Snow Cover Climate of the Maritime Provinces of Canada

C. MARTIN[1] AND W. RICHARDS[2]

ABSTRACT

Snowcover is an important element in various fields like agriculture, wildlife, conservation and winter sports. Environment Canada's climate archive for the Maritime Provinces contains many records of snow on the ground (SOG) or snow depth. However, the data set is incomplete in that 53% of observations are missing. This makes analysis of the data difficult. An empirically-based statistical model called "Depth Change" was used to estimate the missing values. The Maritimes were divided into four regions and the snow season was divided into two periods: "Winter" (November 1 to February 14) and "Spring" (February 15 to April 30). A total of 127 stations were used to determine the relations between SOG and daily maximum temperature, daily snowfall and daily rainfall by using regression analysis for each region and each period. The model was tested on 8 stations and applied to 227 stations across the study area for the 1955-1996 period, which decreased the missing SOG values to 13%. Analysis of the data was done by creating maps showing the probabilities of having 0 cm, ≥10, ≥20, ≥30, ≥40 and ≥50 cm of SOG for bimonthly periods during the snow season. Although the model is not perfect, it effectively estimates SOG values and provides a much better portrait of the Maritimes' snowcover.

Keywords: snowcover, snowdepth

INTRODUCTION

Snow is an integral component of the climate of Canada. In the Maritime provinces, snow is present continuously or ephemerally from four to more than six months of the year, affecting the surface-atmosphere interactions (e.g., the surface energy budget). Thus, snow cover affects the climate which affects all living organisms on site. For vegetation, it can represent a protective blanket against the cold weather, while for animals it can be an obstacle for movement and the search for food. Also, as we all know, human activities are not excluded from adaptations imposed by the presence of snow. It slows down traffic, causes many deaths and it costs a large amount to clear. However, the white stuff is also responsible for winter fun like skiing and snowmobiling. Finally, the snowcover itself is the source of an important stock of water. The spring melt and runoff is the most important hydrological event of the year. It produces floods and it is of primary importance for hydroelectricity production. Consequently, it is easy to understand why the amount

[1] Department of Geography, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9, Canada
[2] Atlantic Climate Centre, Environment Canada, Atmospheric Environment Service, 77 Westmorland Street, Snte 400, Fredricton, New Brunswick E3B 6Z3, Canada

Table 1. Principal Climate Stations with Excellent SOG Data

Name	Province	Station ID	Comments
Campbellton*	NB	8100700	replaced by Charlo A (8100880) in 1966
Charlottetown A	PEI	8300300	
Chatham A	NB	8101000	recently renamed Miramichi A
Fredericton A	NB	8101500	
Greenwood A	NS	8202000	
Halifax Int'l A	NS	8202250	started recording SOG in 1960
Moncton A	NB	8103200	
Sable Island	NS	8204700	stopped recording SOG in 1995
Saint John A	NB	8104900	
Shearwater A	NS	8205090	
Summerside A	PEI	8300700	
Sydney A	NS	8205700	
Truro	NS	8205990	opened in 1960
Yarmouth A	NS	8206500	

* was not a principal station

of snow on the ground (SOG), or snow depth, is an important climatic variable to measure and can be used in the analyses of a wide range of environmental, ecological or economic problems.

In the Maritime provinces, SOG has been observed officially at climate stations operated by the Atmospheric Environment Service of Environment Canada since 1955. Fourteen stations have practically complete SOG records for the period considered in this project, which is from 1955 to 1996 (see Table 1 and then Map 1 (appendix) for location). These are principal or primary stations where meteorological variables are recorded very consistently. However, they are essentially coastal locations and they are fairly distant from one another, offering a very fragmented picture of the distribution of SOG in the Maritimes, especially concerning inland locations. Thankfully, a much denser network of secondary stations exists to complement the principal station network, but many of them did not record SOG until the beginning of the 1980's and it was too often not recorded on a regular daily basis. In fact, of the 227 secondary stations considered in this study, 47% of their SOG data was missing and 115 stations had less than half complete records. These figures include all of the days these stations were operating during the snow season. However, they also include the periods when SOG was not measured at many stations. There was also a preference for the data to be missing when the ground was bare. So it is not possible to do valid statistical analyses on such a biased data set. The amount and character of missing data poses serious problems to the study of SOG in the Maritimes at various spatial and temporal scales.

In contrast to SOG, other meteorological variables, notably temperature (daily maximum and daily minimum) and precipitation (daily total rainfall and snowfall) were consistently recorded. These data offered a good opportunity to estimate the missing SOG values by using a model and thus potentially allowing future snow related studies to use much more complete data sets.

OBJECTIVES

The principal objective of this project was to estimate the missing SOG values from the majority of secondary climate stations in the Maritime provinces (New Brunswick, Nova Scotia and Prince Edward Island) in order to complete the existing data set for the 1955-1996 period. This required a model which would use the available temperature and precipitation data to estimate SOG. A secondary objective was to display these results in the form of maps that would provide a good representation of the long term snowcover conditions in the Maritimes, which could be used in a wide range of fields.

THEORY

The development and ablation of a snowpack depends on a wide range of meteorological variables. The amount of snowfall is obviously the most important factor, because it is the only notable input of material to the snowcover. Once deposited, snow is subjected to wind redistribution, metamorphism and melt which alters its physical properties including its depth, density, snow water equivalent and reflectivity (albedo) (Langham, 1981). In fact, the ablation of a snowpack is a much more complex phenomenon than its accumulation.

First, a fresh snow cover has the tendency to settle from its own weight and by wind transport in the first few days following its deposition. Wind also tends to increase sublimation rates which are not negligible over the course of an entire snow season (Pomeroy and Goodison, 1997). Second, warm air temperatures and solar radiation also cause transformations within the snowcover including melt which tends to decrease the depth of a snowpack. Solar radiation increases as the altitude of the sun increases after the winter solstice. Larger amounts of solar energy tend to increase the rate of melt as the snow season progresses from winter into spring. Cloud cover which affects the amount of solar radiation reaching the surface also plays an important role in the rate of snowmelt. Furthermore, a snowpack tends to get darker as it ages thus absorbing more solar radiation which increases its ablation rate. Release of latent heat near the snow surface accelerates melting. This effect is most notable in coastal areas where humidity is highest. Finally, rain events tend to decrease the depth of a snowpack, because the water contains heat, possibly producing considerable melting (Male and Gray, 1981). An ideal snowmelt model should take all of these factors into account.

THE DEPTH CHANGE METHOD

Since radiation, wind or cloud cover measurements are not observed at most secondary climate stations, it would have been impossible to use a detailed energy balance model to estimate the missing SOG values. In fact, only daily maximum and minimum temperatures and daily rainfall and snowfall are readily available for use. Many authors have used methods with these variables only, achieving fair results (e.g., Brown and Braaten, 1998). The most widely used procedure is the *temperature index* method, which uses coefficients describing the relationship between temperature and change in snow depth above a base temperature, usually 0°C. Some of the better equations also include a term for rainfall. However, ablation and compaction of a snowpack do happen below the base temperature and these types of empirical equations do not offer very good results outside the specific geographical location for which they were calibrated. Moreover, the amount of snowmelt changes throughout the snow season. It increases as the season advances because of changes in the weather conditions and of the snowpack properties (Hughes and Robinson, 1993).

In order to correct these problems, Hughes and Robinson (1993) developed a simple but labor intensive method to estimate changes in snow depth called the *Depth Change method.* It is an empirical and statistical method that uses the existing SOG data set to estimate the missing values. Regression analyses are used to determine the relationship between air temperature and snow depth change in a given region during a specific time period. The equations of the curves are then used to estimate the change in SOG, with the available temperature data. Once this value is obtained, it is subtracted from the actual amount of SOG. Furthermore, any new daily snowfall is added directly to the SOG amount.

Hughes and Robinson (1993) applied this method to four states of the American Great Plains. Each state (North Dakota, South Dakota, Nebraska and Kansas) was a region. The only major consideration for this division was latitude, because of the resulting differences in solar radiation intensity. Although factors like settling, wind transport and sublimation of the snow are not variables, their average effect on SOG is present in the method, because of it's empirical nature. The effect of rain was not considered separately because of the lack of observed cases necessary for the inclusion of this variable in the model. To describe the effects of the changes observed throughout the season, the snow season was divided into two periods, from November 1 to mid-February and from mid-February to April 30. The eight polynomial regression curves obtained (4 regions, 2 per region) had R^2 values above 0.97, which show how well the method conforms to reality in that part of the world.

APPLICATION OF THE DEPTH CHANGE METHOD TO THE MARITIME PROVINCES

The Maritime provinces have a very different climate from the Great Plains. They are mostly surrounded by sea which makes the winter much milder and causes a relatively rapid change in climate as one proceeds inland. Areas near the sea will tend to be windier and have more cloud cover, thus affecting the settling and the melting of the snowcover. The pattern is further complicated by the fact that much of the Gulf of St. Lawrence freezes in the winter, essentially cutting off this important source of heat and moisture. Moreover, although the elevations in this part of Canada are modest, they are not a negligible factor in determining SOG. This is especially true for northern and northwestern New Brunswick and the Cape Breton Highlands of Nova Scotia. The result is a much more intricate SOG pattern than one would observe in the Great Plains, a very continental and homogeneous area. Also, rainfall events in the Maritimes during the snow season are common and therefore cannot be overlooked.

When determining regions for the calibration of the model, one must try to distinguish areas that are similar in climate, without having to directly consider precipitation or temperature patterns because those variables are taken into account in the model. The only notable exception lies between areas that have large differences in snowpack depth, which is linked to snowfall patterns, because areas with deeper packs will encounter more extensive settling, thus affecting the ablation curves (Hughes and Robinson, 1993). Another important consideration was to make sure that the defined regions had enough existing SOG data at well-distributed stations to be confident that the curves would be representative of the entire area.

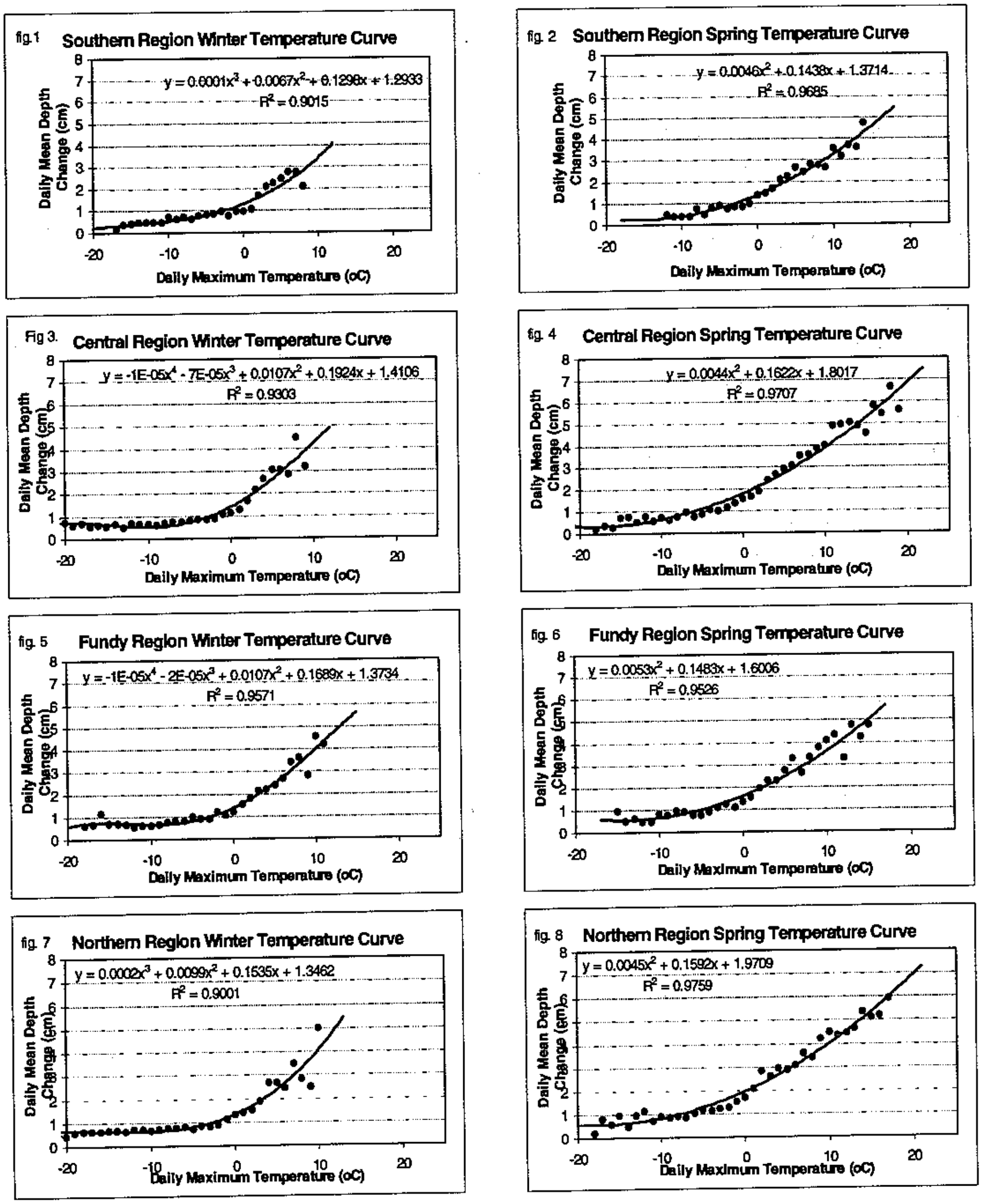
Upon considering what has been said above, the Maritime provinces were arbitrarily separated into four regions (see Map 2 (appendix)). First, **the Northern Region** includes everywhere North of 46° 30' N. The main concern here was solar radiation as determined by latitude, although the fact that these are also the snowiest areas did play a role, especially in the inclusion of northern Cape Breton (Nova Scotia) in this region. Second, **the Central Region** would have included all the areas from 44°30' N to 46° 30' N if it were not for the Bay of Fundy and the Atlantic Ocean. It is therefore restricted to southern New Brunswick minus the Fundy area, most of Prince Edward Island and Most of Northern Nova Scotia. Third, **the Fundy Region** includes the entire Fundy coast and adjacent inland areas North of 44° 30' N. It also includes the southern and eastern areas of Cape Breton which are too far north to be included with the other areas in the vicinity of the Atlantic Ocean. Finally, **the Southern Region** is essentially the area south of 44° 30' N but also incorporates the areas near the Atlantic Ocean in mainland Nova Scotia.

A total of 127 stations were used to calibrate the model. The principal stations were not included in the calibration or the application of the model, despite their excellent data. Secondary stations take their SOG measurements at 8:00 LST and this time also represents the end of the climatological day. However, the primary stations' climatological day is not from 8:00 to 8:00 LST but SOG measurements are taken at 8:00. The daily precipitation records and daily SOG records are not synchronous. This makes it impossible to properly estimate SOG values. The stations with the most complete SOG records, as well as excellent temperature and snowfall and rainfall data, were used for the calibration of the model. They had at least 10 years of relatively good data and up to 42 years (maximum) in a few cases. Twenty-six stations were used in the Northern Region, 25 in the Fundy region, 24 in the Atlantic Region and 52 in the Central Region, which has approximately twice the number of total stations compared with the other regions.

The snow season was divided into 2 periods, "Winter" from November 1 to February 14 and "Spring" from February 15 to April 30. It was noticed that stations in the Northern Region often had snow into May, so the Spring period was extended to May 31 in this region. The data for every station used for the calibration, including daily maximum temperature, daily mean temperature, daily snowfall, daily rainfall and daily SOG, were thus divided into these two periods. Furthermore, the days with rain were separated from the others and they were treated in a different manner.

The climate data is set up in a way that the previous day's conditions determine the next day's SOG, which is measured at the beginning of the day. This is obvious on most days with observed snowfall where the amount recorded is added to the SOG to result in the next day's amount (of SOG). Because this was the general rule, the model was built to add the snowfall to the SOG in this manner. Concerning the effect of temperature on SOG, a change in depth was calculated correspondingly with the daily temperature for every day where the SOG value was present that same day and the following day. Days with any form of precipitation were ignored in this step. Days for which the next day's SOG value was zero were also ignored because it is not known whether or not the depth change had reached its potential under those particular conditions. Finally, data from each station were combined according to their respective region and period (Winter or Spring). All the depth change values for each day were combined in one degree Celsius classes (according to daily maximum temperature) and mean values for each temperature were calculated. Regression curves were then plotted to describe the relationship between temperature and depth change. The eight resulting curves, or temperature curves, are shown in Figures 1 to 8. The R^2 values for these 2^{nd} to 4^{th} degree curves are all above 0.9. The equations of these temperature curves, shown on the graphs, were the ones used in the model.

The second step was to describe the relationship between days with rain and the resulting change in SOG. Multiple linear regression analyses were used in all eight cases of the model



Figures 1 to 8. Temperature Curves for the Four Regions

between maximum daily temperature, daily rainfall and depth change. Daily mean temperature was compared with maximum temperature to determine the best variable for these precipitation curves. The results are shown in Table 2. The R^2 values are very low showing a poor relationship among the three variables. There are most likely other factors that play an important role in the change in SOG on days with rain. Another possibility is that the relationship among the three variables is not linear (to the 1st degree). This is probably the case since the relationship with temperature alone is not linear as demonstrated by the temperature curves. However, other options were not explored. Furthermore, it was determined that daily maximum temperature is a better indicator of change in depth than daily mean temperature as shown by the former's higher R^2 values.

Table 2 Precipitation Curves

Region	Period	Precipitation Curve (T_{max})	R^2 (T_{max})	R^2 (T_{mean})
Southern	winter	y = 0.422665T + 0.077725R + 1.335237	0.114	0.072
Southern	spring	y = 0.220297T + 0.052214R + 2.149599	0.058	0.032
Central	winter	y = 0.552365T + 0.128142R + 1.811408	0.130	0.070
Central	spring	y = 0.288673T + 0.131063R + 1.999937	0.098	-
Fundy	winter	y = 0.350748T + 0.106443R + 1.871258	0.102	0.066
Fundy	spring	y = 0.253937T + 0.085646R + 1.607447	0.085	0.052
Northern	winter	y = 0.503246T + 0.140219R + 2.144020	0.085	0.044
Northern	spring	y = 0.242619T + 0.060240R + 2.816242	0.035	0.008

T = daily maximum temperature (°C) R = daily total rainfall (mm)

After having found all of the regression equations, the model was assembled. A total of 10 scenarios, or cases, had to be accounted for. These scenarios are described below and Figure 9 shows the flowchart of the model. The decision tree was programmed in a *Quattro Pro©* spreadsheet for each region and for each period using the appropriate statistical equations.

The model was built with IF arguments, taking each possible case one at a time:

1) If the SOG value is not missing, the model rewrites the value.

The other 9 cases apply when the SOG value is missing:

Cases 2 to 5 apply when the previous day's SOG value equals zero:

2) If there is no precipitation, SOG = 0.
3) If there is only rainfall, SOG = 0.
4) If there only snowfall, SOG = snowfall amount (cm).
5) If there are snowfall and rainfall, SOG = snowfall - depth change (appropriate precipitation curve)

Cases 6 to 9 apply on days where the previous day's SOG value is greater than zero:

6) If there is no precipitation, SOG = SOG (previous day) - depth change (appropriate temperature curve)
7) If there is only snowfall, SOG = SOG (previous day) + snowfall
8) If there is only rainfall, SOG = SOG (previous day) - depth change (precipitation curve)
9) If there are rainfall and snowfall, SOG = SOG (previous day) + snowfall - depth change (precipitation curve)

The final case:

10). If the temperature or the precipitation data are missing, SOG = -999.

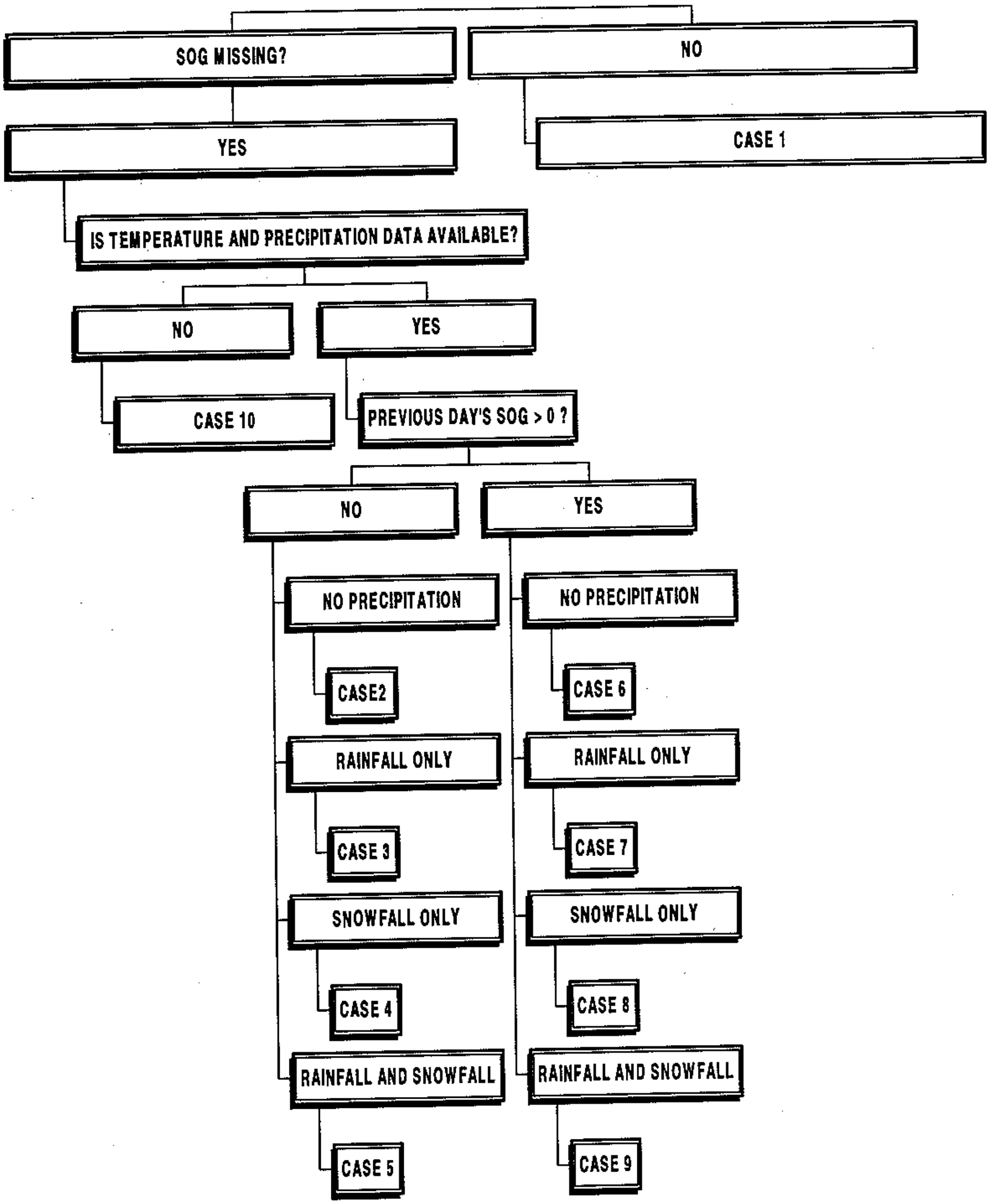


Figure 9. Model Flowchart

Table 3. Stations Used to Test the Model

Name	Province	ID#	Region	Testable years
Albany	PEI	8300060	Central	1987-1993
Bathurst A	NB	8100503	Northern	1992-1996
Dayton	NS	8201136	Southern	1988-1996
Digby Airport	NS	8201601	Fundy	1990-1996
Fredericton CDA*	NB	8101600	Central	1958-1996
Louisbourg*	NS	8203161	Fundy	1980-1996
Malay Falls	NS	8203400	Southern	1987-1996
Pennfield*	NB	8103845	Fundy	1976-1996

* Stations that were also used in the calibration of the model.

TESTING THE MODEL

Eight well-distributed stations across the Maritimes were used to test the Depth Change model (see Table 3).

Since all of the stations having more than 10 years of relatively complete SOG records were used in the calibration of the model, only stations with short periods of data were available for the verification of the accuracy of the model. Stations with recent data records were chosen because in most instances, this period is of more interest to most potential users of the data. However, three stations that were open longer, but used in the calibration of the model, were also tested.

In order to test the model, the first case, i.e. the one that checks if the SOG value is absent, was omitted. In other words, the model estimated the SOG values for the whole snow season with only the November 1 value as a reference. Graphs were plotted comparing the actual SOG values with the estimated ones for all the testable years for each station. Figures 10 to 24 show examples of the results that are representative of the entire graph series.

Before making comments on these graphs, it is important to note that because the model has only one point of reference, it has the potential of making larger errors as the season progresses. In its real application, the model also relies on the existing SOG data. Therefore, the model does not usually have to make over 20 (up to 213) estimations in a row, making its task much more difficult. In fact, only one important mistake during the entire snow season can throw off the estimations by a large amount (e.g., Figures 10, 12, 24), but in most situations an actual SOG value would rapidly correct the problem.

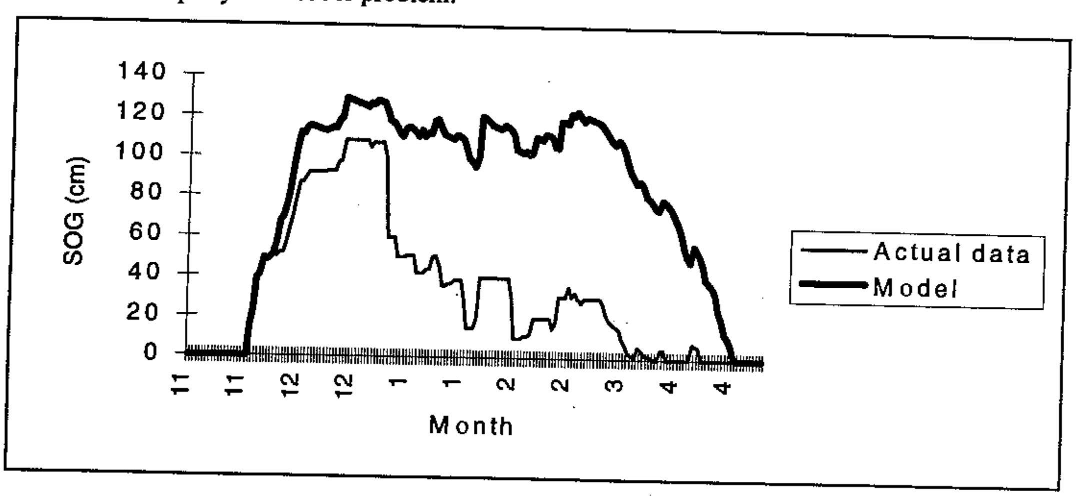


Figure 10. Central Model Test, Albany (1990-1991)

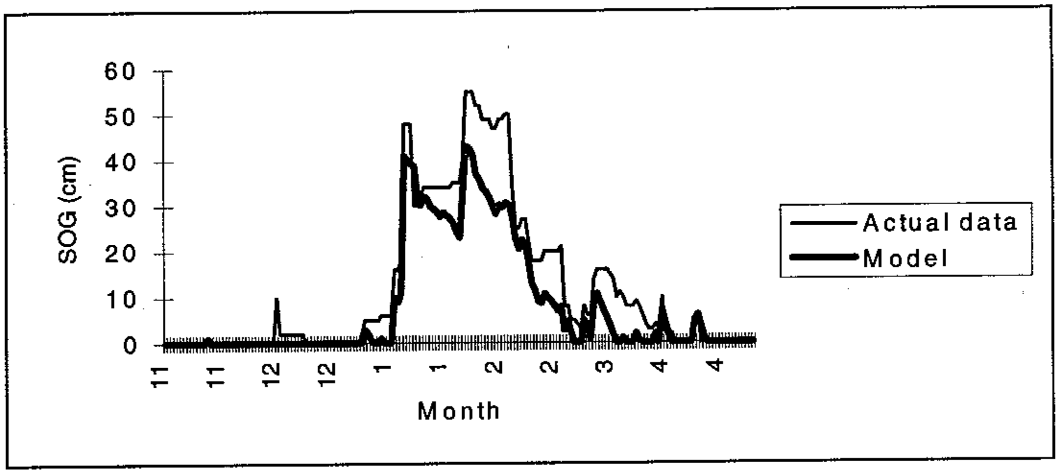


Figure 11. Central Model Test, Albany (1989-1990)

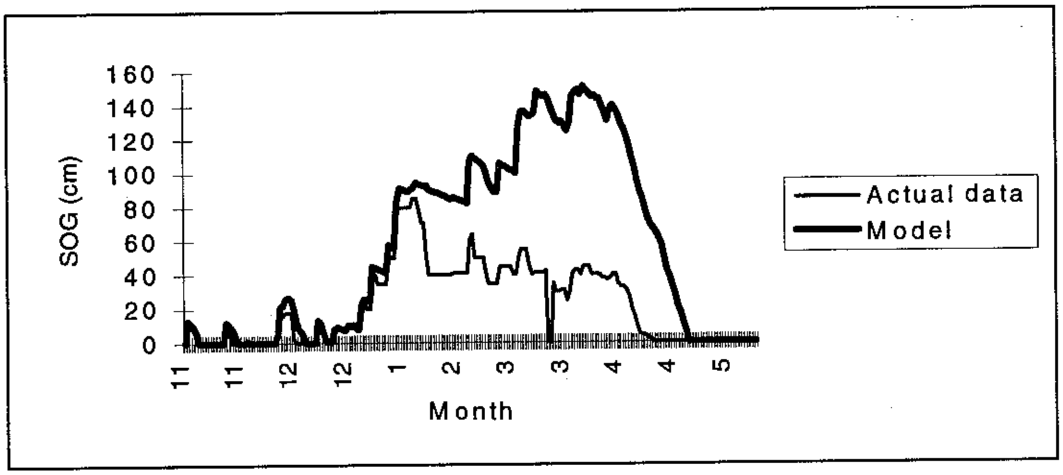


Figure 12. Northern Model Test, Bathurst (1993-1994)

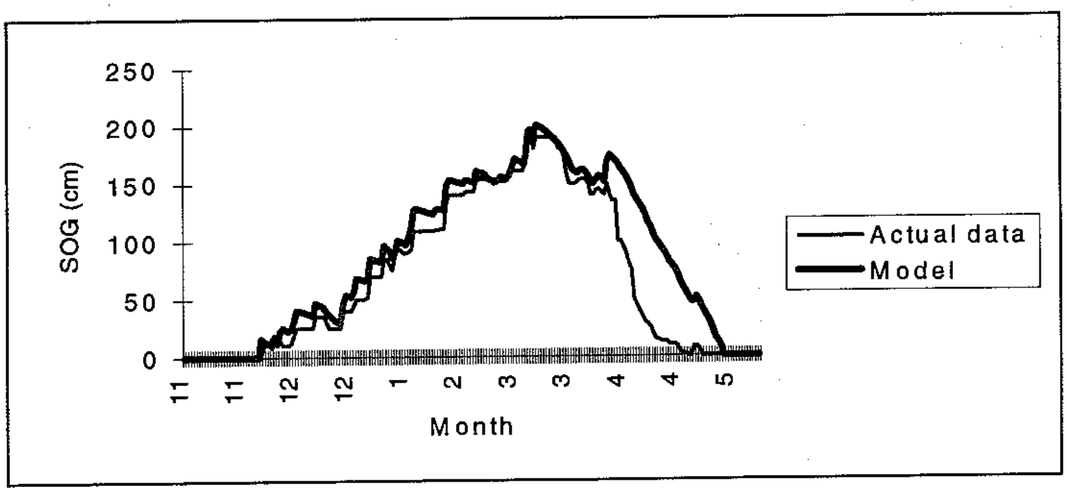


Figure 13. Northern Model Test, Bathurst (1994-1995)

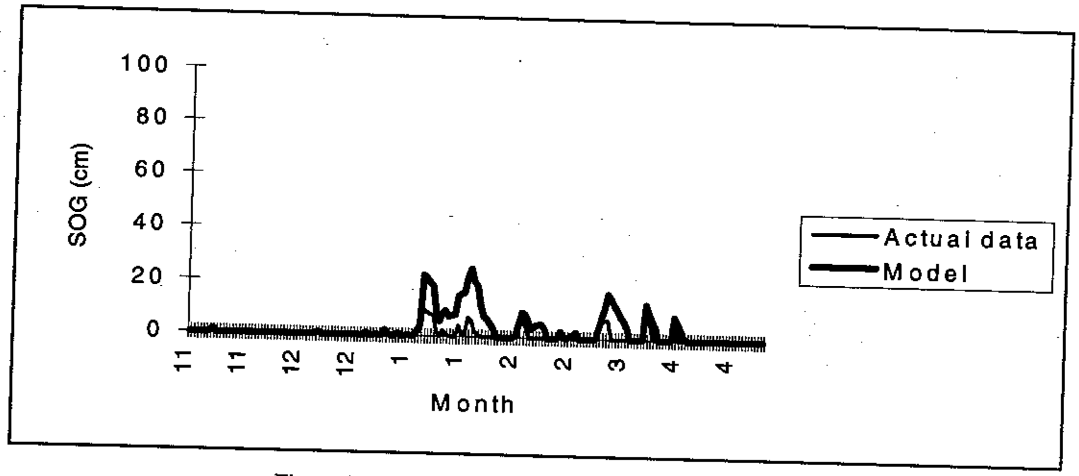


Figure 14. Southern Model Test, Dayton (1990-1991)

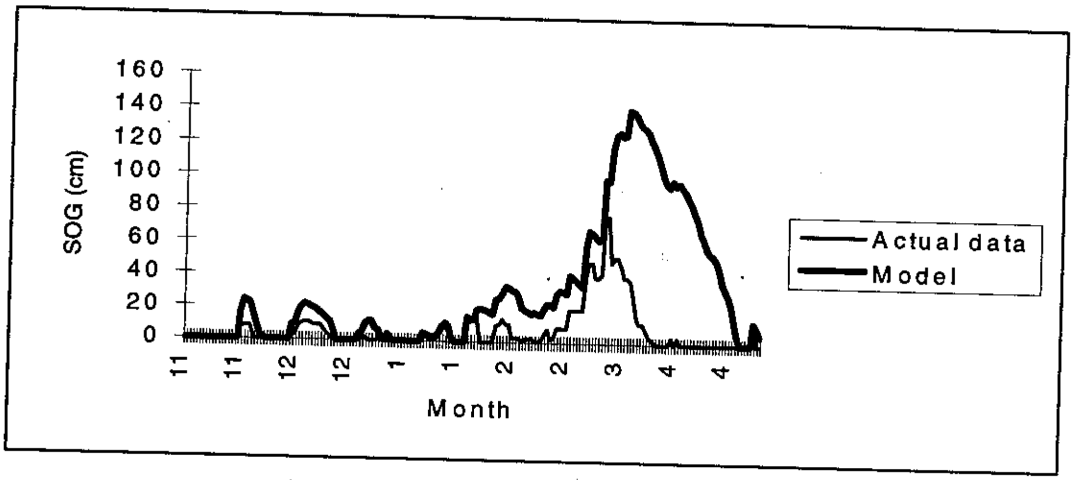


Figure 15. Fundy Model Test, Digby (1992-1993)

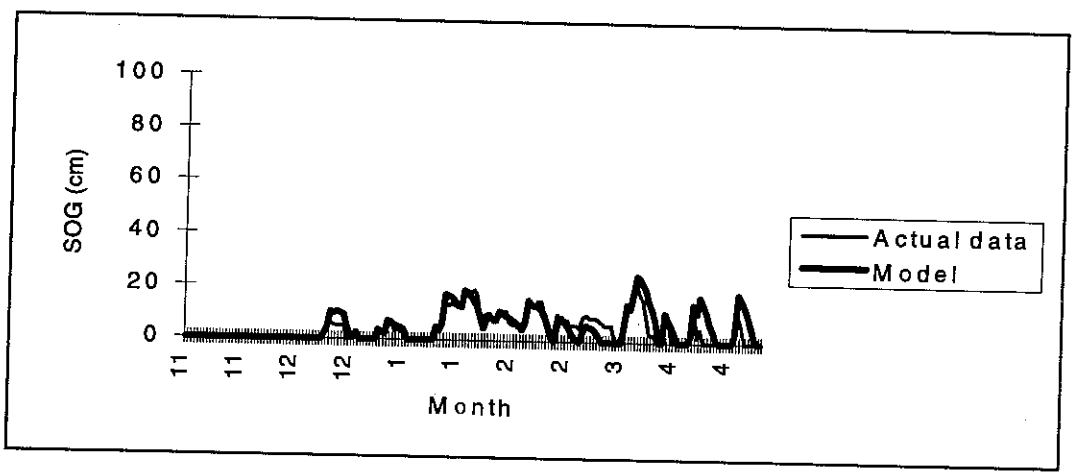


Figure 16. Central Model Test, Fredericton CDA (1988-1989)

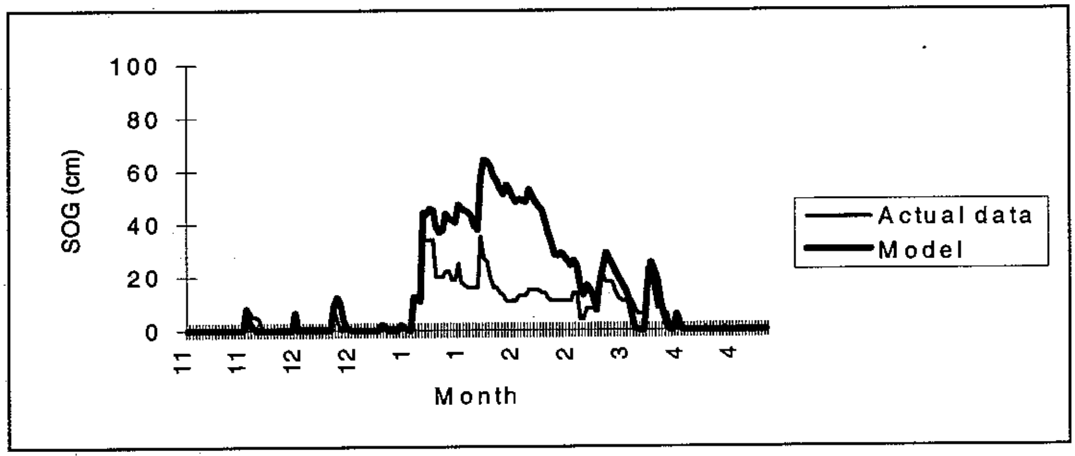


Figure 17. Central Model Test, Fredericton (1990-1991)

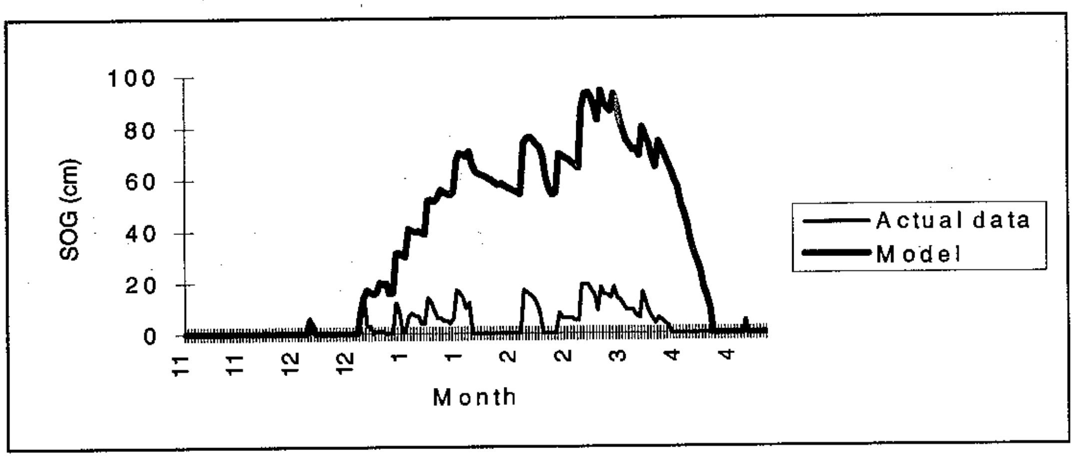


Figure 18. Central Model Test, Fredericton CDA (1993-1994)

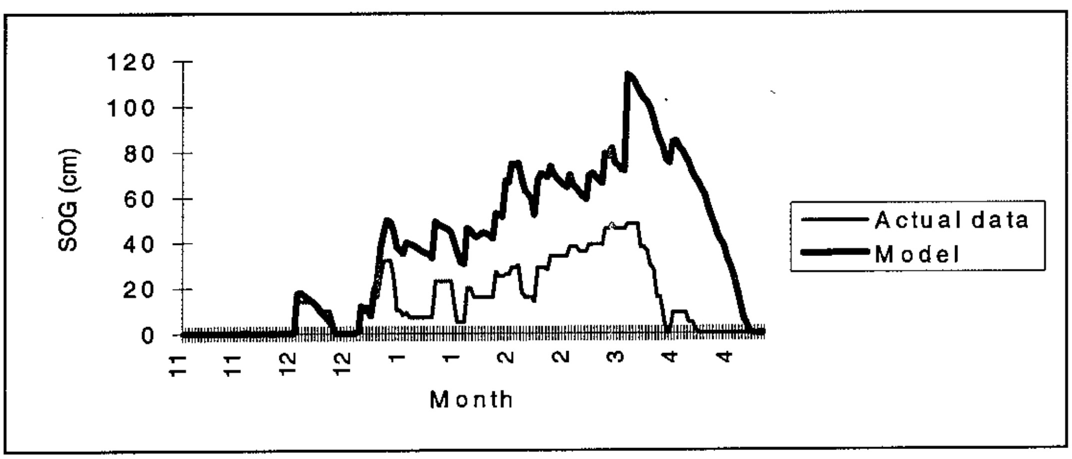


Figure 19. Fundy Model Test , Louisbourg (1992-1993)

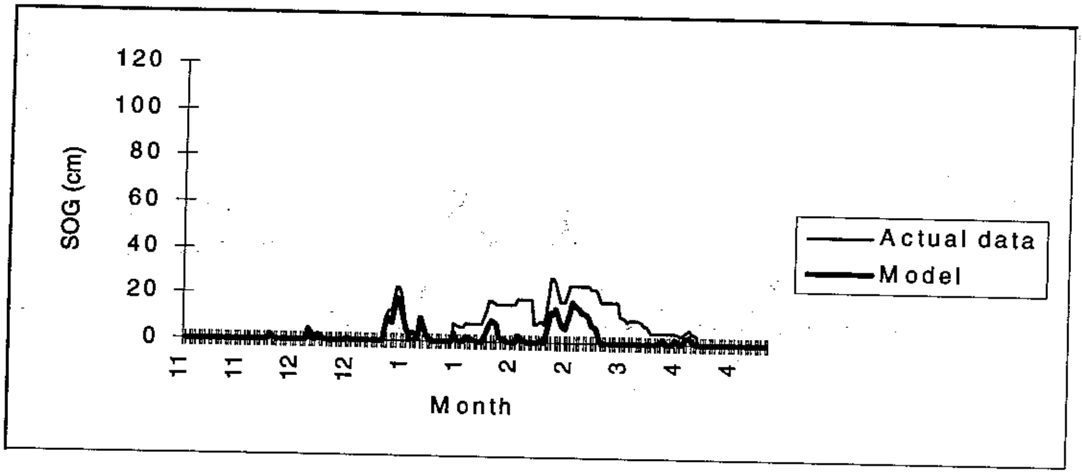


Figure 20. Fundy Model Test, Louisbourg (1994-1995)

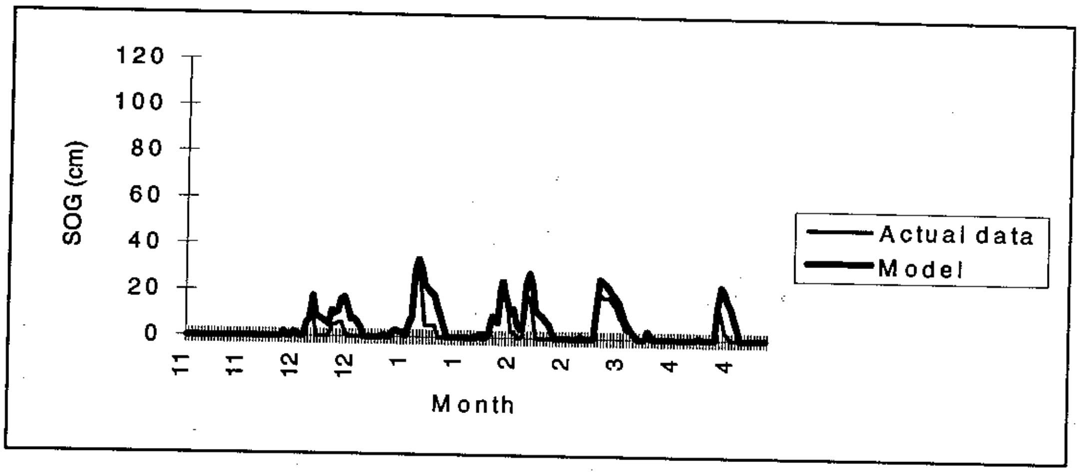


Figure 21. Fundy Model Test, Louisbourg (1995-1996)

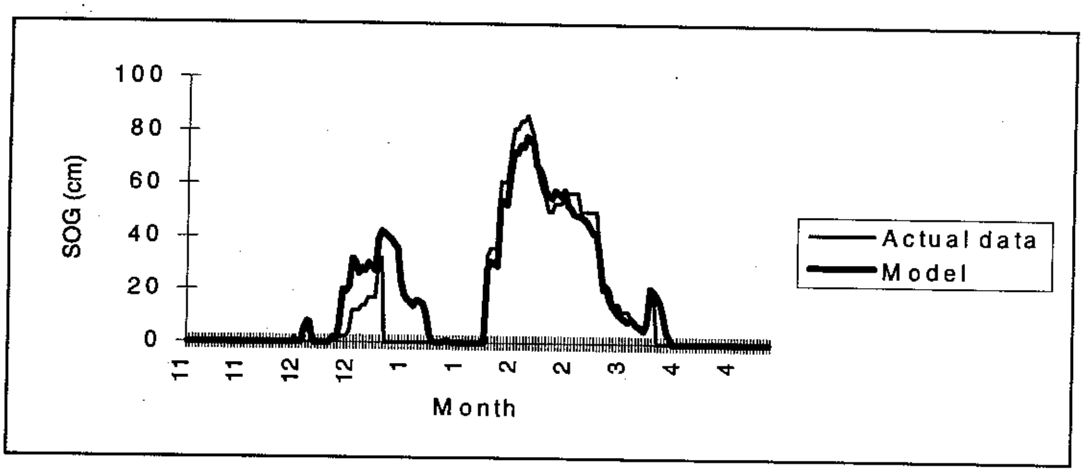


Figure 22. Southern Model Test, Malay Falls (1991-1992)

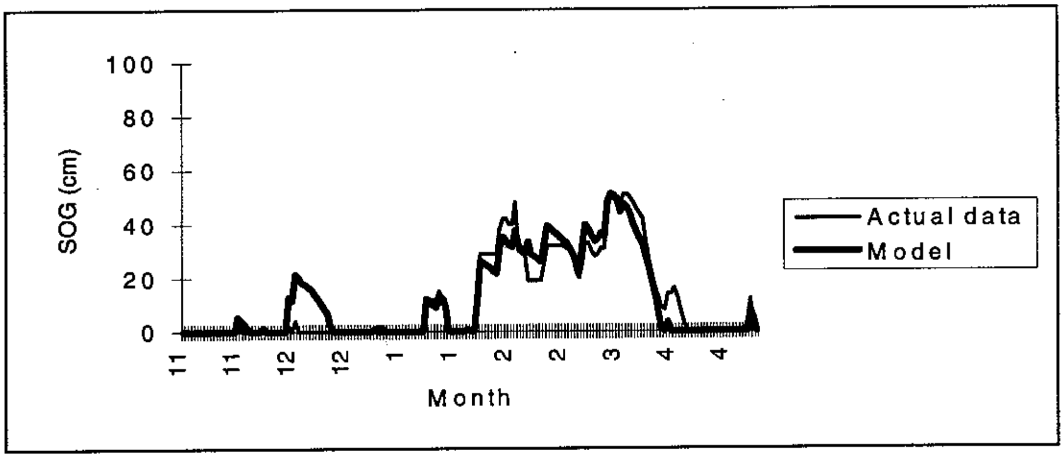


Figure 23. Fundy Model Test, Pennfield (1992-1993)

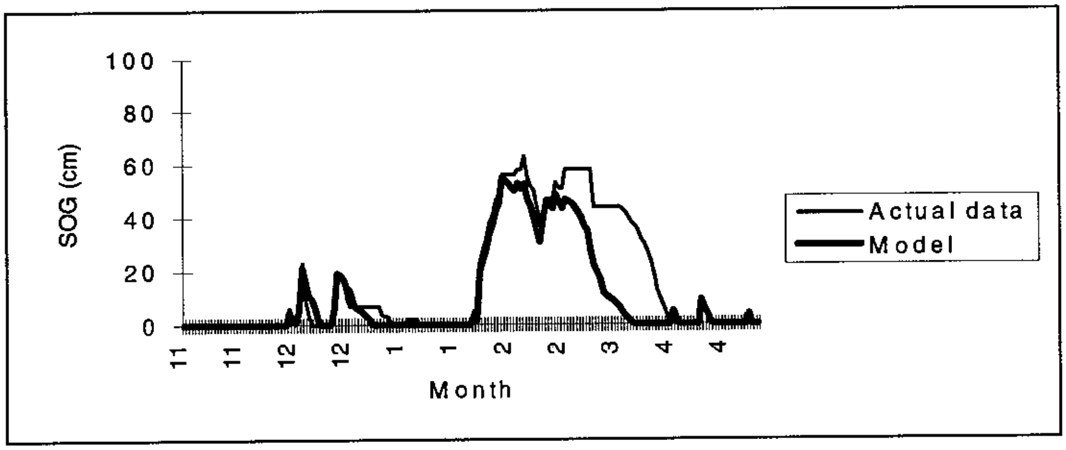


Figure24. Fundy Model Test, Pennfield (1991-1992)

The graphs permit a few generalizations about the model. First, the model follows the actual curves quite well (Figures 10, 11, 12, 13 etc.). It is very rare that the estimated amount increases while the actual amount decreases or vice versa. When it is the case, it is most likely due to observer or instrumental inconsistencies rather than to errors committed by the model. An obvious example of this are the plateaus present in the actual SOG data lasting several days, especially after an important snowfall (Figures 10, 13, 20, 23 and 24). In fact, the occurrence of no settling of the snowpack in the first few days after as snowfall is very unlikely. Second, when the model estimates a value of 0 cm, it is relatively reliable. This is especially the case at the beginning of the snow season (November to mid-December) and at the end of the snow season (April or May). Third, the model estimates are usually better when there is less SOG (figures 11, 14, 16 and 21 as opposed to 10, 12 and 15). This is to be expected because the more snow there is on the ground, the wider the range of possible depth changes. This results in better estimations at the beginning of the snow season (November and December) when there is less SOG. Also, since the snow is new during this period, its properties are generally more uniform, making its reactions to temperature and precipitation more constant than those in the middle or the end of the season. These later periods have a much greater range in snow conditions (density, albedo) making the response of the snowpack to the weather conditions much more variable. Another important characteristic is that since the model does not take in consideration the amount of SOG in its calculation of the depth change, the change in depth tends to be underestimated when there is a deep snowcover and slightly overestimated when there is a shallow snowcover. The fact that deeper snowpacks can potentially settle to a much greater extent explains this observation. Finally, the greatest problem of the model lies with the estimation of depth change on rainy days. The largest errors are arise here because there are many variables that play an important role in this process, namely the temperature of the rain water, the intensity of the rainfall and latent heat release aside from the varying characteristic of the snowpack itself. The model underestimates depth change on days with large rainfalls, while it over estimates on days with little rain. Proper modeling of snowmelt on rainy days is beyond the capability of this limited model. However, slight improvements could be made by attempting to fit different kind of regression curves to the data.

Having said all of the above, the user of the completed SOG data base should use caution when long stretches of continuous estimated SOG values are present, especially when the amount of SOG is high near the end of the snow season. We suggest that strings of 20 or more estimated values, especially when there is more than 100 cm of SOG in the months after February, should be used with caution.

APPLICATION OF THE MODEL

The Depth Change model calibrated to the Maritime provinces was applied to 227 secondary stations opened during varying periods between 1955-1996. This resulted in a substantial increase in the amount of SOG values. Before the application of the model, 47% of the SOG data was present while after the model this figure increased to 87%, which resulted in an increase of 75% in the number of values present. There were 115 stations with less than 50% of their SOG record before the application of the model. However, only 60 stations had less then 75% of their SOG record after the estimations were completed. Figures 25 and 26 show the distribution of the stations according to the completeness of their SOG data before and after the application of the model.

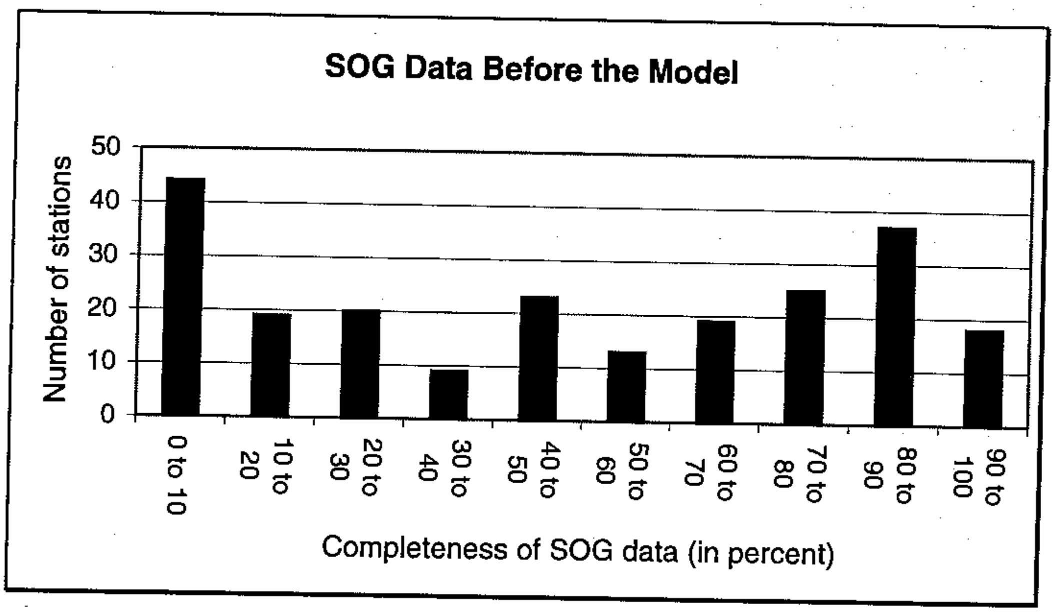


Figure 25. SOG Data Before Application of the Model

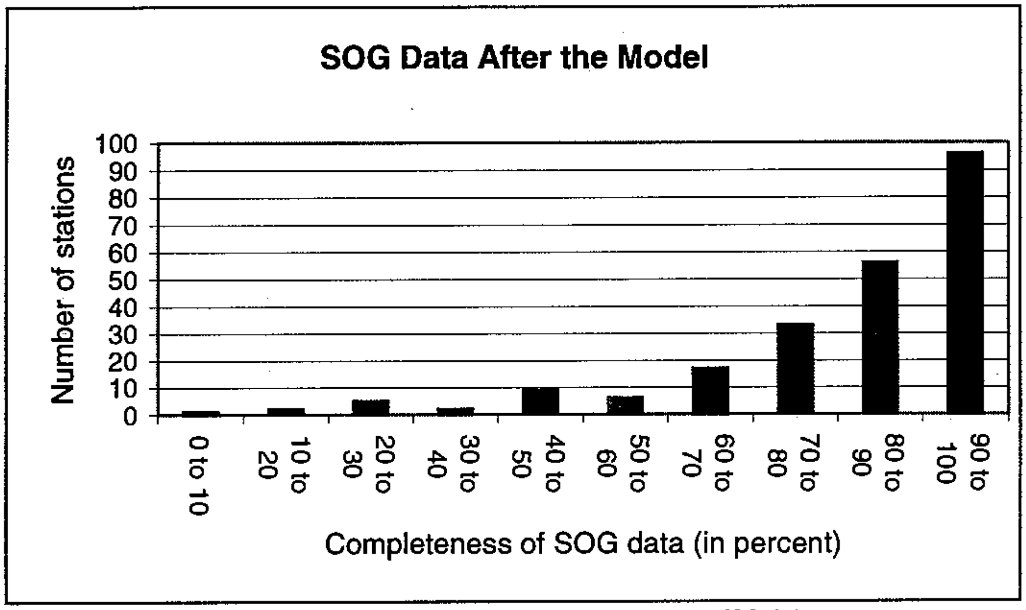


Figure 26. SOG Data After Application of Model

A compact disc with the augmented SOG database was produced. This CD also includes data from 43 other stations that were either principal stations or stations which had SOG data without the temperature or precipitation data needed for the model. The 270 stations are included in the "0-list" file with their geographical co-ordinates and years of SOG data within the 1955-1996 period. All the stations have their own *Excel*8 file with the data presented in an easy to read format. The estimated values are indicated with an "E" present in the column beside the numerical value (in centimeters). Missing values are presented as "-999 ". This data set is available from Environment Canada, Atmospheric Environment Service, Atlantic Region.

ANALYSIS OF SNOWCOVER CONDITIONS

A series of maps presenting the snow climatology of the Maritime provinces were prepared. The probabilities of having a certain amount of SOG (or more) during bimonthly periods using the augmented data set for the 1967-1996 period (30 years) were calculated. Sixty-seven well-distributed sites (Map 1) were used for the maps. The principal stations were the first chosen followed by very good secondary stations with data for the entire period. However, in order to have the best distribution of stations possible throughout the Maritimes, some stations used did not have data for the entire 30 year period, while other data points on the maps were combinations of several stations (see Table 4). The stations with some years missing have at least 20 years of data and the sites that are a combination of stations are composed of stations that were, at most, a few kilometers apart. There are two exceptions: Baccaro has only 13 years of data while the Acadian Peninsula is a combination of three stations over a distance of approximately 50 km along the Acadian Peninsula shoreline. This was necessary to represent the southwest tip of Nova Scotia and northeastern New Brunswick.

Twelve maps show the probabilities of having 0 cm of SOG for the period from November 1 to April 30. We also prepared 60 (5 *12) maps showing the probabilities of having greater than or equal to 10, 20, 30, 40 and 50 cm of SOG for a grand total of 72 maps. A sample series for the 10 cm threshold is included as Maps 3 to 14. Isolines indicating equal probabilities of having the amount of SOG in question were drawn by hand to convert the point data into areal information.

Table 4. Special Data Points in the Analysis

Name	Station ID#	Period	Comments
Acadian Peninsula	----	1967-1996	Bertrand (8100518), Tracadie (8105505) and Haut Shipaggan (8102206)/ 1972 n/a
Alberton	8300080	1969-1996	
Baccaro	8200250	1967-1979	
Bathurst	----	1967-1996	Bathurst (8100500 and 8100502) and Bathurst A (8100503)
Digby	----	1967-1996	Digby Prim Point (8201601) and Digby Airport (8201605)/ 1986-1988 n/a
Edmundston	----	1967-1996	Edmundston Fraser Co (8101301) and Edmundston (810JL00 and 810AL00)
Grand Falls D.	8101904	1967-1992	full name: Grand Falls Drummond
Harvey Station	----	1967-1996	Harvey Station (810220 and 8102201)
Kedgwick	8102300	1967-1994	
Kentville CDA	----	1967-1996	Kentville CDA (8202800) and Kentville CDACS (8202810)
Louisbourg	8203161	1972-1996	
Margaree Forks	----	1967-1996	Margaree Forks (8203422 and 8203423)
McGraw Brook	8102808	1969-1995	
Minto	8103000	1967-1993	
Mt. Carleton	8103256	1973-1996	full name: Mount Carleton
Pennfield	8103845	1976-1996	
Roseway	8204600	1967-1995	
Sable Island	8204700	1967-1995	
Sackville	----	1967-1996	Sackville (8104500 and 8104501)
St Andrews	8104600	1967-1991	
Windsor	----	1967-1996	Windsor Falmouth (8206405) and Windsor Martock (8206415)

An effort was made to make the best representation possible of the Maritimes and consequently some data points are not located between the appropriate isolines. Therefore, there is uncertainty associated with these isolines and a cautious user should include an allowance of at least 10%. This scatter could be caused by mesoscale variation in precipitation, but it is probably closer related to a combination of differences in exposure of the measurement sites of SOG and to error in the estimations by the model.

CONCLUSION

The increase in the number of values in the SOG data set for the Maritime provinces by 75% greatly improves the utility. While the Depth Change method is not perfect, it permits the best possible estimation of SOG with the available temperature and precipitation data. The large number of stations used in the calibration for the Maritimes optimises the equations used for the constituent regions. The small number of station records that were previously available was preventing accurate studies at relatively large spatial and temporal scales. The snow climatology prepared in this document in the form of probability maps is just one way among many to use the augmented data set to describe the snowcover in the Maritimes. The data set will be useful for a variety of scientific, economic and recreational purposes.

ACKNOWLEDGMENTS

We would like to thank Dr. Lien Chow of the Potato Research Centre, Agriculture and Agri-food Canada, Steve Gordon of the N.B. Department of Natural Resources and Energy, Fish and Wildlife Branch, Claire MacInnis and Patrick Tang of the N.B. Department of Environment, Environmental Quality Branch and Environment Canada, Atlantic Region for their financial assistance with this project. It could not have been accomplished without them. Mr. Tang also prepared the augmented data set on compact disc, a very appreciated gesture.

BIBLIOGRAPHY

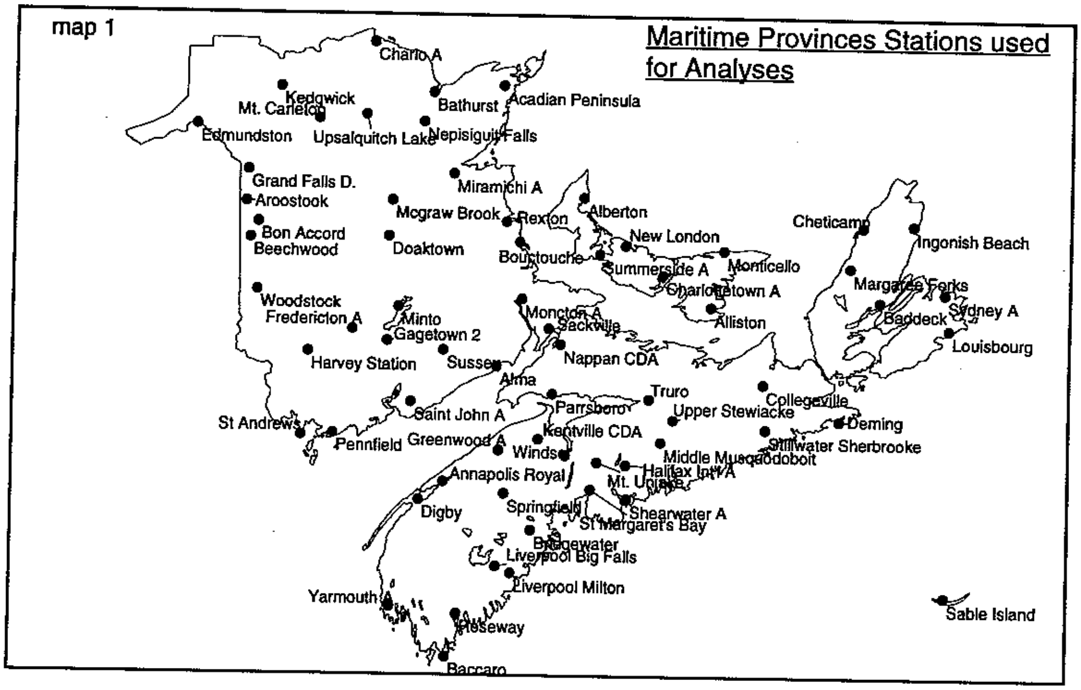
Brown, R.D., and Braaten, R.O. 1998. Spatial and temporal variability of Canadian monthly snow depths, 1946-1995. Atmosphere-Ocean, **36**(1): 37-54.

Hughes, M.G., and Robinson, D.A. 1993. Creating temporally complete snow cover records using a new method for modelling snow depth changes. Glaciology (Snow and Ice), **GD-25**: 150-163.

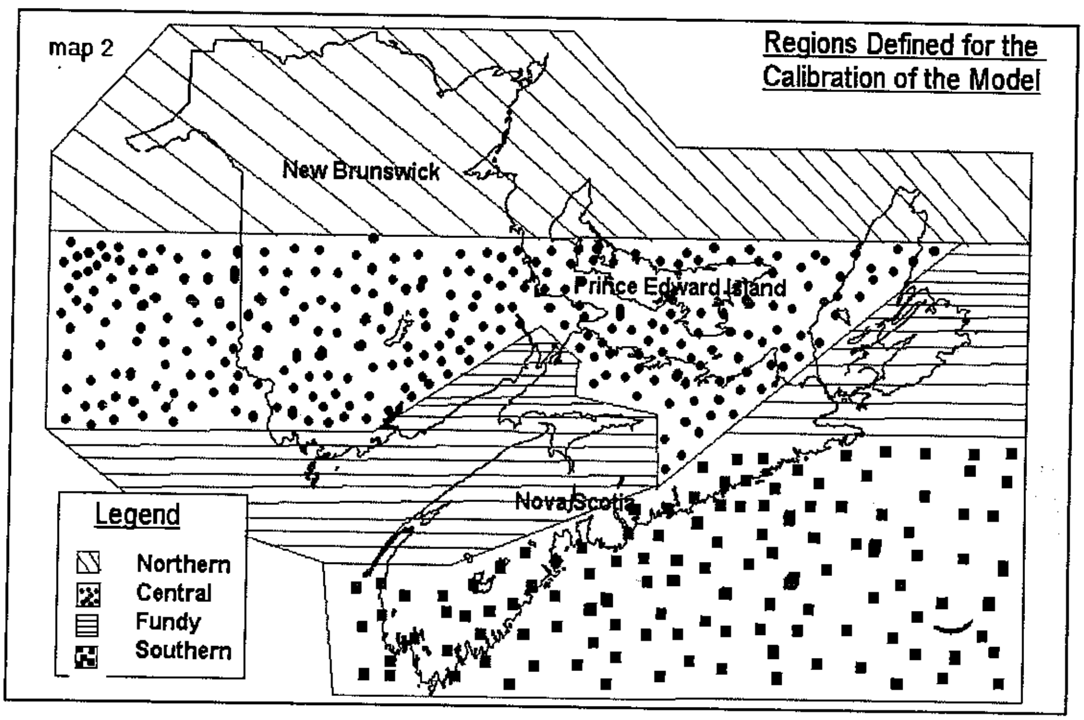
Langham, E.J. 1981. Physics and properties of snowcover, pp. 275-337. *In* D.M. Gray and D.H. Male eds., Handbook of Snow: Principles Processes, Management and Use. Pergamon Press, Toronto.

Male, D.H., and Gray, D.M. 1981. Physics and properties of snowcover, pp. 275-337. *In* D.M. Gray and D.H. Male eds., Handbook of Snow: Principles Processes, Management and Use. Pergamon Press, Toronto.

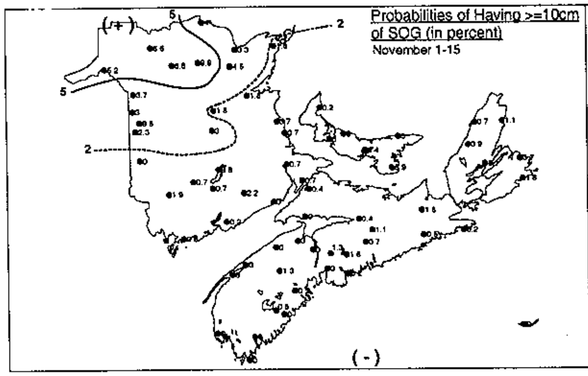
Pomeroy, J.W., and Goodison, B.E. 1997. Winter and snow, pp. 68-100. *In* W.G. Bailey, T.R. Oke and W.R. Rouse eds., The Surface Climates of Canada. McGill-Queen's University Press, Montreal.



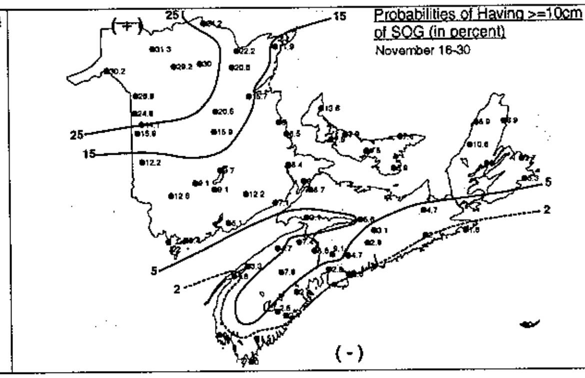
Map 1. Maritime Provinces Stations Used for Analysis



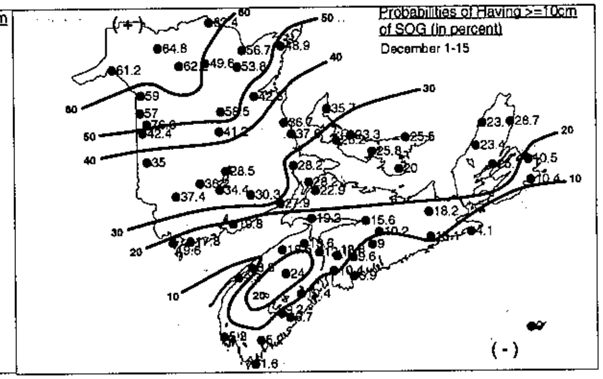
Map 2. Regions Defined for Calibration of Model



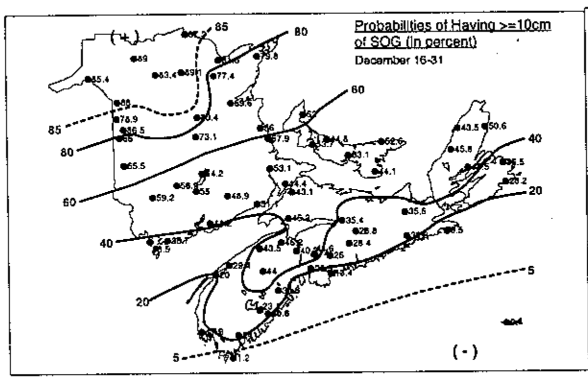
Map 3



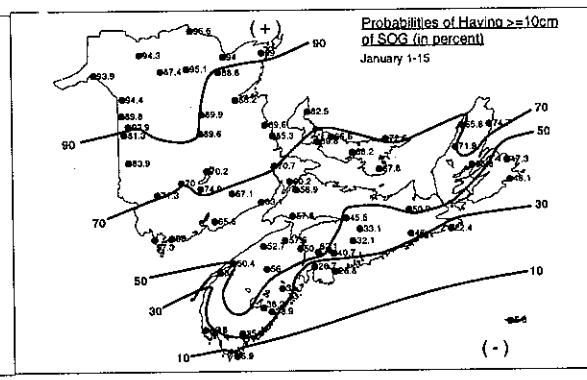
Map 4



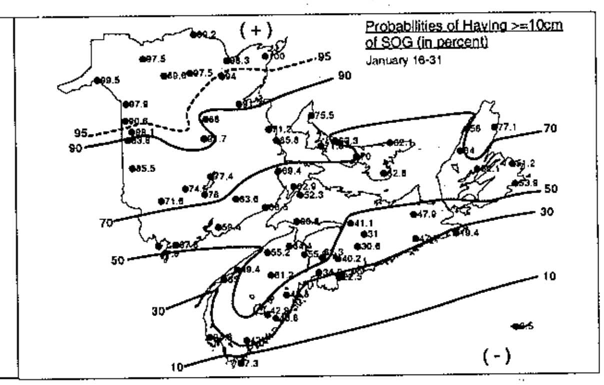
Map 5



Map 6

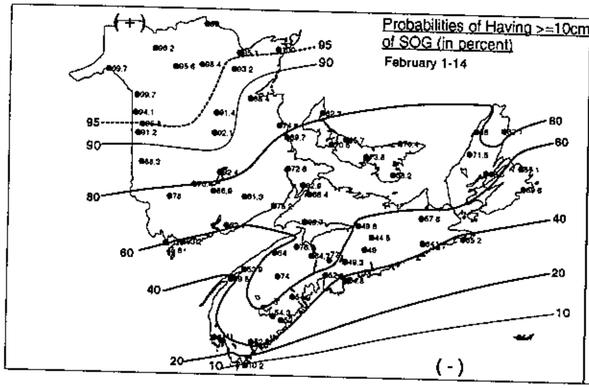


Map 7

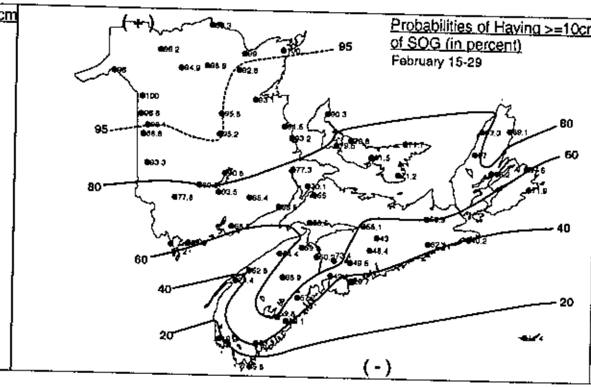


Map 8

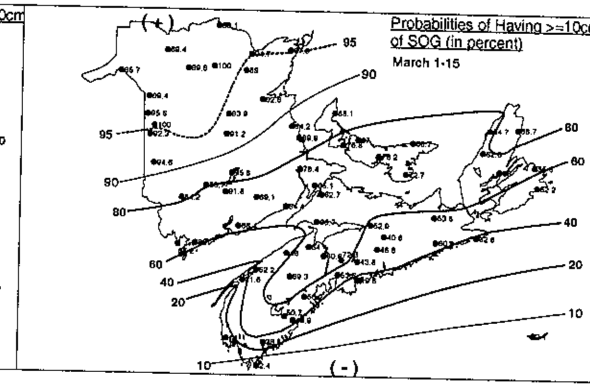
Maps 3 to 8. Probabilities of having >= 10 cm of Snow on Ground, November to January



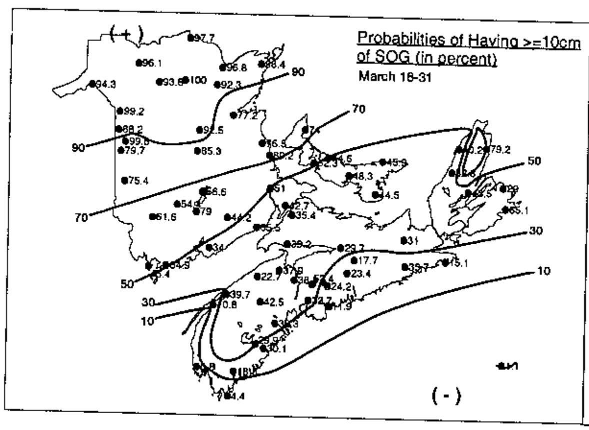
Map 9



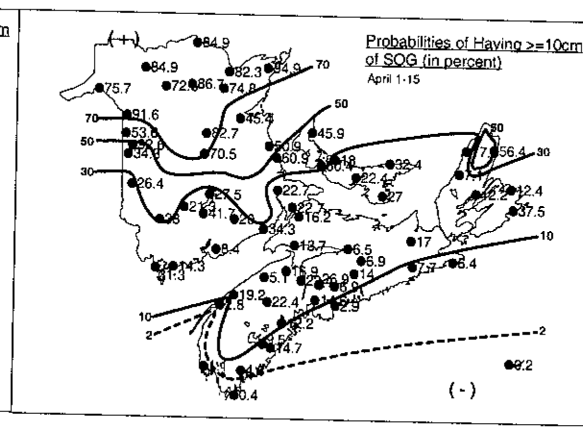
Map 10



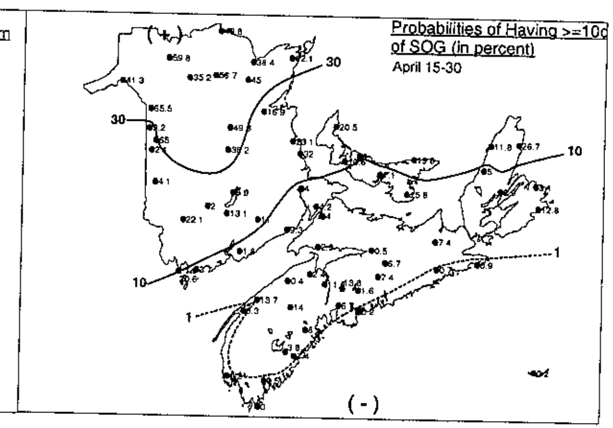
Map 11



Map 12



Map 13



Map 14

Maps 9 to 14. Probabilities of having >= 10 cm of Snow on Ground, February to April