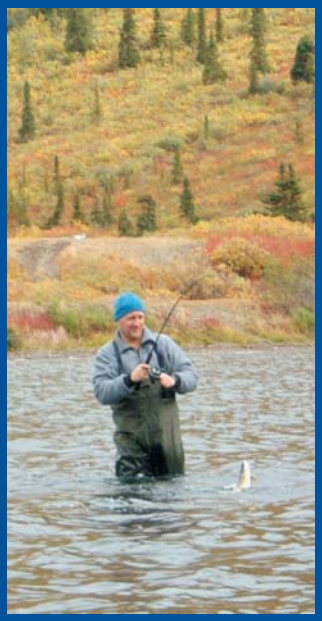
Climate and Water Resources in the Mackenzie Basin:

Science meets Society



The Mackenzie GEWEX Study (MAGS)

Climate and Water Resources in the Mackenzie Basin:

Science meets Society

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Contents

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Management Board Message

It has been a decade since the Mackenzie GEWEX Study (MAGS) was created, as the Canadian contribution to the World Climate Research Program. Our goal was to improve our understanding and ability to make useful predictions of the climate and the water resources in a cold region such as our Mackenzie Basin. Through our research, MAGS has made remarkable contributions to atmospheric and hydrological sciences. As our Study evolves, we plan to expand our work to apply our knowledge on climate variability and human-induced climate change to the management of Canada's water resources.

We have developed a well-functioning research network with partnership among universities, government agencies and the private sector. We owe our success to the congenial collaboration among our scientists and the generous support provided by our partner institutions. We believe there has to be a smooth interchange between scientific research and practical applications. In addition to being committed to scientific excellence, we are also committed to reaching out to the private, government and community sectors that we hope can make use our expertise to address issues of concern. It is with this in mind that this pamphlet has been prepared to communicate our research achievements and to stimulate greater interaction with stakeholders who share our interests and concerns on the implications of a changing climate on the Mackenzie Basin.

We hope that you find the information useful and we welcome your comments.

John Stone
Chairman, Management Board

Program Leader's Message

Through this pamphlet, we wish to reach out to you to share with you some of our exciting findings and to acquaint you with what we can do in addressing issues related to the environment and the resources of the Mackenzie Basin and similar cold regions. We are a group of some 80 government and university scientists who study the waters of the land surface and the atmosphere above. We embarked upon the Mackenzie GEWEX Study in 1994, initially to better understand the weather and climate, water resources and river flow patterns of the Mackenzie Basin. This improved understanding has prepared us to develop computer models that can simulate the connections between water resources and the atmosphere and help us predict how climatic fluctuations and change will affect all forms of water including snow, ice and permafrost.

We collaborate as a team, unfettered by the conventional confines of our research disciplines, to undertake projects that improve our knowledge of the physical environment of the cold region. This pamphlet summarizes our major research achievements. As we make progress in our planned program, we reach the stage when we welcome partnerships with stakeholders who share our interests and concerns regarding the weather, climate and water resources of the Mackenzie Basin. Our mandate is to address issues at the broad, regional level. The expertise in MAGS can make a meaningful contribution to the design of sound environmental and resource management policies and practices for northern Canada.

MAGS research continues to be a success story. Looking forward, we are confident that the application of our scientific results will bring direct benefits to the Mackenzie and other regions in the North.

Ming-ko Woo
MAGS Program Leader

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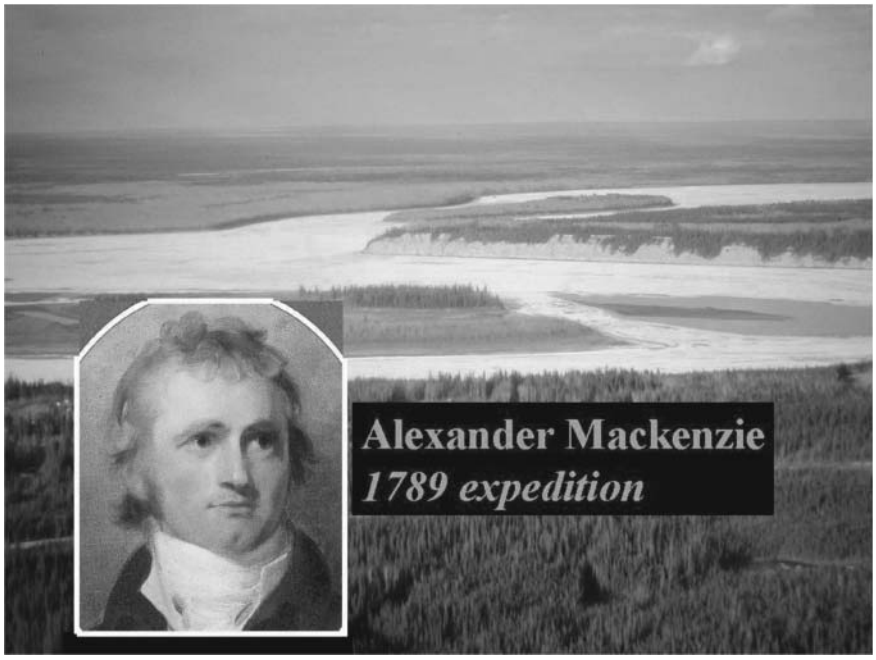

Alexander Mackenzie was a British explorer who on June 3, 1789, set out from Fort Chipewyan with his team of voyageurs, their wives, and a native guide known as "English Chief". Mackenzie hoped to find the Northwest passage and to claim territory for the North West Company. His team followed the large river that flowed west from Great Slave Lake. On July 13, 1789, Mackenzie and his team reached the Arctic Ocean after exploring much of the beautiful, rugged region. Mackenzie was very disappointed to see pieces of ice flowing in the salty waters as he knew he had not found the Northwest passage. He called the river "Disappointment River", and set out for home. In honour of the explorer, the river was later named the "Mackenzie River".

The Mackenzie River is one of the great rivers of the world and is the largest Canadian river flowing into the Arctic Ocean.

- The basin covers a large area (1.8 million km^2) and stretches over 15º of latitude.
- There are six main sub-basins, three great lakes, three major deltas, and more than 30,000 lakes of various sizes.
- The basin crosses three climatic regions (arctic, subarctic, boreal) and four major physiographic regions (Western Cordillera, Canadian Shield, Interior Plains, and Mackenzie Delta).
- The mean annual precipitation is 410 mm and the mean annual evapotranspiration is 237 mm.
- The Mackenzie River discharges about 300 km^3 of fresh water to the Arctic Ocean every year.
- The average monthly temperature is about -25ºC in winter and 15ºC in summer.
- Approximately 75% of the basin lies in the permafrost zone.
- Over 90% of the residents live in the southern part of the basin.

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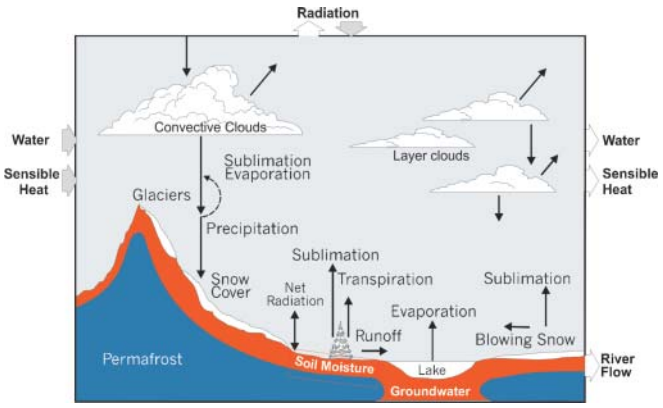
MAGS Goals

The Mackenzie GEWEX Study (MAGS) aims to improve our understanding of the water and energy cycle of the cold regions of the earth. It is the main Canadian contribution to the international Global Energy and Water Cycle Experiment (GEWEX).

Winds in the atmosphere carry water and heat around the Earth. As these winds blow over the lands and oceans, water moves from the surface to the atmosphere by evaporation and from the atmosphere to the surface by precipitation. This exchange of water also carries heat energy back and forth between the surface and the atmosphere. The water and energy cycle refers to this global pattern of circulation and exchanges that is a fundamental aspect of the Earth's climate system.

Our goals are:

- To better understand the way in which climate variability and change affects the energy and water cycle.
- To model changes to the energy and water cycle caused by climate change and climate variability.
- To apply this new knowledge and modelling capability to water resource and environmental issues in the Mackenzie Basin and other cold regions of the world.

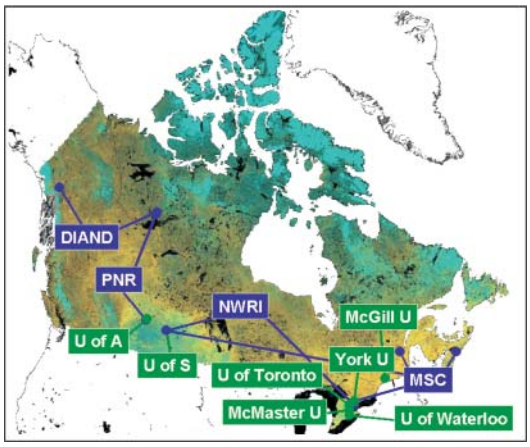


Cold regions water and energy cycle.

MAGS Research Family

Who are we?

MAGS is a collaborative research network made up of nearly eighty government and university scientists from across Canada. The network has expertise in many fields including hydrology, climatology, meteorology, atmospheric physics, remote sensing, computer science, civil engineering, and physical geography.



MAGS Research Network.

The MAGS network approach allows scientists to share a common data pool. It also brings together government and universities, hydrologic and atmospheric sciences, computer modelling and field studies, Canadian and international partners, and scientific and operational agencies. These links are essential to MAGS success.

The management structure and administration were designed to promote and support the scientific program by:

- Facilitating networking among institutions, scientists and stakeholders.
- Co-ordinating workshops and other scientific activities.
- Making our results available nationally and internationally.

What do we do?

Phase 1 of our program (1996-2000) focussed on improving our understanding of the behaviour of the energy and water cycle in the Mackenzie Basin. Phase 2 (2001-2005) concentrates on integrating this new knowledge into computer models that simulate and predict the behaviour of the Mackenzie Basin water and energy cycle. These models will be used to evaluate the impact of human-induced and natural climate variability on water resources in northern Canada and other cold regions. They will also help provide a scientific basis for planning, policy making and improved resource management.

Why the Mackenzie?

The Mackenzie River Basin was selected for this comprehensive study because:

- The major physical environments of northern Canada are represented in the basin making it an excellent natural laboratory for studying cold region processes.
- Global climate models suggest the basin is likely to experience significant climate warming.
- Climate change could change the input of fresh water from the Mackenzie River to the Arctic Ocean. This, in turn, could affect Arctic Ocean currents and influence the global climate.

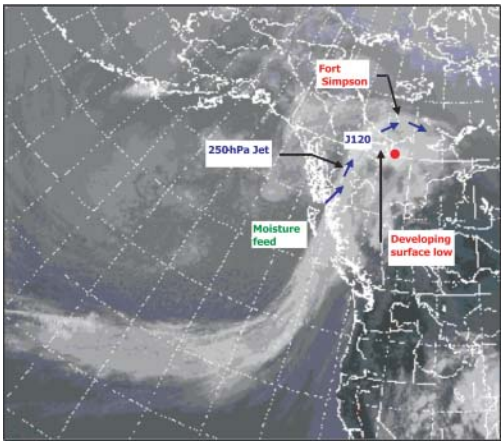
Climate and Weather

Where does moisture in the basin come from?

In winter:

Atmospheric flow into the basin from the Pacific Ocean and its interaction with the physical features of the basin regulate moisture and temperature conditions during winter.

Moisture transport into the northwest coastal region of North America occurs when cyclones initiated over the Pacific manifest themselves into the North Pacific storm track. When onshore winds are sufficiently strong, moisture and energy can be carried over and through the mountain ranges into the Mackenzie. Since the source of the moisture is from extratropical regions in the Pacific, this moisture transport mechanism is often referred to as the “Pineapple Express”.



“Pineapple Express”

The mountains in the west of the basin have a pronounced effect on cold season weather and climate in the basin. If low-level onshore winds are weak the coastal mountains block the windflow resulting in an abrupt turning of the winds to the north. Under these conditions, flow from the coast into the basin would be weak and cold winter conditions would prevail over the basin.

Conversely, if the onshore winds are strong the flow would have sufficient strength to push across the coastal mountains. As the air flows across the mountain barrier, it loses moisture by precipitation and produces anomalously warm and dry winter conditions in the basin.

Thus, the behaviour of large scale (synoptic scale) weather systems far away in the Pacific and separated topographically from the basin by the coastal mountains strongly influence winter conditions in the Mackenzie.

In summer:

Almost 50% of the total annual precipitation occurs in summer. While moisture from the Pacific is the predominant source in winter, this is not true for the warm season.

Although the airflow over the basin remains predominantly westerly during the warm season, our studies have shown that the major source of moisture feeding the larger summer rainfall events is often the southern continental regions or even the Gulf of Mexico.

Lightning strikes cause forest fires.

In some years, as much as half of the summer precipitation occurs as thunderstorms which are supplied with moisture by local evaporation from within the basin. Nevertheless, external moisture sources are important for precipitation production in the basin during summer and close attention must be paid to the potential effects that a changing and variable global climate may have on the energy and water cycle of the basin.

Water Resources

Cold climate phenomena strongly control the flow and storage of water in the Mackenzie Basin and therefore, we emphasize study of cold region hydrologic processes.

Examples of some of our more interesting work are:

- Blowing snow models show that between 20-40% of snow on the ground and in trees can be 'lost' by direct conversion to water vapour during snow drifting events.
- Different parts of the basin vary greatly in terms of their contribution to the Mackenzie river flow. Mountainous sub-basins in the west contribute substantial runoff while the shield and plains in the east contribute relatively little.
- Contrary to popular belief, not all frozen soils and bedrock surfaces are impervious to water. Considerable infiltration of water into cracks in Canadian Shield bedrock and into frozen, but porous, soils can occur and this strongly influences streamflow generation.
- Of the two primary sources of runoff, snowmelt usually surpasses rainfall. During the snowmelt period, water stored as snow over 5-6 winter months is released within weeks generating high flows in the rivers, floods of deltas and riverside wetlands, and rises in lake levels.

Ice-jam flooding can cause costly damage.

- During a relatively warm year (1998), evaporation from the northern Great Lakes (Athabasca, Great Slave, Great Bear) was comparable to that of the southern Great Lakes. More frequent warm years could have great impact on evaporation rates and lake levels.

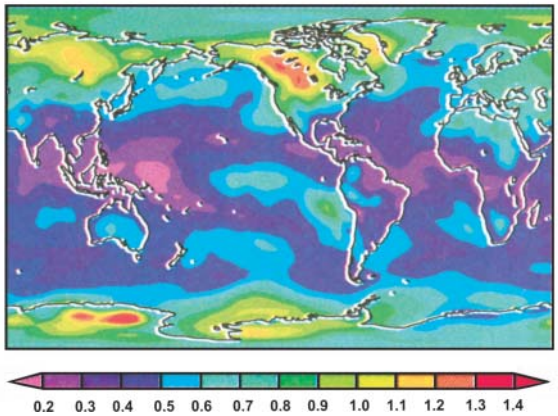
Importance of water resources

Water is the basis of life and affects almost all human activity. Changes to the water resources of the Mackenzie could influence:

- Economic activities such as hydroelectric generation, mining, oil and gas projects, forestry and commercial fishing.
- Transportation by river barge traffic and winter ice roads.
- The availability of safe drinking water.
- Recreational activities such as fishing, hunting, canoeing and boating.
- The reproduction, survival, migration and distribution of wildlife.
- Abundance and distribution of plant species.
- The sustainability of traditional lifestyles.

Consequences of climate variability

The Mackenzie Basin is in that part of the northern hemisphere with the largest year-to-year climatic variability. Climatic variability is expressed in changes in temperature, precipitation, storminess and the length of the seasons. This produces changes in lake levels, river flow and wetland conditions.

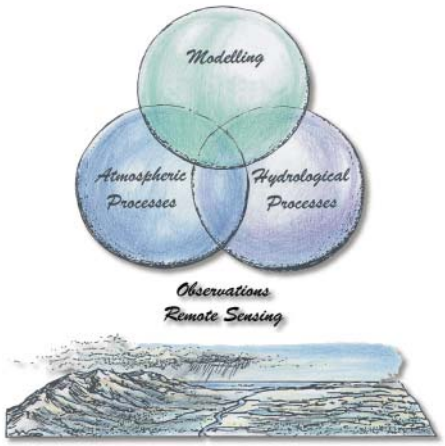


Interannual variance of temperature.
(after Kistler *et al*., 2001)

A special feature of MAGS scientific research is its concern with present and future climate variability as well as climate change and with the impact this can have on the water resources of the north.

Modelling Climate, Weather and Water

Our research has provided an improved understanding of the atmospheric and hydrological processes in the Mackenzie. We are using this knowledge to develop a suite of models that will help us assess the effects of climate variability and climate change on the regional water and energy cycle. Some of the models are new, while others are existing models that were improved through field experimentation.



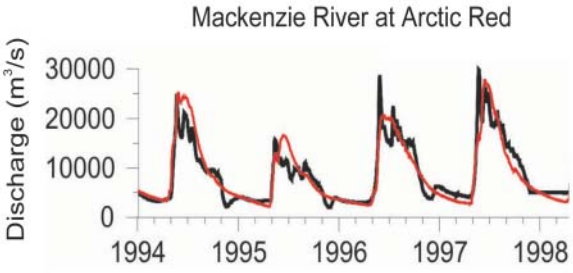
MAGS modelling integrates atmospheric and hydrological processes determined through field observations and remotely-sensed data.

We have developed new more efficient techniques for collecting and organizing data for modelling. One of these allows us to rapidly obtain slope, channel and basin properties through the computer processing of digital topographic data. Other techniques have been developed to extract critical climatic information from remotely-sensed data collected by satellites and instrumented aircraft. The Mackenzie Basin is a large, remote, rugged, and sparsely populated region with few climate and water resource

monitoring stations. Remotely-sensed data are an important source of information to fill the gaps between the ground observing stations.

MAGS suite of models

At the forefront of MAGS modelling activities is the development of a coupled atmospheric-land surface-runoff model. This is a tremendously complex and challenging scientific endeavour. Fundamentally, it involves using a global or regional climate model to predict atmospheric temperature and moisture conditions at an instant in time. This data is then used by a land surface model to calculate evaporation, soil moisture and runoff amounts. The runoff is routed down the river channel to the mouth of the basin. Ideally, the land surface model will also feed evaporation and other data back to the climate model to be used to calculate atmospheric conditions for the next time interval.



Modelled runoff is in good agreement with the observed flows. The black line is measured flow, the red line is simulated flow.

Other MAGS models, such as river models (runoff, spring breakup), lake models (evaporation, storage), frost model (permafrost), runoff models (for Canadian Shield), and blowing snow models are incorporated into the coupled model to improve its performance, but are also being used in isolation to address specific issues.

For example:

- River models can be used to predict the timing and magnitude of spring breakup. This can provide communities forecasting of the event to allow them time to prepare.
- Runoff models can provide valuable information on the timing of peak flows and on river water levels.
- The model for runoff from the Canadian Shield can provide local hydroelectric, mining and other commercial activities a better estimate of how much water to retain in reservoirs and tailing ponds.
- Lake models can be used to predict water levels and length of the ice-free season.
- The frost model can be used to predict the regional effects of climate variability on permafrost along proposed pipeline routes.
- Blowing snow models can provide information on regional snow redistribution.

Model prediction

An important goal of MAGS is a demonstrated improvement in hydro-meteorological prediction for the Mackenzie Basin. Once our models are validated by testing with existing data under current and past conditions, we can confidently simulate the effects of the varying or changing climate on water and weather in the region.

Moving into the Future

As MAGS moves into the future, its contribution to global science will continue through the sharing of our scientific expertise in cold regions, and transferring our results to other regions of the globe. MAGS will accelerate its efforts to meet the objectives of developing and validating models, and applying these models to address scientific, environmental and water resource problems.

The establishment of linkages between stakeholders and scientists will become a key element of our ongoing studies. MAGS scientists will work together with stakeholders through partnerships to apply our new scientific understanding and techniques to the solution of relevant environmental and resource management issues.

Partnerships

MAGS welcomes partnerships with stakeholders who share our interests and concerns regarding the weather, climate and water resources of the Mackenzie Basin. Our experience is on a regional level and we now have the expertise to make a meaningful contribution to the design of sound environmental and resource management policies and practices for northern Canada.

The stakeholders with whom we are best equipped to work include decision makers, practitioners and scientists in other or related fields. We look to these stakeholders to articulate environmental and resource management issues for which our research may be relevant. Our scientists will respond by examining their datasets, models and predictive capability for better ways to address these issues.

We are aware that different stakeholders have different priorities and manage their operations in different time frames. For example, the impacts of short-term climate variability may be most significant to economic activities like hydro power reservoir operation or oil and gas development; while long-term climate change effects on the ecological integrity of the northern region (including seasonality, storminess, snow and ice, animals and plants) may be of greater concern to established communities, residents and the governments.

It is important that both the stakeholders and our scientists find partnership collaborations relevant, the potential outcomes useful, the resources adequate, and the expectations compatible. Such partnership will reap the benefits, expressed as one of MAGS objectives of "assisting the government sector in making informed decisions, providing the private sector with direct and indirect economic gains and enriching the public with information and knowledge to better utilize their resources and to enhance their environmental well-being".

Acknowledgements

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