CHAMP Online Forum
January 30–February 1, 2002

Post Title: What is Arctic-CHAMP?
Posted by: *Larry Hinzman* at 5:25 PM 1/26/2002

The pan-Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP)

There is mounting evidence that the Arctic is now experiencing an unprecedented degree of environmental change. Many of these changes are linked to the arctic hydrologic cycle and are quite possibly the result of both the direct and indirect impacts of human activities. Despite the importance of this issue, the current state of the art cannot adequately establish these potential linkages to global change.

The primary aim of the pan-Arctic Community-wide Hydrological Analysis and Monitoring Program (Arctic-CHAMP) initiative is to catalyze and coordinate interdisciplinary research with the goal of constructing a holistic understanding of arctic hydrology through integration of routine observations, process-based field studies, and modeling. Four goals should guide this effort:

Goal 1: Assess and better understand the stocks and fluxes that constitute the arctic hydrologic cycle.
Goal 2: Document changes to the arctic water cycle, contributing a hydrological component to the multiagency Study of Environmental Arctic Change Program (SEARCH).
Goal 3: Understand the causes of arctic water cycle change and assess their direct impacts on biological and biogeochemical systems.
Goal 4: Develop predictive simulations of the response of the earth system and human society to feedbacks arising from progressive changes to arctic hydrological systems.

This online forum provides an opportunity for the broad community of Arctic researchers to discuss some of the fundamental questions related to the study of the arctic hydrological cycle prior to the ARCSS All-Hands Workshop in Seattle (Feb. 20–22, 2002). The important issues raised in this discussion will be used to guide the development and implementation of this program.

Thanks for your participation,

Charles Vörösmarty
Larry Hinzman

What are the major features and natural variability of the pan-Arctic water balance?

ARCSS Planning Discussion > **What are the major features and natural variability of the pan-Arctic water balance?** > **Introduction**

Post Title: Introduction
Posted by: *Richard Lammers* at 1:22 PM 1/29/2002

The question being asked in this Forum subsection is

"What are the major features and natural variability of the pan-Arctic water balance?"

The Arctic-CHAMP document on which this is based (Vorosmarty et al., 2001, page 34) outlines several gaps in our understanding related to this theme:

1) Fluxes through the water cycle (atmospheric vapor transport precipitation, evaporation, soil water, runoff)

2) Arctic atmospheric teleconnections to the larger climate system

3) Role of seasonal snowpack and permafrost water storages

4) Runoff generation and pathways

5) Continental discharge and connections to sea ice and deep convection

These points are broad in scope and should allow for many entry points for those wishing to discuss their areas of specialty. It is also recognized that these areas necessarily overlap with the other subsection questions. For example points 2 and 5 are closely linked with the subsection moderated by Mike Steele on ocean and atmospheric feedbacks.

In addition to the general themes listed above, we also include a few issues of a more specific nature. They are listed as questions which can serve to initiate additional online conversations:

A) How do changes in global climate affect the hydrological cycle in the pan-Arctic

B) Does a changing climate lead to an increase in extreme hydrological phenomena (e.g. floods, bank erosion, ice jams)?

C) How can we monitor a system when the monitoring system itself is degrading? (see Shiklomanov et al., 2002 for an example of river discharge gauge declines).

D) Do the current models perform sufficiently the tasks we are asking them to do?

E) Are the trends we have observed over the past century significant when viewed through the lens of glacial time scales?

Discussants are encouraged to submit to the forum their own questions, concerns, comments and responses. We invite open and hopefully lively discussion on all topics related to the pan-Arctic water balance.

Richard Lammers
Alexander Shiklomanov

References:

Shiklomanov A.I., R.B. Lammers, C.J. Vorosmarty (2002) Widespread Decline in Hydrological Monitoring Threatens Pan-Arctic Research, EOS Transactions, American Geophysical Union, v. 83, no. 2 (January 8, 2002), pages 13,16,17. Also available at ftp://eos.sr.unh.edu/pub/outgoing/Sasha/Network_paper_final.pdf.

Vorosmarty, C.J., L.D. Hinzman, B.J. Peterson, D.H. Bromwich, L.C. Hamilton, J. Morison, V.E. Romanovsky, M.Sturm, and R.S. Webb (2001) The Hydrologic Cycle and its Role in Arctic and Global Environmental Change: A Rationale and Strategy for Synthesis Study, Fairbanks, Alaska: Arctic Research Consortium of the U.S., 84 pp. Text can be found at http://www.arcus.org/ARCSS/hydro/index.html.

Post Title: Decline in Hydrological Monitoring Stations
Posted by: *Larry Hinzman* at 7:32 PM 1/31/2002

The moderators of this forum question published a very good paper in Eos two weeks ago (Shiklomanov et al., 2002) discussing the decline in river discharge monitoring stations in the Arctic. But, are more gaging stations really needed?

River discharge is the integrated response of a river catchment. However, the processes affecting discharge are so many and so complex that there is no good way to invert the river discharge back to a number of hydrologic processes. Although we need more gaging stations to understand global water balance, I don't think we will learn much more about hydrologic processes by adding more river gauging stations to the existing network. Personally I think we need a coordinated set of research basins, all monitoring snow distribution, snow melt, energy balance, soil moisture dynamics, runoff, evaporation, transpiration and sublimation with complementary techniques.

References:
Shiklomanov A.I., R.B. Lammers, C.J. Vorosmarty (2002) Widespread Decline in Hydrological Monitoring Threatens Pan-Arctic Research, EOS Transactions, American Geophysical Union, v. 83, no. 2 (January 8, 2002), pages 13,16,17. Also available at ftp://eos.sr.unh.edu/pub/outgoing/Sasha/Network_paper_final.pdf.

Post Title: Re: Decline in Hydrological Monitoring Stations (Larry Hinzman)
Posted by: *Alexander Shiklomanov* at 10:07 PM 1/31/2002

I agree with Larry that we need a coordinated set of research basins with integrated monitoring system but I think it would be better to use the existing long-term operated hydrological network as a basis then to establish a new one.
There are several issues concerning the monitoring network in the Arctic drainage I would like to point out:

1. The highest rate of the decline is observed in the remote, northern regions where the network is very sparse and our knowledges about hydrological processes are clearly not enough.
2. Freshwater inflow into the Arctic Ocean is increasing and it may effect on global oceanic processes and climate but an accuracy of inflow estimates is decreasing because of monitoring network degradation. In other hand to find out why it is happening we need information from various parts of the basin.
3. Global warming may increase the probability of dangerous hydrological events and the reliable monitoring network could help to overcome these extreme consequences. Just one example. Huge flood in the Lena river basin last spring was due to very high temperature in the upper basin part. Powerful water wave from south leaded to earlier break up, ice jams and very high water levels.
4. Another problem is a deterioration of quality in hydrometric data as result of decline in discharge measurements. In accordance with our estimates, based on information from 5 Roshydromet regional offices, about 5-10% of the gauges have not had the direct discharge measurements for at least a year. Even worse picture is observed in North America where the volume and quality of hydrological data have significantly decreased because of change of manual to fully automated observations. 0-3 discharge measurements per a year are usual for Canadian down-stream gauges although I think it is not enough to have good quality data even if there is a stable discharge-stage relationship.

All these issues could make more complicated the contemporary hydrological research in the Arctic.

Post Title: Re: Decline in Hydrological Monitoring Stations (Alexander Shiklomanov)
Posted by: *Matt Nolan* at 12:11 AM 2/1/2002

I travelled through eastern Siberia in summer of 2000 and witnessed firsthand that several meteorological stations that were at one time very complete have now fallen into complete disrepair and abondonment. As has been said many times, without distributed met data, we cannot hope to capture the natural variability of these variables. I wonder if perhaps we can launch an 'Adopt-a-Russian-Arctic-Met-Station' program within NSF, to both increase collaboration and maintain data collection?

Post Title: Re: Introduction (Richard Lammers)
Posted by: *dy* at 1:24 AM 2/1/2002

I read the discussions with great interest. I feel precipitation is the key issue in arctic hydrology and climate studies. Knowledge of the amount and the spatial and temporal distribution of precipitation has been a challenge for decades and is still a major challenge in our current efforts to quantify the water and energy cycle of the northern regions. The lack of operational observing stations over the Arctic Basin limited our ability to determine precipitation from

conventional station measurements. Remote sensing of snow water equivalent over terrestrial and sea-ice surfaces may help fill this void in the future as new microwave approaches are developed. Re-analysis of atmospheric models may also provide improved regional estimates. However, we still must rely on the conventional station precipitation measurements for development and/or validation of regional precipitation fields in the northern latitudes (Goodison and Yang, 1995).

Precipitation climatologies and maps of regional to global scales have been derived from the standard national precipitation gauge records that have long been realized as underestimates of true precipitation amounts and incompatible across national boundaries (Legates, 1995a; Sevruk, 1989; Karl et al., 1993; Yang et al., 1998, 1999,2001). These climatologies and maps have been extensively used for large scale hydrological and climatic analyses including evaluation of climate model simulation, input fields in global hydrological models, validation of satellite precipitation algorithms. Legates (1995a) reviewed the existing global precipitation climatologies and found some inconsistency in some regions. More relevant to this forum, Walsh et al. (1998) recently report considerable variation between Arctic precipitation estimates from different sources, and this discrepancy complicates the verification of the model simulations of Arctic hydrological variables, including our understanding of both terrestrial and Arctic Ocean fresh water balances. It has also created uncertainties in climate trend and variation analyses, and in calibration of remote sensing algorithms. As such, it has been realized that a narrowing of uncertainty of the observation precipitation estimates must be a high priority in the context of atmospheric model validation and arctic hydrological investigations (Walsh et al., 1998).

The major factors which contribute to uncertainties in the estimation of precipitation field in the high latitude regions include: 1) sparseness of the precipitation observation networks; 2) uneven distribution of measurement sites, i.e. biased toward coastal and the low-elevation areas; 3) spatial and temporal discontinuities of precipitation measurements induced by change of observation methods and by different observation techniques used across national borders; 4) biases of gauge measurements, such as wind-induced undercatch, wetting and evaporation losses, and underestimate of trace amount of precipitation (Goodison et al., 1998; Yang 1998, 1999). Of the above factors, systematic errors in gauge measurements are particularly important, because these biases affect all types of precipitation gauges especially those used in cold environments.

Studies have shown that these errors can reach up to 50-100% of the gauge-measured records in cold and windy locations (Black, 1954; Benson, 1982; Yang et al., 1998a).

The need to correct these biases especially for solid precipitation measurement has now been more widely acknowledged, as the magnitude of the errors and their variation among gauges became known and their potential effects on regional, national and global climatological, hydrological and climate change studies were recognized. To assess the national methods of measuring solid precipitation, the World Meteorological Organization (WMO) initiated the Solid Precipitation Measurement Intercomparison Project in 1985. Thirteen countries participated in this project and the experiments were conducted at 20 selected sites in these countries from 1986/87 to 1992/93. Thirteen countries participated in this project and the experiments were conducted at 20 selected sites in these countries from 1986 to 1993. Results of the WMO experiment (Goodison et al., 1998; Yang et al., 1995, 1998b, 1999a; Yang and Goodison, 1998) showed that wind speed was the most dominant environmental variable affecting gauge catch efficiency. Air temperature had a much smaller overall effect on gauge catch efficiency, and was found to be more important for mixed precipitation than for snow. Biases in solid precipitation measurements have been quantified for over 20 different gauge and shield combinations (Goodison et al., 1998). The catch efficiency of these gauges varies greatly, particularly for high wind speeds, for instance, from ~20% up to ~70% at wind speed 6 m/s, and shielded gauges generally measured more snow than the unshielded gauges (Goodison et al., 1998).

Recently there have been efforts to implement the bias correction methods to high latitude regions, such as in Alaska, Northwest Territories/Yukon, Siberia, Greenland, and the Arctic Ocean (drifting stations). The bias corrections have resulted in significant higher estimates of precipitation particularly in the high latitude regions (Metcalfe et al., 1994; Goodison and Yang, 1995; Yang et al., 1998a, 1999b; Yang, 1999). For instance, the bias corrections have increased the winter and annual precipitation amounts by up to 50-100% in Alaska and Siberia. The results also show changes in regime and variability (Legates, 1995b; Yang et al., 1998a, 1999a; Yang 1999; Forland et al., 1996). These results clearly show that precipitation amounts in these northern regions are much higher than previously reported and they also point to a need to review our understanding of water balance and the assessment of atmospheric model performance in the arctic regions. We therefore strong suggest that these biases must be documented and corrected in order to obtain a unbiased, consistent data set for large-scale hydrological and climatic investigations of the arctic regions.

Go to http://www.uaf.edu/water/faculty/yang/yang.html to see some of the references.

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Post Title: Re: Introduction (Richard Lammers)
Posted by: *Douglas L. Kane* at 2:24 AM 2/2/2002

It is imperative that we do every thing we can to develop long term data sets. There is no doubt that the more populated temperate regions of the world are far ahead of us in this area. We need to ensure that we maintain existing stations that have long records. Just having met stations and stream gauging stations is not enough. We need to have hydrologic stations that record other processes such as soil moisture and ET. We also need to start collecting spatially distributed data also. Hydrologic models of the future are going to be spatially distributed and we will need such data for input and to evaluate model performance. I also think that we need to establish hydrologic observatories that are simialr to the LTER sites. This LTHOs (Long Term Hydrologic Observatories) would be where we could collect long term data, collect spatially distributed data, carry out intense hydrologic process studies, evaluate process based models, evaluate remote sensing tools, interface with ecological groups, look for long term trends and change, etc. We also have to improve the quality of our data collection. Many of the past measurement methods were of sufficient quality for operational use (water supply, flood forecasting, power generation, recreation, etc.), but they are not of sufficient quality for climate change studies.

We need high quality, long term hydrologic data sets in the Arctic. There are no quick and cheap alternatives.

ARCSS Planning Discussion > **What are the major features and natural variability of the pan-Arctic water balance?** > **Runoff generation and pathways**

Post Title: Runoff generation and pathways
Posted by: *jmcnamara* at 7:16 PM 1/31/2002

Richard included runoff generation and pathways in the list of key gaps in our understanding. Here is a very brief summary of the work we have done on this topic with some thoughts on applications to climate change.

In two papers we showed that as the active layer thickens during the summer in the Kuparuk River basin the storm-scale water budget changes as pathways adjust. Runoff ratios descrease, old water (soil moisture) contributions to the hydrograph increase, and headwater contributions to the larger river increase. Except during the wettest of times, hillslopes without water tracks are essentially disconnected from the stream. Nearly all of the streamflow in small basins can be attributed to hillslope water tracks. In a third paper we showed that water tracks are a product of the presence of permafrost. These changing pathways during a season imply changing pathways for nutrient transport from the terrestrial to the aquatic system.

Question: Can we use the changes that we see now within a thawing season as an analog for long-term changes that may occur in the presence of climate warming?

References
McNamara, J.P., Kane, D.L., and Hinzman, L.D.1999. An Analysis of Arctic Channel Networks Using a Digital Elevation Model. Geomorphology, 29: 339-353.

McNamara, J.P, D.L. Kane, and L.D. Hinzman, 1998. An analysis of stream flow hydrology in an Arctic drainage basin: a nested watershed approach. Journal of Hydrology, 206: 39-57.

McNamara, J.P., D.L. Kane, and L.D. Hinzman, 1997. Hydrograph separations in an Arctic watershed using mixing model and graphical techniques. Water Resources Research, 33(70): 1707-1720.

Post Title: Re: Runoff generation and pathways (jmcnamara)
Posted by: *Bob Bolton* at 9:18 PM 2/1/2002

In the sub-arctic environment, the presence or absence of ice-rich permafrost is the major hydrologic control in stream flow. In the Caribou-Poker Creeks Research Watershed, we have observed that a watershed underlain with a large percentage of permafrost (>50%) consistently displays higher peak specific discharges, a lower specific baseflow between precipitation events, and a faster response time to precipitation events compared to a watershed with lesser amounts (<5 %) of permafrost (Haugen et al., 1982, Bolton et al, 2000). Baseflow in the lesser permafrost watershed tends to be much greater and sustained longer (measurable throughout the winter season) as water is able to infiltrate to deeper groundwater (pools) throughout the watershed.

If the amount of permafrost were to decrease in response to warming climate, we would see greater infiltration to groundwater and then longer recessions. This would in effect reduce the amount of runoff following rain storms and increase the amount of river discharge during the winter.

Bolton, W.R., Hinzman, L., and Yoshikawa, K. 2000. Stream flow studies in a watershed underlain by discontinuous permafrost. IN: D.L. Kane (ed.), Proc. Water Resources in Extreme Environments, American Water Resources Association. pp. 31-36.

Haugen, R.K., Slaughter, C.W., Howe, K.E., and Dingman, S.L. 1982. Hydrology and Climatology of the Caribou-Poker Creeks Research Watershed, Alaska. CRREL Report 82-26, 35 pp.

Are the observed changes in arctic hydrology part of the natural variability?

ARCSS Planning Discussion > **Are the observed changes in arctic hydrology part of the natural variability?** > **Effects of permafrost responses and fire hydrology?**

Post Title: Effects of permafrost responses and fire hydrology?
Posted by: *A. David McGuire* at 9:54 PM 1/31/2002

What are the expected changes to the hydrology of major river basins in the Arctic caused by responses of (1) permafrost and (2) the fire regime to climate warming in high latitudes? Will seasonality of discharge be affected, and if so how? Will the annual discharge of these rivers into the Arctic Ocean be affected, and if so how?

Post Title: Re: Effects of permafrost responses and fire hydrology? (A. David McGuire)
Posted by: *Larry Hinzman* at 1:22 AM 2/1/2002

Research conducted as part of the Frostfire project near Fairbanks revealed that boreal fires will create wetter soils (as compared to non-burned areas) due to decreased transpiration for about 10 years following a fire. After that, the soils in the burned area tend to become drier as the active layer thaws to an extent that allows internal drainage throughout the year. These burned areas were drier than comparable non-burned areas up to 80 years later (and perhaps longer). These changes in soil moisture will lead to subsequent impacts to stream flow and surface energy balance.

Understanding the confounded influences of a changing climate with the impacts of disturbance present a challenging problem.

Post Title: Re: Effects of permafrost responses and fire hydrology? (A. David McGuire)
Posted by: *dy* at 1:59 AM 2/1/2002

Dave

Our recent analysis of long-term discharge data discovered changes in hydrologic regimes of the major Siberian rivers (Lena, Yenesei and Ob) over the past several decades. These include 1) a significant increase in fall and winter discharge at the basin outlets (particularly for the Yenesei basin); 2) an early start of snowmelt period in mid May due to a strong warming in spring season and a decrease of river ice thickness over the Lena River, and 3) a shift of the Ob

River's maximum monthly discharge from spring snowmelt period towards summer season. These changes may impact cross-shelf movement of water, nutrients and sediments to the Arctic Ocean.

We feel that changes we have observed in the hydrologic regimes of these major Arctic rivers are very likely the consequence of changes in synoptic-scale atmospheric circulation, climatic warming, and the active layer and permafrost conditions over Siberia. Based on relevant studies, we hypothesize that warming in Siberia results in higher permafrost temperatures, a deeper active layer, and a longer thaw season. The thicker active layer, having a greater ground water storage capacity, in fact, has more ground water storage amount due to increased precipitation input and snowmelt contribution in early winter. This increased ground water storage and longer thaw season (especially the later freeze-up of the active layer) in turn result in greater contribution of subsurface water to the river systems and hence increase the winter season runoff.

To test and perhaps refine our hypothesis, we are examining the observational evidence of associations between river discharge and atmospheric and terrestrial variables, such as air temperature, precipitation, snowcover, soil moisture, timing and duration of the active layer depth, shallow ground water storage, river ice thickness, and Arctic oscillation (AO) index. Our ongoing research will focus on 1) defining regional hydrologic regime and change; 2) identifying regional climate variation and trends; and, 3) quantifying atmosphere-land interactions.

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ARCSS Planning Discussion > **Are the observed changes in arctic hydrology part of the natural variability?** > **Arctic river discharge trends.**

Post Title: Arctic river discharge trends.
Posted by: *peterson* at 4:49 PM 1/31/2002

The arctic carbon and freshwater forcing feedbacks to global climate change are predicted to have impacts extending far beyond the boundaries of the arctic and far into the new millennium. A critical scientific issue is how soon and how confidently can we distinguish progressive change forced by greenhouse warming from natural variability. If we can accomplish this, we can begin testing arctic data sets against the several GCM and regional models that make predictions about the behavior of the arctic system under climate forcing scenarios. In fact, perhaps we should be more aggressive in comparing hydrologic trends to global model predictions in an hypothesis-testing mode.

Our research group is working on such a test by comparing the long-term trend in arctic river runoff observed over the past 70 years with the freshwater forcing anomaly found in coupled atmosphere-ocean GCMs. The rates of change in arctic temperatures and in river runoff at continental scales appear to be consistent with the range of climate model predictions based upon CO2 forcing from 1860 to present. This could be just a coincidence or a causal linkage. And certainly there are many regional and decadal-scale variations present in the data that are not in the GCM outputs. I think the observed trends in temperature and discharge over the past century are at least partly driven by greenhouse warming.

I believe ARCSS should pursue an aggressive strategy of testing arctic data sets in the context of models and vice-versa even if we cannot prove the causal connection to greenhouse warming or other factors. We need to develop our big-picture understanding even in the face of acknowledged uncertainty. Building the big-picture can sharpen our questions and narrow the uncertainty. This is why we need the CHAMP initiative and synthesis.

Regards,
Bruce Peterson

How does the hydrologic cycle feed back to the oceans and atmosphere?

ARCSS Planning Discussion > **How does the hydrologic cycle feed back to the oceans and atmosphere?** > **Introduction**

Post Title: Introduction
Posted by: *Larry Hinzman* at 12:49 AM 1/30/2002

Atmospheric circulation patterns change seasonally and have complex interactions with ocean circulation, sea ice, and land-surface energy and water fluxes. Among these interactions, the link between the atmosphere and snow cover extent is relatively well established. Snow cover influences the surface energy budget in winter by insulating the surface and in spring by recharging rivers. Clark et al. (1999; citing also Thompson and Wallace 1998) found that the Arctic Oscillation (AO) correlates with Eurasian surface air temperatures. Temperatures in turn affect snow cover. The observed recent decrease in Northern Hemisphere spring/summer snow cover (Groisman et al. 1994) thus likely reflects large-scale atmospheric events.

Recent studies indicate the presence of decadal-scale variability in the extent and thickness of arctic sea ice. Recent trends show decreasing sea ice, especially in coastal/marginal seas. The potential for land/ocean/ice/atmosphere feedbacks and interactions that might occur in such a changing environment is significant, but not well understood.

If we start with an assumption of decreasing sea ice cover near the coast, which is equivalent to an increasing amount of open water, this should lead to more evaporation, which would encourage cloud formation and increasing precipitation. We also note the potential for additional precipitation advected to the coastal region from the central Arctic Ocean and/or lower latitude areas. In summer, increased precipitation would create more runoff and thus more discharge of fresh waters to the coastal ocean. A potential negative feedback might then result, since freshwater tends to stratify the coastal ocean and encourage sea ice growth.

What are other potential feedbacks and what are their impacts to the Arctic system?

Post Title: Re: Introduction (Larry Hinzman)
Posted by: *Mike Steele* at 2:58 AM 1/30/2002

River discharge is a (perhaps THE) major contributor to the high stratification found in much of the Arctic Ocean. Major shifts in the circulation of riverine-influenced ocean waters have been documented over the past decade, shifts that may be forced by N/AO wind stress changes. At the same time, a decrease in sea ice volume and extent has been observed which may or may not be related to reduced stratification in some areas of the Arctic Ocean. Estimates of the upward ocean heat flux that results from reduced stratification currently vary over an order of magnitude. Changes in stratification and sea ice cover may have positive or negative feedbacks on the atmospheric circulation.

Some questions:

How do changes in riverine-influenced oceanic circulation affect the sea ice mass balance?

How do these changes affect the surface heat balance?

How do these changes influence the deepwater convection zones in the North Atlantic Ocean, downstream from the arctic?

How will the arctic respond to an accelerated hydrologic cycle (i.e., more precipitation) that is expected in a global warming (high N/AO state) scenario?

Most numerical models use vastly oversimplified river discharge forcing and physics, and poorly resolve the shallow continental shelves and/or slopes. What is needed to improve these models in order to address the above questions?

Post Title: Re: Introduction (Mike Steele) Available Data Sets
Posted by: *dichtl* at 7:14 PM 1/30/2002

I thought that this CD-ROM data set might be of interest to those researchers that have joined in on this discussion. It can be obtained free of cost as noted below.

The R-ArcticNet: A Regional Hydrographic Data Network for the Pan-Arctic Region

This is comprehensive river discharge database that covers the entire pan-Arctic drainage system, and is available on CD-ROM. The collection comprises data from 3713 gauges and contains monthly river discharge data extending from the 1890s (for four Canadian and five Russian gauges) through the early 1990s, but the majority of data was collected between 1960 and 1990.

The pan-Arctic drainage region covers a land area of approximately 21 million km2 and drains into the Arctic Ocean as well as Hudson Bay, James Bay and the Northern Bering Strait. The collection also includes the Yukon and Anadyr River basins. Most of the drainage basins in the database are greater than 15,000 km2; however, the collection includes all available gauge data from Canada and Russia. Data from gauges measuring large drainage areas are of greatest interest to the regional, continental and global-scale scientific community for modeling purposes.

Individual station data are accessible through a graphical interface, or as tab-delimited ASCII text. Tab-delimited ASCII data are also compiled by hydrological region and as a single file for the complete data set.

The CD can be obtained by contacting NSIDC User Services at nsidc@nsidc.org, or by visiting the product web site at the following URL: http://nsidc.org/data/arcss062.html

Click on "Order CD-ROM" and complete the order form. The CD will be shipped to you cost free.

Post Title: Re: Introduction (Mike Steele)
Posted by: *rhines* at 8:44 PM 1/30/2002

Mike, what is your feeling about how models represent the off-shelf transport of cold waters that end up forming upper 100m of the Arctic water column, and the representation of convective sea-ice processes within the Basin? Is there any hope that this delicate advective/diffusive vertical structure can be modelled?

Post Title: Re: Introduction (rhines)
Posted by: *Mike Steele* at 9:19 PM 1/30/2002
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quote:

Mike, what is your feeling about how models represent the off-shelf transport of cold waters that end up forming upper 100m of the Arctic water column, and the representation of convective sea-ice
processes within the Basin? Is there any hope that this delicate advective/diffusive vertical structure
can be modelled?

Well... I would say that right now there's no large-scale ice-ocean model that does river shelf circulation very well. Part of the problem is your typical model issue, i.e., resolution. In particular, vertical resolution of shelves that can be 1000's of km wide and 100 m or less deep, combined with adequate resolution of the rest of the Arctic Ocean with abyssal depths greater than 4 km. We end up with poor resolution of the shelf, or with sigma coordinates, poor representation of the slope. I guess there's hybrid models and new bottom flow parameterizations out there, right? Maybe these can save us?

Another part of the problem is how river freshwater is numerically represented, i.e., typically as a salinity flux only. Most models don't include volume, heat, or momentum fluxes, which may be quite important. Further, there are strange and wonderful processes that occur during early summer in the arctic as the river discharge signal grows, e.g., overflow of warmish water ON TOP of fast ice, etc. Robbie Macdonald could better comment. Of course this relates to the "nearshore initiative" discussed in another virtual workshop!

And finally, models currently use river discharge forcing that varies anywhere from 0 - 4000 km^3/yr (with "0" modeled using climate restoring on SSS). This is a good example of why it's nice to get hydrologists and oceanographers working together.

Oh... I'd also say that the models do a pretty decent job of modeling the shallow Arctic Ocean surface boundary layer in which there's winter convection forced by ice growth. But perhaps you were referring to deep water formation in the Nordic and Labrador Seas... I'm not too familiar with that subject.

Post Title: Re: Introduction (Mike Steele)
Posted by: *jmcclelland* at 4:45 PM 1/31/2002

In the context of NADW formation, does it matter if freshwater inputs from rivers to the Arctic Ocean get exported as ice or water? Under different scenarios more or less water leaves in one form or the other, but the quantity of total freshwater export is essentially the same (or is it?). Increases in retention relative to export of ice could decrease total freshwater export on the short term, but in general increases in sea ice formation should be accompanied by increases in sea ice export.

Post Title: Re: Introduction (jmcclelland)
Posted by: *jamie* at 11:13 PM 1/31/2002

The ice exported from the Arctic melts in the Greenland Sea-North Atlantic and stratifies the ocean where it matters most to overturning circulation. The point that shouldn't be lost is that, this would occur even if there were no runoff to stratify the Arctic Ocean. Coincidently the ice export volume is the same order of magnitude as the runoff. Zhang et al 2000 indicate the ice export has increased as Arctic Ocean ice thickness has decreased. A feedback that perhaps has not been mentioned is runoff affecting sea ice production and export which in turn affects overturning circulation outside the basin.

Post Title: Re: Introduction (Mike Steele)
Posted by: *weingartner* at 2:04 AM 2/1/2002

I think that the crucial interface between the basin and the land is the shelves where the freshwater runoff is processed and eventually dispersed. This depends on the winds, shelf ice conditions, and the phasing and magnitude of the runoff. A few points to note:

1.) Even if the annual discharge does not appreciably change in the future the timing of it might. Under warming we might expect later soil freeze-up and earlier river breakup and soil thaw. This should result in a more even (than present) seasonal distribution of discharge onto the shelf, a shortening of the seasonal window over which shelf convection occurs, and a freshening of winter shelf waters. Coupled atmosphere-runoff models might provide guidance on how the annual discharge cycle will be altered due to warming and the associated changes in permafrost-active layer structure, rain/snow, heating/cooling, etc.
2.) The Laptev and Mackenzie shelves offer striking contrasts in how sea-ice morphology probably affects winter convection. The rivers feeding both shelves run year-round, although the discharge is markedly reduced in winter. The Mackenzie shelf has a prominent stamukhi zone (ridges and grounded ice floes) that results in a ponding of the Mackenzie runoff through winter. Offshore of the stamukhi zone deep convection can occur. (See papers by Melling, Macdonald and Carmack, etc.). The stamukhi zone is formed by winds causing an onshore drift of ice that is grounded along the landfast ice margin. Offshore winds prevail over the Laptev in winter and there is no stamukhi zone. Presumable the runoff is transported across the shelf and inhibits deep convection here. There are some nice ocean-ice modeling comparisons that could be made between these 2 shelves that would shed light on how freshwater is mixed and modified.

3.) Closely related to the above is the landfast ice zone which extends offshore to ~the 20 m isobath. This can be pretty far offshore on some shelves (~100 km on the East Siberian shelf). Does anyone know why it's offshore limit is the 20 m isobath? Landfast ice is an immobile lid so wind energy is not directly transferred to the underlying ocean. This energy is a major source of nearshore mixing. Hence one is left with a very stratified inner shelf when runoff commences. How might the landfast ice zone change under global warming? Will it be less extensive and if so, does this mean beans to the processing of the runoff?
4.) Once the ice is gone the winds play a big role in transporting/dispersing the freshwater. Upwelling favorable winds will carry it offshore, downwelling favorable winds will trap it in coastal currents and carry the freshwater laterally. How might changes in the winds alter freshwater dispersal mechanisms? What are the consequences of the Mackenzie runoff being carried primarily through the Archipelago rather than into the Arctic basin? One can ask this for other shelves as well. It should alter sites for dense water formation.
5.) Almost finally, many of these shelf processes occur on rather small scales that are missed by the GCMs. There needs to be an effort to marry shelf models capable of dealing with these processes to the GCMs.
6.) Maybe not apropos to this group, but I'd suggest that ARCSS consider a low-cost Arctic cod study. They form a critical link between the lower and higher trophic levels and they are significant to many arctic marine mammals. In talking to subsistence fishermen I understand that these fish can be easily caught through the ice. So consider a monitoring system using subsistence fishermen as the samplers. They could catch the fish and be trained to do a lot of simple measurements. Samples could then be preserved and sent to labs for more sophisticated analysis (condition, stomach contents, genetics, contaminants, whatever). They might serve as one (cheap) measure of the state of the arctic ecosystem. I suspect that in short order one could get villagers from around Alaska and northern Canada to participate. The joint whale work conducted between Barrow and the Chukotka natives might provide a venue by which this could rapidly be expanded to include the western Chukchi as well. Presumably a similar undertaking could be initiated by the Norwegians as well and eventually extend across northern Russia. Among the many useful things that such a program would do would be to permit meaningful participation by arctic residents in climate change studies.

Tom Weingartner

Post Title: Re: Introduction (Larry Hinzman)
Posted by: *claude* at 7:49 PM 2/1/2002

I haven't seen anything so far in the discussion relating to the role of lakes in the energy and water balance of northern basins. Lakes are an ubiquitous feature of the Canadian subarctic and arctic, particularly in the mainland regions, as well as the coastal plains of Alaska, Yukon, and eastern Siberia. Estimates of the areal surface coverage of lakes range from 15 to 30% depending on the particular landscape, which places them as a major component of the terrestrial landscape. Lakes of all sizes exert time lags into energy and water exchange processes because of their ability to transmit solar radiation and to store heat. This is particularly true of large deep lakes of which there are many in high latitude regions. Lakes are also very sensitive to climate change because they are often frozen during the high sun period before, during and after the summer solstice. Thus, climate change in the form of global warming has the potential to greatly enhance the energy and moisture exchange role of lakes at all temporal and geographical scales by stimulating earlier thaw dates. Also, later freeze-back dates means more evaporative moisture will be inserted into the atmosphere during early winter. Because lakes are a major component of most northern atmospheric and hydrologic

systems the ability to model their energy and water budgets is quite critical to our ability to forecast high latitude weather, climate and river flow patterns.

We now have substantial evidence that shallow subarctic and low arctic lakes are the most effective evaporators of any high latitude terrain type. We also know that the large deep lakes in the Mackenzie Basin are at the low end of the evaporation input to the atmosphere under average weather conditions but under very warm ice-free periods as during the major El Niño event of 1998-99 their water loss to the atmosphere rivals that of the Laurentian Great Lakes.

Studies must therefore be carried out to fully understand and model the role of lakes in the energy and water-balance of high-latitute regions, and to forecast the role that lakes will play in the water-balance, energy-balance and hydrology of these regions during climatic change.

Claude

Post Title: Re: Introduction (claude)
Posted by: *Bob Newton* at 8:54 PM 2/1/2002

Hi all -- replying to comments by Mike and Tom, regarding the behavior of river runoff on the shelves, ...
My experience is that one needs pretty tight resolution to capture the "order one" behavior of the spring flood onto the shelf seas. Something on the order of 5 meters in the vertical, at least for the upper 20 m; and on the order of several km in the horizontal. Anything less will distort the dynamics in a way that makes it very hard to force a realistic volume of freshwater into the model domain. ... and as Mike points out, the runoff a primary buoyancy source in the large-scale Arctic budget, so getting the input wrong is a serious mistake.

On the other hand, its not clear to me that getting the small-scale dynamics of the river-shelf interface right is a "sine qua non" for getting a model of the basin-scale distribution of runoff that is useful. Tom's work (with honest-to-god data) and mine (mostly with models) indicates that the Arctic rivers tend to form long coastal plumes. These are surface-trapped, narrow features near their sources and, throught the processes that Tom cites, are more dispersed downstream. But it leads me to the following suggestion:

Could one "skip over" the small-scale dynamics, and model the freshwater inputs as a linear feature, with some appropriate attention paid to the width and intensity of the freshwater inflow as a function of distance from a river.
In this context, ... I'm interested, along with Tom, in the differences between the Lena and Mackenzie. Two very different inflow regimes. But how different is the far-scale distribution of runoff? (Don't know the answer ... maybe Tom or Robie does?)

I think we want to be realistic about the number of scales that can efficiently be represented in useful model runs, and use high-res. shelf runs (validated with data as has been collected by Tom, Eddy, Robie, et al.) to get at "typical" coastal plumes. Then, use admittedly approximate boundary conditions for the basin-scale models.

Re. the inputs: As far as I can tell, the worst thing to do is one of the most common -- to adjust salinity at the river front to represent freshwater addition. I think this might actually result in a coastal flow opposite in direction to the observations. If one can't add momentum and/or mass, then I'd suggest that my proposal above is probably the right approach to get a realistic coastal plume. No. I take it back. This is the 2nd worst thing. The worst thing is to add river runoff AND to relax toward climatology. This really confuses the situation.

bob

Post Title: Re: larger scales and connections to Arctic
Posted by: *rhines* at 9:51 PM 2/1/2002

There are many pieces of the system coming out in the discussion. All seem important yet I think that models/obs are also needed which are good enough and big enough in coverage to see more global effects on the Arctic.

The Arctic Oscillation/NAO is a great organizing principle of this kind, which has roots in the stratosphere and tropics as well as high latitude (eg see Wallace and Thompson, Physics Today Feb 2002 for a nice summary). Are there other hemispheric or global modes that force the Arctic through its Atlantic inflow/deep outflow, Bering inflow, or runoff components? How well do the global coupled climate models predict high-latitude runoff? It seems to us in the ASOF (Arctic-SubArctic Ocean Flux) program that influence can move both north and south, and observing that influence will be valuable. New technologies are available which are beginning to show the sensitivity of the system: for example, high-resolution scatterometer winds (~25 km res over open water) show orographically influenced detail round Greenland, which involves intense winds blowing over the crucial boundary currents and passages; and, gliding autonomous undersea vehicles that will make repeated measurements of hydrography, oxygen, fluorescence, particle scattering even in the difficult seasons and regions. In narrow passages, new kinds of moorings allow currents, hydrography (plus some biologically interesting tracers) and ice to be measured with full depth coverage; isotope tracers of fresh water and nutrient tracers of Pacific water fraction. Water column observations in the ocean exist in very few places with any duration in time, yet where they do, the climate variability signal is huge (eg. Bravo in the Labrador Sea, Mike in the Norwegian Sea, and mooring measurements of the overflow in the Faroe-Shetland Channel). To synthesize these 'Arctic rim' events with the structure of the Arctic Basin ocean circulations, ice movement, runoff and atmospheric forcing should be a goal for the near future. The global perspective is important and yet climate models are particularly challenged (to use the politically correct word) in representing the high-lat processes of most importance.

A dominant event like the increased fresh-water loading of the subpolar Atlantic and Nordic Seas since the early 1960s has many possible origins, and I think it will take some large-scale synthesis to understand them.

Post Title: The role of DEMs in studies of lakes, runoff, and connections
Posted by: *Matt Nolan* at 10:27 PM 2/1/2002

I just wanted to bring up a subject near and dear to my research - Digital Elevation Models. Good DEMs are essential to studying most of the issues presented in this forum. Whether its calculating the surface area of all of the lakes, modeling runoff to ocean, storage in the 'soils', or the connections between them all, good DEMs will make the job easier (and often simply possible in the first place), and this is especially true of Arctic Alaska where the USGS DEMs suck.

I have recently been funded by NSF to acquire a new DEM of the entire Kupuaruk watershed at 5 meter posting and better than 2 m vertical accuracy. This data is true spectacular. My project is basically to validate the data hydrological and produce a distribution package so that all NSF researchers can have easy access to this DEM. The package should be complete in fall of this year. For more info on the DEM technology used, visit http://www.intermaptechnologies.com.

For my research, such data is essential. I study lakes and soil moisture in the Arctic, with satellite, models, and field measurements, and 5 m DEMs turn out to be absolutely essential for much of the work I'm doing. I mean, you can count pingos with this data! You can accurately measure lake shore lines of even small puddles! It is really jaw dropping.

I see this really as just the first step in a new mapping mission for Alaska. We really need help up here in terms of DEMs. I am in the process of coordinating an effort within NSF and NASA to map the entire state. That process is still in its infancy, but one thing that comes to mind is starting a forum like this at some point to gather ideas and impetus for the project, bringing together program managers, vendors, and PIs such that we can work out a plan to move forward. I hope to have some discussions like these at the Seattle meeting as well.

Anyway, at the risk of changing the subject slightly, I would very much like to hear any comments the community might have on how new DEMs would help their Arctic hydrological research (or how the current ones inhibit it) and learn whether other people think that DEMs are a good way to spend NSF money.

Cheers,
Matt

Post Title: Re: Introduction (Larry Hinzman)
Posted by: *HEicken* at 10:30 PM 2/1/2002

Another important component of interaction between the hydrologic cycle and oceanic/atmospheric/ice processes is precipitation, in particular snow, over the Arctic basin and marginal seas. Maybe this is not part of the hydrologic cycle in its strictest definition, but something that warrants a closer look. Obviously data on actual precipitation and snow deposition rates over the Arctic Basin are hard to come by and affected by a number of significant sources of error, but recent publications and data sets out of drifting stations provide a good start. Apart from regional and temporal variability in the freshwater flux into the surface ocean (which may not be all that important in the big picture that includes rivers and sea-ice melt, but others can comment on this), snow deposition on sea ice has a substantial impact on the heat and salt budget of the ice cover and the upper ocean, not only through its insulating properties but also as a key parameter in controlling ice albedo, both in winter and summer. Recent work at SHEBA and in Barrow appears to suggest that both surface melt ponding (another hydrologic feature if there ever was one) and the bulk freshwater retention within the ice cover during summer melt are highly sensitive to the total amount and distribution of snow on the ice.

While aware of the dangers of unnecessarily complicating the picture and models, it might be worthwhile to look in more detail at just what we need to know (and how well can actually know it) about the fluffy part of the hydrologic cycle.

ARCSS Planning Discussion > **How does the hydrologic cycle feed back to the oceans and atmosphere?** > **Arctic freshwater export and thermohaline circulation**

Post Title: Arctic freshwater export and thermohaline circulation
Posted by: *kfalkner* at 10:38 PM 2/1/2002

Regarding ocean/atmosphere feedback, there are a couple of issues yet to be mentioned in this forum that bear on whether/how the freshwater exiting the Arctic affects thermohaline circulation in the North Atlantic. I raise them since they are relevant to understanding the global impacts of the Arctic hydrologic cycle.

In the Greenland Sea, the strength of the gyre circulation determines whether freshwater gets shunted to the West Greenland current or can spread across the region and so inhibit local convection and dense water formation. A strongly doming gyre can counteract an enhanced ice/freshwater export flux through Fram Strait. How do the factors controlling gyre strength and total freshwater export relate to each other? Are they predictably related to the AO? North Atlantic deep water is renewed through overflows at the Iceland-Scotland ridge and the Denmark Strait. How does GIN sea convection impact these overflows? I believe these questions and related ones are the subject of studies to be undertaken by European colleagues as part of their ASOF program.

Freshwater/ice exiting at Fram Strait can most immediately impact convection regions of the North Atlantic whereas freshwater that exits the Canadian Archipelago feeds the region where North Atlantic intermediate water formation occurs. How do the freshwater fluxes through Fram Strait and the Canadian Archipelago relate to each other? Some models suggest that when they show a see-saw relationship such that when flux is high at Fram Strait it is lower through the Archipelago and vice versa. Is this indeed the case and if so what is the cause and what are the implications? How constant is their sum? We know the water mass assemblages of the Arctic underwent a dramatic shift in the early 1990's such that waters of Pacific origin were displaced from the Makarov Basin. How do such shifts affect outflow through the Archipelago passages?

I think it is important to address these questions with both an upstream and downstream view of the system. It might be posited that all one really needs to know is what boundary conditions the Arctic outflows pose on the North Atlantic. However, with that view, we will fail to develop an understanding of what causes variablity in those boundary conditions. Focusing our efforts on what controls variability in the freshwater distribution within the Arctic seems likely to reveal a minimal set of observations that would allow prediction of system modes (in analogy to observations which define ENSO states).

In that regard I think it is important to be able to indentify and distinguish among freshwater sources within the Arctic Ocean. The distributions need to be understood in the context of physical driving factors such as sea-surface height and wind fields. A variety of tracer-based efforts to do so have been undertaken by others and myself. In order to gain even a first order description of tracer distributions, often multi-year data sets are combined. More often than not there is a seasonal bias built in to these first order descriptions and information about sources is inferred. The time is ripe to define, in concert with both modelers and physical obsservaltionalists, a key set of "synoptic" and time-series tracer observations to address issues of variability. These would probably involve time series measurements in rivers, Bering Strait and at a few select sections within the Arctic as well as at sections related to the outflows.

Although my discussion is focused on the climate variability, the exact pathway that freshwaters of various origins take have implications for humans living in the Arctic. For example, some of the highest HCH concentrations in the world's ocean are found in the Beaufort Gyre. Since these waters feed outflows through the Archipelago, this could have implications for the wild life and people in the region.

ARCSS Planning Discussion > **How does the hydrologic cycle feed back to the oceans and atmosphere?** > **Evapotranspired water leaving Arctic?**

Post Title: Evapotranspired water leaving Arctic?
Posted by: *R.M. Holmes* at 9:44 PM 2/1/2002

When water is evapo-transpired in Arctic watersheds, are there significant routes by which it can leave the Arctic other than in ocean currents (i.e., Arctic Ocean to North Atlantic then south…)? In other words, is atmospheric water vapor transport out of the Arctic significant, or does most all water vapor entering the Arctic leave via the ocean?

Max Holmes
Marine Biological Laboratory
Woods Hole

ARCSS Planning Discussion > **How does the hydrologic cycle feed back to the oceans and atmosphere?** > **Roles of ecosystems/humans in feedbacks to climate?**

Post Title: Roles of ecosystems/humans in feedbacks to climate?
Posted by: *A. David McGuire* at 9:47 PM 1/31/2002

Changes in high latitudes may also have consequences for the functioning of the Arctic System that are associated with (a) water and energy exchange with the atmosphere, (b) the delivery of fresh water to the Arctic Ocean, and (c) the exchange of radiatively active gases with the atmosphere (Chapin et al., 2000; Forman et al., 2000). Thus, it is important to understand terrestrial changes that have consequences for the Arctic System because these responses may affect the rate and magnitude of changes that occur high latitudes and elsewhere. Changes in arctic hydrology may affect each of these feedbacks to the climate system. For the water and energy exchange feedback, water exchange with the atmosphere is an important aspect of hydrology. For the feedback with respect to fresh water to the Arctic Ocean, hydrology is obviously involved. For the radiativiely active gas feedback, water is often coupled with CO_2 exchange of vascular plants, and aerobic/anaerobic conditions associated with the water content of soils plays a role in methane exchange. Will hydrological changes impact ecosystems and humans in high latitudes to affect climate? If so, what are mechanisms involved.

What are the impacts of arctic hydrological changes on ecosystems and humans?

ARCSS Planning Discussion > **What are the impacts of arctic hydrological changes on ecosystems and humans?** > **Introduction -- Research on Ecosystem and Human Impacts**

Post Title: Introduction -- Research on Ecosystem and Human Impacts
Posted by: *Larry Hamilton* at 10:46 PM 1/29/2002

Environmental changes across the Arctic affect biological and human communities in many ways. The recent CHAMP report contains tables (5-1 and 5-2) suggesting a few general examples of impacts or points of contact between physical, ecological and social systems. For instance, the ecological consequences of permafrost thaw could include slumping soils that disrupt vegetation; decrease in wildlife trafficability; increased export of C, N, P and sediments; increased likelihood of fire; and greater productivity and sediment loads in lakes and streams. The human consequences of permafrost thaw could include damage to structures (buildings, water and power systems, pipelines) and transportation links (roads, runways); complication of overland travel and subsistence activities; reduction of subsistence resources; and increases in water-borne disease.

Arctic hydrological cycles have "downstream" consequences for humans and ecosystems outside of the Arctic as well.

We could speculate at length about ecological and human impacts from Arctic hydrological change. What are the most obvious and important areas? Are there inobvious but important ones that need attention too?

And then critically, what new research do we need, to address these issues and move us beyond speculation?

Post Title: Re: Introduction -- Research on Ecosystem and Human Impacts (Larry Hamilton)
Posted by: *Orson Smith* at 5:27 PM 2/1/2002

Larry,

I've been involved in a number of recent discussions among engineers of prospective consequences to Alaska infrastructure from global warming. Rural villages on river banks often already have problems with flooding, streambank erosion, reliable water supply in winter, and efficient sites for disposal of solid and liquid waste. A changing Arctic hydrological system will affect all these problems in ways that are now difficult to predict.

Villages with flooding and streambank erosion concerns can expect these trends to accelerate with increased precipitation, more frequent and intense storms, and accelerated thawing of permafrost. I suspect more and more villages will not be economically sustainable at their present locations.

Feasibility studies of any new major public works should consider changes from global warming. Scientific research can aid in these considerations by improving the ability of engineers to predict trends and extreme events (precipitation, storm hydrographs, etc.) on a time scale of 20 to 30 years (e.g., the life of a school building).

Decision-makers should weigh long term costs of building at the present site versus an alternative site on higher, more stable ground. Moving whole villages lock, stock, and barrel all at once may often not be necessary. A road to the new site, built in conjunction with the first opportunity for major public investment, can literally pave the way for a gradual move, as opportunities allow.

These questions offer fertile ground for some great exchanges between scientists, engineers, and public policy makers.

Orson Smith
School of Engineering
University of Alaska Anchorage

Post Title: Re: Introduction -- Research on Ecosystem and Human Impacts (Larry Hamilton)
Posted by: *Matt Berman* at 10:44 PM 2/1/2002

Ice roads have increasingly replaced conventional roads as the preferred means of access to remote resource extraction sites. In addition to the opportunity for substantial cost reduction, ice roads cause far fewer environmental impacts. Ice-bridges are particularly attractive for crossing larger streams and rivers, avoiding the need to construct costly bridges. Table 4-2 in the CHAMP report notes that the average time from freeze-up to break-up has decreased by nearly three weeks in the past century and can be expected to decrease further as the climate warms. Construction of ice roads, however, works best at temperatures substantially below freezing. Thin ice on rivers creates a safety hazard for travelers. The season of safe ice road use across or along rivers depends on hydrological conditions as well as ambient temperature. Have ice road conditions been systematically monitored at fixed sites -- for example, at Dawson, YT, and the Dempster highway crossing of the McKenzie -- so that predictions might be made of the relationship between predictions of regional climate models and local conditions?

Post Title: Re: Introduction -- Research on Ecosystem and Human Impacts (Matt Berman)
Posted by: *Larry Hamilton* at 2:42 PM 2/2/2002

Ice roads and vehicle breakthroughs could be a real problem. I've heard anecdotally that there has already been an increase in accidents – does anyone have data?

As for moving communities, I know at least one (Kivalina) where this has been discussed for some time. The main concern there is shoreline erosion; the Chukchi Sea is consuming the gravel bar on which the village sits, at a rate (hearsay) around 1m/year. It would be expensive, requiring much outside help, to move even this small village to more stable ground. The cost of moving many villages would be huge.

A third issue connects with a pressing fact of daily life in North American arctic communities: fresh water and waste disposal. This is already problematic in many (most?) places, and could easily become moreso with permafrost melting and soil failures.
Major engineering features (buildings, pipelines, roadways etc.) present challenges that are obvious to outsiders, but some of these other potential troubles might be most salient to folks living in arctic towns and villages.

ARCSS Planning Discussion > **What are the impacts of arctic hydrological changes on ecosystems and humans?** > **Will impacts of arctic hydrol. changes on ecosystems/humans affect climate?**

Post Title: Will impacts of arctic hydrol. changes on ecosystems/humans affect climate?
Posted by: *A. David McGuire* at 2:47 AM 1/30/2002

Changes in high latitudes may also have consequences for the functioning of the Arctic System that are associated with (a) water and energy exchange with the atmosphere, (b) the delivery of fresh water to the Arctic Ocean, and (c) the exchange of radiatively active gases with the atmosphere (Chapin et al., 2000; Forman et al., 2000). Thus, it is important to understand terrestrial changes that have consequences for the Arctic System because these responses may affect the rate and magnitude of changes that occur high latitudes and elsewhere. Changes in arctic hydrology may affect each of these feedbacks to the climate system. For the water and energy exchange feedback, water exchange with the atmosphere is an important aspect of hydrology. For the feedback with respect to fresh water to the Arctic Ocean, hydrology is obviously involved. For the radiativiely active gas feedback, water is often coupled with CO_2 exchange of vascular plants, and aerobic/anaerobic conditions associated with the water content of soils plays a role in methane exchange. Will hydrological changes impact ecosystems and humans in high latitudes to affect climate? If so, what are mechanisms involved.

Post Title: Will impacts of arctic hydrol. changes on ecosystems/humans affect climate?
Posted by: *Larry Hinzman* at 6:23 PM 1/30/2002

Shrinking ponds have been reported across Alaska and in the Old Crow Flats of Canada. The processes responsible for the decrease in pond size are probably not the same in all areas, nor are the consequences likely to be the same. We examined ponds on the Seward Peninsula to determine if recent changes in climate have impacted the dynamics of their development and degradation. These investigations included field studies through coring and thermal analyses, ground penetrating radar surveys and historical analyses through archival photographs and satellite imagery. Of the 24 ponds studied, 22 have decreased in area between 1951 and 2000. The two ponds that increased in size appear to be controlled by terrain while the remainder appear to be perched over permafrost. Ground penetrating radar studies near ponds that have decreased in size have shown taliks below the ponds, allowing sub-surface drainage to occur throughout the year. Analysis of meteorological data from Nome, Alaska indicates both warming and cooling trends and increases and decreases in precipitation. But over the last fifty years, the long-term trends do not show marked differences likely to cause drying of the ponds. If these trends continue, this could impact migrating waterfowl and the indigenous people use of that resource. It could also be indicative of wider spread drying of the surface with consequent impacts to the ecosystem and climatic regime.

Post Title: Re: impacts of arctic hydrol. changes on ecosystems/humans affect climate?
Posted by: *Henry Huntington* at 1:34 AM 2/1/2002

I'm curious as to whether hydrological regimes will shift geographically, or if they will change wholesale. I.e., will the Arctic continue to have more or less the same types of regimes in roughly the same proportion (just in different places), or will there be substantially less of some kinds, e.g., permafrost? The reason for asking is that in the past, for humans as well as for biota, migration and movement were means of adapting to changes. Today, we usually view human communities as fixed locations, but people still move frequently and for many reasons. If one community becomes less desirable a place to live thanks to hydrological changes, will people move to another community where conditions are stable or improving? Or if entire regions become less desirable, will people move south to big cities?

A couple research possibilities come to mind. First, trying to find out the extent to which hydrology influences people. This isn't easy, because people may not recognize hydrologic influences on their choices and because speculation about "what if permafrost melts" is difficult to make, but I don't think we have much idea now of the extent to which people's choices are influenced or constrained by hydrology, and exactly how this happens.

Second, how extensive have past hydrological changes been? Do they provide any analog for what we can expect? Is there any evidence in the archeological record of human shifts that can be tied, at least in part, to hydrology? Larry Hamilton urges us to get beyond speculation (or at least to identify research that will get us there), and I think documenting past and current influences of hydrology would be a good starting point.

Post Title: Will impacts of arctic hydrol. changes on ecosystems/humans affect climate
Posted by: *Andi Lloyd* at 3:10 AM 2/1/2002

Particularly in arctic areas with low topographic relief, changes in hydrology associated with permafrost warming/melting seem to have profound impacts on vegetation. We have some rather preliminary data on spruce expansion on the Seward Peninsula that suggest that at highly permafrost-affected sites warming/melting of permafrost can be associated with very rapid switches in plant community composition. If this pattern is a general phenomenon, then in areas where treeline is associated with abrupt changes in substrate condition, as along major river drainages in the low arctic, hydrological changes (particularly those associated with changes in permafrost) would seem to be a necessary precondition for vegetation change. I can see a couple of important research directions with respect to the question of how arctic hydrological change affects terrestrial ecosystems:

1) To what extent are hydrological changes (especially changes in permafrost) directional vs. cyclical? Is the formation then shrinking of thaw ponds that Larry described indicative of a directional change, or is this a cycle of freezing-thawing-refreezing that is continuous? This strikes me as a question that could benefit from a strong interaction between the paleo community and the modern-process community (for lack of a better term).
2) What is the nature of small-scale feedbacks between vegetation and hydrology in areas where permafrost is warming/melting, and how do those contribute to either the cyclical or directional nature of change in permafrost-affected systems? Given that we have at least preliminary evidence for rapid vegetation changes (i.e., conversion of tussock tundra to forest tundra in <100 yrs) associated with changes in permafrost, such feedbacks seem both likely and important, at least on small (i.e., sub-watershed) scales.

Post Title: Re: A look at the past on this issue of hydrol. impacts etc.
Posted by: *JulieBG* at 4:54 AM 2/1/2002

Larry's comment on shinking thaw ponds reminds me of observations David Hopkins and I made doing field work together. Given Davids observations over 4 decades its clear that many lakes of various types are drying out in many areas from Nome to Barrow (that I have seen). Thaw lakes do have cycles of formation and draining but it does seem that these comments

from Larry and Andi are important indicators of change that need study. Eisner and others are currently studying the stratigraphy of superposed thaw lakes (younger lake sediments on top of older lake sediments in repeated cycles) near Barrow and this type of work should be done in other areas to determine if the cycle is natural or if the current rate of drying out and shrinking is exceptional.

The paleorecord can guide us in determining the outcome of changes we see happening now as Andi mentioned. During the last interglacial (marine stage 5e about 132ka to 118 ka) the arctic was slightly warmer than it is now and our observations of this interval give us a plurred picture of the future. There is an extensive literature that shows, for example

1. Sea Ice -- Winter sea ice limits were at least 800 km north of where they are now (so north of the Bering Strait into the southern Chukchi sea). This means waters off shore of Nome and Wales and Gamble and Providenyia were ice free the year around (so more snow on the landscape -- see below). In the summers, the arctic basin may have been completely ice free once in a while though the evidence for that is tentative; nevertheless, the ice was much less extensive in summer.
2. Many (but not all) scientists now believe its likely that most of the Greenland ice sheet had retreated to minimal limits -- raising sea level 4-5 m according to Kurt Cuffey. I understand that the North Grip cores didnt find interglacial ice where they were thought it should be.
3. Permafrost in most areas had a deeper active layer and in some regions like most of Seward Penisula, we think the permafrost may have disappeared completely to allow karst developmment in some of the limestone surface rocks.
4. Vegetation changes were dramatic in response to all of this. Pat Anderson and Russian colleagues hinted that tundra in Chukotka was entirely eliminated as tree line advanced northward. The expansion of Pinus pumila (stone pine), for example tells us of deeper snows across wide areas. Deeper snows will impact the soil response and also increase runoff to rivers and to the ocean. At El'gygytgyn Lake SE of Pevek we see a large increase in the sedimentation rate during this time in response to increased runoff.
5. The ancient beaches of last interglacial age on either side of Bering strait and on St. Lawrence Island contain fossils (marine mollusks, diatoms, foraminifera etc) that indicate water masses bathing these shores were warmer. Moreover, we see a few exotic genera in the assemblages. For example, species now limited to northern Japan made it at least as far as Lavrentiya, Chukotka, across the strait from Big Diomede. Similar range extensions are seen on the Alaskan side even as far north as Barrow. The interglacial beaches, sand and gravel spits and lagoons at least between Pt. Hope and Barrow were much larger and I have always figured it was due to more open water later into the fall. Coastal erosion must have been greater.

There are many more examples . Easier to date are the permafrost, vegetation and soil changes that occurred 8-11 ka when the Arctic experienced an insolation maximum. Abundant wood and perfectly preserved spruce cones etc. in exposures along the outer coast of Baldwin Peninsula (south of Kotebue) date to this time and overlie wood from pervious interglacials. In otherwords, people in Kotzebue should expect the region to become completely forested again as the climate warms and sea ice retreats. In Barrow, near the village, we have dated organic matter from the base of the former active layer dating to this insolation maximum. These deposits are still frozen now (well, as of 1981 the last time I was there) but 10 ka ago, the active layer was 10s of cms deeper than it is now.

As many PARCS folks will tell you, this is probably where we are headed in the arctic with big impacts on the hydrological system and various ecosystems. But... How fast will this happen? In other words, How far are we now from such boundary conditions? Maybe 100 years if feedbacks are intensified? A group of the PARCS PIs are working on this via an NCAR modeling effort and this is an excellent example where our knowledge of the past can help frame the context and scope of observations other groups are making now. The PARCS group has identified "warm arctic" scenarios as a priority and this focus should go hand in hand with modern observations of a changing landscape.

Post Title: Re: A look at the past on this issue of hydrol. impacts etc. (JulieBG)
Posted by: *weisner* at 4:47 PM 2/1/2002

In response to comments on thaw ponds and the thaw lake cycle, discussed by Larry and Julie, the response of these systems to global change is, of course, never straightforward. Our current research on assessing carbon content of drained lake basins and the paleoecology of those basins has thus far indicated that many of these DRAINED basins are relatively long-lived, thus continuing to act as a carbon sink. Many of the 35 basins we have dated so far drained 2500 to 5000 years ago, which is longer than the original estimate for the entire thaw lake cycle. Also, the processes which lead to lake drained are not necessarily due to warming; Ross Mackay suggested that increased snowfall could lead to the damming of lake outlets during spring thaw, leading to overflow and drainage. There is some indication that there has been increased lake drainage in the Barrow region in the past few years; this needs to be verified, however.

Post Title: Re: A look at the past on this issue of hydrol. impacts etc. (weisner)
Posted by: *Larry Hinzman* at 5:32 PM 2/1/2002

The processes controlling pond dynamics will be highly variable depending upon the area. On the Seward Peninsula, the permafrost is quite warm and thin and (in the ponds that we have studied) has thawed completely below the ponds allowing downward drainage. The permafrost around Barrow and on the Old Crow Flats is much thicker so vertical drainage would probably not occur. Near Fairbanks, we are seeing many ponds shrinking in size, but with the construction of roads and re-routing of drainages, it is difficult to quantify the changes in pond recharge areas over time.

In any case, if we can difinitively define the mechanisms responsible for the changes, these ponds may provide evidence on changing water balance.

Post Title: Re: A look at the past on this issue of hydrol. impacts etc. (Larry Hinzman)
Posted by: *claude* at 7:27 PM 2/1/2002

During the last five or six years, residents of communities such as Old Crow, Yukon have repeatedly commented on a drying trend they see in local wetlands, in particular the Old Crow Flats. Similar comments have surfaced in Fort Yukon about wetlands of the Yukon Flats. In Old Crow people are alarmed about this trend because it seems to be something new within the past 15 or 20 years. Some people even fear the Old Crow Flats is drying up. This is of great concern to them as the Flats is a place they have traditionally hunted and trapped, and which they view as their "breadbasket". Recent aerial reconnaissance photos of the Old Crow Flats have revealed several major lakes and a number of smaller ones that have undergone drastic declines in water levels. Many other lakes show less drastic signs of declining water levels. Local residents, the First Nation Government in Old Crow, and the local Renewable Resource Council are very interested in learning more about what is happening and why.

The lakes of the Old Crow Flats are dynamic, exhibiting cycles of expansion, coalescence, draining, and refilling that are probably typical of shallow thermokarst lakes throughout the arctic. It is not surprising that some lakes would be in the drying or draining phases of this cycle at present, but it appears there now are an inordinate number that are drying or draining as opposed to filling or growing in size.

Preliminary results of C14 dates from ponds in the Bluefish Basin, immediately south of the Old Crow Flats, suggest that lakes/ponds went though a drying stage somewhere between 9000-10000 BP, probably in relation with the warmer and drier climate of that period. Between 1800-3000 BP the shallowest lakes/ponds (less than 1 m) were filled with peat. The development of peat, that can also be observed on the Holocene terrace of the Porcupine River, is related to the colder and wetter climate conditions of the region since about 5000 BP. The present climate warming we are experiencing could bring us back to conditions similar to that of the beginning of the Holocene.

With respect to the last point, we are currently monitoring changes in the areal extent of thaw lakes using a combination of aerial photographs (1953 to 1976) and co-registered optical satellite imagery (Landsat MSS/TM and SPOT PLA; 1973-present). Preliminary results from the analysis of the Landsat MSS/TM images indicate a decrease of about 3% in the areal extent of ponds/lakes since 1973.

I agree with Larry H. and others in that a study must be carried out in order to better define the mechanisms responsible for these changes, especially since the processes controlling pond dynamics are indeed highly variable depending upon the area (Barrow, Seward, Old Crow Flats & Bluefish Basin,…).

Claude

P.S. For those interested, we have a paper that was just recently published in the journal The Holocene that describes the response of the Old Crow and Porcupine rivers, YT, to Holocene climate change.

Lauriol, B., C.R. Duguay, and A. Riel, 2002. Response of the Porcupine and Old Crow rivers in northern Yukon to Holocene climate change. The Holocene, 12(1): 27-34.

Post Title: Re: A look at the past on this issue of hydrol. impacts etc. (JulieBG)
Posted by: *Andi Lloyd* at 1:47 AM 2/2/2002

It strikes me from this series of thought-provoking messages that we might want to think about getting a working group (breakout group?) going in Seattle to really consider the opportunities for and obstacles to developing some significant collaborations between researchers working at different temporal scales. It seems clear from this series of messages that this is a topic that is ripe for such collaboration, but we all know that such things do not happen either easily or by default. I'd therefore be really interested to consider in some depth (a) what the specific questions are that are most amenable to cross-fertilization between people working at different time scales, (b), what the conceptual obstacles are for using the paleo record to inform the modern observations and vice versa (e.g., what are the differences in variables measured or temporal/spatial resolution that would need to be resolved?), and (c) whether there are institutional/structural things we can do to encourage, within the CHAMP initiative or some other appropriate framework, formal collaboration among people working on different time scales.

Post Title: Re: A look at the past on this issue of hydrol. impacts etc. (Andi Lloyd)
Posted by: *Larry Hinzman* at 1:57 AM 2/2/2002

We will host a mini-workshop during the ARCSS All Hands Meeting in Seattle (Feb 20-23) to discuss (among many other issues) the topic of scaling across time and space. This is an important concept where great progress can be achieved through collaboration across disciplines. We welcome your participation in Seattle.

Post Title: Re: A look at the past on this issue of hydrol. impacts etc. (Andi Lloyd)
Posted by: *JulieBG* at 2:27 AM 2/2/2002

I completely agree with Andi and am happy to see that Larry Hinzman will organize some group discussions. There is an urgent need to link more of the paleo timescales with the modern observation. We tried to push this at the last All Hands meeting but not much came out of it, unfortunately. Seattle gives us a chance to think again about missed opportunities.