ROAD WEATHER SYSTEMS AND SERVICES
AN EMERGING TECHNOLOGY IN CANADA

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1. Introduction

The total number of RWIS in use in Canada by both provinces and municipalities as of 1999 was estimated to be approximately 100. This is not a large number given Canada's harsh winters and heavy reliance on surface transportation. But things are changing. Canadian road agencies are collaborating on a national effort to deploy these technologies in a highly coordinated manner. We will look at winters and transportation in Canada, factors motivating change, and then describe the proposed solution for Canada.

2. Winter and Transportation in Canada

Through most of Canada, there is a greater than 60% probability of having snow on the ground from mid-November to the end of March (see maps at Annex A). Many of Canada's large urban centres receive in excess of 200 centimetres snow annually. The average annual snowfall for Ottawa, the nation's capital, for example, is 221 centimetres. And many Canadian cities register over a dozen days with freezing rain on an annual basis.

An analysis of transportation in Canada reveals a heavy and growing reliance on road transportation. The diagram in figure 1 below depicts the evolution of the different modes of transportation in Canada since 1950. Transport Canada figures[1] show that more than 90% of people-kilometres and over 70%, by revenue, of freight shipments in Canada rely on roads.

The combination of harsh winters and heavy reliance on road transportation does lead to problems. Transportation Safety Board of Canada statistics provide a classification of road accidents according to severity and road condition. The road conditions reported include dry, wet, oily, as well as a number of specific winter road conditions: snow, ice (or packed snow), and slush. An analysis of all road accidents over the 1990-1998 period yields an average "winter road" (road conditions of snow, ice, packed snow, and slush) accident rate of 364 fatal accidents per year along with a further 21,575 injury accidents per year on average. This represents approximately 13% of the total number of fatal and injury accident rates respectively. One must remember that this does not establish a causal relationship. The full analysis of individual accidents and of all of the factors at play in each case is necessary for that.

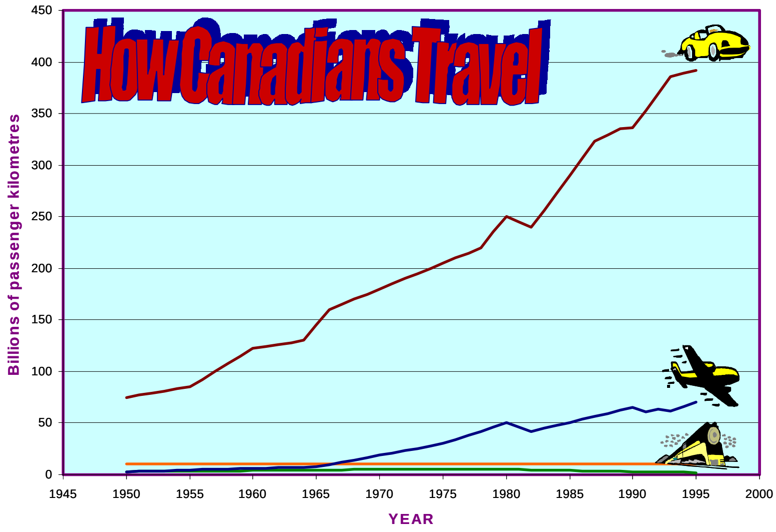

Figure 1. Evolution of Transportation in Canada.

Put in another context, the average annual number of fatalities with winter roads reported in Canada is more than twice the combined total of all fatalities due to all causes in all other modes of transportation. In addition, the average annual number of "winter road" injury accidents is more that 100 times the combined total of all injury accidents due to all causes in all other modes of transportation. Clearly, more attention should be focused on the problems relating to winter driving and winter road maintenance.

3. Winter Road Maintenance and Salt Use

Under the Canadian Constitution, surface transportation is a provincial and territorial jurisdiction. Provinces and territories license vehicles, provide drivers' permits, build roads, and maintain roads. Municipalities and cities are responsible for the maintenance of roads within their boundaries. This includes winter road maintenance, which makes up more than half of the total annual road maintenance budget. So winter road maintenance, which Industry Canada estimates costs $ 1 billion annually, is highly decentralized in Canada.

Salt is abundant and cheap (about 50 dollars Canadian per metric tonne in most parts of Canada) and known to be very effective in restoring road friction. It is therefore widely used for maintaining roads in Canada. With an increasing number of cars on the road and an ever increasing demand for transportation safety, salt use has increased dramatically over the years. Below, in figure 2, is a bar graph showing salt usage by the Ministry of Transportation of Ontario (MTO) for each winter since 1974-75[2].

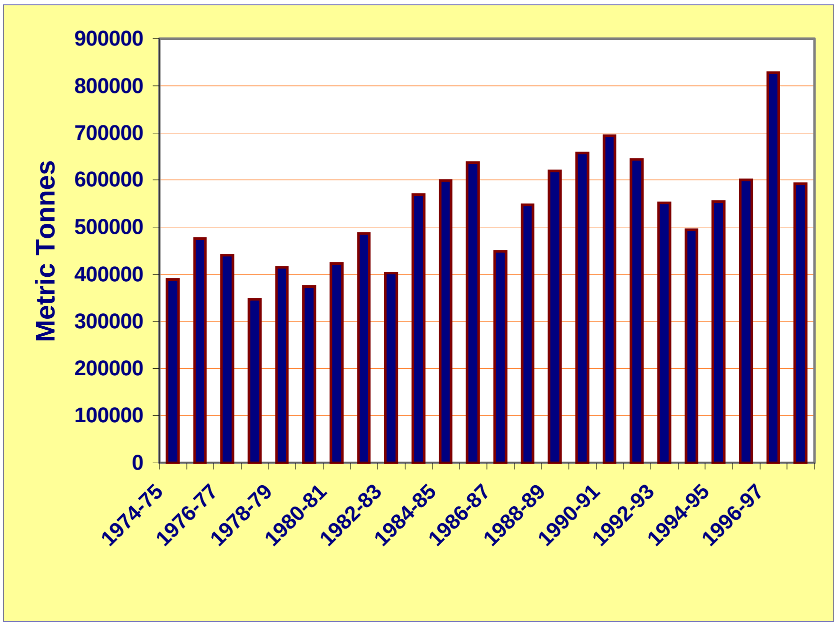

Figure 2. Salt use by the Ministry of Transportation of Ontario.

The variability from winter to winter is due primarily to the varying severity of the winters – amount of snow and number of freeze-thaw cycles. Of course there are other non-weather factors influencing the values on the graph. For example, for the last winter on the bar graph, the winter of 1997-98, the sharp drop in salt usage was due to the fact that the province of Ontario transferred the maintenance responsibility for several thousand kilometres of roadway to counties and municipalities.

It is clear from the bar graph above that reliance on salt use is increasing. Drawing a trend line on the above graph would show a rise in salt use by MTO from 400,000 tonnes to well over 700,000 tonnes, a near doubling over the last 23 years. And the total amount of salt used in Ontario, including that used by all of the municipalities, counties and private maintainers would be much greater.

Data compiled by the Environmental Protection Service (EPS) of Environment Canada from other Canadian provinces shows a similar trend[2]. The EPS estimates that the total annual road salt (sodium chloride and calcium chloride) use in Canada is 4,732,000 tonnes. A board of stakeholders from varied backgrounds had identified road salts as a priority substance for evaluation by the EPS under the Canadian Environmental Protection Act (CEPA). The EPS concluded its 5-year assessment study of the impacts of road salts on the environment and published its findings in August of 2000[3]. Based on the impacts of road salts in the quantities used on animals, plants, and freshwater biota, the study recommended that road salts be declared "toxic" to the environment upon which life depends.

The publication of the report launched the public review period. That review period is now over and none of the submissions from the public and industry were cause to change the final recommendation. The declaration of a substance as "toxic" under CEPA remains however a Minister's prerogative. If road salts were declared toxic, then a risk management phase would commence. CEPA allows 24 months to devise reduction strategies and control instruments followed by a further 18 months to implement them. Road safety is paramount and will not be compromised in any way. Nor will road salts be banned from use. Salts will continue to be the chemical of choice given its price, availability and effectiveness. It is the rate at which salt is entering the environment that is a concern.

4. Proactive Winter Maintenance and RWIS

The CEPA salt study, whether road salts are declared toxic or not, has identified a serious problem after long and detailed study. It will provide very strong incentives for all road maintenance agencies in Canada to look at road salt management and alternative winter road maintenance chemicals and practices. Much can be done to prevent the leeching of salt into the environment through such actions as covering salt piles and piles of "pickled" sand and recovering contaminated snow. The Transportation Association of Canada has published an excellent guide on Road Salt Management to help provincial, municipal, and private road maintainers. Ultimately though some road treatment chemical must be put down on the roads for road safety to be preserved. This is especially true for high-speed, high-volume highways and thoroughfares.

Most provinces and many municipalities in Canada have been experimenting with new pro-active winter maintenance techniques over the last several years. Maintenance managers in Canada generally recognize the importance of treating early, in fact before snow arrives or wet roads freeze, and that it takes much less salt to prevent the bonding of snow and ice to the road than it does to break down a thick bonded layer. Anti-icing, the timely application of freeze point depressants to roads to prevent the bonding, has been actively promoted in Canada for several years. Most agencies recognize that the necessary elements to bring together for an effective anti-icing approach are RWIS, special detailed road weather and condition forecasts, and training to assist the maintenance crews in correctly interpreting all this new information and applying it to their winter maintenance decision processes. In addition, revised chemical application equipment capable of pre-wetting solids as they are spread or, better still, spraying salt brine onto the roads is also required.

Ontario and British Columbia lead in the number of RWIS systems in use. Québec is analysing the results of its' trials and that has led to increased emphasis being placed on training and the maintenance decision process. The province of Newfoundland and Labrador has published a detailed cost benefit study on the use of RWIS in their province[4]. They estimated the benefit-cost ratio of implementing RWIS in Newfoundland to be five to one for the maintenance organization alone.

Calgary, Ottawa, and Kamloops are the Canadian cities that lead in the number of RWIS deployments. Calgary has the longest experience stretching back more than 10 years. The Kamloops trials were lead by the Insurance Corporation of British Columbia (ICBC), the monopoly government insurer for automobiles in the province, and were particularly well done. They very carefully brought together all of the essential elements: road data, pavement forecasts, maintainer training, and brine application equipment. They also very closely tracked the performance and analysed the results. At the end of just two years, they found a 25% reduction in salt use along with a 55% reduction in the use of aggregates. A further study of 4 years of data over 465 lane kilometres revealed a 40% reduction in claims over the 10-year average for "anti-icing" sections of roadway[5].

5. An Optimum Solution for Canada

A large number of maintenance organizations at all levels within Canada are now aware of the potential benefits that could be achieved through pro-active winter maintenance. External motivators such as the looming potential declaration of road salts as CEPA "toxic" and public pressure to provide ever-safer roads and winter mobility are also being acutely felt. But there are significant investments required in both RWIS and retooling of the maintenance vehicles. The new vehicles and spreading equipment can be phased in over time as older vehicles rust out but the RWIS systems require new capital investments. And those investments must be made some years before the benefits start to appear.

The vastness of Canada also presents major challenges. The population in Canada is concentrated in a string of urban centres generally within a few hundred kilometres of the border with the United States. There are nearly one million kilometres of paved roads in Canada and a relatively sparse population to pay for the many RWIS that would be required to achieve the RWIS density presently in place in many European countries[6]. Road temperature, with similar weather conditions, can vary quite dramatically along a road way over fairly short distances just due to physical parameters concerning the road such as type of construction, whether it is over a cut or a fill, proximity to water, soil type, vegetation, elevation etc. Then, of course, the weather varies over space and time as well, in fact quite markedly and regularly in Canada during the winter. These many factors could lead to enormous expenses as all road administrations in Canada begin to instrument their roadways. Clearly, some more organized approach was required for Canada.

RWIS and point pavement forecasts provide excellent information with which to make optimal road maintenance decision - for that specific segment of roadway with the length of the segment being dependant on the physical parameters and meteorological variables at play. Road agencies however are responsible for the entire length of the roadway which motorists travel. And pro-active road treatment implies precise prior knowledge of future road conditions. The goal from the outset therefore must be to try to resolve the future road weather and road conditions over the entire length of the roadway. Several basic approaches are available. These include thermal mapping and numerical weather prediction (NWP).

Thermal mapping involves the development of thermal fingerprints for the roadway which are acquired by driving vehicles with infra-red sensors over the length of the roadway at night under three different weather “types”: extreme which is clear and calm, damped which is cloudy and windy, and intermediate which is partly cloud with some wind. The thermal maps establish a relationship between the point in the roadway that is instrumented with an RWIS and the outlying roadway and neighbouring roadways. This works very well for very moist mild climates where the weather is relatively stagnant. For those climates, thermal maps are an excellent tool for deciding which precise portions of the roadway will drop below freezing and/or below the air dew point.

However, for most parts of Canada, with very few exceptions, the climates are much colder and the weather far more variable. The primary winter road maintenance problem for Canada is snow fighting and most of the snow results from the passage of low pressure disturbances which are very common in winter across the southern latitudes of Canada. By deploying RWIS in integrated networks over the major highway systems, the cyclonic disturbances producing the snow could be more precisely analysed and tracked. By ingesting the RWIS network data into supercomputer models, the evolution of those cyclonic disturbances and their impacts on the road could be assessed more precisely. Recent studies confirm that of the many data sets used to drive NWP, surface data is still one of the most useful in the production of short-term forecasts of precipitation[7].

NWP models provide all of the necessary atmospheric parameters necessary at each grid point to calculate the resultant pavement temperature using heat-balance equations. The current Canadian NWP model, the Global Environmental Multi-scale or GEM model, operates on a 24-kilometre grid. The current surface synoptic data network across southern parts of Canada has observation points approximately 100 kilometres or more apart. Worse, the inter-station spacing increases quite sharply to many hundreds of kilometres spacing within about 3 or 4 hundred kilometres of the US border. Environment Canada also runs experimentally, twice per day for the whole country, a 10-kilometre model called HIMAP. HIMAP benefits from finer geography and its higher resolution (in both grid length and integration time step) to produce forecast patterns more closely resembling reality. The precision of these models however is ultimately limited by the fact that they are essentially meso-scale models being driven from synoptic scale observation networks.

Ingesting high quality RWIS data has the potential to provide the necessary meso-scale data and so increase the accuracy of the models. Placing standard RWIS stations in integrated network at say 50-kilometre spacing would double the available surface data across southern Canada. NWP gridded forecast outputs could be used to generate pavement forecasts at the grid point spacing – so 24 kilometres presently for GEM. Using GEM would already provide twice as many pavement forecast data points as the number of 50-kilometre spacing, for example, RWIS stations deployed. Using HIMAP, which is due to become the operational model within the next year, a pavement forecast could be produced for every 10 kilometres along the roadway. Eventually, the NWP models will go to even higher resolutions and other strategies such as taking account of all of the physical changes in road construction, orientation, aspect, elevation, vegetation etc. along the length of the roadway, may yield pavement forecasts down to road segments of several hundred meters.

6. A Road Weather System for Canada

The key to maximizing the return from the RWIS investments is to deploy high quality RWIS systems in integrated networks about the roadways. All of the road agencies must adopt common standards and station densities (according to climate) within a limited time frame. The data must also be shared with an agency capable of ingesting all of this data and producing the necessary gridded meteorological outputs.

Realizing all of this, the Ministry of Transportation of Ontario (MTO) and le Ministère des transports du Québec (MTQ) met with Transport Canada (TC) and Environment Canada (EC) in October 1999. At that point, a large-scale trial was being considered for the Québec City to Windsor corridor – one of the most densely populated regions of the country. While the proposal had merit, Transport Canada in particular, wanted to involve more provinces from the outset. The main result of this meeting was that leads from MTO, MTQ, and EC were tasked to see if they could interest more provinces.

A series of seven teleconference calls on all aspects of RWIS was already being organized for the four Atlantic provinces (Newfoundland and Labrador, Nova Scotia, New Brunswick, and Prince Edward Island) by the province of Newfoundland and Labrador. These took place in January and February of 2000. Many international experts were invited to participate for select calls. In late February, EC also held a lengthy teleconference call on RWIS with the four western provinces (Manitoba, Saskatchewan, Alberta, and British Columbia). These many conference calls led to a National Road Weather Meeting in Ottawa on 14 April 2000. Nine provinces were in attendance along with TC, EC, ICBC, and the US Federal Highways Administration. The meeting was chaired by MTO. By the end of the afternoon, there was a unanimous agreement to collaborate on RWIS. A working group, with Tom Beckett of Newfoundland and Labrador as chair, was struck to develop a proposal.

All provinces were involved in the identification of the proposal’s basic elements and structure and in contributing text for specific sections. The Proposal for a Road Weather System for Canada (RWSC), now in final form, is seeking the following two basic elements:

1. A cross-Canada integrated network of RWIS stations jointly funded by the individual provinces and territories and Transport Canada, and
2. A core national road weather forecast service provided by the Meteorological Service of Canada.

An “integrated” network would be achieved by having all jurisdictions adhere to common standards and protocols. Each province and territory would agree to apply common core concepts respecting the following:

- RWIS specifications concerning sensors, accuracy, and operating range;
- Exposure of the sensors and siting of the RWIS stations;
- Commissioning, maintenance, and inspection guidelines;

- Polling frequency, data formats, and telecommunications protocols; and
- Data base formats.

Each province and territory would select its own RWIS equipment (meeting the above core concepts) and its own business model (purchase systems or data or lease systems). Each province and territory would also agree to share the data with the other provinces and territories and with Environment Canada who would be allowed to ingest the data into their supercomputer models. Each province and territory would assume the full costs of operating their portions of the national RWIS network (telecommunications and maintenance) and would be responsible for the training of their maintenance personnel to ensure the data is correctly interpreted and applied. Provinces and territories would retain full intellectual property rights over their respective portions of the RWIS network including control of access to the data.

The provinces and territories would petition Transport Canada to provide, in exchange, 50% of the capital costs to purchase and install the RWIS systems. While TC has no mandate to support road maintenance, they do have a historical precedent of providing seed funding for certain essential core national infrastructure. Because the application of RWIS technology and anti-icing programmes promise safety enhancements and salt reductions, the initiative would have the potential to make the surface transportation system safer more environmentally sustainable – two major TC objectives. Under the Proposal, TC would approve the RWIS deployment plans of each province and territory, would lead negotiations with the US on an integrated North American network, and would be assured of accreditation in any publicity of the Road Weather System for Canada.

A major limitation is that TC typically provides funding only for National Highway System (NHS) infrastructure programmes and only if the provinces and territories put up their 50% corresponding share. The NHS is a somewhat controversial but agreed to definition of the major east-west and north-south highways within Canada. Bu it is far more than just the Trans-Canada Highway. The basic NHS length within each province would then provide the starting point for determining which share of the national RWIS network funding each jurisdiction would receive. The other major network funding share consideration concerns the varying winter climates across Canada and how that impacts an optimal RWIS station density. For portions of the country with more "severe" winters, with severe being from a winter maintenance cost perspective, the corresponding RWIS network share should be adjusted upwards. In other words, for portions of the country which receive more snow and freezing rain, the maintenance cost would be higher and the winter driving hazards greater. This would justify a proportionately denser RWIS network in those regions and so a greater share of the total RWIS funding. The opposite is also true. For portions of the country where the winter is bitterly cold and relatively dry, the density of the RWIS networks can be relaxed somewhat and they would receive a smaller share of the total funding.

The many winter severity indices documented in the literature were tested by Dr. Jean Andrey, of the University of Waterloo, against the climates and the winter maintenance costs across all of Ontario[8]. Ontario is a good choice since it has nearly the complete range of all of the widely differing climates available in Canada. Dr. Andrey found the correlations for all of the existing winter severity indices to be quite low and concluded that taking the average annual snowfall and the mean annual number of days with freezing rain provided as good a correlation with winter maintenance cost and salt use across Ontario's maintenance districts as any of the existing indices. These data were obtained for the main climate stations along NHS routes and averaged by province and territory to come up with a mean weather index for each province and territory. The combined NHS length and mean weather index were used to arrive at a funding share that all provinces and territories could agree too.

Under the Proposal, the provinces and territories would agree to deploy their respective portions of the national network within five years of its' acceptance by TC and EC. Depending on provincial funding and RWIS options selected, the Proposal should lead to the deployment of about 500 new RWIS with upgrades to many of the existing 100 or so RWIS systems already in use. The Meteorological Service of Canada (MSC) would perform Quality Assurance and Quality Control (QA/QC) of the RWIS data – necessary in any case prior to ingesting it into its' NWP routines. In exchange for this privileged use of the data, the MSC's main contribution would be to provide core road weather forecast guidance products for use by the private sector in supporting the provincial and territorial winter maintenance programmes. The MSC would also invest in road weather research and development, factor road weather requirements in future weather service plans, provide annual performance reports, and provide assistance with road weather training.

The first version of the proposal was presented to the Council of Deputy Ministers Responsible for Transportation and Highway Safety at their semi-annual meeting held in Ottawa on April 3rd, 2001. Some slight reservations were expressed at the meeting concerning the national RWIS standards and more details on the benefits analysis were requested. The Chair of the Council, the DM of Transport Canada, requested that these portions be revisited and that the Proposal be brought back to the Council again at their next meeting to be held on 19 September 2001.

7. Conclusion

The Road Weather System for Canada is now a mature proposal for serious consideration by senior government officials at the provincial, territorial, and federal levels. It would provide a framework for close collaboration in the deployment of a national integrated network of RWIS stations to serve the National Highway System. It would provide the basic network onto which provinces and territories could build to expand the network over the remaining non-NHS highways within their boundaries. Cities and municipalities could add RWIS systems to the network by respecting the national RWSC standards and so gain entry into the data and products from the broader network.

By allowing the Meteorological Service of Canada to ingest the RWSC data, the provinces and territories would be maximizing the return on their RWIS investments by obtaining enhanced weather forecasts and gridded forecast data sets with which to generate pavement forecasts for many more sites and, eventually, for entire road networks.

The adoption of RWIS technology by the provinces and territories, and in time by the municipalities, within a broader programme of pro-active winter maintenance, will provide safer, more efficient and environmentally sustainable road transportation in Canada at less cost to Canadian taxpayers.

8. References

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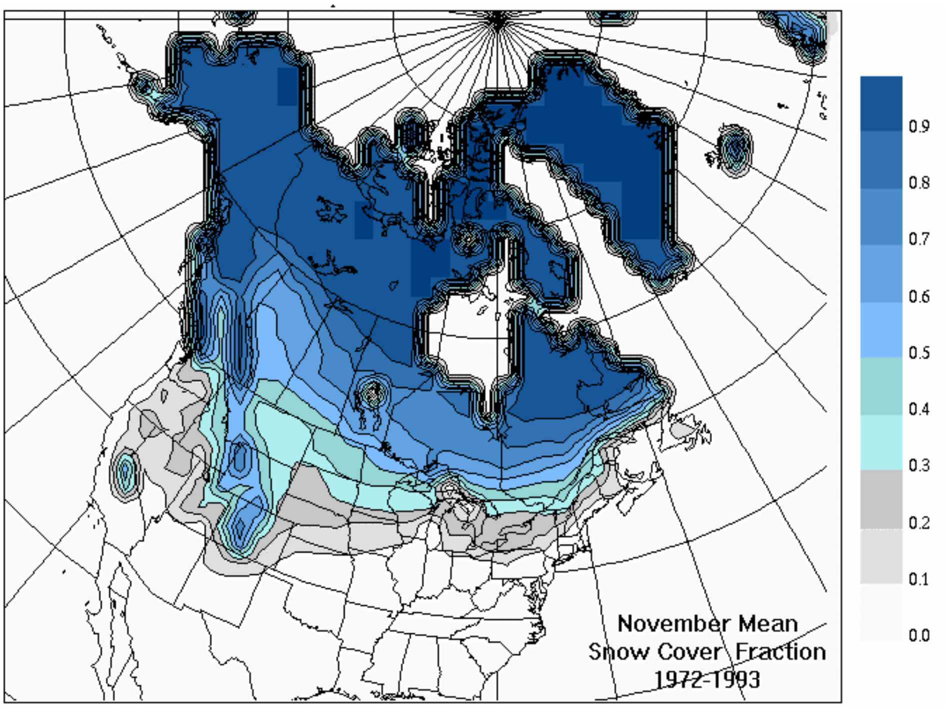
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November Mean
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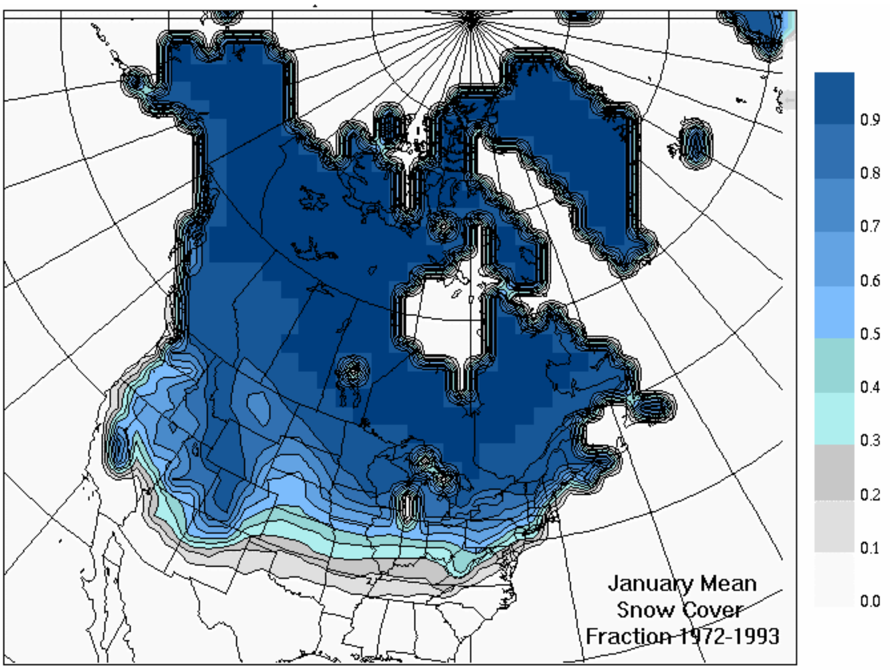
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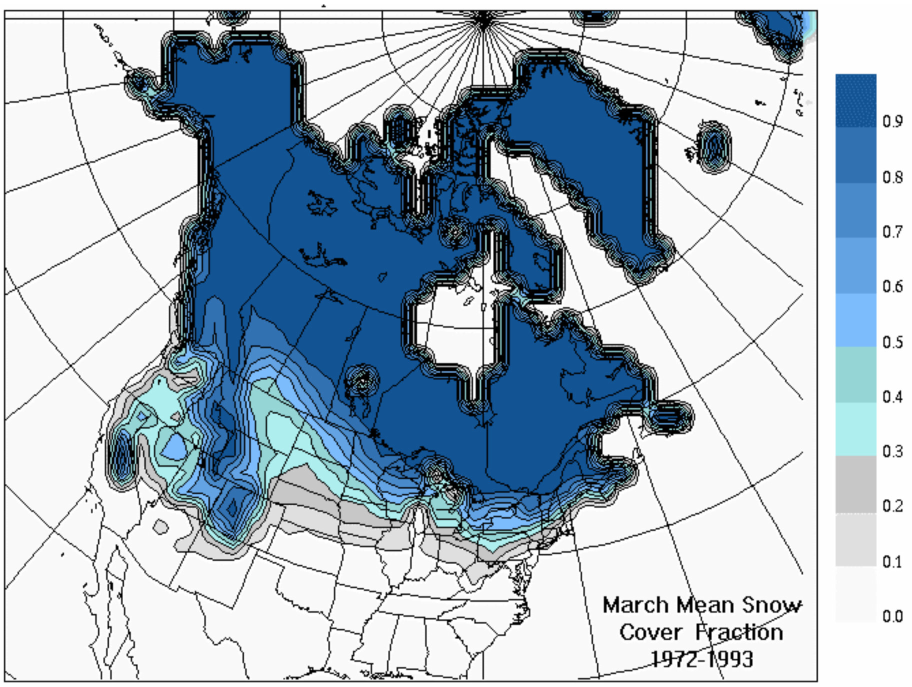
March Mean Snow
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