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Information for Contributors

As a publication of the Canadian Meteorological and Oceanographic Society, the Climatological Bulletin provides a medium of information on climatology. The editorial board gives special encouragement to the submission of manuscripts on applied climatology, e.g., agriculture, climatic change and variability, climate impact assessment, data bases, energy, environment, forestry, health, measurement, recreation, and transportation. Several formats are provided, including the formally reviewed "Research Articles", and the less formal "Notes" section. The latter consists of shorter contributions, such as research notes, surveys, overviews, and book reviews. Submissions from students through their professors are encouraged. News items are welcome, and are placed in a separate "News" section.

Authors, including students, may choose to submit their manuscripts to formal review, or Notes. This should be indicated in the cover letter accompanying the manuscript. Research articles are independently reviewed by at least two anonymous referees. Notes are reviewed by the editor in consultation with the editorial board. Articles are accepted in either English or French. An abstract is required preferably in both English and French.

Contributors should submit manuscripts to Stewart J. Cohen, Editor, Climatological Bulletin, Dept. of Geography, York University, 4700 Keele Street, Downsview, Ontario, Canada, M3J 1P3. All manuscripts should be typed double spaced on one side of good quality white paper, 28 cm × 21.5 cm or its nearest equivalent. The abstract, list of references, tables, and a list of figure captions should be typed double spaced on separate sheets. The total length of research manuscripts should not exceed 5,000 words, exclusive of illustrative material. Comments, reviews, opinions, and news items should not exceed 1,500 words. Furnish an original and three copies if possible, in the order listed below.

TITLE PAGE should include the full names of authors, and professional affiliations.
The ABSTRACT should be less than 250 words, and typed on a separate page.
The TEXT of longer contributions should be typed double spaced on numbered pages, and divided into sections, each with a separate heading and numbered consecutively. The section heading should be typed on a separate line.
ACKNOWLEDGEMENTS are typed on a separate sheet immediately following the text.
If FOOTNOTES are required, they should be typed, double spaced, on a separate sheet under the heading "Notes" at the end of the text.
REFERENCES should be arranged alphabetically by senior author's last name. The text citation should consist of name(s) of the author(s) and the year of publication, for example Jones (1975) or (Jones, 1975). When there are two or more cited publications by the same author in the same year, distinguishing letters a, b, etc., should be added to the year. A reference to "in press" implies that the paper has been accepted for publication. Titles of periodicals should be given in full.
FIGURE LEGENDS must be provided for each figure, and should be typed together, double spaced, on a separate sheet.
ILLUSTRATIONS should be numbered sequentially. Original drawings, lettering, and symbols should be large enough so that after reduction, the smallest character will be at least 1.5 mm high.
Each TABLE should be numbered sequentially. Type all tables double spaced on separate sheets.

Authors should use the International System of units, but may show other units in parentheses. Authors should provide instructions in the margin for any special type required (Greek letters, capitals, bold face, etc.).

Page charges are not levied against the author. Authors of research articles will receive 10 reprints. Notes authors will receive 2 reprints.

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Foreword

The success of any research project in climatology depends on the availability of data. In recent years, increasing attention has been given to the use of proxy data, particularly in studies of climatic change. Besides some well known "physical" data sources (e.g. tree rings, pollen, ice coves), considerable information has been obtained from historical records of farmers, traders, explorers, and others. However, these sources have rarely been utilized in studies of *present* climates. The article by LaDochy and Annett provides an illustration of the use of data on forest fires and transmission line interruptions for a study of lightning.

The effects of increased carbon dioxide concentrations on future climates continues to be a controversial issue. The majority opinion, as expressed by the U.S. National Research Council's CO_2/Climate Review Panel, is that a warming of $3°C \pm 1.5°C$ should be expected from a doubling of CO_2. However, there is a minority view that the future climate will be cooler. This view is presented here in the note by Idso. Readers with opinions on this topic are encouraged to contribute their views to the Bulletin's News and Comments or Notes sections. Longer submissions may be sent in as research articles, which would be formally reviewed by anonymous referees.

Since climatology is considered to be a sub-discipline of geography, research papers are often presented at conferences sponsored by various associations of geographers. The April 1982 issue included a report on the Association of American Geographers meeting. This issue contains reports from three geographers meetings held in Canada and the U.S. in 1983. The Bulletin welcomes submissions of reports on other meetings. These should be sent to the editor as news items.

In previous years, the Bulletin has not had a formal policy on reprints. Beginning with this issue, authors of research articles shall receive 10 reprints. Two reprints will be sent to authors of notes. This policy is printed in the last paragraph of Information for Contributors. Another change, indicated in the second paragraph, is that future submissions should include abstracts in English and French. This policy is similar to that of Atmosphere-Ocean.

Stewart J. Cohen

A damage-based climatology of lightning in Manitoba*

Steve LaDochy and *Clarence H. Annett*

A climatology of lightning in Manitoba is presented. The distribution of lightning strikes for the period 1974–1980 is derived from two sources: records of lightning-caused forest fires, and power outages caused by lightning damage of high-voltage transmission lines. By comparison to these two, lightning-caused deaths and other property damage in Manitoba are insignificant in both frequency and monetary loss. Certain time periods (seasonal and diurnal) and particular locations are identified as being at high risk for lightning strikes. A retrospective comparison of lightning strike records to thunderstorm days and to synoptic situations identifies the frontal thunderstorm as the weather type most likely to produce intense electrical activity and severe lightning damage. In addition, the data point to a strong, previously-unidentified "lake effect" storm intensification pattern downwind from the province's major lakes.

INTRODUCTION

To a meteorologist, lightning is the visible indicator of intense, complex electrical activity which occurs in and around a storm. Accordingly, he is interested in mapping the spatial and temporal distribution of lightning flashes with the highest resolution and accuracy possible. This has been done, with varying degrees of success, using radar (Ligda 1950, 1956; Hewitt, 1953), radio, photographic, and optical techniques (Malan, 1963; Pierce, 1977), satellite and remote sensing techniques (Turman and Tettelbach, 1980; Taranik and Settle, 1981), and other techniques. The aim of such research is to understand lightning as an indicator of storm strength and as a possible precursor of more violent weather such as tornadoes.

*A portion of this paper was presented at the Annual Meeting of the Canadian Meteorological and Oceanographic Society, Ottawa, Canada, May, 1982.

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The layman's view of lightning contrasts sharply with this. From a distance, the layman sees lightning as beautiful, magnificent, and spectacular. As it approaches, lightning becomes a terrible force of damage, destruction, and death. This difference in perception means that the meteorologist's data is of little use or meaning to the layman; in fact, because the layman's data requirement is so much simpler, the reverse is also considered true. Prentice (1977) has stated the layman's point of view succinctly:

> "... where personal danger, damage to structures, interference with power system operation, risk of forest fires, or risk of damage to electronic equipment near ground level are concerned, only the long-term average of the frequency of occurrence of ground flashes in the immediate vicinity is relevant."

Of course, this can be extracted from the meteorologist's comprehensive temporal/spatial distribution data, if these data are available.

The value of lightning occurrence maps derived from reports of damage at the earth's surface is not generally appreciated. Critics might point out that such a map lacks temporal resolution because it is constructed retrospectively rather than concurrent with the events, and that it ignores lightning which causes no damage (cloud-to-cloud or intra-cloud strokes). There is, however, sound rationale for this type of study. Because lightning which strikes the earth usually produces spectacular effects which people notice and remember, it is possible to temporally locate the strike with sufficient accuracy to match it to a particular storm or storm cell. Thus examination of a large number of damaging strikes should allow the identification of a particular storm type or weather type which is highly likely to produce damaging lightning. Such identification is not possible with conventional "thunderstorm day" climatological analyses, which usually give only monthly or seasonal information (Prentice, 1977). In addition, a damage-based climatology may identify geographical areas which, because of topography or for unknown reasons, are at high risk for lightning strikes. These two identifications – storm type and geography – have the greatest utility for promoting the safety of the general public.

The meteorologist may also derive useful information from a damage-based lightning climatology. It is known, for instance, that not all lightning strikes in wooded areas cause forest fires; the characteristics of those strikes which do cause fires are fairly well known (Fuquay, et al., 1972). Electric power companies have long recognized the usefulness of a damage-based climatology of lightning in planning for the protection, maintenance, and operation of high-voltage transmission lines (Wagner, et al., 1942; Golde, 1945; Griscom, et al., 1965). Finally, some information is already known about the relationship of cloud-to-ground strikes and cloud-to-cloud strikes in storms (Prentice and Mackerras, 1977), so the possibility exists for deriving more complete information about a storm from the lightning damage it causes.

MONTH	1976	1977	1978	1979	1980	TOTAL	AVG.
March	–	1	–	–	–	1	<1
April	–	2	–	–	1	3	1
May	5	104	17	–	80	206	41
June	123	68	20	74	134	419	84
July	103	18	27	245	276	669	134
August	134	–	9	54	33	230	46
September	8	–	10	5	1	24	5
ANNUAL	373	193	83	378	526	1,552	310

Table 1 Monthly and annual frequencies of lightning-caused forest fires in Manitoba, 1976-1980.

To demonstrate these points, we have constructed a climatology of lightning in Manitoba which is based on damage reports for those years between 1974 and 1980 where data were available. Manitoba is well suited for such a study. Among the Canadian provinces, Manitoba ranks high in lightning deaths (Chinook, 1979) and in property losses due to lightning-initiated fires (Department of Labor and Manpower, 1975-1981). However, these are only a relatively small part of the damaging lightning strikes in Manitoba. As shown in Table 1, the number of lightning-caused forest fires in Manitoba is very large. Furthermore, lightning-caused power outages on Manitoba Hydro high-voltage transmission lines are frequent during the summer storm season. Since data on both these situations are readily available, it was decided to use them as a base for the lightning climatology.

It is reasonable to question the representativeness of a lightning climatology constructed in this way. Figure 1 indicates the general vegetation distribution and physiography of Manitoba, and Figure 2 gives the location of Manitoba Hydro's main high-voltage transmission lines. The northern third of the province is mixed forest and barren land, but its proximity to the Arctic air mass prevents it from being an area where storms occur frequently. The major part of Manitoba is covered by subalpine boreal forest (predominantly conifers), much of which is administered by the Provincial Forest Service. In the southern quarter of the province, the boreal forest gives way to flatlands and foothills which are devoted to agriculture and are representative of the Great Plains in both climate and physiography.

The standard climatic descriptions (Thomas, 1953; Kendrew and Currie, 1955; Longley, 1972) show that in the summer months southern Manitoba is subject to severe thunderstorms, with the frequency of occurrence diminishing northward. This is shown clearly in Figure 3. Coincidentally, the portion

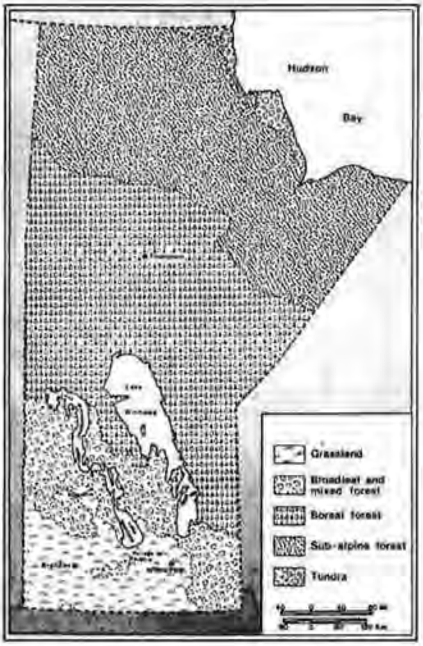

FIGURE 1 Vegetation Distribution in Manitoba. Note that the majority of the province is forested, the extent of forested land approximately coinciding with the Canadian Shield. In the extreme south, the forest gives way to prairies and flatlands which are representative of the Great Plains.

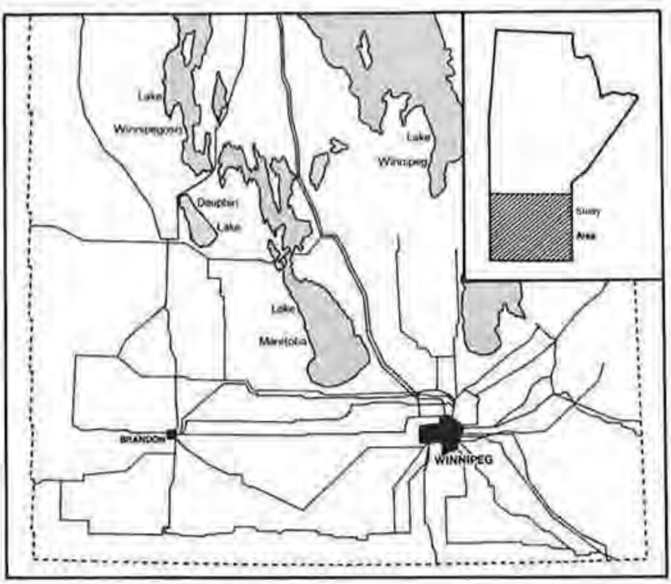

FIGURE 2 Location of 33 KV, 66 KV, and 230 KV transmission lines operated by Manitoba Hydro. Data courtesy of Manitoba Hydro.

of Manitoba not covered by forests but subject to moderately frequent thunderstorms – the south and southwest sectors – is the area most densely covered by high-voltage transmission lines (Figure 2). Thus a climatology based on forest fires and transmission line outages should be representative of Manitoba, since most of the land area will be covered.

FOREST FIRE DATA

In Manitoba, nearly half of all forest fires are caused by lightning. However, there is considerable variance from year to year in both number of fires and acres burned. For the five-year period shown in Table 1, 1978 was the minimum year with only 83 forest fires (44,000 acres burned) and 1980 was the maximum year with 526 forest fires (300,000 acres burned). The cost of suppressing the 1980 forest fires exceeded $5.2 million. Because of the tremendous fire hazard, especially during the summer fire season and in periods of drought, the heavily-forested areas of northern and eastern Manitoba are closely monitored.

Monitoring is carried out by the Provincial Forest Service, which tabulates data on fire location, acres burned, and cost of suppression. These records were made available to us by the Service in the form of a computer printout for 1976-1980. If the fire is known to have been caused by lightning, it is noted on the printout; however, a lightning-caused fire may not become visible to a fire observer until several hours after the initial strike. Comparison of the forest fire records of time and location with storm records (Environment Canada, 1974-1981) allows most questionable fires to be identified as having been or not having been caused by lightning, even though there is some delay before their sightings. From these data, a statistical analysis was conducted.

Figure 4 maps the incidence of lightning-caused fires according to the Provincial Forest Service's designated forest districts. Some bias in Figure 4 is unavoidable, since the forest districts are not uniform in size and the extent of forested area in each district is not the same. For instance, one area of greatest lightning fire frequency is the northeastern part of the province, but Figure 3 indicates that thunderstorm frequencies decrease northward. This fire maximum is produced by the large number of densely-forested acres in the region. The area of high lightning fire frequency east of Lake Winnipeg, however, is also an area of maximum thunderstorm activity in the province. This is clearly due both to the forest density and the high frequency of thunderstorms. Likewise, few fires occur in the sparsely-forested southwest and south-central regions of the province, which record large numbers of thunderstorm days.

Figures 5 and 6 address the temporal distribution of lightning-caused forest fires. Although the reports cover individual fires, restricting the analysis to monthly and annual periods minimizes the inaccuracies and biases which arise in trying to pin down the exact time of origin of a fire from the reports. In Figure 5, it can be seen that statistically July is the peak month for fires, while June ranks second. However, during the five-year period the month

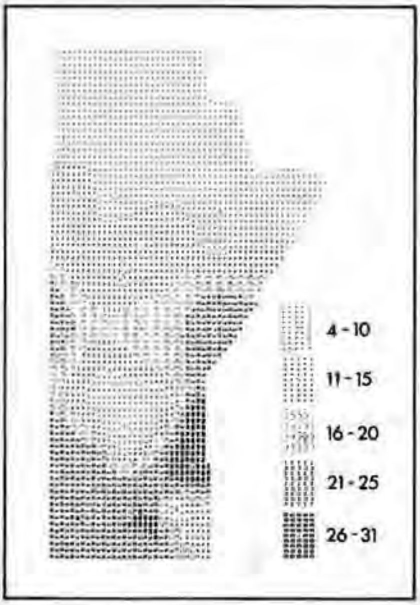

FIGURE 3 Distribution of the average annual number of thunderstorm days in Manitoba, after Lipson (1965).

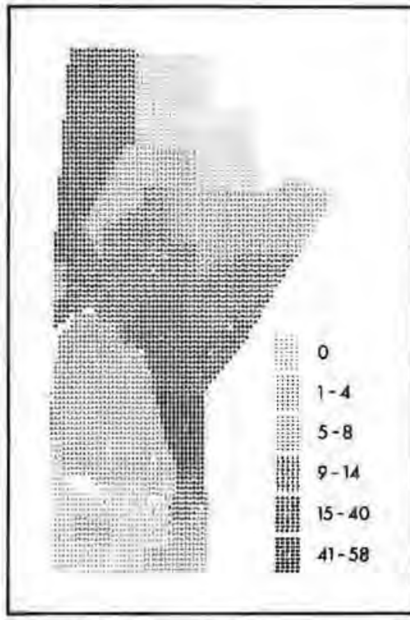

FIGURE 4 Average annual number of forest fires in Manitoba caused by lightning: 1976-1980, by forest fire districts.

with the most fires was May, 1977. This can be explained by noting that a major drought in 1976-77 ended in April; it is well known that peaks in the number of lightning-caused forest fires occur following prolonged dry spells. Figure 5 and Table 1 also indicate that the "fire season" is well defined, and corresponds approximately with the summer thunderstorm season.

The annual number of lightning-caused forest fires is compared to weather data in Figure 6. The decreasing number of fires from 1976 to 1977 is related to the record drought of 1976-77 in Southern and Central Manitoba (LaDochy and Annett, 1982). The drought began in mid-summer, 1976, and ended with a remarkably wet May, 1977 (300% of normal precipitation at Winnipeg). The convective activity accompanying the May rains caused 104 lightning fires, a very large number for so early in the warm season. At first glance, one might suspect that the convective activity was accompanied by more lightning than usual, but in fact the prior drought was the real culprit. Generally, snowmelt would have kept the forests moist until much later in the year, thus making them hard to ignite, but in the winter of 1976-77 there was little snow and the forests were consequently drier than normal. The precipitation/lightning fires relationship tends to be inverse; with a previous dry period, convective storms cause more forest fires than normal because the forests are desiccated. This can also be seen for the summer of 1980, where a record number of fires

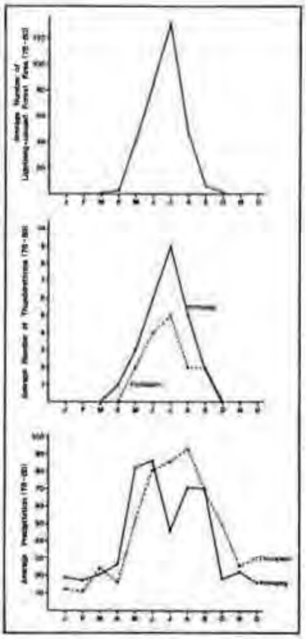

FIGURE 5 Monthly weather data and average monthly frequency of lightning-caused forest fires, 1976-1980.

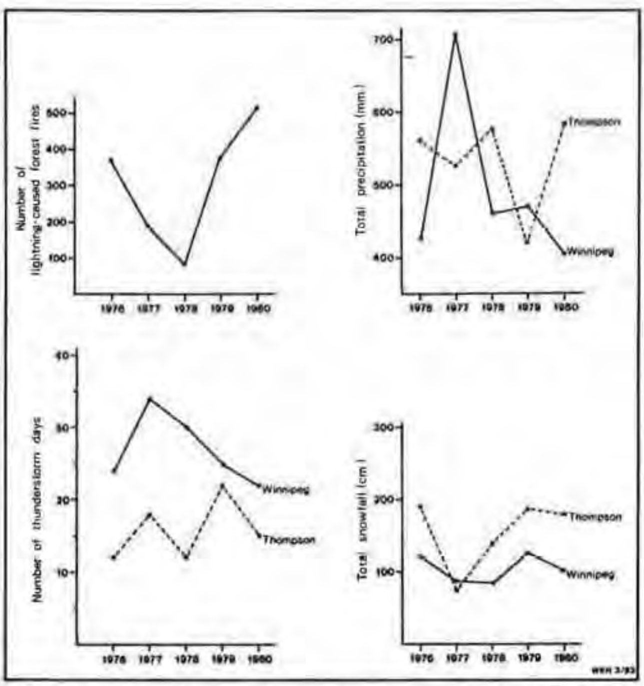

FIGURE 6 Annual weather data and annual number of lightning-caused forest fires for the period 1976-1980. The forest fire data are reproduced from Table 1.

was preceded by a dry 1979 and a drier 1980 which had record high temperatures in April and May. As Figure 6 shows, this is not always reflected in annual precipitation totals or thunderstorm-day statistics because the dry periods seldom coincide with calendar months or years and are irregularly distributed.

TRANSMISSION LINE DATA

The effects of lightning on electrical transmission lines have been well characterized, and strikes which cause power interruptions have unique voltage/ current signatures (Popolansky, 1960). Unlike damage to buildings and other structures which may be struck by lightning, transmission lines damaged by lightning display specific characteristics which leave no doubt as to the origin of the damage and in many cases can be quantitatively related to the strength of the lightning bolt. Additionally, a direct strike to the transmission line is not necessary; the interaction of nearby lightning with the power line corona is often sufficient to produce surges which trip circuit breakers or otherwise cause interruptions (Lewis, 1950). In order to provide reliable electric service to customers, electric utilities monitor their transmission lines closely and keep careful records of power interruptions (Chalmers, 1967). This makes it possible to locate the time and place of a lightning strike quite accurately.

Over 2000 power outages due to lightning occur in Manitoba each year. Manitoba Hydro has kept records of transmission line interruptions since 1961 (Manitoba Hydro, 1971). Recent records are unpublished, but were furnished to us as copies of Hydro system load dispatcher's logs. Some 10,000 reports for the period 1974-1979 were coded and processed by computer to obtain the results of this study. Reports of interruptions are kept at each of the three Hydro regions – Western, Central, and Eastern – according to districts (Figure 7). Each interruption report was identified by the date, hour, and location coded by township/ range/ section. Not all years were available for the three regions. The Eastern region had complete records from 1974-1979, but the Central region had only 1975-1979 complete and the Western region had only 1978-1979 for locations and 1977-1979 for time. The records indicate that lightning is the major cause of transmission line interruptions, in agreement with other studies (Bertness, 1980).

There is reason to believe that the data are reliable; that is, for the time periods listed, all lightning-caused interruptions are reported. Standard Hydro procedure is for any outage which occurs during a thunderstorm to be classified as due to lightning and so recorded, even if there are no apparent reasons for it. On further investigation, some outages attributed to lightning are reclassified. As a check on the overall quality of the data, the rate of lightning strikes per mile of transmission line is roughly in agreement with Chalmers (1967) and Prentice (1977).

FIGURE 7 Regions (labeled) and districts of Manitoba Hydro. Transmission line interruption data are grouped according to districts in this study.

The annual frequency of lightning-caused outages by district for 1975-1979 is shown in Figure 8. Notable are the general south-to-north decrease in frequency and the maximum frequency in an area southeast of the Interlakes region. There is also a pronounced minimum in the Interlakes region itself. The northward decrease is expected because of the decrease in both thunderstorm days (Figure 3) and transmission lines (Figure 2), but the other features of Figure 8 are at first glance somewhat puzzling. For instance, there is considerable variation between districts, although Figure 3 shows that these districts all have about the same number of thunderstorm days per year. This is the result of two factors: the districts are not of uniform size and do not have the same density of transmission lines. Close examination of Figure 8 shows that the larger districts do experience more lightning, as would be expected.

FIGURE 8 Annual frequency of lightning-caused outages by Hydro districts, 1975-1979.

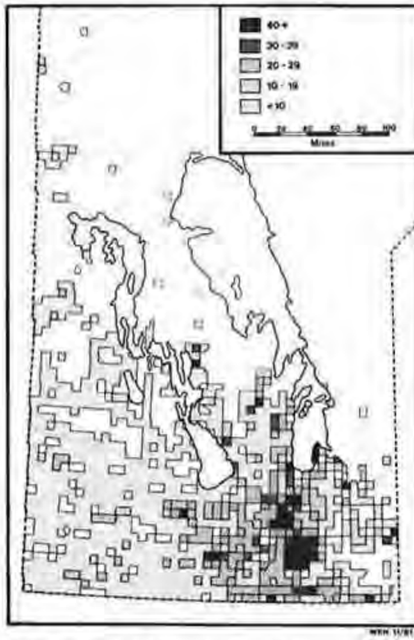

FIGURE 9 Lightning outages by township and range, 1978-1979.

The problem with district size can be partially eliminated by replotting the annual outage frequency data according to township and range (36 square miles). Figure 9 plots the frequencies by township and range for 1978-1979. This indicates a bias toward population centers (which implies a bias toward greater concentrations of transmission lines), notably Winnipeg. In uninhabited areas with fewer lines, less outages are reported. Visual comparison of Figures 2 and 9 confirms this.

It is not advisable to correct the outage frequencies for transmission line densities because the number of transmission lines in an area may not be the only factor influencing lightning strikes. Generally, higher-voltage lines suffer less outages per mile than lower-voltage lines. Also, surrounding terrain and nearby features such as trees or buildings may influence lightning strike rates. We can differentiate the data by looking at the lightning-caused outage frequencies for transmission lines of a single, given voltage. An earlier study (Manitoba Hydro, 1971) calculated lightning strike rates for 66 KV and 115 KV transmission lines. Mapping these rates at the line midpoints, the results are shown in Figures 10 and 11. The patterns for 66 KV and 115 KV lines are not greatly different from the overall lightning outage pattern shown in Figure 8, with a general south-north decrease. The concentration of strikes around Winnipeg and other populated areas is more pronounced for the 115 KV lines than the 66 KV

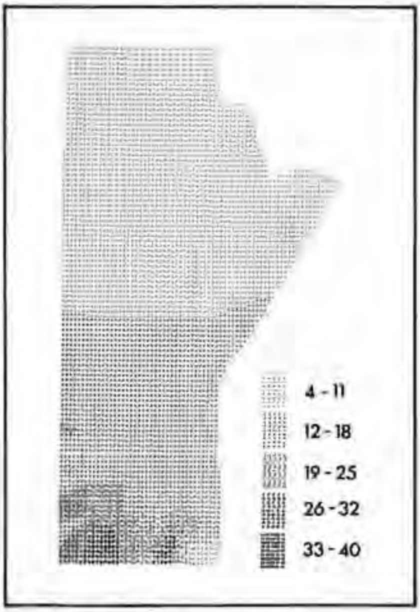

FIGURE 10 Lightning strike rates for 66 KV transmission lines, number of outages per mile of line per year.

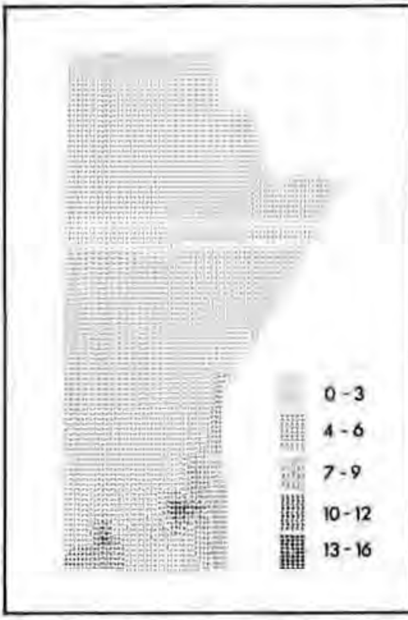

FIGURE 11 Lightning strike rates for 115 KV transmission lines, number of outages per mile of line per year.

lines. Note that the maximum strike rate is over twice as high for the 66 KV lines as for the 115 KV lines, in agreement with the statement made above. Also note that lightning strikes decrease much more quickly from south to north than do thunderstorm days, as do transmission line densities.

The annual lightning outage frequencies for each of the regions of Figure 8 are shown in Figure 12. There is a pronounced difference in the overall outage rate for the regions, and in the year-to-year variation for the period studied. This is mainly an effect of the size of the regions, with the Eastern and Western regions being much larger than the Central region, while the most lines are located in the Western region.

Turning to the temporal variation of lightning-caused outages, Figure 13 shows the monthly outage frequency for 1974-1979 for the entire province and for each region individually. These can be compared directly with monthly forest fire frequency (Figure 5 and Table 1). Again, July is clearly the month of maximum outages, with August second except in the Western region, where May is second. This is probably the result of the unusually large number of thunderstorms in May, 1977, which greatly influences the short period of record used here. In most years thunderstorms begin in May; the cumulative curve in Figure 13 shows that by the end of August, 93% of the lightning outages in Manitoba have occurred.

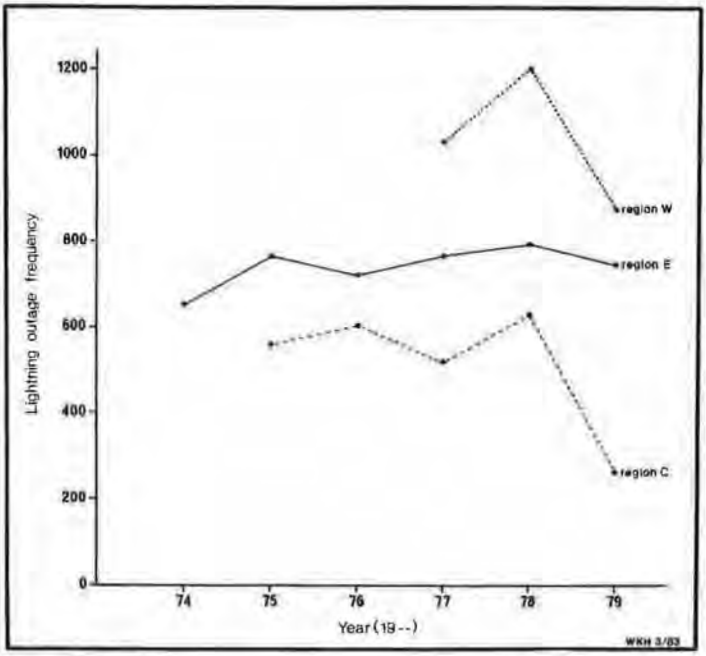

FIGURE 12 Annual lightning outage frequency for each Hydro region, 1974-1979.

The data show that more lightning-caused outages occur in wet months than in dry months. This is to be expected, since much of the province's summer precipitation comes from thunderstorms. Given this, it is interesting to compare the diurnal patterns of thunderstorms and lightning outages. Figure 14 shows the distribution of outage frequency by hour for 1974-1979. Broad maxima occur in the evening, from 4 to 8 p.m. (CST), and in the early morning from 1 to 2 a.m. The deepest minimum occurs in the late morning to early afternoon. As the figure shows, the pattern is least pronounced in the Central region and most pronounced in the Eastern region.

Certain features of Figure 14 are open to question. In examining the original records, several cases were found where the reported time was mistakenly labeled as "a.m." instead of "p.m." and vice versa. In a few cases a 12 hour addition or subtraction makes the outage report match other evidences of thunderstorm activity. The midnight to 1 a.m. minimum and the unusual 1 to 2 a.m. peak in the Eastern region may be the result of such errors which we did not find, as may the Western region's 8 a.m. peak and 8 p.m. secondary peak.

The diurnal pattern of thunderstorms at Winnipeg, a representative station, is shown in Figure 15. When Figures 14 and 15 are compared, it is clear that the patterns match for Manitoba as a whole and for the Central region, with the match being poorer for the other two regions. The slight discrepancy in the

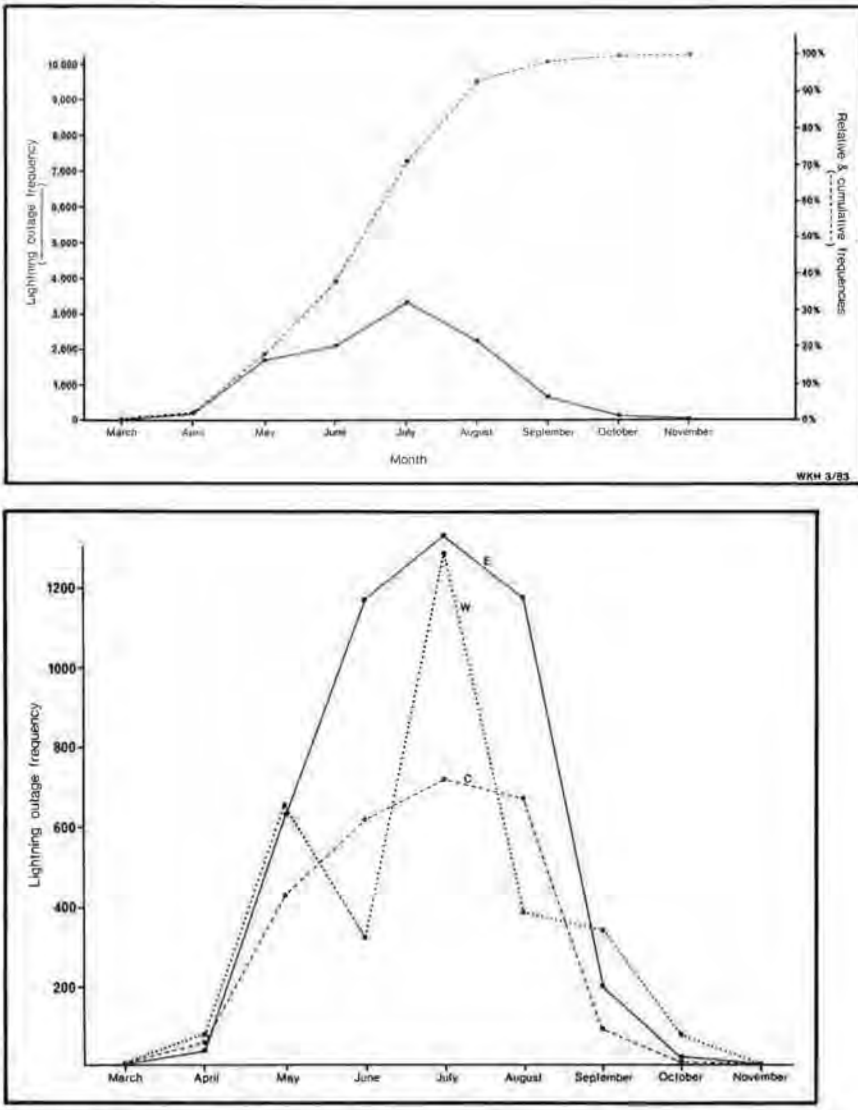

FIGURE 13 Monthly and cumulative lightning outage frequencies for Manitoba (above) and for each region, 1974-1979.

times of thunderstorm minima and of lightning outage minima is probably due to confusion in some of the original data as to whether Central Standard Time or Daylight Saving Time was used. The fact that the maximum for lightning outages occurs earlier than for storms suggests that the most energetic storms (those with the most lightning) occur slightly earlier in the day than the "aver-

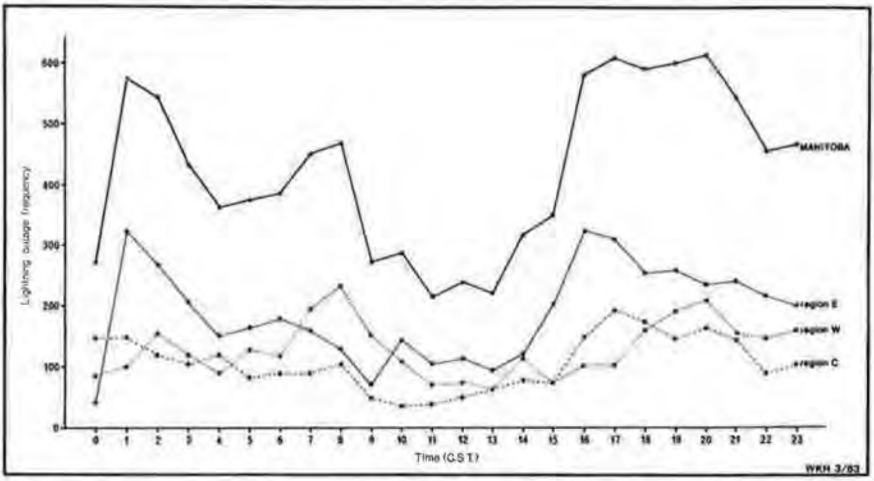

FIGURE 14 Hourly lightning outage frequencies for the Hydro regions and for Manitoba as a whole, 1974-1979.

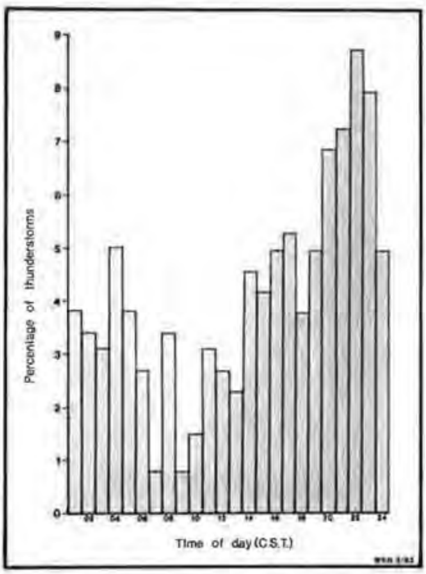

FIGURE 15 Diurnal distribution of thunderstorms at Winnipeg.

age" thunderstorms. The diurnal pattern of thunderstorm activity shown in Figure 15 closely matches that noted by Wallace (1975) for the northern Great Plains of the U.S.

It is interesting to note that the July peak in Manitoba thunderstorms is reflected in both forest fire and transmission line outage frequencies. Hail and tornadoes also occur with maximum frequency in July, indicating that thunderstorms are the most energetic then. Diurnally, hailstorms in Manitoba are concentrated in the late afternoon to early evening hours, and are rare at other times. Tornadoes peak around 6 to 7 p.m. C.S.T. and tend to be concentrated in the hours from 6 p.m. to midnight. This suggests that thunderstorms which occur from midnight to 8 a.m. or so are weaker, but Figure 14 shows that they still produce significant numbers of transmission line outages. Annually, both forest fires and transmission line outages are closely correlated with the thunderstorm season.

To our knowledge, no previous studies have specifically attempted to relate individual storm characteristics to transmission line outages. Accordingly, 27 of the most active storms between 1975 and 1979 were subjectively analyzed according to their spatial extent, temporal evolution, and synoptic conditions. Every 3-hour surface weather map on the storm days was viewed to approximate the positions of lightning outages in relation to synoptic features. Because of the widespread nature of the outages, only quite general relationships could be seen. These storms were chosen according to the criteria that they had caused at least 100 lightning outages in the three Hydro regions, or at least 67 in two regions. Figure 16 shows the lightning outage patterns for two of these storms. The early evening storm of May 25, 1978 produced golfball-size hail and a tornado near Winnipeg. The late-night storm of July 17, 1978 had a much greater geographic extent and produced 376 lightning outages – the greatest number ever recorded by Manitoba Hydro in a single day. For both cases, the maps show widespread outages, but there is clearly some preference for Winnipeg and other populated areas.

Synoptically, Manitoba is subject to three types of thunderstorms: frontal, trough, and air mass. The surprising result of analyzing the 27 individual thunderstorms was that all were frontal thunderstorms. These storms, which clearly produced the most electrical activity, were most commonly found ahead of the warm front, near the apex of the cyclone wave or slightly south of the apex in the warm zone (Figure 17). The surface low often entered southern Manitoba from the south or southwest, and southeasterly flow was most common near the thunderstorm areas. To some extent this is expected. Well-developed surface cyclones should produce cloudiness over the largest area, have the greatest instability, produce the most individual thunderstorms concurrently, and hence display more lightning activity than other synoptic situtations. In some cases electrical storms persisted for several consecutive days, corresponding to multiple low pressure centers moving along the frontal zone and thus maintaining favorable thunderstorm conditions for longer periods of time.

The geographical patterns of thunderstorm days (Figure 3), forest fires (Figure 4), and transmission line outages (Figure 8) also deserve comment.

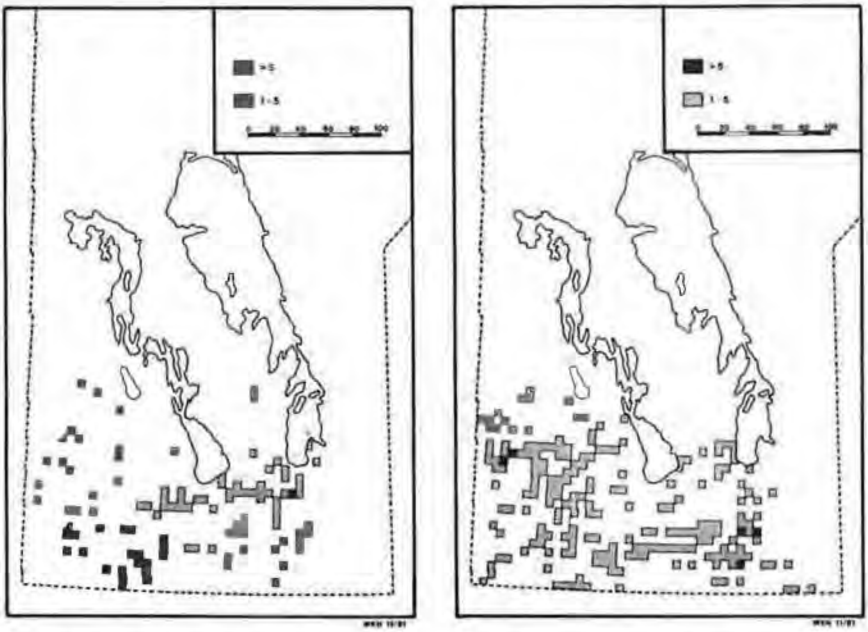

FIGURE 16 Maps of lightning outages in Southern Manitoba for two severe thunderstorms.
a. Storm of May 25, 1978 b. Storm of July 17, 1978.

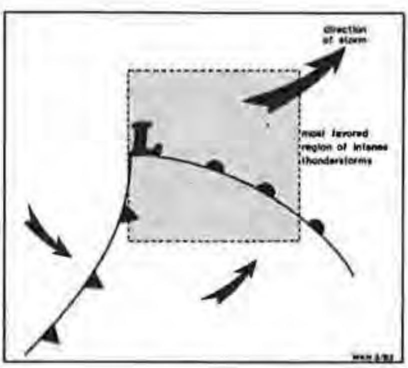

FIGURE 17 Analysis of 27 "active" thunderstorms in Manitoba shows that the most severe frontal storms tend to be just ahead of the warm front, near the apex of the cyclone wave or slightly south of it.

All three clearly show maxima to the east and/or southeast of Manitoba's two large lakes, although the extent and position of each maximum is somewhat biased by the data collection process (as explained above). Synoptic analysis of typical storm tracks in Manitoba shows that the region where these maxima occur is roughly downtrack from the two large lakes, strongly suggesting that the lakes play a part in intensifying thunderstorms which cross them or occur nearby. Several factors have been attributed to the intensification of thunderstorms by large lakes (Eichenlaub, 1979). A climatological study by Changnon (1968) showed that Lake Michigan affected thunderstorms in all four seasons. In winter, the lake, being warmer than land, increased thunderstorms. In summer the lake decreased thunderstorms during the day, when the lake was relatively cool, but increased them at night, when land cooled faster than the water. Other factors mentioned included the lake breeze front, which in some cases may intensify existing weather systems resulting in severe weather, increased friction and increased elevation downwind of the lake surface. Manitoba thunderstorms are indeed nocturnal in summer. East of Lake Winnipeg the land rises and topography roughens. It is not surprising then that lake effects should occur here as the two large lakes are comparable in size to the Great Lakes, where lake effects have been studied. It would appear that additional study of the influence of the large lakes of Manitoba on thunderstorms and other aspects of weather is needed.

CONCLUSION

This study has clearly demonstrated the value of climatological studies of lightning. Forest fires caused by lightning are most prevalent in the summer thunderstorm season, with the peak number of fires corresponding to the month of maximum thunderstorm activity. An increased risk of forest fires is noted in the months immediately following a drought or prolonged dry spell. The number of thunderstorm days is not a reliable indicator of forest fire hazard in a region, because the forest is not uniformly dense over the region; however, thunderstorm-day maps and forest fire frequency maps help identify regions where the potential hazard is greater. Such information would be useful in the spatial allotment of manpower during the fire season and for placing lightning location detectors where they would be of maximum benefit.

Likewise, transmission line outages due to lightning peak in July, and have an annual distribution corresponding closely to the thunderstorm season. Outages are diurnally distributed in approximate correspondence with the hours of thunderstorm occurrence, peaking in the early evening and having a secondary peak in the early morning hours. Transmission line outages show a closer correlation to populated areas than to regions of high thunderstorm days. Synoptic analysis identifies the most electrically active (and thus the most damaging) thunderstorms as being frontal storms, with the most favored location ahead of the warm front and near the frontal apex. Taken together, these facts have implications for Manitoba Hydro regarding the scheduling of standby repair crews, vacation scheduling for crews, and emergency preparedness in general.

Finally, the identification of frequent thunderstorms and high damage risk east and southeast of the Interlakes region suggests a previously unreported "lake effect" and points out the need for more meteorological research on this phenomenon in Manitoba.

ACKNOWLEDGEMENTS

Extensive assistance from Tom Hopko (Manitoba Forest Service) and from Wilf Hrysio, Ernie Hiebert, Harold Yarwood, and Sheldon Seafoot (Manitoba Hydro) is gratefully acknowledged. Data processing was performed in part by student helpers Randall Herron, Kim Kingdom, Barbara Torpey, and Indira Rampersad. The manuscript was typed by Betty Harder with graphics by Weldon Hiebert. The staff of the Linda Hall Library of Science and Technology, Kansas City, Missouri, provided extensive assistance in locating references. Financial assistance for this work was provided by the Atmospheric Environment Service.

REFERENCES

Bertness, Jan, 1980: "Rain-Related Impacts on Selected Transportation Activities and Utility Services in the Chicago Area", *Journ. Applied Meteorol. 19*, 545-556.

Chalmers, J.A., 1967: *Atmospheric Electricity*, 2nd edition, Pergamon Press, New York, 389 p.

Changnon, Stanley A., Jr., 1968: *Precipitation climatology of Lake Michigan basin*, Illinois State Water Survey, Urbana.

Chinook, 1979: "Lightning: Facts and Figures", *Chinook 1*, 38-39.

Eichenlaub, Val L., 1979: *Weather and Climate of the Great Lakes Region*. University of Notre Dame Press, Notre Dame, Indiana.

Environment Canada, 1974-1981: *Monthly Meteorological Summaries*, 1974-1980, Atmospheric Environment Service, Downsview, Ontario.

Fuquay, D.M.; A.R. Taylor; R.G. Hawe; and C.W. Schmid, Jr., 1972: "Lightning Discharges that Caused Forest Fires", *Journ. Geophys. Research 77*, 2156-2158.

Golde, R.H., 1945; "The Frequency of Occurrence and the Distribution of Lightning Flashes to Transmission Lines", *Trans. AIEE 64*, 902-910.

Griscom, S.B.; R.W. Caswell; R.E. Graham; H.R. McNutt; R.H. Schlomann; and J.K. Thornton, 1965; "Five-Year Field Investigation of Lightning Effects on Transmission Lines", *Trans. IEEE 84*, 257-280.

Hewitt, F.J., 1953: "The Study of Lightning Streamers with 50-cm Radar", *Proc. Phys. Soc. London*, 56, 895-897.

Kendrew, W.G., and B.W. Currie, 1955: *The Climate of Central Canada*, Edmond Cloutier, Publisher, Ottawa, Canada.

LaDochy, S., and C.H. Annett, 1982: "Drought and Dust: A Study in Canada's Prairie Provinces", *Atmospheric Environment 16,* 1535-1541.

Lewis, W.W., 1950: *The Protection of Transmission Systems Against Lightning.* John Wiley and Sons, Inc., New York. (Reprinted 1965 by Dover Publications, Inc., New York.)

Ligda, M.G.H., 1950: "Lightning Detection by Radar", *Bulletin Amer. Meteorol. Soc. 31,* 279-283.

Ligda, M.G.H., 1956: "The Radar Observation of Lightning", *Journ. Atmos. Terrest. Physics 9,* 329-246.

Lipson, E.D., 1965: "A Study of Winnipeg Thunderstorms", Canadian Department of Transport, Technical Paper 562, Circular 4198, 18 p. Available from Atmospheric Environment Service, Downsview, Ontario.

Longley, Richmond W., 1972: *The Climate of the Prairie Provinces,* Climatological Studies Number 13, Environment Canada, Toronto, 79 p.

Malan, D.J., 1963: *Physics of Lightning,* English Universities Press Ltd., London, 176 p.

Manitoba, Department of Labor and Manpower, 1975-1981: *Annual Report, Office of the Fire Commissioner,* 1974-1980, Minister of Labor and Manpower, Winnipeg, Manitoba.

Manitoba Hydro, 1971: *Transmission Line Outage Report, 1961-1971,* Manitoba Hydro, Winnipeg, Manitoba, 12 p.

Pierce, E.T., 1977: "Lightning Location and Warning Systems", pp. 497-521 in R.H. Golde, ed., *Lightning, Volume 2,* Academic Press, New York.

Popolansky, F., 1960: "Measurement of Lightning Currents on High-voltage Lines", *Elektrotech. Obz. 49,* 117-123.

Prentice, S.A., 1977: "Frequency of Lightning Discharges", pp. 465-496 in R.H. Golde, ed., *Lightning, Volume 1,* Academic Press, New York.

Prentice, S.A., and D. Mackerras, 1977: "The Ratio of Cloud to Cloud-to-Ground Lightning Flashes in Thunderstorms", *Journ. Applied Meteorol. 16,* 545-550.

Taranik, James V., and M. Settle, 1981: "Space Shuttle: A New Era in Terrestrial Remote Sensing", *Science 214,* 619-626.

Thomas, Morley K., 1953: *Climatological Atlas of Canada,* Meteorological Division, Department of Transport, National Research Council Publication #3151, Ottawa, Canada.

Turman, B.N., and R.J. Tettelbach, 1980: "Synoptic-scale Satellite Lightning Observations in Conjunction with Tornadoes", *Monthly Weather Review 108,* 1878-1882.

Wagner, C.F., G.D. McCann, and C.M. Lear, 1942: "Shielding of Substations", *Trans. AIEE 61,* 96-100.

Wallace, J.M., 1975: "Diurnal Variations in Precipitation and Thunderstorm Frequency over the Conterminous United States", *Monthly Weather Review 103,* 406-419.

Do increases in atmospheric CO_2 have a *Cooling* effect on surface air temperature?

S.B. Idso

For several decades the prevailing scientific wisdom was that increases in atmospheric CO_2 had the potential to significantly raise surface air temperatures, such that a doubling of the CO_2 content of the air from 300 to 600 ppm was predicted to lead to a mean global air temperature rise of from 2 to 4° K (Schneider, 1975: Bach, 1980; Reck, 1982). Then, a few years ago, this concensus estimate was challenged by Newell and Dopplick (1979, 1981) and Idso (1980, 1981, 1982a,b), who contended that the predicted warming was ten times too great. Now, I have found evidence for relationships among historical temperature, CO_2, and industrial carbon production data which indicate that the primary effect of enhanced levels of atmospheric CO_2 may be to actually *cool* the planet instead of warm it.

Consider the data of Fig. 1. Over the period of time for which good atmospheric CO_2 measurements are available, the CO_2 content of the air has increased in essentially the same manner that its precursor, the industrial production of CO_2-carbon, has increased. Thus, we may postulate, as has practically everyone else who has studied the problem, that this same cause-and-effect relationship has prevailed throughout the entire 100-year period from 1880-1980. It then follows that the last century has experienced two distinct eras of atmospheric CO_2 increase: a period of gradual, essentially linear increase from 1880 to approximately 1945, and a period of rapid, essentially exponential increase from about 1945 to 1980 (and beyond). If atmospheric CO_2 has an effect on climate, we may thus expect that some indication of change in surface air temperature may be apparent at the time of transition between the two eras, i.e., at about 1945.

Consider, then, the data of Fig. 2, where the mean air temperature of the globe is broken down into three components, composed of Northern, low and Southern latitudes. In the case of the Southern latitudes, where CO_2 effects are predicted to be minimal (Revelle, 1982), we see a persistent warming trend throughout the entire century. In low latitudes, however, this warming trend is suppressed somewhere near the time of the 1945 transition, with essentially no mean change in air temperature beyond that point. And in Northern latitudes,

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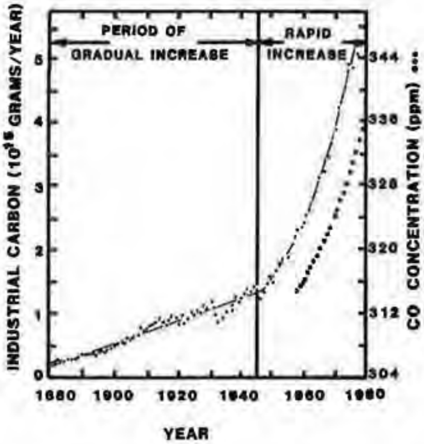

FIGURE 1 The global rate of production of industrial CO_2-carbon (from fuel production data of the United Nations) and the mean global CO_2 concentration (from measurements at Mauna Loa, Hawaii and the South Pol) as functions of time. Adapted from Keeling (1982).

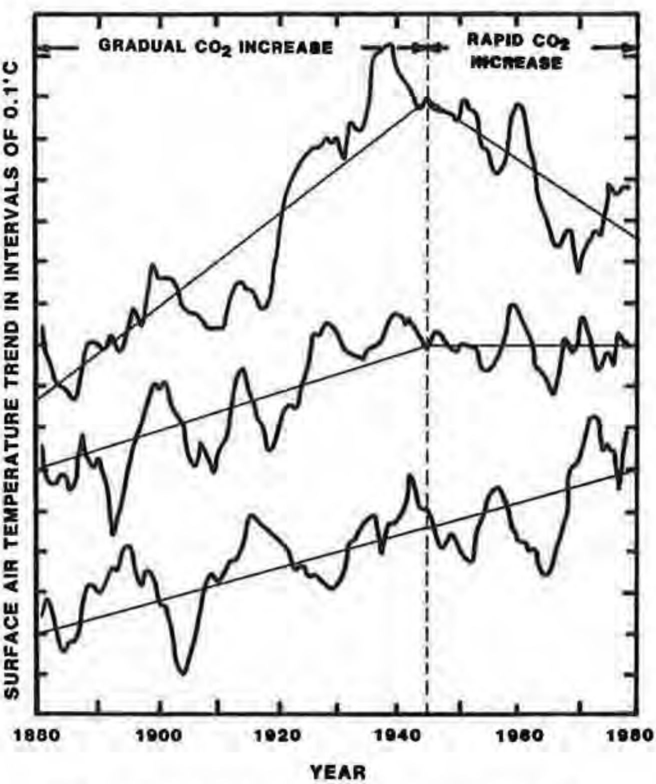

FIGURE 2 Observed trends of mean surface air temperature for: Top – Northern latitudes (90°N-23.6°N), Middle – low latitudes (23.6°N-23.6°S), and Bottom – Southern latitudes (23.6°S-90°S), as reported by Hansen *et al* (1981). I have added the straight lines, drawn by eye, to depict the general trends which appear to characterize the time periods of gradual and rapid CO_2 concentration increase. Adapted from Idso (1982c).

where CO_2 effects are predicted to be greatest (National Research Council, 1982), there is a dramatic change from extreme warming to extreme cooling in the vicinity of 1945.

Of these three temperature trends, the one for Southern latitudes is the least complex, showing but a simple linear increase in surface air temperature over the entire 100-year time span. Thus, simple logic would identify it as the basic tendency for climatic change on Earth throughout the past century. Then, since the other two trends deviate from their common warming tendency at the same point in time, simple logic also posits a common cause for their subsequent behavior; and since this point in time corresponds with the time of transition between eras of gradual and rapid increase in atmospheric CO_2, simple logic further identifies the rapid increase in atmospheric CO_2 content as the cause of the temperature trend changes.

The evidence discussed in the preceeding two paragraphs thus *indicates* (but, of course, does not *prove*) that the primary effect of increasing the CO_2 concentration of the atmosphere of present-day Earth is to depress and not raise surface air temperature; for in Northern Hemispheric regions where CO_2 effects are postulated to be greatest, we see the commencement of dramatic cooling when atmospheric CO_2 concentration begins to dramatically rise. And this is also the picture obtained from satellite data of snow and ice cover: Dewey and Heim's (1981) data for Northern latitudes depict current cooling, while Kukla and Gavin's (1981) data for Southern latitudes depict continued warming.

Perhaps one reason why we have been so long in coming to this straightforward and simple elucidation of the only truly "hard data" pertaining to the CO_2-climate question is that the general circulation models of the atmosphere have for so long predicted just the opposite effects (National Research Council, 1982). With the comprehensive analysis of their shortcomings and the many other evidences which exist for a potential cooling effect of enhanced atmospheric CO_2 provided by Idso (1982c), however, it should now be easier to accept the possible reality of this new interpretation of the data. Especially is this so in light of the recent study of the role of H_2O continuum absorption in the 12-18 μm region of the electromagnetic spectrum conducted by Kiehl and Ramanathan (1982). Prior to the publication of their paper, which appeared in December of 1982, no computer studies of the effects of CO_2 on global climate had included these H_2O continuum effects; and Kiehl and Ramanathan indicate that when these effects are included, the increased downward thermal radiation to the surface of the Earth arising from a doubling of the atmospheric CO_2 concentration decreases to only about a third of what was previously predicted. Furthermore, they note that they have still not accounted for H_2O continuum effects in the 8-12 μm region and that when they finally are included additional significant changes in the results will probably be warrented. Thus, it is easy to admit the possibility that the thermal radiative greenhouse effect of CO_2 may actually be smaller than its opposite interaction with solar radiation; and if this is so, Choudhury and Kukla (1979) have clearly shown how increases in atmospheric CO_2 may have a significant cooling effect on surface air temperature, precisely as the data presented herein appear to indicate.

REFERENCES

Bach, W. 1980. Climate effects of increasing atmospheric CO_2 levels. Experientia 36:796-806.

Choudhury, B. and G. Kukla. 1979. Impact of CO_2 on cooling of snow and water surfaces. Nature 280:668-671.

Dewey, K.F. and R. Heim, Jr. 1981. Satellite observations of variations in Northern Hemisphere seasonal snow cover. NOAA Tech. Rept. NESS 87, U.S. Dept. of Commerce, Washington, D.C.

Hansen, J.; D. Johnson; A. Lacis; S. Lebedeff; P. Lee; D. Rind and G. Russell. 1981. Climate impact of increasing atmospheric carbon dioxide. Science 213:957-966.

Idso, S.B. 1980. The climatological significance of a doubling of earth's atmospheric carbon dioxide concentration. Science 207: 1462-1463.

Idso, S.B. 1981. Carbon dioxide – An alternative view. New Sci. 92:444-446.

Idso, S.B. 1982a. A surface air temperature response function for earth's atmosphere. Boundary-Layer Meteorol. 22:227-232.

Idso, S.B. 1982B. An empirical evaluation of Earth's surface air temperature response to an increase in atmospheric carbon dioxide concentration. *In* AIP Conf. Proc. No. 82: Interpretation of climate and photochemical models, ozone and temperaure measurements, R.A. Reck and J.R. Hummel, eds., Amer. Inst. of Physics, New York, pp. 119-134.

Idso, S.B. 1982c. Carbon dioxide: Friend or foe? IBR Press, Tempe, Arizona.

Keeling, C.D. 1982. The oceans and terrestrial biosphere as future sinks for fossil fuel CO_2. *In* AIP Conf. Proc. No 82: Interpretation of climate and photochemical models, ozone and temperature measurements, R.A. Reck and J.R. Hummel, eds., Amer. Inst. of Physics, New York, pp. 47-82.

Kiehl, J.T. and V. Ramanathan. 1982. Radiative heating due to increased CO_2: The role of H_2O continuum absorption in the 12-18 μm region. J. Atmos. Sci. 39:2923-2926.

Kukla, G. and J. Gavin. 1981. Summer ice and carbon dioxide. Science 214:497-503.

National Research Council (U.S.), CO_2/Climate Review Panel. 1982. Carbon dioxide and climate: A second assessment. National Academy Press, Washington, D.C.

Newell R.E. and T.G. Dopplick. 1979. Questions concerning the possible influence of anthropogenic CO_2 on atmospheric temperature. J. Appl. Meteorol. 18:822-825.

Newell, R.E. and T.G. Dopplick. 1981. Reply to Robert G. Watts' "Discussion of 'Questions concerning the possible influence of anthropogenic CO_2 on atmospheric temperature.'" J. Appl. Meteorol. 20:111-117.

Reck, R.A. 1982. Introduction to the proceedings of the workshop on responsible interpretation of atmospheric models and related data. *In* AIP Conf. Proc. No. 82: Interpretation of climate and photochemical models, ozone and temperature measurements, R.A. Reck and J.R. Hummel, eds., Amer. Inst. of Physics, New York, pp. 1-12.

Revelle, R. 1982. Carbon dioxide and world climate. Sci. Amer. 247(2): 35-43.

Schneider, S.H. 1975. On the carbon dioxide-climate confusion. J. Atmos. Sci. 32:2060-2066.

News and Comments

ASSOCIATION OF AMERICAN GEOGRAPHERS ANNUAL MEETING

The 1983 AAG Annual Meeting took place on April 24-27 in Denver, Colorado. There were 13 climatology sessions, many of which were oriented towards particular themes, especially climate modelling. Four sessions, organized by *Cort J. Willmott* of Delaware and *James E. Burt* of Illinois, were devoted to this topic. One of these was a special session featuring *Robert E. Dickinson* of the National Center for Atmospheric Research in Boulder, who spoke on surface process parameterizations in Global Circulation Models. Among the problems cited by Dickinson are: dependence of albedo on atmospheric transmissivity; modelling of turbulence within the planetary boundary layer; modelling of energy balances for active, dormant, and dead vegetation; dependence of surface and subsurface runoff on vegetation, including canopy interception and uptake of soil water by the roots; and, effects of frozen ground on runoff. The challenge is for modellers to apply results from site-specific research to the macro-scale.

Other climatology sessions on the program included presentations on circulation, drought, synoptic climatology, climatic variability, climatic reconstruction, and a special session on socio-economic impact of climate organized by *John R. Mather* of Delaware. The latter included a paper on the development of a "Weather Stress Index" by *Lawrence A. Kalkstein* of Delaware. This index is based on Steadman's work (see *J. of Appl. Meteorol.*, 1971) and employs data on temperature, relative humidity, and wind speed. Its units are percentage of days less stressful than today. Thus, it is a relative index given as a ratio scale number. Since potential users of such indices are non-climatologists, this information must be presented in a user-oriented format, such as ratio scale anomaly indices, or probabilities of exceeding certain thresholds. Hydrometeorologists have used the latter format when providing data on maximum precipitation amounts for specified return periods. Applied climatologists must continue to develop new ways of providing sophisticated climatic information in relatively simple formats in order to encourage greater use of this information by the public.

Weather modification was the topic of another special session featuring *Stanley A. Changnon* of the Illinois State Water Survey. The modern era of advertant modification began in the late 1940s, and during the following 20 years, government and private industry invested heavily in cloud seeding activities. In recent years, there has been a considerable decline in research funding because there is little consensus on how well cloud seeding works. Several positive aspects were cited, including successes in cold fog suppression and orographic snow enhancement, and the development of greater expertise in cloud physics, measurement (including radar), and impact studies. Future needs include a return to basic research on the life cycle of precipitation systems, and an increased effort to develop better project design and evaluation approaches. Inadvertant modification was also discussed, and although there is greater certainty about impacts, at least on the local scale, more research is needed on meso- and macro-scale effects of urbanization, deforestation, and large-scale irrigation.

Regarding the climatology specialty group, *Richard H. Skaggs* of Minnesota was retained as Chairman. Several proposals were made by the group for the 1984 AAG Meeting in Washington, including a student papers competition, open panels for non-specialist audiences, and an increase in the number of poster sessions.

CANADIAN ASSOCIATION OF GEOGRAPHERS ANNUAL MEETING

The 1983 CAG Annual Meeting was held at the University of Winnipeg on May 30-June 2. G.D.V. Williams of AES Downsview has kindly provided the following notes:

"There were over 180 papers, many in concurrent sessions. I attended sessions on Climatology, Glaciations, Agriculture, the Rural-Urban Fringe, Biogeography, Historical Geography, and Environmental Impact Assessment (EIA), and also parts of a miscellaneous poster session. What follows is a report on the climatology, glaciation, and EIA sessions.

"There were 2 Climate sessions; 7 papers were presented. My own paper "Prairie droughts as indicated by water-based wheat yield estimates" was presented first. I described drought patterns as indicated by water-budget based wheat yield estimates over the prairies and from year to year for 1928 to 1980. I estimated that drought-related wheat crop losses were about $2.1 billion for 1928-38 and the same for 1957-68.

"The second paper "Climatology of the Cypress Hills – an "oasis" in the Palliser Triangle" by *Whiting & Wheaton* of the Sask. Research Council, was presented by *Elaine Wheaton*. The study area is climatologically and hydrologically quite distinct from the surrounding prairies, in that it is cooler in the summer, warmer in the winter, and is sufficiently humid that the streams provide reliable flows throughout the year. Analysis of the climate of the area is hampered by the fact that the climatological station there was in operation for only 10 years, from 1962 to 1972. This information can be supplemented to some extent by observations taken by the local park staff to assist them in forest fire control.

"In "Hailstorms in agricultural Manitoba: a climatological study", *Steve LaDochy,* University of Winnipeg, described his analysis and graphing of spatial and temporal patterns of thunderstorms based on crop insurance data. These data tend to give much better spatial coverage than the meteorological station network, but they are selective and have biases that have to be recognized.

"The paper "Frequency and characteristics of tornadoes of S.W. Ontario" by *Janssen and McBoyle,* U. of Waterloo, presented by *Geoff McBoyle,* was reminiscent of the Saskatchewan one given last year by Blair & Paul. Janssen & McBoyle searched the London Free Press, 1960-79, and found reports of 84 tornadoes and 50 probable ones. They assessed the reliability of the sightings. They concluded that 6 to 7 tornadoes annually could be expected in the area, occurring especially in late afternoon and especially in Lambton and Essex Counties.

"Les types de temps comme outil complementaire de la classification climatique", is by *Joseph Litynski,* U. de Quebec, Trois-Rivieres, who has been working on numerical climatic classification of world climates. This paper described his latest efforts to develop a universal system for using daily temperature and precipitation data in determing weather types for climatic classification purposes.

"In "Assessment of a suburban water balance", *Sue Grimmond,* U. of B.C., described a suburban water balance study which included analysis not only of climatological data but also of readings on the amount of water piped into the area. Actual evapotranspiration in such an area can be considerably higher than what would be possible if the only water were from precipitation over the area, and her approach allowed this to be quantified.

"The final climatological paper was "The location of the treeline in the region of Churchill, Manitoba, as a response to climatic and anthropogenic factors", by *Tim Ball,* U. of Winnipeg, who also presented a related poster paper later. In the area within 60 miles south and 40 miles west from Churchill, the treeline was apparently retreating in the 1700's but much of this was probably due to increasing activities and need for firewood and lumber at Churchill. Farther west there was apparent retreat associated with cooling climate. There was apparently a significant climate change around 1760. Graphs in his poster session showed similar numbers of days with rain up to that year at York Factory and Churchill, 120 miles apart. After that, days with rain at York, which is farther south, were considerably higher than at Churchill. Other data, including wind direction frequencies and thunderstorm occurrences also reflect a change. Ball suggested this corresponded with the end of the "little ice age" there; before 1760 both places were typically N. of the Arctic front and in the tundra zone, while afterwards, the line was N. of York but S. of Churchill.

"*Derek Ford,* McMaster U., organized a special session "Canada: How Many Glaciations? – President's Colloquium". He suggested that the number was very much in question and there could have been as many as 17 major glaciations affecting our land in the past 2 million years. Other speakers discussed evidence in various regions: *Joyce MacPherson*, Memorial U. (Atlantic region), *Serge Occhietti*, U. de Quebec, Montreal (Quebec-Labrador Plateau in N.Y. state); *Terry Day*, U. of Western Ont. (Ont. & mid-continent); *Bill Rannie*, U. of Winnipeg (Prairies); *Stuart Harris*, U. of Calgary (Cordilleral); *John Andres*, U. of B.C. (S.W. B.C.).

"*Tom Meredith*, McGill U., in a paper entitled "Standards in Environmental Impact Assessment", gave an excellent review of the history of the environmental movement, the environmental impact assessment process, involvement by governments and scientists, and how scientists view the process. He suggested that while the process has had many problems and limitations, it is much better than not having it at all.[1]

"A paper "On congruence and relevance of data in the Environmental Impact Assessment process", by *Terry Simmons*, Simon Fraser U. (He's currently working with B.C Hydro) was read by a colleague. It spoke of the problem of the typical "ten-volume" environmental impact reports of the '70s that were "uncritical collections of massive data that didn't relate well to practical needs". It suggested that EIA reports were planning tools and were only as good as their use in planning. It was also suggested that "no new data should be collected unless it's really needed", and emphasis was given to the importance of interpretation, of understanding the practical needs, and of interaction between planners, regulators, and those doing the assessments, from an early stage."

[1]Editor's Note: Tom Meredith has published a paper entitled "Geography and the Environmental Impact Assessment Process" (The Operational Geographer, 1983, 1, 12-14).

The Ontario Branch of the Canadian Association of Geographers (CAGONT) is meeting at McMaster University in Hamilton on October 28-29, 1983. One of the paper sessions to be held at 10:30 a.m. October 29 is entitled "Mass and Energy Fluxes at the Regional Scale" and will include the following presentations:

Ellsworth LeDrew	"Synoptic development in the seasonal sea ice zone of the polar basin."
Wayne Rouse	"The impact of regional advection from Hudson Bay on terrestrial climate."
Ming Ko Woo	"Regional variation of high flows in the Hudson Bay lowlands."

In addition to the above, Wayne Rouse of McMaster informed the Bulletin at press time that there might be a fourth presentation on regionalism of mass fluxes. Further information can be obtained from:

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