AMBIO (2011) 40:3–5
DOI 10.1007/s13280-011-0210-0

Arctic Cryosphere: Changes and Impacts

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Abstract The Arctic cryosphere is a critically important component of the earth system, affecting the earth's energy balance, sea level, greenhouse gases and atmospheric circulation, transport of heat through ocean circulation, ecology and human resource use and well-being. The Arctic cryosphere is, however, changing rapidly with multiple important consequences that will potentially affect the earth system including the human population. The drivers of changes in the Arctic's cryosphere, the recent and projected changes in the cryosphere and the consequences for future climate warming, sea level rise, ecology and human well-being, have been comprehensively assessed by the Arctic Council's Snow Water, Ice, and Permafrost in the Arctic (SWIPA) Project through its Arctic Monitoring and Assessment Programme Working Group. This article introduces the assessment and the associated papers within a special issue of the journal Ambio that extract and present some of the major findings of the SWIPA report.

Keywords Snow · Water · Ice · Permafrost · Arctic · Climate feedbacks · Ecology · Atmospheric circulation · Ocean circulation · Societies · Cultures · Peoples

INTRODUCTION

The Arctic cryosphere is a critically important component of the earth system. It affects the energy balance of the earth, resulting in a net cooling; its dynamic processes affect air and ocean circulation at a global scale; it stores freshwater from seasonal to millennial time scales and thereby regulates the availability of freshwater during the main growth season, and it affects sea level and thus the extent and shape of the earth's land masses, which determines the surface available for human habitation. Furthermore, the Arctic's cryosphere stores or regulates the release of large quantities of greenhouse gases such as methane and carbon dioxide. As the Arctic's cryosphere is experiencing dramatic change due to global warming, it has been the subject of extensive and recent research and assessment.

In 2005, the Arctic Council (www.arctic-council.org) published the comprehensive report "Arctic Climate Impact Assessment" (ACIA) (ACIA 2005) which drew global scientific and political attention to the effects of climate change in the Arctic. Observations of further cryospheric change in the first decade of the twenty-first century that often exceeded the rates of change predicted by ACIA (2005), spurred the Arctic Council to launch a follow up to the ACIA: the "Snow, Water, Ice, and Permafrost in the Arctic" (SWIPA, www.amap.no/swipa) project, the results of which were published in 2011 (AMAP 2011).

The SWIPA assessment builds on peer reviewed literature and has involved approximately 200 scientists and experts. Using the ACIA as the benchmark the SWIPA work synthesized observations and research on recent changes in and across the components of the Arctic Cryosphere and discussed potential effects of changes in a local, regional and global perspective. In its first stages, the project liaised with the International Polar Year (IPY, www.ipy.org) project office and national IPY contacts in order to ensure representation of major relevant IPY projects in the SWIPA assessment. Furthermore, the Arctic Council working group Arctic Monitoring and Assessment Programme (AMAP, www.amap.no) that was requested to carry out the assessment partnered with the International Arctic Science Committee (http://iasc.arcticportal.org), the World Climate Research Programme's Climate and Cryosphere Project, http://clic.npolar.no) and the International Arctic Social Sciences Association (www.iassa.org) to complete the task.

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The SWIPA report (AMAP 2011) is very comprehensive, containing about 542 pages and 12 chapters. The chapters include an introduction to the SWIPA process, chapters on the main climatic drivers of changes in the cryosphere, specific components of the cryosphere (lake and river ice, permafrost, sea ice, snow, small mountain glaciers and ice caps, and the Greenland ice sheet) together with synthesis chapters that bring together consequences of changes in the major cryospheric components for feedbacks to the climate system, sea level, ecology and Arctic societies, cultures and peoples. A final overview chapter sets all this information within the context of progressive interactions over time and space between the changes in cryospheric components and their multiple consequences (AMAP 2011).

GOALS OF THE CURRENT STUDY

The main goals of the current Ambio special issue (Callaghan et al. 2011a [this issue]) are to

(a) summarise some of the extensive key SWIPA chapters.
(b) make this information more widely available to a global audience with multi-disciplinary interests.

We achieve these goals through the identification and focusing on key material from many of the SWIPA chapters by the original lead authors. As the SWIPA chapters were comprehensively reviewed with documented and approved revisions (available from www.amap.no), the authors have ensured that factual material and interpretations are consistent between these original chapters and the condensed separate manuscripts that comprise this special issue. Furthermore, the SWIPA findings have been made more accessible by publishing in the widely distributed journal "Ambio" which is "A Journal of the Human Environment".

STRUCTURE

This special issue of Ambio presents papers that assess: recently observed changes in Arctic Climate that drive and interact with the Arctic's cryosphere (Walsh et al. 2011), recent, on-going and projected changes in snow (Callaghan et al. 2011b, c) and river and lake ice (Prowse et al. 2011a, b, c), and the consequences of these cryospheric changes for feedbacks to the climate system (Callaghan et al. 2011d), ecology of the Arctic (Vincent et al. 2011), and societies, cultures and peoples (Hovelsrud et al. 2011). A final paper synthesizes the results of all these papers and places them within the context of the entire SWIPA assessment (Olsen et al. 2011).

Acknowledgments We thank all the participants in the SWIPA process for contributing to the completion of a comprehensive assessment of the changing Arctic cryosphere, its climatic drivers and multiple consequences. We are particularly grateful to them and the leadership of the SWIPA process for making the SWIPA results available for this Ambio special issue. Numerous national funding agencies supported the SWIPA process and we are grateful for this support. We are grateful for financial contributions to the SWIPA production from Canada, Denmark, Norway and the Nordic Council of Ministers. We are particularly grateful to the Swedish Environmental Protection Agency (grant number 08/210) and the Swedish Research Council FORMAS (grant number 204-2009-45) for the grants to TVC and MJ for the publication of this special issue, to Environment Canada for a further grant to TDP to complete the financing of the publication, and finally to Professor F. Wrona for facilitating this.

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