Arctic Climate[1] Impact Assessment (ACIA)

An Assessment of Consequences of Climate Variability and Change and the Effects of Increased UV in the Arctic Region

NOTE:
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Implementation Plan

Prepared by the Assessment Steering Committee

September 2000

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[1] In this document the word "climate" is used as shorthand that includes climate variability, climate change, ozone depletion and increased UV-B radiation. "Climate change" refers to long-term or permanent trends (over at least ten years) or shifts in climate, while "climate variability" refers to short term (sub-decadal) climatic fluctuations.

Preface

This is an implementation plan for an assessment of the consequences of climate variability and change and the effects of increased UV in the Arctic Region[1]. It is being developed by an "Assessment Steering Committee (ASC)", with representatives of AMAP, CAFF, IASC, Arctic indigenous peoples, and others. The development of this Implementation Plan is in response to a proposal submitted to and encouraged by the Senior Arctic Officials of the Arctic Council in May 1999 and again in November 1999.

The Arctic Ministers at their 2nd Arctic Environmental Protection Strategy (AEPS) Ministerial Conference in Nuuk, Greenland in 1993, noting the existing global cooperation on climate change and stratospheric ozone programs, requested that the Arctic Monitoring and Assessment Programme (AMAP) regularly review the integrated results of these programs to identify gaps in the scope of the monitoring and research and ensure that specific issues related to the Arctic region are placed on the agenda of the appropriate international bodies. AMAP has addressed this request by publication of the "Climate Change" chapter in the report "Arctic Pollution Issues: A State of the Arctic Environment Report" presented to the 4th AEPS Ministerial Conference in Alta, Norway in 1997. This assessment review has been further supported by the more substantial assessment "Climate Change, Ozone and Ultraviolet Radiation," which was incorporated into "AMAP Assessment Report: Arctic Pollution Issues" and presented to the 1st Meeting of the Arctic Council (AC) in Iqaluit, Canada in 1998.

The Arctic Ministers, at their Arctic Environmental Protection Strategy (AEPS) Ministerial Conference in Alta, Norway in 1997, asked AMAP to continue "monitoring, data collection, exchange of data on impacts, and assessment of the effects of contaminants and their pathways, increased ultraviolet (UV) radiation due to stratospheric ozone depletion, and climate change on Arctic ecosystems. Special emphasis is required on human health impacts and the effects of multiple stressors." A draft policy paper prepared by the U.S. representative to AMAP was submitted and discussed at the AMAP Working Group meeting in December 1998.

Further, at the First Meeting of the Arctic Council (AC) in Iqaluit, 1998, the Ministers asked the Program for the Conservation of Arctic Flora and Fauna (CAFF) to monitor and assess "in collaboration with AMAP, the effects of climate change and UV radiation on Arctic ecosystems." To foster this initiative, AMAP and CAFF established an Assessment Steering Committee (ASC) for the climate and UV work. Two workshops were arranged in 1998 and 1999 to document activities that are already ongoing within the Arctic region with respect to observation and assessment of climate change and UV, and to prepare proposals for an observation network and research program.

The International Arctic Science Committee (IASC) in the mid-1990's initiated a number of projects and planning activities on the science and impacts of climate change in the Arctic region. Then, in late 1998, the Executive Committee of IASC suggested that the IASC, in concert with the Arctic Council (AC) and its appropriate subsidiary bodies and the Intergovernmental Panel on Climate Change (IPCC) and its appropriate subsidiary bodies, consider developing and sponsoring "A Scientific Assessment of Consequences of Climate Variability and Change and the Effects of Increased UV in the Arctic Region."

In the spring of 1999, AMAP, CAFF, IASC, IPCC, and WCRP jointly explored the idea of such an assessment with leaders in science, government and other interested bodies. These explorations and detailed discussions led to a formal proposal to the Senior Arctic Officials (SAOs) of the Arctic Council to plan for and conduct an Arctic Climate Impact Assessment (ACIA), including the effects of increased UV radiation, over the next several years.

In February 2000 the third meeting of the ASC was held in Washington DC and the group elected a Chair and Vice-Chair. A formal offer to establish the ACIA Secretariat in Fairbanks, Alaska was received. An ACIA Scoping Meeting was arranged back-to-back with the ASC meeting. This document is updated based on the recommendations from that meeting.

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Introduction

Motivation

Climate variability and change, and more recently, notable increases in UV radiation, have become important issues in the Arctic region over the past few decades. These issues have also prevailed in the international scientific and political scene for over a decade through major programs of scientific research (e.g., WCRP), through intergovernmental assessments (e.g., AMAP, IPCC, and WMO), and through international treaties, protocols and conventions.[2]

The results of scientific research and indigenous knowledge have increasingly documented climatic changes that are more pronounced in the Arctic region than in other regions of the world or are critical to our understanding of global-scale climatic processes. Observations from indigenous cultures of the Arctic indicate that the physical environment, as well as the flora and fauna, has been changing.

It is most essential that a penetrating analysis of these observations and studies be carried out in order to ascertain more specifically to what extent these represent natural variability over years and decades, and, on the other hand, how many are indicators of long-term changes due to human activities. Only then will we be able to tell what future changes can be foreseen and which impacts on life in the North may be expected. The first AMAP and IPCC assessments noted:

- Most inland Arctic areas have warmed in winter by 2.0∞C per decade during the last 30 years, while more coastal regions have shown less severe warming and some records, particularly in the Greenland/Davis Strait area, have even shown cooling (Chapman and Walsh 1993).

- Ozone depletion in northern latitudes and the resultant changes in UV radiation have increased markedly during the past decade, with some sectors of the Arctic experiencing temporarily up to about 20% reductions in ozone and more than a 40% increase in UV radiation (Taalas et al. 1996, 1997).

- Precipitation has increased in some areas at high latitudes by up to 15% over the last 100 years. Most of this increase has occurred during winters within the last 40 years (Bradley et al. 1987**,** Groisman 1991, Karl et al. 1993, Groisman and Easterling 1994, Dahlstrøm 1994, Hanssen-Bauer and Førland 1994).

- Indigenous residents of northern Alaskan villages have reported thawing of previously frozen ground. These observations are confirmed by numerous measurements in Alaska and other parts of the Arctic (Osterkamp and Romanovsky 1996).

- Variations in the geographic ranges of animals have been observed by Native communities in the last several decades. These animals include beaver and moose.

- Cyclone and anticyclone frequencies have increased in some regions in the Arctic between 1952 and 1989 (Serreze et al. 1993).

- Glaciers in the Arctic have generally receded during the last century, contributing some part of the concurrent sea level rise of about 15-30 cm (Revelle 1983).

Since the AMAP and IPCC assessments, further scientific studies have been completed which are particularly relevant to Arctic climate change. In addition, several important research programs have geared up to the point where results are emerging. The 1998 WMO Ozone Assessment (WMO 1998) gave increased attention to Arctic ozone depletion and the recent changes, including new analysis and highlighting the uncertainties for ozone recovery. Some of the recent scientific results of the last two years include:

- There has been increased coastal erosion in the Bering Sea from storm surges resulting from reduced sea ice (Weller 1998).

- Sea ice extent in the Arctic has decreased Arctic-wide by 0.35% per year since 1979. During summer of 1998, record reduction of sea ice coverage was observed in the Beaufort and Chukchi seas (Johannessen et al., 1999; Maslanik et al., 1999; Vinnikov et al., 1999).

- Sea ice thickness has also been reduced by between 1-2 meters in most parts of the Arctic Ocean and the sub-Arctic seas (Rothrock et al., 1999).

- Streamflow discharge of major Siberian rivers into the Arctic Ocean has increased in recent years and is associated with a warmer climate and enhanced precipitation in the river basins (Semiletov et al., 1999).

- Since 1970, the Arctic Oscillation, which is a measure of the strength of the circumpolar vortex, has strengthened. This has been found to be consistent with temperature change in the Arctic (Thompson and Wallace 1998).

- There has been an increased warming of the Arctic Ocean's Atlantic layer and an approximate 20% greater coverage of Atlantic water types, as summarized in Serreze et al., (in press).

- Record low levels of ozone were measured in 2000 in the Arctic with increasing evidence that these levels are likely to continue for at least the next 20 years (Shindell, et al., 1999).

- Ongoing studies indicate that the current UV levels can have a significant effect on fish larvae survival rates.

- General warming of soils in regions with permafrost, derived primarily from Alaskan data, has been observed over recent year, as summarized in Serreze et al., (in press).

Past assessments have shown that the Arctic is important to global-scale processes in at least four important ways:

- The thermohaline circulation dominated by the Arctic Ocean and Nordic Seas is responsible for as a considerable part of the Earth's poleward heat transport and may also serve as a sink for CO_2. Alterations of this circulation, as have been observed during climatic changes of the past, can affect global climate and in particular the climate of Europe and North America. (Broecker et al., 1985a, 1985b, 1990).

- The melting of the Arctic land ice sheets can cause sea level rise around the world. A compilation of studies (Meier 1993) suggests that a global warming of 1^{o}C will lead to ~1 mm per year of sea-level rise from small ice caps and glaciers. The Arctic will supply over half of this total, with an additional 0.3-0.4 mm per year contributed from Greenland (IPCC 1990a) although uncertainties remain about the mass balance of the Greenland ice sheet.

- Arctic soils can act as either sinks or sources of greenhouse gases depending on temperature and moisture changes within the Arctic. Moisture has opposing effects on the concentrations of the two major trace gases: CH_4 flux declines with soil drying while CO_2 flux initially increases (Oechel 1993, 1995, 1997). These changes can influence greenhouse gas warming globally.

- Our current understanding of the Arctic climate system suggests that positive feedbacks in high-latitude systems, including the snow and ice albedo effect, amplify anthropogenically-induced atmospheric changes and that disturbances in the circumpolar Arctic climate may substantially influence global climate (IPCC 1990a, 1992a, 1996a).

Regarding recent changes in climate, it is important to note that different trends have been observed in different parts of the Arctic (Fig. 1). Over the last 30 years, average temperatures in western parts of North America and in Siberia have been increasing, while temperatures in Hudson Bay and Greenland have decreased. In the Scandinavian region, no significant change has been observed. These signals illustrate the complex nature of the response of the Arctic region to climate change. In addition to spatial differentiation, there are variable response times and differences in the magnitude of reactions. These result from the distinctive distribution of land and ocean and from couplings to regions outside the Arctic. This spectrum of change must be captured and sampled in the assessment process.

At this point, there is no consensus of scientific opinion on whether these changes are due to anthropogenic influences or to natural variation. Regardless of the cause, there is a need to synthesize and assess the current observations and their effects to the Arctic. The impact of these changes and potential future changes to ecosystems and particularly to social and economic activities is not well understood and has not been adequately addressed in past assessments. The ACIA will attempt to address these issues in a manner that will be useful to the policymakers and inhabitants of the Arctic.

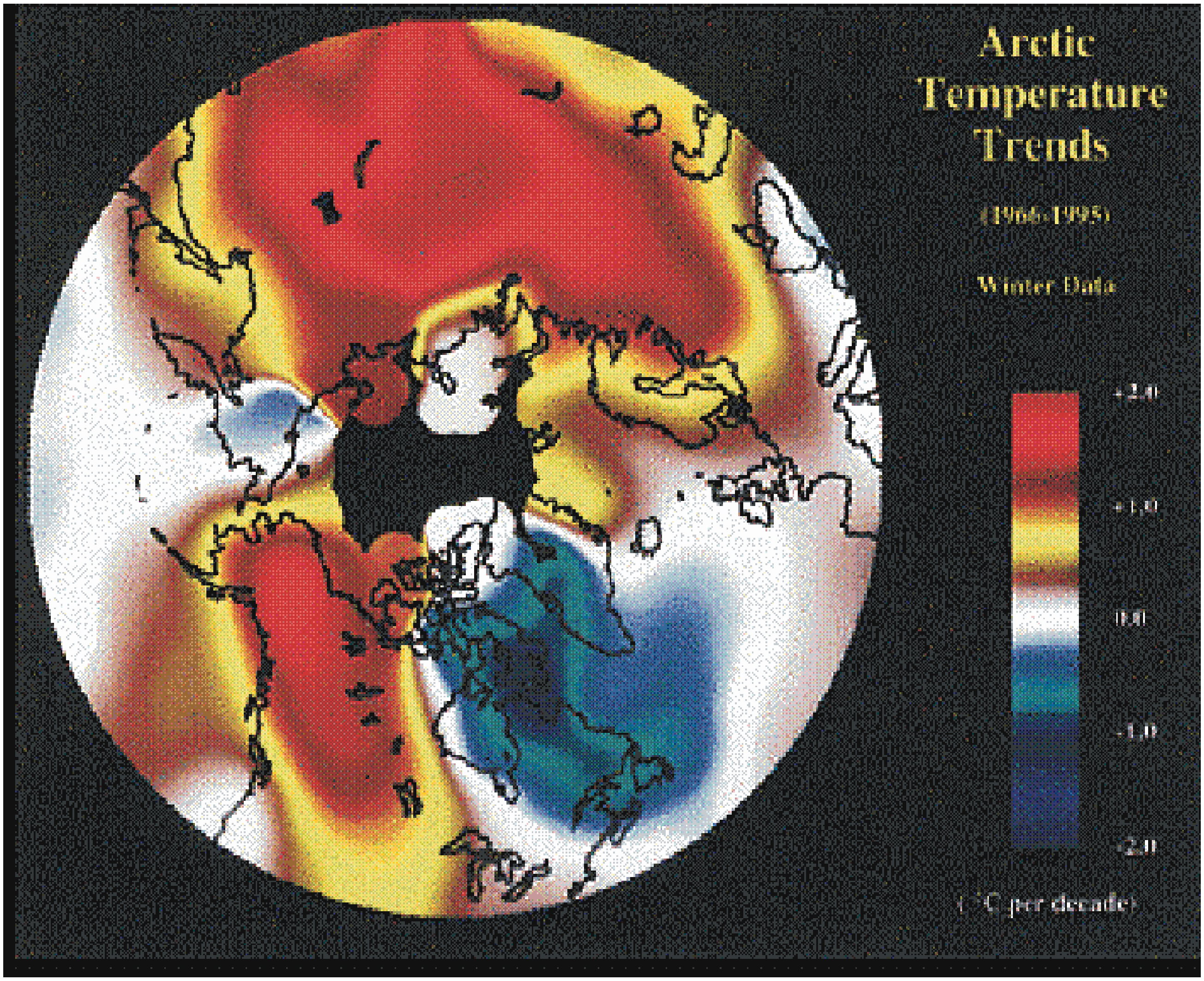

Fig. 1. Observed changes of winter mean temperature in the Arctic, expressed in terms of a linear trend for the period 1966-1995 (Chapman and Walsh, 1993, updated).

In summary, scientific research and indigenous knowledge are increasingly providing evidence of changes in the Arctic region that are regionally specific or unique and amplified compared to those observed in other regions. Past assessments have not adequately addressed the complexity of the impacts of these recent changes or potential future changes to the Arctic people. A number of issues require focused attention through the assessment process. These issues include the effects on fisheries, herding, agriculture, human health, infrastructure and the variety of ecosystems in the Arctic. The impacts are likely to be complex and sub-regional in nature. The adaptation of the Arctic people, including the development of coping strategies will be greatly enhanced by this assessment process.

Goal

The goal of the Arctic Climate Impact Assessment (ACIA) is to:

- ***Evaluate and synthesize knowledge on climate variability, climate change, and increased UV radiation and their consequences, and***
- ***Provide useful and reliable information to the governments, organizations and peoples of the Arctic region in order to support policy-making processes and to IPCC's further work on climate change issues.***

The assessment will include environmental, human health, and social and economic impacts and recommend further actions. This assessment will be conducted in the context of other developments and pressures on the Arctic environment, its economy, regional resources, and peoples.

The ACIA will be strongly based on an analysis of existing and forthcoming information including peer-reviewed publications, indigenous knowledge, and other documented information and data.

The ACIA process will be guided by a short list of questions to amplify the intent, such as:

- What is the state of scientific knowledge concerning changes in climate and UV radiation, and how will current and anticipated changes affect Arctic ecosystems, human health, and social and economic sectors? What are the likely temporal and spatial trends and patterns of these consequences and impacts across the Arctic region?

- What are the current and future environmental stresses and issues for the Arctic region affecting potential impacts of climate change? How might these changes exacerbate or ameliorate existing problems in the region?

- What are the gaps and uncertainties to be addressed by future research, observational/monitoring, and data/informational capabilities for the Arctic region that can better prepare the region and policy makers to reach informed decisions related to climate change?

The approach to the ACIA is perhaps best illustrated in the diagram below (Fig. 2). Global change affects the Arctic climate, which in turn has feedbacks to the global system. The regional climate change affects the ocean, sea ice, glaciers, permafrost, snow cover and river and lake ice. These changes, as well as direct climate change, affect the biota, wildlife and ecosystems of the Arctic region. A further consequence of all these changes is impacts on the social and economic systems of the region. All boxes in this figure are part of the ACIA.

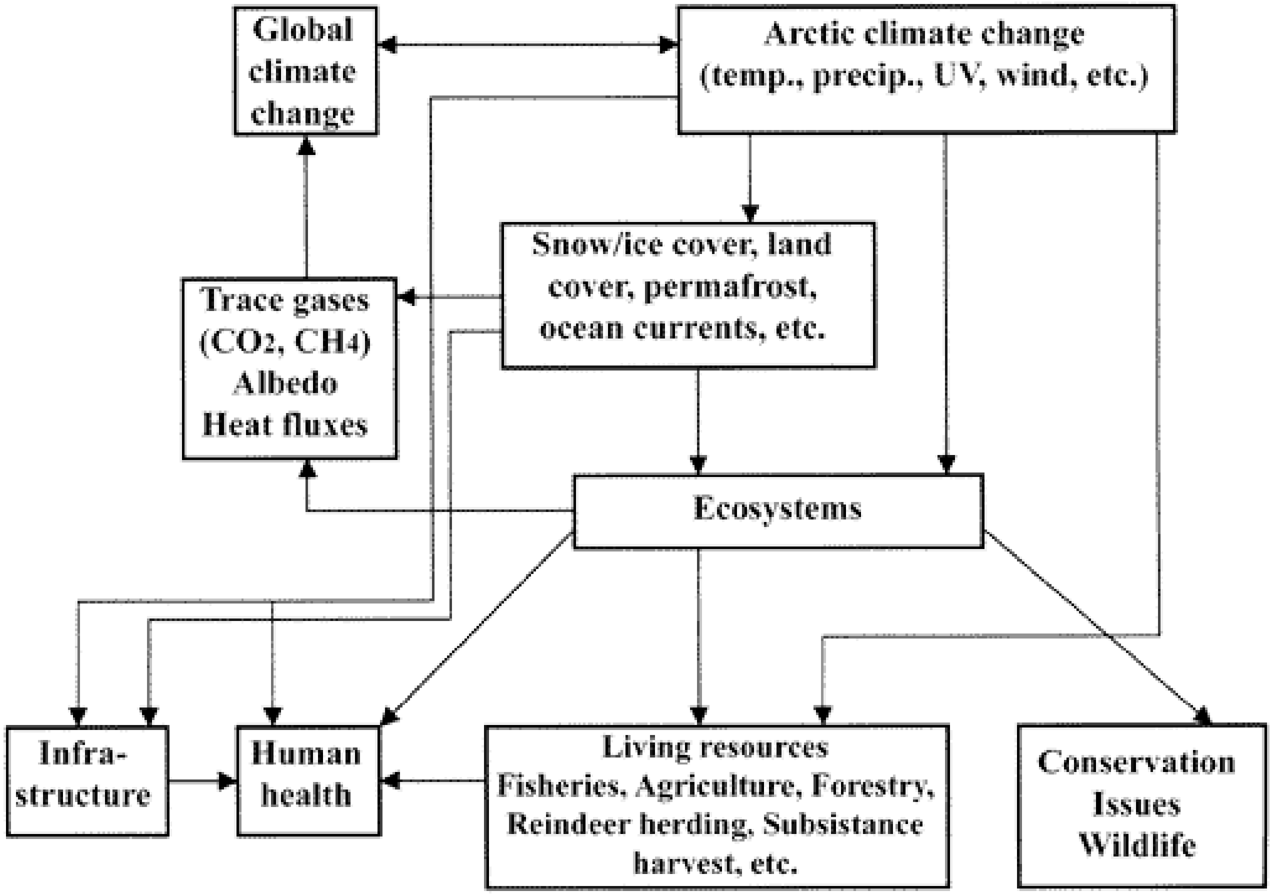

Fig.2. Key interactions among major components of the Arctic climate system and the impact on human activities in the North.

Rationale

Several factors speak for a circumpolar assessment of the consequences of climate change. These include:

There is Increased Focus on the Importance of Regional Scale Assessments. The work of IPCC and others strongly suggests that assessments must be increasingly conducted at geographical scales finer than is now the case and more explicitly across important social and economic sectors of the nations of the world. Hence, IPCC is initiating increased assessment activities at regional scales and several nations are conducting detailed assessments at national/continental scales. The necessary climate models with meaningful regional scale resolution will most likely become much more robust over the next few years. This makes it possible to address the consequences of change at scales that are more directly applicable to understanding the impact on critical social and economic sectors and the regional variations or unevenness of climate change over the region. Additionally, the ACIA will focus on the sensitivity of ecosystems and people to climate change, and work to identify the critical thresholds associated with the expected changes.

There have been some efforts to assess comprehensively all aspects of climate change within the Arctic region. To date, these have focused on specific issues or geographical areas. Examples include studies of the impacts of climate change on particular regions. However, with the exception of AMAP's synthesis (AMAP 1998) and information in the IPCC Second Assessment Report's chapter on polar climate, there has been no Arctic-wide assessment of the consequences of climate change. Regional scales are particularly important in assessing climate change and UV effects on ecosystems and human health, and in accounting for a combination of other pressures affecting the environment.

AMAP, IASC, and others have summarized a number of important results in these assessments. Examination of past records has shown that climate variability can invoke shifts in ecosystems. One example is the northward migration of cod along the west coast of Greenland during the warming from the 1920s up to the late 1930s (Jensen 1939). The warm period came to an end in the late 1960s and the subsequent period consisted of three extremely cold periods attributed to different geophysical events. The West Greenland cod stock has not produced any good year classes since the cooling (Buch et al. 1994). During the warm period of the 1920s to early 1960s, the Norwegian Spring Spawn Herring stock had a feeding migration to Iceland. However, a marked climate shift with a temperature decrease of about 1∞C resulted in the gradual disappearance of the herring from Iceland (Vilhjalmsson 1997). Other efforts include studies on polar bears, on sea ice, and on productivity in the marine environment. As further results emerge in the literature, it is important to synthesize these findings to coordinate current research, identify research needs, and come to a community decision on what is likely to occur in the future.

The WMO Ozone Assessments have given increased attention in recent years to the regional differences in ozone depletion around the world. In particular, the latest assessment (1999) shows that the Arctic is likely to respond to expected levels of ozone depleting substances and climate change than the rest of the world. Our current understanding of the effects of increased UV radiation to Arctic peoples and ecosystems is not adequate to allow for defensible estimates of future changes or appropriate adaptation strategies.

Partnerships Essential to Implement a Circumpolar Assessment Exist.

The nations of the world, including their scientific communities, have engaged in numerous assessments that address a number of environmentally related topics and areas of societal interest, from global issues such as climate change, ozone, and national security, to regional deforestation and desertification. There is growing recognition that such assessments are importantly enhanced if four elements are included:

- The national governments and indigenous and local authorities.
- Non-governmental organizations, the private sector, and other stakeholders with insights about the topic of the assessment.
- The scientific community knowledgeable in the relevant fields.
- A body of information and experience summarizing past changes, and models for large-scale complex assessments.

All four of these elements are present in the Arctic region: the Arctic Council and its subsidiary bodies (AMAP and CAFF); IASC and its linkages to other scientific organizations; Indigenous Peoples' Organizations (IPOs); the emerging University of the Arctic; regional inter-governmental bodies; and various venues for participation by non-governmental organizations and the private sector. The Arctic countries have long-term observation activities in the region and recent political changes have created a background for making the observational data available for international assessment.

Steps should be taken to ensure that all countries will collect data and provide information for the assessment. The linkage with IPCC would enhance the ACIA process and provide connections across all four elements noted above.

Policy Makers Seek Regional Scale Understanding. The intergovernmental policy concerning the consequences of climate change has been set by the Kyoto Protocol and other formal conventions and agreements. The Montreal Protocol and amendments are currently in place for globally reducing ozone depleting substances. However, the influence of climate change on ozone levels in the Arctic is considered in neither of these policies. Efforts to control climate change and ozone depletion concern all nations and, further, the implementation of these "agreements" requires a detailed understanding and assessments of climate change across and within the Arctic region. Assessments, including those produced by the ACIA, need to document: (i) the state of scientific knowledge and understanding of climatic processes across the region; (ii) the consequences of these changes across social and economic sectors relevant to the region as well as effects on ecosystems, biodiversity, and human health; and (iii) the foundations upon which nations and peoples of the region can adapt, adjust, cope and/or take constructive advantage of the opportunities afforded by the changes.

These factors, along with the interests of the governments of the Arctic nations and other stakeholders, set the foundation upon which an Arctic Climate Impact Assessment should be developed and implemented.

Benefits

An assessment of the consequences of climate change in the Arctic region will lead to the development of fundamental and useful information for the nations of the Arctic region, their economy, resources, and peoples. Examples include, inter alia:

- Providing clear scientific evidence on climate and UV variability and change within the Arctic at hemispheric and regional levels, indicating the nature of impacts on human health, the natural environment, including biodiversity, and food and water resources;

- Supporting the Arctic nations' interests and needs to address the consequences of climate and UV variability and change on such issues as human health, food and water resources, and the flora and fauna of the region;

- Identifying gaps in basic knowledge and fundamental data that need to be acquired in order to better understand climate variability and change at a range of scales;

- Providing a clear and structured basis for future research into climate change, UV and their impacts including interactive modeling;
- Identifying key strategies for future monitoring programs (parameters, measurement precision and frequency);
- Providing a foundation for adaptive and coping strategies to be developed;
- Providing benchmarks for future climate assessments;
- Offering guidance with respect to national and international policy on issues relevant to climate change and ozone depletion, including the combined impacts of both.

The nations south of the Arctic will feel the impacts of climate change, but perhaps to a lesser degree. These nations will also benefit from the assessment. Similarly, several non-Arctic nations conduct Arctic research and their scientists can contribute significantly to the assessment.

Structure and Content of the Acia Documents

This Implementation Plan outlines the processes for the development of two scientific assessment documents and a policy document, all three of which will be the documented products of this assessment process to analyze and integrate understandings of the consequences of climate change in the Arctic region, the overall title for which will be an "Arctic Climate Impact Assessment (ACIA)." The ACIA is designed to be carried out with partnerships, outlined above.

The assessment will provide a review of the state of knowledge about climate and UV changes across regions and ecosystems; information concerning environmental and social and economic scenarios; impact assessments for key sectors and environmental and human issues; and synthesis for the whole Arctic region. The assessment will be documented in the following volumes:

- **Scientific Document.** A series of assessment reviews and analyses that lead to an integrated understanding for the Arctic region (across sectors, sub-regions, indigenous and local interests) and for the circumpolar Arctic nations. The scientific document will be fully referenced, and will be composed of detailed scientific and technical information describing current understanding of climate change, climate variability and increased UV radiation and their consequences over the entire Arctic region. The content of the scientific document will be the responsibility of lead authors and writing teams. The volume will be subject to peer review guided by the ASC.
- **Synthesis Document (**max. 20 pages, excluding tables and figures). A comprehensive summary that synthesizes the main findings of the assessment and places in a policy-makers framework the state of our knowledge concerning the consequences of climate change over the entire Arctic region. The synthesis document will be concise, insightful, and could be titled, "An Arctic Climate Impact Assessment: A Summary View." This volume will be prepared by the ASC in concert with a scientific editor and lead authors in a simple, jargon-free language meant for policy-makers and the broader public, and will be subjected to peer review guided by the ASC.
- **Policy Document.** AMAP and CAFF will produce a final document and will relate the information from the synthesis and scientific documents to the policy needs of the Arctic Council and provide recommendations for follow-up measures. AMAP and CAFF will address the question of what strategies can be recommended to cope with current environmental stresses, and possibly lessen the impacts of these changes in the climate and ultraviolet radiation. These recommendations will include advice relevant to national and international policy as well as advice to inhabitants of the Arctic. AMAP and CAFF will present a plan for the SAOs on how this document shall be elaborated.

Appendix 1 shows the proposed areas of focus for the Scientific Document of ACIA. It reflects the increased focus and level of detail on the complexity of biological impacts over past assessments. A number of different physical and response scenarios will be examined to illustrate the range of climate change impacts in the Arctic. Unlike prior circumpolar assessments, this process will involve examination of potentially different responses to climate change on a synthesized basis. The final document will be focused on species, ecosystem and human institutions, including human health and social and economic effects, as well as coping mechanisms, allowing a scientific basis for policy decisions as well as future scientific research. Final structure and emphasis of the Scientific Document will be determined with input from the inhabitants of the Arctic, the response from the Arctic Council and the involvement of the scientific community.

Implementation

Management Structure and Responsibilities

The assessment will be implemented and managed through:

- An **Assessment Steering Committee** (ASC) will provide oversight and general guidance to the assessment process. The terms of reference for the ASC and its membership are attached in Appendix 2.

- An **ACIA Secretariat** has been established to support the work of the ASC. It is located at the International Arctic Research Center of the University of Alaska Fairbanks. The Secretariats of AMAP, CAFF, IASC, and possibly others will assist the ASC Secretariat.

- A **Lead Author Strategy** will be used to conduct the actual assessments. Lead authors and contributing authors will be designated by the ASC based on nominations by countries and organizations. The authors will be chosen based on proven excellence in research, breadth of understanding of the subject, and demonstrated independence from major political or organizational interests. Lead author responsibilities will be developed by the ASC. The lead authors will head writing teams to coordinate and prepare the assessments for each chapter of the scientific document. For some sections of the scientific document, there might be two lead authors, one of them being from an Arctic country.

The assessment will be guided by the ASC in consultation with appropriate organizations and individuals. ASC will, together with IPCC, make a document called "Modes of Cooperation between ACIA and IPCC" in order to ensure good coordination between the two organizations. Participation in the scientific assessment aspects of the process will be inclusive across the science community with relevant experts nominated to and chosen by the ASC. The assessment is designed to serve the interests of the peoples and governments of the Arctic region through the auspices of the Arctic Council and its subsidiary bodies. It will be the responsibility of the ASC to maintain the partnerships with other existing organizations, programs and groups.

As a first principle, the ACIA will be conducted by scientific experts in close partnership with all affected stakeholders and draw from existing national, bilateral, multilateral and regional projects and programs. Workshops and meetings will be held to plan the ACIA in detail and thereafter to perform the assessment to ensure cross-fertilization between relevant scientific areas and disciplines, and stakeholders. Workshops will be hosted by participating countries on a voluntary basis. It will be the responsibility of the ASC to plan these workshops and encourage participation of stakeholders and the best expertise available.

While the ACIA must include all of the Arctic[3] and try to synthesize and overall perspective, there are reasons as well as advantages in also considering smaller regions. Recent trends in ozone, temperature and permafrost are quite different across the Arctic as noted above (e.g. Fig. 1). There are also differences in ecosystems and in the social and economic sectors of various parts of the Arctic. Finally, the availability of existing data bases needed for the impact assessments and the logistics for conducting new research may vary greatly. It is for these reasons that several sub-regions of the

Arctic were considered, at least for some topics, including the following:

1. Nordic Countries, North Atlantic, East coast of Greenland and European part of Russian North.
2. Central Siberia.
3. Alaska, Chukotka, Bering Sea region, and Western Arctic Canada.
4. North-Eastern Canada, Davis Strait, Labrador Sea and West coast of Greenland.

Guiding Principles

A set of principles will guide the implementation of the assessment. The principles address matters of strategy, content, venue, participation, and communication. Their implementation suggests an assessment that is (i) characterized by partnerships among governmental, public and private entities, (ii) focused on specific questions and information needed by policy-makers/stakeholders who are positioned to implement long-term coping strategies, and (iii) characterized by scientific excellence, openness, full participation, transparency, relevance to decision-making, and adequate communication processes.

In order to provide a solid basis for the further development in the Arctic region and necessary political decisions, the assessment should be strictly scientific and include the consideration of all observational evidence of past and ongoing changes that are available. Only in that way will the necessary credibility of the assessment be established and maintained.

The guiding principles are:

- **Breadth of Participation.** The process should be characterized by openness, inclusiveness, and broad participation by natural and social scientists, experts on indigenous knowledge, policy-makers/stakeholders and others with substantive knowledge and insights on the issue. Importantly, assessment activities should include participants from across all appropriate sectors;

- **Credibility of a Scientific Assessment/Open Review Process.** The assessment process should be open and transparent. The assessment is best served by subjecting the products of the assessment to a review, comments, and suggestions by a broad audience of interested individuals, parties, stakeholders and organizations;

- **Uncertainty.** The degree of uncertainty of the conclusions, due to imperfect theoretical models, insufficient data for model validation, and the nature of the assessment, should be made clear;

- **Communicating the Process, the Results and the Final Products.** The assessment process is markedly improved, and in the end more effective, if mechanisms are implemented to communicate broadly and continuously during the actual assessment all of the relevant information regarding the assessment content and process. Most importantly, an assessment should be designed to provide policy-makers, planners, managers, organizations, and often the public, with the documents and other communication media to support the policy-making process;

- **Scientific Integrity and Independence of the Process:** As policy options associated with global-scale issues are sensitive, political and commercial pressures must be resisted so that the scientific integrity and independence of the assessment body is assured; and

- **Language:** The use of simple, jargon-free language in reports meant for policy-makers and the broader public is essential. Journalists and science writers can play a significant role in the integrated assessment process; their involvement at an early stage is highly desirable.

Communication Strategy

Communication between ACIA and interested parties is recognized to be an essential factor in this process. It will be the responsibility of the ASC chair and secretariat to communicate regularly with interested parties.

The ASC has developed a "**Communications and Outreach Strategy**" for the ACIA that includes (i) the plans for the published reports and products, (ii) the development of ways and means for maintaining open and two-way dialogue during the assessment process (e.g., Web-sites, published schedules of meetings, circulation of draft documents, mechanisms for review, etc), (iii) publication policies and procedures, and (iv) other matters that will implement the policies of openness, inclusiveness, and broad participation, and maintain a process that subjects the products of the assessment to open review and comment.

Linkages with Other Assessments

The connections between this assessment and several related international and national/regional assessments will be considered and specific recommendations for cooperation, where appropriate, will be developed. For instance, the ACIA will build on the IPCC Third Assessment. In addition, scenarios of global climate change, including the changes over polar regions to the extent they are described by IPCC, will be used by ACIA. The interaction between the ACIA, IPCC and other organizations is fundamental for the success of this assessment. The ASC will be responsible for developing and implementing these linkages. The ASC should promote two-way communication with other assessment processes. The ASC should seek to be represented in relevant international activities, particularly IPCC assessments, at both the planning and reporting stages, to assure the needs of the ACIA are adequately addressed in these assessments.

Resources and Financial Considerations

Implementing the ACIA as outlined above will require dedicated financial resources. The following guidelines are proposed concerning the development and allocation of resources:

- **In Kind Contributions.** All the expenses for the lead authors, scientific experts, and those serving as government observers [e.g. non-Arctic countries] should be covered by participating countries. The data provided by each of the Arctic countries should be financed and delivered by the countries. This "distributed funding" strategy should enable the ACIA to be supported by participating governments without the need to fund a substantial centralized budget.

- **Joint Programs.** The Arctic region includes eight countries with widely differing geographical size and economic bases. To ensure relevant data from all countries, some joint programs may need to be implemented requiring common funding, both from Arctic countries themselves and other potential funding sources such as the UN, World Bank, EU, etc. The ASC and the Secretariat will coordinate such issues.

- **Costs for Shared Interests.** The Secretariats of CAFF, AMAP, and IASC are expected to allocate necessary resources to secure the respective interests of their parent organization in this assessment.

- **Common Costs.** Some central funding will be required for coordination efforts; supporting authors or scientists with special needs for support (both from within the region and countries outside, including permanent participants); coordinating and evaluating scenarios and other information/data essential to the conduct of the assessment, as well as modeling work; and preparing and publishing the reports. The Lead Country, USA, will cover most of this central funding through the ACIA Secretariat.

The ASC and the Secretariat developed a budget for ACIA, and it is contained in Appendix 5.

Data/Research Needs

The assessment process is founded on the results from scientific research and analysis. Therefore, the ACIA urges that scientific programs of research should be implemented as needed by all interested governments, scientific communities and organizations. Steps should be taken to ensure that current global and national programs are maintained, and where necessary, expanded. Further steps should be made to make sure that data obtained by these programs are available to ACIA needs.

Similarly, the development of long-term circumpolar research and databases (observation and monitoring programs) needed for this and future assessments, should continue. AMAP and CAFF have developed a draft Research and Monitoring Program for Climate Change and UV-B and work on a Circumpolar Biodiversity Monitoring Program is underway.

The ASC and the Secretariat will provide support and information that can enhance the development of research and monitoring programs for the Arctic region. It is hoped that relevant national research and monitoring programs will link to the ACIA process and provide new data for the assessment as soon as they become available. The ASC and the Secretariat will maintain the necessary and appropriate arrangements to assure such coordination.

Progress Reviews, Reports and Evaluations

The ACIA goals are to provide useful information for the Arctic Council, the people of the Arctic, and the scientific community. To assure that the ACIA achieves these goals, the following reporting mechanism will be implemented:

- **Progress Reports.** The ASC Secretariat will prepare and deliver a progress report through AMAP and CAFF at each meeting of the Senior Arctic Officials. The progress report will include any requests for major alterations to the scope or implementation of the existing plans. The ASC and its Secretariat will prepare an **Annual Report** and **Work Plan** for the coming year.

- **Review of the Scientific and Synthesis Documents.** The final review draft of the Scientific and Synthesis Documents will be subjected to peer review to assure scientific quality and accuracy. The ASC will coordinate these independent reviews.

- **AMAP and CAFF** will review the Policy Document through their national networks.

The complete ACIA timeline is outlined in Appendix 3. This timeline contains proposed dates for the reviews discussed above, and will help ensure completion of the assessment in the 2004 timeframe.

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Appendices

Appendix 1
Areas of Focus and Increased Attention for the ACIA

The ACIA is designed to address the critical areas of impacts and consequences of climate variability, climate change, and increased UV in the Arctic region over the next 100 years, especially to ecosystems, human health, and important social and economic sectors of the Arctic region. The implementation plan is designed to address the key issues and the material that follows is presented as an initial framework for the assessment. The ASC is committed to an open process that will continuously evaluate the state of progress of the assessment and adjust/adapt to the suggestions and contributions of the various partners on the assessment process.

The ACIA will address three important questions:

1. **What are the Past and Present Indicators of Changes in Climate and UV Radiation?** An assessment and evaluation of the current state of knowledge of all the indicators of climate variability, climate change, and increased UV as they relate to the Arctic region. This assessment will include identification of knowledge gaps and a recommended priority for filling them.
2. **What are the Possible Changes in the Future?** A set of scenarios that estimate possible future trends and patterns of climate variability, climate change, and increased UV in the Arctic region.
3. **What are the Potential Impacts Due to Changes in Climate and UV in the Future?** A set of candidate "impact topics" that are proposed to be among the key areas in which impacts on the environment, the people, and the ecosystems of the Arctic are most likely.

Section I: What are the Past and Present Indicators of Changes in Climate and UV Radiation?

A. **Introduction:** The synthesis of current knowledge of climate variability, climate change, and increased UV as they relate to the Arctic region will (i) build and extend upon IPCC and WMO Ozone assessments and any other global-scale assessments that document changes in the Arctic region (e.g., IPCC Assessment I, II, III; the AMAP climate change assessment; etc.), and (ii) will document the best available scientific data that either substantiates a consensus perspective and identifies uncertainties regarding climate variability, climate change, and increased UV as it relates to Arctic region. It is proposed that this information be structured around the five key elements of the Arctic environment (i.e., atmospheric, terrestrial, freshwater, marine and social environments, with the cryosphere appropriately integrated in these five). This assessment will be circumpolar in scope, even though some parts may focus on sub-regions, as listed in the Implementation section.

- **Atmospheric Environments –** Climate variability/trends (temperature, precipitation, clouds, ozone, UV radiation, winds, etc.)

- **Terrestrial Environments –** Effects on physical environment (permafrost, snow, soil; effects on ecosystems (changes in species composition, distributions, biodiversity)

- **Freshwater Environments –** Effects on physical environments (glaciers, runoff, river and lake ice); effects on freshwater ecosystems (changes in species composition, distributions, biodiversity)

- **Marine Environments –** Effects on physical environments (temperature, salinity, sea ice, general circulation, convection, coastal erosion); effects on large marine ecosystems (primary production, distribution, recruitment, and growth of fish stocks, effects on marine mammals)

- **Social Environments –** Effects on subsistence lifestyles (hunting, fishing, land use and occupancy); effects on health (UV effects, vector-borne diseases, sanitation, water supply)

Section II: What are the Possible Changes in the Future?

Experience with the IPCC and other assessments have demonstrated that using a number of scenarios provides a consistent foundation for input to the assessment for most regions. The ACIA will use several scenarios specifically developed for the Arctic area, building and extending upon those scenarios developed by the IPCC and any other relevant bodies. These scenarios will be evaluated for their strengths in reproducing past changes and their consistency in predictions. These scenarios will provide a common "input" to the assessment analyses conducted on each of the candidate impacts topics described in the next section (i.e., fisheries, reindeer herding, agriculture and forestry, human health, indigenous people, infrastructure and wildlife/conservation issues).

The major purpose of using these scenarios is to provide several different but consistent climate trends and patterns across all impact topics being analyzed. These scenarios enable the projection of impacts of climate trends in the Arctic region over the next 100 years. The ASC will establish an *ad hoc* group to guide this aspect of the assessment process, and will conduct a workshop to develop the most relevant scenarios for the ACIA. The *ad hoc* group of scientists will coordinate their efforts with the IPCC. It is anticipated that such scenarios will use a two-tier approach in which short-term changes expected by 2030 and longer-term changes by 2100 are considered. The following issues are of central concern:

- Natural variability in the climate system, derived from observations, models and historic/paleoclimate records.
- Climate change due to greenhouse gas increases by 2030 and 2100, at various rates of emission.
- Changes in ozone depletion and resultant UV levels through 2020 and 2050.

- Potential trends and patterns in relevant ecosystem and social and economic factors for the Arctic region and the role such trends could play when combined with climate trends.
- The effects of climate and UV radiation changes on the rates of the accumulation and degradation of key pollutants.

Case studies derived from historic and/or paleoclimate records describing significant changes in climate over the Arctic region that, if applied to future changes in this region, could provide insights into potential impacts. Examples of such case studies include past changes in ocean temperatures that have significantly changed Arctic fisheries; and sub-regional changes in temperature and precipitation patterns that have altered indigenous food supplies.

Section III: What are the Potential Impacts due to Climate Changes in the Future?

The following outline of the different chapters of the assessment scientific document should be viewed as indicative. The more specific structures for the different chapters will be worked out by the lead authors and the Assessment Steering Committee.

The Arctic as Part of the Global Climate System

Chapter 1: Climate System and the Roles of Ozone and UV Processes on the Planet and the Arctic

a. Reference IPCC conclusions, TAR Working Group 1, Chapter 1, global
b. Reference IPCC conclusions, TAR Working Group 2, Chapter 16, Polar (Arctic subset)
c. Reference AMAP (Table of Contents, Chapter 11, items 1-6)
d. Reference UV: AMAP Chapter 11, IASC UV report, WMO Ozone Assessment, Solomon's Nature paper
e. Feedbacks

Chapter 2. Past and Present Changes of Climate and UV: Climate Variability and Change, Ozone Processes and UV Increases in the Arctic Region

a. Arctic paleoclimate and historic record
b. Arctic observational (climate, ozone, UV); indigenous/local knowledge
c. Note sub-regional variability (present vs. paleo)

Chapter 3. Future Changes of Climate and UV: Modeling and Scenarios for the Arctic Region

a. The arctic region as part of the global climate system
b. Focus on the Arctic; regional modeling
c. A set of scenarios and their interpretation, uncertainty and limits of predictability (with or without stabilization)
d. Changes in frequency and extent of extreme events
e. What can be said about future changes for the sub-regions?

Impacts on Physical and Biological Systems

Chapter 4. Hydrologic Aspects, Snow, Ice and Permafrost. Consider across time scales.

a. Precipitation minus evaporation; river runoff; effects on ocean circulation and sea ice
b. Glacier mass balance changes; effects on sea level rise
c. Extent and thickness changes of seasonal snow cover
d. Thawing of permafrost and its effects on structures and ecosystems
e. Changes in river and lake ice and their effects on humans and ecosystems

Chapter 5. Terrestrial and Freshwater Ecosystems

a. Function and structure of arctic terrestrial and freshwater ecosystems
b. Past changes in arctic terrestrial and freshwater ecosystems
c. Vulnerability of the ecosystems to changes in climate and UV
d. Effects of changes in climate and UV on:
    - Carbon and nutrient cycles, soil processes

- Vegetation: productivity, distribution and biodiversity
- Fauna: Abundance, distribution and biodiversity

Chapter 6. Oceanic and Marine Systems

a. Effects on physical environment. Recent variations in:
   - Water mass distribution (temperature / salinity / stability)
   - Sea ice distribution / ice thickness
   - Circulation pattern
   - Thermohaline circulation
   - Atmospheric forcing (AO/ El Niño)
   - Teleconnections
b. Effects on marine ecosystems
   - General description of marine food web, production processes
   - Impacts on:
     - plankton production (primary, secondary)
     - fish stock population parameters (recruitment, growth, migration,
     - distribution)
     - marine mammals
     - sea birds

Impacts on Humans and Their Activities

Chapter 7. Indigenous Peoples and Native Knowledge.

a. Different arctic indigenous peoples and their way of living, including diet
b. Land and water rights
c. Traditional land use, including spiritual sites
d. Social and cultural activities
e. Observed changes in different arctic areas due to climate change and variability
   - Sea ice – thickness and seasonal distribution
   - Snow conditions – length of time of snow cover, thickness etc.
   - Animal/bird/fish arrivals, departures, seasonal distribution, migration
   - Permafrost
   - Tree/plant distribution and production
   - Precipitation, temperature and wind

Chapter 8. Wildlife and Conservation Issues

a. Selected rare and endangered species. Risk analysis
b. Selected wildlife species of societal interest
c. Migratory birds
d. Introduction of alien species
e. Functionality and use of protected areas
f. Management strategies

Chapter 9. Subsistence (reindeer, hunting, marine mammals, fishing, etc.)

a. Fishing – freshwater and marine
b. Hunting/herding – terrestrial and marine (animals/birds)

c. Gathering – berries, mushrooms, etc., firewood
d. As social/cultural activities
e. Change in sea ice/permafrost
f. UV radiation effects on hunting and fishing

Chapter 10. Fisheries and Aquaculture

a. Historical yields of fish stocks, and of aquaculture
b. Analysis of yields versus past climate variability and trends
c. Analysis of UV-B effects on key fisheries and food web species, and aquaculture
d. Projected impacts on fisheries and aquaculture of future climate and UV-B variability and change

Chapter 11. Forestry and Agriculture

a. Animal husbandry (health of species, e.g., cows, sheep)
b. Food crops, e.g., grass, potatoes, barley
c. Productivity and economic value of northern forests
d. Forest health (e.g., insect pests, wildfires)

Chapter 12. Human Health

a. Distribution and pattern of diseases (temperature-related, contaminant-related, etc.)
b. Water supply and sanitation
c. Population growth and demographic change
d. Air pollution
e. Highlight increases in UV

Chapter 13. Infrastructure, including business/industry

a. Hazards due to floods, erosion, permafrost thawing, sea ice changes, etc.
b. Buildings and other structures
c. Oil and gas resource development; mining; pipelines
d. Transportation systems, roads, ports, airports, railroads
e. Communities: waste disposal, water supply, settlement relocation

Synthesis

Chapter 14. A Synthesis: Implications of Climate Variability and Change and UV Increases for the People and Institutions of the Arctic Region

a. Major patterns and variabilities of the change and impacts for the arctic region
b. Implications of such changes for ecosystems and their services across the arctic region
c. Main consequences of socio-cultural change, impacts and vulnerabilities across the Arctic
d. Economic and infrastructural consequences of these changes for the people and institutions of the arctic region

Each of these impact areas in the assessment (ACIA) will be analyzed in a hierarchical manner. Impacts will be considered on a sub-regional basis. Within each sub-region, the assessment will focus on three areas (the physical environment, ecosystems, and people).

Interactions with Lower Latitudes

The connection between the Arctic region and the global system will also be considered. There are a number of feedbacks from the Arctic to the global system, including feedback effects of CO_2 and CH_4 emissions from ecosystems, albedo variations due to changes in snow and vegetation cover, and the thermohaline circulation in the ocean. The Arctic will also affect the rest of the globe in other ways. Glacier melting and permafrost thawing will raise the global sea level. The Arctic as a major source of oil, gas and minerals, as well as fish, will affect the global economy if its renewable and non-renewable resources are impacted by climate change.

Appendix 2
Terms of Reference for the Assessment Steering Committee (ASC) of the Arctic Climate Impact Assessment (ACIA)

An Assessment Steering Committee (ASC) is composed of two representatives each from AMAP, CAFF and IASC, and two persons representing the Arctic indigenous peoples (Permanent Participants). Lead authors, responsible for drafting the Scientific Document, will be members of the ASC (in case of joint lead authorship for a chapter, only one author will be a member of the ASC). The ASC may invite representatives from international organizations that contribute in a major way to the assessment. Through these appointments all Arctic countries shall have a participant in the ASC. If, after recruitment of all lead authors, any Arctic country still does not have participation in the ASC, then that Arctic country will be asked to name a representative to the ASC. The AMAP Heads of Delegation and CAFF National Representatives will be welcome to attend ASC meetings. Liaison participation in the ASC will be extended on a case by case basis.

The ASC operates on the basis of consensus.

The responsibilities of the ASC are to:
1. Oversee the scientific part of the Arctic Climate Impact Assessment (ACIA) process and coordinate all work related to the preparation of the assessment reports;
2. Foster cooperation and cross-fertilization between the sub-topics of the assessment (chapters) and the groups comprising the ASC;
3. Call for and integrate inputs from AMAP, CAFF and IASC, as well as observer countries and/or organizations;
4. Ensure circulation of draft reports to Arctic countries and Permanent Participants for thorough scientific comments;
5. Ensure independent peer review of final drafts;
6. Coordinate and forward assessment results, including conclusions and recommendations, to the AMAP and CAFF Working Groups for drafting of the Policy Document and its recommendations;
7. Cooperate with appropriate international organizations;
8. Identify resource needs for further consideration by AMAP, CAFF and IASC;
9. Report to AMAP, CAFF and IASC.

The ASC will be responsible for drafting the ACIA Synthesis Document. AMAP and CAFF will be responsible for drafting the ACIA Policy Document.

The ASC elects an **ASC Chair and a Vice-chair** for a four-year period, which may be extended. The Chair and Vice-chair will be the principal individuals to guide the implementation of the assessment and will coordinate the work between the ASC, Secretariat and the lead authors.
- The ASC Chair will preside over ASC meetings and carry out any duties entrusted upon the Chair by the ASC;
- The Chair and the Vice-chair will decide on division of labor as appropriate.

An **ASC Executive** will consist of the ASC Chair, Vice-chair, the Executive Director of the ACIA Secretariat, a person representing the Arctic indigenous peoples, and a member ensuring representation of the three main partners:

- The Executive Body will oversee ACIA activities between meetings.

<u>Secretariat</u>

- A Secretariat will be established at the University of Alaska. The Secretariat will serve the ASC and ACIA as needed. An Executive Director for the Secretariat will be appointed and approved by the ASC.

- The Executive Director of the ACIA Secretariat has full responsibility for the implementation of the ACIA Secretariat (organizational arrangements, budget, personal matters, etc.). The Executive Director is encouraged to broaden, where possible, the professional staff with qualified individuals from other countries.

List of ASC Members

Robert Corell, Chair	International Arctic Science Committee (IASC), USA
Pal Pestrud, Vice-Chair	Conservation of Arctic Flora and Fauna (CAFF), Norway
Snorri Baldursson	Conservation of Arctic Flora and Fauna (CAFF), Iceland
Terry Fenge	Inuit Circumpolar Conference (ICC), Canada
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Liaisons:

John Calder	Liaison with NOAA
Karl Erb	Liaison with NSF
Odd Rogne	Liaison with IASC

Secretariat:

Gunter Weller, Executive Director	ACIA Secretariat/USA
Patricia Anderson	ACIA Secretariat/USA
Thomas Murray	ACIA Secretariat/USA

Appendix 3
Draft Time Table

Activities	Planning for the year 2000				Planning for the year 2001				Planning for the year 2002			
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Ministerial and SAO meetings		X		M		X		X		X		M
AMAP / CAFF / IASC			Ca	Am			?				?	
ASC		X	X		X		?		?		?	
Lead and Contrib. Authors	N	S	C		X	X	X	X	X	X	X	X
List of contents			X									
Division of Work.			X									
Scenarios			X									
Modeling			X									
Workshops			X									
Subregional Work			X									
Data and Information gathering				X								
Funding for Common Work		-	-	-	-	-	-	-	-	-	-	-
Publisher							Announce Selection					
Scientific Editor							Announce Selection					
Scientific Doc.											D1	Ci1
Synthesis Doc												
Policy Doc.												
International Symposia											Plan	

Activities	Planning for the year 2003				Planning for the year 2004				Planning for the year 2005			
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Ministerial and SAO meetings		X		X		X		M				
AMAP / CAFF / IASC		?	X		X							
ASC		X	X		X							
Lead and Contrib. Authors												
List of contents												
Division of Work.												
Scenarios												
Modeling												
Workshops												
Subregional Work												
Data and Info. Gathering												
Funding for Common Work		-	-	-	-	-	-	-	>			
Publisher	-	-	-	-	-	-	-	>				
Scientific Editor	-	-	-	-	-	-	>					
Scientific Doc	Co1	D2, C2	Co2 Fd	Int. Rev.	D	Ap, Edit.	Print					
Synthesis Doc	D1	Ci1 Co1	Fd	Int. Rev.	Co2	Ap, Edit.	Print					
Policy Doc		D1 Ci1	Co1	Fd, Ci	Co2	Ap, Edit.	Print					
International Symposia	1st Ann.		2nd Ann. Call pap.		Sel. Abstr		Final Prog.	X				

X = meetings   Ca = CAFF   Ci = Circulation   S = Selection
Co = Comments   FD = First Draft   N = nominations   C = Confirmations

Appendix 4

List of Acronyms

ACIA	Arctic Climate Impact Assessment
AMAP	Arctic Monitoring and Assessment Programme
ASC	Assessment Steering Committee
CAFF	Conservation of Arctic Flora and Fauna
EU	European Union
IASC	International Arctic Science Committee
ICES	International Council for the Exploration of the Sea
IPCC	Intergovernmental Panel on Climate Change
IPO	Indigenous People's Organization
PICES	North Pacific Marine Science Organization
SAO	Senior Arctic Official
TEK	Traditional Ecological Knowledge
UN	United Nations
UV	Ultraviolet Radiation
WCRP	World Climate Research Program