Planned Adaptation to Climate Change: Some Observations From a Recent Science Symposium

1

Fred Roots[1]

[1] *Scientist emeritus*, Environment Canada

Editor's note: The author reflects on the Science Symposium on "Planned Adaptation to Climate Change", from which the papers in this volume emerge. Environment Canada hosted a science symposium titled Planned Adaptation to Climate Change in Victoria, British Columbia, 9-11 March 2009. About 75 people, including researchers, data and information experts, planning and management personnel, and policy-makers from a variety of agencies and authorities shared information, and discussed progress and problems and concepts related to the increasingly important and complex subject of how individuals, communities, and governments can or should cope with and adapt to a changing climate. At the conclusion of the symposium, Dr. Roots was asked to present a general perspective on the meeting and make some comments on issues ahead. His observations follow.

Abstract: In order to assess the progress and desired actions needed for adapting to current and impending rapid changes in climate, it is useful first to ask: "what are the scientific aspects of the concept and the practice of adaptation?", and then to consider the adequacy of the scientific knowledge of climate change and of human behaviour in response to those changes. It is helpful in this regard to review our understanding and basis for adaptive action against the philosopher's "staircase of knowing" that describes the step-wise progression from objective observation to increasingly subjective data, information, knowledge, understanding, and wisdom. Against this background, the various papers, new information and discussions of this symposium highlight or provide a basis for looking at the adequacy of our present understanding of changes and trends in the physical climate, and in policies and public response to climate issues. Some weaknesses and gaps in our scientific understanding of the changes in climate and its consequences for society and the economy, some obvious and apparent paradoxes in public and policy awareness, and obstacles to effective adaptation become evident. Adaptation strategies and actions must have a broad interdisciplinary response from understanding of the dynamics of the physical and biological environment, input from the social, economic and cultural sciences, together with adequate and continuing monitoring of changes in key parameters. It is seen that although there is recent stronger and broader attention to the seriousness of impending climate change and to the urgency of adequate measures to cope with its effects, the issue has long been recognized in the Canadian and North American scientific establishment. Calls for adequate policy response and changes in public behaviour have been largely unheeded to date, and it is hoped that this symposium may help toward more positive action.

Keywords: climate change, adaptation, knowledge

1. Introduction

It was the purpose of the symposium to provide a state-of-Canadian-science update on adaptation to climate change including:

- Climate change science, particularly coupled global climate models (GCMs), regional climate models (RCMs), and statistical downscaling methods for assessing the range of changes that Canada might experience in this century;
- Data availability and tools for developing scenarios for climate extremes, for assessing the risks of climate change at the regional and local scales, and for performing the uncertainty analysis in climate variability and extremes;
- Climate change impact assessments based on mean climate and extreme weather in various sectors such as infrastructure, water resources, energy, health, agriculture, fisheries and transportation; and
- Synthesis of available methods to support adaptation planning and research, and to supply the information for risk assessment studies with coherent uncertainty analysis; and
- An opportunity to observe emerging trends in adaptation science and research.

The symposium brought together top researchers, industry representatives and managers of climate change adaptation activities from across Canada. It provided an opportunity for researchers and decision makers from a wide range of disciplines to share results and information in a national context. The symposium program included invited keynote and plenary presentations, panel presentations, and poster sessions.

Judging by the comments and sustained enthusiasm of the symposium, one can conclude that it was a good meeting. Two days were spent away from the regular work but devoted entirely to subjects each are working on. The topics addressed have been subjects that are deeply cared about for they are very important to our future. Old friends and new acquaintances from across the country have been meeting and building a coherent Climate Change Science community; listening to, absorbing, questioning, and sometimes challenging finished lectures and some unfinished reports of on-going research and data management. This is together with lively discussion with our peers and not a little scheming and frustration over how to get the general public and government decision-makers to accept the fact that a seriously changing climate is upon us and that we all must do something about it. Yes, it has been a good two days.

But we did not come here just to enjoy ourselves and see what our colleagues were doing. We need to ask ourselves: has the Science Meeting achieved its purposes? You will recall that when the symposium was first announced, the purposes were outlined quite specifically. The meeting was to:

- provide an up-date on Canadian science related to adaptation;
- exchange information on data availability, and on tools for developing scenarios and assessing risks;
- show and discuss some example assessments and demonstrations of methods;
- lead to a synthesis of available methods that would support policy and public planning for adapting to climate change;
- highlight new or emerging trends in research in the subject field of adaptation to change.

It is appropriate to consider whether, after two days of presentations and discussions, these purposes were accomplished? My quick impression, at the close of the meeting, is that we touched on or tried to address each of these purposes, except that no one specifically attempted a synthesis of methods to support policy and public understanding. Perhaps we, at the working scientist level, were the wrong group to attempt this. Perhaps "adaptation science" as we understand the subject, is still too immature; or perhaps the synthesis that policy-makers and the public need is not a science matter at all.

2. What is Adaptation Science?

To consider where our meeting fits in the complex and increasingly important subject of adaptation to a changing climate, it is perhaps useful to think back for a moment to first principles. Change in climate, on any scale - from planetary to very local - is like any other change in a dynamic system; simply an expression of Newton's laws of thermodynamics. The climate is a net resultant of energy and moisture flows and the distribution of chemical components, which are themselves the net results of changes in the scale, magnitude, and direction of forces from solar energy and their actions on the planetary architecture and the interactions of its components. Thus, if we talk about the "science of adaptation" we are talking about how do we increase our knowledge of human behaviour in response to a dynamic disturbance of an already dynamically mobile physical/chemical system. This is Newton's Third Law; but on

top of it, we have in adaptation science the subjective implication that we should focus our investigations on how to avoid inconvenience or tragic disruption of the human societies and their institutions which have developed within and have become accustomed to the dynamic climate of the last few centuries (which we now know has been anomalously stable in comparison with preceding millennia).

So there are two essential components to adaptation science: the physical/chemical/biological sciences of climate dynamics, as objective as we can make them; and the behavioural/psychological/economic sciences, which determine whether our increased knowledge will have a societal and policy benefit.

An interesting aspect of this subject is the obvious fact that humans and their societies have, by-and-large, a slower response time to stress than the fluctuations in atmospheric energy flows, but a faster response time than changes in oceanic dynamics or soil/nutrient flows. So, as the environment changes all about us, humans, their values and expectations, and institutions are caught in the middle - the climate, quick-responding ecosystems and life-support systems are changing more rapidly than ever before in human experience and ecological disruption is widespread, while the overall planetary processes are very slow to adjust. The science of adaptation to climate change is, in essence, the science of this dilemma.

With only a few exceptions, most people and most societies are finding that the changes in climate we are currently experiencing in most of the world and which according to our best knowledge today are almost certain to become more profound, are undesirable or, according to some, disastrous. Our libraries and responsible journals are filling with material on this topic (Kolbert, 2007; Lynas, 2007; Draper, 2009). Naturally, our first instinctive reaction, as a responsive and intelligent animal, is, if we cannot move to avoid the effects of the changes, to try to stop the undesirable changes, to remove the cause or reduce their severity. These are the actions or intentions that, at least in the science domain, have come to be called "mitigation". But, as Nicholas Stern and many others have tellingly pointed out, the scale of the problem and the nature of Earth processes is such that any conceivable mitigation action, even if it were successful and applied on an heroic scale, would take a very long time, in human terms, to undo or reverse the harmful changes now in train. Therefore, we must learn to live with, and adapt to what is here and now, and coming. As Stern (2006) states: "Adaptation is the only response available for the impacts that will occur over the next several decades before mitigation measures can have an effect."

3. How can we adapt?

How to adapt? Observations of Nature through geological time, of human species and groups during the last fifty millennia, and organized societies and individuals in the last few centuries – and lots of historical and social/economic studies – show, obviously, two main ways of adapting to a changed environment.

One, move away from the undesirable affected area to a more desirable or productive location. This is migration in one form or another. Nature does it all the time, and our ecosystems as we know them are the result. The Arctic tern who flies 25,000 kilometers annually to find an environmentally suitable place to raise its young, and the urban office worker who has a summer cottage in the woods have much in common. But when the climate itself changes at the places where life support has been previously established, and the choice is to move, or to die in the former place, there must be another kind of migration. In biology, this phenomenon is sometimes referred to as range translocation. It is perhaps best known in regard to marine life, where the oceanic climate changes slowly enough for habitats and their inhabitants to adjust, as for example in the Greenland Sea where the ranges of shrimp and cod have alternated over a couple of centuries in response to fluctuations in water temperature. With humans responding on a shorter time scale to more rapid changes in the atmospheric climate, this option has, in its more severe aspects, led to environmental refugees. We have, unfortunately, several distressing examples in the world today.

The other obvious option is to cope with the changes. How plants and animals cope, in a fixed or limited location, with changes in climate is a whole separate subject. For humans, there are four main paths that people commonly can take to cope with, or adapt to, rapid changes in climate:

(i) they can arrange for economic compensation for short-term changes (for example, crop insurance, loans, subsidies);

(ii) they can change their expectations and sensitivities, and develop new "normals", of behaviour, institutions, and community structures;

(iii) they can develop new technologies and practices; and

(iv) they can take advantage of the new conditions.

I am sure that you can see that modern societies use all of these paths. And this is what the science of planned adaptation to climate change is all about. This is why we are here.

4. How does our Adaptation Science help Canadian societies, and people in other parts of the world, do these things?

Any consideration of the scientific aspects of planned adaptation to changes in climate must be based on a scientific understanding of the climate itself, of its dynamic characteristics, of the forces that influence its various components, and their effects and feedbacks. How good is our understanding of these characteristics and influences? After listening to the talks and summaries of the past two days, and with a little familiarity with the overall subject, I might venture an opinion of where we stand in 2009, in the areas of the natural sciences:

Physical sciences: We have a pretty good handle on the processes, and the range of space and time scales over which they act, at least on land. We are not so good at understanding the causes and dynamics of shifting "weather types" on a regional or sub-regional scale (we are still at the description and monitoring stage); and we are really no good at all in getting answers about the specific climates in rugged mountainous areas or complex coastlines (the amount of detail required overwhelms us and our resources, and we revert to averages, approximations or sample locations, and have learned to accept that). We have some confidence about the large-scale dynamics of the atmospheric climate over large ocean areas, but admit to considerable ignorance of the dynamics of the ocean climate itself (the climate within the water), which we have recently learned is more complex and variable that we had assumed. We are not good at identifying the multiple specific causes of extreme events.

Chemical sciences: Although it is a fallacy to try to separate the chemical aspects from the physical ones, because Nature does not work that way, I think it is fair to say that our understanding of the atmospheric chemistry role in climate change is spotty. We have lots of data and observations on changes in local and regional atmospheric chemistry from industrial activities, and some on the chemical effect of deforestation and other land-use changes, but the effects of these activities, over, say, the thirty years that we take as the basis for climate descriptions are at best shaky. Specific insults like acid rain, the factors leading to smog, or the processes of long-range transport of air

pollution are well-studied and understood; but arguments over the energetics of different LRTAP scenarios show that this is a research problem, not yet good knowledge of the chemistry of changing climate. And we seem to need much more knowledge about the link between ocean chemistry and atmospheric chemistry.

Biological/ecological sciences: I suspect that most people working in or reviewing this incredibly complex subject field will agree that with respect to ecological responses to a changing climate the tasks are just well started, rather than having good knowledge in hand. Every issue of the Journal of Ecology or Climate Change or similar periodicals reports new discoveries or unexpected concepts. On the whole, I think it is fair to say that we are gathering a lot of descriptive information on the effects of changes in climate, or of extreme events, on plant and animal communities, and on changes in biodiversity in selected locations or regions; but the links between physical changes in climate and the rate of response of ecosystems through changes in species communities, changes in habitat or translocation of ranges is a real challenge.

We have, especially in Canada, focused much of our scientific attention in this area on the biological and ecological response to changes in climate, as if the climate is the dominant factor and the ecosystem a passive recipient. But every day, we are learning that the biological component on the surface of the Earth is an important driver and influence on climate. The 2008 conference on "Climate Change and Biodiversity in the Americas", which many here attended and of which the newly-published report is available at this meeting, includes several examples of the feedback effect of a regional ecosystem on climate.

5. Our Staircase of Knowledge

But how do we use this scientific background, extensive although open-ended as it is, to improve planned adaptation to climate change? How do we make our scientific information and knowledge the basis of adaptation? I suggest that here again it may be useful once again to go back to first principles and to consider for a moment the philosopher's *Staircase of Knowing* (Figure 1)(Roots, 1992).

Note that on this staircase, there is a progression from observation of a phenomenon or situation, through data and information to knowledge, understanding and

eventually to wisdom. To proceed from one step to the next, it is necessary to add some subjective human-selected quality. Simple observation or measurement cannot become data unless it is verified according to some approved standard; data by itself does not become information unless it is selected and tested; information does not become knowledge until it is organized and interpreted according to some purpose; knowledge does not became understanding until it is integrated and made comprehensible for some objective or interest area; and judgment applied properly to understanding can become wisdom.

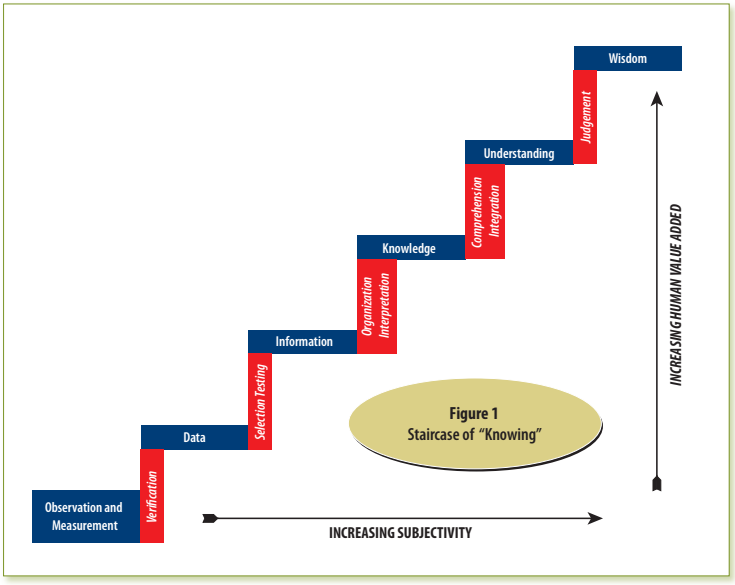

Figure 1 | Staircase of Knowing.

Where does science fit on this staircase? Clearly, on the first three steps, and sometimes it contributes to knowledge, the fourth step. But clearly, information alone will not produce knowledge or understanding, let alone wisdom. How many times have you heard it said that we need more data on this and that, or that if we only had more information, we would know better what to do or would avoid mistakes? Surely, in our world today, especially through its science, we have more data and more information than any people in history; but is our judgment better because of that?

Think, for a moment, of the wisest or most trustworthy person you know. Chances are, that person has information adequate to her or his needs, but the wisdom does not come from the enormity of data that person has, but from integrated understanding and judgment based on the useful information.

I suggest that we keep this staircase and these relationships in mind as we think about the contribution of science to planned adaptation to climate change. The responsibilities of the Adaptation and Impacts Research Division of Environment Canada itself extend from information and knowledge, based on our science, to the tasks of cultivating the understanding among our decision-makers and politicians so that they can adapt to changing environmental conditions and take action with regard to public safety, maintenance of the economy, or public well-being. This will almost always require both technical adaptation and behavioural adaptation, which in turn often require institutional and bureaucratic adaptation.

The various sessions and papers presented at this meeting reflect this situation. This is not the place to comment on individual papers, but we have had a good sampling of the lower part of the staircase. The different models described allow us to organize or simulate what we know about climate changes, and to test our assumptions about the relationships between important factors and influences. We had a progress report on how our understanding, for better or worse, affected building codes, safety, and investment; and several examples or case histories of the application of the increased knowledge and awareness of climatic changes in public life and economy. We learned of the facility for increased accessibility and coherence of information; and several papers displayed methods, schemes, and tools for getting our information to the public or to those who can take action or change behaviour. Some of these are forays up toward higher steps of the staircase, and they are important. And there were up-dates on the progresses and shortcomings of international assessments and thinking in this area, and on the effects of climate change and adaptation efforts on the national economy. All good stuff; as a scientific community, we really benefited from two days of listening to one another. But we are still only halfway up the stairs.

Participants at the meeting made some attempts, mostly informal, to relate issues of adaptability to climate change to the present-day realities of political policy, business interests, public concerns or habits, and the world economy. The evidence of current changes in climate and for future serious changes was so overwhelming that I think we all felt that those who denied it were blind to what was happening and based their

denials on narrow philosophy or rigid faith. We felt strongly that the climate change science community had an urgent responsibility. The problems were crowding in on society, on economic systems, and on policies. There was a general public awareness that "things were happening in Nature which do not bode well for human prosperity or for the environment of the planet", and that something should be done about it. But the issues are so complex, and strike at the very heart of the economies of most of the world and the habitual behaviour of most people, that help is wanted from the group who know most about climate - the climate scientists. It is time to move up the stairs.

6. Paradoxes

Several papers, and much discussion, drew attention to the inherent paradoxes or contradictions that were encountered in trying to put the knowledge and results of climate change science into policies, economic practices, and public awareness/ demand; that is, if one may use the staircase analogy, to move from knowledge to understanding and action. Chief of these problems was the often expressed demand from the public and politicians for certainly in forecasts - "What is really going to happen to the climate of my area, and what will be the effects?" The easy course for individuals and policy-makers to take is to do nothing until there is greater certainty that calamitous things are happening. The cognitive dissidence of psychiatry is very much in evidence in this issue.

Awareness of changes in the environment and economy is widespread and deepening, and knowledge that at least part of the change is due to individual habits and use of our technologies is accepted; but there is reluctance or a feeling of inability to change those habits. The expectation that "everyone, especially those in other countries, should change but that does not really apply to me" is deeply entrenched, together with the notion that unless everyone changes, individual actions will have no effect and will result in individual economic and social hardship. Thus, there is on the one hand a call for strong policies which would curtail further emissions and practices that could harm the environment and climate, but on the other hand there is strong support for policies that increase our use of wasteful technologies and do not curtail the pleasures and practices that have led to the problem - another paradox.

It seems, on reflection, and several participants mentioned this, that the demand for "certainty" about future climate changes is not as strong as is often assumed. There

are instructive examples in other subject fields. People or politicians do not demand certainty in economic predictions, yet they commit large amounts of money on the best knowledge at the time. As another example, the public does not demand certainty in aircraft safety, but is satisfied that the risks are low and the other benefits outweigh those risks. For many people, gambling – playing with uncertainty – is enjoyable. So in many ways the demand for "certainty" seems pointless. But simply saying so as a scientist does not change the demand.

In looking at the problems of making progress in adapting to climate change, I have found it of interest to compare the contrasts and the parallels of two topics of policy and public concern with which I have been associated for a couple of decades - the management of radioactive wastes, and climate change. Both of these topics have a sophisticated science background, with much research, modelling, and monitoring in Canada and internationally; both still have several scientific unknowns; both have an essential public awareness component; both have had political attention at the highest level; and both will involve heavy public investment. Under current concepts and practices, the management of radioactive wastes has a very, very low probability of any harmful release to the environment for thousands of years, but if there were to be a mishap, the consequences could be severe and of a kind quite without parallel in our history. And so, for a small but influential segment of society there is a high alarm component which does not appear to be amenable to penetration by rational science. In contrast, climate change is already happening and the likelihood of it becoming more intense in the next few decades is very high; but the consequences, although almost certainly likely to be very severe, are mainly in the realm of problems familiar to humankind, and of the type which in their milder forms we have muddled-through before. But in neither case is most of the public, despite the alarms and concern, ready to make a significant change in their demand for energy, which lies at the basis of both the radioactive waste and the climate change problem. I think that it helps to have this kind of perspective in looking at the issues before us.

7. Omissions and Weaknesses

While listening carefully to the papers and discussions, I tried to keep my ears open for topics or concepts that I expected to hear about but did not, or which seemed to me to be very lightly touched upon. Of course a two-day meeting could not touch on

all aspects of this wide subject, and it is preposterous for me to pretend to have a broad knowledge, but for what they may be worth here are some impressions from an outsider.

Models: There were good discussions of downscaling and regional comparisons, but no attention to how regional models and modelling of anomalies could improve or were contributing to global models, which themselves are being modified to accept complexities - so-called upscaling. In this area, the climate modellers might learn from the oceanographers, and give attention to ocean/atmosphere coupling variations in short time periods, which are the focus of atmospheric climate change.

Trends: There was some mention of trends in means, and trends in variability, but a thoughtful discussion of these would be of real interest at this stage of our research. "Trends in extremes" is very tricky, even though the media keep calling for it; but a bit more discussion on the scales and causes of extremes would be useful. There is no doubt that assurance of improving skill in forecasting extremes will be most sought-after by the public and investors.

Behavioural sciences: An important gap in our discussions was the absence of modern input from behavioural and psychological researchers on how Canadians at all societal levels, including their politicians, are responding to changing climate and the threats of more severe changes to come. There has been a lot of research in the academic social sciences on how people respond to stress, how they switch or "roll-over" their value systems, etc. It seems that in the social sciences at least, a lot more is known about how people change from, for example, denial to acceptance, than was known a decade ago. This knowledge is pertinent to the science of climate change adaptation, but seems not to have had much attention at the policy or planning level. Southcott (2009), for example, has stated that "Very little research exists on the social and economic aspects of climate change on sustainability in Canada".

First Nations: There was no specific reference to, or input from, First Nations, even though native people have an acute awareness of climate and its changes in the past. Although the rapidity of current climate changes is unprecedented in our human experience, the First Nations have much knowledge of the connections between climate and ecosystems and human living. Sensitive and careful input from the people themselves about changes in climate could be valuable in the present Canadian

situation. There is a growing literature on this. Particularly in Arctic regions, where native peoples are moving from a hunter-gatherer societal organization directly into the knowledge society without the transition through agricultural and industrial societies, there may be much to learn from First Nations about adaptation to a rapidly changing environment.

Economic aspects: We had an excellent review of economic methods and tools that can be used to assess or determine the costs of changes in climate and the economic costs and benefits of various adaptation actions and their results. This was all there was time or space for in our crowded agenda. But to look at the options and expectations of planned adaptation to a changing climate, it would be good to hear a little about the progress of economic modelling of climate changes (à la Nicholas Stern, applied to Canada), about the economics of adapting to climate changes in specific areas such as the grain-growing regions of the prairies, or in the Arctic where actions to adapt to climate-caused changes in living resources have an effect on the spiritual economy as well as the money economy.

Wholly human-centred: All of the issues and considerations of adaptation to climate change that were talked about were assessed from the human point of view. "Planned adaptation" is a subjective human idea. The response of the ecosystem to changed climatic conditions is a process of change that affects further changes in environments or resources, to which humans must adapt; but we gave little attention to ecosystem adaptation itself. This could be considered "unplanned natural adaptation". We did not dwell on it, but in some of the presentations, the authors appeared to look at the changes, and the response to changes, from the point of view of the environment or the planet in its own right. This was refreshing.

8. An Old Problem, Still with Us

The current public and political concern about climate change, and the need to do what we can to mitigate the undesirable effects and to adapt to the new conditions, is of course quite recent. It is true that the changes in climate seem to be accelerating in the past decades, and we are certainly pouring more substances into the atmosphere and changing the land surface in such a way as to further speed up the process. Most of us here at this meeting only began to work on climate change issues in the last ten years; even if we were involved in atmospheric sciences before that, climate change

did not have the same priority. But within the atmospheric science community, the concern has a long history, as science issues go. In 1975 there was an important conference in Toronto entitled "Living with Climate Change", sponsored by the Canadian Meteorological Society, the Mexican Geophysical Union, the American Meteorological Society and the Science Council of Canada. It was attended by leading persons in atmospheric sciences at the time from Mexico, the United States, and Canada, many of whom became familiar figures in climate change issues in subsequent years. I think that it is of interest, and provides important perspective to our work today to quote from the first sentence of the report of thirty-four years ago (McTaggart-Cowan and Beltzner, 1976):

> "There is growing evidence that the world is entering a new climate regime. Both the rate of change of the climate and the amplitude of short-term climatic variations will be much more pronounced than in the recent past."

And the last sentence of the preface reads:

> "We hope that this discussion will be a significant impetus toward furthering our ability to live more securely and more contentedly with climate change."

Could not this statement from 1975 apply equally well to our symposium in 2009? But the group meeting in Victoria was not the only group that was at the time giving comprehensive consideration to the problems of adaptation to climate change. At the same time as the Victoria symposium, an international meeting, organized by UNESCO, on "Climate Change and Arctic Sustainable Development; Scientific, Social, Cultural and Educational Challenges" was held in Monaco. The background paper for this meeting summarizes the issue and the challenges:

"Understanding and responding to climate change is a challenge that requires the combined efforts of the scientific community, civil society, governments, and national and international organizations. Research on climate change must extend beyond assessing causes and monitoring impacts and trends. It is now clear that major change in the world's climate is an unavoidable reality. Adaptation and response are now essential. The development of appropriate adaptation and response strategies has therefore emerged as a central preoccupation of all actors, including the United Nations System."

"Adaptation strategies require a broad interdisciplinary response. They must be rooted firmly in the knowledge-base of scientific monitoring and assessment, which provides data on changes in climate and their impacts on the physical and biological environment. Adaptation to climate change adds a social, economic and cultural problematic as it encompasses the ability of countries to respond to the challenges put before them by the changes in climate."

This is where we are today, and this is our job.

References

Draper, R., 2009. Australia's dry run. *National Geographic*, vol. 215, no. 4, p 34-59.

Kolbert, E., 2007. *Field notes from a catastrophe: man, nature, and climate change.* Bloomsbury Press, New York, 225 p. ISBN 1-59691-130-1.

Lynas, M., 2007. *Six degrees: our futures on a hotter planet.* Random House, New York, 336p ISBN 142620213K.

McTaggart-Cowan, P.D., chair, and K. Beltzner, ed., 1976. *Living with climate change; report of a conference.* Science Council of Canada, Ottawa, 105 p.

Roots, E,F., 1992. Environmental information: a step to knowledge and understanding. *Environmental Monitoring and Assessment,* Kluwer Publications, Dordrecht, vol.20, p. 87-94.

Southcott, C., 2009. *Climate change and sustainable development in Canadian northern communities.* In Climate Change and Arctic Sustainable Development, UNESCO expert meeting, Monaco, abstract, p. 77-78.

Stern, N., 2006. *The economics of climate change.* Report to Her Majesty's Government (UK). Released by Office of Climate Change, UK, Published by Cambridge University Press. Review report.

UNESCO, 2009. Introduction: Meeting Concept and Background. *International Experts Meeting on Climate Change and Arctic Sustainable Development: scientific, social, cultural and educational challenges,* Monaco, 3-6 March 2009, 114 p.