# Climatological Bulletin

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# Bulletin climatologique

Canadian Meteorological and Oceanographic Society

La Société Canadienne de Météorologie et d'Oceanographie

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If FOOTNOTES are required, they should be typed, double spaced, on a separate sheet under the heading "Notes" at the end of the text.
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Publication de la Société canadienne de météorologie et d'océanographie, le Bulletin climatologique offre un moyen d'information sur la climatologie. Le comité de rédaction encourage en particulier la soumission de manuscrits sur la climatologie appliquée (comme l'agriculture, le commerce, l'énergie, l'environnement, la pêcherie, la sylviculture, la santé, les loisirs, les transports, et les ressources en eau), les changements et la variabilité du climat, la prospective climatologique, les applications des modèles du climat (inclus la climatologie physique), et les études régional (inclus les océans). Il est publié grâce à une subvention accordée par le gouvernement canadien par l'intermédiare du Conseil de recherches en sciences naturelles et en génie.

Les auteurs peuvent choisir de soumettre leurs manuscrits aux "Articles", "Notes de Recherches", ou "Nouvelles et Commentaires". Ils doivent l'indiquer sur la lettre d'accompagnement du manuscrit. Les articles de recherche et les "Notes" sont indépendamment soumis à l'examen d'au moins deux appréciateurs anonymes. Le rédacteur en chef examine les "Nouvelles et Commentaires" conjointement avec le comité de rédaction. On accepte les articles soit en français, soit en anglais. Il faut envoyer un résumé, de préférence en français et en anglais.

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# Foreword / Avant-Propos

This issue contains one note that is Canada-wide in scope and one article broadly concerned with the agroclimatology of the eastern portion of the Prairies. This made me think about the topical and geographic coverage of contributions covered in the *Bulletin* in recent years, and I plan to report on this in the August issue.

Ce numéro contient une note concernant le Canada entier et un article sur l'agroclimatologie de la partie est des prairies. Cela m'a fait penser aux sujets et aux régions qui ont caractérisé le contenu du *Bulletin* ces dernières années, et j'en publierai un sommaire dans le numéro d'août.

*Alec Paul*
*Editor / Rédacteur en chef*

# The Biologically Important Thermal Character of the Eastern Prairie Climate

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[Original manuscript received 29 July 1992; in revised form 9 March 1993]

ABSTRACT

The biologically important thermal character of the eastern Canadian Prairies has been described by calculating average, 25% and 10% risk values of the frost-free period and selected thermal parameters. The date-of-maturity of spring wheat, as indicated by a biometeorological-time scale, was also estimated. The results for all climatological stations (146) with at least 15 years of continuous record in the 1929-1988 period were mapped to illustrate the spatial variability of selected thermal characteristics.

Accumulated heat units with higher threshold temperatures had relatively greater spatial variability than heat units with lower base values. Partially for this reason, organisms such as wheat and canola whose rates of growth can be tracked using degree-days base 5°C, generally do well in all areas. Organisms having a higher base developmental temperature, e.g. crops such as beans, and insects such as grasshoppers, whose life stages can be estimated from degree-days base 10°C, are likely to exhibit greater region-to-region variability.

In addition, as the base temperature increased, temporal variability, as measured by areal coefficients of variation, generally increased. Therefore, at a given location there is likely to be more year-to-year variation in the performance of organisms with a higher threshold temperature than in the performance of those with a low threshold temperature.

RÉSUMÉ

On a défini les caractéristiques thermiques de l'est des Prairies, importantes sur le plan biologique, en déterminant les risques de gel correspondant à la moyenne, à 25 et à 10 % pendant les périodes sans gel, ainsi que d'autres paramètres thermiques choisis. On a également estimé la date de maturation du blé de printemps, comme l'indique l'échelle de chronométrie biométéorologique. On a reporté sur un graphique les données recueillies

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continuellement dans les 146 stations de climatologie depuis au moins 15 ans sur une période allant de 1929 à 1988 afin de représenter la variabilité spatiale de certaines caractéristiques thermiques.

L'attribution de températures seuils élevées quant aux unités de chaleur accumulée donne lieu à une plus grande variabilité spatiale que lorsque ces seuils sont plus bas. C'est en partie pour cette raison que des organismes comme le blé et le canola, dont l'unité thermique de croissance de base s'établit à 5 °C, poussent généralement bien dans toutes les régions. Il est probable que la variabilité entre régions sera plus considérable chez les organismes dont le développement repose sur une température de base plus élevée, comme les haricots ou les sauterelles, dont le cycle biologique exige un degré-jour de 10 °C.

En outre, à mesure que la température de base s'élève, on observe une augmentation générale de la variabilité temporelle mesurée au moyen de coefficients de variation régionale. Par conséquent, dans un lieu donné, il est probable que le rendement d'organismes exigeant une température seuil plus élevée variera davantage d'une année à une autre que celui d'organismes se développant à une température seuil plus basse.

## 1. INTRODUCTION

Together with moisture, the thermal character of a region determines the range of agriculture that can be practised. The number of consecutive days without frost sets limits on the classes of crops that can be grown. A more important characterization of the thermal regime of a region is the availability of biologically useful heat units, e.g. degree-days. Heat units can be used as estimators of the phenological development of crops, as well as of agricultural pests, such as plant diseases and insects (Expert Committee on Agrometeorology 1986). In the latter case, heat units can be used operationally to time the application of pesticides for maximum effectiveness, thereby reducing costs and minimizing damage to the environment.

Much of the work characterizing the thermal regime of the eastern Prairie region has centred on calculating average values. Although these averages have been a useful guide to agriculture, they do not define the climatic risks. For example, along with the average frost-free period, it is useful to producers to know the risk of an abnormally short frost-free period. Thus, the main objective of this study was to provide a risk assessment for some of the biologically important thermal characteristics of the eastern Prairies. Once the thermal character of the region has been quantified, this information can be used for making recommendations to producers, for determining crop insurance premiums and for other related applications.

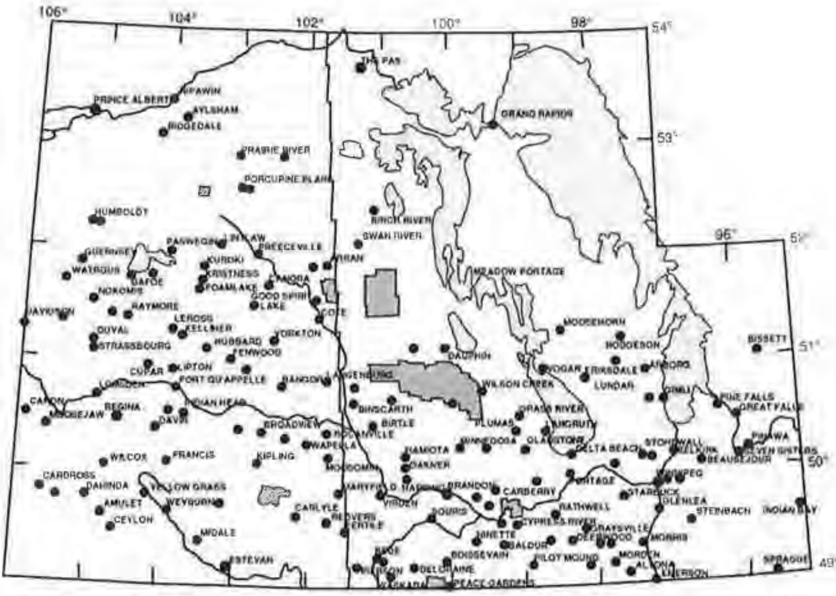


FIGURE 1. The study area with the locations of climatological stations within southern Manitoba and southeastern Saskatchewan that were used in this analysis.

## 2. MATERIALS AND METHODS

### 2.1 *Study Area*

The study area, which may be referred to as the eastern Prairies, extends from 49 to 54 degrees north latitude and from 95 to 106 degrees west longitude (Figure 1). This region, primarily composed of agricultural fields, steps upward from the first prairie plain (approximately 200-300 m) to the second prairie plain (approximately 400-600 m) at the Manitoba Escarpment. The Escarpment features a series of treed upland ridges. The eastern Prairies region, although primarily transitional grasslands, includes some arid grasslands in the southwest and extends into the boreal ecoclimatic zone along its northern and eastern fringes (Canada Committee on Ecological Land Classification 1989).

As previously done for a moisture risk assessment for the same area (Ash *et al.* 1992), all Environment Canada climate stations with at least 15 years of continuous record in the 1929-1988 period (76 stations in Manitoba and 70 in Saskatchewan) were included in the study. This selection procedure maximized the spatial resolution of the analysis. However, the temporal representativeness of the analysis obviously varied somewhat from station to station in accordance with the length of the climate record at each site. Inherent in this analysis is the general assumption that 15 to 60 years of record gives the same climatology.

In the following sections, the results are presented and discussed by province. The Saskatchewan portion of the study area is referred to as "southeastern Saskatchewan", the Manitoba portion as "southern Manitoba". Although this separation is arbitrary and not based on ecoclimatic zoning, it was chosen so that the results could be used by provincial government agencies that are constrained by these political boundaries.

### 2.2 *Frost*

The date of the last occurrence of frost (minimum temperature $\leq 0°$C) in spring, the earliest date of occurrence of frost in fall, and the frost-free period were determined for each year at each climatological station.

### 2.3 *Degree-Days*

Simple degree-days are the excesses of the mean daily temperatures above a base temperature. Maximum and minimum daily temperatures are averaged to give a mean daily temperature. The base temperature is subtracted from this value. Daily degree-days are then summed to give the growing season total.

The choice of a base temperature for a degree-day calculation depends upon the organism under consideration. Base temperatures for plants vary between 2 and 10°C (Dethier and Vittum 1963), while those for insects vary between 5 and 15°C (Wagner *et al.* 1984). In order to provide information relevant to the broad range of organisms of interest to eastern Prairie agriculturalists, annual totals of degree-days above 5, 10 and 15°C were analyzed.

### 2.4 *Corn Heat Units*

An indicator of heat accumulation specific to corn is the corn heat unit (Brown 1963):

$$CHU = 0.9\,(Tmin - 4.4) + 1.665\,(Tmax - 10) - 0.042\,(Tmax - 10)^2$$

where Tmin is the daily minimum temperature (°C), and Tmax is the daily maximum temperature (°C). Corn heat units were calculated from May 15 and accumulated over the growing season to the first hard fall frost (minimum temperature $\leq -2.2°$C).

### 2.5 *Bio-Photo-Thermal Units*

Bio-photo-thermal units recognize the influence of photo-period as well as the effect of temperature on the development of biological organisms. In the present study, Robertson's (1968) biometeorological-time scale for wheat was analyzed. This scale recognizes six phenological events: planting, emergence, jointing,

TABLE 1. The average, lowest and highest station-specific standard deviations, and standard deviation of the standard deviations, of selected thermal characteristics grouped by province.

| Characteristic | Southeastern Saskatchewan Lowest | Highest | Average | S.D. | Southern Manitoba Lowest | Highest | Average | S.D. |
|---|---|---|---|---|---|---|---|---|
| Date of Last Spring Frost | 9.1 | 16.4 | 12.3 | 1.6 | 8.1 | 15.7 | 11.3 | 1.8 |
| Date of First Fall Frost | 5.9 | 26.5 | 13.6 | 4.7 | 5.8 | 26.8 | 11.7 | 6.2 |
| Frost-Free Period (Days) | 11.0 | 34.1 | 19.5 | 5.2 | 11.1 | 37.0 | 16.8 | 5.5 |
| Degree-Days > 5°C | 87.8 | 148.3 | 114.4 | 16.3 | 96.3 | 144.5 | 123.5 | 13.5 |
| Degree-Days > 10°C | 74.4 | 128.8 | 97.1 | 16.1 | 76.1 | 149.5 | 105.1 | 16.4 |
| Degree-Days > 15°C | 52.2 | 98.7 | 71.1 | 13.0 | 48.1 | 113.8 | 78.6 | 14.2 |
| Corn Heat Units | 155.8 | 309.1 | 213.8 | 27.2 | 141.0 | 266.3 | 207.7 | 27.2 |
| Maturity Date (Wheat) | 4.5 | 11.6 | 7.5 | 1.2 | 4.7 | 14.0 | 8.7 | 1.7 |

heading, soft dough and maturity, which are numbered zero to 5, respectively. The general planting dates for wheat near each climatological station for the years 1952-1988 were obtained from Statistics Canada (1989). Planting dates for the earlier period (1929-1951) were estimated from a regression equation relating known planting dates (1952-1988) to soil tractability based on soil moisture budgeting (Selirio 1969; Dunlop 1981; Ash 1991). Subsequent growth stages and maturity dates were estimated by the biometeorological-time scale calculated from daily maximum and minimum temperatures and photoperiods.

## 3. DATA ANALYSES AND INTERPRETATION

The lowest and highest values of the station-specific standard deviations for selected parameters grouped by province (Table 1) provided a measure of the range of temporal variability in the thermal character across the region. For example, the temporal standard deviations for the dates of last spring and first fall frosts ranged from 6 to 27 days. For the frost-free period, the range of the standard deviations in southeastern Saskatchewan was 11 to 34 days and in southern Manitoba, 11 to 37 days. Inspection of Table 1 shows that, across each province, there was a fairly wide range in temporal variability for all of the thermal parameters. No doubt, some of this spatial variation in temporal variability was due to site-to-site differences in the length of climatic record. Another cause of this variation may have been local influences such as lakes or terrain limiting more general extremes in temperatures.

The areal coefficients of variation for specific thermal parameters, i.e. the areal average of the temporal standard deviations as a percentage of the areal average of the temporal means of each parameter, were calculated for each province. These calculations provided scaled measures of each parameter's temporal variability for southern Manitoba and for southeastern Saskatchewan. These results were then used to compare the relative temporal variability of

TABLE 2. Areal coefficients of variation (CV, i.e. the average standard deviation as a percentage of the average value) and the standard deviations of the temporal standard deviations as a percentage of the average temporal standard deviations ($SD_{SD}$) for the two subregions.

| | Southeastern Saskatchewan | | Southern Manitoba | |
|---|---|---|---|---|
| Characteristic | CV (%) | $SD_{SD}$ (%) | CV (%) | $SD_{SD}$ (%) |
| Frost-Free Period (days) | 19.1 | 26.7 | 15.1 | 32.7 |
| Degree days > 5°C | 7.6 | 14.2 | 7.7 | 10.9 |
| Degree days > 10°C | 11.0 | 16.6 | 11.0 | 15.6 |
| Degree days > 15°C | 16.6 | 18.3 | 16.7 | 18.2 |
| Corn Heat Units | 9.7 | 12.7 | 8.6 | 13.0 |

various thermal properties. Thermal properties for which these calculations were done were frost-free period, degree days bases 5, 10 and 15°C, and corn heat units (Table 2).

The areal coefficients of variation for southeastern Saskatchewan and southern Manitoba (Table 2) illustrate the general temporal variability of the thermal characteristics of the eastern Prairie climate. Values of 19.1 and 15.1% for frost-free period for Saskatchewan and Manitoba, respectively, are relatively high. Likewise, coefficients of variation of approximately 10% for corn heat units have practical implications, since the corn heat units requirement of most hybrids is only slightly lower than the number received in an average year. A comparison of the provincial areal coefficients of variation for the three degree-day categories revealed that as the base temperature increased, temporal variability increased. As a consequence, there is likely to be more year-to-year variance in the performance of organisms with a higher threshold developmental temperature, e.g. 10°C for grasshoppers (Gage *et al.* 1976), than in the performance of organisms with a lower threshold temperature, e.g. 5°C for canola (Morrison *et al.* 1989).

To find the risk associated with a particular thermal characteristic, an appropriate frequency distribution was ascribed to each parameter. Null hypotheses, that all the parameters could be adequately described by normal distributions, were formulated. These hypotheses were tested using the univariate procedure of SAS (1985) employing the Kolmogorov D statistic (Stephens 1974). As found by Thom and Shaw (1958) and Dunlop (1981), the thermal characteristics examined in this study were all normally distributed. Therefore, the 25 and 10% risk values of each thermal characteristic could be calculated from their means and standard deviations (Huntsberger 1967). For example, the mean value of the frost-free period (minimum temperatures > 0°C) at Regina, Saskatchewan was 103 days and the standard deviation was 20 days. To calculate the 10% risk value, the standard deviation was multiplied by the t statistic at $P = 0.10$ and 59 degrees of freedom (60 years of record), 1.285. This product was then subtracted from the mean, to give a 10% risk value of 78 days.

A computer contouring technique (SURFER 1987) was used to map the average and the 25 and 10% risk level values for the frost-free period and for other selected thermal characteristics.

The first set of risk maps prepared were those for frost-free period. In most of the region mapped, the average frost-free period was between 95 and 125 days (Figure 2), while the standard deviations were between 11 and 37 days (Table 1). In the case of the 25% risk, i.e. one year in four occurrence (Figure 3), the values were approximately 10 days shorter than the average, and on the 10% risk maps, i.e. one year in ten occurrence (Figure 4), values were approximately 20 days shorter than the average.

The average annual values of degree-days above 5° C in the study area ranged from 1400 to 1700 (Figure 5), while the range of standard deviations was 88 to 148 (Table 1). It follows that the 25% risk map (i.e., one in four year occurrence, Figure 6) generally has seasonal degree-day values approximately 100 less than those on the map of averages. Likewise, the 10% risk map (i.e., one in ten year occurrence, Figure 7) has values about 175 less than the average values.

The average values for degree-days above 10° C ranged from 750 to 1000 (Figure 8). The standard deviations ranged from 74 to 150 (Table 1). As a result, the 25% risk map (Figure 9) generally has seasonal degree-day values which are approximately 70 less than the average values, while the 10% risk values (Figure 10) are about 120 less.

The average seasonal accumulation of degree-days above 15° C for the eastern Prairies ranged from 350 to 500 (Figure 11), while the standard deviations ranged from 48 to 114 (Table 1). In general, the 25% risk map (Figure 12) for degree-days above 15° C has values approximately 50 less than the average values, while the 10% risk values (Figure 13) are approximately 100 less.

As the base temperature of the degree-day accumulations increased, spatial variability, expressed as the standard deviations of the temporal standard deviations for southeastern Saskatchewan and southern Manitoba (scaled by conversion to a percentage of the average temporal standard deviation by province, Table 2), increased. It follows that organisms with lower threshold growth temperatures, e.g. 5° C for wheat and canola, generally perform well throughout the whole of the eastern Prairies (Statistics Canada 1989), but that organisms having higher base developmental temperatures, e.g. 10° C for grasshoppers and corn borers (Gage *et al.* 1976, Showers *et al.* 1983), would be expected to exhibit larger regional variability in their viability.

Standard deviations for annual accumulations of corn heat units were from 141 to 309 (Table 1). Most of the region has average corn heat unit accumulations of 2000-2500 (Figure 14), the 25% risk map (Figure 15) has values about 150 less than the averages, and the 10% risk map (Figure 16) has values about 300 less. Since the earliest grain corn hybrids require more than 2200 heat units to reach maturity, high risks are associated with the production

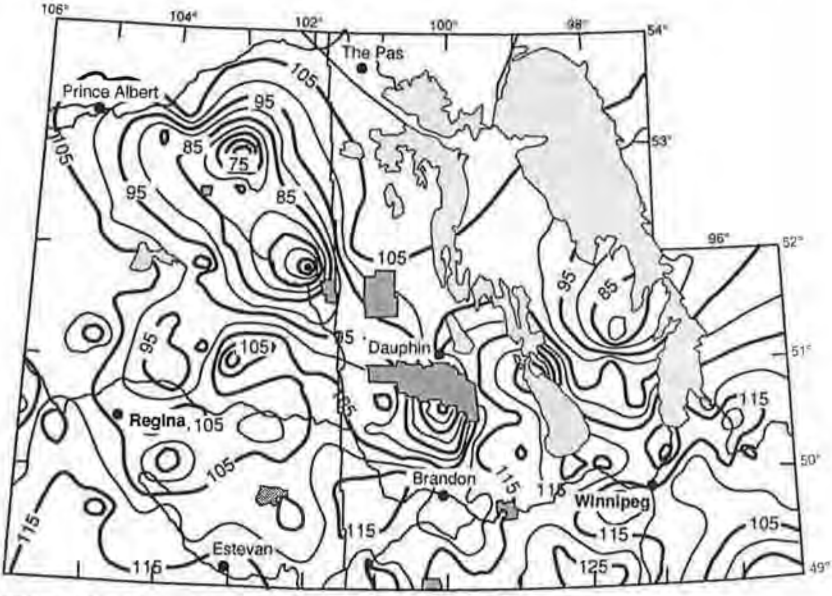

FIGURE 2. Average length of frost-free period above 0°C.

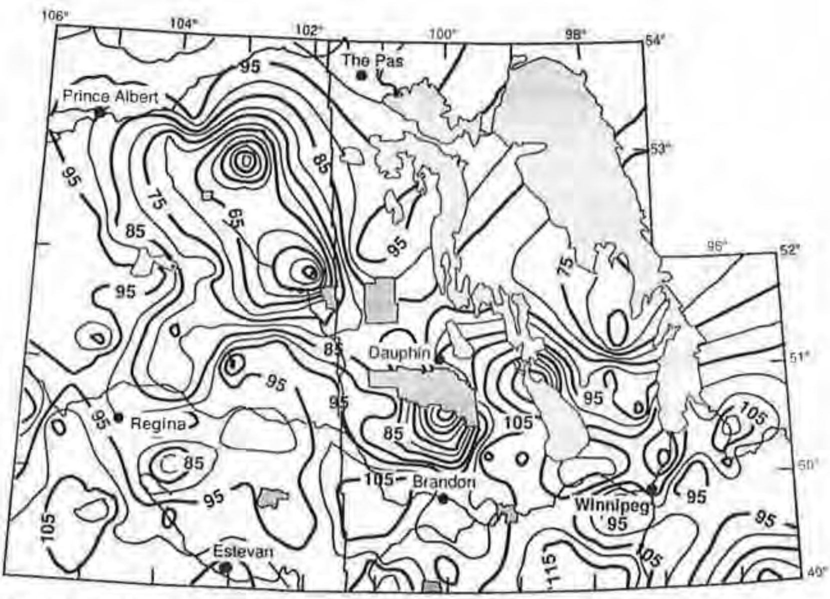

FIGURE 3. Length of frost-free period above 0°C - 25% risk or one in four year occurrence.

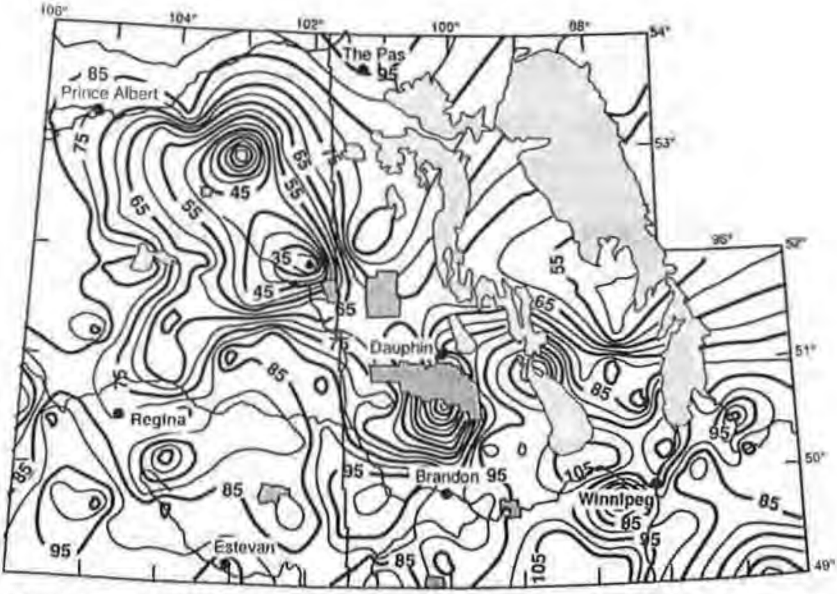


FIGURE 4. Length of frost-free period above 0°C - 10% risk or one in ten year occurrence.

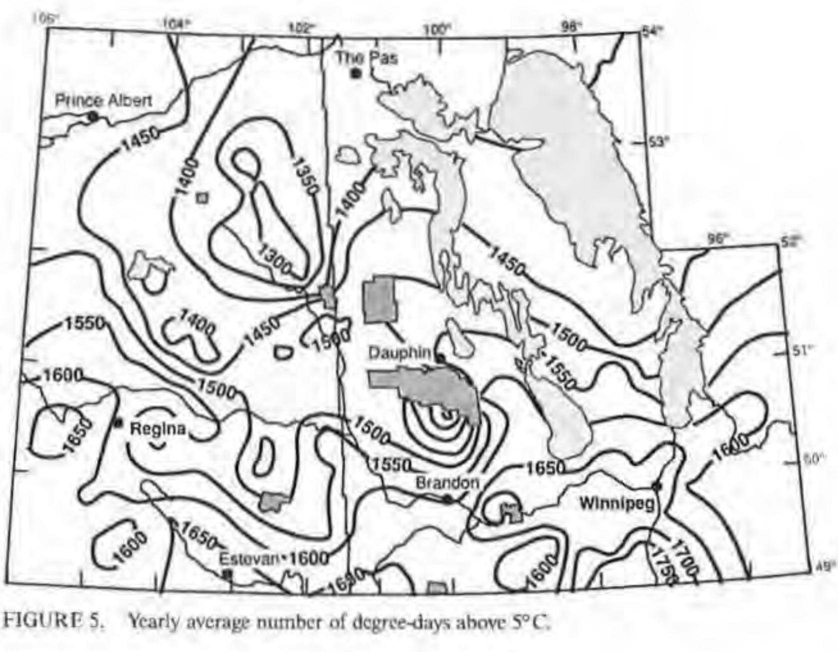


FIGURE 5. Yearly average number of degree-days above 5°C.

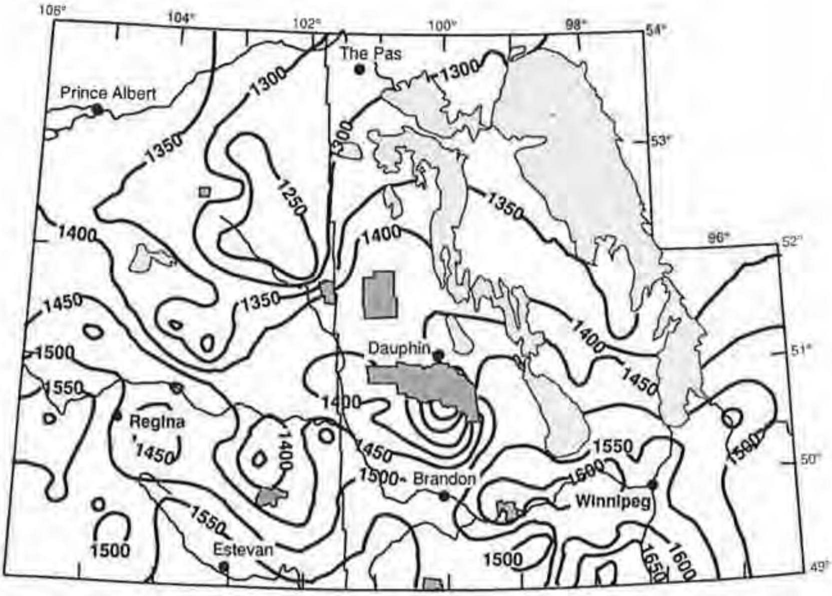


FIGURE 6. Yearly accumulation of degree-days above 5°C - 25% risk or one in four year occurrence.

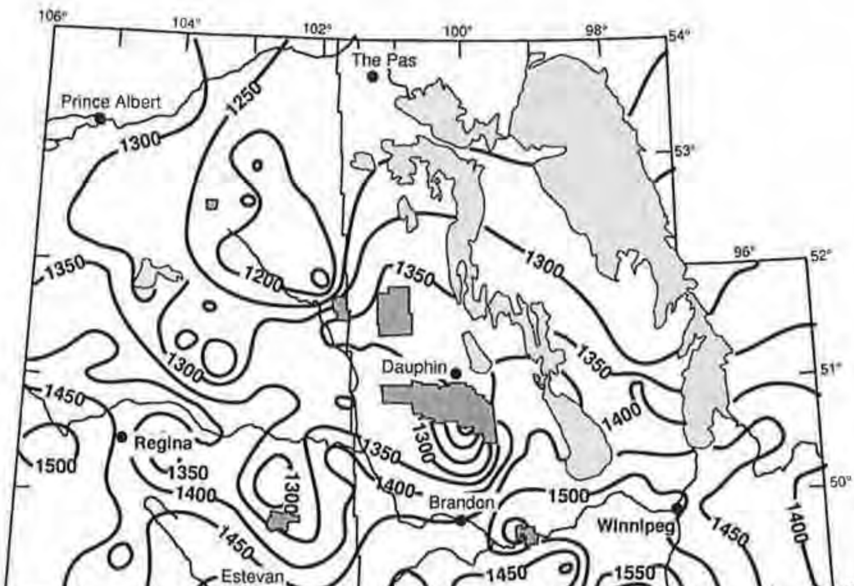


FIGURE 7. Yearly accumulation of degree-days above 5°C - 10% risk or one in ten year occurrence.

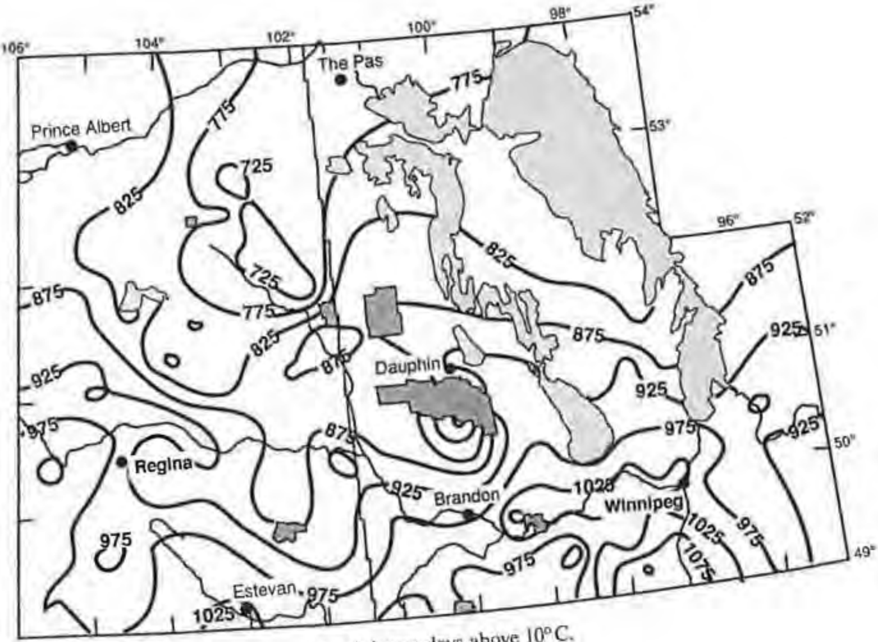


FIGURE 8. Yearly average number of degree-days above 10°C.

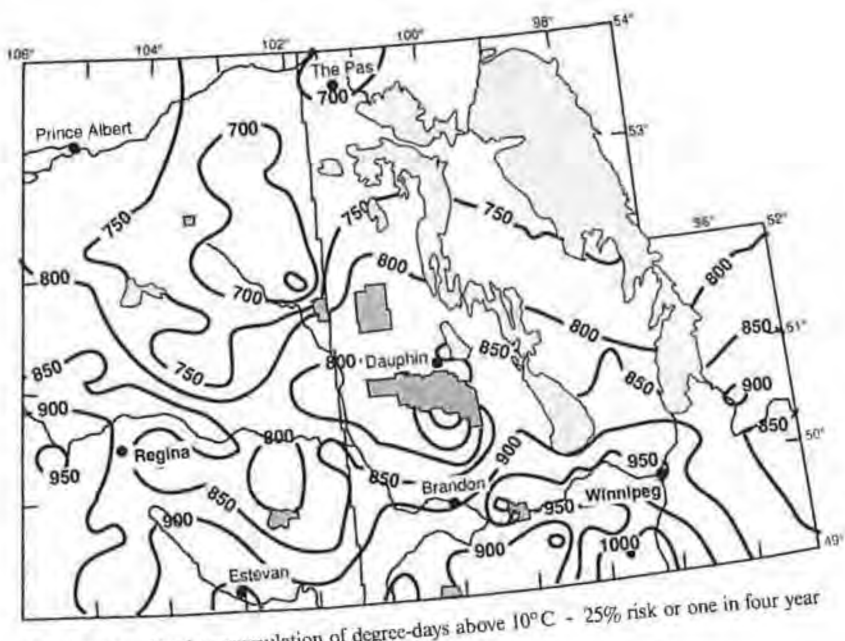


FIGURE 9. Yearly accumulation of degree-days above 10°C - 25% risk or one in four year occurrence.

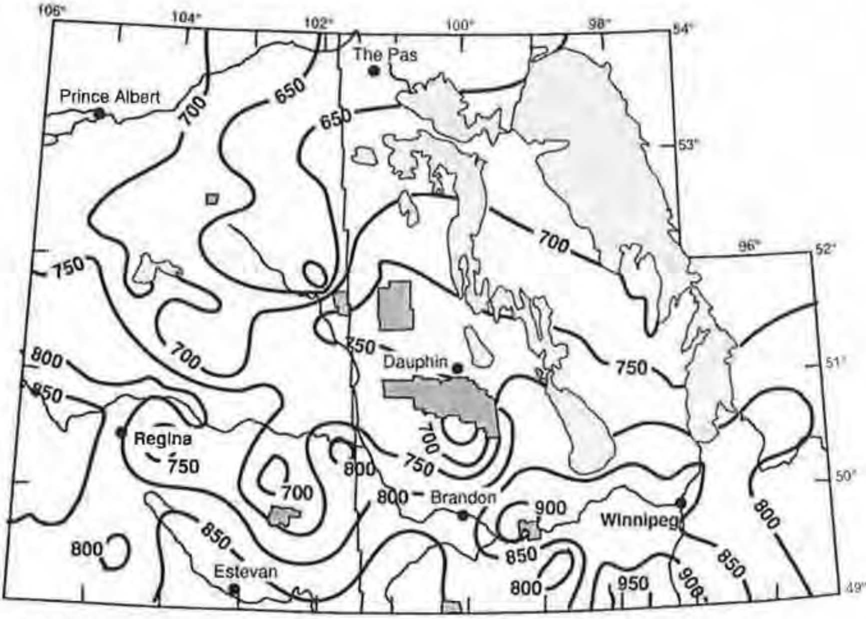


FIGURE 10. Yearly accumulation of degree-days above 10°C - 10% risk or one in ten year occurrence.

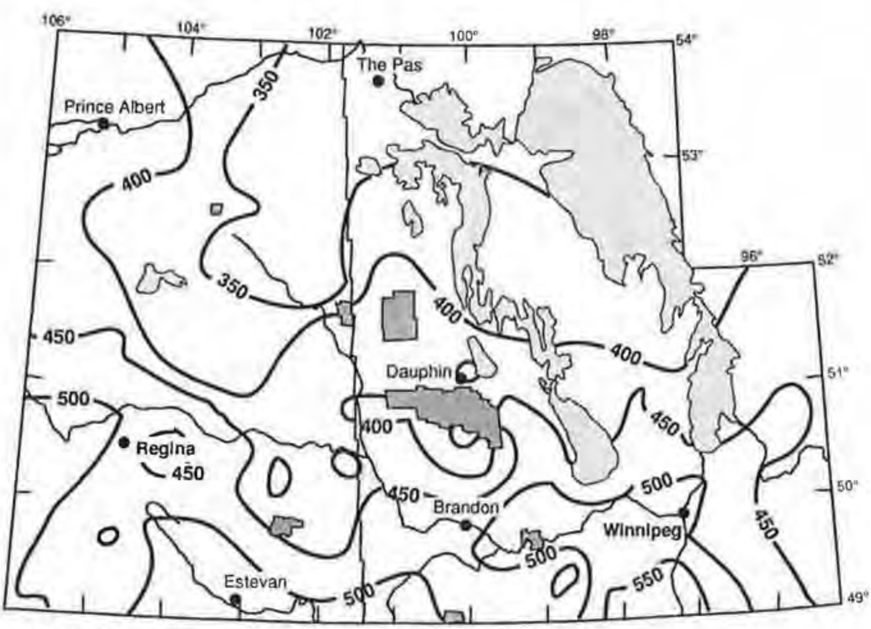


FIGURE 11. Yearly average number of degree-days above 15°C.

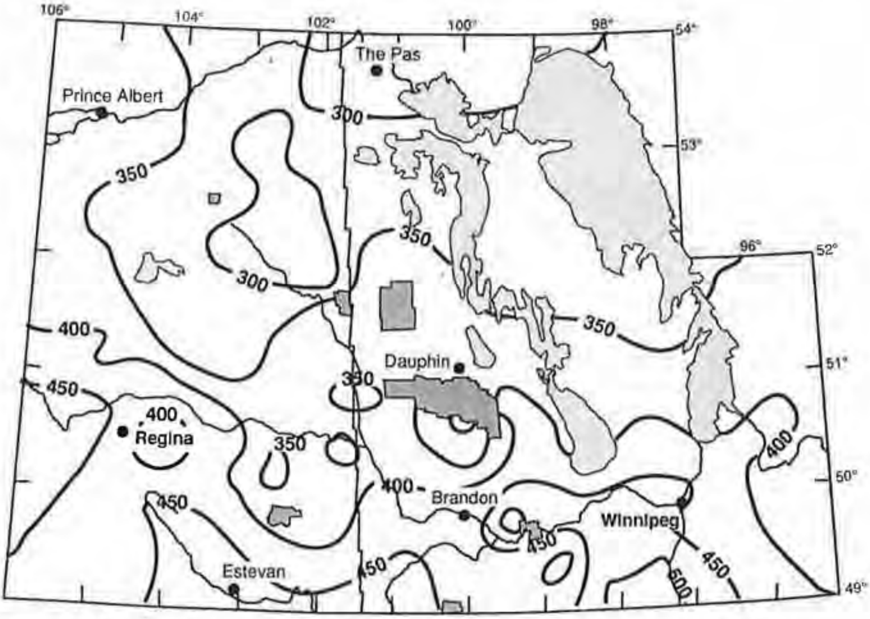


FIGURE 12. Yearly accumulation of degree-days above 15°C - 25% risk or one in four year occurrence.

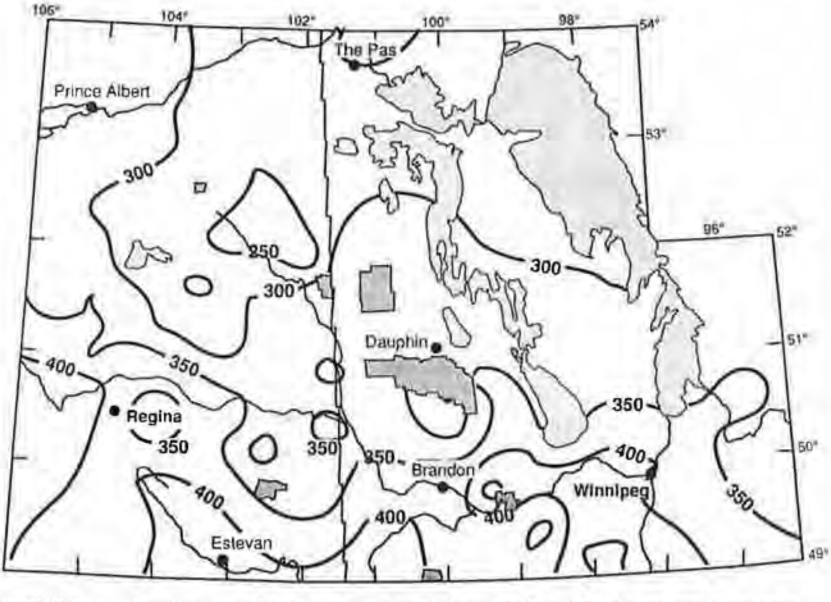


FIGURE 13. Yearly accumulation of degree-days above 15°C - 10% risk or one in ten year occurrence.

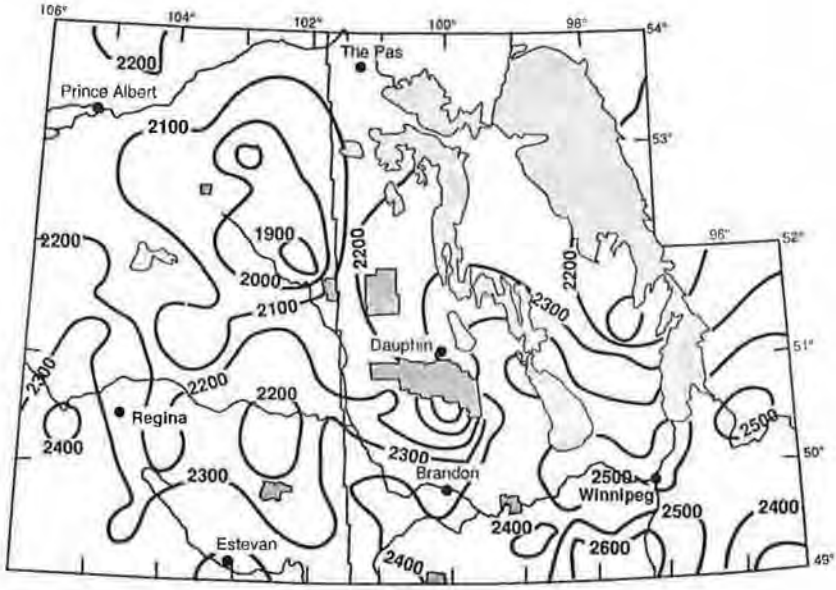


FIGURE 14. Yearly average accumulation of corn heat units

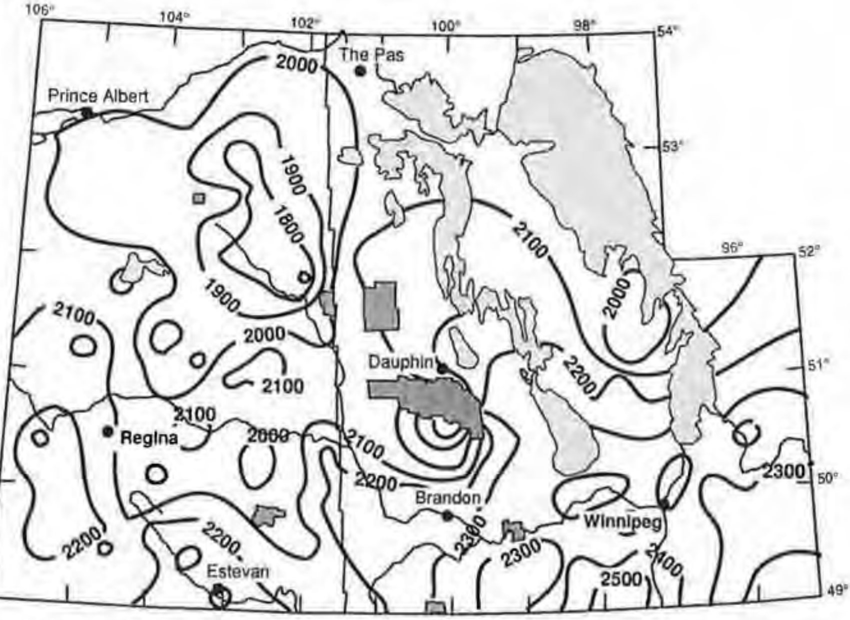


FIGURE 15. Yearly accumulation of corn heat units - 25% risk or one in four year occurrence.

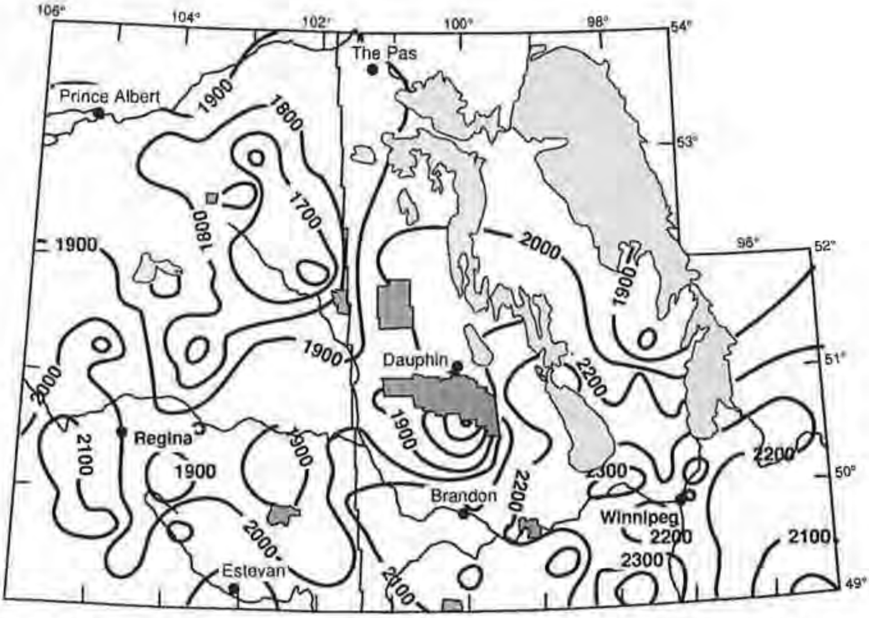


FIGURE 16. Yearly accumulation of corn heat units - 10% risk or one in ten year occurrence.

of this crop throughout a large portion of the eastern Prairies, particularly in southeastern Saskatchewan.

For the southern halves of southern Manitoba and southeastern Saskatchewan, the mean maturity date for spring wheat, based on a biometeorological time scale (Robertson 1968), was August 11 (Julian date 223, Figure 17). The date of maturity becomes later as one moves northward; the average was about August 20 (Julian date 231) in the northern portion of southern Manitoba and in the northeastern portion of Saskatchewan's agricultural zone. The standard deviations of the maturity dates were 5 to 14 days (Table 1). This means that one year in four will have a maturity date 6 days or more later than the average. One year in ten will have a maturity date 11 days or more later than the average date.

## 4. SUMMARY

The biologically important thermal characteristics of the eastern Prairies that were examined in this study were found to exhibit measurable spatial variability. The "warmest" region was found to be south-central Manitoba, and the climate generally became "colder" from southwest to northeast. Areas of higher elevation, such as the upland areas along the Manitoba Escarpment, had shorter

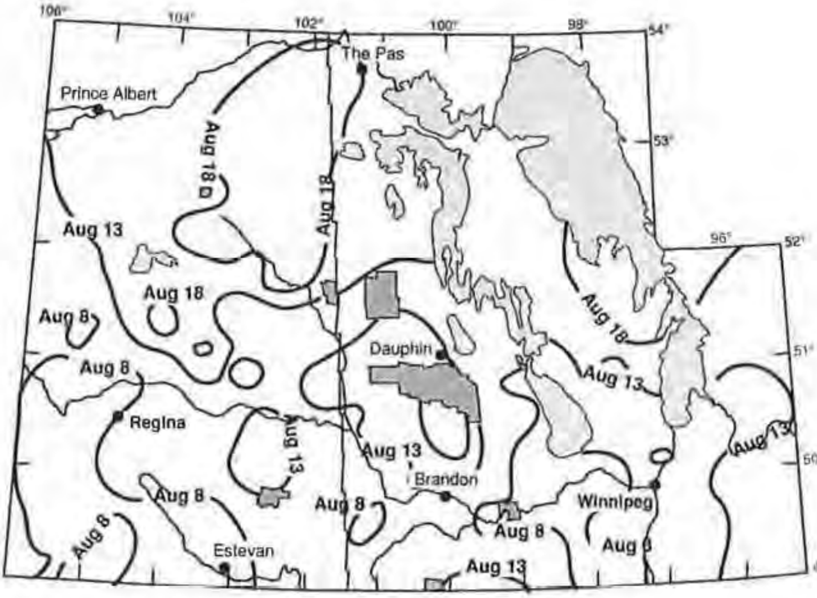


FIGURE 17. Yearly average date of maturity (Julian Day) of spring wheat.

frost-free periods and lower degree-day accumulations than other locations at the same latitude.

A comparison of southern Manitoba's and southeastern Saskatchewan's areal coefficients of variation for degree-days above 5, 10 and 15°C showed that the higher the base temperature, the higher was the temporal variability. This is consistent with the large year-to-year variability in the performance of "heat loving" organisms in the eastern Prairie region. The analyses revealed that heat units with higher threshold temperatures also had greater spatial variability than heat units with lower base values. This explains in part why organisms such as wheat and canola, with modest threshold growth temperatures, generally do well in all areas of the region.

## ACKNOWLEDGEMENTS

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## REFERENCES

Ash, G.H.B. 1991. *An agroclimatic risk assessment of southern Manitoba and* *southeastern Saskatchewan.* M.A. thesis, Department of Geography, University of Manitoba. 410 pp.

Ash, G.H.B., C.F. Shaykewich, and R.L. Raddatz. 1992 Moisture risk assessment for spring wheat on the eastern Prairies: a water use simulation model. *Climatological Bulletin*, 26:65-78.

Brown, D.M. 1963. A heat unit system for corn hybrid recommendations. *Proceedings, 5th National Conference on Agricultural Meteorology*, Lakeland, Florida. 11 pp.

Canada Committee on Ecological Land Classification. 1989. *Ecoclimatic regions of Canada*, Ecological Land Classification series No. 23. Conservation and Protection, Environment Canada, Ottawa, ON. 118 pp.

Dethier, B.E. and M.T. Vittum. 1963. *Growing Degree Days*. New York State Agricultural Experiment Station Bulletin 801.

Dunlop, S. 1981. *An Agroclimatology of Manitoba*. M.A. thesis, Department of Geography, University of Manitoba. 109 pp.

Expert Committee on Agrometeorology. 1986. *Technology transfer and development in agrometeorology. Section II - Examples of methodologies*. Agriculture Canada. Ottawa, ON. 54 pp.

Gage, S.H., M.K. Mukerji and R.L. Randall. 1976. A predictive model for seasonal occurrence of three grasshopper species in Saskatchewan. *Canadian Entomologist*, 108:245-253.

Huntsberger, D.V. 1967. *Elements of Statistical Inference*. Second Edition. Allyn and Bacon.

Morrison, M., P.B.E. McVetty and C.F. Shaykewich, 1989: The determination and verification of a base temperature for the growth of Westar summer rape, *Canadian Journal of Plant Science*, 69:455-464.

Robertson, G.W. 1968. A biometeorological time scale for a cereal crop involving day and night temperatures and photoperiod. *International Journal of Biometeorology*, 12:191-223.

SAS. 1985. *SAS User's Guide: Basics, Version 5th Edition*. Cary, NC: SAS Institute Inc. 1290 pp.

Selirio, I.S. 1969. *Climatological estimation of planting days*. M.Sc. thesis, Department of Land Resource Science, University of Guelph.

Showers, W.B., J.F. Witkowski, C.E.Mason, F.L. Poston, S.M. Welch, A.J. Keaster, W.D. Guthrie and H.C. Chiang. 1983. *Management of the European corn borer*. North Central Regional Publication No. 22. ARS USDA. 24 pp.

Statistics Canada. 1989. *Field Crop Reporting Series* (Catalogue No. 22-002). Crop Section, Agriculture Division, Statistics Canada at Tunney's Pasture, Ottawa.

Stephens, M.A. 1974. DEF statistics for goodness of fit and some comparisons. *Journal of the American Statistical Association*, 69:730-737.

SURFER. 1987. Version 3.00, Golden Software Inc. Golden, Colorado.

Thom, H.C.S. and R.H. Shaw. 1958. Climatological analysis of freeze data for Iowa. *Monthly Weather Review*, 86:251-257.

Wagner, T.L., H.I. Wu, P.J.H. Sharpe, R.M. Schoolfield, and R.N. Coulson. 1984. Modelling insect development rates: a literature review and application of a biophysical model. *Annals of the Entomological Society of America*, 77:208-225.

# Weather and Climate Impacts in 1992 in Canada

*Malcolm Geast*[1]
and
*Andrej Saulesleja*[1]

During the first few months of the year a persistent upper ridge was responsible for spring-like conditions throughout much of the western half of the country, while below-normal temperatures were the rule in the east. The effects were attributed to a combination of the latest El Niño event and the eruption of Mount Pinatubo the previous year. Monthly means were generally four to six degrees above normal from the Pacific coast to Manitoba and two to four degrees below normal from Quebec eastward.

Significant precipitation events during the winter months were mostly confined to the coastal areas. A westerly airflow brought heavy rains to western British Columbia during January and February. Several hundred millimetres fell in some locations. In early February a combination of high winds and a one-day rainfall event exceeding 100 mm in both Victoria and Vancouver produced mudslides and cut power to well over 50,000 homes.

On the east coast, Moncton also had a spectacular February start. During the month's first weekend, hurricane-force winds and an unprecedented 161 cm of snow combined to produce blizzard conditions, setting new one-day and monthly snowfall records. In contrast, there was little precipitation across the Prairies. Combined with the abnormally high temperatures, this resulted in severely depleted soil moisture, and raised concerns for the upcoming planting season.

During the spring a change to the "warm in the west, cold in the east" pattern began to emerge. Much of the eastern half of the country continued to endure below-normal temperatures and above-normal precipitation during March and April. Few areas of the country demonstrated any notable departures from normal temperatures during May. A trend to wetter conditions became apparent as the spring season progressed. Precipitation amounts as low as twenty-five per cent of normal were common from British Columbia to James Bay in March, but by May this situation had improved considerably and most areas of the country were receiving either above-normal rainfalls, or at least enough moisture to enable germination of recently-planted crops.

The shift to cooler conditions in western Canada continued beyond the spring, and with very few signs of any prolonged warming, mean temperatures during the summer of 1992 were below normal for most of the

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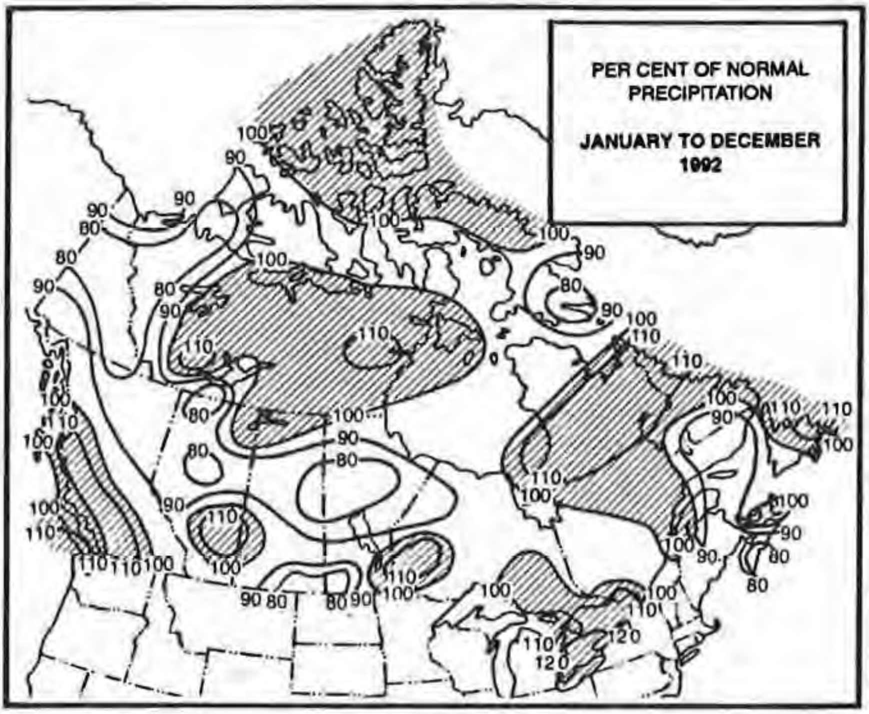
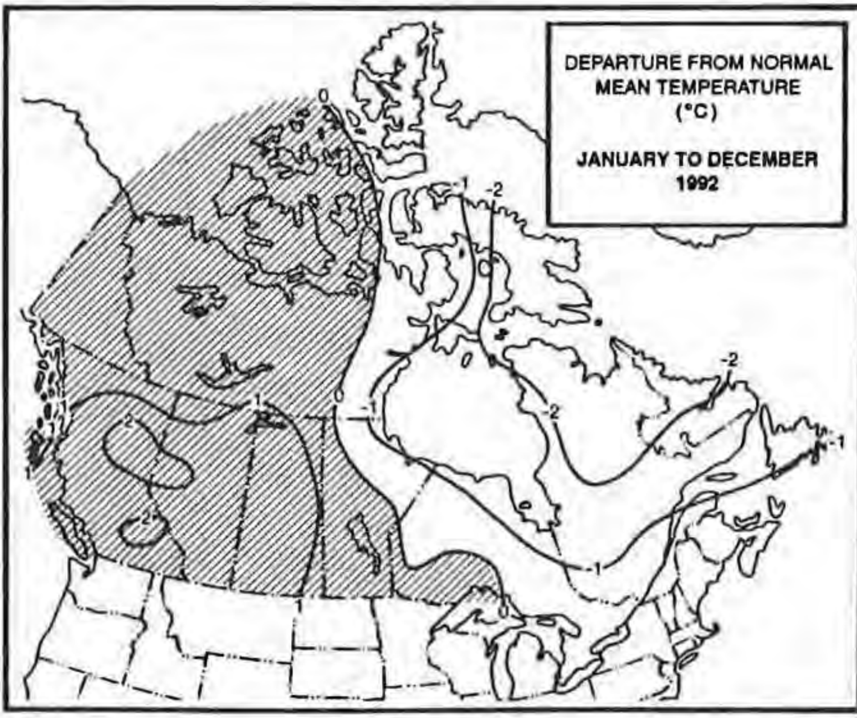



country. One of the few occurrences of summer heat occurred during the second week of June, when daytime highs in all four western provinces exceeded 30° C. However, as with any other incursions of warm air that were to come, this was short-lived, and overnight lows dropped below the freezing mark just a few days later. The cold air that brought this abrupt change rapidly moved eastward, bringing record cold and even snow to parts of eastern Canada. Through the rest of the summer cool conditions persisted, bringing July frost to southern Ontario, and helping to make this the coldest summer in more than 100 years for portions of the Prairie provinces. As a result of the cooler temperatures, revenues for power utilities dropped considerably, largely as a result of reduced usage of air conditioning equipment. Only in British Columbia and the Yukon were summertime temperatures above normal. The combination of warm temperatures and low precipitation in British Columbia resulted in an unusually high number of forest fires, and an increase in expenditure of $20 million in fire fighting costs.

Despite a dry start, overall, this was a wet summer for most of the southern part of the country. Concern was once again raised about soil moisture deficiencies across the southern Prairies as the summer began, but rainfall totals of 50 to 100 mm during July alleviated much of this uneasiness. Of greater concern was the effect of the cooler weather, which slowed crop growth in all




areas east of the Rockies. By late summer the precipitation that fell had become somewhat unwelcome. In early August separate incidents of severe weather flattened crops in southern Alberta, destroyed several million dollars worth of the Niagara Peninsula's fruit crop, and caused $10 million worth of damage in southern Quebec from flooding and downed trees. Late in the month transportation was disrupted and crops were damaged as the result of an almost unheard of snowfall of more than 20 cm across parts of Alberta and Saskatchewan, followed by a severe frost. Flooding occurred from southern Ontario to Labrador as Hurricane Andrew dissipated over Quebec.

After several months in which the country's warmest temperatures had been found in the west, a significant change occurred in September. During the first few days of the month frigid Arctic air spilled down from the Yukon, bringing with it Alberta's second major summer snowfall, and another killing frost for much of the Prairies. This set the stage for a month that would end up two degrees below normal from British Columbia to Manitoba. Largely as a result of the cool and very wet autumn conditions that occurred in all of the country's principal agricultural areas, harvesting of already-poor crops was delayed or made impossible. That problem, when combined with the effects of a summer that was cold and wet, and below-normal amounts of sunshine, resulted in nation-wide crop losses exceeding $2 billion.

Characteristic of the season, highly variable conditions dominated in the autumn. Warm weather which had moved into the east in mid-September managed to extend its influence westward by the end of the month, but by early October was displaced by another frigid air mass that extended from British Columbia to the St. Lawrence Valley. This was to be the pattern for the next couple of months, as incursions of mild weather were quickly replaced by equally short-lived outbreaks of cold air. Significant rain or snow accompanied many of these air mass changes, resulting in above-normal precipitation amounts over most of the country. One of the more notable events came in early October, when a combination or rain, snow, and high winds brought transportation in Newfoundland to a halt, and resulted in damage exceeding $9 million.

As the year ended there was little doubt that winter had returned. Early in December heavy snowfalls were recorded in Ontario and Atlantic Canada, and were followed at mid-month by an unusually early snowfall in southern British Columbia. An extremely cold air mass moved over much of the nation in the last two weeks of the month, dropping overnight lows below -35° C from the Yukon through the Prairies and into northern Ontario.

Overall, 1992 was a cool year for eastern Canada. Despite a cool finish to the year, the warmth felt in the west in the winter and early spring was strong enough to maintain an annual mean one to two degrees above normal from British Columbia to Saskatchewan. For the east there were few episodes of pronounced warming, and as a result the mean temperature varied from a few tenths of a degree below normal near the Great Lakes to two degrees below normal in Labrador and in the Eastern Arctic. The coldest temperature recorded in 1992 was -54° C at Clyde on Baffin Island in January, whereas the warmest was 38° C recorded several times in Kelowna and Kamloops between June and August. Perhaps the most unusual temperatures were found in Alberta; a summer-like value of 24° C occurred in late February at Claresholm, and a wintry -8° C occurred at Pincher Creek in August.

Precipitation totals throughout the country were generally within 10 per cent of the 30-year average. Only parts of the Pacific coast, southern Ontario, and the island of Newfoundland received a significantly larger amount of moisture. Totals in those areas were as much as 30 per cent higher than the usually expected amounts.

Further information: Andrej Saulesleja,
Environment Canada, (416) 739-4330

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The previous list was published in Volume 24(2), August 1990. This new list covers most of 1990, 1991 and 1992. *Climatological Bulletin* sincerely appreciates the time and care taken by the referees listed herein.

La dernière de ces listes a été publiée dans le Volume 24(2), août 1990. Cette nouvelle liste est consacrée à la plupart des années 1990, 1991 et 1992. Le *Bulletin climatologique* apprécie sincèrement le temps et les efforts des arbitres souligné(e)s ici.

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