the issue of uncertainties. One approach to cope with the uncertainties regarding future impacts of climate change to human and natural systems is to use climate scenarios as one component within a combination of decision-support tools. These representations of plausible future climates can help the elaboration of climate adaptation policies by estimating potential consequences of human-induced climate change (Larrivée and Simonet, 2007, in press). This approach, often called the "top-down" approach, stems from R&D development in climate scenarios. Models are then typically used to evaluate impacts and extrapolated to eventually estimate physical vulnerabilities at local levels (Dessai, 2004). However, there are significant challenges associated with this approach, in particular regarding the accumulation of uncertainties, the possibility of non-linear responses to very high greenhouse gas concentrations (IPCC, 2007), the difficulty of estimating economic and social costs or vulnerabilities (Ambrosi, 2004) as well as the potential lack of participation of the user-groups. This is why several authors focus on user-driven research and non-climatic factors which can have great influence on regional scales when added to climate change effects (Kelly, 2000). Thus, climate adaptation policy development also needs data from indicators based on socio-economic components of the studied system to estimate or build local determinants of a strong adaptive capacity (Yohe, 2002). This "bottom-up" approach is based on short temporal and local scales and can be used to develop climate adaptation policies that enhance coping capacity for both human and natural environments (Adger, 2005). In its programs, Ouranos has several projects that combine top-down and bottom-up approaches. In all cases, the organisation's structure and the projects it coordinates allow a two way transfer of information, data, results, priorities and research questions between climate specialists, impacts researchers and user-groups to ensure the evaluation of the most relevant potential impacts and to facilitate mainstreaming of adaptation solutions both during and after projects.

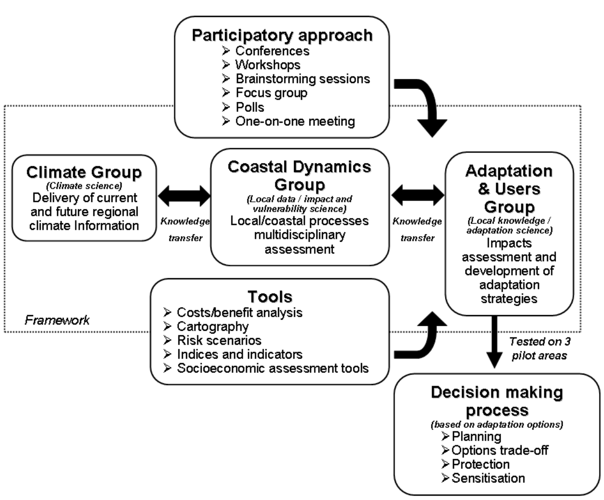

Figure 2 : Coastal erosion project framework

Of its various programs, the one concerning coastal erosion has created one of the organisation's most successful project environments. Figure 2 illustrates the structure of this project located along the coastlines of the Gulf of St-Lawrence in eastern Quebec. The project is led by a public safety official well-known for his interests in integration, crisis situation management, participatory approaches, knowledge of local scale human and physical geography and for his communication skills. The project includes a "climate" group, a "vulnerability" group and an "adaptation and users" group working in parallel and who have agreed on the research questions to be addressed and on the added-value tools and information to be developed. A three-way communication is ensured through a variety of means like face-to-face meetings; brainstorming sessions; surveys; forums and symposiums that take place throughout the project stages (from the project definition to its conclusion).

The climate group develops or applies tools like the CRCM, climate scenarios and historical data trend analyses to assess past and future probabilistic evolutions of the four climatic indices identified by the coastal dynamics researchers and local experts as relevant for coastal erosion processes (e.g. ice cover, freeze-thaw cycles, storminess, water levels). The coastal dynamics group initially used historical trends in coastal erosion and used expert judgment to propose optimistic, average and pessimistic erosion scenarios for the next 30 years for three pilot areas (a few kilometres of coastline selected by 3 communities). This group then uses, for example, outputs from the climate group, from the adaptation and users groups and from their own sectorial research to better assess the probable evolution of the biophysical vulnerability of the selected coastline. The adaptation and users group reassesses potential impacts of the different proposed coastal erosion scenarios, discusses adaptive capacity or even mandate-specific adaptation option studies with the objective of revisiting current practices in coastal zone management. One of the many contributions of having this project structure is the conclusion that simple indices or indicators mapped at the request of interested users can add significant value and facilitate knowledge transfer.

3 Indicators as a knowledge translation tool

This section discusses the development and use of indicators as an interface and knowledge translation tool by Ouranos. This is illustrated by a more detailed look at two specific case studies addressing (1) the development of a set of temperature trend indices for southern Québec, and (2) climate and social indicators assessing public health risks due to extremely high temperature events. The two case studies serve to illustrate how indicators have been developed by Ouranos following a Pressure, State Response (PSR) framework and suggest what the future development for this could be. The PSR framework states that human activities exert pressures (e.g. pollution emissions) on the environment that can induce changes in the state of the environment (e.g. changes in ambient pollutant levels, climate characteristics, water flows, etc.). Society then responds to changes in pressure or state with environmental and economic policies and programs intended to adapt, prevent, reduce or mitigate these pressures and/or environmental damages.

3.1 Case study 1: Development of a set of climate indices in southern Québec

A recent study of Canada's climate shows significant changes in temperature and precipitation occurring during the twentieth century (Vincent and Mekis, 2006). However, because the climate indices used reveal a high degree of spatial variability, Vincent and Mekis (2006) conclude that more detailed research is needed on a regional basis. In 2002, Ouranos, in collaboration with the Quebec Ministry of Sustainable Development, Environment and Parcs, launched a historical data study to examine regional temperature trends across southern Quebec. Consequently, 1960 to 2003 daily minimum and maximum recorded temperature series at 53 stations were analysed and homogenised. Homogeneity problems due to station relocations and changes in observation procedures were addressed using a technique based on regression models and surrounding stations (Vincent, 1998). The technique used to identify inconsistencies/incongruities was tailored to the regional Quebec data set used (Yagouti et al. 2007). Thus, 106 maximum and minimum temperature series were homogenized on various temporal scales (daily, monthly, seasonal and annual). The results of the homogenisation process show that only 36% of the 106 series were homogeneous. Amplitudes of the detected inconsistencies were estimated and corrections were made where necessary to the non homogeneous series. At the end of the process, 52 statistically homogeneous stations were retained. One station was eliminated because of the high percentage of missing values and the many relocations of this station during the time period.

Chosen mainly to provide a general portrait of the southern Quebec climate, the temperature indices computed from these homogenized series were selected in close collaboration with Ouranos' stakeholders. The results show that the surface air temperature has increased in southern Québec over the 1960-2005 period. A significant warming is evident in the west and south while the increasing trends are not as important towards the north and east. The warming is more pronounced during the winter, although many significant increasing trends are also detected during the summer months. The analysis of temperature extremes strongly indicates more nights with very high temperatures in all seasons. The temperature indices also suggest a decrease in the length of the frost season (Figure 3a) and an increase in the length of the growing season (Figure 3b), an increase in cooling degree days (Figure 3c) and a decrease in heating degree days (Figure 3d) as well as an increase in the number of freeze-thaw cycles during the winter (Figure3e) and a decrease in the number of freeze-thaw cycles during the spring (Figure 3f). This study improves our understanding of the trends and variations in temperature and precipitation indices in Southern Québec. The majority of the findings are consistent with those expected in a warmer climate. The observed warming appears to have some beneficial impacts for certain socio-economic activities in Québec, such as a longer growing season and a shorter frost season. However, the warming can also have adverse effects on various industries in Québec, including a shorter tourism season in the winter and increased energy demand for cooling buildings in the summer.

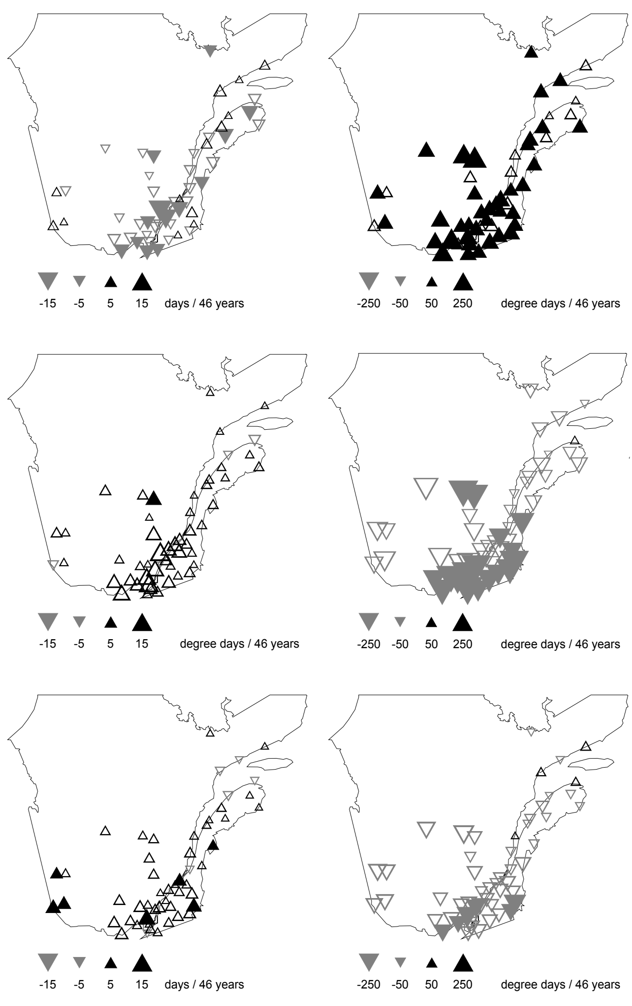

Figure 3 Trends in six temperature indices for 1960-2005.

3.2 Case study 2: Climate vulnerability indicators for assessing public health risks due to extremely high temperature events

A study published in 2005 (Vescovi et al. 2005) demonstrates the feasibility and potential of a risk assessment approach and the development of public health risk indices for a regional impact and adaptation climate change study applied to heat waves in southern Québec. The methodology developed for this study was inspired by the NOAA (1999) vulnerability assessment tutorial, by the EPA (1998) guidelines for Ecological Risk Assessment, by Cutter et al. (1997), Schiegg (2000) and by the Tyndall Centre's research (Adger et al. 2004). Climate variables and socio-economic parameters were integrated via a geographic information system (GIS) tool to produce maps of estimated present and future public health risks.

To characterize current climate hazards, data from 310 Environment Canada stations in southern Quebec were used along with two indices:

1) Mean number of days with Tmax > 30°C, for weather stations with data for at least 16 years between 1971 and 2000 (272 stations). This index was interpolated using the natural neighbour method.

2) Mean number of episodes per year with at least three consecutive days with Tmax > 30°C and Tmin > 22°C. These were computed from daily temperature series within the period 1971 to 2000 for the stations with indexes (1) higher than 2.5 d y-1 (67 stations).

These are based on practical characterizations of extreme temperature events established by the Montreal Public Health Board (MPHB) which recently proposed an operational definition based on a daytime high of 30°C (Tmax) and night time low of 22°C (Tmin) for 3 consecutive days (Drouin et al. 2005).

To characterize future climate hazards related to potential impacts of extreme heat, climate projections for 2039 - 2063 were made using the Canadian Regional Climate Model (CRCM) V3.6.1, driven by the coupled ocean-atmosphere model CGCMII and following the IS92a (IPCC) emissions scenario for greenhouse gas emissions. The CRCM performs climatic simulations at a small-scale resolution (distance between each grid point about 45 km) and for timesteps of 15 minutes.

Social vulnerability was calculated through four social sub-indices determinant for Quebec's reality and considered relevant elsewhere for defining the vulnerablility of human populations to extreme high temperature events. These four sub-indices are:

1) Age index: frequency of people aged 65 and over

2) Poverty index: frequency of low-income earners (LICO-base 2001) by Statistics Canada for rural zones, with the FGT (Foster-Greer-Thorbecke) index by classes of income in 2000 Canadian dollars

3) Social isolation index: frequency of single person households

4) Education index: frequency of people aged 20 and over with less than 13 years of education

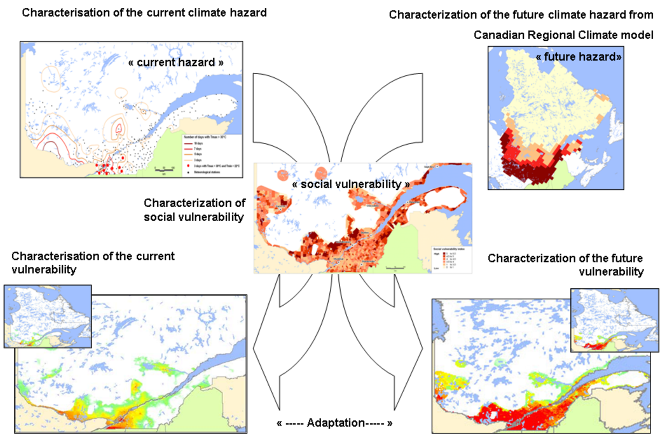

Figure 4 Methodological principle applied to public health risk maps for current and future conditions (adapted from Vescovi et al. 2005)

A comparison of risk maps for present and future conditions (Figure 4) showed that the number of locations where populations would be at risk due to high temperature events would dramatically increase in Quebec over the next few decades. Based upon the assessment of biophysical vulnerability to climate change (which is a relatively new concept combining physical and human processes), this study gives preliminary input to the Quebec public health decision-makers currently developing a spatially explicit on-line analytical processing tool using Web-GIS technology to identify areas potentially vulnerable to climate change.

4. Discussion and conclusion

By creating Ouranos, Canadian decision makers at the national and provincial levels confirmed that V&I&A, in the context of climate change, is a priority. More than simply supporting an integrated scientific program, one additional objective is to develop a structure for analysis of multidisciplinary problems and to promote synergetic work in the search for solutions to climate change adaptation issues in a North American context. By working at a regional scale and enabling links between various researchers and decision-makers, Ouranos provides an opportunity for innovative multidisciplinary, multi-organisational dialogue and facilitates the mainstreaming of adaptation. Various methodologies are used by Ouranos' "scientific brokers" to accomplish this, including face to face meetings; brainstorming sessions; surveys; forums; symposiums and scientific projects which ideally include a climate, a vulnerability and an adaptation component working in parallel to achieve the project objectives. Also, Ouranos develops or tailors several tools to support V&I&A analyses such as the Canadian Regional Climate Model and climate change scenarios applied for priority issues. Using concrete examples taken from Ouranos' ongoing V&I&A projects in Coastal regions, this paper demonstrates how the science developed at Ouranos is used to facilitate knowledge transfer to practice.

Among the knowledge transfer tools available, the development of climate indices and indicators of vulnerability following a PSR framework (such as the one illustrated in Figure 5), is recognised as being very useful for assessing positive and negative impacts to global and regional climate change (OECD, 1993, 2006).

Also, this paper demonstrates how the development of climate indices and indicators of vulnerability (specific and relevant to each of the issues and regions of interest identified by Ouranos) following a PSR framework are useful knowledge transfer tools. This is illustrated by a more detailed look at two specific case studies addressing the development of a set of temperature trend indices for southern Québec, and climate and social indicators assessing public health risks due to extremely high temperature events. The first case study documents how various user-relevant climate variability and extremes indices ("State" of PSR if the climate system is considered and "Pressure" if the problem is examined from the human system point of view) was likely affected at regional scales (southern Quebec) by atmospheric increases in GHG concentrations ("Pressure" of PSR considering the climate system). The latter case study examines how a relatively new concept of biophysical vulnerability to climate change, which combines both physical and human processes, can also be used in the PSR framework.

Thus, assessing trends, processes and warning signals (e.g. extreme temperature events, precipitation events, sea level rise, etc…) or reporting the efficiency of adaptation (and mitigation) strategies are the major drivers pushing towards the development of indicators. In each case, the strength of the metric will be its high diagnostic value in attributing detectable changes to identifiable forcing factors. Indeed, one of the main challenges is to adequately address long term climate change trends with short term managerial commitments (Corfee-Morlot and Höhne, 2003). Thus, for decision-makers, addressing metrics (process and indicators) of diagnostic value, capable of attributing changes to identifiable forcing factors is of great interest to provide a reliable response in terms of adaptation strategies to implement (OECD, 2006).

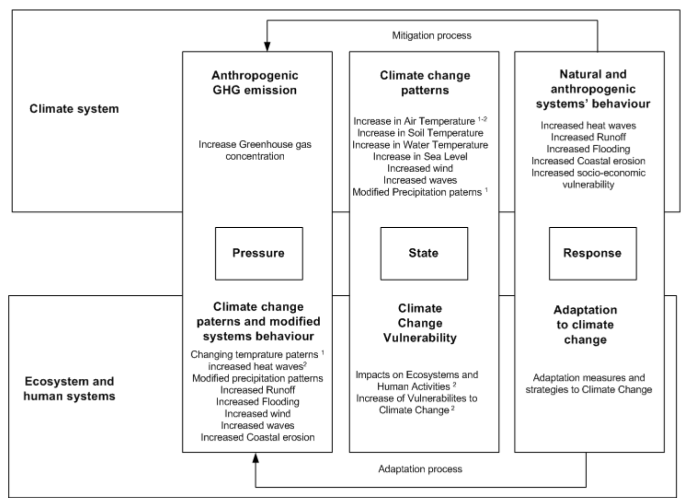

Figure 5 Matrix grouping indicators according to the PSR approach

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