Hydroclimatological Data Rescue, Data Inventory, Network Analysis, and Data Distribution

Greta Burkart, Amy Jacobs, Jessica Cherry (PI)
University of Alaska Fairbanks
International Arctic Research Center and
Institute of Northern Engineering

Year 2 Collaborators: Horacio Toniolo, Bill Schnabel
Ongoing Agency Partners at USGS, BLM, USFWS, ADF&G, UAF, etc
Outline

• Motivation
• Objectives
• Phase 1
  • Creating a Database
  • Acquiring and Inventorying Metadata
  • Disseminating information – project website
• Phase 2
  • Data rescue and ingestion
  • Network Analysis
Project Motivation

• WILDREACH Report & NSSI Emerging Issues
• Establishment of the Arctic LCC
• Agency and researchers need
• Conveyance of institutional knowledge and field data to new generations of stakeholders
WILDREACH report: scientific priorities

- How reliable are the projections for increasing precipitation and evapotranspiration?
- How will the annual precipitation input on the Coastal Plain and Foothills be allocated between winter (snow pack) and summer?
- How will changes in precipitation, evapotranspiration, and active layer depth alter summer surface water availability in shallow-water and mesic/wet tundra habitats?
- How will changing patterns of seasonal runoff affect stream flow?
- What is the contribution of groundwater in various systems, and is it sufficient to maintain year-round flow?
- Will drought conditions and changes in drainage patterns decrease water body connectivity?
- Which Coastal Plain lakes are susceptible to tapping (rapid drainage) and on what time scale?
- What are the expected changes in snowpack characteristics (depth, density, presence of ice layers) and how might these vary on a regional and local scale?
- How much change will occur in the timing of snow melt and snow onset?
- How will the frequency of rain-on-snow and severe winter storm events change?
**WILDREACH report: species that may be impacted negatively by changes in climate and hydrology**

<table>
<thead>
<tr>
<th>Species</th>
<th>Warming temperature</th>
<th>Decreased connections between waterbodies</th>
<th>Drying of aquatic habitat</th>
<th>Change in ice-free/growing season</th>
<th>Increase in winter precipitation</th>
<th>Increase in summer storm events</th>
<th>Increase in rain on snow events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Billed Loon</td>
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<td>Pectoral Sandpiper</td>
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<td>Red Phalarope</td>
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<tr>
<td>Shorebirds</td>
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<td>Common Eider</td>
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<tr>
<td>Broad Whitefish</td>
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<tr>
<td>Dolly Varden</td>
<td>X</td>
<td>X</td>
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<td>Arctic Char</td>
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<tr>
<td>Lake Trout</td>
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<td>X</td>
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<td>Musk Ox</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>Caribou</td>
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<td>X</td>
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</tbody>
</table>
Highlights for *Weather and Climate*:

- Weather data collection is currently ad hoc
- Need a systematic approach to equipment maintenance and data collection, storage, management, and dissemination to assess patterns accurately.
- Agencies and other entities need to work together to inventory existing weather stations, undertake a gap analysis, and invest in an improved well-coordinated system.
- Need for improved weather data collection and management cannot be overemphasized.
Highlights for Hydrology and Lake Drying:

• With ongoing industrial development and environmental change, information from hydrological and meteorological networks in the Arctic is critical to management.

• Information needs apply to rivers, streams, lakes, ponds, and wetlands.

• Remote sensing technologies useful for understanding and monitoring hydrology have yet to mature, but warrant further research and development.

• Status and trends of hydrological processes are poorly understood.

• Changes expected to occur due to climate change are difficult to predict and, given the current paucity of information, may be difficult to document.
Management questions for Hydrology and Lake Drying:

1. What kind of network of long-term stream gauging stations is needed on the North Slope of Alaska?

2. Is the Arctic hydrologic cycle undergoing significant and rapid change in response to climate change and is it well understood how this will affect cycle complexity (floods, drought, etc.)?

3. Are alternative technologies for better quality data collection being developed? If so, will they lead to alternative regulatory requirements?

4. Hydrologic data for individual small headwater hydrologic systems (streams and lakes) are severely lacking, but might these systems, collectively, be very important?
Management questions for Hydrology and Lake Drying:

5. Are there significant data gaps in relating annual surface runoff to annual precipitation?

6. How does snow water equivalent (SWE) vary on a local scale? How accurately can we determine how much water is available in the snowpack at the watershed scale?

7. Spatially and temporally, how does water availability vary on the North Slope? Will energy exploration and development be able to move forward in water challenged environments?

8. How important are ephemeral streams to fish?
Objectives

- Improve data availability and dissemination
- Inventory and acquisition of hydrologic and related data held by state and federal agencies, and the private sector.
- Design a public database to house data and metadata related to hydrology and climate in arctic Alaska and begin to populate with metadata.
- Design and host a simple webpage with metadata, project description, and access to a GIS file with the station locations from the inventory.
- Use retrospective analyses to aid the Arctic LCC and partners in efforts to assess sampling designs for hydrologic monitoring networks.
Proposed project workflow and products for Phase 1 and 2

Design and create database

Develop and document formatting, normalization, and upload methods

Design and create web site

Relevant climate, hydrology, water quality, fisheries data

Data in need of rescue

Electronic data not in online databases

Data stored in online ODM databases

Identify data sources

Interpret, format, standardize, and create metadata

Upload

Acquire and archive data

Rescue as needed

Interpret, format, normalize

Revise metadata

Upload

SQL Server

Geo-Inventory

Rescued

Analysis-ready data

Network Analysis on analysis-ready data

Network Analysis Report

Trend Analysis

Correlation

Cost-surface

Geo-database

Data stored in online ODM databases

Data in need of rescue

Electronic data not in online databases

Data in need of rescue

Electronic data not in online databases

Data in need of rescue

Electronic data not in online databases

Data in need of rescue
Phase 1 -- So let’s get started

• We need a container to hold the data
• We need an interface for people to do simple queries
• We need to be able to do simple visualizations online
• We need the user to be able to download the data in their favorite format
• We need to acquire and ingest metadata
Phase 1 -- So let’s get started

• We need a container to hold the data
  – Want to coordinate with other efforts
• We need an interface for people to do simple queries
• We need to be able to do simple visualizations online
• We need the user to be able to download the data in their favorite format
• We need to acquire and ingest metadata
We need a container to hold the data

• Needs to be compatible with other efforts

SQL Server

Design and create database

Geo-Inventory

Rescued

Analysis-ready data

Link to online ODM databases (e.g. USGS NWIS)
# The Container – available models versus needs

<table>
<thead>
<tr>
<th>Feature</th>
<th>CUAHSI ODM</th>
<th>Berkeley Sensor</th>
<th>SciScope</th>
<th>ArcticLCC Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support hydrologic network analysis</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Link to other databases (WERC, USGS, STORET, etc)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Store point observations</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Store polygon, gridded, and transect observations</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Store hydrology, climate, and, potentially, biological data</td>
<td>P</td>
<td>P</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tables to prioritize processing of inventoried data</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Store ISO 19115 metadata standards</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Link each observation with traceable dataset heritage, including appropriate <strong>citation</strong> and QA/QC information</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Restrict access when necessary</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
SciScope (core only)
Phase 1 -- So let’s get started

- We need a container to hold the data
- **We need an interface for people to do simple queries**
- We need to be able to do simple visualizations online
- We need the user to be able to download the data in their favorite format
- We need to acquire and ingest metadata
What type of queries are needed for network analysis and answering WILDREACH/NSSI report questions?

1. Return all fish/hydrology/climate stations within bounding box (example: 70N 68N 150W 155W)
2. Which parameters are sampled by the above stations and for what period of time?
3. Return all stations that sample x parameter (i.e. temperature) within bounding box y for time period z (example: 1940-present, winter only)?
Potential Queries

Phase 1

**Space**
- **Site Name** from list (FishCreek)
- Entire extent / all sites
- Bounding Box (e.g. 70N 68N 150W 155W)
- Bounding polygon drawn by user
- Bounding circle drawn by user
- Land Management Unit (e.g. NPRA)

**Variables/Categories** (select from list)
- **Variable M** and **Sample Medium N** (e.g. temperature, discharge, precipitation)
- **General Category M** (e.g. Climate, Biota, etc)
- **Value Type** (e.g. derived, observed, model simulation result, report, etc)

**Source** (select from drop down list)
- **Organization** (BLM)
- **Source Description** (Federal Agency)
- **Contact Name** (Rickard Kiemnitz)

**Select Output**
- Sites

**Time**
- *Measured between time X and Y (e.g. X = 1 Jan 1900, Y = 10 Sept 2010)*
- *Measured during > X consecutive years (e.g. X = 10 consecutive years)*
- *Measured during > X years, total (e.g. X = 10 years, total)*

**Potential Query Output**
- All sites with observational data for particular variables or for all variables in a **General Category** collected by a particular organization.

**Bold** text indicates name of existing table or field in inventory/database
- * requires additional table or field for inventory
Phase 1 -- So let’s get started

• We need a container to hold the data
• We need an interface for people to do simple queries
• **We need to be able to do simple visualizations online**
• We need the user to be able to download the data in their favorite format
• We need to acquire and ingest metadata
Data Visualization

Trying to go with off-the-shelf freeware such as SQL Management Studio:
Kuparuk-DS-1F

FID: 362
SiteName: Kuparuk-DS-1F
Latitude: 70.29
Longitude: -149.68

Directions: To here - From here

Tracking Polar Bears

Image © 2010 TerraMetrics
Data: SIO, NOAA, U.S. Navy, NGA, GEBCO

Eye alt: 1315.17 km
Phase 1 -- So let’s get started

• We need a container to hold the data
• We need an interface for people to do simple queries
• We need to be able to do simple visualizations online
• We need the user to be able to download the data in their favorite format
• We need a project website
• We need to acquire and ingest metadata
Example of output in users favorite format

**Space**
- Site Name from list (Lake 9713)
- Entire extent / all sites
- Bounding Box (e.g. 70N 68N 150W 155W)
- Bounding polygon drawn by user
- Bounding circle drawn by user
- Land Management Unit (e.g. NPRA)

**Time**
- Measured between time X and Y (e.g. X = 1 Jan 1900, Y = 10 Sept 2010)
- Measured during ≥ X consecutive years (e.g. X = 10 consecutive years)
- Measured during ≥ X years, total (e.g. X = 10 years, total)
- Measured at irregular or regular intervals ≤ Z (e.g. Z = sporadic, annual, monthly, weekly, daily, hourly, 15-minute, etc)

**Combinations:**
- Measured at irregular or regular intervals ≤ Z from interannual date A to B between years X to Y (e.g. regular intervals, ≤ hourly, 1 May – 1 Jun, 1980 – 2010)

**Variables/Categories** (select from list)
- Variable M and Sample Medium N (e.g. temperature, fish presence, snow)
- General Category M (e.g. Climate, Biota, etc)
- Value Type (e.g. derived, observed, model simulation result, report, etc)

**Select Output**
- Sites
- Variables, medium
- Dates
- Category
- Sampling Interval
- Land Ownership
- Source
- Citation (required)

**Potential Query Output**
All sites, dates, variables, suggested citation, and information about source and sampling interval for variables in a Category collected at regular intervals ≤ Z at specified location, between specific dates, and with ≥ X consecutive years of data.

<table>
<thead>
<tr>
<th>Site</th>
<th>dates</th>
<th>Variable, medium</th>
<th>Citation</th>
<th>source</th>
<th>Sample interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine Site B</td>
<td>xxx-xxx</td>
<td>Temperature, air</td>
<td>xxxxxxxxxx</td>
<td>UAF, WERC</td>
<td>hourly</td>
</tr>
<tr>
<td>Mine Site B</td>
<td>xxx-xxx</td>
<td>Water Level, surface water</td>
<td>xxxxxxxxxx</td>
<td>UAF, WERC</td>
<td>hourly</td>
</tr>
<tr>
<td>Lake 9713</td>
<td>xxx-xxx</td>
<td>Presence, surface water</td>
<td>xxxxxxxxxx</td>
<td>ADFG</td>
<td>sporadic</td>
</tr>
</tbody>
</table>

**Source** (select from drop down list)
- Organization (Fish and Wildlife Service)
- Source Description (Agency)
- Contact Name (Joe Smith)

Bold text indicates name of existing table or field in inventory/database

* requires additional table or field for inventory
Phase 1 -- So let’s get started

• We need a container to hold the data
• We need an interface for people to do simple queries
• We need a tool to be able to do simple visualizations online
• We need the user to be able to download the data in their favorite format
• **We need a project website**
• We need to acquire and ingest metadata
Design and create database

Develop and document formatting, normalization, and upload methods

Design and create website

Relevant climate, hydrology, water quality, fisheries data

Data in need of rescue

Electronic data not in online databases

Data stored in online ODM databases

Identify data sources

Interpret, format, standardize, and create metadata

Ingest

Geo-Inventory

Rescued

Analysis-ready data

Geodatabase

SQL Server

Link to online ODM databases (e.g. USGS NWIS)

Data stored in online ODM databases

Inventory

Geodatabase with downloadable data

Project Website

Relevant climate, hydrology, water quality, fisheries data

Mine Site B

Mine Site B

Mine Site B

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Welcome

Welcome to the ArcticLCC Data Rescue and Inventory of Hydrology-Related data in Arctic Alaska.

Search by keyword or data type:

Submit  Clear Map

OR

View Catalog

If you have any questions or comments about the project, contact:

Dr. Jessica Cherry (loherry@evo.usf.edu)

Water and Environmental Research Center
University of Alaska Fairbanks
641 Duckering Road, R.O. Rev. 76550

International Arctic Research Center
University of Alaska Fairbanks
630 Knowles Dr., R.O. Rev. 76540
Phase 1 -- So let’s get started

- We need a container to hold the data
- We need an interface for people to do simple queries
- We need to be able to do simple visualizations online
- We need the user to be able to download the data in their favorite format
- We need a project website
- **We need to acquire and ingest metadata**
Acquiring metadata

Design and create database

Develop and document formatting, normalization, and upload methods

Relevant climate, hydrology, water quality, fisheries data

Identify data sources

Interpret, format, standardize, and create metadata

Upload

SQL Server

Geo-Inventory

Rescued

Analysis-ready data

Data in need of rescue

Electronic data not in online databases

Data stored in online ODM databases

Link to online ODM databases (e.g. USGS NWIS)

Design and create website

Project Website

Inventory

Geodatabase with downloadable data

Mine Site B

Temperature, air

UAF, WERC

hourly

Mine Site B

Water Level, surface water

UAF, WERC

hourly

Lake 9713

Fish Presence, surface water

AKDFG

sporadic

Inventory

Acquiring metadata

Relevant climate, hydrology, water quality, fisheries data

Identify data sources

Interpret, format, standardize, and create metadata

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SQL Server

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UAF, WERC

hourly

Mine Site B

Water Level, surface water

UAF, WERC

hourly

Lake 9713

Fish Presence, surface water

AKDFG

sporadic
Acquiring metadata

Dear Jane:

As partners of the Arctic Landscape Conservation Cooperative (Arctic LCC), we are creating a geodatabase of meteorological, hydrological, and aquatic ecosystem data from Arctic Alaska and Northwestern Canada (Figure 1). The Arctic LCC will use products generated from this effort to refine conceptual models, guide future research and monitoring efforts, and aid in informed and coordinated management of populations of fish and wildlife. More information about the Arctic LCC can be found at fws.gov/science/shc/pdf/DOIArcticLCCNarrative.pdf.

Our first step is an inventory of existing data. We will gladly accept any information regarding your dataset. If you have data or metadata to contribute, know of a potentially relevant database, are working toward a similar goal of data compilation, or have started to compile datasets, we would love to work with you to increase the availability of existing arctic datasets. To contribute information about your data to this inventory, please see Appendix A, call us, or send (arcticdata@gmail.com) the following information: your contact information, brief description of variables, approximate dates over which data was collected, and a brief description of spatial extent (or shapefile). A finalized version of this inventory will help us determine where to focus additional database efforts.

Our second step is to request and archive datasets, perform data rescue efforts, create standardized metadata, populate a geodatabase that can be accessed online, and link datasets to existing platforms. By contributing data, you will not only help the Arctic LCC, you will also increase citation of the valuable datasets you have collected and ensure that they are archived for the future! Citation information for contributed data will be linked to datasets and proper citation of data will be required. Our team includes dedicated data rescue experts who are eager to turn daunting stacks of field notes, hand drawn maps, photos, slides, digital files and raw datasets into user-friendly, streamlined datasets! Please see Appendix B for instructions on contributing data. If you would like to restrict access to your data, please let us know. We cannot promise to rescue and include all datasets in the final database, but at the very least we will document the need for rescue of your dataset.

See below to view potential database categories and to see more details on contributing to the Arctic LCC inventory and database. Please let us know if you have any questions or comments. Thank you for your time.

Sincerely,
The Arctic LCC Hydrologic Database Team:
Jessica Cherry PhD
Greta Burkart PhD
Jennifer March MS
Amy Jacobs MS

Appendix A

Phase 1: Data Inventory – tell us about your data
To contribute information about your data to the initial Arctic LCC inventory, please call us or send (arcticdata@gmail.com) any of the following information (target data for data inventory: September 2010, though we will happily accept information at any time):

- Your contact information and affiliation.
- Description of datasets and variables (be as brief or detailed as you have time to be).
- Format data is currently stored in (e.g. notebook, spreadsheet, database, 3 track, HDF, slides, photos, etc.).
- Time over which data was collected (if collected over multiple years, indicate which seasons)
- Spatial extent of data using one of the following formats: your own preferred format, brief narrative description of general location, coordinates, shape file, kmz file, or annotated map (e.g. creating and sharing a Google Maps using “my maps”).
- Other relevant information you might want to include about your data. This initial inventory will be updated and finalized at a later date.
## Source Contact List – continues to expand

<table>
<thead>
<tr>
<th>Agency/Project/Division</th>
<th>Starting Contact Point</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK DOT</td>
<td><a href="mailto:michael.knapp@alaska.gov">michael.knapp@alaska.gov</a></td>
<td>X</td>
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Phase 2

- Data rescue and ingestion
- Network analysis
Phase 2 -- Data rescue and ingestion

Design and create database

Develop and document formatting, normalization, and upload methods

Design and create web site

SQL Server

Geodatabase

Relevant climate, hydrology, water quality, fisheries data

Data in need of rescue

Electronic data not in online databases

Data stored in online ODM databases

Identify data sources

Interpret, format, standardize, and create metadata

Upload

Acquire and archive data

Rescue as needed

Interpret and normalize

Link to online ODM databases (e.g. USGS NWIS)

Ingest

Analysis-ready data

Rescued

Geo-Inventory

Inventory

Geodatabase with downloadable data

Project Website

Data stored in online ODM databases

Data in need of rescue

Electronic data not in online databases

Identify data sources

Interpret, format, standardize, and create metadata

Upload

Acquire and archive data

Rescue as needed

Interpret and normalize

Link to online ODM databases (e.g. USGS NWIS)

Ingest

Analysis-ready data

Rescued

Geo-Inventory

Inventory

Geodatabase with downloadable data

Project Website
## Phase 2 -- Data rescue and ingestion

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Phase 2 -- Network analysis

1. Design and create database
2. Develop and document formatting, normalization, and upload methods
3. Design and create website

SQL Server

- Data in need of rescue
- Electronic data not in online databases
- Data stored in online ODM databases

Identify data sources
- Rescue as needed
- Interpret, format, standardize, and create metadata
- Revise metadata
- Upload

Network Analysis on analysis-ready data
- Trend Analysis
- Correlation
- Cost-surface

Network Analysis Report

Data stored in online ODM databases (e.g. USGS NWIS)

Electronic data not in online databases

Relevant climate, hydrology, water quality, fisheries data

Data in need of rescue

Acquire and archive data

Design and create database

Design and create website

Network Analysis on analysis-ready data

Inventory

Geodatabase with downloadable data
Phase 2 -- Network Analysis

• Start to answer some of the WILDREACH/NSSI questions that pertain to trends and monitoring networks
• May look for input from Arctic LCC advisory groups
• Will publish our recommendations based on historical data density and practicality (i.e. maintaining priority watersheds, where are major gaps, cost surface analysis)
• Wrap up in February 2012
Some examples of how this database will help users address NSSI emerging issues and WildREACH questions
Questions related to improving capabilities of remote sensing tools

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<td>What climate and hydrology data is available to compare to lake surface</td>
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<td>areas estimated from remote sensing imagery obtained near Barrow in</td>
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## Questions related to management

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<td>What lakes are deep enough to have fish?</td>
<td>All lake depth data for specific area.</td>
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Questions, Comments?

Cherry, 2010
Data Rescue and Inventory of Hydrology-Related Data in Arctic Alaska

Overall Project Objectives (Phase 1)

- Inventory and acquisition of hydrologic and related data held by entities such as the USFWS, BLM, USGS, NSF, DOE, MMS, UAF, ADNR, ADFG, ADEC, other state and federal agencies, and the private sector. The focus of this inventory will be datasets that can be used to model how hydrologic processes may change and potentially affect fish and wildlife habitat under different climate scenarios.

- Design a public database that will house data and metadata related to hydrology, water quality, climate and aquatic ecosystems in arctic Alaska and begin to populate with metadata.

- Design and host a simple webpage with metadata, project description, and access to a geodatabase with station locations from the inventory.

- Participate in FWS-or agency discussions on North Slope hydrology and hydrologic data.

Overall Project Objectives (Phase 2)

- Improve data availability and dissemination of arctic climate, hydrology and ecosystem data

- Use retrospective analyses of network data to aid the Arctic LCC and partners in efforts to refine conceptual models, select climate change indicators, and develop dynamic predictive models

- Prioritize the locations and parameters for future watershed monitoring efforts that most efficiently answer management questions and reduce the uncertainty associated with predictive modeling
# ArcticLCC Documents

## Table: Documents

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<td>Data Request Document</td>
<td>22 Nov 2010</td>
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<td>Progress Report</td>
<td>23 Sept 2010</td>
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<td>Report Diagrams</td>
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<td>LCC Hydro Com Presentation</td>
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If you have any questions or comments about the project, contact:

Dr. Jessica Cherry ([icherry@iarc.uaf.edu](mailto:icherry@iarc.uaf.edu))

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Water and Environmental Research Center  
University of Alaska Fairbanks  
441 Duckering Bldg, P.O. Box 755860  
Fairbanks, Alaska 99775  
Tel: (907)474-5730  
Fax: (907)474-2643

International Arctic Research Center  
University of Alaska Fairbanks  
930 Koyukuk Dr, PO Box 757340  
Fairbanks, Alaska 99775  
Tel: (907)474-5730  
Fax: (907)474-2643
## Contributors

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Contacts

Dr. Jessie E. Cherry
Principal Investigator
International Arctic Research Center
University of Alaska Fairbanks
920 Koyukuk Drive
P.O. Box 787340
Fairbanks, Alaska 99776-7340
(907)474-6730
jcherry@larc.uaf.edu
IARC website

Dr. Greta Burkart
Project Manager
International Arctic Research Center
University of Alaska Fairbanks
920 Koyukuk Drive
P.O. Box 787340
Fairbanks, Alaska 99776-7340
(907)474-6513
gburkart@alaska.edu
IARC website

Greg Balogh
Arctic LCC Coordinator
greg_balogh@fws.gov
ArcticLCC website
WILDREACH report: potential effects of changes in climate and hydrology on fish and wildlife habitat

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<td>Improve utility of remote sensing data</td>
<td>What ice thickness and lake bathymetry data is available to calibrate data from SAR imagery collected in the Upper Kuparuk River Region between December and May 2010.</td>
<td>Ice thickness and lake depth data for a certain area during select years</td>
</tr>
<tr>
<td></td>
<td>What climate and hydrology data is available to compare to lake surface areas estimated from remote sensing imagery obtained near Barrow in 1982 and 2006?</td>
<td>All variables under the general categories of hydrology and climate for a specific area during a certain time.</td>
</tr>
</tbody>
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WILDREACH report: scientific priorities

Vegetation Community Composition and Phenology
• How will changes in the length and timing of the growing season influence plant phenology, including seasonal changes in nutritional quality?
• How will plant species composition shift in response to long-term climate change, and what are the implications for habitat structure and quality of the prevalent available forage (i.e., digestibility, nutrient content)?
• What is the time scale of expected shrub increase, and how will this vary by species/growth form (low vs. tall shrub) and ecoregion?
• What is the likelihood of widespread conversion from sedge and sedge-shrub meadow to bog meadow (paludification) and how would this affect herbivore and detritus-based trophic systems?
• How will changes in the seasonality of stream discharge and occurrence of flood events influence development of riparian vegetation communities?

Abundance and Phenology of Invertebrates
• How does earlier spring thaw affect timing of life cycle events and peak availability to predators?
• How does temperature affect growth and development of aquatic insects?
• What climate-related changes are likely in community composition of macroinvertebrates in stream, lake, and saturated soil environments?
• How will changes in the distribution and quality of surface waters and shifts from pelagic to benthic productivity in deep lakes affect availability of macroinvertebrates to fish and wildlife?
• How will warming and changing seasonality affect abundance and peak activity periods of biting insects and what are the bioenergetic consequences for caribou in particular?
• How will warming and changing seasonality affect the prevalence of parasites and disease vectors (e.g., nematode parasites of muskoxen and Dall’s sheep)?

Coastal Dynamics
• Will higher water temperatures, sea level rise, and retreat of summer sea ice cause degradation of the barrier island systems of the Beaufort and Chukchi seas?
• Will alluvial deltas continue to build or will rising sea levels outpace potential increases in sedimentation rates?
• How quickly will shoreline retreat result in newly breached lake basins?
• To what extent will coastal erosion, in combination with sea level rise, cause salinization of low-lying coastal areas?
• Will coastal wet sedge meadows establish at a rate equal to loss of this habitat through erosion and inundation?
• Will increased fogginess/cloudiness exert a negative or positive feedback effect on air temperature in the coastal zone? What is the expected spatial extent of this effect?