February 1994

"Wading to Pembina": 1849 Spring and Summer Weather in the Valley of the Red River of the North and Some Climatic Implications

Danny Blair
University of Winnipe, Winnipeg, Manitoba, Canada

W. F. Rannie
University of Winnipe, Winnipeg, Manitoba, Canada

Great Plains Research 4 (February 1994): 3-26

"WADING TO PEMBINA": 1849 SPRING AND SUMMER WEATHER IN THE VALLEY OF THE RED RIVER OF THE NORTH AND SOME CLIMATIC IMPLICATIONS

Danny Blair and **W. F. Rannie**

Department of Geography, University of Winnipeg
515 Portage Ave, Winnipeg, Manitoba
Canada, R3B 2E9

Abstract. *The weather of 1849 in the central Great Plains and western interior of the United States has been reconstructed in numerous analyses of diaries from the mass migration to the California goldfields, military post records, and other archival materials. These studies have demonstrated that the spring and summer periods of 1849 were unusually cold and wet, particularly in the eastern region of the Oregon Trail (near Kansas City). Historical sources from the valley of the Red River of the North of North Dakota, Minnesota, and Manitoba support this contention and extend the climatic reconstruction 1,000 km northward. Spring breakup of the Red River was exceptionally late, snow fell in the Red River Settlement on several days in late May, and widespread, heavy rainfall from June to August caused unusual and protracted flooding of the Red River and its tributaries. Instrumental records from Fort Snelling and Norway House confirm the anecdotal accounts. Similarly abnormal weather was produced by the July, 1958 synoptic pattern and it is suggested that this pattern may provide a suitable large-scale analog than others which have been suggested. As unusual as these observations appear to be when compared with the modern record, they may have been more typical of conditions on the Great Plains in the first half of the nineteenth century.*

Interest in climatic reconstructions of the Great Plains has grown in recent decades, both to better understand the environmental conditions experienced by the inhabitants of the region and to improve assessment of climatic change by placing the modern, instrumental record in a larger perspective. The year 1849 has a special prominence in these reconstructions. Not only was 1849 at the midpoint of a century which began at the depth of the "Little Ice Age" and ended at the transition to the more benign twentieth-century weather patterns, but also in the spring and summer of that

year more than 30,000 '49er gold rush migrants set out on the Oregon and Santa Fe trails for the goldfields of California (Parker 1964). The diaries left by these migrants provide an abundant source of commentary on the "preset-tlement" climate of what was thought to be the "Great American Desert." Analyses of these materials by Parker (1964), Lawson (1974, 1975), and Mock (1991) have shown that the weather patterns encountered by the '49ers were not only at variance with the prevailing notion of the "Great American Desert" but were also highly unusual when considered from a twentieth-century perspective.

These previous analyses have concentrated on the central Great Plains and western interior regions of the United States. In this paper, archival materials from the valley of the Red River of the North (hereafter referred to as the Red River) and the Red River Settlement (the site of present-day Winnipeg, Manitoba), supplemented by instrumental records, are utilized to extend the portrayal of the 1849 weather northward by 1000 km to demonstrate that the conditions described by Parker, Lawson, and Mock were not local but occurred on the northeastern plains of the United States and Canada as well.

Summary of Weather Conditions in the Central Great Plains

In his short paper whimsically entitled *Wading to California*, Parker (1964) drew attention to the discrepancy between the widely-held notion of the "Great American Desert" west of the Missouri River and the unusually wet weather experienced in 1849 by the gold rush migrants across the Great Plains segment of their journey (Fig. 1). The true desert, encountered further west, caused appalling hardships which tended to obscure the rigors of the passage across the plains during what Parker asserted was "one of the wettest years that the Plains have experienced." (Parker 1964:39).

The Great Plains portion of the migration, particularly the Oregon Trail, was examined in much greater detail by Lawson (1974, 1975) who supplemented the narrative accounts of the diarists with analyses of instrumental records from military posts in the region. The departure of the wagon trains from the assembly points on the Missouri River was delayed by uncommonly cold weather in April (and a snow storm late in the month), which retarded the growth of grass needed for forage. Then, as the trains began to move out in late April, exceptional rainstorms inundated the plains, continuing throughout May in the eastern regions.

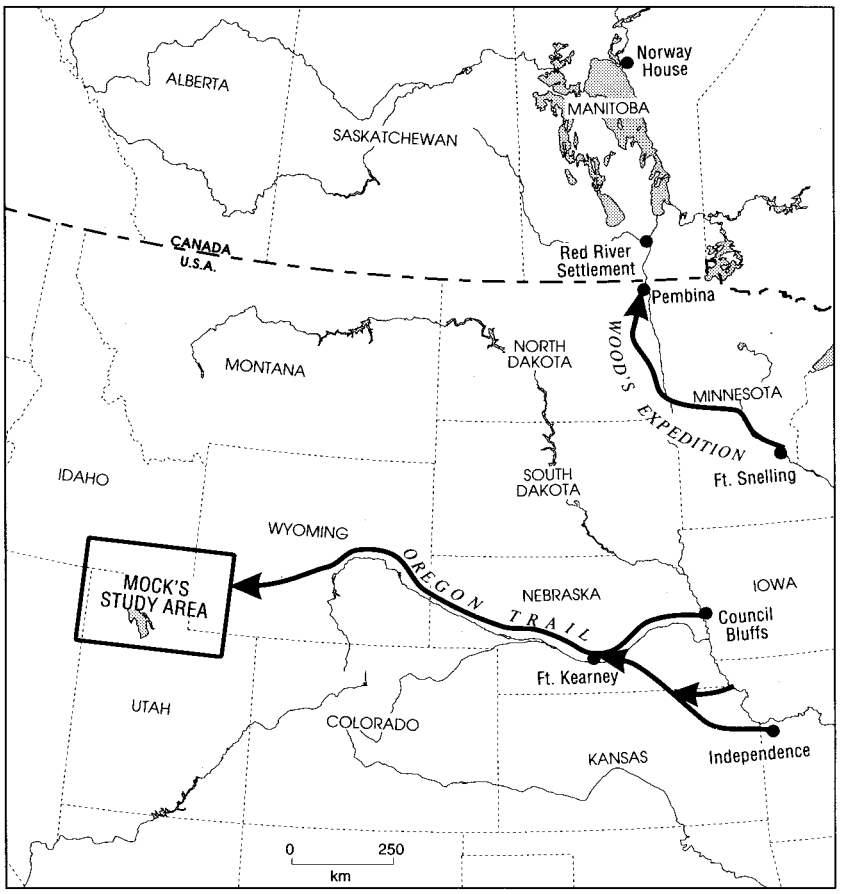

Figure 1. General location map.

For the first half of the trip to California, the pioneer was not plagued with the supposed drought of a Great American Desert, but by cloudbursts of magnificent proportion, swollen rivers, and inundated fords. Accompanied by brilliant electrical displays, "outrageous" downpours driven by winds of "hurricane force" proved devastating to the frail wagon coverings and pitched tents (Lawson 1974:63).

Meteorological records from several military posts in the vicinity of the Oregon and southern trails examined by Lawson (1974) indicate that rainfall in April and May was particularly heavy at Fort Kearny in present south-central Nebraska where the totals for each month had exceedence probabilities of only about 1%. Several other forts to the south and east of Fort Kearny recorded exceptional rainfall in one or both of these months, although Saint Louis Arsenal had only average precipitation. Temperatures at most forts during these months were unseasonably cool or cold; and near Fort Kearny, a light snow fell on May 24.

By mid-May, when the wagon trains were penetrating central and western Nebraska, the storms were decreasing in frequency but were possibly even more violent. Hail, some tornado sightings, and temperatures which alternated between hot and cool were interpreted by Lawson as indicating the passage of rapidly-moving cold fronts. By early June in western Nebraska and eastern Wyoming, however, the storms were becoming increasingly uncommon and spatially random, suggesting a convective (rather than frontal) origin. Now, in the western Great Plains sector, heat, dust, and shortage of water became increasingly problematic.

From mid-June onward, the majority of migrants were moving through the Rocky Mountains and adjacent Great Basin regions of Wyoming, southern Idaho, and northeastern Utah. Mock (1991) analyzed the climatological content of the diaries from this portion of the migration. From the incidence of frost or ice and the frequency and pattern of precipitation, he concluded that the summer of 1849 was abnormally cold and dry in comparison with modern (1936-1987) conditions. Most of the precipitation that did fall appears to have been associated with the passage of cold fronts in cyclonic systems.

In contrast to the increasing dryness being encountered by the migrants on the western Great Plains and Great Basin in the June-August period, the wet spring conditions in the eastern portions of the trails continued or increased through the summer. At Saint Louis Arsenal, for example, monthly exceedence probabilities reported by Lawson were 1% or less from June to August and most stations recorded precipitation of 200 to 300% of normal in at least one of the months from June to August (Lawson 1974). Record total summer precipitation was achieved in 1849 at Saint Louis Arsenal, Jefferson Barracks, and Fort Kearny in the vicinity of the eastern portion of the Oregon Trail, and at Fort Gibson, Fort Washita, and Fort Smith near the eastern ends of the southern trails. High water or flooding was reported in numerous rivers and at Fort Leavenworth the Missouri River was reported to be still "high" on June 24.

Weather Conditions in the Red River Valley Region

Archival materials from the Red River valley offer a rich resource for reconstructions of the nineteenth-century climate. From the beginning of the century, the region was occupied or visited by a succession of educated, literate fur traders, clergy, merchants, administrators, soldiers, and others whose diaries, letters and journals contain abundant commentary on many aspects of the natural environment, particularly weather. Fortunately, these materials are well-preserved. The principal 1849 sources include diaries by Reverends John Smithurst and Robert James of the Church Missionary Society, the letters of Monseigneur Joseph-Norbert Provencher in the Red River Settlement, and the reports of the Woods Military Expedition from St. Paul to Pembina. These are supplemented by brief, useful comments by Father George Anthony Belcourt at Pembina.

Diary entries of Reverends Smithurst and James suggest that although weather in the Red River Settlement in the first half of April was not severe, spring was, in fact, late. For example, on April 18, Reverend Smithurst reported that horses, oxen, and people were still able to cross the ice on the Red River (Smithurst 1849). By April 25, ice conditions and the acknowledged "lateness of the season" were described by Smithurst as being "hard upon those who depend upon fishing" (Smithurst 1849). Heavy snow accompanied by drifting was reported from April 27 to May 2 and Reverend James commented that April 30 was like January. "The ice is still upon the River, not the voice of one singing bird is heard" (James 1849).

The condition of the ice on the Red River provides a particularly valuable phenological indicator of temperature conditions. Rannie (1983) showed that the average ice clearing date in the nineteenth century was April 23 as compared with April 11 in the twentieth century. In 1849, the river did not clear sufficiently for canoes to cross until May 7 (Smithurst 1849), a remarkably late date even for the apparently more severe conditions which prevailed in the last century. Rannie found a strong correlation ($r = -0.79$) between breakup date and March-April mean temperature; a breakup date of May 7 would suggest that the average temperature in March-April, 1849, was approximately 3.5°C below the nineteenth century mean.

A marked improvement in the weather occurred on May 3 and agricultural operations proceeded in earnest for the next two weeks. On May 21, however, cold weather and snow returned (Smithurst 1849). Significantly, light snow was also reported near Fort Kearny on May 24, indicating that the incursion of cold air extended at least 1000 km to the south. The snow continued at least until the next day, but by May 24 the weather in the

Settlement had again turned "fine" and seems to have continued this way until the end of the month.

The most detailed information on summer (June-August) weather comes from the reports of the Woods Military Expedition from Fort Snelling (Minneapolis-St. Paul, Minnesota) to Pembina (on the Red River in present-day North Dakota, 3 km south of the United States-Canada boundary) (Fig. 1). Captain Samuel Woods received orders to investigate the need for and locate a new military post on the Red River and to report on the general state of affairs in the region. The accounts submitted by Woods and Lieutenant John Pope of the Topographical Corps provide detailed commentary on the vegetation, topography, and hydrologic features along the route (Pope 1850; Woods 1850).

The company of Dragoons left Fort Snelling on June 6 and was immediately plagued by widespread, continuous, and frequently heavy rain.

> Our starting was unpropitious; the rains commencing on the 4th continued intermittingly until . . . the 11th. On the west bank of the Mississippi [c. June 13] I made an encampment, where I intended to remain until the weather changed for the better. The rains having fallen so steadily and for so many days, the earth was so saturated with water, that the thickly-matted turf of the prairie would not support the weight of the wagons. . . . The [Sauk River] was much swollen by the heavy rains, and was wide and deep (Woods 1850:10-11).

After three days of dry weather (June 13-15), the expedition set out from Sauk Rapids on June 16 but almost immediately the rain returned and fell "incessantly" (Pope 1850:18), eventually forcing another halt on June 20. On June 26, the party set out again ". . . over bad roads, or rather over a bad prairie . . . that [was] flooded with water and miry" (Woods 1850:12). The next day, the expedition was forced to halt again to await an improvement in travelling conditions.

> The heavy and incessant rain since the 4th of June had so saturated the prairies . . . that it was found absolutely necessary to halt for a few days . . . many were under the impression that the whole country was swampy, but I was informed by the guides that such a season had not been known for twenty years, and that they had never seen the country in such condition before (Pope 1850:18-19).

On July 4, the expedition celebrated Independence Day in a violent thunderstorm and torrential rain.

> The thunder broke over us in such smashing explosions that for two hours our position was torturing beyond description. . . . Many left their tents and stood out regardless of the pelting rain [because of fear of lightning hitting tent poles] (Woods 1850:13).

In the 31 days from June 4 to July 4 inclusive, rain fell on 16 days; the 15 "clear" days were concentrated in three periods (June 14-19, June 22-25, June 28-July 2). To emphasize the amount of rain which had fallen, Woods wrote "On the days marked rainy, we had sometimes the most terrific storms, when the rain fell in torrents and the heavens were in a blaze of light, and the thunder broke over us appallingly" (Woods 1850:13).

Identical conditions had been encountered by Reverend Alonzo Bernard travelling northward from Fort Snelling to Red Lake Mission in northern Minnesota in mid-June. Bernard wrote:

> [The roads] were inundated at frequent intervals by floods resulting from . . . the recent heavy showers . . . the team becoming mired in the deep mud [caused] an unavoidable delay . . . a situation ensued which the rain, now descending in torrents, was not well calculated to relieve (Schell 1911:110).

The Woods party resumed its march on July 6 but difficulties in crossing several normally small streams added to those already presented by the "miry" prairies.

> The prairies were so bad from the drenching rains that had just fallen [that] we were scarcely able to get along. Little drains that usually contain no water, were now almost swimming, and these occurring every mile or two, with the miry conditions of the ground rendered our march slow and exhausting to our teams (Woods 1850:13-14).

The expedition reached the main stem of the Red River on July 12 and spent the next three days crossing the river. From this point, the line of travel northward to Pembina was at right angles to the numerous tributaries which enter the Red from the west, all of which were swollen. The swollen Shey-

enne River had to be ferried and high waters caused similar delays at the Maple, Rush, and Wild Rice rivers.

> Starting at 12 M [on July 17], over a level prairie on which the water stood from two inches to two feet deep almost the entire way . . . we reached Maple River, which Mr. Kittson had bridged; but the water being much higher now than when he crossed it, the bridge had disappeared. . . . There had been such torrents of rain about this time, that the little branches that ordinarily furnish barely a sufficiency of water to allay the thirst of a travelling train were now swimming. . . . About eight miles from Rush river we came upon a little prairie stream much swollen and deep (Woods 1850:16-17).

"Terrible" thunderstorms and torrential rains were described by Woods and Pope on July 17 and 18. Eventually the party detoured westward away from the Red to intersect these streams higher on their courses where discharges were smaller and crossing easier and to take advantage of higher, better drained beach ridges of glacial Lake Agassiz which ran parallel to their line of travel.

From mid-July onward, the travelling conditions appear to have improved somewhat due to the better drainage and easier crossings along the altered route; the weather may also have improved since rain was reported less frequently. The rigors of the previous six weeks' weather and mosquitoes were taking their toll on teams and wagons, however, and it was not until August 1 that the expedition reached Pembina where they "found the Red river and Pembina river with about twenty feet rise in them, and overflowing their banks" (Woods 1850:18). In 57 days since the departure from Fort Snelling, the party had covered 497 miles or less than 9 miles per day (Pope 1850).

The state of the river had been a source of concern to Father Belcourt at Pembina since mid-June: "The water of the river, which is rising rapidly, makes us fearful; a part of the seed put in the low ground is going to be ruined" (Belcourt 1849, June 17).

Information from sources in the Red River Settlement in June and July is relatively scant but in late June, Bishop Provencher confirmed the high level of the Red River and reports of flooding at Pembina.

> The water is extraordinarily high . . . all the rivers are inundated. they say that Pembina is drowned and it is believable from the height

> of the water here. there is already grain in the water and it doesn't appear to have decided to lower yet . . . it rains often and without doubt much more copiously upstream than here (Provencher 1849a, June 26).

> The convoy has left and the water is extremely high. They say that Pembina is drowned; it is not possible to ride on the prairie and the water rises continually. Much wheat perishes because it rains often. . . . M. Belcourt writes me that the wheat [at Pembina] is almost drowned and the soldiers are stopped by the water he thinks. . . . It is very difficult to communicate except by canoe (Provencher 1849b, June 27).

These comments show that June was also unusually wet in the Settlement. Two particular storms were noted by Reverend James in July. In his diary entry for July 8 he reported that "Last night was one constant awful storm of thunder, lightening, wind & rain. The rain continuing, & the ground being almost impassable moderated the attendance [at the church]" (James 1849). On July 29 "A violent storm raged all last night & the whole of today. I have not seen such a fall of rain hitherto in the Country" (James 1849).

The rain appears to have continued through much of August. On August 8, James reported that "the ground was one swamp with the incessant rains." At Pembina, Woods

> waited from the 1st to the 26th of August hoping the country would dry sufficiently for me to pass over it, but was disappointed. The improvement of the prairie by a few successive clear days, a hard rain would restore to their previous impassable condition (Woods 1850:19).

Woods had been invited to pay a courtesy visit to Fort Garry in the Red River Settlement during his stay at Pembina but was prevented from doing so by "almost incessant rains and the conditions of the country" (Woods 1850:20). Instead of visiting Fort Garry, Woods decided to explore the Pembina Mountains 50 km to the west. On August 14, he

> travelled nearly due west for about 8 miles and found the prairie so horribly bad that I turned back. . . . I had a guide who has lived in this country thirty-four years . . . [who] said, after seeing the condition

> of this route, it would be useless to attempt any other. Our horses mired over nearly the whole of the distance (Woods 1850:19).

Flooding continued and on August 28, Provencher wrote

> the water has been so high all summer that there was no way to communicate with Pembina except by water. . . . A company visited his [M. Belcourt's] post and they had to leave because there was no appearance of a harvest at Pembina; the water covered the fields (Provencher 1849c).

Summer (July-August) flooding of the Red River is a highly unusual occurrence. The comments by Belcourt, Provencher, Woods, and Pope indicate that bankfull discharge was, at the least, equalled (and probably exceeded) in the summer of 1849. From the modern (1916-1990) record of July-August discharges at Emerson, 3 km north of Pembina, bankfull discharge in these months has an exceedence probability of less than 1%.

By August 26, when the expedition left Pembina on its return journey, the weather seems to have improved considerably.

> We left Pembina on the afternoon of the 26th of August on our return and had for about fifteen miles the same difficulties to contend with that we encountered going out, but at this point the prairie began to improve. There had evidently not been so much rain as at Pembina and twenty-five or thirty miles further on the roads became good and we travelled without any serious interruptions, averaging more than twenty miles a day until we reached Fort Snelling, the 18th of September 1849 (Woods 1850:21).

Pope separated from the main party and travelled back to Fort Snelling by canoe.

> When the expedition first reached Pembina the incessant rains for weeks previous had caused all the rivers to overflow their banks; but when I embarked to ascend Red River, it had subsided into its usual channel(Pope 1850:34).

Pope's record of astronomical observations provide additional evidence of the contrast in weather conditions on the outward and homeward

journeys. During the entire 57 days of the trip from Fort Snelling to Pembina, he reported solar or star observations for only 3 days (June 24, 29, 30), although this seems to have been one of the duties for which he was attached to the expedition. At Pembina, observations were taken only on August 21 and 22, three weeks after his arrival there. On the return journey, however, he reported solar or star observations on 13 days between August 26 and September 15. A possible explanation for this difference is that clouds inhibited solar/star observation for much of the period from early June to the third week of August and that the last week of August and first two weeks of September had a much reduced amount of cloud cover.

Neither Woods' nor Pope's detailed reports makes any mention of the temperatures experienced during their expedition and from the Red River Settlement sources we learn only that June 29 and July 1 were extremely hot and July 14 was "temperate" (James 1849). It can only be concluded that the temperatures in June, July and August were not particularly unusual for these months in the Red River valley region.

In summary, April in the Red River Settlement seems to have been fair and "pleasant" for the first three weeks, turning colder with snow during the last week. From the very late breakup date of the Red River, temperatures must have been below average. From May 3 to May 21, fine weather prevailed, with no mention of precipitation. Snow and cold returned on May 21-23 but the last week of May was "fine." June, July, and the first three weeks of August were exceptionally wet over a large portion of the Red River valley. Lengthy periods of "incessant" and "continuous" rain separated by brief dry intervals of only a few days, caused flooding on virtually all tributaries of the Red River, and on the Red itself, at least at Pembina. The spatial extent and the duration of the rain suggest that much or most was of cyclonic origin, although observations of thunder, lightning and very high intensity indicate that instability of either convective or frontal origin contributed to the total, particularly in July. The complete absence of commentary on temperatures during the June-August period, combined with the cloud conditions implied by the continuous rain would suggest near but perhaps slightly below-normal temperatures. The last week of August and the first two weeks of September were apparently dry and had a sufficiently broken cloud cover to permit sky observation on the majority of days.

Instrumental records from Fort Snelling, approximately midway between Council Bluffs and Pembina, and Norway House, 460 km north of the Red River Settlement, are in general agreement with these conclusions and with the pattern in the eastern Oregon Trail region to the south described

above. Total precipitation from April to August 1849 was approximately double the 1837-1855 average (Fig. 2a) and was in fact the largest total ever recorded at any of the several station locations in the Minneapolis-St. Paul area from 1837 to the present. Furthermore, with the notable exception of June, every month from April to August had more than double the average monthly rainfall. Mean monthly (April-September) temperatures at Fort Snelling from the beginning of record in 1820 to 1855 (when the station was relocated) are also presented (Fig. 2). Mean temperatures in April and May were substantially below the 36-year average; snow storms late in each month occurred in both the Red River Settlement and along the Missouri River at the Oregon Trail assembly sites. June experienced average mean temperatures, July was slightly below average, and August was again substantially below average.

For Norway House, 460 km north of the Red River Settlement, Chenoweth (1992a, 1992b) has calculated and standardized monthly mean temperatures recorded from 1831 to 1858. The pattern for 1849 is virtually identical to that of Fort Snelling (Fig. 2d). April 1849 was the coldest in the 27 years of record presented by Chenoweth. May, June, and July were only slightly cooler than average, and August was again substantially colder. As at Fort Snelling, September was approximately normal.

A Possible Synoptic Climatology for the Spring and Summer of 1849

It is clear from the above that the weather of the spring and summer of 1849 was anomalous, at least in the modern context, over a large area of the central and northern Great Plains. It is likely, then, that the mean synoptic climatology of the region as would appear in maps of storm tracks or midtropospheric flows was also anomalous during this time period. Unfortunately 1849 pre-dates the availability of surface-pressure maps and upper-level charts for this part of the world, so any appraisal of the synoptic conditions for that summer must be quite limited. Nevertheless, there are sufficient data to attempt a reconstruction. For example, Fritts et al. (1981) reconstructed the pressure, temperature, and precipitation characteristics over North America in the spring and summer of 1849 using a multivariate technique based on western North American tree-ring data. The reconstruction discussed below utilizes a search through modern records for an appropriate synoptic analog.

A successful analog for the spring and summer of 1849, in its most general form, should account for at least the following conditions:

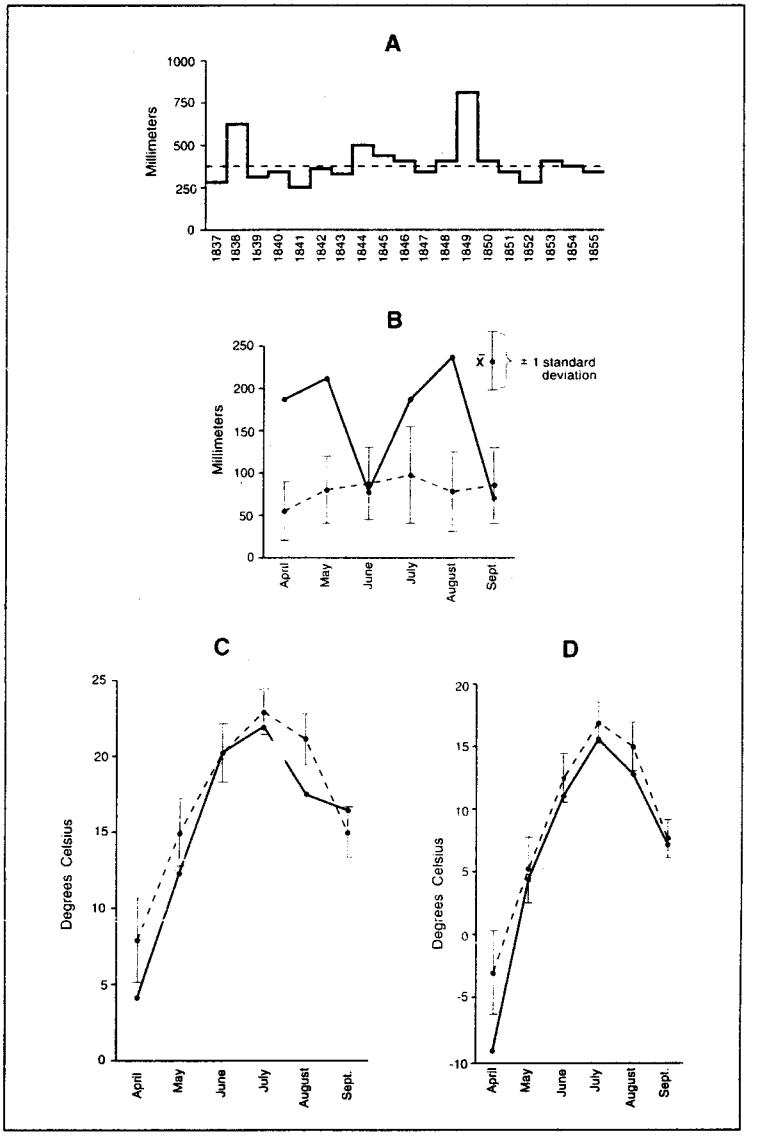

Figure 2. (a) April-August total precipitation, 1837-1855 (bars), and mean April-August total precipitation, 1837-1855 (dashed line), Fort Snelling. (b) Monthly total precipitation, 1849 (solid line), and 1837-1855 mean monthly total precipitation (dashed line), Fort Snelling. (c) Mean monthly temperature, 1849 (solid line) and 1820-1855 mean monthly temperature (dashed line), Fort Snelling. (d) Mean monthly temperature, 1849 (solid line) and 1831-1851 mean monthly temperature (dashed line), Norway House.

1) A cool spring in the Red River Settlement, where the breakup of the Red River was delayed until the first week of May, two weeks later than the nineteenth-century average;
2) Uncommonly cold spring weather, at least until the middle of April, in the central Great Plains;
3) Unseasonably late snowfalls in the Great Plains;
4) Widespread and heavy rains in the central Plains during May, July, and August;
5) Very wet weather in the Red River valley from the beginning of June until the third week of August; and
6) Cool and dry weather in the northeastern Great Basin.

Mock (1991) proposed that the cool and dry weather that affected the northeastern Great Basin and adjacent Rocky Mountains in the summer of 1849 could be explained by a synoptic situation similar to that observed in August 1960 or August 1964. Both of these months had a stronger-than-normal eastern Pacific subtropical high located west of its average position. This produced troughing into the northwestern United States, whereby colder-than-normal air masses could enter the region from the north. Drier-than-normal weather was promoted in the region by above-average surface pressure and the region's proximity to the western side of the dominant trough, where synoptic-scale processes tend to inhibit the formation of precipitation (Klein 1948).

Since the area studied by Mock did indeed have cool and dry weather in August 1960 and August 1964, the atmospheric circulations during these months seem to be adequate synoptic analogs for the summer of 1849 in the region he studied. However, they do not account for the weather conditions that prevailed in the central Great Plains. August 1960 did not produce cooler-than-normal temperatures across a substantial section of the Plains, nor did it produce unusually wet weather (Ludlum 1960). August 1964 did have cold temperatures across a large portion of central North America, and in the central Plains in particular, but, again, precipitation in the central Plains was not unusually heavy (Ludlum 1964).

Mock's analysis sought a synoptic analog that would explain anomalous weather within a limited area of the Great Basin region. A search for a larger scale analog which would also account for conditions on the Great Plains was conducted by the present writers with the aid of Diaz's (1981) eigenvector analysis of summer precipitation over the contiguous United States. Diaz's seasonal eigenvector maps were chosen as the reference maps because the analog being sought was with respect to weather over a number

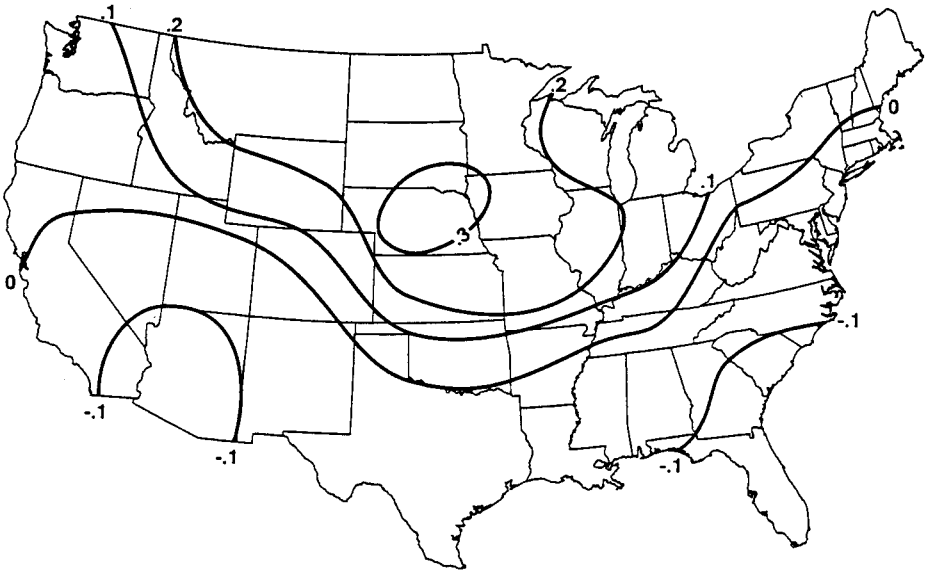

Figure 3. Negative mode of the second eigenvector of standardized summer (June-August) precipitation over the contiguous United States. Negative values indicate below-normal precipitation; positive values indicate above-normal precipitation. Redrawn from Diaz 1981.

of months. The summer eigenvectors were chosen because much of the wet weather that affected the Red River valley in 1849 occurred in June, July, and August. As a first step in the search, Diaz's eigenvectors of standardized summer precipitation were scrutinized and the second eigenvector (Fig. 3) was determined to best represent the apparent precipitation pattern in the summer of 1849. Monthly precipitation maps in *Weatherwise* from those summers of 1946-78 with the most negative second eigenvector scores (i.e. wet in the plains, dry in the far west) were then examined to see which months had precipitation patterns most similar to the apparent precipitation pattern of 1849. The temperature anomaly patterns for these months were also examined.

From this search July 1958 appeared to provide the best analog for the precipitation and temperature conditions which prevailed in the spring and summer of 1849. The interested reader is referred to Canada (1958) and Ludlum (1958) for maps of the July 1958 precipitation and temperature patterns over Canada and the United States. Precipitation was very heavy in

the Red River valley and in the upper Mississippi Valley, Great Lakes, and Ohio Valley regions. A number of the stations in areas that evidently had large amounts of rain in the spring and summer of 1849 received record or near record amounts of rainfall in July 1958. For example, in southern Manitoba, Winnipeg and Emerson had 189 and 156% of their normal July precipitation totals, respectively; Fargo, North Dakota, had 172%; Lincoln, Nebraska, 319%; and St. Louis, Missouri, 215%. Record July precipitation totals (to 1958) were recorded at a large number of stations from Nebraska to Massachusetts, with many stations also establishing records for the most cloud cover, the least sunshine, atmospheric humidity, and soil wetness (Dunn 1958; Ludlum 1958). As in 1849, flooding was extensive as well. In early July the Missouri River exceeded flood stages from St. Joseph, Missouri, downstream, and flash flooding was recorded in Iowa, Kansas, Nebraska, Indiana, Illinois, Ohio, Pennsylvania, and West Virginia (Ludlum 1958). July precipitation was generally light or very light in areas west of the Red River valley in Canada and areas west of the Missouri River in the United States.

Temperatures were also quite low in the west in July 1958, as they were over a significant portion of central and eastern areas of the contiguous United States and southcentral Canada. Mean temperatures were above average in all of British Columbia and along the American west coast.

Thus, the temperature and precipitation patterns of July 1958 seem to fit quite well with those that apparently occurred through the spring and summer of 1849. They are also very similar to the anomaly patterns reconstructed by Fritts et al. (1981) by a completely different method (Fig. 4). The correspondence of the precipitation patterns is, perhaps, the most relevant feature of the analog. The degree to which the temperature patterns match is more problematic, and less important, as the extent and severity of the negative temperature anomalies in 1849 are not based on as much direct and indirect evidence as are the positive precipitation anomalies. However, a statistically significant relationship between mean summer temperature and total summer precipitation in the Great Plains indicates that wetter-than-normal weather tends to occur with cooler-than-normal temperatures (Diaz 1986).

The atmospheric circulation associated with the July 1958 temperature and precipitation anomalies was itself very unusual. Indeed, Dunn (1958) noted that the month's mean circulation, for the Northern Hemisphere as a whole, was of a type that is seldom seen in midsummer. From a North American perspective, the most important features of the circulation were the unusual placements of troughs and ridges. Ridges were observed in the

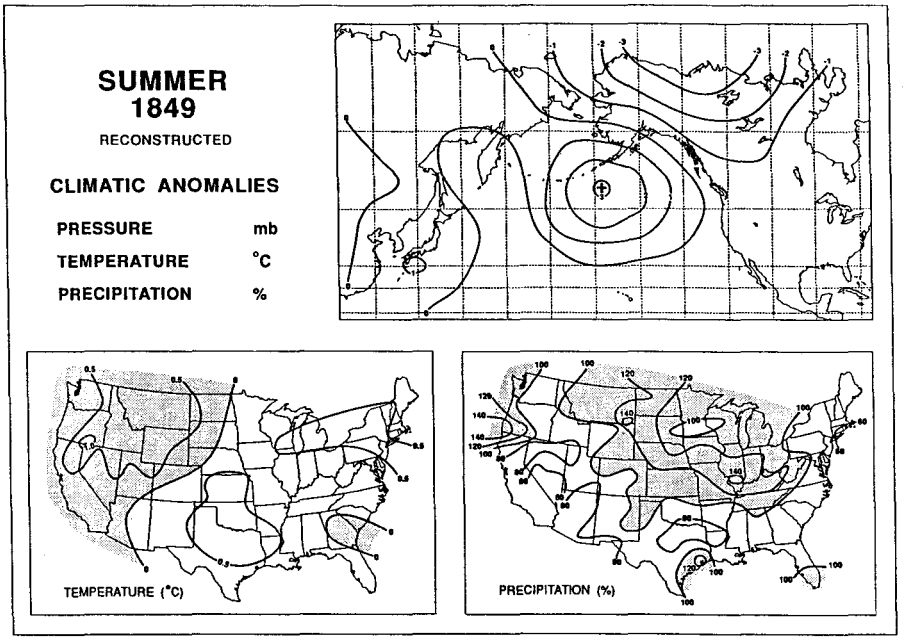

Figure 4. Reconstructed sea level pressure, temperature, and precipitation patterns for summer, 1849; departures from 20th C means. Redrawn from Fritts et al. 1981, p. 204.

mid-troposphere over New England and offshore of British Columbia and Washington, and a large amplitude trough was anchored over central North America (Fig. 5a). Ridging near the west coast is consistent with the surface pressure anomaly map that Fritts et al. (1981) reconstructed for the summer of 1849 (Fig. 4).

Charts of anomalous 500 mb heights for July 1958 show strong positive anomalies along the west coast, smaller positive anomalies off the east coast, and substantial negative anomalies over the center of the continent (Fig. 5b). The pattern is similar to the midtropospheric anomaly pattern that Knox and Lawford (1989) found to be associated with wet early summers (i.e. June and July) in a zone encompassing southeastern Manitoba and the Lake of the Woods region of northwestern Ontario. There are, however, important differences. Their anomaly chart shows lower-than-normal 500 mb heights over the central part of the continent, as does the July 1958 anomaly chart, but their chart does not show a zone of pronounced positive anomalies offshore of British Columbia. Smaller positive height anomalies are evident off the east coast of North America in the 1958 and Knox and Lawford charts, but

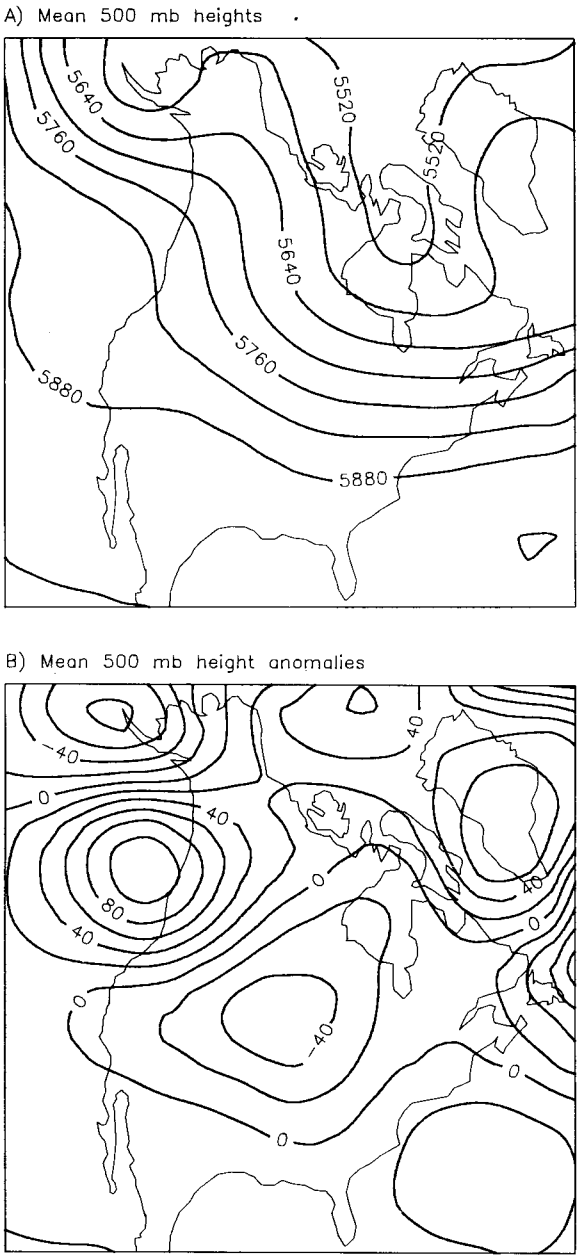

Figure 5. (a) Mean 500 mb heights (meters) in July 1958. (b) Mean 500 mb height anomalies (meters) in July 1958, relative to 1951-80 averages.

most strongly in the 1958 chart. Thus, troughing in the center of the continent is strongly associated with wetter-than-normal weather in the Red River region, but it is evidently quite rare to also have ridging along both coasts in the summer.

As a consequence of the anomalous circulation of July 1958 stronger-than-normal northerly flows were created over much of western North America. This caused frequent invasions of cool air masses into the heart of the continent, thereby extending the circumpolar vortex to a more southerly-than-normal latitude (Dunn 1958); Lawson (1974) inferred a similar atmospheric configuration in his appraisal of the 1849 weather anomalies. These penetrations not only enhanced the creation of below-normal temperatures over a large area of the continent but also above-average amounts of frontal activity and precipitation in the northern and central Plains, where the cold air from the north met tropical air from the Gulf of Mexico.

Although one month has been chosen as the synoptic analog for the spring and summer of 1849, it does not necessarily follow that a particular atmospheric state persisted for four or five consecutive months in 1849. The suggestion being made here is that the anomalous weather conditions observed in the spring and summer of 1849, *as a whole*, could be explained by a mean circulation similar to that observed in July 1958. Still, even if the mean circulation of 1849 were very similar to the chosen analog, it would probably have been interrupted by significantly different circulation regimes. In fact, it should be recalled that the prevailing weather situation in the Red River valley for most of May was apparently not cool enough to warrant mention in diaries and that June does not seem to have been an unusually wet month at some of the reporting stations. Overall, however, the temperature and precipitation patterns for the study period seem to be well-represented by the July 1958 analog.

One possible explanation for the weather of 1849 is that the climate of the Northern Hemisphere was at least temporarily affected by some modifying event, such as a volcanic eruption or an El Niño. The eruptions of Tambora in 1815 and Mount Pinatubo in 1991, among others, showed that a volcanic dust veil may have the ability to produce colder-than-normal weather in North America (Stommel and Stommel 1983; Luhr 1991; Holden 1992), but no eruptions with a large Volcanic Explosivity Index occurred in the appropriate time frame before the summer of 1849 (Hammer et al. 1981; Newhall and Self 1982). Nor does there appear to have been a strong El Niño event in 1849 (Quinn et al. 1987), as there was in the months preceding the chosen analog month of July 1958.

As anomalous as the inferred weather conditions of 1849 might seem, it has been suggested by Lawson (1974), Mock (1991), and others that cool

and wet summer weather in the study area might have been closer to the nineteenth century norm. Temperature and precipitation data from the mid-latitudes of the Northern Hemisphere (Wahl and Lawson 1970; Lamb 1977) suggest that the "Little Ice Age" may have been experiencing a rejuvenation in the mid-nineteenth century, with a more meridional atmospheric flow than has prevailed in the twentieth century (Lamb and Johnson 1959). In the Red River valley region, anecdotal reports by local observers (Table 1) suggest that exceptionally wet summers accompanied by some flooding also occurred in 1806, 1825, 1850, 1851, and 1867, and in 1855 Donald Gunn recorded a remarkable 37 1/8 inches (943 mm) of precipitation from June to August at Lower Fort Garry (Dawson 1859).

Conclusions

Narrative accounts and meteorological records from Minnesota, North Dakota, and southern Manitoba for 1849 show that a very late, cold spring was followed by an exceptionally wet summer throughout the Red River valley region. These conditions are almost identical to those described by Parker and Lawson for the eastern portion of the Oregon Trail 1000 km to the south and indicate that the "abnormal" climatology of that year extended over a much larger area of the Great Plains than their studies implied. A suitable synoptic analog for these conditions, and the dry cool weather which prevailed in the Great Basin region in 1849, is provided by the July 1958 pattern which was characterized by a strong positive pressure anomaly along the west coast and a substantial negative anomaly over the center of the continent. This pattern produced frequent invasions of cool air and enhanced frontal activity on the north-central Great Plains. The 1849 weather does not appear to have been caused by identifiable specific short-term external factors such as volcanic activity or an El Niño, and anecdotal reports from other years in the nineteenth century suggest that such weather in this region may have been less unusual than twentieth century data would imply.

Addendum

After this manuscript was accepted (April, 1993), the region discussed in the paper was revisited by summer conditions which were remarkably reminiscent of those in 1849. From the American midwest to Winnipeg, record summer rainfall and streamflow dominated the news. In the Red River valley, the conditions were a reenactment of those faced by the Woods expedition and the quotations used in the paper would have been as apt in the

TABLE 1
HISTORICAL ACCOUNTS OF EXCEPTIONALLY WET SUMMERS IN THE RED RIVER VALLEY REGION

1806	June 26:	Water extraordinarily high [on the Red River] and continued storms which breed an incredible number of mosquitoes. (Alexander Henry, in Coues 1965, p. 281).
	July 7:	The travelling was tedious from the heavy rains. . . . In many places we found several feet of water; every little hollow formed a pond and every rivulet appeared like a river. Our horses often sunk up to their bellies. . . . The water [on the Red River] was very high . . . They attempted to go [to the east side of the Red] but found the country almost entirely overflowed. (Alexander Henry, in Coues, 1965, p. 285-6).
	August 13:	This summer's extraordinary rain, having overflowed the low country, has caused the buffalo to move to the high lands southward. (Alexander Henry, in Coues 1965, p. 420).
1825	June 12:	The water has risen considerably this year, as has happened sometimes before. It has almost covered the Prairies at Pembina and above and flooded all the houses of the place, not excepting even the chapel, where it has entered to a height of several feet. (Provencher 1825).
1850	June:	As we came northward through Minnesota, we found a great deal of the country flooded, and we had to come by a different route from the one we had travelled two years before. . . . At Pembina, the water extended two miles out from the hill where Mr. Kittson had built his house. We stayed there four days, and then Mr. Kittson sent us in boats to Fort Garry. The expanse of water over which we voyaged from Pembina was in places eight miles wide. (Harriet Cowan, in Healy 1923, p. 30).
1851	July 15:	Already for fifteen days it has been raining, the water rises and rises. (Provencher 1851a).
	July 21:	The abundant rain has done damage to the grain. The water rises continually and could destroy the crop on the low ground. (Provencher 1851b).
1867	August:	We have had a miserable wet summer with rain that has done a great deal of damage to crops in the Red River Settlement where a large part of the French Settlement has been completely flooded and many of their houses carried away. (Walter Trail, in Atwood 1970, p. 80).

summer of 1993 as they were in 1849. At this writing, the synoptic conditions in 1993 appear to have been somewhat different from those of 1958, the analogue year suggested in the paper, and may have included the lingering effects of the 1991 eruption of Mt. Pinatubo and an El Niño. Regardless of the atmospheric cause, however, the dramatic hydrometeorological events of 1993 reinforce one of the objectives stated in the opening paragraph of the paper—to use archival materials to provide a longer perspective within which the modern instrumental records can be interpreted.

Acknowledgments

The authors are grateful to Betty Harder and Weldon Hiebert for their care in the preparation of the manuscript and figures, to Michael Chenoweth for permission to use his Norway House data, to Father Coyle of the Chancery Office in Fargo for providing access to the papers of Father Belcourt, to Norman Haffield of the United States Geological Survey for providing discharge data for the Red River, and to the staff of the Public Archives of Manitoba. Finally, the authors thank the reviewers for their many helpful comments.

References

Atwood, M. 1970. *In Rupert's Land: Memoirs of Walter Trail.* Toronto: McClelland & Stewart.

Belcourt, G. A. 1849. Letter to Reverend C. F. Cazeau, Secretaire de l'Archeveque de Quebec, dated Pimbina [sic], Riv. Rouge, Territoire de Minnesota, 17 juin, 1849. Belcourt Papers, Correspondence 1846-1857 [P 1,328]. Minnesota Historical Society, Minneapolis.

Canada. Department of Transport, Meteorological Branch. 1958. Monthly Record. *Meteorological Observations in Canada July 1958.*

Chenoweth, M. 1992a. Personal correspondence.

Chenoweth, M. 1992b. New light on Canada's nineteenth-century climate: Donald Ross's Norway House weather record. *Weather* 45:286-93.

Coues, E. ed. 1965. *The manuscript journals of Alexander Henry and of David Thompson.* Minneapolis: Ross and Haines Inc.

Dawson, S. J. [1859] 1968. *Report on the exploration of the country between Lake Superior and the Red River Settlement.* New York: Greenwood Press Publishers.

Diaz, H. F. 1981. Eigenvector analysis of seasonal temperature, precipitation and synoptic-scale system frequency over the contiguous United States. *Monthly Weather Review* 109:1,285-1,304.

Diaz, H. F. 1986. An analysis of twentieth century climate fluctuations in northern North America. *Journal of Climate and Applied Meteorology* 25:1625-57.

Dunn, Carlos R. 1958. The weather and circulation of July 1958. *Monthly Weather Review* 86:268-76.

Fritts, H. C., G. R. Lofgren, and G. A. Gordon. 1981. Past climate reconstructed from tree rings. In *Climate and History: Studies in Interdisciplinary History*, ed. R. I. Rotberg and T. K. Rabb, 193-213. Princeton, NJ: Princeton University Press.

Hammer, C. U., H. B. Clausen, and W. Dansgaard. 1981. Past volcanism and climate revealed by Greenland ice cores. *Journal of Volcanology and Geothermal Research* 11:3-10.

Healy, W. J. 1923. *Women of Red River*. Winnipeg, Manitoba: The Women's Canadian Club.

Holden, C. 1992. Post-Pinatubo cooling on target. *Science* 256:1276.

James, R. 1849. Journal of R. James [MG7 B2 CMS A92]. Provincial Archives of Manitoba, Winnipeg.

Klein, W. H. 1948. Winter precipitation as related to the 700-mb circulation. *Bulletin of the American Meteorological Society* 29:439-53.

Knox, J. L. and R. G. Lawford. 1989. The relationship between Canadian Prairie dry and wet months and circulation anomalies in the mid-troposphere. *Atmosphere-Ocean* 28:189-215.

Lamb, H. H. 1977. *Climates: Present, Past, Future. Climate, History and the Future*. London: Methuen.

Lamb, H. H. and A. Johnson. 1959. Climatic variation and observed changes in general circulation. *Geografiska Annaler* 91:94-134.

Lawson, M. P. 1974. *The Climate of the Great American Desert*. Lincoln: University of Nebraska Press.

Lawson, M. P. 1975. Meteorological experiences of the Forty-Niners crossing the Great American Desert. *Weatherwise* 28:250-53, 271.

Ludlum, D. M. 1958. A July heat wave in far west spreads eastward. *Weatherwise* 11:174-75, 178-79.

Ludlum, D. M. 1960. Summer presents a varied fare. *Weatherwise* 13:218-25.

Ludlum, D. M. 1964. Hot July - Cool August. *Weatherwise* 17:236-50.

Luhr, J. F. 1991. Volcanic shade causes cooling. *Nature* 354:104-05.

Mock, C. J. 1991. Historical evidence of a cold, dry summer during 1849 in the northeastern Great Basin and adjacent Rocky Mountains. *Climatic Change* 18:37-66.

Newhall, C. G., and S. Self. 1982. The Volcanic Explosivity Index (VEI): an estimate of explosive magnitude for historical volcanism. *Journal of Geophysical Research* 87, no. C2:1231-38.

Parker, W. 1964. Wading to California: The influence of the Forty-Niners on the notion of the Great American Desert. *Great Plains Journal* 3:35-43.

Pope, J. 1850. *The Report of an Exploration of the Territory of Minnesota.* U.S. Senate Executive Document No. 42, 31st Congress, 1st Session.

Provencher, J. N. 1825. Letter to Bishop Plessis, dated St. Boniface, June 12, 1825. In *Documents Relating to Northwest Missions, 1815-1827, ed.* G.L. Nute, (1942), 430-31. St. Paul: Minnesota Historical Society.

Provencher, J. N. 1849a. Letter to Monseigneur I. Bourget, Bishop of Montreal, dated St. Boniface, June 26, 1849 [MG7 D1]. Provincial Archives of Manitoba, Winnipeg.

Provencher, J. N. [1849b] 1913. Letter to Monseigneur Turgeon, Bishop of Sidyme, Quebec, dated St. Boniface, June 27, 1849. *Bulletin de la Societe Historique de Saint-Boniface* III:270.

Provencher, J. N. [1849c] 1913. Letter to Monseigneur Turgeon, Bishop of Sidyme, Quebec, dated St. Boniface, August 28, 1849. *Bulletin de la Societe Historique de Saint-Boniface* III:276.

Provencher, J. N. 1851a. Letter to Monseigneur I. Bourget, Bishop of Montreal, dated St. Boniface, July 15, 1851 [MG7 D1].Provincial Archives of Manitoba, Winnipeg.

Provencher, J. N. [1851b] 1913. Letter to the Bishop of Quebec, dated St. Boniface, June 27, 1851. *Bulletin de la Societe Historique de Saint-Boniface* III:278.

Quinn, W. H., V. T. Neal, and S. E. Antuñez de Mayolo. 1987. El Niño occurrences over the past four and a half centuries. *Journal of Geophysical Research* 92:No. C13:14449-61.

Rannie, W. F. 1983. Breakup and freezeup of the Red River at Winnipeg, Manitoba, Canada in the 19th Century and some climatic implications. *Climatic Change* 5:283-96.

Schell, J. P. 1911. *In the Ojibway Country.* Walhalla, ND: Chas. H. Lee Publisher.

Smithurst, J. 1849. Journal of J. Smithurst [MA MG7 B2 CMS A96]. Provincial Archives of Manitoba, Winnipeg.

Stommel, H. and E. Stommel. 1983. *Volcano Weather.* Newport, RI: Seven Seas.

Wahl, E. W. and T. L. Lawson. 1970. The climate of the midnineteenth century United States compared to current normals. *Monthly Weather Review* 98:259-65.

Woods, S. 1850. *Report of Major Wood [sic] relative to his expedition to Pembina Settlement and the condition of affairs on the North-Western frontier of the Territory of Minnesota.* United States House of Representatives Executive Document No. 51, 31st Congress, 1st Session.