

ARCTIC HYDRA: THE ARCTIC HYDROLOGICAL CYCLE MONITORING AND ASSESSMENT PROGRAM

¹Thorsteinn Thorsteinsson, ¹Arni Snorrason, ²Charles Vörösmarty
and ²Jonathan Pundsack

¹Hydrological Service, National Energy Authority, Iceland

²University of New Hampshire, USA. E-mail: asn@os.is, thor@os.is

ABSTRACT

The scientific goals of the Arctic-HYDRA project are: To characterize variability in the Arctic Hydrological Cycle (AHC) and examine linkages between atmospheric forcing and continental discharge to the ocean; to assess the historical response of the Arctic Ocean to variations in freshwater input from rivers and net precipitation over the ocean; to attribute to specific elements of the AHC or to external forcing the sources of observed spatial-temporal variability in the land-ocean-ice-atmosphere system; to detect emerging changes in the contemporary state of the AHC in near real time and to place such changes into a broader historical context. Starting during the International Polar Year (IPY), Arctic-HYDRA also forms part of the parallel longer term (10-15 yr) objectives of the ICARPII WG7 project “Terrestrial Cryospheric & Hydrologic Processes and Systems”.

INTRODUCTION

Scientists focussing on issues related to the hydrological cycle in the Arctic have convened several times since 2005 to create and develop plans for a new international research consortium, Arctic-HYDRA. The main overarching questions that this consortium will seek to answer in future studies are:

- What is the role of the unified Arctic Hydrological Cycle (AHC) in the global climate system?
- What are the feedbacks of changes in the Arctic Hydrological Cycle on the regional and global climate systems?
- What are the impacts of changes in the Arctic Hydrological Cycle on the biology, biogeochemistry, and human society?

The plans for Arctic-HYDRA grew out of the need to link various ideas for Arctic research projects that were submitted to the planning office for the International Polar Year (IPY). It is recognized that these questions will not be definitively settled in the time span of the IPY (2007-2009), and hence they are meant to “set the stage” for the Arctic-HYDRA in the context of

other important Arctic science initiatives. The Arctic-HYDRA planning exercise entrained the perspectives of these ongoing or planned studies, as well as the individuals who have contributed to these intellectual frameworks. The Arctic-HYDRA community is in a unique position to ensure that its science agenda, to the highest degree possible, will build on existing questions and those that are cast to complement those of other ongoing projects.

THE ARCTIC IN THE CLIMATE SYSTEM

The Arctic exerts important influence over global climate through feedback mechanisms, by which Arctic processes can amplify initial climate changes (Serreze and Barry, 2005). Examples of such feedbacks are the warming effects of lowered surface reflectivity accompanying such changes as the decrease in snow and ice cover and the northward expansion of forests into tundras. Another important effect is potentially due to increased precipitation and runoff into the Arctic Ocean from adjacent continental areas, which would exert negative influence on deep-water formation and reduce sea ice formation. The resulting slowdown in the worldwide thermohaline circulation would slow the transport of carbon dioxide to the deep ocean, thereby allowing more rapid buildup of CO₂ in the atmosphere. A third important effect is the influence of climatic warming on the exchange of greenhouse gases between the atmosphere and Arctic soils and sediments, where large amounts of carbon are stored (ACIA, 2005).

Arctic HYDRA represents a new, consortium-based international study that aims to provide a quantitative picture of the state of pan-Arctic hydrological system in the years of the International Polar Year campaign and beyond. It will represent a critical benchmark against which to assess future change, with focus on cold land processes, on environmental impacts, the greening of the Arctic, on permafrost and frozen soils, on ecosystems, on changes and variability, aerosols, environmental change and people.

SOCIETAL ISSUES

Water is a fundamental component linking many of the environmental changes in the Arctic region, and society demands answers to how a changing Arctic Hydrological Cycle impacts humans, ecosystems, and earth systems. Specific societal issues of concern include commerce, shipping and resource extraction, pollution, coastal erosion, fisheries, forestry and vegetation changes. The Arctic Climate Impact Assessment (ACIA, 2005) summarized many of these changes, and stressed that not only are many of these already taking place, but they are expected to accelerate over the next 100 years and beyond. Furthermore, Working Group II of the IPCC Fourth Assessment Report stated with high confidence that climate change (e.g. temperature

increases) is affecting natural systems, including changes in snow, ice, and frozen ground/permafrost (IPCC, 2007). There is also high confidence that impacts will include increasing coastal erosion, increasing seasonal permafrost thawing depth, and reduced extent of permafrost and sea ice. While there are both projected benefits and negative impacts of these changes, there is increasing concern about the extent to which the inhabitants of Arctic regions will be able to adapt to these changes in the future.

OBSERVATIONAL STATUS

For process studies and modelling, the Arctic HYDRA consortium will build on existing meteorological, hydrological and cryospheric data sets from the Arctic region. The project will also facilitate the development of both research and sustained observations in the Arctic.

Temperature records, glacier and permafrost observations and data on sea ice extent and thickness all provide strong evidence for Arctic warming in the past decades (ACIA, 2005). A warming of 2-3 °C has been recorded in most of Alaska, in NW Canada and parts of Siberia. On average, annual Arctic temperature has increased by almost twice the rate as that of the rest of the world, with some variations across the region. Precipitation in the Arctic has, on average, increased by 8% in the past century.

Widespread cryospheric changes throughout the Arctic region are well documented. Most Arctic glaciers and ice caps have been in decline since the early 1960s, with this trend speeding up in the 1990s. Less certainty exists about recent changes in the state of the Greenland ice sheet, but the most recent assessments indicate accelerating mass loss from the ice sheet during the 1990s up to 2005. According to the latest IPCC Assessment report, Greenland was in 1996 losing about 96 km³ per year in mass from its ice sheet. In 2005, this had increased to about 220 km³ a year due to rapid thinning near the coast, while in 2006 it was estimated at 239 km³ per year.

The Arctic sea ice cover has been in dramatic decline over the past four decades. Between 1974 and 2003 the annual average sea ice extent decreased by 8% and average arctic-wide sea ice thickness decreased by 10-15%. Recent observations (NSIDC, 2007) indicate that sea ice retreat is more rapid than estimated by any of the computer models used by IPCC in preparing its 2007 assessment.

About 70% of the total terrestrial Arctic drainage area of 22.4*10⁶ km² is monitored at present. The mean annual drainage is estimated to be 3200 km³ and the four largest drainage basins, the Ob, Yenisey, Lena and MacKenzie, contribute about 68% of the total gauged volume discharge to the Arctic Ocean.

THE PROBLEM OF DECLINING NETWORKS AND THE NEED FOR A PAN-ARCTIC APPROACH

Access to comprehensive and reliable data sets on Arctic hydrology is of crucial importance for studies focusing on the role of the Arctic in the climate system. The rivers draining to the Arctic Ocean redistribute moisture from temperate regions to the high latitudes, and also connect very large and heterogeneous areas to the Arctic Ocean and its shelf seas.

The Arctic Runoff Data Base, ARDB, which is collected and maintained at the Global Runoff Data Centre, GRDC, in Koblenz, Germany, provides station information and data series of runoff gauging stations in the Arctic region (GRDC, 2006). With more than 2400 stations represented, this is the most complete international dataset on daily (1024) and monthly (2193) runoff in the Arctic. Another service, containing freely available Pan-Arctic river runoff data, is compiled at the University of New Hampshire, USA. The University of New Hampshire maintains a service providing near-real-time river discharge data for nearly 60 stations (ArcticRIMS, 2007).

Although Arctic nations currently expend about \$100 million annually on the collection of hydrologic data, the number of sites at which data are collected is declining (Shiklomanov and Shiklomanov, 2003). Many sites with long-term records have been discontinued in the past several years as funding has failed to keep pace with costs. As development and resource extraction in the Arctic increases, the need for hydrologic data also increases. The hydrological station network is still very uneven and no observations are carried out in one-third of the region. The observation series are of unequal lengths and numerous gaps exist in several records. Recent studies have highlighted the fact that the decline in station density has been greatest in regions that are projected to undergo the largest increase in temperature during the 21st century; i.e. in areas adjacent to the Barents, Laptev and Kara seas (Bring et al., 2007).

Arctic-HYDRA will provide a framework to:

- Design and execute a systematic process to evaluate the utility of key historical and operational data sets depicting the geospatial distribution of water cycle variables, using biogeophysical information generated over the satellite era and capable of assessing the fully pan-Arctic domain.
- Apply the evaluation process to create optimal deployments of monitoring network and remote sensing resources to construct an operational, contemporary depiction of the pan-Arctic water cycle during IPY and beyond.
- In concert with regional and global modelers, assess the effectiveness of current monitoring resources to detect plausible scenarios of Arctic environmental change.

- To provide feedback to data providers on the efficacy and value of their data sets to the user communities and to propose concrete suggestions on ensuring their relevancy.

TOWARDS AN INTEGRATED SYSTEM FOR ARCTIC HYDROLOGY STUDIES

Cast as a set of scientific objectives to support the overarching questions listed in the introduction, Arctic-HYDRA seeks to:

- Characterize variability in the Arctic Hydrological Cycle (AHC) and to examine linkages between atmospheric forcing and continental discharge to the ocean.
- Assess the historical response of the Arctic Ocean to variations in freshwater input from rivers and net precipitation over the ocean.
- Attribute sources of observed spatial-temporal variability in the land-ocean-ice-atmosphere system to specific elements of the AHC or to external forcing.
- Detect emerging changes in the contemporary state of the AHC in near real time and to place such changes into a broader historical context.

Given the scope of these objectives and the relatively short time-frame of the IPY, Arctic-HYDRA also forms part of the parallel longer term (10-15 yr) objectives of the ICARP-II (International Conference on Arctic Research Planning) Working Group 7 (WG7) project, “Terrestrial Cryospheric & Hydrologic Processes and Systems”. The Arctic-HYDRA project will use IPY as a stepping stone to longer-term, comprehensive water cycle studies (e.g. ICARP-II) and within ISAC (International Study of Arctic Change).

The Arctic-HYDRA project will consist of a core network of observations of the Arctic Hydrological Cycle (Arctic-HYCOS), coupled with a suite of intensive, focused process studies that are based on in-depth measurements and modeling of the individual components of the Arctic Hydrological Cycle (AHC). Furthermore, hydrological models and data assimilation techniques will be developed to generate a comprehensive, integrated description of the AHC including the feedbacks between the atmosphere, cryosphere and the oceans. The project will have a data management and information system in accordance with IPY and WMO protocol. It will establish links with other relevant clusters, e.g., meteorology, climatology, cryosphere, including permafrost, snow-cover and glaciers, biosphere and societal issues affected by the AHC.

CONCLUDING REMARKS

Arctic-HYDRA represents a unique opportunity to advance the science of the Arctic Hydrological Cycle and to establish a legacy of novel and

comprehensive pan-Arctic observational networks that will contribute to global earth observing systems. The project has been endorsed by the ICSU/WMO Joint Committee for the International Polar Year 2007-2008, and the Committee has stated that the proposal ‘includes very strong scientific, education and outreach components and demonstrates a high level of adherence to IPY themes and goals’, and that the activity would represent a ‘prominent and valued part of the IPY program’. Arctic-HYDRA is supported by WMO Hydrology and Water Resources (HWR) Programme, WMO Commission of Hydrology (CHy), WMO Commission for Basic Systems (CBS), WCRP/CliC and the Global Runoff Data Centre (GRDC), and is funded by the Nordic Council of Ministers as an IPY activity. The effort includes participation of representatives from all Arctic countries and Japan, as well as participation of all Arctic National Hydrological Services. Further information is available at: <http://arcticportal.org/arctichydra>

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